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THE MECHANICAL HANDLING AND STORING OF MATERIAL

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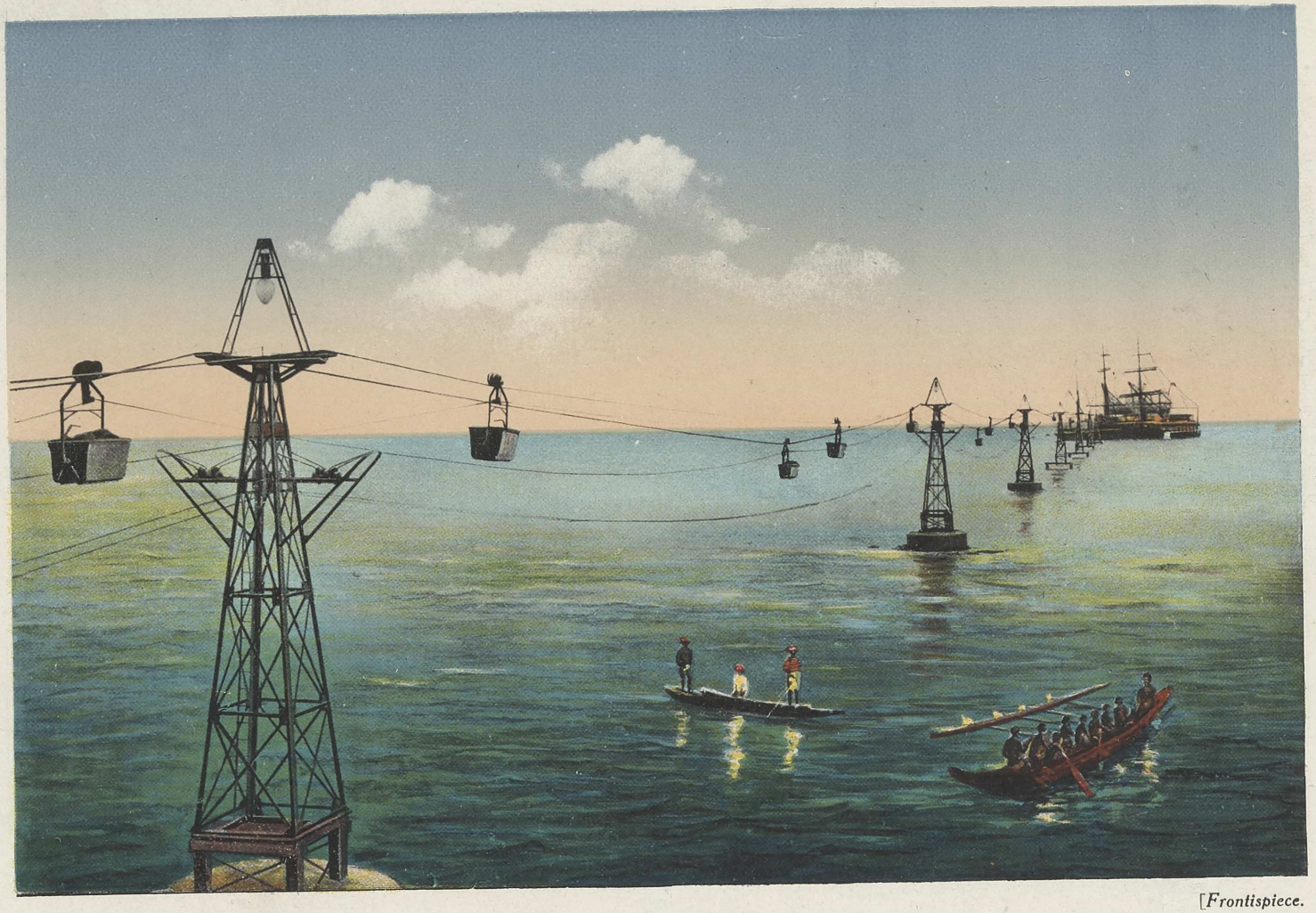

[*Frontispiece.*

DELIVERY TERMINUS OF A ROPEWAY AT THIO ON THE EAST COAST OF NEW CALEDONIA.

(See page 295).

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THE

MECHANICAL HANDLING & STORING OF MATERIAL

Being a Treatise on the Handling and Storing of Material such as Grain, Coal, Ore, Timber, Etc., by Automatic or Semi-Automatic Machinery, together with the Various Accessories used in the Manipulation of such Plant

BY

GEORGE FREDERICK ZIMMER, A.-M.INST.C.E.

With over One Thousand Illustrations

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LONDON
CROSBY LOCKWOOD AND SON
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PREFACE

THE monograph on "The Mechanical Handling of Material," formerly written by me, has been out of print for some time, and in revising that publication for a new issue in the light of modern progress, it was found that the storing or stocking, and conversely, the reclaiming, of material (a subject which was formerly treated with secondary consideration) are now so much bound up with mechanical handling that it would be undesirable, if not impossible, to keep the two subjects apart. Under these circumstances I make the attempt in the present volume to deal with both handling and storing under the extended title of "The Mechanical Handling and Storing of Material."

The portion of the work devoted to the first subject, *Handling*, has been thoroughly revised and is now quite up to date, including chapters on the following new subjects —Coal Face Conveyors, The Mechanical Disposal of Ashes from Steamers, Mono-Rails and Telphers, The Handling of Coke from Coke Ovens, and The Handling of Coal by Pneumatic and Hydraulic Means; while *Storing* embodies all the methods in vogue for so dealing with minerals, chemicals, cereals and other seeds, in conjunction with the mechanical appliances for assembling the materials as well as those for reclaiming them from stock.

It would have been practically impossible for any one person to explore, or be sufficiently conversant with, the whole of the immense field which is now covered by the mechanical handling and storing of material. I have, therefore, supplemented my own practical studies and experiences by a careful perusal and selections from all accessible authorities on this subject.

It gives me great pleasure to acknowledge my indebtedness to the Institution of Civil Engineers, the Institution of Mechanical Engineers, the American Society of Mechanical Engineers, the Verein deutscher Ingenieure, for much valuable information obtained

from their Proceedings; to such technical journals as *The Engineer*, *Engineering*, *Cassier's Engineering Monthly*, *The Iron and Coal Trades Review*, and also to other sources and authorities (acknowledged where they occur in the book) which I have found it most beneficial to consult. I am grateful for the kind and ready permission given to make use of information derived from these sources, and should I have inadvertently omitted to acknowledge any source from which information has been obtained, I apologise.

It should be pointed out that the importance of the subject matter of this volume increases daily, as technical progress is and has been increasing by leaps and bounds in the last decade. There is no factory now that can afford to do without machinery for handling and storing its raw materials and finished products if it is to be a commercial success. The national economy of the civilised world cannot do without the mechanical handling and storing of material, and in conclusion, the toll claimed from the ranks of labour by the European War and the consequent shortage of hands, will force even those who are slowest to adopt modern means to replace the man by the machine wherever possible.

Let this be my excuse, if such be deemed necessary, for venturing again before the technical world.

G. F. Z.

82, Mark Lane, London, E.C.,
January 1916.

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Dansk Ingeniørforenings

THE MECHANICAL HANDLING AND STORING OF MATERIAL

CHAPTER I

INTRODUCTORY

SINCE the introduction of mechanical devices as aids to human effort, there has ever existed a controversy concerning the influence of machinery upon the welfare of the human race. The workman's cry has always been that the substitution of manual labour by mechanical means has diminished his opportunities of employment, and although the fallacy of this argument has been demonstrated from many quarters, the leaders of the men have opposed, as inimical to their interest, those improvements which play a vital part in national economy.

In addition to their adverse attitude concerning the use of labour-saving machinery, the restriction of output has been advocated by the leaders of the Unions as a remedy for unemployment, but this again is unsound reasoning—plausible as it may appear at a casual glance—because the cost of production must be increased by such a policy, and enhanced cost spells diminished sales, which in turn causes diminution of employment. So the advocates of restricted output find that instead of providing a living wage for a greater number of men, the employment becomes more limited, and that the actual effect is detrimental instead of beneficial to the workers.

The spirit of commercial unrest which is abroad to-day finds expression in the new Syndicalism which teaches that all manual wage earners belong to one class, and all the rest of the community to another class. In their crude conception it does not seem to have occurred to the intellectual leaders of the Syndicalist movement that it is only possible for a capitalist to renew his capital by selling the goods for the production of which he has paid wages, and that most of the buyers are themselves wage earners. The capitalist is, in fact, the channel for conveying goods from one wage earner who is paid for the labour of producing them, to another wage earner who pays for the pleasure of consuming them.

There can be no doubt in the minds of those who study the laws of national economy that the lower the cost of production the greater will be the sale of almost all commodities of life, as they become accessible to a larger circle, and the greater the progress of modern civilisation.

H. J. Brackenbury says in an interesting article on "Men and Machines" in *Cassier's Magazine*: "Methods of manufacture and machinery may be brought to such perfection that what now takes a hundred hours of human labour to produce, will in future take only fifty, or even twenty-five. If, then, the people be satisfied with their standard of living, the benefit of rapid production will be felt in the direction of shorter

working hours, rather than in that of cheaper prices. The Americans, who are strenuous people, seem to prefer to work long hours and have a high standard of living.

"Nowhere have the methods of rapid production been carried further than in America, and nowhere are higher wages paid. The benefit of rapid production may, therefore, be either a higher standard of living or more leisure, or a compromise between these two."

In the following H. J. Brackenbury is again quoted: "Imagine—and the cultivation of the imagination is not to be despised by the engineer—manufacturing processes so far improved that the amount of human labour required for the present production of the world were reduced by half. Many believe that the result of this would be to throw half the work-people out of employment. This would not be the true result. The true result would be that, other things remaining the same, every one would be as well off if the workers were paid the same wages as at present and worked for only half the time.

"This, then, is the goal to which we should strive; the goal which we ourselves shall not see, but which will nevertheless be finally reached. If the masters' and the men's leaders would make common cause, and work to this end, much benefit might be obtained in a short time."

If the working classes can be taught that their hostile attitude towards the introduction of machinery is against the technical and commercial progress of the country at large, and against their personal interest in particular, they will change their tactics and welcome modern progress.

It is not to be supposed for one moment that the inventors and users of labour-saving devices are moved by any philanthropic motive, solely to better the lot of their fellow-creatures; neither on the other hand should it be maintained that the introduction of power-driven plant was instigated to deprive men of the opportunity to work; but rather to lower the cost of production for the manufacturer's own benefit and that of humanity as a whole.

"It is," says H. H. Suplee,[1] " important to remember that the human machine, considered as a means of producing mechanical effect, is far too costly and too lacking in efficiency to be used for anything which can be done by manufactured power. Any idea that there is inherent dignity or merit in overstraining human muscle in a wholly undesirable and inefficient manner must be replaced by the certain knowledge that the true method of employing man is by the use of his trained judgment and skill in the control of manufactured power applied through properly designed machinery."

Handling bulky and specifically heavy loads is very hard work, which often leaves the worker unduly fatigued, a condition only too likely to produce in him a brutal tendency, which result is by no means desirable.

From what has been said, it will be evident that the kind of labour which is most readily replaced by machinery is that of the untrained man, who works principally with his muscle, and that the performance of this portion of the world's work by machinery will mean that the man who is to earn his living by his labour must be capable of using his head as well as his hands, and learn at the same time how to do things at once less onerous and more valuable than formerly.

Technical progress can no longer be stigmatised as the enemy of labour, and where the introduction of automatic labour-saving machinery has dispensed with a few labourers, their sphere of action has generally been transferred to more responsible and less laborious work.

[1] In an article entitled "The Replacement of Man by the Machine," in *Cassier's Magazine*.

The frequent strikes of workmen, generally used as levers to raise their wages, which disorganise and sometimes totally paralyse all branches of industry, naturally suggest to the employer the use of mechanical means for handling his raw material and fuel supply, and also the advisability of storing where possible large supplies of these materials in mechanically equipped stores, thereby making himself independent, for a time at least, in that department of his establishment.

From the economic standpoint the introduction of machines for the mechanical handling of material is essentially a question of rentability, *i.e.*, whether the labour saved by the machinery justifies the capital outlay for the plant. If labour is to be had at a low rate and in sufficient quantity, it might be, under efficient supervision, more economical to employ hand labour than to invest large sums in machinery. Such conditions obtain, however, only in new countries, and there only till the standard of living of the natives has been gradually raised through intercourse with, and by the example set by, Europeans. One of the results of cheap labour is that less inducement is held out to introduce labour-saving machinery.

The wages of the unskilled labourer have so much risen of late, that the substitution of the mechanical conveyor for the man with the wheelbarrow and shovel becomes more lucrative.

The application of machinery to both the handling and conveying of heavy and bulky material has of late years assumed a paramount interest. No branch of engineering has so rapidly developed in modern times as the construction of appliances for conveying, loading, and unloading heavy goods, more particularly coal and ore. In the case of grain and seeds, again, the construction of granaries and silo-houses on a large scale has been undertaken, and the aid of automatic machinery more or less sought to provide means of handling this material as far as possible without the assistance of hand labour. The increased competition met with in all branches of manufacture has forced upon capitalists the necessity of economising in every department. The exaggerated importance attached by the followers of Ruskin to hand labour has passed into the region of obsolete and unworkable theories, and labour-saving appliances are everywhere regarded as being absolutely essential to the progress of all industries.

The mechanical handling of grain is of prior date, and it was not till comparatively recent years that the engineer was able to render any effective assistance in the handling and automatic conveying of coal and ore. It was not until towards the latter end of the nineteenth century that the growing demands of industry made it imperatively necessary to store coal on a large scale, and so brought about this mechanical revolution. This movement received greater impetus from the many electric power stations and the extensions of gasworks which have marked the industrial history of the past thirty years.

The loading and unloading of bulk cargoes in and out of vessels and railway trucks used to be effected entirely by hand. In some of the harbours and docks of Africa, India, South America, in the West India Islands, and also in the Far East, this process is still sometimes in vogue for loading vessels, or has been till within the past few years. This primitive mode of handling material is, however, disappearing to make room for mechanical appliances.

The annexed illustration depicts such an instance during the Russian and Japanese War, and shows the coaling of a battleship at Nagasaki, the "Portsmouth" of Japan. Gangs of 50 to 150 natives, both men and women, used to carry the coal in baskets on their heads to and from the ships, the result of their toil being about 3 to 4 tons of coal per carrier per day.

In some ports, New Orleans and St Louis amongst others, the use of wheelbarrows was the first step in the right direction, and superseded the last-mentioned process. The gangs with wheelbarrows consisted of about twenty men, and they delivered on the average 6 tons per man per day. The next step was the adoption of narrow gauge lines with hand trucks, which raised and delivered 10 tons per man per day. By substituting self-unloading trucks for ordinary hand trucks, the capacity per man was raised

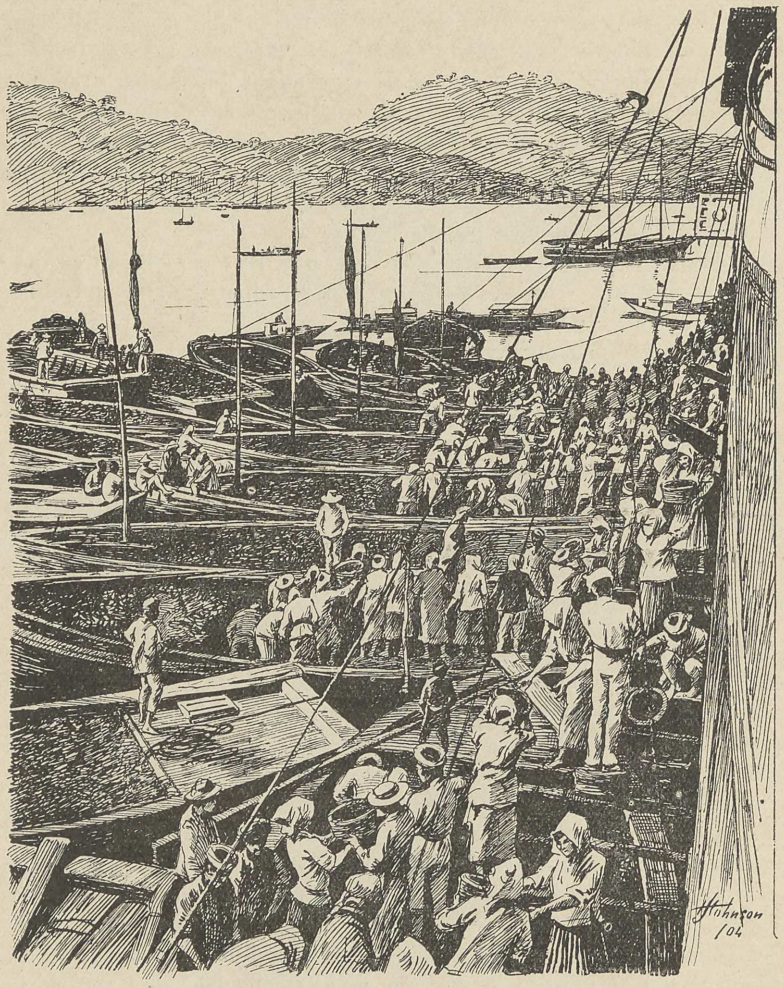


Fig. 1. Coaling of a Battleship at Nagasaki.

to 12 tons per day. But even this improvement gives a far from satisfactory result. The process was too slow, and therefore too expensive, and also subject to strikes and other interruptions. It was not until a few years ago that satisfactory appliances were introduced.

In addition to these considerations, there remains the great difficulty, if not impossibility, of handling the annually increasing quantities of material to be dealt with without the aid of machinery.

Hand labour was good enough in the days when, according to the earliest records, the first coal was shipped from Newcastle in 1226, and landed at Jacob's Lane, in the Fleet, in London; but since then great changes have taken place.

In 1849 the annual production of coal in this country was 107,427,500 tons, of which 13,053,000 tons were exported as cargo or used for steam navigation. The import of sea-borne coal into London is but a small proportion of the coal handled in the principal coal ports of this country. In 1899 the production was 220,094,781 tons, and the export 55,810,024 tons; while in 1913 the coal production was 287,430,473 tons, of which 98,338,104 tons were exported as cargo and used for steam navigation. Besides coal, an immense bulk of other minerals is handled year by year. According to official returns the mineral produce of the United Kingdom for the year 1913[1] amounted to 354,890,867 tons of raw material, this immense tonnage being made up as follows:—

	Tons.
Coal	287,430,473
Iron, lead, zinc, tin, and other ores	16,059,337
Limestone, chalk, gypsum	17,884,128
Slate, clay, oil shale	17,510,720
Salt, sandstone, granite, gravel sand	15,732,706
Other minerals	273,503
Total	354,890,867

It is obvious that such quantities can only be economically handled by mechanical means.

The quantities given for export coal are by no means the total quantity loaded and unloaded, as all the sea-borne coal that is only shipped from home port to home port must be added; whilst the former has only to be handled once at the dock, the latter may have to be handled twice or thrice. In addition to the coal shipped, there is a large bulk which is carried by rail, and should be more or less mechanically loaded or unloaded into or out of trucks.

"**The New Coal Tables—Falling Off in Labour Efficiency.**—The statistical tables published annually by the Board of Trade relating to the production, consumption, and imports and exports of coal in the British Empire and the principal foreign countries, and the production of lignite and petroleum in the principal producing countries, become more and more valuable and interesting with each issue. The information is supplied in a clear and concise form enabling comparison to be made of many different countries one with another over a long series of years. Considering the difficulty in obtaining anything like trustworthy figures from many foreign sources, it is inevitable that much delay must be experienced, and the last 'Coal Tables' issued close with 1912. In some ways this delay is unfortunate, but it enables the information in many cases to be given with greater accuracy.

"One of the most instructive sections of the return is that which deals with the production of coal per person employed, for it throws some light upon the physical, social, and economic relationships existing in the coal-mining industry. As the workings become deeper and further from the shaft, and as more time is occupied in protective operations, the output per person employed will decrease. Again, the same result must follow from general reductions in the hours of labour and from irregularity of employment.

[1] These are the latest statistics available at the time of publication.

On the other hand, unless neutralised by organised opposition, improvements in machinery and method are constantly tending to increase the individual output. It has also been observed that a high rate of wages has an adverse influence upon the effort of the miner. In the coal mines of the United Kingdom during the five years 1886-90, the average quantity of coal produced per annum per person employed (above and below ground) was 312 tons. The quantity has steadily fallen since that period, and in 1912 (the year of the national coal strike) it was only 244 tons—a decrease of about 21 per cent. As the number of persons employed in 1912 was 1,068,751, and the output 260,416,000 tons, there was a diminution of production, as compared with the earlier efficiency of 72,675,068 tons, or an increase of 835,818 persons for the same output.

"According to advance figures (subject to correction) just issued by the Home Office in reference to the output of coal and other minerals in the United Kingdom during 1913, the coal industry has not only made up the deficiency of production caused by the national coal strike in the previous year, but has more than recovered the average rate of progress. In 1911 the output of coal was 271,892,000 tons, in 1912, 260,416,000 tons, and in 1913, **287,411,869** tons. As the number of persons employed above and below ground in 1913 was 1,127,890, the output per person employed was about 255 tons, which shows a small increase above the rate for the previous year, but is the next lowest on record.

"During the period, 1886-90 to 1912, Belgium and France show decreases in efficiency of about 12 per cent. and 5 per cent. respectively, while Germany is practically stationary, having fallen and recovered. Other countries show more or less considerable increases in efficiency, notably the United States, where the production per annum per person employed has increased from 400 to 660 tons, or by 65 per cent."—*Times Engineering Supplement*, 24th April 1914.

Not only have these large quantities of coal to be handled in the course of each year between ships, barges, trucks, and coal stores, but the immense bulk of our grain and seed imports must be dealt with in a similar manner.

According to Board of Agriculture statistics, the United Kingdom consumed in 1913 [1] 16,821,323 tons of cereals, and as the home production only amounted to 5,861,346 tons, the balance of 10,959,977 tons [2] had to be imported. In addition to this, we imported 1,527,225 tons of seeds, principally for the extraction of oil. This gives the respectable total of 18,348,548 tons of grain and seeds to be handled per annum, and this quantity is by no means a fixture, but grows annually to greater dimensions.

The bulk of the imported cargoes of grain and seeds is carried in large ocean-going steamers for which there is only accommodation in our principal ports. The grain, therefore, is in many instances unloaded from the large vessel into smaller ones which can enter the rivers and canals and deliver the grain to its final destination. This means that the bulk of these cargoes of grain has to be handled twice over.

In the introduction of machinery for the automatic handling of such material, America no doubt took the lead, a step which was largely due to the peculiar conditions of that country, where a saving of labour was at that time perhaps more important than in Europe. It must be admitted, however, that in this country and on the Continent the lead taken by America was quickly followed up, and both here and abroad American methods of mechanically handling such goods have been more or less followed.

In round figures it may be taken that the saving of one man's wages warrants the

[1] These are the latest statistics available at the time of publication.

[2] This includes 907,314 tons imported in the form of flour and meal.

investment of £1,000 in machinery; hence in his quest for economy the engineer is ever on the alert to reduce the wages bill, and handle everything automatically.

The modern flour mill may be cited as an example of automatic handling. So perfect is its automatic character that wheat may be unloaded from an ocean-going steamer, stored, cleaned, graded, ground, dressed, packed, weighed, registered, and delivered into a railway truck for dispatch to the consumer without any manual labour whatever. The consequence is that, whereas a few years ago it would have required twenty to thirty men to produce a given quantity of flour, the same result may now be effected by three or four, who are simply employed in adjusting, cleaning, and lubricating the machinery.

Notwithstanding this, it would be rash to assume that the multiplication of mechanical appliances is detrimental to the interests of the worker, though it may be so in isolated cases. On the contrary, experience has shown that his daily life is thereby made easier, his intelligence improved, and his wage-earning capacity increased.

Viewing the introduction and use of labour-saving machinery from a broad and unbiased standpoint, we must arrive at the conclusion that all machines, which have been substituted for actual human muscular effort, have at the same time opened new opportunities for the employment of men, not only to tend such plant—and its usually increased capacity—since their introduction, but also for the manufacture of the new machinery itself; work which previously did not exist.

There is also the use of machines for operations wholly beyond the unaided capacity of the muscular effort of man, even when leaving social economy out of the question.

In the following chapters will be enumerated devices by which the burden of human labour has been lightened by the use of machinery, and the capacity increased of the branch of manufacture concerned.

In the construction of machinery for the mechanical handling of material, the following local conditions have necessarily to be largely taken into consideration. Whether the material is to be elevated or conveyed from the store, the manufactory, or the mine, to the market, to other stores, to the point of shipment, to freight cars, or whether it is to be handled at the point of consumption. Then it depends on the distance to the destination, the quantity per hour, and the nature and size of the material that has to be dealt with.

A review *seriatim* may be taken of the various appliances which have been devised for the conveying and handling of grain, coal, ore, and coke. Coal, which is not only a raw material of prime necessity in almost every branch of industry—notwithstanding the headway being made by oil fuels—but is also a material of considerable intrinsic value, a value which is subject to rapid and sensible depreciation from careless handling, deserves the first place, as no doubt it has been the subject of more careful thought on the part of engineers than any other heavy material.

It may, however, be observed that the same means of automatically conveying and handling coal are very generally applicable to other heavy substances, such as ores and coke, though no doubt the special nature of the material to be handled must always be taken into account.

The loading of ships with coal is a comparatively simple matter. The railway trucks containing the coal may either be lifted and their contents then shot into the ship, or they may be tipped from the quayside, or the coal may be discharged from self-emptying railway trucks. The main point is this, that the coal is allowed to discharge itself by its own weight into a shoot which conveys it into the ship's hold. To prevent depreciation by rough handling, many ingenious forms of discharging apparatus have been invented,

which are one and all intended to reduce or break the fall of the material, thus bringing it into the hold of the vessel in as whole and sound a condition as possible. In order to save trimming in the hold, ships have been specially built with a great number of hatchways, but as yet no satisfactory appliance has been found which will trim coal mechanically in the hold of an ordinary ship.

An important subject is the service of large boiler-houses and gasworks. Here mechanical means are used for filling and discharging bunkers, bins, or silos, and two essential features in such installations are the automatic feeding of the boilers and retorts, and the removal of the ashes and coke.

Much attention has also been devoted to the coaling of railway engines and the feeding of blast furnaces.

The subject as a whole is a very extensive one, and is here divided into—

Appliances and installations which deal with the material CONTINUOUSLY—that is, receive and deliver it in uninterrupted stream—such plant, for instance, as is suitable for factory yards, coal and other mines, gasworks, power stations, etc.

Such installations as serve to handle material INTERMITTENTLY and for longer distances, as light railways, ropeways, and telphers, in conjunction with grabs and other unloading devices.

A number of complete installations in which these appliances are used are illustrated and described in the course of this work.

In dealing with machines of the continuous type it will be evident that the material which is being handled is evenly distributed over the entire length of the elevator or conveyor; thus the apparatus is only burdened with a comparatively moderate weight, a fact which permits of a relatively light construction of the mechanism and its supports. For this reason appliances of this type have often a distinct advantage over machines which must lift a considerable load at one point, because in the latter case the load, consisting of the material under treatment and the receptacle in which it is being carried, is concentrated in one place, and necessarily requires machinery and structure of a heavy description and of more solid construction. Again, in what may be termed the intermittent conveying of material, as for instance in the use of cranes, there is the operation of charging and discharging, to say nothing of the loss of time, sometimes unavoidable, from the return of the empty receptacle, whereas there is no loss of the kind with machinery of the continuous type. The capacity of a crane is really limited, because its speed is not capable of any considerable increase, on account of the heavy weight to be dealt with. To greatly increase the load carried at each lift is often impracticable, because the bucket or skip becomes more awkward to handle, and smart brisk work is then out of the question, whereas with a continuous conveyor it is perfectly possible to enhance the capacity by simply increasing the width of the conveyor as well as the speed within certain limits, always, of course, provided that the supply of the material being handled keeps pace with the increased capacity of the conveyor.

When it is a case of handling large and heavy lumps, cranes are undoubtedly in place, especially where it is a question of quickly clearing barges or railway trucks.

Most important factors in the choice of machinery for given purposes are general local conditions and the adaptation of the machinery to the space available.

The material should be handled as gently as possible if it be liable to deteriorate through breakage, as in the case of coal, which may easily lose from 5 to 10 per cent. of its value through rough handling, and this consideration is even more urgent in the case of coke, as coke dust is almost worthless.

To minimise the cost of upkeep, as the constant renewal of parts of the machinery

will form in some installations a considerable addition to the working expenses, all parts of the machines which are liable to accident, from at times unavoidable rough handling, and from wear and tear, should be capable of being promptly and easily replaced.

The installation should be as free from liability to accidents as it is possible to attain, as human lives and valuable property may be lost by accidents and breakdowns, and last, but not least, even a temporary stoppage of the works may cause serious loss.

The Continuous Handling of Material.—The subject of handling material continuously may be classified under three heads:—

1. Appliances for Lifting in a Vertical Direction, or from one Level to another, commonly called Elevators.

2. Appliances for Moving Material in a Horizontal Direction, commonly called Conveyors.

3. Appliances which combine the two former objects by Elevating and Conveying the Material horizontally at the same time.

In the succeeding pages the older conveying appliances employed for these purposes are briefly described, more space being devoted to those which have recently been introduced.

Conveyors are subdivided—

Firstly, into appliances consisting of a stationary trough in which the material is conveyed by means of a continuous pushing device;

Secondly, appliances with a stationary trough in which the material is conveyed by means of a reciprocating pushing device;

Thirdly, into appliances in which the trough containing the material moves bodily with the material; and

Fourthly, into appliances in which the material is conveyed by a semi-stationary reciprocating trough.

Intermittent Handling of Material.—This subject cannot well be classified under distinctive heads; each device is, therefore, dealt with separately in several chapters of this book.

CONTINUOUS HANDLING OF MATERIAL

ELEVATORS, CONVEYORS, AND A COMBINATION OF THE TWO APPLIANCES

ELEVATORS

A. FOR MATERIAL IN BULK; B. FOR LARGE OBJECTS

CHAPTER II

A.—ELEVATORS FOR MATERIAL IN BULK

Introductory.—The most ancient method of elevating material, although it cannot strictly be called an elevator, is none the less of interest; as all the members composing such a machine are present without, however, the mechanical element, it may be termed a human elevator. Fig. 2[1] is a reproduction of a part of an alabaster bas-relief discovered by Sir Henry Layard. It formed part of the wall decorations of the palace of Sennacherib, the Assyrian king who destroyed Babylon in 694 B.C. The illustration is one of a series representing the building of the palace. The men are captives from the city of Balada, and are raising an artificial mound or platform upon which the palace was erected. The alabaster slab is now in the British Museum.

Elevators in a primitive form have been known and used for a very considerable time, and since their introduction have undergone little alteration except in detail. The term elevator is usually applied to endless belts or chains to which are attached a series of suitably shaped receptacles or buckets. These chains or belts run over two terminal pulleys which are fixed at different levels, the distance from centre to centre of these pulleys being called the length of the elevator.

It is not intended to waste space here by going into details of the construction of the numerous types and patterns of chains and buckets used for elevators, and which are made by specialists with special plant, beyond giving the actual shape of the buckets, as it is obvious that a light chain and buckets of a thin gauge will answer for light materials, whilst heavy chains and buckets should be used for specifically heavy, and especially cutting materials.

Elevators are designed to suit special purposes. For instance, grain elevators are always encased in wooden or iron trunks, the head and foot being also of wood or iron. The position of the elevator trunk in this case is nearly always vertical. The support for the buckets consists either of leather belting, cotton belting, hemp webbing, or india-rubber with insertion. For minerals—coal, coke, cement clinker, and other heavy

[1] From "Engineering of Antiquity," by G. F. Zimmer.

materials—elevators are usually fitted with sprocket wheels and chains which support the buckets. The elevator in the latter case is generally in a slanting position. The buckets are attached to the links of the chain, and intermediate short skidder bars are employed which slide on well-oiled angle-bars on each side. For extra heavy work

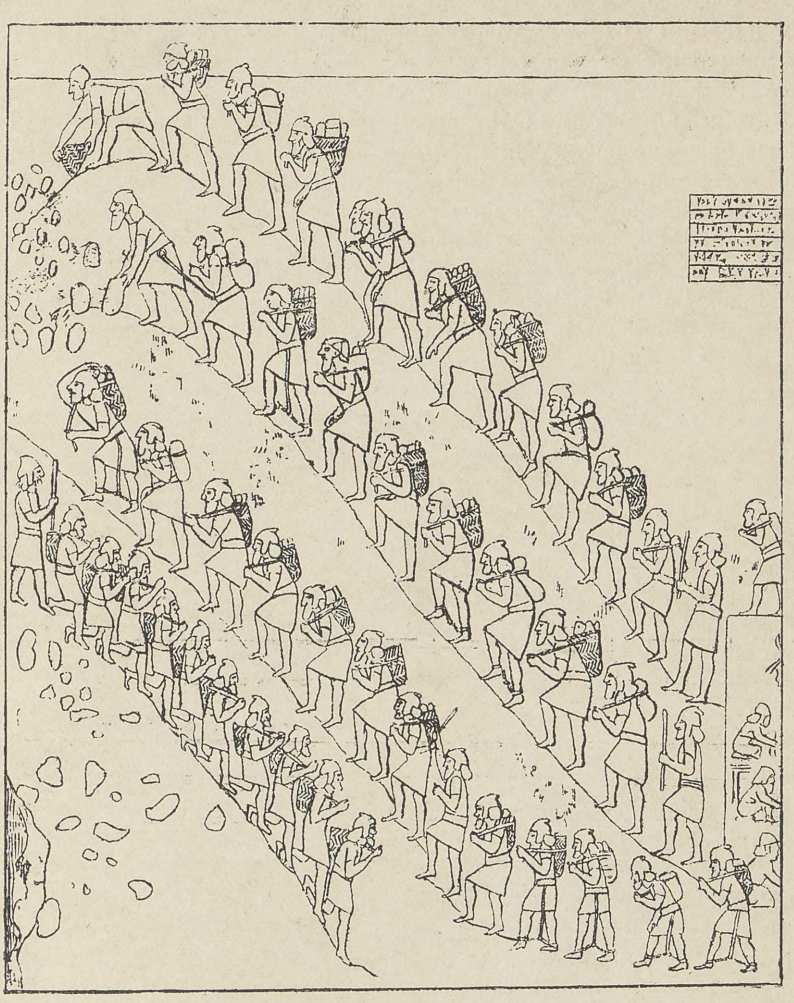


Fig. 2. Human Elevator Constructing a Mound upon which the Palace of King Sennacherib was built.

From a bas-relief of this palace, now at the British Museum.

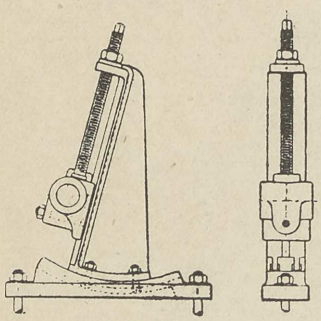
the skidder bars are replaced by rollers. These prevent the buckets and chain from sagging.

Tightening Gears.—Both grain and mineral elevators are generally furnished with tightening gears to keep the belt or chain taut. These are generally arranged at the lower or well end of the elevator, because if placed at the top or delivery end the tightening of the chain or band disturbs the driving arrangements, which should be at the upper terminal. The ordinary tightening gear at the elevator well has this disadvantage, that the space between the bottom of the well and the bucket must vary.

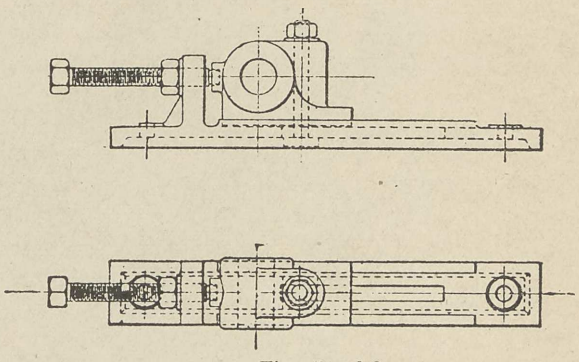
Where grain elevators are concerned this is of little consequence, but in elevators handling coal, minerals, and other material of varying size, it is desirable to keep an even space between the buckets and the bottom of the well to prevent jamming, as shown in Fig. 11. In this case the elevator well is designed to go down with a sprocket wheel when the chain is tightened, and vice versa, whilst the bracket supporting the elevator well remains a fixture. This is only applicable to elevators handling small pieces; for coarser material no elevator wells are used.

There is a third way of tightening elevators without interfering with either the feed or the delivery end, and this is by means of a separate tightening or jockey pulley arranged at some convenient points on their length, in a similar manner to the pulley shown in Fig. 11 (although in this particular instance the pulley is for another purpose).

As a rule, especially with grain elevators, the tightening gear is made as part of the elevator well; but for larger elevators, particularly those which are used for heavy material, the tightening gear is separately mounted on the supporting girders of the elevator framing, and the well is entirely dispensed with. Figs. 3 to 6 show two such tightening gears. Both have an adjustment which will allow of holding the bearing in



Figs. 3 and 4.



Figs. 5 and 6.

Elevator Tightening Gears.

position after tightening. The construction is so simple that it explains itself. The gear shown in Figs. 3 and 4 allows of an adjustment to suit elevators at a variety of inclines. (See also Tightening Gears, page 191.)

To Prevent Choking.—The buckets should be made large enough to cope readily with the feed, and at the same time due allowance must be made for the largest pieces to be elevated. In addition to this, the elevator must be fed correctly. For instance, if fed from a large accumulation of material, say from a stock heap or from a bin or hopper, it would not do to feed the elevator by an ordinary spout or shoot.

In such a case the elevator should preferably be fed by a mechanical feeding device, such as an oscillating feed shoot, making between 30 and 60 oscillations per minute, which deposits at each backward and forward stroke a quantity corresponding to the capacity of the elevator. This precaution is, however, only necessary when dealing with minerals of uneven size (see Feeding Devices, page 202), and would not be necessary when handling grain or seeds. The choking in such cases, if ordinary spouts are used, is due to one of two causes. Either the rush of feed is too great, and is therefore more than the elevator can take up, or else a few large pieces of material have found their way to just above the feed spout and arch it over, thus stopping the feed flowing to the elevator. Feeding devices will obviate both. They will not allow an undue

rush of feed, and will prevent the arching over by keeping the material constantly in motion. These devices may be used not only for feeding from large stock hoppers, but also for equalising the flow of material from smaller hoppers, which are fed intermittently by grabs, etc., or which receive at intervals the contents of trucks or railway wagons, and serve the purpose of paying the material out in a uniform stream, thereby converting an intermittent supply into a continuous one.

The elevator should always be fed from that side on which the buckets ascend, so that the stream of material runs into the elevator buckets, meeting them on their upward journey. This will prevent the material from falling into the elevator well, and does not necessitate the buckets dredging through an accumulation of feed. If elevators are erected at an incline, it is advisable, where possible, to feed them at a point several feet above the well into the up-going strand, as in this case very little will miss the buckets and drop into the well.

Double Chains for Large Elevators.—For elevators of very large capacity two or more strands of chain are sometimes used to support the buckets, but there is a drawback to the employment of multiple strands when using ordinary malleable-iron chains, as the different strands are apt to stretch or wear unevenly and throw the buckets out of parallel with each other. It is therefore always best, when possible, to use one chain of sufficient strength, or chains with double links, that is, two links cast together with a web in the middle. These remarks refer only to ordinary malleable-iron chains, and not to steel or wrought-iron link chains, which are jointed together by steel bolts through bored holes. This latter kind of chain is always used for elevators of large capacities and for heavy materials, such as coal, and runs over polygon or sprocket wheels.

Position of Elevators and their Speed of Running.—The reason why an elevator should sometimes be vertical and sometimes set in an inclined direction is this. In elevating materials of low specific gravity an elevator can be driven at a much higher speed than the elevator which is handling material of higher specific gravity, as a velocity of the material at the delivery which would not injure grain would break up coal and other heavier and friable products. Moreover, the receiving spouts and shoots would be quickly destroyed by the impact of the material. Elevators in a vertical position are therefore only suitable for specifically light material, and can be run at a circumferential velocity of 250 to 350 ft. per minute. Elevators for heavy material must be either wholly or partially inclined, to give a clean delivery without scattering at the much lower speed of 50 to 160 ft. per minute. At a speed of 180 ft. per minute the centrifugal force which helps fast elevators to give a clean delivery ceases altogether, so that the stuff simply falls out by gravity in slow elevators. It is for these reasons that slow elevators for specifically heavy material require so much larger buckets, chains, etc., than grain elevators of the same bulk capacity.

There is a second reason why it is essential to run an elevator for heavy material up an incline, namely, the fact that it is more easily driven; for part of the load is then borne by the inclined supports instead of the whole weight hanging from the driving gear, as in the vertical elevator. The angle at which to fix an elevator in order to get the most favourable results, without occupying too much space, is 45° to 60° to the horizon.

The speed of elevators, which are fixed in a perpendicular position for dealing with grain, etc., depends upon the diameter of the pulley, *i.e.*, the pulley on which the band which carries the buckets is running, because such an elevator, in order to deliver perfectly, must throw the grain a certain distance, which is equal to the radius of the

pulley plus about 1 ft., in order to clear the preceding buckets and to reach the discharge spout, except in cases where special buckets—referred to later—are used. The elevator buckets generally begin to discharge when in the highest position on top of the pulley. To effect perfect discharge from a perpendicular elevator the centrifugal force must be sufficient to overcome the gravity of the material, so that for a specifically heavy material it is necessary to have a greater centrifugal force, *i.e.*, higher speed of elevator than for a specifically lighter material, as no matter with what velocity a body may be thrown off tangentially from the elevator pulley, the moment it is free from its support the attraction of the earth asserts itself and causes the body to eventually fall. If the direction of the material is horizontal, as is the case in the delivery from a vertical elevator, the attraction of the earth causes the body to move in a parabolic curve, and the heavier the body, the more will its path deviate from the horizontal at every instance (see Fig. 7). A light body at a given linear velocity will proceed in an approximately horizontal line for a longer distance than a heavy body, as the earth's attraction is more or less counteracted by the friction of the atmosphere.

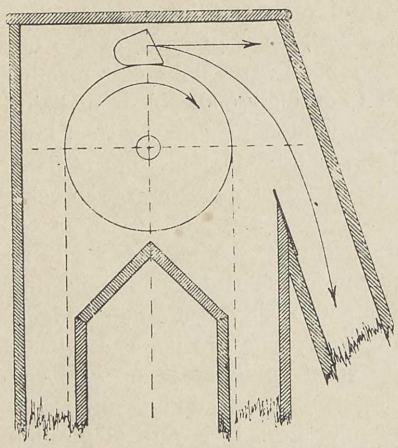


Fig. 7. Diagram showing Discharge of Elevator Bucket.

The centrifugal force of pulleys revolving at the same speed is in direct proportion to the diameter of the pulleys. For example, in a 2-ft. pulley it will be twice what it is in a pulley 1 ft. in diameter running at the same speed; when the speed of an elevator pulley of a given diameter is increased, the centrifugal force increases in proportion to the square of its velocity; consequently the centrifugal force of a pulley 2 ft. in diameter, running at 50 revs. per minute, will be four times the centrifugal force of a pulley of the same diameter running at only 25 revs. per minute. This indicates clearly that in the case of grain elevators it is quite inaccurate to estimate the number of revolutions of the elevator pulley by a fixed belt speed for pulleys of all sizes, which is a mode of calculation too frequently adopted.

In addition to what has been mentioned concerning clean delivery at the top terminal of elevators, the shape of the elevator buckets—correctly chosen for each material—determines also to some extent the useful effect of the theoretical capacity of elevators; for this depends upon the amount spilled on the up-going strand, and that spilled at the top terminal between the buckets and the delivery shoot. If a shallow bucket, intended for soft and clinging materials, is employed for sharp or lively materials, it will fill itself with more than it can carry, and some will fall back at the point where the elevator band begins to turn over the top terminal pulley. A soft and clinging material will fill such buckets equally full, or perhaps even more so, but owing to its nature it will not spill out. The efficiency of elevators finally depends upon the regularity of the feed, so that the buckets are not sometimes overloaded and sometimes only partly full. This can be regulated by a feeding device, as described on page 202.

A grain elevator which has come under the special notice of the author is one in a large Cardiff flour mill. The pulleys are 24 in. diameter by 18 in. on face, and the speed is 60 revs. The buckets are 15 in. wide, project $6\frac{1}{4}$ in. from the band, and are 17 in. pitch. The belt speed is 375 ft. per minute, and 265 buckets passing

per minute is 15,900 per hour. Each bucket holds 10 lb. of wheat, so that the theoretical capacity of this elevator is 159,000 lb., or 71 tons per hour. The actual average capacity is 60 tons of wheat per hour, equal to an efficiency of 85 per cent.

SPEED AND CAPACITY OF GRAIN ELEVATORS OF DIFFERENT SIZE

Diameter of Pulley.	Width of Pulley.	Size of Buckets.	Pitch of Buckets.	Revolutions per Minute.	Speed of Belt per Minute in Feet.	Capacity in Tons and Bushels per Hour.	
Inches.	Inches.	Inches.	Inches.			Tons.	Bushels.
18	11	9×4	17	58 to 62	280	13½	500
21	13	11×4	17	52 „ 56	300	27	1,000
24	15	13×5	18	48 „ 52	310	40	1,500
27	17	15×5	18	44 „ 48	320	45	2,000
30	19	17×5	18	40 „ 44	330	70	2,500
33	21	19×6	19	38 „ 42	340	81	3,000
36	23	21×6	19	36 „ 40	350	95	3,500
42	25	23×7	20	32 „ 34	360	108	4,000
48	26	24×8	21	31 „ 33	400	140	5,000
60	26	24×8	21	31 „ 33	500	170	6,250
72	26	24×8	21	31 „ 33	600	203	7,500

Probably the largest grain elevator in the United Kingdom is that at the Manchester end of the Manchester Ship Canal, which has a lifting capacity of 350 tons per hour.

The following table of capacities of elevators running at different speeds was given by Mr P. W. Britton in his paper on the "Transport and Storage of Grain,"[1] the buckets being 12 in. apart.

Size of Buckets.	Number of Bushels Raised per Hour.		
	Speed = 200 Feet per Minute.	Speed = 300 Feet per Minute.	Speed = 500 Feet per Minute.
6 inches by 4 inches - - -	275	412	687
8 „ 5 „ - - -	600	900	1,500
10 „ 5½ „ - - -	850	1,275	2,125
12 „ 6 „ - - -	1,300	1,950	3,250
14 „ 6 „ - - -	1,600	2,400	4,000
20 „ 6 „ - - -	2,275	3,412	5,687

If placed at any further distance apart, the capacity would diminish in direct proportion, so that with elevator buckets spaced 2 ft. apart, the capacity of the respective elevators would only be half that given in the table.

Unless buckets are of special construction, such as those shown in Fig. 15, it is advisable to keep a space between them not less than that occupied by one bucket, so that an elevator thus fitted with ordinary buckets would be of half the capacity of that of the elevator shown in Fig. 15, provided the buckets themselves were in both cases of the same capacity.

[1] *Proceedings Inst. C.E.*, vol. cxxvi., 1895-96.

In cases where it is necessary to employ large top terminal pulleys (3 ft. and over) in order to obtain delivery of a desired quantity in a given time, the bottom terminal pulley may be of smaller size, in which case the elevator legs are not parallel, but at an angle with the axis of the elevator. Fig. 8 illustrates the usual form of grain elevator.

Speed and Capacity of Mineral Elevators.—As regards data for mineral elevators, it is exceedingly difficult to tabulate such information, as the speed and consequently the capacity of such elevators vary greatly with the nature of the material to be elevated, whether hard, tough, or friable. While it is usual to run coal elevators 90 to 130 ft. per minute, according to the friability of the coal coke elevators run only

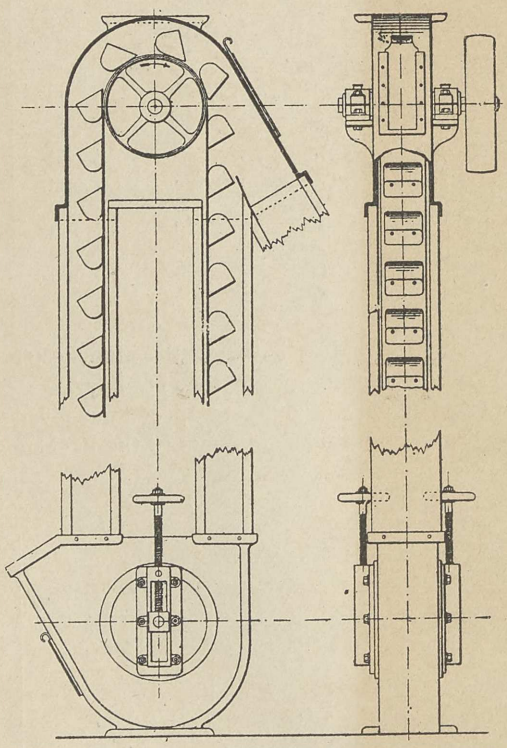


Fig. 8. Usual Form of Grain Elevator.

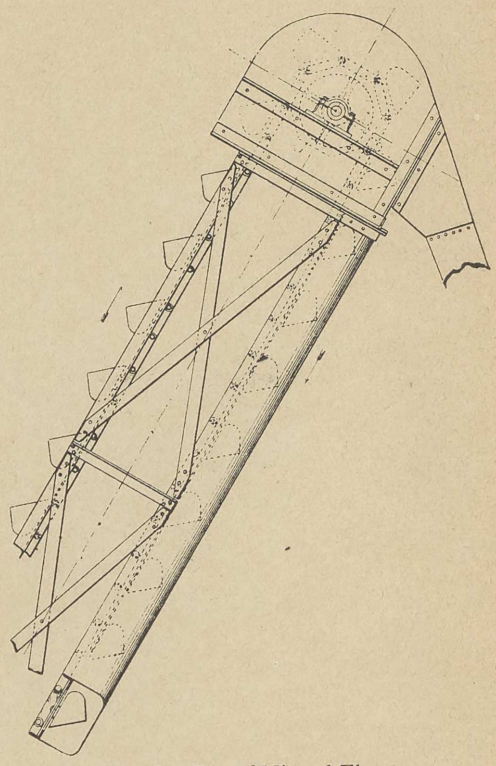


Fig. 9. Top of Mineral Elevator.

at 50 to 90 ft. per minute; while, on the other hand, minerals which do not deteriorate through breakage may be elevated at the rate of 120 to 160 ft. per minute.

The capacity of such elevators depends of course on the speed of travel and on the size and pitch of the buckets. The following table gives a few particulars of the speed and capacity of coal elevators:—

Width of Buckets.	Pitch.	Speed of Travel.	Delivery.
Inches.	Inches.	Feet per Minute.	Tons per Hour.
12	18	120	20
18	18	120	30
24	18	120	40

Figs. 9 and 10 show the most common form of mineral elevator, Fig. 9 representing the top and Fig. 10 the lower part of the same elevator.

Devices to Ensure Clean Delivery from Slow-Running Elevators.—Fig. 11 shows a form sometimes adopted for slow-running elevators, and when the material is of a sluggish nature and not, therefore, discharged readily out of the buckets, or where local conditions, such as want of space, etc., make it necessary to fix the elevator at a steeper incline than 60°. It is apparent that such an elevator as is shown in Fig. 11 must have double strands of chain placed on either side of the buckets,

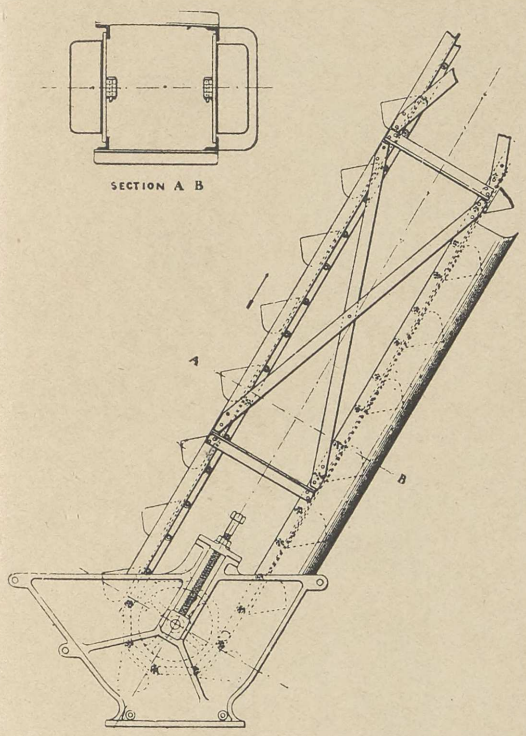


Fig. 10. Well of Mineral Elevator.

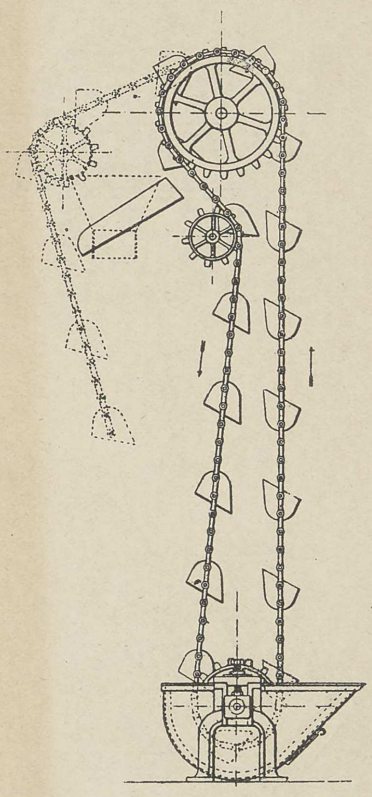


Fig. 11. Special Form of Elevator which Facilitates Delivery.

so that the guide wheels which curve the chain may not foul the buckets. Similar elevators are, however, made with single strands of chain with skidder bars which slide round two angle-bar curves instead of the guide pulleys. This construction is, however, only advisable for small installations.

The same idea is further developed by the adoption of two upper terminals, so as to give the elevator chain a horizontal run between these two terminals (see Fig. 12). A push-plate conveyor is shown as an addition to the elevator, which gives a good idea of the delivery.

The Link Belt Company have adopted an ingenious device to get a clean delivery from a slow-running elevator in a vertical position. It consists of a series of wrought-

iron shoots fixed to the top terminal sprocket wheel (see Fig. 13).[1] These shoots proceed in turn to each bucket at the point of delivery, and lead the material to the

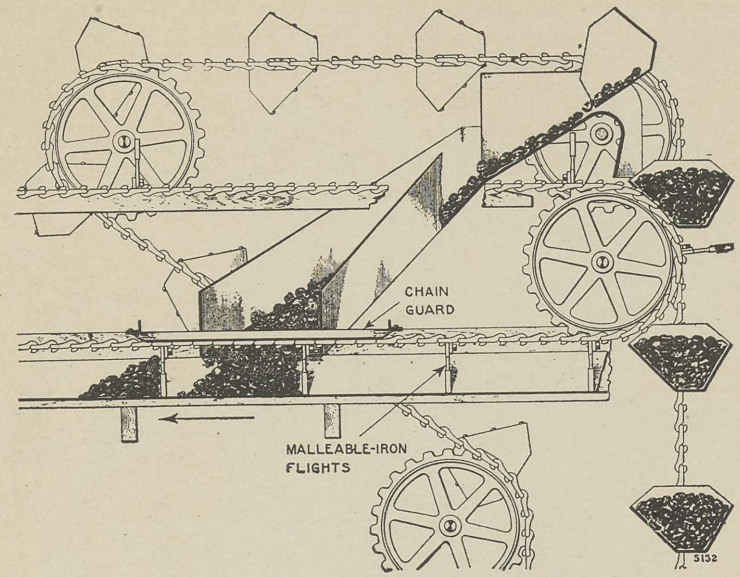


Fig. 12. Elevator with Two Upper Terminals.

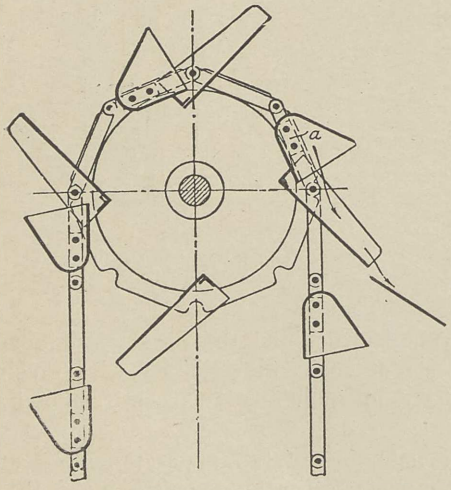


Fig. 13. Top Terminal of Elevator Fitted with Delivery Shoots.

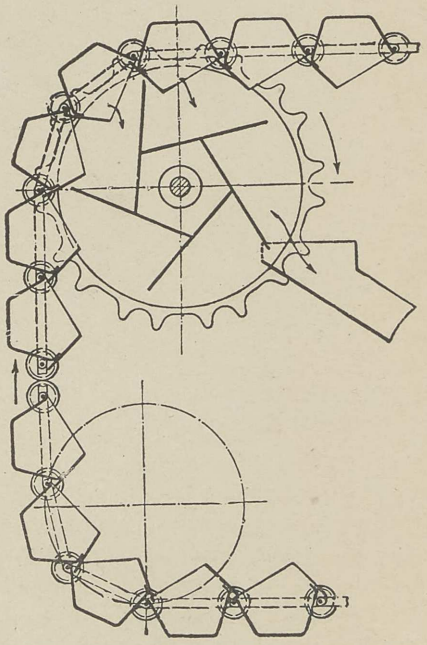


Fig. 14. Elevator with Delivery Shoots between the Top Terminals.

outlet of the elevator. This construction necessitates a double strand of chain, and a pitch of buckets sufficient to clear the revolving shoots.

[1] Hanffstengel, "Die Förderung von Massengütern."

An elevator with one or more upper terminals and two lower terminals is shown in Fig. **14**. In addition to special delivery facilities, it has the peculiar attribute of being capable of conveying horizontally between the two lower terminals, but whether it has one or two top terminals it can only deliver at that point where the chain of buckets traverse the first top terminal. The delivery is unlike that of other elevators, being towards the terminal instead of away from it. In order, therefore, to get a clear delivery the top sprockets are fitted with five plates, filling the space between the two sprocket wheels, and thereby forming revolving delivery shoots, each of which receives the contents of two buckets and leads the material into the delivery shoot proper.

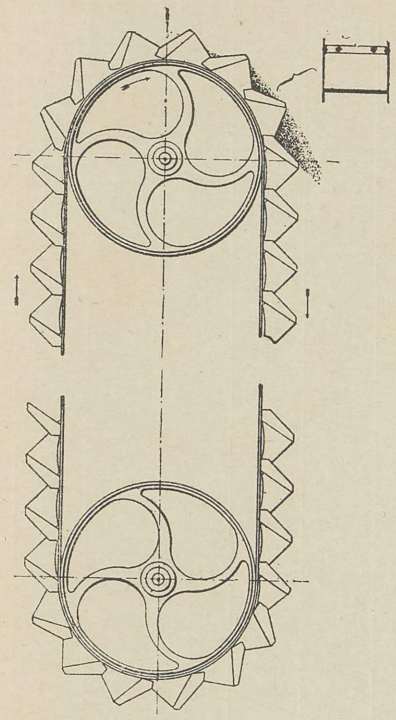


Fig. 15. Continuous Bucket Elevator for Grain.

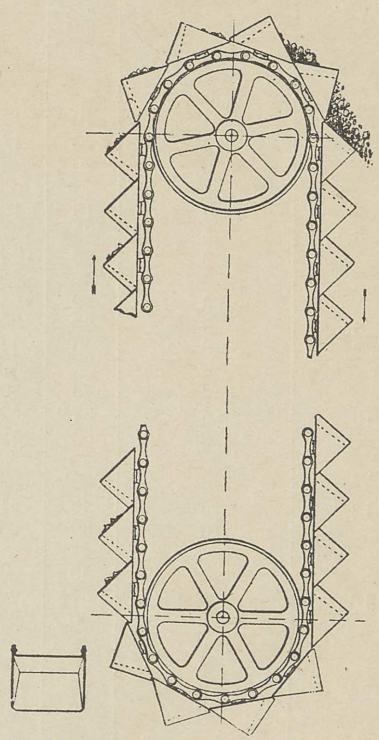


Fig. 16. Continuous Bucket Elevator for Minerals.

Continuous Bucket Elevators.—A very economical form of elevator is one fitted with a continuous chain of buckets. This kind is naturally of a much larger capacity than an ordinary elevator of the same dimensions. It takes and delivers its load with more uniformity, and as the buckets need not plough intermittently through the contents of the elevator well, smoother running is secured. Fig. **15** shows such an elevator for grain, and Fig. **16** for minerals.

The table on the next page gives dimensions of continuous elevator buckets for grain and their capacities in tons per hour at varying speeds.

Elevators for Coke.—The buckets used for coke elevators should be of malleable castings with strengthened lips. They should have skidder bars rather than rollers fixed to the axles, running on the angle iron forming the framework of the elevator on the upward and downward paths. The buckets should also be placed nearer each other

than usual, with the intervening space covered by a light plate, so as to keep all dust from the links and other moving parts.

The shape of the buckets and the angle of the elevator should be so arranged as to give a clean discharge without further devices. The capacity of the elevator must be quite equal to what the conveyor feeding it can ever bring to it, to suit the conditions of discharging from the retorts, which might be almost continuous or very intermittent.

Width of Bucket.	Projections of Bucket.	Speed of Elevator Belt in Feet per Minute.								
		250	300	350	400	450	500	550	600	650
Inches.	Inches.									
	4	10	12	14	16	18	20	22	24	26
4	5	15	17	19	21	23	25	27	29	31
	6	20	22	24	26	28	30	32	34	36
	4	15	18	21	24	27	30	33	36	39
6	5	22½	25½	28½	31½	34½	37½	40½	43½	46½
	6	30	33	36	39	42	45	48	51	54
	4	20	24	28	32	36	40	44	48	52
8	5	30	34	38	42	46	50	54	58	62
	6	40	44	48	52	56	60	64	68	72
	4	25	30	35	40	45	50	55	60	65
10	5	37½	42½	47½	52½	57½	62½	67½	72½	77½
	6	50	55	60	65	70	75	80	85	90
	4	30	36	42	48	54	60	66	72	78
12	5	45	51	57	63	69	75	81	87	93
	6	60	66	72	78	84	90	96	102	108
	4	45	54	63	72	81	90	99	108	117
18	5	67½	76½	85½	94¼	103½	112½	121½	130½	139½
	6	90	99	108	117	126	135	144	153	162
	4	60	72	84	96	108	120	132	144	156
24	5	90	102	114	126	138	150	162	174	186
	6	120	132	144	156	168	180	192	204	216
	4	75	90	105	120	135	150	165	180	195
30	5	112½	127½	141½	157½	172½	187½	202½	217½	232½
	6	150	165	180	195	210	225	240	255	270

General Remarks Concerning Elevators for Grain and other Light Materials.—The driving spindle of the upper terminal should be sufficiently strong to support the weight of the elevator itself as well as the load to be conveyed; the pulley and spindle at the lower terminal are merely guides to keep the belt taut and in the proper position. The elevator foot should be fed at a point not lower than the centre of the pulley, while the discharge at the elevator top should not be higher than the level of the under side of the internal pulley. If the delivery spout be placed higher than this, some of the material will miss the spout and drop into the elevator well, causing a draught of air and an overloading of the elevator, with consequent loss of power, as in such a case a proportion of the material will be carried round and round. The draught of air caused by the particles falling into the elevator well is perhaps of

small consequence when dealing with whole grain, but when elevating flour or finer light material this draught of air is most objectionable, as the dust blows out through all the crevices of the elevator casing, and if any door in the elevator is opened a blast of dust will issue from the opening. If, however, the discharge spout be placed about level with, or, better, a few inches below the under side of the pulley, the discharge will be a perfect one, provided the elevator is running at the correct speed, and the buckets of proper form.

Usually these elevators are cased in a wooden box or pair of boxes or trunks which enclose the elevator legs. A space of $1\frac{1}{2}$ to 2 in. should be allowed between the buckets and the trunk in order to obviate any possibility of the buckets touching the trunk;

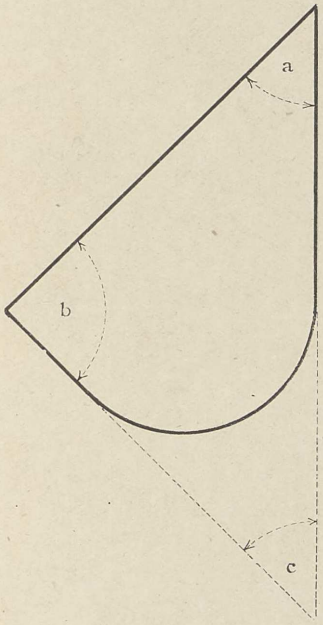


Fig. 17. Bucket for Soft Material.

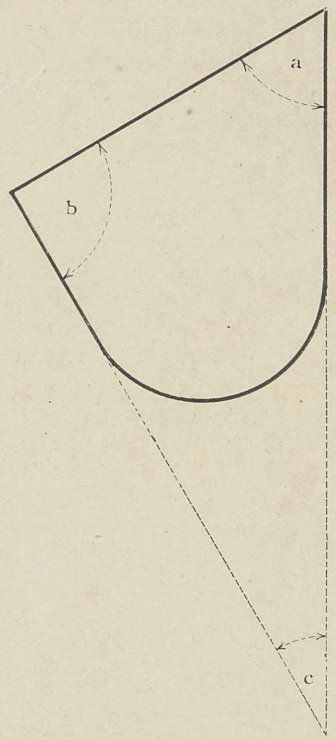


Fig. 18. Bucket for Granular Material.

and further, if the buckets are fitting too close, they are also apt to act as a fan and create a draught, which means dust.

The elevator top which covers the pulley, and which also carries the bearings for the top spindle, may be made either of wood or iron. For ordinary use in flour mills and other factories dealing with light material wood is preferable, as it is easier to attach to the woodwork of the roof or the floor of the building. Iron elevator tops are used in cases where the trunking is also made of iron, in order that it may be fireproof. This particularly applies to the wheat-cleaning department of flour mills, to provender mills, or to fireproof factory buildings.

It is advisable to vary the shape of the buckets for the different products they have to handle. A shallow bucket is best for soft and clinging material such as flour, cement, fine or moist sugar, etc., whilst for harder material, such as cereals, etc., a deeper bucket

will be found preferable. The buckets often met with in older flour mills are of such a shape as to make a proper discharge of their contents well-nigh impossible.

Figs. 17 and 18 show two elevator buckets, the former for soft and clinging material, and the latter for more granular material. The former will be found to fill easily and discharge freely such material as flour, etc. A bucket such as is shown in Fig. 18, if used for soft material, would in many cases not fill completely, but would only allow a heap of stuff to rest on the top, leaving a hollow in the lower portion of the bucket; on ascending, the material frequently drops down to the bottom of the bucket, and when it reaches the discharge spout it will not empty in time to fall into the discharge shoot, consequently some of its load will miss the spout and fall down the elevator trunk. In the bucket shown in Fig. 17, the angles *a b c* should be 45°, 90°, and 45° respectively; whilst in Fig. 18 they should be 60°, 90°, and 30°. The buckets should be made of sheet iron or steel, and riveted or soldered together; the most modern and best buckets are, however, stamped out in one piece of mild steel. The attachment of the buckets to the elevator band is best effected by bolts with mushroom-shaped heads. Clips, which were formerly used for this purpose, lack strength and are liable to break.

In selecting an elevator it is well to allow a liberal margin in its capacity, unless an automatic feeding device is used.

In the following table will be found suitable sizes for flour-mill elevators, with other useful information :—

Size No.	Diameter of Pulley.	Width.	Revolutions per Minute.	Bucket.			Pitch of Bucket.	Capacity in Bushels per Hour.
				A. Length.	B. Width.	C. Depth.		
	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.	
1	9	5	80	$3\frac{1}{2}$	$2\frac{1}{2}$	2	12	25
2	12	6	75	$4\frac{1}{2}$	3	$2\frac{1}{2}$	12	40
3	15	7	60	$5\frac{1}{2}$	$3\frac{1}{2}$	3	15	90
4	18	8	55	$6\frac{1}{2}$	4	$3\frac{1}{2}$	15	145
5	21	9	50	$7\frac{1}{2}$	$4\frac{1}{2}$	4	18	200
6	24	10	45	$8\frac{1}{2}$	5	$4\frac{1}{2}$	18	400

As the different products in a flour mill vary greatly in specific gravity, a further table is appended in which is given in hundredweights the capacity of different sized elevators when working on different products.

The numbers of elevators given in the top row correspond with the dimensions and particulars given in the previous table. The last four lines of the table refer to the products of the breaks of a flour mill, and the weights are based on a sample of wheat weighing 60 lb. to the bushel. Different break products are marked 1, 2, 3, 4, and refer to the break meal as it comes from the break roller mills and enters the elevators. The weights of the various materials per bushel have been carefully taken by the author, and can be accepted as reliable.

In these two tables the speeds given for different elevators are good average speeds for handling most materials in a flour mill. When treating semolina and other comparatively heavy and granular materials, as well as in the handling of wheat, an increase of 10 per cent. is admissible; while, on the other hand, with flour and very fine

material a reduction of 10 per cent. on the speeds is to be recommended. All elevators will work fairly well at a small margin on either side of the correct speed.

Elevators handling material of a lighter nature should not have the buckets as close together as in the case of heavy material, if running at the same speed. In elevators for soft material the delivery spout should also be placed at a lower point, as the lighter material is necessarily slower in clearing the buckets, and with buckets too close together a portion of the material will fall on to the back of the preceding bucket instead of passing into the outlet spout.

CAPACITY OF ELEVATORS, WITH VARIOUS FOOD-STUFFS AND INTERMEDIATE PRODUCTS OF FLOUR MILLS, IN HUNDREDWEIGHTS PER HOUR

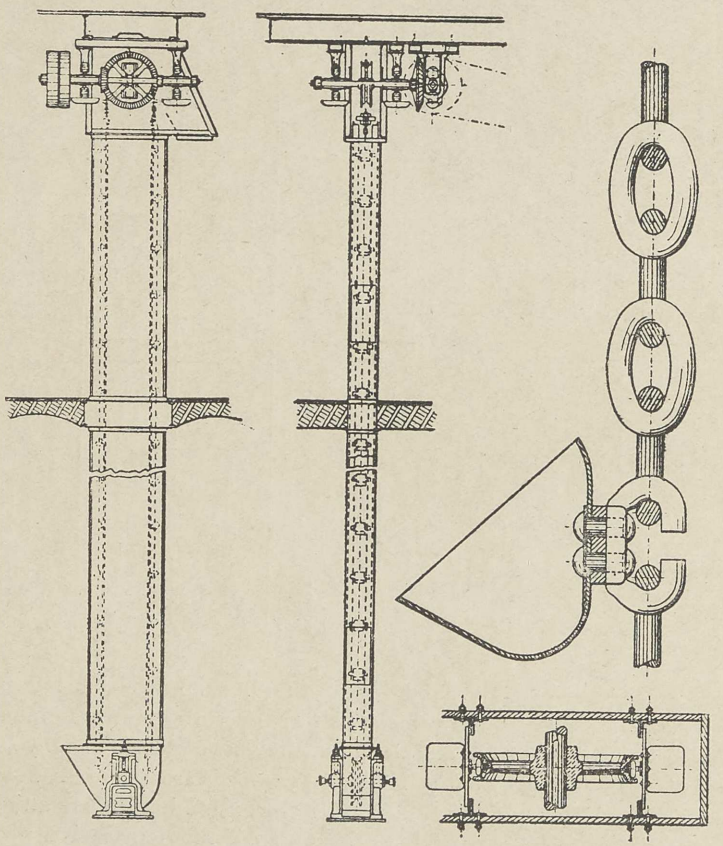
Size of Elevator. (*See previous Table.*)		1	2	3	4	5	6
Wheat		15	24	54	87	120	240
Barley		12	20	45	72	100	200
Oats		10	16	36	58	80	160
Maize		15	24	54	87	120	240
Malt		10	16	36	58	80	160
Beans or peas		16	26	58	94	130	260
Wheat meal or barley meal		10	16	36	58	80	160
Oatmeal		19	15	34	55	76	152
Semolina	Materials handled in Flour Mills	12	20	45	72	100	200
Middlings		11	18	40	65	90	180
Flour		14	22	50	81	112	224
Fine pollard		5	7	16	26	36	72
Coarse pollard or sharps		14	6	14	22	31	61
Chop		12	19	42	68	95	190
Bran		3	5	11	17	24	48
First break		11	18	40	65	90	180
Second break		9	14	31	51	70	140
Third break		5	7	16	26	36	72
Fourth break		4	6	14	22	36	62

If elevators are too small for their load the buckets will be too full, and will commence to spill as soon as they begin to turn over the upper terminal. Flanged pulleys used to be employed for elevators, but they have been generally superseded by ordinary pulleys well rounded on the face. It is most essential that doors should be provided on enclosed elevators for the purpose of examining the elevator top and well. At the former point it will be possible to determine if the delivery is a perfect one, and at the latter to free the elevator easily in the event of a choke. There should also be doors in the elevator legs, preferably on each floor through which the elevator passes if erected in a factory building. At some point in the elevator legs there should be a large door in front as well as at the back of the trunk, preferably near the elevator well. These doors should not be less than 3 ft. in length, and are for the purpose of giving access to the elevator band to allow of shortening it, should this become necessary.

To facilitate tightening, the two ends of the webbing are bound with leather strips about 3 in. wide, and to one end are riveted a pair of straps each some 3 ft. long, and to the other end a corresponding pair of buckles. Whenever the webbing becomes slack it is only necessary to bring this joint to the above-mentioned door and pull up first one and then the other of these straps till the required tension is obtained. Elevator bands

for flour mills and granaries are best made of good textile material, preferably stout cotton webbing. Leather is not advisable, as it never runs as true as a woven band.

The elevator top, if of wood, should always be made in two halves, so that the spindle and pulley can be readily removed for repair if necessary, without dismantling the elevator. The top and bottom spindles must be perfectly level, or the belt will run continually to one side—a fault that is often not discovered until the edges of the webbing begin to fray out. In erecting flour-mill elevators the holes in the floor should be sufficiently large for the elevator trunk to fit easily, and the trunk should not be



Figs. 19 to 21. General Arrangements of Cable-chain Elevator, showing Driving and Tightening Gears.

fixed to the floor, but held in its correct position by wooden fillets, so that should the floor spring under an accumulation of sacks the weight will not be on the elevator leg, nor will the latter be affected by the vibration of the floor.

Iron elevator trunks are often used in fireproof buildings. A very neat way of making them is to use four pieces of sheet iron, the edges of which are slightly bent, while a small pipe open on one side is pushed over these edges in order to fasten them together. If the trunks are made of wood, the point where two boards join should be fitted with iron tongues in order to prevent leakage of dust.

The best and safest plan is to drive each elevator by a separate pulley. Not more

than two should be driven together by the same belt. Frequently a number of elevators are placed in a line, and one driving shaft runs through and drives the whole of the elevators. There are several reasons against this practice. In the first instance, it would be necessary that all the elevators should deliver in the same direction, which

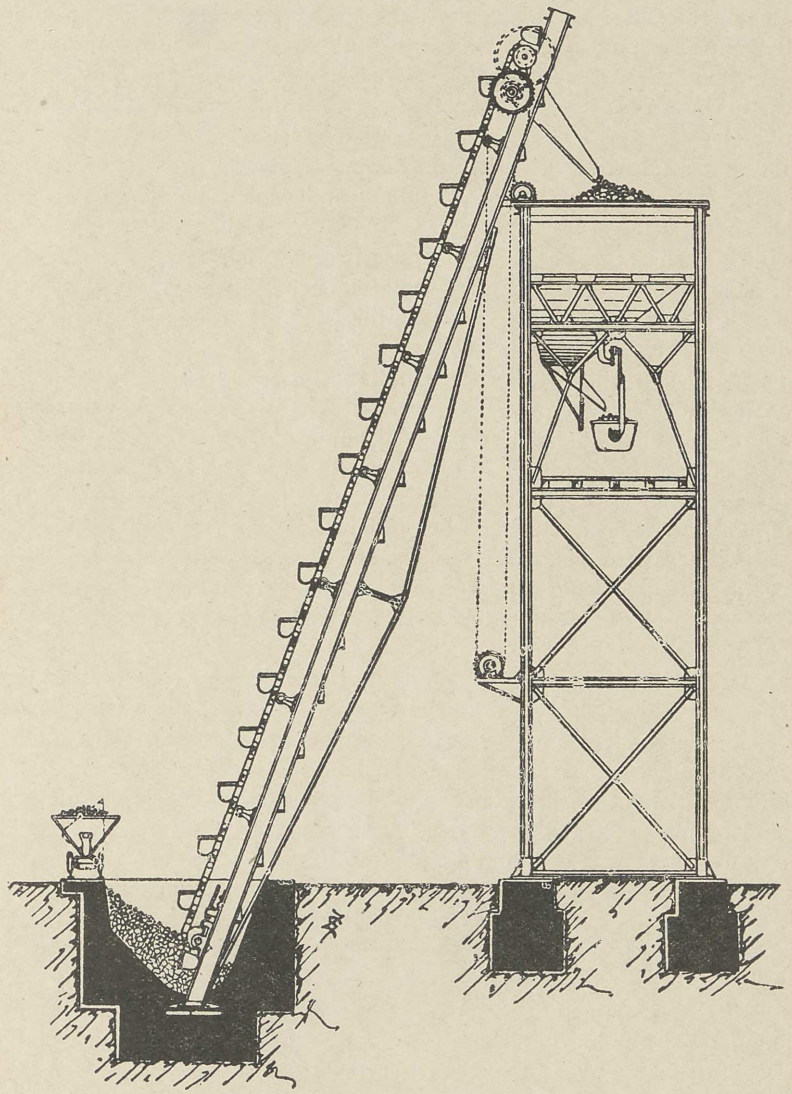


Fig. 22. Mineral Elevator with Concrete Well Feeding Elevated Railway.

may be inconvenient. This difficulty can, however, be overcome by driving the elevator which should deliver on the opposite side by gearing from the shaft passing through the rest of the elevators, making those which ought to deliver in the opposite direction somewhat shorter or longer, in order to make them terminate either under or above this elevator shaft. There are, however, other objections to driving a number of elevators in a line by one shaft. If one of the elevators should choke, the accident is not so

likely to be discovered as in the case of a number of elevators driven singly, for whereas in the latter case the driving belt would come off as soon as the choke took place, in the former the main belt driving the line of elevators would probably, being much stronger, remain in its place, with this result, that the elevator pulley would continue to revolve against the elevator band, which would be held stationary through the accumulation of material. This has frequently been the cause of fires in flour mills, as the friction between the pulley and the band would be sufficient to cause the latter to ignite. The only advantage of having the elevators in one line and driven by one shaft is the saving of expense, and on that account this practice is too often followed, but to drive elevators singly or in pairs is far preferable.

Cable-chain Elevators.—Elevators for handling rough and uneven material are sometimes driven by ordinary grooved pulleys and cable chains. Details of such an elevator are shown in Figs. 19 to 21.

The illustration shows the general arrangements of the elevator, with driving gear at the top and tightening gear at the bottom. The chain and one bucket with its skidder bar are shown to a larger scale, while a cross section shows the angle iron against which the skidder bars of the buckets run.

A Type of Simple Mineral Elevator.—Fig. 22 shows a type of construction which is much in favour, the elevator well in this case being a masonry structure and not a complete iron well. This illustration is more intended to show the construction of the elevator itself, which consists of a pair of I girders braced by stays and rods. The two terminals are fitted to the girders in the usual way, the lower one being, as usual, the tightening one. The elevator chain and buckets, instead of being fitted with slats running upon guides, are here supported and held in a straight line by a series of guide rollers, the bearings of which are bolted to the girders on either side. The elevator here illustrated is used for loading a suspended railway by means of a hopper and shoot.

Gear Drives for Elevators.—For very large elevators, especially in cases where the available space does not admit of the internal elevator pulleys (sprocket or polygon wheels) being of large diameter, spur or bevel wheels having a ratio of 1 : 2 to 2 : 3 should be employed, together with a suitable countershaft.

Power Required for Elevators.—This depends, of course, on the height of the elevator and on the weight to be lifted, but for practical purposes not less than twice the theoretical H.P. should be allowed.

Archimedean Screw Elevators.—These are sometimes used, in which case the screw or worm fits fairly tightly into a cylindrical receptacle. Such elevators must be driven 25 to 50 per cent. faster when used for elevating than when used for conveying on the level.

There is no special feature about this particular type of elevator beyond that which will be found under the head of worm conveyors, with the exception that the worm must be of the continuous type, and that the pitch must not be more than half the diameter of the worm. Such elevators can be driven from top or bottom by bevel gear, the latter being the more general arrangement. Such a driving gear is shown in Fig. 23. The upright worm is erected within a receiving hopper, and the grain is admitted from the hopper to the worm by two or more inlets.

Spouts and Shoots.—The spouts and shoots which receive the feed from elevators in immediate proximity to the latter, should always be made of stout wrought iron, or better still, cast iron. For smaller grain elevators, wood, with a sheet-iron lining, will be found sufficient. It is surprising how quickly even cast-iron shoots are worn through

by the constant impact of the grain, not to mention heavier and harder substances. A sheet of india-rubber about ½ in. thick secured to the point of impact will last longer than a cast-iron plate of the same thickness. The shoots themselves should be at an incline of say 5 to 10 per cent. greater than the angle of repose of the materials handled.[1]

Automatic Feeding Devices for Elevators.—If a system of feeding or unloading is employed which is more or less intermittent, and if the material so unloaded is to be handled further by elevators or conveyors so that the further progress is to be continuous, the feed must be changed from an intermittent to a continuous one. The importance of an even feed in all cases is obvious, as too rapid a heaping up of material may lead to chokes, besides causing an unfair strain which might lead to breakages and an undue consumption of power. If the material be delivered from railway or contractors' trucks, ropeway skips, or grabs, the load should be deposited in a hopper (with an adjustable outlet or gate) sufficiently large to hold one charge of the material to be conveyed. The feed of the succeeding elevator or conveyor can be equalised in such a way that the hopper pays out its contents at the rate at which the elevator or conveyor can take it, while the truck or grab brings the next load.

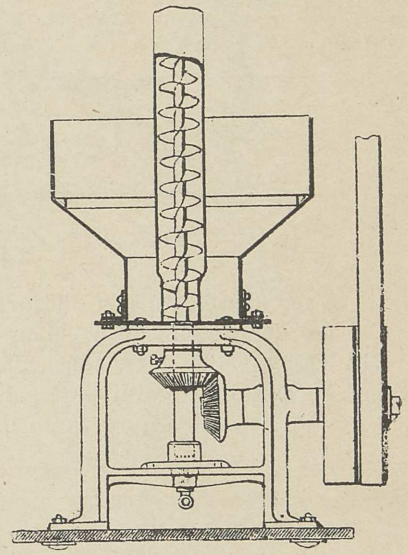


Fig. 23. Driving Gear for Worm Elevator.

In some cases and with some materials it is necessary to provide the exit of the hopper with a mechanical feeding device in order to get uniform delivery. This is the case where the material is not like grain, seeds, or small coal of uniform size, but where large pieces of coal and ore are mixed with the small. One effective device is an inclined table which slides backwards and forwards under the opening of the hopper and allows a certain quantity to leave the hopper at each stroke, which quantity can be adjusted by opening or closing a vertical slide or gate in the side of the hopper. A fairly uniform delivery can also be obtained by having a short spout from the hopper to the conveyor, the incline of which can be varied to give a slower or faster feed. A good plan frequently adopted in gasworks is to fit under the hopper a pair of break rollers which reduce the size of the coal so that it can be more easily handled by the succeeding elevators and conveyors; but even in such cases the feeding devices here mentioned should be used, as the work of a breaker will always improve in proportion to the uniformity of its feed.

Fig. 24 shows a mechanical feeding device for elevators in which a short Zimmer conveyor is used, into which the coal falls through a receiving hopper above. In this case the hopper is fed intermittently by narrow gauge trucks. By the use of a slide or gate the quantity of material it is desired to convey can be regulated. This feeding device can of course be used equally well for feeding other kinds of conveying appliances. It is always well, where possible, to drive the feeding device from the machine which is to be fed, so that when the elevator or conveyor is at a standstill the feed may also automatically cease. This is of great importance, for if arranged otherwise the conveying machine at its feed end would on starting be so full of material, that in attempting to

[1] For inclines of shoots for delivery of coal see page 195.

start it the driving band would most likely come off, or if driven by a chain, breakdowns might take place. The installation shown in Fig. **24** represents the feeding device driven from the lower terminal. This is all right as long as the elevator is a chain elevator, so that its bottom terminal must revolve with the elevator; but such an arrangement would not be suitable with elevators in which the buckets are fixed to a band, as these sometimes slip.

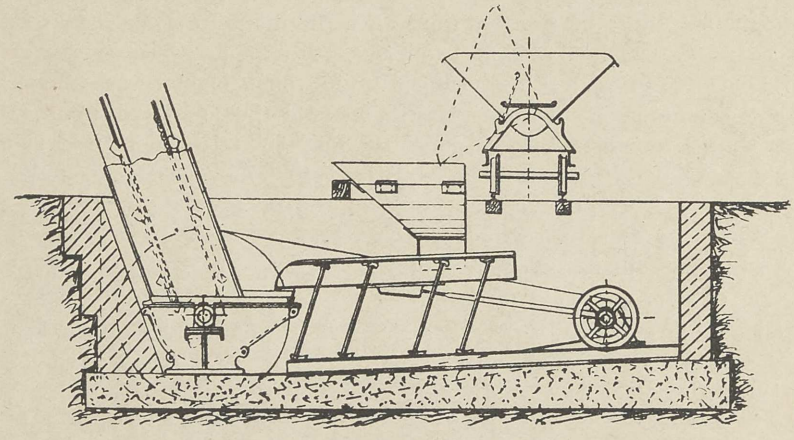


Fig. 24. Mechanical Feeding Device for Elevators.

Another device, which is illustrated in Fig. **25**, consists of a small trough suspended under the delivery end of a bin by four wrought-iron hangers. This shoot is put into oscillating motion by levers attached to one or two of the suspended arms. As the trough swings backward the coal it may contain will not slide backwards with the shoot, but will fall forward through a spout on to the conveyor or elevator to be fed. At the forward

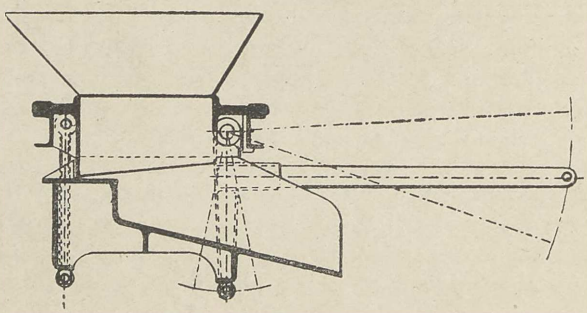
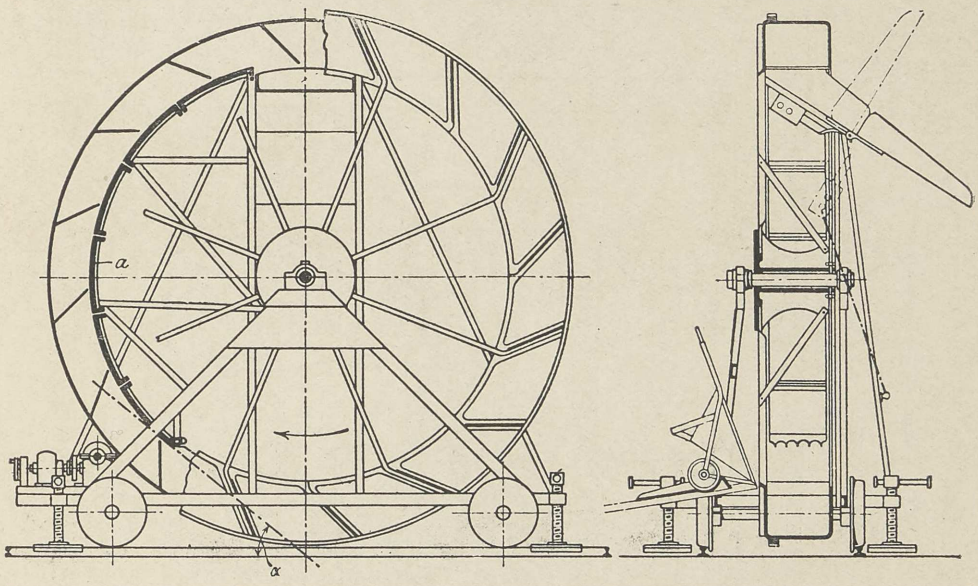


Fig. 25. Oscillating Feeding Device for Elevators.

movement of the shoot the coal from the bin above will slide down into the space that is now left vacant by the pieces that have moved forward, so that the material is gradually and evenly deposited with each backward and forward motion. This shoot is put in motion by a crank and connecting rod in such a way that the throw can be altered at will, and the feed regulated to a nicety. Similar appliances are used in which the shoots are supported on four small rollers moving backward and forward on suitable rails. In such cases the shoot is generally level instead of being at an incline. The speed at which such feeding devices are run depends to a great extent on the size of the material.

If small, the feeding device should take only a little at each movement and repeat the movements frequently; but if the material is large, the movements should be fewer, and a heavier feed should be allowed for each movement. (For other Feeding Devices see Chapter XVIII., page 202.)

An interesting form of elevator,[1] in which both top and bottom terminals are combined into one wheel, the lower part receiving whilst the upper or highest point gives delivery, is illustrated in Figs. 26 and 27. It is used for coaling railway engines, and is installed by the Hungarian Südbahn (Southern Railway) at Nagykanizsa. The apparatus is portable, and consists of a wheel 5 metres, say 16 ft., in diameter, which revolves slowly in the direction of the arrow on its spindle. The boss is long and the spokes are on one side only, to leave the interior of the wheel accessible for the inlet and outlet as well as for the shield *a*. The rim of the wheel is made of channel



Figs. 26 and 27. Coal Elevator in which Both Terminals are Combined into One.

section ⊓ closed at the outside and open towards the middle. This rim is divided into sixteen compartments which represent the elevator buckets.

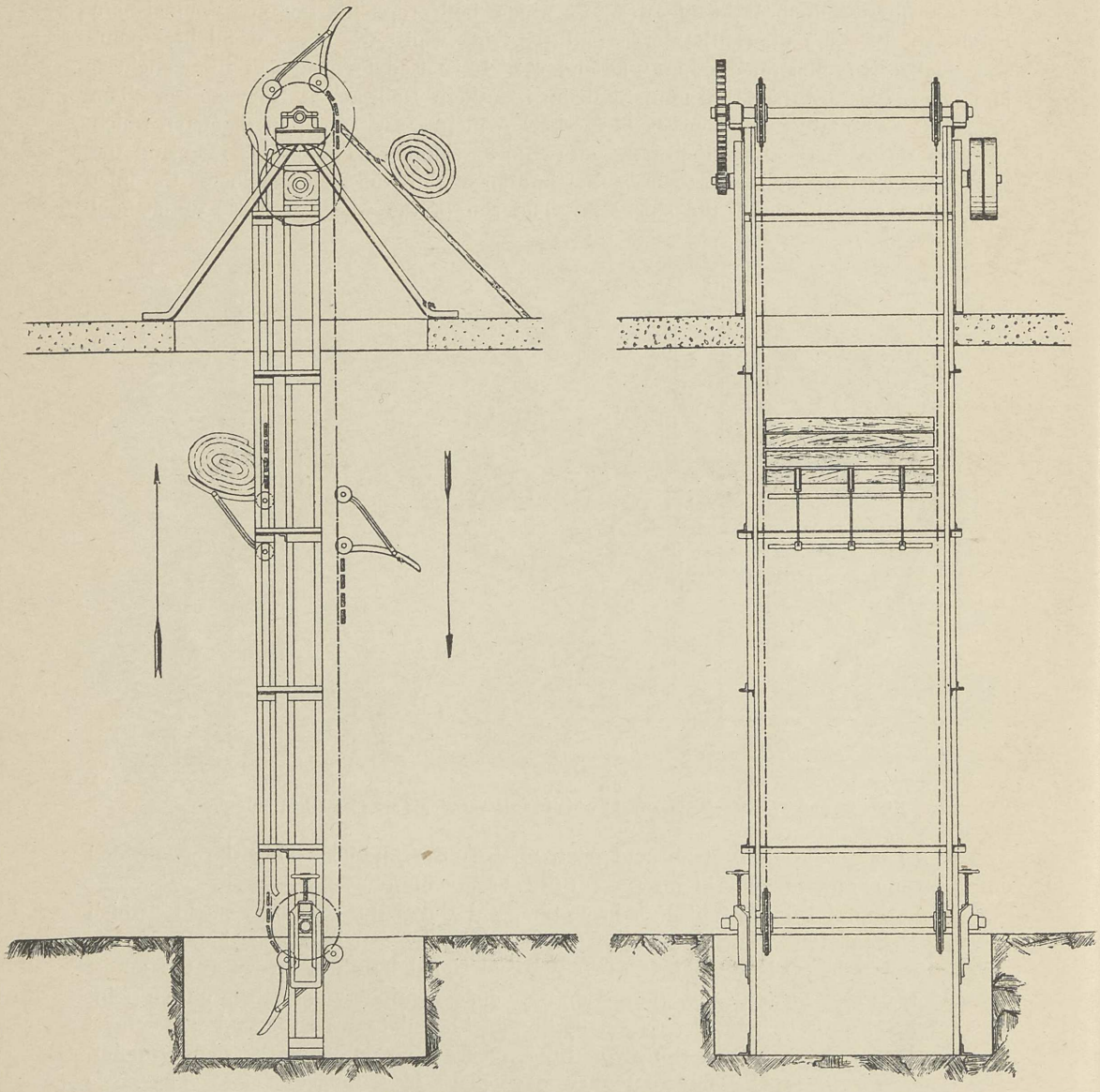
A portion of the illustration is in section, and shows the stationary shield *a* which closes the channel at the inside for that portion where the coal is conveyed more or less on it. It will be understood that when the coal is fed by wheelbarrows at the lowest point, it is carried forward and upward on the outside periphery of the rim until a point is reached, when it is held in position by the shield, and towards the end of its travel it is pushed, as in a scraper conveyor, till it reaches the outlet at the highest point, where delivery to the locomotive tender takes place by a hinged shoot. The angle of repose α of the coal determines the point at which the shield begins.

B.—ELEVATORS FOR LARGE OBJECTS

Elevators of a somewhat similar construction to the foregoing are frequently used for handling sacks, packing cases, carcasses, casks, blocks of ice, etc.; but of course

[1] *Zeitschrift des Vereines deutscher Ingenieure*, 7th August 1909, page 1283.

the elevator buckets, or their equivalents, which have to deal with these large objects, must be shaped according to the loads they are intended to carry. The methods of feeding on or off vary also materially from those elevators described previously.



Figs. 28 and 29. Rigid Arm Elevator.

This does not, however, apply to the elevators for ice in large blocks of say 50 to 60 lb., as these are more like the ordinary elevator but on a very large scale, with double long-link chains running over polygonal terminals. The buckets are a long way apart, so that only one at a time is on the terminal, and the latter is fitted with two revolving shoots for the delivery of the ice. These shoots are similar to those shown in Fig. 13,

but only two buckets instead of four are discharged with each revolution of the terminal.

Rigid Arm Elevators.—The type of continuous elevator shown in Figs. 28 and 29 is extensively applied to the handling of bags, bundles, barrels, and rolls of linoleum, carpets, and felting. The first cost is low, the space occupied small, the power absorbed insignificant, and the saving in labour enormous.

A rigid arm elevator consists of two strands of chain running over two top and two bottom wheels of small diameter, together with the necessary shafts, bearings, reducing gear, and framing. Fastened to the chains at intervals of, say, 10 ft. are projecting arms and struts, shaped to suit the packages to be raised. These arms pick up the packages as fast as they can be placed on the loading grid, and discharge them as the arms pass over the top wheels. Obviously, with this type of elevator there can be only one loading point and one discharge point. Light packages, however, may be removed by hand on the ascending side at any point before reaching the upper terminal.

Similar elevators are used successfully on an incline for handling loose pieces of cloth in finishing factories, wood slats being arranged above the carrying arms to prevent the cloth coming in contact with the chains.

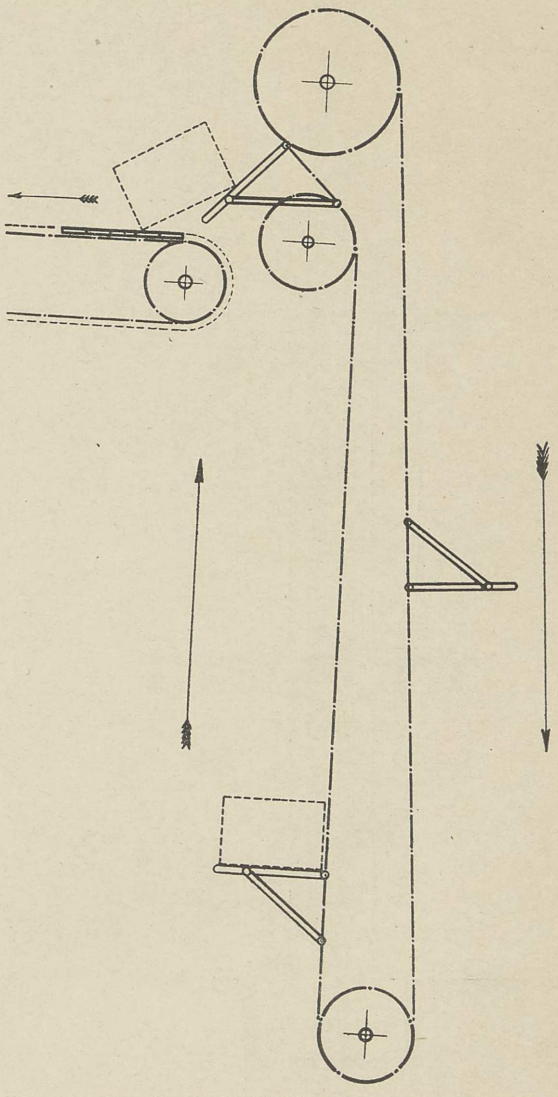


Fig. 30. Type of Rigid Arm Elevator, showing Delivery.

It is sometimes required to discharge the packages on the ascending side of an elevator instead of over the top shaft, and this necessitates a special artifice, as shown by Fig. 30. The top wheels are made of large diameter, and deflecting wheels are added in order to cant the carriers sufficiently for the package to slide off. This principle has been applied to an elevator transferring bales of paper pulp automatically to a slat conveyor erected at a large paper works.

Swing Tray Elevators and Lowerers—A rigid arm elevator is not applicable when several floors have to be served, and where lowering is required as well as elevating. Further, some classes of goods would suffer injury if thrown off upside down

at the delivery point. Hence, for handling goods in bottles, crates, and baskets, the swing tray type of machine is adopted, as illustrated in Fig. 31, which shows an installa-

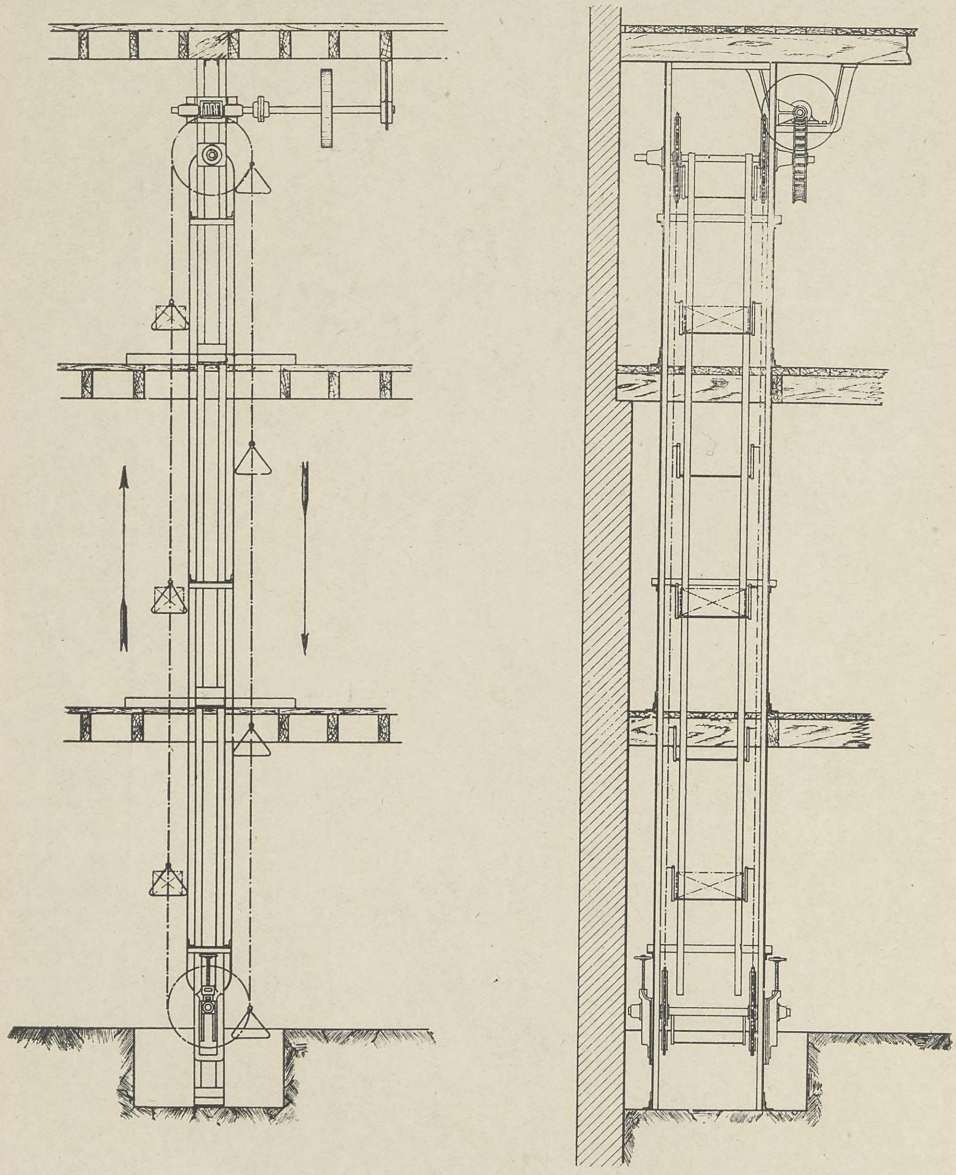


Fig. 31. Swing Tray Elevator.

tion erected by the Chain Belt Engineering Co., Derby, for Messrs W. H. Holmes & Sons, London, for handling tins of paint.

The swing tray elevator or pivoted carrier consists of a series of flat trays or carrying platforms suspended at intervals of a few feet between two endless chains running over top and bottom wheels, together with the necessary driving gear and supporting frame-

work. Guides are also desirable, though sometimes omitted. The packages are generally loaded on the ascending side; but they can be removed from either the ascending or descending trays as may be most convenient. If the packages are not removed at all no harm is done to them, as they simply go round the circuit again. This is a feature of some importance.

Obviously, if the carriers were rigidly attached to the chains the package would be thrown off in passing over the top shaft, but as they are freely pivoted to the chains and the centre of gravity is kept well below the point of suspension, the constant force of gravity preserves the stability of the suspended carriers when passing between the top wheels.

The carrying capacity of a swing tray elevator is very high. Thus, if the trays are placed 5 ft. apart, and the chain speed is only 40 ft. per minute, the rate of working will be 8 packages per minute, or 480 per hour, which can sometimes be increased to twice that number by placing two packages on each tray. Should this rate of working be too great for the particular service required, then the distance apart of the carriers can be increased or the speed of the chain reduced.

The theoretical carrying capacity can be multiplied indefinitely by placing the swing trays closer together and running the chain faster; but the practical limit is fixed by the quickness of the persons feeding and unloading the elevator. This limit is reached when the trays are about 4 ft. apart and the chain speed is about 60 ft. per minute, thus giving a time interval of 4 seconds and a capacity of 15 trays per minute, or 900 per hour.

Naturally the actual rate of working depends a good deal on the size and weight of the packages, the best results being obtained when handling small packages of nearly uniform size and weight. Skips full of cotton cops or bobbins weighing 90 lb., however, can be handled quite successfully at the rate of three a minute, even by young lads, when using suitable loading tables; from which the skips are slid on to the slowly ascending swing trays without being lifted bodily, and slid off the trays at the various unloading points.

The power required to drive a swing tray elevator is surprisingly small. A motor of 1 H.P. is often sufficient, and a large elevator serving seven floors is easily driven by a 5 H.P. motor when handling a steady stream of packages. This economy of power results from the elevator being perfectly balanced, coupled with the slow speed of the main shafts, and the continuous uniform motion of the chains and carriers.

Swing tray elevators are preferably driven at the top and the tension screws placed at the bottom. Then, if the chains are allowed to become slack, their own weight will maintain contact with the top wheels, and the load on the shaft bearings is a minimum. Sometimes these elevators are driven at the bottom, when power is not available on the top floor; but the load on the shaft bearings is thereby increased, and the chain must be kept taut all round the circuit.

It is specially important that the chains should be of ample strength and bearing surface, and provided with suitable attachments for the reception of the pivoted carriers or swing trays. For heavy elevators the Gray pin chain is suitable, while for light duty the Ewart or pinless type of chain is most commonly employed.

Where floor space is restricted and existing machinery is to be cleared, it is sometimes necessary to crank an elevator to get it in the space available, as in the example shown in Fig. 32. This machine lifts and lowers tall cans full of hemp sliver at the rope factory of Messrs Hawkins & Tipson, Blackwall, and was built by the Chain Belt Engineering Co., Derby. It effectively solved a rather difficult problem. Evidently a cage hoist was inapplicable.

Swing Tray or Finger Tray Elevators and Lowerers with Automatic Loading and Discharging Gear are adopted for raising heavier packages than can be moved conveniently by one man, and can often be applied with advantage for

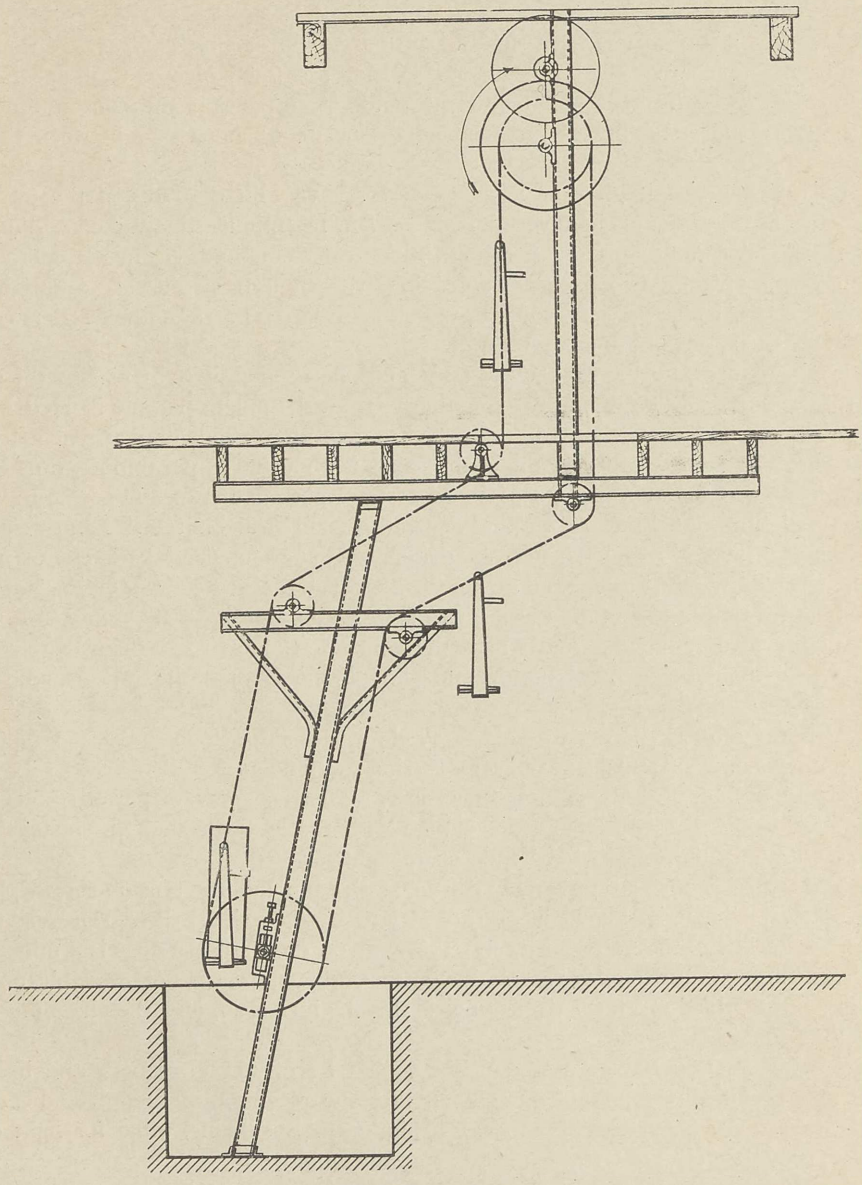


Fig. 32. Cranked Elevator.

much lighter packages, instead of the simple swing tray type. In this modification (Figs. 33 and 34) each pivoted carrier is composed of a centre bar with transverse arms, slung from the chains by two hangers, which are usually malleable-iron castings. At each floor are provided loading and discharging brackets or grids, arranged to intermesh

with the carriers. A box, bag, bale, or barrel placed on any loading grid is gently picked up by the first ascending carrier, taken over the top shaft, and down to the delivery point. Here it meets the inclined discharging arms or fingers, which intercept

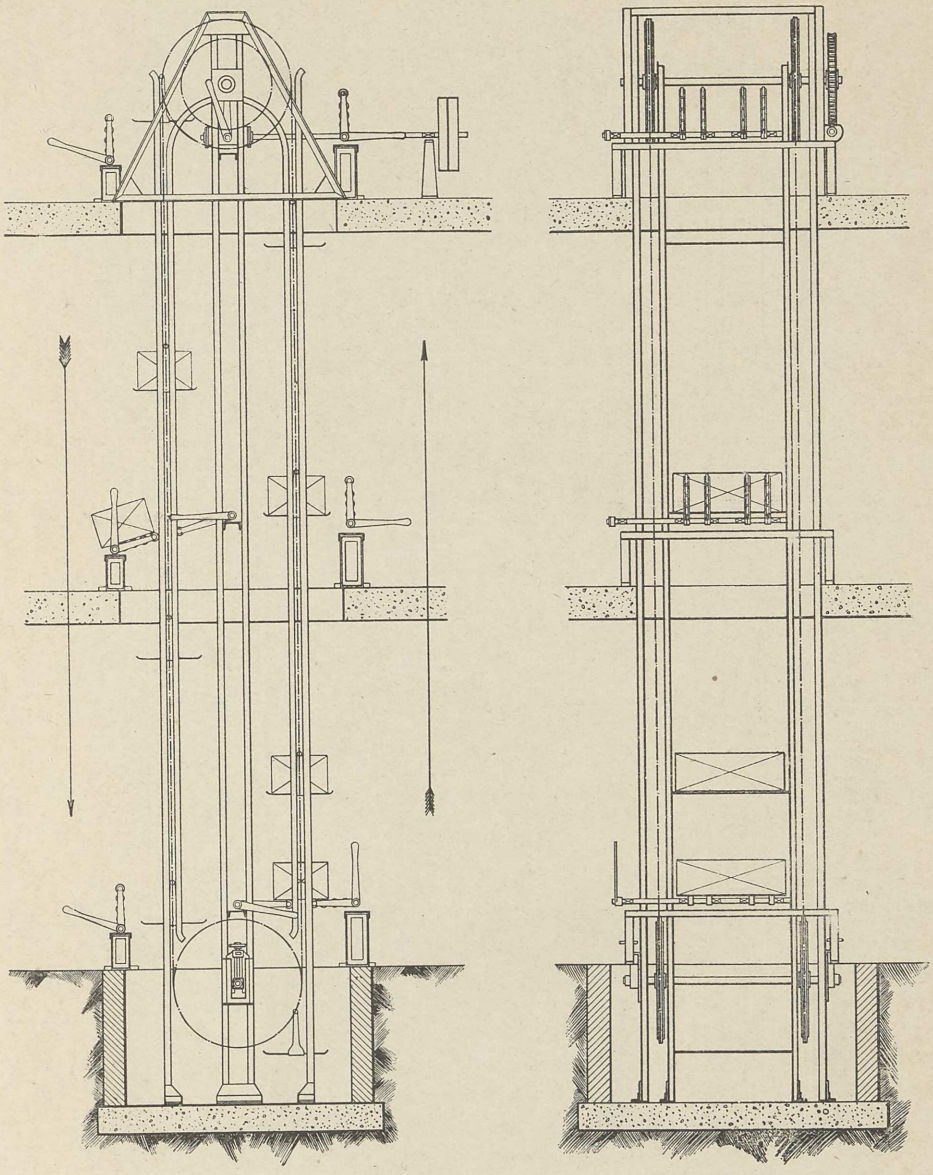


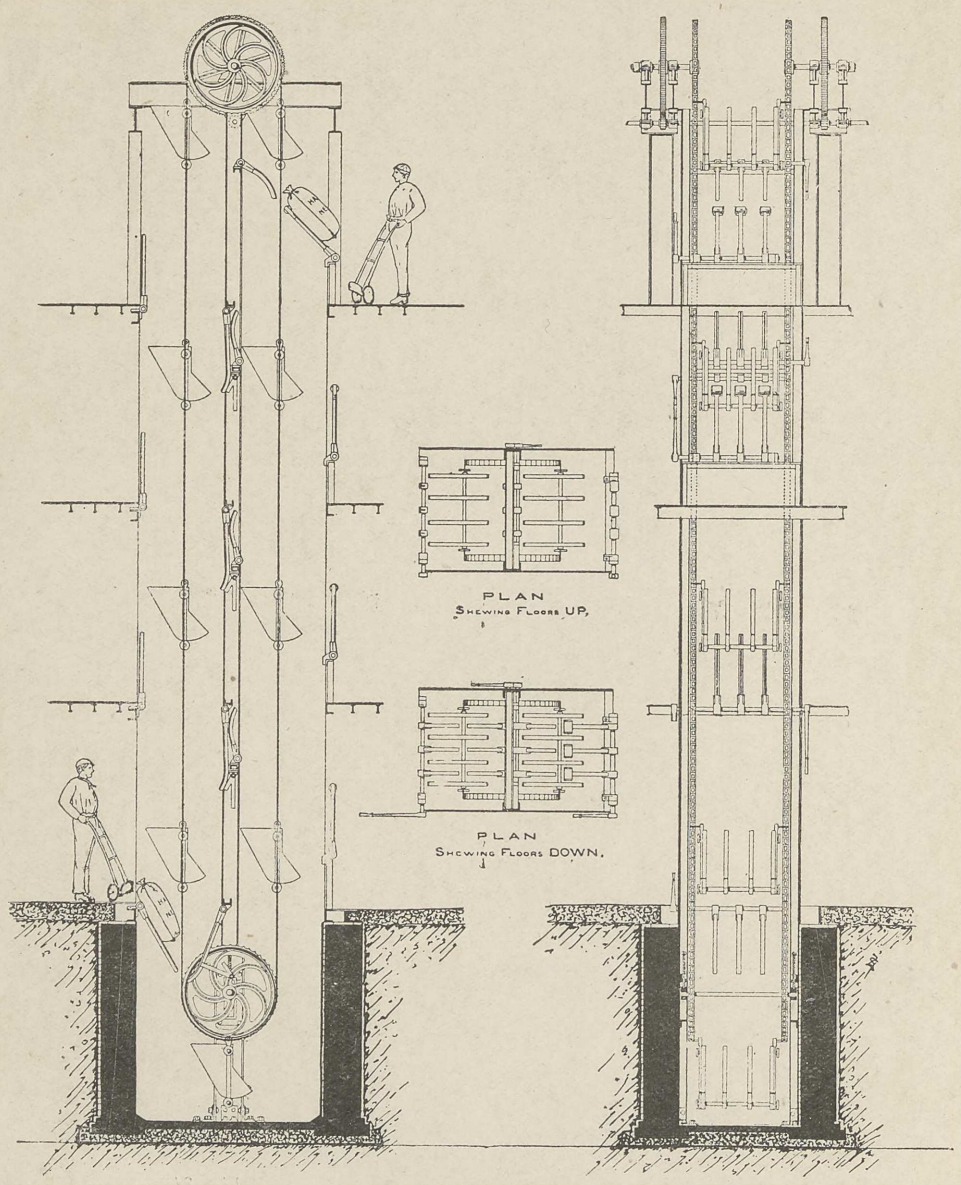
Fig. 33. Fig. 34.

Finger Tray Elevators for Tea Chests, etc.

and remove the package, while permitting the carrier to pass. Both the loading and discharge grids are hinged for throwing them out of position when not in use at any floor, thus enabling the package to pass to the next floor. In this way a regular stream of packages can be delivered automatically at any pre-determined floor. By suitably

shaping the carriers or cradles, the same elevator can be used for handling both boxes and barrels simultaneously.

Hall's Elevators.—The elevator shown in the illustration, Figs. 35 and 36, is



Figs. 35 and 36. Hall's Elevator for Handling Sacks.

for handling sacks; those for handling barrels and carcasses are similar, with this exception, that the appliances for the receiving and delivering of the loads are somewhat different. Fig. 37 shows to a larger scale this portion of elevators for handling sacks, whilst Fig. 38 shows the same for barrels.

Much of the frozen meat, especially mutton, handled in the foreign meat market, is exceedingly hard when it arrives; but some of it, especially chilled beef, is in a very different condition, and the less it is handled the better.[1]

These mechanical devices are therefore very serviceable, not only as labour-saving appliances, but also on account of their ability to handle the material with less injury than is usually the case with hand labour.

The hoist consists of two pairs of chains which run over two pairs of sprocket wheels, one pair being fixed on the top floor and the other on the bottom floor. Attached to the chains at certain intervals are cage-shaped buckets, so arranged as to take sacks, barrels, or the carcasses of animals. Each receptacle will take a whole sheep or a quarter of beef. In the latter case the cages are suspended above their centre of gravity, so as always to be in a perpendicular position. They are loaded on any

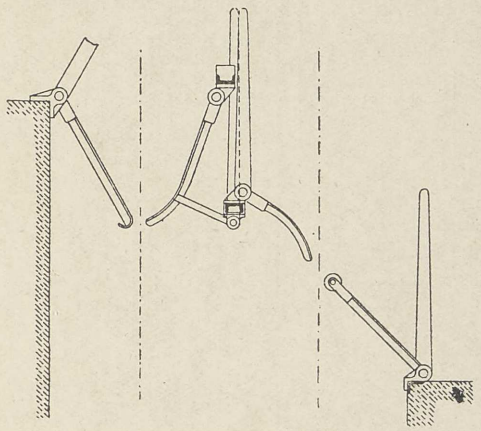


Fig. 37. Elevator for Handling Sacks.

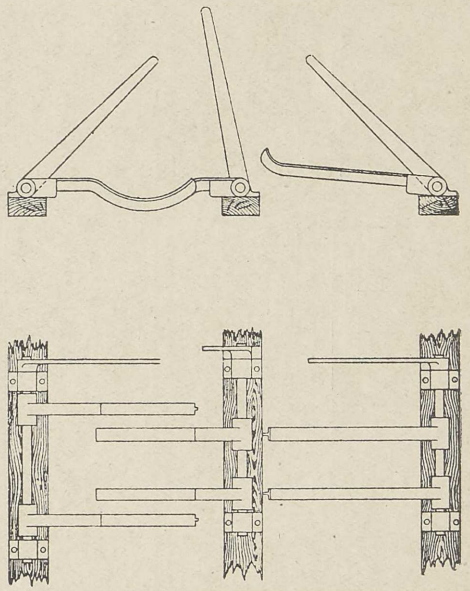


Fig. 38. Elevator for Handling Barrels.

floor that may be convenient and deliver automatically on to any other floor as may be required.

On each floor there is a delivery platform, consisting of five or more steel arms, which may be set to deliver or to receive, or may be moved out of the way altogether by the system of levers which may be worked from any of the floors. Thus at the floor on which the meat, etc., is loaded, the steel platform is set to deliver the carcasses to the cages as they pass, the cages being formed also of steel bars which clear the steel arms of the platforms.

The carcasses are merely placed on these platforms, and find their way, one after another, into the cages as they arrive on the levels of the floors. They pass with the elevator chains over the top sprocket wheels, and as soon as they arrive on one of the delivery platforms the loads are arrested whilst the cages pass on. The platform is inclined at an angle sufficient to allow the load to slide down on to the floor of the

[1] For another form of sack elevator see Figs. 643 and 644.

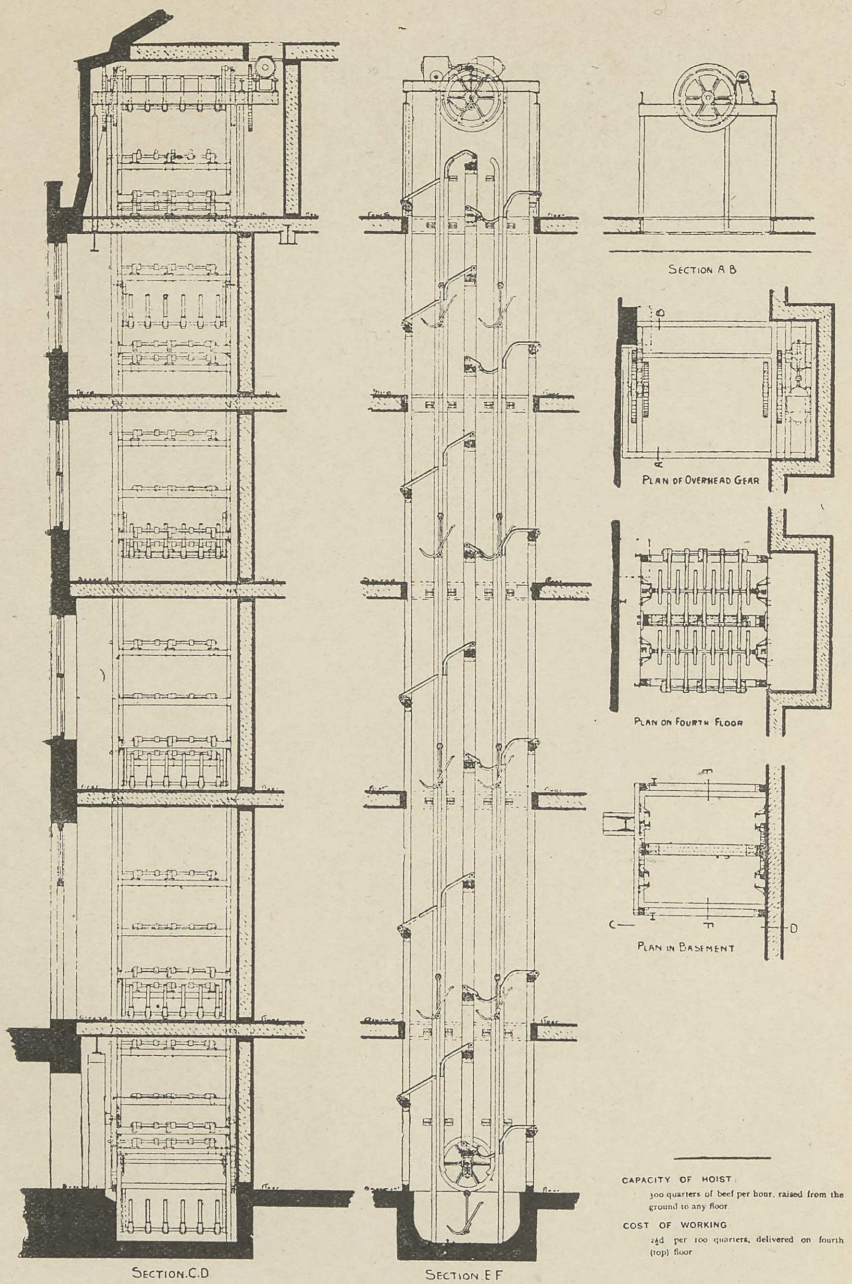


Fig. 39. Hall's Apparatus for Handling Carcasses in Refrigerating Stores.

warehouse. Here the meat is taken up by the man who is attending to the storage, and passed by him into the proper bin.

Fig. **39** represents the apparatus designed for handling carcasses in connection with refrigerating stores in a London meat market.

All the platforms of the floors which are not required for loading and receiving are thrown out of the way by the arrangement of levers already mentioned, which controls the whole system.

Loading, it will be understood, takes place on the rising side of the elevator, whilst delivery is effected on the descending side. Thus if the cage is set to load, say, on the bottom floor of the loading side, the elevator delivers on the other side on the top floor.

All the steel platforms on the loading side may be left undisturbed, as they will be pushed out of the way by the first loaded cage which passes. All those on the delivery side are moved into a vertical position, except those on the top floor, where the carcasses are arrested by a projecting steel platform as previously described, and deposited on the floor.

The illustrations, Figs. **28** to **34**, are from a paper on "Continuous Package Conveyors for Factories" read by Mr W. H. Atherton (General Manager of the Chain Belt Engineering Co., Derby) before the Manchester Association of Engineers on the 15th February 1913; and the appliances shown in Figs. **35** to **39** are the manufacture of J. S. Hall, Newark-upon-Trent.

CONVEYORS

A. Appliances consisting of a Stationary Trough in which the Material is conveyed by Means of a Continuous Pushing Device.

B. Appliances with a Stationary Trough in which the Material is conveyed by Means of a Reciprocating Pushing Device.

C. Appliances in which the Trough containing the Material Moves Bodily with the Material.

D. Appliances in which the Material is conveyed by the Action of a Semi-Stationary Reciprocating Trough.

CHAPTER III

INTRODUCTORY REMARKS

By the name conveyor is generally understood a machine for mechanically transporting materials in a horizontal or slightly inclined direction. In the following seven chapters conveyors of different types are dealt with. Before, however, entering into the various constructions of these appliances, their utility, peculiarity, capacity, and the driving power required, it will be well to give a few introductory remarks as to the behaviour of different materials when being handled by these various machines.

Conveyors of almost all known forms of construction are more or less suitable for the mechanical handling of such materials as minerals, coal, coke, stone, clinker, gravel, seeds, cereals, oil seeds and nuts, but small materials such as cement, plaster of Paris, fine sand, and the powders produced by grinding or crushing the first named substances, as well as sugar, salt, and spices, are all more or less difficult to handle, and indeed only a limited number of types of conveyor can be used for this purpose, and even then often only with indifferent success.

The reasons why fine material is so much more difficult to handle than coarse are various, and one of the principal is the production of dust at the slightest agitation, so that a conveyor which moves the material by a stirring, pulling, or pushing device must be enclosed, to prevent the escape of dust and consequent loss, as well as injury to the workmen. Even with conveyors which perform their functions without this agitation, and in which the material is carried as it is on a belt conveyor, the usual high speed at which these conveyors work will create dust by the resistance of the air to the passage of the material.

There are also other difficulties, caused by the great difference in the consistency of fine materials. Some are of a lively nature and run through the fingers if an attempt is made to get a handful, and this class of stuff needs a close-fitting conveyor, say of the push-plate or worm type, for its handling, as on a belt conveyor there is a great tendency for it to run off, unless the belt is well troughed. Other fine materials are of

just the opposite consistency, almost dead, as, for instance, cement, and if conveyed in a push-plate conveyor have a tendency to lie at the bottom of the trough and let the scrapers travel over the top.

Then, again, there is a difficulty in handling fine materials on account of the tendency of fine particles to enter the working parts of the conveyor, and if the material is of a sharp and cutting nature this is one of the principal drawbacks, as such parts are soon destroyed by wear and tear.

It will thus be seen that for the conveying by mechanical means of fine materials the utility of the existing types of conveyors is considerably restricted. Belt conveyors can be used if the material can be fed on and off without causing dust, and also if the belt travels sufficiently slowly. Whilst all conveyors with agitators can only be used when running slowly or when completely covered in, this is sometimes difficult, particularly with push-plate conveyors, the general construction of which would not permit of covering without complications.

The Zimmer conveyor of reciprocating type appears to be very suitable for handling fine material, because the trough can easily be covered with a dust-tight lid, and there are no stirring or pushing elements to create dust or which are subject to wear; but again there is an objection, and that is that with this type of conveyor fine material can only be conveyed satisfactorily in a very thin layer or stream, and then preferably on a slightly downward gradient, so that here the same objection holds good as with the belt conveyor. Both can be made to do the work, but the capacity is small on the belt conveyor on account of the slow speed, and on the Zimmer conveyor on account of the thin feed, so that both these types, if used for fine material, would have to be made rather wider, and therefore more expensively, for capacities which could be conveyed on smaller conveyors if the material were coarser.

As a *résumé* of the foregoing, push-plate, belt, and Zimmer conveyors cannot be looked upon as the best means of handling fine material under general conditions, so there is only the worm conveyor left. This can be fitted with a dust-tight lid, inlets and outlets, and it has a moderate capacity. It does the work well if the material is not of a cutting nature, and is inexpensive in first cost, but for long distances and large capacities it presents drawbacks which make it not much better than the other types. The driving power consumed is higher than for any other conveyor, and with sharp and cutting stuff the wear and tear on the ordinary intermediate bearings, which must of necessity work surrounded by the material to be conveyed, is very great.

CONVEYORS

A.—APPLIANCES CONSISTING OF A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A CONTINUOUS PUSHING DEVICE

CHAPTER IV

WORM OR ARCHIMEDEAN SCREW CONVEYORS

THE worm or Archimedean screw is undoubtedly the oldest type of mechanical conveyor, and it has long been the only one for fine materials. This simple mechanism, with all its good and bad points, has been practically unsurpassed till within comparatively recent years.

The history of the worm conveyor is difficult to trace, and it is probable that the flour miller was the first user of this labour saver. Whatever purpose the worm conveyor might have served at the time of its supposed invention by Archimedes (287-212 B.C.)

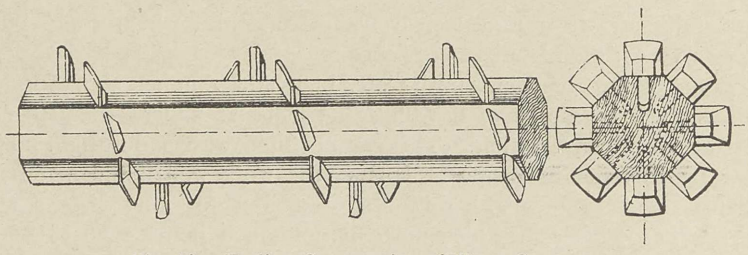


Fig. 40. Earliest Construction of Worm Conveyor.

we know for certain that a crude form of it was employed in flour mills over 250 years ago.

The nature of the worm conveyor is such that only comparatively fine material can be conveyed satisfactorily, and at the time when this conveyor was the only mechanical one, all materials consisting of pieces too large for this type of conveyor were debarred, and had to be moved by hand labour.

Worm conveyors are of the simplest possible construction. They consist of a continuous or broken-bladed screw fixed to a revolving spindle, and the whole is mounted in a suitable trough, so that the revolving screw propels the material fed in at one end of the trough slowly to the other end.

The first specimens of worm conveyors were made of soft wooden octagonal spindles into which round holes were bored, and into these holes were driven hard wood blades with square pegs or shanks. Such a worm is illustrated in Fig. **40**.

In course of time this construction was improved upon by cast-iron spiral sections being threaded on a square iron shaft, which was turned for suitable bearings at intervals from 6 to 10 ft.

Fig. **41** shows such a conveyor, but both this and the wooden type are quite antiquated now.

More modern constructions used at the present day are illustrated in Figs. **42** and **43**. They were probably introduced at the beginning of the nineteenth century.

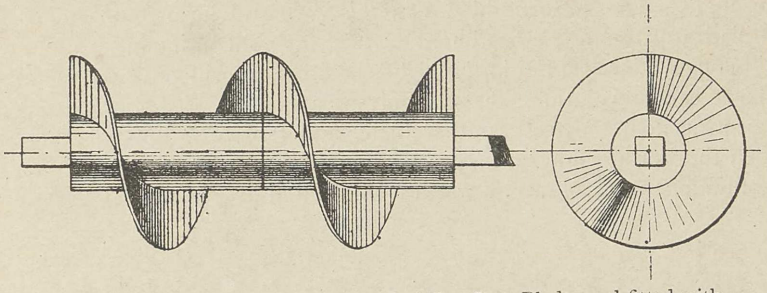


Fig. **41**. Worm Conveyor composed of Cast-Iron Blades and fitted with Square Spindle.

Fig. **42** represents a so-called paddle worm constructed of a series of blades forming together as nearly as possible a complete screw. Each of the blades is fixed to a central shaft or spindle by means of its shank, which is tapped and fitted with a nut. The

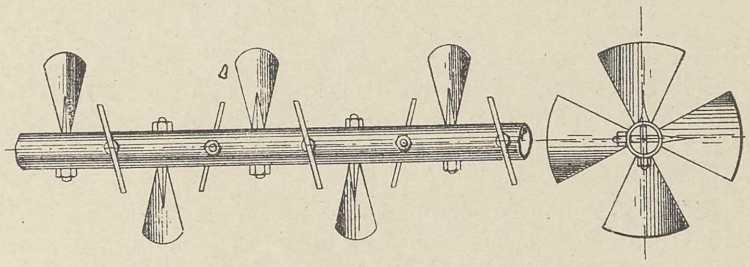


Fig. **42**. Paddle Worm, or Broken-bladed Conveyor.

spindle is made of steam pipe in lengths of about 8 ft., the different lengths being coupled together by turned gudgeons, which answer at the same time as journals for the bearings.

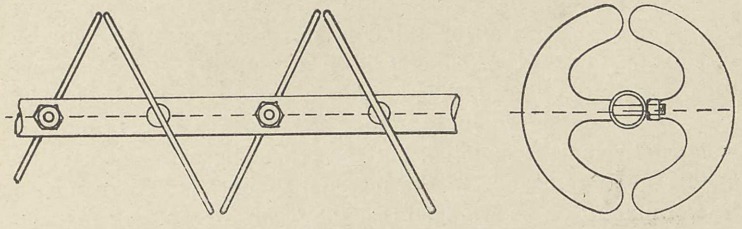


Fig. **43**. Worm with Crescent Blades.

Another type of conveyor akin to the broken-bladed worm is that known as the crescent-bladed worm, Fig. **43**. Each paddle is extended in the form of a crescent, so that it forms practically a semicircle held out from the spindle by the shank. Two crescents form one complete spiral, and thus only two blades are required instead of

four of the ordinary paddles, so that only half the number of holes are required on the spindle.

The chief advantages of the paddle-bladed and crescent-bladed worms are that, if for any reason it may be desired to change the direction in which the material is being conveyed, it is only necessary to slacken the nuts on the shanks and turn the blades to the reverse angle. The crescent blades in this case still form a continuous screw, but the paddle blades on being reversed form a broken non-continuous worm, and though this will still convey the material in the right direction, it will only convey it the width of a paddle at each revolution ; that is, only at a quarter of the proper speed. It is therefore necessary to remove every other blade and replace it on the other side of the spindle, when the worm will again be practically continuous.

The continuous or closed spiral worm is illustrated in Fig. **44**. The only difference

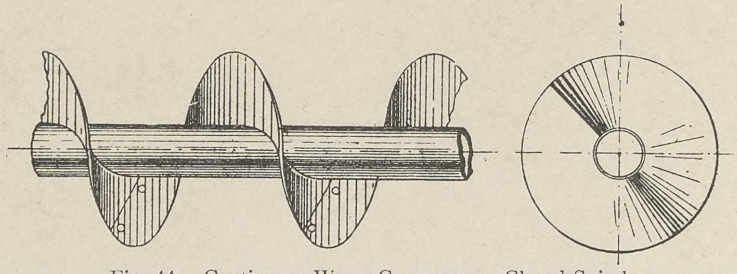


Fig. 44. Continuous Worm Conveyor, or Closed Spiral.

between this and the last-mentioned conveyor consists in this, that the screw is not composed of single blades, but is one continuous sheet-iron spiral, which is secured to the spindle at intervals more or less frequent according to the size and capacity of the worm. The most approved method of construction is to cut a narrow spiral groove in the spindle, and to secure the sheet-iron spiral into this groove.

The usual method employed for producing the close spiral of a continuous worm conveyor has been to cut segments from sheet iron and rivet them together. A later and better method is to run a strip of hoop iron through special rollers in such a way as to thin and therefore stretch it at the outer edge, tapering to the inner edge, whereby a spiral is produced. This is probably the best method for worm conveyors intended for heavy and cutting materials, as the iron strip or hoop may be chosen of any gauge. One of the latest methods of producing the spiral is also from a strip of light hoop iron, but instead of rolling it down to a tapering section the inner periphery is reduced, thus forming a spiral by a series of triangular pleats, as shown in Fig. **45**. This does not only produce a very rigid spiral from comparatively light material, but the projecting pleats also aid the conveying action by offering more resistance to the material to be handled than a smooth blade. Of course the worm must be so arranged that the pleats are on the conveying side of the worm, *i.e.*, point in the direction in which the material is to be conveyed. Such a worm would be most suitable for grain and similar light materials.

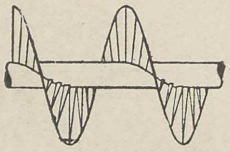


Fig. 45. Showing Construction of Closed Spiral Worm.

There is a fourth form of worm which ought to come under this heading, *i.e.*, the open spiral, sometimes called an anti-friction conveyor. This was introduced about the year 1887, and is a very simple yet efficient conveyor.

Fig. **46** illustrates this appliance, which has the advantage of being inexpensive.

The spirals which form the principal part are rolled by special machines. The illustration shows the mode of fixing the spiral to the spindle.

Fig. 47 shows another method for this.

The spirals are made of various sections, from a round bar about $\frac{1}{2}$ in. in diameter to L or T section. The best form, however, is the flat bar, as shown in the illustration.

In all worms the ratio of the pitch to the diameter must depend upon the kind of material to be conveyed. It ranges from one-quarter to a pitch equal to the diameter of the worm, and even sometimes more. The greater the pitch the greater the capacity and consequently driving power required. It is therefore usual to employ worm conveyors for specifically heavy materials, such as cement, with a small pitch, and those for grain and other light materials with a larger pitch.

The space between the screw and the trough should be either as small as possible

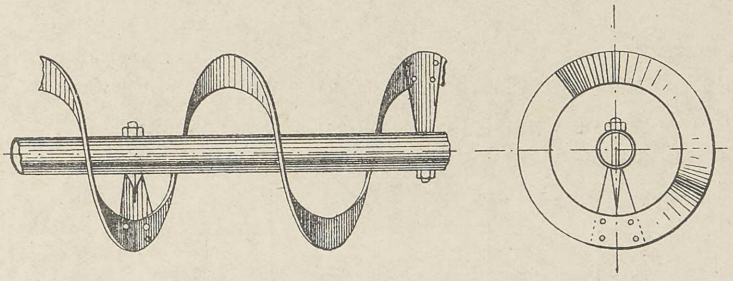


Fig. 46. Open Spiral or Anti-friction Worm Conveyor.

or just a little larger than the size of the largest piece contained in the material to be conveyed, as if fractions of the material are larger than the space, they become wedged between the screw and the trough, and may thereby cause trouble.

Well-made worm conveyors, with well-fitting troughs—*i.e.*, not too tight—of sufficient rigidity not to require too many intermediate bearings, with the latter of a design not to obstruct the flow of the material, are undoubtedly good and serviceable conveyors for all flour-mill products, meal, seeds, cereals, cattle food, crushed seed cakes, material used in the manufacture of linoleum, such as cork powder and sawdust, and as a matter of fact for all fine materials which are not gritty or cutting, always provided the worms are not too long and are not required for too large a capacity.

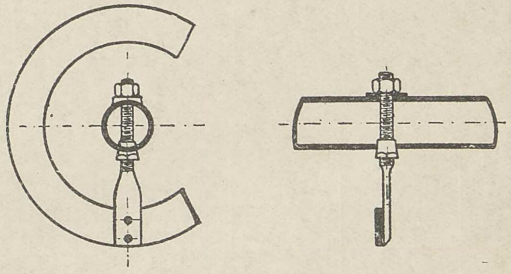


Fig. 47. Method of Fixing Spiral of Conveyor to Spindle.

Worm conveyors of the continuous paddle or spiral types are made with diameters of from 4 in. to 18 in. and even more, but those of 12 in. and over, except for short distances of, say, not exceeding 40 to 50 ft., and for the materials just mentioned, can hardly be called satisfactory. As to the worms of the smaller diameters and for the same materials, lengths not exceeding 150 ft. for 4-in. to 8-in. worms, and 100 ft. for 9-in. to 10-in., should be the limit of their economical utility.

It is true that there are installations to be found in which these limits are exceeded, but they cannot be called economical. In the end it comes to this, that before the

introduction of the Suess conveyor (page 55) there was not a suitable conveyor for really heavy work of this class, and worms were used because there was nothing better.

Close-bladed or continuous worms are also made with a larger pitch for lighter material, generally with a pitch of about two-thirds their diameter. These answer their purpose well, as the capacity of these continuous conveyors is nearer the theoretical capacity than is the case with open spirals or with paddle worms. The reason why closed spiral worms are not often made with a pitch more than two-thirds to three-quarters of their diameter is that it is difficult to bend or roll the blades to a large pitch, but their greater efficiency brings their capacity up to nearly that of paddle and open spirals of a larger pitch.

The following tables give the capacity of continuous, paddle, and spiral worm conveyors of different diameters with their respective pitch and speed. It is obvious that the capacity of a continuous worm is greater than that of a paddle or open spiral conveyor, these two latter being about equal in capacity if other conditions are equal.

Conveyors of double pitch have twice the capacity, and should be driven, if more than 9 in. in diameter, by means of gearing and countershaft, unless they are very short.

CAPACITY OF SMALL PITCH WORM CONVEYORS OF THE CONTINUOUS OR CLOSE-BLADED TYPE FOR HEAVY MATERIALS

Diameter.	Pitch.	Diameter of Hollow Spindle.		Revolutions per Minute.	Capacity.
		Inner.	Outer.		
Inches.	Inches.	Inches.	Inches.		Cubic Feet per Hour.
4	2	1	$1\frac{3}{8}$	130	30
6	3	$1\frac{1}{2}$	$1\frac{15}{16}$	120	60
8	4	$1\frac{1}{2}$	$1\frac{15}{16}$	100	180
9	$4\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{3}{16}$	100	250
10	5	2	$2\frac{7}{16}$	90	300
12	6	2	$2\frac{7}{16}$	90	600
14	7	$2\frac{1}{2}$	$2\frac{15}{16}$	80	900
16	8	$2\frac{1}{2}$	$2\frac{15}{16}$	70	1,000
18	9	$2\frac{1}{2}$	$2\frac{15}{16}$	60	1,300

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF THE CONTINUOUS OR CLOSE-BLADED WORM OF THE MORE USUAL CONSTRUCTION FOR LIGHT MATERIALS

Diameter of Worm.	Pitch of Worm.	Outer Diameter of Hollow Spindle.	Diameter of Internal Bearings and End Gudgeons.	Revolutions per Minute.	Capacity in Cubic Feet per Hour.	Length between Bearings.
Inches.	Inches.	Inches.	Inches.			
4	4	$1\frac{5}{16}$	1	130	70	
5	5	$1\frac{5}{8}$	$1\frac{1}{4}$	120	100	8 feet.
6	6	$1\frac{7}{8}$	$1\frac{1}{2}$	120	175	
7	6	$1\frac{7}{8}$	$1\frac{1}{2}$	110	250	
8	6	$1\frac{7}{8}$	$1\frac{1}{2}$	100	300	
9	8	$2\frac{3}{8}$	2	100	400	10 feet.
10	8	$2\frac{3}{8}$	2	90	500	
11	10	$2\frac{3}{8}$	2	90	650	
12	10	$2\frac{3}{8}$	2	90	850	
13	10	$2\frac{15}{16}$	$2\frac{1}{2}$	80	1,000	
14	10	$2\frac{15}{16}$	$2\frac{1}{2}$	80	1,200	12 feet.
15	12	$2\frac{15}{16}$	$2\frac{1}{2}$	70	1,350	
16	12	$2\frac{15}{16}$	$2\frac{1}{2}$	70	1,550	
18	12	$2\frac{15}{16}$	$2\frac{1}{2}$	60	1,800	

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF THE OPEN-BLADED OR SPIRAL CONVEYOR FOR HEAVY AS WELL AS FOR LIGHT WORK.

Diameter of Spiral.	Pitch of Spiral.	Diameter of Solid Shaft.	Section of Spiral.	Speed for Heavy[1] Materials. Revs. per Minute.	Capacity for Heavy Materials in Cubic Feet per Hour.	Speed for Light[2] Materials. Revs. per Minute.	Capacity for Light Materials in Cubic Feet per Hour.
Inches.	Inches.	Inches.	Inches.				
4	4	$1\frac{1}{4}$ to $1\frac{1}{2}$	$1\frac{1}{4} \times \frac{3}{16}$	100	40	130	60
6	5	$1\frac{1}{2}$	$1\frac{1}{2} \times \frac{3}{16}$	90	120	120	150
8	6	$1\frac{1}{2}$ to 2	$1\frac{3}{4} \times \frac{1}{4}$	80	230	110	300
10	7	2 ,, $2\frac{1}{2}$	$2\frac{1}{4} \times \frac{1}{4}$	70	350	100	500
12	8	2 ,, $2\frac{1}{2}$	$2\frac{1}{4} \times \frac{1}{4}$	60	550	90	800
14	9	$2\frac{1}{2}$,, 3	$2\frac{1}{2} \times \frac{1}{4}$	60	700	80	1,100
16	10	$2\frac{1}{2}$,, 3	$3 \times \frac{1}{4}$	50	950	70	1,400
18	11	$2\frac{1}{2}$,, 3	$3\frac{1}{2} \times \frac{1}{4}$	40	1,100	60	1,700
20	12	$2\frac{1}{2}$,, 3	$3\frac{1}{2} \times \frac{1}{4}$	35	1,300	50	1,900
22	13	3 ,, $3\frac{1}{2}$	$3\frac{1}{2} \times \frac{1}{4}$	30	1,500	40	2,100
24	14	3 ,, $3\frac{1}{2}$	$3\frac{1}{2} \times \frac{1}{4}$	25	1,600	35	2,300

TABLE GIVING DIAMETER, PITCH, AND CAPACITY OF PADDLE WORMS

Diam. of Worm.	Pitch of Worm.	Outer Diam. of Hollow Spindle.	Diam. of Intermediate Bearings and End Gudgeons.	Diam. of Shank of Blade.	Speed for Heavy[1] Materials. Revs. per Minute.	Capacity for Heavy Materials in Cubic Feet per Hour.	Speed for Light[2] Materials. Revs. per Minute.	Capacity for Light Materials in Cubic Feet per Minute.
Inches.	Inches.	Inches.	Inches.	Inches.				
4	4	$1\frac{3}{8}$	1	$\frac{5}{16}$	85	26	120	40
5	5	$1\frac{5}{8}$	$1\frac{1}{4}$	$\frac{5}{16}$	85	65	120	90
6	6	$1\frac{5}{16}$	$1\frac{1}{2}$	$\frac{3}{8}$	80	110	110	170
7	7	$1\frac{5}{16}$	$1\frac{1}{2}$	$\frac{3}{8}$	80	175	110	260
8	8	$1\frac{5}{16}$	$1\frac{1}{2}$	$\frac{1}{2}$	70	220	100	330
9	9	2	$1\frac{3}{4}$	$\frac{1}{2}$	70	320	100	470
10	10	$2\frac{3}{8}$	2	$\frac{1}{2}$	60	400	90	600
11	11	$2\frac{3}{4}$	$2\frac{1}{4}$	$\frac{1}{2}$	60	500	90	750
12	12	$2\frac{5}{16}$	$2\frac{1}{2}$	$\frac{5}{8}$	60	600	90	900
14	14	$2\frac{5}{16}$	$2\frac{1}{2}$	$\frac{5}{8}$	55	1,000	80	1,300
16	16	$3\frac{1}{2}$	3	$\frac{5}{8}$	50	1,350	70	1,800
18	18	$3\frac{1}{2}$	3	$\frac{5}{8}$	50	1,800	60	2,200

Experiments with "Paddle" and "Spiral" Worm Conveyors.—In order to ascertain the respective merits of spiral-worm and paddle-worm conveyors, the author carried out a series of experiments in March 1889, which point to the fact that when running at a slow speed the paddle worm is of greater efficiency, while with a high speed the advantage is on the side of the spiral worm. At a speed—for 4-in. worms—of 150 revs. per minute the efficiency of both is about equal, while if run at higher speeds the spiral worm increases and the paddle worm decreases in capacity.

The following is a summary of the results of the experiments. The material experimented with was sawdust.

[1] Heavy materials include fine coal, cement, sand, ground minerals, fine gravel, plaster of Paris, oxide of iron, etc.

[2] Light materials include grain, seeds, sugar, flour, meal, bran, ice, sawdust, rice, etc.

First Experiment.—The worms experimented with consisted of a paddle worm 4½ in. in diameter by 6 in. pitch, with a spindle of an external diameter of 1½ in., and a spiral worm 4 in. in diameter by 3 in. pitch, on a 1-in. spindle. Paddle worm without intermediate bearing. Spiral worm with one intermediate bearing. Speed of both, 145 revs. per minute.

	Paddle.	Spiral.
Actual capacity in bushels per minute	2·77	1·11
Theoretical capacity in bushels per minute	5·545	2·297
Efficiency, per cent.	49·95	48·324

Second Experiment.—Both worms as above, but the speed of both 300 revs.

	Paddle.	Spiral.
Actual capacity in bushels per minute	3·55	1·97
Theoretical capacity in bushels per minute	11·475	4·762
Efficiency, per cent.	30·9	41·3

Third Experiment.—Both worms reduced to half their length, so that neither had an intermediate bearing, and both running at 300 revs.

	Paddle.	Spiral.
Actual capacity in bushels per minute	4·44	2·61
Theoretical capacity in bushels per minute	11·475	4·762
Efficiency, per cent.	38·69	54·81

Power Required to Drive Worm Conveyors.—The driving power required for worm conveyors depends chiefly upon the weight of the material to be moved, and the distance which it has to be conveyed. The type of the worm, its diameter and speed, enter to a smaller degree into the calculation. It will therefore be sufficient guide to give two tables, one for light and one for heavy materials, from which the approximate horse power can be found.

TABLE GIVING APPROXIMATE HORSE POWER REQUIRED TO DRIVE A WORM CONVEYOR FOR GRAIN OR OTHER LIGHT MATERIAL.

Tons per Hour.	Length of Conveyor in Feet.									
	10	20	30	40	50	60	70	80	90	100
5	0·19	0·38	0·57	0·76	0·95	1·14	1·33	1·52	1·71	1·90
10	0·38	0·76	1·14	1·52	1·90	2·28	2·66	3·04	3·42	3·80
15	0·57	1·14	1·71	2·28	2·85	3·42	3·99	4·56	5·13	5·70
20	0·76	1·52	2·28	3·04	3·80	4·56	5·32	6·08	6·84	7·60
25	0·95	1·90	2·85	3·80	4·75	5·70	6·65	7·60	8·55	9·50
30	1·14	2·28	3·42	4·56	5·70	6·84	7·98	9·12	10·26	11·40
35	1·33	2·66	3·99	5·32	6·65	7·98	9·31	10·64	11·97	13·30
40	1·52	3·04	4·56	6·08	7·60	9·12	10·64	12·16	13·68	15·20
45	1·71	3·42	5·13	6·84	8·55	10·26	11·97	13·68	15·39	17·10
50	1·90	3·80	5·70	7·60	9·50	11·40	13·30	15·20	17·10	19·00

For the sake of easy comparison with other conveyors, the following estimate is based on a load of 50 tons of grain per hour to be conveyed a distance of 100 ft.

An 18 or 20 in. continuous worm will do the work if driven at 60 revs. per minute, and the power required will be $18\frac{1}{2}$ to 19 H.P. To convey cement would absorb somewhat more power on account of the greater friction of the worm blades and the box against the cement, and the greater specific gravity of the cement.

TABLE GIVING THE APPROXIMATE HORSE POWER REQUIRED TO DRIVE A WORM CONVEYOR FOR HEAVY MATERIAL

Tons per Hour.	Length of Conveyor in Feet.									
	10	20	30	40	50	60	70	80	90	100
5	0·33	0·66	0·99	1·32	1·65	1·98	2·31	2·64	2·97	3·30
10	0·66	1·32	1·98	2·64	3·30	3·96	4·62	5·28	5·94	6·60
15	0·99	1·98	2·97	3·96	4·95	5·94	6·93	7·92	8·91	9·90
20	1·32	2·64	3·96	5·28	6·60	7·92	9·24	10·56	11·88	13·20
25	1·65	3·30	4·95	6·60	8·25	9·90	11·55	12·40	14·85	16·50
30	1·98	3·96	5·94	7·92	9·90	12·28	13·86	15·84	17·82	19·80
35	2·31	4·62	6·93	9·24	11·55	13·86	16·17	18·48	20·79	23·10
40	2·64	5·28	7·92	10·56	13·20	15·84	18·48	21·12	23·76	26·40
45	2·97	5·94	9·81	11·88	14·85	17·82	20·79	23·76	26·73	29·70
50	3·30	6·60	9·90	13·20	16·50	19·80	23·10	26·40	29·70	33·00

The principal advantages of a worm conveyor consist in its great simplicity and small first cost. The terminals are much less expensive than those of most other types of conveyors. Short worm conveyors can, therefore, be procured at a much smaller cost than short conveyors of other types.

Worm conveyors are of great service where a mixing of the material to be conveyed is desired. For example, when cement and sand in a dry state are to be conveyed, they will arrive at the delivery end well mixed.

The disadvantages are the large amount of driving power required, the grinding action on the material being conveyed, and the great wear and tear if the conveyor be used for hard and cutting substances.

Troughing and Intermediate Bearings of Worm Conveyors.—Worms are fitted into a wooden or iron trough so as to leave a clearance between the revolving and stationary parts of from $\frac{1}{8}$ to $\frac{1}{4}$ in. The different lengths are supported at intervals of 8 ft. for 4 in. worms, 8 to 10 ft. for 6 to 10 in. worms, and 10 to 12 ft. for 12 to 18 in. worms. A continuous worm is more rigid than a paddle worm, and may therefore be in slightly longer lengths between the bearings, *i.e.*, have fewer intermediate supports.

A detail of great importance in all worm conveyors is the intermediate bearing; this, if cumbersome, obstructs the passage of the material, a drawback which must be carefully avoided. As all adjustable bearings are in halves and of necessity bulky, it is preferable to choose whole or bush bearings, although they lack some advantages that the former possess. The best intermediate bearing is a small phosphor-bronze bush, connected by a short piece of pipe to a cast-iron support. The pipe is screwed into the support and secured by means of a lock nut. The bearing can be oiled through the pipe. Fig. **48** shows such a bearing, and Fig. **49** a simple form of adjustable bearing in halves.

Fig. **50** illustrates another type of intermediate bearing. It is similar to that illustrated in Fig. **48**, with the exception that the bearing is in halves and the cap held in

position by two supports in an oblique position, which give it greater rigidity. Such bearings are suitable for worms of large diameter. The construction almost explains itself, the halves of the bearing being connected by a staple which is U-shaped, and by the two distant pieces which are threaded on the shanks of the staple.

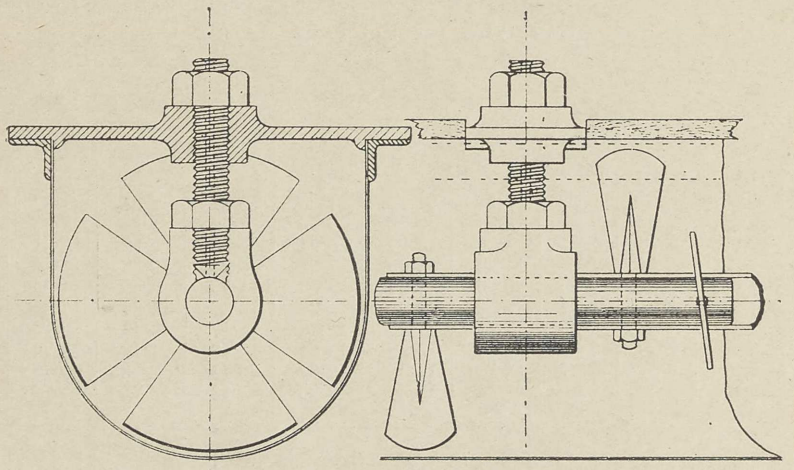


Fig. 48. Solid Phosphor-Bronze Worm Bearing.

Worm conveyors for fine cement and similar materials are frequently built on somewhat different lines, and the tendency is to use more particularly the continuous or closed spiral. The principal differences are the use of a rather larger trough, for instance,

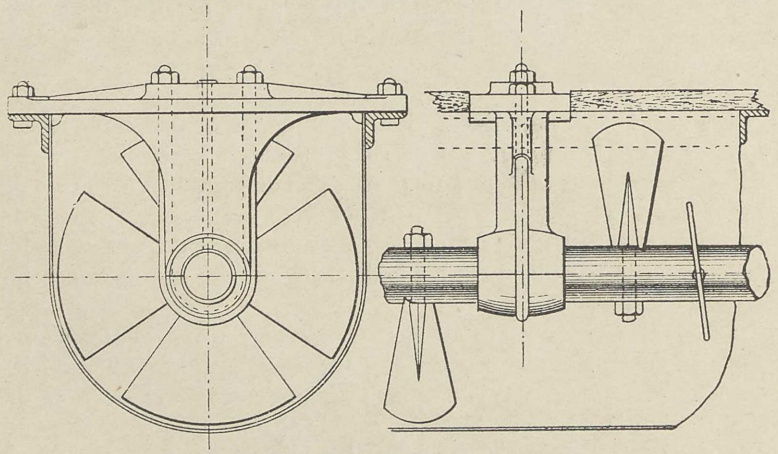


Fig. 49. Worm Bearing in Halves.

an 11-in. trough for a 10-in. worm. This allows of a $\frac{1}{2}$-in. space between the movable worm and the stationary trough, so that the cement in the worm will form its own trough within the iron trough and that there is no wear at all on the trough itself. This arrangement, however, causes more wear on the periphery of the worm spiral, which thereby gradually becomes smaller in diameter.

In one of the largest cement works on the lower Thames, where miles of these worms are in use, the practice is as follows: 10-in. continuous worms fitted in 11-in. troughs with the bearings 10 ft. apart with a pitch of 7 in. and a speed of 80 revs. These worms convey 7, 14 and sometimes even 21 tons of fine cement per hour. As they

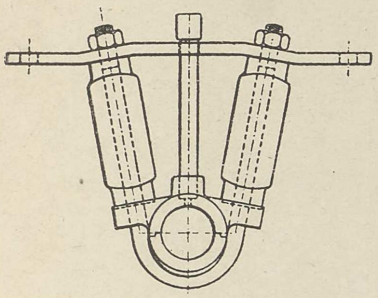


Fig. 50. Worm Bearing in Halves.

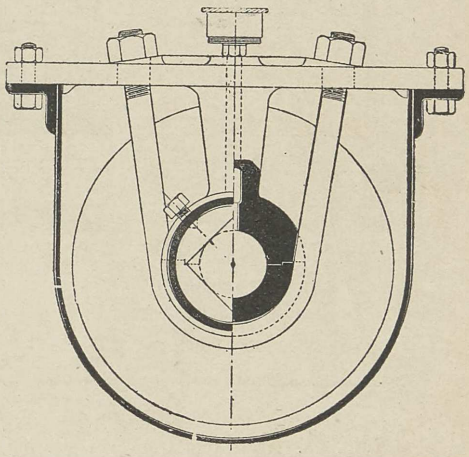


Fig. 51. Cross Section of Worm Conveyor Bearing.

are all driven by electric motors the actual horse power consumed was easily obtainable, and from a number of readings the average power was 1 B.H.P. for every 35 ft. of conveyor when handling 7 tons of cement.

The intermediate bearings are similar to Figs. **51** and **52**, from which it will be

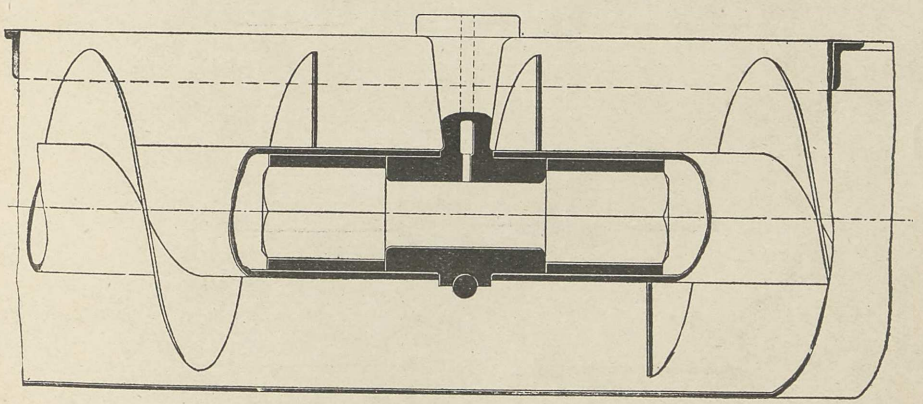


Fig. 52. Longitudinal Section of Worm Conveyor Bearing.

seen that the space between the adjacent sections of the 10-in. worm is very small, only $1\frac{1}{2}$ in.; this is a great advantage, as the break of the blades at the junction is very small and therefore prevents accumulations of the stuff. These bearings have also the further advantage that the working portions are quite away from the injurious influence of the cement.

Fig. 53 is a similar type of bearing, for which it is claimed that it is perfectly dustproof. It is the design of the Conveyor and Elevator Company of Accrington.

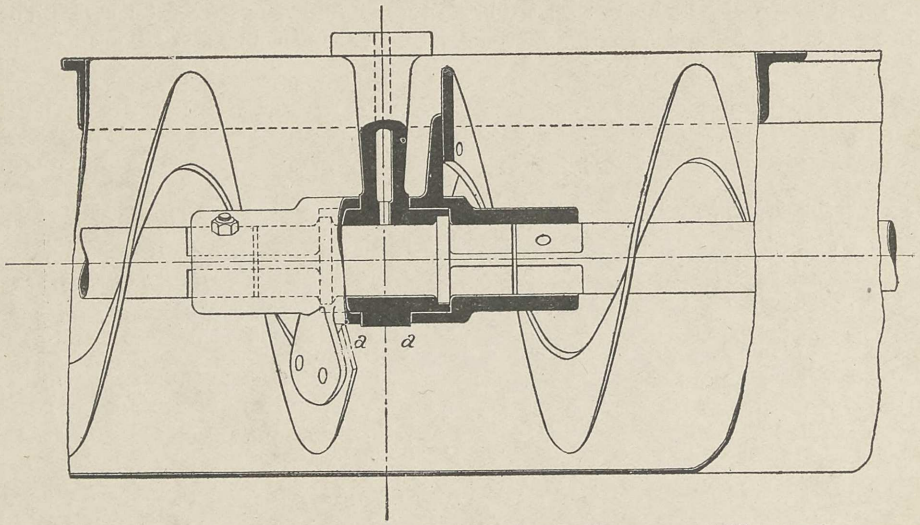


Fig. 53. Dustproof Conveyor Bearing made by the Conveyor and Elevator Co., Accrington, England.

These bearings are lubricated by a viscous grease, which is forced right through the bearing surfaces so that the grease forms a dust collar round the surfaces *a a*.

Couplings for Worm Conveyors.—The different lengths of a worm are coupled

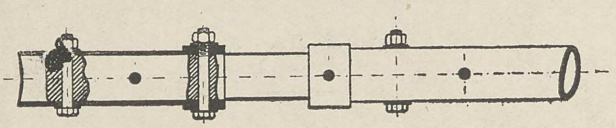


Fig. 54.

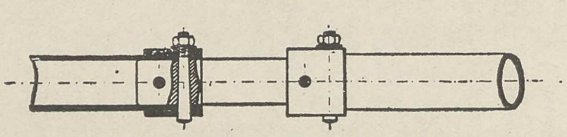


Fig. 55.

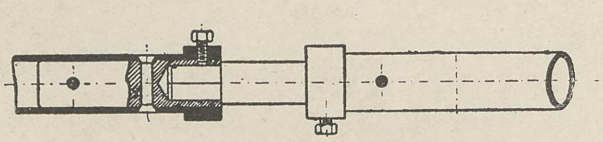


Fig. 56. Types of Worm Couplings.

together in various ways, chiefly by means of gudgeons, a portion of each of which forms the journal for the intermediate bearings. Fig. 54 shows a gudgeon coupling two worm sections. Three bolts, or else the shanks of the worm blades, form the fastening. The end of each worm section is strengthened by a collar which secures the spindle against

splitting. These rings or collars are not necessary when stout steam piping or hydraulic piping is used.

Fig. **55** shows another coupling with a short gudgeon, and two cotter bolts for each fastening. In this case the collar over the end of the pipe is indispensable.

Fig. **56** shows yet another mode of coupling worms together. The coupling consists of two short gudgeons, each with a square hole into which a short coupling piece fits. The advantage of this coupling is that it can be very quickly disconnected, as it is only necessary to slacken the set-screws and push one half of the worm 3 or 4 in. to one side, when the coupling piece can be taken out.

Fig. **57** shows a coupling sometimes used in connection with continuous worm conveyors. The coupling consists of a worm section with a stout sleeve which is split longitudinally, and is secured tightly over the junction of the two halves of the worm.

Drummond End Flights.—When handling abrasive or gritty materials with continuous worm conveyors, considerable wear is found on the flights on either side of the intermediate bearing where the worm is of necessity interrupted. This tends to accumulate material, and imposes extra work on the end flights in pushing it past the bearing into the path of the next section. The interruptions pertaining to the repairs of

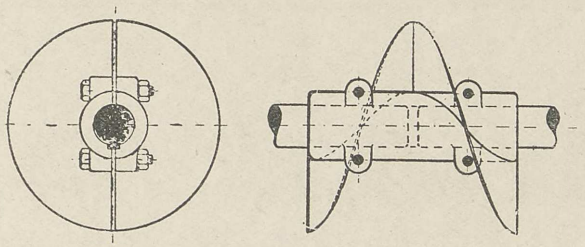


Fig. 57. Coupling for Continuous Worm Conveyor.

such parts are very considerable, and to minimise them these end flights have been introduced by the Link Belt Company. It is the invention of the late D. D. Drummond, vice-president and general manager of the Chicago Portland Cement Co. These flights are made of manganese steel, and are easily renewed, being in halves so as to fit the gudgeon. Ordinary end flights, $\frac{5}{8}$ in. thick, have been known to be destroyed in a few weeks by cement clinker, whilst the improved ones show hardly any signs of wear after six months' work on the same material.

General Remarks.—Delivery of the material from a worm conveyor can be effected at any number of points, it only being necessary to provide a suitable outlet having a slide to close the aperture when necessary. Such an outlet should be as long and as wide as the diameter of the worm, if it is desired to get the whole of the feed through it. This must be so, as the worm delivers only on its leading side, and is practically empty on the other side. The lid which covers the worm box or trough should not be fixed, but should lie loose on top, because in the event of an accumulation of material occurring through the choking of a spout, unless the material in the worm can force the lid and throw the stuff out, the worm, if continuous, will be stripped, or the blades broken, if it be a paddle worm.

Tubular Worm Conveyors.—These consist of cylindrical iron tubes with a continuous spiral fitted to the inner periphery as shown in Fig. **58**. When at work the cylinder revolves bodily round an imaginary axis, supported outside by suitable rollers. This type of conveyor does not strictly conform with the attributes given at the heading

of this chapter, as the trough though stationary laterally, is revolving, but it is essentially a worm conveyor. The advantages are the absence of internal bearings, which are the principal cause of trouble when using ordinary worm conveyors for material of a cutting nature.

The spiral is best chosen of a width equal to one-third of the diameter of the cylinder, *i.e.*, for a 12-in. worm the spiral strip would be 4 in. wide, and thus leave a clear space of 4 in. in the centre of the tube. The best pitch for the screw is two-fifths of the diameter.

The supporting rollers need not be so close together as the internal bearings of ordinary worm conveyors, as the cylindrical body of the tubular conveyor is so much more rigid. The distance apart of the supporting rollers depends upon the strength of the construction, but as a general rule they may be about twice as far apart as the bearings in ordinary worm conveyors.

Intermediate outlets are not impossible, but they are not advisable owing to the complication and expense.

This form of conveyor is more expensive in initial cost, and the fixing is also more costly than that of ordinary worms, but its life is longer. The introduction of this

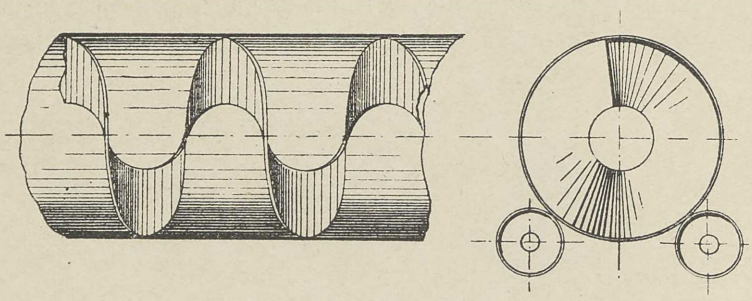


Fig. 58. Tubular Worm Conveyor.

conveyor may be considered to be the first step in the direction of providing a more economical conveyor for fine material.

One of the essential features is that the speed must be chosen within the correct limits. If too high the capacity diminishes, as the centrifugal force counteracts the propulsion; for it must be remembered that with this appliance the forward movement of the material is effected by gravity, inasmuch as through the revolution of the tube the material contained in it is carried up the side in the direction of the revolution until the angle of repose is exceeded, when it is compelled to fall, and is then guided in a slightly forward direction by the spiral attached to the inside of the tube.

The capacity of this tubular conveyor is not very large, as the pitch of the screw must be smaller than with most ordinary worms, say about 0·33 to 0·4 of the inner diameter of the tube, and the number of revolutions is also limited, as already mentioned. It is thus obvious that the greater the pitch of the screw the greater the tendency of the material to cling to the inside of the tube, which tendency is still further encouraged when the centrifugal force begins to exert itself, so that a point is reached where the material is carried too far up the side of the tube, and there is then a tendency for it not to slide forward in its appointed channel but to fall, more than slide, back from its higher position, and so some of the material may fall back into the previous thread of the screw, which reduces the capacity more and more as the speed is increased, and eventually the centrifugal force being greater than the gravity, the material revolves round and round on the inner periphery of the tube and conveying ceases altogether.

The speed at which tube conveyors should run may therefore be slightly slower for a larger pitch of the screw, and vice versa. The following table gives the most suitable pitch and speed, also the capacity of cylindrical tube conveyors of different diameters :—

Diameter of Tube.	Most Suitable Pitch.	Most Suitable Speed. Revs. per Minute.	Capacity. Cubic Feet per Hour.
6 in.	$2\frac{3}{8}$ in.	80	40
8 ,,	3 ,,	75	100
10 ,,	4 ,,	70	200
12 ,,	$4\frac{3}{4}$,,	60	300
14 ,,	$5\frac{1}{8}$,,	55	350
16 ,,	$6\frac{3}{8}$,,	50	550
18 ,,	7 ,,	45	700
20 ,,	8 ,,	40	900
22 ,,	$8\frac{3}{4}$,,	35	1,000
24 ,,	$9\frac{1}{2}$,,	30	1,100

A series of experiments with this conveyor was made in 1868 by Mr Lyster, engineer of the Liverpool Docks. These were fully dealt with in a paper read by Mr Percy Westmacott before the Institution of Mechanical Engineers. The results of these experiments are here given. A tubular worm, 6 in. in diameter and of 2-in. pitch, with a depth of plate of $2\frac{1}{2}$ in. :—

At 60 revs. per minute delivers at the rate of 28 cubic ft. per hour.
,, 80 ,, ,, ,, ,, 36 ,, ,,
,, 100 ,, ,, ,, ,, 30 ,, ,,
,, 140 ,, ,, delivery ceased altogether, and the grain was carried round and round the tube.

A second trial was then made with a 30-in. worm, calculated on the results of the preliminary experiment to discharge at the rate of 50 tons per hour. The length of this worm was 18 ft., and it had a pitch of 12 in., or two-fifths of the diameter. The body of the screw was properly balanced and revolved upon finely adjusted rollers, carried in cast-iron frames. With this worm a speed of 36 revs. per minute was found to be the most effective, and at this speed the grain was carried up the side of the screw about 5 in. above the centre of the tubular casing, and the discharge was $63\frac{1}{2}$ cub. ft per minute, or about 80 tons of wheat per hour—a much better result than had been calculated upon. The power required was 0·40 H.P. per foot run, and the sectional area of the body of grain was 36 per cent. of the whole area of the casing.

A third experiment was also made with a 12-in. worm, and a pitch of 12 in., with a view to ascertain the effect of the quicker pitch. The worm was driven at the same speed of 36 revs. per minute, the delivery being 10 tons of wheat per hour, with a sectional area of only 17 per cent. The pitch of two-fifths of the diameter proved most effective in these trials.

A case in which the tubular worm conveyor is very useful is where grain has to be conveyed from one building to another on a level, but where no bridge is available to which any other kind of conveyor could be attached. The tube can be made as strong as necessary, and trussed by means of a spider in the middle, and a number of tie-rods, as shown in Fig. 59.

Suess Conveyor.—A decided improvement on the tubular conveyor is the Suess conveyor. It consists of a tube of rectangular section made either of sheet steel or wood.

To the four inner sides of this tube are attached oblique blades, forming an unbroken sequence of oblique channels on each side for the whole length of the conveyor. These blades do not extend across the whole sides of the tube, but are only half as wide as the sides, and leave a longitudinal channel quite unobstructed by blades in each of the four corners of the tube. For example, a 12-in. tube (inside measurement) has blades on each side 6 in. wide, leaving a space of 3 by 3 in. in each corner the whole length of the conveyor.

When at work the action is as follows: Supposing the whole of the material in the conveyor rest all along one of the corners, and as this corner slowly moves upwards the underside of the tube changes its horizontal position for a slanting one, and as soon as the angle is sufficiently steep, the whole of the contents of the corner is forced by the law of gravity to slide across the oblique channels into the next corner, and in doing this it travels forward by the pitch of the channels or blades. This process repeats itself four times in every revolution. The very considerable slope of 45 degrees can be given

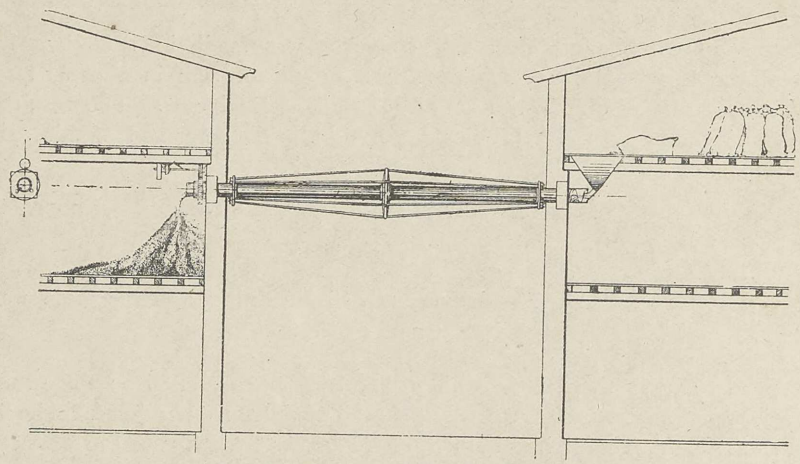


Fig. 59. Example of Tubular Conveyor.

to the blades, so that with each quarter revolution in a 12-in. tube the material moves theoretically 6 in. forward, or 2 ft. with every revolution. This is practically equal to a 12-in. worm with a 24-in. pitch, if it were possible to make such a worm of the ordinary continuous type, which it is not, on account of the difficulty and expense of bending the blades to such a pitch, and for that reason a square tube like the Suess has a much larger capacity than a cylinder of the same size.

With the Suess conveyor a single internal screw formed of four blades would not give a very positive result, as only part of the material would follow the oblique path, and in order to get the highest efficiency the oblique blades are placed at such a distance apart as to form a five-fold or five threaded screw, so that practically every particle is forced forward in its appointed channel.

The conveyor is made in lengths of from 15 to 20 ft., and joined together with flanges. These are turned on the face and periphery, and are used at the same time as supports for the conveyor, resting on a series of pairs of rollers. The rollers are provided with flanges to prevent end movement. There is also a flexible packing ring between each pair of couplings, so that a slight variation from the straight line in the erection is not detrimental.

The driving pulley is made in halves, with a square opening to fit the square tube, and this can be attached at any point in the length of the conveyor most conveniently situated in relation to the driving power.

Conveyors of this design have been built and are successfully at work in lengths up to 250 ft. Fig. **60** shows such a conveyor in a cement works. As this tube conveyor is very rigid, it can also be used for transmitting a limited amount of power, so that at the extreme end, or in any desired position, power may be taken off by fixing a pulley, similar to the main driving pulley, concentrically on to the tube for driving small auxiliary conveyors or even elevators. This is sometimes of great convenience.

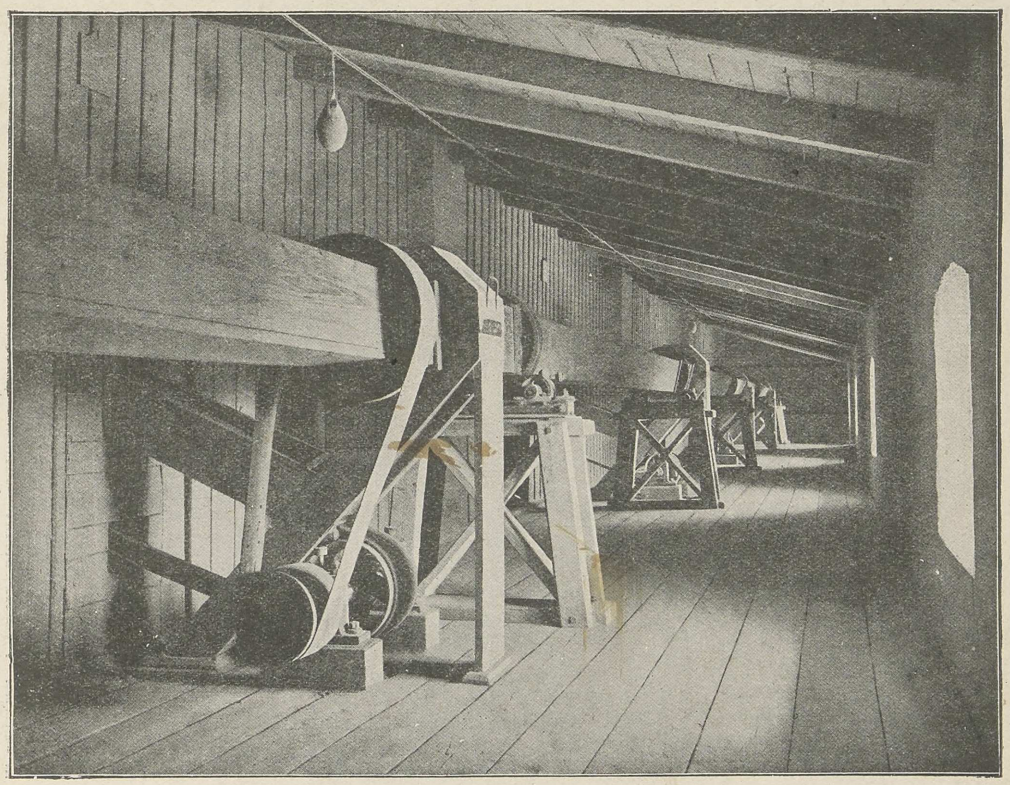


Fig. **60.** Suess Conveyor, 250 ft. long, Conveying Fine Cement at Witkowitz, Austria.

Fig. **61** represents a perspective view and part section of such a conveyor, and Figs. **62** and **63** show cross and longitudinal sections of the same. The illustrations show a wooden tube with metal channels. *d* represents the oblique blades, *e* e^1 e^2 e^3 show the longitudinal channels in the four corners as described above. The spaces *f f* can be covered over with sheet iron. *g* is the filling apparatus which revolves with the tube, and has lifters which scoop up the material fed into the fixed inlet *i* and deliver it into the conveyor tube. *k* and k_1 show the slope at which the material is delivered into the tube. *b* are the ring supports to be used when further supports are desirable in addition to, or instead of, the flange coupling supports. These ring supports *b* are also employed in such positions where at times a portion of the conveyor has to be thrown out of work. For instance, if a conveyor of 100 ft. total length has to deliver for a

lengthy period at a point 50 ft. from the feed end, half the conveyor can be disconnected simply by taking the four bolts out of the nearest coupling, and in order to do so a ring *b* should be near to such a point to carry the tube ends. *c* are the rollers on which the ring *b* or the flange coupling are supported.

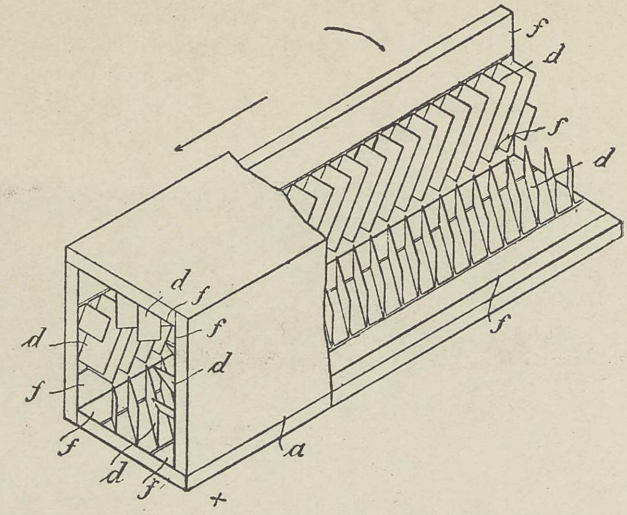
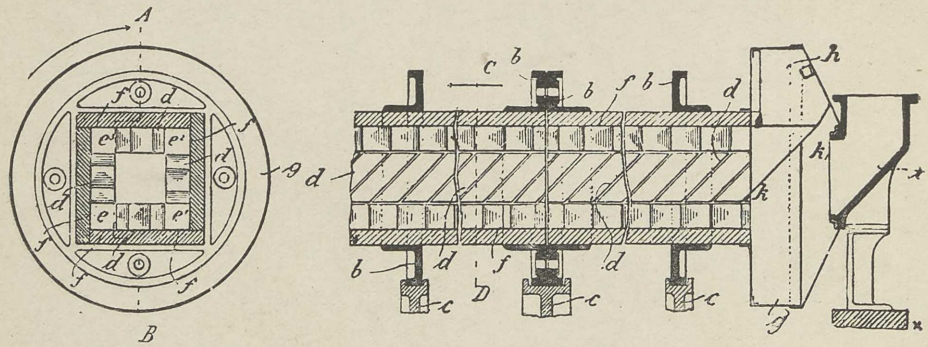


Fig. 61. Perspective View and Part Section of Suess Tube Conveyor.



Figs. 62 and 63. Cross and Longitudinal Sections of Suess Tube Conveyor.

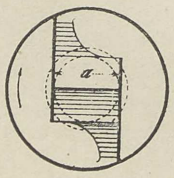


Fig. 64. Enclosed Outlet.

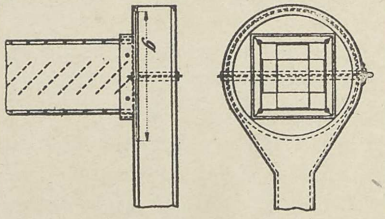


Fig. 65. End Outlet.

The delivery at the opposite end can be either open, so that the material simply drops out, or it can be enclosed, which is preferable, to prevent dust. Such an enclosed end outlet, as well as intermediate inlets and outlets, are shown in Figs. 64, 65, 66, 67,

and **68**. These intermediate inlets and outlets are easily understood from the illustrations, the former having four lifters which collect and deliver into the tube any material fed into the inlet, and yet when there is no material added at any of these intermediate inlets the flow of the material passing by is not obstructed.

The intermediate outlet is a little more complicated, as it contains a loose piece of the tube with its channels, which must be removed to make an outlet, but the change can be effected in a very few minutes.

It will thus be seen that the Suess tube conveyor can be fed from any number of

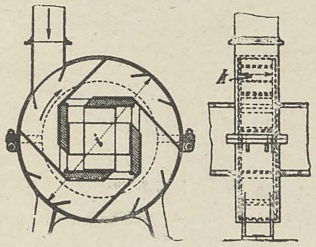


Fig. 66. Intermediate Inlet.

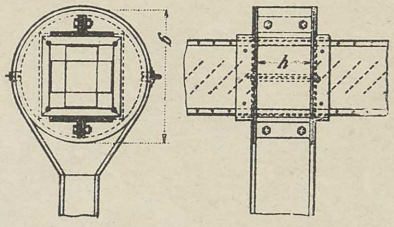


Fig. 67. Intermediate Outlet.

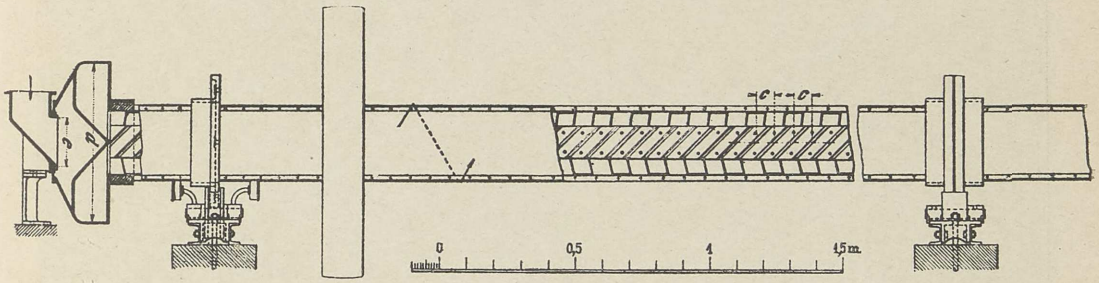


Fig. 68. Suess Tube Conveyor showing Feed End.

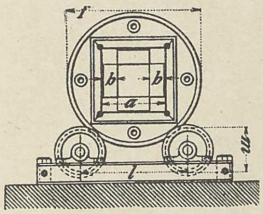


Fig 69. End View.

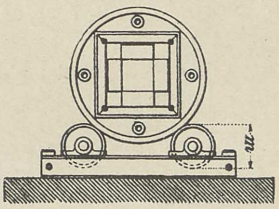


Fig. 70. Cross Section.

points, and that the material can be withdrawn at any convenient point or points. It is therefore most useful, for instance, for feeding rows of silos or bins either one at a time or simultaneously. Fig. **71** shows another Suess conveyor driven by a pair of jockey pulleys.

The lettering of Figs. **64** to **70** correspond with the dimensions given in the table for Suess conveyors of the three principal sizes in inches; the letter *c* in the table represents the pitch of the oblique blades, which stand at an angle of 45 degrees to the axis of the conveyor, and at an angle of 75 degrees to their base at the side of the tube.

Size Number.	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*k*	*l*	*m*
1	7	$1\frac{5}{4}$	$2\frac{1}{2}$	20	7	20	20	6	18	7	16	6
2	$9\frac{1}{2}$	$2\frac{3}{8}$	3	20	7	20	20	8	20	7	16	$6\frac{1}{2}$
3	12	3	$3\frac{3}{4}$	24	8	24	24	10	24	8	18	7

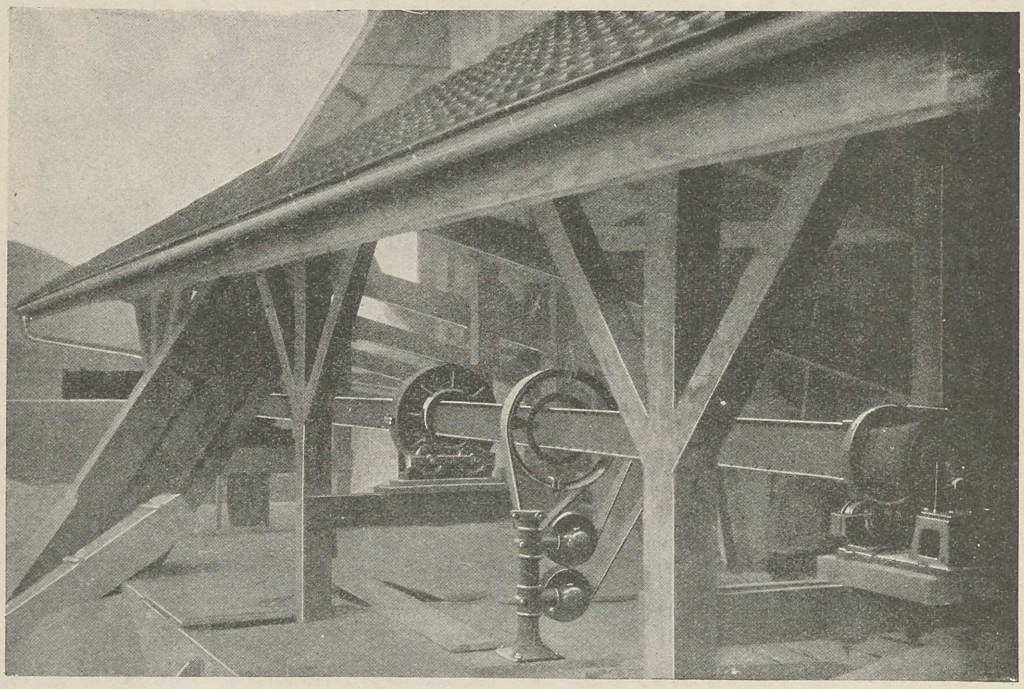


Fig. 71. Suess Conveyor, showing Method of Driving by means of Guide Pulleys.

The following table gives the capacity of the Suess conveyor for the three sizes in tons per hour of Portland cement, at different speeds :—

TABLE GIVING CAPACITY OF SUESS TUBE CONVEYOR

Revolutions per Minute.	Capacity in Tons of Portland Cement per Hour.		
	No. 1.	No. 2.	No. 3.
10	1·2	5·4	8·37
15	2·04	7·2	12·555
20	2·88	9·	16·74
25	3·72	10·8	20·925
30	4·56	12·6	25·11
35	5·4	14·4	29·295
40	6·24	16·2	33·48
45	7·08	18·	...
50	7·92	19·8	...
55	8·76	...	...
60	9·6	...	...

CONVEYORS

A.—APPLIANCES CONSISTING OF A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A CONTINUOUS PUSHING DEVICE—*continued*

CHAPTER V

PUSH-PLATE OR SCRAPER CONVEYORS

THE origin of the scraper conveyor may be found, like that of the worm conveyor, in the oldest industry of the world, namely, flour milling. It is rarely found now even in the oldest flour mills, but being the progenitor of an important conveyor, it may be interesting to give a few details as to its construction.

The box or trough was of wood, and sufficiently deep to carry the whole apparatus, including the return strand. The terminal pulleys were smaller than those of elevators of the same capacity, there being no lifting to perform. Their diameter varied from 10 to 15 in., and the belt which carried the wooden scrapers was rarely more than 2 or 3 in. wide, although the scrapers were from 6 to 10 in. long. The spindles were generally carried in bush bearings, fixed with a flange against the outer side of the box. A tightening gear was seldom used, but a large opening with a lid facilitated the tightening of the band, whilst in the base of the trough a piece of glass fixed flush with the inside of the box showed the miller when his conveyor was at work. The speed of the scrapers was from 100 to 200 ft. per minute.

Push-plate conveyors now vary very much in minor details of construction, but in principle they consist of a fixed open trough made of stout sheets of steel or iron, sometimes of cast iron, rarely of wood. The material to be conveyed is deposited in this trough, and is pushed or dragged along by a series of plates attached at equal intervals to an endless chain, which latter, with its attachments, travels over terminal pulleys, so that only one strand of the chain is at work at a time. The chain should be attached as nearly as possible to the centre of the push-plates. These are not generally allowed to touch the bottom of the trough, and are therefore fitted with skidder bars which slide on well-greased angle-bars forming portions of the framework. Sometimes instead of skidder bars the scrapers are fitted with a pair of small wheels or rollers running on corresponding channel or angle bars, which is a good plan, as it reduces the driving power required, and prevents the noise which in large and badly lubricated conveyors is often disagreeably loud.

The scrapers of push-plate conveyors are of different forms, the commonest being rectangular, though generally they conform as nearly as possible to the shape of the trough. They are sometimes, however, in the form of discs, rakes, or dogs, according to the material to be handled.

Fig. 72 shows a portion of an ordinary push-plate conveyor in two views, in which

every alternate scraper is supported by a pair of rollers. The return strand of the conveyor is shown beneath the conveying strand. This order must be reversed in all cases where the load has to be delivered at intermediate points, as the shoots leading the material away would otherwise foul the return strand, unless the shoot is altogether dispensed with, as in coal stores.

The trough is often made of two pieces of channel iron, with a renewable iron plate riveted or bolted underneath (see Fig. 73). The skidder bars of the leading strand of this conveyor run on slats of hard wood which are fastened on the channel irons, whilst the chain of the return strand runs over guide rollers. Sometimes the

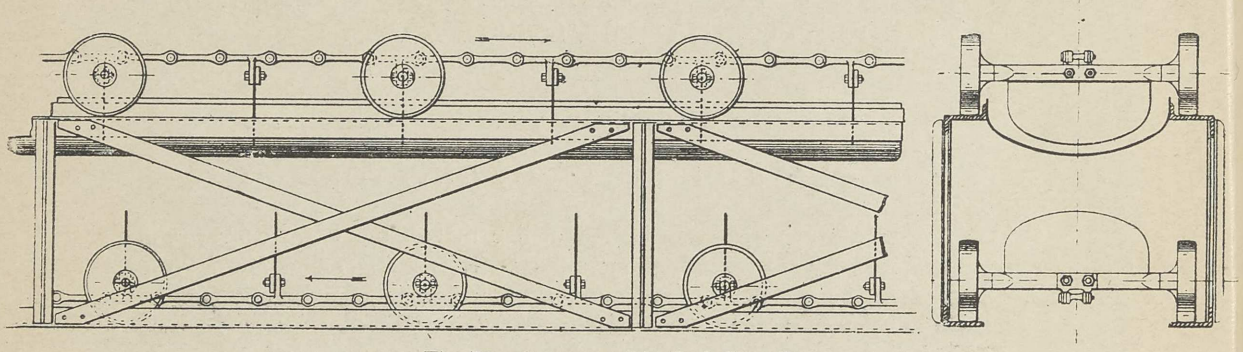


Fig. 72. Conveyor of the Push-Plate Type.

wooden slats are dispensed with, and the skidder bars allowed to run on the trough itself.

The U-link conveyor illustrated in Fig. 74 has a trough similar to that just described, but the pushing agent is altogether different. It consists of a large chain composed of

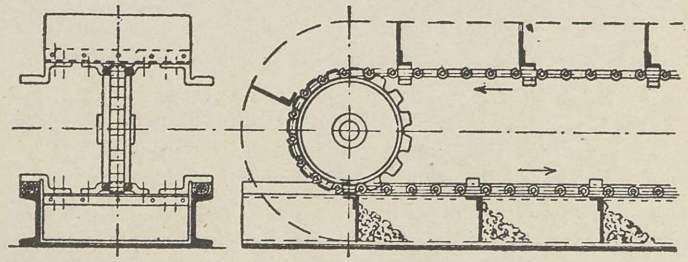


Fig. 73. Further Type of Push-Plate Conveyor.

U-shaped links of flat iron or steel, between which, and on the top of which, the material is conveyed. The links are generally of a pitch equal to their width, and are 3 to 4 in. deep by $\frac{1}{2}$ in. in thickness. The speed at which the chain travels is from 100 to 150 ft. per minute. The terminals are hexagonal, whilst the intermediate supports for the return strand consist of ordinary rollers which are about 6 in. in diameter, and sometimes 15 ft., and even 20 ft., apart.

This type of conveyor is exceedingly strong, and on account of its simplicity and reliability is largely used for bringing the coal to automatic stokers, and also for conveying the ashes and clinkers from the furnaces. The driving power required is small, and it has, moreover, the advantage of small initial cost. There are many boiler-houses where this conveyor is doing excellent work at a cost so low that it need hardly be taken into

account. Its design and construction enable erection and operation where it would be difficult to erect and operate a more complex plant.

The type made by Ed. Bennis & Co., Ltd., for their boiler-house installations,

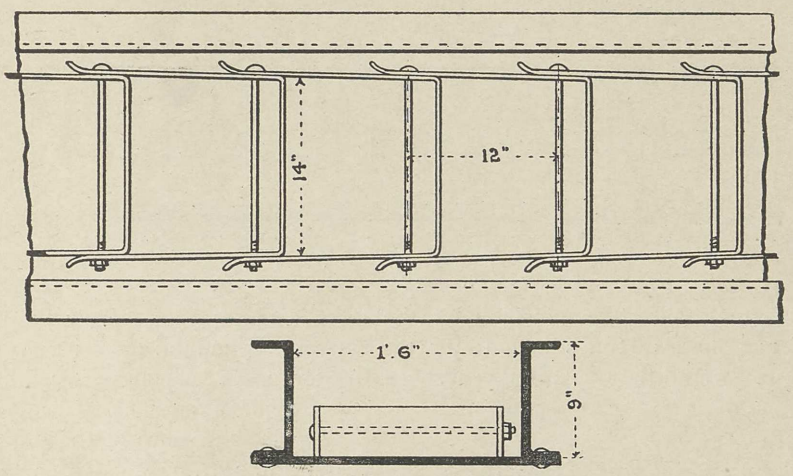


Fig. 74. U-Link Push-Plate Conveyor.

has two short bolts for the joints instead of one long one, and the dimensions and capacities are as follows :—

Size of Trough.		Speed in Feet per Minute.	Capacity in Tons of Coal per Hour.
Width.	Depth.		
Inches.	Inches.		
9	5	18	40
12	7	18	60
15	8	18	80
24	12	18	140

The tensile strength of the link is from 28 to 32 tons to the square inch, with an elongation of 20 per cent. in 8 in.

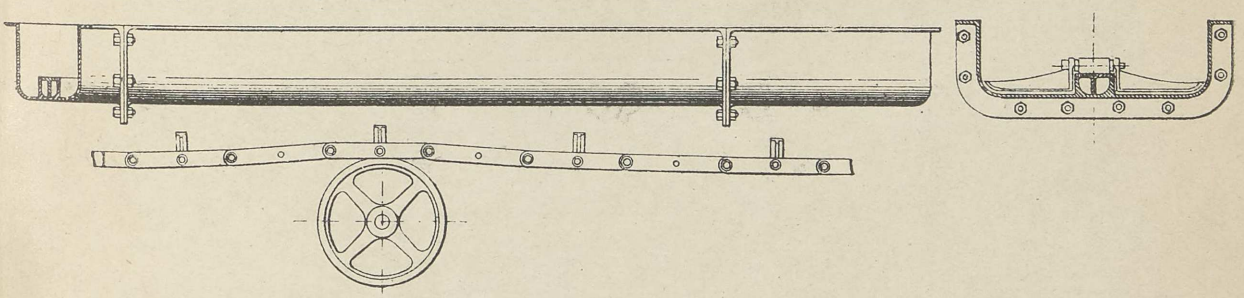


Fig. 75. Push-Plate Conveyor with Cast-Iron Trough.

A further type of conveyor is illustrated in Figs. **75** and **76**. It was originally intended for conveying hot coke at the Manchester Gasworks, but has since been superseded.[1] The work was executed by West's Gas Improvement Co. This conveyor

[1] See also page **145**.

runs in a cast-iron trough 27 in. wide by 9 in. deep. The chain is composed of cast-steel links bolted together, while to each alternate pair of links cast plates are fitted which match the section of the trough, but do not touch the sides or the bottom of it. Between the links which carry the push-plates are placed sliding blocks which rest on a

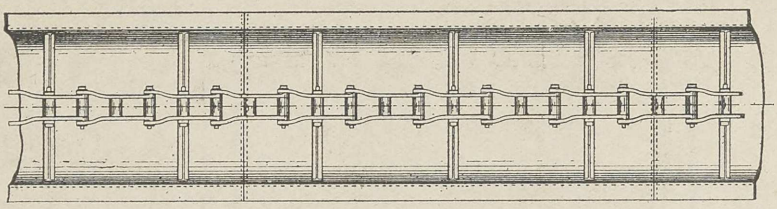


Fig. 76. Plan of Fig. 75.

renewable central rail. The pins joining the links together pass loosely through the small rollers (Charles Hunt's patent) for the purpose of minimising friction and the wear in passing round the track, and whilst on the terminals. This construction is well designed, as the chain pulls its load at or near the centre of the push-plates, and not, as in most cases, above.

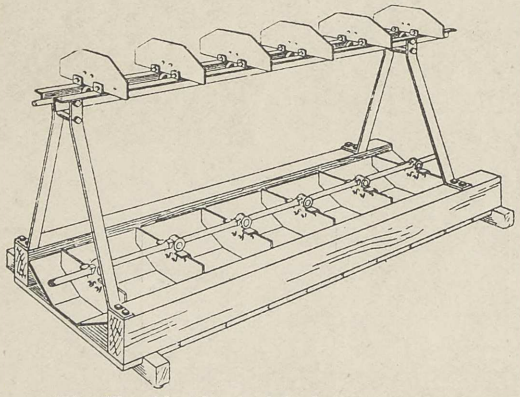


Fig. 77. Monobar and Push-Plate Conveyor.

Fig. **77** shows a form of push-plate or scraper conveyor known as the Monobar conveyor, made by the Link Belt Company, with a single bar between each two scrapers, or a few shorter ones joined up in the usual way, as shown in Fig. **78**.

Figs. **79** and **80** is another type of push-plate conveyor, the design of the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft, its special feature being that in place of the push-plates the conveying chain supports frames which resemble small bottomless boxes, the base for these frames being supplied by the conveyor trough itself. At the sides of this conveyor trough, which is practically a smooth plate, are fixed channel irons in which the guide pulleys of the sections run.

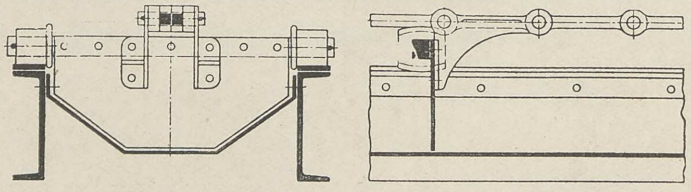
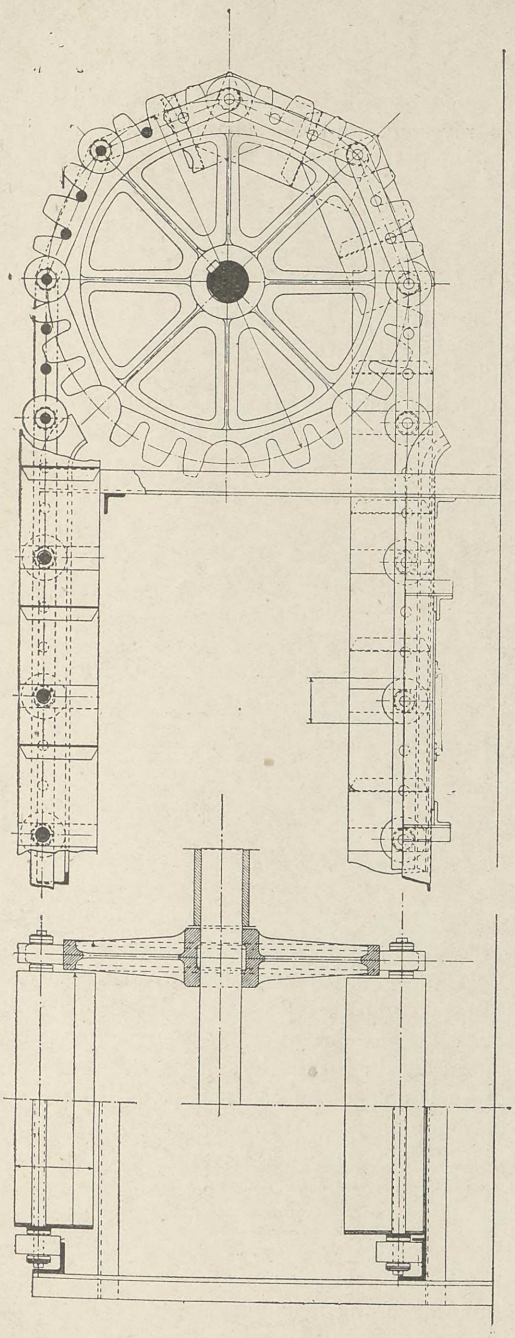
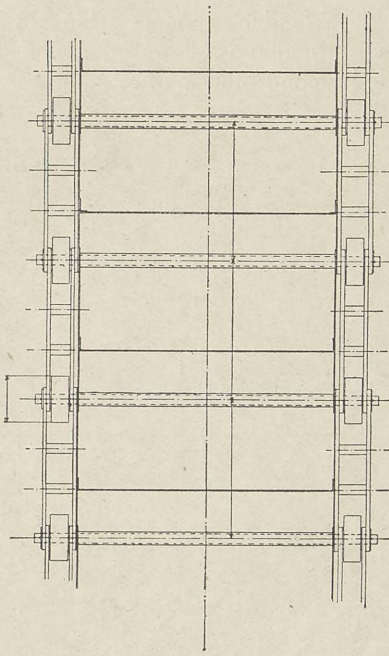


Fig. 78. Type of Push-Plate Conveyor.

For the return half of the conveyor the angle iron takes the place of the channel, the chain of this conveyor being composed of long links which nevertheless run on a specially designed and constructed circular wheel, instead of running over a polygon wheel, as is generally the case. Each link of the chain is fitted with two studs—in addition to the two ordinary pins—which fit into suitable grooves in the two terminal wheels.





Figs. 79 and 80. Push-Plate Conveyor with Travelling Sides.

The advantage of this type of conveyor is that it can be used at a considerably steeper incline than an ordinary push-plate conveyor. A further advantage is, that there is no friction between the sides of the channel and the material being conveyed, the sides not being stationary, but travelling with the push-plates, as described.

For material of a non-cutting nature, such as wood chips, tan, peat, and other light goods, the usual order is sometimes reversed, and the chain fixed below the scrapers, running in a groove in the bottom of the trough. The push-plates in these cases are often made of hard wood.

Some forms of push-plate conveyors, *e.g.*, when the chain is attached in the centre of the plates, can be used for double service by directing the return strand through a second trough either above or below the original one. When sufficient headroom is not available the terminal wheels may be arranged horizontally instead of vertically, so as to have both strands in the same plane, and in this case also the conveyor may be made a double service machine by adding a second trough for the return strand. This construction is, however, confined to single chain conveyors. Such conveyors are used among other purposes for stock pile installations (see Fig. **918**, page 654).

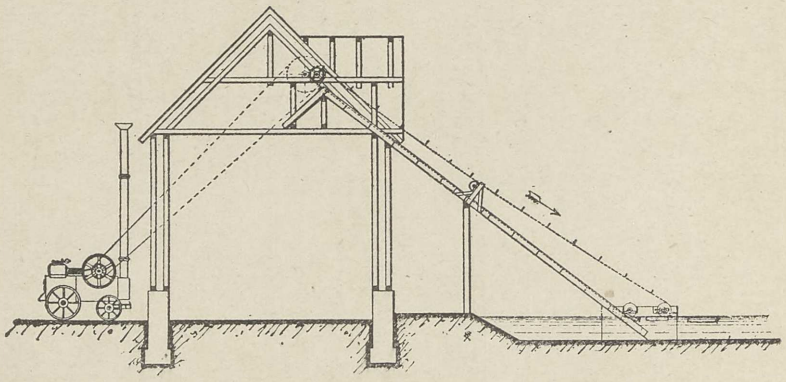


Fig. 81. Push-Plate Conveyor for Ice.

Ice Conveyors.—Scraper conveyors, or perhaps more correctly elevators for ice-houses, are used particularly on the Continent. They were perhaps more often used before the introduction of refrigerators, but are still in general use in the vicinity of the Baltic Sea. These appliances very much resemble push-plates. The trough in which the ice slides up into the ice-house is made of wood, while the scraper plates are attached in the usual way to the chain, and drag the ice up the incline.

Fig. **81** shows a cross section through such an ice-house. The pieces of ice are floated into the lower end of the trough, where they are brought into contact with the plates, pushed up the inclined trough, and finally deposited in the store.

Capacity of Push-Plate Conveyors.—This depends on the size of the trough, and the pitch and speed of the plates. The pitch of the plates ranges from 18 to 36 in., and the speed of travel from 50 to 180 ft. per minute. For coke and other friable substances the speed should not exceed 50 to 100 ft. per minute, whilst in cases where the breakage of the material is of minor importance, the maximum speed of 180 ft. per minute may be employed.

For example, a conveyor with a trough 24 in. wide, having the plates 24 in. apart, and running at a speed of 100 ft. per minute, would convey 67 tons of coal per hour. A push-plate conveyor for coke with a 27-in. trough, and with malleable-iron plates

24 in. apart, running at 48 ft. per minute, would deliver about 20 tons of coke per hour.

TABLE GIVING APPROXIMATE CAPACITIES OF RECTANGULAR TROUGHED PUSH-PLATE CONVEYORS FOR COAL IN TONS PER HOUR AT A SPEED OF 100 FEET PER MINUTE

Width of Scraper.	Height of Scraper.	For Horizontal Conveyors. Pitch of Scraper Blades.			For Conveyors with Blades 24 in. pitch and inclined at		
Inches.	Inches.	16 in.	18 in.	24 in.	10°	20°	30°
10	4	17	15	11	9	7	5
12	4	22	19	14	12	9	6
12	5	26	23	17	14	11	8
15	5	35	31	23	20	16	11
18	6	...	40	30	25	20	15
18	8	...	60	45	36	28	24
20	8	...	...	52	42	33	28
24	8	...	...	67	60	48	36
24	10	...	...	86	75	60	45

Capacities for other speeds in proportion.

Power Required to Drive Push-Plate Conveyors.—This must depend on the nature of the material to be conveyed and on the condition of the trough. For instance, cement clinker and coke would take more power to convey than coal; but as this type of conveyor is altogether unsuited for hard and cutting substances on account of the great wear and tear, no examples are here given of a conveyor for such materials, the following figures being for coal conveying.

A push-plate conveyor, 100 ft. long, conveying coal at the rate of 50 tons per hour, will require a driving power of 12 H.P.

Timber Conveyors.—A conveyor on the same underlying principle, but of a much more substantial design, is frequently used in the lumber trade of North America. This conveyor will handle large baulks of timber. The chains of the conveyor are very strong, and are fitted at regular intervals with jagged or dog links, which lay hold of the timber or tree and drag it on a suitable support for long distances. The timber is often transported in rafts on the rivers, or the single stems are floated to an incline on the bank where these conveyors are erected, the lower terminal reaching sometimes a few yards below the water level. A man stands on the floating tree or trunk and directs one end on to the conveyor, which drags it out of the water direct to the saw-mills. Figs. **82** and **83** show two such conveyors, the former for light loads, the latter for logs up to 4 ft. in diameter.

Push-Plate Conveyors with Double Chains.—In this case the chains are attached to the two sides of the push-plates, preferably protected by being concealed in recesses in the sides of the trough. Such conveyors are to be recommended when it is desirable to have the trough unimpeded by chains above the plates. This form of construction has also the advantage that the chains are attached at a central position, which is most effective. Belonging to this category is the hot coke conveyor (Figs. **206** to **209**),[1] the plates of which are sometimes in the form of rakes, and sometimes in the form of plain iron bars. This latter design is quite admissible for coke when in large pieces, and therefore as efficiently pushed by a bar as by a plate, whilst the rake is more

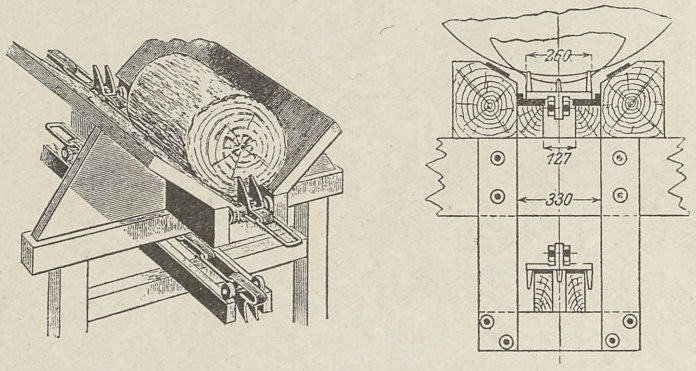
[1] See pages 153 and 154.

substantial, and therefore resists the action of the hot coke better than a plate, which offers a larger surface to the damaging effect of this material.

Cable Trough Conveyors.—These differ from those previously described in that the pulling or pushing element is a cable instead of one or more chains, and that the iron or steel disc attachments which propel the material have no additional support, such as skidder bars or rollers, the trough forming the only support.

The trough is either V or U shaped, and generally of wood lined with sheet iron, or of iron plates only, according to the nature of the material to be conveyed.

The rope is generally a cable of 1 in. diameter, and the disc flights are of cast iron, in halves, and are clamped on to the cable with bolts. The coupling generally used is



Figs. 82 and 83. Timber Conveyors.

in design the same as the ordinary disc flight shown in Figs. **84** and **85**, the ends of the rope being lapped and passed through the clamp, with the ends of the rope diverted

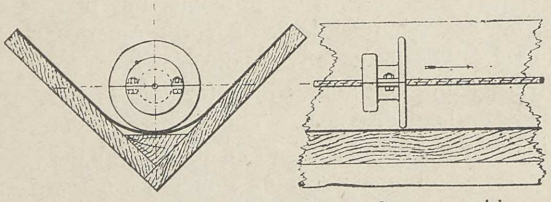


Fig. 84. Type of Cable Trough Conveyor with V-shaped Trough.

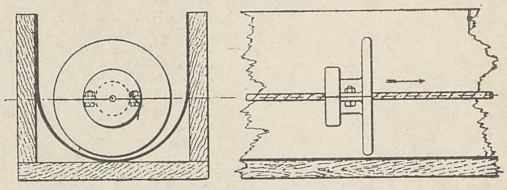


Fig. 85. Type of Cable Trough Conveyor with U-shaped Trough.

to either side so as to fit the gaps of the sprocket wheel. This kind of conveyor is suitable for conveying light and bulky material, preferably in a straight line and down an incline. It is well adapted for handling timber, blocks, chips and shavings, peat, pulp, hay, etc., but is also sometimes used for heavier materials.

The speed of travel is 100 to 120 ft. per minute. Figs. **84** and **85** give two longitudinal and two cross sections of two forms of trough cable conveyors.

Fig. **86** illustrates a complete installation of this type of conveyor, showing the two terminals in plan and elevation, as well as a cross section through the conveyor.

Fig. **87** shows this type of conveyor fitted with metal troughing. It also illustrates the manner in which two such conveyors are driven at right angles.

The method of feeding and withdrawing the material at intermediate points is simple with this conveyor. The former presents no difficulty, as the trough is open, and

can, therefore, receive the feed at any point. The latter is effected by means of outlet slides at any point, for a flat-bottomed trough; for a V-shaped trough flap doors hinged

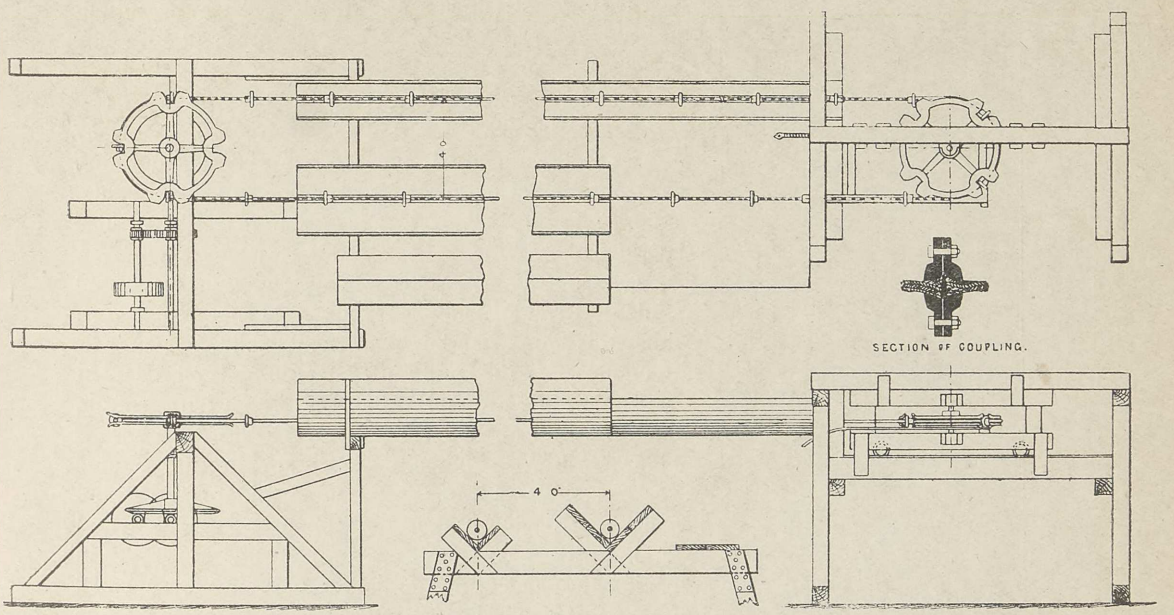


Fig. 86. Complete Installation of Cable Trough Conveyor.

on either side, forming a V-shape when closed; and for troughs with a semicircular base, hinged flaps of the same semicircular form are employed, which are so arranged as to

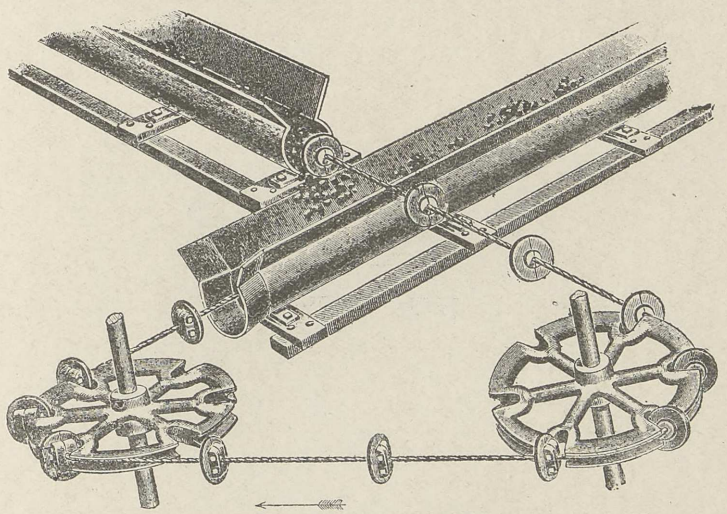


Fig. 87. Angle Station of Cable Trough Conveyor.

form a shoot for the material as it leaves the conveyor. With these outlets the only precaution necessary is to provide a central support for the conveying discs when the outlet is open, to prevent them catching, as this would result in a breakdown.

The horse power consumed by these conveyors cannot be given, as they are mostly used on a downward gradient, when they may even produce power. If on a level or slightly downward incline the power consumed is about the same as for ordinary scraper conveyors of the same capacity.

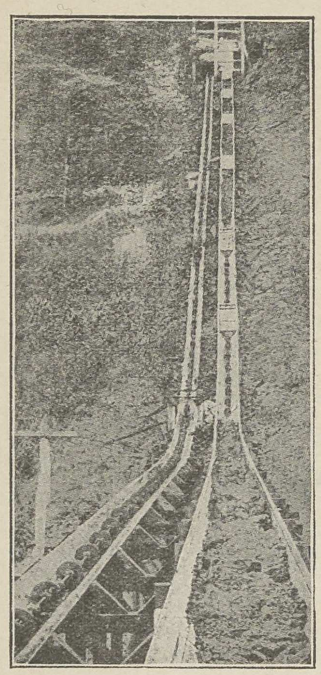


Fig. 88. Retarding Cable Trough Conveyor at the Mines of the Logan Consolidated Coal and Coke Co., Matewan, W. Va., U.S.A.

Cable Trough Conveyor of the Jeffrey Manufacturing Co.—Cable trough conveyors may also be used as inclined retarding conveyors for lowering coal from higher to lower levels, work which, as a rule, is performed by means of a system of colliery tubs. The plant here illustrated (Fig. 88) is of special interest, because it replaces the old tram system, and has several points of advantage in its favour. Its first cost is less, while it is simple and requires practically no power or attendance. In the plant illustrated the coal is discharged over the ordinary tippler at the head into a hopper, from which it is fed on to the conveyor, which in this case is a Jeffrey wire rope with disc-shaped attachments running over special sheaves at the terminals and operating in a V-shaped trough. When the conveyor is loaded and working with a continuous feed, it acts as a retarder in keeping the coal from running away by itself. A small motor is generally necessary to start the conveyor, while when running with a full feed a brake is used to keep it in check. By this system coal may be carried to the shoots or cars below with but little breakage, and at the rate of 100 to 140 tons per hour. In the plant illustrated the distance from the upper to the lower level is 500 ft. Formerly colliery tubs were used, but as this

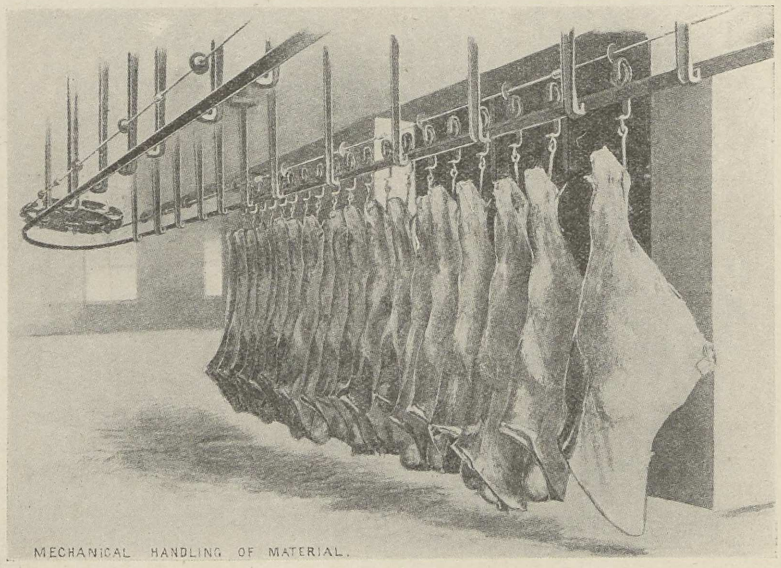


Fig. 89. General View of Meat Conveyor.

system has proved a practical success in America, it will doubtless find favour in other countries for work under similar conditions. This plant was erected by the Jeffrey Manufacturing Co., of Columbus, U.S.A., for the mines of the Logan Consolidated Coal and Coke Co., at Matewan, W. Va., U.S.A.

Slaughter-House Conveyors.—A modification of this type of conveyor is used for handling carcasses in slaughter-houses when the trough is dispensed with altogether. A general view of such an appliance is shown in Fig. **89**, whilst Fig. **90** shows the detail

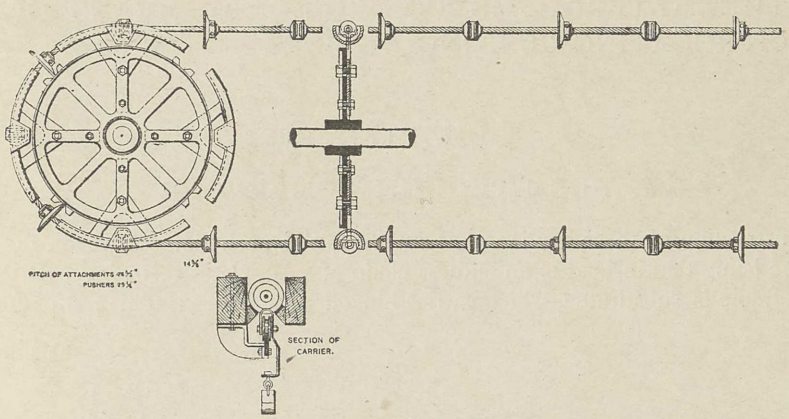


Fig. 90. Details of Meat Conveyor.

of one of the driving terminals, and the construction of the conveyor itself. This conveyor consists of a steel cable to which are connected at regular intervals two kinds of attachments, the smaller one being for the purpose of driving the rope from the terminal, whilst the larger and disc-shaped attachment is intended to engage and push forward the trolleys from which the beef and pork are suspended.

The illustrations explain themselves. Such a plant is at work at the packing house of John P. Squires & Co., Cambridge, Massachusetts, U.S.A., and was erected by the Steel Cable Engineering Co., Boston, U.S.A.

CONVEYORS

B.—APPLIANCES WITH A STATIONARY TROUGH IN WHICH THE MATERIAL IS CONVEYED BY MEANS OF A RECIPROCATING PUSHING DEVICE

CHAPTER VI

PUSH-TROUGH CONVEYORS

THE construction of these appliances is similar to the push-plate conveyor, the principal difference being that instead of an endless chain of push-plates revolving over the trough, a rod or frame is substituted, which carries hinged push-plates. This rod or frame has a

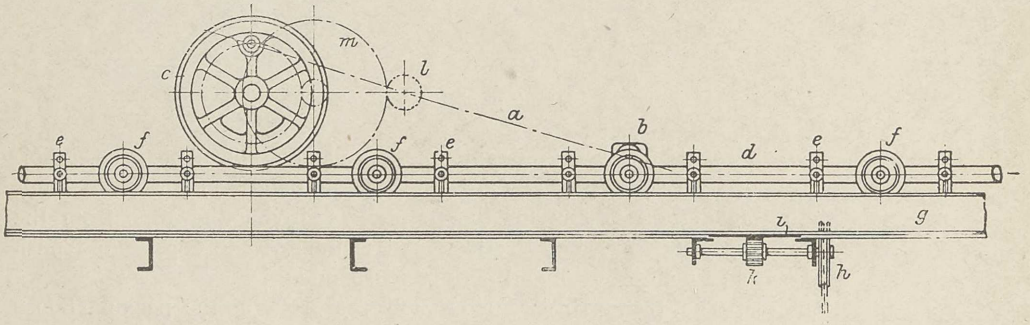
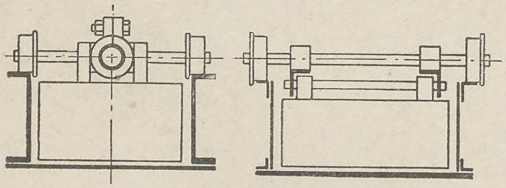


Fig. 91. Push-Trough Conveyor with Outlet.

reciprocating movement, so that the plates act like push-plates in the forward movement, while they disengage, and, being hinged, slide over the top of the material at the backward stroke. Fig. **91** shows such a conveyor of the most usual design. The trough is generally made similar to that of the push-plate, *i.e.*, with two ⊏ irons, and a plate at the bottom riveted to the under flange of the two ⊏ irons.



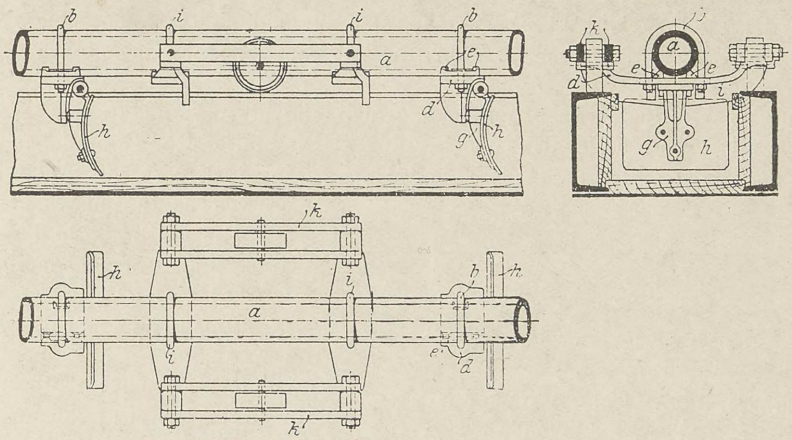
Figs. **92** and **93**. Methods of Hinging the Push-Plates.

The reciprocating rod or frame is carried at intervals by pairs of rollers, which revolve on the upper flange of the ⊏ iron trough. The two usual methods of hinging the spades or push-plates are shown in Figs. **92** and **93**. The oscillation is given to the rod or frame with its hinged blades by a crank and connecting rod, as shown in Fig. **91**, which represents the pipe construction. An outlet manipulated by a chain-wheel, rack, and pinion is also indicated upon the drawing. The dotted circles represent the electro-motor and countershaft.

The push-plates are 18 to 30 in. apart, the stroke is equal to the pitch of the blades, and the speed 50 to 60 strokes per minute.

The capacity is the same as for push-plate conveyors of the same dimensions, etc.

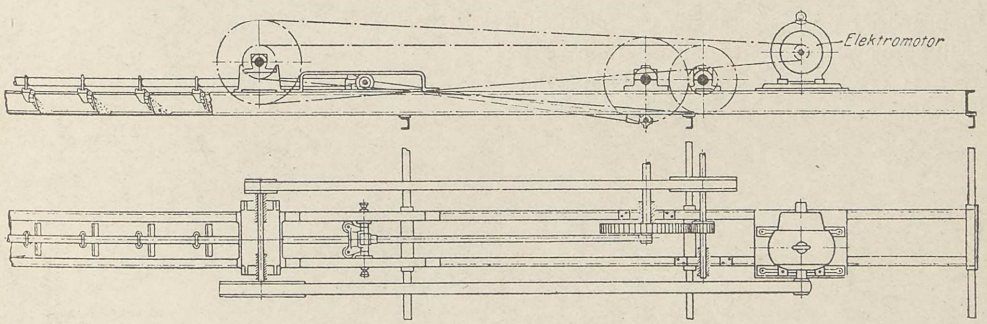
Push-trough conveyors have a restricted use, as the blades will not readily engage with large material. They are principally used in foundries to convey foundry sand.



Figs. 94, 95, and 96. Push-Trough Conveyor for Foundry Sand.

They will also handle all other fine materials, as well as ashes and small coal to the size of nuts, ordinary sand, gravel, etc.

Figs. **94**, **95**, and **96** illustrate a similar conveyor, several of which are at work on foundry sand in a large German foundry, and made by Vereinigte Schmirgel und Maschinen-Fabriken, Hanover-Hainholz.[1] The description of the previous illustration will make a



Figs. 97 and 98. Showing Motor and Method of Reducing Speed.

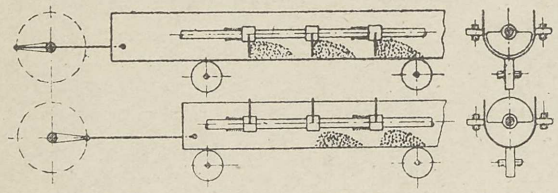
repetition unnecessary, and it may suffice to say that this conveyor is nearly 100 ft. long. Figs. **97** and **98** show the motor and the mode of speed reduction. The principal feature of the construction is the curved form of the blades, and the differential roller supports for the reciprocating device. For the latter it is claimed that the power consumption is reduced.

It has been found that the wear is greatly reduced by lining the trough with wood, which material is less affected by the foundry sand than iron.

[1] *Zeitschrift des Vereines deutcher Ingenieure*, 1909, page 1225.

This type of conveyor is also used in the United States for handling salt from grainers. The trough is there made of hard maple wood, and the base sometimes lined with crude $\frac{1}{2}$-in. plate glass. The reciprocating motion is slow, and obtained either by a connecting rod and crank similar to those already described, or by an hydraulic cylinder. The stroke is 5 ft. and the feathering blades 24 by 6 by $\frac{1}{8}$ in., placed 3 ft. pitch and heavily galvanised. These conveyors are frequently 200 ft. long, and it is believed that when the base is lined with glass they may safely be made 300 ft. long. Such conveyors have been at work for four years handling the salt from sixteen grainers, each 176 ft. long by 13 ft. wide.

There is a further type of conveyor which, though differing from the foregoing, ought to be dealt with under the same heading. It is built on the Commichau principle, in which case the trough oscillates as well as the plates. This conveyor is illustrated in Figs. **99** and **100**, which show it in its extreme forward and its extreme backward position. The upper drawing shows the trough on the point of starting the forward movement, pushing the material forward by means of plates attached to the longitudinal rod. The lower illustration gives the conveyor ready for its backward movement, the plates having been turned upward through a turning motion of 180° of the spindle instead of being hinged as in the former case.



Figs. 99 and 100. Push-Plate Conveyor on the Commichau Principle.

It is only in short conveyors that the trough receives a backward and forward motion. In the case of greater lengths the spindle with its plates performs the backward and forward as well as the turning motion, while the trough remains stationary. Conveyors of this type are said to have been built for considerable lengths, but they appear to be more generally used for short lengths. It is said that a trough 12 in. wide will convey 50 tons of coal per hour.

It is claimed for this appliance that it is more suitable than worm conveyors for handling material of a sticky nature.

CONVEYORS

C.—APPLIANCES IN WHICH THE TROUGH CONTAINING THE MATERIAL MOVES BODILY WITH THE MATERIAL

CHAPTER VII

BAND CONVEYORS

Historical and Introductory.—The credit of this invention, at all events the underlying principle of its present form, is due to Mr George Fosbery Lyster, engineer of the Mersey Dock and Harbour Board, who in 1868 carried out a series of experiments on behalf of that body in order to ascertain what type of conveyor was most suitable for the mechanical handling of grain. The experiments were initiated on worm conveyors of different types, which, however, proved altogether inadequate for large granaries and silo warehouses, principally on account of their small capacity and the great driving power required. Mr Lyster then began to experiment with endless travelling bands, and after a few preliminary trials with small canvas bands, made further trials with a band 12 in. broad. This band was run at different speeds to ascertain the highest velocity at which such conveyors could be worked with safety and economy. It was also desired to practically test the most suitable speeds for different kinds of grain.

A speed of 8 ft. per second was found to be the maximum for light grain, such as oats, while careful experiments showed that even bran and flour could be conveyed at this speed without such material being thrown off the band by the resistance of the air to its passage. A speed of about 9 ft. per second was found suitable for heavier grain, such as Indian corn, peas, etc. The capacity of this 12-in. band when fed to its fullest extent was found to be about 35 tons of grain per hour, the band then travelling at the speed of 8 ft. per second.[1]

Mr Lyster found by his experiments that grain had no tendency to fall off the band, and that even single grains when placed near the edge remained in position while passing over the carrying rolls at the speeds mentioned.

Like other mechanical inventions, the band conveyor had to pass through a period of disappointments. It was feared that a flat band would spill the grain, and the supporting rolls were therefore hollowed out in the middle to give the band the form of a trough. This was all right as far as conveying was concerned; but on the other hand, the bands employed, which were composed of cotton webbing covered with rubber, wore out in a very short time, because, owing to the varying diameters of the curved roller and the consequent variation of the circumferential velocity at different points of the roller, a grinding action was set up between the rollers and the band, the velocity of the latter being of course the same for the whole of its width. This grinding action destroyed the bands. Later on further trials confirmed Mr Lyster's experiments, showing

[1] *Proceedings Mech. Eng.*, August 1869.

that grain could be conveyed in all security on a perfectly level band provided it were properly delivered thereon, *i.e.*, at the same speed as that at which the band was travelling. Band conveyors for grain often run perfectly flat, except at the point or points where grain is fed to them; but at these points two separate cylindrical curving rolls are applied, which slightly hollow the band for a few feet, and then allow it to lie flat again on its supporting rollers.

These endless bands run over terminal pulleys, and are in addition supported on their way by a series of rollers, which are more frequent on the loaded than on the empty strand. Such conveyors are usually fitted with some kind of tightening gear to keep the belt in tension.

Supporting rollers are fitted at intervals of 6 ft. to the upper or working strand of the band, and at every 12 ft. on the lower or return strand. Sometimes it is desirable to use both strands of the band for conveying purposes, thus making it a double service machine, in which case the supporting rolls for the lower strand must be as close together as for the top. In such a case the terminal pulleys should be larger than usual in order to give the two strands a greater distance from each other, to allow sufficient

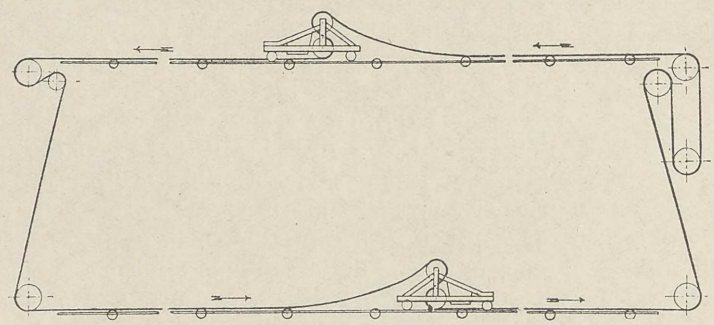


Fig. 101. Band Conveyor suitable for Conveying on Both Strands.

space between the strands to conduct the grain to the lower band, and discharge it again before reaching the other terminal. The two strands can be run any distance apart by using two additional guide pulleys for the terminals, as shown in Fig. **101**. In such a case one band might run along the top floor of the granary whilst the other travelled along the bottom. Throw-off carriages are indicated on both top and bottom bands.

The tightening of a band conveyor is effected in a similar manner to that of tightening elevator bands,[1] *i.e.*, by means of two screws which push or pull the two pedestals of one terminal pulley further away from the other terminal; but as such an appliance does not admit of great latitude, it is insufficient for very long conveyors. In such cases the tightening gear would consist of a pulley, held in tension by weights, over which the belt passes. This tightening pulley can be placed at any point on the return strand of the belt, but is generally situated at the end opposite to the driving end of the conveyor.

Fig. **102** shows a tightening pulley as used at the terminal.

In Fig. **103** is illustrated a form of tightening pulley which can be applied to any part of the returning band.

It is undoubtedly preferable to use tension screws for tightening the band if it be possible, and in cases where throw-off carriages with fixed pulleys are used, and where

[1] See Tightening Gears, page 191.

the conveyor is not too long, there is no objection to this course; but if throw-off carriages of the swivelling type are used, as in the case where the material has to flow on the band past the throw-off carriage, it becomes necessary to have tightening gears with weighted pulleys. As to the allowance to be made for tightening belts, that must greatly depend on the quality of the band. A good conveying band, with a breaking strain of say 400 lb. per ply per inch width, requires an allowance for tightening of 4 per cent. This

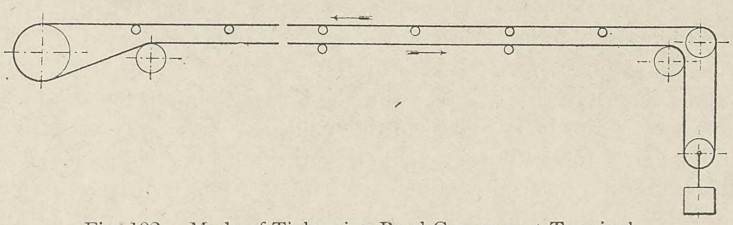


Fig. 102. Mode of Tightening Band Conveyor at Terminal.

would indicate that with a band of good quality even of great length the screw tightening gear can be employed if otherwise suitable.

Where permissible, belt conveyors should always be erected sufficiently high above the floor, so that any accumulation of material which may be spilled, or, in the case of fine powders, that may be carried back by the return strand, cannot interfere with the rollers

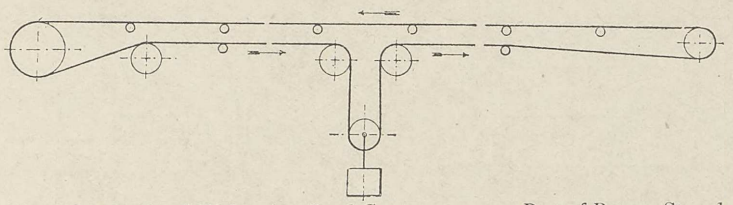


Fig. 103. Mode of Tightening Band Conveyor on any Part of Return Strand.

by coming into contact with them. A sufficient space under the return half of the belt also makes it more convenient to clear up any such accumulations at intervals.

To withdraw the feed from a band conveyor at any intermediate point, a throw-off carriage is employed, and the credit for the invention of this device is largely due to the

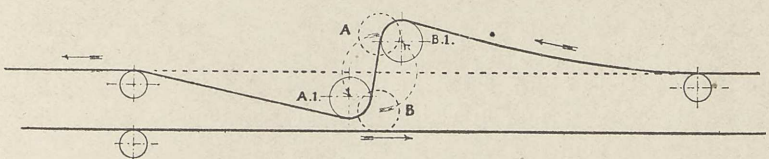


Fig. 104. Diagrammatic View of Throw-off Carriage.

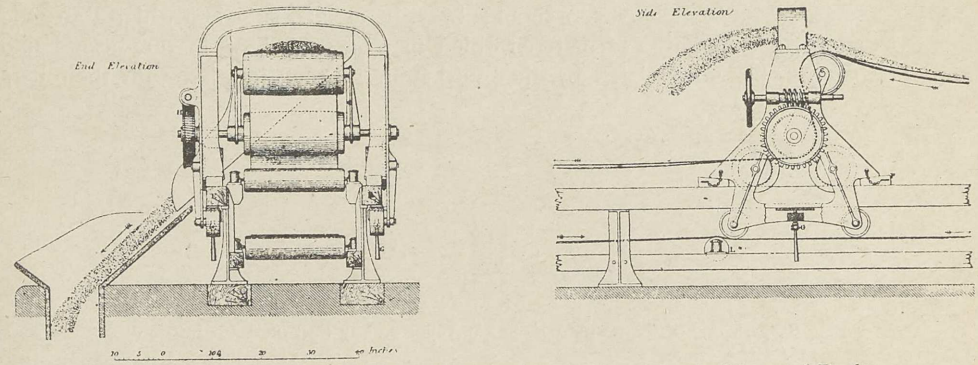
experiments of Mr Lyster. To remove the grain he made trials with several contrivances, including air blast and brush devices driven from the band itself. Both methods, however, gave but indifferent success. In both cases a most objectionable amount of dust was raised. Moreover, the friction of the brushes on the band proved in time injurious to the latter. The idea then occurred of diverting the stream of grain by means of an upward deflection of the carrying band, thus casting the grain clear of the band and into the air for a short distance, so that it could in falling be caught and led off through a spout on either side as required. The device consisted in principle of two guide pulleys which in most

cases can be turned round a common centre by means of worm and worm wheel. When out of use one guide pulley is above and one below the band, which runs through between them but without touching them. If delivery of the material is required at a certain point, the throw-off carriage is pushed into position and the guide pulleys are turned round the common centre in the direction of the arrow, so as to raise one part and lower the other part of the band as shown in Fig. **104**. In this illustration the dotted circles A, B, indicate the guide pulleys when out of use, while those in full line A_1, B_1 show the position of the pulleys when the throw-off carriage is in use.

As soon as the grain arrives at the throw-off carriage, it leaves the band by its own momentum, and is received in a hopper which forms part of the apparatus. It is then spouted sideways to its destination clear of the band.

This arrangement for withdrawing the grain from the band proved a complete success, and has been universally adopted. The throw-off carriage, designed for the use of the Liverpool Docks in 1868, was probably the first of these devices, and is shown in Figs. **105** and **106**.

It consists of a pair of wrought-iron rollers centred in gun-metal bearings in a



Figs. 105 and 106. Adjustable Throw-off Carriage Designed for the Liverpool Docks.

rocking frame, which is hung in a movable carriage running upon the top of the timbers of the wooden framing that supports the travelling band. The carriage is moved to any position along the length of the band where the grain is required to be discharged, and is there secured by wedges and clamping screws.

The rocking frame is rotated in either direction, by means of worm and worm wheel, to bring the pair of rollers into action in the proper position for throwing the grain off in the same direction as that in which the band is running, while the rollers are turned back into a horizontal position to be clear of the band when the carriage is required to be moved to any other point on the length of the band. A curved spout is attached to the carriage for receiving the stream of grain in its fall and leading it off on either side of the band.

The throw-off carriage shown in Fig. **107** is of a very simple kind without adjustment. It has a clamp by means of which it can be secured in its position. The diagram shows also the receptacle for the grain and the alternate outlets on either side with valve arrangements.

This appliance having no means of adjustment, when not in use must always be moved to the terminus. It is also sometimes made with a third outlet which delivers the grain back again on to the band if intermediate delivery is not required. In such

a case the position of the carriage when not in use is immaterial, as the grain can proceed through this third outlet uninterruptedly.

Band conveyors can be fed without any difficulty; but it has been found necessary to slide the grain upon them from the feeding hopper through a shoot rather less than half the breadth of the band and set at an incline of 42½ degrees to the horizontal, to give the grain falling upon the band a horizontal velocity nearly equal to that of the band.

It is very important to regulate the feed of the band, if only to minimise wear as much as possible, especially when conveying coal and other sharp-edged material. The material should not strike the band vertically, whilst the height from which it falls must be reduced as much as possible to allow of a gentle drop.

As the flow by gravity of grain of various kinds and in varying condition through a spout differs considerably, it is advisable to place a pair of oblique side rollers at the point where the grain falls upon the band as already mentioned, for the purpose of preventing the tendency of the grain to spread. In passing heavy quantities of grain along the band for a considerable distance it has also been found expedient to apply

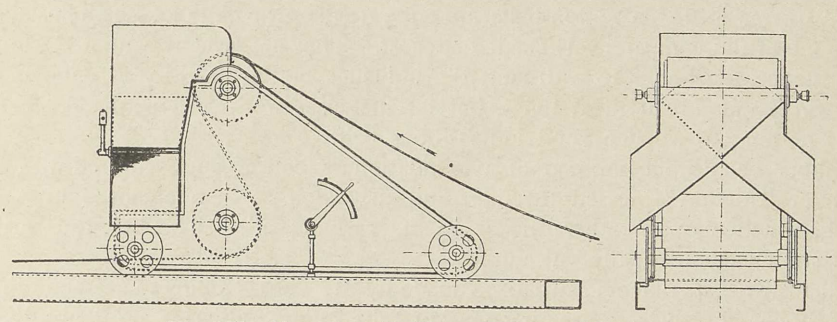


Fig. 107. Non-adjustable Type of Throw-off Carriage.

at intervals pairs of these oblique side rollers, which are carried in movable frames which can be set at any required spot.

All conveyors which are intended for intermediate delivery by means of an adjustable throw-off carriage must be fitted with tightening gears as shown in Figs. **102** and **103**, because the use of such throw-off carriages necessitates additional length of conveyor band, which must be disposed of whenever the carriage is out of use. These tightening arrangements provide suitable accommodation for such extra length of band.

As there is sometimes a tendency for the band to make a side movement on its rollers, so that the centre of the band is not in the centre of its supports, the employment of one or more pairs of small rollers placed against the edge of the belt is sometimes resorted to to prevent this, but this should not be necessary if the belt is well made, and if the idlers are all parallel and true.

Belt conveyors require no particularly rigid structure, and are, therefore, very suitable for temporary or contractors' work, provided that the conveyor is of itself suitable for the work.

The belt conveyor is now a very popular means of conveying both heavy and light materials. When first introduced, about 1868, by Mr George Fosbery Lyster, engineer to the Mersey Dock and Harbour Board, it was used for conveying cereals and seeds only, but between the years 1885 and 1890 a number of more or less experimental plants were erected for minerals, and the credit for this extension of the utility of band

conveyors is principally due to Mr Thomas Robins. At the present day thousands of installations are successfully at work, handling almost all kinds of material; hot and sticky substances being almost the only ones for which this method of transportation is unsuited.

The accompanying illustration, Fig. **108**, represents a form of band conveyor constructed by the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft for conveying coal. The illustration shows clearly the type of tightening gear employed. It also gives the main drive with its two tightening pulleys in plan and elevation, the throw-off carriage, and a cross section through one of the termini, as well as one intermediate section through the band.

The difference in construction between conveyors for grain and minerals consists chiefly in the quality of the band and the form of the supporting idlers and, whereas for grain curving rollers are only occasionally used, conveyors for minerals are fitted with curving rolls for the entire length of the loaded strand, forming it into a continuous trough.

The following is a more detailed description of the principal parts constituting a modern band conveyor.

The Belt.—The most important part of a belt conveyor is undoubtedly the belt. Stitched canvas or woven cotton belts are often used, particularly for small installations, on account of the comparatively small first cost. They are usually saturated with some oily substance, the better to withstand the influence of the weather. Balata, and even woven wire bands are used at times, but for first-class work of a permanent character there is nothing to equal a good india-rubber belt.

Rubber belts are composed of a foundation of cotton duck covered with rubber solution or "friction" pressed together, and the whole is then enclosed in a rubber covering, which may be rather thicker on the carrying side. The belt thus produced is then stretched and finally vulcanised.

Exhaustive experiments have been made by Mr Thos. Robins to ascertain the best class of rubber coverings to use for conveyor belts. Pure rubber is, no doubt, the most serviceable material, as it is almost indestructible, and as the rubber suffers very little wear from contact, even with sharp and cutting materials, but as pure rubber is exceedingly costly, it is practically beyond the reach of ordinary users, and the experiments alluded to were made to ascertain what kind of admixture to the rubber will deteriorate its wearing qualities least.

It is interesting to find from these tests that even steel wears faster than rubber under a heavy sand blast, and under conditions to which a belt would be exposed when handling minerals. The following diagram (Fig. **109**) and table show the wear on the different materials subjected to a uniform sand blast for forty-five minutes :—

Rubber belt	1·0	Woven cotton belt, high grade	6·5
Rolled steel	1·5	Stitched duck, high grade	8·0
Cast iron	3·5	Woven cotton belt, low grade	9·0
Balata belt, including gum cover	5·0		

The object of the rubber covering is two-fold. The thicker covering on the upper side is to resist abrasion, and the remainder of the cover is for the purpose of protecting the body of the belt from moisture. Since the rubber solution, forming the "friction" with which the duck is held together, is not absorbed sufficiently by the fibres of the cotton duck to make the body of the belt waterproof, and, as the cotton where exposed absorbs moisture as readily as the wick of a lamp, it is most important that the outer covering should be perfect, particularly if the belt is exposed to the wet.

It is also necessary to see that the belt does not in any way rub against any hard

substances, as any abrasion or cut in the covering, sufficiently deep to admit the moisture to the cotton, may cause serious damage to the belt, as the rubber loosens its hold on the damp cotton, forming blisters, which soon elongate along the belt through the compression and extension of the inner parts when passing over the terminals.

The number of plies of duck of which the belt is composed must be such as to make the belt sufficiently rigid to support the maximum load between the supporting idlers without sagging. This is the only condition which need be observed for ordinary conveyors of medium lengths. According to Mr C. K. Baldwin, of Chicago, the number of plies should be as follows: belts of 12 to 14 in. wide should be not less than three ply; belts 16 to 20 in. wide not less than four ply; belts 22 to 28 in. not less than five ply; while not less than six ply should be used for belts from 30 to 36 in. in width.

For extra long conveyors, however, and in cases where one or more additional belts or other machinery are to be driven from the end terminal of a conveyor, the tensile strength of the belt has to be taken into consideration, and the belt so constructed that the tension is not more than 20 to 25 lb. per inch per ply, although a good belt should have a breaking strain of about 400 lb. per ply per inch. The Robins type of belt is made with a flexible central portion by stopping off some of the plies of duck at varying distances from the edge, and by

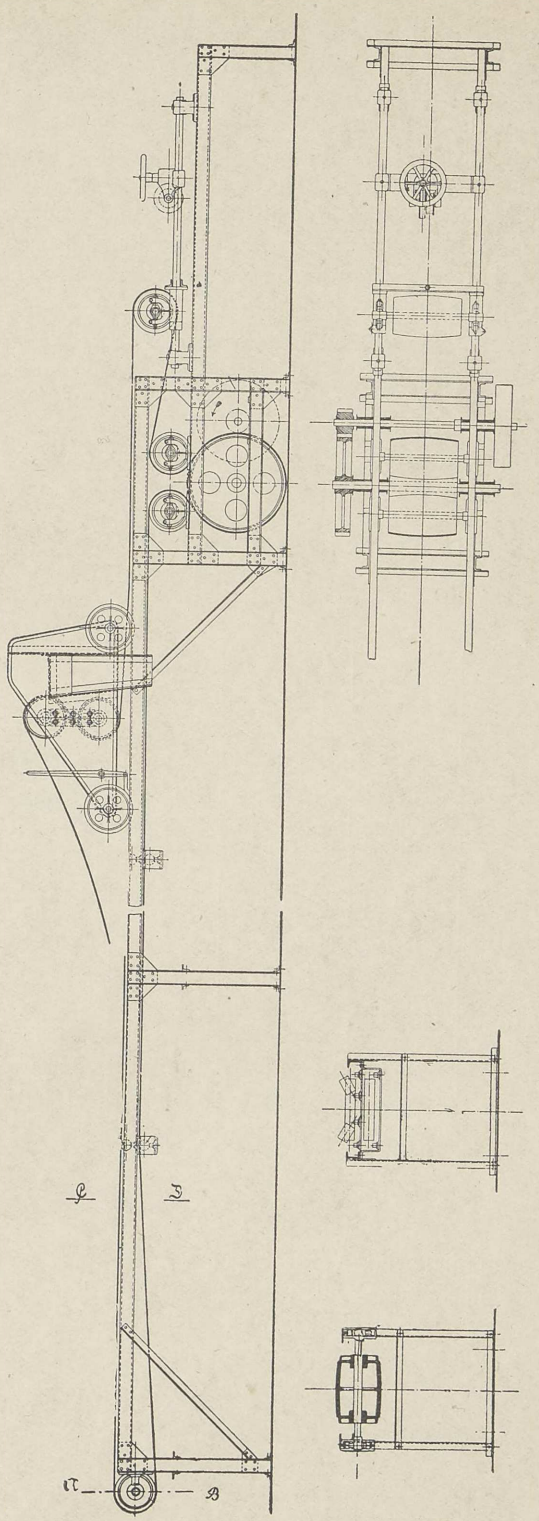


Fig. 108. Coal Conveying Plant of the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft.

substituting a thicker layer of india-rubber to make up for the missing duck. This not only makes the belt conform more readily to the troughing shape of the idlers, but the thicker layer of rubber also reduces the wear and tear which naturally comes in the middle of the belt, whilst the stiffer edges of the belt support the trough between the idlers, and give it the necessary tensile strength.

Some very interesting tests have been conducted by Mr Edwin J. Haddock, of Columbus—the results of which appear in the *Proceedings of the American Society of Mechanical Engineers*—as to the behaviour of conveyor belts under tension, more particularly to ascertain the effect of initial tension on the tractive force of conveyor belts on the driving drum.

The driving terminal used for the test consisted of a drum 42 in. diameter, with the snubbing idlers so arranged as to give a belt contact of 180°, the tail terminal being so arranged as to exercise a variable tension in a horizontal direction by means of a rope running over a pulley to receive a weight.

The weights suspended were as shown in the following table, and the experiments were made in the order given :—

TABLE SHOWING THE EFFECT OF DIFFERENT TENSIONS ON THE SAME TERMINAL OF A BELT CONVEYOR

Tension Weight.	Initial Belt Tension.	Amperes.	Effective Pull on Belt.	Belt Strain.	
				Maximum.	Minimum.
650	325	14·0	260	455	195
800	400	16·5	330	565	235
1,300	650	24·0	550	925	375
1,500	750	29·0	690	1,095	405
2,000	1,000	38·0	650	1,475	525
1,500	750	31·0	750	1,125	375
1,250	625	25·0	575	913	337
1,000	500	22·0	490	745	255
750	375	18·0	370	560	190
3,000	1,500	56·0	1,450	2,225	775

NOTE.—The weights are given in lbs.

Beginning with a weight of 650 lb. and gradually increasing to 1,500 lb., the belt stretched but slightly, but under the additional 500 lb. with a total of 2,000 lb. the belt elongated about 3 ft. in its total length of 158 ft. The belt then remained without further stretching whilst running under the weight. On removing the load gradually to 750 lb., the belt recovered 15 in. of the stretch; while under a load of 3,000 lb. it stretched 3 ft. 8 in., or 8 in. more than under the 2,000 lb. load. The belt was then run under the 3,000 lb. load for thirty minutes without changing its length appreciably.

The belt strain caused by the application of the last weight being 1,500, is equivalent to a stress of 31·25 lb. per inch per ply. The belt being 12 in. wide and four ply, this is not far short of the manufacturer's guarantee of 40 lb. per inch per ply as the ultimate working strength of rubber-covered cotton duck belting.

The best method of joining conveyor belts is by butt joint with ordinary belt fasteners.

Conveyor belts will last longer if they are not strained over too small rollers or terminals, if not troughed too deeply, and if the troughing rollers are kept away from the terminals at least a distance of six times the width of the belt.

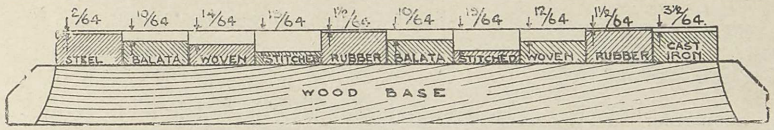


Fig. 109. Diagram showing Amount of Wear of Various Materials after being subject to an Equal Abrasion.

It may be noted that bands made of woven wire are sometimes used in connection with coal-washing plants. As these bands have much in common with belts of textile material, they may be handled in much the same way, and run at a high speed, nearly 10 ft. per second. To ensure a proper grip, the driving terminals must be faced with rubber, leather, or lagged with wood. Such bands are not very durable, their tendency to stretching and their relatively high price being against their more frequent adoption.

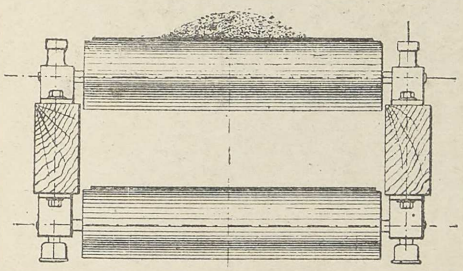


Fig. 110. Supporting Roller for Grain Conveyor.

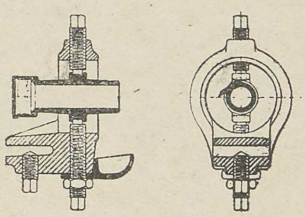


Fig. 111. Idler Roller Bearing for Band Conveyor.

Troughing of the Belt.—Not many belt conveyors are used at the present time with flat belts, on account of the larger capacity of troughed conveyors. The ordinary conveyor belt, with uniform plies of duck across the whole surface, is naturally stiff, and, if forced to assume the shape of a deep trough, is bound to suffer, as the adherence between the plies of duck and the rubber coating are strained and distorted by the ever-repeated process of bending. This type of belt, if otherwise suitable for the material to be conveyed, should never be bent more than into a shallow trough.

For deep troughing the type of belt advocated by Robins is advantageous, as only a belt of this type can stand the strain of being continually shaped into a deep trough. This kind of belt has a natural tendency to trough, as the sides are stiffer than the middle.

Idlers.—A supporting roller or idler for a grain conveyor is shown in Fig. 110.

These supporting rollers are 4 to 6 in. in diameter, and are sometimes made of wood, but more often consist of steel tubes to which spindles with conical end gudgeons are secured. These gudgeons generally run in suitable bush bearings, which should be well lubricated.

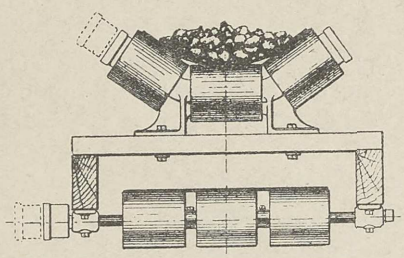


Fig. 112. Support for Band Conveyor of the Robins Conveying Belt Co.

A more elaborate bearing is the one illustrated in Fig. 111. It consists of a neat cast-iron bracket which can be clamped to the angle-iron framework of the band conveyor without necessitating the drilling of holes in the same. The bearing is adjustable up and down, while one end is formed into a Stauffer lubricator, which can be filled with a viscous lubricant. This bearing being long and movable, will adjust itself to the position of the spindle, so that friction should be reduced to a minimum. The appliance is also fitted with a removable cup for the reception of any surplus lubricant.

Sometimes curving rollers are used at intervals in addition to the point or points where the conveyor receives its feed. The type most generally in use is that illustrated in Fig. 112, and a modification of the same principle for wider belts, shown in Figs. 113, 114, 115, and 116. The former was first introduced by the Robins Conveying Belt Co.

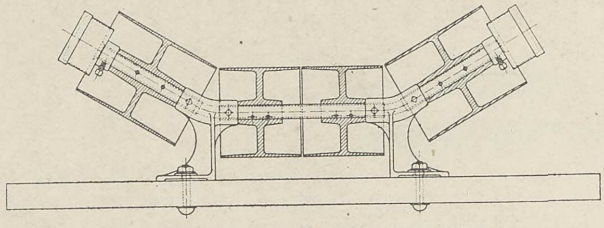


Fig. 113. Four-Roller Troughing Idler.

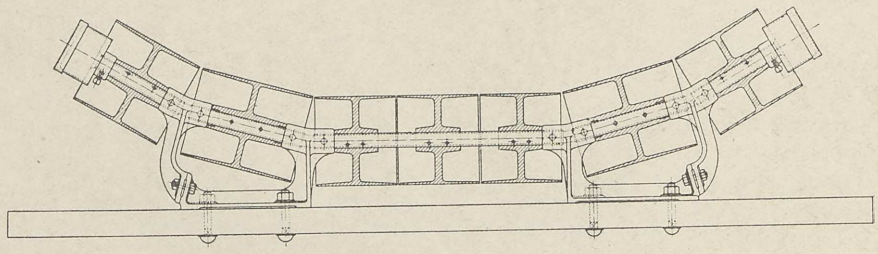


Fig. 114. Seven-Roller Troughing Idler.

about 1885, and is now almost universally used either as illustrated or with slight variations.

Theoretically, it cannot be considered correct to use idler pulleys of small diameter for narrow belts, and larger ones for wide belts, as is generally the case. The belt speed should be taken into consideration, and fast-running belts should be fitted with larger, and slow-running ones with smaller, diameter rolls. Conveyors for grain and seed, which almost invariably run faster than those for minerals, generally have the

smallest diameter idlers, which is obviously wrong, as a glance at the following table illustrates.

With a belt speed of from 200 to 600 ft. per minute a 4-in. roller will make from 190 to 570 revs. per minute.

A	5-in. roller at the same speed will make			150 to 460 revs.
A	6	,,	,,	125 ,, 375 ,,
A	7	,,	,,	110 ,, 330 ,,
A	8	,,	,,	100 ,, 300 ,,
A	9	,,	,,	85 ,, 255 ,,
A	10	,,	,,	75 ,, 225 ,,

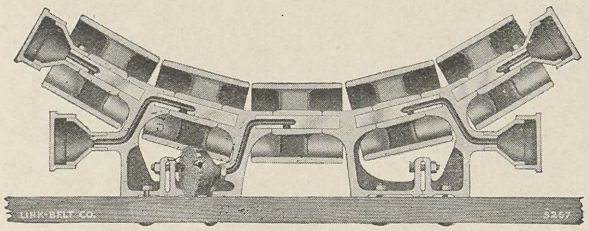


Fig. 115. Five-Roller Troughing Idler of The Link Belt Co.

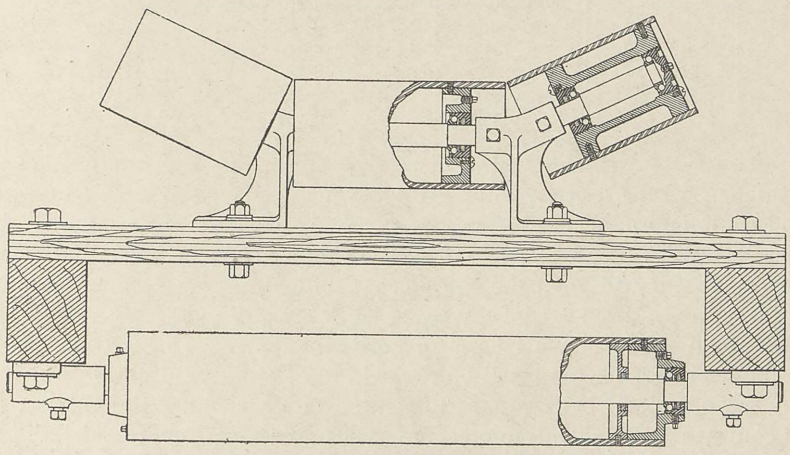


Fig. 116. The "Conweigh" Ball-bearing Troughing Idler.

From this table it will also be seen that the speed of the idler pulleys, except those of 4 in. and 5 in., at the high speed, is not too high to ensure satisfactory running, and, if properly lubricated, the weight of the belt alone should be sufficient to turn them easily. Should any of them become stuck it will be due to grit or insufficient lubrication.

The greater the number of rollers in each idler frame, and, therefore, the shorter each individual roller, the smaller the chance of damage by attrition to the belt in case of any one roller becoming fast.

The slope of the idler pulleys for troughing, as first introduced, stood at an angle of 40° to the horizontal, but was subsequently changed to anything between 30° and 25°, so as to avoid too sharp a bend in the belt. Later designs for wide belts use idlers with five and six rollers, to form a trough resembling a section of a circle. This gives sufficient

troughing to carry a large capacity, and ensures the centring of the load, thereby increasing the tendency for the belt to run straight.

Ball bearings for idlers have of late been introduced with great success. The advantages of this construction are obvious, as these idlers run so easily that it is quite impossible for them to get stuck, to the detriment of the belt or the expenditure of driving power. The makers of the idlers are The Conveying Weigher Co., of New York.

Fig. **116** shows one of these sets of idlers, from which it will be seen that the whole of the bearing is enclosed in a dust-tight chamber in the interior of the rollers. The space is filled with sufficient lubricant to last from six to twelve months, according to whether the conveyor runs long or short hours.

The distance apart of the supports depends upon the weight of the material to be carried, and also upon the rigidity of the belt, a troughed belt being naturally more rigid than a flat one. The following table gives this information under average conditions and for troughed belts :—

Width of Belt.	Number of Plies in Belt.	Pitch of Idlers.	
		For Minerals.	For Grain and Seed.
Inches.		Ft. In. Ft. In.	Ft. In. Ft. In.
10 to 16	3 to 4	4 6 to 5 0	5 6 to 6 0
18 ,, 22	4 ,, 5	4 0 ,, 4 6	5 0 ,, 5 6
24 ,, 30	5 ,, 6	3 6 ,, 4 0	4 6 ,, 5 0
32 ,, 36	6 ,, 7	3 0 ,, 3 6	4 0 ,, 4 6
38 ,, 48	7 ,, 8	2 6 ,, 3 0	3 6 ,, 4 0

Support of Return Strand.—The idlers supporting the return strand should be about twice as far apart, or say from 6 ft. to 12 ft.

Provided the return idlers are not too small in diameter, there is no detriment in spacing them a little further apart than stated, as the sagging of the return belt caused by this has a tendency to keep the working strand taut. The distance between these idlers has been known to be as much as 20 to 25 ft.

Lubrication of Idlers.—This is of great importance. Oil, of course, is the best lubricant; but as this is likely to spill on the belt, it is better to use a viscous lubricant, particularly when rubber belts are used, as the oil may injure the rubber. Grease-lubricated conveyors take slightly more power, but grease is a more suitable lubricant, as, when forced into the bearings in the usual way, it forms an effective dust protector for the journal.

Driving Terminals.—The driving mechanism of a belt conveyor is the simplest possible. It consists, in its original form, of a terminal or driving drum, or pulley, supported by a substantial spindle and pedestals, to which the driving power is applied. The terminal at the other end is similar, but is usually fitted with an adjustment for keeping the belt taut. These terminals are so simple and so well known that there is no call for going into further details, except to say that the drums should be stronger than ordinary pulleys, with a good rim and sufficient arms, particularly for wide conveyors, and they should be well rounded on the face. It is also advisable to secure the driving drum to the spindle with two keys 90° apart.

The following table gives the diameters and widths of terminal drums and guide and idler rollers, which are recommended for ordinary conditions.

If the pulley or drum is less in diameter than the dimensions given in the table,

the belt may not be sufficiently pliable to adhere closely to the pulley, and it is, therefore, questionable whether the full benefit of the pressure will be obtained.

DIMENSIONS OF TERMINALS, GUIDE PULLEYS AND SUPPORTING ROLLERS

Width of Belt.	Number of Plies in Belt.	Width of Pulleys and Rollers.	Diameter of Driving Terminal Pulleys.	Diameter of End Terminal Pulleys.	Diameter of Tightening and Throw-off Pulleys.	Diameter of Supporting Rollers.
Inches.		Inches.	Inches.	Inches.	Inches.	Inches.
10	3	12	15-18	12-15	12	4[1]
12	3	14	15-18	12-15	12	4[1]
14	3	16	15-18	12-15	12	5[1]
16	4	18	21-24	15-18	15	5[1]
18	4	20	21-24	15-18	15	6
20	4	22	21-24	15-18	15	6
22	5	24	24-30	18-22	18	6
24	5	26	24-30	18-22	18	8
26	5	28	24-30	21-24	18	8
28	5	30	24-30	21-24	18	8
30	6	33	30-36	24-30	21	8
32	6	35	30-36	24-30	21	8
34	6	37	30-36	24-30	21	8
36	6	39	30-36	24-30	21	8
38	7	41	36-42	30-36	24	10
40	7	43	36-42	30-36	24	10
42	7	45	36-42	30-36	24	10
44	8	47	42-48	36-42	27	10
46	8	49	42-48	36-42	27	10
48	8	51	42-48	36-42	27	10

Position of Drive.—At first it was a generally accepted rule that the tight side of the belt should, by preference, be used for conveying, as this is in a flatter condition than the other, particularly in cases of installations with flat belts. This practically meant that band conveyors should always be driven only at the end at which they discharge their load, but it has been demonstrated within the last few years, that conveyors work well on either the tight or slack side of the belt. This has increased the utility of the band conveyor considerably, as under these conditions it is quite immaterial from which terminal the conveyor is driven. Indeed, it might be driven at any point of its length between the terminals by employing multiple pulley drives to get sufficient contact between the driving drums and the belt. For this purpose, the belt passes over two or even more pulleys, which may be geared together, so as to revolve at the same periphery speed. Similar multiple pulleys have also been used for terminal drives in cases of extra long conveyors, and particularly in cases where the conveyor works in dusty places, or where in the cold season there is the possibility of belt and pulleys becoming slippery through dust or ice. To some extent the slip may be prevented by lagging the driving drum with india-rubber, and, according to Mr Haddock, an advantage of 7 per cent. is obtained in tractive power, so that a drum with rubber lagging will be useful not only for larger conveyors but also in cases where a slipping may be feared.

With the single pulley drive at either of the terminals, the belt must always be kept taut by some tightening device, as the grip of the driving drum on the belt depends upon this, whilst with a multiple pulley drive, the grip of this group of pulleys on the belt is so great that sufficient tractive force can be exercised without relying on the tension of the belt.

It has been urged that the belt will not stand being bent over pulleys in both directions when in tension, which is necessary with multiple drives, but with a first-class

[1] Fast-running conveyors, at say a belt speed exceeding 500 ft. per minute, should have 6-in. diam. rollers.

belt and drums of sufficient diameter no separation of the plies has so far been experienced. It will, however, be well to wait before giving a final decision on this subject, until installations with multiple pulley drives have been in use for a sufficient number of years, to see whether the life of a belt under these conditions is as long as with the ordinary terminal drive. At any rate, the ability to drive the conveyor from either terminal is of the greatest advantage. Frequently, two conveyors working in the same direction, one from the other, or from the same point in opposite directions, have been driven by one motor by the latter being situated at the junction of the two conveyors.

Driving Power.—The power required for driving belt conveyors is comparatively small; in fact, there is probably no conveyor system which is so economical on this point. The calculation is influenced by a great number of considerations, of which the number of plies and, consequently, the stiffness of the belt, the distance apart at which the supports are placed and the nature of the driving arrangement form the principal items, in addition to the load, length, and speed of the conveyor. The method of lubrication and the state of the atmosphere also influence the power consumed, and, as this latter as well as other conditions cannot be considered as permanent, it appears of little use to give formulas for elaborate calculations, as these would only be right for certain specific conditions. Opinions of experts also differ so much on this subject—which was shown during the discussion on the interesting papers of Messrs Titcomb, Baldwin, and Peck, read before the American Society of Mechanical Engineers—that it will probably be better, more to the point, and more useful to the user to give a table of horse powers calculated to give a sufficient margin of power for small contingencies. This table gives the power required for horizontal conveyors, which will be less for a downward and more for an upward incline.

HORSE POWER REQUIRED FOR BELT CONVEYORS 100 FT. LONG RUNNING AT A SPEED OF 100 FT. PER MINUTE, AND WITH A NORMAL LOAD OF THE DIFFERENT MATERIALS

Width of Belt in Inches.	For Handling Heavy Ore.		For Handling Coal.		For Handling Grain.	
	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.	H.P. Consumed by Conveyor.	Additional H.P. Consumed by each Throw-off or Tripper.
10	·775	·25	·540	·25	·486	·25
12	·961	·50	·675	·50	·594	·25
14	1·147	·50	·840	·50	·702	·25
16	1·550	·50	1·080	·50	·810	·50
18	2·013	·75	1·316	·50	·952	·50
20	2·343	·75	1·512	·75	1·092	·75
22	2·838	1·00	1·792	·75	1·358	·75
24	3·636	1·25	2·250	·75	1·740	·75
26	4·320	1·50	2·670	1·00	1·925	·75
28	5·040	1·75	3·090	1·00	2·118	·75
30	5·760	2·00	3·540	1·25	2·310	1·00
32	6·747	2·25	4·096	1·50	2·707	1·00
34	7·254	2·50	4·416	1·75	2·950	1·00
36	8·151	3·00	4·768	1·75	3·200	1·25
38	9·348	3·25	5·635	2·00	3·815	1·50
40	10·168	3·50	6·355	2·00	4·130	1·75
42	10·906	3·75	6·405	2·25	4·725	1·75
44	11·644	4·00	7·790	2·50	5·320	2·00
46	12·505	4·25	7·175	2·75	5·915	2·25
48	13·366	4·50	7·560	3·00	6·895	2·50

It is a surprising fact that the power consumed by a band conveyor running empty may be as much as 35 per cent. to 75 per cent. of that consumed by the loaded conveyor, the percentage depending principally upon the load, length, and speed of the conveyor. It is obvious that the power consumed by the terminals does not increase *pro rata* with the length of the conveyor, and, therefore, the power thus consumed by the terminals of short conveyors may be the principal factor, but it becomes more and more insignificant as the conveyor is lengthened, whilst the power consumed in turning the idlers increases in direct proportion to the length and load of the conveyor, so that with short conveyors running idle the percentage of power consumed is smaller than with long conveyors.

The power required for band conveyors for grain is less than with any other grain conveyor. An 18-in. band travelling at 500 ft. per minute would convey 50 tons of grain per hour, and if 100 ft. long would consume 4·5 H.P.

Speed and Capacity.—The speed and capacity of belt conveyors depends entirely on the nature of the material to be handled and the width and shape of the belt. Materials like grain and seeds can be conveyed at the highest speed, as such materials will not be damaged by being delivered at a great velocity. The limit of speed is, therefore, only set by the resistance of the air to the passage of the material. If the grain or seeds are heavy, a speed of 500 to 700 ft. per minute is admissible, whilst if it contains much dust or chaff, or if the grain itself is light, like oats, the speed should not exceed 400 to 600 ft. per minute. Wheat and barley are generally conveyed at a speed of 500 to 550 ft., whilst maize, beans, and other heavy seeds may be conveyed at the maximum speed of 600 ft. per minute.

The speed of belts for coal and minerals is altogether different. Here the speed is, in many cases, limited by the friability of the material and the consequent dust creation and deterioration of some materials through the impact at the delivery point. This refers particularly to coal and coke. There is an exception to this in cases in which the material does not deteriorate by breakage at the impact, but where the band has to run slower on account of fine material being mixed with the coarse, so that the same consideration comes into force as in the case of grain conveyors.

The best speed for large pieces is 150 to 250 ft. per minute, and the speed increases in proportion for material of a smaller size to a maximum speed of 700 to 750 ft. per minute.

The shape of the belt has also a great influence on the capacity, and flat or very shallow trough belts cannot carry as much as deeper troughed belts. The following table gives the safe load for a belt, in cubic feet per minute, by multiplying the area of a uniform load with the speed in feet at which the belt travels:—

TABLE SHOWING SECTION OF LOAD IN SQUARE FEET WHICH CAN BE CARRIED WITH SAFETY IN A CONSTANT STREAM ON BELT CONVEYORS IF THE MATERIAL IS SMALL AND UNIFORM

Width of Belt in Inches.	Area or Cross Section of Load in Square Feet.		Width of Belt in Inches.	Area or Cross Section of Load in Square Feet.	
	For Flat Belts.	For Troughed Belts.		For Flat Belts.	For Troughed Belts.
10	0·015	0·05	30	0·203	0·47
12	0·026	0·06	32	0·253	0·53
14	0·042	0·08	34	0·29	0·60
16	0·055	0·11	36	0·33	0·66
18	0·07	0·15	38	0·367	0·75
20	0·085	0·18	40	0·41	0·83
22	0·114	0·23	42	0·455	0·91
24	0·139	0·28	44	0·506	1·00
26	0·164	0·33	46	0·557	1·08
28	0·19	0·40	48	0·608	1·12

Capacity of Belt Conveyors for Grain and Seeds

Width of Belt in Inches.	Capacity in Tons per Hour at a Belt Speed of							
	400 ft. per Minute.		500 ft. per Minute.		600 ft. per Minute.		700 ft. per Minute.	
	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.	Heavy Grain.	Light Grain.
10	8	6	10	8	12	10	14	11
12	15	10	18	12	22	14	26	17
14	22	14	27	18	33	22	38	25
16	30	19	37	24	44	29	51	34
18	37	26	46	32	55	38	65	45
20	47	32	58	40	70	48	82	56
22	60	40	75	50	90	60	105	70
24	73	48	92	60	110	72	128	84
26	87	58	108	72	130	86	152	101
28	100	67	125	84	150	101	175	118
30	116	78	145	98	174	118	203	137
32	133	90	167	112	200	134	233	157
34	153	102	192	128	230	154	268	179
36	173	116	217	145	260	174	303	203
38	193	130	242	162	290	194	338	227
40	217	144	271	180	325	216	379	252
42	240	160	300	200	360	240	420	280
44	266	176	333	220	400	264	466	308
46	293	192	367	240	440	288	513	336
48	320	212	400	265	480	318	560	371

Capacity of Belt Conveyors with Troughing Rollers for Minerals

Width of Belt in Inches.	Capacity in Cubic Feet per Hour at a Belt Speed of 100 ft. per Minute.	Maximum Advisable Speed in Feet per Minute.	Capacity in Cubic Feet per Hour at the Maximum Advisable Speed.	Largest Piece of Mineral not to Exceed	Speed of Belt in Feet per Minute for Conveying Coal Containing Pieces of the Size given in the Previous Column.	Capacity per Hour of Coal as per Previous Column.	
				Inches.		Cubic Feet.	Tons.
10	...	...	...	...	...	...	...
12	400	300	1,200	2	300	1,200	24
14	500	300	1,500	2	300	1,500	30
16	700	300	2,100	3	300	2,100	40
18	900	350	3,150	4	275	2,475	50
20	1,100	350	3,850	5	275	3,025	60
22	1,400	400	5,600	6	250	3,500	70
24	1,700	400	6,800	8	250	4,250	85
26	2,000	450	9,000	9	225	4,500	90
28	2,400	450	10,800	12	225	5,400	108
30	2,800	450	12,600	14	200	5,600	112
32	3,200	500	16,000	15	200	6,400	128
34	3,600	500	18,000	16	200	7,200	144
36	4,000	500	20,000	18	180	7,200	144
38	4,500	500	22,500	19	170	7,650	153
40	5,000	550	27,500	20	160	8,000	160
42	5,500	550	30,250	21	150	8,350	165
44	6,000	600	36,000	22	140	8,400	168
46	6,500	600	39,000	23	130	8,450	169
48	7,000	600	42,000	24	125	8,750	175

If the capacity is great, the width of the belt is determined by the load, but where the quantity is small and contains large pieces, the size of the largest piece determines the

width of the belt. In both cases the speed of the belt should not be faster than is necessary to carry the load, and it is often better to carry a bigger feed on a slower belt than a thinner feed on a faster belt. As a general rule it may be taken that with belt conveyors for

	The Speed of the Belt may be from
Minerals	400 to 700 ft. per minute.
Heavy grain and seeds	500 ,, 700 ,,
Light grain	400 ,, 600 ,,
Coal and coke	300 ,, 500 ,,
Sacks and other big loads	150 ,, 300 ,,
Passengers	100 ,, 150 ,,
Sorting and picking	20 ,, 60 ,,

The belts of conveyors generally keep clean from adherence of the materials they carry, but with some materials, such as clay, sugar, salt and other sticky substances, there is a tendency for the belt to convey small particles past the delivery point and deposit them where they may become a nuisance. In such cases, rotary brushes (manipulated from the belt) have been used successfully. Where materials containing acids or other corrosive fluids are conveyed by belt conveyors, the whole of the metal portion of the machinery, including the finished surfaces, should be painted with graphite or white lead paint.

Inclined Belt Conveyors.—Belt conveyors can be used not only in a horizontal position, but also with a slight upward or downward gradient. They can also be designed to embody all these three attributes in one and the same conveyor, provided the change from one to the other is accomplished by a gentle curve.

The maximum incline at which a belt will convey depends upon the angle of repose of the material to be handled and on its formation. The presence of a large proportion of spherical pieces, for instance, will not permit of a steep gradient, as they have a tendency to roll back.

It may also be noted, by observing a belt running up a comparatively steep incline, that there is a slight jar conveyed to the material wherever the belt negotiates a guide roll, which jar has a tendency to start some portion of the load to roll back. It is, therefore, recommended to place the supporting rollers closer together on all inclines, and particularly so where the maximum gradient is reached, thus keeping the belt more even and so doing away with the jar.

Materials like loose gravels, pebbles, or clinkers from revolving kilns, or all-round materials, which have a tendency to run backward, must not be conveyed on an upward gradient of more than 10° to 15°.

Conveyors for all other materials containing large pieces may have an upward gradient of 15° to 20°, without affecting the capacity, whilst material of a uniform and fine nature, such as sand, small coal and minerals, will negotiate an incline up to a maximum of 23°.

Ridgway's Belt Conveyor.—The latest innovation in belt conveyors appears to offer some advantages over the existing types. It was brought out by the Ridgway Belt Conveyor Co., of New York.

It consists of two bands running on top of each other instead of the ordinary single band. The idler rollers are cylindrical, similar to those shown in Fig. **110**, and the band is, therefore, running flat; to this inner band are fixed at intervals concave wooden blocks, on which the upper band rests and forms a trough. With this arrangement the lower band is scarcely subjected to any wear and tear, as it never comes in contact with the material; only the upper band, therefore, requires renewing at a comparatively small cost, as the two bands are each only about half the thickness of the single bands generally in use.

Band Conveyors for Larger Individual Loads.—Cotton band conveyors, if the loaded strand is supported at frequent intervals, are also suitable for carrying sacks, pieces of cloth, and light packages, if free from nails, hoop iron, and sharp projections liable to cut the band. They are comparatively cheap in initial cost, easy to drive, and

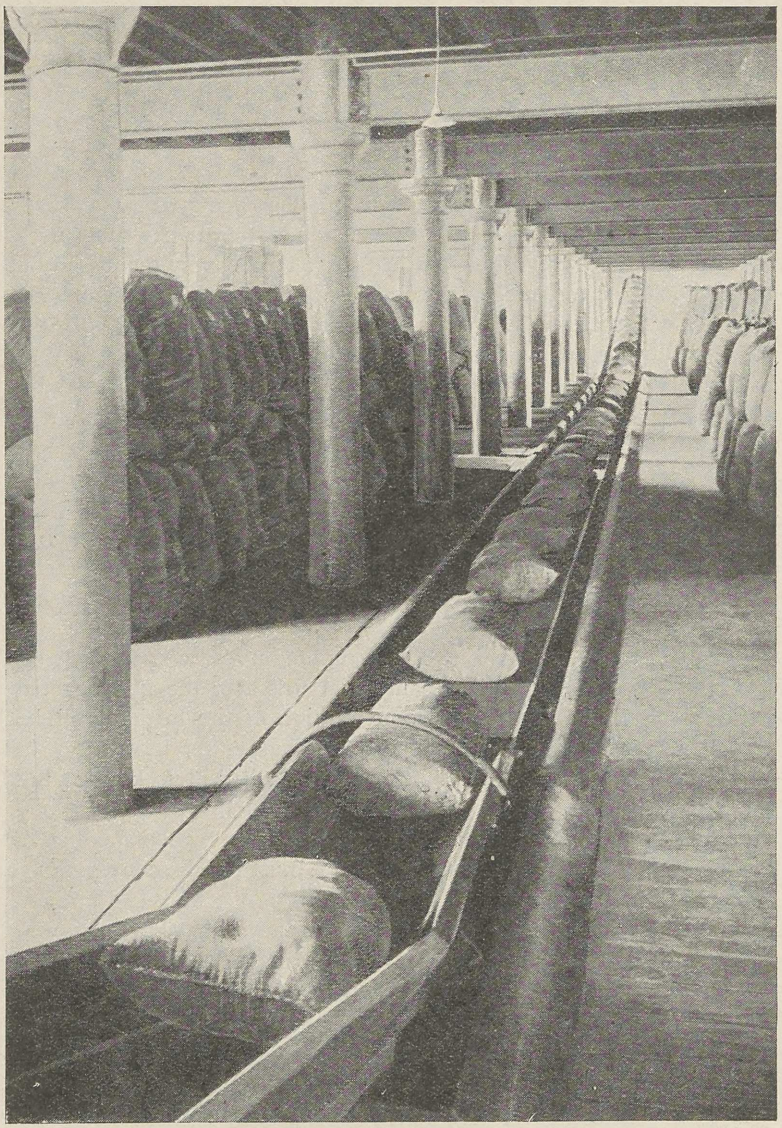


Fig. 117. Sack Conveyor at the Mills of Messrs Leetham & Sons, York.

quiet in operation; the last feature being sometimes of special importance. Band conveyors, however, are not so suitable or so durable as chain and slat conveyors for heavy packing cases.

A sack conveyor installed at Messrs Leetham & Sons' Flour Mills, York, is illustrated in Fig. 117; it shows the conveyor loaded with sacks as they are taken from the warehouse

to the loading platform at the railway station. The sacks are delivered from the end of the conveyor at a sufficient speed to slide down a shoot and over an inclined table, practically into the man's hands ready for stacking in the wagon. There is another siding on the other side of the conveyor, and when the table is reversed the sacks slide over for the purpose of loading into another truck on that side. This loading process can go on without being interrupted, because whilst one truck is being loaded the full one can be removed and an empty one put in its place.

With this conveyor, twelve railway wagons can be loaded in one hour by two men.

The conveyor itself is a band of the ordinary construction, with the exception that it is built rather more substantially, and that the supporting rollers are 18 in. apart instead of 6 ft. The conveyor is altogether 350 ft. long, and the band is 26 in. wide.

This installation was the work of Messrs Spencer & Co., Ltd., of Melksham.

The "Sandvik" Flexible Steel Belt Conveyor.—This flexible steel belt, recently introduced by the Sandvik Iron Co., of Sandviken, Sweden, is undoubtedly an interesting addition to our mechanical appliances for handling material, as it has increased the application of the belt conveyor to hot and sticky substances, for which the textile belt is not suitable. The belt is similar to the steel measuring tapes known to every one, but of course of larger dimensions. It is produced from charcoal steel, cold rolled and hardened, of a thickness of $\frac{3}{4}$ to 1 mm., or approximately 19 to 20 B.W.G. It has a tensile strength of about 3 tons per inch width for bands 1 mm. thick. The widths so far manufactured are 10, 12, and 16 in., the latter being at present the limit, but several bands may be used to form one wider belt. The belts are rolled in lengths of 300 m., or say 328 yds.

As regards the mechanical appliances necessary to carry these steel bands—their nature varying so much from that of textile belts—the supports must of necessity differ in several essential points, the most important diversion being that the terminals must not be less than 1 m. (40 in.) in diameter, and that the supporting idlers may be greatly reduced in number, or altogether dispensed with. The necessity of the large terminals is obvious, as the constant bending of a steel band over smaller pulleys would soon destroy it, and as the bands are highly polished, and remain in that condition, a large pulley surface is necessary to afford sufficient grip on the driving terminals. The reduction in the number of idlers, or the dispensing with them altogether, seems to be one of the greatest advantages attached to the use of this new system, as these parts of a band conveyor are always the greatest source of trouble, and the weak point in an otherwise excellent appliance. In cases where no idlers are used, the steel belt runs in the bottom of a wooden trough, and owing to the polished state of the steel and the constant polishing action taking place during the working of the conveyor, no perceptible resistance is offered to the progress of the band when the speed is once up, and such a support being continuous and unbroken—contrary to the support by idlers—they form excellent conveyors for a great many purposes, particularly for out-of-door work.

Another advantage not to be lost sight of is the facility with which the load can be removed at any point by a V-shaped or oblique plough, as those objections mentioned in connection with steel plate conveyors do not obtain with a smooth steel band. Last, but not least, the cost of the belt is said to be only one-third of that of a good textile rubber belt. As the life of the latter belt when exposed to the weather is considerably shortened, the Sandvik belt deserves special attention for exposed positions, as it is impervious to atmospheric influences. This is demonstrated by about one hundred installations running in Scandinavia under climatic conditions

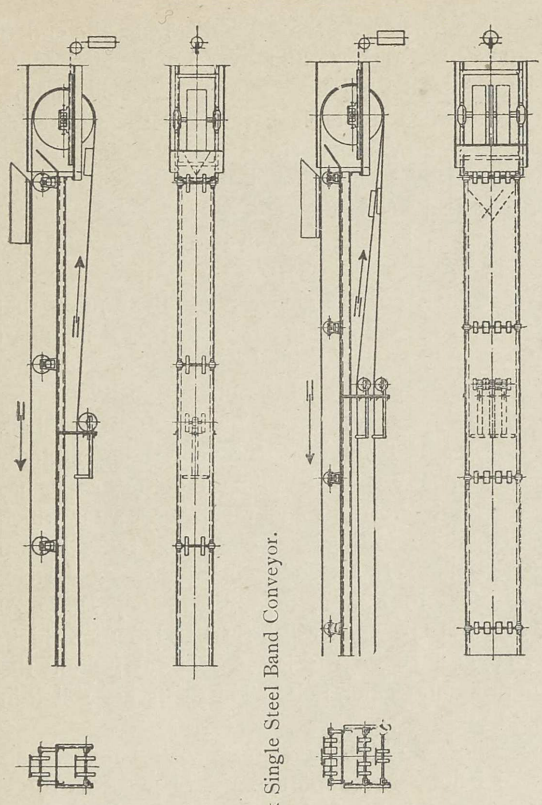


Fig. 118. Sandvik Single Steel Band Conveyor.

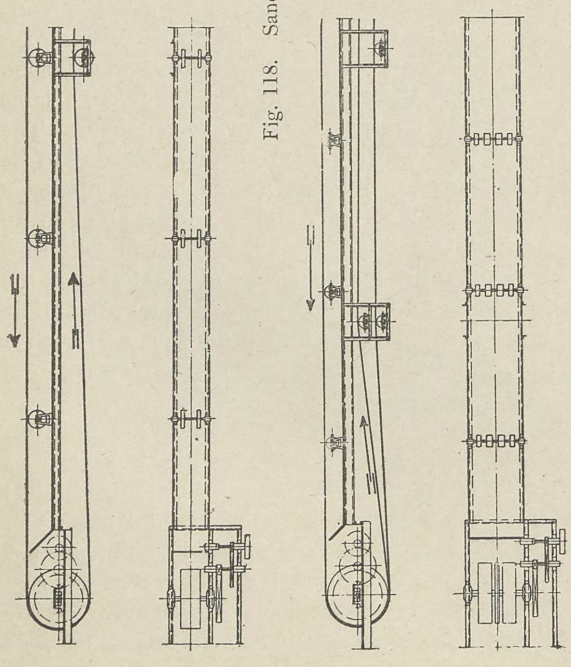


Fig. 119. Sandvik Compound Steel Band Conveyor.

which are more trying than in this country.

The general arrangement, with the few exceptions mentioned in the preceding remarks, of this steel band conveyor is similar to that of the ordinary belt conveyor. This may be seen from Figs. **118** and **119**, the former being a single band 16 in. wide. The latter is a compound band composed of three widths; two bands run side by side leaving a space of about 4 in. between, and this space is covered by a third band running over the gap, and overlapping the two side bands by about 4 in. The centre band is put on with a little less tension than the other two, in order to secure an easy fitting of the bands, and as the greater part of the load is always carried in the centre, its weight will tend to keep the middle band tightly against the others. The band is joined transversely by a row of rivets, the holes being countersunk. About 16 ft. from the head end of the return strand is a kind of steering gear, which keeps the band in its proper position. This will be described later.

The Terminal Drums.—These, as already mentioned, should not be less than 40 in. in diameter. They are also narrower than the band, contrary to the practice in textile belts, and this is to prevent any particles being caught between the bands and the drums. The terminals are generally ordinary pulleys, wood lagged, and covered with a rubber coating, similar to that used for ordinary rubber-covered conveyor bands. As it is very important that no hard

substances should lodge between the terminals and the belt, some scrapers are arranged on the band to prevent this.

The driving and tail terminals are shown to a small scale in Figs. **118** and **119**. With a combined band there are three terminal drums, one for each of the bands, and to

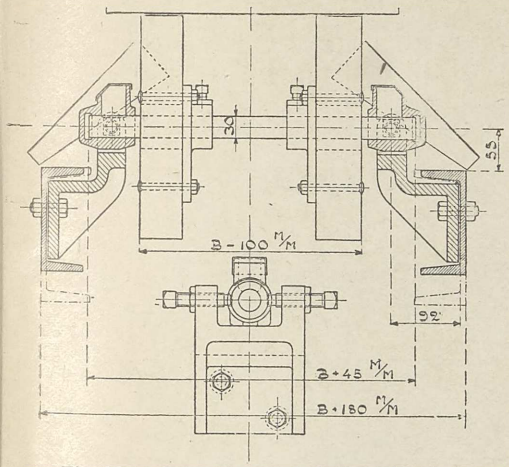


Fig. 120. Idlers for Sandvik Steel Band Conveyor.

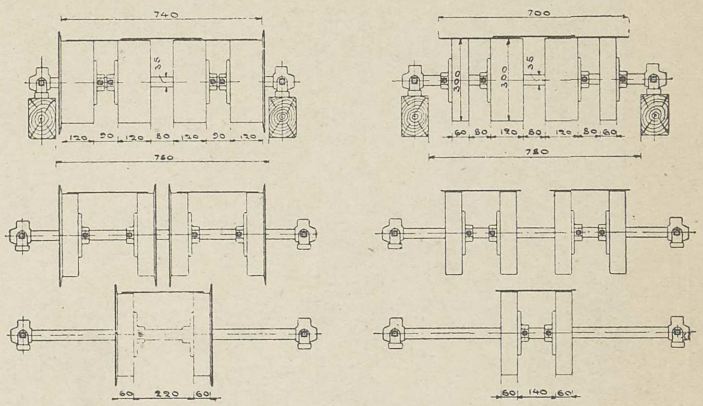


Fig. 121. Idlers for Sandvik Compound Steel Band Conveyor.

overcome the difficulty of any alteration in speed of the middle band, the drum for this is not keyed to the spindle, but runs freely on it. At the tail end one of the side sheaves is keyed to the spindle, and the other two are loose. The tail or tightening terminal is fitted with a movable tension frame of timber, which is held taut by a weight in order to compensate for any expansion which may be caused by the load or temperature.

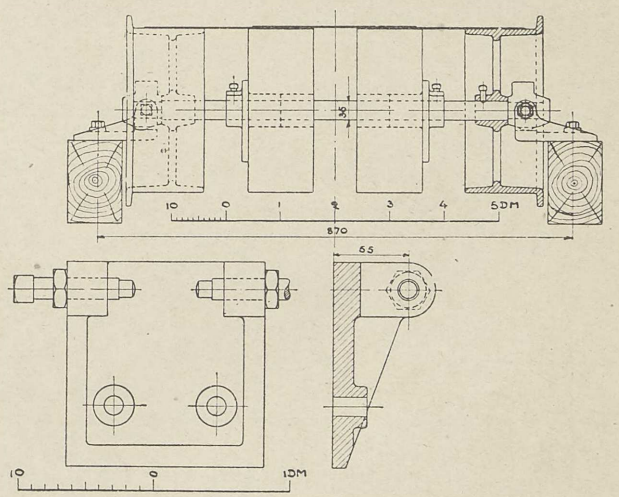


Fig. 122. Idlers for Sandvik Compound Steel Band Conveyor.

Idlers. — It has already been mentioned that these conveyors can work without idlers, but such an arrangement is only for a limited number of purposes. For more important installations idlers are used; they are 12 in. in diameter, and much narrower on the face than the width of the band. Such idlers are shown in Figs. **120**, **121**, and **122** for single band and compound band conveyors. At intervals flanged idlers are used to prevent the belt from travelling to one side. The distance between the idlers varies from 6 to 16 ft., according to the weight of the material to be carried, and the return idlers may be as far as 40 ft. apart. On account of their rigidity steel bands can never be troughed.

The Steering Gear.—This appliance, the position of which has already been mentioned, is illustrated in Fig. **123**, and the approximate position is shown in Figs. **118** and **119**. The gear consists of a pair of idler rollers connected to a swivel, which is again connected to an iron frame fitted with hardened steel cheeks, which control and lead the

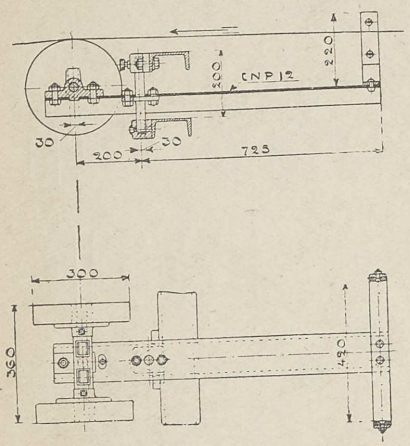


Fig. 123. Steering Gear for Sandvik Steel Band Conveyor.

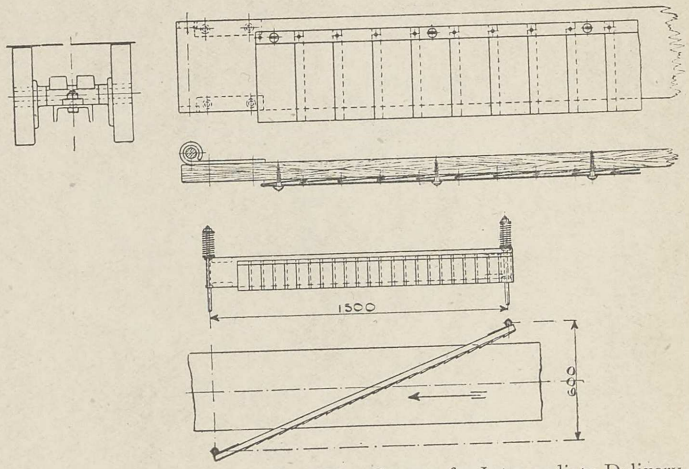


Fig. 124. Scraper for Intermediate Delivery from Steel Band Conveyors.

band in a straight line on to the terminal. In order to get sufficient power, this pair of idlers are placed a little higher than the rest of the idlers, to get more weight on them.

Intermediate delivery is effected by a plough either V-shaped or set obliquely

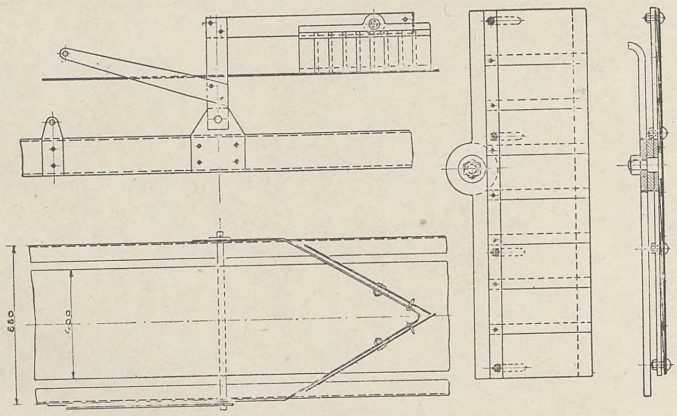


Fig. 125. Plough for Intermediate Delivery from Steel Band Conveyors.

across the band. The plough consists of a number of steel plates which overlap and form one continuous scraper. The illustrations, Figs. **124**, **125**, and **126**, which show different forms, explain themselves.

Inclination.—Inclines can be negotiated by these conveyors. The gradients, of course, depend, as with other conveyors, on the nature of the material, but in a general way an incline of 14° is permissible. The following table gives the capacity and horse power required from actual experience :—

CAPACITY AND HORSE POWER CONSUMED BY THE SANDVIK BAND CONVEYOR FOR LENGTHS OF 100 M., OR SAY 328 FT., THE SPEED OF THE BELT BEING 300 FT. PER MINUTE.

Width of Belt.	Capacity in Cubic Feet per Hour.	Horse Power for Materials with a Specific Gravity of 1.
Inches.		
10	180	1·2
12	550	1·3
16	950	1·6
28	3,000	2·5
40	7,500	3·4

Advantages and Disadvantages of Band Conveyors.—The great advantages of band conveyors are: the small driving power required to manipulate them, their

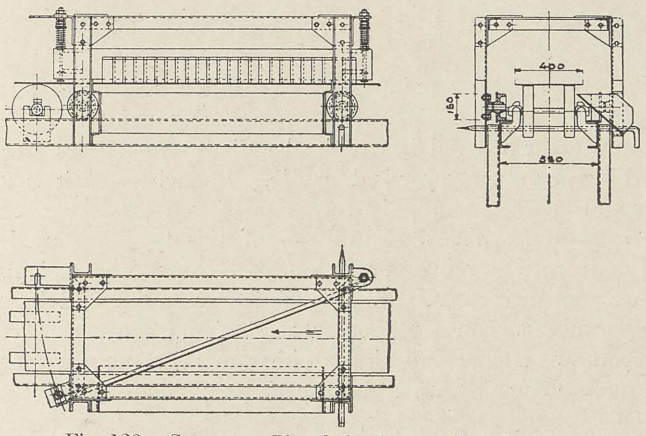


Fig. 126. Scraper or Plough for Intermediate Delivery from Steel Band Conveyor.

noiseless and smooth working, their large capacity, non-injury to the material during the process of conveying, and their comparative security against breakdowns. It goes without saying that these advantages obtain only where first-class conveyors are installed, in the design of which all circumstances as to the nature of the material to be handled, the speed of travel, the number and size of the supports, the construction of the terminals, and the system of lubrication have been carefully considered.

The disadvantages are: the feed cannot be withdrawn at intermediate points without the use of a more or less cumbersome throw-off carriage, while in most cases the feed will have to be stopped if the delivery of the band is to be changed to a different point, and the great many small bearings which have to be oiled and kept in repair. As the rollers make 150 to 600 revs. per minute these require considerable attention, unless ball-bearing idlers are used.

CONVEYORS

C.—APPLIANCES IN WHICH THE TROUGH CONTAINING THE MATERIAL MOVES BODILY WITH THE MATERIAL—*continued*

CHAPTER VIII

STEEL PLATE CONVEYORS, SLAT CONVEYORS, PICKING BELTS, AND CONTINUOUS TROUGH CONVEYORS

STEEL PLATE CONVEYORS

It is evident that there must be a point at which band conveyors of textile rubber and similar material can no longer be effectively used, and that point is reached when sharp and cutting substances or material has to be handled. Sometimes also a firmer base than that afforded by a band conveyor is desirable. In such cases it is usual to employ endless bands, so to speak, composed of a series of iron plates connected to suitable chains running beneath the plates. Conveyors of this type are used in the same manner as band conveyors of rubber or cotton. Of course the steel plate conveyor is a more cumbrous appliance, travels at a much lower speed, and has a much more restricted field of usefulness than a rubber or textile band conveyor. The segments of steel plate conveyors are attached to chains either of malleable, cast, or wrought iron. The former are more frequently used because they can more readily be shaped, with suitable attachments, for any special work, and all kinds of carrying plates can easily be fitted to them.

Ordinary Ewart-type chains are not much used, because they wear rapidly, and are very liable to breakages when used for such heavy work; and though broken parts can no doubt be readily replaced, yet an accident to a conveyor must cause stoppage and delays. The form of conveyor more generally used is one in which the links are of malleable cast iron and are joined together by hardened steel pins, with renewable wearing parts such as made by the Chain Belt Engineering Co. Where such conveyors are required for extra heavy and especially rough work, or where stoppages would be most detrimental, it is usual to use steel chains, the links of which may either be short after the style of the Gall chain, or consist of long forged links of the same length as the width of the plates.

This type of conveyor generally delivers only at the driving terminal; but should intermediate delivery be required, a delivery scraper is fixed across the band at an angle of about 45°, to scrape the whole or part of the feed of the band into a shoot, or on to a stock heap. If the intermediate delivery is not confined to one or more fixed points, and if it be desirable that delivery should take place at any point in the length of the conveyor, a scraper is mounted obliquely on a suitable carriage which can be moved into any position for the purpose of intermediate delivery. Such an arrangement is in use at the coke yard of the Southall Gasworks.

The withdrawing of the feed from such a continuous steel plate has this drawback, that the frequent joints in the band produce a rasping action on the material during the

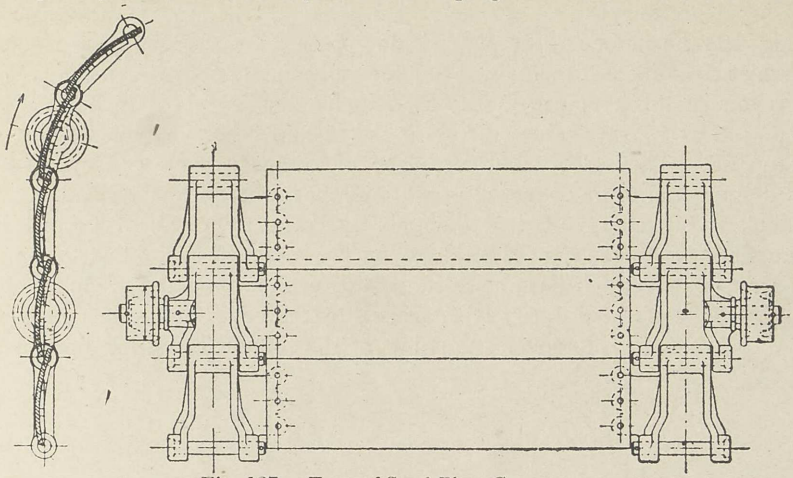


Fig. 127. Type of Steel Plate Conveyor.

process of scraping off, which is detrimental to such material as friable coal, and sometimes causes sufficient loss to make such an appliance impracticable.

Figs. 127 and 128 illustrate conveyors of this class. The convexity of the links in

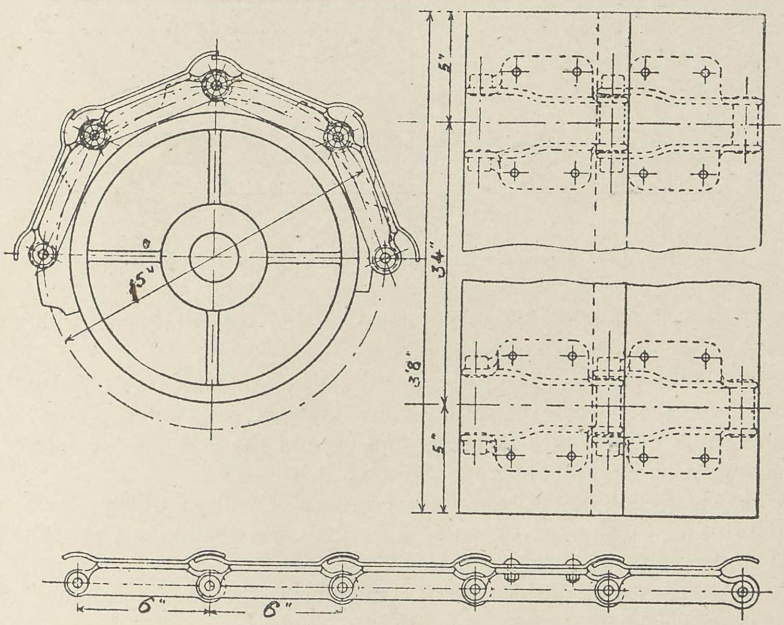


Fig. 128. Steel Plate Conveyor.

Fig. 127 gives them great strength, and is especially intended to facilitate the delivery of the material as the band reaches the terminal pulley.

In some of the best designed conveyors, each short segment of band is fitted with a narrow curved strip which is either part of the segment or is riveted in such a position

as to make a leakage between adjacent sections impossible, as the strip is just over the butt joint of the two sections. This strip is curved to allow the segments to bend freely when passing the terminals.

In Fig. **128** the surface of the plates is not convex but flat, with the exception of a slight curve at the joint just mentioned to allow of the plate ends interlocking.

Conveyors of this type are mostly used to handle large coal in collieries, and are often employed as picking tables for sorting coal and other materials whilst they are being conveyed. They also take the place of ordinary band conveyors, where the nature of the material to be conveyed would injure a rubber or textile band.

The belt is often supported at intervals by stationary rollers over which it travels. In more modern types (see Fig. **127**) the rollers are attached to the links and travel with them, an arrangement which has the advantage of economising the driving power. The screeching of belts of the ordinary type, caused by the edges of the belt rubbing on the side angles, is avoided. Moreover, the points of the support being fixed relatively to the

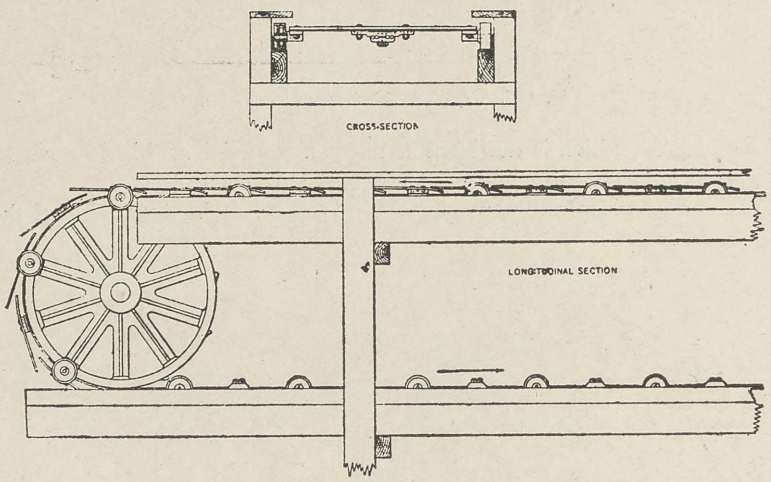


Fig. 129. Conveyor for Sorting Chips in Wood Pulp Mills.

belt, there is none of the irregular up-and-down motion sometimes met with on inferior bands, and the whole action is much smoother.

Fig. **129** represents a steel plate conveyor built by the Steel Cable Engineering Co., which is used for the purpose of sorting chips in wood pulp mills. These conveyors very much resemble colliery picking bands, and beyond the fact that the framework is of timber, they might be used for the same purpose.

Every second section of the band has its own guide pulleys, which run on angle-iron tracks in the side of the framework, as seen in the cross section. The different plates overlap each other to make leakage impossible.

Unlike other conveyors of this type here mentioned, the one in question is driven by cables instead of by chains.

The tightening of these conveyors is effected in a similar manner to that of band conveyors, and the speed at which they run is 60 to 120 ft. per minute, according to the purpose for which they are employed.[1] The lower speed is adopted when the material is to be picked over.

[1] See Tightening Gears, page 191.

Metal plate conveyors are principally used for conveying coal, and have the great advantage of handling it so gently as to avoid breakage, provided of course that the delivery is at the terminal. There may be one drawback to the use of these conveyors beyond the keeping in repair of numerous small wearing parts, and that is that the driving gear must always be at the delivery terminal of the conveyor to make the upper or working strand the tight side of the conveyor.

SLAT CONVEYORS

Chain and Wood Slat or Lattice Conveyors are most useful for conveying bales and packages in factories, also for sulphate of ammonia in bags. A typical example is given in Figs. **130**, **131**, and **132**, showing elevation, plan, and cross section. Slat conveyors are used largely to carry substances in bags, also general merchandise packed in boxes and crates, or made up in pieces or bales. They can be made partly horizontal and partly inclined, and with either a single or double strand of chain, to which are bolted a series of narrow boards or slats (usually from 1 to $1\frac{1}{4}$ in. thick), forming a continuous travelling platform.

The terminals consist of one or two pairs of chain wheels; the bearings of those forming the tail end sliding in slotted frames, in order to permit of the extension of the chain being taken up by tension screws from time to time. Cast-iron supporting rollers or idlers about 9 in. diameter are provided at intervals of 3 ft. or more, the shafts running in plain or bushed bearings fitted with Stauffer grease lubricators. The outer rollers have a single guide flange; the inner rollers are plain. The bearings of the idlers are usually bolted to continuous channel steel beams.

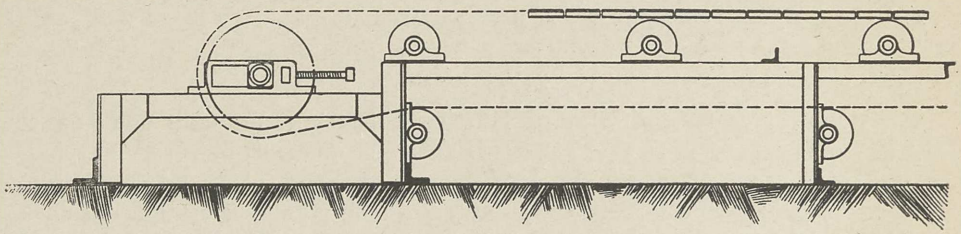
A conveyor on similar lines has been erected by the Chain Belt Engineering Co. It is 204 ft. long, the slats are 24 in.; it travels at 50 ft. per minute, and handles 600 sacks of sulphate of ammonia of 2 cwt. each per hour. The chain used is No. 500 Gray Chain, 6 in. pitch.

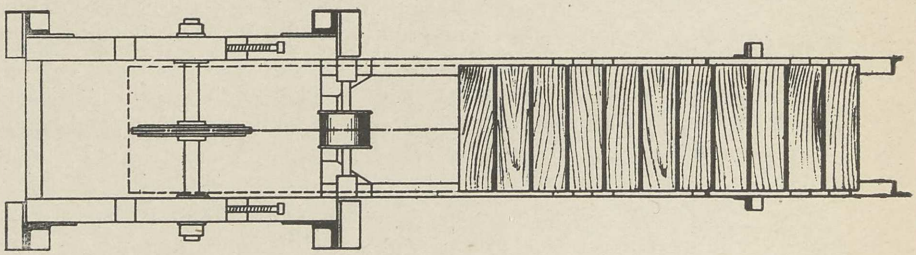
In an alternative design of slat conveyor (Fig. **133**) the slats are furnished with brackets and travelling wheels or rollers of small diameter, running on angle-iron tracks. This design has the advantage of avoiding the slight up-and-down movement of the packages in passing over fixed supporting rollers, due to the sag of the chain. Also the slats need not necessarily be close together, but can be spaced a foot or two apart in some cases. On the other hand, there is more difficulty in lubricating numerous travelling wheels than fixed bearings, and they are less secure and durable. Moreover, rollers revolving in contact with wood slats work more quietly than cast-iron wheels running on angle-iron tracks. A conveyor on these lines, built by the Chain Belt Engineering Co., is worthy of note. It is 470 ft. centres, moving 2 cwt. bags of sugar at a large sugar refinery. It is driven by a 20 H.P. 3-phase motor at a speed of 70 ft. per minute. In this case the hard wood slats are 30 in. long and bolted to two strands of chain. The main lattice steel girders of the conveyor bridge are 7 ft. 6 in. deep, and are supported 20 ft. above the yard level by lattice steel towers and cross girders.

Double Service Chain and Slat Conveyors are also sometimes used. The special feature of this type of conveyor is that the return strand of chain and slats is not led back empty, but the two strands travel on the same plane in opposite directions, generally side by side, and both are utilised for carrying material. In this case the terminals are, of course, also placed horizontally. This conveyor is extremely useful for moving open crates, bottles, jars, tins and other goods needing careful handling. If the articles are not taken off they simply go round the circuit again and cannot be thrown off (see Fig. 254 on page 189).

PICKING BELTS OR TABLES WITH OR WITHOUT LOWERING ENDS

Picking belts or tables are used for removing stones and other impurities from coal





Figs. 130 and 131.

and other minerals. They have also a place in cement works, where they are used for the purpose of picking the clinkers over.

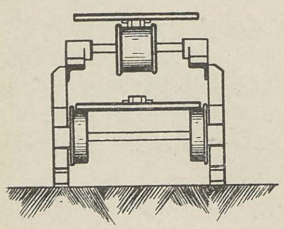


Fig. 132. Cross Section of Wooden Slat Conveyor.

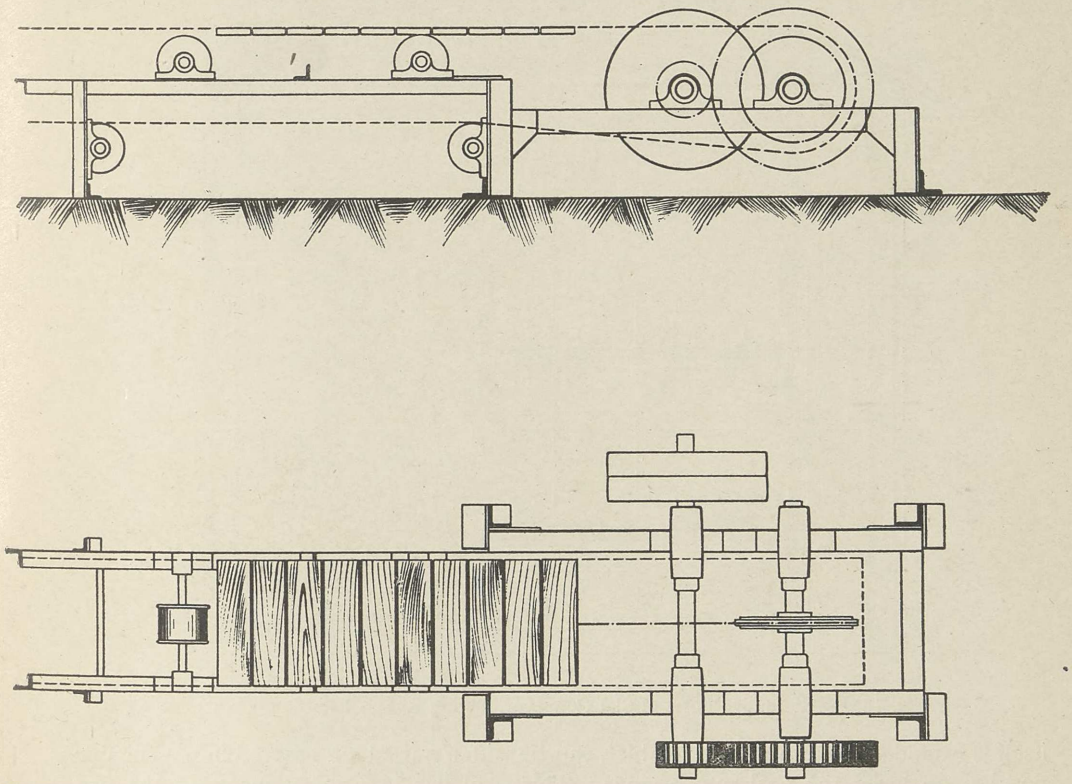
Picking belts or tables in the form of ordinary band or steel plate conveyors have been described in the foregoing pages, so that it is not necessary to describe their construction; but it may be useful to set forth the manner in which these appliances and their accessories are used.

In width, picking belts may vary from 3 to 5 ft.; 4 ft. 6 in. will be found a very suitable width if picking is to be done from both sides.

A great diversity of material is used for picking belts: but canvas, india-rubber, or woven wire is seldom used, at least not for the heavy work of dealing with South Wales and other large coal, where a hard surface is absolutely essential as well as substantial framework and carrying arrangements.

A very important matter is the discharge of the coal from the belt. If a fall of any depth is permitted, breakage results, and to some extent the result of the previous

screening is vitiated. It is on this account that in some cases the picking belt has been provided with a jib extension, of which it is the special function to load the coal into wagons. If a separate loading device is used, a second fall seems to be unavoidable as the coal passes on and off the lowering device.



Elevation and Plan of Wooden Slat Conveyor.

The Koch belt is the nearest approach to a flexible steel band, and if it were a thoroughly practical appliance it would be an ideal picking belt. It consists of separate plates curved to form segments of the terminal drums (see also Fig. 127) carried upon double link chains and provided with rollers. The curvature given to the plates makes them very rigid transversely, but unfortunately the belt cannot be so made that the discharge shoot can be closely applied to the nearly cylindrical end. Hence, if placed high up to prevent any fall of the coal, the smaller particles will fall through the gap. The usual form of belt, composed of flat plates, attached to two or three link chains according to the width of the belt, has this drawback, that the delivery over the end can only be made by setting the receiving shoot well below the centre of the terminal drum, on account of the backward and forward motion on the end, according as the flats or the angles of the polygon drums are presented to the receiving shoot.

To overcome this difficulty, Howe's delivery shoot, Fig. 134, has been introduced, and has proved fairly efficient. The shoot A is so suspended as to have a tendency to lie close up to the belt terminus, and two upturned horns B at either side are kept in contact with the conveyor plates, and serve to make the shoot follow and conform to the motion of the plates. In the illustration, the shoot A is shown as a short screen to

remove any fine coal produced after the coal leaves the first screen. This improvement is occasionally met with. As mentioned elsewhere,[1] in some instances the picking band

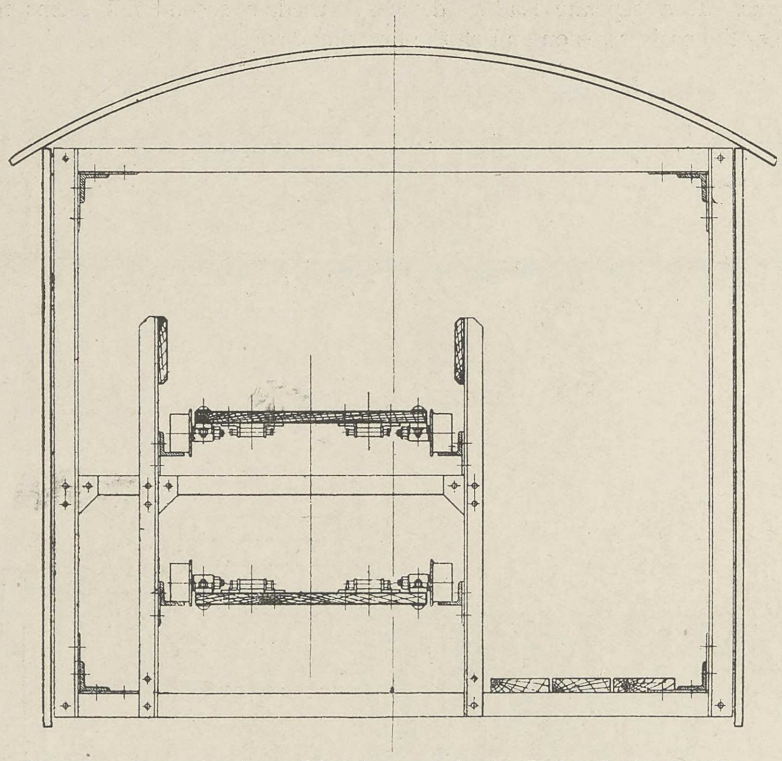


Fig. 133. Alternative Form of Slat Conveyor, having Rollers fixed to the Slats.

itself is extended to form a jib end which can be either raised or lowered into a suitable position, to lower the coal into wagons. This plan has two objections. In the first

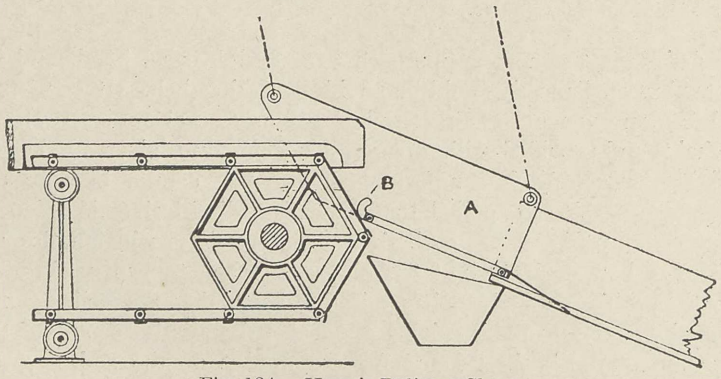


Fig. 134. Howe's Delivery Shoot.

place, the jib must be long enough to be at an angle at which the coal will not roll off it. As a consequence, the back portion of the wagon cannot be conveniently reached, and when starting to load, the coal has to fall at least the depth of the wagon, as the

[1] See Cornet Conveyor, page 109.

return belt on the under side has to clear the side of the wagon. The terminal drum of necessity occupies a considerable space, unless the belt is composed of very narrow plates and short links. In the second place, the return belt on the same side has to make a bend forming an obtuse angle at the top of the jib end, and if the plates have a normal amount of lap there is the danger of their being stripped off the links. This

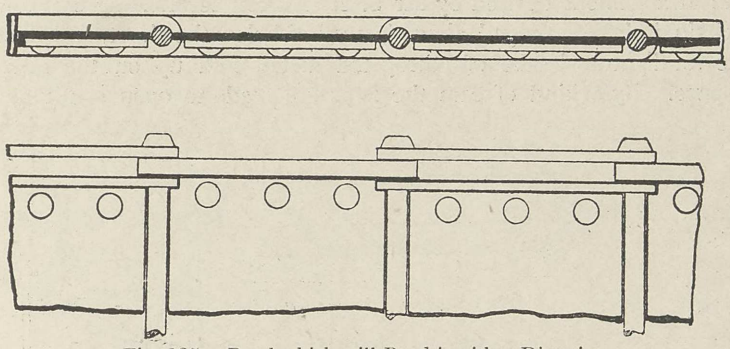


Fig. 135. Band which will Bend in either Direction.

latter difficulty may be met by making the links so that the centre of the pins coincide with the line of the plate (see Fig. 135).

In this case the belt bends equally well in either direction; but wear and tear in

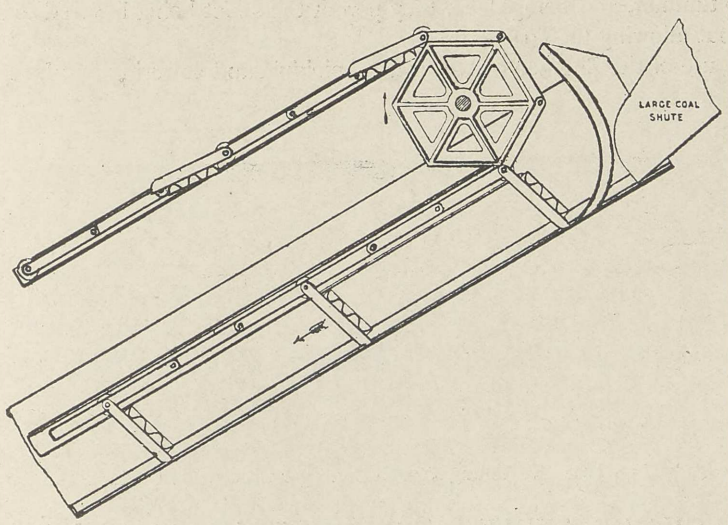


Fig. 136. Everett's Loading Device.

the joints will gradually cause gaps between the plates and the pins through which small coal may drop, this being an objection to an otherwise good design.

A much better plan is the provision of a separate lowering belt with shorter links, so that terminals of smaller diameter can be used, which may be four-sided only. This belt may be provided with a plain shoot in which the chains travel with the angle-bars between them at intervals, the angles serving to prevent the coal from running down the belt. Even under these conditions the hinder part of the wagon cannot be reached, and at the front end some drop of the coal is inevitable, for, if the cross-pieces are steeply

inclined, the larger fragments of coal will topple over them, while if they are made higher to prevent this, they require more room for clearing the wagon on the under side.

A vertical arrangement would appear to be the most suitable. Wrightson's coal shipper [1] and Soar's loader [2] may be cited as suitable devices for loading work.

A further step towards the solution of the problem is seen in Fig. 136,[3] which represents an arrangement devised by Mr S. A. Everett for loading coal down a shoot. The return chain is here arranged above instead of below the shoot, and the obstructing plates, made for lightness' sake of corrugated metal, fold up on the return side, to economise space. By a kind of cam the flaps are made to open gently as they come

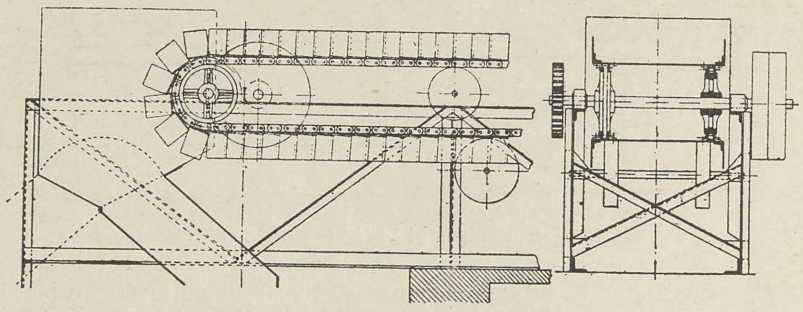


Fig. 137. Type of Continuous Trough Conveyor.

over the top tumbler, and being deep, they permit the shoot being lowered to a very steep incline without allowing the coal to fall.

For the use of the Zimmer conveyor as a picking and lowering band, see pages 116 and 117.

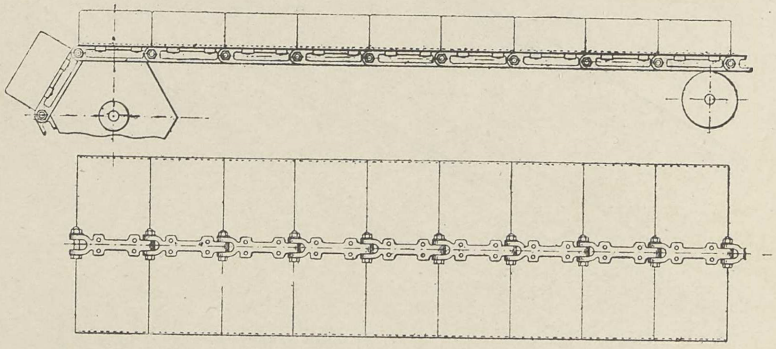


Fig. 138. Travelling Trough Conveyor with Single Chain.

CONTINUOUS OR ENDLESS TROUGH, TRAY, OR PAN CONVEYOR

This conveyor is practically the same as the metal plate conveyor, with this exception, that each segment has its sides turned up to form a channel, as is shown in Fig. 137. The endless trough travels over two terminal pulleys, one of which is adjustable to take up the wear in the joints of the chain.[4] The sections of trough are also frequently fitted with small supporting rollers which run on angle-bars in the same manner as metal

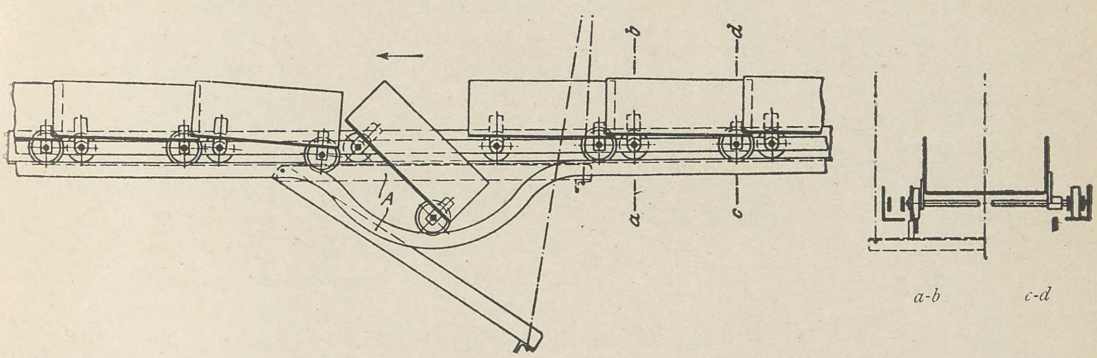
[1] For description of Wrightson's Coal Shipper see page 600.
[2] Soar's Coal-lowering Apparatus, page 615.
[3] From a description of Loading Devices in *The Iron and Coal Trades Review*, 6th April 1900.
[4] See Tightening Gears, page 191.

band and push-plate conveyors. These travelling trough conveyors have this advantage over push-plate conveyors, that they take less power and cause less breakage to the material. With this type of conveyor, however, intermediate delivery is out of the question.

Fig. **138** shows a portion of such an endless trough conveyor with single strands and hexagonal terminals, which explains itself. This class of conveyor can also be used for small inclines without loss of capacity—inclines of 15° being quite permissible. In fact it may be used to convey up inclines up to 45°, but in such a case the segments of the conveyor are provided with projections which prevent the material from sliding back (see pages 138 and 139).

The speed of travel is 60 to 120 ft. per minute, or somewhat less than that of push-plate conveyors. There seems, however, to be no reason why they should not run at the same speed. The capacity can easily be found by multiplying the area of the trough by the speed of travel. Such conveyors have been made in lengths up to 500 ft., and for capacities of 100 tons per hour.

Intermediate Discharge.—It has been mentioned above that continuous trough



Figs. 139 and 140. Continuous Endless Trough Conveyor of the Link Belt Engineering Co.

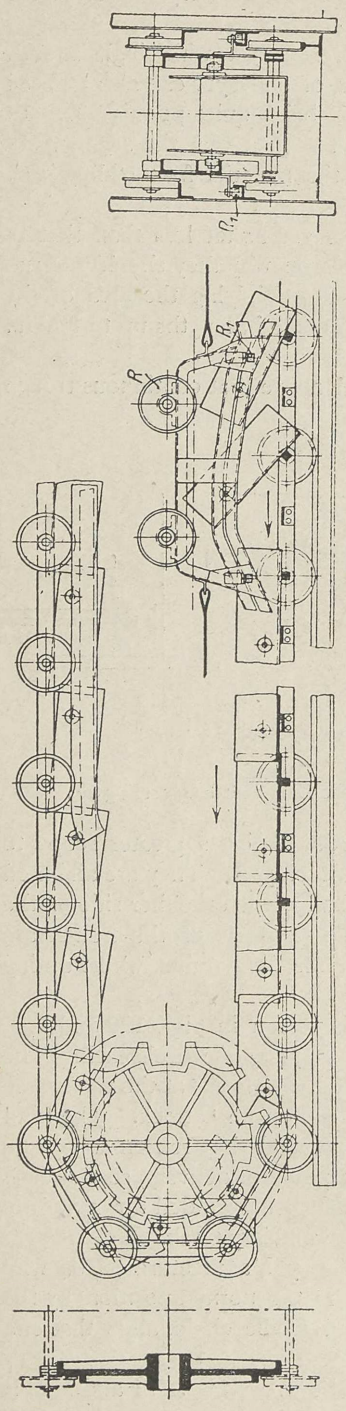
conveyors are only applicable for end delivery, and in order to give a greater scope to this type of conveyor several important devices have been developed. They are all based on the same fundamental principle, namely, to have two chains, one on either side of the trough (instead of underneath the trough), to which the segments of the trough are swivelled at one end, so that the loose end can be dropped for discharging, whilst during conveying this loose end is held up in some way or another.

The construction of the Link Belt Engineering Co. is shown in Figs. **139** and **140**. The pans forming the trough overlap, and are fitted with two pairs of wheels each. The foremost pair has a spindle or axle which runs right through and forms at the same time the pivot of the links of the chain, and this pair of wheels run on an L track. The hind wheels have a shorter axle so that they are closer to the pan, and they run on a separate flat iron bar. The latter can be interrupted at the point or points of delivery, so that each pan in succession is dipped down and discharged, the wheels being guided down and up again on to the continuation of the flat iron track by a short auxiliary track.

This construction is somewhat simplified by the Jeffrey Manufacturing Co., who employ one L track only, so that the front axles remain in the normal position by the tension of the chain, whilst the back axles, which are free from the chain, allow that end of the pans to drop for discharging.

A conveyor, not unlike the preceding, and which is shown in Figs. **141** and **142**, is

built by the Berlin Anhaltische Maschinenbau Aktien Gesellschaft. This differs in principle from the former in so far that the front end of the pan is raised for tipping, instead of the back end being lowered. This design has the advantage that a movable discharge carriage can be used, which facilitates the discharge at all points, whereas the conveyors previously described could only deliver at a number of predetermined points.



Figs. 141 and 142. Continuous Trough Conveyor.

Each pan or segment of the trough is fitted with one pair of running rollers at the back end, the fore part resting on a flat iron bar riveted to the links of the chain. There are also two small rollers, one on each side of the fore part of the pan, and these engage with the rails of the tipping gear, and so empty each segment as it passes. The tipping gear is suspended on the rollers R and small channel rails.

Another example is the conveyor of the Bromberger Maschinenbauanstalt, Fig. **143**. Here each segment of the trough has a projection like a handle on the under side. This comes in contact with a roller, and as the front end of the pan is pivoted to the chain, and therefore kept in position vertically, the back part of the pan is lifted, and this releases the previous segment, which rests on a ledge of the former, as seen in the illustration.

The Humboldt Company have a similar conveyor, though it consists of a series of bars instead of the sheet-iron pans. This is shown in Figs. **144** and **145**. The bars of the grating of which each segment consists are hinged at A and held together by the bolt S. The links K of the chain form a raised edge to the trough (see cross section). The free ends of the bars are held up by the pendulum bracket B during conveyance. At the point of discharge is the tripper C, and as soon as the rollers R_1 come in contact with this, the pendulum bracket is bent out of its perpendicular position, and the loose end of the bar is released and falls down as shown in the illustration. The guide plate D afterwards raises the segment into its former horizontal position, where it catches again as before. The ends of the bars are cut obliquely, so as to fall behind the bracket B′, like the latch in a lock.

The Tipping Tray Conveyors of Babcock & Wilcox.—These are illustrated in the diagram, Fig. **146**. Here the discharge is independent of the track, and each pair of rollers keeps to the normal rails, the tipping being effected by a lever B, attached to the forward end of each unit. The adjustable trip-

ping gear A is raised into position, and as the lever B engages with the tripper A, the buckets are discharged. At the driving end the units are guided round the terminal by an attachment C, and when leaving this the units of the tray hang down in a vertical

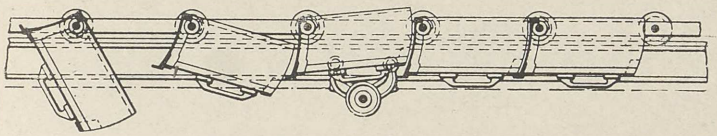


Fig. 143. Further Type of Continuous Trough Conveyor.

direction, so as not to impede the fall of the material conveyed, in the event of no delivery shoot being found desirable. The chains, with their guide rollers used in these conveyors, are the same as those used in the gravity bucket conveyor of the same firm.

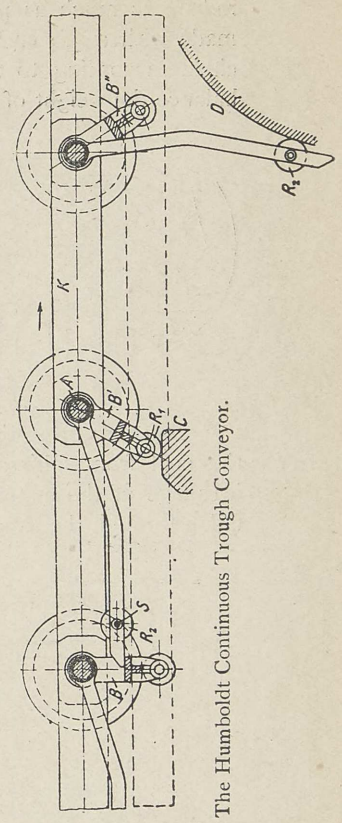
TABLE GIVING DIMENSIONS, CAPACITY, AND SPEED OF THESE CONVEYORS

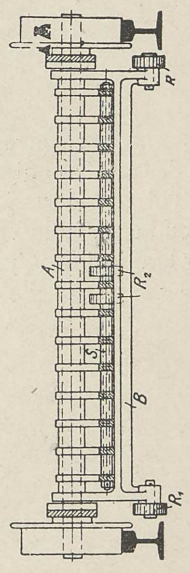
Width of Trough.	Depth of Trough.	Pitch of Chain.	Capacity in Tons of Coal per Hour.
Inches.	Inches.	Inches	
12	4	12	35
16	6	12	50
22	6	12	80
30	6	14	150
36	8	14	200
42	10	14	300

The normal speed of the conveyor is 60 ft. per minute, and the capacities given above are for these speeds, the maximum speed being 80 ft. per minute.

Smaller conveyors on the same principle, with capacities of from 6 to 20 tons per hour, are also made, but they have only single chains instead of double, the widths for these varying from 6 to 12 in. with a chain of a pitch of 6 in.

In cases where these conveyors are used for removing ashes and clinkers from boiler houses the whole of the working parts are covered on both sides at the loading point with sheet-iron guards, which are curved inwards at the top, covering the upper edge of the trough, so that no ashes can come in contact with the chain of the conveyor.





Figs. 144 and 145. The Humboldt Continuous Trough Conveyor.

The Cornet Conveyor shown in Fig. 147 differs materially from the foregoing. This conveyor is used in connection with coal handling plants for loading and at the same time sifting coal. In this case the material to be conveyed is carried not on iron plates, but on a grating of round iron bars which are attached at both ends to the two driving chains. The idea is to carry the large coal on the grating in order to screen out through the apertures such small coal as may be mixed with it. The coal falls direct from the screen on to the band, receiving a further screening as it passes along in a horizontal direction, and is then loaded directly into the railway trucks. To

reduce as much as possible the fall of the coal, the delivery terminus of the band is made with a jib end, and can be raised or lowered by means of a small winch and chains according to the level of the coal in the truck. A counterweight is used to balance the weight of the movable end.

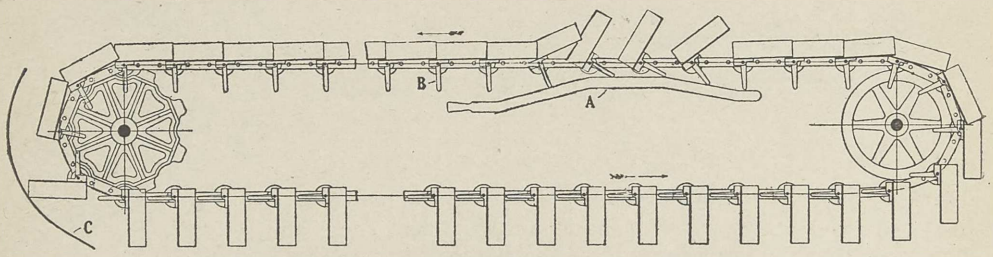


Fig. 146. Babcock & Wilcox's Tipping Tray Conveyor.

To every other link of the chain are fastened iron buckets, which serve to prevent the coal from falling when on the inclined portion of the conveyor, and so prevent breakage of the material. These buckets also serve to collect the small coal which has fallen through the bars as the chain goes back empty, scraping it together after the manner

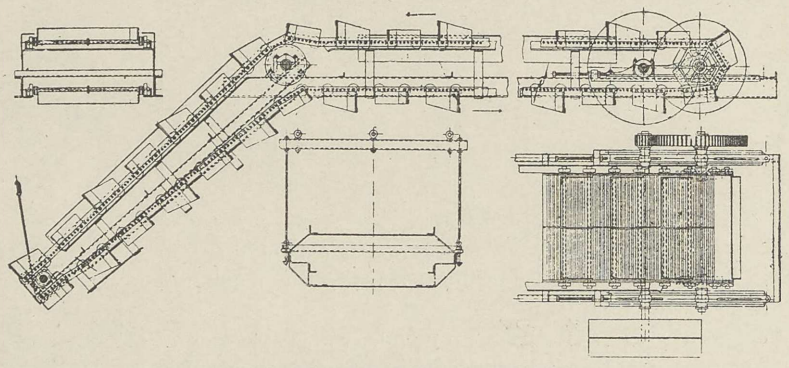


Fig. 147. Cornet Conveyor with Lowering Jib End.

of a push-plate conveyor. For this purpose the ends of every other scraper bucket are extended so that only half the buckets act as scrapers.

This apparatus is driven from a hexagonal terminal which is mounted, together with its countershaft, in adjustable brackets, for the purpose of tightening the band. The other terminal is only four-sided to save head room.

Each link of the conveyor is fitted with a pair of small rollers running in grooves

CONVEYORS

D.—APPLIANCES IN WHICH THE MATERIAL IS CONVEYED BY THE ACTION OF A SEMI-STATIONARY RECIPROCATING TROUGH

CHAPTER IX

VIBRATING OR RECIPROCATING TROUGH CONVEYORS

This group embodies the latest developments of the conveyor. In principle it consists of troughs which receive the material to be conveyed at one end and deliver it at the other end by means of a succession of suitable backward and forward movements of the troughs. It may therefore be classed with the two previous types, *i.e.*, the band and the travelling trough conveyor, as in all three conveyors the material is, so to speak, conveyed in the trough without the use of a stirring or pushing agent, as is the case with worm, push-plate, and cable trough conveyors. It is obvious that every kind of material which deteriorates through rough treatment should be conveyed on appliances of the former types.

The credit of the introduction of this appliance in its original form is due to Herr Eugen Kreiss, of Hamburg.

There are several varieties of the vibrating trough conveyor. In some, the trough makes a reciprocating motion by means of a crank and connecting rod, whilst the trough itself is supported on rollers (Thomson's patent) or portions of rollers (Marcus's patent); others are actuated by a cam, or by cranks with some kind of quick return motion.

The support of the trough in its reciprocating motion has been effected by links and by spring legs in an oblique position, the latter form being more generally used for two reasons.

Firstly, these spring legs are securely bolted at one end to the floor or other support, and at the other to the conveyor trough itself, and consequently require no lubrication.

Secondly, the combined action of the reciprocating motion of the trough and of the rocking of the spring legs causes the material to travel faster in the trough with a given stroke of the crank than with any other support.

The Zimmer Conveyor.—This is built on the above principle. The diagram in Fig. 149 illustrates its action. The diagram is greatly exaggerated, as the movements are too minute to show on a small scale diagram. The lines A, B represent the bottom of the trough; C, C are two of the spring legs. The lines in full show these legs at the extreme backward position of the crank D, and the dotted lines also show A, B, C, C in the forward position of the crank. Let E be the object to be conveyed. At the moment the trough moves forward and upward, E is thrown also forward and approximately at right angles to the slanting legs C, C, and before E has time to complete its short parabolic course, the trough has been moved by the crank into its original

position to receive it, when the same process repeats itself again and again, the progress of the object being indicated by E^1, E^2, E^3. In reality the horizontal movement of

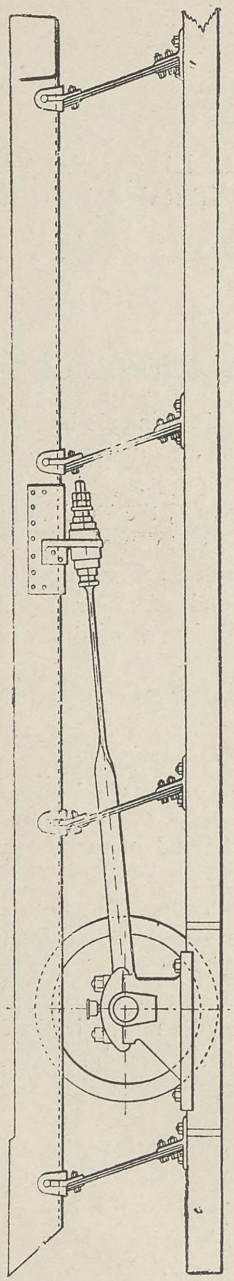


Fig. 148. Elevation of Zimmer Conveyor.

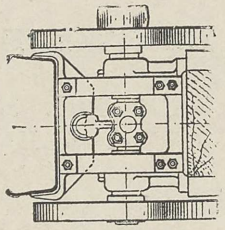


Fig. 150. Cross Section of Zimmer Conveyor.

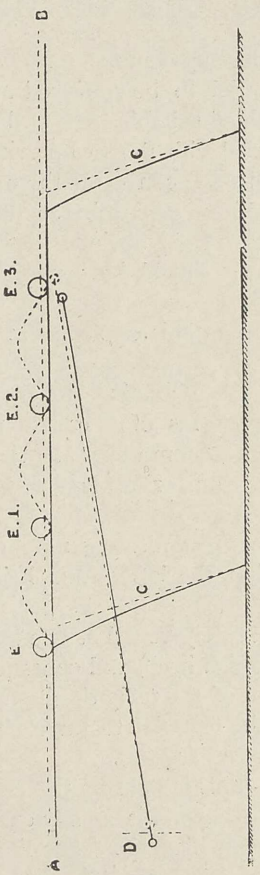


Fig. 149. Diagram showing Action of Zimmer Conveyor.

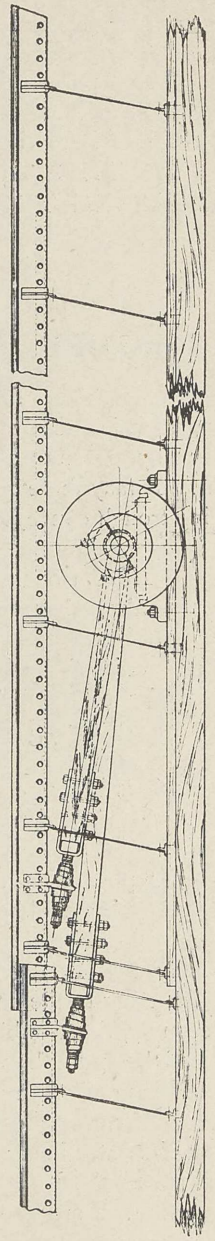


Fig. 151. Elevation of Balanced Zimmer Conveyor.

the trough is only about 1 in., and the vertical between the dotted and the full lines only $\frac{1}{8}$ in. If the trough is full the material moves, as it were, in a solid mass. There is neither friction between the particles of material nor between the trough and the product, as it is a hopping and not a sliding motion which propels the material.

Figs. **148** and **150** show one of these conveyors in elevation and in cross section. It is of the original type with a few improvements. Such a conveyor would be suitable for lengths of 50 ft., and for widths up to 24 in. It has been shown that the original conveyor could only be used in comparatively narrow limits; but this appliance has now been improved, and is well known, especially in colliery districts, as the "Zimmer Conveyor." It is used in lengths up to 500 ft. for narrow widths, and in widths up to 6 ft. 6 in. for short lengths. The essential improvement which rendered it possible for this conveyor to be made in such proportions was the introduction of the balancing device, by means of which the conveyor is made in two halves, one being about 2 in. higher than the other, so that one half delivers into the other half. The two sections are manipulated by triple and multiple cranks which stand at an angle of about 180° to each other. One half of the conveyor moves

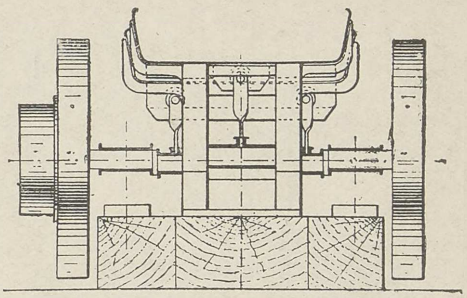
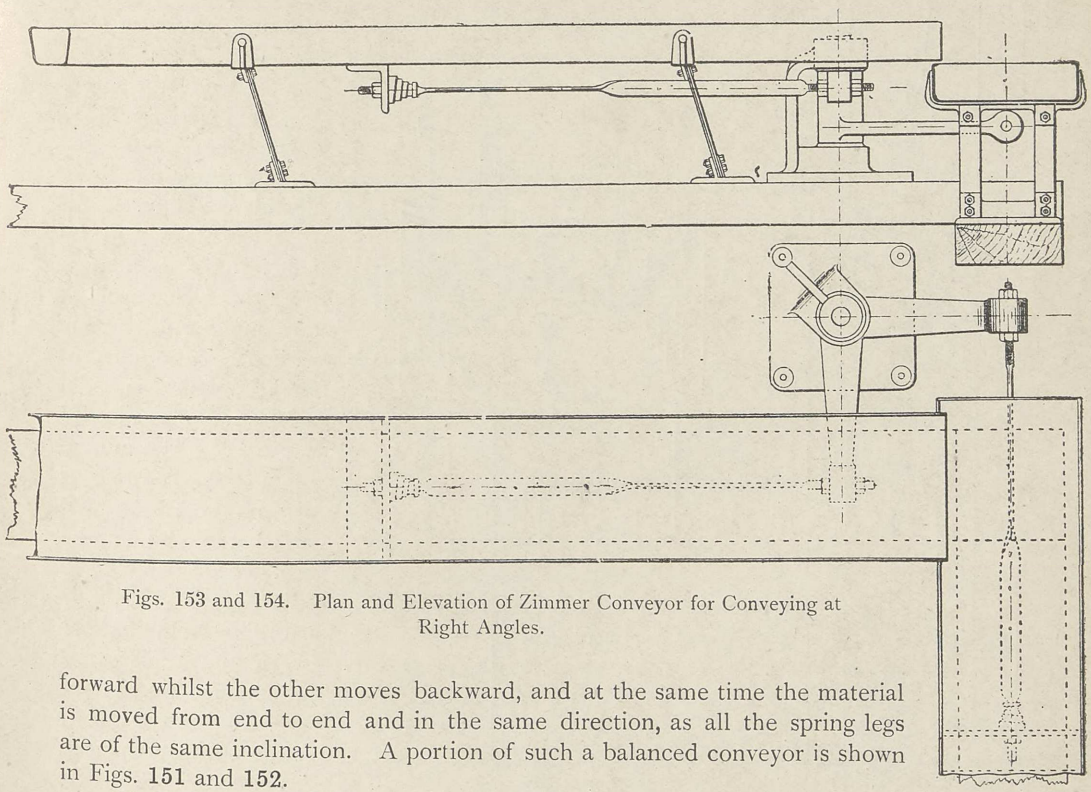


Fig. 152. Cross Section of Balanced Zimmer Conveyor.

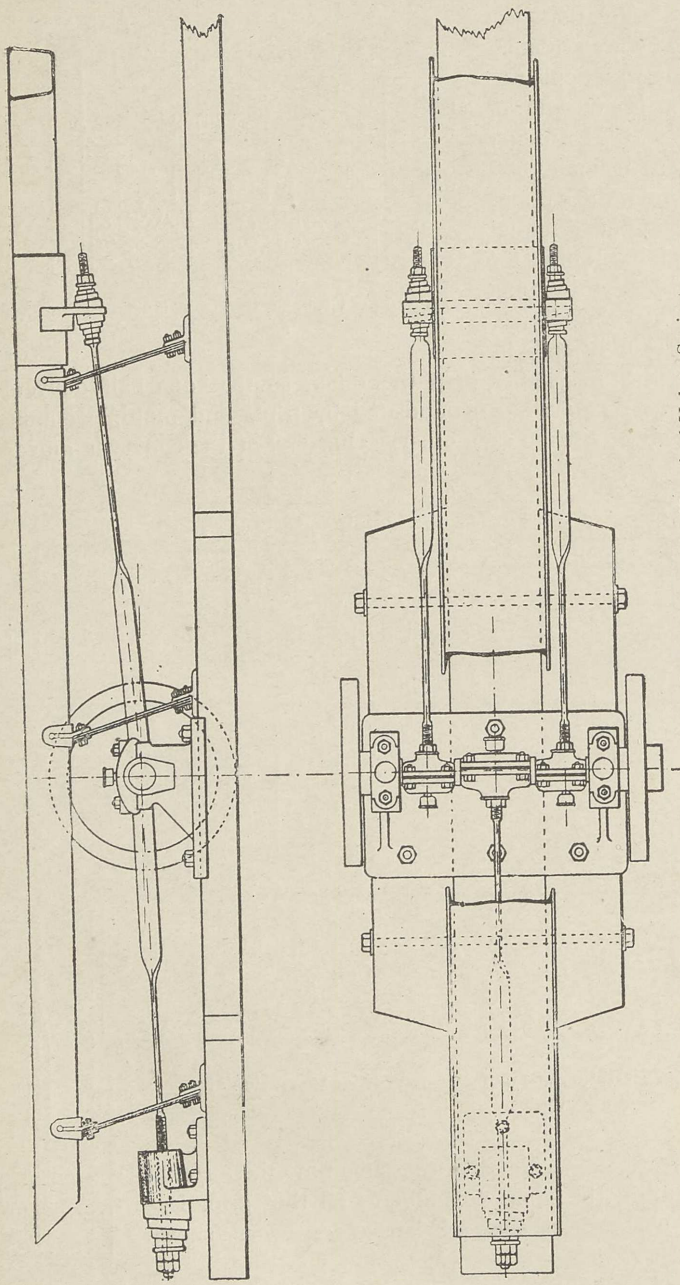


Figs. 153 and 154. Plan and Elevation of Zimmer Conveyor for Conveying at Right Angles.

forward whilst the other moves backward, and at the same time the material is moved from end to end and in the same direction, as all the spring legs are of the same inclination. A portion of such a balanced conveyor is shown in Figs. **151** and **152**.

Figs. **153** and **154** show a similar arrangement of balanced conveyors, the two sections of which work at an angle to each other, one half balancing the other. Ordinary balanced conveyors are necessarily driven at or near the centre of their length. In cases where this is not convenient, they may be driven at one end, as shown in Figs. **155** and

156. In this type the balancing of the conveyor is effected by means of a powerful volute spring, which is compressed and released by one of the cranks and connecting rods, instead of being coupled to one half of the conveyor. This acts as an accumulator, receiving and storing the surplus energy of the conveyor at its backward movement, and giving it up again as soon as the crank has passed the dead centre, where it is utilised to pull the conveyor back against the springs.



Figs. 155 and 156. Zimmer Conveyor Balanced by Terminal Volute Spring.

The Zimmer conveyor can be used to work partly in one direction and partly in another direction, by reversing the incline of the spring legs, and by joining the segments of the troughs at the junction by a flexible coupling.

The load can be fed into or withdrawn from these conveyors at any number of points without cessation of work. The material travels at the rate of 40 to 70 ft. per minute when the conveyor is driven at 300 to 370 revs. per minute, but the best speed is 300 to 350 revs.

The coupling between the trough and the connecting rod is not rigid, but two strong volute springs are placed on either side of the attachment. This is for the purpose of allowing the trough itself to exceed the stroke of the crank by a fraction of an inch on either side, and as the radius of the crank is in most cases less than $\frac{1}{2}$ in., the total travel of the trough with each revolution of the crank is but little more than 1 in.

The work of conveyors on this principle is not limited to a horizontal direction, as they can equally well be used for conveying material up and down inclines. They may be worked in a standing or hanging position, the conveyor in the latter case being suspended by its spring legs from the structure above.

The success of this conveyor is largely due to its simplicity and to the small driving power required, especially when it is fitted with the balanced drive, as in such a case half the spring legs are always in tension while the other half are relaxed, so that the power which has been stored in half the legs is utilised for tightening the other half immediately the crank has passed its dead centre.

The following tables give the capacity of this conveyor in tons of coal and coke per hour for different sized troughs :—

CAPACITY OF ZIMMER CONVEYOR FOR COAL

	Width of Trough in Inches.								
	12	14	16	20	24	36	48	60	72
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Trough 4 in. deep -	6-7	7-8	8-9	10-12	13-15	...	...	...	...
,, 6 ,, -	9-10	12-13	13-15	16-18	18-20	30-32	35-40	45-50	50-60
,, 8 ,, -	...	...	...	...	25-30	35-40	50-60	60-70	70-80

CAPACITY OF ZIMMER CONVEYOR FOR COKE

	Width of Trough in Inches.								
	12	14	16	20	24	36	48	60	72
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Trough 4 in. deep -	3½-4	4-5	5-6	6-8	8-10	10-13	16-19	19-22	22-26
,, 6 ,, -	...	...	...	...	12-14	16-19	24-28	28-33	33-39
,, 8 ,, -	...	...	...	...	16-19	22-26	33-39	39-46	46-53

The capacities given in the tables are for conveyors in a horizontal position. An incline of only 5 per cent. downwards will increase the capacity with some materials up to 10 per cent., while an incline upwards will reduce the capacity accordingly.

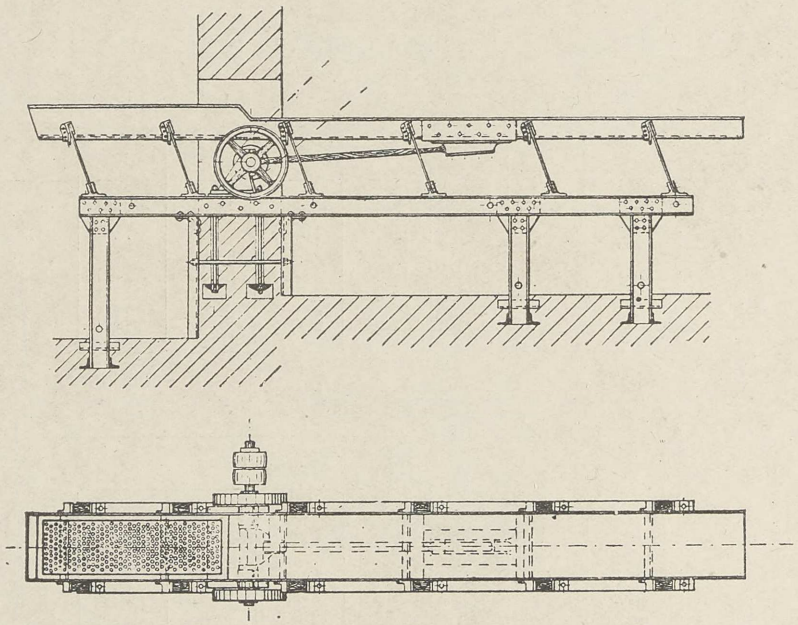
The driving power required may be judged from the following example. A Zimmer conveyor 100 ft. long, conveying a load of 50 tons per hour, will require 8·75 H.P.

The advantages of this conveyor are that it will convey any kind of material in large or small pieces, and cause next to no breakage to even the most friable material on account of its gentle action. By the use of ordinary slides in the bottom of the trough, the material can be withdrawn at any number of points. There are but few parts, and fewer still to get out of order, whilst a special feature is the absence of a multiplicity of bearings and travelling gear.

This conveyor is used for a variety of purposes, a few of which are herewith illustrated and described.

Figs. **157** and **158** show the conveyor for draining purposes in connection with a coal-washing plant. The head end of the conveyor being fitted with a perforated plate, allows the water to at once escape, whilst the coal is conveyed to the further end. The conveyor has a slight upward incline; thus should any water remain with the coal, it will tend to run back towards the feed end where it can escape through the perforations.

The conveyor can also be used as a picking table, as the oscillating motion of the trough does not inconvenience the pickers after the first few minutes, and it has this advantage, that the coal is always uniformly spread out over the whole surface. Hence picking is much easier work on this kind of conveyor than on the ordinary steel plate table, where the coal remains in heaps just as it has been deposited on the band, and has therefore to be spread for examination by the pickers.



Figs. 157 and 158. Zimmer Conveyor as used for Draining Purposes in connection with Coal-Washing Plant.

Fig. **159** shows two Zimmer conveyors at work, which are used for picking purposes, at the Amelia Pit of the Cramlington Coal Co., Ltd.

This conveyor is also extensively used in collieries, etc., not only for conveying, but also for classifying or sorting coal and other minerals into different sizes. When used as a screen, the machine is fitted with an interchangeable sieve which divides the trough into an upper and lower deck or compartment; the fine material which has been sifted out by this perforated plate is conveyed on the bottom of the conveyor until an outlet is reached. The sifting action is so sharp, that a perforated plate of 6 or 8 ft. in length is sufficient in most cases to effect the separation. The sieves for different sized coal required can therefore be made of such lengths as to coincide with the row of sidings on which the trucks to be loaded can stand (see Fig. **160**). Such a plant is at work in a Belgian colliery, where the coal is divided into a great number of sizes, each truck receiving coal of a different size. Fig. **161** shows a Zimmer Patent Balanced Screen of this kind to a larger scale.

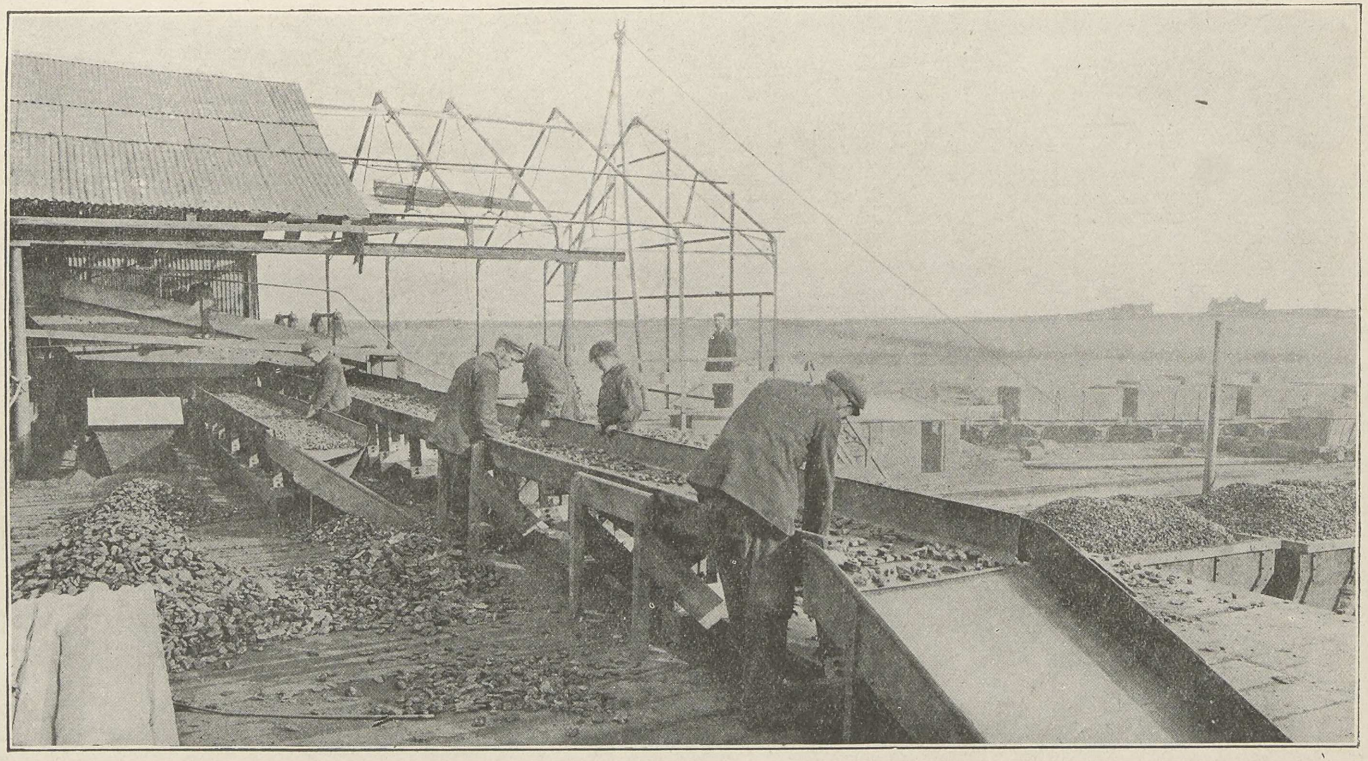


Fig. 159. Zimmer Conveyor as used for Picking Purposes.

The Weiss Feeding Appliance.—The feeding device illustrated in Figs. **162** and **163** is the invention of Mr Weiss, manager of the gasworks at Zürich, and has been designed for the purpose of automatically and uniformly feeding this type of conveyor with coal from silos or stock heaps.

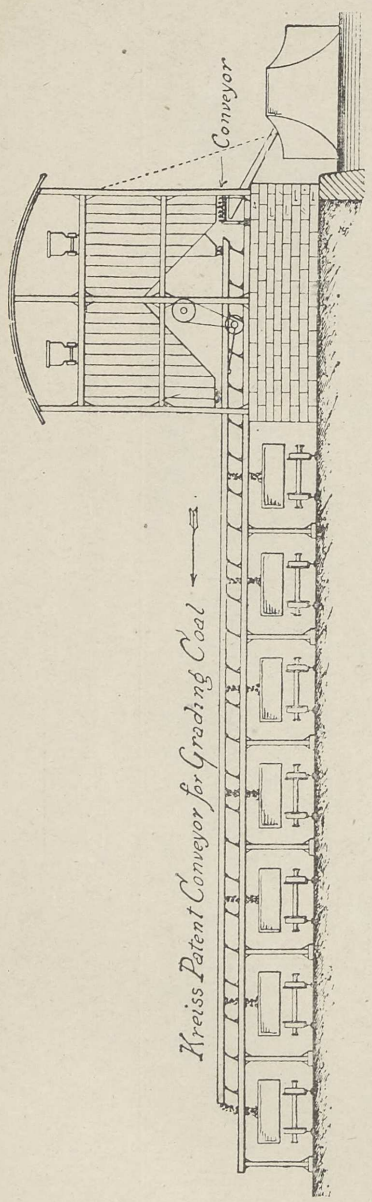


Fig. 160. Zimmer Conveyor as Classifier for Coal.

The illustration represents the apparatus in elevation and cross section. The conveyor is fixed in a tunnel, with the feeding appliance over it, in connection with the hoppered bottom of the coal store.

The feeding device consists principally of a table above which the coal enters. This table is set into an oscillating movement, and thus allows the coal to drop from its sides into a small hoppered trough, from which it finds its way on to the conveyor. The oscillating motion is imparted to the table by a lever connected to the conveyor. This lever can be thrown in and out of gear, and it is obvious that when thrown out, and the table at rest, the flow of coal will cease.

The Norton Conveyor.—This is another type of reciprocating conveyor, and unlike those previously described, the trough is supported on inclined links, the stroke is much larger, and the speed of running much less. The conveyor consists of the usual wrought-iron trough, which in this case receives its reciprocating motion from an eccentric, and in order to balance the conveyor, the trough is made in two equal portions, which reciprocate in opposite directions. The motion is given by rocking levers (see Fig. **164**), which shows the principle in diagrammatic form, which will be understood from the previous remarks. The diagram shows the development of this conveyor for screening purposes to classify the coal as well as to convey it. The number of inclined supports are comparatively few, as compared with the previously described conveyor. The speed of the eccentric is about 90 revs. per minute, and the stroke imparted is from 5 to 6 in., which is said to produce a forward motion of the material in the trough at the rate of 40 ft. per minute. From these particulars the capacities of the various sized troughs can be ascertained.

One of the most important features of this conveyor in connection with its use in collieries is the reciprocating loading extension, which is worthy of more than a passing remark. The loading or lowering device is so coupled to the conveyor or screen proper, that the stroke is automatically adjusted, and thus made suitable to every incline of the shoot, that is to say, at the steepest downward gradient, when the loader reaches to the bottom of the coal truck, and when the coal would run

down by gravity at the ordinary stroke, this motion is only about 1 in., whilst when the incline is lessened as the truck is gradually filled from the shoot, the stroke increases automatically until when level it is as long as that of the screen. This diversion in the length of the stroke is produced by two levers, one on each side of the lowering jib, one end of each of these levers being hinged to a sliding block fixed to the floor, whilst the other end is guided by two rocking levers with slots (the rocking levers are manipulated by the screen). These two levers are connected on both sides at about the centre of their length to the lowering shoot, in such a way that when this is steep the ends of the levers are in the lowest position of the slots in the rocking levers, where the stroke is short, and as the shoot is raised the two lever ends ascend in the slots of the rockers to where the stroke is longer. The lowering shoot is 20 ft. long, and of course as wide as the conveyor screen from which it is fed and driven. The free or delivery end of this loading device is supported and adjusted by a small winch, a wire rope, and balance weight.

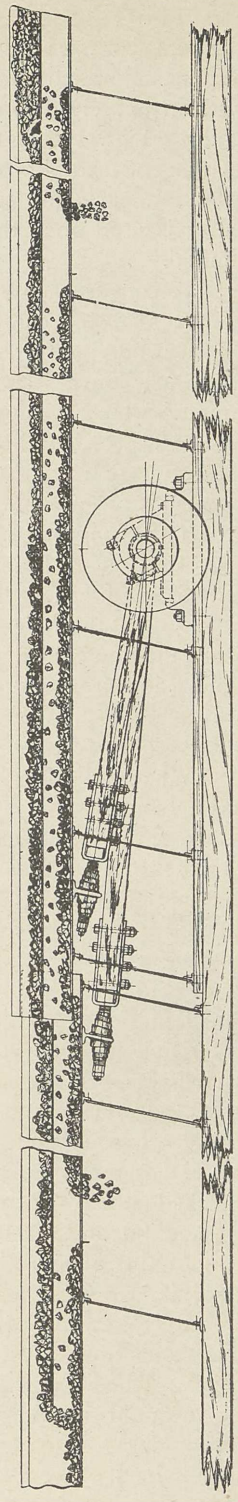
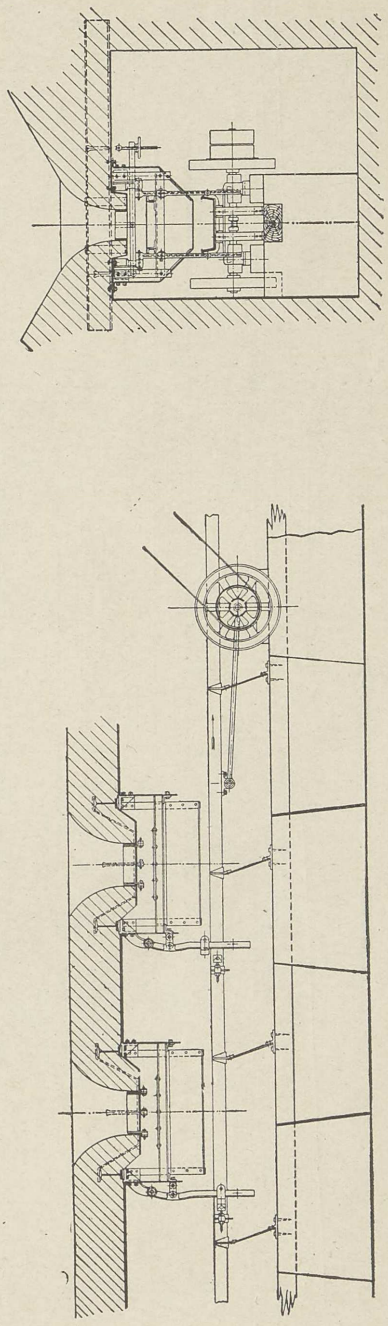


Fig. 161. Zimmer Patent Balanced Screening Conveyor.



Figs. 162 and 163. Weiss Feeding Appliance in connection with Reciprocating Conveyors.

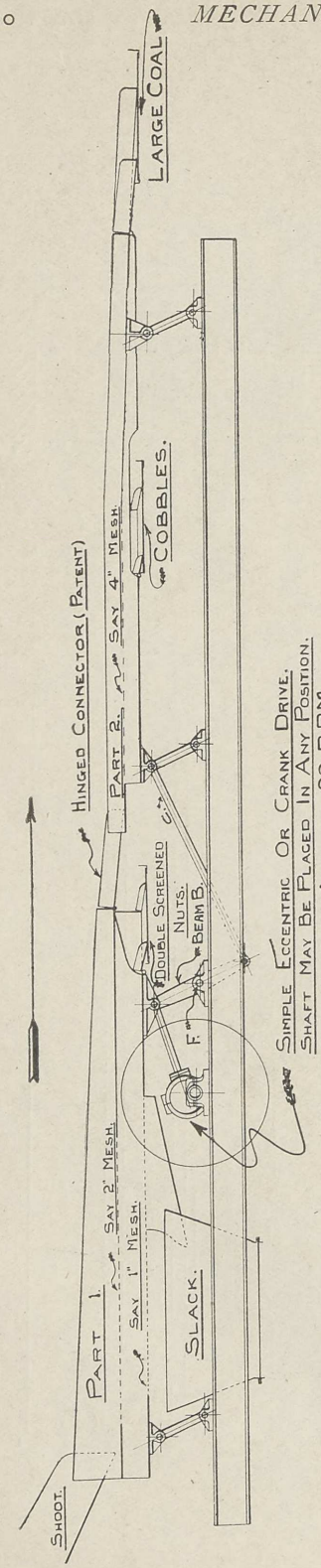


Fig. 164. Norton's Patent Reciprocating Conveyor.

The Torpedo Conveyor.—A reciprocating conveyor has recently been introduced under this name, which presents some new features and an entirely different principle to the foregoing. Figs. **165** and **166** show the two types of this conveyor in elevation and cross section. The former is the standard type, whilst the latter is used when the available head room is limited.

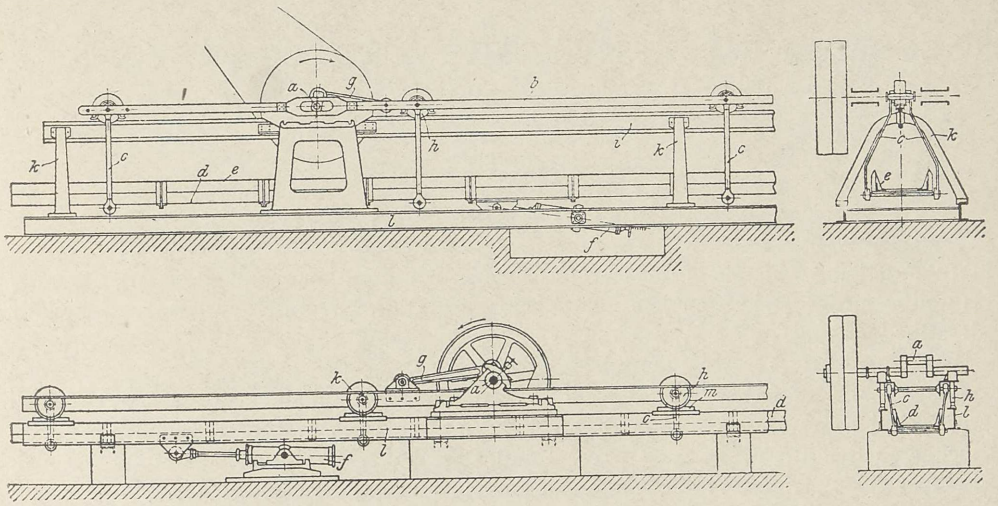
A conveyor according to Fig. **165** consists of the following component parts: the trough *de* suspended on rockers *c*; the crank drive *ag* which conveys an oscillating motion to the frame *b*, which is supported by rollers *h*, rail *i*, and brackets *k*; and lastly of the dashpot *f* with its connection to the trough. Fig. **167** is a perspective view of the same.

The conveyor in the lower illustration, Fig. **166**, differs from the one previously described in so far that the upper rail is dispensed with, so that the rollers *h* revolve on the channel *l*, or rather on chilled iron rollers *m*; the rockers *c* being in this case much shorter. The troughs are of angles and sheet steel plates similar to other reciprocating conveyors.

When the conveyor is at work the carriage has a reciprocating motion of 8 in., due to the crank, and this motion is imparted by the links *c* to the trough. Such a swinging or pendulum-like motion being equal in either direction would give no forward movement to any material deposited in the trough, and this motion does not come into being till the motion in one of the directions is arrested prematurely by the dashpot *f* and its connection. The action is then as follows: the material in the trough swings with the trough and has therefore the same velocity, but before the motion has reached its full extent the progress of the trough is gently checked when the material slides on by its momentum, and is thus conveyed by the repetition of this action. The normal speed of the crank is 52 revs. per minute, and the stroke 8 in.

Reciprocating conveyors do not deserve this name until a certain minimum speed has been reached. In the case of the torpedo conveyor this appears to be at a little over 40 revolutions. At 52 revolutions the best results are obtained. According to Baron Hanffstengel,

if the links *c* are 14 in. long, the stroke 8, and the speed 51 revolutions, the actual stroke of the trough is 9 in., and the average speed of conveying 62 ft. per minute. He also found that the material followed the backward stroke of the trough for 3 to 4 in.



Figs. 165 and 166. Torpedo Conveyors in Elevation and Cross Section.

The Marcus Conveyor.—This reciprocating conveyor consists of an open trough, the movements of which are essentially backward and forward in the same plane, unlike the Zimmer and Norton conveyors, which have, in addition to a similar movement, a swinging up-and-down motion determined by the arc described by the inclined supports. As this latter motion, which is the principal cause of the forward movement of the material in these conveyors, is absent in the Marcus conveyor, some other means had to be found to give the propelling action. This has been provided by an ingenious crank drive with a drag-link, which gives the trough and its load a slow forward movement and a quick return, so that the inertia of the material in the trough overcomes the friction offered by the trough and slides along whilst the trough returns. The forward movement of the material is said to be four-fifths of this stroke with each revolution of the crank. The trough is supported on rollers and channel stools, and the roller paths are fitted with renewable wearing flats, the rollers being kept in position by steel spindles and spiral springs. The speed at which these conveyors run is from 60 to 90 revs. per minute.

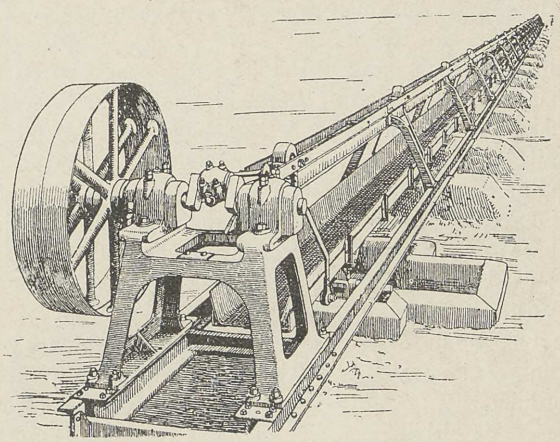


Fig. 167. Perspective View of Torpedo Conveyor.

COMBINED ELEVATORS AND CONVEYORS

CHAPTER X

GRAVITY BUCKET CONVEYORS

THE underlying principle of this type of conveyor is utilised for handling material in bulk, as well as for larger independent loads. Conveyors for the former purpose are generally described as :—

Gravity or Tilting Bucket Conveyors.—These conveyors consist of two endless chains or ropes held at fixed distances apart by suitable bars, which are fitted with small rollers at each end. Every link, or sometimes every second link, carries a bucket, so that the whole is an endless and unbroken chain of buckets, which are not, however, fixed like elevator buckets, but are movable and suspended above their centre of gravity.

When this conveyor is at work the buckets will always be in an upright position, whether they are moving horizontally or vertically. Each bucket carries its load to the point at which its delivery is required, and here it is generally met by some adjustable tripping device which tilts each bucket in turn, and thus empties the contents.

The gravity bucket conveyor enjoys great popularity, especially in America, and the details of some of the best forms have been most carefully designed. Where coal has to be conveyed to overhead bunkers in boiler-houses, this kind of conveyor certainly has great advantages. Instead of using a separate conveyor to bring the coal from the railway sidings and installing an elevator to raise it to the level of the bunkers, at which point a second conveyor must be used to distribute the coal from the elevator to the different compartments of the bunkers, one travelling bucket conveyor will perform these three operations, while sometimes the returning and therefore empty strand of buckets is used to convey the ashes away from under the boilers. This latter use is, however, bad practice, as an expensive installation used for handling alternately coal and ashes is not economical, since the damp ashes—which by the way only represent 10 to 15 per cent. of the coal—are highly corrosive and will rapidly destroy an equipment which with ordinary care would last for many years if used for coal alone.

The driving gear is in some cases not unlike that of the ordinary chain-driven elevator, but more often it is independent of the conveyor, and actuates it by a series of pawls attached to a wheel, each of which pushes the conveyor forward, link by link. Or sometimes there is a wheel, with suitable projections, which are of the same pitch as the buckets, and which gear, as it were, into a portion of the continuous chain of buckets either on the inside or on the outside of the strand.

The devices for loading each of the buckets without spilling the material are of great importance in this type of conveyor. They are very numerous, and are fully detailed later.

Figs. **168** and **169** show sections of two distinct types of the travelling bucket conveyor, the "Hunt" and the "Bradley."

The speed of travel of these conveyors is slow, and the necessary capacity is obtained by installing buckets of a size corresponding to the load to be conveyed. The normal rate of travel is 40 ft. per minute, but it can be either increased or decreased within limits of 25 and 50 ft. according to circumstances. The power required is comparatively small, and depends to a large extent on what proportion of the length is used for elevating.

A conveyor of this type offers the undoubted advantages of handling material in the gentlest possible manner, and of consuming but little power. One main drive is sufficient for a whole installation. The material can be fed to or withdrawn from the conveyor at any point. But it has this disadvantage, that if one portion of the installation breaks down, the whole is at a standstill; whereas, if different appliances are used for elevating and conveying, a portion of the whole may be at work. Moreover, there are a large number of journals to be lubricated and kept in repair. The former operation is, however, automatically effected in some of the best conveyors.

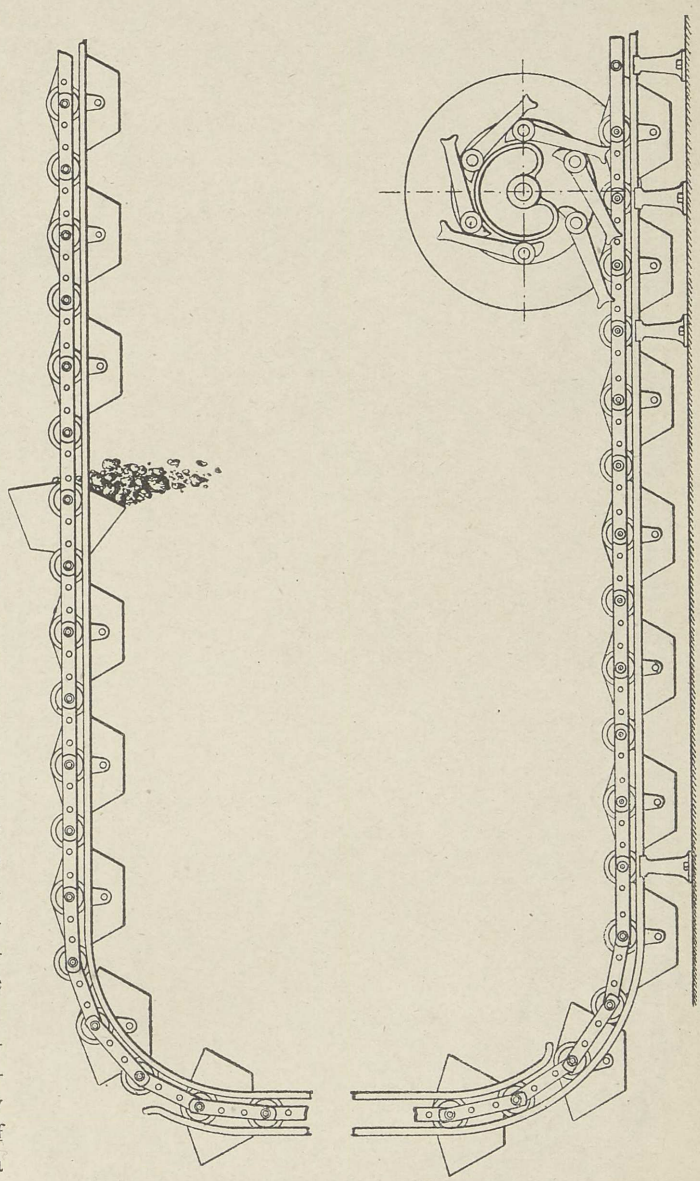


Fig. 168. The Hunt Conveyor.

The Hunt Conveyor.—The Hunt conveyor, which was probably the first successful one of this class, consists of a double link chain carrying a series of pivoted buckets suspended in such a manner that they maintain their vertical position, and are free to revolve on their axes at all points of their path except at the place in which they discharge, this operation being effected in a very simple and efficient manner by means of a cam action, whilst the buckets on being released right themselves and are ready to be refilled. The buckets pass through the cycle of their motions continuously, filling and emptying at any given points, the discharging being so simply performed that

by merely moving a lever the contact can be made or broken. The action is complete, the buckets being so tipped that nothing is allowed to remain in them after they pass the discharging point.

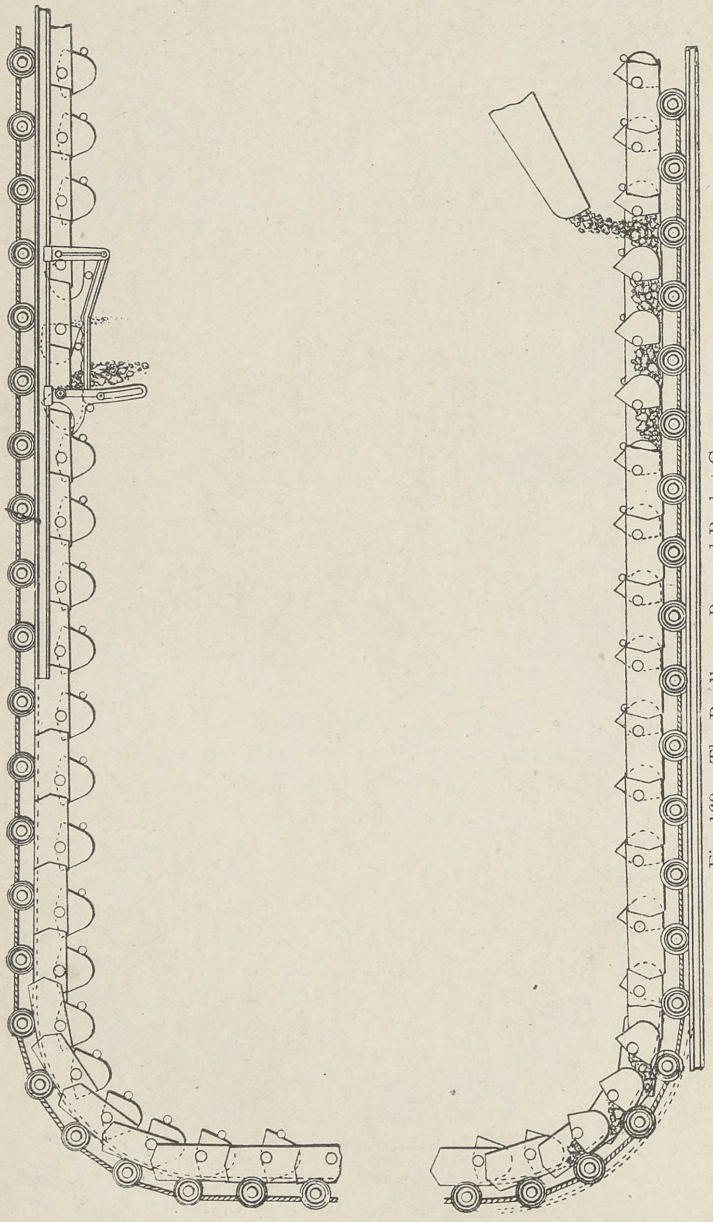


Fig. 169. The Bradley or Pan and Bucket Conveyor.

The chain is centrally supported and centrally driven, the wheels being placed between the links of the chain, while each alternate pair of wheels has an axle traversing the space between the two chains and correctly maintaining the distance between them, thus preventing distortion or alteration of the track gauge.

The buckets are suspended on pivots projecting from the inner side of the chain, and are so arranged that by withdrawing two pins each bucket can be removed from the conveyor without disturbing any other part.

The wheels are so made that each will carry enough lubricant to provide for a certain period of running without attention.

The track consists of a special section of headed rail, joined together in convenient lengths by double fish plates, securely bolted through the rails, and resting upon cast-iron standards, to which the rails are bolted by means of hook bolts, obviating all drilling of holes, and consequent reduction of the rail section.

The curves which change the direction of the movement of the buckets are, as far

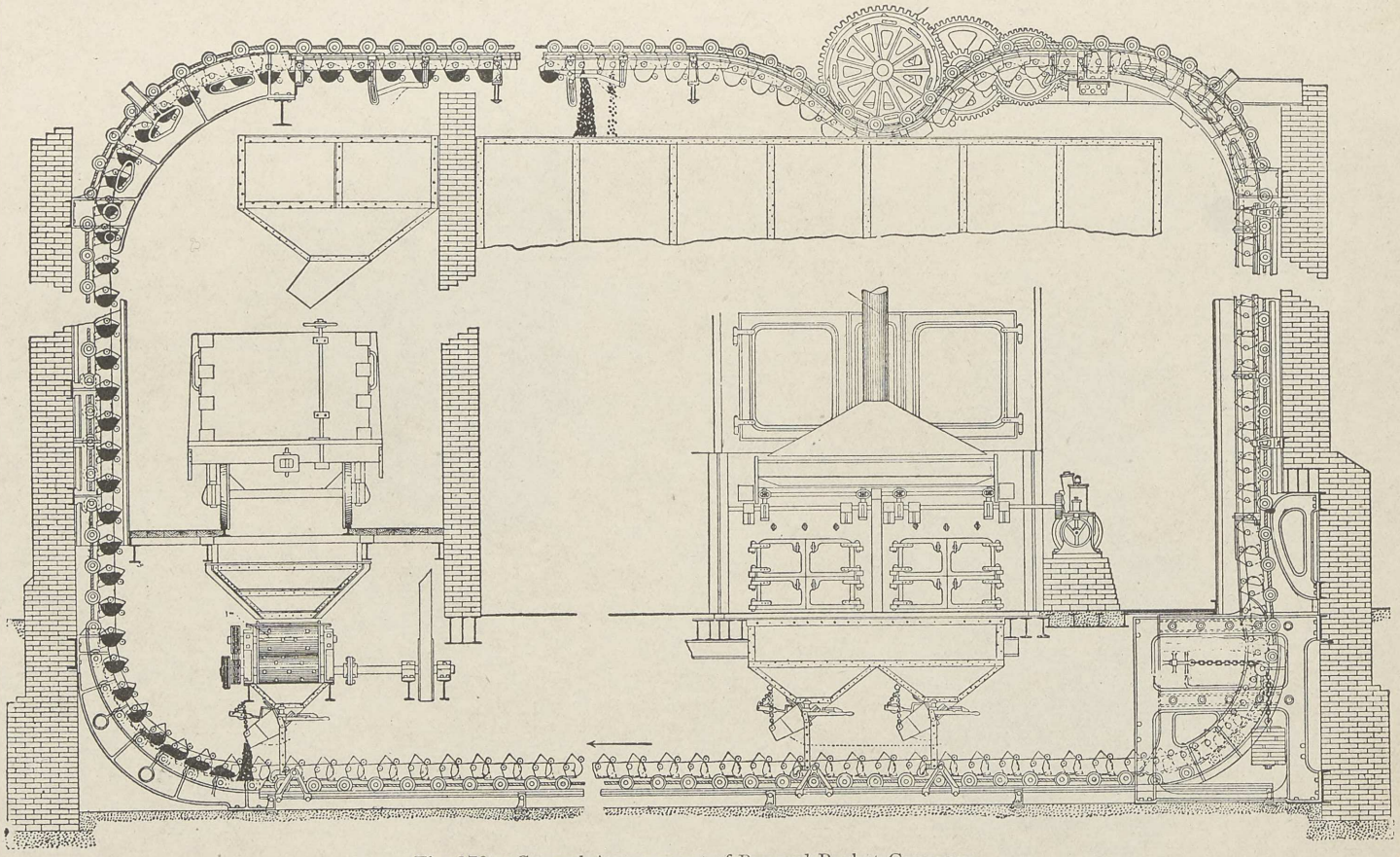


Fig. 170. General Arrangement of Pan and Bucket Conveyor.

as possible, formed as free wheels. Each pair of wheels is bored, turned, and keyed on a steel spindle, running in bushed and automatically lubricated bearings. The wheels of the conveyor chain are thus at rest and move round with the curved wheel rims, thus minimising friction and preventing wear at these important points where the stress is greatest on the conveyor chain.

By this improved and combined provision for movement a great reduction in the driving power has been effected. The tightening curve is provided with slide-blocks and tension screws, which enable it to be moved so as to take up any slack in the chain which may be formed.

The automatic continuous filler consists of a short endless chain, carrying seven funnels and supported in a frame, the funnels successively covering the buckets of the conveyor, and as the filler chain is driven by contact with the conveyor chain, the spacing and filling is accurate and uniform. These funnels and chains move round an oval track formed in the filler frame, and are supported on wheels similar to those of the conveyor chain.

The driving gear is so designed as to propel the chain by means of pawls which successively engage with the cross studs of the chain (see Fig. 168) and give a central thrusting action. The two parts of the chain are driven equally and simultaneously.

Robt. Dempster & Sons build a similar conveyor fitted with the Toogood Patent Equalising Gear, a description of which is given on page 192.

The Babcock & Wilcox Gravity Bucket Conveyor.—This is also on the original Hunt system, but improved in details. To begin with, the chain links are bushed and the supporting rollers are carried on the bushes, and the parts are not only interchangeable, but the axles and bucket studs are also reversible, and in practice it has been found that where lubrication is well attended to during the earlier stages of the installation, fine smooth surfaces are obtained in all the wearing parts of the chain. Each bucket is stamped out of one sheet of mild steel. The driver and wheel curve bearings are now made self-aligning, with larger bearing surfaces, consequently binding and extra friction is avoided in the driving gears and shafting.

For complete installations of this conveyor see Chapters XL. and XLI.

The Bradley or Pan and Bucket Conveyor.—This conveyor is the design of W. H. Bradley, of the Consolidated Gas Co. of New York, and is built by the Steel Cable Engineering Co., of Boston, U.S.A., and others. In its perfected form it differs considerably from the original type, and includes a great number of improvements. It consists of a continuous trough built in sections, and supported on axles and guide wheels running on suitable rails. There is one axle to each segment of the trough, and in each segment a bucket is pivoted to the sides.

The axles are securely clamped to two endless steel cables instead of the chains which are generally used on conveyors of a similar type. This conveyor can be loaded when ascending, in which case the material is fed from a spout, and the process is similar to the feeding of an elevator. Material can also be fed at any point on the lower horizontal strand, as the conveyor itself consists of an endless trough similar to a continuous trough conveyor. Thus, when the conveyor runs horizontally, the endless trough receives the feed; but as soon as the ascent begins, each short section of trough empties itself into its respective bucket, so that when ascending the buckets are separately suspended from their pivots, and the trough runs empty at the side.

The discharging of the buckets is performed by a tipping device which can be so set that the contents of the buckets can be discharged at any desired point. The upper

surface of the tipping gear is slightly corrugated, so as to give the bucket a jarring motion, which shakes out any material that might otherwise adhere to the sides.

Fig. **170** gives a general outline of such a conveyor when receiving coal. The illustration shows on the left the railway truck which brings the coal and takes away the ashes. The truck is preferably self-unloading, and beneath it is shown a coal-breaker which reduces the coal to a more uniform size, and then delivers it in a regular feed to the ascending buckets of the conveyor, which deposit it in the bunkers over the boilers.

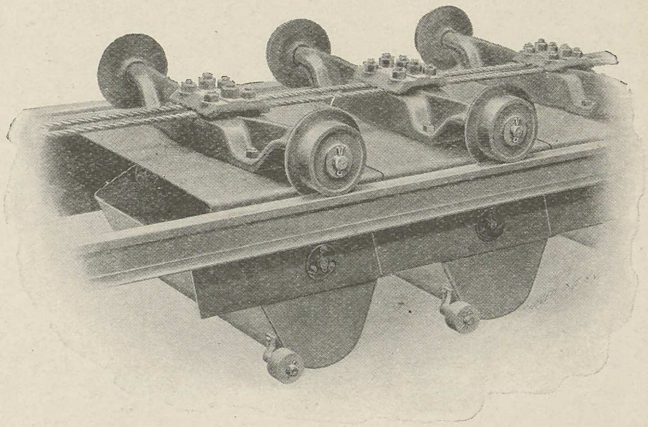


Fig. 171. Position of the Pans and Buckets on the Upper Strand.

The return portion of the conveyor, when not in use for carrying coal, can be used for removing the ashes. One of the boilers is shown in the illustration, from which it will be seen that the ashes are collected in hoppers which deliver in a similar manner to those beneath the coal-breaker, so that the ashes can be deposited into the conveyor whenever it is available for this purpose. They are then discharged just above the hopper, from which the contents can be loaded into trucks at intervals. The illustration clearly shows the driving gear, the feeding and tipping devices, as well as the arrangements for keeping the chain taut.

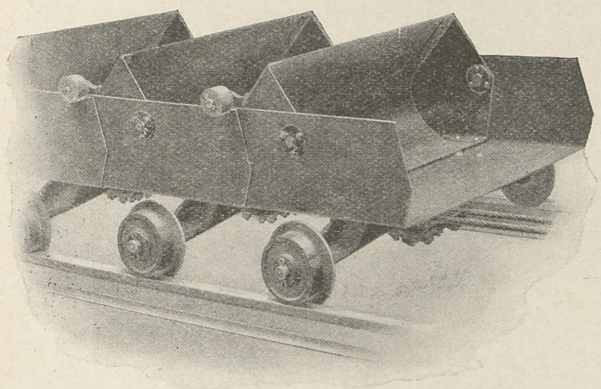


Fig. 172. Position of Pans and Buckets on the Lower Strand.

The buckets of this conveyor are made of stamped steel. In the continuous pan section there are no joints whatever, as the sections can be bent out of one piece, and overlap each other to prevent leakage. They depend for their alignment with each other upon the wheels and axles upon which they are supported, and for their pitch upon the cables which connect them.

Each bucket is provided with a small roller which is used for its discharge. It is claimed for this conveyor that it is very easy to replace any portion should this be necessary, as the clamps by which the axles are attached to the cables are fully accessible along the entire upper strand. This will be seen from Fig. **171**, which shows a portion of this pan and bucket conveyor in position on the upper strand.

Fig. **172** shows a portion of the same conveyor on the lower strand.

Fig. **173** represents the ordinary feeding device, from which it will be observed

that spilling is impossible, as the conveyor forms a continuous trough, so that what one bucket misses must drop into the next one.

Fig. **174** illustrates a similar feeding device used with material of a slightly sticky nature, an attachment giving the delivery spout a slight shaking to prevent clogging.

In Fig. **175** the conveyor is erected in a tunnel with two baffle plates over, so that the coal or any other material to be conveyed can be thrown into the conveyor from the floor on either side.

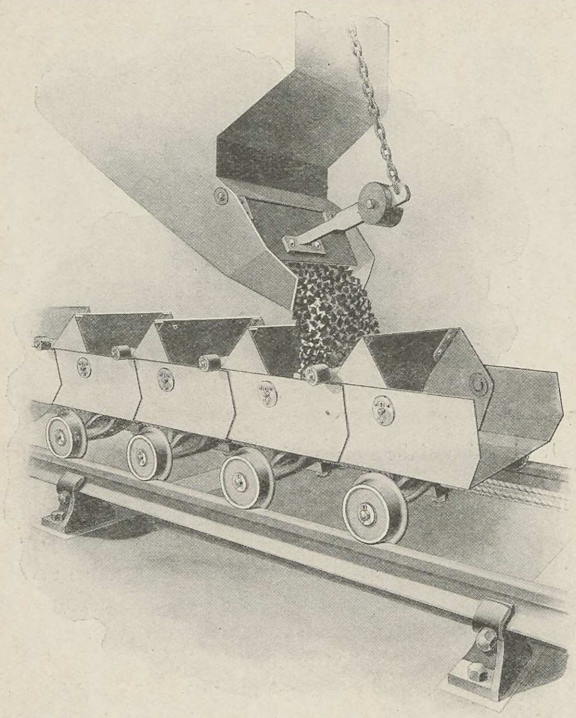


Fig. 173. Feeding Device for Pan and Bucket Conveyor.

The Link Belt Company's Conveyor.—Fig. **176** shows the manner in which the buckets manufactured by this company are overlapped, as an expedient to prevent leakage at the loading point. It will be seen from the illustration that the overlapping is obtained by suspending the buckets at extensions of the links of the chain, instead of from the usual support at the pin of the chain, so that in passing round a corner wheel the buckets travel in a larger circle than the chain. The illustration shows that as soon as the link begins to bend over one of the corner terminals, the point of suspension of the previous bucket is raised above its neighbour, so that the buckets gently disengage themselves from their overlap without in any way knocking against each other when negotiating corners.

The following table gives the dimensions, capacity, and speed of this conveyor:—

Bucket.	Pitch of Chain.	Carrying Capacity of Bucket in Cubic Feet.	Capacity in Tons of Coal per Hour.	Speed in Feet per Minute.
Inches.	Inches.			
18 × 15	18	0·68	15-20	30-40
18 × 21	18	0·94	20-30	30-40
24 × 18	24	1·68	40-50	40-50
24 × 24	24	2·24	55-70	40-50
24 × 30	24	2·80	75-100	40-50
24 × 36	24	3·36	90-120	40-50
30 × 24	30	3·50	95-120	45-60
30 × 30	30	4·37	110-160	45-60
30 × 36	30	5·25	140-190	45-60
36 × 36	36	8·50	210-330	50-80

The Bar-Link Conveyor.—This conveyor, which is built by the Steel Cable Engineering Co., is another form of the tilting bucket conveyor, and has the buckets

so arranged that they can be loaded at any point on the lower strand without the necessity of employing a loading device. Any spilling between the buckets is prevented by placing an additional axle and guide pulleys between each pair of buckets, the extra spindle being in such a position that when the buckets are on the lower strand it covers the space between each pair. The buckets are held in position while being loaded by a roller attached to each one. This roller travels on a separate guide rail as shown in the illustration. These rollers will also keep the bucket in position upon the upper strand, and during the process of discharging. The axles are connected by steel bar links, and the guide wheels are fitted with self-lubricating attachments. The illustration (Fig. 177) shows all the corner guides, as well as the loading and discharging devices and the driving gear.

Swinging Bucket Conveyor.—The swinging bucket conveyor (Fig. 178) is similar to the Bar-Link Conveyor just described, with this difference, however, that the buckets are suspended at one end instead of in the centre. This arrangement is intended to facilitate their discharge. During conveying on the lower strand the buckets are held in a horizontal position, and so readily receive the feed. The illustration shows the feeding device, the delivery and the attachment for turning the buckets over into their original position, as well as the automatic tightening arrangement.

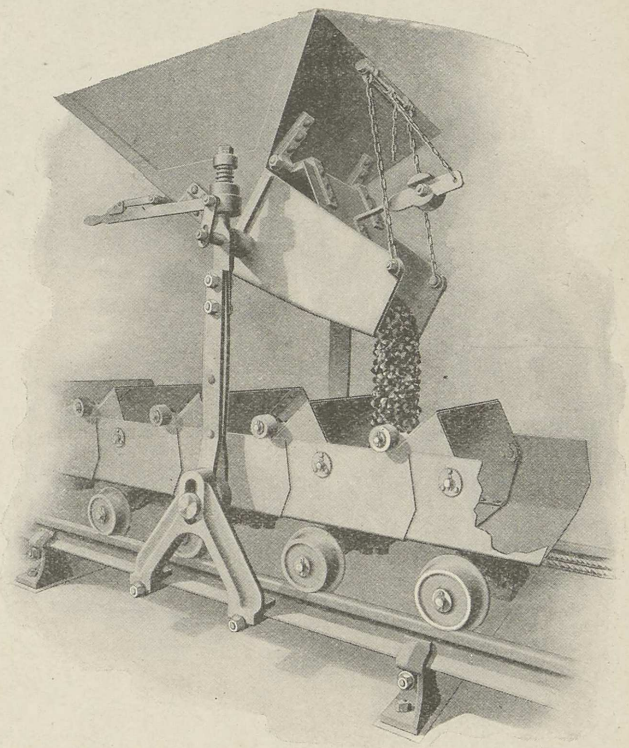


Fig. 174. Feeding Device for Sticky Material with Pan and Bucket Conveyor.

Continuous Bucket Conveyor.—A type of conveyor which empties itself not by tilting the bucket, but by opening it, is the continuous bucket conveyor built by the Steel Cable Engineering Co., of Boston. The buckets in this case are divided longitudinally, and hinged for the purpose of discharging. The conveyor itself is used in a similar manner to other travelling or tilting bucket conveyors. It will therefore suffice to show the bucket in its delivering position only. This is represented in Fig. 179.

There is a diamond-shaped frame made of round iron bars, with which the buckets engage when approaching it. This opens the halves, and allows them to close gently as the bucket passes off at the other end.

The Humboldt Conveyor.—A later development of the system is the Humboldt gravity bucket conveyor, which was designed to overcome the drawback of other

conveyors of similar type, namely, inability to work except in one plane, or at least with only a very slight deflection. It is claimed for the Humboldt conveyor that it will go round any incline backward and forward in both planes, and that it is therefore

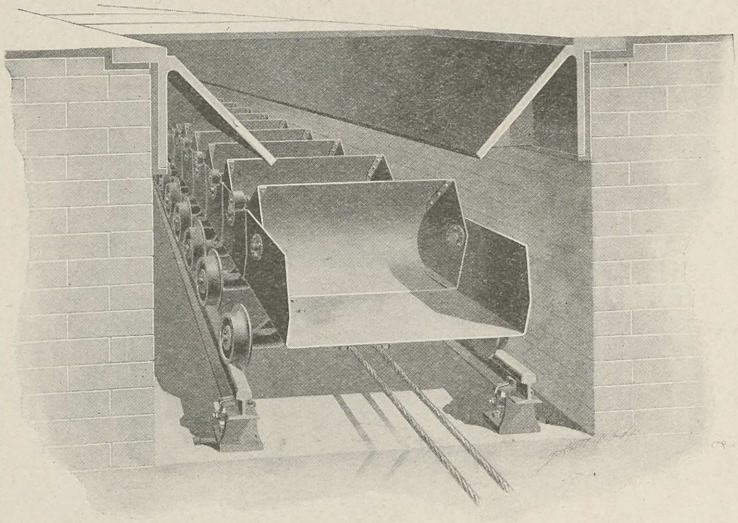


Fig. 175. Pan and Bucket Conveyor receiving Feed from Floor on either Side.

adaptable for installations where the ordinary travelling bucket conveyor would be useless, or where more than one would have to be used, and the material transferred from one to the other. The conveyor under consideration consists of a number of

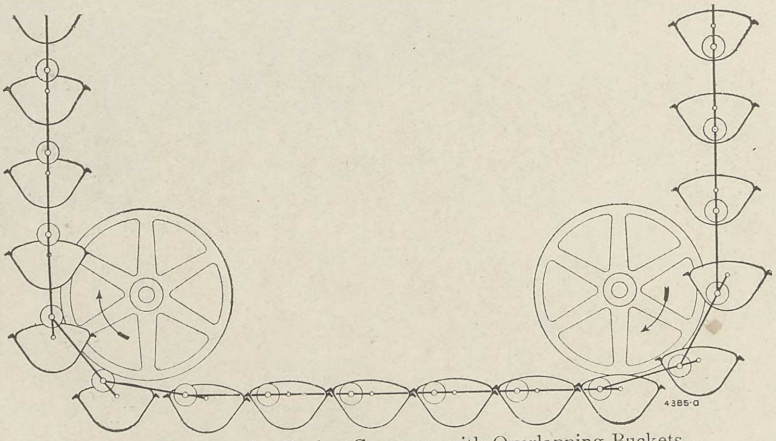


Fig. 176. Gravity Bucket Conveyor with Overlapping Buckets.

miniature carriages, which are each fitted with two spindles and four wheels. The carriage resembles a small contractor's truck (see Figs. **180** and **181**); it is pivoted above its centre of gravity, round which pivot it can be tilted. The trucks are coupled together by a central coupling bar, and these coupling bars allow not only of an upward and downward motion, but also of a side movement within certain limits. The conveyor is supported on a pair of rails similar to other conveyors of this type, and where curves

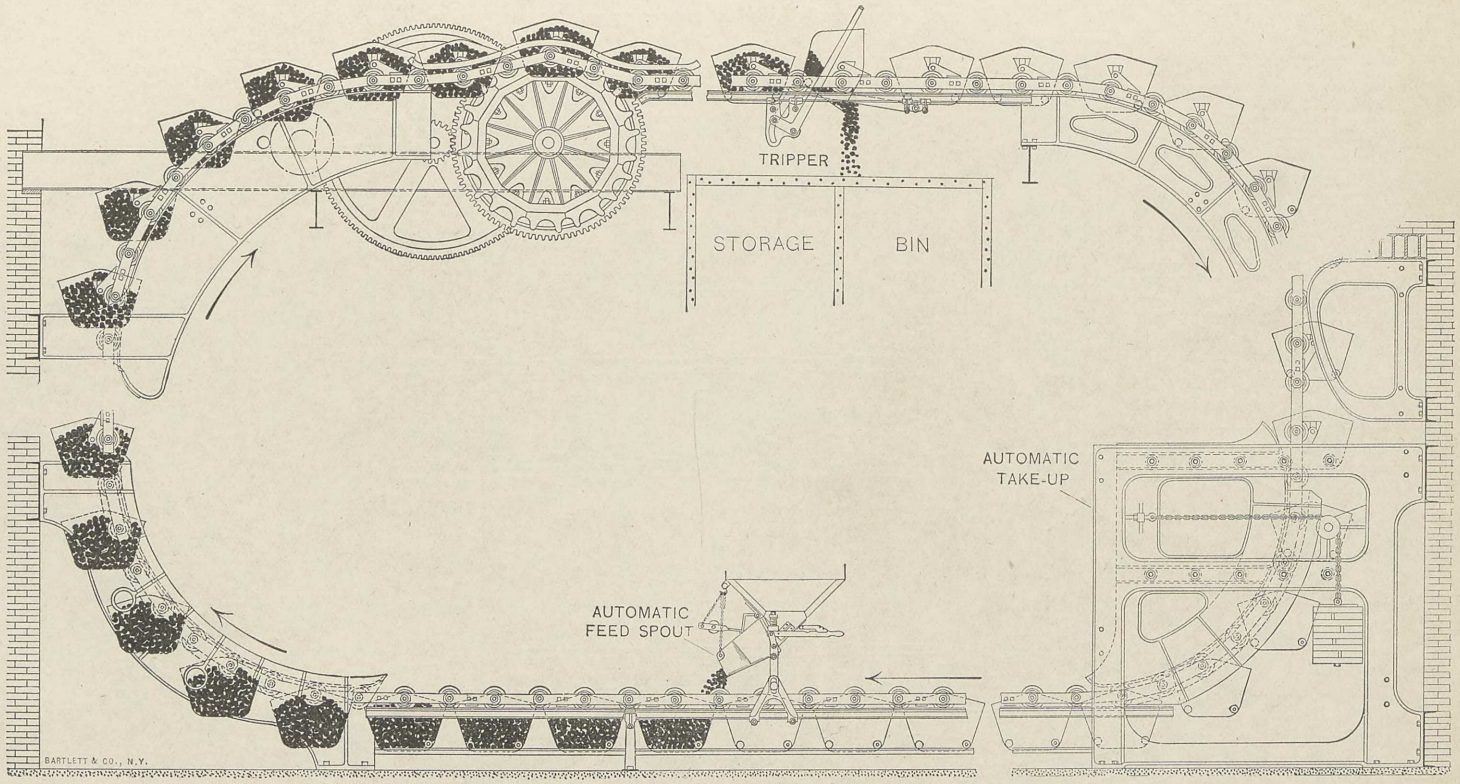


Fig. 177. General Arrangement of Bar-Link Conveyor.

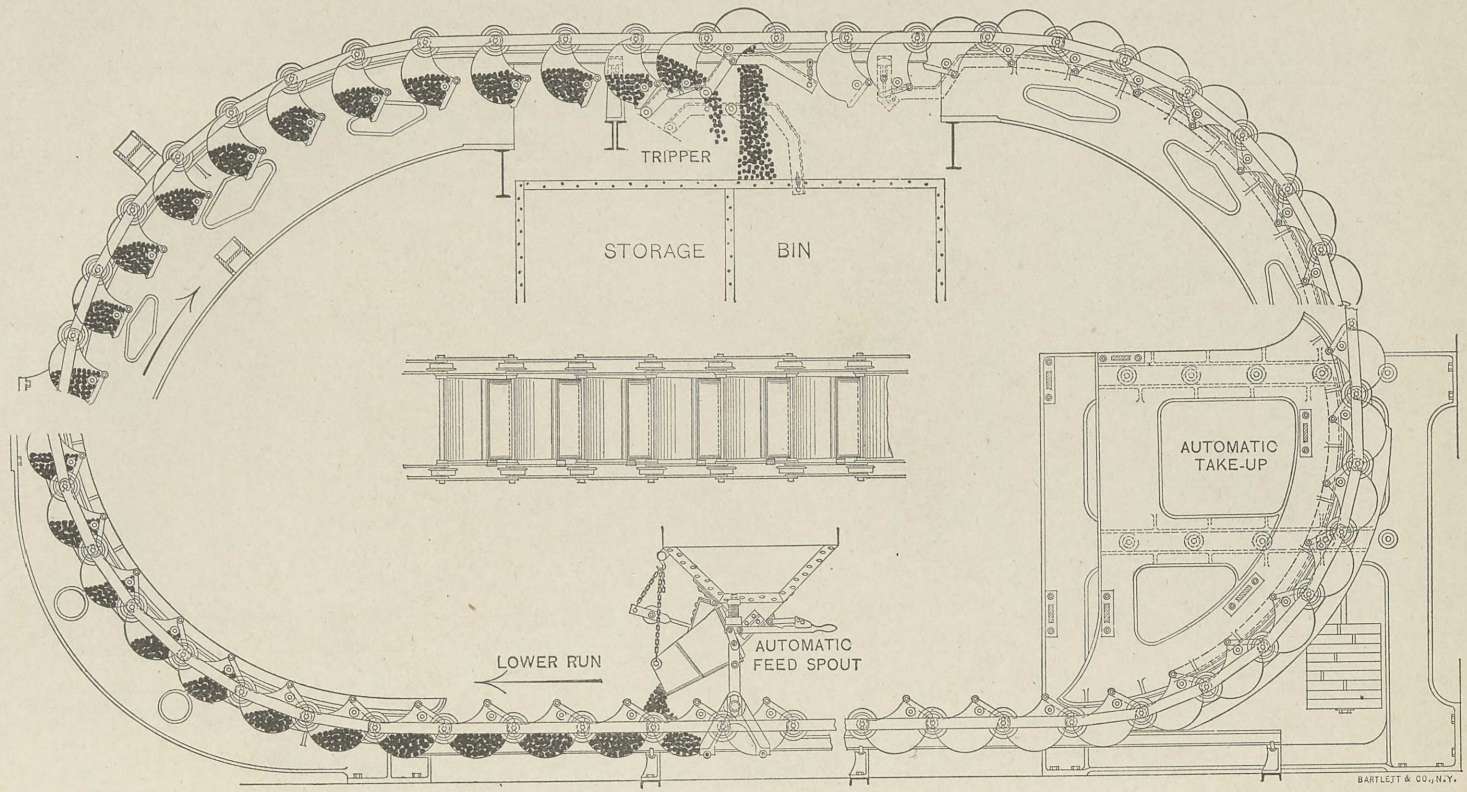


Fig. 178. General Arrangement of Swinging Bucket Conveyor.

have to be negotiated there must be a second pair of rails above the wheels to guard against derailment. The axles are provided with sufficient lubricant to last for several months.

The pitch of the buckets—being necessarily large for these conveyors—influences the dimensions of the driving drum, which must be larger than that of other conveyors of the tipping bucket type.

As the buckets must be some distance apart, to allow sufficient freedom when going round curves, it was necessary to have a special feeding device. This consists of an outlet controlled by a valve which opens automatically every time a bucket presents itself beneath it, and as the buckets can be set further apart for elevators of small

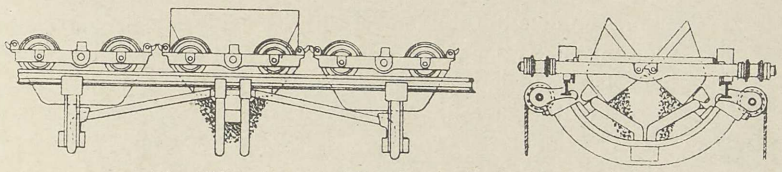
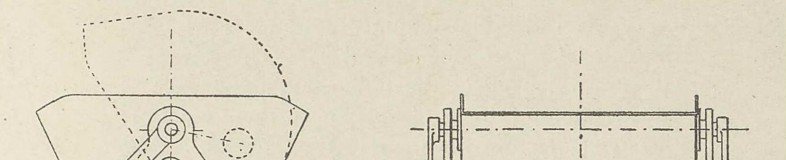


Fig. 179. Portion of Continuous Bucket Conveyor.

capacity, the opening of this slide can be set to suit any pitch of buckets. On the other hand, should a higher capacity subsequently be required in any installation, the buckets can be set closer together, and thus the filling machine is correspondingly altered to suit the pitch of the buckets. Such intermittent feeding devices present no difficulty for small material, but for large coal they would be a decided hindrance



Figs. 180 and 181. Humboldt Conveyor.

to the efficiency of the conveyor. (This applies to all conveyors where the buckets are not close together.) These buckets are emptied in a similar manner to those of the conveyors already described. This conveyor is reported to be successfully at work in several boiler-house installations, as well as for coaling locomotive engines. It is built in six sizes for gauges of 20, 24, 28, 32, 36, and 40 in., with a capacity for each bucket of $\frac{1}{4}$ to $\frac{1}{2}$ cwt. of coal. The buckets are placed at a pitch of 20, 30, 40, and 50 in., and it is claimed that a capacity of over 100 tons per hour can be reached. It is said that the speed of this conveyor can be varied from 30 to 100 ft. per minute. There seems, however, no apparent reason why this particular conveyor should run faster than any other swinging bucket conveyor, to which type it closely conforms. It is built by the Humboldt Engineering Works Co., of Cologne.

The Schenck Conveyor.—This is shown in Fig. 182. It differs in many

respects from other known conveyors of the gravity bucket type. The point of suspension is in the same plane as the centre of the chain and not above, as in the Humboldt conveyor, and the units have only one pair of wheels and only one axle, which latter serves also as the link bolt of the chain. It is claimed for this conveyor that little power is required to drive it, and that by the special construction of the buckets and links the conveyor can move in any direction and plane, and the strand of buckets can even be twisted when a change of direction to a new plane is required. If this twist is not necessary for the general arrangement of the conveyor, a coupling bar takes the place of the small swivelling muff couplings which are shown in the illustration. The illustration also shows the detail of the bucket with its single axle, its substantial frame, the hinge-like attachment on the axle, and the couplings between the buckets, the whole being designed to withstand the greater strain caused by the altered conditions of arrangement of these conveyors.

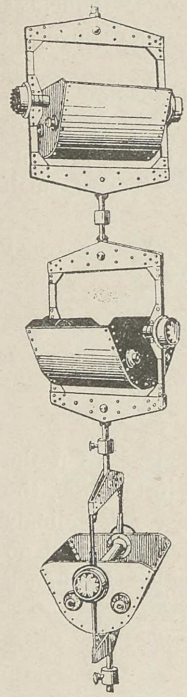
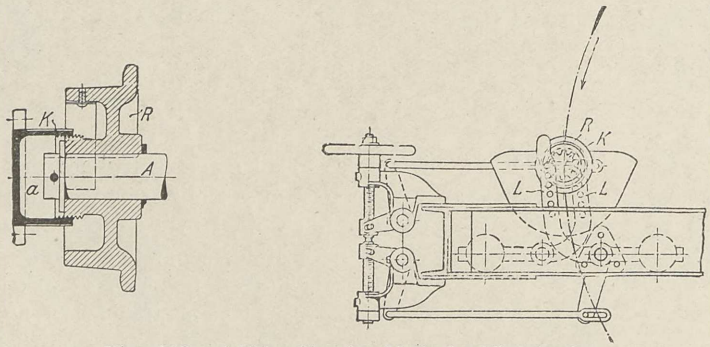


Fig. 182. Schenck Gravity Bucket Conveyor.

The buckets are comparatively light, but strong, a piece of gas pipe covers the axle, and is secured by two small castings to the sides of the bucket. The method of lubrication is shown in Fig. **183**. K is a kind of Stauffer cup which screws on to a boss of the runner wheel R either by hand or by the arrangement indicated in Fig. **184**. When the grease is entirely used up the lid has left the thread, and therefore hangs loosely over the boss, so that the attendant can readily see when it has to be refilled. The Stauffer can also be tightened automatically whilst passing over the terminals, as will be seen from Fig. **185**.

A considerable amount of power may have to be transmitted through curves in long conveyors. This means the creation of side stresses, which affect the frame and the wheels of the units, and the construction of these details must therefore be more substantial in this type of conveyor than in those which travel in a vertical plane only. Fig. **185** shows the driving gear with a large drum directly connected to an electric motor by means of worm reducing and spur gearing.

A feeding device for a conveyor of this type is shown in Fig. **186**; the design is,



Figs. 183 and 184. Showing Methods of Lubricating.

however, varied somewhat according to the size of the material to be fed. The action is as follows: The slide S closes the feeding hopper T, and opens the same intermittently whenever a bucket is underneath ready to be charged; the opening of the slide S is performed by the running rollers R of the conveyor chain coming in contact with the two

levers H (one at each side of the chain). The illustration shows one of the buckets just at the point of contact with the levers H, and therefore beginning to open slide S for charging the next following bucket. As soon as the levers H have reached the position marked by the dotted line, the levers are released by the rollers, and the springs F and dashpot P close the slide again gently.

The tipping device is shown diagrammatically in Fig. 187. Such devices may be used either at one or more predetermined points, or they may be mounted on wheels and rails, so that they can be used at any point of the horizontal strand of the conveyor running over the bunkers. The diagram shows the tipping device in two positions, the first in action and the second out of it. A is the tripper; it engages with the small rollers on each of the buckets which it tilts up to empty. To put the tripper into action the chain Z is pulled, which by levers *a*, *b*, *c* raise the tripper A into position, where it is retained by the catch H, levers *e* and *f*, and weight G. All passing buckets are now emptied until the bunker is nearly full and the coal reaches flap K, when any further coal arriving pushes this flap in the direction of the arrow. This motion of the flap releases catch H by levers *c d* and *e f*, so that the next bucket pushes the tripper A over into the second position, and the buckets pass full to the next point of delivery.

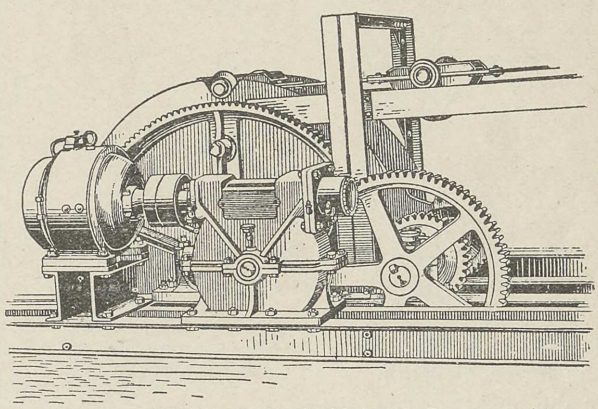


Fig. 185. Driving Terminal of Schenck Conveyor with Motor.

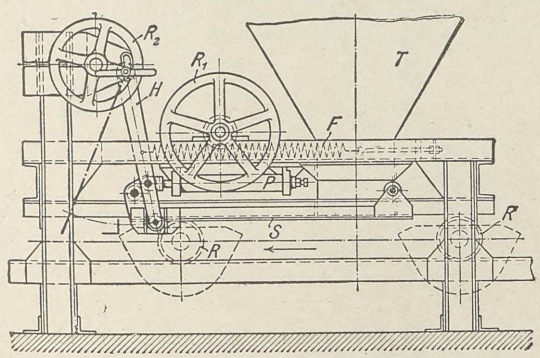


Fig. 186. Feeding Device for Schenck Conveyor.

A number of Schenck coaling plants have been erected in recent years, and some of these have conveyors of over 1,000 ft. in length, with a capacity of 35 tons per hour.

Fig. 188 illustrates part of a complete installation, which gives a good idea of the flexibility of the conveyor. The two bottom or loading terminals are for coal or ashes, as the case may be. The outward extension about half-way up shows how the discharge may be effected at an intermediate point, and at the upper portion of the illustration the main delivery into the bunker is shown; here the conveyor runs at an angle of 90° to the portion receiving the load at the lowest end of the conveyor.

Prevailing conditions have often made gravity bucket conveyors with universal movements indispensable, as with them a whole coaling installation can be served by one conveyor, instead of several conveyors and elevators.

The Bleichert Conveyor.—In this conveyor flexibility in all planes is achieved in an entirely different manner. In the first place, the double rail track is dispensed with,

which is probably one of its best features, as this tends to make the strand of the conveyor more flexible for curves on a horizontal plane, and each unit has only one running rail in the central direction of the chain. It will be seen that with such an arrangement the strand of the conveyor chain is in lability, so an auxiliary rail above the wheels becomes necessary for guiding the rollers in their horizontal passages at top and bottom (the vertical portion, of course, requiring no rails whatever). This construction makes it imperative that the buckets should be divided into two compartments, one on either side of the central roller (see Fig. 189). This development offers rather more difficulty at the loading point, particularly in conveyors of small capacity, where the units are not close together, as two shoots are necessary, one for each section of the bucket. The same circumstance makes this system impracticable for plants of very small capacities, as each of the two buckets forming one unit would be too small in such a case. The links of the chain are composed of two ⊃-shaped bars which surround the rollers, so that the two open ends *a a* and *b b* meet in the centre and are traversed by the axle of the roller, which forms at the same time the pin for the chain, and carries a bucket at each of its overhanging ends.

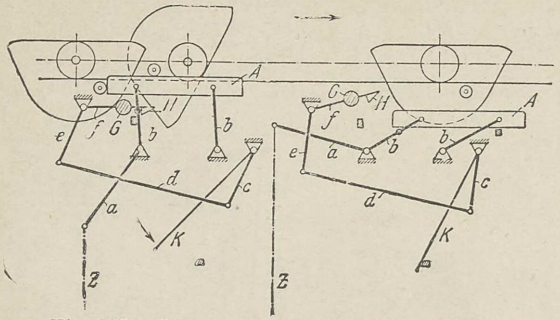


Fig. 187. Diagram showing Method of Tipping.

The closed ends of the ⊃-shaped link segments of each unit are joined together by a short

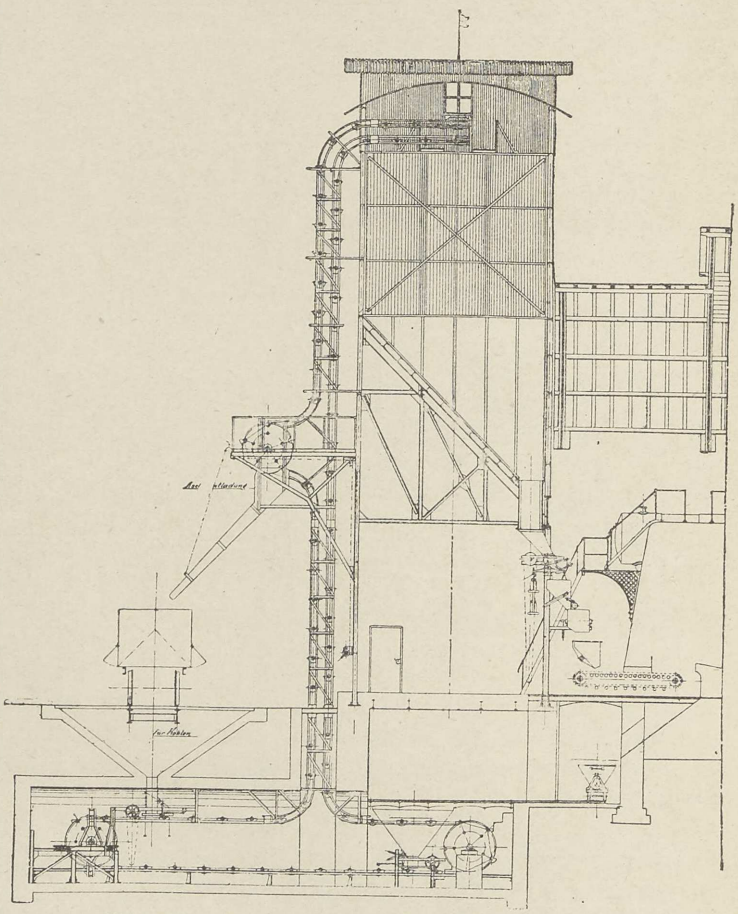


Fig. 188. Showing Portion of Complete Installation of Schenck Conveyor.

swivel link connection which permits flexibility in all directions. The delivery at the top is similar to the methods adopted by the Hunt and other conveyors of this type. An installation of this kind, with a capacity of 100 tons of coal per hour, a chain of 284 yards in length, and with a lift of 35 yards, takes only about 15 H.P., an exceptionally low figure, undoubtedly due to the single rail and consequent reduction of friction.

There are several other designs of conveyors of the tilting bucket type, which do not, however, present features sufficiently distinctive to entitle them to separate descriptions.

The Link Belt Company build a similar apparatus. It has the form of an ordinary elevator with V-shaped buckets supported symmetrically by two chains (see Fig. **190**). For the transport in a horizontal direction the buckets act as scrapers in the troughs provided for the upper and lower strands.

The illustration shows how the buckets elevate the coal and push it along the horizontal carrying run until discharged through gates in bottom of trough. The length of the horizontal run can be increased as desired up to the limit of the strength of the chains, and gates added as may be necessary.

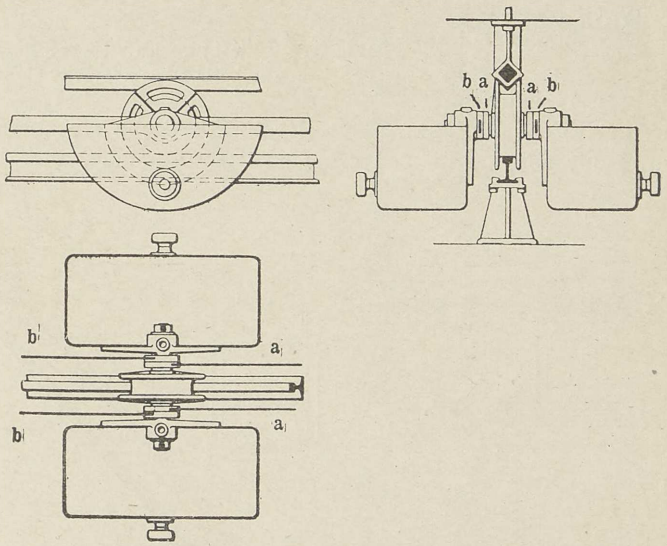


Fig. 189. Bleichert Gravity Bucket Conveyor.

The elevator described and illustrated on page 18 can also partly be classed under this chapter, as it will convey horizontally on the bottom strand, but the delivery is confined to one point.

Continuous Travelling Trough Conveyor with Partitions.—This conveyor has much in common with the continuous trough conveyor, but as it both elevates and conveys the material, it has been included in this chapter. It can be used not only for conveying on a level, but will also admit of conveying up inclines, and will even work in a vertical position. A conveyor of this type is built by the Steel Cable Engineering Co., under the name of the rigid partition conveyor. It is driven, like most of their conveyors, by steel cable, and each section of the trough has its own guide wheels, which run on suitable rails, as shown in Fig. **191**. The discharge is similar to that of an ordinary elevator.

Each section has a partition across its lower portion which forms a kind of bucket. The illustration shows the feeding of the conveyor at the level portion, the material being fed on in the same way as it is on the pan and bucket conveyor. It is used for minerals, coal, etc., and is also employed to handle coke which has been quenched but is still hot.

Fig. **192** shows a portion of the same kind of conveyor in a horizontal and vertical position. The feeding device and delivery shoot are clearly seen, as well as the automatic tightening gear for keeping the steel cable taut. Unlike Fig. **191**, the discharge of this kind of elevator and conveyor combined takes place on the lower strand. A

trough, therefore, must be provided for the horizontal portion of the lower strand. This trough is fitted with doors or slides, so that delivery can be given at any desired point. In the case illustrated, the delivery is given by a horizontal door held in position by a chain. This can be closed, and some other door opened elsewhere. The partitions in the buckets act like the scraper plates of a push-plate conveyor in this trough.

Conveyors for Handling Larger Individual Loads in both Horizontal and Vertical Directions.—Appliances on the same principle as the gravity bucket conveyor are often used for tea chests, barrels, cases containing cube sugar, soap, etc., as long as they are all of a uniform size.

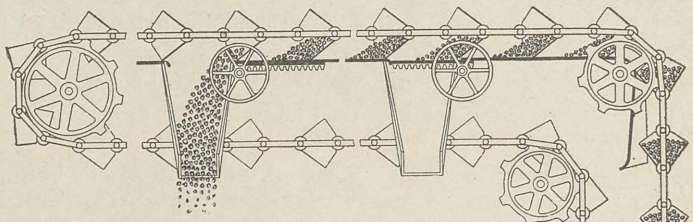


Fig. 190. Elevator with V-shaped Buckets, which can also be Used as a Gravity Conveyor.

By a slight modification to a vertical swing tray elevator, the same type of machine can be readily adapted for conveying goods horizontally, after having been raised vertically; the chains being now provided with small wheels or rollers running on angle-iron tracks as diagrammed in Fig. 193. By this means there results an enormous extension in the scope and utility of the machine; which further emphasises its marked superiority over the intermittent cage hoist, for the movement of large quantities of similar packages.

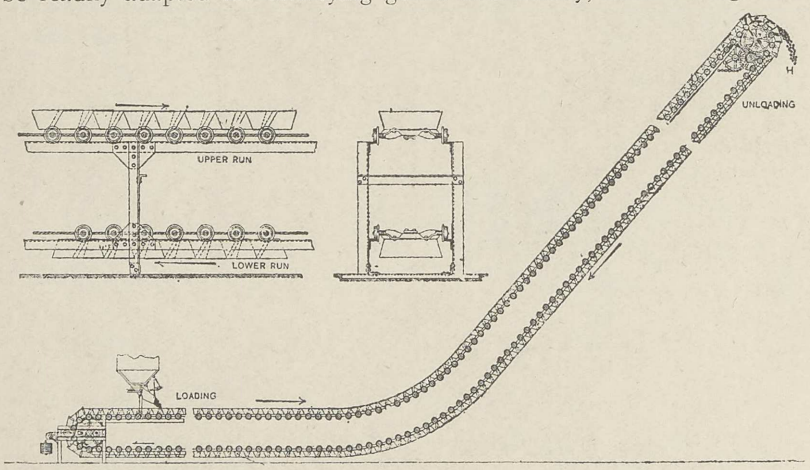


Fig. 191. Continuous Travelling Trough Conveyor with Partitions.

It is evident that the path of the chains is not confined to the vertical and horizontal directions. The path may be inclined at any angle, or even curved; a variety of possible combinations being thus available. The nature of the path is determined by the site, the relative positions of the machines and workers to be served, and the impediments to be cleared. Of necessity, every conveyor has to be designed specially to suit the local conditions and requirements. Standardisation and production in quantities are clearly impossible in the case of conveyors where no two are precisely alike in form and dimensions, although certain details, such as chains, have been standardised.

An interesting example of such a type of conveyor is illustrated in Fig. **194**. It is for the purpose of handling skips containing cops of cotton yarn to and from the conditioning cellar in the spinning mill of Messrs Eckersley's Ltd., Wigan. The conveyor was built by the Chain Belt Engineering Co., of Derby.

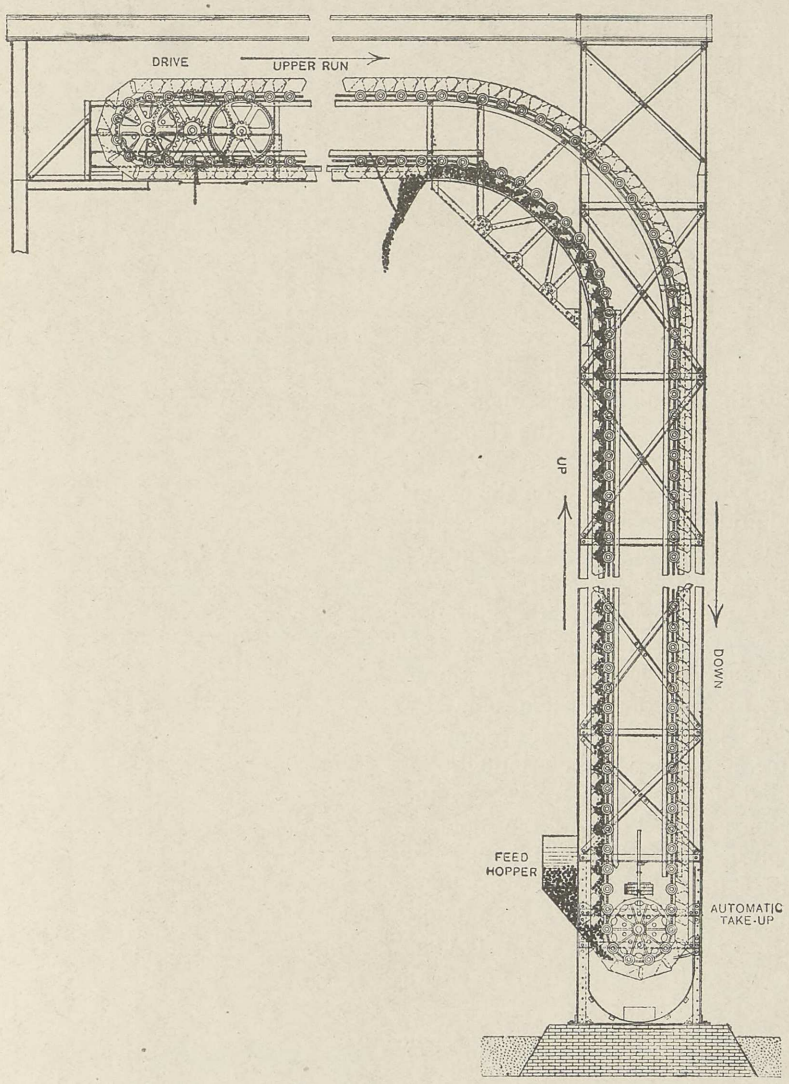


Fig. 192. Continuous Trough Conveyor with Partitions in a Vertical and Horizontal Position.

It will be noticed that the path of the chains is one of considerable complexity; indeed, the entire conveyor is unique of its kind. It runs continuously ten hours per day, and is now found to be indispensable. The speed is about 40 ft. per minute, and the carrying capacity 150 skips per hour, weighing 90 lb. each, with the swing trays 16 ft. apart. The swing tray bottoms are of hard wood, and measure 3 ft. 9 in. by 2 ft. 2 in. The two strands of chain have a total length of nearly 1,000 ft.; and yet the

whole conveyor can be driven by a belt $1\frac{1}{2}$ in. wide, the power absorbed being unexpectedly small. The skips travelling in one direction from the spinning rooms to the conditioning

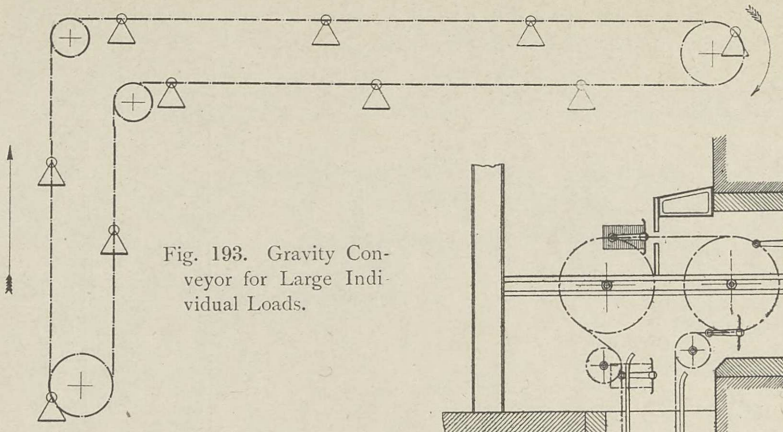


Fig. 193. Gravity Conveyor for Large Individual Loads.

cellar, balance those returning in the opposite direction to the winding room, where they are taken off by lads. Thus the resistance is chiefly frictional.

By providing finger trays on the chains and special grids at the feeding and discharge points, it is often feasible to arrange for the automatic picking up and delivery of packages. An example with the adoption of the finger tray system is given in Fig. **195**. This takes bundles of loose newspapers from the printing room to the dispatch room of a London daily paper. Here, on account of the available floor space in the printing room being limited, it was necessary to run the conveyor in a tunnel below the floor, a cross section being shown in Fig. **196**. The carriers are 6 ft. apart, and the capacity of the machine is twelve bundles per minute, or 720 per hour, equal to about 173,000 copies per hour. It runs night and day with intervals of rest.

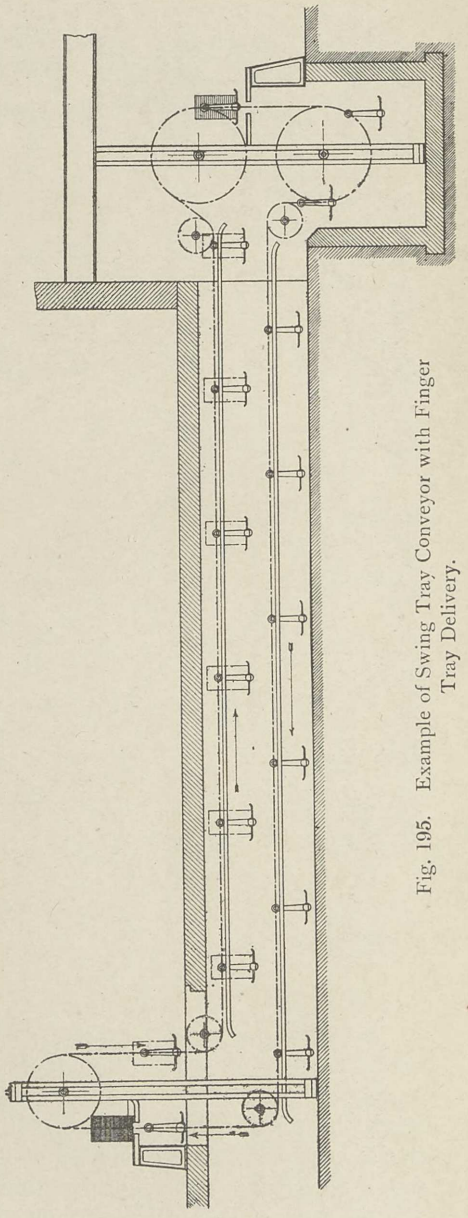


Fig. 195. Example of Swing Tray Conveyor with Finger Tray Delivery.

This analysis of the different types of package conveyors will be concluded by reference to a special form of pivoted or tipping carrier conveyor, provided with discharging mechanism, which can be thrown into gear at pleasure for tipping out the contents of the carriers at several delivery points, as shown at A, B and C in Figs. **197** and **198**. It was erected in the year 1907 for the Gourock Ropework Co., Ltd., Port-Glasgow, for conveying bobbins 8 in. diameter and weighing 13 lb. each, at the rate of 400 per hour. The length is about 150 ft.

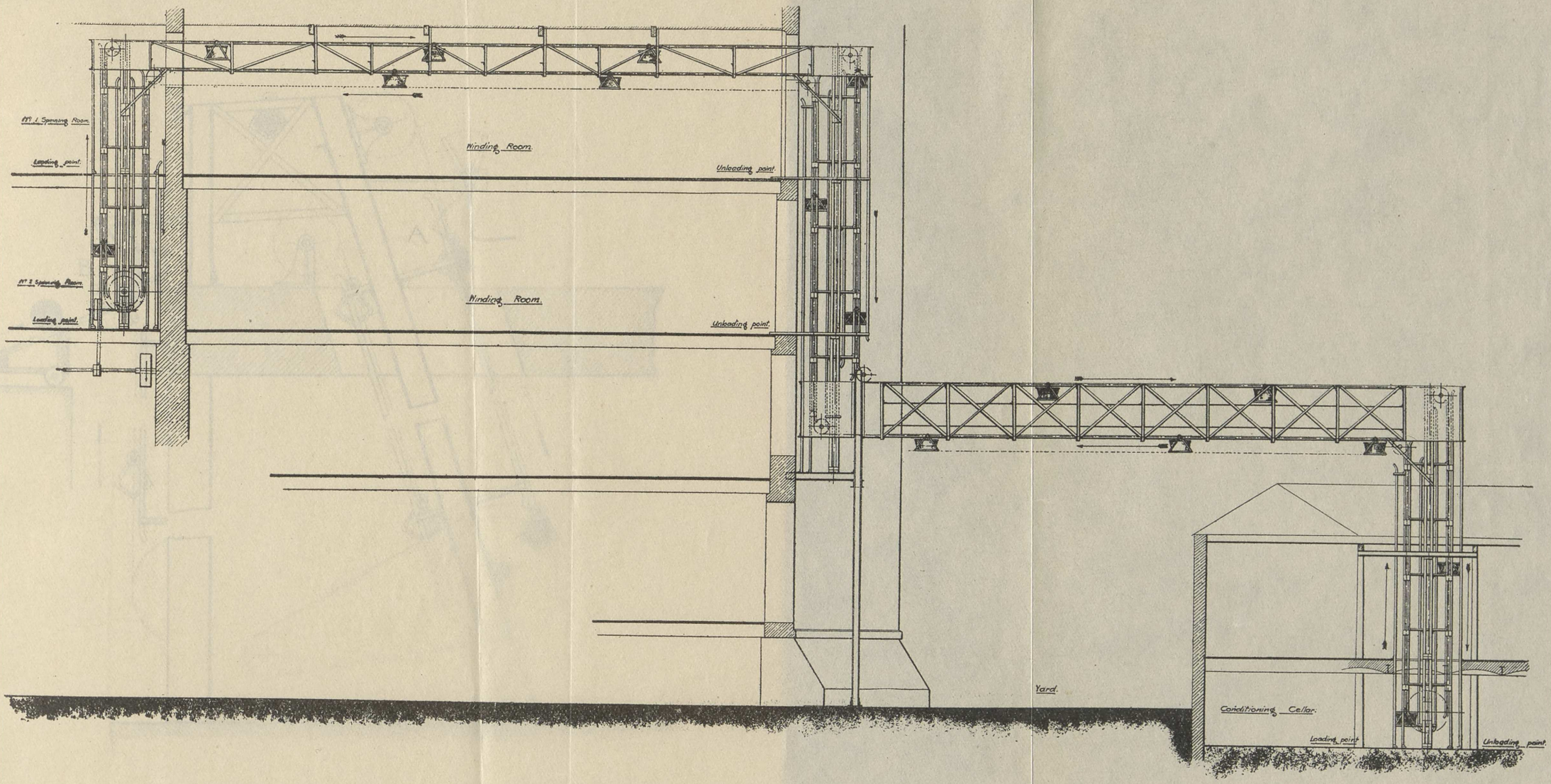


Fig. 194. Continuous Package Conveyor in a Spinning Mill.

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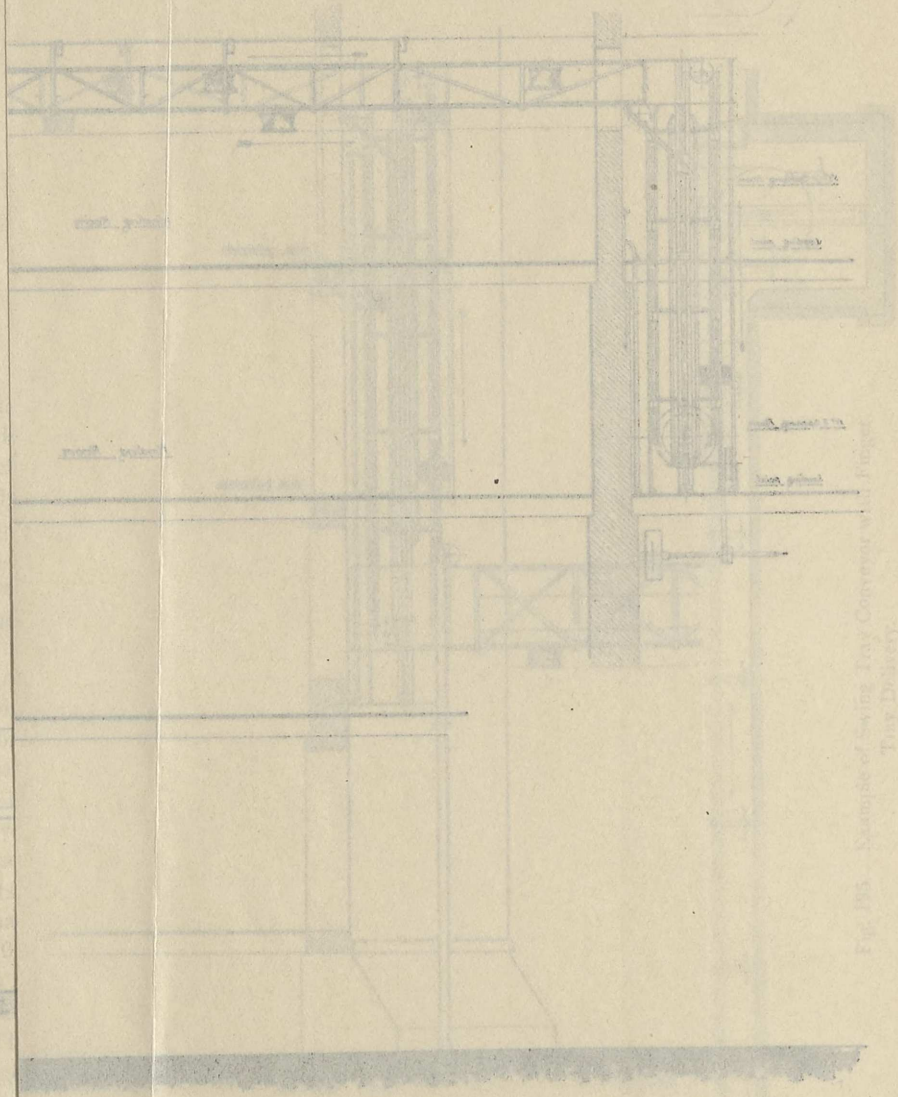

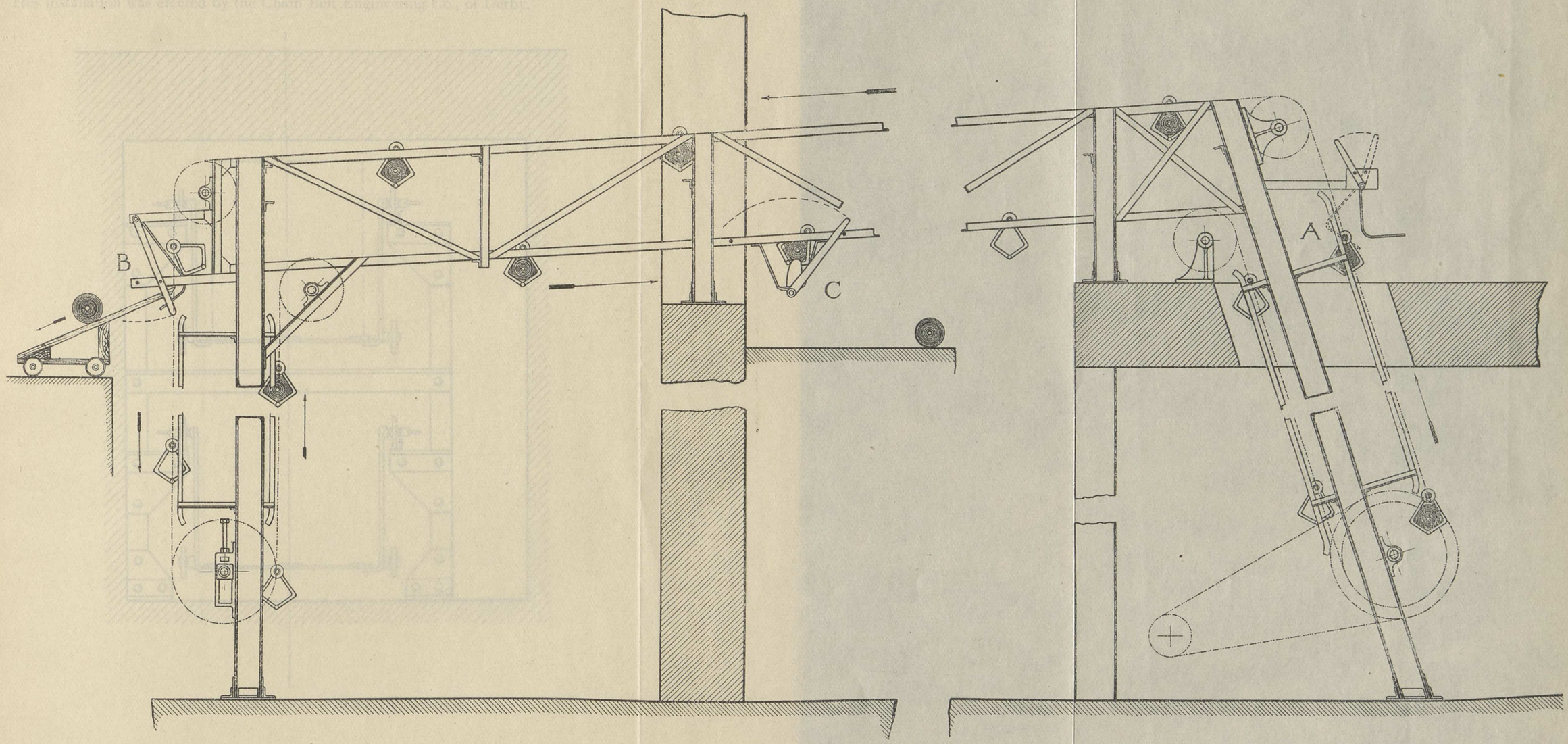

Fig. 197 and 198. Continuous Package Conveyor in a Scotch Ropeworks.

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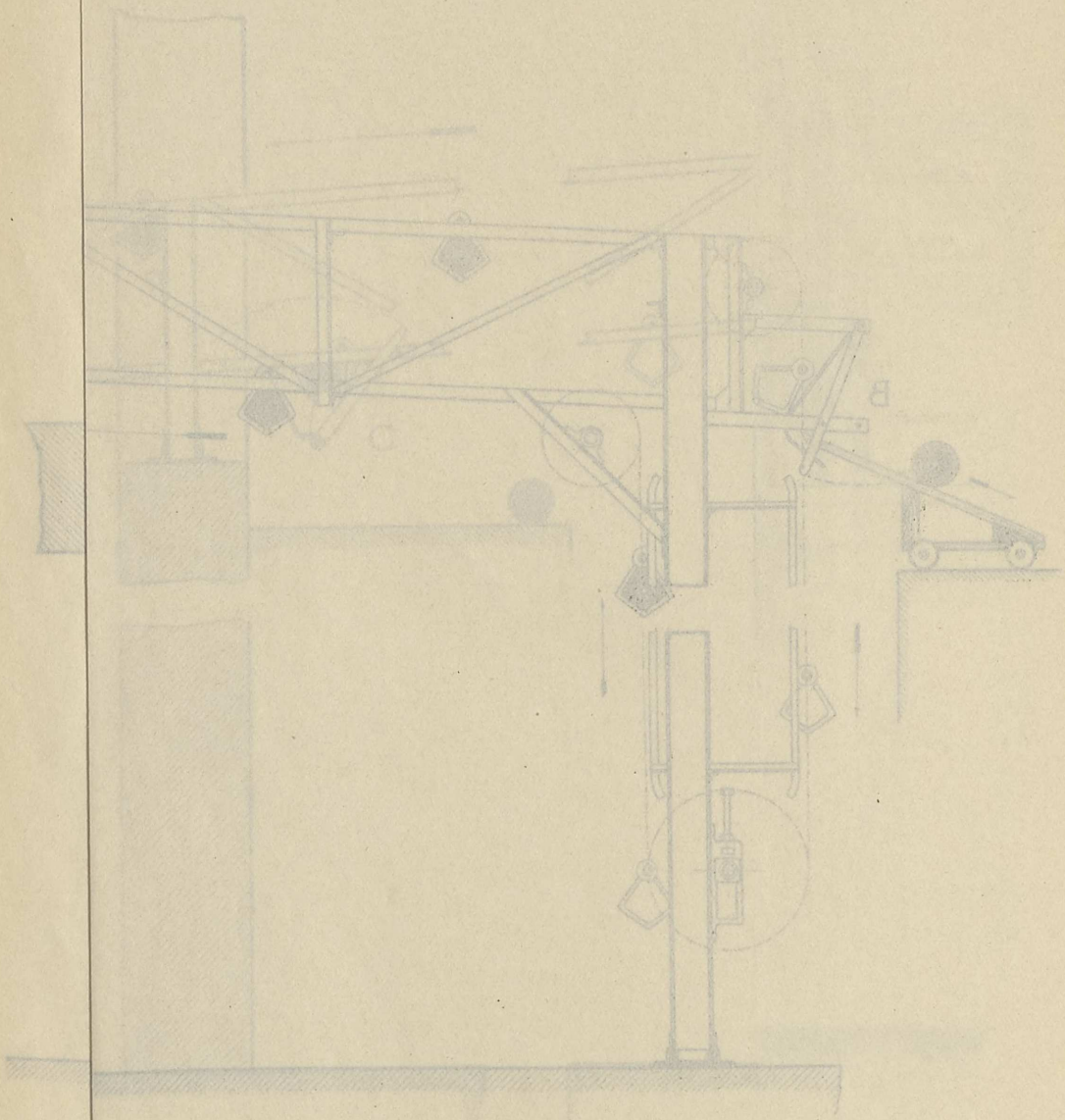

B

between the terminals, and it is driven by a 5 H.P. electric motor. It proved so successful that a second conveyor of the same type was installed in the following year. With this form of conveyor it is feasible to discharge light packages not only from the descending carriers, but also from the ascending carriers and those moving horizontally. This installation was erected by the Chain Belt Engineering Co., of Derby.

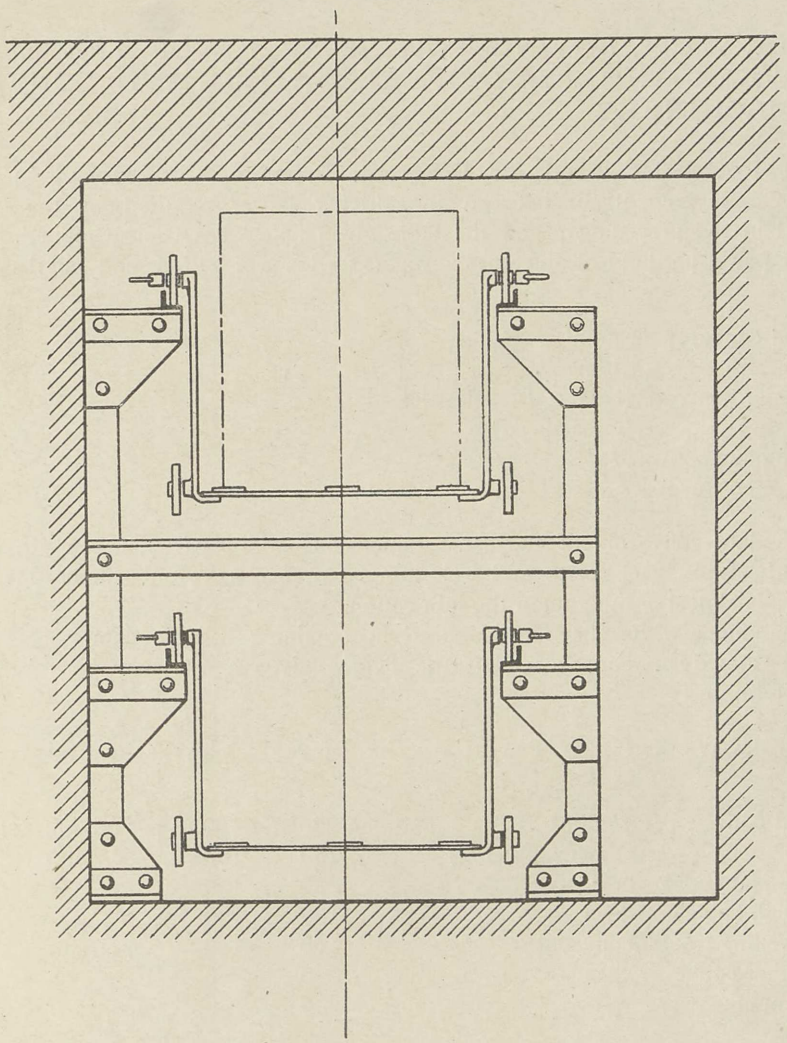


Fig. 196. Cross Section of Swing Tray Conveyor.

CHAPTER XI

SUMMARY OF DRIVING POWER, SPEED OF TRAVEL, AND WEAR AND TEAR OF ELEVATING AND CONVEYING MACHINERY

Driving Power Required for Different Types of Conveyors.—In order to afford an easy comparison between the driving power required by the conveyors described in the preceding pages, the table given below has been compiled. It gives the horse power per hour of different conveyors for loads of 50 tons and lengths of 100 ft.

	Horse Power.
Band conveyor for grain	4·8
,, ,, minerals	5·0
Zimmer conveyor (balanced)	7·75
,, ,, (unbalanced)	8·75
Push-plate conveyor	12·8
Worm conveyor	25·0

Push-plate conveyors of the same dimensions and capacity, when fitted with a pair of wheels on each plate and well lubricated, may take only about 5 H.P., but this depends almost entirely upon the lubrication.

Some difficulty has been experienced in obtaining reliable data concerning the power consumed by conveyors, but the figures given above may be relied on for practical purposes.

COMPARATIVE RATES OF TRAVEL OF THE DIFFERENT TYPES OF CONVEYORS[1]

					Average Speed.
Band conveyor (for grain)	between	250	and	700 ft. per minute	475
,, ,, (for heavy material)	,,	150	,,	700 ,, ,,	425
Push-plate conveyor	,,	50	,,	180 ,, ,,	115
Trough cable conveyor	,,	100	,,	120 ,, ,,	110
Travelling trough conveyor	,,	60	,,	120 ,, ,,	90
Zimmer conveyor	,,	40	,,	60 ,, ,,	50
Worm conveyor	,,	40	,,	60 ,, ,,	50

Wear and Tear of Elevating and Conveying Machinery.—It may be of interest to compare the cost of upkeep of elevating and conveying plant of different types given in the following table.

With the exception of the last item, the following table has been compiled by the late Mr W. R. Chester, of Nottingham, who, as engineer to the Nottingham Gas-works, tabulated this valuable information from plant under his personal supervision.

[1] The above speeds are taken from conveyors in actual work, but the author can see no reason why push-plate, trough cable, and travelling trough conveyors should not run at 60 to 180 ft. per minute.

The last item in the table was furnished by Mr Weiss, the engineer of the Zürich Gasworks, where several Zimmer-type conveyors have been at work since 1898.

Apparatus.	First Cost.		Tons of Material Transported.	Distance of Traverse.	Cost for Repairs and Renewals.			Description of Material Conveyed.
	Total.	Per Foot Run.			Total.	Per Ton.	Per Ton for 100 Ft. of Traverse.	
	£	£ s. d.		Feet.	£ s. d.	d.	d.	
Elevator - -	1,554	4 4 0	335,237	74	86 1 6	0·061	0·082	Coal.
,, - -	819	6 6 0	178,541	58 & 72	679 6 8	0·913	1·405	Partially hot coke.
,, - -	428	5 7 0	37,685	40	7 4 0	0·046	0·115	Oxide of iron and lime.
Push-plate conveyor	296	2 9 4	149,350	30	70 6 0	0·113	0·377	Coal.
,, ,,	1,486	5 3 11	29,769	90 90 106	110 11 3	0·891	0·938	Hot coke.
Plate-belt conveyor -	2,026	3 12 6	149,350	125 125 125 125 60	2,311 0 0	3·714	2·070	Hot coke.
Canvas band - -	443	4 10 0	say 10,000	98	40 0 0	say 1·00	say 1·00	Small coke and breeze.
Band conveyor -	296	2 9 4	149,350	30	70 6 0	0·113	0·377	Coal.
,, ,, -	172	1 11 3	2,180	110	42 1 1	4·63	4·21	Sulphate of ammonia.
Zimmer conveyor -	1,767	1 0 6	250,000	21 conveyors Total length 1,722 ft.	15 0 0	0·114	0·0003	Coal.

CHAPTER XII

THE HANDLING OF HOT COKE IN GASWORKS

The substitution of machinery for manual labour in the conveyance and handling of hot coke in gasworks, coke-oven installations, and elsewhere, presents many special difficulties, owing to the hard and friable nature of the material, and its more or less red-hot condition. Its hardness gives rise to severe wear and tear of the conveyor trough or band, and any roughness in handling causes considerable loss by the production of coke dust or "breeze," which is not only worthless, but, moreover, enters the joints of chains and other moving parts, and grinds them away, even when the coke is being quenched with water, as in that case the water often washes the small gritty particles into the wearing parts. The sudden changes of temperature to which the conveyor is subjected, also, produce expansion and contraction, causing warping and buckling of the conveyor or its parts.

Very few attempts have been made as yet to employ mechanical conveyors in connection with coke ovens. The Author, therefore, proposes to deal more particularly with conveyors suitable for use in gasworks, as he believes that larger conveyors of similar design may be eventually adopted in coke-oven installations, which play such a prominent part in the iron and steel industry.

From an economical standpoint, the substitution of machinery for manual labour in handling coke does not present the same advantages as in the case of coal, principally because the wear and tear is so much greater, necessitating much heavier and more costly machinery, so that mechanical coke-conveying plants can only be recommended for large establishments. The hand labour involved in quenching, carrying, and stacking coke has been known to cost 1s. per ton, but under the most favourable circumstances a man can remove hot coke from the retort house of a gasworks to the coke heap at the rate of about 15 tons per day, so that the cost for hand labour in such a case would be about 3d. per ton of coke handled. To this would have to be added the cost of repairs and renewal, interest on capital outlay, etc., which would not exceed 1d. per ton of coke dealt with. The most favourable total cost for hand labour might therefore be taken at 4d. per ton. According to the calculations of the late Mr W. R. Chester, M.Inst.C.E., who had several years' experience with push-plate and metal-band conveyors for handling hot coke, the average cost of repairs and renewals for a conveyor 100 ft. in length was $1\frac{1}{2}$d. per ton of coke handled. The cost of such a conveyor would be, approximately, £600, and as it would be capable of conveying 30,000 tons of coke per annum, 5 per cent. interest on the capital outlay would represent about $\frac{1}{4}$d. per ton of coke conveyed. The driving power for such a conveyor would depend very much upon its state of repair, but allowing $\frac{1}{4}$d. per ton it may be assumed that the total cost, including driving power, would not exceed 2d. per ton of coke handled. The substitution of machinery for hand labour thus appears to have effected a saving of 2d. per ton, and it should be taken into consideration that in conveyors of the most modern type the wear and tear and the driving power consumed would be less than in those of the Nottingham Gasworks, on which Mr Chester based his calculations.

The late Mr G. E. Stevenson, formerly engineer of the Gaythorn Gasworks, has stated that the saving effected by substituting a conveyor for hand labour in wheeling the coke from the retort house to the yard, amounted to $4\frac{3}{4}$d. per ton of coke handled, this being the difference between the wages of the twelve men formerly employed and the cost of the conveyor now used, together with the wages of the one man employed to superintend the whole of the machinery.

In the method of removing coke by hand usually employed in gasworks, one man rakes the coke out from the retort into a barrow placed under the mouthpiece, whilst a second man quenches it with water from a hose or bucket, after which it is wheeled out of the retort house into the yard.

The first improvement on this method was the adoption of cage-like tipping-barrows or trucks, running on narrow gauge rails either in front of the retorts or on the furnace floor below. The hot coke is discharged directly into these trucks, in the latter case through suitable openings in the floor, each truck generally holding the contents of one retort. The truck is then pushed outside the retort house, and the coke is there quenched with a spray of water, the truck meanwhile standing over a grating connected with a drain which leads away the surplus water. Above the truck is an inverted funnel with an uptake to lead away the fumes and vapour. When the coke is completely quenched, the truck is pushed to the coke heap and its contents are there tipped, or sometimes the trucks are elevated by means of a lift to the level of the coke hoppers or stock heap, and discharged on to either. In addition to manual or animal labour, endless rope haulage has been employed, and in some cases small locomotives have been used. For large gasworks these methods are altogether inadequate, and the mechanical equipment of such works cannot be regarded as complete without suitable hot coke conveyors and overhead bunkers for holding the coke ready for loading into trucks or carts.

Very few of the earlier installations for the mechanical handling of coke are still in use, most of them having been discarded after a short period of troublesome and expensive working. The first hot coke conveyors of note were built about the year 1898, and were of the push-plate type (see Fig. 76), having a trough 27 in. in width composed of cast-iron sections, and push-plates of malleable cast iron. The latter were attached, at 24 in. pitch, to a central chain, and were dragged along on a renewable wrought-iron bar, the wear on the chains being taken by iron blocks fixed to the links and capable of being replaced when necessary. The return strand of the conveyor was led over guide pulleys, either underneath the bench floor or high up out of the way of the retorts. The speed at which these conveyors ran was about 48 ft. per minute, and their capacity was about 20 tons per hour. They performed their work well, but were unsatisfactory in other respects. Their life was short, under the trying conditions to which they were subjected, and the expenditure on repairs and renewals of parts was very heavy. The chain, being central, suffered severely from the action of the hot coke, to which it was fully exposed. The first complete installation of this kind was erected at the Gaythorn Gasworks in 1898, to the design of the late Mr G. E. Stevenson; this plant was discarded in 1903 for the reasons above mentioned, and also on account of the excessive breakage of the coke.

The conditions to be aimed at in the design of a hot coke conveyor are: simplicity; small number of wearing parts; interchangeability of wearing surfaces and of worn and broken parts; protection of wearing and working parts from contact with the hot coke; and ability to keep the temperature of the conveyor itself as even as possible, in order to avoid distortion of its parts through sudden heating or cooling. The latter conditions can, in the Author's opinion, only be attained in conveyors of the push-plate type, in

which the hot coke is continually changing its position, thereby heating up the whole conveyor gradually and uniformly; whilst the former conditions depend on the details of the construction of the chain and trough, and have been met in a variety of ways. It may be urged that a conveyor of the push-plate type requires more power to drive it, and causes more breakage of coke and greater wear of the trough than does a tray conveyor; but in the Author's opinion the advantages of the push-plate type more than counterbalance these defects. The wear of the trough of a conveyor of the push-plate type, caused by the action of the hot coke, is after all not so great, especially when the trough has once been worn smooth, if the conveyor chains are of small pitch, and if the polygon terminals are not less than eight- or ten-sided, so as to ensure a fairly uniform speed of travel. Moreover, there is practically no limit to the thickness of the bottom plates of the troughs of these conveyors; there is, in fact, no reason why the bottom of the trough should not be of concrete slabs.

The more modern hot coke conveyors in use in gasworks are all more or less of one type, consisting of substantial iron troughs, 2 ft. to 2 ft. 6 in. in width, in which scrapers are manipulated by a chain, or more often by two chains, travelling at a speed of 30 ft. to 60 ft. per minute. When two chains are used, they are either concealed in suitable channels in the sides of the trough, or placed outside the trough altogether. Conveyors of the plate or tray type, although they tend to protect the chains from the coke, and cause less wear of the trough, do not appear to have been so successful. In conveyors of this type the coke rests on the plates and moves with them, so that the plates become damaged by excessive heating, whilst the heat soon spreads to the chains, which must suffer considerably unless the trough in which the conveyor travels is filled with water up to the level of the plates.

An attempt to prevent breakage of the coke, and at the same time to reduce the wear of the trough, has been made by constructing the push-plates in such a form that they support the coke to some extent, thereby preventing, wholly or partially, its contact with the trough. This type of conveyor may be termed a combination of the push-plate and the travelling-plate conveyor, and to some extent it protects the coke from breakage, but, on the other hand, the "breeze" which is always present will find its way between the pushing agents and the trough, so that the protection afforded to the latter is more or less inconsiderable.

The chains employed in hot coke conveyors are nearly all of the long-link type, but differ widely in details of construction. Formerly the links were usually either forged or of malleable cast iron, but these have now to a great extent been superseded by links of Hadfield manganese cast steel, with forged pins of the same material. The advantages of this material are that it contains fewer blow-holes than ordinary cast steel, and is more durable under the severe conditions to which such chains are frequently exposed. The ultimate tensile strength of the chains is very much greater with this material, but it is not advisable to reduce the sectional area of the links in proportion, especially as the elastic limit of the manganese steel is rather low; and although the material is suitable for general use on hot coke conveyors, it should not be employed when likely to be exposed directly to the action of the hot coke.

The following are descriptions of nine conveyors used for handling hot coke. Of these, the first four are of the tray or plate type, in which the coke is carried on plates, trays, gratings, etc.; the fifth, the West conveyor, is intermediate between this type and the push-plate type, as in it the coke is partly carried and partly pushed along; and the remainder are of the push-plate type.

The New Conveyor Co.'s Hot Coke Conveyor.—This conveyor consists

of a water-tight trough, through which pass closely-fitting tray plates attached to a single chain. These plates are 1 ft. 6 in. to 2 ft. in width, and 13½ in. in length; they are joggled downwards at one end to receive the flat front part of the succeeding plate, in order to prevent the "breeze" from penetrating beneath the carrying plate. The chain now used is constructed entirely of steel, having steel bushes secured to the inner links and steel pins to the outer links. Small rollers are attached by means of angle-brackets to the under side of the conveyor plate, to carry the plates and chain, and, as they run in water, oiling is dispensed with. The chain has a breaking strength of 29 tons. The brackets which carry the rollers are made of manganese steel, either as shown in Fig. 199, or in one piece with the spindle or pin. The rollers are 2¾ in. in diameter, and are also of manganese steel. The framework which carries the whole conveyor is built of angle-bars. To prevent side play of the return strand, rubbing strips are fitted above the lower angle bars of the conveyor. The speed of travel of these conveyors is about 45 ft. per minute, and the capacity when handling coke from 20-ft. retorts is about 30 tons per hour.

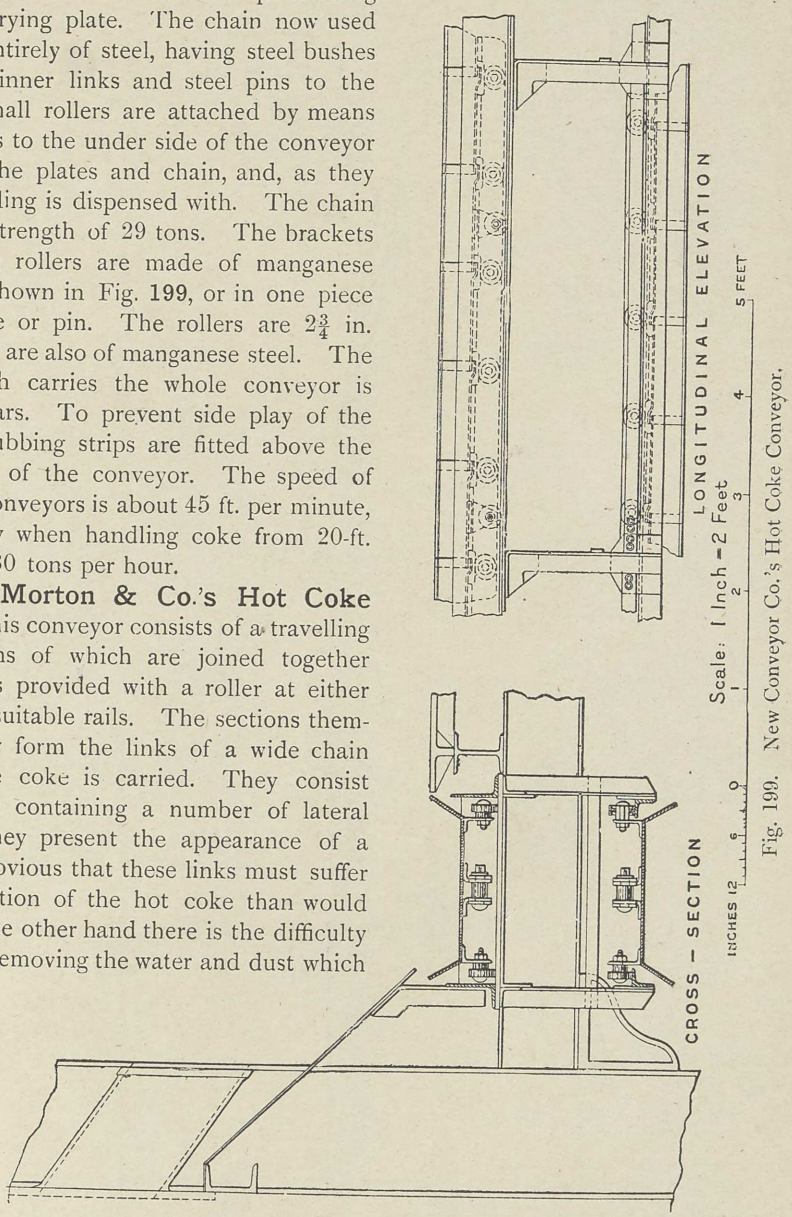


Fig. 199. New Conveyor Co.'s Hot Coke Conveyor.

Graham, Morton & Co.'s Hot Coke Conveyor.—This conveyor consists of a travelling tray, the sections of which are joined together by steel spindles provided with a roller at either end running on suitable rails. The sections themselves practically form the links of a wide chain upon which the coke is carried. They consist of steel castings containing a number of lateral slots, so that they present the appearance of a grating. It is obvious that these links must suffer less from the action of the hot coke than would a plate, but on the other hand there is the difficulty of catching and removing the water and dust which escape through the grating; this is effected by means of a trough beneath the grating, and a scraper.

Marshall's Hot Coke Conveyor.—This conveyor was designed by Mr F. D. Marshall, of the Copenhagen Gasworks. It consists of a water-tight wrought-iron trough, fitted on either side with a series of guide rollers, upon which the two conveyor chains run. Both guide wheels and chains are amply protected by sheet-iron coverings. The chains consist

of wrought-iron links, and attached to each alternate link are metal cradles which form the connection between the two chains, and which carry the coke. The bottoms of

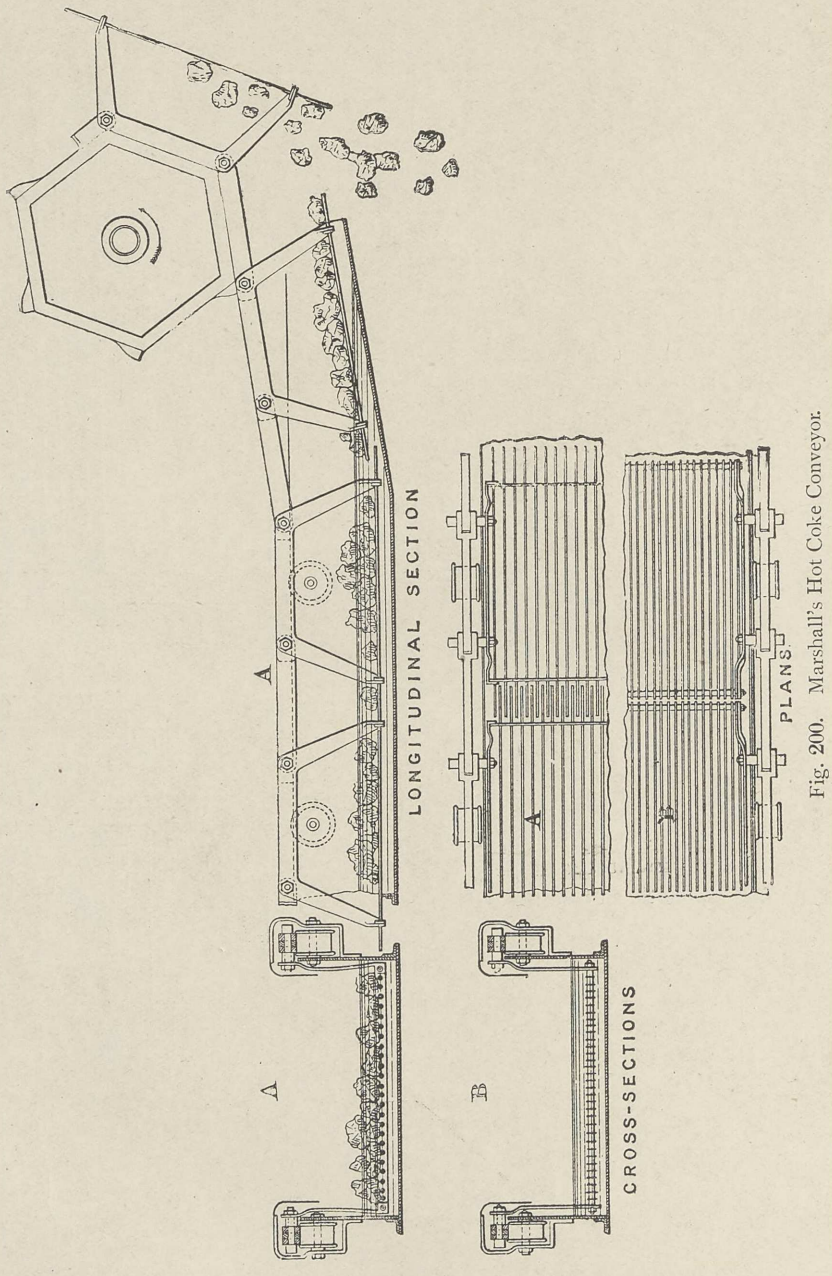


Fig. 200. Marshall's Hot Coke Conveyor.

these cradles are formed by a series of iron bars, which may be either round bars, as shown at A, or flat bars, as shown at B (Fig. 200). The conveyor trough is kept partially filled with water, so that the lower portion of the cradle is always well

submerged. In this conveyor the cradles, whether constructed of flat or round bars, are not likely to be distorted by heat, even should the water supply run short, and any extension or contraction of the bars due to varying temperature cannot affect the pitch of the chain. The conveyor is driven in the usual manner by hexagonal terminals, and the coke is discharged as the cradles pass round the delivery terminal. One drawback to this conveyor is the accumulation of breeze in the trough, but the provision of means for removing this should not be a difficult matter.

Bronder's Hot Coke Conveyor.—This conveyor, Fig. **201**, designed by Mr G. A. Bronder, of New York, somewhat resembles the gravity bucket conveyor. It runs in a water-tight trough filled with water to a certain level, the water being slowly circulated by mechanism resembling a water wheel. The chain of buckets runs in the trough, the sides of which form the rails for the supporting rollers. The whole conveyor is covered in along its entire length, and the lower edge of the cover dips into the water in the trough, making an air-tight joint. The flue thus formed is connected at each bench with a number of shoots, through which the coke drops into the conveyor buckets; when not in use these shoots are covered. At the ends of the trough and flue, a large pipe leads to an exhauster, which draws away the steam and vapour created by the quenching process, and sends it to a chimney which carries it off above the roof of the retort house.

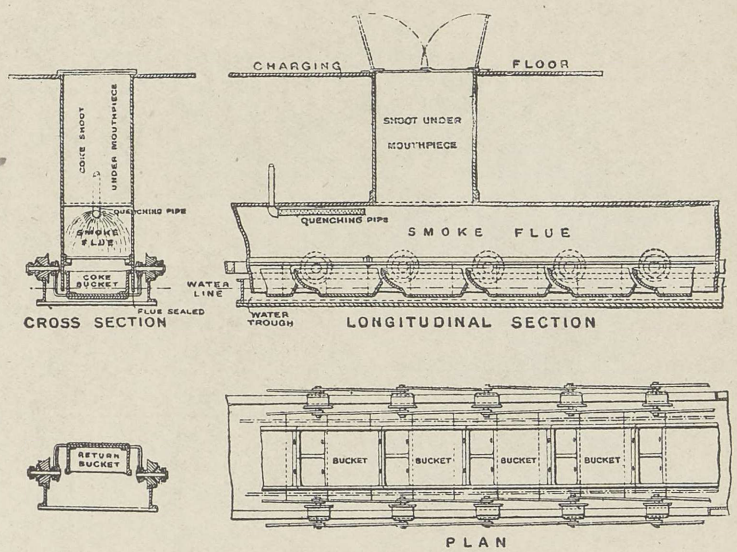


Fig. 201. Bronder's Hot Coke Conveyor.

The conveyor buckets are connected by brackets of horse shoe shape, which extend upwards beyond the sides of the buckets and are connected with the links of the driving chains. When the conveyor is at work, the covers of the mouthpieces are opened and the coke is discharged into the buckets; at the same time the water valves are opened, thereby quenching the charges and spraying them as they pass beneath the water outlets. Scrapers are provided to collect and deliver into a collecting chamber at one end any "breeze" which may have escaped the buckets. The propeller wheel already referred to takes the water from this collecting chamber and forces it again to the other end of the trough.

West's Hot Coke Conveyor.—This conveyor consists of a substantial trough in which one wide chain travels, partly carrying and partly dragging the coke. The original of this type of conveyor was introduced many years ago, and it was probably the first conveyor for this purpose. The illustration (Fig. **202**) shows the present form, which consists of an outer iron steel trough with hard cast-iron internal trough lining and renewable side pieces. The bottom plates are loosely fixed and kept in position by

means of the angle-bars on which the chain drags. The chain has a pitch of 12 in., and the pins in the hinged joints are $1\frac{9}{16}$ in. in diameter by 8 in. in length in the bearing. Each link consists of a cast block, with eyes at each end for the joint pins, and provided with an arm on each side extending to the sides of the trough, the ends of these arms sliding on the angle-bars fixed at the corners of the trough. The links are connected together by two steel side links and hinge pins. These side links have slotted ends, so that they can be passed over the head of the pin when the side links are at right angles with the chain blocks. When in line with the blocks the projections at the sides of the blocks prevent the side links from becoming disengaged from the pins. The wear of the chain on the trough is minimised by hard cast-iron shoes fitted thereto. There being only one chain, only one sprocket wheel is required at each terminal; this is made with

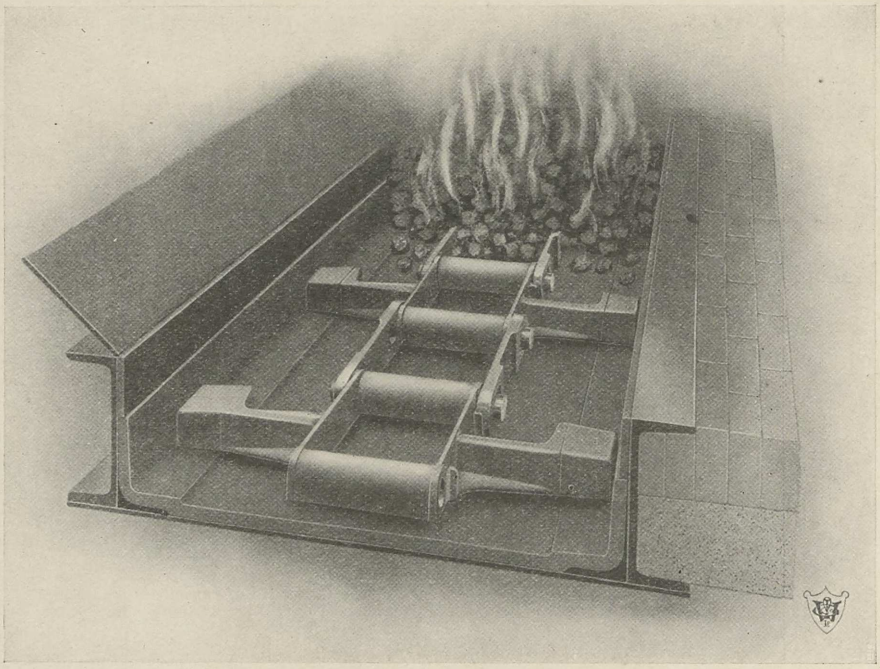


Fig. 202. West's Hot Coke Conveyor.

teeth $6\frac{1}{2}$ in. in width. The chain described is designed for conveyors 500 ft. in length, running at a speed of about 40 ft. per minute. During the use of the conveyor, quenching water is run into the trough as is usual with all hot coke conveyors.

Wild's Hot Coke Conveyor.—This conveyor consists of a substantial trough, 2 ft. to 2 ft. 6 in. in width by 9 in. in depth, which may be either of cast iron or of steel. In Fig. **203** it is shown supported by cast-iron brackets, to which are secured the rails for supporting the two strands of the chains; the return strand of the chain is shown beneath the trough, both chains being outside the trough and secured on either side to the push-plates, so that only the scraper comes in contact with the hot coke. The chains are usually composed of ordinary welded links of 12 in. pitch. They are, however, sometimes made of manganese steel. Every second link carries a push-plate, so that these plates are 24 in. apart. The push-plates are connected by means of arms to the axles, which carry 6-in. flanged rollers, $1\frac{1}{2}$ in. in width on the face. The advantage of

this type of conveyor is that the chains, etc., are outside, and that only the push-plates come in contact with the hot coke, so that the wear of the pins and rollers, as well as of the chains, is minimised.

The De Brouwer Hot Coke Conveyor.—This appliance, which is illustrated in Fig. **204**, is employed to a considerable extent in both Continental and British gasworks, and was designed by the Belgian engineer whose name it bears. The conveyor consists of an open rectangular wrought-iron trough of substantial construction, 1 ft. 8 in. to 3 ft. in width, and 3 to 6 in. in depth, extending along the entire front of the retort settings. This trough is fitted with renewable cast-iron bottom plates with raised strips along each side, forming continuous ledges along which run two strands of chain, joined at intervals of about 2 ft. by flat cross-bars.

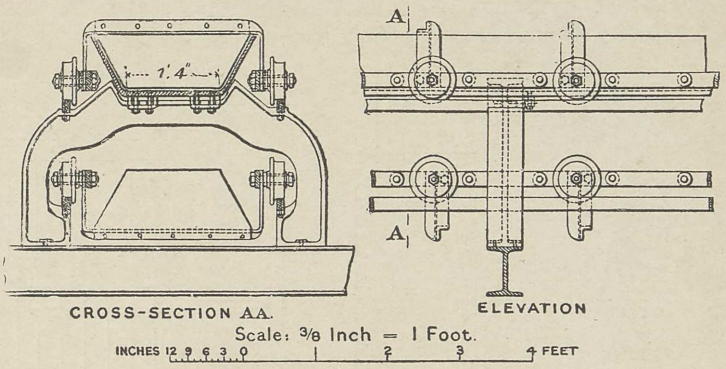


Fig. 203. Wild's Hot Coke Conveyor.

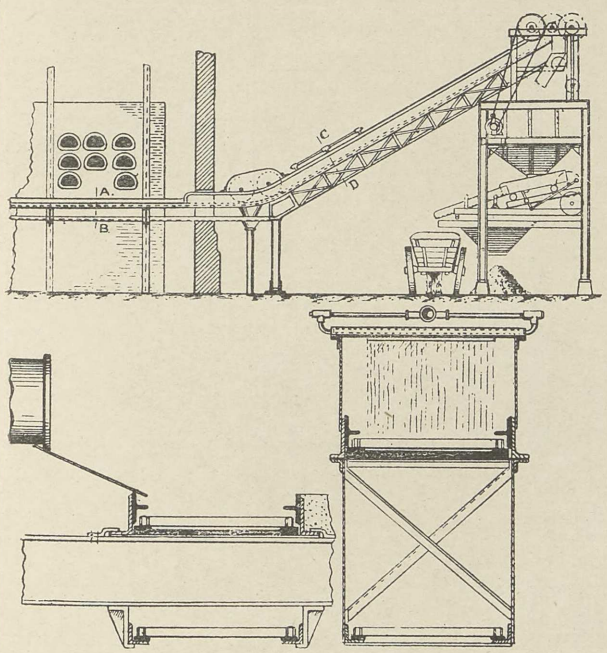


Fig. 204. De Brouwer Hot Coke Conveyor.

The chain consists of block links, alternating with double side links, the bosses of which work in holes in the blocks, and are held together by steel rivets. The blocks being deeper than the links, take all wear caused by running along the track. The chains are protected from coke falling into them by cover angles or tees bolted to the sides of the trough, as shown in the illustrations. The return strand of the chain is usually carried on a path formed of steel angles, with cast-iron wearing strips bolted on. This may be arranged under the floor as shown in Fig. **204**, or carried on brackets overhead.

These conveyors are usually arranged horizontally in front of the retort bench, but work equally well up to an angle of 35°, or if extra deep cross-bars are used, up to 45° or 50°.

Before the hot coke is fed in, the trough is filled with water to a certain depth throughout its length. The coke, as soon as it is drawn along by the conveyor bars, which act as push-plates, sweeps the water before it along the trough. This action

continues for some distance up the slope at the delivery end, the water thence flowing back like a miniature cataract on the partially quenched coke, thoroughly saturating it and completing the quenching process. As the red-hot coke leaves the retorts it is

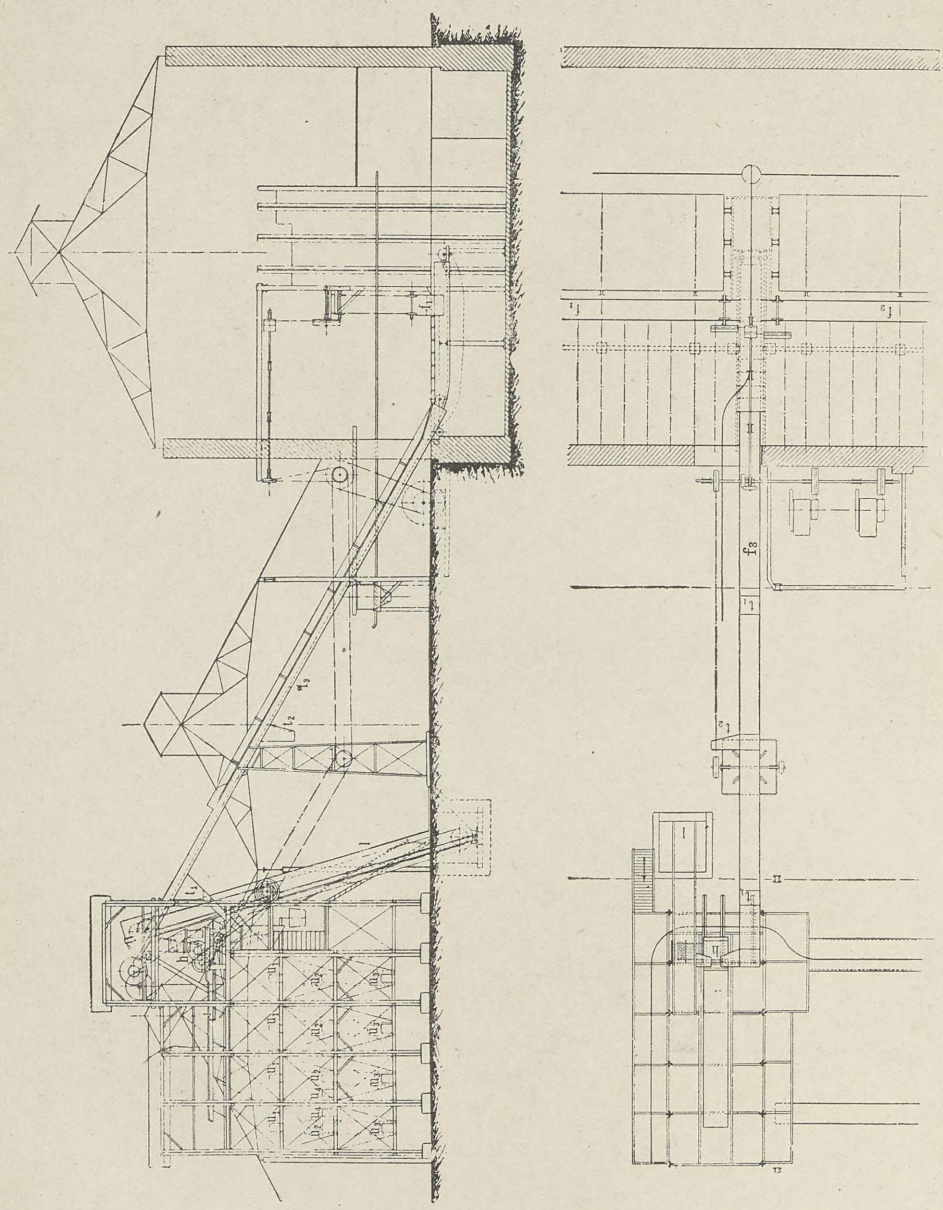


Fig. 205. Plan and Elevation of Hot Coke Conveyor at the Gasworks, Basle, Switzerland.

directed into the trough by a deflecting plate or shoot, and is drawn forward by the cross-bars.

The coke can also be quenched by sprays of water arranged at intervals along the trough, or where part is arranged on the incline, automatic sprays are arranged as shown at C D in Fig. **204**. This part of the conveyor is completely closed in, so that the coke may

be kept in contact with the steam for as long a time as possible, to ensure its being thoroughly quenched. This arrangement has the advantage of keeping the steam away from the retort house, the covered-in portion acting as a chimney and drawing the steam to the upper end.

The illustration (Fig. **204**) shows the conveyor in elevation, and also the two sections of the portion in front of the bench and the incline. The conveyor is shown delivering into a hopper with a screening plant underneath for extracting small coke and "breeze," and delivering the large coke into carts or wagons.

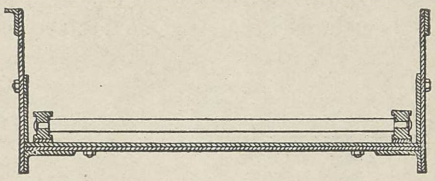


Fig. 206. Cross Section of Trough and Chain of Early Form.

A typical coke-conveying installation at the gasworks, Basle, Switzerland, in which the De Brouwer conveyor has been used, is shown in Fig. **205**. The installation was built by the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft, and is shown here to illustrate the steep incline at which some of these conveyors are worked, and also to show that the coke can by this arrangement be thrown off the conveyor at any desired point.

There are five points at which the coke can be thrown off either to railway trucks or into carts, or into a series of silos, or it may be fed on to a reciprocating conveyor which grades the coke into different sizes.

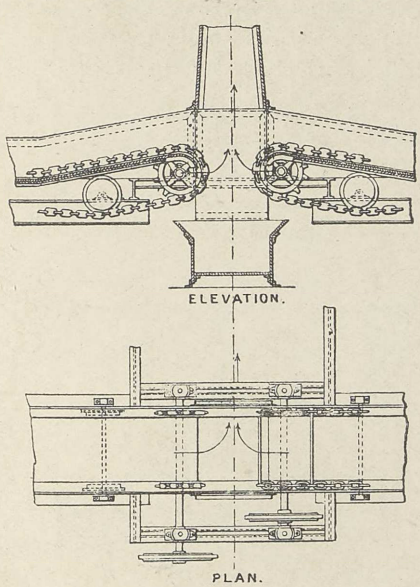


Fig. 207. Merz Modification of De Brouwer Conveyor.

The De Brouwer conveyors are shown both in plan and elevation. Those marked f_1 and f_2 discharge their load into the inclined conveyor f_3, which ascends at an angle of nearly 30°.

The exit t_1 is for withdrawing the coke without classification, and the exit t_2 serves the purpose of withdrawing the coke which has been produced during the working of the nightshift, and storing it on the ground in a heap. This method has the advantage that the night coke can thus be stored, obviating the necessity of running the machinery in the coke store during the night. The coke thus accumulated is lifted in the morning by the elevator l to the coke breaker h, and is then classified by a reciprocating screen i into different sizes and deposited into hoppers u_1, u_2, and u_3. The coke withdrawn during the daytime is run to the terminal of the conveyor f_3, and is thence spouted to the coke-breaker h and duly classified. There is this advantage in storing the coke in the hoppers u_1, u_2, and u_3, that from the top hoppers u_1 elevated railways can be fed; hoppers u_2 are high enough to discharge their contents into railway trucks; while from u_3 the coal can be withdrawn into lower receptacles such as hand-carts, etc.

The late Mr E. Merz, formerly engineer of the Cassel Gasworks, introduced some improvements in the construction of this conveyor; the bottom and sides of the trough are made double, with a lining (Fig. **206**), so that if desired the interior of the troughing can readily be renewed, the changing plates being fastened by bolts. If considerations of space should render it convenient to have the return strand of the chain carried under the

conveyor trough, this can be effected without making the conveyor more than 8 in. in depth throughout. The inclined ends of this conveyor, and also the shoot which receives the coke and a portion of the uptake which leads away the fumes, are shown in Fig. 207. In the plan is shown the support for the terminals, one with the chain on, and the other with the chain removed. Another modification of the De Brouwer conveyor is that of Mr F. D. Marshall, of Copenhagen. The object of the device is to equalise the flow of water by providing a sort of sluice for withdrawing the excess of water at any point in the trough. This arrangement is shown in Fig. 208. The channels by which the water is drawn off are fitted with lids, in order to facilitate cleaning. The chief merit of this arrangement appears to lie in preventing the water from flooding that section of the trough which abuts on the inclined plane, as at that point the accumulation of water is sometimes so great that it overflows the trough.

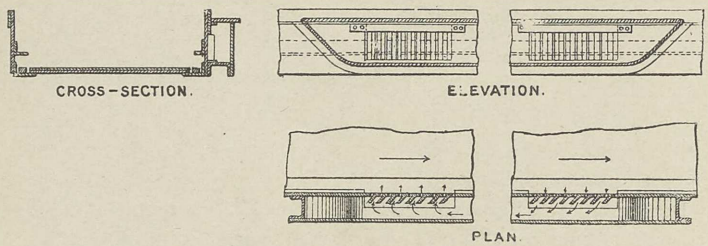


Fig. 208. Marshall's Modification of De Brouwer Conveyor.

Merz Hot Coke Conveyor.—This conveyor owes its origin to a desire to improve one of the first De Brouwer conveyors which was erected at the Cassel Gas-works, and which gave considerable trouble owing to its very light construction. The late Mr E. Merz contended that the round or octagonal bars of the De Brouwer conveyor had not sufficient hold on the coke, which was liable to slip back over or under the bar; and also that with the short links in vogue at the time it was impossible to obtain chains of absolutely even lengths. He therefore designed the conveyor shown in Fig. 209. Instead of the chains running in the bottom of the trough, they are concealed in a suitable groove at the top, and the bars connecting the chains are replaced by cast-iron rakes, which are supported by rollers. The prongs of the rakes being set at an angle, the conveyor trough is relieved of a portion of the weight of the coke, thus reducing the work, and also the wear of the trough. The conveyor is built in two different patterns, viz., with the supporting rollers on the ends of the rakes, or with the supporting rollers fixed to the trough so that the chain travels over the rollers. The former construction is illustrated in Fig. 209, and the latter in Fig. 210, which also shows the general arrange-

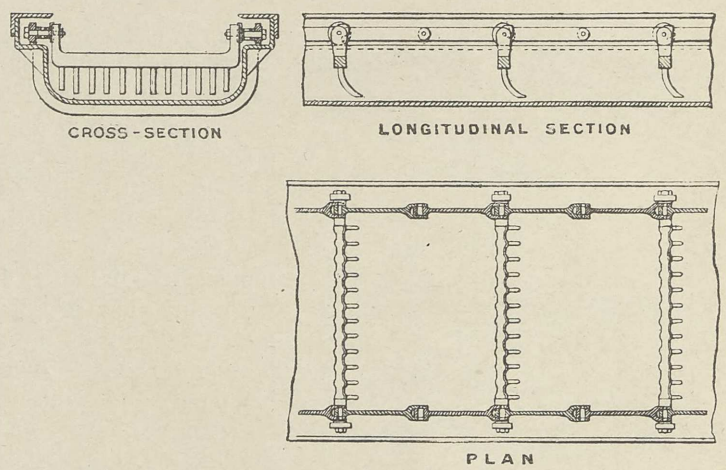


Fig. 209. Merz Hot Coke Conveyor.

ment of the conveyor. The trough is made of cast iron, and consists of sections of about 4 ft. 8 in. in length, joined together by flanges. The Merz conveyor at the Cassel Gasworks is 190 ft. in length, travels at the rate of about 30 ft. per minute, and when in full work consumes about 5 H.P.; it has been at work for about sixteen years, and so far has given very little trouble. Fig. **211** gives a photographic view of this conveyor.

Dempster's Hot Coke Conveyor. — This conveyor, designed by Messrs R. Dempster & Sons, Ltd., of Elland, Yorkshire, and illustrated in Fig. **212**, is so constructed as to keep the chains, rollers, and bearings out of reach of the hot coke and of the quenching water. The trough is built of plates and angle-bars, with renewable cast-iron liner plates at the bottom, which are prevented from shifting by flat steel strips bolted on the inside of the angle-bars; the cast-iron plates are thus free to expand and contract along the trough. On the outside of the trough, at about 3 ft. pitch, are bolted small iron brackets carrying turned steel spindles; working on these spindles are flanged cast-iron rollers which support and guide the chains. The chains used are composed of interchangeable malleable cast-iron links, with parallel sides, connected together by square-headed hardened steel pins which do not project at the sides. The rollers being attached to the trough instead of to the chain, the weight of the chain is diminished whilst the rollers and lubricators are easy of access even when the conveyor is running. The rakes or scrapers are of cast steel,

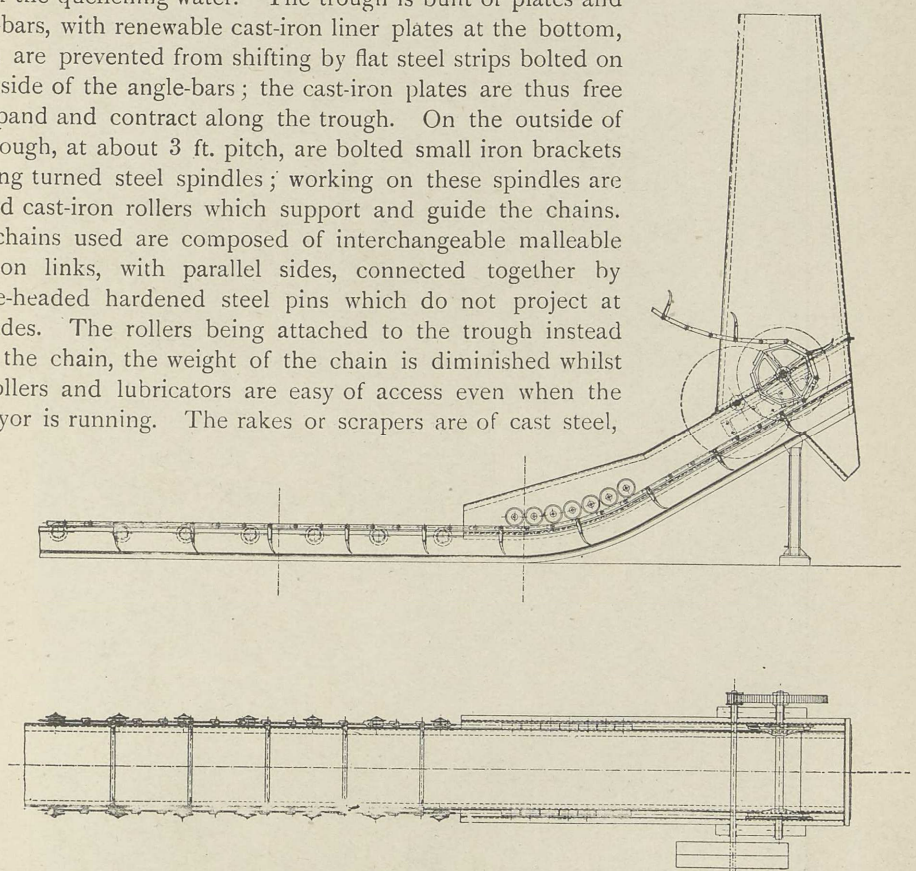


Fig. 210. General Arrangement of the Merz Hot Coke Conveyor.

and are designed to minimise the breakage of the coke by reducing the tendency to crush it between the scraper and the trough. In order still further to prolong the life of the chains, the terminals are fitted with the Toogood equalising gear, to be described (Fig. **260**). This conveyor may also be worked on an incline of say 30° to 40°, thus acting also as an elevator. Such a conveyor, having a trough 2 ft. in width, and rakes at 3 ft. pitch, travelling at 35 ft. per minute, would easily deal with the coke from ten beds of 20 ft. inclined retorts, provided the conveyor were made with a run of about 50 ft. outside the retort house, or from the last bed of retorts.

In all conveyors of the push-plate type it is essential to lead the delivery end up an incline; this is generally done for convenience in delivery, but its principal use is

in completing the quenching of the coke. As soon as the ascent is reached, a wave of water falls back on the coke and materially assists the final quenching. This wave is supplemented by a copious final spray. The most important effect of the inclined delivery flue, however, is in quenching the coke by means of vapour. The flue, and sometimes a large portion of the conveyor as well, are closed, and lead to an uptake or chimney. The presence of a great volume of steam or vapour in these flues excludes

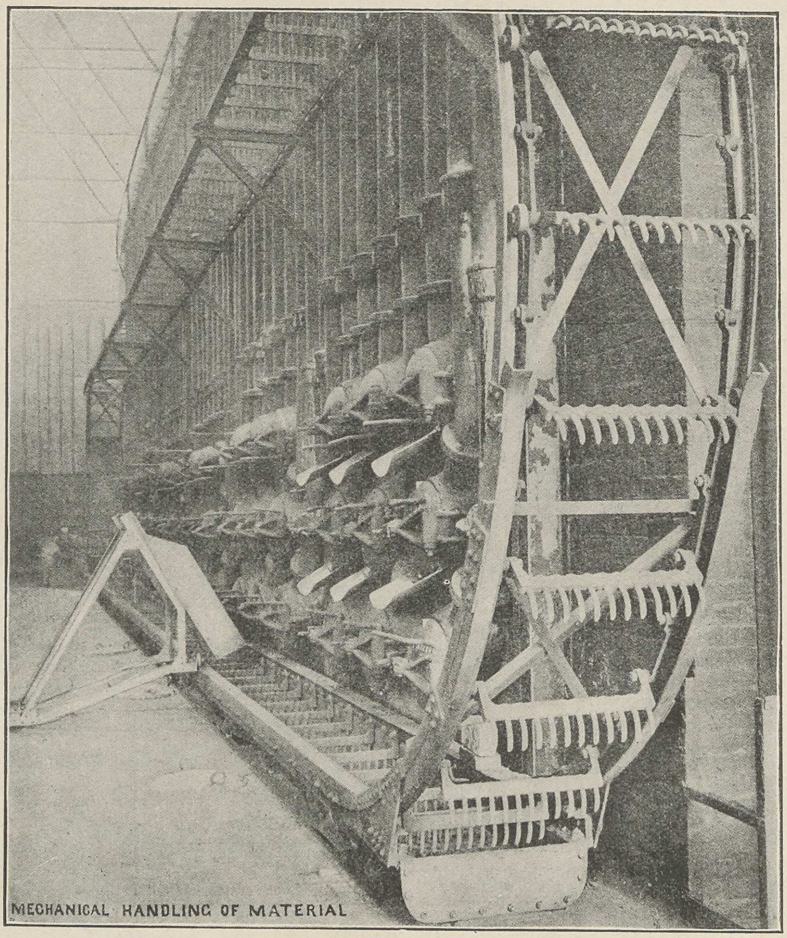


Fig. 211. Photographic View of Merz Hot Coke Conveyor at Cassel Gasworks.

the air from the coke, so that at the end of its journey through the inclined flue it is still hot enough to evaporate the surplus water, yet not sufficiently hot to ignite again, which is a matter of great importance and a safeguard against fire. The introduction of automatic devices for turning the spraying water on and off as the hot coke approaches and leaves the spraying points has recently engaged the attention of several manufacturers, and this is an important improvement in large installations, where the whole contents of a 20-ft. retort are deposited on to the conveyor over a space of only 5 or 6 ft. of its length, the conveyor being then practically empty for some yards.

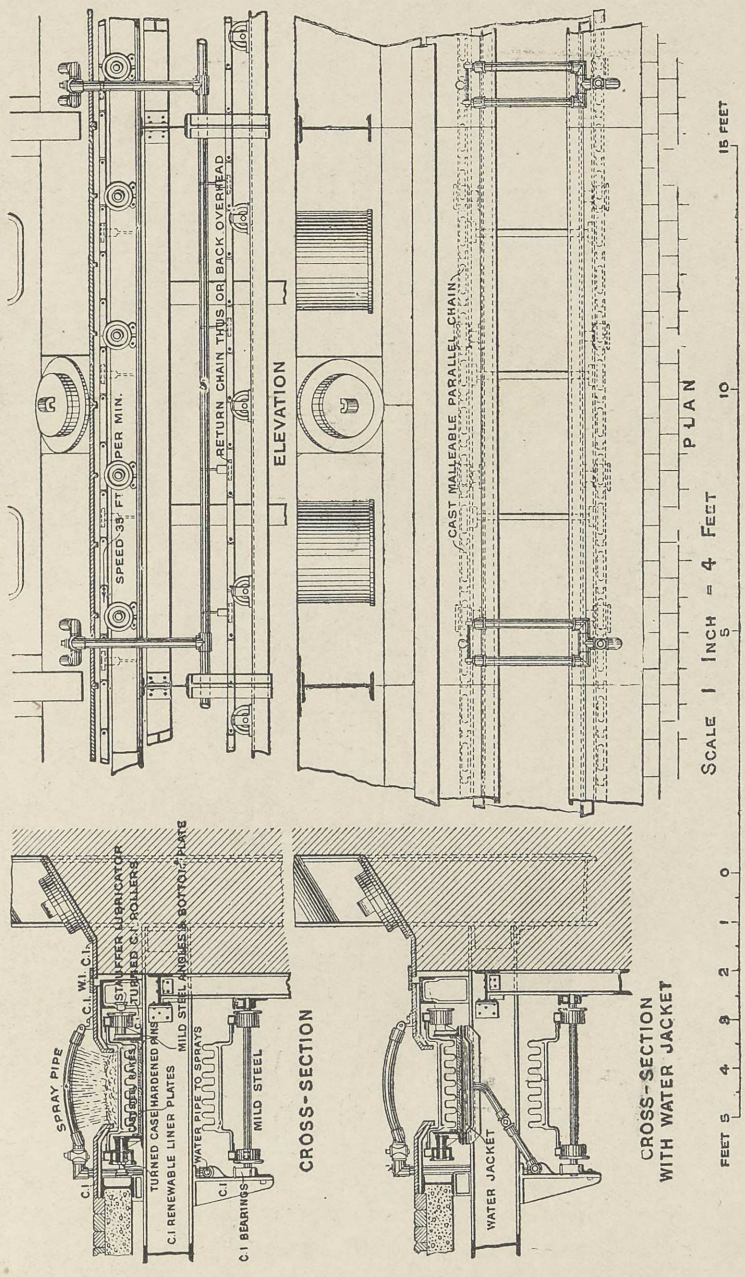


Fig. 212. Dempster's Hot Coke Conveyor.

Coke-Breaking and Sorting Plant.—Fig. 213 shows on a large scale a coke-breaking and sorting plant by the Berlin Anhaltische Maschinenbau Aktien-Gesellschaft.

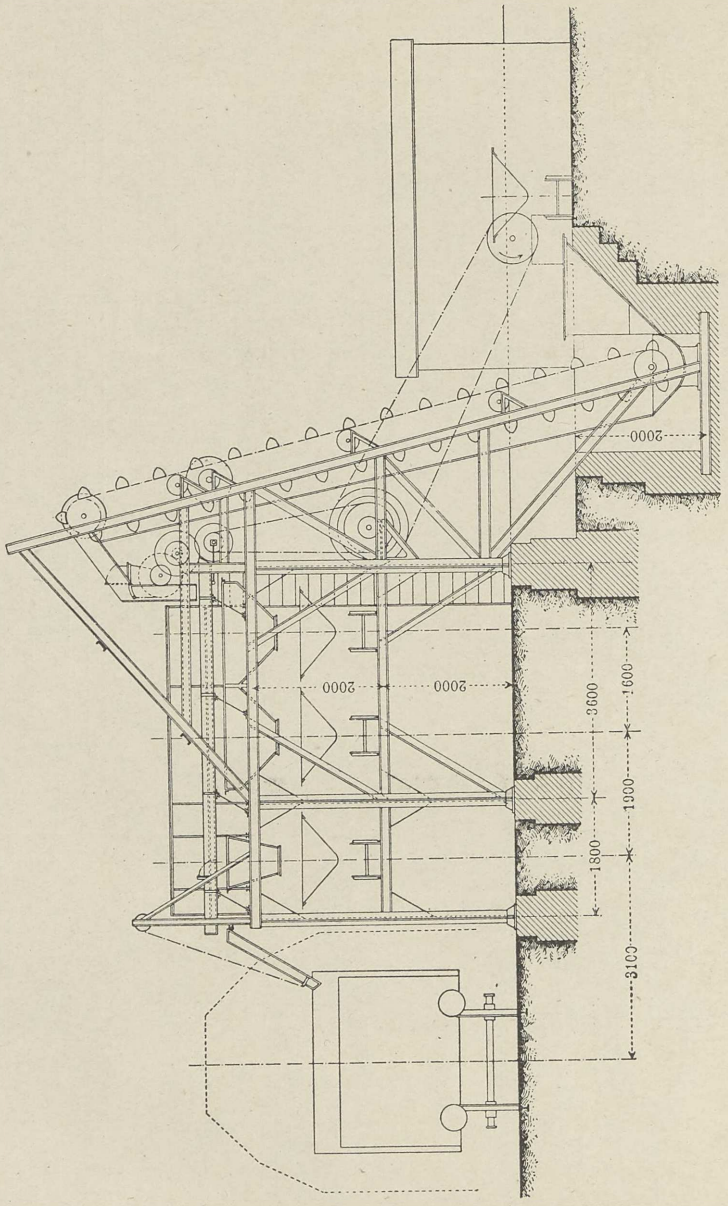


Fig. 213. Coke-Breaking and Sorting Plant. (The dimensions are millimetres.)

The illustration almost explains itself. The coke is brought to the elevator by narrow gauge trucks, is taken up and passed through the coke-breaker into a reciprocating conveyor, which is fitted with perforated plates, and classifies the coke into four sizes.

CHAPTER XIII

COAL FACE CONVEYORS

MECHANICAL appliances for removing coal and other minerals from the working face are very old, and some crude devices were used, it is believed, even by the ancient Egyptians. The last decade witnessed great activity in this direction in consequence of the thick coal seams becoming exhausted, and thin seams can only be economically worked by coal-cutters and coal face conveyors in one form or another. The advent of the mechanical coal-cutter in connection with the long wall coal face makes the face conveyor not only more applicable to coal getting, but almost indispensable. The Eight Hour Act has further emphasised the importance of mechanical appliances for economical working under ground. Space does not permit of going fully into this vast subject—sufficient to fill a large volume by itself[1]—so it is only proposed to give a general idea of the different systems without entering into the application of the machine in the mines, as this would be beyond the scope of this book. There is also a great similarity between some of the appliances. The most important are mentioned, and references are given for those who wish to be more fully informed as to where fuller descriptions are to be found. The oldest methods were probably a kind of sledge, which was dragged along the working face to the loading point by ropes and blocks, or a skip travelling on a rope, which was stretched along the roof of the seam, and on which the skip was pushed along by hand and tipped into the tub in the gate. This was used in the eighties. Isolated appliances, the outcome of the inventive genius of the coal getters or the engineer, have enjoyed only a local popularity, and none of these has become established as an economical labour-saving appliance. A detailed description of the manual conveyors would have only historical value; suffice it to say that they consisted of a small tram or a long low receptacle with a capacity of a few hundredweights, which were applied in some thin seams with varied success. As the capacity is very limited, this method is only applicable in seams where the absence of suitable driving power or some other circumstance preclude power-driven devices.

The systems now in use may be divided into four classes: **A.** Appliances in which the coal is carried in a receptacle; **B.** Appliances in which the coal is carried on an endless band; **C.** Appliances in which the coal is dragged along in a fixed trough by a chain or scrapers; **D.** Appliances which propel the material either by a simple reciprocating motion down an inclined trough, or by a more complex motion on the level, and even slightly uphill.

Class A.—Appliances in which the coal is carried in a receptacle. Appliances under this head generally involve small capital expenditure, and consist of one or more small coal tubs upon rails running in front of the coal face. At the gateway a bridge is formed and a full-sized tub placed underneath, which receives the contents of the smaller tub or tubs through an outlet controlled by a slide. The small tub is made with sloping sides and mounted upon axles, which allow the bottom of the tub to approach close to

[1] A volume of over 300 pages, with 274 illustrations and 5 plates, has been written exclusively on this subject by Arthur Gerke, of Bochum, 1913, entitled "Ueber Abbauförderung."

the rail level, and one of the sides near the coal face is lower to facilitate filling. In this class are included the Mickley[1] and the Bothwell[2] conveyors, which consist of low trucks which are pulled along in front of the coal face. With the latter type of trucks, trains are formed consisting of as many as twenty-four trucks. The Gibb[3] conveyor (see Fig. 214) consists of eight or nine segments, each of which is supported by four cast-steel wheels. The first and last segments have closed ends, so that the whole is like one receptacle. Such a conveyor is in use at the Muiravonside Colliery in Linlithgowshire. It consists of nine segments with a total length of 56 ft., 16 in. wide and 8 in. deep at the side of the coal face, and 14 in. deep at the other side; this conveyor holds $2\frac{1}{2}$ tons of coal.

Similar appliances of the same class are the Bunker conveyor,[4] and the Cummings & Gardiner,[5] Walton & Rayner,[6] and Thomson conveyors.[7] All these conveyors pass backward and forward along the coal face to the gateway where they deposit their load

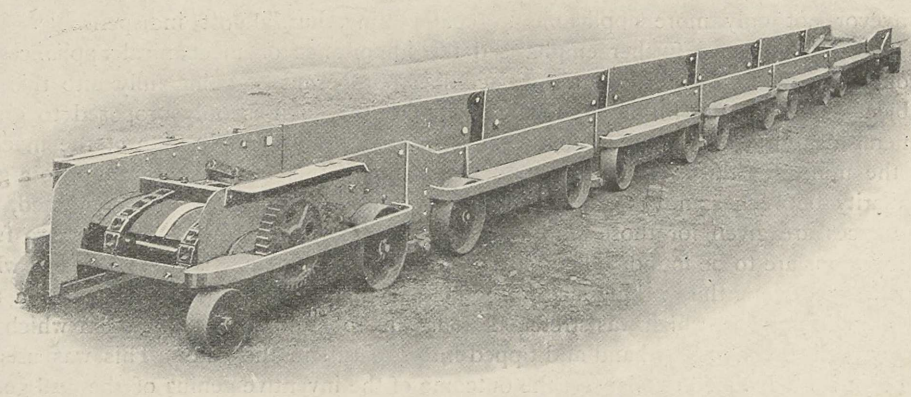


Fig. 214. Gibb Coal Face Conveyor.

into ordinary mine tubs, and sometimes they pass beyond the gate to the coal face on the other side, alternately taking the coal from the face on either side of the gate.

All these appliances run on rails of ordinary section except the Bothwell which runs on a U-shaped channel, and the Thomson, which is not supported by wheels, but slides in U-shaped channels. The drive is by steel rope which passes over rollers at the terminals, manipulated by hand or pneumatic gear. The unloading is effected in various ways. The Mickley and Bunker conveyors deliver through openings controlled by slides; the Bothwell has an automatic tipping device by which each segment delivers its load by

[1] Mickley. This is more fully described in the *Transactions of the North of England Institute*, vol. lv., page 176.

[2] Bothwell. This is described in *The Colliery Guardian*, II., 1909, page 622.

[3] Gibb. This is fully described in *The Colliery Guardian*, II., 1909, page 59.

[4] This is described in *The Colliery Guardian*, II., 1911, page 1286, and *The Transactions of the Institute of Mining Engineers*, 1912, page 391, also in "The Coal Age," 1912, page 643.

[5] Cummings & Gardiner, *Colliery Guardian*, II., 1911, page 167.

[6] Walton & Rayner. Described in *Colliery Guardian*, I., 1911, page 1228.

[7] Thomson. Described in *Iron and Coal Trade Review*, 1909, Nov. 26, and "Coal Age," 1912, page 645.

tipping up by gravity, and assuming its former position as soon as empty. Walton & Rayner employ a textile band which rests with its upper strand in the bottom of the segments, which are set in motion when the train is in the unloading position at the gateway. Cummings & Gardiner, as well as Gibb, use a steel band employed in a similar manner. Thomson's conveyor (Fig. 215), which is essentially a trough open on one side, is emptied by an oblique scraper as it passes over the bridge at the gate.

As regards capacity the Mickley conveyor at the Prudhoe Pit of the Mickley Coal Company is handling 5 tons per hour. The installation of the Cummings & Gardiner conveyor at Hampstead Colliery has increased the output from 2·7 tons to 4·5 tons per man per shift. The Bothwell conveyor of the Bothwell Park Colliery has increased the

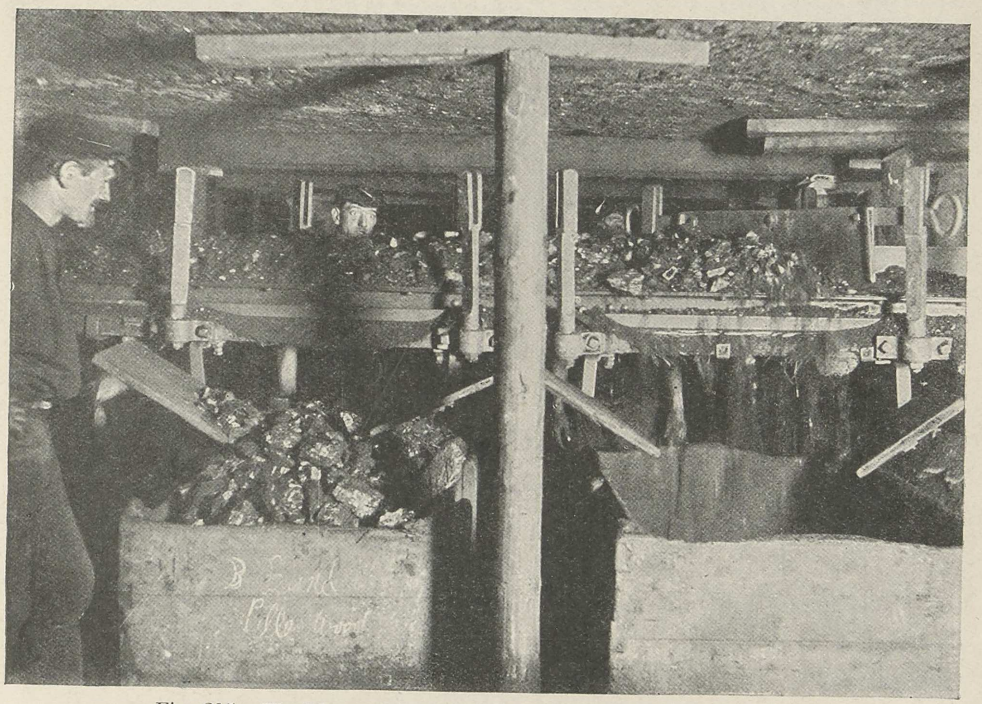


Fig. 215. The Thomson Coal Face Conveyor. View from Coal Face.

output from 2 tons to 6·5 tons per man per shift. The Gibb conveyor at the Muiravonside Colliery has a capacity of 13 tons per hour.

Class B.—Appliances in which the coal is carried on an endless movable band. As band conveyors are fully dealt with in Chapter VII., it will only be necessary to mention any peculiarities for this particular use of a well-known type of conveyor (introduced by Richard Sutcliffe, of Wakefield). For the band itself hemp or flax is most serviceable. Jute cotton and the bass of the ancient lime tree are also used, but they do not last as long, and occasionally woven wire bands are employed. All textile bands suffer much from the damp atmosphere in the mines, and to avoid this they are impregnated with various substances such as balata ; tar being also used for this purpose.

The width of the band generally varies between 20 and 24 in. The idlers with their frames are kept as low as possible, so that the conveyor may be applicable in small seams. Where troughing idlers are used they are, for the same reason, in a more shallow position

than is the usual practice. As regards inclines, up-gradients of 5 per cent., and downward gradients of 12° are within working limits.

The advantages of these belt conveyors are their suitability for an uneven floor, as the band can accommodate itself to the bends in the floor and roof. The power for driving them is considerably less than for other appliances, and the working is both noiseless and dustless, which is of great importance. The disadvantages are the great wear and tear caused not only, as already mentioned, by the atmosphere, but as these conveyors, in common with all other coal face conveyors, have to be removed and re-erected constantly nearer the receding face, the re-erection does not always get the care necessary to ensure all idlers being at right angles to the band and parallel with each other, and in consequence the band travels with a snake-like side motion, whereby the edges are injured and frayed by contact with other objects. The loading is not so easy

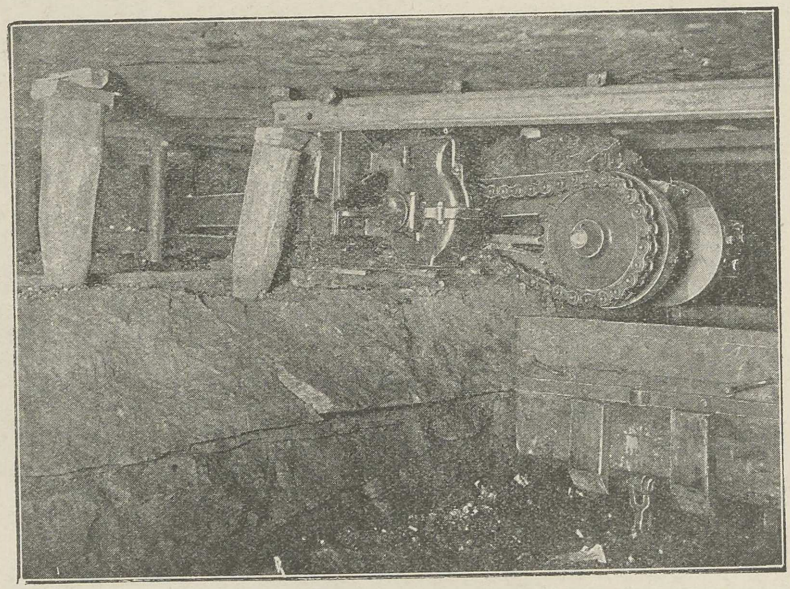


Fig. 216. Blackett Conveyor Delivering Coal into Main Gateway.

as with other appliances, and an occasional dropping off of pieces of coal is also complained of, and finally, for wet mines they are quite unsuitable.

Class C.—Appliances in which the coal is dragged along in a fixed trough by a chain or scrapers. The best known and oldest conveyor of this type is that of Blackett [1] (Fig. 216). These machines are to all intents and purposes scraper conveyors (which have already been fully dealt with in Chapter V.), the principal feature being that they are built as low and compact as possible in order to leave sufficient head room for the coal to be put in and conveyed even in thin seams. The chain scrapers are now of the form of very large Ewart or Lee type of chain. Other scraper conveyors are by Greaves,[2] Vinton,[3] Ritchie & Sutcliffe.[4] In order to still further reduce the height of the conveyor,

[1] Fully described in *The Colliery Guardian*, I., 1905, page 580.
[2] Fully described in *The Colliery Guardian*, II., 1906, page 7.
[3] Fully described in "Mines and Minerals," 1907, page 200.
[4] Fully described in "The Coal Age," 1912, page 644.

Greaves leads the return strand of the chain back to the head end in a separate compartment in a very ingenious way, so that only a minimum of space is required.

The Allardice Coal Face Conveyor, Fig. 217, consists of an endless chain with trough, extending the full length of the face, sliding over the floor, and manipulated by a haulage gear. The return of the chain is overhead, being supported about every 9 ft. A suitable tension gear is provided at the top end of the face.

The chain consists of links made from flat bar, 9 in. pitch, with suitable scrapers arranged every 3 ft., which pass over sprocket wheels at each end of the face. The sprocket wheels are driven by the haulage gear through treble reduction machine-cut gearing which is placed in the main road, which is made wide enough for a double road.

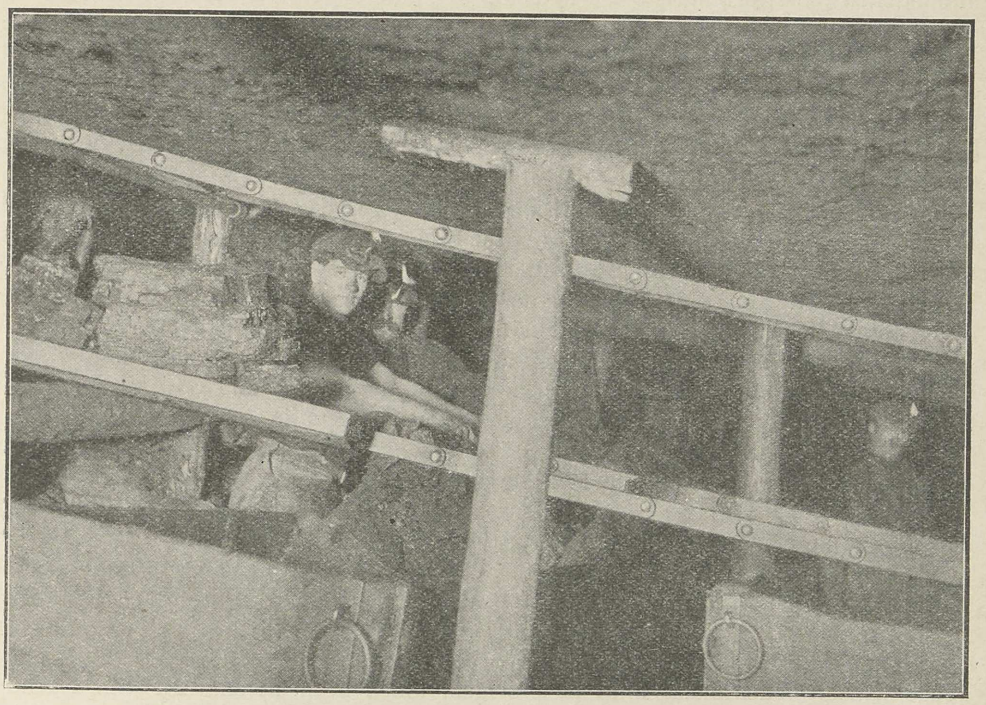


Fig. 217. The Allardice Coal Face Conveyor.

The chain for the haulage gear passes over this road, and the coal is delivered into tubs without any special devices. The main road is driven 15 to 20 ft. ahead of the coal face to allow of empty tubs being brought forward, so that no delay takes place in their filling.

In some coal face conveyors, including that of Ritchie & Sutcliffe, textile bands are used as scrapers which are supported by rollers, or slide on the bottom of the trough.

Class D.—Appliances which propel the material, either by a simple reciprocating motion down an inclined trough or by a more complex motion on the level, and even slightly uphill. The latest development of coal face conveyors is the reciprocating trough or *Rutsche*,[1] which, owing to its great simplicity, promises to make rapid headway, for if simplicity is always desirable in all machinery, it is especially so for appliances at the

[1] This conveyor, having been introduced in German collieries first, the German name Rutsche (plural, Rutschen) is often used in this country, but the Author suggests "Jog-trough" as an expressive English name.

coal face, where all mechanical devices are more roughly used, and more subject to injury than in any other industry. The principle is simplicity itself, and one wonders why it has not been employed before. Such conveyors consist of an open sheet-iron flat-bottomed trough with slanting sides, or the trough may be semicircular, which is supported by chains from the timbering, or from trestles, or by rollers from below. A reciprocating motion is imparted to such troughs either by hand or motive power, and as the original conveyors were inclined, being used in inclined seams, the material moved or slid forward and downward at the down-stroke, whilst it remained stationary at the up-stroke. The speed of travel depends on the method of support, the stroke, and the incline.

The oldest form is the suspended trough conveyor. With this system it must be borne in mind that the stroke must come to a stop when the supporting chains or links are in a vertical position, that is to say, the stroke must not extend equally on either side of the points of suspension, as then there would be no forward motion, at least not in a horizontal conveyor. The action is therefore as follows: When the conveyor is at rest all the supporting links or chains hang vertically down; as the stroke begins the trough is lifted, as it moves on the path of an arc described by the suspended links. During this motion the coal in the trough remains stationary; as the end of the stroke is reached the trough will be in its highest position, and it then begins the forward stroke. During this the coal likewise remains stationary, that is, moves the trough, but as soon as the lowest point is reached the motion is reversed, and the cycle of motions repeated, but owing to the velocity imparted to the coal during the downward motion it slides on and does not come to rest till the trough has nearly completed its backward stroke. This motion is repeated again and again, and it is obvious that the length of the stroke and the incline, if such should be available, will materially affect the speed at which the coal travels in the trough. The links supporting the trough, it will thus be seen, do not travel at the forward stroke beyond their vertical position, and it is regulated by the stroke of the pneumatic engine, which does not permit an extension of the movement.

The aforesaid refers to conveyors suspended on chains or links either from the timbering of the roof or from special trestles.

If the trough is supported from beneath on rollers, and a sufficient fall should be available, the rollers may move on the floor of the seam, or parallel with it on short lengths of upturned channel iron; but if the seam is level, or nearly so, these rollers must move on a path similar to that indicated by the suspended links, that is, short sections of rails or wedge-shaped wooden blocks must be provided, which begin at one end with a gentle incline and which become steeper towards the end of the stroke. If a number of pairs of rollers are attached, running on such inclined rail sections, the behaviour of the coal in the trough will be the same as in the suspended conveyor, and it will be conveyed in the same way.

The troughs of these conveyors are best made of Siemens-Martin steel sheets from 2 to 4 mm. thick (14 to 9 B.W.G.), and joined up out of lengths of 10 ft. each. As to the width of these troughs, when first introduced there was a tendency to make them rather large, 24 to 28 in. wide and 12 to 13 in. deep, but these have been found unnecessarily large, and the best size has been found to be 16 to 20 in. wide and from 5 to 8 in. deep.

Coal face conveyors should work with as little noise as possible, and it has been found that small troughs well filled work more quietly than wider ones with a thinner load. It has also been found that conveyors of the smaller dimensions are quite capable of coping with the output of the seams, that is, keep pace with the men who load them.

At first most of the troughs were made of 2 mm. (about 14 B.W.G.) sheets, but it was found that they soon wore out, and if the plates were 3 to 4 mm. (about 10 to 9

B.W.G.), the total weight of the trough was naturally increased from 50 to 100 per cent., which made more powerful motors necessary. It was also found that the middle of the bottom of a flat-bottomed trough wore through first, so that the troughs had to be scrapped when the sides and a portion of the bottom were still good. A middle course was then adopted by some of the best makers, and the troughs were manufactured out of specially rolled sheets, which were thin at the sides and gradually thickened in the middle, and in the proportion in which the wear has been observed. Semicircular troughs were made of similar sheets, fortified similarly by an extra thickness at the points where the wear was found to be most prominent. This method has the advantage that the weight of the trough is brought to a minimum and its lasting qualities to a maximum, and that the whole trough wears uniformly.

The methods of coupling up the different lengths of the trough of one long conveyor are very numerous. At first the practice was adopted of making the ends flanged, and bolting the units together with a narrow kind of fish plate on each side of the flanged joint, but these loose parts were constantly lost by the men, and the process had the disadvantage of being too slow. More modern methods include few or no loose parts, and allow a slight flexibility at the joints, so that slight curves in the level of the seam may be followed by the conveyor. In suspended conveyors the weight of the trough itself has been utilised for tightening the joints by combining the links of suspension with a coupling device.

The details of the supports, both hanging and rolling, vary more or less in the machines of different makers, but the essential principle is the same, so that it is not proposed here to give much space to them, as the number of varieties is so great that it would require many pages to do them all justice.

The motors are nearly all of the compressed air type. Attempts have been made to use electricity as motive power, but the pneumatic principle is so obviously the most suitable that it is not to be wondered at that it has held its own. To use an electro-motor, a quick rotary motion has to be converted into a slow reciprocating motion, whilst the movement of the pneumatic engine with its slow reciprocating motion is so similar to that of the coal face conveyor that it may be coupled direct to it; therefore it is only those who have no pneumatic plant in their mine who will consider electric drives.

Pneumatic engines are used either directly coupled to the conveyor trough by a connecting rod, the engine being fixed to the ground underneath, or they are coupled by the intervention of levers, rods, or cables. One of the latest methods is to fix the motor to the trough itself, and adjust the movement by a chain anchored at one end to the ground and at the other to the engine, which may be single or double acting.

Direct-coupled motors generally occupy less room, and are more easily shifted as the face recedes, and the initial cost is less than that of the gear-coupled motor; on the other hand, the former are more noisy, being fixed with the conveyor close to the coal face instead of some distance away (probably in the gateway). They must be moved every time the conveyor is moved, and, being placed under the conveyor, have a tendency to occupy more height, which may be an objection in working small seams.

Both types of motors vary in the number and length of the strokes. For conveyors on an incline, where gravity is one of the conveying powers, direct-coupled motors are generally and preferably single-acting with a long stroke, as their action gives the coal a greater momentum, and therefore a greater forward movement at the change of the stroke; whilst for more horizontal conveyors, where gravity does not come into play, double-acting motors are better, with more frequent and shorter strokes. In order to adapt motors to all the conditions in the same pit some of the types have been made with adjustable strokes.

The stroke given by the motor to the conveyor is from 6 to 16 in., and the number of strokes from 50 to 100 per minute; the speed of travel of the coal in the trough varies from 1 to 5 ft. per second.

Single-Acting Motors.—These can only be used for conveyors so situated that the motor has only to lift or perform one half of the stroke, whilst the weight of the conveyor and its load are responsible for the return stroke.

The first motor of this type was built by Gebrüder Eickhoff, and consists of a cylinder with piston and piston rod. The latter extends out through one end of the cylinder and is coupled to a crosshead and two rods, the latter guided on both sides of the cylinder, and these two rods are again coupled by a crosshead which is connected up to the conveyor, either directly or indirectly. If the inlet valve is opened the compressed air enters the cylinder and forces out the piston rod, and with it lifts the conveyor and its load a part of its stroke, when the air supply is cut off and the stroke completed by the expansion of the air and the inertia of the moving conveyor. After the conveyor has come gently to the end of its stroke the gravity of the load exerts itself, so that the conveyor makes its backward stroke automatically. At the same time the piston in the cylinder is reversed; before, however, the stroke is quite finished the air is automatically admitted into the cylinder again. It will thus be seen that only one end of the cylinder is connected with the compressed air mains, whilst the other is open to the atmosphere. The valve gear consists of two trippers on the piston rod which manipulate the slide valve, so that either compressed air is admitted or the cylinder put in communication with the outer air.

The latest *Flottmann* engine, which is fixed directly to the conveyor trough, differs materially from the foregoing, and is strictly speaking a single-acting engine. Figs. 218 to 220 give a good idea of the details of the working parts. The cylinder is open at both ends, and in it move two pistons connected by rods to the junction of two pairs of toggle levers. The illustration represents the two pistons at the beginning of their cycle of movements, that is, close together and with the port for the admission of compressed air open; the pistons are now forced apart, and with them the toggle levers. This action forces the two impulse brackets, to which the other ends of the toggles are joined, and as one of these brackets is anchored by a chain to the ground, and the other is bolted to the conveyor trough, the latter is forced to make its up-stroke. The air in the cylinder is now allowed to escape, and the weight of the trough by the toggles forces the pistons back to the first position.

The working of the gear is as follows: As the pistons are forced apart, and when nearly reaching the end of the stroke, one of them uncovers a port leading to a small auxiliary cylinder with piston, rod, and slide valve, the latter at the extreme end. As a portion of the air enters now behind the piston the slide valve is pushed forward and cuts off the air supply to the main cylinder. The movement of the slide valve at the same time pushes a rod out at the opposite end, and when the weight of the trough completes the return stroke one of the collapsing toggle levers pushes this rod back again, and thereby reopens the inlet for the compressed air, at the same time pushing the small auxiliary piston back to its first position.

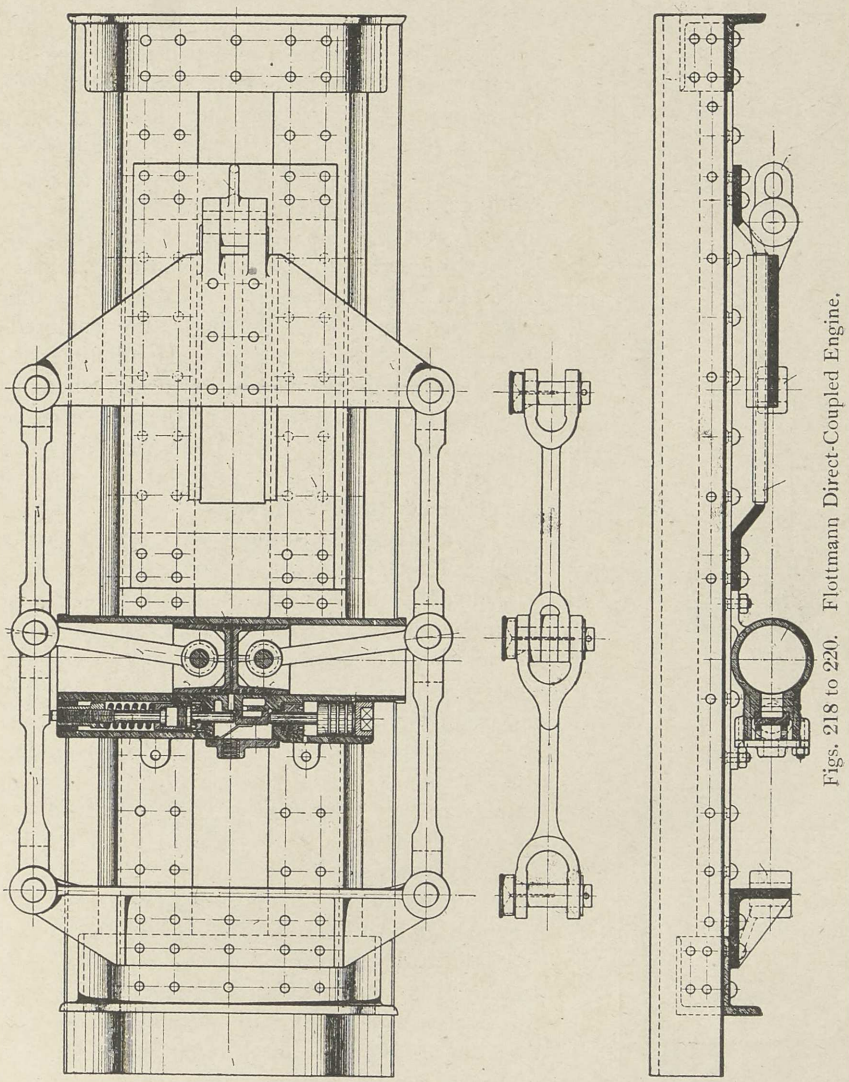
The impulse bracket, which is anchored by the chain, is guided by a sliding block and groove fixed to the conveyor trough to ensure the movement of the toggle levers being symmetrical.

Double-Acting Motors are all those which admit compressed air alternately on both sides of the piston, and which move the conveyor in both the forward and backward stroke. The valve or slide gears are either inside or outside the cylinder and consist of

various forms of valves and slides. The cut-off is always so arranged as to utilise the expansion of the air, whilst a few are on the compound system.

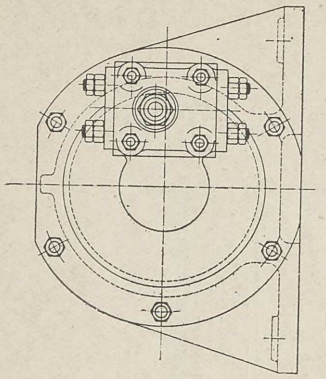
The Korfmann Conveyor is one of the latest types. It is supported on wedge-shaped runners which can be placed in a variety of positions to suit level or inclined seams.

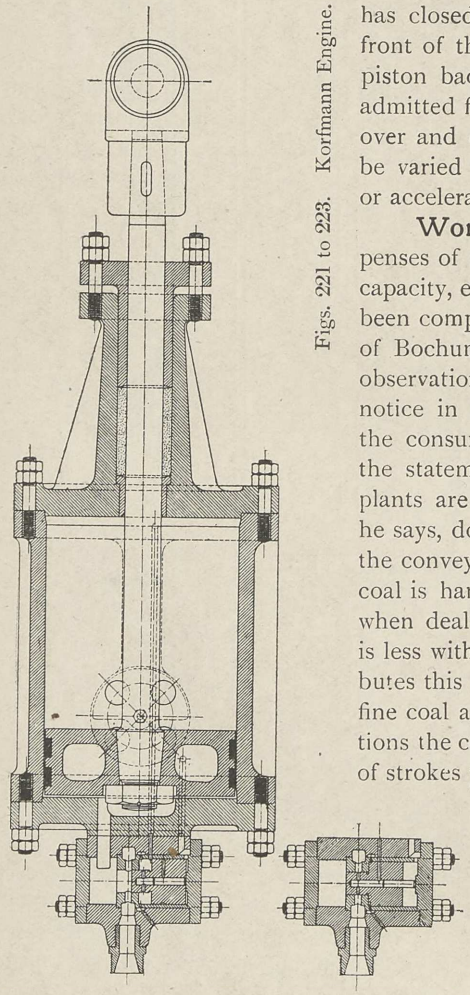
The engine is noteworthy for its comparative simplicity. Figs. **221** to **223** show



Figs. 218 to 220. Flottmann Direct-Coupled Engine.

this in section, also a separate section of the slide box in the second position, and an end view. The first position of the slide valve (shown in the upper section) rests, owing to its own weight, in the lowest position. As the compressed air is admitted it passes round the annular channels in the gear box and cylindrical slide valve and through radial openings, the central passage and port behind the piston pushing it forward. The cylindrical portion or piston of the slide gear is compounded, and consists of the lower main portion fitted with an upper wing, and has in addition a small plunger in its





Figs. 221 to 223. Korfmann Engine.

lower end. Two small openings may be seen in the main cylinder near the back and front ends; these communicate by means of channels with the valve box. As soon as the main piston has uncovered the first of these openings, some of the air passes under the piston of the slide gear and raises the same (see lower section) and thereby cuts off the air supply, and the main piston completes its stroke by the expansion of the air in the cylinder, and at the end of the stroke uncovers an exit (not shown in the illustration) for the air. In the second position (see lower section) air is admitted over the small lower pin-like plunger, which is pressed down, holding the remainder of the cylindrical slide block up. In this position air is at the same time admitted to the front end of the main piston, which thereby makes its return stroke. During this, as soon as the piston has closed the first of the ports, the enclosed air in front of the piston is compressed and forces the valve piston back into its first position again, when new air is admitted for the next stroke, and the same cycle repeated over and over again. With this engine the stroke can be varied by turning a semicircular disc which retards or accelerates the exit of the air.

Working Expenses.—As regards working expenses of reciprocating coal face conveyors (Rutschen), capacity, etc., the most reliable information available has been compiled by Arthur Gerke, a well-known engineer of Bochum, Germany, from his own tests, and from observations of cases which have come under his own notice in German mines. He says, when referring to the consumption of compressed air per minute, that the statements of the manufacturers of the different plants are very confusing. The quantity of air used, he says, does not so much depend upon the length of the conveyor, as on the condition of the coal. If large coal is handled the air consumption is much less than when dealing with fine coal, likewise the consumption is less with dry than with wet coal, and Mr Gerke attributes this circumstance to the greater friction caused by fine coal and wet coal. In addition to these considerations the consumption of air is variable with the number of strokes per minute.

The following table[1] is a *résumé* of air consumed, but as the quantity of coal handled was not taken into consideration, the result does not in any way prove the superiority of one conveyor over another, but only serves as a guide to the approximate air consumption.

[1] From "Ueber Abbauförderung," by Arthur Gerke.

CONSUMPTION AND COST OF COMPRESSED AIR FOR DRIVING RECIPROCATING COAL FACE CONVEYORS, OR RUTSCHEN

System.	Diameter of Motor Cylinder in Inches.	Pressure in lbs. per Inch.	Consumption of Air per Minute in Cubic Feet	Cost of Compressed Air.		Length of Trough in Feet.	Incline of Seam in Degrees.
				Per Cubic Metre [1] at the Pressures given in Column 3.	Per Ton of Coal Conveyed.		
Carlshütte [2] - -	8	68-75	70½ [4]	·05	1·2	525	15
,, - -	10	45	70½ [4]	·0375	·1375	131	20
Flottmann - -	8	45-60	18	·25	1·0	262	3-20
,, - -	10	75	16	·025	·281	229	2-5
,, - -	11½	45-60	26	·187	·2275	164	2-12
,, - -	11½	75-90	18	·1625	·2275	262	2-12
,, - -	14	75-90	21	·1625	·2725	238	2-12
Würfel & Neuhaus	10	52	...	...	1·875	210	22
,, ,,	12	45	...	·3125	·9	394	13
,, ,,	12	75	41	·125	·75	262	0-5
Eickhoff - -	9	38	18	·156	·46	295	0-15
Degenhard - -	6 [3]	60	76	·187	1·5	328	0-10
Hinselmann -	6 3/8 [3]	38	43	·156	·968	295	0-15
,, -	9	60	14	·225	·2625	328	10

The variation of cost in the above table of compressed air per ton of coal handled is from ·1375 to 1·875 pence. In Germany it is considered that 5 pfennige or ·625d. is a reliable average figure.

Experience gained in German collieries shows that the life of a compressed air motor is about five to six times as long as that of the conveyor trough, whilst that of an electro motor is about ten times as long, so that the wear and tear of the motor may be calculated to be from ½d. to 1½d. per ton of coal handled. From observations in the working of a large colliery, where many such conveyors are at work, it is safe to assume that :—

A trough of 2 mm. 14 B.W.G. will handle 30,000 tons of coal and 18,000 tons of dirt.
,, 3 ,, 11 ,, ,, 50,000 ,, ,, 30,000 ,,
,, 4 ,, 9 ,, ,, 70,000 ,, ,, 40,000 ,,

The dirt or spoil which is mentioned above is not of a cutting nature and the figures given are for the life of the trough.

It is calculated that the cost of the wear on the trough works out at from ½d. to 1d. per ton of coal handled.

The working expenses tabulated from the above experiences with these conveyors in Germany, per ton of coal handled, are as follows :—

	Per Ton of Coal Handled.
Driving power - - - - - -	·625 penny
Wear on motor - - - - - -	·125 ,,
Wear on the trough - - - - -	·625 ,,
Lubricant - - - - - -	·1 ,,
Repairs - - - - - - -	·375 ,,
Cost of erection and re-erection - - - -	·625 ,,
	2·475 pence.

[1] 1 cubic metre = 35·3166 cubic feet.
[2] The motors are not of the latest type.
[3] Twin motors.
[4] Air not under pressure when measured.

Concluding Remarks.—Belt and scraper conveyors require less driving power than reciprocating trough conveyors (Rutschen). In other respects they are about equally as serviceable, but the latter are generally of a lower initial cost. Concerning the respective merits of Rutschen, those suspended on chains or links are more difficult, and therefore more costly, to move with the face; they depend on the timbering and their use is restricted to seams of certain limits. The type with independent trestle supports are more costly still in labour for moving, and also share the restrictions as to size of seam with those previously mentioned, but they have the advantage of being independent of the timbering of the mine.

Those supported on rollers are the least expensive and simplest to move, are independent of the timbering, and are applicable to the smallest workable seams. From the above it appears likely that conveyors of the roller supported type will soon become as popular in this country as they are already on the Continent, where they are very largely used. The information contained in this chapter should be sufficient to build coal face conveyors of the Rutschen (Jog-trough) type in this country.

CHAPTER XIV

CASTING MACHINES

CASTING machines are, to all intents and purposes, conveyors; they receive their load of iron in a liquid state at one terminal and deliver it at the other in the form of pig iron. The receptacles for the metal form at the same time the moulds for the pigs. The fundamental principle is that of a continuous bucket conveyor, built on lines to conform with the enormous duty they have to perform, and as they deliver at the terminal only, the units or moulds are rigidly connected with the links of the two chains to which they are attached.

Casting machines were first introduced in the United States and it is estimated that over 50 per cent. of the pig iron is handled by such machines. Of late years a few of these machines have been introduced into this country and the Continent.

The chief advantages of mechanically casting and conveying pig iron consist in an enormous saving of labour, and also in the production of sandless pigs, as well as saving the large space occupied by the pig bed. In America such pig iron commands a premium of 1s. to 1s. 6d. per ton above pigs cast in the ordinary way, because melting more easily, it requires less fuel in the cupola. Mechanically cast pigs are smoother and cleaner, and of a more uniform size. Again, any waste in the casting process by runs of pig-bed scrap is avoided, while it is also claimed that such iron is more uniform and homogeneous. Further advantages are claimed in that the furnace can be tapped whenever it is most convenient, while the whole output is cooled and delivered into trucks without being touched by hand.

One of the principal advantages, as far as labour is concerned, is the avoidance of the clearing of the pig bed by hand labour, which is exceedingly arduous, and in the hot season of the year the men are not infrequently overcome by it, but with the advent of the lifting magnet, which is used for this purpose with great success (see chapter on Grabs), the casting machine no longer monopolises this advantage.

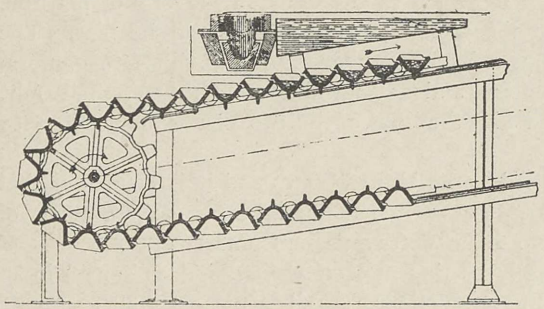
The disadvantages are that the iron suffers in fracture, that is to say it deteriorates in point of texture, which is due to the chilling effect of the mould and the subsequent submersion in water, as well as to the vibration of the mechanism during the solidification of the iron in the mould. (The chilling of the pigs may or may not have an injurious effect upon the later use of the iron, and it is believed that for steel making it is no detriment, but when the iron is bought by fracture it might affect its market value.) And lastly, the breakdowns to which such machines are subject.

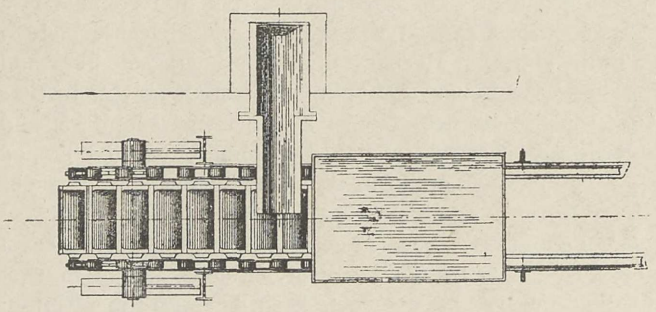
As yet only a few of these installations are at work in this country, the first being probably that erected in 1898 at the works of the Millom and Askam Hematite Iron Co., Millom, who adopted the "Uehling" machine, the use of which has, however, been discontinued. The second plant was that introduced at the works of the Palmer Shipbuilding and Iron Co., Jarrow-on-Tyne, who adopted the "Heyl and Patterson" machine. These two machines are similar in design, the principal difference being that in the case of the "Heyl and Patterson" machine the pigs are cast in moulds whilst partly submerged in water. There is also a minor detail in the device adopted for preventing the adhesion

of the pigs to the moulds. To guard against this the moulds are in the "Uehling" process coated with a spray of lime water, whilst in the "Heyl and Patterson" machine they are coated with soot.

There are two further types of casting machines, the "Ramsay" and the "Hawdon." The former is unlike either of the two first-mentioned appliances, in so far as the moulds are placed round the circumference of a large revolving table. The "Hawdon" machine is partly in a straight line and partly in a circular form. Several "Hawdon" casting machines are at work in this country and on the Continent, as well as in America.

The great difficulty in the mechanical handling of molten metal lies in the enormous weight of the metal, moulds, chains, etc., to say nothing of the great heat. Such machines must be exceedingly strong and substantial, that they may suffer as little as possible from the heat to which they are subjected, and from the weight they have to carry. The expansion of parts of these machines, caused by the heat, the resultant excessive wear and tear, as well as the difficulty of keeping them lubricated, was found a serious obstacle by the builders of such machines. The moulds last only about nine months, and in addition to this great wear and tear on the machines the fracture of the pigs produced by them is spoiled, and as in this country iron for foundry purposes is generally sold by fracture and not by analysis, it does not find so ready a market.

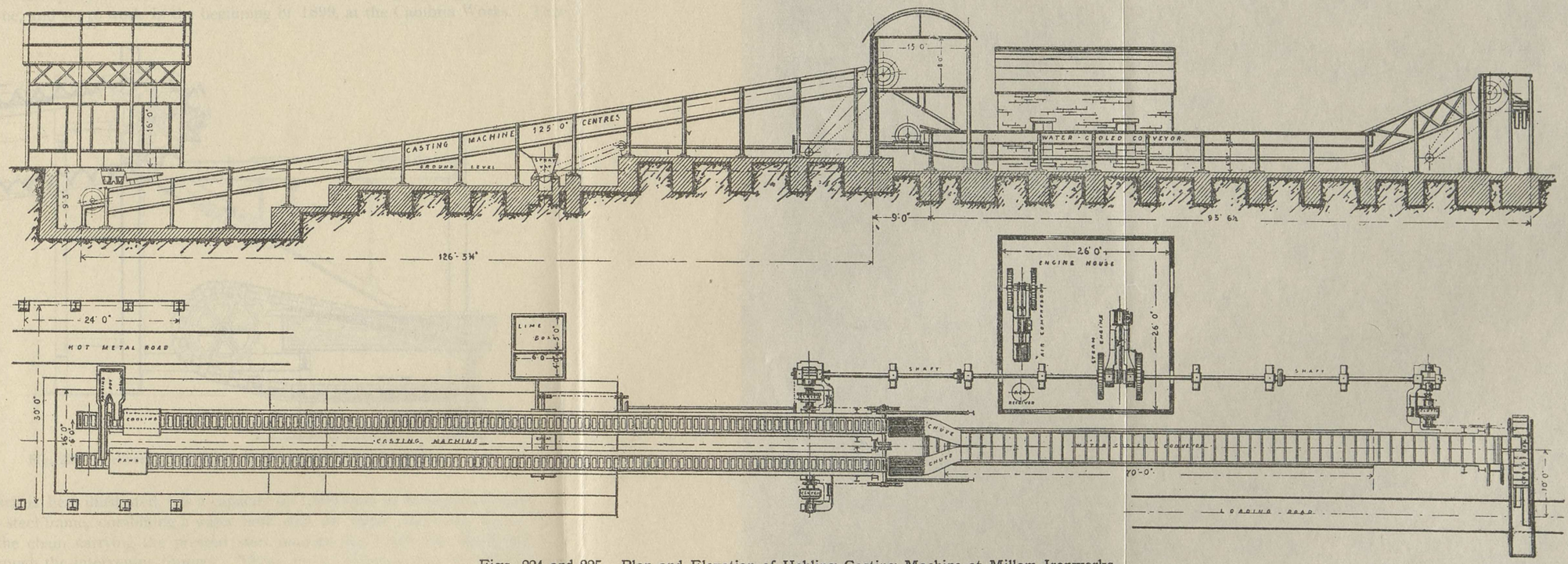




Figs. 226 and 227. Feed Terminal of "Uehling" Casting Machine.

The "Uehling"[1] Casting Machine.—This machine consists of two casting conveyors and one cooling conveyor, the latter taking the pigs from the two former, as shown in Figs. 224 to 228. Each of the two casting conveyors is about 125 ft. long, and consists of 260 moulds. The moulds travel upwards at an incline of 9°, and are carried over sprocket wheels at each end. The conveyor travels at such a rate as to give each mould ten minutes to pass from end to end. This allows the iron sufficient time to solidify before reaching the other terminal. The solid pigs are then precipitated down two chutes leading to the tank of the third conveyor, which is nearly 100 ft. long. This third conveyor is of the metal band type and travels in a tank for a distance of about 70 ft., the water being deep enough to cover the pigs as they lie on the conveyor. The pigs are carried through the tank, and are raised at the other end to a sufficient height

[1] *The Engineer*, 4th August 1899; *Engineering and Mining Journal*, 5th January 1901; *Iron and Coal Trades Review*, 25th November 1898 and 2nd June 1899; *Stahl und Eisen*, 1897, No. 16; 1898, No. 13; 1900, No. 1.



Figs. 224 and 225. Plan and Elevation of Uehling Casting Machine at Millom Ironworks.

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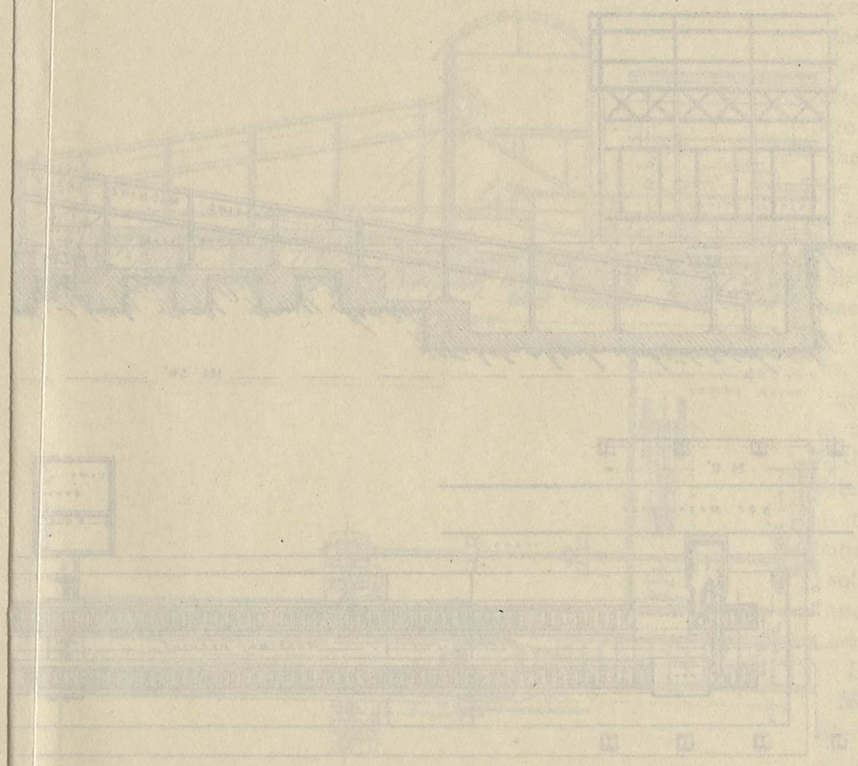


to be lowered into railway trucks. The different charges of the furnace being successively cast with this machine, the moulds are kept thereby at a low red heat.

To prevent the metal adhering to the moulds, they are coated by a spray on their return journey to the pouring pot. The capacity of the machine is 1,500 tons per day of twenty-four hours.

The "Uehling" machine at the Bethlehem Steel Co.'s Works, U.S.A., is 165 ft. long and travels at the rate of 22 ft. 6 in. per minute up the usual incline, the moulds being spaced at a pitch of 12 in. It is driven by a 40 H.P. electro-motor, and the capacity is twenty-three pigs per minute weighing 110 lb. each.

The "Heyl and Patterson" Casting Machine.—The first of these machines erected in this country was, it is believed, installed by the Palmer Shipbuilding and Iron Co., Jarrow-on-Tyne, and set to work in the beginning of 1899, at the Cambria Works. This

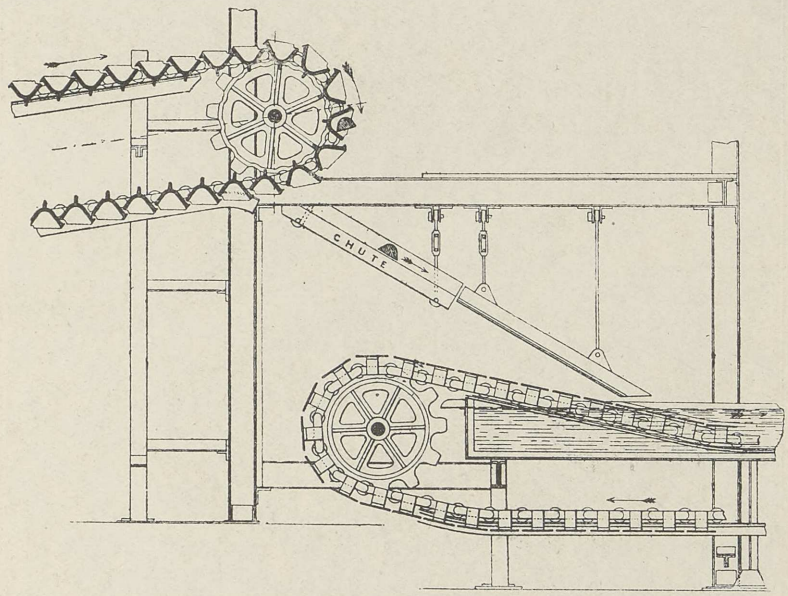


Fig. 228. Delivery of the Pigs from Casting to Cooling Conveyor.

machine, which is here illustrated, has a capacity of 1,500 tons in twenty-four hours. It consists of a steel frame, combining a water tank with an upper and lower track, upon which runs the chain carrying the pressed steel moulds into which the liquid pig iron is poured through the intervening runners. These are so arranged that the two or more rows of moulds can be fed simultaneously.

The principal feature consists in this, that the pouring of the metal takes place into moulds whilst partly submerged in the water contained in the tank. The moulds travel in that condition for a sufficient length of time to allow the metal to solidify, after which they are quite submerged and travel through the tank to nearly the other end of the machine, at which point the chains run up a slight incline to the loading end.

The moulds on their return journey pass over two furnaces in which crude oil or similar material is burning, and being still damp, readily receive a covering of soot which adheres to their interior and lips. The heat of the furnace also serves to so complete the drying of the moulds that they are ready for refilling.

Fig. 229 is a general view of the machine looking towards the delivery end, which shows clearly a portion of the moulds as they are partly submerged.

Fig. 230 is a view of the delivery end. The two strands of moulds are driven from one shaft by spur wheels, and are fitted with friction clutches so that either one strand or both may be used.

Fig. 231 represents two furnaces for drying and coating the moulds. These are mounted on wheels and can be withdrawn when the machine is out of work. The moulds as they leave the water tank travel up an incline sufficiently high to give easy discharge for loading into railway wagons, each being fitted with a pair of runner wheels, 8 in. in diameter, similar to the machine previously described.

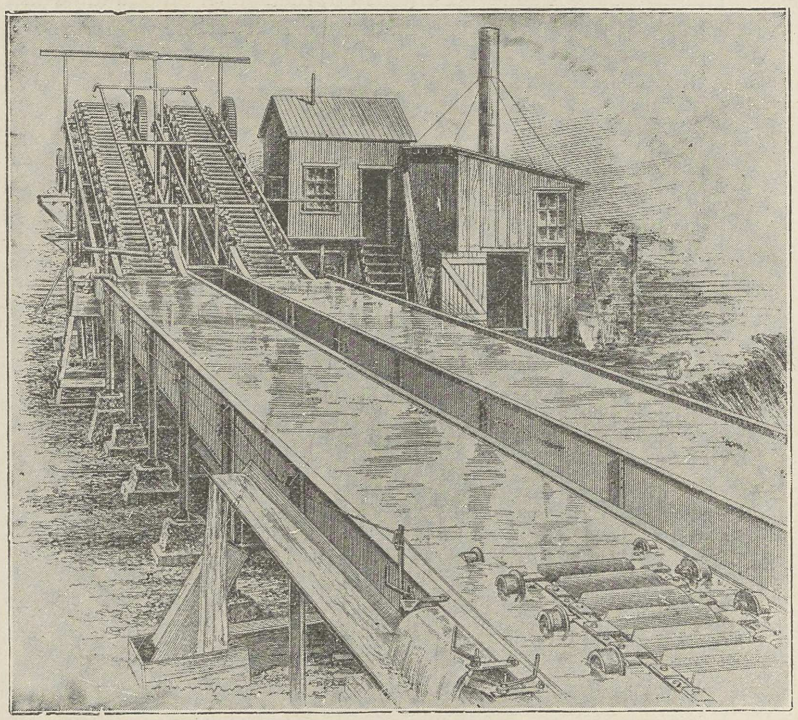


Fig. 229. "Heyl and Patterson" Machine looking towards Delivery End.

The chain consists of links of a 24-in. pitch which are joined together by pins 2 in. in diameter. The conveyor is not so long as in the "Uehling" machine, and the power consumed is 14 H.P.

The "Ramsay" Casting Machine.—This machine was built for the Tennessee Iron and Railroad Co., Birmingham, Alaska, U.S.A., and varies considerably in form from those previously described, though the principle itself is very similar. The "Ramsay" machine consists of a girder of an annular shape, the sides being of sheet steel, and riveted together with angle irons. The intervening space is intercepted periodically by steel staiths. This circular girder rests upon eighteen pairs of wheels, the axles being supported by bearings bolted to the girder. A section through the girder itself with its supports is shown in Figs. 232 and 233.

The moulds which receive the liquid metal are fitted with small trunnions which fit

into a pair of bearings on the rims of the circular table. The inner periphery of the circular girder is fitted with toothed segments, which form a complete circle for the purpose of revolving the whole apparatus. The toothed segments, which gear with the driving wheels are shown in *a*, Fig. 232.

Figs. 234 and 235 show the casting machine in plan and elevation. The plan also shows the engine coupled to three shafts, to the ends of which small spur pinions are keyed which cause the table to revolve in the direction of the arrow.

The filling device is shown in Fig. 232. The metal is poured first from a ladle into a chute A, by which it reaches the revolving filling drum B. The latter is driven by spur wheels, and the other side opposite to the drive is supported by three rollers fixed to the bracket C. Both A and B are lined inside with fireclay. The drum B has six radial apertures, and is caused to revolve at exactly the same circumferential velocity as the moulds, so that the six exits are, so to speak,

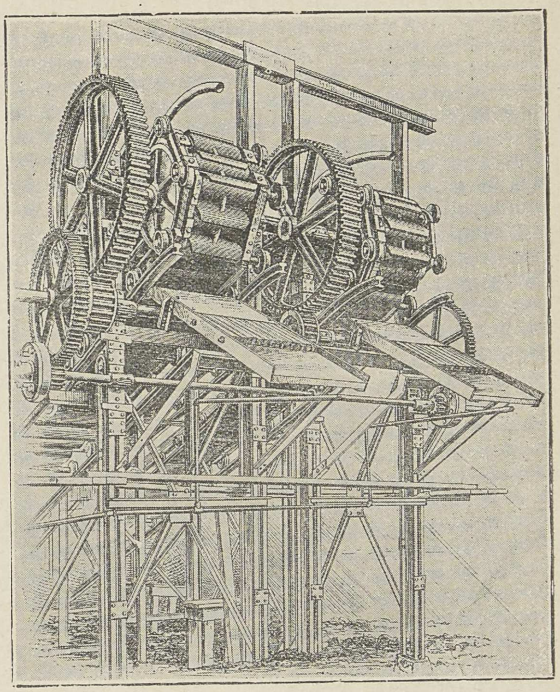


Fig. 230. Arrangement of Discharging End of "Heyl and Patterson" Machine.

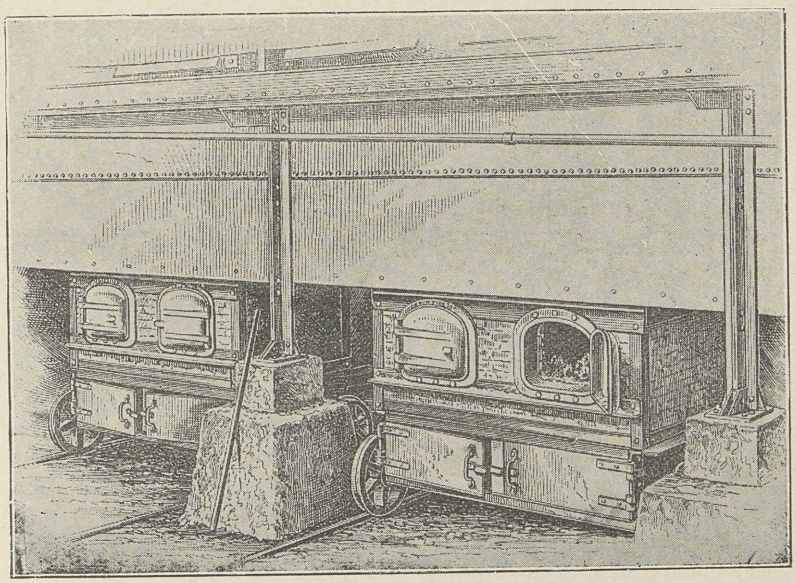


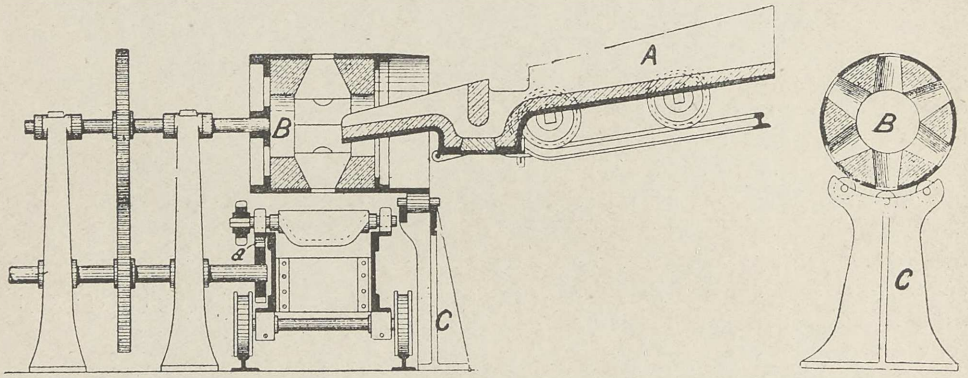
Fig. 231. Drying Furnaces for Moulds in "Heyl and Patterson" Casting Machine.

in pitch with the moulds, and the spilling of iron is thereby avoided, even if the moulds do not overlap each other, as is usual in some casting machines. The liquid metal in the moulds is cooled by sprays of water from a pipe which is shown in Fig. **234**. The delivery point is shown in Fig. **236**. A short length of tooth-rack *b* engages with the wheel keyed to one of the trunnions of each mould for the purpose of reversing it. At the moment of tilting, each mould receives a series of taps at the back from three hammers shown in the illustration.

Immediately behind the tipping device there is an appliance on the principle of an injector. This coats the interior of the moulds with lime water similar to the process employed in the "Uehling" machine.

The railway wagons in which the pigs are loaded are brought to the point of delivery through a cutting in the ground, as seen in Fig. **234**.

The "Hawdon" Slag Casting Machine.—This is the design of Mr William Hawdon, who has for some years been connected with Sir B. Samuelson & Co.'s Newport Iron Works, Middlesbrough. Fig. **237** gives a longitudinal view of the machine. AA are two endless chains made of long steel links fastened together by pins or rivets. B



Figs. 232 and 233. Filling Device of the "Ramsay" Casting Machine.

is the driving shaft. C are the two pulleys over which the endless chains pass. These pulleys are driven from shaft B by geared wheels.

The moulds which carry the slag are shown in plan and cross section in Figs. **238** and **239** as fixed to the chains. It will be seen that they are bolted on to a chain A by means of lugs on the under side.

The endless chains move in the direction of the arrow *a*. The slag is conveyed from the furnace by means of a trough F, whence it flows into the moulds which pass beneath it, then through the tank D, and on over the pulleys E. As the moulds pass over these pulleys the slag is tipped out in trucks, tip wagons, or other suitable vehicles, and is further cooled by means of water sprinkled from pipe H fixed over the truck F^1.

To take up any wear in the chain, a worm and worm wheel are placed at JKL. These are connected by means of links MN to the spindle of the terminal E, and the attendant can at any time adjust the chain as required.

This machine was originally devised for the purpose of saving the labour which is entailed in breaking up slag balls and wheeling them, by means of barrows, into hoppered barges for conveyance to sea, there to be tipped. But it is equally adaptable to cases where the slag is deposited on the ordinary slag tip or mountain.

The saving of labour and of the wear and tear of plant as against the ordinary

method of running into balls is claimed to be very considerable. The slag thus made is very suitable for road making, and especially for concrete, some thousands of tons having been sold for that purpose.

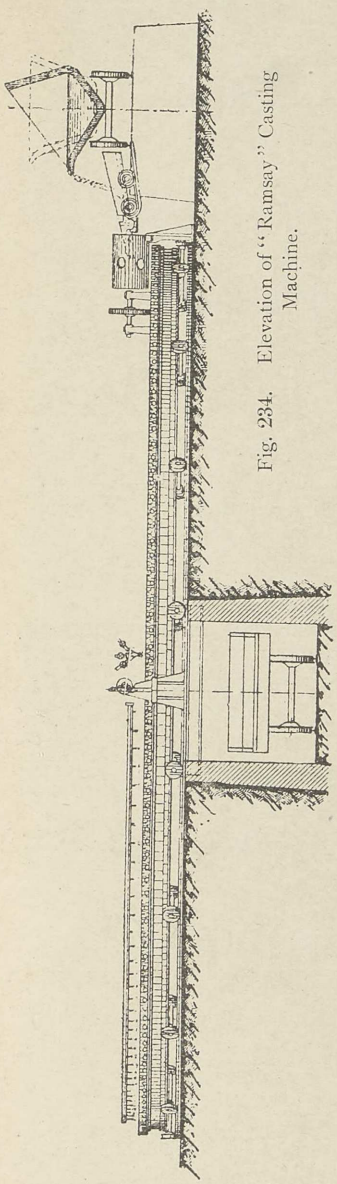


Fig. 234. Elevation of "Ramsay" Casting Machine.

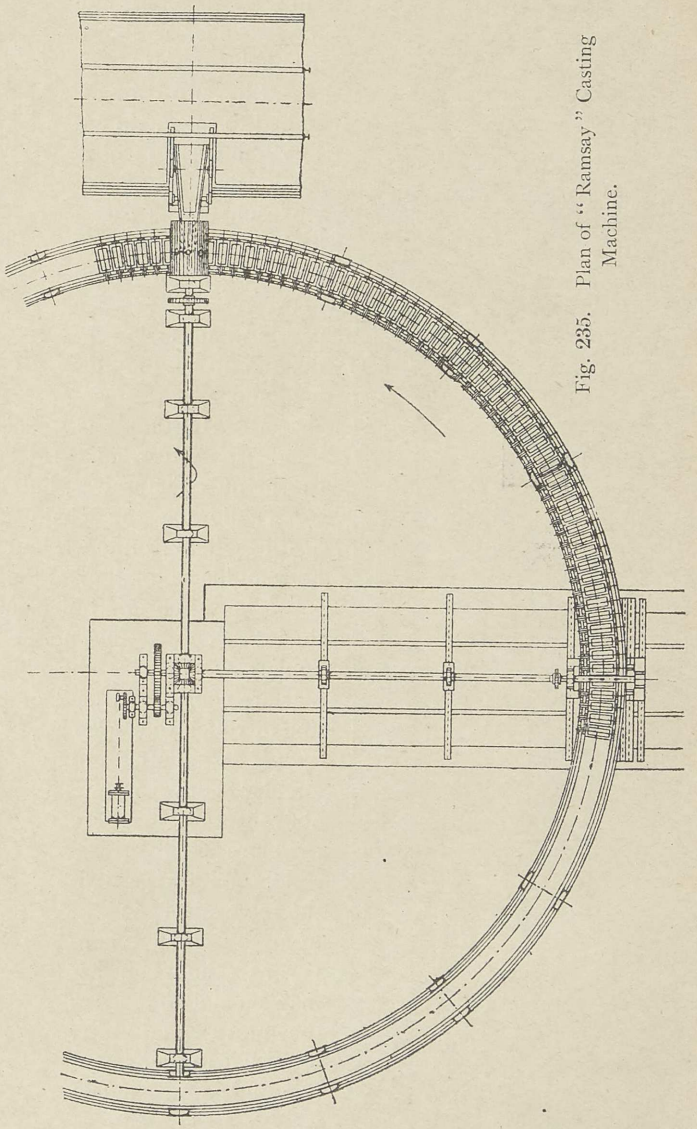


Fig. 235. Plan of "Ramsay" Casting Machine.

The "Hawdon" Casting Machine.—The machine illustrated in Figs. 240 and 241 is by the same designer as the machine previously described.

The general design of this pig-iron casting machine is much the same as that of the older type of slag machine, but it has been arranged more particularly for dealing with iron, and also with a view to keeping the moulds dry on their return for refilling.

The moulds in the slag machine are dipped in water, while in the machine for iron they are to be kept dry. A secondary machine of circular shape is used for the cooling process. The pigs, when cool, are discharged from the circular conveyor, and ascend the elevator into railway wagons, as shown in the illustration.

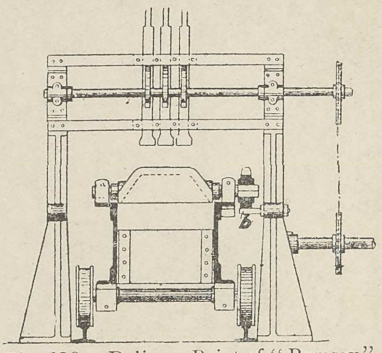


Fig. 236. Delivery Point of "Ramsay" Casting Machine.

The moulds attached to the chain are very similar to those previously described. On each one is cast a lip to prevent the flowing iron from falling between them as they pass in succession to the mouth of the tilting ladle.

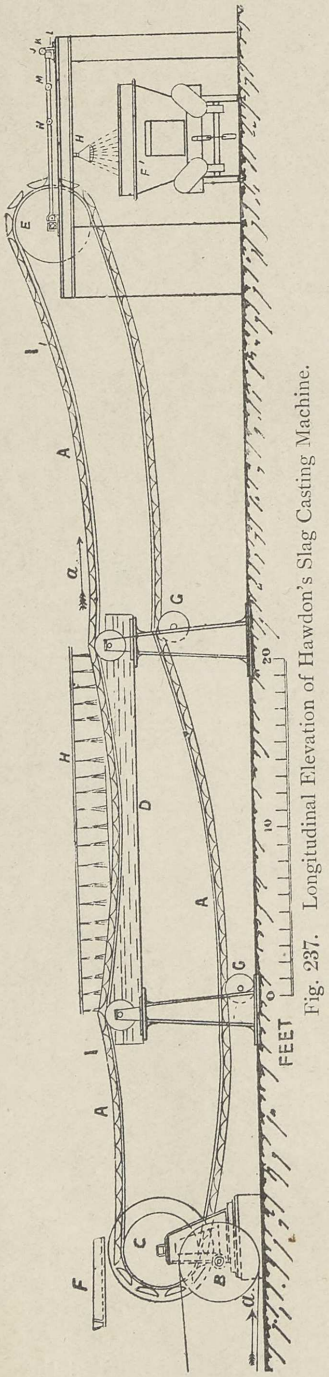
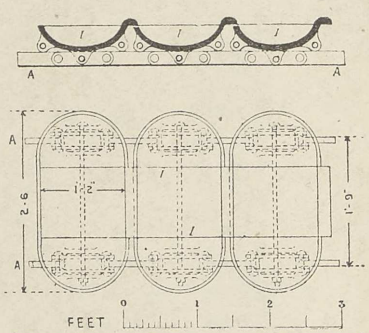


Fig. 237. Longitudinal Elevation of Hawdon's Slag Casting Machine.

Mr Hawdon has specially provided for the heavy weight to be carried. He has not attached the rollers to the moulds themselves, but has fixed them to the framework, allowing the chain to run over the rollers, the bearings being of brass, and at such a distance from the hot moulds as to allow of the free use of lubricant.

The supporting rollers are placed at frequent intervals, thus preventing any undue wear on the chains. This applies as much to the circular conveyor, on which the pigs are cooled in a tank of water, as to that in a straight line in which they are cast.

It is important to notice that all the bearings in the circular conveyor are above water, and are therefore easily accessible. With regard to the removal of the pigs from the circular conveyor to the wagons, it may be noted that, as they move round under water with the conveyor, they come in contact with a fixed plate or plough which pushes them off and into the elevator which delivers them on the wagons placed alongside.



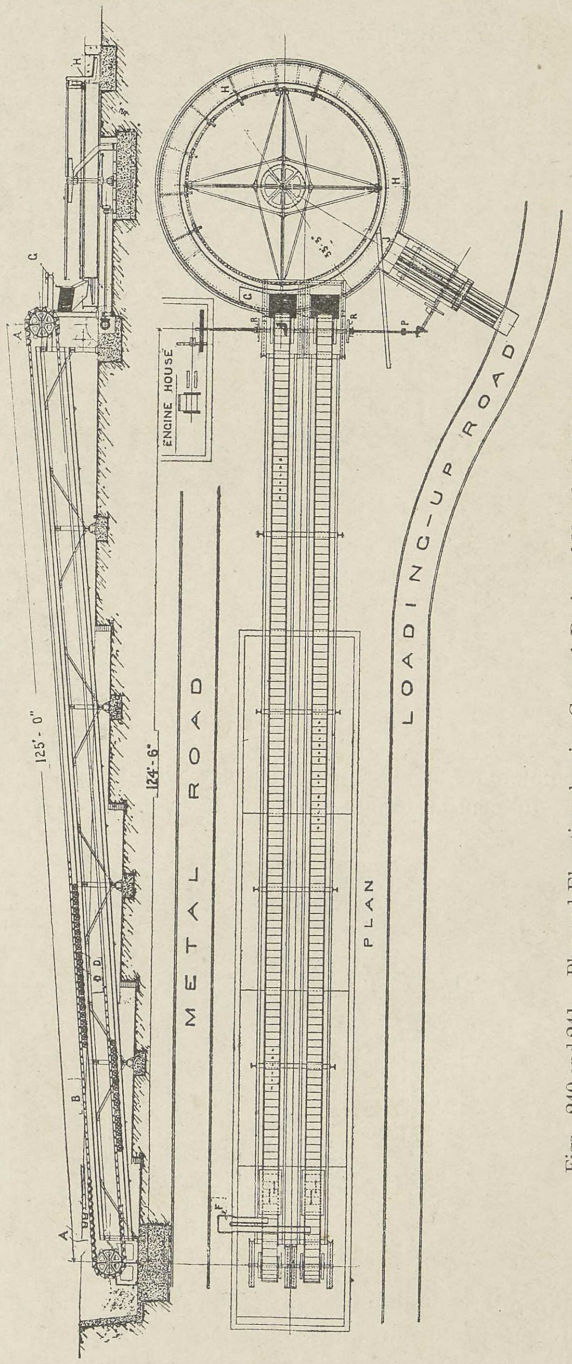
Figs. 238 and 239. Moulds of Hawdon's Slag Casting Machine.

Fig. 242 represents this elevator as used for loading the pigs from the cooling conveyor.

Figs. 243 and 244 give some of the details of the conveyor itself.

The lettering given below describes the different parts of the machine, and refers to Figs. **240** to **244** :—

A. Moulds. B. Chain carrying moulds. C. Brass block fitted into chain to take the wear of the pin. D. Rollers carrying chain. E. Brass bearings for roller shaft. F. Spout to convey metal from ladle to moulds. G. Shoot to convey pigs to cooling conveyor. H. Table of circular conveyor or cooler. J. Inclined plate or plough, which removes pigs from cooling conveyor to elevator. K. Elevator which lifts pigs into trucks from cooling conveyor. L. Fixed bars between which the elevator works. M. Rake of elevator. N. Shoot. P. Clutch for driving elevator. R. Sprocket wheels.



Figs. 240 and 241. Plan and Elevation showing General Design of Hawdon's Pig-Iron Casting Machine.

The Casting Machine of the Ironworks of the Aplerbecker Hütte. — This machine was built by the Deutschen Machinenfabrik A. G. The essential features of this machine consist of two comparatively small turntables placed close together, the outer circumferences of which are fitted with tipping moulds for the iron. The liquid metal is led to these turntables by an oscillating trough with two side and one end outlets. This trough receives a rocking motion round its longitudinal axis, so that the two side outlets discharge the metal into the receptacles of each table alternately. It will thus be seen that the tables (each of which has 64 moulds on its circumference) are stationary during the pouring process, and whilst the mould of one is filled the other table is moved forward presenting a fresh mould to the rocking shoot, which is immediately reversed and fills it. When the moulds have passed 270°, or three-quarters of a revolution of the table, and the iron has congealed, the moulds are here turned 180° and tapped to release the pig into an iron wagon underneath. The moulds remain in their inverted

position for the remainder of their journey, during which they are coated with a spray of lime water.

Unlike the Ramsay machine already described, which has about 200 moulds in its

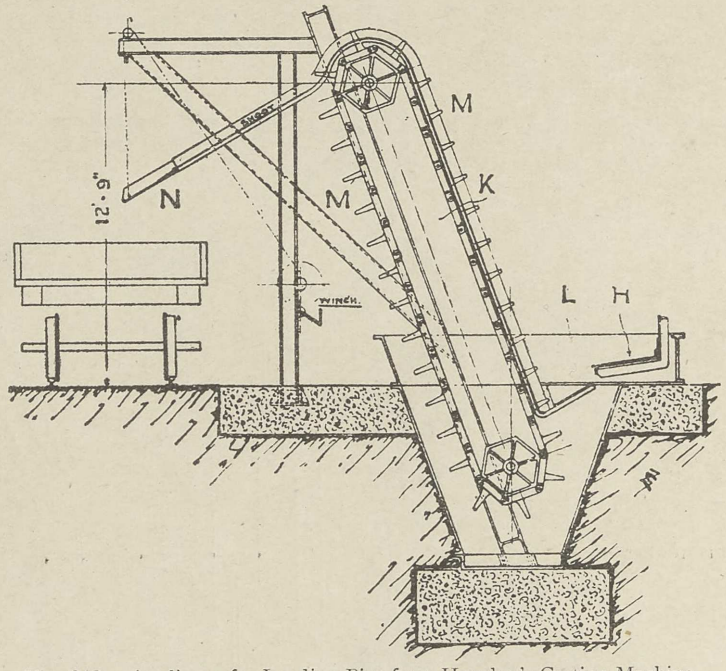
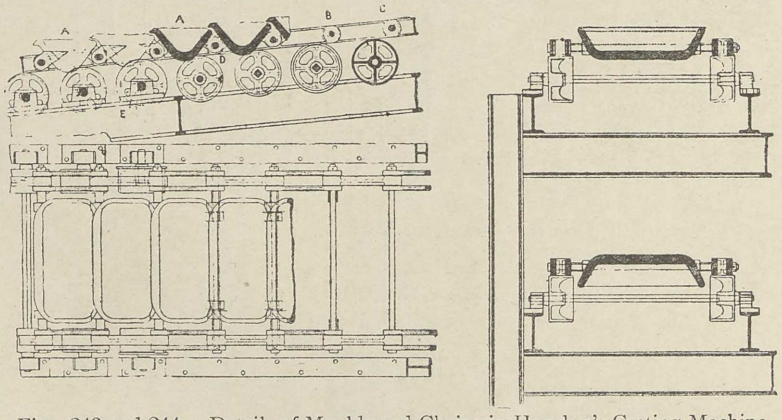


Fig. 242. Appliance for Loading Pigs from Hawdon's Casting Machine.

circumference, and which runs on rails, the present machine is supported by a very powerful central upright shaft, to which the circumference is suspended by steel structural



Figs. 243 and 244. Details of Moulds and Chains in Hawdon's Casting Machine.

work, and in addition is supported by rollers. The outer trunnion of the moulds carries a star-like attachment which encounters on its journey a fixed tripper at the discharging point, and a bent channel keeps the moulds in this position until another tripper just before the pouring point brings them into their original position ready to receive another charge.

All the movements are actuated by hydraulic machinery. The turntables revolve by means of an oscillating pawl engaging a toothed wheel.

Should any hitch occur to either of the turntables during the pouring of the metal, the driver of the machine can set the pouring trough into a middle position and discharge the metal by the end shoot already mentioned and let it run into an emergency pig bed beyond the two turntables, so that the rest of the iron in the pouring pot can be disposed of.

A machine on the same principle has since been built by this firm for the Westphalian Iron Works which is reported to be a success, the only difference being that hydraulic power has been discarded in favour of electricity.

CHAPTER XV

MISCELLANEOUS CONVEYORS, MOSTLY FOR SPECIAL PURPOSES AND NOT CLASSIFIABLE UNDER ANY OF THE PREVIOUS CHAPTERS

Roller Conveyors, Live Rollers, or Roller Trains.—These differ from roller runways in the important detail that the rollers are mechanically driven, and the revolutions of the rollers carry the material forward, either on the level or on an upward or downward gradient, whereas in the roller runway (see page 197) the object to be transported travels by its own gravity over a series of rolls down an incline, the load revolving the rollers as it passes over them.

Roller ways without driving power can be, and indeed are, used on the level or incline in connection with rolling mills where red-hot girders newly rolled are pushed over such roller ways, but in these cases the rolling mill furnishes the driving power and conveys it to the small rollers by the object itself, the rollers merely reducing friction or resistance which would otherwise be offered to the progress of the rolled bar, girder or rail.

Power driven roller conveyors are used in plate glass factories, in rolling mills for handling ingots, and in engineering works, to take away the products of cutting shears, saws, or other machine tools; carrying away objects in course of manufacture which are too heavy or bulky to be easily removed, and which, if not continuously cleared away, would encumber the machine tools producing them. The upward gradient for these roller conveyors is limited by the amount of friction between the rollers and the material.

The original type of such roller conveyors is exceedingly simple in principle, but not in construction. The rollers are placed fairly close together and each is driven by a pair of bevel wheels from a small shaft which runs alongside at right angles to the roller spindles and forms a portion of the conveyor. The rollers, of course, all revolve in the same direction and must therefore not touch each other. The difficulty in the construction is principally due to the close proximity of the parts to each other, and as the driving wheels should be smaller in diameter than the rollers, in order that they should not project above them and thereby obstruct the passage of the material conveyed, or be exposed to damage, the rollers must either be larger than would otherwise be necessary, or the wheels must be very small.

The "Thomas" Roller Conveyor.—A great improvement in this type of conveyor has been made by the Belgian engineer, A. Thomas, who has overcome the difficulties above referred to as will be seen from the conveyor illustrated in Fig. **245**. Here the rollers are all loose, *i.e.*, they do not run on axles or bearings, but revolve on rotating rings, every fifth or sixth pair of rings being driven by a pair of mitre wheels; the rings with their driving spindle being on a lower level than the rollers, give ample space for fair sized mitre wheels without their projecting above the carrying plane, level with the top surface of the rollers. The upper of the two cross sections (see Fig. **245**) shows one of the driven pair of rings, while the other cross section shows a pair of the loose rings, unconnected with driving power. The working of the conveyor depends on the driving

power that is imparted to one pair of rings being conveyed by one of the rollers placed loosely upon this pair and the next, so that the next pair of rings is revolved by the roller resting on top; in like manner is the rotating power transmitted by the second pair of rings to the second roller placed upon them, and the third pair, and so on. The rollers are reduced at both ends where they rest on the rings, so that the material conveyed cannot damage the surface which revolves on the rings.

The advantages over the old type are smooth running, and therefore smaller expenditure of driving power, smaller initial cost, and infinitely less expenditure for repairs, for if one of the rollers should be broken or damaged it can simply be lifted out and a spare one dropped into its place.

One of these conveyors has been at work at the Société Anonyme d'O Ugree-Marihaye since 1909; it is 225 ft. long and consists of 277 rollers each 8 in. in diameter, and placed at a pitch of 10 in., every seventh pair of rings being fitted with a driving

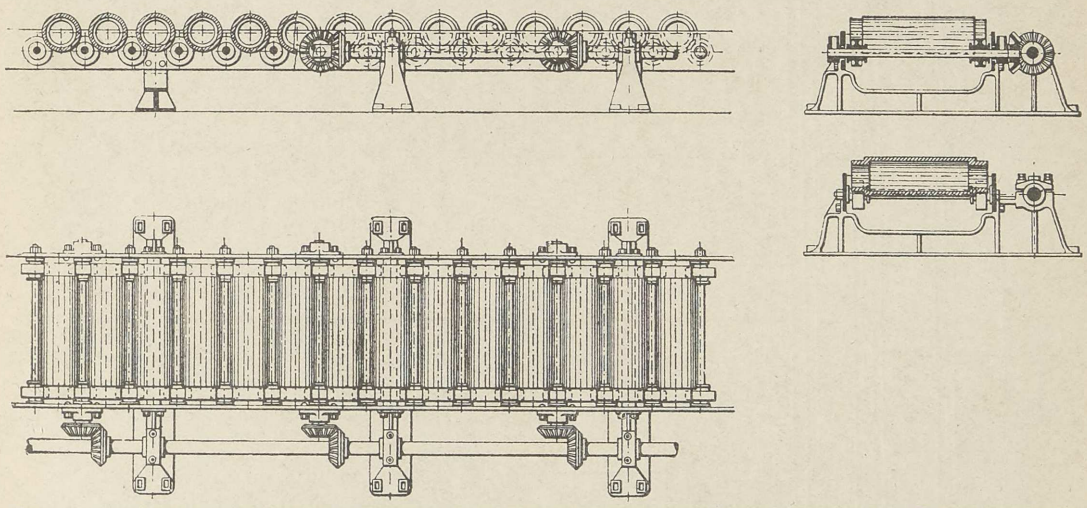


Fig. 245. The "Thomas" Roller Conveyor.

wheel. The material conveyed is bloom crop cuttings, and the driving power required is 20 H.P.

Bolinder Timber Conveyors.[1]—These conveyors are made on the same principle as the live rollers or roller trains, only as the timber so conveyed is always in long lengths the rollers are much further apart.

A conveyor of this type was in use at the Millwall Docks for many years for conveying boards, but unfortunately it was destroyed by fire in 1912. These conveyors are somewhat on the principle of a band conveyor; but whereas in the band conveyor the band is driven, and causes the supporting rollers to revolve, in the Bolinder conveyor the rollers are made to revolve, and thus propel the boards placed upon them. Fig. **246** shows a section through the conveyor on its supporting structure, with the elevators which lifted the boards on to the conveyor. It also shows another section and a longitudinal elevation of the conveyor.

The rollers AA were of cast iron, and 10 in. in diameter by 2 ft. 6 in. long, pitched 5 ft. apart, and driven by a small steel shaft about 1 in. in diameter, running the whole

[1] *Timber Trade Journal*, 13th July 1901.

length of the conveyor, each roll being geared to this shaft by a pair of bevel wheels with a ratio of about 3 to 1.

The rollers projected slightly through the bottom of the trough, in which the boards travelled at the rate of 150 to 200 ft. per minute, the rolls themselves making 60 to 80 revs. per minute. The boards to be conveyed must be more than 10 ft. long, so as always to rest on not less than two rollers.

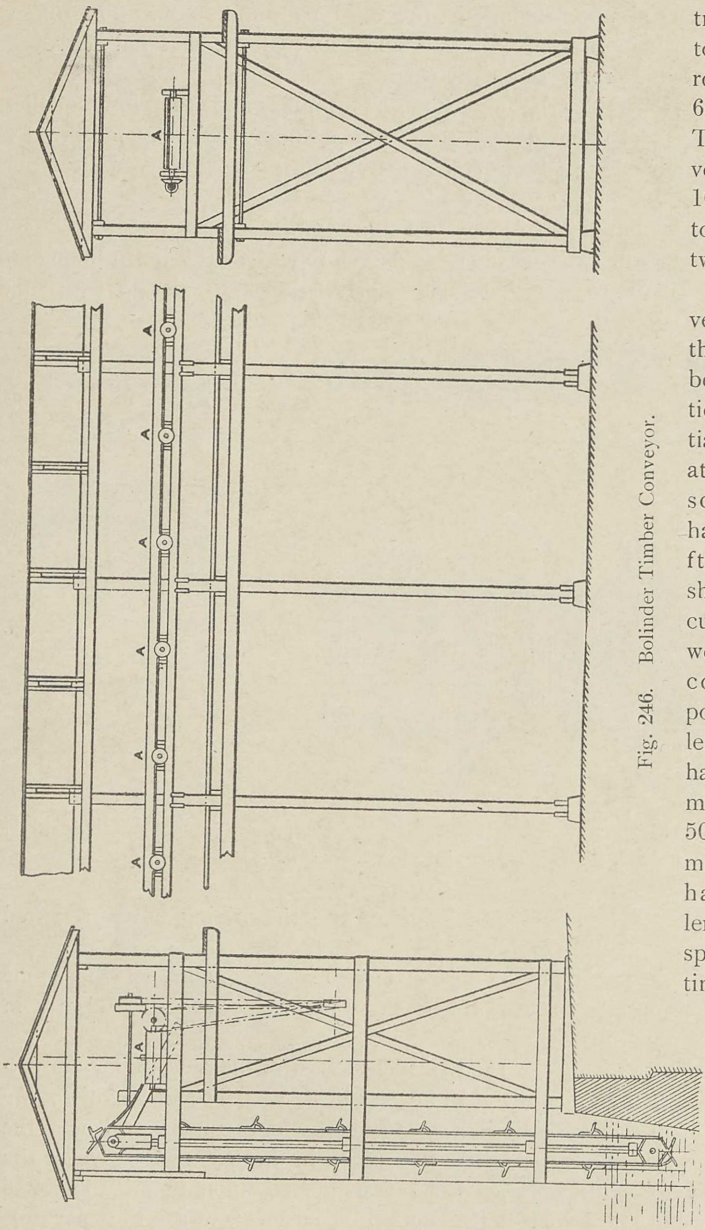


Fig. 246. Bolinder Timber Conveyor.

These conveyors are very simple and effective, the most remarkable feature being that their construction admits of their negotiating curves. (The one at the Millwall Docks described several curves having radii of 170 to 190 ft.) The steel driving shaft is sprung into these curves and appears to work well, though no doubt it consumes more driving power than the straight lengths. The conveyors have a separate electromotor of 5 H.P. for every 500 ft. of their length, the motor itself being placed half way. Successive lengths of 500 ft. are speeded to convey the timber at 180 and 200 ft. per minute respectively. These conveyors will deliver about 200 standards[1] of 5-in. by 7-in. "battens" in ten hours, and other sizes in proportion.

Fig. 247 shows a general plan of that portion of the Millwall Docks where the Bolinder conveyor was at work. The line indicated by arrows illustrates the whole length of the conveyor with its curves.

[1] One standard of wood is 120 pieces 12 in. long by 11 in. wide and 1½ in. thick, or its equivalent, *i.e.*, 165 cub. ft. of timber. 3·3 standards make up one load.

Fig. **248** shows a photographic view of the same conveyor.

Fig. **249** represents the delivery appliance by means of which the planks are lowered

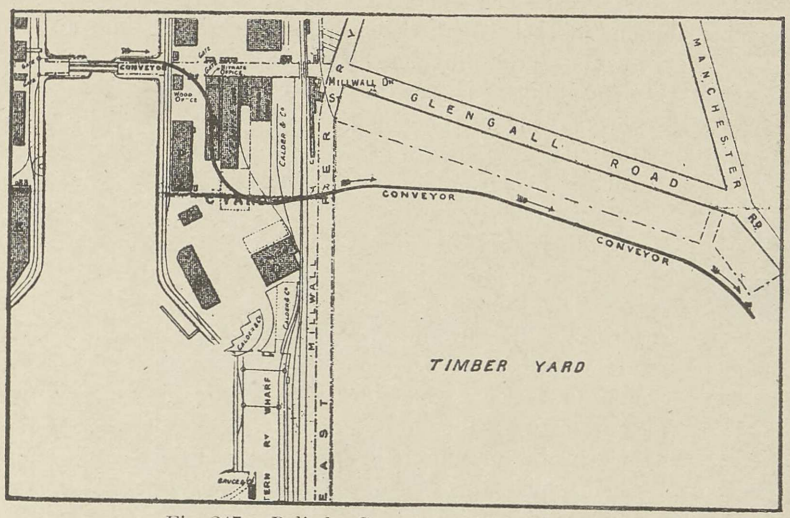


Fig. 247. Bolinder Conveyor at Millwall Docks.

to the ground. This appliance is movable and runs on a single rail, so that it can be put into any position.

Fig. **250** gives a photographic view of the same lowering device.

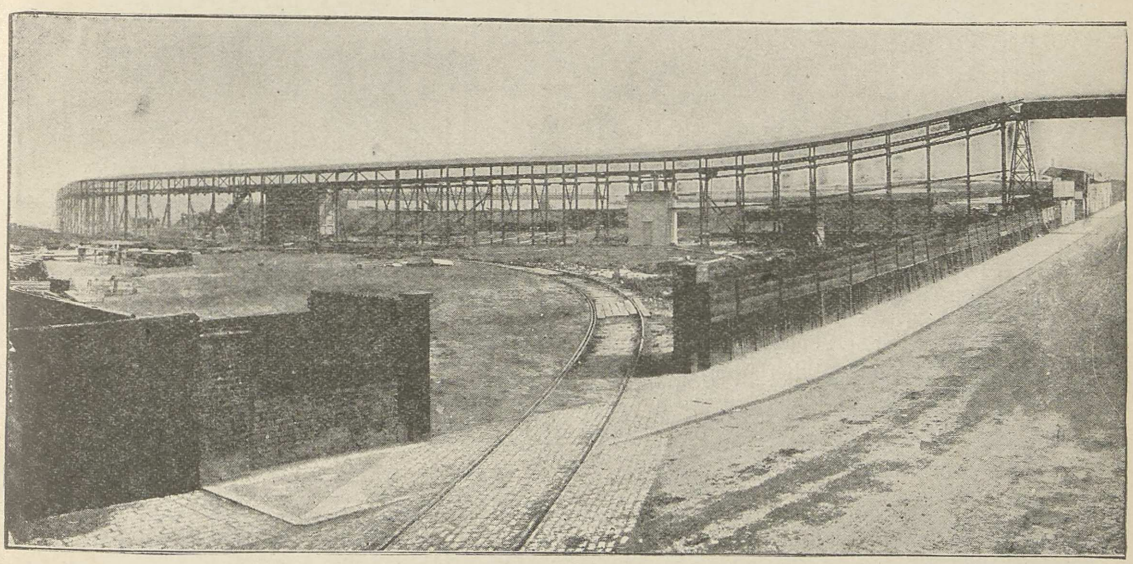


Fig. 248. Bolinder Timber Conveyor crossing Great Eastern Railway and East Ferry Road.

A portable conveyor on similar lines is built by Messrs Bolinder, movable on wheels, for use in timber yards. Fig. **251** illustrates this appliance, which practically explains itself. Its principal feature is this, that it is built in such a way as to allow of its temporary erection at different parts of the timber yard. The time taken in connecting,

say, 100 ft. of this conveyor would be about twenty minutes. The conveyor is built in sections (one of which is represented in the illustration). They are each 20 ft. long, and are joined together by steel cotters. The respective lengths of shafting are also coupled together, the end of each length being square, and fitting into a square socket on the succeeding length of shafting. These conveyors will deliver about 100 standards of 3-in. by 7-in. "battens" in ten hours, while the capacity on other sizes of timber would be in proportion.

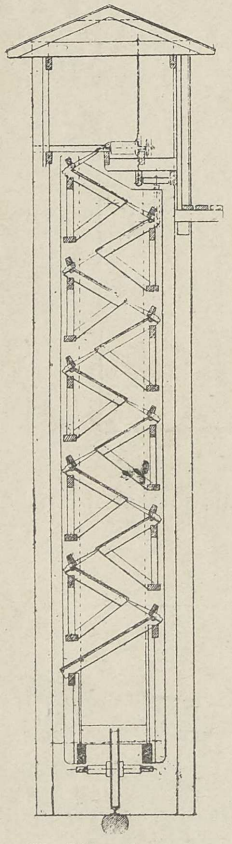


Fig. 249. Lowering Appliance in connection with Bolinder Timber Conveyor.

The same firm have also recently introduced a new timber conveyor which appears to be a great improvement on the old one. It consists of an endless chain which runs over two terminal pulleys of suitable design. The chain itself consists of a series of rollers, the distance from roller to roller being about 3 ft.

Fig. **252** shows details of the chain; also special link with rollers.

Fig. **253** shows a portion of the conveyor as mounted in the timber yard.

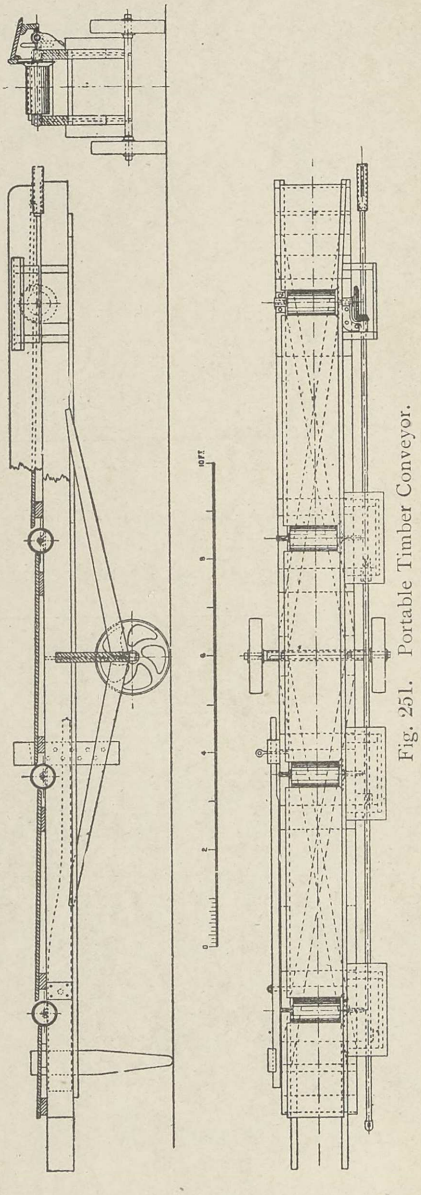


Fig. 251. Portable Timber Conveyor.

It will be readily understood that as the conveyor is set in motion, the rollers, which run on supporting timbers, revolve, whereupon the timber to be conveyed is not only carried by the rollers, but is also pushed forward by virtue of the revolution of the rollers, so that its progress is considerably accelerated. The chain has a speed of 90 ft. per minute, and the timber is conveyed practically at 180 ft. per minute. These conveyors are built in lengths of 1,000 ft., with one driving gear. Such a length is said to take 6 H.P. to drive. The total length of such conveyors, composed of coupled units of 1,000 ft., is unlimited, and if driven by electro-motors the driving arrangements will require very little preparation. They pass round curves with a radius of not less than 150 ft. for deals 30 ft. in length by 1 ft. wide. Longer deals would require a greater radius in proportion.

In addition to the advantage already mentioned of greater speed of delivery, it has the further advantage that both top and bottom strands can be used for conveying. It is obvious that when two or more conveyors are coupled together the timbers will readily travel from one length to another; but where the lower strand is also to be used for conveying, small auxiliary conveyors are used to remove the timber from the lower strand past the terminals to the lower strand of the next conveyor.

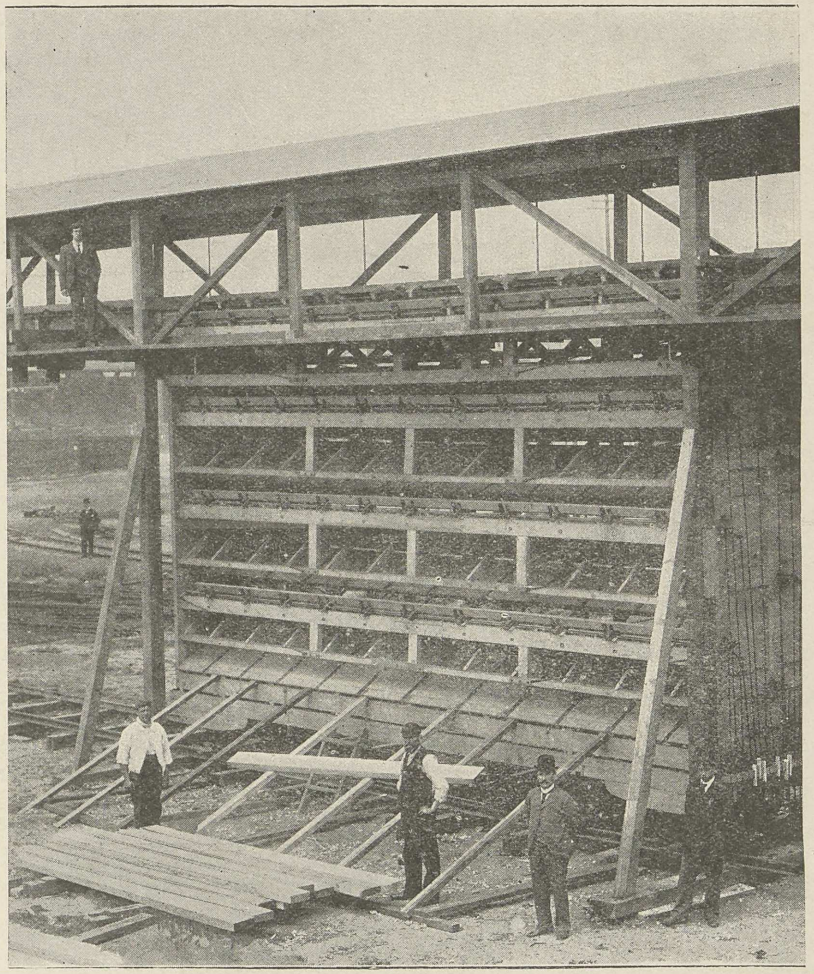


Fig. 250. Photographic View of Lowering Device in connection with Bolinder Conveyor at Millwall Docks.

The capacity of this new conveyor is 160 standards in ten hours.

There are many other conveyors in use for conveying timber, principally in the timber districts of America and in the vicinity of the Baltic Sea. These are not, however, individually described, as they do not present any new features. They are all more or less of the same type as the trough cable conveyor, and work in pairs or in greater numbers. The attachments are so pitched as to simultaneously engage with beams or planks, and so convey them up inclines or in a horizontal direction. Very frequently

pitch chains are used instead of cables, when the attachments are not in the form of discs, but rather in the shape of claws (see page 68).

Conveyors for Bottling Stores, etc.—Among the smaller industries into which conveyors have found a ready introduction is the bottling industry. The principal conveyors used are the roller runways and the slat or tray conveyor.

Fig. **254** illustrates a double service conveyor installed in the bottling stores of the Manchester Brewery Co., Ltd. An unusual feature in this case is the loop standing out at right angles to the main body of the conveyor. The chain used is the Dodge cable

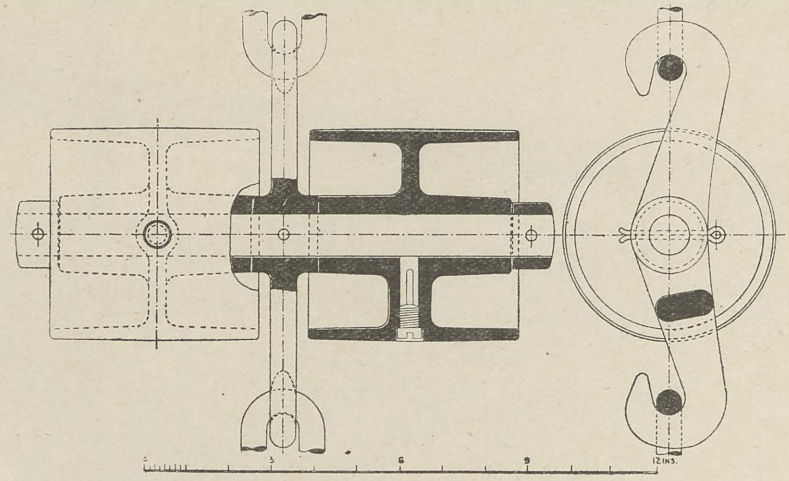


Fig. 252. Latest Type of Bolinder Timber Conveyor.

type with renewable malleable-iron bearing blocks. This chain, being flexible in two planes at right angles to each other, is not compelled to move in a horizontal path. Thus the direction of motion may be partly horizontal and partly inclined, and the axes of the

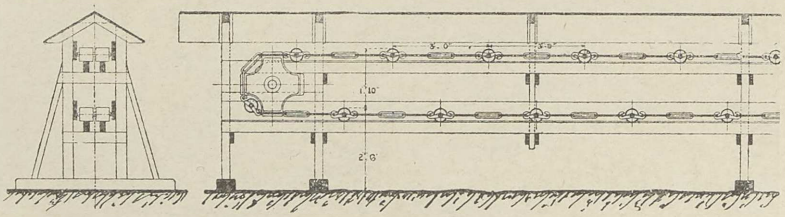


Fig. 253. Latest Type of Bolinder Timber Conveyor as used in Timber Yards.

terminal shafts may also be inclined, though usually vertical. It is driven by a 5 H.P. direct current electro-motor, and was erected by the Chain Belt Engineering Co., Derby.

Another interesting example of a double service conveyor is in a mineral water factory.

In this instance one strand runs down the centre of the factory while the return strand runs along an external loading-out stage, from which motor wagons receive their supplies. Thus the same conveyor is utilised both to take returned empties into the building and to carry full boxes to the various vehicles ranged alongside the stage in the yard. The striking economy and convenience of this method of working is obvious, in comparison with the old method of trucking in and out by hand

A third example of a double service conveyor is that in which the conveyor connects two buildings separated by a yard. It carries washed bottles in a continuous stream from the washing machines in one building and over a bridge to the filling machines in

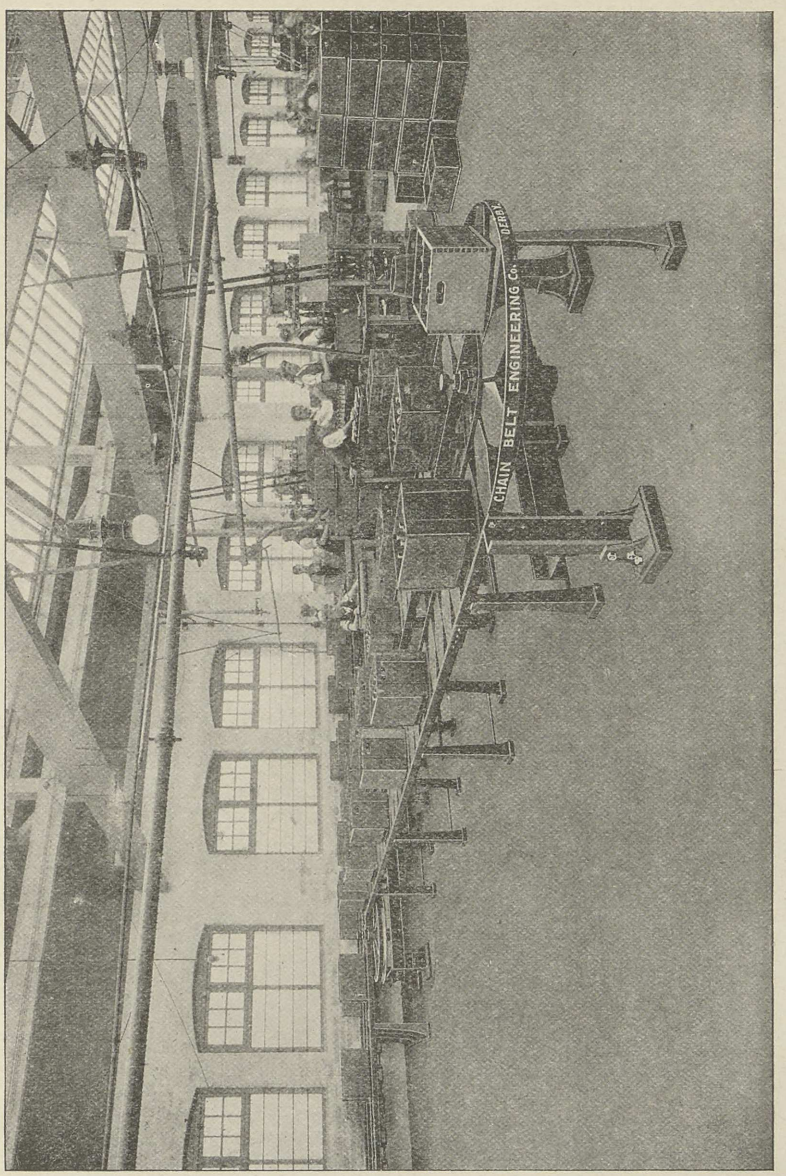


Fig. 254. Double Service Slat Conveyor in a Bottling Store.

another building at the rate of 240 bottles per minute, or 14,400 per hour, the chain speed being 40 ft. per minute. During the journey the inverted bottles are draining, and there is always a reserve supply of clean bottles on the conveyor for the fillers to draw upon without labour or waiting.

Fig. **255** shows a double service slat conveyor for bottles, illustrating the driving gear.

It also shows one of the roller runways for the cases containing full bottles. The conveyor is arranged for labelling the bottles during their conveyance. The installation is at the Manchester bottling store of the Cornbrook Brewery Co., Ltd., and is the work of the Chain Belt Engineering Co., of Derby.

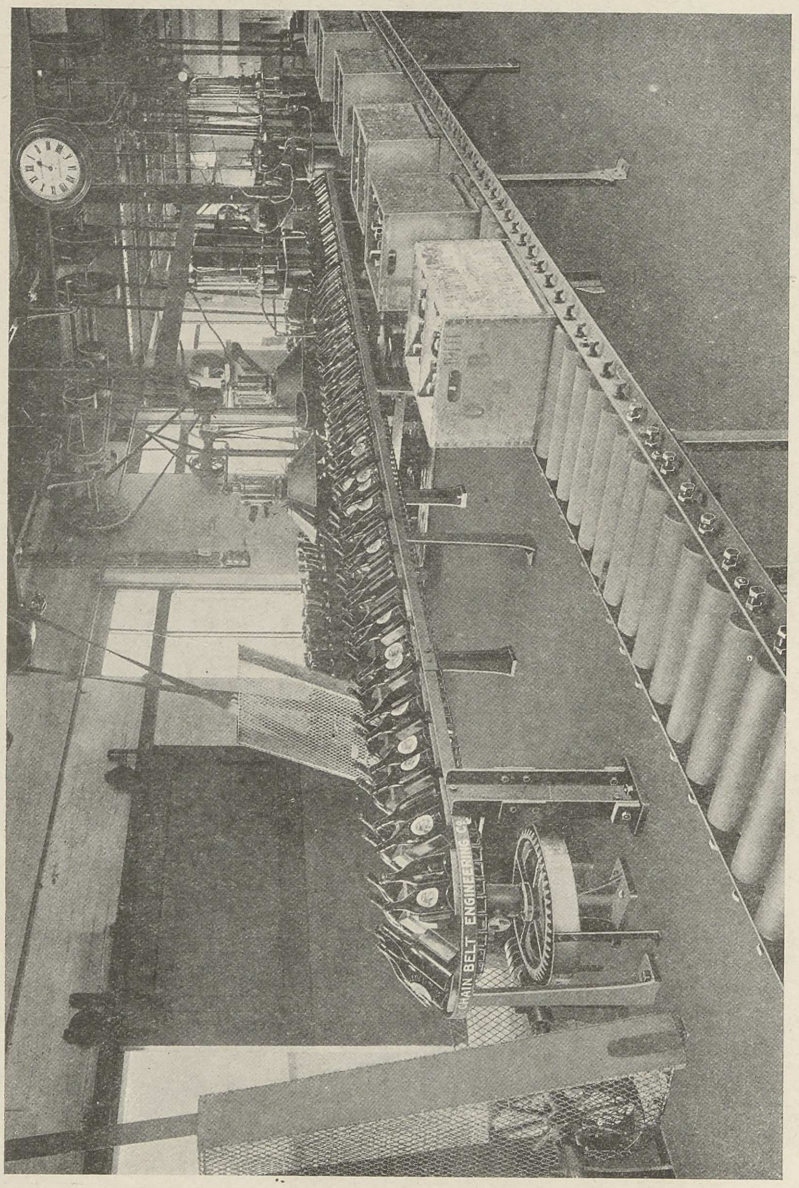


Fig. 255. Double Service Slat Conveyor and Roller Runway in a Bottling Store.

CHAPTER XVI

TIGHTENING AND EQUALISING GEARS FOR ELEVATORS AND CONVEYORS

TIGHTENING GEARS

THE same sort of tightening gears can be used for a variety of elevators and conveyors. Those shown in Figs. 3 to 6, page 12, are also suitable for small conveyors, but the adjustment will not allow of great latitude.

The tightening gear shown in Fig. **256** is more suitable for tightening a conveyor chain or band, although as shown it allows of only a short movement. Tightening gears of the same design can be made of much greater lengths. The adjustment screw is fitted with a nut, so that the position, once adjusted, can be firmly secured. The screw can also be fitted with a hand wheel, which is often more convenient.

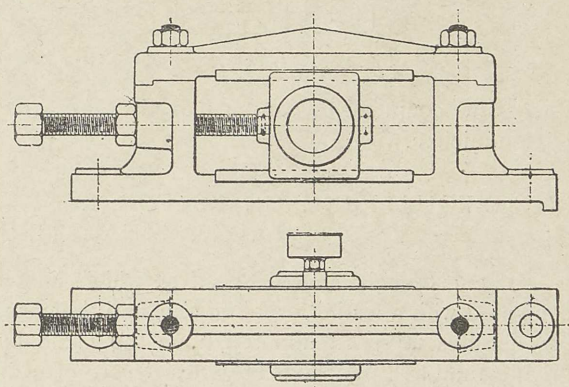


Fig. 256. Tightening Gear for Conveyors.

Fig. **257** shows a similar tightening gear, manipulated by screws and hand wheel. This gear is particularly suitable for long conveyors where a great deal of adjustment is required, as the position of the tightening gear can be altered on a base plate into a variety of places.

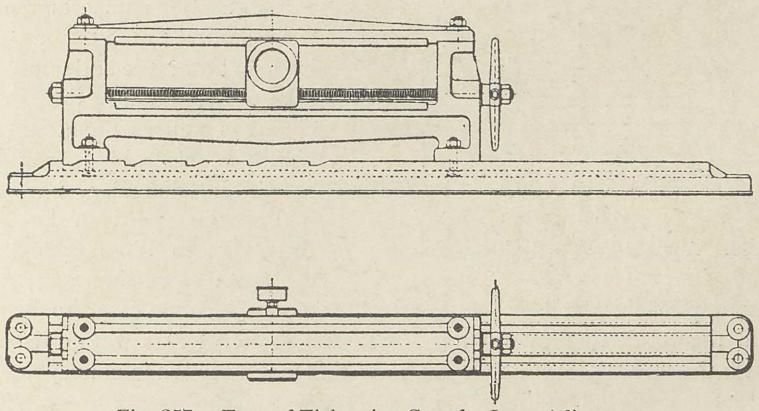


Fig. 257. Type of Tightening Gear for Long Adjustments.

The band or chain should always be tightened at the terminal opposite to that carrying the driving pulley, but where this is not practicable the gears shown in Figs. **258** and **259** are suitable for the driving end of elevators or conveyors in cases where

the respective machinery is driven by spur gear and countershafts. It will be seen from the illustrations that the tightening gears consist of two bearings movable in a sliding frame, the two bearings being movable together in the correct position corresponding to the radii of the spur gears, so that when the chain requires tightening both terminal

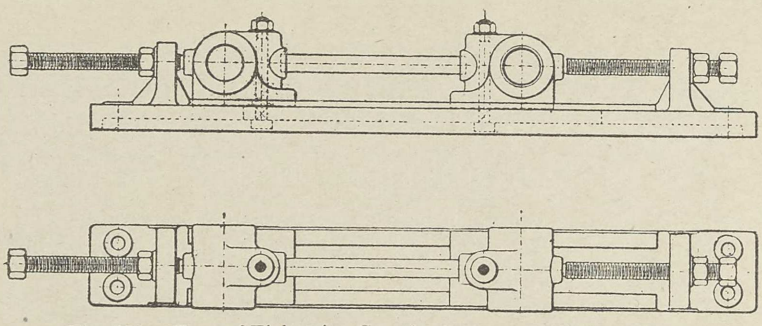


Fig. 258. Type of Tightening Gear for Conveyors with Spur Gears.

wheel and countershaft can be moved at the same time. These types are the designs of Commichau.

SPEED-EQUALISING GEARS FOR LONG-LINK CHAINS DRIVEN FROM HEXAGONAL TERMINALS

The extremely limited speed at which long-link chain conveyors can be run, as compared with a leather or fabric one, and the consequently limited output, is due to the irregularities in speed imposed upon the chain by the necessarily non-circular form of driving tumbler. To take the special case of a five-sided tumbler, it may be of interest to point out that the velocity of the belt, when the tumbler is rotating at uniform angular speed, varies as much as 25 per cent. during the cycle caused by the passing of a single cant of the tumbler, or with an hexagonal tumbler as much as 15 per cent. This imparts a pulsating or jerky motion to the chain. It will thus be seen how rattle and consequent wear take place, and how the strain on the chain as well as the driving power is hereby considerably increased.

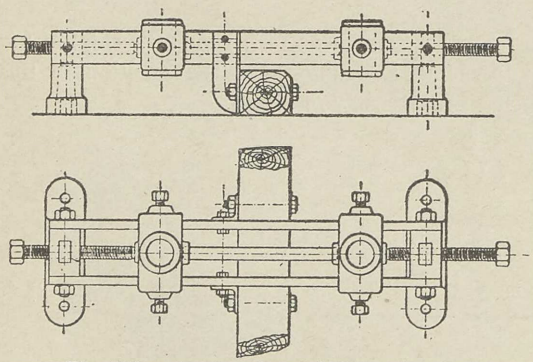


Fig. 259. Another Type of Tightening Gear for Conveyors.

This difficulty has practically limited the speed of long-link chain conveyors to 100 ft. per minute, and the speed-equalising gear, by compensating accurately for this, enables the permissible velocity in some cases to be practically double, with the result that a conveyor of half the sectional area will do the work when provided with this gear. It will thus be seen that not only is the conveyor itself much cheapened but a great lightening of the supporting structure results from the decreased weight of unit length of conveyor.

The Toogood Gear.—The equalising gear, introduced by Mr H. J. Toogood, ensures uniformity of speed of the conveyor chains even when long-linked chains and hexagonal terminals are employed, and enables lighter chains, with long links, to be

adopted without making the terminals unduly large in diameter, thus reducing the number of wearing parts, and in consequence securing economy in first cost, is illustrated in Fig. **260**. The countershaft A is driven by belt or gearing, at a constant speed; a second countershaft B is geared to the terminal spindle C in the ratio of 1 to 6, so that B completes one revolution every time a point of the hexagonal terminal is uppermost. The two spindles A and B are geared together by wheels of equal diameter, which are bored sufficiently out of centre to make the ratio of d^1 to d^2 vary inversely as the radius of the terminal, while D, the distance from centre to centre of the countershafts A and B, remains constant.

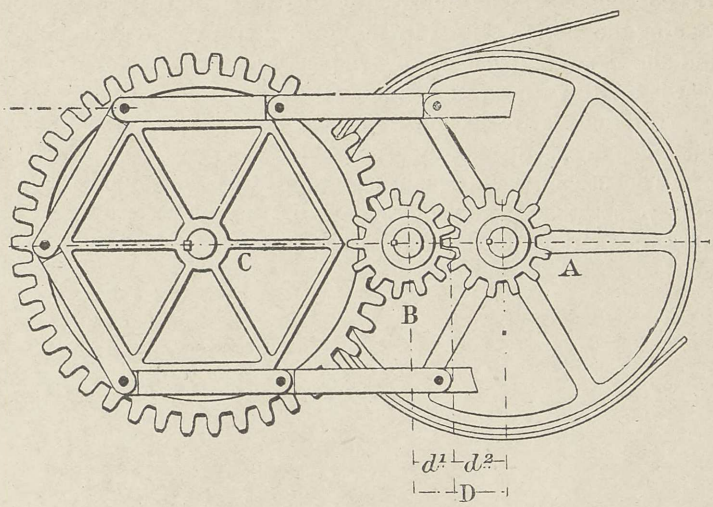


Fig. 260. Toogood Equalising Gear.

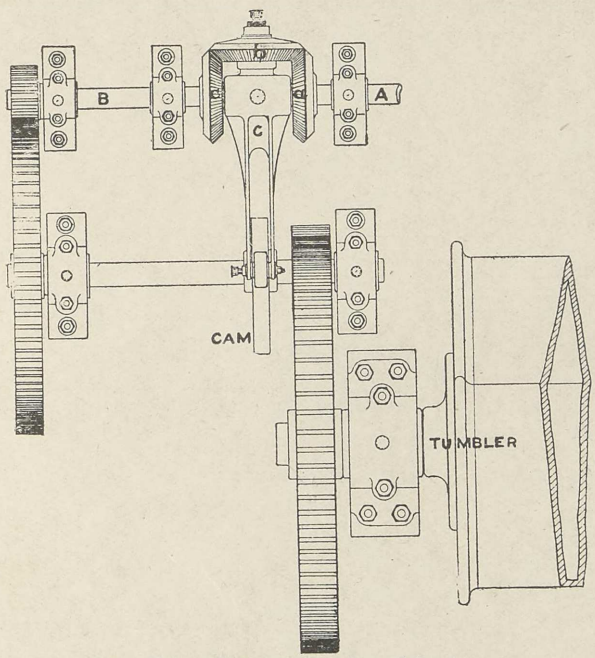


Fig. 261. Barling Patent Equalising Gear.

The Link-Belt Gear.—Another equalising gear is that of the Link Belt Company, which consists of a wheel and one pinion only. The former has a waved or undulating circumference, and fits an eccentric pinion, the number of elevations and depressions of the spur wheel equalling the number of teeth in the conveyor wheel. The pulsating motion of these gears exactly counteracts the variations of chain speed, and eliminates the destructive strain set up by the constant accelerations and retardations that would result from the use of circular gears.

The Barling Gear.—The principle of this invention consists in varying the angular velocity of the driving tumbler by the intervention of an epicyclic train operated by a cam, and is shown diagrammatically in Fig. **261**. The shaft A is coupled direct to the motor and thus turns at uniform angular velocity; it carries the wheel *a* which through the idle wheel *b* gears with the wheel *c*. The wheel *b* rides loose

on a pin carried on a lever C, which can be rocked about its axis by the rotation of the cam. Imagine the shaft A held stationary. It is plain that if the arm or lever C be rocked, motion will be imparted to the shaft B through the wheel *c*. When the shaft A is rotating the motion caused by the rocking arm or lever C is superposed upon the shaft B and the cam is so cut as to compensate exactly for the shape of the tumbler. This gear is built by Fraser & Chalmers.

If terminals are octagonal or more sided they approach nearer to the circle, and the difference in speed is hardly perceptible.

The use of such equalising gears is recommended for chain-driven elevators and conveyors with hexagonal terminals, but it is better to avoid having hexagonal pulleys altogether and use those with not less than eight sides.

CHAPTER XVII

CONVEYING BY GRAVITY

TROUGH-SHAPED inclined shoots are largely used to convey material by gravity to and from mechanical devices for handling such materials. The angle at which such shoots are fixed depends on a variety of circumstances. If the material is not friable or likely to be injured or deteriorated in value by quickly descending the shoot on a steep gradient, and coming more or less abruptly to rest at the lower end, there is no particular need to take precautions, and the shoot can be erected to connect the receiving point with that of delivery, as long as the gradient is sufficient to ensure the descent of the material.

When the material is friable and deteriorates by breakage, the incline of the conveying shoot must be so chosen that the material will only just slide down, and that in so doing it cannot attain a velocity sufficient to injure it. These remarks refer particularly to coal,[1] and it may therefore be of interest to give a few inclines at which coal will descend a shoot in safety. The inclines are given in inches per yard.

Mine coal (large and small as delivered in colliery tubs)	15¾ in.
Cobbles	14½ ,,
Nuts	15 ,,
Slack or smut (dust coal)	19 ,,
Cannel coal	14½ ,,

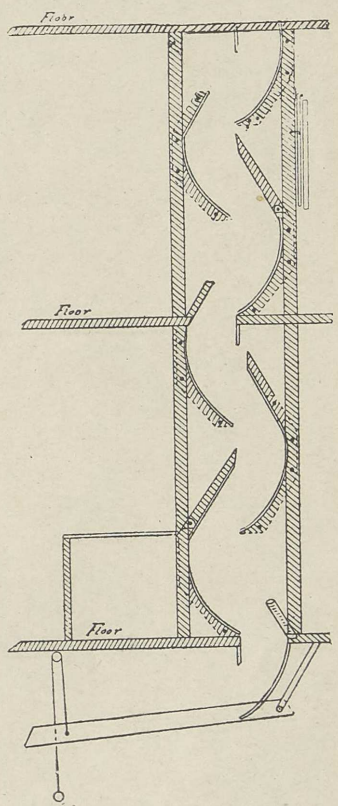


Fig. 262. Gravity Sack Shoot.

The incline of a shoot depends generally upon the coefficient of friction between the material and the shoot and also on the form of the pieces. The incline varies from 30° to 60°, the lower figure being for such materials as washed gravel, coarse dry sand, and cement clinker from the revolving retorts, and the other extremes would be for fine cement, moist sugar, salt, washed coal, etc. It will be seen from the above that a wooden shoot, for instance, would have to be steeper than an iron one. The safest plan in doubtful cases is always to rig up a short length of experimental shoot, especially if not much fall is available.

Gravity Sack Shoots.[2]—If sacks have to be lowered from one floor to another, and the distance between the two terminals of the shoot is sufficiently great for a straight

[1] For shoots from elevators, see page 26.
[2] From *The Miller* of 4th December 1911.

run, there is no difficulty in arranging such a device, but if the sacks have to be lowered perpendicularly, gravity sack shoots are the best means for handling all goods in sacks, such as flour, grain, cement, sugar, etc. Fig. **262** shows such a shoot, which is fitted inside with a number of slides or baffles which, while directing the course of the sack downwards, prevent it from attaining an excessive velocity. The sack glides from curve to curve until it reaches its destination either on a take-off table on any floor of a warehouse or to an inclined shoot leading to either rails or vessel. The take-off table is hinged and can be closed up out of the way when not in use. This useful device was first brought out by Messrs Sutton, Sharp & Hardwick, of the Imperial Flour Mills, Ellesmere Port, where it has proved thoroughly satisfactory, the gliding motion preventing any damage to sacks, which can be fed in on any of the upper floors and taken off at any lower one. The apparatus takes very little room and is inexpensive to install. It will work equally as well with sacks of 50 lb. as with those of 280 lb.

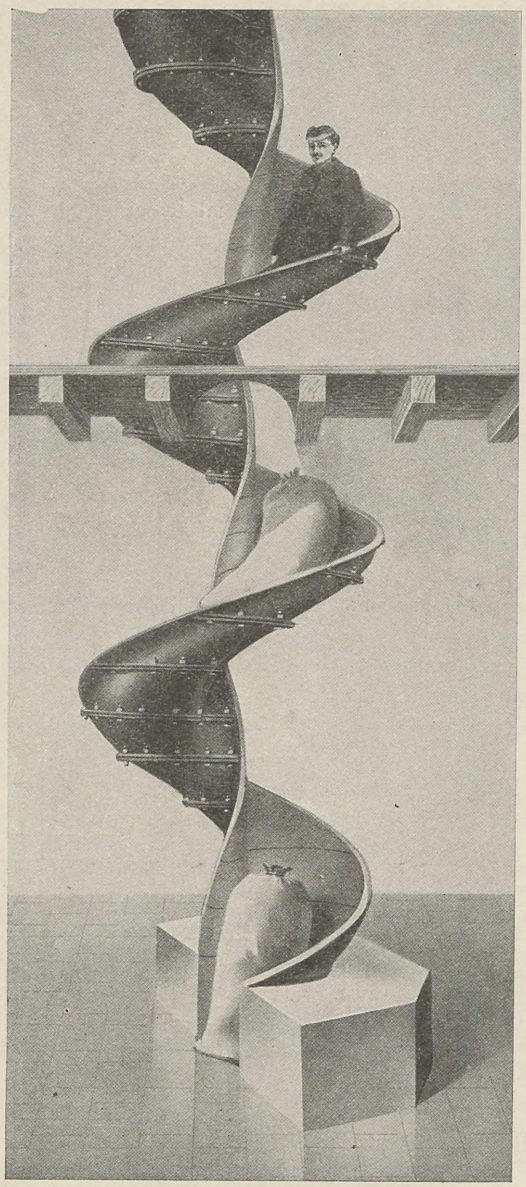


Fig. 263. Spiral Gravity Shoot of Cast Iron.

Spiral Gravity Shoot.—An ideal method of lowering sacks vertically from a higher to a lower level is the spiral sack shoot. Figs. **263** and **264** show it in two forms, the former being of cast iron and the latter of timber. The apparatus is self-supporting like a spiral staircase, and the cast-iron one in particular may be used for sacks and also for such goods as small barrels, boxes and packages of almost every description. The diameter is 170 cm. or 5 ft. 8 in. Eight segments of the cast-iron one form one complete spiral, and the weight per foot is just about 1 cwt. The makers are Richard Simon & Sons, Ltd., of Nottingham.

A gravity shoot on the same principle as the foregoing, but for much larger packages, is shown in elevation and plan in Figs. **265** and **266**. It is the first of its kind and size to be constructed, and was built by Francis Norton, Junior, & Co., of London, to convey

cases from a top floor to the cellar of a London warehouse. The cases or casks are started at the top on a short length of roller runway, and vary in size up to 2 ft. 6 in. cube, and in weight up to about 4 cwt. The time taken on the journey down the shoot of course varies with the size of the case, but the maximum time does not exceed about 10 sec. On the last run of the shoot near the basement the speed of the cases is broken by several large steel spring brakes, and at the extreme end there is a plated upward incline to a small platform upon which the cases land.

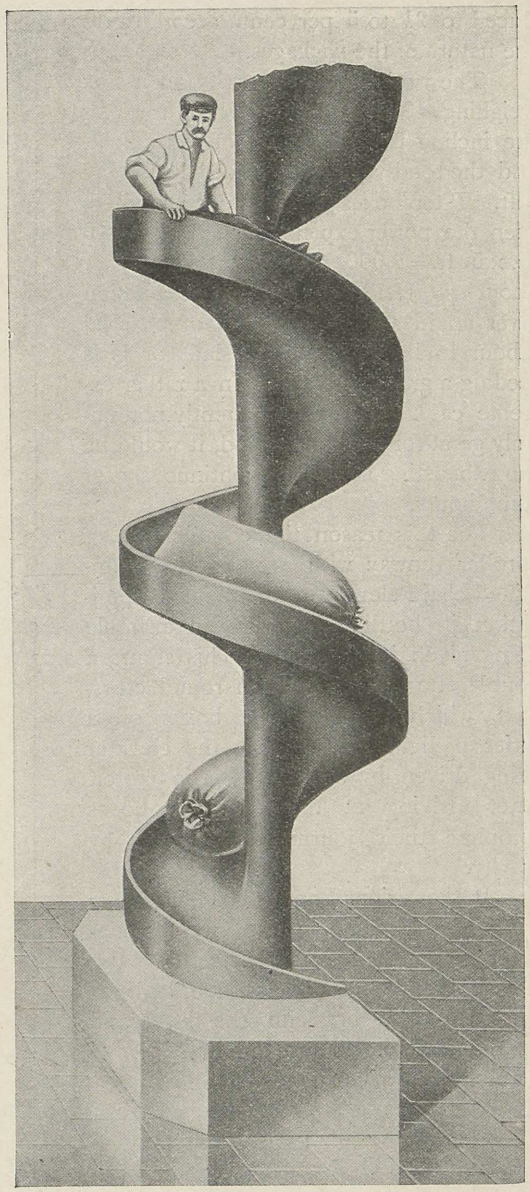


Fig. 264. Spiral Gravity Shoot of Timber.

Inclined Roller Runways or Gravity Conveyors.[1]—For materials in sacks, cases, or parcels, or individual loads of more or less uniform size, roller runways are often used. During the past ten years roller runways, as shown in Fig. **267**, have been largely adopted for moving boxes of regular shape having smooth bottoms, especially in bottling factories. As auxiliary appliances, these gravity conveyors are very convenient and easy to apply. Their attractiveness lies in their cheapness and in their applicability where no running shafting or electric power is available. Another valuable feature is the ease with which they can be led round curves. The carrying capacity of a roller runway, however, is much less than that of a continuous power-driven conveyor, and the useful length is, as a rule, limited according to the height available at the feeding point.

In the case of an ordinary inclined shoot of wood or steel plate, there is considerable friction between the sliding body and the surface of the shoot. A roller runway is an artifice to reduce the friction to a minimum, by substituting freely-revolving rollers for the shoot bottom. The usual diameter of the rollers is about $2\frac{1}{2}$ in. and the pitch from 4 in. to 6 in., according to the size of the box. The rollers are made of thin solid-drawn steel tubing, and mounted

[1] W. H. Atherton, "Continuous Package Conveyors for Factories."

on either hardened pivot bearings or on ball bearings. In this way the gradient of a roller shoot or runway can be reduced to $2\frac{1}{2}$ to 5 per cent., according to the nature of the packages.

The work done by gravity on a box weighing 40 lb. in falling 100 ft. along the incline is the product of the weight, and the total vertical displacement of say 5 ft. If ten boxes per minute are handled, then the power expended will be 10×40 lb. $\times 5$ ft. $= 2{,}000$ ft.-lb. per minute, or about $\frac{1}{16}$ H.P. This little calculation gives an idea of the amount of physical labour to be done by the lads or girls feeding a gravity conveyor in a rather extreme case. Though apparently not unduly great for a short period, it would be too exhausting if kept up continuously for some hours.

For this reason the combination of a roller runway with a power-driven inclined chain elevator finds frequent application in bottling factories, an example being given in Fig. 268. This shows a double strand elevator with round crossbars, which push up the boxes on a series of light steel rollers, the elevator being driven by a small electric motor. After arriving at the top, the boxes complete their journey of 110 ft. by gravity.

In the various London establishments of the Direct Supply Company for soda-water siphons, the cases containing the full or empty siphons are handled on roller runways, both on the level and on the incline. Those on the level have, of course, to be

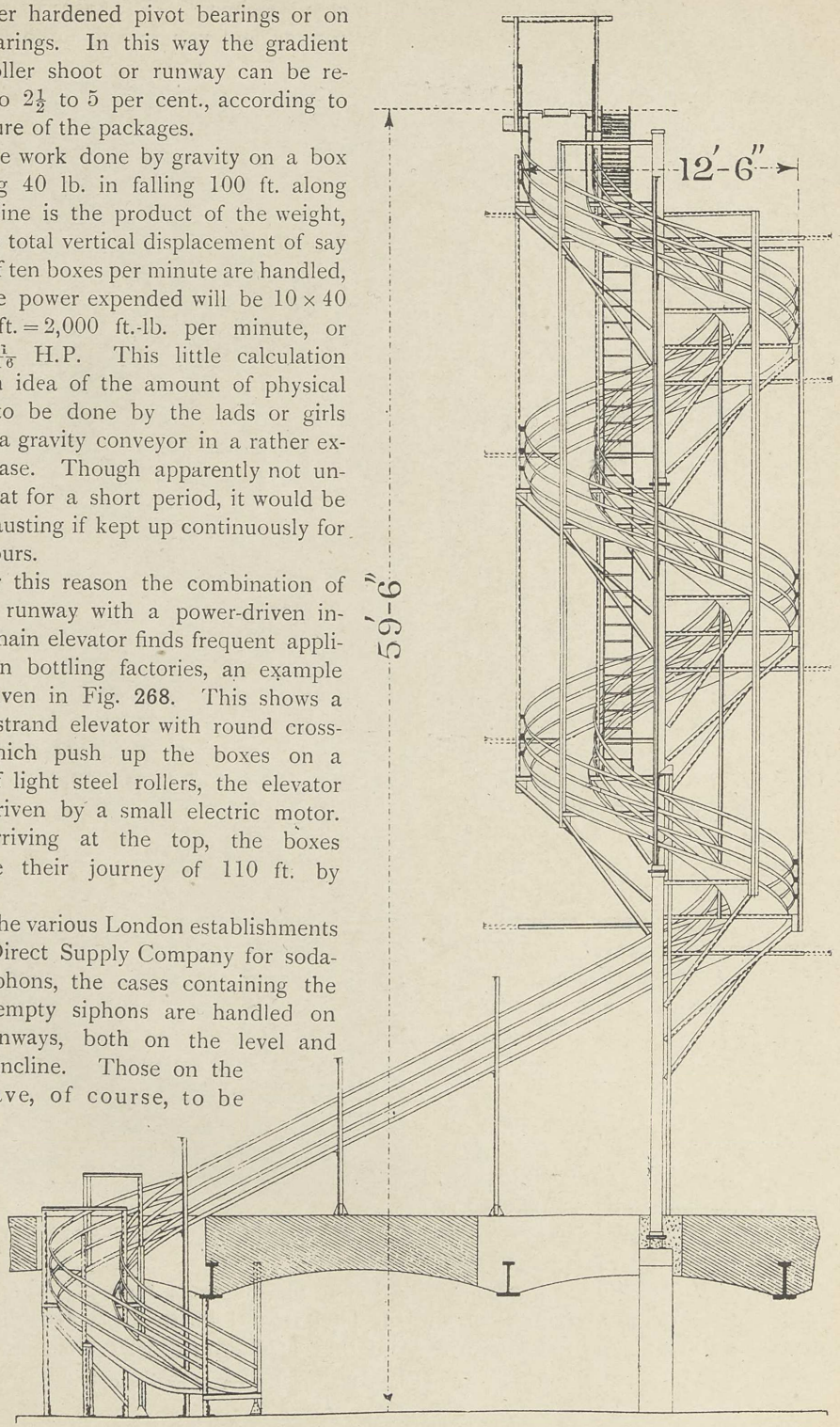


Fig. 265. Spiral Gravity Shoot of Large Capacity.

pushed by hand, but as soon as they reach the incline they descend by gravity.

The cases hold twelve siphons and measure 20 in. long by 15 in. wide by 14 in. deep, and weigh $\frac{3}{4}$ cwt. each. The rollers of the runway are 9 in. pitch, 14 in. long, and $2\frac{1}{2}$ in. diameter. The spindles are fixed to the frame, and the rollers revolve on balls. One

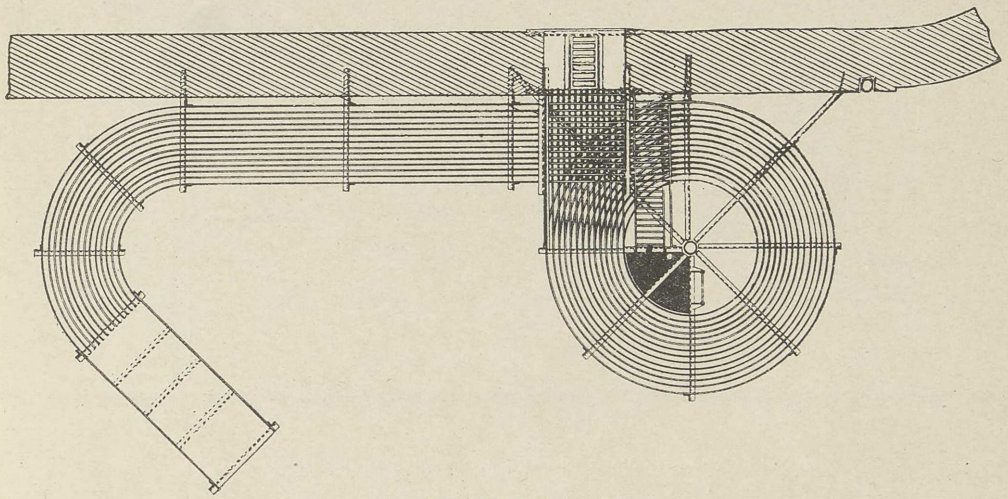


Fig. 266. Plan of Fig. 265.

of the inclines is 50 ft. long, having a fall of 18 in. in its length, and the boxes run down the incline in 17 sec. Another is 120 ft. long with only 26 in. incline. This is for empty cases, and it has a curve of half a circle at the base where the cases are taken off. As this is a very slight incline an occasional push becomes necessary.

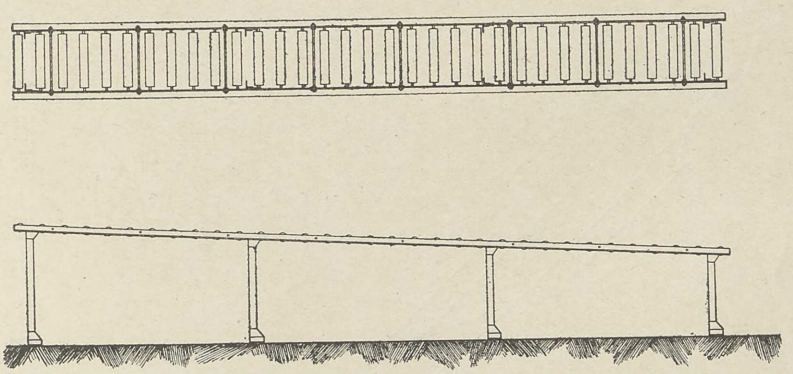


Fig. 267. Inclined Roller Runway.

The saving of labour may be demonstrated by the following instance. At a large bottling store in London seventy lads were formerly employed in one department. They gave a good deal of trouble, and caused much waste in breakages. Eight years ago three conveyors were installed, and the lads stopped. On the same floor space the output had doubled, the breakages greatly reduced, and only thirty girls were now employed instead of seventy lads. That meant a saving of about £1,000 a year in wages alone, while the

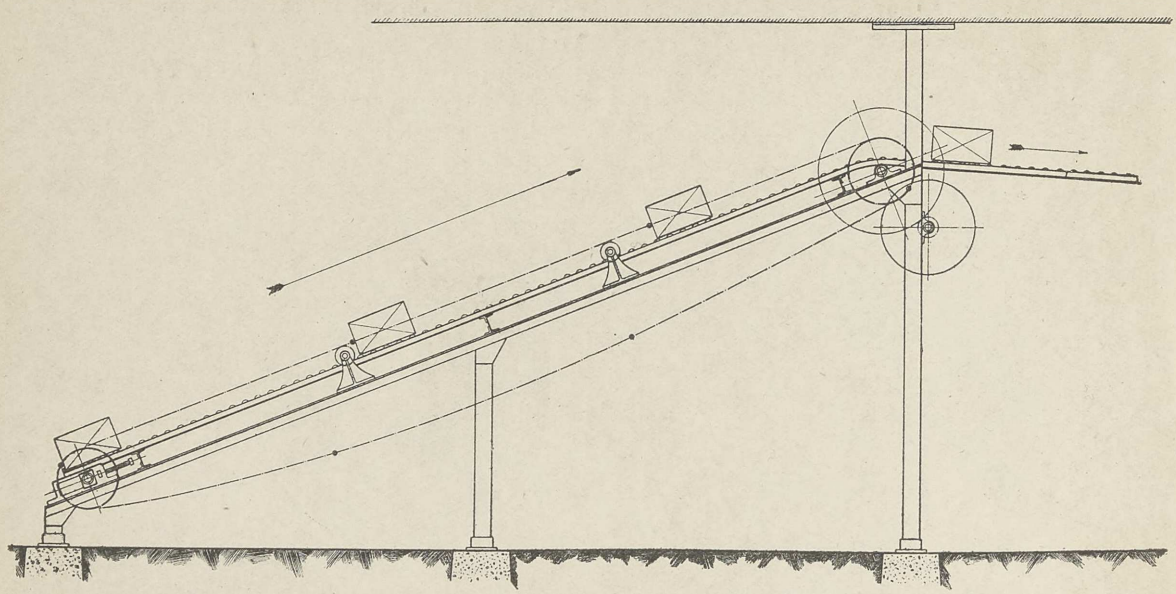


Fig. 268. Inclined Elevator for Feeding Roller Runway.

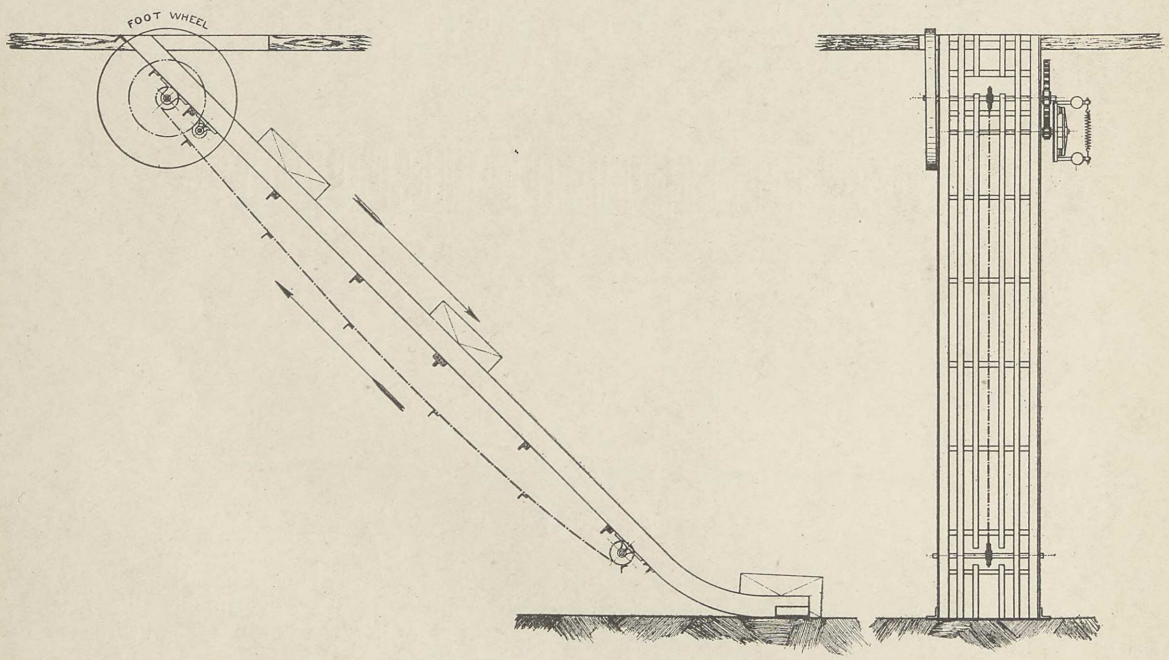


Fig. 269. Automatic Lowering Device for Packages.

conveyors cost only £500. Hence it was easy to understand the satisfaction experienced by the purchasers.

Automatic Lowerers.—A vertical swing tray elevator is often used successfully for lowering through several floors, as well as for elevating. When required for lowering only, a belt drive is convenient for regulating the rate of lowering and acting as a brake, although the consumption of power is practically nil. Where no motor or other source of power is available, however, an automatic brake, controlled by a governor, may be fitted instead, and the lowering done entirely by gravity. The main objection is that the swing trays will seldom come to rest in the most suitable position for loading, a fault from which positively driven lowerers are free.

Fig. **269** shows a modification of an ordinary inclined shoot, in which the rate of descent of the packages is automatically controlled by means of an endless chain, fitted with skidders, and a centrifugal governor geared to the top shaft. These inclined automatic lowerers are sometimes hinged at the top, although usually fixed.

Other examples of conveying by gravity may be found in the chapters on "Endless Chain and Rope Haulage," "Ropeways," and "Cableways."

CHAPTER XVIII

AUTOMATIC FEEDING DEVICES

C. KEMBLE BALDWIN, of Chicago, Ill., read an interesting paper on "Automatic Feeders for Handling Material in Bulk,"[1] of which the following is an extract. The illustrations of the devices are not intended to show the construction, but to illustrate the principles involved, so that they may be compared.

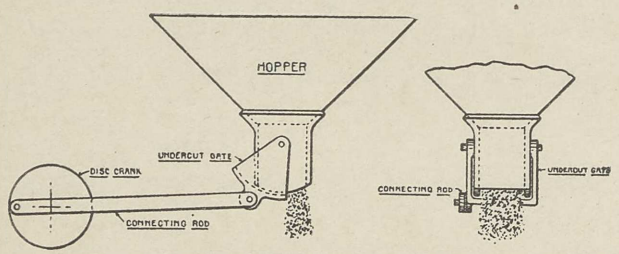


Fig. 270. Undercut-Gate Feeder.

The automatic feeder not only saves the expense of an attendant to adjust gates, but ensures a constant and regular feed, irrespective of the size of the material.

Fig. **270** shows the undercut-gate feeder, with a body either of cast iron or steel plate, pivoted near the top of the undercut gate, which is swung back and forth by a connecting rod from crank or eccentric. This type of feeder is best adapted to fine-sized, free-flowing material. As the feed is intermittent, the feeder is generally used in connection with chain or bucket conveyors, the strokes being timed to feed material between the flights, or into the buckets. The capacity may be changed by changing the length or the number of strokes. As the length of stroke is more easily changed, it is preferable to use a crank rather than an eccentric, as in practice the quick return of the eccentric has not been found of sufficient value to offset the great advantages of a crank with an adjustable throw.

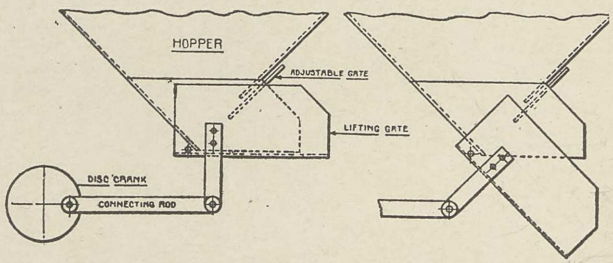


Fig. 271. Lifting-Gate Feeder.

The lifting-gate feeder, shown in Fig. **271**, also gives an intermittent feed, and is therefore principally used with a chain or bucket conveyor or elevator. The shoot is hinged, so that when down the material will flow out of the hopper, but when raised above the angle of flow of the material the discharge is stopped. The moving of the shoot may be accomplished by a connecting rod receiving motion from either crank or eccentric. This feeder will handle material regardless of size, but it must be free-flowing material, so that it will move by gravity when the shoot is lowered to the angle of flow. The capacity may be adjusted by varying the number of strokes; also, in a measure, by increasing the length of the stroke,

[1] Read before the American Society of Mechanical Engineers at the Washington Meeting, May 1909.

thus increasing the maximum angle of the shoot and causing the material to flow more quickly.

The screw-conveyor feeder, illustrated in Fig. **272**, will deliver a constant stream of material, but in this case the material must be of such a nature that it will flow by gravity to the screw. The capacity can be changed only by altering the speed of the screw shaft. This type of feeder has a large field in the handling of pulverised material, such as coal, cement, etc.

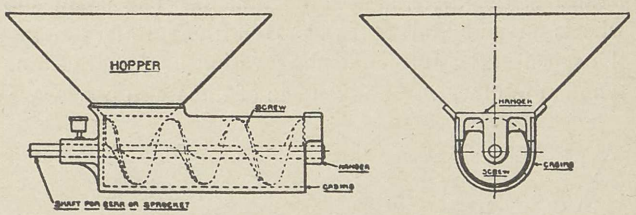


Fig. 272. Screw-Conveyor Feeder.

The roll feeder, shown in Fig. **273**, is extensively used in the mineral industries for handling both large and small materials. The roll is so located under the hopper that the material will not flow when the roll is stationary, but when rotated it will carry the material forward. The capacity is determined by the speed and width of the roll, and the thickness of the stream, as fixed by the adjustable gate. The roll feeder has been successfully used in handling iron ore, coke, and stone from the bins to the weigh cars for furnace charging. Edison used this type for feeding ore and stone from bins to crushing rolls. The disadvantage is the head room required, owing to the large roll necessary to satisfactory operation. For handling mine-run material the roll should be 6 ft. to 8 ft. in diameter, and in many cases it is not possible to obtain this space.

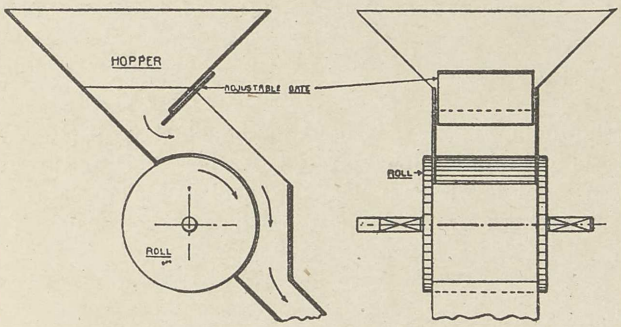


Fig. 273. Roll Feeder.

The rotatory-paddle feeder, Fig. **274**, acts not only as a feeder, but as a measuring device. It is used for fine material which flows readily from the blades. The capacity is fixed by the speed of the paddle shaft.

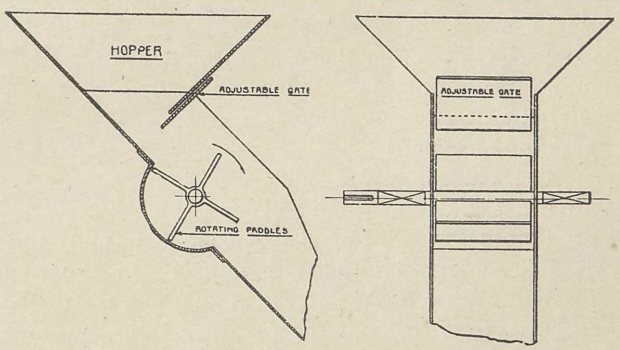


Fig. 274. Rotary-Paddle Feeder.

The revolving-plate feeder, shown in Fig. **275**, is used mostly for feeding stamp-mills. The inclined plate driven by gears, placed either above (as shown) or below, moves the material out of the hopper where it is scraped off by the skirt-board. When the skirt-board is made adjustable, sticky material may be handled by this feeder, because the curved plate will scrape the material off the

revolving disc and into the shoot. The capacity is fixed by the speed of the plate and the location of the adjustable gate.

Fig. 276 illustrates the apron-conveyor feeder used for handling material of all sizes. The conveyor may be of any of the various types of apron flights, depending upon the nature of the material to be handled. The chain should be provided with rollers or wheels travelling on track to prevent the apron from sagging. The capacity is fixed by the speed of the apron and the position of the adjustable gate. The disadvantage of this type is the inherent disadvantage of the apron conveyor. Should the flights become bent or buckled, the material leaks through or catches between them. It has an advantage over other feeders in that it may be used to carry the material a greater distance. A rubber or canvas belt may be used in place of the apron, in which case the belt is supported by idlers placed close together.

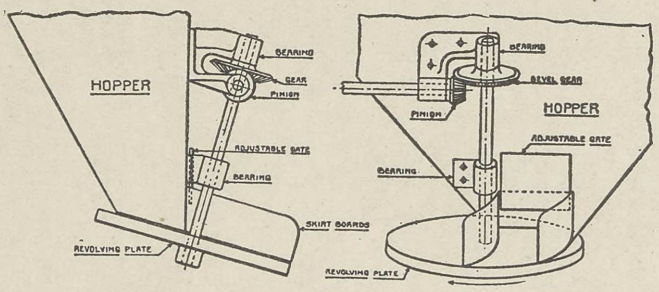


Fig. 275. Revolving-Plate Feeder.

The swinging-plate feeder, shown in Fig. 277, is used for handling coal and such material of all sizes. It consists of two castings pivoted at their tops and swung alternately so as to move the material forward on the bottom plate. The plates are moved by connecting rods from a crank or eccentric through a rocker shaft. The capacity is fixed by the length and number of the strokes, but as it is limited to the amount of material displaced by the plates, a wide range is not possible. The disadvantages are the lack of adjustability and the tendency of the material to pack. It will also be noted that the feeder is not self-cleaning, so that the bottom plate always contains material which is very liable to freeze in the winter.[1]

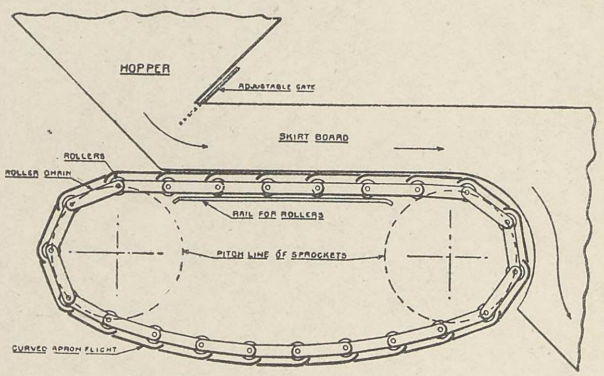


Fig. 276. Apron-Conveyor Feeder.

The plunger feeder, illustrated in Fig. 278, is similar in operation to the swinging-plate feeder in pushing the material along the bottom plate. The plunger may be built either in one or two parts, moving ahead alternately and driven through a rocker shaft, as in the case of the one previously described. The capacity is fixed by the number and length of the strokes and the location of the adjusting gate. This type has the same disadvantages as the swinging-plate feeder, the most serious being that it is not self-cleaning.

Fig. 279 shows the reciprocating-plate feeder, consisting of a plate mounted on four wheels forming the bottom of the hopper. When the plate is moved forward, it carries the material with it, and when it is moved back the plate is withdrawn from under the

[1] This defect does not obtain in the English climate.

material, allowing it to fall into the shoot. The plate is moved by a connecting rod from crank or eccentric. The capacity is determined by the length and number of the strokes and the location of the gate. The disadvantages are the lack of adjustment and the inability to clear the feeder of material.

The shaking feeder, Fig. **280**, consists of the shaker-pan located under the opening in the bottom of the hopper at such an angle that the material will not flow when the pan is stationary. When given a reciprocating motion by the crank and connecting rod, the material is moved forward on the pan. The front end of the pan is carried by a pair of flanged wheels; the back end is suspended by two hanger-rods, each being provided with a turn-buckle so that the angle of the pan may be varied. The crank having an adjustable length of stroke, there may be three variables, viz., number of strokes, length of stroke, and inclination of the pan. As the number of strokes is difficult to change, and the others easily changed, the feeders are usually designed for about seventy-five strokes per minute, a number determined by experiment. The angle of the pan is fixed by the capacity desired and the nature of the material handled. For coal, stone, ore, etc., 8° to 10° is sufficient, while clay and other sticky substances require from 15° to 20°. The length of the stroke varies from 4 to 12 in., so that a large range is possible.

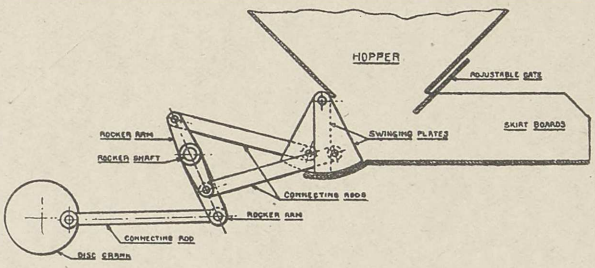


Fig. 277. Swinging-Plate Feeder.

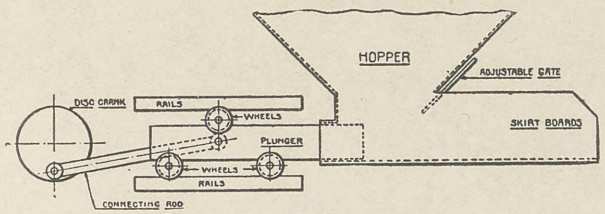


Fig. 278. Plunger Feeder.

A feeder designed to handle 400 tons per hour of mine-run coal was changed in five minutes to deliver 30 tons per hour by shortening the length of the stroke and lowering the pan until nearly horizontal.

Not only has this feeder the widest possible range in capacity, but it is self-cleaning, a very important feature in countries where there is a severe winter. From the illustration it will be noted that the pan is placed under the opening, and the material rests directly on the pan, so that when the pan is moved the material in the hopper is moved, which prevents the material from bridging.

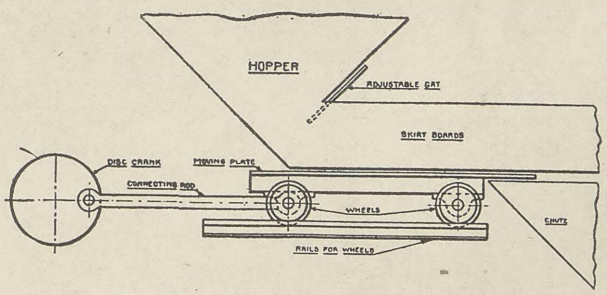


Fig. 279. Reciprocating Plate-Feeder.

The shaking feeder has none of the disadvantages of the other types for general use, and possesses many advantages which the others lack. Owing to its great flexibility it is

more easily standardised, and will successfully handle practically any material, regardless of size or condition. The power required by all of the types is so small that it is not an important consideration. The shaking feeder mentioned above, which handled 400 tons of coal per hour, required but 3·5 H.P.

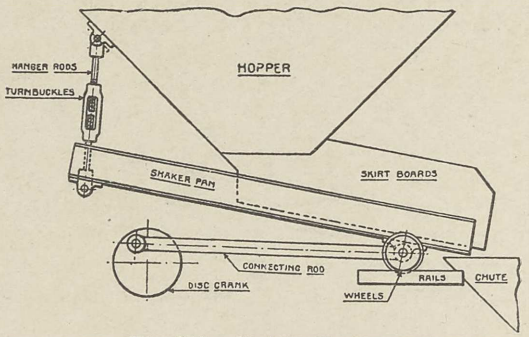


Fig. 280. Shaking Feeder.

Intermittent feeding devices for elevators and gravity bucket conveyors can be so adjusted and synchronised that the load for each bucket will be ready to be fed into the buckets as soon as they present themselves at the feeding point.

For other Feeding Devices see pages 27, 118, and 134.

CONTINUOUS HANDLING OF MATERIAL
BY PNEUMATIC AND HYDRAULIC MEANS

CHAPTER XIX
THE HANDLING OF MATERIAL BY PNEUMATIC MEANS

By the use of pneumatic conveyors material is carried without coming into contact with any mechanical appliances. It is, so to speak, floated in a current of air from which it is separated at the delivery point. To ensure the material floating more or less in and with the air, it is essential that it should not be of great specific gravity, and therefore pneumatic systems of transportation are mostly generally used for transporting such commodities as grain, malt, seeds and cotton, although potatoes, chemicals, cement, ashes, and even coal, can also be conveyed pneumatically.

The greater the specific weight of the material, the greater must be the velocity of the air in the conveying pipes, otherwise the stock will have a tendency to separate from the air during travel, thus blocking the pipes, especially if these are horizontal or nearly so.

Very considerable power, however, is required to propel air at great speed, and as pneumatic conveyors and elevators are probably the least economical type as regards the power necessary to work them, this excessive power is the more serious the heavier the material to be handled.

About the year 1863 experiments were made with a view to elevating grain by means of air currents, and since then many patents have been taken out for appliances to solve this problem in different ways.

Among the earliest and most important patents were those of Merrill, of Brooklyn, in 1873; of L. C. Renard and C. M. De La Haye, of Paris, taken out in America in 1879; of Jaacks & Behrns, of Lübeck, taken out in Germany in 1880; of Lyman Smith, taken out in America in 1882 and 1883; of Frederick W. Wiesebrock, of New York, taken out in the United States in 1884; of the Rev. George M. Capell, of Stony Stratford, Northampton, taken out in England in 1884; of Oscar Bothner, of Leipzig, Germany, taken out in 1896. Most of the early inventors suffered disappointment because they strove to discover what might be termed a grain pump. The first practical application of pneumatic power to the conveying of grain was in 1887, when the Cyclone grain transfer barge was constructed at Cleveland by Lyman Smith, and used for transhipping grain from lake vessels to canal boats.

An obvious advantage of such a system over a combination of ordinary elevators and conveyors is, that in unloading ships the suction pipe can be readily conducted within the hold so as to reach every corner and confined space therein; hence such appliances save a large amount of manual labour in trimming grain which is necessary with any other grain unloading appliance.

The only valid objection to pneumatic elevators is the heavy initial cost of their installation, and the large expenditure for fuel necessary to produce the air current. In other words, like all other pneumatic methods of power distribution, it is notoriously

uneconomical. Within the last few years, however, certain modifications to the system have rendered it a little more economical. Whilst formerly pneumatic elevators and conveyors were only suitable for large installations, where such difficulties were of minor importance, to-day they may be employed for smaller installations also.

With the building of larger ships, the need for speedy discharge, and the desire to be independent as far as possible of manual labour, have in the past decades been the means of introducing pneumatic elevators to a considerable extent, notwithstanding their heavy initial cost.

The actual process of conveying by air is the same whether suction or blast is used, and it depends upon local conditions which of the two methods is the more suitable in each particular case. In the following descriptions pneumatic conveyors for grain are dealt with under the following three heads:—**1. The Blast System; 2. The Suction System; 3. The Combined Suction and Blast System.**

THE BLAST SYSTEM

This is generally employed for greater distances of delivery than the suction system is suitable for, and also where it is more convenient to have the air compressor at the feeding end than to have the exhausters at the delivery end. The distance between the feeding and delivery points may be 1,000 ft., and in cases where the material has to be distributed to a number of points this form is very useful.

To give a practical illustration of one way in which the blast system works, let us assume that it is required to load a ship from a lighter lying alongside. A barge called a machinery barge is fitted with a steam boiler, a set of air-compressing engines, and a quantity of flexible piping long enough to reach from any part of the lighter to the furthest corner of the ship to be loaded. To the inlet end of this piping where the grain enters, termed the nozzle, a smaller pipe is inserted. This pipe is in communication with the air compressor at the other end. A valve is fitted to it for admitting compressed air to the nozzle or shutting it off.

When a lighter comes alongside to be discharged, a flexible pipe with its grain inlet nozzle is pushed into the grain, while the other end is led over the hatchway of the ship to be loaded. Upon the air compressor in the machinery barge being set to work, and the valve opened in the compressed air supply pipe, the air naturally rushes up the pipe and escapes at the other end which terminates over the hatchway. If the hand be put over the nozzle where the compressed air enters, a strong suction will be felt, strong enough to draw in any granular material lying in close proximity to it. The action is similar to that of an injector, so that if the inlet nozzle be immersed in the grain to a depth of 12 to 18 in., the induced atmospheric air following the compressed air will take the grain around it to the mouth of the inlet nozzle, carry it up the pipe and deliver it into the hold of the vessel.

The blast grain elevator brought out by the Atmospheric Grain Elevator Co., Ltd., under the Barclay & Walker patents, raises from 10 to 50 tons of grain per hour. It was erected for experimental purposes at the works of the Compressed Air Power Co., Ltd., Birmingham, with whom the firm made arrangements for the use of their compressed air.

In the course of the experiment, six pipes were used for elevating maize to a hopper placed 40 ft. above the ground. In order to register the quantity of maize moved by means of the blast elevator during one hour, the hopper discharged the maize into a "Chronos" automatic weighing machine, which indicated the quantity handled.

Of these six pipes, one was fitted up to raise 50 tons of material per hour to the bin, 40 ft. above the ground; two were made to elevate each 20 tons per hour to a hopper at

the same elevation; two to each carry 15 tons of grain per hour to the same height; and one to convey the grain 40 ft. in a horizontal line, and then to the hopper described as being 40 ft. above the ground. The pipes acted as conduits, the grain being carried to its destination by the force of the air current, which, owing to the construction of the nozzle at the end of the pipe, sucked up the grain by reason of the blast entering the conduit pipe through the nozzle.

Fig. **281** shows the system adopted in practice by the Atmospheric Grain Co. for discharging grain from a vessel to a mill, warehouse, or to another vessel.

After a series of experiments, the nozzle shown in Fig. **282** was adopted. It consists of an annular jet nozzle fitting at the entering end into the contracted throat J of the discharge trumpet J′, secured at its wide end to the first length of pipe of the grain conduits C. The inner nozzle I is screwed into a deep socket B and fitted with a lock nut *b* for regulating the opening of the annular jet of air issuing at J. The compressed air enters at D. The inlet end of the nozzle I is formed into a short trumpet H for leading in the grain. Of course the shape of the trumpet is altered if the nozzle is used horizontally or in an oblique position.

THE SUCTION SYSTEM

This is the most frequently used of the three systems, although it is believed that it will not convey for distances much over 500 ft. In this appliance—which is more particularly applicable where material from different points is to be collected to one central point—the exhauster is placed at the delivery end of the installation.

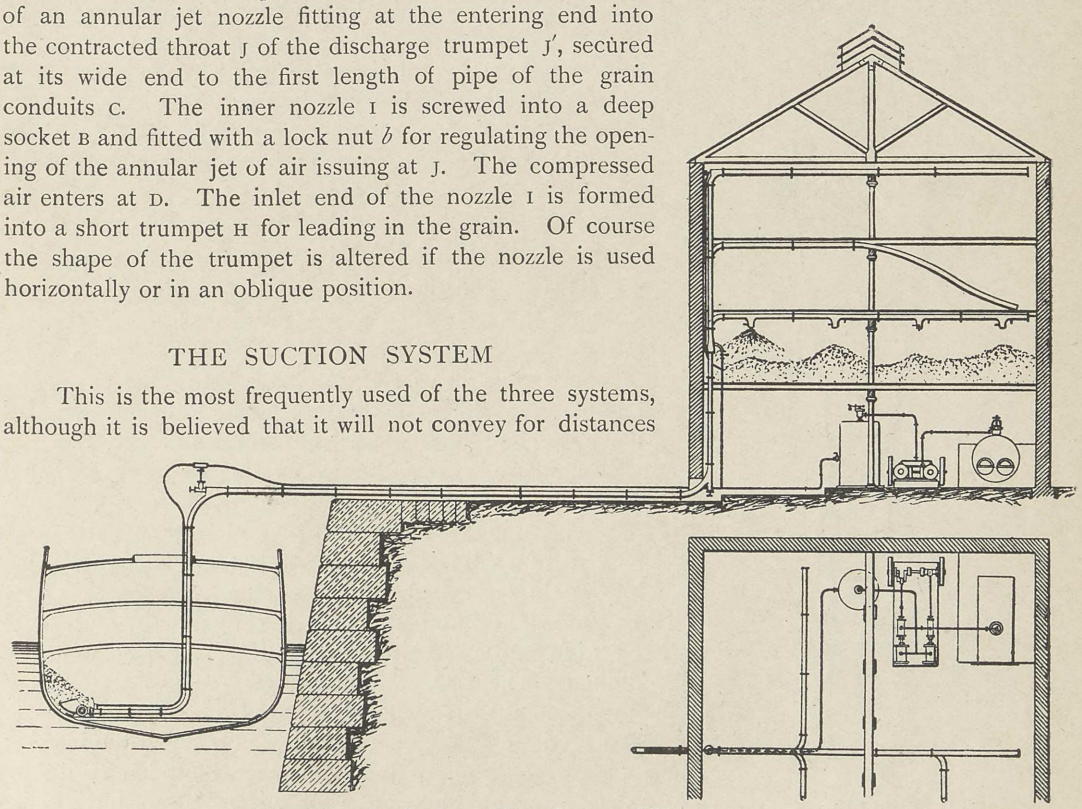


Fig. 281. Application of Blast System of Elevating.

This system in its earliest form undoubtedly owes its existence to F. E. Duckham, M.Inst.C.E. The principle of his elevator will be readily understood from the following introductory description, bearing in mind what has already been said in regard to elevators working by compressed air. The plant of the Duckham system consists essentially of an air-tight vacuum tank or receiver, 8 to 14 ft. in diameter, and about 10 to 20 ft. high. This tank is hopper bottomed, and is erected, if floating, on a machinery barge, or if stationary in a building, at such a height that grain falling from the bottom of it, after discharging through an air-lock, could be delivered by gravity down

a shoot to the grain-receiving vessel or other destination. This vacuum tank is placed in communication with the exhauster by means of a pipe.

Two or more ranges of pipes may be attached to the vacuum tank. These pipes are flexible and are all of sufficient length to reach to the furthest corner of the vessel to be discharged. The end of the pipe where the grain enters is of special design, to be described later on. It is generally called a nozzle, but necessarily it bears but little resemblance to the blast nozzle of the previous type. When the exhausters are started a partial vacuum is formed within the tank or canister through a connecting pipe, and upon the nozzle end of the pipe being immersed in the grain to a depth of a few inches, the air is drawn in at the orifice of the nozzle, which carries it up the pipe to the vacuum tank.

The air, by sudden expansion from a 5 or 6 in. pipe into a large vacuum tank, allows the grain to fall to the bottom of the tank and pass away by means of an air-lock valve, whilst the air is drawn down through a connecting pipe into the air-pumps, and is led away from them by pipes.

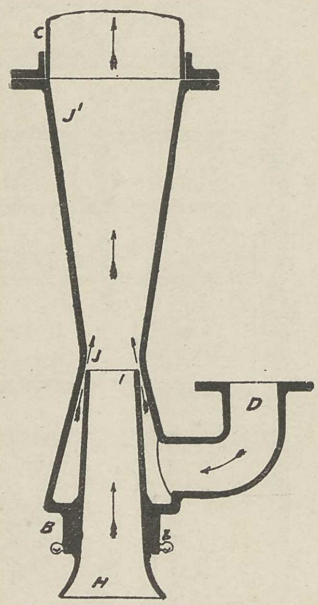


Fig. 282. Blast Nozzle of Pneumatic Elevator.

COMBINED SUCTION AND BLAST SYSTEM

This combination is sometimes used when the distance to which the grain is to be conveyed exceeds 1,000 ft., or in the event of grain having to be collected from a variety of points to a central station and distributed again to a number of points some distance away. For such installations the best position for the compressor and exhauster is somewhere between the two terminals, whichever may be most suitable to the locality.

This system of transmitting grain by pneumatic means consists of a combination of the blast and suction systems. The grain is sucked into a vacuum chamber as already mentioned, and from this tank is conveyed by means of a blast of compressed air through flexible pipes to any point desired. The tank may be divided into two sections, and fitted with a system of valves in such a manner that the two sections of the tank are alternately under the influence of blast or suction, or the grain may be discharged through an automatic or other valve from the vacuum tank into a second air-tight chamber which is in communication with the compressed air chamber. This chamber is fitted with a grain-discharging pipe, and the grain is forced through it by means of the compressed air as already described. There have been several practical applications of this latter system which appear to have given satisfaction.

Messrs Haviland & Farmer experimented with the blast system for some years, but after much experimenting with the patents taken out by Walker and others between the years 1886 and 1890, it was found that such difficulties were inherent in the blast system of elevating as seriously to interfere with any chance of ultimate success, and it was therefore abandoned by them. The velocity at which the grain travelled in the pipes was so great as to break the grain on reaching the bends in the pipes, and even where the berries were not actually broken, the husk was abrased, the action in the pipes being like that of a decorticator. A yet greater objection was the dust nuisance, as the grain and the accompanying air current escaped together from the delivery end of the

pipes, and the air became laden with dust and fine siliceous matter to such an extent as to render it impossible for men to remain in the ship's hold for the purpose of trimming whilst the elevator was at work. This latter objection was not suspected by the patentees until a plant had been shipped and set to work on the Danube, when this proved an absolutely fatal objection to the use of the machine.

Duckham's System.—The first modern suction elevator was erected by the Millwall Dock Co., under the Duckham Patents,[1] the first of which was taken out in the year 1890, and it is under these patents that all the existing pneumatic elevators at present in use in the United Kingdom were constructed. As the principle has already been outlined, it will now suffice to give the details of the different working parts of the invention. One of the chief items is the air trap through which the grain finds its exit from the tank without destroying the vacuum. This is effected by an ingenious arrangement illustrated, together with the tank, in Fig. 283.

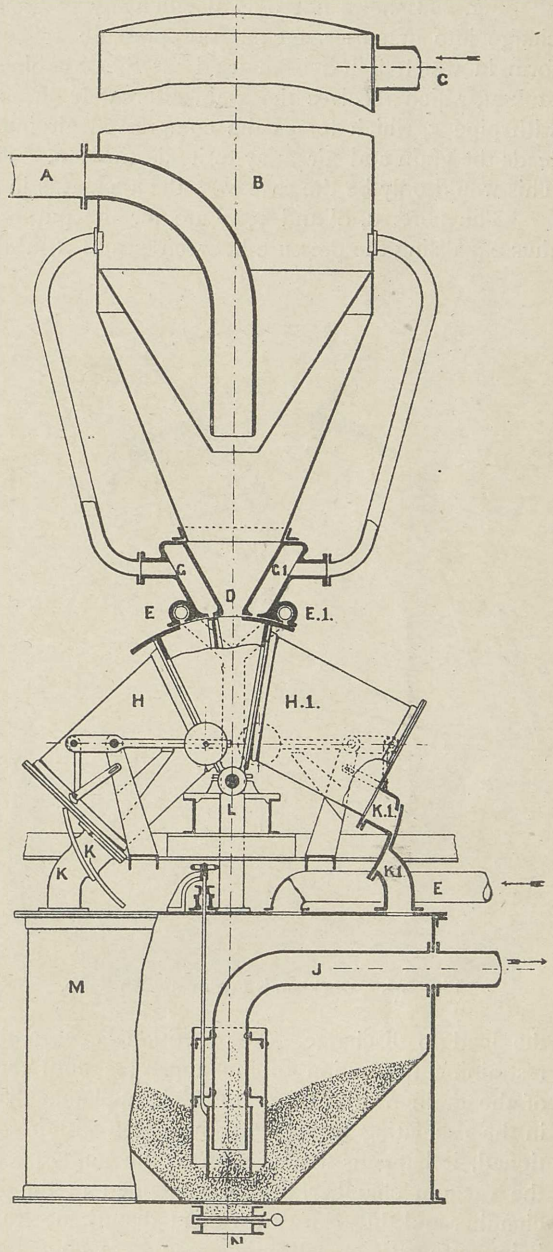


Fig. 283. Duckham's System of Pneumatic Elevating.

The pipes A and C are connected to the tank B, the former leading to the grain store or to the ship to be unloaded, and the latter to the exhauster. Beneath the tank B is the apparatus which withdraws the grain from the tank automatically without destroying the partial vacuum in the same. The apparatus consists of a receptacle divided into two compartments H and H^1, which oscillates on its axis L, so that alternately H and H^1 will receive the grain through the aperture D. The delivery spouts K and K^1 open and close with the same oscillating

[1] Duckham's pneumatic elevator and conveyor are described in *Engineering*, 29th January 1897, 14th July 1893; also in *The Engineer*, 19th February 1897 and 8th April 1898. See *Proceedings Inst. C.E.*, vol. cxxv.; see also *Proceedings Inst. Naval Architects*, 31st March 1898.

movement, so that when H[1] receives its load its exit K[1] is closed, and the inlet to H is closed whilst it discharges its load through K, which is open.

Fig. 283 shows not only the delivery of grain by suction, but also its further discharge into granaries, etc., by air pressure. Thus the apparatus is illustrated in the form in which it has been used for the combined system of blast and suction. The tank M, which receives the grain alternately through the pipes K and K[1], is connected with pipe E, which forces the compressed air into the tank, and by the use of pipe J leads the grain and air away to its destination. The grain can also be withdrawn by N. This would only be the case were the apparatus in use under suction alone.

The ports G, G[1] and E, E[1] are for the purpose of establishing communication, and thus equalising the pressure between B and H, H[1] during the filling, or rather just before the filling operation takes place, and between M and H, H[1] just before the discharge begins.

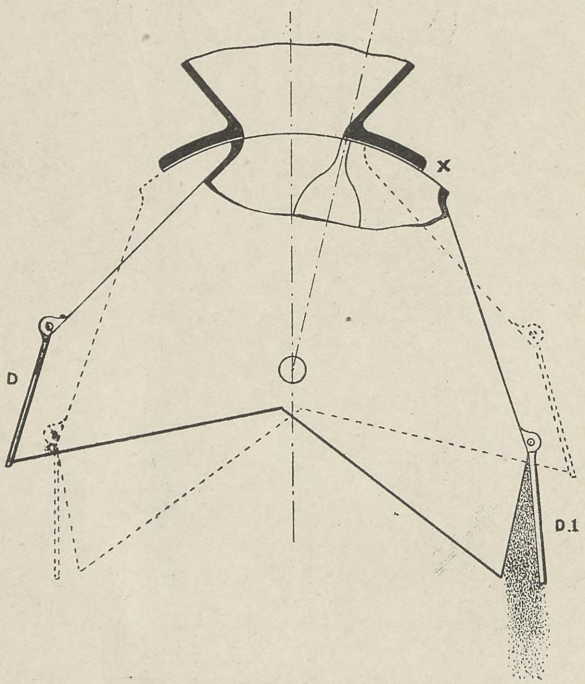


Fig. 284. Duckham's Pneumatic Air Trap.

In the later types the air traps in use with the Duckham pneumatic elevators, especially those for suction only, have been much simplified; their present construction is shown in Fig. 284. The illustration shows the rocking air trap in the two positions, one in full and the other in dotted lines. The exits from the two compartments D and D[1] are hinged flap doors with india-rubber linings. They are held closed through the vacuum within during loading. When one compartment is full the whole apparatus falls over to the other position, and in so doing first shuts off the inflow of grain and with it the vacuum, and then opens a port X which establishes communication with the outer atmosphere, upon which the valve D[1] opens and allows the load to discharge. The partition between the two compartments is weighted, thus restraining the action of the apparatus until the compartment is full, when the weight of the grain overbalances it. This appliance has done excellent work, but as the air in the oscillating pockets has not been withdrawn, as in the apparatus previously mentioned, it happens that as soon as the empty pocket is brought into communication with the vacuum chamber, the air contained in the pocket expands rapidly into the vacuum chamber and thus causes a violent disturbance to the grain in the latter. The apparatus being automatic or self-acting requires a comparatively loose fit, and it is difficult therefore to make it anything like air-tight, and such leakage means a great waste of driving power. However, the extreme simplicity of this trap was something in its favour.

Fig. 285 shows the construction of the suction nozzle which explains itself, the action being similar to that of an injector. The suction pipe which connects this nozzle with the vacuum chamber is about 6 in. in diameter, and consists of plain wrought-

iron piping for the straight lengths and flexible hose for the bends. . The hose is armour-plated inside and covered with india-rubber with insertion to keep it air-tight.

Experiments have shown that the construction of the nozzle is not of very great importance provided that it is easily adjustable, its essential function being to adjust the proportion of grain to a given quantity of air passing through the pipe, and as the proportion of grain must be smaller when the pipes are longer, or the grain heavier or lighter, it is important that the adjustment should be easy to make.

For the sake of completeness the very simple delivery nozzle which is used in connection with the combined system is here also given in Fig. 286. It consists of an iron pipe about two or three times the diameter of the supply pipe, and the length five to ten times the diameter of the latter.

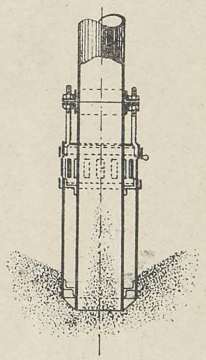


Fig. 285 Duckham's Suction Nozzle.

The pipe which leads from tank M (Fig. 283) is connected to the delivery nozzle, and as soon as the air which carries the grain expands in the wider nozzle, the velocity of the grain is reduced, and it runs out of the pipe in a uniform stream. This method of delivery has been successfully applied in several instances, the most important being the floating elevator "Garryowen" at Limerick and the "Leitrim" at Sharpness.

The combined suction and blast system can only be used effectively in cases where the grain has been sufficiently freed from dust before delivery, or in cases where the dust would be no objection.

With the Duckham system a partial vacuum of 7 to 10 in. of mercury is necessary to work the conveyor. With this vacuum the grain travels in the pipe at the rate of 30 to 50 ft. per second. One pipe has then a capacity of 30 to 40 tons of grain per hour. As one of the vacuum tanks is fed by at least two pipes, the capacity of a single installation through one air trap is 50 to 60 tons per hour.

The power consumed in driving such an installation is about 3 H.P. per ton of grain to be conveyed per hour. This is exceedingly high in comparison with ordinary bucket elevators. It means that a Duckham plant with a capacity of 100 tons per hour and a 60 ft. lift would consume 300 H.P. A bucket elevator would lift the same quantity of grain with only 10 H.P.

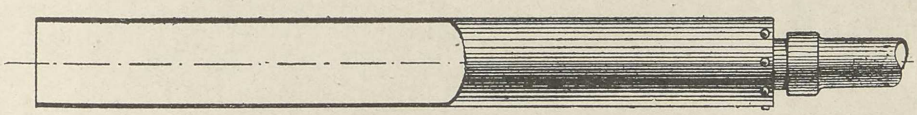


Fig. 286. Duckham's Delivery Nozzle.

Figs. 287, 288, and 289 show a complete installation of the Duckham elevator for discharging grain ships. It was built by G. Luther, of Brunswick, for the Hamburg-American Line. It has a capacity of 150 tons of grain per hour, and has proved capable of very good work. A dust collector which is here employed is marked in the drawing. It is intended for the purification of the air before it goes to the exhausters.

Haviland & Farmer's System.—This firm, after abandoning their original system, now work on the same system as that of Duckham. They claim to have made a number of improvements, and certainly some of their innovations are very noteworthy. They have paid special attention to the purification of the air between the vacuum chamber and the exhausters. In order to prevent wear and tear and consequent loss of driving power owing to the leakage of the air past the exhauster pistons, they have also

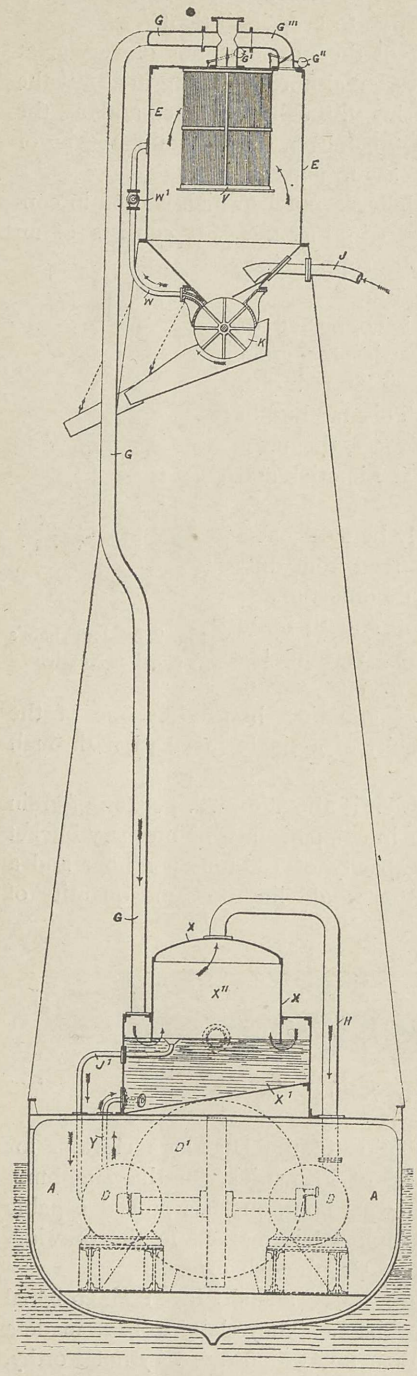


Fig. 290. Machinery Barge Built on Haviland & Farmer's System.

introduced a new air trap under the vacuum chambers which works on a different principle altogether to Duckham's.

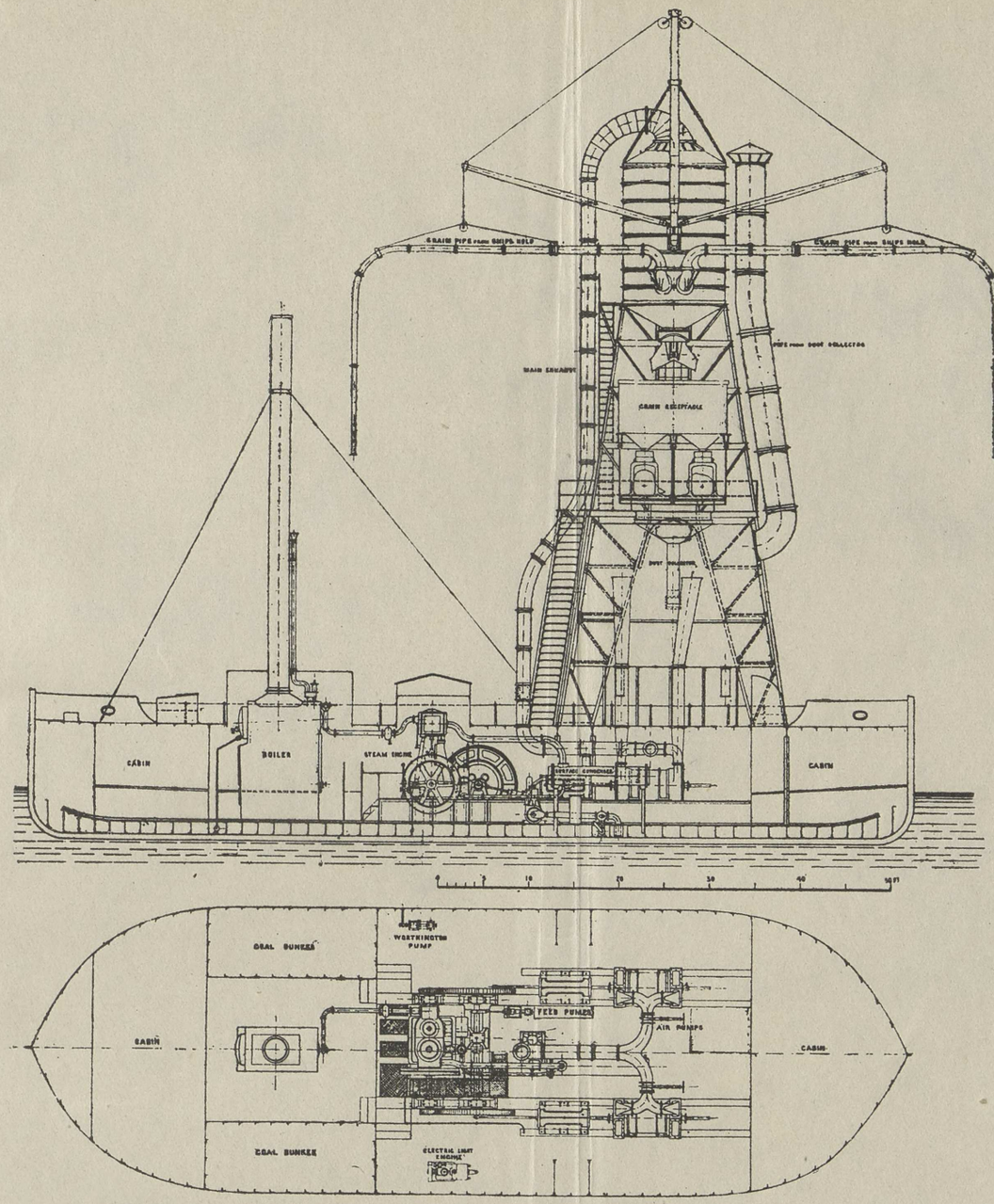
They also use a device for packing the pistons of the exhausters by means of water, with the object of entirely doing away with the loss of power occasioned by the slackness of the pistons, and of lubricating and cooling the walls of the cylinders, thus reducing heat and friction and the resulting wear and tear. The water is admitted through a hollow piston rod to the body of the piston under pressure, and from thence is allowed to escape through small openings and to press against the walls of the cylinders, thus preventing any air passing the pistons. The makers attach great importance to this invention, which they confidently anticipate will effect a great improvement in the working of pneumatic grain elevators.

Fig. **290** represents a machinery barge, as built by Messrs Haviland & Farmer. It shows the filter dust collector, which has been introduced into the exhaust chamber, as well as the water dust collector on the deck of the machinery barge. Undoubtedly these dust collectors are of great advantage, as they will retain the most harmful dust, but it is questionable whether the water dust collector will entirely collect the finest dust.

They claim that the use of their dust collectors will permit of the pistons being fitted with ordinary metallic packing rings, and that metallic valves may be used on the exhausters.

The illustration shows a tank which has a patent gauze chamber which is for the purpose of keeping back coarse dust and chaff, whilst the water dust collector is for the purpose of eliminating the finer particles of dust which are not retained by the filter dust collector. Upon the elevated grain and air entering the vacuum tank E, through pipe J, the greater portion of the dust, husks, etc., is prevented by the fine gauze filter V from entering the suction pipe G leading to the fine dust collector X. Some of the coarse impurities are deposited along with the grain and with it discharged through the air-lock revolving wheel valve K, and thence taken by spouts and deposited in the warehouse or the lighter.

To prevent the air scattering the grain as the former rushes out of the pockets of the wheel valve K, and blows up through the grain as each pocket



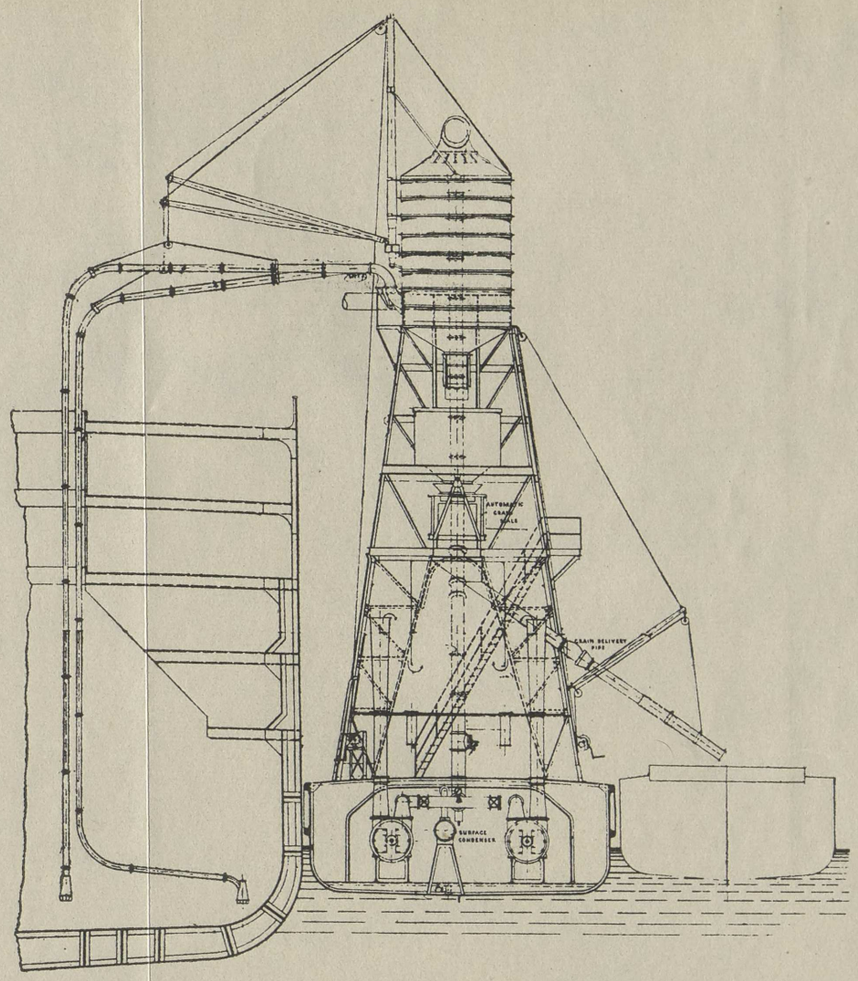


Fig. 287, 288, and 289. Complete Installation of Duckham's Pneumatic Elevator, built by Luther, Brunswick, for the Hamburg-American Line of Steamers.

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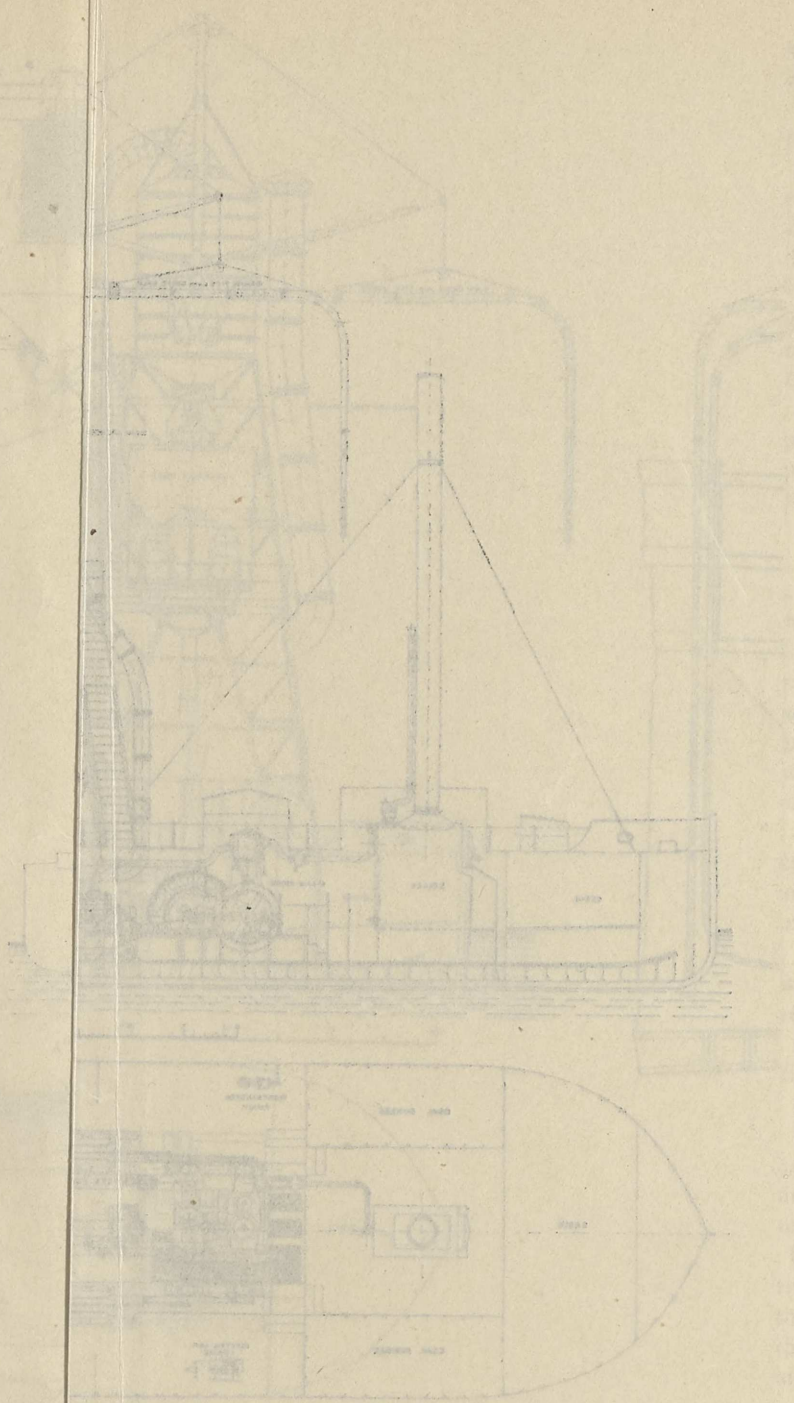
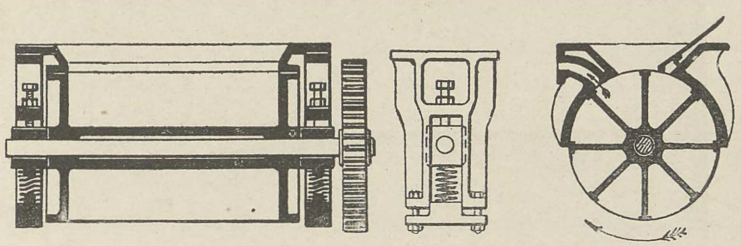


in turn comes under the aperture in the bottom of the vacuum tank, the air is previously withdrawn from them by a pipe W, the valve W′ being open.

When a winnowing effect is desired for the purpose of drawing the dust from the cargo, the valve G′ in the suction pipe connected to the gauze filter is shut, and the valve G″ on the pipe G‴, communicating also with the vacuum pipe and vacuum tank, is opened. This allows the dust and husk laden air to be withdrawn and deposited in the dust collector. The valve W′ is also partly or quite shut, which causes the air contained in the pockets to blow through the grain as it falls into them. By this arrangement the grain cargo can be delivered, either with a minimum loss of weight, or, on the other hand, the dust, husks, etc., may be extracted to clean the grain, should this be essential.

X represents the water dust collector, the under part X′ of which is filled with water, sealing the bottom of the vacuum chamber X″. Above this, and communicating with the exhausters D, D, is a further pipe H. The pipe G conducts the dust-laden air from the overhead vacuum tank E to the dust collector X, whence it is drawn by the vacuum into the chamber X″ through the seal of water, leaving the dust behind, and the purified air is drawn by pipe H to the exhauster. Water is fed into the under part of the dust collector X by a small pump. By this arrangement dusty air is prevented from entering the exhauster. This is very important, as the dust from grain contains a large percentage of silica, which naturally causes wear and tear if it gets into the cylinder.



Figs. 291, 292, and 293. Haviland & Farmer's Air Trap.

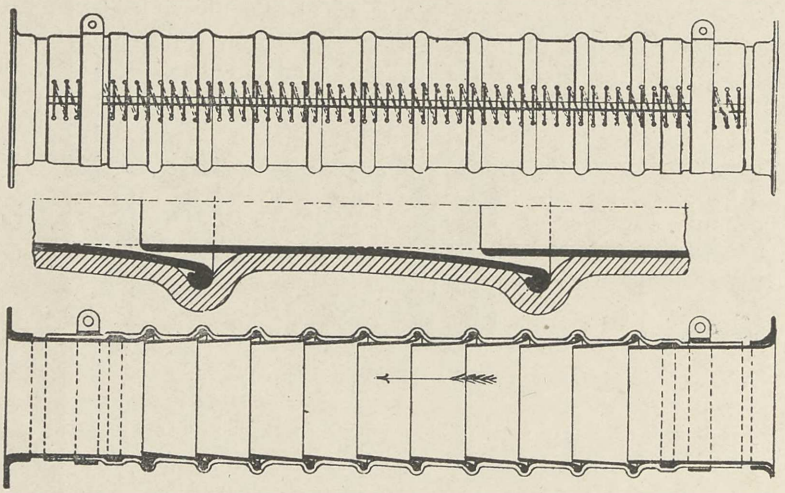
The arrangement of the dust collectors admits of either eliminating the dust altogether, or if need be, returning it to the cargo of grain, so as not to diminish the weight. The dust in the latter case is only held in suspension at the time, and then put back with the discharged grain.

The importance of this improvement is apparent, as merchants have sometimes complained of the loss of weight where pneumatic machinery has been used for unloading cargoes. The air trap employed consists of a revolving wheel valve, Figs. **291**, **292**, and **293**, which contains eight pockets in its circumference. These fit into a casing, and the wheel is driven at a suitable speed by power from the engine, so that the capacity of the revolving pockets is about equal to that of the grain discharged from the exhaust chamber. It is obvious that a valve of this description can be made to fit more nearly air-tight than the Duckham trap, and therefore loss by leakage is much reduced. This air-lock has the additional advantage that the pockets are much smaller than those in the Duckham air trap. Hence, though the filling of each individual bucket has to be effected more frequently, the amount of air carried into the exhaust chamber is less at each time. Thus the draught is not so severe even if used for the purpose of causing a winnowing effect, while the call upon the exhauster is more uniform. Of course with both the Duckham and Haviland & Farmer air traps, the pocket to be filled with grain before going into register with the exhaust chamber is full of air of atmospheric pressure, and it is obvious that the exhauster must remove this air in order to keep the vacuum

intact, either directly or indirectly; therefore a small volume of air admitted frequently will cause less strain on the exhauster and ensure more uniform working suction than will larger volumes of air admitted at longer intervals.

Most modern pneumatic plants are now fitted with revolving air traps on the principle brought out by Haviland & Farmer, but much improved in detail. (See Figs. **291** to **293**.) In the latest developments of the system by Mr Mitchell an improved Duckham type of trap has been introduced.

The Haviland & Farmer apparatus is provided, as already mentioned, with an exhaust pipe by means of which the air can be exhausted from the trap before it is filled with grain. A similar system of exhaust was in use in the early appliances of Duckham (see Fig. **283**). It is difficult to say what effect the discharge of air from the Duckham pocket into the vacuum chamber has, but it would appear that the grain running into the pocket is met by the air trying to enter the vacuum chamber, which will not allow of the pocket being filled until the air pressure has been equalised. The grain suction pipe is illustrated in Figs. **294** to **296**.



Figs. 294, 295, and 296. Haviland & Farmer's Grain Suction Pipe.

The pneumatic elevator on the blast system erected by Messrs Haviland & Farmer, which is at work at Sulina on the lower Danube, has now been reconstructed with the above-mentioned improvements, and is giving great satisfaction, as will be seen by the following figures.

In 1901 the average quantity of grain per month passed through the machine was 19,197 tons. In 1902 the monthly average was 20,450 tons, giving an average annual tonnage for the two years of 237,000 tons. The largest quantity dealt with in any one month was 38,978 tons, but the machine was capable of handling up to 50,000 tons per month. The result of a trial made to test the efficiency of the pneumatic grain elevator in the lower Danube in 1902 shows that with 375 indicated H.P. 160 tons of grain per hour were elevated to a height of 56 ft. The plant was reconstructed to the suction system in 1898 and further improved in 1903, after which 181 tons per hour were elevated to the same height with 350 indicated H.P., a much more satisfactory result. This shows conclusively that the principal imperfections of the original Duckham system were due to the leakage of the air trap and the imperfect exhauster, or rather the want of precautions to protect the exhauster from the injurious effects of the wheat dust.

These defects having been removed, the consumption of power has been reduced to about 2 H.P. per ton of grain handled.

The difference in the power consumed, between the Duckham machines built in this country and on the Continent, is to a great extent owing to the air-pumps of the Continental machines being vertical and altogether of more suitable construction than the horizontal machines which were used with the earliest Duckham machines in this country.

The Most Recent Additions to the Pneumatic Grain-Handling Plant at the Millwall Docks.[1]—These new additions consist of a "dolphin," elevators, and silos, together with a granary having 7½ acres of open floor storage, situated at the north-west of the inner dock. The equipment provides for the discharging and weighing of 550 tons of grain per hour ex ship, and for its delivery into granary, silo, or barge. In practice about one-third goes ashore, the remaining two-thirds to craft.

The pneumatic suction plant, Figs. **297** to **300**, is erected on a wooden jetty 350 ft. long by 25 ft. wide on the dock side of which the ship is moored. It is placed parallel with the quay wall at a distance of 50 ft. from it. The intervening water space which is occupied by barges is spanned by four girder bridges which connect the "dolphin" with the delivery floor of the silo on the quay. The deck of the "dolphin" is 14 ft. above Trinity high-water mark.

The sides and ends of the machine-room are built of timber and the deck of the "dolphin" forming the roof is at this part caulked with oakum and run with pitch. The boiler and engine rooms project 10 ft. above the upper deck and are cased in with steel plates.

There are on the "dolphin" four suction elevators, with a capacity of 75 tons per hour each. The power is supplied to these elevators by the machinery placed within the "dolphin," consisting of a vertical compound condensing engine capable of developing 900 I.H.P. at a pressure of 130 lb. per square inch.

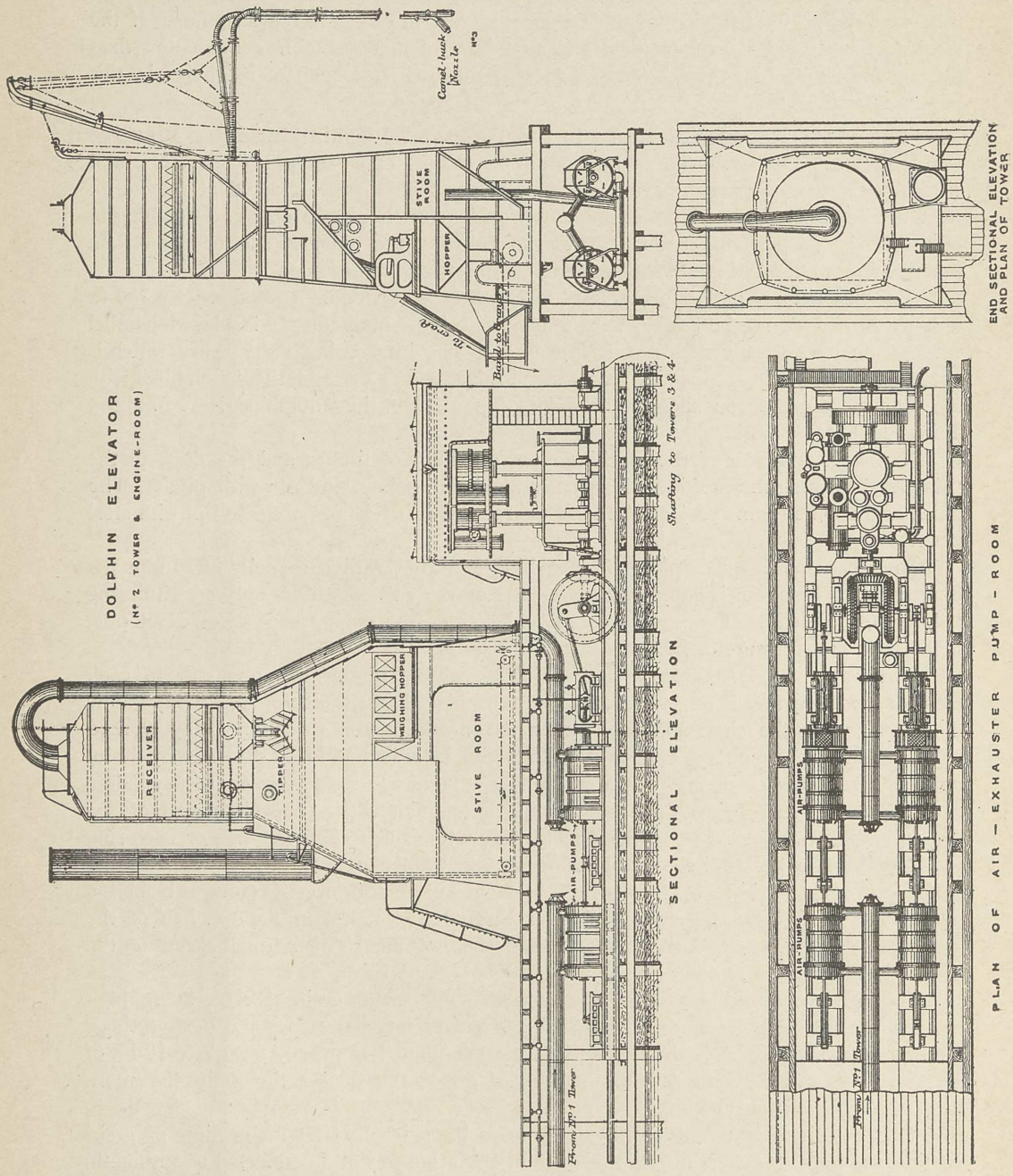
The power is transmitted to four pairs of exhaust pumps, *i.e.*, one pair to each elevator tower, by means of a 9-in. main shaft and helical gear-wheels of steel. Hydraulic pin-couplings on the shaft admit of either the north or south section being worked independently. The pumps are double acting with cylinders 46 in. in diameter by 60 in. stroke. Each pair of pumps works in tandem, the piston rods between the cylinders and also the tail ends being supported by slippers on guide bars. The pistons are of cast iron with junk rings and ¾-in. mica packing. The lower half circumference of each ring is of solid gun-metal of inverted T-shape with a wide flange to give greater bearing surface and reduce friction. The pump covers are of box form connecting with suction and delivery air-pipes, the air being drawn through the ports on the top half of the grid-plates, and discharged through those on the bottom. The normal speed of the pumps is 40 revs. per minute.

On each elevator tower there is a vacuum chamber or grain receiver 20 ft. high and 14 ft. in diameter constructed of steel plates with internal angles and baffle fittings. The vacuum maintained in these chambers by the pumps is usually from 7 to 10 in. of mercury, but varying with different classes of grain; the denser the grain the more complete is the vacuum required.

Each receiver or "canister" has two valve branches for the connection of grain suction pipes and is coned at the lower end in the usual way and connected to automatic

[1] Extract from a paper entitled "Some Recent Grain Handling and Storing Appliances at the Millwall Docks," read by Magnus Mowat before the Institution of Civil Engineers on 2nd March 1909.

oscillating air-locks or "tippers" of the Duckham type, which are of 5 bushels capacity and discharge about nine times per minute.



Figs. 297 to 300. Latest Pneumatic Grain-Handling Plant at the Millwall Docks.

The grain is sucked from the ship's hold to the "canister" to a height of say 80 ft. through "Armadillo" pipes varying in diameter from 6 in. at the receiving end to 10 in.

at the "canister." These pipes are made of conical steel plate rings 6 in. long overlapping each other, the whole being taped together with flax webbing and encased in a jacket made of leather, or of canvas impregnated with rubber. The pipe is made up in lengths of 10 ft., which are coupled together with bolt couplings having internal rubber washers to keep them air-tight. Steel taper pieces are used to reduce the diameter to 6 in. at the lower end where connection is made with the nozzles. The steel rings resist the wear by friction of the grain and the enveloping hose makes the joints of the cones air-tight. The pipe is supported by chains slung from derricks and is so flexible that a 10-foot length may be bent to a quarter circle.

The nozzles are of steel of 6 in. internal diameter and about 2 ft. long; the adjustable sleeve outside allows an air space of 1 in. all round. This sleeve must be adjusted to give the necessary supply of air. This is a most important factor, as the vacuum obtainable is directly controlled thereby. The range of the sleeve may be taken as 2 in. for extreme positions. With good oats it may be raised an inch and a half above the nozzle but with sluggish wheat it will have to be brought down half an inch below it. By lowering the sleeve more air is admitted; this is required for higher lifts or when the pipes are much curved for getting under the coamings. There are two varieties of nozzle used, "straight" and "camel back," the latter type being kept for working under coamings or in places inaccessible to the straight nozzle.

From the canister, where the air and grain are separated, the latter passes through the tipper into a weighing hopper, where it is drawn off by means of a slide valve into the weighing machine. That portion of grain intended for shore goes through weighing machines and thence by hopper to a band conveyor on the bridge spanning the 50 ft. to the quay. The remainder is weighed and passed direct into craft alongside through steel spouts, being either sacked on platforms, slung from the "dolphin," or it may be moved in bulk.

Before finding its way to the atmosphere the exhaust air from the pumps is passed through a "stive-room" or settling chamber of 3,000 cub. ft. capacity; these stive-rooms form the lower part of the towers. Here any dust which may have passed through the pumps impinges on baffle plates, is collected by a mechanical scraper gear, and is led eventually to the canister through a by-pass, being again incorporated with the grain to maintain its weight.

There are two floating elevators with a collective output of 250 tons per hour. The machinery is of the type already described, but is placed on floating steel tanks or barges, which are capable of being navigated in the dock. The larger vessel known as "Mark Lane No. 3" has two towers and is 90 ft. long, a smaller "Mark Lane No. 2" has one tower and is 65 ft. long, the beam in each case being 24 ft., and the draught 10 ft. The discharge is direct to barge only, from which the grain, if required for housing, is transferred to the travelling bins by means of grabs.

What appears to be an important feature in this new installation at the Millwall Docks is the tapering pipes. Mr Magnus Mowat, M.Inst.C.E., has carried out a series of experiments to determine the efficiency of these tapering pipes as compared with the 6-in. cylindrical pipes of the earlier plants, and the tests have shown that on the same receiver two of the taper pipes dealt with more grain than three of the 6-in. cylindrical pipes working under similar conditions. He also found that the velocity of the air in the pipes is approximately 100 to 150 ft. per second, and that the mixture of grain and air might be averaged at 1 to 50.

Although the latest installation at the Millwall Docks provides 3 I.H.P. per ton of grain lifted, Mr Magnus Mowat states that actually only 2·5 H.P. is required per ton per

hour. At the Surrey Commercial Dock, in a similar pneumatic installation, 2·16 I.H.P. was consumed per ton per hour. The lift in this case is 12 ft. less than at Millwall, and the cylinders of the air-pumps are water-jacketed.

In comparing the power consumed by pneumatic elevators, it must be borne in mind that in some cases of unloading there are 80 ft. of vertical and 100 ft. of horizontal pipes, which means conveying for some considerable distance, and entails consequent expenditure of power.

Mr F. S. Tuckett states that with the last machine built on the Duckham system at the East Ferry Road Engineering Co.'s Works, working under ordinary conditions with steamer cargoes of 3,000 to 4,000 tons of bulk grain, an average quantity of 197 tons per hour can be removed with a crew of seventeen men and an engine-room staff of five, whose total wages amounted to £1. 6s. 8d. per hour. The coal consumption is 4·75 lb. for every ton of grain lifted. Allowing for coal at £1 per ton, and for stores at $\frac{1}{8}$th of a penny per ton of grain lifted, the cost of unloading these cargoes amounts to $2\frac{1}{4}$d. per ton of grain.[1]

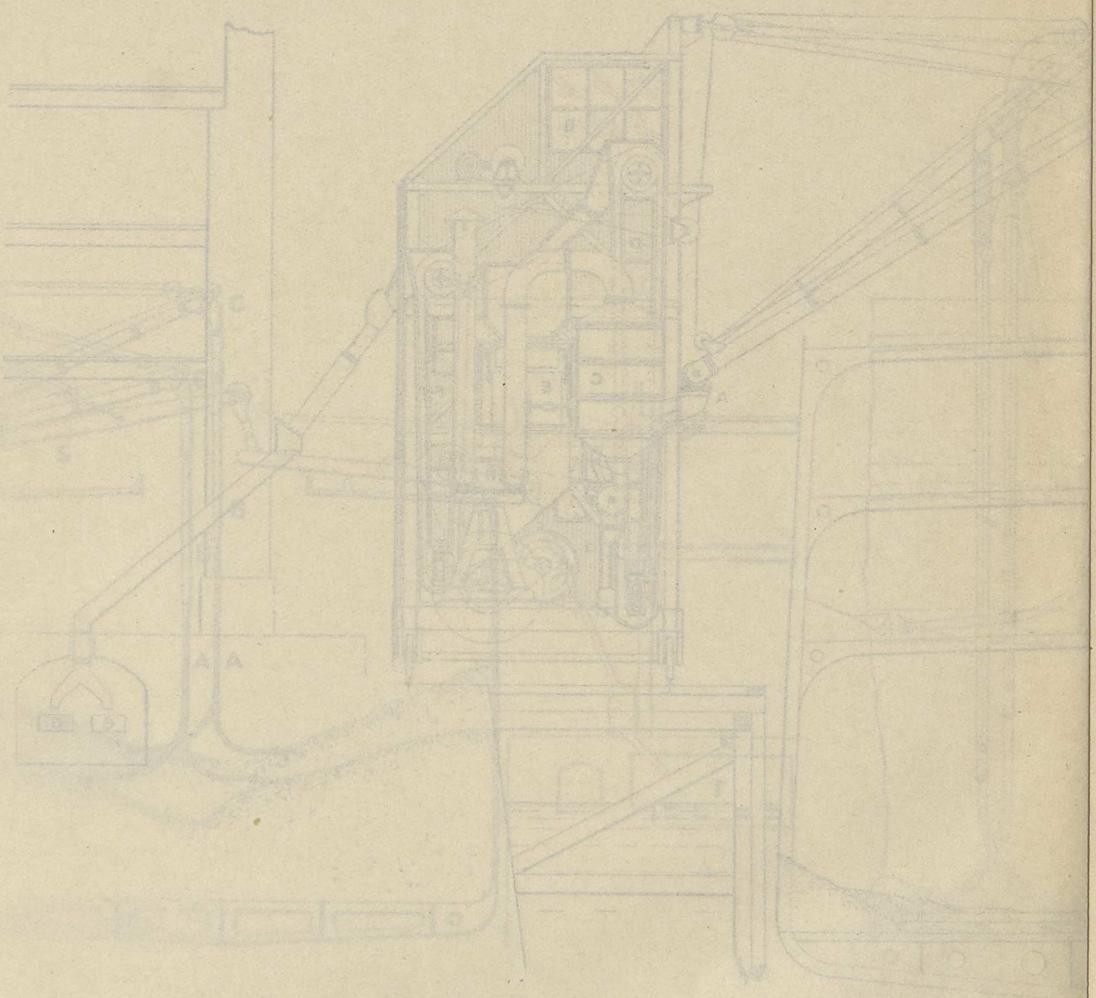
Mitchell's Improved Pneumatic Elevator.—Mr A. H. Mitchell, for many years engineer to the late London Grain Elevator Co., and now on the engineering staff of their successors, the Port of London Authority, has had unique opportunities for experimenting with and investigating practically every known system of grain handling by pneumatic means. He has diagnosed the reason of the failures of some, and followed up or further developed the latent good points in others, and he is undoubtedly one of the best authorities of the day on this subject. The writer is indebted to him for a number of interesting interviews, and the following description of the latest developments introduced by him on this important method of grain handling is the outcome of these interviews.

In the original elevators a tendency was discovered for the speed of the grain in the pipes to accelerate, during the whole of its journey, and thus enter the "canister" at an extremely high velocity. To rectify this obvious fundamental defect, the diameter of the pipes was increased as they approached the "canister" in order to reduce gradually the velocity of the air. This idea was developed on the lines that if the pipes receiving the grain from the hold were kept practically vertical, the initial velocity in the lower portion of the pipe would be sufficient to carry the grain a very considerable height without the further expenditure of energy. The existing machine was altered, therefore, in such a way that the expanded pipes were carried far down into the hold of the ship, and the upper end was joined to a more or less sharp bend of considerably enlarged cross section, and from here the pipe was conducted at a downward gradient to the "canister." This down pipe is of a diameter sufficiently large to reduce the speed of the air current as the grain slides down by gravity. As a further development the large vertical pipe below the bend was made telescopic, so that without the addition of more pipe the grain could be lowered down in the hold. This utilisation of the kinetic energy in the grain has led to a considerable decrease in the amount of power required.

A typical example of a plant on these lines, built by Henry Simon, Ltd., of Manchester, is shown in diagram Fig. **301**, which represents a floating pneumatic elevator with a capacity of about 200 tons per hour. It will be seen that the pipes are not only telescopic but that the inclined down pipe forms a boom which can be slewed sideways, and at the same time luffed vertically.

The plant is mounted on a steel pontoon. The suction pipes are of small diameter

[1] For a comparison of the merits of the pneumatic elevator and the bucket elevator for unloading ships, see pages 213 and 474.



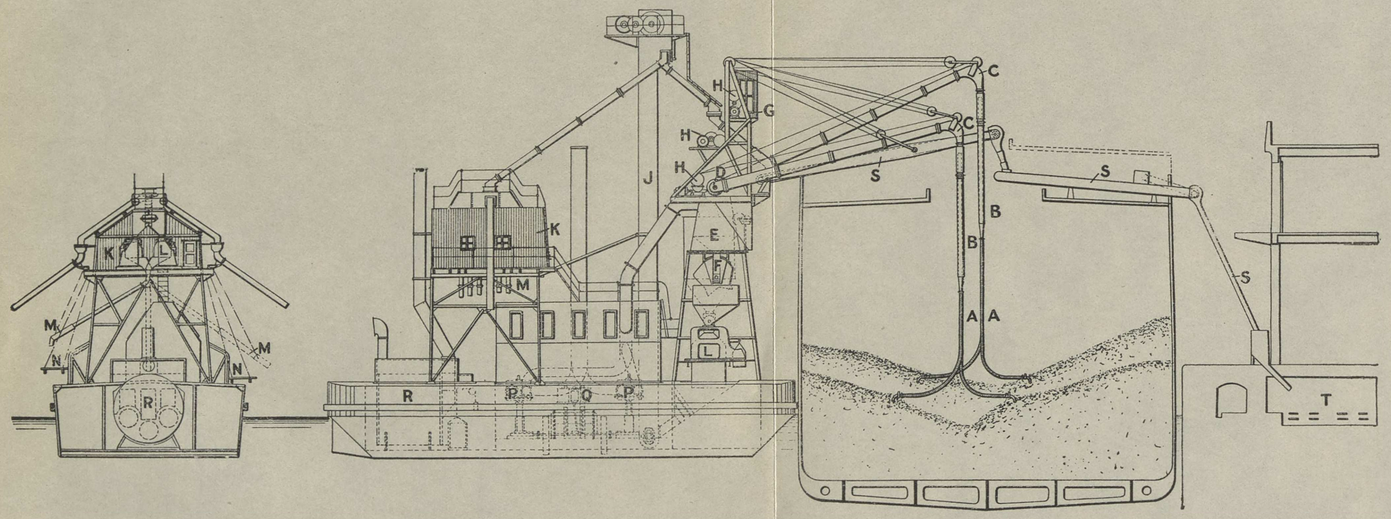


Fig. 301. Floating Pneumatic Elevator.

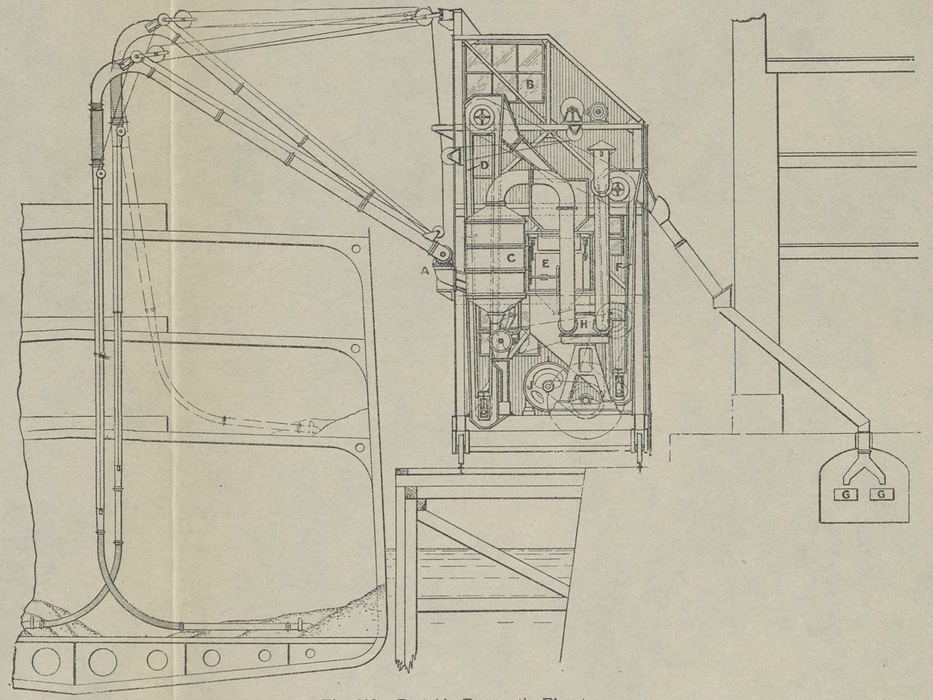


Fig. 302. Portable Pneumatic Elevator.

A Flexible pipes. Additional sections can be inserted.
B Patent telescopic pipes, giving variation in length of 15 ft.
C Bends.
D Socket joint and turntable.
E Grain receiver.
F Tumbling-box seal.
G Driver's cabin.
H Electric winches.
J Elevator feeding weigh-house.
K Weigh-house.
L Automatic grain weighers.
M Flexible spouts.
N Sacking-off platforms.
P Vacuum pumps.
Q Main steam engine.
R Boiler.
S Shore conveyors and shoots.
T Subway band conveyors under warehouses.

A Universal joint, enabling grain pipes to be luffed or slewed.
B Driver's cabin.
C Grain receiver with internal dust collector.
D Bucket elevator feeding weigher.
E Automatic grain weigher.
F Bucket elevator to swivelling delivery pipe.
G Band conveyors in subway under warehouses.
H Vertical reciprocating pump.
J Main electric motor.

[*To face page* 221.

at the intake end, considerable initial velocity being thus imparted to the grain, and this velocity is made use of to complete the travel of the grain to its highest point at the bend C. The diameter of the pipe gradually increases from the lower length to the bend. After the bend the pipes incline downwards to the receiver E, and this part of the transportation being thus largely effected by gravity, a saving in power is consequently obtained. The pipe boom is connected to the receiver through a socket joint and turntable D, which enables the boom to be luffed through an angle of 30°. At the same time the boom and the whole structure carrying the electric winches H, and control cabin G, can be slewed through more than half a circle, enabling a grain ship to be worked on either side, end on, or broadside on. The grain is distributed among six automatic weighers and delivered through flexible spouts M to lighters on either side of the pontoon, to the sacking-off platform N, or ashore by means of band conveyors and shoots.

Owing to the elevated position of the "canister" in the original elevators they became rather top heavy, but the development of the down pipe idea has now led to an entirely new type of machine. The grain in the first place runs into quite a small receiving chamber E, which is placed low down on the deck of the pontoon, thus removing at once the enormous amount of top weight and every possibility of capsizing. The grain is discharged from this "canister" into the well of a bucket elevator J, and the power required to drive this is saved many times over in the economy effected through the expanded pipes. This arrangement permits of a higher weighhouse which, instead of having a divided grain hopper, as formerly, which may give a list to the machine, has only one central hopper of about half the size of that required with the old type, and cannot produce any alteration in the trim of the pontoon.

To provide for the various widths as well as heights of steamers, the pipe booms are arranged to form a crane, and can be raised, lowered, or luffed, whilst the "canister" becomes the kingpost of the crane upon which the whole can revolve, so that the pipe can instantly be swung to port or starboard, or otherwise adapted to meet the requirements of the hold.

A further improvement is effected by placing a substructure upon which the crane stands out of the centre line of the pontoon, whereby it is possible to adapt the pipes quite readily to ships varying from 40 to 90 ft. beam, since they will have a much greater reach over one side of the pontoon than over the other, whilst the reach over the end is arranged to be half way between the two.

In order to avoid the enormous "stand-by" losses involved by the use of boilers, oil engines are introduced instead of steam, and these are geared to turbo-exhausters of the compound type instead of pumps, thus doing away with all valves and piston leakages.

The grain is extracted from the receiver or "canister" E by a tipper of the Duckham type, which has been found after many years' experience to be the most reliable and satisfactory method of extracting the grain. It differs from its predecessors in so far that the sides, ends, and rubbing surfaces are packed to avoid leakage, and for the old system of gravitation tipping a mechanical backward and forward motion so many times a minute is substituted.

The rotary wheel trap or seal appears at first sight to be more scientific, but owing to the shallow depth of the pockets, even with a trap 3 ft. in diameter, their tapered form and the enormous number of blades passing per minute, they were extremely liable to break down caused by foreign matter in the grain. It will be seen that owing to the tapered form of the pockets when half full, according to their bulk capacity, they are more than three parts full by vertical measurement. This brings the top surface of the

grain, and with it the foreign matter, very near to the top of the blades. A mechanically operated tipper, owing to its slow movement and its much greater depth of receiver, whilst giving the advantages of the rotary seal, entirely overcomes its defects.

A similar type of elevator, but mounted on wheels and a rail track on the quay, is shown in Fig. **302**. In this case the inclined pipes will be seen leading into a "canister" from which the grain is discharged into a bucket elevator, and raised into a weighing machine, then re-elevated for delivery into pockets in the warehouse wall; this installation was also built by Henry Simon, Ltd.

Small Pneumatic Grain Elevators.—Installations of small capacities have recently been introduced, particularly for the use of millers, maltsters, oil-mills, and the like. The one here described is that at Messrs Leetham & Sons' Flour Mills, York.

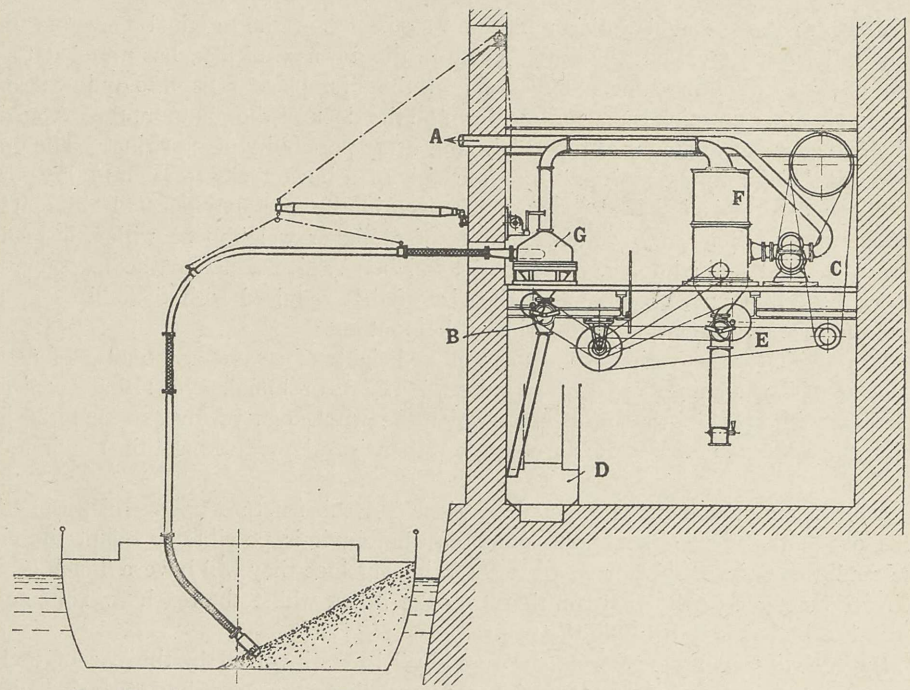


Fig. 303. Pneumatic Grain Elevator at Messrs Leetham & Sons' Flour Mills, York.

Fig. **303** shows the whole installation in diagrammatic form. As these small plants are very similar to the large ones already fully described, it will suffice to mention that D is an existing elevator into which the pneumatic installation has to discharge its load, G is the receiver, F the filter, C the blower, B the air trap, and A the exit for the spent air; E is another air trap through which the dust from the filter may be drawn off into sacks.

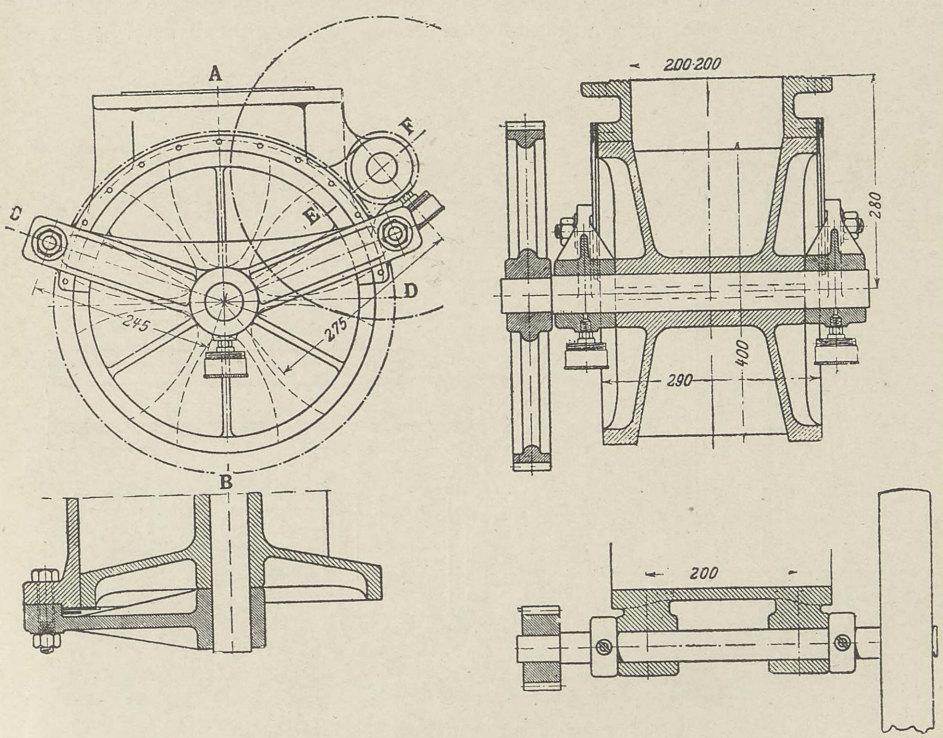
The capacity of the plant is 18 tons of grain per hour, and the driving power consumed is 15 H.P. It has, however, handled up to 22 tons per hour, with an expenditure of 18 H.P. These figures are very satisfactory, principally owing to the lift being only about 15 ft.

The only details which deserve a fuller description are the air traps B and E, Figs. **304** to **307**. They consist each of a wheel with six compartments fitting as nearly air-tight as possible into a frame, which is cast in one piece with the grain inlet; the same frame also carries a small countershaft with a pinion which is geared into a large wheel,

which in its turn revolves the main portion of the trap slowly. The wheel, with its six compartments, is 16 in. diameter, and 8 in. wide inside.

Another small pneumatic installation is at a mill at Sowerby Bridge, and was erected by Messrs R. Boby, Ltd., on the Topf system. The pipe is 4 in. diameter, the total length being 360 ft., and the lift is about 10 ft. The plant had a guaranteed capacity of 10 tons per hour, but it has easily dealt with 14 tons, with a consumption of 25 H.P.

Power Consumed by Plants of the Latest Type.—The most up-to-date plants now made consume a little under 2 H.P. per ton of grain handled per hour, to an average height, and with an average length of piping. The power consumption is, however, still very excessive for the actual conveying work performed, and if pneumatic



Figs. 304 to 307. Details of Revolving Air Traps.

elevators are largely used in spite of this fact, as well as the enormous initial cost, it must be put down to the extreme flexibility of their application to unloading grain vessels, their clean working, and the saving of all hand labour for trimming, as the suction nozzle can be brought into all nooks and corners, and almost literally every grain can be collected out of the hold.

The Pneumatic Removal of Ashes from Boiler-Houses.—Labour-saving devices for this purpose are one of the latest additions to the ever-increasing number of such appliances. In small boiler plants the ashes are easily handled more or less mechanically by a skip-hoist or elevator leading to an elevated receptacle to hold the ashes in suspension for loading into trucks or carts by gravity. Such equipments are satisfactory and inexpensive. The upkeep, though proportionately high, is not large in amount. Generally speaking, mechanical conveyors for ashes are unsuitable unless very

strong and costly, as lubrication is difficult or impossible. They are, therefore, rapidly corroded.

Ashes have been dealt with on board ship, and disposed of overboard by pneumatic or hydraulic means, but the credit of the introduction of a somewhat analogous system for stationary boiler installations is due to the Darley Engineering Co., of Pittsburg, who have erected upwards of thirty pneumatic ash-handling plants. Fig. 308 shows one of these installations in diagrammatic form. The main ash duct *a* passes close in front of the boilers and beneath the stokehole floor, but level with the floor are inlets before each boiler, into which the ashes are raked or swept, and which are closed with a lid when in use. The pipe leads to a large receptacle *b* with cone-shaped top and bottom, and raised sufficiently high so that the lower end can deliver when opened into a railway truck. The upper cone joins a suction pipe connected to an exhauster *c*, for small

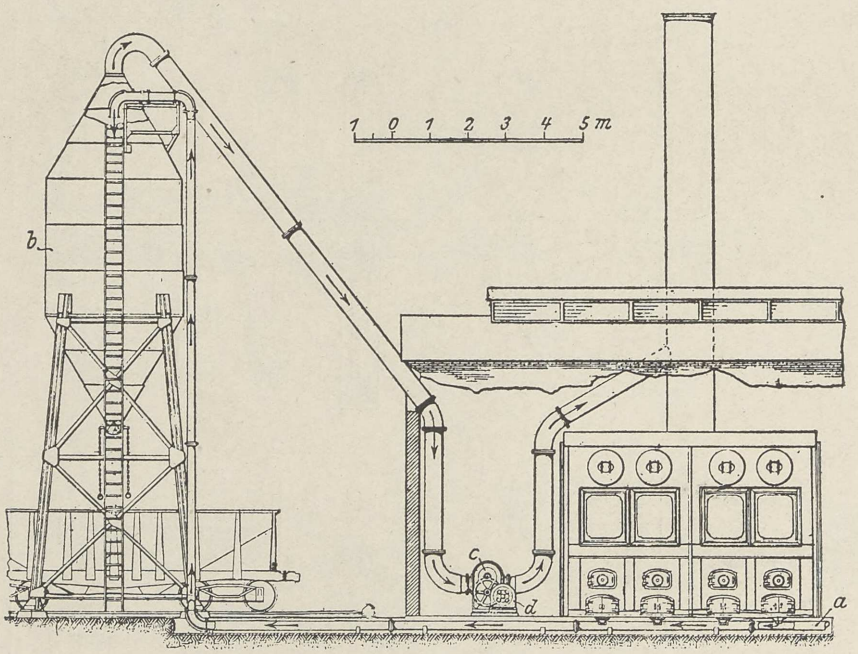


Fig. 308. Darley Pneumatic Ash-Handling Plant.

installations, and for large ones to an air-pump. The outlet of this is connected with the chimney whereby the draught is increased. At the top of the ascending pipe, and just before the ashes reach the receptacle *b*, they are subjected to a water spray to avoid dust, and consequently wear on the exhauster. In addition to this the air is withdrawn from the tank through a dust collector. The special rotary exhauster is simple and efficient for small capacities, but for larger ones a cycloidal blower is used.

It is a known fact that in all pneumatic installations for grain, etc., the material travels in the central portion of the pipe, so that no abrasion takes place at the sides of the pipe, except where corners are negotiated, so it is necessary to make the bent portions of the pipe not only of a fairly large radius, but also to fit them with renewable cheeks, and as ashes and clinker are of a most cutting nature the wear on this part is reduced to a minimum by having wearing blocks, *d*, of manganese steel, as shown in Fig. 309.

Suction conveyors have no moving parts in contact with the ashes. They are

dustless, practically noiseless, and the cost of repairs is only a fraction of that necessary with mechanical conveyors.

The duct *a* is made either of steel or cast iron, and is of a diameter of 6, 8, or 10 in. for capacities of 4, 6, and 10 tons per hour respectively. The tank *b* is made either of steel or concrete.

In installations for cold climates the receptacle *b* is fitted with a steam pipe to prevent the damp ashes from freezing together, which would prevent them leaving the outlet for removal.

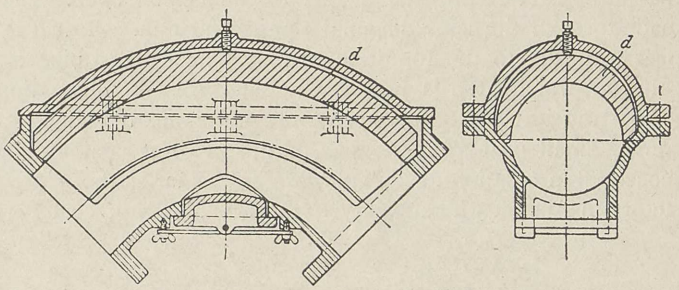


Fig. 309. Details of Bend in Pneumatic Suction Pipe for Ashes and Clinkers.

An important feature of the Darley Suction Conveyor is that while removing the ashes, it also removes the hot gases escaping from the ash hoppers, which are such a serious nuisance in the basements of boiler-houses.

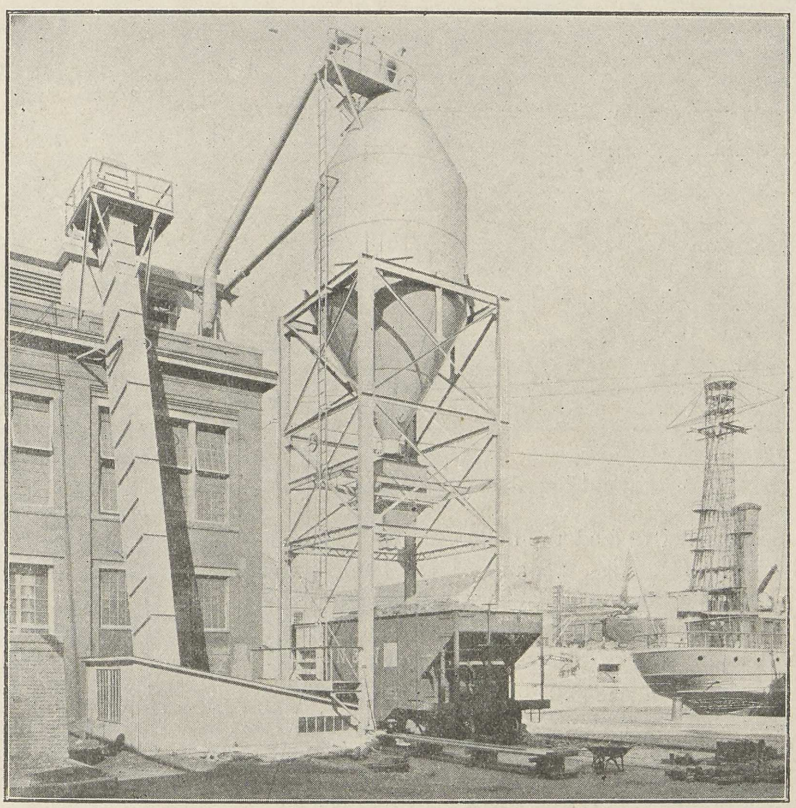
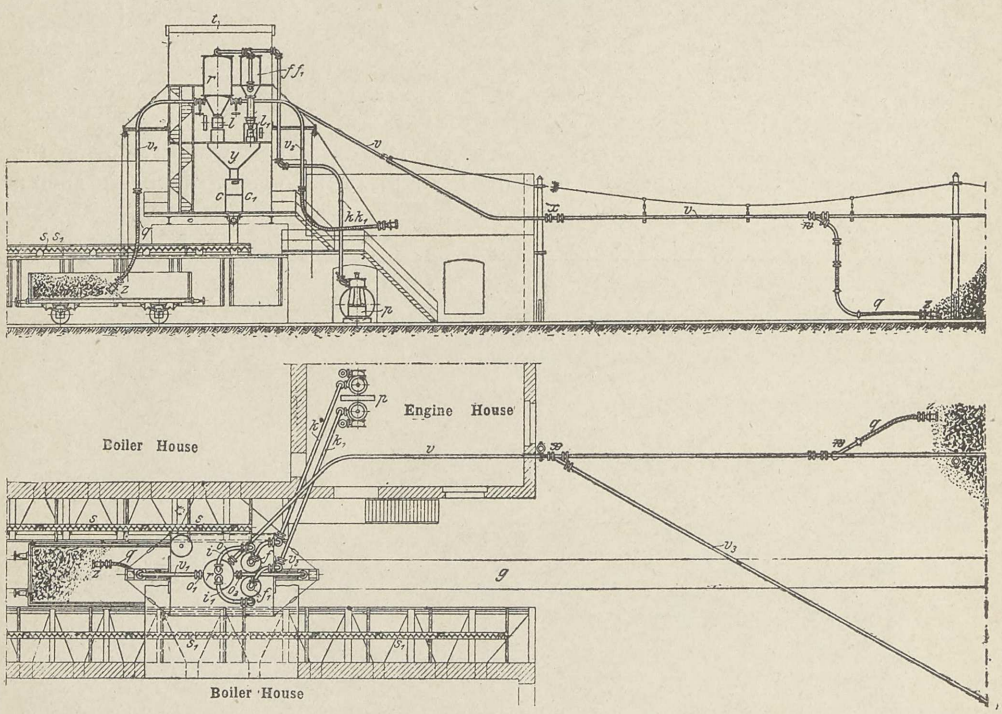


Fig. 310. Pneumatic Ash-Handling Plant at the Norfolk Navy Yard of the United States Government.

Quite a number of these pneumatic conveyors are used in the power stations of the United States Government. Fig. **310** shows the 60-ton tank of the Central Power Plant, Norfolk Navy Yard. Provision is made for weighing the ashes taken from this tank, for the purpose of testing the quality of the coal. The connection with the exhauster is made through the large diagonal pipe. The 8-in. ash duct is led underground and then rises vertically to the top of the tank. The exhaust pipe is led to the tank *via* a dust collector, which latter is, however, not shown in the illustration.

Pneumatic Coal Conveyors.—After many tedious attempts it is now possible to convey small coal from the size of dust to nut coal by pneumatic means. The first successful installation for this purpose has, as far as the writer is aware, been erected in a factory in Austria where twenty 10-ton truck-loads of coal per twenty-four hours have to



Figs. 311 and 312. Pneumatic Coal-Handling Plant.

be conveyed in order to feed the boilers in the two boiler-houses situated on both sides of the railway line (see Figs. **311** and **312**). The continual demand for coal throughout the twenty-four hours cannot be regularly supplied by the railway, so that as a safeguard a stock pile of coal is kept in an open yard about 500 to 600 ft. from the boiler-house.

Before the erection of this pneumatic plant the coal was conveyed in small trucks by hand labour from the wagons or the yard to the boiler-house. From the illustrations it will be seen that the pneumatic installation has been erected just above the railway siding and between the two boiler-houses. It is contained in a tall building *t*, and the coal is delivered from it by a cross worm conveyor to either or both of the two worms *s* and s_1 which distribute it to the coal bunkers. The component parts of this pneumatic plant are not unlike those already described, and consist of the receiver *r*, two filter chambers *f* and f_1, and twin air-pump *p*, the latter being in the engine-house. Two pipes

i and i_1 lead from the top of the receiver r to the lower ends of the filters f and f_1, and from the lid of these the two pipes k and k_1 lead to the air-pumps p. Below the receiver is the air trap l, and below the two filters are two similar traps l_1. The former has an outlet for the coal, and the latter for the dust, so that all the coal, large and small, is again reunited in the hopper y. The lower end of the receiver r has three inlets, o, o_1, and o_2, with valves for the conveying pipes v, v_1, and v_2. The longest pipe v leads to the stock heap in the yard; v_3 is a branch leading to the second stock heap about 130 ft. away, and the pipes v_1 and v_2 lead straight down to the coal trucks on the siding g.

The *modus operandi* is as follows: After two of the valves o are closed so that only one of the pipes v is in communication with the receiver r, a flexible pipe q, with a suction nozzle z, is connected to the pipe, and the nozzle dipped into the coal, as shown in Fig. 313. Air is now sucked out of the filters and through the connecting pipes out of the receiver, when a mixture of air and coal enters the nozzle z, pipes q and v, into the receiver. The air traps are of the revolving type already described, and deliver, as mentioned, into the hopper y. The coal then passes through automatic weighers c and c_1, and, as already mentioned, into the worms s and s_1. The dust from the filters is mixed in again in the same proportion as it is received by the nozzle, so that the coal delivered into the worms is exactly of the same quality as received from the stock heap or the railway truck.

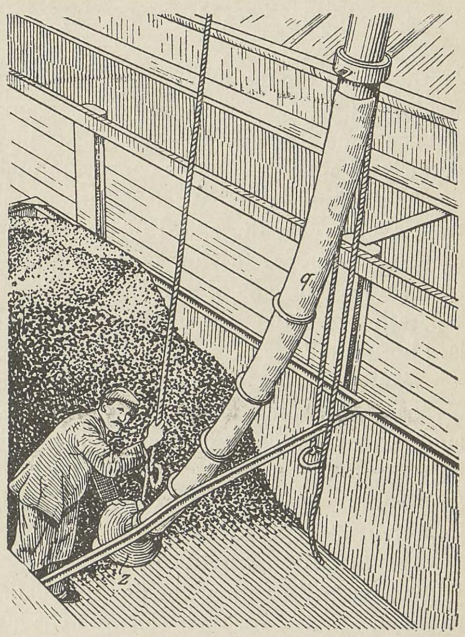


Fig. 313. Suction Nozzle of Pneumatic Coal Conveyor.

The saving of labour effected by the installation was such as to cover its first cost in two years. In addition to the saving of labour there is also the advantage that the coal is emptied more completely out of the trucks, and that there is no loss through the production of dust, which was a great nuisance when hand labour was employed. The installation was built by Seck, of Dresden.

For further installations see "Coal, Coke, and Ash-Handling Plants for Boiler-Houses, Gasworks, etc.," page 641.

CHAPTER XX

CONVEYING MATERIAL BY HYDRAULIC MEANS

In the United States experiments have been satisfactorily conducted, in which small coal was mixed with and conveyed in a stream of water through pipes, and at the destination the coal was allowed to settle whilst the water was led away. What has been said in connection with pneumatic conveyors applies also to this system, viz., the material to be conveyed should not have a specific gravity much greater than the medium in which it travels, otherwise the speed of the mixture in the pipes must be greater, and therefore the expenditure of driving power higher. This rule applies to the conveyance of coal by means of currents of water. The flow must be swift enough to prevent the coal from separating and depositing, thereby blocking up the pipes, particularly where these are laid horizontally.

Material from dredgers, such as sand and mud, is frequently conveyed by such means, water being mixed freely with the material, which is thus conveyed on to waste land. This fact can only be briefly mentioned without going into details, as it would be beyond the scope of this work, in which also dredgers and power shovels have been omitted, as digging and excavating, and not conveying, are the primary and more important objects of these appliances.

Hydraulic Conveying at the Hammersmith Borough Council's Electric Light Installation.—The first installation of this kind was erected for the Hammersmith Borough Council for their electric light installation, the power house being situated some 600 yds. from the river Thames, where the coal is received in barges. The capacity is from 30 to 60 tons of coal per hour, which is pumped, as it were, through 8-in. Mannesmann tubes. The mains are laid in the streets in the form of a large S-bend. Both delivery and return pipes are placed close together; these are socket and spigot pipes in lengths of approximately 30 ft.

At the coal wharf a large mixing tank is erected, which is fed by a grab that lifts the coal from the barges, and after it is passed over an automatic weighing machine, it is deposited in a tank in the proportion of 15 per cent. of coal to 85 per cent. of water. A powerful electrically driven pump, built by Messrs Gwynnes, Ltd., forces this mixture at a high velocity through the pipes to the receiving tank at the electricity works. Here the coal sinks to the bottom of the tank, and a second and similar pump drives the water through the return pipes to the mixing tank, while another grab lifts the coal out of the reception tank and deposits it in huge storage tanks capable of holding 6,000 tons of coal. The pipes are laid approximately level, but rise about 15 ft. near the delivery terminal. The process is automatic, and the same water is used over and over again.

The installation was estimated to cost £15,600, but as previously the coal had to be conveyed by cart at a cost of approximately 7d. per ton, it is estimated that an annual saving of £1,577 may be effected.

The installation was designed by Mr G. G. Bell, electrical engineer of the Hammersmith Borough Council, and erected about the end of 1914.

CHAPTER XXI

THE MECHANICAL DISPOSAL OF ASHES FROM STEAMERS

THE tendency to utilise mechanical means for handling material has become more and more general, and important new fields for their operation have, within recent years, been opened up in the mechanical disposal of ashes and clinkers from the stokeholds of steamers.

Development of Ash Ejection.—In the days of marine engines of small horse power, and consequent small coal consumption, the refuse of the stokehold was easily dealt with by hand labour, being brought up in buckets and emptied over the side. When the coal consumption had somewhat advanced, simple ash hoists were introduced, still utilising the bucket, and the general procedure remaining much the same, except that mechanical means were employed to raise the buckets to the deck level, or a few yards above it.

The ashes or clinkers—in other words, the refuse from the boilers of large steamers—accumulate so fast that they have to be removed about every four hours from the furnace. After being cooled with water, they are generally filled into large iron tubs on wheels, which sometimes run on rails to a suitable position, whence they can be raised to the deck, and the ashes tipped overboard at intervals.

The older methods employed ordinary hoists, by means of which the tubs were either raised through a special duct or a shaft, or more often one of the ventilating shafts was used for their passage. On the deck corresponding rails were provided, upon which the tubs were lowered and pushed to the side of the ship, and emptied into hopper shoots leading overboard.

The Ash Hoist.[1]—All ash hoists have certain drawbacks or restrictions; they cause the intolerable nuisance of ashes being blown all over the deck of the vessel, to the annoyance and discomfort of passengers and crew. This is especially the case with passenger vessels in hot climates, owing to the ashes being blown into the cabins through the open portholes; if their operation is restricted to night time, the noise produced by them is almost equally objectionable. Ash hoists are also restricted to steamers working without forced draught, on account of the communication which the pipe affords between the stokehold and the open; worst of all, they are too slow and altogether inadequate for large steamers. With modern equipments of more powerful engines, and, consequently, much larger coal consumption, the disposal of ashes called for a more effective method; this led to the introduction of the hydro-ejector, which, as the name implies, ejects the ashes by hydraulic force, or, rather, by jets of water under pressure, outside the ship's side, above the water line. This system answers very well, and is largely used in merchant steamers, in spite of sundry drawbacks; but in the case of battleships it was soon decided that the piercing of the armour to provide outlets for the ash tubes was undesirable on account of weakening the armour.

Hydro-Ejectors.—Hydro-ejectors were first introduced by Horace See, of New

[1] Ash hoists are fully described in an article by the author in *Cassier's Magazine* of August 1912.

York, and his system is shown by Fig. 314. On the floor of the stokehold is fixed a hopper A, fitted with a water-tight lid B, and fastenings *g h*. The hopper A is joined to the ejector pipe C, at the bottom of which is a hydraulic nozzle F, regulated by cock E, and fed by the pressure main D. Pipe C is bent at its upper end and delivers its load overboard above the water line; it is also fitted with an air valve I, through which air may be admitted during the conveying action, and a cock *c* for emptying the water out of the apparatus after use.

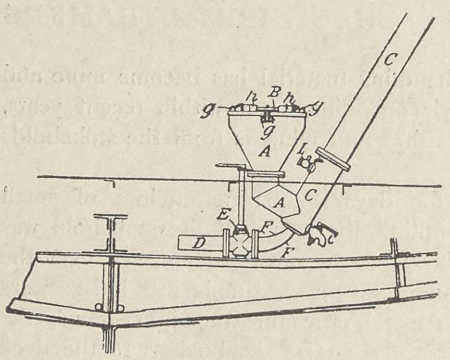


Fig. 314. Arrangement of See's Hydraulic Ash Ejector.

The ejector works as follows: After the cocks and valves *c*, E and I have been closed, the lid B is opened and the hopper A filled with ashes; the pressure pump is now started. As soon as the gauge indicates the required pressure, the cock E is opened quickly and the water under pressure enters through jet F at a high speed and forces the ashes through pipe C overboard. At the same time, tap I is opened to admit air, which acts like an injector in dispersing the ashes. If the coal has a tendency to cake and the ashes contain large pieces of clinker, a grating is placed on top of the hopper and the large pieces are broken with a hammer, so as to prevent the choking of the pipe C. But this has the drawback that, unless the pressure gauge is carefully watched and the cock opened at the exact moment, the pipe D or the pump might be injured; so the same inventor has added an automatic device to prevent this. In this scheme the jet nozzle is closed by a rod which carries two pistons of different diameters, and a spring also holds this rod in position. The whole is enclosed in an iron cylinder which communicates with a branch pipe from the hydraulic main. As soon as the right pressure in the main is reached, the valve opens automatically and the ashes are ejected. When the ashes have been disposed of, a three-way valve is so set as to permit the water to escape in front of the piston, when the nozzle will automatically close.

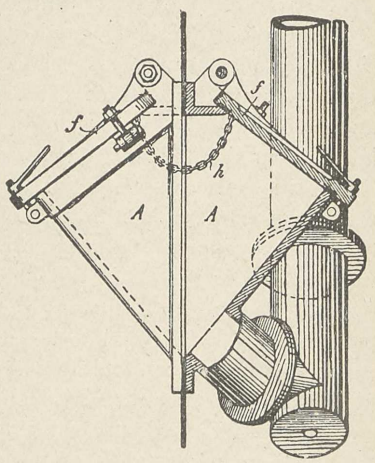


Fig. 315. Arrangement of See's Ash Ejector to serve two Stokeholds.

Generally, one ejector is used in connection with each stokehold; but the inlet can also be duplicated to serve two stokeholds, as shown in Fig. 315; *f f* are the two lids of the hoppers A A, and are so connected by a chain *h* that only one can be opened at a time. This construction has, however, several obvious disadvantages.

As there is always a tendency for the finer ashes to accumulate in the bottom of the hopper, where they are out of reach of the water jet, Thorne has constructed a hopper as shown in Fig. 316. This permits a portion of the water from the hydraulic main *h* to pass through a narrow channel *g* into the hopper, and thus keeps it clean. The amount of water so used can be adjusted by the valve *f*.

Another method is that of Hochstein, shown in Figs. 317 and 318. It is for a

similar purpose to See's attachment; both have the object of preventing shocks in the hydraulic mains at the setting to work of the apparatus and preventing unsatisfactory starting owing to insufficient initial pressure. This is achieved, particularly by Hochstein, by allowing the pump to be always at work, and his apparatus permits, by the movement of a lever, to utilise the

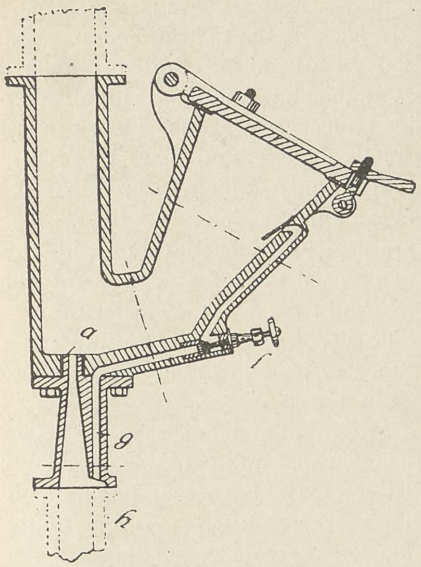


Fig. 316. Outline of the Thorne Hopper.

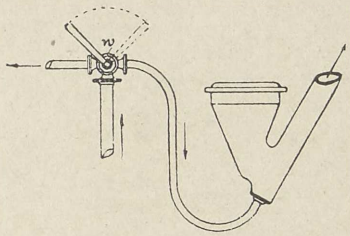


Fig. 317. The Hochstein Three-way Valve.

water either for the ejector or to return it into the sea. The simplest form is the application of a three-way valve *w*, shown in Fig. **317**, which explains itself; it shows the hydraulic main leading into the valve *w*, which conducts the water either into the ejector or right away. In Fig. **318** the hydraulic main enters at *e*, and the water can enter either through jet *b* to the ejector or through jet *c* to some other exit; the jets *b* and *c* are respectively opened or closed by the valves *k* and *i*, which latter form part of a hollow spindle with the openings or ports *d*, *f* and *g*. Attached to this spindle are the pistons *r* and *s*, of different diameters. When the three-way valve *a* is opened, as shown in the drawing, the pipe *p* forms a communication between the hydraulic supply and the larger of the two pistons, and thereby opens jet *b* and starts the ejector with full pressure. When valve *a* is closed, the water enters the ports *d*, in the hollow spindle, and passes through ports *g*, below the smaller piston, and forces the valves into the position shown—that is, the ejector valve *b* is closed and the water escapes through the ports *f* and exit *c*. It will thus be seen that by opening or closing valve *a* the ejector is started or stopped immediately.

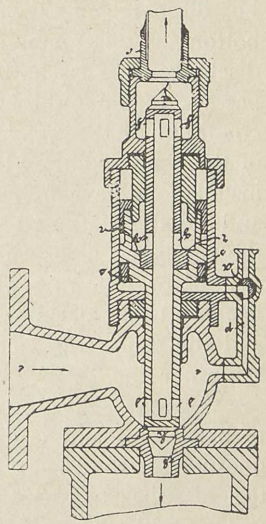


Fig. 318. Hochstein's Method of Preventing Shocks in the Hydraulic Mains.

As it is most essential, for obvious reasons, that the discharge of the ashes should take place at will, either at the port or starboard side of the steamer, ejector installations have either to be provided in duplicate, with the exit on different sides, or if one installation only is to be used, it must be provided with alternate exits, one to port and one to starboard. A scheme providing for this, and also the invention of Hochstein, is shown in Fig. **319**, where *a* represents the ash hopper, *b* the ejector pipe, and *c c* the two outlets. The valve attachment c^1 by a simple movement conducts the ashes to either side. The two smaller illustrations, Fig. **320**, show

two sections through the principal parts with the movable distributor d and the bend b^1 of the ejector pipe.

The hydraulic ejector by Körting, of injector fame, is represented in Fig. 321, and shows distinct advances in the right direction. The ejector pipe b leads by a bend into the larger pipe c, which terminates at the ship's bottom, with an alternative side outlet under water at the side, as shown in dotted lines; d is a perforated plate to prevent dust, while e is an air inlet, which ensures that the water level is the same in the pipe c as outside. The following data are available in connection with this ejector: The water used was of a pressure of 180 lb. per square inch, and passed to the ejector through a $2\frac{1}{2}$-in. pipe. The ejector used 3,300 gals. of water to eject 7 to 8 tons of ashes to a height of 13 to 14 ft. through a 4-in. pipe.

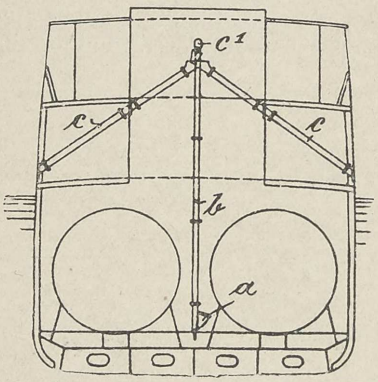


Fig. 319. Hochstein's Method for Discharging Ashes to Port or Starboard of a Vessel.

Ejector Pipes.—The bends in the ejector pipes, which are practically indispensable in all the foregoing installations, have been found to be subject to enormous wear and tear, as, owing to the centrifugal force when negotiating bends, all the abrasion takes place on the one side and under the most adverse circumstances. The pipes have, therefore, been made with thicker metal on the side most affected, and also with renewable liners, as well as lined with glass, which is harder than ashes and so reduces the wear.

There can be no doubt that, where possible, the ideal exit for he discharge of the ashes is vertically down through the ship's bottom, as this method has the following distinct advantages. The discharge pipe is short and straight (without bends); it makes the passage of pipes through the bunkers and decks unnecessary; the condition of the weather is immaterial to the successful expulsion of the ashes, contrary to side delivery above the water line, as such installations have frequently to be fitted in duplicate, on the port and on the starboard side, as already mentioned, so as to enable the discharge of ashes to leeward in all weathers, and even then a head or following wind will cause the seas to carry the ashes back on to the deck, as well as into the stern tubes and sea suctions, and the ashes will cause scoring of the skin plating at and below the water line.

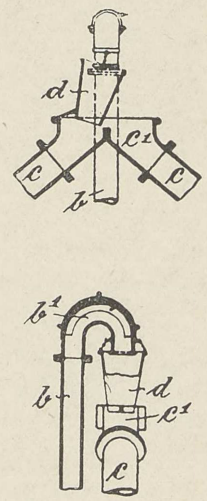


Fig. 320. Details of the Principal Parts of Fig. 319, in Front and Side Views.

Latest Developments.—With the advent of the recent types of battleships and cruisers with their powerful turbine engines, the question of the mechanical disposal of the now enormous quantities of ashes has become a most important one. The non-interference with the existing structural arrangements was a *sine qua non*. The Admiralty, while seeking a solution of the difficulty, experimented with an ejector used in the French Navy, with a discharge through the bottom of the ship, but it did not answer the requirements of the British Navy; the naval authorities, therefore, experimented in the same direction, and eventually produced a system by which the clinkers, ashes, and other refuse were first crushed

and then expelled by pneumatic pressure through an opening in the bottom of the ship.

Before describing the system adopted by the British Navy, let us investigate the French system just mentioned.

The compressed air ash ejector of Brouquière & Baze is shown in Fig. 322. The ashes are deposited in the apparatus through the opening C, which closes water-tight; this door C is manipulated by the piston and rod of the pneumatic cylinder *a*; the pipes *m* and *i* bring the supply from the main. The ashes deposited in the hopper A are agitated with water by a stirring device manipulated by spindle *b*. The exit of the hopper A is closed by a floating valve *c*, which may be opened by the rope *d* connected to a piston in the pneumatic cylinder *e*. Water can be admitted into the hopper A from the body O, which is normally full of sea water, through the tap *g*, whilst the compressed air is admitted by cock *h*. The delivery pipe B for the ashes may be closed by gate valve *k*.

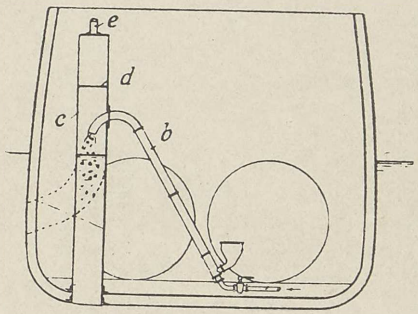


Fig. 321. Arrangement of Körting's Hydraulic Ash Ejector.

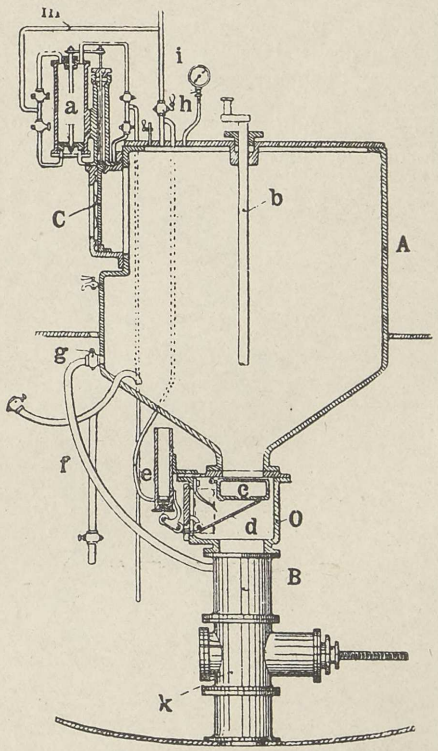


Fig. 322. Compressed Air Ash Ejector of Brouquière & Baze.

The apparatus acts as follows: Compressed air is admitted below the piston in cylinder *a*, whereby the door *c* is opened; after the filling of the hopper, door *c* is again closed by admitting air above the piston of cylinder *a*. The gate valve *k* is now opened to admit sea water, whereby valve *c* is automatically closed and tap *g* is opened to let water in by pipe *f*, so that the hopper is filled, when the stirrer is set to work. Compressed air is now admitted beneath the piston of cylinder *e*, which, by means of the rope, opens the floating valve *c* into the position shown dotted, to give a free exit to the mixture of ashes and water. Compressed air is at the same time admitted by cock *h*, which forces the ashes out.

The system on which the ashes are disposed of in the British Navy consists of two types, and are built by J. Stone & Co., Ltd., of Deptford, which two systems are described as follows. The pneumatic underline ash and clinker expeller, used largely in His Majesty's Navy, and the hydro-pneumatic underline ash expeller specially designed for the first-class turbine battleships and cruisers. The former type discharges vertically downwards, while the second discharges generally through the side of the vessel beneath the water line, as shown in Fig. 323. It was necessary to have a side discharge in this case, owing to the fact that the main condenser suctions

in the latest turbine battleships are situated in the bottom of the ships, so that an ash discharge vertically downwards would make it possible for some of the ashes to be taken into the suctions, with disastrous results.

Stone's underline pneumatic ash and clinker expeller consists of a hopper into which the ashes, etc., are shovelled as they come from the furnace: from the hopper the material falls into a pair of crushing jaws, which reduce it to a convenient size for effectual discharge. The ashes so reduced are now admitted intermittently into a revolving drum, which at one period of its revolution receives a charge, whilst at another period it allows this charge to escape into the sea, whilst at no time does it allow a communication between the sea and the ship's compartment. Finally, a gate valve is built between the exit and the working part of the apparatus, to be closed only if repair should be necessary. An engine combined with an air compressor furnishes the driving power for the crusher and drum, and also the pneumatic supply for the same.

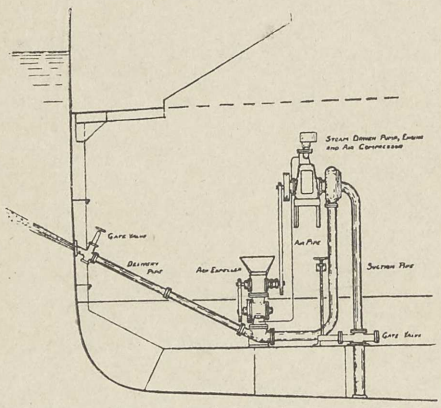
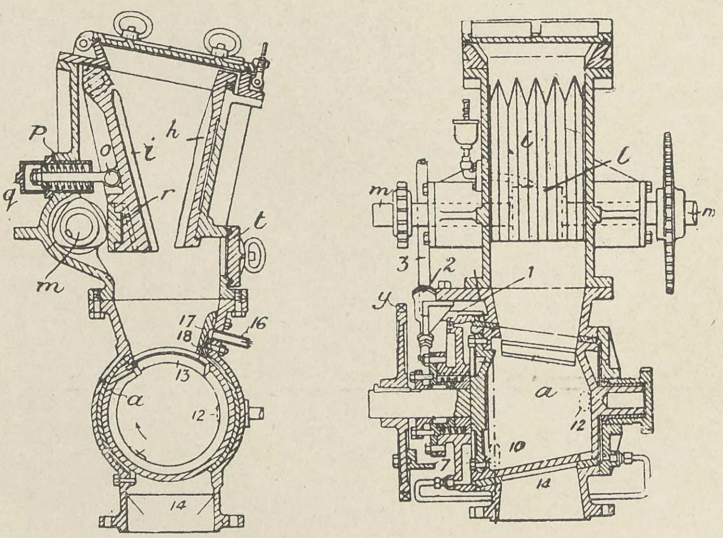


Fig. 323. Diagram of Stone's Patent Hydro-Pneumatic Underline Ash Expeller used for Naval Purposes.

Figs. 324 and 325 show the crushing jaws *i* and *h*; the latter is fixed, whilst the former is hinged at the top, and reciprocates at its lower end by means of a three-



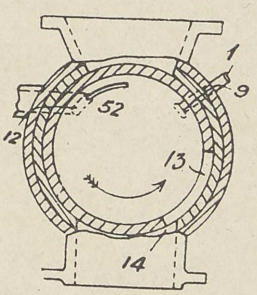
Figs. 324 and 325. Arrangement of Crusher for Breaking Clinker for Discharge through Stone's Expeller.

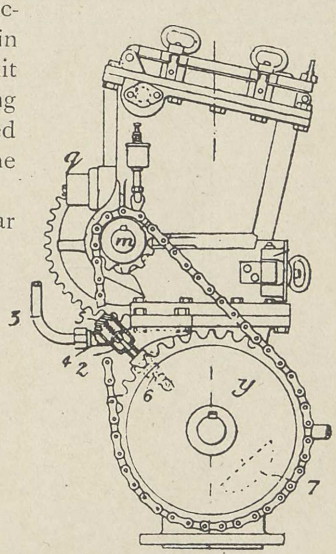
lobed cam, which is keyed to the spindle *m*. A draw-back rod, actuated by a spring P, in case *q*, keeps the face of the jaws always in contact with the cam face *r*. The shaft is driven by roller chain and chain wheels at a speed of 60 revs. per minute, giving the hinged jaw about 180 double strokes per minute. There is an inspection door to give access to the lower part of the hopper, and the whole apparatus can be

closed by a water-tight cover. A water spray is provided to wash out and keep the hopper clean. Two further views of this apparatus are given in Figs. **326** and **327**.

The revolving drum under the hopper is conical, and fits like a cock into its casing. The hollow drum is supported by two bearings, and the whole consists of one casting; there is but one opening, 13, in the revolving cone, which coincides alternatively with the inlet and outlet of its casing. The chain wheel *y* receives power from the crusher spindle. To assist the expulsion of the ashes, compressed air is admitted into the drum by air pipe 3 and valve 2; this valve is opened as soon as the drum has attained the position at which the air cannot escape out of the hopper; there is a tripper, 7, on the chain wheel *y*, which opens the valve 2 just at the right moment once in every revolution; the air is then admitted by pipe 1 and the opening 10. At the position of the drum, as shown in Fig. **324**, water is also admitted by pipe 16 and the spreaders 17 and 18, which cause a spray and prevent the creation of dust. Fig. **327** shows an outside view, from which the tripper 7 and the air valve can be better seen. In the sectional view, Fig. **326**, the drum is shown in the position in which opening 13 is just finishing its discharge into exit 14; the compressed air prevents the sea from entering whilst the ashes escape; just before opening 14 is closed again by the revolving drum, a communication with the atmosphere is formed by opening 52 and pipe 12.

The hydro-pneumatic underline ash expeller is similar to the last, and a general disposition is shown in Fig. **323**. In this arrangement a stream of water, which is drawn from the sea by a centrifugal pump, is continually moving through a discharge pipe which passes underneath the expeller.





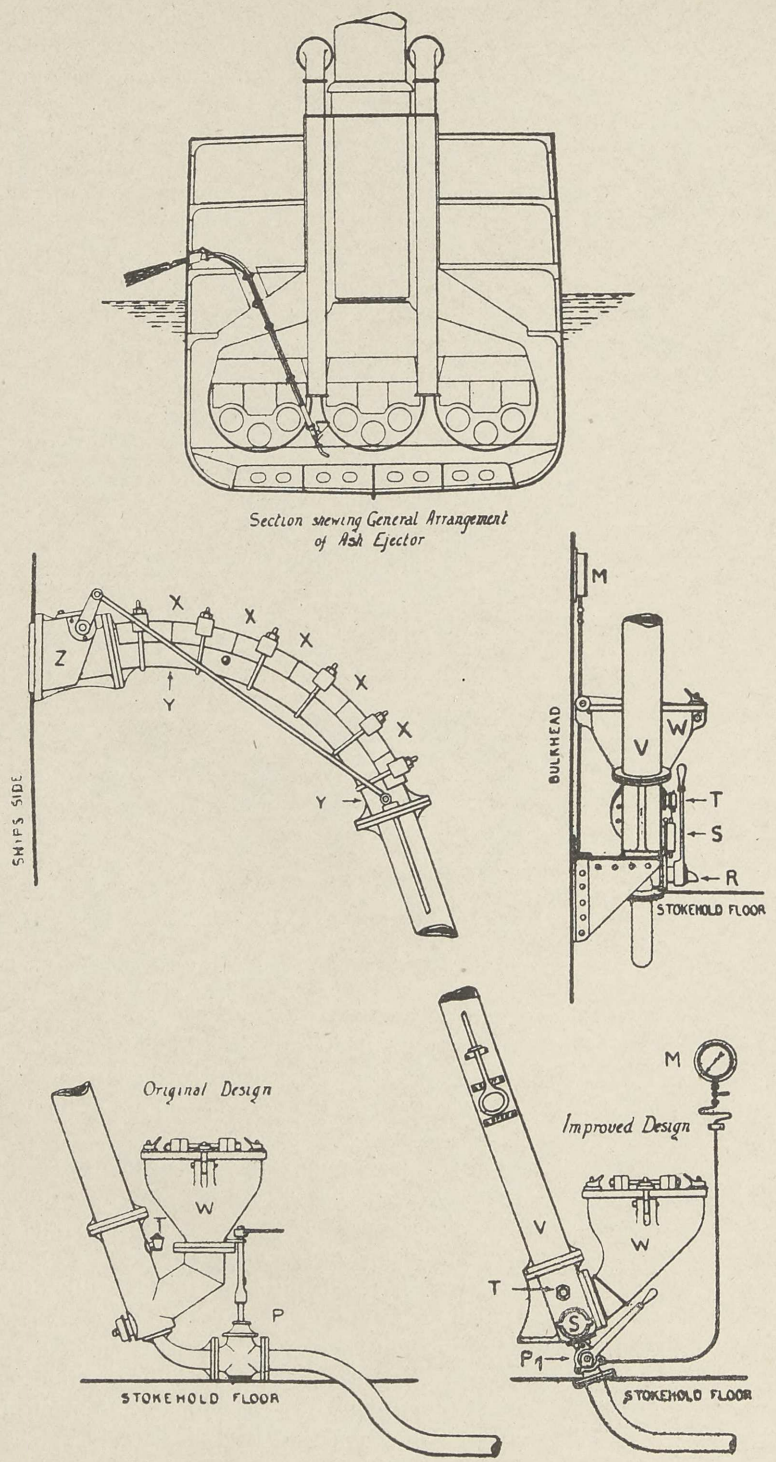
Figs. 326 and 327. Details of Crusher and Drum of Stone's Ash Expeller.

The ashes and other refuse are shovelled into a crushing hopper, whence they pass into a double-ported revolving drum, similar to that above described, which alternately presents its openings to the hopper and to the moving stream of water beneath, so that the ashes are caught by the stream and carried, not overboard, but several feet clear of the ship's side, or bottom, according to the place from which they are discharged.

Both the air compressor and the centrifugal pump are coupled to a two-crank, single-cylinder steam engine, which is also used for driving the crusher and the revolving drum.

The ash discharge pipe may be either vertically downwards through the bottom of the ship, horizontally through the side, or inclined at an angle as shown in Fig. **323**.

Both types of underline ash expellers are fitted with knife blades at the drum and its casing, to shear off any material which might find its way between the working surfaces; as well as with a safety action, by which the entry of extra hard material causes the breakage of a small safety pin and stops the machine. Upon the shearing of this pin the steam-driven compressor is immediately stopped by an automatic arrangement, which makes a steam governor unnecessary. These pins are easily replaceable, and a number are carried as spare parts.

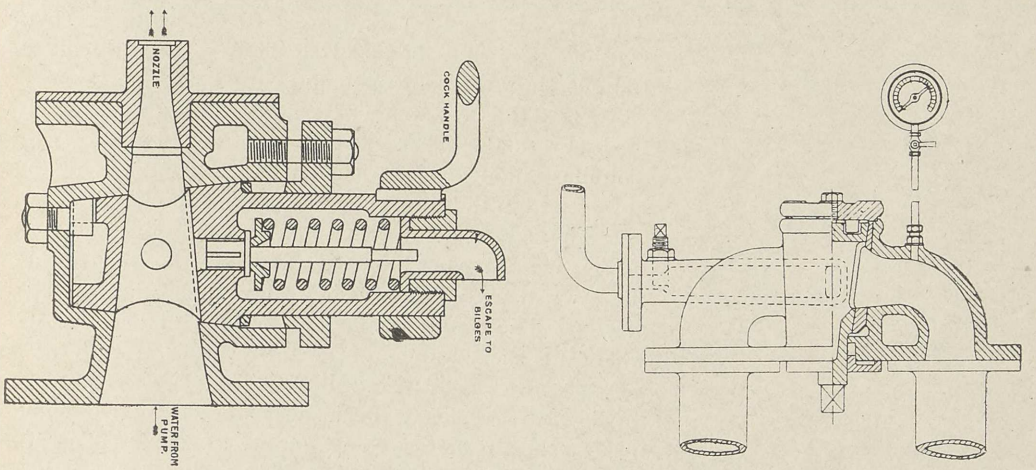


Figs. 328 to 332. General Arrangement and Details of Trewent & Proctor's Ash Ejector.

All the later vessels of the British Navy are now fitted with these ash expellers, as well as the most important of the liners, including those of the Cunard, White Star, P. & O., etc.

The system introduced by Horace See, though exceedingly simple, requires very careful attention to all its details, and although an ejector of imperfect design may handle the ashes very well, the cost of renewals and repairs, and, shall we say, the life of the machine, depend upon the excellence of construction of the vital parts.

Figs. **328** to **332** show one of the ejectors as now made by Trewent & Proctor, Ltd., and installed in steamers, with the details to a larger scale. The system has already been described in its general outline, and is so simple that it requires very little comment. W is the receiving hopper for the ashes: it is fitted with a grating to prevent very large objects from falling in; this hopper is also fitted with a water-tight lid. T is the knee piece which supports the lower terminal of the apparatus: it also bears the nozzle for the jet, an inspection hole S, and an air inlet. P is the control cock for the ejector jet



Figs. **333** and **334**. Two Types of Trewent & Proctor's Control Cock.

from the hydraulic main. M is a pressure gauge, D the hydraulic main, V the discharge pipe, V the bent portion of the delivery pipe, X removable segments of the same pipe, and Z the ship's side valve.

The operation is as follows: As soon as the pressure in the main from the pump has reached 190 to 200 lb. per square inch by the gauge M, the control cock P is opened quickly, when the pressure will fall to 150 lb., and must be maintained at that. The jet so admitted into the discharge pipe will eject any ashes or clinkers filled into the hopper W at great speed through the ship's side valve Z, which, of course, has been opened previously. The control cock P is a very important part of the system, and we, therefore, give a separate illustration of it in Fig. **333**; the bore of the cock is gently tapered from the supply pipe to the nozzle, and the interior of the movable part of the cock is fitted with an escape valve which opens at a pressure of 200 lb., and has an outlet to the bilges. The nozzle is loose so that different sizes can be fitted to suit different heights of lifts for the ashes; the cock is also sometimes fitted with a by-pass branch for use when the ejector is shut off. A modified form of the control cock is shown in Fig. **334**; this type is fitted on bulkhead and connected by a separate pipe to the ejector piece T; the nozzle in this case is fitted to this latter part; as the illustration

shows, there is a by-pass branch and a pressure gauge. The whole apparatus connecting the pump to the nozzle must stand a pressure of 200 lb., and the hydraulic mains must have as few bends as possible.

Having now dealt with two of the principal forms of receiving terminals, we will see some of the equally important delivery terminals. Fig. 335 represents the construction of a ship's side valve, which dispenses with the usual bend shown in Fig. 329 at the top of the ejector pipe, as the ashes are deflected in the desired direction by a plate inside the valve; renewable side and bottom plates are also provided. The principal feature of the valve is the elimination of the bend and the curved sliding shutter which closes the discharge opening between the deflecting plate and the ship's side. A hydraulic cylinder is sometimes used in connection with this to open the valve automatically when the ejector is working, and which closes by a weight as soon as the apparatus becomes idle.

Figs. 336 and 337 show a patent revolving cock outlet, fitted with a deflecting plate, which answers the same purpose as that in Fig. 335. This type is used for destroyers where lightness is a consideration, and for small steamers. The two illustrations show the cock open and closed.

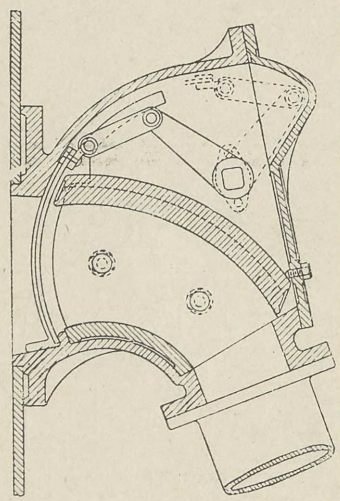


Fig. 335. Ship's Side Valve of Ash Ejector.

Fig. 338 is yet another type of outlet with deflectors to discharge the ashes close to the sides of the vessel. The illustration explains itself. The apparatus is quite housed within the ship when out of use and closed.

The same ejector with slight modifications is used on steamers carrying horses to discharge the dung from the lower deck. Fig. 339 shows the application of the ejector. The refuse is swept or swilled to the ejector where it is sucked up and ejected overboard.

Stone's Ash Expeller.—The latest type of Stone's ash expeller is exclusively worked by hydraulic means, the apparatus being known as Stone's Patent Hydraulic Ash Expeller. Figs. 340 and 341 show the construction. The first illustration shows the expeller shut off, and the second when in use. The working part of the machine is entirely below the stokehold floor, the receiving hopper being on the level with the floor, so that the ashes and clinkers can be swept into it.

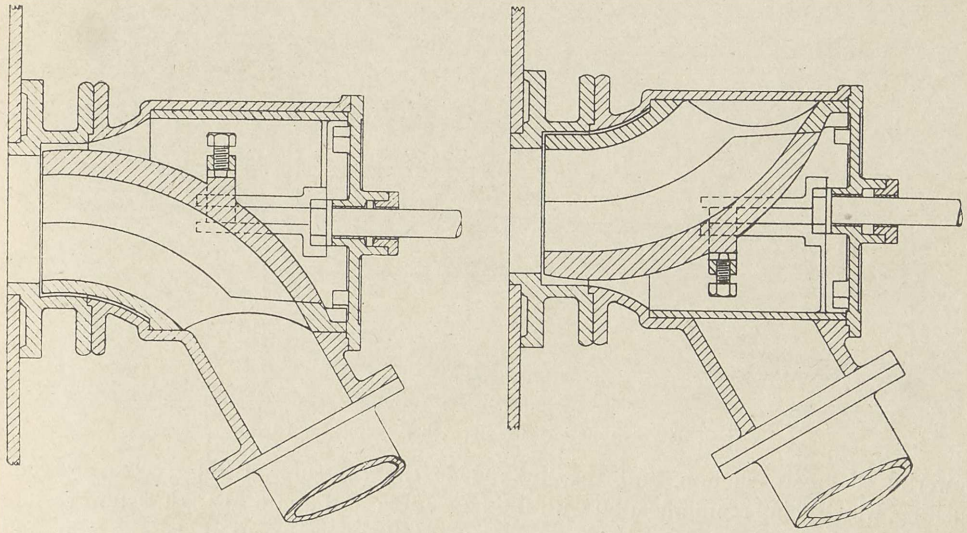
The expeller consists of the receiving hopper already mentioned, and this is fitted with a grating reaching into the hopper to within a few inches of the sloping bottom of the hopper, thus preventing larger pieces entering the apparatus than can be conveniently and safely expelled.

A number of auxiliary water jets play upon the ashes so as to swill them down the gentle slope of the hopper, and bring them to the point where they come in contact with the induced current.

A copious water supply at a pressure of from 15 to 20 lb. per square inch from a centrifugal pump is used in the ejector, which is sufficient to eject the ashes, etc., at a rate of 20 ft. per second from the ship's side. It is of importance that this speed should be maintained, and it is one of the functions of the apparatus to do this automatically.

The *modus operandi* is as follows: The ashes are swept so as to fall through the grating A into the hopper B, and proceed from this as already mentioned by the aid of

auxiliary water jets into the small hopper or chamber C, the passage between B and C being interceptible by an automatic hydraulic ram D. This is normally open when the ejector is at work, but throttles the communication automatically immediately any



Figs. 336 and 337. Revolving Cock Outlet in the Open and Closed Positions.

overfeeding should retard the speed of ejection, and thereby temporarily checking the admission of ashes. As soon as normal conditions are re-established the ram withdraws automatically, and so makes the full opening again available. The ram in its movement

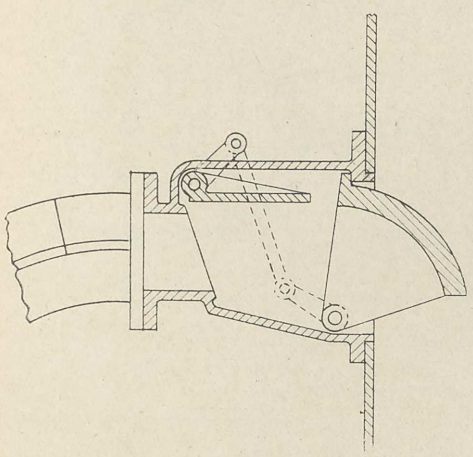


Fig. 338. Valve Outlet with Deflector.

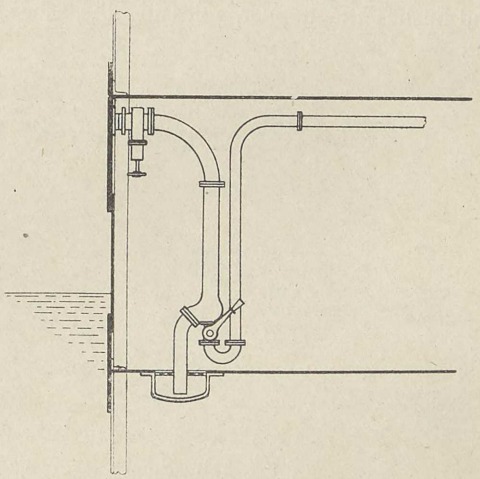


Fig. 339. Ejector for Dung.

does not only control, as we have seen, the communication between B and C, but it also controls the starting and stopping of the flushing jets in the hopper B, and thereby checks or accelerates the movement of the ashes.

The hydraulic ram D is a differential one; it fits into the cylinder E in such a way

as to offer surfaces of different areas to the water pressure at both sides. The smaller area of the ram is exposed to the sea water pressure (due to the immersion of the ship), and the larger area to the secondary cone flow between G and H.

As soon as the flow of the ejector water from the jets F, G, and H is sufficiently

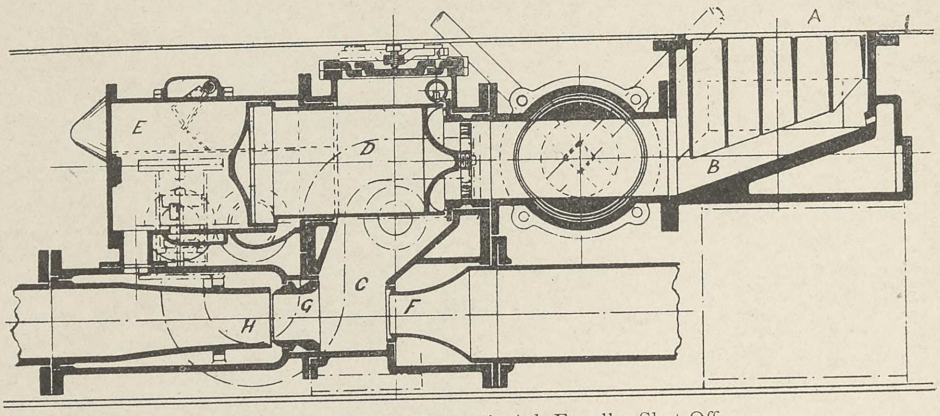


Fig. 340. Stone's Hydraulic Ash Expeller Shut Off.

powerful to create suction, and thereby reduce the pressure at the secondary cone opening, which is in communication with the larger area of the ram, the sea water pressure on the smaller area of the ram becomes sufficiently powerful to move the ram and open the way for the ashes; these remain, however, stationary in the hopper until the small auxiliary jets of swilling water are started, which happens as soon as the ram has completed its full stroke and has reached the extreme backward position. In this position the large end of the ram exposes a port to the water on the small area, which opens a valve by a piston to which the large ram acts as a valve, and then passes on and flushes the hopper, releasing the ashes.

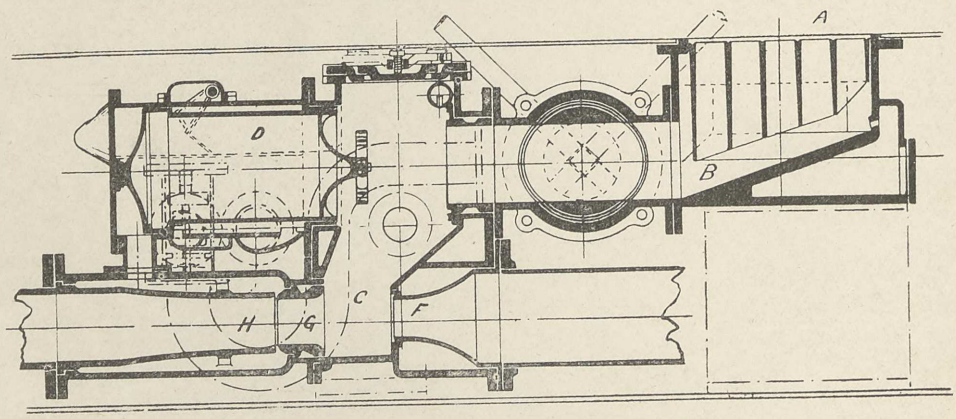


Fig. 341. Stone's Hydraulic Ash Expeller when Working.

Should the quantity of ashes with the incoming flush from the hopper be too great, and therefore reduce the speed of the ejector flow and simultaneously allow pressure to form on the larger area of the ram, and so overcome again the sea pressure at the smaller area, the ram moves forward again sufficiently to cut off the flushing water, and reopens immediately the correct speed is re-established.

If the water jet of the expeller should be stopped purposely or accidentally whilst the ship's side valve is still open, the seas entering the discharge pipe would enter also the cone opening G H, and act upon the larger area of the ram and so immediately close any communication between the sea and the stokehold.

The ashes which have been admitted into the chamber C are expelled immediately by the jet from nozzle F into the sea. Cone opening G, being the only part exposed to more than ordinary wear and tear, is interchangeable. At the end of the ram a valve is formed for closing the exit from the base of the hopper B; there is also a scraper provided for the purpose of cleaning the seat of the valve, preparatory to its finally

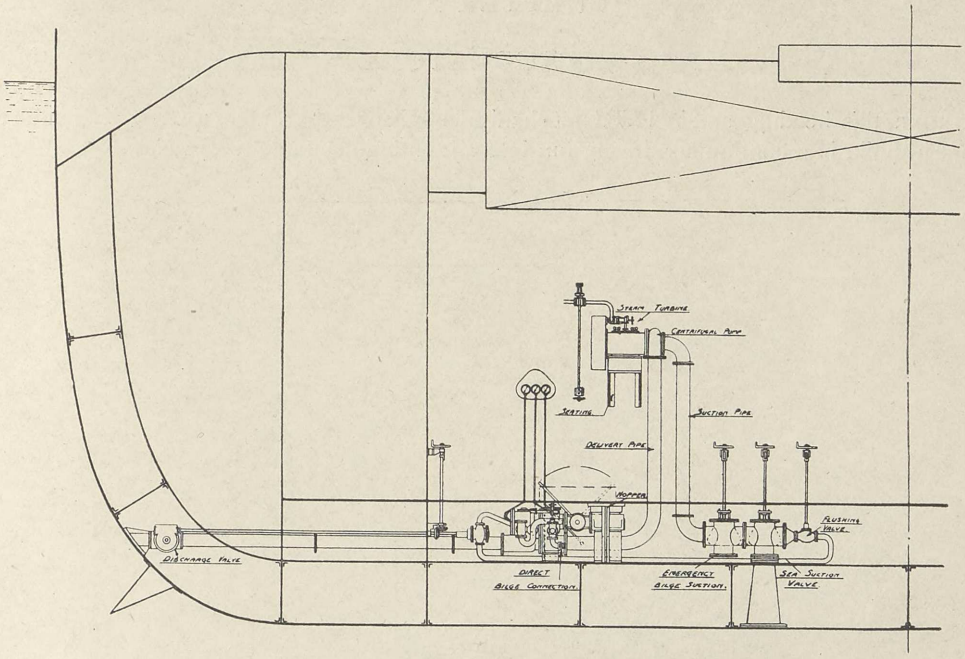


Fig. 342. Section of Ship showing General Arrangement of Stone's Ash Expeller.

closing, and a stream of water, issuing from a point immediately above the valves, swills away any ashes which may adhere to the valve or its seat.

The working of the expeller is noiseless, continuous, and automatic. The horse power expended in working one of these is 30 brake H.P., when expelling ashes at the rate of 10 tons per hour.

The "Mauretania" was the first vessel fitted with such an installation, and at the trial as many as four barrows of ashes were expelled in one minute. The "Aquitania" is being fitted with seven of these expellers, and four of the new Iron Duke class of battleships are fitted with three each. This expeller is the outcome of many experiments which have been conducted by Messrs Stone during the last three years.

INTERMITTENT HANDLING OF MATERIAL

CHAPTER XXII

INTRODUCTORY

UNDER this heading are included mechanical appliances by which material is handled not in bulk, in a continuous stream, but intermittently in suitable receptacles.

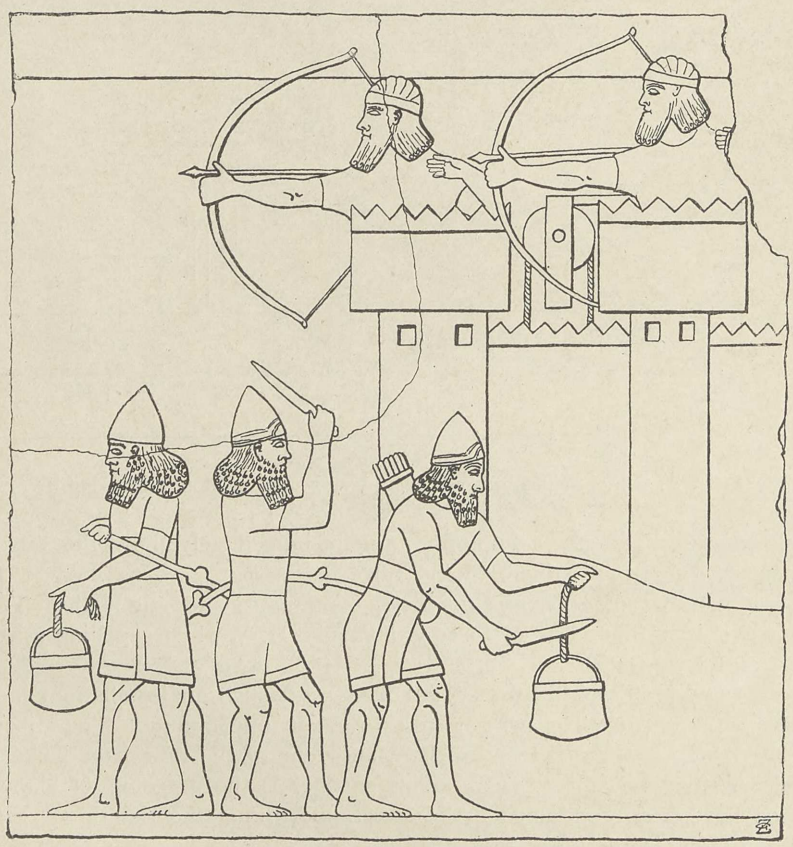


Fig. 343. Assyrian Bas-Relief showing Use of Rope and Block, from the Original in the British Museum, with the Upper Left-Hand Corner Restored.

In continuous handling plants the material is transported in an unbroken stream, or practically so, but in intermittent handling the material is filled into and carried in large receptacles; or where the individual objects to be conveyed are too large to be taken

into such receptacles, they are handled individually by suitable supports in a succession of single loads. The form of the receptacles, when such are in use, varies according to the method adopted, and to the nature of the material being dealt with.

The methods of intermittent handling described in the following pages include :—

(*a*) **Endless Rope and Chain Haulage**, in which the load is contained in narrow gauge trucks running on ordinary rails, and propelled by a continuous hauling rope between the receiving and delivery terminals.

(*b*) **Ropeways, Aerial Cableways**, and **Appliances for Coaling at Sea**, where a similar process to the preceding one is employed, with the exception that instead of the receptacles running on rails on the ground, they are suspended from a rope above the ground.

(*c*) **Mono-Rails and Telphers.**—In this method a solid iron or steel rail takes the place of the rope, and instead of a traction or haulage rope, the load is generally propelled by means of small electro-motors built into the carriage, and the current is taken from a live cable fixed in close proximity to the rail, and parallel with it.

(*d*) **Blast Furnace Hoists**, which generally consist of a pair of skips or buckets with wheels running on suitable rails up a sharp incline to the furnace top, the hauling cable raising a full and lowering at the same time an empty skip.

(*e*) **The Handling of Coke from Coke Ovens**, which includes a great variety of methods of dealing with individual charges from batteries of coke ovens.

The choice of method of conveying must depend on the nature of the ground, and the elevation to which the material has to be conveyed.

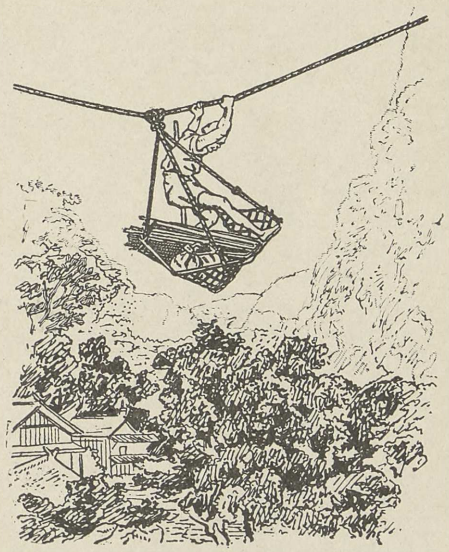


Fig. 344. Primitive Chinese Ropeway.

The rope plays a most important part in three of the above methods of handling, and it may, therefore, be interesting to explore the history of the rope, as rope haulage in one form or another is almost as ancient as the rope itself.

The late Sir Henry Layard, whose discoveries at Nineveh laid bare the daily life of the Assyrians, unearthed in a palace at Nimrod, at the site of Calah, a bas-relief depicting the siege of a castle in the campaign of Tiglath-Pileser III., about B.C. 550. In the carving, Fig. 343, the principal figure is that of a warrior, who is depicted as cutting the rope to which the besieged had attached buckets with which they were attempting to draw water from a source outside the castle wall. The rope ran through a pulley-block, and had evidently a bucket attached to each end, one coming up full, whilst the other went down empty. This bas-relief is about 2,260 years old, and undoubtedly depicts a primitive form of rope haulage. Pulley-blocks, which are also closely connected with ropeways, are also of considerable age ; they were known to the ancient Egyptians, and in the museum of Leyden may be seen a sheave and pulley-block of Egyptian origin to which great antiquity is assigned. The sheave is of fir wood, and the block of tamarisk. The rope found with these relics of an almost pre-historic past has also

been preserved. It consists of strands, twisted together, made out of the fibres of the date palm.

So far as is known, the ancients, though they made extensive use of fibre rope, were apparently not much acquainted with wire ropes, which are, of course, an essential feature in modern rope haulage. It is certain that the Assyrians practised the art of beating metal into wire, but there is no evidence to show whether or not they twisted it into ropes. It is said that the Chinese not only knew of, but actually used wire ropes 1,500 years ago, in the form of short ropeways for crossing rivers. The method is shown in Fig. **344**. A fine specimen of bronze rope was found in the buried city of Pompeii and is now preserved in the Museo Borbonico at Naples. Unfortunately no information seems to be available as to the purpose to which this wire rope was applied, but its discovery in buried Pompeii is significant in view of the very modern date that has been claimed for the introduction of wire ropes.

CHAPTER XXIII

ENDLESS ROPE AND CHAIN HAULAGE

THE principle of this system consists of a rail track on which the trucks are conveyed by means of an endless hauling rope, or sometimes a chain, to which they can be attached and detached at certain fixed points without the necessity of stopping the rope, thus keeping up a constant supply of trucks to or from the workings. The rope or chain generally engages automatically with the tubs or trucks as soon as it comes within reach of them, but disengages as soon as the tubs have reached the higher level where they come outside the reach of the chain. The empty tubs are returned on the second pair of rails and are lowered in a similar manner.

Although endless rope and chain haulage is mostly used for short distances, it is also equally applicable for greater lengths of journey, and endless ropes or chains are frequently used for haulage over considerable distances. The difficulty about such installations lies chiefly in carrying the rope over uneven ground; the change of level, of course, necessitates a change in the direction of the rope, and also in deviations from the straight line, where sharp curves have to be turned.

The power can be supplied by a stationary engine or electro-motor, either direct or transmitted, or by an ordinary clutch and drum arrangement attached to a line shaft, or finally by the gravity of the material.

The rails are laid on the ground, except where it is essential that the ground space should remain unobstructed, and in such cases they are raised on more or less lofty structures.

Endless Chain Haulage.—Appliances of this description running up inclines, upon which the trucks are hauled by chains, are principally used in collieries and other mines, and very rarely for long distances. They are, however, often installed for the purpose of raising the trucks to a sufficient height for them to run down again for a longer distance on a gentle incline by gravity.

They are usually termed tub-hauls, or creepers, and consist of an endless chain fitted with claws at intervals of about 12 ft. and having tension adjustment, a pair of chain wheels, main and back shafts, countershaft, driving gear, and channel or angle iron guides. The chains generally used are of the "Ley" or the "Gaston" type.

Chain Haulage for Hand Carts.—An endless chain with suitable attachments is used on inclines to assist the labourers to ascend ramps by the chains engaging with the axles of their hand carts. Such an appliance is in use at the Pequonnock Dock at Bridgeport, Connecticut, U.S.A., and was built by the Remo Inclined Truck Elevator Co., of New York. The endless chain of this device runs in a well-lubricated channel iron 4 in. wide. Fig. 345 shows the arrangement in use, and it will be seen from this illustration that only the upper strand of the chain projects above the floor level of the ramp. The speed of the chain is about 18 in. per second, so that 960 trucks may be raised per hour. A 5 H.P. electro-motor furnishes the driving power. The installation is used for loading ships with miscellaneous goods, and the incline of the ramp varies with the tide.

Fig. 346 represents a colliery tub taken up an incline by means of a link chain with special attachments which engage with the axle of the tub, and thus convey it up the incline. The endless chain travels over two polygon terminals, one of which is fitted with tightening gear. There are many similar devices; the one here illustrated is manufactured by Messrs Coulson & Co., Ltd., of Spennymoor.

Endless Rope Haulage.—This is of far greater importance than chain haulage.[1] The speed of haulage depends largely on the state of the running track; a well-laid line with properly constructed onsetting point (where the trucks are joined to the rope) can be worked quite satisfactorily up to a speed of 5 miles an hour, and at that rate 1,000 to 1,200 trucks per hour can be handled. With a rough track which may be laid on spoil banks or tailings dumps, the speed should be reduced to about 2 miles per hour, at which rate trucks can be handled with ease and safety.

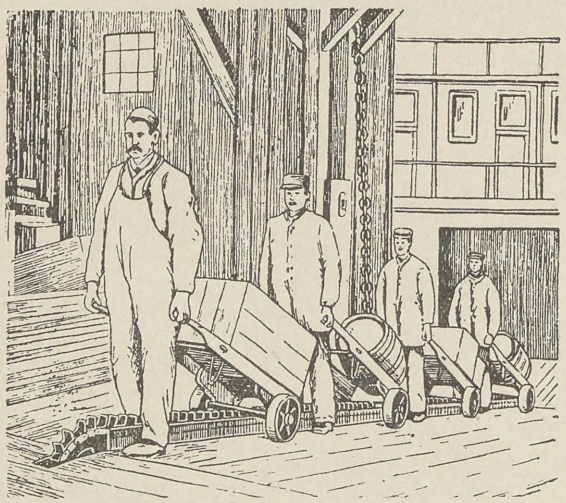


Fig. 345. Chain Haulage for Hand Carts.

Where curved wheels are used to work haulages around corners, a high rate of speed is not desirable, as even with the best constructed track there is always a great deal of wear and tear on both the truck and the rails in negotiating the small curves which the radius of the curve wheels necessitates. The amount of deflection off the straight for a curve wheel should be between 15° and 30°. If the angle at the intersection is too flat the rope is likely to leave the wheel, and, on the other hand, should the angle be too acute, the curve, which by necessity has usually about a 3-ft. radius,

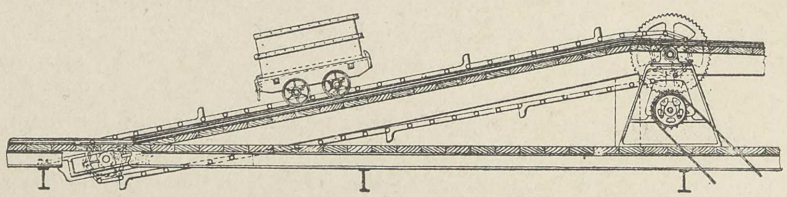


Fig. 346. Example of Chain Haulage for Colliery Tubs.

is too sharp for the truck to work around with any degree of safety. As a support to the rope, a roller fitted to a swinging arm should be placed on the on-coming side of the wheel, and as a further precaution against the rope leaving the wheel, the latter should be slightly elevated on the off-going side of the rope.

In running inclines a grade of 1 in 8 (12½ per cent.) is about the limit for a fast travelling haulage, although at a lesser speed inclines 1 in 6 can be worked. The grade to a large extent is limited by the speed of the haulage, as with a fast rope and a steep

[1] Extract from the very complete paper by Mr H. G. Kay, entitled "Rope Haulage," and read before the Chemical, Metallurgical, and Mining Society of South Africa.

incline the trucks are likely to up-end as soon as hooked, and also at the starting and stopping of the rope. The usual method of attaching a truck to the rope of an endless haulage is by means of a "jockey" (see Fig. 347), a V-shaped iron fork fixed to the top of the truck body, into which the rope is forced until the necessary grip is obtained. The form of "jockey" most commonly used in earlier days was bent out of $\frac{1}{2}$-in. round iron into the form of a V with a long arm projecting downwards from one corner to form a means of attachment to the truck. An improvement on the above is the wrought-iron fan-tail "jockey," made in the shape of a U with the opening slightly tapering towards the bottom, and the jaws are also broadened at the top, so that when the truck receives the pull of the rope and the "jockey" turns slightly in its bracket, the slot holding the rope is partly closed up at the top, owing to the overlie of the fan-shaped jaws, thus locking in the rope and tending to prevent it from rising and pulling out of the "jockey."

A very successful "jockey" is constructed with renewable jaws. Fitted to the top of the pillar is an oblong cast-iron box into which the two jaws are set, these being held in position by means of a wedge driven down between them and through the bottom of the box, this wedge also being held fast by a small wedge and split pin. With this arrangement each jaw can be given a quarter turn when worn, thus allowing the use of four wearing faces before new jaws are required.

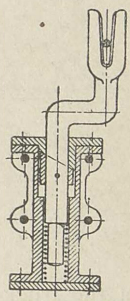


Fig. 347. Rope Clip or Jockey used in connection with Rope Haulage.

In laying a haulage track the rail on the side to which the "jockey" points must be slightly elevated, so that the rope is brought directly over the centre line between the two rails, and to prevent unnecessary wear and tear on the rope, rollers or hard wood rubbing blocks are placed at intervals between the rails to carry the sagging rope.

A most important item in the haulage is a properly constructed onsetting point. The grade feeding the trucks to the onsetter should be such that when the truck reaches the rope for hooking, the speed of the rope and truck are exactly the same. Should the speed of the truck be either greater or less than the speed of the rope a sudden jerk will take place on hooking, which is very detrimental to the life of the rope.

At a fast feeding onset, brakes should be used to regulate the run in of the trucks, also a contrivance to turn the "jockeys" automatically into the right position for hooking, and as a further safeguard against the trucks leaving the rails at the point of hooking, check rails should be placed for a short distance on each side of the onsetting point. The catenary curve connecting the down grade to the onset with the up grade of the incline requires special attention in laying out, as upon this the rate of hooking largely depends. The rails must follow a line which is parallel to the natural curve taken up by the rope, and to maintain the rope permanently in this position a weight or other tension device is employed. This device, with its frame, also takes up the expansion or contraction in the rope due to stretch or change of temperature; a well-balanced and sensitive rope is absolutely essential to a fast-feeding haulage.

At the point of disengaging the trucks an "apex" is formed with a down grade sufficiently steep to cause the truck to overrun the rope, and this change from a pull to a push on the rope causes the "jockey" to come square with the rope and easily free itself. On a long steep incline, or, in fact, on any haulage which is at all permanent, automatic disengaging frames should be used in order to dispense with labour. The frames are made in various ways; a cheap and effective one is in the form of a double cross frame carrying two long timber runners (see Fig. 348) placed parallel to the track,

and just sufficiently high to clear the top of the truck body. Fixed high up and between these runners, and at the off-going end, is a bar with a roller carrying the rope; and as the truck reaches the frame the body is slightly raised until it comes into contact with the runners, when the rope is pulled out of the "jockey" and the truck released automatically from the rope.

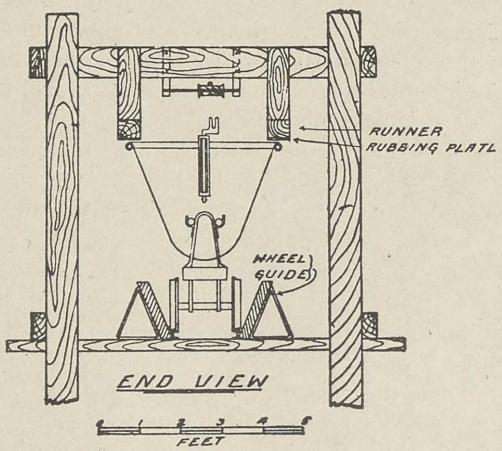


Fig. 348. Automatic Disengaging Gear for Rope Haulage.

Another arrangement for a disengaging frame consists of a double frame carrying two lengths of channel iron set parallel to the rope, and just sufficiently wide apart to allow it to pass freely between them, and up over a similar roller at the off-going end. As the truck reaches the frame, the rope passes up through the slot formed by the channel irons, and as the opening is only wide enough to admit the rope, the latter is pulled out of the "jockey," and the truck disengaged.

A form of haulage very suitable for spoil heaps and tailings dumps, consists in having the "jockey" fitted to the side of the truck carriage, instead of on to the body, as is the usual practice. With this arrangement the truck can be tipped without being released from the rope, and consequently there is no time or labour lost in disengaging or rehooking. A haulage of this description is very economical, as from the time the truck is filled at the bin, and hooked to the rope, there is no need to handle it until it is returned to the filling bin again, the tipping, righting, and disengaging all being done automatically. With this arrangement trucks negotiate curves of 12 ft. radius by a series of rollers set about 2 ft. 6 in. apart, and just on a level with the "jockey" on the truck. These curve frames (see Fig. 349) are held in position by ballasting them down with sand bags or stones, and can be easily shifted bodily forward as the dump extends.

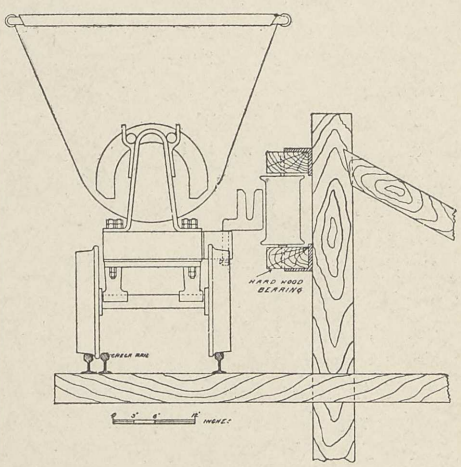


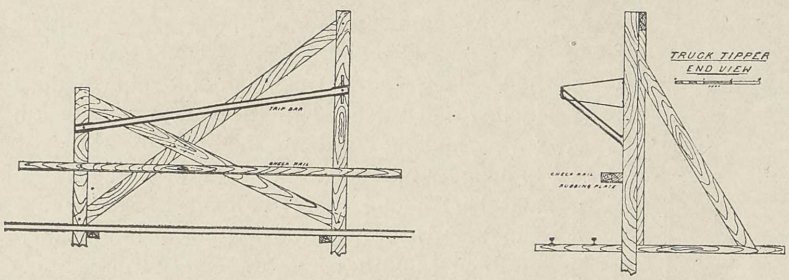
Fig. 349. Side Roller for Negotiating Curves.

A serviceable truck tipper (see Figs. 350 and 351) consists of a frame carrying a length of rail or pipe set at such a height as to just catch the top of the truck body; this tipping bar is placed diagonally across the track with the on-coming end, about 1 ft. outside the rails, and the off-going end over the centre line of the track. As the truck reaches the tipping bar, the body runs along it, and is pushed over to one side until it is overbalanced and tipped,[1] a check bar being placed over the truck wheels to prevent the carriage capsizing also. The same principle is applied to the "truck righter"; a

[1] For descriptions of other self-emptying trucks, sometimes employed on such lines, see chapter "Unloading by means of Specially Constructed Self-emptying Hopper Wagons," page 494.

length of rail or pipe is bent into the form of an inclined plane, and set alongside the track, so that the lower end of the incline will just catch under the down-turned lip of the truck body, and as the truck is drawn along the incline, the body is raised until it regains its upright position (see Fig. **352**).

At the Premier Diamond Mines endless rope haulages are used throughout the workings. The main haulage of one installation has three changes of grade, the steepest being 1 in 8, or 12½ per cent.; the tracks are laid with 40-lb. rails set on wooden sleepers, width between up and down tracks 6 ft. The rope is of plough steel, 1¼ in. diameter, travelling about 4½ miles per hour. The rate of hooking on this haulage is from 1,000 to 1,200 truck loads per hour, although over 26,000 loads have been hauled in a working



Figs. 350 and 351. Automatic Truck Tippers.

day of twenty-one hours, and over 140,000 loads in the week. The length of incline from onset to apex is 3,123 ft., and the vertical lift 239 ft.

Another haulage plant at the same mine has two changes of grade, 1 in 8·9 (11·2 per cent.) and 1 in 8 (12½ per cent.), respectively. The tracks are also laid with 40-lb. rails, 8 ft. centres between tracks; the rope is the same and travels at about the same rate, and has the same capacity as the previous haulage referred to. The length of incline is 2,425 ft., and the vertical lift 270 ft.

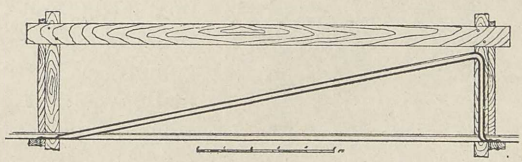


Fig. 352. Automatic Truck Righter.

Fig. **353** represents an appliance for the same purpose as Fig. **346**, in which the tubs are conveyed uphill by ropes, which engage with the "jockey" at the top of the tub instead of with the axle as in the preceding drawing. It also shows the two terminals with the driving gear, and the tightening arrangement by means of a weight at the lower terminus.

Other Examples of Rope Haulage, where, however, the rope engages with the lower part of the trucks, are represented in Figs. **354** and **355**, which show the method employed by Bullivant & Co. for detaching a truck from the hauling rope. The detacher, which is fixed upon the sleepers, automatically uncouples a clip on the rope, when the lever of the clip strikes against the detacher. Figs. **356** and **357** show the same clip as fitted with a connecting rod and draw-bar with springs, which reduce the shock which may take place in attaching the clip to the rope. The head of the clip is fitted with two springs which connect to a bracket attached to the truck as shown. When the clip is released by the automatic detacher (see Figs. **354** and **355**), or by hand, the springs lift the clip clear of the rails, as shown in Figs. **356** and **357**,

thus allowing the detached trucks to pass over cross-overs. Fig. **358** shows another form of coupling suitable for light loads; this is not unlike the "jockey" described previously. This clip can be so arranged as to automatically detach itself from the rope by the following method: The sheave shown is raised above the centre line of the rope, so that as the clip approaches the sheave the rope is lifted clear of and thus detached from the clip, which latter is turned out of the way by striking the sheave. When connecting to the rope, the clip must be turned back. A sheave, as described above, is placed in a suitable position for the rope to drop from the sheave into the clip.

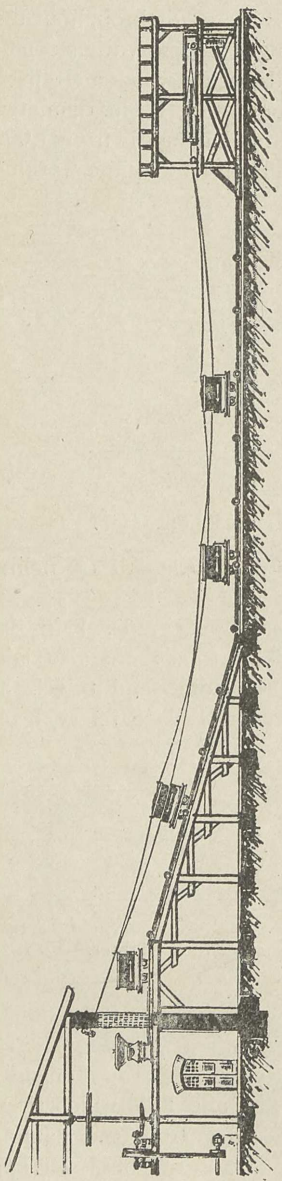


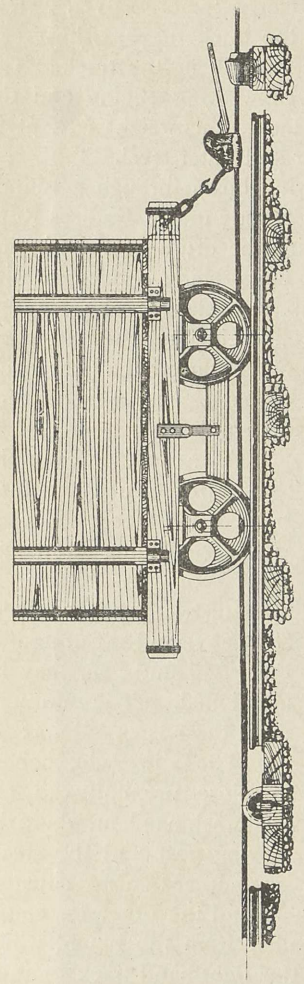
Fig. 353. Example of Rope or Chain Haulage for Narrow Gauge Railways.

An automatic rope haulage plant, built by Bullivant & Co., fitted with brake gear is shown in Figs. **359** and **360**. The loaded trucks are brought to the top of the incline and attached to the rope on the left-hand track (when looking down the incline); the rope passes to the brake gear and thence to a turn-round or terminal wheel and back along the right-hand track (looking down incline), and down to the bottom of the incline, a distance of about 4,000 ft.; here the empty trucks are attached to the rope.

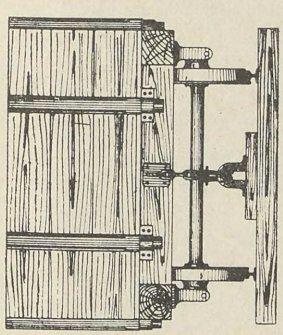
A capstan is used for conveying the full trucks to the top of the incline, and here, after being connected to the rope, they descend, thereby generating a considerable amount of power which is used for working an air compressor connected to the brake gear by a train of gear wheels. The air from the compressor is stored in a receiver, which is shown on the top of the engine-house, and this receiver communicates by means of pipes with the capstans on the top and bottom of the incline, which are used for marshalling trucks. The whole of the winding gear and compressor plant is controlled by levers located on the platform of the control tower, from which a man has the whole incline under his observation.

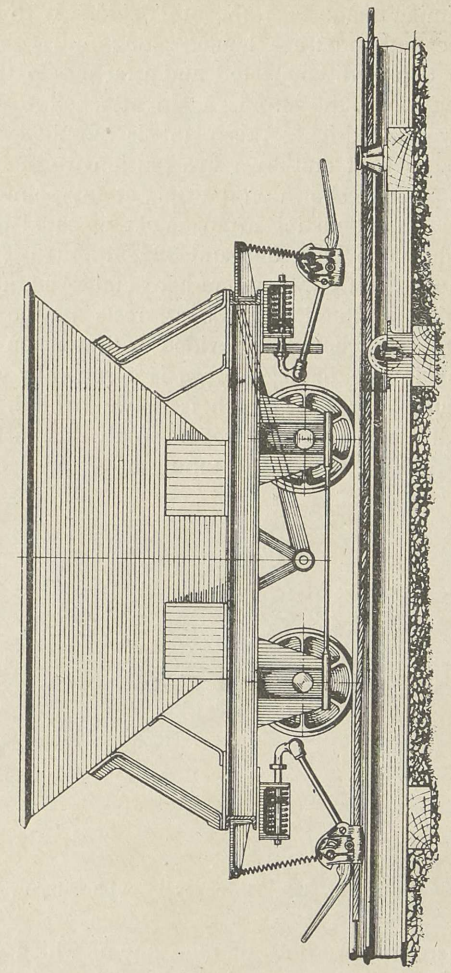
After the full trucks have been detached from the rope on the left-hand track at the bottom of the incline, the empty trucks are attached to this rope, and at the same time those at the top of the incline, on the right-hand track, are replaced by full ones. When this has been completed the order is reversed and the full load this time moves down, on the right-hand track, hauling up the empties on the left-hand one.

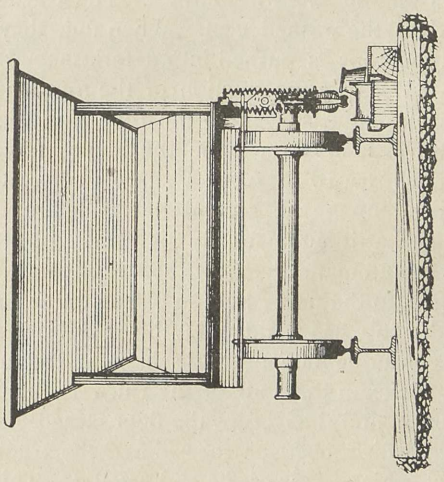
A truck haulage installation, also by Bullivant & Co., erected on a pier, is shown in Figs. **361** and **362**. In this arrangement it will be seen that the haulage rope passes down the inside of the tracks (that is between the two rail tracks) until it comes to the cross-overs. Here it dips down below the pier level, round two sheaves to the outside of the track, in which position it continues till the cross-over is passed, when it returns *via* two other rollers to the position between the tracks again; the return of the rope is effected in



Figs. 354 and 355. Automatic Truck Uncoupling Device.







Figs. 356 and 357. Automatic Truck Uncoupling Device.

a similar manner on the other side. With this arrangement the clip is attached to the rope and the truck hauled along until within a short distance of the cross-over. Here the clip is disconnected and attached to the rope outside the track to pass the cross-over, when the clip is again attached to the rope on the inside of the track. The power for driving this plant is supplied by a steam-driven winding engine and the rope is kept taut by a live tension weight. By a winding tackle this weight is kept in the position shown on drawing, at any point between the pier and water level.

An interesting arrangement of canal haulage, for drawing boats through a tunnel, is shown in Figs. **363** and **364**, although it does not come strictly under Endless Rope Haulage. By the system here employed, a rope, after passing the drum of the winding engine in the haulage boat, rests in the canal bed, the ends being connected with suitable anchorage, provided with tension gear to take up any slack. The winding gear in the haulage barge is electrically driven, the current being supplied from an accumulator boat which is drawn behind. When the motor is started the boat hauls itself along the fixed rope. With this installation a train of barges may at one time be drawn through the tunnel at a speed of from two to three miles per hour.

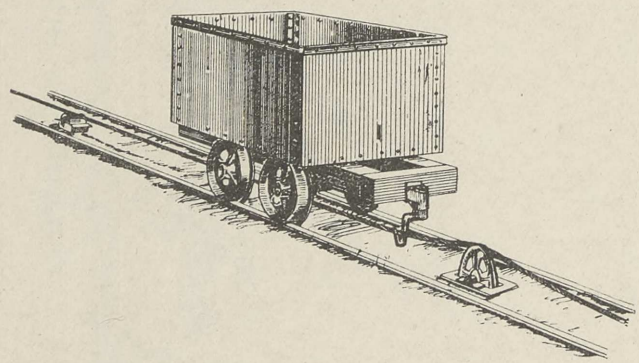
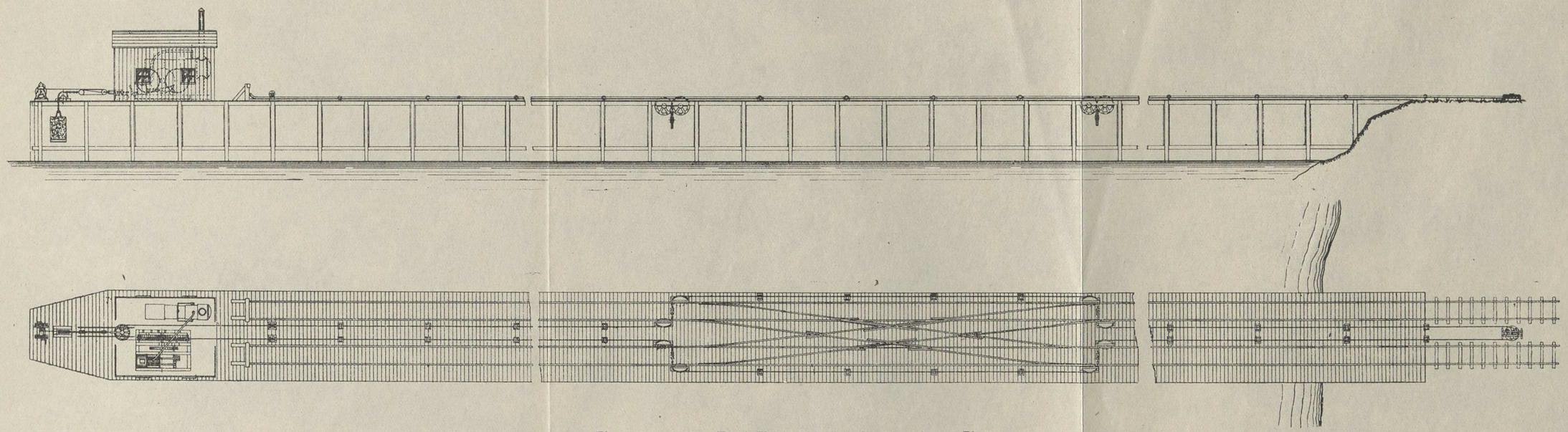


Fig. 358. "Jockey" Coupling below Truck.

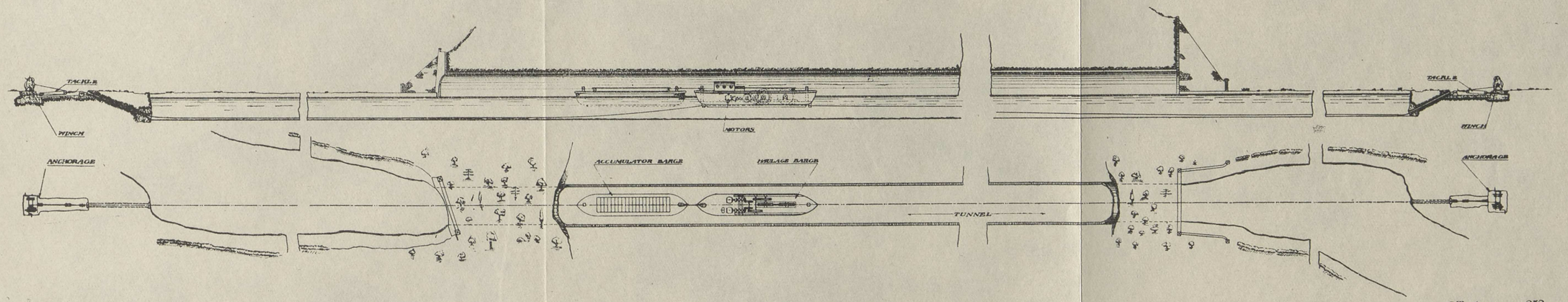
As a typical example, the rope haulage plant erected by Georg Heckel, at the Röchling Iron and Steel Works at Völklingen, in the district of Saarbrücken, Germany, and illustrated in Figs. **365** and **366**, may be mentioned. The arrangement there is as follows :—

The railway commences in close proximity to the coal-washing plant, where the driving gear and the steam engine are also situated. There are two lines of rails, one of which is for loaded trucks and the other for empty ones on their return journey. The trucks or tubs are loaded from the bin A, which receives the washed coal. When full, they are run on to the right-hand track of rails, and the rope is pushed into a fork-shaped clip attached to the front of each tub (see Fig. **347**). By the traction of the rope, the clip engages firmly as the fork turns on its axis and adjusts itself to the rope, and the truck is then carried along. The distance of travel is 264 ft., while the angles traversed are as much as 90°, and the inclines as much as 10°. After a sharp incline, the tubs turn round at the terminus B, and descend upon the second line. Before reaching the lower terminus the rope is so raised that it automatically disengages itself from the clips. The trucks discharge themselves automatically. Fig. **368** represents one of the tubs, the two sides *a*, *a* being so hinged to the upper portion of the frame that the flap doors open outward. The bottom of the tub has a ridge in the middle and slopes from there towards the flap doors, thus ensuring a complete discharge of the tub when these doors are opened.

Beneath the body of the truck is fitted a powerful spring which depresses the two levers *b*, and thus keeps the door closed. At the end of each of these levers *b* there is a latch which overlaps the side of the truck. Another lever *c* is fitted underneath the truck which carries at its end a roller. This is for the purpose of compressing the spring



Figs. 361 and 362. Truck Haulage Installation erected on a Pier.



Figs. 363 and 364. Arrangement of Canal Haulage for drawing Boats through a Tunnel.

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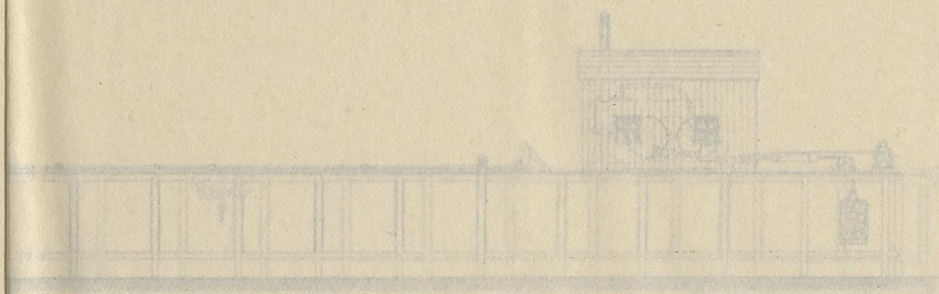
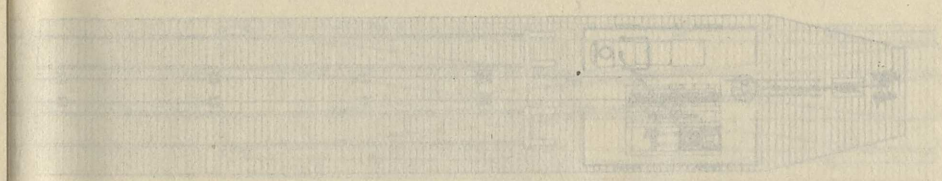
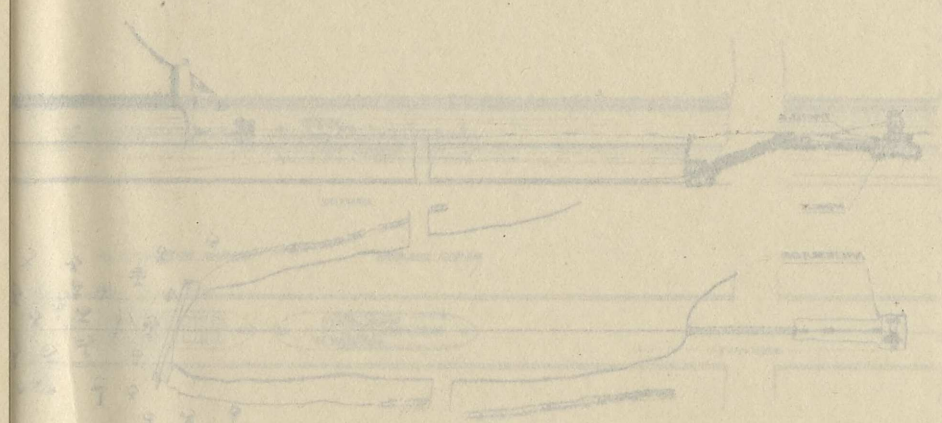
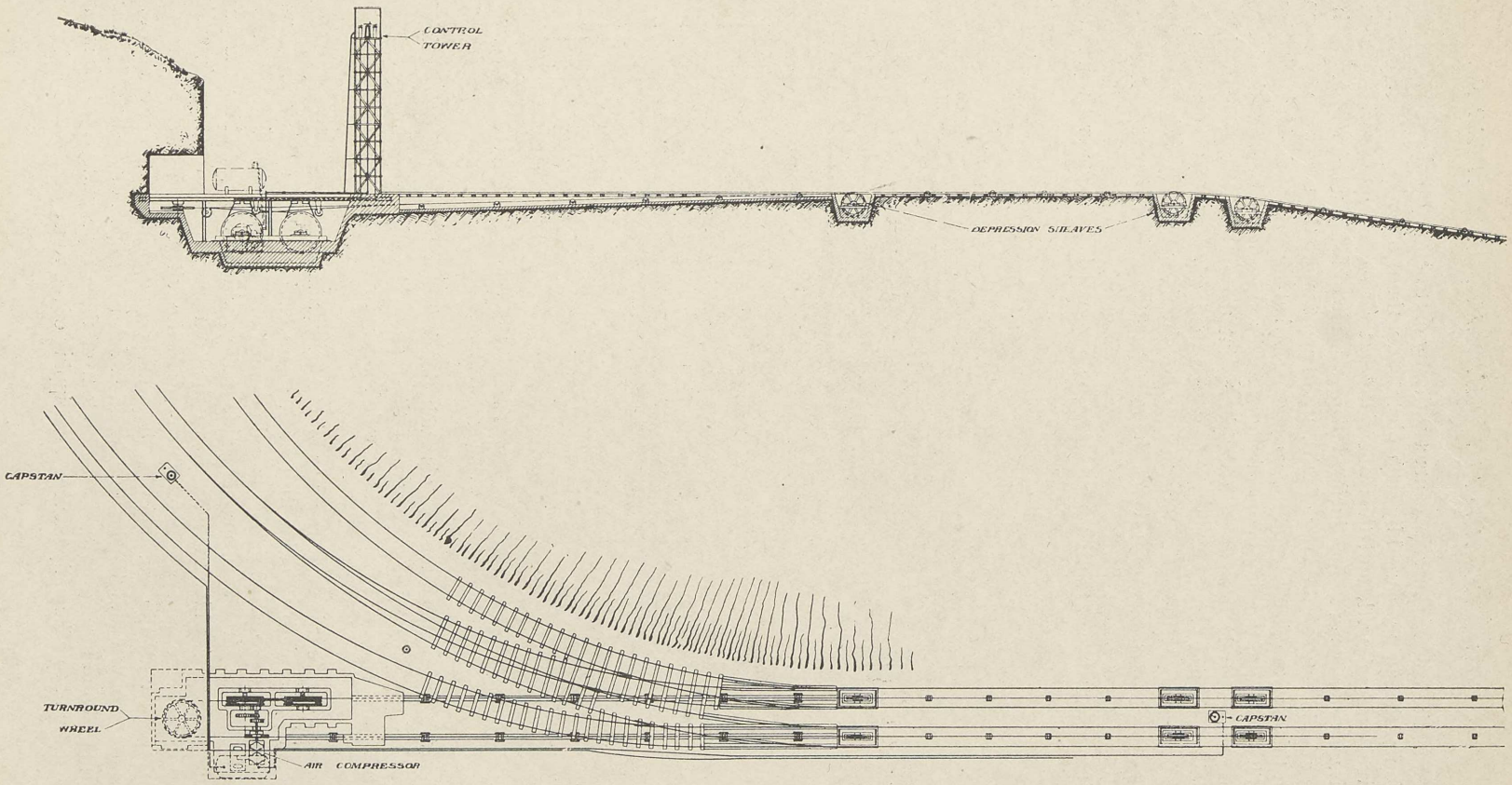






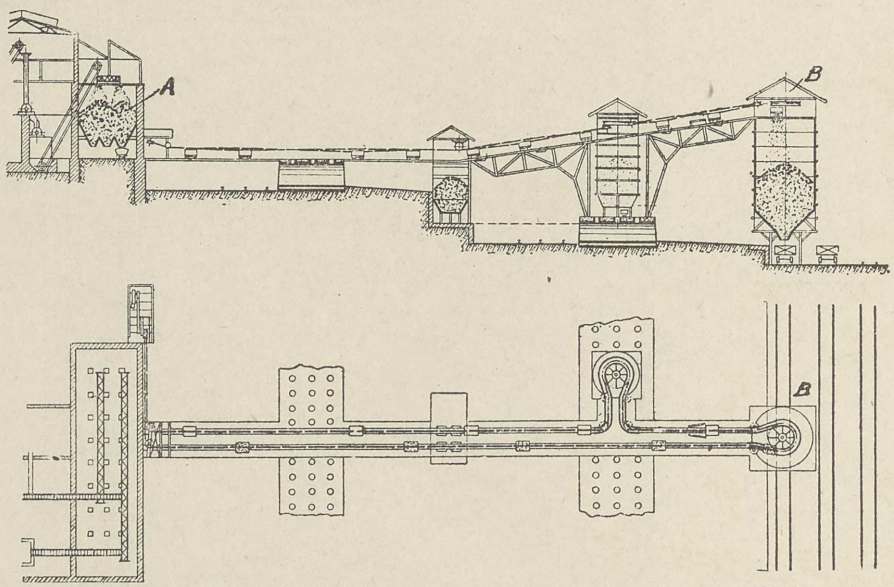


Figs. 359 and 360. Automatic Rope Haulage Plant fitted with Brake Gear.

as soon as the roller comes in contact with any obstruction on the line. By the compression of the spring, caused by such obstruction, the two levers which hold the sides of the truck are released, and thus allow the latter to open outwards. The unloading contrivance consists of a short inclined plane *d* made of flat iron (Fig. 367), which is fitted in the middle between the lines of rails, at the point where the trucks are to be unloaded, and in this way the discharge of the coal is effected at any one of the three destinations.

The closing of the side doors of the trucks is also effected automatically. For this purpose immediately beyond each delivery point there are fitted on both sides of the track oblique rails *e* (Fig. 369), at the height of the lower edge of the movable sides *a*, *a* of the truck, and at the end of these rails are fitted two rollers with powerful springs. As the truck passes with open doors, the rails *e* gently close the doors by pressing them behind the levers *b*.

In consequence of the sharp curves to be negotiated, the tubs are kept rather short,



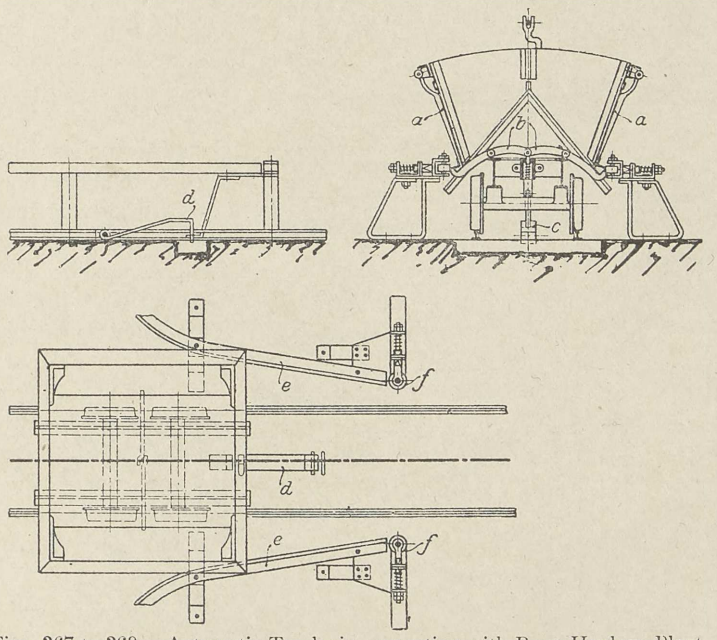
Figs. 365 and 366. Rope Haulage Plant at the Röchling Iron and Steel Works, Völklingen, Saarbrücken.

and the distance between the axles is such that it is not possible for the back wheels to be lifted off the rails by any pressure of the rope on the clip which is fitted to the front. The tubs are entirely of iron, and weigh over 13 cwt., having a capacity of about $17\frac{3}{4}$ cwt.

The ropes are driven at the rate of 100 ft. per minute by a double-grooved pulley connected by a suitable gearing to a small steam engine. From this driving pulley the rope passes over two guide pulleys in a downward and upward direction. At the bottom of the loop thus formed is another guide pulley, which is weighted for the purpose of tightening the rope, which then passes to the commencement of the track, where there are two more guide pulleys, one of which guides the full rope, while the other guides the return rope. With the exception of the wheels supporting the return strand, all the pulleys are grooved and lined with leather, which is stamped out in small pieces, which stand on end and form grooves in the bottom of these rope pulleys. This arrangement has been found to effectually prevent any slipping of the rope.

The use of forked clips for engaging the trucks necessitates the rope running at all times at an equal distance above the line of rails. To ensure this, at those points where the inclination of the track alters, special guide pulleys are used. These consist of a series of rollers fitted round the circumference of a revolving disc. The spaces between the rollers will accommodate the clips on the trucks. Vertical sheaves have been used, and the ropes are also guided in a lateral direction by a similar contrivance. In order to meet sharp curves in the track, channel irons have been used in place of the ordinary rails. These have been bent to the correct curve, and the sections are of such dimensions as to allow of but little play for the wheels in the groove (see Figs. **370** and **371**). Special sections of rail are used to join up the channel iron to the rails, so as to gently guide the wheels from one section to another. Otherwise the illustrations explain themselves.

To prevent interference with the traffic by a runaway tub which might become



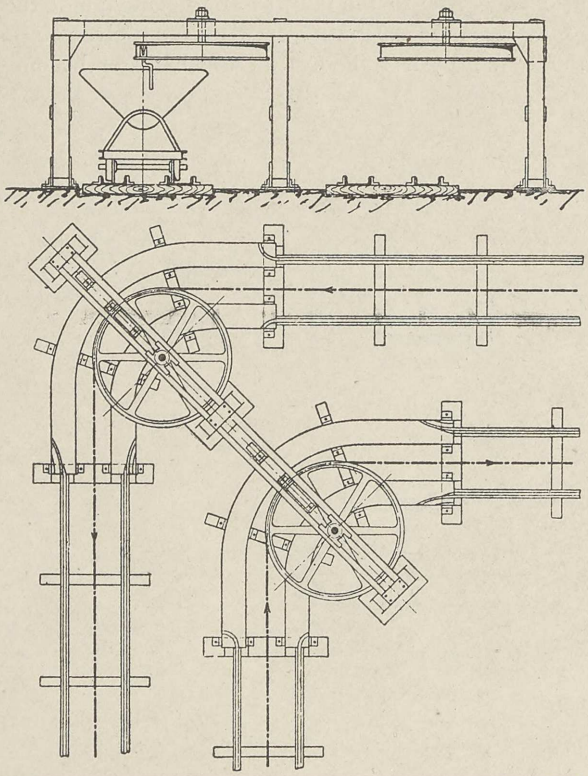
Figs. 367 to 369. Automatic Trucks in connection with Rope Haulage Plant.

disengaged, there are placed upon the inclined portions of the track stops, built for trucks travelling uphill, as well as for those moving in a downhill direction. Figs. **372** and **373** represent these appliances.

The stop for tubs travelling in an upward direction consists of two levers which are fitted side by side in the track, and are coupled together by a horizontal axis round which they can rotate in the direction of the haulage. The axle is situated beneath the track, while the upright arms project above it (see illustration). In this position they are maintained by a weight. As the truck ascends the line, the axles of the wheels press the upright levers forward, and the truck passes over them without hindrance. Should the tub, however, by some accident, become detached, the levers catch and stop the descent because they do not admit of any backward movement. The shock to which the upright levers would be exposed under these circumstances is lessened by a powerful volute spring. The appliance for the descending truck is as follows: At certain distances from each other two pairs of levers, similar in construction to those just described, are fitted to

the track. These levers are coupled together beneath the line so that both pairs must move together.

Fig. 373 shows the levers in both positions, one being in dotted and the other in full lines. It will be seen that they stand at a certain angle to each other. Their action is as follows: As the truck descends, the axles of the wheels depress the short levers, and thus raise the longer and lower levers in an upright position standing at right angles to the track. As soon as the tub has left the first levers, these will swing back to their original position, and thus pull down the long lever for the tub to pass over unhindered. Should, however, the tub descend at an unusual speed, as would be the case if a truck became disengaged, it would reach the lower levers before they had time to descend and thus stop the tub, the shock being again taken by a powerful volute spring. The distance between the two pairs of levers must always be accurately adjusted to the size of the tubs and their normal speed.



Figs. 370 and 371. Angle Station of Rope Haulage Plant.

The driving gear of a similar installation built by the same designer, and for the same firm, is shown in Figs. 374 and 375. This plant is for handling 150 tons of iron ore per hour, but is capable of dealing with 300 to 360 tons. The driving gear is actuated by an electro-motor, and the rope pulleys are between 12 and 13 ft. in diameter. The transmission from the motor to the rope wheels is effected by three pairs of spur wheels and three countershafts, thus reducing the speed of the motor to give the rope a travel of 200 ft. per minute. After the rope (which is $\frac{7}{8}$ in. in diameter) has passed over the two main pulleys A and B, it is conducted over a horizontal pulley C, which is mounted on a carriage and connected with a weight which is suspended on a chain from a tower built for the purpose. This is necessary in order to take up the stretch of the rope, which is 32,800 ft. long. The rope itself has a breaking strain of 29 tons, but it is only strained during the ordinary working to a load of 4 tons. The trucks are put on the lines at a pitch of about 35 to 40 yds. Each truck holds $1\frac{1}{2}$ tons of ore, and the incline of the line is very slight.

Further interesting examples of rope haulage[1] are found at Düdelingen, Lorraine, for handling the iron ores from the Minette mining districts, one of the principal sources of iron ore in Germany. The ore deposits are so situated that they have to be

[1] From an article by Fr. Tillmann, *Zeitschrift des Vereins deutscher Ingenieure*, 12th March 1910.

got through a drift in the side of the mountains. In the older installation it was the practice when using rope haulage to convey the ordinary mining trucks to a raised position on the bank, and there transfer their contents into self-emptying trucks, which were then taken by a second haulage installation to the ore pockets for further treatment. It is obvious that this method could be much simplified by one haulage system, without transferring the load, by using the self-emptying trucks in the mine and conveying them in one operation to the ore pockets. This has been done at Düdelingen, and the installation has been successfully at work since 1908. The mining authorities were rather reluctant to adopt this system, owing to the danger of any of the self-emptying trucks discharging their loads on the inclines underground, but the construction of the trucks makes such an accident almost impossible. The installation handles the material in one unbroken operation from the face to the pockets, but there is a second haulage plant on similar lines, which takes the ore from the ore pockets to the blast furnace of the same company, a distance of $2\frac{1}{2}$ km., say 2 miles. The self-unloaders used are shown in Figs. **376** and **377**, built on the Heckel principle. The capacity is about 2 tons of ore, and the weight of the trucks is nearly 1 ton. The wheels are of cast steel and fitted with roller bearings. The illustration explains the other details of construction. The opening of the side doors calls, however, for some little further description. The two doors are held closed by the catches *a*, and are opened by the lever *b*, which, in order to release the catches *a*, must make a downward movement (a similar catch with an upward movement might release the load by coming in contact with a piece of ore lying between the rails). The apparatus acts as follows: A pair of channel rails *c* are fixed in the centre of the track hinged at one end and raised at the other, but if not in use the raised portion can be lowered to bring it out of action. As soon as the truck approaches these channel rails *c*, a double pin in lever *b* engages with two channels and forces lever *b* down, which releases the doors. The ore pocket with its approach is shown in Fig. **378**. This pocket is 330 ft. long, and has a capacity

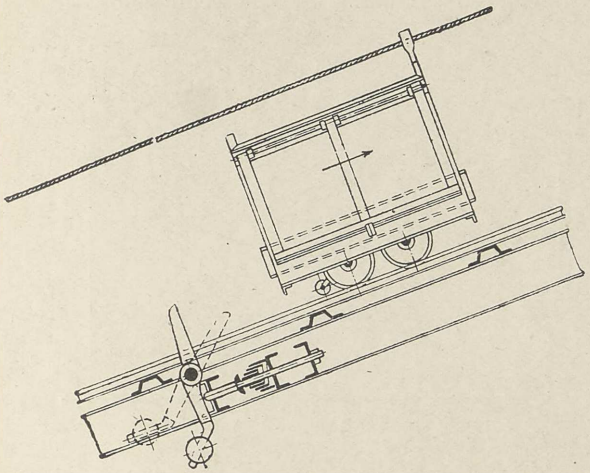


Fig. 372. Stops Built for Tubs Travelling in an Upward Direction.

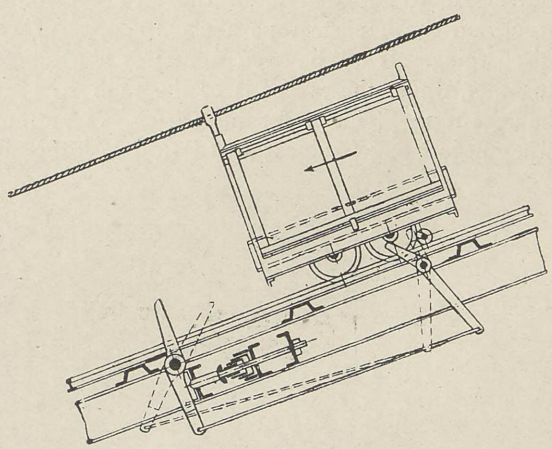
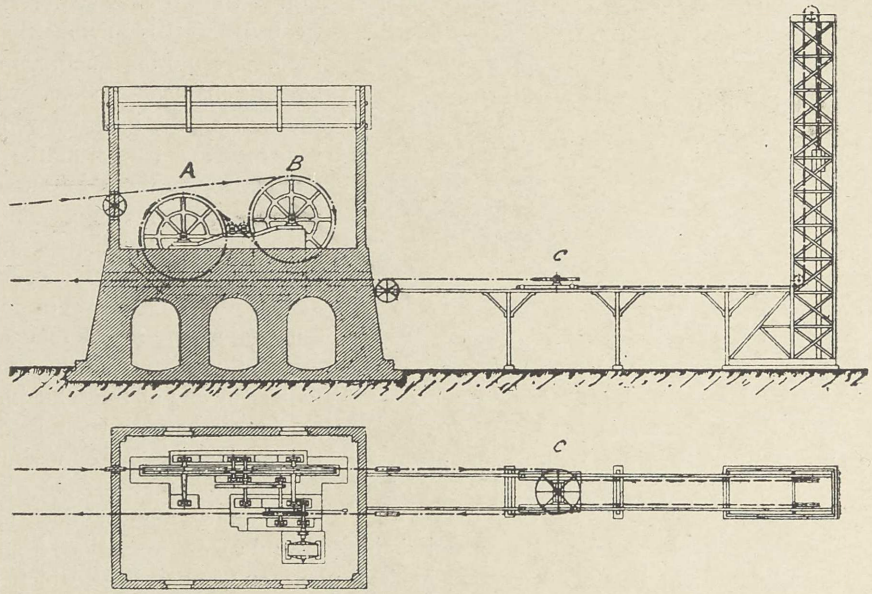


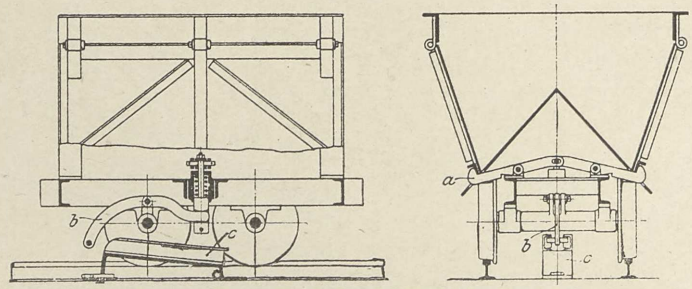
Fig. 373. Stop for Tubs Travelling in a Downward Direction.

of 1,000 tons of ore. The haulage rope is elevated above the track, and the trucks ascend a gentle incline as shown on the right-hand side of the illustration; they then negotiate a curve, at the end of which they land on the top level of the ore pocket. The trucks then pass through this building and descend empty on the



Figs. 374 and 375. Driving Gear for Rope Haulage Plant.

other side to the bottom of the mine as shown. Fig. 379 illustrates three of the trucks on the haulage rope above the ore pockets, the first one being at the point of discharging. It will be seen from this illustration that a number of trucks are coupled together, whilst the two ends of the train so formed are clamped at both ends to the haulage rope. This is for the purpose of preventing the running forward or backward when negotiating inclines; that is to say, if the train goes up hill the front chain will be



Figs. 376 and 377. Automatic Self-Unloading Trucks for Rope Haulage Plant.

tight, and if it goes down hill the back chain will be tight. Two of the trippers, *c*, before mentioned, are shown in this illustration. The bar screens above the ore pockets are for the purpose of letting small material through, whilst the large pieces can be fed on to a grinding machine and reduced. Fig. 380 shows another view of the same, with an approaching train and a number of trippers *c*, any one of which can be made to engage,

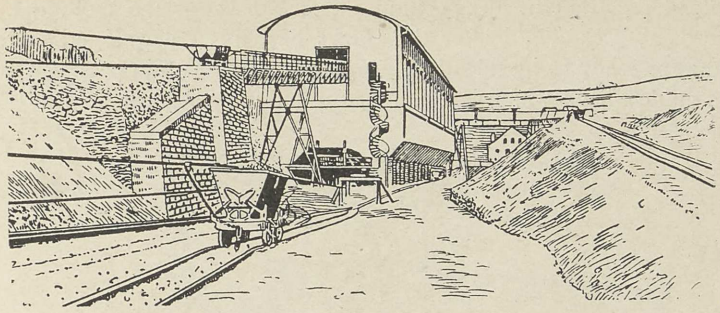


Fig. 378. Rope Haulage Plant in Connection with Ore Pocket.

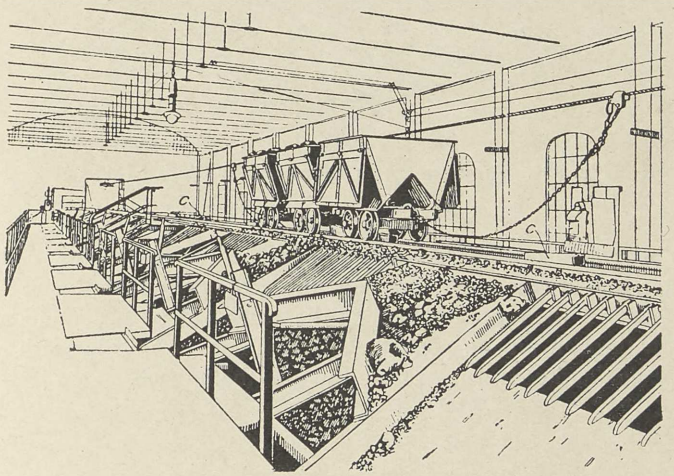


Fig. 379. Rope Haulage Trucks Discharging into Ore Pockets.

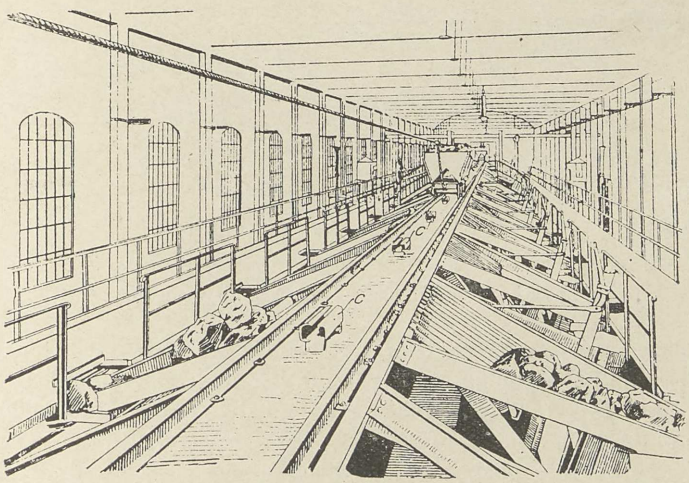


Fig. 380. Rope Haulage over Ore Pockets.

and thus unload the train in any position. Fig. **381** shows the method by which the doors are automatically closed after the trucks have been discharged and before they return to the mine ready to be reloaded. Fig. **382** shows a train passing a curve and the eight pairs of guide wheels which lead the rope round the curve can be clearly seen; there

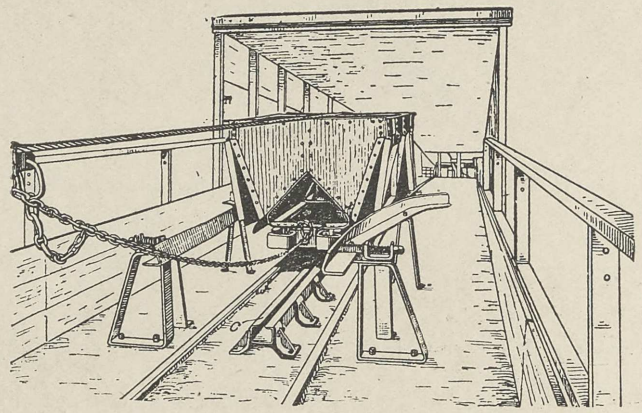


Fig. **381.** Arrangement for Automatically Closing Doors of Rope Haulage Trucks.

are forty such wheels to conduct the rope round the various curves. These rollers are 5 ft. in diameter, and are made of cast steel, the grooves in them being sufficiently deep for the attachment on the ropes for hauling the trucks to be accommodated. Fig. **383** shows a section through an ore pocket, also three lines of rails beneath for drawing the ore from the pocket and conveying it from there to the furnace.

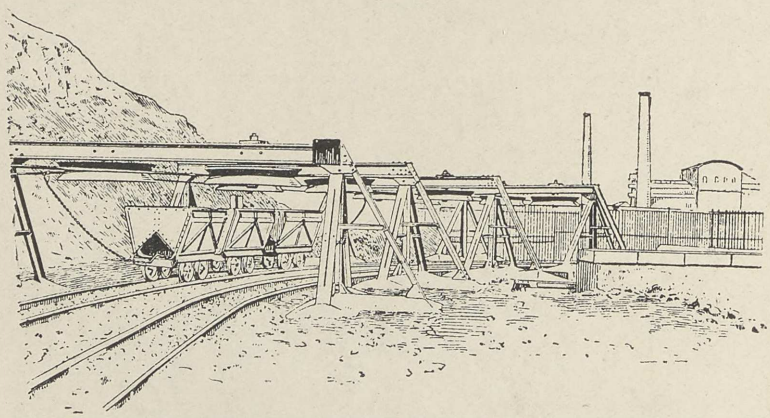


Fig. 382. Rope Haulage Train Negotiating a Curve.

The haulage plant was erected for 1,800 trucks for over 3,000 tons of ore in ten hours. The speed of the hauling rope is 150 ft. per minute, and the length between the terminals is slightly over 1,000 yds., but it is intended to extend it to 2,000 yds. Owing to the incline of the drift, a motor of 250 H.P. was necessary. In the second installation the distance from the ore pockets to the blast furnace is 2,500 yds., and owing to the more level road, a motor of only 180 H.P. was necessary.

A rope haulage plant of an unusual design is that of the Soc. Anonyme des Hauts Fourneaux & Fonderie de Pont-a-Mousson, France.

This is for handling 180 tons per hour of iron ore. The most interesting portion is

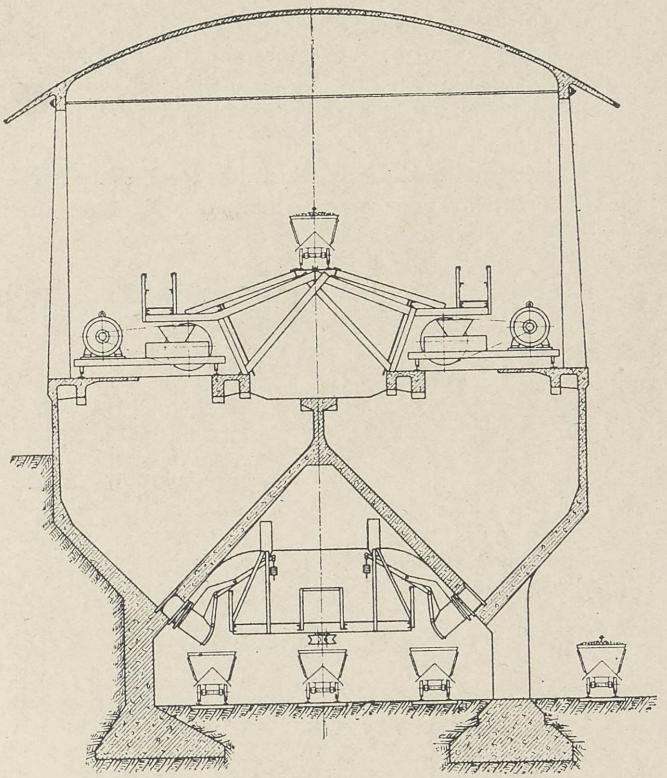


Fig. 383. Section through Ore Pocket showing Rope Haulage Plant.

a movable bridge running on a rail track on each side, and commanding the whole of the ore pocket; the position of the bridge can be moved when the haulage plant is in motion. The self-unloading trucks hold $1\frac{1}{2}$ tons of ore each, whilst their weight is approximately 1 ton each. The haulage rope (Glinz Patent) is compounded from chain and rope, the lengths of rope are about 12 yds. each, and they are coupled to each succeeding length by a short piece of chain. A portion of this compound chain and cable is illustrated in Fig. 384. The trucks are attached to the cable chain by the usual "jockey," the chain portion being dropped on to this. The cable is endless, and the plan, Fig. 385, shows the same in dotted line, the arrows giving the direction in which it moves. The ore, as it comes from the mine in trucks, is emptied by two tips B into a small hopper, the

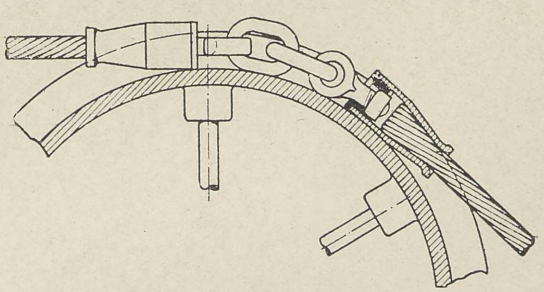
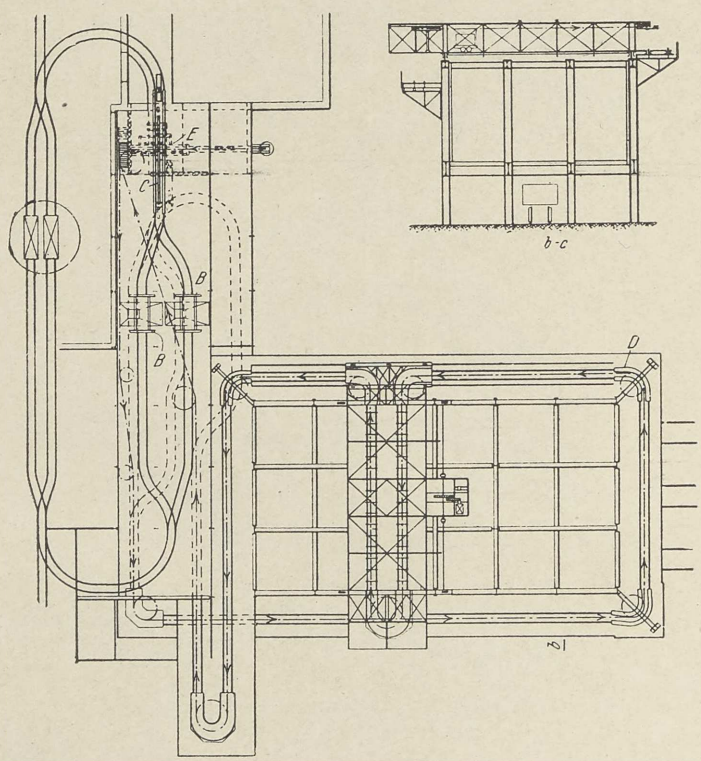


Fig. 384. Compound Chain and Cable Haulage Rope.

empty trucks being raised sufficiently by the chain haulage C to return by their own gravity to the pit mouth. Beneath the small hopper just mentioned the self-unloaders for the haulage plant are filled. The trucks are then attached and ascend an incline of 20°, and by the time point D is reached they are on a level with the top of the ore pockets. The trucks are then led in the usual way from their own track on to the bridge, where they are emptied and return again to the starting point, following the track shown by dotted lines and arrows. The bridge is manipulated by one man, who has his seat in a cab, which is shown in Fig. 385 on one side of the bridge. The installation is fitted with safety appliances to prevent any trucks running away on the inclines. The speed of the cable chain is 100 ft. per minute, and with a truck every 12 yds., or 150 trucks per hour, is equal to 225 tons' capacity. The driving power is provided by a 20 H.P. motor, and one of 10 H.P. for manipulating the bridge.



Figs. 385 and 386. Rope Haulage Plant of the Soc. Anonyme des Hauts Fourneaux & Fonderie de Pont-a-Mousson, France.

CHAPTER XXIV

ROPEWAYS

MODERN industry has made the widest use of ropeways (which are probably the oldest form of conveyor, except the worm), as that method of handling material is termed, which consists of drawing buckets or skips on ropes, and by means of ropes such buckets being filled with the material to be handled, and being automatically or otherwise discharged. In this and the two following chapters is given a succinct description of all the principal systems of rope and cable haulage, with some account of the various purposes to which ropeways and aerial cableways are applied.

Ropeways may be divided into three sections :—

1. *Ropeways proper, for conveying purposes only.*
2. *Cableways, which convey and hoist the material at the same time* (see Chapter XXV.).
3. *Appliances for coaling at sea* (see Chapter XXVI.).

The origin of ropeways is, like that of many other flourishing institutions, lost in the mists of antiquity; but it seems quite possible that this means of transporting material was practised by the ancients, who had made more progress in engineering than they are often credited with. It may be objected that no traces remain of these ropeways, if ever they existed. It must be borne in mind, however, that then, as now, ropeways were often essentially transitory works, erected for special purposes, and bound to disappear as soon as the needs that called them into existence had passed away. Moreover, ropes are not objects that are calculated to defy the effects of time, especially hemp ropes which must have been used.

A curious old print (see Fig. 387) gives a graphic delineation of a ropeway that was erected by a Dutch engineer, Adam Wybe, of Harlingen, for the city of Dantzig in 1644.

This ropeway connected the city ramparts with a hill outside the town known as the Bischoffsberg. A single endless rope was passed over pulleys suspended on high posts, two of which were embedded in the city moat. The rope carried a number of rather diminutive buckets, which were filled with earth on the hill, and were discharged at a certain point on the ramparts. Probably the earth was used for strengthening the fortifications. The empty buckets were returned to the starting point on the same rope, which ran back on another line of posts. This was simply an endless rope running between two not very distant points.

The modern ropeway may be said to date from the adoption of wire ropes. It is a remarkable fact that, although, as already stated, wire ropes were known to the Romans eighteen centuries ago, they were not, with a few exceptions, pressed into the service of modern engineering till the nineteenth century was well advanced.

The practical use of twisted wire rope seems to be of no earlier date than the thirties; they are reported to have been used in England in 1832. The pioneer in this field is believed to have been a German engineer, Professor Albert, of Clausthal, who introduced these wire cables into his native land in 1834.

The first English patent for ropeways was taken out on the 20th July 1868, by Charles Hodgson, and the Continental pioneers were Theobald Obach, 1870, and Adolf Bleichert, 1873, and on these inventions most of the modern ropeways are more or less founded.

As far as the author has been able to ascertain, the first ropeway of any note erected on the single rope system was built in the year 1860, in the Hartz Mountains, by Baron F. F. von Dücker. The first ropeway on the double rope system, that is to say, with hauling rope and rail rope, was also built by him between the years 1868 and 1870. For

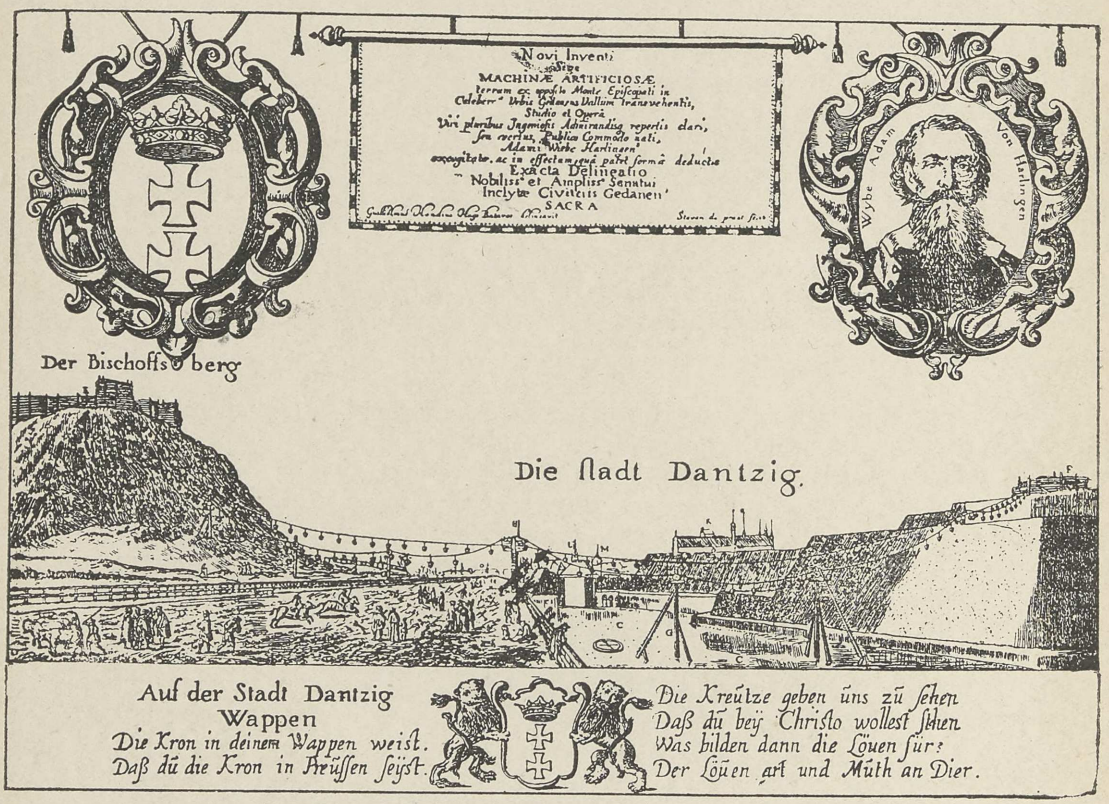


Fig. 387. An Early Ropeway erected for the City of Dantzig.

the further development in the early stages we are indebted to Kremer, Bleichert, and Otto, who in 1874 made these conveyors a practical success.

First of all, it may be stated that the prime cost and working expenses of ropeways are relatively moderate. Of course, the manufacturer who intends to put up a ropeway should estimate exactly what work it will have to do, so as to proportion his outlay to the useful effect he desires. The working expenses should be moderate, as even extensive ropeways require but a small working staff. The cost of repairs and upkeep must necessarily be considered, but good material, sound workmanship, and above all suitable construction, will, in this as in other cases, reduce expenses to a minimum. One great advantage of a ropeway is, that it may be worked over ground that would be impracticable for a tram or railway, except at a prohibitive cost for such items as embankments, cuttings, and tunnels. Indeed, it may be said that in dealing with rough or mountainous ground

the methods of ropeway and railway engineers are diametrically opposed, for whereas the one in laying out the line seeks easy grades, to avoid as far as possible irregularities, the other ignores, as a rule, the conditions of the ground, and follows a bee-line from point to point. Up and down gradients which balance each other may be ignored, and the driving power arrived at by taking the mean gradient between the terminal points.

In cases where the mean gradient is in favour of the load, the ropeway may become self-acting, and under certain conditions may even develop surplus energy. The ideal ropeway should go straight from point to point, the rope being supported wherever the ground lends itself to the erection of standards, which should, however, not be raised higher than necessary. With regard to the altitude of standards, however, the engineer is necessarily limited by the ground. It may be noted that since so many engineers of eminence devoted themselves to the building of ropeways, great improvements have been made in the details of construction, and in particular that the high trestles which were so marked a feature of the earlier ropeways have to a great extent been suppressed. It is probable, too, that the power used in working ropeways has been very considerably reduced by the selection of gradients in favour of the load. It is further contended that ropeways are independent of weather conditions, and this is no doubt true to a certain extent, because in a mountainous country a heavy fall of snow, which would stop the working of a tramway, would rarely interfere with the working of a ropeway. But it is a question if even the best constructed ropeway can always be worked in high winds and gales, though on this point experts differ. It is usual, however, to protect dwellings and thoroughfares over which ropeways pass by guards or safety nets.

Ropeways[1] have undoubtedly the advantage of simplicity of construction, and should not under ordinary conditions be subjected to interruptions from the gear getting out of order, though of course ordinary care must be exercised by the staff, which, as already observed, need not be extensive. Much skilled labour should not be required in connection with a ropeway. Beyond one competent engineer to superintend the working of the line, unskilled labour should suffice. The power required is relatively small, and under some conditions no driving power at all is required. In many cases, however, the ropeway erector must take into consideration the capital that may be absorbed by "wayleaves," because unless the ropeway is run entirely over his own ground he will be compelled to come to some arrangement with the proprietors of the land over which the ropeway will pass. This is termed a "wayleave."

It is understood that on the Continent landowners are not generally over exacting with regard to "wayleaves," but in this country the reverse seems to be the case. More than one ropeway system which might have rendered good service has had to be abandoned because of the excessive value placed by landowners on the "wayleaves" they were asked to grant. This is the more regrettable as the ropeway interferes little, if at all, with the land over which it passes. The amount of ground required for the supports is so trifling as to be practically a negligible quantity, while the line itself in no way interferes with the cultivation of the ground underneath.

Ropeways have their limitations; and although they can be carried over the most difficult ground if in straight lines, curves considerably increase their expense and working cost, necessitating as they do the erection of angle stations.

The modern system dates back little more than three decades, but during this period the distances which can be traversed and the loads which can be carried have undergone remarkable developments.

[1] The Author is indebted to Mr W. T. H. Carrington, M.I.C.E., for portions of the following description.

The exact form of ropeway which it may be found desirable to adopt, will no doubt vary widely with the nature of the ground and of the work required to be done. In the same way details of construction, such as the kind of material for the supports, will depend more or less on local conditions. In some cases wooden supports may be found quite sufficient, while in others iron may be preferable.

Ropeways are very frequently used for conveying timber from distant forests remote from navigable waterways, in mountainous and roadless tracts of land where the conditions are such that the stately tree must either remain in its native forest, or if it is to serve man's purpose, it must be brought forth over gorges and ravines by the only possible conveyor for such a purpose—the Ropeway.

Ropeways may broadly be divided into two grand divisions, namely, *Single* and *Double*. In the first case the load to be moved is carried by an endless running rope forming the ropeway. In the second the load is suspended from a traveller or runner drawn along the fixed rope by a separate traction rope commonly known as the hauler.

The subdivisions of these two main types are many, and are due to diverse conditions as regards ground and the load under which they have to work. There is no doubt that in planning a ropeway, particular attention must be paid to the ground, as well as to the loads that are to be carried.

The Single Ropeway.—This system is the oldest and simplest, and in its most primitive form it has already been mentioned, as one was erected for the city of Dantzig in the middle of the seventeenth century.

In this system one endless running rope is used, supported upon a number of roller supports carried upon trestles or standards. The rope passes at one terminal round a driving drum from 6 to 10 ft. in diameter, which gives the motion to the rope at a rate of speed of from 3 to 4 miles per hour; the other terminal is similar, but instead of giving motion it keeps the rope tight by a suitable tightening gear. The loads are carried in receptacles fitted with simple curved hangers pivoted in a Λ shaped saddle, which holds sufficiently tight by frictional contact to the rope, and therefore travels with the same. The suspended frame of the load-carrier is also fitted by the side of the Λ-shaped saddle, with the small grooved pulley which engages at the terminals with a shunt rail, and thus disengages itself from the running rope, and becomes stationary on this shunt rail for filling or emptying, after which it is pushed on to the returning rope.

It is generally considered that the single ropeway is more suitable for short distances and moderate weights, and where the inclines to be negotiated do not exceed 1 in 3, nor the individual loads 5 to 10 cwt. With single ropes, spans of lengths greater than 200 to 300 ft. should be avoided, unless on very broken ground or over deep valleys where spans of considerable length are unavoidable. We shall, however, see in the succeeding pages that experts, who devoted their energy almost exclusively to single ropeway designs, have achieved much better results than the above, and that they do not hesitate to apply the single rope system to practically any conditions and capacities capable of being handled by a ropeway. We have seen the extreme simplicity of the single ropeway from the foregoing, and will now go a little more closely into the details already outlined.

An endless wire rope would run round two terminal wheels or drums, the said rope being supported between these drums on suitable pulleys, the diameters of which would vary according to the size of the rope. These pulleys would be carried on posts or supports of iron or timber at a sufficient height to enable the carriers (as the skips or other receptacles in which the material is conveyed are termed) to clear all obstacles, even when the rope may sag. These carriers hang from the rope

and pass supporting pulleys by means of a curved hanger, pivoting in the Λ-shaped saddle which rests on the rope, and attached at its lower end to the skip. The saddle is an iron frame, fitted with friction blocks of wood, rubber, or composition, to cause sufficient adherence to the rope, and to enable the carrier to pass with the rope up inclines and over the pulleys. The frame carrying these friction blocks is usually made of malleable cast iron, and is provided with wings at each end which, as the carrier arrives at the supporting pulley, embrace or pass between the flanges of the pulley rim, when passing over the same. The frame which carries these friction pieces is fitted with two small wheels, carried on spindles attached to it, which are known as shunt wheels. Their function is to remove the carrier from the rope at terminals or curves, where shunt rails are placed. These rails are held in such a position that when the carrier approaches the terminal the small wheels engage with them and lift the saddle from the rope, enabling it to pass to where the loading or unloading is required to be done, or round the curve wheels. The impetus derived from the speed of the rope (which averages 4 miles an hour) is sufficient to enable the carrier to automatically clear itself from the rope. This form of ropeway consists, therefore, of one endless wire rope driven by suitable gearing, and supporting carriers which travel with it either by means of friction or mechanical clips.

A modification of this form of ropeway is one in which the carriers hang from and move with a single rope, being rigidly fixed on it. This system is recommended for routes on which steep inclines and sudden changes of level occur. As guide or depressing pulleys may be placed wherever necessary without obstructing the passage of the carriers, the vertical angle of the line may be changed at each support. Although this form of ropeway is similar in all such respects as driving and tightening gear and pulleys to the first-mentioned system, there is this important difference, that the carrier does not rest on the rope, but is clipped to it by a steel band which embraces it, being tightened by a suitable arrangement. As the carriers are fixed, they obviously must move with the rope, and, owing to the arrangement of the terminals, they will necessarily pass round the terminal wheels.

The driving wheel is usually in the form of a special clip drum, and the terminal wheel, where the tightening takes place, is so arranged that the passing of the carriers can be easily effected. When it is desired to unload, the carrier is allowed to strike a catch which causes the bucket to capsize or to open at the bottom.

Loading, which is a more delicate operation, can be effected by a variety of devices, all more or less ingenious and efficient. Thus a carrier can be loaded either while passing the driving drum, or at a point adjacent thereto, for instance by means of hoppers or cages moving at the same speed as the carrier and operated by it; or again, the ropeway may be run at the slow speed of 2 to $2\frac{1}{2}$ miles per hour, in which case the carriers can be loaded or discharged on passing the terminals by hand labour. An interesting example of this kind of ropeway is mentioned by Mr Carrington as having been erected in Ceylon on a tea plantation. This has a length of about 3 miles, and passes over several steep ridges. The leaf (in bags) is placed in the carriers (which are in the form of cages) as they pass the driving terminal. This driving terminal is operated by wire rope transmission communicating the power required from a turbine $\frac{3}{4}$ mile away. The ground is so broken as to necessitate the use of several guard wheels, the function of which is to depress the rope; as the load passes, its weight relieves the pressure on the guard wheels, and enables it to pass under the guard wheel, which again performs the office of

depressing the rope. In this case the loads on arriving at the tightening and discharging terminal are lifted by hand off the carrier; but a simple automatic arrangement can be provided, by means of which a projecting bar is allowed to strike the carriers, whereupon the bags are delivered automatically.

The Double Ropeway.—In the double ropeway, which is the most generally diffused type in these days, the load is carried on a fixed rope, which serves much the same function as a railway, except, of course, that the railway rests on sleepers, while the rope is carried through the air. This rope is fixed and taut, whilst the load is drawn by the second rope, which is called the hauler. The return is similar on a parallel fixed rope. This kind of ropeway is applicable in cases where the loads to be transported exceed 400 tons per day; where individual loads exceed 6 cwt.; where the incline exceeds 1 in 3, and where long spans are necessary.

The lock-coil rope which has been largely substituted for the old type of spiral rope is here illustrated (see Figs. **388**, **389**, and **390**). It is undoubtedly possessed of great strength, and has been installed under conditions involving heavy work and great strain on the ropeway.

A ropeway of this type is erected somewhat as follows:—

Two fixed ropes are stretched parallel to one another, about 7 ft. apart, and supported

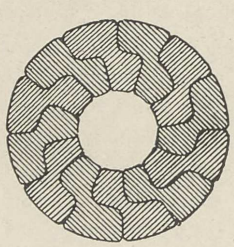


Fig. 388.

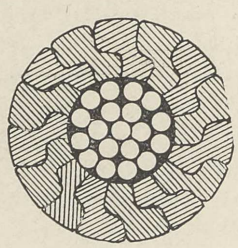


Fig. 389.

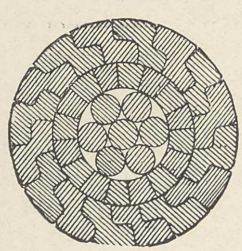


Fig. 390.

Sections through Lock-Coil Rope.

by posts, fitted with saddles, at a distance of about 300 ft. from one another. The ropes are anchored at one of the terminals and tightened at the other by suitable gear. The carriers run on the fixed ropes as on a rail, and are fitted with running heads carrying steel grooved wheels. The hanger from which the load is suspended is pivoted from the carrier, and the load is conveyed at a speed of 4 to 6 miles per hour by an endless hauling rope, operated by driving gear at one end, and controlled by tightening gear at the other. The hauling rope is attached to the carrier by an automatic clip which will release itself by touching a bar on arriving at the terminal station, but will hold sufficiently tight to enable the hauling rope to drag the carrier up inclines. The grip of the hauling rope on the load may be supplemented by knots or sleeves on the former, or by means of a suitable casting inside the rope at certain points, so as to make an enlargement at the point where the clip engages. With slight inclines the pressure of two pulleys or plane surfaces on each side of the hauling rope is sufficient, but in the case of sharp inclines, where the pressure on the hauling rope is severe, the clip attached by means of wedges may be used. With lines erected on this system, shunt rails and driving and tightening gears are used, just as in the single rope lines. At each of the supports rollers have to be provided on which the hauling rope rests when it sags between the carriers. These rollers are provided with guide bars to increase the range of support, and guide the hauling rope into the above-named pulleys, should it be deflected from the vertical.

A line on this system, of about 1,800 yds. in length, is at work in Japan, running mostly at an incline of 1 in $1\frac{1}{2}$. It is used to carry ore from the upper terminal to the lower. Such is the power generated by the descending loads, that it has been found necessary to absorb the greater part of it, so as to render the line amenable to the control of a hand brake. With this view a hydraulic brake was introduced, in which the revolving fan drives the water against fixed vanes which again repel it. By this means about 50 H.P. was absorbed, and the speed regulated to a nicety by adjusting reaction vanes against which the water impinges.

A variation of this system is that of a *single fixed rope*, on which one carrier, hanging from the fixed rope, is drawn to and fro by an endless hauling rope. This kind of ropeway has been found useful under conditions where moderate quantities have to be transported in heavy loads or pieces, or where spans of considerable length have to be worked over. Inclines up to 1 in 1 can be worked, and a span up to 2,000 yds. used, while loads up to 5 tons may be carried. The endless hauling rope is operated by any available power, the driving gear being arranged with reversing motion so that the direction in which the carrier runs may be changed as required by the attendant. The fixed rope is supported on posts spaced at intervals varying with the nature of the ground, while the hauling rope is carried on pulleys fitted with guide bars and placed in the centre of the post over which the carrier passes, the posts, of course, being so arranged as to allow of the carrier clearing them. The return hauling rope may be supported on an outside pulley mounted on an arm of each post. The hauling rope is attached to the carrier head by suitably placing a pendant which causes it to pass under the saddle transom.

A ropeway, erected on this system by Messrs Bullivant, is at work on Table Mountain, at the Cape of Good Hope, and has a length of 5,280 ft. This line commences at the sea level, and following the ground on posts spaced about 300 ft. apart, takes a span of 1,500 ft., rising to a projecting rock 1,480 ft. above the starting point. Resting upon this support at this point, it again makes a span of 1,400 ft. to an upper terminal 2,170 ft. above the lower one.

Another type of ropeway is that which consists of two *fixed ropes* with an endless hauling rope, in which one carrier will run in one direction, while the other runs on a parallel rope in an opposite direction. Such a ropeway can be used over long spans where individual loads amounting to 5 tons have to be transported. It would be suitable in cases where the ropeway could be worked by gravity, the descending load moving by its own weight, while the empty carrier ascends. In such cases spans of 2,000 yds. or more may be safely negotiated, and loads of 6 tons carried.

Gripping and Other Coupling Devices,[1] by means of which the carrier is attached to the hauling rope, are some of the most important details of a double ropeway, and must fulfil the following conditions:—

Firstly, the attachments must have such a grip on the rope that the carrier can ascend inclines of 45° in safety without tendency to slipping.

Secondly, the hold or grip on the rope must be entirely by friction, as any bending of the hauling rope by the coupling will inevitably shorten the life of the rope.

Thirdly, the apparatus should be so arranged that the amount of grip is adjustable according to the circumstances, taking the wear of the rope and climatic and atmospheric influences into account; and

[1] The facts and illustrations are taken from an article by A. Pietrkowski in *Stahl und Eisen*, 18th November 1908.

Lastly, the operation of coupling and uncoupling should be performed automatically at predetermined points.

Under the second heading it should be mentioned that sufficient compression of the rope to obtain the necessary grip is in itself by no means advantageous to the rope, so that a tendency to bending it would aggravate the evil very considerably.

Under heading three comes the consideration of sufficient latitude in the inability of adjustment to allow for the variation in thickness which is often noticed after the rope has been at work for some time; this also includes splices, and the slippery condition of the rope from wet and hoar frost.

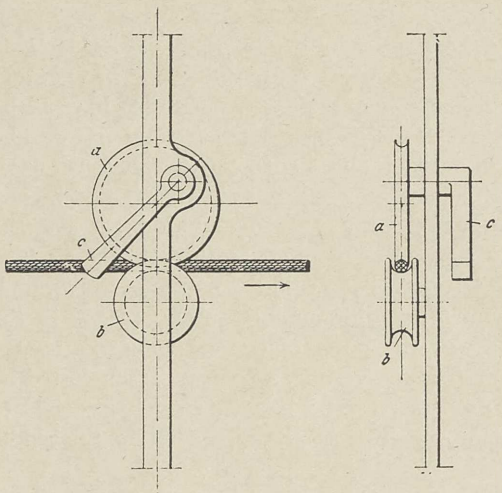


Fig. 391. Obach Coupling.

Appliances which satisfy these conditions are in use at the present day, and we will now pursue their development in chronological order.

Fig. **391**. This coupling, designed by Obach, dates from 1870 and is probably the first device of this kind ever made. It is an application of the principle of the eccentric and is exceedingly simple. The rope rests on roller *b* and the eccentric *a* is turned until it grips the rope which travels in the direction of the arrow (see drawing), and thereby helps to tighten the eccentric against the rope, and as the grip on the carrier depends solely on the friction between rope and eccentric it is not very great. The method of coupling or uncoupling is exceedingly simple, being effected by either dropping or lifting lever *c*. The weak points of this early appliance are that in the event of a temporary slackening of the speed of the rope, the carrier, by reason of its momentum, would proceed faster than the rope and would thereby create a tendency to loosen the coupling, so that if any of the carriers were on an inclined portion of the rope they might run back.

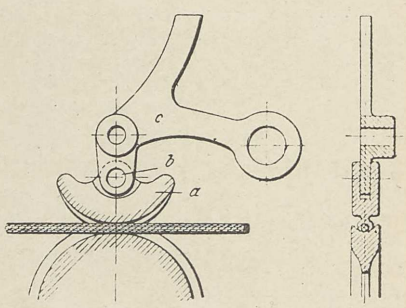


Fig. 392. Bleichert-Otto Coupling.

To remedy this defect was the first move towards an improvement, and the outcome was a new appliance brought out in 1874 by Bleichert & Otto; this is shown in Fig. **392**. The essential feature of this appliance is a reversal of the action of that described previously, that is to say, the eccentric *a*, or rather an eccentric segment, has its smallest radius towards the rope instead of vice versa, so that in whichever direction the rope or the load may pull, it has a tendency to grip and hold fast. As, however, this arrangement by itself does not give a very large latitude, the turning point *b* of the eccentric has been made movable at one end of the bracket *c*, so that by the additional movement of the angle-bracket *c* the relative position of the eccentric to the rope can be changed within larger limits.

The grip of this improved coupling is, however, not sufficient for heavy duty, as it

also depends solely on the friction between rope and eccentric. The appliance, Fig. **393**, was a further step in this direction by the same firm. It consists of a roller *a*, and a segment of an eccentric *b*, which is movable around a pin *c*; this pin couples the eccentric to an extension *d*, which is guided in a cast-iron bracket where it can move up and down; this extension *d* can be manipulated by a second eccentric *e*. To the axle of this second eccentric is fixed a lever *f*, provided with a handle, and it will be seen that by the movement of this handle the eccentric *b* is pushed down upon the rope in that position as shown in the drawing. The rope is gripped by the eccentric *b*, but the eccentric motion, or grip of eccentric *e*, has not yet come into force, and this will give an auxiliary grip when the rope pulls in either direction. This apparatus is quite satisfactory for ropeways which negotiate moderate inclines and for moderate loads. More modern installations, with inclines exceeding 1 in **3** and heavier loads, require a coupling of still greater gripping power. Experts realised the difficulty of such a design, and therefore adopted the expedient of a rope with knots as an easy way out of the difficulty. These knots were attached in a variety of ways to the rope at fixed intervals, each knot

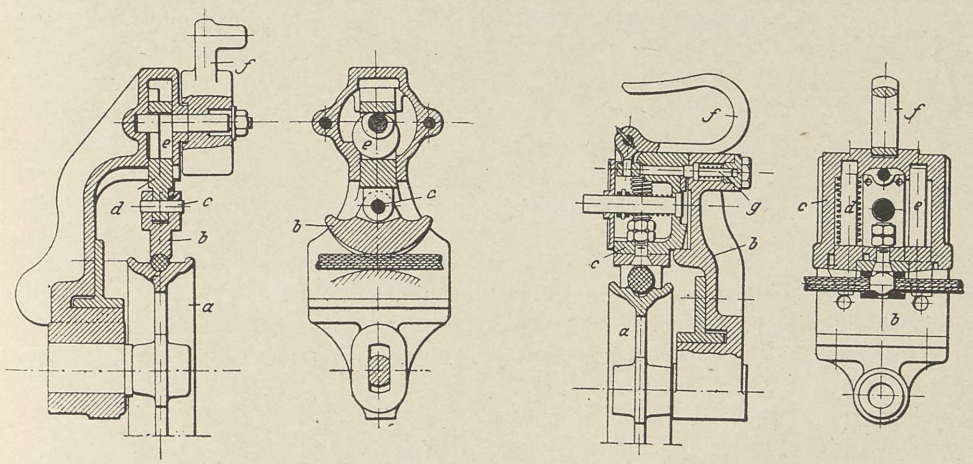


Fig. 393. Bleichert Couplings. Fig. 394.

engaging with the coupling of one of the carriers, and this had the advantage of distributing the load uniformly over the rope, but it had the drawback over the previous method of attaching the loads promiscuously, in that the capacity of the ropeway cannot so easily be altered. It is not here intended to describe at length the various methods of attaching the knots to the rope; they were either securely attached to the strands of the rope and thereby made fast, which, as we shall see later, was not found a good plan, or they were made movable so that they could be taken off and fixed in a fresh position. They also had the advantage of being attached quickly and easily, but they lacked security in their position and were apt to shift. A rope thus fitted with knots would not require a gripping device, but rather what is known as a locking grip or coupling, so it was necessary to reconstruct the coupling to accommodate it to these altered conditions. The illustration, Fig. **394**, shows a design of Adolf Bleichert's, which consists of a rope roller *a* and bracket *b*, which carries the sliding block *c*, and this carries two bolts or pins *d* and *e*, which latter have at their base peculiarly shaped fangs or claws. The bolt *d* admits of a vertical movement and is held in its normal position by a spiral spring. The method of coupling the carrier to the rope is performed as follows:

As soon as one of these knots approaches the coupling it lifts the fangs of the bolt *d* and slides underneath, its progress being arrested by the fangs of bolt *e*. The spiral spring replaces the fangs of bolt *d*, so that the coupling and carrier must now travel with the rope. The hook *f* is connected with the pawl *g*, and is for the purpose of uncoupling the carrier.

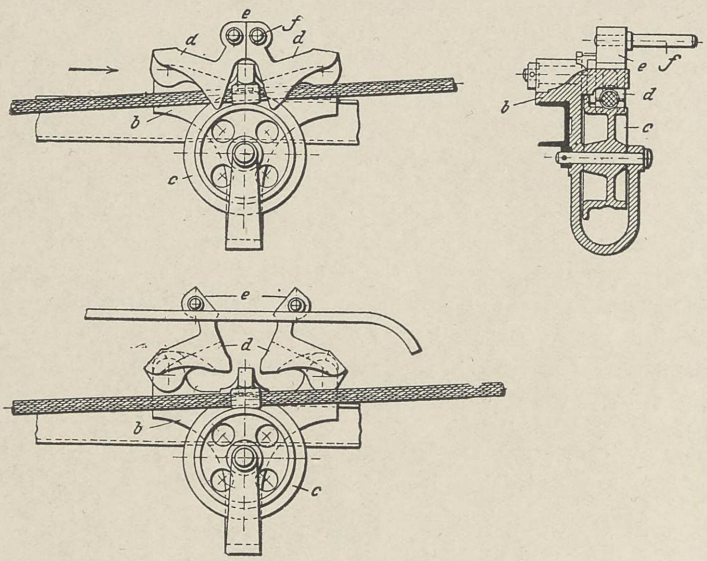


Fig. 395. Elligen Coupling.

Another construction for the same conditions is that of Elligen shown in Fig. 395. This consists of the frame *b*, roller *c*, and catches *d*, which latter are the chief features of the coupling. They are arranged on either side of the roller *e*; in the illustration these are shown in the lowest position, as they rest upon each other at *e*, the rods *f* engage with a short length of rail at the stations and thereby lift the catches, thus uncoupling the rope as shown in the lower picture. The uncoupling process is similar to that of the previously described appliance.

Owing to the insecurity of some of the knots on the rope, and the great wear on both sides of the knots caused by these couplings, it was realised that their employment did not solve the difficulty in the best and most economical way, and further efforts were made to design such a coupling as would give sufficient grip for steep inclines and heavy loads without the use of knotted ropes.

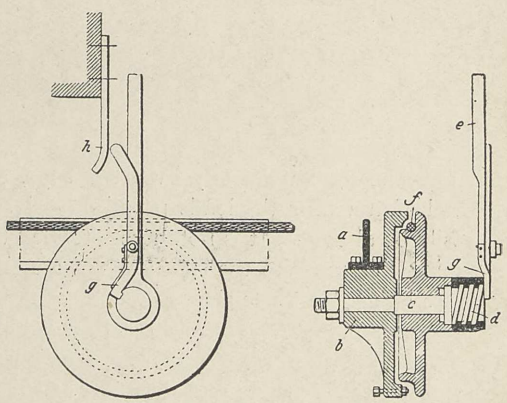


Fig. 396. Otto Coupling.

Theodore Otto abandoned the eccentric principle for these couplings in 1877 and introduced a gripping device on the screw-vice principle. It would occupy too much space here to explain why this screw device was not introduced before, but the chief difficulty was that a certain clearance between the gripping device and the rope was always necessary; and to close the jaws when sufficiently far apart until a sufficient grip was obtained, the coupling lever would have to traverse a larger segment of a circle for a screw device than for an eccentric device (the latter takes less than 90°), and if so short a movement of the tightening lever is chosen for a screw device, the pitch of the screw has to be so steep that there is a danger of its coming undone through

a little vibration, unless an automatic catch is provided to prevent this, and that is the plan adopted by Otto. His device is shown in Fig. **396**; *a* shows the portion of the carrier to which the apparatus is attached, which consists of the disc *b* with pin *c* upon which latter is a second disc which can revolve on the same, and which is controlled by the thread *d*. When the handle *e* is turned, the loose disc is pressed against the fixed one and thus holds rope *f* as in a vice, the catch *g* snaps into position and keeps the grip tight. The coupling operation is performed by hand, whilst the uncoupling is effected automatically by tripper *h*. If the clearance mentioned above is somewhat reduced, so that a lesser movement of the lever is sufficient for the grip, the catch can be dispensed with as the thread of the gripping screw is shallower. Fig. **397** shows such a coupling; the arrangement is similar to the foregoing but more like a vice. In order to intensify the gripping power the gripping portion has a slight bend in it (see illustration). This coupling is used by hand only, and the tendency to bend the rope cannot be looked upon as advisable, at least from the economic point of view.

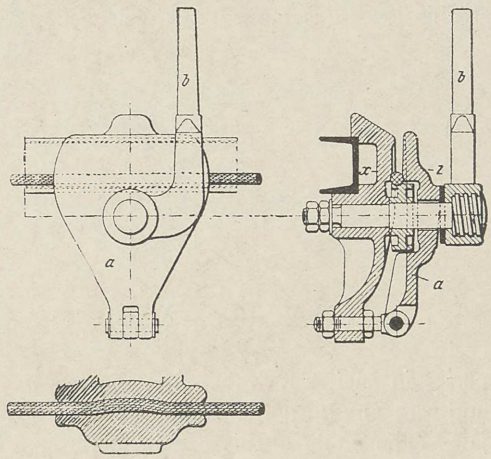


Fig. 397. Improved Otto Coupling.

In the meantime Obach experimented, independently of Otto, with a coupling on the vice principle, but realised that the rope mus tbe gripped in its central position in order to get the tightest grip, and at the same time cause the least injury to the rope. This prompted him to abandon the vice principle with a single screw and substitute

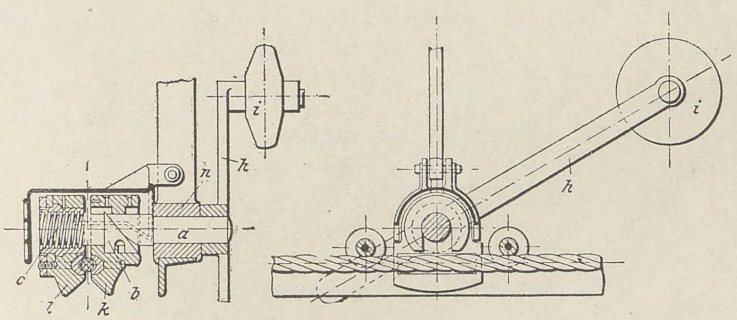


Fig. 398. Werner Coupling.

for it a gripping device with a right and left handed thread, which has the advantage that both the gripping plates move towards each other, and that, without making the thread of the screw too steep, the arc described by the coupling lever is not more than 180°. This principle was further developed by Alexander Werner in 1885, who improved on the idea by using different threads on the two halves of the grip, the one with a fast pitch, whilst the other was fitted with a fine thread, so that each half of the coupling had to perform a different kind of movement, and altogether they exercised a very powerful grip on the rope. One of these devices is shown in Fig. **398**

in front view and section. The component parts are a spindle *a* which carries a right-hand thread of a steep pitch marked *b*, and a portion *c* with a fine left-hand thread. Both portions of the screw fit into and carry each half of the gripping portion *l* and *k*. The spindle *a* is secured to the carrier frame *n*, round which point the carriage is suspended, and the lever *h* which is keyed to the spindle carries a balance weight *i*. If this lever *h* is moved to the left the jaws open, whilst, if it is turned to the right, it

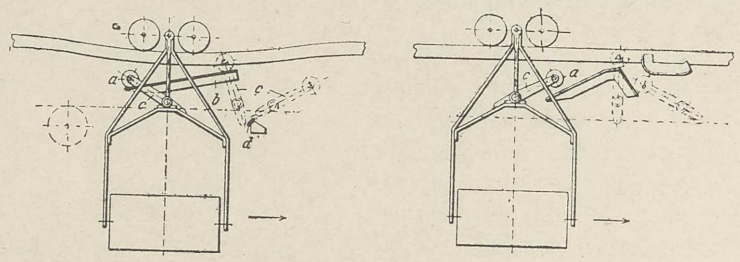


Fig. 399. Application of Werner Coupling.

closes in such a way that first the jaw *k* with the quick thread closes upon the rope, and with any further movement of the lever the small pitch screw will close the other jaw. The whole of this can be performed by a movement of not more than 90° of the starting lever. Fig. 399 shows the automatic opening and closing of the grip. To couple up, the workman pushes the carriage in the direction of the arrow when the starting lever *a* engages with an inclined plane *b*; this lifts the lever in an upright position when the lower end of the lever *c* engages with the tripper *d*, which forces the coupling lever right over through an arc of 90° in the beginning of this movement, which secures the clamp to the rope. The uncoupling which is shown in the same illustration is a reversal of the action, as may be seen in the various positions in dotted lines.

In the year 1887, Mr J. Pearce Roe devised and employed a clip for a ropeway under his own supervision, where the grip was obtained through two wedges placed normally on a horizontal plane, which gave excellent results on gradients of 1 in 2. In this clip the amount of gripping was in direct proportion to the steepness of the grade, and, therefore, exactly what was wanted. Unfortunately the device was too costly to be generally used.

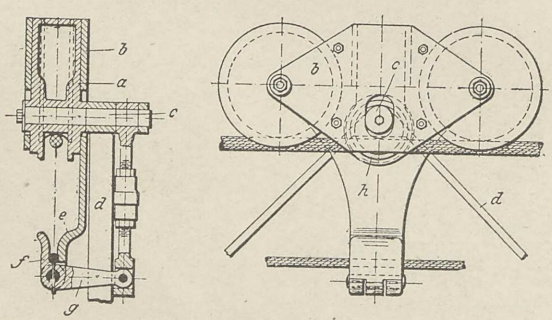


Fig. 400. Bleichert's "Automat" Coupling.

In 1894, about the same time that the Werner Coupling, which went under the name of "Universal Clip," was at the zenith of its popularity, a different principle altogether was introduced by Paul Spitzek. It occurred to him that the weight of the carriage itself might be utilised for coupling it to the hauling rope. Attractive as this idea appears at first sight, the bringing into practice represents many difficulties all due to one main cause, *i.e.*, the fact that one half of the gripping device would have to be attached to the trolley on the rail rope, and the other portion to the carrying frame which is suspended from it, and which might be at right angles to it when the rope is horizontal; or it may form a sharp or obtuse angle when the carriage negotiates upward or downward

inclines. The problem has, however, been solved in 1896 by the introduction of a device by Bleichert, illustrated in Fig. 400. This grip goes by the name of the "Automat," and consists of a sliding block *a*, which moves in a vertical direction in the frame *b*. A pin *c* is attached to this block, and the carrying frame *d* is suspended from this pin. One of the jaws *e* is rigidly connected with the framework of the trolley, whilst the other one *f* is connected to the sliding block *a* (and indirectly to the pin *c*) by a connecting link *g*. The throwing in and out of this coupling is effected by slightly raising or lowering the load on the rope. The roller *h* is for this purpose, as this rests on small auxiliary rails at the loading or unloading stations. It is claimed for this coupling that the grip is sufficient to fulfil all the requirements of the modern ropeway without the use of knotted ropes.

Advantages and Disadvantages of the Two Systems.—As regards the initial outlay, the single ropeway is simpler; having only one rope and requiring no expensive couplings, it is therefore less costly, although the supports should be closer together, as it is more difficult to keep a running rope taut than a stationary one. The working expenses, that is the labour, would be the same in both systems.

The double ropeway is more applicable to difficult routes deviating from the straight line. It can negotiate steeper gradients and, finally, it is more suitable for large individual loads than the single rope system; firstly, because corners are more easily turned with a double ropeway; secondly, because the Λ-shaped saddles do not exercise such a positive grip as some of the gripping devices of the double ropeway; and thirdly, because the rail rope is stronger, tighter, and thus more rigid, to cope with heavy individual loads.

A rope of the single system can be minutely examined and oiled whilst passing through one of the terminal stations, but with a double ropeway a man has to travel in one of the skips for this purpose.

Cost of Transport.—This must necessarily vary with the conditions, but generally speaking the working expenses of a ropeway compare favourably with those of a railway. On some well-planned and well-laid ropeways the wear and tear of the ropes, which is actually the largest item of expense, is said to be between $\frac{1}{8}$d. and $\frac{1}{4}$d. per ton per mile. Broadly speaking, the cost of handling must vary with the natural obstacles on the route and the quantities to be carried.

An example which may be mentioned to show the wear and tear of rail ropes is that of a ropeway erected by Messrs Bullivant & Co., Ltd., in Spain, which was employed to convey loads of from 300 to 350 tons per day a distance of 1 mile between Badovalle and Ortuella, so that it is estimated that one rope carried over 160,000 tons. As the ropeway was at work incessantly from July 1893 to July 1895, the cost of rope renewal meant an expenditure of $\frac{1}{4}$d. per ton per mile. The rope when new had a breaking strain of $29\frac{1}{20}$ tons, and the test showed that the disused rope had still a breaking strain of $27\frac{1}{2}$ tons.

As will be seen later, Ropeways, Ltd., estimate the total cost, including, in addition to rope wear, all renewals, grease, stores, etc., at $\frac{1}{2}$d. per ton per mile. The figures given do not, however, include cost of labour or power, which two items vary with every installation.

Cost of Maintenance.—One of the most important questions in a ropeway installation is the cost of maintenance, and as this is almost exclusively confined to the renewal of the rope or ropes, it may be well to investigate this subject more fully. It is obvious that the function of and the demand upon a rail rope is different to that of a haulage rope. The former would naturally have to be made of the stoutest possible wires

to form a rigid, smooth, and lasting rail for the load to run upon, whilst the latter, which would not be exposed to much actual external wear, but mainly to that due to tension, should be composed of thin wires of good quality steel, in order to give flexibility and strength.

Now with a single ropeway both demands of tensile strength and rigidity are made upon one and the same rope, and it must therefore be apparent that a rope must be chosen which meets these demands. As it is difficult to arrive at a happy medium to meet such diverse conditions, the single ropeway is under a disadvantage. The single

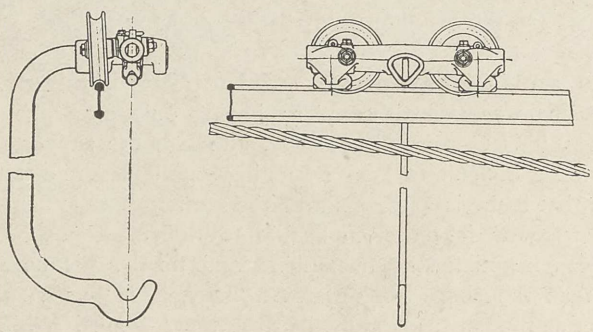


Fig. 401. Single Rope Carrier employed by Ropeways, Ltd.

rope, though always running, is working under similar conditions to the fixed rail rope of the double ropeway; only instead of the rope with its load running over stationary rollers as in the first case, the running rollers with their load pass over the stationary rope in the second case. The stationary or rail rope of the double ropeway may be subjected to greater local strain, and consequently wear more at certain points of its length, and being a fixture may wear principally on the uppermost side, whilst the single rope, which

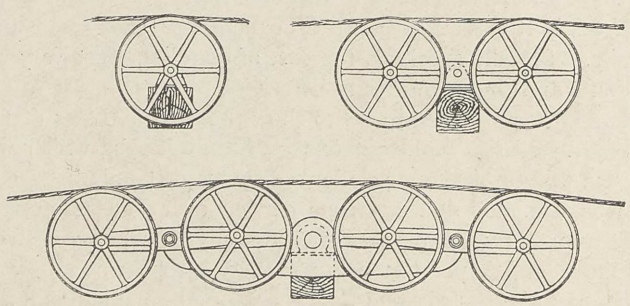


Fig. 402. Grouped Sheave Mountings with Balance Beams.

constantly travels the whole route, must of necessity wear equally on the whole of its length, as every portion must negotiate any point causing extra wear, and as it always revolves slowly round its own axis it is worn equally all round. The rail rope of the double ropeway can of course be relaid from time to time, whereby this defect might be minimised.

If we summarise the foregoing we find that the two ropes of the double ropeway can be better adapted to their diverse requirements than the single rope, which has to combine both requirements in one rope. On the other hand, the rail rope of the

double ropeway is under certain circumstances subjected to greater and always to more or less unequal wear.

It appears, therefore,—and this is borne out by practical results,—that there is not much to choose as to the expense of rope renewals, provided that both types are designed equally skilfully, and that no excessive loads or spans are attempted.

Installations by Ropeways, Ltd.

The attention of Ropeways, Ltd., of which Mr J. Pearce Roe is managing director, has been chiefly confined to the design and construction of installations on the single

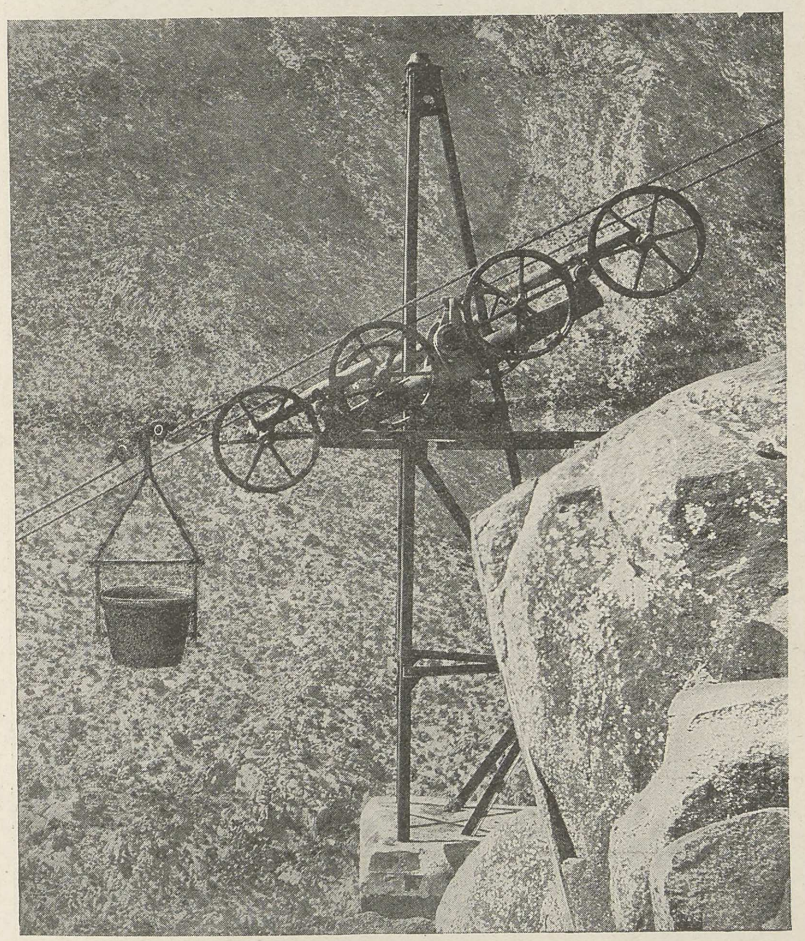


Fig. 403. Quadruple Balanced Beam and Sheaves.

or mono-cable system, and the double or bi-cable type is only used by them where short lines of heavy capacity are required. By careful attention to details, this firm have mono-cables running which are carrying 150 tons per hour, working grades exceeding 1 in 2 over rough and mountainous country.

The saddle which enables them to negotiate such steep gradients is shown in Fig. **401**.

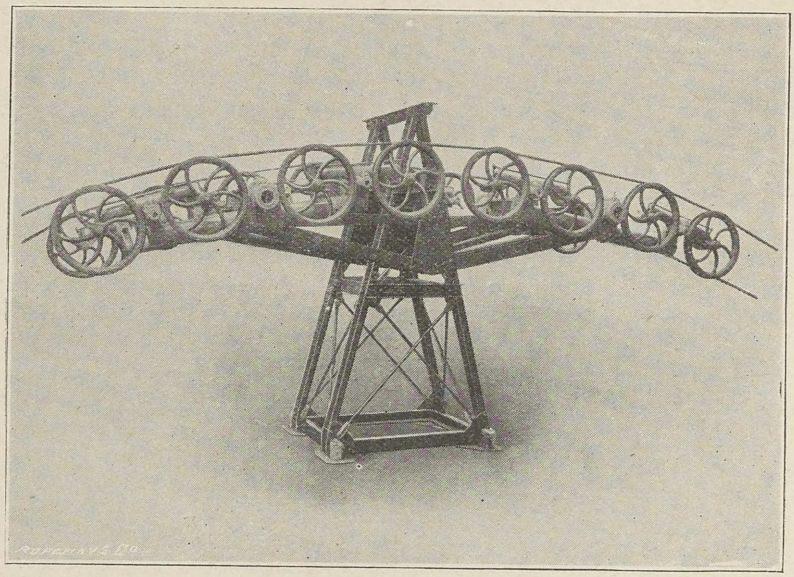


Fig. 404. Multiple Balanced Beam and Sheaves.

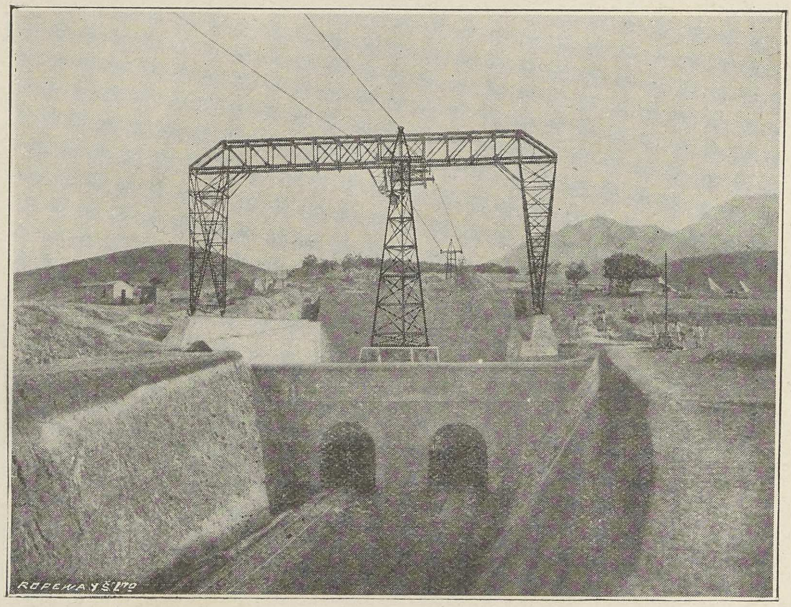


Fig. 405. Portion of Ropeway of the Compañia Minera Minas del Riff at Melilla.

The two surfaces which come in contact with the rope have two wart-like projections, each of which fasten between the coils of the rope and prevent any slip.

One of the features of this system is the groups of balanced sheaves which were first introduced for supporting the rope. Illustrations of their single, pair, and multiple balanced beams and sheaves are shown in Figs. **402**, **403**, and **404**.

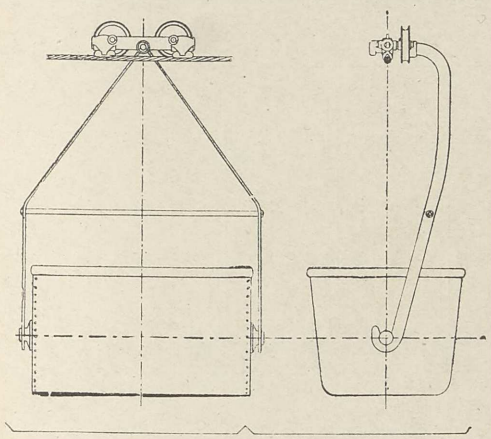


Fig. 406. Ordinary Bucket for Ore, Coal, etc.

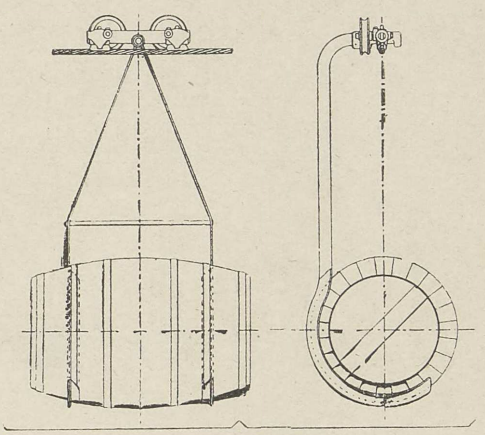


Fig. 407. Carrier for Barrels, Sacks, etc.

Grouping sheaves in this manner simplifies the construction of ropeways, and enables long spans to be worked without undue pressure on the supporting sheaves, as the balanced beams allow the sheaves to adjust themselves and follow the angle caused by the rope passing over them, so that by this means the pressure is equally divided all the time on every sheave with no detrimental effect on the rope. An example of this kind

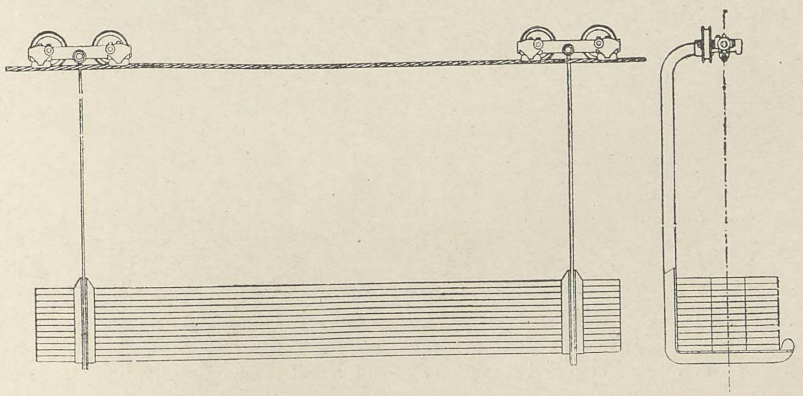


Fig. 408. Carrier for Timber.

may be cited in the installation for the Tominil Mexican Mining Co. The ropeway in this instance is 2,400 m. in length, and runs over a series of rugged ridges, and only eight trestles of 3 m. each in height are employed for supporting the rope, the longest span being 810 m.

A very similar line on the same system is now in course of construction in Bolivia, where one span measures over 1,000 m. between supports.

The greatest length worked in one continuous section on the system in question is the lower half of a ropeway built for La Compañia Esplotodora de Salinas, in Chili, which is 8,500 m. long between stations, or in other words, requires an endless rope of 17,000 m. The heaviest line is that installed for the Compañia Minera Minas del Riff, at Melilla, which nominally carries 150 tons per hour, but which has been actually run with a capacity of 170 tons per hour (see Fig. **405**).

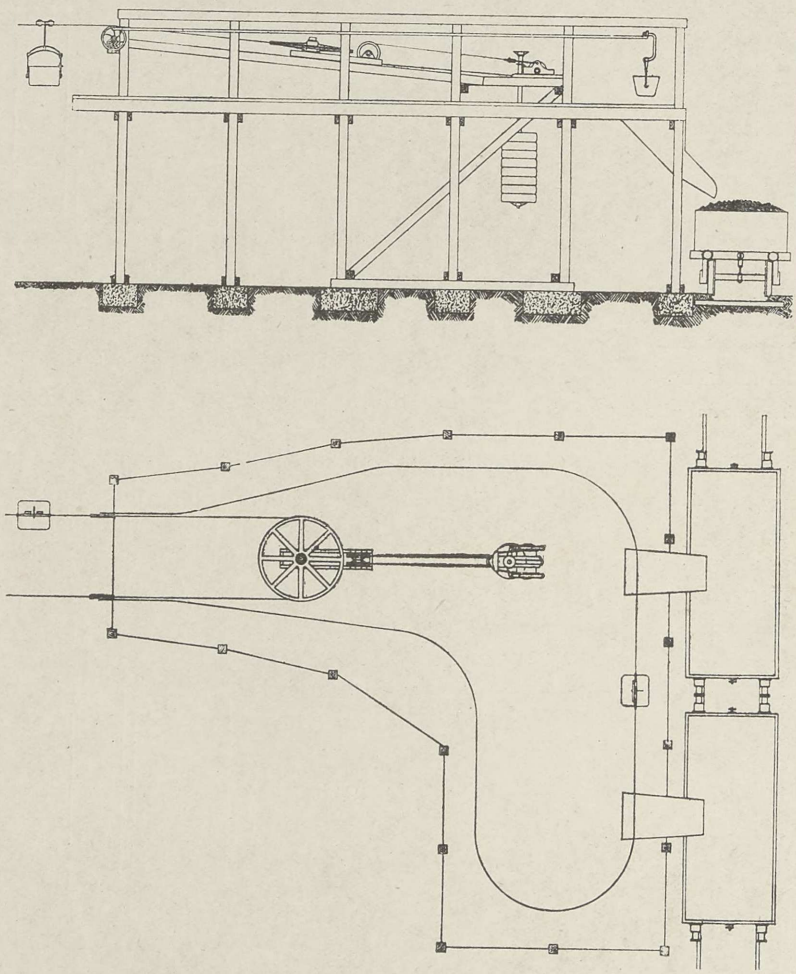


Fig. 409. Plan and Elevation of Tension and Discharging Station.

A series of lines having a total length of 23 km., built in 1903 for the Bacares Iron Ore Co., give a good example of the exceedingly low rope wear on this system. On two of the ropeways, the ropes in each case have transported over a million tons of ore. Among other instances of long lives of ropes is a line built for the Cork-Bandon South Coast Railway, the same rope has now been running for twelve and a half years, and on an installation constructed for Messrs Newell at Dalbeattie, the original rope has been working for twelve years. At the present time both these ropes are in good condition.

Figs. **406**, **407**, and **408** illustrate a few forms of carriers used for different purposes.

Fig. **409** shows plan and elevation of unloading and tension station built on the single rope system by the above-named firm.

Figs. **410** and **411** give examples of Roe's unloading stations, Fig. **410** being a terminal for driving by power, whilst Fig. **411** represents a loading terminal for a gravity driven line, showing band brake. These brake stations are also fitted with hydraulic resistance regulators to automatically govern the speed of the ropeway.

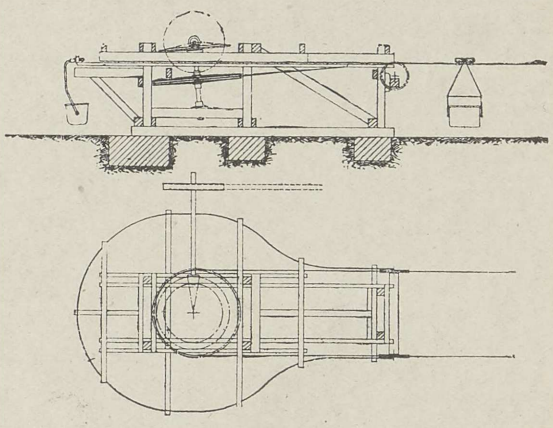


Fig. 410. Plan and Elevation of Driving Terminal.

Fig. **412** represents an angle station. This is at a point where the ropeway diverges slightly from a straight line. It is in use on the Mazapil Copper Co.'s ropeway in Mexico, which ropeway has a capacity of 250 tons per day of ten hours.

By careful analysis of costs of stores and general renewals on various installations, these can be taken roughly at ½d. per mile per ton of material carried on average lines of about 40 tons capacity, and varies incidentally with the load or capacities above or below. This cost includes rope wear, all renewals, grease, stores, etc. It is, of course, impossible to give ton-mile rates for labour and power, but it can be taken that five men are capable of working a straightforward installation of a capacity up to 60 tons per hour, and a length of 4 miles, if the material carried can be handled cheaply through bunkers and shoots without introducing any special automatic appliances. On some lines labour in operation is less, employing no more than three hands all told, in installations of up to 80 tons per hour capacity.

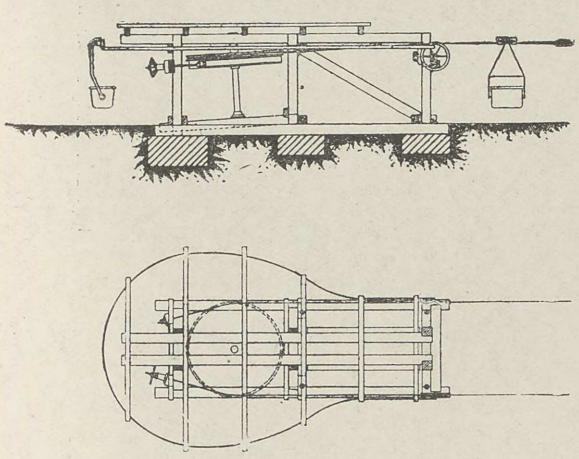


Fig. 411. Plan and Elevation of Brake Terminal.

At the present time Ropeways, Ltd., are installing what is believed will be the longest ropeway in the world, for the Dorada Railway Extension Co. of South America. This line will have a length of 45 miles (73 km.) measuring the distance horizontally, but as the ground over which the line will run is exceedingly mountainous, the actual length over the trestles will greatly exceed this. The line is divided into fourteen stations, and the power required for driving it will be about 400 B.H.P., produced by a hydro-electric plant which is being erected on one of the local rivers. The installation is to convey general merchandise between the two towns of Mariquita and Manizales in the Republic of Colombia, South America,

and will have a maximum capacity of 20 tons per hour in both directions at the same time throughout the whole length.

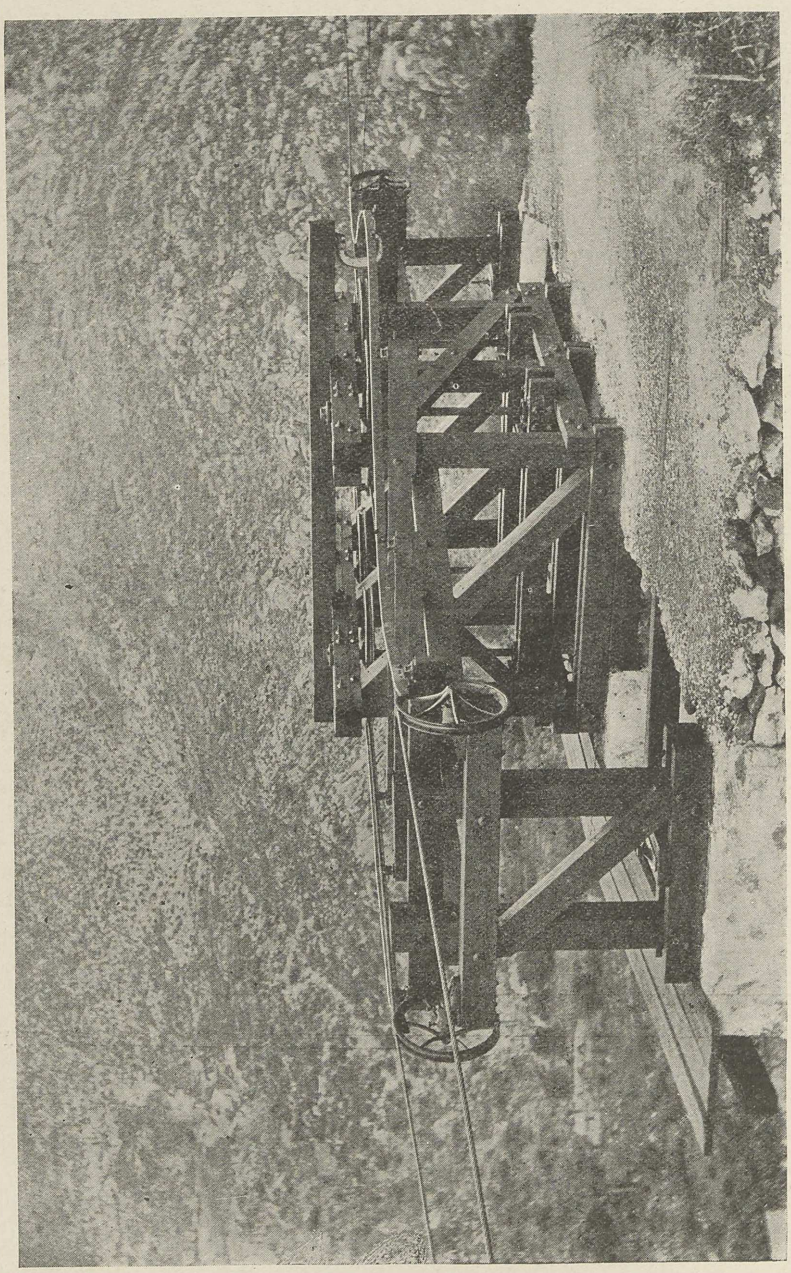


Fig. 412. Angle Station on the Ropeway of the Mazapil Copper Co.

Ropeways Erected by Bullivant & Co., Ltd.

Ropeway at the New Beachy Head Lighthouse.—In consequence of serious encroachments of the sea in the locality of Beachy Head, the Corporation of the Trinity

House decided in 1899 to abandon the well-known lighthouse on that promontory and erect another structure on the foreshore beneath.

It having been deemed desirable to establish the workyard at the top of the cliff at a height of about 400 ft. above the sea, it became necessary to construct a ropeway of a special character for the purpose of carrying loads to a staging erected a little beyond low-water line on the shore at the site of the proposed lighthouse, which lay about 600 ft. from the base of the cliff (see Fig. **413**).

Mr W. T. H. Carrington, M.I.C.E., the consulting engineer to Messrs Bullivant & Co., Ltd., having in consultation with Mr Matthews prepared the necessary designs for the ropeway, the construction of the latter was entrusted to that firm. The chief

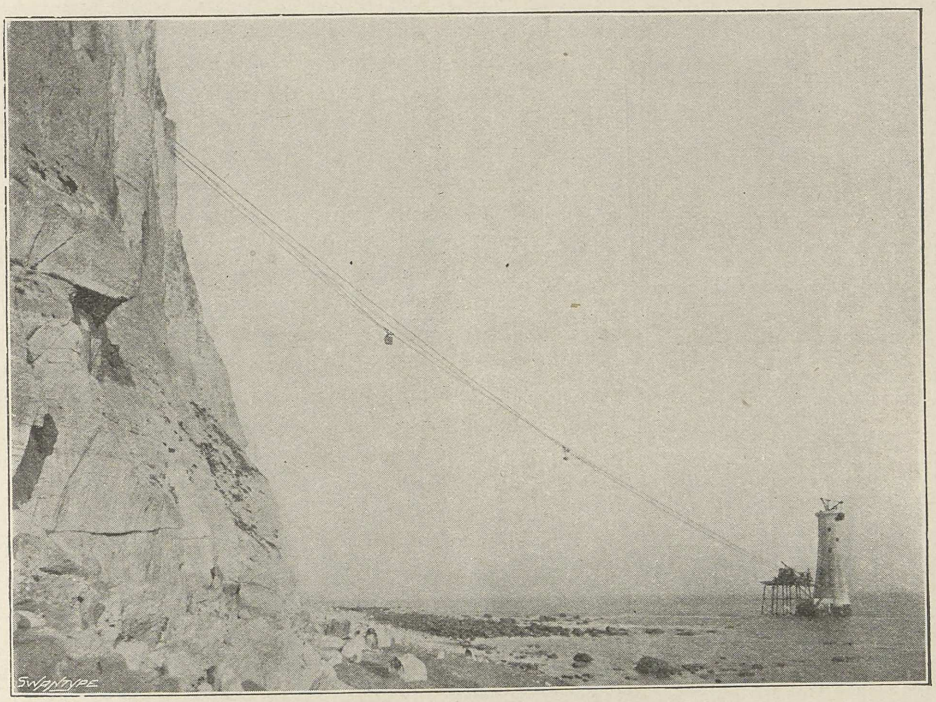


Fig. 413. General View of the Ropeway.

work the ropeway was required to perform was to transport blocks of granite weighing about 4 tons each for the construction of the lighthouse; but it had also to transport the machinery needed in the building, such as pumps, steam engines, cranes, etc., as well as all the cement, shingle, etc. In addition to this it was also necessary that the ropeway should provide a convenient means for the conveyance of the workmen down to and up from their work on the lighthouse (see Fig. **414**).

As in ordinary working the descending load draws the ascending load up, a modification was necessary in order to provide for bringing up workmen when no materials are ready to send down. A small auxiliary steam engine is therefore provided.

The arrangement of the plant is as follows: Two fixed ropes—one 6 in. in circumference with 120 tons breaking strain, and the other $5\frac{1}{2}$ in. in circumference with 100 tons breaking strain—are stretched parallel to each other between the termini.

These ropes terminate at the upper end at a massive wooden trestle carrying tension bars fitted with thimbles suitably supported in brackets on its summit, to the outer thimbles of which the above-named fixed ropes are attached, the strain being transmitted through the tension bars to tie-backs which are attached in the rear, transmitting the strain to the anchorage further in the rear. Thus the fixed ropes, at the point where the strain is most severe, are not subjected to any bending action.

At the lower terminal it is necessary to transmit their strain to an anchorage in the rear of the staging, since the staging itself is not constructed to safely take any side strain. The lower ends of the fixed ropes are, therefore, attached to double screw tightening gears, which in their turn form the end of the back tie-bars. These are made of steel bars connected by pins, terminating in anchor bars which are buried in the chalk at the bottom of the sea some distance in the rear of the staging, concrete being filled up round them and placed over them in such a quantity as to resist the pull.

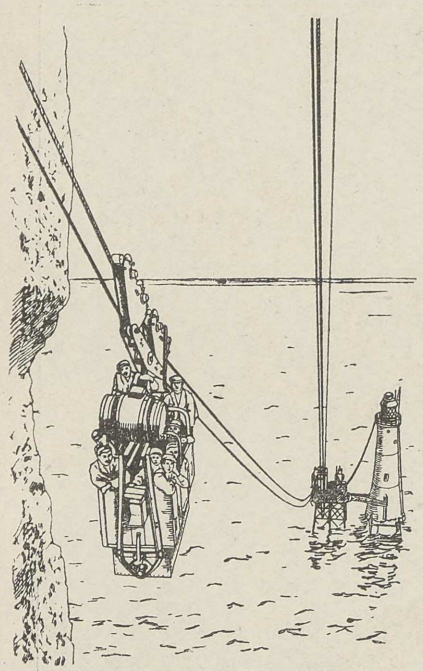


Fig. 414. Men Returning from Work.

The tightening is accomplished by an arrangement of two screws, combined so that when the tightening is effected by one screw, the other acts as a fulcrum and reduces by one half the strain necessary to apply on the screw for tightening. This tightening gear, with a drift of about 8 ft., is carried on a strong wooden frame placed on the staging above referred to, and advantage is also taken of this frame to carry suitable lead-on pulleys and a wheel, round which the return hauling rope passes.

The stones, the heaviest loads, always descend on the 6-in. rope, while on the parallel rope a balance load is run, which the stones descending draw up, thus considerably reducing the necessary brake power. This system of working is necessary only in the transport of the stones and very heavy loads. Each rope is used indiscriminately for the transport of lighter loads. It is estimated that the working strain on the 6-in. rope is about 30 to 34 tons, and that on the lighter rope 25 to 27 tons.

On each fixed rope is placed one carrier. That for carrying stone is fitted with an eye, to which the Lewis bolts in the stone are shackled; that for the balance load is fitted with a receptacle capable of containing 2 tons of ballast or chalk, and, in addition, is fitted with a wooden shield with doors. The lower portion, which holds the ballast, is arranged to tip without disturbing the upper portion or shield, which, when the receptacle is empty, is employed for the carriage of about a dozen workmen.

A similar receptacle and shield can be attached to the carrier provided for carrying stone on the 6-in. rope when the carriage of workmen or of ballast, cement, etc., is required.

Attached to the two carriers is a running head, which has four steel wheels, which run on the fixed rope. These wheels are articulated in pairs, so that each has an equal pressure on the rope. Attached to each of these carriers is a hauling rope, which, on arriving at the upper terminal, passes over a pair of 6-ft. pulleys, and thence is led to a

brake gear in the rear. Attached also to these carriers is a balance hauling rope which is led to the lower terminal, and, passing over two 4-ft. guide pulleys, is led round an 8-ft. return wheel, which, as has been stated above, is carried on the frame on which the tightening gear slides.

The brake gear consists of two 8-ft. diameter wooden grooved wheels, each fitted with a brake sheave, the whole being carried on a vertical shaft. These brake straps are supported on one standard, and brought together at the other standard by means

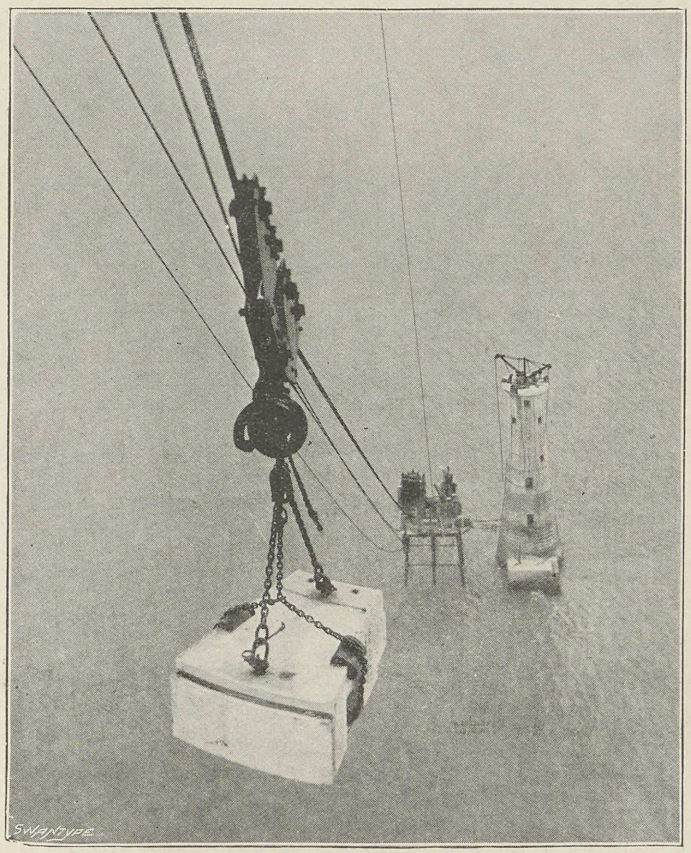


Fig. 415. Last Stone.

of levers working in opposite directions operated by screws. A suitable suspension arrangement was provided to keep the brake straps free from the flanges of the brake ring. Subsequently, owing to the necessity of applying steam power for bringing up workmen, etc., a bevel rim was fitted to the lower brake wheel, which, working in conjunction with a bevel pinion carried on a shaft, in connection with a steam engine, is employed when it is necessary to work the line by steam.

As it is necessary that the man who works the brakes shall have a full view of the movement of the carriers, chain wheels are fitted to the screws which operate the brakes; these communicate by chains with two other chain wheels with hand wheels fitted to the trestle frame which stands at the edge of the cliff.

The hand wheels are placed close to one another, so that when the brakesman is operating the ropeway with one brake, he has another immediately in reserve should anything fail. As a matter of fact, one brake strap will control the load; the other, therefore, serves as a spare one.

The hauling rope passing round the upper brake wheel returns and passes round the tension wheel, then again returns to the brake gear, passes round the lower brake wheel, and in its turn is led to the head wheel and down to the carrier to which it is connected.

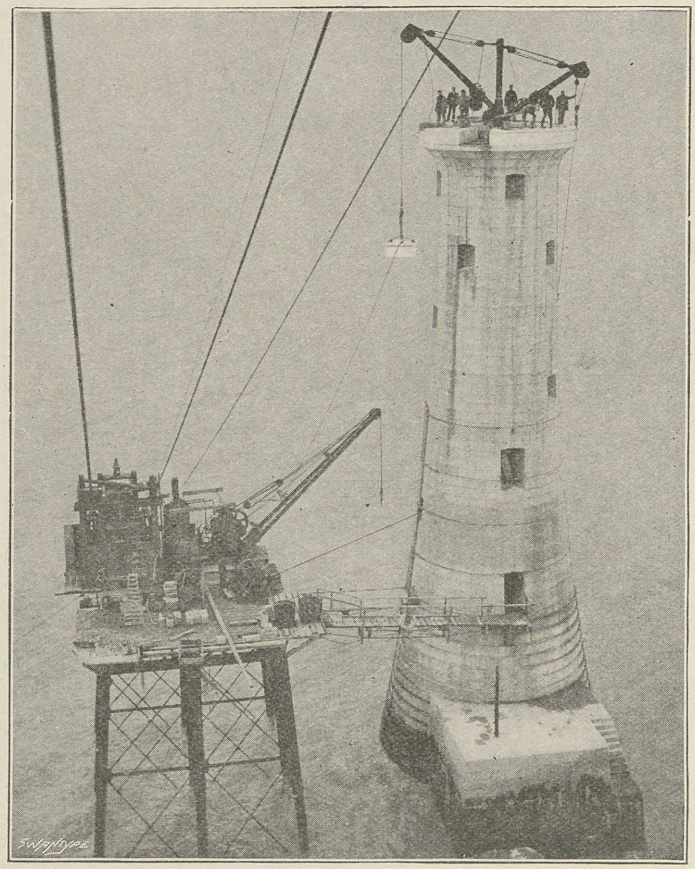


Fig. 416. Last Stone being put in Position.

For the loading of heavy weights, a lift, worked by hand, is provided in the loading position of the carrier on the 6-in. rope, which, as stated above, is the only one employed for the carriage of stone. The lift, which is fitted with a moving platform provided with rails, is supported by locking gear in a position which brings the stone from the depot on the rails of a tramway. This having been done, the load is raised by operating a twin-grab winch, which simultaneously moves four ropes attached to the four corners of the platform. As soon as the stone has been raised sufficiently it is shackled to the running head, and the platform with the truck is allowed to descend slowly into a pit, which is sufficiently deep to allow the stone, suspended from the carrier, to pass over the platform

and empty truck. As this platform and truck descend slowly, the strain is allowed to come gradually on the carrier, and therefore on the ropeway. After the carrier has departed with its load hanging from it, the platform of the lift is raised, with the empty truck on it, and arriving in locking position, the truck is run off. This operation is repeated every time a stone is sent down.

Figs. **415** and **416** show the conveying and putting in place of the last stone.

The erection at Beachy Head was carried out by the contractors under the supervision of Mr Havelock Case, M.I.C.E., resident engineer for the Beachy Head Lighthouse Works.

Ropeway in the Anaimalai Hills.—The Anaimalais (elephant mountains) of Southern India are an important centre of timber supply. The forests in this region, though much overworked in the past, still contain a large supply of exploitable wood of valuable kinds, chiefly teak, which is handled by a wire ropeway. The climate being unhealthy, this range of hills is almost uninhabited by man, but is infested with wild animals.

Under the system formerly employed in working these forests, the huge logs were dragged by elephants from the felling compartments to the side of a 2-ft. tramway, and transported on trolleys to the end of the line, whence they were sent down the ghaut road by bullock carts into the nearest town, about 50 miles distant.

These methods have been reformed by the establishment of a saw-mill in the forest driven by a Pelton water wheel, where the timber is sawn into marketable sizes. By the erection of a wire ropeway overlooking the plains, the use of the ghaut road—the most costly section of the journey—is dispensed with. The wire ropeway takes off from the lower end of the tramway line, while its lower terminus is close to the main road. The sawn wood is conveyed from the saw-mill by the tramway direct to the wire ropeway, and in this way reaches the foot of the mountain.

The ropeway was erected by Bullivant & Co. for the Forest Department of the Madras Government. A loaded carriage travels down a main fixed rope by gravitation, hauling up an empty carriage on the same rope. The two carriages meet in the centre, and are there transferred by an arrangement described below. The descending carriage is controlled by an endless hauling rope adjusted below the main rope, passing twice round a brake drum, and kept in check by a powerful brake strap, and a large deeply-grooved wheel at the foot.

The hauling rope is clipped on to the two carriages on the right-hand side, looking in the direction in which each is travelling.

The ropeway between the terminals is 6,318 ft. long, and the length of line actually traversed by the carriages 5,284 ft.

It became necessary to advance the starting platform sufficiently to bring the central or transfer platform on to a ridge within easy distance of the rope. The total fall from terminal to terminal is 1031·58 ft.; that from the upper terminal to the starting platform 109·50 ft.; from the starting platform to transfer staging, 488·70 ft.; from the transfer staging to the lower terminal, 433·38 ft. The rope crosses two main valleys and a number of ravines, the ground being much broken up and rocky in parts.

There are six main spans of 554, 1,675, 510, 600, 355, and 712 ft. respectively. The rail rope is $2\frac{7}{8}$ in. in circumference, while the hauling rope is $\frac{7}{8}$ in. in circumference. The brake drum is 4 ft. inside diameter.

The brake strap is adjusted to the upper half of the drum and acted on by a handle at the side. The lower part of the drum is cased with hard wood and hollowed out to prevent the folds of the rope overlapping. The axle of the drum runs easily in deep substantial bearings. The large grooved wheel at the foot is 4 ft. in diameter.

The hanging supports consist of two curved wrought-iron plates 3 ft. long, forming a circular opening at the top 8 in. in diameter, and connected at the lower end by a grooved saddle in which the rope rests, sloped at the ends to prevent injury to the rope.

The saddles are of cast iron, of similar construction, and are used in a few places, resting upon wooden brackets and supports projecting from them conveniently near the line.

The carriage consists of two curved wrought-iron hangers, connected together by pieces of timber with grooved runners, 9 in. in diameter, with 1½-in. grooves. The carriages were first used with two wheels, but experience has shown that it is best to use four wheels. Four clips are attached to each carriage. Each clip is provided with a clamping screw, while the hauling rope is attached to the right-hand side of the descending carriage.

The nearer the wheels are brought together the more easily the carriages will travel. When the wheels are placed some distance apart, they do not travel on the same plane, and set up much friction on the rope.

The first step towards the installation of the wire ropeway was the selection of the most convenient line, and clearing it—a by no means easy matter, as it lay through thick forest. The supports were then set up.

The unreeling of the rope followed, commencing, of course, from the bottom of the line. This was sent out on a large iron reel or bobbin, the total weight of the rope and reel being about 4 tons. An axle was passed through a hole in the centre, and the reel was swung clear of the ground.

It was at first intended to unwind the rope and carry it uphill on the shoulders of coolies, placed at intervals of 30 ft., but the broken nature of the ground made this difficult, and eventually elephants were attached to the end of the rope to haul it up. The friction caused by the rope dragging along the ground was, however, so great, that at the end of the journey no less than nine elephants were at work in addition to a large body of coolies.

Spliced into the end of the rope was a massive thimble, or eyelet. This was attached to the chain, and the rope was fixed to its upper anchorage. It was then raised on to the supports, connected to the anchorage cable at the lower end, and hauled in by means of a winch, provided with the necessary two and three sheave blocks. Sufficient tension was obtained to give a dip in each span of about one in forty.

The unreeling of the hauling rope followed, and the two ends were joined. This rope is, of course, adjusted below the fixed rope, and drawn reasonably tight. The up-and-down sides are arranged 18 in. apart, corresponding with the distance between the inner edges of the clips on the carriage, and kept in that position by means of fixed guide wheels, which lead the rope to the drum and large wheel at the foot. It was a matter of some difficulty to overcome the friction set up in this rope, which checked the loads. The design of rollers had to be changed several times, the last and most successful being large grooved pulleys, about 18 in. in diameter, running easily on their bearings, and provided with wooden guides placed above them to lead the haulage rope into the grooves.

The supports for the hangers and saddles vary in height from 8 to 75 ft., and consist as a rule of two uprights and a stout 8-in. cross-bar. In a few instances standing trees have been utilised as uprights.

The method of working the ropeway is as follows: The weight of the load has hitherto not been allowed to exceed about 22 cwt. of timber, and though it is possible to send down rough logs of that size, the work has been confined to the transport of railway sleepers and sawn scantlings of different sizes.

As soon as it is ascertained that all is ready below, that is to say, that the previous load has been removed and the haulage rope clipped on to the empty carriage for the ascent, the hauling rope is detached from the left-hand side of the loaded carriage and lowered on to the rollers below, and the carriage is started, descending at high speed, some 20 miles an hour, to the central station, being kept under control by the brake drum. The two carriages meet here and are stopped at a distance of about 10 ft. from each other, according to the length of the scantlings. The trolley and lever are then brought opposite to the empty carriage, and the cross-bar engages it; the outer end of the lever is pressed down to raise the grooved wheels off the rope and then pushed forward for a few inches to clear it. The lever is then raised at the end, and the empty carriage, with the hauling rope attached to it, falls downwards slowly, till it is low enough to clear the loaded carriage. The latter is then advanced slowly, and the trolley with the empty carriage comes forward on the rail a corresponding distance, and by means of the lever the carriage is raised and replaced on the rope.

The slow forward movement of the loaded carriage is obtained by means of the brake drum, which is provided with gearing, while the drum is slowly revolved by hand. The carriages are again started, and the arrival of the empty carriage at the starting platform indicates that the load has reached the foot.

The supporting chains are provided with a hook and ring always placed on the outside, so that they can be released at once when the load becomes detached. The hauling rope is then removed from the clips on the right-hand side, and the up-rope placed on those of the opposite side of the carriage, the same procedure being followed at the starting platform, and the new load is immediately attached, after taking the precaution above mentioned to prevent the premature slipping of the carriage.

The line is kept clear of growth, and the starting platform is so arranged that the central platform is easily visible from it. Flag signalling is found to be the quickest, easiest, and safest method, and the brakeman is kept in communication with the look-out man on the platform.

This method of transferring appears to be somewhat primitive, involving the use of superfluous manual labour, but in the opinion of Mr H. H. Gass it is the best means of working, and is preferable to an automatic arrangement, which, he thinks, would be certain to come to grief continually, and cause both carriages to fall off the rope. The lever arrangement works well and expeditiously.

The loads can be run down at the rate of about two an hour, and the saving is very considerable, so that if it were possible to work throughout the year with sufficient material, this ropeway would show a handsome profit. Its output of work is far in excess of that of the saw-mill, and it can be worked in all weathers.

It was at one time feared that damage might be done to the ropeway by wild elephants, as the hauling rope is within their reach in many places, but though they are often on the line, no damage has been done hitherto.

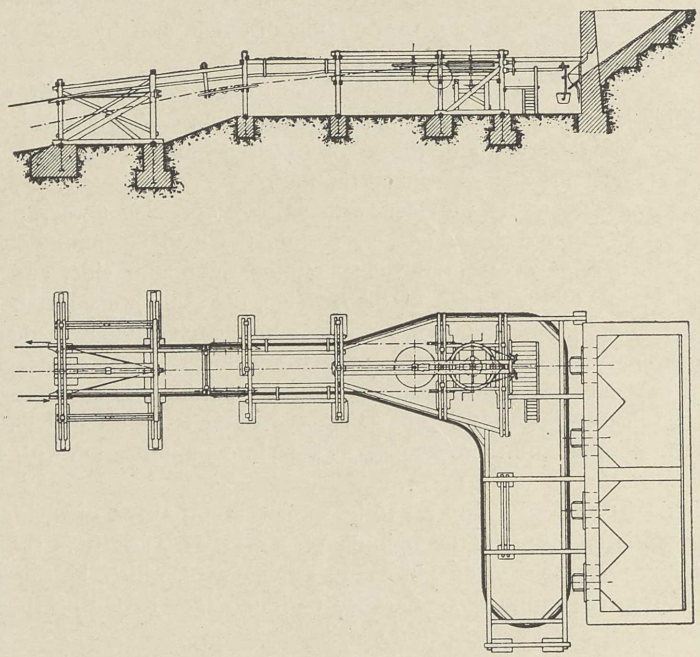
The ropeway has been a great success, but its construction in such a part of the country was beset with difficulties, because of the heavy weight to be moved, and the absence of skilled labour, the only available labour being that of the aboriginal tribes.

The single rope was adopted in order to save expense, and as the working season is short, and a single rope can easily cope with the quantity to be dealt with, the addition of a second rope may well be deferred for some years until the present rope is so worn as to be unsafe for heavy loads, when it can be used for the upgoing empty carriages.[1]

[1] H. H. Gass in *Page's Magazine*, August 1903.

Ropeways Erected by Bleichert's Aerial Transporters, Ltd.

A typical loading terminal or station by this firm is shown in Figs. **417** and **418**. Two arrows at the left of the diagram indicate the direction of the haulage rope, and therefore the side at which the empty buckets arrive and the full ones depart. The two rail ropes have their last support at the first cross-beam of the wooden structure, with a diversion to the centre, and are anchored at the second cross-beam, so that the shunt rails start and return from and to this last support. In the third bay, that is between the third and fourth cross-beams, the buckets are automatically uncoupled. Here a man receives a bucket, pushes it along the shunt rails to one of the four outlets of the ore pockets, and when full conducts it to the third bay again, just opposite to where the uncoupling took place, and here the full bucket is again coupled to the



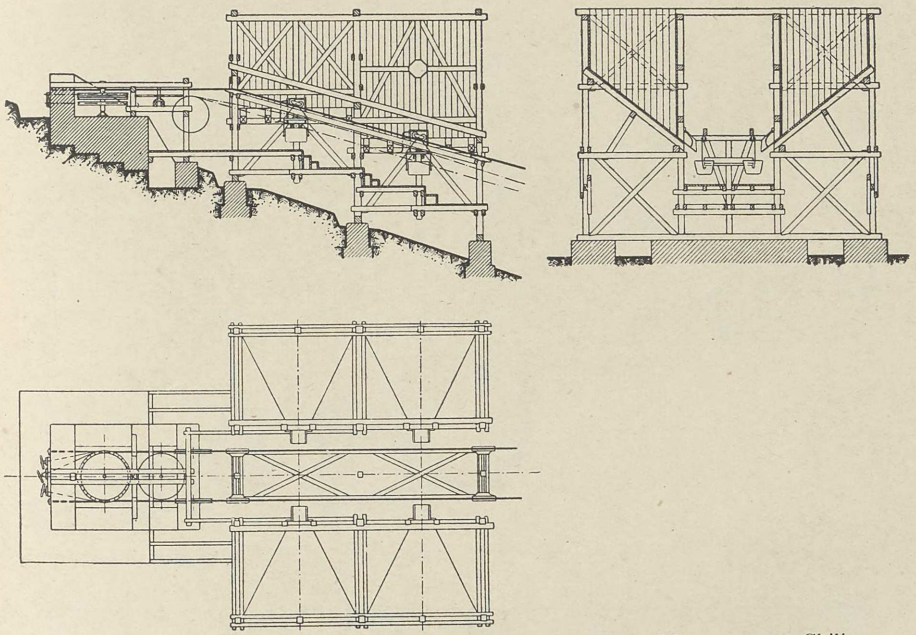
Figs. 417 and 418. A Typical Loading Station.

haulage rope, and left to proceed on its journey; the man now steps over to the other side again and is ready to receive the next bucket.

The two terminals of a short double ropeway of the Chilian Copper Mine of Catémou are shown in Figs. **419** to **423**. The line is worked by gravity, three brakes being used at the upper terminal to adjust the speed of travel to between 10 and 20 ft. per second. On each of the two rail ropes there is only one bucket, and this is fixed to the rope, and adjusted in such a position that when the one bucket is under the loading shoot of the upper terminus, the other is just over the delivery silo of the lower terminus. As soon as the bucket is full it receives a slight push and descends, pulling the empty bucket up on the other rope, so that the buckets have to be filled alternately from the silos arranged on either side of the top terminal. Although the line is short and of small capacity it is interesting as it has a single span of 1,115 m., or 3,657 ft., which is probably the longest single span yet employed.

An unusual arrangement of the terminals of two distinct ropeways belonging, however, to the same colliery establishment is indicated by the diagram, Figs. **424** and **425**. The two ropeways connect the collieries in question with an enormous spoil heap, the property of a third mining undertaking, and have been installed for the purpose of bringing the spoil to the pits for packing purposes. The spoil is now no longer taken to the top of the heap, but is brought by Talbot self-unloaders and dumped into a row of twenty-two large pockets erected at the side of the spoil heap (see cross section A B, Fig. **425**). Each of the pockets holds about 200 cub. yds. of spoil, or together 4,400 cub. yds., which is a sufficient quantity to equalise any fluctuation between supply and demand.

The two collieries are each approximately 5 miles from the spoil heap. The terminal stations of the two ropeways are indicated by squares at the right and left of



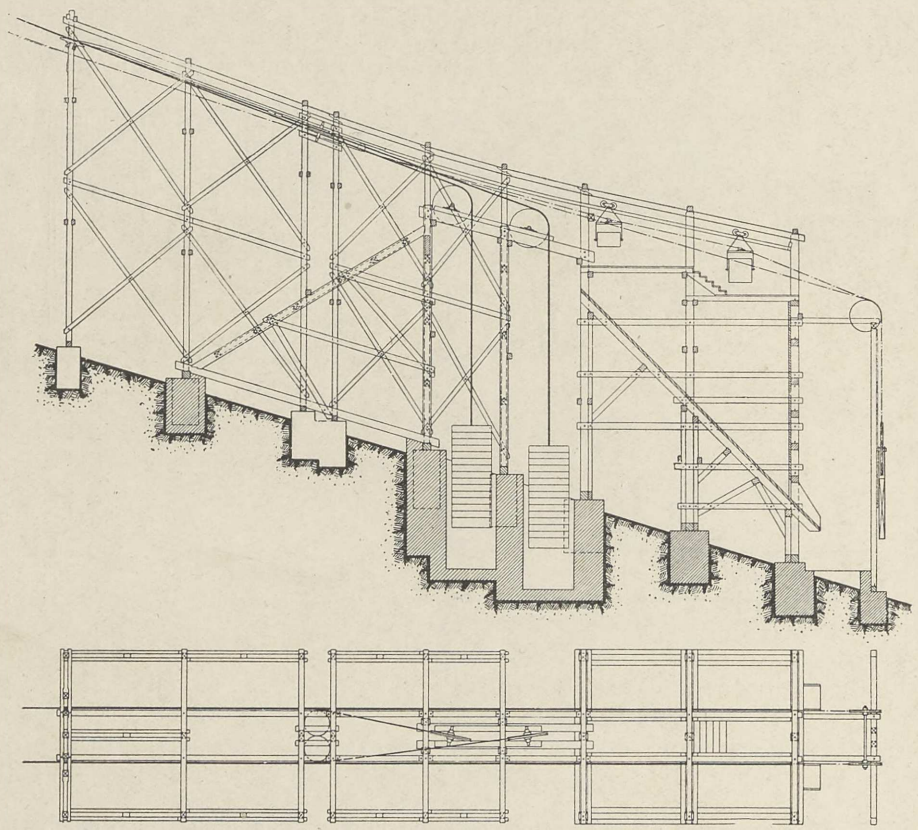
Figs. 419 to 421. Plan and Two Elevations of Upper Terminal of Ropeway at a Chilian Copper Mine.

the plan. The terminals are connected with the hoppers containing the spoil by two suspended mono-rail installations manipulated by an endless rope. The skips are filled whilst travelling at the slow rate of 6 in. per second in front of the exit shoots of the pockets, and when full are transferred to the ropeway stations.

The angle station of an important installation resembles somewhat an end station of a normal ropeway, with, of course, the exception that the angle station combines in itself the tail terminus of one section of the line and the head or driving terminus of the second section.

Very frequently the second section of the line, or rather its endless hauling rope, is driven or retarded from the terminal drum of the first section; this is especially so if the first section has a sufficient incline to work by gravity, and has sufficient power to spare to operate the second section. Such an installation is represented in the diagram, Figs. **426** and **427**. Here the hauling rope of the first or upper section is deflected by a

battery of rollers on entering the station, is then led over a pair of guide sheaves on to the terminal drum which has two grooves, and from this the rope passes over an intermediate drum and finally on to an adjustable drum for tightening the rope. A weight is attached for this purpose, which hangs in a pit together with the weights which keep the carrying ropes taut. The second and lower section is driven from the same upright spindle which carries the end drum of the upper section. This drum has also two grooves and a similar intermediate drum being intercepted as before, to afford a better grip. The haulage rope of the lower section leaves a station after also passing a battery of rollers.



Figs. 422 and 423. Elevation and Plan of Lower Terminal of Ropeway at a Chilian Copper Mine.

In smaller installations the same haulage rope runs through the station without interruption.

An angle station for a slight diversion of the line is shown in diagram in Figs. **428** and **429**. It is automatic, that is, no attendant would be necessary, as the buckets will transfer themselves from one rail rope to the other on shunt rails, remaining all the while coupled to the haulage rope which is guided gently round the angle by four rollers on each ; the rail ropes terminate at this point, and are kept taut by weights.

A typical example of one form of bucket is shown in Fig. **430**. The bucket itself is made as usual of steel sheets with the top edge strengthened, and is suspended from a flat iron frame. The bucket is arranged to tip its contents as soon as the lever, shown

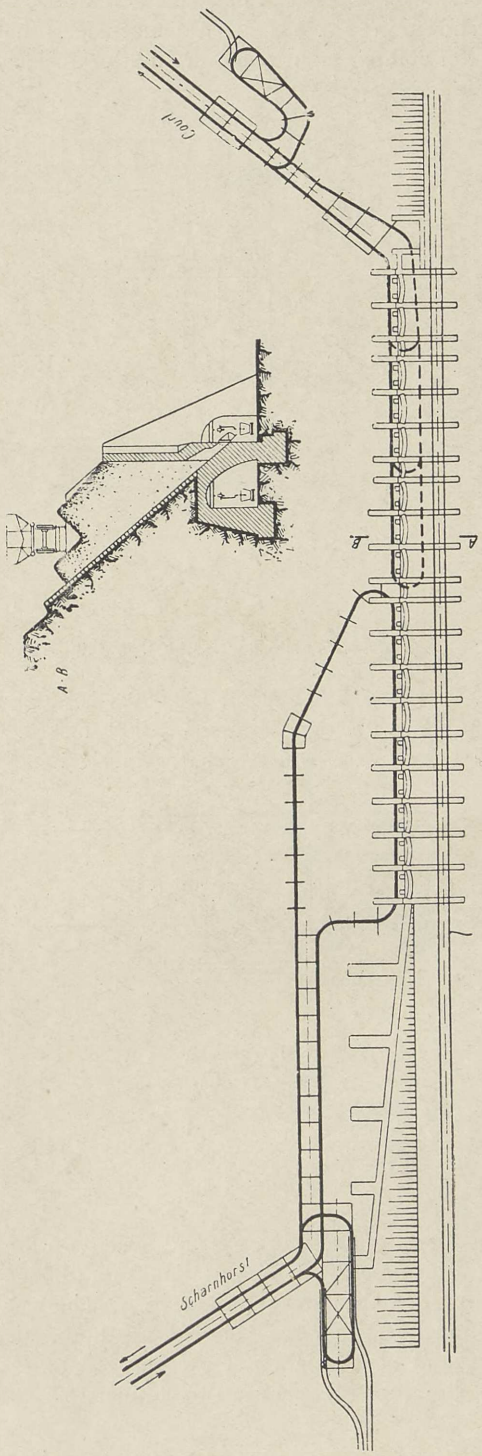
in the side view, touches a tripper; the point of suspension of the bucket being, as is usual in such cases, slightly below the centre of gravity. The grip or coupling for the hauling rope is here shown above the rail rope as is customary in cases where only gentle inclines are negotiated.

The other receptacles are made to suit the varying nature of the material. These small Bleichert couplings for an upper haulage rope have the advantage that at the terminals, and when negotiating curves, no shunt rail is necessary as the clips will pass round the guide wheels and terminals. With the haulage rope below the rail rope this would not be possible except with an arrangement similar to that shown in Fig. **431**. This diagram shows also a different type of bucket with its accessories, having four rollers. Here the clip is so designed that one portion also carries the pin for the suspension of the frame for the bucket.

It is frequently expedient to transfer mining tubs from their rails to a ropeway in order to place them again on to rails at some distance away, as this saves the transferring of the material from the mining tub to the ropeway bucket, and at the terminal of the ropeway back again into tubs; for such purposes of suspending mine tubs different methods are employed. The one shown in Fig. **432** consists of one complete carrier with coupling for the haulage rope, and a trailer to support the other end of the tub, the chains with hooks carrying the tub. For larger installations two carriers may be employed, or complete framework may be used to receive the tub, but the last method naturally increases the weight on the rope considerably.

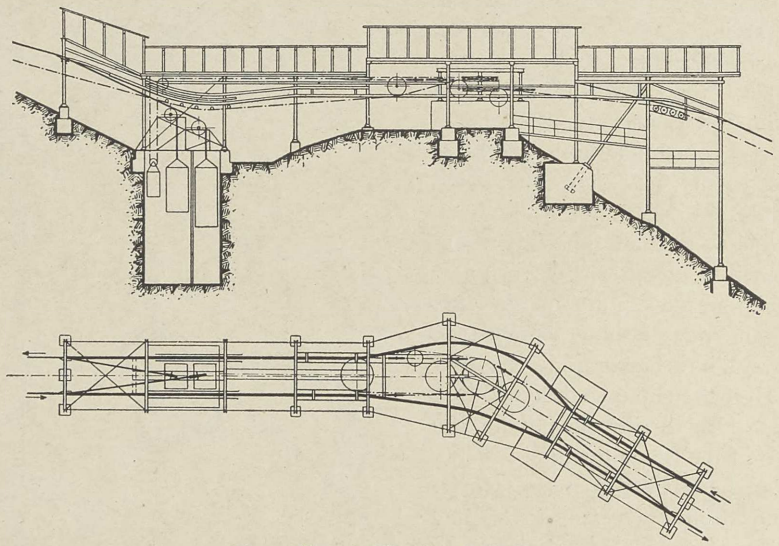
The ropeway of the Powel Duffryn Steam Coal Co., for the disposal of spoil from their pits, is of interest, as the line has to negotiate several curves. The capacity is 100 carrier loads per hour. Fig. **433** shows part of this line, which is on the Bleichert system.

The Vivero Iron Ore Co., in Northern Spain, has installed five ropeways



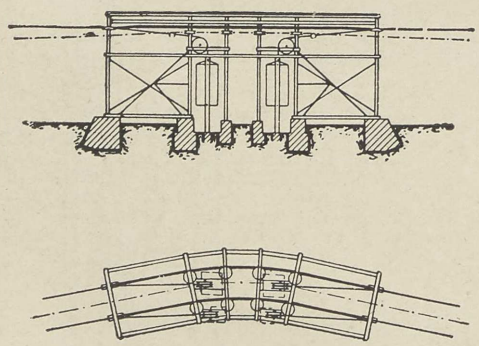
Figs. 424 and 425. Combined Loading Station of Two Distinct Ropeways.

by Bleichert, for conveying the iron ore from the mines to the seashore, with delivery stations reaching far out into the sea to make it possible to load into ships holding 3,000 tons, which can be loaded in twelve hours. A portion of one of these ropeways is shown in Fig. **434**. The receptacles hold 1 ton each and are conveyed at the rate of 250 per hour, one every fourteen seconds.



Figs. **426** and **427**. Angle Station.

A ropeway 35,000 m. (38,000 yds.) long in the Andes Mountains of the Argentine Republic with one terminus 3,500 m. (3,800 yds.) high was erected by Bleichert and conveys ore which was previously handled by carts at the expense of £2. 13s. per ton, and is now conveyed by the ropeway at a cost of 1s. per ton. There are twenty-five spans of between 320 to 350 m. (350 to 380 yds.) over valleys up to 200 m. (217 yds.). This line has weathered the heaviest snowstorms without interruptions. The return strand of the line is used for general merchandise and for conveying drinking water to the mountains.



Figs. 428 and 429. Angle Station for a Slight Diversion of the Line.

One of the most difficult ropeways over the most broken country was erected by Adolf Bleichert & Co. for the purpose of conveying timber from the slopes of Zlatibor in the Black Mountains, and the plains of Zrnivrch and Tara, to the river Drina, where it is formed into rafts and floated on the Danube to Belgrade.

This line is at present 6,000 m. (6,561 yds.) long, but will be extended as the clearing of the timber proceeds. There is a gradient of 800 m. (874 yds.), and 18 tons of timber are handled per hour, including stems up to 18 m. (say 20 yds.) long, and of a weight not exceeding 3 tons. The longest span is 790 m. (864 yds.) and the ropeway passes two tunnels of 400 m. (437 yds.) and 26 m. (28 yds.),

respectively. At the delivery terminus the timber leaves the rope on suitable shunt rails which extend to a ramp where the stems are taken off and rolled down an incline to the river.

Fig. **435** represents a portion of another ropeway installation for conveying timber from forests, erected by the same firm at Oberaudorf in Bavaria. The length of the line is 600 m. (656 yds.), and has a downward gradient of 340 m. (371 yds.). Six journeys are made per hour, each load consisting of about 4 cub. yds.

The frontispiece shows a portion of an interesting ropeway installation by Bleichert, erected at Thio on the east coast of New Caledonia, to convey ore from important nickel mines to a convenient loading station out at sea, the coast being too rugged for ships to approach nearer.

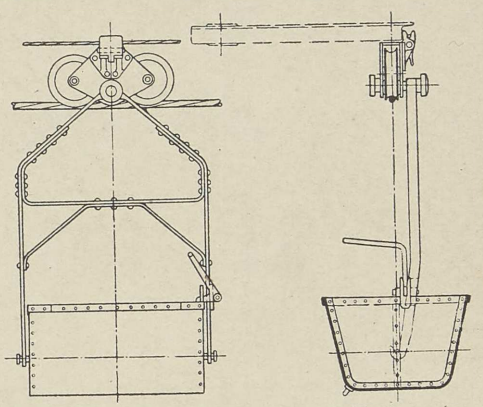


Fig. 430. Bucket Carrier with Haulage Rope above the Rail Rope.

Ropeways Erected by J. Pohlig

Mr R. E. Commans has described the construction of a Pohlig ropeway which is at work at the Lake View Gold Mines in Western Australia. This ropeway is employed to transport ore from bins erected alongside the shaft to the top of the 50-head stamp-mill, situated at some distance off on the hillside, to secure the advantage of natural gravitation in dealing with slimes and tailings.

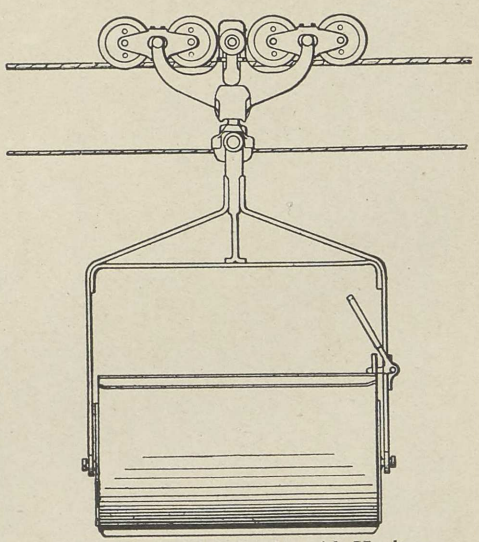


Fig. 431. Bucket Carrier with Haulage Rope below the Rail Rope.

The carriers, like most modern appliances of this type, are suspended slightly below the centre of gravity, so as to permit of easy tipping and discharge. They are attached to hauling ropes by grips which are thrown in and out of gear automatically, and released at the unloading stations. Ropeways on this system have been erected with capacities varying from 50 to 2,000 tons per day of ten hours. Sometimes when considerable quantities have to be transported a double line is built, although a single line built recently in Lorraine, at Kneuttingen, having a length of about 6 miles, transports some 1,428 tons per day of twenty-four hours. As already seen, ropeways have been carried over longer distances than this, about 20 miles and over having been spanned in different parts of the world.

Fig. **436** is a typical example of a long single span, the distance between the supports being 875 yds. The ropeway is that of the Brick and Tile Works, Friedrichssegen, Ems, Germany, the total length of which is 2,363 yds.

Fig. 437 gives a view of an angle station, at which the ropeway, by describing a curve, changes its direction. It was erected for the Wissener Mining and Smelting Co.,

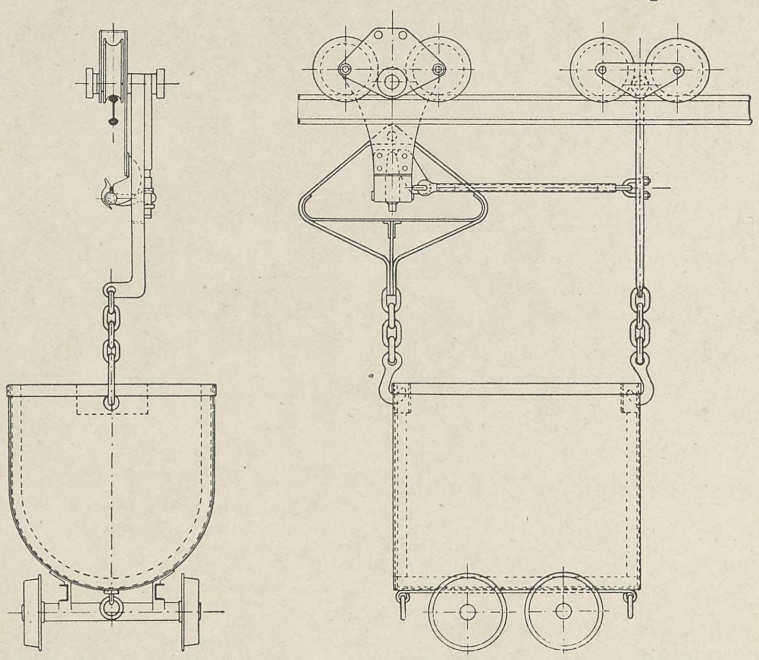


Fig. 432. Double Carrier for Mining Tubs.

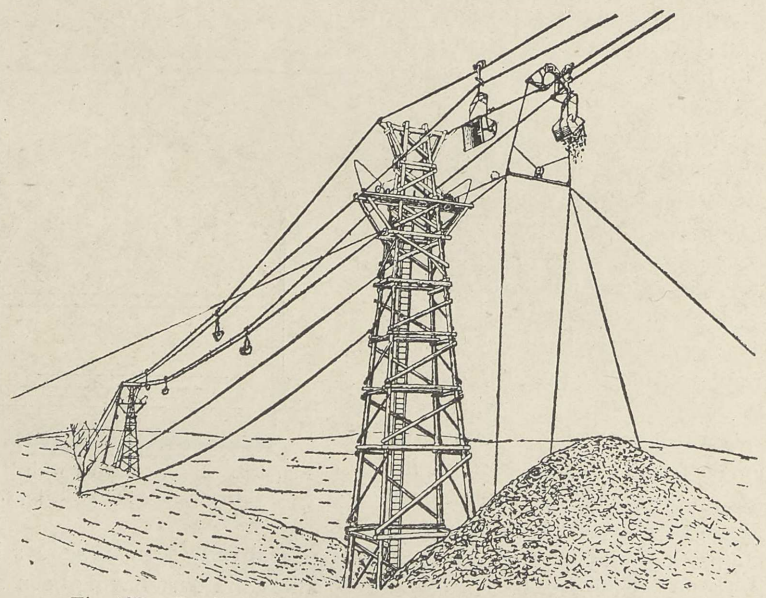


Fig. 433. Portion of the Ropeway of the Powell Duffryn Steam Coal Company.

near Wissen, Germany. The construction of the angle station allows the carrier to remain on the rope during its passage through the curve without the aid of shunt rails,

thereby dispensing with attendance at this station. The total length of the ropeway is 4,500 yds. It is used for the transport of iron ore.

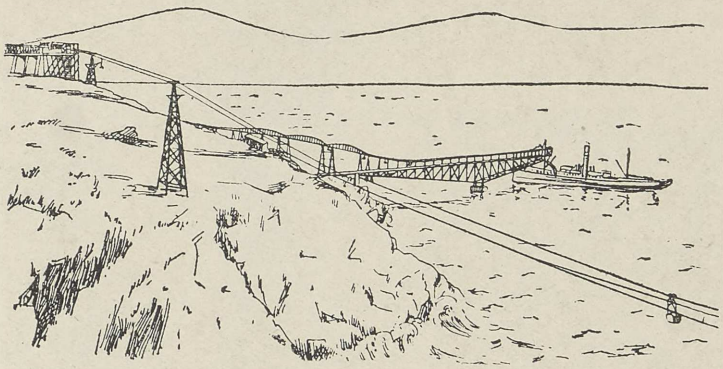


Fig. 434. Delivery Station of one of the Vivero Iron Ore Co.'s Ropeways.

Fig. **438** shows another view of the same ropeway representing a long span over a river. The ropeway passes obliquely over a bridge, and is supported by the trestles on the opposite bank. The safety net for the protection of the bridge is also visible.

Fig. **439** represents a portion of a ropeway erected in the Isle of Elba for conveying ore from the mines to the coast. At the ship loading terminal, which is seen in the distance, the contents of the skips are tipped into vessels.

Fig. **440** illustrates a portion of a ropeway executed for the Dutch Government in Java. This line has been erected for the transport of stones. The length of the ropeway is 10,000 yds. There is a difference between the levels of the terminals of 123 ft., owing to which a 17 H.P. portable engine is sufficient to drive the line.

An interesting example of a very tall trestle is shown in Fig. **441**, which is a portion of a ropeway of the Mount Lyell Mining and Railway Co. in Tasmania.



Fig. 435. Ropeway for Timber at Oberaudorf.

A portion of a ropeway between the Hilltop Colliery, Durham, and the coke ovens at Malton is illustrated in Fig. **442**, which shows an intermediate angle station, the weights for keeping the rope taut being clearly shown on the structure.

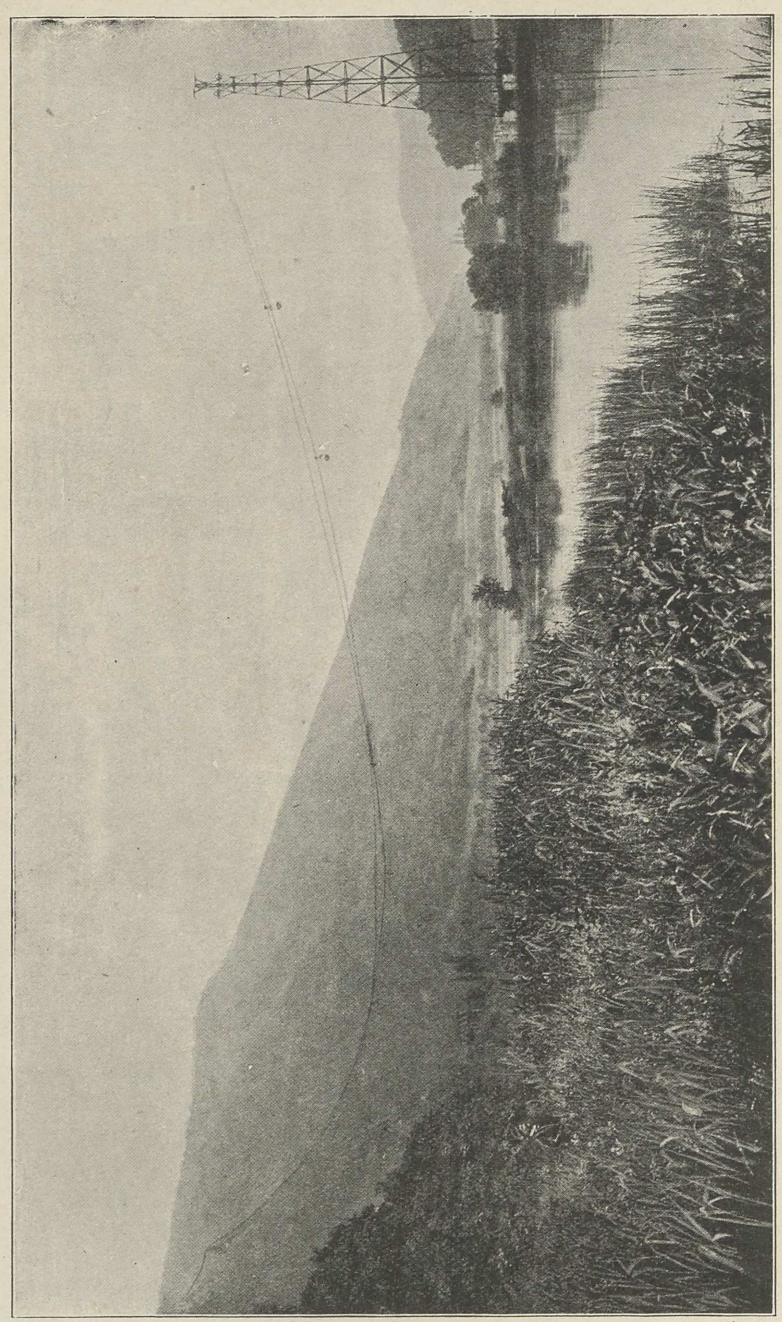


Fig. 436. Span of 875 yds. of a Pohlig Ropeway at Ems, Germany.

Colonel S. A. Sadler, proprietor of the Malton Colliery, entrusted the erection of this ropeway to Mr R. E. Commans, the English representative of Messrs Pohlig. It is one of the longest ropeways in this country, having a total length of 3,520 yds.

The very fine delivery station of a ropeway for ore in Northern Chile is shown in Fig. **443**.

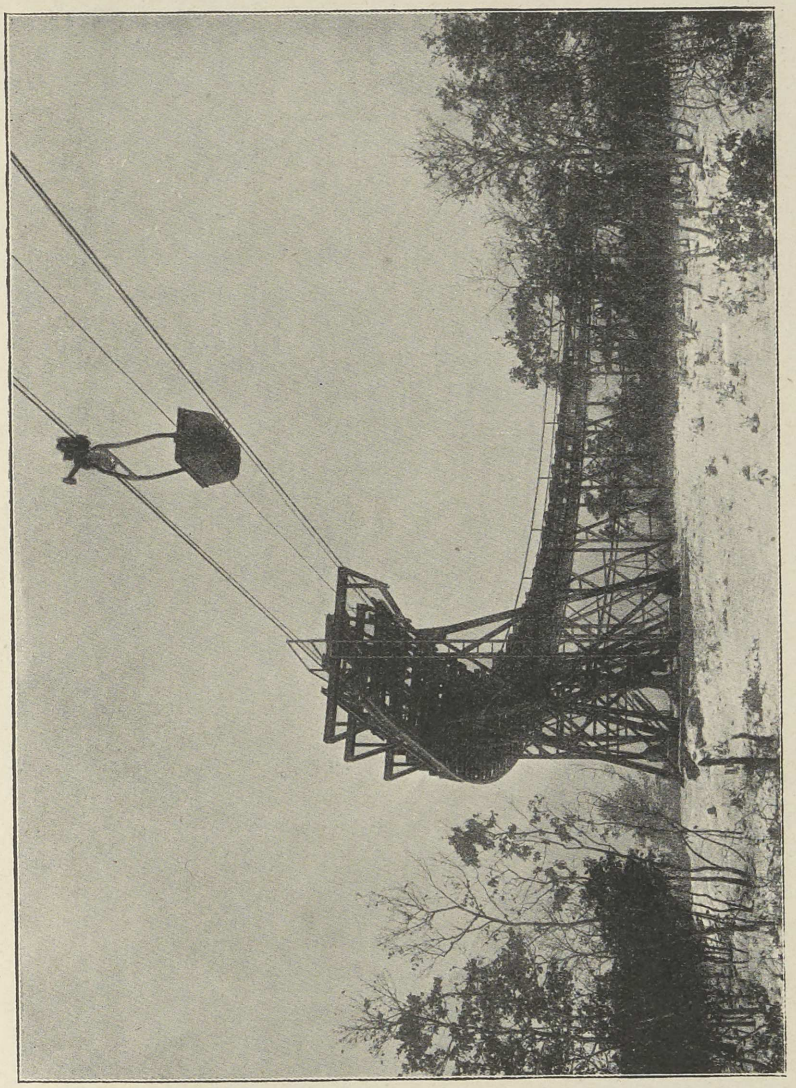


Fig. 437. Angle Station of Pohlig Ropeway, near Wissen, Germany.

Ropeways by J. M. Henderson & Co.

An interesting installation, built by J. M. Henderson & Co., of Aberdeen, on the single rope system, was erected in Tasmania a number of years ago. The ropeway is 3,432 ft. long between the terminals, and is used by the North Mount Lyell Copper Co., Ltd., Gormanstown, Tasmania, for conveying copper ore. The capacity is 60 tons

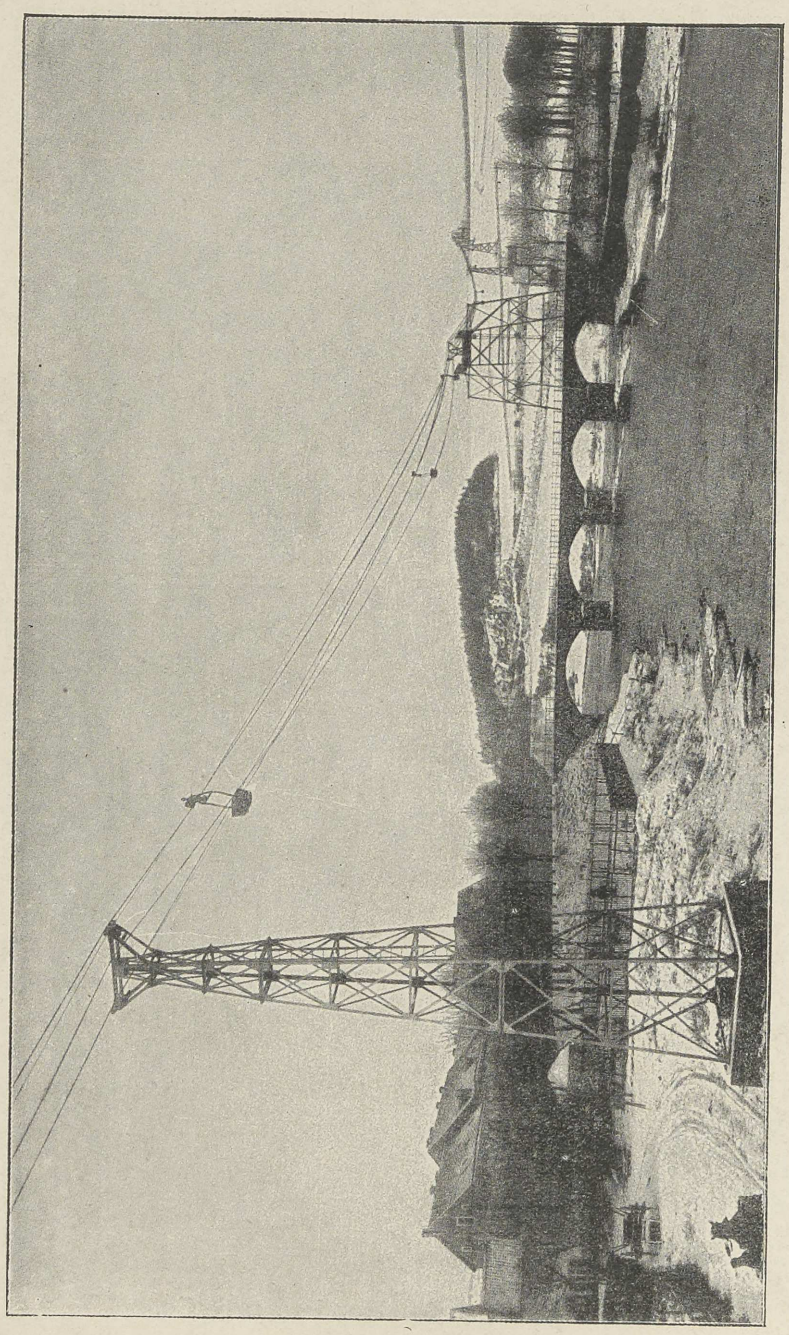


Fig. 438. Portion of Pohlig Ropeway near Wissen, Germany.

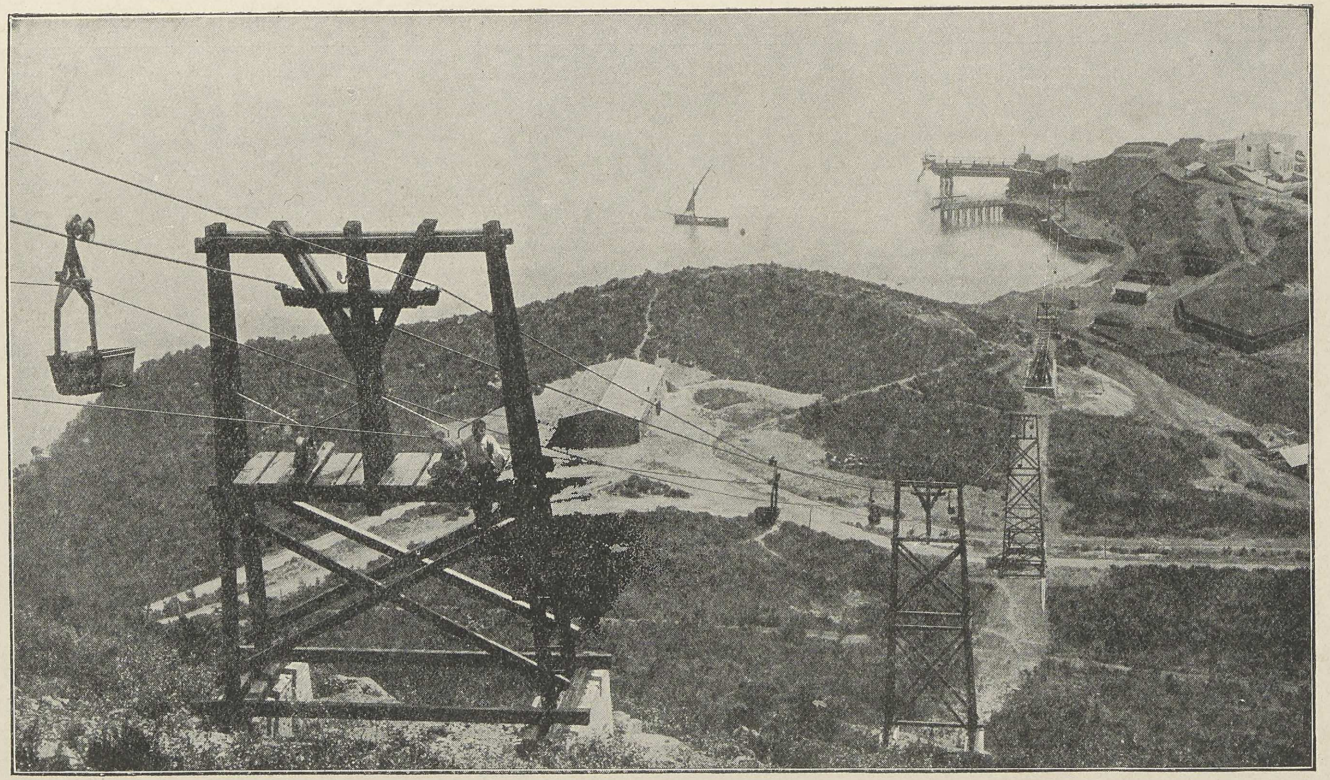


Fig. 439. Portion of a Ropeway in the Isle of Elba.

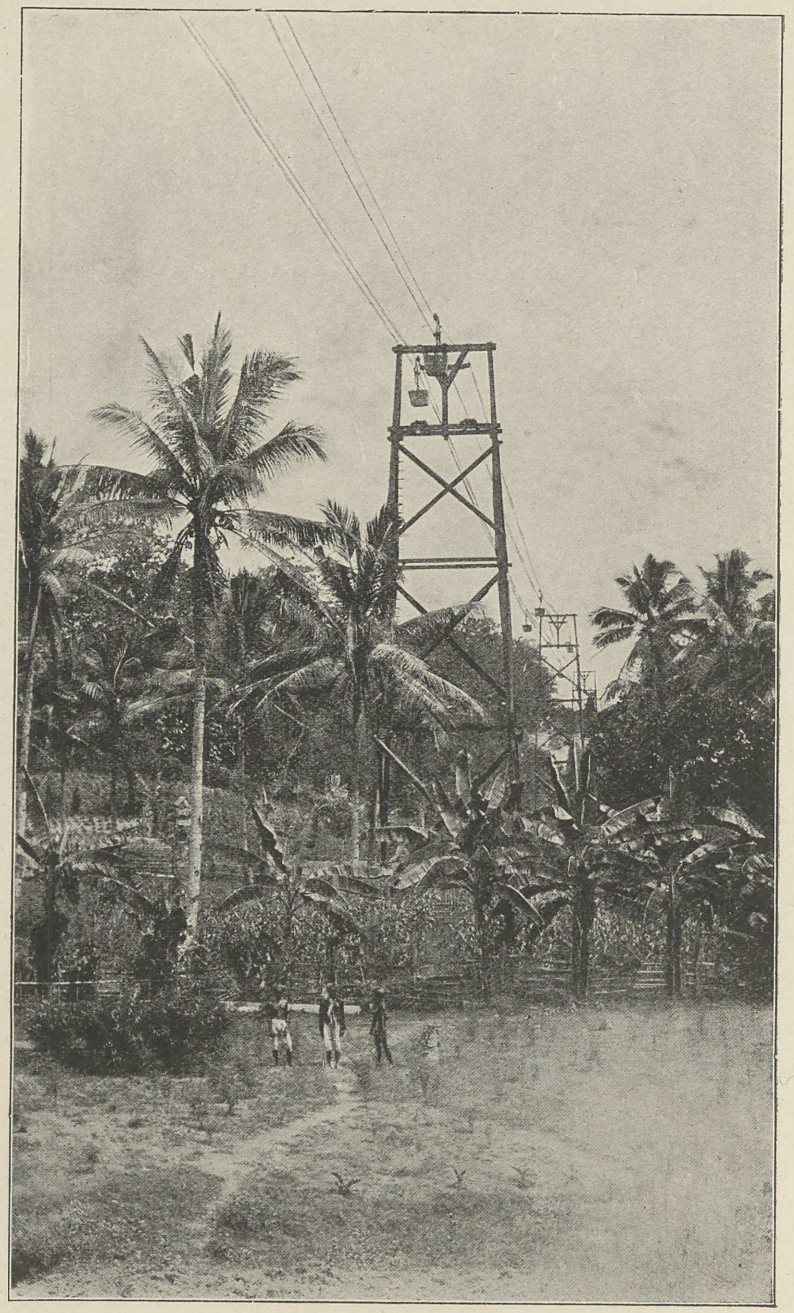


Fig. 440. Portion of a Ropeway erected for the Dutch Government in Java.

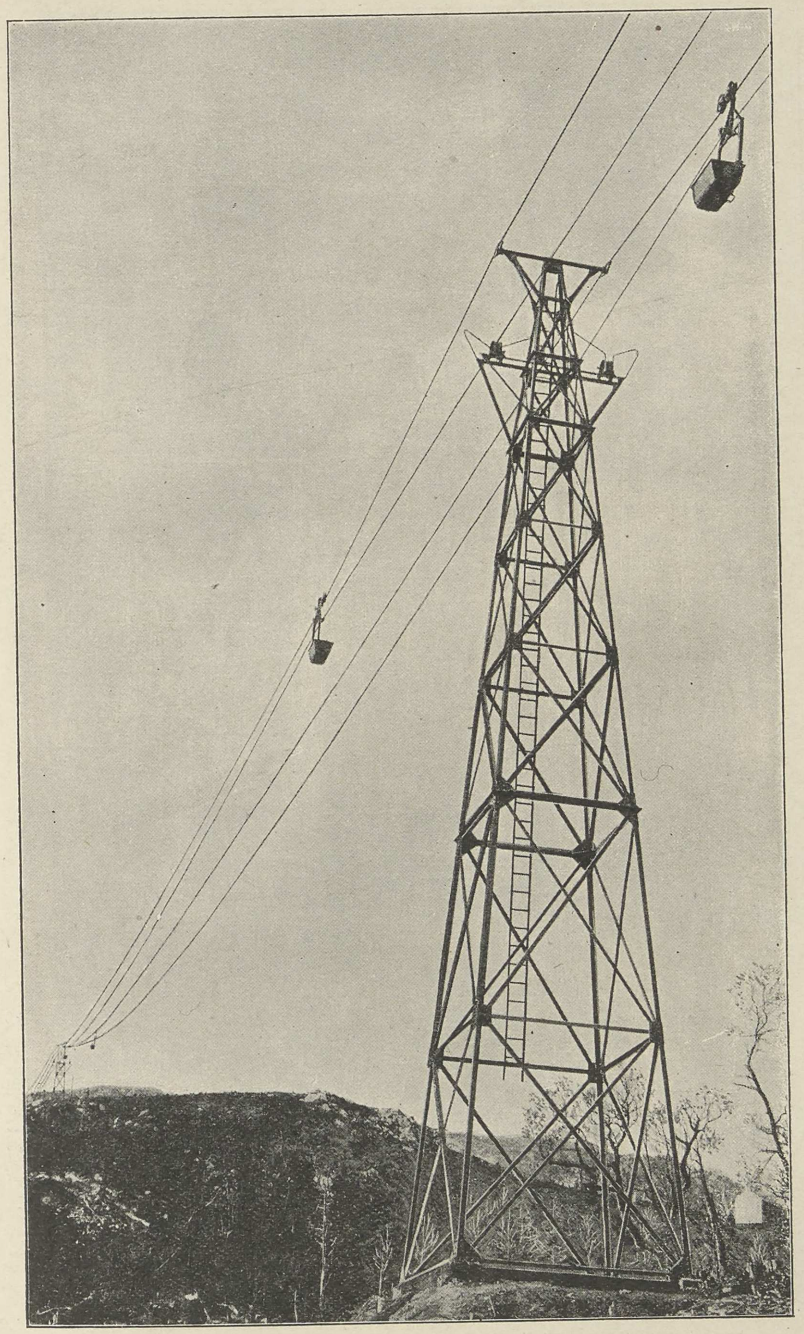


Fig. 441. Portion of the Mount Lyell Mining and Railway Co.'s Ropeway in Tasmania.

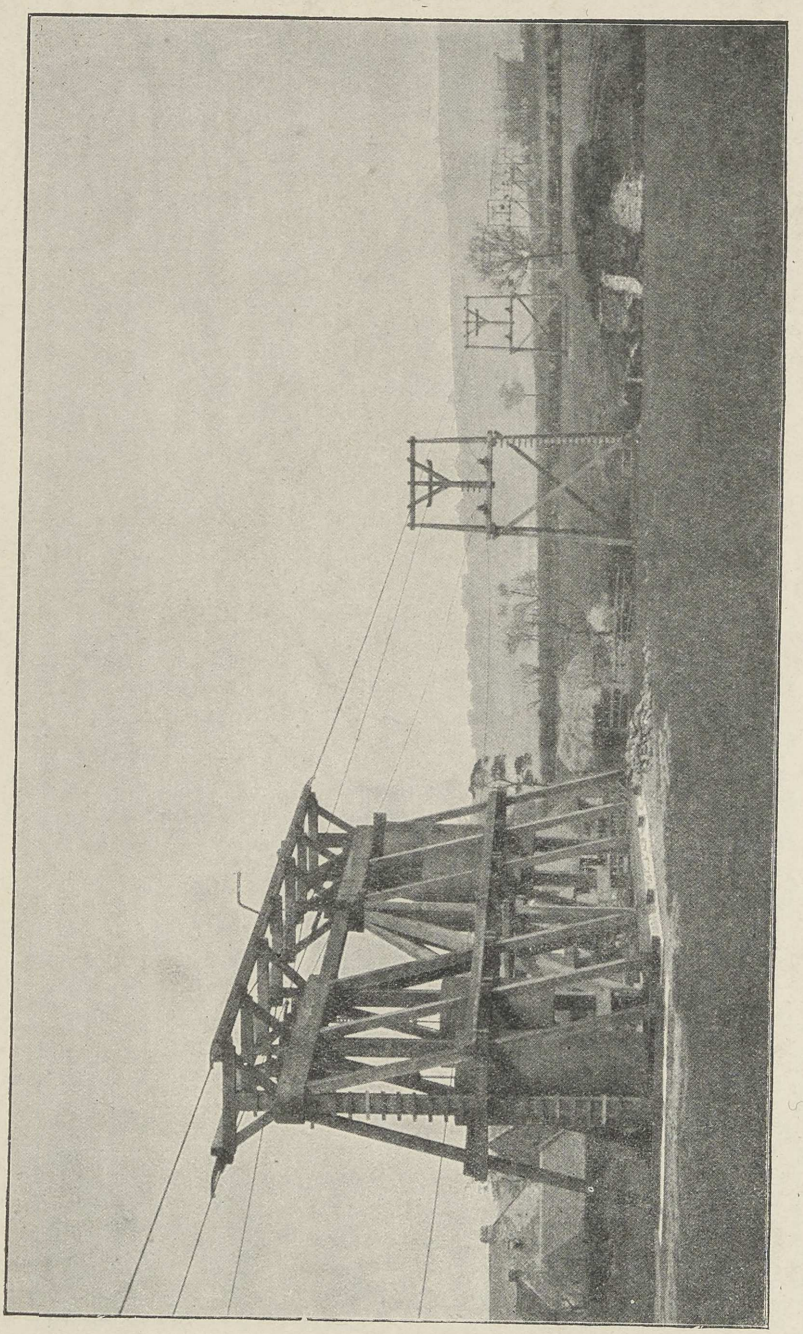


Fig. 442. Intermediate Tightening Station of the Ropeway between the Hilltop Colliery, Durham, and the Coke Ovens, Malton.

per hour, and the inclines about 1 in 5. There are a hundred buckets in use,

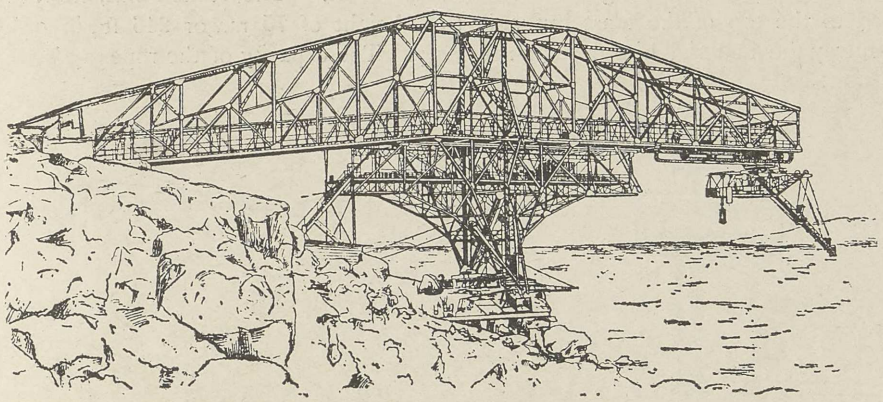


Fig. 443. Delivery Station of a Ropeway for Ore in Northern Chile.

supported on eight trestles, the highest of which is 77 ft., whilst the lowest is 24 ft. The illustration, Fig. **444**, shows one of the high trestles.

Amongst other installations erected by this firm, perhaps the most interesting is that at Clee Hill, Shropshire, used for transporting broken stone from a quarry to the railway. This ropeway, which is also on the single rope system, is the longest of its type in this country. It is about $3\frac{3}{4}$ miles in length, and is capable of conveying about 60 tons of material per hour in individual loads of about 10 cwt. The ropeway is arranged in two straight lines connected by means of an angle station. A secondary ropeway, about 230 yds. in length, with a series of short shunt rail sidings, is erected at the quarry for facility in loading the stone into the skips. Storage bins of large capacity are provided at the unloading terminal into which the material is discharged direct from the skips suspended on the terminal shunt rail. The material is discharged direct from the storage bins to the railway wagons as required. There are altogether 270 skips in use supported on fifty-five trestles, varying in height from 30 to 60 ft.

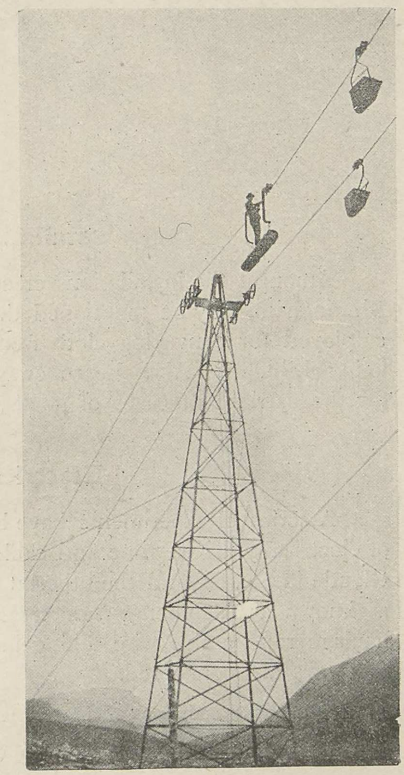


Fig. 444. High Trestle of the Ropeway of North Mount Lyell Copper Co., Gormanstown, Tasmania.

Installation by Ernst Heckel

An unusual ropeway installation for the disposal of furnace slag was erected by Ernst Heckel for the Röchling Works at Völklingen in 1910, and the delivery terminal above the spoil heap is shown in Fig. **445**. This station is supported by a ferro-concrete mast 3 m., or nearly 10 ft., in diameter, and as the spoil heap grows the station is raised into a higher position. Originally the mast

was 50 m., or 164 ft., high, and in 1912 it was raised by a further 60 m., or 197 ft., giving the mast a total height of 110 m., or 360 ft. The station was, however, not raised to the top of the mast but only to a height of 75 m., or 246 ft., in order not to convey the material higher than necessary. The capacity of the ropeway is 180 tons per hour.

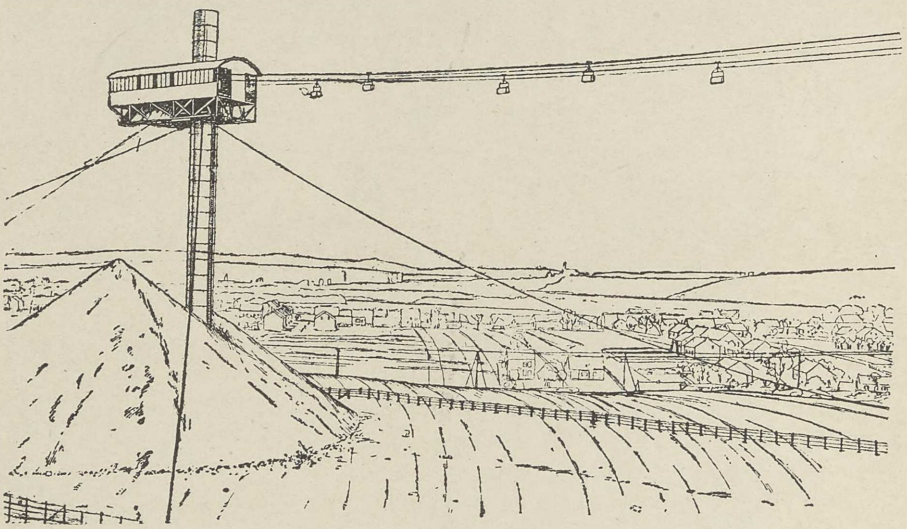


Fig. 445. Ropeway Terminal over a Spoil Heap.

Installations by J. & E. Wright[1]

Amongst the installations erected by Messrs J. & E. Wright, of the Universe Works, Birmingham, may be mentioned the aerial ropeway at the Tottington Mills, Lancashire, employed for conveying cloth from the dye to the finishing works, the length of line being 1,600 ft. Also the ropeway used by Messrs J. & J. M. Worral, Ltd., Salford, for the carriage of cases of goods, the length of line being 780 ft.

Electrically Driven Ropeways

A series of experiments have been made, and as a matter of fact small installations of electrically driven rope and cableways have been executed, one of which is at work at Glynde in Sussex, and the other at Weston in Somerset. This method of driving, which is known as Telpherage, possesses undoubted advantages, as it dispenses with the haulage rope, a live wire taking its place, but it is as yet only in its infancy as far as ropeways are concerned.

For further descriptions of above systems of ropeways see "Aerial or Wire Rope-Ways," by A. J. Wallis-Tayler.

[1] See Hipkin's "The Wire Rope and its Application" (Birmingham, D. F. Tayler & Co., Ltd.).

CHAPTER XXV

AERIAL CABLEWAYS OR CABLE-CRANES[1]

An important development of the ropeway is the aerial cableway, which may be defined as a hoisting and conveying device employing as a trackway a suspended cable in one clear span. The term "cableway" as well as the special application of the process is of American origin. The cableway is designed to handle single loads intermittently in a suitable receptacle over moderate distances by means of travelling, hoisting, and propelling lines. The main cable, supported high in the air over its terminal towers, provides a roadway independent of obstructions or the conformation of the ground. It may cross a gorge, valley, stream, road, or railway, depending on no support, except at its terminals. It does not interfere with the passage of wagons, trains, or boats below the cable, so that the work can be carried on simultaneously at several points in the line. Its single engine is manipulated by one man, who may control the whole work of loading, transporting, and dumping, in many cases without the aid of other help.

In its earliest form the cable hoist conveyor was made in two designs, one suitable for downward inclines only, in which the carriage descends by gravity and where one haulage rope only is required; this type is often employed in quarries. The other (the more important of the two) is applicable either to horizontal lines or to lines where the incline is not sufficient for the carrier to descend by its own gravity, in which case the hoisting and conveying are effected by two separate ropes.

The classes of cableways mostly used are of three types; the simplest form being the stationary cableway, having fixed towers at each end. Another form employs travelling towers at each end which can be moved on rails laid parallel to each other; while the third, for radially travelling cableways, employs a fixed tower at one end, and a travelling tower at the other which can be moved over a curved track round the pivoted or stationary tower as a centre.

The limit of span for aerial cableways is about 2,500 ft., although spans of 3,000 have been negotiated. The carriage being secured to an endless line which absolutely governs its movement, may travel at a very high speed if desired, 1,800 ft. per minute or even slightly more—a maximum of 3,000 ft. has been reached in the United States—and the load lifted and conveyed may be up to 20 tons on moderate spans. In this country, however, the most usual speed is from 500 to 750 ft. for travelling, the hoisting speed being about 200 to 300 ft. per minute.

The work performed, in the simplest form, is the lifting of a bucket or skip previously filled by labourers and conveying the load along the cableway to the end where it is dumped by another man. This system is used for trenching, the cableway being set up over and in line with the trench. The material from the excavation is carried back along the line and dumped to back-fill the trench and for similar work. The whole cableway is moved forward from time to time, as the work proceeds.

[1] Extracts from an article by Sterling H. Bunnell on "The Cableway and its Uses," from *Cassier's Magazine*, are embodied in the following.

At the other extremity are the heavy cableways used for wide excavations, the operations performed being the dragging of a huge self-loading scraper-bucket, the hoisting of this bucket when filled, and its transportation and final dumping near the end of the cableway on the spoil bank raised at one side of the excavation. The cableway here comes into direct and successful competition with the heavy boom-derrick doing the same work but with a substantial saving in first cost and certainly no disadvantage in operating expense. Such installations are used for building retaining walls, concrete bridges, dams, and dock work, and not only for removing the material excavated, but also conveying to the workmen the necessary material such as concrete, blocks of stone for building purposes, baulks of timber, steel plates or other structural work.

Any of the well-known forms of automatic buckets to pick up their own loads may be used. Ordinary grabs or "orange-peel" buckets serve to load or unload sand, coke, coal, and any other loose materials from or into boats, stock piles or bins. Dredging of channels, excavating for docks, and similar operations are carried on from solid ground with economy and speed, and heavy excavating buckets or dredges are now used for this work, for which formerly only a steam shovel could be employed. A heavy drag line, operated by a powerfully geared drum turned at a slow speed, tows the bucket along the cableway, the steel cutting edge shaving off a layer of earth, which rolls up on itself in the bucket. When the scraper is full the bucket is hoisted, propelled along the cableway, and dumped at any desired point. The draught may be varied by simply changing the position of the carriage with respect to the bucket; this power of altering the angle of draught is, of course, of great importance, because in this way the bucket can be easily adapted to the character of the material and the required depth of cut.

The cable for such operations is stretched transversely to the excavation as in digging a canal, and the scraper works from the centre towards the side of the channel, dragging up the bank as it fills.

A cableway properly equipped for such excavations is adaptable equally well to work with most forms of bucket, and is thus readily adjusted to the requirements of whatever conditions may be found.

The designing of a cableway suited to any special requirement needs experience and sound judgment. The main cable is of steel wires, and as great flexibility is not essential, this may be of flattened strands. Lang-lay or locked-coil rope gives a greater wearing strain than the regular twisted-strand rope. The main cable passes at each end over terminal towers, of which the head tower containing the engine is generally higher than the tail tower, sometimes by as much as 20 ft. The cable is securely anchored to the ground, the anchorage being of stone or concrete, and is put in position by tackle-blocks and rope; the usual sag allowed with full load suspended at its centre is about 5 per cent. of the span, the resulting strain on the cable being five times the weight of the carriage and load, plus two-and-a-half times the weight of the suspended cables between the towers. If the proportion of the load and span permit, the sag can be less than 5 per cent., thus allowing a reduction in the height of the towers. Since the strain on the anchorage connections is heavy, and failure of the support very dangerous, the attachment should be most carefully placed; a heavy log may be buried transversely to the cable in a trench in the ground, the main cable being attached to the centre of the log, thus having the log resting against masonry or concrete foundations and undisturbed ground. If so-called "dead-men" are used they may be buried in a mass of concrete if the erection is to be permanent, or attached to a massive anchorage of masonry or concrete with steel rails or beams embedded to distribute the strain of the cable. On permanent work it is

advisable to connect the guys to anchorages separate from the main cable, so that failure of the one need not affect the other. The towers would thus be safe even though the main cable should break away.

The supporting towers are usually of timber in temporary installations, whilst steel structures are used for permanent work, or where timber is not obtainable. A frame timber tower is commonly used for trenching apparatus, with one back and one or two front guys on each tower; for tall towers the main timbers must be spliced and trussed. For more substantial work four posts are used, and one guy at the rear to take the strain on the cable. Steel frame towers are designed like other structures, dispatched in sections, and put together at the site.

Installations with movable towers must have the main cable held taut by counter-weights, or the guys must be shifted from time to time. The moving of the towers is performed by tackle-blocks and line, the main hoisting engine furnishing the driving power. If convenient, the tail of the fall used for moving the tower may be hitched to the hoisting block, and the hoisting drum operated to move the tower. For permanent installations endless chains and separate engines are generally used for moving the towers.

The cableway with travelling towers can perform all the functions of the travelling crane without limitations of reach.

The travelling carriage of the cableway is a simple frame of steel bars carrying two sheaves running on the main cable, and other sheaves over which the hoisting rope runs. Telpherage systems require carriages with framing on one side of the rope only, so that the carriage may pass the towers supporting the main cable at intervals. The sheaves in the lower part of the carriage perform the same functions as the upper block of a tackle, and the hoisting line or lines may be single and directly attached to the bucket, or make any number of turns about blocks to reduce the strain on the lines. As lubrication is likely to be neglected, the carriage should be provided with hard steel axles and good anti-friction bushings for its sheaves.

A few explanatory remarks on the method by which this aerial dumping of loads is effected may not be out of place. The carriage is drawn along the cable by an endless or hauling rope which passes from the carriage over the head tower, and several times round the winch drum on the engine, to secure frictional hold, then back over the head tower to the tail tower, returning to the rear end of the carriage. The hoisting rope passes from the engine over the carriage to the large fall block for raising the load. An auxiliary rope, the dump line, comes from the other side of the same drum of the engine and passes to a smaller block attached to the rear end of the skip. The hoisting rope carries the whole weight of the skip, while the dump line comes in slack but at the same rate of speed. When the bank or other discharging destination is reached, the dump line is shifted to that section of the drum having an increased diameter, and being thus drawn in at a higher rate of speed, the load is discharged.

The most difficult problem of the cableway is the judicious selection of the hoisting rope. The strain upon it, and therefore the sag, varies with the loading or unloading of the bucket. For cableways of short span and for light work a single hoisting line may be led from the drum of the engine around a sheave in the top of the adjacent tower over to the carriage, and down over a sheave to the bucket. Enough permanent weight on the bucket, or bucket tackle-block, is supplied to keep the hoisting rope up off the ground. With this arrangement the hoisting rope must be wound or unwound with the traversing rope to maintain the height of the bucket. The out-haul end of the traversing rope must also support a strain equal to that in the hoisting line in addition to its own initial tension. This strain is generally taken off the traversing rope by

carrying the hoisting line up around a sheave in the bucket block, over a second sheave in the carriage, and on to the tower opposite the engine, in the manner well known in crane practice. This permits of hoisting or lowering the bucket simultaneously with traversing the carriage. The varying strain of the load upon the hoisting line, with the varying sag resulting, is counteracted in one of several ways.

The most usual method is to hold up the horizontal part of the hoisting rope by a series of idler pulleys in carriers running on the main cable. One method of spacing them is by connecting them at equal distances along a chain. The tendency of the slack chains to foul each other, and the heavy strain on the traversing rope, as they are stretched out behind the advancing carriage, limit the use of this system to slow speeds. Another method provides an extra wire rope carrying knobs or bosses attached at intervals, known as the button rope. The carriers ride on a steel horn projecting from the end of the carriage, and embrace the button rope by jaws or loops of varying width. The buttons are made of regularly increasing size, beginning from the tower across the span. The first carrier to be dropped has the narrowest slot, and is caught by the smallest button, which has passed through the wider jaws of the other carriers without interference. In this way each carrier is taken off by the button corresponding, and the hoisting rope is held up at equal distances by suitable sheaves provided in the carriers.

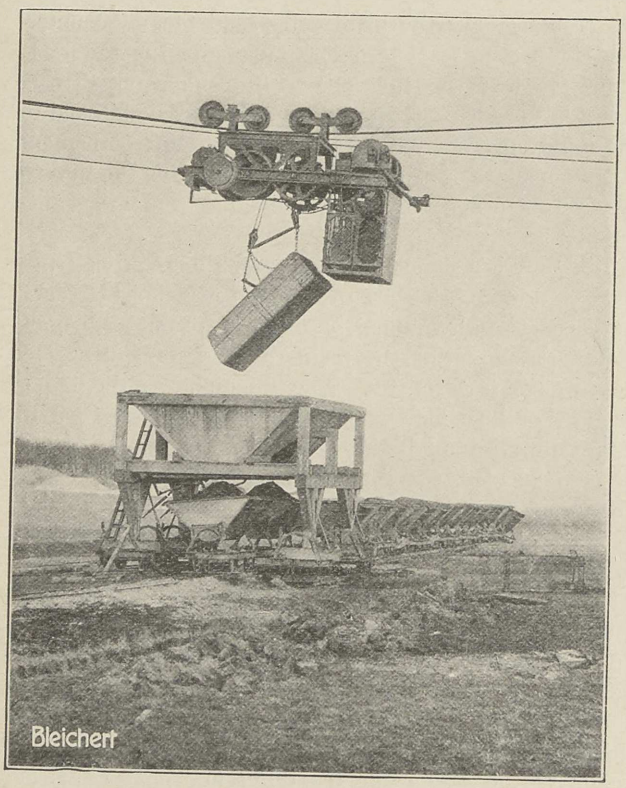


Fig 446. Discharge of the Skip of a Travelling Electrically Driven Bleichert Cable-Crane with Man-Trolley into a Portable Hopper for Loading Trains of Trucks.

In order to avoid the striking of the buttons by the carriers, the patented differential rope system of spacing has been devised. The button rope is replaced by two smaller lines suspended side by side, and spreading like the sides of a wedge, being held apart by suitably graduated blocks fastened between the ropes. The carriers are partly supported by long rollers resting on both ropes. As the carriage runs out from the tower the diverging differential ropes pick each carrier successively off the carriage. This affords a smooth-running carrier system suited to the highest speeds.

Another system employs trolley carriers running on the main cable and propelled by the traversing rope so that they proceed at some definite fraction of the speed of traverse. The simplest is the half-speed carrier, in which a single sheave in contact with the main cable sheave and with the traversing rope below propels the carrier frame so

that it supports the hoisting rope at a point always midway between tower and carriage. This reduction of the unsupported span to one half is sufficient for the successful operation of most cableways, though similar travelling carriages geared to one-fourth and three-fourths speed have been used for unusually long spans. Slippage, if it should occur, causes no trouble, as the carriers are forced together by the main carriage whenever it approaches close to the tower, and are thus brought back occasionally to the common starting point.

Still another system of supporting the hoisting rope is in occasional use. In this an endless hoisting line is provided strained initially to support itself with the same sag as the main cable. At a point on this line there is attached the end of the fall rope which supports the buckets from the carriage. By advancing the endless hoisting line and holding back on the endless travelling rope the fall rope is drawn out and the bucket hoisted. There are at least two objections to this system. The load cannot be hoisted close to the tail tower, as a branch rope leading to the fall-blocks would foul the tower sheaves. With a three or four part line and a high lift this prevents the use of a portion of the cableway. The wear on the hoisting line is as great as on the traversing line since both must slide across their spool drums as they are overhauled, and any attempt at high speed will cause the endless hoisting line and branch fall rope to twist up and foul.

With a single hoisting line, the only practicable form of bucket is a single skip filled by hand and dumped by unlatching it and allowing it to turn over, or lowering it on to inclines which tilt it to liberate the contents, or by setting it down until the chain supporting one end can be unhooked either by hand or automatically, and then hoisted again for emptying. For rapid excavation, dredging, or unloading, self-filling and self-dumping buckets with two hoisting lines are required. One of these lines may lift and the other close an "orange-peel" or "clam-shell" bucket; or one may be attached to each end of the skip, the contents of which are dumped by hauling up one end or letting down the other. The two cables must be wound up together and at the same speed for hoisting, or separately actuated for filling and dumping, so that the manner of operating them in connection with the engine is of much interest. It is evident that the skip may be dumped either by lowering the open end or by raising the other; this may be accomplished by winding both lines on a single drum with special accessories. To dump by lowering one end of the skip the hoisting drum is stopped after the load has been raised, the dumping line is clamped by a steel power brake and the drum is allowed to run down until the skip is inclined sufficiently. The dumping line between brake and drum slackens during the progress and tends to pile up on itself when the drum is again started forward, which might damage the wire rope by bending and crushing where the coils cross. To dump by raising the back of the skip, the dumping line must be wound up at a faster rate than the hoisting line. One way to accomplish this is to provide an enlarged central portion on the drum whose two ends carry the hoisting and dumping lines respectively, and a slotted flange between this portion and the portion carrying the dumping line. By a suitable shifter this line can be thrown against the flange, and entering one of the slots be passed over to the larger diameter where it is wound up faster than the hoisting line on the smaller diameter, and raises the end of the skip as desired.

The limitations on the two systems of dumping just described are that one will only dump while the skip is going down, and the other while it is going up. Further, the available head room between the skip and the top of the spoil bank, or the side of the hopper or railway car into which the load is to be dumped, is diminished by the necessity

of either letting down the skip in dumping it, or leaving sufficient height above to allow raising one end enough to dump the contents. To reduce this lost head room as much as possible, the two hoisting lines may be connected directly to the skip instead of carrying them round fall-blocks, and thence to the tail tower; the speed of hoisting is then the same as that of the hoisting rope, and no head room is lost by tackle-blocks; but the two lines must be wound in or out with the traversing line of the carriage.

The result of the combination is that dumping by clamping the dumping line and lowering the front of the skip must be done while the carriage is stationary, and does not work well for dumping into cars, for either the man in charge of the dumping cannot reach the skip to guide it, or the skip is brought down within reach, and fouls the dumped material in the car before clearing itself. The other method of winding in the dumping line at a higher speed can be applied only while the carriage is running towards the engine, since the dumping line can only be shifted while winding up. In order to dump near the tail tower it would be necessary to stop the carriage, and, if required, lower the load sufficiently to leave head room for the dumping block. If spoil banks are to be raised at both ends of the cableway, both systems must be applied together with all the attendant complications. These may, however, all be avoided, and aerial dumping easily effected at any point on the line with the carriage stationary or moving in either direction by using similar but separate drums for the hoisting and dumping lines. A standard three-drum hoisting engine thus actuates the complete cableway, the drums being operated together in either direction, or one or more as desired may be lowered under the control of the brake. This form of cableway engine is necessary for operating self-closing grabs of all types. As such buckets may be found necessary or convenient to deal with all materials encountered in excavating, the use of the three-drum engine is preferable to the method of holding or winding in one line as described. But little extra care is necessary on the part of the engineman in keeping the skip level when using independent lines, as it is only necessary to keep the dumping line well slacked off, the skip taking its own level as it hangs by its chains from the hoisting rope.

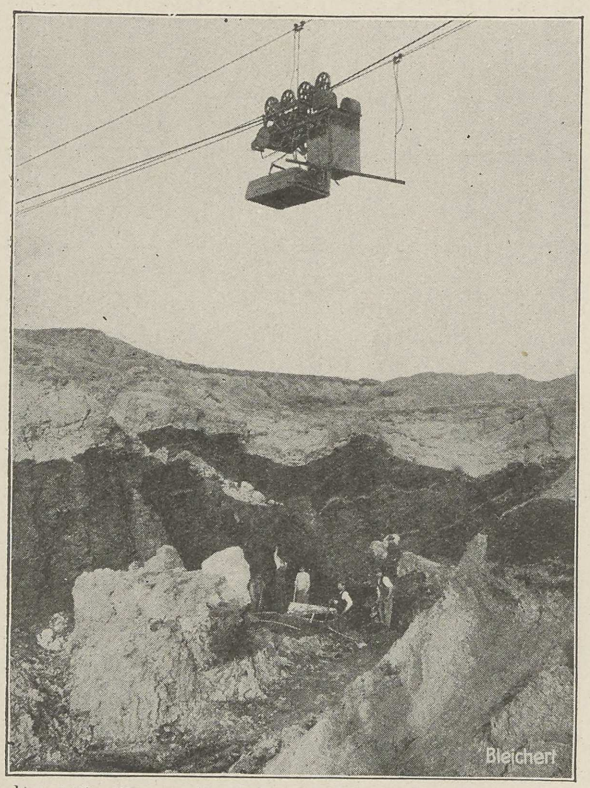


Fig. 447. Electrically Driven Bleichert Cable-Crane with Man-Trolley for Lignite Workings. (The operator has the skip always in view, even when lowering it into a pocket.)

A little trouble may be experienced on long spans and with heavy loads from the varying sag of the main cable as the carrier takes up or drops the load. The sagging of

the cable in hoisting increases the amount of line to be wound in. When the load must be dropped on the centre of the span, the cable, if relieved of its load, suddenly flies up in the air; care must therefore be taken to dump the load slowly in order to avoid disarranging the carriage and lines by a violent upward jerk.

With some forms of movable cableways where the distance between the towers cannot be kept uniform, a main cable is provided with a tension equaliser; one method is by pivoting the tail tower at the base, having a counterweight against the tension of the cableway; another method is to employ a stationary tower with a large sheave at its top, round which the main cable is led to a counterweight, but as the bending of a heavy steel cable even round a large sheave is objectionable, the counterweight is better attached at one end to a kind of bell-crank, to the other end of which the main cable is fastened. Yet another method is to connect the end of a cable to a tackle which forms a short portion of the span, the smaller and more flexible cable of which is carried over the tower to a lighter counterweight.

Some balance system is also required where one terminal of a cableway is supported on a barge or float which rises and falls with the tide, and particularly where the cableway inclines upwards from a floating tower to a higher point on shore.

Installations with permanent steel towers movable on parallel tracks may be used for coal storage plants in the same way as bridge cranes are used. A fan-shaped or semi-circular stock pile, reached by a cableway with one stationary tower on the water front, so constructed as to allow the carriage to travel out over the edge of the wall, effects the unloading of scows and barges with very great economy.

Cableways of the Lidgerwood Manufacturing Co.—The cableway has been brought to great perfection by this firm. Their standard type is on the general lines already fully described. The main cable used varies in diameter from $1\frac{1}{2}$ to $2\frac{1}{2}$ in., and ordinarily consists of six strands of nineteen wires each, and the material used may be crucible steel, or a selected plough steel.

The middle and rear wheels of the carriage are generally arranged in an equalising frame, and the fall rope or hoisting rope is supported at regular intervals (as already described in the general remarks) by the Lidgerwood-Miller patent button-stop fall-rope carrier. These carriers also support at the same time the in-haul rope, and where a dumping rope as well is used, these carriers support all three ropes. The latest form of these carriers is made hinged at the top according to Spencer Miller's patent, which equipment absorbs the shock when cableways are used at a great speed. These hinged supports are shown in Fig. **448**.

The Lidgerwood cableway steam hoist is equipped with reversible link motion, and the usual form includes two friction drums of large diameter, each being equipped with powerful band brake. These drums may be operated either together or independently, and the ropes travel at the same rate of speed when both drums are engaged; the load may therefore be transferred at a uniform height for any distance along the cable, or raised or lowered at any point along the span. The conveying or traversing rope is carried either on a wide phase drum, using separate in-haul and out-haul ropes with fixed ends, which run on or off the drum, or a curved drum is used, around which the conveying rope takes four or five turns to prevent slipping. A typical steam hoist is shown in Fig. **449**.

Electrical cableway hoists are now also built very largely by Messrs Lidgerwood; these being of the same general type as steam hoists with respect to drums and gearing, etc. In large and heavy duty cableways the magnetic control with master controller is generally employed; the ordinary drum control being used in the smaller sizes.

Among the first travelling cableways constructed by the Lidgerwood Manufacturing Co. were those used on the Chicago Drainage Canal in 1890, and they proved very efficient, but numerous improvements have since been made. Fig. 450 shows details of cableway used on the Chicago Drainage Canal. A later design was employed on the Nebish and Livingstone Channels near the Canadian border, being of the general type employed in the Chicago Drainage Canal. On the Nebish Channel work, 1,600,000 cub. yds. of solid rock place measurement were removed by these cableways to an average depth of 15 to 16 ft., and great economy in loading the skips was effected by the use of steam shovels which had a $2\frac{1}{2}$ yds. capacity. The steam cableway skips used were 8 ft. square by 2 ft. 6 in. deep, the weight of the loaded skips averaging 8 tons, and the monthly output of the four cableways so in use averaged 65,000 place yds. In one month 76,752 place yds. were the output allowed and paid for by the Government; this represents an average output of 3,073 yds. for each of the twenty-four days. One of the cableways made a monthly record of 29,490 yds. place measurement. More recent and conspicuous examples of similar installations are the cableways employed in the construction of the Gatun Locks, Isthmus of Panama. Thirteen electrically operated Lidgerwood cableways were employed for that work, eight of which, arranged in four pairs, handled the concrete for building the lock, the span in every case being 800 ft., and the loads handled 2 yds. of concrete, or about 6 tons. Similar cableways were used for unloading rock from barges, and depositing the same on storage ground. The span for these was also 800 ft. and each was equipped with a 74 cub. ft. grab bucket.

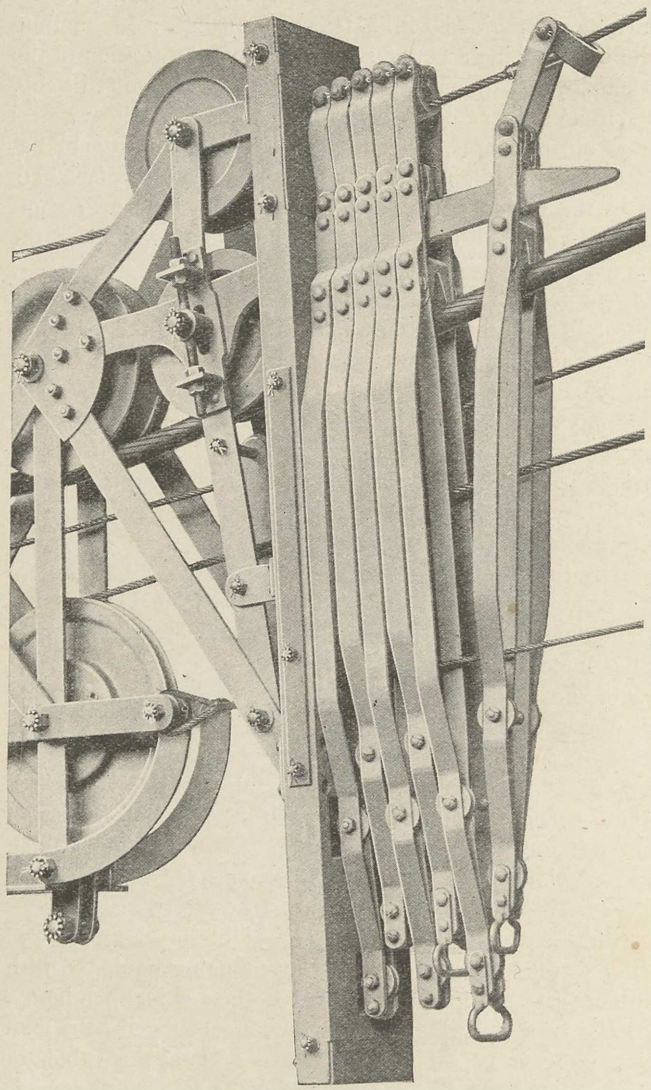


Fig. 448. Button-Picking Fall-Rope Carrier, showing the Action of the Shock-Absorbing Carrier Head.

Cableways may be used for a great variety of other purposes. For instance, the

Onomea Sugar Co., of Hilo, in the Sandwich Islands, have erected a cableway for handling cargo on a rugged coast where vessels often cannot get into the dock. The loads are swung over the small boats by a stationary derrick.

In mining enterprise the cableway has already played no inconsiderable part.

The Ottawa Gold Milling and Mining Co., of Lake of the Woods, Ontario, Canada,

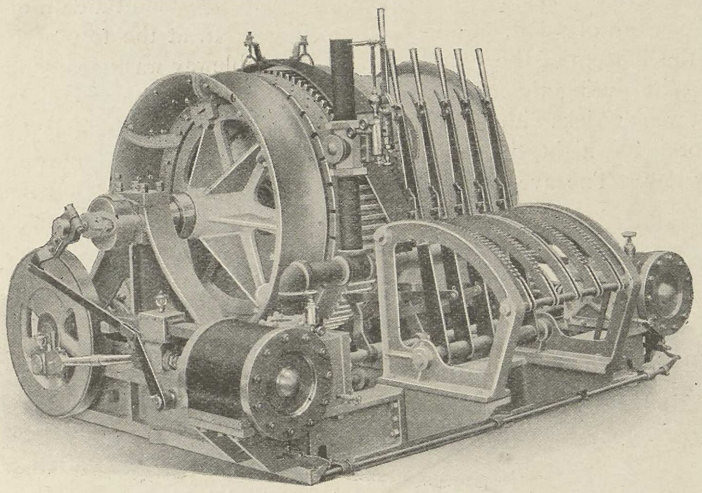


Fig. 449. Lidgerwood Steam Hoist.

employ a Lidgerwood cableway to unload gold ore from lake barges and deliver it over the main line of the Canadian and Pacific Railway to their mill at Keewatin, Ontario. The span of this cableway is about 450 ft., whilst the load carried varies from 2 to 3 tons. A clearance of over 22 ft. is given over the cableway, which is itself 20 ft. above the lake. The tail tower, 75 ft. high, stands on piles driven into the lake, and to these

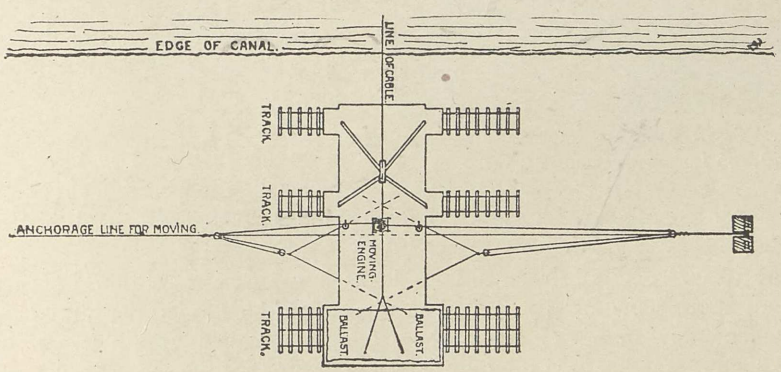


Fig. 450. Showing Details of Cableway as used on the Chicago Drainage Canal.

piles the cable is also anchored. The material is automatically dumped into the ore bins at an elevation of 43 ft., and at the rear of the ore bins is the 80 ft. head tower, from which the operator has a clear view of the entire work.

The barges are moored under the cable between the tail tower and shore. A special feature of this cableway is a bell-hoist installed at the base of the head tower, which is driven from a line shaft in the mill, which is in turn run by water power.

In the construction of marine and semi-marine works, such as breakwaters, locks, dams, etc., cableways have been used with good effect. At Johannesburg, in the Transvaal, the Consolidated Gold Fields of South Africa used a cableway in the construction of a masonry impounding dam intended to store water for the stamp-mills on the Rand. The stone, concrete, and all the necessary material was conveyed and delivered into a ravine about 120 ft. in depth, in which was built a dam of a total length of 500 ft., of a width of 46 ft. at the bottom, and 10 ft. at the top, and of a height of 165 ft. from the bottom of the foundation. This cableway was used nine hours during the day and nine during the night, with only one day lost time in eight months. It regularly fed three derricks with all the building material, and assisted in laying stone during the day. Working at night, the cableway delivered 225 stones for the use of the derricks the following day. The average load was 3 tons. Cableways are much more portable than ropeways, and, if necessary, can be moved considerable distances at no great cost.

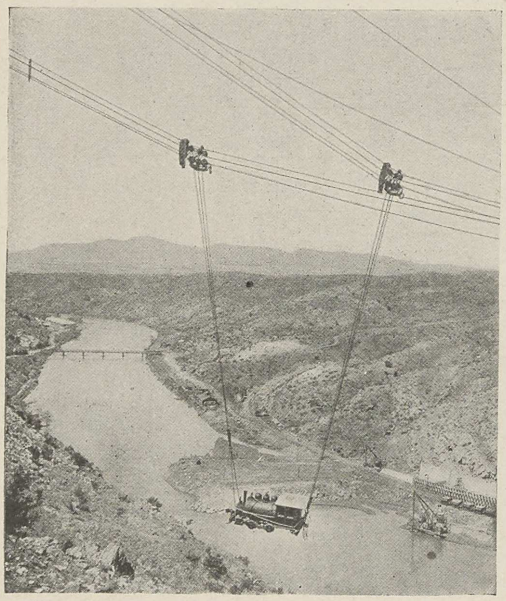


Fig. 451. Two Lidgerwood Cableways taking a 20-Ton Locomotive across River.

Cable Hoist Conveyors by Bleichert & Co.—Fig. **452** illustrates a cable hoist conveyor built by Bleichert & Co., of Leipzig-Gohlis, in which the rail rope is sufficiently inclined to allow the carriage to descend by gravity. One rope only is required in this case to manipulate the hoist, which is used for quarry work.

Fig. **453** is a hoist of a similar kind, having two principal terminals for unloading. Although there is a slight incline, it is not sufficient to allow the carriage to run back on its own account. Two ropes are therefore necessary for the purpose of manipulating it, in addition to the rail ropes.

Fig. **454** is a similar installation in which one terminal is fixed, whilst the other can be moved in a circular direction.

Fig. **455** shows a hoist of a slightly different kind, provided with steel terminal towers mounted on wheels.

As the quay front on rivers and in docks is always costly, new industrial establishments are more economically erected at what might be termed the hinterland, that is, some distance away from the quay, where land is obtainable at a lesser cost. This procedure has become possible by the use of one or another type of conveyor, continuous or intermittent, to bring the raw materials to the works, and to return the finished merchandise for shipment on the quay. One of the appliances frequently used for this purpose is the cable-crane, as it admits of a space between the terminals sufficient to serve in most cases, and the initial cost, as well as that of the working expenses and upkeep, are small.

The above applies equally, though in a different sense, on a coast which might be inaccessible for loading and unloading without the erection of costly harbours or quays. With a cable hoist such structures may be saved. An installation of this latter kind is

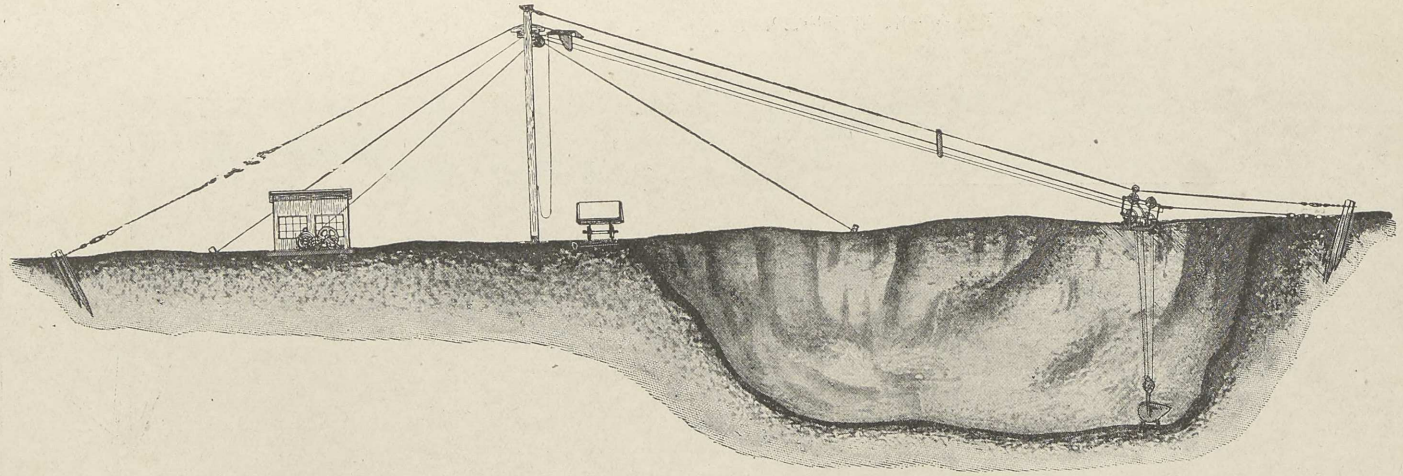


Fig. 452. Inclined Hoist Conveyor, as used for Quarry Work.

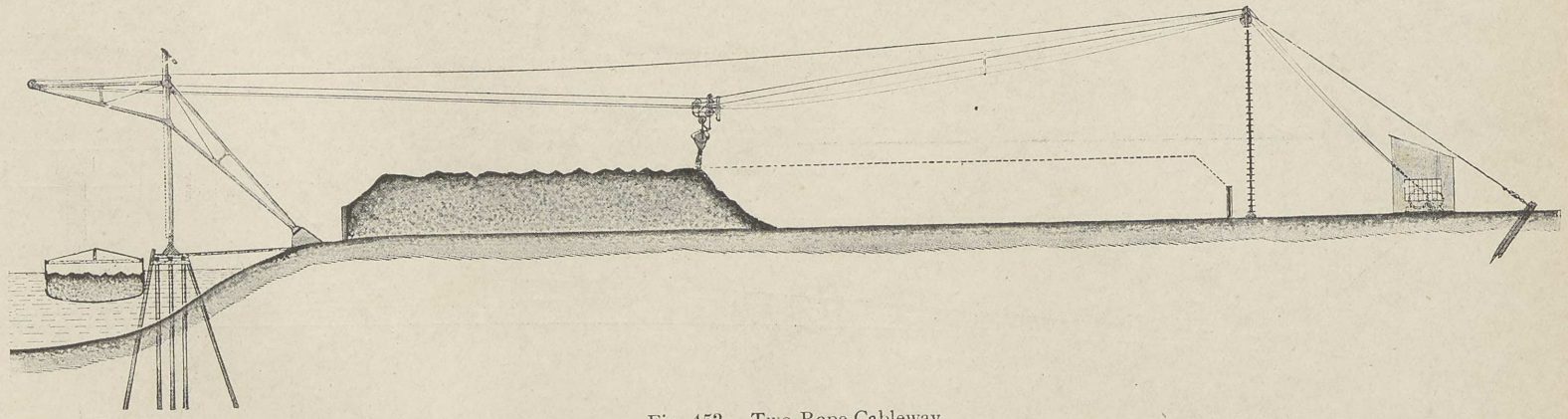


Fig. 453. Two-Rope Cableway.

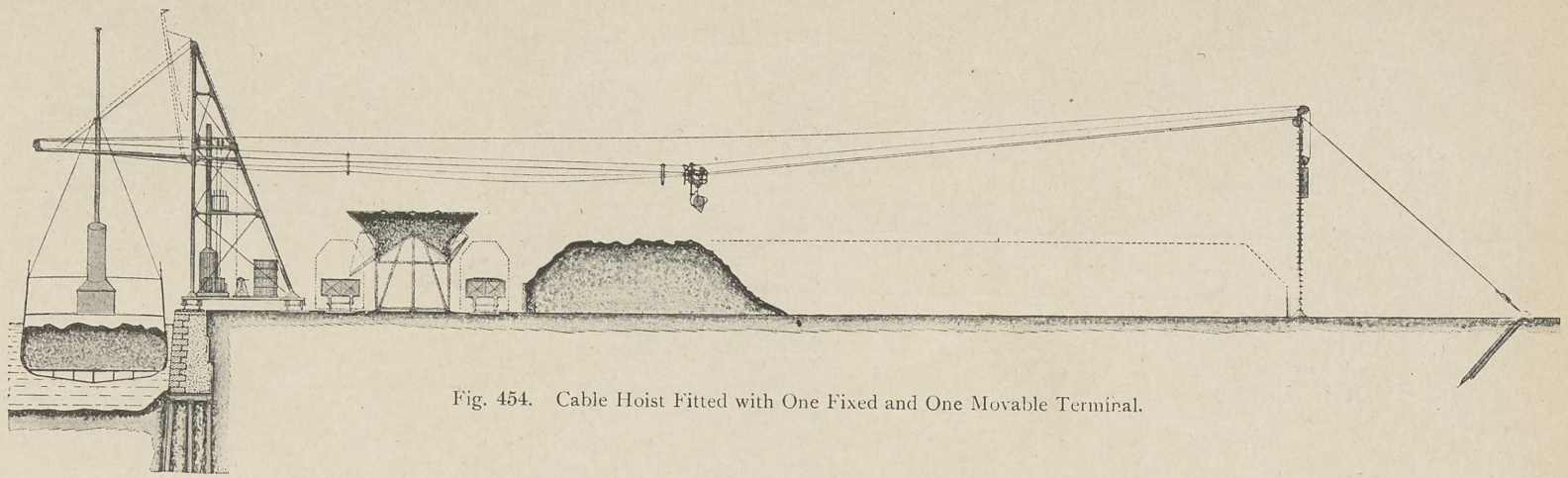


Fig. 454. Cable Hoist Fitted with One Fixed and One Movable Terminal.

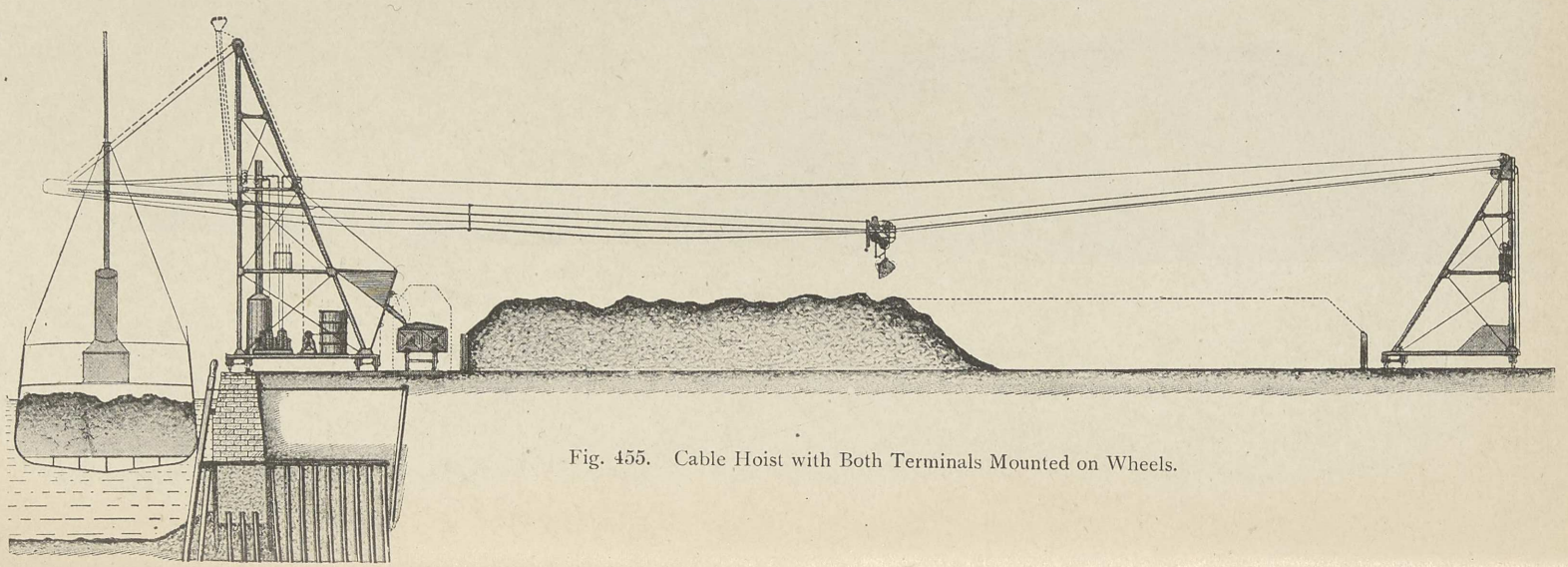


Fig. 455. Cable Hoist with Both Terminals Mounted on Wheels.

shown in Fig. **456**, erected by Bleichert & Co. It represents a double cableway with which the ore is transferred in skips from the ore pockets at the mine to the ship. The same cable hoist may be used as well for the removing of ballast from the ships as for the delivery of other goods from the ship to the mine. Similar installations may be used for the coaling of ships.

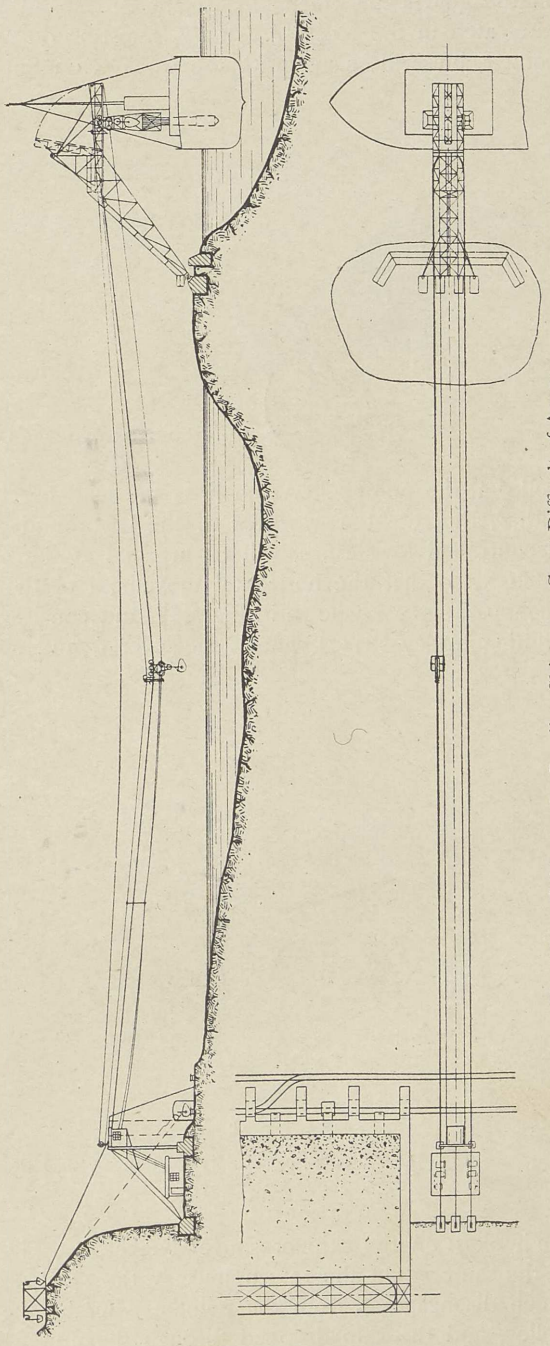


Fig. 456. Cableway for Loading Ships on a Coast Difficult of Access.

The "Calhoun" Cableway.[1]—This is in some respects not unlike the cableways already described. It is built by D. J. Calhoun, of Chicago.

Fig. **457** represents the skip being automatically filled, after being lowered at the correct angle into a heap of coal. It is hoisted by the hauling rope from either of the two terminal towers, similar to Lidgerwood's.

The travelling trolley is conveyed by the hauling rope to a predetermined point, where a catch x has been fixed to the rail rope. This locks the traveller in position, so that the skip may be hauled up on the inclines of the stock heap and there filled. When the skip has been raised, the trolley disengages itself from x, and runs with its load to the discharging point y, where the skip is automatically emptied. In the illustration, points x and y are shown close together, but these can of course be fixed in any suitable position. By means of a second hauling rope the trolley is again conveyed to the loading point, and on its way is arrested by the tripper z, which only comes into play at the forward movement of the trolley, and has the effect of so disengaging the fall block with its skip that it again reaches the stock heap.

The trolley is shown in two views in Fig. **458**, and consists of plates A and B, suspended on pulleys C and D. Between the plates is placed the sheave E,

[1] The Author is indebted to Professor M. Buhle for the following description.

which serves to connect the loose sheave and fall-block G with the trolley. When the skip is on the ground, the surface *ab* of the part T, which is movable on the pin F, rests on the guides *cd*, which are attached to A and B, so that the pin *h* of the block G can catch in the recess *b*. If *ab* is resting on *cd*, the pawl L no longer rests on the point *e*, but will engage with the catch X on the rail rope (see Fig. **457**), holding the

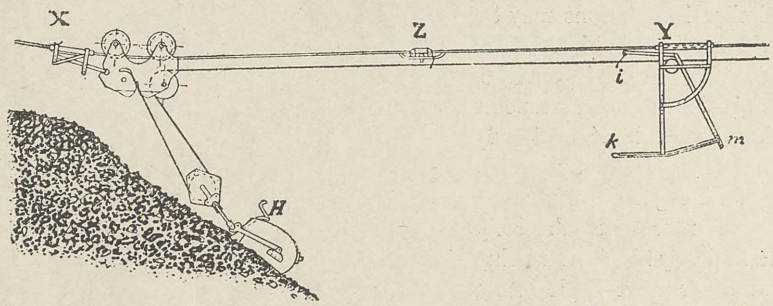


Fig. 457. Showing Action of Calhoun Cableway.

trolley at the point *g*. As soon as the load has been raised, and *h* has thus engaged with *b*, the shield T revolves to the left round the pivot F, while the pawl L, which is controlled by springs, will be arrested at the point *e*, and the hook M releases the catch X, so that the horizontal movement of the trolley can commence. The throw-off apparatus Y is shown in Fig. **457**, and consists essentially of the levers *i*, *k*, *m*. The running trolley strikes against the lever *i*, and at the same time the lever *k* engages

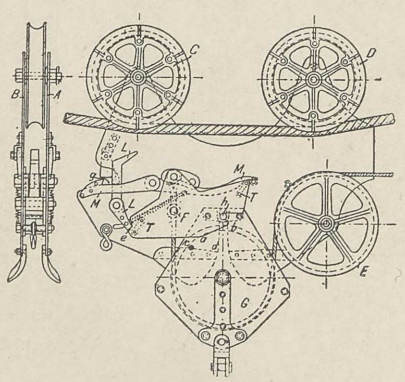


Fig. 458. Travelling Trolley used on the Calhoun Cableway.

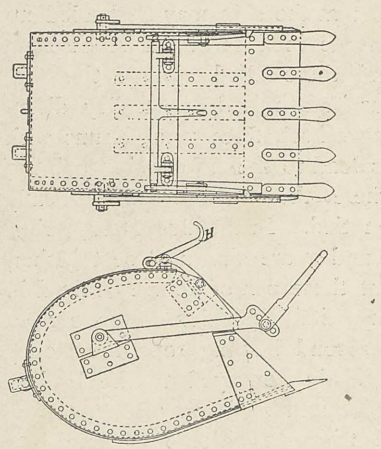


Fig. 459. Skip or Shovel Bucket used on Calhoun Cableway.

the hook H on the skip or shovel bucket (see Fig. **459**), and thus effects the discharge of the same. On the return journey the pawl L comes in contact with the tripper Z, which disengages L from the point *e*, whereby the fall-block G is disengaged from the trolley, and the skip dropped through the upward movement of the shield T.

Fig. **460** shows a larger view of the tripper Z. It may be noted throughout that all shocks are borne by the hauling rope and not by the rail rope.

The trolleys are built in three sizes to take skips of 15, 28, and 43 cub. ft. capacity. The corresponding diameters of the main or rail cables are $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ in.

An approximate idea of the capacity and working cost may be formed from the fact that the trolley can make the double journey of a track of 250 ft. long in one minute. At this speed the largest skip can convey over 600 cub. yds. of material in ten hours.

Three men are required to manipulate such a plant, and the coal consumption of the driving engines is said to be 1 to $1\frac{1}{2}$ tons per day under ordinary conditions.



Fig. 460. Large Scale View of Tripper.

Cableways of John M. Henderson & Co.—In these cableways the carriage or carrier (see Fig. **461**) is usually provided with three wheels. These are supported on an articulated frame which allows them to accommodate themselves to any curves the rope may assume.

Some of Henderson's cableways are fitted with a device by means of which the skip can be emptied at any point by the operator in charge. The arrangement for this consists of an additional narrow drum on the winding gear, and a small wire rope between the traveller and the rear end of the skip similar to Lidgerwood's; also special slings, hoisting blocks, and controlling apparatus at the engines.

Fig. **461** represents the usual design of the Henderson traveller or load carriage, and the accompanying numbering refers to the different parts shown in the diagram.

Two interesting examples showing the utility of the cableway for different classes of work are illustrated in Figs. **462** and **463**.

Fig. **462** represents three Henderson cableways with a span of 750 ft. each, and for

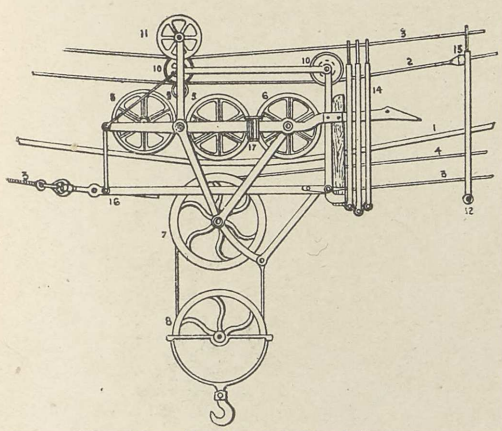


Fig. 461. Henderson's Load Carrier.

1. Main Cable.
2. Button Rope.
3. Travelling Rope.
4. Hoisting Rope.
5. Load Carriage Wheel on Levers.
6. Load Carriage Wheels.
7. Hoisting Pulley.
8. Hoisting Block.
9. Small Guide Pulley for Travelling Rope.
10. Button-Rope Pulleys.
11. Large Guide Pulley for Travelling Rope.
12. Rope Carrier Pulleys.
13. Pin for Rope Carrier Pulleys.
14. Rope Carrier.
15. Button.
16. Tension Screw and Nut.
17. Oil-Pot.

loads of 5 tons, the respective heights of head and tail towers being 60 and 50 ft., the engine cylinders having an 18-in. stroke, and being 11 in. in diameter. These cableways are used by Messrs Pearson & Co., Ltd., for excavating work at the Dockyards, Malta. The terminal on either bank and the progress of the excavating work can be clearly seen. Similar installations have been or are being employed on dock construction at Gibraltar, Hong-Kong, Buenos Aires, and Simon's Bay, South Africa.

Fig. **463** shows a similar cableway with a span of 1,000 ft. for loads of $2\frac{1}{2}$ tons. The

terminal towers are respectively 60 and 72 ft. high. This cableway was erected for the purpose of constructing a viaduct over the Cannington Valley for the Axminster and Lyme Regis Light Railway. The piers of the viaduct were erected without the use of any scaffolding, and solely by the use of the cableway. Some of the piers are 72 ft. in height, and are composed of massed concrete.

Cableways of a similar design have been used for the construction of the Vauxhall and Kew Bridges. Cableways have also been used for the erection of viaducts at Kirkcaldy, Durham, and in Devonshire.

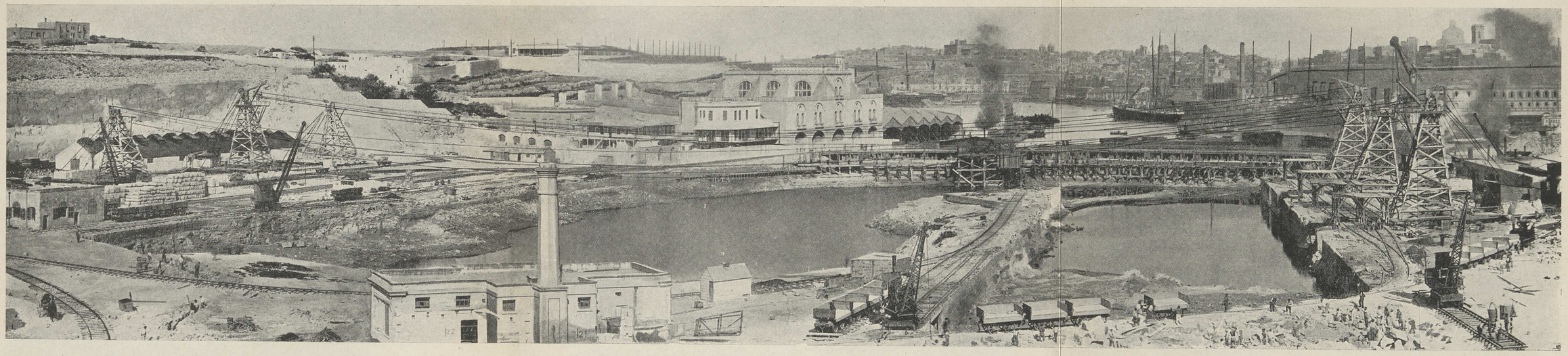


Fig. 462. Cableway erected at Dockyards, Malta, showing Terminals on either Bank.

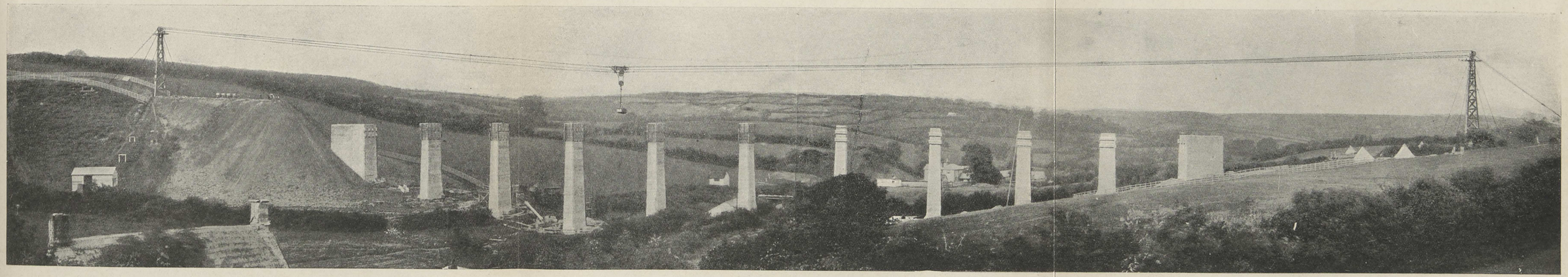


Fig. 463. Cableway erected for the purpose of constructing a Viaduct over the Cannington Valley.

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CHAPTER XXVI

COALING VESSELS AT SEA

By this is meant the transference of coal from a collier to a vessel while under way, or at any rate in the open sea, to avoid the necessity of going into port, whereby sometimes considerable time is lost. When coal can be transferred while the vessel is under way in the direction of her destination, a minimum of time will be wasted, and that solely on account of the speed being slower than usual.

There are two distinct methods of coaling at sea: the first is with the two vessels alongside, which is at all times a dangerous process, and only possible in calm weather; for naval purposes it will, therefore, never be universally used. The other method is end on, when one of the vessels takes the other in tow at a safe distance, and the transference of coal is made by some form of cableway, and this can be done in practically any weather.

Historical.—Mr Spencer Miller has made this process his special study, and read two papers before the American Society of Naval Architects and Marine Engineers on 16th November 1899, and in 1900,[1] to which the Author is greatly indebted for the following information.

A paper entitled "Coaling Ships in Squadron on the Open Sea" was delivered by Lieutenant R. S. Lowry, R.N., before the Royal United Service Institution, London, 13th April 1883. In Lieutenant Lowry's plan, special coal boxes or boats holding about a ton of coal were carried by a collier and conveyed to the warship by lines, hoisted on deck, emptied, and returned. These boxes were made buoyant by air-tight chambers. This system was fully discussed, but was evidently not considered practicable.

In 1887 a paper entitled "Coaling Ships of War at Sea" was read before the same Institution by Lieutenant C. E. Bell, R.N., and was fully discussed by Admiral Boys, the late Vice-Admiral Colomb, Commander Campbell, Captains Fitzgerald, Henderson, and others.

Lieutenant Bell remarked on this occasion that his excuse for putting his views before the Institution would be found in the utterances of Captain Scott, whom he quoted as follows: "I think, moreover, that you require, if you have groups of squadrons, some equal coaling power or means of coaling at sea which we have not yet hit upon." And then he says: "I feel sure that all officers will agree with me that coaling from broadside at sea is impossible, except in very calm weather, and that even then it is attended with great risk to both men and material employed." And "I am sure I am supported in such belief by all who have considered the subject, that the only way by which the great difficulties and dangers of coaling at sea can be overcome and the work carried out successfully with the least possible delay, and absence of danger both to men and material, is by coaling from bow to stern." Also, "I do not make any claim to originality—in fact, I believe that the same idea has occurred to many officers who have given any consideration to this subject; and in fact, on submitting a sketch of the present plan to Sir J. H. Cammerell a short time ago, he then told me it had suggested itself to

[1] See also *The Engineer*, 19th January and 27th July 1900.

him some years back, and he believed it was the only way in which it could be done."

Lieutenant Bell's Requirements.—Lieutenant Bell says: "Any satisfactory plan of coaling at sea must satisfy the following requirements:—(1) Rapidity; (2) safety; (3) ability for the ships engaged in the operation to proceed with the minimum diminution of speed. These three requirements are absolutely essential to the success of any plan, but there are others of no little importance; (4) necessity of keeping coal dry; (5) minimum of labour to be employed; (6) little cost for material necessitated."

Lieutenant Bell's Plan.—The plan suggested by Lieutenant Bell is that shown in Fig. **464**, in which it will be seen that he first took the collier in tow of the warship, and then added an inclined and elevated cable attached low down to the aftermast of the warship and to the top of the foremast of the collier. To this elevated line a trolley was suspended capable of running along the strand. Two ropes are shown, one fastened to the rear and one to the front of this trolley, the one leading to the warship and the other to the collier. The hawsers, in his system, crossed from the stern of the warship to the bow ports or other convenient places of the collier. He proposed to carry five bags at a time, carrying about 220 lb. of coal per bag. The bags were to be hoisted, by some arrangement not shown, from the deck of the collier to the suspended cable, and there attached by a man stationed on the foreyard for that purpose. By these means he proposed to satisfy all the requirements he had laid out—namely, rapidity, safety, etc. In referring to the fact that his appliance costs but a trifle, he added—"I would at the same time insist that no expense should be considered too great to carry out this most important, I may say all-important, operation, in those cases where it may be essential to the success or safety of any ship or ships in the Navy, or any expedition that may be engaged in."

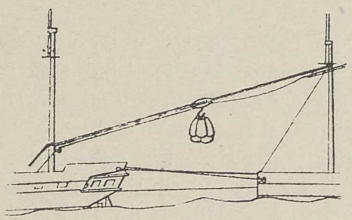


Fig. 464. Diagram showing Bell's Plan for Coaling at Sea.

Discussion of Lieutenant Bell's Plan.—The discussion that followed was very severe, for, as it will be observed, there were no means provided for maintaining a uniform tension on this elevated and suspended wire, and if the vessels so rigged were pitching ever so little, one of the two following events would occur, and probably both after a short time. By the ships pitching toward each other, the coal bags would be likely to be dropped into the sea, and by pitching away from each other the foremast of the collier would be unshipped or the suspended cable snapped. Commodore Campbell said: "I do not agree with him, but I admire his principle, and I sincerely hope that this paper will help to give another blow to the happy-go-lucky system, and assist us in bringing about that systematic organisation of every detail for which the Navy is now crying out with one voice, and which is now happily receiving the special attention of our rulers." Lieutenant Tupper said, amongst other things: "I think the practice of coaling ships at sea ought to be made just as much a drill and evolution as are many other operations which have to be performed." The chairman of the meeting, Admiral Boys, said in relation to Bell's plan: "But if these ships should get in any seaway whatever, the operation, I believe, must break down."

Lieutenant Tupper's Plan.—Lieutenant R. G. O. Tupper, R.N., submitted a different plan for coaling vessels at sea, as shown in Fig. **465**.

His plan provided an endless rope, starting from the stern of the collier in tow of the warship, passing over an elevated support on the foreyard, thence to the aftermast

of the warship. This endless rope was to have buckets of coal secured to it at frequent intervals, and the whole was to be operated by a capstan, the coal being thus passed from one ship to another. This plan was of course subjected to the same criticisms as that of Lieutenant Bell, namely, that in any seaway whatsoever the cable would either be dropped into the sea by excessive slack or snapped by pitching in the reverse direction.

Low's Plan.—The Hon. Phillip B. Low secured a patent, 10th July 1893, on a plan practically the same as that Lieutenant Bell described in his paper six years earlier, but with the important addition of a counterweight secured to the end of an elevated carrying cable (Fig. **466**).

This counterweight was so arranged as to maintain a constant tension on the suspended cable, regardless of the motion of the ships. The use of a counterweight to maintain a constant tension on a suspended wire rope would be successful in any stationary plant on shore. His plan was tested by the United States Navy Department in October 1893. The test took place on board the U.S.S. "San Francisco" and the U.S.S. "Kearsarge." The distance from the shears of the cruisers to the upright poles on the colliers was about 235 ft., hence the distance between the vessels was somewhat less than 200 ft. The transmission wire, as the inventor called it, was secured to the deck of the "San Francisco," supported by a pair of shear-poles at the stern, then run on

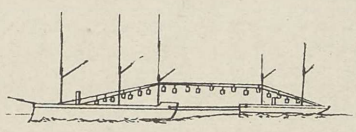


Fig. 465. Diagram showing Lieutenant Tupper's Plan for Coaling at Sea.

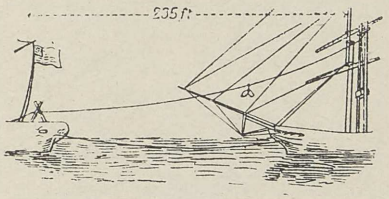


Fig. 466. Low's Plan for Coaling at Sea.

an incline to a gin-pole at an elevation of about 32 ft. above the foremast of the "Kearsarge," which played the part of the collier, and so gave a gradient of about 8° to the horizontal between the rope terminals and the vessels. After the cable was threaded through the gin-block it was bent backwards, while to the end was secured a counterweight of about 1,600 lb. The bags of coal weighed nearly 200 lb., and the time required to travel from the pole-head on the collier was about fourteen seconds. To hoist and send over ten bags of coal occupied some twenty minutes, giving about the rate of $2\frac{2}{3}$ tons per hour. The Board of Naval Officers were instructed to report on the trial, and their official report was that in rough weather the apparatus would not be of the slightest use in transferring coal from one vessel to another. The apparatus was reported to have worked well; but as the sea was calm, it was impossible to say what would have been the result in a moderate sea. As the sea became heavier, the distance between the ships would have to be increased for safety, and there would have to be a corresponding increase in the height of the gin-block in order to give a proper inclination to the connecting rope. Presuming that the distance between ships was increased 300 ft., the same angle of inclination preserved, and the same height of shear-poles on the warship, then the gin-block on the collier would have to be 70 ft. above the deck of that craft, as this would reach to the truck of the foremast of the collier. It is clear that to attempt to attach bags of coal at such a height would be difficult, if not altogether impracticable, especially in a rolling sea. Even then the capacity, whatever it might have been at

200 ft., must be something less at 300 ft. distance between the ships. In order, therefore, to increase the capacity of this device, it would be necessary to increase the load; but as it will be noticed that with a 200 lb. load a 1,600 lb. counterweight was employed, a 400 lb. load would require a 3,200 lb. counterweight, while a 600 lb. load would require a 4,800 lb. counterweight, and so on. The element of danger to the ship in carrying any such counterweight would seem to need consideration. If the tow-line should snap, this weight would be pulled up to the gin-block, and as something would then give way, the dropping counterweight would do great damage.

John E. Walsh's Plan.—Fig. **467** illustrates a plan patented by John E. Walsh, of New York. The cable R, attached at one end to the towing boat, inclines upwards and bends over a pulley-block O, near the head of the foremast, thence bends under the pulley-block O, carrying a counterweight W. The rope is bent many times, and must therefore carry a very large counterweight to sustain the requisite tensions in the rope R. The objections which have been made to Low's inclined cable and counterweight apply equally well to the Walsh plan.

The illustration also shows overhead derricks for hoisting the load out of both hatches to platforms on the masts, the platform on the mainmast being somewhat

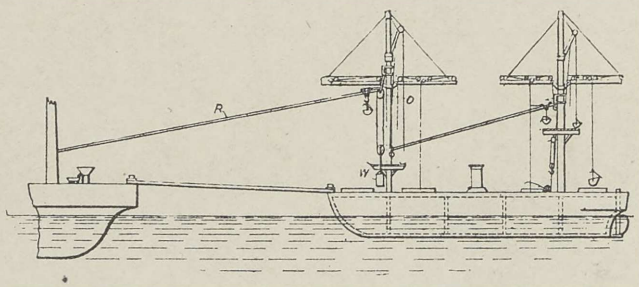


Fig. 467. Diagram showing Walsh's Plan for Coaling at Sea.

higher than that on the foremast, and an auxiliary inclined cable between the masts adapted to carry the coal forward.

Spencer Miller, the author of "Coaling Vessels at Sea," maintains that any hoisting device of this class elevated to any height will be impracticable in a rolling sea. If the load is to be hoisted at all on ships at sea, it should certainly be steadied between guides.

Lieutenant Niblack's Paper.—Lieutenant A. P. Niblack, in a paper on "Coal Bunkers and Coaling Ships," read before the American Society of Naval Architects and Marine Engineers in 1893, presented a most complete argument for the necessity of rapid coaling as a factor in efficiency, giving full data respecting the speed with which the ships then built in the United States could be coaled in harbour. He says: "Our crack ship, the 'San Francisco,' could only take in coal at Sandy Point at the rate of 10 tons per hour, and ordinarily she takes three days, working hard, to fill up. Efficiency in ship's crew must also be supplemented by the best mechanical arrangements practicable, and the coal must be able to go anywhere and to stay there." Coal supply and rapid coaling are in his view most important factors in efficiency, not only in emergency, but also in times of peace, as the time spent in coaling ship is time wasted. He proceeds to give figures representing the average of three or more good actual performances of each ship, and shows that the "Chicago," the "Charlestown," and the

"Newark" coaled at the rate of 30 tons per hour. He quotes from the British manœuvres, giving the average of the "Thunderer" at 17½ tons, and of the "Anson" at 51·6 tons per hour, the latter using the Temperley transporter.

The first test by the British Admiralty in coaling at sea took place in the middle of August 1890, some 500 miles south of the Azores, and 1,000 miles or more from the African coast, with 2,000 fathoms water under the ships' bottoms. Thus all the conditions of being at sea were amply fulfilled.

The ships that coaled were the "Ajax," "Camperdown," "Audacious," "Iron Duke," "Northampton," "Immortalité," "Aurora," "Neptune," "Conqueror," and "Minotaur." They took varying amounts—in all cases the minimum necessary to take them back to Torbay, some 1,800 miles distant. One ship, the "Howe," evaded coaling, and had to go into Vigo. The rest, although their captains protested strongly in several cases, took coal. There were three full colliers with the fleet, and each ship took an average of 350 tons, at the usual harbour rate, or nearly so. The sea was smooth to look at, but there was a heavy Atlantic swell. Each collier was lashed alongside a battleship, with thick fenders between. Towards the end of the operation the swell increased, and a considerable amount of "moral suasion" was required with at least one collier captain. The coal was taken in in derricks at the main deck ports. One or two ships had torpedo beams broken, and one collier sustained some dents in her side; but no material damage was done. The ships were kept bows on to the swell, and so there was no rolling. All, however, pitched somewhat, and the colliers when they began to get light pitched rather violently. It was this pitching which did such damage as was sustained.

British ships coaling in harbour, where they were completely surrounded by colliers, and working Temperley transporters [1] and whips combined, have coaled 150 tons per hour.

Difficulties of Coaling at Sea during the Spanish-American War in 1898.—Mr Spencer Miller quotes some paragraphs which appeared in the daily press while the conflict was being waged. The *Commercial Advertiser* published on 26th June 1898 the diary of their correspondent, who was on board the United States battleship "Iowa," but only that part is quoted which has reference to the coaling problem.

"June 7, 1898. . . . The collier 'Justine' is alongside, and we started in coaling. The 'Justine' has not the coaling capacity of the 'Merrimac,' but she is a fine steamer, very strongly built. In a seaway this is a great advantage, for though we gave her some pretty hard knocks, no holes were punched in her sides. Since she comes right alongside of our harbour belt, she can be the only sufferer. She is also very convenient to coal from. Working three forward hatches we were able to take aboard very easily 260 tons before supper-time.

"June 8, 1898. . . . Much to our disappointment we find that we cannot get the 'Justine' again to-day, as she was ordered over to the 'Brooklyn,' and we had to content ourselves with the 'Sterling,' to our sorrow. We had every fender out possible, big rope fellows too, that will stand any amount of knocking, but no sooner had the 'Sterling' come alongside than she came up heavily against the side of our ash chute and opened a hole in her side. There was nothing to do but send the carpenter's gang aboard and shove her off for repairs. Every one is disgusted with the 'Sterling' for having sides like paper.

"June 11, 1898. . . . We tried to coal again from the 'Justine' to-day. Made all preparations, and even started sending the coal aboard; but before we got more than a dozen bags on, the ships knocked together again so badly that we had to cast the collier

[1] For description of Temperley Portable Transporter, see page 442.

off and give it up again. It is most aggravating, for now we must clean up the ship, only to start in coaling again on Monday."

Thus it will be seen that while coaling was begun on the 7th, yet on the 8th, 9th, 10th, and 11th practically no coaling was accomplished, although each and every day the ships needed coal, and it was most important that they should have it. It may be interesting to know that this same collier "Justine," after discharging a single cargo of coal, was returned to Newport News and laid up a long time for repairs, the bill for which exceeded £200.

It is commonly believed that Admiral Cervera's defeat was directly due to his being short of coal and provisions, which brought him into the harbour of Santiago de Cuba to fill his bunkers. But had he been speedy in coaling after he arrived there, he probably could have escaped from the harbour, because the American vessels were also short of coal, as will appear from the messages exchanged between Admiral Sampson and Commodore Schley and the Navy Department, as they appeared in the report of Captain Crowninshield, Chief of the Bureau of Navigation. The following message was sent from Commodore Schley to Admiral Sampson: "Arrived 21st May off Cienfuegos. . . . Expect difficulty here will be to coal from colliers in constant heavy swell. Other problem easy compared with this one so far from the base." On the same day Admiral Sampson received this dispatch from Commodore Schley, dated 24th May: "Coaling off Cienfuegos is very uncertain. Having ascertained that the Spanish fleet is not here, I will move eastward to-morrow, communicating with you from Nicholas Mole. On account of short coal supply in ships, cannot blockade them if in Santiago. I shall proceed to-morrow, 25th, for Santiago, being embarrassed, however, by 'Texas'' short coal supply, and her inability to coal in open sea. I shall not be able to remain off that port owing to the generally short coal supply of squadron, so will proceed in the vicinity of Nicholas Mole, where the water is smooth, and I can coal 'Texas' and other ships with what coal may remain in collier." So much has been said on this subject that it is only necessary to remark that had Commodore Schley been in possession of colliers fitted for coaling at sea, especially during his journey from Cienfuegos to Santiago, there would have been no occasion for his leaving Santiago unguarded a day after his arrival.

French Experiments.—While the Spanish-American War was in progress the French were making experiments in this problem of coaling at sea. The Paris correspondent of the *Times* wrote on 28th July 1898, in reference to the coaling with the Temperley transporter, as follows:—

"An interesting point in these manœuvres has been the attempt to coal at sea. The collier is lashed to the ship, and the ship then steams ahead. A speed of 10 knots is said to have been reached, but other information points to a lower speed by some knots.

"The 'Japon,' a collier, 3,000 tons, furnished with a Temperley transporter, while steaming 6 knots in a rough sea and strong breeze, succeeded in coaling the 'Marceau' and 'La Touche Treville' with 200 tons of coal. It was a successful beginning, but the operation was not continued so long as desired, it being interrupted in the case of the 'Marceau' by way of precaution, and in the case of 'La Touche Treville' on account of an accident to the 'Japon,' which had to return to Toulon for repairs. This problem does not seem to have been fully solved, as proved by the damage sustained by the 'Japon.' The French Admiralty is confident of a decisive result, for it has just decided that the 'Japon' is to remain permanently attached to the Mediterranean reserve squadron.

"Coaling and revictualling in motion is the question now before all the great

navies, and as such experiments cannot be made in the dark, it is certain that all nations will almost simultaneously have the necessary apparatus for coaling ships to be supplied at sea, so that they can be sent to the greatest distance without running short, at the moment of combat, of either food or coal."

Coal Supply.—The Spanish-American War and its lessons furnished the naval officers of foreign Powers with points of interest. For instance, a paper on coal supply was written by the late Vice-Admiral P. H. Colomb, R.N., entitled "Coal Supply, Speed, Guns, and Torpedoes in Naval Marine War."[1] As regards coal supply, Vice-Admiral Colomb said: "We get speed and certainty for voyages made under steam, and the full advantages are reaped in peace time, because coal supply can be exactly arranged for and calculated according to the work required of it, for that can be known; but for the warships in war no such special arrangements and calculations are possible. Coal supply can be treated only generally before the war breaks out. No one can say beforehand whether it has been advantageously or economically allotted."

Spencer Miller's System.—His plan, devised in 1893, was to stretch an elevated cable from the stern of the warship to the bow of the collier in tow, one end to be securely fastened to the warship and the other end wound round a compensating engine, similar to the steam towing machines. The load running on this cable was to be conveyed by an endless rope. It was expected that the compensating engine would keep an equal strain on this elevated line irrespective of the pitch of the vessels so connected. In

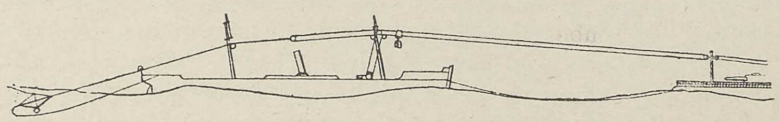


Fig. 468. Woodward's Plan for Coaling at Sea.

March 1898, Lieutenant J. J. Woodward, Naval Constructor, stationed at Newport News, Va., invited plans and prices for a device embodying much the same general ideas. A few weeks later, in April, a plan was sent to Mr Woodward, and he in turn transmitted it, with favourable recommendations, through the Chief Constructor, to the Secretary of the Navy. It was not, however, until August of the same year that any understanding was arrived at with the Navy Department whereby the work of construction could be begun. The plan, considerably modified, was submitted to a Board of Naval Officers, consisting of Rear-Admiral Ramsay, President; Mr Thomas Williamson, Chief Engineer; and Commander J. L. Tanner. They considered the device "feasible in moderate weather." Thereupon the Department contracted with the Lidgerwood Manufacturing Co., of New York City, U.S.A., to have the apparatus installed on board the collier "Marcellus." So much time, however, was lost in negotiations, that before the work of construction was begun, the war had come to an end.

On 15th October 1898 experiments were performed in New York Harbour with a tug towing a sloop, using a quarter-sized model. Shear-poles were mounted on the tug, and blocks on the mast of the sloop, the distance between points of support being 100 ft. An endless rope was employed, being used in accordance with the sketch shown in Fig. 468.

The experiment was performed in a storm, which was so severe that the sloop shipped water over the bow, and both boats rolled and pitched very badly. In spite of this, however, the bags of coal were conveyed across the space as though the sea were

[1] This paper appeared in *Cassier's Magazine*, August 1898.

smooth, the sheet anchor serving efficiently as a compensator, and maintaining a perfect tension on the endless conveying cable. The principle of the "Miller" conveyor, as used on the U.S.S. "Marcellus," is shown in Figs. **469** and **470**, but when tested at sea it actually had an additional rope above the conveying ropes which was led astern, terminating in a sheet anchor. This device is now called the Marine Cableway. It is intended to be utilised by ships stationed at a distance of from 350 to 500 ft. apart. It might possibly work successfully at a greater distance, but such an experiment has not yet been tried. The vessels are connected by an ordinary cable, and the towing vessel gets under way at a speed ranging from 4 to 8 knots per hour, according to the condition

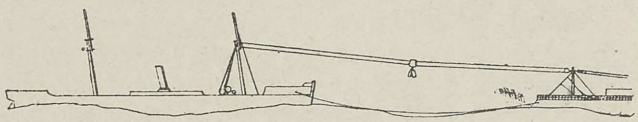


Fig. 469. General Arrangement of Spencer Miller's Plan for Coaling at Sea.

of the weather and the sea which is running. A speed of 5 knots in moderately rough water has been found sufficient to keep the cableway taut and to maintain the proper distance between the craft, unless a tide or some unusual current is encountered.

The appliance which has been fitted to the "Marcellus" may be described as follows:—

An engine, with double cylinders and double friction drums of special design, is placed just abaft the foremast of the collier. It has two steam cylinders 12 by 12 in. A $\frac{3}{4}$-in. diameter steel rope is led from one drum over a pulley at the mast-head, and thence to a pulley at the head of shear-poles on the warship, and returned to the other drum.

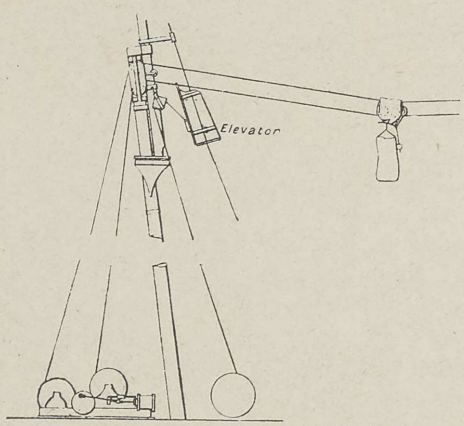


Fig. 470. Details of Spencer Miller's Plan for Coaling at Sea.

The engine moves in the same direction all the time, and tends to wind in both strands of the conveying rope. A novel form of load carriage is suspended from this rope. It is provided with a gripping device on the upper strand and wheels to run on the lower strand. This carriage conveys two loaded bags, weighing 420 lb. each, suspended from a bail, which hangs in a hook below the carriage. A hoist takes the bags from the deck, lifting them to the mast-head, while the conveyor carriage, coming in from the mast-head, locks itself under the bail. As soon as the bail is released by a man under the trestle-trees, the engine operator hauls in the lower parts of the conveyor line. The upper part of the conveyor line is therefore drawn from the rear drum, slipping the specially contrived friction devices. Thus the carriage passes from collier to ship, the tension being sufficient to ensure the bags clearing the water between the vessels. The rope is drawn in at a speed of 1,000 ft. per minute, and if the points of support—mast-head and shear-head—do not vary, the upper strand will be drawn out, under tension of about 3,000 lb., at the same rate of speed. If, however, the distance is increased during the transit of the load, the extra rope called for is given by the slipping of the upper part from the drum. This increases

the speed of the upper strand. On the other hand, if the ships reduce the distance between points of support, the speed of the upper strand is reduced.

When the carriage reaches the pulley at the shear-head, it collides with it—at reduced speed—and thus striking, releases the lower hook, and the two bags and their bail drop into the canvas shoot and slide to the deck of the warship. Loads drop in this manner at the rate of one per minute. The empty carriage is drawn back by the rear drum, the forward drum being thrown partially out of friction.

An auxiliary $\frac{3}{4}$-in. rope, known as the sea-anchor line, is stretched above the two strands of the conveyor line, and under a pulley on the carriage. This rope is attached by a "knock-off hook" to the superstructure of the vessel, and rests in a "saddle" on the shear-head, whence it leads through the carriage over pulleys at the head of the foremast and mainmast of the collier, and runs on astern several hundred feet into the sea.

To the end of this rope a drag or sea anchor is attached, made of canvas in the form of a cone. This sea anchor is selected in reference to the speed at which the ships are to travel. In a smooth-water test, speeding at 6 knots, a drag 7 ft. in diameter at the base was used. During the rough-weather trial, the same anchor seemed to give the required tension at 5 knots.

The sea-anchor line is to support the carriage, when empty, on its return to the collier. It permits the conveyor line to be slack, and prevents the overturning or twisting of the carriage. Doubtless at times it helps also to support the load in transit across, but instantaneous photographs taken during the transit of the load show the sea-anchor line slack, thus demonstrating that the tension device on the conveyor line is sufficient to keep the load above the water during transit.

The tests which were made by a Board of United States Naval Officers showed that from 20 to 25 tons of coal per hour could be delivered from the collier to the vessel even when a moderate gale was blowing. The towing vessel, which in this instance was a United States battleship, consumed from 3 to 4 tons of coal per hour. Consequently the amount actually received into the bunkers ranged from 16 to 20 tons, which would be an average of 375 tons in twenty-four hours. It is claimed that such a low speed would not be necessary in regular service, and that the vessels might proceed at a speed of from 8 to 10 knots an hour if desired. However, the consumption of coal on the towing vessel would be largely increased unless the collier could proceed under her own steam. There is a danger, however, that the proper distance to be maintained might then be lessened, whereupon the cable would sag, and thus cause a cessation of operations.

While one of the principal advantages claimed for the system is that a battleship or merchant liner can take coal on a voyage without the necessity of entering the harbour, thus saving time, the process of transferring fuel can also be thus carried out with a minimum of hand labour. One man is required at the hoisting engine, which is very similar to the steam winch now used for transferring cargo on board the large merchant steamships. A squad of twenty men is required in the hold of the collier to fill the bags and deliver them to the deck, while another squad of from fifteen to twenty transfer the bags to the lift. But one man is ordinarily required to do the overhead work, and he is stationed in the trestle-trees of the collier; but for greater safety, two men are employed when the weather is rough and the ship is pitching heavily. The only hands who are required on the receiving ship are stationed at the top of the platform or shear-head to empty the bags into a canvas shoot and return them. There is, of course, a force of bunker trimmers in the hold. In coaling the battleship, it was found that the loads

could be transferred at the rate of one a minute without great difficulty, although the rate of loading was somewhat slower, the average being 3 or 4 tons per hour less.

The experiments which were conducted by the American Navy with this system aroused such interest that a number of American shipowners are considering the idea of utilising the apparatus for supplying coal to liners at such points in harbours where the water is too shallow to admit of placing the fuel on board their ships when loaded by the usual methods. It is understood that further official trials are to be made with a view to supplying victuals as well as the necessary coal supplies while at sea.

The matter was then taken up in England by the late Temperley Transporter Co., who, in co-operation with Spencer Miller, and without changing the original idea, have paid great attention to the details of the scheme, making various improvements with undoubted success.

The diagram, Fig. **471**, serves to illustrate the general principle involved. The collier is in tow of the battleship, being drawn by two hawsers, which are secured along the stern and to the collier well back from the bow.

There is every reason to believe that this apparatus will be an ultimate success, provided that the coal can be conveyed in sufficient quantities, which appears now to be the only difficulty, although portions of the apparatus are still in the experimental stage.

The principle of coaling at sea under way can hardly be considered as established

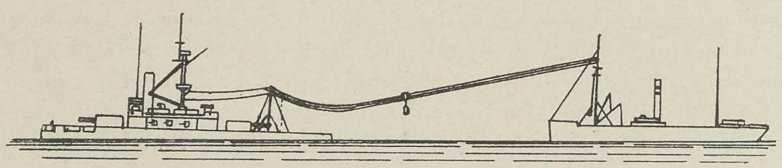


Fig. 471. Diagram showing the Temperley-Miller Plan for Coaling at Sea.

by the comparatively few experiments already made. It is to be tried off and on for a year or so with various battleships and cruisers, but the final official adoption of the scheme may, however, be considered certain with the above proviso, because of the strategical advantages involved.

The difficulties which have been mentioned bear out Lieutenant Bell's misgivings as to coaling from broadside. It is, however, not unlikely that, with adequate means to keep the ships apart, broadside coaling will be neither impossible nor impracticable. One of the latest schemes brought forward is that of Mr A. C. Cunningham, civil engineer in the United States Navy, and Mr William Seaton, of the C. W. Hunt Co., of New York City, by means of which it is alleged that broadside coaling from ship to collier can be effected with impunity. The vessels are kept apart by a current of water pumped from one ship against the other either by special pumps, or by the use of existing bilge pumps. The lashings will be kept taut by means of water jets which are the equivalent of elastic struts. These jets take the place of the fenders, which were, owing to their unsatisfactory work, the cause of the abandonment of broadside coaling. Any breakdown to the pump or pumps might, however, prove fatal to the success of this scheme.

Fig. **472** represents the Spencer Miller marine cableway, as used for coaling vessels at sea, and shows the U.S. battleship "Illinois" receiving coal from the collier "Sterling"; in this instance the operating winches are placed upon the battleship.

Fig. **473** shows the adaptation of the Spencer Miller method of coaling ships at sea

as used by the Lidgerwood Manufacturing Co. The Russian battleship "Retvizan"[1] is here shown receiving coal from the cruiser "Asia" in the Baltic Sea. The "Retvizan" is equipped with a marine cableway operated by electric winches. This equipment was

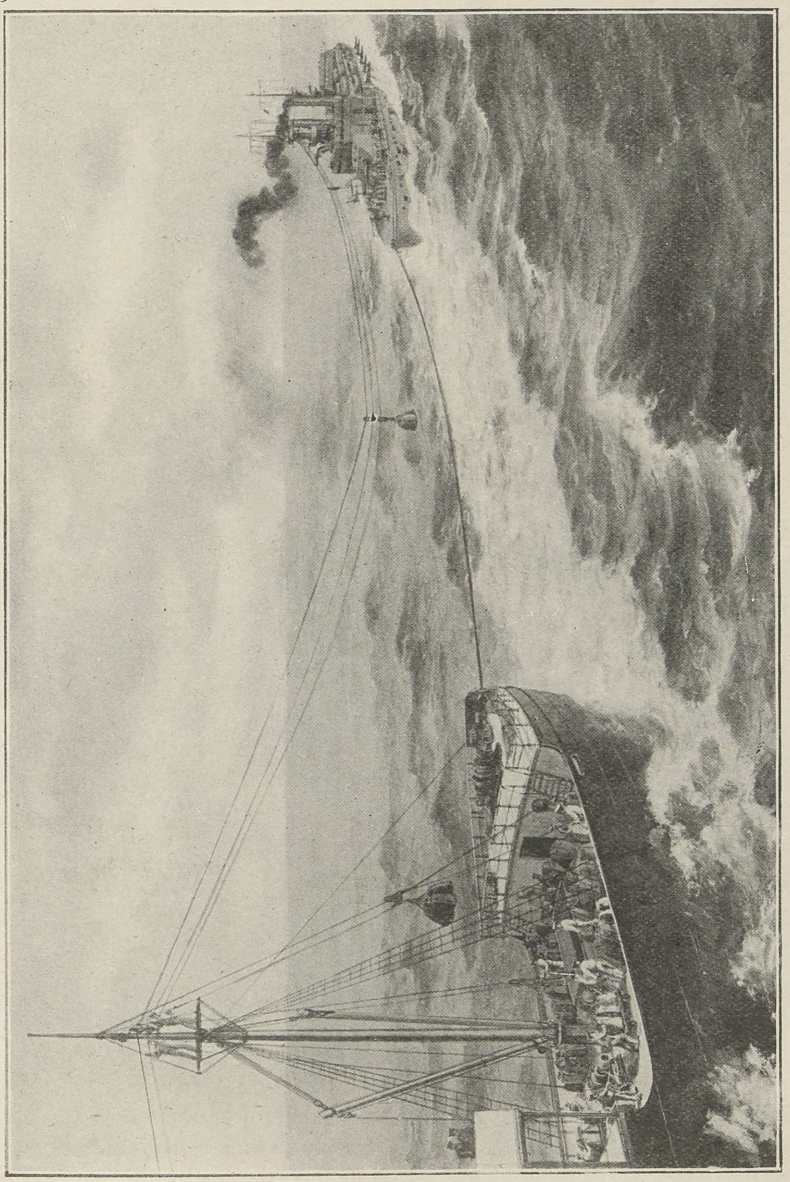


Fig. 472. U.S.S. "Illinois" receiving Coal from the Collier "Sterling."

put on after the ship was constructed. The electric winches built are of limited power, owing to want of space, and it is not contemplated to handle more than $\frac{1}{2}$ ton of coal at a time. After the tests were completed, Captain Stchensnovitch, commanding the

[1] This is the ship so heavily torpedoed during the Russian and Japanese War, and finally sunk at Port Arthur, December 1904.

"Retvizan," in a letter of congratulation to Mr Spencer Miller, the inventor, wrote as follows: "Witnessing this last success, I am sure that your system of coaling at sea will be adopted by all the navies of the world. . . . The Trial Board reached the conclusion that the marine cableway works very satisfactorily, and is well worth adoption for general use on board war vessels."

During the Russian-Japanese War ten of the largest battleships and cruisers of the Baltic Fleet were fitted with marine cableways similar to that installed upon the "Retvizan" to enable the fleet to coal at sea in their journey to the Far East. These

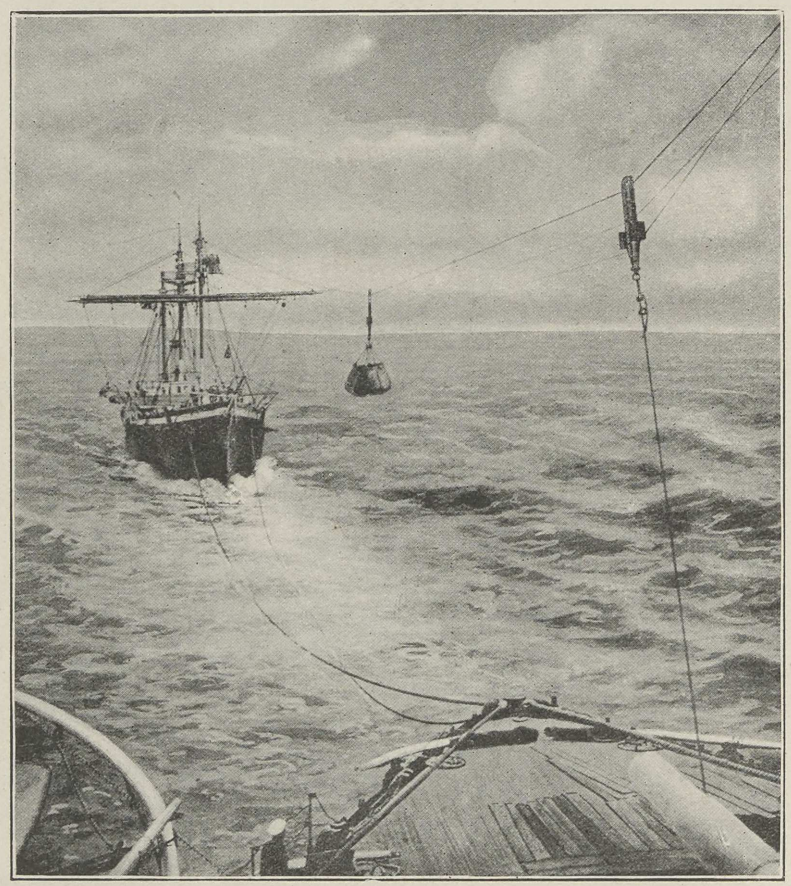


Fig. 473. "Retvizan" receiving Coal from the Cruiser "Asia."

cableways permit the ships to be 300 ft. apart in a smooth sea, and 800 ft. apart in a rough sea; at this distance, however, the loads have to be reduced to half a ton.

G. Lene's Plan to Keep Ropes Taut.—His method to take up the slack of the rope, and pay it out if necessary, is as follows. The conveying rope descends from the mast-head of the coal-receiving ship over an apparatus resembling a hydraulic cylinder with plunger and multiple sheaves, similar to that used in manipulating lifts, except that it is for compressed air. After the rope has passed over the sheaves of this apparatus it ascends again to the mast-head, and returns to the winding engine of the collier. If the distance between the ships is reduced the plunger of the pneumatic

device is forced out, which separates the multiple sheaves and thereby takes up the slack, and in the reversal of conditions the plunger is driven back in the cylinder by the extra tension, and the necessary extra length of rope is paid out. The apparatus is capable of keeping the rope at the same tension between the limits of the maximum and minimum distance between the vessels. There are obvious, if not serious, objections to this, viz., that the rope must pass over eight or twelve comparatively small sheaves, which is not good for the rope, and also adds to the driving power consumed. Such a coaling appliance has been experimented with in the German Navy, and found capable of transferring 50 tons of coal per hour.

Latest Developments.[1]—Considerable success has attended the experiments under the Navy Department of coaling at sea, the latest demonstration being with an improved type of the Lidgerwood-Miller marine cableway. In the latest experiments, which were conducted as an acceptance test of the contractor's equipment, the naval collier "Cyclops" was used in conjunction with the U.S.S. "South Carolina," and the test was conducted on Saturday, 12th April 1913.

The contract of the Navy Department with the builders of the system called for a delivery of 480 tons of coal in a period of eight hours. The mechanism was operated for six hours under most unfavourable conditions of weather, and was pronounced a success. The maximum amount of fuel transferred within an hour was 83 tons. The test was conducted for four hours, or long enough to convince the naval board that the system would answer all the purposes of the service. The transfer of coal from the "Cyclops" to the "South Carolina" at sea in a driving rain, with the collier rolling 20°, was preceded by a dock trial. The test was observed by a board composed of Captain Thomas Snowden, in command of the "South Carolina"; Naval Constructor L. B. M'Bride, of the Bureau of Construction and Repair; and Lieutenant Halsey Powell, of the U.S.S. "South Carolina." Under this improved system of coaling at sea all of the gear is installed on the collier.

The plant includes an automatic tension engine, and even the mast necessary to erect on the coal-receiving ship is carried, when not in use, on board the collier.

In order to attach the load to the cableway carriage all the lines are hauled down to the deck, and a group of bags hooked on. The haul-down gear is then released and the conveying engines set in motion to convey the load. This load travels at very high speed, attaining a maximum of 3,000 ft. per minute. The load carriage is provided with an automatic tripping device. When the load arrives over the deck of the battleship it collides with a bumper block which actuates this automatic trip, thus releasing the load. Before the load is released the cableway is let down at the battleship so that the bags of coal are dropped only a few feet.

The regular winches and regular gear of the battleship are used to lower the bags to the battleship's deck, making it possible for a collier to tie up to any battleship and coal. The fuel is delivered at the rate of five or six bags, carrying 700 to 800 lb., on each trip, or a total delivery of 3,500 or 4,000 lb. The rate of delivery is from 50 to 60 secs. in a distance of 500 ft. between the collier and the battleship, which in the recent test were steaming at the rate of from 7 to 8 knots. The maximum amount of coal transported within an hour during this test was 83 tons.

On board the battleship some difficulty was encountered in taking away the coal from the forecastle on account of the driving rainstorm. The cableway was frequently stopped in its operation to enable the men on the battleship to clear away the coal. In

[1] From the "Army and Navy Register" (Washington), 17th May 1913.

spite of these difficulties, however, more coal was transferred than ever before, and justified the opinion, freely expressed by naval observers who witnessed the test, that the cableway was capable of a delivery of 100 tons per hour. It was also observed that the best record was in the last hour of the test, which showed that the machine did not have a fatiguing effect upon the men.

An important feature is the automatic tension engine, designed and constructed to meet the demands of the Navy Department. This engine, in connection with the marine cableway, has supplanted the sea anchor. It maintains the supporting cable at the requisite tension and deflection independently of the speed of the ships. After the cableway is set up and the engine adjusted for the required tension it needs no further attention, other than oiling, throughout coaling operations.

The automatic tension engine is a single drum horizontal engine, having 10-in. by 10-in. cylinders, and capable of maintaining a strain of approximately 3,000 lb. The drum is 20 in. in diameter by 23 in. face, and connected to its shaft through the medium of springs allowing a limited rotation of the drum on the shaft. Changes of tension in the rope cause this drum to rotate to a limited extent. This motion of the drum operates through the medium of a nut, screw, or lever; a controlling valve regulates the amount and pressure of the steam supplied to the cylinders. These changes in tension in the rope are communicated to the steam supplied to the cylinders in such a way that the rope will be paid out or taken up as demanded. That is to say, an increase in tension causes a reduction of steam pressure, permitting the rope to overhaul the engine and restore the tension to normal, while a reduction of tension causes an increase of steam pressure, thereby causing the engine to take up slack and thus restore the tension.

The conveying ropes for moving the load along the main cable are operated by two automatic tension engines of smaller power than those for the main cable. These are high speed engines, having the spring drum mounted directly on the crankshaft. One of these engines operates the in-haul rope, the other the out-haul rope, pulling in opposition to each other; the automatic control compensates for the lengthening and shortening of the conveying lines as in the main cable tension engine. In addition to the automatic control, the controlling valves can be manually operated.

The manual operating gear of the two engines is interconnected and controlled by a single lever. When this lever stands vertical (mid-position) both engines have the same inpulling power, so that the load remains stationary on the cable. When this lever is moved in the direction in which the load is to travel the inpulling power of the engine controlling motion in said direction is increased, while the inpulling power of the other engine is decreased. In other words, one engine overhauls the other when the load is in transit.

In the test which took place on 12th April the tension of this engine was 17,000 to 18,000 lb., and never showed the slightest disposition to slacken nor unduly tauten the main cable.

Oil Fuel Bunkering at Sea.—The automatic tension engine is the essential element in the marine cableway; it can also be used for supporting an oil hose between two ships when fuel bunkering at sea. The desirability, in a heavy sea, of this automatic tension engine to maintain a uniform tension in the supporting line from which the hose is suspended at frequent intervals will be readily appreciated.

CHAPTER XXVII

MONO-RAILS AND TELPHERS

NARROW gauge railways in industrial establishments are being rapidly superseded by the more convenient mono-rail, whilst the telpher is making a slow but sure inroad into works of greater magnitude.

MONO-RAILS

Two-rail surface tracks on which the vehicles are propelled, either manually or by horses or locomotives, are very much in the way of other traffic, especially in congested passages and factory rooms. The overhead mono-rail from which the vehicles are suspended occupies space which is of lesser value, and in many cases conditions obtain which involve the absolute necessity of transport at a considerable height from the ground, and there is a good deal to be said in favour of suspended overhead traffic. Some of the introductory remarks in the chapter on Ropeways also apply here. Among the obvious advantages of this system are the following: mono-rails being out of the way of other traffic, remain clean and unobstructed, and therefore offer less resistance to the movement of the vehicles, and the latter, having generally only two wheels, run more easily than four-wheeled receptacles, as the friction is reduced. The condition of the ground, whether even or otherwise, does not influence the construction of a mono-rail system, and the floor is unobstructed by rails, turntables, etc., whilst the vehicles can either be suspended sufficiently low for a man to push them whilst walking on the ground, or so high up that they do not interfere with other traffic, or with obstructions, such as plant or machinery, on the ground.

The track may be supported from the ceiling or other part of the building, or from constructional iron or wood work. It may negotiate sharp curves and gradients, adjusting itself to most requirements. In small installations the track may be a light rail of selected section, or may consist in its simplest form of a flat iron bar, the vehicle being suspended from a two-wheeled trolley upon these rails. If the point of suspension is too high above the ground for manual propulsion, cable or electrical haulage may be resorted to, or the line may be so laid as to work by gravity if it is only required to transport goods in one direction. For large installations the rails are of more substantial section and the supporting girders are correspondingly heavier, a suspended locomotive being frequently used to pull the train of vehicular receptacles.

TELPHERS

The ideal form of mono-rail traction is the telpher; the name signifies the application of electricity as motive power to vehicles on a mono-rail. (Telphers are, however, driven by oil or petrol motors, where electric energy is not available.) The credit of the invention of the telpher is due to Professor Fleeming Jenkin, M.Inst.C.E., who died in 1885. The name was chosen by him, and is derived from the Greek *tele*—far, and *pherein*—to bear, to carry. A telpher consists of a suitable bogie or trolley, running

generally on a single rail and supporting in a suspended position a receptacle to carry the load. The bogie or trolley is fitted with and propelled by an electro-motor which collects its current by a small trolley pole from the single, double, or triple overhead conductors, arranged alongside and supported on the track structure.

There is no limit to the distance of travel, and the telpher may either be a man-telpher, that is, accompanied by an attendant, who from his cab starts, stops, lowers, or dumps his load and returns for a further one; or it may be so arranged that all movements are automatic, so that the telpher with its load, when released at the loading terminal, travels automatically to a predetermined position, dumps its load and returns empty to the starting point for a new load. Some of the man-telphers are fitted with one or two electric winches to pick or lower loads at any point on the line, and in order to save labour some are so constructed that the attendant can lower himself or rise with the load to detach or attach it on the ground. Such appliances are made by the Link Belt Company.

Automatic telphers have been perfected to an astonishing degree. They are provided with a perfect automatic block system, the passing telpher establishing its own electric connection, so that no second carrier can enter the line within a predetermined distance of that in front, and if one is stopped for some cause or another all the succeeding ones will stop at the same distances apart. To give a full description of the intricate electrical fittings would occupy more space than is available.[1]

Telphers for large and bulky loads are fitted with a trailer, or double telphers are used, either direct connected or geared; the latter is generally the case where an excessive gradient has to be negotiated. The speed of travel varies from 4 to a maximum of 20 miles per hour, according to the nature of the load, the capacity required, and the gradient of the track.

The track may lead over buildings and across rivers. It is sometimes bracketed to the sides of buildings, at others supported on the open land on Λ-brackets. The load can be switched on to branch lines over track switches, which the telpher man himself operates from his cab. The telpher man can also reverse his machine at will, open and close doors, run the entire length of the storehouse or shop, and pick up loads without any previous preparation. In and out handling from the works is equally well performed by the same telpher, and there is no limit as to distance.

Mono-rail telphers have been more particularly applied to gas and electricity undertakings for the purpose of handling the large quantities of coal and coke which have to be continuously dealt with in such works, and are employed in nearly all the largest gas and electricity works in this country, also in some on the Continent. These appliances seem to be particularly applicable where the duty is heavy and continuous, and where the route to be traversed is anything but in a straight line, and also where branch runs have to be made off the main road.

These telpher machines are usually designed to travel upon a single rail, which is generally bolted to the top flange of rolled steel girders of suitable depth and flange width—according to the span between the available supports. There may be as many curves and branch turnouts as are necessary—the design of the machines being such that any reasonable curve can be negotiated with ease and safety.

They have been built for dealing with loads up to 4 tons, but there is no reason why heavier loads should not be dealt with if the necessity arises.

[1] Automatic telpherage is fully dealt with by A. J. Wallis-Tayler in his book, "Aerial or Wire Rope-Ways"; also by Dr P. Stephan in "Die Drahtseilbahnen," an English translation of which is under preparation.

The lifting speeds range from 60 ft. per minute with heavy loads, to 200 ft. per minute with light loads with a long lift. The travelling speeds may be anything from 500 to 1,000 ft. per minute, according to the nature and length of the run.

Telphers by Strachan & Henshaw, Ltd. (Figs. **474** to **479**).—With these telphers the whole of the load is carried on four manganese steel wheels, which are built in pairs into swivelling bogie trucks, the trucks being each pivoted independently into the main hoisting frame by universal joints. These universal pivot joints are practically frictionless, and do not depend for strength upon any pin connection. The load is directly supported solely by heavy mild steel interlocked stirrups, which have ample freedom and flexibility. The result is that all twisting strains liable to be set up, and due to the surging of the load, or sharply negotiating the curve in the track, are entirely eliminated from the main frame and bogies, and from the swivel connections between them. The four travelling wheel axles are mounted in roller bearings which are built on to the two steel trucks.

The bogie carries the whole of the travelling mechanism complete with the motor. The motor is connected to two travelling wheels by a silent link chain, which forms a triangular drive between the motor pinion and the two spur wheels keyed directly to the two wheel axles. The motor is so mounted as to permit the tightening of the driving chain. The second bogie carries the other two ungeared wheels, and also the rear C-hanger for supporting the outer end of the hoisting frame. The C-hanger is a solid mild steel forging, and is freely pivoted in the wheel track, as well as at its connection to the main frame. The two bogies are connected together above the track level by a substantial coupling bar with pivoted ends.

The hoisting gear, complete with motor, is built into a rigid frame composed of rolled steel or H-channels, all parts being carefully balanced about the centre line, so that when it is suspended from the bogie trucks the whole frame hangs plumb and level with its centre of gravity directly under the centre of the track.

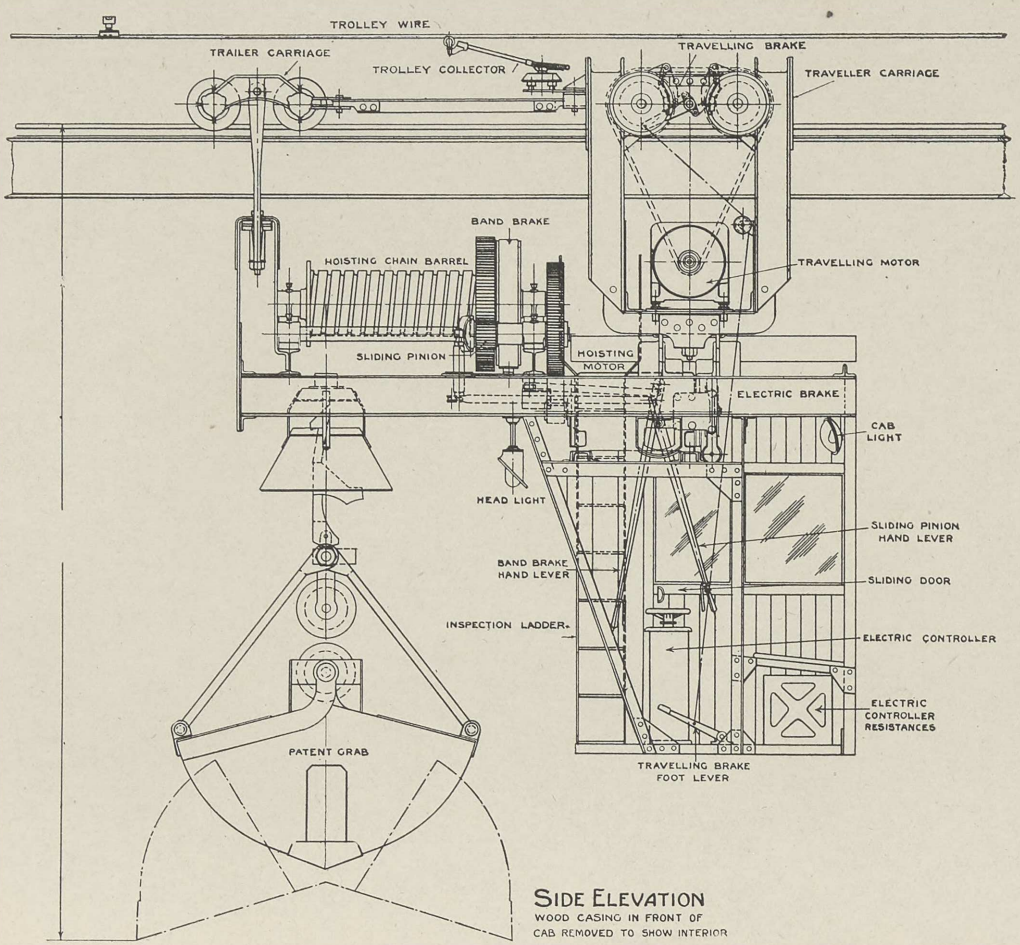
The hoisting barrels (twin drums for long loads, and single drums for grab or bucket) are placed with their axes parallel with the track, and so disposed laterally that the centre of the rope or chains falls exactly in line with a vertical line through the centre of the track.

It will thus be seen that the whole load is perfectly balanced about the centre of the track, and is all applied directly on the centre of the running rail; this ensures smooth and steady running at high speed, with a very small amount of wear and tear on wheels and rail.

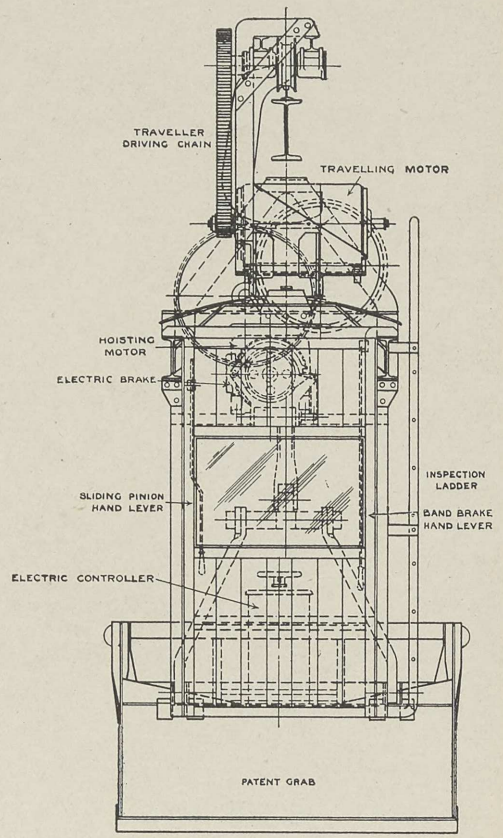
A cabin for the operator is attached to the under side of the main frame; a seat is always provided for the driver, and the controller brakes and emergency switch, etc., are all placed within easy reach. The starting resistances are also placed within the cabin as a rule, though sometimes it is found convenient to vary this arrangement. For working in the open or in dusty situations the cabin is boarded right up; for ordinary indoor work, however, the cabin is left open, with just sufficient guards to prevent the driver falling out.

The type of machine shown in Figs. **474** and **475** is generally used for conveying coal from barges to coal-store ground, or boiler-house bunkers, and any automatic grab or bucket can be used with it.

The telpher shown in Figs. **476** and **477** is generally adopted for gasworks duty. This machine has been developed more particularly for the purpose of handling coke, hot or cold, from all types of gas retorts, horizontal, inclined, or vertical, and has been successfully applied for this purpose in many gasworks.



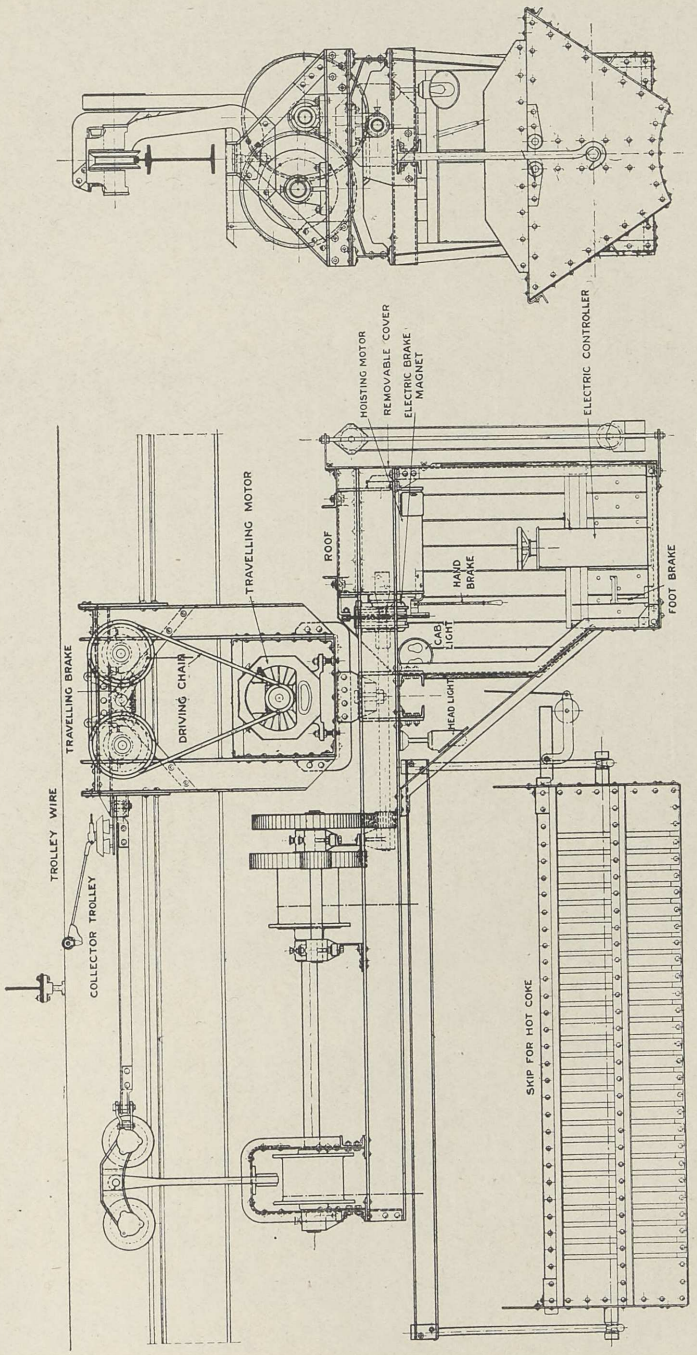
SIDE ELEVATION
WOOD CASING IN FRONT OF CAB REMOVED TO SHOW INTERIOR



END ELEVATION

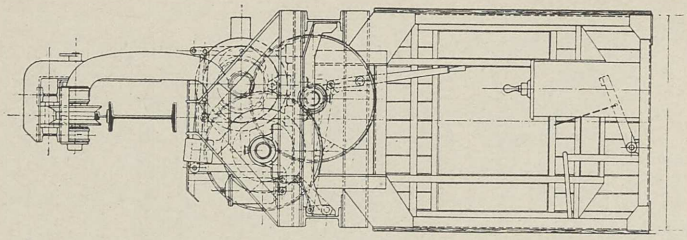
Figs. 474 and 475. Telpher for Conveying Coal from Barges to Coal Store or Boiler-House.

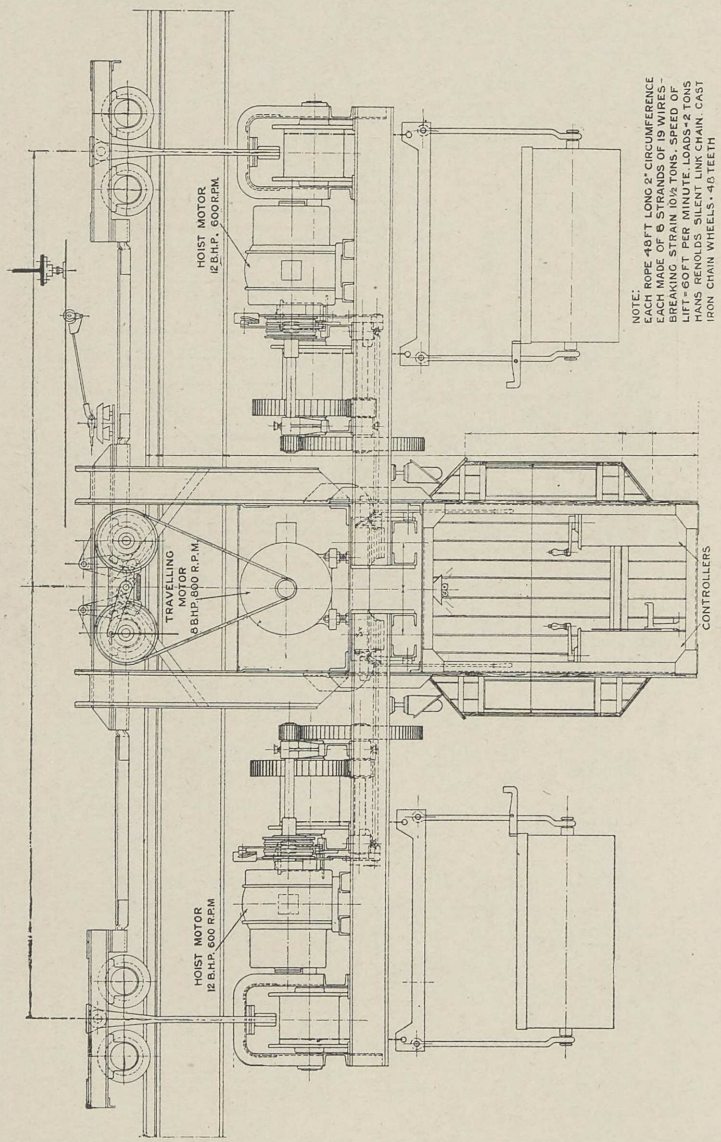
An arrangement, as shown in Figs. **478** and **479**, is adopted in smelting works, where



Figs. 476 and 477. Telpher for Handling Coke from Gas Retorts.

it is often found convenient to carry the load of ore and fuel at the same time, so that on each journey the machine makes, a properly proportioned charge may be carried to





Figs. 478 and 479. Telpher for Handling Two Skips.

the furnace. The same machine is also suitable for dealing with long loads, such as timber baulks or metal bars up to 30 ft. in length.

Automatic Telpher Installation by Adolf Bleichert & Co.—This interesting example is for a chemical factory, and is remarkable on account of the adaptability of the line to the existing condition. The raw material is unloaded from barges by means of a crane and grab, and transferred to a hopper from which the cars of the telpher are loaded. The cars electrically block each other automatically, and thus stop before the loading point until the preceding car has been dispatched, when they will automatically advance to be loaded. The raw material is carried to the stock shed as shown in Fig. **480**, where it can be automatically discharged at any desired point. Winch cars run on the same track to re-handle the material (see Fig. **481**). These lower the empty buckets to the ground level of the shed and pick up and carry the loaded ones to the factory where



Fig. 480. Telpher Conveying Raw Material to the Stock Shed.

the material undergoes the process of manufacturing. A ropeway with a total length of 5,000 ft. was also installed here for the purpose of handling the finished products. The cars for this are filled at the loading point whilst suspended on a mono-rail, and run under electric power to the foot of an inclined section of the track ; here they are drawn up to the height of the rails in the roof of the shed by the rope, to which they couple automatically, and again release on reaching the top (see Fig. **482**). The telpher cars then cross the factory yard on a long elevated bridge at the end of the finished product storage shed (Fig. **483**), in which they travel along three tracks connected by switches. As with the line for raw material already described, the discharge can here also be effected automatically at any desired point of the storage shed. After this the telpher cars again return automatically to the loading point, and the process is repeated.

A telpher skip, with bottom door discharge for handling coke, also built by the same makers, is represented by the diagrams, Figs. **484** and **485**. It is considered that

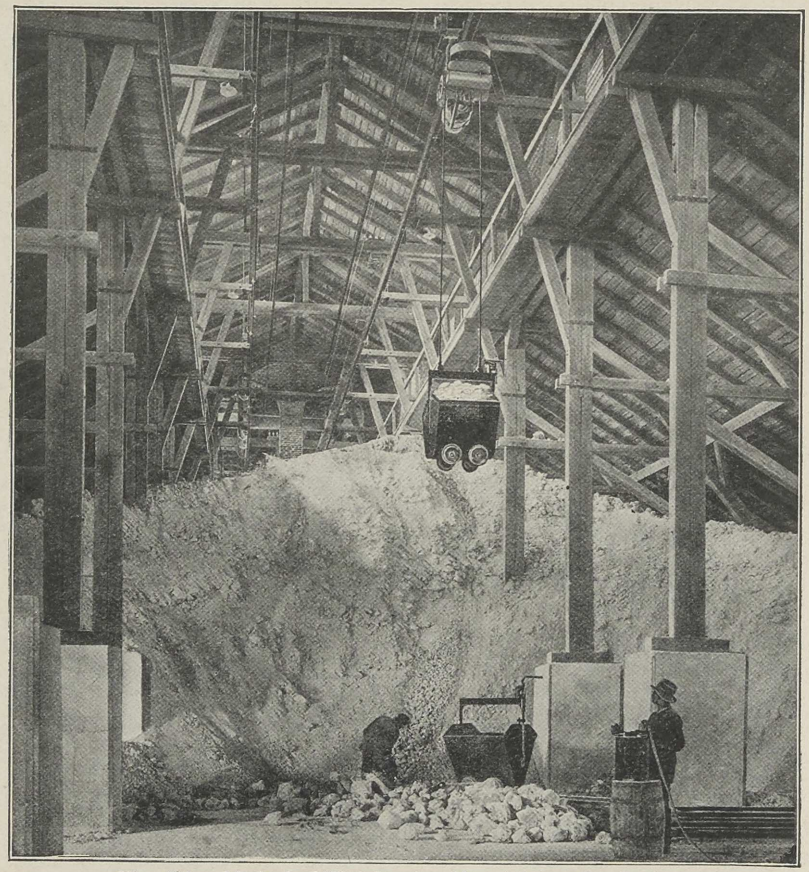


Fig. 481. Method of Withdrawing Material from Stock Shed.

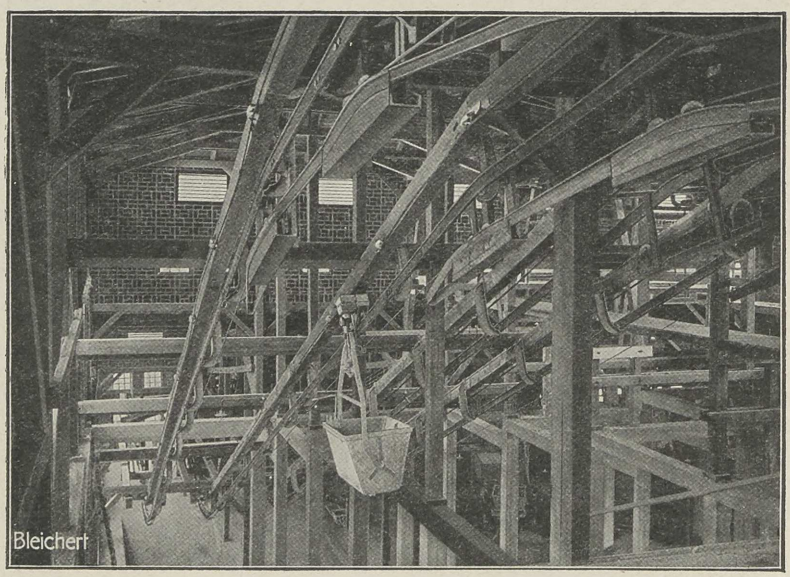


Fig. 482. Telpher Car Negotiating an Incline.

such a mode of discharge is less likely to injure coke or coal. The same appliance is made with and without a winch; in the former case the skip is lowered on to the coke or

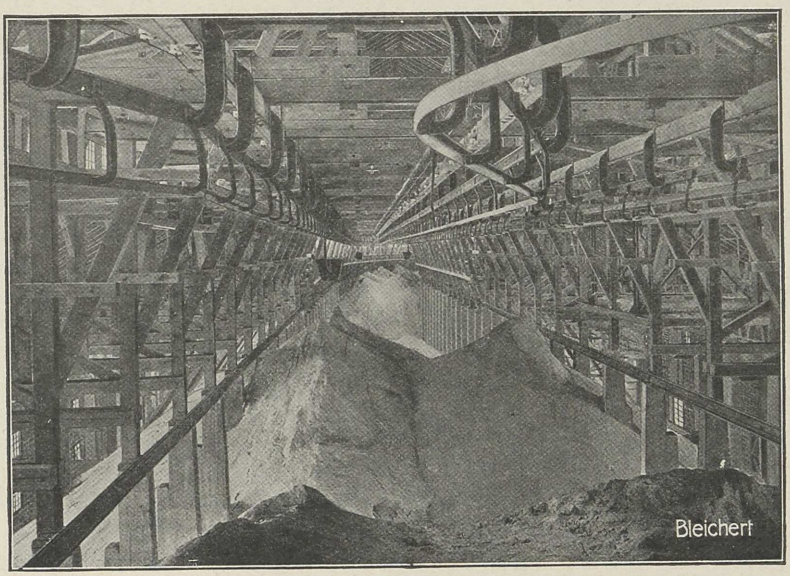
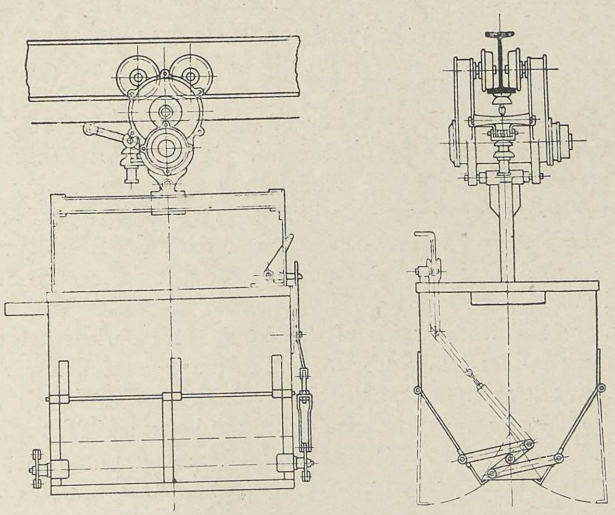


Fig. 483. Telpher Cars Delivering into Storage Shed.

coal heap before the bottom doors are opened. The arrangement of the locking of the two doors is such that they are automatically released on the lever at the upper end coming in contact with the tripper.



Figs. 484 and 485. Telpher Skip with Bottom Door Discharge.

CHAPTER XXVIII

HANDLING RAW MATERIAL IN CONNECTION WITH BLAST-FURNACES

FURNACE HOISTS

Ordinary elevators are not serviceable for feeding blast-furnaces, the ore, limestone, and coke being too uneven in size, and each of these three materials must be handled separately, and in different proportions, and in addition to this the feeding must be more or less intermittent; all these conditions call for an elevator of a different type from the ordinary. The older appliances were ordinary platform lifts, similar to those used for passengers. The ore, after being weighed in tip trucks, was pushed on the lift and taken to the top of the furnace, and then tipped into it.

Modern furnace hoists consist of a skip on wheels, which is raised on rails up a sharp incline to the top of the furnace, into which it automatically discharges its load.

These furnace hoists or single-bucket elevators, not being automatic and continuous, require some hand labour, however little it may be, for the purpose of filling the bucket at the lower terminal; the discharge at the other terminal generally being automatic. A single-bucket elevator will do excellent service where it is necessary to raise occasional loads to a considerable height, as for the service of blast-furnaces. For this purpose elevators are almost universally used, and generally go under the name of furnace lifts or hoists. It is rarely now that one meets with the old-fashioned vertical hoist or lift. There are certain accessories to modern furnace hoists the use of which are calculated to greatly increase their efficiency. For instance, the opening of a slide is all that is necessary for the purpose of filling the buckets when they are ready for a charge, and it is in these accessories (on which the efficiency of the elevator more or less depends) that a great many ironworks are still very far behind. It is not an unusual sight to see the iron ore heaped up with a shovel and filled into small gauge railway trucks which are pushed by hand to the lift, an operation which requires a large staff of men for loading and moving the wagons to and from the platform of the lift. Even if a modern elevator has been introduced, the full benefit will not be felt until the appliances conveying to it are automatic and mechanical.

Therefore, in erecting installations of this kind, more or less automatic, it is most important that the whole plant should be worked in such a way as to be one mechanical installation divided into two sections, namely—

(*a*) The section for conveying the material to the hoist, and (*b*) the hoist itself.

It was in the United States that mechanical appliances for this purpose were first introduced, and many of the larger up-to-date furnaces are now fitted with a device of this class. It is essential that such elevators should be built in a very substantial manner, as breakdowns would stop the working of the furnace, with possibly disastrous results. The elevators are mostly so arranged as to obviate manual labour at the point of delivery at the top of the furnace, and the material, be it iron ore, limestone, or coke, is taken up a skip-load at a time and emptied automatically into the furnace. It

is also essential that the feeding device which admits the material into the furnace should be so arranged as to distribute the material evenly, and at the same time to do so without allowing the gas to escape.

The general construction of these elevators consists of an inclined iron-trussed bridge upon which the rails for the ascent and descent of the trucks are laid, whilst the hoisting gear for the manipulation of the trucks is laid on the ground level. The rails, when they reach the upper terminus, are generally bent into a more or less horizontal position, so as to tilt the truck for unloading purposes. In addition to this, the back wheels are supported either by rails that are bent at the terminus, or else they have a different diameter on either side of their flanges, so that during the ascent the truck runs on its normal wheels, whilst at the terminus the larger diameter wheel engages with short lengths of extra rails and thus assists the automatic clearance.

To balance the dead weight of the bucket or car a counterweight may be used, or a double track may be employed, so that the empty car will descend on the one track whilst the loaded car is being drawn up on the other. In such a case the distributing hopper on top of the framework must have an elongated form, so as to take the charges alternately from buckets on either track.

Another plan which has been recommended is to lay the two tracks above each other, and to run one car on the upper and the other on the lower rails. The two cars will pass each other at about the centre of the bridge, where there will be plenty of room for them to clear each other. At the terminals, that is to say, at the loading and discharging points, both will be in a suitable position for filling and discharging.

The difference in the capacity of the cars, of course, depends a great deal on the system on which the furnaces are worked and on their capacity. In the Brown Hoisting Machinery Co.'s apparatus the capacity of the carriers is generally 2 tons of ore or 1 ton of coke, while the cubical capacity is 110 ft., and the hoisting speed 300 ft. per minute.

The time occupied in raising the load to a furnace 80 ft. high would be 20 secs., discharging it takes 4 secs., and returning it 10 secs., or 34 secs. altogether for each turn.

The speed at which the bucket travels is 5 ft. per second, which, if no counterweights are used, would require a motor of about 100 H.P.

Another estimate is for a motor of about 150 H.P. for a truck of about 150 cub. ft. With a car of a capacity of 240 cub. ft., intended to serve a furnace of 550 tons daily capacity, the service would require ninety charges (which would each take two truckfuls of ore and lime and as many of coke) in twenty-four hours; therefore the car would have to make 360 ascents, and only four minutes could be given to each turn, including the filling of each truck.

Furnace Hoists of the Brown Hoisting Machinery Co.—Fig. 486 represents a typical installation of a furnace elevator as designed by The Brown Hoisting Machinery Co.

The stock of iron ore, coke, etc., required for use during one day is kept in large silos or bins, constructed of iron and wood, at the foot of the elevator. The main stock pile is kept on the open ground in the store yard, and from this the silos are served with the material to be used immediately. The material which has been brought by rail or from a distant part of the works is conveyed along an elevated railway and down an incline into the store hoppers. The trucks which are used for this purpose are hoppered to both sides, and discharge their load through two longitudinal hinged doors on each side of the truck. One of these trucks can be seen in position on top of the silos in the illustration.

The details of a store yard must, of course, in a great measure depend on the conditions under which the material is received.

The bucket of the elevator receives its charge from one of the three hopper-bottomed bins. A weighing machine is provided so that a record of each charge can be kept. As soon as the truck is full it is hoisted, and its contents emptied into the furnace. The hoist is electrically driven, and the electro-motor is placed in a cabin shown in the illustration.

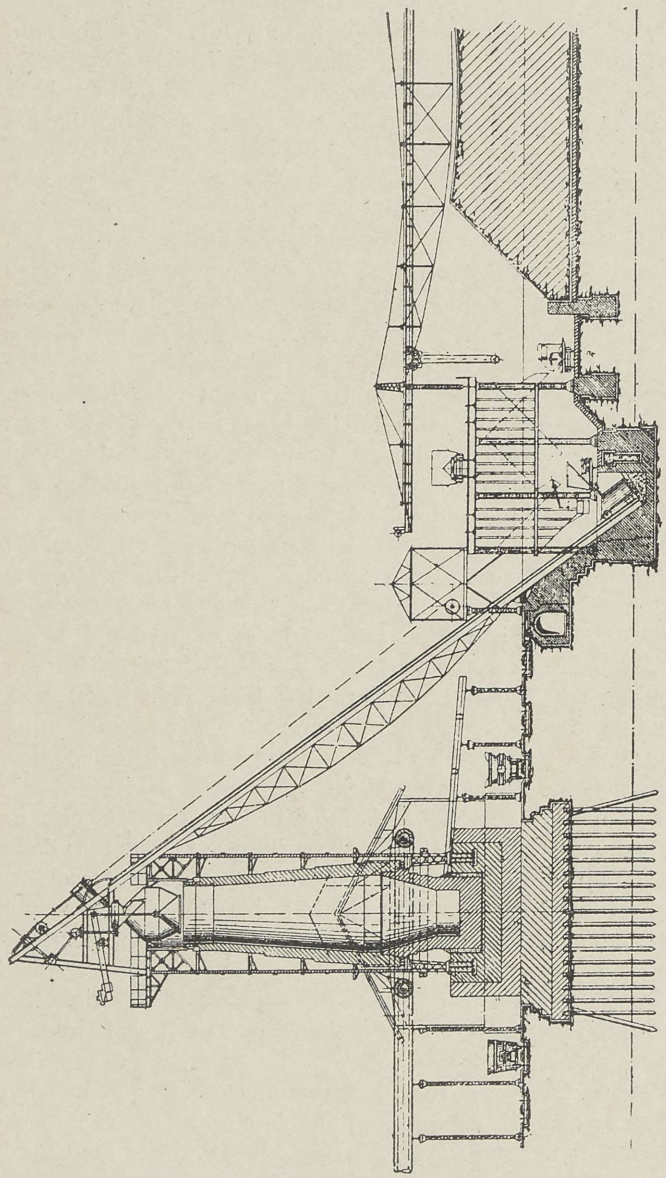
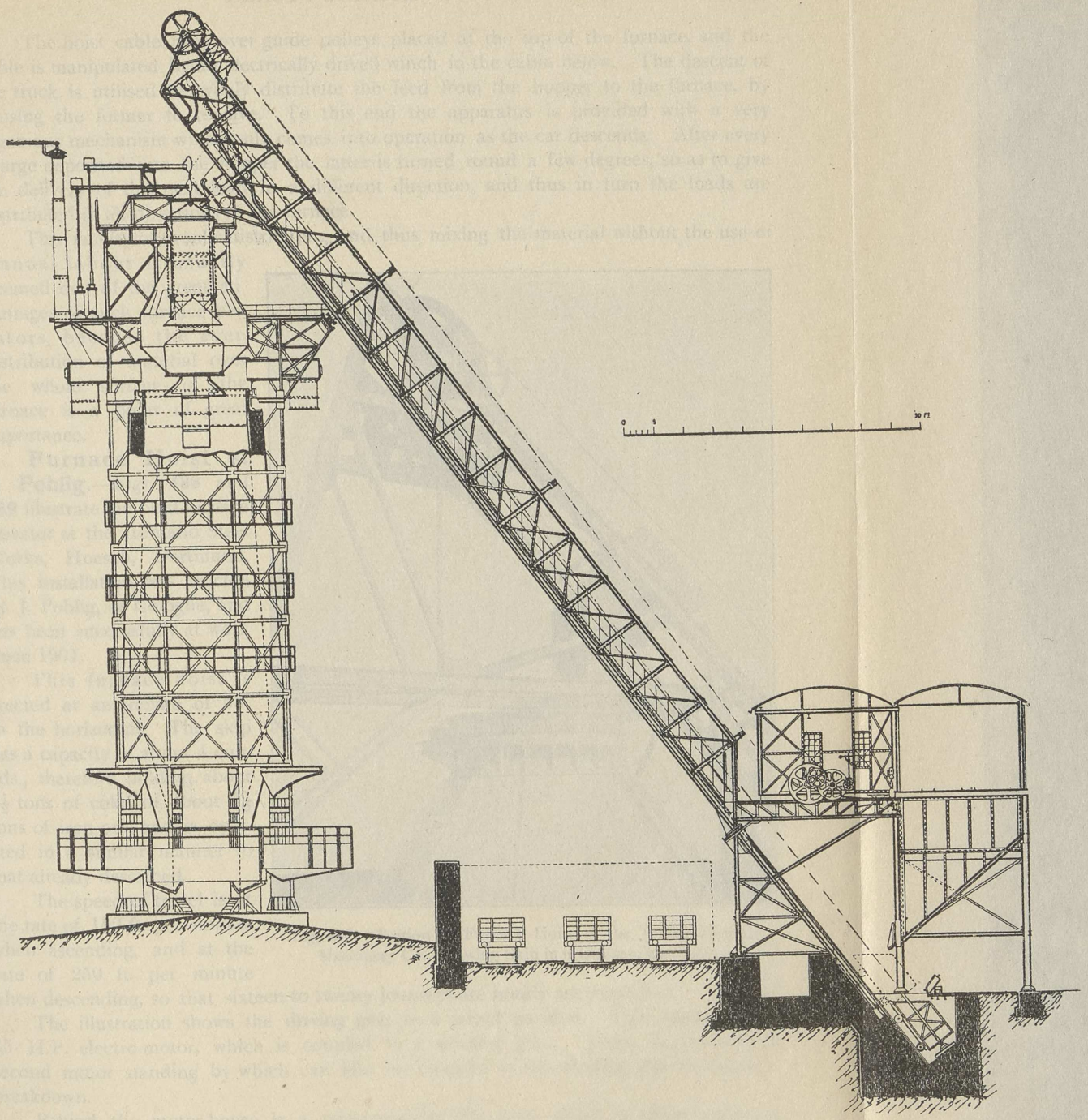
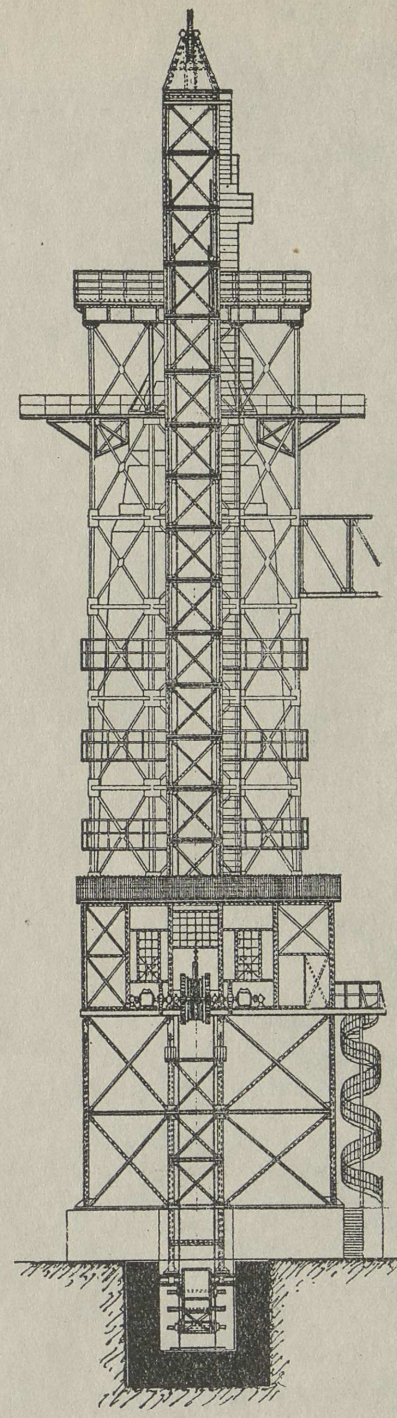


Fig. 486. Typical Furnace Elevator.

The emptying of the skip is effected in the following manner: The ordinary rails, on reaching the entrance to the furnace, are bent in a level direction so that the front wheels as soon as they reach this position proceed horizontally, whilst the back wheels, or rather that portion outside the flange, engage with a second pair of rails which are laid close to the ordinary track, and proceed in the same direction as the latter. The truck then rises until the floor of the skip has reached an angle of 45°, when it automatically discharges its contents, as shown in the illustration, where one of the buckets is depicted in the position of unloading.

Fig. **487** shows a portion of a similar installation in which the skip is approaching the furnace top. One of the rear wheels with flange in centre is clearly visible. In this case the rear wheels engage with two short lengths of rails which are slightly further apart than the main track, so that the rear wheels proceed in a straight line. The main rails have been bent over a short distance in a horizontal direction, which gives the bucket the unloading position shown in the illustration.





Figs. 488 and 489. Blast-Furnace Elevator at the Iron and Steel Works, Hoesch, Dortmund.

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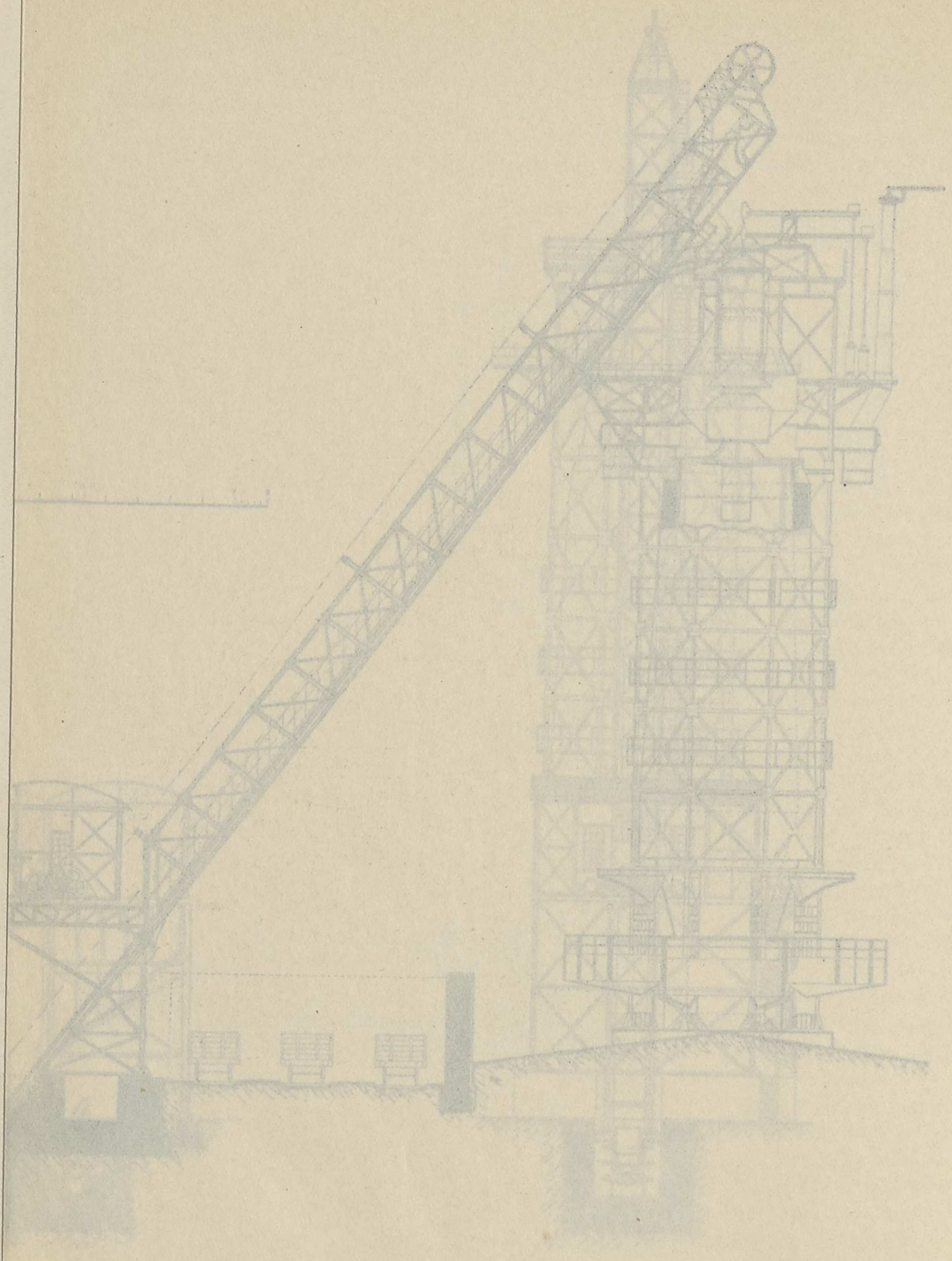


The hoist cable runs over guide pulleys placed at the top of the furnace, and the cable is manipulated by an electrically driven winch in the cabin below. The descent of the truck is utilised to evenly distribute the feed from the hopper to the furnace, by causing the former to revolve. To this end the apparatus is provided with a very ingenious mechanism which only comes into operation as the car descends. After every charge deposited into the hopper the latter is turned round a few degrees, so as to give the delivery of the next load in a different direction, and thus in turn the loads are distributed in all directions in the furnace.

This faculty of evenly distributing and thus mixing the material without the use of manual labour is usually deemed one of the great advantages of such furnace elevators, because the even distribution of material over the whole surface of the furnace is a point of great importance.

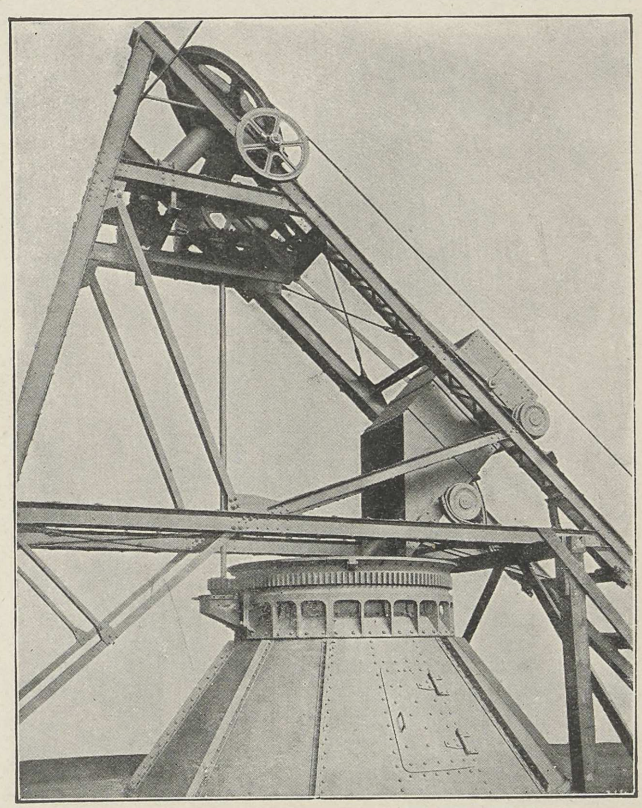


Fig. 487. Portion of Furnace Hoist of the Brown Hoisting Machinery Co., showing Skip in a Discharging Position.

Furnace Hoist of J. Pohlig.—Figs. **488** and **489** illustrate the blast-furnace elevator at the Iron and Steel Works, Hoesch, Dortmund. This installation was erected by J. Pohlig, of Cologne, and has been successfully at work since 1901.

This furnace hoist is erected at an incline of 53° to the horizontal. The skip has a capacity of about 4 cub. yds., therefore holding about $1\frac{1}{2}$ tons of coke, or about $3\frac{1}{2}$ tons of iron ore, and is operated in a similar manner to that already described.

The speed of travel is at the rate of 150 ft. per minute when ascending, and at the rate of 250 ft. per minute when descending, so that sixteen to twenty journeys are hourly accomplished.

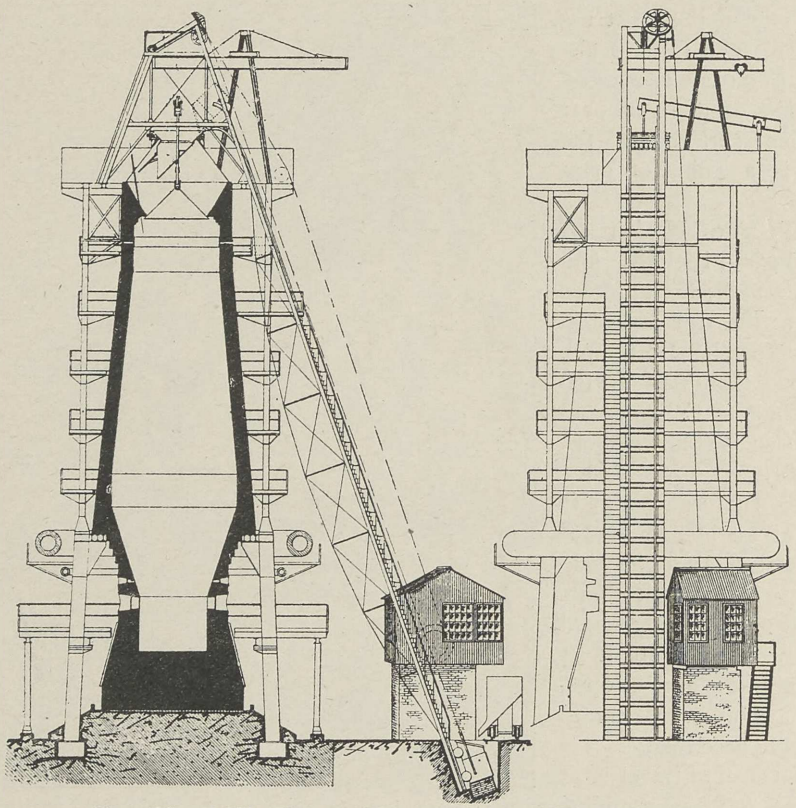
The illustration shows the driving gear in a raised position. This consists of an 85 H.P. electro-motor, which is coupled to a winding gear. There is, however, a second motor standing by which can also be coupled to the winding gear in case of a breakdown.

Behind the motor-house is a receptacle for the coke, which is either conveyed to it by means of narrow gauge trucks, or is brought by tipping trucks on the low level.

Furnace Hoist at Palmer's Shipbuilding Co.—One example of the American elevator applied to British furnaces is that illustrated in Figs. **490** and **491**, which

represent the Brown hoisting and automatic distributing gear applied to the new furnace of Palmer's Shipbuilding Co. at Jarrow.

So completely automatic is this arrangement that one man can completely control the hoist. The inclined structure is built entirely of steel. All the bearings of the rotating parts are of the dust-proof pattern, fitted with large and easily accessible oil cells. The mineral distributor is substantially built of cast iron, and is actuated by a pinion keyed on a shaft which, by a suitable gearing and clutch, is connected with the main hoisting machine, and this in such a way that when the bucket is ascending the clutch is out of gear. When, however, the bucket is descending, the clutch is thrown



Figs. 490 and 491. Furnace Hoist of the Palmer Shipbuilding Co., Jarrow-on-Tyne.

in gear, and turns the distributor several degrees. The proportions of the bucket are such that four full loads constitute a charge.

The capacity of the bucket is 120 cub. ft., and the hoist equipment is capable of handling 1,300 tons of material per day. The bucket is built of steel plates, elliptical in section, and is fitted with a false steel plate lining on the inside, so arranged as to be easily renewable.

The hoisting engine is of non-reversible type, with double cylinder, 12 in. in diameter, with 15-in. stroke, and is equipped with hand friction brake and a powerful friction clutch.

In order that the hoist operator may at any time be able to ascertain the exact

height of the burden of the furnace for the purpose of preventing under or over charging, four rods are let into the top of the furnace through suitable openings, and the rods are connected with dials situated in the hoist operating house, so that as the rods are lowered into the furnace they indicate the exact height of the stock.

Another indicator fixed up in the cabin consists of a graded dial connected to the bell by a light wire rope. Its gearing is such that a drop of 1 in. of the bell corresponds to a 3-in. pointer deviation on the dial. There is also an automatic indicator for

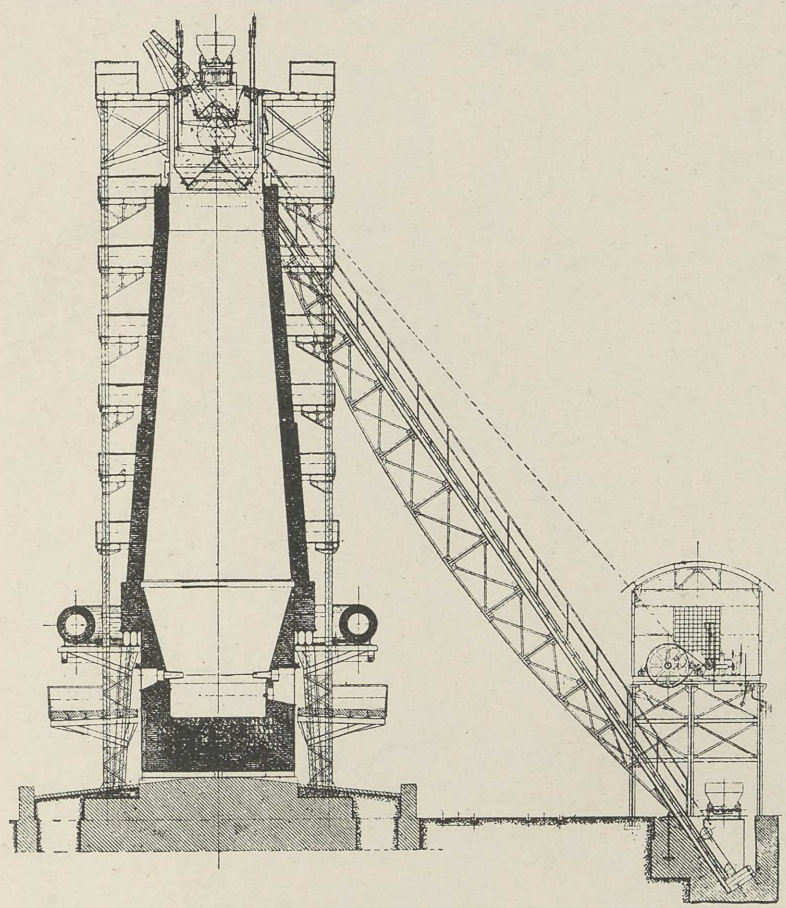


Fig. 492. Lürmann Furnace Hoist.

signalling the number of buckets from each charge, the latter being indicated by the hoisting drum. The dials of all the indicators are prominently placed in the operating house so as to be well within the view of the hoist attendant.

Lürmann Furnace Hoist.—Another modification of the inclined furnace hoist has been designed by Lürmann, of Osnabrück. In his opinion, it is a defect in the older types that, as the car is tipped, the coarser material is shot at one side of the hopper, while the finer material will lie in a heap on the other side. Moreover, the throw has the effect of breaking the coke, and thereby wasting it. Reference has already been made to the remedies for this defect. But over and beyond this objection

to the older type of inclined furnace elevator, Lürmann correctly maintains that with only one hoist for each furnace any breakdown will bring the work of the furnace to a standstill.



Fig. 493. A Typical American Furnace Hoist.

Fig. 492 shows one of a couple of furnaces which have been connected by a gantry or bridge, against the centre of which, and between the furnaces, two inclined elevators are fixed.

The hoist car, which will take 6 to 20 tons of ore, as it is charged from the pockets, is bodily drawn up on the cradle of the elevator, and as it reaches the top, the rails on

the gantry correspond with the rail portion of the cradle, and the car is carried by its own weight down a slight incline to the furnace, emptying itself as it passes over the conically shaped mouth.

As the loaded car automatically runs towards one of the furnaces, it raises a counter-weight, which, as soon as the car is discharged, draws it back to the lifts.

The Lürmann principle has undoubtedly this advantage, that in case of a break-down of one of the two elevators, the other could be used to serve both furnaces. A second advantage no doubt is this, that the rails of the cradle, when in its lowest position, correspond with the rails which lie parallel to the furnaces and run right under the store bins from which the car is to be filled.

Furnace Hoists of the Brown Hoisting Machinery Co.—Fig. **493** shows an American furnace elevator erected by the Brown Hoisting Machinery Co.

This hoist consists of an inclined iron-trussed bridge reaching from the floor of the stock house to the top of the furnace shell, and from thence over the top opening of the furnace. On this inclined bridge are laid the rails, on which travels a skip or car containing a charge of from 1 to 3 tons as may be desired.

The track is so arranged at the top that the car automatically discharges itself as already described. The hoisting is effected by a two-cylinder engine, with a friction clutch drum, installed at the foot of the incline, while the skip is lowered to the bottom for refilling by means of a powerful foot brake, without reversing the engine.

Fig. **494** shows a portion of the Carrie furnaces of the Carnegie Steel Co., with the conveying plant serving them. It was the work of the Brown Hoisting Machinery Co. The coal-tip on the right deals with the material which is received by rail. The material discharged from the rail trucks into the bin is withdrawn into buckets holding about 10 tons each. These buckets are placed on the electric cars, each of which can hold four buckets. The buckets are then picked up by the Brown travelling crane, as shown in the illustration, and the ore is emptied into the stock piles or into the bins in front of the furnace. From the bins the ore is drawn out through suitable openings into electric travelling trolleys, one of which is shown in Fig. **598**, page 427. These are so made as to hold one charge of the elevator skip which takes the material to the top of the furnaces. The trucks are equipped with weighing machines, so that the exact quantity required can be taken at each trip.

An elevator for loading coal on similar lines is described under the heading "Coal Loaders at the Japanese Port Miike," page 595.

The same principle used to be applied to grain elevators, but the only example is probably that of the Liverpool Dock granaries (see page 670). Small hoists for the disposal of ashes from steamers, on the same principle, are also used sometimes.

THE HANDLING OF ORE FROM SHIP OR STOCK PILES TO FURNACE HOISTS

The Hoover & Mason Ore-Handling Plant.—This very interesting plant has been installed at the South Works of the Illinois Steel Co., U.S.A., and the makers, Messrs Hoover & Mason, Chicago, claim that it has solved problems which have confronted engineers for years past. They point not only to the quick discharge of the ore from the hold of a vessel, but also to its stocking in the blast-furnace yard, where it is always readily accessible; to its economical handling by means of the bin system, in connection with coke and limestone, and to its continuous delivery at the top of the blast-furnace.

This plant has now been in operation for a considerable number of years, and comprises a complete equipment for receiving the ore by water, unloading it from the vessels, stocking, and finally delivering it to the furnaces.

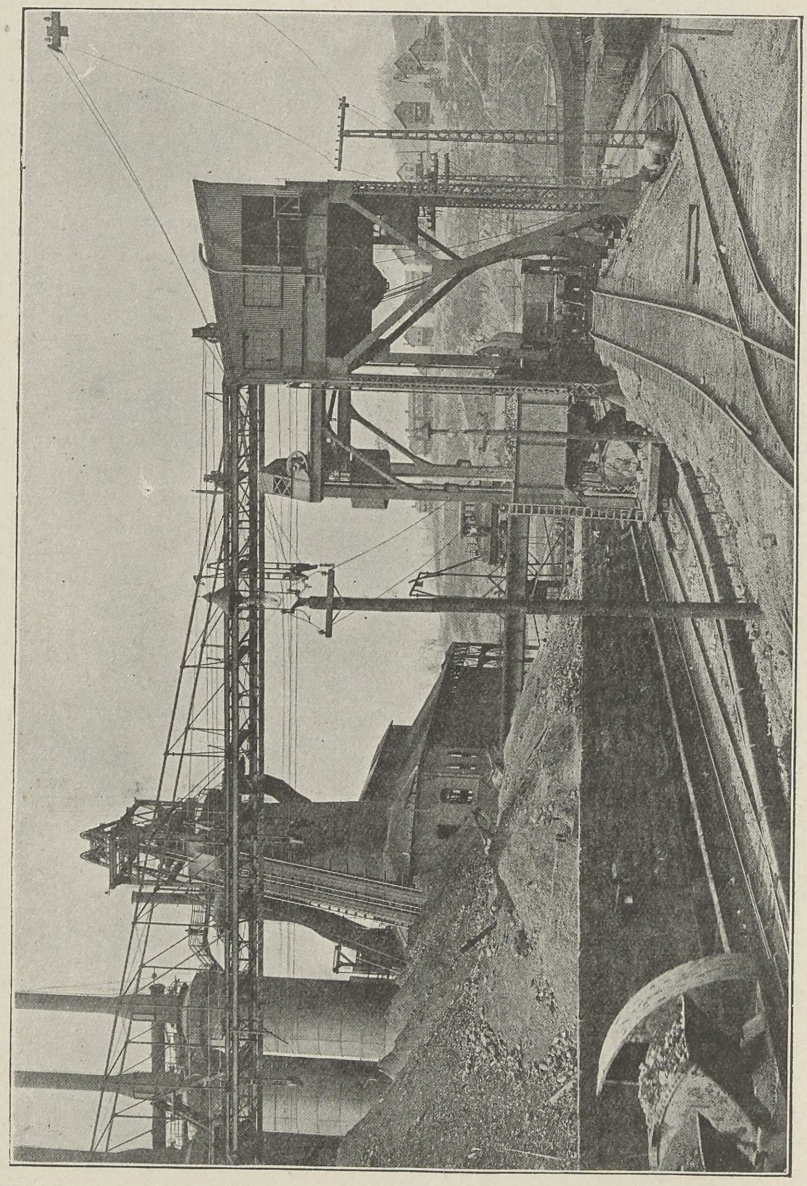


Fig. 494. Portion of the Furnaces of the Carnegie Steel and Iron Co.

A feature of this plant is the utilisation to the fullest extent of the peculiar position of the furnaces, which are directly served by lake steamers, a considerable portion of the ore coming direct from the mine to the furnace.

The general outline of the scheme is shown in the plan, Fig. **501** ; and to a somewhat larger scale in the elevation, Fig. **495**.

A long line of unloaders, fifteen in number, is placed at the dock front, thus making it possible to simultaneously attack every hatch in a large lake vessel. Each unloader manipulates a 5-ton grab, operated by one man, and makes sixty trips per hour, giving a gross capacity to the first half of the vessel of 3,000 tons per hour.

The unloaders deliver the ore into trucks for carriage to distant points, or into the adjacent concrete trough-shaped ore pocket in their rear. In this manner, practically the first half of the cargo is discharged in the first hour.

The residue of the cargo has to be brought to a point beneath the hatchways before it can be taken out by the grabs. This is effected by a series of scrapers, one at each hatch, operated by an engine installed on the unloader on the shore, which controls the scrapers in the hold by light ropes.

The diagram, Fig. **496**, represents a part section through the vessel; whilst Fig. **497** is a part plan of the vessel showing method of mechanical trimming.

The scraper has a resemblance to a giant hoe, and weighs more than a ton. Its form is shown in Fig. **498**. The ore is handled by alternately moving this scraper backwards and forwards, the point to which it returns empty being regulated by changing the position of the sheaves as shown in the plan view of the vessel, Fig. **497**. Thus the entire cargo can be unloaded without hand labour. The discharge of the cargo, with the necessary clean up to get the vessel ready for another load, has been accomplished in four hours.

The unloaders receive steam from the blast-furnace boilers through a line laid in a conduit, and along the dock front in a tunnel within the concrete trough construction, each unloader being connected with the main by a flexible pipe.

As regards soft or hard ores the capacity differs but little. The work of stocking the ore or transferring it direct from the vessel to a trough 600 ft. long immediately in the rear of the unloaders, or from the stock pile to the furnace pockets, is accomplished by means of two high-level cranes, each 520 ft. long, which are traversed by electric trolleys, each of which contains mechanism for the control of 10-ton grabs, and commands all the various materials for the furnace, including a reserve stock of limestone and coke. Each crane is controlled by a single operator, who can at will pick up 10 to 15 tons, and transport it to the furnace hoist, the hoisting speed being 100 ft. per minute, while the conveying speed of the heavy trolley is 1,000 ft. a minute.

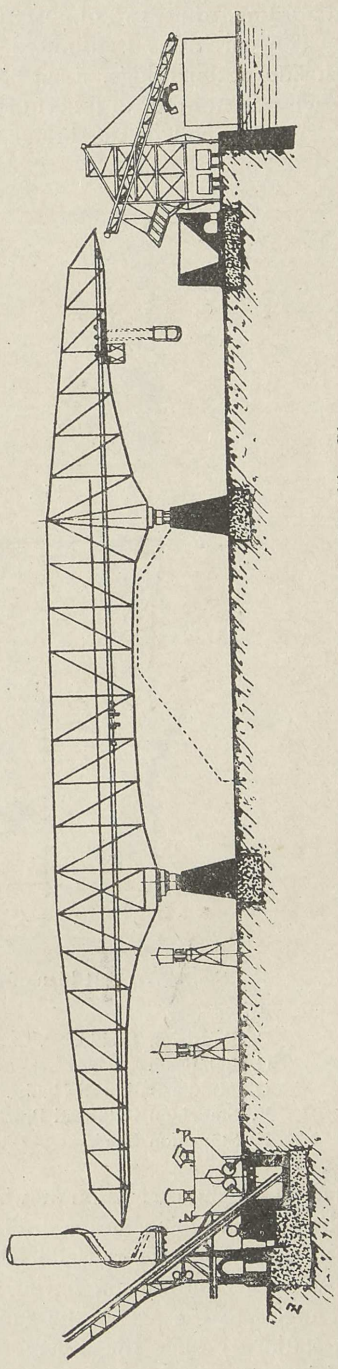


Fig. 495. Elevation of Hoover & Mason's Ore-Handling Plant.

Street car electro-motors, with brakes and controllers, are used throughout the installations, two 125 H.P. Westinghouse railway motors accomplishing the digging and hoisting, whilst two of 35 H.P. give the transverse motion to each trolley.

The current is transmitted to the trolley by conductor rails, one being placed on each side of the bridge, about 23 ft. apart. Two cast-iron shoe collectors are provided to each rail, in order to prevent sparking under maximum demands of 900 amperes.

At each end of the bridge provision is made against a runaway, in the shape of

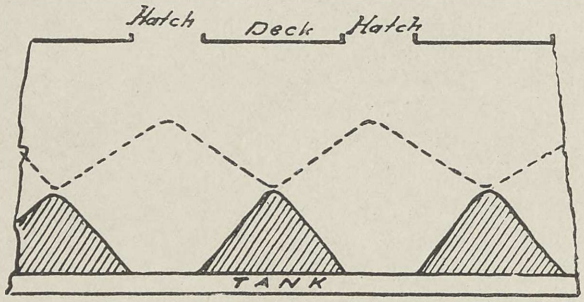


Fig. 496. Part Section through Vessel.

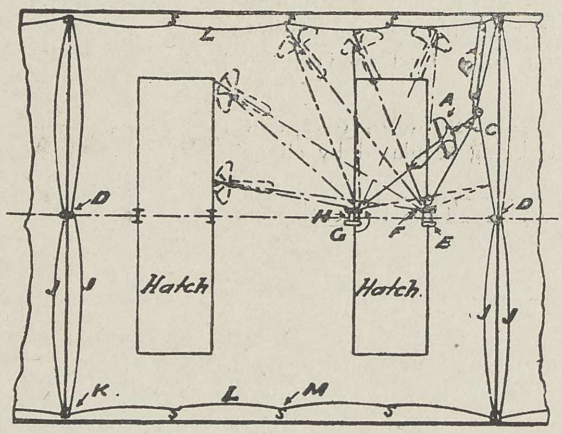


Fig. 497. Part Plan of Vessel showing Method of Mechanical Trimming.

A. Scraper.
B. Pull-back Tackle.
C. Bulkhead.
D. Middle Bulkhead Hooks.
E. Stanchion Bulkhead Bracket.
F. Stanchion Block.
G. Sleeve Nut.
H. Stanchion.
J. Bulkhead Pennant.
K. Double Eyebolt for Bulkhead.
L. Side Pennant, $\frac{3}{4}$-in. Rope.
M. Hold-back Hooks.

twelve Westinghouse friction drawheads which act as buffers. These have been found very efficient in checking heavy trolleys. The bridges rest upon standard gauge tracks, placed upon concrete walls 33 ft. high. The transporter itself has a novel function in respect to its movement, having the capacity to assume positions not necessarily at right angles to the axis of the supporting tracks. One end of the bridge may thus be kept stationary while the other end is moved a distance of 300 ft., thereby giving an elasticity to the work which is highly desirable.

In this way all the operations at the furnace side of the ore yard may be effected

without moving the transporter upon its track. The total weight of each truss, including the supporting trolleys, is about 450 tons. The supports for each truss over the walls are as follows: On each trolley is a turntable, similar to a swing-bridge turntable, but the trusses also rest upon a nest of parallel rollers on the south walls, which permit of a variation in span length due to the obliquity resulting from the angular movement of the bridges. During the time the crane is traversing the length of the ore yard the work of excavating and delivering is not interfered with, both operations proceeding simultaneously.

The furnace pockets shown in Fig. **500** have a capacity of 3,000 tons of ore, 1,000 tons of coke, and 500 tons of limestone. These are double pockets, the south tier being almost entirely used for the storage of coke and stone and the north tier for ore. A large portion of the ore is conveyed direct to the pockets by the crane, but as the ore

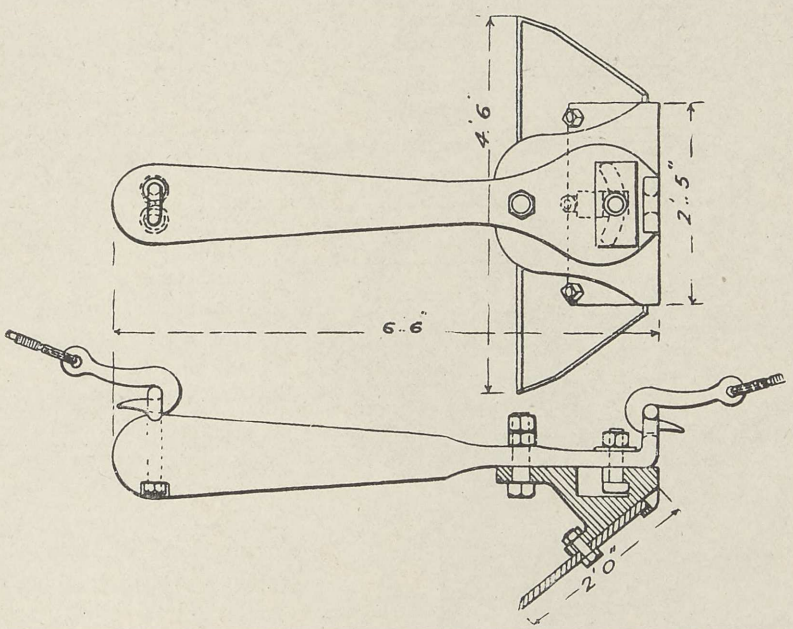


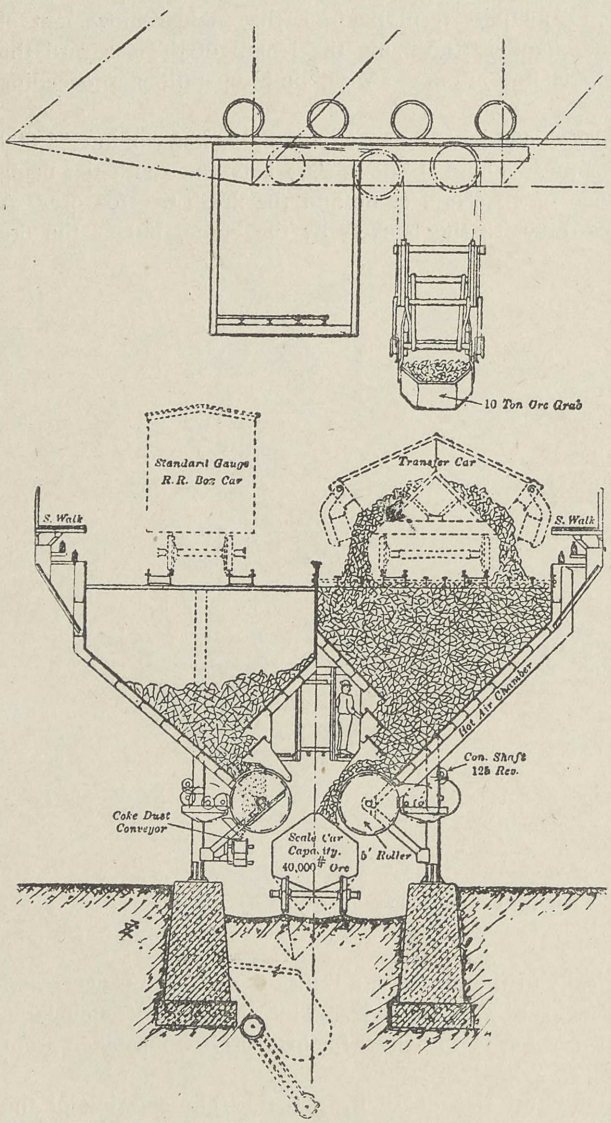
Fig. 498. Plan and Section of Scraper used in connection with Hoover & Mason's Ore-Handling Plant.

yard could not be placed symmetrically to the furnaces, a transfer car became necessary. The body of this transfer car is 26 ft. long by 18 ft. wide. This bridge is of such large dimensions that the bridge operator can forthwith deliver his load of 10 tons taken from the trough or from the stock heap.

The grab, when open, commands an area of 19 ft. by 6 ft. The skewing of the ore bridge, which brings the grab in position across the line of the axis of the pockets, necessarily affects the size of the car.

The dumping or discharging is effected at the side, the opening of the doors being effected by gravity, while they are closed by a small motor. To avoid danger of collision with scattered lumps of ore the operator's car is placed upon a sort of outrigger. The size of the car permits of the ore being delivered to either side of the pockets. The car body is of great weight, and thus the shock of receiving a mass of 15 tons is minimised. The car is electrically operated by one man who travels with it, controlling it by ordinary

tram-car devices. The ore pockets were constructed of steel throughout, and designed to prevent the formation of arches in the ore mass and consequent interruption in the feed. The sectional view, Fig. **500**, shows how this is accomplished by louvres. These louvres also afford access to the pockets in the case of a few very sticky ores, which, despite the louvres, have a tendency to choke. The withdrawing of ore from the pockets is effected by a rotating cylinder 5 ft. in diameter. The aperture for the exit of the ore is in all cases equal to the width of the pocket, so that the ends of the pocket are vertical. When it is desired to withdraw ore, these rollers are set in motion, forming a feeding device which carries the ore out of the pocket, and to a considerable extent loosens up the mass within the pocket. These rollers are actuated by a motor-driven continuous running shaft, which can be geared to them by a friction clutch.



Figs. 499 and 500. Showing Hoover & Mason's Ore and Coke Pockets and Scale Car.

The rollers on the coke side are perforated, and efficiently act as screens in separating the dust from the coke (see Fig. **500**).

A hot-air chamber is placed under the ore bins in order to prevent their contents from freezing in cold weather.

One weighing truck only is needed for each furnace. In the course of a year one man has kept a large furnace full without difficulty. Each weighing truck has two compartments, each holding a skipful (see Fig. **500**). All material delivered to the furnace is weighed before entering the skip. The weighing truck is driven by electricity. The weight of each increment is recorded upon a strip of paper by the balancing of the beam, and is thus placed beyond the reach of any tampering, an unimpeachable record being kept of the total weight of material fed into the furnace. The coke is distributed along a considerable length, and not, as is often the case, into two large ore bins, delivering directly into the skip. The advantages of this plan are, firstly, that it enables

a large number of coke cars to be run over the pockets and unloaded simultaneously; secondly, it obviates the drawback of these large pockets, as the proportion of dust entering the furnace at one time is minimised; thirdly, it is found that by putting the coke through a weighing truck the dust therefrom prevents the ore from sticking to the truck, and thus quickens the discharge. The fact that one man can maintain the furnace shows sensitive and rapidly delivering pockets. The operator need not quit his station for any purpose. He can control either truck or pockets from one position, pendant cords somewhat like a bell-rope being conveniently placed, and by simply pulling the rope he can, in a few seconds, load his car. The load on the car is indicated

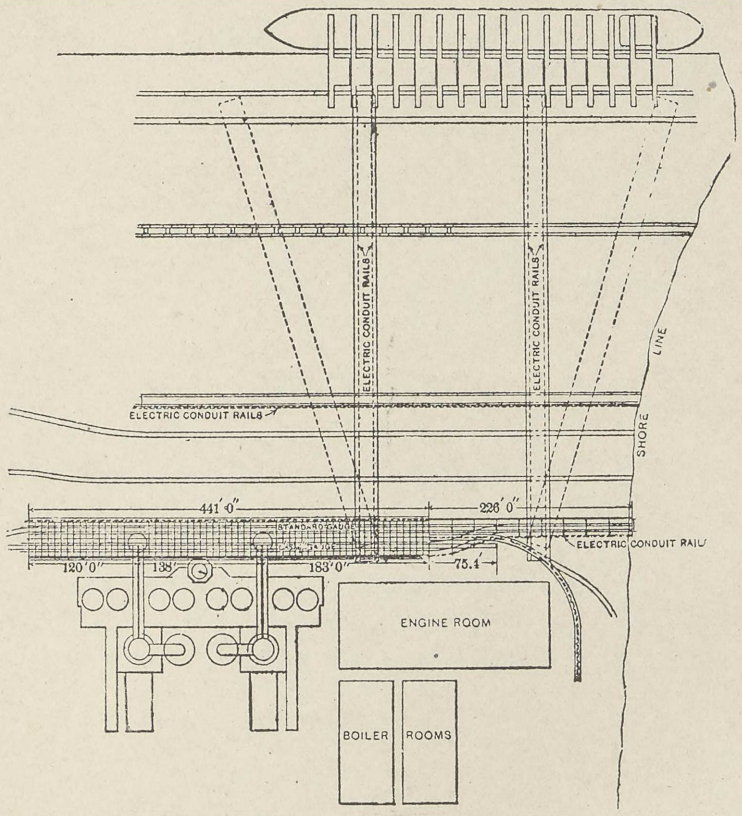


Fig. 501. Plan of Hoover & Mason's Ore-Handling Plant.

by a hand on the dial. Buttons of different colours are placed on this dial, each button corresponding to a load of ore, coke, or limestone. The operator pulls the cord until the index finger travels to its proper position; he then releases it, and the charging ceases.

In both the 5 and 10 ton grabs the path of the cutting edge through the material and the inclination of the tray follow certain lines which it is claimed have been found most efficient for digging ore. The construction of these grabs permits of the path being altered to suit any given material. It may be of such a character as to make an even cut of 6 or 8 in. below the surface over the area contained in the closing stroke, or a cut to any other depth (within certain limits) that the nature of the material may

call for. The ore trough is essential for two considerations; firstly, in the event of its being desired to speedily discharge a vessel, as the shorter the distance the ore is moved the more quickly this will be accomplished; secondly, the stock pile should at all times be accessible to the transporter which takes the ore to feed the furnaces. All ore taken from the vessel's hold, except such as is immediately dropped into trucks for carriage to more distant points, is unloaded into the trough at the rear of the unloaders, and thence is distributed by the 10-ton grabs into the stock yard or directly into the pockets situated near the furnace. Thus the fifteen 5-ton grabs can be constantly at work removing the ore from vessels, whilst the 10-ton grabs can either be feeding the furnaces from the stock pile or removing the ore from the trough to the stock piles.[1]

[1] The Author is indebted to the *Iron Trade Review*, of Cleveland, Ohio, and to the *Iron Age*, of New York, for the above description.

CHAPTER XXIX

THE MECHANICAL HANDLING OF COKE FROM COKE OVENS

THE industrial history of the past fifty years may be called absolutely distinct from that of any preceding period, and we see a complete revolution in all that part of our social life which is effected by industrial and mechanical appliances. This is specially so in regard to labour saving devices; it is a remarkable fact, however, that those arts whose functions it is to make the daily life of the toiler more endurable, were the last to be touched and invigorated by the talisman of the twentieth century inventive activity.

The toiler at the coke oven is, perhaps, one of those whose arduous labours are made more unendurable by the intense heat, the steam of the quenching, and the sometimes stifling sulphur fumes, in which he has to perform his duty, and yet there are only comparatively few coking establishments which have taken any steps to ameliorate the lot of these workers, and to benefit commercially by the same means.

Coke ovens, whether antiquated or modern, whether charged and drawn by hand or by machinery, give employment to great numbers of men who perform the operations of quenching, breaking up, spreading, and finally loading the coke, all of which take considerable time, and are therefore expensive.

The coke ovens themselves, and their more or less mechanical appliances, do not here concern us; may it suffice to say that a great many modern installations in this country and abroad are now met with, which are fitted with the most elaborate up-to-date charging and discharging appliances, but yet the means of handling the coke after it has left the ovens have been sorely neglected, probably on account of the great difficulty which this problem presents, and though this chapter is devoted to this particular subject, it is a question whether any of the numerous improvements given in it may be looked upon as the final solution of the problem.

Mr A. Thau, who is closely connected with the subject in this country as well as on the Continent, has written an able paper on this important question, which has appeared in "Glückauf," and the author is indebted to him for the facts which form the basis of the following.

It is difficult to separate the mechanical handling of coke as it leaves the ovens from the quenching process, and both are, therefore, taken together for this reason as well as for that of completeness in investigating an important process of a vast industry.

The old method of dealing with coke from the ovens, and one which is still in vogue in probably the majority of coke oven installations, is very simple, as it is altogether devoid of mechanical contrivances. In front of the ovens there is a wide hearth or platform with a slight inclination away from them. The hearth is covered with cast-iron plates, and on the side opposite the ovens there are one or more lines of rails for the trucks into which the coke is to be finally loaded. The hearth, as a rule, is at its lower side on a level sufficiently high for the coke to be dropped by gravity into the trucks. The slight gradient of the hearth is for the purpose of allowing the surplus quenching water to run away, and in order to prevent this water from running into the railway trucks there

is a gutter with drainage about a yard away from its lower edge and running the whole length of the hearth.

The *modus operandi* is as follows: As soon as the coke has been pressed out of the oven it is played upon with a hose, and quenched externally; the coke is then broken up and raked apart with hooks and rods, and is finally quenched throughout. As soon as the surplus water has evaporated and the coke is sufficiently cooled it is forked into barrows and transferred into the railway trucks on the adjoining track.

This is all very simple, but also very cumbersome, and attempts have not been wanting to replace this method by mechanical devices; certain conditions, however, have to be observed, whether the treatment is manual or mechanical, and it is therefore well to make this quite clear before going closely into the mechanical means employed.

The coke should be drenched immediately it leaves the oven, and, if possible, before it has had time to come into much contact with the air, as otherwise it will become discoloured and of less value. Then it is of great importance that the quenching and cooling should be uniform throughout the whole mass, as otherwise pieces might reignite in the railway trucks and damage them; it is therefore necessary to spread the coke well, let it cool for at least a quarter of an hour, and thus give time for the heat of the material to evaporate the surplus moisture and become uniformly cool. The coke as loaded should not contain more than 4 to 5 per cent. of moisture. Large coke alone is loaded into the railway trucks; the breeze and imperfectly coked portions, such as occur in ovens of old pattern, and round the doors of ovens with horizontal flues, should be eliminated.

The object of the systems now to be described is to substitute mechanical means for one or more of the operations hitherto performed by hand, and thereby to reduce the cost of production as well as to make the work of those employed less onerous.

It has already been mentioned that railway trucks to be loaded should be so situated, relatively to the platform, as to prevent waste from breakage, and yet to enable the operation to be carried on conveniently, say 18 in. from the platform to the top of the trucks; if it is more the fall of the coke into the trucks is too great, and likely to break the coke and thus lessen its value. Such a position between the truck and the hearth is undoubtedly the best, but in older installations it is frequently found that the hearth is much lower than that, and since the hearth, and with it the ovens, cannot be raised without rebuilding the whole installation, matters can sometimes be improved by lowering the siding for the trucks sufficiently to bring them below the hearth, but where this is impossible there is no other alternative but to lift the coke from the hearth into the trucks. Under such circumstances the best plan is to fill the coke into iron crates or into skips, preferably with bottom discharge, and raise them by a crane over and into the railway trucks. Grabs are unsuitable on account of the brittle nature of the coke. In order to save shunting, loading cranes in large installations are made with a sufficient reach of jib to load two or three lines of trucks.

Where coke ovens serve blast-furnaces direct, the coke is generally forked into tip-trucks, which convey it to the furnace, or the skips may be placed by the crane on platform wagons, as is the custom at the Port Clarence Ironworks at Middlesbrough. Here large electrically driven platform trucks are used to carry the skips to the furnaces, some distance off. In this particular case the height of the platform truck is such as to be on a level with the hearth, but this arrangement is here mentioned as it might equally well be applied in cases where the height of the platform truck is lower.

Having now dealt with these expedients under existing circumstances, we will pay attention to mechanical installations for more modern cokeries, where the hearth is higher than the trucks.

One of the first attempts at mechanical loading was the installation of a portable band conveyor, mounted on wheels, and running on three rails right across the hearth, as shown in Fig. **502**, constructed by Coulson & Co., Spennymoor. The conveying band *a* reaches close to the ovens *b*, and can traverse the whole of the hearth in front of the battery of ovens. The delivery end reaches to the middle of the trucks. The conveyor is fitted with electric motor, and the current is taken from an overhead wire on lamp standards by a trolley, so that the motive power is available in whatever position the

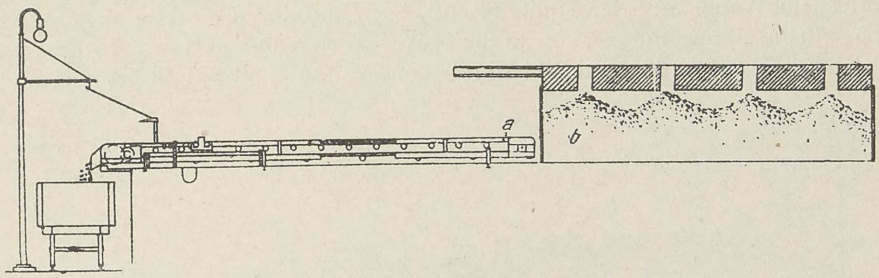


Fig. 502. Portable Coke Conveyor by Coulson & Co., Spennymoor.

conveyor may stand. The conveyor is driven close to the quenched and cooled coke to be loaded, set in motion, and the coke is then put on with the usual large forks which leave the breeze on the hearth. The utility of these and similar transporters is somewhat marred as the quenched coke on the hearth restricts the movements of the conveyor to narrow limits, and therefore makes it impossible to load the coke in the rotation in which it is pressed; it has rather to be taken from the spot where the conveyor may happen to stand. There is no apparent mechanical objection to erect such bands on carriages

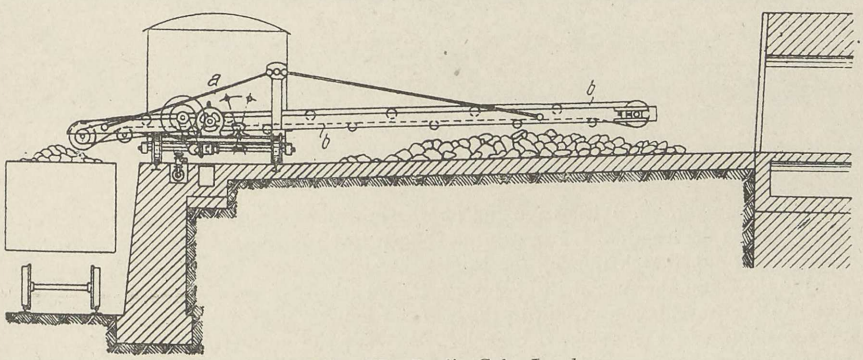


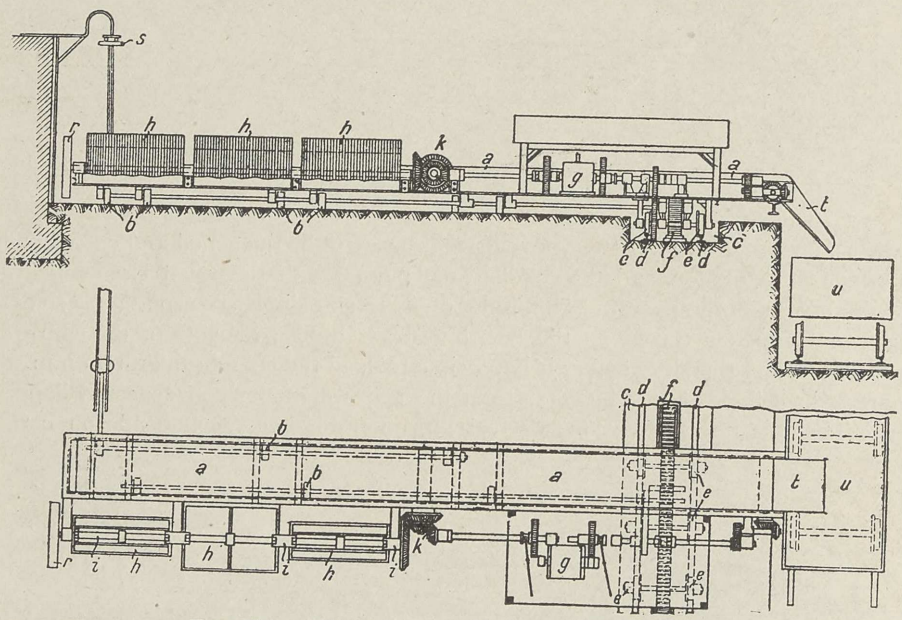
Fig. 503. The Baglin Coke Loader.

sufficiently high to clear the coke on the hearth, but then the rails would have to be cleared for its passage. The latter difficulty has been overcome by the Baglin machine (Fig. **503**), which has been built since 1908; it is movable on a carriage *a* and a pair of rails at the lower end of the hearth, so that the apparatus can be moved freely, and the coke may be loaded in the rotation in which it is pressed. The conveyor *b* covers the major portion of the hearth and reaches to the centre of the truck, the shorter section is furnished with a weight to balance the longer end. The carriage *a* has a covered-in driver's stand with motor and countershaft, and is self-propelling. Although the coke has to be lifted by the men with the forks a little higher than in the previously described

scheme, it has the advantage that men can load it from both sides, and, furthermore, when one truck is full, the band may be stopped with the full load on it, and driven to the next truck to be filled.

There is, however, the great disadvantage common to both systems, that a large gang of men have to be employed to load the coke by hand, and whether they load it on to a band conveyor or into a skip or crate, to be subsequently moved by a crane, is really of little consequence, so the apparent advantage of the conveyor over the crane and skips is more or less illusionary, and the working expenses will probably be much the same.

Mechanical appliances have quite recently been introduced for coke ovens fitted with level hearths for lifting the coke on to the conveyors, and thus dispensing with a gang of hand labourers. Figs. **504** and **505** show a conveyor so fitted with lifting appliances; it



Figs. 504 and 505.—Kickert's Method of Handling Coke.

a. The conveyor. *b*. Wheels running on the hearth without rails. *c*. Recess in hearth. *d*. Rails running the length of the hearth. *e*. Flanged wheels which determine the path of the machine. *f*. Toothed rack running the length of the hearth, by means of which and a wheel coupled to the motor the machine can traverse the length of the hearth. *g*. Motor, coupled at one end to the travelling gear, and to the conveyor and the coke-lifting apparatus. *h*. Coke-lifting apparatus (see Fig. **506**). *i*. Spindle. *k*. Gearing of countershaft. *l*. Levers carrying the lifters. *m*. Lifters. *n* and *o*. Forming a revolving frame. *p*. Strip which fills the space between lifters and conveyor. *q*. Guide for coke from lifters. *r*. Flywheel. *s*. Live rail. *t*. Shoot. *u*. Truck.

is that of Kickert, at Wattenscheid, Germany. The previous description of similar appliances will render a detailed description unnecessary, and the explanation of the letters of reference will be sufficient for the understanding of the drawing.

The lifters *m* are so supported and guided that at their lowest position they come close to the hearth to pick up the coke, whilst in ascending they move inward in order to clear the rail *o*.

When coke, sufficiently cooled, is ready for loading, the machine is driven up to the coke, and the three sets of lifters, the teeth of which are about as far apart as the prongs

of a coke fork, lift the coke on to the conveyor whilst the machine slowly advances (see Fig. **506**).

A well-designed form of conveyor for coke ovens is the work of Mr Joseph Müller, of the Matthias Colliery, at Essen, in Germany. This appliance is intended to take the coke as it comes from the ovens in a red-hot state and at once quench it in water, to allow it to dry and be discharged on a sieve or grate, and finally to load it into wagons or boats in one continuous and automatic operation.

A diagrammatic view of the apparatus by which this is accomplished is shown in Fig. **507**. In front of the outlets of the coke ovens there is a tank B, which is kept full of water. The right end of the tank has a sloping side. In this tank is placed the carrier and conveyor, which consists of a strong frame on

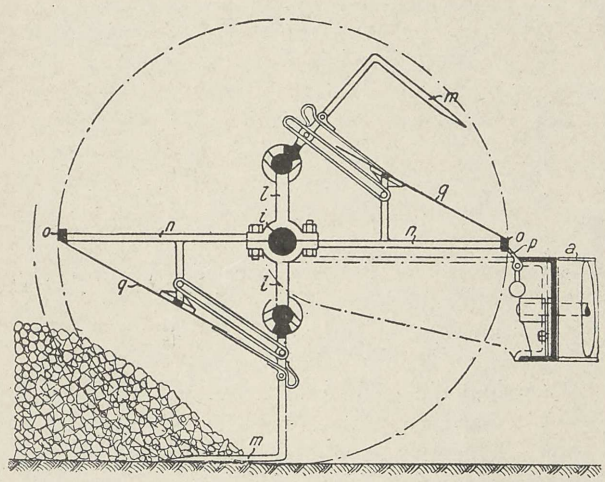


Fig. 506.—Cross Section through one of Kickert's Lifters.

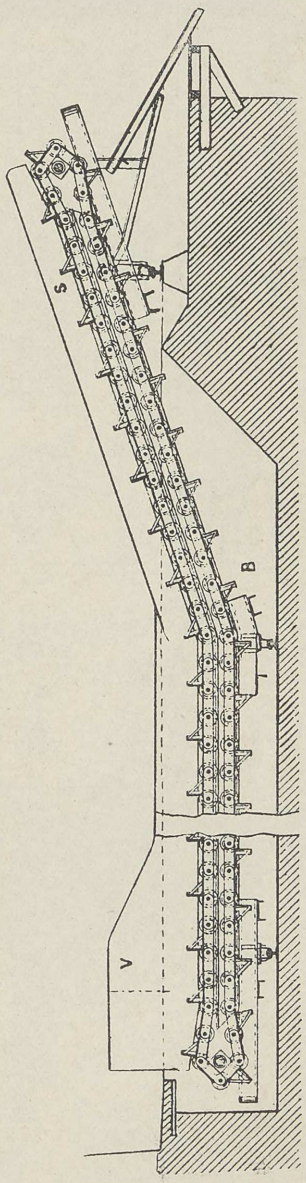


Fig. 507. Müller Hot Coke Conveyor.

wheels which runs on three transverse rails, allowing the whole apparatus to be moved crosswise in the tank. Strong side beams of plates and bars form the frame of the carrier. Cross-bars and stays serve to strengthen it laterally. That part of the carrier frame near the oven is built horizontally, and is completely immersed in the water. The other part rises gradually, and as its further end is entirely out of the water and so high that there is sufficient room below it for a sieve or grating at s, which may be built in one with the carrier, or may form a separate part of the apparatus. The sieve or grating may be made with movable bars, or the latter may be fixtures. When arranged separately from the transporter frame, the sieve may run across the whole width of the tank.

The carrier band consists of two chains, one at the right and the other at the left edge. They are connected laterally by means of bolts, which bolts form at the same

time the axles for the carrier wheels upon which the chains are carried forward. Plates riveted or bolted on the chains, and each reaching from one side to the other, of exactly the width of the pitch of the chain links, form together a continuous platform.

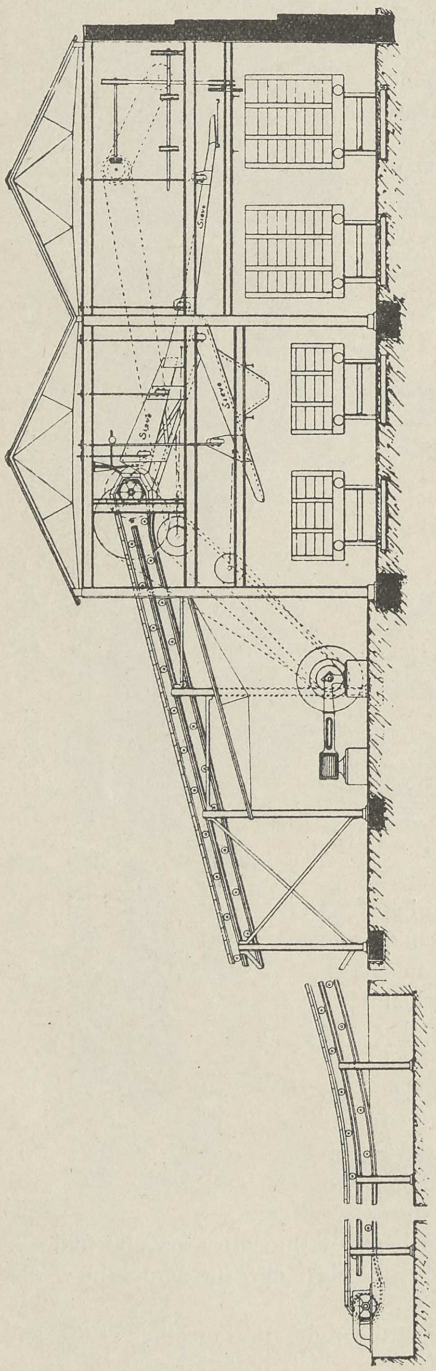


Fig. 508. Elevation of Hot Coke Conveyor at Dumbrick Pavell.

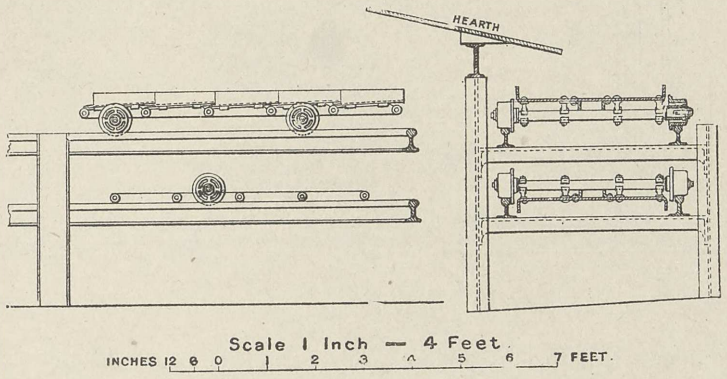
The coke coming from the furnace in a hot glowing state is pushed directly upon the carrier chain into the tank, where it is quenched and slowly carried forward. At the further end it is raised out of the water, and upon the rising part of the carrier chain the water can run off and the coke is dried, the heat contained in it quickening the drying process, so that it arrives almost dry at the end, where it is thrown automatically upon the grating, and after the breeze has been eliminated by the latter the coke is discharged into wagons.

The transporting band or table moves between two inclined side shields v, which are so fixed to the carrier frame that the plates pass below the lower edge of the shields, thus preventing the escape of any coke. The rails or guides for the chain wheels are formed by the channel irons which are parts of the carrier frame. The upper horizontal flange carries the upper chain, while the lower horizontal flange carries the lower or returning chain.

When a coke oven has been emptied, and the coke from it has been quenched, conveyed away, and loaded, the whole apparatus is shifted sideways in front of another oven ready for discharge.

In the installation at the ironworks at Dumbrick Pavell the hot coke conveyors are erected in front of and parallel with the hearth. The coke is partly quenched on the inclined hearth and then raked into the conveyors which are 3 ft. wide, and 392 ft. 6 in. long, from centre to centre of terminals. The trays are made of $\frac{1}{4}$-in. mild steel plates with edges turned up to form sides. Each tray is riveted to a manganese cast steel driving link 15 in. pitch, and the links are coupled together with pins of $1\frac{1}{4}$ in. diameter. On every third tray is bolted an axle with two wheels, each of 6 in. diameter. The axles are made of mild steel, the ends of which are lapped with blister steel and welded, and are machined, bored, and hardened. The

wheels are of cast iron bored out to fit the ends of the axles, and kept in position with collars on the inside, and nut and washer on the outside. The hollow ends of the axles are lubricated by viscous lubricant, a brass plug being screwed in the end. Lubrication is effected by a boy standing at the side of the conveyor and giving each brass plug a turn with a spanner, which causes the lubricant to flow to the outside of the axle. The wheels run on rails supported on girders. The driving drums are of cast



Figs. 509 and 510. Coke Oven Conveyor at Dumbrick Pavell.

steel and hexagonal, with renewable teeth. The conveyor has a speed of 30 ft. per minute, but only works intermittently. At present it conveys 150 tons of coke per twenty-four hours.

Fig. **508** shows an elevation of the installation.

Figs. **509** and **510** give an elevation and a cross section showing the conveyor on a larger scale.

It is a fact that people sometimes go out of their way to introduce elaborate mechanical devices, when by a judicious general arrangement much might be done by gravity and without mechanical handling. A case of the latter category may be cited in connection with the coke ovens of the Mitchell Main Colliery, Barnsley. Here the hearth is erected on parallel rows of cast-iron stanchions, not as usual on walls and masonry arches, so that there is room under the ramp for the sidings and the coke trucks; above the hearth there are a series of openings or traps of 18 to 20 in. square, to which angle-iron coamings are riveted, and they are fitted with lids. When the coke has been quenched, spread, and cooled on the hearth, it is shovelled down these holes into the trucks; the angle-iron coaming to the openings is there to prevent the quenching water from running into the trucks.

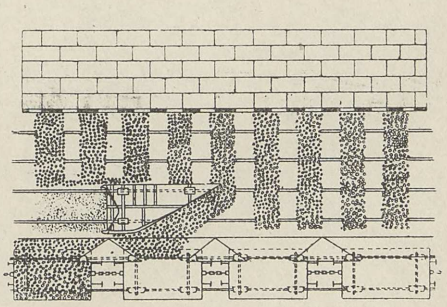


Fig. 511. Coke Loading Device of Grégoire.

A different principle is that of Grégoire, Seraing, in Belgium, shown in Figs. **511** and **512**. In this system the coke is moved after cooling on the ramp by a mechanically driven plough running on two lines of rails parallel to the battery, which pushes the coke into the trucks. The plough is driven, as shown in Fig. **512**, by a motor and the transmission *a*, *b*, *c*, *d* and the chains *e* and *f*, which gear on to the back axle. The carriage,

which is a triangular plough, runs on three wheels, two behind and one in front; the latter is controlled by steering wheel *g*. The two lines run into one at the extreme end of the hearth, so that by running the plough first on the front rails, disposing of the coke in front, and then on the back rails, the coke is pushed from the back forward, to be finally loaded by a second journey of the plough along the front rails. In order to negotiate

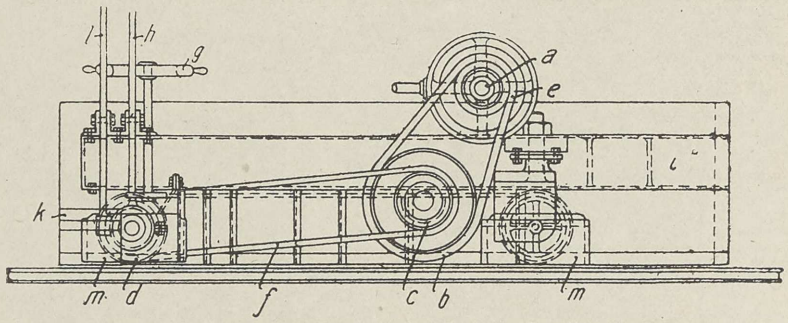


Fig. 512. Section through Grégoire's Coke Loading Device.

these points and rather sharp curves more easily, one of the back wheels is loose on the axle, but can be coupled up by the hand lever *h*. The carriage is protected by iron plates attached to the frame *i*, and the oblique ploughing plate is bent at the bottom similar to a ploughshare, so as to lift the coke, and it reaches to within an inch of the hearth plates. At the base of this triangular carriage is a plate *k*, which can be lifted or lowered by hand lever *l*. The wheels are protected by guards *m*, and in addition to this, there are sweepers provided to keep the track clear from coke. Along the front edge or the hearth are a series of hopper shoots to correspond with the truck into which the plough pushes the coke, and as this plough does not come close down on the hearth, the breeze is left, and can be collected on the return journey of the plough, by the plate *k*, which can be lowered right down on to the hearth plates. As far as the writer is aware, this machine has not been tried in practice, and there are several obvious objections, one being that conditions as shown in Fig. **511** will probably never obtain, as some of the coke may not be ready in the rotation in which the machine can move it. The description has, however, been given as a link in the chain of possible development on an entirely different principle.

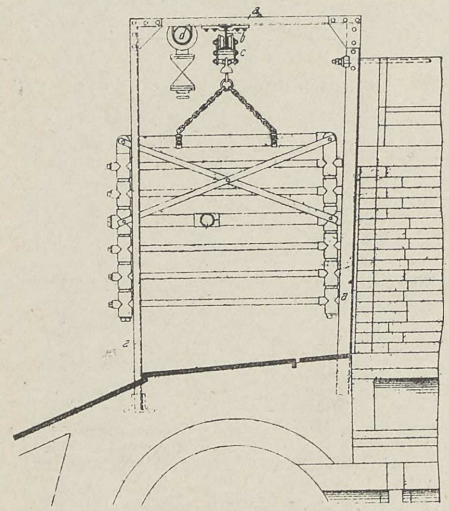


Fig. 513. The Oldest Form of Quenching Device for Coke.

Quenching by mechanical devices is now largely used in modern installations, and they consist generally of a framework constructed of pipes perforated on the side towards the coke; these frames are moved in front of the oven door so as to drench the coke as it is forced out by the coke pusher.

The oldest form of quenching device, which forms the basis for all further improvements, is shown in Figs. **513** and **514**. In an installation of this kind a framework *a* is

erected and fastened to the ovens. This supports a longitudinal girder *b*, on the bottom flange of which moves the trolley *c* that supports the quenching apparatus on a swivel and two chains, in such a manner that it can be easily conveyed to any of the ovens of the battery which may be ready for pressing. The water main *d* has a number of T-pieces with valve and hose connection, so that the main may be connected with the apparatus wherever wanted. The arrangement of the sprinkling pipes is seen from the illustration, and consists of six or more pairs of pipes according to the height of the ovens, the middle and the top one of a larger diameter; the former because they serve as a connection to the main, and the latter for the sake of strength, and also in order to give an extra copious supply of water on top of the coke cake, where it is always more or less divided or open, as this is the best way of getting quenching water to the interior of the coke before breaking it up. When the apparatus is in position and connected to the main the oven door is lifted, and the coke is pushed slowly through the quenching apparatus. It has already been mentioned that the hearth must have a slight fall, away from the ovens. This is particularly necessary when this form of quenching is adopted, as it necessitates the use of a large quantity of water in very close proximity to the ovens, and it is, therefore, advisable to give an extra gradient to the hearth of not less than 10 per cent. to prevent the water from entering the ovens.

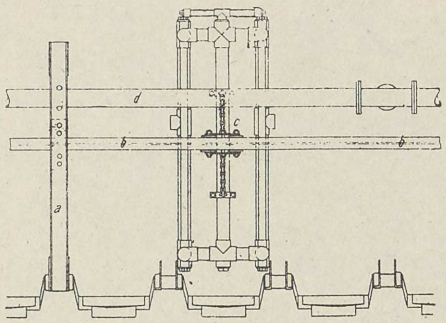
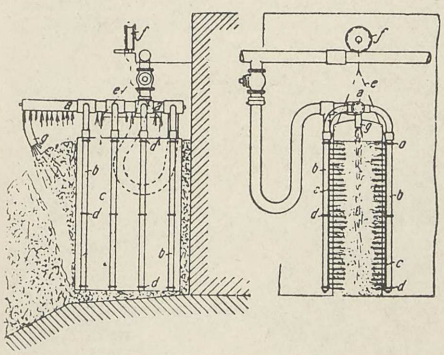


Fig. 514. Sectional Plan of Quenching Device shown in Fig. 513.

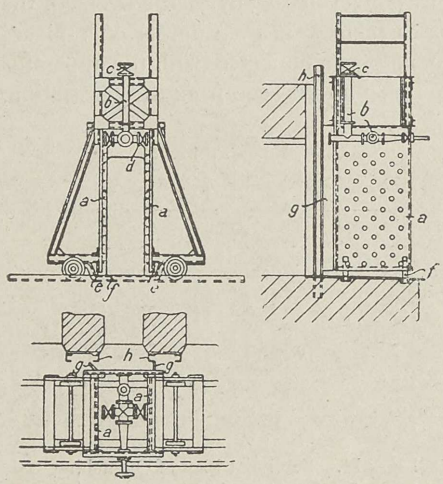


Figs. 515 and 516. The Darby Coke Quencher.

It has been found that if the coke is pressed at a speed of 6 ft. per minute the automatic quenching can be done thoroughly. If the mechanical appliances of the ovens do not permit of so slow a speed, it is advisable to push for a distance equal to the reach of the quenching pipes; then stop and quench for one minute; then push again, and so on. The quenching of the coke in this manner saves very considerably in labour, and the appearance of the coke is excellent; on the other hand, it must be mentioned that the water-quantum used is two to three times as much as in the old-fashioned way, and in consequence of the slow pressing the rod and head are exposed to the temperature of the oven for a considerable time, so that even if they are made of cast steel they will require more frequent renewal. In spite of these, the advantages are of such importance that mechanical quenching processes are largely used, particularly in Great Britain.

The well-known Darby coke quencher is shown in Figs. 515 and 516; its special feature is provision against the access of the atmosphere to the coke. The appliance consists of the main pipe *a*, which branches off into smaller pipes *b*. To exclude the air plates *c* are employed to close the space between the pipes, and the spray of water passes through a great number of small nozzles which are screwed into the pipe, and extend

through the plates *c*, which latter are held by staples *d*. The whole is suspended from the main water supply pipe by rollers *f* and chains *e*. Pipe *a* has a further extension, and a branch *g* which supplies a copious stream of water against the front of the coke, and after this begins to break, to its inner parts.



Figs. 517, 518, and 519. Coke Quencher of the A. G. für Kohlendistillation at Gelsenkirchen, Germany.

The coke quencher of the A. G. für Kohlendistillation at Gelsenkirchen (Figs. 517 to 519) differs from the last described apparatus inasmuch as the nozzles, which are liable to become choked, particularly when dirty water is used, are omitted, and the pipes are replaced by two water jackets, forming water chambers *a*, which are continuations of the oven sides. The water is admitted through the main pipe *b*, which is connected with the flexible supply pipe by means of the sluice valve *c*, and issues through perforations in the inner walls of the chambers. The flow is regulated by taps *d* between the pipe *b* and the chambers. The latter are closed at their lower extremities by plate *e*, which can be removed for cleaning purposes. The apparatus is mounted on an iron frame running on four wheels on channel-iron tracks, which are filled up between the wheels by inverted channel-irons *f*, so as not to impede the pushing operation. Two pivoted vertical strips *g* fit against the oven door frames *h*, and prevent access of air and

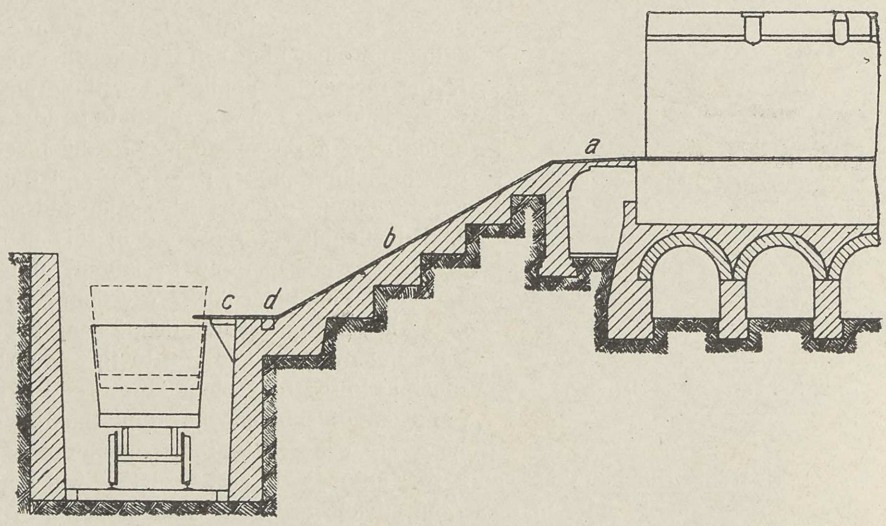


Fig. 520. Hearth with an Incline of 15° to 30°.

waste of coke. The water pressure for these appliances must be at least 75 lb. per square inch, so that the jets are forced out of the perforations with sufficient pressure. This obviously means a larger water consumption.

The handling and quenching methods hitherto described are practically all for

platforms or hearths which are nearly level, and have only sufficient slope to allow the quenching water to run away, and some of the appliances must be looked upon as the best that could be done under existing circumstances, whilst the tendency in new cokeries, both in England and on the Continent, is to place the ramp at an angle of 15° to 30° to the horizontal according to the method of loading which may be chosen. Fig. **520** shows such an arrangement. In front of the oven doors is a nearly level space *a*, about 6 ft. wide, which rounds off into the slope *b*; the former serves for quenching the coke when done by hand, affords a suitable passage to attend to the ovens, and finally forms practically a continuation of the oven base and a support for the head of the coke-pusher, so that the coke can be ejected to a sufficient distance. If a quenching machine is employed, the rail track is arranged on this upper nearly level platform. The slope terminates in a lower horizontal portion *c*, and at the bottom of the slope is a gutter *d* covered with perforated plate to carry off the superfluous quenching water. The railway track is sunk so that the upper edge of the trucks is either flush with the lower platform, or better, projects somewhat above same, as shown in the illustration; in either case the coke has to be lifted into the trucks by means of forks, which separate the large coke from the small. These sloping platforms are convenient, so far as the handling of the coke is concerned, as the coke falls to pieces as soon as it overhangs the greater slope of the ramp, and thereby saves hand labour; it also, after cooling, slides down with little help, and avoids the use of barrows. Such an installation is, however, more expensive on account of the necessary excavations and the higher elevation of the ovens themselves.

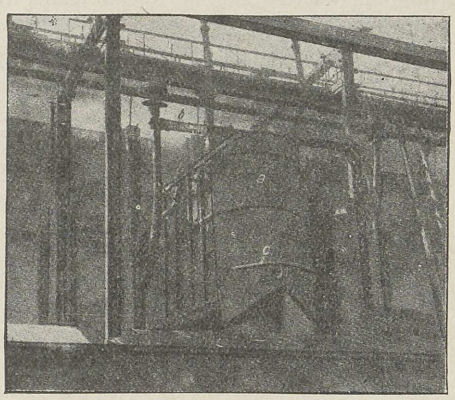


Fig. 521. Peel's Antibreaker.

At the cokery of the Seaton Carew Ironworks, West Hartlepool, the ovens are mounted at a sufficient elevation to allow the sloping platform to deliver direct into the coke bunkers, from which the quenching water is excluded by a rail and gutter at the bottom of the slope; this rail also keeps back the small coke and breeze. The water main and hydrants for the quenching machine are carried on a bridge above the bunkers. The arrangement is convenient, as enabling the coke to be delivered to the bunkers, and again from there to the trucks, with a minimum of hand labour, and without mechanical appliances; but is expensive to construct owing to the height of the substructure of the coke ovens. Mechanical quenchers are nearly always used with such installations, but with these steep ramps there is a tendency for portions of the coke to become detached from the solid mass during the quenching, and roll down the incline and so break up. This is practically prevented by suspending a number of rods about a yard long in front of the quencher so as to give the coke a little support, but "Peel's" Antibreaker, Fig. **521**, is more effectual.

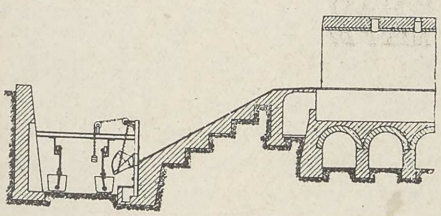


Fig. 522. Coke Oven Installation at Rheinhausen.

Here the front end of the quencher is closed by an iron plate or shield *a*, fitted with strengthening ribs and suspended on a rail track for the purpose. A series of sprinkling pipes is arranged inside the cover plate and supplied with water from a distributing pipe *b* at the top. A triangular recess cut out of the bottom edge of the cover prevents the coke from jamming inside the quencher. An external perforated spraying pipe *c* is arranged on the cover plate, so as to complete the quenching of the issuing coke. This arrangement is simple, cheap, and acts in a highly satisfactory manner.

Mechanical appliances for loading coke after quenching, and in connection with steep ramps, are in use in a great many cokeries now. Fig. **522** shows such a scheme as used at the coking plant of the Friedrich-Alfredhütte, Rheinhausen. The chutes are swivelled and provided with balance weights, and deliver the coke into trucks running on a rope track which conveys them to the furnaces. Unless forks are used for moving the

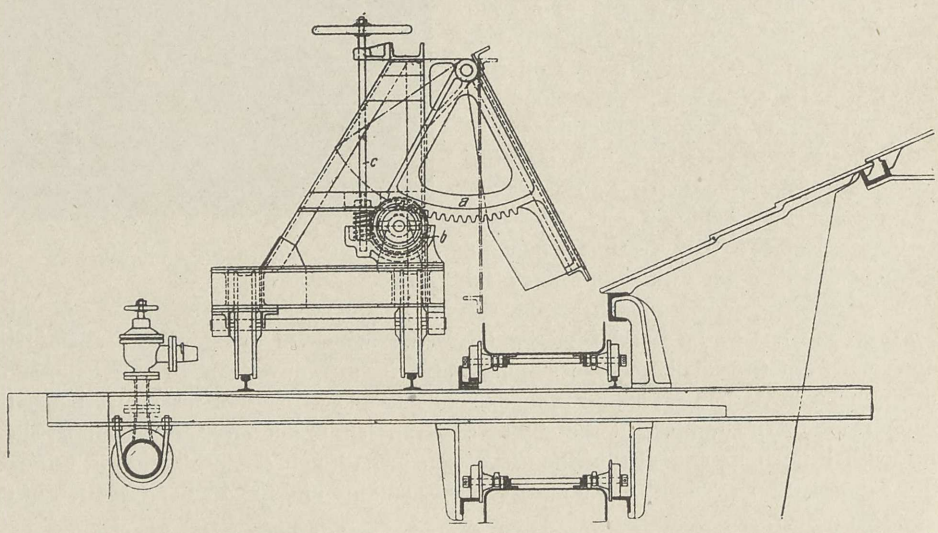


Fig. 523. Showing Method of Feeding Coke on to Tray Conveyor.

coke down to the trucks, the small coke and breeze cannot be separated. Otherwise, the illustration explains itself.

By far the most popular method of conveying the coke is a continuous tray conveyor which runs the whole length of the hearth, and which frequently ascends at the delivery terminal and deposits its load into a sifting and classifying plant prior to its further disposal. With this system, largely used in British cokeries, the lower end of the ramp terminates in a perforated plate reaching as far as the edge of the conveyor and draining away the surplus water. To prevent the coke from falling down on to the conveyor before it has sufficiently cooled, a number of swinging loading flaps are arranged at the bottom of the ramp. In small batteries, in which only one charge is loaded at a time, these numerous flaps may be replaced by one portable flap or door mounted on a four-wheeled truck running on rails parallel and on a level with the conveyor. Fig. **523** shows such an appliance of Koppers. This truck, which is moved by hand, carries four flaps, which are brought into the desired position by means of a toothed quadrant *a* engaging with a pinion *b* operated by a hand wheel on a vertical shaft *c* through worm gearing. When the flaps are set on the slant, as in the illustration, they hold back the coke, but when vertical they allow it to fall on to the

conveyor to be removed. With this system the ramp is at an incline of from 30° to 40°; this is sufficient for the coke to slide down; with a lesser incline the flaps are not necessary, and the coke is then raked down. One of these appliances is used at the Manvers Main Colliery.

A similar plant is that of the Soc. Ilva, at Bagnoli, near Naples; it was built by F. Méguin & Co., in Dillingden. In this the conveyor consists of short links and stout $\frac{5}{16}$-in. plates, terminating at the side of the trough by short angle-iron rims; each second link is provided with a spindle and a pair of wheels. The links and bolts are of manganese steel, whilst the rollers are of chilled iron, with addition of steel;

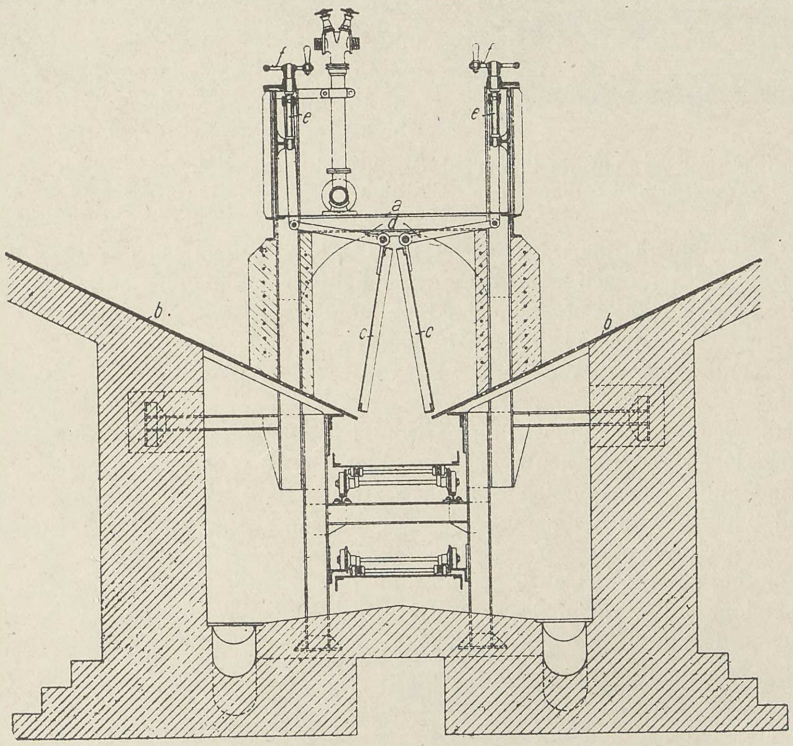


Fig. 524. Coke Conveyor of the Soc. Ilva, at Bagnoli, near Naples.

they are also self-lubricating with a viscous grease, so as to exclude dust. This conveyor is 328 ft. from centre to centre of terminals, is about 3 ft. wide (850 mm.), and handles the coke from two batteries of sixty ovens each, being placed centrally between the two hearths (see Fig. **524**). The driving power is furnished by a 12 H.P. electro-motor, which is exceedingly moderate for so large an installation, especially as the delivery end raises the coke to a sufficient height to deliver into a screen, from which the fine coke falls into a bunker, whilst the coarse is conveyed by a swinging shoot into mono-rail sling skips, which are conveyed by the Telfer system to the sloping hoist of the blast-furnace.

The quenching of the coke is effected by means of flexible hose from hydrants on gangway *a*, situated above the conveyor at suitable intervals. The lower end of each ramp *b* is closed by flaps *c* suspended from the gangway, and operated by a bell-

crank *d*, screw spindles *e*, and hand wheel *f*. This device admits the regulation of the supply of coke to the conveyor and protects the coke from breakage. This plant has been in operation for over a year, without any stoppage or repairs being needed.

The system of handling coke by tray conveyors has undoubted advantages, and the only reason why they do not receive universal adoption in the coking industry may be sought in the want of confidence in this type of conveyor, as well as in the great wear and tear caused by the cutting nature and often considerable temperature of the coke. A breakdown of the conveyor means practically the suspension of the workings, even if spare parts are kept and repairs can be quickly undertaken. To make this type of conveyor more immune from breakdowns by dispensing with the numerous joints, in the presence of which lies the greatest source of trouble, Wangeman, of Berlin, has introduced a conveyor which resembles in principle the well-known band conveyor running over terminal drums and idlers *b* at frequent intervals (Fig. 525). The band proper consists of a number of parallel wire cables *c*, each with a core of longitudinal non-conducting material, such as asbestos; these cables are connected by stout lateral wires into a band of great substance and resistance. The coke is allowed to slide down the plates *a*, so as to lie in the central part of the band, and thus protect the idlers with their bearings from dust.

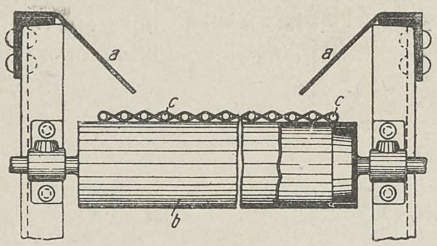


Fig. 525. Jointless Band Conveyor Introduced by Wangeman, of Berlin.

As an example of equipment for horizontal coke platforms, the Burnett quenching and loading device may be mentioned (Fig. 526). It consists of a quencher *a* closed at the top and ends, and extending the full width of the platform; it is made of deeply corrugated boiler plate, the corrugations being horizontal, and, like the Darby quencher, provided with a system of outside pipes spraying water over the coke block through nozzles pointing inwards, which are protected from frictional contact with the coke by the corrugations. The quencher has no bottom plate, but is closed at the outer end by a plate, and at the inner end by a slide. The steam liberated in quenching escapes through holes in the top. It is supported on rollers *b*, and lateral girders *c*, at a height of about half an inch above the platform, and can be run along the battery of ovens by means of wheels *d*. The quencher is moved to and from the ovens by means of the drum *e* and the wire rope *f*. Under the carriage is a sunk conveyor to transport the coke to the screen. Winch *g* is for the purpose of raising the oven door after the quencher has been placed in position. The charge is now pressed into the quencher, which is moved a little to one side so that the doors of both the oven and quencher may be closed, when the coke block is quenched in its enclosure. As soon as no more steam rises from the above-mentioned openings, the quenching process is complete. To enable screened coke to be loaded direct, independently of a conveyor, the apparatus may be modified so that sufficient space is left between it and the railway track for a screen, adapted to be raised and lowered by ropes running over pulleys, and

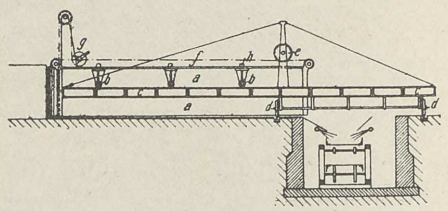


Fig. 526. The Burnett Quenching and Loading Device.

to enable the rail track to be laid on a higher level. The coke can be delivered into a bunker and raised by a bucket elevator to the screen. The Burnett machine is simple, but requires plenty of room which is not always available in old cokeries.

The Méguin loader for coke (Fig. **527**) was built for a Belgian cokery, and consists

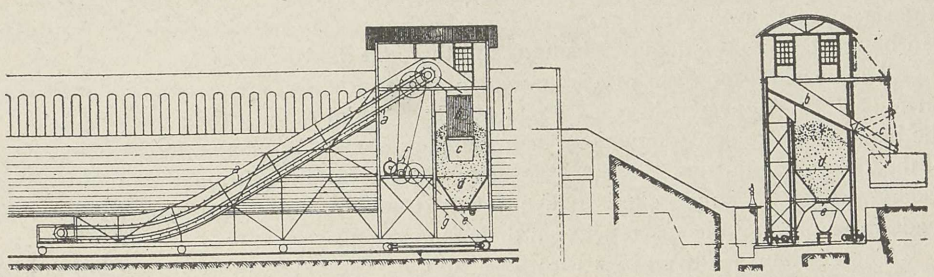


Fig. 527. The Méguin Loader.

of a portable contrivance having a screen connected with an inclined plate conveyor *a*, with angle-iron sides. It delivers the coke to a bar screen *b*, provided with a balanced swing extension *c*, enabling the coke to be loaded into any desired truck. The screenings fall into a bunker *d* with a discharge slide *e*, the conveyor is driven by a belt from shaft *f*, and the travelling motion of the whole carriage is transmitted by chain *g*.

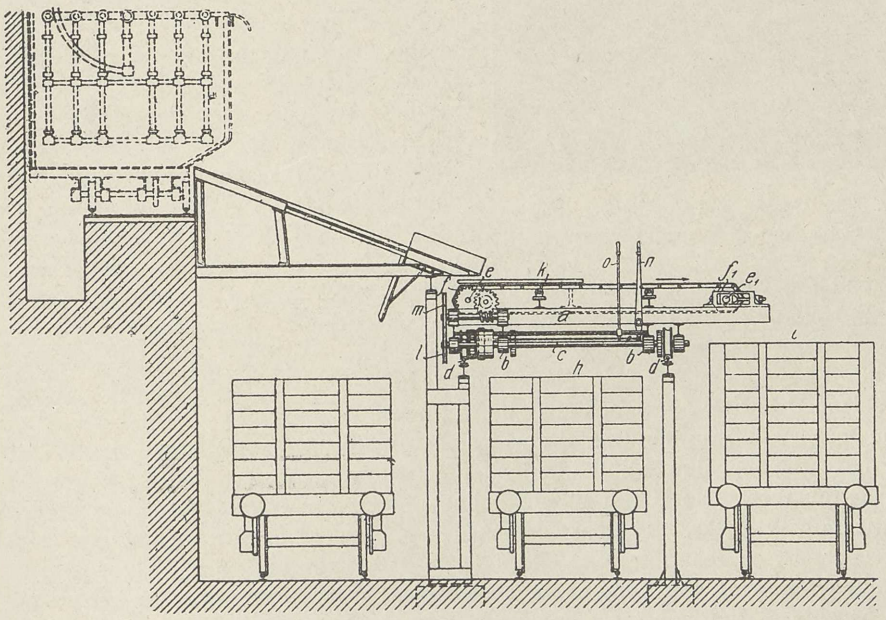


Fig. 528. Portable Loading Device of Allport.

As the illustration shows, the Méguin loader runs on a rail track parallel with the ramp, and between it and the siding for the coke trucks; the ramp is sufficiently steep for the coke to slide down readily. There is a tendency to make the hearth or ramp still shorter and steeper so as to use it simply as a means of conveying by gravity, instead of its original purpose, *i.e.*, for cooling, and we shall see that in some instances the

hearth has been dispensed with altogether. Whether this curtailing or omission is altogether a wise plan cannot be determined until installations on such lines have demonstrated their practical advantages by the test of time.

The Allport loader (Fig. 528) belongs to the category of installations with short ramps. Here the coke is mechanically quenched, and then slides over a bar screen (the slack falling into a truck) on to a wide band conveyor mounted on a carriage which can be moved into the loading position, and there fill the trucks.

The machine consists of a frame *a*, with its bearings *b* and axles *c*, which is raised on rails *d*; the conveyor has hexagonal terminals *f* and f_1, with their spindles *e* and e_1; the band is of wire construction, and can therefore be used to make a further classification of the coke, by adjusting the mesh so as to allow a certain portion to fall through into truck *h*, whilst the large coke is delivered into truck *i*. These conveyors are preferably made in pairs when the space between them is covered by plate *k*.

The machine is driven by a wire rope running parallel with the ramp, and engaging the wheels *l* and *m*, which in their turn are connected by worm and worm wheel to the conveyor, and also to the gearing for the movements of the carriage; these movements are controlled by levers *n* and *o*.

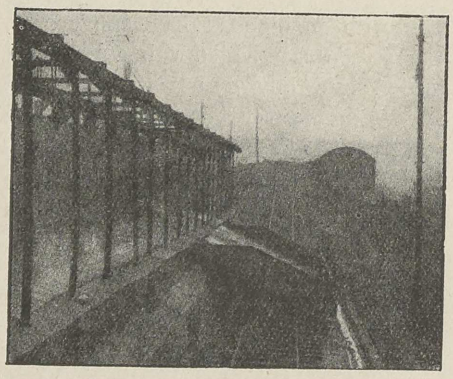


Fig. 529. Cooling and Loading Receptacle at the New Brancepeth Colliery.

The first installation which was erected at the Wharncliffe Woodmoor Colliery, near Barnsley, was unfortunately not a success, as the coke was delivered into the trucks so hot as to set them on fire. Several modifications of this system have been made by the inventor and others, but no thoroughly satisfactory results have been obtained; the best modification is a more substantial conveyor on which the coke is re-quenched and allowed to cool before it is set in motion to fill the trucks.

The form of loading appliance mostly used in English cokeries for very short slopes is that at the New Brancepeth Colliery (see Fig. 529), an iron receptacle about 30 ft. long, and running on a track parallel with the coke ovens. This receptacle slopes at an angle of about 40°, and forms a continuation of the hearth, its upper edge being flush with it. The sides are of iron plate, and the lower end of the receptacle is closed by two balanced lattice doors operated by worm gearing. Ropes attached to either end of the receptacle are wound on drums which can be operated alternately by motors, so as to move the machine to and fro along the battery. Where the coke is to be loaded at once, the receptacle is run up an incline to a screen over which it is emptied direct into the railway trucks. The bar screens are so arranged as to have the same slope as the receptacle, so that the coke slides down at a uniform speed. These screens are generally 30 ft. wide, the same as the receptacle, but in large plants the screen may be twice as wide as the receptacle or conveyor truck, so that each load may rest a while for further cooling. Where space does not permit the use of an inclined track, as at South Brancepeth, a hoist is used.

A similar installation to that of the New Brancepeth Colliery, but on a more extensive scale, is now in use at the cokery of the Woodward Iron Co., Woodward, U.S.A. Here the receptacle is much larger and of a slightly different form, whilst the coke is quenched by pipes with flattened nozzles placed on the top

of the coke ovens, there being one pipe for each oven, so that no flexible pipes need be used.

On a similar apparatus at the Cargo Fleet Works the conveyor truck carries its own motor, and the balanced receptacle for the coke can be raised and lowered by ropes and pulleys. While the coke is being pushed out of the oven past a quencher, the loader is moved slowly onwards so that the coke is evenly distributed in the receptacle, the small and breeze falling through the bottom grid into a bunker underneath, which is emptied at intervals. When full the loader is run to the railway truck that is to be loaded.

The loading machine consists of a substantial framework on wheels which runs on a track in front of the ovens. The raising and lowering of the balanced coke receptacle is accomplished by the same motor which drives the machine, and which is fitted below the breeze bunker, together with its gearing and countershaft. The position of the

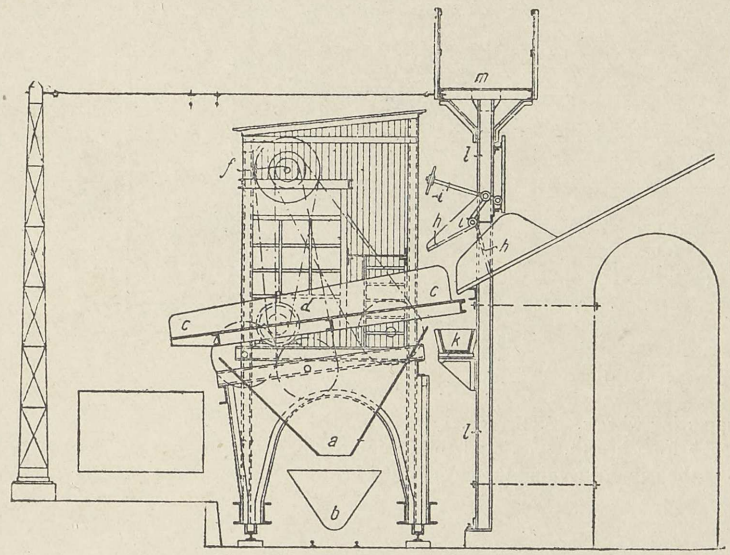


Fig. 530. The Humboldt Loader.

a. The bunker for small coke and breeze. *b*. The truck for the same. *c*. A balanced reciprocating screen. *d*. Electro-motor. *f*. Countershaft. *h*, *i*, *i*. Gate which admits the coke from the hearth, with adjustment. *k*. Trough for surplus quenching water. *l*. Steel standards supporting gate *h* and gantry *m* from which the coke is quenched.

motor under the receptacle being unfavourable on account of its being exposed to the moisture and heat of the load, a simplified form of loader has been installed to serve the ovens producing blast-furnace coke; in this case the bottom of the receptacle is horizontal. The quenching of the coke is completed by hand, and the coke itself is discharged by hand into the trucks for charging the blast-furnace.

Some of the latest coke loaders have been built in connection with short and steep hearths, where the coke is quenched completely on the hearth, and when cool transmitted by gravity on to the loading machine. There is a rail track for such special loaders, running between the hearth and the siding for the coal trucks. These appliances have been built to suit ramps sufficiently high above the coke trucks for the coke to be transferred to the loading device (between hearth and truck) by gravity, and modifications of the same principle have also been recently installed to suit hearths which are considerably below the coke trucks' siding.

An installation of this type, built by Humboldt, is shown in Fig. **530**; it rests on four wheels.

A modification of the foregoing is the installation of F. Méguin, erected at the cokery of De Wendel at Gross-Moyeuvre (see Fig. **531**). The machine is supported and

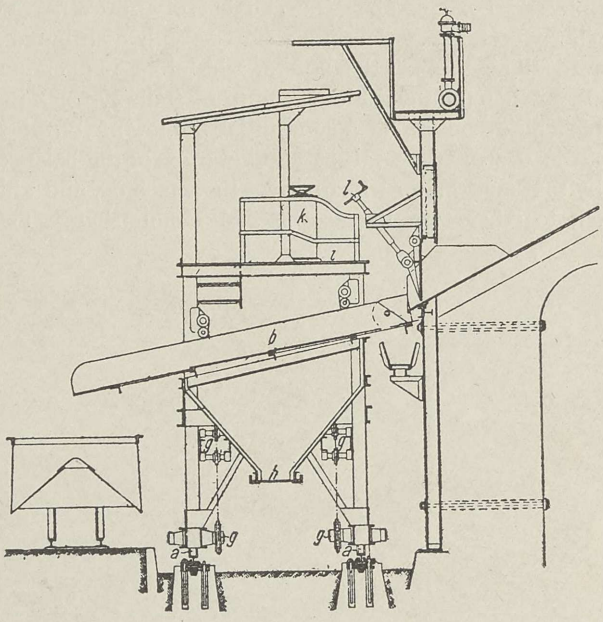
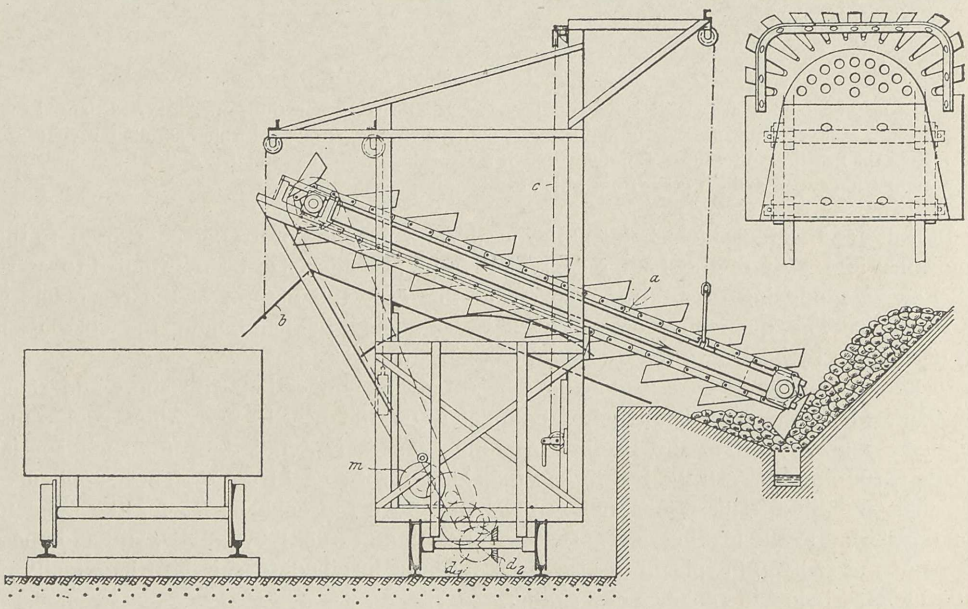


Fig. 531. The Méguin Loader.

a. Supporting wheels. *b*. Screen. *g*. Chain-drive for travelling gear. *h*. Adjustable gate to admit coke from hearth. *i*. Stand for operator. *k*. Starter for motor. *l*. Hand wheel for manipulating the gate for feeding the coke on the hearth.

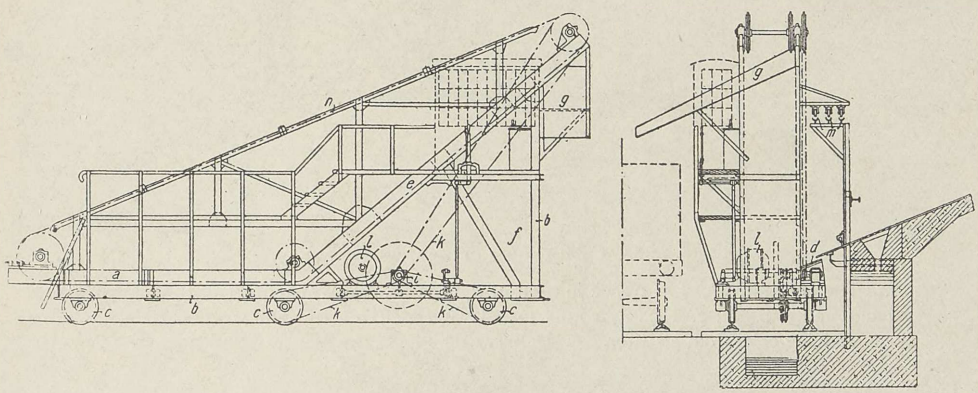


Figs. 532 and 533. Brunck Coke Loader.

travels on three pairs of wheels, the screen being about 15 ft. long by 6 ft. 6 in. wide.

In the foregoing installations the relative positions of the hearth and the siding are such that the coke is moved by gravity all the way to the truck, whilst in the following examples it has to be mechanically raised on account of the higher position of the coke truck siding.

The Brunck coke loader is a kind of scraper elevator which drags the coke up an inclined path into the truck (see Figs. **532** and **533**). The machine is mounted on a travelling carriage on the standard rail track, and is used in connection with a short steep hearth which ascends again slightly to form a pocket for the accumulation of the coke ready for the loader. The diagram explains itself. Being mounted on a standard gauge the machine has the advantage that, in case of a breakdown of the loading device, the coke trucks may be loaded by hand on the track of the machine. The larger detail



Figs. 534 and 535. Fabry Coke Loader.

a. Scraper-belt. *b*. The structure. *c*. Three pairs of travelling wheels. *e*. Inclined portion of scraper conveyor. *f*. Bunker for small coke, covered with bar screen for the elimination of the same. *g*. Loading shoot. *h*. Return strand of scraper conveyor. *i*. Countershaft. *k*. Chain drive for conveyor. *l*. Electro-motor.

represents one of the buckets. Such a system is successfully at work in a French cokery.

The plant illustrated in Figs. **534** and **535** is the design of Mr Fabry, director of the Simplex Coke Oven Co., of Sheffield.

The two chains of the scraper conveyor are connected together at regular intervals by short lengths of chain. One of these machines can serve a battery of 100 coke ovens.

One of the coke loaders of the Coppée Company is shown in Fig. **536**. Here the siding is practically on the same level as the lower end of the hearth, so that an excavated channel becomes necessary for the receiving end of the loading device. On the other hand a great amount of initial expense is saved by keeping the battery of ovens close to the ground, as no substructure is required.

At the Belgian coke ovens where this installation is at work, 100 tons of coke are loaded per hour, and only one man attends the machine. The motor for the conveyor is of 10 H.P., whilst that for the travelling gear is 20 H.P. The speed of travel is about 140 ft. per minute. The same firm have modified the design to suit local conditions, and where the space is confined an elevator with a single bucket has been used in a vertical position, manipulated by steel ropes.

Another class of loading machine dispenses with the coke ramp altogether. Such machines are exposed to heavy wear and tear, not only from the coke itself, but also from the great heat and the corrosion from the acid vapours, so that their construction is connected with many difficulties. As steel or wrought iron cannot resist these

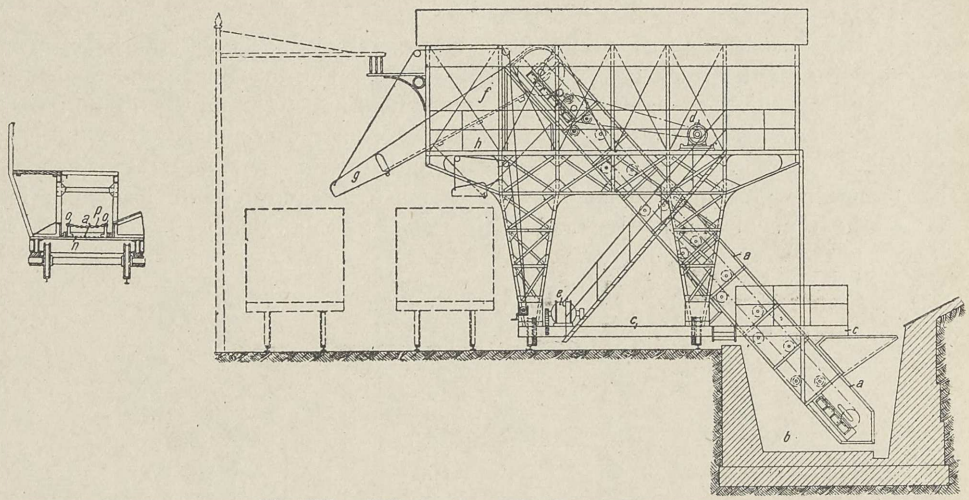


Fig. 536. Coke Loader of the Coppée Company.

a. The elevator. *b*. The trench in front of the hearth. *c*. Girders carrying the overhanging receiving end. *d* and *e*. Electro-motors for elevator and for travelling respectively. *f*. Bar screen receiving coke from elevator. *g*. Delivery shoot. *h*. Bunker for small coke.

conditions, cast iron is used as much as possible in the building of these machines, and especially for parts where the extra weight is of less consequence.

A machine of such a type was supplied about 1900 by the Wellman-Seaver Co. for the Lackawanna Steel Co.'s Works at Buffalo, U.S.A., to serve ten batteries with 940 ovens (Fig. 537). Two longitudinal walls are built in front of the ovens, and on these are placed open sheet-iron receptacles *a* (two for each battery) connected with the ovens by a platform *b*. Each receptacle holds a charge of coke, which is quenched from the platform, the surplus water draining away through the perforated bottoms into a gutter between the two walls, and through drain *c*. The track for the coke trucks is beyond the outer wall, and is served by a portable crane, provided with a running head *d* for tilting and discharging the receptacles. Two rigid arms *e* hook at *f* into eyes *g* on the receptacle, the hooks being locked by an electro-magnet *h*, so as to prevent a release before the proper time; at the opposite side the two hooks f_1 and wire ropes hold the receptacle, the hooks being likewise locked by the electro-magnet *i*, so that they cannot work loose; the ropes are protected by two telescopic tubes *k* against the vapours, as well as to prevent these whipping when wound on drum *l*. Two motors manipulated

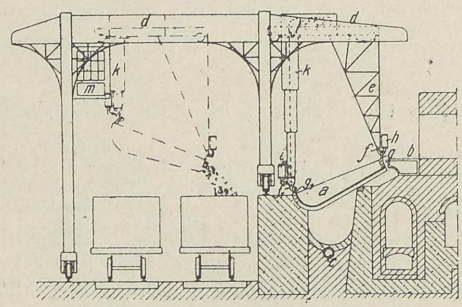


Fig. 537. The Wellman-Seaver Coke Loader.

from driver's cab *m* serve for the travelling gear of the loader and for the manipulation of the receptacle. When the latter is filled with the contents of an oven, and after the coke is quenched, it is lifted approximately horizontally by means of the ropes, and carried by the crane to the empty truck, where the coke is emptied by tilting as shown in the illustration. The apparatus has answered well, and the amount of wear is small, the only drawback being that the coke is not screened. Hence the device is restricted to works where the coke is consumed on the premises.

At the Lebanon Works of the same company is a similar installation at work for two batteries of 232 ovens, for which also two each of four receptacles are in use. In these installations the appearance of the coke is of less importance, but the loading apparatus of Moore, Philadelphia, effects the quenching and handling of the coke in a more careful manner, the air being excluded, and a silvery coke, resembling that from beehive ovens, is

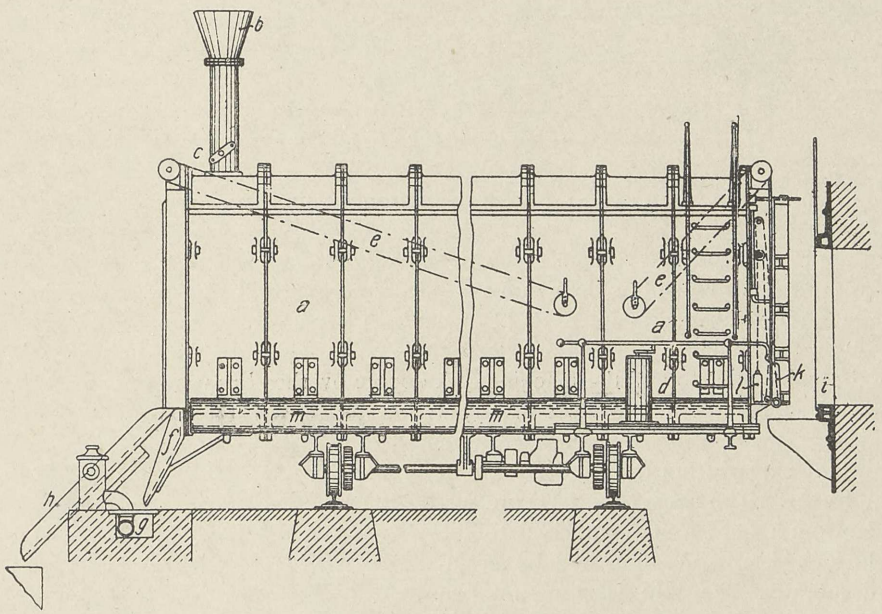


Fig. 538. The Moore Quenching and Loading Machine.

obtained. The device consists of an iron chamber as large as a coke oven, which is mounted on a travelling carriage operated by electricity (see Fig. 538). The chamber is enclosed in a shell divided into several vertical compartments *a*, with a short chimney *b* at the forward end, provided with a throttle valve *c*, the space between the compartment and shell being partly used as a water jacket. Strong doors at each end can be operated from the driver's stand *d*, the two sections of these double doors being opened and closed by ropes and pulleys *e*. An open slit is left under the front door for the escape of the surplus quenching water through a gutter *f* into the drain *g*. The coke falls down a chute *h* into the railway truck. The two halves of the door next the oven fit against the oven door frames *i* when open. A lever *k* raises a small flap from the bottom of the chamber, to make a joint with the oven, and prevent the escape of water at that end; the flap is balanced by the weight *l*. The quenching water is introduced from the hydrants by a hose connected with a pipe on the machine frame.

The working of the apparatus is illustrated in Fig. 539, in which *a* is the battery of

coke ovens, *b* the coke pusher, *c* the quenching machine, *d* a stationary pusher at the end of the battery, and *e* a railway truck, belt conveyor, or screen. The machine is placed in position opposite the oven to be emptied, the chimney valve is closed, and the water pipe connected with the hose ; the door next the oven is then opened, and the chamber is filled with coke, the rear door is closed, and the water turned full on for several minutes, until it begins to drain away freely, whereupon the supply is shut off, and the machine is run along to the stationary pusher, where all the doors are opened and the coke expelled into the truck opposite. This machine is used in America, but is too expensive to justify its more general adoption, especially now that less stress is laid on the appearance of the coke than was formerly the case, and simpler forms of quencher give similar results at less cost.

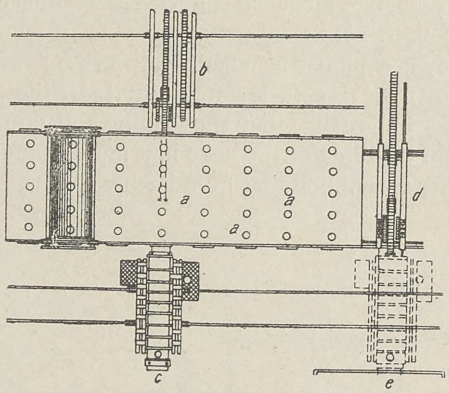


Fig. 539. General Arrangement showing an Installation of the Moore Machine.

An apparatus of an entirely different type to all the foregoing is that of Illig, made by A. Bleichert & Co. (Fig. **540**). Close in front of the oven doors is a longitudinal water trench *a*, over which travels a framework *d*, with a suspended receptacle *b* with sloping bottom, preferably of perforated sheet iron, and fitted with a sliding door *c* on the side remote from the ovens. This receptacle is slung on two chains, adapted to be wound on drums in the upper portion of the frame by motor *e*. The winding and travelling motors are reversible, and are operated from the cab at the top of the machine. A double overhead runway g g_1, with rounded ends, and supported by two structures *f*, is provided at the rear of the machine, and conveys the skips *h* from the quencher round to the trucks. The skips (Fig. **541**) are suspended from a bent arm *a* attached to the wheel truck *b*, which is operated by an enclosed motor. The skip is slung on two wire ropes adapted to be wound on a double drum *e* by means of a second motor. Current is supplied to both motors through a live wire *f* and collector *g*. The skip is closed by bottom flaps *h h*, operated by a lever *i*, provided with a contact piece. The motors are switched in and out of action by portable switches, which enable the skips to be stopped and discharged at any desired point, and also to run at definite intervals. Two men are sufficient to work the plant, and the *modus operandi* is as follows: The quenching machine is put into position in front of the oven to be discharged with the receptacle up, which is, however, lowered immediately the machine is in position ; the coke is then pushed into it and thoroughly quenched. When the coke has been quenched, and the machine moved aside to enable the oven door to be luted up, the receptacle is raised again, the attendant turns to the runway, on which the empty skip is waiting, switches on the lifting motor, which lowers the skip, the latter being then filled automati-

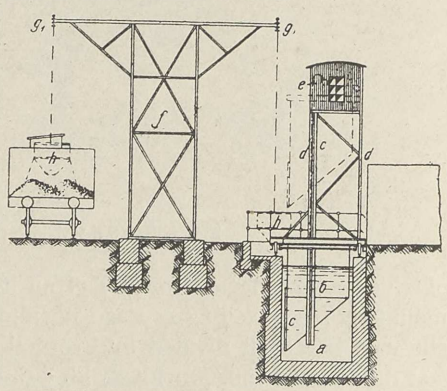


Fig. 540. The Illig Coke Loader.

cally from the receptacle, raised again, and moved off on the runway. Meanwhile the man at the discharging station has set his switch to discharge the oncoming skip into the desired truck. The trench is covered to prevent accidents, and to keep it clear of coke droppings, by a travelling cover of corrugated plates, running over hexagonal drums at each end, and fixed on to the quencher in such a way as always to completely cover the trench; also when the quenching receptacle is travelling in either direction, one of the terminal drums of this cover is driven by an electric motor by worm and pinion gear, the speed of travel being 18 ft. per minute.

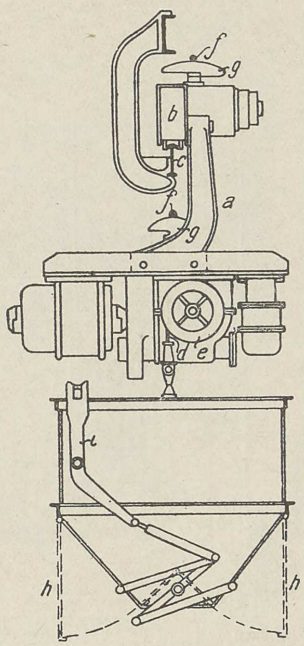


Fig. 541. The Skip of the Illig Loader.

This system has been further improved and simplified by using the quenching receptacle at the same time as a skip, and delivering the coke direct either over a sieve into a bunker, or into railway trucks, so as to dispense with the separate loading device. Such an installation is shown in Fig. **542**. This illustration shows a section through the pit or canal in front of the battery. The water receptacle *a* is here portable on wheels, and is divided into two compartments *b* and *c*. The perforated quenching vessel *d* is suspended from a cable *e*, and when moving along the canal drags the water receptacle *a* with it. The funnel *f* is shown in position before the oven to be pushed, so that the coke falls through this into the quencher. When this has received the contents of the oven, the whole apparatus is drawn by the cable *e* to the end of the battery where the water tank *a* remains stationary, whilst the quenching vessel *d* ascends out of the water, guided by *g g*, and discharges into bunker *h*, after which it returns in like manner to the next oven to be dealt with. The great advantage claimed for this system is that the quantity of quenching water used is the smallest possible, and as the water is always at a high temperature, the percentage of moisture in the coke becomes less as the residual heat in the latter evaporates the adherent moisture more readily during transit from pit to bunker.

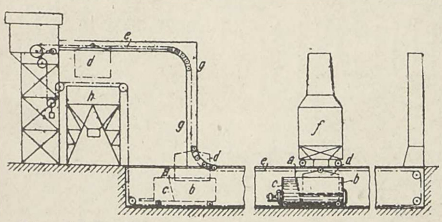


Fig. 542. The Coke Quencher and Loader of Bleichert.

Stole, of Farlowitz, in his latest coke plant (Fig. **543**), has adopted a water trough or canal similar to the installation shown in Fig. **540**, but the canal is not for quenching purposes in this case, but to float the hot coke receptacles, like boats, to the quenching tower, a power-driven water wheel creating the necessary current for the conveyance of the coke receptacles. The *modus operandi* is as follows: A floating receptacle is placed in front of the oven to be pressed, which receives the charge which is superficially quenched under a water spray. The vessel is now released, and the final quenching proper is not performed until the floating skip reaches the quenching tower *a*. Here it is emptied on to a grating *b*, and completely quenched by the quencher *c*; the chute *d* is now lowered and the coke is raised by the lift *e*, either for classification, or into railway trucks, leaving the breeze beneath the bar screen. Since the skips float rather deeply in the water, they do not

suffer to any great extent from the hot coke. So far this system has only been used in gasworks, but it is also to be adopted for coke ovens.

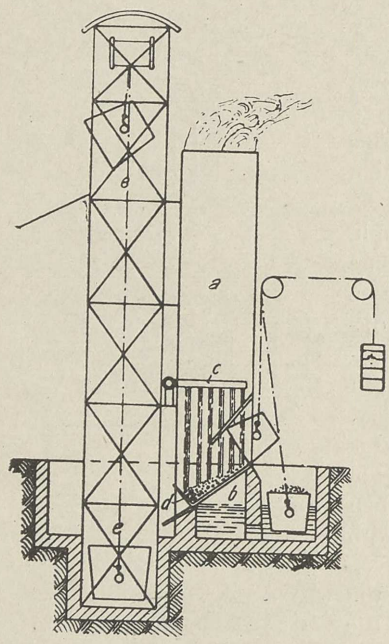


Fig. 543. The Coke-Handling System of Stole, of Farlowitz.

Lastly, we have to deal with those appliances for which there is no hearth necessary at all, and in which quenching, sifting, and loading are performed as a continuous process. An installation of this type is that of "Méguin" (Fig. **544**); the machine is mounted on wheels and runs along the front of the ovens on rails. The coke is pushed past a long quencher *a* (consisting of a network of spraying pipes), and over a sloping chute into a hopper *b*, through the adjustable chute off which the coke falls on to a travelling band *c*, the lower terminal of which dips into a water tank *e*, so that the coke is thoroughly quenched on its way to the screen *d*, which delivers the large coke on to a chute leading to the railway truck, whilst the screenings are discharged into a special hopper. The overflow water from the quenching tank runs into a drain extending the whole length of the battery, the tank being replenished with water from a trench *f*, by means of a centrifugal pump *g*, coupled direct to the motor operating the machine. Since the conveyor *c* is sufficiently long to hold a full charge from one oven, the machine, when filled, can be run to any part of the track for discharging into trucks, so that all shunting is dispensed with. For blast-furnace work, the machine discharges into hoppers, from which the charging skips can be loaded.

A modified form which was successfully installed at the cokery of the Soc. des Mines de Béthune, Bully (Fig. **545**), consists of an inclined conveyor delivering the coke to a

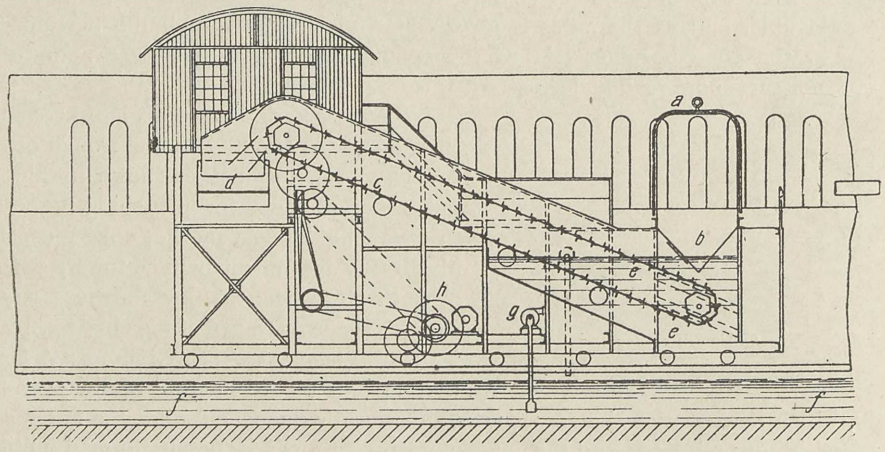


Fig. 544. Showing the Portable Quenching, Sifting, and Loading Machine of Méguin.

screen forming a part of the machine and loading it direct into trucks. The coke is exposed to the action of a quencher, and the work is afterwards completed on the

conveyor by additional jets. The sections of the conveyor are made of perforated sheet iron, with side plates 12 in. high. The conveyor consists of three chains connected to each other by cross-pieces, and a narrow gangway for the attendants is provided on either side of the conveyor. The delivery end of the machine is provided with a jigging screen, and the whole is mounted on a substantial frame running on wheels in front of

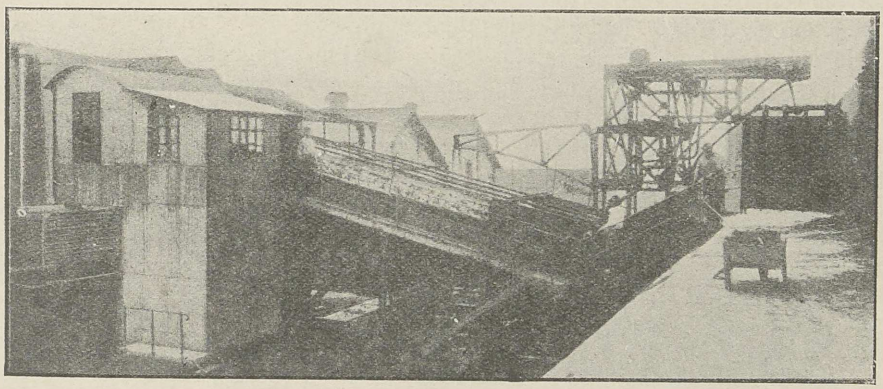


Fig. 545. The Méguin Machine at the Coke Works of the Mines de Béthune in Bully les Mines.

the battery. The quencher and loader are moved from one oven to another by a slewing crane, operated from the main motor by ropes; and a contrivance with intermittent motion, between the quencher and conveyor, enables the coke to be spread out for completing the quenching.

Another somewhat different type is the machine of Kellner & Flottmann, of Düsseldorf, used at the Herne cokery of the Hüstener Gewerkschaft (Fig. **546**). In front of the short ramp *a*, and about 6 ft. lower, is a second broader level *b*, with the rail track for the machine. The apparatus, like those formerly described, is self-contained; the floor, as it were, of the machine consists of a grating *c*, the bars of which are attached to two frames in such a way that those secured to the frame *c* can alternately be raised and lowered by means of a roller *f*, whilst the intermediate bars remain stationary. The screen is operated by eccentric shafts *d* and *e*, on which the screen frames are loosely mounted in guides c^1. On the side away from the ovens the screen has a cast-iron hinged extension *g*, which is lifted up while the coke is being received, but falls down automatically when the screen is tilted, and forms a chute for the discharge of the large coke to the trucks. The screenings fall into the hoppered bunkers of perforated plate in the underbody of the carriage, so as to allow the quenching water to escape. The quenching water is drawn from a conduit *h* below the track through a suction pipe *i* by means of a centrifugal pump, which delivers the water to a series of sprinkling pipes *k* above the screen. The machine deals in each operation with the whole charge of one

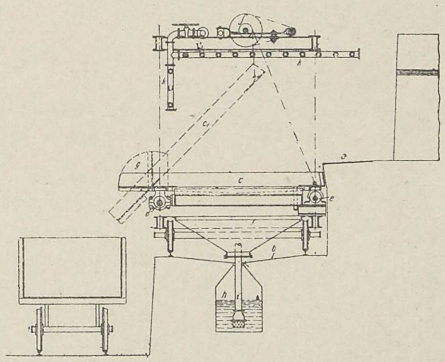


Fig. 546. Coke-Handling Machine of Kellner & Flottman (Schumacher System).

of the ovens, which may be discharged into any of the railway trucks in waiting by raising the grating c^1 as shown in dotted lines. The agitation the coke receives from the bar screen not only disposes of the breeze, but it loosens the coke lightly, and with a minimum of breakage, for the easier access of the quenching water to all parts, and a more uniform cooling. The screenings are delivered at intervals to a classifying plant at the end of the battery. The whole machine can be worked by one man, and is operated by a 35 H.P. motor, a 6 H.P. motor driving the pump.

The latest machine which automatically receives, quenches, screens, and delivers the whole charge of an oven into any available truck along the whole line of coke oven, is that of Goodall, and it is at work at the Weardale Steel, Coal, and Coke Co., Spennymoor, as well as at several other large establishments (Figs. **547** and **548**). The machine consists of a large iron frame running on eight wheels, on rails placed in the

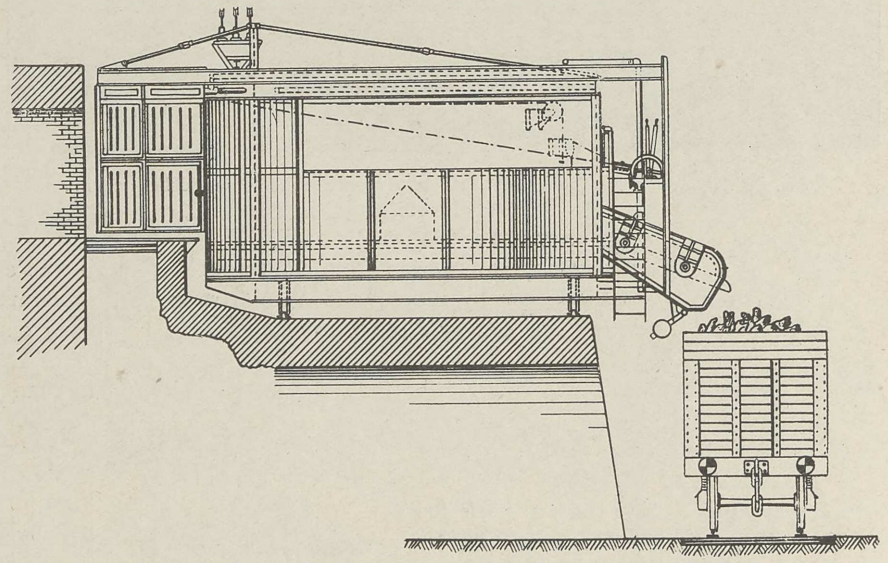


Fig. 547. Elevation and Cross Section of the Goodall Machine as Manufactured by W. J. Jenkins & Co., Ltd., of Retford.

position usually occupied by the bench or quenching floor. It is fitted with motor and gearing to propel it along the rails in either direction, and to revolve the table or coke receptacle, and drive the shaking screen. In the centre of the frame there is a substantial cast-steel footstep bearing, which receives a short vertical spindle. From this axle, leading to the periphery, horizontal girders are fixed which are connected at their extremity by a cast-steel ring having teeth at its lower edge, and forming a large wheel which gears into a pinion on a horizontal shaft. Below this turntable there is a rail bent into a ring-form, which gives the table support and stability, by means of a ring of rollers running on the same. The framework of the table so formed is covered with interchangeable perforated cast-iron plates, so as to form a revolving table 20 ft. diameter to receive a charge of coke; the table is surrounded by plates, which are also lined again with interchangeable cast-iron plates up to the height of 3 ft. There is a slot-like opening, with guide plates, in this outer cylindrical ring on the oven side of the machine, sufficiently large to allow the cake of coke to enter. Directly opposite this

opening is a large floor in the same cylindrical casing, manipulated by a winch and chains in such a way that when the door is closed the inside of the casing is a complete ring, but when open the door projects inwards and reaches to the centre of the turntable, and being fitted with plough-shaped castings on the back, acts as a scraper to remove the coke from the revolving table. Under the doorway is arranged either a fixed or jigging screen, and the coke coming from the table falls on to the screen and passes thence, properly screened, into the railway wagon. A receptacle below the screen, which is emptied periodically, receives the breeze and small. Above the revolving table, as well as down the sides of the cylindrical casing, is a net of water pipes, perforated so as to act as sprays for quenching the incandescent coke, and a small hose for spraying water by hand is also provided, to play in any direction that may be necessary.

The method of working the machine is as follows: First, the huge apparatus is driven along the rails and placed opposite the oven to be discharged; the oven door and the receiving slot having first been opened, the pushing then commences. As soon as the red-hot cake of coke enters the machine the water is turned on and the quenching begins. When the coke has reached about one-third across the table, the latter is caused to revolve in the direction of the clock. The coke then rests on the table, and the continued motion of the latter, combined with the continuous forward motion of the cake of coke, gently promotes the distribution of the contents of the oven over the revolving table; the quenching operation proceeding all the while by water being sprayed on to the coke both from above and sideways until at last all the coke is on the table, which is now stopped and the machine moved a few feet out of the way so that the oven door may be put on at once. The water is now shut off, and a reasonable time allowed for steaming and drying, say ten minutes, after which the table with its load of coke is slowly revolved, and the attendant with his hand hose sprays water on any red places until the whole of the coke is quenched. Surplus water drains away immediately through the perforated plates in the table, and so avoids over-wetting of the bottom coke. The small breeze which passes through with the quenching water collects in large bins between the rail track, divided off transversely by walls; here the breeze settles at the bottom and the water percolates through to a drain, so that the remaining breeze may be collected from time to time.

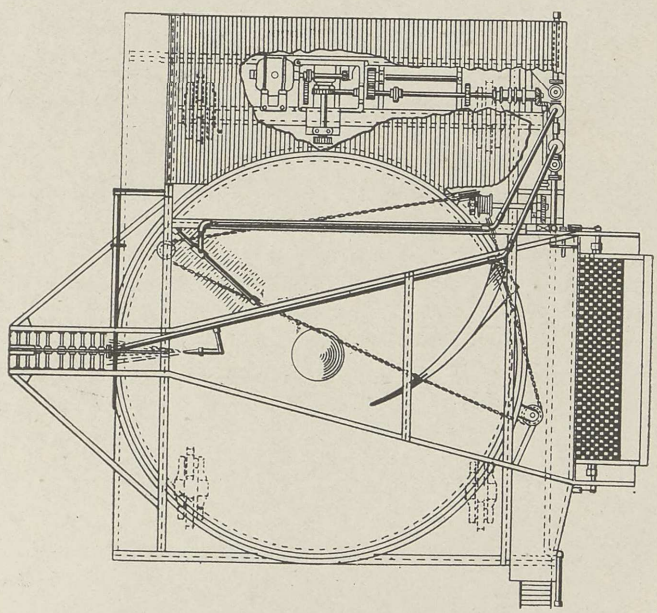


Fig. 548. Plan of Goodall Machine shown in Fig. 547.

The quenching being completed after about ten minutes, the flexible water connection between the fixed main and the machine is disconnected, and the same is propelled along

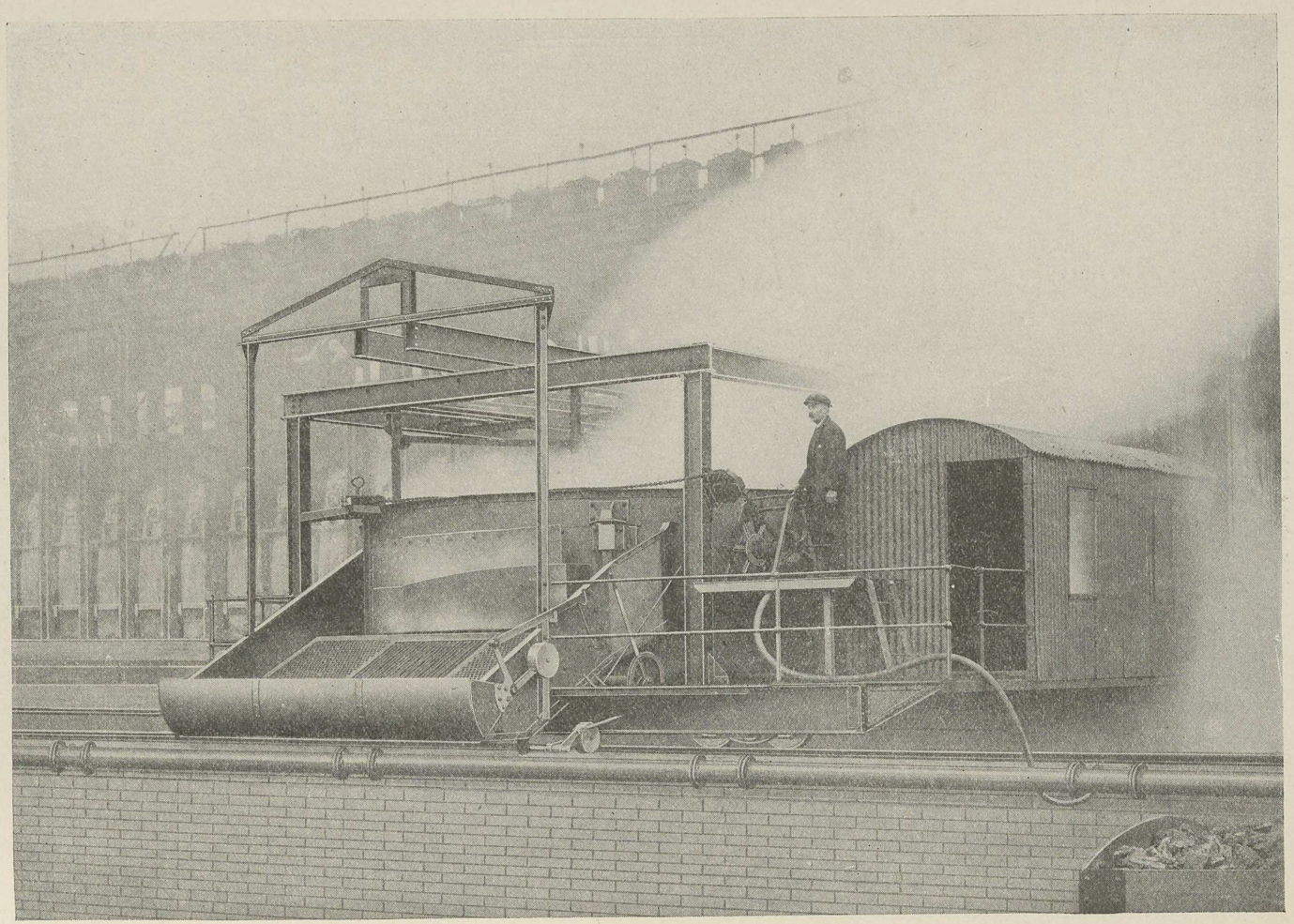


Fig. 549. The Goodall Machine, showing the Coke being Screened and Loaded into Wagons.

the rails to any waiting wagon, either in front of, or some way beyond, the oven from which the coke came. The discharging door is then opened a little way, at first inwards, and the table revolved in a counter-clockwise direction; the coke is, in consequence, gradually pushed out by the plough-like door on to the screen, which is set in motion by means of gear from the motor, and the screened coke is automatically loaded into the wagon (see Fig. **549**).

One of the important features of the system is the expeditious way in which the coke is handled; the time occupied from the start of the push to the time when the door is on the oven again ready for recharge is only eight minutes, and the whole operation, from the beginning of the loading into the wagon, including the steaming or drying period, does not require more than twenty-seven minutes.

The principal advantages of this machine are its great simplicity, in spite of its automaticity (the weight being only about 28 tons), and the fact that the hot coke comes only in contact with renewable cast-iron plates, a material which is least affected by it.

The installation at the Weardale Steel, Coal, and Coke Co., at Spennymoor, has been at work for nearly two years; it serves a battery of sixty ovens, with a yield of 1,700 tons per week, and is attended by two or three men only, as against twenty-one to twenty-seven when the coke was quenched and loaded from an ordinary hearth by hand. In addition to this advantage, the breakage of coke is less by $\frac{1}{2}$ per cent., and the moisture contained is below 2 per cent.

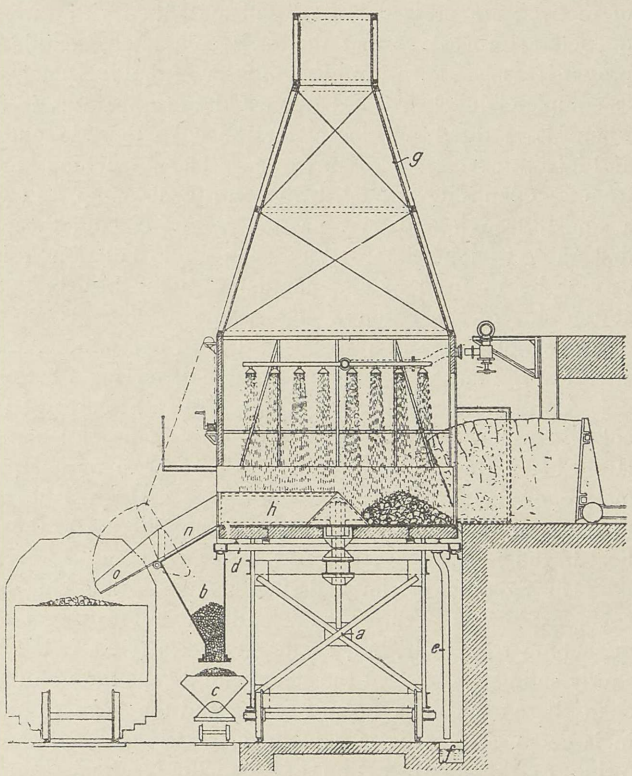


Fig. 550. Méguin Modification of Goodall Machine.

a. Travelling frame. *b*. Bunker for breeze. *c*. Breeze trucks. *d*. Annular receptacle for surplus quenching water. *e*. Waste-water pipe from *d*. *f*. Waste-water gutter. *g*. Vapour duct. *h*. Iron rim which prevents the coke from falling out at the side. *n*. Grating for eliminating fine coke. *o*. Loading shoot.

The machine is driven by a three-phase electric current from the central station close to the works, but it is, of course, equally adaptable for steam power.

The Goodall principle has been modified by F. Méguin & Co., of Dillingen, as illustrated in Fig. **550**. In addition to the alterations, which may be seen from the diagram, the scraper for discharging the coke has been so modified that it is actuated by the revolving table. The lettering given under the illustration will

explain the diagram, after the full description which has been given of the Goodall machine.

Some of the latest coke-handling plants have been designed with a view of excluding the air more effectually during the quenching process, to produce coke of silvery colour as obtained from the old-fashioned beehive ovens.

The first installation on these lines was that by Moore, erected in an American cokery, but its very high cost is against its more general adoption. The machine has been simplified by Humboldt. The quenching chamber into which the entire contents of an oven are pressed is enclosed and filled with vapour or steam created during the quenching process, so that the air is completely excluded, and the quenching apparatus proper is suspended within the interior of the receptacle. As soon as the cake of coke is completely enclosed and quenched the apparatus is driven to the end of the battery where it is tilted sufficiently for the coke to slide out by gravity, either over screens and into trucks or on to conveyors. The quenching water is pumped by the apparatus from an open water trough by a centrifugal pump, and the surplus water is returned to a similar trough, and after passing a settling tank the clean water is returned into the first water trough again. With such an installation it is obvious that the coke siding cannot be in front of and parallel with the hearth, but must be at right angles, and at the side of the battery. The whole machine is mounted on twelve wheels running on three rail tracks at a speed of 160 ft. per minute, and only one man is required to attend to the machine, which is capable of serving a battery of one hundred ovens.

A still more effectual exclusion of the air is obtained by complete submersion of the coke in water. This process has been in use for some time in gasworks, but it has lately been applied on a larger scale to coke ovens with great success. An essential feature of the process is that both coke and quenching water leave the machine at so high a temperature that the moisture still adhering to the coke is evaporated by the latent heat in the coke.

During the experimental stages, when submerging large quantities of incandescent coke, explosions occurred sufficiently violent to throw the coke and water out of the quenching receptacle, but, as might be expected, it has been found that if the coke is slowly submerged so that the steam can escape through the interstices of the incandescent coke, these explosions do not occur, and the coke so quenched is of a firm quality and in large pieces. This is explained by Schöndeling, the pioneer of the system, to be owing to the gentle action of quenching; the steam rising from the portion first quenched being superheated, by passing through the still incandescent coke, to such an extent that the difference of temperature between the coke and the quenching medium is comparatively small, and its quenching action very gradual, whilst chilling the coke from above will contract it suddenly and make it brittle.

The first plant on the Schöndeling system was erected in 1910 at the Gasworks, Agram, in Germany, and a typical installation of the kind is shown in Fig. **551**.

The coke receptacle *a* is composed of double walls, and takes the whole charge of an oven. There is a communication between the double wall space and the lower portion of the receptacle, so that the little water contained at the beginning in the space between the walls will quench the coke in the bottom of the receptacle; the quenching tanks *d* are large enough to contain sufficient water to quench three or four charges without replenishing.

When the oven door has been opened and the machine placed in position the pushing is commenced, and the coke enters through the passage *e* into the coke receptacle *a*, which rests in the water tank *k* during the filling. The quenching process

takes place slowly from the bottom upwards until the whole of the coke is submerged. The receptacle or skip *a* is now slowly raised and the water allowed to run out of side openings into the water tanks *d*; when the water has run off the skip is raised further, and tipped automatically by rollers and guides (as shown in dotted lines) on to the screen *g*, and thence to the truck.

The same machine is built in different ways. In some installations the skips are detachable, and are placed on a wheeled base and conveyed thus intact with their load to

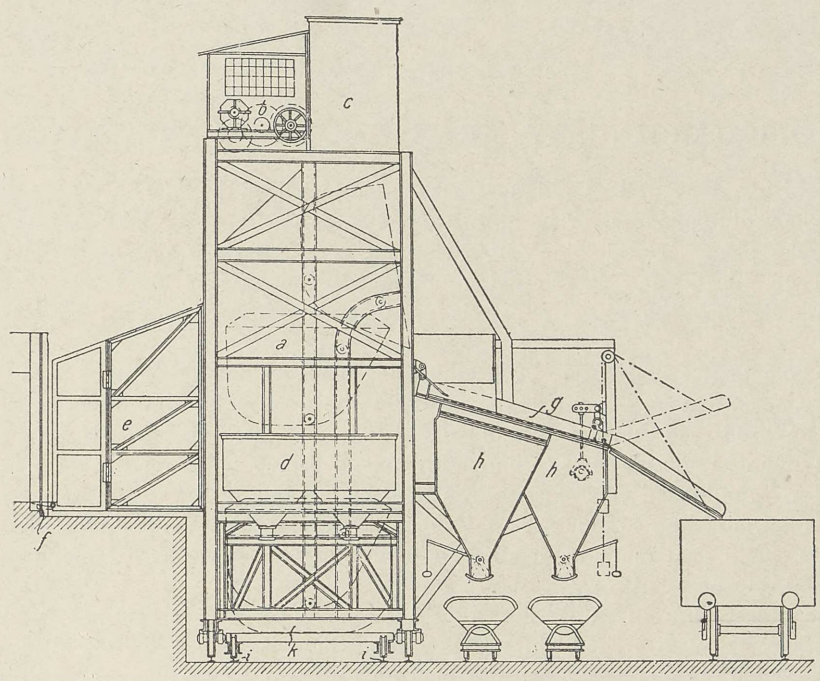


Fig. 551. Schöndeling System for Quenching and Loading Coke.

a. The coke receptacle. *b*. Winding gear for lifting and lowering the receptacle. *c*. The steam or vapour duct. *d*. Two quenching water receptacles (communicating with each other). *e*. Shield between oven and quenching apparatus. *f*. Flap which bridges over the gap between the oven door and the apparatus. *g*. Screen on which the coke is emptied. *h*. Receptacle for small coke. *i*. Rails on to which the apparatus runs. *k*. Water receptacle in which *a* stands whilst receiving a charge of coke.

where the coke is required. In some machines the tank *k* is dispensed with, and the water enters into the space between the double walls of the skip from the tank *d*; when tank *k* is used the skips are generally of single iron sheets, and double walled. The weight of the skip in some machines is balanced by weights. Two men only are necessary to manipulate such a plant, and with it are capable of handling the contents of six or seven ovens per hour.

Similar installations, but with slight modifications, are at work at Zeche Radbod and Zeche Bismarck, in the Ruhr district of Germany, also one at Zeche Neumühl.

UNLOADING AND LOADING APPLIANCES

CHAPTER XXX

DISCHARGING BY MEANS OF SKIPS AND GRABS

Boats and barges as well as railway trucks usually deliver material at the point where the mechanical appliances for its further conveyance are located, and here the transfer has to take place. Hand labour at this point is out of the question if the plant is to be economical, or if labour-saving appliances can do the work wholly or even partially. Perhaps the most frequently used appliances at this stage are skips and grabs.

To operate any kind of bucket for unloading purposes a crane of some description is necessary, such cranes often being fixtures on the quay side, and when large vessels have to be discharged they are used in pairs or in even greater numbers. Not infrequently they are mounted on rails so as to be readily moved to any point on the quay at which the boat to be unloaded may most conveniently be moored.

It is not, however, so much the object of this chapter to give a technical description of cranes, as to deal more in detail with such skips and grabs as are manipulated by cranes and transporters.

The oldest form of skip consists of a large bucket suspended slightly below its centre of gravity by an arched bail with a catch, which keeps the bucket in an upright position. Such buckets have a capacity of from 1 to 3 cub. yds., and are lowered into the boat and there filled by hand. When full, they are raised by the crane and swung to the unloading position, when the catch being withdrawn, the buckets tilt and discharge their contents. This mode of unloading is used for grain as well as for minerals, but has to a great extent been superseded by the self-filling grab, as the latter dispenses with hand labour in filling.

Grabs are frequently used for excavating purposes, perhaps as much so as for handling grain and minerals. Although the earliest grab known only dates from 1703 there is every reason for believing that appliances of this type were in use at an even earlier period. In 1703 the French Academy of Science approved of the design of a machine for excavating purposes, a description of which was published by them. This appliance was the invention of a M. Gouffe, and had the outward appearance of the modern grab. It was provided with serrated edges that cut into the ground, and was operated by two ropes and a bar which gave the cutting edges a downward pressure, the two ropes being manipulated by two windlasses. There are other designs too numerous to mention which have from time to time sprung up, only to disappear again. The grab of to-day is perhaps one of the most familiar of modern labour-saving appliances.

Self-Dumping Buckets.—Before passing to a more minute description of grabs, one or two types of mechanical self-dumping buckets may be mentioned, one of which

is illustrated in Fig. **552**. These generally consist of a large tub with hinged bottom doors; such appliances were used at the Millwall Docks for unloading grain before the Duckham pneumatic elevator came into use. These tubs have the advantage of being light, as they hold 60 bushels of grain, or nearly 3 cub. yds., and weigh only 5 cwt. The bottom is divided into two halves which are hinged to an iron bar traversing the bottom of the tub, and the lower edge is so contracted as to form a truncated cone 6 in. in height; thus the diameter of the lower portion is 1 ft. less than that of the main portion of the tub.

The lower rim is so machined as to fit the hinged bottom. The bucket is suspended by a length of $3\frac{1}{2}$ in. wrought-iron tubing passing through the bearing B, and having a suspending eye at the top and an attachment C for four connecting rods D at the lower end. When suspended from the eye the bottom door supports the shell portion of the tub. When filled the tub is lifted by the crane and deposited on a circular opening in the top of the receptacle where the load is to be discharged, and as the crane continues to lower, after the shell of the tub has reached its seat, the doors open (as shown in the dotted lines) and the grain discharges. The doors shut automatically as soon as the crane lifts the empty bucket off its seat.

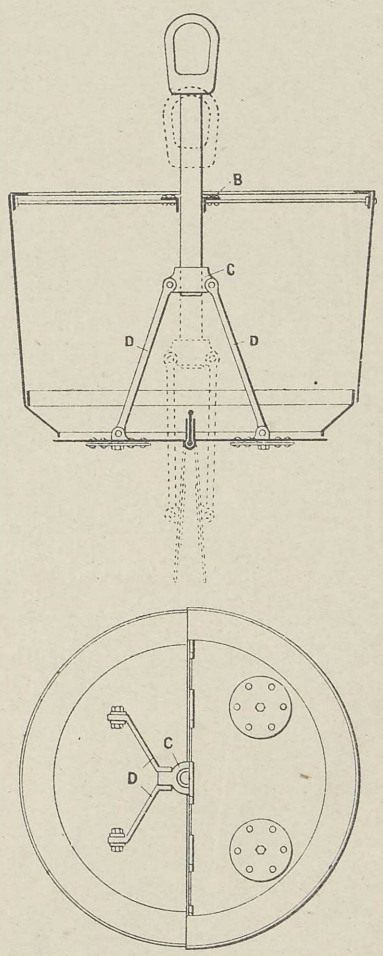


Fig. 552. Mechanical Bucket formerly in use at the Millwall Docks.

Self-Discharging Skip of Taylor & Hubbard.—This is similar to the foregoing appliance, as will be seen by Fig. **553**. It must be filled by hand as is the previous one, but discharges its load automatically, after the manner of a single-chain grab described later. The automatic gear A, which is suspended from the jib-head of any ordinary crane, discharges automatically at any predetermined point to which the gear may have been raised or lowered. The mechanical working of this apparatus, which can be operated by one man, is clearly shown in Fig. **553**.

The flaps forming the bottom of the skip are connected by links F F to the rod G, which is attached to the lifting chain, while the body of the bucket has connected to it a sleeve H, through which the rod G passes, and which has a conical top with a shoulder H^2. The automatic gear is independent of the jib. Bell crank triggers J, adapted to engage the shoulder H^2, have projections J^1 sliding in slots in the sleeve A, and are normally pulled upwards as shown by springs a^1. Projections engaging slots in the part A limit the lateral play of the triggers J. On raising the loaded bucket the triggers J are forced apart by the conical end of the sleeve H, and then close under the shoulder H^2 as shown. On lowering, the weight of the bucket pushes the triggers down so that their horizontal arms engage projections K^1 on the arms K, which are forced inwards by springs, and on further paying out the chain the bottom of the bucket opens. The bucket itself is

supported by the triggers J. As in lifting, the weight of the bucket is again taken by the chain. The triggers turning on the fulcrums J^1 are pulled outwards by their springs, so that on again lowering, the sleeve H drops, and its shoulder H^2 engages the arms K, releasing the triggers J, and allowing them to return to their normal position ready for the next operation.

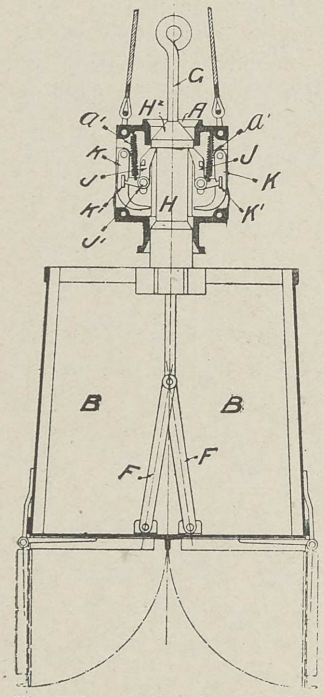


Fig. 553. Self-Discharging Skip of Taylor & Hubbard.

An intermediate form between the skips just described and the grab is illustrated in Fig. **554**,[1] which shows the jaws in an open and in a closed position. This appliance is used for a variety of purposes—for unloading minerals and grain for instance—in which case the receptacle is filled by hand, and then swung by means of the crane into position so as to deliver to the spot at which the discharge is required, when the contents can be deposited by means of the two outer chains. It will be readily seen that the discharge of coal from this appliance is more gentle than from the skip previously described.

In the earliest grabs, owing to their slow speed of working, chains were used for lifting and closing the jaws; the higher speed at which grabs are now worked makes chains unsuitable on account of the greater wear, their noisiness, and their ability to break without giving any warning.

Generally speaking, ordinary chains are rarely used, but mostly those of special design are employed.

Grabs may be roughly divided into two sections—those working with one rope and those with two or more. The inducement for the employment of one-rope grabs is that existing cranes can be used to manipulate them, while for two-rope grabs it is necessary to install a special winding gear on the crane in order to accommodate and

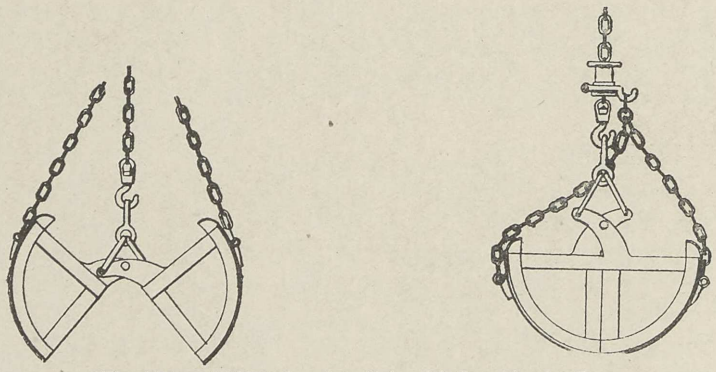


Fig. 554. Self-Discharging Skip with Semicircular Jaws.

separately actuate the two ropes. With a one-rope grab the single rope when tightened will first close the grab and then immediately lift it. The cycle of movements in the one-rope grab is practically unalterable. It is lowered open upon the material, closed and

[1] *Magazine of the Thames Ironworks*, June 1900.

lifted and discharged suddenly in its highest position by a catch which releases the grab so that the material by its own weight forces the grab open, and so escapes. The disadvantage of these appliances when handling friable material such as coal is obvious, particularly when used for forming stock piles. When the pile is high the damage to the falling coal is not so great, but as the point of discharge cannot well be altered, the coal has to drop a considerable distance when the pile is low. Another disadvantage is that one-rope grabs are generally heavier, more costly, their centre of gravity is higher up, and they are, therefore, more liable to tilt over when lowered on to the material.

The two-rope grabs, which have a separate rope for lifting and for discharging, although they require more expensive winding gear, have the advantage that they can be gently opened and discharged at any height, and they may be lifted or lowered when open. In case of breakage of one of the ropes the grab would still hang by the other. With such grabs the two ropes should be the same size, as during the discharge the full weight rests on the second rope instead of on the hauling rope.

Experiments have shown that the greatest resistance to the movements of the jaws is towards the end of the closing motion; it is therefore advisable in the construction of grabs to choose means for the transmission of the power, to give the second half of the closing motion the greatest power, such as may be produced by the closing of toggle levers.

The desire to build grabs which not only open wide but have a scraping and gathering action has led to the introduction of a compound movement for the jaws. If hinged at a stationary point the jaws of a grab are bound to describe a segment of a circle with their cutting edges, whereas the path of a grab with compound movement describes a curve more like an ellipse, which increases its gathering and filling actions. These have generally so powerful a closing action that even large pieces of ore can be crushed in order to accommodate them in their jaws. Grabs of this description are those of Hoover & Mason; Hulett (which is built by the Wellman-Seaver-Morgan Manufacturing Co.); the Temperley grab; and that of the Brown Hoisting Machinery Co. (*q.v.*).

When unloading railway trucks and small barges, grabs should be used only for material that can be easily handled by them, such as grain, coal, coke, etc. With heavy materials which are much more difficult to handle, the weight of a suitable grab would be so great that the receptacle to be unloaded might suffer damage.

"Orange-peel" grabs are not suitable, as they are liable to cause injury by their sharp points; it might also be mentioned that they are heavier and more expensive than a two-jaw grab of the same capacity. They are most suitable for excavating purposes, such as for sinking wells, etc.

Grabs hinged at the haunches, that is from the extreme outside of the frame, get a greater leverage, and therefore a more powerful closing of the jaws, and so are the most suitable for large pieces of hard material.

Salomon's Experiments with Grabs on Dry Sand.[1]—A series of observations have been made by Mr B. Salomon, the results of which were published in the *Zeitschrift des Vereines deutscher Ingenieure* in 1886.

He found that the resistance of the grab as dug into sand increased with the depth to which the grab penetrated, and he maintained that his experiments taught him that this increased resistance is also essentially dependent upon the shape of the grab jaws, or rather on the position of the fulcrum to the radius of the curve of the jaw.

Perhaps the simplest way in which to explain the results of these experiments is to

[1] Dingler's *Polytechnisches Journal*, 2nd May 1903, pages 283 and 284.

imagine a flat, very thin, and perfectly smooth spade dug into sand in the direction of its plane. In that case the only resistance caused will be to the progress of the cutting edge of the spade, that is to say, to its cutting action, because the grains of sand lying directly in the path of the blade are pushed to one side.

But suppose the blade of the spade to be thicker and somewhat curved, like the jaws of a grab, then it will displace a certain amount of sand which must be pushed aside in proportion to the depth of the curve. In such a case the sand will either be compressed, or, if the blade does not enter a great depth, the sand displaced will be pushed outwards on the oblique side of the spade in the direction of the line AB (see A, Fig. **555**). According to the resistance of the sand the line AB forms an angle Y with the horizontal. The angle $Y = 45°$, assuming $\frac{X}{2}$ to be the natural angle of repose of the material. The resistance thus set up increases very considerably should the surface of the spade or jaw be rough, and, as shown in A, Fig. **555**, the sand is heaped up as the spade enters the ground, being displaced by the body of the spade. A similar resistance is felt on the other side of the blade, to which must be added the friction between the blade and the sand.

So far it has been assumed that the sand was level on either side of the blade, and

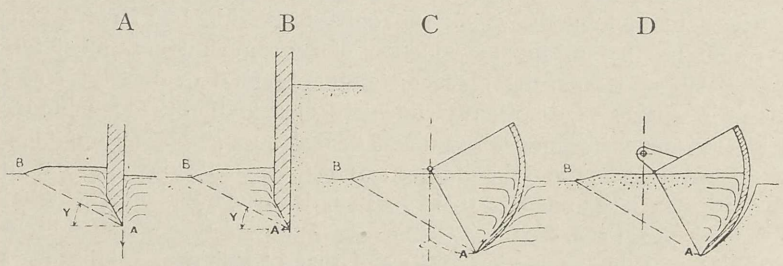


Fig. 555. Diagrams showing Action of Grab.

that the blade entered vertically, as shown in A, Fig. **555**; but if B, Fig. **555**, is accepted as a truer picture of what actually takes place, namely, that the sand is heaped up much higher on the right or interior side of the grab, then it is obvious that the resistance is greater on the right side.

According to Mr Salomon, the total amount of resistance can be considerably lessened by a judicious shaping of the digging blade. A grab with cylindrically shaped jaws was therefore chosen, the axis of rotation coinciding with its radius (see C, Fig. **555**). Even with this there will be a considerable amount of resistance on the outer walls of the blade, because the material lying below cannot escape, but must be compressed. Salomon found that when the axis of rotation was placed slightly above the centre of the radius of the blade, as in D, Fig. **555**, the outer resistance was diminished, and the internal digging power of the jaws increased. The sum total of these experiments, although of small practical value, point to the advisability of slightly raising the axis of rotation of the jaws.

It was, however, judiciously pointed out by Baron Hanffstengel that in these experiments the point of rotation was fixed, and that on that account a fairly great pressure between the sand and the grab jaws could be set up, whereas in practice the total vertical pressure cannot at the most exceed the weight of the grab with its contents, and will probably be less, as a portion of the weight is held by a chain.

Mr Salomon says that the higher the point of rotation is removed from the centre,

the greater the power necessary to raise a given quantity, on account of the compression of the material between the two jaws of the grab, as may easily be understood from Fig. **556**. No doubt the amount of matter scooped up increases in proportion as the gripping point is raised, but the difficulty of closing the jaws is proportionately increased.

Instead of shifting the action of rotation in this way it would in many cases be more advantageous to form the cutting edge of the blade in a straight line instead of a curve, as shown in Fig. **557**, as in such a case the blade will penetrate into the material better at the first onset.

If the weight of the grab be insufficient, the jaws will have a tendency in closing to lift themselves out of the material after having sunk to some depth, while the cutting edge of the jaws will describe, instead of an arc, a curve as shown in the dotted lines A C, Fig. **555**, C, and in consequence the grab will not take its full load.

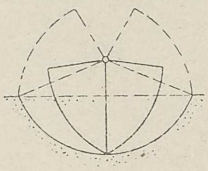


Fig. 556.

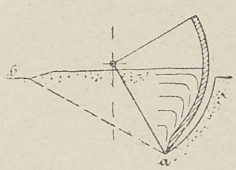


Fig. 557.

The illustrations give a clear representation of the movement of the laws of ordinary grabs hinged at or near their centre, but what has been said does not refer to grabs which are hinged from their haunches. In that case the action is different altogether, as the filling of the grab does not depend in the first instance upon the jaws entering the material to some depth through the drop of the grab from a certain height, but depends entirely on a scraping action which will be understood from Figs. **558** and **559**, the latter showing not only the scraping but also the closing action of the toggle levers.

The Efficiency of the Grab.—The usual effect of a grab depends to a great extent not only on the shape of the jaws but also on the nature of the material to be

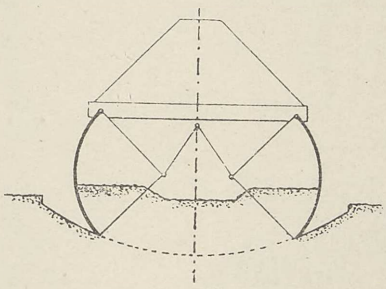


Fig. 558.

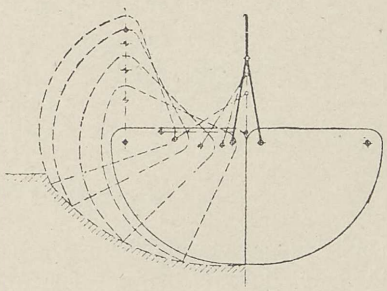


Fig. 559.

handled. The jaws of any grab will more readily handle a light material of a uniform size than one which has a greater specific gravity and contains large pieces. There is no difficulty whatever with most kinds of grabs in the handling of grain, sand, small coal, etc., but when dealing with a material like iron ore a grab which would fill to its full capacity on the former materials would barely fill to half its bulk capacity on the latter.

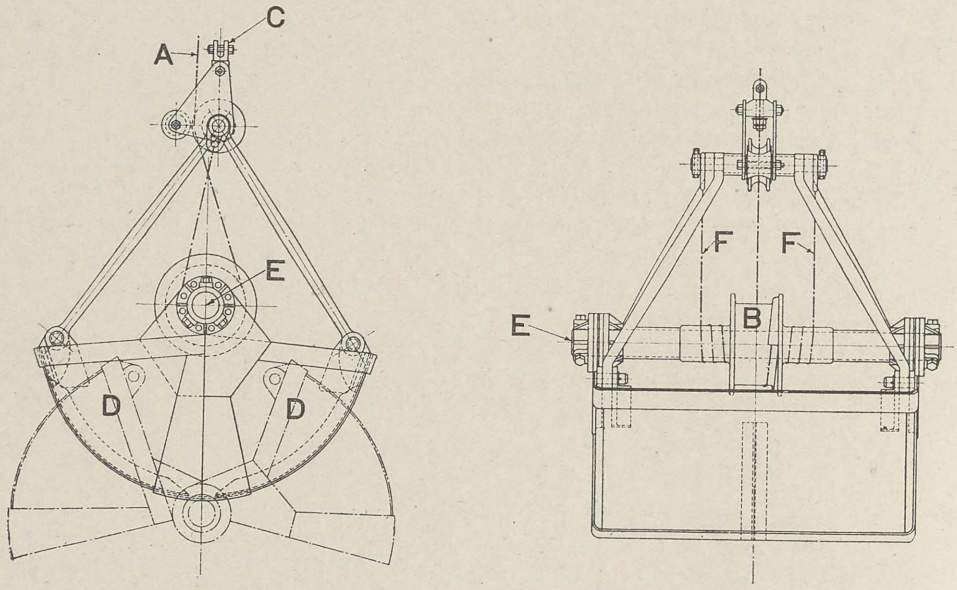
The angle of repose of the material is also an important factor in the filling process, as the greater the angle of repose the more difficult it is to gather the material into the grab.

It has also been maintained that the handling of coke or coal by grabs was detrimental on account of the breakage which was deemed inevitable; but there is really no need for such breakage if a grab of suitable construction and design is used. As a

rule the grab is dropped down on the material, which is bound to break under its weight, but there is no occasion to do this with any grab, as it makes little or no difference to the amount raised. They will fill just as readily when laid gently down on the material, as the action is in this case a gathering one, and the grab through this action buries itself in the heap. With grabs of this kind used in this way there need be no more breakage than in filling skips by hand.

The Priestman Grab.—This grab was one of the first to be placed on the market in this country. It was originally operated by two chains, one for closing and hoisting, and the other for opening. There are now, however, many different designs of grabs in use working with two, three, or four chains or ropes, as well as others operated by a single chain only.

An ordinary design of "Priestman" Grab is illustrated in Figs. **560** and **561**. A is



Figs. 560 and 561. Priestman Two-Chain Grab.

the hoisting and closing chain, which is fixed at one end to the drum B, and at the other to the crane hoisting barrel. The opening chain (or frequently wire rope) is attached to the head of the grab at C. The two jaws D D are hinged together by the strong central shaft E. The method of operation is as follows: The opening rope is held on the brake, and the hoisting chain is paid out; the shaft E thereupon falls, and the jaws open, as shown in dotted lines (Fig. **560**). The action of opening unwinds the side chains F F from the two ends of drum B, and this winds a short length of hoisting chain on to the centre portion of the drum. The grab is then lowered open on to the material to be lifted, and the opening rope being released, the hoisting chain is wound up, thus causing the side chains F F to haul down the top shaft E, thereby closing and filling the grab. On further winding up the chain A, the grab is lifted with its load to the place of discharge, and is emptied in the manner already described. It will thus be seen that if the full weight is carried on chain A, the grab is closed, and if from point C, it is open.

To increase the digging power, a multiple arrangement of sheaves is frequently fitted in place of the drum B, and different designs of jaws are provided for handling various materials.

In working two-rope grabs, cranes specially designed for the purpose should preferably be employed in order to obtain the best results. As, when grabbing, the question of output is generally of the first importance, it is obviously best, in order to make the

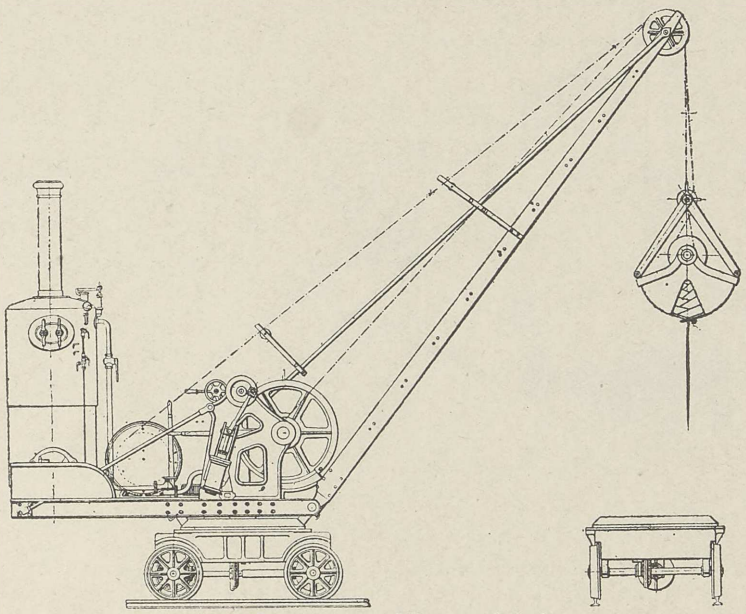


Fig. 562. Example of Crane and Grab.

installation economical, to have a crane which will operate the grab at the highest speed, even if the first cost be somewhat greater.

The " Priestman " grab crane, as shown in Fig. **562**, has been designed to meet these

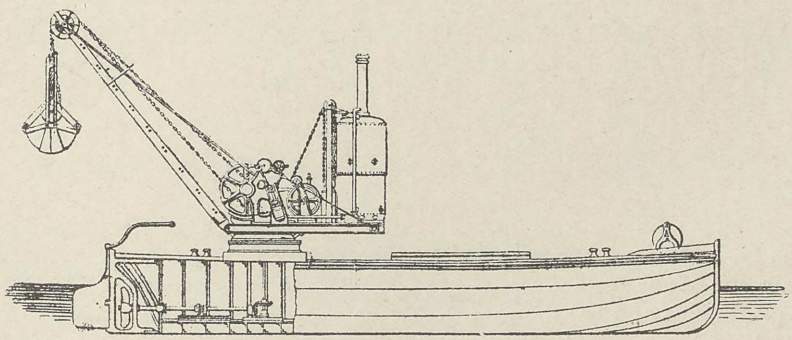


Fig. 563. Crane and Grab mounted on a Barge.

conditions. Normally seventy to eighty lifts can be made per hour, or probably nearly twice the number obtainable with some ordinary cranes.

These appliances are used for discharging grain, coal and other heavy material, as well as for dredging purposes. Generally speaking, the mechanical details are identical; the cranes only differing in the way in which they are mounted according to the purposes they have to serve. Thus they may either be fixed on quay walls, mounted on wheels, or

installed in suitable barges, the latter being more often used for dredging purposes, as shown in Fig. **563**.

Fig. **564** illustrates a very usual method of using grabs for unloading barges and depositing the material in railway trucks.

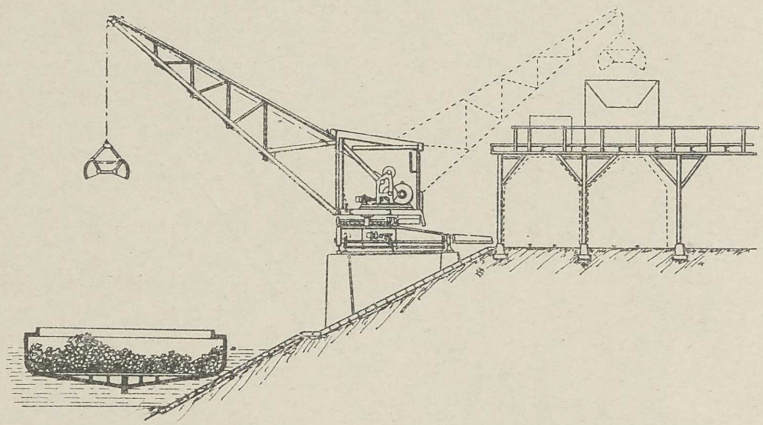


Fig. 564. Crane and Grab for Unloading Purposes.

Approximate Quantity of Material One Man can Raise with a Priestman Grab per Day of Ten Hours from an Average Depth of 20 Feet.

Capacity of Bucket or Grab, in Cwts.	Grain, in Quarters.	Small Coal, Shingle, etc., in Tons.	Coke, in Tons.
3	...	..	...
5	...	...	...
10	1,200	200	125
20	2,400	400	200
30	3,200	550	275
40	4,000	700	350

The Hunt Grab.—Another type of a two-chain grab is the Hunt grab, illustrated in Fig. **565**.

The principal difference between this and the Priestman grab is that whereas in the Priestman type the jaws are swivelled to the centre of the grab and closed from the outside, in the Hunt grab the jaws are swivelled at the haunches (Hone's patent) to an **A**-shaped frame, and are drawn together at the centre, which effects a rather more powerful closing action. Moreover, as the jaws open wider, they can take in a larger quantity of material at each lift. One chain is attached to the drum A on spindle B, and the other chain is fixed to the frame. If the first chain be released and the second chain held tight, the grab opens. The short chains are not attached to a second spindle as in the previous grab, but to the top of the framework, as in the latest Priestman grab.

The Mohr & Federhaff Grab.—A two-cable grab is built by Messrs Mohr & Federhaff, Mannheim, Germany, and is illustrated in Figs. **566, 567**, and **568**. Its action is similar to that of the "Hunt" grab, with this exception, that the cables which close the

jaws pass over three pulleys before being attached to the frame of the grab to effect a still more powerful closing of the jaws. In two-chain grabs the second cable or chain is not always wound on a second drum of the crane, but is often held by an independent drum and brake in connection with a balance weight, a method devised by Messrs Priestman, which acts as follows :—

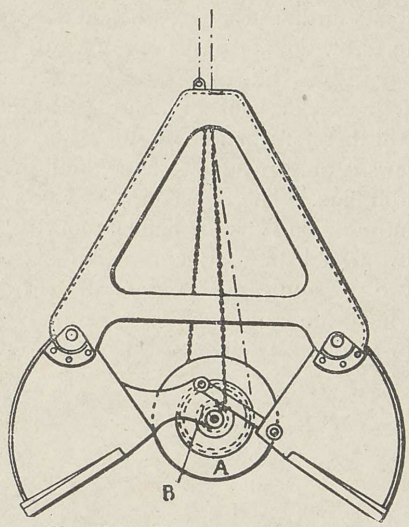
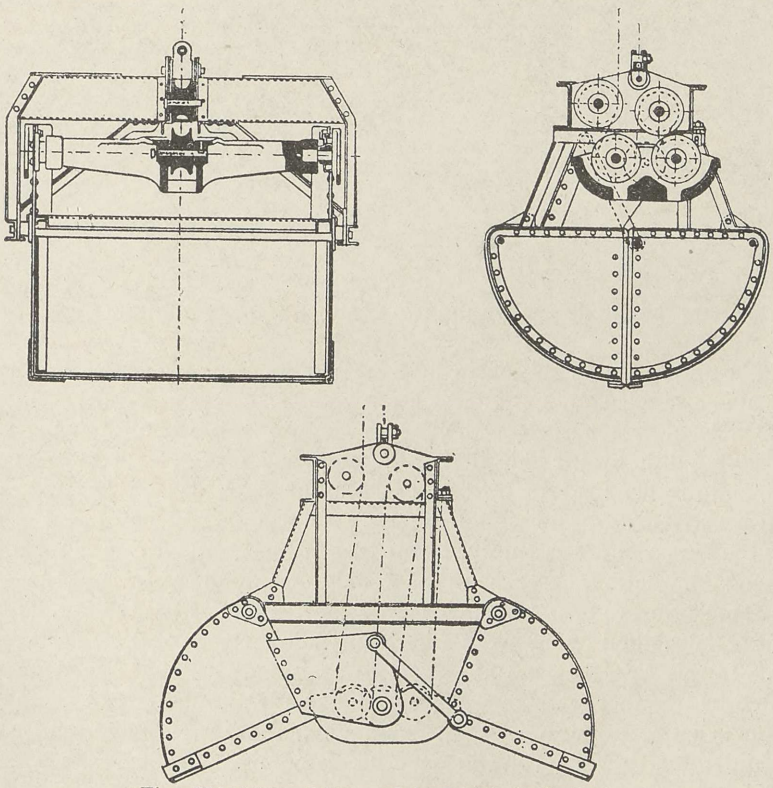


Fig. 565. Hunt Two-Chain Grab.

The cable which opens the grab is attached at the crane end to a drum which is loose on a spindle. Cast together with this drum is a second one of smaller diameter from which a second cable leads over a guide pulley to a balance weight. This weight is held in position between two guides, generally behind the crane house, and is fitted with a safety catch to prevent it from falling in case of the rope breaking. The loose drum is ordinarily provided with a band brake manipulated by a special locking lever. As the drum is thus held fast by the brake and the main cable lowered, the jaws of the grab are opened. By a slight modification, this apparatus may be made to act automatically, in which case the spindle is made to revolve by means of a chain connected to the main drum of the



Figs. 566, 567, and 568. Mohr & Federhaff's Grab.

crane. On the spindle a thread is cut to which a nut is fitted, the latter being of an easy fit and so weighted as to prevent it from revolving with the spindle. Instead of that, it passes along the thread till a point is reached which forms an obstruction to its further progress, when it has to revolve with the spindle, which movement is used to throw the apparatus out of gear.

The Jaeger Two-Chain Grab.—The grab illustrated in Fig. 569 is built by J. Jaeger, of Duisburg, and is designed for an approximate capacity of $2\frac{1}{2}$ cub. yds.; it will therefore handle about 2 tons of coal at a time. The framework which carries the jaws is of a triangular shape, built of angle iron with gusset plates, and stiffened with flat iron bars. The upper cross-bar consists of two channel irons, and there is a second and movable cross-bar of similar construction, which is guided in its up-and-down motion on two iron bars of square section marked A A. This movable cross-bar is connected by two pairs of toggle levers to the two jaws of the grab which are fixed to the point from which the radius of the jaw body is described. The jaws are hinged on the Hone principle. The chain which carries the load is divided into two before entering the grab

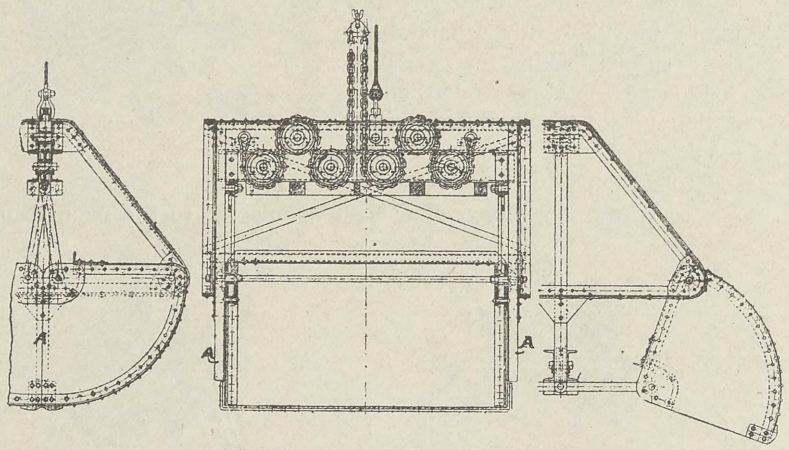


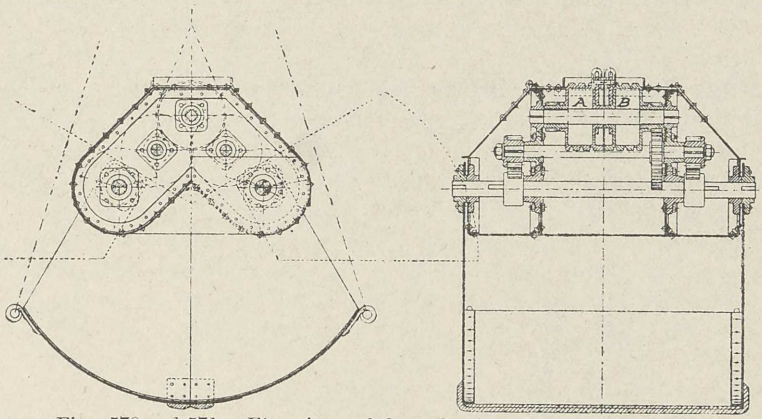
Fig. 569. Jaeger's Two-Chain Grab.

and the action is, therefore, identical on either side, each chain being led over three pulleys which are mounted between the two channel irons forming the fixed and movable cross-bars.

The illustration shows the chain and the pulleys in the position in which the two cross-bars are close together, and in which the grab is therefore closed. The opening of the grab is effected by a steel rope which is attached to it slightly out of the centre; thus the grab hangs a little to one side during the emptying process. If the one rope is now slackened, and the hauling rope held in position, the movable cross-bar descends, which movement is accelerated by a cast-iron weight. The downward movement of this cross-bar forces the jaws asunder as shown. The jaws of this grab open extra wide, the toggle levers forcing them further apart than they would move by their own weight.

The same firm are also building a grab for handling larger lumps, in which the movement is transmitted by means of wheels instead of chains and blocks (see Figs. 570 and 571). In this case the jaws are keyed to the spindles which support them, and are manipulated by the wheels, which are also keyed to the spindles. The chain supporting the load acts on two drums which are mounted on the same spindle, and placed close together, and these drums revolve in opposite directions, coinciding with the movement

of the jaws. The chain is divided before entering the grab, and is attached to the two drums A and B. Each drum is cast together with a pinion with fifteen teeth, which are



Figs. 570 and 571. Elevation and Cross Section of Jaeger's Two-Chain Gear-Driven Grab.

geared to wheels with forty-two teeth, these again being attached to two intermediate spindles on either side, which are fitted with two pinions of ten teeth each geared into

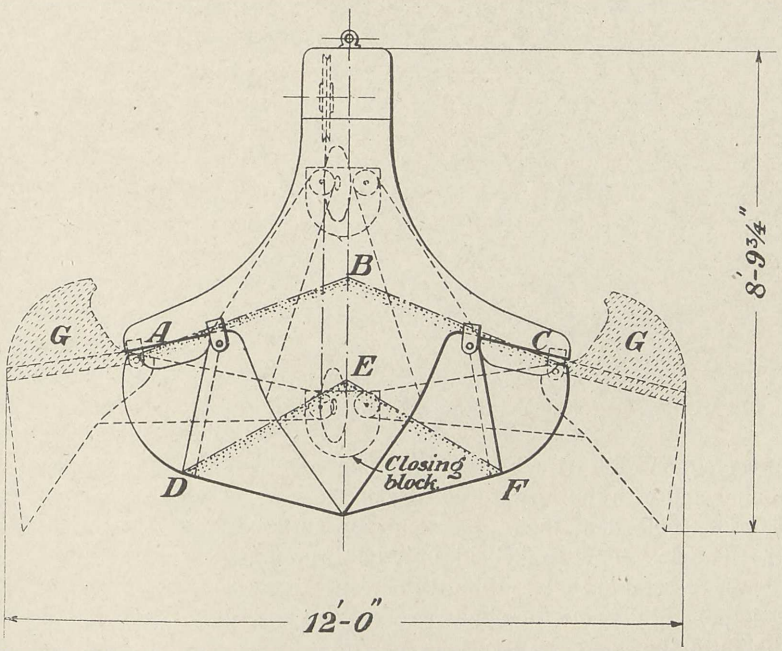


Fig. 572. Elevation of the Brown Hoisting Machinery Co.'s Two-Rope Grab Bucket.
(The width of the Grab is 5 ft.)

wheels on the jaws, and thus open and close them. The latter are, as a matter of fact, only segments of wheels, each being about one-third of a whole wheel.

The gearing and the two countershafts are all enclosed in a sheet-iron casing, which is visible in the illustration, and are therefore protected from grit or any other foreign

substance. The jaws are manipulated by means of a chain which is divided into four strands, each of which is attached to one of the four corners of the grab. This construction of grab is limited in its use on account of the division of the chain, which will not admit of its being raised as close to the top of the jib as would be the case with grabs of other design.

Two-Rope Grab of the Brown Hoisting Machinery Co.—The grab, which is illustrated in Fig. **572**, has a capacity of 2 tons, and is used for unloading coal as well as for handling ore; it is also made for a capacity of 1 ton. The larger size, when used on coal, will handle 84 cub. ft., and when used on iron ore about 35 cub. ft., which would mean approximately 2 tons of either material.

When handling coal, the pile taken by the grab is indicated by the line A B C. When handling ore the attachments G G are removed, leaving the ends of the jaws open; the grab can thus only take a pile of ore as indicated by the line D E F.

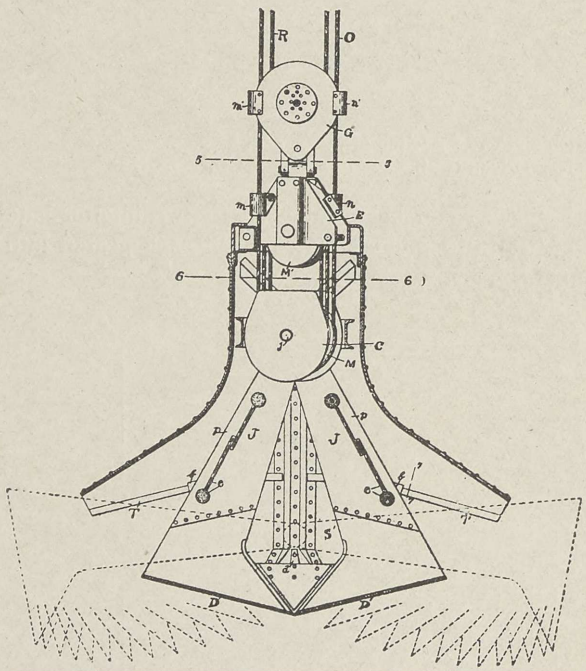


Fig. 573. Cross Section through Brown Grab.

This form of grab works satisfactorily with coal of all sizes, and it is specially claimed for it that it will handle very large pieces. It also works successfully with nearly all kinds of iron ore, with perhaps the exception of some of the lumpiest Swedish ores. It has, however, been proved capable of handling all kinds of Spanish ores satisfactorily. The illustration gives over-all dimensions of the grab when open.

The accompanying drawing, Fig. **573**, shows a cross section through the grab when closed, with dotted lines indicating the path of its jaws from an open to a closed position. To the housing of the grab is fastened (to obtain the compound movement) a rail or track T, upon which are hung sliding blocks or pieces *bb*, pivotally connected with the forward portion of the jaws JJ, which are composed of two parallel sides *pp*, joined at their outer ends by cutting blades DD which are set at a sharp outward angle. The parallel sides *pp*, however, are cut away and recede upwardly from the lower or scraping edges toward their upper ends, so that when the jaws JJ are brought together and the grab thereby closed, a small portion of the sides will remain open.

In the form shown in the drawings, the front and rear of the jaws are preferably unenclosed, and extend out beyond the housing when opened to their outward limit. The sides *pp* are stiffened by diagonal ties *ee*.

Centrally within the housing of the grab is the block C, carrying a series of sheaves M, mounted upon a common journal or shaft *j*. The block is provided with trunnions which fit into vertical guide grooves on the inside of the casing. The lower ends of these grooves are closed so that the descent of the trunnions is limited.

At the upper end of the framing is a second block E, containing another series of sheaves M, which in the construction illustrated are one less in number than the sheaves of the lower block or head C. The sheaves in the blocks C and E are set at an oblique angle to the framing, so that the sheaves and off-running portion of the operating rope shall come on the centre line of the top of the grab. Rope guides or eyes *m n* are provided on opposite sides of the block E, with centres corresponding to the centre lines of the grab. Hinged to the block E is the hoisting block G, having rope guides or eyes *m' n'* at either side, being just opposite the guides or eyes *m n* on the block E. O is the rope whereby the grab is closed or allowed to open; it passes downward through the eyes *m'* and *n'*, around the sheave in the upper block C, thence upward round a corresponding sheave in the upper block E, down around the next adjacent sheave in the block C, and so on around any remaining sheaves, when the outgoing portion of the mechanism is carried up through the eyes *n* and *n'* to the hoisting mechanism. R is the hoisting rope, which is reeved round the hoist block G, and connected with the winch in the usual manner.

The grab is operated by lowering it on to the material by paying out both the hoisting and the operating ropes. When in proximity to the material the hoisting rope is held taut and the operating rope O is slackened. The block C being thus freed, will, by reason of its weight, descend within the framing or the housing of the grab, being guided vertically by the trunnion grooves, and at the same time carrying with it and depressing the pivoted inner ends of the jaws JJ. It is evident that by this movement the said jaws being pivotally connected near their outer ends to the sliding blocks or pieces *b* and *b*, mounted on the guides T, said blocks will be forced outwardly along the track T, and carry with them the outer ends of the jaws JJ, and the grab will thereby be opened. The contour of the track T is such that in connection with the vertical movement of the head C, the blades DD in their course in opening and closing will be constrained to describe any desired curve or course within the grab's limits—such, for instance, as that indicated by the dotted lines in Fig. 573. In practice, particularly where material is to be taken from flat surfaces or from against the sides of a bin or barge, the path of the blade-like part D should at the initial movement of closing descend with a sharp curvature that diminishes as the jaws approach each other, whereby the material is first penetrated by the jaws to some depth to ensure a purchase and load, and is then scraped together within the jaws of the grab.

As indicated by the drawings, the downwardly projecting pieces S' serve to prevent the escape of material at the sides where the jaws are closed, and by leaving the rear of said jaws unenclosed any surplus load above the capacity of the grab will be forced out without in any way crowding within the grab, and thereby interfering with its proper working.

Both illustrations show the Brown grab with guide bars T (which are connected to the movable fulcrums of the jaws) in a straight line. These guide bars can, however, be made in any other shape, in which case the curve described by the cutting edges of the jaws will differ correspondingly.

Hone's Single-Chain Grab.—The first successful single-chain grab was undoubtedly that on Hone's patent, originally manufactured by the Thames Iron Works and Shipbuilding Co., Ltd., and now by Priestman Bros., Ltd., Hull. Although of comparatively recent origin, this grab has undergone many changes in design.

The original patent, which was obtained by George Hone in 1882, consisted essentially of an oblong bucket fitted with a shifting bail, which was worked by a spring manipulated by an attendant on the crane by means of a string. The bucket descended

in a vertical position, the line was then drawn taut, when the spring released the bail, and, changing its position, locked the apparatus, then by a circular motion the load was filled and raised.

The patent for the Hone grab as now manufactured was granted in 1894. It is illustrated in Fig. 574, and apart from being the first single-chain grab, it was the first which pivoted the jaws from the haunches.

The working parts of the grab consist of a rising and falling sheave block A (called the sliding block), having two vertical loose sheaves mounted in it, and arranged to rise and fall within a guide of four vertical angle steels of the framework. A single vertical loose sheave B, mounted on a circular horizontal plate, this plate forming a cap to the four vertical angle steel guides mentioned above, and having suitable holes in the plate for passing the crane chain through. A crosshead C, situated below the sliding block, and also free to rise and fall in the same four angle steel guides, has a fixed vertical central pin with a semicircular notch across it. The top end of the pin is so arranged as to enter the vertical hole in the lower end of the sliding block, and the bottom extension of this pin is formed into lugs, to which the closing rods D D connecting the jaws are attached, so that when the crosshead is lifted in the guides the jaws are closed. This horizontal locking pin fits into a horizontal hole through, and at the bottom of, the sliding block, in such a position that half its diameter passes through the notch in the vertical pin on the crosshead. The locking pin has also a notch in it, in such a position that when the notches come opposite each other the crosshead pin is free to disengage from the sliding blocks. The releasing lever E is "swung free" on one end of the locking pin, and having a balance weight F at its back short end, the long end at the other side of its centre is free to rise. A vertical stop and balance weight is fixed to the locking pin, and is of sufficient weight to keep the pin always locked. To this plate two stop pins are fixed, and the long end of the releasing lever E is always bearing against the top one in consequence of its balance weight. The second stop pin fitted on the same plate lower down is only provided for safety. A ring G is hung from the jib-head, of sufficient diameter to allow the vertical framework to enter it easily, but not large enough to allow the long end of the releasing lever to pass without being either depressed or raised. A vertical oil-checking cylinder H is fixed at its upper end to the top horizontal plate of framework, and its piston rod passes through a gland at the bottom end of its cylinder, a suitable vertical clearing hole in the sliding block being provided, and is then attached to the crosshead C.

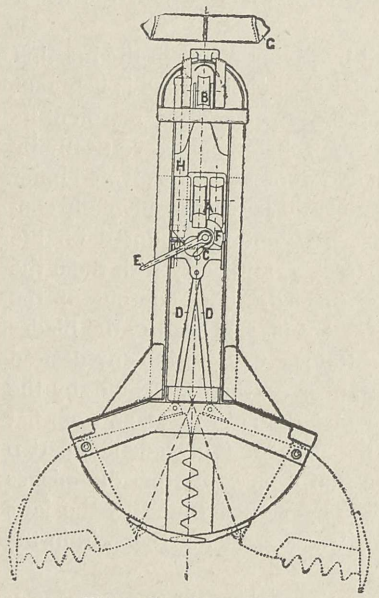


Fig. 574. Hone Grab.

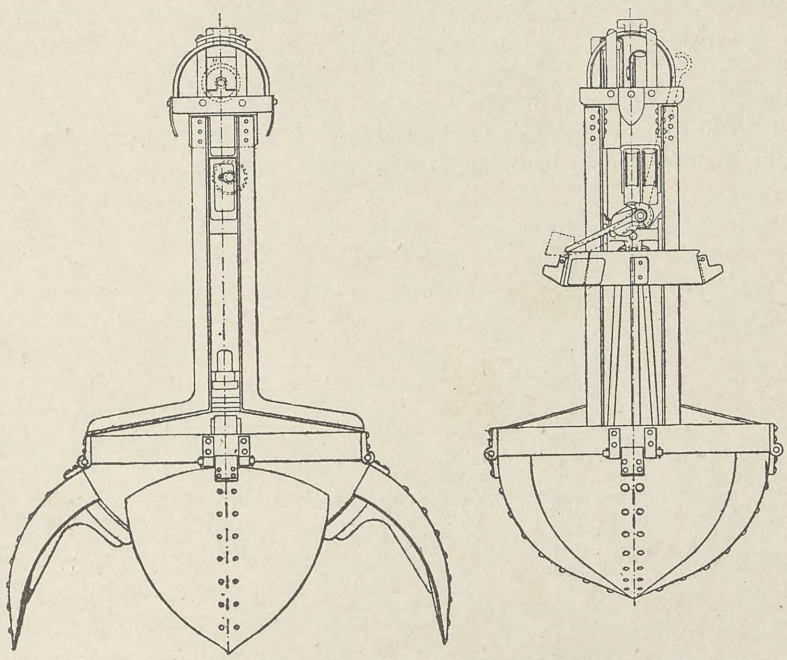
The grab is worked as follows:—

The ring G is hung from the jib-head at any required height which suits the point of discharge.

To rig the chain, the free end of the crane chain is passed down through the central hole of the top plate, then under one of the sheaves in the sliding block below, up through second hole in top plate, under the second sheave in sliding block, and up again to the under side of top plate, to which it is attached by a bolt and lug, no special link

being required. The operation of rigging the chain in the grab is exactly similar to reeving a double and single chain block, and can be effected by any unskilled labourer.

As soon as the grab has been lowered on to the coal (the crosshead C being at the bottom of the guides, and the sliding block A at the top of the guides) the sliding block will, by its own weight, and the overhaul of the chain, run down the guides until the crosshead pin enters the hole in the bottom of the sliding block. This also lifts the balance weights and the machine becomes locked. The grab is now ready to dig, and on starting the crane to "heave up," the sliding block and crossheads are pulled up between the guides at a leverage of 4 to 1, until the grab is completely closed. The load is then lifted to the



Figs. 575 and 576. Hone Grab with Four Jaws (sometimes called an "Orange-Peel" Grab).

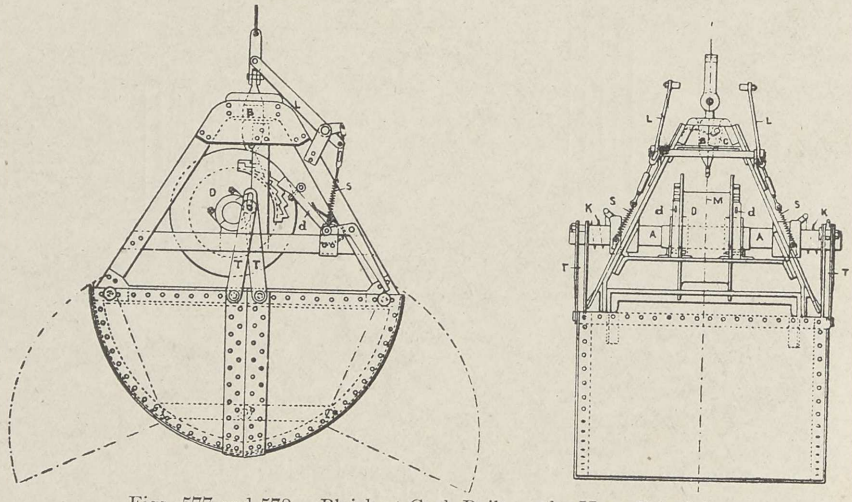
required height, and the top portion of the grab must also be so far through the ring G that the long end of the releasing lever has been depressed by the ring, and having passed through it, has swung back again against the top pin. On lowering the grab, the releasing lever E comes in contact with the top edge of releasing ring G, thus lifting the stop plate and turning the locking pin until the two notches come opposite each other, when the crosshead, being released, falls from the sliding block, and the jaws and closing rods drop with it. The piston rod gently descends at the same time, thus preventing shock to the machine, or the scattering of the material. On lowering clear of the ring, the releasing lever and locking pin reassume their positions by means of their balance weights, and the grab is once more ready to be lowered into the barge.

Figs. **575** and **576** show the same grab made with four jaws instead of two. This form is used chiefly for excavations under water and for extra stiff clay.

The following table gives dimensions, weights, and capacities of the Hone grab :—

Size.	Dimensions of Grab when Closed.	Approximate Weight of Grab.	Capacity, in Cubic Feet.	Rate of Discharge in Tons of Coal per Hour with Ordinary Steam Crane at about 40 ft. lift.
	Ft. In. Ft. In.	Cwt.		
No. 1	3 6 by 3 6	13	15	20
,, 2	4 0 ,, 3 6	14	18	24
,, 3	4 0 ,, 4 0	17	23	29
,, 4	4 0 ,, 4 6	21	30	37
,, 5	5 0 ,, 4 0	22	35	43
,, 6	5 0 ,, 4 6	24	39	45
,, 7	5 0 ,, 5 0	29	44	50
,, 8	6 0 ,, 6 0	48	78	72

At the Becton Station of the Gas Light and Coke Co., the collier "Eleanor," having a cargo of 2,750 tons of coal, was discharged in sixteen and a half hours by three No. 7 Hone grabs, manipulated by hydraulic cranes.



Figs. 577 and 578. Bleichert Grab Built on the Hone Principle.

The Bleichert Grab.—Another single-chain grab is illustrated in Figs. **577** and **578**. This is built on the "Hone" principle by Messrs Adolf Bleichert & Co., of Leipzig. The action is as follows :—

In the closed position the two short outer chains KK are wound round the spindle A, whilst the inner chain M hangs loosely in the interior, or lies on the top of the material contained in the grab. The movable portion B is held in position by pawl C. The drum is held by the two pawls *dd* and the ratchet segments which form part of the drum. In order to discharge the load the two levers LL are made to touch an obstruction which is suspended from the head of the crane, and is adjustable up or down. As this is in a fixed position, when the grab is being lifted the levers LL are forcing down, by means of two short chains, the pawls *dd*. The drum D, which is fixed to the spindle A, is compelled to revolve through the weight of the grab and its load, so that the two small chains KK unwind from the spindle A, whilst the hitherto slack chain M winds itself on to

the drum D during the process of opening. As soon as the apparatus has thus been discharged the main chain begins to lower, when the levers LL, being released from the obstruction, are pulled back into their original position by the springs SS, while the pawls *dd* hold the drum D in its position, and thus keep the jaws open as the grab plunges into the material to be elevated. If the rope or chain be now further lowered, the part B sinks by its own weight into the opening in the top of the framework, and in so doing the pawl C is pushed to one side and held in that position by another small catch. The hoist chain is now pulled up by the crane, B is now no longer held in position, and as it is pulled out of the framework, pulls with it the chain M so as to unwind it from the drum D. The revolutions of the drum, and with it of the spindle A, wind up the two small chains KK, and pull up the levers TT, thus closing the jaws. As soon as the grab is thus closed, the chain is lowered once more for a foot or so. B re-enters its former position, and is now again held in place by the pawl C, which has in the meantime been released. As B re-enters the frame, the chain M is released and lies loosely on top of the load as the drum is now fixed. The grab is now ready to be lifted and swung into position for delivery.

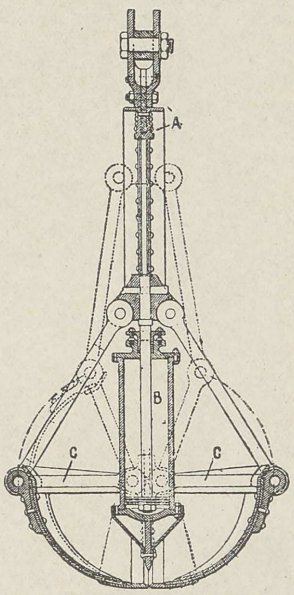


Fig. 579. Pneumatic Grab of the Beard Dredging Co.

Pneumatic Grab.—A grab operated by compressed air is built by the W. H. Beard Dredging Co., of New York. The jaws are opened and closed by means of air pressure. The contention of the inventor is this, that the grab when embedded in the material to be raised should be closed without pulling a chain or rope, as this might have a tendency to loosen the hold of the jaws upon the material, with the effect of diminishing the load to be raised.

From the chain of the grab (Fig. **579**) is suspended a frame A, which carries the air cylinder B and the crosshead guide which supports levers CC. Although this grab has only one chain its manipulation is somewhat complicated.

There are two air-pipes to be raised and lowered with the grab, one to connect the upper and one to connect the lower end of the cylinder with the compressed air vessel. This is effected in the following manner: A drum is fixed to the jib-head of the crane, and to its hollow spindle the two air-pipes are attached by means of stuffing boxes on either end. The two flexible air-pipes leading to the grab are rolled upon the drum, one end of each being connected with the main pipe through the stuffing boxes. As the grab descends, the pipes unroll from the drum and cause the latter to revolve, thus winding a rope (on the end of which is a balance weight) upon the drum, so that as soon as the grab ascends again the weight on the rope turns the drum in an opposite direction and winds the two pipes up again, so that they are always taut no matter in what position the grab may be. To manipulate the grab a three-way valve is used, two of the exits communicating with the upper and lower ends of the cylinder, and the other with the compressed air vessel.

Hydraulic Grab.—This grab (Fig. **580**) is similar to the last mentioned, but is operated by hydraulic power. The arrangement of the jaws and their guides is similar to the Priestman principle.

The casting upon which the jaws are hinged is connected to the cylinder by

powerful vertical rods. The lower large piston closes the jaws, whilst the upper is for the purpose of withdrawing the former, and thus opening the jaws. Both pistons are connected together by rods, and the stuffing boxes are easily accessible. This apparatus is said to be satisfactorily at work in the United States.

Electrically Driven Grab.—Grabs have lately been fitted with electro-motors, so that all the work the crane has to perform is to lower the grab on to the material to be raised, in an open condition, when the current is switched on to the motor which closes the grab, and similarly opens it after it has been conveyed to its destination. As the capacity of the grab depends to some extent upon its own weight, it is obvious that a grab so fitted will have an increased weight, which adds to its efficiency. The rope cannot lessen the hold of such a grab on the material as it does not come into action until the grab is closed. This seems an ideal solution, but the construction presents several difficulties, one of which is the reduction of speed from the fast running motor to the very slow closing action of the grab; the gearing which transmits the power is, therefore, necessarily very heavy. This appliance is especially suitable where a heavy grab is necessary. Figs. **581** and **582** show an example of the application of the principle to a Continental grab built by the Augsburg-Nürnberg A. G. This is particularly applicable for heavy ores, and the closing power is exceptionally great. This grab has been used for handling Thomas phosphates, which is one of the most difficult materials to deal with, and for which a heavy grab is particularly suitable. The weight of the grab alone is 6 tons, and it has a capacity of approximately 2 cub. yds.; the grab actually lifted in one operation over 3 tons of this material. The electro-motor is of 15 H.P., and the transmission of power from this to the jaws is effected by worm and worm wheel, two pairs of spur wheels, and a chain drive.

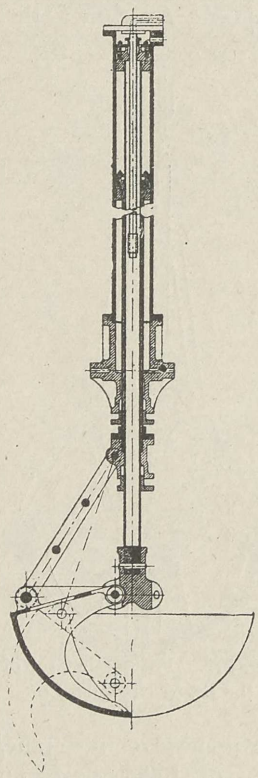


Fig. 580. Hydraulic Grab.

Appliances Similar in Principle to Grabs.—These take the form of huge tongs and are frequently used in the iron and steel industry for handling large single loads.

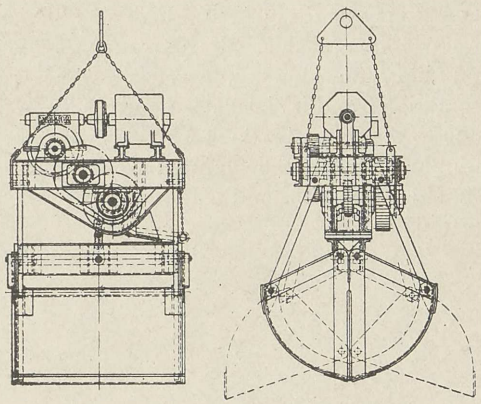
An interesting example of a similar appliance for unloading short lengths of timber out of barges has been described by Professor Buhle.[1] The timber handled is used for manufacturing wood pulp, and the pieces, which are very similar to mining props, are about 6 ft. long and do not exceed 1 ft. in diameter. Figs. **583** and **584** show this appliance open and closed. The action very much resembles that of a grab, with the difference that the appliance must not be opened until the timber has been lowered on to the ground or on to the timbers already accumulated, so as not to disarrange them. The weight of the appliance is close upon $1\frac{3}{4}$ tons and it will handle on an average $1\frac{1}{4}$ tons of timber at each grip, which is equal to about 3 cub. yds. It is used in connection with a man telpher, and installed on a long bridge crane which spans the store yard, and makes thirty to thirty-five journeys per hour.

The Lifting Magnet.—Although this latest and most useful appliance cannot, strictly speaking, be called a grab, it so nearly fulfils the same essential functions that it must be included in this chapter.

[1] *Zeitschrift des Vereins deutscher Ingenieure*, 15th May 1909.

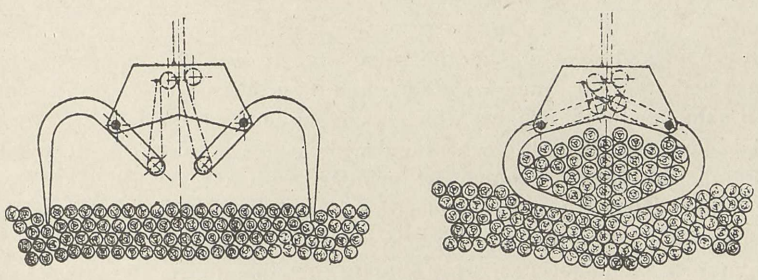
The earliest attempts to utilise on a large scale the affinity of the magnet for iron and steel are said to have been made at the Otis Works in Germany, as early as 1889, for lifting and conveying blooms, and a little later by the Illinois Steel Co. in the United States for iron plates. The pioneers of a really serviceable lifting magnet of commercial value were S. T. Wellman, who in 1895 used them for handling plates and slabs, and D. B. Clark, the electrical engineer of the South Works of the Illinois Steel Co., who subsequently improved the design.

[1] The manufacture of lifting magnets of both the Wellman and Clark types was taken up by the Electric Controller and Manufacturing Co. (then the Electric Controller Supply Co.) about 1898. A special magnet testing machine was designed and installed and much valuable data secured bearing on the design of the lifting magnet.



Figs. 581 and 582. Grab Manipulated by Electric Motor.

Many magnets of the Clark type have been manufactured and sold and have given excellent results in the handling of smooth homogeneous material, such as plates, blooms, and slabs; these magnets were, however, useless for handling rough and detached material, such as pig iron, crop, ends, and scrap. A magnet which would readily lift a steel ingot weighing 10,000 lb. would not lift a single pig of iron weighing 100 lb. Many were the disappointments encountered in solving the problem of overcoming the electrical and mechanical difficulties of a principle, which was practically solved when the electro-magnet was discovered in 1820 by Ampère. Success



Figs. 583 and 584. Grab for Timber such as Mine Props.

came slowly, but that it has been attained is proved by the fact that the lifting magnet is to-day the greatest labour-saving device which the progress of electric engineering has achieved.

The first commercially successful lifting magnet for handling pig-iron scrap and miscellaneous magnetic material was placed on the market in March 1905. This was built in two sizes known as No. 1 and No. 2 type S. Magnet. Hundreds of these magnets have since been placed in the service of the iron and steel industry, and it may

[1] Compiled from an article, "Recent Improvements in Lifting Magnets," in the *Industrial Magazine* of December 1908.

be said that they possess lasting efficiency; and the price, size, current consumption, and lifting capacity are in reasonable proportion to their own weight. They have, in fact, become satisfactory and reliable tools. The makers, however, have not been content to rest upon the satisfactory results thus far obtained with the type S. magnets, but have been constantly at work on improvements both in the direction of dependability and in increased efficiency in the handling of material.

Unquestionably a successful lifting magnet must withstand more severe abuse and rough handling than any other type of electrical apparatus. In operation they are suspended from the hook of a crane, frequently not equipped with a lowering brake, so that it may be dropped at a high speed upon the material to be lifted; then it is swung when in use against cars, boxes, piles of pig iron, etc., and must be capable of withstanding the blows and shocks which result. It must operate under all weather conditions, and its insulation must withstand the voltage much higher than line voltage due to the inductive kick which occurs when the circuit of the magnet is opened. Its winding must not be injured by the heat which is generated within it, and preferably should also withstand external heat when the magnet is called upon to handle hot material.

The accompanying illustration, Fig. 585, is a section through a typical S. A. magnet, and shows the arrangement of the parts, which by experience have been found to meet the severe and exacting requirements of the service. A is an annular casting of special electrical steel, forming the body or framework of the magnet; it is heavily ribbed on both the upper and outer surface, the ribs serving as cooling surfaces. They are so disposed as to stiffen the magnet case, and at the same time to add to the cross section of the magnetic surface. To this frame rings for supporting the magnet on the crane are also secured. B is the core of the magnet which is surrounded by the winding C. This winding is composed of a series of coils, each wound with a conductor in the form of a copper ribbon or strap, the turns of which are insulated with asbestos ribbon. Neighbouring coils are mechanically separated and electrically insulated by non-combustible insulating discs D. The coils are wound upon a heavy brass form E, which resembles a spool with one head removed. This form serves to support the coils during the process of winding, and ensures coils of uniform and perfect shape, since there is no danger of springing or otherwise distorting the winding. After the last or uppermost coil is wound and the outer disc of insulation in place, the entire winding is rigidly clamped to the forms by means of radial straps F, which are bolted and locked in place, thus making the winding and the brass form which carries it a rigid unit. The completed winding is then dried in a heated chamber under a vacuum, and when the initial drying process is completed, the winding is impregnated with a plastic insulating compound—first under influence of a vacuum and then under air pressure, and finally is again dried under a vacuum. This results in a winding not only fireproof, but what is of still greater importance the winding is thoroughly waterproofed. The completed winding is then placed in the magnet case.

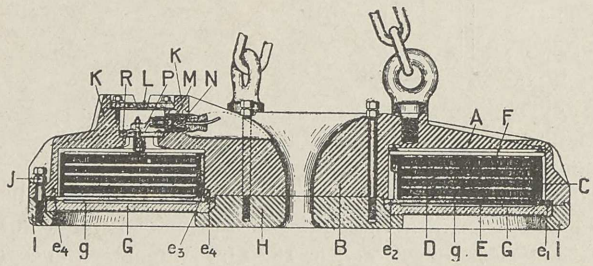


Fig. 585. Section through Lifting Magnet.

It will be noted that the form E is provided with an outer flange e_1, and an inner flange e_2, in addition to the central upwardly-extending flange e_3, which centrally supports the winding. The inner and outer flanges are carefully finished, and engage with finished surfaces on the inner and outer pole faces of the magnet case, thus completely sealing the lower face of the winding chamber, a water-tight joint being ensured by clamping the flanges in place with screws e_4, e_4, spaced 4 in. apart entirely around the flanges e_1 and e_2. Since the winding is clamped to the form E by the radial clamp F, and the form E is clamped in the magnet case as already mentioned, it will be readily seen that the winding is rigidly held against displacement. With the winding thus assembled in the magnet case, the lower face of the coil form E is covered by a heavy annular plate G of (non-magnetic) manganese steel, which in turn is held in place by pole shoes H and I, bolted respectively to the inner and outer poles of the magnet case. Both the pole shoes are provided with shoulders, which protect the clamping bolts from sheering strains. At the heads of the outer pole clamping bolts J are located between adjacent ribs on the outer surface of the magnet case, where they are protected from abrasion. In the sectional view it will be noticed that the practically non-magnetic manganese steel plate G carries raised shoulders around its inner and outer peripheries by means of which the plate is made to seat against the magnet poles, and an air space or cushion is left under the winding at *g*. This results in the shocks taken by the outer plate G being transmitted directly to the magnet frame, instead of being taken by the windings as would necessarily be the case if a plain bottom plate were used.

The pole shoes are so disposed with respect to the outer plate G that none of the clamping surfaces can become battered over, and therefore the plate G as well as the whole wearing surface may always be readily renewed.

The terminal cavity is surrounded by a ridge KK cast integral with the magnet case, and of a thickness to make it as strong as the magnet case itself. The terminal cavity is closed with a heavy steel cover L, which seats against a gasket to form a water-tight joint, and is firmly bolted in place, the heads of the bolts being protected from abrasion by the ridge of the terminal cavity. All the terminal parts are thus enclosed in a waterproof box of steel, the terminals themselves being of the plug type, which permits of quick attachment and detachment of the service wires. The female members M of the terminal are enclosed in an insulated tube, so that a ground or short circuit cannot result even if the service wires are left hanging from the crane with the current on. The insulating tubes are each encased in a steel tube to prevent abrasion of the insulation, and these steel tubes fit closely into babbited openings N in a side of the terminal chamber. The male member P of the plug connectors is mounted upon a heavy plate R of fireproof insulating material, which closes the entrance to the winding chamber and is seated upon a gasket to effect a water-tight joint. The plugs proper are separable from the terminals by removing the nuts which hold them in place. The plugs, and also the plate R, may therefore be removed without throwing any strain on the connections to the winding; the connections consist of loops of very flexible copper ribbon, these loops being stowed away in the box-like ends of the terminal studs. This construction permits of great flexibility, and at the same time makes it impossible for the flexible leads which connect the two ends of the magnet windings to come accidentally into contact. These features show how carefully the design of type S. A. magnets has been considered and worked out from the mechanical and electrical standpoint.

Fig. 586 shows a lifting magnet of the Cutler-Hammer Co., Milwaukee, U.S.A., from which it will be seen that here the terminal box is separate, and not cast together with the body of the magnet, and that the whole apparatus is held together by through bolts.

The following figures have been obtained, during the test of a 50-in. magnet of this type, at the plant of the Youngstown Sheet and Tube Co.:—

Total weight of pig iron unloaded from steel gondola -	109,350 lb.
Weight of average lift (including small lifts when cleaning up the car) - - - - - -	785 „
Trips required to empty gondola - - - -	139
Current on magnet - - - - -	1 hr. 15 min.
Current off magnet - - - - -	50 „
Time consumed in unloading gondola - - -	2 hrs. 5 „
Current required to energise magnet - - -	30 amperes at 220 volts.

From the foregoing figures the cost of operation is easily calculated, assuming cost of current to be 1½d. per kilowatt hour; 30 amperes at 220 volts correspond to a power consumption of 6,600 watts which was required for one hour and fifteen minutes; this gives a total power consumption of 8·25 kw. hrs., which at 1½d. per kilowatt hour gives a total of a little more than one shilling for the cost of current for energising magnet required during the period to unload the pig iron.

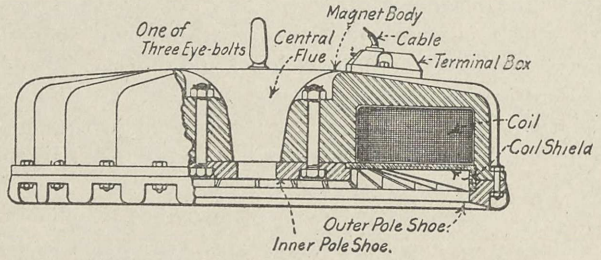


Fig. 586. Cutler-Hammer Lifting Magnet.

The following table gives the capacity on different materials, for the four sizes of lifting magnets made by the Cutler-Hammer Co.:—

Material Lifted.	Diameter of Magnet.			
	36 In.	42 In.	52 In.	60 In.
	Lb.	Lb.	Lb.	Lb.
Pig iron for casting machines -	800	1,170	1,9·0	2,340
Pig iron cast in sand - - -	720	1,100	1,800	2,160
Boiler plate scrap - - -	630	1,080	1,440	...
Scrap wire - - - - -	450	540	720	900
Rail cuttings and crops - - -	720	1,200	1,620	...
Skull cracker - - - -	10,800	18,000	18,000	22,500
Weight of magnet -	1,630	3,000	4,700	6,800

The magnet of the Witton-Kramer Electric Tool and Hoist Co., of Witton, Birmingham, which is shown in Fig. 587, differs from those previously described particularly in that the windings are treated similarly to the type S. A. magnet with the exception that it is immersed in a boiling asphalt compound, and the coils are kept under great pressure in this liquid at a temperature of approximately 200° Fahr. The shield which protects the coil is either of non-magnetic manganese steel or of an extra hard phosphor bronze, and the pole shoes are generally bolted to the casing, but in some instances they are soldered.

The controllers for these magnets are of the drum type, and in some cases oil-

immersed. Non-inductive resistances are employed to take up the induction of the coil when breaking the circuit.

The wiring necessary for operating lifting magnets consists of a twin cable, which is led over a system of pulleys provided with a counterweight to keep the cable taut. In the case of jib cranes this cable is connected to the supply in the crane cabin, but for travelling cranes it is usual to install two trolley wires alongside the bridge and to provide special collectors to collect the current. A spring drum may sometimes be employed upon which the cable is wound and unwound as the crane is in use.

The method of working a magnet crane is similar to that of any electric crane, with the addition only of an extra controller for exciting the magnet when lowered on to the material to be lifted, and for releasing the load at the destination.

The holding capacity of magnets depends largely on the nature of the material which is to be handled, such as the magnetic quality of the load, the temperature of the material (which should not be above black heat), the shape of the material, and the size of the pieces. For general guidance it may be assumed that a magnet is capable of lifting a solid piece of steel with machined surface of not less diameter than the magnet itself, having approximately a weight of fifteen times that of magnets under 2 ft., or eight to twelve times the weight of magnets from 2 to 3 ft. in diameter, and five to six times the weight of magnets from 3 to 5 ft. diameter.

For such materials as sand-cast pigs, or heavy scrap iron, the lifting capacity decreases considerably, as the material does not conform to the surface of the magnet. When handling iron or steel plates the load depends on their size; sometimes up to six plates deep can be lifted according to the thickness and weight of the plates and the type of magnet.

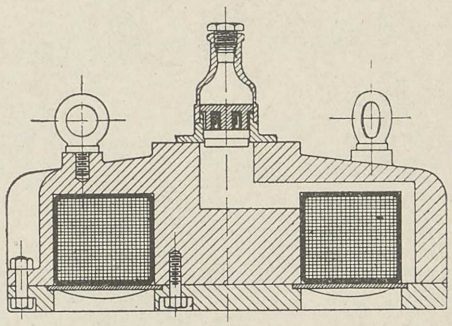


Fig. 587. The Witton-Kramer Magnet.

During the times the plates are suspended on the magnet it is possible, by passing the current through resistances, to drop one plate at a time and still hold the remainder.

Lifting magnets are made round, oval, square, or oblong, and the surface of the magnet should also have a shape as near as possible to that of the objects generally lifted by it; for instance, if used for lifting iron pipes the lifting surface of the magnet should be hollowed out to fit, and by the same rule if used for a "scull cracker" the surface should be concave. Where long or bulky objects have to be lifted, a number of smaller magnets are suspended from girders or frames in order to cover a larger surface of the objects being dealt with.

Lifting magnets are not only used for handling iron and steel in all its forms in the ordinary way of manufacture and shipment, as well as in engineering works, but they are also great labour-saving appliances for breaking up cast-iron scrap, as the same magnet will not only handle it before and after it is broken, but will also lift and drop the "skull cracker" with which the scrap is broken up. They can also be used for pile driving or to take the place of any other mechanical clutches.

Lifting magnets are only constructed for direct current and are best driven from the mains without the intervention of cut-outs. In some cases it is advisable to install an additional accumulator battery to work in parallel with the dynamo, so that should the latter break down, the accumulator will hold the load.

An up-to-date lifting magnet is no more likely to fail and drop its load than is a hoist cable or chain.

One of the great economies in raising loads with lifting magnets, as compared with ordinary cranes, lies principally in the saving of the time wasted in slinging the material with chains prior to its being raised, and the removal of the chains at the destination. Another is that practically all ground men become unnecessary.

The Hulett Unloader.[1]—To empty open barges some grabs, manipulated by cranes, can be used, which will discharge nearly the whole contents of the boat, rendering hand trimming practically unnecessary. In discharging larger vessels, however, which have narrow hatchways, like those in universal use on the great American lakes, the

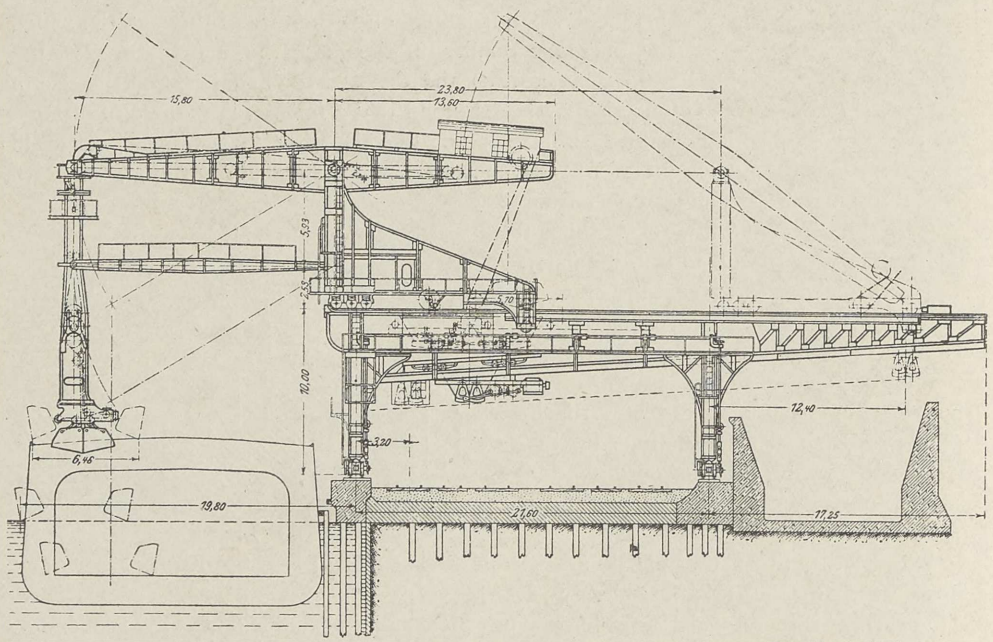


Fig. 588. Hulett Unloader as Used by the Pennsylvania Railroad Co. at Cleveland, U.S.A.

ordinary grab can only attack the material which is directly beneath the hatchway, the rest having to be trimmed up to the point which the grab commands.

To obviate this necessity for trimming, the American engineer, Mr G. H. Hulett, of the Wellman-Seaver-Morgan Co., Cleveland, Ohio, has successfully designed a discharging apparatus which can handle the material lying out of normal reach by drawing it towards the hatchway. The machines are built by the Wellman-Seaver-Morgan Co., and the first installation was made at the iron ore docks of the Pittsburg and Conneaut Dock Co., of Conneaut, Ohio, in 1898. In these unloaders the clamshell, which is of large capacity, was rotated after entering the hatch, so as to extend lengthwise of the boat, enabling it to reach the ore tributary to each hatch. The latest and most up-to-date installation of this type, as used on the banks of the great American lakes, is that of the Pennsylvania Railroad Co. at Cleveland, Ohio, which was completed in

[1] The Author is indebted for the foregoing facts and figures, as well as the illustrations, to an article by A. Bergman, of Stockholm, which appeared in *Zeitschrift des Vereins deutscher Ingenieure* of 28th February 1914.

the year 1912. It is intended for handling both ore and coal, but only the section for handling ore has so far been completed. It consists of four machines, one of which is shown in Fig. **588**. The entire machine is mounted on four rails, and has altogether thirty-two wheels, which have been grouped into eight bogies. Fig. **589** shows one side

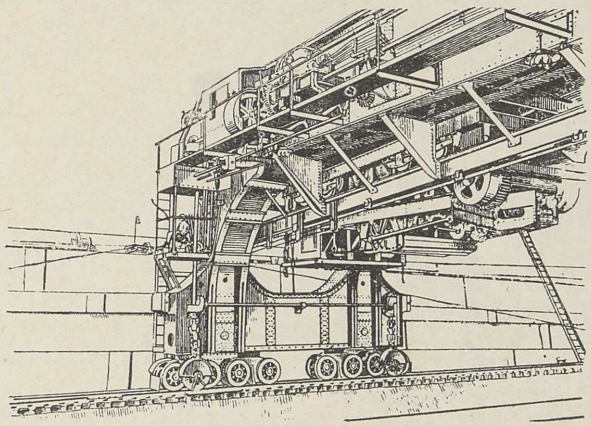


Fig. 589. Portion of Structure supporting Hulett Unloader.

of the lower structure. The travelling gear receives motion from an electro-motor of 150 H.P. (at 450 revolutions). The carriage of the unloader proper, which travels on this structure, has twelve wheels in front and four at the rear end, and there are also at the

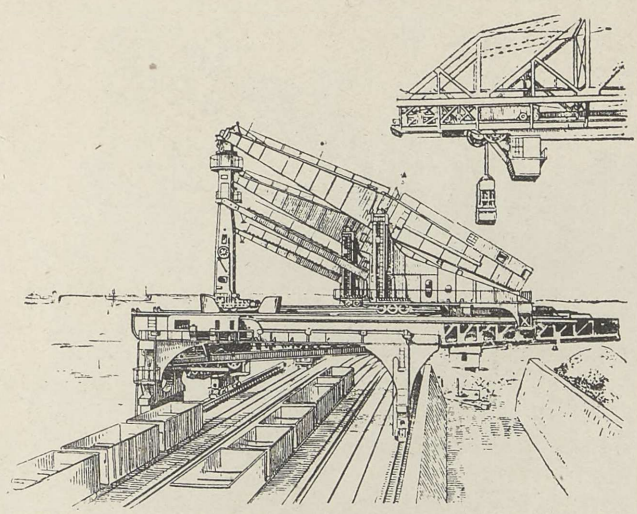


Fig. 590. Hulett Unloader Depositing into Portable Bunker.

back two further wheels which press against a rail above in case of a tilting of the apparatus. The carriage of the unloader supports a balance beam, which carries the unloader itself on its vertical iron arm, whilst the winding gear is situated at the rear end of the beam.

The winding drum of the lifting gear is manipulated by a 300 H.P. electro-motor and electro-magnetic brakes. Four $1\frac{1}{4}$-in. cables are connected to the drum, and lead

down to the lower part of the structure, where they pass over sheaves and up again to the end of the balance beam. The travelling gear of the carriage of the unloader is connected to a 100 H.P. electro-motor (at 250 revolutions).

The grab is so supported on its column that it can revolve around its vertical axis $\frac{7}{8}$ of a revolution in either direction, so that altogether a movement of $1\frac{3}{4}$ revolutions can be performed; this motion is given by a 35 H.P. electro-motor. The opening and closing of the grab are controlled by chains, which wind and unwind on three drums on one common spindle. The axis of the grab does not coincide with that of its column, but is eccentric by 2 ft. The spindle of the drum for manipulating the grab is connected by two intermediate gear-driven spindles, and by two cables which connect them with the winding gear at the rear end of the balance beam, and are manipulated by a 100 H.P. electro-motor. This gear is also fitted with an electro-magnetic brake and a flexible coupling, which absorb any stresses which might be caused by the closing of the grab. The weight of the grab and its support is balanced to within 4 tons by a balance weight.

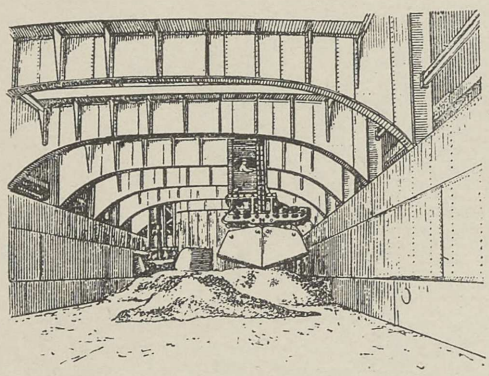


Fig. 591. Hulett Unloaders in Hold of Vessel.

The arrangement in this latest installation is such that the ore can be deposited in a

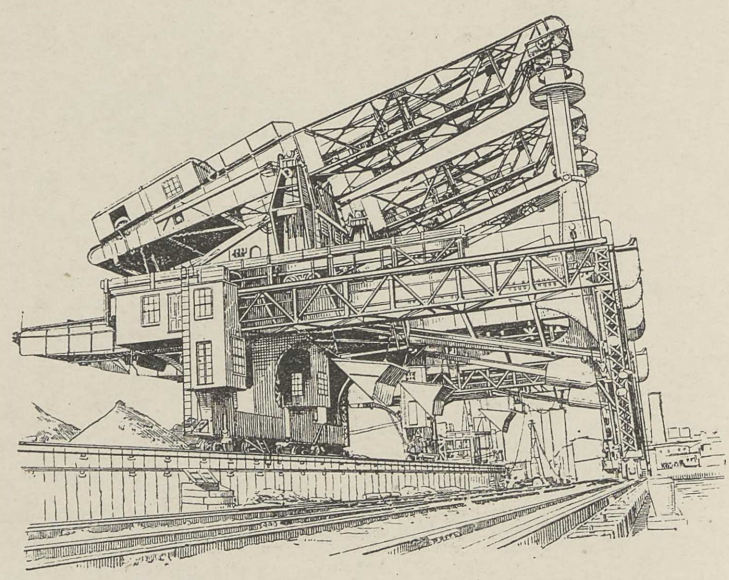


Fig. 592. Perspective View of Hulett Unloaders.

portable bunker so that very little time is lost, the grab in order to unload only having to travel back a short distance. This portable bunker is connected with a weighing mechanism, and its contents may be drawn off into railway trucks, etc. Fig. 590 shows

the unloader depositing its load into this portable bunker, whilst Fig. **591** shows two unloaders in the same hold, one being open and the other closed. This illustration also shows the position of the driver's cabin. Two such travelling bunkers are used so that one can be emptied into railway trucks whilst the other is being filled by the grab. The grab capacity is 17 tons of ore, and as the bunker holds 70 tons, it is practically filled by four grab loads. Three men are required to manipulate one machine. All movements of the grabs are controlled by one man. The travelling gear of the crane carriage, and the manipulation of the bunker, is under the control of the second man, whilst the third manipulates the under-carriage. The capacity of these latest Hulett unloaders varies from 500 to 1,000 tons per hour, depending upon the depth of the ore in the hold, and the construction of the ship to be unloaded. As an example may be cited the unloading operations in the dock at Ashtabula, Ohio, in 1913, when eight 15-ton unloaders, working in sets of four, from two separate harbour basins, unloaded 70,000 tons of iron ore from eight steamers in twenty hours—an average of 437½ tons per machine per hour. In this time calculation the berthing of the ships and the making fast in the docks is included. In this case the ore was deposited directly into railway wagons, 1,319 being required, each containing 53 tons, that is, one wagon every fifty-five seconds.

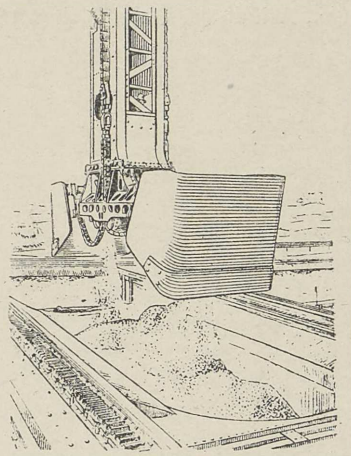


Fig. 593. 10-Ton Grab of Hulett Unloader.

Up to the year 1914 fifty such unloaders had been erected, and with the exception of two were engaged in unloading ore and handled over 50 per cent. of the total tonnage of ore shipped on the great American lakes. The

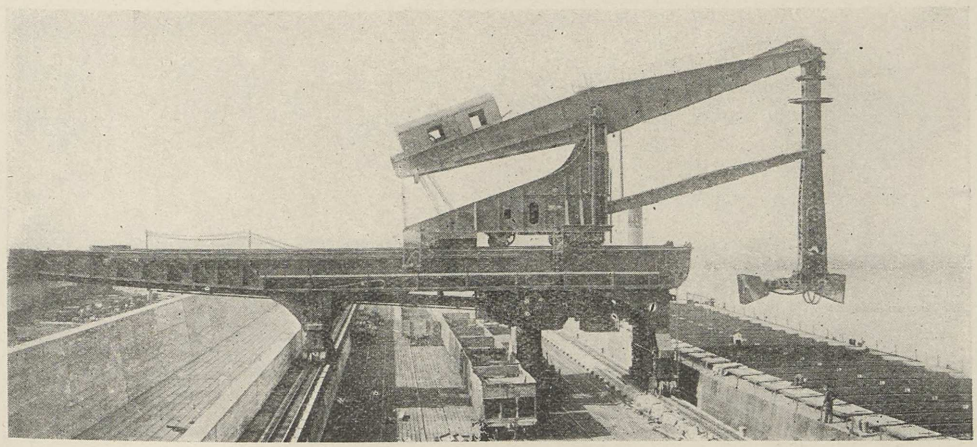


Fig. 594. Hulett Unloader at Ashtabula.

other two, which were erected in 1913 at Fort William, Ontario, in Canada, for the Canadian Pacific Railway Co., are for the unloading of coal.

This latter plant consists of two automatic unloaders equipped with 8-ton scoops, a man-trolley stocking bridge carrying a 9-ton grab bucket, and a transfer car system with

trestle and bins. The plant has a capacity for unloading a 10,000-ton boat in fifteen hours. Most of the latest machines are entirely electrically driven; some, however, are driven by steam or hydraulic power.

Fig. **592** shows unloaders of the Pennsylvania Railroad Co., which grab 17 tons at a time. Fig. **593** shows the 10-ton grab of a similar installation of the Corrigan McKimey Co.

A 15-ton capacity Hulett unloader at the plant of the Pittsburg and Conneaut Dock Co., Ashtabula, Ohio, is shown in Fig. **594**.

CHAPTER XXXI

TRANSPORTERS, BRIDGE OR CANTILEVER CRANES

PERHAPS one of the most important improvements that has been effected of late years in the mechanical handling of material is in connection with discharging ships to granaries, warehouses, or stock yards erected on or near the quay side.

The first step in advance which superseded hand labour was taken when cranes were erected and used for the clearance of cargoes. At this stage it became the practice to fill coal in the ship into skips of cylindrical shape, which were hoisted and then discharged through a hinged door into the trucks.

This system is still in use to a considerable extent, but it has the disadvantage of calling for an inordinate amount of hand labour, and is therefore economically wasteful. An improvement on this method is the use of grabs which generally require a special kind of crane, and will effect a sensible saving in time. In later years the hoisting crane or transporter has been combined with a bridge or gantry which commands the whole length of the quay side, store, or yard. In or on these gantries mechanical means for conveying the material are erected, and every operation incidental to the reception and further handling of the material is effected by machinery. Such installations have been variously called transporters, bridge or cantilever cranes.

They can be either steam or electrically driven, and it is claimed that the first of the latter type were erected in 1901 by the Brown Hoisting Machinery Co. for the North-Western Fuel Co.[1] They can be divided under two general heads :—

(*a*) Transporters in which the winding gear is mounted in a movable cabin, and accompanies the load from the ship to the point of delivery.

(*b*) Transporters in which the winding gear is situated in a cabin fixed in the structure of the crane, and is connected by cables and chains to the running head which carries the load.

TRANSPORTERS WITH MOVABLE WINDING GEARS

These transporters are perhaps not so much used as those with stationary winding gears, probably for the reason that the structure has to be erected on a more substantial scale, and is therefore more expensive. It has, however, several advantages, the principal one being that the handling of the material is better under control of the attendant as he accompanies the load in his cabin, which also contains the winding gear and motor.

Such transporters are numerous, but as they all bear a great resemblance to each other, it will suffice to give only a few examples.

Electrically Driven Grab Transporters at the Coal Yard of the British Admiralty at Devonport.—The British Admiralty have erected four electrically driven grab transporters, forming one installation, part of which is illustrated in Fig. **595**. It

[1] Described by Mr G. H. Hutchinson, chief engineer, North-Western Fuel Co., in his paper presented to the American Society of Mechanical Engineers.

will be observed from the illustration that the transporters are of very large size, and that the driver with his cab accompanies the load.

These particular machines are arranged to travel around a sharp corner in the store ground, and also to stand at varying angles to the track. Two machines can stand at

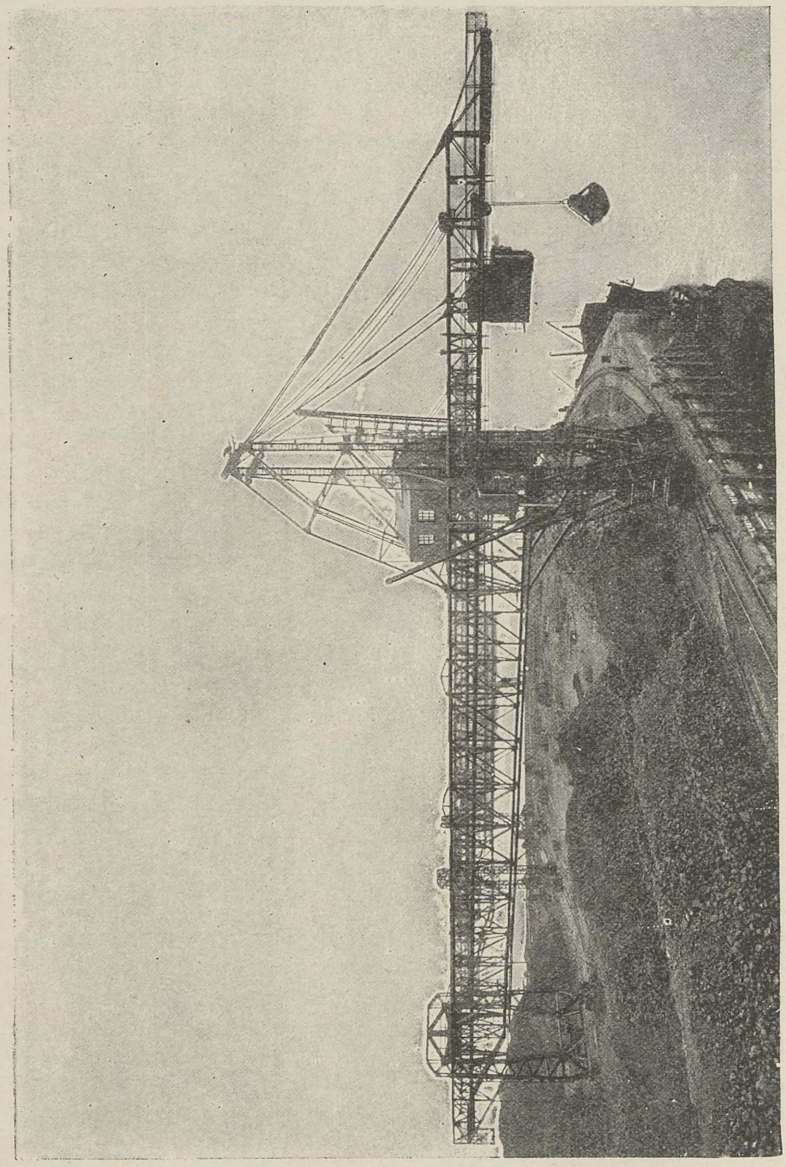


Fig. 595. One of Four Electrically Driven Grab Transporters for British Admiralty.

such angles that the grabs can work from the same hold, but discharge the coal to different portions of the yard. The advantage of such an arrangement is readily understood. Similar conditions can be obtained when loading vessels from the store.

The machines run on double rails at each end, placed close together, and no square tower is provided. The transporters were arranged in this way so that very little space

near the quay front should be taken up by the machines, and that cranes could pass between the coal heaps and the transporters.

Each machine is provided with a 2-ton grab, and can discharge coal from the collier to the centre of the coal yard at the rate of 100 tons per hour.

The length over all of the transporters is nearly 400 ft., and the height of the lower chord of the bridge above rail level is 34 ft. The depth of the bridge is 19 ft.

This method of unloading coal costs $\frac{3}{4}$d. per ton, which includes driver, and current consumed.

The special advantage of this system is, that when handled by these grabs, the coal can be stored to a greater height than when handled by bucket, and whereas coal is never stacked, in British dockyards, more than 18 to 20 ft. high by buckets, it is often stored to 34 ft. by transporters and grabs. This means an increase in the capacity of the store ground of nearly 100 per cent., which often proves to be of very great value indeed where the store ground is restricted. Careful observations show that heating does not take place when this depth of coal has been stacked by these grabs.

It is claimed for these transporters that they are more economical in working than the rope-haul system. Other advantages claimed are: that the driver has a perfect view of his work under all conditions; the track is not confined to a straight line; the parts to be kept lubricated are all collected in one cabin; and all rope sheaves are entirely omitted. The power required to drive is less in this system, as very little is lost between the gear and the grab compared with that lost when ropes have to be led around a large number of pulleys.

This installation was erected by Fraser & Chalmers, Ltd., of London and Erith.

Coal-Handling Plant at Duluth.[1]—A coal-handling plant which is said to be the largest plant in the world for handling bituminous coal was completed in 1911 at Duluth, Minn., for the Pittsburg Coal Dock Co., a subsidiary of the Pittsburg Coal Co. The plant is designed for unloading coal from lake boats to the storage yard, and for loading on to cars. An interesting feature of the plant is a mechanical screening apparatus of new design and large capacity. The plant has a storage capacity of 1,000,000 tons, and an unloading capacity, as shown by recent tests, of 900 tons an hour, including the delay in cleaning up the holds of vessels unloaded. While working in free coal it is estimated that the plant will discharge 1,500 tons an hour from a boat to the storage yard. The plant was designed and erected by the Brown Hoisting Machinery Co., Cleveland, Ohio.

The coal-handling equipment includes three two-span bridges, shown in Figs. **596** and **597**, extending from the unloading dock and two single-span bridges. Each span is of 242 ft. The yard is covered by the bridges, which are operated back and forth on a runway 1,250 ft. long. Each two-span bridge and one of the single-span bridges is equipped with a man trolley, which carries a two-rope Brown grab-bucket, with a capacity of 230 cub. ft. or $5\frac{1}{2}$ tons, and an operator's cab. The single-span bridges are arranged to register with any of the two-span bridges so as to make a three-span bridge or a continuous runway for a trolley over any one of the two-span bridges, and one of the single spans, a total distance of 726 ft. The operating mechanism is arranged so that when a single-span bridge is connected with a two-span bridge the three spans are operated as a unit. The single spans may also be operated as independent bridges. The single span not provided with a trolley is operated by using one of the trolleys from a two-span bridge. The two-span bridges have a cantilever extension of 78 ft. out over the dock

[1] From *The Iron Age* of 7th December 1911.

and there is a 35-ft. cantilever extension from the rear end of each of the single-span bridges.

Each man trolley is designed to carry a load of about 10 tons, to hoist the full load of the bucket at the rate of 225 ft. per minute, and to travel along its runway at 1,200 ft. per minute. Each bridge, when carrying a loaded bucket, can propel itself along its own runway at a speed of 60 ft. per minute.

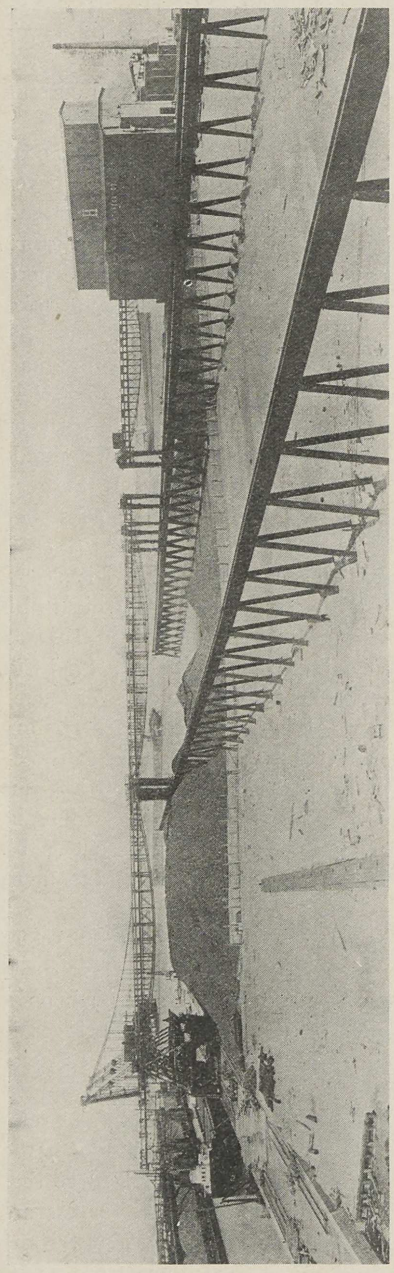


Fig. 596. Coal-Handling Plant at Duluth.

The front or water end of each two-span bridge, Fig. 597, is carried on a portal pier equipped with bins for loading coal into hopper or gondola cars. The centre and rear end of the two-span bridges and the forward end of the single-span bridges are carried on shear legs, each shear leg running on a single line of rail. The shear leg rails are supported on trestles constructed of steel girders carried on steel A frames. There is one single rail trestle or runway, and one double rail trestle. The former is for the shear leg at the centre of the two-span bridges, and the latter is for the rear shear leg of the two-span bridges, and the shear legs of the single spans. The distance from the foundations to the top of the rail on the trestles is 35 ft. 6 in. The rear ends of the single-span bridges are carried on inverted piers.

The piers for the two-span bridges are each supported on four equalising trucks, each truck being mounted on four 24-in. double-flanged, cast iron, chilled-tread wheels. The wheels on each pier are connected by a train of gearing and shafting to the moving gear mechanism located on the bridge span, near the bridge support. Each inverted pier at the rear end of the single spans is carried on two sets of equalising trucks, each truck supported on eight similar wheels. In addition the rear pier that carries the screening apparatus has for partially carrying that apparatus one equalising truck supported on six 24-in. wheels, each truck travelling on two lines of rails spaced 2 ft., centre to centre. The six-wheel truck acts as an idler only. All of the wheels in each of the eight-wheel trucks are driven, being connected by a train of gearing and shafting to the moving gear mechanism located at the top of the pier. Under the other rear pier one half of the wheels are similarly connected to the moving gear mechanism. Each shear support in the bridges is mounted on two single-rail equalising trucks, each truck being supported by four wheels.

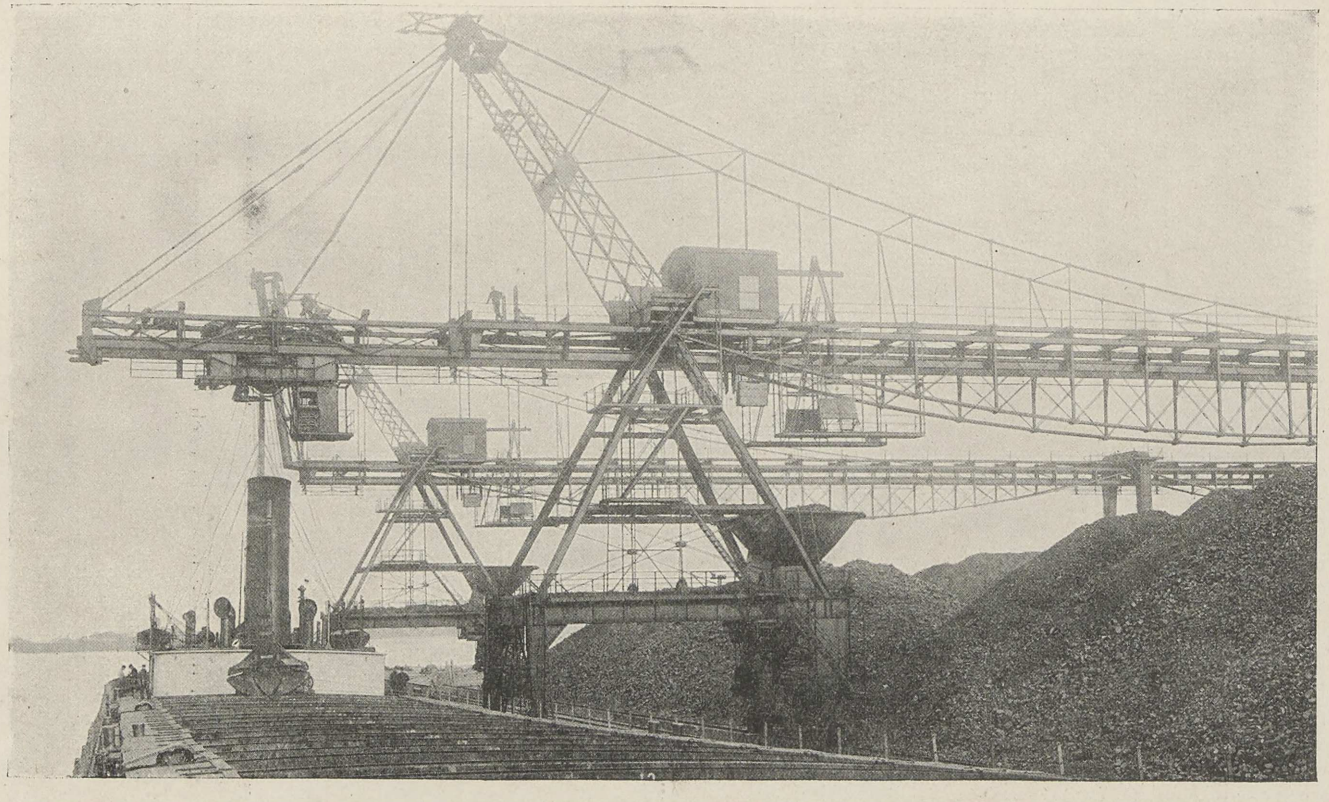


Fig. 597. Front Ends of two of the Two-Span Bridges at Duluth, that in the Foreground being in Extended Position.

The shears support the bridge span on sliding bearings under the top chords. The cantilever extensions from the dock end of the two-span bridges are supported from the top of masts over the pier (see Fig. 597). Attached to the cantilevers are hinged aprons that can be raised and lowered.

The moving gear for each bridge crane is operated by a motor in a house over the pier support. This motor is controlled from the operator's cab on the man trolley, when the trolley is brought to a point immediately under the moving gear house. The man trolleys are so designed that the operator can turn the bucket through an angle of 90°.

In general the operation of the screening apparatus at the rear is as follows: The coal is first placed by the grab bucket in a 30-ton receiving bin. It is then passed over a shaker screen to a pivoted conveyor for delivering it into cars. The coal going through the shaker screen passes into a small bin beneath, delivering to an elevator, by which it is either delivered to revolving screens for preparing small sizes, or directly into the screening bin for delivering it to a belt conveyor discharging on a screenings stock pile.

By this arrangement, when lump coal is being loaded, a car load each of stove, nut, and screenings may be taken at the same time. In case lump coal is being loaded and there are no orders for the smaller sizes, the screenings can be delivered from the elevator direct to the screening bin, which in turn will deliver the screenings to the belt conveyor for the stock pile. When taking general screenings from the stock pile for sizing and loading, they are dumped by the grab bucket into the receiving bin and handled as described.

The bins are of parabolic form. The 30-ton bin is equipped with a large reciprocating gate operated by power. The screening apparatus for handling the coal passing through the shaker screen has a capacity of 200 tons an hour.

The other rear pier is equipped with a 30-ton bin, gate, and chute for unloading coal into gondola cars, a screening bin and elevator for screenings, and chutes for unloading screened coal into box cars in connection with box-car unloaders. Beneath the screening chute is a 50-ton bin for catching the screenings. In connection with this screening equipment is a bucket conveyor for raising the screenings to a point from where they are discharged by gravity to a screenings pile on the water side of the pier, or carried by a belt conveyor and discharged in cars on the second track on the other side of the pier.

The electrical equipment is arranged to operate on 440-volt, 3-phase, 25-cycle, alternating current. The motor equipment includes the following, in addition to the motors in connection with the screening apparatus, all furnished by the General Electric Co.: three 112 H.P. motors for moving the three two-span bridges and a 112 H.P. motor for operating the single-span bridge that has the extensive screening equipment; one 50 H.P. motor for moving the other single-span bridge; one 225 H.P. motor in each of the four trolleys for hoisting; two 112 H.P. motors in each trolley for the trolley travel; one 5 H.P. turntable motor in each trolley for rotating the grab buckets; one 2 H.P. clutch motor in each trolley, and one 15 H.P. continuous running motor for operating the screening elevator and conveyor in the pier of the single-span bridge not containing the extensive screening equipment. The travel motor on each bridge is operated by a general electric drum-type controller. The hoist motor on each trolley is operated by a master-operated magnetic controller. The trolley travel motors on each trolley are operated by a master-type controller.

During tests of the plant the steamer "J. S. Ashley," with 8,983 tons of lump coal, was unloaded in ten hours and fifteen minutes, and the cargo of the "J. E. Upson," 8,747 tons of the same grade, was taken out in ten hours and fifty-five minutes actual working time. While working in free coal, each bucket averaged nearly 6 tons to the lift.

In 1913 a similar installation with longer span bridges was erected on the Pittsburg Coal Co.'s Dock No. 5 in Superior, U.S.A.

Electric Travelling Trolley of the Brown Hoisting Machinery Co.—A most important part in high-level cranes is the trolley with its motor. It can, of course, travel on any gantry or bridge of suitable construction.

Fig. **598** represents an electric travelling trolley. The illustration explains itself. This trolley is used to draw ore and limestone for blast-furnace purposes from the ore bins, and convey it to the furnace hoist, where the bottom door of the receptacle is opened and the ore discharged into the skip of the furnace hoist.

Electric Travelling Trolley of the Temperley Transporter Co.—Fig. **599** illustrates a travelling trolley fitted with a Hone grab. It is shown with its electro-motor, also the cable from which the current is taken. The illustration also shows the operator's seat, and the levers, by means of which the trolley as well as the grab are manipulated.

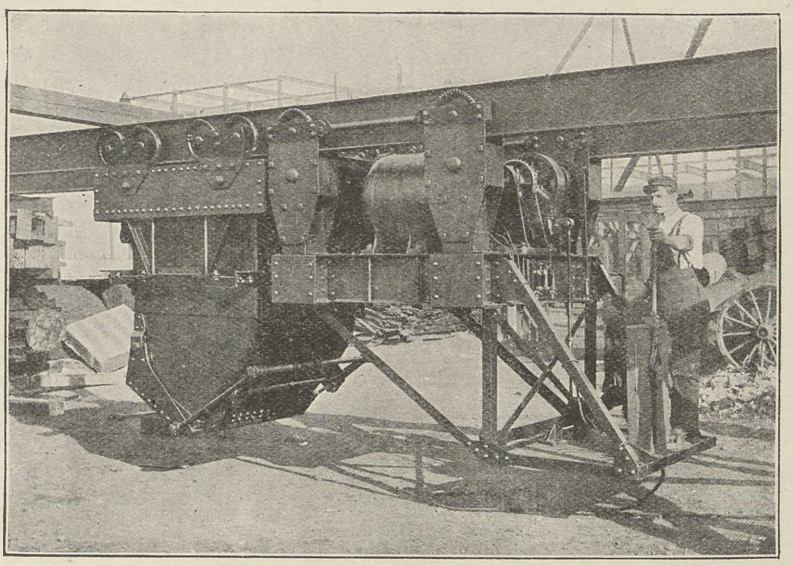


Fig. 598. Electric Travelling Trolley as used for Feeding Furnaces.

The capacity of the grab is 3 tons; it rises 50 ft. per minute, and the trolley travels at a speed of from 400 to 500 ft. per minute.

For other examples see chapter on "Storing Coal and other Minerals in Stock Heaps and Silos," page 650.

TRANSPORTERS WITH STATIONARY WINDING GEARS

These transporters undoubtedly owe their origin to American enterprise, and are largely used in the United States in a variety of forms, similar in appearance and general operation to that in which the winch accompanies the load, but the structure need not be so substantial, as smaller loads are generally dealt with, and in addition to the load the weight of the traveller or running head only need be taken into account as against the weight of the movable cabin with the winch and motor. But as this type is sometimes built from 60 to 80 yds. in length, the construction must be sufficiently rigid to resist, in addition to its own weight, the influence of high winds. It has also this advantage,

that the velocity with which the load can be moved is greater than when a travelling cabin is used and a heavier load has to be handled; the speed being from 12 to 14 ft. per second, as against 5 to 6 ft. per second in the other type.

American transporters generally run at higher speeds than those usual in Europe; too great a speed is, however, not advisable, on account of the strain caused to the structure by the stopping and starting of the running loads.

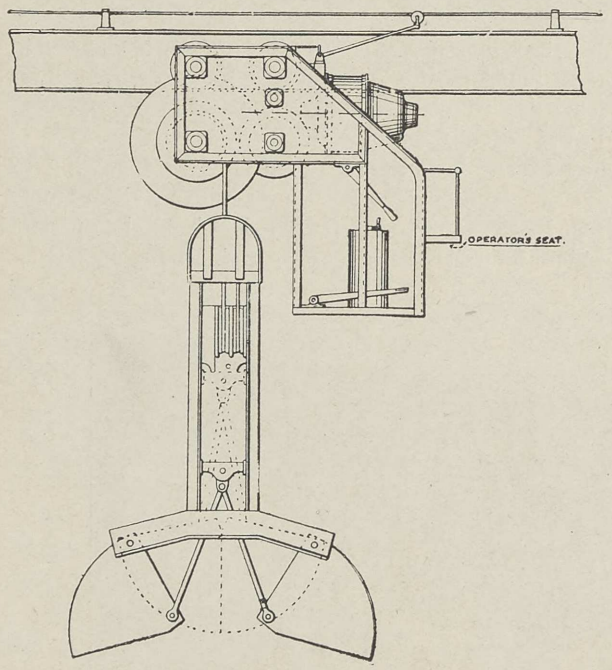


Fig. 599. Electric Travelling Trolley fitted with a Hone Grab.

The principal difficulty with bridge cranes with fixed winches is the complicated leading of the rope or ropes, and the consequent great wear and tear on the ropes caused either by the ropes being bent in two directions, or by their being led over small sheaves.

The use of chains would obviate this difficulty; but these are unsuitable, not only on account of their weight, but also because they lack the elasticity of wire ropes, and are therefore more likely to break under the strain caused by the sudden stopping and starting, and also by the shocks occasioned by the use of grabs at the loading end of the apparatus. It is probably on this account that some firms prefer to fit their transporters with ordinary skips instead of with mechanical grabs. With the latter the wear and tear on the ropes is certainly greater.

Instances have been known where wire ropes have had to be replaced after working

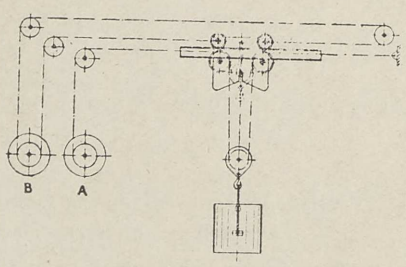


Fig. 600.

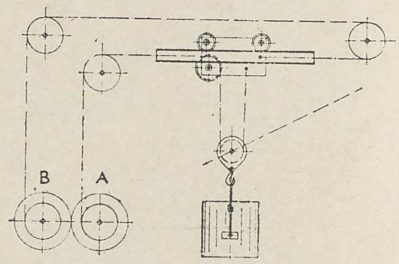


Fig. 601.

only a few weeks. If grabs are used it is best to use a one-rope grab, because a two-rope grab will complicate the handling of the plant.

Another difficulty in the use of transporters with stationary winches arises from the fact that the man manipulating the winch cannot control the operations so well as if accompanying the load. It is, therefore, sometimes necessary to employ a signalman

in a prominent position who can communicate with the men in the hold and the operator in the winch cabin. These minor disadvantages have, however, not materially checked the progress of this type of crane, as its quicker unloading speed, easier manipulation, and smaller first cost have opened up a large field for it.

The illustrations, Figs. **600** to **610**, show, in diagrams, the most usual forms of manipulating the traveller, with its load, from the winch or winches. Transporters of this type are by no means new, but have been used for a number of years on a small scale on the principle shown in Fig. **600**, where the rope which lifts the load is fixed at one end of the structure, and at the other to the drum A, and supports the skip after passing over the fall-block. If the position of the running head is changed by the drum B, the load remains at the same distance from the ground. A represents the drum for raising and lowering the load, whilst B is the winch for moving it horizontally. The constant bending of the steel rope over the two pulleys on the traveller and over the fall-block offers considerable resistance to the movement of the load; yet over short distances such transporters do satisfactory work. For long lengths and for a quick rate of travel this construction is unsuitable. It can, however, be used to advantage when the load is so held as to relieve the rope during the lateral movement of the running head, as shown in dotted lines, when the fall-block is held in its topmost position by a catch suspended from the running head.

In such a position, and with the load supported by the head itself, the rope will bend freely and without much wear and tear during the horizontal movement of the load. The position of the load close to the running head is also an advantage, as it checks the swinging, pendulum fashion, and admits therefore of a quicker starting and stopping, but it must be raised to its fullest extent and locked before the horizontal movement can take place. It also entails a small loss of time for the locking and unlocking of the load in its raised position.

When ore or other material that does not deteriorate by being dropped is being conveyed, it will be unnecessary to disengage the fall-block, and lower the load down the pile before tipping the bucket.

Such difficulties as are met with in the plan shown in Fig. **600** are obviated in the scheme illustrated in Fig. **601**. In this both conveying and elevating ropes are under the same tension. The two drums A and B are loose on their spindles, which are, however, coupled together by spur wheels, the drums being connected to the spindles by friction clutches, either separately or jointly. The drum A is for elevating only, but both drums A and B must be in motion when the traveller is moved in either direction. This construction enables the operator by simply pulling the hauling ropes to raise or lower the loads in an oblique direction, as is indicated by the dotted line in Fig. **601**. The angle is 2 : 1 to the horizontal. The side movement of the load is, therefore, twice as great as the up-and-down movement, but the proportion can be altered by using different fall-blocks, or to meet cases where the motor speed varies according to the load. For short chains used in conjunction with a grab, this oblique movement of the load is most convenient. The principal advantage is that the horizontal and vertical movements of the load are independent of each other, and that the traveller may be moved horizontally with the load in any position. For transporters with high speeds it might be an advantage to convey the skip in as high a position as possible, to avoid the pendulum movement of the load. With this construction both winches A and B must be of the same power, as both ropes are under the same tension.

A similar design is shown in Fig. **602**. Both winches A and B can be turned either in the same or in opposite directions, this being accomplished by the use of a pair

of wheels, of friction clutches, and of a third wheel C, which can be coupled between the two larger spur wheels. If both drums revolve in the same direction, they both wind up the rope, and thus elevate the load; whereas, in the other case, one drum winds up as much rope as the other pays out, and the load is therefore conveyed in a horizontal direction.

In a scheme such as is illustrated in Fig. **603**, the load is supported on an endless rope which is wound round the conveying drum B, and by means of this drum can be

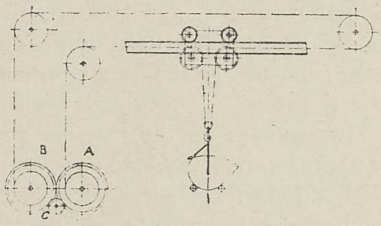


Fig. 602.

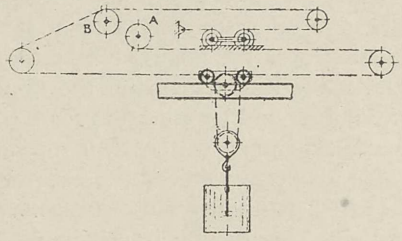


Fig. 603.

drawn either backward or forward. The drum A is for lifting and lowering the load by shortening or lengthening the endless rope which supports it, this being accomplished by a pair of jockey pulleys, as shown in the illustration.

The demand for transporters with less complicated winding gear led to the introduction of those worked by one rope only, and their action is illustrated in Fig. **604**. One end of the rope is attached to the winding drum of the winch and the other to the traveller. Supposing the winch to be standing, the load would descend by its own gravity

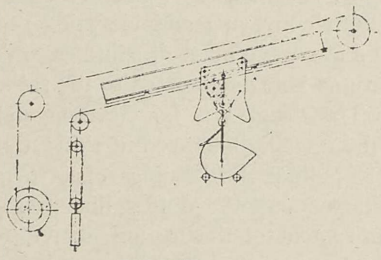


Fig. 604.

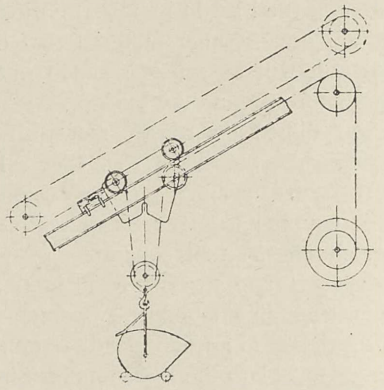


Fig. 605.

and move the running head or traveller in an upward direction; but in order to prevent this, the traveller is secured to the girder upon which it runs by a catch and notches cut in the girder. As soon as the load has been raised to its topmost position, and the fall-block has entered the traveller as shown, it is retained there by a hook, which automatically releases the catches that locked the running head to the girder. On a further movement of the winding drum, the load proceeds in an upward direction, and when empty, the running head returns automatically down its own support. The crane is manipulated as follows: The traveller is pulled by the winch past one of the notches near which the unloading is to take place. The rope is then somewhat slackened to

allow of a slight return of the traveller on its support, whereupon the catch will engage with one of the notches, and lock it in position. At the same time this releases the load, and by slackening the rope the load will be lowered. In order to accelerate the return of the traveller, the incline of the girder is placed at about 1 : 4. This is necessary, as the weight of the rope has to be drawn along with the head. If such an incline be prohibitive on account of local conditions, or if the transporter be of sufficient length to cause the weight of the rope to hold the traveller back, or to prevent it moving at a sufficient speed, a balance weight is used to accelerate the downward movement as shown.

Another and frequently used method, which is practicable for working with one rope, is illustrated in Fig. **605**. The skip is here suspended from the fall-block in the usual manner, and the supporting girder for the traveller is fixed at an angle of about 30°, which angle is sufficient to prevent the running head with its load from moving upward when the winch is at a standstill. In fact, if the angle be made steeper, the load is inclined to run downwards, so that it is necessary to provide a stop block in order to prevent it from running too low. In the position shown, the load can be raised or lowered while the traveller remains stationary, but when raising the load beyond the topmost limit, so that it touches the traveller, the latter with its load will ascend the girder, and the load can then be discharged. The empty skip can only be lowered when the running head comes against an adjustable stop, as shown. The fact that this system requires such a very steep rail girder will account for its use being confined to comparatively short reaches, and to its mostly being used for unloading ships in connection with other methods of conveying, the transporter in this case only being used to transfer the material from the ship's hold to a conveyor which takes it to its destination; whereas transporters with horizontal or slightly inclined rail girders are more generally used to convey the material from the ship to its final destination without the intervention of an auxiliary conveyor.

Transporter of the Brown Hoisting Machinery Co.—The transporter of the Brown Hoisting Machinery Co., Cleveland, Ohio, is one of a popular type. It is usually made so narrow that three or four can be placed close together to unload from the same ship, or at least one can be set to work over each hatchway. The general construction of the iron trussed bridge depends upon the span of the crane, but the supports are usually made in such a way that the transporters can be moved obliquely across the rails which carry them. Either the support on the quay or that further inland can be moved independently as circumstances may permit. This is accomplished by one support moving on a double track of rails whilst the other moves on a single track, both being connected with the bridge by a swivel joint which allows of this oblique position. The unloading is usually effected by means of a grab, which holds 1 to 2 cub. yds., whilst ordinary skips are also sometimes used. A weighing machine is sometimes fitted, by means of which each load can be weighed independently as it passes a certain portion of the track. Some of the earlier appliances of this firm were erected at one of Krupp's establishments; four were erected on the Rhine near Duisburg, for unloading ore, which is the chief material imported. Each transporter is driven by a 45 H.P. electro-motor, running at a speed of 200 to 500 revs. per minute. This has been geared to the winding drum by wheels in the proportion of 1 to 4·6.

The manner in which the rope is connected from the winding drum to the traveller or running head is shown in Fig. **606**, whilst Figs. **607** and **608** show the details of the traveller itself.

As long as the load is being elevated, the traveller is mechanically fixed, and is therefore prevented from following the direction of the hoisting rope. As soon as the load is lifted sufficiently high for the fall-block to touch the traveller, the latter is

uncoupled, and the load automatically held in that position, so that any further winding of the rope will move it in a horizontal direction. When the load has been discharged, the traveller returns, its speed being controlled by a brake, until it has reached the point where it fixes itself, after which the further slackening of the rope will permit the descent of the skip. The inclines of the girder are in this case 1 in 8; but this not being sufficient to allow of the traveller going back on its own account, a travelling rope with a balance weight had to be used for the return of the empty skip as shown.

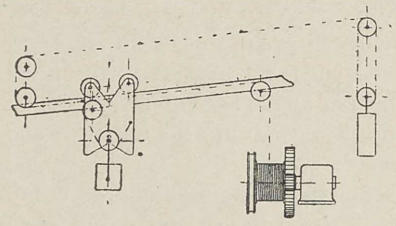


Fig. 606.

The traveller is represented in Fig. **607** at the moment when it reaches the lowest point determined by the fixture *a* which enters into the space provided for it in lever b_1, and couples itself as shown in dotted lines as soon as the traveller reaches the end of its journey.

The lever b_2 is moved simultaneously, thus giving rod *c* a downward motion. This action also moves lever *d*, which swivels round point *e* to the right at the top, and to the left at its lower end. This action releases the pulley and the fall-block with the load. The skip is now descending, and whilst doing so the head or traveller is held in position by lever b_1. After the skip has been filled and raised, the projecting spindles of the fall-block touch the forked end of rod *c*, which is thereby raised, so that *b*, b_1, and *d* are all replaced in their original position. Thereupon *a* is released by *b*, and lever *d* again holds the load, which, with the traveller, can proceed to the right. The skip is made to discharge its load automatically. It has a natural tendency to tip forward, but is prevented from tilting by the levers, which rest in grooves on the sides of the skip.

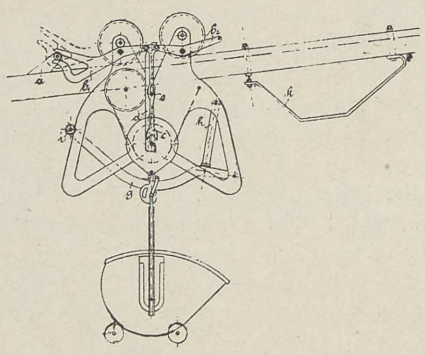


Fig. 607.

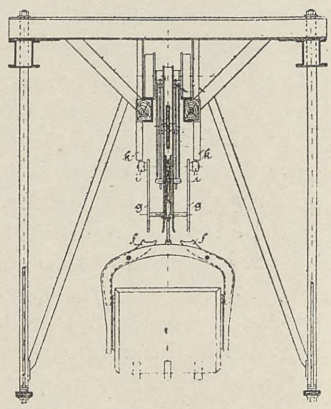


Fig. 608.

The traveller is fitted with levers *g g*, which are held in position by springs in the tube *h*. One end of the lever is fitted with rollers *i i*. These rollers touch trippers *k k* which are fixed in the discharging position. Thus the levers *g g* will be lowered by the incline on trippers *k k* until they come in contact with levers *f f*, and release the skip, allowing it to discharge itself. This method of unloading is, of course, only used when minerals are being handled, as a fall from a height would in the case of coal be detrimental.

Fig. **608** shows a cross section through the trestle bridge of the transporter. The

crane can be moved at the rate of 3 ft. per second; whilst the movement of the traveller is 13 and 20 ft. per second when moving in an upward and downward direction respectively. The capacity is from 300 to 500 tons per day of ten hours, eight or more trimmers being employed to fill the skips.

The last of these four transporters was erected at a later date, and was fitted with all the most recent improvements. The rope was guided as shown in Fig. **609**, from which it will be seen that the lifting and conveying ropes are running on separate drums. The two winding drums are loose on the spindle, and are connected by two bevel wheels and four pinions. The four pinions are mounted in a ring which can be fixed or allowed to run loose. All drums are loose on the spindle, and can be coupled to it by friction clutches. This transporter has the advantage of dispensing with the use of more or less complicated fixed stops. It can be stopped and unloaded at any point, and the skip need not be lifted to its topmost position before the traveller is put in motion, for if both conveying and lifting drums are started, the traveller with the skip will rise in an oblique direction, which movement can be utilised to fill the skip from a heap of material lying at its natural angle of repose.

The winding gear with its rope connection, shown in Fig. **609**, can also be modified in so far that the lifting drum can be dispensed with (see Fig. **610**). Such a device is

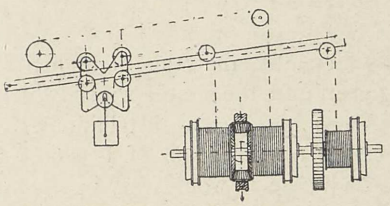


Fig. 609.

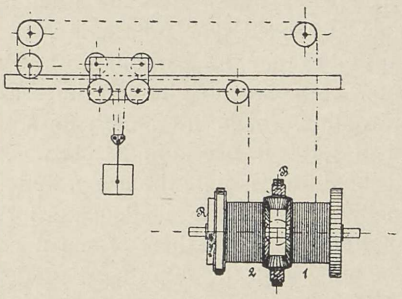


Fig. 610.

used by the C. W. Hunt Co., and also by the Brown Hoisting Machinery Co. The ropes are in this case both run over the sheaves in the traveller and secured to the suspender on which the skip hangs. The winding gear works as follows:—

The drum 1 is cast together with its driving wheel. It is keyed to the spindle, and can move in both directions. Drum 2 can be coupled to the spindle by the friction clutch R. Both drums receive and pay out rope on the same side, and are coupled together by gearing as shown in Fig. **609**. The ring B in which the four bevel pinions are fixed can be held by a band brake. If the load is to be elevated, both ropes are thrown in, the effect being that both drums revolve in the same direction, and as the four pinions are not fixed, they revolve freely, and are therefore out of action. The load can, by means of the band brake, either be held in suspension or lowered. If the traveller runs either forward or backward, the drums must revolve in opposite directions.

The Temperley Transporter.—In conveying coal, grain, and other heavy goods, the Temperley transporter, now manufactured by Sir William Arrol & Co., Ltd., of Glasgow, has undoubtedly rendered excellent service. It is used for the delivery of coal from lighters or barges, as well as from vessels lying at wharves, into boiler-houses, while it has also been found most useful for the loading and unloading of grain vessels.

This appliance is so largely used that it is worthy of a full description. Mr Joseph Temperley, the inventor, had for many years been engaged in the shipping industry in

London, and had observed the inadequacy of old-fashioned methods of discharging vessels in the port of London. His invention dates from about the year 1892, when turret ships and whalebacks first made their appearance. The original Temperley transporter consisted essentially of a long I-shaped section beam with a traveller running on the lower flange. The beam was triced up to the movable framework or shear legs, whilst the traveller was worked by two ropes engaging on the two drums of a double-barrelled winch. The apparatus was so arranged as to command the hold of a vessel and a point from 20 to 30 ft. overboard. This was the earliest type as designed for turret ships, but the inventor was not altogether satisfied with his work, as the apparatus appeared to him rather too complicated for general use, especially on board ordinary cargo steamers which have their own winches, and which carry derricks from which the beam of the transporter can be suspended. He accordingly simplified the gear, so that his appliance could be used with an ordinary ship's winch on which a single rope is paid out or hauled in.

In the later transporter the running head or traveller is fitted with an ingenious automatic device, by means of which it may be arrested and held stationary while the load is being either lifted or lowered. This device also keeps the load in suspension while the traveller is moving. The British Admiralty and many foreign Governments have adopted and successfully applied the conveyor to the rather difficult task of coaling warships.

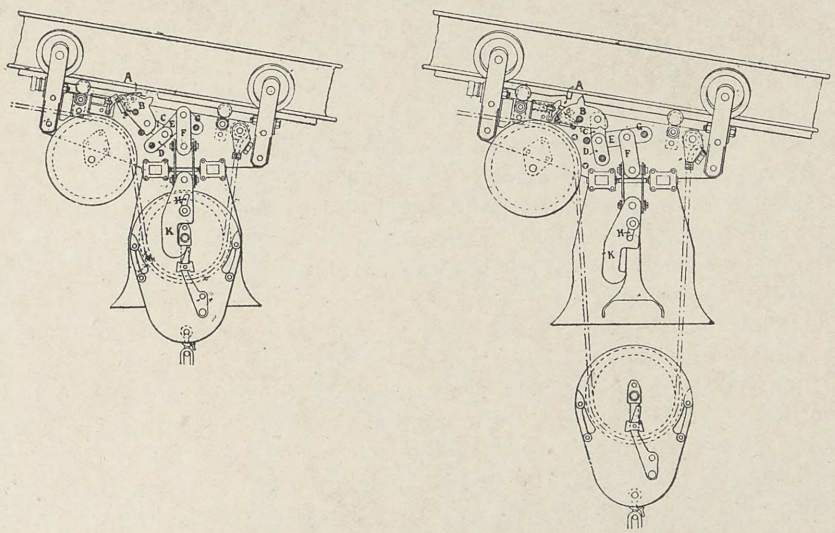
Temperley transporters are used under a great variety of conditions, both in the portable and fixed type on staging, or on gantries, at inland points, as much as, and perhaps more than, for harbour work. The original length of track of 40 to 50 ft. or so has now been extended to ten times as much, or even more, whilst the speed of lifting and travelling, which, in the early days, was about 150 ft. per minute, is now raised to a speed of 1,400 ft. per minute. It was, of course, inevitable that this great increase of speed should necessitate the use of better winding gear, and the simple winch which was originally used is quite inadequate for these modern high-speed installations. This transporter consists of three principal parts, namely, of a steel beam of I-section, which may be hung from the ship's mast or derrick, in which case it would vary in length from 30 to 65 ft., or as an alternative it may be supported on shore by an iron-work trestle frame, in which case the length of the track may be considerably extended; secondly, of an automatic traveller; and thirdly, of a winch which operates the traveller by a wire cable.

Assuming this transporter were being used on board a ship, it would be attached by wire slings to the end of an ordinary derrick, and would then be held up and secured by guy ropes in an inclined position across the vessel to command both the hatchways and the quay, or any lighters or barges which might be alongside. The pulley end of the I-shaped beam should be higher than the other end, towards which the movement of the traveller is effected by gravity. The angle at which the beam is inclined may be varied to suit the precise nature of the work. The beam may project over either side of the vessel. It remains in a fixed position, and should be quite rigid when at work, except that it should be free to swing laterally on its swivels. A steel wire rope is passed over the sheave of the traveller and runs over the fixed pulley at the end of the beam, and over two leading blocks, one being placed at the head and the other at the heel of the derrick. This wire rope is attached to the drum of an ordinary steam winch which is placed on the deck of the vessel.

The load can be discharged at any number of fixed points on the length of the beam. Such points or stops are usually placed about 5 ft. apart, all these operations being under the control of the attendant.

The traveller or running head is made in two distinct forms; one being double

purchase with fall-block, and the other single purchase without fall-block. The former is shown in Figs. **611** and **612**. In each case the traveller is held in position on the beam by the locking block B, whilst the load is being lifted or lowered, and, on the other hand, the load is sustained by the hooks K whilst the traveller is being moved along the beam. The locking block B and the sustaining hooks K are connected together by a system of levers and links in such a manner that the movement of the block B, in the act of locking the traveller to the beam, withdraws the hooks K out of gear with the fall-block —which is then free to descend—and conversely, the movement of the hooks into gear with the fall-block effects the release of the traveller from the beam. An important feature is that the relative movements are so arranged that the movement of the block K into gear with the beam is almost complete before the hooks begin to withdraw from the fall-block, and, on the other hand, the movement of the hooks into gear with the fall-block is almost complete before the block begins to come out of gear with the beam. Also, although B actuates K to release the load, and K actuates B to effect the release



Figs. 611 and 612. Showing Sliding Block and Traveller of Temperley Transporter.

of the traveller, the final small movement to complete the locking of the traveller and the sustaining of the load is in each case forcibly completed the other way about. That is, the weight of the escaping load completes the revolution of the block B, and the forced revolution of the block B in coming out of gear with the beam forces the hooks into complete gear with the fall-block. It will be noticed that in both positions, Figs. **611** and **612**, all the parts are securely locked by two pairs—lever and link—just over the dead centres.

In Fig. **611** the fall-block is "home" in the traveller, and the latter is unlocked from the beam on which it runs, and can be drawn along the transporter beam, the load during its travel being supported from the hook marked K in the figure. Should, however, the hauling rope be paid out instead of being hauled in, pawl A catches on the notch, causing block B to rotate on its pivot, and its projecting tooth to engage in the large notch shown. The weight of the traveller, tending to make it slide down the beam, causes block B to begin to rotate into the position shown in Fig. **612**, the rotation being forcibly completed by the weight of the load dragging down the hooks and forcing two pairs of

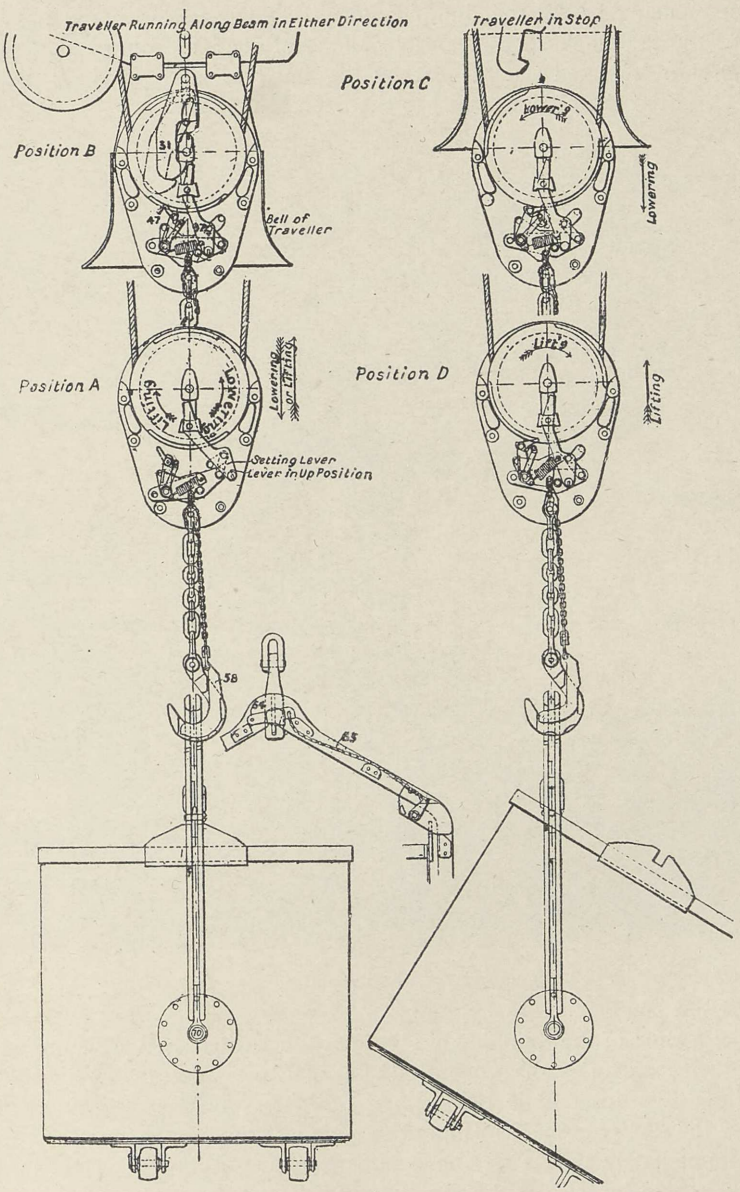
links EG and CD a little beyond the straight line—or dead centre—thus forming a double deadlock to the system. One end of this block is connected to a system of links lettered C, D, E, F, G. In Fig. **611** the links D and E are nearly in a straight line, and thus the weight of the fall-block, which is in position, as shown by the link F G, exerts no pressure on block B. What little pressure there is tends to keep B against its stop in the position there shown. Referring to Fig. **612**, the tooth on B engages with a notch, and by means of link C pulls the two links D and E into the position shown. The hook K and the link F then descend, being dragged down by the weight of the fall-block. The hook is provided with a cam slot shown at H, in which engages a fixed pin. This cam slot is of such a shape that as the hook K descends it is swung to the left, as shown in Fig. **612**, thus releasing the fall-block, which, on paying out the lifting rope, descends freely, completing the rotation of B, explained above. On raising the block again, striking pieces on it will come in contact with hook K, and raising the latter, will force up link F. The latter, by means of link E, will then pull over links C and D from the position shown in Fig. **612** into the position shown in Fig. **611**, thus unlocking the traveller, and at the same time hook K comes again into position to suspend the load, as in Fig. **611**. That is to say, the conditions of Fig. **611** are restored, except that the small pawl A now slopes up to the left instead of to the right, as there shown. It therefore follows that on slackening the rope, this pawl no longer catches on the beam, and the traveller is free to run down the latter on paying out the hauling rope. Generally the traveller is, in these circumstances, allowed to run to the very end of the beam, where a projecting block of metal catches the tooth on the block B, which thus locks itself without any assistance from the small pawl, but the traveller can also be brought to rest at any intermediate point.

When the traveller is locked to the beam, as shown in Fig. **612**, lifting or lowering is accomplished by hauling in or paying out the rope in the ordinary way. If it be desired to release the traveller, the operator has only to haul in the rope until the fall-block has entered the bell, and in so doing has brought the mechanism of the traveller into the position shown in Fig. **611**, when the traveller is free to move either up or down the beam. If it be desired to cause the traveller to move up the beam, the operator has only to continue to haul in the rope until the front part of the traveller has passed the point at which it is desired to lower, when by a reversal of the winch the traveller will engage with the first stop it encounters, and the load will be lowered. If the traveller is to descend the beam, all the operator has to do, after having released the traveller, is to pay out the rope and the traveller will descend along the beam—passing all the intermediate stops because the toggle has not been cocked and is therefore inoperative; the arresting of the traveller at the intermediate stop when moving down the beam is a very simple matter. It is only necessary to allow the carriage to pass the stop, when, by drawing it back in an upward direction, the toggle will become cocked, after which, as the rope is again paid out, the traveller will engage with a stop, and the load be lowered at that point. As the traveller moves up or down the track, the cam tooth can pass a stop with a clearance, but as the cam reaches the bottom stop it will, without the cocking of the toggle, automatically engage with it, and as the rope is paid out, the load will automatically be lowered.

The mechanism for dumping and travelling, described below, is in reality the gear which deserves to be called automatic. Position A, Fig. **613**, shows the dumping mechanism when the loaded skip is being lifted, the dumping mechanism of the fall-block having been thrown completely out of gear by the setting lever being placed in the position in which it is shown.

On the fall-block entering the traveller, the dumping mechanism is brought into

the relations shown in position B, by the point of the sustaining hooks 31 throwing the setting lever 37 into the position shown in this diagram. In this position the load is carried either up or down.



Figs. 613 and 614. Showing Various Positions of Traveller and Skip of Temperley Transporter.

On the traveller engaging with a stop on the beam at the point at which it is desired that the load should be lowered, the fall-block is released from the traveller, and the position of the dumping mechanism is altered to that shown in position C,

Fig. 614. It will be observed that the dumping toggle 47 has been turned over, and is pointing in the opposite direction.

With the mechanism in this position the skip is lowered to the point at which it is desired to discharge its contents.

On commencing to lift, the dumping toggle 47 engages with the notch 34 on the periphery of the fall-block sheave, and by the continued movement of the sheave the latch of the skip is pulled out of gear by the wiper 58 and its chain acting through the lever 64 and the chain 65 attached to the latch of the skip.

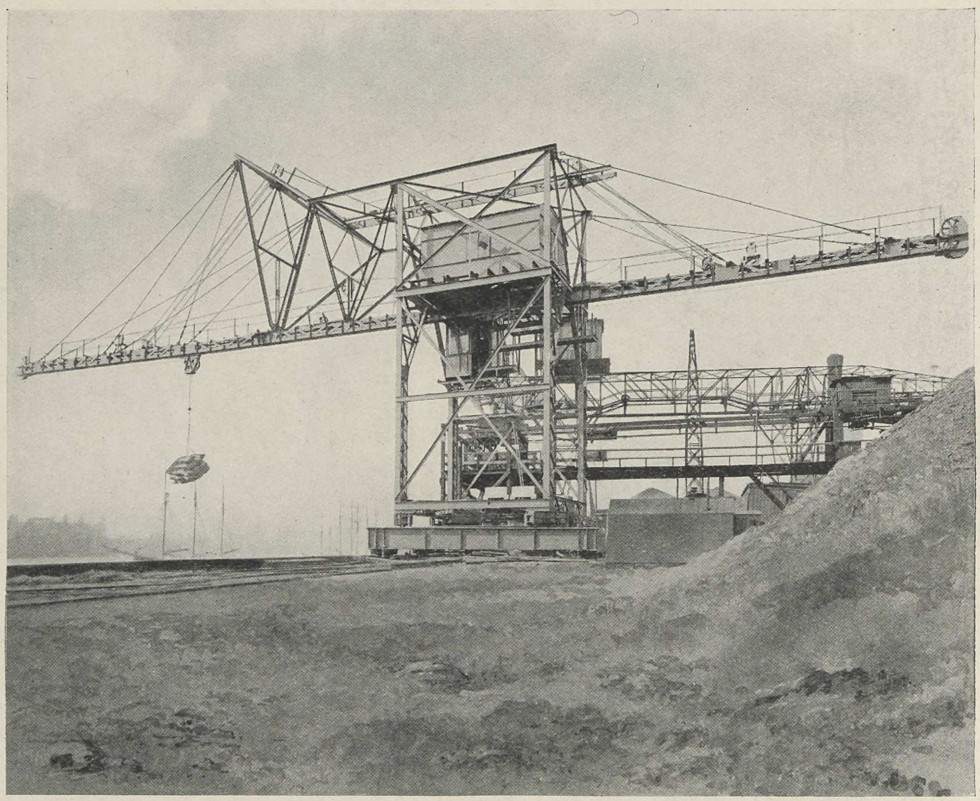


Fig. 615. Temperley Travelling and Slewing Transporter.

A special feature of the dumping fall-block is the setting lever 37, by means of which the dumping mechanism is thrown entirely out of gear, so that by no possibility can the skip be automatically upset while being lifted from the weighing machine. If the men omit to throw the dumping mechanism out of action by the movement of the setting lever, the bucket immediately upsets on the commencement of lifting. Thus the operators, although they cannot be hurt by the upsetting of the bucket, are forcibly reminded of the results of their negligence.

A later form of this transporter has been fitted with two-rope grabs for handling hard lumpy coal, and similar material, with the advantage that the lifting and lowering can be carried on whilst the traveller is being transported along the beam without either operation interfering with the other.

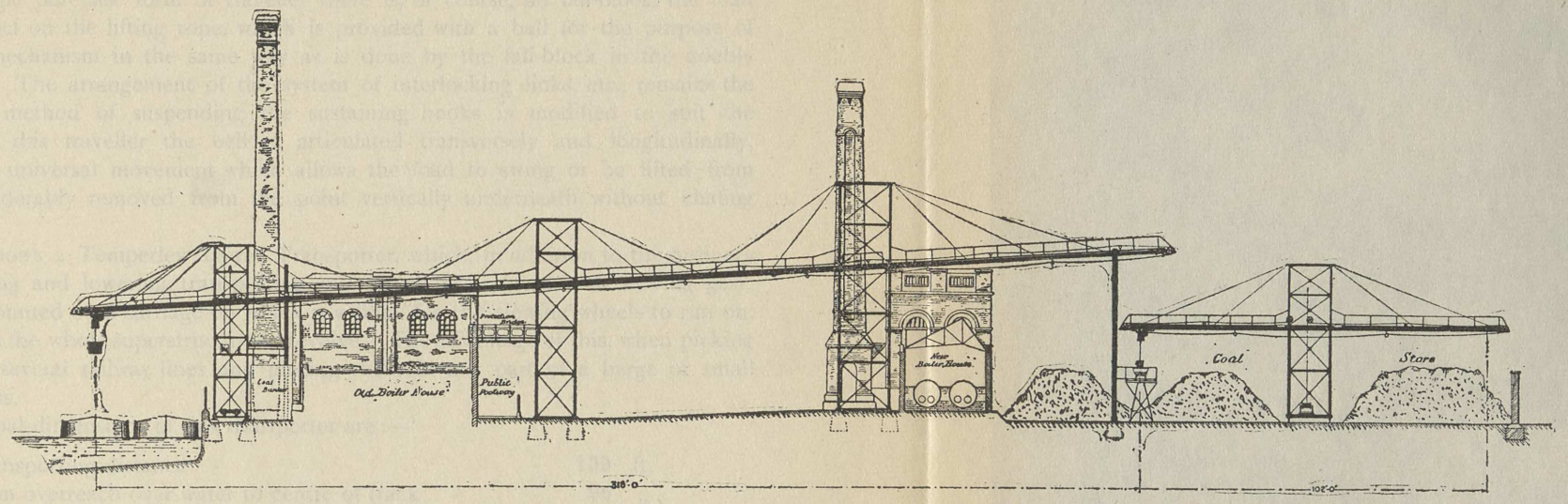


Fig. 616. Cross Section of Site of Temperley Transporters at West Middlesex Waterworks.

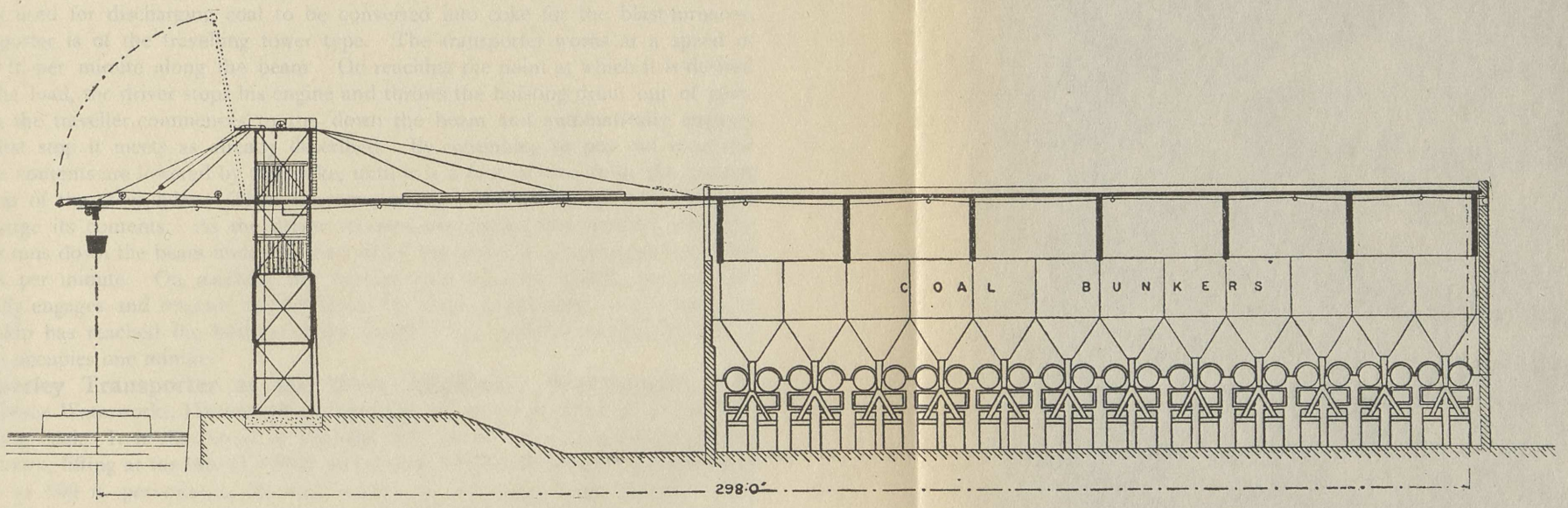


Fig. 617. Longitudinal Section showing Fixed Transporter for Lifting and Transporting Coal from Canal to Bunkers over the Boilers at West Ham Electric Generating Station.

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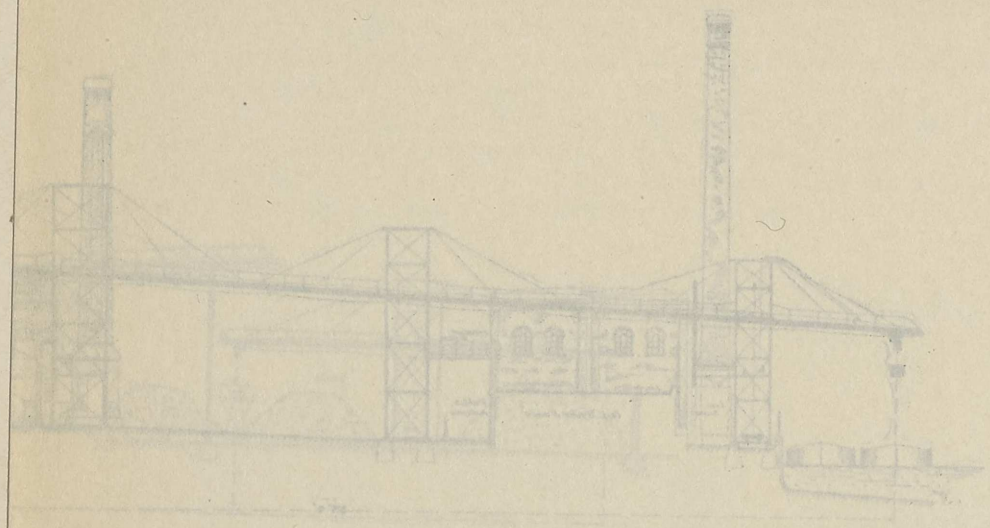
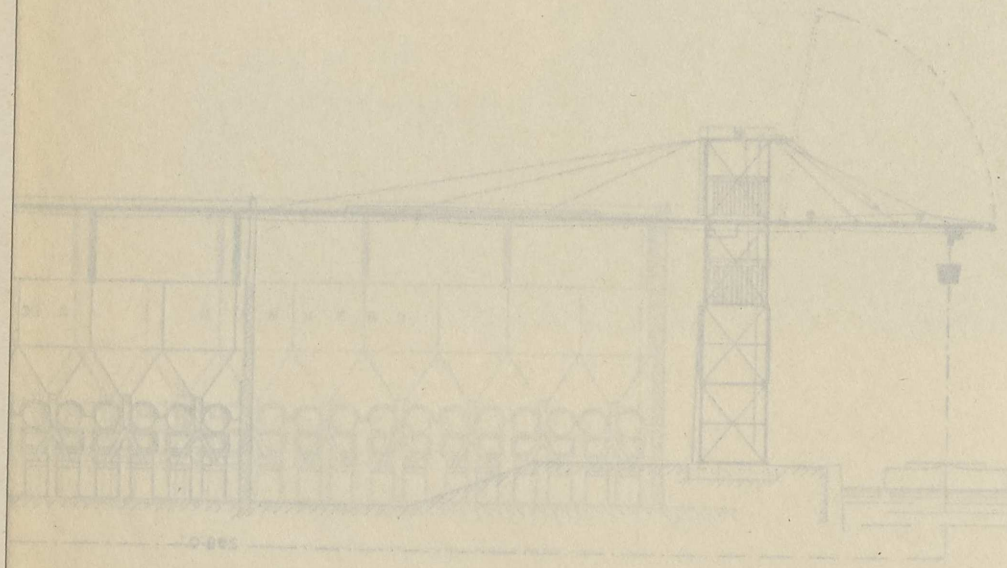




In the single purchase form of traveller there is, of course, no fall-block, the load being lifted direct on the lifting rope, which is provided with a ball for the purpose of actuating the mechanism in the same way as is done by the fall-block in the double purchase form. The arrangement of the system of interlocking links, etc., remains the same, but the method of suspending the sustaining hooks is modified to suit the conditions. In this traveller the bell is articulated transversely and longitudinally, permitting of a universal movement which allows the load to swing or be lifted from any point considerably removed from the point vertically underneath without chafing the rope.

Fig. **615** shows a Temperley Tower Transporter, which, in addition to the ordinary motions of lifting and lowering, transporting and travelling, is fitted with slewing gear. The tower is mounted on a carriage on which is a track for the slewing wheels to run on, and this enables the whole superstructure to revolve. The advantage of this, when picking up goods from several railway lines and placing them in any part of a barge or small vessel, is obvious.

The principal dimensions of this transporter are :—

Total transporting distance - - - - -	139	ft.
Maximum overreach over water to centre of track - -	96	,,
Maximum overreach over land to centre of track - -	43	,,
Gauge of track - - - - - -	26	,,
Working load - - - - - -	$2\frac{1}{4}$	tons.

Temperley Transporter at the Vizcaya Works, Bilbao.—A typical installation of the Temperley transporter may be seen at the Vizcaya Works, Bilbao, in Spain, where it is used for discharging coal to be converted into coke for the blast-furnaces. This transporter is of the travelling tower type. The transporter works at a speed of 700 to 800 ft. per minute along the beam. On reaching the point at which it is desired to lower the load, the driver stops his engine and throws the hoisting drum out of gear. Thereupon the traveller commences to run down the beam and automatically engages with the first stop it meets as already described. By continuing to pay out rope, the skip and its contents are lowered by the brake, until it is a foot or two from the ground or at the top of the stock heap. Then, on commencing to lift, the bucket will automatically discharge its contents. As the driver reverses the engine, the traveller with the empty skip runs down the beam under the control of the brake at a speed of from 800 to 1,000 ft. per minute. On reaching the bottom stop over the vessel, the traveller automatically engages and releases the fall-block, the driver continuing to pay out rope until the skip has reached the bottom of the vessel. The cycle of operations with a $1\frac{1}{2}$-ton load occupies one minute.

Temperley Transporter at the West Middlesex Waterworks.—The West Middlesex Waterworks, Hammersmith, have also a modern installation of this type for unloading coal. It is illustrated in Fig. **616**, and consists of a fixed transporter for loads of 30 cwt., lifting at the rate of 150 ft. per minute, and transporting along the beam at a speed of 800 ft. per minute, the total length of the beam being 328 ft. The travelling transporter is for the same load and speed, and the total length of the beam is 100 ft. The fixed transporter takes its loads from the barges and conveys them over a public footpath and two boiler houses, and delivers either to these boiler-houses or to the store yard beyond. The travelling transporter can command the whole length of the yard, and is also used for bringing the coal to the fixed transporter which conveys it to the boiler-houses.

Temperley Transporter at West Ham Electric Station.—Fig. 617 shows a similar installation. It conveys the coal from the canal to the bunkers over the boilers. The length of this conveyor, which has a capacity of 2 tons, is 298 ft. The height of the lift is 45 ft., and the length of beam 315 ft.

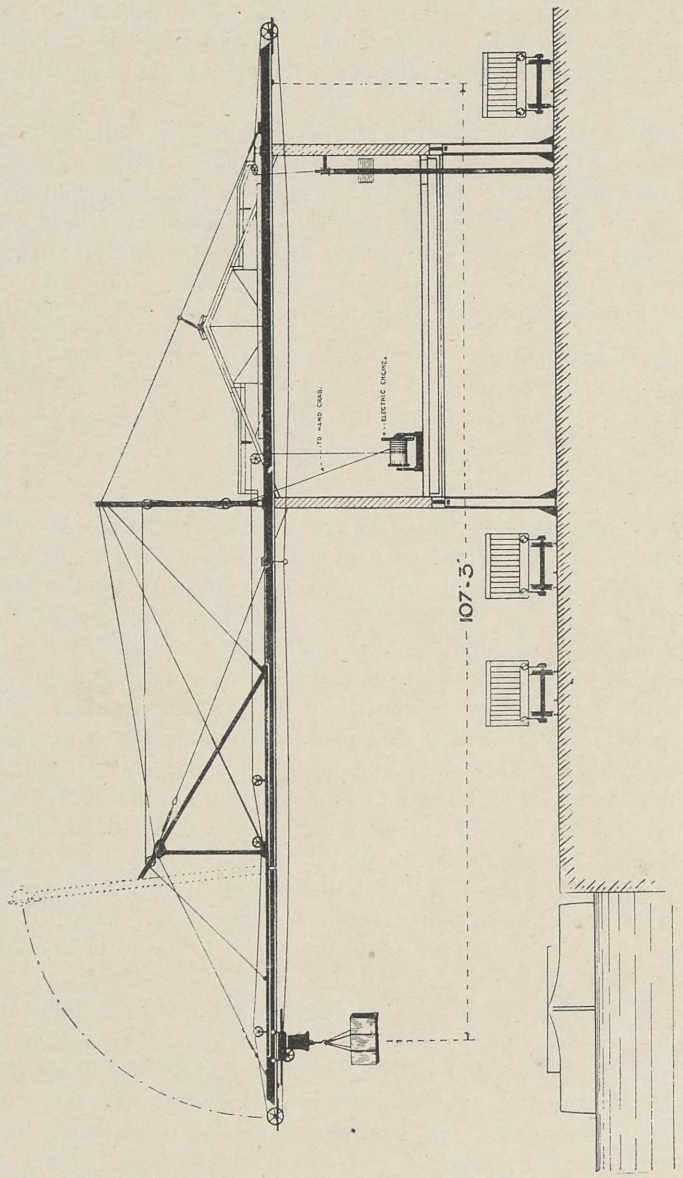


Fig. 618. Cross Section of Stores at the Royal Arsenal, Woolwich, showing Transporter for the Storing and Shipping of War Material.

Temperley Transporter at Woolwich Arsenal. — An illustration of this interesting installation is given in Figs. 618 and 619, the latter being a photographic view. One of the transporters is shown with its jib end extended in working position, whilst the other is shown with its jib end moved out of the way.

These transporters command a range of travel of 170 ft. and are for loads of $1\frac{1}{2}$ tons. They are used for shipping military stores at the Royal Arsenal.

Temperley Patent Grab Transporters.—The more general advantages of a Temperley transporter are accentuated when the hoisting and transporting of material in bulk is effected by means of high speed grab machinery. These transporters are accordingly fitted with hoisting and transporting machinery, by means of which the operations of hoisting and lowering and that of transporting may be carried on separately or together without either operation in any way influencing or interfering with the other.

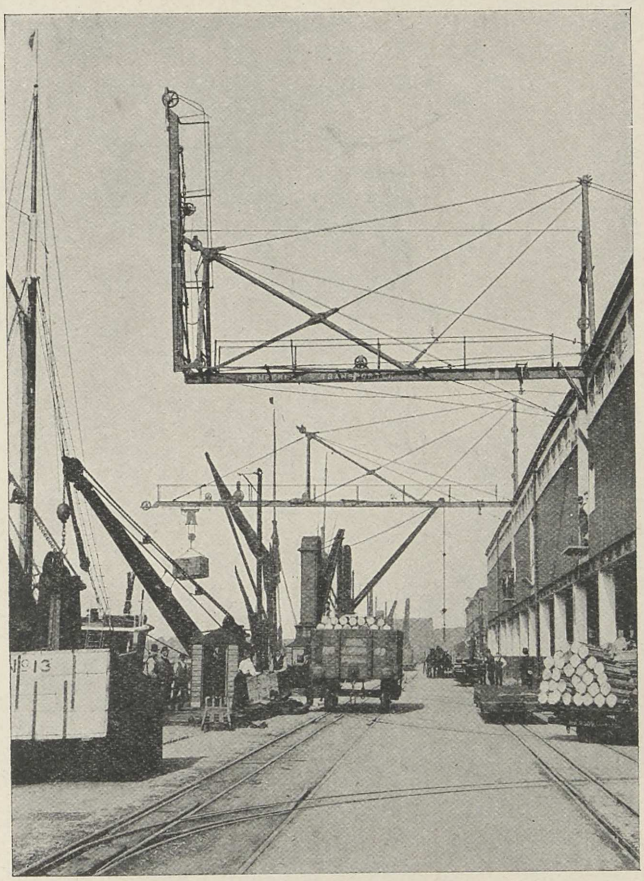


Fig. 619. Temperley Fixed Transporters for Storing and Shipping Military Stores at the Royal Arsenal, Woolwich.

The load may thus be carried along the shortest trajectory from the point where it is picked up to that where it is delivered.

The same machinery also gives complete command over opening and closing of the grab, these operations being effected either quickly or slowly in any desired position at the will of the operator. The grab may thus be lowered close down to the stock heap, and the material deposited with little breakage or dust. The hoisting or lowering and the transporting may be conducted at varying speeds, and the grab may be transported either open or closed.

Fig. **620** represents two electric travelling and slewing bridge transporters, built to

the order of the Buenos Ayres Great Southern Railway for handling coal by means of automatic grabs at the freight terminus at Buenos Ayres.

All the operations of the transporter are controlled by one driver from a platform on the tower, so situated as to command a good view of the work.

An electrically driven travelling hopper weighing machine travels along the bridge girder over the coal bunkers.

The Temperley Portable Transporter.—This is a self-contained apparatus similar to that already described, but intended chiefly to be used on vessels and operated by the ship's winch. It consists of an automatic traveller of either the single purchase or the double purchase type; the usual beam on which the traveller runs, suspended

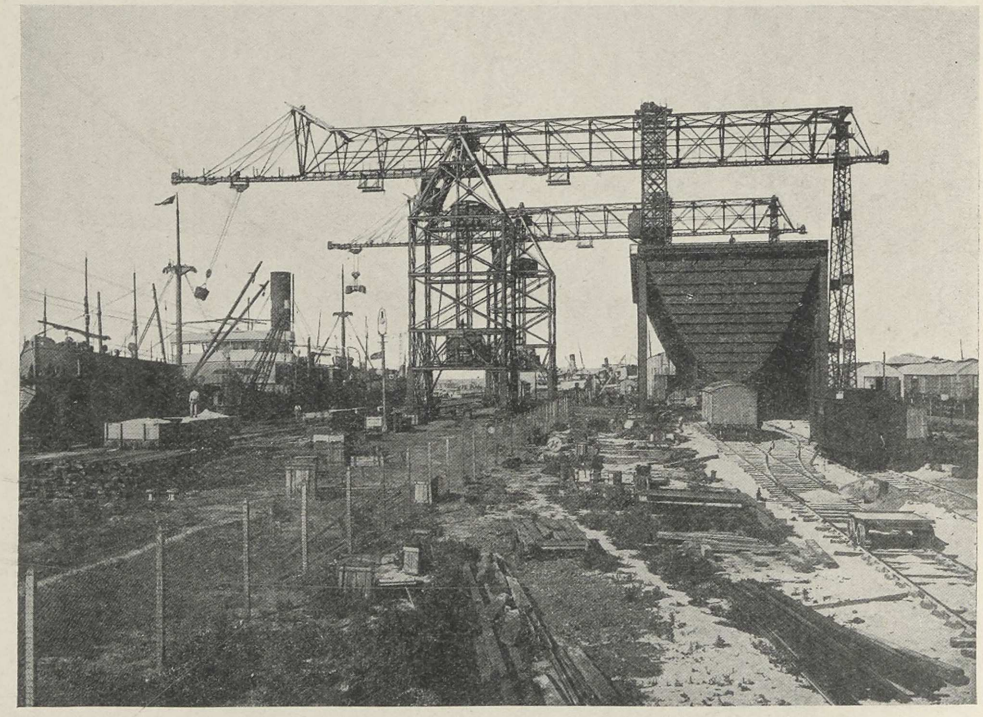


Fig. 620. Two Temperley Electric Travelling and Slewing Transporters.

from any convenient support, such as the ship's derrick or a span between the masts, and held in an inclined position of 1 in 3 by guys; and a lifting rope which is led to the ship's own winch for lifting, transporting, and lowering the load. For use on vessels the transporters are made from 30 to 65 ft. long, in multiples of 5 ft., and for loads up to 30 cwt.

Transporters of the M'Myler Co.—Transporters similar to those previously described have been built by the M'Myler Co., of Cleveland and London, the difference being too slight to warrant a further description.

Fig. **621** shows a small installation erected by this firm for the purpose of conveying the material from the ship to the railway truck. It is of interest chiefly on account of the unusual way in which the jib end of the transporter is disposed of when the latter is out of use. These ends are, as a rule, raised up out of the way, but in this case the

end is lowered beneath the main structure into the position shown in dotted lines. This is accomplished by means of rope *d*. The rollers *a*, which are at the extremity of the jib end, move in the groove formed by two channel irons, which are bolted to the structure, the rope *b* remaining unaltered. This rope is guided in a similar manner to that shown in Fig. **609**, but as this transporter works in conjunction with a two-rope grab, an additional rope is employed for the opening of the grab. Such installations are successfully at work on the Providence river, Indiana, U.S.A.

Transporters Erected for Messrs Jones & Adams, West Superior, U.S.A.—This installation is illustrated in Figs. **622** and **623**, which give plan and elevation of the crane; it consists of three Brown bridge tramway cranes, operated by electric power. The three transporters are shown running side by side on the same lines of rails, and are used for unloading coal from vessels and conveying it to stock piles or into railway trucks. At a recent test it was found that the capacity of three of these transporters was about 2,500 tons of coal in ten hours. The average capacity is, however, 60 tons per transporter per hour, or one trip per minute.

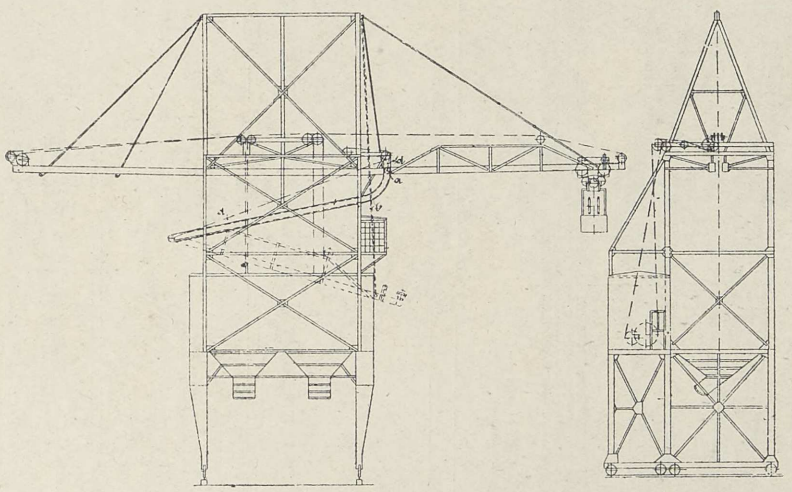


Fig. 621. Transporter of the M'Myler Co.

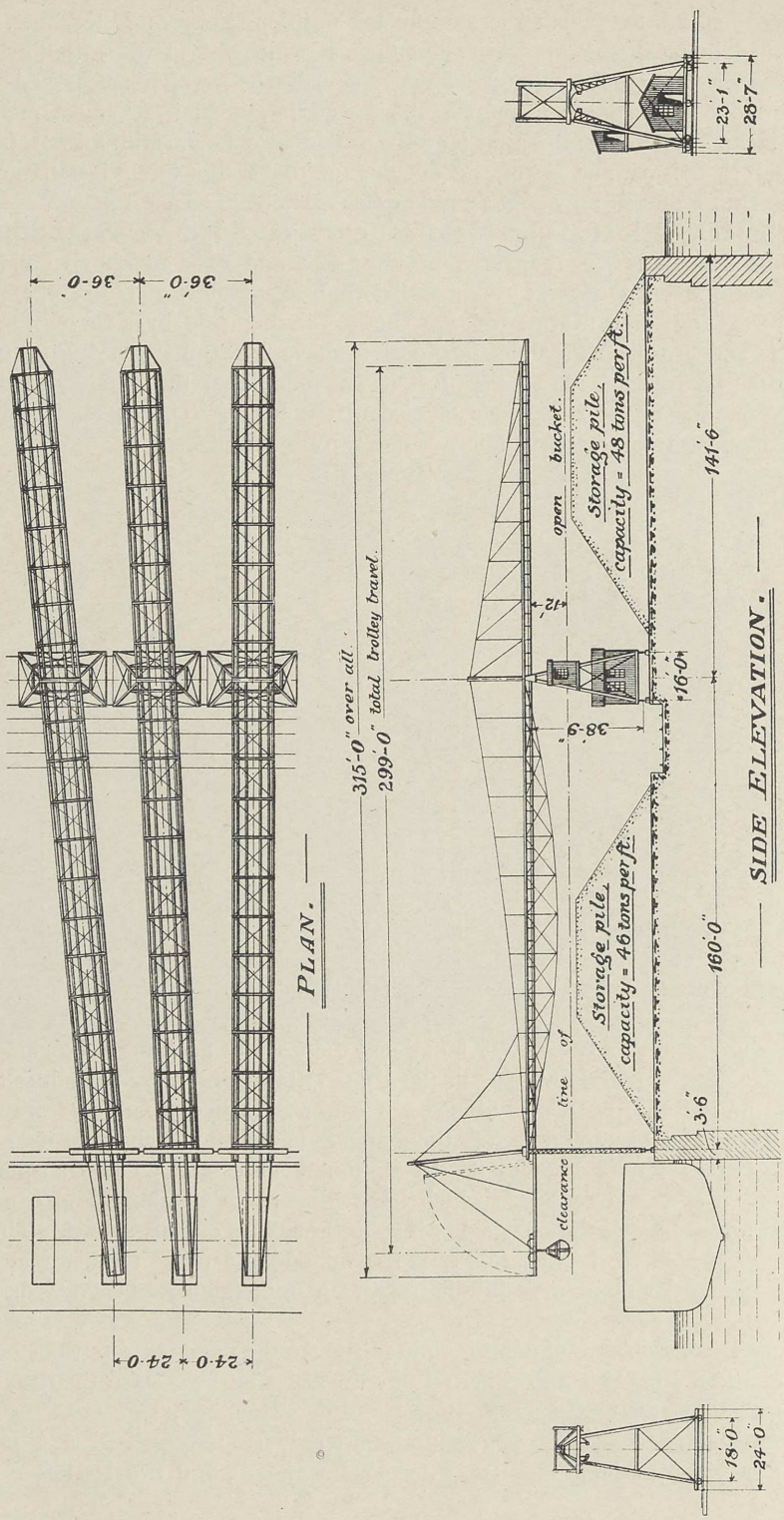
The grab used was of a capacity of 1 ton, and the test was made with Hocking coal, which is one of the most lumpy coals in the United States, and more resembles Scotch coal. When the test was made, every bucket of coal was carried from the front of the quay to a distance of about 150 ft. before the grab was allowed to discharge.

The illustration renders a minute description unnecessary. The transporter is manipulated from a machinery house which has a driver's cabin above, and can move backward and forward along the quay side over the three lines of rails shown. The grab is lowered into the hold, and when full, raised again, and the coal or other material is brought over the stock pile or over railway trucks, where the grab is opened to discharge its load.

The same installation can, of course, be used to take the material from the stock pile with the grab, and discharge it into either railway trucks, or into vessels at the quay side.

This installation was erected by the Brown Hoisting Machinery Co.

Bleichert's Transporters.—The transporter illustrated in Fig. **624** consists essentially of a bridge girder B with two extensions A and A^1, and two trestles P and S



Figs 622 and 623. Plan and Elevation of Transporters Erected for Messrs Jones & Adams, West Superior, U.S.A.

both mounted on wheels. The bridge or gantry is designed for the sole purpose of supporting the running head with its load. The main support S, which also encloses the motor-house, rests on two lines of rails. The trestle P on the quay side is very light in comparison with the main support, and is so coupled to the gantry that it gives sufficiently to make allowance for any expansion or contraction of the bridge through a change of temperature. The extension A is so hinged that it can be moved out of the way of the ship's tackle, as shown by dotted lines. It can be raised by the small winch W, and lowered by its own weight and by the use of a brake. The skip, which runs the whole length of the gantry, can be unloaded either into a stock heap or into railway trucks, as may be seen from the illustration. Two independent ropes are used for the manipulation of the transporter, the one for lifting and the other for conveying. The action is as follows :—

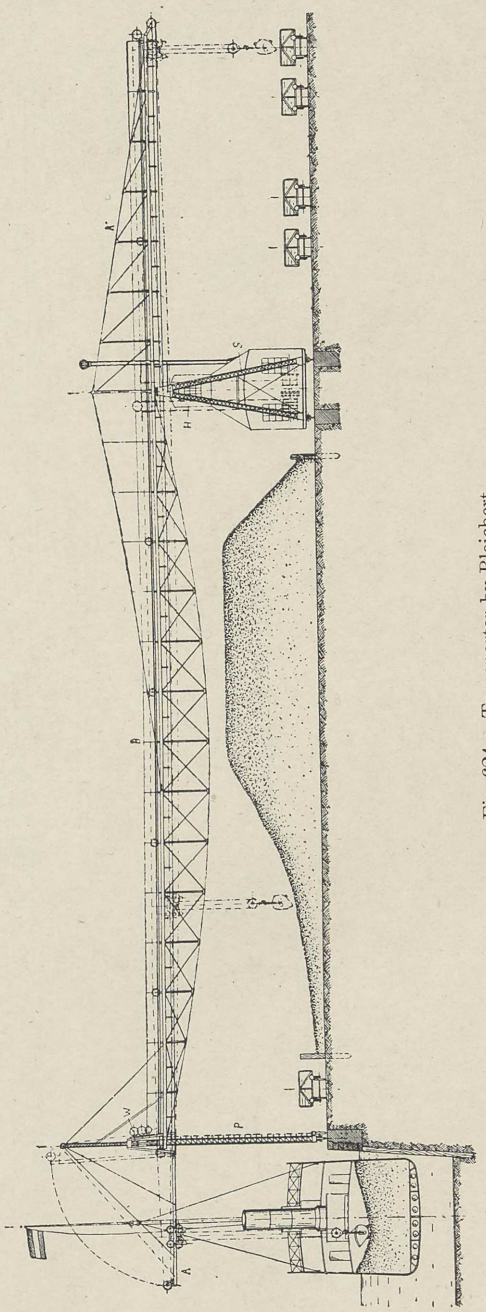


Fig. 624. Transporter by Bleichert.

The skip, after being filled in the ship's hold, is raised to its fullest extent, so that the fall-block engages with the traveller, whereupon the lifting rope has no further load to carry. The conveying rope is then brought into action, and the traveller with its load is brought to the discharging point and there tipped. As the plant is mounted on wheels it can be moved forward or backward to discharge the ship without altering its position. The operator's cabin, marked H in the illustration, is so placed as to give a good view of the unloading operations.

The time occupied by one skip in travelling from and returning to the ship is about one minute. The contents of the skip weigh $1\frac{1}{2}$ tons. In order to avoid any loss of time several skips are always in use. The average capacity is 500 tons in ten hours. This, of course, depends very much on the number of trimmers who fill the skips, and the nature of the material to be unloaded. It would be increased if a grab were used instead of the ordinary skip.

Fig. **625** also illustrates a transporter designed by Bleichert, which is similar to the one already described, but is much shorter, being only used for unloading ships into

railway trucks. The bridge or gantry A A is supported by two uprights P at a sufficient distance apart to allow room for two lines of rails. The steam engine and boiler are

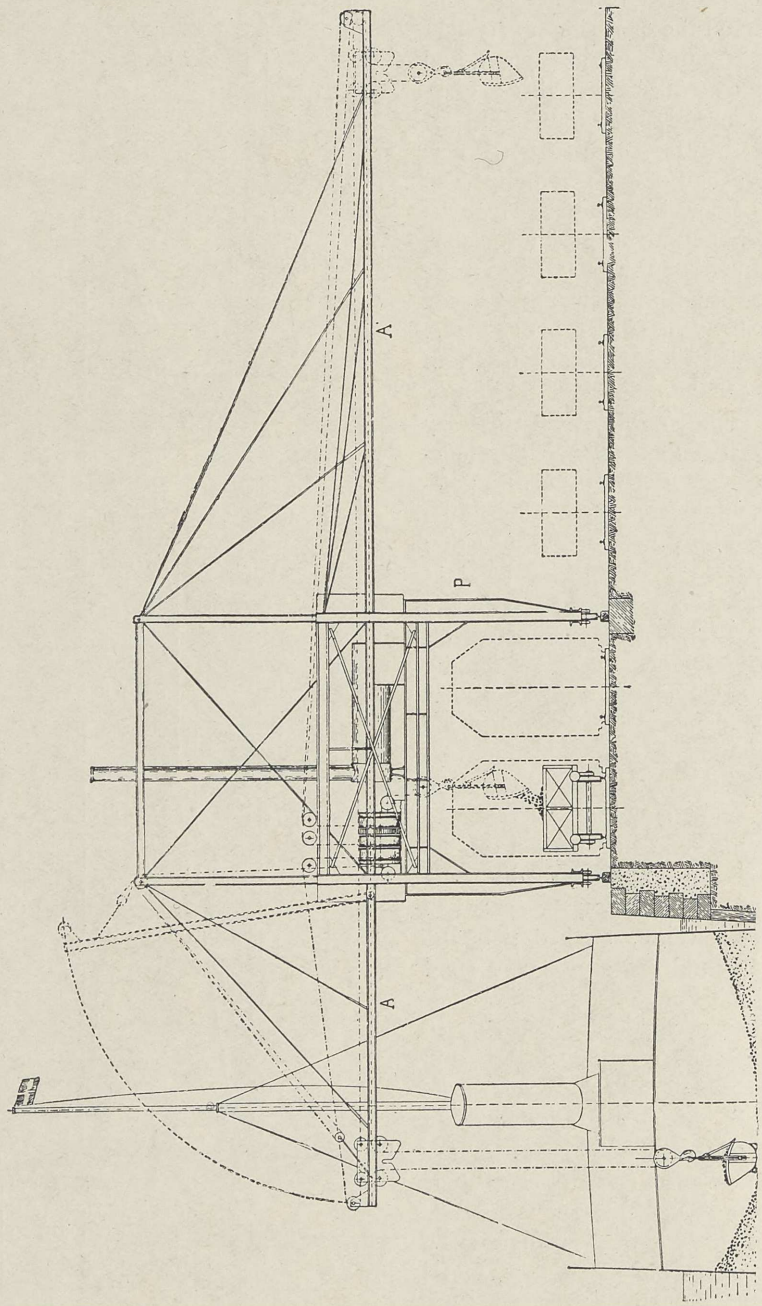


Fig. 625. Transporter by Bleichert.

shown in the illustration, and their weight gives additional stability to the structure. The jib end of the bridge can be raised in a similar manner to that of the one previously described, and the action of the machine is very similar. The capacity of any of these

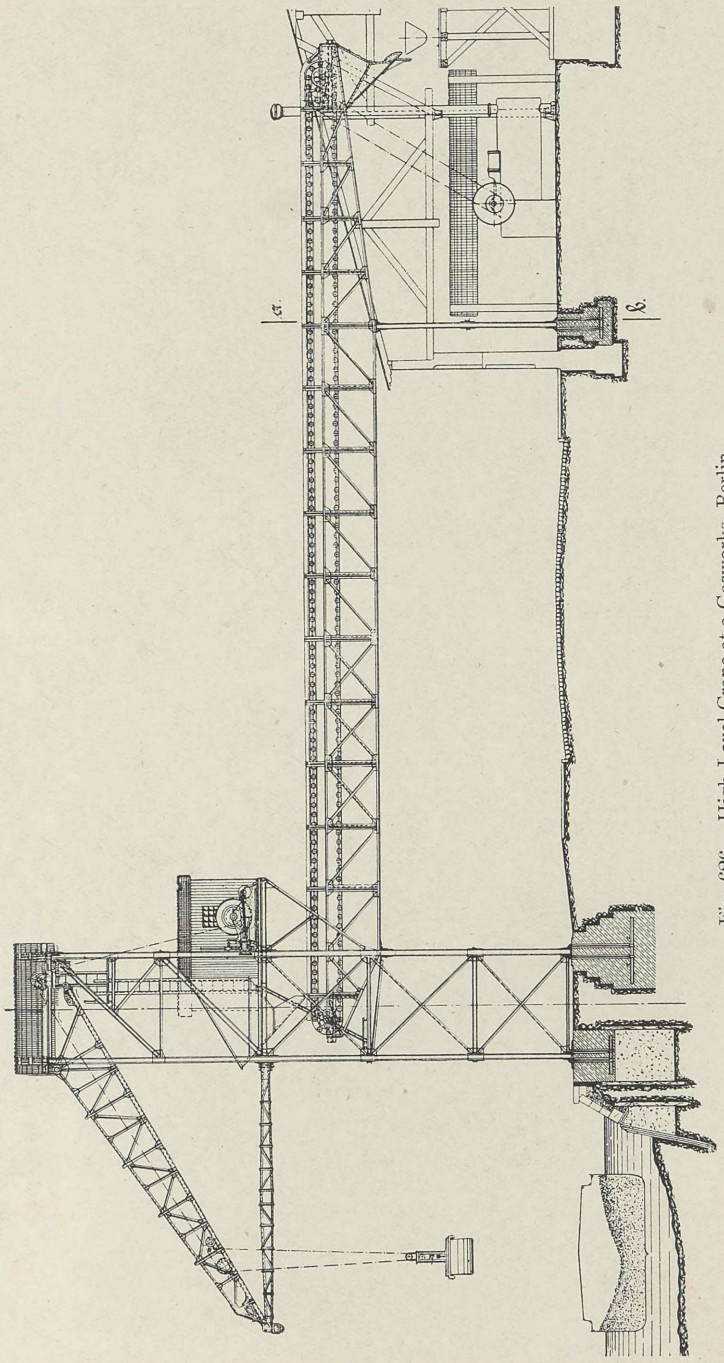


Fig. 626. High-Level Crane at a Gasworks, Berlin.

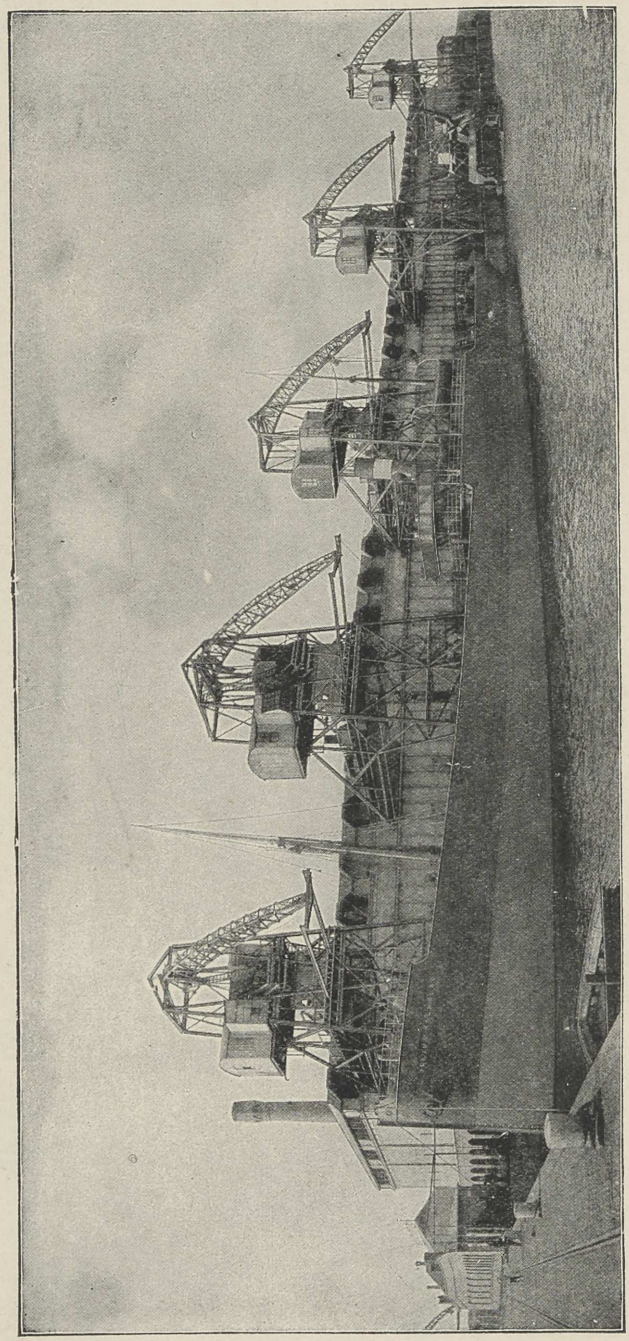


Fig. 627. Coal-Unloading Plant of the Danish Coal Co., Copenhagen.

transporters can be doubled by having two sets of rails for two travellers on the same gantry.

Transporter Erected at a Berlin Gasworks.—A transporter in conjunction with a steel band conveyor is illustrated in Fig. 626.

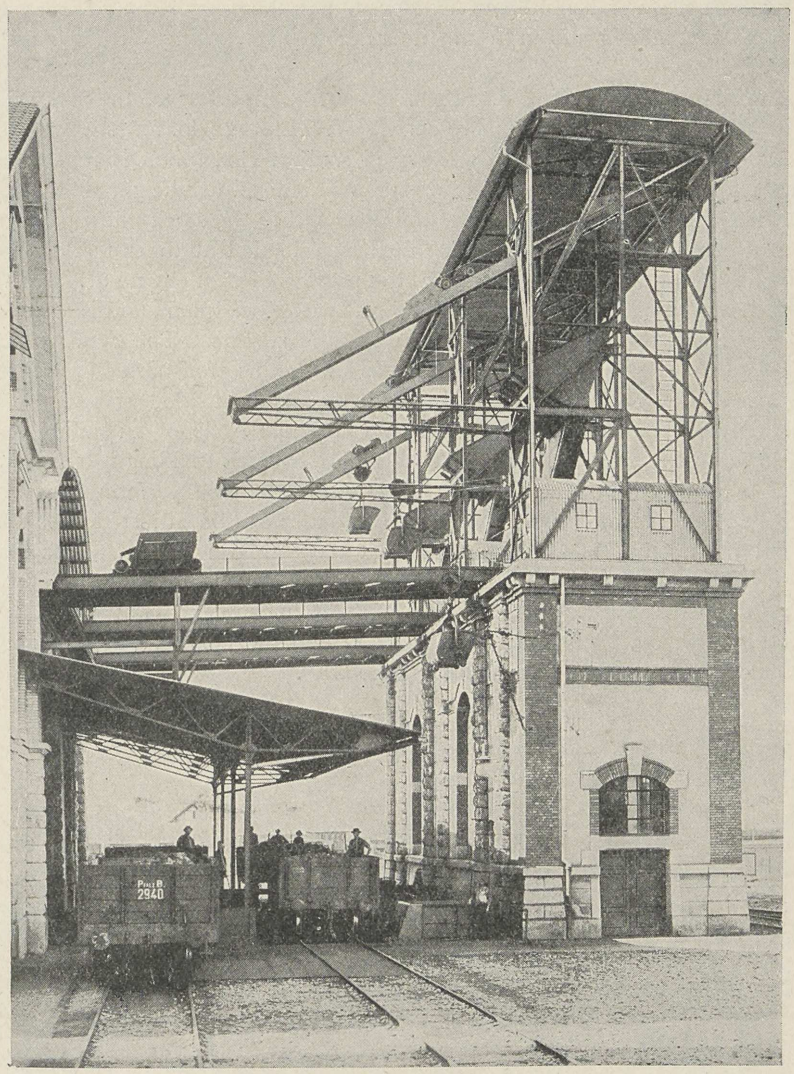


Fig. 628. Coal-Unloading Plant in connection with Hunt's Automatic Railway at the Zürich Gasworks.

This plant was built by Pohlig, and consists of the ordinary type of "Hunt" transporter in conjunction with a grab. The coal, after being unloaded from the barge, is deposited into a hopper, from which it is admitted to the steel band conveyor, which takes it to the gasworks.

Transporters at the Coal Store of the Danish Coal Co., Copenhagen.—

Fig. 627 shows an installation for the Danish Coal Co.'s store at Copenhagen, in which may be seen five transporters of this type which unload the coal into a store.

Transporters at the Zürich Gasworks.—Fig. 628 shows a similar installation erected by the same firm, in which three transporters are working side by side. This is the coal-receiving installation for the gasworks, Zürich, Switzerland. After the coal has been received by these transporters, it is deposited in the cars of the "Hunt" automatic railway. One of these is shown in the illustration just starting on its journey to the coal store.

Transporter of the C. W. Hunt Co.—A transporter of the most recent and improved type is that designed by Messrs C. W. Hunt & Co. for the Lincoln Wharf Power Station of the Boston (U.S.A.) Elevated Railway Co., which is remarkable for its enormous capacity. Bituminous coal is unloaded and raised to a height of 90 ft. above the water level from the hatch of the vessel, and delivered to the stock pile or into overhead bunkers above mechanical stokers. The coal is unloaded at the rate of 320 tons per hour by one transporter. The driving power is provided by an engine of 300 H.P. which also drives the coal-breaking machinery that forms part of the plant, and is for the purpose of breaking the coal into suitable sizes for automatic stokers. The capacity of the coal-breaker is 5 tons per minute. The grab in use with this transporter has a capacity of 2 tons with each lift, and the time occupied in raising the loaded grab to the overhead hopper is only six seconds. It is said that the whole cycle of unloading operations, including lowering the grab, running it out on the jib, opening it, filling it by its own action with 2 tons of coal, raising it again and discharging it, can be performed in twenty-two seconds. The crane is mounted on wheels, so that it can be adjusted to the hatchway. The jib end of the crane is 40 ft. long, so that the grab can be run out to a sufficient length to take the coal from the hold of the largest ships.

See also Hoover & Mason's Ore-Handling Plant, in chapter "Handling Raw Material in connection with Blast Furnaces" (page 353); and the chapter "Storing of Coal and other Minerals in Stock Heaps and Silos" (page 650).

CHAPTER XXXII

UNLOADING VESSELS BY MEANS OF BARGE OR SHIP ELEVATORS AND MARINE LEGS

BARGE ELEVATORS

THESE are essentially elevators as fully described in Chapter II., page 10. They vary from those principally in the form of the elevator well, which is frequently not entirely enclosed but only made of skeleton work, so that the material to be handled can enter freely. The driving arrangements at the upper terminal necessarily differ from those of an ordinary stationary elevator, as the position of the terminal in relation to the driving shaft is constantly varied as the quantity of material in the barge is lessened. With regard to the suspension of the apparatus from the supporting structure, this must be effected in such a way as not to burden the top pulley spindle with the weight of the elevator.

The simplest form of support is that which allows of merely an up-and-down motion. Such an installation would, however, only be suitable for very narrow canal barges, as through inability to rack the appliance from side to side of the barge a great deal of cargo trimming would be necessary. The more usual method of support is to suspend the elevator from a jib-like steel structure in such a way as to allow it a pendulum-like or racking motion so that it can be made to reach from side to side of the barge. Either of the above methods is suitable for barges in non-tidal rivers and canals. For tidal rivers where the barges are frequently compelled to take the ground at low tide, so that they become stranded and therefore a fixture, barge elevators are frequently fitted for such purposes to the end of a jib-like steel structure which allows of their slewing sideways and being luffed. In the former case applying to canals and non tidal rivers the barges are so moored that the elevator descends into the hold at one end, and the mooring is changed as the cargo is removed. With the latter type, which allows of a slewing action, a greater reach is obtained to make up for the inability to move the barge when stranded.

Barge elevators are generally used in connection with flour mills, breweries, and oil mills, as well as at small gasworks for handling material of small and uniform size. Grain and seeds, such as cotton or linseed, as well as small nuts and other small material, can readily be cleared out of a ship's hold by lowering the elevator into the bulk of the material to be conveyed, when it will feed itself. All that is required on the part of the driver is to keep lowering the elevator as the vessel is cleared.

For larger material barge elevators are subject to the same limitations as ordinary bucket elevators in regard to handling material containing larger fragments. Barge elevators may either be supported from the factory building itself, from the end of a steel gantry, or may be arranged portably on wheels to run along the quay wall; this latter method also overcomes the difficulties mentioned above for unloading stranded barges.

For large capacities, say 40 tons per hour and over, pneumatic grain elevators are coming into more general use, owing to the great advantage of saving trimming expenses

although on the other hand the driving power consumed is considerably greater than that for bucket elevators.

The following examples are grouped under three heads: **Stationary**, **Portable**, and **Floating Barge Elevators**, these latter being sometimes called Marine Legs.

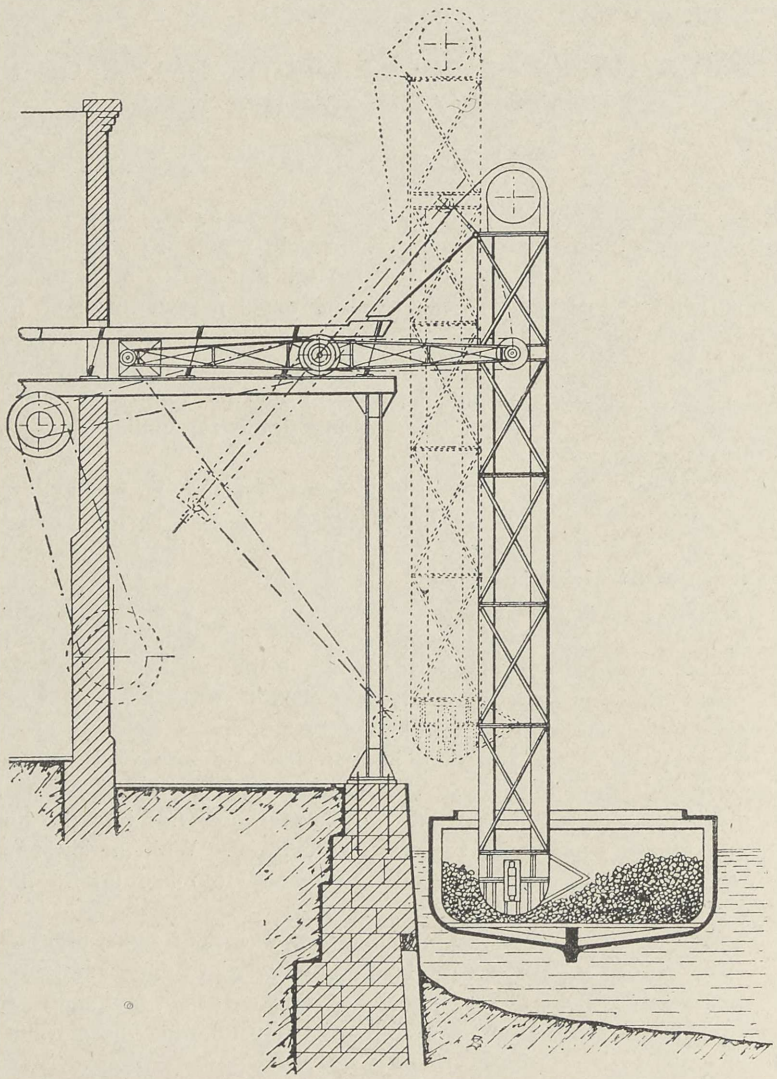


Fig. 629. Barge Elevator for Unloading.

STATIONARY BARGE ELEVATORS

Spencer's Barge Elevators.—These are of the types already outlined, and are so well known that they do not need any illustration. A typical installation is that erected at the wharf of Messrs J. Dudin & Sons, London, where three such elevators are at work. They are made with steel casings and have each a capacity of 30 tons per hour. Each elevator is supported on the jib by means of spring hinges, which are sufficiently

flexible to prevent any damage to the elevators from any side movement which might be caused by the traffic in the river during their use. They were built by Spencer & Co., Ltd., of Melksham.

Barge Elevator for Coal.—This was erected by Messrs Graham & Morton for the Tonbridge Gasworks, and is illustrated in Fig. 629. The full lines show it in working position, whilst the dotted lines show it at rest, and placed out of the way of the canal traffic. The elevator is lowered into one end of the barge to be emptied, and the coal is trimmed into the elevator well by shovels, and as the barge is emptied its

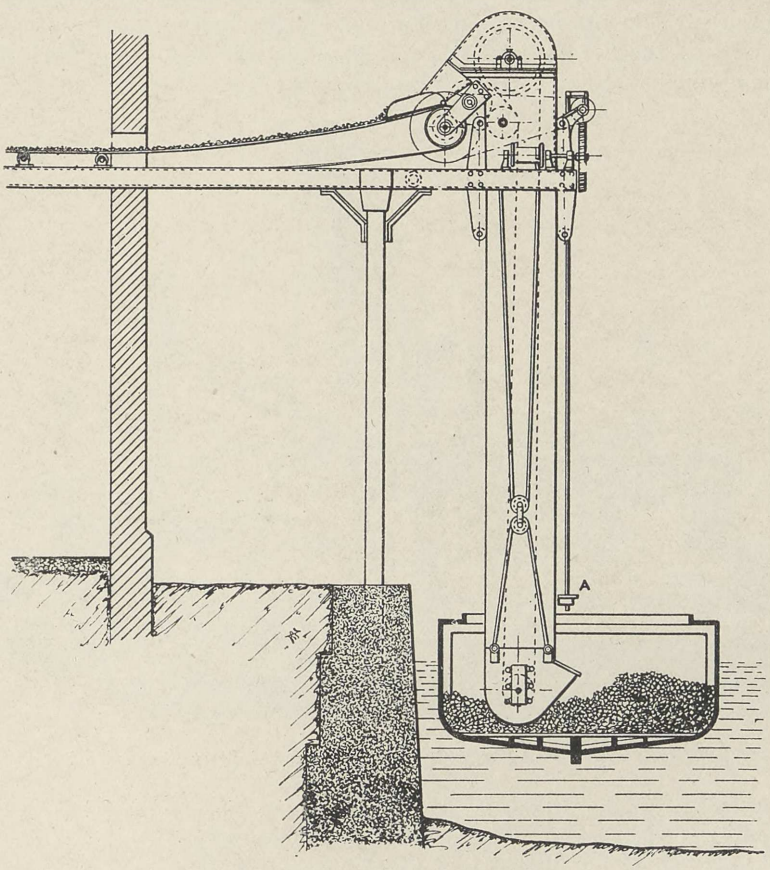


Fig. 630. Further Type of Barge Elevator.

position is altered, as described. The elevator at the top terminal delivers its load by means of a hinged shoot into a Zimmer conveyor, which distributes the coal over the store by a number of outlets. The elevator is suspended at a point 6 ft. below the top spindle on a steel beam 16 ft. long, which has a balance weight at the other end to equalise its weight.

This mode of fixing has the advantage that the elevator can be moved round its support and swung into any position across the width of the barge. The winch on the supporting column controls the raising and lowering of the elevator.

A barge elevator for grain, small coal, etc., would be arranged just as that shown in the illustration, with the exception that the elevator bottom has no inlet spout, but is

of open construction, to admit the grain to the elevator well to be received by the buckets.

Fig. **630** is a similar design of a barge elevator feeding a band conveyor. The elevator itself is driven from the conveyor, the latter receiving its motive power at the opposite end. It is suspended by two steel ropes; one end of each can be wound upon one of two drums, on either side of the elevator casing. The hand wheel A controls the gear for lowering and raising. This is effected by means of power obtained from the band terminal. Each drum is fitted with a worm and worm wheel. The elevator must always be in a perpendicular position, and is there maintained by four small guide rollers which prevent any side movement, but allow of an up-and-down motion.

As the rise of the elevator is only a few feet, owing to the barges being shallow and there being no tidal variation in the river, the gearing of the band to the elevator is in

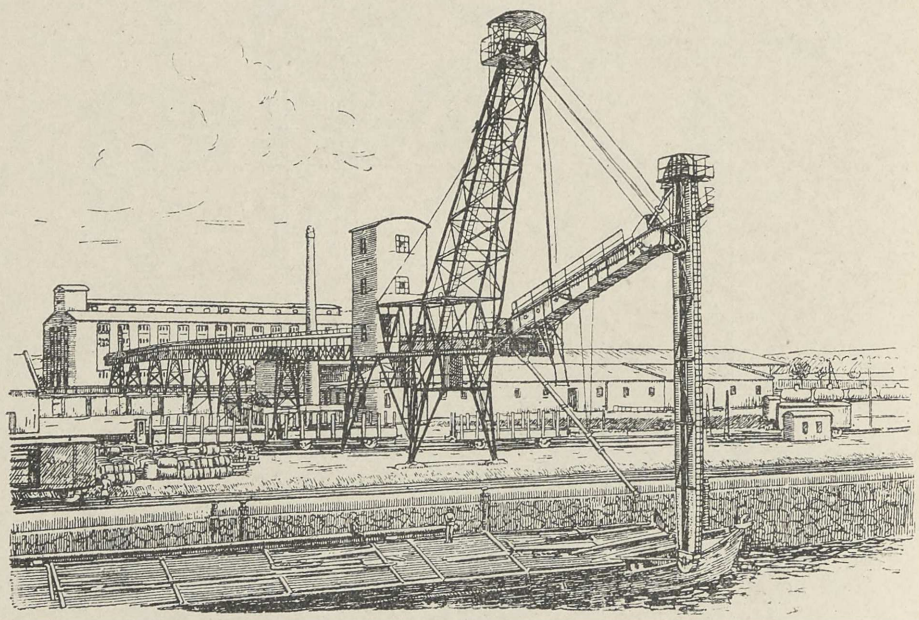


Fig. 631. Perspective View of Barge Elevator and Granary at Dresden-Reisa.

no way detrimental to the arrangement, for even if the elevator and band are at their highest points the efficiency of the latter is not in any way impaired.

The whole of this installation is equally suitable for unloading grain, etc., with the slight modification at the elevator well already mentioned.

Barge Elevator for Grain in Connection with Granary at Dresden-Riesa, on the River Elbe.—This installation is unique, and varies from those previously described in possessing two unusual features. The first is inability to erect the receiving terminal close to the quay wall, owing to the portable cranes of the Harbour Authorities having to travel in front of it; the second is the great distance the grain has to be conveyed to reach the warehouse, there being no site available nearer the harbour. As a matter of fact the distance the band conveyor has to deliver from the edge of the quay wall to the granary is 812 ft., and the raised gantry which encloses the band traverses fifteen lines of rails and three roads.

A good general idea of the installation is given by Fig. **631**, which shows the

suspended barge elevator with the jib containing the first band conveyor. It also shows the small structure in which the grain is freed from dust, and the iron gantry in the distance leading to the granary. Fig. **632** represents a view of the receiving end at the river side which overhangs the two lines of rails along the quay wall. The barge elevator is driven by a 15 H.P. electro-motor mounted on the top of the elevator itself, which also drives the band conveyor in the jib.

The foundations for the terminal at the river side are 36 ft. deep owing to the poor condition of the ground, the very heavy load, and the length of the jib, which latter is sufficiently long to reach over one into the middle of a second ship to unload it. The main band conveyor which communicates between the small structure on the gantry—already mentioned—and the granary, is led over four drums at the river side terminal to keep the two strands of the conveyor sufficiently far apart to get a clear delivery for the grain from

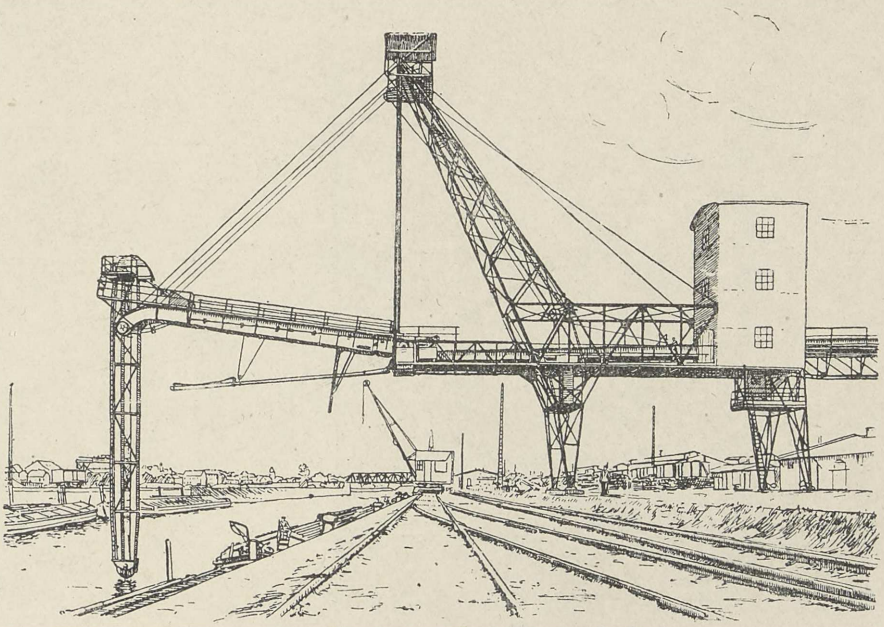


Fig. 632. Side View of Barge Elevator for Grain.

the lower strand of the band, as both strands are used for conveying to or from the warehouse; the other terminal in the granary is led over three fixed drums and one loose one for tightening; this terminal with its driving motor is shown in Fig. **633**.

There is also a third band conveyor working with both the upper and lower strands which connects the main band with that in the jib, and which also takes the grain from the main band *via* an elevator in the small structure to a long loading shoot which delivers the grain into barges. The capacity of the installation, which was built by the Seck Engineering Co., of Dresden,[1] is from 50 to 60 tons of grain per hour.

Banana Unloader.—An elevator on similar lines to the Mitchell Cantilever Grain Elevator (described later) is shown in Fig. **634**. It is adapted for travelling along a quay, and unloading bulk goods such as bananas, carcasses, etc. At the lowest position

[1] From an article by W. Spielvogel in the *Zeitschrift des Vereins deutscher Ingenieure* of 20th September 1913.

of the delivery terminal the bananas are dropped on to a band conveyor. This illustration particularly shows the extraordinary adaptability of the two levers in reaching from an extreme height to an extreme depth. The dotted lines show the apparatus in the housed position, and the two smaller views indicate the two extreme working positions.

Banana Carriers for Loading and Unloading Vessels.—The carrier shown (Figs. 635 and 636) was installed for the United Fruit Co. in 1903, at the I. C. Ry. Co.'s Wharf, Mobile, Ala., under the patent rights of Messrs Edleston & Harris, by the Link Belt Co.

The machinery consists of a canvas apron, attached to cross-bars between two chains in such a manner as to form pockets into which the bunches of bananas are placed, as shown. These pockets automatically adjust themselves to the direction of travel, and handle fruit without bruising or breaking the bunches. It is adjustable to depth of hold and height of tide.

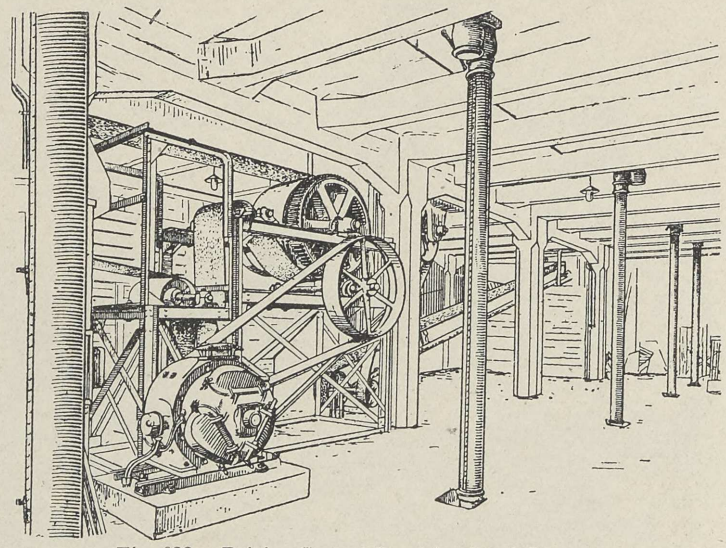


Fig. 633. Driving Gear of Receiving Band Conveyor.

A similar apparatus is in use at New Orleans. It consists of an endless belt carrying canvas pockets, and is so arranged that one end may be introduced into the hold of the steamer through the hatchways, and the other situated contiguous to the railway trucks. The band is kept in a continuous slow motion by an electric motor. The bunches of bananas are taken from the ship's hold, laid in the moving canvas pockets, and then elevated and conveyed to a point opposite the door of the railway truck, where they are removed and hung or piled in the truck for shipment.

Before the introduction of these labour-saving appliances, the bunches of bananas were carried from the ship by labourers, a large number of whom were employed for this purpose. In raising the bunches on to their shoulders, and in carrying them along a rather uneven way from the ship to the wharf and thence into the truck, a good deal of the fruit was damaged, and the bunches themselves were frequently jammed and disfigured. The present method, in addition to assuring the transfer of the fruit from the ship to the cars in thoroughly good order, results in the saving of a notable amount of time and labour.

PORTABLE BARGE ELEVATORS

These are very similar to the elevators attached to factory buildings and gantries for the purpose of clearing grain, coal, and similar materials from ships' holds. As has previously been explained, they can be used for coal only when it is of a fairly uniform size.

Barge Elevator for Grain.—A typical example of a movable barge elevator

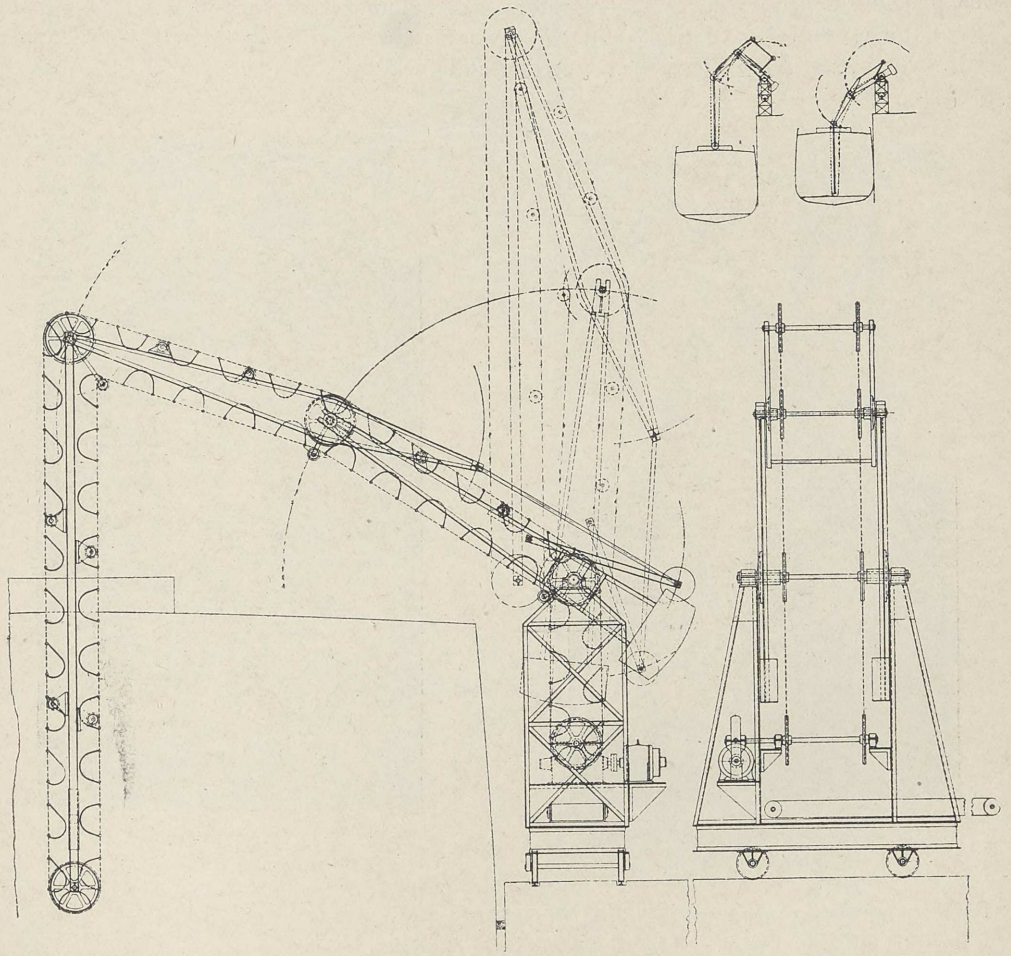


Fig. 634. Banana Unloader.

is that at work at the Eagle Oil Mills of Messrs J. Rank, Ltd., Hull, and which was built by Messrs Spencer & Co., Ltd., Melksham. It is driven by electricity, it is self-propelling, and is capable of raising 60 tons of seed per hour. The whole of the machinery for operating the elevator is erected in a corrugated iron cabin, which is movable with the elevator on the track. Travelling gear is provided in order to minimise the necessity of trimming as much as possible, as at low tide these barges lie on the mud, so that it would not be possible to move them for unloading purposes. The elevator delivers in any position of its travel through a telescopic shoot on to a

band conveyor, carried on a gantry, which afterwards discharges through a suitable spout into the mill.

The electric current is conducted along the face of the warehouse wall, which is fitted with a number of wall plugs, from any of which a connection can be made by flexible cable to the motor.

Barge Elevators of Unruh & Liebig.—The installation illustrated in Figs. **637** and **638** consists of two elevators mounted on a movable carriage with steam engine and boiler. One of the elevators is a fixture, whilst the other is suspended from the jib end of a derrick, and can thus be lowered into the hold. There is a conveyor between the delivery end of one and the feed end of the other elevator, so

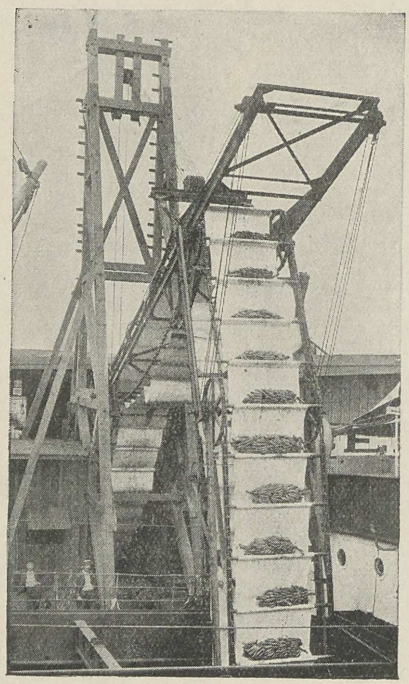


Fig. 635. Carrier receiving Bananas in Hold of Vessel.



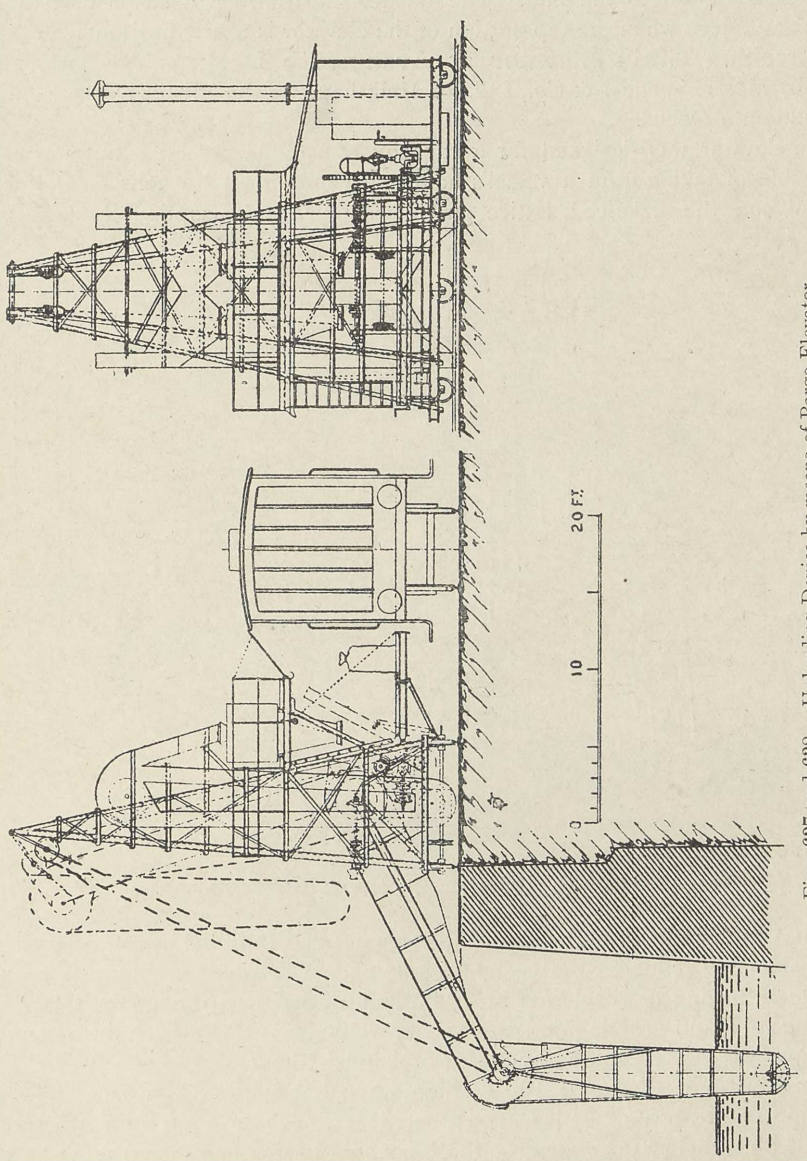
Fig. 636. Carrier depositing the Fruit on Deck.

that no matter in what position the movable elevator stands the material is conveyed from one to the other. The fixed elevator delivers into the hopper, so that the grain, etc., can be filled in sacks before it is loaded into the railway trucks. The illustration here given is a front elevation and side view of the design of Messrs Unruh & Liebig, Leipzig.

A similar installation by the same designers is shown in Fig. **639**. This is rather more compact, but is only suitable for quay sides where no attention need be paid to the varying tides. It is driven by an electro-motor, the cable which supplies the current being concealed in a leather tube so as to allow the truck the necessary latitude in its movements on the quay. The hopper which receives the grain is fitted with an automatic weighing machine.

Barge Elevator at a Copenhagen Flour Mill.—This installation, also erected

by Messrs Unruh & Liebig, has been at work since 1882, and is used either for conveying the grain direct to the silo warehouses of the mill, or for loading into railway trucks upon the quay. It is suitable for discharging grain from sea-going vessels. The capacity is about 60 to 80 tons per hour.



Figs. 637 and 638. Unloading Device by means of Barge Elevator.

The installation, which is illustrated in Fig. **640**, consists of a rectangular carriage mounted on suitable rails, to the end of which is attached a fixed derrick. The elevator itself is attached to the derrick, and can thence be lowered to any desired point.

The elevator can be lengthened or shortened by an ingenious arrangement, which may be seen from the illustration. The position in which it is shown is with the band

and buckets extended to their utmost limit. If it be desired to shorten it, the head gear of the elevator itself is pulled back so as to take up the surplus band and buckets, this backward movement of course altering the delivery point. In this device a number of suitable outlets A A are provided which lead to the band conveyor, and this in its turn takes the grain to the mill. The buckets are of such a shape that they do not spill the grain even when the top portion of the elevator is nearly horizontal.

Travelling Grain Elevator at Avonmouth Docks.—This installation was erected by Messrs Spencer & Co., Ltd., of Melksham, for the Bristol Docks Committee at the Avonmouth Docks.

The elevator was designed for a capacity of 75 tons per hour, but was proved on test capable of taking from a vessel's hold rather more than 100 tons of grain per hour. It is built on the balanced lattice girder principle, and has double elevator legs so

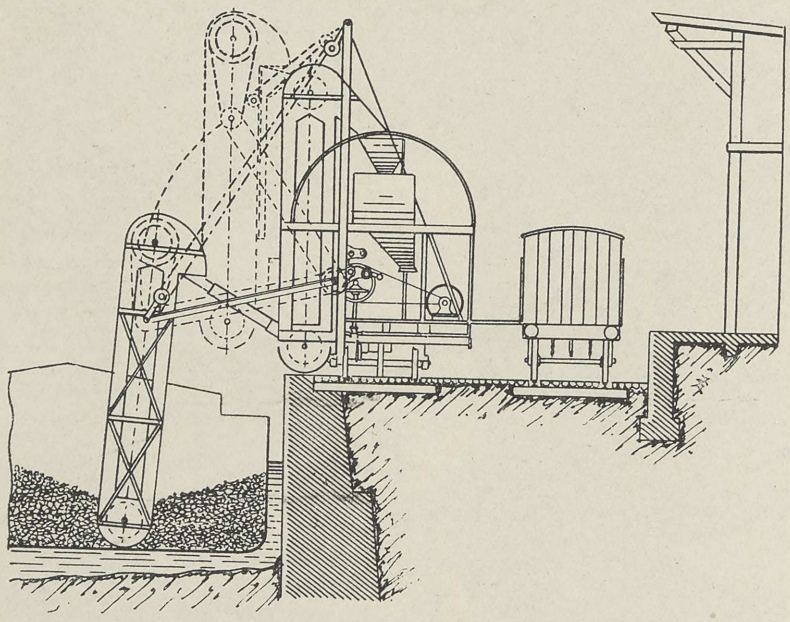


Fig. 639. Unloading Device with Barge Elevator.

arranged as to operate on both sides of the steamer's shaft-tunnel or cargo-parting boards, thus considerably reducing the cost of trimming. The whole structure is mounted on eight wheels, having a wheel base of 20 ft., and arranged to run on rails laid down at 12 ft. gauge. Hand gear is fitted to these travelling wheels in such a manner that the whole apparatus may be shifted by means of manual labour.

The elevator itself stands 100 ft. high when housed, and is capable of unloading vessels up to 55 ft. beam. It is so constructed as to lift the grain from any level within a range of 25 ft. below the coping of the quay, and to rise clear over the vessel's hatches when such are 22 ft. above the coping edge, thus having a total range of travel of no less than 47 ft. up and down.

The elevators are fitted with buckets 13 in. wide which are pitched 12 in. apart.

Fig. **641** shows the elevator in a housed position when not in use.

Fig. **642** shows it at work taking grain from a vessel's hold and delivering to the granary alongside. The total weight of the whole apparatus is between 90 and 100 tons,

and there are no less than 18 tons of balancing material used in the back end of the lattice girder.

This installation is driven by electro-motors, one motor being provided to drive the

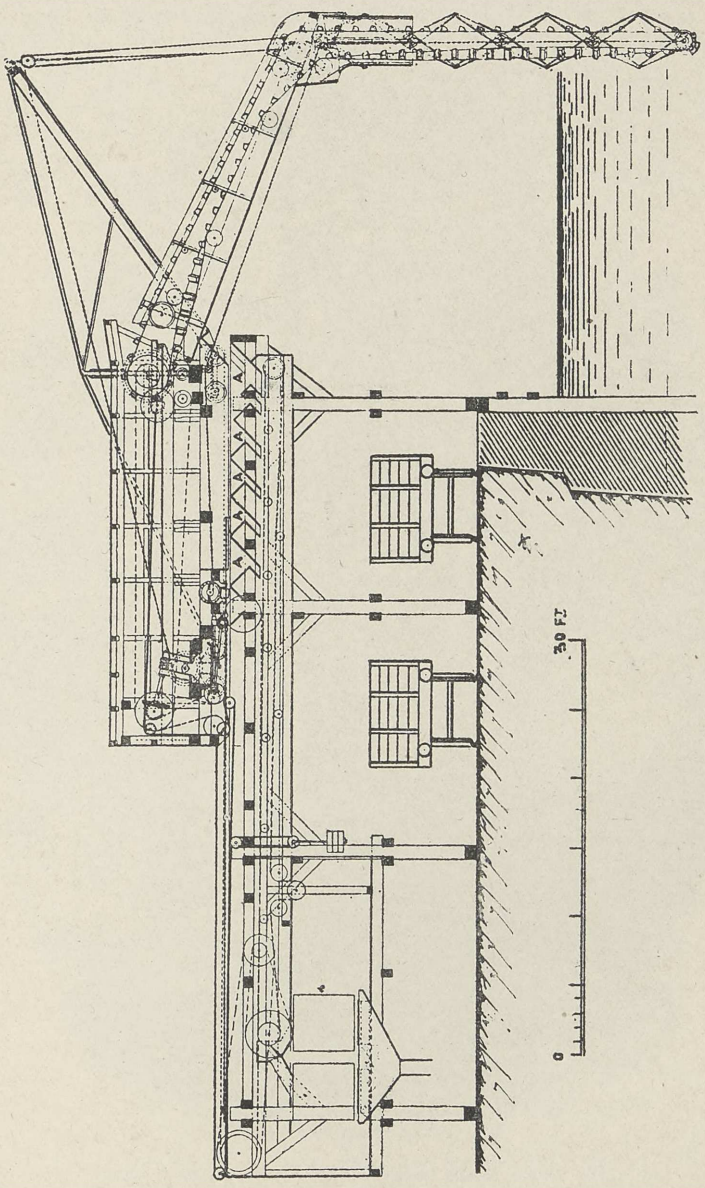


Fig. 640. Barge Elevator at Copenhagen.

elevator and the receiving band conveyor, which is connected therewith, also the controlling hoist. Another motor is provided for driving a set of power trimming gears used for trimming the grain to the elevator.

A band conveyor attached to the lattice girder conveys the grain from the elevator by telescopic shoots to the transit shed alongside. The trimming gear for feeding the

grain to the elevator in the vessel's hold consists of four large wooden grain trimming shovels or ploughs, driven by a suitable winch from an electro-motor.

The plant[1] proved so satisfactory that the Docks Committee ordered a similar but larger installation for their grain docks in Bristol.

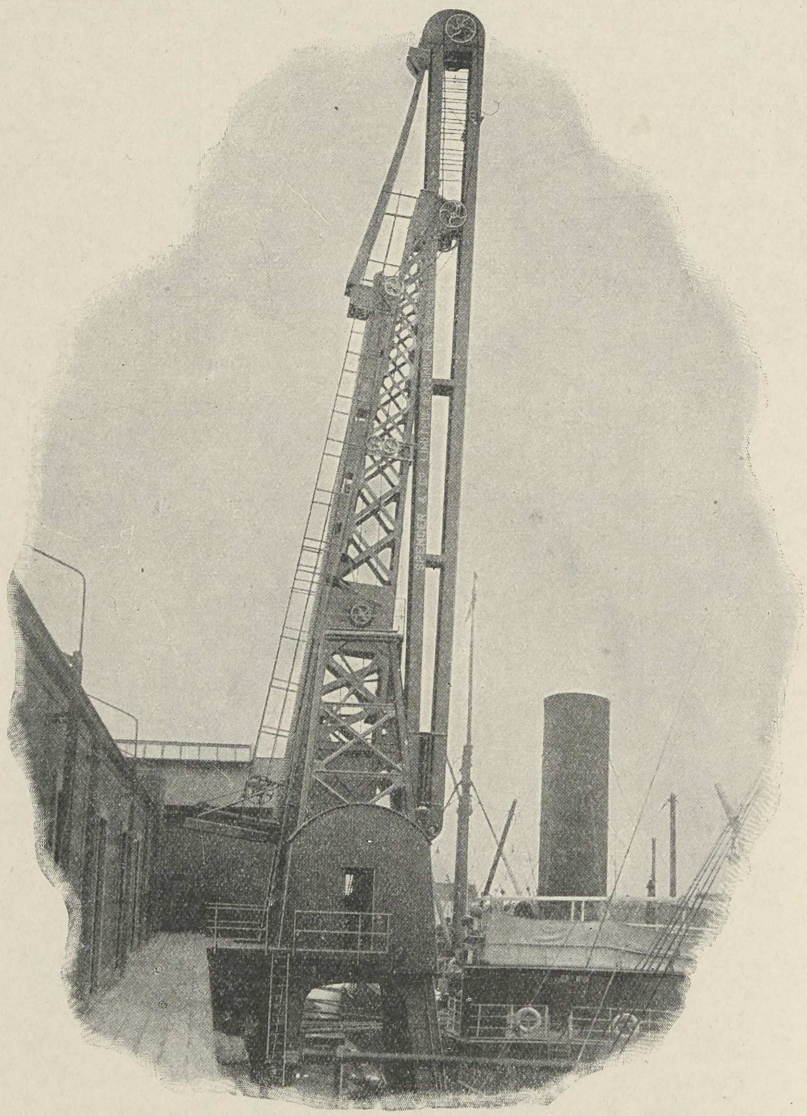


Fig. 641. Ship Elevator at Avonmouth Docks in Housed Position.

Barge Elevator for Handling Sacks.[2]—A somewhat more complex device is for the unloading of goods in sacks from barges to warehouses. Such installations are more especially for seeds, grain, etc., which are more generally handled in sacks, such

[1] *Milling*, 6th June 1903.

[2] From an article in *Zeitschrift des Vereins deutscher Ingenieure*, 30th November 1912.

as Indian wheats, some oil seeds, nuts, flour, coffee, peas, lentils, salt, moist sugar, cement, etc.

Hitherto such goods have been unloaded by intermittent appliances such as cranes, mono-rail telphers, or other elevated devices manipulated by chains or cables, which have the decided disadvantage of having to waste time waiting for the return of the empty receptacle for the next load; this is unavoidable with all intermittent methods of handling. The first installation to solve the problem of unloading such goods in a continuous operation, similar to the handling of bulk goods, was erected on a quay on the Danube at Vienna in 1910-11 by Amme, Giesecke & Konegen, of Brunswick, Germany.

Sacks have been conveyed for years by band conveyors on the level or on slight inclines, so that this part of the present installation presents no novelty; what had

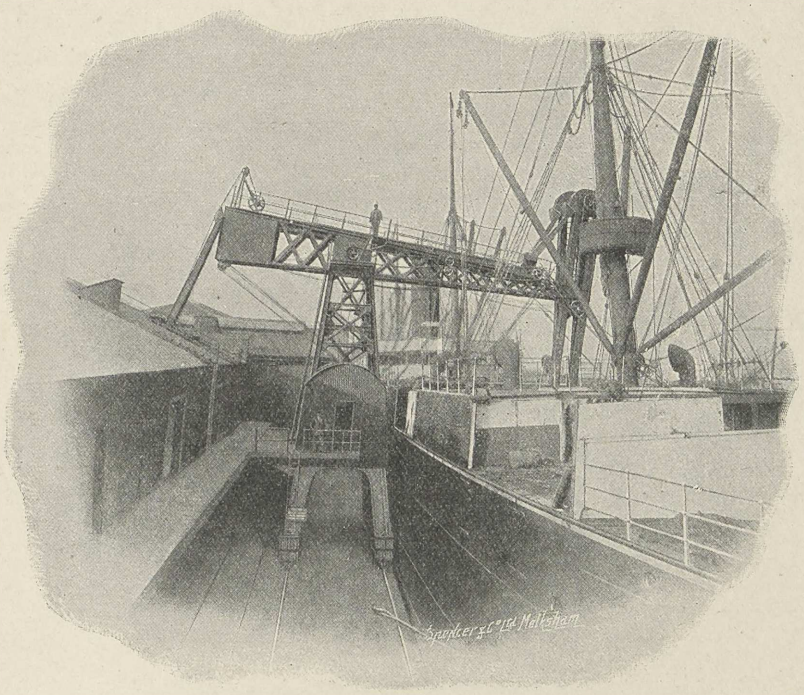


Fig. 642. Elevator at Avonmouth Docks when at Work.

hitherto been unknown was the use of an elevator in combination with such band conveyors.

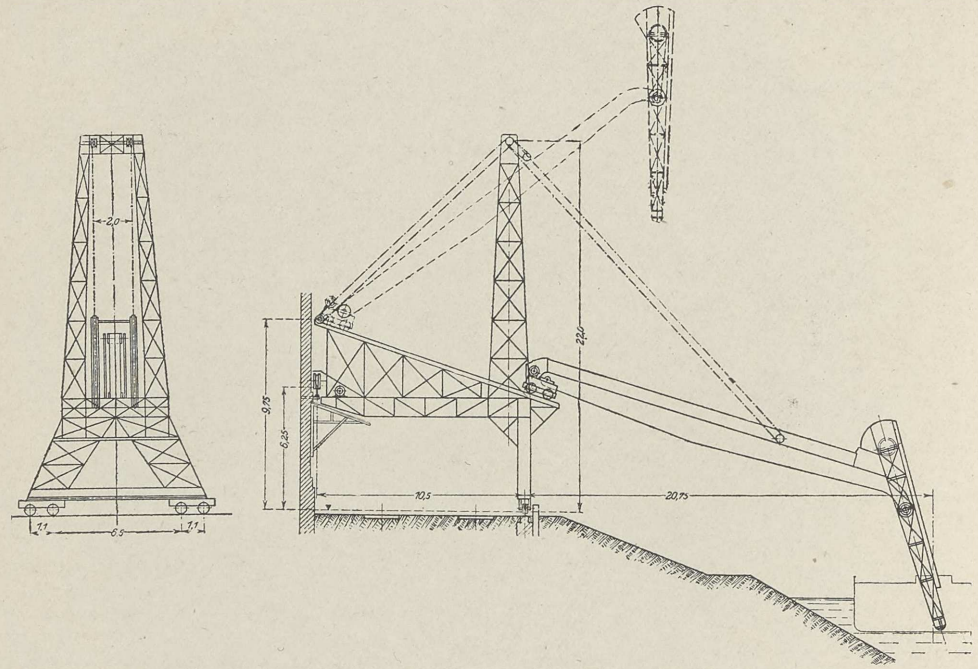
The elevator consists essentially of the usual upper and lower terminals with two chains, which are transversely connected at intervals by cross bearers upon which the sacks stand. The elevator is slightly inclined, and the space between the chains is fitted with a wooden back against which the sacks lean and slide during their ascent.

Figs. **643** and **644** show the general arrangement of the unloader, whilst Fig. **645** shows the relative position of the unloader to the warehouse. It will be seen from these illustrations that the banks of the Danube are of a gentle incline, and although there is no tide the water level varies considerably at different seasons of the year. The sloping banks make it imperative that at high water the barges to be unloaded shall come nearer to the warehouse. It is thus necessary to have the jib which receives the sacks from the

elevator supported on the land side on a movable carriage which travels up on an inclined path, so that the relative position of all parts shall be the same for varying water levels.

The unloader is portable so as to reach the different holds of the large Danube barges. It travels at a speed of about 3 ft. per minute, and the height of the tower carrying the jib is 22 metres or 72 ft.

The *modus operandi* is as follows: A gang of men place the sacks upon the receptacle of the elevator, which delivers them on to the belt conveyor in the jib (for details of this see Figs. **646** and **647**). Inside the receiving shed, and parallel with the inclined part of the land support of the jib end, is a second band conveyor which removes the sacks from the first one, and deposits them through one of the windows into the



Figs. 643 and 644. Barge Elevator for Handling Goods in Sacks.
(The dimensions are in metres.)

warehouse, where a similar elevator receives them and delivers them at the top of the building, there to be disposed of, by sliding and spiral shoots, all over the warehouse, or into carts and railway trucks. The elevator inside the building is so arranged that by the removal of a portion of the back board of the elevator the sacks may be delivered on any floor.

Electricity is the driving power used and is supplied by an 8 H.P. motor for the travelling gear, the winding tackle for raising the jib end up its inclined path if necessary, and also for driving the second band conveyor. The second motor is of 5 H.P. and manipulates the sack elevator and the band in the jib. Five hundred or six hundred sacks of 160 lb. each are handled per hour, equal to an annual total of 100,000 tons.

This installation has now been at work for a sufficient length of time for it to be pronounced a complete success, and the cost of unloading has been reduced by it to one-third of the cost of the hand labour previously employed.

Portable Barge Elevator for Grain.—A device which is portable in more than one sense is worth special mention on account of its unique construction. It is built by Mohr & Federhaff, and consists of the usual barge elevator, to the delivery end of which is hinged a worm in a tubular casing. The latter is arranged telescopically so that a portion of the casing may be withdrawn and thus form a shoot for the delivery of the grain as it leaves the worm (the whole being in an inclined position). Fig. 648 shows this device suspended from the hook of an ordinary crane in the lowest position, so that the worm which receives the grain from the elevator just reaches a portable sacking apparatus for filling the grain into sacks. For high tide and bigger ships the whole tackle is raised by the crane, when the telescopic worm casing extends automatically. The worm does not then reach the entire length of the tube, but in that position the incline is sufficient for the grain to fall by gravity down to the end and deliver as before. When the crane is to be used for ordinary goods, the whole apparatus is closed up and deposited in a stand erected for it somewhere on the quay out of the way, but yet within reach of the crane. An electro-motor is fitted to the elevator head, geared by spur wheels to the elevator spindle, and from this by chain on to the worm.

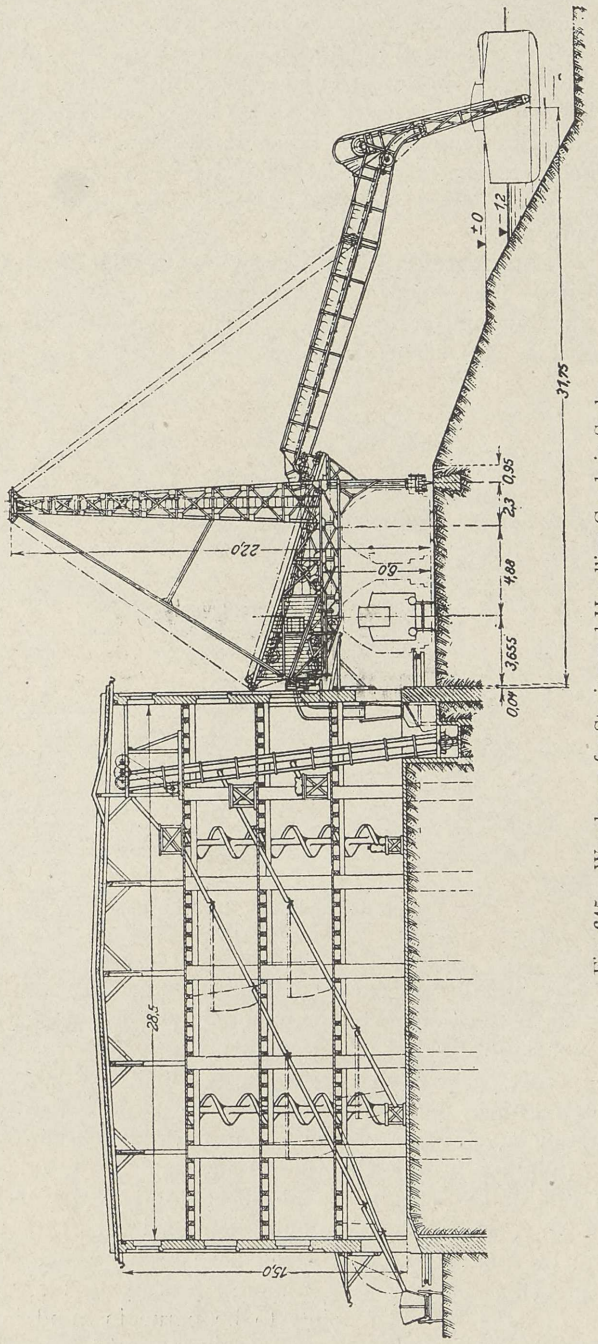


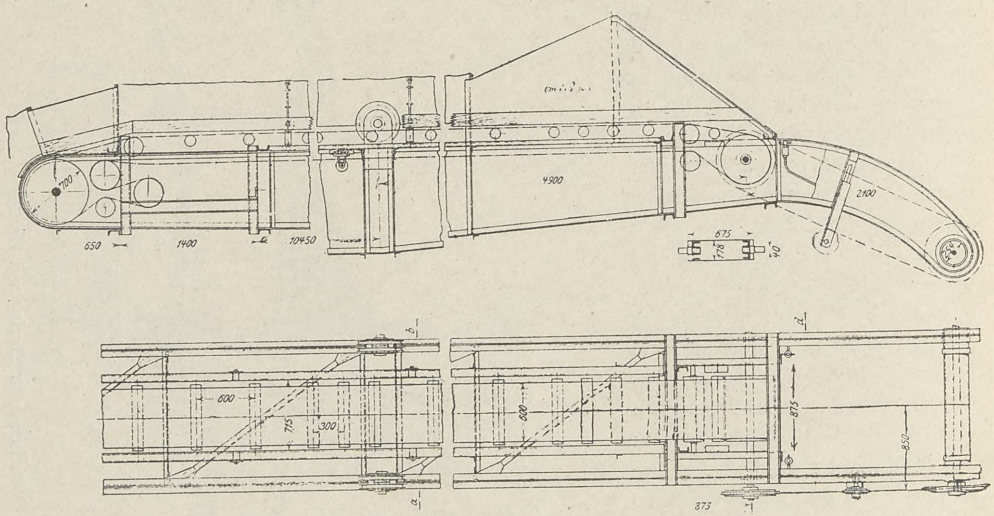
Fig. 645. Warehouse for Storing and Handling Goods in Sacks.
(The dimensions are in metres.)

The obvious advantage of such an installation for small ports is the small initial expense, as the same crane can be used for ordinary cargo as well as for unloading grain in bulk. It has also the further advantage that the unloading device, being suspended

with its motor from a hook on the crane, is exceedingly flexible, so that almost all points of the ship's hold can be reached, which reduces trimming to a minimum. The capacity of this device is 40 tons per hour.

The housing of the device is fairly simple. By means of the hand wheel and chain *a* and *b*, the worm is raised sufficiently to disengage from a portable weighing house, when an auxiliary electric winch on the crane shortens the rope *c*, so that the telescopic worm closes up till it is home in position *d*, where it is held closed by an automatic catch. If rope *c* is now slackened the worm drops close to the side of the elevator and the whole apparatus can be swung out of the way and housed till required for future use.

The Mitchell Cantilever Grain-Discharging Elevators at Dunston-on-Tyne.—The Co-operative Wholesale Society, Ltd., have installed, in connection with their flour mill at Dunston, two large ship-discharging elevators of an unusual design (see Fig. **649**). These elevators are the last link in a chain of improvements and develop-



Figs. **646** and **647**. Jib with Band Conveyor for Handling Sacks.
(The dimensions are in millimetres.)

ments which have been carried out in connection with this establishment. Formerly the whole of the foreign grain required for their mills had to be discharged at the docks lower down the river and from thence brought by steam barges to the mill at Dunston. In order to save all the expenses of storing and handling large quantities of grain several times, the Directors decided to put up a most complete plant for discharging and storing large cargoes of wheat. At the jetty on the eastern side of the mill steamers up to 7,500 tons can lie alongside at any state of the tide and by means of the two elevators a very quick delivery can be effected. The elevators were designed on the principle of Mr A. H. Mitchell, the bulk grain engineer of the Port of London Authority. They are the first of the kind which have been erected as travelling elevators on shore, the Mitchell Patent having been more especially used in connection with floating elevators.

One of the chief points to be borne in mind in designing the installation was the rise and fall of the tide (20 ft.). The essential feature of these unloaders is that the jib, which supports the elevator, is not in a fixed position, and owing to an ingenious arrangement of balance weights the jibs can be moved backward or forward, the effect being

that the elevator can be worked in a vertical position and still reach all parts of the ship's hold. For instance, when working in after-holds it is possible by tilting the jib

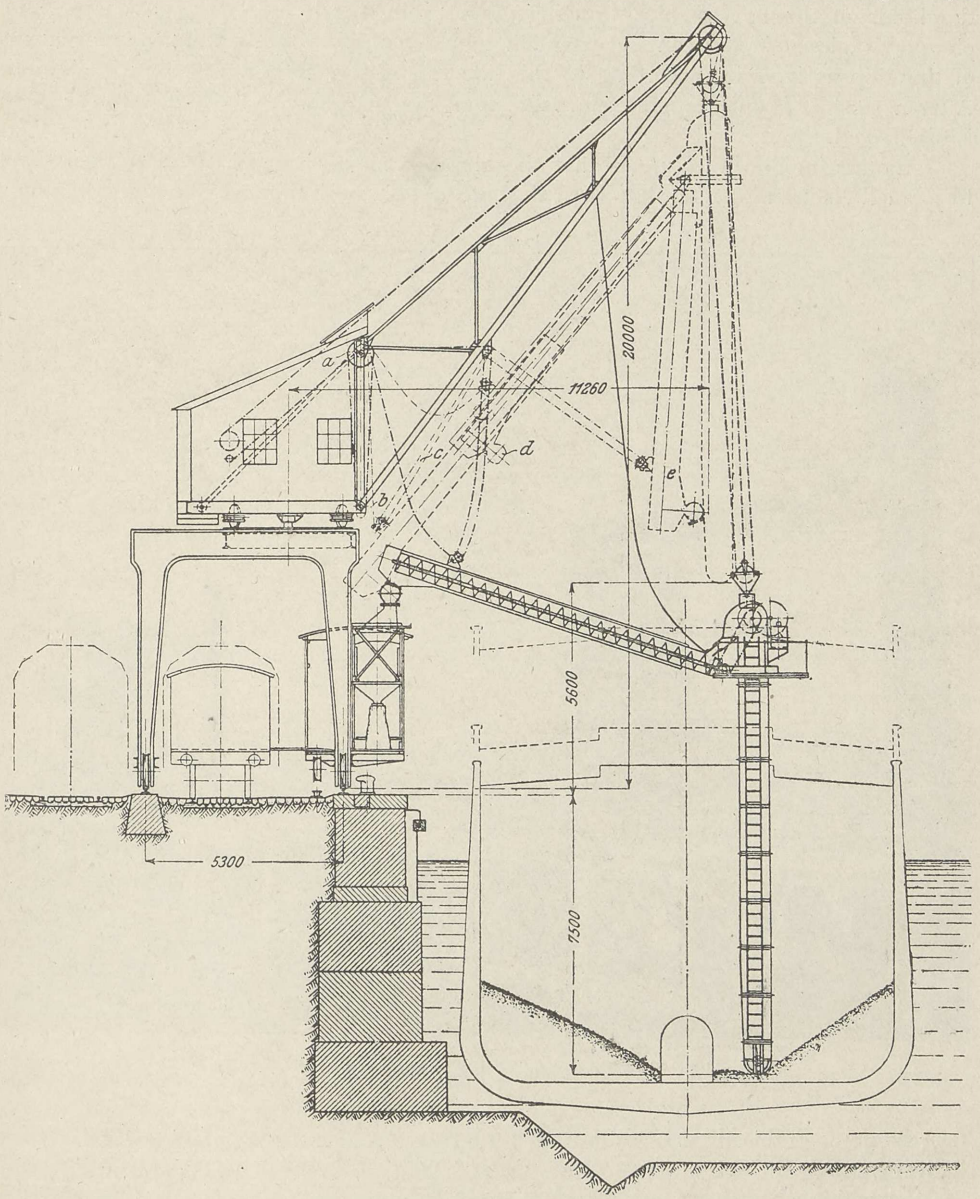


Fig. 648. Portable Barge Elevator Suspended from Hook of Ordinary Crane.
(The dimensions are in millimetres.)

post forward for the elevator to reach over the further side of the shaft tunnel and still remain in a vertical position. The same applies when working on the near side.

The unloaders are carried on strong underframes with long wheel bases ; four wheels at each end are provided and connected to an electro-motor, so that the apparatus can travel along the jetty to reach any hold of the ship.

The top of the balance post, carrying the jib, is 35 ft. above the jetty, so that the combined movements of the jib and post make it possible to take the elevator out of the holds of the largest ships bringing grain to this port, even at high water. The elevator is telescopic and can be extended to a length of 73 ft., so that the movements of the ship as it varies according to the tide can readily be followed by the elevator. After a steamer is once moored alongside it is not necessary to move it until the cargo is discharged.

Another important feature is that the elevators may be turned round on their bases by a small electro-motor, so that when they are not at work they may be housed entirely

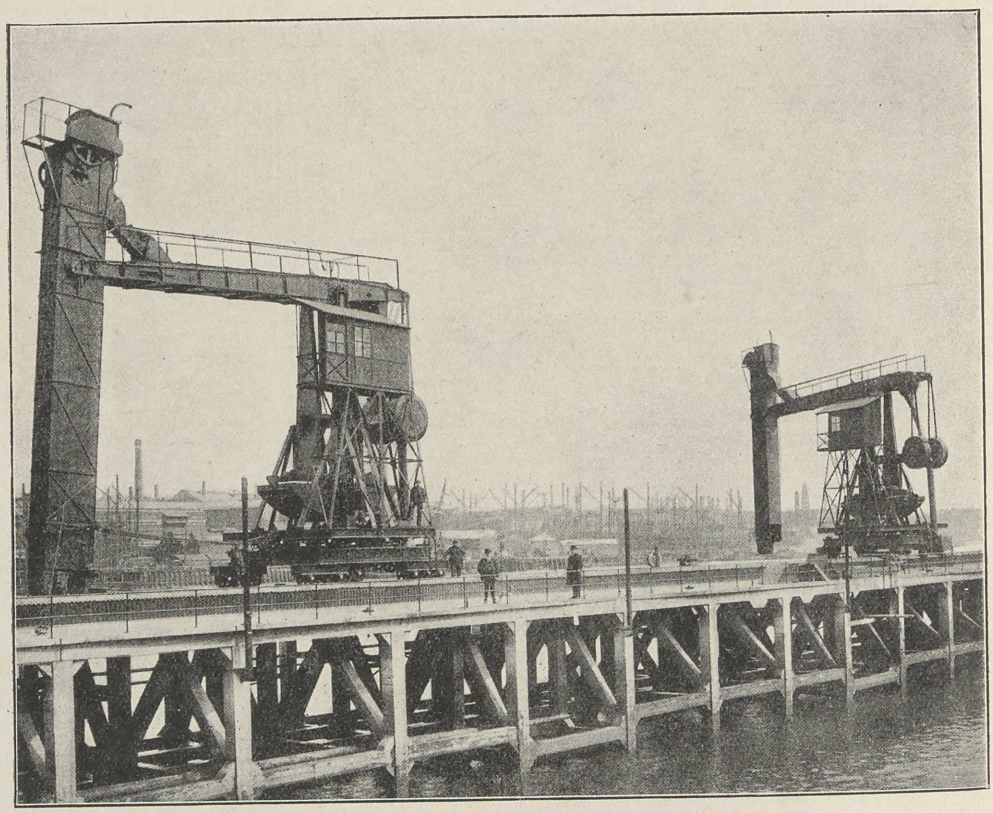


Fig. 649. Two Travelling Ship Elevators at Dunston-on-Tyne.

over the jetty so that there is no portion projecting over the river. The elevator buckets deliver through an automatic telescopic shoot on to a band conveyor which has been erected within the jib and is therefore protected from the influences of the weather. The grain is then delivered by another shoot to a band conveyor which runs along the quay. There is a total absence of long driving chains, as an electro-motor is provided for each motion. The motor for driving the elevator is fixed on the top terminal and drives direct by gearing. A separate motor is provided to drive the belt conveyor and also for each of the motions, travelling, turning, jib controlling, post tilting, and for raising the telescopic elevator, in all seven motors for each unloader.

On the side of each appliance is the driver's cabin, which is placed at such a height

that the driver has a good view of the hatchway in which the elevator is working. The switchboard is in the cabin as well as the other gear in connection with the electric installation. The whole is so well arranged that one man can take the elevator out of one hold, travel to another hold, and start work again without any assistance.

The guaranteed capacity of each elevator was 100 tons per hour, but from the first that quantity has been considerably exceeded, 120 tons being easily handled. During the first few weeks of working, several cargoes of grain amounting to over 40,000 tons were discharged most satisfactorily. As an instance of quick dispatch it may be mentioned that a cargo of 7,500 tons of wheat was discharged in less than five days. The installation was built by Amme, Giesecke, & Konegen, of Brunswick.

There are no practical reasons why installations similar to the foregoing should not be mounted on pontoons and thus be converted into floating barge elevators, as the mechanical arrangements are practically identical with those of the floating Mitchell cantilever elevator described later.

FLOATING ELEVATORS OR MARINE LEGS

Floating Derrick Elevator.—The derrick elevator erected for the late London Grain Elevator Co., now absorbed into the Port of London Authority, is the invention of Mr A. H. Mitchell, engineer of the old company.

This derrick unloading elevator is shown in Fig. **650**, which represents it ready to be lowered over the ship's side for unloading purposes.

It has been designed for unloading grain from the largest types of American liners engaged in the grain trade (such vessels as the "Minnehaha" and sister ships of the Atlantic Transport Co.) into lighters for conveyance into other coasting vessels or into warehouses.

The first elevator of this type was built by Spencer & Co., Ltd., of Melksham. The whole plant consisted essentially of four parts. Firstly, the pontoon; secondly, the travelling car, containing the engines and the various driving gears; thirdly, the support, consisting of lattice girders and shear legs; and fourthly, the elevator itself, which is lowered into the ship's hold. The pontoon is built of steel, and is 75 ft. long by 24 ft. wide, and has a draught of 8 ft. It is square at the bow so that it can be brought close to the side of the vessel which is to be discharged. The deck of the pontoon is specially strong, and is fitted with a track, the rails of which run from bow to stern, and are 7 ft. apart. The travelling car moves on these. There are two vertical boilers in the stern, one being sufficient to drive the plant, the other only being used in case of emergency. Ample bunker space is allowed amidship.

The pontoon is self-propelling by means of a small marine engine and a pair of screw propellers. The space in the hold not required for bunker purposes is filled with ballast to ensure the stability of the vessel. The trolley, which is 17 ft. long by 9 ft. wide, rests on the rails on six wheels. The range of its motion from end to end is 36 ft. It is conveyed backward or forward by a pair of wire ropes which are fastened at one end to the pontoon and at the other end to the drums of the winches. The engine, which is in the centre of the trolley, is a 30 H.P. of double-cylinder type, and is connected with the boiler by flexible pipes, the connection being made in the centre of the revolving drum in such a way that the piping rolls itself on or off the drum as the trolley moves backward or forward.

The large lattice girders of the derrick shown in the illustration are carried on trunnions on the forepart of the trolley, while the main shaft, which drives the elevator

and conveyors, passes through these hollow trunnions. In front of these is the gearing for raising or lowering the main jib, and the gearing for moving the elevator to a vertical

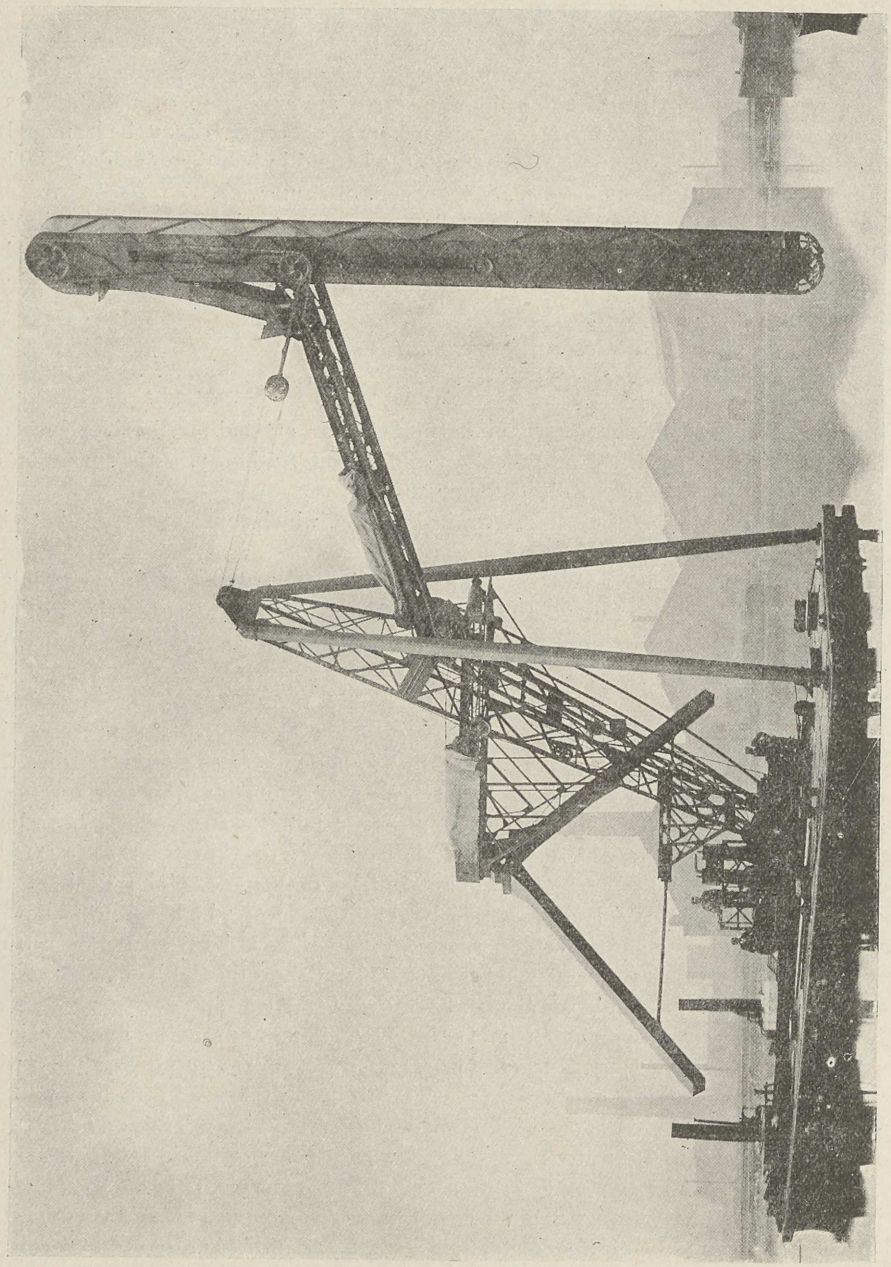


Fig. 650. Derrick Elevator ready to be Lowered over Ship's Side.

position. The trolley is cased in, and forms the attendant's cabin, in which all the levers for manipulating the different parts are placed. The housing has been removed for the purpose of taking the photograph from which this illustration was prepared. The

structure at its supports is formed of two pitch pine shear legs in the bow, one on either side, and a lattice steel back leg which is about 50 ft. long. These shear and back legs are connected together at the top by a steel pin and collars, the back leg being hinged to the trolley and the front legs to the deck of the pontoon. All these parts can readily be raised to any angle, allowing perfect freedom for the trolley to move backward and forward on deck. The elevator is supported by a jib which is hinged to the back leg, as shown in the illustration. On this jib is fitted a band conveyor 2 ft. 6 in. wide, which is necessary, as the elevator itself dips deep down into the ship's hold, and the grain may have to be conveyed up or down to reach its destination.

Just below the jib on the other side of the back leg extends a cantilever (also fitted with a band conveyor) projecting over the stern of the pontoon, at the end of which are two long shoots for the delivery of the grain. The buckets are 20 in. wide, and of the continuous type, similar to those illustrated in Figs. **15** and **16**, page 19.

The elevator is 53 ft. long, and has a vertical range of 18 ft., and when in its highest position the head is 90 ft. above the water level, and has a clear 40 ft. between the elevator well and the water level. This is necessary to reach over the side of large ships. It can discharge grain from a ship with a 40-ft. beam and a hold 45 ft. deep. The driving

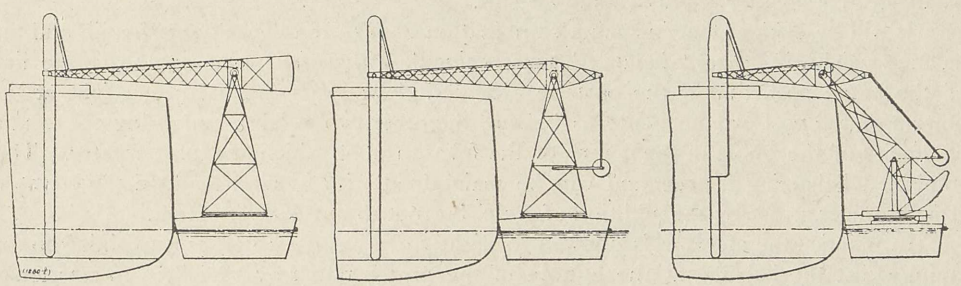


Fig. 651. Fig. 652. Fig. 653.

Diagrams showing Development of Mitchell's Cantilever Grain Elevator.

power required is 20 B.H.P. and the capacity is 150 tons per hour, and this can be kept up provided the trimmers can keep pace with it.

These elevators are in use at the Victoria and Albert and also at Tilbury Docks.

The elevator can be housed very neatly when out of use, in which case it lies flat upon the deck, and the delivery shoots are drawn in, so as not to project over the sides of the pontoon. The position of the shear legs is then approximately at an angle of 35° to the deck.

The expeditious way in which the marine leg can be set to work may be gauged from the test in which it was lifted over the bulwarks of a ship 30 ft. 6 in. above the water level, lowered into the hold to a depth of 43 ft., and started to work delivering grain in seven minutes.

The Mitchell Cantilever Grain Elevator.—This is the best known and most efficient type of a floating apparatus which can unload a cargo of grain from the largest ocean-going steamer. As its development may be of interest, it is fully given here. It is, of course, only proposed to deal, in these introductory remarks, with the general arrangement for manipulating the machine, as the elevator itself presents no new features.

The earliest type was constructed as shown in diagram, Fig. **651**. It consists essentially of a self-contained elevator suspended from a balanced rocking jib supported at the top of a stationary lattice steel post. The objection to this construction lies chiefly

in the enormous top weight which necessitates a wide pontoon to ensure stability. This will be better realised when it is considered that in order to unload large ships with side beam the jib must be very long in order to reach to the side remote from the pontoon with the elevator leg; this necessitates very considerable balance weight. Such a machine also lacks facilities for adjustment; if, for instance, the elevator has to work on the near side of the pontoon it becomes necessary to warp the pontoon off the ship, and these not infrequent readjustments involve a considerable waste of time.

The first-mentioned effect of the top weight has been overcome by the construction shown in diagram in Fig. 652. In this case the elevator leg and its jib are balanced by a weight carried comparatively low down on levers pivoted at the centre of the post, these levers being of equal length to the back end of the jib, and the connecting link of such a length that jib and levers are always parallel; by such a parallel motion the apparatus is in balance in any position. As the balance weight is now low down, a narrower pontoon may be employed and still give sufficient stability.

The second defect is overcome in a construction shown in the diagram, Fig. 653, which represents the final development of the present marine leg. It will be seen from the diagram that in addition to the first improvement the post itself is pivoted and balanced by a counterweight at its lower end.

It will be evident that in such a combination the centre of gravity of the jib and the balance weight, if properly balanced, must coincide with some point on the centre line of the crane post, and if the post be extended downwards the balance weight at the bottom of the post can be made to balance the other two weights and bring the centre of gravity of the whole to the centre of the fulcrum upon which the post rotates. This combined balancing is true, and can be maintained with a fixed load on the elevator. It is, however, upset by the addition of grain, but not to any serious extent.

In practice the elevator is allowed to slightly overbalance to allow it to sink into the grain, whilst the balance at the bottom of the post is rather overweighted to counteract any capsizing tendency.

The result of this combination of levers is to give an extraordinary range of motion to the elevator leg, and at the same time to allow practically no movement of the centre of gravity of the whole.

The elevator can, therefore, be placed upon a turntable and worked either side on or end on with impunity, and when required for towing can be turned right round and the elevator stowed upon the deck or rested upon the weigh-house, as shown in the drawings.

The removal of all capsizing movement also enables a very much smaller barge to be used, thereby reducing the capital cost and taking up less room at the ship's side.

The line drawing, Fig. 654,[1] illustrates one of two floating elevators built upon this system to the order of Messrs C. J. King & Sons, Bristol, by Messrs Spencer & Co., of Melksham, Wilts. The maximum capacity of these elevators is 120 tons per hour.

The leg, which is telescopic, has a total length extending to 44 ft. and 27 ft. when closed. The endless chain carrying the buckets is so arranged that when the leg is lowered, as much chain is let off in front as is taken up at the back, so that it remains at constant length and even tension.

Each elevator is driven by a direct coupled electro-motor of 16 B.H.P. at the head of the elevator, thus doing away with all driving chains. It is carried on the end of a cantilever jib of 30 ft. centres, which is in turn carried on the top of a cantilever post

[1] The illustrations are reproduced from *The Engineer* of 9th July 1909, while the description is from information kindly furnished by Mr A. H. Mitchell.

of 26 ft. 6 in. centres, the post rotating on trunnions carried on the top of the turntable 16 ft. 6 in. above the deck.

The top of the jib is provided with a conveyor band which carries the grain from the elevator to a shoot running down the post, which in turn discharges into swivelling shoots through the deck into the well of a second, but stationary, elevator. These swivelling shoots are so arranged that they automatically adjust themselves for every movement of the elevator leg. The band is of canvas and rubber, and is provided with diagonal ribs to facilitate the grain running uphill when the jib is dipping downward more than 20°. The ribs are placed diagonally so that they will run over the return idlers without shock.

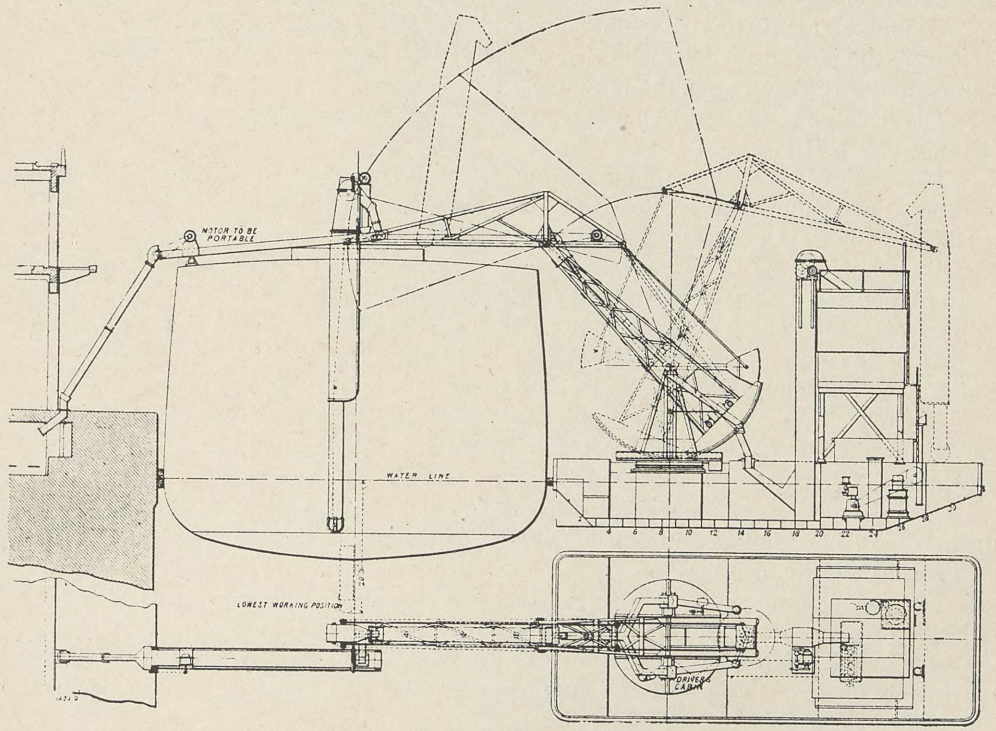


Fig. 654. Mitchell's Floating Barge Elevator.

The grain is re-elevated by the deck elevator to any required height, and delivered into a hopper from which it is weighed and delivered.

Weighing is accomplished by six "Avery" automatic scales, three on each side, which deliver either into sacks, or shoot loose at will. The elevators are also provided with a means of delivering grain loose and unweighed to barges on either side, and also with a portable conveyor for delivery ashore to bands on the quay when necessary.

The range of motion is very extensive, the elevator being able to work from a point 20 ft. 3 in. below the water line, and it can also be lifted clear over the side of a steamer having 40 ft. freeboard.

When required for towing, the elevator can be turned right round after the manner shown in dotted lines and stowed over the top of the weigh-house in a position of absolute safety.

The barge upon which the elevator is built is 65 ft. long by 26 ft. 6 in. over all, and has a depth of about 10 ft. 6 in.

The power is generated on board by means of a high speed direct coupled generating set, the engine being built by Messrs E. S. Hindley & Sons, Bourton, Dorset, and the electrical machinery by Messrs Cromptons, of Chelmsford.

The engine is supplied by suction gas from a plant using anthracite coal. The engine runs at 600 revs. per minute, and transmits continuous current at 110 volts, this voltage having been found most satisfactory for grain work. The current is supplied by means of a concentric connection under the elevator to a driver's cabin attached to the side which contains all the various controllers.

The motor for driving the conveyor is placed at the back end of the jib. Those for raising the jib and the telescopic leg are placed at the bottom of the post whilst the slewing motor is placed upon the turntable. They are each of 4 B.H.P.

The deck elevator is driven by a direct coupled motor placed at the head of the elevator, of 9 B.H.P.

The engines have a maximum output of 50 B.H.P., but the average used when working at maximum capacity does not generally exceed 30 B.H.P., of which about 14 is taken by the main elevator, and the balance by lights and auxiliary machinery.

The whole of the operations for placing the elevator into the ship and controlling it are carried out by one man from the driver's cabin, the time taken to get into the ship or out being about seven minutes. No use whatever is made of the ship's gear except for the purpose of trimming the grain to the elevator leg. (In some of the earlier types the ship's tackle had to be used to get the elevator leg into the hold.)

A similar, but smaller plant, with a capacity of 100 tons per hour, was built by the New Conveyor Co. for the London Grain Elevator Co. Here the buckets are $10\frac{1}{2}$ in. apart and 320 buckets pass per minute.

Two similar elevators, but constructed to run along the quay instead of being placed upon barges, have been constructed for the Co-operative Wholesale Society, Dunston-on-Tyne, as already mentioned.

Floating elevator or marine legs may be preferable to the pneumatic system of unloading cargoes if the grain is stored in a convenient and accessible position, such as if a large hold without obstructions is to be emptied, as the driving power required per ton is only about 1 to $1\frac{1}{2}$ H.P. or approximately half that consumed by a pneumatic plant.

Unfortunately, however, such conditions do not often present themselves, in fact Mr Mowat states that at the Millwall Docks not more than 10 per cent. of the cargo is so stored that it can be handled by the bucket elevator. Cargo steamers, particularly from the Black Sea, contain sometimes many parcels of wheat which have to be kept separate, so that only hand labour or a pneumatic plant can do the work.

A case may be mentioned of a ship which contained forty-seven parcels, which meant different handling for each parcel of grain. Each one had to be taken out carefully by the pneumatic apparatus and cleared before the mats which separate the parcels could be removed to give access to the next parcel. It would be impossible to do this with elevator legs. In some cases the thickness of grain between the separation mats is not more than 2 ft. The only alternative to the pneumatic elevator in such cases is, as already mentioned, the old hand method of bushelling into sacks and making use of the ship's winches and gear to hoist the grain on deck and tip it into barges alongside.

Other difficult cases in which the marine leg is no good are those of cargo steamers

in which grain is carried in empty coal bunkers, or where it is stored at the side of the propeller shaft tunnel which runs through the hold at the after end of the boat; it is obvious that in such cases the grain can only be reached by the pneumatic elevator.

After the marine leg or bucket elevator, when unloading cargoes of grain, has cut down to the bottom of the ship's hold a large quantity of grain heaped at the natural angle of repose remains all round the hold, and every bushel of this will have to be trimmed to the elevator before it can be handled by it. With the pneumatic system the position of the grain is quite immaterial, and wherever it may be, whether under the hatch-coam or elsewhere, the suction pipes can be led to the grain and remove it from the hold. The suction pipe in the hold is controlled by one man.

CHAPTER XXXIII

FLOATING LOADING DEVICES, INCLUDING SELF-EMPTYING BARGES

With the advent of larger vessels the difficulty of loading bunker coal has increased. The larger the ship the more difficult it is to bunker from the quay wall, and for years past the tips for loading have been made portable within narrow limits to accommodate themselves to some extent to the position of the ship, but even with this improvement the adaptability of a floating loading device can never even be approached for portability by a device on shore. On the other hand it can hardly be expected that such floating loading devices can compete as regards capacity with the enormous quantities of cargo coal which may be poured into a vessel by the tips on the quay wall. For bunkering, however, and as an auxiliary to the tip from the waterside, the floating loader is invaluable.

These latter are of two types: (A) Those self-contained and carrying the coal to be transferred, generally known as self-unloading or self-trimming barges; and (B) those which

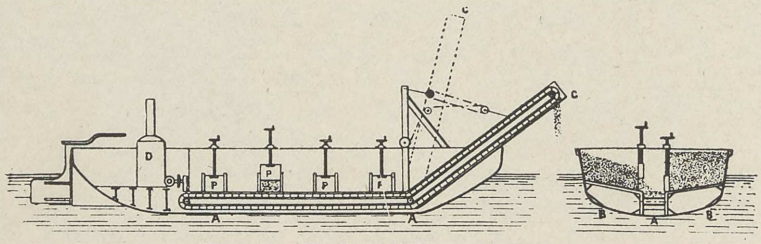


Fig. 655. Paul's Self-Trimming Barge.

carry no cargo of coal, but transfer by mechanical means the contents of a lighter or barge into another vessel.

Self-trimming barges are used for the purpose of transferring their contents, which may be grain, coal, etc., to other vessels, or to the receiving elevators or conveyors of granaries and coal stores.

A.—SELF-EMPTYING OR SELF-TRIMMING BARGES

Paul's Self-Trimming Barge.[1]—One of the oldest self-trimmers, which is, however, not entirely automatic, is the design of the French engineer, M. J. Paul, and will, it is claimed, successfully handle grain, coal, sand, etc.

Fig. **655** shows such a barge, which has a double bottom forming a hollow space BB on either side of the channel A, in which a travelling trough conveyor is fitted in such a way that its delivery end over the bow is movable like a derrick. Section AC of the conveyor can, therefore, be raised or lowered to suit the requirements of the delivery. The angle must not, however, exceed 45°. When not at work the movable part can be housed as shown in dotted lines. The contents of the barge are fed to the conveyor through the

[1] This barge has been minutely described by Professor Buhle.

openings P, which are adjustable by means of slides, hand wheels, and screws. In order to enhance the carrying capacity of this barge, the sloping bottom has been made rather flat so that some hand-trimming is necessary. D represents the engine and boiler.

Clarke's Self-Trimming Barge.—One of these barges has been in use at Liverpool for upwards of twenty years by the Liverpool Barge and Coaling Co. Fig. **656** shows an elevation in diagrammatical outline, whilst Figs. **657** to **660** show four cross sections giving the different stages of discharge, and they show also how coal of different kinds may be mixed on delivery.

In the space between the double keelsons of the barge a gravity bucket conveyor *a* is provided, which takes the coal to the upper structure and delivers, after passing two automatic weighing machines, to the delivery shoots *b*, *c*, *d*, and *e*. There are

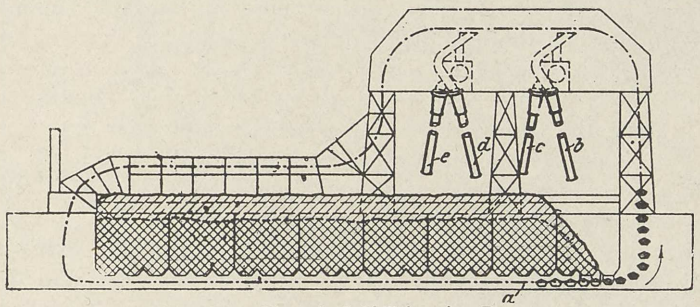


Fig. 656. Clarke's Self-Trimming Barge.

two such barges used at Liverpool, with a capacity of 1,300 tons each, which can be transferred at the rate of 230 to 250 tons per hour; they require six men each to handle them.

In addition to the barges on the Clarke principle, just described, the Hamburg-American Line has a similar installation on order for the Hamburg harbour, which shows that although this system is more than twenty years old, it is still considered up to date.

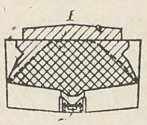


Fig. 657.

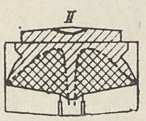


Fig. 658.

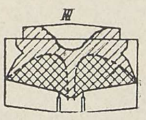


Fig. 659.

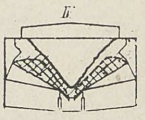


Fig. 660.

The barge is to be fitted with a crane and grab, so that it can be replenished all the time without having to come alongside for recharging, as there are no suitable tips available at Hamburg for this purpose. The capacity per hour is 250 tons for the gravity bucket conveyor, and for the crane and grab, for replenishing, 150 tons. The height of lift is 48 ft., which is lower than that at Liverpool.

It might be mentioned that it is inadvisable to make such floating loaders too high and top-heavy, and to afford much resistance to the wind in the superimposed structure, as a high wind and an empty barge might prove disastrous; this was probably considered when ordering the self-unloading barge for Hamburg, as somewhere about Christmas 1912 two loaders capsized there.

Self-Trimming Barge in New York Harbour.[1]—This is on the same principle

[1] This barge was fully described in the *Journal of the American Society of Naval Engineers*, February 1901.

as the one just described and is successfully employed for the purpose of conveying coal. It has this advantage, that it is really self-trimming, and empties itself completely. It creates but little dust, and the coal is weighed automatically before delivery into the bunkers of the vessel.

Fig. 661 represents a longitudinal section through the barge. A A A are the compartments in which the coal is deposited. Each compartment is fitted at the bottom with three slides, which are opened and closed by hydraulic machinery illustrated in Fig. 662. Below the row of slides is a tunnel in which a gravity bucket conveyor is fixed, which is driven by a small engine and boiler at the stern of the vessel.

The contents of the different compartments are in rotation deposited on the conveyor and moved in the direction of the arrow. On reaching the stern, the conveyor ascends, and the buckets are emptied in their highest position into the automatic weighing machines W W, from which the coal slides down the shoots S S into the bunkers of the steamer to be loaded (see Fig. 663). The shoots S S can be raised or lowered by winches. Fig. 664 represents a cross section through this self-trimmer showing the hydraulic machinery for raising the floor of the compartments A after they have partially emptied themselves, for the purpose of automatically completing the discharge. Coal can be unloaded from this barge at the rate of 100 tons per hour. Two such self-trimmers are used, one at either side of the vessel.

Self-Trimming Barge of the Pittsburg Coal Co., Cleveland, Ohio, U.S.A.—This barge was built by the C. O. Bartlett & Snow Co., and the illustration, Fig. 665, shows a longitudinal section through the barge, giving a general view of this self-trimmer, and showing the construction, which is as follows:—

The barge is about 165 ft. long by 25 ft. beam, and is large enough to carry 750 tons of coal in addition to her machinery. The main body of the barge is divided into a series of hoppers, each 10 ft. wide, which extend nearly the entire length of the hull. The hoppers A are arranged in two rows, one on each side, leaving the tunnel in the centre, which extends from end to end through the barge. Each of the sixteen hoppers communicates with the tunnel by an outlet B, which is 3 ft. square. From this the coal can be deposited on conveyor E, running through the tunnel. The conveyor consists of two strands of a very heavy chain, to which are connected plates, which form, with the chain, a type of push-plate conveyor. The coal is allowed to pass from one of the hoppers A to the conveyor, and is then removed to the terminus, which is raised slightly above the level of the rest of the conveyor. The load is then delivered to the elevator E, which is built in a stout sheet-iron frame with ample supports for the guides of the buckets. It is manipulated by two strands of chain, in the centre of which the buckets are hung for the purpose of giving a perfect delivery, as shown in the illustration. The coal is discharged into hopper H, which is mounted on a turntable. Immediately beneath the hopper is the well of an inclined elevator, the delivery end of which is so arranged that it can be raised or lowered, and so convey the coal into vessels, which are to be supplied with bunker coal, at any angle from the horizontal up to 45°. To the delivery end of this elevator is attached a telescopic shoot which can be swung round to accommodate itself to the hatch of the boats to be coaled. The whole apparatus, including hopper H, is mounted on a turntable, which gives every facility for directing the delivery shoot into any position. The motive power for this inclined elevator is provided by a separate steam engine C, which is mounted on the top of the turntable.

It will be seen that the delivery of the coal can be effected on either side of this coaling barge. There is also a second engine D, which is placed on the deck of the barge

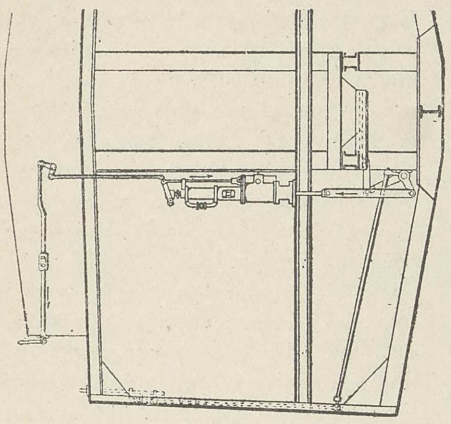


Fig. 662. Hydraulic Machinery for Controlling Slides.

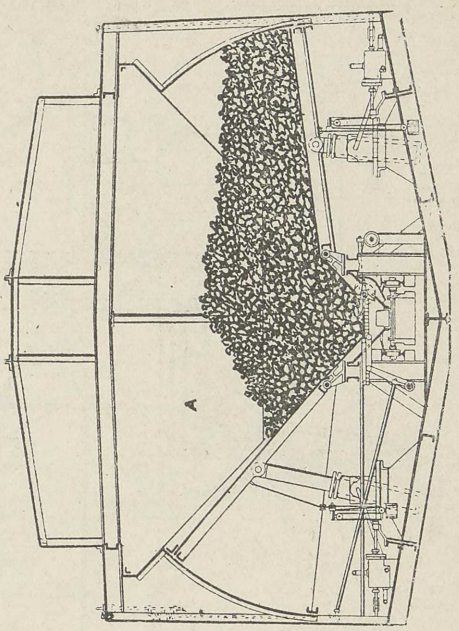


Fig. 664. Cross Section through Self-Trimming Barge.

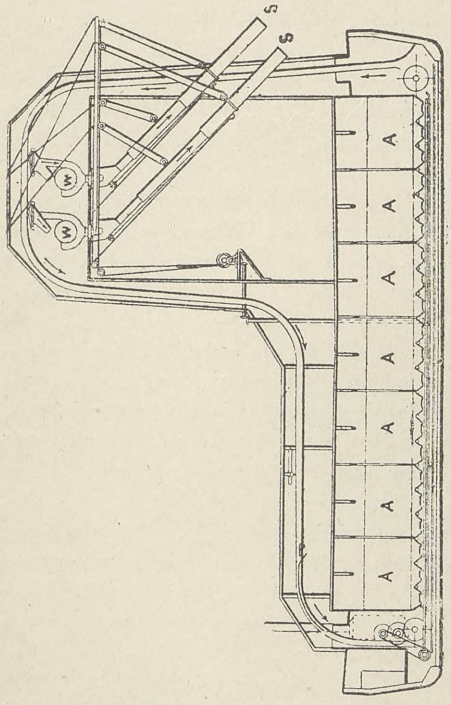


Fig. 661. Longitudinal Section through Self-Trimming Barge.

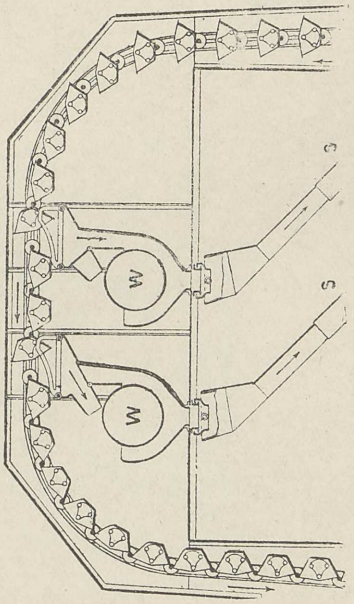


Fig. 663. Discharging Points in Self-Trimming Barge.

for operating the conveyor and elevator E, as shown. Both engines are fed from the boiler F. The unloading capacity is over 200 tons of coal per hour.

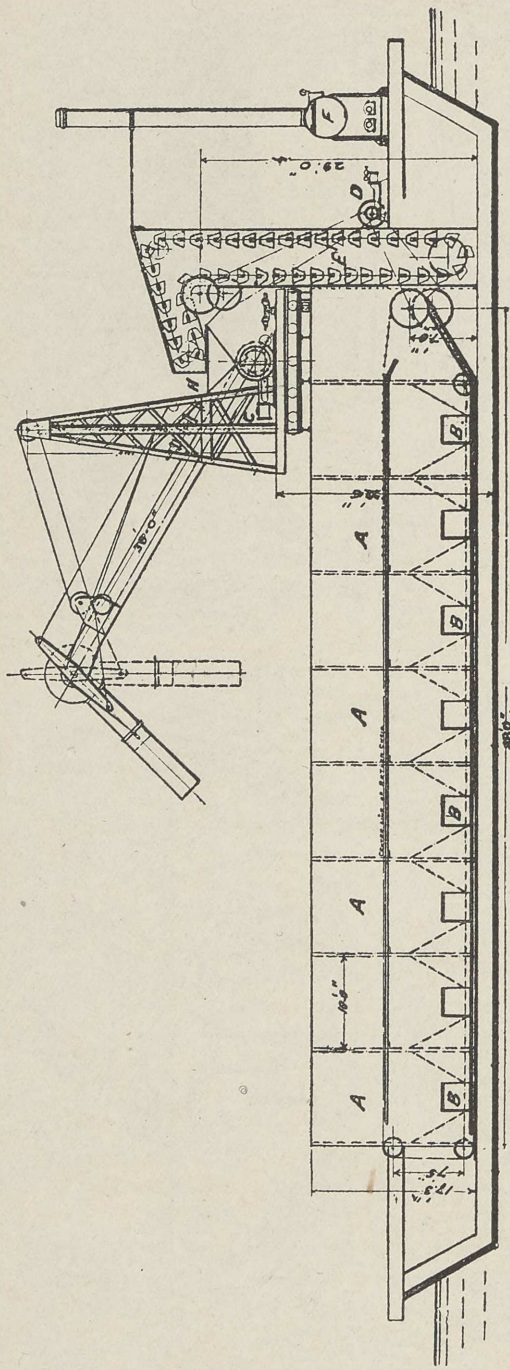


Fig. 665. Longitudinal Section through the Self-Trimming Barge of the Pittsburg Coal Co.

Coaling Barges of Werf Conrad, Haarlem, Holland.—This is a well-known type in Continental docks, and one such installation is in use by the Hamburg-American Line at Hamburg.[1] Figs. **666** and **667** show a diagram of the same, and Fig. **668** shows a perspective view. The bucket elevator *a* passes under the coal bunkers A, which deliver the contents through openings governed by slides; *b* is an automatic weighing machine. The conveyor passes up the jib *c* and delivers from a receiver down the shoot *d* to the liner. The shoot *d* is manipulated by a 5-ton crane at the end of the jib. The length of the hoppered barge is 157 ft., 36 ft. beam, and 30 ft. deep. The holding capacity is 800 tons, with a draught of 14 ft., and the delivery is at the rate of 200 tons per hour. Seven men only are necessary for all the work. A 100 H.P. compound engine drives the machinery as well as propels the barge.

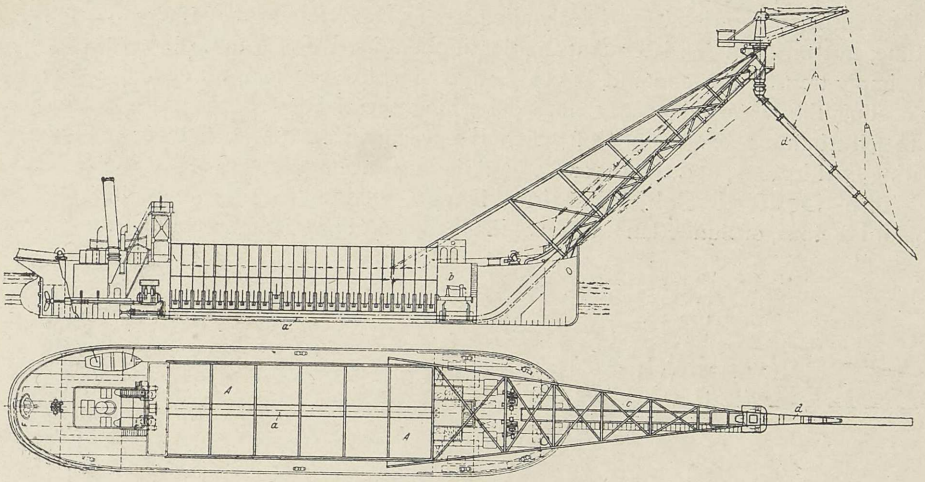
Although the whole construction gives one the impression of stability, it seems at the same time ungainly and difficult to moor in a suitable position for loading.

There are various other self-unloading appliances, and one of the latest examples is the self-unloading collier, the "Hermann Sauber," built by Messrs William Doxford & Sons, Sunderland, which has a total discharging capacity of 800 tons per hour. The time taken to unload 5,000 to 6,000 tons would be from six to eight hours, and six men only would be required.

The Coaling Barge at Doxford Wharf, Sunderland.—This

[1] At Rotterdam similar ships are in use: the "Pluto" since 1905, "Prosper" since 1907, and "Harpen" since 1909. They all transfer coal at the rate of 100 to 250 tons per hour.

barge is more compact than the last, and can deliver its coal when berthed alongside the liner, as will be seen from diagrams, Figs. **669** to **671**. The capacity is 1,900 tons,



Figs. 666 and 667. Werf Conrad Coal Loader.

and the whole of the contents can be transferred to the bunkers of a liner in four hours. The *modus operandi* is as follows: Two steel plate conveyors, *a* and a_1, receive the coal from the hoppers A A and deliver at *b* by a shoot on to the elevator *c*, which again

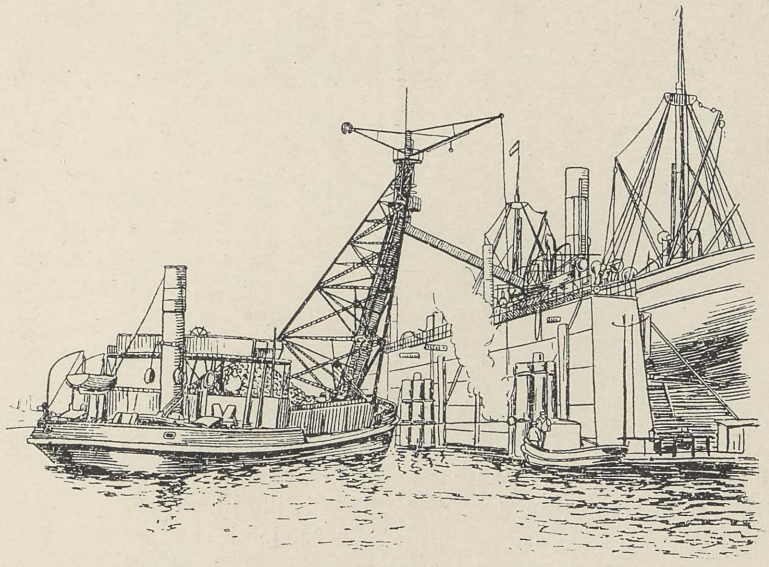


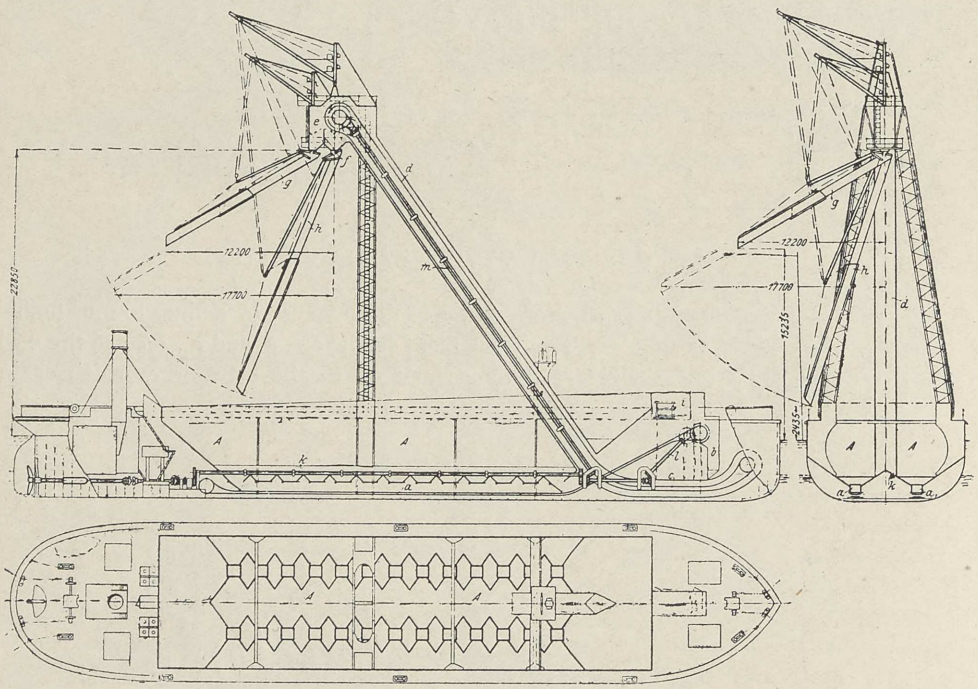
Fig. 668. Perspective View of Werf Conrad Coal Loader.

delivers at *e*. The slide *f* regulates the final delivery to shoots *g* and *h*, and thence to the bunkers of the liner.

As modern liners require from 5,000 to 6,000 tons of bunker coal, it would mean that the coaling appliance would have to make at least three journeys to replenish its

contents; or two such barges would have to be at work, one discharging whilst the other replenished; or, thirdly, the bunkering could be done partly by a stationary tip at the dock side, and partly by one of these loaders from the water side. This shows that the systems hitherto described are hardly adequate for bunkering large liners in a minimum of time, but we shall see later that the floating loading devices that carry no cargo coal, but simply transfer the contents of coal barges to ships' bunkers, have adequate capacity for coaling the largest liners. Before describing these, however, we must mention two more self-trimming barges, one of which is specially built to work in conjunction with floating coal loaders, and the other for handling grain.

The Doxford Self-Trimming Barge.—These barges are built by William Doxford & Sons, of Sunderland, to serve the loaders. Fig. **672** shows one of these barges:



Figs. 669 to 671. Coal Loader at the Doxford Wharf, Sunderland.
(The dimensions are in millimetres.)

A is the coal receptacle, B the conveyor, and C and D the final delivery. The general arrangement is not unlike that shown in Figs. **666** and **667**, but the delivery shoot is only just high enough to deliver into the elevator of the loader. The capacity of each barge is 650 tons of coal, which is paid out into the loader at the rate of 250 tons per hour. A barge of this kind feeding its loader is shown in section in Fig. **676**.

Philip's Self-Trimming Lighter.—This is illustrated in Fig. **673**, which gives a longitudinal section of the same, whilst a cross section is shown in Fig. **674**. Fig. **675** gives the two ends of the lighter on a larger scale. These boats were designed and equipped by Messrs Spencer & Co., Ltd., of Melksham, for the London Grain Elevator Co.

There is a fleet of twenty-six of these lighters, each of which carries a load of 200 tons of grain from Tilbury to the Port of London, some of the large grain steamers not usually coming up higher than Tilbury. The lighters discharge grain at the rate of

120 tons per hour into a barge elevator, which receives it and discharges it into the granaries of the Port of London Authority.

Between the double keelson of the lighter runs a band conveyor of the ordinary type, the band being 28 in. wide. This band delivers into the elevator situated at the stern of the lighter. Both elevator and conveyor are driven by an electro-motor of $6\frac{1}{2}$ B.H.P. The bottom of the barge is hopper-shaped, as may be seen from the cross section. Although the angle is not sufficient for the whole of the grain to discharge automatically, but little trimming is required to remove any small portions of grain which may remain at the sides after the bulk has been cleared. The openings from the barge to the band are adjustable, and are controlled by means of hand wheels, one at each end of the barge controlling one half of the outlets.

B.—FLOATING LOADING DEVICES

If an expensive loading device has to go backward and forward to replenish its contents, as would have to be the case when loading large liners, it would not be in the least economical, as it would be doing work which a less expensive barge might just as well do, whereas, when continually served with an uninterrupted supply from smaller self-

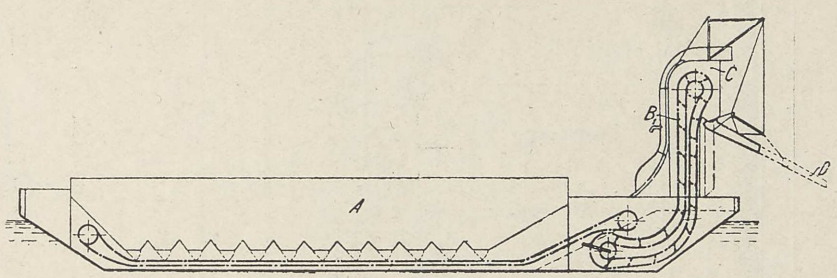


Fig. 672. Doxford Self-Trimming Barge.

trimming barges, an up-to-date loader can handle a surprisingly large quantity in a given time.

Floating Loader built by Smulders, of Schiedam, Rotterdam, Holland.—When tested for speed and capacity before being taken over at the dock of Rotterdam, this device transferred 1,057 tons of coal per hour from the lighter to the bunkers of a liner, probably the smartest performance of the kind on record.

The elevator stands obliquely athwart the barge, and the incline is alterable to reach right across the ship. This manipulation is performed by hydraulic power, whilst the unloading apparatus is driven by steam power. The inclined elevator is driven by an upright shaft geared on to the upper terminal, and the driving power for the whole plant is furnished by two compound engines of 180 H.P. each. The diagrams, Figs. **676** to **678**, are on the same principle, but adapted for different purposes. In both cases the main elevator receives the coal from an automatic self-trimming barge at the point indicated by an arrow. Fig. **676** shows the application of a shorter elevator for serving the bunker inlets at the side of the liner, whilst in Figs. **677** and **678** the elevator is longer and capable of distributing the coal to the side bunkers as well as to those amidship. *a* is the main elevator, *b* and *i* are the supports for the same, as well as for the distributing shoots *c* and *d*, which in their turn supply the coal to the shoots *e f* and *g h*, which lead to the various bunkering holes.

Typical Floating Elevators at the Hamburg Dock.—One of these is

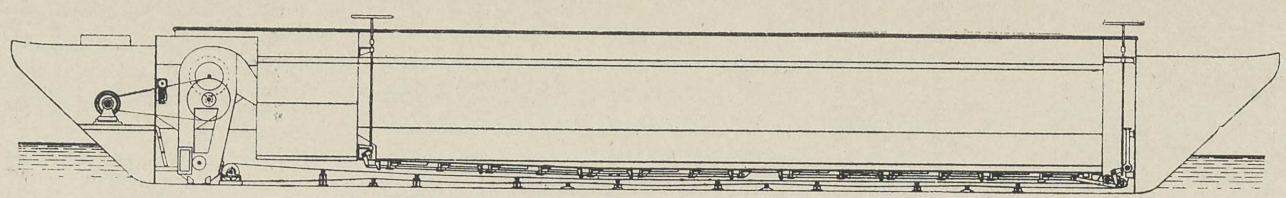


Fig. 673. Longitudinal Section through Philip's Self-Trimmer.

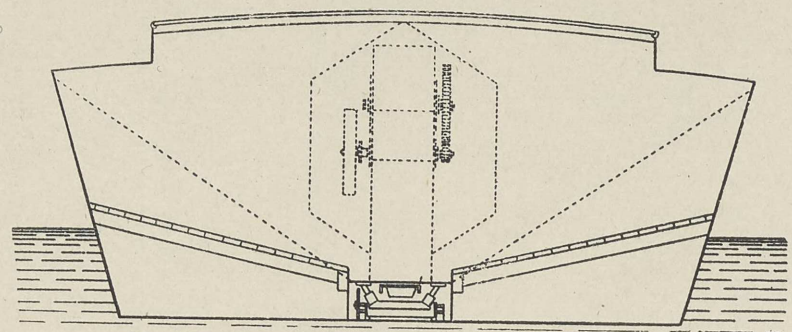


Fig. 674. Cross Section through Philip's Self-Trimmer.

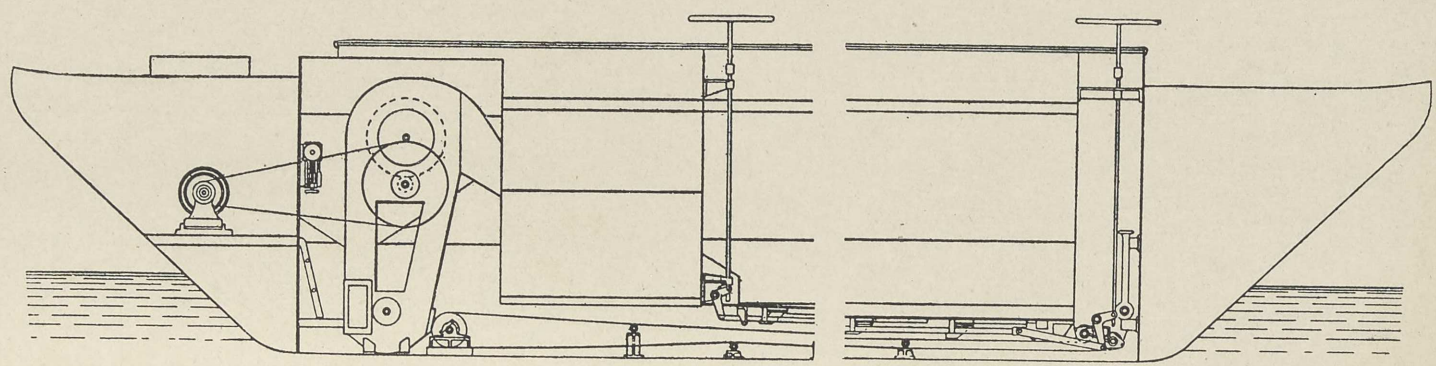


Fig. 675. Giving View of Stern of Philip's Self-Trimmer, also Bow of the Same.

shown in Fig. 679, of which the barge is 114 ft. long by 40 ft. beam. It will be seen that this is hardly as advanced as some of the appliances previously described. The coal is taken by a grab out of an ordinary lighter on a 36-ft. boom, and shot into a receiving hopper *a*, from which it passes to breaking rollers *b*, and thence up to elevators *c* and *d*, one longer and one shorter, from which the coal is paid out in a uniform stream through the shoot *e* into the bunkers; the varying lengths of the elevators are to suit different sized steamers. The installation is one of a number built for the Hamburg-American Line in 1907 by Gebr. Burgdorf, of Altona, on the lines of similar loaders of the Electric Light Co., in the harbour of New York.

A further example is shown in Fig. 680. Here the grab lifts sufficiently high in one operation to dispense with the elevators. *a* is the receiving hopper which delivers either to spouts *c* and *d*, which lead to the side bunker, or on to a band conveyor *b*,

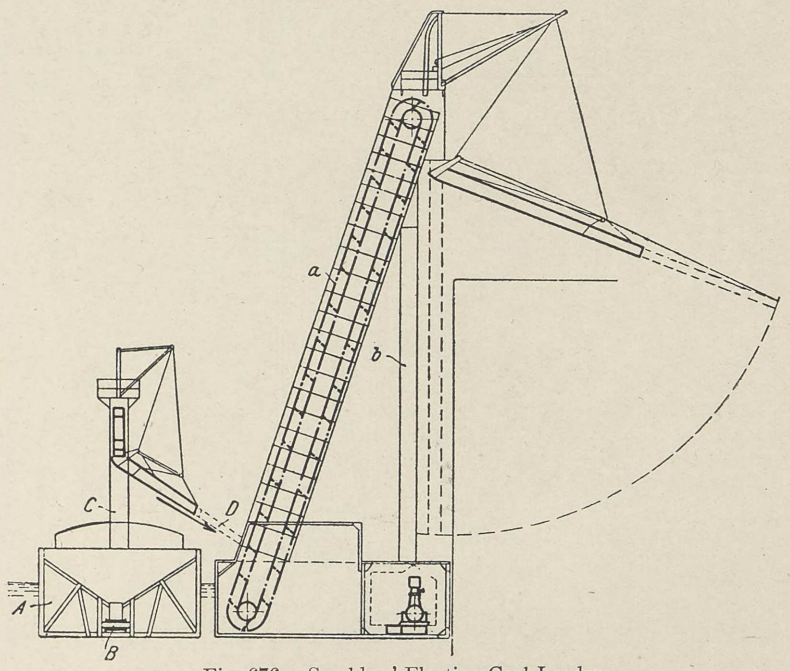
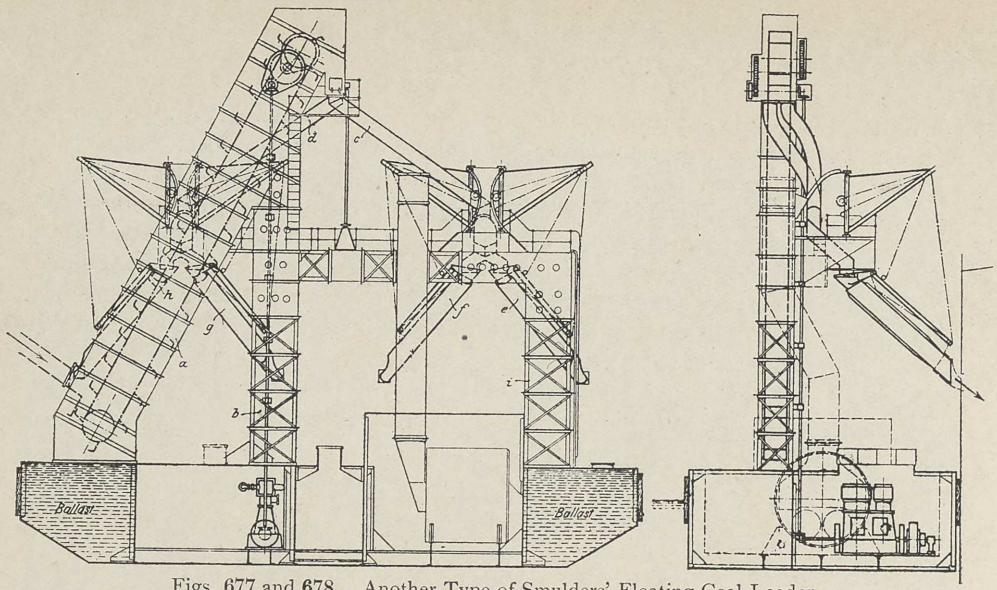


Fig. 676. Smulders' Floating Coal Loader.

which can be raised or lowered to feed into midship bunkers. It must here be pointed out that the arrangement of the cabin for the operator so high up (close to the receiving hopper *a*) is not very satisfactory, as the working is much slower on account of the care which has to be exercised by the driver not to injure the lighters with the grab. The loader previously described has a grab which is only raised 25 ft. and will handle 150 tons per hour, whereas this plant with a lift of 75 ft. has only a capacity of 50 to 60 tons per hour. In this installation two men were necessary, as the winch was situated below in the barge and the two men, one on the top in his cabin, and the other below at the winch, had to be carefully trained to work together. This was afterwards altered, and the winch below with its brakes was manipulated by the man in the cabin by means of pneumatic connections, a decided improvement, although the capacity has not reached that of the earlier type with the elevator. The grab is raised at a speed of 12 ft. per second, lowered at 25 ft., and travels at the rate of 7 to 8 ft. per second.



Figs. 677 and 678. Another Type of Smulders' Floating Coal Loader.

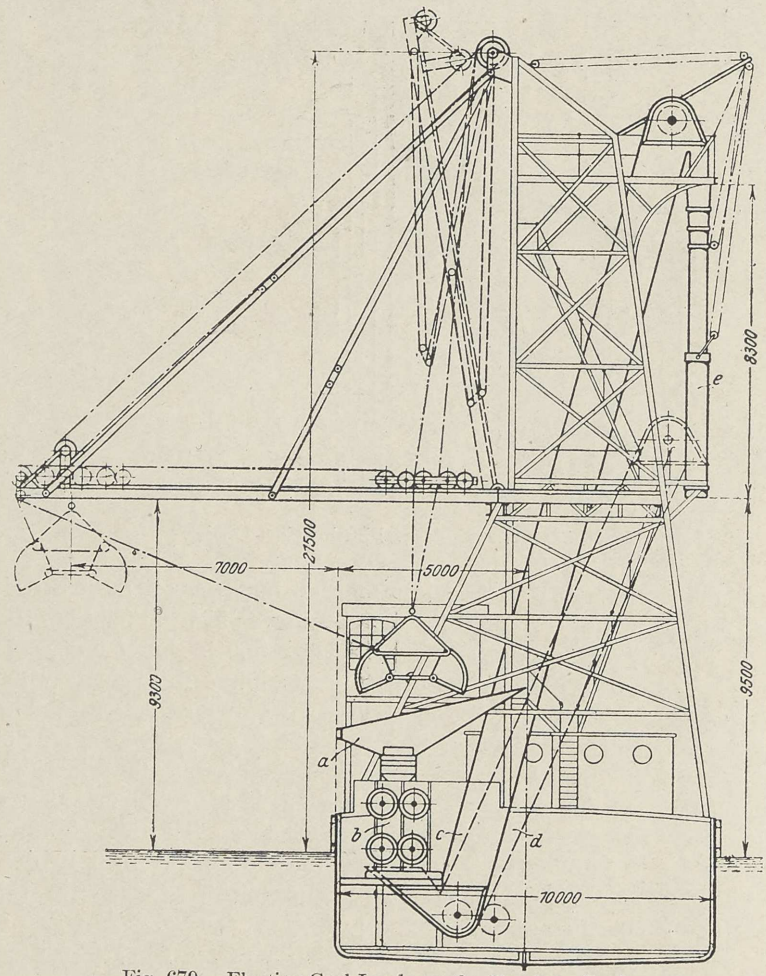


Fig. 679. Floating Coal Loader at the Hamburg Dock.
(The dimensions are in millimetres.)

Floating Grab Transporter at Table Bay Harbour.—This very fine installation, which was built by Messrs Frasers & Chalmers, will be readily understood from Figs. **681** and **682**. Several loading devices fitted with grabs have already been described more fully. The explanation given on the diagram will make this example quite clear.

Loader at Rotterdam.—A floating loading device used in the harbour of Rotterdam is shown in Fig. **683**. It is similar to the loader, Fig. **679**, but has the additional band conveyor contained in a double lattice girder of jib *d*, which takes some or all the coal across the ship into a portable receiver *f* on the quay wall; this com-

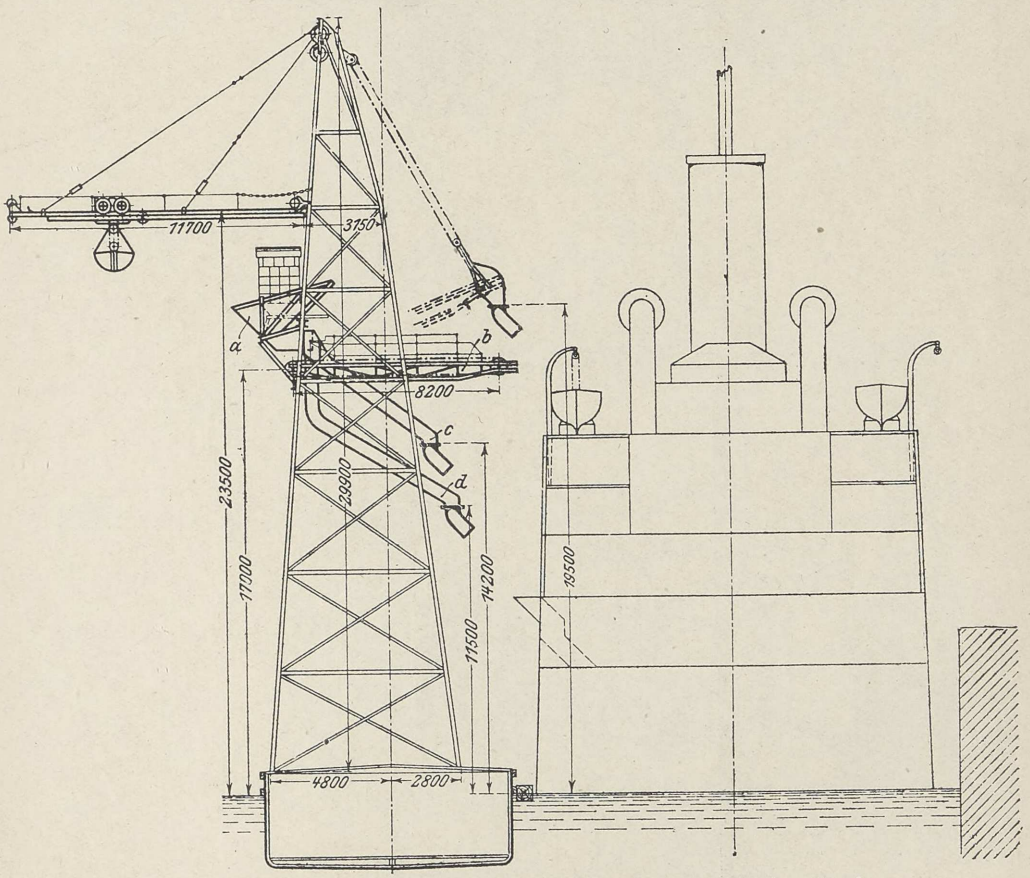
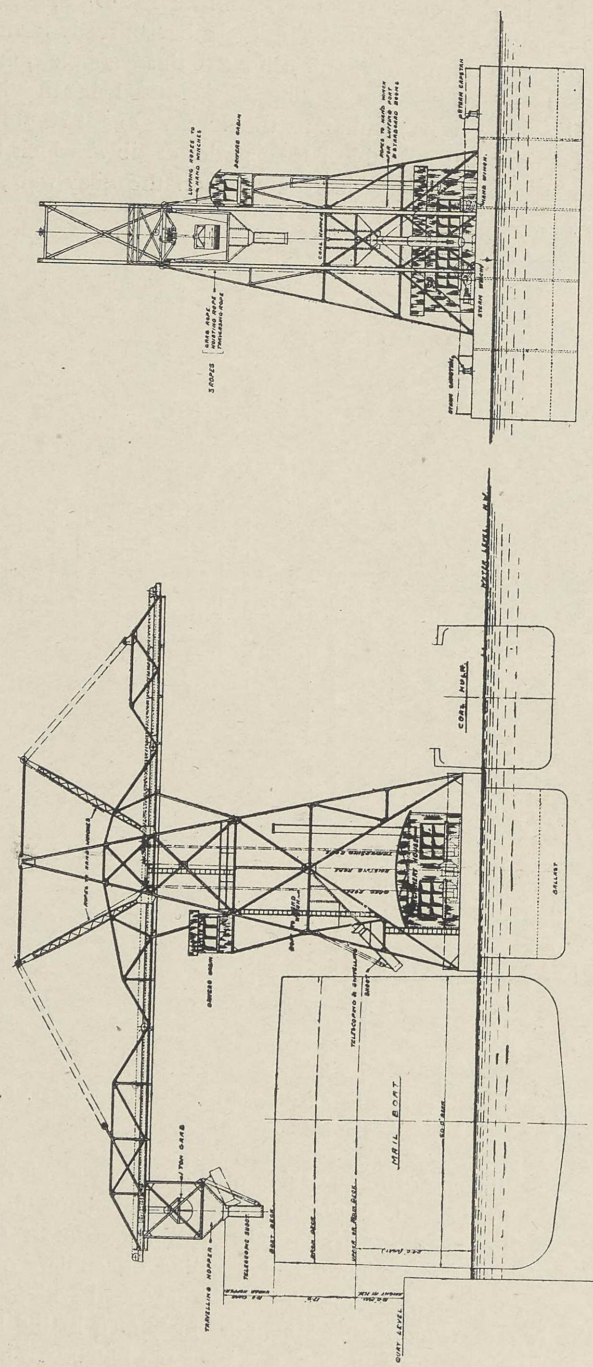


Fig. **680**. Another Example of Floating Coal Loader at the Hamburg Dock.
(The dimensions are in millimetres.)

municates with the bunkering holes on the quay side of the ship by shoot *e*, so that with this installation the bunkers on either side of the ship can be filled simultaneously.

The Lidgerwood-Miller Marine Transfer for Broadside Coaling in Harbour.—This coaling device was designed and installed on colliers of the United States Navy for the purpose of rapidly discharging their own coal with a minimum of hand labour. Before the introduction of this apparatus forty men in the hold and two at the winches would discharge 30 tons of coal per hour per hatch. With the marine transfer one man at the winches can discharge 138 tons per hour without men in the hold.

Unlike other similar devices, the track for the load is here not on a rigid rail but



Figs. 681 and 682. Floating Transporter at Table Bay Harbour.

a taut cable (see Figs. **684** and **685**). The cables manipulating the grab bucket lead from the drum of the winch over an overhead block, which is supported at a high point above the hatch, the bucket normally plumbing the hatch. The pendant portion of the bucket cable passes through a swinging block, the purpose of which is to deflect the bucket cable, thus swinging the latter in the manner of a pendulum, from the position where it takes its load to the delivery point. The swinging block is operated by two swinging cables, which are attached thereto and extend in opposite directions round the leading blocks at the end of the outstretched boom, and thence to the drums of the swinging winch.

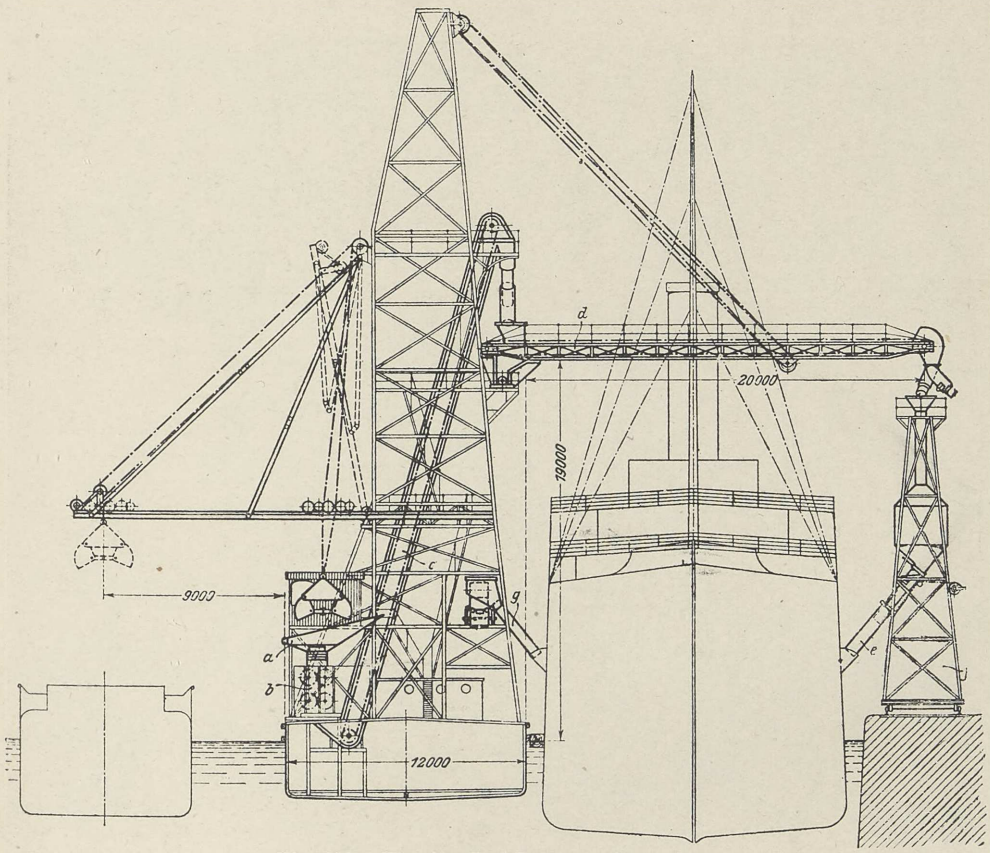


Fig. 683. Floating Coal Loader at Rotterdam.
(The dimensions are in millimetres.)

It will thus be seen that there are two separate winches for operating the marine transfer. One winch ("bucket winch") controls the opening and closing of the grab bucket and the vertical motions thereof, while the second winch ("slinging winch") controls the horizontal motions.

The winches have double $9\frac{1}{4}$-in. by 10-in. cylinders with piston valves. The gears are completely enclosed to exclude foreign substances. Each winch has a piston type reverse valve. The bucket winch is provided with a metallic brake which is not affected by weather conditions. The control of each winch consists of one pump handle lever, which in mid-position stops the winch; lifted, hoists the load; lowered below mid-position, lowers the load. The reverse valves are of special construction, absolutely controlling

the hoisting and lowering of the load at any speed. These winches will handle a $1\frac{5}{8}$ cub. yd. bucket weighing 4,000 lb. filled with 1 ton of coal, with 150 lb. steam pressure. The rated capacity of the winches is 100 tons per hour. The actual capacity attained under test as mentioned was 138 tons per hour. The average time occupied by each trip of the bucket is twenty seconds.

In the first installations for the U.S. colliers "Vestal," "Prometheus," and "Hector" the winches were of the metallic friction drum type, each being controlled by its own operator. In the latest development of the marine transfer the winches are

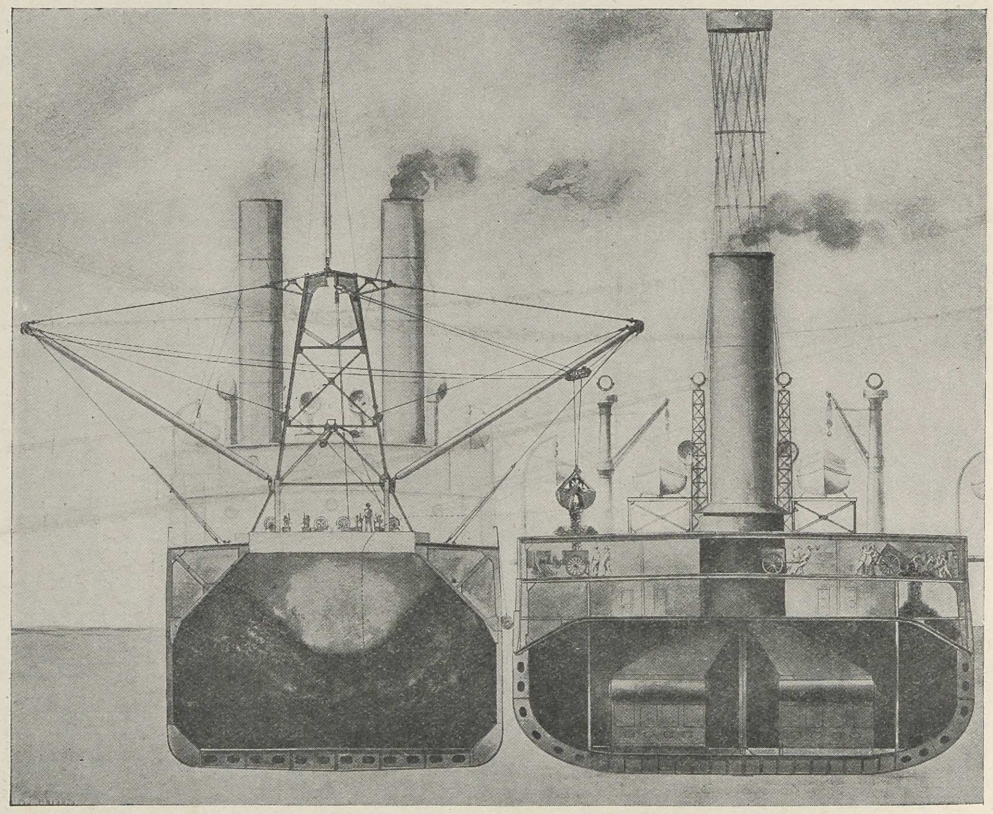


Fig. 684. The Marine Transfer as Installed on U.S. Colliers "Neptune," "Jason," and "Orion."

so designed that they can be controlled by a single operator by two hand and one foot levers; a second foot lever is provided but is only used occasionally for the adjustment of the lines. These ships have very tall masts, thus providing a very high point of support for the overhead block, which is desirable as it greatly reduces the strain in the booms and rigging.

The record of the official test for the two operators with their two winches is 190 tons per hour from a single hatch, made in 1909 with the collier "Hector."

The later installations for two winches (see Fig. 686) with one operator are equipped on the U.S. colliers "Neptune," "Orion," and "Jason." Structural steel A-frames are

mounted between the hatches, these structures being connected by a fore and aft girder to which the overhead blocks are attached (see Fig. **684**). These girders are also provided with a track-way for the fore and aft transfer of coal for purposes of trimming and bunkering coal. The actual capacity attained under test was 138 tons per hour per hatch. Fig. **685** shows the U.S.S. "Jason" coaling the U.S.S. "Mars."

Floating Coal-Loading Devices Fitted with Temperley Transporters.—These are largely used. They either transport their own contents to the ship to be bunkered, or they transfer the coal from a barge to the bunkers of the vessel, so that the loading device lies between the barge and the vessel.

As an example may be cited the one in use at Portsmouth, which holds 12,000 tons of coal for bunkering men-of-war, and carries four towers fitted with twelve transporters, so that the coal can be transferred at the rate of 600 tons per hour. A similar but some-

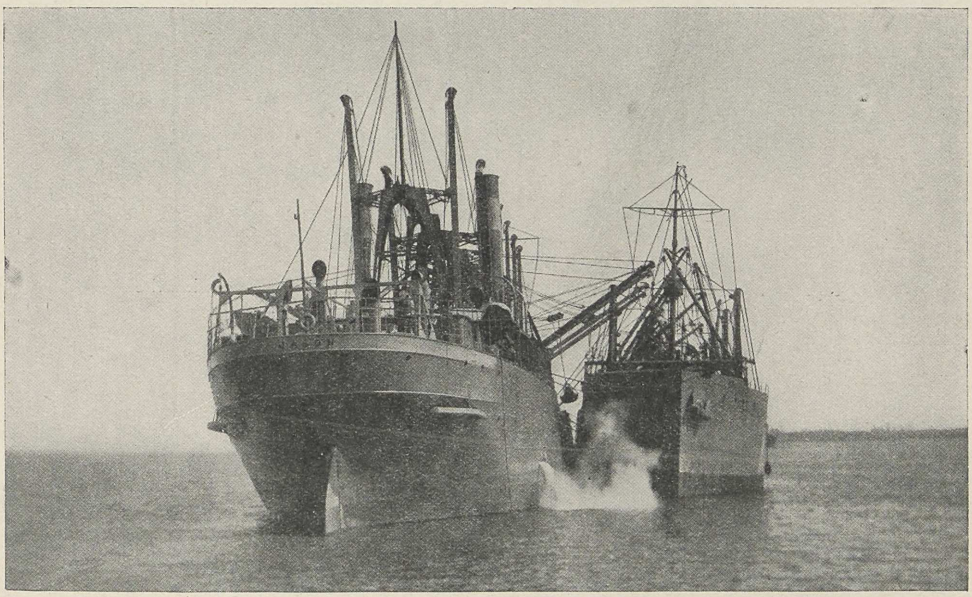


Fig. 685. The U.S.S. "Jason" coaling U.S.S. "Mars."

what smaller installation was built by the Thames Ironworks for Devonport. It has a capacity of 100 tons of coal, which can be transferred to the bunkers of other ships at the rate of 50 to 60 tons per hour. The coaling ship "Neptune," built by the Maryland Steel Co. for the American Navy, is of different construction. Here the running heads or trolleys supporting the grab do not run on girders similar to other transporters, but on taut wire cables.

Portable Transporters.—These are usually called in the service "Temperleys," and are used in the British Navy for coaling H.M. war vessels, hundreds having been supplied to the British Admiralty, and a considerable number to the French, German, Russian, Italian, Austrian, Portuguese, Japanese, Chilian, Brazilian, and Argentine Governments. Fig. **687** shows a small coaling craft so fitted. They are also used in increasing numbers on merchant vessels carrying coal, ore, and other cargo in bulk.

General Remarks.—From the description of these coaling devices it will be seen that considerable strides have been made of late in the design and development in this

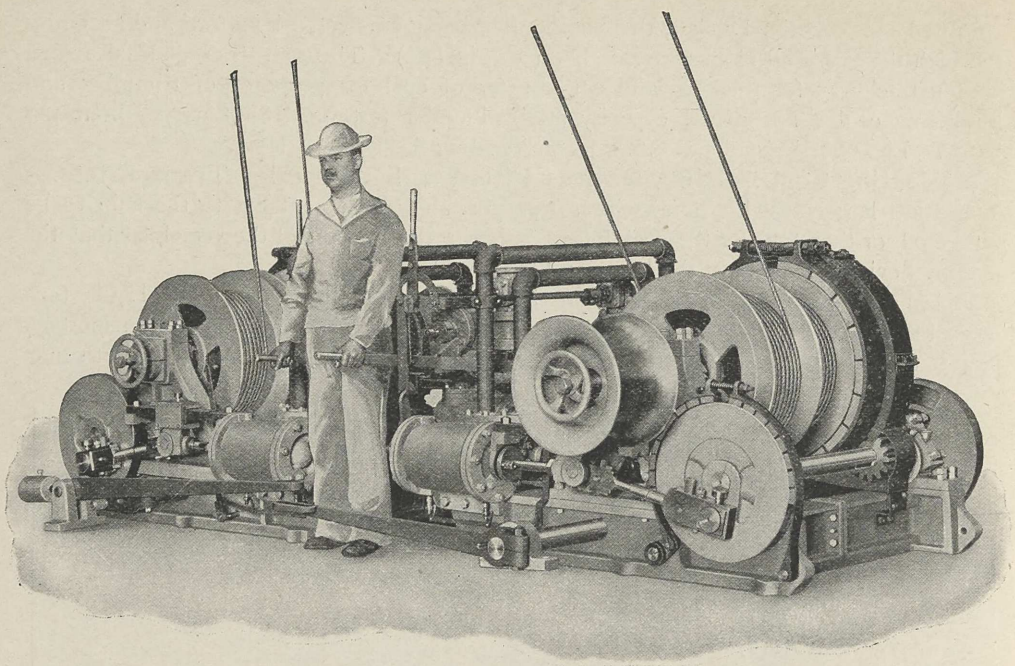


Fig. 686. Marine Transfer Winches for One-man Control, for Operating the Marine Transfer.

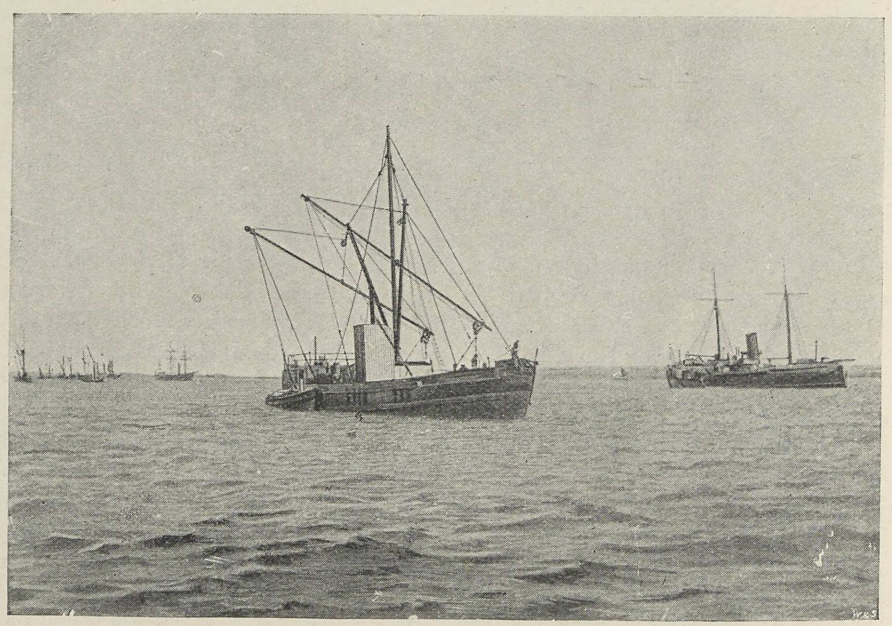


Fig. 687. Small Coaling Vessel fitted with two Temperley Transporters.

direction, and although we are probably better equipped in this country at our principal coal ports than any other country for mechanically disposing of cargo coal, we lack in other ports the facility for transferring bunker coal mechanically into ships, and in this respect some of the Continental ports, particularly that of Hamburg, are in advance. In the Port of London, even, a great deal of hand bunkering may be seen, in spite of the continual labour troubles, and where mechanical means are used they are often of the most primitive kind, consisting of a barge with a couple of steam winches which raise the coal in baskets out of the lighters, and then transfer it to the bunkers. By these primitive means, and with nine men filling the baskets in the lighters and emptying them into the bunkers, as well as three men working the winches, etc.—in all twelve men—only 240 tons in ten hours are handled, at a cost of 9d. per ton.

In addition to the expense and the time required for hand bunkering, there is a further drawback in the fact that the ship has to be cleaned down after this method of bunkering, whilst this is not necessary after mechanical bunkering.

Notwithstanding the above-mentioned facilities, available at some of the Continental ports, the North German Lloyd at Bremen still bunkers almost exclusively by hand.

UNLOADING OF RAILWAY WAGONS

This subject may be divided under two heads, namely :—

A. UNLOADING BY MEANS OF SPECIALLY CONSTRUCTED SELF-EMPTYING HOPPER WAGONS, GENERALLY WITH HINGED DOORS; AND

B. UNLOADING RAILWAY WAGONS BY MEANS OF TIPS OR HOISTS

CHAPTER XXXIV

UNLOADING BY MEANS OF SPECIALLY CONSTRUCTED SELF-EMPTYING HOPPER WAGONS

SELF-EMPTYING railway trucks occupy a place of the first importance among labour-saving appliances, though British railway companies hardly appear as yet to realise their full importance. The commercial success of many an industry, and especially of that of the production of pig iron, depends to a great extent upon the efficiency and economy of the transport arrangements,[1] and in this self-emptying trucks play a most important part.

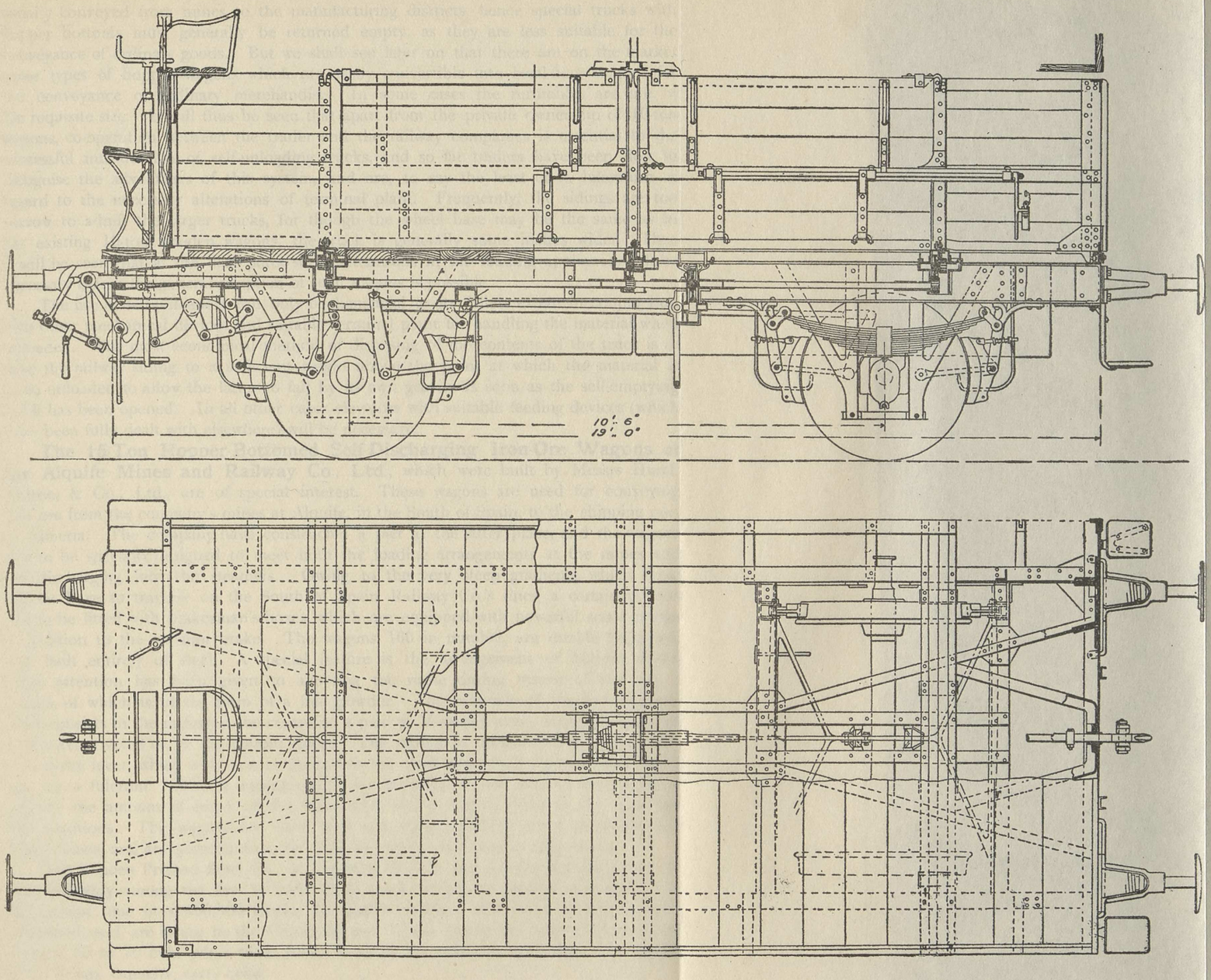
The enormous saving to be effected, not only by the adoption of self-emptying railway trucks but also by giving them a considerably increased capacity as compared to the usual 10-ton railway trucks, is demonstrated by the following figures. For instance, a steel works receiving daily 200 truck-loads of ore and coal would, at a low estimate, pay for the unloading of each truck say only one shilling. This means a yearly expenditure for unloading alone of £3,000, but that sum could be almost entirely saved by the adoption of self-unloaders.

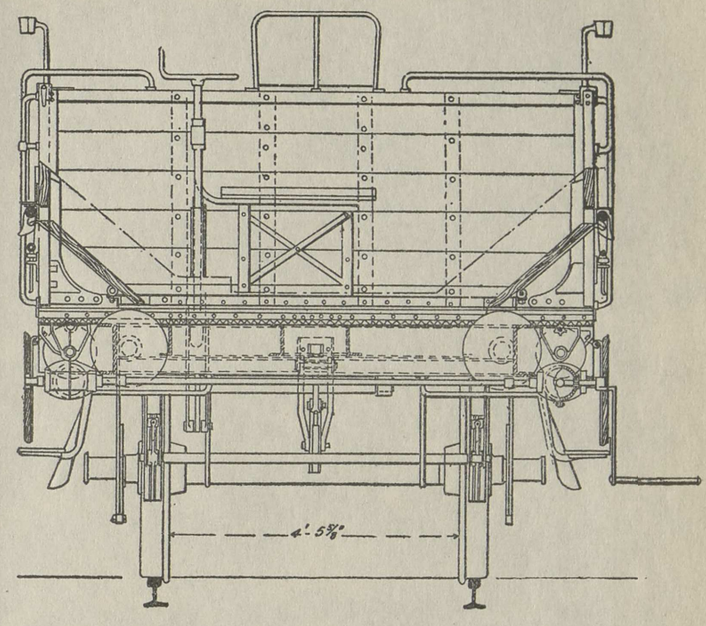
The speed with which such trucks can be discharged saves demurrage and the trucks may be returned for reloading oftener, thus fewer wagons are needed. They are economical in the commercial sense, when the distance to be traversed is not too great, so that say two journeys per day can be made, though it is essential that the quantity to be handled should be sufficient for whole trains to be formed of these self-emptying trucks; special trucks having generally to return empty is not a serious matter for short distances and when whole trains of empties can be returned together.

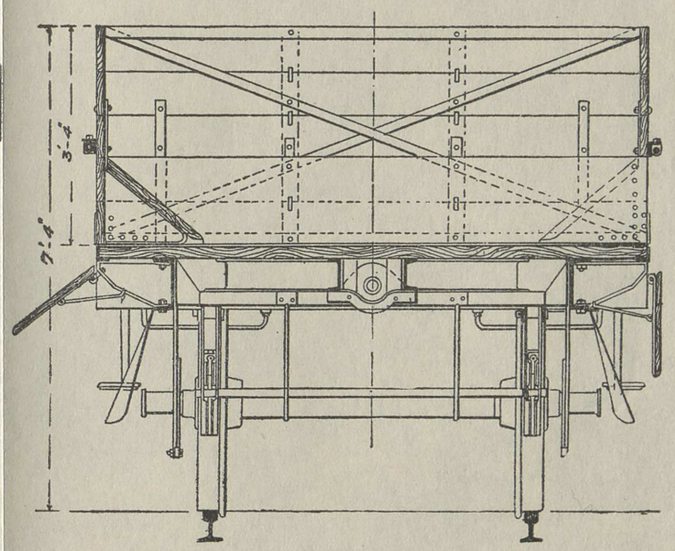
A factor which militates against the general adoption of large capacity self-emptying trucks for the carriage of coal, either consigned to ports or intended for inland consumption, is the height of the loading screens at some of the pits. The clearance is usually so small, that an increase in height means, in many cases, that wagons cannot be shunted under the screens to be loaded.

Another difficulty is this, that self-unloading trucks for coal, minerals, etc., are

[1] Those specially interested in this subject will find much useful information in a pamphlet entitled "Private Owners' Wagons," by S. R. Blundstone, published by The Railway Engineer, 15 Farringdon Avenue, E.C.







Figs. 688 to 691. Self-unloaders on the Baden State Railway.

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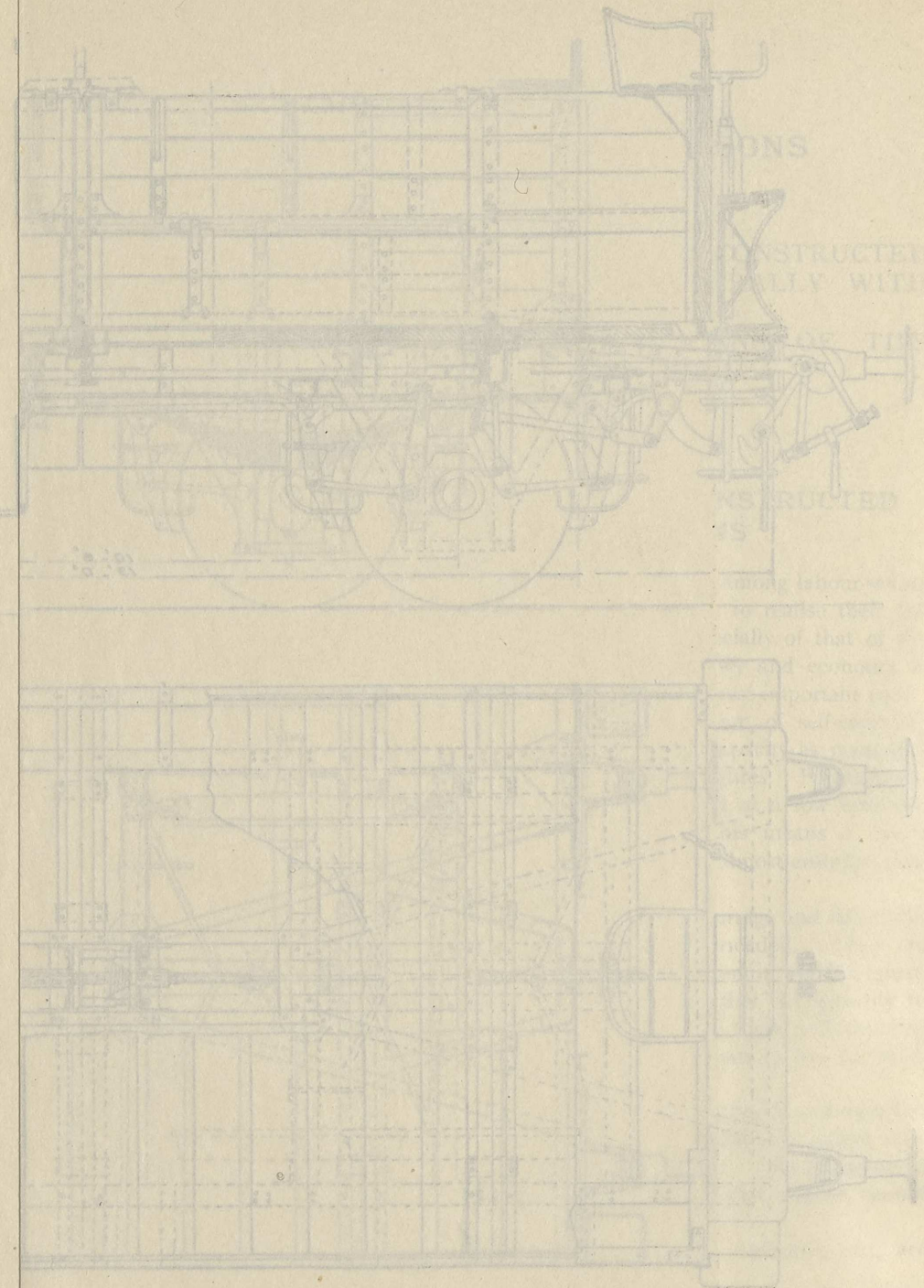


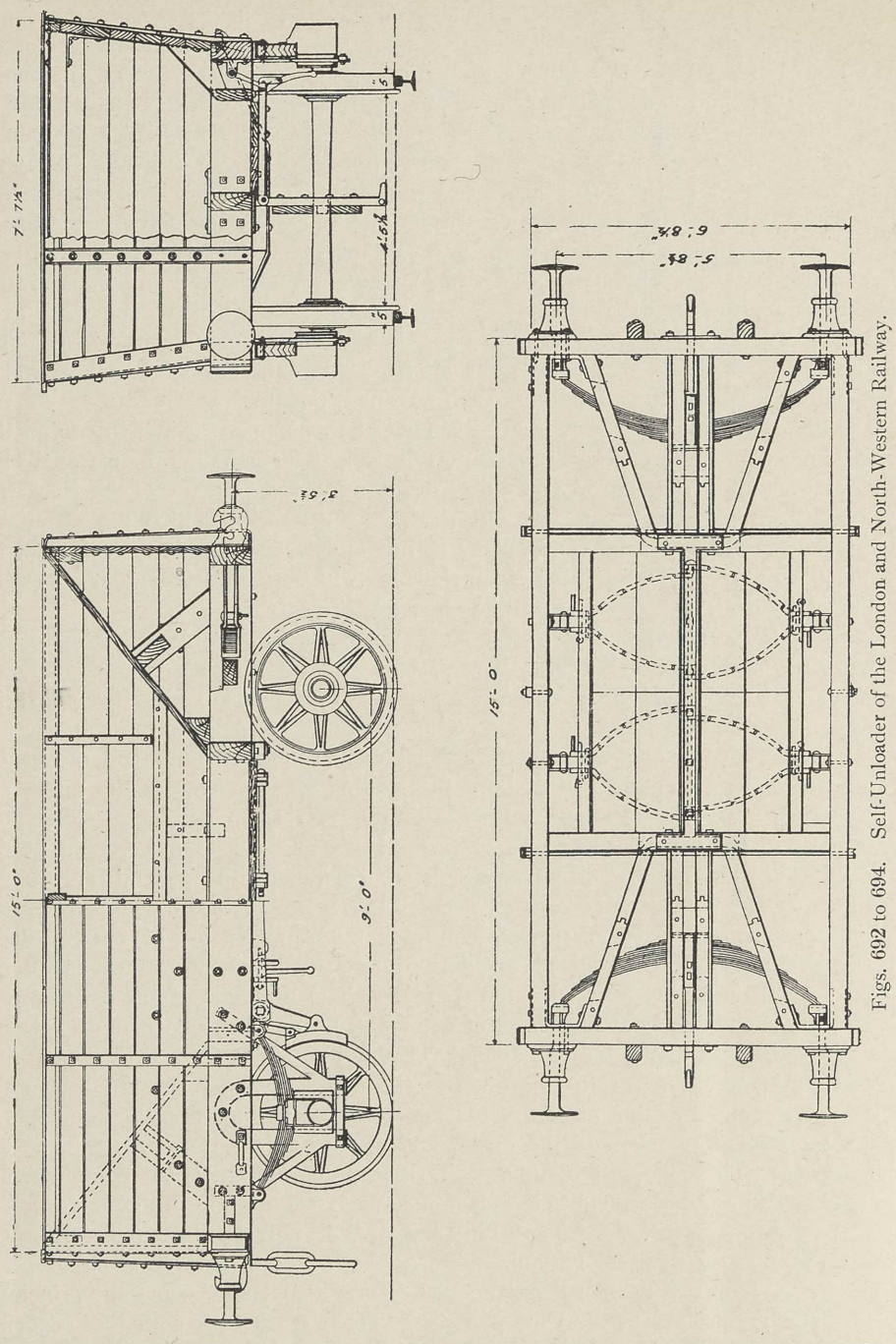
usually conveyed from mines to the manufacturing districts, hence special trucks with hopper bottoms must generally be returned empty, as they are less suitable for the conveyance of ordinary goods. But we shall see later on that there are on the market some types of hopper wagons which are easily convertible into level-floor wagons for the conveyance of ordinary merchandise. In some cases the turntables are not of the requisite size. It will thus be seen that apart from the private ownership of 10-ton wagons, co-operation between the trader and the railway companies is essential to the successful introduction of self-unloading trucks, and so far traders have been slow to recognise the advantages of this system, and are, to say the least of it, lukewarm in regard to the necessary alterations of terminal plant. Frequently, the sidings are too narrow to admit the larger trucks, for though the wheel base may be the same as in the existing 10-ton wooden wagons, the truck is generally some inches wider. Thus it will be seen that at the coal ports some alterations in the loading appliances will be necessary before the general adoption of such wagons is possible.

The use of self-unloaders can only be beneficial to its fullest extent in conjunction with other mechanical devices and suitable terminal plant for handling the material when unloaded. The most economical method of disposing of the contents of the truck is to raise the railway siding to a sufficient height above the point at which the material is to be unloaded to allow the latter to fall by its own gravity as soon as the self-emptying truck has been opened. In all other cases elevators with suitable feeding devices (which have been fully dealt with elsewhere) will be necessary.

The 15-Ton Hopper-Bottomed Self-Discharging Iron-Ore Wagons of the Alquife Mines and Railway Co., Ltd., which were built by Messrs Hurst, Nelson, & Co., Ltd., are of special interest. These wagons are used for conveying iron ore from the company's mines at Alquife, in the South of Spain, to the shipping port of Almeria. The company have constructed a pier at the latter place, and the wagons had to be specially designed to meet both the loading arrangements at the mines and the discharging into the steamers. Owing to the very steep gradients which these wagons have to traverse on the South of Spain Railway Co.'s lines, a certain portion had to be fitted with brakesman's boxes, which are equipped with powerful screw brakes in addition to the vacuum brake. The wagons, 160 in number, are double hoppered, and built entirely of steel. A special feature is the arrangement of bottom doors. Close attention has been given to avoiding the waste during transit of any ore, a portion of which is in the form of a fine powder. The principle of the door arrangement consists in the raising at the centre of a pair of V-shaped arms, which are attached to brackets riveted on to the bottom doors. The motion is transmitted by a cross-shaft to a centre lever, which is in turn connected to the door arms by a separate lever which acts on a fulcrum. Suitable arrangements are provided at one side of the wagon to regulate the amount of travel of the doors, and also to secure them in the open and shut positions. The wagons are fitted with side spring buffers, screw couplings, and safety chains, and are quite equal to the class of rolling stock used in this country.

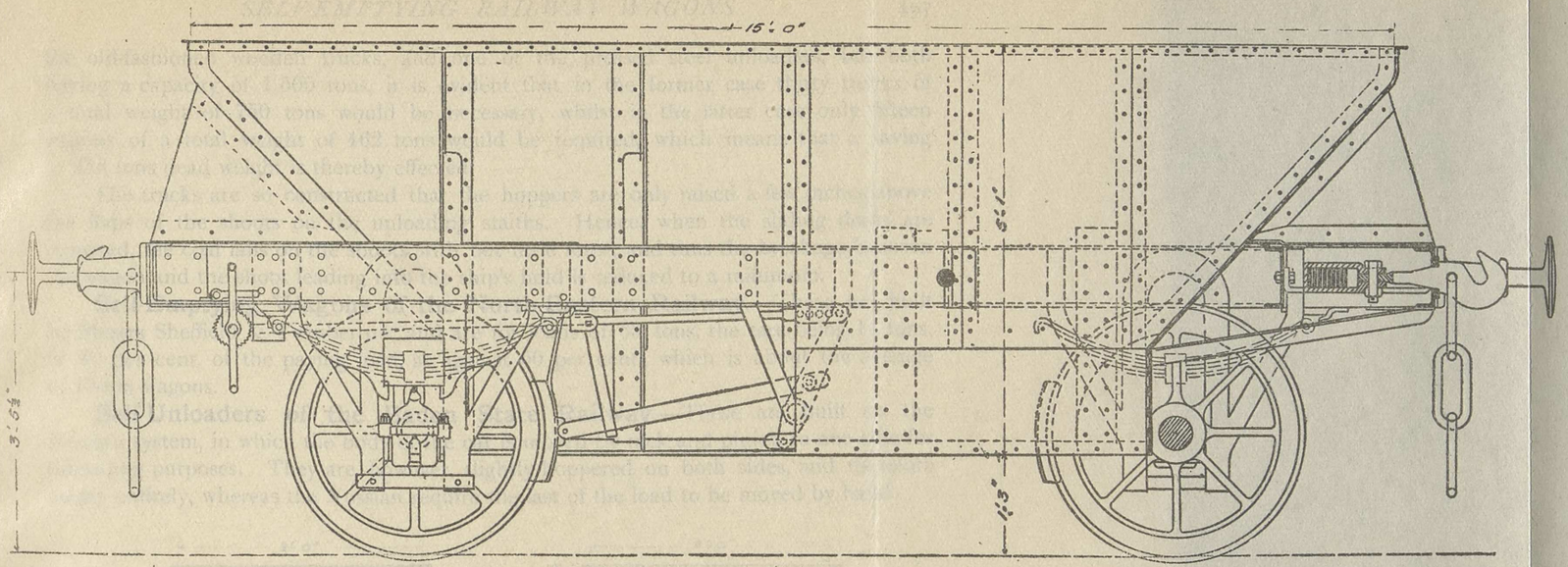
The Lehoen Pressed Steel Co., of Pittsburg, U.S.A., and the Pressed Steel Car Co. were probably among the first to build these trucks largely of pressed steel parts. At the present time over 400,000 trucks, the bodies of which have been built principally of pressed steel, are in use in the United States. These trucks are built with capacities of from 30 to 70 cub. yds.; those from 30 to 50 are used for coal, while the largest, up to 70 yds. capacity, carry coke.

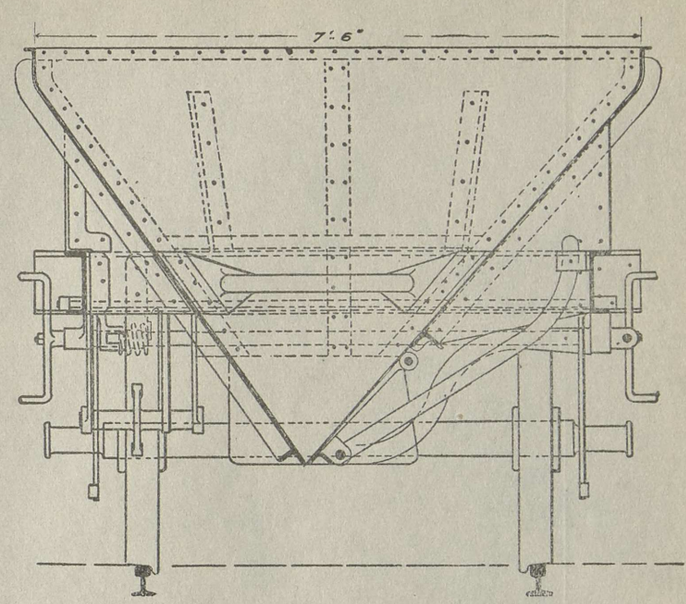
It must not be supposed that these steel wagons are more expensive than the old-fashioned wooden ones, or that they compare unfavourably when the capacity per

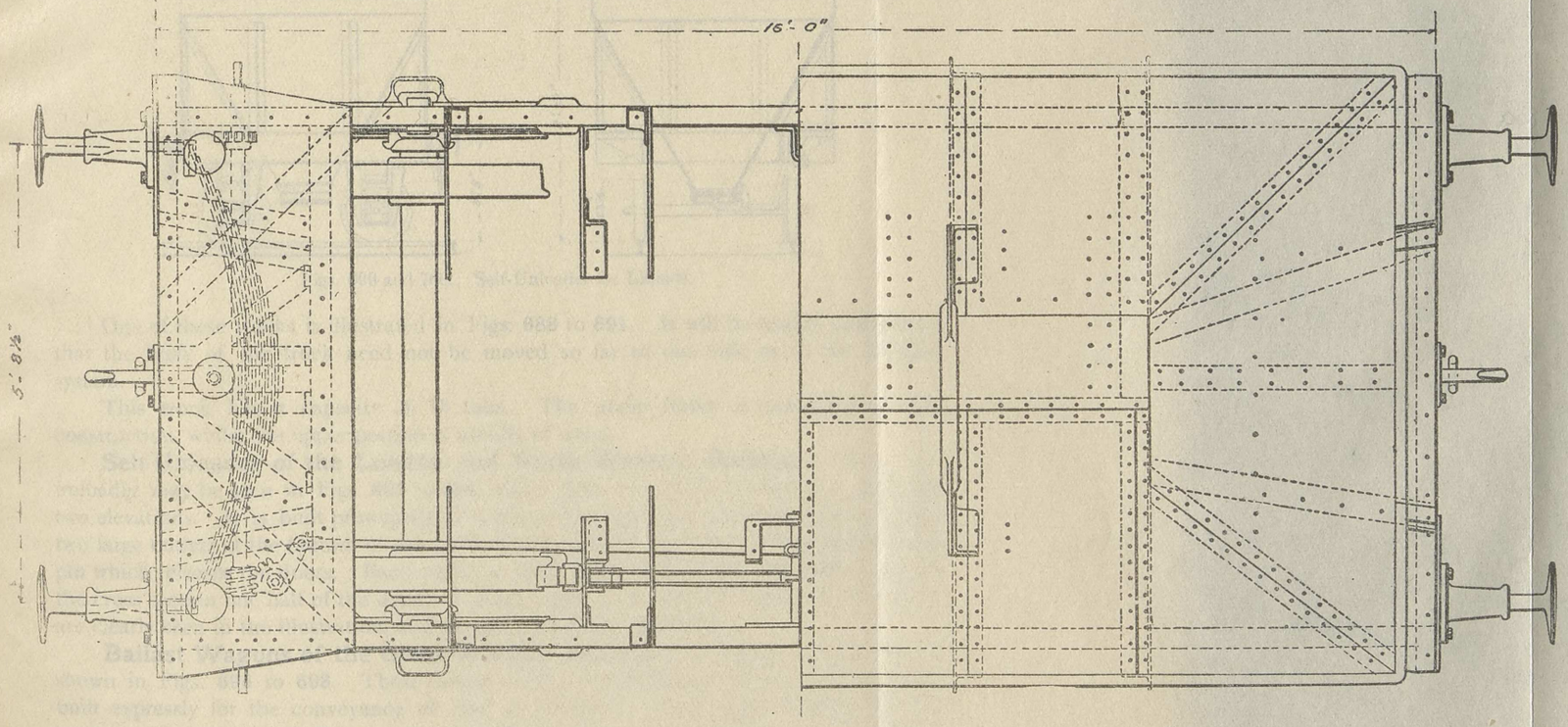


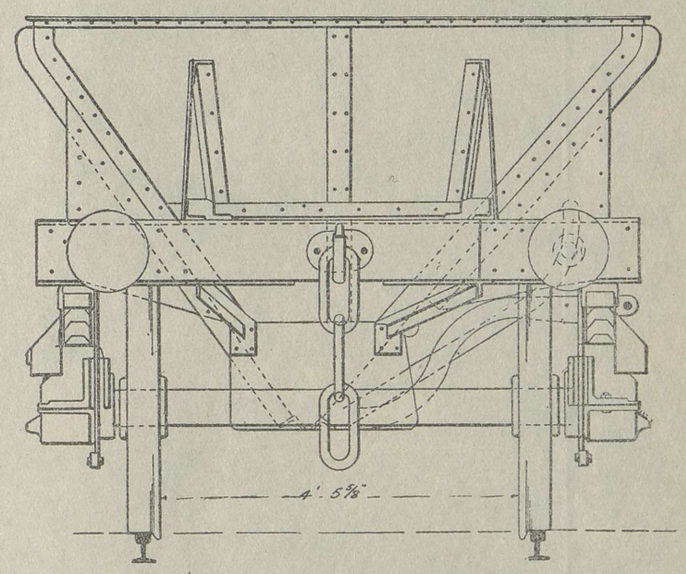
Figs. 692 to 694. Self-Unloader of the London and North-Western Railway.

ton is compared with the total cost. The wear and tear on the steel ones is also considerably less than in the case of wooden trucks. The weight of a wooden truck of a capacity of 30 tons is 15 tons, whilst that of a pressed steel self-discharging truck of a capacity of 50 tons is 15½ tons. Thus, comparing two trains, one composed of









Figs. 695 to 698. Ballast Wagons of the Great Western Railway.

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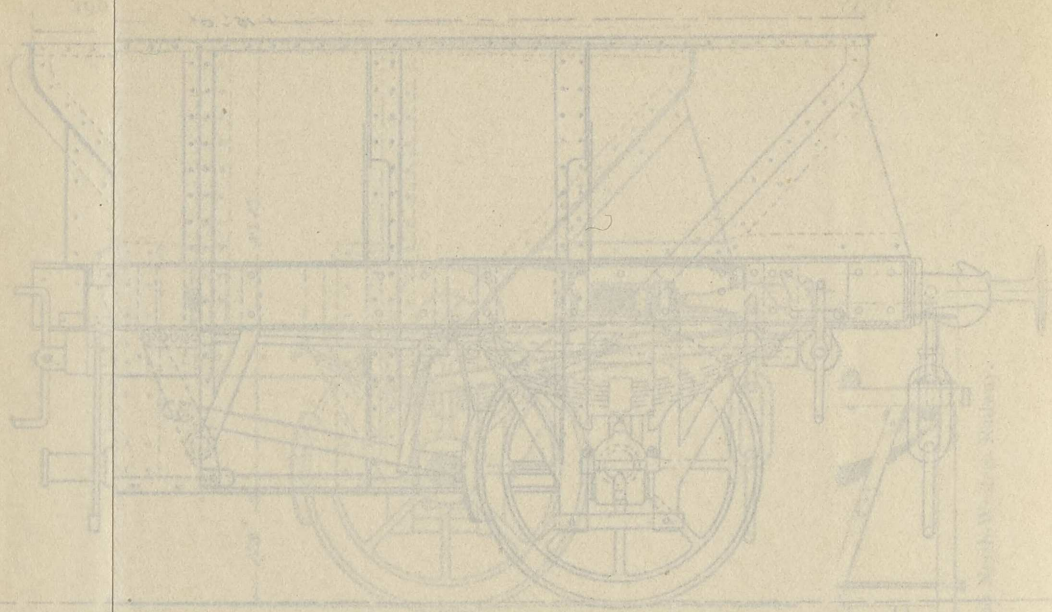
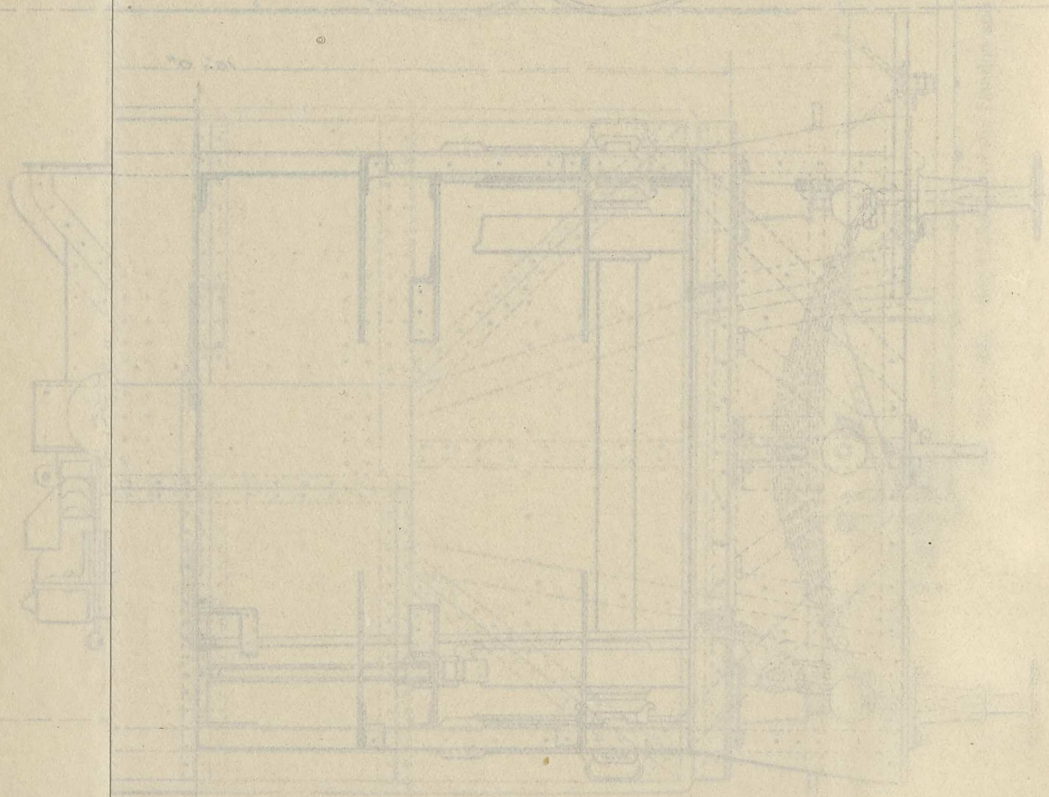


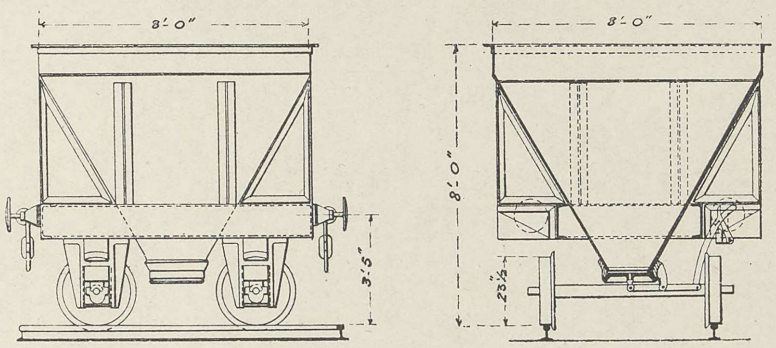


the old-fashioned wooden trucks, and one of the pressed steel unloaders, but both having a capacity of 1,500 tons, it is evident that in the former case thirty trucks of a total weight of 750 tons would be necessary, whilst in the latter case only fifteen wagons of a total weight of 462 tons would be required, which means that a saving of 288 tons dead weight is thereby effected.

The trucks are so constructed that the hoppers are only raised a few inches above the flaps of the shoots on the unloading staiths. Hence, when the sliding doors are removed, the coal falls on the shoots with but little force, and thus the breakage between the wagon and the shoot leading into the ship's hold is reduced to a minimum.

Self-Emptying Wagons of the North-Eastern Railway.—These are built by Messrs Sheffield & Twinberrow, and are for loads of 35 tons, the tare being 14 tons, or 40 per cent. of the paying load, as against 50 per cent., which is about the average of 10-ton wagons.

Self-Unloaders of the Baden State Railway.—These are built on the Nossian system, in which the body of the car is moved by rack and pinion to one side for unloading purposes. They are, however, slightly hoppered on both sides, and therefore empty entirely, whereas the Nossian require the last of the load to be moved by hand.



Figs. 699 and 700. Self-Unloader for Liquids.

One of these trucks is illustrated in Figs. **688** to **691**. It will be readily understood that the body of the truck need not be moved so far to one side as in the Nossian system.

This truck has a capacity of 18 tons. The under frame is generally of iron construction, whilst the upper portion is usually of wood.

Self-Unloader of the London and North-Western Railway. — This self-unloader may be seen in Figs. **692** to **694**, which show one of these trucks in plan and two elevations. It is built principally of wood, is hoppered, and discharges its load from two large outlets at the bottom of the truck, the discharge being effected by withdrawing a pin which releases the doors. Each outlet is really again divided into two halves, and in the cross section one half of the outlet is shown open. All the other parts of the wagon are clearly seen in the illustration, and require no further description.

Ballast Wagons of the Great-Western Railway.—A wagon of this type is shown in Figs. **695** to **698**. These ballast trucks, though self-unloading, have not been built expressly for the conveyance of coal or minerals. They were designed for the purpose of depositing ballast on the permanent way. The operation of laying and spreading is effected as the train moves slowly forward, but there is no reason why wagons of this type should not also be used for the delivery of coal or minerals. The

illustrations should explain themselves. The whole truck is hoppered and terminates in two large outlets. These wagons were built in connection with the "Rodger's" ballast system.

The train containing these self-emptying trucks has a rear van attached to it with the

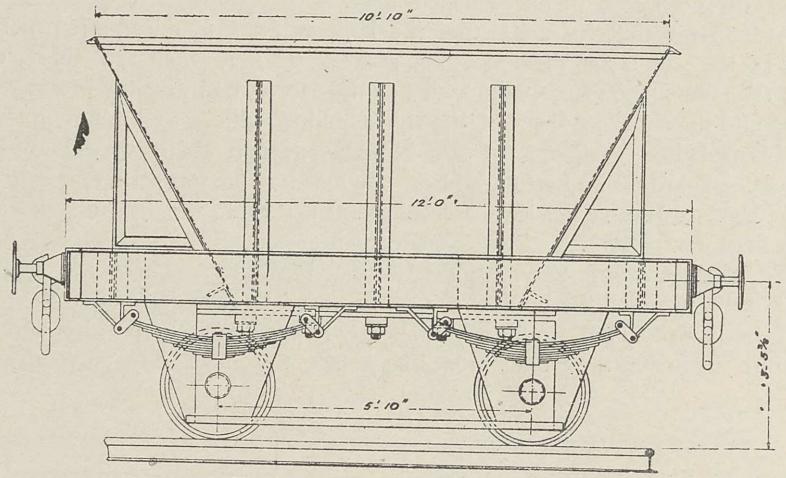


Fig. 701. Type of Self-Unloader.

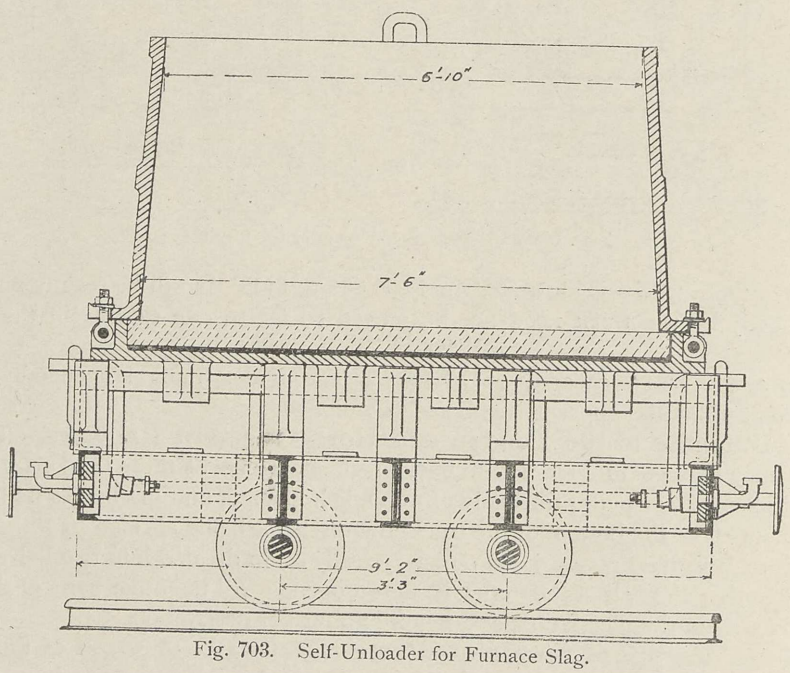


Fig. 703. Self-Unloader for Furnace Slag.

plough. The nearest hopper to this plough is emptied first, the hopper in advance always being opened just before the preceding one is empty. The plough, following the trucks and being a rear vehicle of the train, spreads the ballast evenly, and leaves the road in perfect condition for the traffic. The whole operation of spreading the

contents of a train of fifteen trucks, containing about 180 tons of ballast, can be carried out in from eight to ten minutes. In this system only two men (the brakesman and his mate) are required to perform the whole operation, which formerly required thirty to forty men, and occupied some hours.

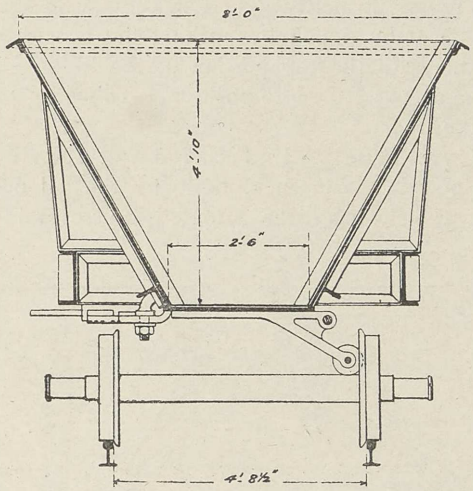


Fig. 702. Cross Section of Fig. 701.

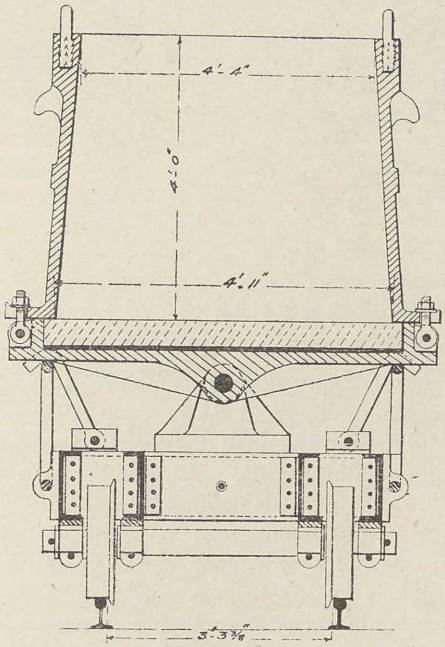


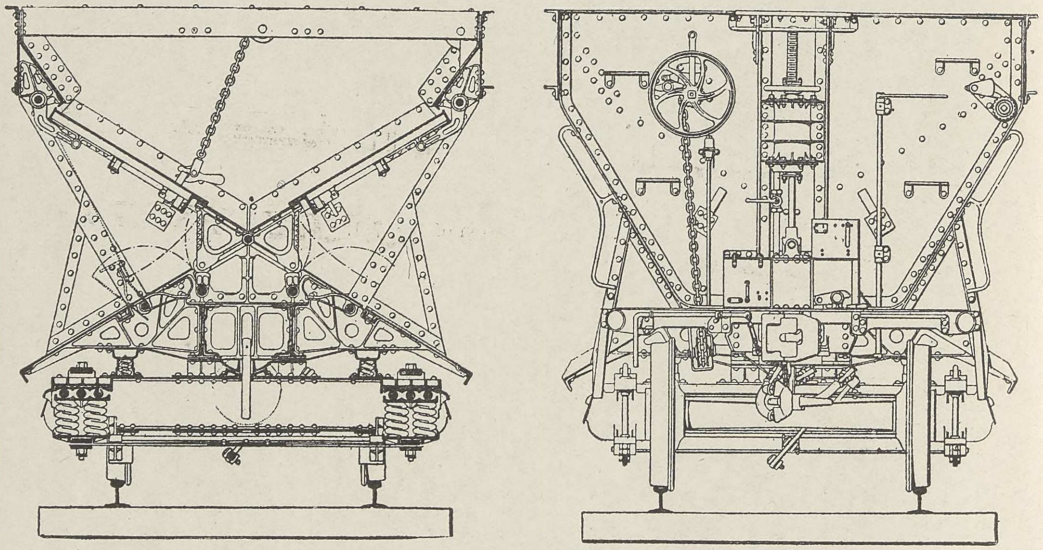
Fig. 704. Cross Section of Fig. 703.

Self-Unloaders Built by Willich, of Dortmund.—Figs. **699** and **700** represent a special truck which is fully hoppered with one outlet. This is designed for the conveying and discharging of materials such as slurry, slag, lime, etc., and has a capacity of 6 cub. yds.

The same firm also make a number of other trucks specially designed for different purposes. Figs. **701** and **702** show one of their special trucks for ore, coal, coke, slag, sand, etc. It is hoppered in both directions and fitted with two large outlets.

Figs. **703** and **704** show a truck specially designed for the conveyance of furnace slag. The illustrations represent the truck in longitudinal and cross section, and explain themselves. The truck can be tipped by pushing the fastenings to one side, and the slag is discharged together with the top portion of the truck. The latter is afterwards picked up by the crane and put back into position. The sides of the car being tapered, the slag readily leaves the truck.

The Goodwin Coal Truck.—In Figs. **705** and **706** are shown an end view and cross section of the Goodwin coal truck, built by the Gloucester Railway Carriage and Wagon Co., Ltd., which has been adopted on several of the American coal carrying lines.



Figs. 705 and 706. End View and Cross Section of Goodwin Coal Truck.

The body of the truck is built upon two plate girder sills 21 in. apart. These girders are 18 in. deep at the middle, and $9\frac{1}{4}$ in. deep at the ends. The space between the sills is left clear for dumping the load between the rails, and from each sill there is an apron or floor inclining downwards. The two ends of the truck are connected by top side plates 18 in. deep, and it is divided in the centre by a transverse bulkhead, so that either of the two compartments can be dumped independently of the other. To the top side plate on each truck, in each compartment, there is hinged a swinging door which, when the truck is loaded, rests on the projection of a movable section in the bottom of the hopper, which is composed of two narrow movable sections hinged to the longitudinal shaft. Each bottom section is held in position by a tripping device, by means of which the said movable section on either side of the truck may be released as it swings downwards, inclining towards the apron, thus releasing the swinging door and permitting the discharge of the load. The apron is hinged along its middle line longitudinally, so that the upper portion can be swung upward. When the upper section of the apron is set in this position and the swinging door released, the latter strikes against

and is held by a spring on the raised portion of the apron, and the contents of the truck are discharged between the sills and inside the rails of the track.

The dumping devices are arranged to be operated either by hand or by compressed air, hand dumping being accomplished by means of a wheel at the end. When equipped for pneumatic dumping, an air cylinder is attached to the outside end of the truck in proximity to the hand wheel.

A few methods of discharging are shown in Figs. **707**, **708**, and **709**. The truck is 35 ft. 11 in. long over the end sills, 8 ft. 10 in. wide over all, while the extreme height from top of rail is 8 ft. 6 in. The carrying capacity is 40 to 60 tons of ore, and with the load heaped it amounts to about 40 cub. yds.

Self-Discharging Ballast Wagon of the Leeds Forge Co., Ltd.—This wagon is arranged to discharge its contents in whatever direction is required, either at one side or the other, or at the centre, or in different directions together, and so that the rate of discharge in any one direction can be regulated and stopped, when required, independently of that in the other directions. An alteration from any one direction to any other may be made during the progress of discharge, or the discharge may be entirely stopped at any or all points before the wagon is empty.

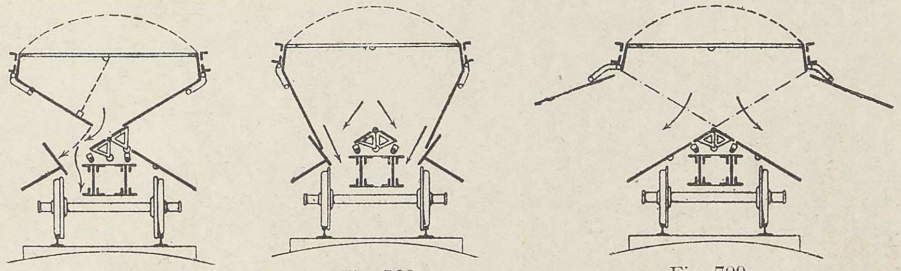


Fig. 707. Fig. 708. Fig. 709.

Methods of Discharging with the Goodwin Self-Emptying Truck.

An illustration of one of these wagons as supplied to South American and to Indian broad-gauge railways is given in Fig. **710**. Similar wagons have been supplied to the Indian metre-gauge railways, and to the South-Eastern and Chatham Railway.

The opening and closing of the doors, and regulation of the amount of material discharged, are entirely under the control of the operator standing on the platform of the wagon, so that it can be used for discharging ballast on the line. On the South-Eastern and Chatham Railway a full train load of 133 cub. yds. of ballast was discharged in twenty minutes with only three men in attendance, while an ordinary ballast train composed of fourteen 7-ton trucks, and holding only 98 cub. yds. of stone, took one hour ten minutes, with 28 men in attendance, to discharge its load on the same piece of road.

It will be seen from the illustrations that the operating gear is strong and extremely simple, and is not liable to get out of order. The control can be arranged either from an end platform or from the ground.

The diagram also shows how this type of wagon can be constructed with provision for the addition of a flat door to enable it to be used as an ordinary flat-bottomed wagon, and how also, if desired, it may be provided with drop sides and ends to facilitate the loading and unloading of rails, timber, etc.

Fig. **711** shows another type of hoppered wagon built, among others, for the Madras

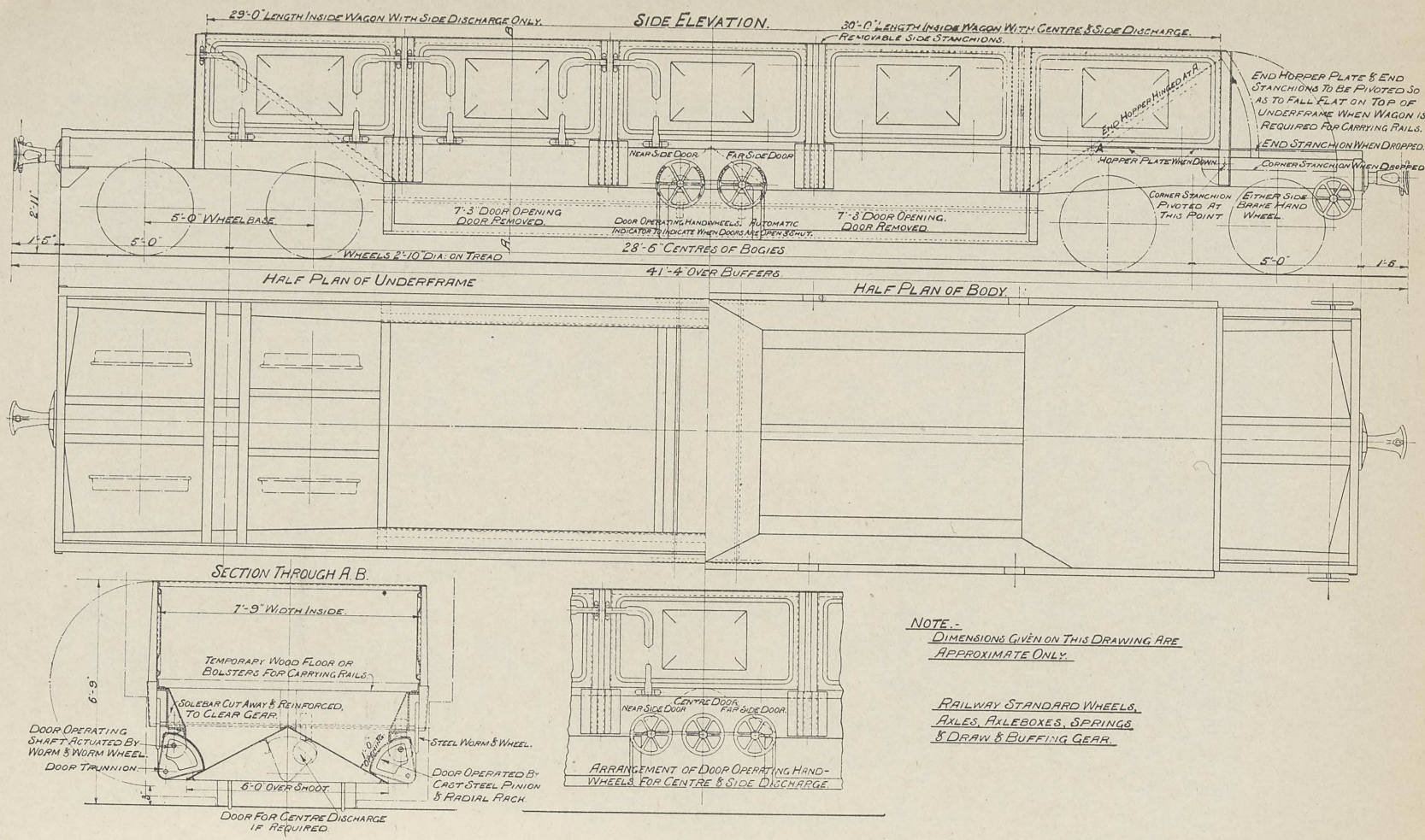


Fig. 710. Self-Discharging Bogie Wagon of the Leeds Forge Co., Ltd.

Load	40 tons		40,000 kgs.
Gauge	3 ft. 6 in.		1,067 mm.
Length over Buffers	41 ft. 4 in.		12,598 mm.
Length of Body	30 ft. 0 in.		9,145 mm.
Width over all	8 ft. 4 in.		2,542 mm.
Height over all	6 ft. 9 in.		2,060 mm.
Capacity	810 cub. ft.		23 m³.
Tare Weight	18 tons 10 cwt.		18,796 kgs.

Railway, the principal dimensions being height, 10 ft. 10 in.; gauge, 3 ft. $3\frac{3}{8}$ in.; load, 18 tons 10 cwt.; capacity, 450 cub. ft.; and tare, 8 tons 11 cwt.

Self-Discharging Drop Bottom Wagon of the Metropolitan Carriage, Wagon, and Finance Co., Ltd.—The wagon illustrated in Fig. 712 is designed for carrying coal and general merchandise on the South Manchurian railways. The floor is formed of sixteen doors, which are hinged to two central girders running the whole length of the wagon, these girders forming one box girder which carries the load, and takes the buffer and drawbar strains. The doors are operated from each corner, and when closed make a level floor to the wagon. A small hand wheel releases the safety catches, and the doors are raised and lowered by a lever handle working, through spur gearing, a worm and screw to each pair of doors, the latter being fitted with ball bearing footsteps. Each handle operates four doors, and all the gearing is cased in to ensure efficiency. A hinged door is placed in the centre of each side of the wagon to make it applicable for loading ordinary goods. The underframes and floor doors are built up of mild steel channels, plates, and angles; and automatic couplers with tandem buffing and

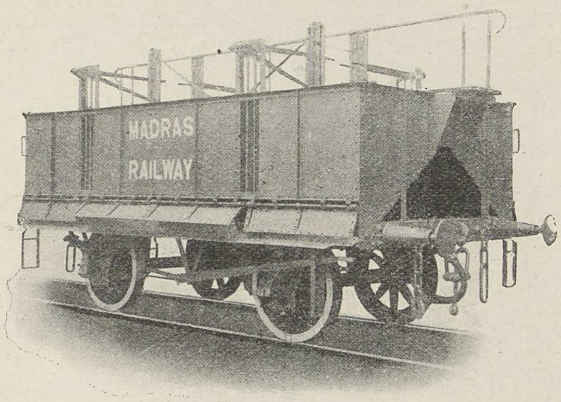


Fig. 711. Side-Discharge Ballast Wagon.

draw-gear are fitted. Westinghouse quick-acting brakes are likewise provided, working in conjunction with a hand brake. The bogies are of the standard American type, with girder bolster and nests of spiral steel springs. The wheels have steel disc centres with steel tyres and axles.

Capacity and Leading Dimensions

Capacity.	Dimensions.
Load (in pounds)	100,000 lb.
Capacity (in cubic feet)	1,790 cub. ft.
Length over headstocks	41 ft. 9 in.
Length inside	40 ,, 0 ,,
Width inside	9 ,, 3 ,,
Height inside	4 ,, $10\frac{1}{4}$,,
Centres of bogies	30 ,, 0 ,,
Journals	10 in. × $5\frac{1}{2}$,,
Gauge	4 ft. $8\frac{1}{2}$,,
Tare	21 tons.



Fig. 712. 50-Ton Self-Discharging Coal Wagon of the South Manchuria Railways.

60-Ton Self-Propelled Hopper Wagon.—Self-unloading trucks with the large capacity of 60 tons have been installed by the Virginian Railway Co. in connection with their coal loading and shipping scheme at Sewell Point, Norfolk, Virginia. These self-unloaders deserve special notice, as they are motor-driven or self-propelling; one of them is shown in Fig. **713**. The motive power is produced by two 90 H.P. electro-motors, one at each end of the wagon. The unloading doors are manipulated by compressed air.

Self-Unloaders of the Pennsylvanian Railway.—This company has recently

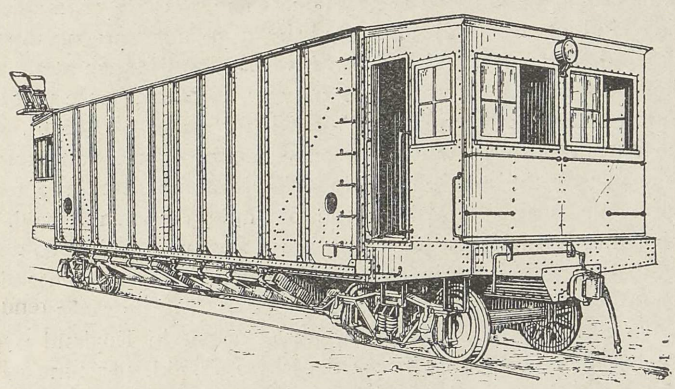


Fig. 713. 60-Ton Self-Propelled Hopper Wagon.

installed one thousand coal and coke wagons, which are some of the largest ever made. One of these is illustrated in Fig. **714**. The wagons unload through bottom outlets on each side, affording eight openings for the material to pass, presenting a total aperture

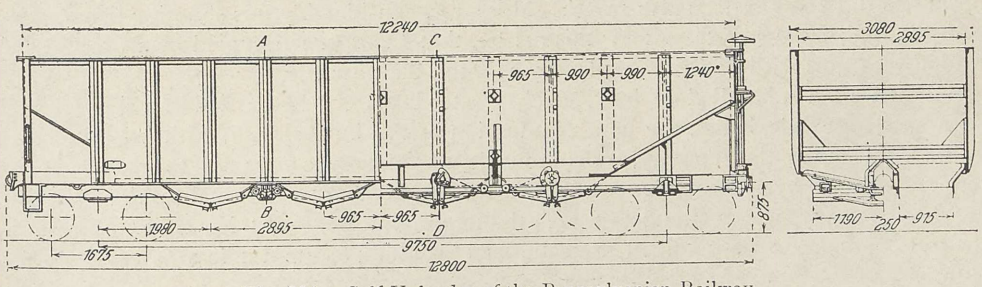


Fig. 714. Self-Unloader of the Pennsylvanian Railway.
(The dimensions are in millimetres.)

of 80 sq. ft. The length of the body of the wagon is 40 ft., the carrying load 45 tons, and the capacity is 2,400 cub. ft.

Bulk Transit of Grain by Means of Railway Trucks.—The bulk transit of grain has been brought to great perfection in the United States, and there is no doubt that in this country some progress has been made amongst the larger inland flour millers. It may freely be admitted, however, that to many mills in this country the bulk transit of grain would be of little or no use, but on the other hand there seems to be a large field for its adoption in granaries and merchant mills of fair capacity, of which the inland position makes the mechanical handling of material (at least at the terminals) a matter of vital importance.

The mills that may fairly dispense with the bulk handling of grain are at the two

ends of the scale, namely, the small country mills, to which grain is brought in farmers' carts from the immediate neighbourhood, and the large port mills, which receive foreign wheat either directly from ocean-going steamers at the quay side or from barges that have been loaded in bulk or with sacked goods from the ship. One of the strongest arguments in favour of the bulk transit of grain is the saving in terminal charges which the general adoption of such a system would be likely to bring about. Under present conditions, no doubt, railway companies may fairly argue that it would be unreasonable to ask them to reduce terminal charges whilst only a fraction of the larger merchant millers of the kingdom have adopted the system. The possible economies of the bulk system of grain handling are well illustrated by a comparison of the freight rates between Chicago and New York, and between Liverpool and Manchester.

Taking the rates current at the close of year 1902, the rate per ton between Chicago and New York amounted to about 15s. 6d. for about 800 miles, while the rate per ton between Liverpool and Manchester on a haul of 31 miles amounted to 6s. 11d. Thus it will be seen that the rate on the long haul amounted to about one-fifth of a penny per ton per mile as against $2\frac{3}{4}$d. per ton per mile on the short haul. There is no question but that railway freights for grain are excessive in this country, generally speaking, and although in this as in other problems many factors enter into the composition of the rate, yet it is clear that the handling of grain in sacks tends to keep up the high rates. One of the lowest rates for grain current in England is probably that which is in force between Hull and Newcastle, where 7s. 6d. per ton is charged on a haul of 110 miles, equivalent to about eight-tenths of a penny as against one-fifth of a penny for 800 miles' haul in the United States.

It is easy to understand why the bulk handling of grain is likely to effect great economies in transport. The labour bill is considerably reduced, and as covered trucks are used, no waterproof sheets are to be provided, while the item for labour in connection with these sheets is also saved. Moreover, considerably less shunting is required with the bulk system of transit for this reason, that the space occupied by a 7-ton truck loaded with sacks will not be exceeded by a 20-ton bulk car.

When grain is handled in bulk, much greater loads can be carried in a single train. At a moderate calculation, the general adoption of the bulk system, with self-emptying railway trucks, in this country, would enable the railway companies to reduce their terminal charges by at least 33 per cent. According to *Milling*, a journal to which thanks are due for many facts in connection with the important question, "No miller can realise the full economy to be obtained from the bulk handling of grain unless he has his own siding."

To show how wide-reaching are the economies possible with a well-organised system of bulk transit, it may be noted that the difference at most of our ports between the overside and the quay rate amounts to about 7d. per ton. Under the present system of sack handling the miller is often compelled to buy *ex* quay; whereas with a reasonable track-to-car rate, millers whose grain was handled in bulk would be able to buy *ex* ship. Moreover, the petty pilfering which goes on more or less where sacks of grain are handled would be rendered well-nigh impossible by the use of bulk trucks, which could be sealed or locked, thus reducing the liability of shortage to the lowest minimum.

Amongst British millers who have already adopted the bulk system of grain handling are the Scottish Co-operative Wholesale Society, at their Chancelot Mills at Leith, and Messrs Watson, Todd, & Co., of Birmingham. Perhaps one of the best examples now to be seen in England of bulk grain handling is afforded by the Industrial Co-operative Society's Mills at Leeds. The bulk of the wheat used in these mills is bought at Hull,

and is conveyed in the Society's boats to a transit silo on the banks of the river Aire. This installation may be considered a receiving station for the mill's raw material. Two bulk cars are continually passing between the mill and these transit silos, taking wheat away as fast as the boats are unloaded. These cars were built by the Society's own workmen, and have a carrying capacity of 5 tons each. The method of loading and unloading is most simple. The roadway passes right under the silo bins, and as the bulk trucks are drawn in at one end of the building they can be rapidly loaded and passed out at the other end. By a simple lever arrangement a slide is opened in the hopper of the bin from which it is required to draw wheat, and in two minutes 5 tons of wheat have entered the car. Then the slide is promptly closed and the car passes on its journey to the mill. It is alleged that not more than three minutes are required for passing the empty car into the silo warehouse at one end and taking it out loaded at the other end. On arrival at the mill the cars can be unloaded with a minimum of labour by a simple tipping device, receiving hopper and elevator. The latter lifts the wheat to the top of the mill, where it is passed over two warehouse separators which deliver into the storage bins. Not more than two and a half minutes are, it is said, required for unloading each truck.

There is no doubt that before the bulk handling of grain can come into general use in this country it will be necessary to devise a thoroughly practical form of truck. The first cost of such rolling stock would soon be recouped by the undeniable economies incident to this system. So far as the author is aware, but one railway company, the Lancashire and Yorkshire, have provided trucks of their own design for this particular traffic. These trucks have a length over head stocks of 35 ft., and a width of 8 ft. The inside height at the sides is 6 ft. 1 in., and at the centre 7 ft. 1 in., and the capacity is 1,563 cub. ft. The wheel base of the bogies is 5 ft. 6 in., with 25 ft. between bogie centres. They have a carrying capacity of about 30 tons of wheat, but have been criticised by millers on account of the large amount of trimming that is required before they can be entirely emptied. It is, by the way, alleged that this particular design was a sort of compromise between the purely bulk grain truck and a truck that might be used for other kinds of merchandise, such as cotton, which are carried on this particular line. What is required is a truck of large capacity that can be securely fastened, so as to prevent tampering with the loose grain, and will automatically discharge at its destination without the necessity of hand trimming. Messrs Spencer & Co., Ltd., of Melksham, have built a truck for carrying loose grain which is provided with a hoppered bottom, but if it be desired to use this truck for sacked goods, a flat floor can be laid over the hoppers. A very good bulk truck is built by the Metropolitan Carriage, Wagon and Finance Co., Ltd. In adapting the bulk system to the conditions current in this country, it should always be borne in mind that the immense loads of grain which are carried over the main trunk lines of the United States would be out of place in Great Britain, where flour mills are on a much more modest scale than the giant merchant mills which are to be met with at certain points in the winter-wheat, and especially in the spring-wheat belt of the United States. Again, but few of the dock companies of the United Kingdom are prepared to handle bulk grain, that is to say, to load bulk cars. The Manchester Ship Canal Co. has, however, provided automatic scales and loading shoots, by means of which loose grain can be weighed and shot into trucks adapted for this traffic. The Manchester grain silo and elevator are well provided with railway sidings, being connected with every railway system running into Manchester, so that here are to be found all the elements for a rapid extension of this system of grain handling on the railways of Lancashire, Yorkshire, and of the

Midlands. All that would seem to be required are more convenient bulk trucks, which the railway companies should provide, and tipping pits or hoppers to receive the grain in bulk from the flat-bottomed trucks which are tipped to empty, or from hopper-bottomed self-emptying trucks, which should be provided by the owners of sidings where grain is received in bulk trucks for the service of either flour mills or granaries.

Hopper-bottomed trucks are to be preferred on account of their quicker discharge. Unfortunately such trucks would not be of much good for other purposes. The author would suggest covering the wide end of the hopper with an iron grating composed of flat iron bars with a mesh of 2 to 2½ in. This grating could be used as a floor for the reception of sacks. The mesh would not be too open to walk upon, and the grating would not be in the way when filling or emptying loose grain.

The Lidgerwood Rapid Unloader.—This can hardly be called a self-emptying railway truck, it really being a self-unloading train of trucks, whose vehicles are discharged in quick succession by mechanical means.

This appliance is used on a complete train of flat-bottomed trucks with a guard on one side and open ends, the spaces between being bridged over by steel aprons hinged to their ends. By means of a cable and a plough the whole of the trucks are mechanically emptied. To begin with, the whole train is loaded by a steam navvy, the train of trucks forming one continuous trough without any divisions.

When a train of this character arrives at the dumping station with its load the locomotive is disconnected and leaves the train in charge of the dumping engine. A typical method of unloading is as follows: between the dump engine and the train is a special car on which a Lidgerwood winding drum and engine are arranged. The whole train is moved up to the point of entrance upon the actual dumping position, and here a chain is temporarily stretched across the track just back of the car containing the winding drum, the ends of the chain being secured to two suitable poles on either side of the track. The free end of the steel cable on the winding drum is now attached to the transverse chain. The dump engine now goes forward carrying the train with it, the winding apparatus permitting the cable to unwind at the forward movement, which continues until the rear of the train has arrived at the two poles. The cable now extends all along the pile of spoil, and the end which has been temporarily secured to the transverse chain is now unfastened and attached to the great plough on a separate car, this plough having a single face extending obliquely across the floor of the train. The train itself is now in the desired position on the dumping spot, and the actual unloading is accomplished by operating the winding engine and drawing in the cable. The plough is drawn along the whole train, its great weight and form being sufficient to maintain it in proper position as the ploughing goes on. The spoil is pushed off the train on the open side, and falls in a long ridge close to the track.

The trucks used are 39 ft. 8 in. long by 8 ft. 9 in. wide inside, the one side being 3 ft. high. The doors are hinged from the top so as to swing in an outward direction. Twelve such trucks were loaded in thirty minutes on one of the American lines, and over 4,000 cub. yds. of material have been handled by the steam shovel and train per day.

The cost of filling such trucks on the Kansas City Southern Railway, U.S A., for the months of March, April, May, June, and July 1900, is stated to have amounted to 2.89 cents per cubic yard, or about 1½d.

The Lidgerwood system was employed to a very large extent in the construction of the Panama Canal, chiefly on that part which was named the Tabernilla Dump.

At one dumping point, Tabernilla, a total of over 34 miles of track was shifted

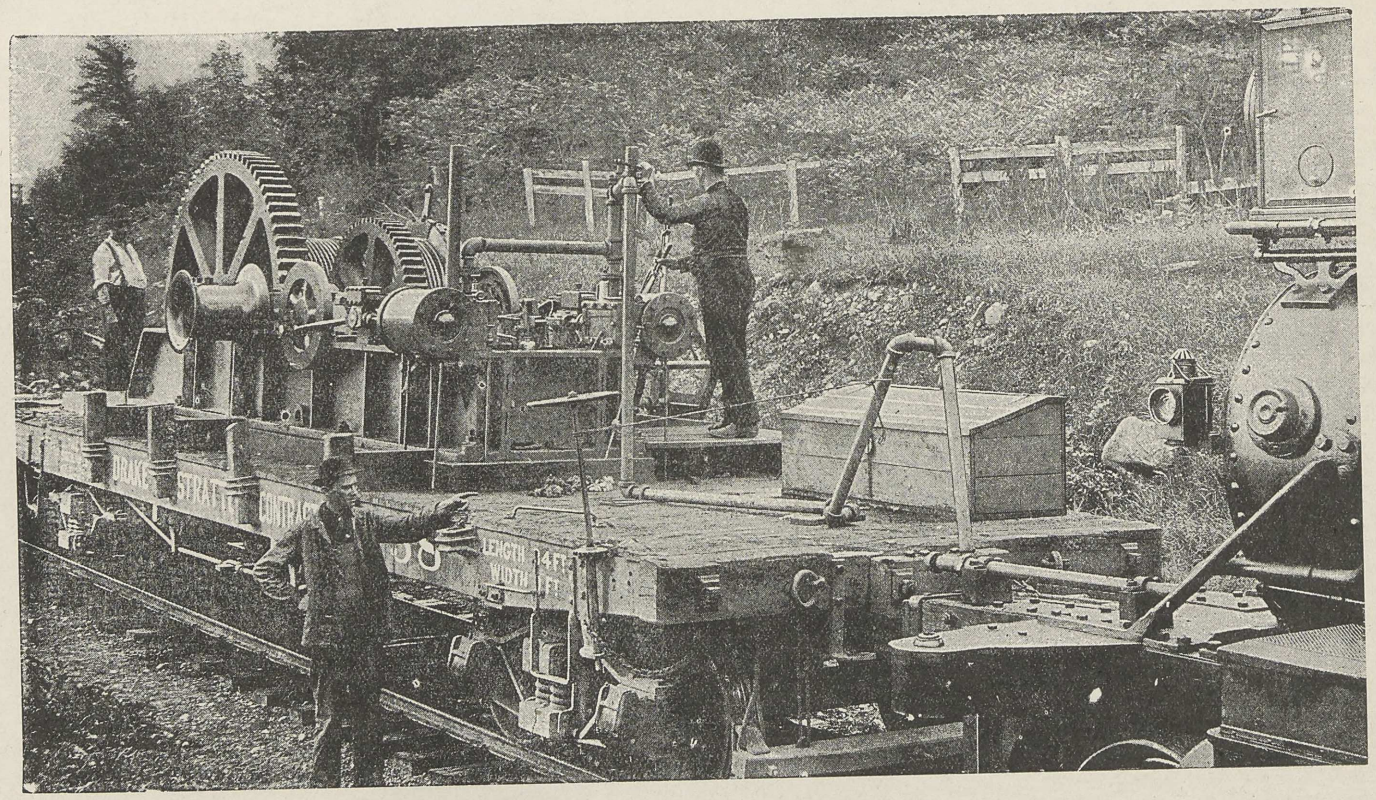


Fig. 715. The 25-Ton Pull Lidgerwood Unloader Engines.

during a month, and as this implies the relaying of $1\frac{1}{4}$ miles of track per day, we may get an idea of the rapidity with which the dump piles were growing. On a typical day fifty trains, each containing sixteen wooden cars having a capacity of 20 cub. yds. each, would be unloaded by the ploughing method at Tabernilla alone. This work was performed by four unloaders, so that a single unloader handled, on an average, 4,000 cub. yds. per day, or 500 cub. yds. per hour. At Tabernilla there were, in addition to the four unloaders, two spreaders for dispersing the soil, two trackshifters, one pusher engine, and one switch engine.

Fig. 715 gives a full view of the unloading mechanism, which is built for 25 tons' pull. The illustration shows the way in which the steam supply from the locomotive boiler is taken to the engine of the winch, the pipe being fitted with flexible joints to allow for any movement or vibration.

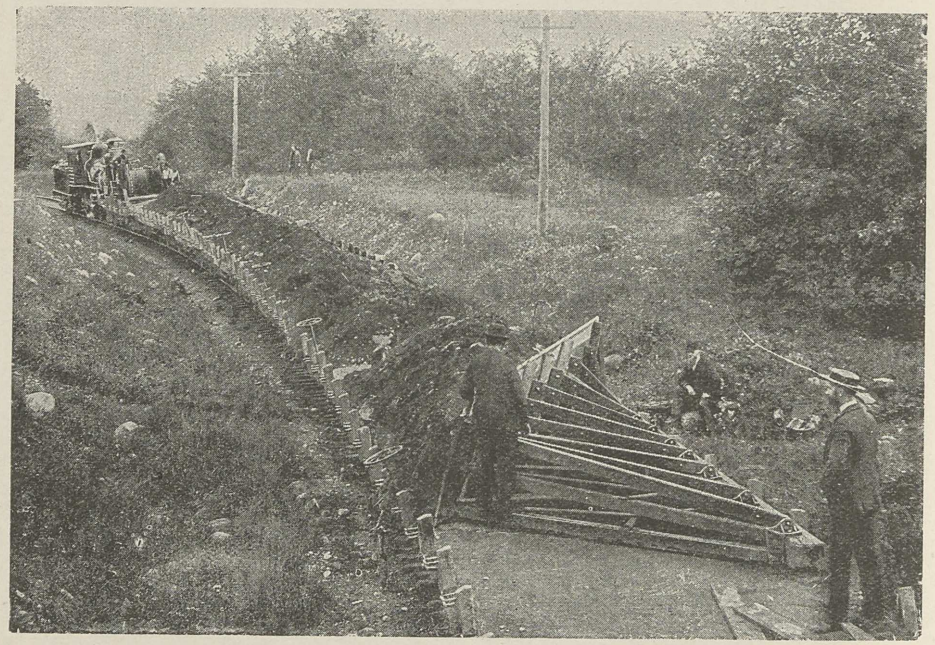


Fig. 716. Rear View—Loaded Train with Plough.

In Fig. 716 the loaded plough may be seen at work unloading a train. The winding gear near the locomotive engine can also be seen in the distance.

This device is the design of the Lidgerwood Manufacturing Co., of New York.

The Western Dump Cars of the Western Wheeled Scraper Co., of Aurora, Illinois.—The Western dump cars are used for contractor's work, similar to the Lidgerwood, and have been largely used in the construction of the Panama Canal; in the building of railways on the Mesabe Range, in stripping the over-burden from the ore beds; in the Florida phosphate fields; and on practically every great constructional work that has been accomplished in the United States of America. Figs. 717 and 718 show two views, back and front, of one of the trucks in the dumping position. The bed or platform of the car is pivoted longitudinally in the centre, and will dump on either side. When dumping, the hinges bolted to the centre sill under the platform move on the pedestal castings, which are bolted to the draft beams. The connection consists

of a flat bar which drops loosely into the socket of the pedestal in a perpendicular position, the upper end of the bar being held between the lugs of the platform hinge by a pin. The weight of the car does not rest upon the horizontal pin, which passes through the hinge so that there is no liability of bending the pin. The arms operating the doors act automatically. When the platform of the car is tipped, the toggle strikes a plate fastened to the car frame and holds the door from dropping with the platform. Either side opens as the car is dumped and closes as the platform is returned to an upright position, both automatically and instantly. The door arms are pivoted, both where attached to the door and to the platform, in such a manner that, as the platform is tilted, the doors are thrust outward and upward from the load, so that no part of the load as it moves is thrown against the door, and any danger of derailing the car by the impact is removed. When the platform is dumped the open side door is brought to a position nearly parallel with the bottom of it.

On account of the free vent for discharge and the acute dumping, angle, anything that can be loaded into the cars will clear the side board in dumping, so that heavy rocks and boulders of frozen earth in large masses can be easily handled.

The beds or platforms are held in position by chains on each side connecting with the truck, and provided with spike and ring fastening, which can be released by the hand or foot while the car is in motion. These safety chains practically avoid all possibility of the car dumping accidentally, which might cause serious mishaps.

The arms and the toggle-jointed levers which operate the side door are all connected to the platform and not to the truck, so that when the side chains are unlatched, the platform and truck are entirely separable.

During dumping the platform is not held rigidly to the trucks, but is permitted to rise slightly from the pedestal at the moment of the shock, so that there is no tendency to lift the truck from the rails. In the event of derailment and rolling down an embankment the platform and truck automatically separate, causing less damage to the car and making its replacement on the track much easier. The bearing on which the platform turns in dumping is of such construction and adjustment as to make the dumping and returning of the platform to position very easy. The dumping angle of the cars is from 45° to 75°.

At the dumping ground of Gorgona, during the construction of the Panama Canal, eight trains consisting of twenty-five cars each were used, and as the cars had a capacity of 17 cub. yds., we have a daily total of 3,400 cub. yds. brought in this one type of car to this one dump. At Mamei, 10 miles away, both large and small Western cars were dumping 1,500 or 1,600 cub. yds. per day, and so also at other points. Three trains of large dumping cars were run daily from Bas Obispo to the side of the great dam carrying 1,200 or 1,300 cub. yds. of rock to be dumped on to the south toe of the structure. This haul was one of 24 miles.

The "Hunt" Automatic Railway.—A practical method of carrying heavy material, such as coal and ore, from wharfside or railway to the stock heaps or storage bins, is the "Hunt Automatic Railway," operated entirely by gravity, no motive power or manual labour being required. The salient point of this system consists in the sufficiency of energy which is acquired by the loaded truck descending an inclined track. This energy is utilised, after the discharge of the load, for returning the empty truck to the place whence it started.

The railway is loaded at the upper terminal with ore or coal from a small hopper into which the unloading grab discharges. One man is sufficient to operate the installation; he loads the truck by opening a slide in the small hopper, but its further

progress being entirely automatic he does not accompany it. It runs down the track, discharges its load at any predetermined point, and then returns empty to the receiving terminal. The time taken in making a trip of 300 ft., dumping the load, and returning to the starting point, is about fifty seconds. As the loaded truck descends it gains in speed, and as it approaches the end of its trip it raises a weight by means of a wire cable and tripper with which it comes in contact. At this point the load is automatically discharged, when the inertia stored in the aforesaid weight is given up again to the truck to afford it a sufficient start, so that its own momentum will carry it back again to the starting point. It is important that the raising of the weight should form a gradual movement, in order to minimise to the utmost any stress on the various parts of the mechanism.

Fig. **719** shows the details of such a plant at work at the Avonbank Electricity Works, Bristol, and erected by Messrs Babcock & Wilcox, Ltd. A general drawing of this installation will be found facing page 640.

The ordinary method of discharging these trucks is by opening the sides by means

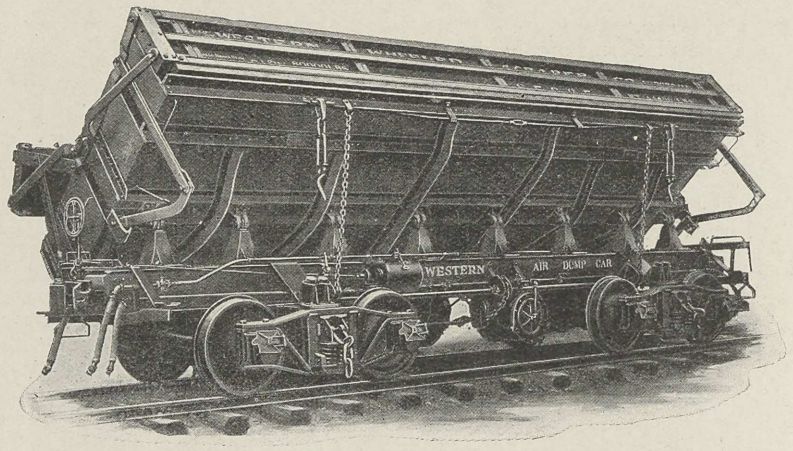


Fig. 717. Western Dump Car (Back View).

of a tripping block placed on the track, to let the load out on both sides.[1] The floor of the truck is Λ-shaped in order to run the material clean out (see Figs. **720** and **721**).

The sides are hinged, but the lower ends are fastened, not to the truck, but to each other; thus if one is unfastened, both are open. The load is always evenly discharged, and there is practically no risk of the truck overturning, though the gauge is a very narrow one, being only 21 in. from outside to outside of rail heads. These cars are built of wood, and lined with sheet steel, and are provided with self-lubricating bearings, rubber springs, and steel axles. The bearings are of a peculiar construction, and are so arranged that the car will run round a curve of 30 ft. radius with practically the same ease as on a straight line. The steel wire rope which raises the weight is detached from the truck, except during the time that the car is raising the weight, and receiving the impulse to return. Curved tracks are admissible, but should be as near the feeding terminal as possible; they require special rails to suit the flexible running gear used on these cars. All material received over the railway can be weighed by placing platform scales on the track at the loading end. The attendant who loads the trucks can also, at the same time, weigh the loads, and enter the weight in the tally book as the trucks are running down

[1] For similar self-unloaders see Chapter XXIII. on Rope Haulage, pages **255** and **258**.

the track. On account of the width of the truck, and owing to the distance to which the side doors open out, the scale beam must be further away from the end of the platform than usual. If desired, automatically registering weighing machines may be used, for description of which see Chapter XLIII.

The "Hunt" automatic railways are suitable for distances not exceeding 600 ft. The trucks are built in two sizes, the smaller carrying 1 ton and the larger 2 tons, and they have been chiefly used for handling coal, but are equally suitable for other heavy material, such as ore, phosphates, clay, etc. The construction of the truck, including the shape of the base, is varied according to the nature of the material to be conveyed.

Amongst "Hunt" automatic installations may be mentioned one at the Storey Coal Yard, Brooklyn, New York, where two trucks on separate tracks distribute all the coal hoisted by a 2-ton grab to a pocket which holds 7,000 tons.

The Calumet and Hecla Mining Co., Lake Linden, Michigan, U.S.A., use five 2-ton cars which run on twenty-seven automatic tracks. The "Hunt" system may also be

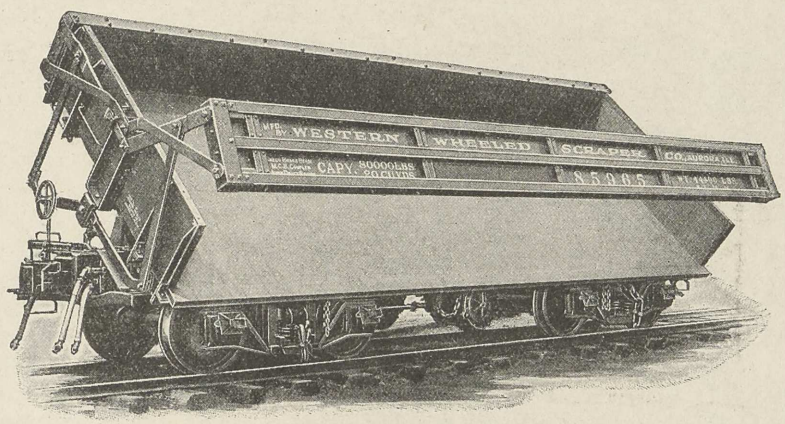
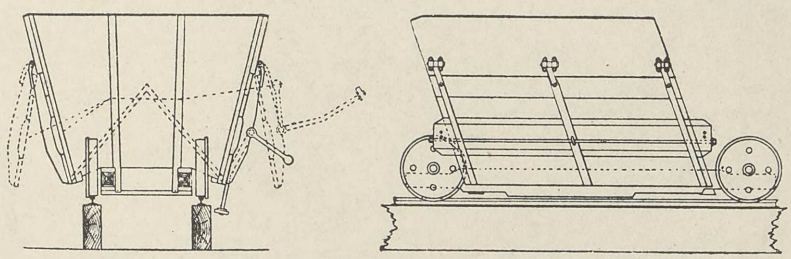


Fig. 718. Western Dump Car (Front View).

seen in operation in Dublin, where it is used by the United Tramways Co. At Ludwigshafen, on the Rhine, it has been installed by the Westfaelisches Kohlen-



Figs. 720 and 721. Truck Used for Hunt's Automatic Railway.

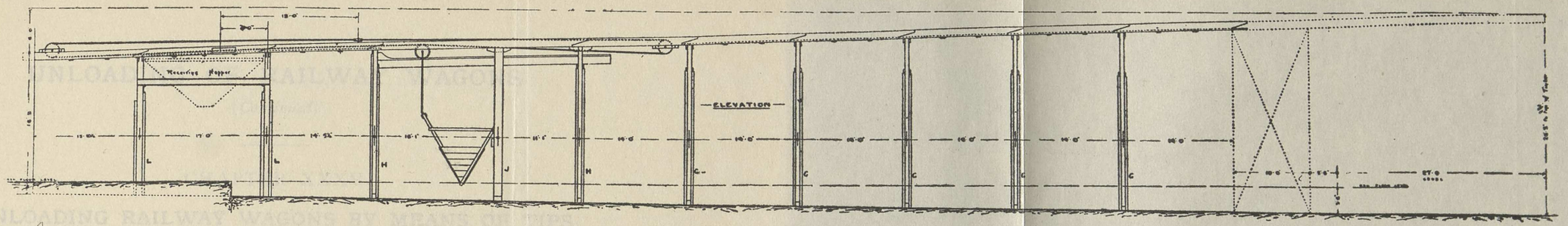
Syndicat, also at the Gasworks of Zürich, which latter plant is illustrated and described on pages 449 and 450.

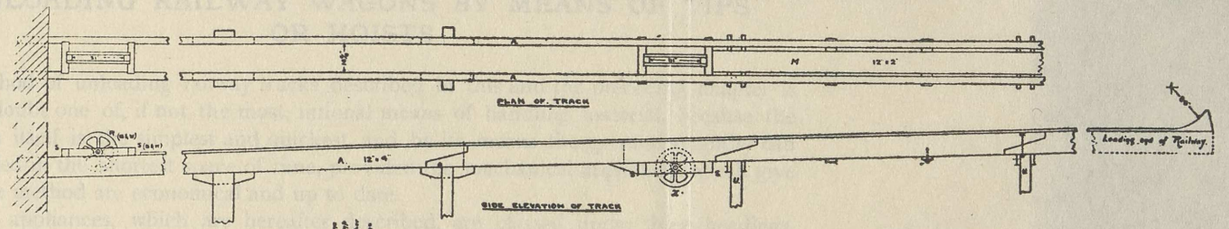
The principle of this automatic truck is very simple, but the conditions under which it is used vary widely. For instance, it may be made to serve the largest coalyard by means of many separate tracks converging on one or more points. The track or tracks

may be placed at any height, and, if desired, the truck may be made to dump from an elevated track at any given point, to build a pile of coal in the storeyard. The track on which the car runs may be carried by a movable bridge (controlled from the hoisting tower) which will itself serve a wide area. The Lehigh Coal and Iron Co.'s Wharf at West Superior, Wisconsin, U.S.A., is 2,000 ft. long and 300 ft. wide. It is equipped with nine movable elevators and seventy-five "Hunt" automatic railways. The unloading capacity of this plant amounts to 7,000 tons per day.

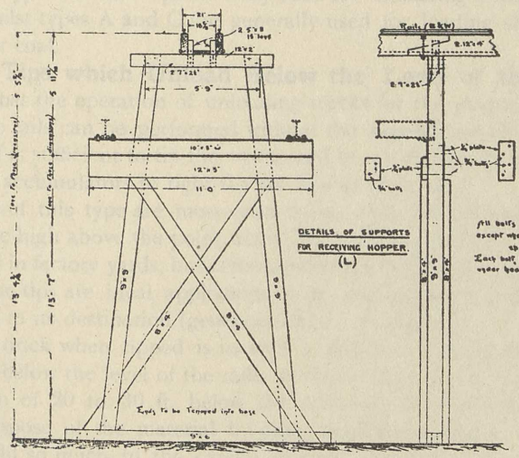
This system is not suitable for large or friable coal on account of the rather rough discharge.

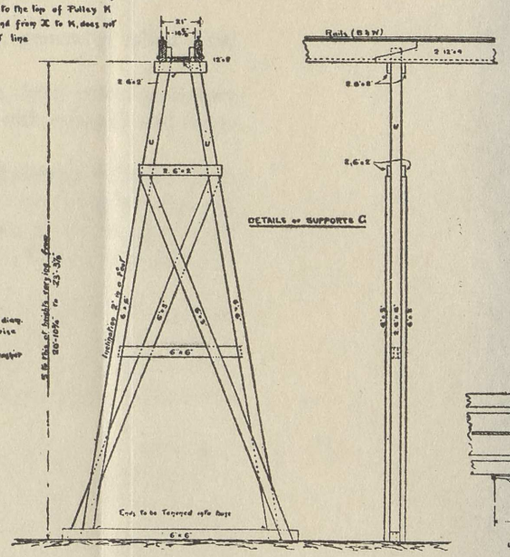
The origin of this device is somewhat curious. The first "Hunt Automatic Railway" was built in 1871, and appears to owe its existence to a strike of coal wharf operatives. History does not state where this first railway was erected, but it was doubtless in or about New York, the home of the C. W. Hunt Automatic Railway Co.

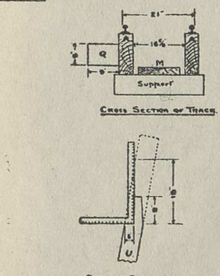


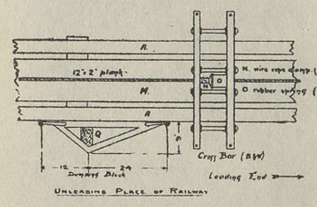


NOTE:—
Carry one end of the wire rope over the pulley X, thence over the top of K, around, and secure the end to the finger B of Y. Then carry the other end under the Car, through the Cross Bar P, spring O, and clamp N, thence over the Pulley R, and back to the top of Pulley K and fasten to the finger B of W. The greatest care must be taken that the part of the Rope from R to K, and from X to K, does not chafe. If a finger is in the way, bore a 2 inch hole and run the Rope through it. The Rope must run in a straight line









AVONBANK ELECTRICITY WORKS - BRISTOL.

DETAILS OF CONSTRUCTION OF AUTOMATIC RAILWAY

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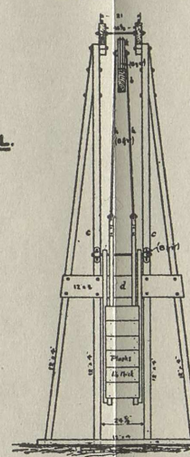

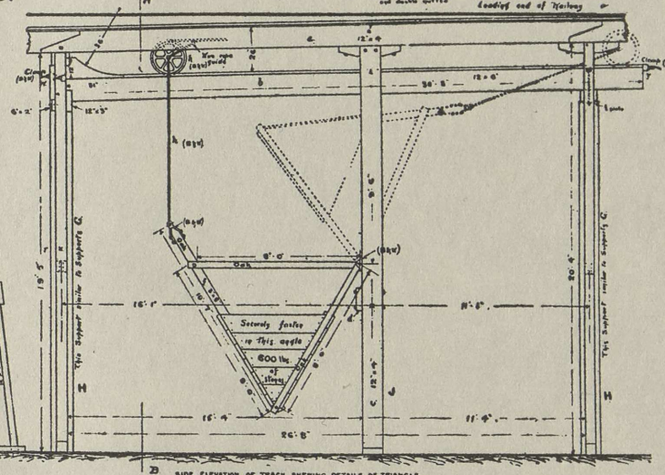

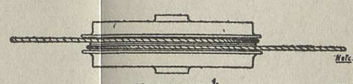

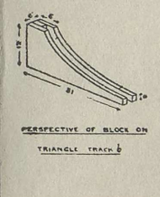

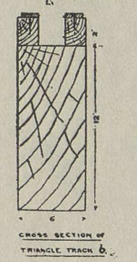

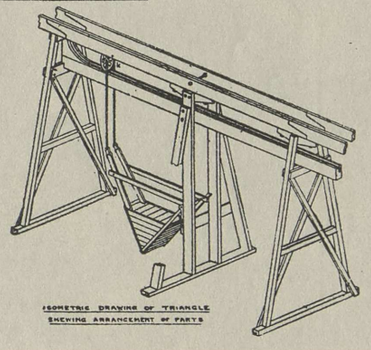

Fig. 719. General View and Details of Installation of Hunt's Automatic Railway at Avonbank Electricity Works.

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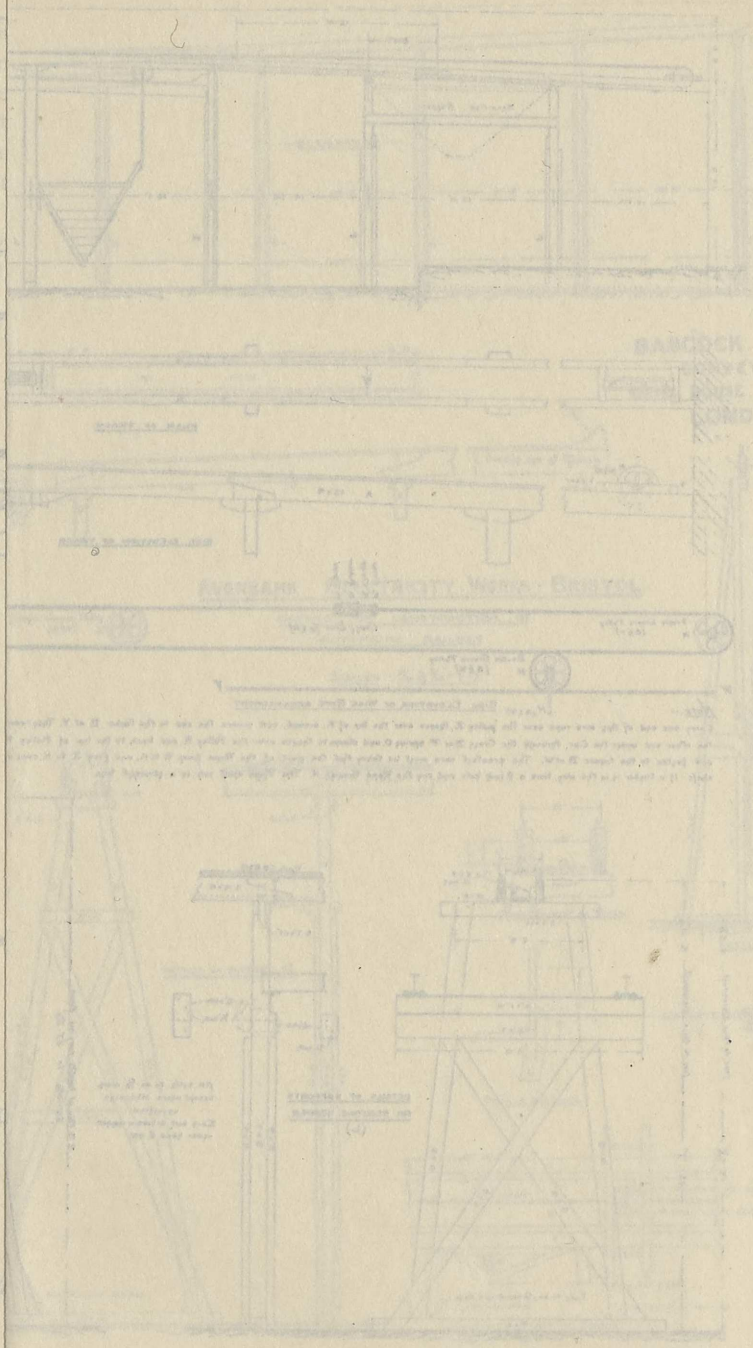


UNLOADING OF RAILWAY WAGONS

(Continued)

CHAPTER XXXV

UNLOADING RAILWAY WAGONS BY MEANS OF TIPS OR HOISTS

THE method of unloading railway trucks described in this and the preceding chapter is without doubt one of, if not the most, rational means of handling material, because the operation itself is the simplest and quickest, and by its means the greatest quantity can be handled in the shortest space of time, provided the mechanical appliances which give life to the method are economical and up to date.

The appliances, which are hereafter described, are classed under three headings. Each of these three different types of tips is suitable for a different purpose, mainly depending upon local conditions, such as the height of the railway siding or quay above the water level in the port, river, or other destination of the material to be unloaded. The three types of tips are the following :—

A. Tips which unload below the level of the railway lines, also called Gravity Tips.

B. Tips which unload on the same level as the railway lines.

C. Tips which unload above the level of the railway lines, generally called Coal Hoists.

The type B is more particularly used for unloading coal, etc., from trucks in factory yards, whilst types A and C are generally used for loading ships with minerals and cargo or bunker coal.

A—Tips which Unload Below the Level of the Railway Lines.—It is obvious that the operation of unloading trucks for the purpose of depositing the contents below the rails can be performed without the expenditure of power, as the weight of the coal itself is sufficient to tip the truck, and to use the inertia either directly or after being stored in accumulators to right the truck after emptying.

Tips of this type are most economical when the rails on which the trucks arrive at the tip are high above the point where the coal is to be received. This condition obtains but rarely in factory yards, but is frequently met with on the banks of tidal rivers. In such cases these tips are ideal appliances, as no driving power is required, and the material is conveyed to its destination (generally ships) by gravity.

The truck when tipped is in such a position that the front edge of the platform is 6 to 8 ft. below the level of the rails, so that if the rails are not above the ground level an excavation of 20 to 30 ft. below the rails may be necessary, in order to receive and further dispose of the material by other mechanical means (see Fig. **730**). Such excavations add so much to the capital expense, that tips of this type are rarely economical unless, as stated above, the rails are well above the ground level.

The following are a number of examples of coal tips of this class :—

The Old Newcastle and Cardiff Tips.—The old Newcastle and Cardiff tips are

here described as being of historical interest. They have done good work in the past, but are now generally superseded by tips of later type. They are only applicable where the trucks are on the wharf at a high level, or where the railway lines are raised on staiths, from which elevation the coal is deposited by gravity down the shoot into the vessel. Hopper-bodied wagons, or wagons with hinged end doors, are employed to load into the shoot. In Newcastle the former wagon is more often used, and in Cardiff the latter.

These balanced tips consist of a suspended cradle or platform A (Fig. 722), sliding

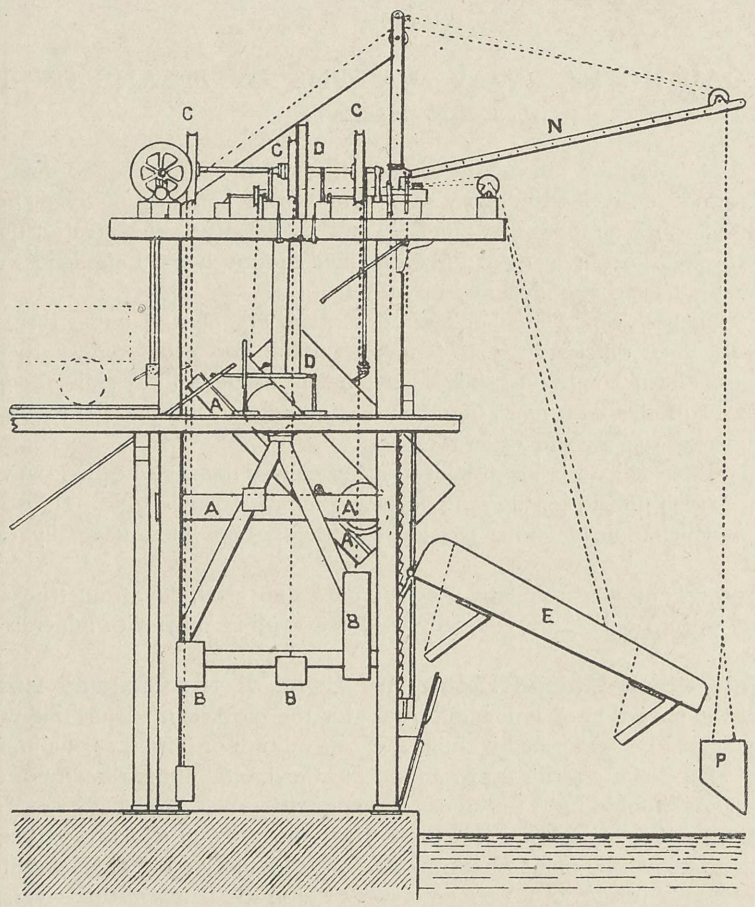


Fig. 722. Balanced Gravity Tip of the Old Cardiff Type.

in vertical guides, and supported by balance weights B connected to it on either side by chains passing over pulleys C at the top of the framing, upon which are brakes D for controlling the motion of the cradle. The balance weights are sufficient to raise the cradle and empty wagon, but are not equal to the load when a full wagon is upon the cradle. The contents of the wagons D are discharged through an end door into an inclined shoot E extending over the ship's hatchway, and sometimes having screens at the bottom for separating the dust from the coal. The brake is then released, and the cradle with the empty wagon rises to the top again, the wagon is run off into a siding, and the

cradle is then ready to receive another wagon. Crane N and lowering device P are employed in order to minimise breakage.

By the use of tips of this construction a height of 9 ft. is lost by having to lower the cradle sufficiently to tip the wagon. A gradual increase in the size of the ships to be loaded rendered it necessary to prevent this loss of effective height in the tips, in order to raise the shoots to the level required by the increased height of the decks of the ships. Instead of lowering the cradle, therefore, the tail end is hauled up by a winch worked by hand, thus converting it into a tip discharging on the level of the rails instead of below. This tedious process was subsequently superseded with great advantage by hydraulic machinery, consisting of a simple Armstrong crane cylinder with a 9-in. ram and double pulley connected to the tipping chain. This system has been adopted in reconstructing the old balance tips at both the east and west docks at Cardiff. The first balance tips constructed at the west docks received the wagons on the cradle at a level of 18 ft. above the quay, but the increased size of the ships to be loaded has necessitated raising the railway and the framing of the tips 3 ft. higher, making the level for the wagons at the west dock 21 ft. above the dock coping, or 22 ft. above the water. The coal tips at the east dock were originally constructed at this higher level, but in consequence of such large vessels being loaded there, the height of the additional tips constructed has been further increased by 6 ft., giving a height of 27 ft. above the coping.

As it is necessary to adjust the level of the shoot to the actual height of each ship, in order to reduce breakage of coal as much as possible, the heel of the shoot is attached to the frame of the tip so as to slide in a vertical groove. The shoot is carried by adjustable chains with balance weights and winches, so that the inclination as well as the height of the shoot can be changed if necessary.[1]

This short history has been given here for the sake of completeness, although the converted tips really belong under heading B.

Hydraulic Tip at Dortmund.—A hydraulic coal tip of some interest is at work in the harbour of Dortmund in Germany. It is on the Schmitz-Rohde principle, and was built by Friedrich Krupp, Grusonwerk, Magdeburg. This tip consists essentially of a platform swinging on a horizontal axis. The coal trucks are pushed on to this platform and tip with the latter, emptying themselves over the end into the barge. The apparatus works without the expenditure of outside power, so that there is no necessity for a motor. The principle is to utilise the energy due to the weight of the contents of the truck when lowered, and to store it in an accumulator, to be used again for raising the platform and truck when the latter is empty.

This is a great improvement on similar installations in which this energy is lost by absorbing it in a brake, as in that case motive power must sometimes be provided for lifting the truck. The tip can be used for the rolling stock of all the lines which bring coal or coke to the harbour of Dortmund, and for loads of 10 to 15 tons, the only condition being that the trucks are fitted with hinged end doors. Figs. **723**, **724**, and **725** illustrate the tip. A is the platform which swings round the trunnion G. The forward end of the platform is suspended by the hydraulic ram F of a movable supported cylinder B. To the other end of the platform a balance weight is attached. The cylinder B communicates with an accumulator D, the connection between the two being controlled by a valve and manipulated by a lever C, and in the control of this valve lies the whole manipulation of the tip.

[1] This description is taken from a paper read by Mr John M'Connochie before the Inst. Mech. Eng. See *Proceedings Inst. Mech. Eng.*, August 1874, pages 125 to 130.

The action of the tip is as follows:—
As the truck is being pushed on to the platform its two front wheels depress two

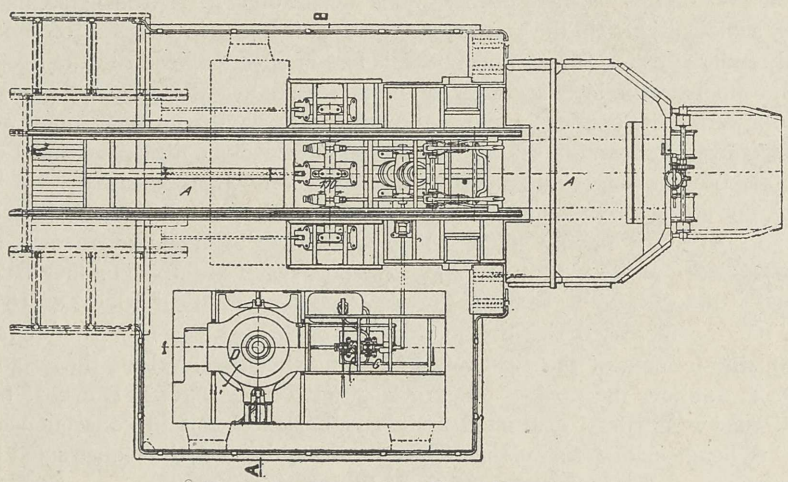


Fig. 723. Plan of Coal Tip at Dortmund.

levers, which action releases two strong hooks that hold the axle of the front wheels. This is seen in Fig. 724. The hooks and the levers manipulating them are concealed

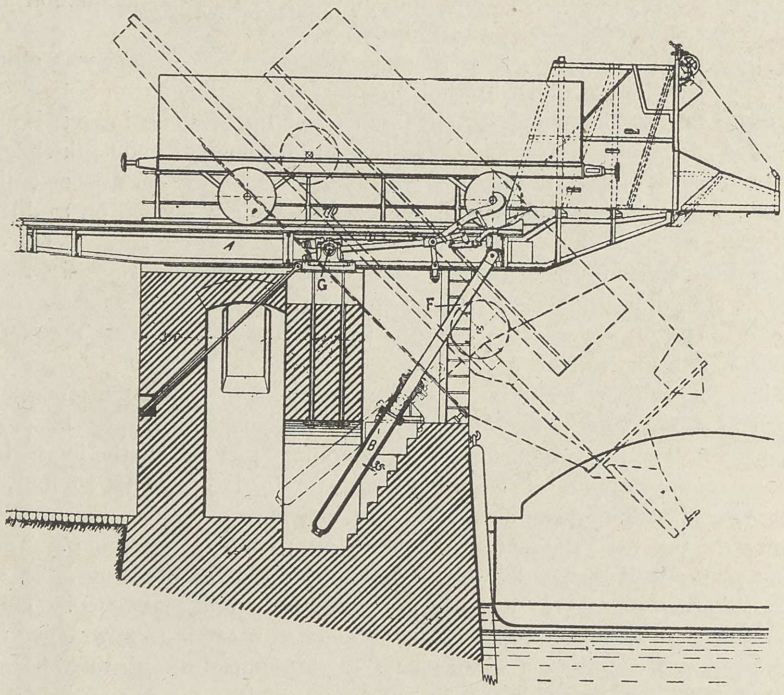


Fig. 724. Longitudinal Elevation of Tip at Dortmund.

below the platform when out of use, and do not therefore interfere with the brake tackle under some of the trucks. The truck and the levers holding it are coupled

to the axle of the platform, not rigidly, but by means of volute springs to reduce the impact.

The truck is allowed to move into a position in which its centre of gravity is on the water side of the centre of the platform. The weight of the load causes a pressure in the cylinder B of about 300 lbs. to the square inch. The pressure in the accumulator is, however, only about 255 lbs. The valve is now opened, and as there is a difference in the pressure of cylinder and accumulator of 45 lbs. to the square inch, the weight of the truck pushes the ram into the cylinder, thereby lowering the platform, and the truck begins to discharge. During the tipping process the centre of gravity of the truck alters its position in such a way as to increase its leverage. The momentum of the load does, however, decrease as the load of the truck is getting less. At the angle of 45° the platform and truck have reached their maximum travel, at which the latter is empty. The speed of the descent can be regulated by throttling the communication between hydraulic piston and accumulator by means of lever C, which is closed altogether as soon as the lowest position is reached.

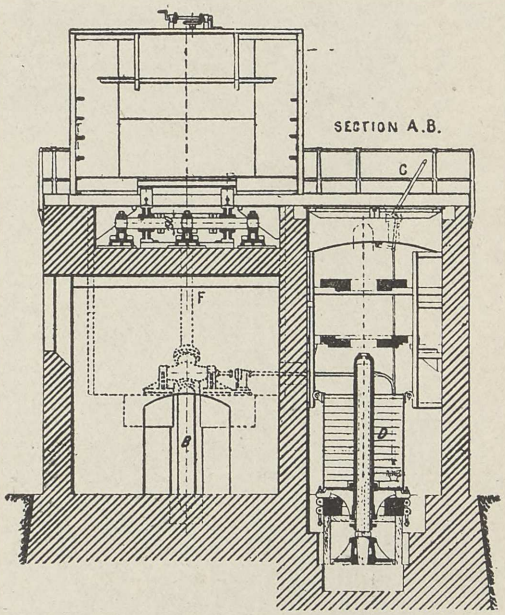


Fig. 725. Cross Section of Tip at Dortmund.

The coal as it leaves the truck falls into a shoot which forms an extension to the platform, the sides of which, to prevent waste, are somewhat higher than the truck. The end of the shoot can be so adjusted as to let the coal fall gently into the ships or barges which are to be loaded. As the load on the ram F becomes less towards the end of the operation, the pressure is reduced to about 210 lbs. When the valve is now re-opened the surplus pressure in the accumulator is sufficient to raise the platform into its original position. The valve is manipulated by a lever C over the accumulator on that part of the structure which is not movable. From the same spot a second lever can be used which actuates another valve, which allows the water to escape from the cylinder B to the open, in case the load in the truck should not be sufficiently heavy to force the water out of B into the accumulator. As the momentum decreases during the tipping process, the valve must be closed almost immediately after the platform has begun to descend in order to economise the pressure in the accumulator. Finally, there is a safety valve which opens automatically in case of extreme pressure in cylinder B through the valve having been closed too soon. This valve admits the water into the accumulator. The plant is provided with a hand pump, which is used when the cylinder and accumulator are first filled, and also to replenish any loss through leakage, and also in cases where the cylinder B has to be relieved into the open as stated above. A mixture of glycerine and water is used in the apparatus to prevent freezing.

It takes five men to manipulate the tip. One operates the valve and lever C, two are placed in the shoot and go up and down with it to regulate the discharge by means of two small winches, whilst two push the trucks on to and off the platform.

As the goods' station is on the same level as the quay wall, the coal train is taken up a sufficient incline, and there is a slight fall from the point about half-way between the

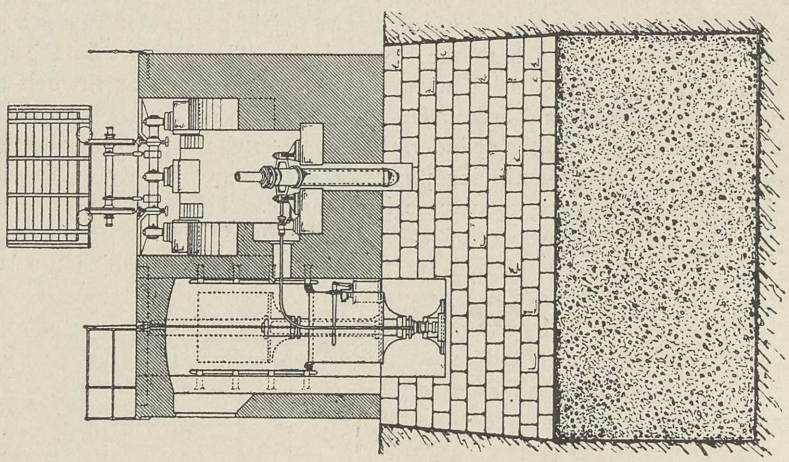


Fig. 727. Cross Section of Tip at Ruhrort Harbour.

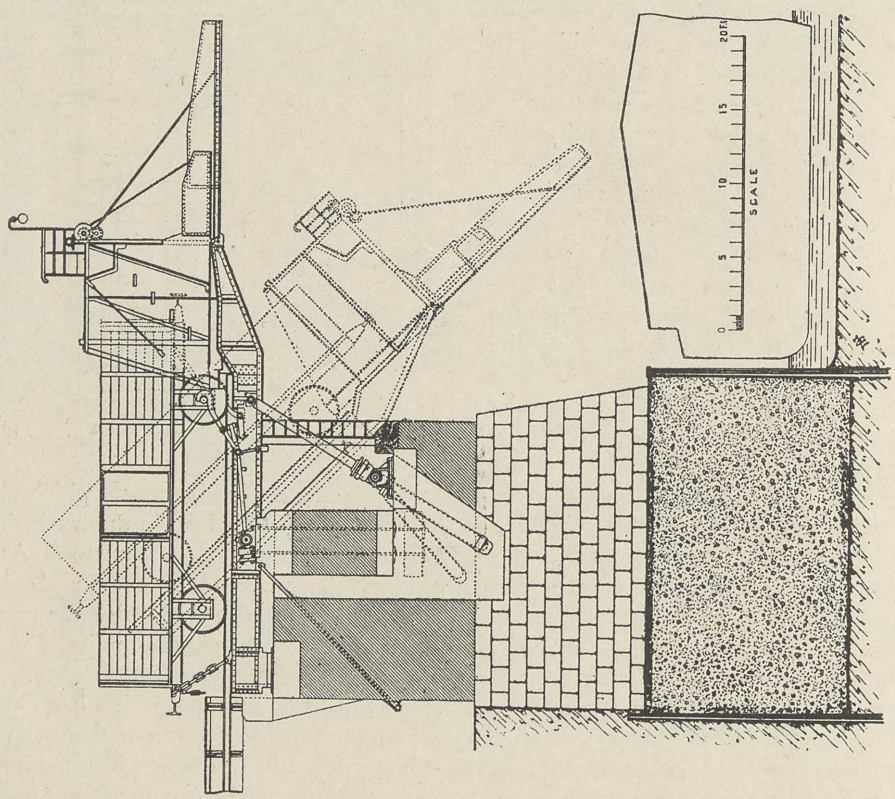


Fig. 726. Longitudinal Elevation of Tip at Ruhrort Harbour.

platform and the tip, so that the trucks run down by their own gravity to the latter. They pass a turntable on their way to and from the platform of the tip.

The Coal Tip at Ruhrort Harbour.—This is very similar to the tip just described,

and was also built by Krupp, of Magdeburg. It is illustrated by a longitudinal and cross section in Figs. **726** and **727**.

Two perspective views of the same are given in Figs. **728** and **729**. The con-

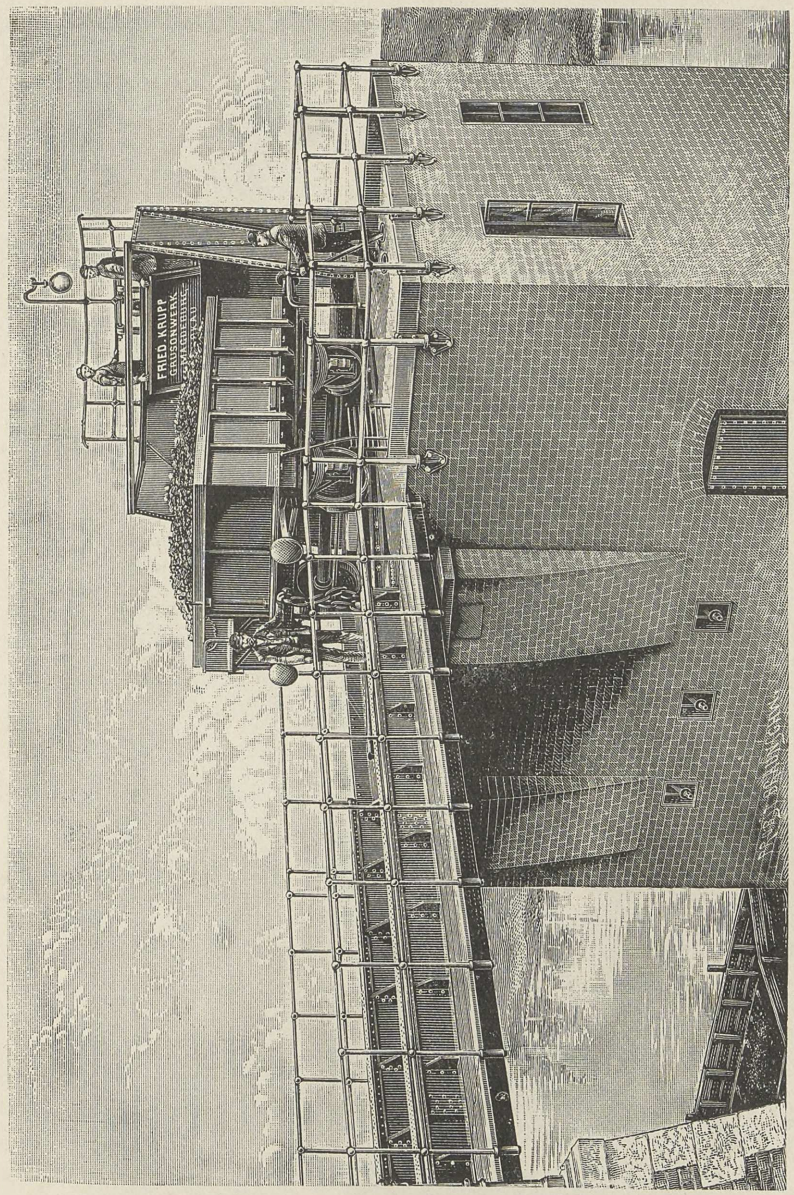


Fig. 728. Perspective View of Tip at Ruhrort Harbour.

struction is almost identical with that of the tip at Dortmund, and needs, therefore, no further description.

A similar appliance to the last mentioned is the work of Rudolf Dinglinger, of Coethen, Germany. It is illustrated in Fig. **730**. This plant acts almost precisely in the same manner as the last. The valve and hand wheel, which are visible in the

illustration, break and open the communication between the hydraulic cylinder and the accumulator (the latter not being shown). This device is intended for unloading coal in factory yards, and disposing of it by elevator either into the coal stores or into the bunkers

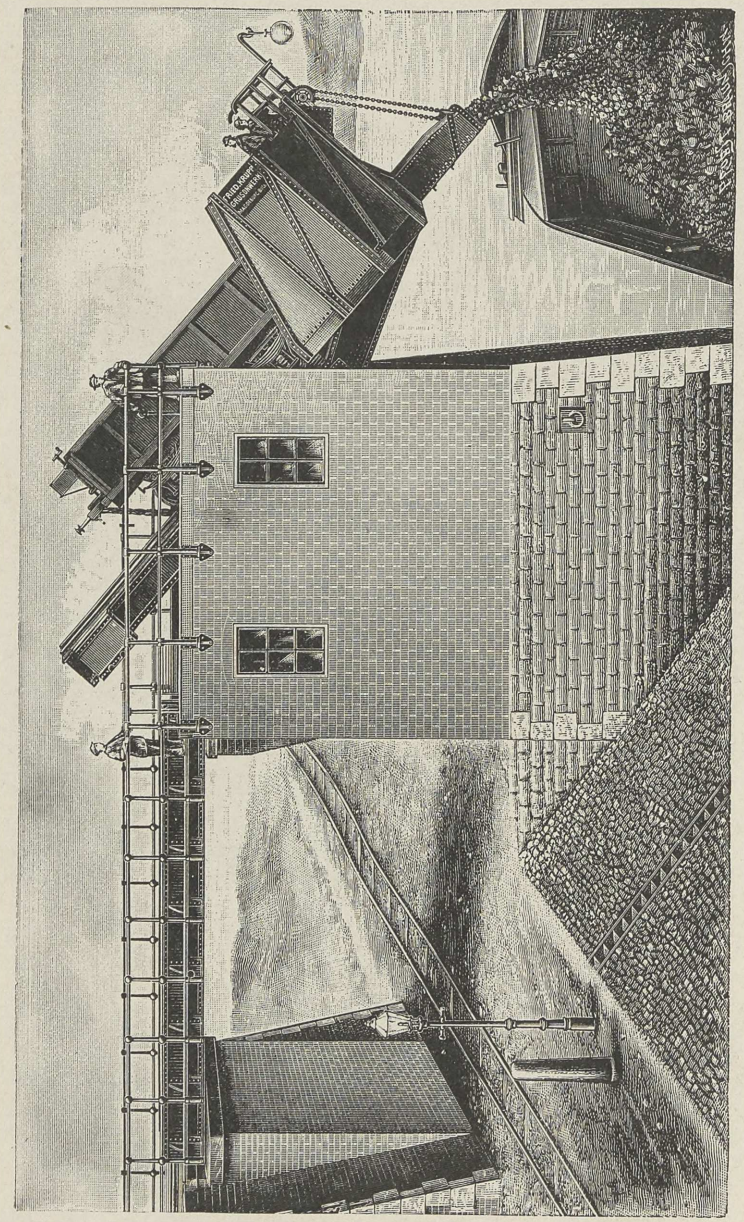


Fig. 729. View of Tip at Ruhrort Harbour in Unloading Position.

over the boilers. In many cases it is necessary to provide such a tip with a coal-breaker between the hopper and elevator.

Coal Tips at Bethune.—Unlike the tips previously described, which tip and empty themselves on a transverse axis, the tip of the Compagnie des Mines de Bethune

turns on a longitudinal axis. The installation, which is illustrated in Fig. 731, was erected for the purpose of quickly discharging coal, brought from the Marles Colliery, at a small expenditure of driving power. As will be seen from the illustration, the quay wall, which has been constructed by the Marles Colliery Co., is at a sufficient height above the water level to allow of a discharge from the quay to the barges by gravity. This automatic tip is the design of Messrs Taza and Villian, of Annezin. It consists essentially of a substantial platform having a frame of wrought iron, which supports a portion of a railway track of standard gauge. Loaded trucks are pushed on to this platform, and then a very small expenditure of power is necessary to set the tip in motion, whereupon the coal is deposited in an inclined shoot, which leads, by means of an additional piece of spouting, to the river. As soon as the coal has been discharged, the tip returns with the truck to its original position, when the truck is pushed off the

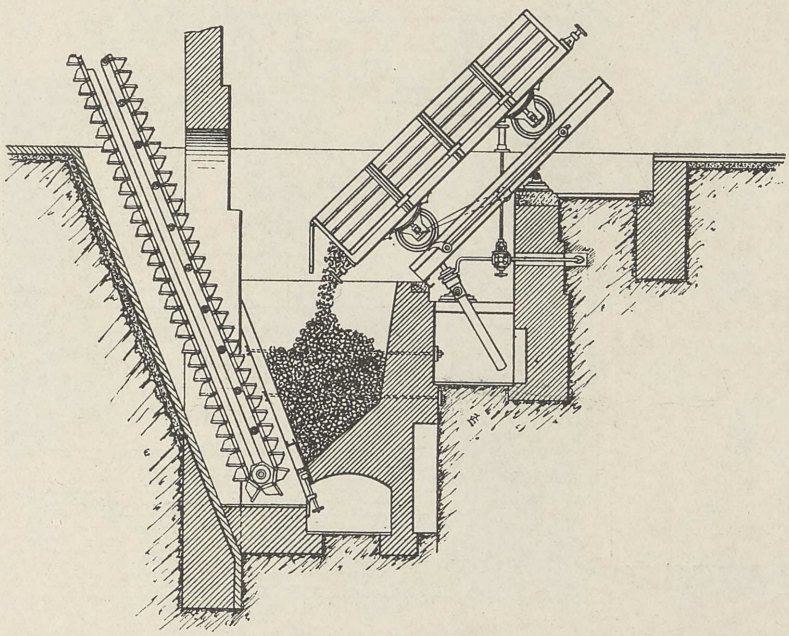


Fig. 730. Tip for Power Stations and Factory Yards.

platform by the next full truck. This process is an exceedingly simple one, but, as in the case of the appliances previously described, some precaution needs to be taken to prevent a shock, and also to provide for an automatic return of the tip to its original position. To this end a hydraulic brake has been constructed in conjunction with a balance weight. This brake consists of a cast-iron cylinder, 16 in. diameter, which is erected beneath the platform within the quay wall. A piston which fits the cylinder is connected with the platform of the tip by a connecting rod. Both ends of the cylinder are connected to the hydraulic main, the outlets being controlled by valves. Thus when the platform is being lowered during the discharge of the contents of the truck, the piston forces the water out of the cylinder, and by regulating the outlet by means of the above-mentioned valve the process of lowering can take place without shock. The return movement of the platform to its level position is controlled by the balance weight. The truck with its load of 10 tons of coal is pushed upon the platform, which is, by the way, supported upon two

trunnions 8 in. in diameter, which are placed slightly out of centre with the platform so as to give it a natural inclination to sink towards the waterside. The balancing device consists of two weights secured by iron bracings to the lower portion of the platform. The total weight of the two is 5 tons, or somewhat more than the weight of the empty truck. As soon as the load has left the truck there will be a tendency for the counter-weight to replace the platform in its original position.

During the return of the platform, the hydraulic cylinder and piston are again brought into action to prevent a too quick return of the platform, and thus avoid shock. The railway trucks are specially constructed for this particular purpose, and have hinged side doors instead of the more usual end doors. The whole load of 10 tons is discharged

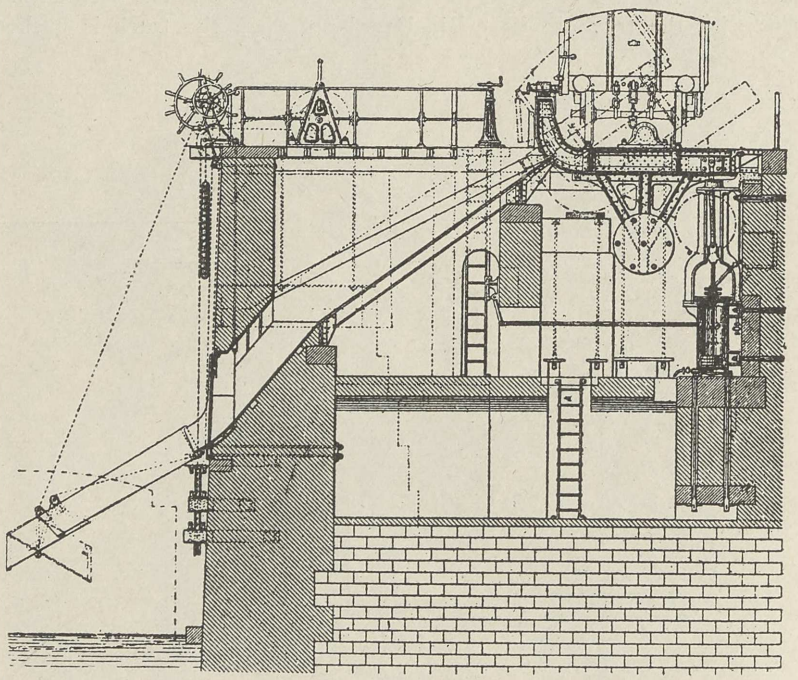


Fig. 731. Tip at Bethune.

into a shoot which is of sufficient capacity, the outlet of this shoot being so contracted as to let the coal out into the barge in a gentle and more or less uniform stream.

It is generally so arranged that the same time is allowed for the coal to empty itself out of the shoot into the barge as it takes to bring back the empty truck into its original position and replace it by a full one. A number of capstans have been erected at the quay by means of which the barges can be quickly put into position for loading. One man is sufficient to operate the tip. Two such tips are now at work at Bethune, and as each is capable of dealing with twenty-five trucks of 10 tons each per hour, 5,000 tons per day of ten hours can be handled, and a speed of five wagons in ten minutes has been accomplished. These tips have the undoubted advantage that the empty trucks can never be in the way of the full ones, as all trucks, both full and empty, are moved in the same direction and on the same road.

A device similar to the Bethune coal tip was erected by the Société Charbonnière,

of Lens;[1] also by the Bruay Mining Co., Calais,[2] in connection with their loading basin at the north of Bethune. The capacity is rather less than in the case previously described, as it will only handle seventy wagons of 10 tons each per day.

The Noeux Co.'s Tip.—This device, which is again similar to those just described, is illustrated in Fig. 732. It has been used at the dock of the Noeux Co., in connection with the canal of La Bassé à Aire.

There is a fixed hopper or frame formed of two ribbed cast-iron cheeks solidly bolted to the wall of the wharf, on which is fixed a crane for handling a movable shoot. This movable shoot is connected to the fixed hopper by a spout which can be turned in any position around a vertical axis, and distributes the coal over the area thus commanded.

The trucks are of special construction, and their bodies consist of three boxes of a capacity of $3\frac{1}{2}$ tons each, which are tipped separately.

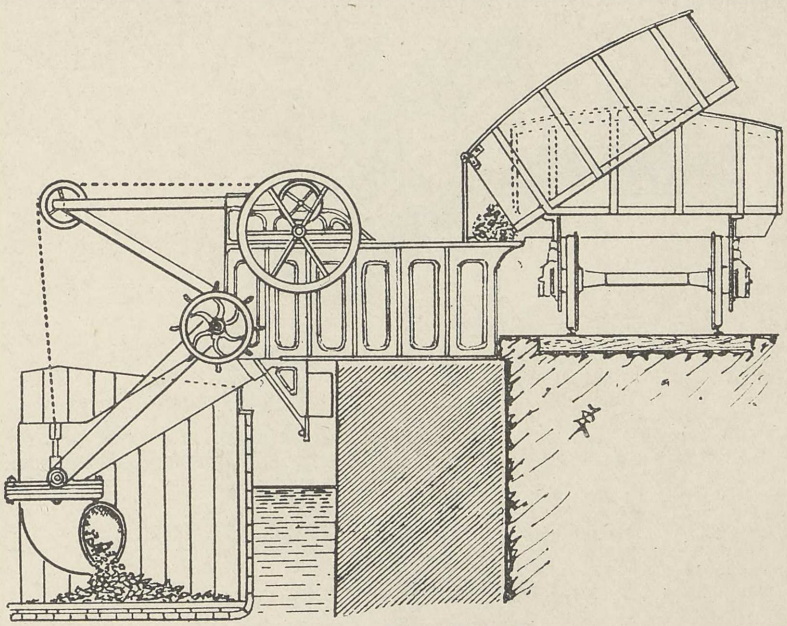


Fig. 732. The Noeux Co.'s Tip.

On the side next the hopper the boxes are provided with doors hinged horizontally at the top, and engaging in clips which are fastened a little back upon the ends of the car. At the bottom of this door two pins are fastened which work laterally, and are caught, when the box rests on the truck, by two dogs attached to the sill.[3] With this arrangement, when the box is raised from the back, the pins on the door are gradually set free from their dogs, and at a certain point the door becomes unfastened and opens for the passage of the coal. On the return, when the box is empty, it drops back on the under frame, the pins catch under their dogs, and the door is fastened. At the

[1] A description of this arrangement will be found in the *American Engineer and Railroad Journal*, February 1894, page 70.

[2] This appliance was described in the *American Engineer and Railroad Journal*, March 1894, page 112.

[3] A description of this arrangement will be found in the *American Engineer and Railroad Journal*, March 1894, page 112.

Noeux station the boxes are raised by means of a hydraulic ram, whilst at the loading wharf they are manipulated by an ordinary crane.

Coal Tip Built by Pohlig.—Another device which comes under this heading is that built by J. Pohlig, of Cologne, and illustrated in Fig. **733**. The truck is held in position by a chain at the tail end, whilst the front buffers rest against a support specially constructed for this purpose, to take the weight without straining the buffer springs. Unlike the tips previously described, the one under consideration is manipulated by a band brake. The end of the cradle is weighted so as to bring it back to its original position when the truck is empty. The band brake is of such power that the truck can be held in any position. The tip is also fitted with a hand winding gear to be used if, in exceptional cases, the truck should not go back to its original position. Another and later type of tip by the same firm is shown in Figs. **734** and **735**.

The Stevenson Coal Tip.—This tip is illustrated in Figs. **736** and **737**, and is also manipulated by gravity, and requires, therefore, no driving power. The mode of

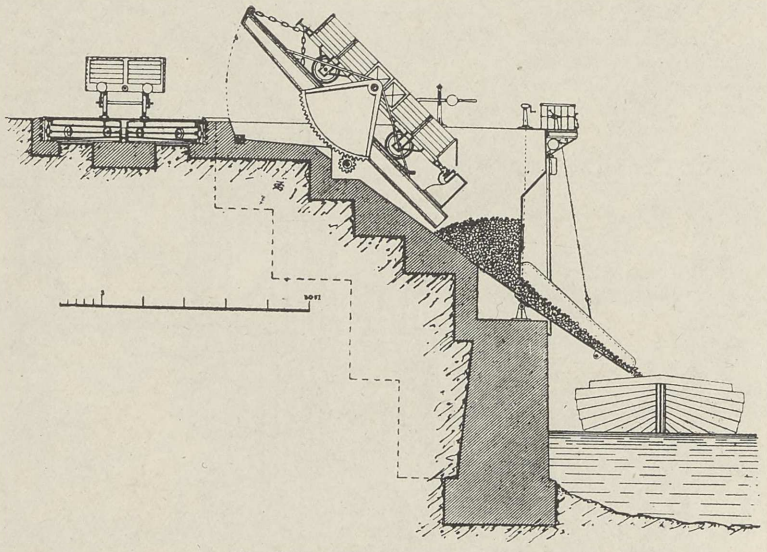
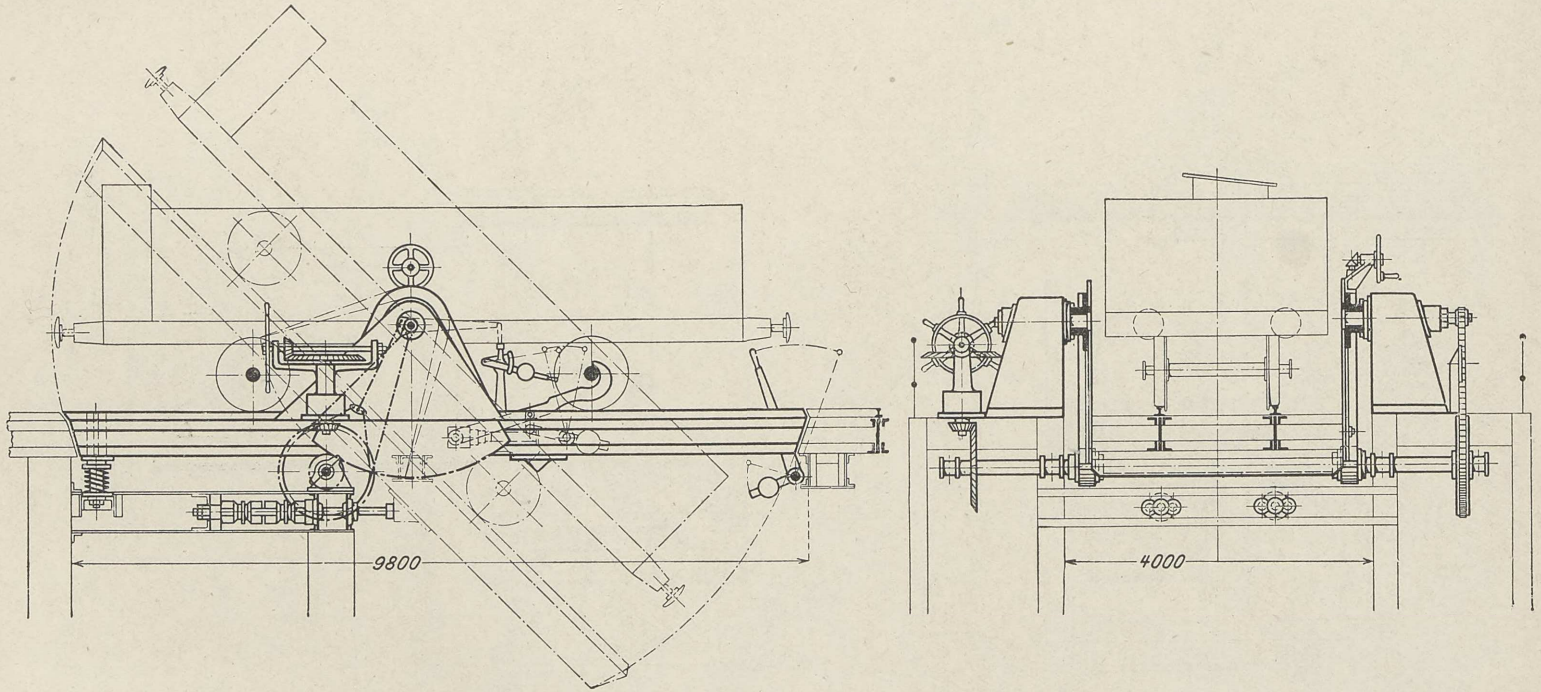


Fig. 733. Tip Built by Pohlig.

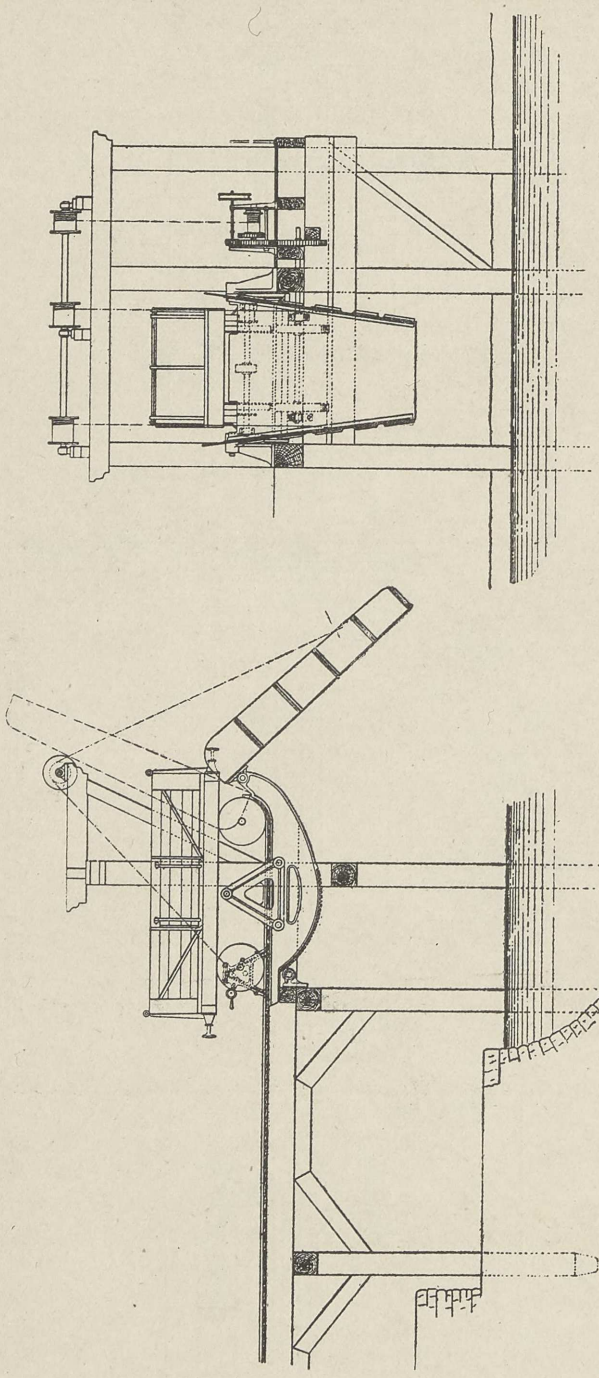
working is to run the truck on to the tip, which is kept in a horizontal position by means of a powerful brake. The position of the truck is such that its own weight will overbalance it as soon as the brake has been released. After the discharge of the truck it returns automatically into its original position. It is fitted with a shoot which can be housed out of the way when not in use, or the angle of which can be adjusted to suit the circumstances.

Figs. **738** to **740** represent another type of Stevenson's coal tip very similar to that just described. The illustrations show the appliance in plan and elevation, and the tip is shown, in Figs. **738** and **739**, in its discharging as well as in its horizontal position. This particular tip is arranged so as to overhang the quay wall, in order to get the discharge of the tip right on the barge to be loaded.

Figs. **741** to **743** show a further development of the Stevenson tip. The illustration consists of a longitudinal elevation and two cross sections, one through the tipping portion and the other through the framework extension. The appliance is arranged in such a way that it can be racked in and out. The whole apparatus is mounted on a



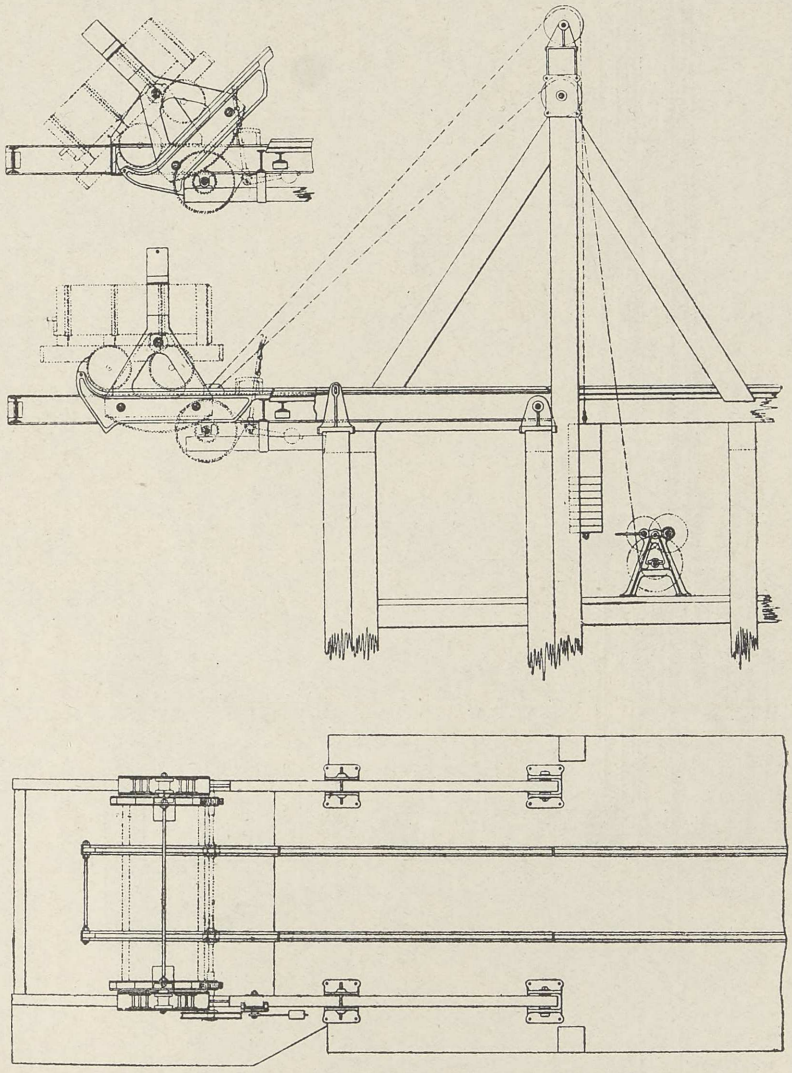
Figs. 734 and 735. Modification of Tip shown in Fig. 733.



Figs. 736 and 737. Stevenson's Coal Tip.

framework consisting principally of two long girders, so that the apparatus can be pushed in and out, but in all other respects the tip is the same as Figs. **736** and **737**.

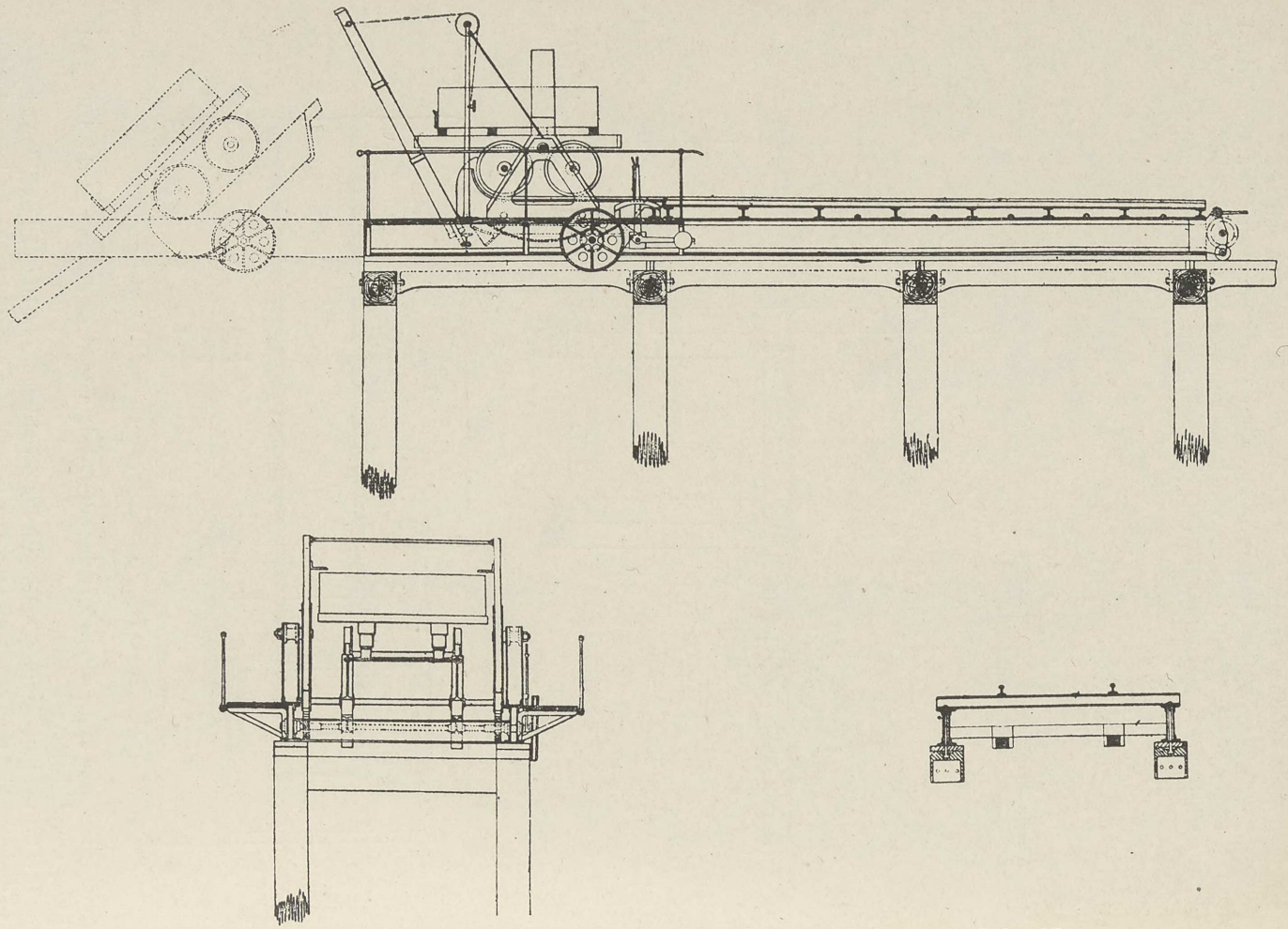
Sunderland Gravity Coal Shipper.—The River Wear Commissioners at Sunderland have installed a 20-ton gravity coal tip, which was supplied by Cowans, Sheldon, & Co., Ltd., of Carlisle. The apparatus, Fig. **744**, presented some entirely new features: it has



Figs. 738 to 740. Another Type of Stevenson's Coal Tip.

two large swinging arms, carrying at the outer ends a steel cradle and at the back end a heavy counterbalance weight.

It is for the purpose of dealing with hoppered wagons of 10 to 12 tons' capacity and is so designed that they can, under the easy control of a powerful brake, be lowered safely by gravity right down to, and even into, the ship's hold before they are discharged, thus minimising the breakage of the tender coal handled at that port. The empty wagons are



Figs. 741 to 743. Longitudinal Elevation and Cross Section of Coal Tip built by Stevensons, Ltd., of Preston.

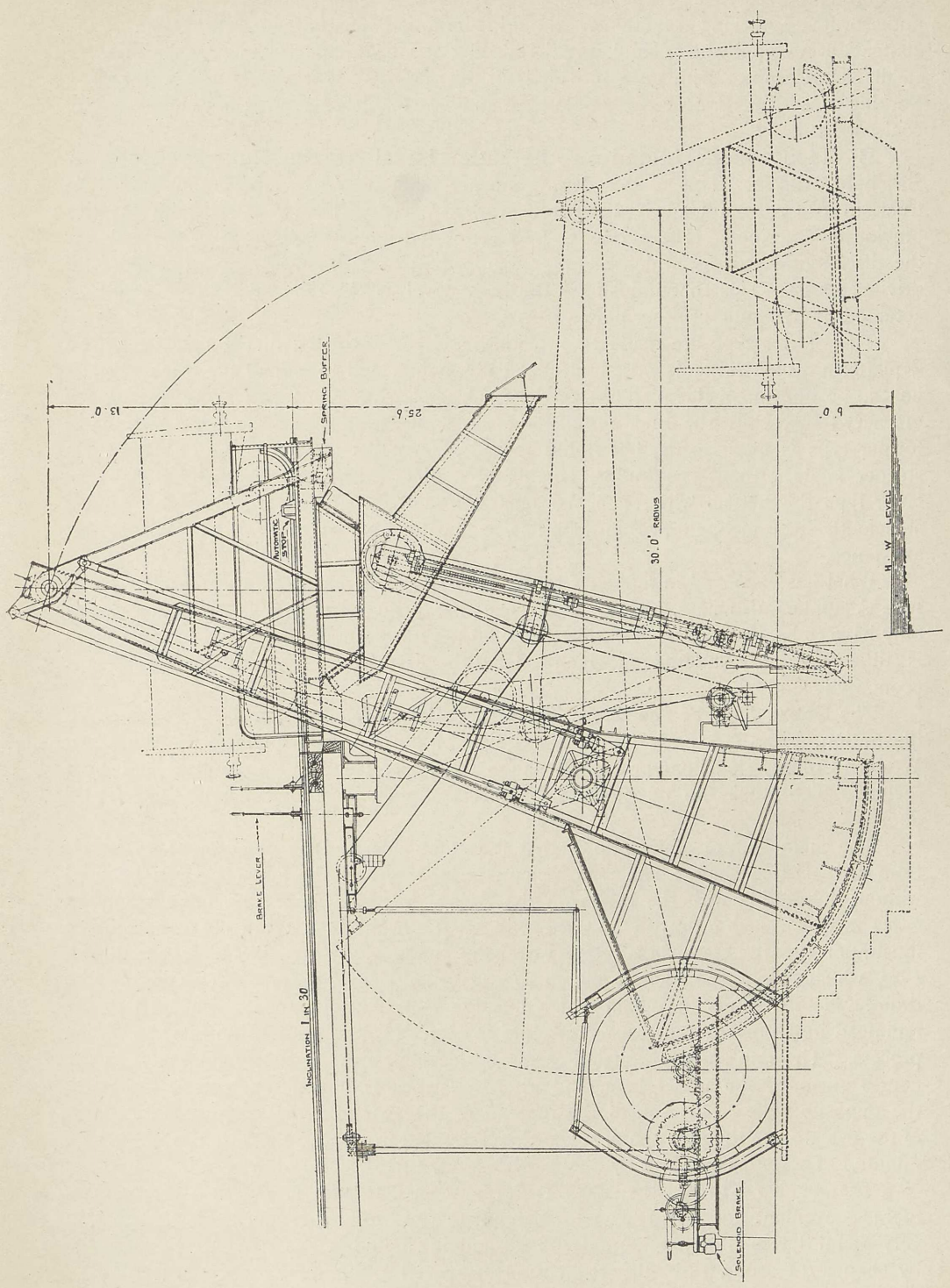


Fig. 744. Gravity Coal Shipper at Sunderland.

then brought back by means of the counterbalance weight, no machinery being required under ordinary working conditions. Should it be found necessary to return part of the contents of a wagon when completing the loading of a boat, this is done by means of a small electric motor with gear, provided for the purpose. The apparatus has now been working successfully for a considerable time and is capable of dealing with 500 tons of coal per hour.

B—Tips which Unload on the same Level as the Railway Lines, or Slightly Above.—Tips of this description are manipulated by raising one end of the truck in order to unload it, the reverse process having been followed with the tips previously described. There one end was lowered beneath the level of the rails for the discharging process, which allows of unloading with practically no expenditure of driving power. Tips that unload on the same level as the rails must in all cases be actuated by hydraulic or other power.

Tips of this type are made of two kinds: either a portion of the rails is laid on a platform, which latter is raised mechanically at one end to unload the truck which is held in position upon this platform, or the truck remains with one pair of wheels on the ordinary track, whilst the other end of the truck is raised by lifting the back axle. The former type is more costly, but it has the advantage that the trucks can be tipped to a steeper angle without the buffers coming in contact with the rails, whilst with the latter type the buffers will touch the rails before the platform of the wagon is at a sufficiently steep incline for some materials, such as damp coal, to clear the truck without assistance.

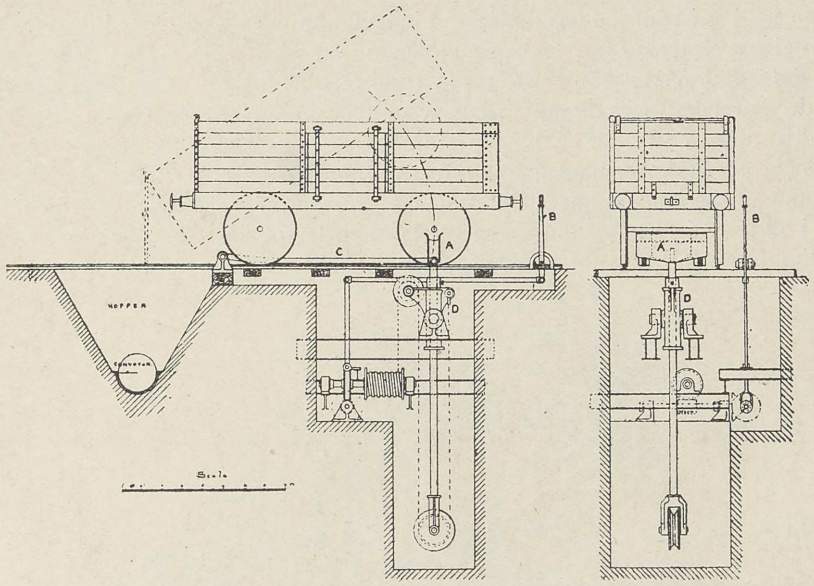
What has been said in reference to the disposal of the material with regard to tips of type A applies also here, with the difference that if an excavation is necessary it may only have to be 15 to 20 ft. deep, instead of 20 to 30 ft. in depth, but such an excavation is still a very costly undertaking which reduces the usefulness of the tip more or less if economy is studied.

The Power Tips of the Great Western Colliery Co., Pontypridd.—The annexed illustration, Figs. **745** and **746**, is the design of Mr Davison, engineer of the Great Western Colliery Co., Pontypridd. It shows the apparatus in a longitudinal and cross section. The trucks to be emptied by this tip must be provided with hinged end doors.

The main feature of this tip is that it can be operated by a motor or by a belt from any existing shaft. The rails remain unbroken, and the apparatus can be used without interfering with the traffic on the siding. It is evident that there are many cases in which such a tip can be used with great advantage. It will be seen from the illustration that the rear axle is brought over the ram-head A when the lever B is thrown over, which causes the friction clutch to engage with the worm shaft actuating the drum, and thus winds the chain which lifts the ram. Radial rods C are fixed to the ram-head and prevent the truck from moving out of its position during the lifting process. The ram passes through a cast-iron sleeve D with trunnions guiding it in the course given by the radial bars, and when the truck is tipped the lever is moved to the opposite side. This causes the reversal of the gear and the consequent lowering of the truck on to the rails again. The time occupied in tipping the truck is about one minute. These tips are built by Sheppard & Sons, Ltd., of Bridgend.

The Double Tip at the Cardiff Corporation Electricity Works.—Where it is more convenient for any reason to manipulate tips from above instead of below, a very useful device is the one here described and illustrated in Fig. **747**. It was designed by Sheppard & Sons, Ltd., Bridgend, to meet special requirements where space did not

permit of the underground type being installed. The advantages of such an arrangement for more general use are obvious. Working parts are readily accessible for examination



Figs. 745 and 746. Tip in Use at the Great Western Collieries.

and repairs, whilst the obtainable angle of tip is such that even wet material may be freely discharged. This is not always possible with the non-platform ram tip, in which the

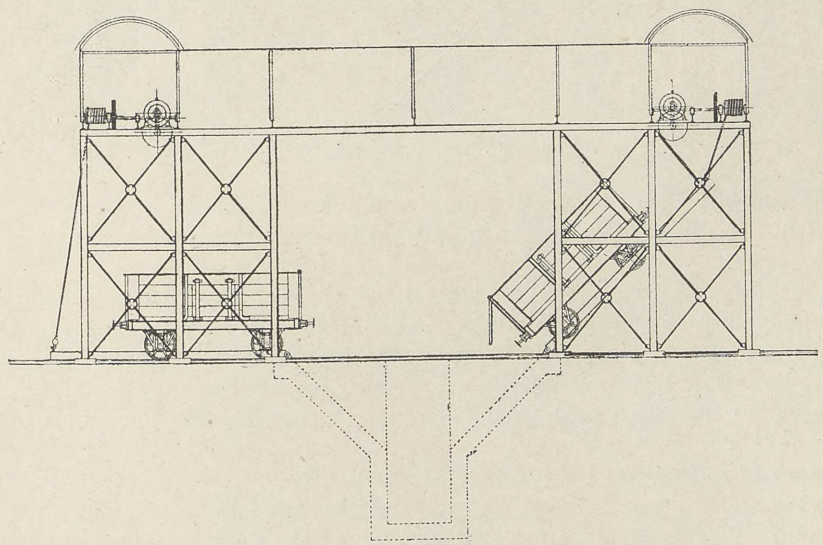
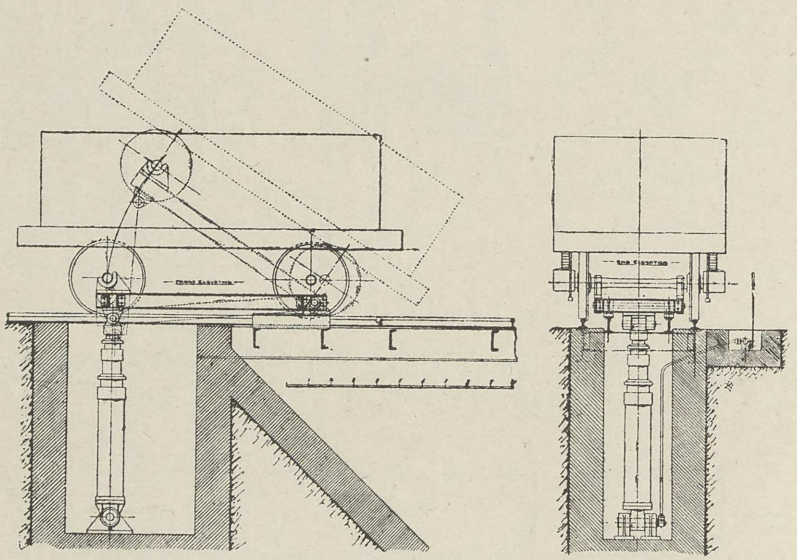


Fig. 747. Double Tip at the Cardiff Corporation Electricity Works.

angle of tip is limited by the buffers coming in contact with the permanent way. This system of end-tipping has also an advantage over some others, inasmuch as the whole

strain is put upon the wagon through the two axles, so that there can be no damage to the wagon as would be the case if lifted by the buffers, and the springs and axle-boxes cannot get out of position.

The tip consists of the usual platform hinged at one end, and fitted between the rails so as to give a clear way for the wagon to pass over when not in use. This platform is double the length of the wheel base of the trucks; thus there is a leverage of two to one of the dead weight to be lifted, in favour of the gear. The back axle of the truck is engaged by a cross member of the platform, having two wrought-iron plates fixed on each side, which prevents the axle slipping off as the truck is raised. Plates are also fitted on the framing of the cradle under the front axle, so that, if necessary, the whole truck can be lifted off the rails to obtain a sufficient angle for emptying. The winding rope travels across the drum, and thus the angle of the rope to the cradle is never excessive.



Figs. 748 and 749. Tip at the Brentwood Gasworks.

The simplest form of drive is from a countershaft by open and cross belt. The countershaft is driven by a motor of 10 H.P., the power required to tip a 12-ton wagon.

In practice, two truck tippers are often provided as in the illustration, one on either side of the hopper, so that if the end door of the wagon comes in the wrong direction for the one tipper it would be right for the other. A turntable in conjunction with one tipper would obviously answer equally well, though the difference in cost between a well-made turntable and the tipping apparatus would be trifling, whilst the first-named would entail more labour in operation.

Tip at the Brentwood Gasworks.—The installation illustrated by Figs. **748** and **749** is at work at the Brentwood Gasworks, and as the coal is taken in there at the rate of only 10 tons, or one truck-load, per hour, the slower working tip answers the purpose quite as well as one fitted with a more powerful pump, and consequently having a quicker action.

The hydraulic lifter and pump were built by the Leeds Engineering and Hydraulic Co., Ltd. The pump is a very small one, and is always at work when coal is being.

unloaded. This does not cause any waste of power, as the water only circulates between pump and tank. When the truck is ready to be tipped the water from the pump is forced into the hydraulic cylinder by turning a lever which controls a valve, when the ram slowly lifts the back portion of the truck off the line, whilst the front wheels rest against stop-blocks. The coal begins to discharge from the removal of the tail-board till the truck has been lifted to an angle of 45°. To lower the truck on to the line the water is allowed to escape from the cylinder into the tank out of which the pump is fed. This can be done slowly by carefully opening the valve.

Coal Tip of Pohlig.—A powerful platform tip is that built by Pohlig, of Cologne, shown in Fig. **750.** The platform is pivoted at its fore end, and is raised above the level of the ground by hydraulic force applied to its centre. The truck, of course, moves

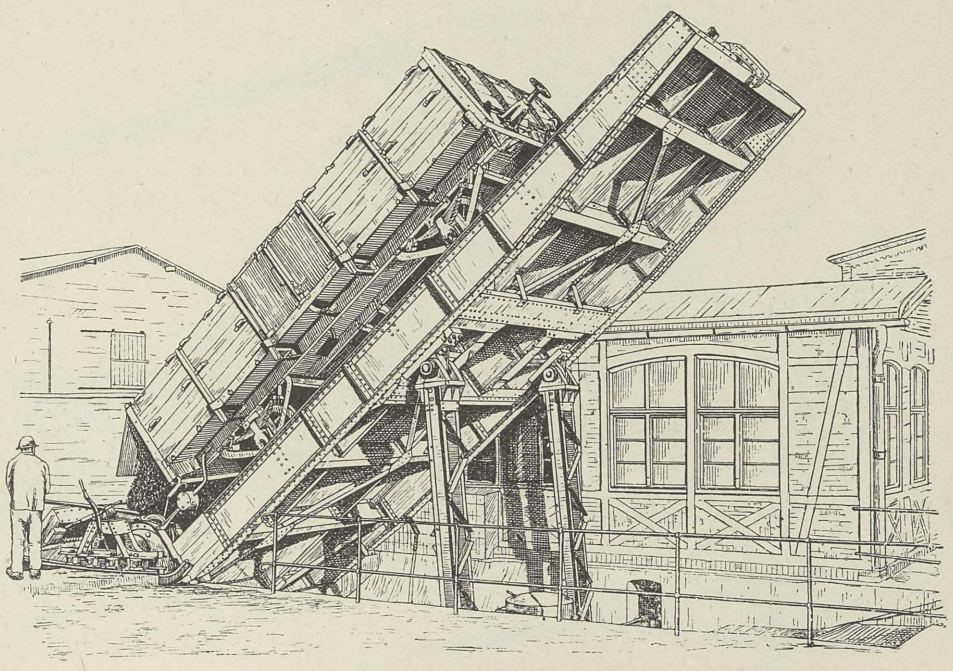


Fig. 750. Coal Tip as built by Pohlig.

with the platform until it is tilted at an angle of 45°, at which angle the rest of the material is discharged into the hopper or other receptacle on a level with the line. To minimise the expenditure of power, the weight of the platform is balanced by counter-weights. In other respects this platform is designed exactly on the plan of the cradle used in the other automatic tipping devices built by the same firm, which are described elsewhere.

To prevent a sudden drop of the heavy platform and its truck, which might happen if some portion of the gear were accidentally to give way, this tip is provided with a safety brake which holds the truck and platform so that in case of breakage it cannot move either up or down any faster than at its normal speed.

Tips in Factory Yards.—For use in factory yards the tips previously described have the inherent disadvantage that, unless the railway siding is raised on some structure above the ground level, it is difficult to dispose of the material unloaded by them, as

mentioned before, without the use of large pits in the ground to accommodate, or form in themselves, a receiving hopper for the contents of the truck, and also to accommodate an elevator well or some other device for getting the material out of this hopper again. Now such underground receptacles are, as every one knows, a source of endless trouble, owing to the ground water which in some cases makes their use all but impossible without sinking iron tanks into the ground. This being so, any tip which discharges a little higher above the ground will save so much excavation, trouble, and expense.

These circumstances were the incentive which led Professor Aumund, of Dantzig,[1] to design a tip which is on an entirely different principle[2]; he sets himself the task to construct a tip which discharges high enough to altogether avoid, or greatly lessen, the necessity of excavated receivers, and one which dispenses also with heavy platforms and

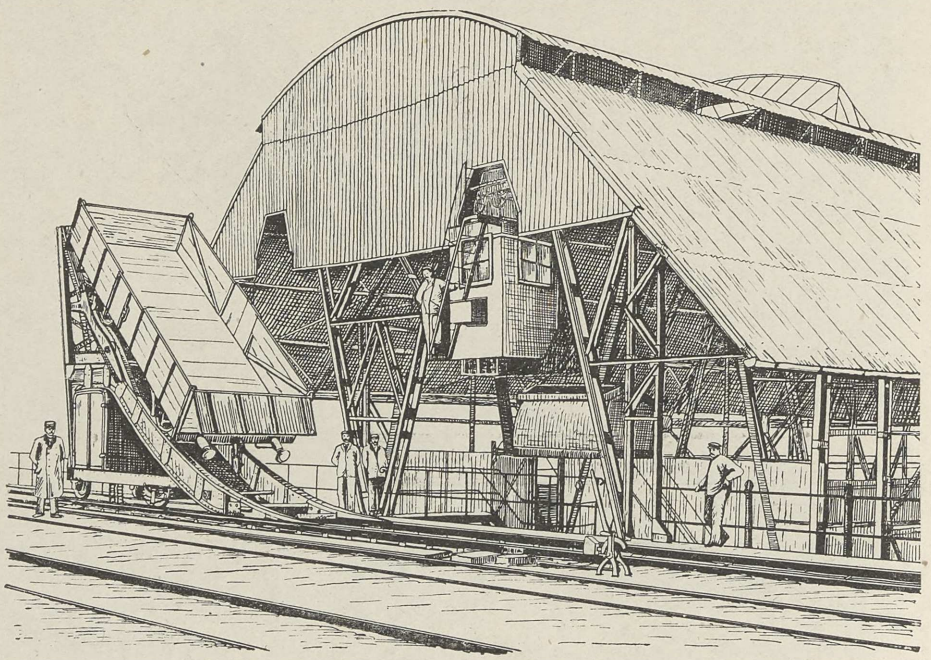


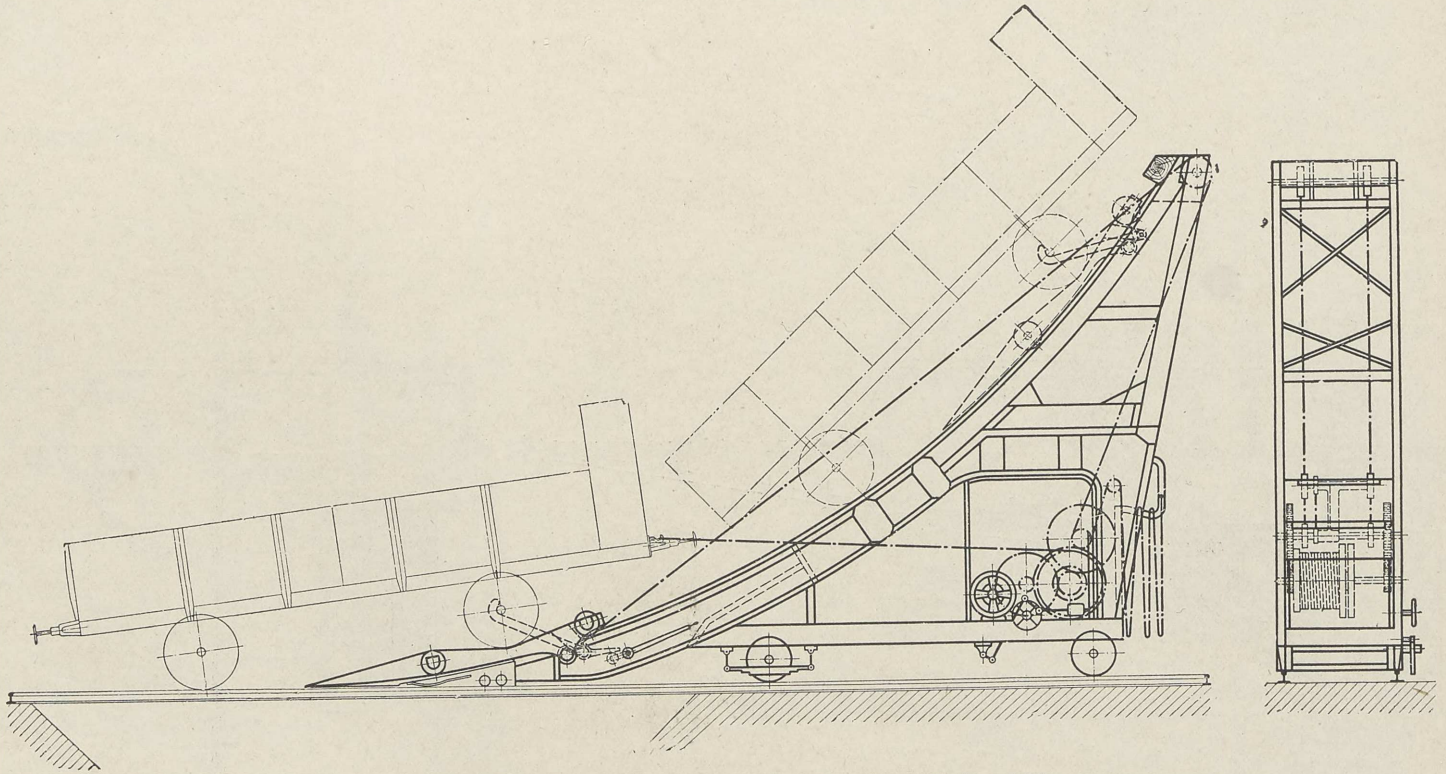
Fig. 751. Portable Curved Tip at the Hague Gasworks.

gears, and which might be used independently of costly foundations. It is an essentially portable tip, which he names "Curved-tip," as the truck is raised on to the curved rail track until it is in such a position that it will unload by an end door. Tips on this principle are not only built portable and stationary, but also with a revolving upper part or turntable, so that the trucks may be discharged at any angle with the railway track.

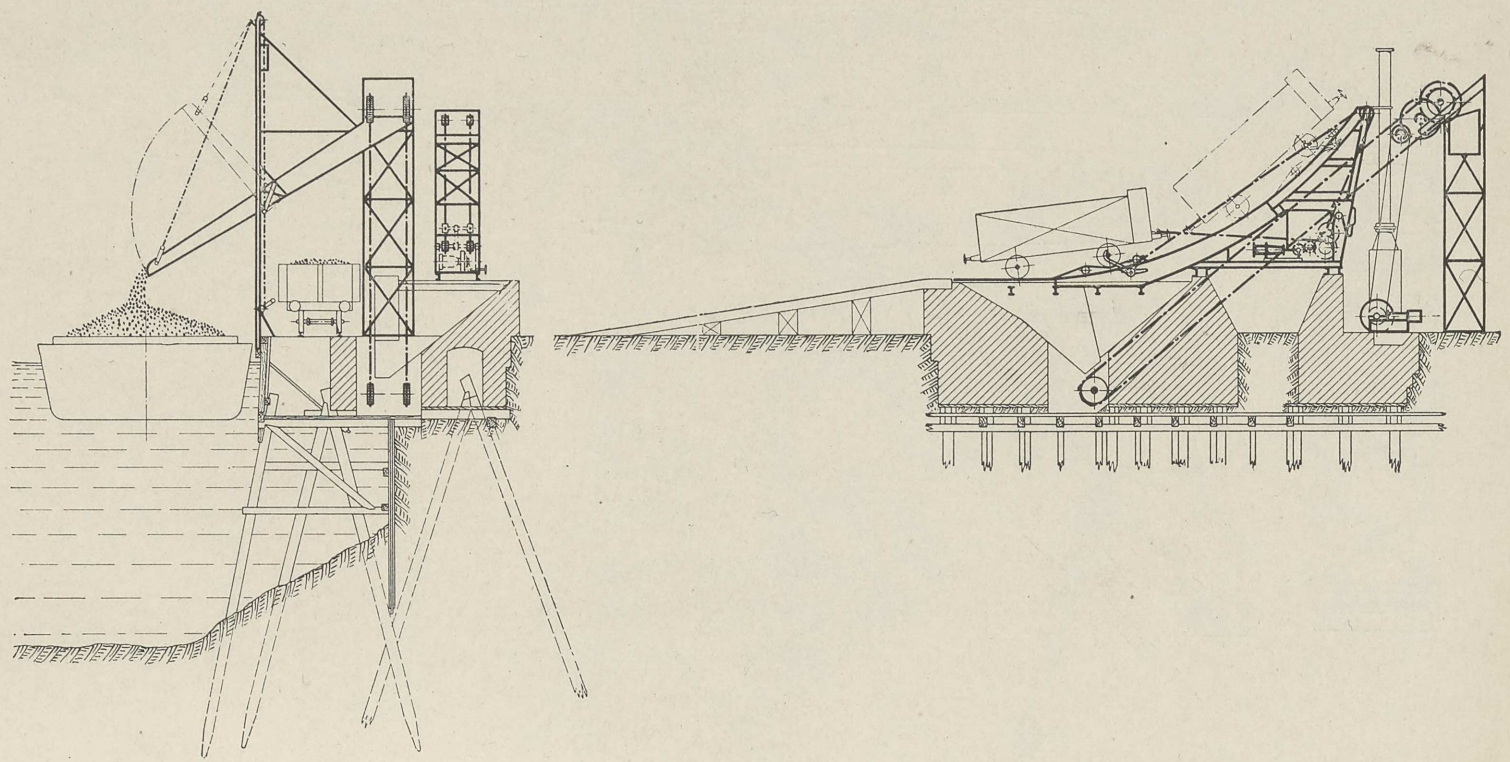
An example of a typical curved tip is shown in Figs. **751** to **753**; the first illustration shows a perspective view of a truck at the point of discharge, whilst the two latter show side and end elevation of the same tip. It will be seen from the illustrations that the

[1] From an article by Professor Aumund in the *Zeitschrift des Vereins deutscher Ingenieure*, 1909, page 1437. The author is indebted to Messrs Pohlig, of Cologne, the makers of this type of tip, for the illustrations.

[2] Although some of these tips discharge considerably above the line, it has been thought advisable not to divide these descriptions under this and the next heading, though that course would have been strictly correct.

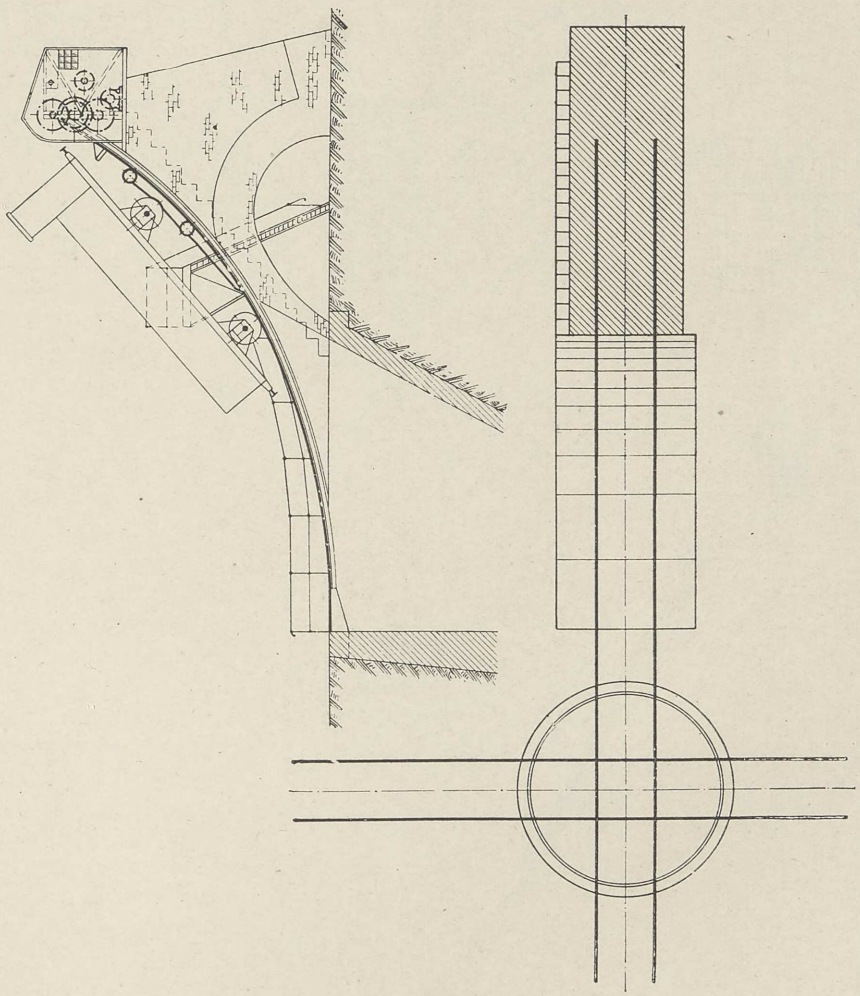


Figs. 752 and 753. Diagrams showing Principle of Portable Curved Tip.



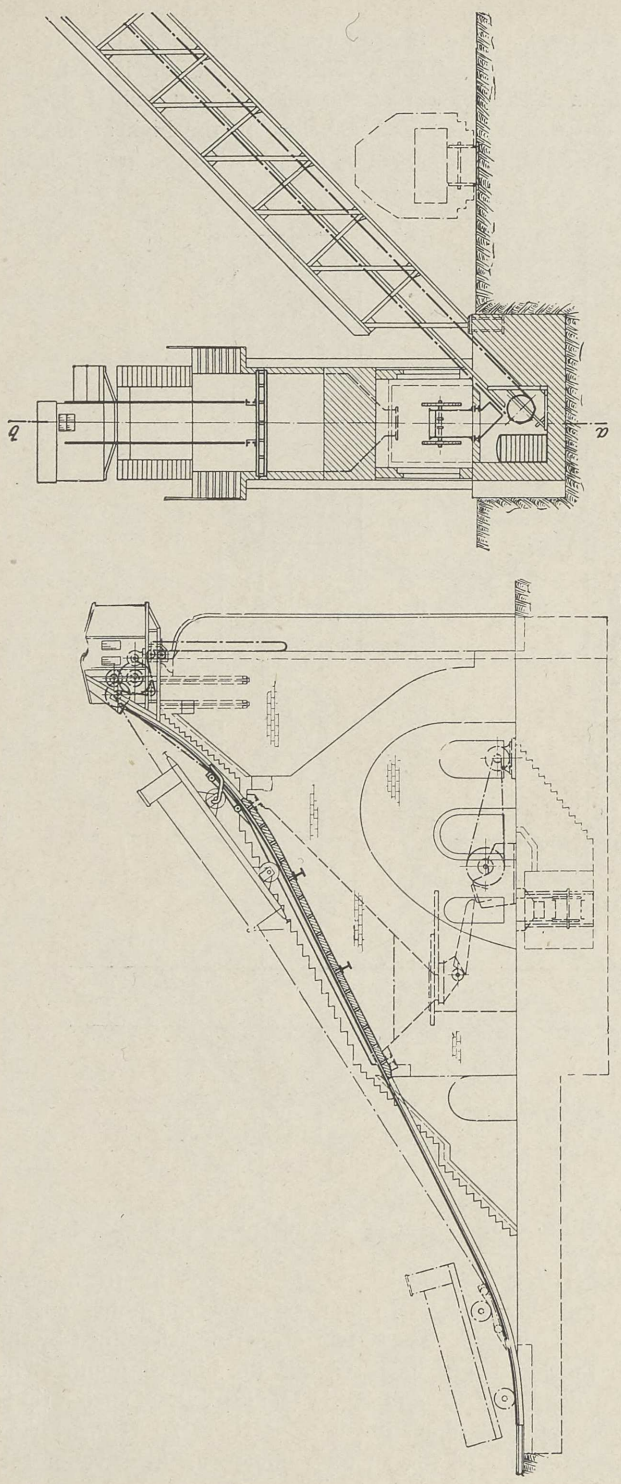
Figs. 754 and 755. Curved Tip at the Harbour at Bremen.

essential feature is the curved rail track, which in this case is portable, running on wheels and on a standard gauge rail track. The curve of the rail track is so chosen that the truck first ascends very gently, and at the extreme end the buffers of the largest truck do not touch the rails. Figs. **752** and **753** show that the truck is first pulled upon a low bogey, to which one axle of the wagon is secured, and also in the highest position where it delivers the load. A capstan, which is part of the gear of the tip, first pulls the



Figs. 756 and 757. Tip at the Liège Gasworks.

truck to be emptied on to the bogey, and as soon as it is in that position the hoisting gear is started, and immediately the chains begin to pull, two powerful hooks engage automatically with the front axle of the truck. These two chains are shortened by the hoist until the whole truck with the low bogey have reached the highest point. The unloading takes place between the angles of 45° and 55°. The capacity of such a tip is 150 tons per hour and the electro-motors manipulating it from 15 to 25 H.P., varying with the height of lift. The power consumed for 10 tons unloaded, inclusive of the

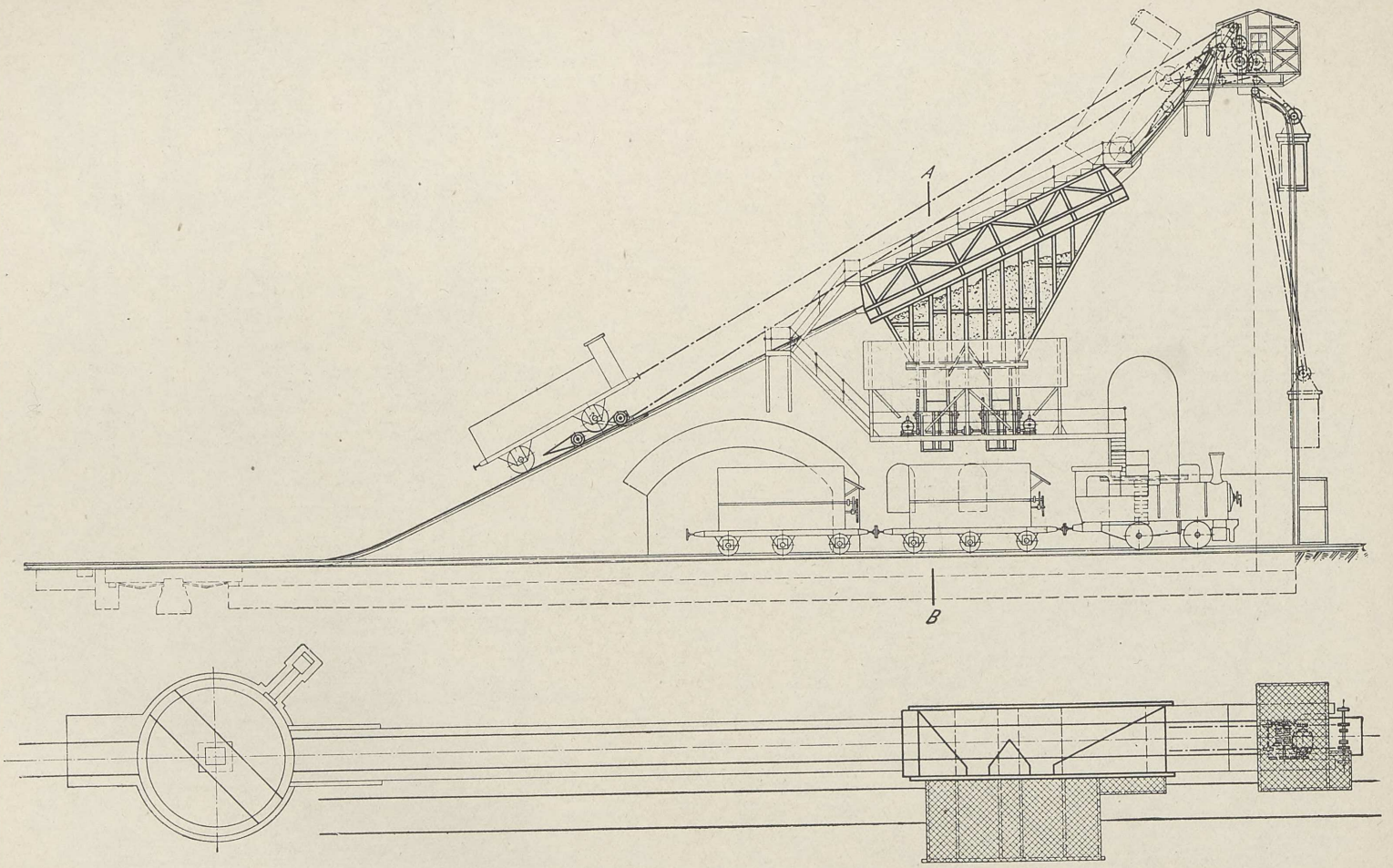


Figs. 758 and 759. Curved Tip at the Reisholz Electricity Works.

capstan, is ·3 kilowatt. After the truck is discharged it is allowed to descend into the first position (see illustration), where it leaves the bogey on its own account, as the hooks holding it are automatically released as soon as the lowest position is reached. It is usual to have a branch siding for the empties so that the progress of the full truck is not impeded and the tracks are laid with a slight downward incline. Figs. **754** and **755** show the same tip, but stationary instead of on wheels, at Bremen Harbour, where it has been installed by the North German Lloyd Co.

Another construction is to have the curved bed for the tip formed of a block of concrete or masonry, as shown in Figs. **756** and **757**, with a motor house and drivers' stand at the top. This installation is at work at the Gasworks of Liège. The stationary appliances just alluded to are worked in identically the same manner as the portable ones, but they lend themselves better for a somewhat greater lift and thereby save excavation for the further disposal of the material, as the trucks are lifted frequently by these appliances 5 to 10 ft. above the rail level.

As regards cost of unloading, from actual figures derived from the installations, it may be seen that if 240 tons have to be handled



Figs. 760 and 761. Curved Tip for Iron Ore and Limestone at a Westphalian Blast Furnace.

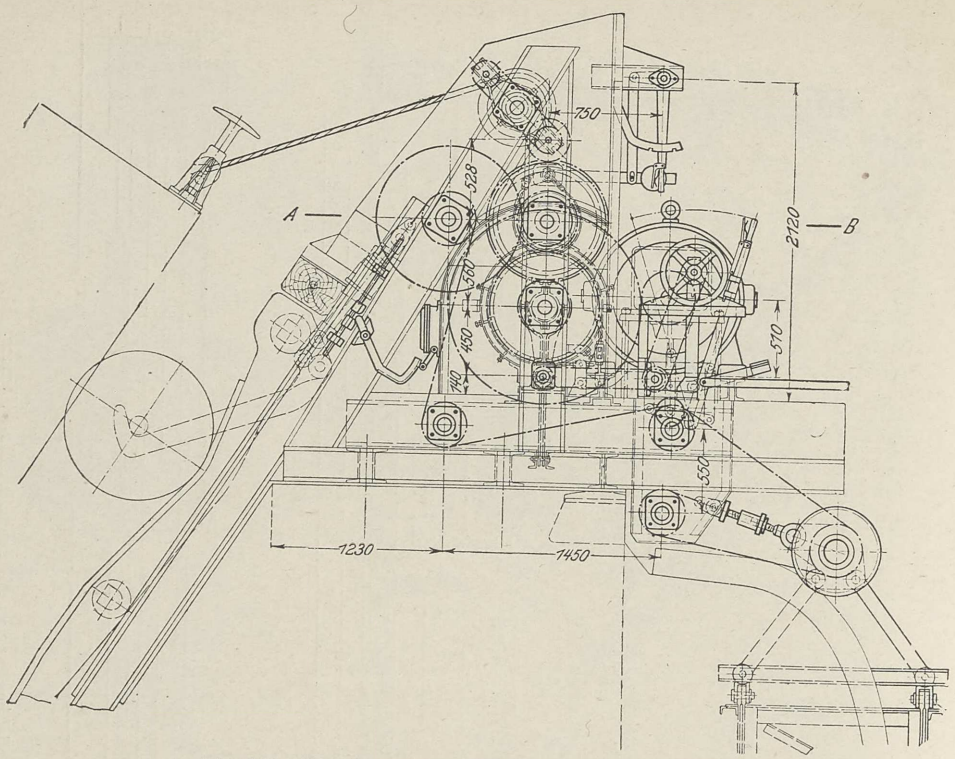


Fig. 762. Side Elevation of Winding Gear for Curved Tip.
(The dimensions are in millimetres.)

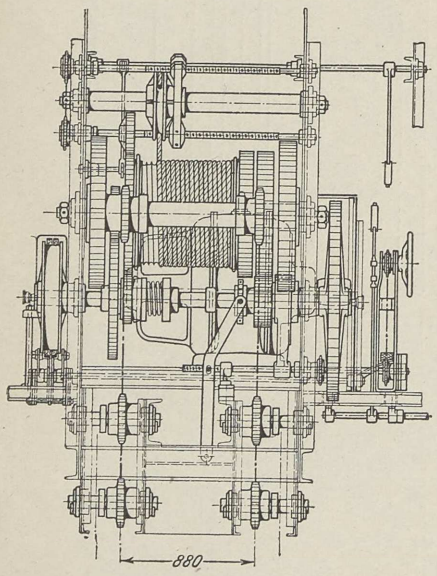


Fig. 763. End Elevation of Fig. **762.**

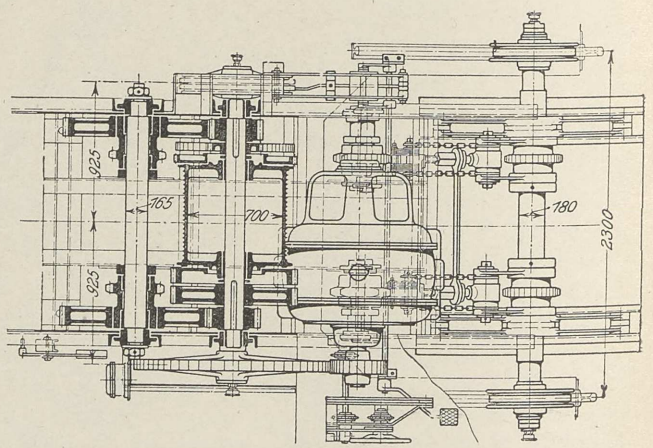


Fig. 764. Plan of Fig. **762** (Section A B).
(The dimensions are in millimetres.)

daily, the capital expenditure for such a tip is fully warranted from a commercial standpoint.

The tip shown in Figs. **758** and **759** is the same, but on a larger scale. Here the small bogey is let down over an inclined portion of the track at an angle of 30°, and the truck is raised up this incline with the end door closed, and this is not opened until the curved tipping portion of the track is reached. In this particular case the coal is discharged into an elevated receptacle. It has been found that coal trucks can be raised at an angle of 30° with the greatest safety, and no shifting of the coal takes place at this incline, neither is there any additional pressure against the end door. The expenditure of power is ·7 kilowatt per 10 tons of coal handled, so that, inclusive of labour, the cost of handling 10 tons is a fraction over twopence, and when handling more than 7,000 double loads (of 20 tons each) per annum, the expenditure on the installation is justified; at 7,000 the total expense, including the capital account, is equal to that of hand labour.

An interesting installation on the same principle is shown in Figs. **760** and **761**. An ore pocket holding 60 tons is here filled by the trucks, and such a tip almost answers the same purpose as a hydraulic coal tip, but the initial cost is very considerably less. The weight of the truck is balanced by a weight which is seen at the back of the structure. The capacity of this plant is twelve 20-ton trucks per hour, and a 68 H.P. motor manipulates the tip. Figs. **762** to **764** show the winding gear which can be used as a capstan to draw the wagons near, and revolve the turntable as well as lifting the load. The power consumption for a 20-ton truck at the rate of 150 tons per hour is 1·5 kilowatts. Such an installation becomes commercially economical when handling over 275 tons per day.

A further and most useful development of the Aumund system is a portable tip, which may be handled in the same manner as ordinary rolling stock; it may therefore form one of the units of a mineral train, and be used for unloading at the destination of the train. For this purpose the tip is mounted like a turntable upon a low carriage, and fitted with motors according to local circumstances, taking the power from existing mains, or fitted with a primary motor of the oil or petrol type coupled to a dynamo. Figs. **766** to **769** are diagrams of electrically-driven tips of this description. Their use is precisely similar to those already described, with the exception that the turntable (driven by a separate motor) is used when the truck on the tip has been raised to an angle of 30°, and when the table has been turned to an angle of 90° with the line of rails, the end door is opened and the lift completed to an angle of from 45° to 55°. When the truck has discharged its load the turntable is used again, continuing in the same direction for another 90°, so that the truck may now leave the tip at the opposite end to that at which it entered. If used in this way the whole mineral train can be unloaded truck by truck, and the empties reunited for the return journey. These tips are self-propelling, and can therefore be used in a variety of ways, even dispensing with the locomotive when the mineral train has only a short distance to travel. The wheel base and the distribution of the load upon the permanent way does not exceed the usual limits, so that these tips can be used in the way described on all sidings where ordinary railway engines travel. Eight trucks of 10 or 20 tons can be tipped per hour. The lifting motor is of 25 H.P., whilst those manipulating the turntable and for self-propelling are of 8 H.P. each. The power consumed is ·5 kilowatt per every 10 tons handled. One driver and two labourers are necessary, and the cost of unloading by these tips in Germany is reckoned to be just under 1½d. for every 10 tons of coal handled. Such tips are economical if the amount handled annually exceeds 6,300 trucks of 20 tons; for quantities below this they are not more economical than hand labour.

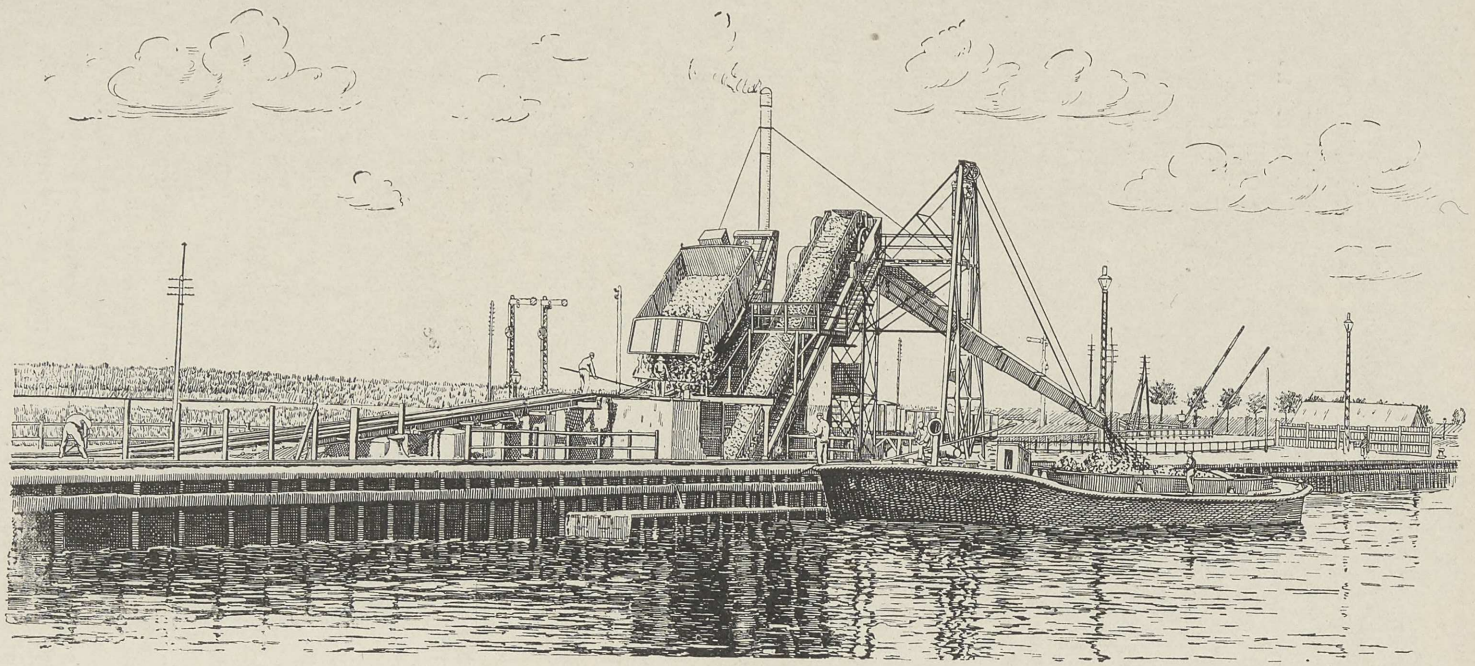
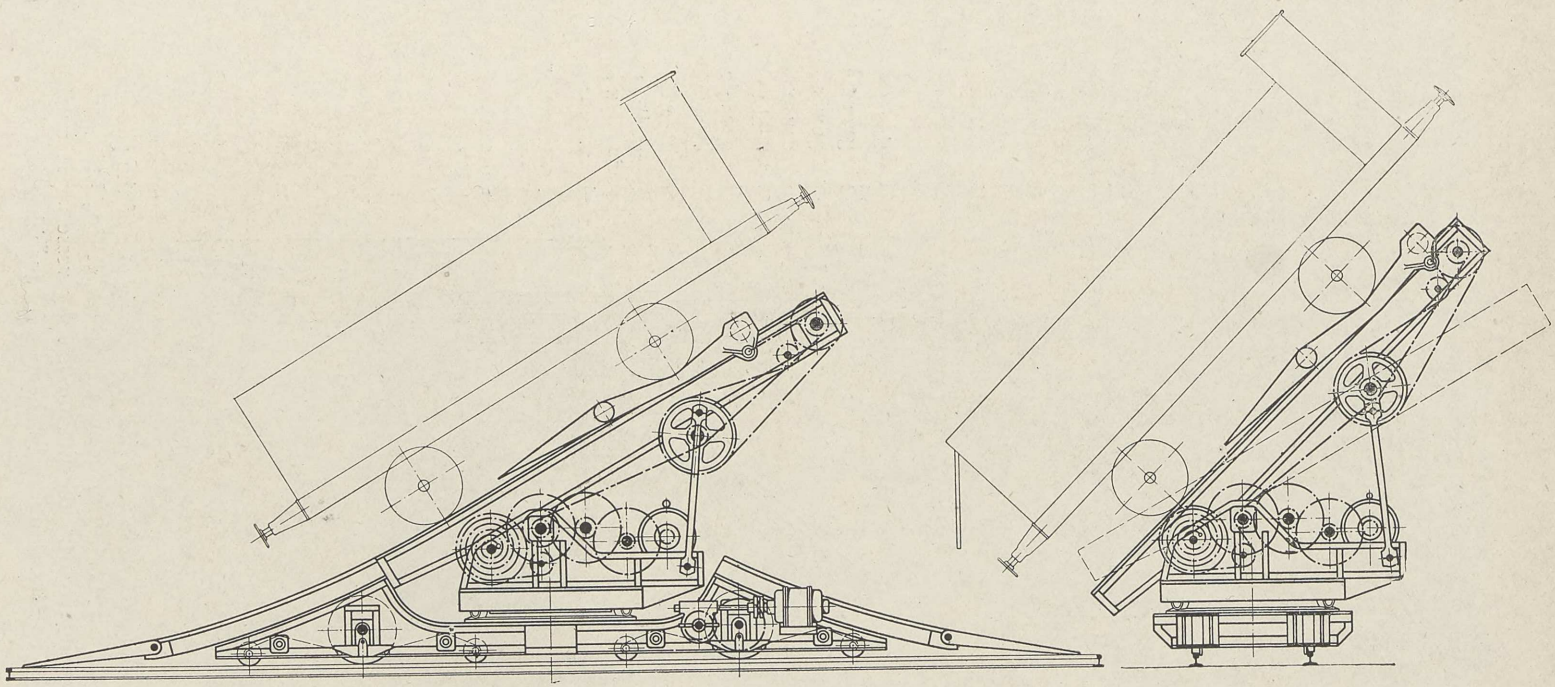
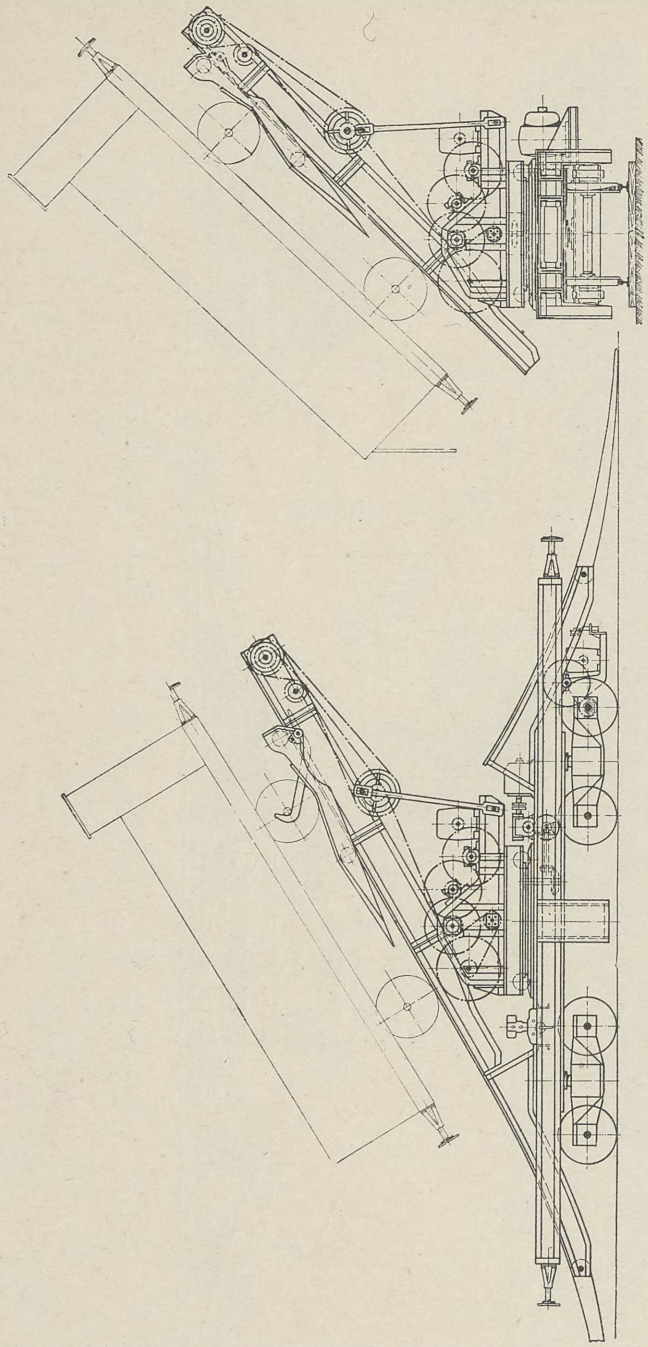


Fig. 765. One of the Installations of the North German Lloyd Co. at the Harbour at Bremen.



Figs. 766 and 767. Portable Turntable Tip driven by Motor from Electric Main.



Figs. 768 and 769. Portable Turntable Tip driven by Petrol Engine and Electric Motor.

C—Tips which Unload Above the Level of Railway Lines, generally called Hoists. — The tips under this head are undoubtedly the most important of the three types, and are generally used in cases where a quay wall is not very high above the water level, or where large ocean-going steamers (the holds of which naturally extend above the level of the quay) have to be loaded with coal and other minerals.

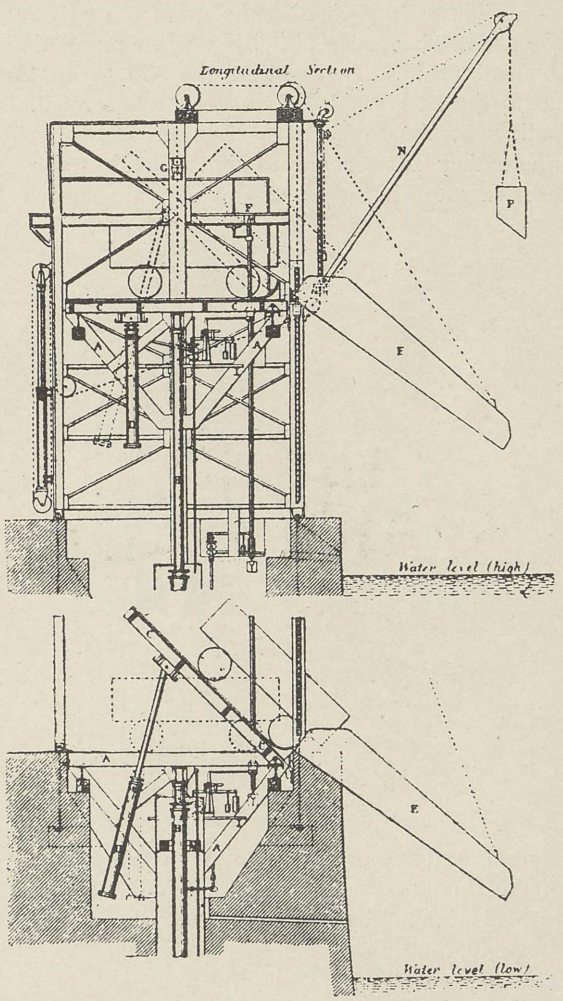
It is obvious that in this third type of tips a great expenditure of power is necessary, because not only has the coal to be lifted to a level considerably above the quay walls, but the speed at which it has to be done is great.

The first mechanical coal tips of this description were lifted and tilted by hydraulic power. Such coal tips are still the most generally used, but electrically driven tips are beginning to be advocated. It may be said that the loading of coal ships has called into use a greater variety of hydraulic appliances than almost any other operation in the mechanical handling of material. The credit is undoubtedly due to Lord Armstrong, one of the pioneers of the hydraulic system, whose firm, Sir W. G. Armstrong, Whitworth, & Co., Ltd., have always been well to the front in building hydraulic tips for loading vessels. It must be admitted that no fixed rule can be laid down as to the type of machinery to be employed in each

individual case, as a great deal must depend upon position and local conditions. This applies not only to the various systems, but also to the various types of hydraulic machinery.

Sometimes direct acting cylinders below the cradle are the most suitable, whilst in other cases hydraulic cylinders at the side of the structure manipulate the cradle by means of cables or chains as the case may be.

The first coal tips of this description erected by Sir W. G. Armstrong, Whitworth, & Co., Ltd., consisted of a set of four at Cardiff, and another set of four at Newport. These were erected in the year 1858, and were followed in 1859 by the two tips at Swansea, and in 1861 by two at Briton Ferry. The latter were very similar to the Cardiff tips, which are of the type generally built by the Armstrong firm. Since those days, however, the power and height of the lift has been very considerably increased with the increased size of ships, and so-called anti-breakage cranes have been added.



Figs. 770 and 771. Elevation of Cardiff Tip.

The Cardiff Tip.—The general type of the first Armstrong hydraulic tip and hoist is shown in elevation in Figs. **770** and **771**, whilst Fig. **772** gives a plan of the same. Tips of identical construction are now being built with a lift of 40 ft. and over above the quay.

The cradle A which carries the wagon is raised by vertical hydraulic ram B, whilst the cradle itself is guided at its four corners by the framework, and the loaded wagon is raised to the level of the shoot E. The upper portion C of the cradle forms the tipping frame, and is pivoted at the front and tipped with the wagon upon it by means of a second hydraulic cylinder D below the cradle, and attached to it as shown in Figs. **770** and **771**. The cylinder oscillates on trunnions to follow the motion of the tipping frame, the hydraulic main being connected to the cylinder through one of the trunnions.

The whole apparatus can be controlled by a man standing on a side platform F, at the top of the structure, with the levers controlling the machinery close at hand. The raising and lowering of the shoot E for adjusting both height and inclination are automatically effected and are quite independent of hand labour. Two short arms

project at each side of cradle A under the top end of the shoot. When the cradle is elevated the shoot is also carried up with it to any desired level, and is held in that position by weighted pawls, which fall into vertical racks secured at each side to the frame. By holding these pawls disengaged from the racks, the shoot may be lowered with the cradle to any level. The shoot is also secured by a safety chain on each side, which is fixed in each new position by a clip.

The two arms that lift the shoot are so balanced as to hang vertically and clear of the shoot when out of use, but when required they are thrown into action by pulling a small chain. The end of the shoot can also be raised or lowered in a similar manner, so as to give a greater or lesser fall, by means of two chains carried over pulleys at the top of the structure, and brought down the centre, one at each side, where they are secured to the frame by clips at the desired level. Whenever it is necessary to shift these chains they are pushed upon strong hooks fixed at the edge of the cradle, and then by lowering or raising the cradle the point of the shoot is raised or lowered as desired, and the chains are again fixed in a new position by the clips. In some districts, South Wales for instance, where the coal is very friable, it is necessary to take special precautions for reducing the loss by breakage, which occurs in discharging the coal wagons into the ship's hold, and for this purpose the anti-breakage crane N has been introduced. For further development in this direction see description of the Penarth tips (page 557), in which full details of the Thomas Anti-Breakage Box[1] are given. The receptacle used in conjunction with this crane N is the iron skip P, holding about 1 ton of coal. It is hopper-shaped, with a hinged flap door for discharging at the bottom, and is suspended from an independent light jib crane N, fixed at one side of the tip frame, and having hydraulic lifting and turning motions. In commencing to load a ship, this bucket is filled from the shoot E, then lowered to the bottom of the hold, and there emptied by pulling up the bolt which secures the flap door. This process is repeated until a conical heap of coal is formed sufficiently high to reach nearly to the hatchway, after which the shoot is allowed to discharge freely without the use of the bucket and delivers close down upon the heap, a vertical drop being thereby prevented. The point of the shoot is somewhat contracted so as to check the speed of the coal down the incline. At this point the discharging sometimes requires a little assistance by hand, and is thus kept under control whilst the bucket is being filled. The whole process is effected much quicker than it takes to describe it, the discharge of the bucket in the ship's hold being self-acting, as the bolt which holds the flap door is fastened to a chain which is fixed to some portion

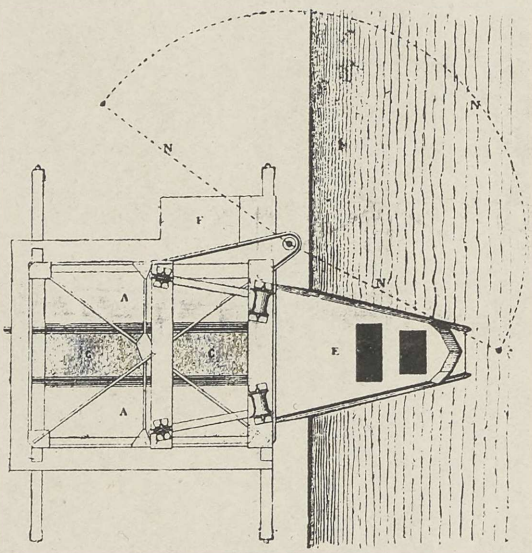


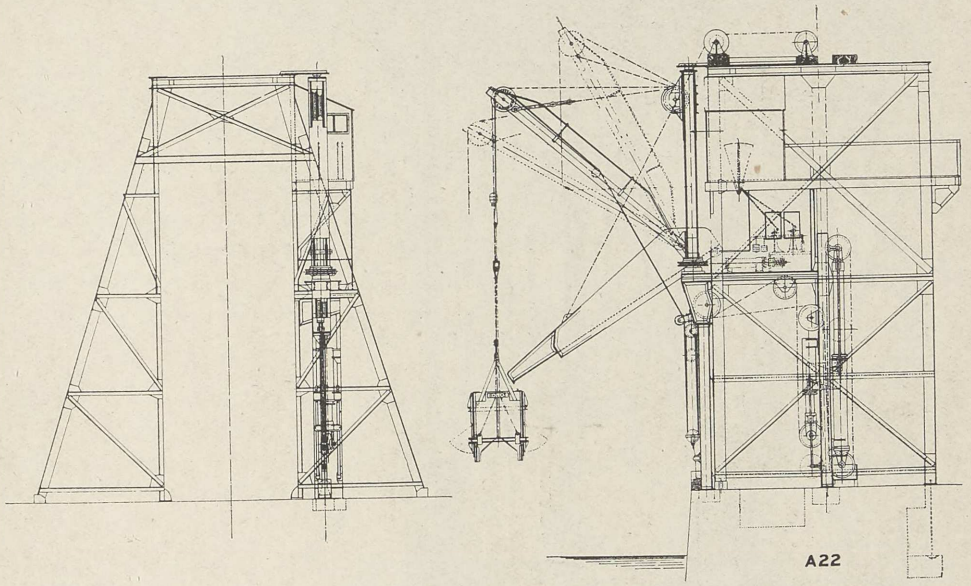
Fig. 772. Plan of Cardiff Tip.

[1] Other anti-breakage appliances are described and illustrated in the chapter, "Loading Coal into Ships otherwise than by Tips" (page 595).

of the rigging or deck, and thus the door is automatically released as soon as the bucket has reached the point of discharge. This anti-breakage crane may also be used with advantage for discharging ballast, as well as for filling into wagons the small coal that passes through a screen sometimes fixed in the shoots.

The latest tips of Sir W. G. Armstrong, Whitworth, & Co. are fitted with "Burntisland" anti-breakage boxes (see Figs. **773** and **774**), so named from being first fitted on one of the hoists of the North British Railway Co. at Burntisland Dock. The appliance consists of a box fitted with side doors and a tripping ring, which automatically opens the box at any predetermined level when it is lowered.

Notwithstanding all these precautions, the proportion of dust found in the coal when the ships are discharged at the end of the voyage is generally very great. This



Figs. 773 and 774. Armstrong-Whitworth Tip fitted with "Burntisland" Anti-Breakage Box.

breakage is undoubtedly partly due to want of care in trimming the coal in the ship's hold.

Hydraulic Tips at the Barry Docks.—Another hydraulic tip with a direct acting ram is illustrated in Figs. **775** and **776.** It is the design of Sir John Wolfe Barry, and was erected by Sir W. G. Armstrong, Whitworth, & Co., Ltd., at the Barry Docks. This hydraulic coal tip consists of a substantial wrought-iron framework supporting the shoot for conveying the coal into the hold of the vessel, and at the same time serving as carrying guides for the lifting cradle on which the coal wagon is raised to the level necessary for discharging into the shoot.

The cradle itself is manipulated by two direct acting cylinders and rams (having a lift of 37 ft.), placed below the cradle as shown in Fig. **775.** One of these rams is so proportioned as to balance nearly the whole weight of the cradle, and is in constant communication with the hydraulic main. The action of this ram is somewhat similar to a balance weight. The water which is forced into the cylinder during the lifting of the cradle is returned to the main during the lowering.

The function of the second ram is to lift the load and the unbalanced portion of the

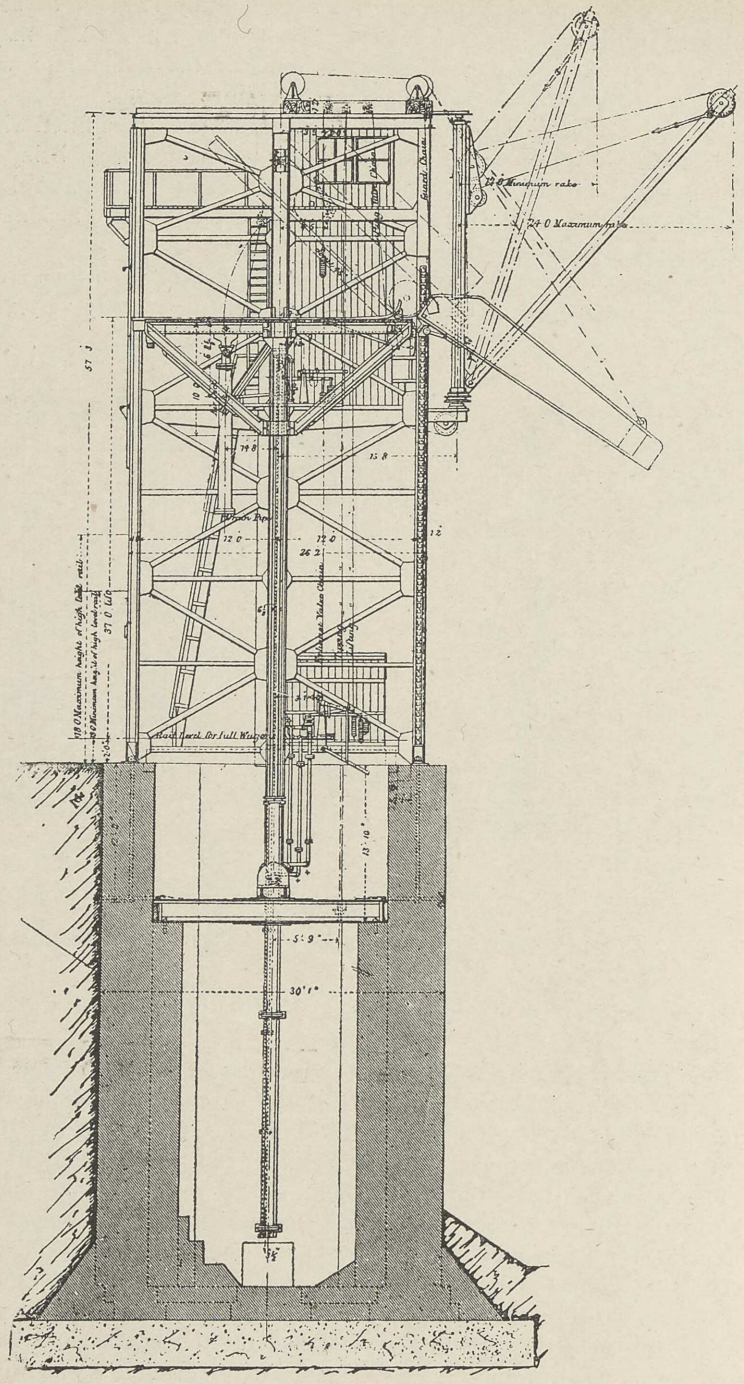


Fig. 775. Hydraulic Tip at Barry Docks (Side View).

cradle. There is a third ram working in an oscillating cylinder attached to the rear of the cradle for tipping the upper portion of the cradle, which is pivoted at the water side, and by which the discharge of the coal through the end door is effected. The water pressure for this tipping cylinder is taken from the main lifting ram, the action being similar to that of the preceding tip, and a load of 19 tons can be lifted and tipped. The tips were originally fitted with anti-breakage shoots to reduce the breakage of coal while passing down the shoot, but these were some time ago replaced by ordinary shoots fitted with a single door at the point of discharge for controlling the flow of the coal.

The adjustment of the shoot at the proper level and the housing of it when out of use is effected by the cradle itself, the front of which carries levers for taking the weight off the heel of the shoot in raising or lowering it. In the same way the delivery end of the shoot can be raised or lowered by chains, which can be connected to the cradle when necessary. On one side of the framing is a hydraulic anti-breakage crane, with a box of 3 tons' capacity, similar to the crane previously described. The whole manipulation of the tip is effected by hydraulic cylinders in the usual way, and all machinery is adjustable to suit any conditions. The hoist and crane valves are all operated by a man standing in an elevated cabin on one side of the hoist (see Fig. **776**).

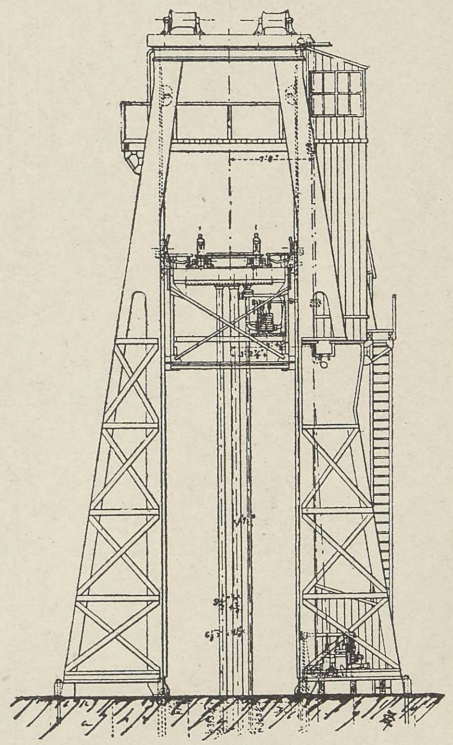


Fig. 776. Hydraulic Tip at Barry Docks (End View).

The tips illustrated in Figs. **777** and **778** [1] are by the same designers and makers, and for the same docks. The principal difference between these tips and the one last described is that no part of the machinery is below the quay level. The two lifting cylinders below the cradle in the previous tip are replaced in the present case by four direct acting cylinders, contained in box girders which also form the four guides for the cradle. The lift in these tips is the same, viz., 37 ft., and the guides extend some distance above the top of the framing. The anti-breakage crane is for a load of 2 tons and is in other respects similar to the last described. The tips are so arranged that they can at any future time be converted into movable hoists should this be desirable.

[2] There are now thirty tips at the Barry Dock, all hydraulically driven, and 4,000 H.P. are stored up in the accumulators for use at any moment. This is an actual storage of foot-pounds always at disposal and ready, and at no more cost than the original outlay and the occasional addition of a few more gallons.

As to the volume of work done, this is more or less a traffic problem. When ships

[1] From *Engineering*, 22nd March 1896.

[2] Remarks made by Colonel F. W. Tannett-Walker during a discussion on a paper read before the Institution of Mechanical Engineers, 20th January and 17th February 1911.

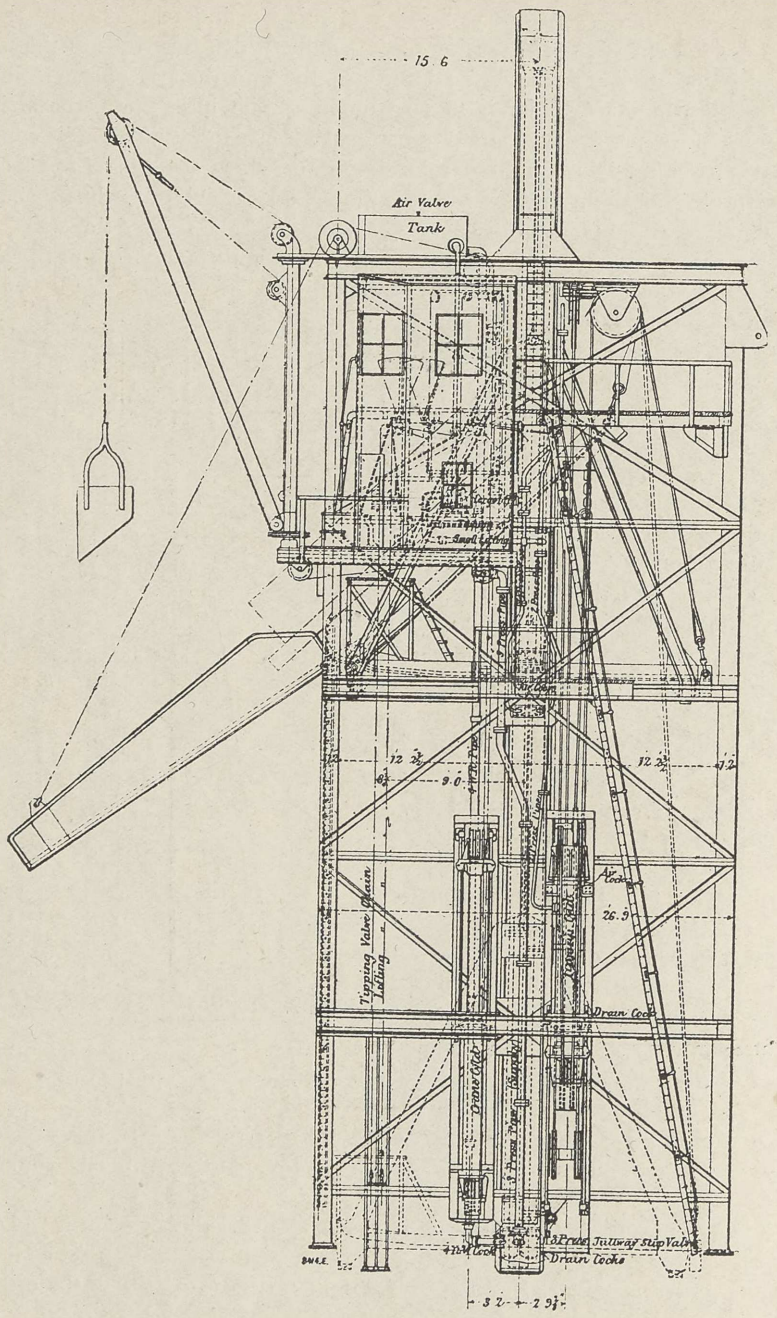


Fig. 777. Side View of Hydraulic Tip at Barry Docks.

come in on one tide and want to go out on the next, as much as 4,000 tons of coal have been shifted in six and a half hours.

Coal Tips at Newport.—A couple of tips, again similar to the last, have since

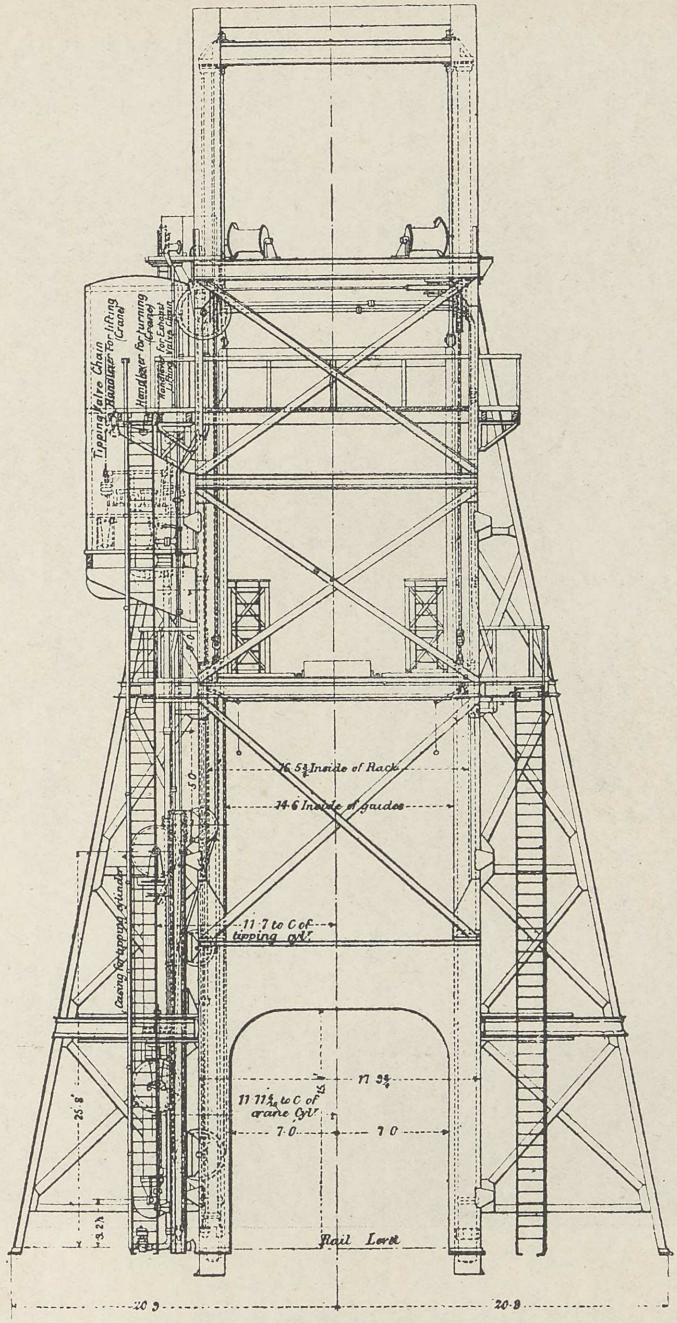


Fig. 778. End View of Hydraulic Tip at Barry Docks.

been erected at the Alexandra Dock, Newport, Mon. They have, however, a lift of 3 ft. more than the previous one, or 40 ft. in all, and their capacity is about 300 tons of coal per hour. For working the wagons to and from the tip, Armstrong's capstans of 1 ton hauling power are used.

Movable Tip at Cardiff.—This was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., and is similar to the tips previously described. The capacity is 19 tons, whilst the lift of the cradle is 31 ft. This tip is very like one of those at Rotterdam, with the exception that the lifting machinery, which consists of a ram and cylinder with multiplying

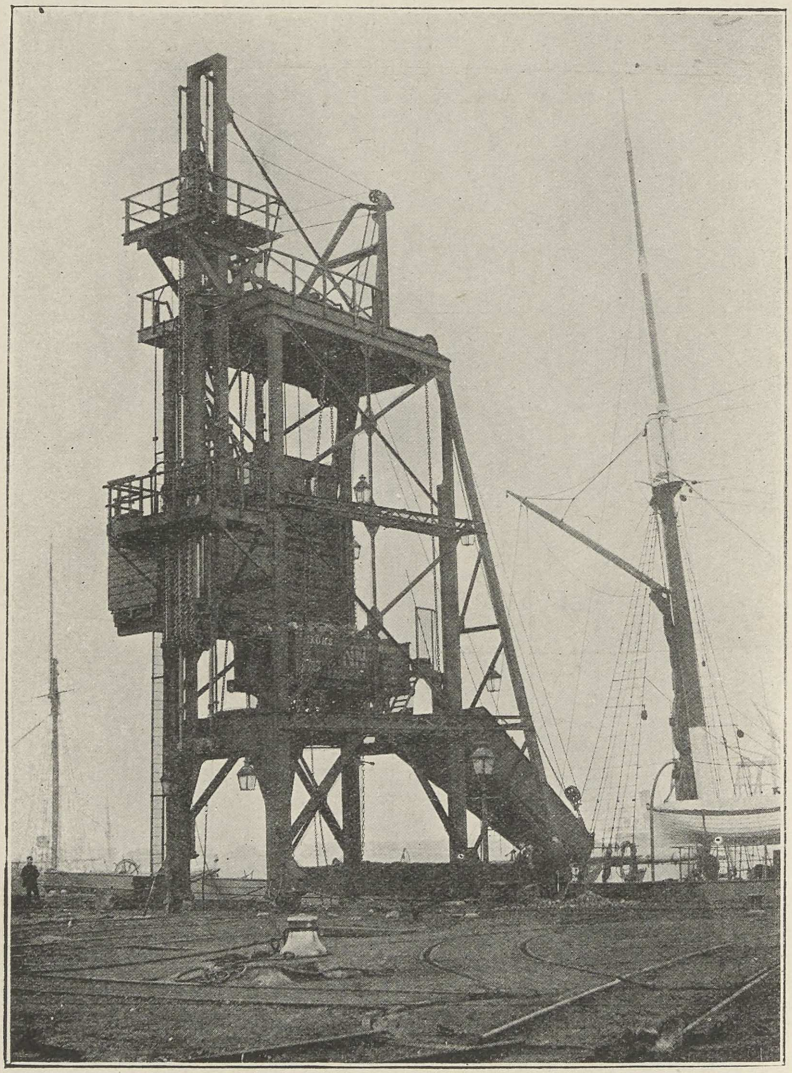
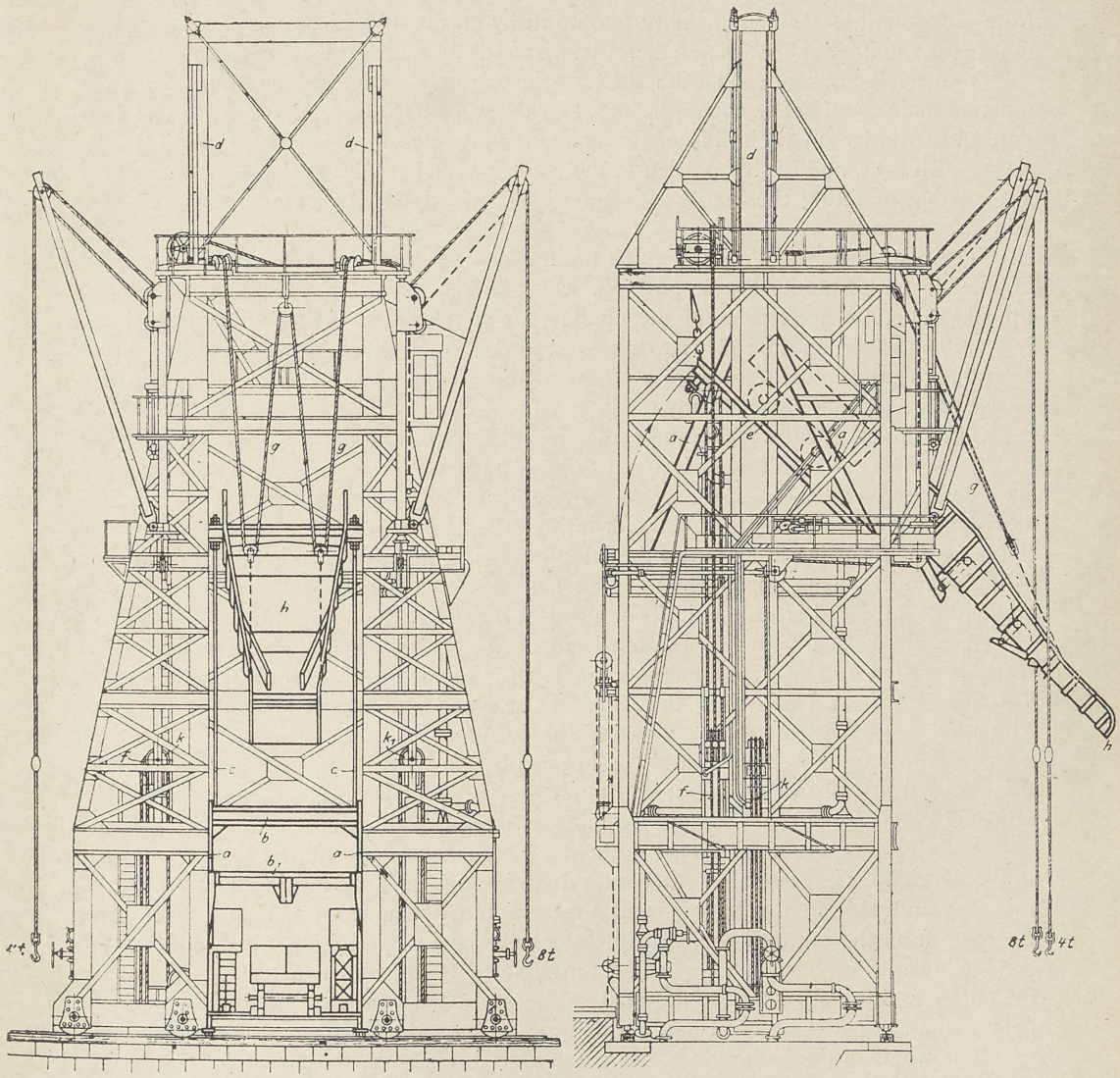


Fig. 779. Movable Tip at Cardiff.

sheaves, is placed on the back of the framing. It is mounted on wheels, which allow it to be moved to and fro on the quay to reach the hatchways of vessels, there being on the quay a number of lines, opposite to any one of which the hoist can be placed; these lines radiate from turntables communicating with the full and empty railroads. These tips are most serviceable, as they enable two hoists to work into the same vessel, which, owing to

the constantly varying position of the hatchways, two fixed hoists would very rarely be capable of doing. Fig. **779** illustrates this tip.

Coal Tips at Penarth Docks.—One of the four movable tips at Penarth Docks is illustrated in Figs. **780** and **781**. These four new movable tips are placed on the north



Figs. 780 and 781. Movable Tip at Penarth Dock.

side of Penarth Dock Basin, and resemble those at Cardiff, but have a total height of 96 ft.; they are capable of being rapidly moved by means of hydraulic hauling engines. Every part of the machinery of this hydraulic tip, the cradle, tipping, control of the shoots, and the movement and working of the anti-breakage cranes and boxes, is under the control of one man in the high cabin on the east side of the tip. All the machinery, which has to work under pressure, has been tested to carry a pressure of not less than

2,000 lb. per square inch, and the working pressure is 750 lb. per square inch. Each tip was constructed to fulfil the following requirements :—

A loaded wagon having been placed upon the cradle, to lift it 45 ft. above the quay, tip the contents of the wagon into the shoot, return the wagon to the quay level, and run it off the cradle within thirty seconds—and this can be accomplished. The cradle is lifted from the ground level to any height up to 45 ft. by means of four direct acting hydraulic rams, two on either side of the cradle. These are as follows :—

Two small rams, one on each side, are in constant communication with the high-pressure mains, and act as counterbalances for the weight of the cradle itself. The large ram and cylinder on each side of the cradle are intended to deal with the weight of the wagon with load, and of that portion of the cradle not balanced by the small rams. They are capable of lifting the cradle with a fully loaded 10-ton wagon upon it at the rate of 180 ft. per minute.

The platform or cradle upon which the trucks are raised is shown in the front view in the illustration at its lowest position, whilst in the side view it is shown raised and tipped. The A-shaped sides of the cradle *a* are connected at the top by a girder *b*, this is again connected by the rods *c c* to a second girder which slides in the guides *d d*, which extend above the actual framework of the structure. The second girder is manipulated by the four hydraulic rams already mentioned.

The appliances for working the cradle are fitted with automatic stops b_1, so that, the height at which the tip shoot is required to work having once been fixed, the cradle when started ascends to the tipping point, where it is automatically stopped, so that the attendant has only to start the cradle for lifting, when he is free to handle the lever for tipping without further attention to the lifting of the cradle. Again, in lowering, as soon as the wagon has been tipped, the top man has only to open the release valve and the cradle descends, and is automatically stopped as it reaches the bottom.

Each tip is fitted with two anti-breakage cranes and Thomas's patent anti-breakage boxes (see Figs. **782** and **783**), and is capable of "boxing" (as it is termed) as rapidly as the coal can be delivered into the shoot. The small anti-breakage crane is also fitted with slewing gear for conveying coal screenings ashore.

The tip shoots *h* are 24 ft. long, but can be lengthened up to 30 ft., and in order that the coal may slide gently out of the shoots to avoid breakage, they can be rapidly adjusted by means of ropes *g g* and *f*.

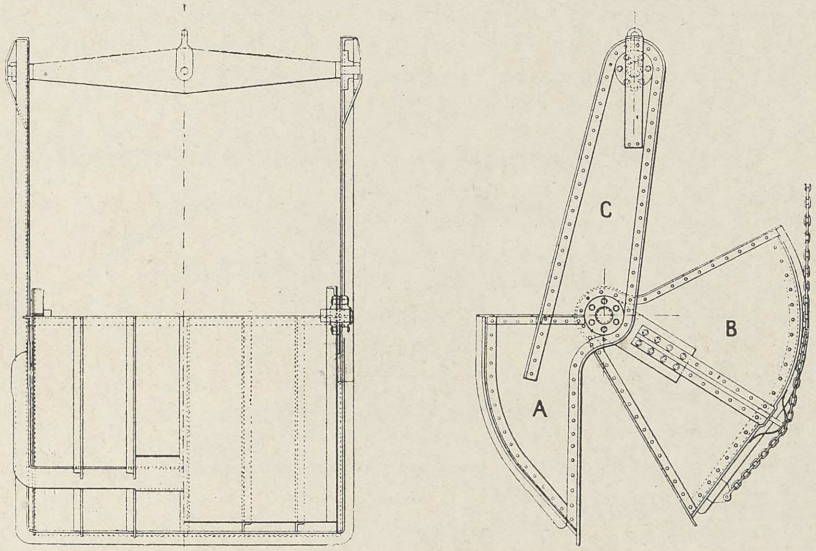
The tips are quite large enough to hold a 10-ton wagon of coal, the largest size used in the district. The shoots are fitted with double wings for assisting in the trimming of the coal and also in the boxing, and they are further made to radiate 5 ft. in either direction from the centre line of the tip, so as to assist in minimising the trimming. In connection with each tip is a traversing turntable platform, and two turntables, one for the empty and the other for the full load. These platforms are also fitted with hydraulic capstans of a capacity of 2 tons' pull, which can be moved to suit the position of the tips.

The whole of the hydraulic power required is brought to these tips by two mains, each 8 in. in diameter, so arranged that in the case of the failure of either one or the other, it is possible, by an arrangement of stop valves and branches connecting them together at intervals, to cut out any section of these pipes and so turn the water past the defective section. The return water is carried back by a 12-in. main to the hydraulic engines. Two large accumulators are fed from these mains ; one at the eastern end of the tips, the other at the engine-house. The water is pumped by three pairs of compound "tandem" engines, collectively capable of delivering 1,440 gals. of water at a pressure of 750 lb. per square inch per minute.

The sidings are so arranged in connection with these tips as to facilitate the mixing of coal and ensure rapid dispatch. Provision is made by which all wagons are weighed when coming in and reweighed when going out, the exact weight of the coal thus being ascertained, no matter what the tare of the wagons may be. The sidings are so laid out that a full train can be put upon either. They will together hold a cargo for a steamer of 2,500 tons, and are so constructed, with a slight rising gradient to the centre, and a falling gradient thence to the tip, that the men engaged at the tips manipulate the whole train load and work it down without the assistance of locomotives.

The capacity of these tips as regards dispatch may be gathered from the following data :—

On 23rd May 1901 the S.S. "Gatesgarth" arrived in the dock at 8.10 on the morning tide, and immediately proceeded to the four-tip berth. After bunkering with one tip, she commenced to take in her cargo at 9.15 A.M., finished at 11.50 A.M., and



Figs. 782 and 783. Thomas's Anti-Breakage Box.

sailed on the same tide, having taken on board a cargo of 2,333 tons in two hours and thirty-five minutes. On 26th July 1901 the S.S. "Bangarth" arrived in the dock at 11.45, and at 11.55 all four tips were at work, and she was charged with 2,154 tons of coal by 1.55, *i.e.*, in two hours.

Thomas's Anti-Breakage Box.—This is the invention of Mr S. Thomas, dock superintendent at Penarth, and is illustrated in Figs. **782** and **783**. It has a capacity of $2\frac{1}{4}$ tons, the main object of its design being non-breakage of coal when working rapidly. It is in two sections, A and B, which hang vertically from the same bridle C, and are hinged together near the top of the box, being so arranged that when the box is empty the act of lifting it by a rope causes the box to close automatically, and it is closed while being loaded under the shoot of the tip. An auxiliary rope is attached by an eye-bolt and chain to the heavier half of the box, and passes up to the end of the jib of the crane which works the box, passing thence over a sheave on the outside of the jib, while the end is brought back down to the deck of the ship, where it is fastened at any desired length.

Upon the anti-breakage box being filled with coal, it is lowered into the hold through the descent of the main lifting rope of the box; the auxiliary rope tightens and the box opens as shown. As soon as the contents are discharged and the main rope is lifted to bring the box back up to the shoot again, the auxiliary rope becomes slack and the box automatically closes, and is then ready for loading again.

The box is made of steel plates, angle irons, and T irons. It may be added that this box is a great improvement upon the former system of anti-breakage boxes used at Cardiff. The old style of box had a bolt for securing the door, but when working rapidly it frequently happened that this bolt did not drop into the right hole, consequently the door would open at the wrong moment and the coal was liable to be dropped too far and broken.

The Penarth installation was built to the design of Mr T. H. Riches, M.I.C.E., chief engineer to the Taff Vale Railway Co., by Messrs Fielding & Platt, Ltd., of Gloucester, whilst the engines and hydraulic machinery were built by Messrs Tannett, Walker, & Co., of Leeds.

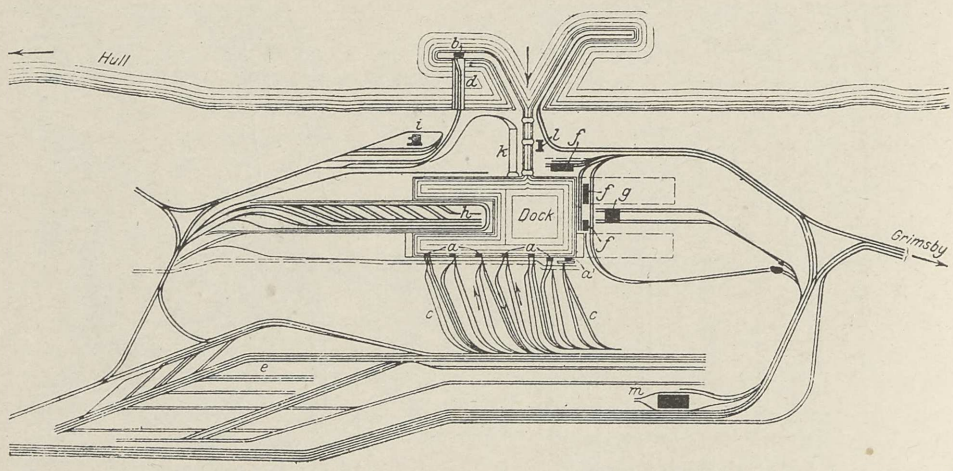


Fig. 784. Plan of Immingham Dock, showing Position of Coal Tips.

Coal Tips at Immingham Dock.[1]—Probably the largest installation in this country for loading ships with cargo coal is that recently equipped by the Great Central Railway Co. at Immingham (opened on the 22nd July 1912) on the estuary of the Humber, where this company spent nearly $2\frac{3}{4}$ millions sterling on the dock.

The coal shipped from this newest English harbour comes from the coal fields of South Yorkshire, Nottinghamshire, and Derbyshire. The equipment of the harbour includes seven large tips on the south bank of the dock. The tips are generally of the same type as the six large tips at Cardiff, but with an increased capacity of 300 tons each per hour. This enhanced capacity is chiefly due to the more perfect general arrangement of approaching the tips, in respect of the facility with which the full trucks move on to the tips and the empty ones move out of the way. The general disposition of the railway lines and the position of the tips will be seen from Fig. 784. Six of the tips *a* are stationary, whilst a^1 is movable on rails (those at Cardiff are all six movable).

Whilst the capacity of the Cardiff tips is handicapped by the time lost in disposing of the empty trucks, at Immingham this loss is reduced to a minimum by having special

[1] For full description see *Engineering*, 14th and 21st June 1912.

sidings for the full as well as for the empty trucks, and by the way in which they run to and from the tips by the incline of the rails. The rails for the full trucks are on the ground level, whilst those for the empties are raised on staiths whereby they are entirely out of each other's way, and the use of turntables is dispensed with. The rails *c* approaching the tips can accommodate 2,560 full trucks, and the network of lines *e* supplying the former can accommodate an additional 9,120 trucks, so that nearly 11,700 full trucks with 117,000 tons of coal can be in waiting for the seven tips. When the loading is in full swing the seven tips can dispose of 50,000 tons per day into the ships. In addition to this there is a further tip *b* in the Humber for bunkering the steamers without having to enter the dock, which is likewise served by separate lines of rails *d* in a similar manner raised on staiths. Finally there is the movable tip a^1 in a line with the other six stationary ones. This portable tip is served by an elevated line of rails of about 100 yds. in length, which is about equal to the travel of the tip and parallel with it.

The tips themselves are on the same principle as those at Cardiff and most other British ports, hydraulically driven; so it appears that the efforts made in some quarters to introduce electrically driven tips have failed to demonstrate their superiority, or this latest installation would probably not have been driven hydraulically. In general appearance these tips are so similar to a number of those already illustrated, that it would be superfluous to give illustrations of them.

The hydraulic system, which had its birth in this country, is undoubtedly generally preferred for manipulating this class of machinery, in spite of the efforts made on the Continent to drive such appliances electrically, and surprise was expressed there that such a modern installation as that of Immingham should be hydraulically driven. The prejudice against this system on the Continent has probably in part to be accounted for by the colder climate there, and the difficulty of preventing the freezing of the mains, etc. Apart from climatic influences the balance of advantages seems in favour of the hydraulic over the electrically driven tip. In the first instance hydraulic tips are less expensive in first cost, they are far less complicated and can be attended by unskilled men, which would be hazardous with electricity. With regard to the question of economy, it may appear at a casual glance that electric motive power can be more economically adjusted to the work, but if we take into account that the load of the tip is in most cases the same, the lack of accommodation in hydraulic power to varying loads does not enter into the calculation, and when the load varies, as on the Clyde and in other docks, multiple rams are now employed, so that on account of economy no advantage can be claimed for electricity, provided always that a sufficient number of hydraulical appliances are to be served from the same mains to warrant the installation of an up-to-date plant.

In order to meet further developments in the size of the ships of the future, the new hoists have been provided with a greater lift, and in all probability, with one exception, these tips are the highest yet constructed, the range being 70 ft. above the rail level, except in one in which it is only 56 ft. The wagon at this height is tipped at an angle of 45°. The tips deal with end-tip or bottom-door wagons of a gross weight of 30 tons, the dimensions of the wagons provided for being 25 ft. long over the buffers, 8 ft. 3 in. wide, and 8 ft. 8 in. high. The full wagons are drawn on to the cradle at the quay level and empties are run off on an overhead viaduct. There has also been a general advance in the speed at which these tips operate, and 180 ft. per minute is the rate that has been adopted with a pressure of 300 lb. per square inch on the accumulators at the power house.

The hoists are double-powered, being capable of dealing with wagons of either 30 or 20 tons' weight, including contents.

The framing is constructed of steel plates and angles, braced vertically and horizontally, and secured to the concrete foundations by eight wrought-iron bolts and nuts. The hoist-cradle is similarly constructed. The floor is timbered on each side of the rails. The tipping frame, which is also of steel, is hinged at the front end of the cradle, and is fitted with rails having turned-up ends, while to the rear is a cross-beam, to which the tipping ropes can be attached. The two hoisting ropes are $7\frac{1}{2}$ in. in circumference, and have a breaking strength of about 195 tons. The tipping ropes are of $4\frac{1}{2}$ in. circumference, with a breaking strength of 72 tons. The cradle guides are formed of steel angle-bars bolted to timbers, which are carried on the sides of the framing. On the under side of the frame is a hopper, built up of steel plates and angles, for dealing with hopper wagons, an automatic tumbling apron being fitted to bridge over the space between the lower edge of the hopper and the heel end of the main shoot.

The lifting machinery consists of three hydraulic cylinders bolted to steel girders, and secured vertically to the side of the framing. The plungers in the cylinders are of cast iron, and work downward through a gland acting on the cross-head. This is fitted with guides, one on each side, working on wrought-iron guide bars, each of which is carried at three points by brackets fixed on the girders on the hoist cradle. The cross-head is fitted with sheaves for taking the tipping ropes, as well as the multiplying sheaves for the lifting ropes, the ratio being 2 to 1. Conveyance sheaves are also fitted on the frame. One of the cylinders is arranged to be in constant communication with the accumulator, so as partially to balance the weight of the cradle and minimise the amount of pressure water used. When the maximum load of 30 tons is being lifted, all three cylinders are in use; but for raising 20 tons two cylinders suffice.

The hydraulic cylinder for tipping the cradle is placed over the lifting cylinders. The multiplying sheaves fitted in this case are in the ratio of 2 to 1. The arrangement of the lifting and tipping ropes is such that the tipping-frame can be tipped at any point of the vertical range of the cradle.

The shoot, which is of steel plates and angles, is fitted with hinged doors at the nose end, adjustable by chains to regulate the flow of coal. The outer end is raised or lowered by steel wire ropes, each $4\frac{3}{4}$ in. in circumference, and having a breaking strain of 80 tons. The shoot projects 25 ft. from the face of the framing when at the usual angle for working. The maximum height of the under side of the nose end is 56 ft. for five of the hoists and 42 ft. for one hoist above the quay level when the shoot is at the usual angle for shipping coal. A lengthening piece (6 ft. long) for the shoot is arranged for, and slides on the shoot, being adjustable through a worm and a rack by hand gear on the cradle.

The working valves for the lifting and tipping machinery are of the balanced mitre type, having cast-iron casings with gun-metal spindles and seats. The valves are placed at the bottom of the framing, and are operated from the working cabin placed on the framing of the hoist. The valves in connection with the hydraulic engine for operating the shoot are located in the same place. There is also, adjustable from the working cabin, the automatic cut-off gear fitted on the lifting motion to bring the cradle to rest at any predetermined height. Stops are fitted on the rail level at the entrance to the hoist, and these are actuated automatically through levers and counterweights by the rise and fall of the cradle, the arrangement being such that the stops come into action, and prevent the wagons running into the hopper well when the cradle is raised. The hoisting and tipping machinery is, of course, encased in corrugated steel sheeting, fixed on steel frames.

The whole of the pipes—pressure and return water—are solid drawn steel tubes of the Mannesmann type.

At this dock eight tips, twenty-five cranes, as well as the dock gates, are manipulated by hydraulic plant (*i* in Fig. **784**) consisting of four double acting pumps, each of 600 H.P.,

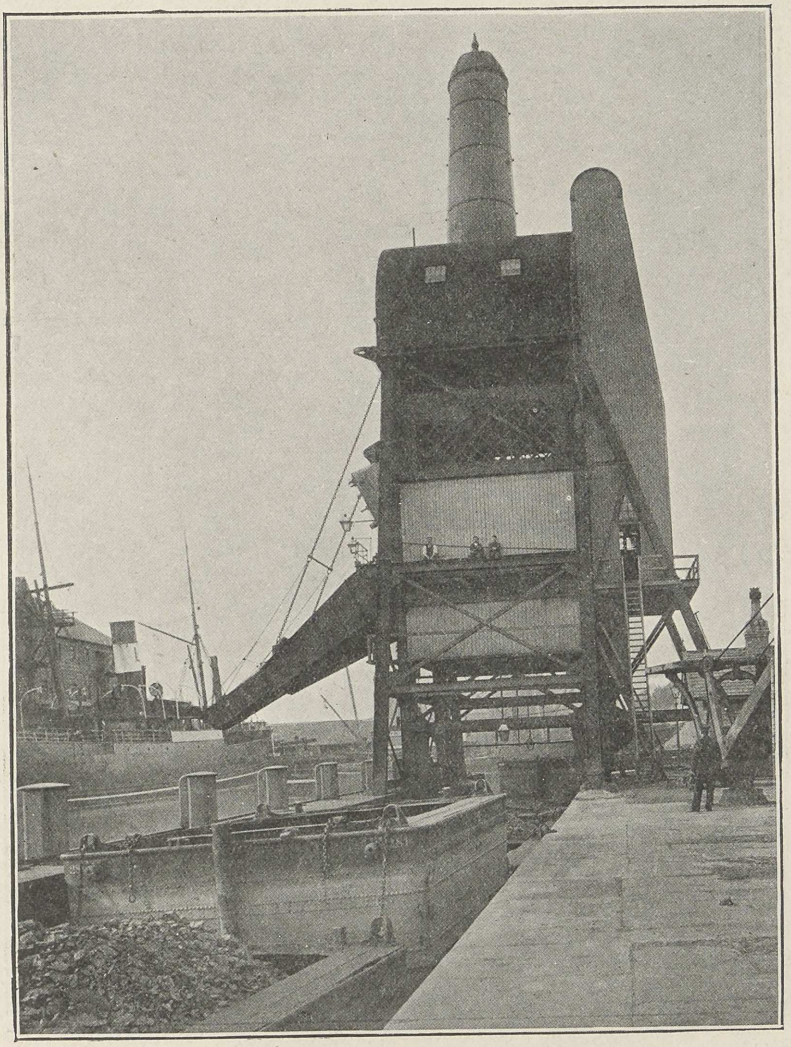


Fig. 785. Side View of Coal Tip at Goole Docks.

with a capacity of 40 cub. ft. of water at a pressure of 815 lb. per square inch, with the necessary accumulators.

The seven tips in the inner dock were built by Sir W. G. Armstrong, Whitworth, & Co., and the one outside the dock by Head, Wrightson, & Co., Ltd.

Coal Tips at the Goole Docks.—These unique tips are illustrated by two photographic views, Figs. **785** and **786**, and also by a sectional diagram, Fig. **787**, although,

strictly speaking, they do not come under this heading, as they do not deal with railway trucks, but tip barges which contain coal. These compartment barges (which are each 13 ft. by 30 ft. by 6 ft. 6 in. deep) are brought down the Aire and Calder navigation. The boats pass along the canal in long strings, articulated together, and on reaching the dock they are floated, one at a time, on to the submerged cradle of one of the coal hoists.

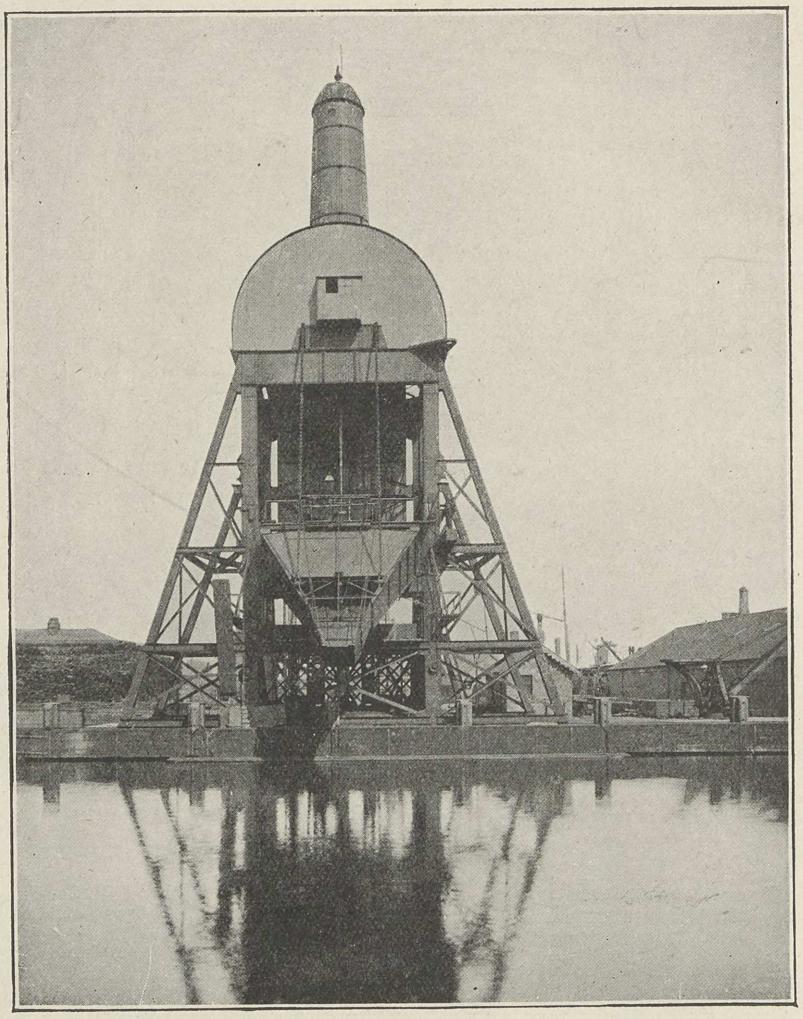


Fig. 786. Front View of Tip at Goole Docks.

The cradle is then lifted till the barge is clear of the water, when clips are made fast to the rear of the barge, securing it to the cradle. The lifting is then continued until the barge reaches a height of 35 ft., when it is turned over sideways and deposits the coal into a shoot by which it is conveyed to the hold of the vessel. The empty boat is then returned to a horizontal position, the cradle is lowered and the empty boat floated off. Each barge holds from 25 to 35 tons of coal. The lifting of the cradle is effected by direct acting hydraulic cylinders placed vertically above the cradle, pistons with piston

rods being connected to it. The tipping movement in the first tip was effected by rotary hydraulic engines and chains, but in the later tips it is effected by cylinder and ram with multiplying sheaves and chains. These tips were built by Sir W. G. Armstrong,

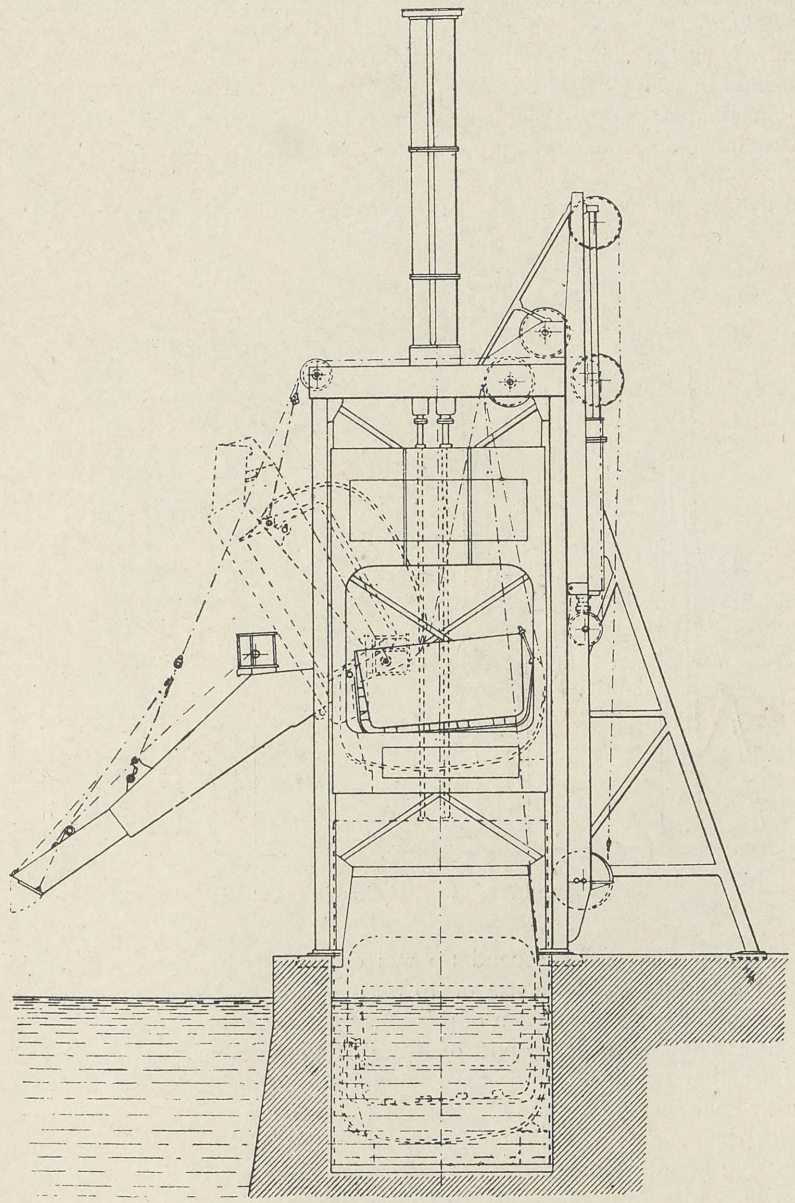


Fig. 787. Sectional Diagram of Tip at Goole Docks.

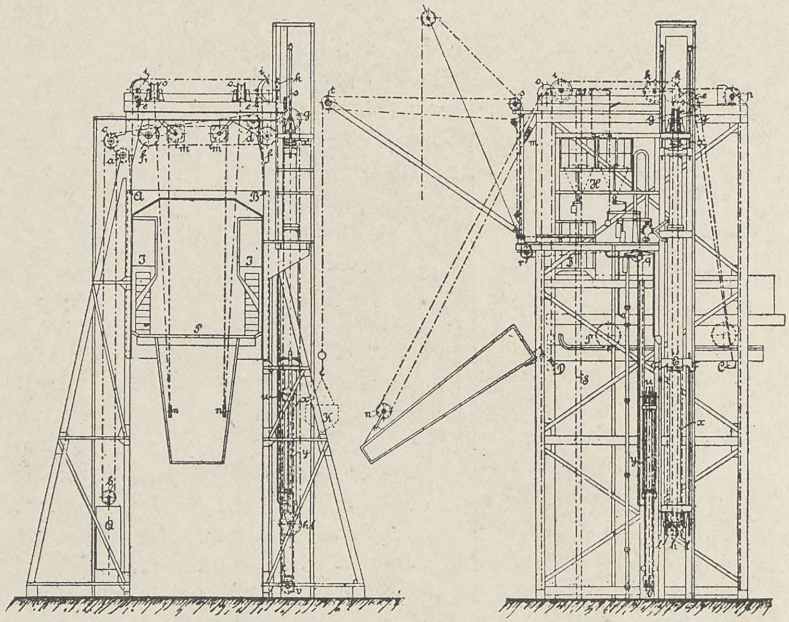
Whitworth, & Co., Ltd., the first being erected in the year 1863, the second in 1888, and the third in 1900.

Coal Tips at Rotterdam.—The port of Rotterdam, from which a large proportion of the coal from the Westphalian coal fields is shipped, had long experienced the

want of a simple and efficient coal tip. The traffic in coal for export as well as for navigation purposes had grown enormously. The annual tonnage, which did not amount to 50,000 tons in 1890, had in 1900 grown to nearly half a million tons.

The tip—which was the first to be erected on the Continent and which is illustrated in Figs. **788** and **789**—was built more or less on the lines of the tips in use at English ports, and its construction was entrusted to Sir W. G. Armstrong, Whitworth, & Co., Ltd. It was erected in 1887 and did most satisfactory work. It was driven from the existing hydraulic mains at the harbour, which are under a working pressure of 900 lb. to the square inch, and was for trucks holding 10 tons of coal, and designed for a lift of 33 ft.

Shortly after the starting to work of this tip the increased traffic rendered it necessary



Figs. 788 and 789. First Hydraulic Tip at Rotterdam.

to double the capacity, and a second tip was ordered from the same firm, this time for trucks holding 15 tons and for a rise of 40 ft., the latter to be accomplished in thirty-six seconds. Fig. **790** is an illustration of this tip.

The first hydraulic tip at the port of Rotterdam is suitable for all four-wheeled trucks used on lines that terminate at or have connections with Rotterdam. The framework is principally constructed of rolled girders, but wood is also used. P represents the cradle or stage for the reception of the trucks to be discharged. It is suspended from four chains at C and D, and is actuated by the hydraulic rams x, x', the former of which has a larger diameter, with four sheaves h and l, and works downward, whilst the latter, x', is smaller, works upward, and is fitted with only two sheaves g. The chains which are connected to the stage P, at C, are guided over the sheaves e, f, g, h to the hydraulic cylinder, and are attached at point E. Other chains lead from D to F over the sheaves i, k, l.

When the stage is in its lowest position, and the hydraulic ram x is forced down,

the stage moves upwards, as all four chains are tightened equally through pulleys *h* and *l*. When the stage has reached the level of the discharge shoot, the water is shut off at *x* and turned on at *x'*, which has the effect of lifting the stage from point C by the chains passing over pulley *g*, and so tilting it to a slanting position, which discharges the truck. The stage is then levelled again, by allowing the water to escape out of *x'* and then out

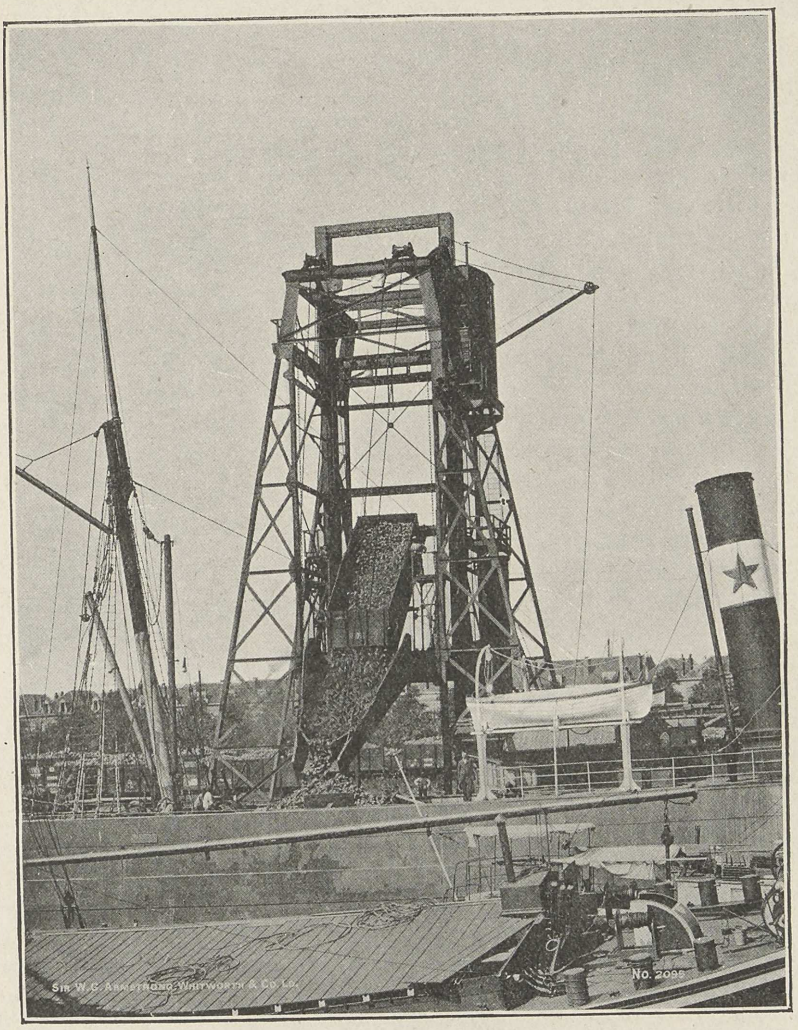


Fig. 790. Second Hydraulic Tip at Rotterdam.

of *x*, so that it drops by its own gravity; it is operated from point H, but there is an automatic stopping gear at the highest and lowest position actuated by the rod S. The weight of the stage itself is balanced by the weight Q, which hangs on a chain, the two ends of which are attached to A and B, and pass over the sheaves *a*, *b*, *c*, *d*. T T are two points from which the discharge of the trucks can be observed, and helped by hand if necessary.

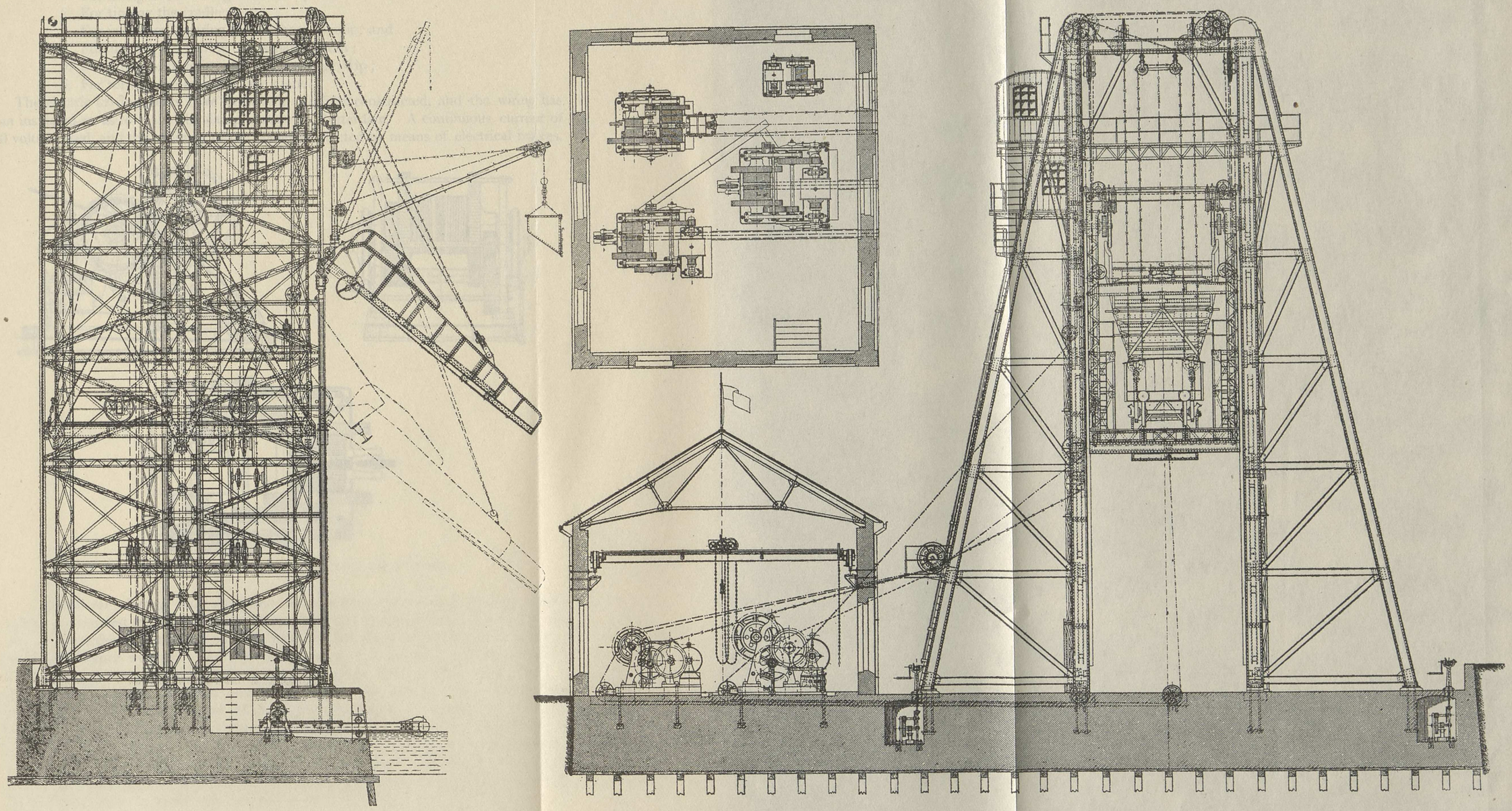
A small crane with skip K is also provided for lowering coal in smaller quantities

from the large shoot, as already mentioned, for preventing breakage of the coal. The chain is manipulated by the hydraulic cylinders *y*, and the sheaves *u* and *v*. It is further guided over pulleys *q*, *v*, *s*, *t*. For the side movement of the crane an additional hydraulic cylinder z is provided. The hydraulic pressure which works the tip is 750 lb. to the square inch, which is sufficient for ordinary trucks, but when trucks of 15 tons' capacity have to be tipped, the pressure can be increased to 900 lb. per square inch.

The two tips sufficed to cope with the traffic until about 1898, when they were working almost day and night, and it was decided to erect a third tip. As the hydraulic power supply of the harbour authorities was taxed to its utmost limits after the erection of the second tip, and as some trouble had been experienced caused by the frost, and breaking of the mains through sinkage of the ground, it was decided to drive the third coal tip by electricity.

The Electrically Driven Tip at the Harbour of Rotterdam[1] is the design of Mr H. A. van Ysselsteijn, engineer to the city authorities. Messrs Nagel & Kaemp, of Hamburg, constructed the tip, while the electrical plant was the work of Messrs Siemens & Halske, of Berlin. The order for the third tip was passed to the contractors in 1897, but owing to some unforeseen delay it was not started to work until the beginning of 1901. This electric coal tip is illustrated in Figs. **791**, **792**, and **793**. The general dimensions are similar to those of the tip illustrated in Fig. **778**, which was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., but the framework was made stronger. The special novelty in the design is this, that the driving gears controlling the different motions have been placed in a separate engine-house erected close to the tip, each movement having its own electro-motor. Another feature peculiar to this third Rotterdam tip is that the delivery shoot is so constructed that it can be extended if coal has to be shipped into vessels of extra wide beam. It is thus equally suitable for loading coal into ocean-going steamers or into vessels for river and canal traffic. The wagons are drawn to the tip by an electric capstan, and are pushed upon the cradle; after discharging, they are returned on another line of rails. The framework is, as has already been stated, similar to that of the Armstrong tips, but there are four uprights on each side of the cradle, the two centre ones of which also act as lateral guides for the up and down motion of the cradle. The four uprights on each side are stiffened by trussed girders, which are secured to a substantial foundation. The main uprights are girders of ⌶ section, and are composed of and riveted together with angle irons. The struts are made of channel section. The bases of the uprights are secured to cast-iron footplates, which in their turn are secured to the foundation. The arrangement of the winding gears for the different movements of the tip in a common engine-room has been adopted because it is held that the gears are thus under better control, and can be kept under the supervision of one man, whereas, if they were situated at the different points where their action was required, each individual winding gear would require its own compartment to protect it from the weather. It would also, under such conditions, be altogether impossible for one man to manipulate all these gears. The slewing gear for the anti-breakage crane has been erected in the cabin of the operator, as may be seen in the illustration. This is the only part of the machinery for operating any portion of the coal tip which is not situated in the engine-room. Although the winding gears have been erected in the engine-house, they are all under the complete control of the operator, who can stop or start any of them from his cabin at the top of the tip. The connection between the operator's cabin and the engine-house by means of levers would have been exceedingly complicated. All connections, therefore, are electrical, even the brakes on the winding machinery being

[1] Illustrations reprinted from *Zeitschrift des Vereines deutscher Ingenieure*.



Figs. 791, 792, and 793. Electric Coal Tip at the Harbour of Rotterdam.

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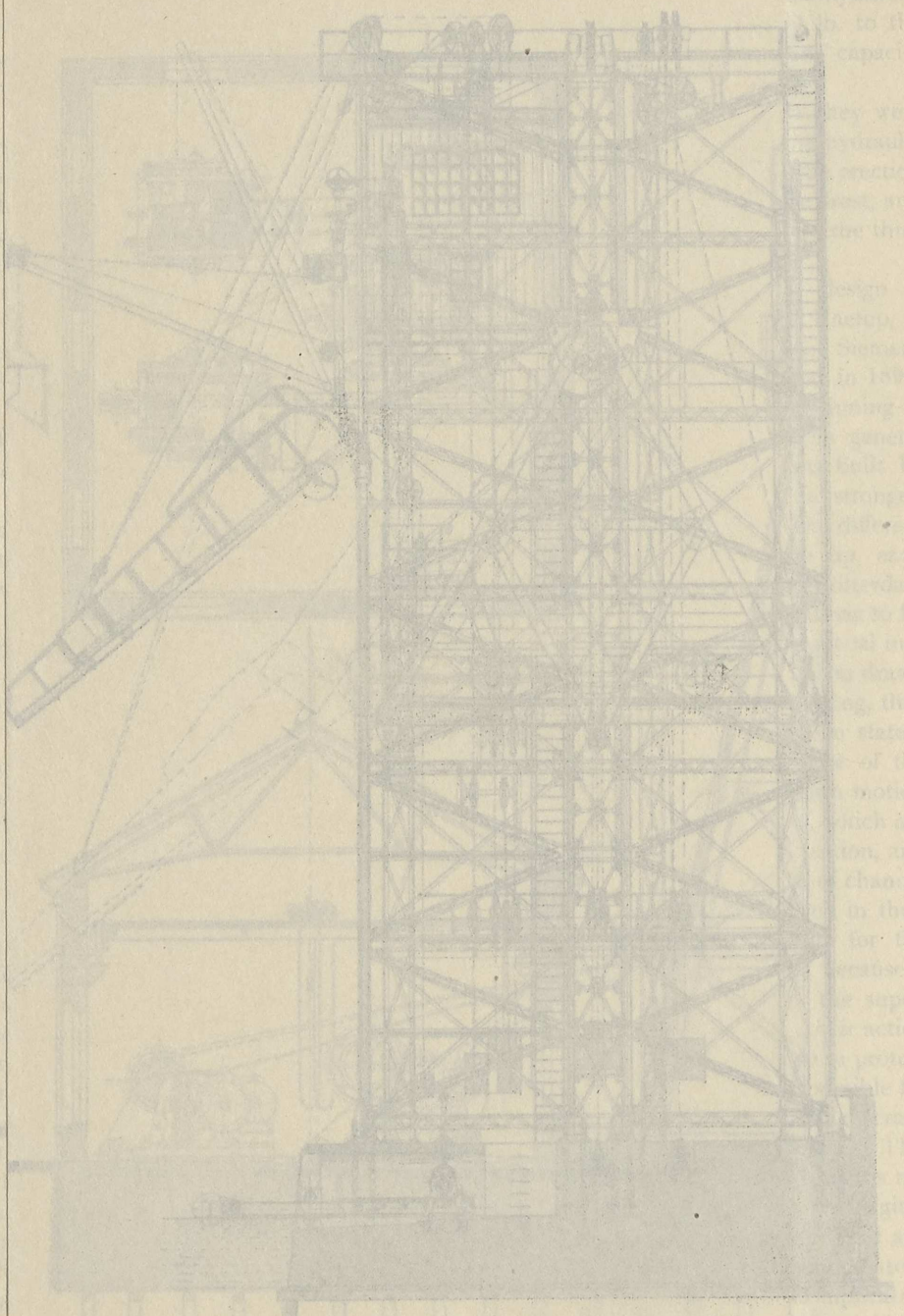
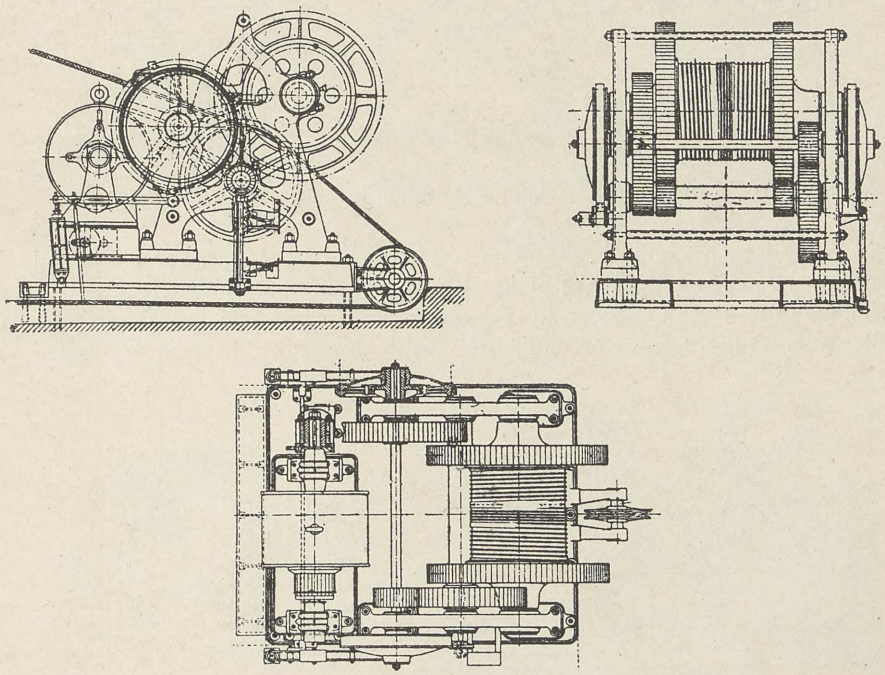


thrown in and out of gear by small electric motors. The following six winding gears have been erected :—

1. For lifting and lowering the cradle ;
2. For tipping the cradle ;
3. For raising or lowering the discharge shoot ; and
4. For altering the incline of discharge shoot ;
5. For lifting or lowering the anti-breakage skip ;
6. For turning the anti-breakage crane.

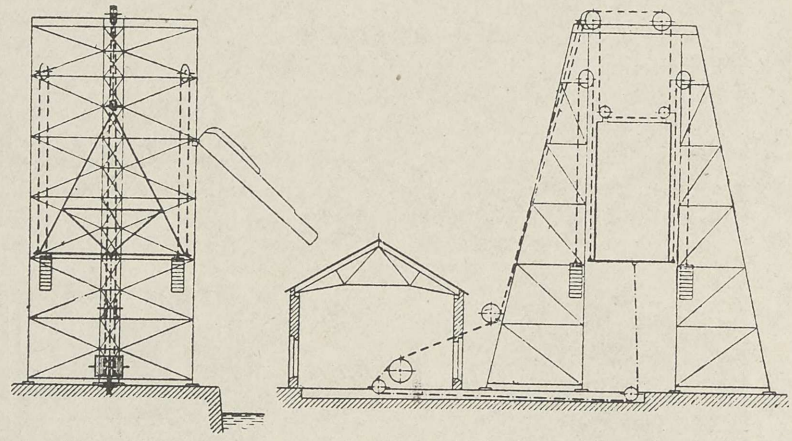
The electric driving gears have been very carefully constructed, and the wiring has been insulated so as to resist the damp climate at Rotterdam. A continuous current of 500 volts is used, and the lowering of the cranes is effected by means of electrical brakes.



Figs. 794 to 796. Winch for Raising and Lowering the Cradle.

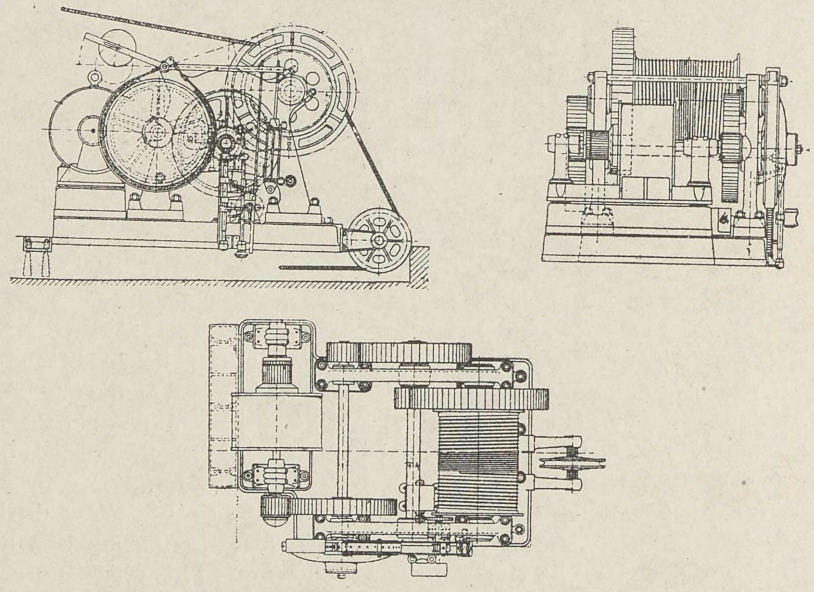
1. *Winch for Lifting and Lowering the Cradle.*—The weight of the cradle, including the heaviest full coal truck, is 50 tons, and this is raised at the rate of 1 ft. per second. The action is illustrated by Figs. **797** and **798**, which also shows the arrangement of the balance weights. The rope used is a steel wire rope, both ends of which wind on and off the grooves of the winding gear (Figs. **794** to **796**), so that there is always the same tension on either end of the rope. The electric motor driving this winding gear is of 130 H.P., runs at 370 revs. per minute, and is mounted on the same bed-plate as the winding gear. The drum has a diameter of 40 in., which is necessary as the wire rope has a diameter of $1\frac{5}{8}$ in. The gearing for reducing the speed from the motor to the winding drum consists of two countershafts and spur wheels. The gear wheels are of cast steel, except the pinion of the motor, which is of raw hide. The first of these countershafts is fitted with a brake at each end, which enables the operator to stop the load in free suspension, when the current is cut off. As soon as the cradle has

reached the top of the frame, the current is automatically cut off by an arrangement on the second countershaft. During the lowering of the cradle the weights on the band



Figs. 797 and 798. Diagrams showing Method of Raising and Lowering the Cradle.

brakes are lifted by a small electro-motor. The gear of the brake is also fitted with a dashpot so as to ensure the brake action being smooth when thrown in or out of gear. The winding drum has, in addition to the grooves for the two rope ends, a third groove for a smaller rope for the purpose of pulling the cradle down should repairs be needed, or for

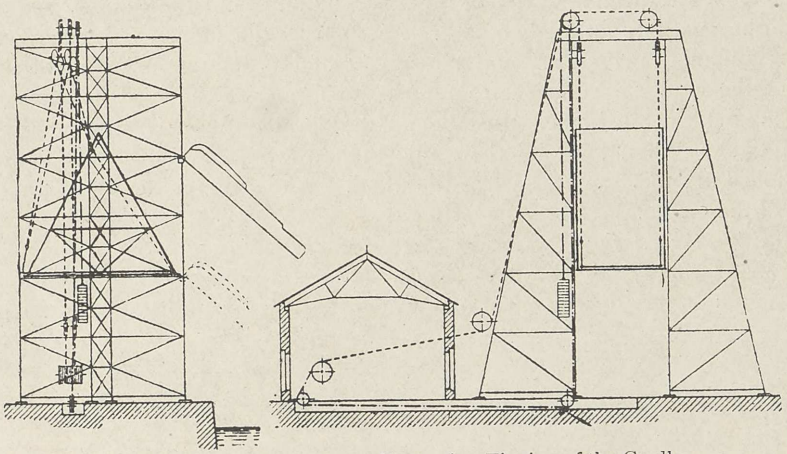


Figs. 799 to 801. Winch for Tipping the Cradle.

trial purposes, supposing the cradle should have to be lowered without a wagon on it. This rope is not usually on the drum, but is only put on in case of emergencies, as the cradle being practically balanced, will not descend without an empty truck. All bearings

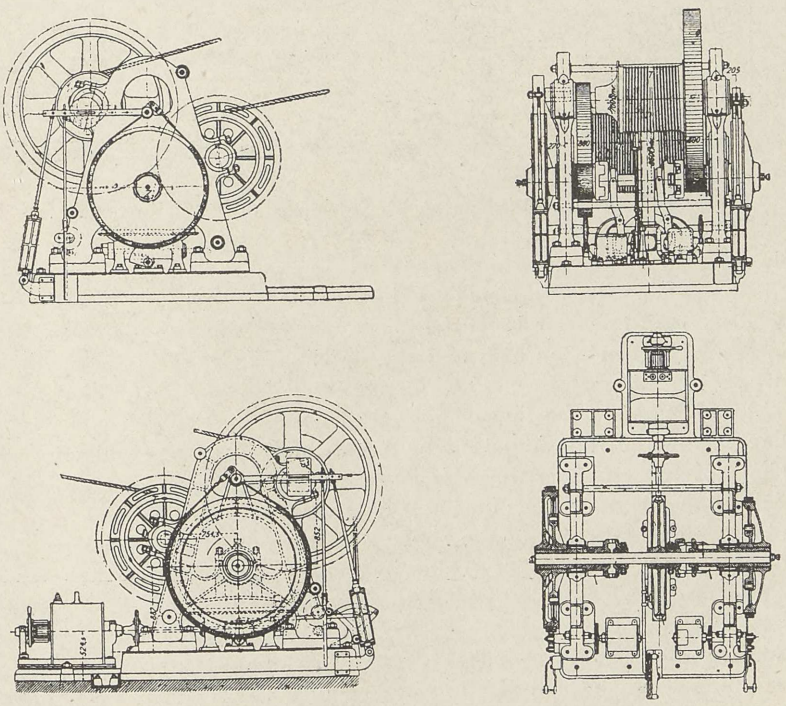
of the winding gears and guide pulleys are of the roller type, friction being thereby reduced to a minimum.

2. *The Winch for Tipping the Cradle.*—This is illustrated in Figs. **799** to **801**. The tipping process is thus effected: The portion of the cradle which supports the coal



Figs. 802 and 803. Diagrams illustrating Tipping of the Cradle.

wagon is hinged by two trunnions on the water side, while two ropes at the back raise the movable part of the cradle for the purpose of tipping the contents of the truck. The diagrams, Figs. **802** and **803**, show the connection of the ropes between the winch and

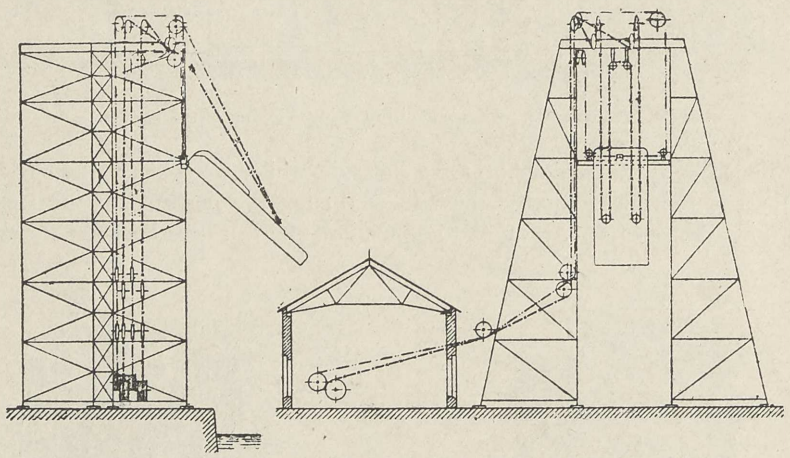


Figs. 804 to 807. Winch for Raising and Lowering the Discharge Shoot.

the tip. With this arrangement the winch may run idle during the raising or lowering of the cradle.

There is also a third groove on the drum of this winch, for the purpose of keeping the tipping ropes taut. This winch is very similar to the preceding one, but the electro-motor is of 60 H.P., running at 530 revs. per minute, and the tipping portion of the cradle can be raised to an angle of 50°. As soon as the incline has been reached the current is automatically cut off, and the weight of the empty truck and of the tipping portion of the cradle is sufficient to return the former to the level position, the speed being regulated by the brake. Just before the level position is reached the brake is pulled up tight. When lowering the cradle both the brakes of the hoisting and tipping gear are released; this is necessary as the winch has to run round idle again during the lowering of the cradle.

3 and 4. *Winch for Raising or Lowering the Discharge Shoot, and Winch for Altering the Incline of the Discharge Shoot.*—These are illustrated in Figs. **804** to **807**. The apparatus is fitted with two independent sets of winding gear, which can be



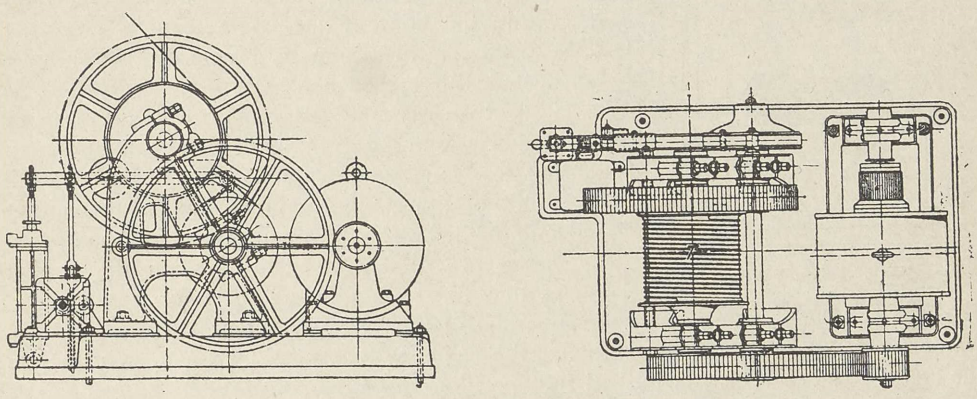
Figs. 808 and 809. Diagrams showing Manipulation of Discharge Shoot.

alternately coupled to the electro-motor, thus only one of the two operations can be performed at a time. The reversing of the coupling is done by hand. One of the winding gears serves to raise or lower the shoot, and the other to alter the incline. The rope connection between the winch and the tip is shown in Figs. **808** and **809**, from which it will be seen how the ropes operate the shoot. The dotted lines which indicate ropes are clearly marked; the line composed of dashes and crosses controls the incline of the shoot, whilst the rope indicated by dashes and dots raises and lowers the shoot itself. The movement of this winch is designedly rather slow, as an alteration either to the height of the shoot or to its incline is only very occasionally made.

The raising and lowering of the shoot is at the rate of 3 in. per second, whilst the movement of the end of the shoot to alter its incline is performed at the rate of 4 in. per second. The motor which drives this double winch is of 17 H.P., and runs at 700 revs. per minute, and as the difference in speed is so great a worm and worm wheel are used here. One of the two winches is fitted with a band brake, the weight of which is lifted or lowered by a small electro-motor, similar to all the other brakes on the winches. On either side of the frame of the tip, against two of the main supports, are

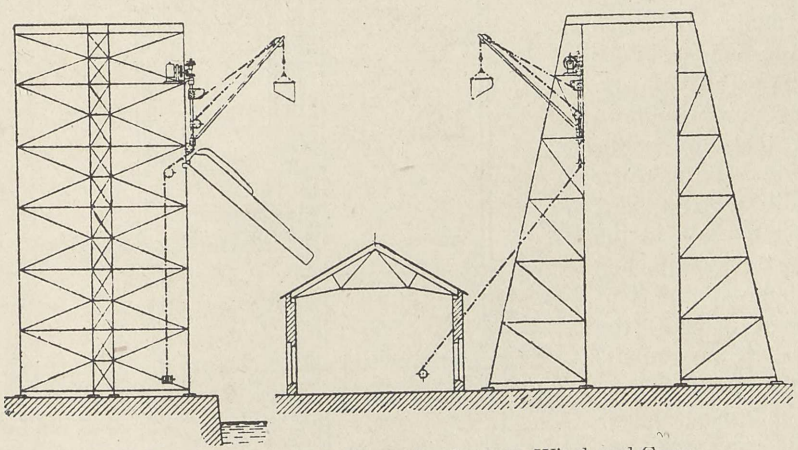
fitted tooth racks into which the two pawls of the shoot are geared, so as to relieve the ropes of the tension until the shoot is to be raised or lowered again. No power is required to lower the shoot, as its own weight is always sufficient to turn the winch as soon as the brake has been released.

5. *Winch for Lifting or Lowering the Anti-Breakage Crane.*—This is illustrated



Figs. 810 and 811. Winch for the Anti-Breakage Crane.

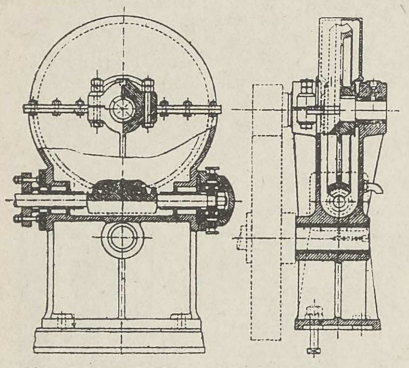
in Figs. **810** and **811**. The crane itself is fitted to the frame of the tip in the usual manner, and the winch will lift the weight on the crane at the rate of 2 ft. per second. The connection between the winch and anti-breakage crane, by means of wire ropes, may be seen from Figs. **812** and **813**, which explain themselves. The winch is driven by an 18 H.P electro-motor, which runs at a speed of 630 revs. per minute, and the brake is similar to those previously described.



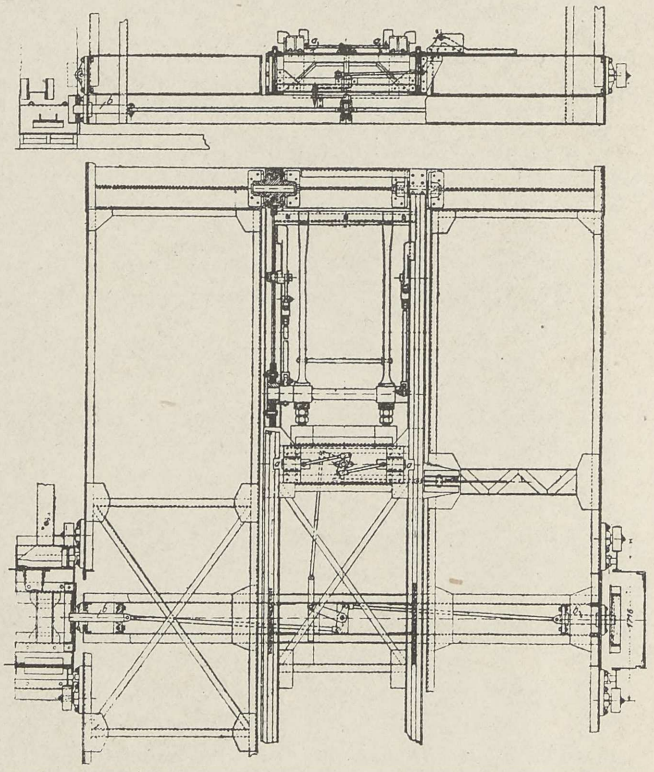
Figs. 812 and 813. Rope Connection between Winch and Crane.

6. *Winch for Turning the Anti-Breakage Crane.*—This is illustrated in Figs. **814** and **815**. The motor is connected to the turning gear by worm and worm wheel, and a pair of spur wheels. The whole apparatus is so small and is so seldom used that the operator's cabin was undoubtedly the most suitable place for it. The motor is of 4 H.P., making 1,000 revs.

The Cradle.—This is of substantial construction, and is fitted with rollers which run against the guides of the framework of the tip. The sides are A-shaped, and there is a connecting piece at the top end which joins the two together. On the water side are two stands, accessible by steps, on which an attendant can take up his position. The tipping portion is built within the floor of the cradle, and is just wide enough for the two main girders—which are connected with each other by a framework of angle iron—to carry the rails upon which the truck stands. A strong girder at the end extends across the two longitudinal girders, which run the full width of the cradle, and the ends of this girder are provided with attachments, to which the tipping cables are attached. The rails on the tipping portion of the cradle are level for about three-quarters of their length, but are slightly bent upwards for the last quarter, thus bringing the truck to a standstill when it is pushed on the cradle. As the truck is pushed into position two automatic catches *a a* are forced forward and prevent it from running backward. This is shown in illustration, Figs. 816 and 817, which gives the details of the working parts of the cradle in plan and elevation. Coupled with the two catches *a a* are two further catches *b b* which secure the cradle in its position when empty. These are now withdrawn in order that the cradle may ascend. To make the truck still more secure, the coupling chain at the end of the truck is attached to the cradle itself. This arrangement allows the truck to advance to its most forward position. As soon as the tipping process begins the truck rolls forward into this extreme position, and in doing so, it automatically secures its front axle by two substantial hooks, which are pressed upward. The action will be clearly understood from Figs. 818 and 819, which represent the hooks which fit the front axle of the truck. They are coupled together



Figs. 814 and 815. Winch for Turning Anti-Breakage Crane.

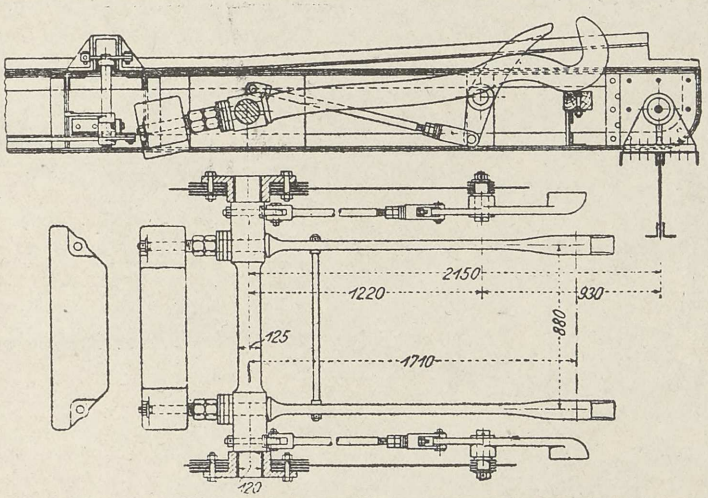


Figs. 816 and 817. Details of Working Parts of Cradle in Plan and Elevation.

and are fitted with a balance weight; the levers at the sides are pressed down by the front wheels of the truck, and cause the two hooks to rise. The method adopted in this tip is identical with that of the original Armstrong tip. The cradle is balanced by counterweights which move up and down within the framework of the tip, and the tipping portion itself is balanced in a similar manner. Provision is also made for catching the cradle automatically should one of the ropes break accidentally.

The Discharge Shoot.—This shoot extends from the tip to about the middle of an average sized ship. The upper or feeding end is 12 ft. wide, but the shoot tapers at the tail end to 6 ft. 6 in. To this narrow end a lengthening piece is attached for extending the shoot, so that it can reach to the middle of the largest steamers. This piece is attached to a central girder beneath the shoot, and as it is mounted on rollers it can be pushed backwards and forwards as required by means of a worm and worm wheel. The extension is principally used for loading offside bunkers.

Figs. **820** to **822** give illustrations in plan and elevation as well as a cross section of

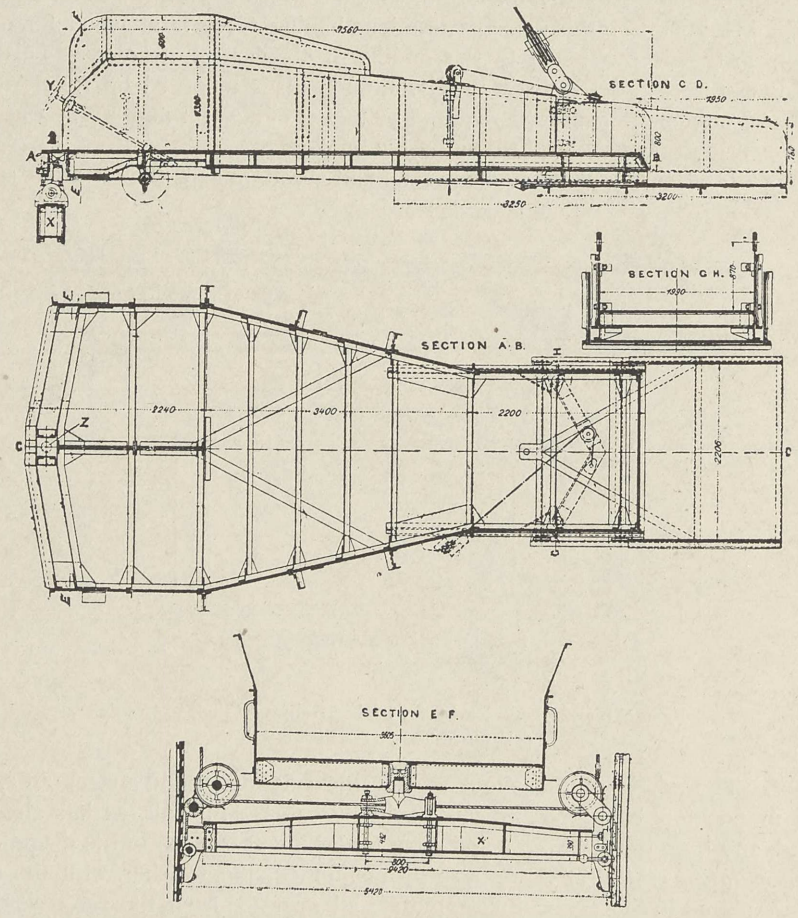


Figs. 818 and 819. Device for Fixing Railway Truck to Cradle.
(The dimensions are in millimetres.)

the shoot. The whole of the shoot is movable sideways round a steel pin Z, which is secured in position by cross girder X, held by cables and pals as has already been described, and both the steel pin Z and cross girder X can be seen in the diagrams.

Manipulation of the Tip.—As already mentioned, the winches, with the exception of one, are placed in the engine-house, but are all operated from the cabin at the top of the tip, from which point the attendant can have all movements under his observation. The electrical starting and stopping gears are arranged on two floors of the cabin, which are illustrated in Figs. **823** to **825**, and shows a section through the cabin, with plans of the upper and lower floors. On the upper floor will be found the starting gears for the lifting and tipping winches, and also for operating the discharge shoot, whilst on the lower floor is the starting gear for the anti-breakage crane, as well as the turning movement for the same. The stopping and starting gear for lifting and tipping are marked A and B. These are situated behind the manipulator, who faces the levers A^1 and B^1 from which the gear is operated. C is the starting gear for raising and lowering the discharge shoot; D is the trap door leading to the lower floor; E, on the lower floor, is the turning gear for the anti-breakage crane; whilst F is for raising and lowering the same; G being the

space for the counterweight. The ordinary position of the attendant is between A^1 and B^1, and with his right hand he manipulates the raising and lowering of the cradle, whilst with his left hand he controls the tipping operation. With the backward movement of the lever the load is raised, whilst with the forward movement it is lowered. There is a safety appliance which prevents the tipping lever from moving during the raising and lowering of the cradle, and vice versa. The normal position of the levers is in the centre of the index, and as soon as one of the levers is moved in either direction, the other lever is



Figs. 820 to 822. Elevation, Plan, and Cross Section of Shoot.
(The dimensions are in millimetres.)

automatically locked until the former lever has again reached the central position. In addition to the operating levers, the cabin is fitted with the usual electrical instruments and cut-outs.

An electrically driven tip, similar to the foregoing, was installed in 1901 in the Dutch harbour of Emden; it has a capacity of fifteen trucks, together 225 tons, per hour.

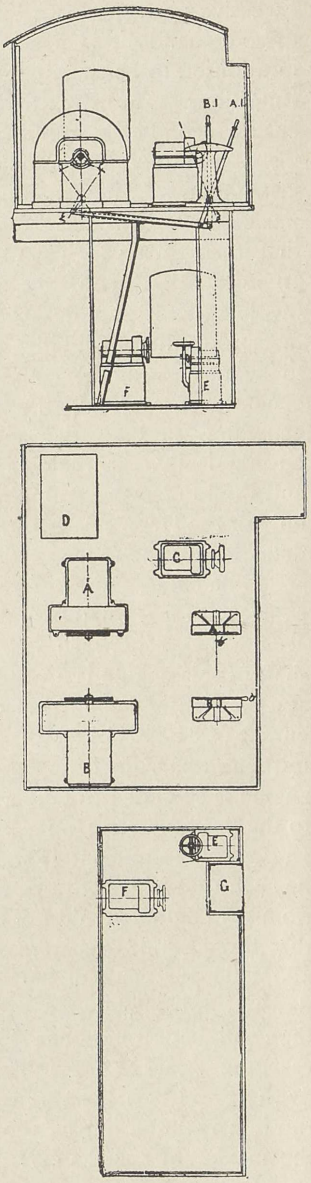
At Rotterdam the full trucks approach the tip, and the empty ones leaving have to pass the same turntable; this causes delay and reduces the capacity considerably. Two turntables are used at Emden, which is a decided improvement.

The Electric Tips at the Rothesay Dock on the Clyde.[1]—These tips are a vast improvement on those of the Continental type previously described.

The question was raised as to whether hydraulic or electric power should be employed by the Clyde Navigation Trustees, and in order to ascertain which of the two was more economical, two cranes were erected side by side in the Princess Dock, one being manipulated by electric and the other by hydraulic power. These were observed closely for a considerable time, and the result obtained was so favourable that no doubt was entertained as to the advantages of electricity for dealing with the ordinary class of machines such as cranes, capstans, etc. The installation of several large coal tips, however, rendered the problem one which had not hitherto been faced in this country. The mechanical difficulties in connection with such hoists had already been solved at Rotterdam and Emden, but the difficulty of dealing electrically with a large amount of horse power required in a very short period, together with the necessity of providing for rapid acceleration and retardation, and absolute control under all conditions, will be readily appreciated.

It was at this stage recognised that the problem had developed into one which could not be adequately dealt with by the mechanical engineering department, without expert electrical advice, and Mr Walter Dixon was appointed to collaborate with Mr Baxter, chief mechanical engineer to the Trustees, in the preparation of the scheme to embody the complete equipment of the dock.

The Power Station.—It is generally recognised that where a reliable supply is available it is desirable to take advantage of such supply and thus obviate a considerable capital expenditure. In many cases, however, an objection arises to this course, as the supply available is usually on the three-phase alternating current system, which, while it may be satisfactorily employed, is not so suitable for dock purposes as a direct current; so that if the best results are to be obtained, an appreciable portion of the capital which might otherwise have been saved by dispensing with steam-raising and generating plant, might have to be used for providing, converting, and transforming plant. In spite of such a supply being available at Rothesay Dock, it was deemed best to erect a generating station, as it was hoped that the electric supply would be produced at lower cost by a plant specially designed for the purpose.



Figs. 823 to 825. Section through Cabin, also Plans of Top and Bottom Floors.

The generating station, comprising boiler, engine, and condenser houses, suitable

[1] Abstract from a paper on the "Modern Electrical Dock Equipments," with special reference to electrically operated coal hoists, read on 20th January 1911 by Messrs Walter Dixon and G. H. Baxter before the Institution of Mechanical Engineers, with the Author's comments.

stores and offices, was erected in a convenient central position on the north quay of the inner basin. It is well known that the intermittent working of dock machinery causes excessive peak demands. If generating plant is designed of sufficient capacity to meet these demands it is necessarily large in proportion to the average load, and as a result, in addition to being expensive in first cost, it does not run under the most economical conditions. In order, therefore, to keep the plant within reasonable dimensions and to ensure economical running conditions, it has hitherto been the invariable practice to install a battery of accumulators with a reversible booster plant, in connection with dock installations. The possibility of adopting such a system, which has many good points, was carefully considered for adoption at the Rothesay Dock, but while it was recognised that it serves a very useful purpose under certain conditions of varying demands, such an installation would not adequately meet the more stringent requirements of the case involving as it did the special demands on the coal tips. It was therefore decided to investigate the possibilities of further developing the system, where excessive loads have to be dealt with, by coupling a prime mover, either electrically or steam driven, to a generator in conjunction with a flywheel. It was apparent that if these special coal hoist generators, and a further generator for supplying power for ordinary dock purposes, could be practically constructed in combination with a flywheel it would be very economical, and would dispense with the usual battery of accumulators, the flywheel taking care not only of the larger peaks due to the coal tip, but also of the smaller and more frequent demands for the other appliances.

The combination eventually designed consists of a high speed engine of the triple-expansion type, capable of developing about 450 B.H.P. as a normal load, when running at any speed between 320 and 375 revs. per minute. Direct-coupled to the crank-shaft of this engine is a continuous-current main generator, capable of producing current at a constant voltage irrespective of speed and load. This generator, which has a normal output of 340 E.H.P. with a considerable overload capacity, is used for supplying power to the ordinary dock appliances. The end of the main generator shaft remote from the engine is extended to take a special flexible coupling, by means of which it is connected to the flywheel shaft on which is mounted the flywheel and two coal hoist generators. In designing the plant it was intended that the storage of power in the flywheel should be such that with both tips working with full load and to their full lift, the average demand from the engine should not exceed its normal rated power. By trial it was ascertained that these conditions were fulfilled, and that, even with the main generator loaded to about 63 per cent. of its normal output in addition to the tips working as above, the demand only slightly exceeded the normal output of the engine with a drop in speed of the combination of about 20 per cent. The flywheel is entirely enclosed in a cast-iron case, the object of providing this being that, should the power required to maintain the flywheel and two hoist generators at normal speed prove excessive, the former could be run in a vacuum, but as the power required was only about 20 E.H.P., when running at the maximum speed of 375 revs. per minute, the installation of the necessary gear for producing the vacuum was considered quite necessary. Of course the above power is only consumed when the coal tips are in operation, and under ordinary working conditions considerable economy is effected by disconnecting the flywheel by means of the special coupling referred to above, when the engine and main generator run as an ordinary generating plant.

The Tips.—The two tips first erected, each of the high level and fixed type, are so arranged that the loaded wagons are run on the tipping platform at the quay level, raised to the required height and tipped, after which the empty wagon is lowered to the high

level inclined viaduct, leaving the hoist platform or cradle at a height of about 17 ft. from the ground and gravitating to the siding, the cradle then being lowered to the ground level to receive the on-coming loaded wagon.

Hoist No. 1 is fixed on the east quay of the outer basin, and No. 2 on the north quay of the inner basin, No. 1 being suitable for lifting to a height of 50 ft. and No. 2 to a height of 60 ft. Each hoist is capable of raising, tipping, and lowering wagons carrying 20 tons of coal, with a gross weight of 32 tons, as well as those of the ordinary type at present in use holding 6 tons and upwards.

It is always expedient to decide the working speeds of dock appliances in relation to the complete cycle of operations of which they form a part, but this is particularly so in the case of coal hoists, as so many operations are involved in addition to the actual hoisting of the load, that a high speed of hoisting, while causing a considerable increase in the first cost of the machinery and also in the power required for working, does not result in a corresponding high rate of coaling, unless it is possible to deal with the other operations—such as disposal of coal in the ship, getting into position of the loaded wagon, and the running off of the empty wagon—so expeditiously that advantage can be taken of a high hoisting speed.

After careful consideration of the cycle of operations necessary to ship the maximum quantity of coal, under the system of coaling generally in vogue at docks on the Clyde, where end-tipping wagons are used, it was decided to adopt a mean hoisting speed, allowing for acceleration and retardation, of about 100 ft. per minute with full load, corresponding to a time of thirty seconds for the full height of 50 ft.; this speed, with a full unbalanced load and a combined mechanical and electrical efficiency of 72 per cent., being equivalent to about 300 E.H.P. in the motor.

Perhaps the most difficult motion of a coal hoist to deal with electrically is the tipping, as this has to be accomplished very expeditiously through a comparatively short distance, usually a maximum of 45°,[1] and with a degree of accuracy very difficult to attain under such varying conditions and loads. It is always necessary to accelerate quickly, and sometimes to stop suddenly and thus give an impetus to the material being shipped, so that it will leave the wagon without sticking. Frequently this motion has to be repeated through small angles of travel several times before the whole of the material leaves the wagon. To tip the full wagons to a maximum angle of 45° in six to nine seconds requires power almost identical with that for hoisting, so that the motors for the two motions are duplicates.

The design of the structural work and arrangement of shoot, jib cranes, and other auxiliary apparatus is on the usual lines, the essential difference being that all the gearing is at the top of the structure, which has been designed to carry this additional weight, and not, as at Rotterdam and Emden, in as eparate building by the side of the hoist. As mentioned above, separate motors are employed for the hoisting and tipping motions. The hoisting motor drives, by means of an elastic coupling and also an ordinary jaw-coupling, a pinion which engages with a spur wheel upon the countershaft, this spur wheel and pinion running in a cast-iron casing. At each end of the countershaft a pinion is fixed which engages with the spur wheels firmly fixed to the hoisting drums, the drums being so arranged that the ropes go directly to the cradle without the intervention of guide pulleys. The whole of the gearing, with the exception of the motors, is erected

[1] It has been observed by Mr William H. Patchell that in tipping a full truck of large coal it could be done at a comparatively low angle, probably 38°, but in tipping small coal, particularly if it had been washed, there was some difficulty in emptying it out at 45°; and if for any reason the tipping had to be interrupted and there was half or quarter of a truck still to tip, it had to be practically raked out.

upon a cast-iron bed-plate to obviate errors in erection, and both motors are mounted upon one base-plate, which is bolted to the gearing base-plate. For the purpose of taking up the slack of the tipping rope during the raising of the platform, a third drum, of barrel shape towards one end, is connected to one of the hoisting drums. The tipping motor is a duplicate of that for hoisting, and the gearing generally is similar, excepting that only one drum is employed.

In view of the heavy loads to be dealt with, and the precision with which the cage and tipping cradle have to be brought to a stop at any predetermined position, the brake gear is of great importance. The brakes for both hoisting and tipping are of the friction clinch type, the brake bands being kept tight during the hoisting, and the clinches revolving freely in the hoisting direction. By this means the load is held in suspension immediately power is disconnected from the motor. In lowering, the brake bands are released by electro-magnets in the usual way. Due to the fact that the hoisting and tipping motors are duplicates of each other, it has been possible to provide a simple arrangement by means of which one motor can work both motions in case of breakdown to either motor, thus enabling coaling to be proceeded with and avoiding any serious delay in the departure of a vessel.

There is only one control lever, which works in a quadrant or frame, and by moving this lever in the various positions the attendant has control of the hoisting, tipping, and jib crane, the only other controller being a small one for controlling the slewing of the jib crane. Gearing is arranged in connection with this control-lever frame, which automatically renders it impossible for any of the motions to exceed their predetermined efforts, and it is also impossible for the attendant at starting to move the lever at such a rate as to accelerate at too great a speed and consequently throw an undue load upon the generating station. In fact, at all points of possible danger, the automatic adjustments come into operation, and prevent any damage from error of omission or commission on the part of the attendant. In actual working it has been found that the control is so perfect that the cradle can be brought to rest quite smoothly at any desired position, and in a similar manner the tipping platform can be quite smoothly stopped at any desired position. The wagons while on the hoist and when being run off are thus protected from the rough usage to which they are frequently subjected during coaling operations.

In Table 1 the specified cycle of operations is tabulated, from details obtained at the official trials. Comparing these with the results tabulated in Table 2, which were obtained in February 1909, after two years' working, it will be seen that the time required for coaling through the cycle of operations is considerably shorter.

Since the first two coal hoists were erected and set to work, two additional hoists have been installed, practically duplicates of the first two; for the result of some years' working did not suggest any modification or improvement for the further hoists, the only practical difference being that the two later hoists were for a higher lift.

Efficiency.—At the official trials in May 1907, which were taken when the hoists had done practically no coaling under actual working conditions, the following readings were taken upon hoist No. 2:—

Total unbalanced load	32 tons 0 cwt. 1 qr.
Height lifted	60 ft.
Time hoisting	36 seconds.
Speed of hoisting	100 ft. per minute.
H.P. due to load	217·3 load H.P.
Current	500 amperes.
Voltage	450 volts.
Electrical H.P.	301·6.

These readings show a combined efficiency of 72 per cent., which figure is within that guaranteed by the contractors.

During the coaling of a ship on 10th February 1909, particulars of which are tabulated in Table 3, several ampere and voltage diagrams were taken.

TABLE 1

Details of Specified Cycle of Operations.	Gross Weight.		
	Tons, $16\frac{5}{20}$.	Tons, $18\frac{18}{20}$.	Tons, $28\frac{5}{20}$.
	Sec.	Sec.	Sec.
Securing wagon on cradle and raising to a height of 50 ft.	33	33	33
Tipping loaded wagon	7·5	7·5	9
Lowering platform with empty wagon to cradle chamber	7·5	7·5	9
Lowering cradle with empty wagon to high level viaduct	24	24	24
Uncoupling and running wagon off	14	14	14
Lowering empty cradle from high level viaduct to ground	14	14	14
Total time per cycle	100	100	103

TABLE 2

Details of Actual Cycle of Operations.	Gross Weight.		
	T. C. Q. 16 5 2	T. C. Q. 18 6 0	T. C. Q. 28 3 0
	Sec.	Sec.	Sec.
Securing wagon on cradle and raising to a height of 57 ft.	30	30	31
Tipping loaded wagon	8	8	9
Lowering platform with empty wagon to cradle chamber	6	6	6
Lowering cradle with empty wagon to high level viaduct	24	24	24
Uncoupling and running wagon off	8	8	8
Lowering empty cradle from high level viaduct to ground	12	12	12
Total time per cycle	88	88	90

The following *résumé* is from the diagrams taken :—

Gross load	16 tons 17 cwt.
Speed of hoisting	92·75 ft. per minute.
H.P. due to load	106 load H.P.
Current	225 amperes.
Voltage	440 volts.
Electrical H.P.	132·7.

These readings show a combined efficiency of 80 per cent. The instruments used for taking the electrical readings were fixed in the generating station, thus the readings include distribution losses.

TABLE 3

Number of Wagons Dealt With.	Total Time of Coaling.	Equivalent Number of Wagons per Hour.	Height of Lift.	Weights.			Tons of Coal per Hour.	Time per Cycle.	Total Units.	Units per Cycle.	Units per Hour.	Units per Ton.	Tons per Unit.
				Gross Weight.	Net Weight.	Average Weight of Coal per Wagon.							
	M. S.		Ft. In.	T. Cwt. Qr.	T. Cwt. Qr.	T. Cwt. Qr		Sec.					
30	31 37	57	27 10	416 10 2	252 14 0	8 8 1·9	479·5	63·2	25	0·833	47·44	0·098	10·1

The result shows that the efficiency of the hoists had considerably improved during the two years' working, and, as it was obtained at half-load, further clearly demonstrates the high efficiency of electricity over wide ranges of working.

Working Cost.—The cost of the electrical energy, including coal, water, stores and oil, wages, repairs, etc., is ·89d. per unit. This cost is estimated as an average, with a consumption of approximately 560,000 units per annum. The capital charges increase this figure to about 2d. per unit.

The particulars obtainable for hydraulic power, variously estimated at from 2d. to 1s. 9d. per 1,000 gals. at a pressure of 750 lb., cannot obviously be on the common basis, but in any case the fact must be recognised that whereas the supply of electricity to any given quantity of work is a direct measure of work done, the supply of water in the case of hydraulics is always more than the quantity required, and therefore some of it is wasted; this waste may vary from 5 to 50 per cent. (what is here termed waste does, in a modern installation, however, not exactly apply, as such water is always returned to a second set of accumulators).

Two gals. of water per minute, at a pressure of 750 lb. per square inch, is reckoned equal to 1 H.P.

The conclusions to which Messrs Baxter and Dixon came were: Firstly—Electric and hydraulic systems are equally reliable. Secondly—The cost of working with electrical and hydraulic power is equal for full loads, but under variable and low load conditions electric power is cheaper. Thirdly—Electrical power has now the equivalent of a hydraulic accumulator. Fourthly—Electrical power can be applied to all dock appliances, and has greater flexibility than hydraulic power.

It must be mentioned here, with regard to the first conclusion, that we have only five or six years' experience with electrical tips, whilst with hydraulic ones we have, thanks to the genius of Lord Armstrong, an experience of over sixty years, and we know that some of the earliest tips, though perhaps not up to date, are still as serviceable as ever they were.

With regard to cost under the second conclusion, this was based on the cost of 9d. per 1,000 gals. of pressure water. This estimate is considered excessive by hydraulic experts, and it is asserted that hydraulic power can be produced at from 2d. to 3d. per 1,000 gals.

In addition it might here be mentioned that hydraulic coal hoists or tips have an advantage over electric hoists, as it is not necessary to employ wire ropes either for lifting, tipping, or balancing, the wire rope being often a source of anxiety to those in charge.

Working Results.—The coal and other material shipped by the two hoists during twelve months was 556,419 tons. The units consumed during this period totalled 80,164, and the number of wagons dealt with 70,604. During this period as many as 23 tons of coal per unit have been shipped, while, including all distribution losses and

also the power necessary for the working of all auxiliary apparatus on the hoist, including the jib crane, adjusting of shoot, and shoot point, etc., the current consumed over the whole period only averaged one unit per 6·94 tons of coal shipped. As emphasising the adverse conditions under which the hoists are at present working, it will be noted that 70,604 wagons were handled in shipping 556,419 tons of coal, or an average of only 7·88 tons of coal per wagon.

Referring again to the coaling of 10th February 1909, a note was taken of the speed of working under ordinary conditions, when thirty wagons were shipped into the vessel in thirty-one minutes thirty-seven seconds, which is at the rate of fifty-seven wagons per hour, the height lifted being 27 ft. 10 in., and the total weight of coal shipped 252 tons 14 cwt. Had the wagons been as large as the hoists are constructed for, the total quantity of coal shipped would have been at the rate of 1,140 tons per hour. As mentioned above, these results are tabulated in Table 3, and, in order to enable a comparison to be made with the results obtained at Newport, these results are adjusted in Table 4 to an assumed height of lift of 46 ft. From this table it will be noted that, while the average quantity of coal per lift given by Mr Macaulay was 11 tons 2 cwt., for Rothesay Dock it was only 8 tons 8 cwt. 1·9 qr., so that electric hoists with wagons containing a similar quantity of coal to those at Newport could have loaded an additional 117 tons, making a total of 477 tons 6 cwt. per hour.

TABLE 4

	Cycles per Hour.	Time per Cycle.	Gross Weight.	Tons of Coal per Hour.	Energy per Cycle.	Energy per Hour.	Height of Lift.	Energy per Ton of Coal.	Cost per 1,000 Tons Shipped.	
									Water at 9d. per 1,000 Gals.	Electricity at 1d. per Unit.
		Sec.	Tons.				Ft.		*s. d.*	*s. d.*
Newport -	40	90	710	444	280 gals.	11,200gals.	46	25·22 gals.	...	...
Rothesay Dock	43	84	596·8	362¼	1·104 unit	47·481 unit	46	0·131 unit	18 11	10 11

Referring to Table 4, it will be seen that the consumption of energy for coaling by electric hoists, including distribution losses, is 0·131 unit per ton of coal shipped when working to a height of 46 ft. This at 1d. per unit is equivalent to 10s. 11d. per 1,000 tons of coal shipped.

For coaling by hydraulic hoists the consumption is shown to be 25,220 gals. of water, which at 9d. per 1,000 gals. is equivalent to 18s. 11d. per 1,000 tons of coal shipped, showing a saving of 8s. per 1,000 tons in favour of electricity.

With reference to the comparative cost of generating hydraulic and electric power, it may be here mentioned that the above figure of 9d. per 1,000 gals. has been assumed as a fair average of the varying figures obtainable.

Respecting the question of economic working, experience has shown that even with the additional load due to the added power requirements at the dock—rendered necessary by the installation of two additional hoists—the actual costs as regards current, cost of maintenance, and upkeep of plant, are well within the figures originally estimated.

Attention might be drawn to the fact that the most economical speed at which to run tips for shipping coal is 100 to 120 ft. per minute; many tips run faster, 150 to 200 ft., but in consequence they have to wait for something, either trucks getting on or off, or for

the trimming work on the vessel. With the moderate speed of 100 to 120 ft. one truck per minute can be shipped with a tip of any height. The higher speeds entail heavier power plant, higher wages, more damage to wagons, and more wear and tear all round.

In comparing the merits of electric and hydraulic tips, Mr G. H. Baxter also states that for varying loads the electrical power adjusts itself quite economically to the load, a condition impossible to obtain in hydraulic tips, although considerable improvement has been obtained by the employment of multiple rams. This, however, can only be considered as a partial solution of the problem, as it depends on the discretion of the man in charge as to what number of rams he will use. As a matter of fact, when manipulating tips with trucks of varying loads, as is the case on the Clyde and other docks, it is practically impossible to make the necessary adjustments at every position for the most economical working, whereas electricity adjusts itself quite automatically to the varying conditions.

Mr Aspinall has collected some interesting information concerning the time wasted during the twenty-four hours in the use of coal tips, as well as of ordinary coaling cranes. This information was given by him when presiding at the Institution of Mechanical Engineers during the reading of the paper by Messrs Dixon and Baxter. Mr Aspinall does not mention the docks at which these figures were taken, but he mentions that 1,000,000 tons of coal are handled per annum.

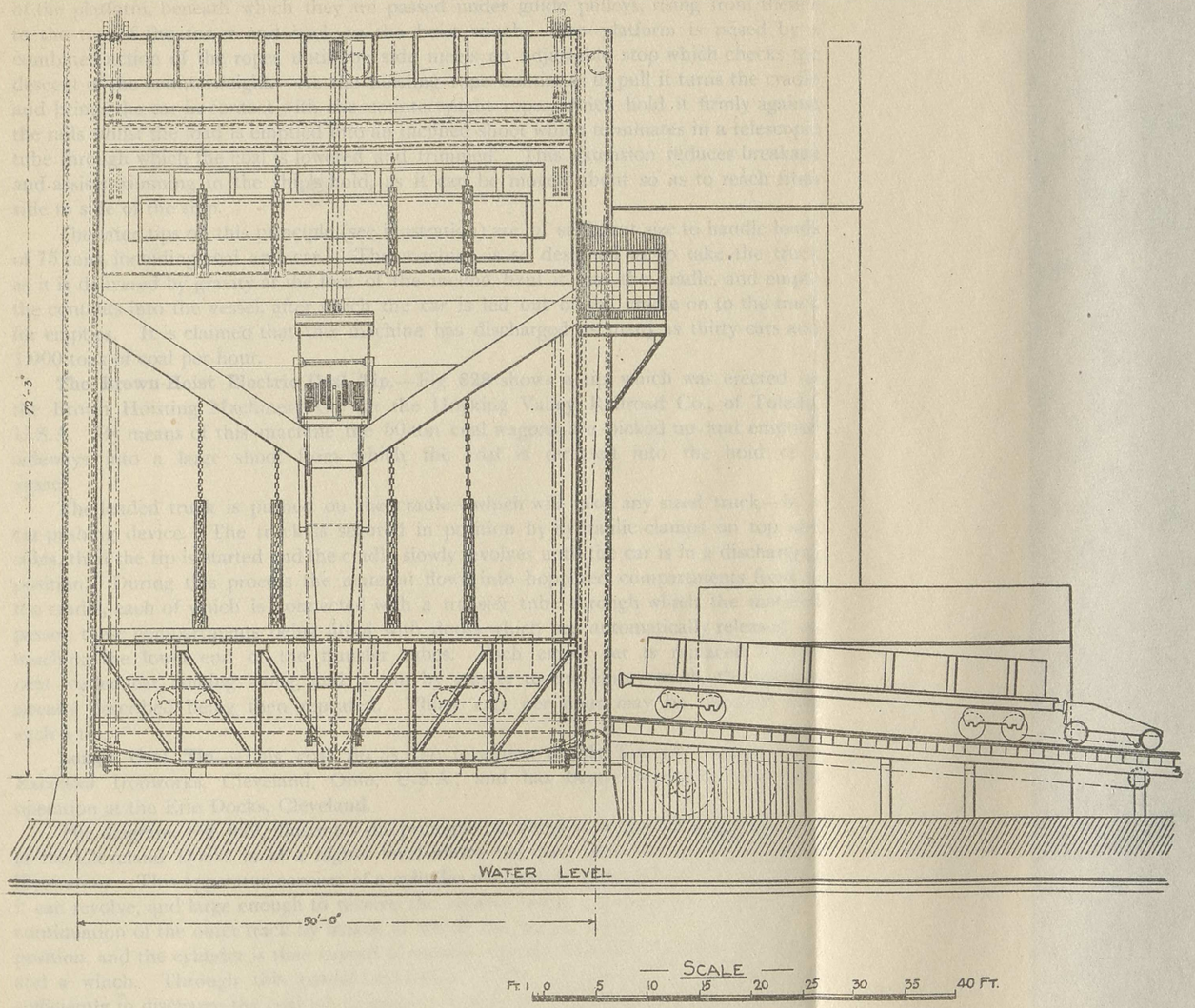
TEST OF THREE MONTHS' WORK, SHOWING PERCENTAGE OF TIME OCCUPIED IN EACH KIND OF OPERATION

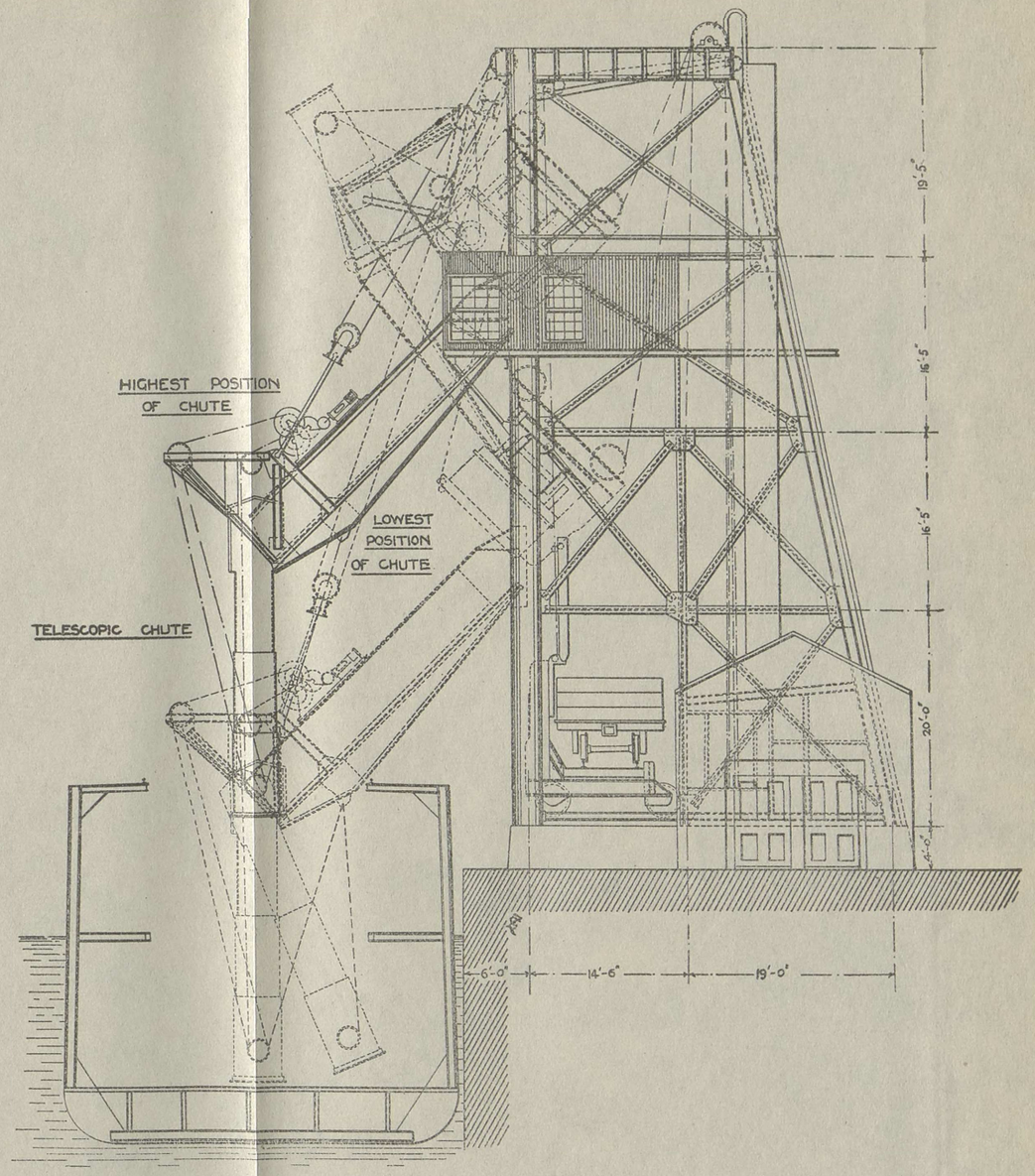
	Two Hoists Combined.	Two Cranes Combined.
	Per Cent.	Per Cent.
Tipping and handling	53·49	64·19
Waiting ships	8·24	5·04
Waiting coal[1]	1·14	1·38
Adjustment of shoot	3·07	...
Swinging and changing	4·89	3·88
Trimming in holds	12·25	8·24
Meal hours	15·75	15·28
Other causes	1·17	1·99
	100·00	100·00

This leaves the time actually occupied in tipping, handling, and packing the coal on to the boat 53·49 per cent. in the case of a hoist, and 64·19 per cent. in the case of a crane, being a clear gain of 11 per cent. in favour of the crane.

M'Myler Coal Tips.—The tips built by the M'Myler Manufacturing Co., of Cleveland, Ohio, are for the purpose of discharging cars which need neither be hopper-bottomed nor have hinged end doors for unloading. The trucks are tipped by rolling them over laterally when they have reached the required level in the tip. Such a tip is illustrated in Figs. **826** and **827**, and consists essentially of a steel tower, similar to the Armstrong type of tip, which forms the guide for the cradle; the latter is provided with a rigid side towards the vessel to be loaded. Wire ropes are attached to the top of this side, passing upwards over the guide pulleys to a counterweight running in a groove at the rear of the tower. The hoist ropes are attached to a lower point on the same side

[1] This refers to the time occupied in getting the trucks on to the tip or on to the crane.





Figs. 826 and 827. Latest Type of the M'Myler Coal Tip (Car Dumper), sixteen of which are at the principal ports upon the great Lakes in America.

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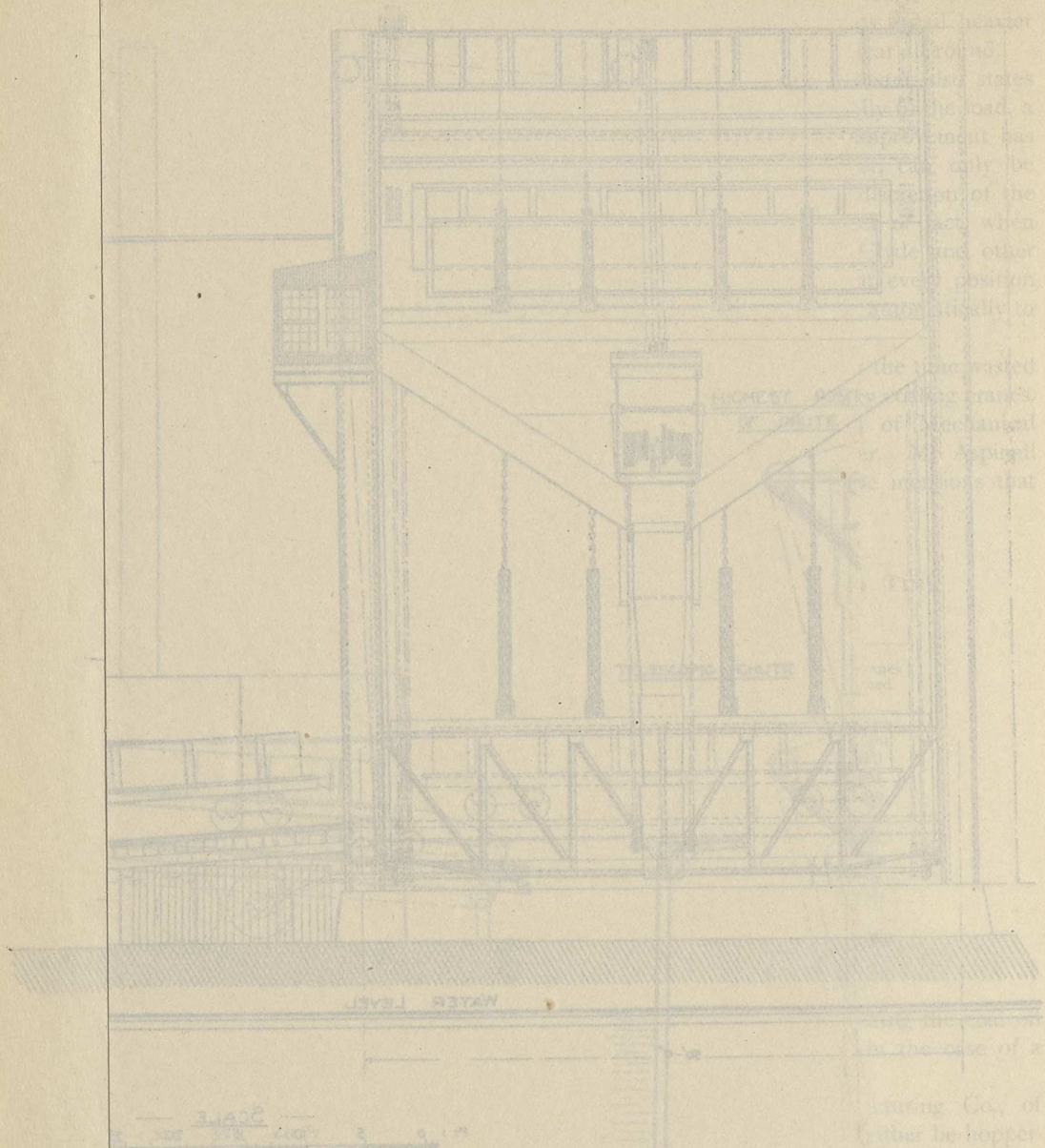


of the platform, beneath which they are passed under guide pulleys, rising from thence to the top of the tower and back to the hoist winch. The platform is raised by a combined action of the ropes until the side meets an adjustable stop which checks the descent of the counterweight. As the hoisting rope continues to pull it turns the cradle and brings the car in contact with the counterweight ropes, which hold it firmly against the rails whilst the load is emptied into an inclined shoot which terminates in a telescopic tube through which the coal is lowered and trimmed. This extension reduces breakage and assists trimming in the ship's hold, as it can be moved about so as to reach from side to side of the ship.

The later tips on this principle (see illustration) are of sufficient size to handle loads of 75 tons, including coal and car.[1] The machine is so designed as to take the truck as it is delivered by gravity at the foot of the incline, haul it into the cradle, and empty the contents into the vessel, after which the car is led out of the cradle on to the track for empties. It is claimed that this machine has discharged as many as thirty cars and 1,000 tons of coal per hour.

The Brown-Hoist Electric Coal Tip.—Fig. **828** shows a tip, which was erected by the Brown Hoisting Machinery Co. for the Hocking Valley Railroad Co., of Toledo, U.S.A. By means of this machine the 50-ton coal wagons are picked up and emptied sideways into a large shoot from which the coal is directed into the hold of a vessel.

The loaded truck is pushed on the cradle—which will take any sized truck—by a car-pushing device. The truck is secured in position by hydraulic clamps on top and sides, then the tip is started and the cradle slowly revolves until the car is in a discharging position. During this process the material flows into hoppered compartments fixed to the cradle, each of which is connected with a transfer tube through which the material passes, these compartments being fitted with doors which are automatically released on touching the lower end of the transfer tubes. Each empty car is replaced by the next loaded car coming along, and is run by gravity to the empty track, the process already described being then repeated. Thirty cars per hour may be handled with such a tip.

Long's Coal Tip.—This coal tip is the invention of Mr Timothy Long, of the Excelsior Ironworks, Cleveland, Ohio, U.S.A., and has been successfully put into operation at the Erie Docks, Cleveland.

The diagram, Fig. **829**, illustrates the principle on which it works, although the one at the Cleveland Docks is at a higher level above the quay than the tip shown in this illustration. This apparatus consists of a cylinder mounted at each end on rails on which it can revolve, and large enough to receive the railway truck. Within the cylinder is a continuation of the outer track by means of which the wagon enters. It is clamped in position, and the cylinder is then caused to revolve towards the shoot by means of cables and a winch. Through this partial revolution of the cylinder the wagon is tilted sufficiently to discharge the coal into a shoot or hopper, after which the cylinder is rolled back to the starting point, where the wagon again assumes its normal position and is pushed out by a full one. The cylinder is 40 ft. in length and has an internal diameter of 11 ft., whilst the outer diameter is 16 ft. It consists of a strong framework, and has openings of sufficient size for the coal to pass through in the discharging position.

The capacity of this tip is stated to be three hundred cars, or 7,500 tons of coal, per

[1] This tip has been fully described in a paper read by Mr J. D. Twinberrow before the Institution of Mechanical Engineers. See *Proceedings Inst. M.E.*, 1900, page 574.

day of twenty-four hours, and it is reported to have discharged three American bogie trucks into a vessel in three minutes.[1]

Coal Tip by Pohlig, of Cologne.—Fig. 830 represents a coal tip built by J. Pohlig,

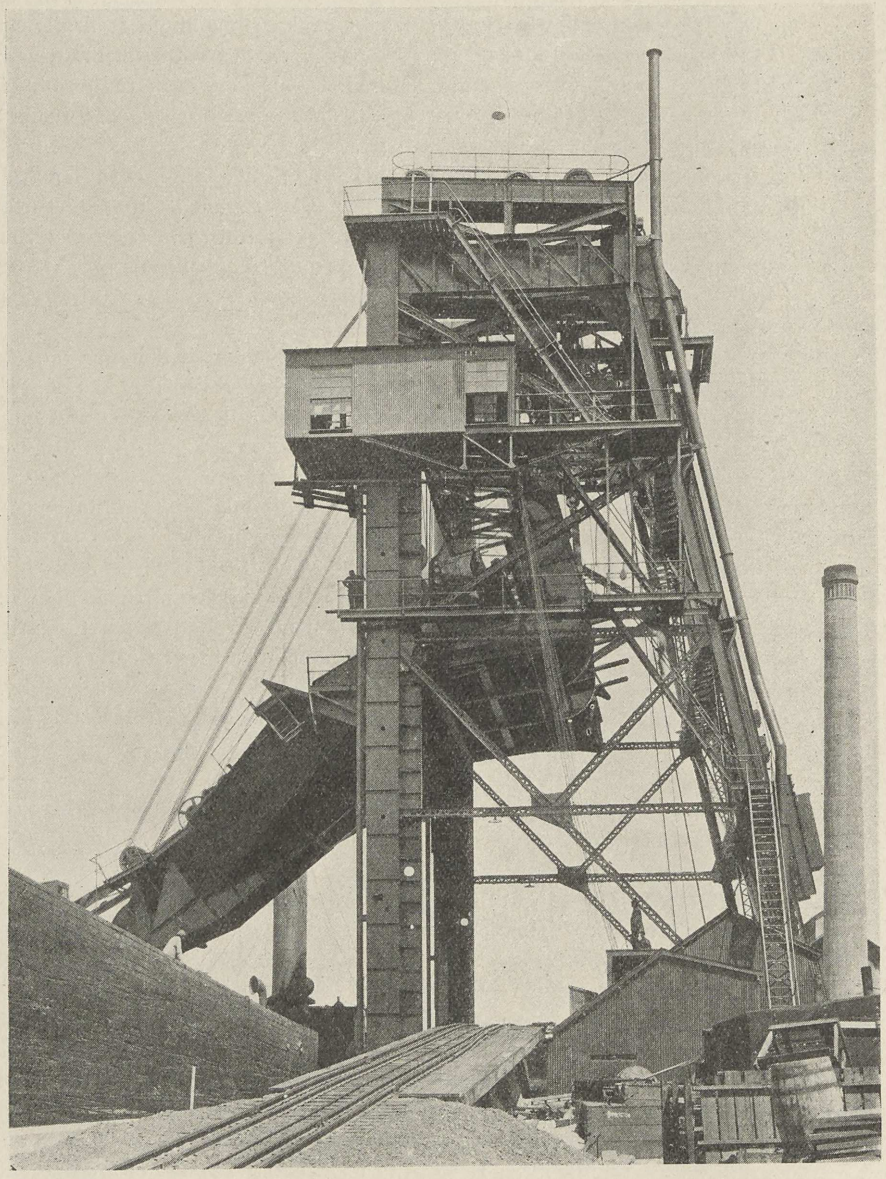


Fig. 828. Brown-Hoist Coal Tip.

of Cologne. Unlike those previously described, the railway truck in this tip is not taken up in a perpendicular direction, but at an angle of 45°. The truck to be unloaded is

[1] This tip was described in the *Scientific American*, 16th November 1895, page 312; also *Engineering*, 21st August 1896, page 211.

pushed forward upon the cradle and put into position. The cradle is fitted with four wheels and ascends on the rails, to the top of the inclined structure, where these rails are so arranged that as soon as the cradle has reached the highest point the front wheels are lowered sufficiently to put the cradle and truck in a position at which the coal will leave the truck. The engine and winding gear necessary for this installation are placed at any suitable point in close proximity to the tip itself. The cradle is so balanced that the winding gear has only to perform the actual work of elevating the coal. There is also a safety brake to prevent the cradle descending at an excessive speed, even if the cable of the winding gear should snap. The truck discharges its load into a hopper, from which it is fed by a shoot into barges. If the hopper is kept full there will be but little breakage in the delivery of the coal, and if carefully manipulated by means of the hand wheel the coal will leave the lower end of the shoot at the same rate at which it enters the hopper. With these tips the truck must always be elevated to the same level; they are therefore only suitable for non-tidal rivers and for vessels of uniform dimensions.

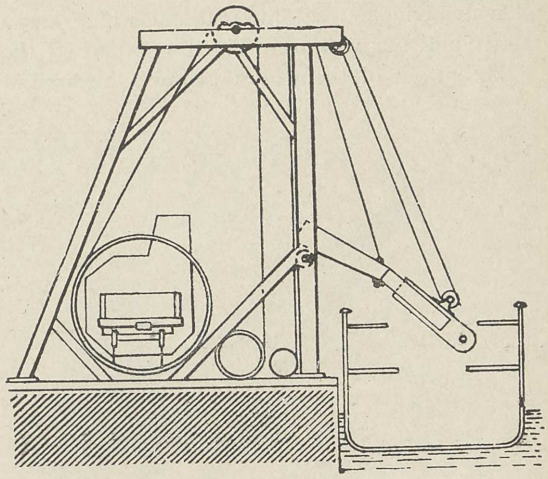


Fig. 829. Long's Coal Tip.

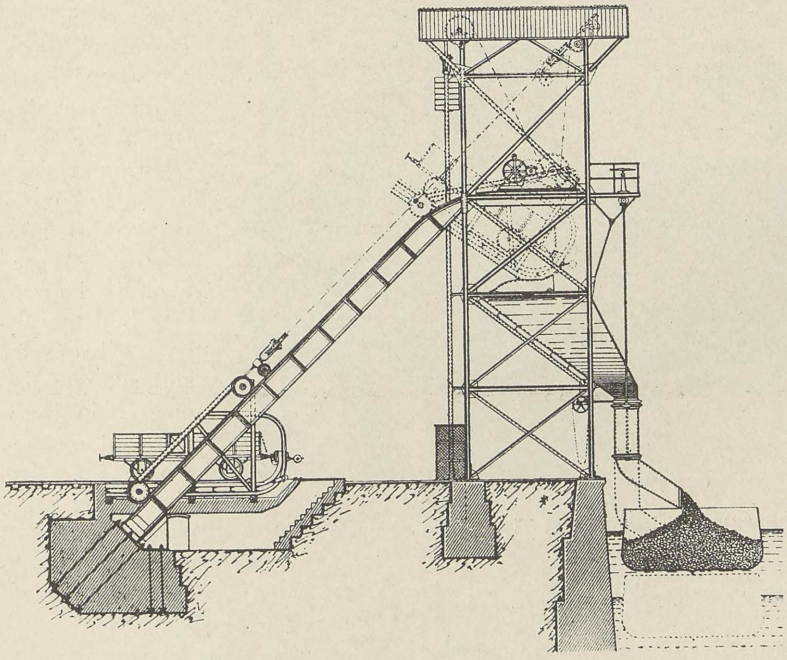


Fig. 830 Coal Tip Built by Pohlig.

Hydraulic Crane Tip at Middlesbrough.—An entirely different type of coal-loading apparatus is illustrated in Fig. 831, and represents the movable hydraulic crane tip at Middlesbrough for loading coal direct from the docks into ships. It consists of a heavy pillar revolving on a built pedestal, which has an archway large enough to pass a locomotive and box wagons. The lower part of the pillar is carried in a footstep attached to the bottom of the pedestal above the archway, while the upper bearing of the pillar is formed by the top of the pedestal. The pillar carries jibs pivoted on a pin at its heel, the radius of which can be varied within wide limits by a hydraulic cylinder and ram placed in an inclined position at the back of the pillar, this ram being connected with the head of the jib by girders. The turning of the pillar and jib is effected by hydraulic cylinders placed at the back of the pillar, alongside the lifting cylinder, and acting on a chain which fits into a cupped drum round the top of the pedestal. The lifting mechanism is placed within the cheeks of the pillar, and consists of a hydraulic cylinder with rams and multiplying sheaves. There is also a tipping cylinder placed between the turning cylinders on the back of the pillar, and acting upon the tipping chain by which the rear end of the wagon is tipped up. Attached to the lifting and tipping chains is a cradle, for receiving coal trucks of either end or bottom door pattern, which fits into a seat which can be placed on the rails at any point without in any way cutting up the quay. The moving of the crane is effected by a hydraulic engine placed in the pedestal connected to the travelling wheels by shafts and gearing. This hydraulic crane has a lifting power of 15 to 30 tons, the height of lift being 66 ft. It was built by Sir W. G. Armstrong, Whitworth, & Co., Ltd., and is one of the latest developments of this kind of tip.

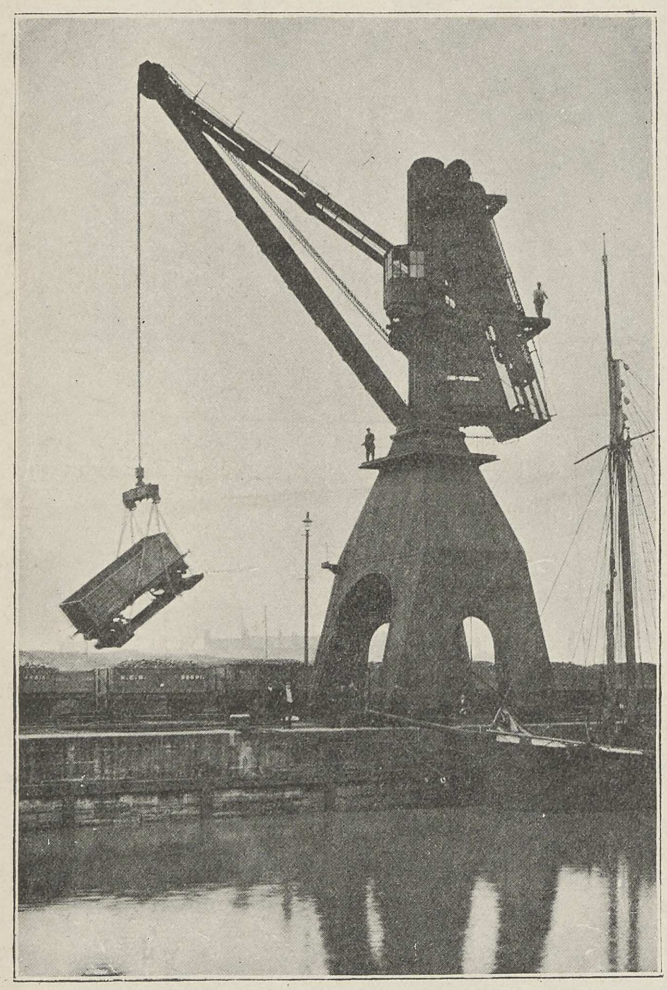


Fig. 831. Hydraulic Crane Tip at Middlesbrough.

Similar cranes were erected at Avonmouth Docks and elsewhere, but with the

earlier tips it was necessary to have a pit between the rails into which the cradle for the reception of the railway trucks fitted. The crane at the Avonmouth Docks was built for handling coal from the local coal fields near Bristol, from the Radstock district; for South Wales coal which comes *via* Severn Tunnel, as well as for coal from the Forest of Dean and the Midlands. It lifts the truck on the cradle, which is then swung over the hatchway, the coal being tipped into the vessel. A similar tip is also used at Fleetwood. The crane travels on rails laid alongside the quay, and the cradle is so constructed that the trucks can be picked up from and deposited upon the rails at any point where the crane may be. The truck rests on the cradle which fits between the rails, so that the wagon may be run off at the opposite end to the point at which the loaded trucks enter; thus no sidings or turntables are required, and the train of wagons can be lifted and tipped in succession while the empty trucks are taken away on the same line of rails and in the same direction. The cradle is worked by the outside pair of chains, which are manipulated by a different cylinder and ram from the one actuating the tipping.

The tipping is arranged from the centre chain, which separates above the swivel, its two strands passing, at this point, over guide pulleys on the lifting beam above the cradle, to which both lifting and tipping chains are attached, the tipping chain being made fast to the rear end of the vessel. The lifting and tipping motions are each controlled by hydraulic power, and are operated by a man standing in a cabin in the front of the crane pillar.

A tip similar to that just described is installed at Bremen, Germany.[1] With this tip the coal truck to be discharged is run on a platform which forms part of the track passing along the quay side. The crane then picks up this platform with the truck upon it, and swings it round until the end of the car is over a large hopper, which is suspended from the upper arm of the same crane over the ship to be loaded. The truck arrives here in a horizontal position on its platform, as it has been elevated simultaneously by two sets of hydraulic hoists, one of which is connected to the front and one to the rear chain supporting the platform. By raising the rear chains the platform is tilted until the load has been discharged in this suspended hopper. The manipulator's cabin is in front of the crane, and in full view of the whole of the operations. The crane has been built for loads of 26 tons, the extension of the jib end being 26 ft., whilst the load can be raised to a height of 32 ft. The special jib which supports the hopper has a radius of 36 ft. and a lift of 45 ft.

This installation was built by C. Hoppe, of Berlin. Similar cranes, but of larger proportions, are being built in America.

The Cowans Sheldon Crane Tip.[2]—This is again of similar construction; it is built by Cowans, Sheldon, & Co., Ltd., of Carlisle, and is intended for loads of 25 tons which are lifted by a single chain. The lifting and turning are effected by hydraulic power, the hydraulic piston being placed horizontally under the quay, and being manipulated from a cabin erected by the side of the jib crane.

The radius is 34 ft. 6 in., and the height from quay level to the centre of the jib top pulley is 50 ft.

Lewis and Hunter's Coal Tip at Cardiff Docks.—This system consists of a tip discharging its load on a level with the line. Self-discharging railway trucks can also be used, in which case the tip is not necessary. The tips, which are mostly used in this system, discharge the coal into a skip which holds the contents of the wagon, and the

[1] This tip has been described in a paper read by Mr J. D. Twinberrow on the "Capacity of Railway Wagons as affecting Cost of Transport." See *Proc. Inst. Mech. Engineers.*

[2] This tip has been described in *Engineering*, 29th April 1898, page 531.

coal is elevated in this skip by a hydraulic jib crane, swung round over the hatch, lowered into the hold of the vessel, and there emptied. The crane is capable of travelling with its load along the quay wall, and is thus able to reach hatches at varying distances from the tip. With 10-ton wagons 293 tons of coal have been tipped on board a steamer with one crane in an hour. One crane is therefore capable of working at the rate of 30 skip-loads per hour. The actual working rate in practice is, however, lower than this, and the following record, published by the patentees, gives the time taken and the quantity of coal loaded with two cranes :—

Name of Steamer.	Quantity.	Time.	Tipping Operations per Hour with One Crane.
	Tons.	Hours.	Tips per Hour.
Lancashire	5,817	20	14·5
Asama	5,833	30	9·7
Knight Companion	6,411	34	9·4
Runic	6,218	28	11·0
Rhympha	3,303	16	10·3
Isle of Anglesea	2,033	13	7·8
Inchlonga	4,133	27	7·7
Orsino	2,781	12	11·3
Nedgid	3,910	13	15·0
Wingates	2,866	11	13·0
			Average, 11·0

A case may be mentioned of a steamer which went into berth at 5 P.M., and by 5.30 next morning had taken in 1,609 tons of coal, an average, after deducting stoppages, of 189 tons per hour, so that in this case 1,609 tons were shipped by one crane in eight and a half hours. The net loading time, after deducting delays, incurred in waiting for coal of the S.S. "Samoa" was twenty-eight hours, in which time she took in 7,484 tons of cargo and 1,750 tons of bunkers, or an average of 330 tons per hour. The S.S. "Iran," which was loaded by four cranes, took on board 9,213 tons of coal in a net loading time of twenty-six and a half hours, or on an average 347 tons per hour.

This system is the invention of Sir William T. Lewis (general manager) and Mr Charles Hunter (engineer) of the Bute Docks, Cardiff, and has been adopted by the Cardiff Railway at their Roath Dock, Cardiff.

Tips similar to the foregoing, in which the railway truck is emptied into ordinary and mechanical skips holding the full contents of the truck, which are then emptied into the ship's hold, have been designed by Mr G. T. Wart, colliery manager of the East India Railway; also by the Wellman-Seaver-Morgan Engineering Co., Ltd., Cleveland, Ohio. Besides these may be mentioned the Butler and Fielding system.[1]

Other noteworthy devices are intermittent appliances in which the contents of the truck are emptied, either on or below the level of the rails, into a hopper from which they are transferred by a smaller skip to the ship, and then lowered into the hold.

Good examples of this type of tip are those erected in 1893 for the East India Railway; also the one erected at the Kidderpur Dock, Calcutta, both by Sir W. G. Armstrong, Whitworth, & Co., Ltd. In the latter instance each skip holds one half of a wagon load, or about 5 tons. The Rapier Coaling Crane may also be mentioned, as well as the Beckett system, which is the invention of Mr W. T. C. Beckett, deputy agent and chief engineer, Bengal-Nagpur Railway, as they also belong to this type of coal tip.

[1] This system was fully described in the *Engineer* of 2nd June 1893.

CHAPTER XXXVI

COLLIERY TIPS OR TIPPLERS

THE coal tips described in the preceding chapter are mostly intended for the purpose of manipulating standard gauge railway trucks, but there is no reason why similar appliances should not be built on almost identical lines for the purpose of emptying colliery tubs. Appliances for this purpose are, probably on account of their smaller size, of very different construction. They are generally known as "tipplers," and are built in a variety of forms, in most cases extremely simple, and too well known to require detailed descriptions, those delivering backward always being preferable, as they cause less breakage than those delivering in a forward direction.

A few types of more recent date are worthy of notice, and are here fully described.

It will be seen that these coal tipplers are mostly of the type which discharge below the level of the rails.

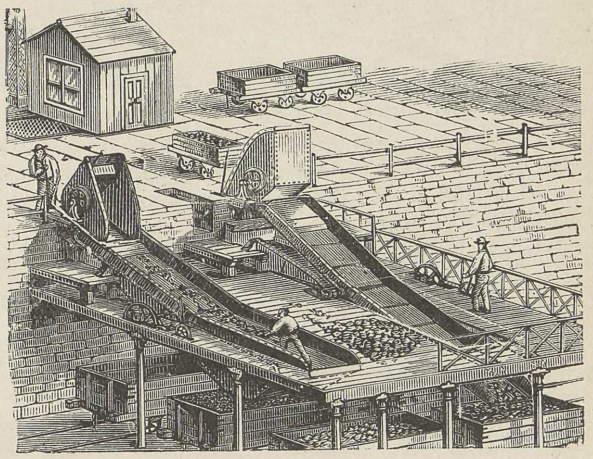


Fig. 832. Perspective View of Rigg's Tipping Machines.

Of the many improvements introduced for the purpose of minimising breakage, the devices for tipping coal with the least possible damage stand perhaps first, as the value of coal is in almost all cases dependent upon the size of the pieces received by the consumer. From its arrival in the tub or tram at the pit's mouth each transfer has the effect of more or less diminishing its value. Though the more friable kinds of coal sustain some damage by abrasion, more or less inseparable from transit in railway trucks, the most serious injury is generally incurred in tipping at the pit and in loading on shipboard. At collieries many different devices have from time to time been adopted with a view to preventing breakage, but these devices necessarily vary with the character of the coal in different districts. Thus, in Monmouthshire and South Wales the iron trams are provided with hinged end doors or bars, which are removed on the forewheels falling into recesses at the head of the screen; or else the necessary angle of delivery, about 35°, may be obtained by a tram being placed on an oscillating platform so arranged as to allow of its tipping to the required angle of clearance.

The so-called "box-tubs"—that is, tubs having no doors—are also variously tipped in balanced and unbalanced frames either backwards, forwards, or sideways on to the screen, sometimes under the control of a brake. In cases where the coal is not heaped above the top of the tub, a horizontal door is sometimes shut down upon it, and not

released until the tub is inverted over the screen. All these methods are bound to cause a certain amount of breakage, and are therefore superseded in modern collieries by more scientific tipplers.

Rigg's Colliery Tippler.—A tippler which greatly reduces breakage is that designed by Mr James Rigg, of London.

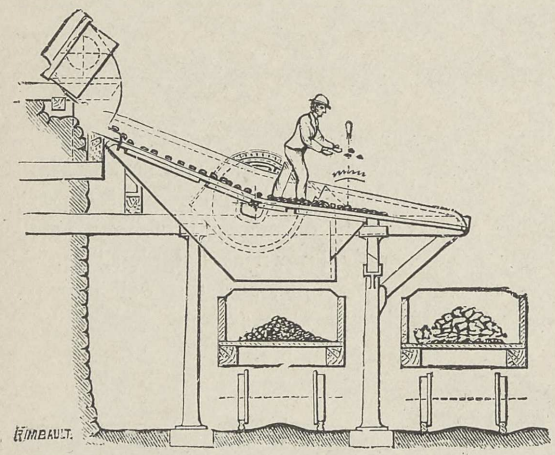


Fig. 833. Screen Receiving Tub-load of Coal.

The rotating bonnet which receives the tub is so balanced that the position of the centre of gravity depends upon the tub being loaded or empty, and therefore causes it, under control of the brake, either to tip forward and empty itself, or to return unloaded. Within this bonnet is a horizontal hinged door, which has an important function to fulfil, as at whatever speed the machine may be working, this door will act as a regulator to the flow of coal, while gradually but steadily yielding to its pressure. In reality it combines with the shoot in spreading the coal over the screen or sieve, into which it is generally discharged.

Fig. **832** gives a perspective view of these tipping machines working in connection with Rigg's curved balanced screens.

The diagram, Fig. **833**, shows the screen in its normal position receiving a tub-load of coal, which passes down the incline and is gradually brought to rest under the lower screen bars, as shown in Fig. **834**.

The brake is again released, and the screen returns to its starting position to receive another load, these operations being effected during the period necessary for changing the tubs in the tip above.

The slack or small coal which has been eliminated by the screen is received in the fixed hopper shown and thus passed into its own trucks.

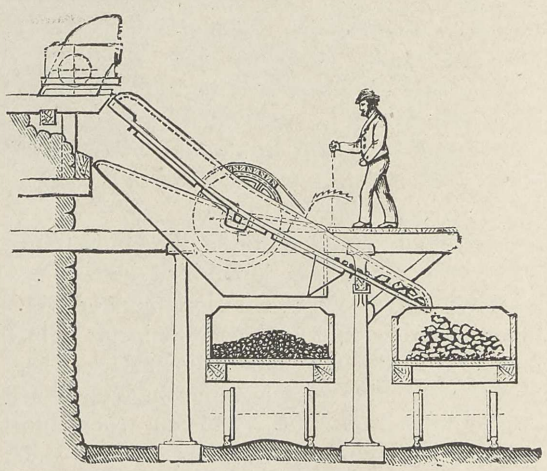


Fig. 834. Screen in Stationary Position.

Fowler's Patent Gravity Tippler.—During the past few years this tippler, which also works by gravity, has come into considerable use in this country. It is, of course, much smaller than the three-tub tippler (to be next described), and does not require any more height at the rail level than an ordinary power-driven tippler.

It was originally built of cast iron, but Messrs Heenan & Froude, Ltd., who have taken up the manufacture, are building it of mild steel for the handling of large material.

It is claimed that thereby the diameter is decreased, the cost of construction reduced, and the durability of the tippler enhanced. It has a tipping capacity of eight tubs per minute.

The tippler is also fitted with an ingenious arrangement which holds the tub in position in the cage by a system of automatic claws that grip the spindles of the tubs. This arrangement is perfectly automatic, and consists of four claws in each of the two compartments. When the tippler is empty for the ingress of a tub, these claws are backed clear out of the way, but as soon as the tippler commences to revolve, the claws

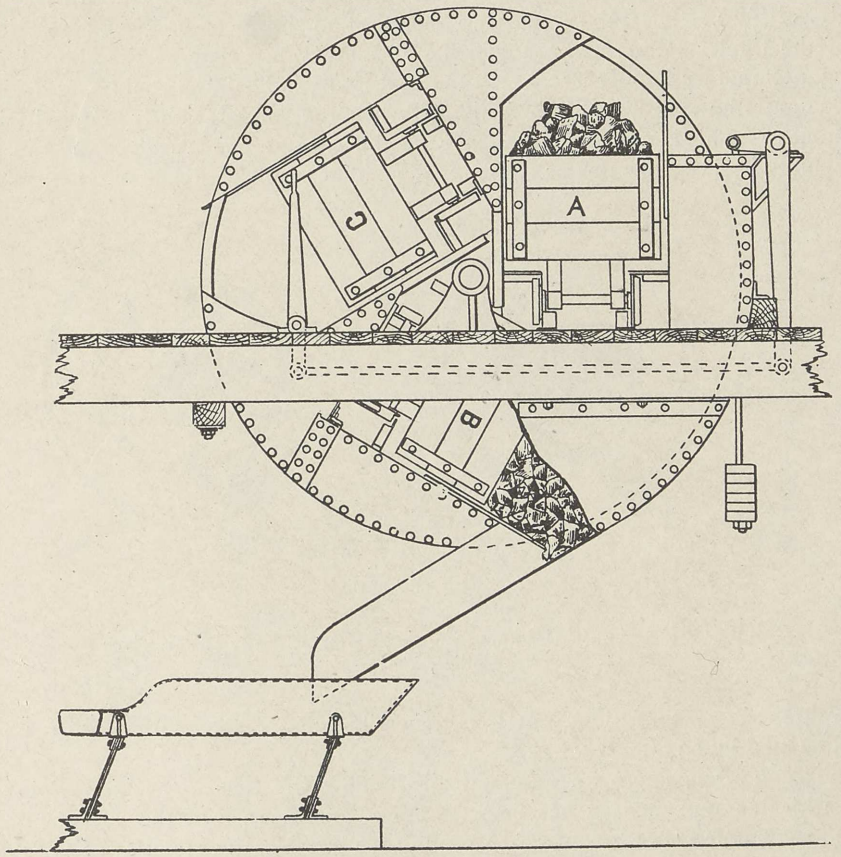


Fig. 835. Sam's Coal Tippler.

immediately move out and tightly grip the tub till it again reaches a horizontal position, when they automatically release their hold.

Sam's Coal Tippler.—The "Sam's" coal tippler is a modification of the tip previously described, and combines the simultaneous handling of three tubs, so that the speed at which each tub is unloaded does not exceed the speed at which ordinary tubs are cleared.

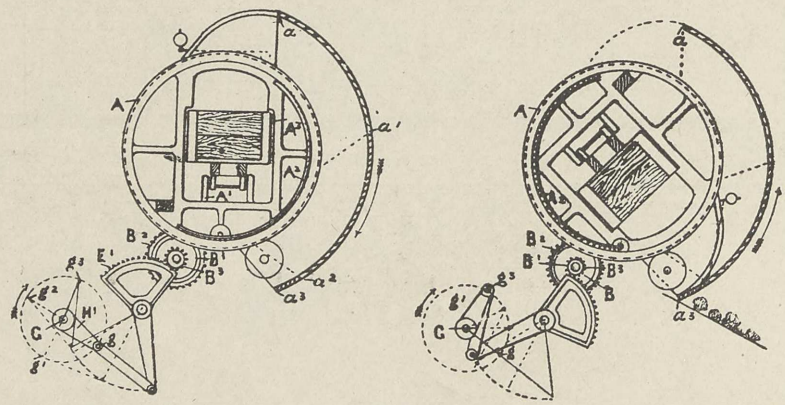
It is built by Messrs Heenan & Froude, Ltd., and has several excellent features. It has hitherto only been used for emptying colliery tubs, but there is no apparent reason why it should not be built on a scale large enough to take standard gauge railway trucks.

This appliance is illustrated in Fig. 835, from which it will be seen that the tippler

contains three compartments for three tubs which run in one cage, the rotation being caused by the weight of the loaded tub A. The *modus operandi* then is as follows:—

The loaded tub from the weighing machine is run into the tippler with sufficient velocity to eject the empty tub at the other end by the impact. When at rest the tippler is held in position by two powerful brakes which pass round the two end rings. These brakes are actuated by a lever arrangement under the control of the attendant.

On the movement of a lever the brakes are released, and the tippler rotates one-third of a revolution, and is again brought to rest in that position. This brings tub C into the position just vacated by tub A. C is then removed and replaced by a new and full tub as before. The tub A takes up the position shown at B, in which position the side of the tippler stands at an angle of 30°, an oblique plate at the side of the tub forming a temporary hopper into which the coal is discharged, the coal being held in this position until the succeeding tub is tipped, when the tub previously emptied takes the position at C. This is of great importance, as the stop at point B gives the tub time to gently empty itself. This tippler can be made with a cage which will automatically arrest



Figs. 836 and 837. Diagrams showing Action of Rigg's Power-driven Colliery Tippler.

itself in three different positions, but it is generally found more convenient to allow it to be manipulated by an attendant.

The same arrangement for automatically holding the tubs in position while tipping is used with this appliance, as has been described in the case of the "Fowler" tippler. That is to say, four claws are made to automatically seize the spindles of the tub until it reaches a horizontal position, when they automatically release themselves.

These tipplers are made in sizes running from 6 to 10 ft. in diameter. They consist of two mild steel rings built up of channel steel and joined to the centre boss by channel steel arms of the same section, which are held together by gusset plates, as shown in the illustration. The end rings are joined together by side plates of $\frac{1}{2}$-in. metal and also by angle irons which form the rails for the tub. The whole apparatus is suspended on a mild steel shaft of 4 in. diameter which revolves in two substantial cast-iron bearings.

Rigg's Power-driven Colliery Tippler.—The tip on this system describes a rotary oscillation only, and not a complete revolution, as is generally the case.

This power-driven tippler combines all the advantages of the gravity tippler, with the increased speed necessary to enable a large output to be fed on to the picking belt.

The speed of the oscillation is slow only during about 10°, while the coal passes from the tippler to the belt or to the intermediate jigging screen.

The diagrams, Figs. **836** and **837**, show the means by which the varying forward and return oscillations are obtained. Fig. **838** is a side elevation of the actual machine.

The shaft G, Figs. **836** and **837**, is driven at a uniform speed, the pin *g* on the crank

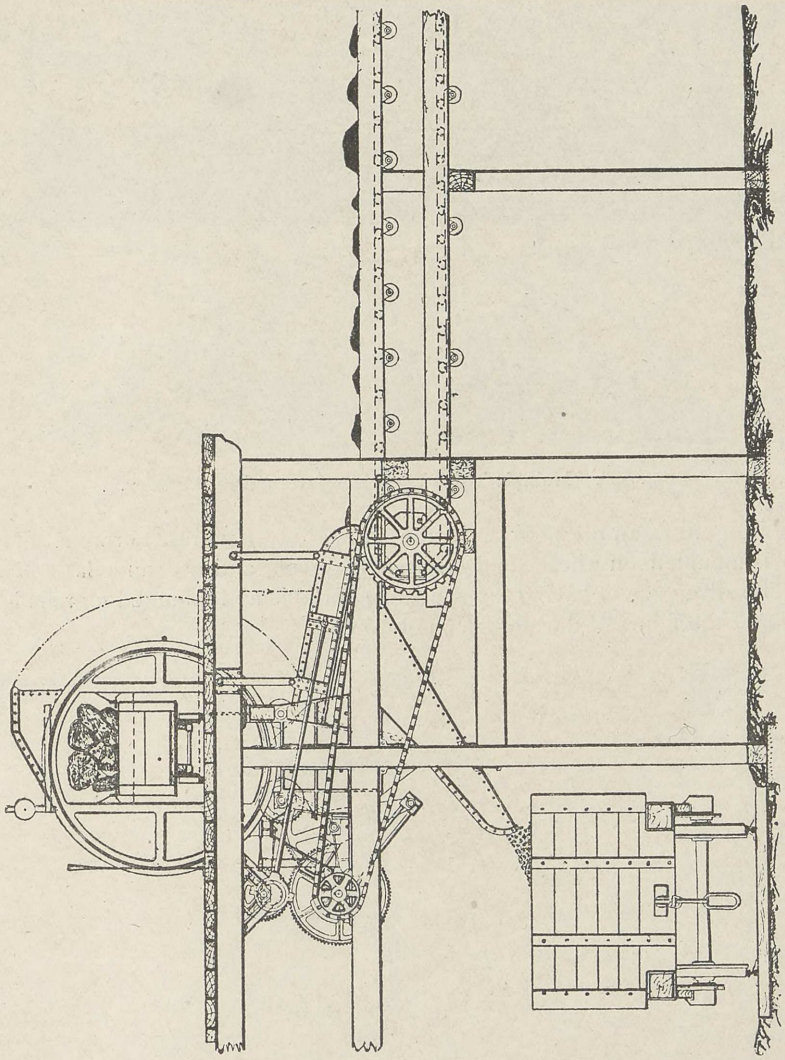


Fig. 838. General View of Rigg's Power-driven Colliery Tippler.

H^1 being connected to an arm, and the toothed segment E^1 communicating motion to the pinion B^3 and also to the wheel B^2, which is geared into the rack A^2 attached to the tippler A. One revolution of the shaft G causes the double oscillation of the tippler through the arc indicated by the dotted lines. It is important to observe that the three equal arcs, $g\ g^1$, $g^1\ g^2$, $g^2\ g^3$, of this portion of the path of the travelling crankpin correspond, as stated, with the varying velocity of travel of the tippler, as indicated by the letters $a\ a^1$, $a^1\ a^2$, and $a^2\ a^3$, and this variation, as well as the return of the empty

tub, is well adapted to secure an extremely rapid motion when coal is not leaving the tippler, and a slow one prior to, during, and for a brief period after its delivery.

Multiple Tips.[1]—A tip which will manipulate a whole train of small gauge trucks is shown in Fig. 839. It was built by G. Heckel, of Saarbrücken, for the purpose of

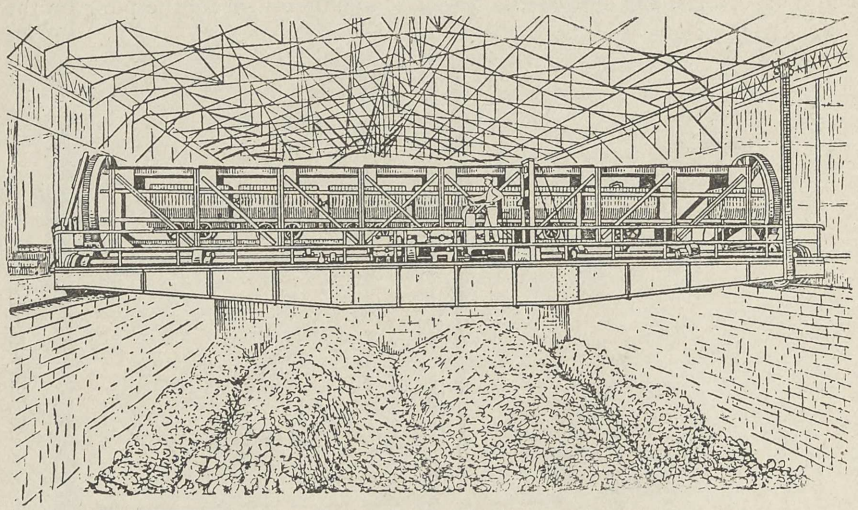


Fig. 839. Multiple Tip at the Mines des Landres, Lorraine.

depositing iron ore in an ore pocket, at the Mines des Landres, Lorraine. The whole apparatus is mounted on wheels and electrically driven, and accommodates six to eight trucks. The advantage of having the appliance portable and mounted on rails is obvious, as it facilitates the filling of the silo from end to end.

[1] From an article by Fr. Tillmann, in *Zeitschrift des Vereines deutscher Ingenieure*, 12th March 1910.

Newport Hydraulic Hoist - -	·164	kilowatt-hour per ton of coal raised, 46 ft.
Rothesay Dock Electric Hoist -	·131	,, ,, ,, ,,
Fowey Electrically driven Conveyor (exclusive of tipping)	·095	,, ,, ,, ,,

Before, however, proceeding to describe more fully coal shippers in which a belt conveyor forms the principal feature, we will give details of one or two other methods.

Coal Loaders at the Japanese Port Miike.[1]—The quay of the new dock of the colliery at Miike, the property of the Mitsui Mining Co., is 460 yds. long, so

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CHAPTER XXXVII

LOADING COAL INTO SHIPS OTHERWISE THAN BY TIPS

As early as 24th February 1903, when the Author's paper on the "Mechanical Handling of Material" was discussed before the Institution of Civil Engineers, the Author in reply to the discussion made the following statement:—

> "He thought Mr Apjohn's statement, that nothing could be much better than the appliances used for dumping the whole of the contents of railway wagons into ships, was open to question. The appliances Mr Apjohn referred to were largely used, and were probably the best that had been used so far; but why should a railway truck weighing 5 tons be raised 50 to 60 feet, in order to empty 10 tons of coal into a ship's hold? The structures for such coal-tips must be exceedingly strong, and the power required by the machinery, even with the balancing-devices in use, was enormous. Would not a tipping-device on the level of the rails, depositing the coal in a hopper (which required no driving-power), and inclined elevators for raising it, be much simpler, lighter, and require less driving-power? The elevator, or part of it, could be made to swivel like a jib, and thus be raised or lowered to suit the position of any ship to be loaded."

The above is practically the latest practice in loading ships, as will be seen from these pages.

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CHAPTER XXXVII

LOADING COAL INTO SHIPS OTHERWISE THAN BY TIPS

Coal shippers are now largely used, where formerly only coal tips or hoists were employed, and as an introduction to this chapter we cannot do better than give the following remarks, made by Mr R. T. Smith during the discussion on the paper on the Rothesay Dock read before the Institute of Mechanical Engineers in January 1911.

Mr Roger T. Smith, electrical engineer of the Great Western Railway, mentions the following five advantages of the belt conveyor over the tip for shipping coal :—

"1. That for the same capacity the initial cost of the conveyor was from one quarter to half that of a tip or a hoist.

"2. That the load factor at which the machine worked was 80 to 90 per cent., because the maximum load was the same as the average load.

"3. That there was a greatly reduced weight on the tower supporting the free end of the conveyor (which was adjustable) as compared with the weight of the hoist, thus lessening the cost of foundation or the cost of the jetty, if a jetty were necessary.

"4. There was a possible saving in land for sidings, because instead of all the sidings having to come end on, as was necessary for the tip or hoist, they were much better arranged parallel with the quay.

"5. There was an enormous reduction in the maximum demand on the power supplied."

It might, however, be mentioned that the quay space required for such loaders would prohibit their use on the Clyde and at some other ports.

The economy of coal loaders on this system depends principally on the life of the belt, and as good quality cotton and rubber belts can be obtained for a guaranteed delivery of 1,000,000 tons of coal, the cost per ton of coal shipped is infinitesimal as far as the wear of the band is concerned.

Mr R. T. Smith also gives the following comparisons of power consumed for different systems of coal tipping and shipping :—

Newport Hydraulic Hoist - -	·164	kilowatt-hour per ton of coal raised, 46 ft.
Rothesay Dock Electric Hoist -	·131	,, ,, ,, ,,
Fowey Electrically driven Conveyor (exclusive of tipping)	·095	,, ,, ,, ,,

Before, however, proceeding to describe more fully coal shippers in which a belt conveyor forms the principal feature, we will give details of one or two other methods.

Coal Loaders at the Japanese Port Miike.[1]—The quay of the new dock of the colliery at Miike, the property of the Mitsui Mining Co., is 460 yds. long, so

[1] The description and illustrations of these loaders are taken from an account by H. Nölke, in *Zeitschrift des Vereines aeutscher Ingenieure.*

that three large steamers can load at the same time. In close proximity to the quay wall is an area set aside for storing coal. This is shown in Fig. **840**, which represents a section through the general loading arrangement, which is as automatic and labour saving as it is possible to make it.

The coal is brought, after classification by standard gauge trucks holding 8 tons, from the five pits of the company; it is then either loaded immediately into steamers by two new loading devices or it is deposited on the storage heaps.

There are five elevated lines of rails serving these stores, with five tunnels under, so that, with the exception of a little trimming, the coal may be withdrawn at a great rate of speed, and with a minimum of labour. The tunnels are each nearly 200 yds. long, and the depôt will hold about 50,000 tons of coal.

The loading system is on similar lines to a modern blast-furnace hoist but portable. Fig. **841** shows a perspective drawing of one of these loaders. From Figs. **840** and **841** it will be apparent that the receiving ends of the loaders move along the quay in a trench, parallel to the quay wall, and this is widened into bays or pockets, separated by piers or walls from each other, over which two lines of rails are laid which feed the loaders, *i.e.*,

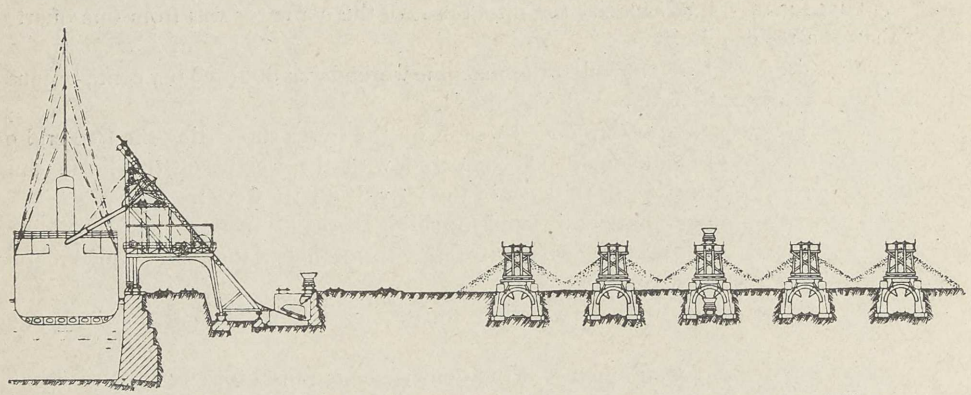

Fig. 840. Elevation showing Arrangement of Coal Store and Loader at Port Miike.

one for the full trucks nearest the coal store and the other for the empty trucks nearest the quay.

The loading apparatus with its details may best be seen from Figs. **842** and **843**, the former of which also shows one of the loading bays in section. Centrally in each bay is fixed what forms the lower terminal of the track of the loader, which latter is placed centrally with one of the bays. At the back of each bay is an adjustable hopper shoot, so that the contents of an 8-ton truck can be transferred instantaneously to the dumping skips *f* of the loader. The inclined plane of the structure forms an angle of 50° with the horizontal; it is provided with the rails *a a* and *b*, which are fixed to the structure, whilst a third pair of rails *c* is arranged in a telescopic manner, so that the rails with their upper or unloading terminals may be moved at will between the limits c_1 and c_2 in order to accommodate themselves to the tide and the size of the ship to be loaded. As soon as the loader has been moved centrally with the bay where the coal is to be loaded the rails are coupled up at *q*; the gauges of the three lines of rails are 13, 14, and 15 ft. respectively; the upper ends of the rails *c* are bent first in a horizontal, then in a vertical direction, as seen in the highest position at c_1. The dumping skip *f*, which is large and shallow, runs on two pairs of wheels, the foremost pair of which run on rails *b* and *c*, and have a flange in the centre, whilst the hindermost pair run on the outer rails *a*. In

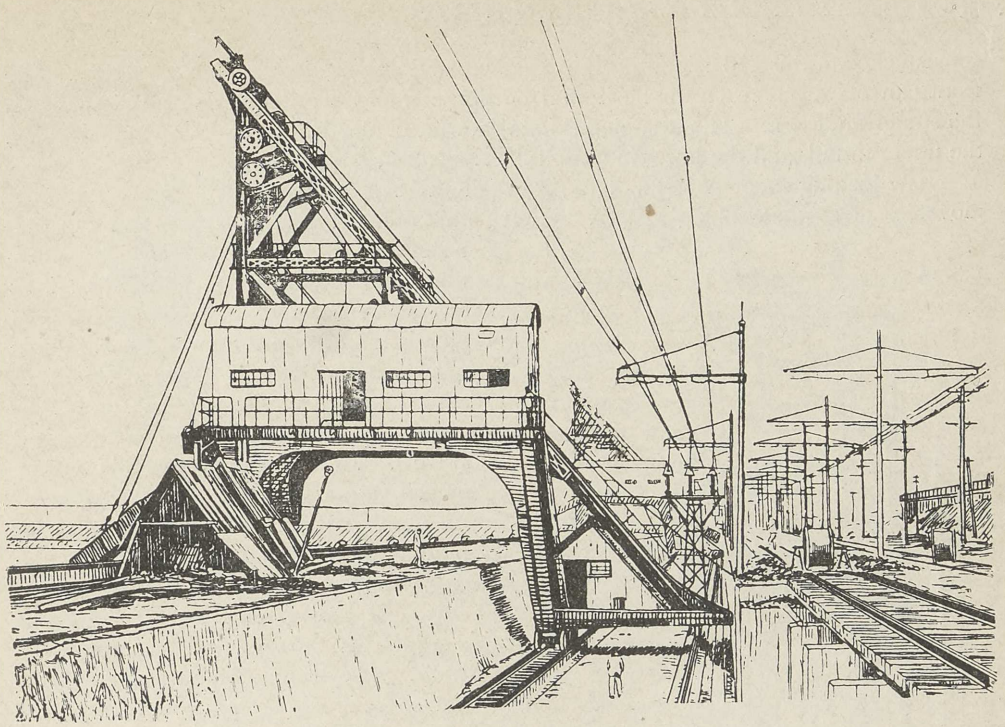

Fig. 841. Perspective View of Coal Loader at Port Miike.

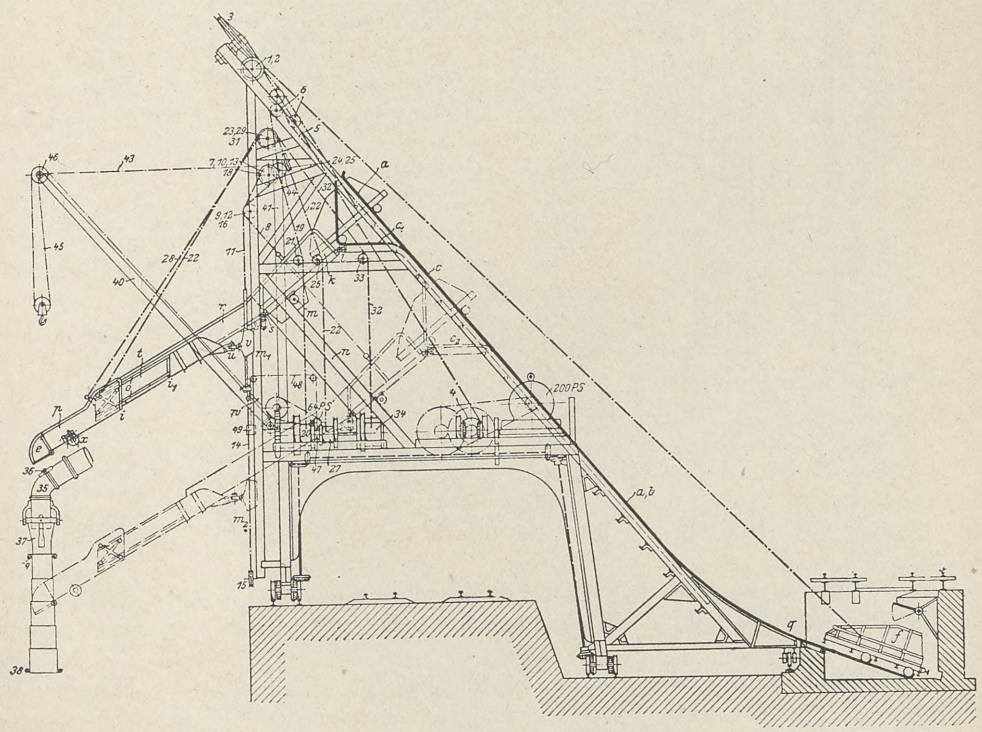

Fig. 842. Diagram of Coal Loader at Port Miike.

consequence of this provision, the skip tips over and empties its contents as soon as the front pair of wheels reach the horizontal portion of rails *c*, as the back wheels remain on the straight rails *a a*. The dumping skip is shown to unload in its two extreme positions, the upper in full, and the lower in dotted lines.

The loading shoot consists of the four parts *k*, *r*, *t*, and *p*, and its lower portion is movable as a whole along rail *w*, between the points m_1 and m_2, to allow of the necessary adjustment to suit all conditions for loading. The portion *p* allows of a telescopic movement between points *i* and i_1, on eight rollers and guide rails *o*, by means of hand wheel *x*, to alter the reach of the loading arm. Portion *r* of the shoot is movable round swivel *s*, whilst *t* and *p* may likewise be moved round joint *u*; these movements are more particularly for the purpose of getting the shoot out of the way of the ship's tackle when moving into position. Valve *e* at the extreme end of the shoot is adjustable to regulate the speed of delivery. The main portion of the shoot *k* is fixed at its upper end to rails *c* by joint *l*, and at the lower end is supported by the two wheels *m* running on rails *n*, which latter are parallel with rails *c*. Part *r* is hinged on to *k* by *s*. The upper end of portion *t* is hinged by *u* to the sliding blocks *v*. All adjustments of the loading shoot are such as to enable the operator to hold them in any position within their travel.

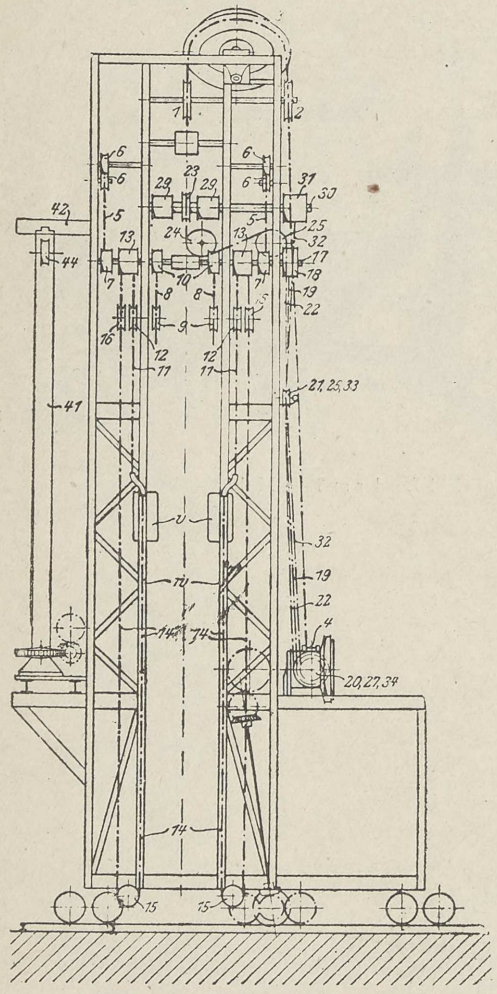

Fig. 843. End View of Fig. 842.

The hauling rope runs over guide rollers 1 and 2, and also over drum 3, and is fixed to the winding drum 4. The two ropes 5, which manipulate the rails *c*, run over rollers 6, and are fixed to the drums 7; whilst the ropes 8, for raising and lowering the main portion of the shoot, run over rollers 9 to drums 10. The sliding blocks *v* are likewise joined to their ropes 11, run over rollers 12, and to their drums 13; whilst a second pair of ropes 14 proceed from the lower portion of *v* over pulleys 15 and 16, also to drum 13.

The three pairs of drums 7, 10, and 13 are all on spindle 17, to the outside end of which is fixed a further drum 18, which receives motion for the shaft by rope 19 from drum 20 over guide 21.

The lower end of the shoot portion *r* is manipulated by rope 22 running over guide rollers 23, 24, 25, 26, and drum 27. In a similar manner is shoot portion *t* manipulated

by ropes 28 and drum 29. Spindle 30 carries the drums 29 and 31, and from the latter rope 32 leads over guide 33 to drum 34.

It will thus be seen that all the movements of the rails *c*, the main portion *k* of the shoot, and the sliding block *v*, are manipulated from the same spindle and move therefore together. Minor adjustments can be made in the incline of the lower end of the shoot by the ratchet and tooth rack couplings (Fig. **844**), which are inserted between the ropes 11 and 14, manipulating the sliding block *v*.

After the loader had been at work for several months, an anti-breakage device was added in place of section *p*; it consists of joint 36 and bend 35, which is connected by a universal joint to the upper end of a telescopic shoot. The utility and the object of this addition are obvious; when the telescopic shoot is not required the extreme ends 38 and 39 may be fastened together by the rings shown, or the whole may be raised round joint 36 by the crane 40.

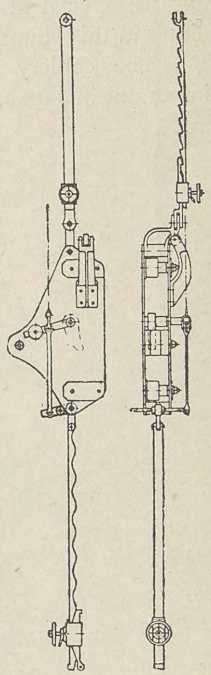

Fig. 844. Details of Coupling for Adjusting Shoot of Port Miike Loader.

The motive power for these loaders consists of two electrically driven winches of 200 H.P. and 64 H.P. respectively, which are situated in the engine-house seen in Fig. **841**. Direct current is used of 500 volts. The speed of the skips is about 3 ft. per second, so that the raising and emptying of the load and the return of the empty skips will take one minute, thus the whole cycle of loading operations gives a theoretical capacity of 480 tons per hour for each loader, each charge being 8 tons, but as a few seconds are lost for filling the skips, the actual average capacity is 5,000 tons per day of twelve hours, or say 416 tons per hour.

Fig. **845** is interesting, as it gives a view of the two loaders during their erection; it took forty-seven days to erect the first, and forty-two days for the second.

The principal advantage of this loading system over that of the usual coal tips, in which the railway truck is raised bodily and emptied, is saving of time, as none of the tips accomplish the whole cycle of operations in so short a time. It is true that some tips have a much larger capacity, but the reason for that is, that much larger loads are handled with each operation, some of the trucks raised and emptied holding up to 50 tons of coal.

With the ordinary coal tip so much time is lost in moving the trucks to be emptied on to and off the cradle, whilst in the loading machines at Miike time is saved in this way, because as soon as one skip is filled with the contents of a truck, the skip ascends, and before it is returned empty, the next truck is ready to tip its load into it. In order to construct a loader of a larger capacity it would only be necessary to provide an installation with a larger skip, as the time occupied by the cycle of operations would be practically the same for a larger load. The disadvantage of the loader is, however, one which varies with the quality of the coal, and may be so great as to more than outweigh its advantages by the breakage of the coal. With ordinary tips, some breakage is unavoidable, and is caused during the tipping of the truck, by the abrasion of the coal, and by the impact between the coal and the lowering shoot; we need not consider the damage caused in the shoot proper, as similar conditions will obtain with both types, provided the shoots are suitable. Now, with the loader under consideration the breakage should, therefore, be about the same at the dumping point if loads of the same bulk are handled;

or if anything the advantage will be with the loader, as the emptying of a shallow skip should injure the coal less than that out of a rectangular truck, because there is less drop and the thickness of the layer of coal is likewise less. Be this as it may, the greater part of the breakage caused in the transferring of the coal from the railway trucks to the skips will be additional, as we may be justified in making an allowance for a little less breakage at the top of the loader. Now, this may be a serious matter if tender coal has to be handled, and yet with some coal it may be of so little consequence that the first named advantages of the loader more than balance the extra breakage.

The port of Miike, at which the above described coal-loading installations are now at work, is the most important centre of the Japanese coal industry. These devices deserve special attention, as they differ so much from the appliances generally used either in this country or in Europe or America.

The colliery of Miike, the property of the Mitsui Mining Co., is the most important in Japan, with a daily output of 5,000 tons; and as the old harbour was only

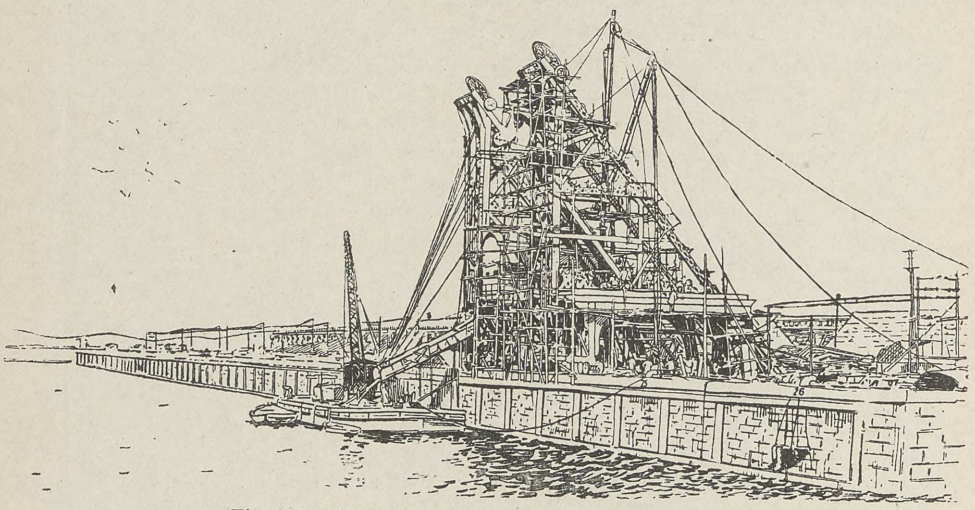

Fig. 845. View of Port Miike Loaders during Erection.

accessible to sailing ships, the company extended and modernised the harbour at a cost of 5,000,000 yen, or over half a million sterling, so that now large steamers can load there, whereas of old the coal had to be transhipped at Kuschinotzu, a distance of over 50 miles, from sailing ships to steamers.

The general scheme is the design of Director Dan, and chief engineer Kuroda, of the Mitsui Colliery Co., and the loaders were built by Head, Wrightson, & Co., Ltd.

The Wrightson Coal Shipper.[1]—The illustration, Fig. 846, represents a device erected at the staiths of the Cramlington Coal Co., in the Northumberland Dock on the Tyne. It was designed by Sir Thomas Wrightson, M.Inst.C.E., in conjunction with Mr Morrison, manager of the Cramlington Co., and was erected by Messrs Head, Wrightson, & Co., Ltd., of Stockton-on-Tees.

The coal is in this case brought in at a high level and discharged into the hopper immediately above the level of the first conveyor. At the lower end of the hopper a door of sufficiently large dimensions to allow the largest pieces of coal to pass, permits

[1] *The Engineer*, 6th and 13th August 1897; and *Iron and Coal Trades' Review*, 3rd May 1901.

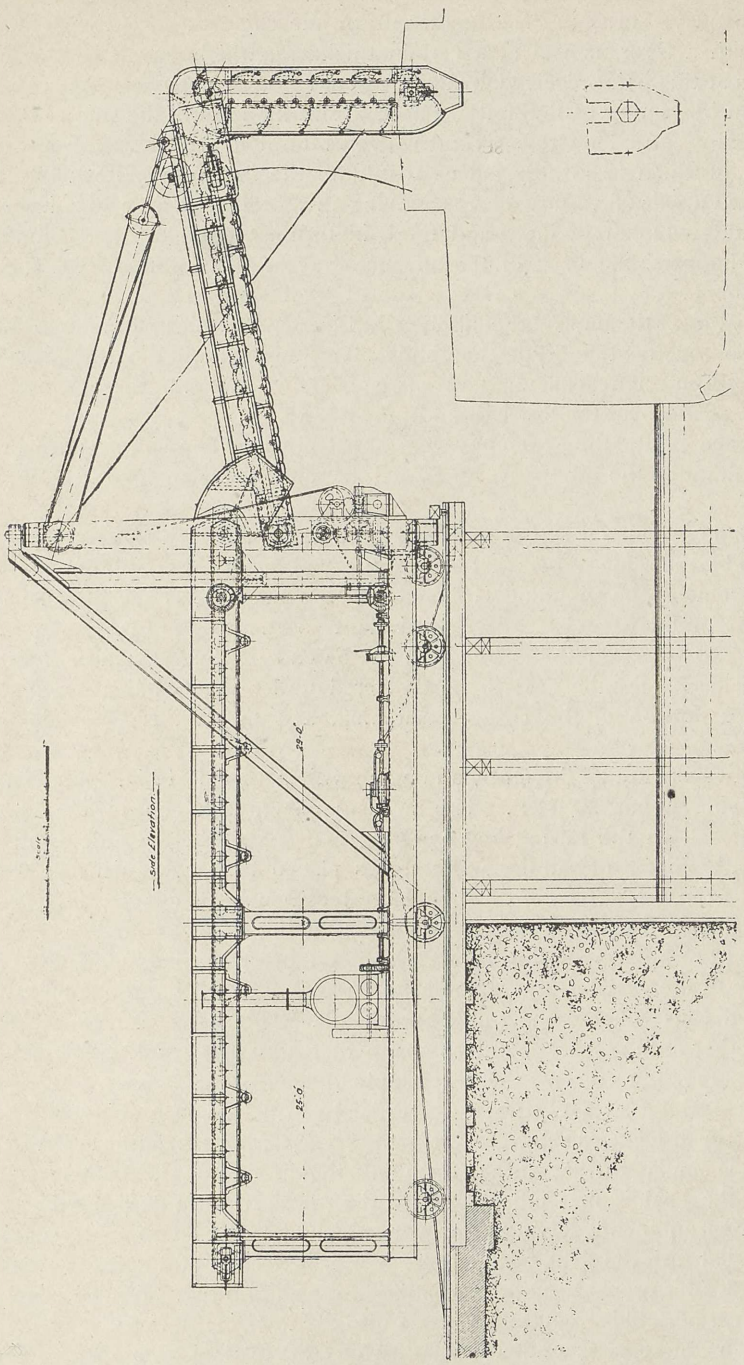

Fig. 846. The Wrightson Coal Shipper.

the coal to run out on to the inclined conveyor. This conveyor, in moving forward towards the quay, draws the coal gently down the slope through the door, filling the conveyor with a layer of coal of a certain thickness, which travels to the edge of the quay. It is at this point received by another conveyor mounted on a jib, the outer end of which can by gearing be lowered or raised to suit the level of the ship to be loaded.

The coal is carried on this second conveyor until it arrives at the end of the jib, the position of which is so adjusted as to plumb the hatchway. At the end of the jib are suspended a pair of vertical chains moving in a trunk; these chains have large trays upon each alternate pair of links, and these in turning round the top drum form themselves into hoppers, the back of the advance tray and the front of the following tray forming a hopper.

The coal from the end of the jib belt is directed into this naturally formed hopper. As the trays clear the top drum, they slide at an angle down the trunk, the coal being gently lowered until it reaches the level of the coal in the hold, where it discharges itself as the chain passes over the lower drum of the device.

The speed of the different conveyors is as follows: The shore conveyor travels at 40 ft. per minute, the jib conveyor at 60 ft., and the hanging conveyor at 52 ft. per minute.

The whole machine is self-contained upon a platform which can be moved backward and forward by the same power that drives the conveyors. In addition to this loading of the coal, some of the trimming is effected by the machine, as the jib is so arranged as to slew right and left over a space equivalent to the length of the hatchway. The vertical trunk, being upon the swivel joint at the end of the jib, can be deflected into a position which enables the coal to be delivered under the coamings of the hatchway, thus saving a portion of the cost of trimming, and the further breakage involved in that operation.

The conveyors are all driven by an engine with a pair of 10-in. cylinders, the power expended being about 20 H.P. The man in charge can control the speed of the conveyors as well as the raising and lowering of the jib, and the racking in and out of the platform, by means of handles and clutches placed in a convenient position. As an alternative to the retarding conveyor, a large rectangular or circular box or trunk can be suspended from the jib to receive the coal from the second conveyor. A large valve is arranged at the bottom of this trunk, which, on being opened, allows the coal to flow into the hold of the vessel at the same speed as that at which the top is being filled from the conveyor, thus keeping the trunk always full. This valve can be controlled by a cataract or other form of brake, and so made that after the trunk is emptied the valve rises to the top ready to receive the next supply of coal.

Coal Loaders at Grimsby.—In order to load coal into ships with a minimum of breakage, the appliances shown in diagram, Fig. 847, have been installed at Grimsby. This loader is similar to that in the Northumberland Dock on the Tyne (see above), but at Grimsby the coal is first unloaded from the trucks by a tip discharged at the level of the rails on to an inclined band conveyor, which delivers on to a Marcus conveyor *b* running parallel with the dock wall and capable of delivering at a number of points under the portable loader proper to suit the position of the ship's hold. A steel plate conveyor *c* supported by a portable structure *a* delivers into the lowering device *d*.

Although the coal is undoubtedly carefully handled by this device, considerable damage must be done to it by transferring it from the truck to the band, from this to the Marcus conveyor, and then again from this to the lowering device. There are two such installations with a capacity of 1,000 to 1,200 tons per hour each.

The Loading of Coal on the Humber.—In order to cope with the increased trade created partly by the development in the South Yorkshire coal field, the Hull and Barnsley Railway Co. have erected and put into use upon the western portion of their new pier at the Alexandra Docks, Hull, two electrically driven coal conveyors, by means of which coal is being shipped at the rate of 600 tons per hour over each conveyor, the total being 1,200 tons when the two appliances combine their efforts on the same steamer. They have since added a third conveyor of the same capacity.

The question of breakage of coal has for a long time engaged the attention of the exporters, and in this connection consideration has been paid by the above named railway company to the necessity of reducing breakage to the lowest possible minimum, and the design of these new conveyors is calculated to achieve this end.

The loaded wagons gravitate to a turntable, then to a hydraulic tip, and the coal when tipped slides out of the wagon into a hopper, and on to an inclined rubber belt

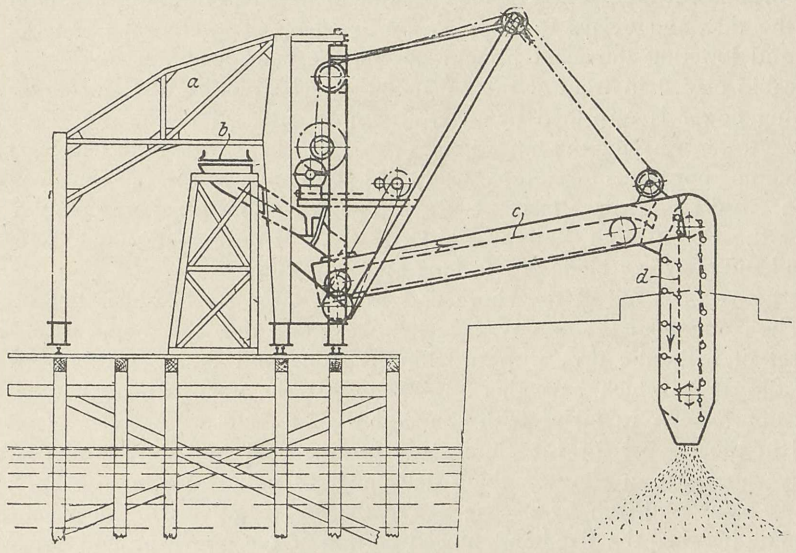

Fig. 847. Coal Loader at Grimsby.

placed beneath this hopper, which immediately conveys the coal to an adjustable telescopic shoot which is capable of reaching the coamings of the ship's hatchways, and is provided with a lateral shoot to reduce trimming. The empty wagon passes over the turntable and thence to the empty sidings to make room for the next loaded wagon, which follows immediately in its wake. The conveyors manufactured by Spencer & Co., Ltd., to the requirements of Mr R. Pawley, the engineer of the Hull and Barnsley Railway, are similar in design with the exception of the difference of a few feet in length. Each apparatus consists of an endless band conveyor 42 in. wide, and approximately 475 ft. long, running at a speed of 400 ft. per minute, and fed by a tipping gear and hopper, at the shore end, delivering the coal at the water side by a system of adjustable jib and steel shoots.

In order to obtain the advantage of an entirely unobstructed area at the top of the receiving hopper, the rail girders along the top, instead of being fixtures, are carried by substantial brackets from longitudinal fulcrums, and are carefully balanced, so that by means of a series of levers connected with the hydraulic ram, these girders swing outwards

just previously to the tipping of the truck. In order to further avoid the breakage of coal, a steel tipping plate or apron is provided at the hinged end of the cradle, which rises from the top level of the hopper to the height of the wagon floor. A continuous surface is thus formed down which the coal may slide gently into the hopper.

The troughed band conveyor receives a continuous feed from this main hopper by means of an adjustable gate actuated by hand wheel and gear. The outward end of the conveyor is carried by a hinged and balanced jib, giving ample vertical play. The shoot at the main jib end is telescopic and capable of a radial motion, extending 15° on either side of the centre line, whilst the further end of this shoot is provided with a second radial shoot, having circular ball bearings, and enabling delivery in the vessel's hold to be made over a complete circle if required. The luffing movement of this second shoot and telescoping of the first shoot are performed by hand through chains, chain wheels, and worm gear. It will thus be noted that not only is a gentle delivery of the coal ensured by these means, but the plant is thereby capable of loading out to any size of craft at any state of the tide, and delays to shipping are avoided. The control of the winches for hoisting and lowering the main jib and slewing the main shoot, is conducted from the driver's cabin placed in front of the substantial steel structure at the end of the jetty. The driving power is furnished by an electro-motor situated in the motor-house at the base of the tower, carrying the hinged end of the jib; here also is the necessary gear and drop tightening apparatus for automatically taking up any slack in the conveyor band.

The Coal-Loading Plant at Port Talbot.—This plant was built by Spencer & Co. for the Port Talbot Railway and Dock Co. It deals with 700 tons of coal per hour, the band conveyor being 207 ft. long by 42 in. wide.

The conveyor is fed at the shore end from a large steel hopper beneath the rail level. The contents of the railway wagons are emptied into this hopper by means of a double set of hydraulic tips, with two hinged rising and falling platforms working in opposite directions, which have this advantage, that the wagons need not be turned if they do not happen to arrive with the end door foremost. A series of gratings are provided in the hopper for the elimination of fine coal and dust, which is taken by subsidiary shoots to an elevator which delivers it to railway wagons on another set of rails. The plant is driven by electric power, the motor and driving gear being situated in a building between the fixed and hinged portion of the conveyor, and the loading-out operations are controlled from the driver's cabin erected above the steel structure upon the edge of the quay.

Coal-Shipping Plant at Port Talbot Docks for the Port Talbot Railway and Dock Co.—This plant was supplied by Fraser & Chalmers to the Port Talbot Railway and Dock Co., and comprises a travelling and a stationary installation. The travelling one consists of an underground hopper receiving the coal from an electrically driven tip from end-door wagons on to an inclined belt conveyor, which later delivers on to two similar, but horizontal, conveyors, running parallel with the quay front, each fitted with a travelling tripper arranged to deliver the coal on to the belt of the travelling tower, which in turn delivers to the boat by means of a shoot. The stationary plant consists also of an underground hopper and an electrically driven tip delivering on to an inclined belt which feeds direct into the boats, the outer end of the conveyor being hinged, which gives a range of delivery similar to the other one, viz., from the water level to a height of 60 ft. above; both conveyors may therefore be used for loading all sizes of boats. The capacity of each plant is 1,000 tons per hour. The travelling plant is illustrated in Fig. 848.

The Coal Shipper at Middlesbrough.—An installation of the North-Eastern

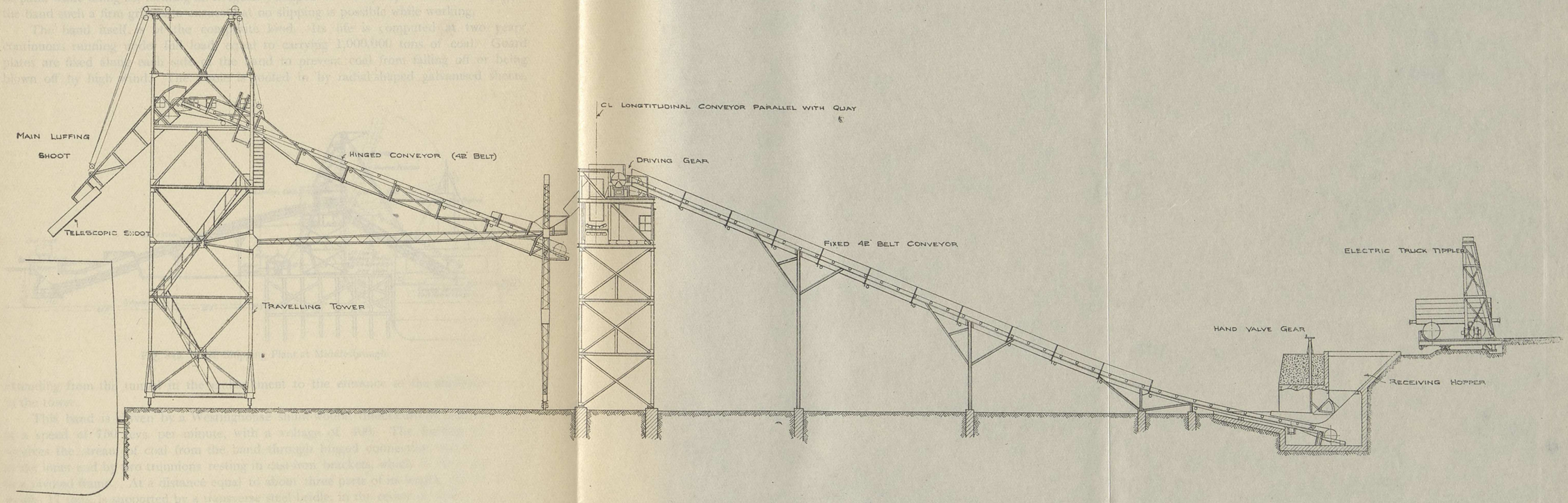

Fig. 848. Coal Shipping Plant at the Port Talbot Docks for the Port Talbot Railway and Dock Company.

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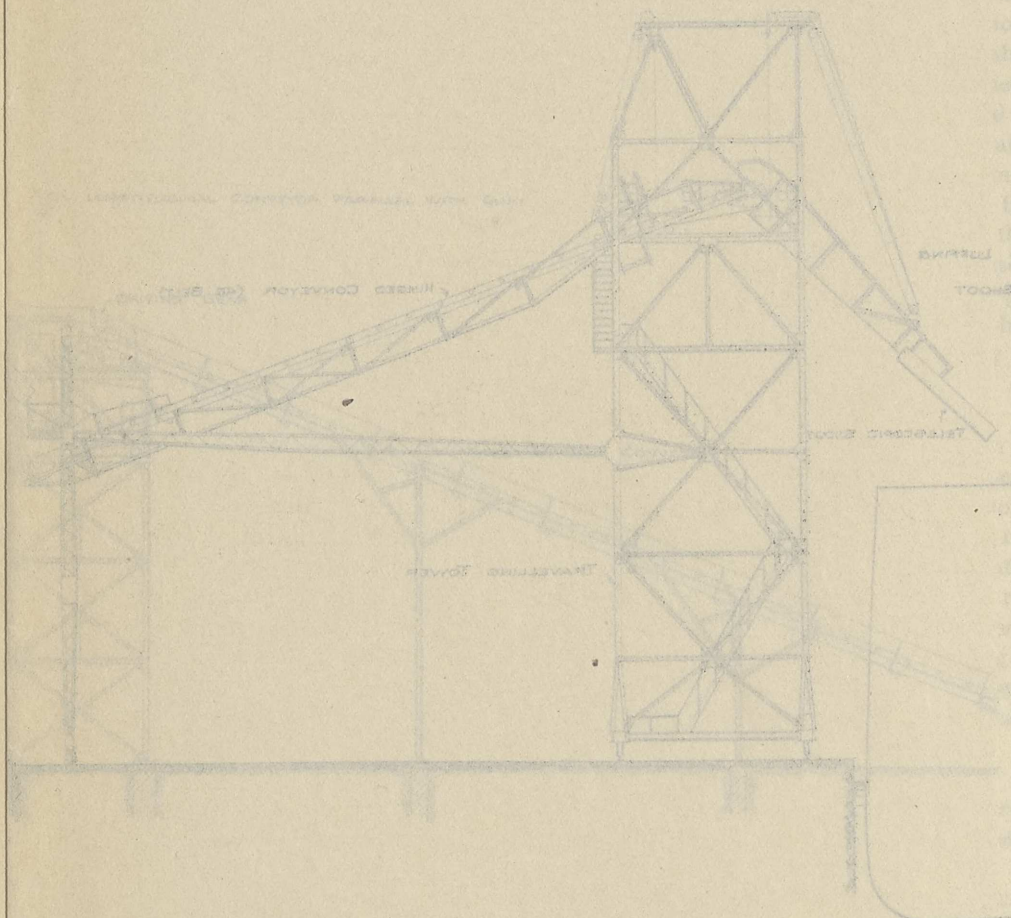


Railway Co. is illustrated in Fig. 849. The coal-carrying band is 42 in. wide and 310 ft. long, travelling up an incline of about 20°; it has a capacity of about 30 tons of coal, and is fed from a hopper in the embankment under the railway line. The feed on to the band is regulated as in similar previously described installations.

The belt is kept clean by a revolving brush, in length equal to the breadth of the band, which is placed in contact with the band immediately the stream of coal has been delivered. The band now brushed clean assumes the flat shape as usual on the returning bottom side, and soon after leaving the brush it is led over two large drums, its path, while doing so, forming an irregularly shaped S. The object of this is to give the band such a firm grip as to ensure that no slipping is possible while working.

The band itself is of the composite kind. Its life is computed at two years' continuous running under full load, equal to carrying 1,000,000 tons of coal. Guard plates are fixed along each side of the band to prevent coal from falling off or being blown off by high wind. The whole is roofed in by radial-shaped galvanised sheets,

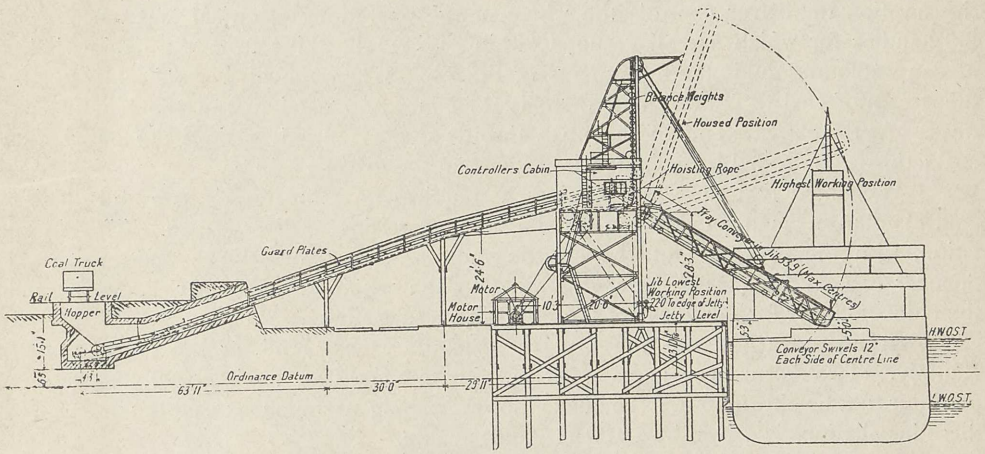


Fig. 849. Coal-Shipping Plant at Middlesbrough.

extending from the tunnel in the embankment to the entrance to the machinery room in the tower.

This band is driven by a Westinghouse shunt-wound direct-current motor running at a speed of 750 revs. per minute, with a voltage of 400. The loading jib which receives the stream of coal from the band through hinged connecting shoots is borne at the inner end by two trunnions resting in cast-iron brackets, which in turn are bolted to a pivoted frame. At a distance equal to about three parts of its length, the jib, which weighs 17 tons, is supported by a transverse steel bridle, in the centre of which is carried a cast-iron sheave. Through this sheave is rove the hoisting wire rope, which is led up to a set of sheaves in the bonnet or topmost structure, and is thence taken downward and attached to the cast-iron hoist drum. This drum shaft also carries a worm, which gears with the worm wheel on to which the hoist motor is directly connected. The motor is a Siemens' series-wound machine of 10 B.H.P., running at a speed of 550 revs. per minute. The bridle also carries two stout wire ropes, attached one on each side of the sheave, which are led up to the bonnet in the same way as the hoisting rope, and which, after passing round sets of guide sheaves, have each a line of twenty-two counter-balance weights attached.

In the process of hoisting the jib the weights are automatically passed over one by one from the direct line of counterpoise to the line of the dead end by which they are supported. As the hoisting proceeds and the weights are taken up by the dead end, the line of weights on each side of the structure gradually assume the U-shape or festoon form, until, when the jib is housed and almost perpendicular, only two weights a side remain in direct counterbalance. Thus at whatever point in the arc described during the travel of the jib there is always the correct number of weights in direct counterbalance, the others being suspended from the dead end. The jib has also a lateral travel of 12° each side of the centre line allowed for by the pivoted frame and limited by an ingenious arrangement of wire guy ropes. This is necessary to meet the fore and aft ranging of the ship taking in the cargo or bunker coal.

The highest position of the jib at which coal can be shipped is 18° above the horizontal. The coal is conveyed by means of an endless belt of steel plates or trays running the whole length of the jib, 54 ft. centres, driven through a friction clutch on the main shaft in the tower and operated from the driver's cabin in the structure. From this position the driver controls the whole of the operations, electrical and mechanical, the handles for which are all grouped within easy reach, whilst from the cabin window he can watch and guide the movements of the jib. When the jib is sufficiently low for the stream of coal to fall down it, there is, of course, no need to run the belt of steel trays. At the extreme end of the jib a throttle door is fitted to limit the opening for coal; this is controlled by a single wire rope from the driver's cabin.

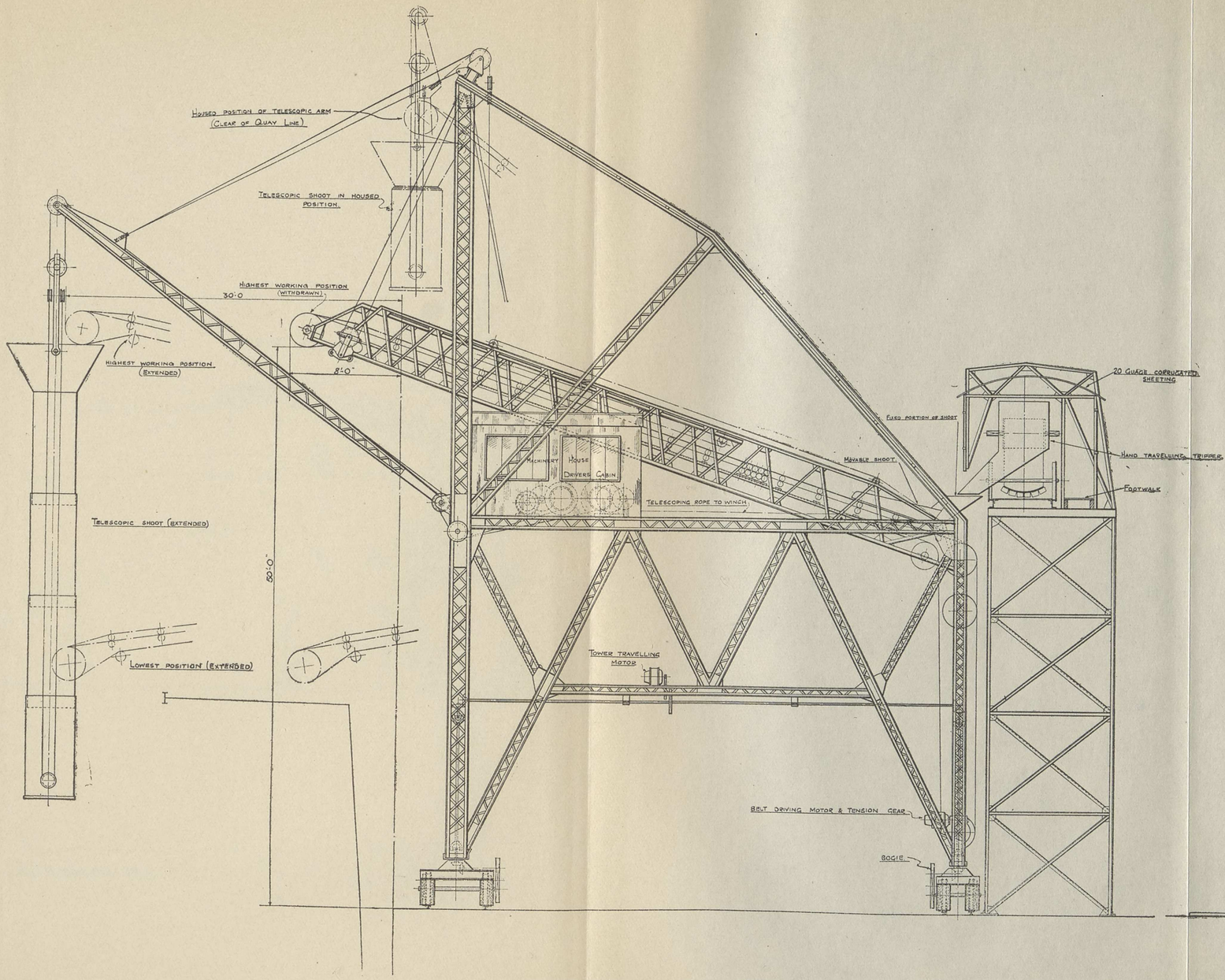
It is claimed that the whole equipment requires no more for its safe and efficient control than a man of average intelligence exercising ordinary care. The installation, with the exception of the electric motors, was manufactured and erected by Spencer & Co., Ltd., Melksham, according to the requirements of Mr T. M. Newell, the chief engineer for the docks of the North-Eastern Railway.

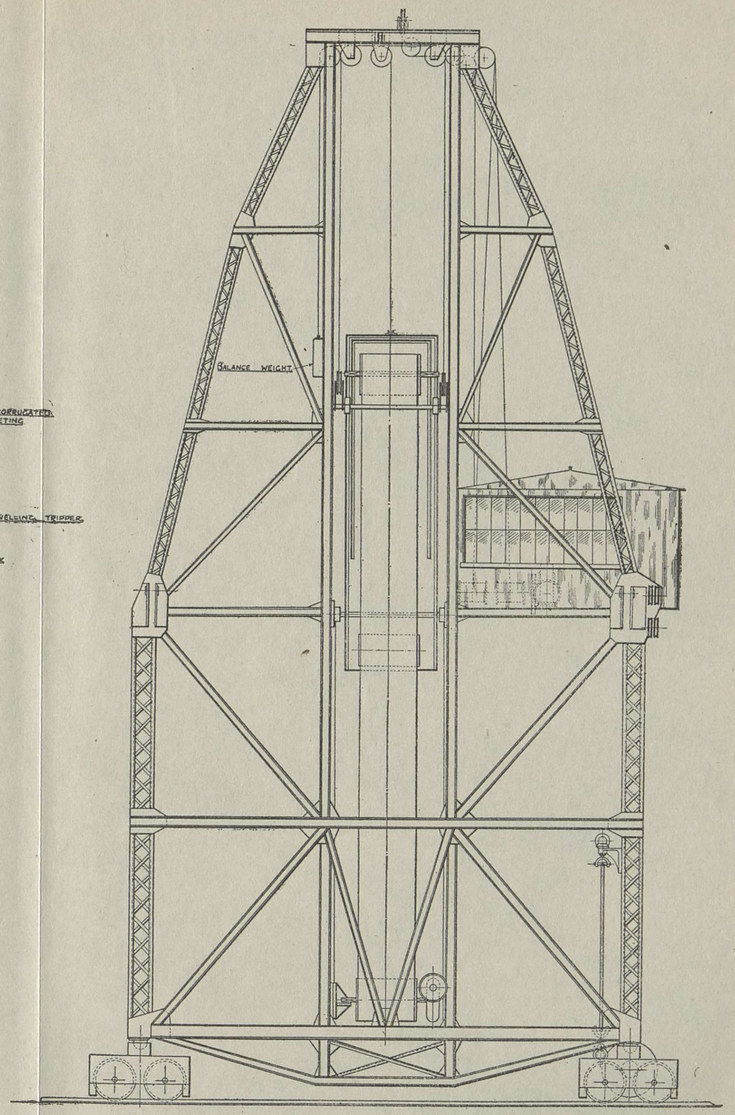
Other examples are those at the Victoria Dock, Hull, of the North-Eastern Railway. Two belt conveyors, each 42 in. wide, are used for loading 600 tons of coal per hour to a height of 40 ft.; they have, however, done as much as 750 tons. Each of these installations is driven by a 100 H.P. gas engine.

At Hartlepool on the staith between the old harbour and the Victoria Dock are eight similar belt conveyors for loading coal, also handling 600 tons, with a maximum of 750 tons per hour; in this case only a 25 H.P. motor has been provided for each.

On the Tyne at the Albert Edward Dock several similar belt conveyors are installed, while at their Tyne Dock the North-Eastern Railway have five; these latter being the first to be used for shipping coal. They are also used at Blyth, while at Whitehaven a belt conveyor shipper has recently been erected for loading 500 to 600 tons of coal per hour, and this is fitted with the latest form of anti-breakage device consisting of a spiral shoot, resembling a spiral staircase, for the coal to slide down, which terminates in a revolving shoot at the bottom end for distributing the coal and thus saving trimming.

Coal-Shipping Plant at Durban for the South African Railways.—This important plant is one of the latest designs for loading coal from trucks into steamers. It consists of a M'Myler Car Dumper or Tip capable of handling 75-ton trucks at the rate of fifty trucks per hour. This tip delivers the coal either to a belt conveyor or to a series of railway trucks with bottom door discharge which are handled by an existing transporter. The belt conveyor which receives the coal is fixed on an inclined gantry and conveys, elevates and discharges on to one of two belt conveyors which run parallel to the quay wall. Each of these conveyors is provided with a travelling throw-off carriage or tripper which can discharge the coal at any point along the quay. The





Figs. 850 and 851. Coal Shipping Plant at Durban for the South African Railways.

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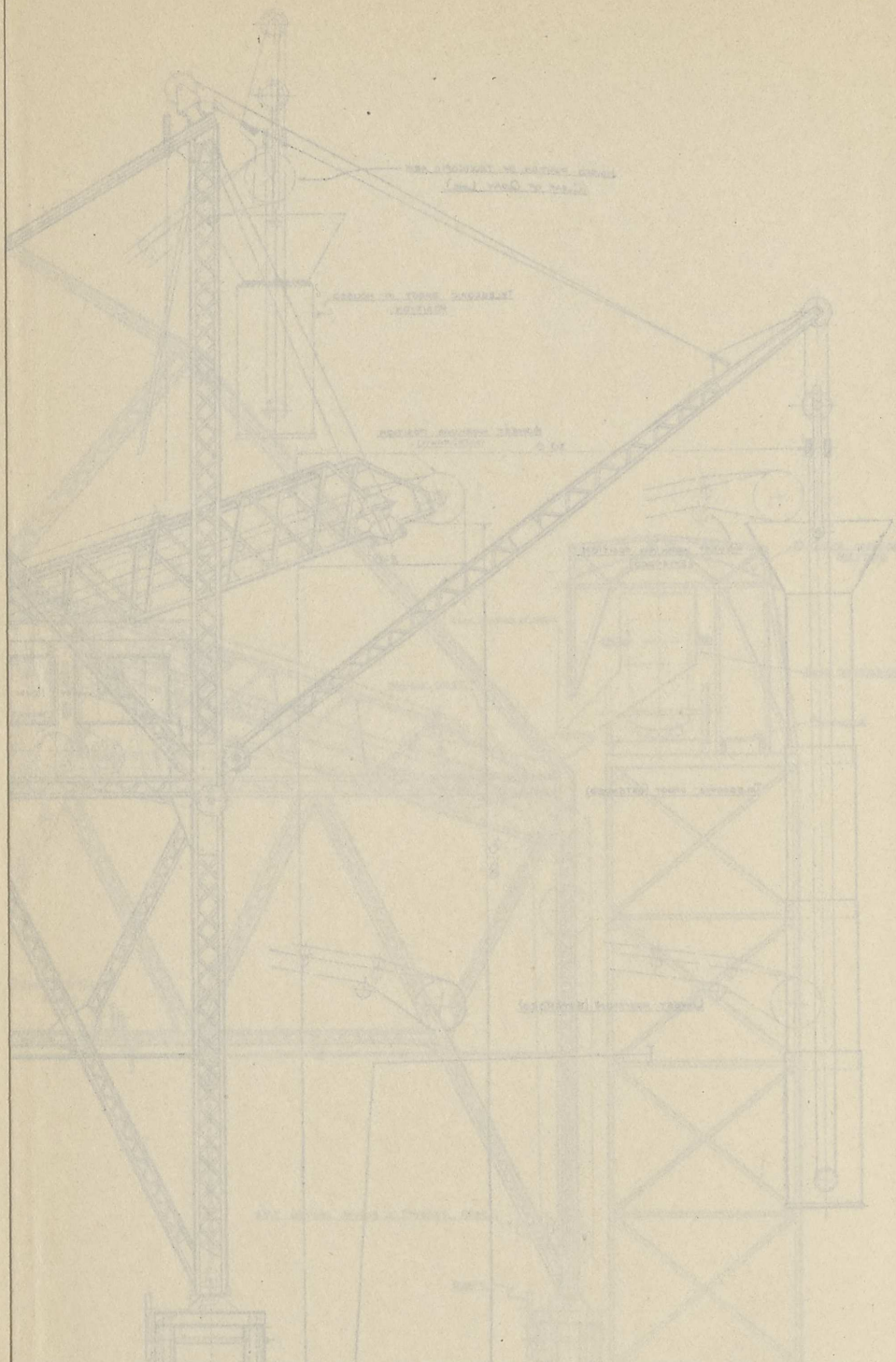

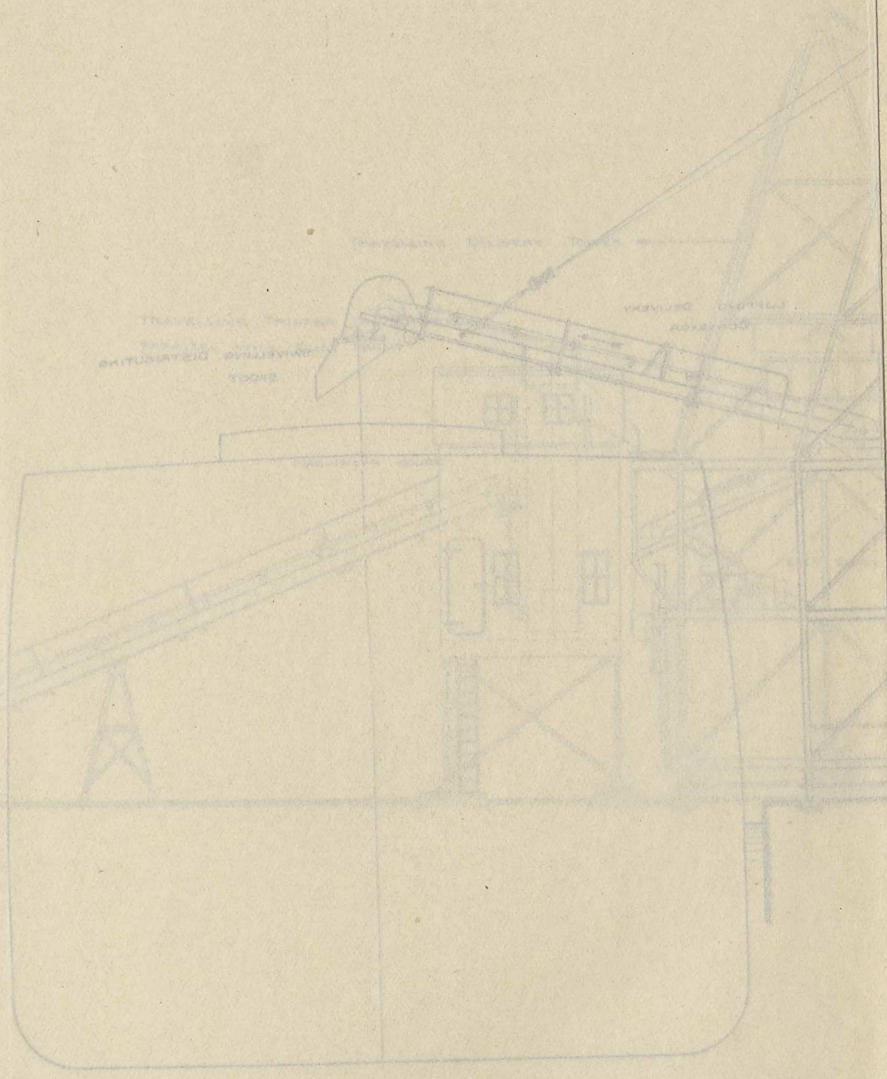

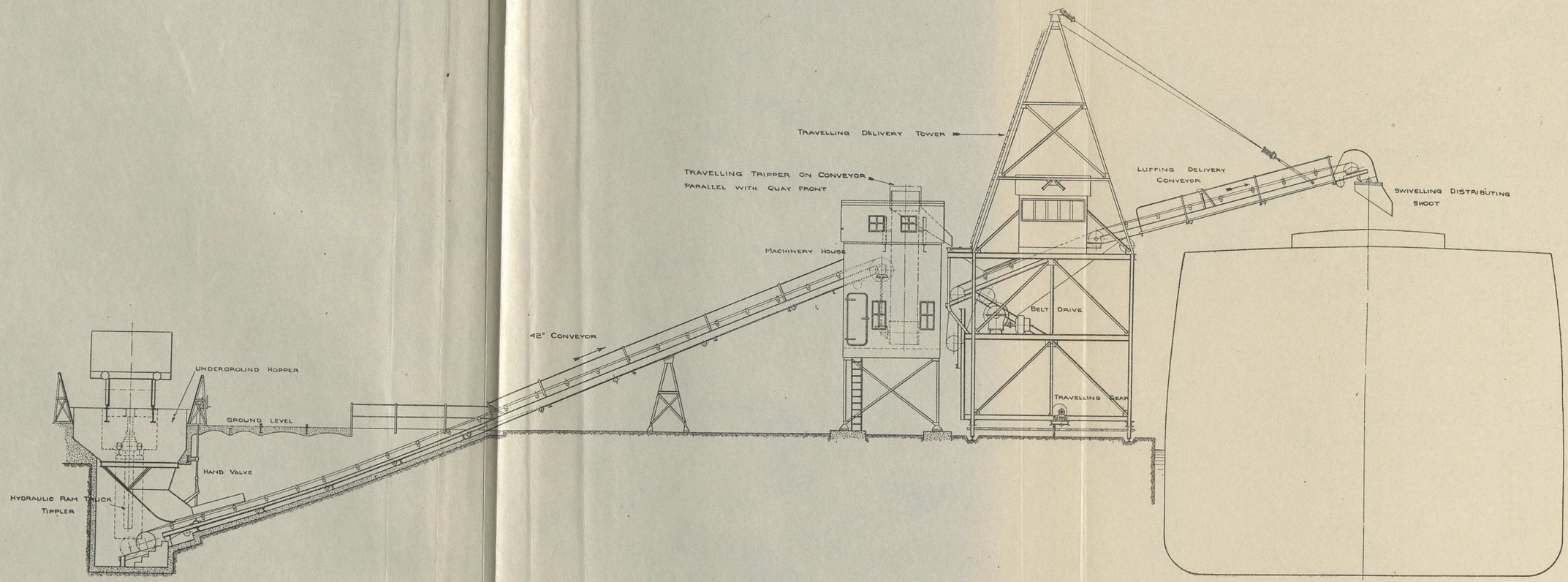

Fig. 852. Coal Shipping Plant at the Kidderpur Dock, for the Commissioners of the Port of Calcutta.

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inclined conveyor is fitted with a Merrick Weightometer[1] for the purpose of accurately weighing the coal passing over the same.

The travelling tripper on the quay conveyors delivers the coal to the receiving hopper of a telescopic conveyor carried on a travelling tower (see Figs. **850** and **851**). As will be seen from the illustrations, the conveyor with its tower has a very wide range of operation. It is capable of discharging coal at any height up to a maximum of 50 ft. above the quay level or a total height of 60 ft. above the water line. It can also be adapted to deliver at a distance varying from 8 to 30 ft. from the edge of the quay wall so that any size boat calling at the port can be coaled by this installation.

The great flexibility, which is a special feature of these loaders, is obtained by the very simple arrangement of making them both hinged and telescopic, so that by a combination of these two facilities the discharging terminal can be placed in any position required within the limits mentioned.

A telescopic anti-breakage lowering device is also provided which can be used either during the preliminary part or during the whole of the loading operation. The shoot is lowered into the hold of the vessel until the lower end reaches the bottom; the coal is then fed in at the top until the telescopic shoot is full, when it is gradually raised to allow the coal in the shoot to pass out at the same rate as it is fed in at the top by the conveyor. In this way the coal can be lowered into the ship without a drop, and breakage is thus obviated. The plant has been so designed throughout as to handle the coal gently, with considerable success, and at no point of its transit has the coal a direct fall.

The guaranteed capacity of the plant is 700 tons per hour, but the actual capacity is over 1,000 tons per hour. The installation was supplied by Fraser & Chalmers, Ltd.

Coal-Shipping Plant at the Kidderpur Dock, for the Commissioners of the Port of Calcutta.—Two separate plants have here been installed, each as per Fig. **852**. They consist of an underground hopper fitted with a hydraulic tip to unload the railway trucks. These hoppers feed the coal on to an inclined belt conveyor which in turn feeds a horizontal conveyor running parallel with the quay front, from which the coal is discharged by means of a tripper to a third or loading conveyor mounted upon a travelling tower.

The plant is arranged to feed coal to the holds of two vessels lying at two berths without moving them, thus considerable time is saved from the beginning to the end of the loading operations. The capacity of the plant is 500 tons per hour, and it was built by Fraser & Chalmers, Ltd.

Wall's System of Coal Loading.[2]—Mr Samuel M. Robins, superintendent of the New Vancouver Coal Co., Nanaimo, B.C., when facing the difficulties incidental to an antiquated system of end-on wharves (relics of the Hudson's Bay Co., the original owners of the mines), from which he had to feed a fleet of steam colliers of 4,000 to 6,000 tons burden, engaged in carrying steam and household coal to San Francisco and the southern parts of California, was impelled to install a more modern system of coal handling.

Mr Robins utilised the wharves by heightening and increasing the approaches, and erecting bunkers of great capacity close to the point of loading, thus preparing the way for Mr Wall's apparatus, which was commended by the Minister of Mines of British Columbia.

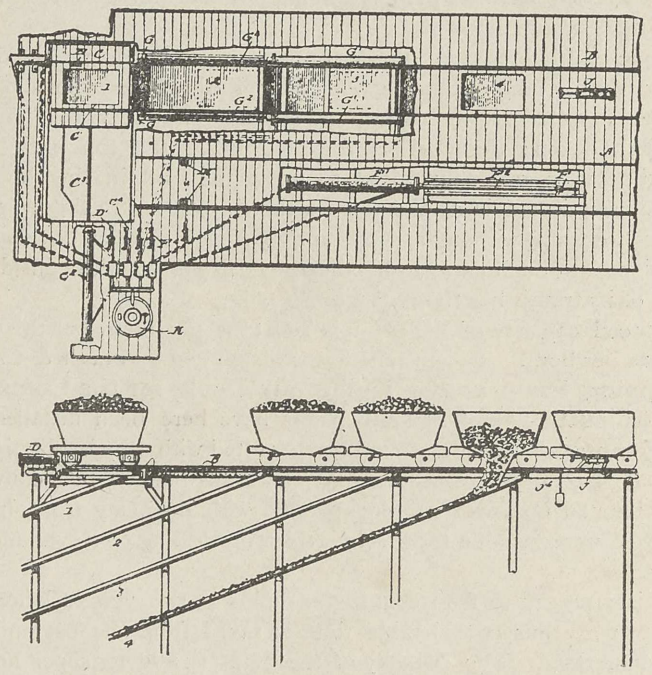
The depth of the water at the docks is such that any vessel can lie safely alongside.

[1] The Merrick Weightometer is described on page 720.

[2] *The Iron and Coal Trades' Review*, 24th November 1899.

The bunker capacity at and near the docks has been so extended as to be capable of holding a very large reserve stock. The company's engineer, Mr W. H. Wall, has designed and erected an ingenious loading apparatus at these docks which is worked by steam power, and which has greatly facilitated rapid loading. The speed at which a vessel may be loaded is only limited by the time required for trimming the cargo in the hold of the vessel. One of the company's steamers, the "Titania," plying between Nanaimo and San Francisco, having suitable hatches, takes her full cargo and bunker coal, amounting to 6,000 tons, in twelve hours.

The coal-laden hopper wagons or trucks, each containing 5 to 6 tons of coal, are hauled from the bunkers to the approaches of the loading shoot by a 40-ton locomotive, each train containing twenty wagons. They are there left for dumping without further



Figs. 853 and 854. Plan and Elevation of Wall's Coal-Loading Device.

aid from the locomotive in shunting, etc., the locomotive being fully occupied in hauling empty and full trains to and from the bunkers and the mines.

In Figs. **853** and **854** may be seen the double tracks A and B, which serve each of the sets of loading shoots along the supply track A. The train of laden trucks is drawn by a grip dog to within one truck length of the end, where it is held in check by a safety stop which prevents the truck coming along the supply track until the carriage C is in a position to receive a truck. The dog then draws the end truck on to a transferring carriage (which is mounted on trolley wheels running on a transverse track), is pushed across the trackway until it registers with the parallel dumping track B, and unless unloaded into the first or highest shoot through the opening in the carriage, the truck is pushed by a piston rod on to the dumping track, as far as the shoot opening into which its contents are to be dumped (suitable to the height of the water, see Fig. **855**). When emptied, the truck is taken hold of by the double dogs situated on either side

of the track (so as not to interfere with the shoot openings), and pushed along the dumping track, over the automatic lifter J, which secures the trap door of the truck when it is passed along to form a train of empties. In the meantime the transfer carriage has been drawn back by the piston rod C^3 (attached to it and forcing it in both directions) till it registers with the supply track. The grip dog draws the train of loaded trucks one truck length towards the end, and then forces a loaded truck on to the carriage, which transfers it to the dumping track as before described, the whole operation only occupying about twenty-five to thirty seconds per truck. The four levers work on specially constructed valves, and efficiently control the pressure. C^1 is an opening in C for dumping into the highest discharge shoot; C^3, piston rod attached to the carriage, moving it in both directions; C^4, lever controlling pressure in D to piston rod which forces the truck off carriage on to dumping track B; E, catch locking truck on carriage until it registers with track B; F, grip dog for moving trucks singly or the whole train of loaded trucks along the supply track A; F^1, cylinder to operate grip dog F by piston rod F^2, controlled by lever F^4; G G, grip dogs for moving trucks on dumping track B in a pair to avoid openings in the platform being openings into chutes; G^1 G^1, pair of cylinders to operate grip dogs G G by piston G^2; 1, 2, 3, 4, openings in platform for dumping into shoots for different levels of water; J, automatic lifter for trap door of truck, after dumping contents; K, stationary boiler, if required.

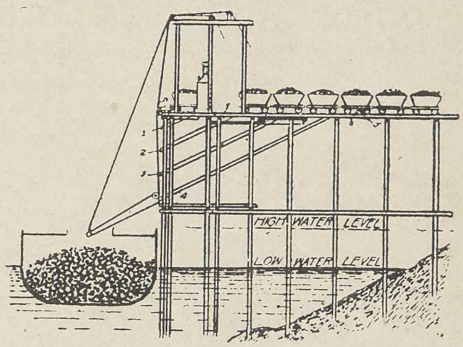


Fig. 855. General View of Wall's Coal-Loading Device.

Figs. **853** and **854** show a plan and elevation along the dumping track B, and Fig. **855** an application of the apparatus to loading a collier. The quantity of coal that could be thus dumped into a vessel can be placed at an average of 550 tons an hour for each loading shoot, and two shoots could be worked simultaneously at suitable distances apart to suit the hatches of the vessel. As many as 750 tons per hour have been loaded by one shoot.

The cost of loading say 5,500 tons of coal with a "Wall" apparatus is but 46s.

The plant may be driven by hydraulic power, steam, or compressed air.

It is said that fifty years ago the time taken to load a 1,000-ton vessel in this locality was between three and four weeks. This is not surprising when it is remembered that ships used to be loaded in those days by Indian women, who took out baskets of coal in their frail canoes which they handed up over the side of the vessel as she rode at anchor in the middle of the harbour.

A similar system, but much simpler, is in use at the Tyne Docks, near South Shields, and it is thus described in a paper read by Mr J. D. Twinberrow before the Institute of Mechanical Engineers:—

"Durham and Northumberland coals are transported in self-discharging railway trucks, the shipment being effected from timber staiths which contain hoppers fitted with spouts, projecting laterally over the vessels lying alongside. Tyne Dock, near South Shields, in Durham county, holds the record for the monthly and yearly tonnage placed on board. The arrangement is entirely self-acting, the wagons being run down the central roads by gravitation. In passing the short length of sharp inclination they acquire sufficient impetus to travel through trailing points on the rising grade, by which they are

brought to rest and their positions reversed. They then take the points leading to the hoppers where they discharge their loads and run back on the 'empties' road. The ease and rapidity of the process, the small number of men employed, and the absence of costly machinery are features which stamp this plant with the character of an engineering feat of the highest order. If such staiths were introduced into districts where the end discharging wagons are in vogue, the erection of a simple gantry over each hopper would enable these vehicles to tip their loads, so that they could be continued in service until gradually replaced by high capacity hopper wagons. Bogie wagons of any length could easily be accommodated, and owing to the diminished friction of large wagons fitted with axle boxes for oil lubrication, the gradient of the roads might be reduced."[1]

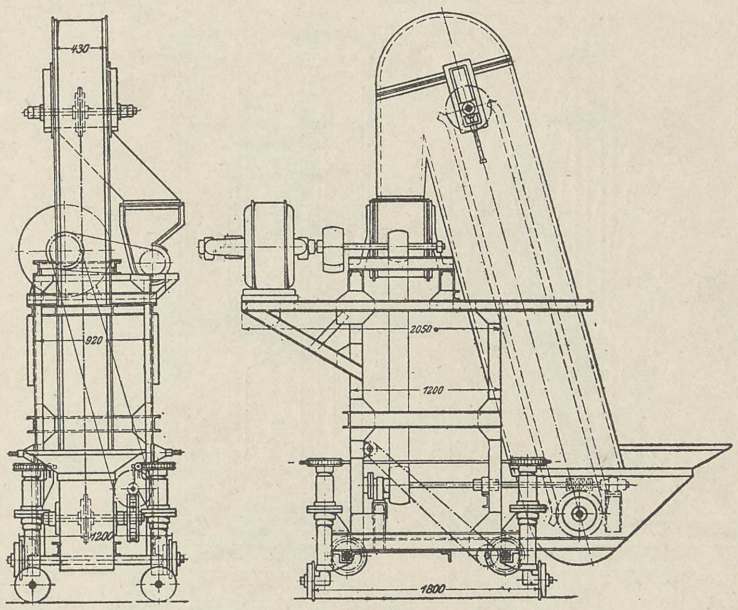
The gravity system of loading is almost universally used in the United States and also in Spain where existing conditions permit of its use. It might be mentioned that an installation in the South of Spain can load as much as 8,000 tons in twenty-four hours from one double-sided installation, entirely by gravity, without the expenditure of any power, and with the assistance of only twelve men.

[1] See "Capacity of Railway Wagons as affecting Cost of Transport," by J. D. Twinberrow (*Proc. Inst. Mech. Engineers*, 1900, page 573).

CHAPTER XXXVIII

MISCELLANEOUS LOADING AND UNLOADING DEVICES

THE ever-increasing cost of hand labour, as well as the ease with which electrical power can be led to, and connected with, portable mechanical appliances, has opened a great field for such devices, either mounted on rail tracks or on ordinary carriage wheels which need no rails. One of the essential features of such installations is great simplicity in



Figs. 856 and 857. Portable Loading Device for Salt.
(The dimensions are in millimetres.)

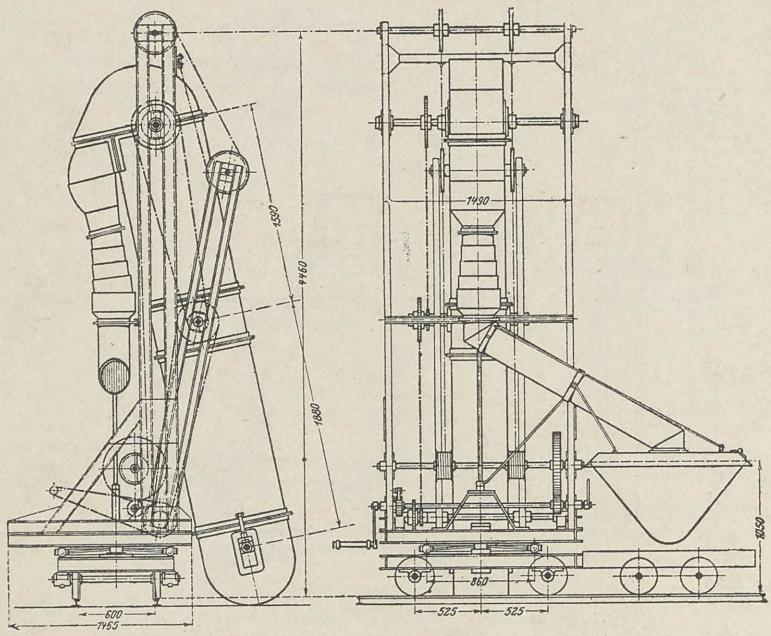
handling them, as they are generally operated by the most unskilled of labourers. Figs. **856** and **857** show a portable loading device by Fredenhagen.[1] This particular machine is designed for loading salt from a heap into trucks which are placed beneath the discharge shoot. The diagrams show that the platform of the truck is provided with four pairs of wheels, so placed that the whole machine may be reversed on the rails. The two pairs of wheels shown on the track can be raised by screw tackle and worm, and worm wheels; each pair of wheels being coupled so as to move simultaneously, and the effect of raising one set of wheels is equivalent to bringing the other four (which stand at right angles to them) down. The whole machine is then lifted by hand and turned 90°, if more convenient in that position for loading.

The elevator, which constitutes the principal portion of the device, is driven at the lower terminal by a belt and worm gear from an electric motor, and the elevator well is

[1] The facts and the illustrations are taken from an article by Hub. Hermanns in the *Zeitschrift des Vereines deutscher Ingenieure*, of 5th June 1913.

widened so that the material can be easily shovelled in. This would practically complete the machine for many purposes, but in this particular case, the installation being for handling salt, a short worm conveyor is inserted between the delivery from the elevator to the truck, presumably to break up any conglomeration of the salt. The worm so used is driven by a separate belt from the motor.

A similar plant by the same firm is depicted in Figs. **858** and **859** for handling dusty material. As the method of reversing the machine previously described on the rails must be looked upon as rather a primitive way of doing things, the present machine is so built that the whole upper part can be rotated on a turntable running on a ball race. The incline of the elevator is alterable, and as the well is open at the circumference (protected by bars as usual), it can be pushed into the heap to be removed when it will feed itself. The elevator is raised or lowered by a small winch driven by hand, and the delivery



Figs. 858 and 859. Portable Loader for Dusty Material.
(The dimensions are in millimetres.)

shoot is made with a universal joint and telescoped. The final delivery into the tipping trucks is through a shoot, which is connected to the centre of the lid fitting the truck, to prevent dust escaping. The electro-motor is geared by three countershafts and chains to the upper terminal of the elevator, and the lower one is fitted with a tightening gear. The speed of the elevator is 120 ft. per minute, and the capacity, when handling minerals, up to 30 tons per hour.

Fig. **860** represents a somewhat similar machine, but unlike the previous one, where the elevator head was in a fixed position, the order is here reversed, and the lower terminal is a fixture. The carriage of this machine is fitted with ordinary road wheels, and is therefore independent of rails. A frequent method of using this device is by feeding it with one or more self-contained and portable band conveyors, one of which is shown in the diagram, and also alluded to on page 614. The drive is geared to the lower terminal of the elevator, and the extreme positions of the latter are shown in dotted lines.

A special appliance for raising acetylene slurry from a pit into trucks is shown in Figs. **861** and **862**, and is also the design of Fredenhagen. The pits are of a smooth

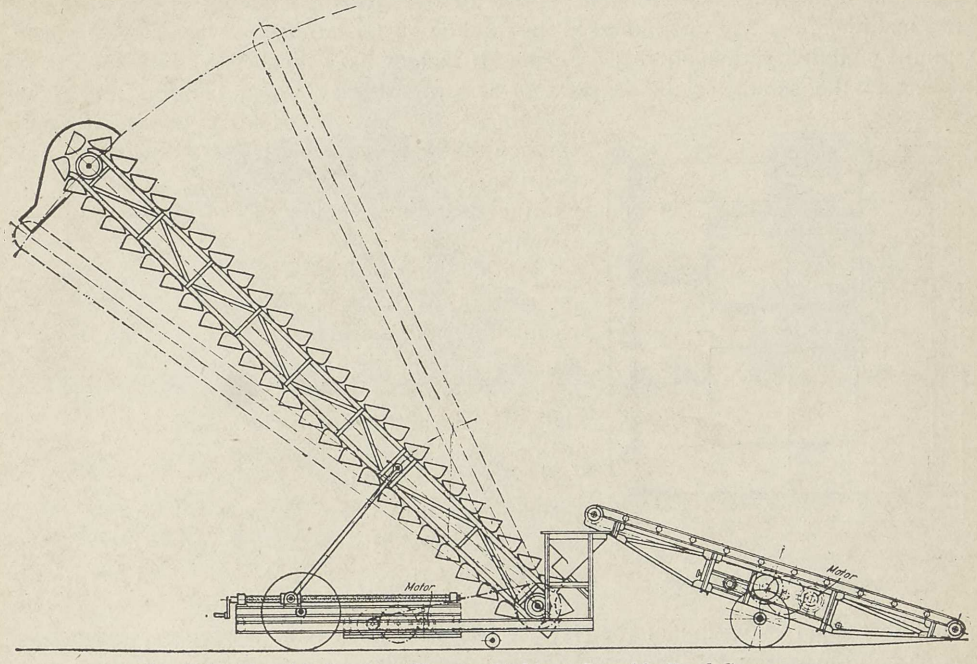
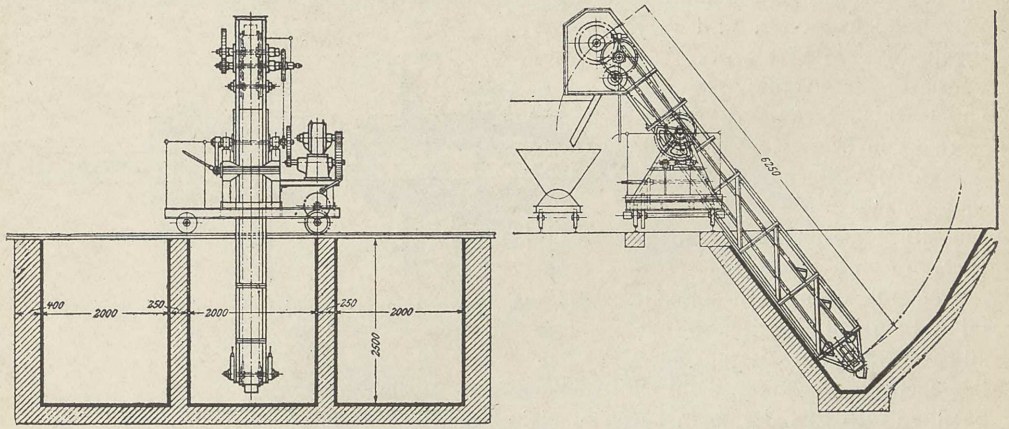


Fig. 860. Portable Loading Elevator Fed by a Portable Band Conveyor.

finish inside, being rendered with cement, and into this the lower or receiving end of the elevator dips; the driving gear and the remainder of the gearing being carried on a



Figs. 861 and 862. Portable Apparatus for Raising Acetylene Slurry.
(The dimensions are in millimetres.)

portable platform on rails. The elevator is enclosed and Fig. **863** shows a cross section. The casing tapers getting wider at the lower terminal, the elevator chains are depressed at the delivery point by two jockey pulleys for better delivery, the material being of a somewhat sticky nature. Fig. **864** shows one of the buckets which, instead of

the usual skidder bar, has a projection on the carrying link which answers the same purpose. The buckets are 24 in. pitch, and the upper terminal is 24 in. and the lower 16 in. in diameter. The swinging support of the elevator is shown in Fig. **865**. The two main bearings A A are secured to the framing of the carriage. They support a hollow spindle B and keyed upon this are the two flanges C C which carry the elevator; also keyed to the spindle is the segment of a worm wheel E which controls the inclined position of the elevator. The driving spindle passes through the hollow one and is geared, as shown, on to the upper terminal. The incline is altered by a hand lever and a ratchet on the worm spindle.

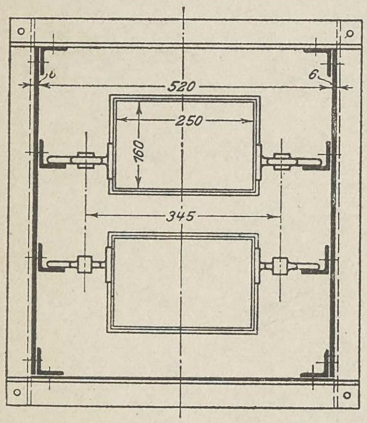


Fig. 863. Cross Section of Elevator shown in Figs. **861** and **862**.

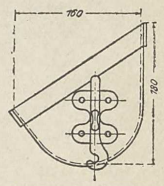


Fig. 864. Detail of Elevator Bucket.

For handling coke from the heaps in gaswork yards many simple and useful appliances are made. They are often fitted with a short reciprocating or revolving sieve to separate the breeze, and also occasionally with a coke breaker. Figs. **866** and **867** show the outline of such a machine by Stotz. The carriage is on ordinary cast-iron wheels and therefore independent of rails, and can be moved to any spot in a level yard within reach of the electric mains. The coke is shovelled into the hopper extension of the elevator well which has a bar screen to prevent pieces too large from entering. The motor, geared to the elevator and screen, also gives motion to the carriage when necessary. The rest of the arrangement is sufficiently clear from the diagram; these appliances are generally used for retailing coke from gasworks.

Loading Salt into Railway Trucks.—Such loading devices may be used for all materials in bulk which are to be loaded into closed railway trucks, and are exceedingly useful labour savers, and very inexpensive in first cost; they consist of a large oblique tapered shoot which terminates into a worm conveyor *l*, Fig. **868**. The worm is driven by an electro-motor fixed to the back end of the worm casing, and moves therefore with the worm. The movements are in both horizontal and vertical direction, so that all parts of the railway truck may be reached sufficiently to fill the truck without any hand labour. A 10-ton truck can be filled with this device in seven to eight minutes. The salt is conveyed by a worm to hopper *k*, from which it is admitted to the loader by an inlet valve.

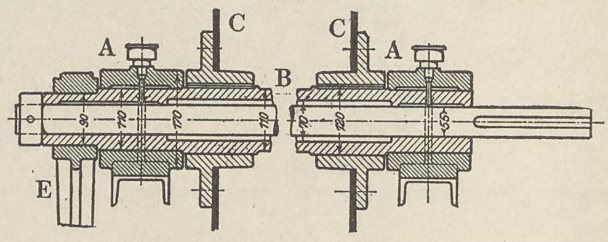
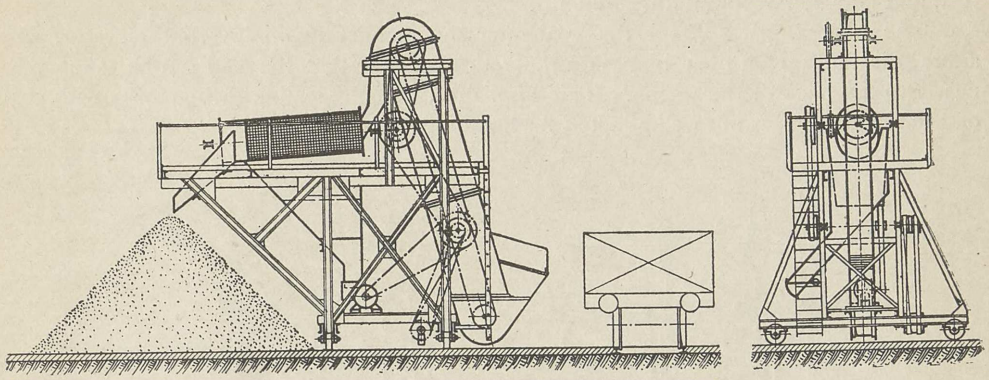


Fig. 865. Pivoted Support of Elevator shown in Figs. **861** and **862**.

Portable Band Conveyor.—The Robins Conveying Belt Co., as well as other specialists in belt conveyors, build a portable band conveyor, self-contained, with a motor attached, in a light steel frame. The motor may be for steam, pneumatic, or electric power. One of the terminals is fitted with tightening gear and the whole frame is mounted on wheels, so that it can readily be put into position wherever it may be

required. Several lengths can be joined together, or they can be used in such a way as to deliver one upon the other.

Soar's Coal-Lowering Apparatus.—This apparatus is built by the Chain Belt



Figs. 866 and 867. Portable Coke-Handling Plant.

Engineering Co. It is illustrated in Figs. **869** and **870**, and works as follows: A A are hinged plates bolted to Ewart chains B, and work in the direction shown by arrows. The chains that carry the plates are driven by the Ewart chain C, which, when a picking table

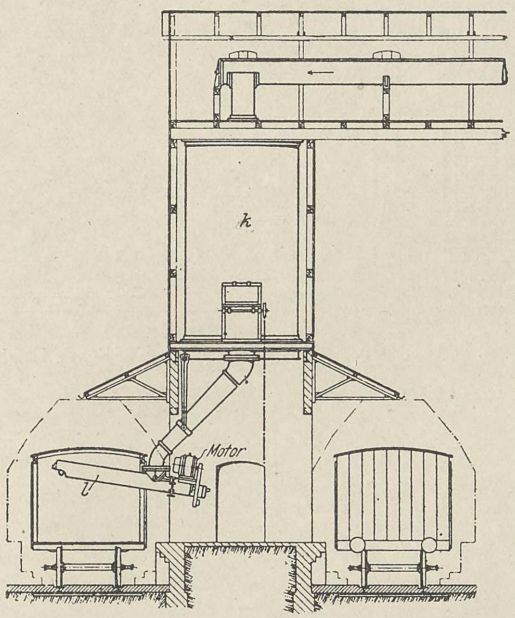


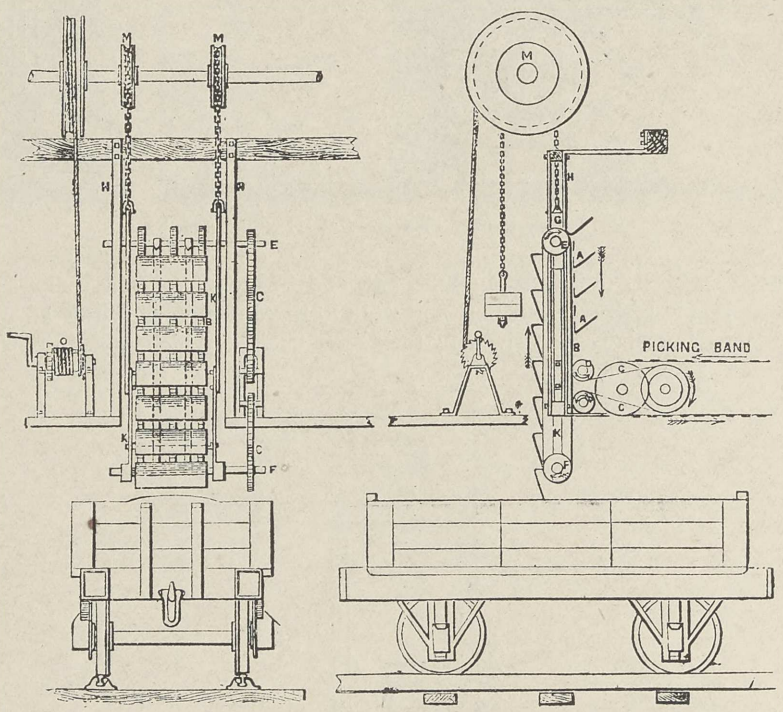
Fig. 868. Device for Loading Salt into Closed Railway Trucks.

is used, is driven from the terminal of the picking table by means of spur wheels. The driving chain C passes over the driving wheel round the tension pulleys D D over the top and bottom terminals E and F. As the chain C cannot slip, the relative position of the plates to the screen or picking band is not affected during the process of lowering or raising the apparatus.

The shaft E works in two slide blocks G, which slide between guide bars H H; bolted to these guide bars are two distance bars K K which carry shaft F.

The apparatus is suspended by chains with counterbalance weights over chain wheels M M, and is raised or lowered by winch O.

The hinged plates lower the coal after the manner of an inverted elevator, and afterwards fold up on their hinges on the return side, so that the coal can be taken very nearly to the back of the wagon. This appliance, though dealing satisfactorily with coal of a moderate size, is not well adapted for handling very large pieces.



Figs. 869 and 870. Side and Front View of Soar's Loader.

MISCELLANEOUS INSTALLATIONS

CHAPTER XXXIX

THE COALING OF RAILWAY ENGINES

As far as England is concerned, mechanical appliances have not been used very much for the coaling of locomotives. The old methods are still in wide use, baskets or other receptacles, holding about 1 cwt. of coal, being carried, often by hand, from the platform in the coal yard to the tender of the engine. It is also quite usual to employ small cranes worked by hand or by motive power for coaling locomotives, a most expensive proceeding,

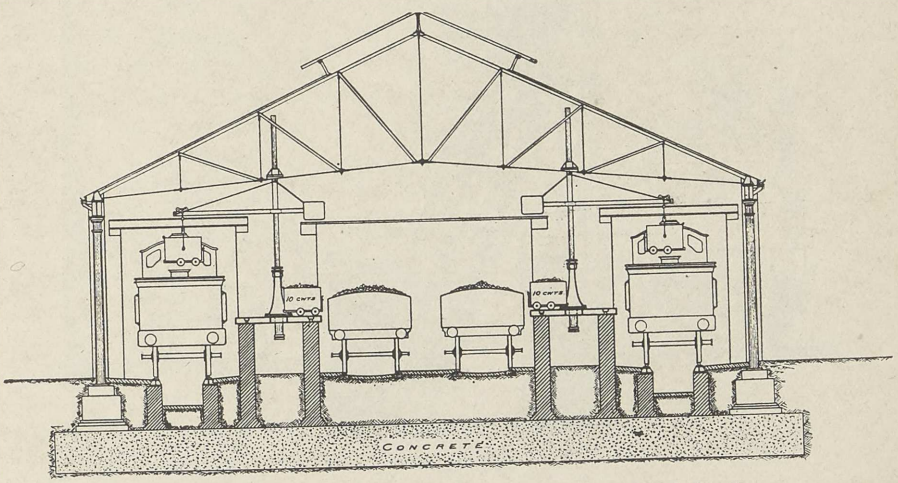


Fig. 871. Section of Old Coaling Stage at Crewe North Shed.

but it is to be hoped that the efficient locomotive coaling installations on American lines will soon find favour with the all-too-conservative British railway companies, as they have done on the Continent. It pays to install mechanical equipment if 100 to 150 locomotives have to be coaled per day.

Old Coaling Stage at Crewe.[1]—The old coaling stage at Crewe consists of two decks, on each of which are placed three hydraulic cranes of 1 ton capacity (see Fig. 871). Between these decks are two sets of rails on which the full coal wagons stand, and on the other sides of the decks from the coal wagons are the roads on which the locomotives stand for coaling.

The wagon road and the engine road are on the same level, and the top of the deck is about level with the bottom of the wagon. The men have, therefore, to dig down into

[1] Extract from a paper read before the Institution of Civil Engineers by C. T. B. Cooke, M.I.C.E.

the coal, lift it over the side of the wagon, and deposit it into boxes of 10 cwt. capacity. These boxes or tubs are provided with castors so that they can be pushed about the deck at will and brought within the radius of any one of three hydraulic cranes by which they are picked up for emptying the contents on to the tender.

The increasing consumption of coal at the Crewe depot, and other causes, make the cost of transferring the coal from wagon to tender work out at 3·69d. per ton. This high price, and the fact that the tonnage dealt with annually at this coaling stage is the largest on the London and North-Western system, were two of the principal factors leading to consideration of the adoption of a mechanical coaling plant, which is fully described later.

Improvements have been made in coaling methods at Swindon and other railway centres where the coal wagon is raised and side door wagons are used.

Coaling Railway Engines on the South-Eastern and Chatham Railway

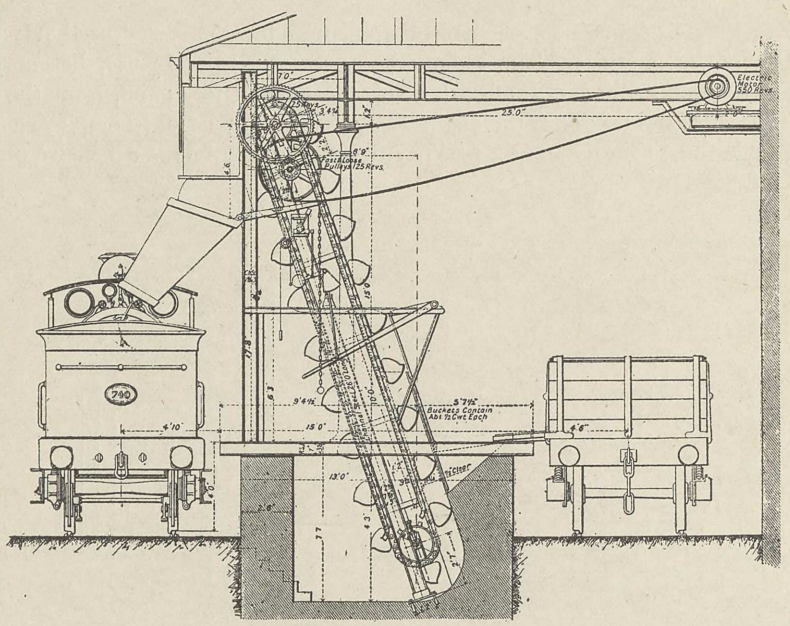


Fig. 872. Elevator for Coaling Railway Engines at Slades Green.

—Some noteworthy improvements were carried out at Slades Green by Mr S. Wainwright, chief mechanical engineer of the South-Eastern and Chatham Railway. For coaling the engines the coal stage is fitted, as shown in Fig. 872, with a bucket elevator which, after having undergone several modifications, has been given an extended trial with considerable success. The elevator consists of twenty buckets, each capable of containing about ½ cwt. of coal loosely filled. These are secured to an endless chain which runs over two sprocket wheels, one mounted on the upper end of the frame under the roof of the stage, the other at the lower end in a pit some 7 ft. below the floor of the coal stage, into which pit the coal is shovelled direct from the wagons on the inside road.

An electro-motor is placed on a bracket on the engine-house wall about 20 ft. away; it makes about 500 revs. per minute, and drives (by means of covered-in belting) a countershaft on the elevator frame, while a pinion on this shaft gears into a large spur wheel, which drives the top terminal, the latter making about 25 revs. per minute. Working at this speed the buckets deliver coal down the shoot to the tender at the rate

of about 1 ton per minute. To avoid jamming the buckets in the pit by an accumulation of coal, and so preventing the motor from starting, an automatic switch has been devised, which by the action of raising a slide and admitting coal into the pit, starts the motor before the slide is sufficiently raised to admit coal in any quantity, a water spray to lay the dust being simultaneously turned on. The coal is delivered close to the top of the tender, gear being provided to lift the shoot clear of the chimney and cab of the engine.[1]

American Practice.—Extensive coaling installations have there been erected for locomotives.[2] They are much larger than similar installations in Europe, as in America they have been able to centralise and make more economical arrangements, and also the country being new, the value of the land occupied by these installations is considerably less than in European countries, where the already existing arrangements often only admit of a limited space for the installation of such plant. Finally, the exceptionally high wages in the United States are a special incentive to mechanical equipments, for which reason comparatively few small installations are to be found.

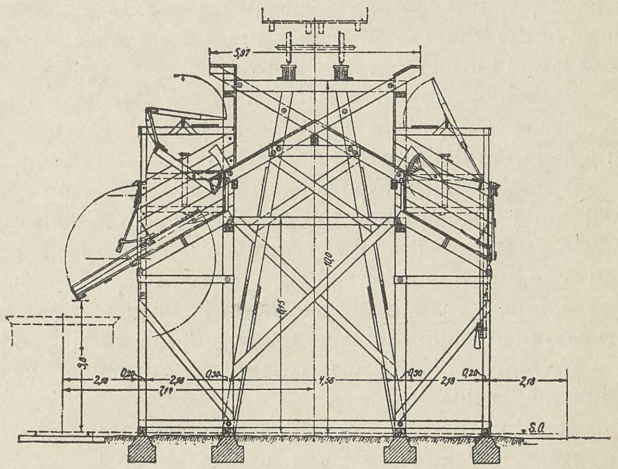


Fig. 873. Cross Section through American Gravity Coaling Installation.

(The dimensions are in metres.)

The most universally adopted method of coaling railway engines consists of timber ramps constructed of trestle-work, up which the coal wagons are hauled by a locomotive; here the coal trucks, which are hopper-bottomed, are dumped into pockets, the outlets of which are sufficiently high above the ground for the coal to be shot direct by means of a shoot into the tenders. Such installations are extravagant for space, which would probably not be available in England except in one or two places; but the fact that the land has in many cases been given free of cost in America makes the study of space economy less important. It is obvious that the greater the incline of these ramps the shorter will be their length. The most usual incline is one of 6 per cent. or 1 in 16·7, at which incline one locomotive can haul three 50-ton wagons. If the local conditions do not permit of the necessary space for such a ramp, and a steeper incline becomes necessary, the wagons are hauled up by a rope, which service is occasionally performed by locomotive. The inclines are then up to 20 per cent. and even more. The high level rails at the top of these ramps have frequently a slight downward gradient in the opposite direction, so that a wagon cannot accidentally run down. A further precaution against accidents is the use of safety switches. Fig. 873 shows a cross section through the highest portion of one of these devices, from which it will be seen that

[1] From *The Engineer*, 23rd May 1902.

[2] "Lokomotivstationen nordamerikanischer Eisenbahnan," by Dr Blum and E. Giese, *Zeitschrift des Vereines deutscher Ingenieure*, 8th Feb. 1908.

locomotives can be coaled at either side, and provision is also made for coal to be stored under its trestles. In one of the installations of the Pennsylvania Railway at Bergen Hill near Jersey City 150 locomotives are coaled daily. The advantage of this system of coaling over the more old-fashioned one used in America is that a reduction of hands from fourteen to five is effected, and the cost of loading coal into the tender of the engine is only a small fraction over ½d. per ton. This does not include the weighing of the coal, which is not feasible with this method of coaling; but in the old-fashioned method the cost was 6d. or 7d. per ton including weighing.

About the year 1907 coaling installations with gravity bucket conveyors (hereinafter called mechanical coaling appliances) were introduced and erected by Hunt, the Link Belt, and the Robin Belt Companies. They were at first received by railway companies with much enthusiasm, which was, however, checked later on account of the following defects:—

Firstly.—The finer mechanism of the gravity bucket conveyors is more subject to breakdowns under the rough treatment it might receive, and by coal getting into the driving gear through careless handling, as a breakdown to the conveyor means a breakdown of the whole installation. Breakdowns have been known to cause stoppages which have lasted for fourteen days or over.

Secondly.—Objection is taken to the storage of large quantities of coal in enclosed receptacles on account of risk of spontaneous combustion, a risk intensified by oil dripping from the conveyor on to the coal.

Thirdly.—Such installations are only suitable for comparatively small coal, and large coal would therefore have to be broken, which diminishes its value.

Fourthly.—During frosty weather it has happened that the coal has frozen together and large lumps thus formed have refused to leave the hoppers.

Fifthly.—The whole installation is of greater initial cost, which is only justified in the case of exceptionally large traffic, and the working and maintenance expenses are high.

Sixthly.—It is difficult to extend the capacity of such an installation should increased traffic render this necessary.

It might be mentioned that in spite of the above, such installations, fitted with mechanically equipped coaling appliances, are largely used where space is confined and where the creation of coal dust must be prevented.

To sum up, both systems are used; the local conditions generally determine which method is to be employed; and the ramp has not been superseded by the bucket elevator coaling station.

The mechanically equipped coaling devices are all of practically the same type, though some discharge the coal on one side only whilst others deliver to right and left, the largest ones serving as many as four lines of rails. They all receive the coal, by self-discharging hopper wagons, into a pit below the line (see Fig. 874), feeding into the gravity bucket conveyor. The structure is sometimes of iron, but more often of timber along the side of the lines for extending right across them, and having hinged shoots which lead from the lower end of the hoppers to the tender. One or more such outlets are used which can be turned out of the way when not in use. There are generally a greater number of outlets, so that several locomotives can be coaled at once, and also because different sorts of coal are used, the railway companies generally using for ordinary purposes tender coal, which produces much smoke, because it is the cheapest. It is, however, unsuitable for express trains, and for this purpose harder coal has to be used. The overhead silos are, therefore, equally divided into two compartments, the larger one for soft and the smaller for hard coal. The installations are generally so arranged that the siding upon which the

coal is brought in is not the same as that upon which the engines are coaled, so when an installation spans four lines of rails for coaling four engines at the same time one or two sidings on either side are used for the coal wagons.

An example of the above is the coaling plant for the railway engines of the Philadelphia and Reading Railway, United States of America. This extensive installation is illustrated in Fig. 874. Four locomotives can be simultaneously coaled and supplied with water and sand. There are two "Hunt" conveyors, one for coal and one for conveying the ashes from the engine to the receptacle provided for them. Between the coal and ash hoppers is a small hopper for sand which is shown in the illustration. The capacity of this plant is 600 tons of coal per day and five loads of ashes. Nearly 500 main-line and suburban locomotives call at this station every twenty-four hours. Similar installations are employed by the Boston and Albany, and other United States railways.

The staff employed consists of eleven men during the daytime, and one man during the night. The labour is divided as follows: One foreman, one stoker, one man in the coal tunnel, one in the ash tunnel, one man above for wetting ashes, four men for filling the tenders, and one for filling the locomotive water tanks. During the night-time one man in attendance sees to the loading of the locomotives with coal.

The desire to coal a greater number of engines has been the incentive to further developments whereby the engines are not fed direct from the elevated silo, but from a bridge spanning the railway which transfers the coal by small trucks on rails from the silos through small pockets and hinged shoots on to the tenders. This method has the advantage that the coal can be weighed before delivery. Another great advantage is that the relative positions of the coal receptacle and the coaling siding are more or less immaterial, so that space of lesser value can be utilised for the erection of mechanically equipped coaling appliances.

The coaling installations being confined to the most important junctions, which are often great distances apart, it is necessary to provide locomotives with coal at intermediate stations. These auxiliary coaling facilities are not necessarily confined to the stations, but are sometimes erected on any convenient spot on the line; such installations are very similar to those previously described but on a much smaller scale.

A different system again is that used on the Southern Pacific Railway, where the coal is stacked in a small heap, as shown in Fig. 875, and removed by a crane and grab to a portable hopper from which the engines can be coaled. The illustration explains itself, and it need only be mentioned that the hopper is not portable in order to adjust itself to the position of the tender or engine, but for the reason that the whole length of the stock pile can be transferred and the portable hopper moved forward as the one end of the pile becomes exhausted. It is said that the cost of transferring the coal in this way amounts to one penny per ton. This last installation is perhaps the starting point for stocking larger quantities of coal, to which there is now a greater tendency than ever in the United States. Formerly coal for not more than five or six days was kept in stock, and this was frequently stored in railway trucks and on sidings. The more modern method of storing it is in stock piles or heaps, which are described in Chapter XLI.

Coaling Station of the Munich Central Railway.—This was erected by J. Pohlig, of Cologne, Hunt's patent conveyor being used. The installation shown in Figs. 876 and 877 consists of a steel structure, which supports, in addition to four large coal hoppers, the necessary conveying machinery. The plant has been erected over a tunnel, through which the lower strand of the Hunt conveyor runs. Above this tunnel is a coal hopper built of masonry, over which run three lines of rails. The coal is brought to this receptacle by self-emptying railway trucks, and can be withdrawn by a series of

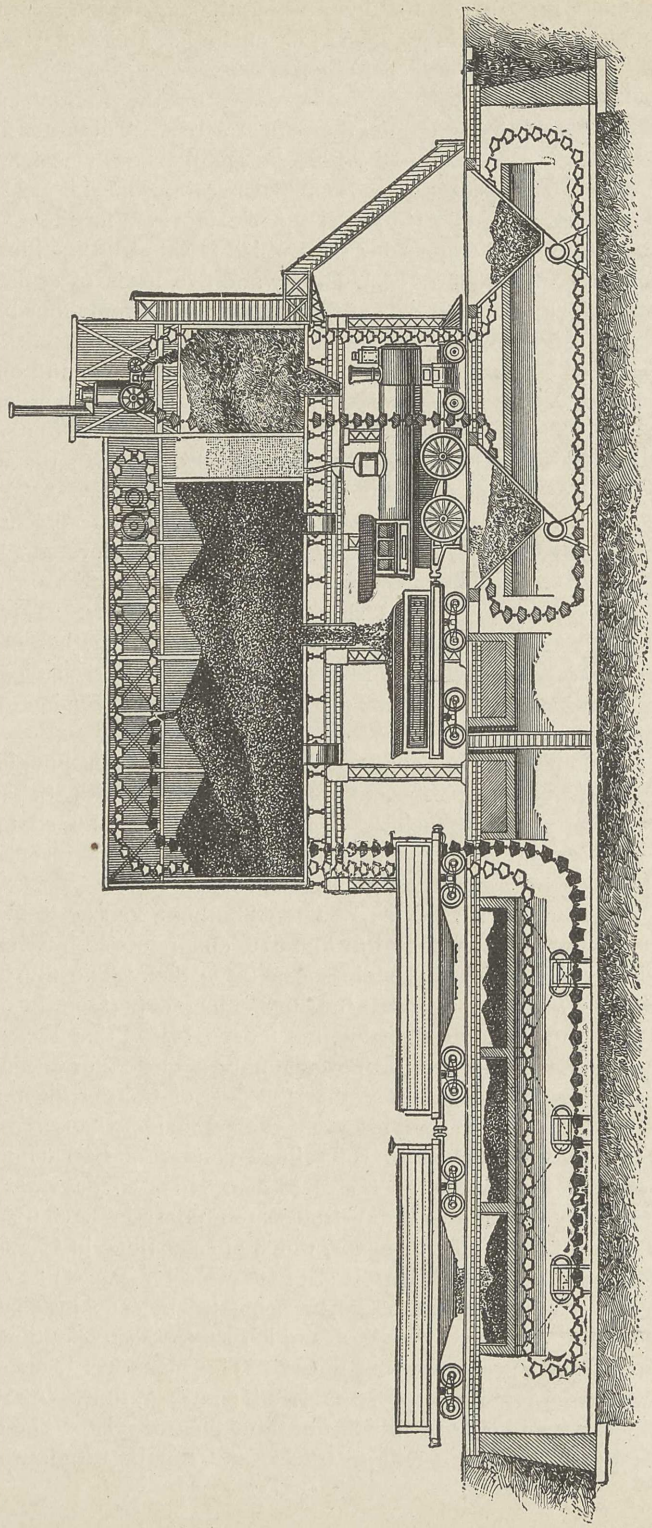


Fig. 874. Coaling Plant for Railway Engines on the Philadelphia and Reading Railway, U.S.A.

sixteen outlets on to the conveyor, which takes the coal to the top and delivers it to any one of the four hoppers, from which it can be withdrawn to fill the locomotive tenders on each side of the structure at a moment's notice.

Coaling Station for Railway Engines at Antwerp.—This is illustrated in Fig. 878. Conveying is done on the "Hunt" principle, the coal being deposited in the first instance by self-unloading railway trucks, into a hopper beneath the level of the rails, and it is taken from there by a gravity bucket elevator into the elevated bunkers, which are fitted with measuring devices. From here the coal is lowered to the tender of the engines (the length of the conveyor chain is 500 ft.). The speed at which the conveyor runs is from 35 to 40 ft. per minute, with a capacity of 30 tons per hour. The expenditure of power is 16 H.P.

The hoppers into which the railway trucks are emptied are capable of holding 2,200 tons, whilst the elevated bunkers will together hold 100 tons. The measuring arrangements are such that coal of three different kinds may be fed to the tenders. The conveyor is at the same time used for the removal of the ashes from the engines, dumping them into a separate hopper to be taken up by the conveyor to a compartment of the overhead hoppers, whence they can be removed at any time.

Three men are employed to work the plant—one to look after the machinery and the electro-motor which drives it, one to stand by at the filling of the conveyor, and one to superintend the delivery of the coal to the engines. This installation was built by Pohlig, of Cologne, and was set to work in 1899.

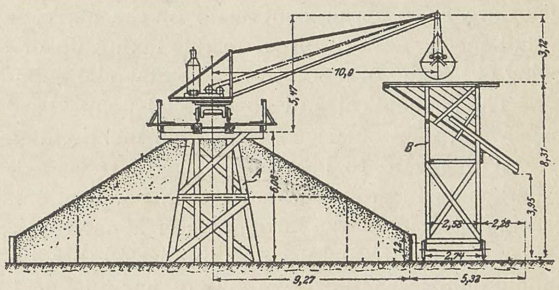


Fig. 875. Coaling Installation as used on the Southern Pacific Railway.

(The dimensions are in metres.)

Locomotive Coaling Installation of the London and North-Western Railway at Crewe.[1]—The London and North-Western Railway Co. have recently built, at their large locomotive running-sheds at Crewe, a coaling plant, and it is believed that by the introduction of this machinery the hitherto generally accepted British method of coaling by hand, or by devices necessitating considerable hand-shovelling, has for the first time been completely abandoned. By means of the new plant the coal is removed automatically from the wagon, conveyed to and stored in overhead bunkers, measured and placed on the tender without spadework of any description. The plant, which is the first of its kind in this country, was built by Messrs Babcock & Wilcox, and is the joint design of Mr Cooke and that firm.

It is desirable to describe shortly the conditions which existed before the advent of the mechanical apparatus, and also to say a few words generally on the question of handling coal mechanically for the use of locomotive engines.

It may be advisable to state here certain factors which have militated hitherto against the adoption of coaling machinery for locomotives in England, and also the reasons which led to the installation of the type of plant now described. The points to which careful consideration had to be given were :—

1. The cheap rate at which coal is now dealt with by hand.

[1] Extract from a paper read before the Institution of Civil Engineers by Mr C. T. B. Cooke, M.I.C.E.

2. The impossibility of obtaining reliable statistics of a plant suitable for British requirements.

3. The large size of coal mined in England.

4. The class and size of coal wagons in use.

5. The restricted area available in most steam-shed yards.

6. The regular and adequate supply of coal between colliery and steam-shed.

7. The high cost of land for extensions and alterations to yards.

8. The impracticability of one plant capable of dealing economically with coal between (i) wagon and tender; (ii) wagon and stack; and (iii) stack and wagon or tender.

9. The varied local conditions existing at steam-sheds on any one line.

10. The large outlay necessary for installing a plant, and the cost of working various plants.

11. The breakage of coal.

It is unnecessary to enlarge upon points Nos. 1 to 5, but as regards No. 6 it is found that, in those countries where long distances separate collieries from locomotive depots, it is absolutely necessary to keep large stocks of coal on hand, to carry over delays or stoppages; such stacks really represent a combination of current and stock coal. They are, so to speak, continually on the move, and the conditions render it essential to install mechanical means of readily taking up or putting down the coal, manual labour being out of the question from a commercial point of view.

The economical and commercial points have been dealt with fully in Mr Cooke's paper, and want of space forbids their mention here.

With regard to breakage, it has been stated, on the authority of results of actual experiments in America, that "each per cent. added to the slack means a reduction in earning capacity of the locomotive of about 1d. per ton of coal fired, besides an average loss of unburned[1] fuel itself of another ½d. per ton for every 1 per cent. of slack." This should emphasise the desirability of handling coal in such a manner that the minimum quantity of slack will be formed. The large amount of slack created by the present manual handling is perhaps not generally realised, and the following statement may come somewhat as a surprise. After a tender had been loaded in the ordinary manner, and the coal had been broken by the fireman to a suitable size, the proportion of slack left ranged from 13 per cent. in the case of Welsh coal, to 2·3 per cent. in the case of North Staffordshire coal, although particular care had been taken to start the experiment with wagons from which all slack had been removed by hand.

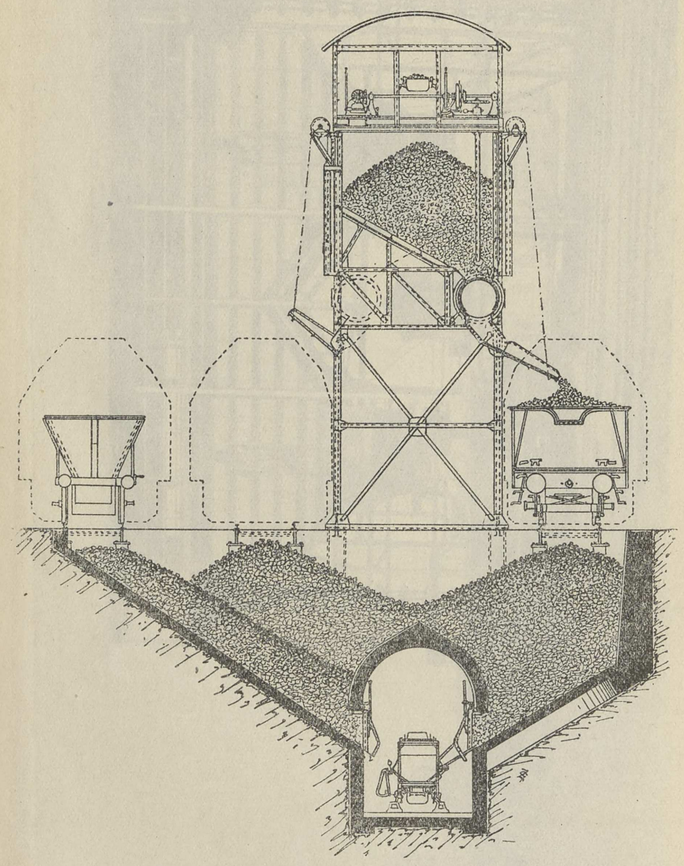
When to this is added the slack which is in the wagon when it arrives at the coal stage—in this case 10·2 per cent. in soft coal, and 2·9 per cent. in hard coal—the total is sufficient to make one pause to consider how this waste may be avoided. (In this test "slack" means all the small coal which was passed by a riddle with ½-in. mesh.)

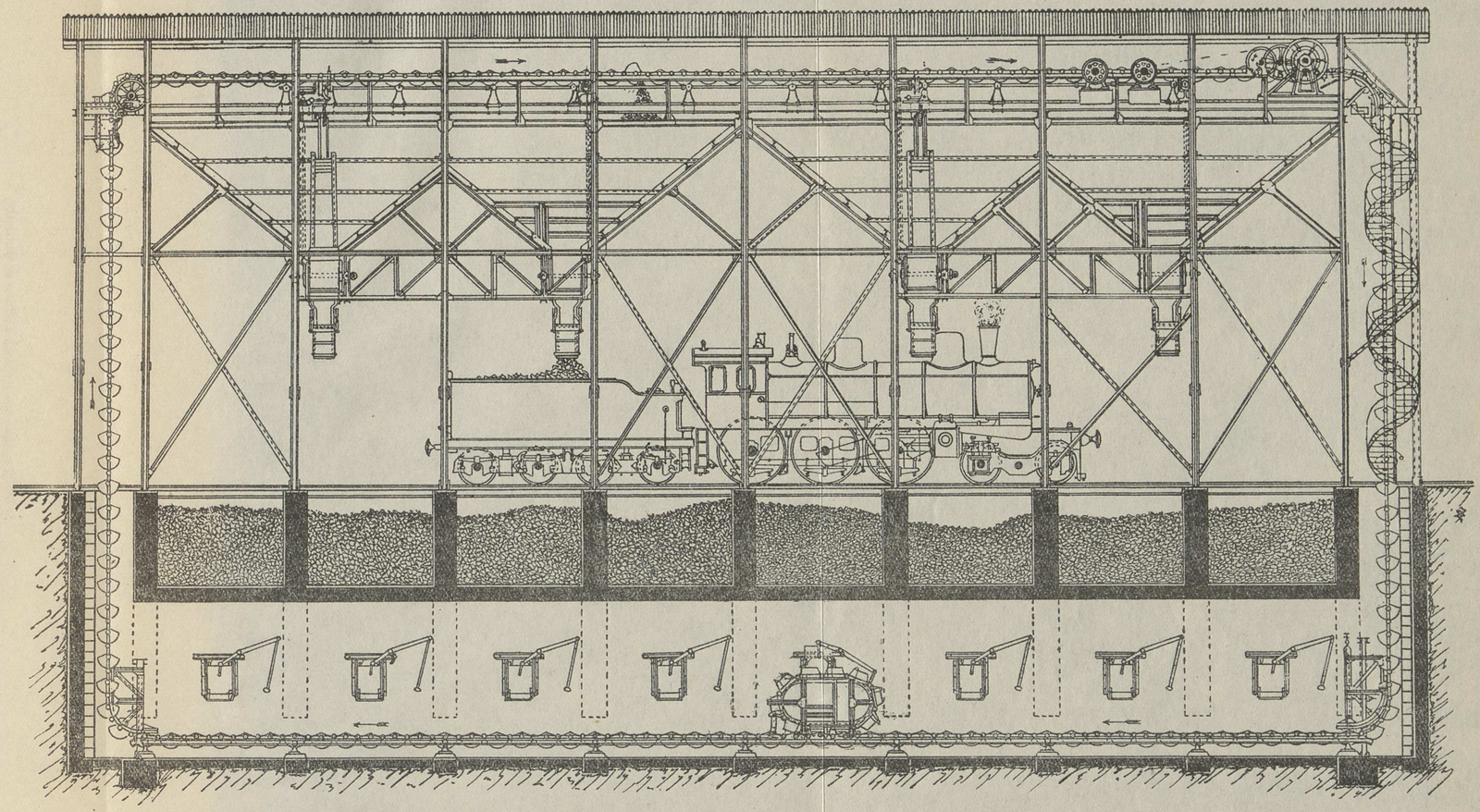
Mechanical plants should therefore be designed with a view of dropping the coal as few times as possible between wagon and tender, minimising the height of fall, sliding the coal where possible, and delivering it in such a size that no additional breaking by the fireman is required.

At the Crewe north steam-shed, at which about 130 engines are permanently stabled and about the same number are coaled daily, the quantity of coal transferred from truck to locomotive every twenty-four hours is about 450 tons, or 140,000 tons per annum.

The plant, which is shown in Figs. 879 and 880, consists of a wagon tipper, an

[1] This is the small coal which is lost through being drawn straight through the tubes as soon as it reaches the firebox, or which is blown off the tender.





Figs. 876 and 877. Coaling Station of the Munich Central Railway.

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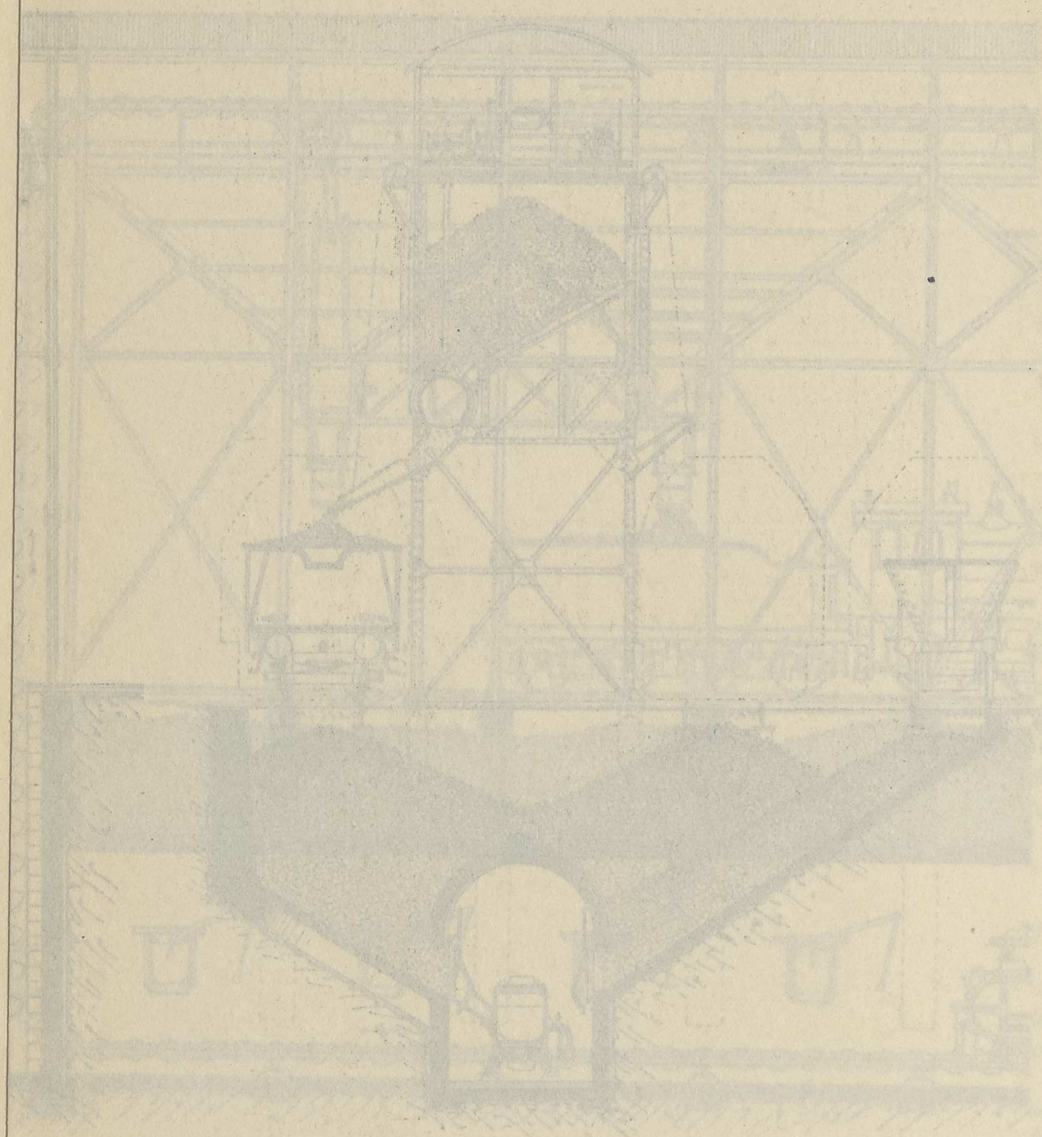

Figs. 870 and 871. Coaling Stages at the Munich Central Railway.

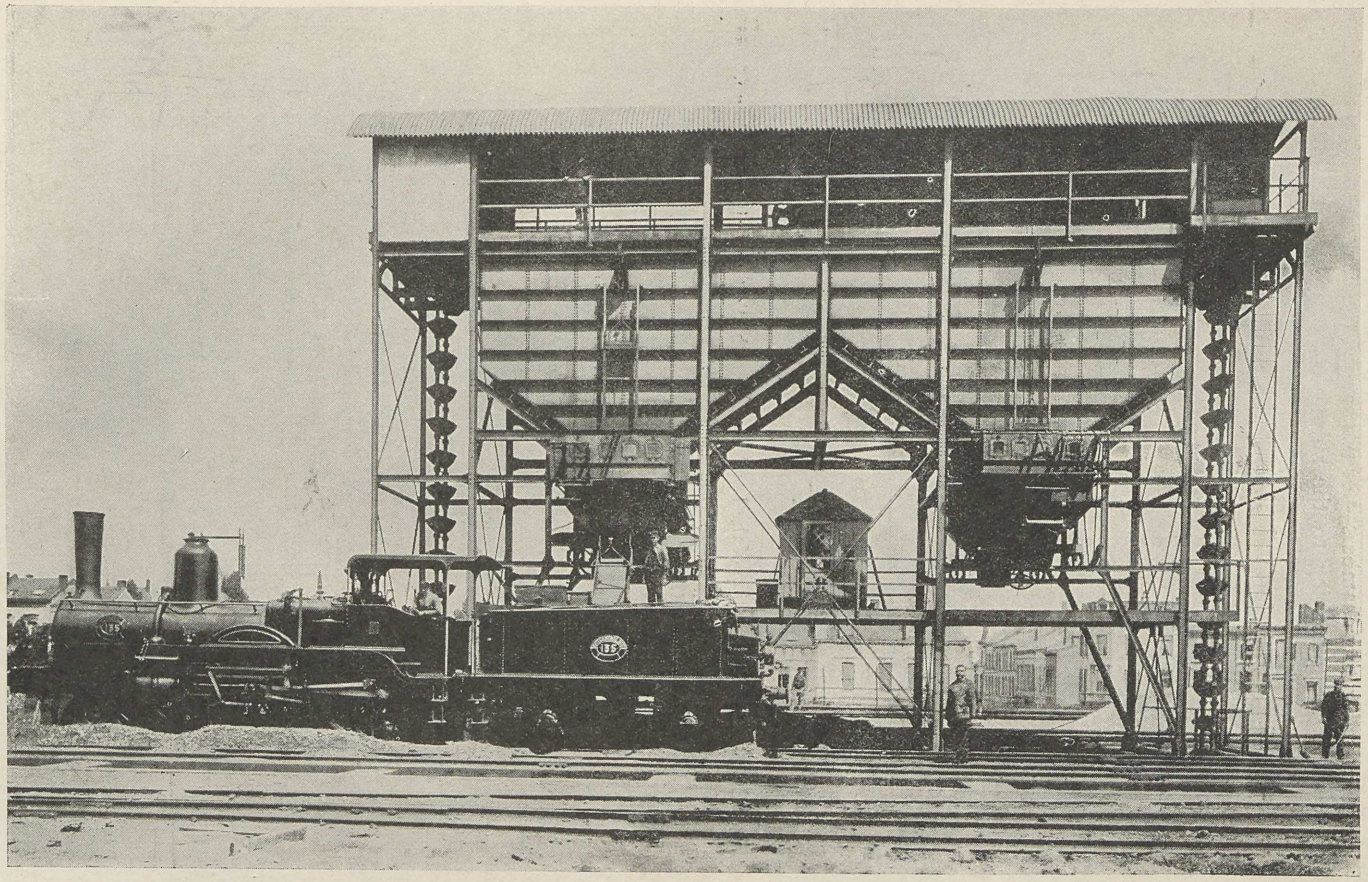

Fig. 878. Coaling Station for Railway Engines at Antwerp.

underground hopper, a coal-breaker, a tipping tray conveyor, an elevated bunker, and shoots—including calibrating chambers—for discharging the coal on to the tenders.

As the coal wagons belonging to the railway company have neither side nor end

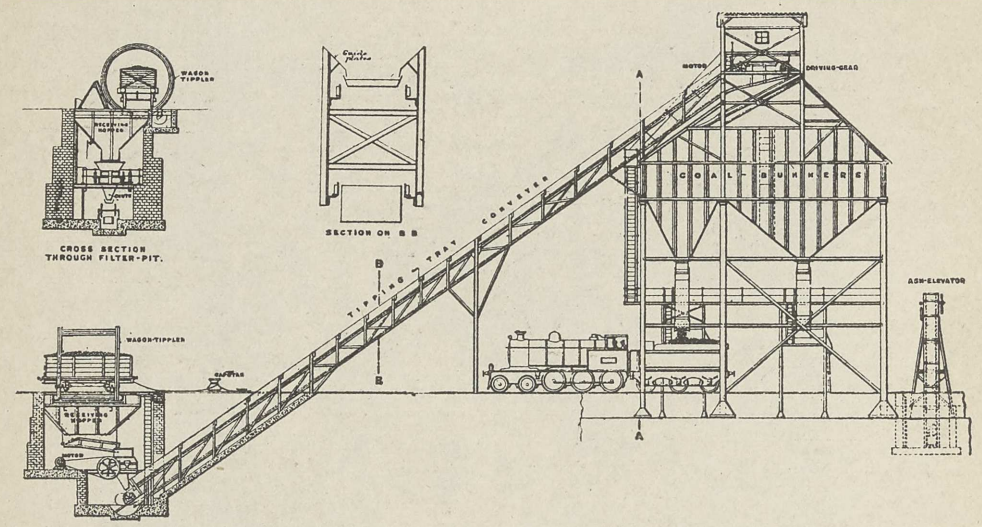

Fig. 879. Coaling Installation of the London and North-Western Railway at Crewe.

doors, a "tippler" (on the principle of those used in collieries), capable of dealing with wagons of up to 10 tons capacity, became the initial part of the apparatus.

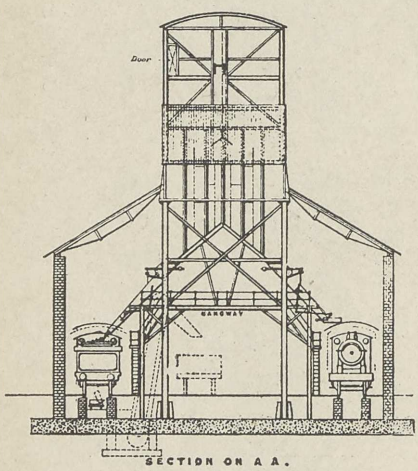

Fig. 880. Cross Section through Fig. 879.

An inclined baffle plate fixed to the tippler rings, in conjunction with the fixed plate of the hopper, serves to retain the bulk of the coal in the wagon until it is nearly in its lowest position, and thus tends to minimise breakage—a very important point when dealing with the soft Welsh coal often used.

The hopper holds about 20 tons, and is carried by cross girders in a brick-lined pit.

The coal is fed from this hopper by a jigging tray through an adjustable door—worked from ground level—into a two-roll breaker, where the large lumps are reduced to 8-in. cubes. This breaker is belt-driven by an independent direct current electric motor of 10 H.P., which also operates the jigging tray. The coal passes, with the large lumps broken, to the conveyor trays, which carry it to the overhead storage.

Particular care has been taken to reduce the fall at all points to the minimum, and after passing through the breaker the coal slides a short distance on to the conveyor trays. Notwithstanding all precautions some breakage is bound to occur, especially when working with Welsh or soft coal; although, so far, there has been no apparent increase in coal consumption from this cause.

The conveyor is of the well-known Babcock-Wilcox "tipping tray" type, running at a speed of 70 ft. per minute and capable of lifting about 60 tons per hour. Adjustment is provided for at the bottom end, while the driving gear is situated at the top under the bunker housing, and consists of a 660-volt direct current electric motor of 9 H.P., driving through a belt and train of machine-cut gear wheels, the effect of which is to give a very quiet drive.

All coal is delivered over the end of the conveyor track, but in order to prevent any breakage at this point a special form of balance plate retains it on the trays until the lowest point of the terminal pulley is reached, when it has a fall of only about 1 ft. on to the inclined shoot which delivers it to the requisite division of the bunker.

In approaching the design of the bunkers it was necessary to weigh carefully the relative advantages of the large bunker against those of the small bunker, and in this case the balance was on the side of the former. The bunkers were therefore designed to hold 300 tons; this is more than enough to coal all engines during the night without the conveyor working, and it is thus possible to send up during the hours of daylight all the coal required, and to save double-manning the wagon tippler and conveyor.

Owing to a large number of main line engines being loaded with two classes of coal, namely, Welsh and "hard," it was necessary to provide separate storage for each class. The bunker is accordingly divided into two main parts, to store 100 tons of Welsh and 200 tons of "hard" coal.

Working on the large bunker principle necessitates special arrangements to break the fall from the delivery shoot to the bottom of the bunker, when the latter is fairly empty in the mornings. This is done by special baffle plates in the case of the "hard" coal, and by spiral shoots in the case of the Welsh coal. The coal is thus delivered with a minimum of breakage, even when the bunkers are completely empty.

There is an outlet on each side of each division of the bunker, or four outlets in all, so that tenders can be coaled on both sides at the same time. The outlets in question measure 2 ft. by 2 ft., and are provided with undercut balanced doors, worked by hand, which up to the present have been very successful and free from "jams." By opening one of the doors coal is permitted to flow into a calibrating chamber formed in the shoot between bunker and tender. The bottom end of this chamber is closed by a door, worked by a lever conveniently situated, and it is so arranged that the contents of the calibrating chamber are equal to 10 cwt. On the upper door being shut and the lower door being opened, the 10 cwt. of coal is free to slide on to the tender. The shoots are built at an angle of 45° to the rail.

The lower doors have adjustable hinges, which allows the capacity of the calibrating chamber to be varied until the best average is arrived at. It has been found possible to set these bottom doors so exactly that the difference between the calculated weight delivered to the tenders and the known weight sent up to the bunkers was only 4 tons 1 cwt. in a month's working, or about 1 ton per calibrating chamber per month.

This method of obtaining the weight has therefore proved quite satisfactory; so also has the speed of coaling—as much as 6 tons being put on in three minutes, as against 5 tons in fifteen minutes with the old system under the most favourable circumstances.

The average daily quantity of coal placed on tenders is now about 450 tons, and the new plant performs this task with a staff of three men by day and one by night, the conveyor being at work approximately ten hours per day.

At present between 140 and 150 engines are coaled per twenty-four hours, and the coal can be placed on the tenders at the rate of 2 tons per minute; these figures will show that, so far as speed of coaling is concerned, there is a large margin of time in reserve.

Under the new condition of things an engine coming off the turntable would proceed in the following way, and would be detained for the time stated for each process :—

Cleaning smoke-box of ashes	4 minutes
Filling tank at water column	$3\frac{1}{2}$,,
Cleaning tubes	$4\frac{1}{2}$,,
Coaling engine	4 ,,
Dropping fire	8 ,,
Total	24 minutes

These are the actual times taken by the several operations, and, as they are per-

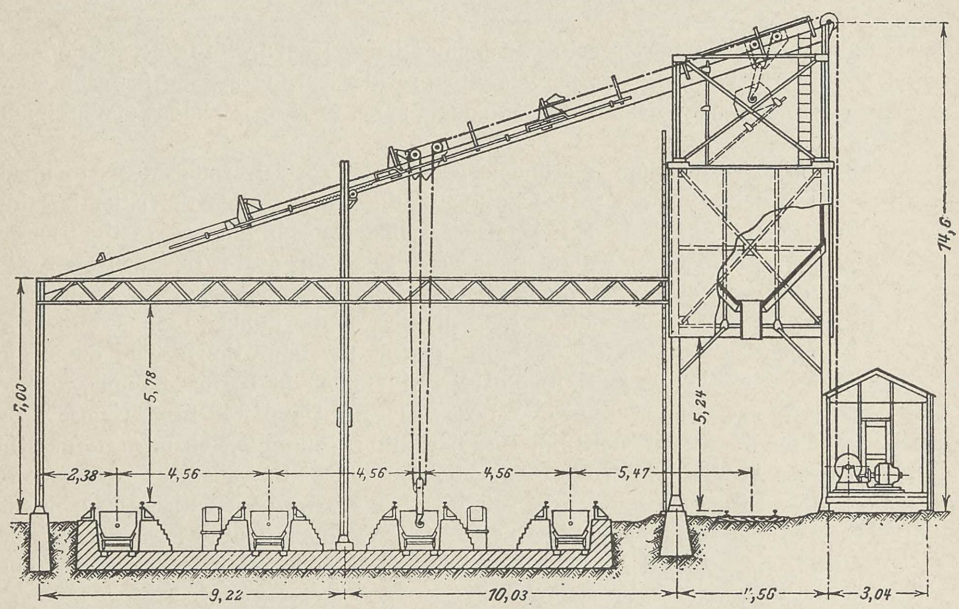

Fig. 881. Typical American Plant for the Removal of Ashes from Locomotives.
(These dimensions are in metres.)

formed in places only a few feet apart, little additional time is occupied in moving from one place to another. Under the old conditions the time taken was one and a quarter to one and three-quarter hours.

An elevator for coaling railway engines is illustrated and described in the chapter on Elevators, see page 29.

The Removal of Ashes from Locomotives.—This operation is often effected by the same mechanical appliances which supply the coal to the engine. A pit is frequently excavated between the rails, into which the cinders and ashes are dropped. In these pits there are sometimes receptacles which are removed when full by cranes of some kind, or the pits are without such receptacles and are emptied from time to time by

grabs. Fig. 881 shows an installation of the former kind employed at the shunting station of McKees Rock of the Pittsburg and Lake Erie Railway at Pittsburg, showing four lines, so that eight locomotives can clear their refuse at the same time. The diagram explains itself and shows how the receptacles are raised and tipped into an overhead ash and clinker receptacle from which they may be withdrawn into railway trucks. The installation is electrically driven and similar ones have been erected with extensions at both sides of the overhead ash silo.

CHAPTER XL

COAL, COKE, AND ASH HANDLING PLANTS FOR BOILER-HOUSES, GASWORKS, ETC.

The Handling of Coal.—The coal-handling equipment of a boiler-house usually consists of an elevator in conjunction with one of several types of conveyors, or of a gravity bucket installation combining the work of an elevator and conveyor. In general, slow speed machinery is recommended for such work, as it is more immune from breakdowns, has a longer life, and smaller maintenance expenses; on the other hand, the initial cost of such machinery is enhanced.

The driving mechanism should be substantial and yet as simple as possible. It should be borne in mind that the detail of construction of any one type of conveyor, important as it may be, is not the all-important factor, but rather the general scheme of the equipment and the design in its broader features should be adapted to the work required, so that the upkeep and working cost will be a minimum, and that the system as a whole may do the work as efficiently as possible.

The mechanical appliances for handling coal and ashes have been fully described in the previous chapters, but the bunkers holding the coal for immediate use above the boilers justify more than a passing notice.[1]

Ordinary rectangular hopper-bottomed bunkers are well known and frequently used, but the type of self-cleaning suspension bunker, either of boiler plates or reinforced concrete, require a few general remarks. Such bunkers have come to the fore of late years, and are likely to be used universally in installations in the future. The construction is very simple. From two main supporting girders steel straps are suspended at close intervals, and they are covered on the inside by steel plates, the steel straps taking the full weight of the bunker and contents and transmitting it to the longitudinal girders on each side. The maintenance of a steel plate bunker is comparatively high on account of corrosion, and hence the reinforced type has been introduced. With this latter system the steel straps forming the support are laid with ferroinclave (a special crimped steel sheet) or other reinforcements, with an inside lining of cement and an outside cement sheathing, the ferroinclave sheets forming the reinforcement for the concrete linings. Such bunkers are practically indestructible. Fig. 882 gives an illustration of such a bunker in the general power plant of the United States Navy Yard at Norfolk, in conjunction with a travelling weighing hopper for the coal distribution from the bunkers.

The required capacity of bunkers depends upon the interval during which the supply may possibly be interrupted, but generally provision is made for no longer a period than one week, and longer interruptions may be provided for by stock heaps in close proximity to the boiler-house, from which the bunkers may be replenished.

Coal bunkers of large capacity were formerly often placed in a separate building alongside the boiler-house, or the retort-house of gasworks, but the great advantage and saving in labour in having the bunkers suspended above the boilers or retorts—to feed them by

[1] See also the introductory remarks in Chapter XLI., "Storing of Coal and other Minerals in Stock Heaps and Silos."

gravity instead of shovelling the coal up from the floor when stoking—is too obvious to require further comment. When once a week's supply is in suspension above the boilers or retorts no interruptions, owing to accidents to the conveying or elevating machinery, can occur, and there is time to repair breakdowns.

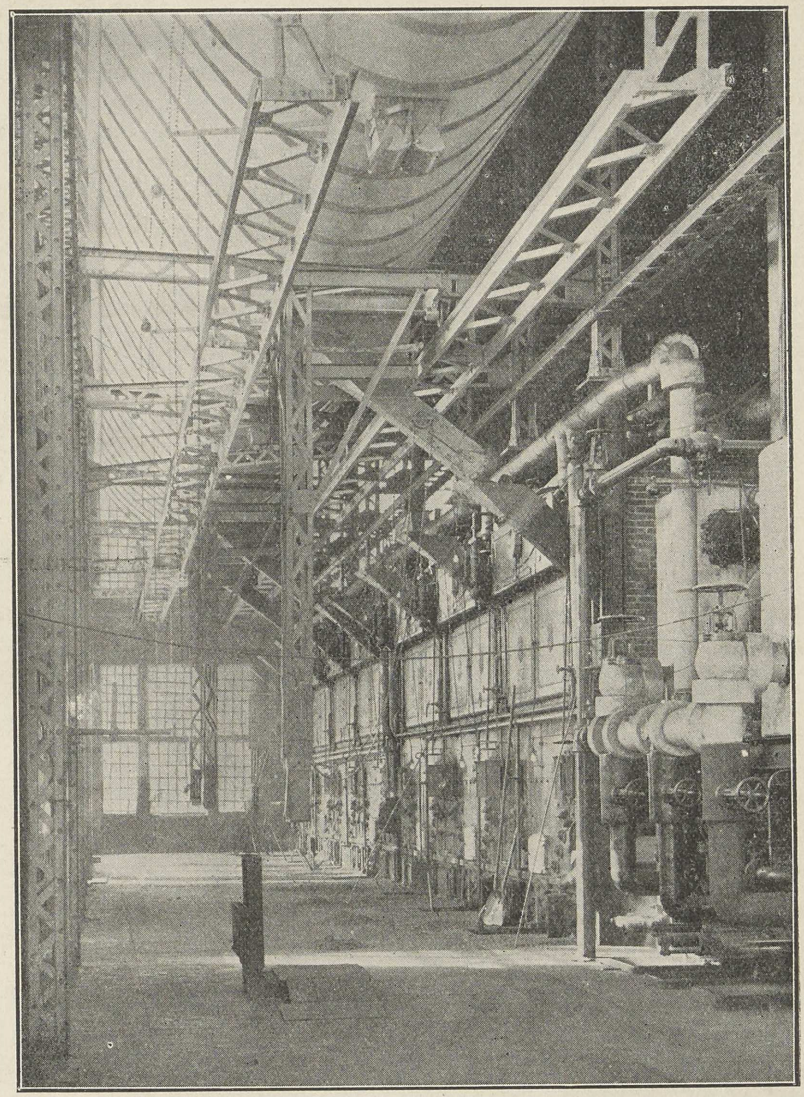

Fig. 882. Suspended Coal Bunker in Boiler-House.

The Handling of Ashes and Clinkers.—This is a far more difficult problem than that of moving the coal, owing to the abrasive nature of ashes and clinkers. They may also be very hot or dripping wet. Their cutting nature causes excessive wear on machinery of any type which may be employed for moving them, and if hot they are the cause of distortion of such parts of the machines which are not of cast iron, in addition

to which they may cause fire in the ash bunkers, or even explosions, if these receptacles are closed and thus prevent the escape of gases. Wet ashes damage mechanical conveyors and will not deliver readily, whilst pneumatic installations will not handle them at all, and finally in cold climates the wet ashes will freeze together in the bunkers, making their discharge into trucks impossible, unless the bunkers are fitted with heating apparatus.

There is, however, no apparent reason why the ashes should be either too hot or too wet to be handled in suitable conveyors in well-managed establishments. If for some reason or other the ashes should be too hot or sopping wet, they can be handled intermittently by skips or mono-rails, or by the car and skip system which is advocated by the R. H. Beaumont Co., of Philadelphia. This consists of a hopper on rails pushed either by hand or electricity, which collects the ashes from hoppers under the boilers, and an electric skip car to raise and discharge them into overhead bunkers. Of course the

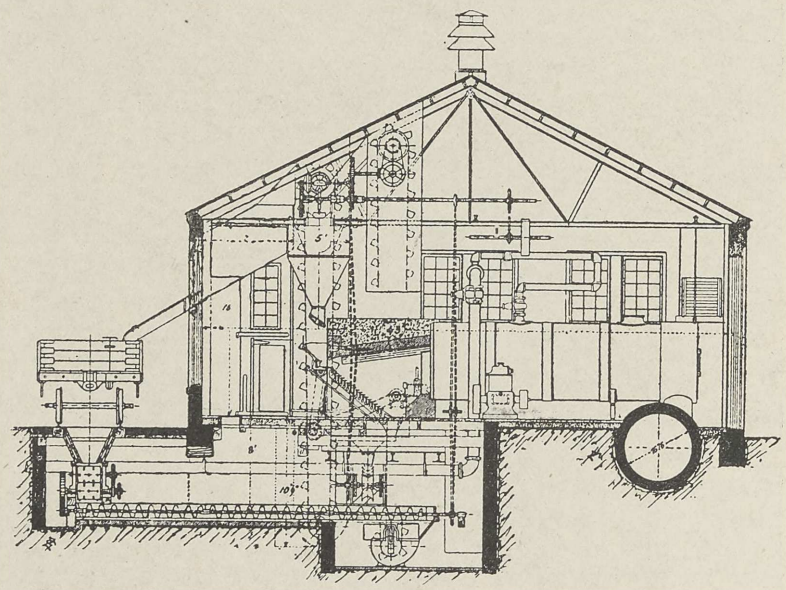

Fig. 883. Cross Section through Coal-handling Plant at the Juniata Works, Altona, Pittsburg.

system will answer equally well for all ashes in all conditions. If the local conditions are favourable the ashes may be collected in a hopper under each boiler and at intervals discharged into railway trucks which pass beneath.

Ash bunkers are generally square or cylindrical with a hoppered base, and if closed they should be ventilated, if there is a possibility of the ashes arriving hot, in order to guard against explosions.

The Use of Telphers in Gasworks and Power Stations.—Telphers fitted with a grab or clam-shell bucket are frequently used when handling coal, and with special tipping receptacles when handling coke. If the material to be handled is coal, it can be elevated from the cars, pits, stock heaps or barges, and with rehandling or retransferring, can be transported to the storage yard, to elevated hoppers, to the boiler room or to the furnace door. The coal can be raised and carried from the storage yards by the same clam-shell buckets to the boiler room. Electricity, through the telpher, hoist and bucket, does all the work, one telpherman the directing.

BOILER-HOUSE INSTALLATIONS

Coal-handling Plant at the Juniata Works, Altona, Pittsburg.[1]—This is illustrated in Figs. 883 and 884, and is probably one of the earliest installations of its

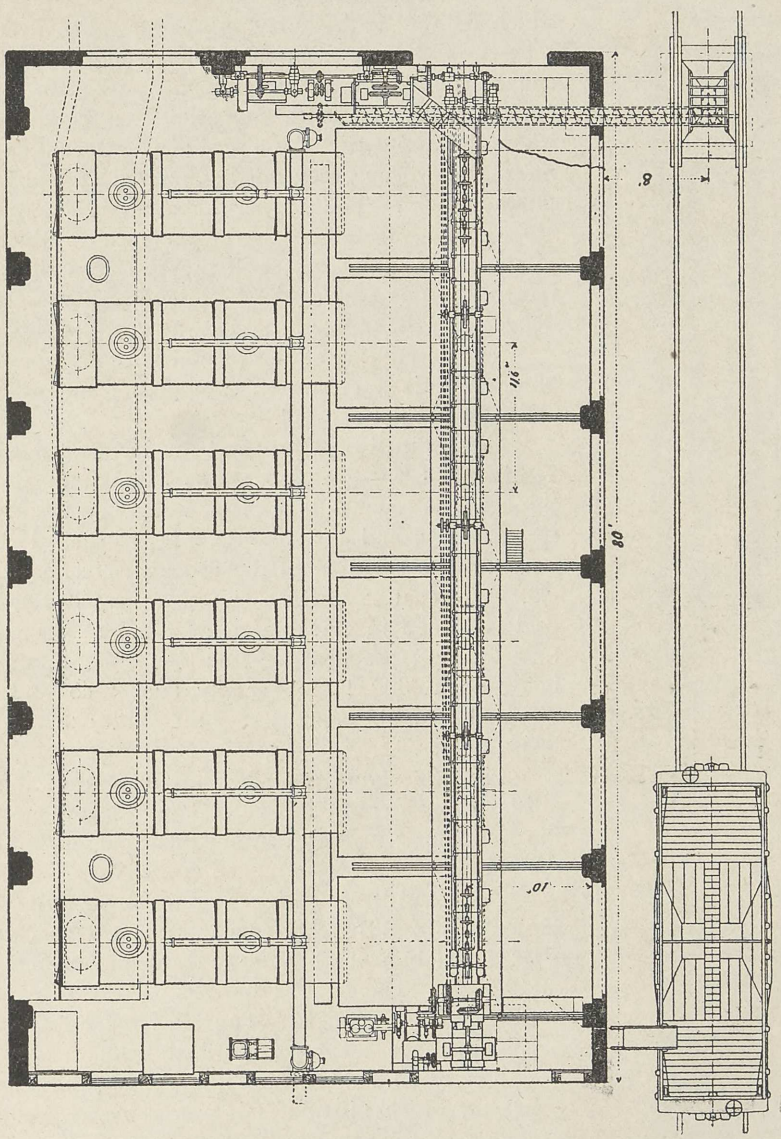

Fig. 884. Plan of Coal-handling Plant at the Juniata Works, Altona, Pittsburg.

class, the worm conveyor, which is now almost obsolete for such purposes, being here used for taking the coal from the railway trucks to the boiler-house.

This plant is designed to feed six boilers of 150 H.P. each, simultaneously clearing away the ashes. It absorbs 25 H.P., and since its erection only two men have been

[1] The author is indebted to Professor Buhle, Technische Hülfsmittel, for the following description.

required for the boilers. The coal is discharged from the railway trucks into a hopper over a coal-breaker, in which it is reduced to the size of road metal, before being carried by a worm conveyor to one of the elevators (see accompanying illustration). It is then elevated to the top of the building, where it is deposited in a push-plate conveyor which delivers it to the hoppers over the boilers. The ashes and clinkers from the boilers slide down through suitable outlets on an underground push-plate conveyor, and are conveyed to the opposite side of the building, where they are carried by a second elevator into a special receptacle, whence they can be lowered at intervals into railway trucks. The hopper for ashes is shown in the cross section, as well as the movable shoot which leads to the railway trucks. It will thus be seen that coal is received at one end of the building whilst the ashes are delivered to the railway trucks at the opposite end.

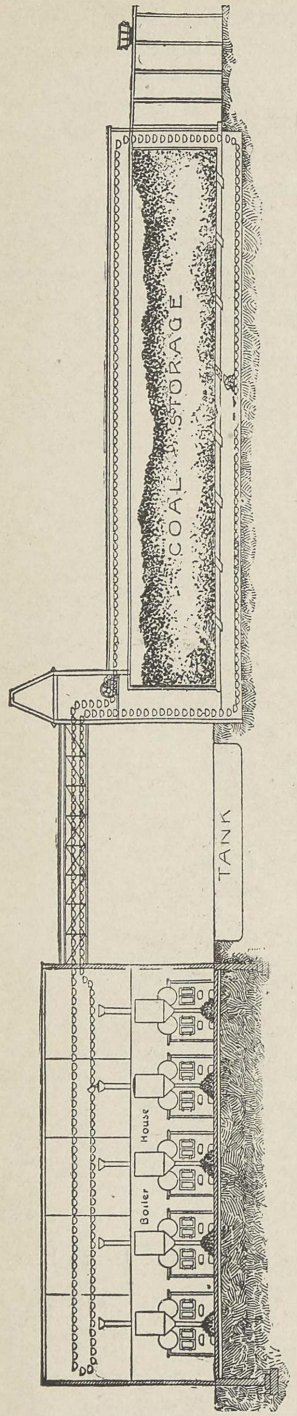

Fig. 885. Coal-handling Plant at Fifty-Seventh Street Station, Brooklyn Heights Railroad Co.

The description of this plant has been given because of its historic interest. In a modern plant, worm conveyors would not be used.

Coal-handling Plants at the Brooklyn Heights Railroad Co.—Fig. 885 shows a longitudinal section through one coal-handling plant, which consists of a coal store, gantry, and boiler-house. It is installed at Fifty-Seventh Street Station of the Brooklyn Heights Railroad Co. The coal store has a capacity of 8,000 tons. The coal is loaded in trucks and conveyed to the store by rope haulage, the distance from the store to the wharf being about 800 ft. A gravity bucket conveyor takes the coal from the store across the gantry to the boiler-house proper.

Fig. 886 shows a further installation of the same railway company, but in this instance the top portion of the building is occupied by a large coal bunker, whilst the boilers beneath are arranged on two floors.

Coal-handling Plant at the Brooklyn Waterworks.—Fig. 887 represents this plant, which includes a large coal bunker of 2,000 tons capacity erected above the boilers. The coal is brought to the spot by self-emptying railway trucks. The receiving hopper is connected with the coal-breaker, which reduces the coal to a size of $2\frac{1}{2}$ in. cube before it enters the gravity bucket conveyor, which distributes it over the whole store. It will be seen from the illustration that although the conveyor runs the whole length of the boiler-house, the feeding end changes its direction and runs at right angles to the main length of the conveyor. The ashes from the boilers are removed by narrow gauge self-emptying railway trucks.

Coal-handling Plant at the King's County

Electric Light and Power Station, Brooklyn, U.S.A.—A longitudinal section of this installation is shown in Fig. 888. Here again the coal store is above the boilers. The coal is received by water, and is hoisted from the barge to a height of 125 ft. by a grab. It is then broken to about the size of road metal, after which operation it is weighed, then removed to the store by the "Hunt" automatic railway. There is an outlet from the coal bunker over each boiler.

Coal-handling Plant at the United Tramway Power Station, Dublin.—

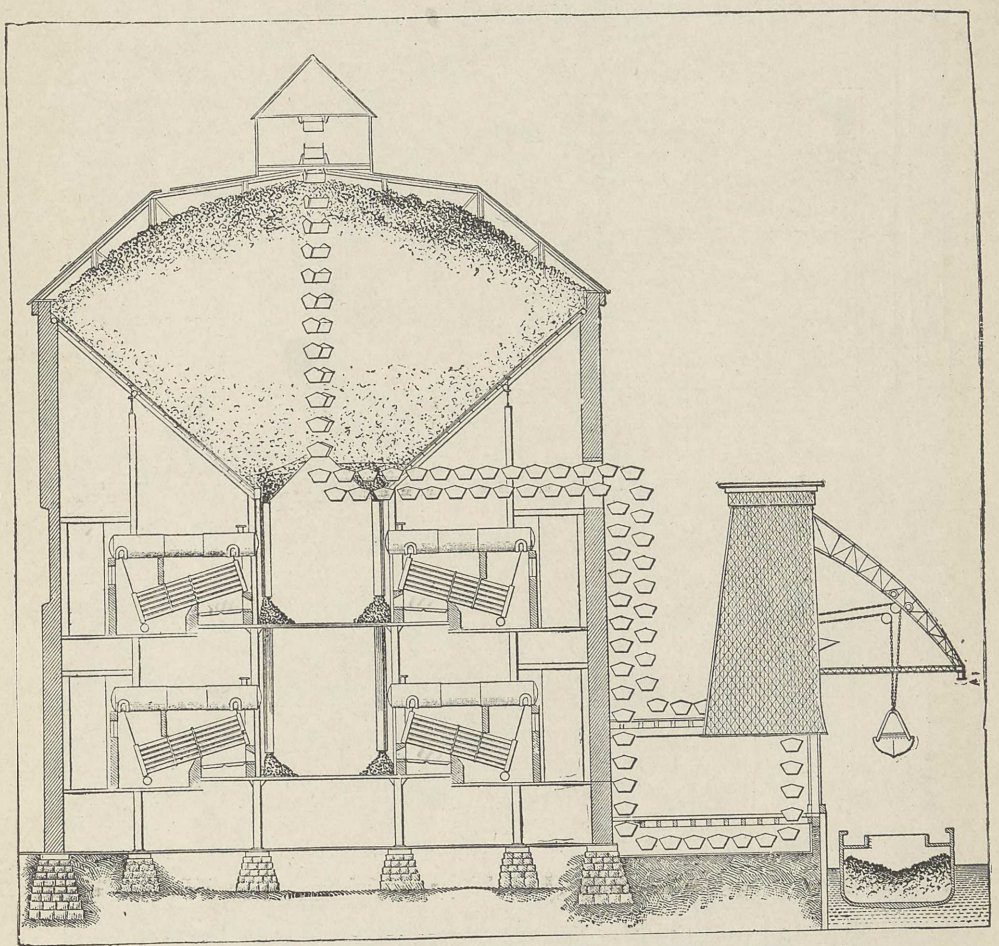

Fig. 886. Coaling Plant at Eastern Station, Brooklyn Heights Railroad Co.

This plant is illustrated in Fig. 889. The coal is taken from the barges by means of a grab, and delivered into weighing machines; after weighing it is passed through a coal-breaker, which reduces it to a size not exceeding $2\frac{1}{2}$ in. cube. There are two coal stores, the first of which is filled by Hunt's automatic railway, while the coal store over the boilers is fed by an ordinary gravity bucket conveyor from the first-mentioned store. The ashes from the boilers are lifted by the same conveyor and deposited in a bin as shown, and from this point they can be disposed of by means of a spout.

The boilers are fed by automatic stokers, each of which is fitted with an automatic weighing machine to keep a record of the coal consumed.

Coal-handling Plant of the Central London Railway Co. at Shepherd's Bush.—This is a similar installation to those previously described, and one gravity

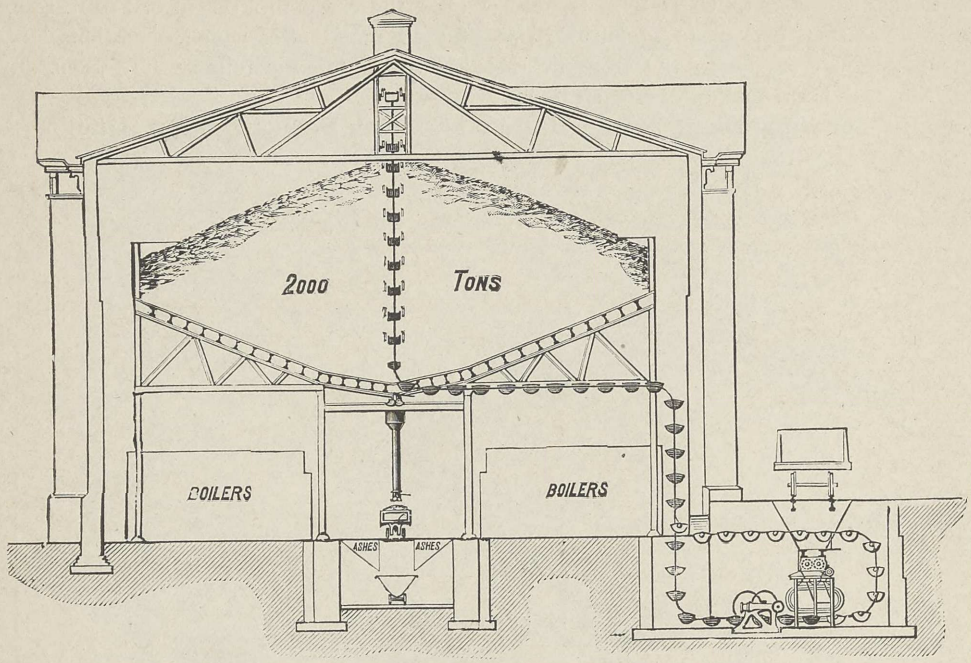

Fig. 887. Coal-handling Plant at the Brooklyn Waterworks.

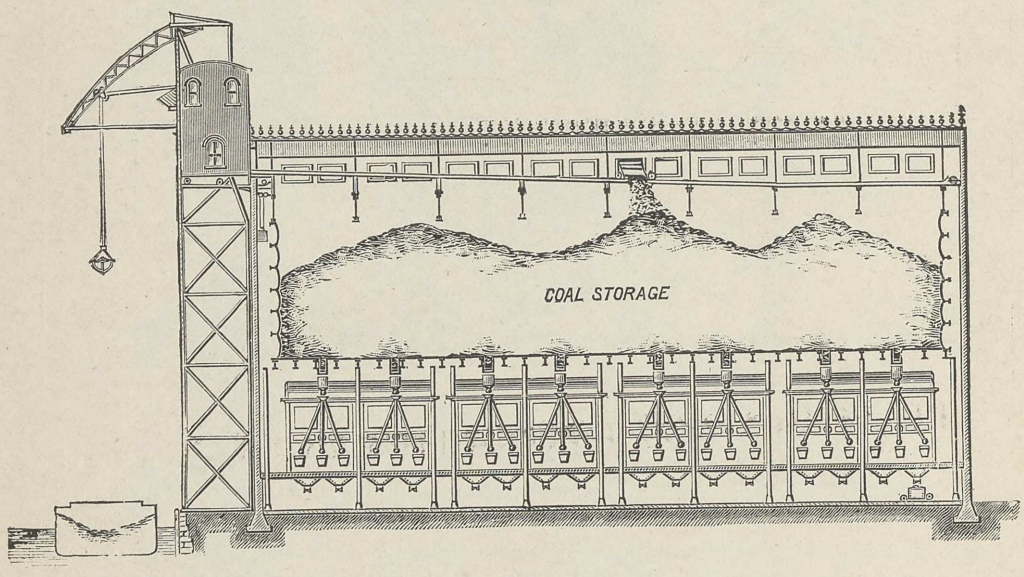

Fig. 888. Coal-handling Plant, King's County Electric Light and Power Station, Brooklyn.

bucket conveyor handles both the coal and the ashes. The ashes are deposited in the end bunker, so that they can be shot into the same railway trucks which bring the coal, as will be seen from Fig. **890**.

Zimmer Conveyor for Feeding Boiler-Houses.—Fig. **891** shows a boiler-house installation in which a Zimmer patent conveyor is used for bringing the coal to the boiler-house, whilst a similar conveyor is used in a tunnel underneath for conveying away the ashes. Very frequently this conveyor is used in conjunction with automatic stokers.

An interesting installation for feeding boiler-houses with small coal is shown in Fig. **892**. The conveyor employed is the Zimmer conveyor, which receives its load from another conveyor of the same type running at right angles to it at the far end. The conveyor is fixed on the boiler-house roof, and the coal is delivered by shoots to the boiler-house floor.

This installation is in use at the Shipley Collieries, Derby.

A Typical Babcock & Wilcox Equipment of an Installation of Coal and Ash Bunkers and Stock Yard.—Fig. **893** represents an arrangement of outside coal storage with delivery into, and discharge from, the same, by means of a gravity

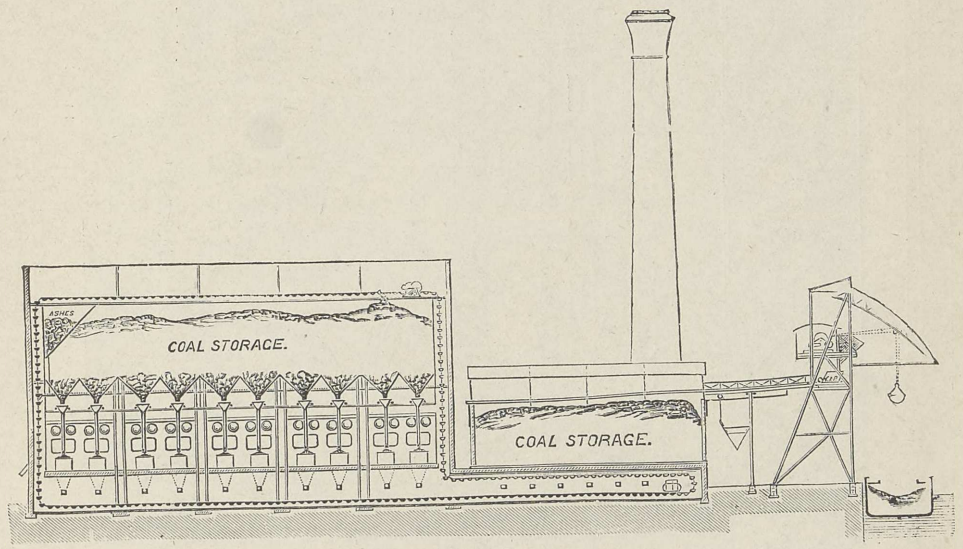

Fig. 889. Coal-handling Plant at the United Tramway Power Station, Dublin.

bucket conveyor, the discharge from the silo being into the overhead bunkers. This arrangement requires very little description, the drawing being self-explanatory. Briefly, however, it is as follows :—

Coal is delivered from the trucks into a receiving hopper, fed into the conveyor by means of a rotary filler, and either delivered into the coal storage outside, or carried inwards and delivered into the overhead bunkers.

Ashes can be taken from the basement under the boilers, and delivered into the ash bunker shown midway in the conveyor system.

In discharging coal from the store, a series of valves are operated by levers, and allow the coal to flow by gravity into a travelling rotary filler, which serves all the openings. This filler supplies and regulates the coal to the conveyor, which rises, and passing horizontally, delivers into the overhead bunkers. A little study of the illustration will show the process clearly.

Coal-handling Plant at the Avonbank Power Station, Bristol.—Figs. **894** and **895** show the general arrangement of this installation of the Bristol Corporation.

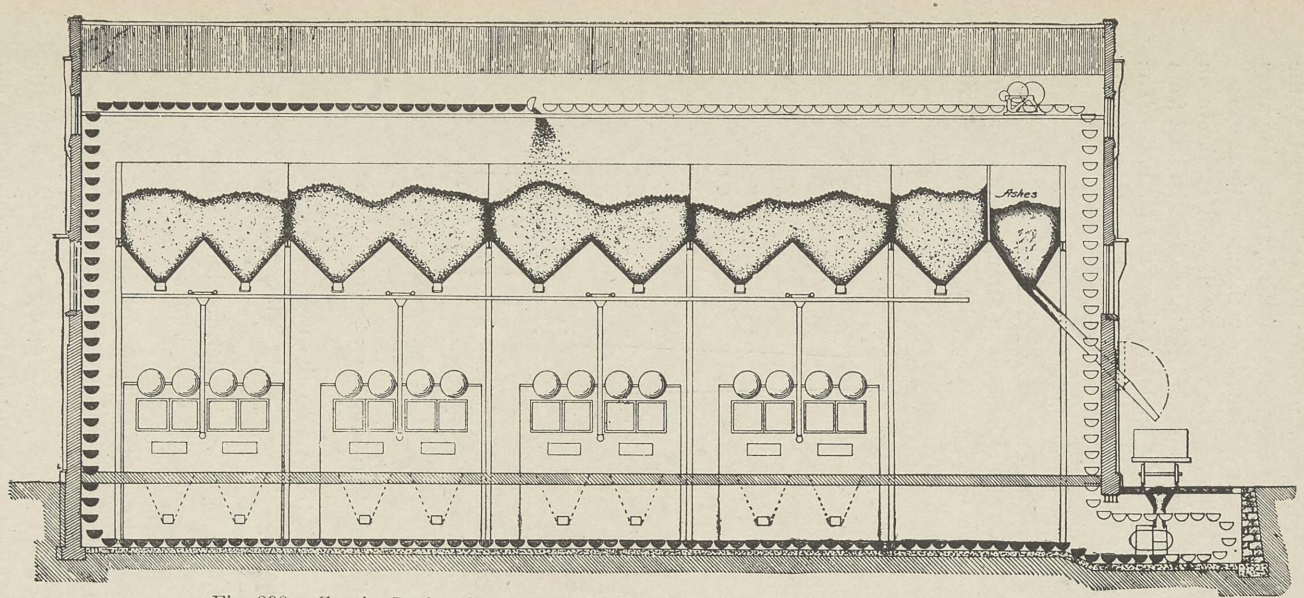

Fig. 890. Gravity Bucket Conveyor at the Shepherd's Bush Station, Central London Railway.

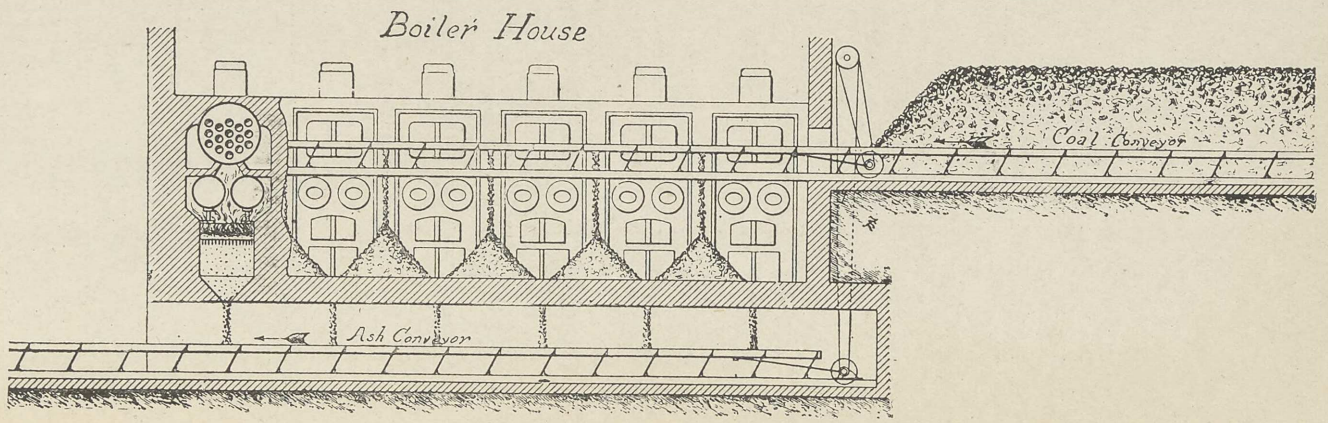

Fig. 891. Zimmer Conveyor as used in Boiler-Houses.

A combination of a Hunt automatic railway and a gravity bucket conveyor is used in this plant, the former being employed for carrying the coal from the receiving hopper and weighing machine on the river side to the chute which feeds the gravity bucket conveyor.

The automatic railway wagon receives coal from a weighing machine on the tower, descends by gravity along the incline to a filler pit, into which it deposits its load and returns by means of the accumulated energy as already described.[1] From this point the coal is dealt with in the ordinary way, being fed through the automatic filler, after which it is carried upwards and inwards and dumped into the overhead bunkers, whence it is discharged by chutes into the stoker hoppers, the capacity being about 40 tons per hour.

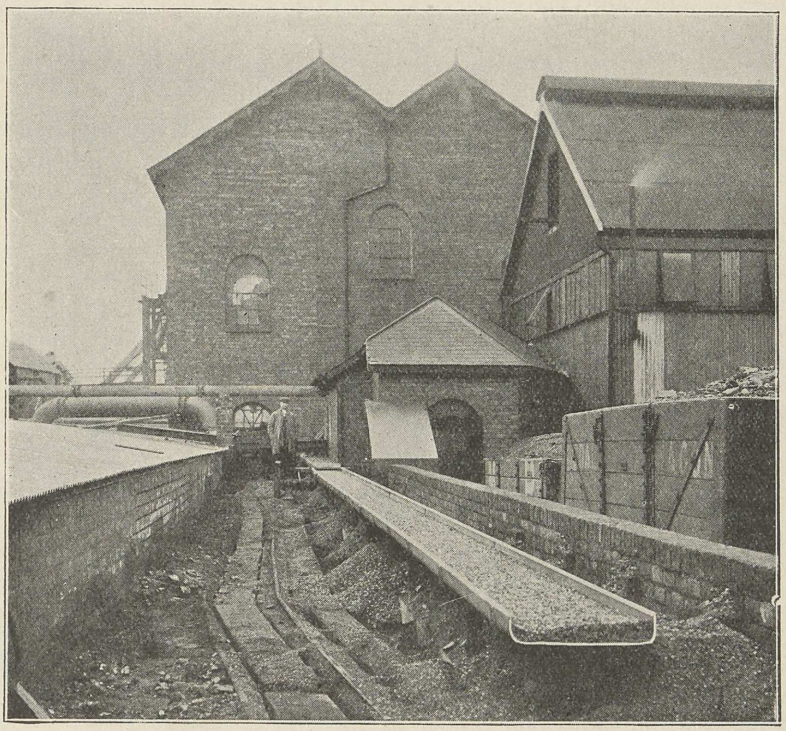

Fig. 892. Zimmer Conveyor for Feeding Boiler-Houses, as used at the Shipley Collieries, Derby.

As the coal used at this station is of a specially fiery nature, the plant has been provided with an arrangement for retrimming, as shown in the illustrations. To this end the coal bunker is fitted with four chutes (three of which are shown in the illustration), through any one of which the coal when desired may be discharged into the conveyor by means of the movable filler, which is placed over the latter on the track beneath the boiler-house floor.

Coal-handling Plant at the Aston Manor Electric Power Station.—A gravity bucket conveyor is used here, the normal capacity of which is 22 tons per hour. This can be increased if necessary to 25 tons, and all the ashes can be discharged at any time without interference with the coaling.

Briefly, the method of coal and ash handling is as follows :—

[1] For further description of the "Hunt" Automatic Railway, see page 511.

The coal (small) is delivered in barges alongside the filler pit, situated under the ash tower, and is shovelled by three or four men direct from the barges into a longitudinal receiving hopper, at the rate of 4 to 5 tons per hour per man, costing about 2d. per ton in wages. From the receiving hopper the coal is delivered by the filler into the conveyor buckets passing beneath. It is then carried inwards, ascending to the upper strand over the bunkers, where it is automatically dumped at any desired point. The buckets, after being dumped, descend and return under the boilers, receiving the ashes by shovelling directly from the ash pits. They are then carried outwards, towards and over the ash hopper where they are dumped, and descend to the filler pit again to be charged with coal. The ashes can be retained in the hopper until convenient times for discharging, which operation can either be effected into barges or carts as desired.

The motive power is supplied by an electro-motor of the British Thomson-Houston enclosed type, which is geared directly to the countershaft of the conveyor.

This installation is the work of Messrs Babcock & Wilcox, Ltd.

Coal and Ash Handling Plant of the Powell Duffryn Steam Coal Co., Aberaman, South Wales.—Figs. 896, 897, and 898 show a system of overhead bunkers and the conveyor for serving them. The first half of the plant was supplied in 1906 by Messrs Babcock & Wilcox, and the extension half two years later.

The arrangement is quite evident from a study of the illustration, and is in accordance with the general practice in such installations, the coal being delivered by wagons into a receiving hopper, and the conveyor taking the coal from there by means of a filler, elevating, and carrying it horizontally above the overhead bunkers, and delivering into any section as required. From these bunker divisions the coal is delivered by means of special valves and chutes into the stoker hoppers.

Ashes are dealt with by the same conveyor, being delivered into an ash bunker outside the main building, and taken from thence by carts or other conveyances.

The normal capacity of this conveyor is 40 tons of coal per hour, but it can be increased economically to 50 tons if necessary.

Coal-handling Plant and Store at the Buenos Ayres Grand Central Electric Power Station, Argentine Republic.—Fig. 899 represents a system of coaling boiler-houses direct from steamers or barges alongside the wharf.

Two gantry cranes, travelling parallel with the wharf, are capable of taking by means of grabs 1 ton charges of coal from the steamers or barges, delivering it into conveyors—carried on the horizontal girders of these gantry cranes—which in turn deliver the material into either one or other of a pair of conveyors marked B and B^1 on plan. These conveyors run in opposite directions, and both discharge over another pair of conveyors marked C and C^1 running at right angles to them. The conveyors B and B^1 are the patent tipping tray type (described on page 108), and have at certain times the further duty to perform of collecting coal from railway wagons underneath.

Two travelling cranes are carried by the gantries supporting these conveyors, which collect material from railway wagons on the ground line and deliver it into hoppers, to which they are yoked, these hoppers delivering the coal, and regulating the quantities, into conveyors B and B^1 which again deposit into conveyors C and C^1. These latter conveyors both deliver into and collect from the coal silo, but before being delivered into the silo the coal is broken and weighed automatically in its transit from conveyors B and B^1 to C and C^1.

In discharging from the silos conveyors C and C^1 deliver into two other conveyors D and D^1, travelling in a similar manner to B and B^1, in opposite directions to each other, and delivering, therefore, right or left according to requirements. These conveyors

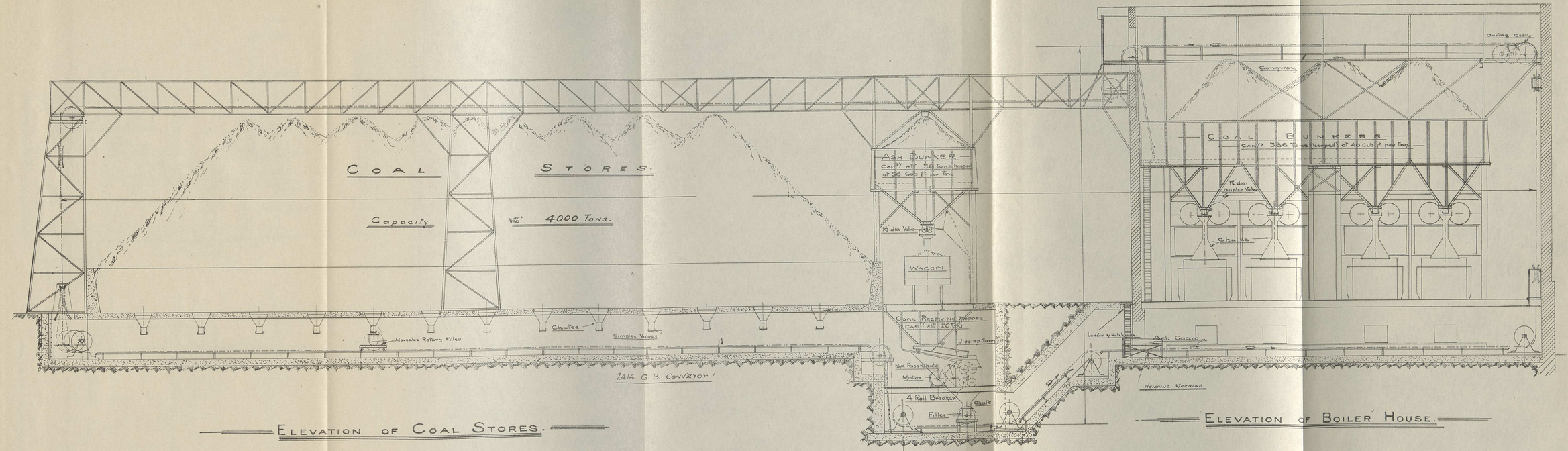

Fig. 893. A Typical Babcock & Wilcox Equipment of an Installation of Coal and Ash Bunkers and Stock Yard.

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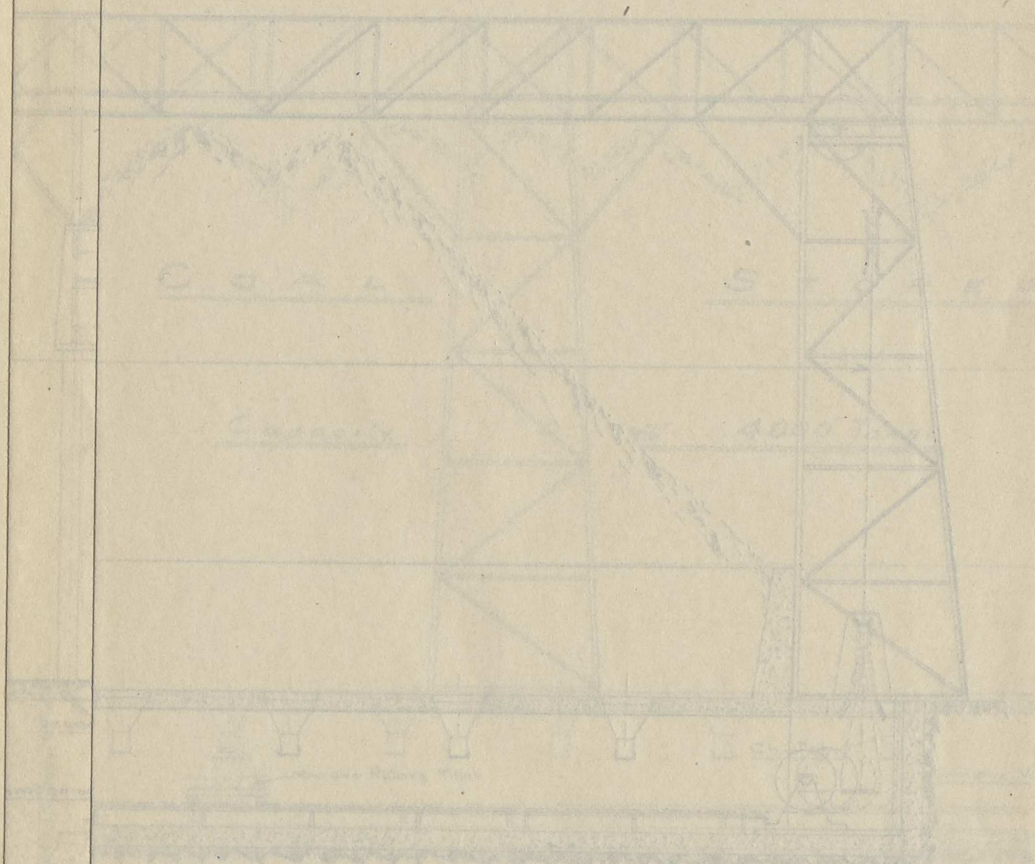

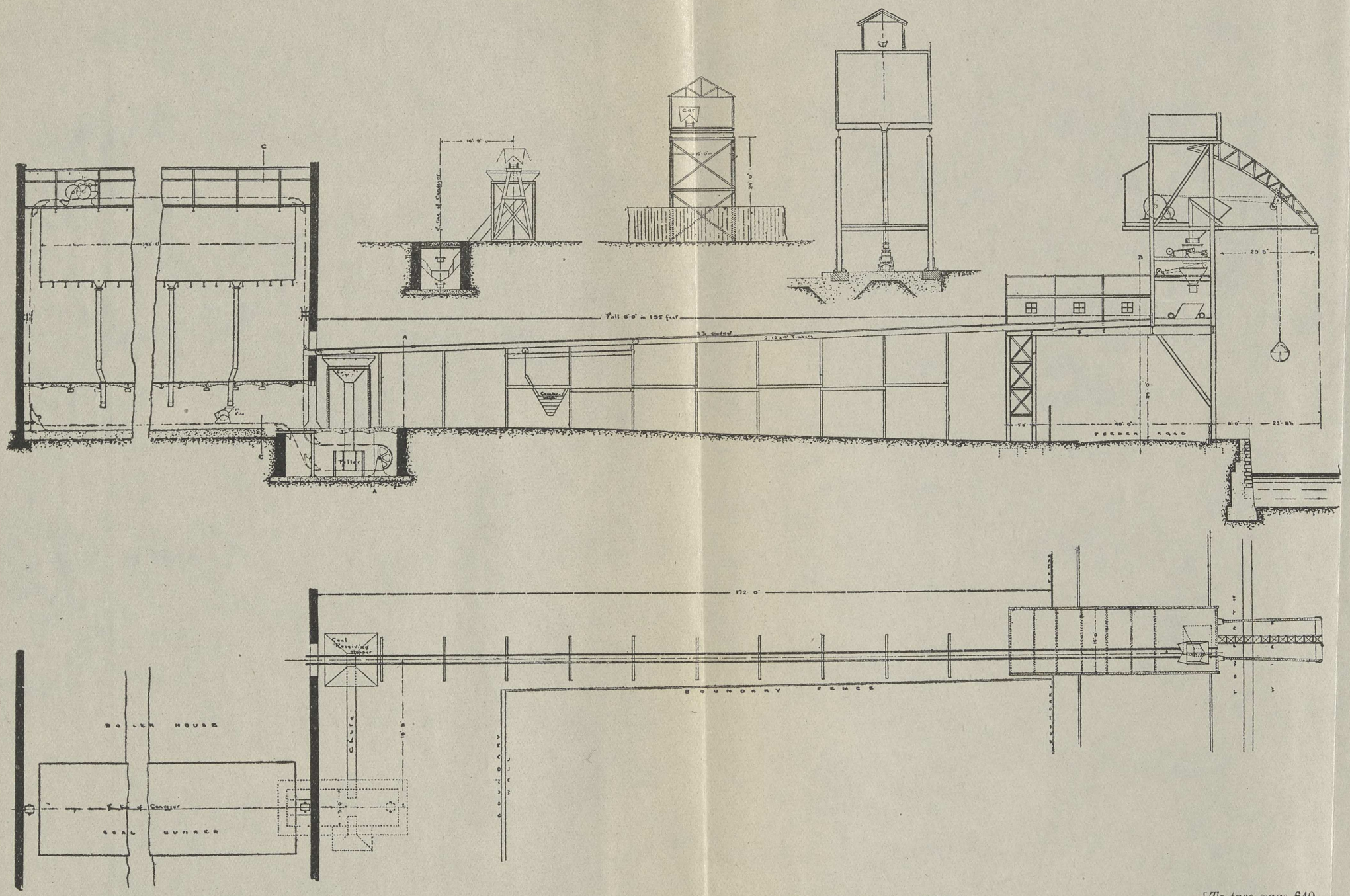

Figs. 894 and 895. Coal-handling Plant at the Avonbank Electricity Works, Bristol.

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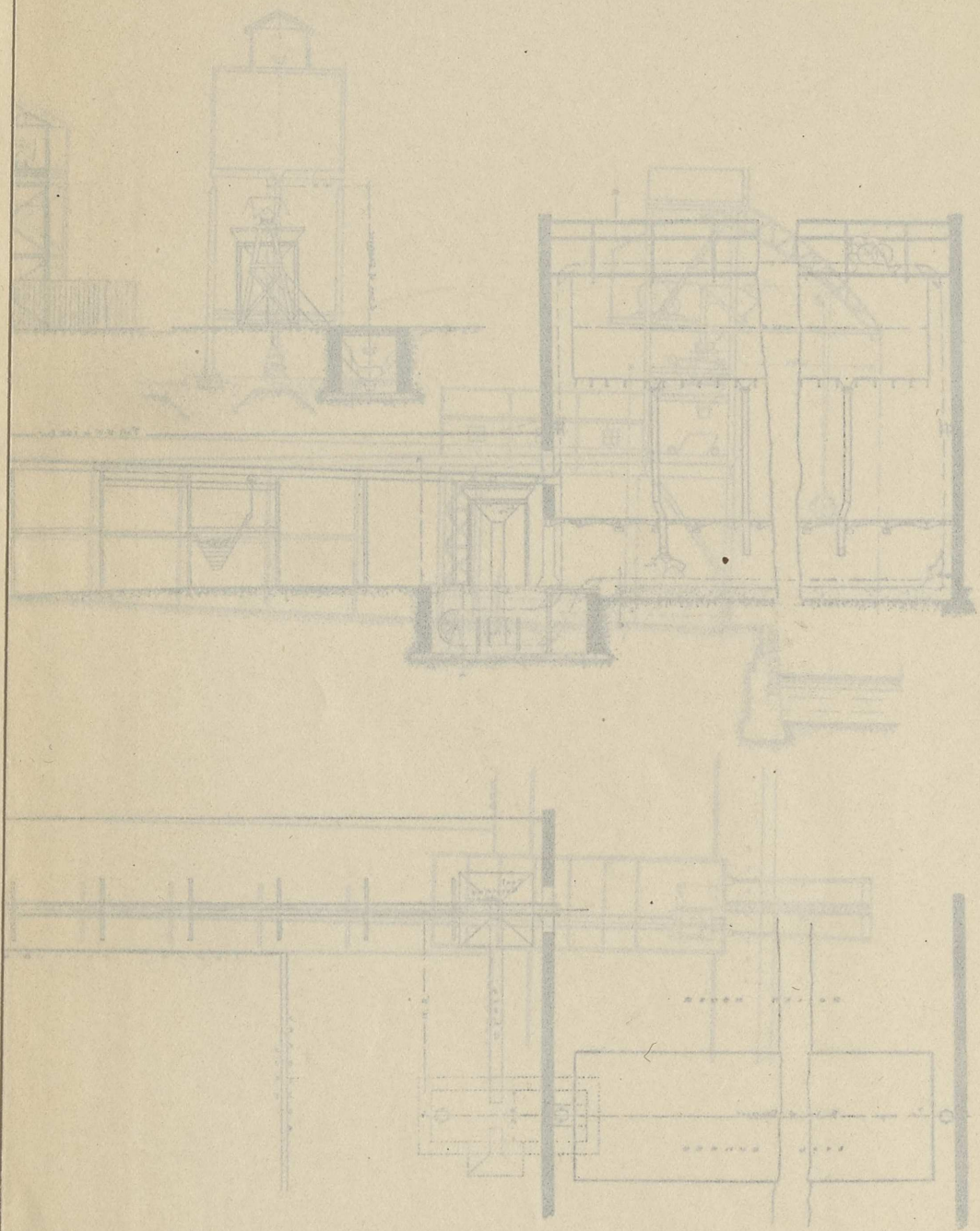
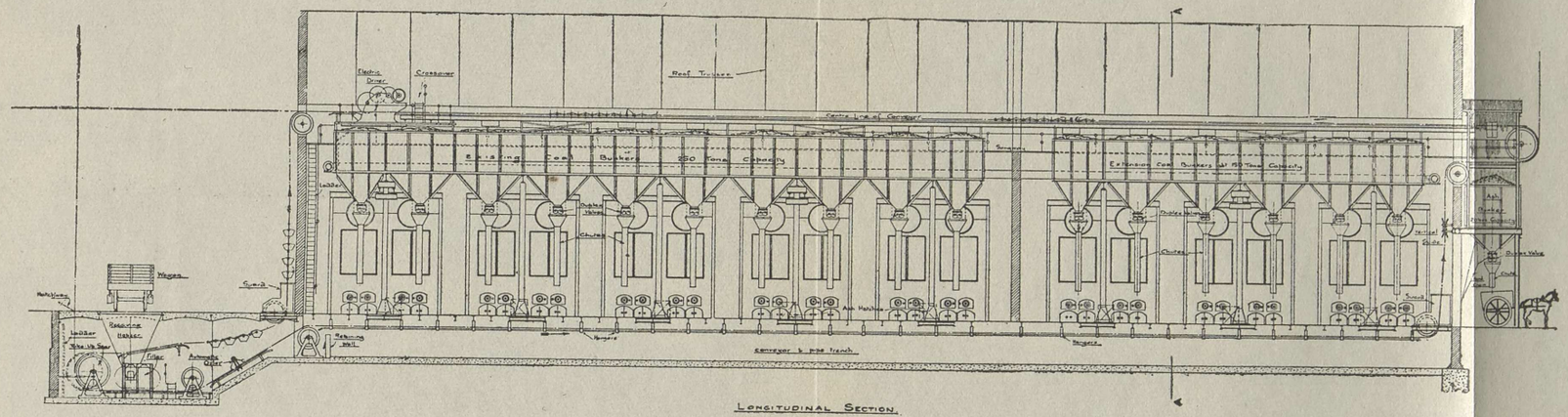
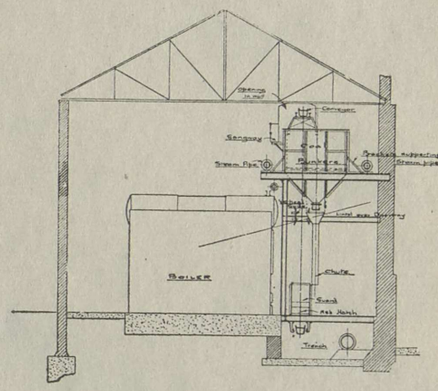
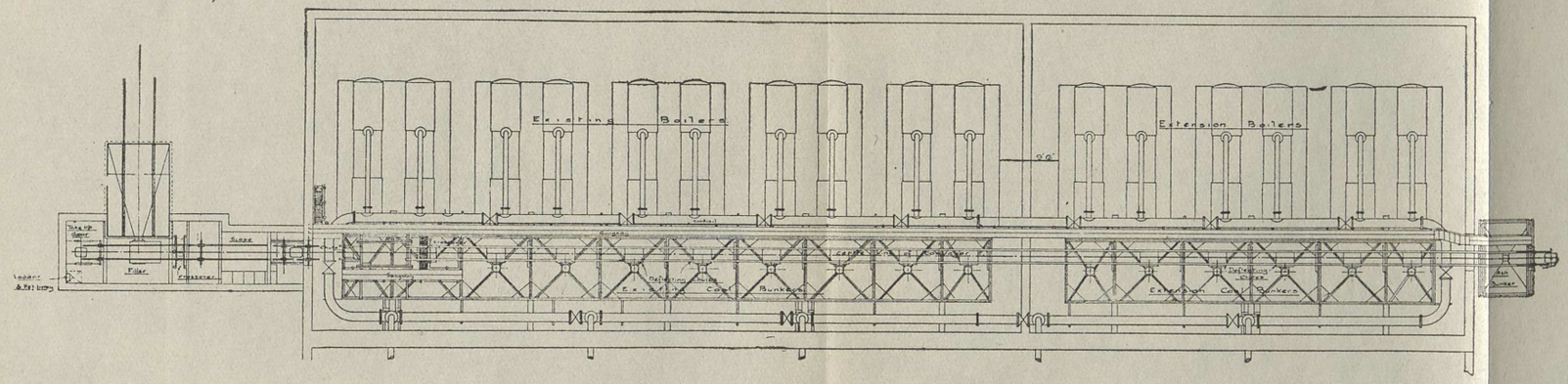




LONGITUDINAL SECTION.



SECTION ON A-A.



PLAN

Figs. 896, 897, and 898. Coal and Ash Handling Plant of the Powell Duffryn Steam Coal Company, Aberaman, near Aberdare, South Wales.
(Erected by Babcock & Wilcox, Ltd.)

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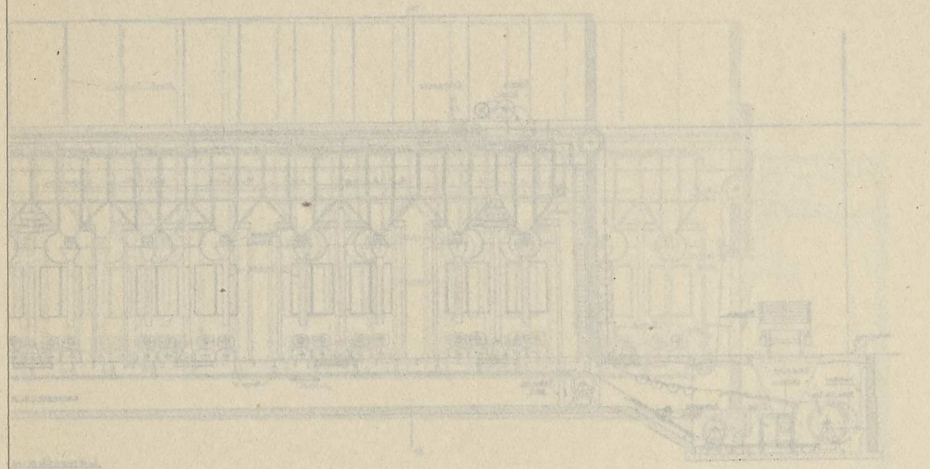

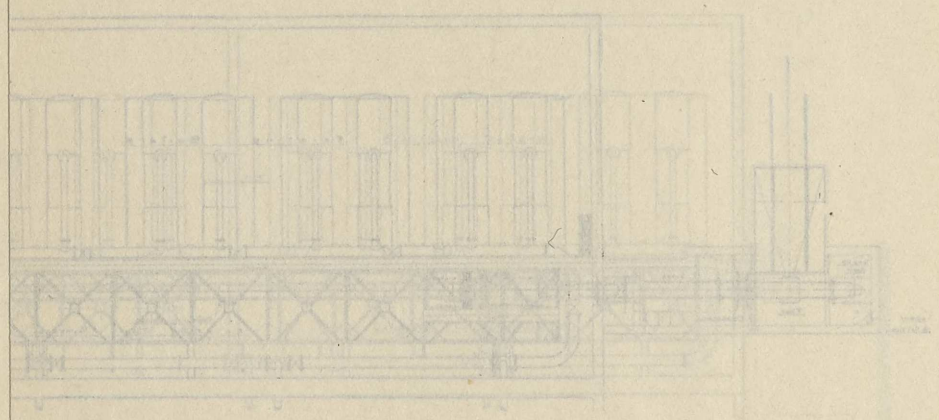

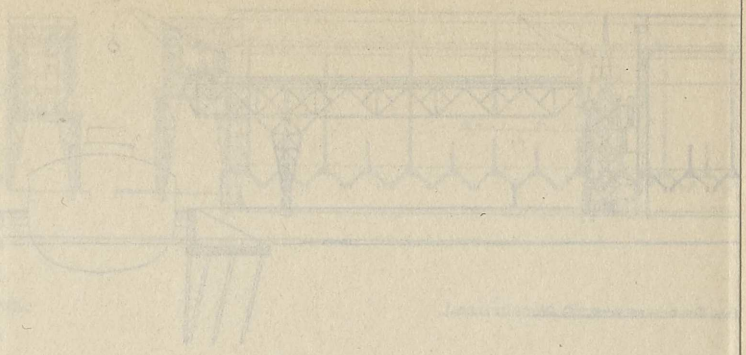

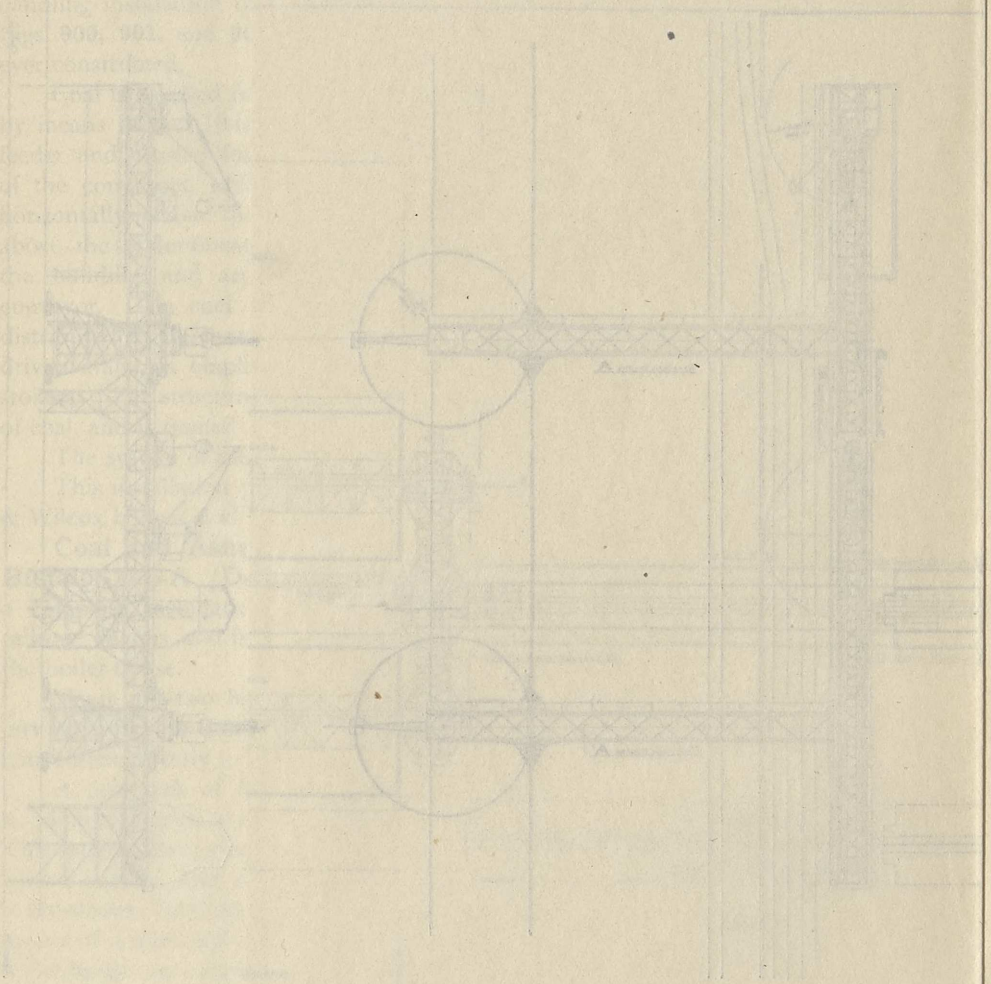

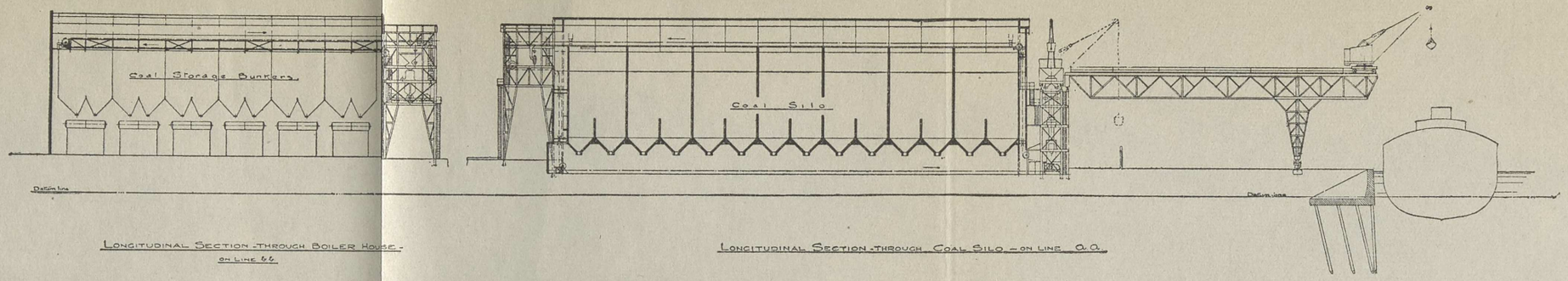

LONGITUDINAL SECTION THROUGH BOILER HOUSE — ON LINE b b

LONGITUDINAL SECTION THROUGH COAL SILO — ON LINE a a

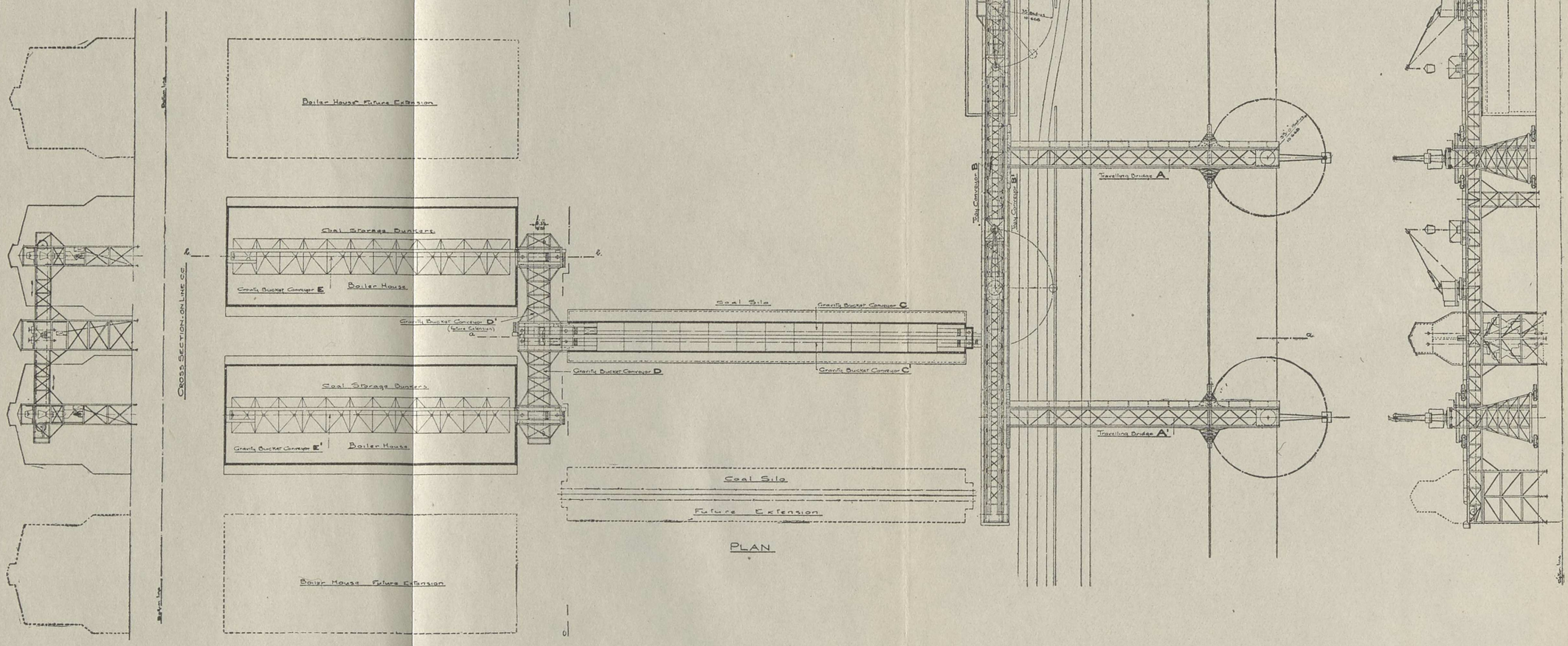

Fig. 899. Buenos Ayres Grand Central Electric Power Station, Argentine Republic.

General arrangement of Babcock & Wilcox Coaling Plant for Usina Grande, Buenos Ayres, comprising:—

2 Travelling bridges, **A** and **A1**, with 2 cranes and grabs. Capacity: each 50 tons per hour.
2 Patent tipping-tray conveyors, **B** and **B1**. Capacity: each 100 tons per hour.
2 Gravity bucket conveyors, **C** and **C1**. Capacity: each 100 tons per hour.
2 ,, ,, **D** ,, **D1**. ,, ,, 50 ,, ,,
2 ,, ,, **E** ,, **E1**. ,, ,, 50 ,, ,,

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deliver into overhead conveyors in the boiler-houses which supply the overhead bunkers.

The process then can either be direct from the ship into the overhead bunkers in the boiler-houses, or from the ship into the silo, afterwards to be delivered into the boiler-houses according to requirements.

The capacities of the various conveyors are given in the illustration, Fig. **899**.

This installation is by Babcock & Wilcox, Ltd.

Coal and Ashes Handling Plant at the Massachusetts Cotton Mills, Lowell, U.S.A. (Darley System).—The general arrangement of the coal and ashes handling installation of the Massachusetts Cotton Mills, of Lowell, U.S.A., is shown in Figs. **900**, **901**, and **902**. This is probably the largest pneumatic conveyor equipment ever constructed.

Coal is handled from the track hopper, some 600 ft. distant from the boiler-house, by means of two 10-in. section conveyors. Beneath the track hopper is an automatic feeder and crusher for delivering the coal at a predetermined rate to the two intakes of the conveyors, which rise vertically to the roof of the building, and then extend horizontally across the intervening buildings to two 45-ton receiving tanks mounted above the boiler-house, as shown. The two exhausters are located in the monitor of the building, and are so arranged that either exhauster can operate either suction conveyor. The coal can be dropped directly into one end of the storage bunker, or distributed by the motor-driven car. A 5-ton weigh-hopper, mounted on an electrically driven crane, is employed to draw the coal from the bunker and discharge it to the stokers. The structure is of steel; the bunker is of reinforced concrete, holds 5,500 tons of coal, and is framed in with the building columns.

The system of ashes handling may be readily understood from the illustration.

This installation provides for handling the coal and ashes of 10,000 H.P. Babcock & Wilcox boilers, and is the design of the Guarantee Construction Co., of New York.

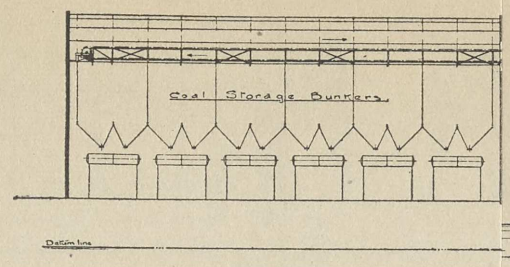
Coal and Ashes Handling Plant of the Pierce-Arrow Motor Car Co., Buffalo, U.S.A. (Darley System).—The diagrams, Figs. **903**, **904**, and **905**, show a complete installation, using Darley pneumatic conveyors, for handling coal from railway wagons and from outside reserve storage, as well as dealing with the ashes from the boiler-house.

There are two batteries of boilers, and an 8-in. suction pipe extends from the ash pits to a 60-ton storage tank located over the adjacent siding, to deliver ashes as convenient directly to cars for removal from the yard.

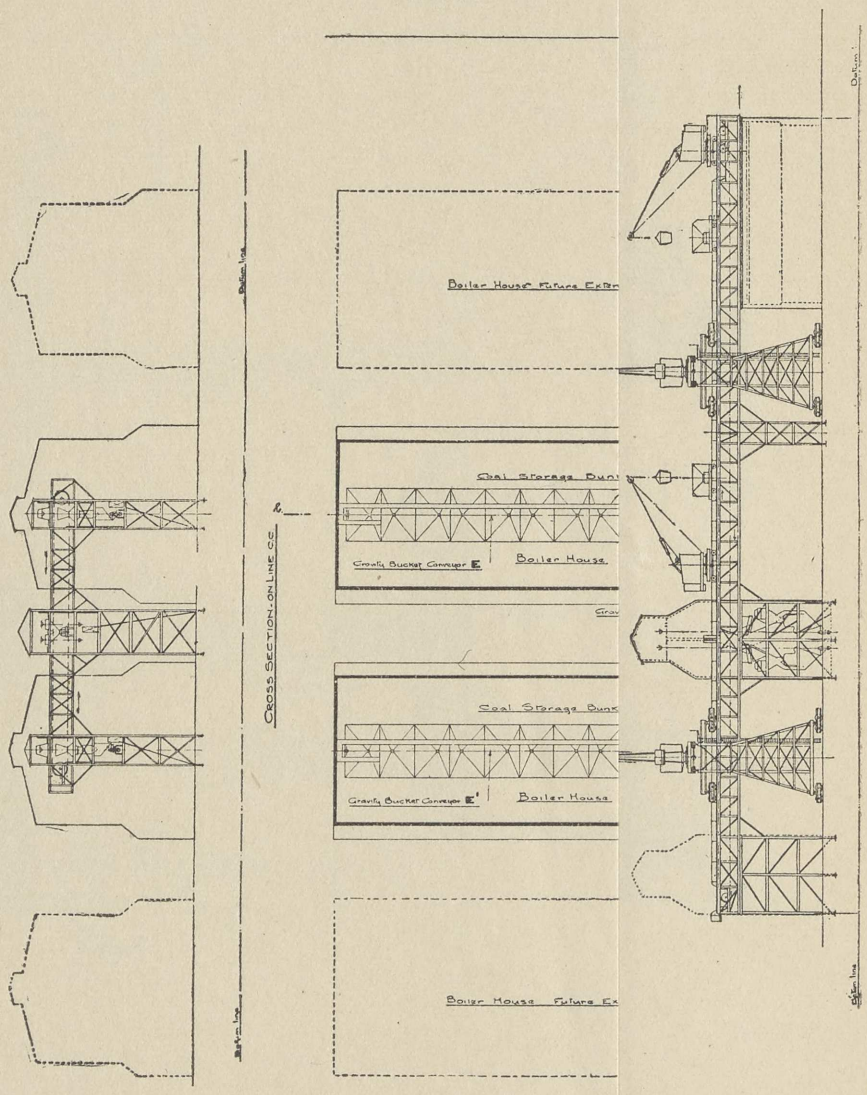
A coal tank of 100 tons capacity is mounted at one end of the boiler-house, and is connected with a track hopper on the siding on which coal cars enter the premises. This suction duct connects, by means of a swivel elbow at the foot of the vertical riser, with a suction line extending out beneath the reserve coal storage. Ordinarily, coal is transferred from the 100-ton storage to the overhead bunker in the boiler-house by means of a motor-driven car, but the track for this car continues out of doors beyond the boiler-house on a trestle to provide for the reserve storage heap. For the boiler stokers a travelling hopper is employed, provided with scales, as shown in section. Both the coal and ash conveyors are operated by a single turbine-driven exhauster, shown in one corner of the boiler-house.

This installation is also the design of the Guarantee Construction Co., of New York.

Ashes-handling Plant of the New South Wales Government Tramways, Sydney, Australia (Darley System).—Figs. **906** and **907** show an



LONGITUDINAL SECTION THROUGH BOILER HOU
ON LINE 66



2 Travelling bridges, A and A
per hour.
2 Patent tipping-tray conveyor

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The process then can either be direct from the ship into the overhead bunkers in the boiler-houses, or from the ship into the silo, afterwards to be delivered into the boiler-houses according to requirements.

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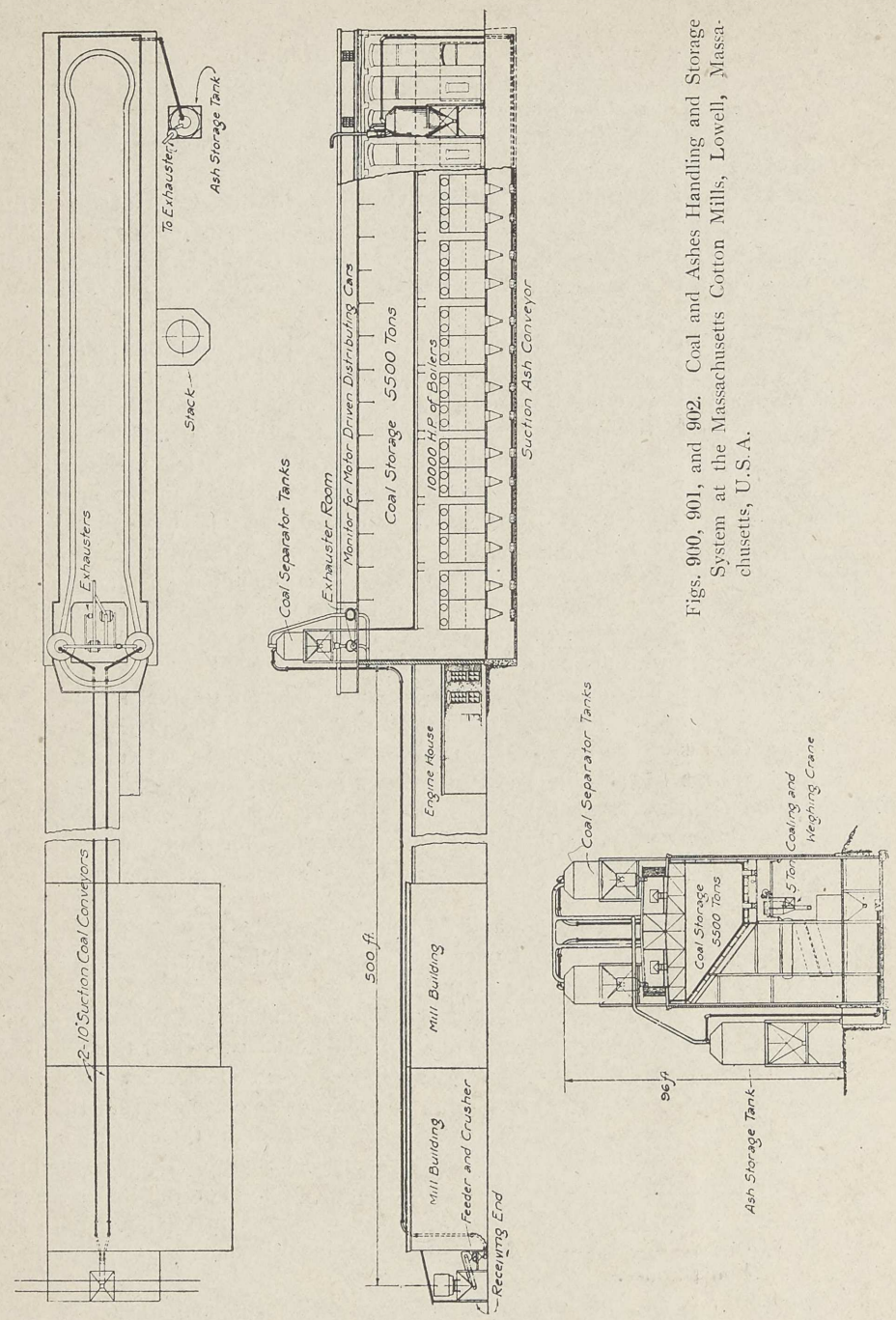
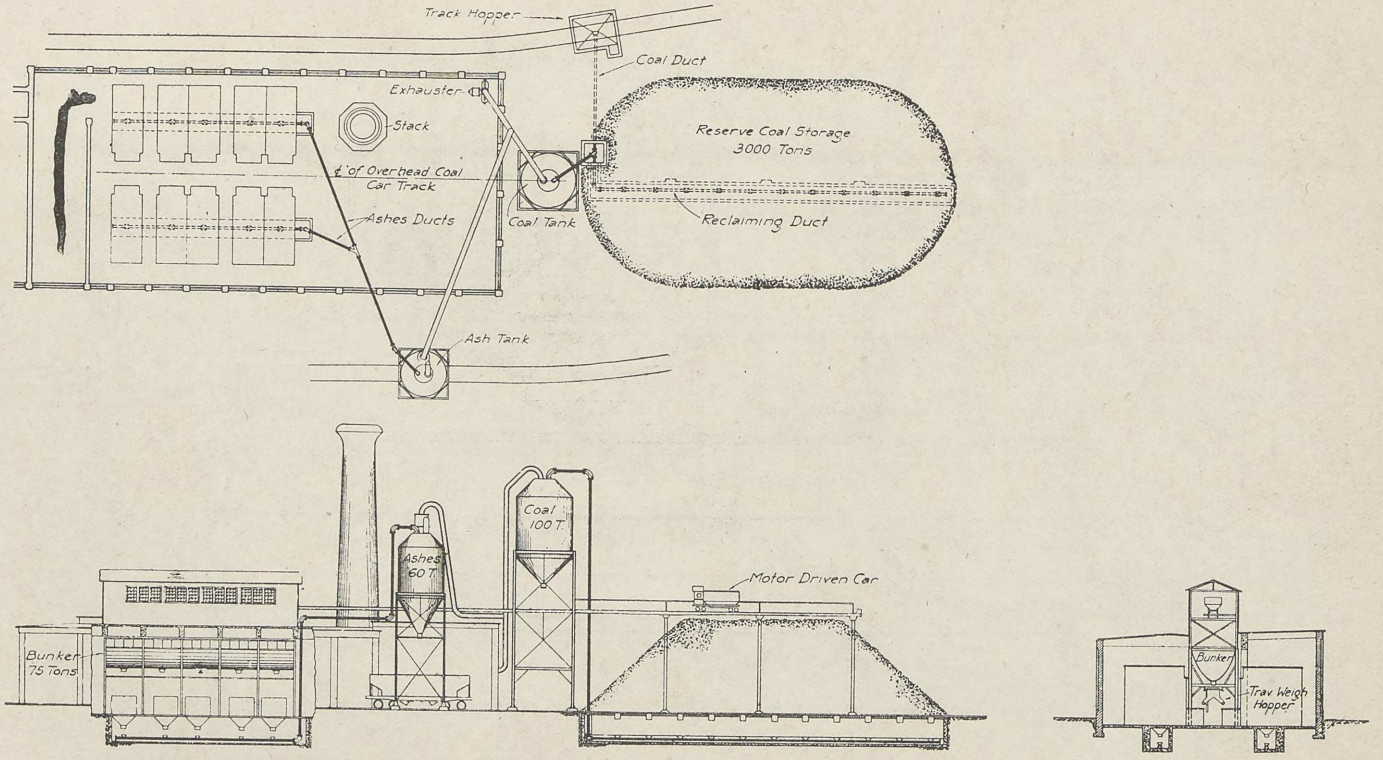
Ashes-handling Plant of the New South Wales Government Tramways, Sydney, Australia (Darley System).—Figs. **906** and **907** show an



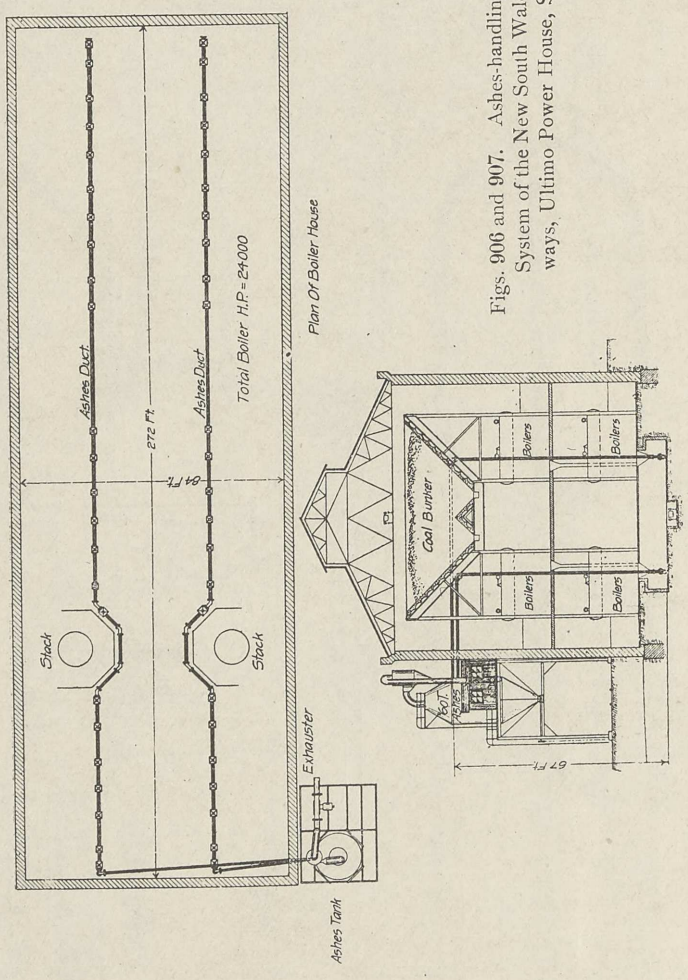
Figs. 900, 901, and 902. Coal and Ashes Handling and Storage System at the Massachusetts Cotton Mills, Lowell, Massachusetts, U.S.A.



Figs. 903, 904, and 905. Coal and Ashes Handling and Storage System of the Pierce-Arrow Motor Car Co., Buffalo, New York.

installation of pneumatic ash conveyors which has replaced a previous mono-rail with tipping bucket. The path of the carrier is unchanged, but it now handles coal only.

The suction ducts run along both sides of the basement and immediately beneath



Figs. 906 and 907. Ashes-handling Plant on the Darley System of the New South Wales Government Tramways, Ultimo Power House, Sydney, Australia.

the ash pit. As the bases of the chimneys could not be tunnelled conveniently, the pneumatic pipes pass round them at angles of 45°.

GASWORKS INSTALLATIONS

Coal-handling Plant at the Darmstadt Gasworks.—A Bradley conveyor is used here running through the whole of the building, as shown in Fig. **908**. The top

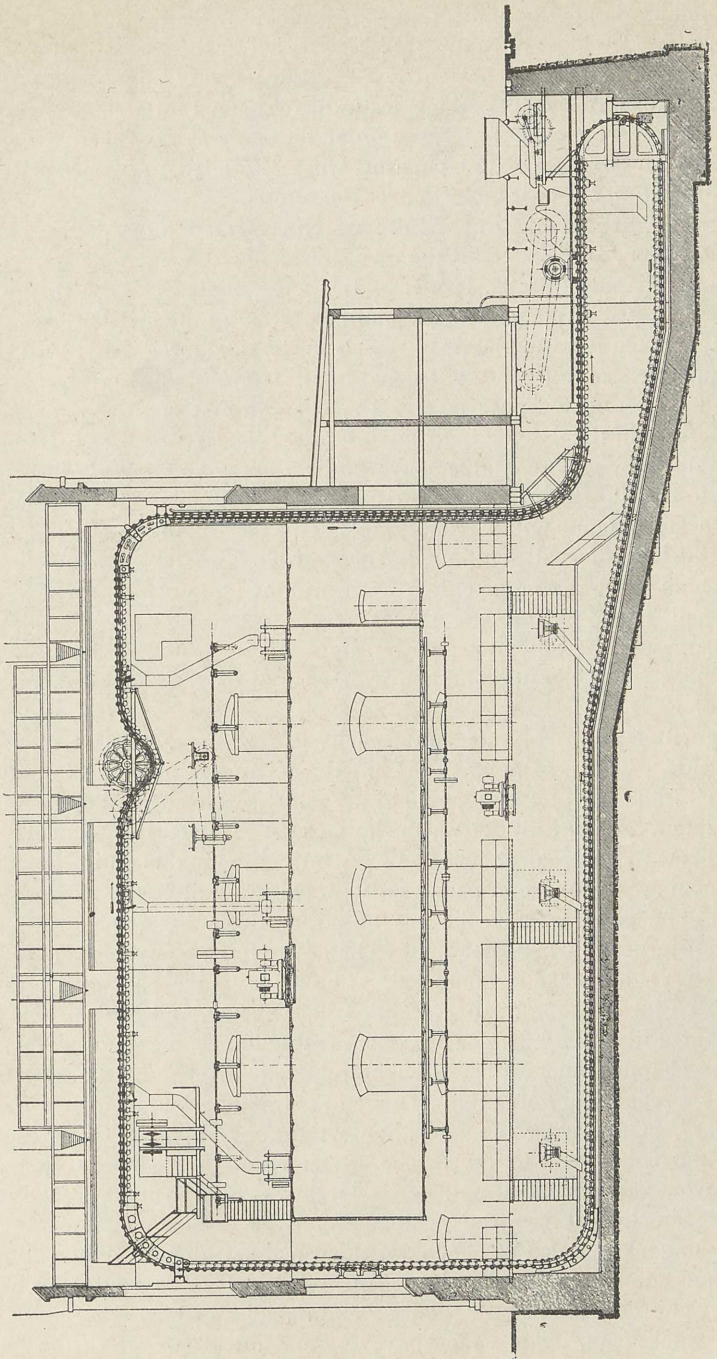


Fig. 908. Coal-handling Plant at the Darmstadt Gasworks.

strand is high enough to feed three band conveyors. These deliver to the coal silos in the store, which are hopper-bottomed, and are each provided with fifteen Weiss feeders (which are illustrated in Figs. **162** and **163**). These deliver the coal into three reciprocating conveyors placed in tunnels beneath the silos, the delivery ends being visible in the illustration, and also the shoots which lead the coal on to the bottom strand of the Bradley conveyor. The coal thus taken from the store is conveyed by means of the Bradley conveyor to the top of the building, where it is fed into push-plate conveyors. These in their turn fill the coal hoppers over the retorts.

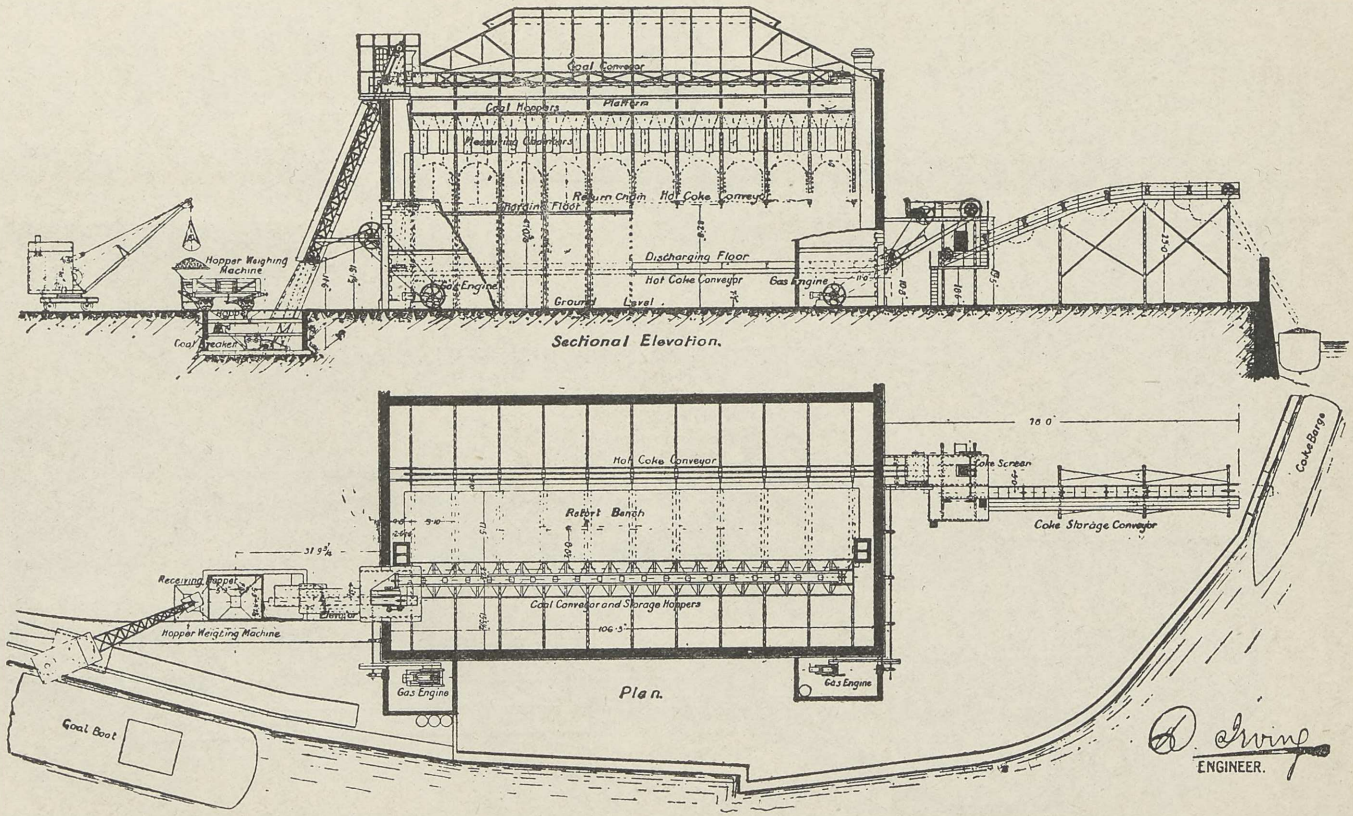
Coal and Coke Handling Plant of the Bristol Gas Co.—This is a very complete installation, and illustrates the mechanical handling of coke and coal in all its stages. It is the design of Mr D. Irving, M. Inst. C.E., engineer of the Bristol Gas Co.

Figs. **909** and **910** give a general plan and elevation of the installation.[1]

The coal is taken from the holds of vessels in the tidal river Avon, then weighed and broken to a suitable size to be further treated by the elevator and conveyor which remove it to the inclined retorts. These receive the coal without any such manual labour as would be necessary in the case of horizontal retorts. The coke, after carbonising, leaves the inclined retorts by gravity, and is conveyed by a hot coke conveyor into a yard at the opposite end to that in which the coal is received. The unloading of the coal is effected by means of a steam crane and a Hone grab. This part of the installation is capable of dealing with 30 tons of coal per hour. The grab empties its load into a hopper and weighing machine which discharge either direct into the elevator well, or, if the coal is not sufficiently small, it passes through a coal-breaker before going to the elevator. The elevator discharges at the top into a push-plate conveyor which distributes its load into overhead hoppers. The elevator and conveyor as well as the coal-breaker are driven by a gas engine of 12 H.P.

The original plant was of sufficient capacity to feed an additional retort-house now erected alongside. The coal hoppers are fitted with measuring devices and shoots, to convey the coal from any of the hoppers to the retorts, which can thus be filled without any manual labour. As already stated, the hot coke is removed by a conveyor suspended from girders beneath the retort-house floor. Above it, along its entire length, are water pipes for quenching the coke as it passes on its way. Several of the conveyor covers can be removed at the point where coke has to be received, the remainder of the plates continuing undisturbed, so that the men in charge are not inconvenienced by the vapour always arising when hot coke is quenched. The plates move backward away from the retorts, so as to form a shoot for the reception of the coke, and at the same time shield the men in charge from the heat. The conveyor trough is 2 ft. 3 in. wide, and is constructed of two channel irons with a wrought-iron plate riveted to the bottom, which is also fitted with a renewable iron strip. The return strand of the chain is carried overhead on guide pulleys. On leaving the retort-house the conveyor ascends an incline of 30° and delivers the coke, first to the screen which removes the breeze, and thence by another conveyor, partly inclined and partly level, which deposits the coke in a heap in the yard. The erection of overhead receptacles for the coke is contemplated, so that its discharge into wagons can also be effected without manual labour. The end of the coke conveyor extends so near to the river bank that the coke can be loaded by a shoot into coke barges. The conveyor at its highest end is 23 ft. above the ground, so as to command the stock heap. The coke conveyors and the screen are driven by an 8 H.P.

[1] The author is indebted to Mr D. Irving for the illustration which accompanies the following description.



Figs. 909 and 910. Plan and Elevation of Coal and Coke Handling Plant of the Bristol Gas Co.

gas engine, erected in a small engine-house at the end of the building opposite to that in which is installed the gas engine driving the coal-handling plant.

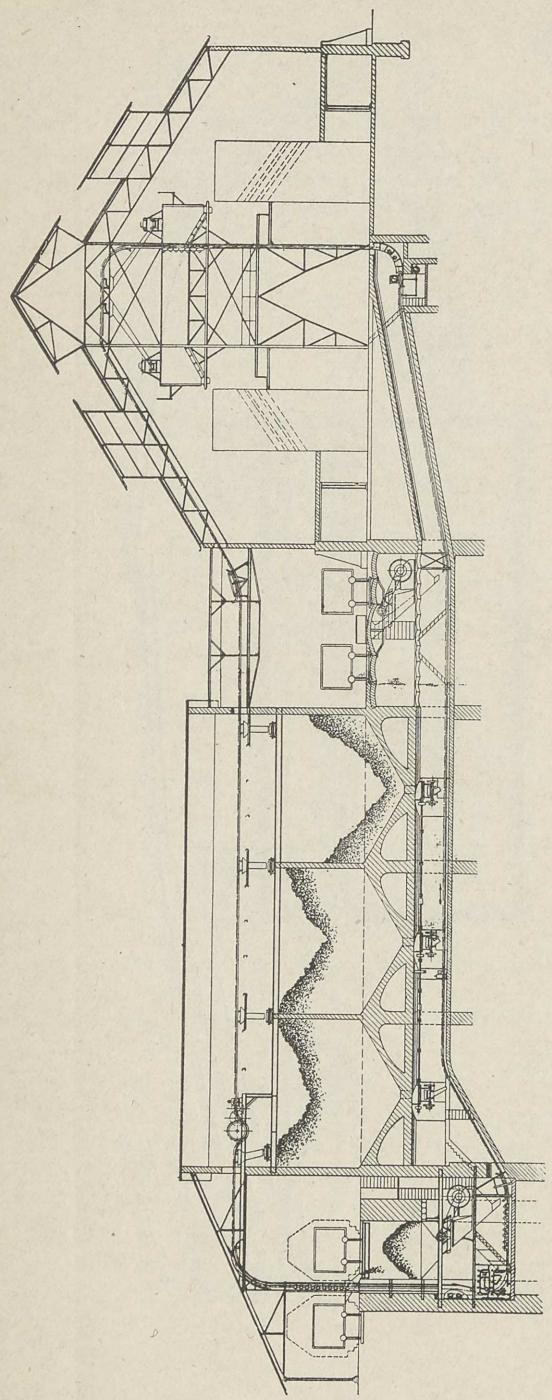


Fig. 912. Section through Coal-handling Plant at Nuremberg Gasworks.

Coal-handling Plant at the Nuremberg Gasworks.—This plant is on similar lines to that at the Darmstadt Gasworks, but in this instance two Bradley conveyors are used, with a capacity of from 45 to 50 tons per hour. The coal wagons here discharge their load into hoppers (see Fig. 911).

The large coal is then conveyed to the coal-breaker, after the "smut" has been sifted out. Having left the breaker, it is deposited in one of the conveyors. The advantage of having two conveyors is obvious, as in the first

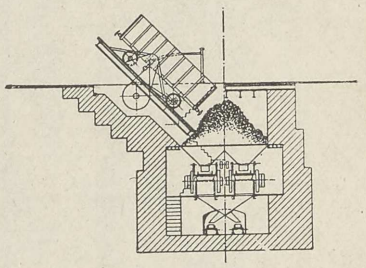
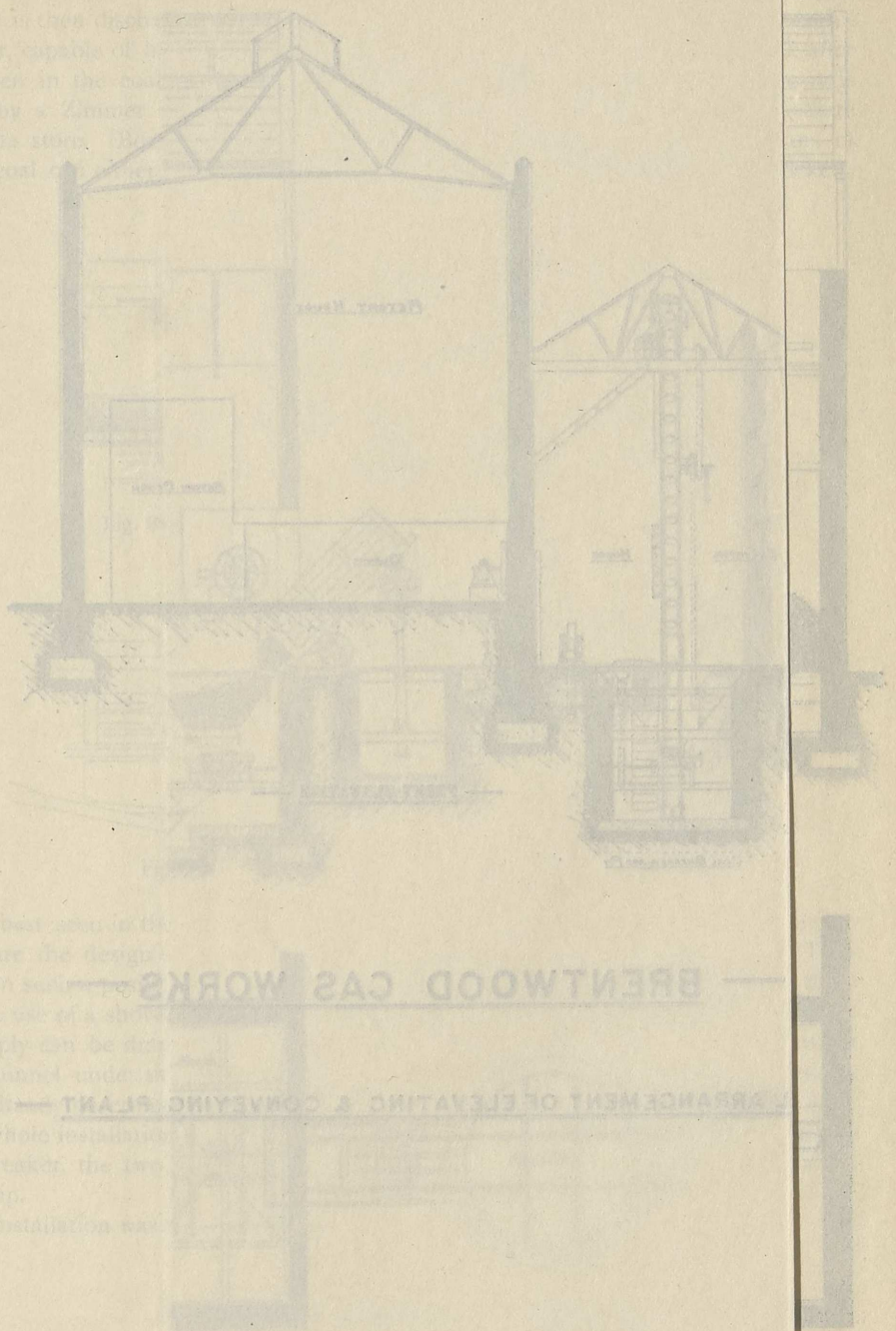


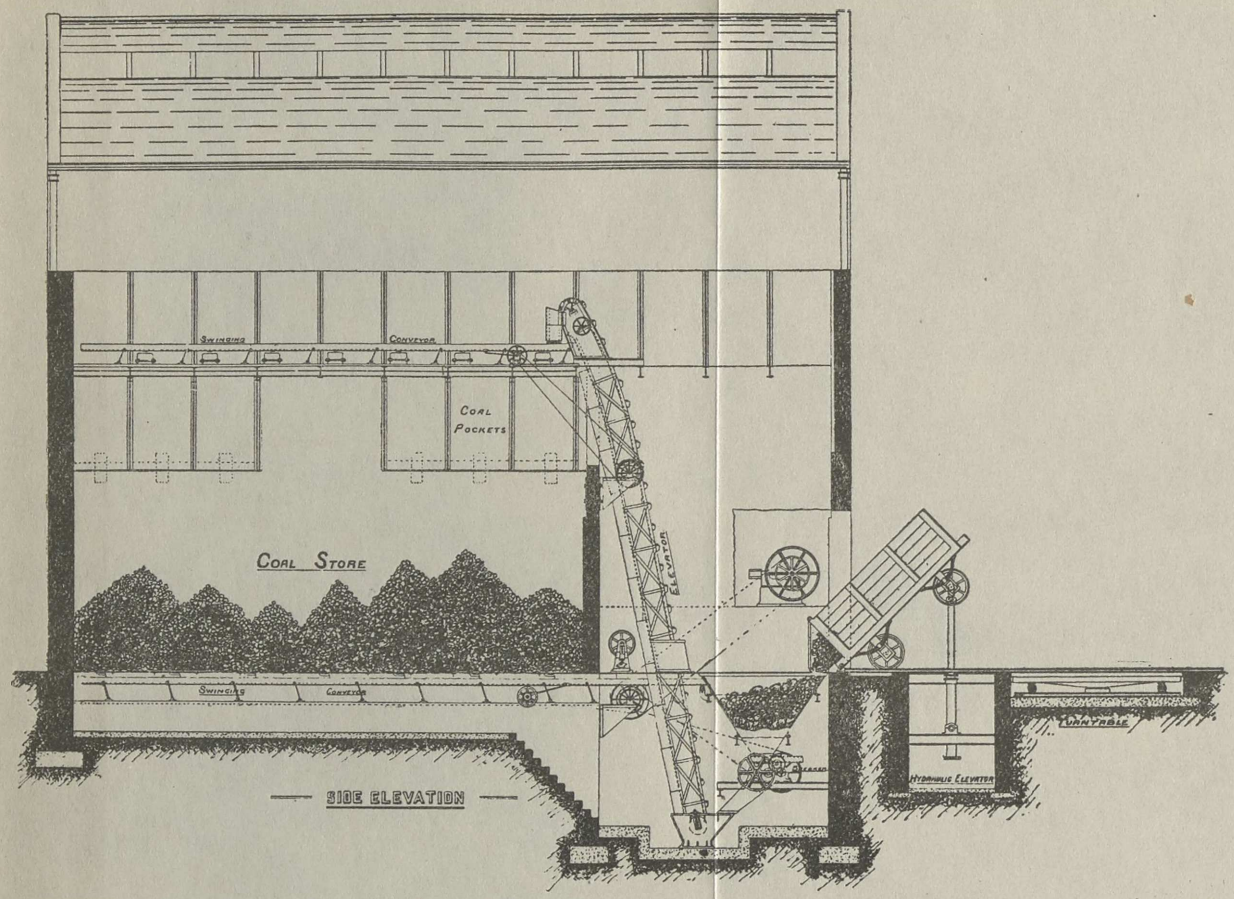
Fig. 911. Coal Wagon Discharging its Load.

place two railway trucks can be discharged at almost the same time, and further, one of the conveyors can be used for taking coal from the store to the retort-house, while the other is receiving coal. Having the conveyor in duplicate is also a great safeguard against breakdowns.

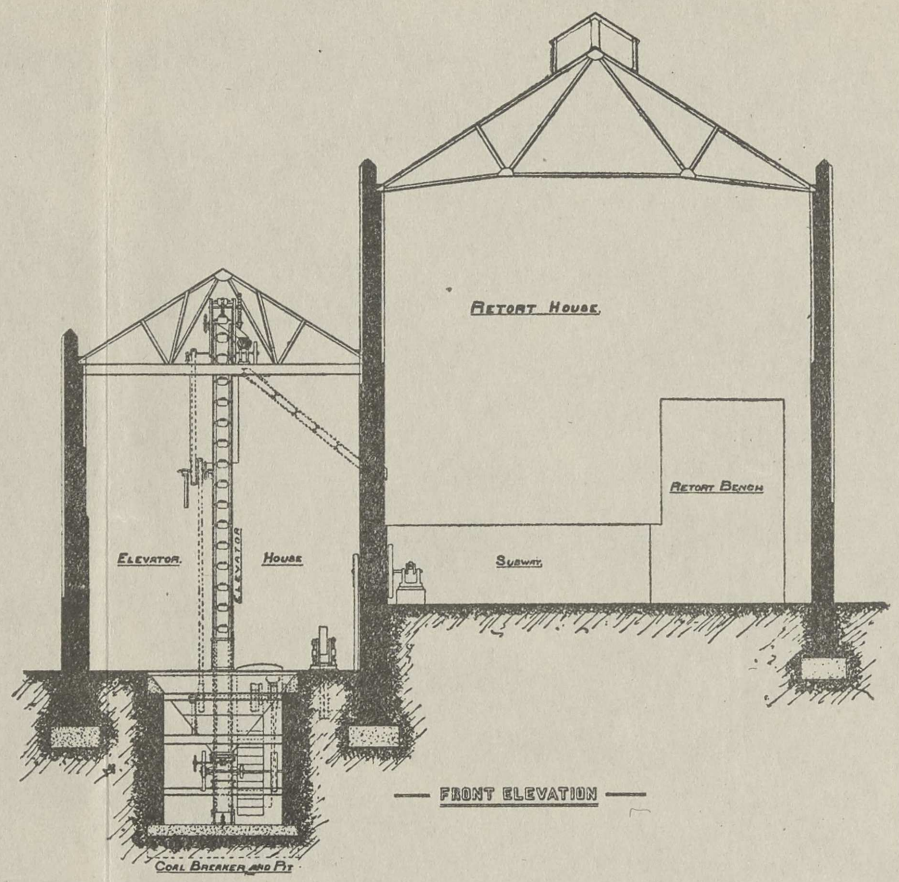
A section through the installation is shown in Fig. 912.

Fig. 913 shows a section through the coal stores. In both views the band conveyors at the top and the reciprocating conveyor beneath the silo bottoms can be seen. Fig. 914 gives a general plan of this complete installation.

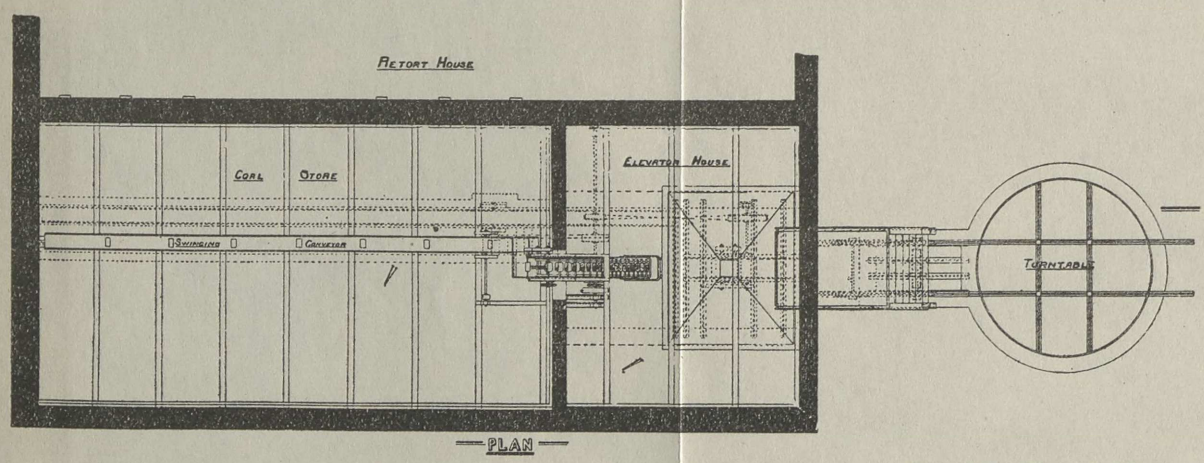




— SIDE ELEVATION —



— FRONT ELEVATION —



— PLAN —

— BRENTWOOD CAS WORKS —

— GENERAL ARRANGEMENT OF ELEVATING & CONVEYING PLANT —

Figs 915, 916, and 917.

[*To face page* 649.

Coal-handling Plant at the Brentwood Gasworks.—The Brentwood Gasworks have a small but completely automatic coal-handling installation. Figs. **915**, **916**, and **917** give two elevations and a plan. The coal arrives in ordinary trucks with hinged end doors; is then discharged by means of a hydraulic tip, and is deposited in a wrought-iron hopper, capable of holding the contents of the truck, about 10 tons. The coal, after being broken in the coal-breaker, is elevated to the top of the coal store, where it is conveyed by a Zimmer patent conveyor to the extreme end, or to any intermediate point of the store. Beneath the conveyor are fitted six tipping shoots, by means of which the coal can either be dropped to the bottom of the store or into the coal pockets,

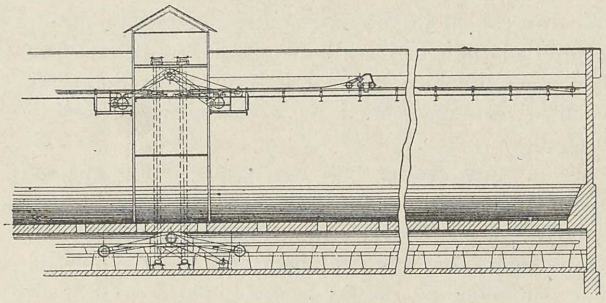


Fig. 913. Section through the Coal Stores at Nuremberg Gasworks.

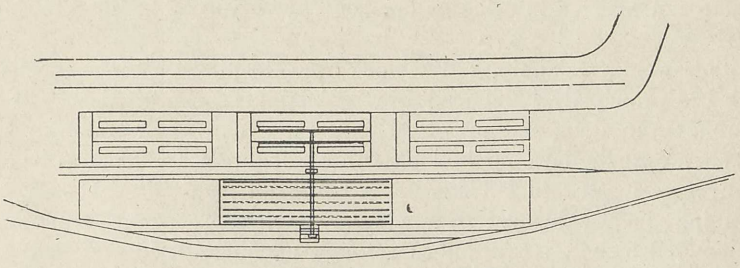


Fig. 914. General Plan of Complete Installation.

which are best seen in the cross section, Fig. **916**. These pockets are quite an innovation, and are the design of Mr R. M. Couper, the then engineer of the gasworks. They terminate in such a position that the scoop for feeding the retorts can be filled from them without the use of a shovel. Whenever the pockets are empty, and no coal is being taken in, the supply can be drawn from the coal store by means of a second Zimmer conveyor fixed in a tunnel under the floor of the store, when it can be elevated and conveyed by the plant already described.

The whole installation is driven by a steam engine of 10 H.P., which manipulates the coal-breaker, the two conveyors, the elevator, and also the pump which works the hydraulic tip.

This installation was designed by the author.

CHAPTER XLI

STORING OF COAL AND OTHER MINERALS IN STOCK HEAPS AND SILOS

Coal and other minerals which do not materially deteriorate through the influence of the weather when stored in the open are generally accumulated in stock heaps or piles, over which mechanical equipments are erected for their deposition and withdrawal. Other materials, such as salt and chemicals, are similarly stored but under cover, as also is coal for household purposes.

The mechanical equipment varies with the nature of the material. Coal and coke requiring gentle treatment to prevent breakage should preferably be deposited by continuously working conveyors and elevators, and less frequently by intermittently working devices, such as grabs suspended from telphers and other mono-rails, or by the Hunt Automatic and other self-unloading railway trucks. This naturally also depends on the coal itself, whether it is in large or small pieces, and on the degree of friability; American coal being less friable, for instance, than the average English coal. Materials such as ore, which are not affected in value by breakage, are generally handled by intermittently working devices.

The withdrawal or reclaiming of the stock from the pile is likewise effected in various ways, which are principally influenced by the friability or otherwise of the materials. Those immune from deterioration by breakage are generally withdrawn by grabs or shovel-buckets, whilst the best method of withdrawing coal and coke is by continuously working conveyors located in culverts beneath the pile, and in such cases the mineral store is not infrequently heaped over a ferro-concrete hoppered structure, from the lowest portion of which it is withdrawn through openings fitted with gates which communicate with the culvert and its conveyor. There are, of course, exceptions to this, and friable materials are sometimes both deposited and withdrawn by grabs or shovel-buckets (suitable grabs of large capacity do not injure average coal more than some continuously working conveyors), as such installations are less costly in the first instance, the same appliance being used for both stocking and reclaiming.

Local conditions also play an important part in the choice of the most suitable means to be employed. For instance, where coal is to be unloaded by grab from barges and delivered on to a stock heap, it may be better to retain the coal in the grab, telpher it to the pile and there gently lower it, than to transfer it to a conveyor, as this would cause more damage. On the other hand, if the coal arrives by rail and is unloaded by a tip, an elevator and conveyor, or combination of the two, would be chosen. When varying levels of ground are available and favourable, or sufficient space, so as to run sidings up trestle-work or embankments at a gentle incline, it may be possible to bring the material in hopper wagons to rails above the store or silo and so discharge into them and withdraw from culverts, as already mentioned. Or if the store can be arranged on the hillside, both loading and unloading can be most conveniently and economically arranged.

Whatever general arrangement may be chosen for storing coal, the most important

consideration is to deposit it gently with the minimum of drop, and when once deposited, break bulk as rarely as possible. It is impossible to prevent some breakage of the coal however gently it may be handled; mechanical handling, being inflexible, necessarily involves a number of transfers from hopper to shoot and from shoot to mechanical appliance, and so forth, but the fall at each point of transfer can and should be reduced to a minimum.

Coal is handled with care at the colliery, and after journeys of often hundreds of miles is delivered in good condition containing, perhaps, only a small percentage of slack; it is paid for at a rate proportionately high to its size and, if carelessly handled at the storage installation, it arrives at the furnace door at a greatly reduced value. American coal, as has already been mentioned, is harder than our average coal, and that used for railway engines in that country is also smaller, but notwithstanding this the breakage at some of the American coal stores is appalling. At the Session of the International Railway Fuel Association, held at Chicago in May 1913, this subject was discussed at great length, particularly in view of the modern locomotive coaling stores. Some details concerning a case of the Chicago Rock Island and Pacific Railroad revealed the fact that some coal which was delivered from the colliery with 42 to 45 per cent. of slack contained, after being handled by the coal plant, 72 to 75 per cent., and in the case of lump coal which contained only 25 per cent. of slack this was increased to 65 per cent. This incidentally shows how much lump coal suffers from rough treatment.

Coal handled by grab or shovel-bucket must of necessity suffer some damage, and particularly so if it has to be grabbed twice, *i.e.*, on delivery and on withdrawal, as may be the case with a stock pile without subterranean facilities; if large grabs are chosen, however, and those with gentle action, it may be possible to effect no more breakage than if the coal were transferred with a shovel by hand.

Spontaneous Ignition.—An important precaution when storing coal is to guard against spontaneous ignition, and to this end it is usual not to heap bituminous coal higher than from 15 ft. to 20 ft., but this must, however, depend upon the nature of the coal. The Western Fuel Co. on the great American lakes store bituminous coal 30 ft. high. Warm rain during or shortly after stacking coal, as well as the compression, and the effect of dumping from some height, are elements of danger. The height of storage does not apply so much to silos as to stock heaps, as in the former the coal is withdrawn from the bottom and the whole mass is, therefore, set in motion whenever some is withdrawn. This also applies to piles with culverts beneath.

Some useful points on this subject were given by Mr Irving, the President of the Southern Association of Gas Managers.[1]

At the Stapleton works of the Bristol Gas Co., of which Mr Irving has charge, all coal is stored in the open. The stores are 450 ft. long and 72 ft. wide, paved with blue brindle bricks and thoroughly drained. Coal is delivered into the stores by two sets of overhead rails, carried on steel girders, which are supported by iron columns. The coal is dropped from hopper-bottomed railway trucks to the ground, and is stored to a depth of about 20 ft. During the past few years the Bristol Gasworks have been troubled with cases of spontaneous combustion. Great care has always been taken with the coal stocks, especially with those coals that were known to have any tendency to heating. A number of 1-in. pipes, to each of which a letter or number is attached, were usually inserted throughout the stock of coal, into which a thermometer could be lowered, and the temperature observed and daily recorded; and when any part of the stock gave indications of heating, that portion was worked out as soon as possible. It has rarely

[1] From *The Iron and Coal Trades' Review.*

been found, even with the most active coals, that the rise of temperature would exceed from 3° to 5° C. in twenty-four hours—that is, in the first stage of heating. But after a certain degree is attained, the action is much more rapid; and where air is available it is destructive.

Various theories have been put forward to account for the spontaneous combustion of coal; and they may be summed up under two heads, viz., (1) the decomposition of iron pyrites, and (2) the oxidisation of the coal. In the case of coal mines, there is a third theory—that of friction. However this friction may operate in coal mines, with regard to the cases under consideration friction as a cause of heating may be dismissed.

It is very generally admitted that in the presence of moisture pyrites undergo oxidisation and disintegration, furnishing additional fresh-cut surfaces of coal to absorb oxygen; the chemical action develops heat and the further oxidation of the coal.

Every one knows that coal varies considerably in chemical composition and also in physical structure. Given a number of fine coal particles containing rich hydrocarbons in the presence of moisture and atmospheric oxygen, and we have all the elements required.

Heating always takes place in the small coal; but cases have been known where large coal, and also nuts, lying against small, or covered by small, have developed spontaneous combustion. It would seem in some cases that the interstices, or air spaces, formed between the large and nut coal provided the necessary atmospheric oxygen which, acting upon the hydrocarbon particles of the small coal, sets up chemical action and the heat produced develops a certain peculiar chemical change in the coal. One of the first indications of heating is the steam, or vapour, which usually escapes from the stack by the line of least resistance, which may be far removed from the seat of the cause. As the heat develops, certain gases are evolved of the acetylene series, which give a distinctive and peculiar odour, exactly the same as that found in coal mines. The odour is characteristic, and exclusive to the gases evolved from spontaneous combustion. No one could mistake this odour, which can be detected even at a considerable distance.

Mr Irving states that he suspects that there is some kind of chemical action induced when coals from different collieries are mixed together, different to some extent from simple oxidation.

Friction cannot apply to the hold of a ship or coal stored on land. Oxidisation is certainly one cause, if not the chief cause, of spontaneous combustion.

Coals stacked not more than 6 or 7 ft. deep never showed any tendency to heating. In this case the heat of oxidisation is carried off in the atmosphere, without raising the coal to the temperature necessary to induce active or destructive chemical change, and little or no damage is done to the coal. Attempts have also been made to ventilate by running air shafts through the coal stack; but the latter state of that coal has been worse than the first, because the air, instead of keeping the coal cool, supplied the necessary oxygen, and greatly facilitated the destruction of the coal.[1] Several suggestions or recommendations have been made to prevent the heating of, or to cool the already heated, coal in ships. The application of steam pipes is compulsory in vessels carrying coal under the American flag, and Professor Lewes some time ago suggested the distribution of cylinders of compressed carbonic acid gas, secured with fusible plugs, throughout the coal cargo.

Coal should, of course, in all cases be received as dry as possible, and care taken so that no damp coal is covered up with dry.

[1] This may depend upon the size of the air shafts.

Mr G. H. Hutchinson, chief engineer to the North-Western Fuel Co., St Paul, Minneapolis, United States of America, says:[1] "The first step in handling a coal fire is to get direct access to the fire by rehandling the hundreds, and frequently thousands, of tons of coal within the inverted cone tributary to the small area at the bottom of the pile, where the fire starts. It is sometimes also necessary to isolate the burning area to prevent the fire spreading. After the fire is uncovered, it can be extinguished by the use of water and the rehandling of the smouldering or burning coal. The application of water, however, to the top of the original coal pile is ordinarily useless and frequently increases the fire. While the liability to spontaneous combustion cannot be entirely eliminated, a clean dock surface and the absence of combustible foreign matter within the coal pile, and, after the coal is in storage, careful watching and prompt rehandling upon the first indication of heating, reduce the liability to a minimum."

As all mechanical appliances for mineral stores have been fully dealt with in previous chapters, it will suffice to give a number of the typical examples showing the general arrangement without entering into the details of their construction.

Stock Piles on the "Dodge" System.—Such installations are essentially American. In this country they are not so necessary, owing to the closer proximity of the coal fields to the principal centres of consumption—such as blast-furnaces—and the facilities for rapid and regular delivery, except perhaps as a safeguard against the effects of labour troubles, trade booms, etc.

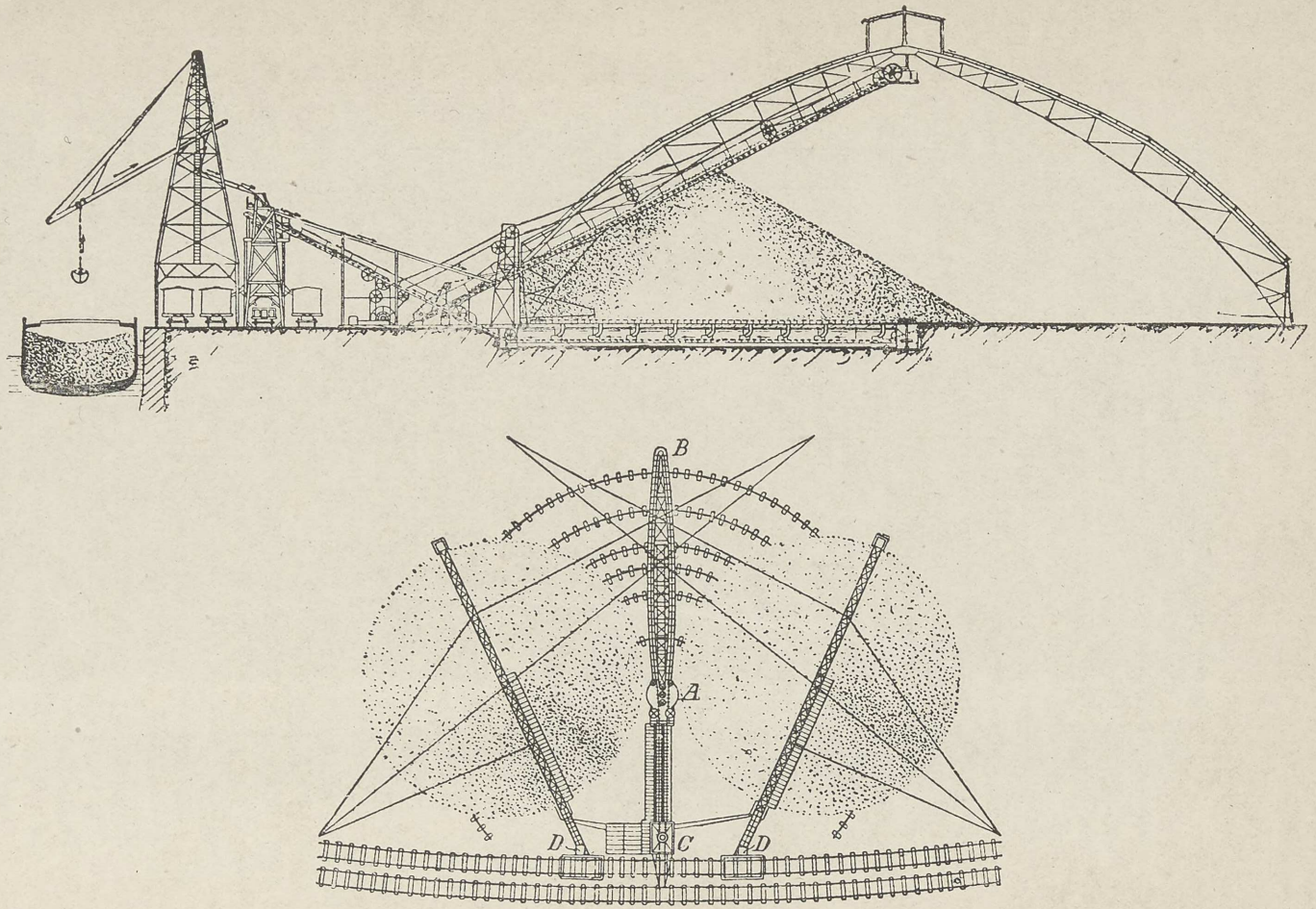
Stock piles on this system are almost exclusively used for storing anthracite coal, as bituminous coal cannot be stored in such high piles, which are frequently 60 ft. high and 200 ft. in diameter. There seems, however, no reason why such appliances should not answer equally well for storing other minerals. For storing anthracite coal the "Dodge" system is eminently useful, as the demand for that coal fluctuates greatly, and if stored in large quantities between the coal fields and the market, a continuous instead of a spasmodic working of the mines becomes possible and a convenient base of supply is provided.

Mr George E. Titcomb, of New York, read an interesting paper on "Hoisting and Conveying Machinery" before the American Society of Mechanical Engineers in 1908, from which the following description has been taken. The standard "Dodge" plant consists essentially of a push-plate or chain and flight conveyor supported by shear trusses D D (Fig. 919), constituting a trimming machine which piles the coal with a minimum of breakage, delivering it upon the ground or at the ascending apex of a conical pile as it is formed.

The withdrawal or reclaiming of the coal is begun by the open side conveyor A B, which is pivoted at A and runs on a number of circular ground-level tracks extending between and over the area to be covered by the piles. This conveyor works against the edge of the pile, and follows up the receding edge as the coal is removed; it is operated by power and is so devised as to be fully under the control of one man. All the coal is tributary to the reloading conveyors, and is carried without intermediate transfer up the incline to the reloading tower C, where it can be delivered either directly into cars or after having first been screened.

In detail the "Dodge" system, as usually applied to open-air storage on levelled ground, consists of two trimming machines and the pivoted ground conveyor which travels radially between them (see Figs. 918 and 919), forming one group or unit. A

[1] In a paper on "The Handling of Coal at the Head of the Great Lakes," presented at the Spring Meeting, St Paul, Minneapolis, 1914, of the American Society of Mechanical Engineers.



Figs. 918 and 919. American Scraper Conveyor for Building Stock Heaps ("Dodge" System).

coal storage plant consists of a number of these groups, which may be of equal or of varied capacities. The shear trusses are fixed to correspond with the angle of repose of the coal, the front truss of each group, *i.e.*, the truss adjacent to the track-hopper or receiving point, containing the conveyor. This conveyor runs in a trough, having for a bottom a continuous steel ribbon about 12 in. wide, which is wound upon a drum at the foot of the truss, and is paid out only as demanded by the formation of the pile; this feature provides a gentle discharge of the coal and prevents breakage.

Modifications of the standard "Dodge" system have been made to meet local conditions. Hillside storage has been increased by mounting the trimmer conveyors on cantilever trusses, so as to fully command the storage area after the initial and comparatively small gravity capacity has been reached. Where a continuous or oblong pile of maximum capacity is needed, instead of a conical one, a travelling trimmer is used, supported at the lower end on a power-driven truck, and at the upper end on a column-supported track. Stocking or reclaiming is accomplished as in the standard group plant; the reloading machine being of the traversing instead of the pivotal type.

Where climatic severity makes covering of the coal necessary, the "Dodge" system has been found especially adaptable. A prominent installation of this kind employs a circular building with trussed dome-shaped roof. The coal is brought to the dock by boat, and unloaded by a tower hoist, from which it is spouted by gravity to the chute of the trimmer conveyor. The construction of the trimmer permits it to be mounted on one of the roof trusses of the building. The reclaiming from the pile is effected by means of the pivotal reloader, which commands the inner circumference of the building, and delivers through floor openings to a push-plate conveyor running horizontally in a tunnel, from a position beneath the centre of the pile to a point outside the building. From here it rises on an incline to the reloading tower from which its discharge is transferred through screening chutes to cars. No exterior bracing is required for these buildings, as they are strengthened against bursting pressure from the mass of coal by a continuous circular bulkhead, which is supported free of the floor by anchor bolts extending inwardly from the I-beam posts of the annular wall.

In another type of covered storage plant the house area is of rectangular form, the building being divided to store equal quantities of egg, stove, and nut coal, the aggregate capacity totalling up to 100,000 tons. The equipment consists of three standard "Dodge" trimming conveyors for stocking the coal; three open-top carriers running in underground tunnels for reloading; three reloading towers provided with screens; three gravity-discharge transfer conveyors; and three screenings conveyors. The three trimmer conveyors and three transfer conveyors, or three reloading conveyors and three transfer conveyors can be operated simultaneously. Each machine handles 1,500 tons per day of ten hours.

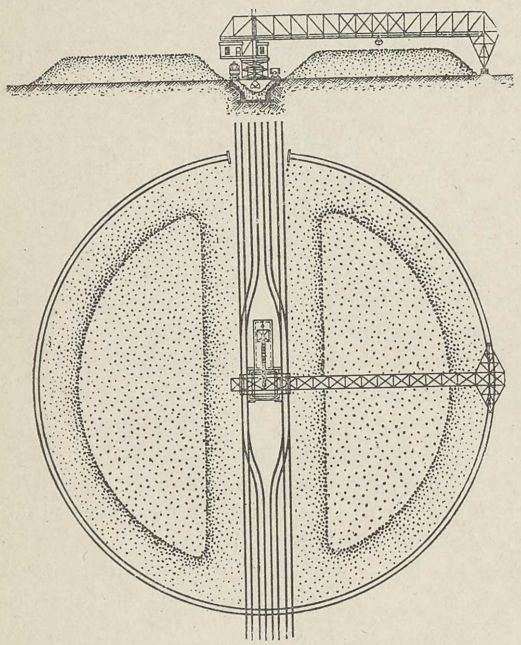
The power plant for a "Dodge" system installation may include steam or electrical equipment, the generating outfit comprising a central unit from which distribution may be effected through a piping or wiring system to convenient points for direct operation. The equipment of a large plant of eight piles of 60,000 tons each includes four 16-in. by 20-in. 150 H.P. engines, so located that one engine drives the machinery of each two-pile group. In a 240,000-ton plant two 225 H.P. alternating current, 440-volt, 25-cycle, 3-phase motors drive the machinery of the 60,000-ton piles, while that of the 30,000-ton piles is controlled by motors of 150 H.P.

In 1906 a 200,000-ton covered anthracite storage plant on this system for stocking coal 60 ft. high was installed on Section 2 of the North-Western Fuel Co.'s Superior

Dock No. 1, and in 1910 an addition was made which increased the storage capacity of this plant to 265,000 tons.

The capacity of the plants erected under the "Dodge" system aggregates a total of about 5,000,000 tons. While official figures are not obtainable for publication, it is guaranteed that the labour cost of either stocking or reclaiming on an active plant will not exceed four cents (say 2d.) per ton.

Coal Store of the Philadelphia and Reading Railways at Richmond Harbour, Philadelphia, United States of America.—This is probably one of the largest coal stores in the world, the harbour of Philadelphia being the centre of the very extensive coal traffic of the Reading Company, who own not only the collieries, but also harbours, railways, and ships. The coal arrives from the collieries in complete coal trains, the contents of which are, if possible, discharged direct into the ship, being drawn up inclines on to staiths where the trucks discharge through bottom doors and by gravity shoots into the vessels.



Figs. 920 and 921. Stock Heap of the New York Central Railway at Dewitt.

It is, as a rule, impossible to entirely dispose of the coal thus, so it is piled up in a stock heap which will hold 180,000 tons. The store consists of six cone-shaped piles (on the "Dodge" system), two of which will hold 40,000 tons, two 30,000 tons, and two 20,000 tons.

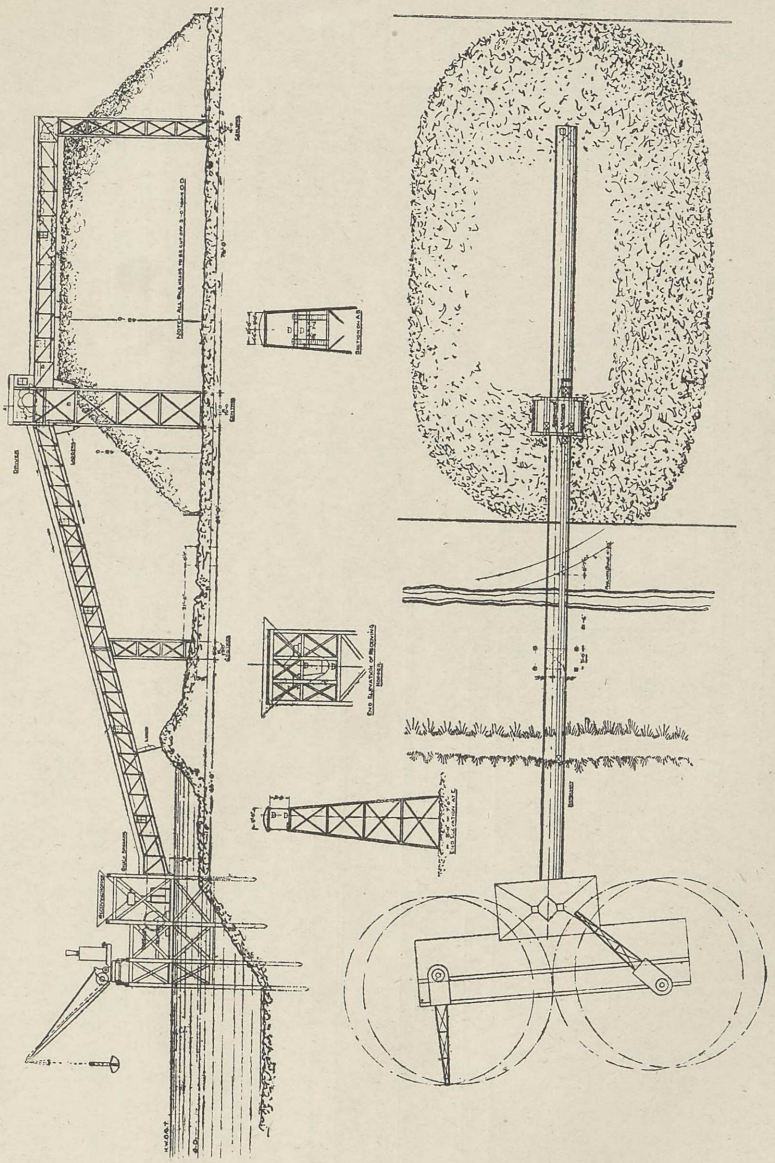
Two parabolical bridge girders are erected to form an angle with each other, slightly larger than the angle of repose of the coal; these girders are held in position by guy ropes. The coal is discharged by bottom door wagons into a hopper between the rails from which it is conveyed up one of the girders by a push-plate conveyor. The withdrawal of the coal from the heap is effected in a manner similar to that employed in the installation previously illustrated and described.

The cost of stacking the coal varies with its size, from one halfpenny to one penny per ton for coal $1\frac{1}{2}$ in. cube to 8 in. cube, and one farthing to a maximum of twopence halfpenny for the removal of the respective sizes. This difference in cost is accounted for by the fact that the small coal will run on its own account into the conveyor whilst the large coal requires some assistance.

Stock Heap of the New York Central Railway at Dewitt.—This is illustrated in Figs. 920 and 921. Through the centre of the pile four lines of rails are laid, of which, however, only the two outer ones proceed straight through; these sidings are for the accommodation of the hoppered bottom wagons which bring the coal. As may be seen from the cross section there is a V-shaped trench, into which the wagons discharge, and the coal is then taken by grab and transferred on to the pile. The bridge crane can traverse the whole circle for distributing the coal, working from one

centre, the diameter being about 425 ft. The coal can, of course, be transferred by grab from the trench direct on to the tenders of engines.

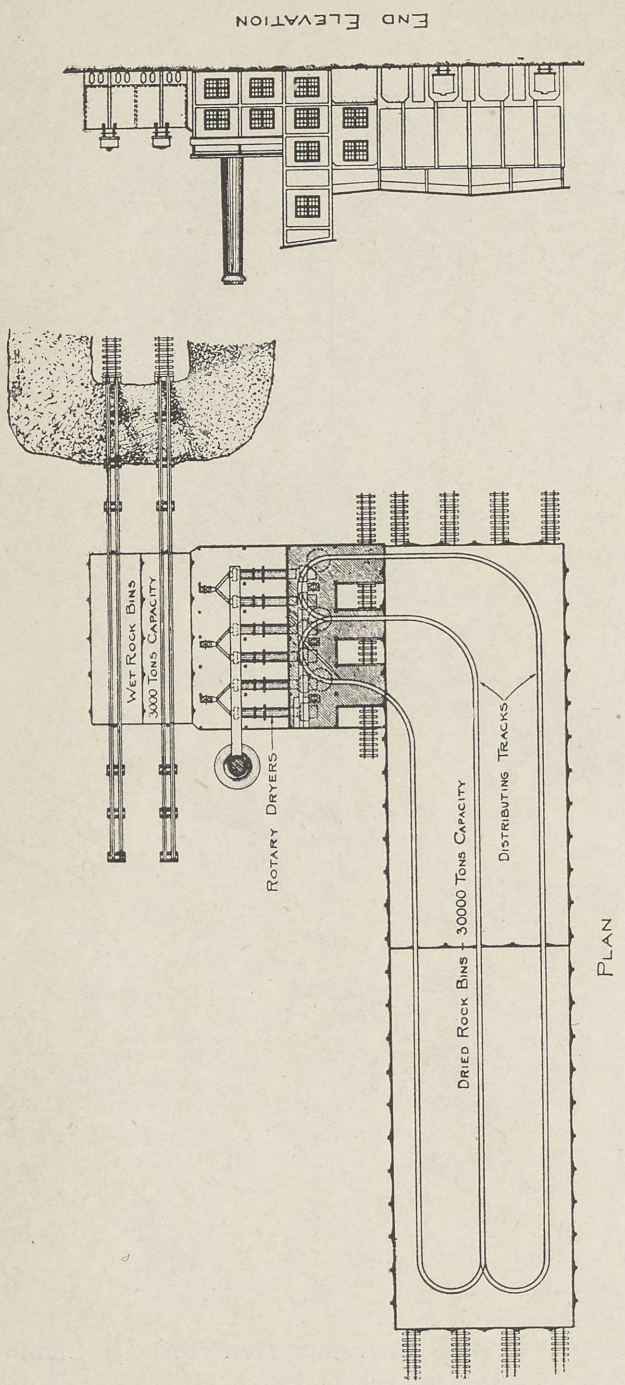
A similar installation of the same railway company is at Albany Station. It might



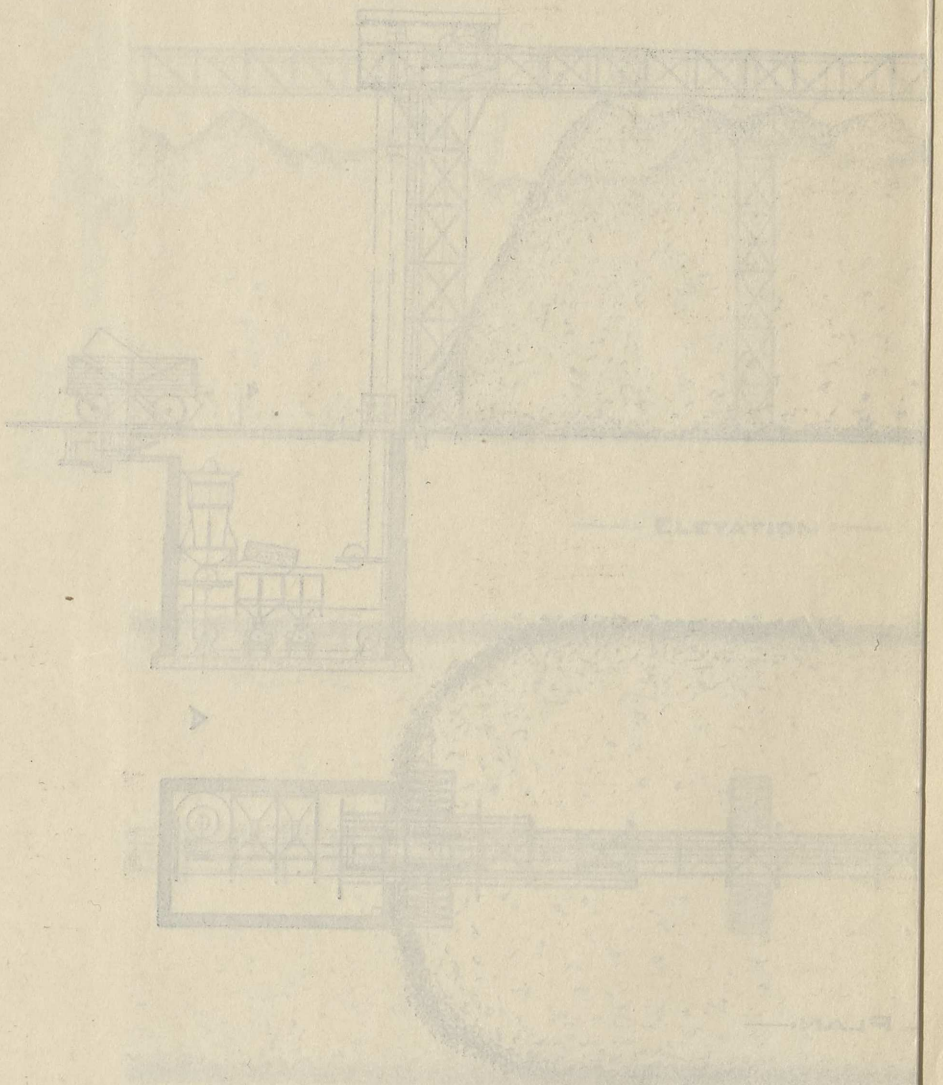
Figs. 922 and 923. Gravity Bucket Conveyor in Connection with Chalk-handling Plant.

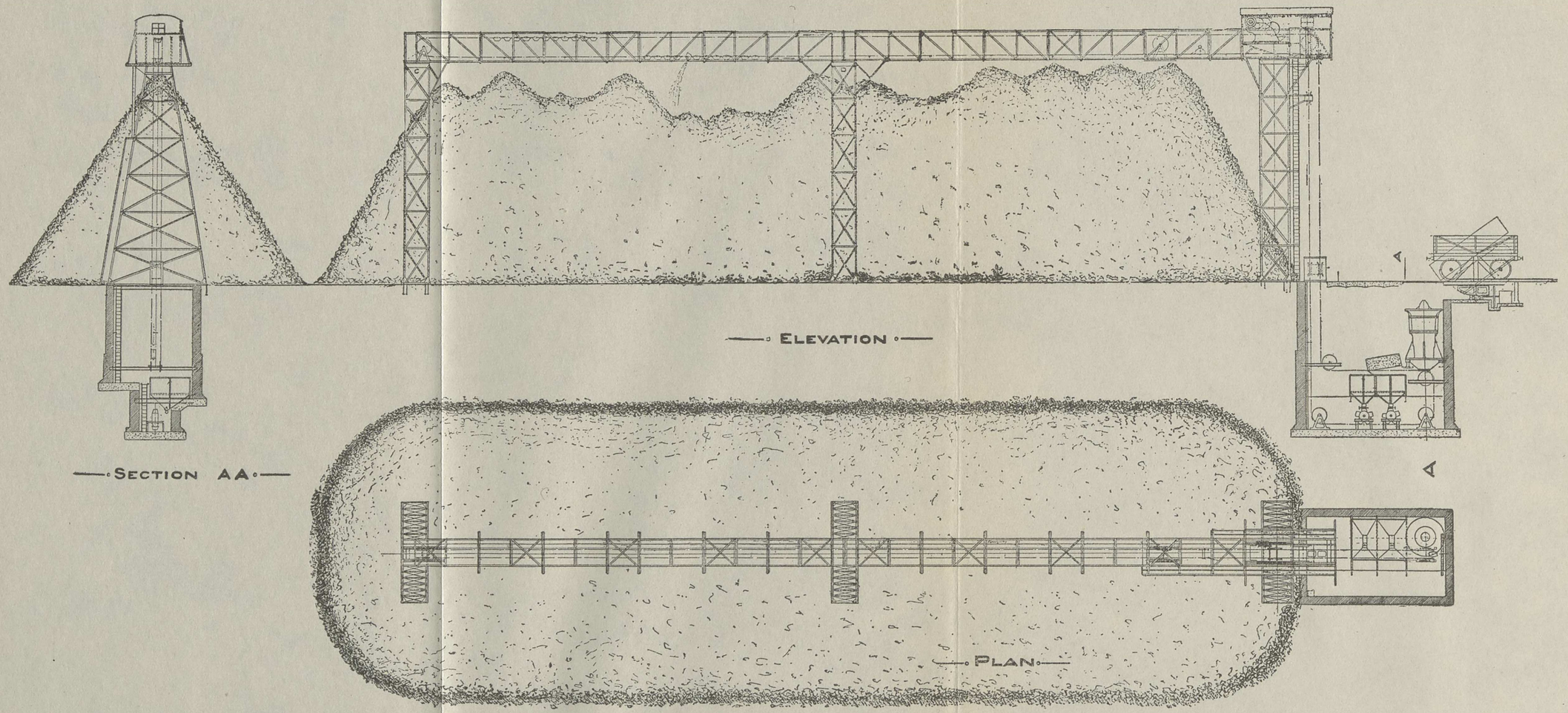
be mentioned that very similar installations could be erected square instead of round, which appears to be more economical as regards space.

Gravity Bucket Conveyor as used in Connection with a Chalk-handling Plant.—This installation, illustrated in Figs. 922 and 923, is used for conveying broken chalk for cement manufacture. The material is delivered alongside in barge loads, and is discharged by means of two steam cranes and grabs into a double



Figs. 924, 925, and 926. Phosphate Drying and Storage Plant of the Amalgamated Phosphate Co., Chicora, Florida.





Figs. 927, 928, and 929. Mechanically equipped Ore Stock Pile at the Smelting Works of the Cape Copper Co., Briton Ferry, near Swansea, erected by Babcock & Wilcox, Ltd.

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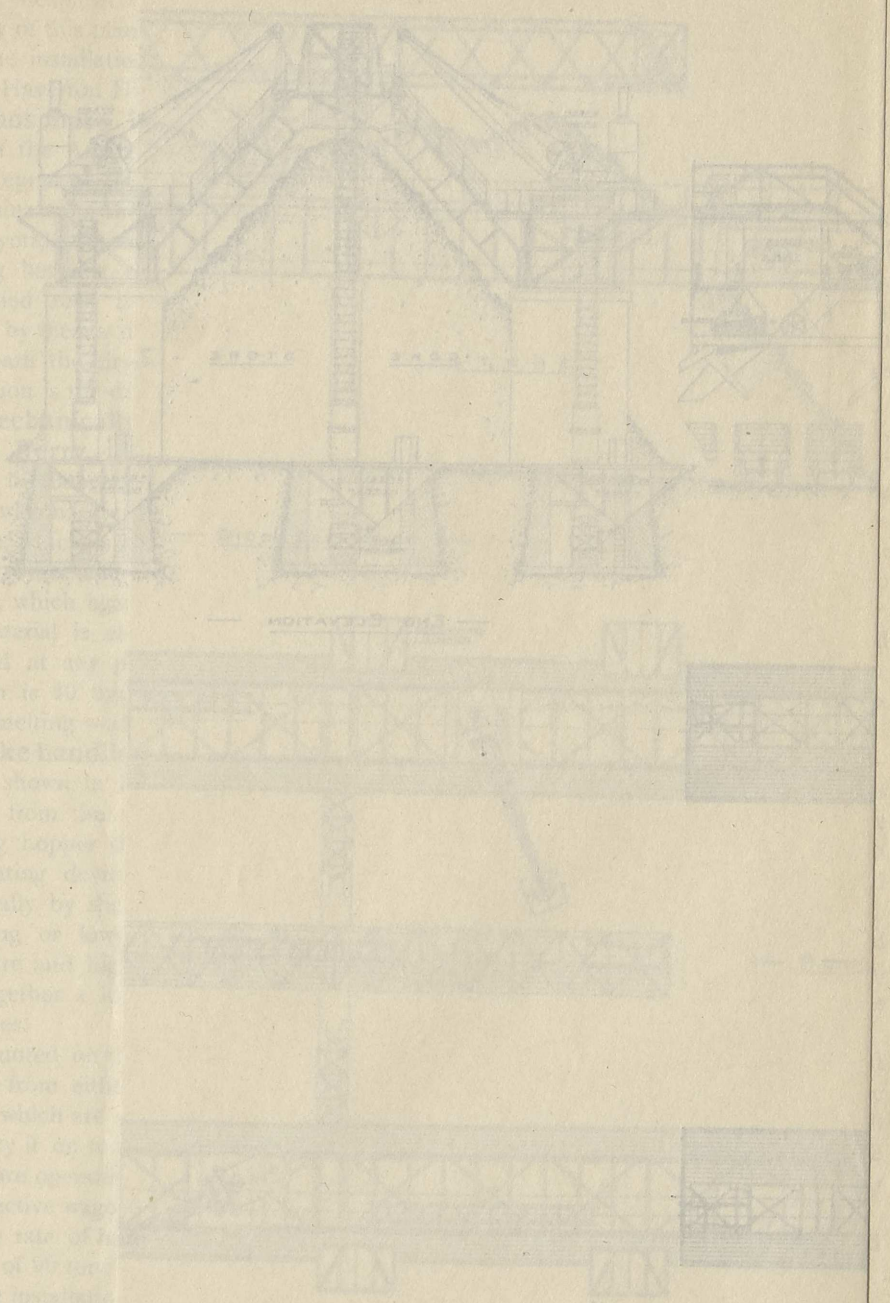
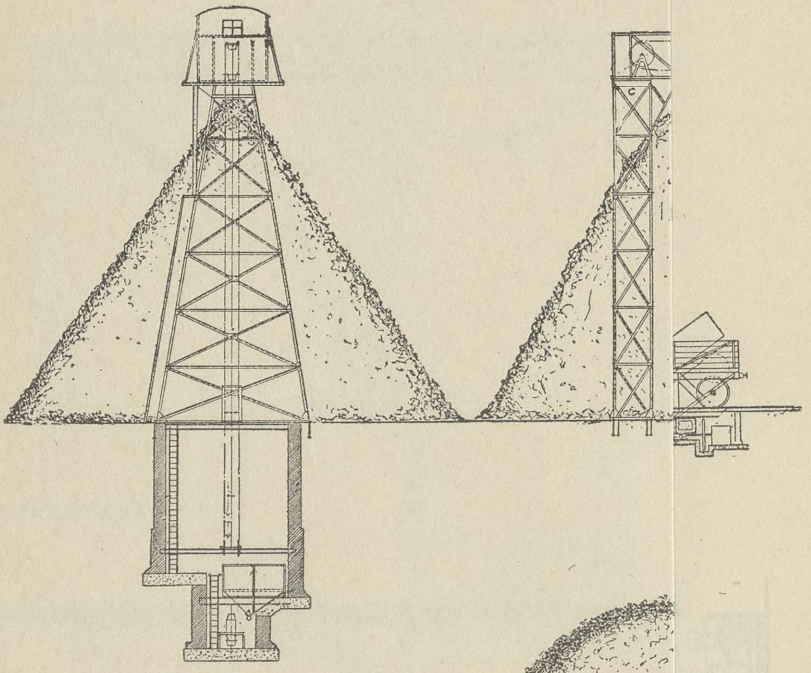
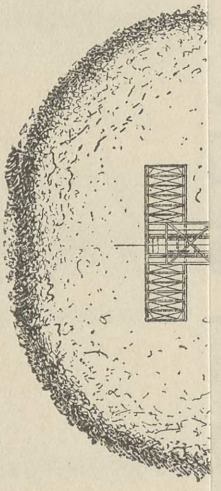




SECTION AA



Figs. 927, 928, and 929. Mechanicall

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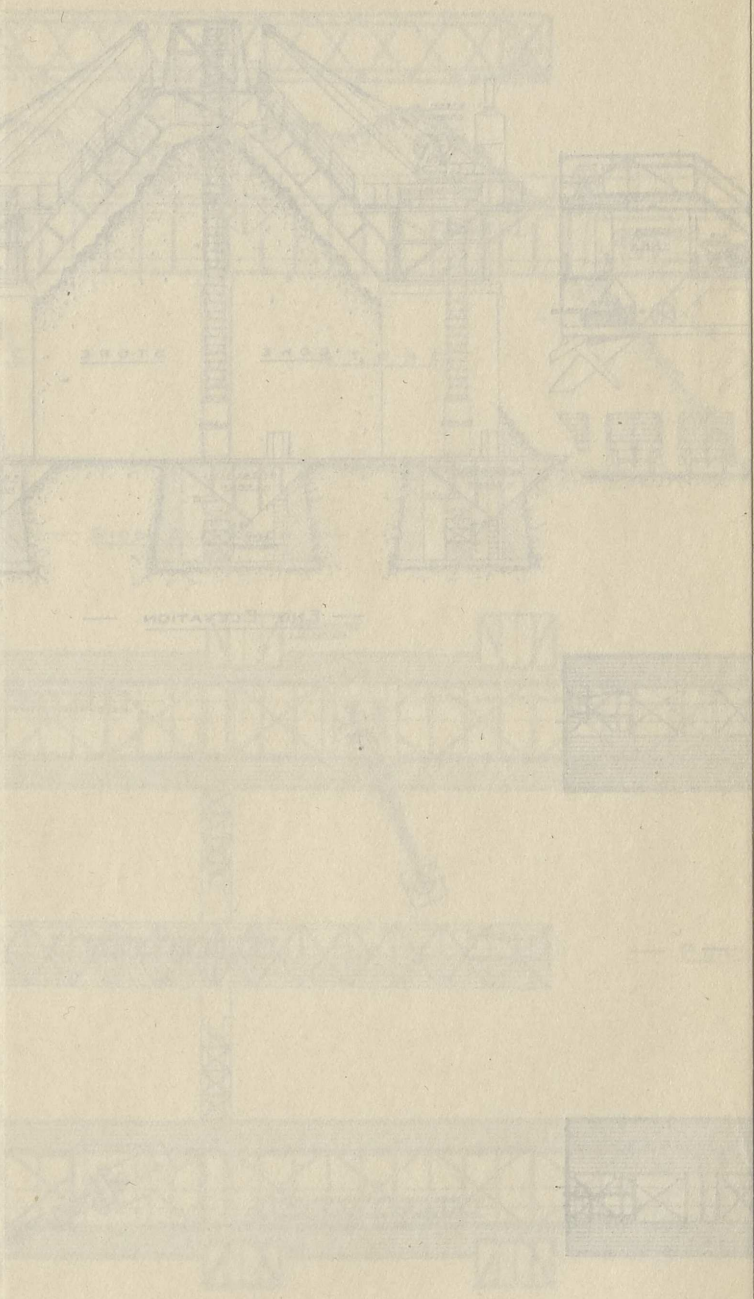

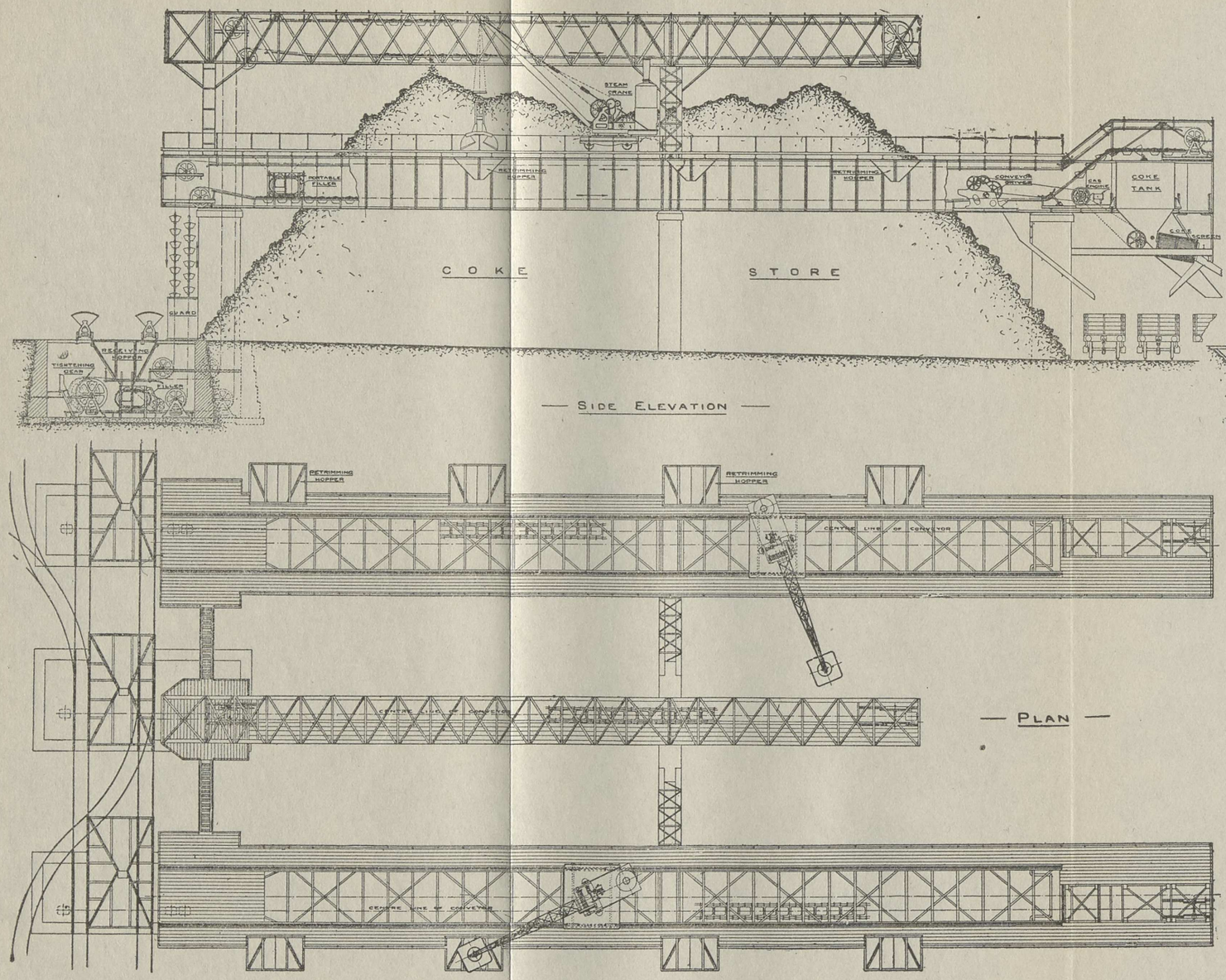

Figs. 930, 931, and 932. Mechanically equipped Coke Store at the Provan Gasworks, Glasgow Corporation, erected by Babcock & Wilcox, Ltd.

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receiving hopper on the jetty. These hoppers deliver into two breakers which reduce the chalk to a suitable size for handling in the cement works, and it is delivered into a stock heap, in the first instance, by means of a gravity bucket conveyor. The capacity of this plant is 60 tons of broken chalk per hour.

The installation was erected by Messrs Babcock & Wilcox for Messrs Caseborne & Co., Haverton Hill-on-Tees.

Phosphate Drying and Storage Plant (Darley System).—A complete plant of the Amalgamated Phosphate Co., of Florida, is shown in Figs. **924** to **926**, which represent the general scheme of operation of a modern pebble phosphate plant. The trains from the mines are run over the wet bins of 3,000 tons capacity to a stock pile beyond. From the former the rock is drawn by three belt conveyors. The mill building between the wet and dry bins contains the elevators and oil-burning driers. The dried rock is elevated, screened, and then distributed in the 30,000 tons dry storage by means of three motor-driven cars. Standard gauge phosphate cars are run in beneath the dry bin on the four tracks and are served by the loading spouts. The installation is the design of the Guarantee Construction Co., of New York.

Mechanically Equipped Ore Stock Pile of the Cape Copper Co., Briton Ferry.—The general arrangement of an installation for handling broken ore erected by Babcock & Wilcox, Ltd., is shown in Figs. **927** to **929**. Standard gauge railway wagons are brought to the point indicated on the elevation, and are placed on a cradle, which is tipped over into the small hoppers which supply the material direct to gyratory breakers, after which the material is conducted by means of a shoot into hoppers, which again in turn deliver into the rotary fillers of the gravity bucket conveyor. The material is elevated to the necessary height, carried over the storage space, and delivered at any points required, forming a large heap of ore. The capacity of the conveyor is 40 tons per hour, and the ore is taken away according to the requirements of the smelting works.

Coke-handling Plant at the Provan Gasworks, Glasgow Corporation.—This is shown in Figs. **930** to **932**, and the process is briefly as follows: The coke is brought from the retorts in tip wagons by small locomotives, and discharged into the receiving hopper shown on the side elevation. The coke immediately passes through a regulating device into the fillers of the conveyors and is elevated and passed horizontally by these conveyors over the heap and discharged at any points required. The wing or lower conveyors will build two outer heaps to a certain height, and the centre and higher conveyor will fill up the centre to a much greater height, forming altogether a long heap with three ridges, the centre ridge being higher than the outer ones.

Mounted on the gantries of the wing conveyors are travelling cranes, and these lift the coke from either the centre heap or from the lower wing heaps, delivering it to the hoppers which are shown in plan in connection with the wing conveyors, which latter will then carry it on to the screens shown at the extreme right of the side elevation. These screens are operated by a gas engine, and discharge the screened coke, breeze, etc., into the respective wagons set aside for this purpose.

The rate of handling of each of the conveyors is 30 tons per hour, or a combined capacity of 90 tons per hour.

The installation was erected by Messrs Babcock & Wilcox, Ltd.

Coal Storage Plant of the Indianapolis Light and Heat Co.—This installation (Fig. **933**) is unique in that provision has been made for submerging the coal under water to prevent spontaneous combustion. The plant has a total storage

capacity of 13,000 tons, and provides against coal shortage due to strikes at the mines or on the railways, and to car shortage.

The plant consists of a concrete pit 300 ft. long by 100 ft. wide and 28 ft. deep. It is 18 ft. below ground level, having a 10-ft. wall rising above the ground. Below the ground the wall slopes at an angle of 45°, this being done only to reduce the cost of construction. This makes the pit 72 ft. wide by 272 ft. long at the bottom. The

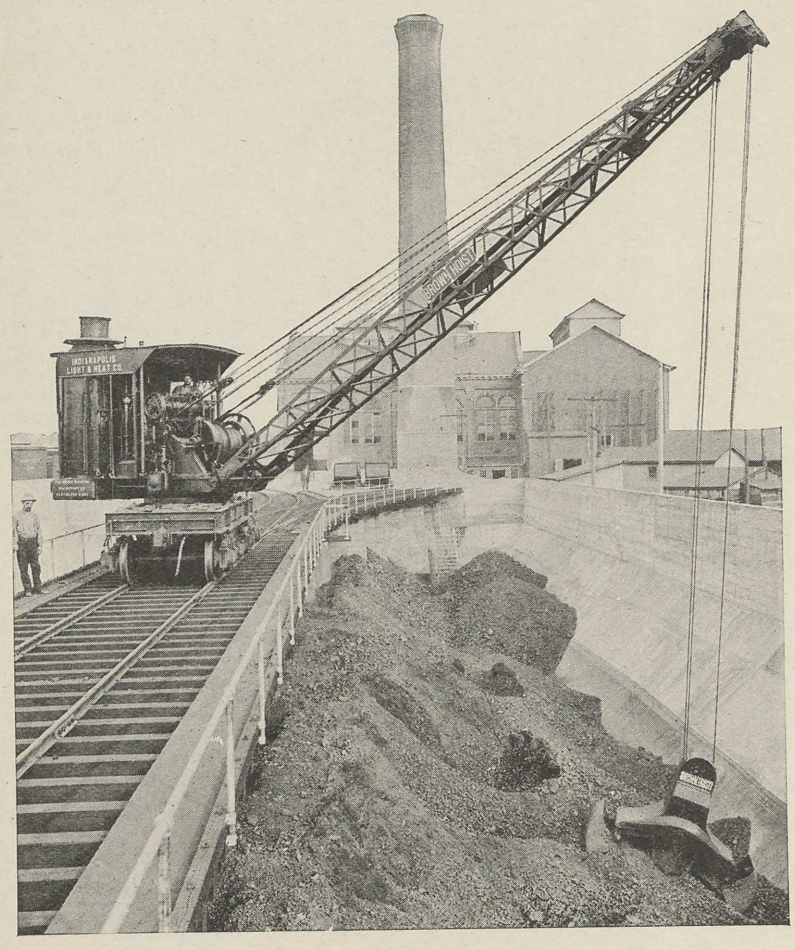


Fig. 933. Coal Storage Plant of the Indianapolis Light and Heat Co.

concrete is from 12 to 18 in. thick, and is reinforced throughout with twisted $\frac{1}{2}$-in. square rods to withstand any pressure from water that may rise in the gravel around the pit.

Through the middle of the pit lengthways there is a row of concrete piers placed 15 ft. centres. These piers support a trestle on which runs a standard gauge track. A 15-ton Brownhoist locomotive crane travels back and forth on this trestle, handling the coal on both sides with a Brownhoist 2 yd. coal grab bucket, suspended on a 40-ft. boom. The crane and bucket are operated by one man from his stand in the cab; the crane doing the switching of the cars off and on the trestle. The coal cars are run out on the trestle with the crane and dumped, and when the coal is required in the power house, it

is loaded into cars by the crane and carried to the boilers. 40-lb. rails are embedded in the bottom of the pit, 18 in. pitch, with $\frac{1}{2}$ in. of the head standing above the surface to prevent the bucket from striking the concrete.

The pit is filled with water up to the ground level, and covers 13,000 tons of coal. The water is pumped into the pit by a 4-in. centrifugal pump, taking the water from the pump-house supply well, and it enters the pit at the ground level. Through the centre of the pit and beneath the trestle there is a trough 12 ft. wide and 1 ft. deep, which serves as a drainage. It is fitted with a drain pipe which carries the water to either of two manholes, one at each end of the pit. The outlet openings are protected by gratings to prevent any coal from entering the drain pipe.

The pit was designed by Thos. A. Wynne, Vice-President of the Company, and was built under his supervision. The locomotive crane and bucket were furnished by the Brown Hoisting Machinery Co., of Cleveland, Ohio.

Mechanically Equipped Salt Store.—An interesting store mechanically equipped for storing and withdrawing salt or any similar material in bulk is shown in Fig. **934**. The principal mechanical agent in this case is a mono-rail, the skips or buckets of which

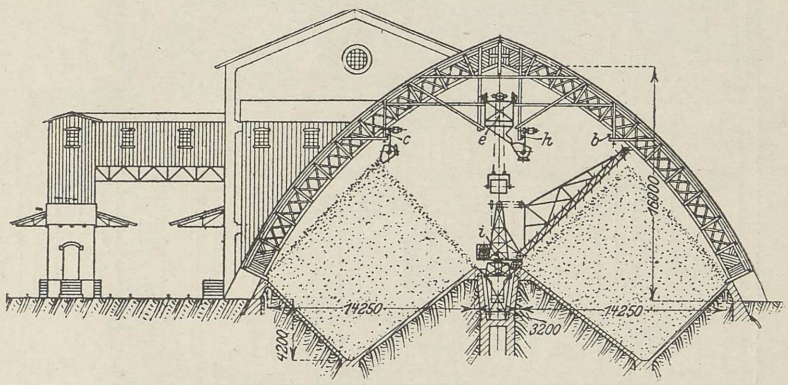


Fig. 934. Mechanically Equipped Salt Store.
(The dimensions are in millimetres.)

are used either to bring salt in or to take it out. The length of the store is 42 m., or 138 ft., and it holds 5,000 tons of salt. It is attached to a mill in which the salt is ground and the mono-rail telphers bring it on two lines *b* and *c* for warehousing, whilst line *h* is used for withdrawing the salt to the railway siding. When loading from lines *b* and *c* the self-tipping skips discharge automatically as shown. For withdrawing from line *h* the skips are filled from a loader *e* which is kept full by the portable device *i* and an electrically driven hoist skip. The device *i* consists of a scraper conveyor which travels the whole length of the store and takes the salt from the heap to the hoisting skip. The conveyor can work at any angle either as shown or it can dip down into the hopper bottom of the store and fetch the salt from there. The capacity of the mechanical installation is 60 tons per hour, two skips being used, and the driving power consumed is only 3 H.P. The plant was built by Messrs Luther, of Brunswick.

The Storing of Coal in Silos.—The most economical method of storing coal or minerals is in elevated silos or bins. This system has been adopted for many years as far as grain and seeds are concerned, but it is only of comparatively recent years that it has been adopted for the storing of coal and minerals, more particularly on the Continent and in America.

Some establishments have found it expedient to erect extensive silo or bin systems for storing coal, and have equipped the same with complete mechanical plants.[1] Figs. **935** to **939** illustrate the coal store which has been used by Messrs Possehl & Co., Altona, since 1896.

This store was designed to receive coal coming by boat up the Elbe, screening it, and then dispatching it either by rail for inland use, or by vehicular traffic for local consumption. Small coal is discharged from steamers, by means of a ship's elevator, of a capacity of 60 to 70 tons per hour, whilst large coal is unloaded by a crane and grab of a capacity of 40 to 50 tons per hour. The small coal which has been unloaded by the ship's elevator is stored in fifteen silos. These silos are hopper-bottomed, and the whole of their contents can therefore be withdrawn with a minimum of labour. Six of the fifteen silos are set apart for such coal as require screening.

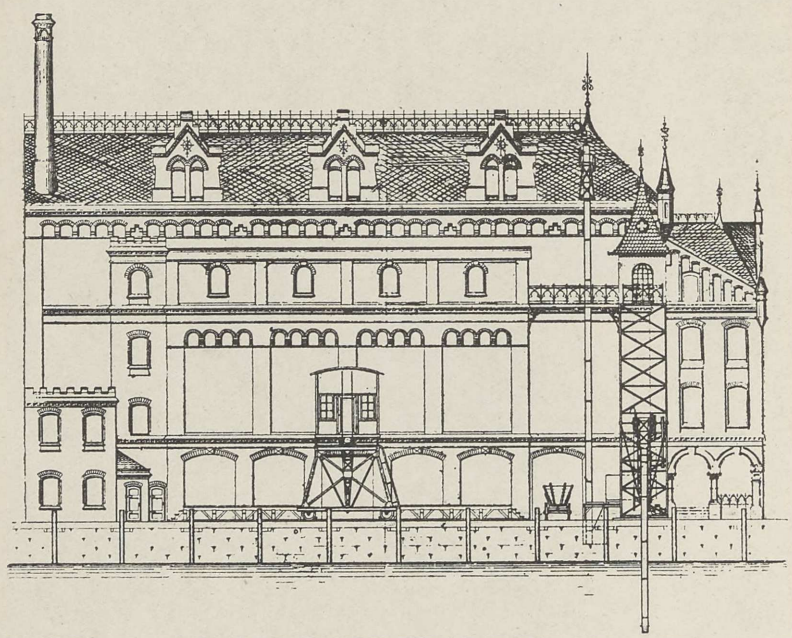
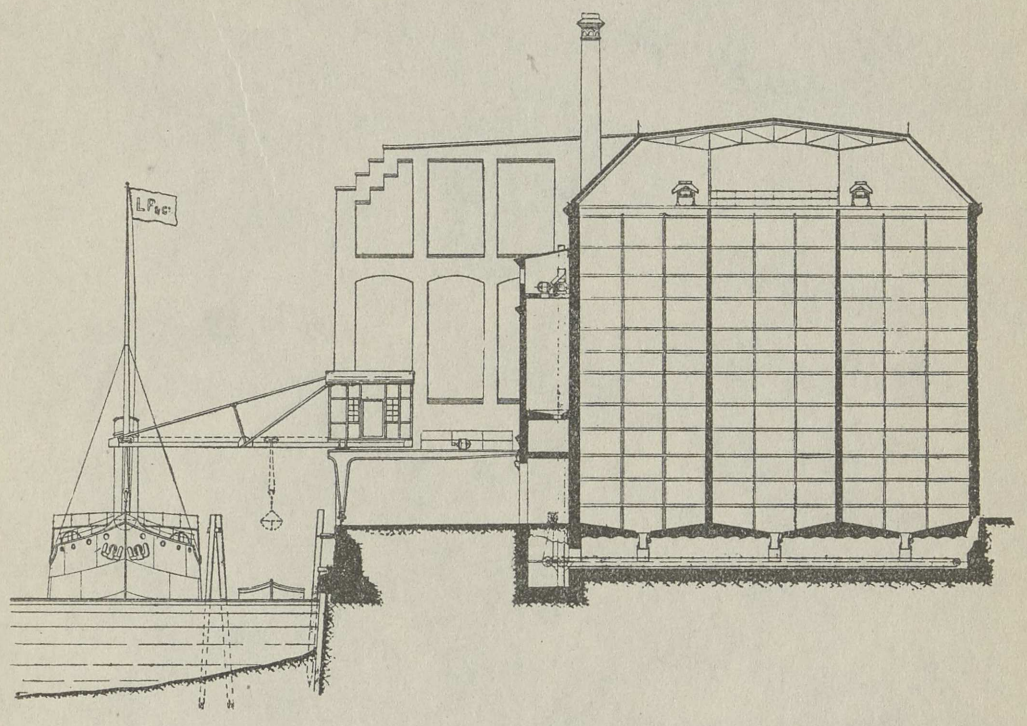


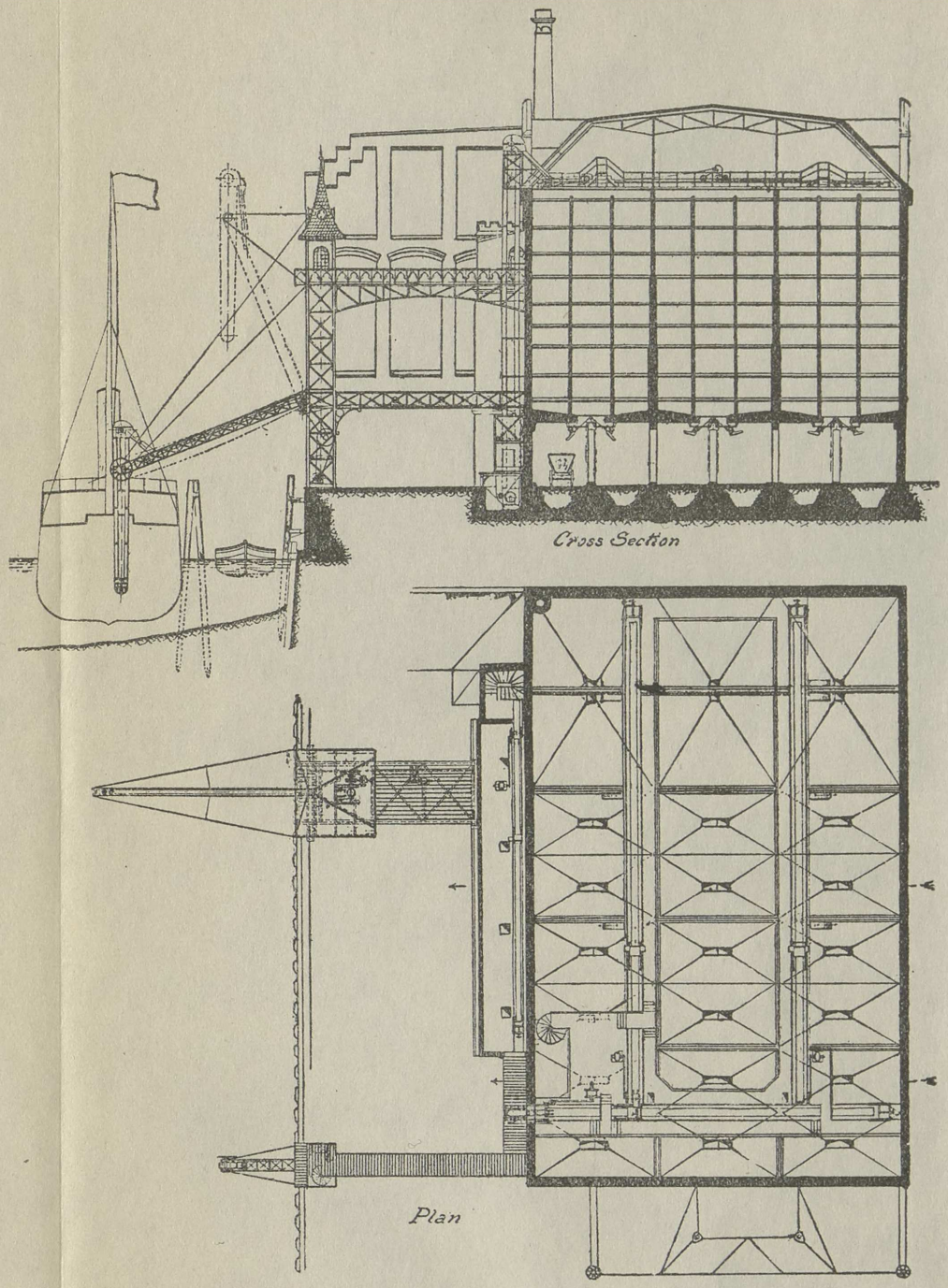
Fig. 939. Elevation of Coal Store, Altona.

The main store contains six silos 69 ft. in height, reaching down to the level of the ground, and nine silos of a height of 50 ft. The former measure 27 ft. 6 in. by 21 ft. 6 in., and hold 1,000 tons, whilst the latter have a floor area of 27 ft. 6 in. by 28 ft. 6 in., and hold 800 tons. On the quay is an iron tower containing an elevator, and connected with the main store by two gantries.

The ship's elevator is suspended from one end of a derrick which is supported from the tower. The elevator discharges the coal on to a band conveyor which has been erected within the derrick. This band in turn discharges its load on to a second band running on the lower gantry, delivering into an automatic weighing machine, whence it slides down a shoot to the well of an inner elevator which takes it to the top of the building, and to another band conveyor which is provided with a throw-off carriage to the various silos, almost identical with a granary installation.

[1] For installations of this class, but solely for feeding boilers, see "Coal, Coke, and Ash Handling Plants for Boiler-Houses, Gasworks, etc,," page 630.





Figs. 935 to 938. Silo Coal Store at Altona.

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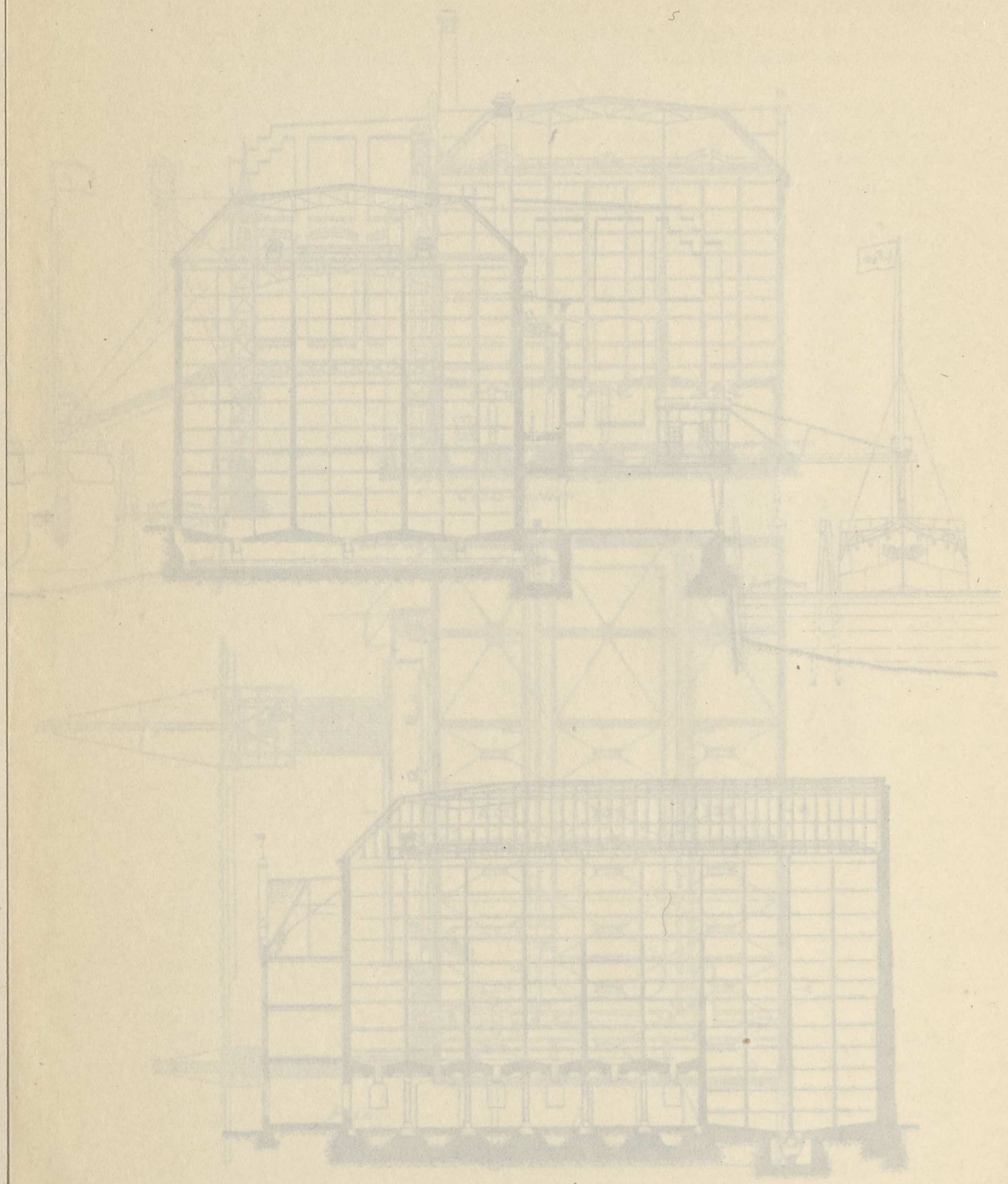


On the ground floor is a movable automatic weighing machine that can be brought into contact with any of the silo outlets, the coal being thus automatically withdrawn and weighed at the same time. This refers to the nine silos only. The remaining six, for coal to be screened, extend to the ground, and are connected with two band conveyors. These deliver the coal to another elevator which takes it up to the top of the building, from which it is conveyed by a band to the screening appliances, and thence into a series of smaller silos ready for loading into vehicles.

The whole installation is driven by electricity, and when in full work only consumes 120 H.P., which is generated by a vertical engine of 150 H.P. coupled direct to the electro-motor. A similar engine, but of only 45 H.P., is held in reserve for use when only a portion of the plant is required.

In these stores great care is taken to record the temperature at regular intervals, and thermometers enclosed in iron pipes are fixed in the different silos for this purpose, as a means of guarding against spontaneous combustion.

This installation is the design of G. Luther, of Brunswick, by whom it was erected, and to whom the author is indebted for the description and illustrations given above.

In Continental ports like Hamburg, coal stores either on this or a similar system are absolutely necessary, and they are also becoming popular in all great industrial centres.

General Remarks concerning the Warehousing of Coal.—With regard to the storage of coal largely imported from Great Britain, for the use of gasworks in Germany, the practice is to heap such coal up in the bin, or sometimes in little hillocks, 50 ft. high or more. German coal, however, could not be dealt with in this way. The English Gasworks at Berlin make a practice in the winter of storing 60,000 tons of English coal in one uncovered yard, and no instance of spontaneous combustion is on record. On the other hand, German coal, which is used in the City Gasworks of Berlin and Charlottenburg, and also in the power house of the Berlin Electric Co.'s works, is stored in much thinner layers; but in spite of this precaution explosions have often taken place, and serious loss has occurred from this cause. Westphalian coal, on account of the high proportion of sulphur it contains, seems more exposed to this risk than Silesian coal. In each store house where German coal is kept in any quantity some precautions must be taken against fire risks.

The civic authorities of Berlin require gasworks provided with railway sidings to maintain in store 30 per cent. of one year's requirements, but works which are dependent for their supply on water and canal traffic are compelled to keep about 70 per cent. of a year's consumption in stock on account of the possibility of obstruction of the waterways by frost.

As land is very dear in cities, it is clear that instead of spreading such coal on the ground, or packing it away in covered sheds, it will be more profitable to store it in silos which can be filled to a great depth. But as the higher coal is stacked, the greater the risk of combustion, some means must evidently be adopted to guard against this danger. The following is the plan devised by Professor Buhle, town architect of Charlottenburg.[1]

To reduce the depth of the layer of coal, the silos are divided into two or more sections, placed one over the other. These sections are completely separated, and are filled, emptied, and aerated quite independently. The coal is brought by boat, and carried by a gravity bucket conveyor to the top of the silos, and may be passed as desired by a shoot to an upper bin, or by way of a second spout into a lower bin. The spouts

[1] *Zeitschrift des Vereines deutscher Ingenieure*, 9th July 1900.

are provided with slides which may be opened or closed for the purpose of filling either the upper or lower bins. The same spouts also serve to ventilate the lower bins.

Coal brought by rail or by wagon is carried by subterranean shoots provided with cut off valves to the lower strand of the gravity bucket conveyor.

To lessen the danger of combustion it is perhaps above all things necessary to keep the height of the layer within certain limits, but another excellent means of combating this risk is to provide means of turning over the coal and clearing the bins whenever desirable.

The contents of the upper bins are discharged into railway trucks or carts and wagons by means of slides and shoots which are provided with valves, while the lower bins are discharged by a gravity bucket conveyor either direct or *via* the upper bins. For turning over the coal from the upper to the lower bins the slides communicating with the two may be used. The turning over, however, must not be repeated too often, on account of the breakage caused to the coal.

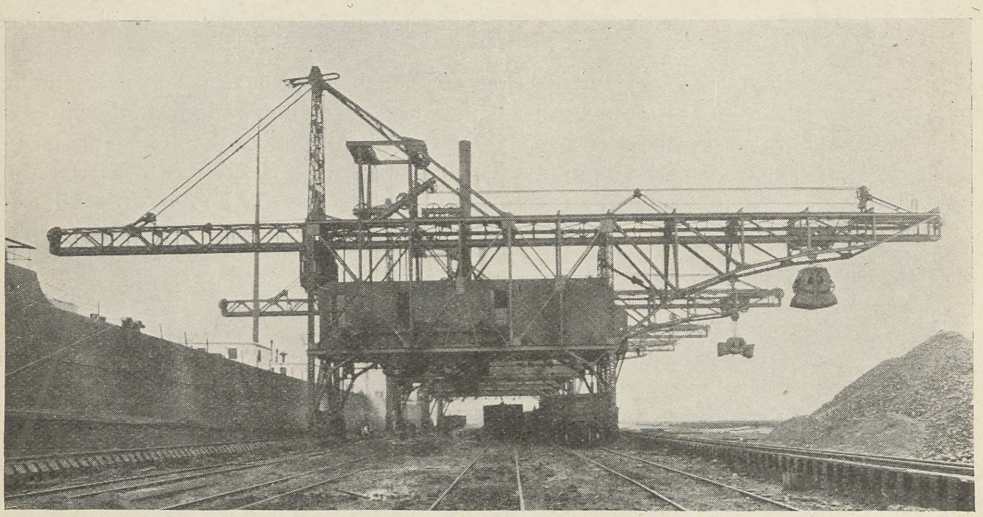


Fig. 940. Ore-handling Plant of the Wheeling and Lake Erie Railroad, Huron.

The temperature of the bins is exactly recorded from time to time by thermometers, which give the maximum temperature, the former being enclosed in iron pipes which descend into the coal.

The low cost at which the handling of the coal may be effected is, of course, the most essential feature in this system of storage. Another important point in this installation, in which it differs from any of its predecessors (including the 30,000 ton store of the Danish Coal Co., of Copenhagen), is its accessibility from all sides. Except for the necessary gangways, which of course take up a little room, the whole of the stores have been utilised for storage purposes. When the upper bins have been cleared they may gradually be filled from the lower, and this operation, carried out at a minimum of expense, has the undoubted advantage of aerating and cooling the coal.

The Mechanically Equipped Ore Pile, as in use by the Wheeling and Lake Erie Railroad, Huron, Ohio, is illustrated in Fig. **940,** which shows four stacking machines. They are built by the Wellman-Seaver-Morgan Co., are rope operated and

handle a Hulett automatic grab bucket having a capacity of 5 tons of ore. They are equipped with weighing hoppers for the purpose of weighing the ore before placing it in cars for road shipment. The cantilever at the end of the machine is provided for stocking purposes, and the machine can rehandle the ore from this stock pile into weighing hoppers, to be discharged into road cars.

In addition to the foregoing, reference may be made to the following installations mentioned in other chapters :—

The Coal Loaders at the Japanese Port Miike, see page 595, the mineral silos under "Rope Haulage," see page 259, and Boiler-House Installations, page 633 and following pages. Also some examples in the chapter on "Transporters," and the Hoover & Mason Ore-handling Plant included in the chapter "Handling Raw Material in Connection with Blast-Furnaces," page 353.

CHAPTER XLII

THE WAREHOUSING OF GRAIN

Silo warehouses are intimately connected with the mechanical handling of material, as grain and seeds must be conveyed to and from silos or floor warehouses by mechanical means, and the storage of grain in elevated silos will admit of its being withdrawn by its own gravity without the aid of manual labour.

A silo warehouse has obvious advantages over a floor warehouse as far as labour saving is concerned, but it is also an undoubted fact that some grain, particularly home-grown English and other soft wheat, is better stored in floor bins, because grain stored in high silos is subjected to great pressure, which has a tendency to raise the temperature of damp wheat. If it must be stored in silos it is necessary to turn it over at intervals.



Fig. 941. Ancient Egyptian Granary, from

The problem of how to store grain engaged the attention of the early Egyptians and of other nations of antiquity. Two distinct systems of grain storage were known to the ancients. The most primitive way was in all probability that of storing grain in pits or excavations in the ground, the object being to keep the grain as far as possible from contact with the air. This system is still in extensive use in Turkey and other Eastern countries, an instance in point being the rock pits of Malta in which wheat is stored to-day.

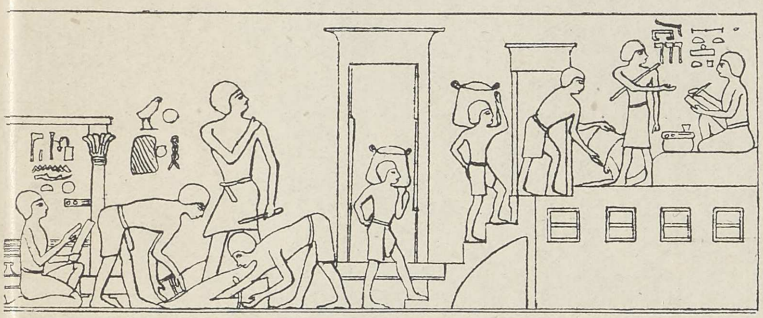
The ancient Egyptian granary illustrated in Fig. 941 [1] is from a fresco in the tomb at Beni-hasan, twelfth dynasty after Lepsius, and represents the officers of the Nomarch Khnumhotep at Beni-hasan with the scribes and functionaries of the government. On the left is the treasury, where the gold and silver rendered in exchange for grain is weighed, and the amount booked; in the middle is the steward of the estate, who records the amount of corn bought; and on the right the sacks are filled with grain and carried into the granary under the supervision of an official, and a clerk records the quantity deposited in the store.

Later on another and radically different system was adopted, which is still used even in this country. This method consisted in spreading grain over a floor of hard earth or concrete, and of bringing it as much as possible in contact with the atmosphere by turning the layers of grain over from time to time.

In modern days the ancient practice (which is undoubtedly the most correct one) of more or less excluding the air from stored grain has been to a great extent reverted to.

[1] From "Engineering of Antiquity" by the same author.

When new grain is brought into a granary it begins to sweat, and a rise of temperature is perceptible as well as a peculiar smell, which proves that not only does water escape but also a volatile oil. There must also be an escape of carbonic acid, for the heating of the grain can only be produced by the combustion of some of the solid substances, the starch being likely to suffer greater reduction than the small percentage of fat and protein. In order to keep the grain as nearly as possible at its right weight and in good condition it is necessary to prevent heating and only to promote evaporation of moisture artificially. This can be effected in various ways, the most common being to store the new grain in thin layers on the floor and turn it over frequently, until sufficiently conditioned to keep in silos. The method of turning wheat over in silos is less effectual, especially in the case of very new wheat, than the former method. When wheat is thus stored in thin layers the grains absorb oxygen constantly and issue carbonic acid in exchange for the oxygen taken up; they are in fact in a state of slow combustion. The hygroscopic nature of the grain is responsible for this action, as the grain absorbs moisture in a damp atmosphere and gives off moisture in a dry atmosphere. According to Muntz, the more the air is renewed the moister the grain, and the higher the temperature the greater is the issue of carbonic acid. It follows then, from the above, that in order to store conditioned grain to the best advantage it should be kept in a dry and cool place, and the air excluded as much as possible.



a Fresco in the Tomb at Beni-hasan.

Some experiments as to the keeping quality of grain were made by Mr Doyère,[1] who in 1820 constructed a silo in which grain was kept for eight years. When the French Government ordered an investigation of the subject in 1855, Mr Doyère reported that the system of storing grain in silos greatly retarded decay, and that corn containing 21 per cent. of moisture and in contact with the air gave off 17 mg. of carbonic acid per kilogram per hour, or 408 mg. per day, while with the air excluded and at an average temperature of 68° F., the carbonic acid given off per day was only 120 mg. From this it would appear that grain exposed to air decomposes three and a half times as fast as when stored in enclosed silos. The experiments of Professor Tyndall[2] and of the late Mr Pasteur also bear out this conclusion.

The above, of course, refers only to the storage of grain in good and sound condition. New and damp grain containing a large percentage of moisture would not be safe from decomposition even if stored in perfectly air-tight silos. Such grain must be dried or conditioned artificially, stored in shallow bins, and turned over frequently until it is in a suitable condition for keeping.[3]

The origin of grain warehouses is attributed to Hungary, but these early examples

[1] "Conservation des Grains par l'Ensilage," by L. Doyère, Paris, 1862; and "Silos, Ensilage, and Silage," by Dr Manby Miles, New York, 1889.

[2] "Essays on the Floating Matter of the Air," Second Edition, London, 1883.

[3] *Proceedings Inst. Civil Engineers*, vol. cxxvi., Paper No. 2815, by P. W. Britton, on the "Transport and Storage of Grain."

were comparatively small structures, and do not appear to have been provided with any noteworthy appliances for the mechanical handling of grain.

It is to America that the credit belongs of designing granaries capable of holding immense quantities of grain and seeds, and of equipping these warehouses with machinery to obviate as far as possible the necessity of employing hand labour in the handling of the grain. In these warehouses (known in America as "Elevators") air is excluded as far as possible, but in all modern granaries there is this important departure from the original method, that the grain is stored, not in the earth, but in silo bins or some other structure above ground.

Silo warehouses[1] have been known in America since 1846, when they first came into general use, and large installations have since then been erected at all the most important grain producing centres, as well as at the points where grain is exported. It was not, however, until the beginning of 1880 that the first silo warehouse of any great capacity was built in New York. One of the most valuable features of the American silo system is this, that it enables the agriculturist to store his grain cheaply under the best conditions, and to hold it until the market is favourable to a sale. He can also mortgage his grain while he is waiting for a fair price.

In America this system has been carried out on an enormous scale. A holder can store his grain in a granary, say at Chicago, and can withdraw grain of a similar grade from some other warehouse, say at New York. In fact the grain trade there is carried on somewhat after the manner of the clearing house in the money market.

Comparing the floor system with the silo system for the storing of grain, it may be mentioned that where silos are applicable the same capital outlay will provide a granary of the latter type which will accommodate twice as much wheat as one on the floor system.

Silos, their Shape and their Construction.—Silos may be either square, circular, or hexagonal, and may be built of wood, brick, concrete, iron, or a combination of the two latter—reinforced concrete. The choice of material depends to some extent upon climatic conditions. The most suitable material for square bins is wood, for circular bins iron, and for hexagonal bins brickwork or concrete. Circular silos are the strongest, but are less economic in space than the other two forms. A large number of circular iron silos are used in America, the space between four large bins frequently being occupied by a smaller one.

Wood,[2] as a material for building silos, has the advantage of being light, strong, inexpensive, a non-conductor of heat, and hygroscopic. It has also the further advantage of yielding to an unequal pressure or to a possible settlement of the structure. One of the most usual forms of construction is perhaps that known as the early American system, or "cribwork," which consists of flat strips of wood nailed one on top of the other, and overlapping each other at the corners, so that alternately a longitudinal and a transverse batten extend past the corners. Short pieces of timber are nailed down on the spaces forming alternate gaps, so that the whole silo wall is solid to the end. This is undoubtedly a strong form of bin, but it has certain disadvantages. The planks are liable to dry-rot and cannot be renewed except with great difficulty.

Bricks or cement are suitable materials for the construction of silos, as they are bad heat conductors; they are, however, lacking in hygroscopic properties. The drawbacks

[1] To avoid misunderstanding, the term "elevator" (which is in America largely applied to these warehouses) has not been adopted in this book, as in this country the word is exclusively used with reference to ordinary elevating machinery and not to granary buildings.

[2] Paper by Mr P. W. Britton on the "Transport and Storage of Grain," also paper by Mr J. Whitaker, A.M.Inst.C.E., on "Silo Granaries for Modern Flour Mills."

to the use of such material are—its weight, the consequent necessity for stronger foundations, and the need for making the divisions thicker than when using wood.

Iron has the distinct advantage that the silo walls can be thinner than in the case of any other material, but its non-absorbent nature, and the fact that it is a good conductor of heat, curtail its use for this purpose, as it transmits to the grain every change in temperature, and therefore causes condensation against the silo walls, with the consequent formation of rust and mould.

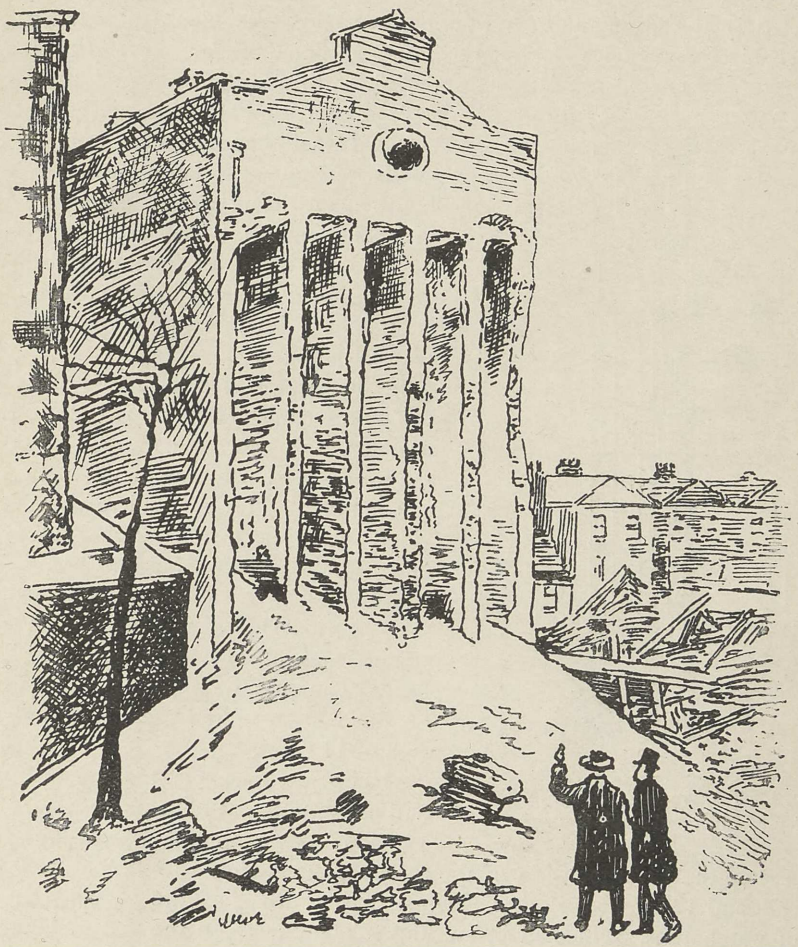


Fig. 942. Collapse of End Wall of Silos at Isleworth.

Ferro-concrete is the material most largely used at the present day. If well constructed, no detriment will be caused to the structure through uneven expansion of the material. The first type was probably the Monier, followed by the Hennebique, and constructed of an iron or steel framework filled in with concrete, whilst the most modern construction consists of steel rods embedded in cement.

In the case of silo walls constructed of brickwork, these should be built in cement and not used until they are thoroughly set, or better still, hoop iron should be built in, at least at the end walls. Fig. **942** shows the results of non-observance of this rule.

The illustration represents the collapse of the end wall of a silo warehouse at Isleworth on the Thames. The brickwork of the wall and the grain contained in the five end silos were all deposited on the adjacent ground.

Granaries at the Liverpool Docks.[1]—These granaries were probably the first of any note to be erected in this country and fitted with mechanical appliances for handling grain, and although they are not silo warehouses, they are here described on account of their historic interest.

In 1868, to meet a want that had been long felt in the port of Liverpool, there were erected for the storing and conditioning of grain, large blocks of warehouses fitted with mechanical appliances designed by and executed under the supervision of Mr Lyster, the docks engineer. Although erected for this particular object, the warehouses were at the same time so designed and constructed that they could be used as ordinary goods warehouses, a large portion of the warehouse plant being available for the handling of general goods. The plant of these warehouses is designed for loading and discharging grain in bulk or in bags, also for transporting grain into different parts of the building and for ventilating it.

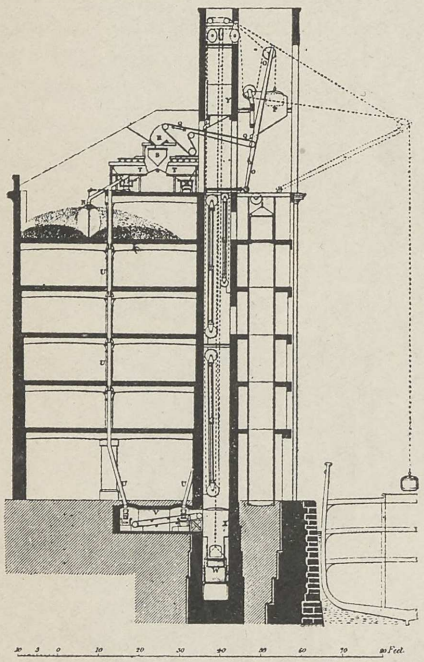


Fig. 943. Transverse Section through Portion of Liverpool Dock Granaries.

The largest vessels can lie alongside, and can be discharged either directly on to the quay, or their cargo can be conveyed to the top of the warehouses or to any of the floors. Proper accommodation for rail and road traffic is provided, and goods are discharged or loaded direct from or into wagons or carts. The warehouses on the Liverpool side are situated at the Waterloo Docks, and contain an aggregate storage area of $11\frac{3}{4}$ acres, including the quay floor. Those on the Birkenhead side are erected on the margin of the great float, and have an area of 11 acres.

The warehouse plant is similar in principle and construction at both warehouses.

The dock around which the blocks of warehouses on the Liverpool side of the river are situated is 570 ft. long, 230 ft. broad at one end, and 180 ft. at the other. Three sides of the dock are occupied by separate blocks of warehouses, connected by gantries. The blocks on the east and on the west sides are 650 ft. long and 70 ft. wide, while the blocks at the north end are the same width and 185 ft. long. Each block contains five stories, as shown in the transverse section (Fig. **943**). Above the top or fifth storage floor, and partly in the roof, some of the machinery is erected, while below the quay level are wells and arched subways to receive machinery. There are five discharging berths for large vessels, namely, one at the north block and two at each of the east and west blocks. Additional accommodation is also provided for small vessels. In the centre or north block is placed a steam engine of 370 H.P. which, in addition to driving the whole of the warehouse plant, supplies power for working the dock machinery and the bridges over the entrance.

[1] From a paper by Percy Westmacott, *Proceedings Inst. Mechanical Engineers*, August 1869.

The principal operations to be effected by the aid of machinery were as follows:—

Discharging grain in bulk from vessels or small craft directly on to the quay; discharging ordinary merchandise direct on to the quay, or carrying it to any floor of the warehouse, and loading outward-bound vessels; lifting and lowering sacks, bags, and other merchandise on lifts and hoists to or from any floor; elevating, screening, weighing, and distributing grain, and conveying it to or from all parts of the warehouses to any other part and back again as required for conditioning damp or heated grain.

The best means of effecting these operations were the subject of much consideration and of many and costly experiments, particular attention being paid to the question of the kind of power to be used, and the most convenient, economical, and practical method of applying and distributing the power.

Ultimately it was decided that a hydraulic system of power distribution best met the requirements of the case, electric driving not having been thought of at that time. As the result of experiments, band conveyors were adopted for transporting grain horizontally from one part of the warehouse to another. The maximum quantity of grain conveyed

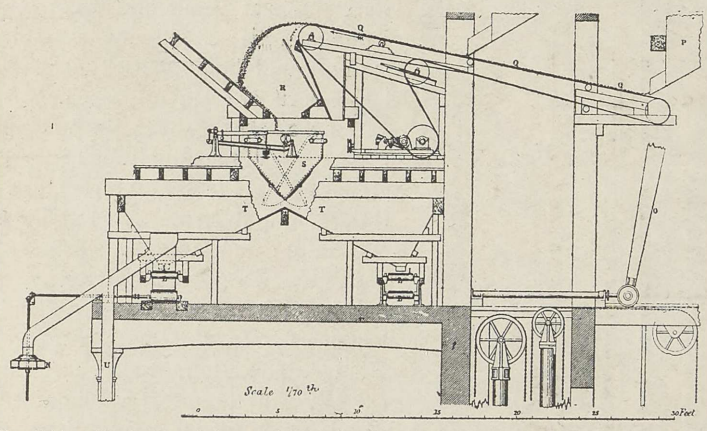


Fig. 944. Grain Receiving and Distributing at the Liverpool Dock Granaries.

by an 18-in. band is at the rate of about 70 tons per hour, and it was ascertained that the power required to drive the band when fully loaded and delivering at that speed was infinitely smaller than with a worm.

In order to save labour in spreading the grain over the floors of the warehouses, and also to condition it by ventilation, a revolving fan with a scattering action was tried with success as shown at N in Fig. **943**. This fan is placed 9 ft. 6 in. above the ground, and at its usual speed of 250 revs. per minute deposits the grain over an area of 45 ft. in diameter.

Five hydraulic cranes for discharging vessels are fixed in towers specially constructed in the warehouses, one of which is shown at O in Fig. **943**. These cranes are arranged for raising grain in skips containing 21 cwt. of bulk, at a maximum rate of 50 tons per hour.

The hopper P (Fig. **944**) into which the grain is dropped from the skip holds about 8 tons of grain, and from this hopper the grain is diverted into two streams, and allowed to flow through spouts fitted with regulators on to two 18-in. inclined bands Q.

The construction of the elevators (Fig. **943**) for raising the grain from the bottom to the top of the warehouses is shown to a larger scale in Fig. **945**. The wrought-iron skip

w, capable of holding about 1 ton of grain, is slung from the lifting chain by an arrangement of bars and levers provided with guiding rollers running between upright timbers, which are so arranged that on arriving at the top the bucket tips over and discharges the grain into the top hopper Y. This hopper delivers the grain upon the same inclined cross bands Q that convey the grain from the outer crane hopper P. The bottom hopper X feeding the elevator is made in two sections, the upper of which, protected by a grating, receives the bulk of the grain.

The clear aggregate storage area of all the floors, except quay and silo spaces, is 48,918 sq. yds., and at 4 qrs. per yard would give a storage capacity for say 196,000 qrs. of grain. There are six silos constructed of bricks and capable of containing 3,500 qrs., the total storage thus being 199,500 qrs.

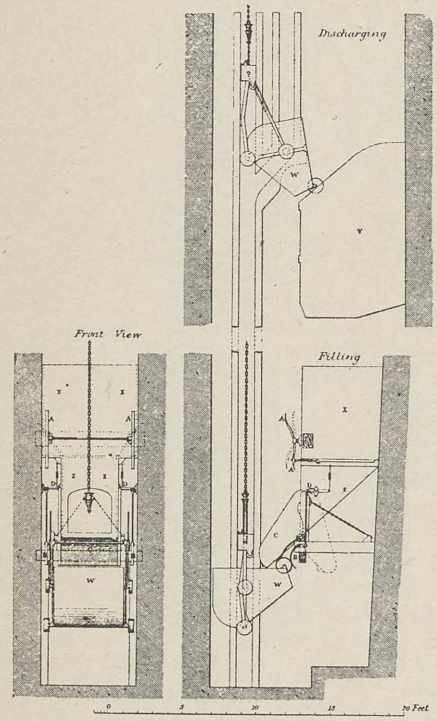


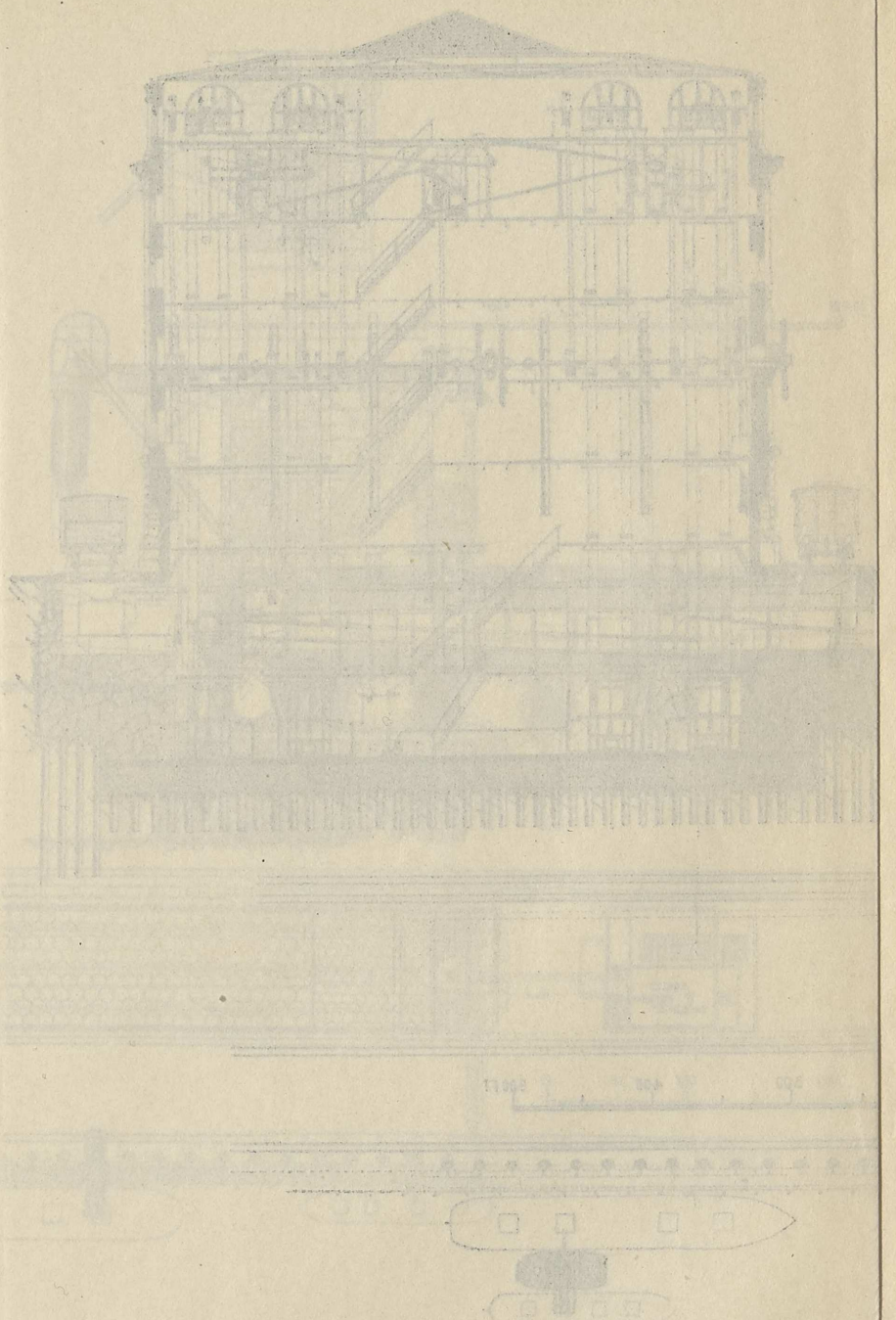
Fig. 945. Grain-Receiving Elevator at the Liverpool Docks Granary.

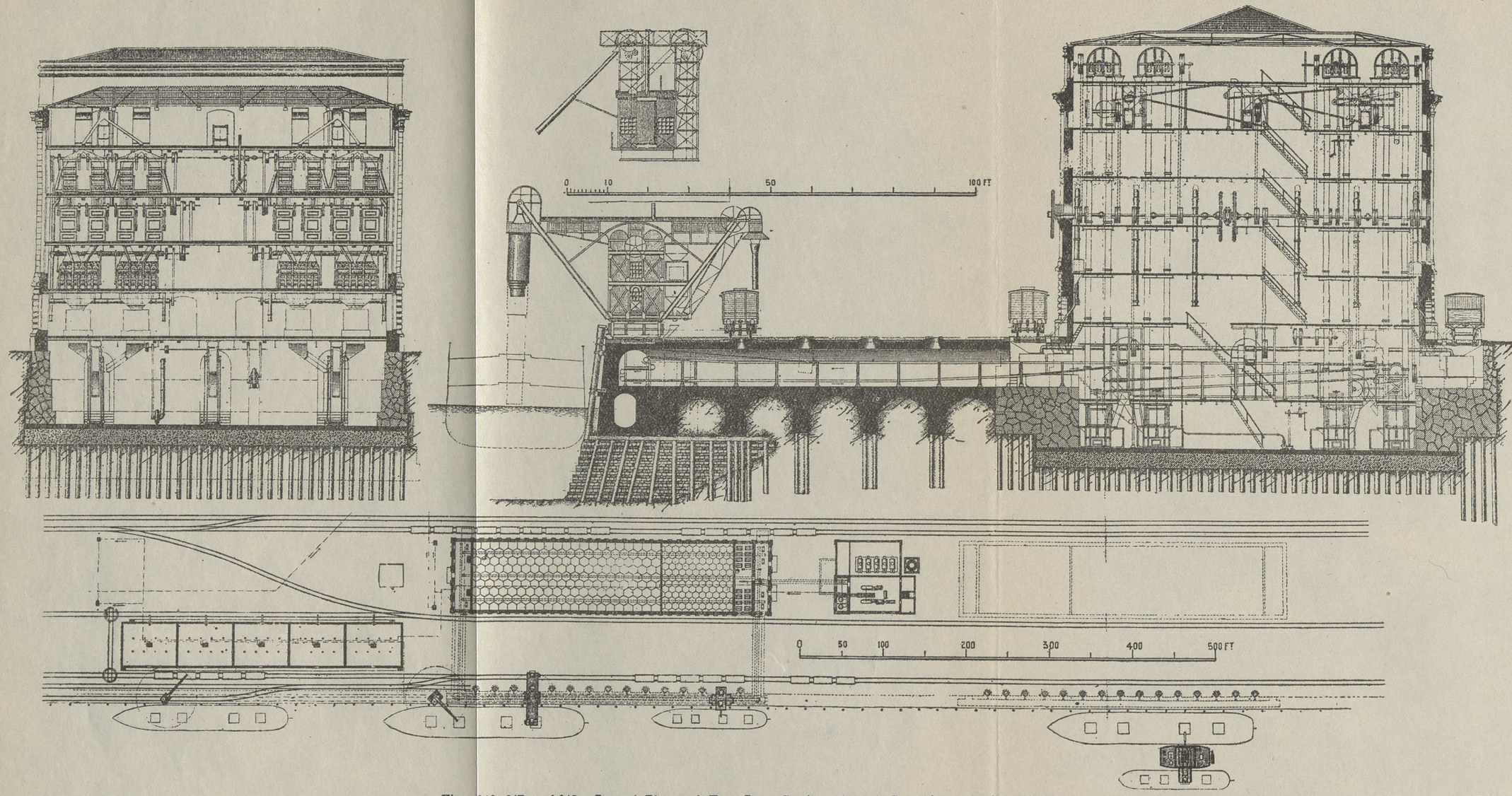
Granaries at Braila and Galatz, Roumania.—Amongst the first silo warehouses of any great capacity that were erected in Europe for the storage of grain were the silo warehouses at Braila and Galatz, in Roumania. Roumania is essentially a grain-producing country, and her prosperity largely depends on her exports of grain and seeds.

Late in the eighties the Roumanian Government realised the importance of erecting modern granaries at the two chief ports, Braila and Galatz, and the sum of 21,500,000 francs was allotted for that purpose. The credit of designing these two great granaries, the general plan of which, by the way, is practically identical, belongs to Mr H. Saligny, a high official of the Roumanian State railways. The entire mechanical plant of these two warehouses was supplied and erected by George Luther, of Brunswick, Germany, the contract being signed in 1887.

Before describing these granaries, it may be well to dwell briefly on the grain trade of Roumania, which increased by 50 per cent. between 1880 and 1888. Roumania affords a striking example of the economical use of grain-handling machinery where a great bulk of material has to be dealt with, even in a country where labour is very cheap.

The chief agricultural products of the country are maize, wheat, barley, rye, and oil seed. In 1880 the export of grain from the Roumanian ports amounted to 1,324,090 tons; by 1888 it had increased to 1,951,905 tons. Approximately half the exports from Roumania go by steamer down the Danube and through the Mediterranean. Although Braila and Galatz are not exactly seaports, being both situated on the Lower Danube, yet they are accessible to sea-going steamers. As it is a ten hours' run from the Black Sea to Braila, it is in contemplation to economise by building a further granary at Constanza. Such a step appears the more essential seeing that at the rate at which the traffic increases, these two granaries will before long be inadequate to the demands upon them. These two warehouses superseded a certain number of private granaries which





Figs. 946, 947, and 948. General Plan and Two Cross Sections through Granaries at Braila and Galatz.

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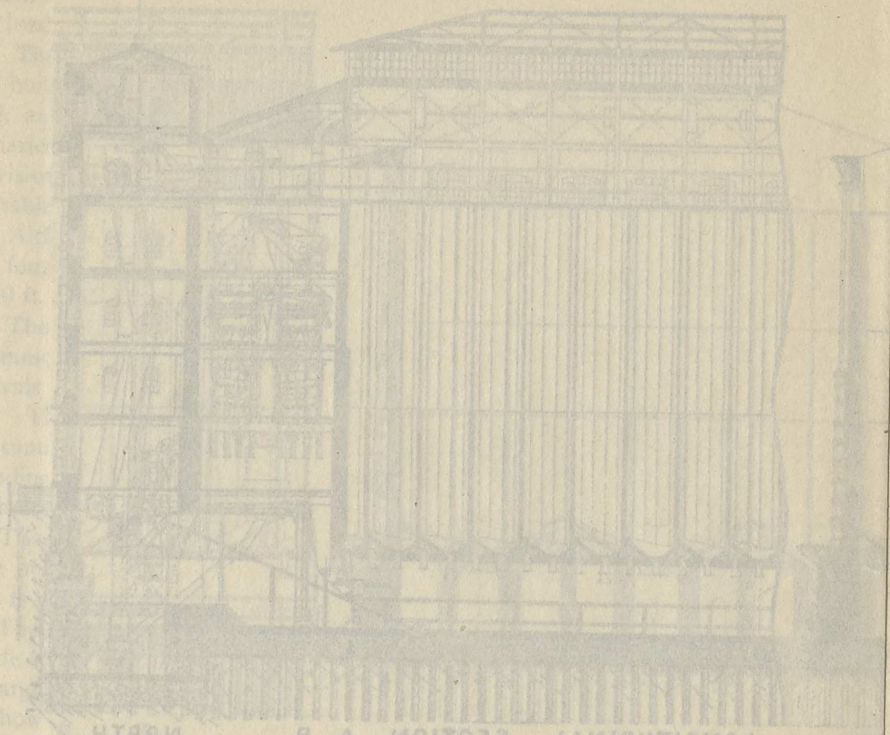
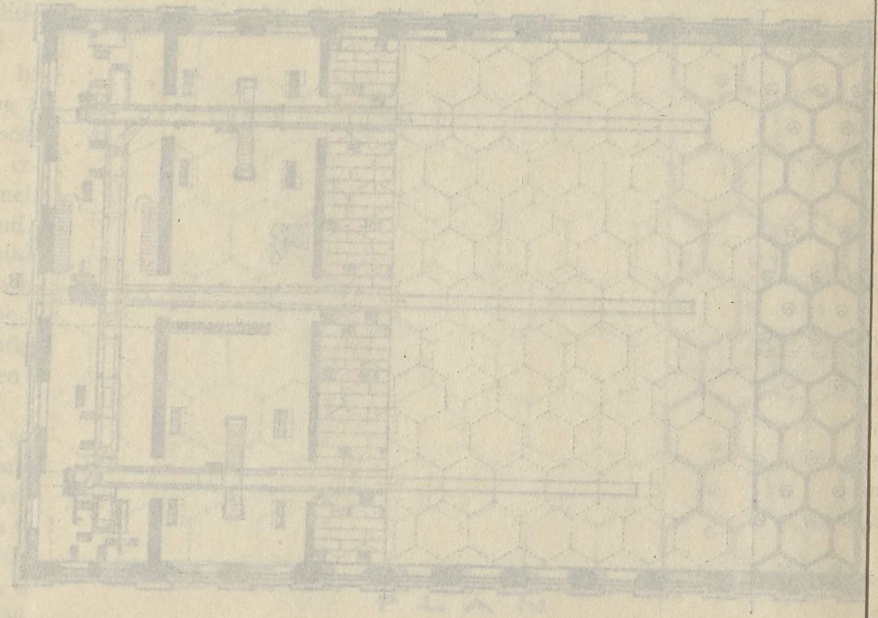
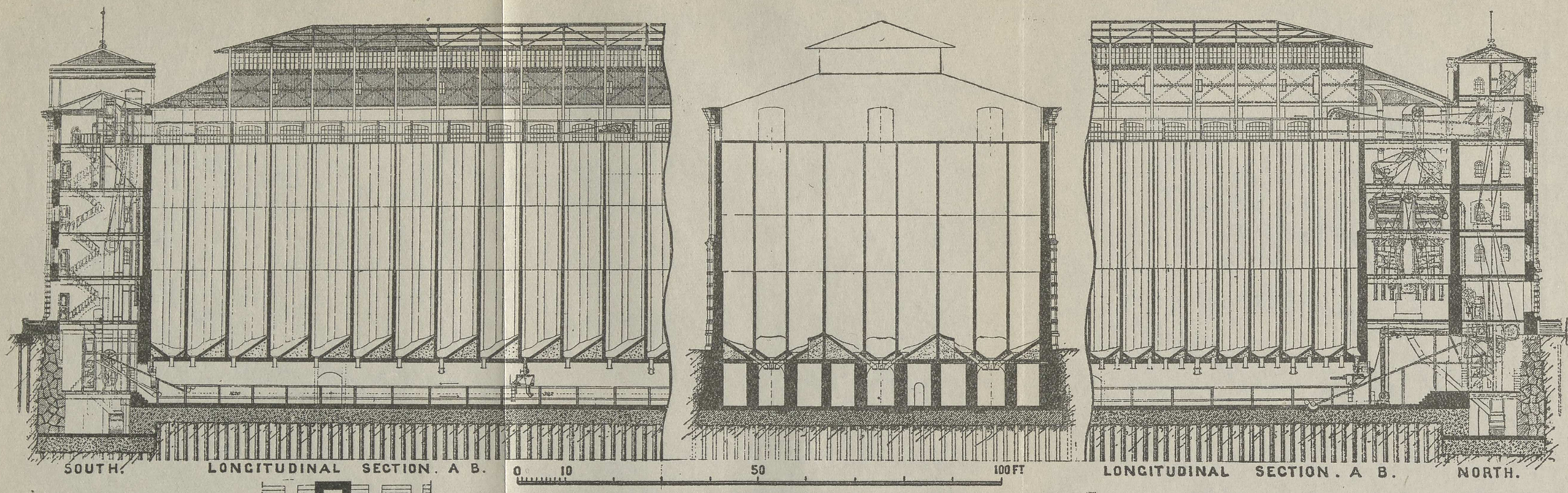


LONGITUDINAL SECTION, A B. NORTH.



Plan, Longitudinal and Cross Sections [illegible page 678.



Figs. 949, 950, and 951. Ground Plan, Longitudinal and Cross Sections through Granaries at Braila and Galatz.

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existed at both Braila and Galatz. These were, however, one and all situated at some distance from the quays, and lacked modern grain-handling machinery. In those days the loading of ships with grain was a cumbrous and expensive process.

The Granary Buildings.—The marshy nature of the banks of the Danube precluded the building of the granaries on the river bank. It was therefore decided to excavate, both at Braila and Galatz, a basin 1,640 ft. long by 400 ft. wide, and to erect the granaries on the quay wall of these basins. In building both these silo warehouses provision was made for doubling the installation at some future time should this be desirable.

Although these silos were built at some distance from the actual river bank, it was found necessary to erect them (as well as the quay walls) for their whole length of 1,640 ft. on piles.

The illustrations show in cross section a tunnel of considerable dimensions for the accommodation of a band conveyor. Besides these there are along the quay walls, at intervals of 23 ft., fifteen well-like receptacles of a depth of 20 ft. and a diameter of 6 ft. These are connected with the above-mentioned tunnel by shoots. (The use of this tunnel will be more fully described later on.) There are also two transverse tunnels extending to the ends of the silo building. One of the sections shows these tunnels, which are all intended for the reception of band conveyors.

The silo-house lies back at a distance of 115 ft. from the quay wall, the ground space occupied being 394 ft. long by 92 ft. wide. The height of the building to the eaves is 60 ft.

The granaries with their accessories are illustrated in Figs. **946**, **947**, and **948**, which include a small scale ground plan and two cross sections. Figs. **949**, **950**, and **951** give, to a larger scale, the plan of the granaries in longitudinal and cross sections. Figs. **952** to **956** show plan and four elevations of the engine and boiler house.

The foundations of the granaries were laid on a system of more than 5,000 piles. In addition to this, the foundations of the building extend to a depth of 23 ft. into the ground. Immediately on top of the piles is a layer of concrete which brings the level of the basement to 17 ft. 6 in. below the outer ground level. Both ends of the building terminate in two higher parts to accommodate the staircases, elevators, automatic scales, and driving gears. The centre portion of the building which encloses the silos is covered by a roof with large skylights. The whole of the basement is intersected by tunnels which run the entire length of the building. The tunnels are each 10 ft. high, and are intercepted at three points by cross tunnels connecting the nine transverse silos. Above these tunnels rise the silos themselves. They are 55 ft. high, and of a hexagonal shape.

The building material used for these silos was Monier plates, which consist of cement slabs with wire insertion or foundation. These insertions project at the ends of the slabs, and when the latter are set in position, corner cavities are formed into which these ends are inserted. The cavities are then filled up with semi-liquid cement, which, when hardened, forms a solid block. The silos in both granaries are made in two sizes, about one-fourth of the area being occupied by cells measuring 8 ft. 2 in. across, whilst the remaining cells have a measurement of 11 ft. 6 in. Between the silos and the northern annexe, in which the stairs, etc., are situated, is an elaborate grain-cleaning plant.

Further north still, in a separate building some distance away from the actual silo-house, is the engine and boiler house, the arrangement of which will be seen from Figs. **952** to **956**. This building is divided into four sections, more than half being occupied by the boilers, while one section is taken up by the steam engine. All these buildings

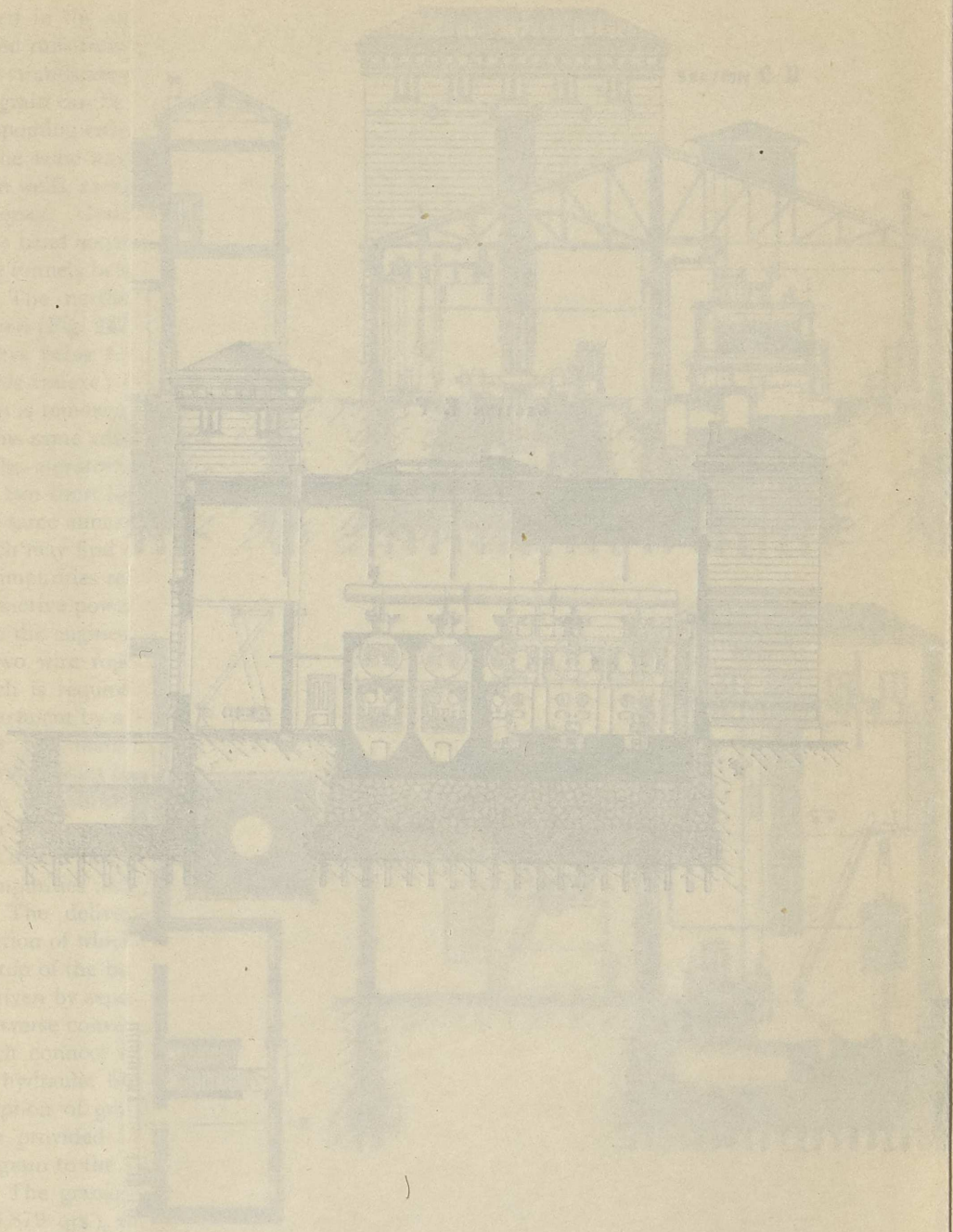
are covered by an iron roof which is amply provided with skylights. The five boilers and the 500 H.P. engines were installed with a view to the future extension of the plant. The engine is of the compound condensing type, with a high-pressure cylinder of 27 in. diameter, while the low-pressure cylinder is of 52 in. diameter. The stroke is 50 in. The flywheel, built in eight sections, has a diameter of 21 ft., and is grooved for twenty 2-in. ropes. The engine makes 60 revs. per minute. The water for the jet condenser is taken from the river basin. The southern portion of this structure which lies nearest the silo warehouse is raised above the roof of the engine and boiler house, and forms a tower which contains the main shaft, with its pulley receiving the drive by means of the twenty ropes from the engine. There, too, is the hydraulic pumping installation. In the northern portion of the same building is the storekeeper's department on the lower floor, whilst the upper floor is set aside as a living room for some of the attendants. The granary is surrounded by a system of sidings, with turntables and hydraulic capstans, which greatly facilitates the work of loading trucks from, or unloading them into, the silo elevators.

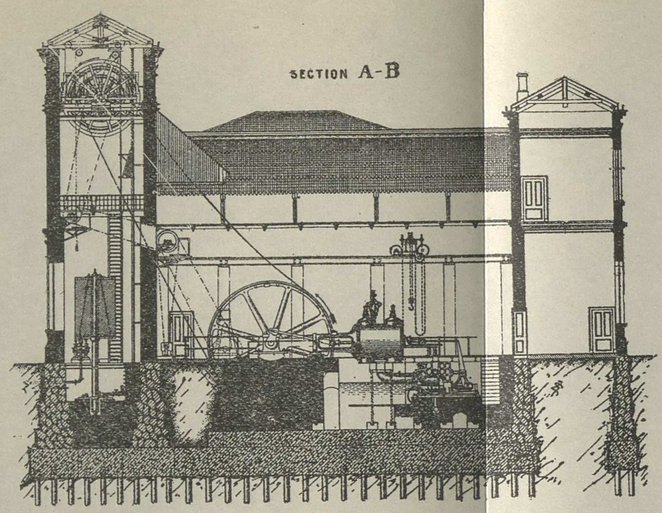
The Mechanical Equipment of the Granaries.—The whole of the grain-handling plant with which the granaries are equipped is designed as much for the reception as for the discharge of grain.

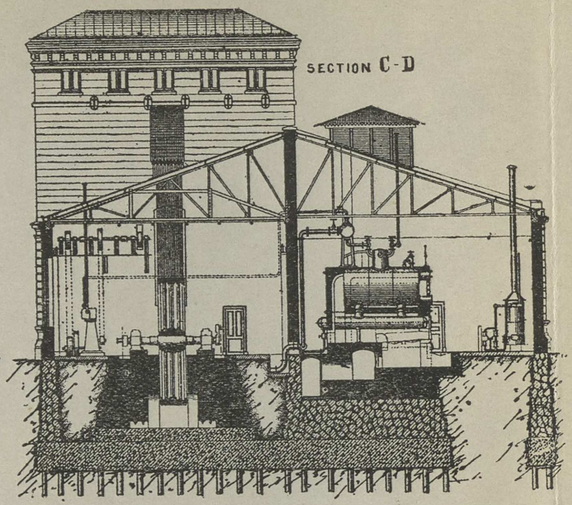
At the edge of the quay are rails with a gauge of 11 ft. 6 in., upon which run two mechanical unloading appliances. The first consists of a telescopic elevator which can be lowered into ships or barges, and which raises the grain and delivers it to one of the two band conveyors at the head of the apparatus, each of which in its turn feeds automatic weighing machines with an hourly capacity of 75 tons. These weighing machines either discharge their load through a manhole in the ground on to a band conveyor, which runs in the tunnel parallel to the quay walls, or the grain is again elevated by means of a second elevator in a slanting position, which delivers the grain at a sufficient height to render easy the loading of railway trucks on the siding which runs parallel with the quay (see Figs. **947** and **948**). The driving power is provided by a pair of vertical compound engines of 35 H.P., the steam being generated by two vertical tubular boilers. The boilers are fed by two water tanks. A turning gear, which can be driven from the engine or by hand, will so reverse the position of the whole apparatus that the portion which overhangs the water can be turned inland, or vice versa. The whole of the apparatus is mounted on a platform provided with six wheels, the end ones of which are geared to the shafting and move the whole of the unloading plant by power. The unloading capacity is 150 tons of grain per hour.

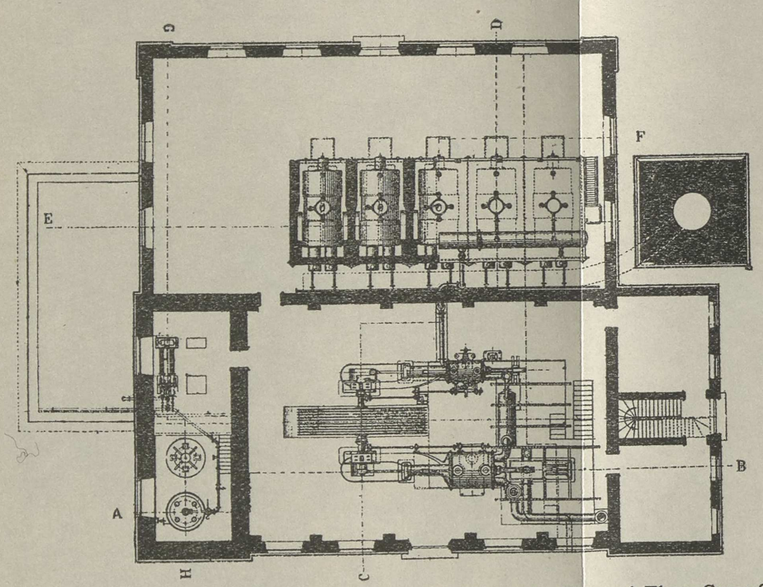
For the purpose of loading ships the telescopic elevator is turned towards the granary, when it can be lowered into any of the fifteen grain wells which are constantly fed with grain by the longitudinal and either of the two transverse bands coming from the silos. The action is then almost identical with that of loading the grain from the boat to the railway trucks, with the exception that the sleeve from which the grain is delivered is lowered down into the ship's hold instead of into the grain wells. The second loading device is exclusively for loading ships with grain, and is therefore not reversible. It is built on a similar trolley to the last-named apparatus, and is provided with two boilers and a 35 H.P. engine, precisely as the last mentioned. There are two vertical elevators of the ordinary type, one of which fits exactly into the grain wells, into which it can be lowered, whilst the second elevator receives the grain from the first after it has passed through two weighing machines, whereupon it is finally discharged down the telescopic shoot into the ship's hold.

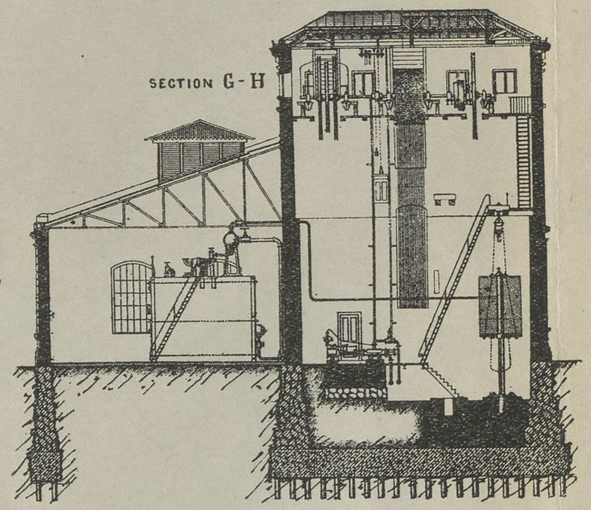
The grain, which is received from barges and other vessels, and is intended to be

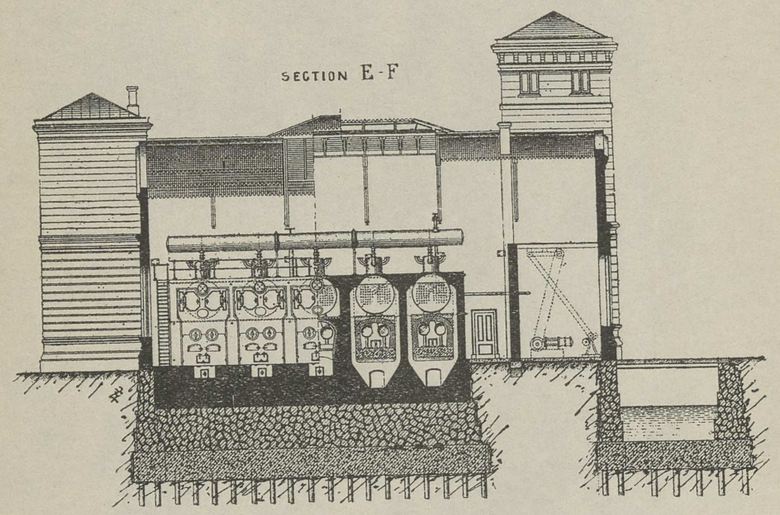












Figs. 952 to 956. Plan and Three Cross Sections through Engine and Boiler Houses, also Electric and Pumping Station of the Granaries at Braila and Galatz.

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stored in the silos, is spouted to the longitudinal band conveyor, of which the upper strand runs from north to south, while the lower strand runs in an opposite direction The strands are so far apart that both can be simultaneously used for conveying. Thus the grain can be taken from the barges either to the northern or southern cross conveyor, by spouting either to the lower or to the upper strand of a longitudinal band conveyor. In the same way grain may be taken from either end of the silos to any one of the fifteen grain wells, as may be most convenient for the loading of ships moored at either end of the quay. Grain is distributed to the silos as soon as it is received by any one of the three band conveyors, while for discharging there are three similar bands in three of the nine tunnels below the silos.

The northern section of the receiving machinery, which is shown in the cross section (Fig. **947**), contains four elevators in iron casings, the diameter of the internal pulleys being 4 ft. by 28 in. The northern cross conveyor terminates in the basement of this annexe; here, too, terminates the second cross conveyor, by means of which the grain is removed from one silo to another for ventilating purposes. On the upper floor in this same annexe is a further cross band conveyor, which distributes the grain raised by the elevators to any of the longitudinal bands which lead to the silos. There are also two short longitudinal bands for feeding the grain to the wheat-cleaning department. The same annexe contains two centrifugal pumps for the purpose of removing any water which may find its way through the foundations. Provision is also made for sacking off the impurities removed from the grain in the adjoining cleaning department. Some of the motive power is also distributed from this section, the main shaft receiving 270 H.P. from the engine-house, giving off its power to the third floor above the ground by means of two wire ropes. This is the whole of the power with the exception of the 80 H.P. which is required for driving the grain-cleaning plant, and which is conveyed to this department by a separate rope. A portion of the 270 H.P. is conveyed from the main shaft just mentioned to the other end by means of another steel rope. The grain-cleaning plant is very complete, and is fitted with cockle and barley cylinders to free the grain from all intermingled seeds. The whole of this plant is divided into two sections, each of a capacity of 150 tons per hour. There are also facilities for weighing the grain as it enters and leaves the cleaning department, so as to ascertain the exact percentage of impurities removed during the cleaning.

The deliveries from the band, etc., are connected with a strong exhaust, the function of which is to eliminate the dust. Some provision is made for dust rooms at the top of the building, in which the dust so removed can settle. The southern annexe is driven by separate wire ropes, as mentioned, and contains the terminus of the southern transverse conveyor, as well as a short cross conveyor similar to those on the other side which connect the elevators with the conveyors. It also contains the staircase and the hydraulic lift and appliances for sacking off the grain. There are four pits for the reception of grain arriving by rail, one at each corner of the building. These pits are each provided with two automatic weighing machines, which, in their turn, discharge the grain to the corner elevators which deliver it to the top bands.

The granary at Braila contains 334 silos which have a capacity of 377,560 hl. (129,879 qrs.), whilst that at Galatz contains the same number of silos with a capacity of 346,080 hl. (119,050 qrs.).

The new granary at Constanza will shortly be opened for public use, and this will make the third granary which will be operated and owned by the Roumanian Government. The capacity of this new granary is 441,320 hl. (151,813 qrs.).

The Alexandra Grain Warehouse, Liverpool.—This is of special interest,

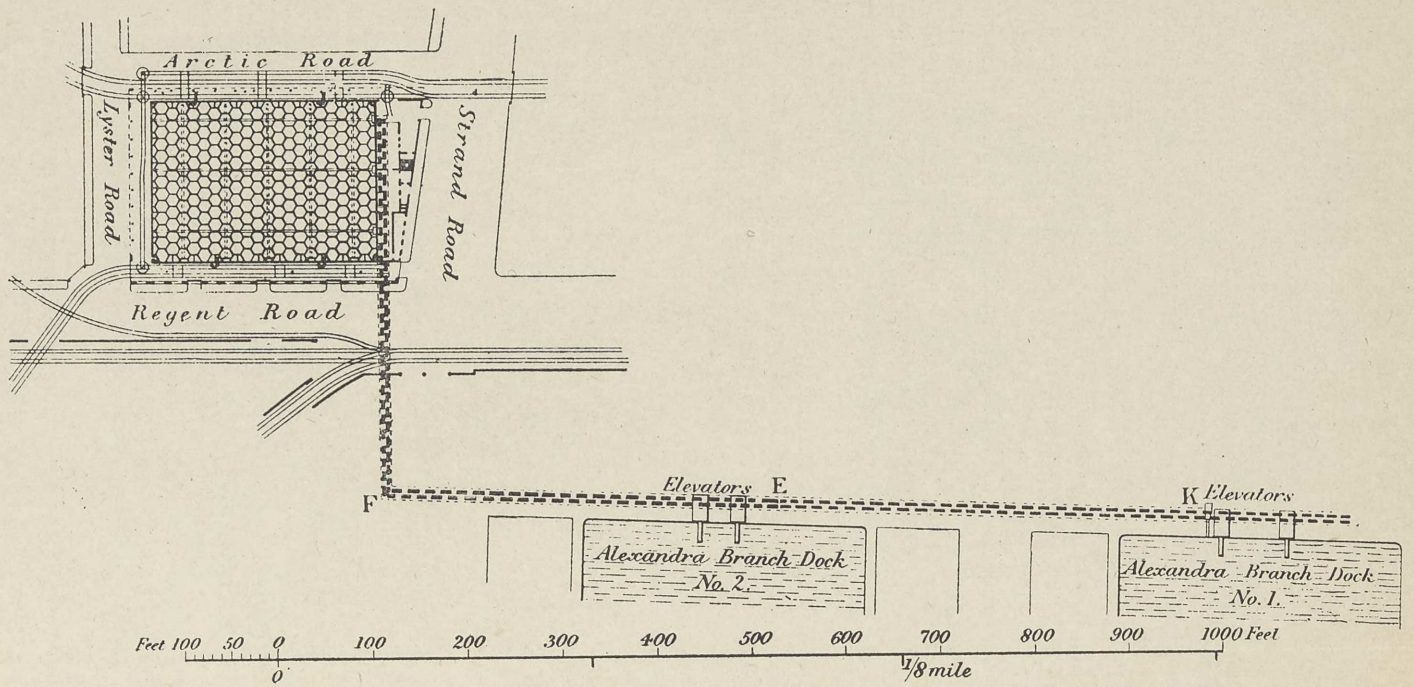


Fig. 957. Ground Plan of Alexandra Grain Warehouse.

being one of the first installations of silo granaries in this country. An excellent description of this warehouse was given by Mr William Shapton in a paper read before the Institution of Mechanical Engineers, from which the following account has been taken.

The objects aimed at in designing this granary were: Firstly, the greatest storage

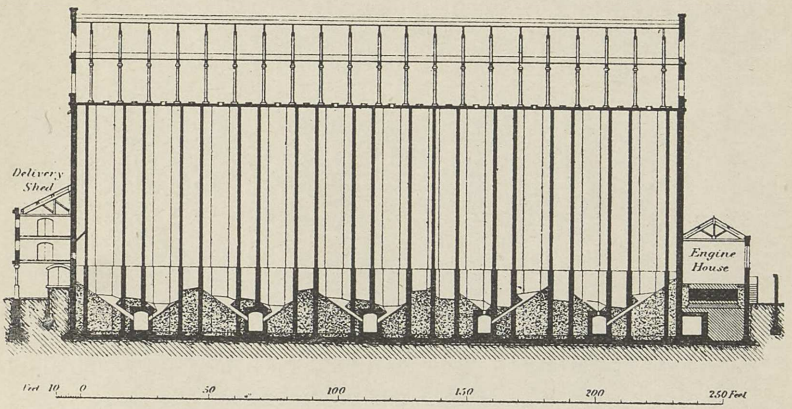
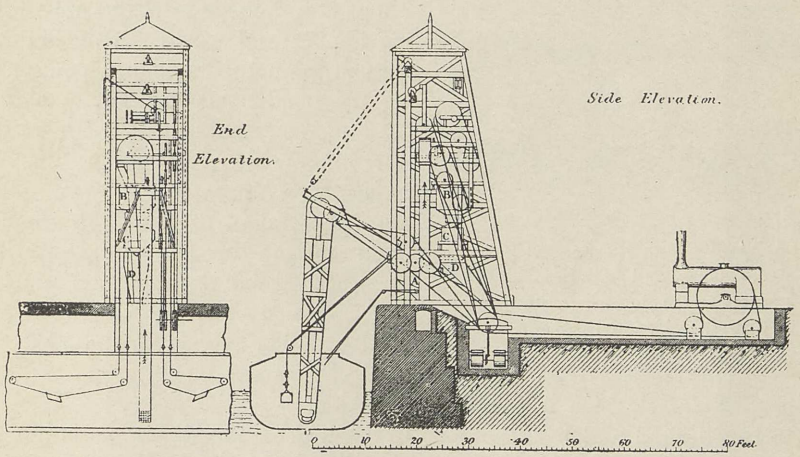


Fig. 958. Longitudinal Section through Granary of the Alexandra Warehouse, Liverpool.

capacity on a given area of ground; secondly, economy of construction; thirdly, immunity from fire risk; fourthly, economy of labour in the several processes of discharging from the ships, receiving into the granary, turning over to keep the grain in marketable condition, bagging, weighing, and delivering into railway wagons or carts.



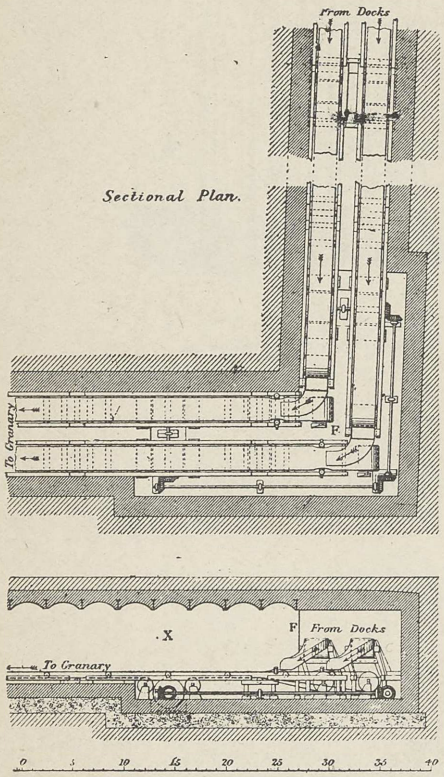
Figs. 959 and 960. Dockside Receiving Elevators of the Alexandra Grain Warehouse.

Building.—As shown in the plan, Fig. **957**, the building stands at a considerable distance from the dock side.

On three sides it has direct communication with the London and North-Western, the Lancashire and Yorkshire, and the Midland Railways, for the delivery of grain. The front is occupied by boilers, engines, and offices. The dimensions in plan are 240

by 172 ft., within which are contained 250 hexagonal bins of brickwork, each measuring 12 ft. across the angles by 80 ft. in depth, besides a large number of half bins next to the main walls, which are used exclusively for delivering into sacks. The total capacity of the bins is 80,000 tons. On three sides there are lean-to sheds, in which the processes of weighing, sacking, and delivering are carried on. The walls of the bins are 14 in. thick up to a height of 27 ft., and 9 in. for the remaining 63 ft. (see Fig. **958**).

The top of each bin is provided with a fireproof cover, through which there are manholes with raised lips for the passage of the grain. These raised lips are intended to prevent water from penetrating into the interior of the bins.



Figs. 961 and 962. Plan and Section of Subway under Quay and Roadway showing Band Conveyor connecting the Branch Dock with the Alexandra Grain Warehouse.

Elevators.—The grain is lifted from barges by four elevators on the dock side, and is conveyed to the granary on the bands running in subways which pass under the quay and Regent Road. At No. 1 Alexandra Branch Dock there are two outside elevators (Figs. **959** and **960**), each having a nominal lifting capacity of 75 tons per hour.

The grain is elevated from the hold of the barges by these elevators, lifted 43 ft., and delivered into receiving hopper A, from which it is again lifted 32 ft. by a second elevator inside the tower. It is then received into a second hopper B, thence it flows by gravity to a weighing hopper C underneath, which weighs 2 tons at a time, and delivers into a distributing hopper D beneath. This hopper holds enough grain to maintain a continuous feed for the band conveyors, and is at the same time of sufficient capacity to receive the intermittent deliveries from the weighing hopper C. Mechanical shovels or scrapers are employed in the hold for trimming the grain to the elevators, and are operated by ropes wound on a friction winch in the tower, which has an alternate reversing motion. The ropes are guided into the hold by snatch-blocks, so as to move the scrapers alternately in a fore and aft direction.

When it is desired to deliver the grain to the dock-side sheds instead of into the bins, it is discharged either through spouts from the top of the inside elevator, or from the distributing hopper beneath the weighing machine. Portable bands supported on trestles are used for removing grain from this point to the floors of the sheds.

At No. 2 Alexandra Branch Dock there are two similar towers with elevators and other appliances as above described, each elevator having 100 tons' nominal lifting capacity per hour, but being capable of discharging and weighing at the rate of 145 tons per hour.

Band Conveyors.—The grain is carried from No. 1 Branch Dock elevators on two

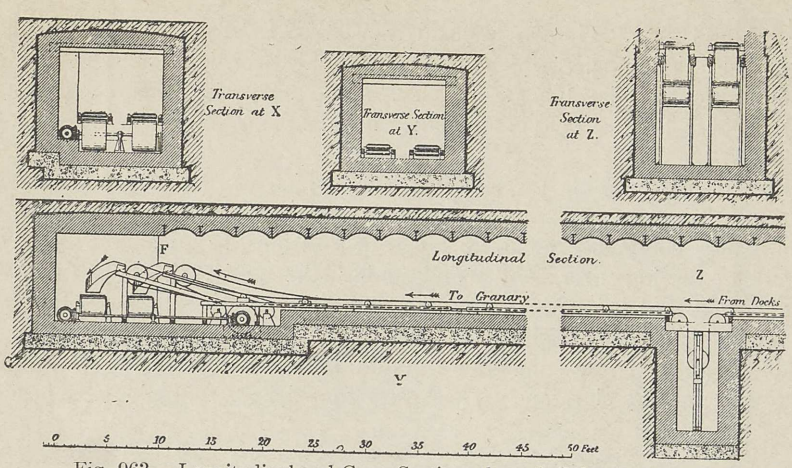
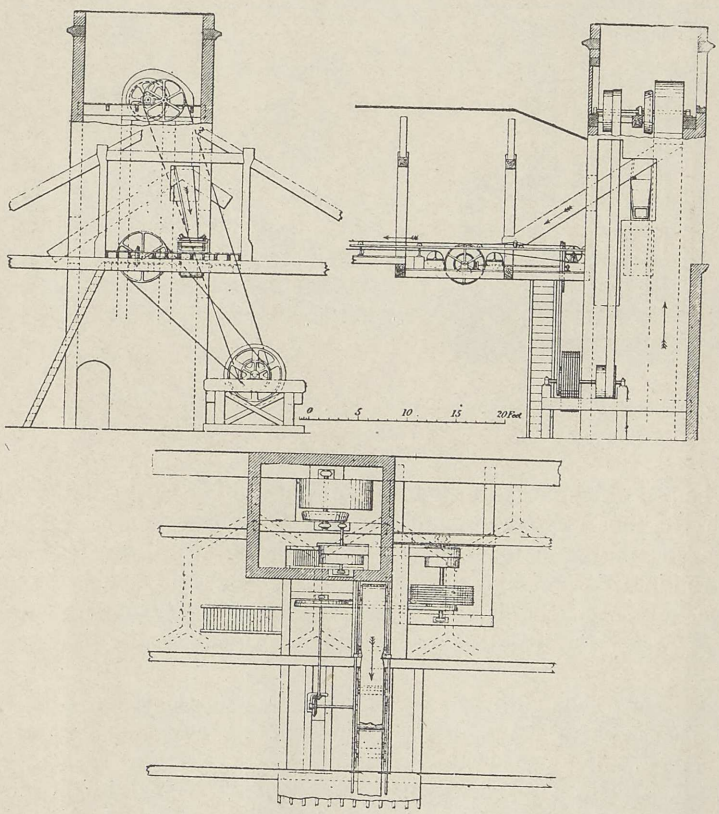


Fig. 963. Longitudinal and Cross Sections through Subway connecting Branch Dock with Alexandra Grain Warehouse.



Figs. 964 and 965. Plan and Elevation showing Receiving Elevators at Alexandra Grain Warehouse.

18-in. bands to a point E (see Fig. **957**) near No. 2 Branch Dock, from which it is thrown off upon either one of two 28-in. bands, and carried to the corner junction F

(see Figs. **961** and **962**). Here it is again transferred to another pair of 28-in. bands running nearly at right angles, which deliver it simultaneously to any two of the three 150-ton main receiving elevators (see Figs. **964** and **965**, which show a plan and two elevations). These lift it 132 ft., and deliver it to three 28-in. bands on the top floor of the building.

The bands have movable throw-off carriages, which can be placed in any required position for throwing the grain into the spouts which conduct it to the bins. These three 28-in. bands command the entire range of 250 bins, or an area of 40,280 sq. ft. For delivering, turning over, and conditioning the grain, there are five 100-ton receiving elevators, and ten 22-in. bands, five of which are in subways below the silos, while five are above (see Fig. **958**).

Movable hoppers conduct the grain from the bottom of the bins to the bands which convey it to the delivery elevators. These elevators deliver through hoppers G, H, and

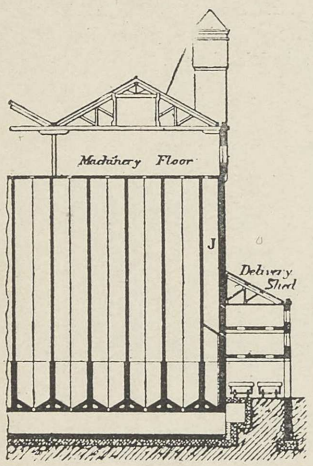


Fig. 966. Transverse Section through Granary.

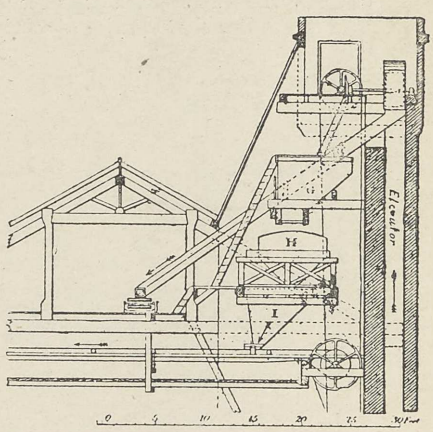


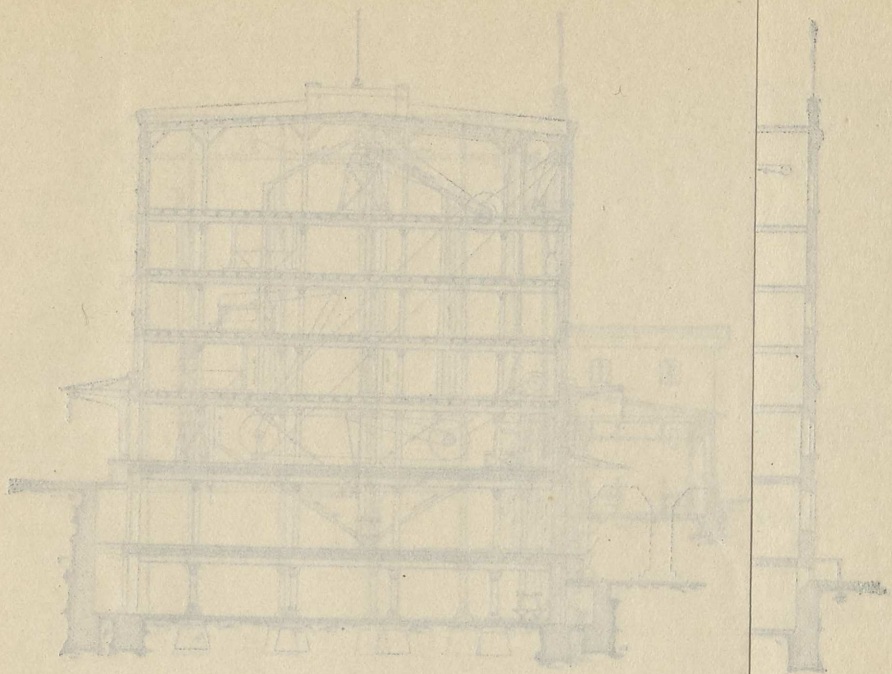
Fig. 967. Delivery of Elevators to Granary.

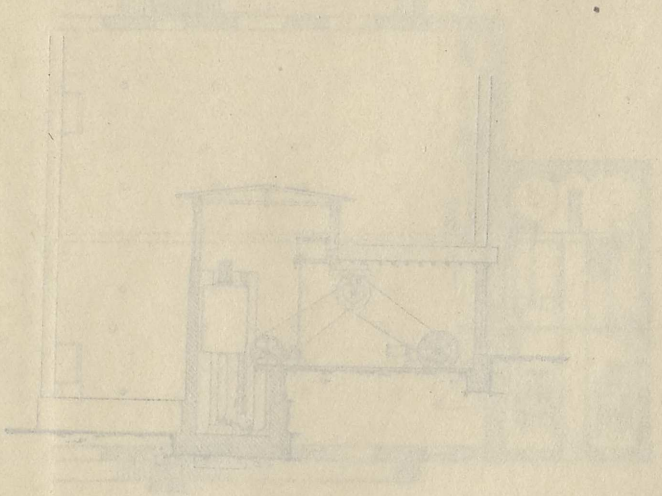
I to the top bands, which carry the grain back again, either to the bin whence it came, or to a fresh bin, thus thoroughly ventilating and separating it. For delivery into carts or railway wagons, the grain, after being elevated, is delivered into receiving hopper G, whence it is run into the weighing machine H by the attendant who looks after the feed and discharge, and also records the weight. Below the weighing machine there is a delivery hopper I for receiving and conducting the grain to the delivery bins J (see Fig. **966**).

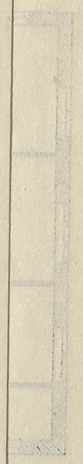
These bins have spouts which pass through the external walls of the building into the delivery sheds where the grain is again weighed, after which it is sacked and delivered to carts or railway trucks.

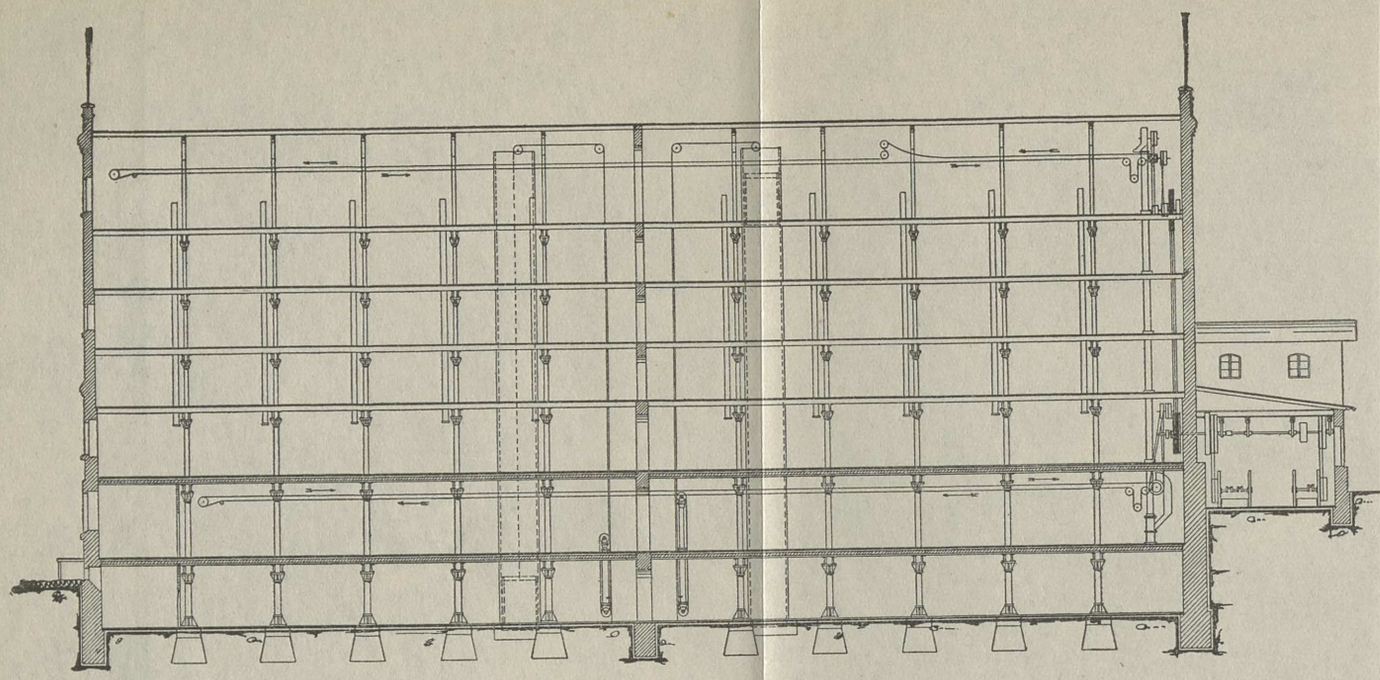
Granaries of the City of Stuttgart.—Before placing their contract the city authorities invited tenders, offering a prize for the best design. This, together with the order for the installation, was awarded to Rudolf Dinglinger, Coethen, Anhalt, Germany.

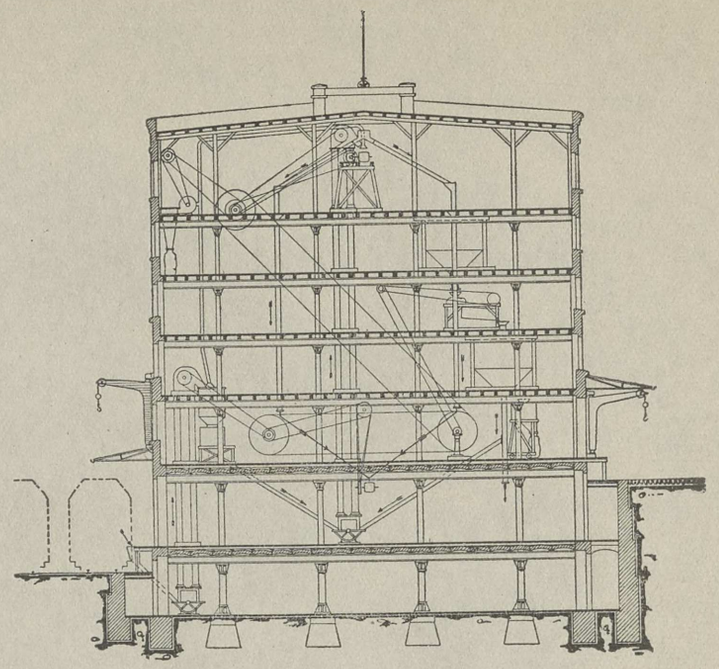
The warehouse is of the non-silo type, and the grain is stored on the various floors in bulk or sacks ; other goods can also be warehoused. The engine-house accommodates two

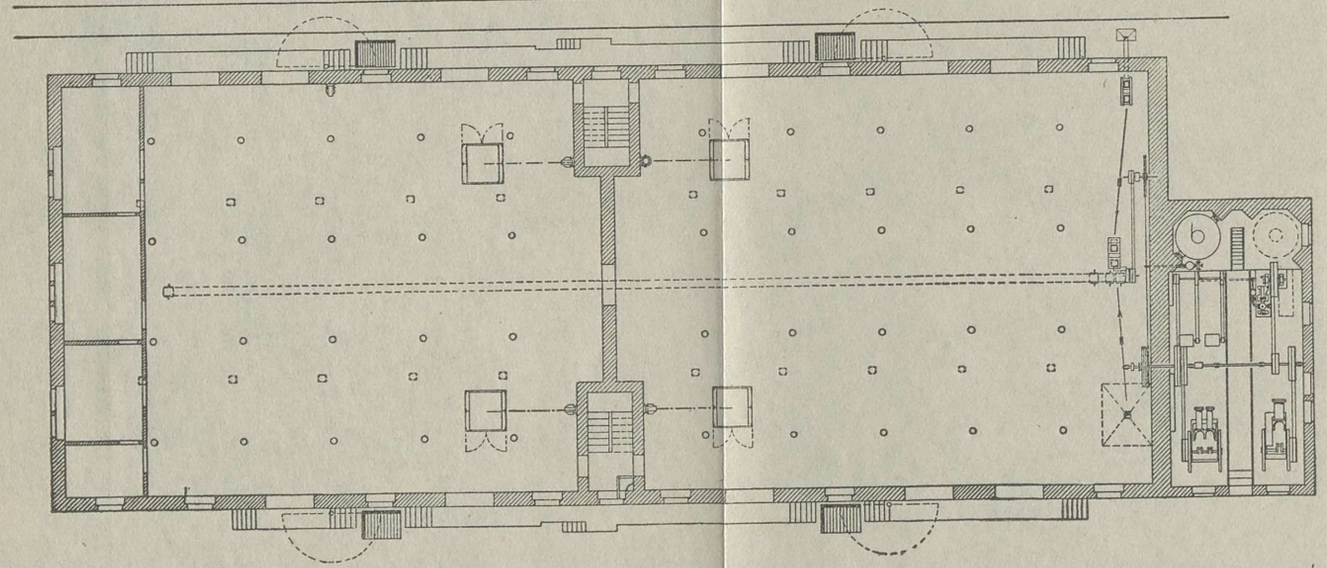


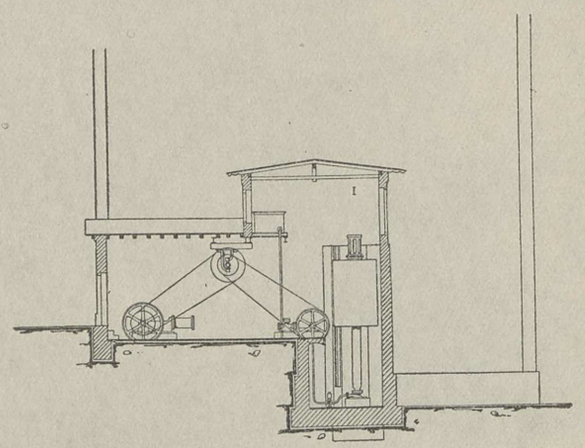












Figs. 968 to 971. **Plan and Elevation of Granaries at Stuttgart.**

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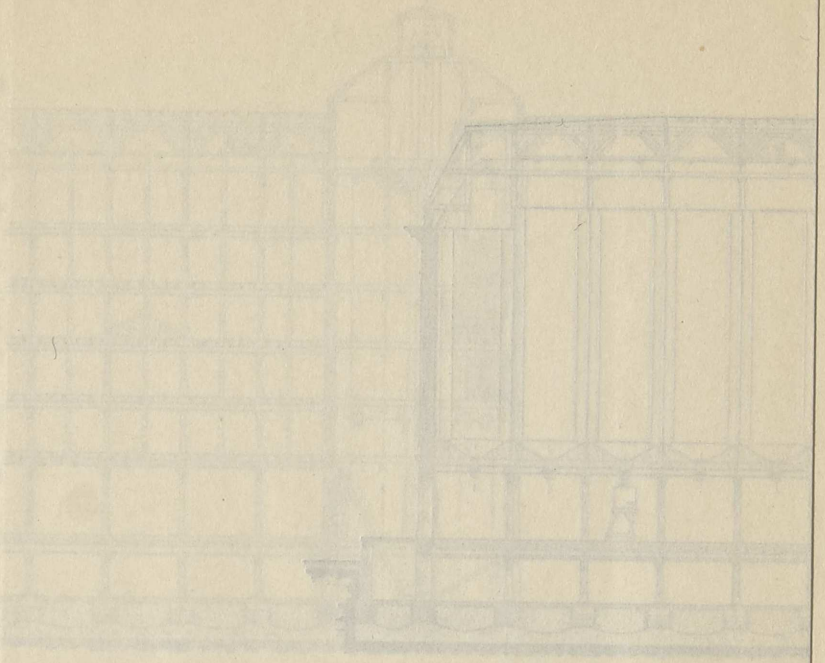

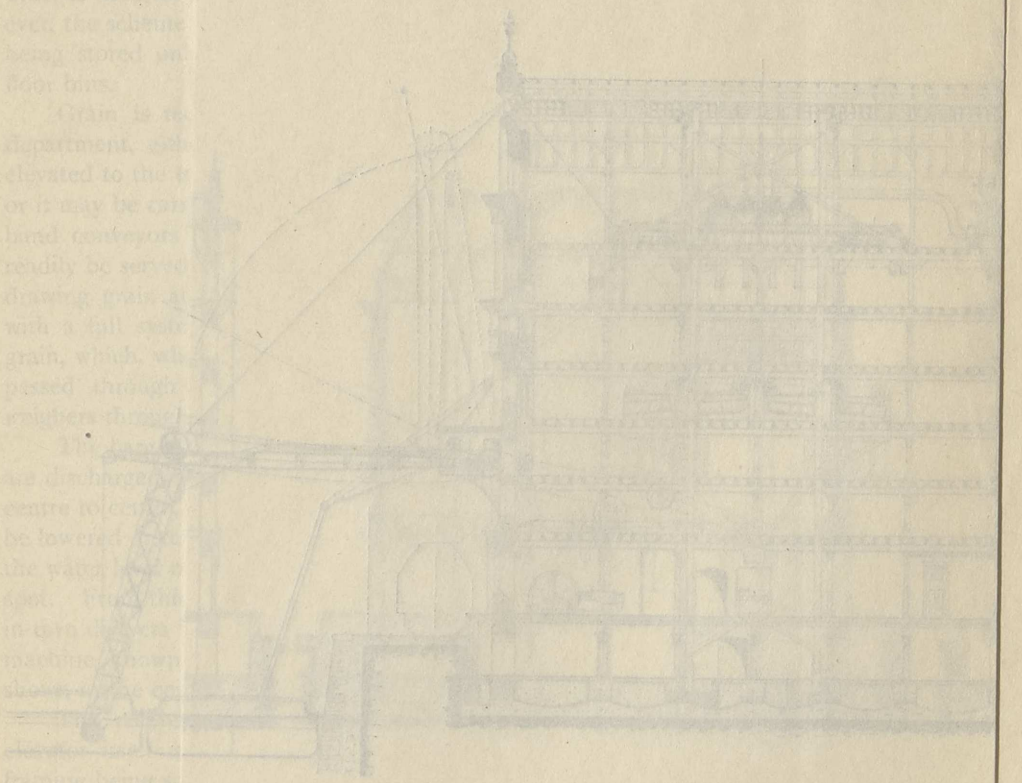

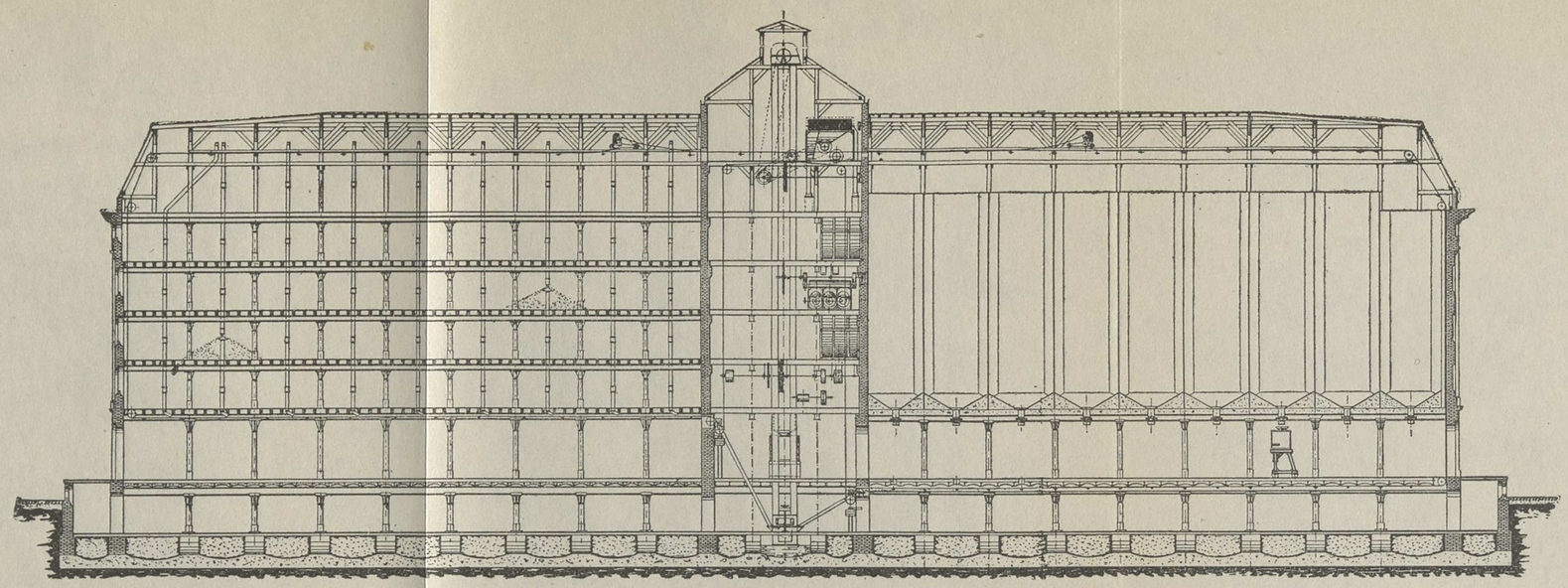

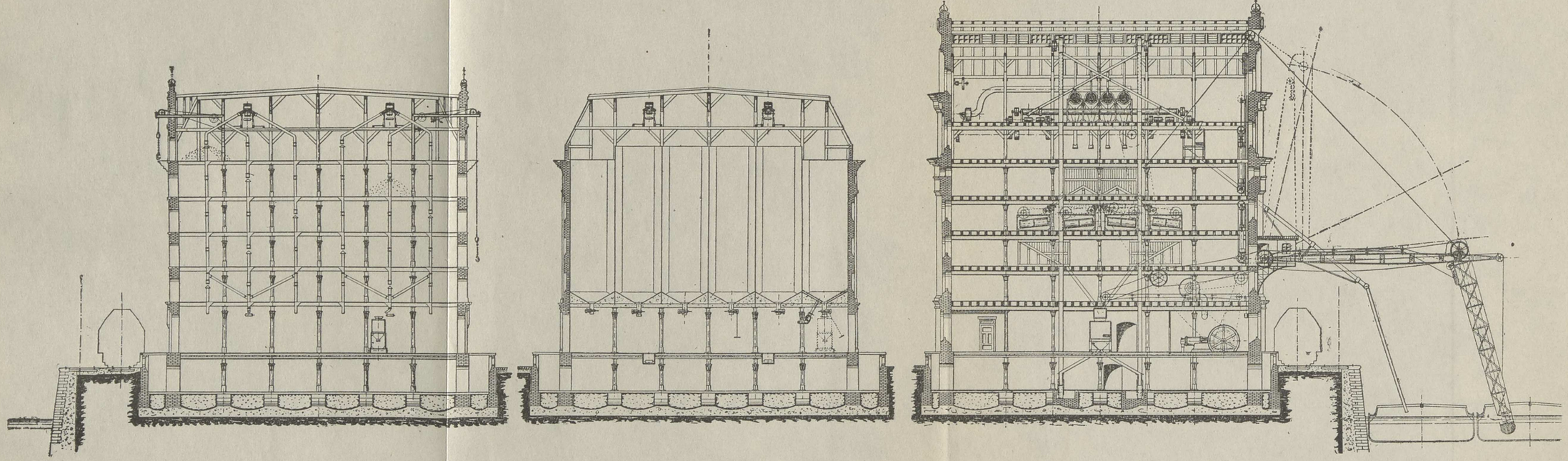

Figs. 972 to 975. Longitudinal and Three Cross Sections through the Granary at Breslau.

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gas engines, and also the hydraulic installation for manipulating the lifts, etc. (see Figs. **968** to **971**).

The grain is received by the elevator from the railway siding, and is delivered to the weighing machine, whence it is carried by a second elevator to the top of the building, and fed on to a band conveyor extending the whole length of the building. This is provided with a throw-off carriage which will allow the grain to be deposited in any part of the warehouse. Pipes reach from floor to floor, so that by means of the band conveyor and movable throw-off carriage the grain can be deposited on any floor of the granary from the one band conveyor at the top. There is a second band conveyor on a lower floor, which will take the grain from any of the floors, either to the elevator to be again elevated, or to be loaded. The second elevator is in the middle of the building, and can also, by means of an alternate spout, deliver to the hopper over the cleaning machine, whence the grain reaches the second hopper, the lower portion of which is fitted with a weighing machine for weighing the grain into sacks. The smallest of the four illustrations (Fig. **971**) is a section through the engine-house showing one of the gas engines, a pump, and an accumulator.

Granaries at Breslau.—These were also designed by Rudolf Dinglinger. The illustrations, Figs. **972** to **975**, show a longitudinal section through the whole of the granary, as well as three cross sections. The cleaning plant is installed in the centre of the building, grain being stored on either side. One wing is provided with silos, the other is used for storing grain on the floors. Since these granaries were designed, however, the scheme has been so far modified that the silos have been superseded, the grain being stored only on the floor of the warehouses, the entire granary being fitted with floor bins.

Grain is received at the centre of the building exactly in front of the cleaning department, either by rail, or by means of one of two barge elevators. After being elevated to the top of the building, it may either be passed through the cleaning plant, or it may be carried by a band conveyor to either of the wings to be stored. The top band conveyors are fitted with throw-off carriages, so that any part of the granary can readily be served. The lower strands of these band conveyors are also used for withdrawing grain and feeding the cleaning plant, which consists of a warehouse separator with a full system of cockle and barley cylinders for eliminating any seeds from the grain, which, when received, and prior to its delivery to either of the two elevators, is passed through an automatic weighing machine. There are also further automatic weighers through which the grain is passed before being sacked.

The barges can be brought alongside right under the receiving elevator, where they are discharged, as shown in the illustration, Fig. **975**. This elevator is 36 ft. long from centre to centre, and has a capacity of 40 tons per hour. It is so arranged that it can be lowered or raised to the level of the grain in the barges, and can also adjust itself to the water level of the river. The delivery of the elevator always takes place at the same spot. From this point the grain is removed through a spout to a second elevator, which in turn delivers it to the automatic grain scale, whence it passes through a grain-cleaning machine known as a warehouse separator, where it is again spouted to the elevator shown in the centre of the grain warehouse.

The receiving grain elevator can be raised or lowered by a small winch. The elevator itself is one of the chain type, with sprocket wheels at top and bottom, the framing being substantially constructed of angle iron and timber.

The wheat elevated from the barge is, of course, in an unclean condition; the weighing machine, however, keeps an accurate record of all material, dirty or otherwise,

which passes in a continuous stream through the different elevators to the cleaning machines. The grain, as it passes from these latter, is by no means perfectly clean,

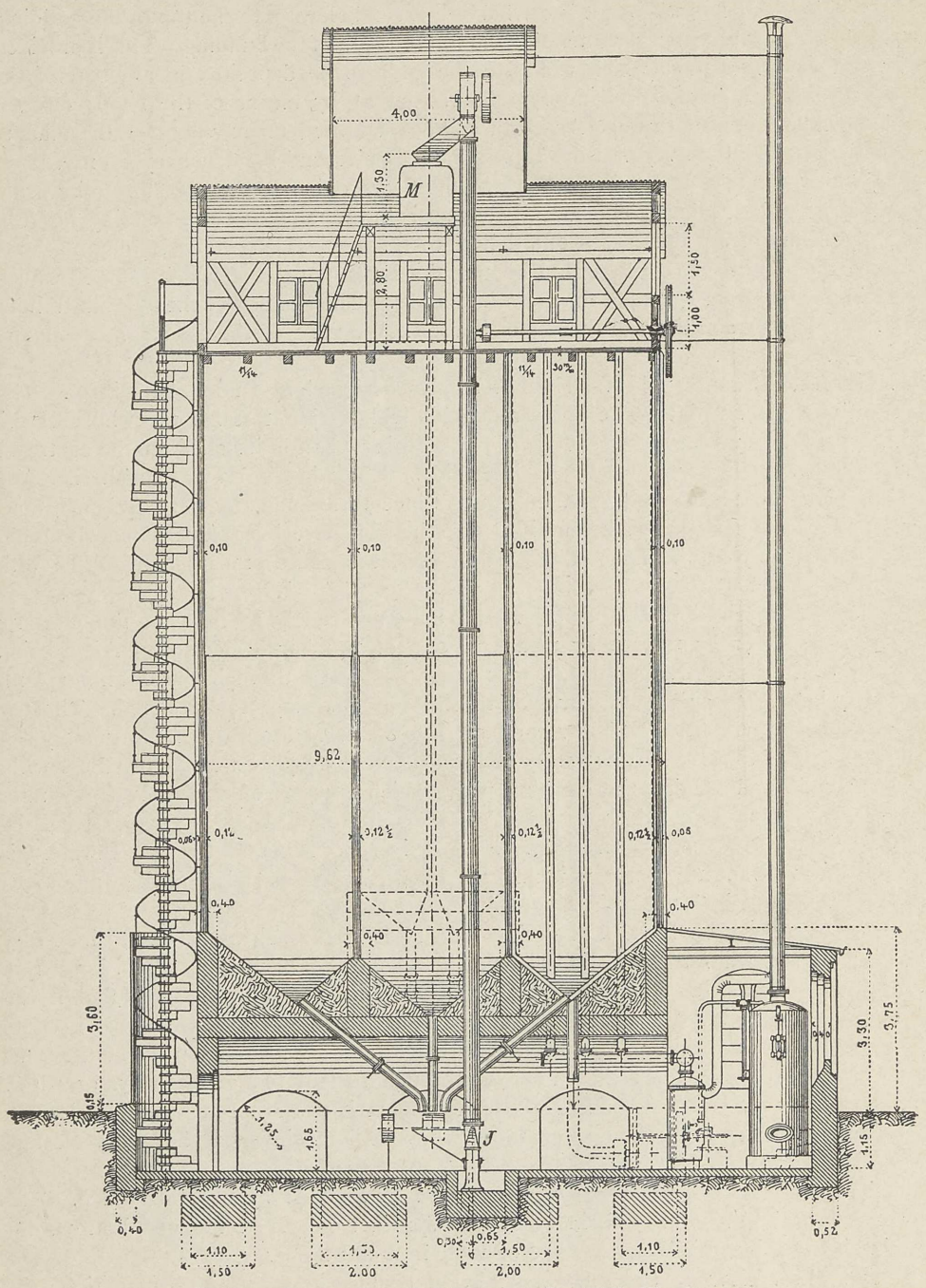


Fig. 976. Section through Dinglinger's Small Silo Warehouse.
(The dimensions are in metres.)

but all such gross impurities as string, sticks, or any large foreign matters, as well as a certain amount of dust, are eliminated in this preliminary process.

Small Silo Warehouse Designed by Rudolf Dinglinger.—The illustrations, Figs. **976** and **977**, illustrate a silo warehouse with a capacity of 700 tons of grain. The silos are built with masonry hoppers, whilst the upper part of the structure is of wood.

The installation consists of an engine and boiler house on the ground floor, which also accommodates a receiving installation. The grain can be received at either side of the building, either from farmers' carts or from self-discharging railway trucks, and can be carried from either side by conveyors to elevator J, which delivers it at the top of

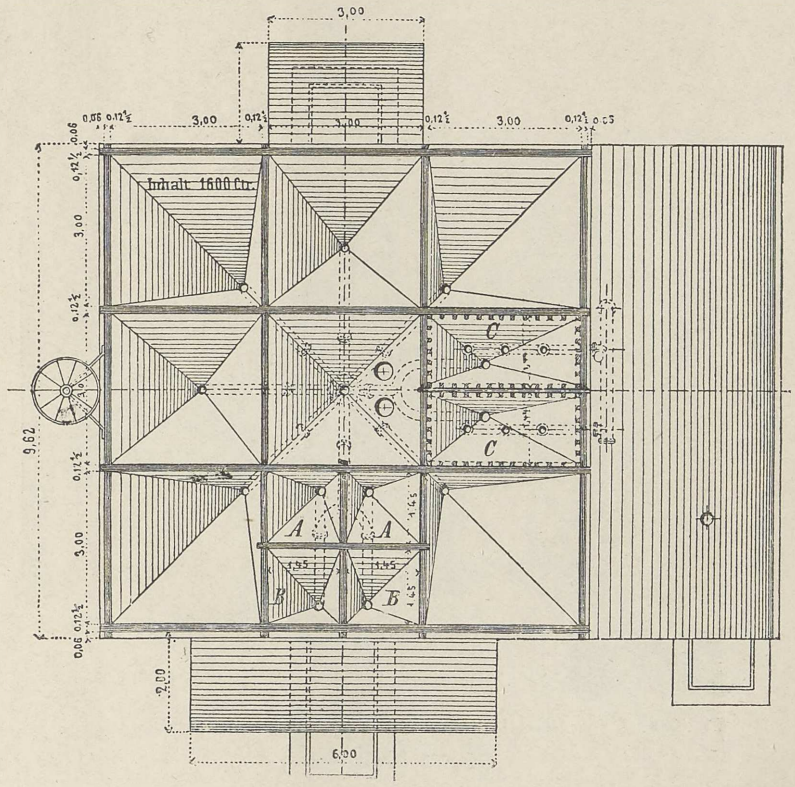


Fig. 977. Plan of Dinglinger's Silo Warehouse giving Section through the Silos.

(The dimensions are in metres.)

the building in a special lucum erected for the accommodation of the elevator head. The elevator discharges in the first instance into an automatic weighing machine M, whence the grain can be conveyed to any of the nine silos. As the elevator has been erected nearly in the centre of the warehouse, it is possible to feed the silos without the aid of any conveying machinery. The contents of the whole of the silos can also be spouted back again to elevator J by means of cast-iron pipes in connection with the receiving band conveyors, which are also for the purpose of turning the grain over.

Some of the silos are not quite so deep as the others, and are for the accommodation of grain which has to be cleaned; from them it can be spouted to the cleaning machinery, from which it is removed to elevator J to be transported in a clean state into

one of the other silo bins. Two of the nine silos have been subdivided, one in two divisions C C, and one into four divisions A A and B B. Subdivisions A A are intended for grain to be cleaned; B B for grain ready to be loaded into railway trucks. Silos C C are for damp wheat, and are furnished with steam pipes for drying purposes.

Silo Granaries at the Sun Flour Mills, Bromley-by-Bow.—This is one of the earlier installations of this class, and affords an excellent illustration of the timber silo. Figs. **978** and **979** clearly indicate the general arrangements of this warehouse. The wheat is distributed by adjustable barge elevators, ordinary elevators, and band and worm conveyors.

The granaries in question are situated on the river Lea, and are placed by that

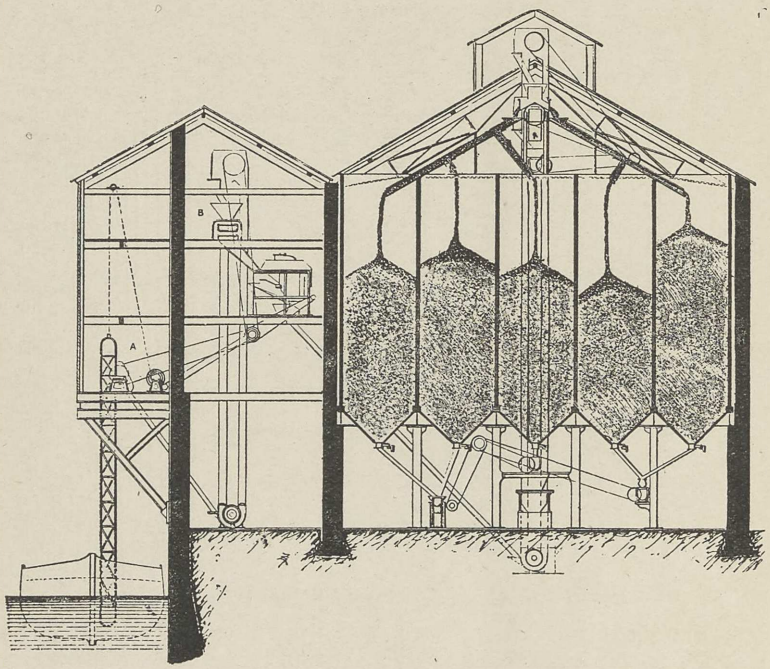


Fig. 978. Cross Section through Silo Warehouse and Receiving Station of Granary, Bow.

waterway in direct connection with the Thames; whilst the Lea flows by one side of the mills, the other side is served by another waterway known as the Limehouse New Cut.

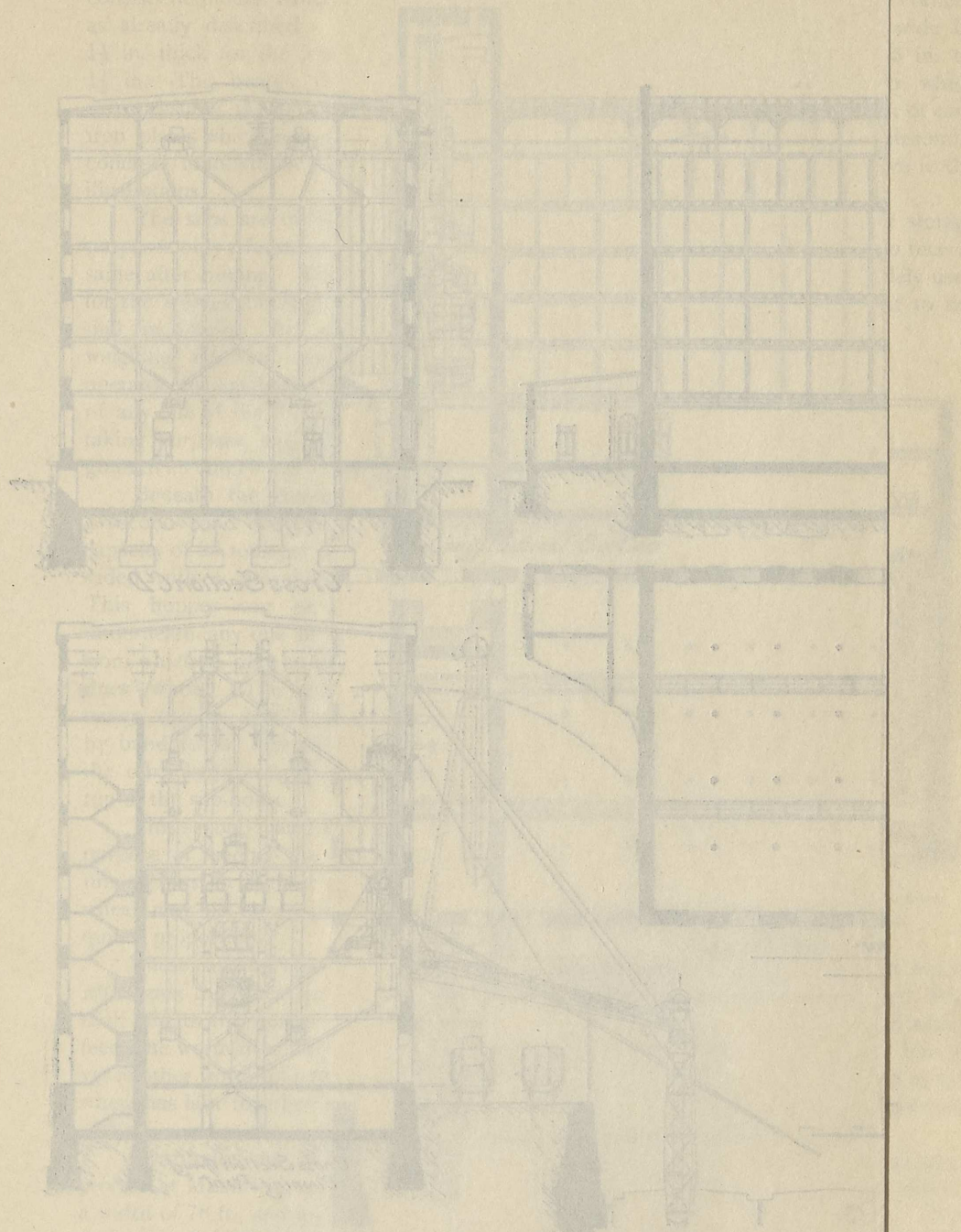
The mill is separated from the wheat warehouse by fireproof walls and iron doors. The grain receiving and handling plant was manufactured by Messrs Thomas Robinson & Son., Ltd., Rochdale.

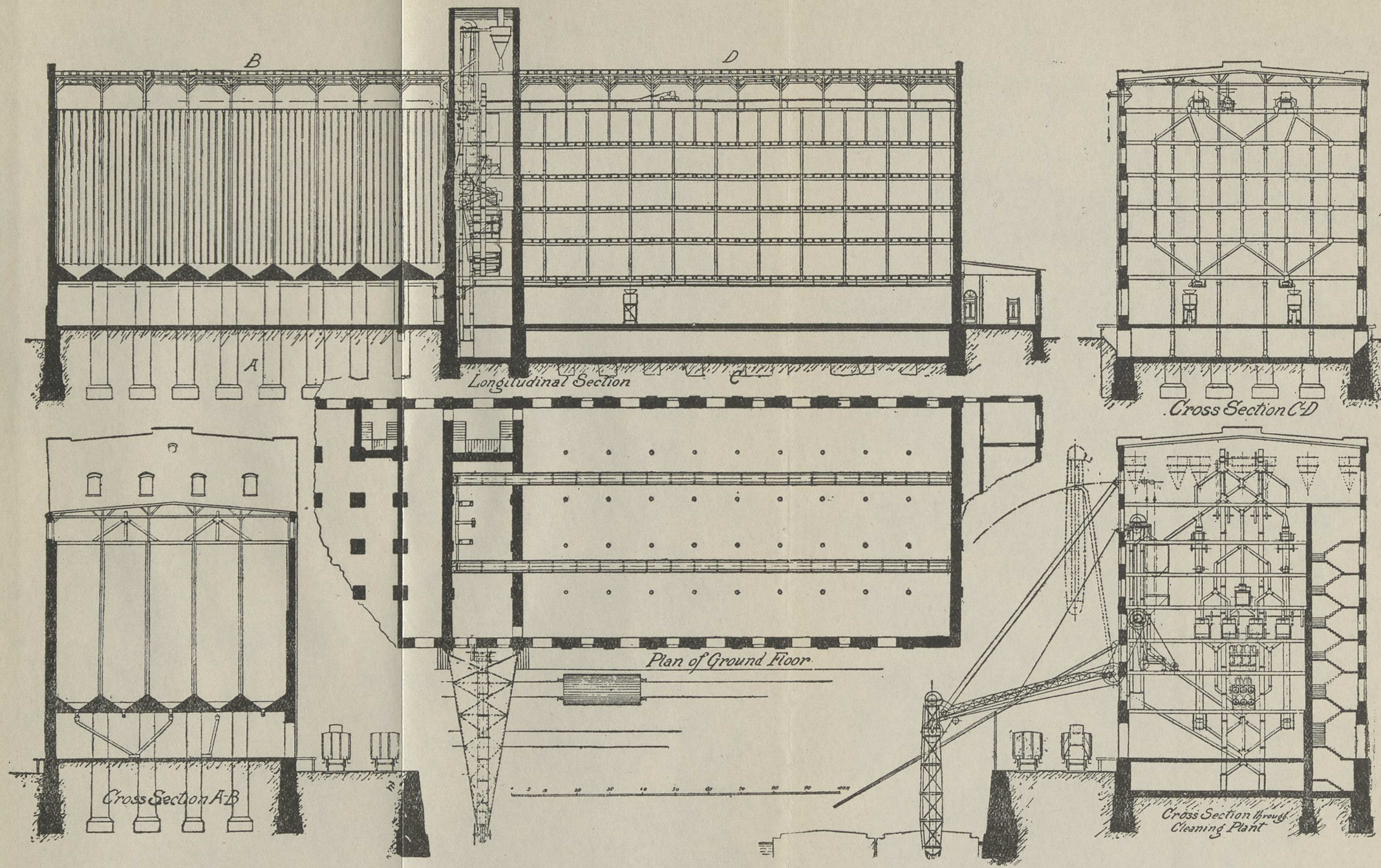
Fig. **978** shows a cross section through the receiving elevator, the preliminary cleaning, and the silos themselves.

In the silo warehouse itself the grain is distributed by means of a band conveyor which runs under the apex of the roof, and which has a throw-off carriage which is shown in Fig. **979**.

By means of a system of spouts the grain can be deposited in any of the silos. The installation consists of thirty-three silo bins, each being 36 ft. deep and 9 ft. square.

The walls of each silo are constructed on the American "Cribwork" system, which





Figs. 980 to 984. Granary at Mannheim in Plan, Longitudinal and Cross Sections; also Section through Silos, Floor Granary, and Cleaning Department.

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consists of planks nailed upon one another, and overlapping each other at the corners, as already described. The strips of timber used for these silos are 5 in. wide by $1\frac{1}{2}$ in. thick for the lower portion of the silo; in the upper the battens are 3 in. by $1\frac{1}{2}$ in. The boards thus fastened together form wooden walls of strength which can withstand the pressure from the grain in the silo. The silo bottoms consist of cast-iron plates which rest on girders and columns, the latter being supported on substantial concrete foundations. The columns, girders, and hopper bottoms are all shown in the illustrations.

The silos are utilised for three different purposes. Twelve are used for storage purposes only; fourteen others for the purpose of mixing the wheat; and six to receive same after mixing. This accounts for thirty-two bins. The remaining bin is solely used for the storage of English wheat, which does not arrive by water, but is brought to the mill in trucks. An automatic weighing machine enables the operator to weigh the contents of any one of the silos for stock-taking purposes, and return the grain to an empty one.

Beneath the storage bin is a second band conveyor with a capacity of 25 tons per hour, provided with a movable hopper. This hopper can be brought underneath any one of the silos from which it may be desired to draw wheat. The grain thus drawn can be readily conveyed by band to an elevator feeding the other band conveyors at the top of the silo-house.

This second band is for the purpose of feeding the fourteen mixing bins, in any one of which wheat may be mixed in the required proportions.

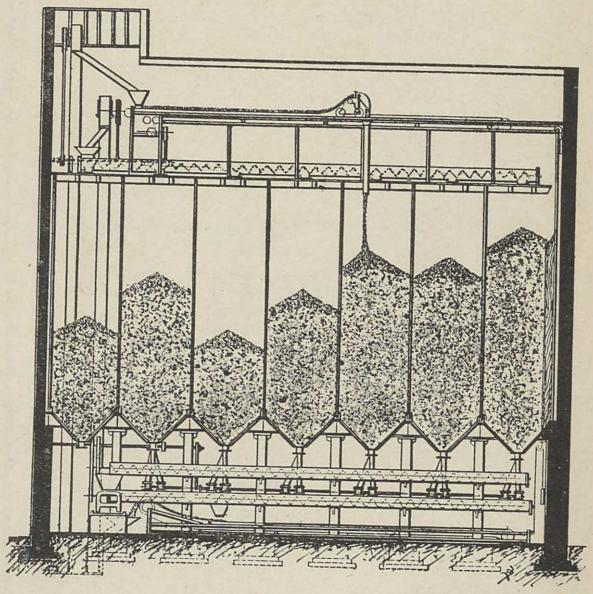


Fig. 979. Longitudinal Section through Granary at Bow, showing Throw-off Carriage and Band Conveyor.

These mixing bins are fitted with automatic mixers mounted on top of a worm, which mix the wheat in the required proportions, taking as much as is required from each silo to the worm. This mixing worm is in connection with another elevator, which feeds the worm over the top of the six blending bins. Beneath these blending bins is yet another worm into which the contents of any of these bins can be fed as soon as the wheat has lain together for a sufficient length of time, after which it can be drawn off and conveyed to the weighing machine before being removed into the mill.

Granaries at Mannheim in Germany.—These granaries, which have been erected at Mannheim on the Rhine by G. Luther, of Brunswick, have a length of 370 ft., a width of 78 ft., and are 78 ft. high. Their total capacity is 2,000 tons of grain. This granary is divided by transverse walls into three sections, one containing the silos, the second being used for storing grain on open floors, whilst the third or middle portion contains the grain-cleaning plant. This very complete installation is illustrated in Figs. **980** to **985**.

On the quay side a large ship or barge elevator is connected with that part of the building which contains the wheat-cleaning plant. There are four main elevators in the interior of the granary. The plant further consists of the necessary band conveyors, throw-off carriages, and automatic feeding devices, and of two elevators from the cleaning department. There is also a complete grain-cleaning plant specially designed for cleaning barley. Means are provided for ventilating the silos in which new and damp wheat is stored. There is an elaborate system of pipes for distributing the grain to its several destinations. The whole plant is driven by electro-motors. That section of the ware-

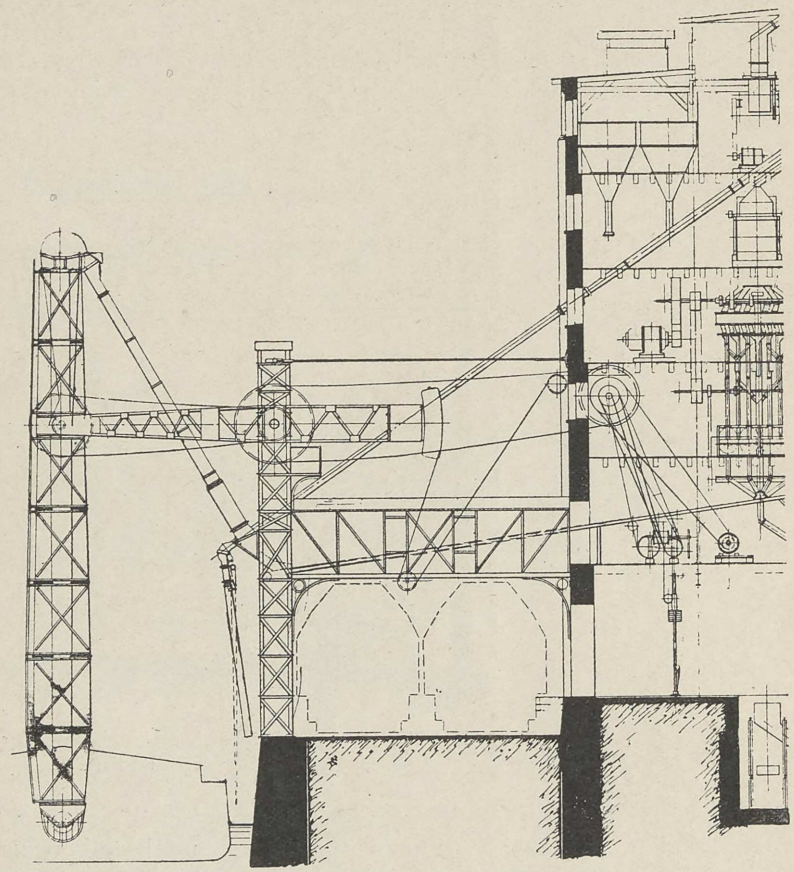


Fig. 985. Cross Section through Cleaning Department of Granary at Mannheim, showing Barge Elevator with its Connection to the Main Building.

house not occupied by silos can be used for warehousing other goods, if not required for grain. With this view a lift has been provided for loads of 1 ton, and this extends from the cellar through all the floors, and therefore communicates with the whole of this portion of the building.

The elevators and conveyors throughout the installation are capable of dealing with 100 tons of grain per hour, whilst the barley-cleaning plant has a capacity of 5 tons per hour. This installation is so complete that four distinct operations are possible.

1. A ship may be unloaded into silos or on to the warehouse floors, and may

simultaneously be loaded either from the silos or from the floors of the warehouse with different kinds of grain.

2. A cargo may be unloaded either into silos or on to the floor, and at the same time the grain may be cleaned.

3. Grain may be cleared from a ship, mixed with other grain that has previously been received, then fed into any desired section of the granaries.

4. Grain may be cleaned, mixed, and restored in any department of the warehouse, and transmitted from one ship to another.

The Granaries at Dortmund.—A grain warehouse possessing features of interest has been erected at Dortmund, in Germany, by the local co-operative society, from the design of F. Correll, civil engineer, of Neustadt an der Haardt.

The building is of brick on a base of hewn stone, all the beams and supports being of timber. This granary is built on the quay, and consists of two sections. The larger section is given up to the storage of loose grain in low bins on the floors, while the second or smaller section is a silo-house (see Figs. **986** and **987**).

The building is 78 ft. high, and consists of seven floors, including attic and basement.

The basement is chiefly used for storing provender and similar goods, in addition to which grain in sacks is also stored. The bulk of the grain is contained in the silos and on the five main floors. The latter section has accommodation for 1,675 tons, whilst in the silo bins about 825 tons can be accommodated. Thus the granary has a total storage capacity of 2,500 tons.

The silos are built on the American system, being constructed of planks $1\frac{1}{2}$ in. in thickness, nailed one over the other.

In the four silo bins at the north (entrance) side of the building grain can be stored to a depth of 47 ft., whilst the available depth of the four bins on the south (canal) side of the building is 42 ft. Some of these silos have been specially prepared for the reception of damp wheat, and were christened "hospital" bins by the engineer. In these particular bins wooden arms are built in a transverse direction, and crossing each other, form square or diamond-shaped sections, thus breaking up the mass of stored wheat, and sensibly promoting the freer circulation of air through the bin by reducing the pressure on the lower layers. These wooden cross arms are of triangular section, and being slightly hollowed underneath, allow the air to come in contact with the grain. This air can be warmed if desirable.

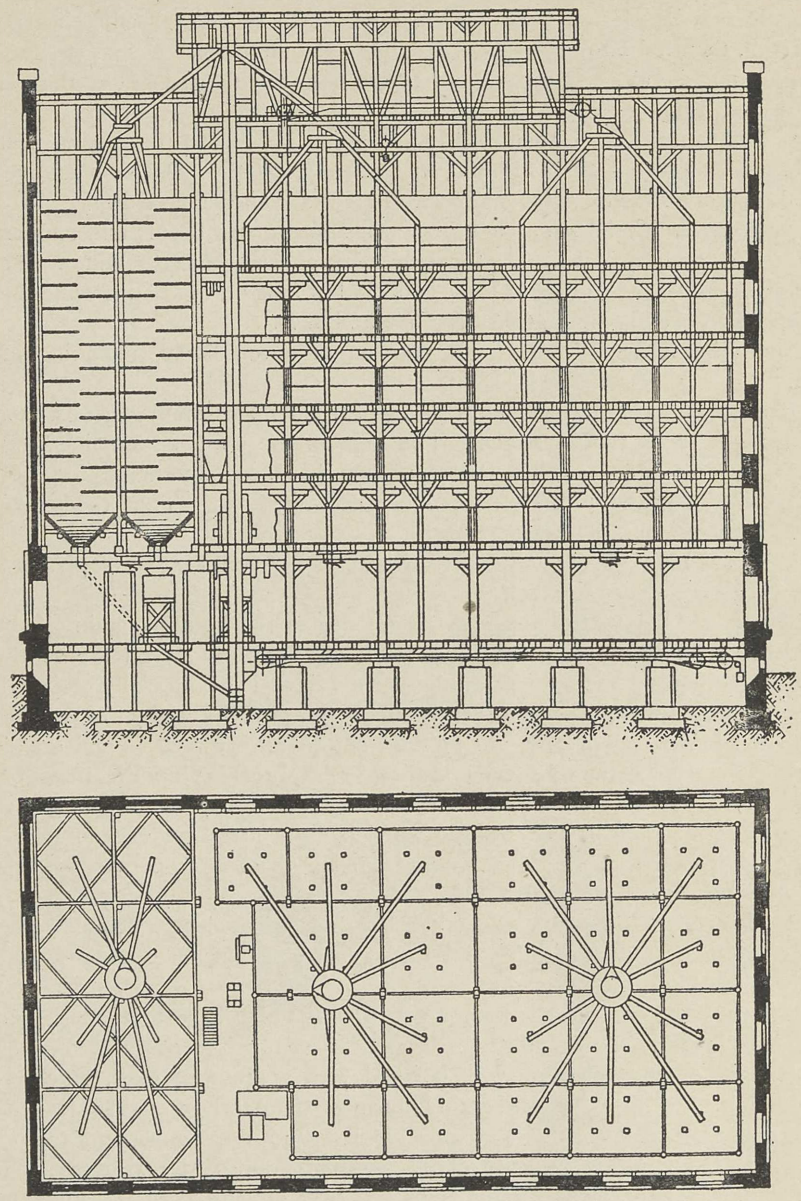
On the five floors there are altogether 105 bins of moderate height. These bins are fitted with removable side walls, and the twenty-one bins on each floor lie exactly under or over those on the other floors.

Close to the windows on each floor are two bins which have been specially adapted for storing damp grain. To aerate these receptacles as much as possible, one-half of the side walls consist of an iron framework covered with a fine wire mesh which gives free ingress to the air. In these bins the grain is heaped to a depth of about 5 ft.

The grain as it reaches the warehouse is fed into the hoppers of the receiving elevator, which has a lifting capacity of 20 tons per hour, and carries the grain to a cleaning machine. The cleaned grain is passed over an automatic weighing machine, and is then either sacked or taken back through a spout to the elevator which has a lifting capacity of 25 tons per hour, and takes it up to the attic. From the head of this elevator the grain is either distributed to some bin on one of the floors of the main granary, or is sent to one of the silo bins in the silo-house.

It may be noted that the grain is carried through a spout and a belt conveyor to

one or other of the turntables, as the apparatus may be termed which serves to distribute the grain through spouts to any of the floor or silo bins, or, if it be desired, the grain can be shot again into the basement, whence it is conveyed to the main elevator to be

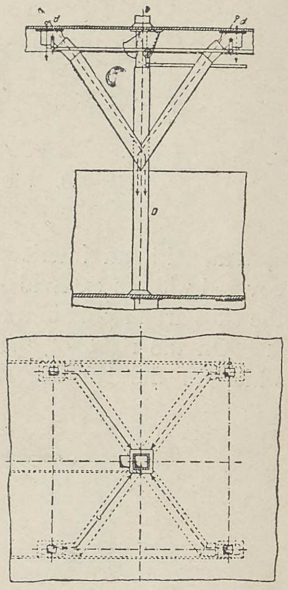


Figs. 986 and 987. Plan and Cross Section of Granaries at Dortmund.

turned over once again, as under the basement ceiling is a band conveyor which was erected for this purpose.

The turntables in the attic can readily be controlled from the floor below by means of a hand lever, and the grain directed into the required spout; thus, on arrival, it can

be poured into any bin on the top floor. For its further distribution the following special arrangement has been provided. A vertical spout passes through the centre of each series of bins lying one under the other, whilst at the bottom of each bin are four apertures from which, by means of connecting spouts, the grain can be conveyed either into the bins on the floor below or into the main spout (see Figs. **988** and **989**). This spout may be utilised for a variety of purposes; either for shooting grain through to the bottom of the warehouse, or for mixing different kinds of wheat, without the flow of grain through the connecting spouts from one bin to the bin beneath being interrupted. By closing the connections between the delivery spouts of the bins on one floor with the main spout, grain can be taken from any of the upper floors into any of the floors beneath. This wide range of operation is rendered possible by the ingenious system of distributing valves designed by Mr Correll.



Figs. 988 and 989. Arrangement of Grain-distributing Spouts.

The working of these valves, which can be controlled from the basement by chains, may be seen from the illustrations. In Fig. **990** the simplest form of valve is shown in two views; *a* is the connecting spout through which grain may be taken, *via* the main spout, to any desired floor beneath, whilst *b* shows the mouth of the spout from which grain falls from a bin on any one floor into the bin lying immediately underneath on the floor below. If there is no necessity for taking grain straight away through one floor, the valve provided is as shown in Fig. **991**.

If the valve be placed in a central position, the grain on the floor below can be mixed with grain from any floor above through the conduit *a*; and if it be desired to mix grain from several floors, conduit *b* is provided as part of the valve. From the different positions of the valves in Fig. **992**, the direction in which the grain to be mixed must flow can easily be seen.

If it be desired to let grain through from one bin to its fellow on the floor below, and at the same time to carry grain to delivery spout *a* in a downward direction, one of the walls of conduit *b* is bent back, and takes a cup-like shape. This cup is open at the top with an outlet *l* at its lower end (see Fig. **993**).

To prevent grain getting between the valves and their casings, slides are arranged over the valves, and are made to exactly fit a section of the casing.

At the quay side of the warehouse an apparatus has been provided for clearing the grain vessels as they lie by. It is adapted to unload grain either loose or in sacks.

This unloading apparatus can handle from 150 to 300 sacks per hour.

The machinery inside the granary is driven by one electro-motor of 12 H.P.

Spencer's Granary Floor Spouting.—A similar principle to that described in connection with the Dortmund granaries has been used by Messrs Spencer & Co., Ltd., of Melksham, for several years, and on these lines they have built a number of granaries.

There appears to be a growing tendency to store certain kinds of grain, especially home-grown wheat, in floor bins instead of in silos. Fig. **994** shows two devices adopted by Messrs Spencer to deposit the grain in a series of floor bins above each other, and to withdraw the grain from one bin to another for the purpose of turning it over. In the

section on the left-hand side this system is shown as applied to floor bins with level floors, whilst the right-hand section shows an installation for floor bins with hoppered bottoms. The latter are preferable, as they require no trimming whatever. The drawing will be readily understood by the aid of its descriptive legends.

Silo Warehouse at the London and India Docks.—This granary, illustrated in Fig. **995**, has a total capacity of about 25,000 qrs., and is built on the American

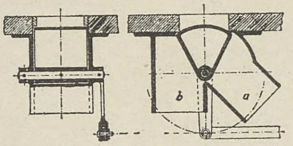


Fig. 990. Simplest Form of Grain-distributing Valve.

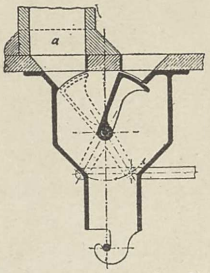


Fig. 991. Alternative Form of Grain-distributing Valve.

system, with an interlaced timber structure resting on iron columns. The walls are covered with an external steel casing. The total height of the building is over 100 ft.; the silos are fifty-six in number, each about 10 ft. square by 50 ft. deep.

On the right of the picture is an intake plant about 100 ft. from the granary, while on the left are the barges taking grain from the large silos of what was

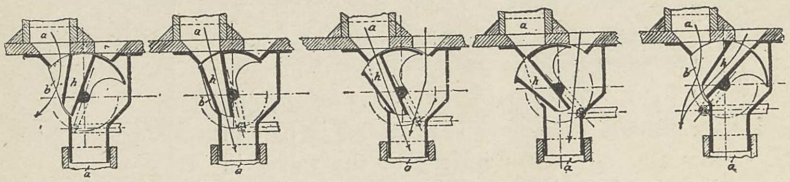


Fig. 992. Grain-distributing Valves in Different Positions.

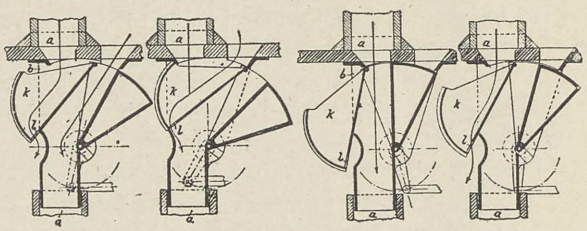


Fig. 993. Grain-distributing Valves in Different Positions.

originally the London Grain Elevator Co. The intake plant has a capacity of 100 tons of wheat per hour, and includes appliances by which the grain is automatically weighed into the bins. There are six automatic grain scales, each weighing the contents of one sack at a time, on the sacking-off platform, which has an arrangement whereby it is always kept at the correct level for delivering to barges.

The main delivery floor of the granary is about 8 ft. above ground level and is level with the tops of railway trucks. On this floor are a number of portable automatic weighing machines which can be placed beneath any bin, and so deliver to railway trucks or vans.

The whole of the plant is driven by electro-motors, one for each machine. There are two main elevators, two bands conveying at the top of the silos and two underneath, so

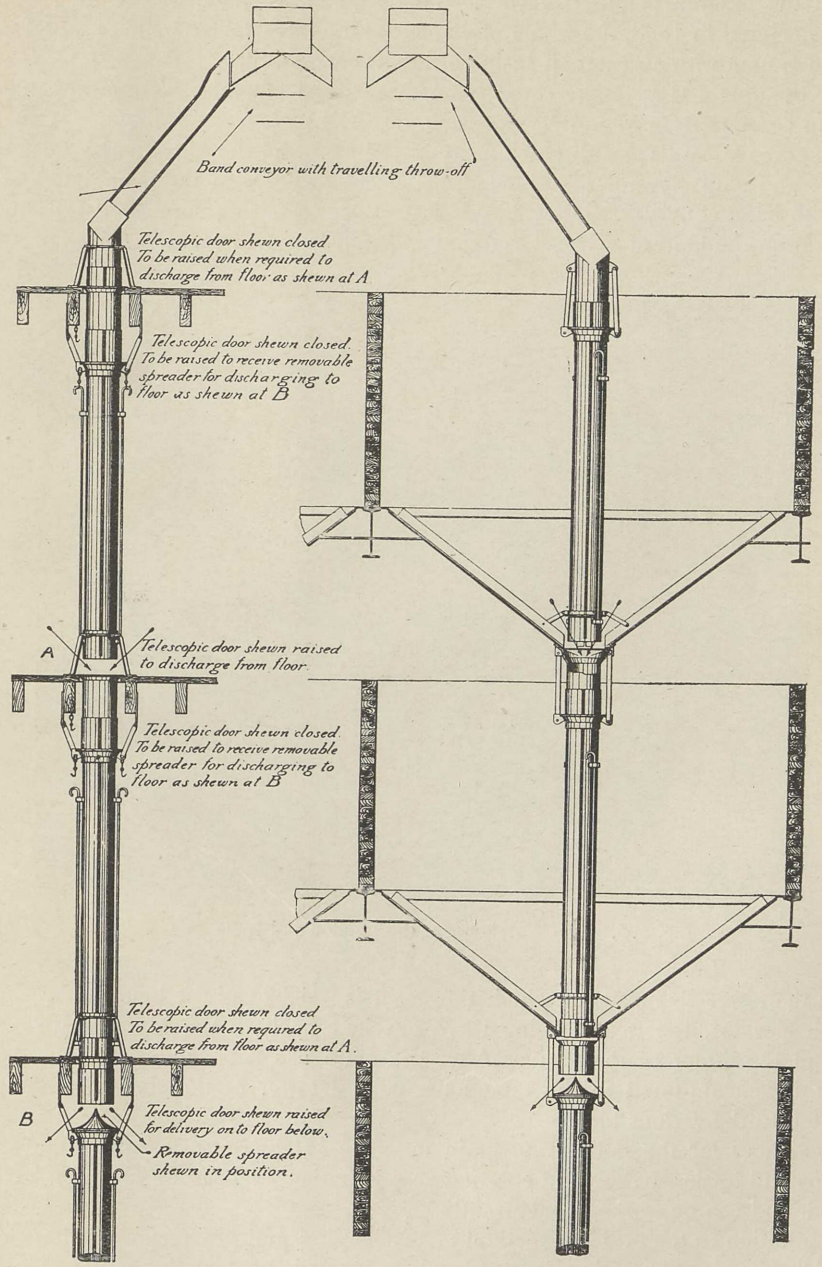


Fig. 994. Spencer's Granary Floor Spouting.

that grain may be taken from barges, delivered to silos, turned over from one conveyor to another, or delivered to the weigh-out house and main delivery platform simultaneously.

This installation was erected by Messrs Spencer & Co., Ltd., of Melksham.

The First Grain Warehouse, Manchester Docks.—The general arrangement of this important warehouse is shown in Figs. **996** and **997**, one being a general plan and the other a perspective view. This granary, which is 448 ft. long by 80 ft. wide, was erected in 1898, the whole of the superstructures being built of wood on the American system with an external casing of brickwork and tiles.

The building has a storage capacity of 40,000 tons of grain. There are 226 bins, varying in capacity from 37 to 300 tons each.

The granary stands at a distance of about 340 ft. from the side of the dock, where the tower and ship elevator are situated, being connected with the main building by a gantry with band conveyor. The elevator is capable of raising some 350 tons of grain per hour from the hold of a vessel containing a full cargo of grain. Arrangements are

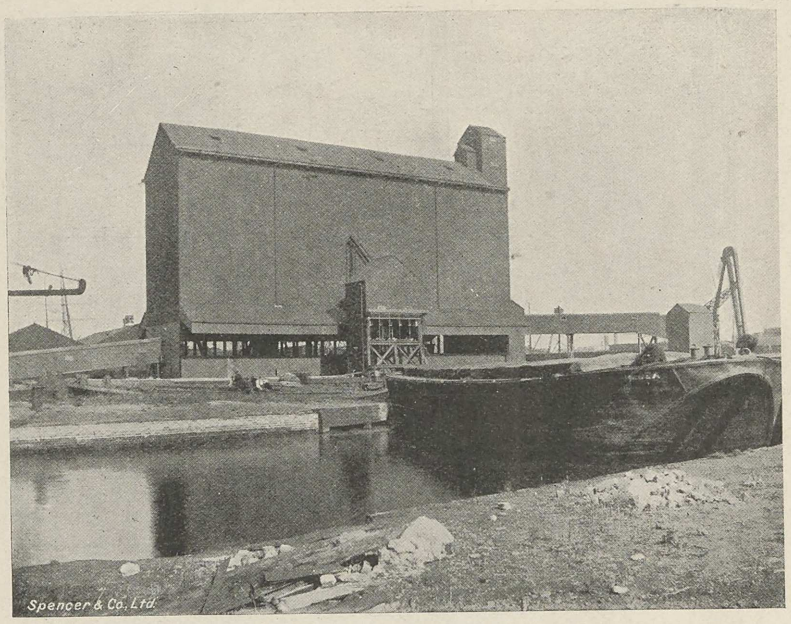


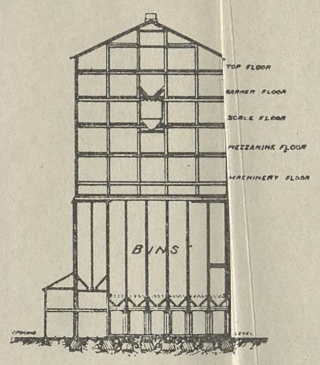
Fig. 995. Silo Warehouse at the London and India Docks.

made in the tower by means of which the grain is weighed whilst being conveyed from vessel to elevator, the weight being there checked by both the representatives of the vessel and the owner of the grain. After the grain has been conveyed into the main building, it is again lifted to the top of the central tower of that building, and thence distributed to the various bins.

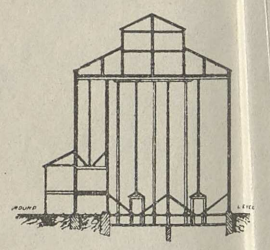
Appliances for the delivery of grain upon an extensive scale into railway trucks, road vans and lorries, barges and coasting vessels (either in bags or in bulk), have been provided, and can be worked concurrently.

In addition to the ordinary method of discharging grain by means of ship elevators, one of Duckham's pneumatic elevators has been provided, which is employed *inter alia* for dealing with small parcels of grain, and with grain stored in positions which cannot be reached by the ordinary ship elevator.

Power is supplied for the working of the elevator and the various band conveyors in the main building, as well as leading thereto and therefrom, by two sets of horizontal



SECTION THROUGH AA



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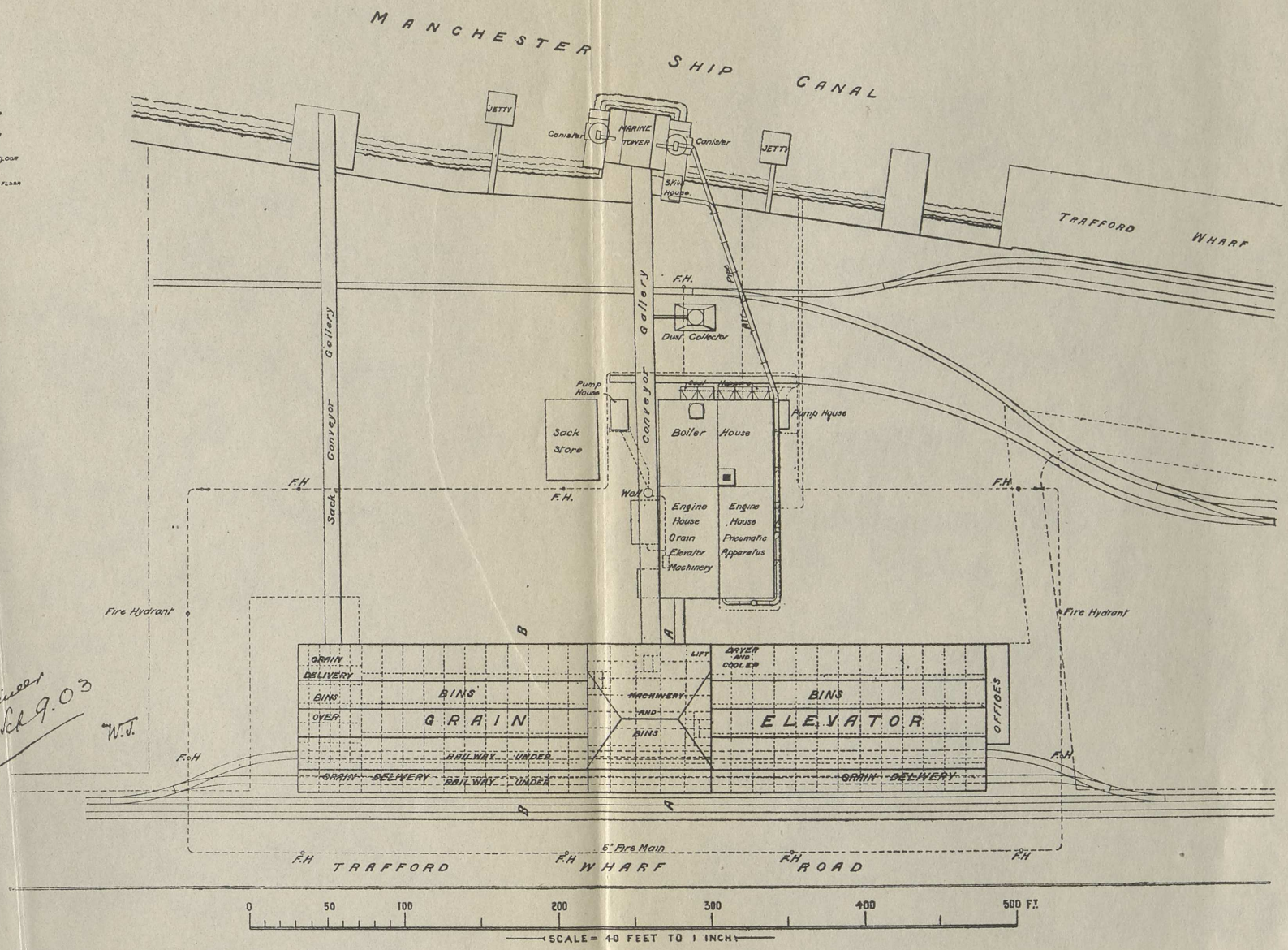

Fig. 996. Plan of Grain Warehouse, Manchester Ship Canal.

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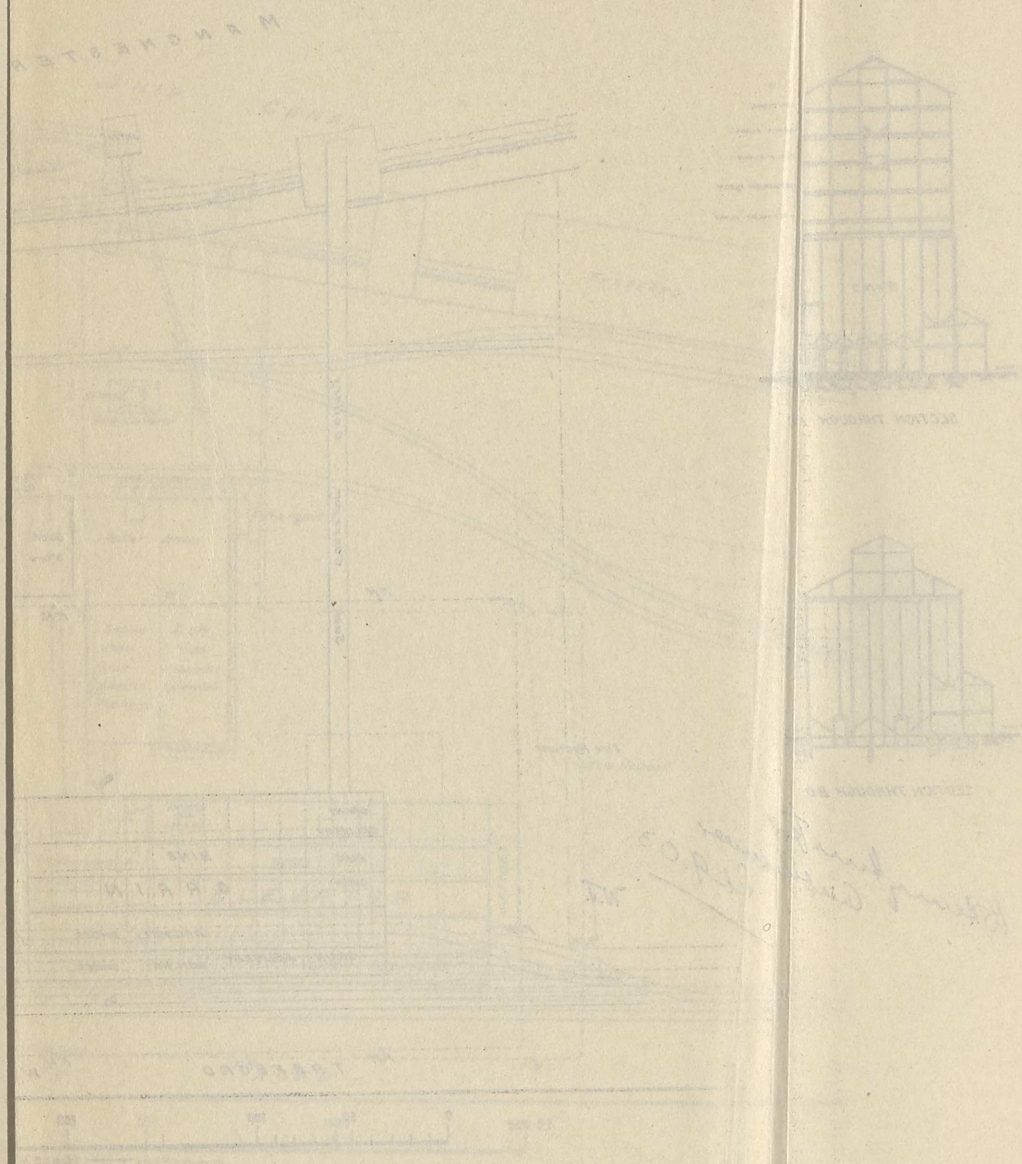


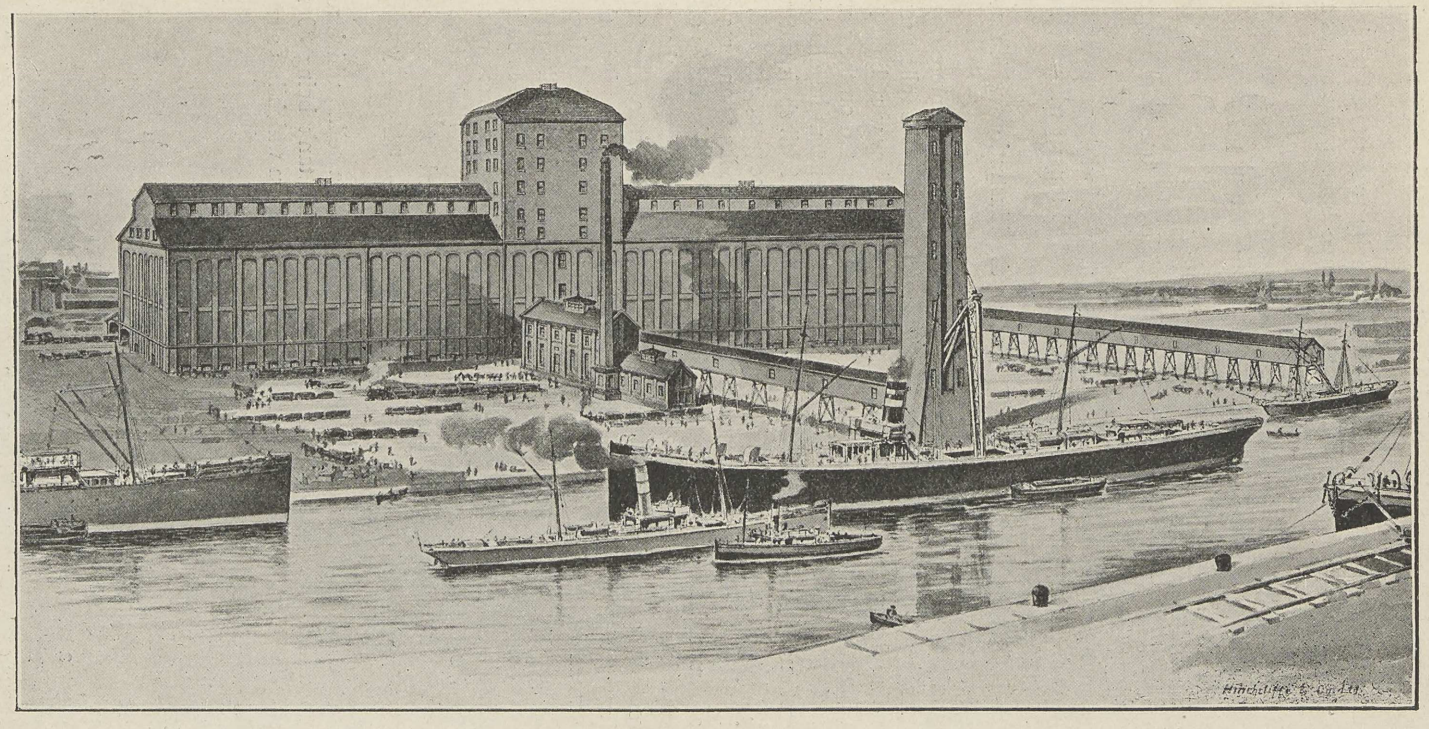


Fig. 997. General View of Manchester Ship Canal Granary.

Corliss compound engines of 500 H.P., fed with steam by two Galloway boilers working at 100 lb. pressure.

The power for the pneumatic apparatus is provided by two sets of triple-expansion vertical engines of 600 H.P., supplied with steam by three boilers working at a pressure of 160 lb. per square inch.

The following operations can be performed simultaneously at the warehouse:—

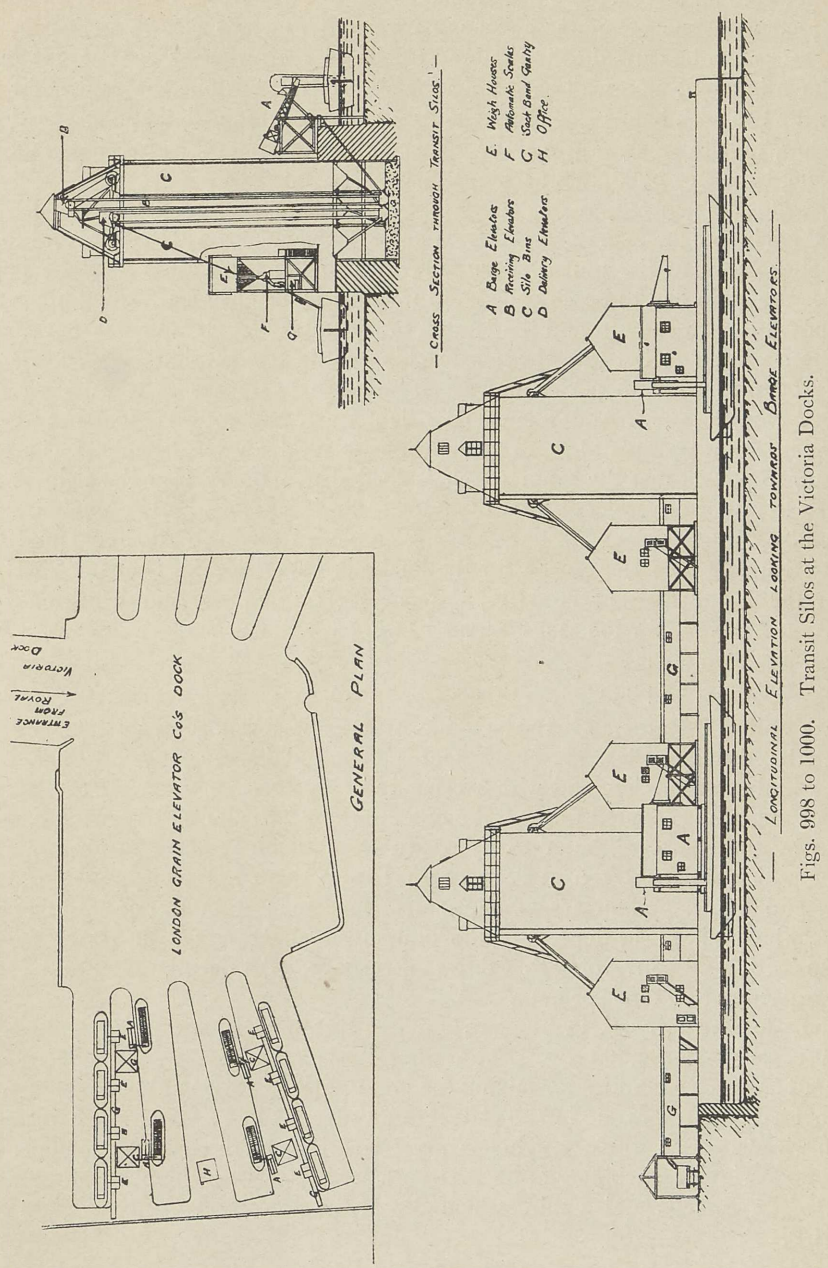
1. Discharging from vessels alongside at the rate of 350 tons per hour.
2. Weighing in tower at the water's edge.
3. Conveying and distributing into any of the 226 bins.
4. Moving grain about for changing bins or for delivery, and weighing in bulk at the rate of 500 tons per hour.
5. Sacking grain, weighing and loading sacks into forty railway wagons and ten carts.
6. Conveying into barges or coasters at the rate of 150 tons per hour if in bulk, or 250 sacks per hour if sacked.

The author is indebted to Mr W. H. Hunter for the illustrations which accompany the above description.

The Transit Silos on the Thames.—These form a most interesting group of installations. Although only used as transit silos, they are silos in the fullest sense of the word, and therefore deserve to be mentioned in this chapter. They were built for the old London Grain Elevator Co. by Spencer & Co., Ltd., and are situated on the south side of the Victoria Docks. They consist of four complete and independent installations. The area of this portion of the Victoria Docks is 50 acres, half of which is water, and the other half land. The space is oblong in shape, and is shown in the plan, Fig. **998**. At each end three peninsulas project into the water, thus forming four docks of an area of 2 acres each for the accommodation of the barges. The water in these berths is of sufficient depth to accommodate all ships which can enter the Victoria Docks, so that the largest ships can have their cargo discharged, weighed, or transported into smaller up-river barges, to railway trucks, or into the large flour mills that have been built there. All these operations can be carried on under cover, and are therefore quite independent of the weather. The four transit silos, two of which are shown in the illustration, Figs. **999** and **1,000** (which also gives explanatory notes), are situated on the south-west and north-west peninsulas, leaving one peninsula for the probable further extension. Each silo-house marked C on the drawing is divided into nine bins or silos, eight of which are used for storage purposes only, whilst the middle space is used for the accommodation of staircases, elevators, etc. Each of the eight silos is 12 ft. square by 80 ft. deep, and has a capacity of 1,000 qrs. of grain.

The silos are erected on a massive cast-iron tank forming a cellar, which rests upon a concrete foundation 6 ft. in thickness, the bottom of this tank being 30 ft. below the water level. They are built on the interlaced timber system which has already been described, being formed of "battens" nailed on top of each other, the pieces interlacing. The silo bottoms are so constructed that there are no joins in the corners, thus dispensing with rivets at these points, as they are apt to obstruct the flow of the material, and prevent the silos from emptying completely. These silos are supported on rolled steel girders which rest on cast-iron columns. The outside of the granary is covered with corrugated iron, and the roof is covered in a similar manner. The silos are about 100 ft. high, and carry a substantial iron roof which also covers two gas engines for driving the three delivery elevators, one of a capacity of 120 tons per hour, and two of a capacity of 100 tons each per hour. There is no occasion for conveyors, as the elevators which rise above the tops of the silos can readily deposit the grain into any one of them.

In connection with each silo is a barge elevator having a capacity of 120 tons per hour, which is driven by a separate gas engine. This outer barge or receiving elevator



Figs. 998 to 1000. Transit Silos at the Victoria Docks.

discharges its load into the elevator well inside the warehouse. Each delivery elevator leads to a discharge shed in which the grain is weighed. In this shed is a large receiving hopper (marked E in the illustration), below which are six automatic weighing machines

all fed from this hopper. After weighing, each machine discharges itself automatically into sacks, which are then ready to be loaded into barges or railway trucks. The four installations are all on exactly the same lines as the one described. Each pair of granaries is provided with one common sack conveyor band which is 308 ft. in length, so that the full sacks can be carried to the railway trucks as soon as they can be got ready by twelve men in connection with each weighing shed. There is one gas engine for driving each of the two sack bands. These sack bands are so arranged that the speed can be either slow, to take sacks, or it may be higher for the purpose of conveying grain in bulk for loading barges or bulk grain cars.

The silos are generally fed by a fleet of twenty-six of Philip's patent self-discharging lighters.[1] These lighters are charged from ocean-going steamers at Tilbury, and towed by special steam tugs to the transit silos. Previous to the installation of these important granaries the grain had to be unloaded and weighed by means of a floating hopper which was exposed to all weathers, and the motion of the unloading elevator was not conducive to accurate weighing; but with the new machinery it is now possible to discharge at the rate of 100 tons of grain per hour from each hatch by means of the derrick elevator described on page 469. And whereas the lightermen had formerly to be at work night and day, it is now possible to make all deliveries to receivers by daylight. The arrangements are so perfect that the grain which is loaded at Tilbury into the lighters can be delivered to rail or private craft from the transit silos in six hours. The whole installation is driven by fourteen gas engines, three being employed for each silo-house and two for the sack bands. The gas engine for the intake or barge elevator is one of 20 H.P., the one for the inside elevator 36 H.P., the one for turning over and delivering the grain 28 H.P., and the two for the sack bands 15 H.P. each. The actual power consumed is, however, less than this.

Fig. **1001** gives a photographic view.

A Typical Modern Granary.—Fig. **1002** shows a very compact granary equipped with interlaced timber silos. It consists of a balanced barge elevator with a range of 20 ft. up and down motion, and with a capacity of 60 tons per hour. From this barge elevator the grain is spouted through the outer annexe into the silo warehouse, where it is lifted by the shorter elevator to a hopper, from which it passes through a weighing machine which weighs 1 ton at each charge; from there it is conveyed into a second hopper, and into a preliminary grain-cleaning machine; from thence again to a third elevator, which takes it to the top of the building, and delivers it into a series of silos by means of a band conveyor with a throw-off carriage. All the elevators and conveyors have a capacity of 60 tons per hour.

The silos are forty-six in number, and are 8 ft. 6 in. square by 80 ft. deep, having a total capacity of 24,000 qrs. The whole installation is driven by electricity, and the plant has special facilities for mixing the grain as it is leaving the warehouse. It is also provided with a separate intake elevator of a capacity of 30 tons for the reception of English wheats. The whole warehouse plant is driven by three electro-motors: one for the top floor with its machinery of 38 B.H.P., a second driving the plant in the receiving annexe of 24 B.H.P., and a third which drives the conveyors on the ground floor of 10 B.H.P.

Granary at the Avonmouth Dock.[2]—A large installation of grain-handling plant has recently been completed at the Royal Edward Dock, Avonmouth, Bristol.

[1] See page 482.

[2] Extract from *The Engineer*, 10th July 1908 and 25th September 1909.

Grain is imported in very large quantities at Bristol, and the port has always been famous for the rapid discharge of this commodity. With its recently acquired additional

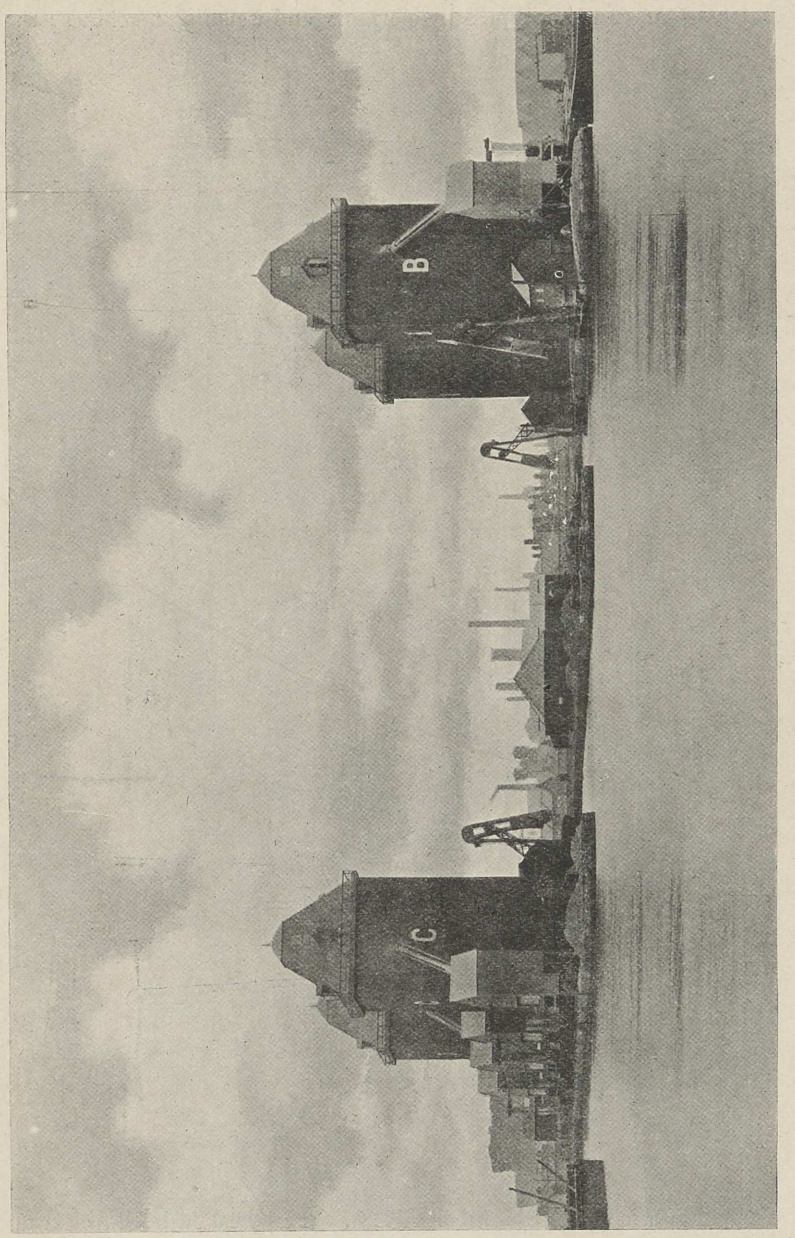


Fig. 1001. Four Transit Silos of the Port of London Authority at the Victoria Docks.

storage capacity, combined with the very latest machinery, this western port claims to be one of the first in discharging, storing, and distributing grain.

The fine building consists of nine floors measuring 222 ft. long by 72 ft. wide, and is on the east side of the dock in the rear of No. 2 Import Shed. The structure is of

ferro-concrete (Hennebique system), and rises 89 ft. from the ground level to the roof parapet. In the foundations ferro-concrete piles 14 in. square and averaging 50 ft. in length were used. The granary will hold 50,000 qrs. of grain and is capable of extension when necessary. One end is occupied by elevators and weighing machines; the middle

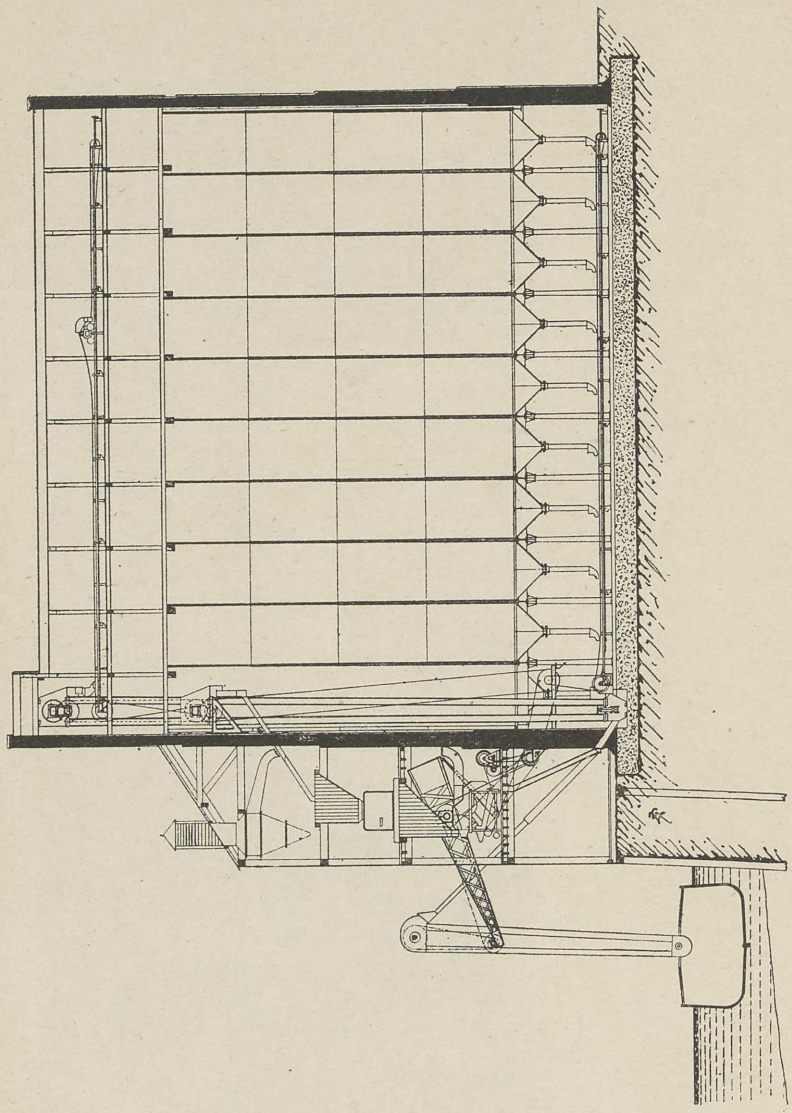


Fig. 1002. A Typical Modern Granary.

portion of the building is divided into silos 11 ft. 9 in. by 10 ft. in the clear and 50 ft. deep. The lower end of each silo is hoppered and has the usual valve by which the grain is withdrawn. The other end of the building is designed as a floor granary.

On both sides of the granary are double track railway sidings over which roof coverings are constructed. The sides of the building facing these tracks are open to a height of about 12 ft. from the ground level.

The interesting and complex equipment for handling the grain by conveyors and elevators was supplied by the New Conveyor Co., of Smethwick. They are designed to carry grain at the rate of 400 tons per hour continuously from the wharf side to the granary, where it is automatically weighed, checked, and deposited in the various silos or upon the floors. This result is attained by the adoption of subways, without in any way obstructing the traffic at the wharf or in the neighbouring roads and railway sidings.

In the rear of the dock wall is a tunnel for the conveying bands. The width of this tunnel, which extends along the entire length of the dock wall on the east side and is returned thence at an angle of 90° to the new granary, varies according to the number of belts in a particular position. Abreast of No. 1 transit shed at the south end of the dock, the tunnel is 9 ft. wide in the clear and 7 ft. in height. At No. 2 shed it is 16 ft. wide and increases to a maximum of 45 ft. in width near the granary itself. The total length of the tunnel is about 1,740 ft. It is constructed throughout of ferro-concrete.

The conveyors are of the endless-band type, arranged in parallel lines in the tunnel. The bands, which are made of cotton and india-rubber, are 22 in. wide, and are capable of sustaining a tensile stress of 800 lb. per inch of width. The idlers are about 6 ft. apart, and automatic tension gears are provided. The speed of the band is 650 ft. per minute, which speed represents 100 tons of grain carried per band per hour. The grain is, in the first instance, elevated and discharged from the ship into portable hoppers on the wharf. These hoppers fit over cast-iron shoots built into the wharf and communicating with the above-mentioned tunnel. Valves are provided in the hoppers, and on the lower ends of the wharf shoots for the proper regulation of the grain as it is discharged into the shoots and upon the conveyor bands.

The first section of the tunnel contains two conveyor bands 570 ft. long between terminals, and each band is fitted with portable distributing shoots, which receive the grain from the wharf shoots, which are spaced about 52 ft. apart along the dock side, enabling the bands to receive grain practically at any part of their length. The wharf shoots are covered by a special water-tight cover when not in use. The two conveyors in the first section of the tunnel are continuous throughout the section, forming with the addition of two other bands four complete and independent conveyors, each having its own 30 B.H.P. motor, tension gear, and receiving shoots. These four conveyors are 750 ft. long between terminals, and are broken at about 200 ft. from the forward end for convenience in driving, each motor being arranged to drive approximately an equal length of band. The two conveyors in the first section of the tunnel are disposed at the dock side of the tunnel, and can be fed directly from the wharf shoots. In the second section the third and fourth conveyors are fed indirectly from the wharf shoots by means of short cross conveyors mounted on travelling carriages above the main bands. These carriages traverse the whole length of the second section of the tunnel, the cross band receiving grain from any one of the wharf shoots and discharging upon either of the second pair of main bands by way of a two-way distributor. The cross travelling bands are each driven by a 15 B.H.P. enclosed motor mounted on the carriage. The four conveyor bands are continued through the second tunnel section to the junction with the third section, where the tunnel makes a square turn and runs from the dock wall to the basement of the granary. The conveyors in the third section are about 320 ft. between terminals, and to equalise the drive some 200 ft. length of bands in the second section are driven at the angle by means of cut bevel gearing and roller chain drives. Thus each length of band per motor is approximately equal, and similar 30 B.H.P. motors

are adopted for each conveyor. The conveyors in the third section are provided with travelling throw-off carriages for use near the extreme end where the tunnel opens out into a spacious chamber near the granary basement. Here the grain is weighed by automatic weighing machines and discharged into the boots of the four main elevators, each capable of lifting 100 tons per hour to the top of the floor of the granary. The main elevators deliver the grain to the four bands traversing the whole length of the granary over the heads of the silos and grain floors, and by means of travelling throw-off carriages provided on each of the bands the grain is discharged into any one of the seventy-eight silos or upon any of the grain floors. The four weighing elevators and four main elevators are driven each by a 30 B.H.P. motor, each motor at the same time driving a length of conveyor band. The grain floors are fitted with 12-in. diameter steel shoots, continuous through all the floors down to the sacking-off platform, valves being fitted for receiving and discharging the grain at any floor. An interesting feature in connection with this machinery is the arrangement of "re-elevating" bands in two small subways constructed under the granary. By means of these conveyors grain can be taken from any silo or any part of the floor granary, reweighed and re-elevated to another silo, or placed upon any other floor as may be desired, or heated grain can be circulated from silo to floor or vice versa, and small parcels of grain can be removed from the silo to a floor to make room for incoming grain. Each of these bands is driven by a 15 B.H.P. enclosed type motor. For the dispatch of grain to coasting steamers or to other small craft a special conveyor for carrying loaded sacks or loose grain has been erected in an overhead gallery. The inner end of this conveyor extends below the sacking-off platform. The sacks or loose grain are passed through openings in the platform on to the band, and are delivered at the dock side through shoots into various craft. This conveyor is fitted with two-speed gear, the band speed for loose grain being 650 ft. per minute, and that for sacks 200 ft. per minute. The band is in two sections of unequal length. The inner section of 450 ft. is driven by a 30 B.H.P. motor and the outer length of about 220 ft. by a 15 B.H.P. motor placed in a house below.

All the elevators and conveyors are driven from their respective motors by cut gearing and roller chains.

Immingham Dock Granary.—The general arrangement will be seen from the illustrations, Figs. **1003** and **1004**. Figs. **1005** and **1006** give two cross sections; whilst the granary itself is represented in plan by Fig. **1007**; the top floor in Fig. **1008**.

The dimensions of the building are about 127 ft. by 137 ft. 6 in. Of the latter dimension 74 ft. are occupied by the silos, whilst the remaining 63 ft. 6 in. constitute the floor granary, which extends to six floors above the ground floor.

The silo portion of the granary consists of 82 silos, each 10 ft. square in the clear, and the height from the hoppered silo outlet to the floor above the bins is approximately 50 ft. The walls of the silos are 6 in. thick, reinforced with horizontal and vertical rods in both faces. The bins are designed to act independently, that is to say, one bin may be full of grain and the adjoining bins empty without causing undue stress to the structure. All internal angles are finished with a 3-in. splay, and $\frac{5}{8}$-in. rods are provided at 12-in. intervals across the corners to form ladders for access to the bins. The bottoms of the bins are splayed to the outlet and have reinforced concrete varying from 4 in. to $5\frac{1}{2}$ in. in thickness, with beams formed in the angles under the walls, practically of triangular form, with a width of 3 ft. at the bottom. The bars from the walls and the sloping bottoms are carried well into these beams, which are in turn connected to the columns which serve to support the bins. The silo bottoms are of cast iron.

The external walls of the silo portion of the building are formed of 8 in. of concrete

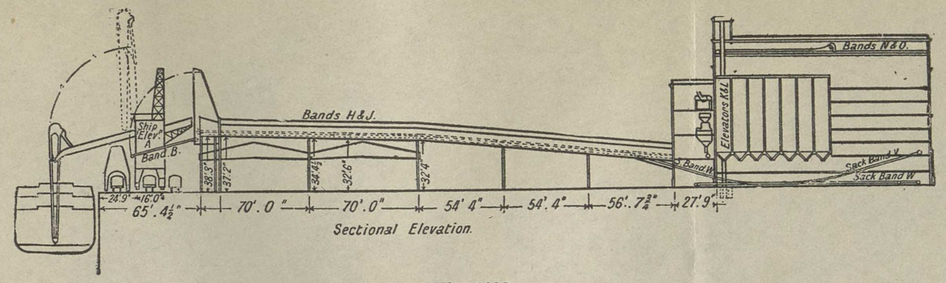


Fig. 1003.

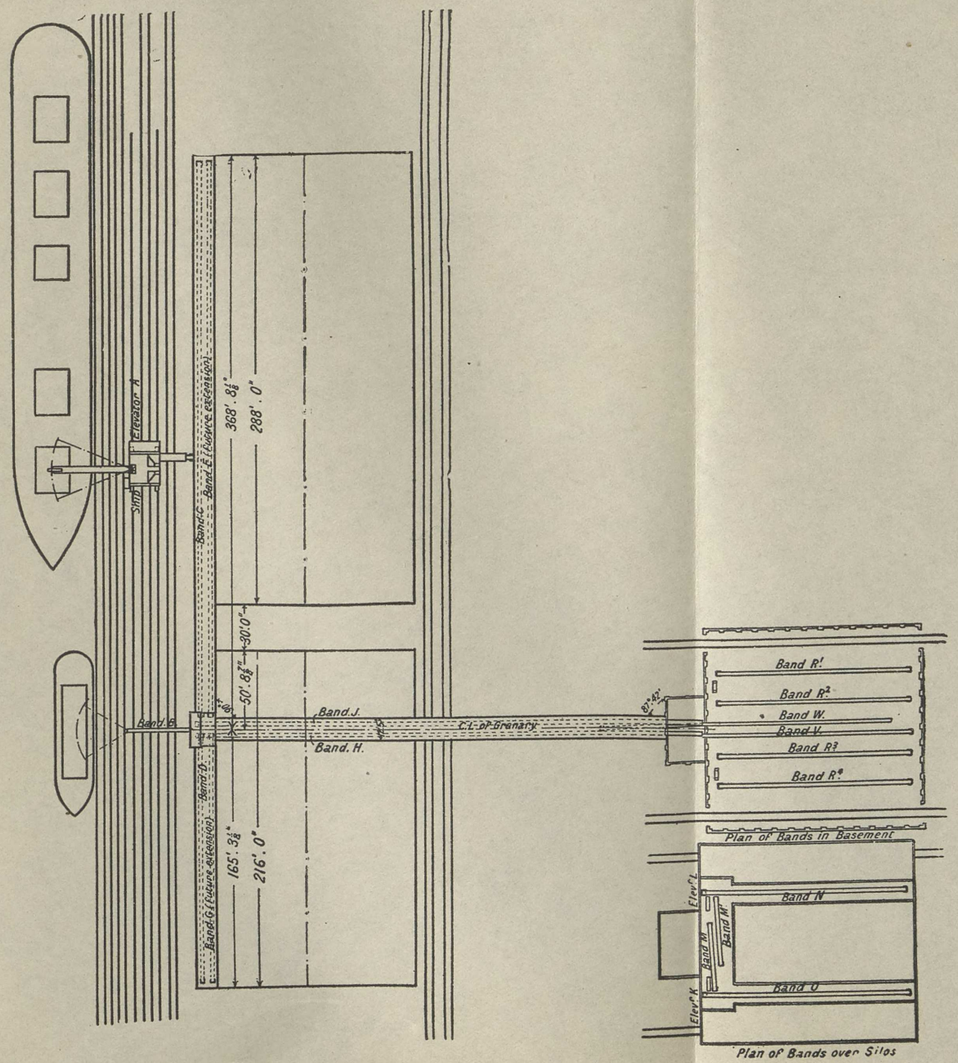


Fig. 1004.

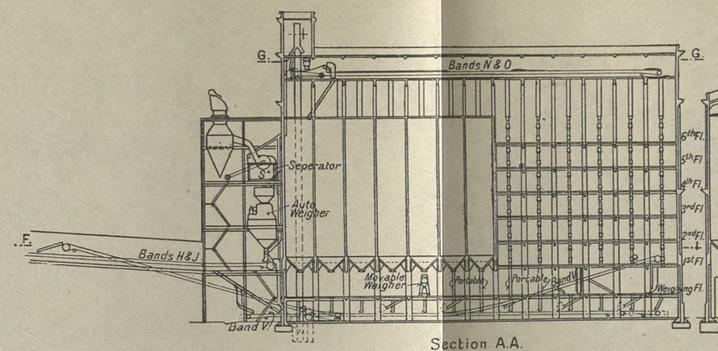


Fig. 1005.

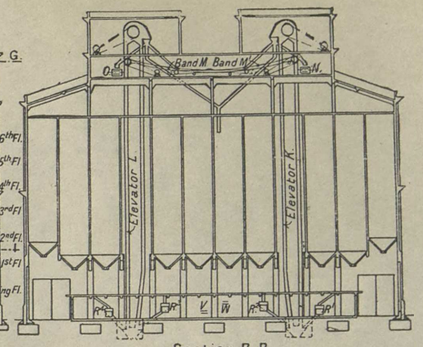


Fig. 1006.

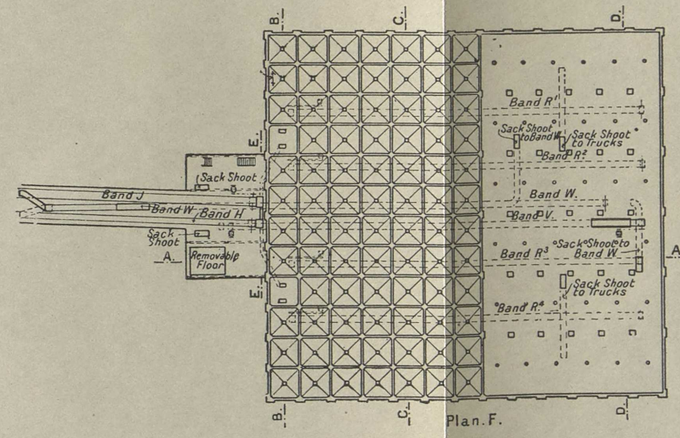


Fig. 1007.

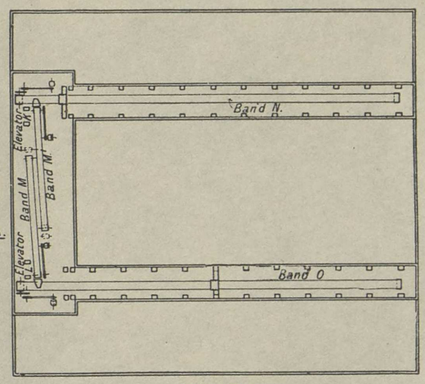


Fig. 1008.

IMMINGHAM DOCK GRANARY.

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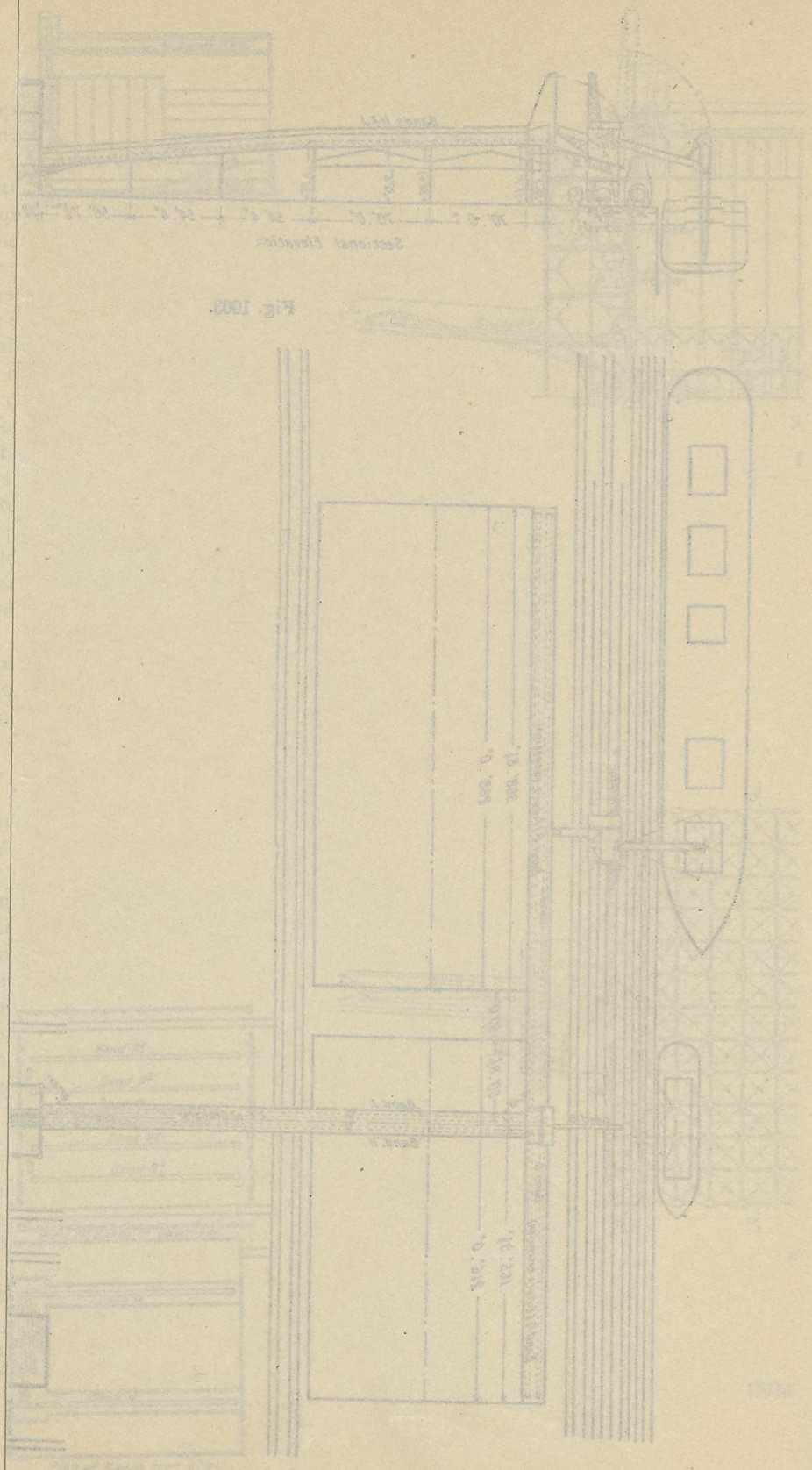


in the lower 25 ft. and 6 in. above this level, with piers 3 ft. wide at 10-ft. centres projecting 5 in. on the outside of the building and having a flush face on the inside. The string-course and cornice, which are of reinforced concrete and hollow in the interior, were cast on a form of collapsible centre in convenient lengths and built in position as the walls were carried up. The floor over the silos is formed of 4 in. of concrete, reinforced with $\frac{3}{8}$-in. rods in both directions and finished with granolithic. The size and details of the columns vary, those attached to the walls as piers being generally 3 ft. wide and projecting 8 in. or 10 in. from the face of the wall, whilst the reinforcement consisted of eight lines of vertical reinforcement, well tied with links at about 8 in. pitch. Those under the bins vary from $21\frac{1}{2}$ in. square to $22\frac{1}{2}$ in. square, reinforced with eight bars varying from $1\frac{1}{2}$ in. to $1\frac{5}{8}$ in. diameter, four of these being placed at the corners of the column, whilst the remainder are placed in the interior to form a square core with a $5\frac{1}{2}$-in. side. The outer rods are tied with $\frac{3}{8}$-in. links at 8-in. centres, while the inner rods have no binding on account of the large amount of concrete around them.

The floors of the granary portion of the building, which adjoins the silos on the opposite side to the receiving house, are designed to carry a safe loading of 3 cwt. per foot super., are 5 in. thickness, carried on secondary beams having a span of 10 ft. 6 in., which in turn are carried by main beams spanning about 20 ft. The slabs were made 5 in. thick and are reinforced with $\frac{1}{4}$-in. bars at $4\frac{1}{2}$-in. centres across the span of 7 ft., these bars being continuous over three bays, and similar bars at 12-in. centres are placed at right angles to these. The secondary beams are 8 in. deep and 6 in. wide, reinforced with $1\frac{1}{8}$-in. twin rod and hangers and bonders about 12 in. apart, while the main beams are 18 in. deep and 7 in. wide, reinforced with a $1\frac{3}{4}$-in. twin rod, with provision for shearing stress. The interior columns are 26 in. square and have fourteen vertical bars, ten placed near the outer surfaces, having a diameter of $1\frac{5}{8}$ in., and the remaining four are placed within the core and have a diameter of 2 in., the whole being bound by $\frac{3}{8}$ in. links at 8-in. centres. The external walls are 6 in. thick in the panels, whilst floor beams which come against the exterior are carried by projecting piers 3 ft. wide.

The towers at the receiving house end are carried 32 ft. above the cornice of the main buildings, and these are formed with 6-in. walls strongly reinforced, and have a reinforced concrete string-course and cornice of similar construction to that previously described. The receiving house at the back of the silos is 43 ft. by 27 ft. 6 in. by 67 ft. high, and has three floors.

The concrete throughout was mixed in the proportions of 9 cub. ft. of aggregate, $4\frac{1}{2}$ cub. ft. of sand, and 224 lb. of cement. All the floors are finished with granolithic paving composed of five parts of granite to two parts of cement. The concrete foundations were carried on wooden piles driven in groups proportionate in numbers to the loads to be carried, as many as eight being placed together in some instances. The piles varied from 45 ft. to 50 ft. in length, and the soil in which they were driven was a thick mud.

Quite apart from its constructional features, this grain storage installation is of more than ordinary interest, by reason of its machinery equipment and the efficient conveying plant which has been introduced. The store is capable of holding 20,000 tons of grain, partly in silos and partly on open floors. As will be gathered from the illustrations, two overhead gantries, which are fitted with band conveyors, form the means of communication between the receiving shed of the granary and the ship elevator. The latter, which is of the travelling type, runs on rails and forms a complete machine in itself, having bands, elevators, weigher, and motors. It is so constructed as not to interfere with the free

passage of railway trucks along the dock side, being raised on legs, which is a novel feature. The leg of the elevator can not only be raised and lowered, but it can also be swung from side to side, thus enabling a large area to be covered without it being necessary to change the position of the boat which is in course of unloading. The ship elevator, when not in use, can be raised out of the way, and this raising and lowering is effected by means of an electrically driven winch in the tower, and the elevator is balanced by weights, which greatly facilitates the operation. The elevator is capable of dealing with 150 tons of grain per hour. Vessels in any position on the quay side can be dealt with, and the following sequence of operations briefly explains the method of unloading.

The ship elevator is lowered into the hold, and the grain elevated, weighed, and passed on to 27-in. wide band conveyors in the gantry parallel to the wharf, which feed on to either of the two bands, one 27 in. and the other 36 in., in the other gantry. The grain is then elevated by one of two 150-ton per hour elevators to the top of the silo building, and from thence it is distributed to any required bin or storage room.

The front gantry, alongside which the ship elevator travels, is 530 ft. long, and grain is taken in from the ship elevator at any point along this distance. The approach gantry leading to the receiving house is 300 ft. long. There are eighty-two bins and six storage floors, and these latter are each arranged with thirty-six floor spouts, which are fitted with sliding sleeves at the top and bottom, by means of which the grain may be fed to or taken from any floor. By raising the top sleeve and placing a conical cap or spreader on to the spout, the grain may be distributed over the floor to any required height. To discharge the grain it is necessary to raise the bottom sleeve and to lower the same when sufficient grain has been drawn off. For taking out sacks from the granary, they are carried on the bands in the approach gantry to an outside conveyor in the centre of the front gantry, delivering direct to ships and barges. This conveyor may be housed in a tower in the centre of the front gantry. The band is completely enclosed, and there is thus no risk of the grain being damaged when being loaded out. This band may also be used for loading out in bulk.

On the first floor of the building are six Avery portable grain weighers with sacking-off appliances. The grain, when sacked off, can be delivered by sack shoots either into trucks or on to sack bands, which extend along both gantries and thence through shoots into boats. The outgoing grain can also be handled in bulk with equal facility. On the ground floor a number of conveyors are placed, and these are fed from the silos, and delivery of the grain is effected to either of the elevators. These conveyors are used for turning over purposes. The bands, over the silos and floor storage, are capable of dealing with 300 tons of grain per hour.

The machinery equipment includes twenty-two motors with an aggregate of 270 H.P. The majority of the motors are back-geared, and the band conveyors and elevators are driven by chains, thus obviating the use of the large gear wheels generally found on elevator heads. This method of drive is stated to have proved very satisfactory, light, and remarkably free from noise. The power is transmitted to the travelling ship elevator through a series of plugs placed along the front gantry, a loud speaking telephone being meanwhile connected up by the single plug.

In conclusion, it may be said that the buildings were constructed by Stuart's Granolithic Co., Ltd., of Bedford Row, W.C., and the gantries and grain-handling machinery were manufactured and erected by Henry Simon, Ltd., of Mount Street, Manchester—all to the requirements of Mr J. B. Ball, M.Inst.C.E., the engineer-in-chief of the Great Central Railway Co.

SOME OF THE PRINCIPAL GRANARIES IN GREAT BRITAIN

Name of Owner and Title of Granary.	Material Used and Nature of Granary.	Capacity. Qrs.
Bristol Dock Co.—		
Avonmouth Dock Granary	Floor granaries	60,000
Portishead Dock Granary	,, ,,	60,000
Princes Wharf Dock Granary	,, ,,	70,000
Clyde Navigation—		
Meadowside Granary, Glasgow	Floor and silo granaries of ferro-concrete	144,666
Co-operative Wholesale Society, Ltd.—		
Granary, Dunston-on-Tyne	Silos of ferro-concrete	42,000
Eagle Oil Mills Co.—		
Eagle Oil Mills and Bon Accord Mill Silos	Silos of wood with steel bottoms	33,133
W. Gilyott & Co.'s Wilberforce Warehouses—		
No. 1. Garrison Side, Old Harbour, Hull	Floor warehouses	65,000
No. 2. High Street, Old Harbour	,, ,,	20,000
No. 3. High Street, Old Harbour	,, ,,	15,000
Great Central Railway Co.—		
Immingham Dock Granary	Silos and floor granaries of ferro-concrete	93,333
A. Guinness, Son, & Co., Ltd., Dublin—		
Malt Stores, St James' Gate Brewery	Silos of brick and concrete	125,000
Hurtley & Sons, Ltd.—		
Wilmington Flour Mills, Hull	Silo warehouses	24,000
Lancashire and Yorkshire Railway Co.—		
Silo Granary, Wyre Dock, Fleetwood	Silos of timber	150,000
Leith Grain Warehousing Co.—		
Patmore Elevator and Grain Silo	Silos of timber	125,000
Liverpool Grain Storage and Transit Co.—		
Nos. 1 and 2 Alexandra Grain Warehouses	Silos of brick	373,333
London and South-Western Railway Co.—		
Southampton Dock Granaries	Floor warehouses	304,000
Manchester Ship Canal Co.—		
Manchester Grain Silo	Silos of timber and brickwork	186,666
Manchester New Grain Silo	Silos of ferro-concrete	186,666
Mersey Dock and Harbour Board—		
Liverpool Dock Granary	Floor and silo warehouses of brick and ferro-concrete	199,500
Birkenhead Granary	- - - - - -	233,730
Oldham Roller Mills Granary	Silos of brick	23,778
Port of London Authority—		
East India Dock Granary	Silos of timber with steel bottoms	40,000
London and India Docks Granary	Silos of timber	25,000
Millwall Dock Granary	Floor and silo warehouse of brick	100,000

Name of Owner and Title of Granary.	Material Used and Nature of Granary.	Capacity. Qrs.
Port of London Authority (*continued*)—		
Royal Victoria Docks Silo	Silos of timber and steel	25,000
Surrey Commercial Dock Warehouses—		
North Side of Greenland Dock	Floor granaries, built of timber	82,000
North Side of South Dock	,, ,, built of brick	141,000
South Side of South Dock	,, ,, ,, ,,	48,000
Transit Silos on the Thames	Silos of timber with concrete bottoms	32,000
Joseph Rank, Ltd.—		
Rank's Grain Silos, Hull	Silo warehouses	20,000
Rishworth, Ingleby, & Lofthouse—		
Granary Swan Flour Mills, Hull	Silos of wood with iron hoppers	33,000
Sun Flour Mills Granary, Bromley-by-Bow	Silos of timber	32,013
W. Vernon & Co.—		
Silos at Mersey Docks	Hoppers of ferro-concrete	40,000
Victoria Dock Silos	,, ,,	56,000

The above table is by no means complete; it contains only those granaries which are well known, and the information concerning which is common knowledge. On account of the present state of war it has been considered prudent and in the national interest to withhold the locality and capacity of all granary installations of more recent date.

THE AUTOMATIC WEIGHING OF MATERIAL

CHAPTER XLIII

THE AUTOMATIC WEIGHING OF MATERIAL

When handling material automatically, it is often desirable to keep a record of its weight; also of the total tonnage dealt with, so as to check deliveries of coal, grain, etc. It is also essential to keep a record of the contents of vessels filled mechanically, as well as of silos, bunkers, and other receptacles.

Automatic weighing machines which are used as a means to this end may be classified under three types. In one the material is weighed at the point of receiving from or delivering to the elevators or conveyors which handle the material, in which case it actually passes through a weighing machine. A second type of weigher is attached to certain kinds of conveyors, and records the weight of the passing load without bringing the material itself in contact with the hopper of a weighing machine. There is also a third type which is used for weighing material intermittently in larger quantities. There are advantages and disadvantages in each method.

In the first type, termed **Hopper Weighing Machines**, the record of the weight is more accurate. This is, of course, an important matter if material of a valuable nature is being handled, but these machines have their limitations. To begin with, the material to be weighed must be of a fairly uniform size, that is to say, big pieces must not be mixed up with small particles. Then again, with these machines considerable headroom is necessary, which is not always available, as a stationary hopper must be provided into which the elevator or conveyor can deposit the material before feeding it into the weighing machine, and there must also be a second hopper beneath the weighing machine to receive the material leaving it. In addition to these two hoppers, the height of the weighing machine itself must be taken into consideration. This difficulty may be overcome by the use of an elevator, but there is also the drawback incidental to the breakage of friable material, and the consequent production of dust. In the case of coal the last objection would probably be the most urgent.

The second type, termed **Continuous Weighing Machines**, will record with sufficient accuracy coal, ore, cement, etc., as it is passed along by a conveyor of the belt, tray, plate, or gravity bucket type. The driving mechanism derives its motion from the conveyor itself, so that the record is not deranged by any variation in the speed of the conveyor. These machines require no extra headroom, produce no dust, and are not calculated to triturate the most friable material; but on the other hand, the record obtained is not so reliable as that of the hopper weighing machines.

The action of the first and second types is more or less continuous, as a constant stream passes through or over both kinds of weighing machines. Even with a hopper type the delivery can be made to a certain extent continuous.

The third type, termed **Intermittent Weighing Machines**, are for the purpose of weighing material contained in skips, buckets, or trucks, which, during the conveying process, pass a certain point where the weighing apparatus is stationed. They are used in connection with ropeways, mono-railways, and telphers, and may be arranged so that the load is stopped in its progress during the weighing operation, or they may be non-stop weighers, where the weight of the load is recorded during transit. Such appliances can, however, only be used successfully when the tare of the receptacle is known and has been adjusted to exactly the same in all the units which may be used for the conveyance of the load. The weighing machine itself generally weighs each separate lot, and adds the successive weights up to a total.

In selecting a weigher it is, of course, necessary to take all the conditions into consideration. Broadly speaking, it may be said that the hopper weighing machine is most suitable for grain, seeds, small coal, etc., the continuous weighing machine for coal and minerals, whilst with the intermittent weighing machine material of any kind may be conveyed in the receptacle passing over the weigher.

HOPPER WEIGHING MACHINES

The "Chronos" Automatic Grain Scale.—This was the first machine for the purpose of automatic weighing, and is the design of Messrs Reuther & Reisert, of Hennef-on-the-Sieg, Germany (see Figs. **1009** and **1010**).

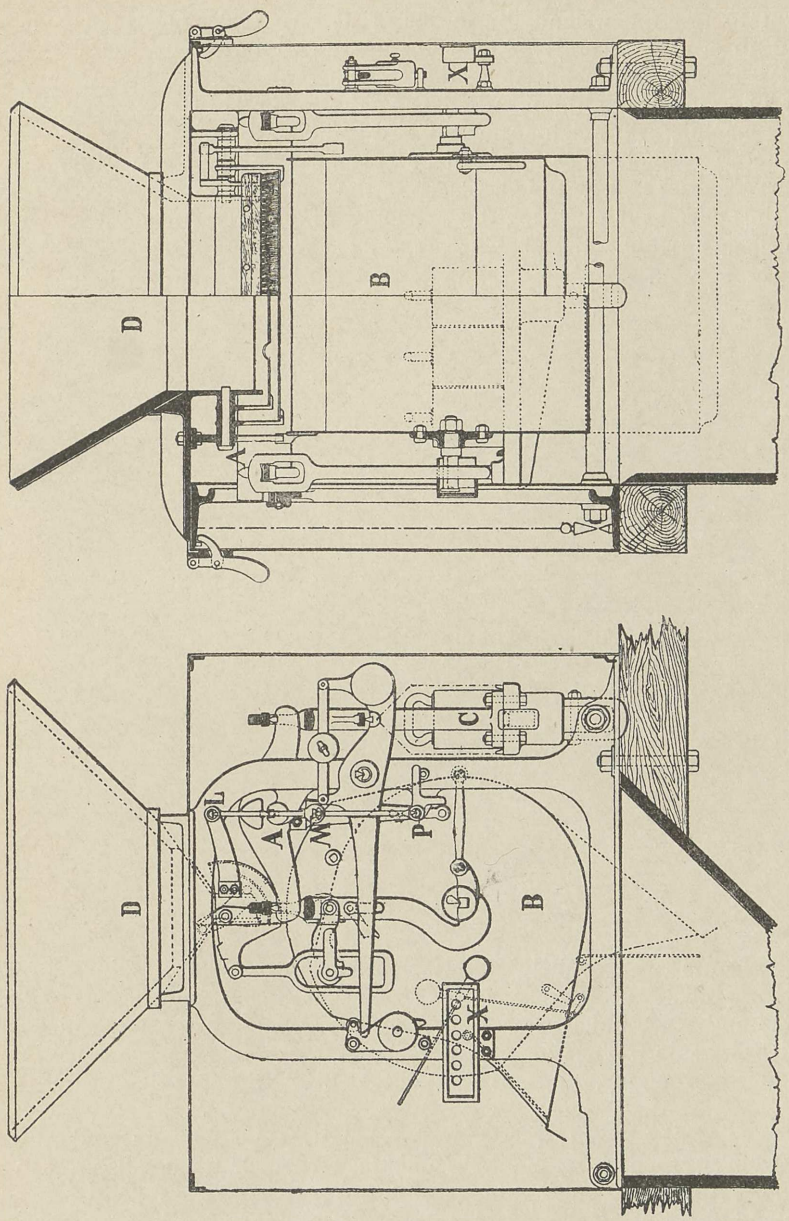
This weigher consists essentially of a beam scale A, of the usual kind, with arms of equal length, to one of which is suspended the weight C, and to the other a skip B for the reception of the grain, such a skip being capable of rotation on an axis, and being provided with two apertures for the respective operations of receiving and discharging, whilst from the other arm there also hangs a beam board which will take any ordinary kind of weight.

Over the recipient is placed a hopper D, underneath which play two valves, or rather gates, which regulate the flow of feed. The grain pouring through the hopper soon fills up the recipient B, until suddenly the upper gate partially closes, thus shutting off the greater part of the feed, and letting in only two thin streams of grain, which together make up the exact weight set on the beam board. As soon as that point has been reached, a stud attached to the pointer of the beam scale comes in contact with a toggle joint P M L, which serves to support the second flap and bends the former down. The effect of this is to completely close the inlet, while simultaneously a hook, which has kept the recipient in an upright position for taking in the feed, is released. The skip then tips forward about 40°, this movement being sufficient to empty it of its contents, but as soon as this has been accomplished it regains its former position, the index X registering the weighing, whereupon the two inlet valves are opened, and it is again held fast by the hook. With the re-entry of the feed the operation already described is repeated. Each revolution of the skip, and therefore each discharge of a given weight of grain, is registered on a dial attached to the front of the scale. The two illustrations, Figs. **1009** and **1010**, give a clear idea of the movement of the skip B, as well as of the action of the "Chronos" machine.

To reduce friction to a minimum and to ensure smooth work, it has been the aim of the makers of this machine to shorten as much as possible the arc traversed by the skip in its tipping motion, hence it had to be provided with an outlet distinct from the inlet. Moreover, the recipient has been so shaped and hung, that while the grain, seeds, or other materials are being fed through the inlet, the bottom of the skip

remains in a horizontal or nearly horizontal position, while, during emptying, the angle is slightly more than the angle of repose of the grain.

The weight of the outward flap is sufficient to keep the discharge opening shut



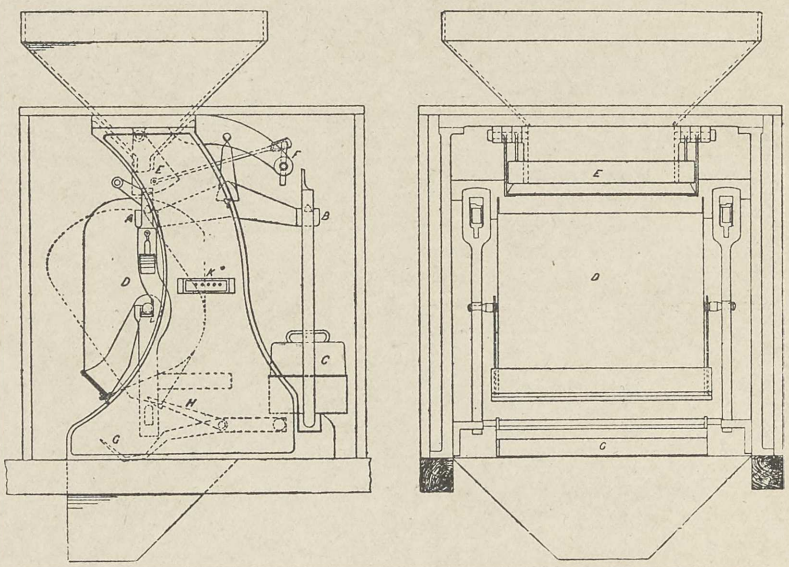
Figs. 1009 and 1010. "Chronos" Grain Scale, showing Action of Skip.

during the filling operation, while it swings forward and allows a free passage to the discharging grain as soon as the angle is enlarged by the revolution of the recipient. Meanwhile the discharge gate has fulfilled its appointed function in preventing any portion of the grain from spurting outwards and escaping before the right time.

The setting of the scale appears to be a very simple operation. By a turn of a small lever the mechanical parts of the weigher and the beam scale are entirely disconnected. The beam will then swing loose like the beam of an ordinary scale, while the pointer will play freely whether the board be weighted or not. It is thus easy at any moment to test the weigher by means of its own scale, and this operation can be effected in a few seconds without in any way interrupting the work. If any discrepancies should be manifest in the weighing, they can be corrected by the adjustment of a small weight, and when once this weight has been set in its proper position, the machine will weigh accurately and continue to do so.

If desired, the whole apparatus can be covered by a sheet-iron casing, which will leave no part exposed except the glass face of the dial register. The casing can then be locked, thus effectually removing the possibility of any tampering.

This machine is built in eighteen sizes, for charges from 12 to 3,300 lb. of grain, and with a corresponding capacity of from 32 to 3,240 cwt. of grain per hour.



Figs. 1011 and 1012. "Nomis" Automatic Beam Scale.

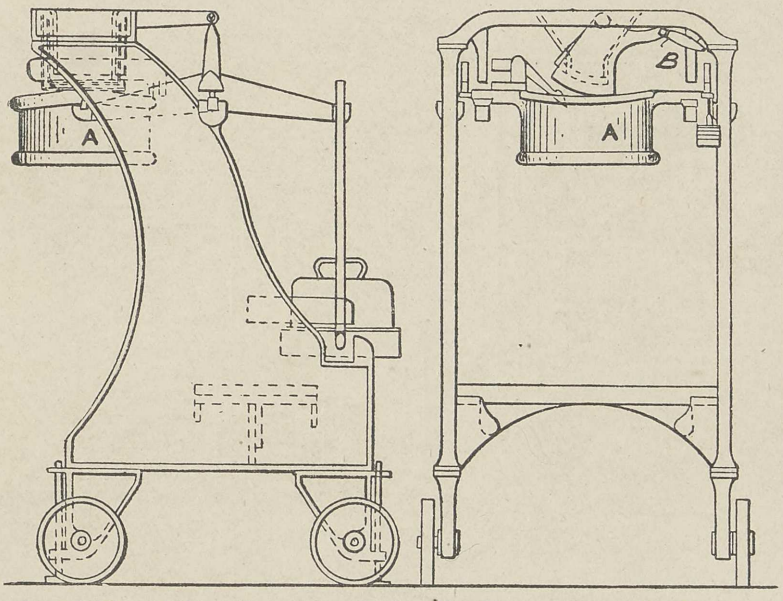
The "Nomis" Automatic Beam Scale.—This machine is built by Richard Simon & Sons, Ltd., Nottingham. It is of very simple construction, and is illustrated in Figs. **1011** and **1012**, which show front and side elevations of the machine with the inlet and delivery skip. The side elevation shows the grain hopper both in its normal position and when empty, and also in dotted lines the position it takes during discharge.

This machine is a beam scale, having equal arms A B, with a standard weight C suspended from the end B of the beam, and the receptacle D hanging from A at the opposite end. Above is a valve arrangement E, which admits grain and other similar substances, and also cuts off the flow when the correct weight has been admitted. The mechanism used to obtain this result is very simple. A side weight acts, together with the skip D and the inflowing weight of grain, to overcome the inertia of the dead weight on the other arm, and to shut the first of the two valves, so that the inflowing grain is reduced to two small streams when the correct weight has been nearly reached. The adjustable side weight compensates for the stream of grain in the act of falling at the

moment of closing the valve. The final cut-off is caused by the rising of the arm B of the scale with the weight C as the grain recipient descends.

A steel pawl lifts the crank F coupled direct to the valve E, so that as soon as the crank is over the dead centre, the weight of the valve is called into action to close itself. After closing, the valve moves forward sufficiently to release the catch supporting the skip D, which, being pivoted somewhat below its centre of gravity, immediately tilts, and in so doing uncovers the discharge opening at the bottom through which the grain leaves the bucket. The discharging wheat strikes a rocking plate G, secured to the frame of the machine. This brings down a hook H, which holds the bucket in position until it has emptied itself, after which it is released and swings back to be refilled, closing itself and opening the inlet valve by its momentum, while simultaneously it actuates the counter K and so registers the weighing.

Should the discharge spout from the weighing machine become blocked, owing to



Figs. 1013 and 1014. Simon's Sack-Filling, Weighing, and Recording Machine.

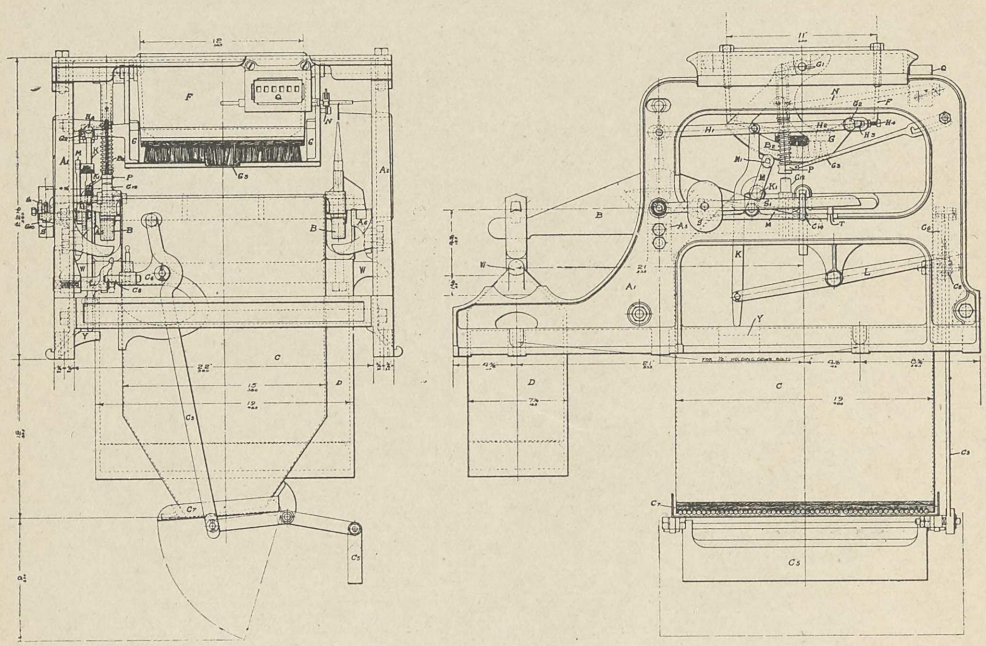
the machine weighing more than the shoot below can take away, the machine stops automatically and recommences work as soon as the accumulation has subsided. The short substantial beam of the machine secures rigidity and reduces vibration, which means that the oscillation during the weighing is reduced to a minimum. It also facilitates a quicker succession of weighings, as many as four per minute having been accomplished. The machine is chiefly used for weighing grain and seeds. It is built in ten sizes, having capacities of 2 to 500 qrs. per hour, and ranging in height from $12\frac{1}{2}$ to $89\frac{1}{2}$ in. for the different sizes.

Simon's Automatic Sack-Filling, Weighing, and Recording Machine.—A modification of the machine just described is illustrated in Figs. **1013** and **1014**.

Instead of the weighing hopper, a sack is attached to the machine which serves for sugar, flour, coffee, rice, grain, seeds, etc., ordinary standard weights being used It is claimed for it that it is a great labour-saving device, and is accurate to an ounce in 2 cwt. There is a counter in connection with it which records the number of sacks thus filled and weighed. All that the attendant has to do is to attach the empty bag

to the cylinder A, and pull down the handle B, whereupon the sack is automatically filled with the correct weight. It can then be tied up and another one attached. This portable weighing machine should be of great service under silo floors, where grain from different silos has to be filled into sacks, as it can be put in position under any silo, and connected by a sleeve or temporary spout with the hopper bottom. It is also made for suspending under the silos.

Avery's Automatic Grain Scale.—This automatic weigher is built by W. & T. Avery, Ltd., Birmingham, England. The diagrams, Figs. **1015** and **1016**, show the scale when empty. A_1 and A_2 are the side frames in which are fixed the main bearings A_5 and A_6; in these rest the knife edges of the beam B having suspended at one end the iron box D, at the other end the receptacle C in which the grain is weighed, and so arranged that the box D exactly balances the hopper C. The former is constructed to hold the required quantity of dead weights, and being made with a sloping top, no dust,



Figs. 1015 and 1016. Avery's Automatic Grain Scale.

etc., can lodge thereon. It also has a hinged lid which can be fitted with a lock to prevent any tampering with the weights.

The weigh hopper C has a door C_7 at the bottom, which is automatically opened and closed when required.

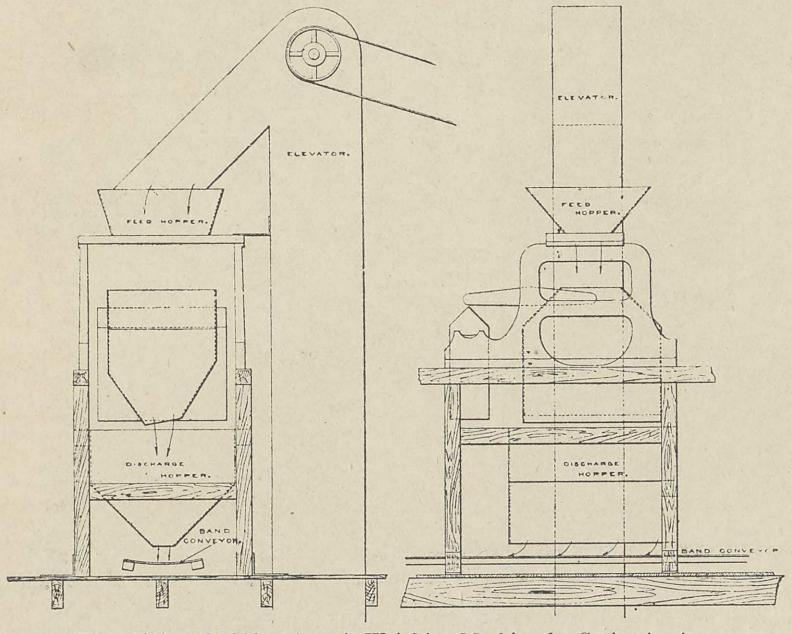
The supply of grain is regulated from the shoot F by a weighted valve G hinged at G_1 with an aperture G_3 in its front edge. A pin G_2 attached to the valve G works in the slot H_3 of the lever H_2 so that when the locking levers H_1 and H_2 are down (as shown in Fig. **1016**) the valve G is prevented from opening. These locking levers H_1 and H_2 are connected with the lever L by a weighty rod K fitted with a steel roller K_1, which, when the rod is raised, rests on the knife edges or roller M_1 fastened to the trigger M, the latter being so pivoted as to swing underneath by its own weight.

The door C_7, at the bottom of the weigh hopper C, is kept shut during the weighing operation by the bar C_3 attached to the toggle C_6. This toggle is pivoted to the hopper, and fitted with a striking bolt C_8, which, when the scale is required to weigh

automatically, is drawn out until it overhangs the lever L. The door is so arranged that when open the weights C_5 and C_6 exert only a slight tendency to close it, thus a little of the grain at the top will keep it open, and automatically stop the machine from working until the weigh hopper C is empty.

The action of the scale is as follows: On weights to the required quantity being placed in the box D, that end of the beam B is depressed until the projections V_1 on the box D rest on the side frames A_1 and A_2; the other end of the beam rises, and by means of the projection C_{12} catching under the pendant P attempts to lift the valve G, but being prevented by the locking levers H_1 and H_2, it only compresses the pendant spring B_2. (This also causes the box D and weights to descend gently without any jar to the machine.)

On the free end of the lever L being depressed, the other end raises the rod K and breaks the locking joint formed by the levers H_1 and H_2; this releases the valve G



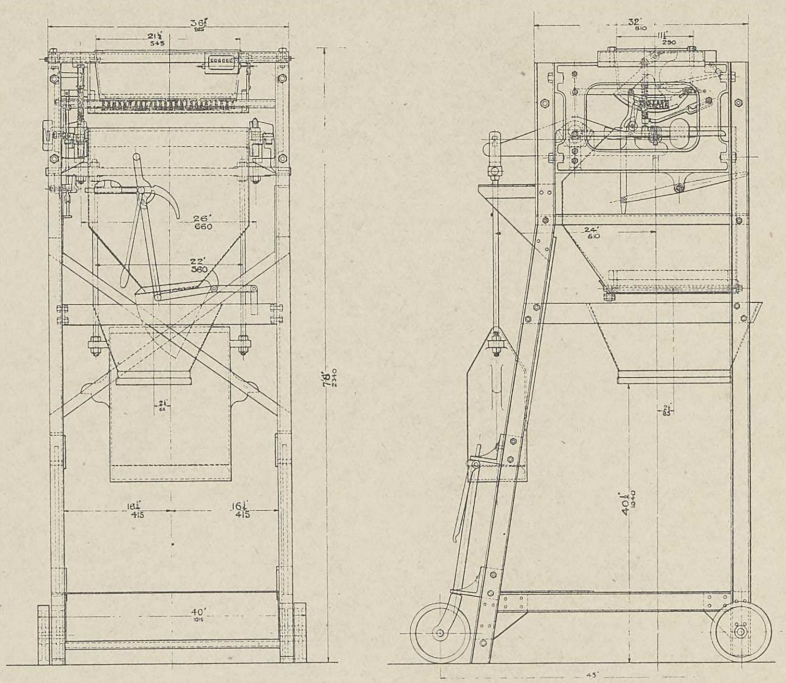
Figs. 1017 and 1018. Avery's Weighing Machine for Grain, *in situ*.

which, owing to the pressure of the spring B_2, flies wide open, lifting the levers H_1 and H_2 with it, and admits a full stream of grain from the shoot F; this goes on until the weight of the grain in the hopper C, assisted by the weight of the valve G, depresses the beam B until it no longer supports the valve, which swings to again as far as it is allowed by the pin G_2 in the slot H_3 of the lever H_2.

The levers H_1 and H_2 are supported by the rod K resting on the knife edge or roller M_1 in the trigger M. The only grain now coming into the scale is what can flow through the small aperture G_3 in the valve G, and this amount can be adjusted by means of the screw H_4 regulating the length of the slot H_3. This dribble of grain goes on until the weight of grain in the hopper C is equal to the dead weights in the box D, when the beam comes down to the horizontal, and by means of a projection C_{10} draws away the trigger M from beneath the rod K which falls on to a stop and brings the levers H_1 and H_2 with it; these by means of the pin G_2 completely shut the valve G and lock it as before. The falling of this rod K raises the free end of the

lever L which, by catching the striking bolt C_8, opens the door C_7; this remains open until all the material has been discharged, when the door swings to again and the striking bolt C_8 coming down depresses the lever L, which starts the whole operation over again.

It will be noticed that when the weight of the grain in the hopper C exactly balances the weights in the box D, the valve G immediately shuts, but the grain in suspension at the time falls into the hopper and would be overweight were it not compensated for by an adjustable weight S on the bar S_1 which rests on the beam during the weighing operation, but afterwards catches a stop on the frame so that the beam finally swings clear of all the working parts, and conclusively proves that there is a perfect balance.



Figs. 1019 and 1020. Avery's Automatic Weighing Machine for Sacking-off Purposes.

The ordinary register or counting apparatus Q is so attached to the lever L as to keep a record of the number of weighings performed by the scale.

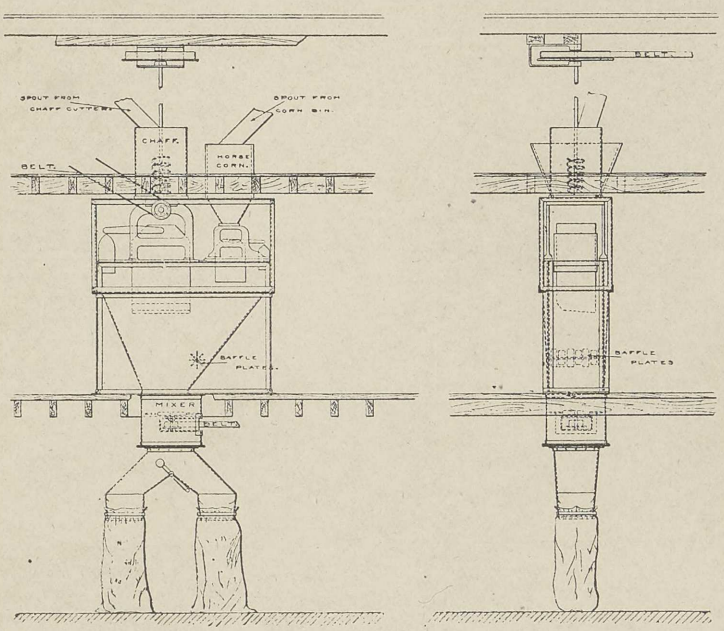
Figs. **1017** and **1018** show one way in which the Avery Weighing Machine is installed in warehouses, etc., for the purpose of weighing grain in bulk. The grain is received, elevated to the top of the warehouse, and carried by means of band or other conveyors to the silos. The illustration shows the elevator, and also indicates the position of the weighing machine between this apparatus and the conveyor which further disposes of the grain.

The scale is placed on a suitable staging, and fitted with a feed hopper above and a discharge hopper below, each of which are of a capacity slightly in excess of that of the weigh hopper of the machine. The spout from the elevator leads into the feed hopper, and after the grain has passed through the scale and been weighed and registered, it drops into the discharge hopper, whence it falls gradually on to the conveyor which distributes the grain to the silos. The opening in the hopper can be so adjusted as to feed the conveyor gradually.

This machine is built in twenty-four sizes from 12 to 96 in. in height, the respective capacities for the different sizes being from 20 to 12,000 lb.

Avery's Automatic Weighing Machines for Sacking-off Purposes.—The Automatic Net Weigher (see Figs. **1019** and **1020**) is built on the lines of the machine described above, but is specially constructed to meet the requirements of those who prefer to have their material weighed net, and then delivered into sacks. The machine is a great labour saver; one man can work it, filling, weighing, and counting automatically about four sacks per minute.

The machine cannot discharge until the man has the empty sack in position ready to receive the load, when he simply touches a lever which causes the machine to discharge and make another weighing ready for the next empty sack. Every discharge of the machine is registered, thus keeping an accurate record of the number



Figs. 1021 and 1022. Avery's Weighers for Chaff and Grain.

of sacks sent out. Each weighing balances as soon as the grain is cut off; the operator sees this balance.

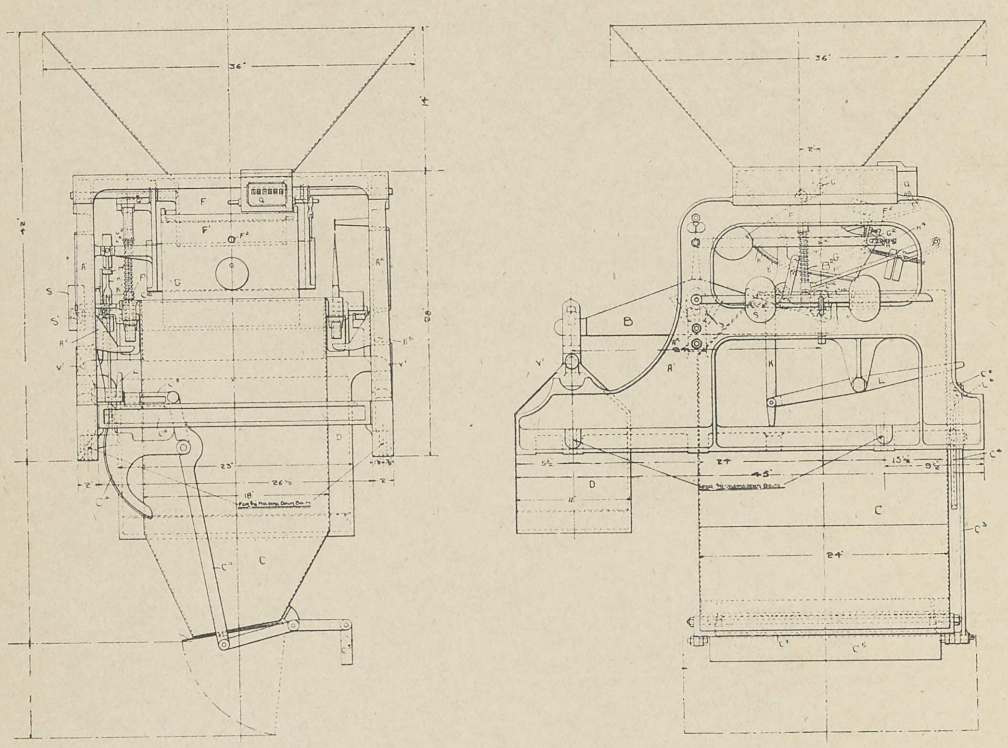
Avery's Automatic Gross Weigher possesses the chief features of the Net Weigher, but it weighs the sack and material together. The speed of working of this machine is not so quick as the Net Weigher owing to the time necessary to attach the empty sack to the bag holder by a strap and clasp. Both machines being portable they can be moved about from place to place.

Avery's Automatic Machine for Provender Mills.—The automatic weighing of chaff is admittedly difficult, because the extremely light nature of this material necessitates a large quantity in the weighing hopper before any weight and consequently power can be obtained, and also because chaff from its nature will not run readily in spouts and hopper-shaped receptacles. For these reasons many forage and provender mills have hitherto employed measuring devices for chaff, the grain being added in the proper proportion by means of weighing machines.

Figs. **1021** and **1022** show an installation in which Avery weighers are used both for

chaff and grain; in this case there are two machines. Such installations are now at work both in this country and abroad, notably at the Midland Railway Co. Provender Stores at Oakham, where there are four complete sets. When it is desired to weigh chaff it is usually for the purpose of obtaining the correct percentage of chaff and corn in a mixture of the two for feeding purposes. The small machine used for weighing the corn is the ordinary type of weigher as already described, and is so connected with the chaff scale that they discharge together.

Above this chaff scale is a stirring device which ensures an even flow of the material from the hopper to the scale. This hopper is connected by spout with the chaff-cutting



Figs. 1023 and 1024. Avery's Automatic Scale for Coal, etc.

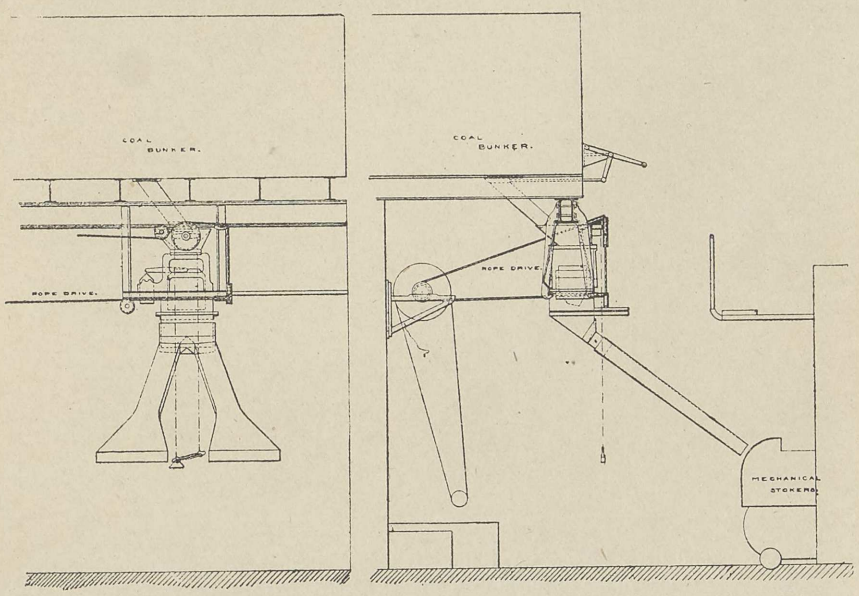
The lettered description for Figs. **1015** and **1016** (Avery's Automatic Grain Scale) applies to this illustration also, with the exception that for weighing small coal the aperture during the dribble period is arranged between a hinged flap F^1 and the valve G. The adjusting screw F^2 is for varying the size of this aperture.

machine. Just below the chaff hopper is a small pulley driven by a belt, which is attached by a spindle to the valves in such a way as to automatically aid in lifting them when required by the machine. Both machines simultaneously discharge into the large hopper below, and right on to the mixer, which consists of a rapidly revolving spindle studded with spikes and driven by a belt as shown. This is to prevent the corn, owing to its greater weight, from falling into the sack quicker than the chaff. The inside of the hopper is fitted with a row of baffle plates which can be so adjusted that the corn discharges into the mixer in a more uniform stream than would otherwise be the case. From this mixer the provender falls into a breeches

piece and thence into either sack as required. These machines are best fitted with glass-panelled covers, which not only obviate any escape of dust, but also prevent any tampering with the mechanism.

Avery's Automatic Scale for Weighing Coal, Coke, Minerals, and Similar Materials.—This weighing machine is very similar to the one for grain already described, and is illustrated in Figs. **1023** and **1024**. A machine with a hopper capacity of 2 cwt. per discharge is usually installed for weighing small coal in connection with bunkers, etc. It is worked by gravity alone and requires no power either electrical or mechanical to operate it. The machine is fitted with locking gear which prevents any coal passing through unweighed.

These automatic coal weighers are chiefly employed in boiler-houses, and the majority of the leading electric power stations at home and abroad are now equipped with these machines. In particular the Glasgow Corporation may be mentioned as



Figs. 1025 and 1026. Method of Employing Avery's Scales in a Boiler-House of the Glasgow Corporation Electricity Department.

among the latest users of the Avery machine; they have installed some forty of them, one of which may be seen in Figs. **1025** and **1026**.

By means of these automatic weighers the mechanical stokers are automatically fed with coal from the bunkers above, and a record is kept of the total consumption of fuel. The machine is supported on brackets bolted to the girders and has a feed hopper above which is connected by spout with the coal bunker. As the coal passes through the scale, its weight is duly recorded; it then falls into the discharge hopper below, and thence into the spouts which feed the stoker hoppers.

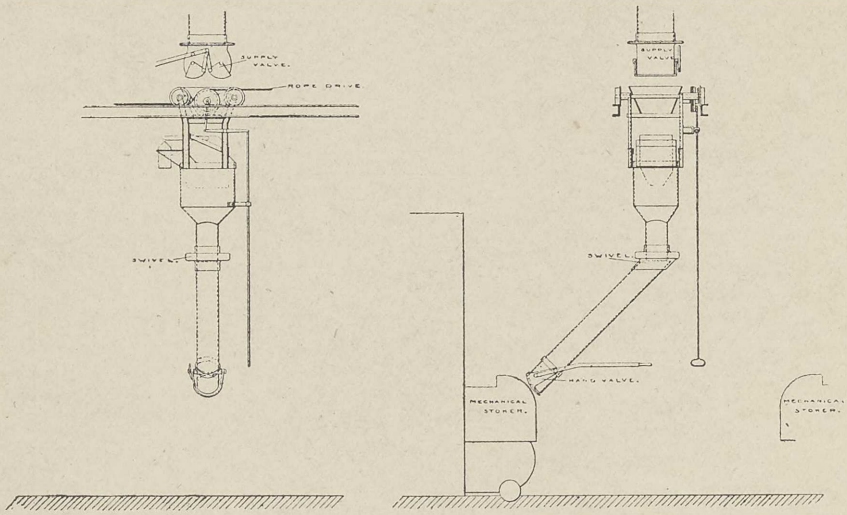
Charge after charge is weighed and delivered to the stoker hoppers until the spouts leading to them are quite full, whereupon the weighing machine stops automatically. As soon, however, as sufficient coal has been used by the stokers to clear the shoot, the weighing machine will recommence work, and in this way always adapts itself to the consumption of coal.

Instead of fixing a machine beneath each coal bunker, another method is to have one large machine fitted on a travelling frame which runs on rails overhead and can be

brought under each bunker as required. The travelling machine is moved along on flanged wheels on a track underneath the bunkers by means of a chain drive actuated from the boiler-house floor. A machine of this type is illustrated in Figs. **1027** and **1028**.

Automatic coal weighers of larger capacity, say half-ton, or one or two tons per discharge, are also supplied for weighing the intake delivered from barges, railway trucks, etc.

The "Simplex" Grain Scale.—This machine is illustrated in front elevation and side view, Figs. **1029** and **1030**. Its mechanism is simple, the working parts are few, and there is not much that is likely to get out of order. A machine weighing 100 lb. at a charge will make about three weighings per minute. It will be seen from the drawing that there is a solid iron ball weight A. In a machine taking charges of 100 lb., this ball will weigh 50 lb., the same as the weight B underneath. The receiving hopper is on the opposite side of the weigh-beam, and when it has received its



Figs. 1027 and 1028. Avery's Portable Weighing Machine, as used at the Boiler House of the Sheffield Corporation Electricity Department.

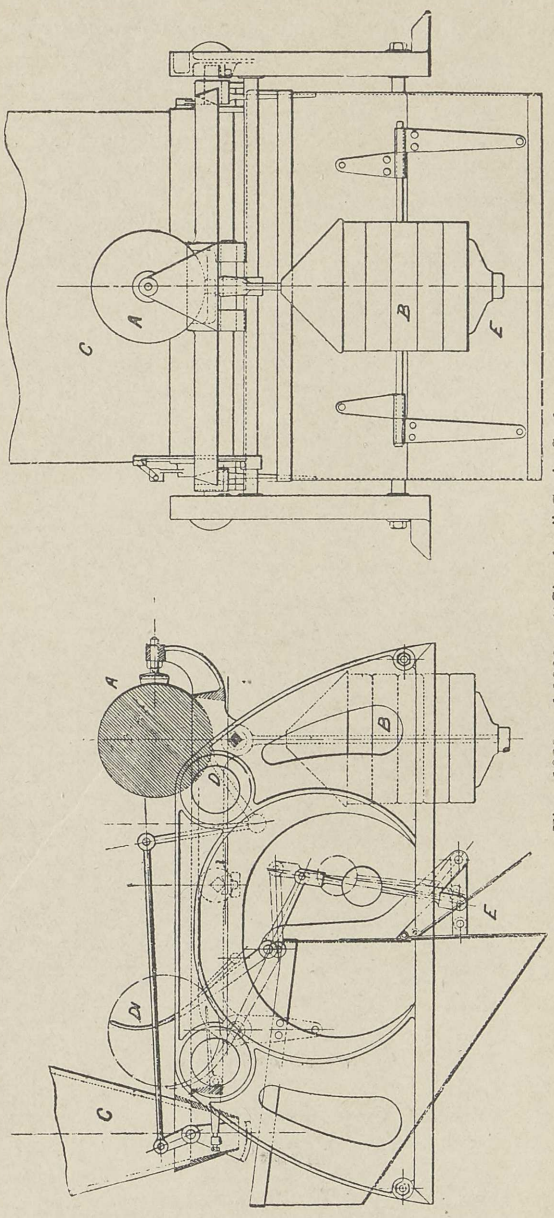
100 lb. of wheat from the feed hopper C, it tilts up the runners on which the ball A rests, and at the instant the ball moves towards the hopper on its runners it comes in contact with a semicircular lever D, which cuts off the supply; while by the time it has reached the hopper it touches another lever D^1, which releases the discharge gate E at the bottom of the hopper and allows the grain to escape. As soon as the skip is empty the runners of the weight tilt up again and the ball begins its return journey. Immediately the ball commences to move in the opposite direction the recipient closes again through the release of a lever D^1, and as soon as the ball reaches the terminus it turns the feed on by means of the first-mentioned lever D.

There is no time wasted between the weighings, but the most remarkable point about the machine is this, that it works altogether noiselessly, there being no clicking and engaging of levers in catches, as is the case with many other weighing machines. The discharge door E is practically locked during the drop of the skip, and as there is no connection between the feed gate and the skip, there should be no danger of the discharge gate getting blocked, as the feed gate cannot open during the discharge on account of the heavy ball not being able to return and open the gate until the grain in the hopper has been removed.

The "Simplex" weighing machine is built in six sizes, the respective machines being for charges weighing from 20 to 100 lb., and the machine occupies a height of only 18 in. to 2 ft.

CONTINUOUS WEIGHING MACHINES

"Blake-Denison" Continuous Weigher.—This machine is so constructed that it will weigh material in the course of being conveyed. Thus a section of the conveyor is also made a portion of the weighing machine. The principle upon which it is constructed is that of weighing the contents of a given length of conveyor at intervals of time corresponding with the travel of such length, and automatically recording such weight. Thus, if the machine is made to weigh 10 ft. of conveyor at a time, it will weigh and record every time 10 ft. has passed, and so every section will be weighed consecutively, with, it is claimed, a maximum error of $\frac{1}{2}$ per cent., and the continuous totalised record can be read as frequently as necessary.



Figs. 1029 and 1030. "Simplex" Grain Scale.

The special features of the weigher are:—

1. A steelyard balanced to suit the unloaded conveyor and arranged to rise accurately in proportion to the load.
2. A gripping device to hold the steelyard fast at suitable intervals.
3. A measuring gauge or quadrant to ascertain the weight indicated by the steelyard when so held.
4. A recording mechanism to show the result.

The section of the conveyor to be weighed is supported on a roller or other suitable device which is suspended from the vertical rod of an ordinary multiple lever platform weighing machine.

To balance the load upon the conveyor as it passes over a roller, the mercurial dashpot is used, the hollow piston of which is suspended from a fixed point on the lever, in place of the usual sliding weights on a graduated lever (see Fig. **1031**).

The dashpot consists of a carefully turned vertical piston, its lower part dipping

into a bath of mercury, and loaded sufficiently to cause it to be submerged some distance in the mercury before the machine is in balance unloaded. It will be seen that when the heavier load comes on the machine the lever rises, and the greater portion of the piston comes out of the mercury until the balance is again established. At the same time a small hole in the hollow piston allows the mercury to escape comparatively slowly. This arrangement acts as a dashpot for steadying the oscillations of the lever when the latter takes up a particular position due to the weight of the length of conveyor and the load on it.

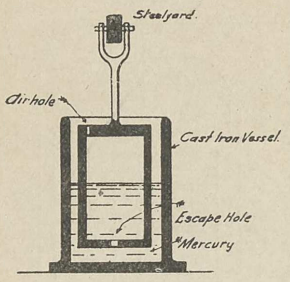


Fig. 1031. Dashpot.

The registering mechanism is shown in Fig. 1032. The cam A causes the levers E to move to the right, and this thrusts the steelyard F of the weighing machine against a surface so roughened as to prevent it from slipping. Another cam then permits the registering quadrant (which is moved to the right by a system of levers actuated by gravity) to move freely to the right, a movement which is only checked by the clamped steelyard F. As the quadrant moves to the right the ten pawls ride over the teeth of the registering wheel. There is a brake on the registering wheel which acts immediately the quadrant is at its left-hand limit. This is to prevent the momentum of the wheel from carrying it on.

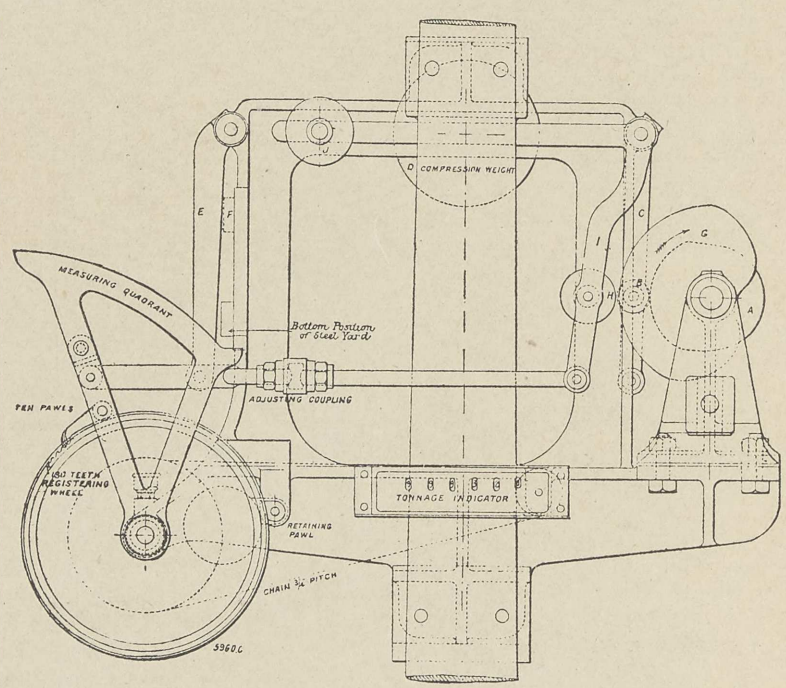


Fig. 1032. Diagram showing Cam and Quadrant Arrangements as used with the "Blake-Denison" Weighing Machine.

The cam G causes the quadrant invariably to move back to the same left-hand limit, the pawls engaging and carrying the registering wheel with the quadrant.

It is therefore evident that the rotation of the registering wheel is dependent upon the extent of the movement of the quadrant to the right. This is determined by the position of the weighing lever, and this again by the weight on the machine. The two

cams A and G are on one shaft, and this is driven by bevel wheels from one of the conveyor terminals.

Each of the ten pawls is one-tenth of the pitch of the teeth of the ratchet wheel in advance of the next to its left. The maximum slip is therefore one-tenth of a tooth. In the latest machines a conical clutch is used instead of the ratchet wheel and pawls; this improvement eliminates all loss of motion and ensures still greater accuracy. In the machines already built the cycle occurs every five seconds, and is as follows: The steelyard is free for about three seconds, during which time it assumes the position proportional to the load upon that section of the conveyor which is supported by the weighing machine. It is then gripped by the action of the first cam, the second cam immediately allowing the measuring quadrant to move forward until it touches the steelyard, where it remains until pushed back by the further motion of its cam; the first cam then releases the steelyard. The weight is recorded by the backward motion of the measuring gauge. There are thus four motions—gripping, measuring, recording, and releasing—which occupy somewhat less than half the time of the whole cycle. It will be readily understood that when the steelyard is at its lowest position it must touch the measuring gauge at its stationary position, as there can be no motion of the latter if the steelyard indicates no load. It has, however, proved impracticable to allow the steelyard to touch the gauge at the lowest position, for two reasons:—

Firstly, it is difficult to adjust the steelyard so accurately that it touches the gauge and yet exercises no pressure upon it.

Secondly, the vibration of the conveyor gearing, etc., sets up oscillations in the steelyard which would allow the gauge to occasionally gather a few pounds and so introduce an error. This difficulty has been overcome by balancing the steelyard at a point somewhere above zero, and then subtracting a corresponding amount of weight each time a weighing takes place.

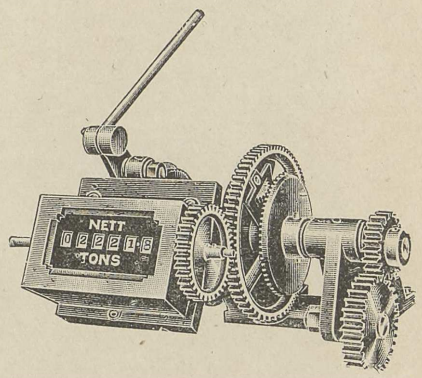


Fig. 1033. Registering Device as used with the "Blake-Denison" Weighing Machine.

Thus, for instance, if the steelyard is so balanced as to remain in a position corresponding to $\frac{1}{2}$ cwt., when there is no load on the conveyor, the measuring gauge will register on its return stroke $\frac{1}{2}$ cwt. each time. But if a device is introduced for deducting $\frac{1}{2}$ cwt. from the register each time, the motions cancel each other, and the register remains unaltered. The device referred to consists of a set of wheels, two of which gear with a pinion carried upon an arm of the wheel driving the counter (see Fig. 1033).

If the two bevel wheels move an equal amount, but in opposite directions, the result will be that the pinion is merely revolving upon its axis. But if one of the wheels moves more than the other, the pinion will be driven forward or backward accordingly, and will carry the registering wheel with it. To the spindle of one of these bevel wheels is attached a ratchet wheel having a suitable number of teeth—where the lever is balanced at $\frac{1}{2}$ cwt. the number would be forty—while a lever and pawl operated from the camshaft drives the ratchet wheel one tooth every cycle, deducting a corresponding amount from the register. The other bevel wheel is driven from the measuring gauge.

The counter or register thus operated records the quantity of material passed over the conveyor during a given period. The measuring gauge or quadrant consists of a vulcanite plate securely fastened to a light steel frame. The frame encloses a finely divided steel ratchet wheel, and carries a set of ten pawls of different lengths engaging

the said wheel. This confines, as has already been remarked, the error due to loss of motion between the pawls and the wheel to one-tenth of a tooth. There is also a set of ten retaining pawls attached to a fixed stud on the body of the machine. The large steel ratchet wheel is keyed upon a spindle connected with the registering counter, while the frame carrying the pawls swings freely upon the boss of the wheels. This frame has a reciprocating motion imparted to it by means of the cam previously described. This machine is built by Messrs Samuel Denison & Son, Ltd., Leeds.

The Merrick Weightometer.—This continuous weighing machine consists of weighing levers and steelyard or beam, similar in principle to those of the usual platform scale, but of such design that a short section or portion of the working strand of the conveyor can be suspended from the weighing levers. Fig. **1034** shows such a machine applied to a portion of a band conveyor, whilst Fig. **1035** gives a diagrammatic sketch of the integrator.

The weight of the load on the suspended portion of the conveyor, regardless of its distribution, is at any instant automatically counterbalanced by the buoyancy of a cylindrical iron float suspended from near the long end of the weighing beam, and

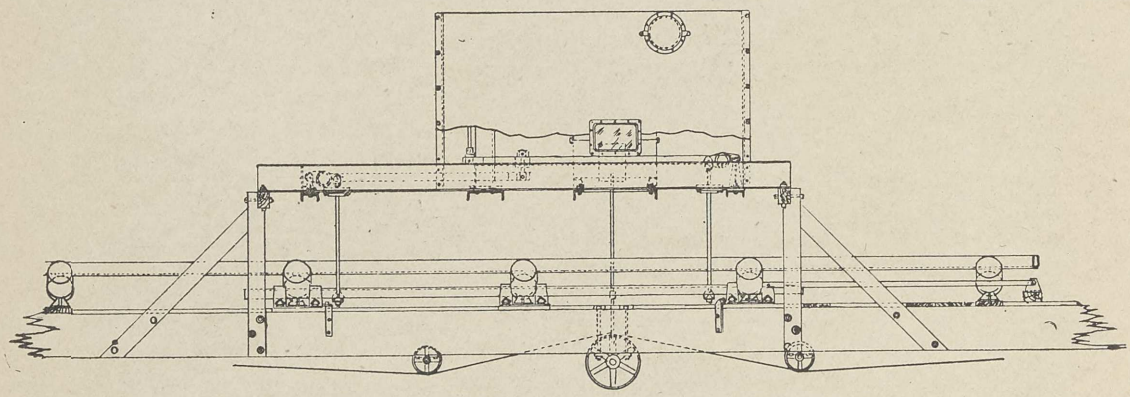


Fig. 1034. The Merrick Weightometer in connection with a Band Conveyor.

partially immersed in a bath of mercury. Any increase or decrease of load on the levers will either raise or lower the float in the mercury until the loss or gain in buoyancy compensates for the variation in load.

The function of this float is to ensure the movement of the beam from its zero position (that is when the conveyor is empty) being proportional to the weight of material at any instant on the suspended portion of the conveyor. The extreme end of the beam is connected with a totalising mechanical integrator, which derives its other factor from the travel of the conveyor by means of suitable gearing from a jockey pulley on the return belt, or a sprocket wheel if on a chain-driven conveyor.

The integrator continuously totalises the product of two quantities, one proportional to the weight of material suspended, and the other to the travel of this material. The result, therefore, represents the total weight of material, and is plainly indicated by a register in units and tenths of units of either ordinary or metric tons.

For cases where the material handled adheres to the conveyor in a varying amount, an attachment is added which automatically counterbalances the variable weight of the empty conveyor. This avoids frequent adjustment to meet the changes in the weight of the empty conveyor and material that may adhere thereto. A magnetic counter can be applied which will duplicate the reading of the scale register in an office or at any other point remote from the scale itself and present the record.

The Integrator.—This consists of an aluminium disc, around the periphery of which are mounted rollers Y free to revolve. These have their axes tangential to the edge of the disc and form practically a continuous annular roller.

The disc X is fixed to a spindle and can revolve in bearings on the frame Z. This frame is mounted with a bearing at either end, so that it can rotate around an axis coincident with the plane of the disc and at right angles to the axis of the disc. On one end of this frame Z is an arm, the extremity of which is connected by a link to the long end of the weigh-beam. Thus any movement of the beam, caused by an increase of the load on the belt, tilts the frame through an angle, the sine of which is proportional to the vertical movement of the float and again proportional to the load on the suspended portion of the conveyor.

Four pulleys U U, Q Q guide a small endless belt W round the disc, and touching the rollers thereon at two points diametrically opposite. Pressure rollers V keep the belt and disc rollers in contact. A weighted take-up pulley T assures an even tension in the belt, and compensates for any stretch. The two pulleys U U are geared together and are driven by mitre gear from a bend or jockey pulley under the return belt. The belt driving the integrator thus travels at a speed proportional to that of the conveyor.

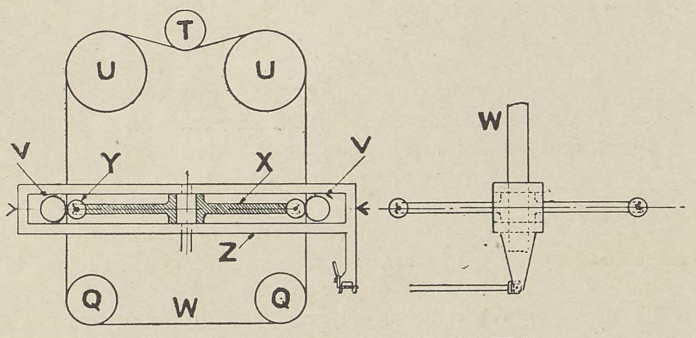


Fig. 1035. Diagram of Integrator of Merrick Weightometer.

So long as the axes of the rollers Y are parallel to the direction of the integrator belt, the motion of the latter will only affect them to the extent of revolving the rollers on their own axes. This condition corresponds with a zero position of the beam, that is, when there is no load on the conveyor. If, however, the beam is deflected by the loading of the belt, the frame Z and disc X will be correspondingly tilted; this will incline the axes of the rollers Y with respect to the integrator belt, then besides rotating them the belt will push the rollers sideways across its face at the rate proportional to their inclination. As the rollers Y cannot slide on the disc X, they will rotate around its axis; consequently the speed of rotation of the disc is proportional to the deflection of the beam, the movement of the float, or the load on the conveyor. The amount of this motion is thus a measure of the weight of material carried by the conveyor during the period of observation. Thus the revolution counter mounted on the disc shaft will record and totalise the weight carried in any units for which the mechanism is designed.

A glance at the disc when the conveyor is running empty will determine whether the dead weight of the idlers, etc., plus the weight of the belt or buckets, is correctly balanced, so that the net weight of the material is recorded. Should the dial remain stationary, or move backward and forward between two constant limits of travel, the adjustment is correct. Should the dial make a plus or minus gain it is not, and the proper balancing is obtained by means of a weight on the steelyard. This weight

is carried on a screw and is similar to that on the ordinary platform scale, as the terminal screw moves the balance weight.

Avery's Patent Automatic Conveyor Weigher and Totaliser.—An adaptation of the weighing mechanism of the Hopper Weighing Machine to a conveyor of the band or similar type is shown in the illustrations, Figs. **1036** and **1037.**

The conveyor passes over the weighing platform, to which two or more of the guide rollers of the conveyor are secured; the length of such platform being dependent

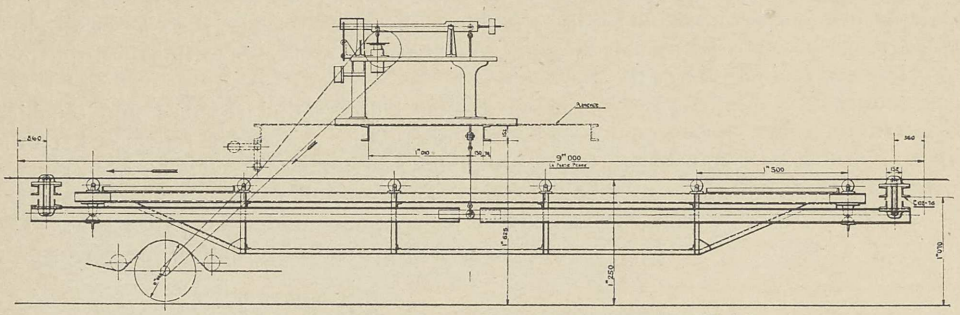


Fig 1036. Side View of Avery's Automatic Conveyor Weigher.

upon the type of conveyor employed and the speed of travel. The apparatus, however, is designed to meet all the usual conditions of speed, etc., with conveyors of the belt, tray, or bucket types, and as the mechanism is operated by a chain drive from the conveyor shaft it automatically adapts itself to speed variations.

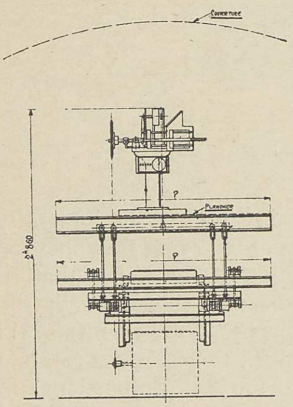


Fig. 1037. End View of Fig. **1036.**

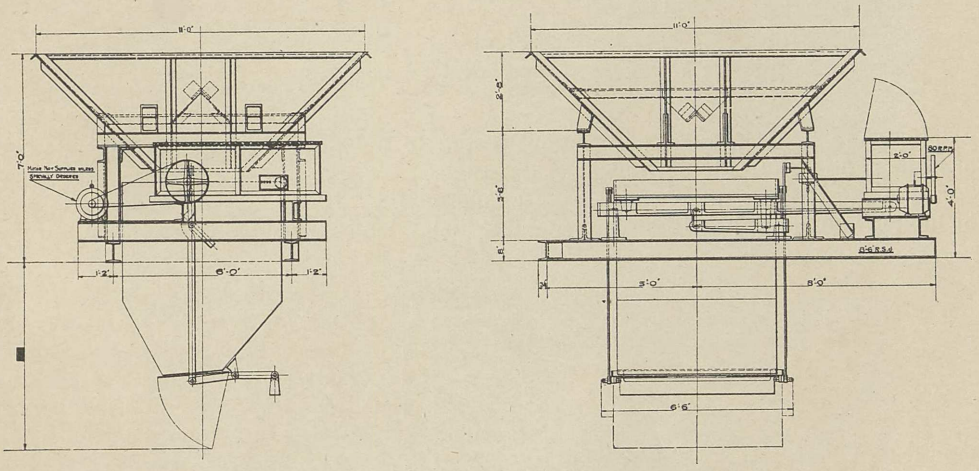
The platform is connected to the steelyard by the usual levers, and as a counterbalance to the load, a plunger carried upon the steelyard dips into a mercury dashpot. When the steelyard has assumed a position corresponding to the load, it is gripped at its extremity by a spring, which is operated by a cam, driven from the main shaft through bevel wheels.

The weight upon the apparatus is represented by the height of the steelyard at its outer extremity, and this is ascertained by a measuring device in the form of a plate shaped to an acute angle and placed at right angles to the steelyard. This plate is pushed out to its full extent at each revolution by a crank, and is brought back to position by a weight suspended from a chain on the one member of a double sprocket, the second member of the sprocket being connected by a chain to the totalling counter, and the weight is registered as soon as the measuring device comes into contact with the steelyard, when the cycle of operations is complete.

INTERMITTENT WEIGHING MACHINES

Avery's Patent Automatic Hopper Weigher and Totaliser (Figs. **1038** and **1039**) consists of the Avery patent totalling mechanism attached to weighing levers which carry a hopper of sufficient capacity to contain the contents of a full grab or skip. The grab or skip discharges directly into a hopper, which is carried upon a rigid framework and supported independently of the machine. This hopper is

constructed so as to take up the shock of the falling coal and to conduct the coal into a second hopper, which is part of the actual weighing machine. As the coal reaches the weighing hopper, the scale automatically begins to work by the immediate rising of the steelyard; and as it rises the poise weight commences to travel forward, and this continues until the weight of it is sufficient (owing to the added leverage it has gained) to overcome the weight of the coal in the weigh hopper, when the steelyard will fall and be in equilibrium. Connected to the poise weight by gearing is a special counter which records and adds together the weight of the coal. As soon as the weighing operation has been completed, the discharging gear comes into action, causing the door of the weigh hopper to open and discharge its contents into the shoot below. When the last piece of coal has left the weigh hopper the door automatically shuts and locks itself, ready for the next weighing, and simultaneously the poise weight upon the steelyard returns to the starting point. No feed valves are required; consequently this machine will weigh any size pieces from nuts to the largest lumps. The power required for operating this machine may be obtained from a small motor of $\frac{1}{2}$ H.P.



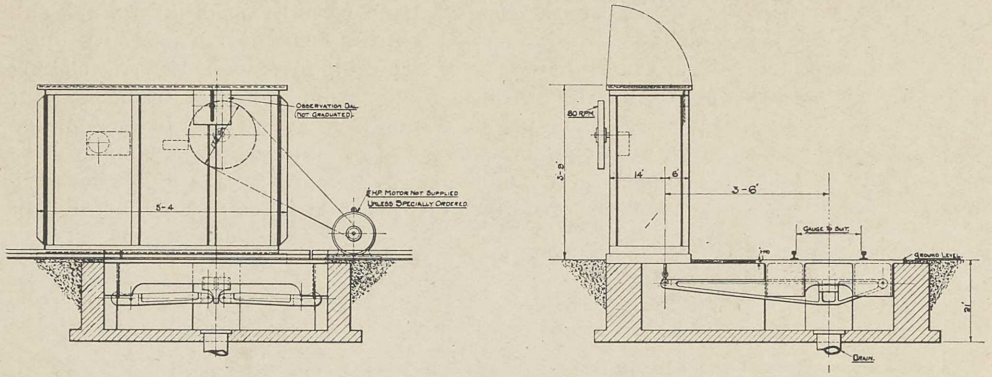
Figs. 1038 and 1039. Avery's Automatic Hopper Weigher.

The figures indicated by the totalling counter are read by the person in charge at the commencement of weighing each barge load, etc., and again at the finish. The difference between the two accounts, of course, represents the sum total of the coal carried by that particular barge or truck.

Avery's Patent Automatic Truck Weighbridge and Totaliser.—This machine is illustrated in Figs. **1040** and **1041**. It automatically weighs all trucks brought on to the platform and registers the weights upon a special counter, so that the total net weight of material passed over the track during any period can be seen at a glance. The number of trucks weighed is also automatically recorded. Only $\frac{1}{4}$ H.P. is required to operate the mechanism. A loaded truck coming upon the weighbridge automatically sets the mechanism in action, while empty trucks or people passing over the platform have no effect upon the records. These machines are built for any size of truck and gauge of rail, and can be fitted with a system of truck controllers which prevents the same truck being weighed twice over. If it is desired to record the weight of each individual load instead of the total weight this machine can also be fitted with printing mechanism. The weighing is then performed automatically as usual, but it is necessary to pull a handle after each weighing in

order to print the weight upon a ticket or roll of paper. The weight thus recorded is determined solely by the machine and is beyond the control of the person who pulls the printing handle.

Avery's Colliery Tub Weighing Machine.—This machine is intended for



Figs. 1040 and 1041. Avery's Automatic Truck Weighbridge.

weighing ore, etc., in tubs, and is constructed to automatically register the number of loads and total up the net weight of the same.

Fig. **1042** gives an illustration of this machine. It has a capacity of 2,500 lb., including 700 lb. tare. It is self-contained, and is entirely constructed of iron, with a

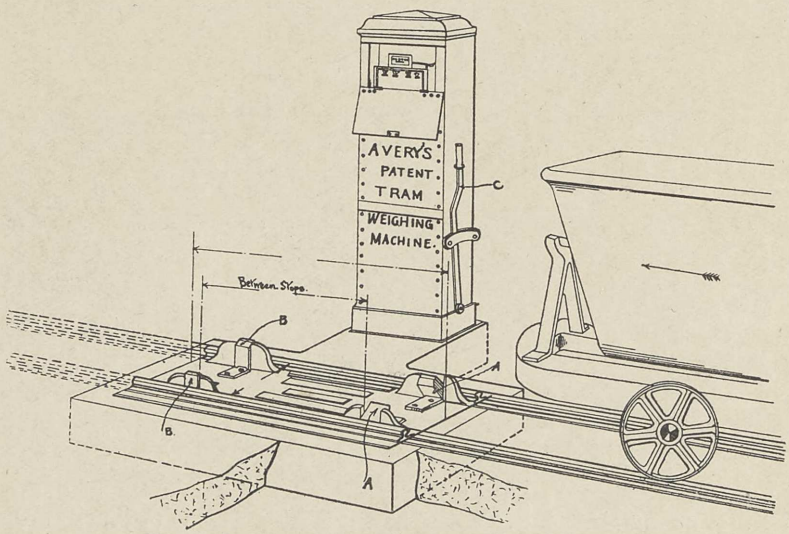


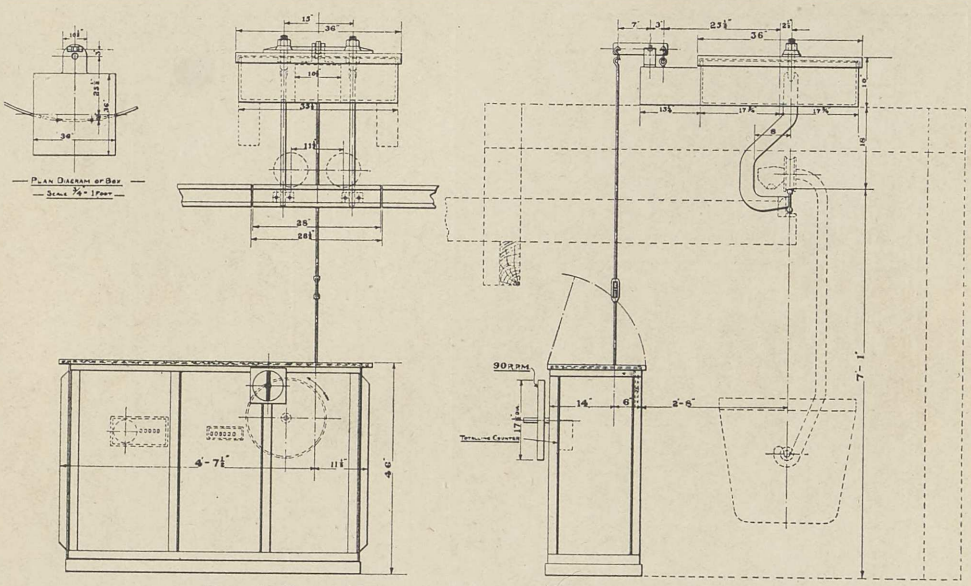
Fig. 1042. Avery's Colliery Tub Weighing Machine.

platform arranged to suit the length of the truck, and fitted with steel rails to a gauge of say 18 in. Movable stops are affixed to the rails to prevent the tubs being moved on or off the machine, the use of which is explained later.

The pillar mechanism is enclosed in a dust-proof wrought-iron case, fitted with doors secured with locks and keys, so that some person in authority may obtain a record of the weighings at any desired time, and have access to the mechanism as often as is

necessary. Attached to the side of the pillar is a wrought-iron hand lever for actuating the movable stops on the rails. Inside the pillar is fitted an automatic self-registering mechanism which will record the total net weighings during twenty-four hours or any other given time, up to 1,000,000 lb., by divisions of 25 lb., the net weight of each load not exceeding 1,800 lb. A counter is also attached to the inside of the pillar to automatically record the number of trucks passed over the machine.

The method of using is as follows: Assuming that the machine is empty, and that the truck coming towards it is in the direction of the arrow, the stops A A being open will allow the truck to come on to the platform until it reaches and is blocked by the stops B B. Before the next truck can come on to the machine, the hand lever must be pushed back, when the operation described above may be repeated. By the mere manipulation of lever C, the attendants can keep an accurate record of the total number



Figs. 1043 and 1044. Avery's Automatic Overhead Weigher.

of weighings, which is, of course, a register of the number of trucks passed over the machine as well as an account of the net weight of each.

All the tubs would, of course, have to be adjusted to a given tare, so that the weighings would be registered as the absolute net weight of the material in the trucks passing over the machine. Should the total weight be likely to exceed 1,000,000 lb. in the given period, the mechanism could be adapted to register 10,000,000 lb. or more if required.

Avery's Patent Automatic Overhead Weigher and Totaliser.—Figs. **1043** and **1044** show a machine very similar to the Automatic Weighbridge described above, but it is designed to suit an overhead track. It can be attached to runways of all descriptions, and is especially suitable for weighing buckets carried by a ropeway. This machine is also fitted with a totalling counter which automatically registers the net weight of material carried; the number of weighed buckets is also recorded.

CHAPTER XLIV

TABLE GIVING WEIGHTS OF VARIOUS MATERIALS

	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
Ashes, coal	44	51	...
Asphalt, solid	156	14·35	...
*Asphalt, broken, loose	120	18·6	...
*Ballast, loose	112	20	...
Barley	39	57·5	50
Barley meal	35	64	45
Basalt, solid	189	11·85	...
*Basalt, broken	170	13	...
Bath stone	123	18·2	...
Beans, horse	50	45	64
Beans, white	47	48	60
Bean meal	43	52	56
Blue Lias, solid	154	14·5	...
*Blue Lias, broken	140	16	...
Bones	50 to 70	32 to 45	...
Bone meal	56	40	...
Bones, calcined	23	95·5	...
Bone charcoal, wet	60	37·33	...
Buck wheat	37	61	47
Castor beans	36	62	46
Cement clinker	100	22·4	...
Cement, fine	120	18·7	...
Cement, Portland	86 to 90	26 to 22·6	...
Cement, Roman	100	22·4	...
Chalk, solid	125 to 150	18 to 15	...
*Chalk, lumps	77	29	...
Clay, solid	80 to 120	28 to 18·5	...
*Clay, stiff, loose	78	28	...
Clay-shale, solid	155	14·45	...
*Clay-shale, broken	93	24	...
Clover seed	47	48	60
*Coal, average mixed broken	50	45	...
Coal, anthracite, solid	95	23·5	..
*Coal, anthracite, loose	53	42·3	...
Coal, bituminous, solid	78	29	...
*Coal, bituminous, loose	50	45	...
Coal, Cannel	79	30	...
*Coal, Cannel, loose	50	45	...
*Coal, Welsh, loose	52	43	...
*Coal, Scotch, loose	53	42	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
*Coal, Newcastle, loose	48·7	46	...
*Coal, Lancashire, loose	48·6	46	...
*Coal, Derbyshire, loose	56·6	48	...
*Coal charcoal, loose	18	124	...
*Coke, broken	30	80	...
Concrete	120	18·7	...
Coprolites	100	22·4	...
Cotton seed	36	62	46
Derby-stone, solid	150	15	...
*Derby-stone, broken	135	16·6	...
Earth, loose, average	78	28·7	...
Earth, mould, average	74	30·2	...
Flax seed	43	52	56
Flour	43	52	56
Flaked maize malt	10	240	12
Granite, solid	165	13·5	...
*Granite, broken	150	15	...
Grass seed	11	48	14
Gravel, average	109	21	...
Gravel, coarse	98	23	...
Graphite	140	16	...
Gypsum, solid	143	15·4	...
*Gypsum, broken	120	18·7	...
Gypsum, plaster of Paris	105	21·25	...
Hemp seed	30	74	44
Horse beans	50	45	64
Ice	58	38	...
*Ice, broken	50	45	...
Indian corn	45	49	58
Indian corn, meal	41	54	53
Iron ore, Clydesdale	190	12	...
Iron ore, brown	236	9·5	...
Iron ore, red	320	7	...
Lias, broken	140	16	...
Limestone, solid	161	20	...
*Limestone, broken	90	25	...
Lime, quick	53	42	...
Linseed	37	61	53
Locust beans	23	97	29
Logwood, fine	18	124·5	...
Maize	45	49	58
Maize meal	41	54	53
Malt	30	74	38
Malt, green	17	131	...
Manure, artificial	56	40	...
Marble, average	169	13·2	...
Marl	79	28	...
Mortar	86	26	...
Mud, dried	95	23·5	...
Mud, damp, pressed	115	19·5	...
Mud, wet, fluid	110	20·5	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

	Lb. per Cubic Foot.	Cubic Feet per Ton.	Lb. per Bushel.
Oats	30	75	40
Oat meal	39	57·5	50
Ore, pulverised, average	220	10	...
Oxide of iron	55	40	...
Paper (wet) as from revolving drums used for making paper boards	57	38·9	...
Peas	50	45	64
Pea meal	43	52	56
Peat, dry	11	200	...
Phosphate	100	22·22	...
Phosphate meal	110	20	...
Pitch	60	37	...
Plaster	98	23	...
Plaster of Paris	105	21·25	...
Plumbago	140	16	...
Portland cement	86 to 90	26 to 22·6	...
Portland stone	150	15	...
*Portland stone, broken	142	15·8	...
Potatoes	47	48	60
Quartz	150	15	...
*Quartz, broken	142	15·8	...
Quartz sand	170	13	...
Quick lime	53	42	...
Rape seed	36	61	40
Rye	41	55	53
Salt, rock, solid	131	17	...
Salt, dried	56	40	...
Salt, cake	70	32	...
Salt, fine	42	52	56
Salt, coarse	45	50	...
Sand, river	117	19	...
Sand, pit, fine	95	23·5	...
Sand, pit, coarse	100	22·5	...
Sand, moulding	77	29	...
Sandstone, solid	150	15	...
*Sandstone, broken	140	16	...
Shingle	88	24·5	...
Slate	157	14·2	...
Snow, fresh fallen	6	380	...
Sugar, lump	60	37·5	...
Sugar, crystal	56	40	...
Sugar, fine	55	40·7	...
Sugar, brown	56	40	...
Timothy seed	35	63	45
Turnips	43	52	55
Water, fresh	62·42	35·88	...
Water, sea	64	35	...
Wheat	47	48	60
Yorkshire stone	154	14·5	...
*Yorkshire stone, broken	142	15·9	...

* The weights of these materials are only approximate, and vary greatly with the size of the pieces.

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APPENDIX

TRADE DIRECTORY

Of Firms of Repute who are Makers of the different Machines for the Mechanical Handling and Storing of Material

Classified under Heads corresponding with the Chapters of the Book

ELEVATORS

Allen, Edgar, & Co., Ltd., Imperial Steel Works, Tinsley, Sheffield.
Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Chain-Belt Engineering Co., Colombo Street, Derby.
Conveyor & Elevator Co., Accrington.
Drakes, Ltd., Halifax, Yorks.
Jeffrey Manufacturing Co., Columbus, Ohio, U.S.A.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Robinson, Thomas, & Son, Ltd., Rochdale.
Rose, Downs, & Thompson, Ltd., Old Foundry, Hull.
Sheppard & Sons, Ltd., The New Foundry, Bridgend, Glam.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
Spencer & Co., Ltd., Melksham, Wilts.
Turner, E. R. & F., Ltd., Ipswich.
Wilkins Wire Rope Co., Ltd., Eastwood, Notts.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

WORM CONVEYORS

Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Conveyor & Elevator Co., Accrington.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
Turner, E. R. & F., Ltd., Ipswich.

PUSH-PLATE OR SCRAPER CONVEYORS

Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Chain-Belt Engineering Co., Colombo Street, Derby.
Conveyor & Elevator Co., Accrington.
Drakes, Ltd., Halifax, Yorks.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.

BAND CONVEYORS

Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
British Ropeway Engineering Co., Ltd., 34 Fenchurch Street, London, E.C.
Chain-Belt Engineering Co., Colombo Street, Derby.
Cowans, Sheldon, & Co., Ltd., St Nicholas Works, Carlisle.
Denison, Saml., & Son, Ltd., Hunslet Foundry, Leeds.
Drakes, Ltd., Halifax, Yorks.
Fraser & Chalmers, Ltd., 3 London Wall Buildings, London, E.C.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Nortons (Tividale), Ltd., Hecla Works, Tipton, Staffs.
Rose, Downs, & Thompson, Ltd., Old Foundry, Hull.
Sandvikens Jernverks Aktiebolag, Sandviken, Sweden.
Sheppard & Sons, Ltd., The New Foundry, Bridgend, Glam.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
Spencer & Co., Ltd., Melksham, Wilts.
Sutcliffe, R., Universal Conveyor Works, Horbury, Wakefield.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

STEEL-PLATE CONVEYORS AND PICKING BELTS

Allen, Edgar, & Co., Ltd., Imperial Steel Works, Tinsley, Sheffield.
Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Chain-Belt Engineering Co., Colombo Street, Derby.
Jeffrey Manufacturing Co., Columbus, Ohio, U.S.A.
Sandvikens Jernverks Aktiebolag, Sandviken, Sweden.

SLAT CONVEYORS

Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Chain-Belt Engineering Co., Colombo Street, Derby.
Conveyor & Elevator Co., Accrington.

VIBRATING OR RECIPROCATING TROUGH CONVEYORS

Marcus, Hermann, Gereonshaus, Cöln, Germany.
Nortons (Tividale), Ltd., Hecla Works, Tipton, Staffs.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

GRAVITY BUCKET CONVEYORS

Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Drakes, Ltd., Halifax, Yorks.

Jeffrey Manufacturing Co., Columbus, Ohio, U.S.A.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Spencer & Co., Ltd., Melksham, Wilts.
West's Gas Improvement Co., Ltd., Albion Ironworks, Miles Platting, Manchester.

CASTING MACHINES

Samuelson, Sir B., & Co., Ltd., Newport Iron Works, Middlesbrough.

COKE CONVEYORS FOR GASWORKS

Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
Drakes, Ltd., Halifax, Yorks.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Strachan & Henshaw, Ltd., Whitehall Iron Works, Whitehall, Bristol.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

COAL FACE CONVEYORS

Korfmann, Heinr., jr., Maschinenfabrik, Witten a. d. Ruhr, Germany.
Sutcliffe, R., Universal Conveyor Works, Horbury, Wakefield.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

SPIRAL GRAVITY SHOOTS

Morton, Francis, jr., & Co., 110 Cannon Street, London, E.C.
Simon, Richard, & Sons, Ltd., Phœnix Works, Basford, Nottingham.

ROLLER RUNWAYS

Chain-Belt Engineering Co., Colombo Street, Derby.
Morton, Francis, jr., & Co., 110 Cannon Street, London, E.C.

PNEUMATIC ELEVATORS AND CONVEYORS

Robinson, Thomas, & Son, Ltd., Rochdale.
Seck Engineering Co., Ltd., 79-81 Mansell Street, London, E.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
Spencer & Co., Ltd., Melksham, Wilts.

ENDLESS ROPE AND CHAIN HAULAGE

Bagshawe & Co., Ltd., Dunstable Works, Dunstable.
Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
British Ropeway Engineering Co., Ltd., 34 Fenchurch Street, London, E.C.
Bullivant & Co., Ltd., 72 Mark Lane, London, E.C.
Wilkins Wire Rope Co., Ltd., Eastwood, Notts.

ROPEWAYS AND AERIAL CABLEWAYS

Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
British Ropeway Engineering Co., Ltd., 34 Fenchurch Street, London, E.C.
Bullivant & Co., Ltd., 72 Mark Lane, London, E.C.
Lidgerwood Manufacturing Co., Caxton House, Westminster, London, S.W.
Pohlig, J., A.-G., Cöln-Zollstock, Germany.
Ropeways, Ltd., Eldon Street House, South Place, London, E.C.
Wilkins Wire Rope Co., Ltd., Eastwood, Notts.

COALING VESSELS AT SEA

Denison, Saml., & Son, Ltd., Hunslet Foundry, Leeds.
Lidgerwood Manufacturing Co., Caxton House, Westminster, London, S.W.

MONO-RAILS AND TELPHERS

Arrol, Sir Wm., & Co., Ltd., Dalmarnock Ironworks, Glasgow.
Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
Denison, Saml., & Son, Ltd., Hunslet Foundry, Leeds.
Fraser & Chalmers, Ltd., 3 London Wall Buildings, London, E.C.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.
Pohlig, J., A.-G., Cöln-Zollstock, Germany.
Strachan & Henshaw, Ltd., Whitehall Iron Works, Whitehall, Bristol.

BLAST-FURNACE HOISTS

Brown Hoisting Machinery Co., Cleveland, Ohio, U.S.A.
Pohlig, J., A.-G., Cöln-Zollstock, Germany.

HANDLING OF COKE FROM COKE OVENS

Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.

SKIPS AND GRABS

Arrol, Sir Wm., & Co., Ltd., Dalmarnock Ironworks, Glasgow.
Pohlig, J., A.-G., Cöln-Zollstock, Germany.
Priestman Bros., Ltd., Holderness Foundry, Hull.
Rose, Downs, & Thomson, Ltd., Old Foundry, Hull.
Taylor & Hubbard, Kent Street Works, Leicester.

BARGE ELEVATORS OR MARINE LEGS

Armstrong, Whitworth, & Co., Ltd., Sir W. G., 8 Great George Street, Westminster, London, S.W., and Elswick Works, Newcastle-upon-Tyne.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
West's Gas Improvement Co., Ltd., Albion Ironworks, Miles Platting, Manchester.

SELF-UNLOADING RAILWAY TRUCKS

Leeds Forge Co., Ltd., Caxton House, Westminster, London, S.W.
Lidgerwood Manufacturing Co., Caxton House, Westminster, London, S.W.
Metropolitan Carriage, Wagon, & Finance Co., Ltd., Saltley, Birmingham.

COAL TIPS OR HOISTS

Armstrong, Whitworth, & Co., Ltd., Sir W. G., 8 Great George Street, Westminster, London, S.W., and Elswick Works, Newcastle-upon-Tyne.
Cowans, Sheldon, & Co., Ltd., St Nicholas Works, Carlisle.
Sheppard & Sons, Ltd., The New Foundry, Bridgend, Glam.

COLLIERY TIPS OR TIPPLERS

Allen, Edgar, & Co., Ltd., Imperial Steel Works, Tinsley, Sheffield.
Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Nortons (Tividale), Ltd., Hecla Works, Tipton, Staffs.

COAL SHIPPERS

Cowans, Sheldon, & Co., Ltd., St Nicholas Works, Carlisle.
Fraser & Chalmers, Ltd., 3 London Wall Buildings, London, E.C.
Spencer & Co., Ltd., Melksham, Wilts.
Sutcliffe, R., Universal Conveyor Works, Horbury, Wakefield.

MISCELLANEOUS LOADING AND UNLOADING DEVICES

Armstrong, Whitworth, & Co., Ltd., Sir W. G., 8 Great George Street, Westminster, London, S.W., and Elswick Works, Newcastle-upon-Tyne.
Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Bleichert's Aerial Transporters, Ltd., Egypt House, 36 New Broad Street, London, E.C.
Spencer & Co., Ltd., Melksham, Wilts.

COALING OF RAILWAY ENGINES

Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Fraser & Chalmers, Ltd., 3 London Wall Buildings, London, E.C.

COAL, COKE, AND ASH HANDLING PLANTS FOR BOILER-HOUSES, GASWORKS, ETC.

Arrol, Sir Wm., & Co., Ltd., Dalmarnock Ironworks, Glasgow.
Babcock & Wilcox, Ltd., Oriel House, Farringdon Street, London, E.C.
Chain-Belt Engineering Co., Colombo Street, Derby.
Drakes, Ltd., Halifax, Yorks.
Jenkins, W. J., & Co., Ltd., Beehive Works, Retford, Notts.
New Conveyor Co., Ltd., Smethwick, near Birmingham.
Seck Engineering Co., Ltd., 79-81 Mansell Street, London, E.
Spencer & Co., Ltd., Melksham, Wilts.

Strachan & Henshaw, Ltd., Whitehall Iron Works, Whitehall, Bristol.
Taylor & Hubbard, Kent Street Works, Leicester.
West's Gas Improvement Co., Ltd., Albion Ironworks, Miles Platting, Manchester.
Zimmer Conveyor Co., 82 Mark Lane, London, E.C.

STORING OF COAL IN STOCK HEAPS AND SILOS

Ropeways, Ltd., Eldon Street House, South Place, London, E.C.
Spencer & Co., Ltd., Melksham, Wilts.
Taylor & Hubbard, Kent Street Works, Leicester.

GRAIN SILOS AND GRANARIES

Robinson, Thomas, & Son, Ltd., Rochdale.
Seck Engineering Co., Ltd., 79-81 Mansell Street, London, E.
Simon, Henry, Ltd., 20 Mount Street, Manchester.
Spencer & Co., Ltd., Melksham, Wilts.
Turner, E. R. & F., Ltd., Ipswich.

AUTOMATIC WEIGHING OF MATERIAL

Avery, W. & T., Ltd., Soho Foundry, Birmingham.
Libra Scale Co., Greek Street Chambers, Leeds.
Simon, Richard, & Sons, Ltd., Phœnix Works, Basford, Nottingham.

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