WATER LIFTED By COMPRESSED AIR

CATALOG No. 73

THE INGERSOLL-SERGEANT DRILL COMPANY

First Edition

Form 73

1905

Water Lifted

BY

Compressed Air

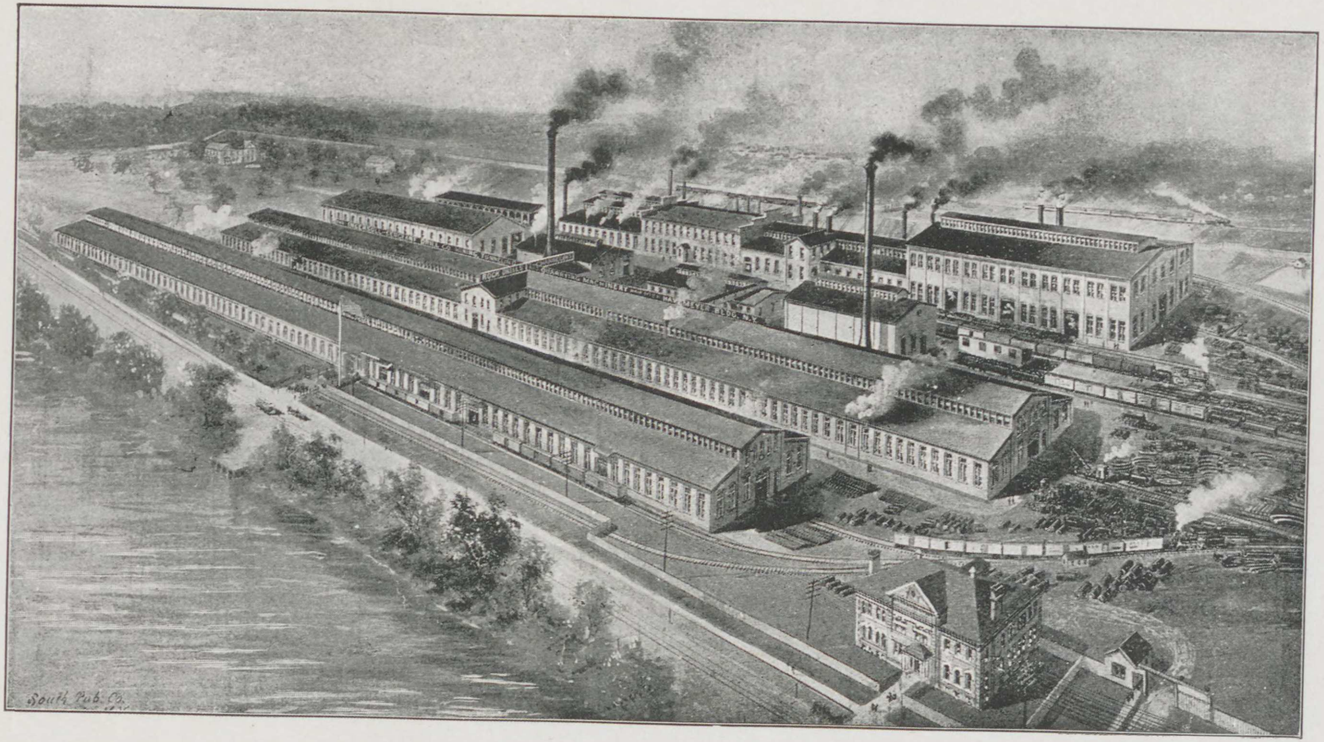
FOR

Municipal, Manufacturing, Irrigation or Other Water Supply

THE

INGERSOLL-SERGEANT

DRILL CO.



Works of the Ingersoll-Sergeant Drill Co., at Easton, Pa.

THE INGERSOLL-SERGEANT DRILL CO.

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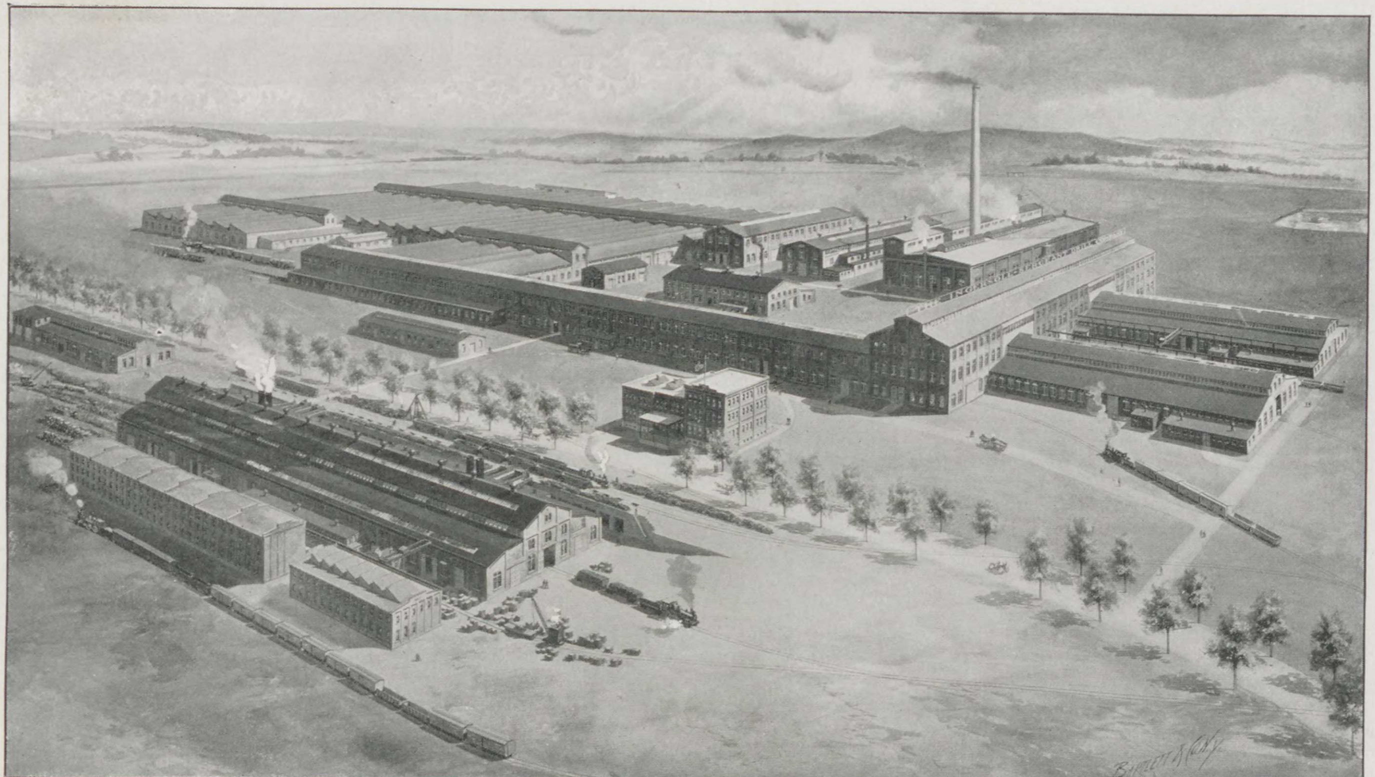


Works of the Ingersoll-Sergeant Drill Co., at Phillipsburg, N. J.

THIS catalog serves to convey a general idea of the possibilities of compressed air for pumping water, and to outline the general conditions to be met. The Ingersoll-Sergeant Drill Company will gladly make suggestions as to the requirements of your particular case if you will fill out one of the question blanks at the back of this catalog and send it to the nearest office of the company.

Air Lift at Fort Madison (Iowa) Water Works.

THE "AIR LIFT" SYSTEM.

DURING recent years much progress has been made in the art of pumping water by compressed air. The Ingersoll-Sergeant Drill Company has done pioneer work in this line, having been the first to employ Dr. Julius J. Pohlé, who is acknowledged to be the original inventor of the "Air Lift." At first all systems for lifting water or liquids by compressed air were admitted to be extravagant, but with a large experience now behind us, and with marked improvements in air compressor economy, the Air Lift has made valuable strides. We have found that a properly installed Air Lift System requires the attention of the engineer, who should, in the first place, specify a suitable compressor provided with automatic attachments, and he should design the air and water pipes to accomplish the best results. Each case should be treated by itself, and advice given in accordance with the conditions that exist in each well to be pumped. We have an experienced corps of engineers, and are prepared to furnish specifications and advice free of charge.

Patents.

The Ingersoll-Sergeant Drill Company owns all right, title and interest in the Pohlé Air Lift patents. These patents are broad and protective, covering the most economical means by which water is lifted from wells by compressed air. There are many systems in use, but those familiar with the subject admit that the "Pohlé System" stands supreme in its simplicity and economy. The "Pohlé" patents cover broadly many other systems, and persons are hereby advised that, in using any system which infringes the patents owned by this company, they are doing so at their own risk.

Air Lift Pumping.

WATER SUPPLY FOR PUBLIC USE.

With the decrease in surface water supply, due to cutting down the forests and meteorological changes, the population has increased enormously, cities have grown together, the country population has become more dense, and the danger of pollution of surface streams of water has increased a hundred-fold. As the years go on, and population and industries multiply, the question will become a more and more important one.

Filtered Water Expensive.

Filtration has not proved as successful as some of its enthusiastic promoters had hoped. Such plants usually cost many times over the expense of a good artesian supply. In one of the finest interior cities, using about twenty million gallons, it was found that, everything figured in, filtered water delivered to the user actually costs four to five times as much as would an Air Lift supply.

Artesian or Well Supply.

Many of our interior sections must depend upon well water, and there are few districts where an ample supply is not to be secured from wells properly made. This water is generally pure and wholesome. It is also of uniform temperature the year round—cool and pleasant in the summer, because the underground pipe and soil temperature remain uniformly low. In winter, well water, being warmer than that taken from lakes and rivers, is not so apt to freeze, and, from all considerations of temperature and purity, well water is greatly to be preferred. Many cities located on rivers having a gravel bed formation find that, by placing wells of suitable construction far enough back from the bank, there is a natural filter bed, leaving the water perfectly clear, even when the river itself is chronically muddy. When river or other surface water is good the wells may be drilled close to the edge, the water flowing down from the top of the wells.

Even when the supply near the surface is either scanty or unsafe, it is usually possible to sink driven wells to greater depths, thus "casing off" all suspected water and drawing only from deeper rock or gravel veins removed from all danger of surface contamination. The natural head from lower veins often maintains the water near the surface so that power only need be expended for moderate lifts.

There are not many underground formations where wells should be located close together. Such wells may affect or rob each other, and it is usually best to spread them out on a line across what is known to be the underground flow. Some finely creviced or tight rock formations have a strong head with but little capacity, and wells in such formations, if pumped hard, yield but little additional water.

Air Lift Plant of the Schmulbach Brewing Co., Wheeling, W. Va.

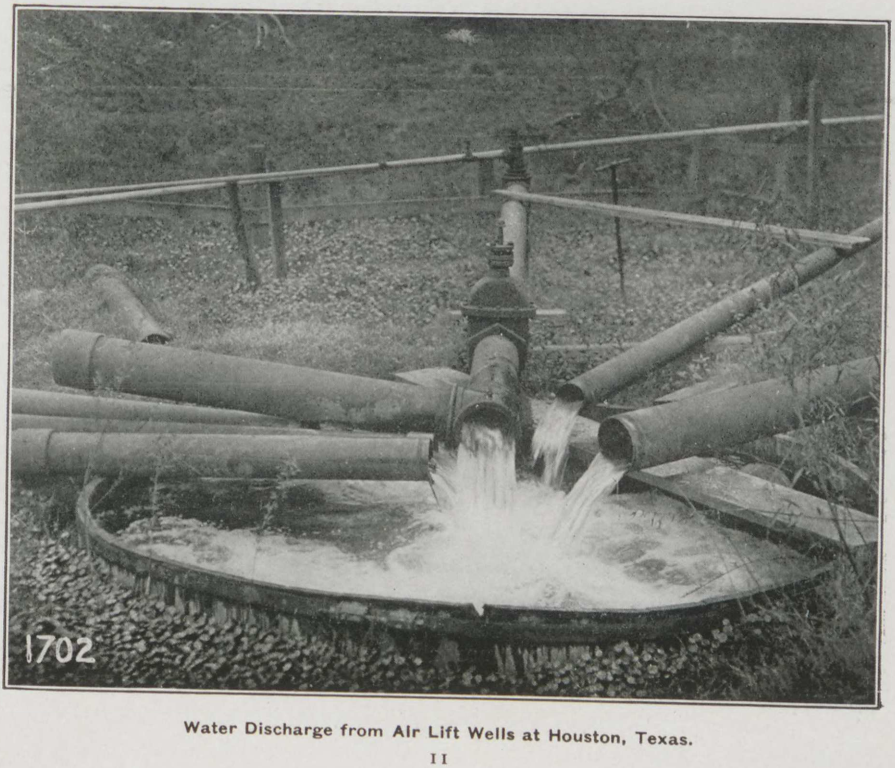
The tank shown is close to the well and of such height that the water flows by gravity to the Brewery, some distance away.

They should be scattered and pumped moderately, maintaining a low and economical lift. In other cases, one well in a group will give as much water as all together, and more territory must be drawn on. This introduces difficulties in detached pumping units and labor cost, which are well met with the Air Lift, as an economical central air compressor can be put in at the main pumping station and operated by the usual engineering force and the air piped to any distance or in different directions, and to **any number of wells, no matter how scattered.** In this way the entire corporation area is available for a supply. Air transmission is safe and clean; it is simple and easily controlled. There is little or no wear, and, once adjusted, the wells need no attention for years, the control resting in the speed maintained at the central station.

Uses for the Air Lift.

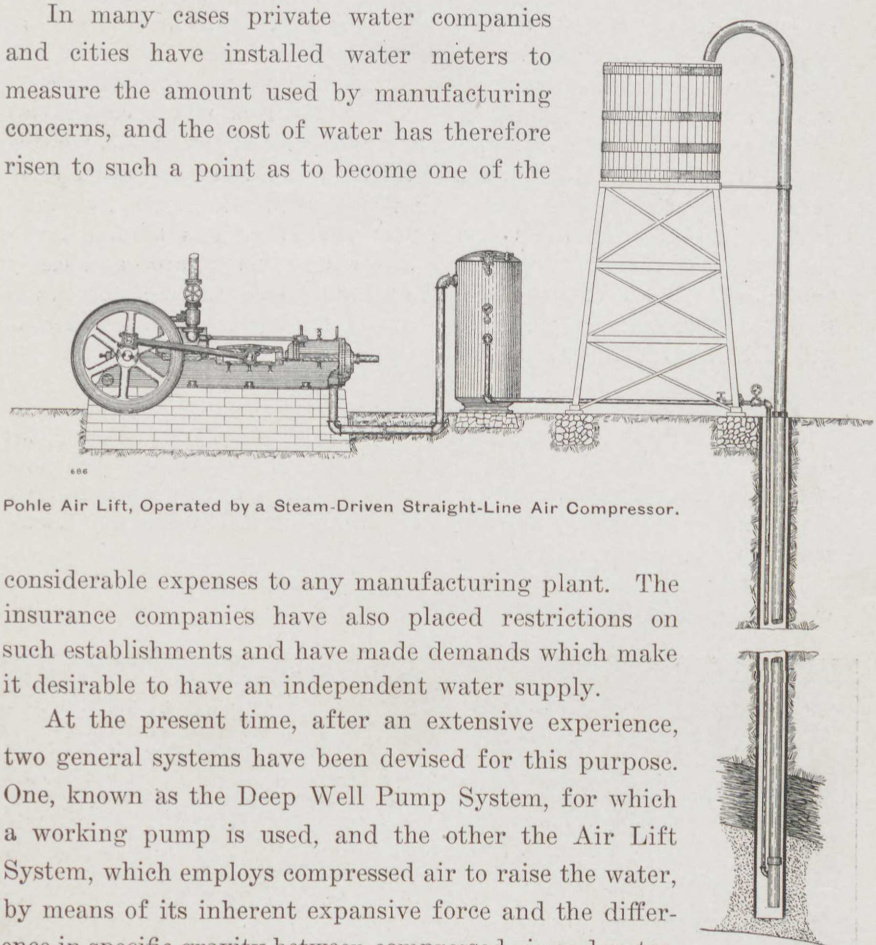
City and town water works, asylums and hospitals, plantations, railway water tanks, irrigation, private country houses, pumping mines, ice manufactories, breweries, cold storage and packing houses, textile mills, dye works, bleacheries, sewerage installations, dry docks, seaside water works, stock farms, etc.

In fact, anywhere and everywhere that clear and abundant water is needed.



Water Discharge from Air Lift Wells at Houston, Texas.

In many cases private water companies and cities have installed water meters to measure the amount used by manufacturing concerns, and the cost of water has therefore risen to such a point as to become one of the



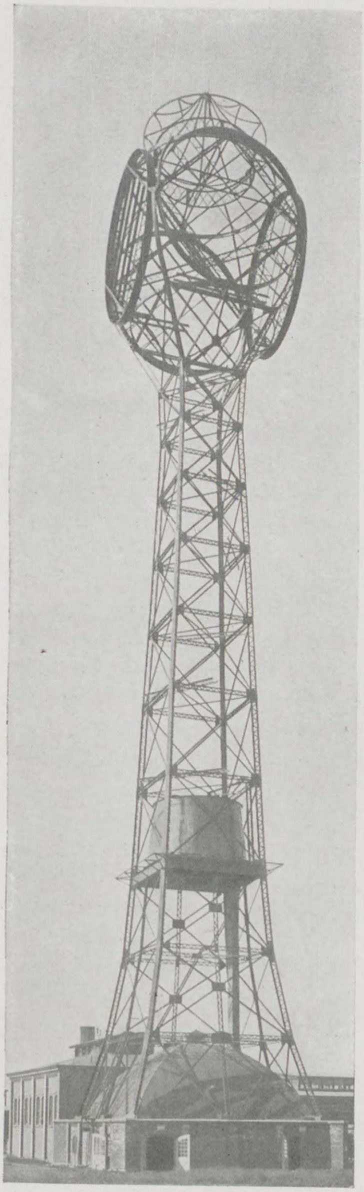
Pohle Air Lift, Operated by a Steam-Driven Straight-Line Air Compressor.

considerable expenses to any manufacturing plant. The insurance companies have also placed restrictions on such establishments and have made demands which make it desirable to have an independent water supply.

At the present time, after an extensive experience, two general systems have been devised for this purpose. One, known as the Deep Well Pump System, for which a working pump is used, and the other the Air Lift System, which employs compressed air to raise the water, by means of its inherent expansive force and the difference in specific gravity between compressed air and water.

The Equipment Required.

The Air Lift involves the use of an air compressor, located where the expense of attendance is least; an air receiver adjacent to this compressor; a pipe line for conveying the air from the receiver to the wells; one or more wells drilled to a depth proportionate to the height of the lift and the depth of the water strata below the surface; air and water pipes running down inside of these wells, about one-half their vertical length being submerged when at work, representing the pumping apparatus proper.



Air Lift of the John Stephenson Co., Car Builders, Elizabethport, N. J.

No Complication.

After thorough trials had been made with the many forms of "adjustable foot pieces," "regulating nozzles," etc., that some have so greatly favored, we have found that all such devices are useless, as they add much to the complication and nothing to the efficiency of the Air Lift. We have found several instances where people had been induced to put devices of this sort into their wells, and had the pleasure of pulling up the piping to remove them, as they had become stuck or stopped up with rust and sand. It is unreasonable to expect working parts that fit closely to remain in working order when exposed to the action of a mixture of water, compressed air containing oxygen, and sand.

Special Combinations.

Special combinations are sometimes made, an example being the engine constructed for the water works at Ocean Grove, N. J., from designs made by Mr. E. K. Conover, and installed in 1894.

This outfit consists of a duplex Corliss condensing engine with two Ingersoll-Sergeant air cylinders and two Conover water cylinders arranged tandem behind the steam cylinders. The compressor operates 20 driven wells, raising the water to a tank at the surface, into which dips the suction pipe of the pump cylinders, which in turn force the water to a standpipe for storage and service pressure. By the installation of this outfit the supply of water has been doubled and the fuel consumption cut in half. Other economies were effected so that a most gratifying saving resulted. Compared with a separate compressor and water pump this combination outfit has much to recommend it to the attention of water works engineers.

THEORY OF THE AIR LIFT.

Opinions differ as to the true theory of the Air Lift. A common Air Lift case is one where we have a driven well in which the water has risen approximately near the surface. We place in this well a large pipe for the discharge of the water. This is known as an " eduction pipe." This pipe does not touch the bottom of the well, but is elevated above it so as to freely admit the water through its lower open end. Alongside of this pipe, either on the outside or within, is a small pipe properly proportioned and intended to convey compressed air to a point near the bottom of the eduction pipe. It is usual to provide what is called a "foot-piece," which forms the nozzle connecting the air pipe with the water pipe, but in what is known as the "central pipe system" this foot-piece is not used, the air pipe being placed within the eduction pipe to a point near the bottom, where it discharges the compressed air into the water column.

The air pipe is connected with an air receiver on the surface, which is in or near the engine room, in which there is an air compressor. This air pipe is provided with a valve on the surface. Before turning on the air the conditions in the well show water at the same level on the outside and inside of the eduction pipe. At the first operation we must have sufficient air pressure to discharge the column of water which stands in the eduction pipe. This goes out *en masse,* after which the pump assumes a normal condition, the air pressure being lowered and standing at such a point as corresponds with the normal conditions in the well. This is determined by the volume of water which the well will yield in a certain time and the elevation to which the water is discharged. Here comes in the value of experience in laying out the pipes, which should be proportioned to meet normal conditions.

The Frizell System or Lifting by Bubbles.

It was at first supposed that in all air lift cases the water was discharged because of the aeration of the water in the eduction pipe, due to the intimate comingling of air and water. Bubbles of air rising in a water column not only have a tendency to carry particles of water with the air, but the column is made lighter, and, with a submergence or weight of water on the outside of the eduction pipe, there would naturally be a constant discharge of air and water. This is known as the Frizell System, and where the lifts are moderate—that is, where the water in the well reaches a point near the surface—it is very likely that the discharge is due to simple aeration.

Piston-Like Layers.

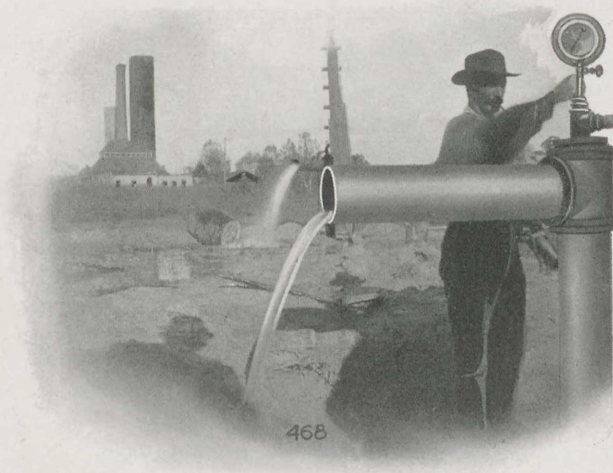
Most air lift propositions are deep well cases—that is, the water is lifted a distance greater than 25 feet; and just in proportion as the lift is increased do we get away from the aerated form idea and reach the Pohlé System of piston-like layers. To understand the distinction and the importance of proper pipe proportions let us take an exaggerated case, where we have a lift of, say, 100 feet and a diameter of eduction pipe of 12 feet. Such a case as this is impracticable, and no matter how much air is discharged into this pipe it is likely to rise in the shape of bubbles, some of them larger than others, because as they ascend they cohere; but piston-like layers can only be formed in so large a pipe as this under conditions where there is a sufficient head or height of discharge and an enormous volume of water. In other words, the volume of water admitted to this pipe of large diameter must be sufficient to keep pace with the large volume of air admitted.

The economy of the Air Lift System is in direct proportion to the capacity of the well to form piston-like layers, and the reason why these layers are formed is that after the first discharge there is kept up a constant struggle between the air under pressure and the head of water on the outside of the pipe, each one seeking to enter the lower end of the eduction pipe. When the air pressure is greater than the head of water a certain volume of compressed air is admitted into the eduction pipe. The water in this pipe is at that time moving rapidly upward; that is, its momentum has been established. Hence the air takes up this velocity and goes upward with the water. If a sufficient quantity of air has been admitted in proportion to the diameter of the pipe, and if there is a sufficient pressure in this pipe to prevent the free discharge of the air, we can see how readily this bubble of air spreads itself across the diameter of the pipe in a piston-like condition. The reason why this air piston is not elongated and continuous is that the free discharge of the air, aided by the velocity with which everything in the eduction pipe is moving, causes a fall in the air pressure just sufficient to allow the head of water to press the water into the air space from the open end of the eduction pipe. In other words, as the air pressure is slightly lowered, the water pressure, which was nearly equal to the air pressure, becomes a little greater and a piston-like layer of water enters the pipe, shutting off the air. This "chunk" of water rises in the eduction pipe with velocity equal to that of the air, and, as it has plugged off the air nozzle, there is a momentary rest, during which the air has a chance to accumulate greater pressure, and just as soon as its pressure overcomes that of the water the conditions are reversed and another "chunk" of compressed air is discharged into the pipe, shutting off the water for an instant. This process is continuous and as regular as the movement of a pendulum.

As these "chunks" of air approach the surface they are gradually enlarged, because of the reduced load upon them, and it is likely that before they reach the surface there is a general breaking up of the piston-like layer conditions; but it is important that each plant should be installed with the idea of maintaining the piston-like layers as far as may be possible.

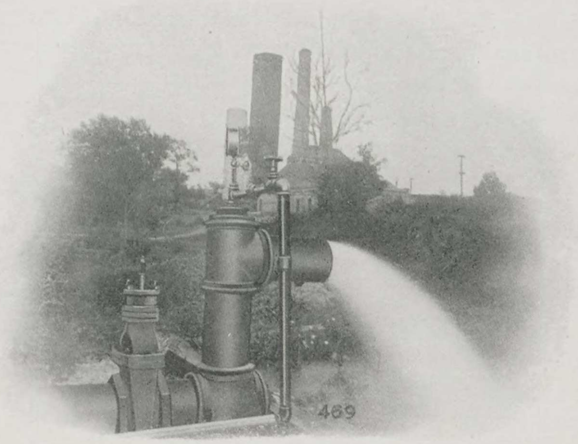
Yield of Well Increased.

One of the reasons for the success of the Air Lift System is that it increases the yield of the well from two to seven times, and we can cite many instances where this has been demonstrated. This is well illustrated by a comparison of the two pictures of the wells at the water works, Houston, Texas, as shown on this and the opposite pages. They show some of the thirty wells operated by one compressor. The power-house and standpipes are shown nearly half a mile beyond. At a test made by the Dixon Water Company, of Dixon, Ill., two 8-inch wells,



Wells at the Houston (Texas) Water Works, Showing the Flow Without the Application of Compressed Air.

flowing 100 gallons of water per minute, were made to yield 1,261 gallons by the Air Lift System. As much as 900 gallons of water per minute have been forced from a single 6-inch well, but this is an extreme case with a remarkably strong well, and the economical rate is much lower—say, up to 300 gallons per minute from a 6-inch, up to 600 gallons from an 8-inch well. The Air Lift will handle all the water a well can yield, but if a certain 8-inch well is equal to a flow of only 100 gallons, the Air Lift, of course, cannot pump more. Its large capacity comes from the fact that there is little in the well to interfere with the flow of a continuous stream the full size of the bore hole, if that quantity will come into the well. There are no moving, finished or working parts underground—simply two pipes which, when ad-



Wells at the Houston (Texas) Water Works, Showing Flow with the Application of Compressed Air.

justed, need not be seen for years; the single machine being in the compressor room, subject to the same working conditions as a steam engine, lasting as long and requiring no more attention. None of the working parts of the compressor come in contact with the water, and they may, therefore, be properly lubricated, wearing indefinitely.

In one of the earliest city plants where the water source was fine sand and the original yield was 70 gallons per minute it is now 170 gallons, due solely to the application of the Air Lift pump. Several other wells were improved proportionately. Nearly all wells, whether driven in sand, gravel or rock, **increase steadily with use,** the steady, even flow toward the wells cleaning out and enlarging the water-carrying channels and crevices, causing the well to draw from a larger area.

Water Is Cooled.

In breweries, ice factories and for condensing purposes it is, of course, important that the water pumped be as cold as possible, and many have adopted the Air Lift because they find that water pumped in this way is from 2 to 3 degrees colder than in the well, and from 10 to 40 degrees colder than surface water. This is due to the expansion of air, which abstracts the heat from the water, with which it is in close contact.

Water Is Purified.

A feature of the Air Lift, entirely outside all considerations of comparative cost, is that its use improves or purifies the water pumped. Prof. Drown, of Lehigh University, says: "The success of filtration is largely dependent upon aeration." With naturally filtered rock or sand water, entirely shut off from surface pollution and pumped by the Air Lift, ideal conditions are reached. There is a most complete aeration or mixture under pressure, and as the water flows upward mixed with the air it separates and throws off most of the sulphur gas, precipitates much of the iron, retards or prevents the growth of vegetable matter, germs or organisms, and results in clear and palatable water. Air Lift water remains clear and sparkling after long exposure.

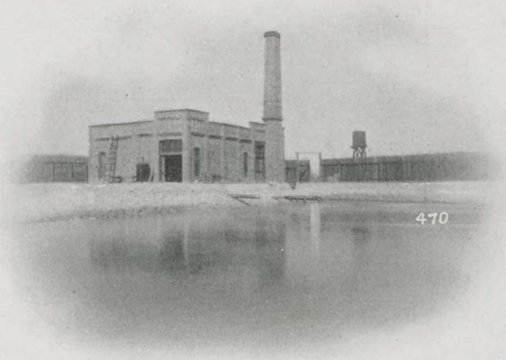
Well water which had been condemned by Boards of Health has been approved and praised highly by the same Board later when pumped from the same wells with air.

There are some wells unfit for manufacturing use because so strongly impregnated with sulphur, iron and acids. With the Air Lift these wells become available, and the air as it leaves the discharging water has a pronounced odor, but the aerated water analyzes 90 per cent. less impurities. There are some elements on which the air has no influence, but the general effect is to improve.

As an instance, to show the value of aeration, we may cite the case of the Asbury Park, N. J., Water Works. This water is very strongly impregnated with iron, and when pumped by a steam piston pump was practically unfit for domestic use. By the use of the Air Lift, however, 2,500,000 gallons as clear and wholesome as spring water are daily delivered into the standpipe.

Compressors May Be Any Reasonable Distance from the Well.

As compressed air can be conducted for miles with little loss, the compressor may be placed in the engine room directly under the care of the present engineer and the air conveyed in uncovered pipes to the wells, which may be any reasonable distance away.



Air Lift Plant at City Water Works, Corsicana, Texas. Pumps from Wells About Two Miles Apart.

One Compressor Can Pump from Different Groups of Wells.

Where large quantities of water are required it is usually necessary to pump from a number of wells, and by the Air Lift System this can be done with only one compressor; as, for instance, at the water works of Ocean Grove, N. J., where they pump 2,500,000 gallons daily from a series of twenty wells, all quite a distance apart and almost a half a mile away from the compressor; or at Camden, N. J., where 5,000,000 gallons are raised at a distance of over 4,000 feet from the compressor. The wells themselves require no attention, as they are regulated by the flow of air, and it makes no difference how many wells are on the same line, how they are scattered, or how far away. The principle is the same, and it is simply a question of a properly arranged pipe line, and valves for each well. Where good water is not at hand an air line can usually bring it from a distance cheaper and better than by any other means.

Free Condensing Water for Water Works.

There is perhaps no other situation in mechanical engineering where so great a saving in fuel consumption can be effected with so small an investment as by the use of a condenser in water works plants operating piston pumps and air compressors. Usually no extra expense whatever is incurred for pumping the water for condensing, as a part of that regularly handled by the plant can be passed through the condenser before it is pumped into the service mains.

The total amount of water handled by such a plant is so great in proportion to the amount needed for condensing purposes that the increase in temperature is of trifling importance compared to the saving in fuel effected.

As an example, we cite a plant installed by this company in north Texas, consisting of a Corliss air compressor having both steam and air cylinders duplex cross compound. This is lifting water more than 300 feet vertically from three drilled wells. The additional lift into the standpipe by the piston pump is over 100 feet more. Still, under even these severe conditions, both the compressor and pump are run condensing, and the saving in fuel pays for the condenser every few months. The temperature of the water in the standpipe is raised so little that many citizens on being questioned stated that they had noticed no difference.

It Pays to Pump Water Especially for Condensing Purposes.

Let us look into this question a little further by using actual figures. We will assume in one case a 100 H. P. simple non-condensing engine, in first-class working order, so that it runs on a steam rate of 36 pounds per horse-power hour and supplied with steam from a first-class boiler plant giving an evaporation of 9 pounds of water per pound of coal, equal to 4 pounds coal per horse-power hour. To make a severe case, we will assume that this plant will run but 10 hours per day and 300 days, or 3,000 hours per year. This gives an annual coal consumption of 600 tons.

The extra power required to operate an air compressor to pump condensing water for this plant, even lifting it as much as 75 feet vertically, would be under 10 H. P.; but say 10. This makes a total horse power required of 110. But the reduction of the coal consumption by running condensing would be from 25 to 35 per cent.; but say only 25 per cent., or to a coal rate of 3 pounds per horse-power hour. One hundred and ten H. P. at 3 pounds gives an annual coal consumption of 495 tons, or a saving per year, at the lowest estimate, of 105 tons. At $2 per ton this is 10 per cent. on $2,100—far more than the usual cost to make the change.

If the above should be considered a case specially favoring the application of a condenser, we will take another case, already assumed to be a fairly economical plant, having a 500 H. P. compound non-condensing Corliss engine, or compressor, running only 3,000 hours yearly, steam rate 22 1-2 pounds and evaporation of nine to one, as before. This would require annually coal amounting to 1,875 tons. Adding 10 per cent., as before, for power to lift condensing water, gives as the total power 550 H. P. In this case we will only assume that the condenser brings the water rate down to 18 pounds, or a reduction of 20 per cent., giving a coal rate of 2 pounds per horse-power hour. Five hundred and fifty horse power at 2 pounds coal gives yearly coal required as 1,650 tons. Yearly saving in coal, 225 tons, or, at $2 per ton, 10 per cent. interest on $4,500—far more than the usual cost of equipping with compressor and condenser.

No extra labor is required, as the compressor can be located in the engine room and looked after by the old force. But there is a saving of over 10 per cent. in the handling of coal and ashes and a reduction of the work required of the boiler plant.

If an evaporation of 7 pounds of water per pound of coal is taken as the basis of figuring (and this is nearer the average) and the plant runs more hours per year, the saving can easily be made three times the above figures. Again, it is not usual that it would be necessary to lift the water as much as 75 feet vertically, as water suitable for this purpose can usually be found nearer the surface.

Another instance of the material saving in fuel consumption as a result of pumping water especially for condensing purposes may be found in the experience of the Husted Milling Company of Buffalo, New York. An 8-inch well was drilled to a depth of 325 feet, when a strong stream of water was reached. The water rose to such a height in the well that when pumping 400 gallons per minute the lift to the surface was 50 feet. It was quite cold, the temperature being about 50 degrees, and so impure that it could be used for no other purpose than condensing.

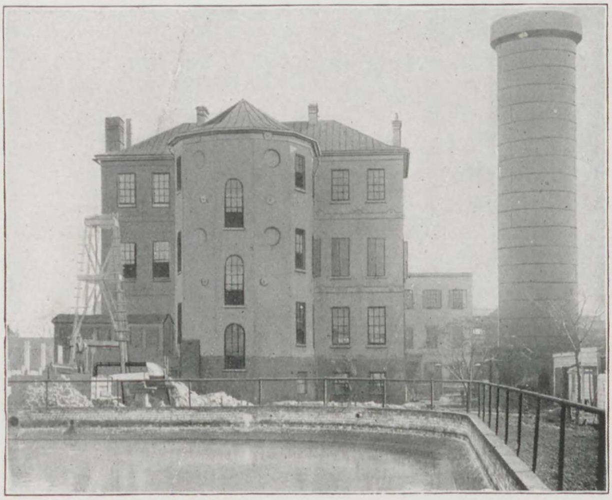
This company had a 26x48-inch Corliss engine, the load on which was about 600 H. P. Steam was furnished by three return tubular boilers, two of 100 and one of 140 H. P. capacity. A low pressure steam cylinder, 52x48 inches, was added to the engine, making it tandem compound. A jet condenser giving a good vacuum was also installed.

Since this change, despite the fact that they have been compelled to reduce the steam pressure to 100 pounds on account of the age of the boilers, these same boilers are doing the same work, and in addition are also furnishing steam for the condenser and to operate a 12 and 14¼x14-inch Class "A" Straight Line air compressor, which is used for the Air Lift. Only one fireman of the two employed heretofore is now needed, while the coal consumption has been cut from 8 tons to less than 4 tons for a 15-hour day. The change has further resulted in increasing the H. P. of the engine by about 150. Altogether the saving is summed up at from $3,000 to $3,500 per year.

If you will advise us fully as to the type and size of your engine and boiler plant, kind and cost of fuel, and all other data that you have pertaining to your power plant, with available information regarding the underground water supply, we will probably be able to make you a proposition that will show a clear saving of from 15 to 50 per cent. of your fuel bill, at an additional cost that will show **a return on the investment of from 10 to 50 per cent.**

Sand Is No Obstacle.

Almost all wells are troubled to a greater or less extent with inflowing sand. This sand, mixing with the water, cuts out suction and deep well pumps in a very short time, causing much annoyance,



Water Works at Charleston, S. C.

delay and expense. It has no effect on the Air Lift, however, as sand and gravel in the water form no obstacle and do not interfere with its action. This was demonstrated very effectually at the Charleston, S. C., water works, where over 200 tons of quicksand were pumped from a single well. At another place several cartloads of pebbles and stones were pumped out of a well using 3-inch water pipe, some of the stones being 2 1-4 inches in diameter by 4 inches long. The illustration on this page shows the Charleston station, the piles of sand being 8 feet high in places and extending over much of the yard. This is a deep well, sunk at great expense, and originally yielding but 103 gallons per minute. Two months' pumping with the Air Lift exhausted the quicksand, when the well yielded 250 gallons per minute of pure and clear water. In this case there is another well a mile away which starts and stops with the compressor without attention.

Economy Compared with Other Systems.

It is natural that at first the Air Lift System should have been lacking in the efficiency now possible. Its rapid growth in favor everywhere shows a foundation of solid merit and an adaptability to certain conditions which no other pumping system can meet so well. Some have thought the system lacking in economy, but their judgment rests on results obtained with improper methods of well piping in connection with inefficient compressors, from which satisfactory results on a "foot-pound duty" standard could not be expected.

The superior air compressor of to-day operates with a half or quarter of the fuel for a given power formerly required. Refinements in well piping and a better understanding of conditions have reduced both the pressure and the volume of air needed. There are now so many successful plants at work, meeting all the different conditions of volume and lift, that the design is reduced to a scientific basis.

An Air Lift test was recently made in Indiana which affords an opportunity for comparison between the efficiency of the Air Lift System of pumping and one of the best and most economical deep well pumps made.

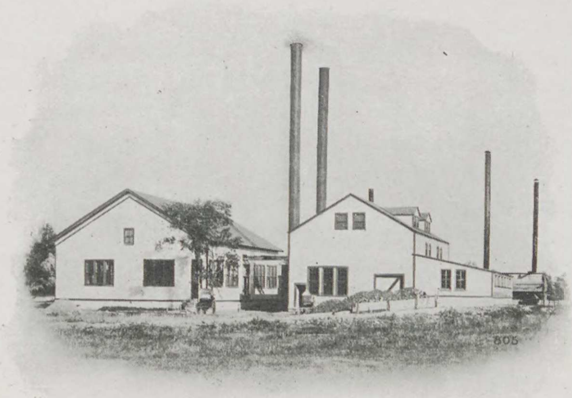
This Indiana water works for over a year used a second-hand 16 & 18¼ x 18 inches Class "A" Ingersoll-Sergeant compressor to operate an Air Lift furnishing a temporary water supply. Recently the pump company obtained permission to make a test, and installed two of its belt-driven pumps, with cranks and pitman, giving a double acting effect with a definite length of stroke.

In this case the pumps were driven by an ordinary portable engine and boiler. The test was conducted by a well-known consulting engineer, who was employed by the city to make tests to determine which system should be adopted. As a result of these tests, which were very thoroughly made, it was definitely shown that the deep well pump raised 60 gallons of water per pound of coal burned under the boiler, while the Air Lift plant, under the same conditions, raised 300 gallons per pound of coal burned.

These tests were unbiased and reliable, and afford an idea of the relative efficiencies under like conditions. Admitting a much higher efficiency for the pump in cases where economical engines are used, it should also be borne in mind that the efficiency of the Air Lift plant can be increased by using Corliss compound compressors, and that a power-driven deep-well pump such as was used in this case is much more efficient than the more usual type, which is driven by a direct-connected steam head, so that the comparison would be about the same for average conditions.

Air Lift Plant of the Standard Beet Sugar Co. at Ames, Neb.

Capacity of 900 gallons a minute. Air pressure, 75 pounds. Lift, 200 feet.



Power House of the Elizabethtown Water Co., at Springfield, N. J.

Cost of Pumping with the Air Lift.

This question is usually asked without giving several items which largely determine the answer. Thus, coal at $2 is one thing, at $4 another. Again, some wells are nearby and in other plants the pipe investment is greater because of scattered wells. When furnished with full data we can usually state the cost very closely, and a comparison with the present cost will often show a saving sufficient to pay for the outfit in from one to three years.

Speaking generally, the average cost per thousand gallons pumped depends on the size of plant and height of lift. In a 4,000,000 gallon plant, with a 50-foot lift, it is about ⅓c. per 1,000 gallons. In a larger plant, with a 35-foot lift, with coal at $2, it is about 1½ mills. In another case, where the lift is 75 feet and the capacity 1⅓ million gallons, the cost is 1c. per 1,000 gallons, coal costing $2. In a plant pumping 3,000,000 gallons 75 feet high, the cost is 4.5c., and where the lift is 50 feet, 3.5c. In Pennsylvania, a plant giving 175 gallons per minute at 75-foot lift, costs 1⅓c. per 1,000 gallons. In a proposed municipal plant, 100,000,000 gallons per 24 hours, 50-feet lift, and with coal at $1.50 a ton, the cost figured 1 mill or 1-10c. per 1,000 gallons, including all fixed and operating expenses.

In another case, involving the handling of about 15,000,000 gallons of water 30 feet high every 24 hours, using compound condensing compressors, and with coal at $2 per ton, other figures being estimated on a very generous basis, the cost nets about $2.50 per 1,000,000 gallons, or about 2½ mills per 1,000 gallons. These figures cover fuel, oil, labor, sinking fund, interest and taxes.

In one New Jersey plant, yielding 1,750 gallons per minute, the use of Ingersoll-Sergeant Corliss Air Lift machinery has doubled the quantity of water with only one-half the fuel formerly required by another make of compressor.

In many cases the introduction of the Air Lift may be effected at little expense, often involving the purchase only of an air compressor, a receiver, and a small amount of pipe, but the following is estimated on a basis which will cover the greatest amount of expense likely to be incurred, with a view of showing particularly that the interest and depreciation charges under the most extreme conditions are not likely to develop into formidable figures. The following is a list of the complete equipment for an Air Lift plant to raise 1,500,000 gallons per 20 hours, or 1,250 gallons per minute. Total lift, 75 feet:

Air compressor, complete, ready for foundation and piping.

Air receiver.

85 H. P. of boiler, with feed pumps, etc., bricked up and ready for use, including building and value of ground so occupied.

Tank, say 19,000 gallons capacity (15 ft. x 14 ft. 6 in.), including suitable timber framework to bring tank 75 feet above water level.

Two 12-inch wells, each 135 feet deep, cased.

450 feet 7⅝-inch light casing (water discharge pipe).

500 feet of 3-inch casing (air pipe in wells).

1,000 feet of 4-inch air line from receiver to wells.

1,250 feet of 12, 10 and 8-inch cast iron distributing main, leaded joints, from tank to works, laid below frost (air line laid in same trench).

All other pipe and fittings.

Compressor, receiver and tank foundations, say 18,000 brick, laid in cement.

Excavation for foundation, say 75 cubic yards.

Special automatic governing mechanism.

Total estimated cost of complete plant, ready to run, as above $8,750.00.

This is intended to include everything which may be considered as a legitimate expense in this connection. In many cases the buildings, boilers, tanks, wells, pipe lines, ground space, and other items do not represent a present expense, being already on the ground.

From the figures on the opposite page we may estimate the cost of operation, as follows:

Cost of Operation.

Engineer, double shift, at \$2.25 per day, \$4.50; $\frac{1}{5}$ time chargeable to pumping plant, per day....................	\$0.90
Fireman, double shift, at \$1.75 per day, \$3.50, on the basis of one man required for each 250 H. P. of boiler for 85 H. P. per day..	1.19
Fuel, 85 H. P., 20 hours, say $4\frac{1}{4}$ tons, at \$2 per ton, per day.	8.50
Oil, waste, and sundries, say...........................	.60
Interest on investment of \$8,750 at 5 per cent., figuring eleven 25-day months, or 275 working days per year, per day...	1.91
Deterioration, covering sinking fund, repairs, etc., providing for renewal of complete plant every ten years same basis as interest but 10 per cent., per day.................	3.18
Insurance and taxes at 1 per cent., as above, per day.......	.32
Total estimate cost of pumping 1,500,000 gallons per day, 75 feet high, under the above conditions...............	\$16.60

Cost of each 1,000 gallons (\$16.60 ÷ 1500), \$0.01107.

Kent, quoting the National Meter Company as authority, gives the cost of water in the States as follows:

Average minimum price per 1,000 gallons in 163 places, .094.

Average maximum price per 1,000 gallons in 163 places, .28.

With extremes ranging from $2\frac{1}{2}$c. to \$1 per 1,000 gallons.

As a usual thing the water rate in most manufacturing cities in the Central States runs in the neighborhood of 8c. to 10c. per 1,000 gallons supplied. In some of the larger Eastern cities it runs up to $12\frac{1}{2}$c., and even higher, and in some cities of the second and third class goes as low as 5c. per 1,000 gallons. At 5c. per 1,000 gallons the yearly water bill on the above basis amounts to........\$10,625.00

And at the figures given above, \$0.01107............. 4,566.37

A yearly saving on the above basis of................. \$6,058.63

Saving Effected.

This equals a profit of $69\frac{1}{5}$ per cent. on the estimated investment of \$8,750.00, or is the same as a dividend of 20 per cent. on an investment of \$30,293.15. With the actual cost of the plant less than is figured above, as it would really be in the majority of cases, the saving would be still greater. In many cases the operation of the plant does not involve the extra expense of engineer and fireman, and these items may be deducted. In other instances the fuel cost, either through the use of high duty air compressors or through lower cost of coal, may amount to much less. The only other items which amount to much are those of interest and deterioration, and we have already seen that these have been taken on the outside extreme. In a plant pumping about 3,000,000 gallons per 20 hours, 75 feet high, where the cost of the fuel delivered is 85c. a ton, but the other expenses are figured even more liberally than is shown by the above estimate, the cost per 1,000 gallons is about $0.0084.

And in the same case, but pumping 50 feet high, about $0.006.

Small Plants Also Economical.

As the figures given may give the impression that the cost of pumping with a small plant may run disproportionately high, we will investigate in that direction also. In most small plants an inexpensive belt or steam actuated compressor may be used, entailing no additional attendance expenses and no extra boiler, building or tank investment, and in some cases there would be no additional cost for well, etc. Belted compressors will often bring an underloaded engine up to an economical point. Excluding tank, boilers and building, but making proper allowance for well, piping, steam-driven compressor, receiver, foundation, freights, erection, etc., assuming that the tank and well are close to the work, we find that for a plant to pump 175 gallons per minute, or 352,000 gallons per 24 hours, 75 feet high, the total investment is not likely to exceed $1,500. The interest, deterioration, insurance and tax charges, as above, aggregating 16 per cent., net, on this sum per day.................................... $0.87

A proportionate allowance for fuel at $2 per ton, attendance, oil, etc., should not exceed per day............. 2.50

Total cost of pumping 252,000 gallons per day........ $3.37

Cost per 1,000 gallons................................ $.01\frac{1}{3}$

Cost of this amount of water at 5c. per 1,000 gallons per year of 275 days................................$3,465.00

And at $1\frac{1}{3}$c. per 1,000 gallons........................ 924.00

Net saving effected per year with a plant costing $1,500..$2,541.00

or a dividend of 169 per cent. on the investment. Certainly one had better borrow the money rather than neglect such a saving as this. In many instances a surprising saving may be effected when the water is now being obtained by means of deep well pumps by throwing the outfit aside and installing the more economical Air Lift System.

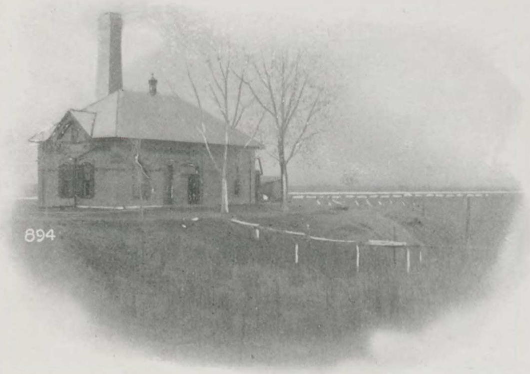
First Cost Not the Only Consideration.

The cost per 1,000 gallons is not always the most important matter. In municipal supply, quality is important beyond all considerations of cost.

In some cases water of inferior quality is being used at a considerable disadvantage because of its accessibility. In one instance river water, highly impregnated with sulphur coming from coal mines above, resulted in an expense of $5 to $8 per day from the grooving and pitting of rolls in a steel-working establishment. The effect on the boilers was very bad and represented an important item of expense in repairs and extra fuel burned. In such a case as this it might be well to go off even a mile to sink wells in some desirable location, the superior quality of the water so obtained reducing in many ways the cost of manufacture. In this case the lost output through pitted rolls, shut downs, injury to plant, or the increased rolling capacity with cold water and saving in boilers cannot well be expressed in dollars.

In some instances deep well pumps have been thrown out and the Air Lift installed, primarily because of the thorough aeration of the water resulting in throwing off most of the sulphur and other objectionable qualities.

Again, with a copious and inexpensive water supply, condensers may be attached to the main engine, resulting in a saving of 20 to 30 per cent. of the whole fuel bill.



Power House of Air Lift Plant at Fort Madison, Iowa.

LIMITATIONS OF THE SYSTEM.

Quantity Unlimited.

There is no limit as to the quantity that can be handled, except the capacity of the wells to furnish the water.

Distance Unlimited.

With a properly designed piping system the loss of power in the transmission of compressed air is trifling, and compares very favorably with any other method. It varies practically as the distance—that is, the loss in four miles is approximately twice that for two miles, with the same size pipe. With electricity the loss would be four times, or as the square of the distance.

As the Air Lift pump is automatic in its action there is no objection to having the source of water supply at a distance from the power station.

There are successful plants in the oil country where areas of ten square miles are supplied through over forty miles of air lines from one central plant. It is claimed that one of these burns 85 per cent. less fuel than was formerly required for the 375 working wells operated.

Height of Lift Unlimited.

There seems to be a prevailing idea that the Air Lift system is not adapted for lifts of much more than about 200 feet vertically, but this is far from being well founded. We have more than twenty plants in one oil field pumping a mixture of salt water and oil on actual lifts of from 600 to 1,200 feet, in most cases with an air pressure of less than $\frac{1}{3}$ pound per foot of actual lift, and in some cases less than $\frac{1}{4}$ pound.

In the Rocky Mountains there is an Air Lift working at a mine, taking air from a high pressure pneumatic locomotive service main and lifting 160 gallons of water per minute, more than 700 feet vertically.

All the air that this pump gets passes through a 5-32-inch round hole drilled in a solid plug cock.

These are regular Air Lift plants, without any valves or working parts in the well.

Especially Adapted for Very High Lifts.

The fact is that the Air Lift pump, as improved and installed by this company at the present time, is especially adapted to very high lifts, because it is under these conditions that all forms of deep well pumps give the most trouble from broken rods, valves, and pipes, and the lowest efficiency, owing to friction and leaking leathers and valves.

We are prepared to furnish proposals for furnishing Air Lift outfits specially designed for **any lift, no matter how high,** so long as there is a reasonable amount of submergence available.

Submergence Limits.

The percentage of submergence means the percentage of the **total vertical air lift column** (measured vertically from the point of air admission at the bottom to the point of water discharge at the top) which is submerged in the solid liquid column in the well **when pumping.**

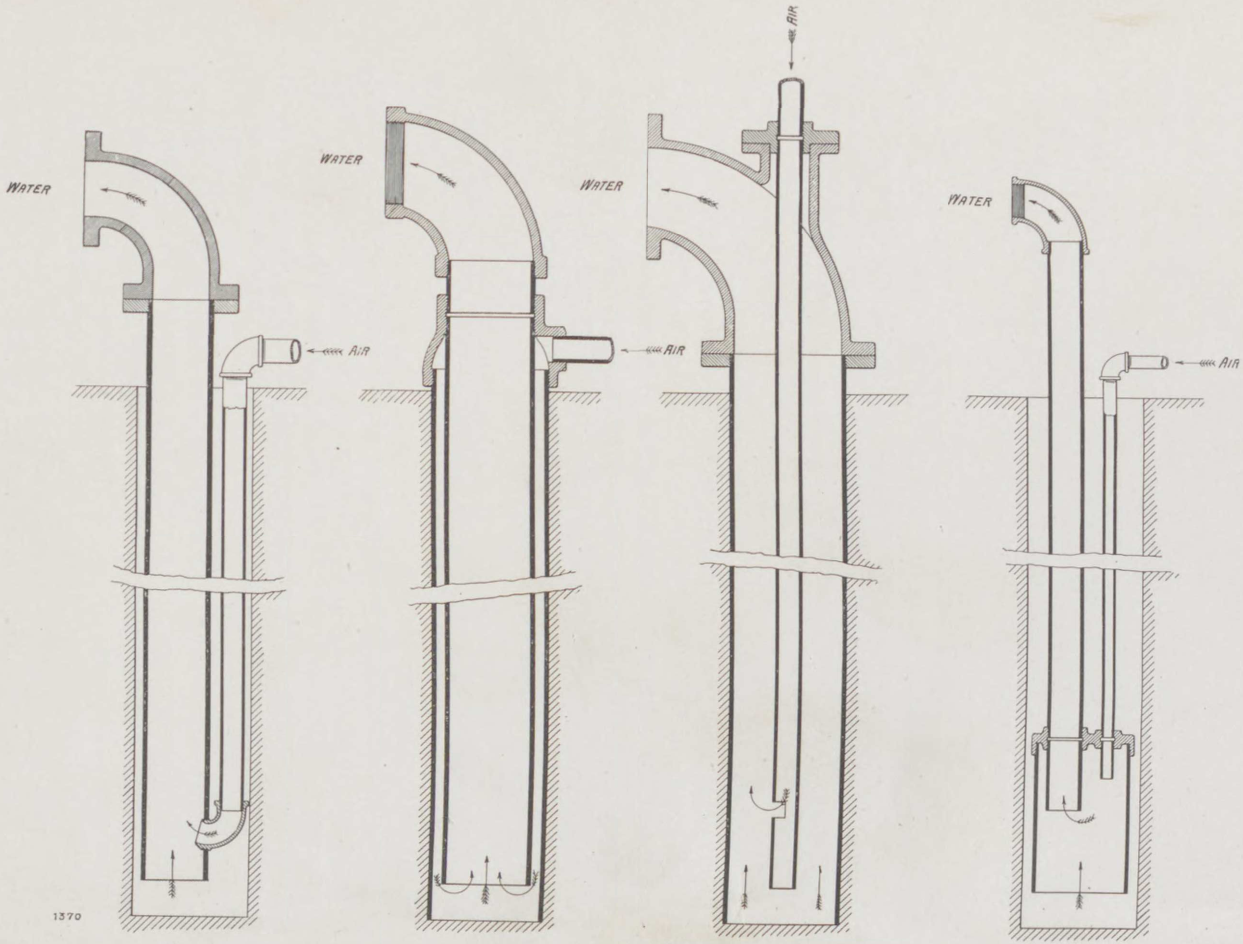
Neither the liquid level in the well when not pumping, nor the depth of the well, nor the level of the surface of the ground necessarily affects the submergence percentage, because when the pump is started the liquid level may fall 2 feet or 200; the point of discharge may be 10 feet below the ground surface *or* 100 feet above; and the well may be 1,000 feet deep, with the pipes extending only 200 feet down.

For example, with a well 800 feet deep, pumping water level 300 feet below, and point of discharge 100 feet above the surface, the pipes extending 700 feet below the ground surface, the total vertical height of the column is 800 feet, and the submergence 400 feet or 50 per cent., the lift being the same, a favorable condition for satisfactory work. We have plants working satisfactorily, under special conditions, on less than 30 per cent. submergence, and some with over 75 per cent., but usually the best economy is attained when it is about 60 per cent.

However, before you abandon a hard proposition as hopeless, or continue to suffer constant expense from breakdowns, let us tell you what compressed air will do.

We have installed a large number of successful municipal plants, too many to undertake to give a complete reference list here. Those interested will be referred to the nearest similar plants on request. We have put in so many plants under all conditions that our methods of economical plant arrangement will be of the greatest value to our clients.

We have connections with responsible and successful well experts, and erecting engineers, and are thus in a position to arrange for complete plants, furnishing the right system of well piping for given conditions and not being limited to the use of obsolete piping systems, narrow in their proper range of use. Air Lift pumping is a specialty, and much depends upon an accurate understanding of the well and water bearing strata, so when asking for quotations, inquirers should closely follow the question sheet at the back of this catalog, and define clearly what conditions are to be met.



No. 1 No. 2 No. 3 No. 4

Methods of Piping Wells.

METHODS OF PIPING WELLS.

All wells are not alike, and consequently the method of piping which might properly be applied to one would be unsuited to another. Each well represents a problem requiring special study. We are peculiarly well situated for solving such problems, because of our large experience in installing the Air Lift System all over the world. It is our fixed policy not to recommend the adoption of the Air Lift unless we are convinced that it will pay the customer to use it. On the opposite page are shown four distinct methods of well piping, each differing from the others. Each has its uses, and will only operate most efficiently and economically under certain conditions.

Of these methods of piping, we apply that which will operate with the greatest economy, depending upon the conditions, the height of lift, the volume of water, as well as the depth of casing, nature of well strata and other considerations. There is a great variation in results with the same method, if conditions differ, and piping which will work well in one case will give entirely different results elsewhere, though to the novice the conditions seem identical.

Method No. 1. Pohlé Air Lift.—Fig. 1.

In the Pohlé or Side Inlet, shown in Fig. 1, the air and water pipes are placed alongside of each other in the well, and connected at the bottom with an end piece. This method should be used when the well is sufficiently large to admit of the air and water pipes being placed side by side from top to bottom. This is the most economical system, and its advantages are marked at medium and high lifts.

We make standard side inlet devices or foot pieces and clamps for this type as follows:

Air Pipe Connection.	Water Pipe.	Size Well.	Maximum Economical Capacity on Moderate Lift.
½ in.	1 in.	3 in.	7 gallons per minute.
¾ in.	1½ in.	4 in.	20 " " "
1 in.	2 in.	4½ in.	35 " " "
1 in.	2½ in.	5 in.	60 " " "
1¼ in.	3 in.	6 in.	90 " " "
1½ in.	3½ in.	7 in.	120 " " "
1½ in.	4 in.	8 in.	160 " " "
1½ in.	5 in.	9 in.	250 " " "
2 in.	6 in.	10 in.	350 " " "

Larger sizes furnished to order.

The size of air pipe in well depends upon its length, and the volume and pressure of air to be used.

In cases of necessity the capacities given can be increased 20 to 40 per cent., but at a decreased efficiency in operation, this depending upon the height of lift and other conditions. Under some conditions, the given capacities have been doubled.

Method No. 2. Saunders Air Lift System.—Figs. 2 and 4

In some instances a well does not admit the use of the side inlet system, when the Saunders air lift system may be used. A central tube is suspended inside the well while the air passes down between it and the well casing. The water is then discharged through the central tube, as shown in Fig. 2.

Where the well is not cased a special pipe of less diameter than the well is inserted to a point reaching to a suitable depth and air inlet and discharge pipes are inserted in the manner shown in Fig. 4.

In estimating the capacity of this system it is usual to allow quantities as follows:

Height of Lift.	Gals. of Water per min. per sq. in.—Area Water Pipe.
25 ft.	10 to 11 gallons to each square inch area of water pipe
50 ft. to 125	12 to 15 " " " " " " " " "

In the case of salt wells with a natural flow, or those in which water is pumped down to dissolve the salt, and later is raised as brine, we advise the use of this system. See special mention of this subject on page 41.

Method No. 3. Central Air Pipe System.—Fig. 3.

The third or central air pipe system reverses the arrangement already described, and is used to obtain the greatest possible output for a given size of well-casing, provided the well is cased to admit of a 50 per cent. submergence of the air pipe, which is suspended inside. The air passes down the central pipe, the water and air discharging between the air pipe and the well casing. The size of the air pipe depends on length and volume of air it is to carry and pressure. This is not as economical as 1 and 2, but may be used where the well is very strong and a great deal of water is wanted from a few wells.

The proper size of air pipe for different sized casings and the capacity to be expected are about as follows, depending on the lift and submergence:

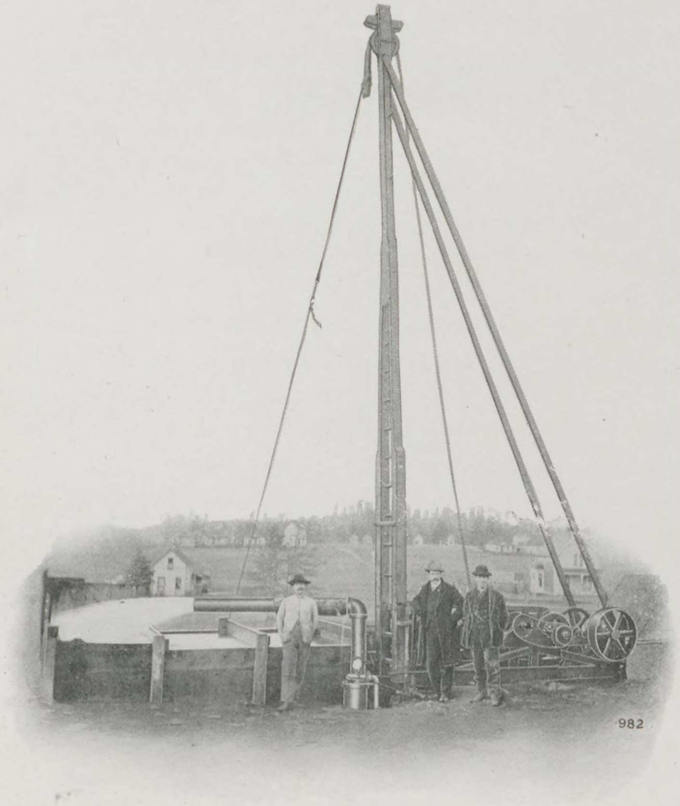
Size of Casing.	Size of Air Pipe.	Capacity.
3½ in.	1¼ in.	80 to 100 gallons per minute
4 in.	1½ in.	100 to 150 " " "
5 in.	2 in.	150 to 250 " " "
6 in.	2 in.	275 to 375 " " "
8 in.	2½ in.	500 to 650 " " "
10 in.	2½ in.	775 to 1000 " " "

Compound Air Lift.

Where a part of the water only is used at a high elevation about the works, it is an easy matter to put in a supplementary air lift, taking its supply from the distributing main and raising it in a second or compound lift to the point desired, thus avoiding the expense of raising the whole volume of water to the full height.

When wells are shallow, not large in capacity, and the lift high for the submergence under ordinary methods, we have secured successful "compound" results by raising the water to the surface, allowing it to flow by gravity into one well near the tank, thus supplying the necessary submergence to give the higher tank delivery.

Each of these has its special field of utility, and a choice should not be made without a full knowledge of your conditions.



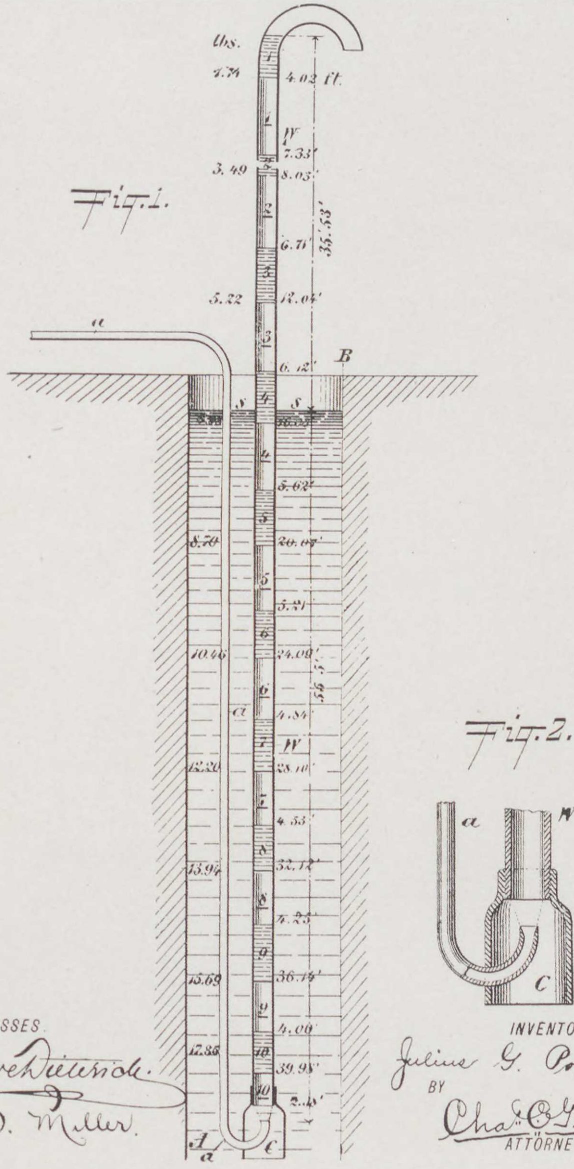
Air Lift Plant at Tacoma, Wash.

(No Model.)

J. G. POHLÉ.

Process of Elevating Liquids.

No. 487,639. Patented Dec. 6, 1892.



WITNESSES.

Gustave Dieterich.

Ed. D. Miller.

989

INVENTOR

Julius G. Pohlé

BY

Chas. E. Gill

ATTORNEY.

THE MODERN "POHLÉ AIR LIFT."

Dr. Julius G. Pohlé, the inventor and patentee of the "Pohlé Air Lift" system of pumping, was associated with this company until his death in 1896, since which time his system has been further improved and developed by a wider application and broader experience.

POHLÉ AIR LIFT PUMP PATENTS.

The Ingersoll Sergeant Drill Company, until recently the sole licensee, has now purchased all right, title and interest in patents No. 347,196, August 10, 1886; No. 487,639, December 6, 1892, and No. 532,699, January 15, 1895, comprising the invention of Dr. Julius G. Pohlé for lifting water by compressed air. These patents are broad and fundamental, covering the most economical and the most simple means by which the Air Lift may be utilized.

From time to time imitations have appeared, but no one has devised a system as simple or economical as that thoroughly covered by the Pohlé patents, which are now the property of the Ingersoll-Sergeant Drill Company. For this reason all Air Lift plants furnished by us are fully protected against infringement suits, to which purchasers of other systems are liable.

On pages 38 and 39 is a reproduction of Patent No. 487,639, dated December 6, 1892.

UNITED STATES PATENT OFFICE.

JULIUS G. POHLÉ, OF JERSEY CITY, NEW JERSEY.

PROCESS OF ELEVATING LIQUIDS.

SPECIFICATION forming part of Letters Patent No. 487,639, dated Dec. 6, 1892.

Application filed October 24, 1891. Serial No. 409,7c1. (No model.)

To all whom it may concern:

Be it known that I, JULIUS G. POHLÉ, a citizen of the United States, and a resident of Jersey City, in the county of Hudson and State of New Jersey, have invented a certain new and useful Process of Elevating Liquids, of which the following is a specification.

The invention relates to the art of elevating water by compressed air; and it consists in improved processes and apparatus whereby the compressed air is delivered in bulk into the lower end of the water-eduction pipe and the water and air are caused to ascend through said pipe in distinct alternate layers of definite dimensions.

The object of the invention is to successfully and practically effect the elevation of the water to a much greater height than has heretofore been deemed economic with compressed air and to avoid the results due to an intimate commingling of the air and water, as well as to dispense with all valves, annular spaces, and solid pistons. In accordance with my invention the air is not directed into the water in the form of fine jets or bubbles, which would very readily commingle intimately with the water, but is delivered in mass, and the water and air ascend in well-defined alternate layers through the eduction-pipe.

In the art of raising water by means of ejectors it is essential to use a continuous and rapid current of steam or air, which by its velocity and momentum forms, primarily, a vacuum into which the water flows by suction. From thence it is secondarily drawn along by the induced velocity current of the steam or air thus used. In my process, which I term the "air-lift" process or method, it is not necessary to create a vacuum at all, nor is it necessary to use a velocity current for the purpose of raising water, for its action depends, primarily, upon the gravity force of the liquid into which an eduction-pipe is submerged, and, secondarily, it depends upon the elastic energy stored in compressed air when used in the manner to be described. I have discovered that when air of suitable pressure is allowed to enter in a constant stream and in suitable quantity into an eduction-pipe at or near its lower end when it is submerged in water, while its upper end rises above the water about the same distance that its lower end is submerged, the compressed air thus introduced will at first expel the standing water from the pipe in an unbroken column free from air, and subsequently, by the continued inflowing of the compressed air under a pressure just sufficient to overcome the resistance of the water outside of the eduction-pipe, it will arrange itself in alternate layers with the water, while the latter flows into the lower end of the eduction-pipe by force of gravity until it is discharged at the upper or exit end of the pipe. This alternate interposition of determinate quantities of air between the also determinate quantities of water elongates the entire column of air and water, thus facilitating, without materially adding to the weight of the column, the discharge of the water at a higher level than would be the case were these air sections or layers absent. I have also discovered that under the above-mentioned conditions the compressed air will not escape through the water overlying it, and also that the water overlying the compressed air will not fall back through the underlying air while both are in upward motion, but find that the elasticity stored in the compressed-air layer, pressing alike in all directions, forms a temporary water-tight air-piston, which lifts the water above it to its final discharge without appreciable loss by leakage or so-called "slippage," while this compressed-air piston after having expended its elastic energy in work of lifting water is dispelled with only a practically unimportant loss of power. To elucidate this process of pumping more clearly, I will refer to the accompanying drawings, in which—

Figure 1 illustrates a central vertical section of an apparatus embodying the invention; and Fig. 2, a like section, on an enlarged scale, of the lower ends of the air and discharge pipes, and in which—

A B designate an Artesian well or its equivalent; S, the surface of the water-level; W, an eduction-pipe submerged therein (being represented as three inches in diameter to correspond with the lengths and weights of the water and air layers) and having at its lower end the enlarged extension C, and *a* indicates the air-conveying pipe, coming from any source of compressed air and terminating with an upturned exit end within the enlargement C several inches below the mouth of the eduction-pipe proper. The exit end of the air-pipe is enlarged by beveling off the inner edge thereof in order to permit the free delivery of the air in mass or bulk, and thus to avoid the formation of air-bubbles. The enlargement C of the pipe W is of sufficient area to compensate for the space occupied by the exit end of air-pipe *a*, and said end of said pipe *a* passes through the vertical side of the enlargement C, as shown, and derives support therefrom.

The drawings represent the apparatus in a state of action pumping water, the shaded sections within the eduction-pipe W representing water-layers and the intervening blank spaces air layers.

At and before the beginning of pumping the level of the water is the same outside and inside of the discharge-pipe W—incidentally, also, in the air-pipe. Hence the vertical pressures per square inch are equal at the submerged end of the discharge-pipe. When, therefore, compressed air is admitted into the air-pipe *a*, it must first expel the incidental standing water before air can enter the eduction-pipe W. When this has been accomplished, the air-pressure is maintained until the water within the eduction-pipe has been forced out, which it will be in one unbroken column, free from air-bubbles. When this has occurred, the pressure of the air is lowered or its bulk diminished and adjusted to a pressure just sufficient to overcome the external water-pressure. It is thus adjusted for the performance of regular and uniform work, which will ensue with the inflowing air and water, which adjust themselves automatically in alternate layers or sections of definite lengths and weights. It will be seen in the drawings that the lengths of the water-columns (shaded) and air (blank spaces) 1 and 1 are entered at the right of the discharge-pipe W; also, that under the pressure of two layers of water 1 and 2 the length of the air column 2 is 6.71 feet long, and so on. The lengths of aggregate water columns and the air columns which they respectively compress are also entered on the right of the water-pipe. On the left of the water-pipe are entered the pressures per square inch of these water columns or layers. Thus the pressure per square inch of column 1 is seen to be 1.74 pounds; that of 2, consisting of two columns or layers 1 and 2, each 4.02 feet long, to be 3.49 pounds, and that of 10, consisting of nine columns or layers of water 1 to 9, inclusive, each 4.02 feet long, and one of 3.80—viz., layer 10—feet in length to be 17.35 pounds, and the aggregate length of the layers of water is 39.98 feet in a total length of ninety-one feet of pipe. It will be noted that the length of pipe below the surface of the water in the well is 55.5 feet, and that the difference between this and the aggregate length of the water layers (39.98) is 15.52 feet—that is, on equal areas the pressure outside of the pipe is greater than the pressure on the inside by the weight due this difference of level, which is 47.65 pounds for the end of the discharge-pipe. It is this difference of 15.52 feet, acting as a head that supplies the water-pipe, puts the contents of the pipe in motion, and overcomes the resistance in the pipe. In general the water layers are equal each to each, and the pressure upon any layer of air is due to the number of water layers above it. Thus the pressure upon the bottom layer of air 10 in the drawings is due to all the layers of water in the pipe, (17.35 pounds,) and the pressure upon the uppermost layer of air 1 is due to the single layer of water I at the moment of its discharges beginning—viz., 1.74 pounds per square inch. As this discharge progresses this is lessened, until at the completion of the discharge of the water layer the air layer is of the same tension as the normal atmosphere.

The quantitative relations of the air to water are determinable, but vary with the relations of submergence to lift, diameter of pipe, temperature, and atmospheric pressure, and range from 1.5 to more volumes of normal air, compressed to an adequate pressure, for each volume of water raised by this process. The best efficiency is attained when the submersion is three-fifths of the total length of the eduction-pipe. Whatever the submergence or lift may be, in order to secure the desired continuous upward flow of the contents of the eduction-pipe without stoppage or downward dropping of the same it is necessary that the air as introduced into the pipe should be in quantity sufficient to form, immediately upon its issue from the air-pipe bubbles which will expand across to fill the eduction-pipe from side to side and make distinct piston-like layers, entirely separating the portions of the water column between which they enter said pipe. Where the bubbles are smaller than this, they will pass up through the water, and, while necessarily elongating the water column, will not exert the positive elevating power that my pipe-filling air layers, entirely dividing the layers of water from each other, do.

The enlargement at the lower end of the eduction-pipe I have found to be of advantage, not only as compensating for the space taken up by the air-pipe, but, where the mouth of the latter is well below the upper end of the enlargement, as facilitating the formation of bubbles sufficiently large to make the desired pipe-fitting piston-like layers, rapidly and continuously following each other at very short intervals in the flow up the eduction-pipe. When the body of water first standing in the eduction-pipe has been forced up out of the latter by the compressed gaseous fluid used, the fluid pressure is preferably diminished, as indicated hereinbefore. In practice I so reduce the pressure to a point below the weight of the column of liquid which, standing in the eduction-pipe above the point of entrance of the gaseous fluid, has been removed, as stated.

It is evident that the process above described is applicable to all other liquids besides water—such as petroleum-oil, saline solutions, brewers' and tanners' liquors, sewage, &c.—and therefore I do not limit the invention to the elevating of water. Neither do I confine the invention to compressed air alone for the purpose of raising liquids by this process, but claim any aeriform body, such as natural gas and steam when used in oily liquids.

What I claim as my invention, and desire to secure by Letters Patent, is—

1. As an improvement in the art of elevating liquid, the process which consists in submerging a portion of an open-ended eduction-pipe in a body of the liquid to be raised and continuously introducing into the liquid within the lower part of the pipe a series of bubbles of compressed gaseous fluid containing enough of the fluid to expand immediately across the pipe and fill the same from side to side, forming pipe-fitting piston-like layers at or just above the point of their entrance into the pipe, whereby the column of liquid rising in the pipe after the forcing out of the liquid first standing in the latter is subdivided by the gaseous fluid into small portions before it reaches the level of the liquid outside of the pipe, and a continuously upward-flowing series of well-defined alternate layers of gaseous fluid and short layers of liquid is formed and forced up the pipe, substantially as and for the purpose specified.

2. As an improvement in the art of elevating liquid, the process which consists in submerging in the body of the liquid to be raised a portion of an open-ended eduction-pipe having an enlarged chamber on its lower end and continuously injecting into such enlargement well below its upper end gaseous fluid under pressure to form bubbles in the pipe above the enlargement large enough to extend across from side to side of the pipe proper and form pipe-fitting piston-like layers therein interposed between and entirely separating well-defined layers of liquid in the pipe, substantially as and for the purpose described.

3. As an improvement in the art of elevating water or other liquid, the process which consists in submerging a portion of an open-ended pipe in a body of the liquid to be raised, removing the upper portion of the column of liquid within the pipe and injecting into the latter at a point well below the level of the liquid in which the pipe is submerged gaseous fluid in quantity sufficient to form bubbles, which will expand immediately across the pipe and fill the same from side to side and under pressure less than the weight of a column of liquid in the pipe extending from the point of entrance of the gaseous fluid to the level of the body of liquid surrounding the pipe, so that a continuous upward-moving series of alternate well-defined gaseous fluid and liquid layers will be formed in and forced up the pipe, substantially as and for the purpose described.

Signed at New York, in the county of New York and State of New York, this 23d day of October, A. D. 1891.

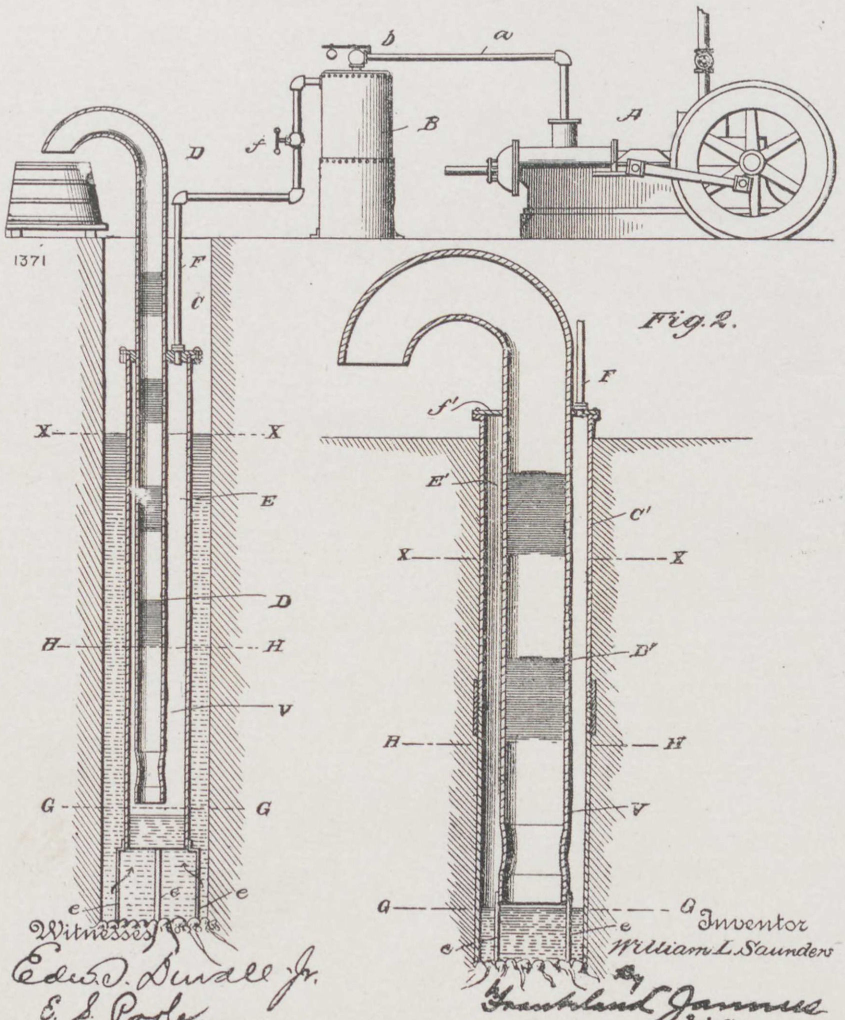
JULIUS G. POHLE.

Witnesses:
CHAS. C. GILL,
ED. D. MILLER.

(No Model.)

W. L. SAUNDERS.
Air Lift Pump.

No. 597,023. Patented Jan. 11, 1898.



THE SAUNDERS AIR LIFT SYSTEM.

Differing in several important features from the Air Lift patented by Dr. J. G. Pohlé, Mr. W. L. Saunders has patented a system in which the discharge takes place through the central tube which is at all times surrounded by the compressed air. Referring to the illustrations from Patent No. 597,023, as shown on the opposite page, the operation of the device is as follows:

Compressed air, produced from any source (A), passes to the well (C) and into the air-tight chamber (E), formed by the outside pipe, which may be either the casing of the well (Fig. 2) or an inserted pipe resting on the bottom of the well (Fig. 1), but open to permit free ingress of water. Extending down into the casing, but not quite to its bottom, is the discharge pipe (D). There are no valves, rods, pistons or working parts, and no features other than those mentioned. Pipes must, however, be properly proportioned to obtain the best results.

The space between casing and discharge pipe is obviously termed the "Pressure Chamber." When idle, without air pressure, the water will stand at the normal ground level in both the pressure chamber (E) and discharge pipe (D). As the air pressure in (E) is increased the water is gradually forced down and back into the well until the end of the discharge is uncovered. Instantly a portion of the air escapes into the discharge pipe (D). This lowers the pressure in the chamber (E), and immediately the water rushes in and up the pressure chamber (E) and discharge pipe (D) to some point (HH) before the water and air pressure balance, when the water is again forced out, the air as before escaping through the discharge pipe. This time, however, the air in rising and expanding pushes before it that quantity of water which just previously had rushed into the discharge pipe. This water was already in motion, and had a certain velocity upward. To increase this velocity the discharge tube is restricted and formed into a "venturi" near the bottom, a method materially assisting to start the water up the eduction tube.

In operation, the surface of the water in the pressure chamber is pulsating up and down past the bottom of the discharge pipe. Entering the tube as a solid column of water with considerable velocity, each wave is followed by a definite volume of compressed air, and rushes up the central pipe (D) in a series of water plugs or pistons. The air by the time it reaches the outlet has expanded to about atmospheric pressure. The air cannot escape past the solid moving pistons of water, and, therefore, each cubic foot of air exerts all its contained energy in useful work. Of especial utility is this form for cases where corrosive liquids, such as brine solutions, are to be raised.

CLAIMS FOR THE SAUNDERS AIR LIFT.

The claims for the Air Lift, invented by Mr. W. L. Saunders, are given in the patent as follows:

1. The herein-described method of pumping, which consists in supplying directly to the open lower end of a valveless delivery pipe surrounded by an open-bottom chamber continuously supplied with a gas under pressure, of charges of the liquid and of the gas under pressure and in alternation.

2. The method of pumping, which consists in supplying to the open lower end of a valveless delivery pipe surrounded by a submerged pressure chamber having its lower end permanently open to receive the liquid and continuously supplied with a gas under pressure, of charges of liquid and of gas at a high velocity and in alternation.

3. In a pumping operation the process of raising liquid, which consists in supplying to a pressure chamber permanently open at its lower end to receive the liquid, and provided with a downwardly-extending delivery pipe, also open at its lower end, said lower end located near the opening of the chamber, of compressed air at a point near the upper end of the pressure chamber from a constant source of supply, admitting liquid to the open end of the chamber and of the delivery pipe under sufficient momentum to force itself into the delivery pipe and also to cause an increase of the pressure of the compressed air in the upper part of the chamber, until the momentum of the water entering the chamber is overcome thereby, when the water is forced down and out of the chamber into the well, and the excess of air pressure allowed to escape up the delivery pipe, forcing the water before it, and vice versa.

4. The combination with a well to be pumped, of a delivery pipe, the lower end of which is open to receive the water and which extends below the normal water level, a pressure chamber surrounding said delivery pipe, and permanently open at its lower end to receive the water, connections between the upper part of the pressure chamber and an independent source of compressed air or other gas, whereby, under the variations of pressure in the chamber due to the momentum

of the head of water and the escape of part of its contents, the air and water will pulsate above and below the mouth or exit of the eduction pipe, and portions escape thereinto alternately.

5. The combination with a well, of a pressure chamber closed at its upper end and permanently open at its lower end to permit free inflow of water, of a delivery pipe arranged within the pressure chamber and extending below the normal water level, and open at its lower end to receive the water from the well, and an independent source of compressed gas connected with the upper end of the pressure-chamber, whereby under a constant flow of gas under pressure from the independent source into the pressure chamber the gas and liquid will pulsate about the lower end or mouth of the delivery pipe, alternately entering the same.

6. In an air-lift pump the combination of a delivery pipe extending below the normal water level, a pressure chamber inclosing part of said delivery pipe and extending down below the lower or inlet end thereof, and permanently open at its lower end to receive the water connections between the upper part of the pressure chamber and an independent supply of air under pressure, and means for regulating the pressure of air supplied to the pressure chamber.

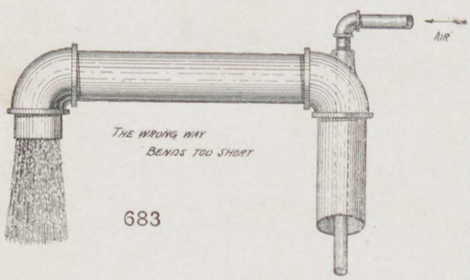
7. In an air-lift pump the combination of a stationary delivery pipe formed with a contracted portion near its lower extremity, a pressure chamber surrounding said pipe, said chamber permanently open at its lower end to receive the water, and valveless connections between the pressure chamber and an independent source of compressed air at one end, and with the water at the other end, whereby the head or normal level of the water in the well and the pressure of air from the tank will always oppose each other in the pressure chamber, causing them to pulsate above and below the lower end of the delivery pipe, air and water escaping thereinto in alternation.

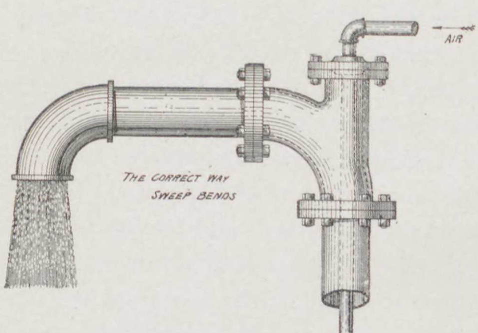
8. In an air-lift pump, the combination of a delivery pipe formed with a contracted portion near its lower end or mouth, a pressure chamber surrounding said pipe and permanently open at its lower end to receive the liquid and supplying compressed air thereto from above in alternation with the supply of liquid, and connections between the pressure chamber and an independent source of compressed air.

ARRANGEMENT OF WELLS AND PIPING.

Proper piping up of wells is a feature counting largely in the success of an Air Lift system, whether working one or several scattered wells. The introduction of unnecessary valves, elbows, angles and bends will cause a loss of air pressure, cut down the efficiency of the plant very largely, and should be avoided as far as possible.

It is therefore well to lay out beforehand the wells and piping, placing the wells and reservoir so that pipes can be run direct, with the fewest possible bends, elbows and valves. Pipes should all be made of a size sufficient to carry air to the wells and the water away with the least practicable resistance.





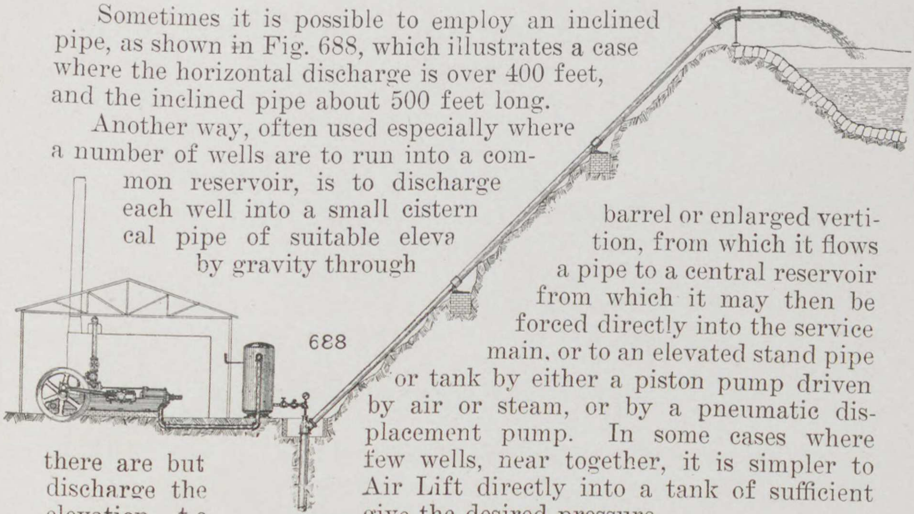
The tables given on pages 88 and 89 afford a means of determining the sizes of pipes necessary to transmit a given volume of free air with a predetermined drop, or conversely, the reduction of pressure which will occur in a given length where a certain size pipe is used. To the actual lengths, as measured from plans, or on the ground, should be added the increase or allowance for valves, tees and elbows, as given in the table, page 89.

It is for this reason that the use of long sweep elbows and tees is recommended, especially for water. In many cases elbows can be avoided by making long bends of pipes. If this is done the bends should be made smooth, regular and free from dents or kinks.

In laying out and piping up an Air Lift system the horizontal distance to which the discharge is conveyed by air should be made as short as possible. Thirty to fifty feet may be taken as the practical limit for satisfactory results. In special cases this has been considerably exceeded, but we do not recommend anything beyond the figures given without a full knowledge of the case.

Sometimes it is possible to employ an inclined pipe, as shown in Fig. 688, which illustrates a case where the horizontal discharge is over 400 feet, and the inclined pipe about 500 feet long.

Another way, often used especially where a number of wells are to run into a common reservoir, is to discharge each well into a small cistern cal pipe of suitable eleva by gravity through



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barrel or enlarged vertition, from which it flows a pipe to a central reservoir from which it may then be forced directly into the service main, or to an elevated stand pipe or tank by either a piston pump driven by air or steam, or by a pneumatic displacement pump. In some cases where

there are but discharge the elevation t o

few wells, near together, it is simpler to Air Lift directly into a tank of sufficient give the desired pressure.

Carry as Low Air Pressure as Possible.

When running several wells together which require different air pressures, engineers sometimes put throttle valves on all the wells and in regulating them too finely raise the receiver pressure to a point far above that required to run the highest pressure well. All this excess pressure represents power thrown away, and the practice should not be allowed. It is in such cases necessary to have throttle valves on all the low pressure wells and to often have them nearly shut but the well that requires the highest pressure to operate it should be run with the valve wide open, or nearly so, and then the other wells regulated to take what air they need, forcing the rest of it to the high pressure well.

An ordinary globe valve proves to be the best regulating valve except for very high pressures. Gate valves or plug cocks cannot be regulated as closely and cannot be so readily set at the same point after having been closed. A second globe valve may be used for stopping and starting, thus leaving the economical adjustment of the regulating valve undisturbed.

The brief descriptions just given call attention to a few working combinations, but by no means exhaust the arrangements which can be made. They will suffice, however, to illustrate the wide applicability of this means of raising water. If there is any question or uncertainty regarding your special case we shall be glad to correspond with you and arrange for one of our experts to personally examine your property with an idea of advising and furnishing an estimate.

OTHER APPLICATIONS OF THE AIR LIFT.

In addition to its value for raising water, compressed air lends itself with especial facility to the difficulties involved in handling brine from salt wells, for raising acids, acid solutions, and other liquids of high specific gravity and corrosive character. In manufacturing establishments it is indispensable for ore leaching, handling dye, paper pulp and fluids. In sugar refineries, or any place where gritty particles and chemical solutions are encountered, and for many other purposes which will suggest themselves, the Air Lift has no equal.

There are no working or moving parts of any sort in contact with the liquid, and in consequence the few pipes and tanks necessary for storage and moving the liquid can be made of materials unaffected by the fluid. Even wooden pipes are sometimes used.

Salt Wells.

Brine of a profitable saturation is secured and the output greatly increased. We have equipped many such plants which have not cost a penny since installed, and now operate with perfect satisfaction. We have a special method of piping salt wells developed by a wide experience, which increases the life of the system and avoids difficulties common to this class of well.

One Example.

An example of unusual interest is the salt wells of Messrs. Buckley & Douglass Lumber Company.

These wells are 2017 feet deep, the last 30 feet of which is solid rock salt. They are cased 8 inches down to 616 feet, the balance being a 7-inch uncased hole. A 4½-inch pipe extends entirely to the bottom of the wells, which provides an annular space around its outside between it and the walls of the wells. Inside of this pipe is a 3-inch liquid discharge pipe extending down 985 feet. At the bottom the outer pipe has a reducer fitted to it, so that if the 3-inch pipe should rust through and drop it would be caught and could be pulled up by the outer pipe.

The fresh water is run down outside of the 4½-inch pipe and kept up to within about 100 feet from the top of the well. It dissolves the rock salt at the bottom, and is lifted up through the central 3-inch pipe, the air being forced down the annular space between the outside of the 3-inch and inside of the 4½-inch pipes.

This is practically the arrangement of pipes employed in the Saunders Air Lift system, described on page 34.

The piping was changed to this system because the central air pipe gave a great deal of trouble by corrosion, which attacked not only the air pipe, but the inside of the well casing also, and the air pipe was liable at any time to corrode through and drop.

By changing to the system referred to, the corrosion is confined to the inside of the 3-inch discharge pipe, so they have but one pipe to corrode instead of two. Since this change the trouble has been practically eliminated, and the system has proved most satisfactory and efficient.

The compressor is a "Straight Line 'Class AC'" Ingersoll-Sergeant machine, with steam cylinder 22 inches in diameter, and compound air cylinders $18\frac{1}{4}$ inches and 9 inches, all with a 24-inch stroke.

They pump three wells at a time, and with the compressor running at moderate speed secure about 600 gallons of brine per minute.

Compressor Power House for Operating an Air Lift.

COMPRESSED AIR IN GENERAL PUMPING OPERATIONS.

In the foregoing pages applications of the Air Lift pump have been discussed and the limitations of its field of usefulness outlined. But there are other problems in the lifting and handling of water and other liquids, for which the Air Lift does not offer the best solution. Yet, though the method of its application is different, compressed air is still a most useful and economical agent in meeting the peculiar requirements of these situations. The machinery employed in these other operations may be broadly classified under three heads, which will be discussed in order,—displacement pumps, direct-acting piston or plunger pumps, and power-driven pumps.

Displacement Pumps.

The displacement pump is almost the essence of pumping simplicity, and, if its first promise were borne out, it would be a most powerful factor in pumping problems. As it is, within its recognized field, it has shown a fitness which qualifies it peculiarly for the work. In its essentials it consists of two barrels, or cylinders, which are filled and discharged alternately, the charge in each cylinder being directly discharged or displaced by the admission of the required volume of compressed air through a valve automatically controlled. The fundamental requirement is a complete submergence of 3 to 6 feet. The cylinders are filled at no expenditure of power, discharged with the minimum of friction loss. The pump operates independently of dirt or grit. There is no packing, no leakage. It starts and stops automatically and uses air exactly in proportion to the volume of water discharged. It will run for weeks without attention and requires practically no repairs. Standard sizes have capacities up to 1,500 gallons per minute. The height to which these pumps will lift water is limited only by the air pressure used, and, by an arrangement of several in series, almost any height can be attained with ordinary moderate air pressures.

Used alone or in connection with an Air Lift pump, the displacement system is a neat solution of the problem of small municipal water supply. The pump itself is submerged in a pond or reservoir supplied from a natural source, or from artesian wells pumped with the Air Lift. In the latter case, one air plant will supply both Air Lift and pump. No stand-pipe is required, the elastic air pressure in the pump forcing the water directly into the service mains in a continuous stream. Only the simplest machinery is required; attendance becomes a minimum, and the entire system is simple, efficient, almost automatic, and very economical in both first cost and operation.

In mine work, the displacement pump is especially useful in handling the accumulated water in sumps, dips, entries, etc., its requirement of complete submergence being borne in mind. It is also peculiarly effective in subways and tunnels, in automatically discharging the seepage or leakage water which accumulates in a sump. It may also serve in the basements of factories and warehouses which are subject to occasional inundations by floods or high water, its utter disregard of dirt and small debris being of peculiar value in such cases.

The same apparatus, but in a slightly modified form, is employed in manufacturing establishments for elevating acids and heavy chemical solutions, or for pumping marl, paints and other semi-fluids. In these cases the air valve is so located that it is not affected by contact with the liquid, or by corrosive fumes arising from it. The device has also been successfully employed in elevating sewage.

The capacity of the displacement pump is determined by the size of the cylinders or chambers, and the volume of air available. Using air at ordinary pressure from a common single stage air compressor and with a lift not exceeding 250 feet, the efficiency of the displacement pump is certainly higher than that of the usual direct-acting plunger pump, under the same conditions of lift and pressure. No plunger pump can handle as much water as the displacement pump, with equal pressures and volumes of air. In the latter machine, 1 cubic foot of free air compressed to 90 pounds pressure is easily the equivalent of 175 foot-gallons, or 1,450 foot-pounds of work. In preliminary calculations, it may be taken that, for each cubic foot of water pumped to an elevation of 210 feet, 9 cubic feet of free air will be required, compressed to a pressure of 90 pounds. This includes a fair allowance for losses in leakage, air absorbed by the water, and the small excess required to start the flow.

Direct-Acting Piston or Plunger Pumps.

The direct-acting piston pump, of simple or duplex type, has a most unenviable reputation as a "steam-eater." It is one of the most uneconomical devices known. Generally speaking, the simple pump is a little more economical than the duplex, but even the pump builder figures at 150 pounds of steam per horse power hour in his pumps. Some claim only 125 pounds. Others, in strictest confidence, will confess to from 175 to 250 pounds. The facts are elusive, but the first figure is a happy medium, and will serve the purpose in emphasizing the utterly wasteful character of the direct-acting pump, especially when it is remembered that the ordinary automatic steam engine, itself no miser of steam, requires 30 to 35 pounds of steam per horse power hour. Experiments have shown that under average conditions hardly 50 per cent. of the indicated horse power of the driving cylinder is utilized in the pump cylinder, the rest being absorbed partly by the engine as machine friction, but principally by the friction of the water in passage through valves and chambers.

From these facts it follows that when it is attempted to apply compressed air in place of steam to direct-acting piston pumps, the result is likely to be a system of air-consumers painful to the manager and ruinous in the reduction of profit. But if electricity were to be adopted in place of steam as a motive agent, the engineer who attempted to apply an electric motor to an old piston pump would do so at a most serious risk to his reputation as a man of sense as well as an engineer. He would more likely replace the old "steam-eaters" by high grade duplex or triplex power pumps, geared to motors and operating at high efficiency. Yet it is a piece of folly as rank as that already cited to apply compressed air, with any hope of economy, to a badly cut and worn steam pump, with driving cylinders probably incorrectly proportioned to the work, and a clearance out of all reason. If the same care and skill is exercised in applying compressed air as in adapting electric power, a pneumatic engineer being retained to select proper compressed air pumps and lay out a correct distribution system, compressed air as a power for pumps will be in much better repute. For the electric pump is characterized by high first cost, frequent attention, liability to short-circuits and burn-outs in damp locations, expensive maintenance, and annoying loss of time in repairs. Even a properly designed air-driven direct-acting pump may not show such intrinsic high net efficiency, but the compressed air system cannot be drowned out and lends itself more readily than the electric to the securing of economical results; and *results* are most important and desirable things. In a compressed air pumping system, with power properly produced, delivered and applied, there is no question whatever as to the saving in net horse power from coal-bin to pump.

The subject of pumping with air-driven, direct-acting pumps is a vast and important one, which, be it here confessed, has been sadly neglected not only by engineers in general, but by the manufacturers of air machinery themselves. It is worthy of closest study, and it is encouraging to note that it is to-day receiving the attention it deserves. Where compressed air is to be used for pumping exclusively, several methods of satisfactorily meeting the conditions are available, the merits of each one to be carefully weighed in the scale of local conditions.

One of the simplest and most efficient of these methods is that known as the "return pipe" or "closed circuit" system. In this the same air is used over and over again, the exhaust from the pumps being piped back to the compressor under a limited back pressure. The compressed air is a transmitter of power pure and simple, just as is a belt or transmission rope. But the medium never wears out, can be carried to any distance and at all angles, has no inherent friction, and enjoys the highest transmission efficiency. The system eliminates all trouble from freezing, since the air is used repeatedly and moisture once removed cannot be returned. While it requires two pipe lines instead of one, the pipe cost is often less because of the smaller pipe size permitted. The pump cylinders will be smaller because of the higher M. E. P., and the losses in clearance, often enormous, are entirely eliminated. But the greatest economy is secured in compression, the system being based upon the well-known fact that the greatest losses in compression occur at the lower pressures.

For instance, 8.46 H. P. are required to compress 100 cubic feet of free air from atmosphere to 30 pounds pressure. But if the initial pressure was 30 pounds the same amount of power would produce a pressure of 90 pounds. Now suppose this air at 90 pounds was applied to a pump exhausting at 30 pounds, the exhaust being piped back to the compressor, where the exhaust pressure became the initial pressure of compression. The available effective pressure at the pump would thus be 90 minus 30, or 60 pounds, and the power required in compression would be 8.46 H. P. On the other hand, suppose 100 cubic feet of free air was delivered to the pump at 60 pounds pressure, exhausting at atmosphere. This would give the same available, effective pressure at the pump and the same volume of free air, but it would be secured at the expenditure of 13.42 H. P. The return pipe system, therefore, of which the first instance is an example, in this case secures a saving in compression alone of 4.96 H. P.

Take an example of the working of the principle at higher pressures: 13.42 H. P. will compress 100 cubic feet of free air to 60 pounds pressure, starting at atmosphere. Starting with this air at 60 pounds the same power will compress it to 350 pounds, giving on the return pipe system 290 pounds available pressure with 60 pounds back pressure, all with the same amount of power required to secure 60 pounds available pressure with the open system. These examples illustrate the principle and possibilities of the closed pipe system. A reheater at the pump will secure additional economy. Losses through leakage in transmission will be supplied by a small "booster" compressor. Or where a limited amount of air is used from the system for purposes other than pumping, it will be withdrawn from the low pressure pipe and exhausted direct, the "booster" in this case being increased in capacity to supply this volume withdrawn from the circuit.

When pumps are only one, and perhaps a minor, application of the air of a plant, the return pipe system is not the best to adopt. In such cases high economy can be secured by the use of compound or triple pumps, reheating the air after each expansion. This may reduce the air consumption to one-half or one-third its value in a simple pump of the same capacity. In some cases this same result may be secured by the use of three pumps in series, reheaters being used as before after each expansion and the exhaust from one pump being supplied to the next, with a larger air cylinder. To secure the maximum of economy by this means, the air cylinders must, of course, be properly proportioned. Crank and flywheel pumps, essentially direct-acting and driven by air used expansively, have also been used with great economy in large units. Other methods of applying air expansively to pumps will be discussed under the next classification.

A common instance in which air for pumping would effect a material saving is found in factories and shops where a separate pumping station is maintained at a distant source of supply, to furnish water for the plant. One of two methods is usually employed, either the station contains separate small boilers (often in duplicate) with an attendant, or else a long steam line is run from the factory boiler plant to the pump. In the first method fuel is burned and steam generated in small uneconomical boilers. If the station is inaccessible by wagon or track, the fuel is probably high-priced. A separate attendant is required, combining the functions of engineer and fireman. Oil and waste are required for this little plant. The result is that the net cost of pumping is probably more than the cost of any other feature of the plant. In the second method, with a long steam transmission, two things result: First, there is a heavy condensation in the pipe, increasing the already enormous steam consumption charged to the pump; second, the capacity of the pump is reduced under the low steam pressure and wet steam due to condensation in the pipe. The economy (?) by this second method is probably about as high as by the first. Consider now the possibilities of air as applied to these cases. In all probability the factory has already a steam plant where steam is generated in high grade boilers with high economy of fuel. A high grade air compressor installed in the main engine room will use this steam economically. In the first case, an air pipe line will be laid to the pump, and the major expense of fuel and the entire expense of attendance and maintenance at the pump station will be removed. For even when a small slide valve compressor is used and the air applied to the old pumps, the actual fuel required to do the pumping with the compressor may be no more, and will probably be less, than under the old scheme, simply because of the greater steam economy of the larger boilers and the fact that the compressor may operate on the return circuit system described. The boilers will be left in place as a reserve when the main boiler plant is shut down. In the second case, the air compressor will be connected to the pipe line already laid, and the loss in pipe condensation and low pump performance is eliminated. The distant pumping station is now under full control of the engineer in the main plant, who visits the pumps perhaps once a day to fill the oil cups.

If still higher economy is desired a small reheater of simple form may be installed at the pump and the fire maintained in it by the fireman from the main plant, in a few visits daily. These represent instances in which a saving will be secured by the use of compressed air even in an uneconomical piston pump. But the greatest economy will be secured only when the compressor is designed for the work, the pump cylinders properly proportioned and the details of transmission and reheating correctly planned. While it is thus seen that it pays well to abandon the pump boilers and install air compressors in an old plant, in new installations a much greater saving can be effected by the use of air. For the first cost of boilers, settings and buildings is eliminated, going far toward paying for the air compressors.

Power-Driven Pumps.

The greatest advantage in the use of the power-driven pump when air is the driving power lies in the fact that it permits the expansive use of the air and makes possible the saving resulting. One instance of the expansive use of air for pumping was mentioned above, where the direct-acting crank-and-flywheel pump is employed. But greater possibilities along this line lie in the use of high grade expansive air engines direct-connected, belted, or geared to some form of duplex or triplex plunger pump, or to the simple, compound or turbine types of centrifugal pump in its various forms. Pumps of the first class are suitable to all duties where the direct-acting type could be used. But in connection with an economical air engine they are capable of an economy far beyond that of the second class.

Centrifugal pumps have come into prominence in recent years, and in the large modern compounded types are capable of lifts up to 2,000 feet. They have the advantage, shared with the displacement pump, of easily handling dirty, gritty water and that containing debris. Indeed, they have been extensively employed as suction dredges in harbor and drainage work. Nor are they limited to water in their application. They are compact and reliable, and in every way satisfactory. Used in connection with expansive air engines, they assure a high degree of economy in pumping operations.

Where the magnitude of the operation justifies it, the use of the "return pipe" system with expansive engines on pumps of this class will, in connection with reheaters, secure the very highest efficiency. In any case, where expansion is employed, and the location permits it, reheaters should be used. The extent to which reheating may be carried is a mooted question, but most recent investigations seem to indicate that initial cylinder temperatures of from 500 to 700 degrees

Fahrenheit may be employed, without attaining a mean cylinder temperature destructive to lubricants. The possibilities of expansion with such temperatures are not yet fully realized.

Reheating, of course, removes all difficulties from freezing at exhaust, by raising the terminal temperature. But even where there is no reheating, proper precautions will prevent all trouble on this score. The use of after-coolers at the compressor, the provision of ample receiver capacity, the proper grading of transmission lines, with a small receiver at the lowest point from which accumulated moisture may be drawn through a draincock—these safeguards remove all moisture from the compressed air, and when there is no water there can be no freezing.

There are some makeshifts for preventing freezing, such as lubrication with glycerine or the injection of a small water jet into air cylinder or exhaust port. But these are essentially makeshifts and should receive no consideration in a properly planned plant.

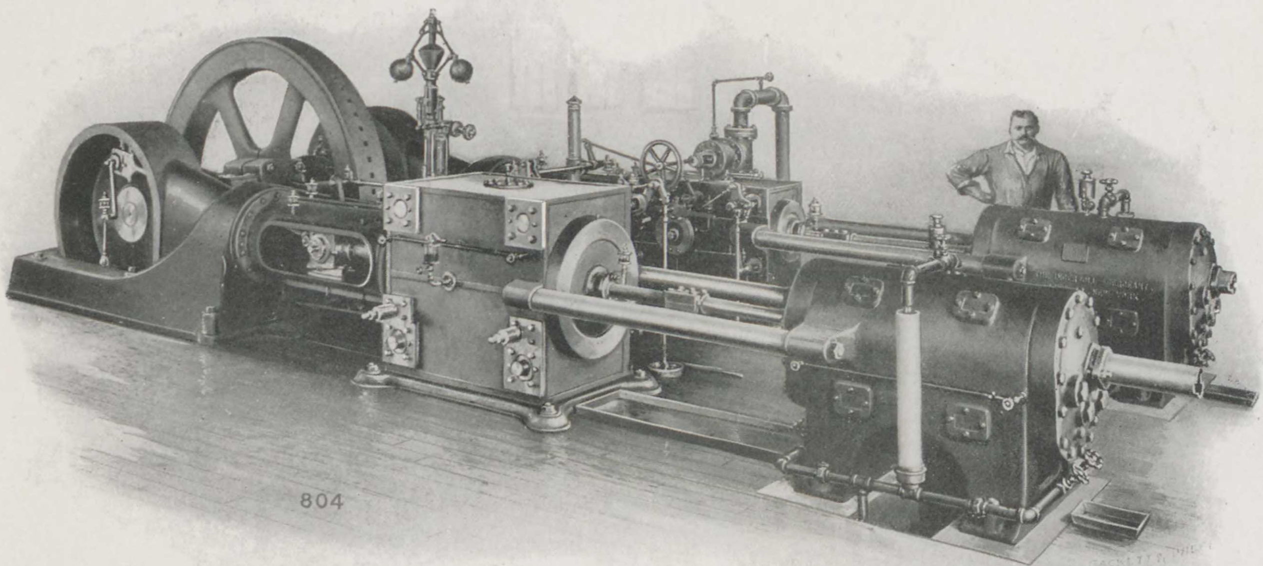
In Conclusion.

In conclusion be it said that the subject of pumping with compressed air is a very broad one, requiring the combination of the best engineering skill with sound practical experience. The pages preceding have shown some of its possibilities and made clear the fact that extreme economy need not be neglected. Water can be pumped by compressed air with good results and high economy, and this in places where steam is forbidden and electricity, even at its best, would be very much at a disadvantage.

The rules on page 94 are designed to be of assistance to engineers or others figuring on operating pumping plants by compressed air. They will aid in considering ordinary steam pumps. But in every case it is better that full information as to conditions be placed in the hands of the machine builder, who will then be able to properly advise. The Ingersoll-Sergeant Drill Company, therefore, subjoins the list following as a guide. Upon receipt of the information tabulated, they will advise in full.

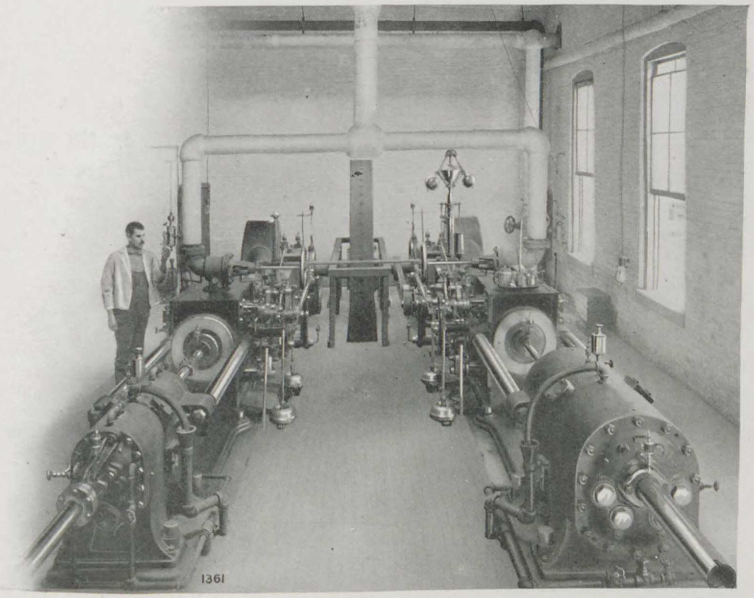
1. Total vertical lift between water levels.
2. Total horizontal distance.
3. Rise and fall of water level.
4. All cylinder dimension of pumps now in use.
5. Diameter and length, and number of elbows, in water pipe leading from pump to point of discharge.
6. Diameter, length and vertical height of suction pipe.

7. Amount of water required per minute, in gallons.
8. Hours per day plant is to run.
9. Horse power of boilers now required to run pumps.
10. Steam pressure on present boilers.
11. Purpose for which water is used.
12. Amount of coal per hour at present burned to run pumps.
13. Distance from proposed compressor to pump.
14. Character of water as to acids, grit, debris, etc.
15. Cost of fuel.



Corliss Air Compressor at the Springfield (N. J.) Air Lift Plant of the Elizabethtown Water Co.

The compressor has a capacity of 1993 cubic feet of free air per minute and pumps from 53 driven wells, scattered over an area of 107 acres. The wells vary from 250 to 750 feet in depth and 6 to 10 inches in diameter. The final maximum air pressure used is 95 pounds.



An Ingersoll-Sergeant Corliss Air Compressor with Simple Steam and Compound Air Cylinders.

This type of compressor is sometimes used for operating large Air Lift plants.

ABOUT AIR COMPRESSORS.

As the efficiency and satisfactory working of an Air Lift outfit largely depends upon the character and operation of the machine for compressing the air, you should make no mistake in the selection of your air compressor.

Low First Cost.

We do not advise equipping a plant with a cheap compressor, as the wastefulness and shortcomings of such machines are likely to damage the general reputation of the system. It was early found that many of the cheap and inefficient compressors first sent out had to be replaced before the best results could be realized, because the repairs, annoyances and delays incidental to their use made up a great many times over the difference in the first cost between such a compressor and one which was built for high-duty service and continuous operation year after year.

Delays through breakdowns are costly in the double sense of repairs and inconvenience from the failure of the water supply. In the case of municipal water works, shutdowns throw the community open to serious danger from fire.

Best Is the Cheapest.

The old saying, "The best is the cheapest, irrespective of cost," is true of air compressors, as well as any other article.

It is a fundamental fact in business, and especially in the air compressor business, that a high-grade machine, the best in its line, does and always will command a higher price. The difference in price between the best compressor and one not so good, divided by the

Testing an Air Lift Pump, Bad Axe, Mich.

number of days in the ten or fifteen years of use, amounts to but a few cents a day, and this may be regarded as cheap insurance against breakdowns, incidental delays, or fires.

The high reputation which Ingersoll-Sergeant compressors enjoy is the result of maintaining their position in the forefront through continued improvement in material and methods of construction.

This admits of only the best grades of metal in every detail and workmanship of the most exact and reliable character. The metals which are used in their construction are 25 per cent. better than are called for in the United States Government specifications.

A variety of types to meet different conditions are manufactured by this company. Some of the compressors most suited for air lift work are illustrated on pages 60 to 70. Full information as to sizes, dimensions and capacities is contained in the Compressor Catalog which will be sent on request.

Selection of an Air Compressor.

The type of compressor best suited depends upon the conditions existing in the customer's power plant. If there is available sufficient engine power which will always be running whenever it is necessary to operate the Air Lift, a belt-driven compressor can usually be installed most economically, especially for small and moderate quantities of water in manufacturing establishments where the engine in use is a Corliss or other highly economical type. But it does not pay to run a large engine especially to drive a small compressor for more than a very short time.

If there is available cheap electric current and no spare steam or belt power we can furnish compressors built to be driven direct by an electric motor, the motor to be furnished either by our customer or by ourselves. Sometimes a water power may be used to operate either a belt-driven or direct-connected compressor. We can furnish machines complete, connected to Pelton or turbine water wheels.

For medium and large quantites of water it is usually best to put in complete steam-driven compressors having either Meyer cut-off or Corliss steam cylinders, often compounded, and in many cases run condensing, using in the condenser the water pumped by the compressor before passing it to its final uses.

The size of the compressor depends on the quantity of water to be pumped and upon the lift and *not upon the number of wells.*

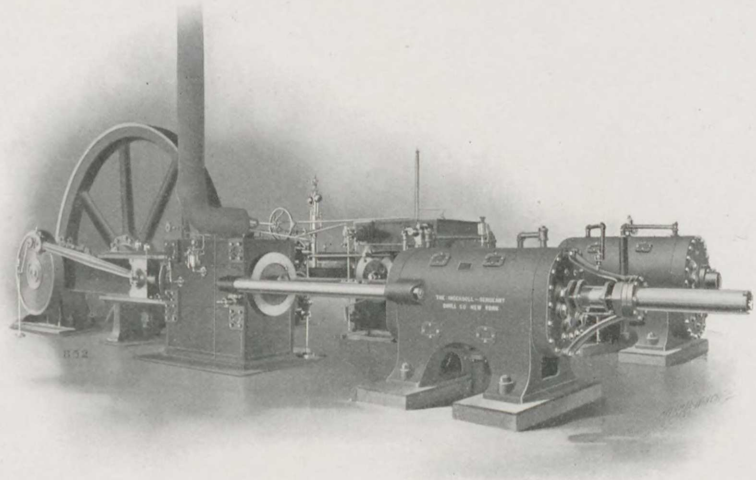
The design of the steam end depends mostly upon the steam pressure available and as to whether a condenser is to be used.

The design of the air end and its size relative to the steam end depends upon the vertical lift to be met and the depth of submergence that will be available; in other words, upon the air pressure that will be required to give the best results.

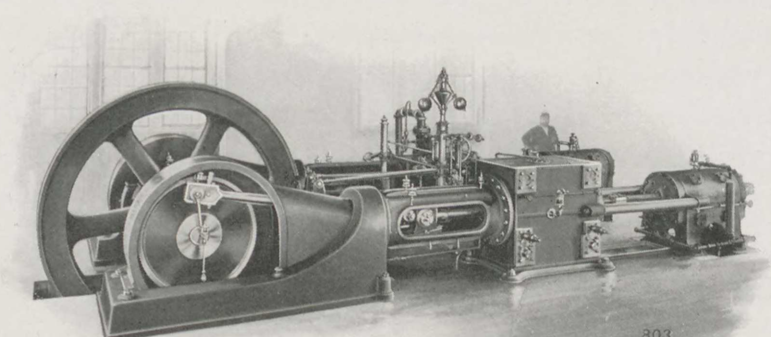
These points are all best left to us to determine, as our wide experience has fitted us to make the best selection for the interests of our customers. In order that we may understand your conditions fully we should have full information as asked for in the question sheet to be found at the back of this catalog.

STEAM-DRIVEN COMPRESSORS.

Duplex and Half Duplex Corliss Compressors Class "C."



Girder Frame, Duplex Air.

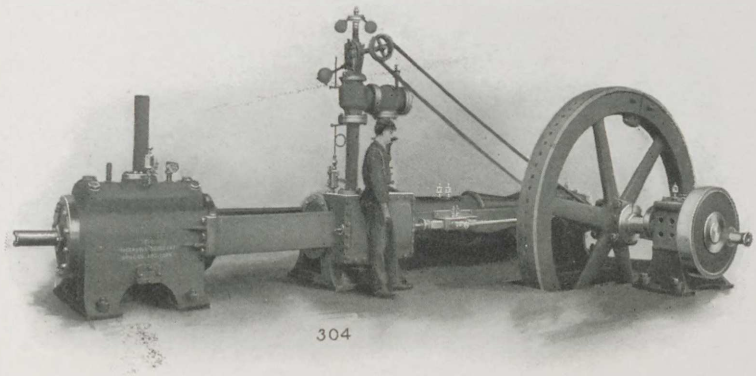


Heavy Duty Frame, Duplex Air.

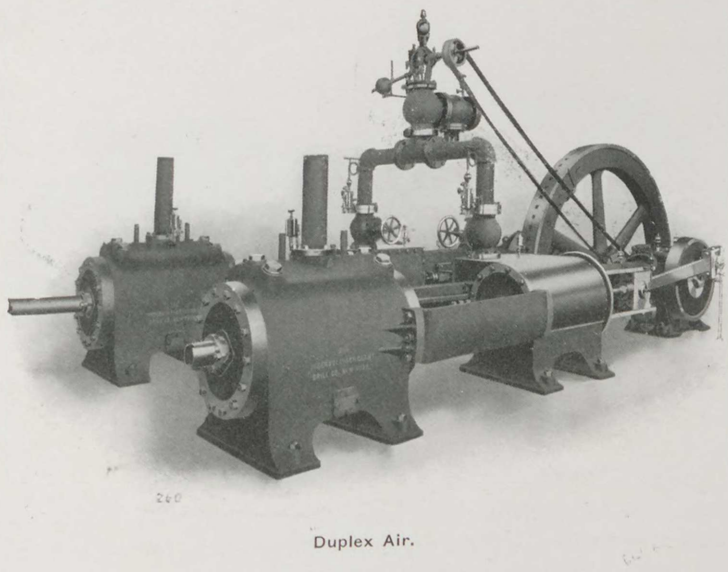
These compressors are built with all combinations of air and steam cylinders and for all air pressures. They are suited for all lifts of large or medium capacity.

STEAM-DRIVEN COMPRESSORS.

Duplex and Half Duplex Class "G" and "GC."



Half Duplex.

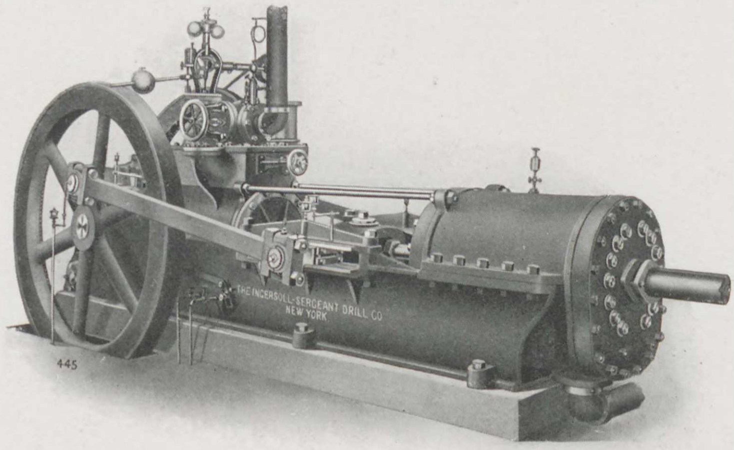


Duplex Air.

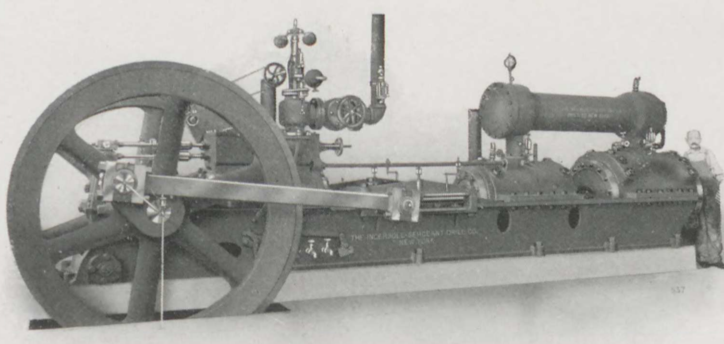
These compressors are built with all combinations of air and steam cylinders, for air pressures from 15 to 700 pounds per square inch and in capacities from 177 to 4,940 cubic feet of free air per minute. They are suited for all lifts of large or medium capacity.

STEAM-DRIVEN COMPRESSORS.

Straight-Line Class "A" and "AC."



Simple Air.

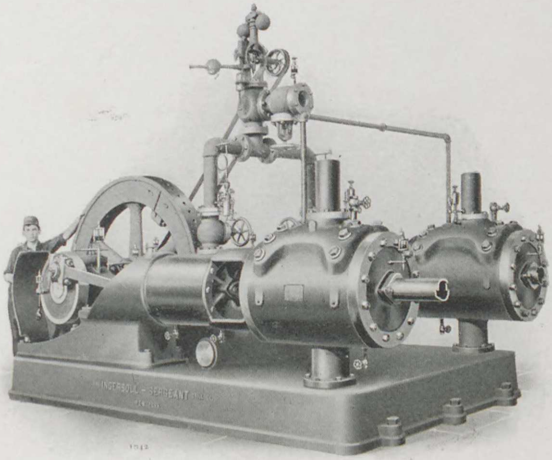


Two-Stage Air.

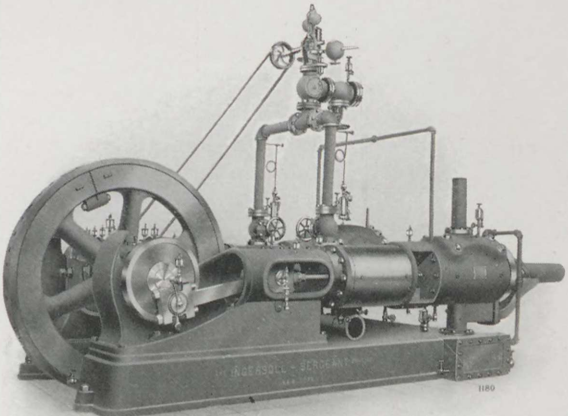
These compressors are built with simple steam and simple or compound air cylinders, for air pressures from 15 to 700 pounds and in capacities from 177 to 1,904 cubic feet of free air per minute. The single stage machines are suitable for lifts of 200 feet or less and of medium capacity. The two-stage machines can be used for greater lifts of like capacity.

STEAM-DRIVEN COMPRESSORS.

Duplex Self-Contained Class "H" and "HC."



Duplex Air.

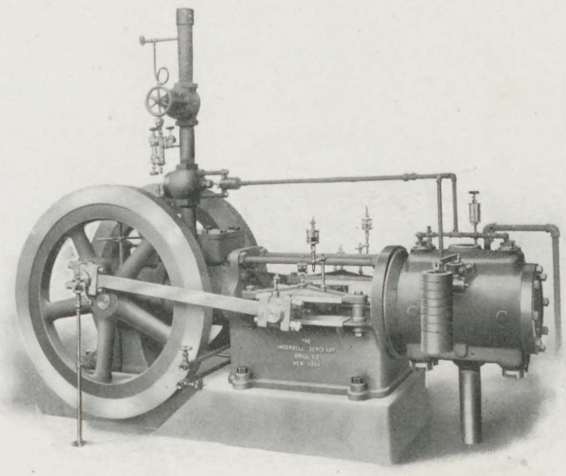


Two-Stage Air.

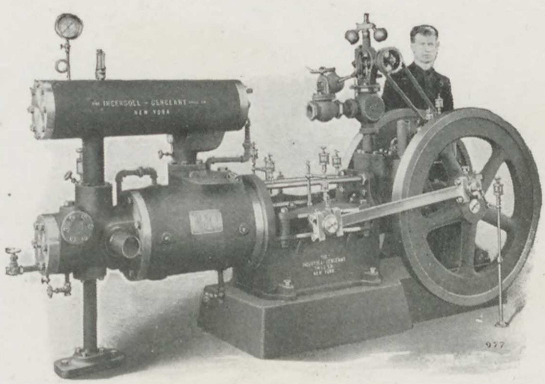
These compressors are built with all combinations of air and steam cylinders, for air pressures from 15 to 700 pounds per square inch and in capacities from 58 to 2,216 cubic feet of free air per minute. The single stage machines are suitable for lifts of 200 feet or less and of moderate to large capacities. The two-stage machines can be used for greater lifts of like capacities.

STEAM-DRIVEN COMPRESSORS.

Small Straight Line Class "F" and "FC."



Simple Air.

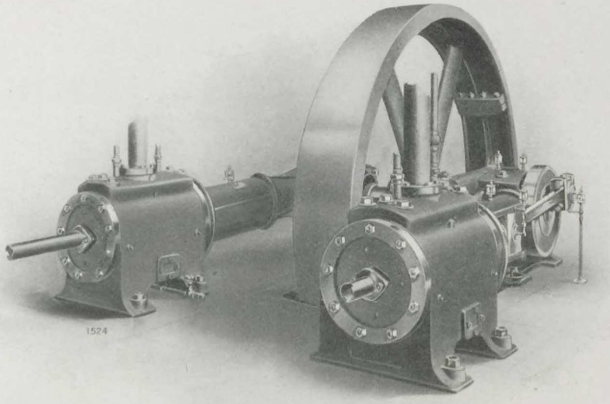


Two-Stage Air.

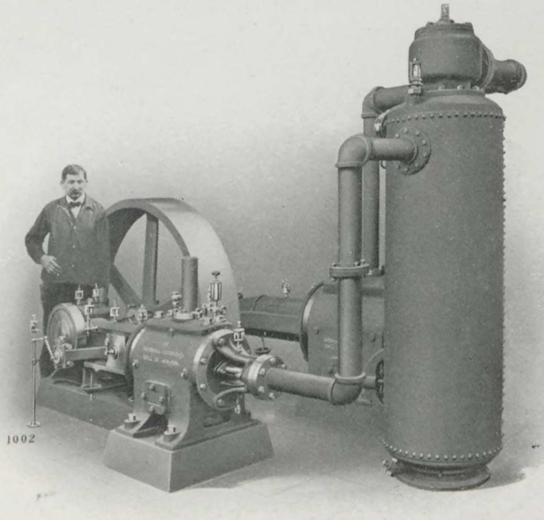
These compressors are built with simple steam and simple or compound air cylinders, for air pressures from 15 to 1,000 pounds per square inch and in capacities from 15 to 523 cubic feet of free air per minute. The single stage machines are suitable for lifts of 150 feet or less and of small or moderate capacity. The two stage machines can be used for greater lifts of small capacity.

POWER-DRIVEN COMPRESSORS.

Duplex and Half Duplex Class "D" and "DC."



Duplex Air.

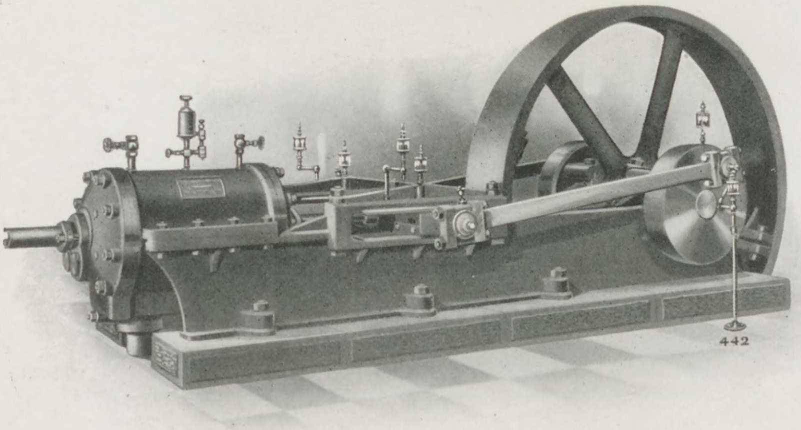


Two-Stage Air.

These compressors are built with duplex or compound air cylinders for any form of power drive, for air pressures from 15 to 700 pounds per square inch and in capacities from 176 to 4,358 cubic feet of free air per minute. They are suitable for all lifts of medium capacity.

POWER-DRIVEN COMPRESSORS.

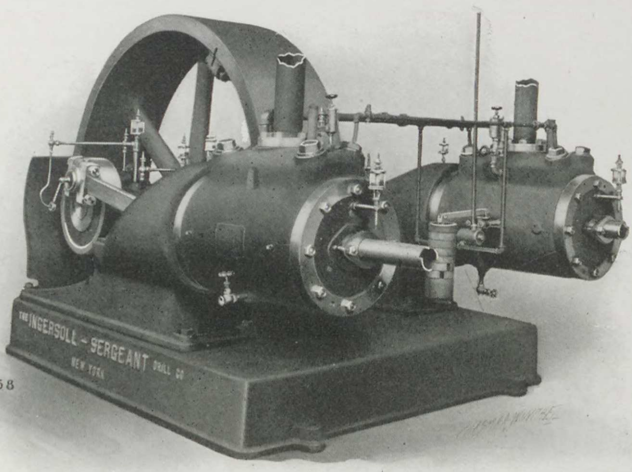
Straight Line Class "B."



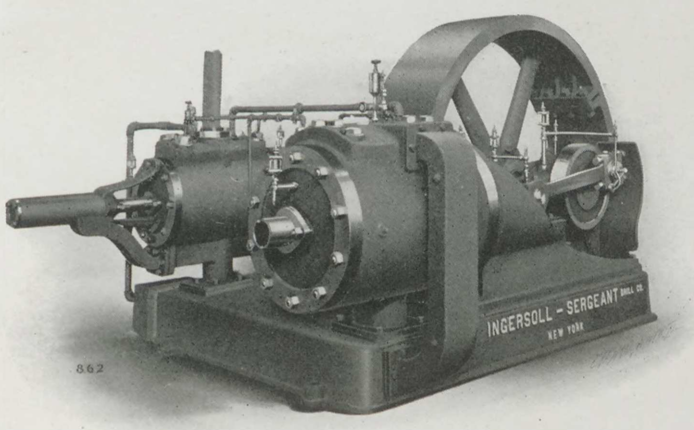
These compressors are built with simple air cylinders for any form of power drive, for air pressures from 20 to 100 pounds per square inch and in capacities from 177 to 924 cubic feet of free air per minute. They are suitable for moderate lifts of medium capacity.

POWER-DRIVEN COMPRESSORS.

Duplex Self-Contained Class "J" and "JC."



Duplex Air.

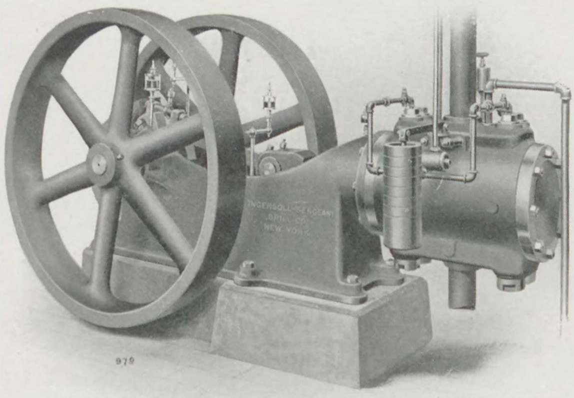


Two-Stage Air.

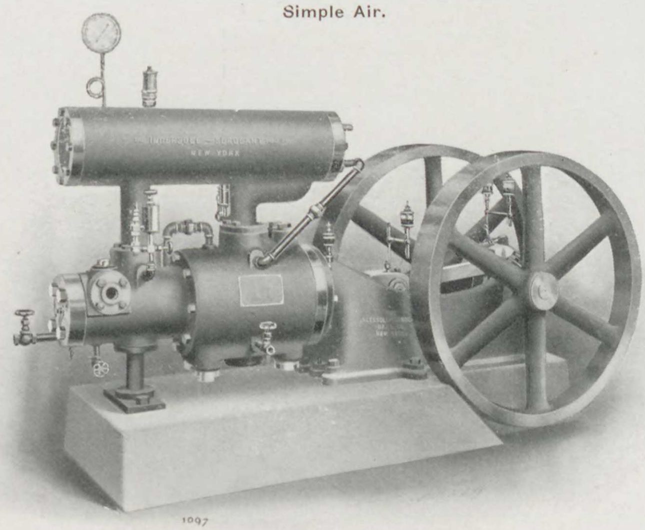
These compressors are built with duplex or compound air cylinders for any form of power drive, for air pressures from 15 to 700 pounds per square inch and in capacities from 58 to 2,216 cubic feet of free air per minute. The single stage machines are suitable for lifts of 200 feet or less and of moderate to large capacities. The two stage machines can be used for greater lifts of like capacities.

POWER-DRIVEN COMPRESSORS.

Small Straight Line Class "E" and "EC."

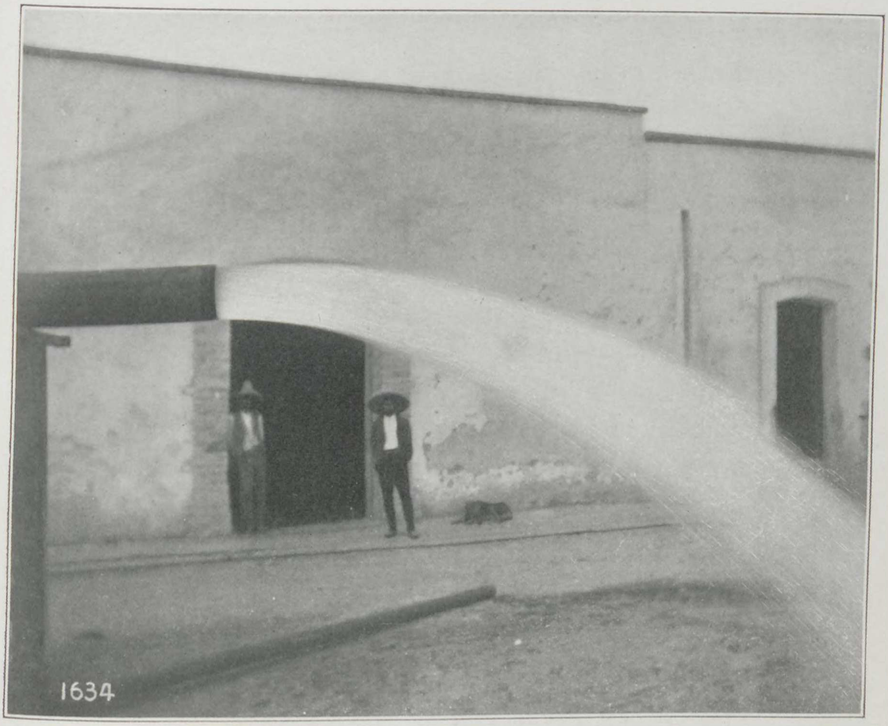


Simple Air.



Two-Stage Air.

These compressors are built with single or compound air cylinders for any form of power drive, for air pressures from 15 to 1,000 pounds per square inch, and in capacities from 15 to 526 cubic feet of free air per minute. The single stage machines are suitable for lifts of 150 feet or less and of small or moderate capacity. The two stage machines can be used for greater lifts of small capacity.



An Air Lift Plant at a Cotton Plantation, near the City of Mexico, Mexico, showing the flow from the well when the Air Lift is in operation.

While the power-driven types of air compressors, illustrated on the preceding pages, are shown for belt-drive, they can be furnished for gear or chain drive to electric motor or Pelton water wheel. Full details as to the possible modifications of these types, with sizes and dimensions, are given in the Compressor Catalog, which will be sent on request.

RECORD OF EXPERIENCE.

It is impossible to list any standard Air Lift plants, as the conditions vary so widely. Two plants with identical requirements are very rare indeed. It is interesting, however, to note just what is accomplished where the Air Lift is in practical operation. We have selected a few paragraphs from some of the many letters received from our customers as chronicling a record of experience well worth reading.

Increasing the Flow.

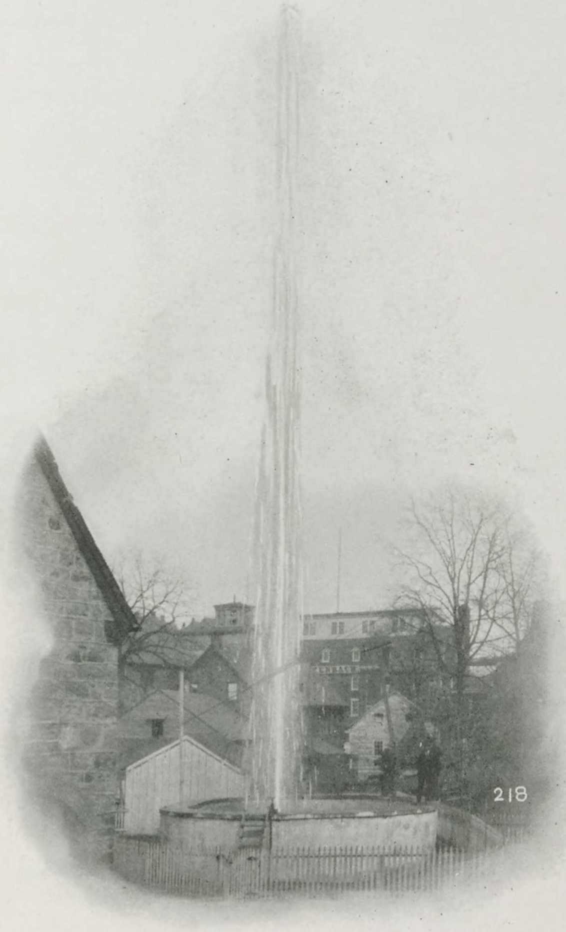
Geo. W. Chandler, City Engineer at Canton, Ill., writes concerning their Air Lift plant:

"We have had one of your air compressors at work for the last three years. I would say that the actual cost laid out on the compressor, for the three years that it has been in service, is comparatively nothing. As the machine is regulated by the governor working automatically after turning on the steam, and oiling, it takes care of itself and does the work of lifting 400 gallons per minute, from the one artesian well. After using the Air Lift process for three years in our artesian well I can see no difference in the amount of water obtained from the well; if any, I think that the flow is increased."

Obtaining More Water.

Here is the comment of Mr. T. W. Burns, of the Fairbury, Ill., Water Works:

"I am obtaining more water with the Air Lift than I could with any form of pump that I have ever seen. I am so well satisfied with the superiority of this system that I have recommended it to several committees from other places that have been here seeking information as to the best system of pumping water from deep wells. While I have only one compressor and one pump I haven't been compelled to shut the water off from the town in four years."

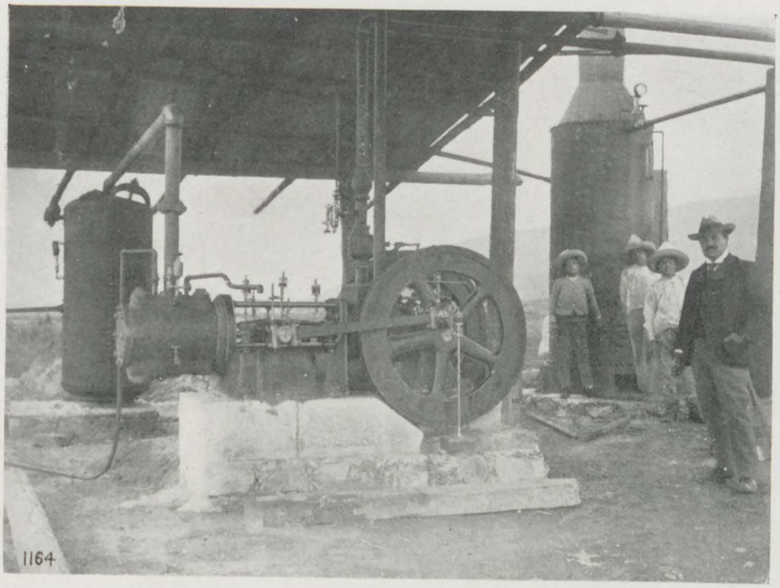


Flow of Water From a Well Operated by an Air Lift.

Eight Years of Service.

To the point is the statement of Wm. J. Corkindale, Superintendent of the Calumet Lighting Company, at Harvey, Ill.:

"We put in a straight line compressor of your make in 1895. In 1901 we put in a Corliss type of your make and both machines have given us good satisfaction. During the past eight years I do not believe that our repairs have cost us to exceed twenty dollars. We are getting twice as much water out of our wells as we did under the old system."



Air Compressor Plant at a Hacienda near Mexico City, showing a Class "F" Compressor, Air Receiver and Boiler.

Compared with a Deep Well Pump.

An interesting comparison of the Air Lift System and deep well pumps is made by E. L. Church, Superintendent of the Water Department of the City of Harvard, Ill.:

"Before putting in the system we used a deep well pump, but found our well (1,600 feet deep) unable to stand a steady service for only a short time, and our pump was continually getting out of order. Since putting in the Air Lift, although an increasing demand for water, we have not exhausted the well, even after several hours' steady service at a much increased capacity over the old pump. We don't know how much more capacity the well may have. Besides this we have had no repairs and no trouble."

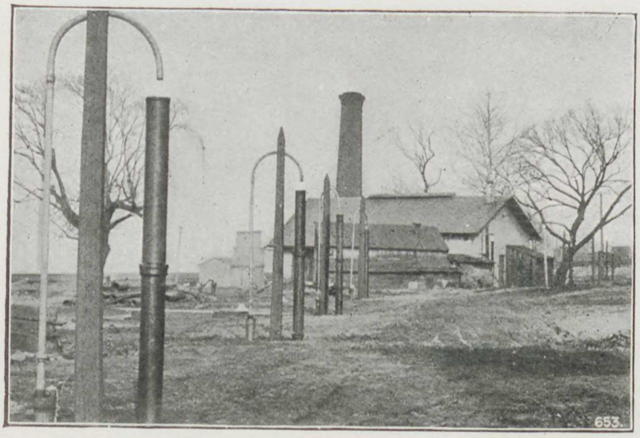
Discharge Pipe from an Air Lift at a Hacienda near Mexico City. The Compressor Plant, as Illustrated on the Opposite Page, is shown in the Background.

Three Times as Much Water.

Some idea of the efficiency of the Air Lift System is given by John Ernest, Chief Engineer of the Hoopeston, Ill., Water Works:

"After air compressor was in place and connected we pumped a day to have everything in good order outside of reservoir. On the next day we put the well for a test for quantity, and we found that the Air Lift furnishes nearly three times as much water as the deep well pump. By measurement we find we raise 16,000 gallons of water every 40 minutes.

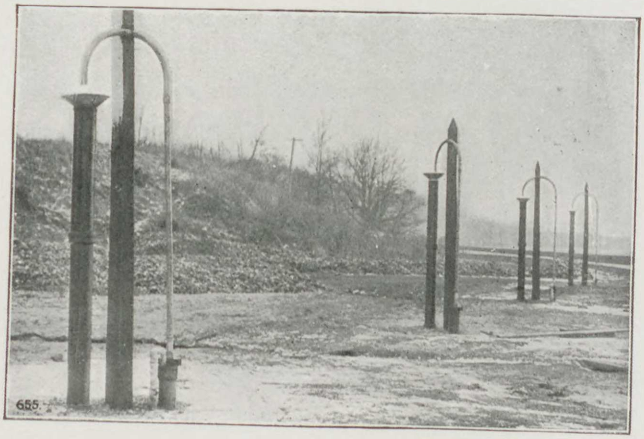
"We are highly pleased with the Air Lift and compressor, and we can recommend it to anybody that wants a modern outfit to get water quick and plenty, and to get rid of the clumsy deep well pump."



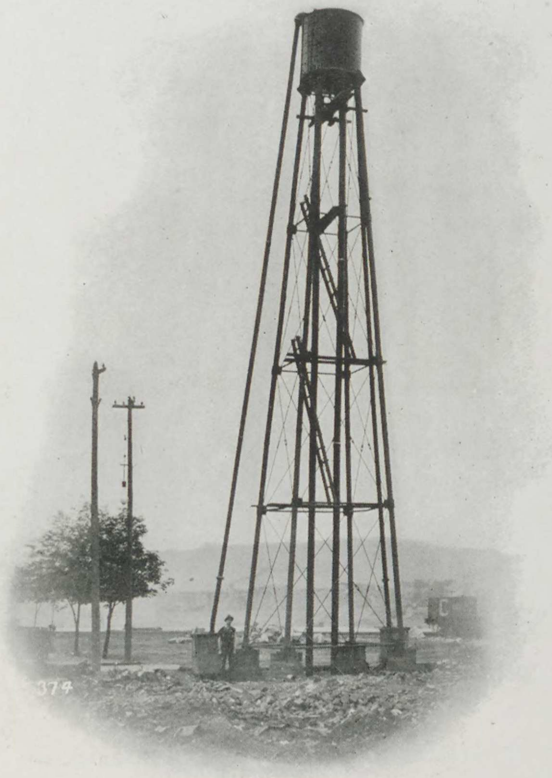
Air Lift Plant at the Government Hospital for the Insane, Anacostia, D. C.

Twenty wells driven along the Anacostia River. They are from 200 to 300 feet deep.

The risers shown in the illustration are used to give a head sufficient to force the water into an adjacent reservoir.



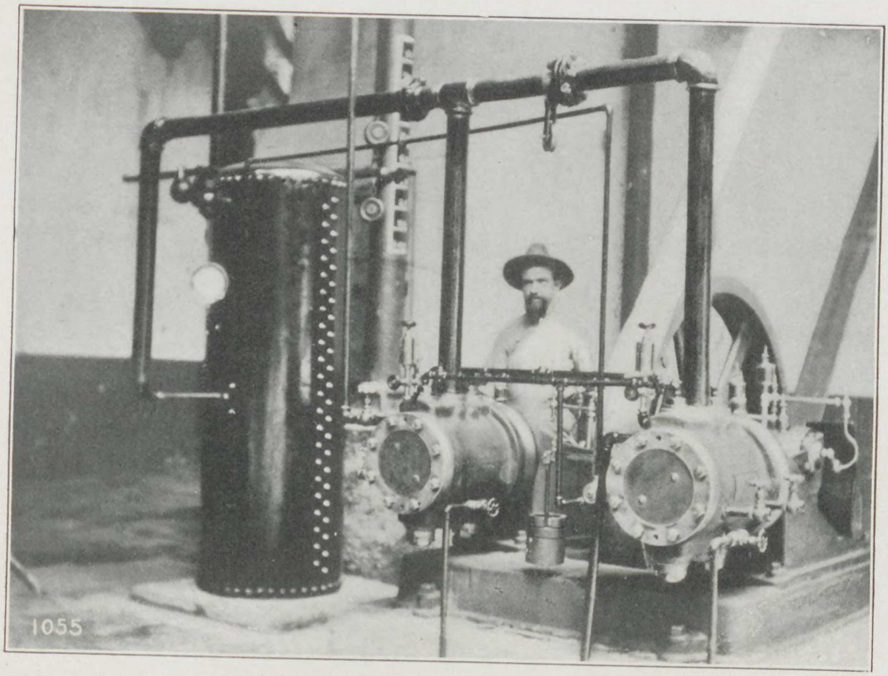
Air for pumping the wells is obtained from a duplicate plant consisting of two Class "A" Compressors.



Not a Minute's Trouble in a Year and a Half.

A good record this, for an air compressor which has been in operation for a year and a half at the Argos, Ind., Water Works. The Superintendent, A. A. Yarick, says:

"It has not given one minute's trouble and not one cent's worth of repairs since it was started. The well that it works on is a 6-inch well, 116 feet deep, and we only use 35 pounds of air to operate it. The compressor has increased the flow of the well, as you will plainly see, as we have a reservoir that holds 800 barrels that we pump into. The first time that I filled the reservoir it took 1 hour and 40 minutes; the second time, 1 hour and 30 minutes, and the last time, about three months ago, it took 1 hour and 15 minutes to throw the same amount of water. This does not go to show that it decreased the water in the well, but I know that it has increased the flow in this well that I operate."



Air Compressor Plant to Operate an Air Lift at the San Antonio Abad Cotton Mills, Mexico, Showing a Class "J" Machine and an Air Receiver.

Flow Strong and Steady.

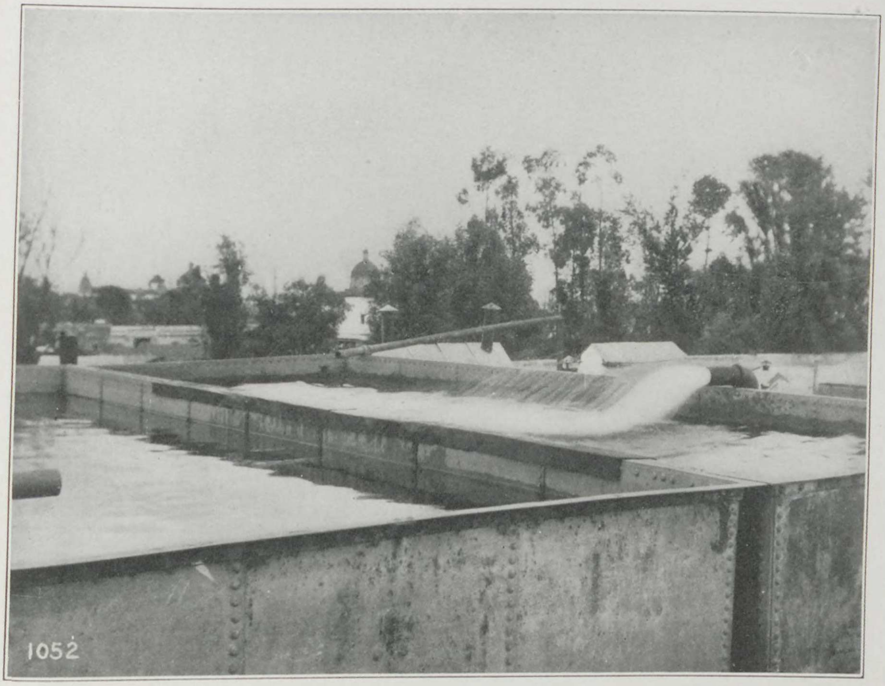
Three years of service at the village of Maywood, Ill., brings the following from the Chairman of the Village Finance and Water Committee:

"The machinery is in good condition after its three years of use, and we find our waterflow to be as strong and as steady as it was before during the time of the deep well pumps we had in at first. We have had practically no repairs or improvements to make and have been lifting an average of 350,000 gallons a day during all this period."

Not One Cent for Repairs.

W. B. McHenry, Mayor of Rochelle, Ill., tells of that city's experience with an Air Lift plant installed four years before:

"The supply from the well is as strong to-day as the first day the compressor was started. During this time we have not been obliged to shut down for any repair whatever, and the compressor has not cost the city one cent for repairs."



Reservoirs for the Air Lift on the Roof at the San Antonio Abad Cotton Mills, Mexico City, Showing 5-inch Discharge Into the Tanks.

Increased Flow 84 Per Cent.

A case where the demand for an increased water supply was met by the Air Lift System is instanced by Superintendent Arthur McArthur, of the Dubuque, Iowa, Water Works:

"With the use of air we have increased the normal flow from our 10-inch wells fully 84 per cent., with comparatively small increase in coal consumption.

"There has been no diminution in the flow from the wells, and, in fact, we can see a slight increase."

Cost of Eight Years' Service.

A record for eight years of service is given by W. E. Reynolds, Clerk of the Board of Trustees of Public Affairs at Celina, O.:

"We have been using the Ingersoll-Sergeant Drill Company's compressor and Air Lift for pumping water at our plant for the past eight years with the best results. The expense in the way of repairs on the machinery to present would not exceed $30, notwithstanding the fact that our consumption of water is double what it was when the plant was installed."

Air Lift Plant at Plattsmouth, Neb., showing an Elevated Trough which brings the water from the Wells to the Reservoirs.

Convinced by a Test.

One of many instances where actual tests have proven the value of the air lift system is given by J. C. Goodrich, Superintendent of the Water Works at the city of Grinnell, Iowa:

"We began using the new compressor about the first of March and have run it an average of 13 hours per day ever since, pumping at the rate of 130 gallons per minute, with no expense for repairs.

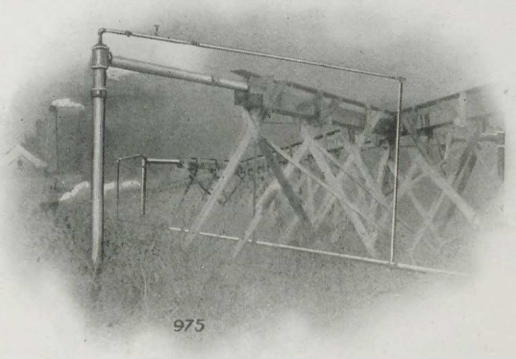
"We will admit that we were skeptical at first in regard to the efficiency of the air lift, but are now satisfied that it is the ideal way to raise water from an artesian well, as we have proved by actual test we can pump water cheaper with the air lift than with the ordinary artesian pump."

Wells a Mile Apart.

A great advantage of the Air Lift System over other methods of deep well pumping is pointed out by Superintendent B. Lewis, of the Corsicana (Tex.) Water Supply Company:

"We have been using your air machine on two wells for about four years, and in February, 1902, we put on a third well. Your machine was guaranteed to blow two wells a mile apart, but it successfully blows all three of our wells, and the last well is as far from the centre on one side as the second well is on the other side, of the city. When we put on the third well we increased the speed a little—about 15 revolutions per minute.

"The three wells have a natural flow of about 95,000 gallons per day. We blow out about 700,000 gallons per day, and we see no decrease since we began with them."



Air Lift Plant at Plattsmouth, Neb., showing the Wells Emptying into the Elevated Trough Shown in the Illustration on the Opposite Page.

Better Than the Deep Well Pump.

Users of the deep well pump may read with interest the statement of E. P. Fisher, Superintendent of the London, O., Water Works Company:

"I had in use for three years a deep well pump which required incessant use to supply the daily consumption of water.

"Last summer I put in one of your Air Compressors, by which I am enabled to get the same supply in from three to four hours' work with the compressor.

"The wells are as strong to-day as they were before we commenced to force them with air, and it has enabled me to meet any increased demand to come."

Seven Years' Repairs.

The record made by an air compressor and Air Lift installation made for the city of Elkhorn, Wis., is given by the Superintendent of the plant, Paul Prisk:

"The machine has run about seven years without any repairs except two valve springs, and has given satisfaction to the city. We get out of our well at least 50 gallons per minute more than with the deep well engine it displaced. After five years I thought the air pipe would need looking after, and we pulled it up and measured the water level and found it the same as it was seven years ago. I made a test of well this year, and after eleven (11) hours' pumping the air pressure was the same as at the start. Our lift is heavy, 160 feet to water level, and it requires an air pressure of 118 pounds to the inch, so you see our 12x12¼-inch compressor is worked hard and has stood the test of seven years without any breakdown."

Discharge Pipe at One of the Wells. Air Lift Plant, Ravenna, O.

Increased the Delivery Many Times.

C. W. Wiles, Superintendent of the Delaware, O., Water Company, gives some interesting facts concerning his experience with the air lift:

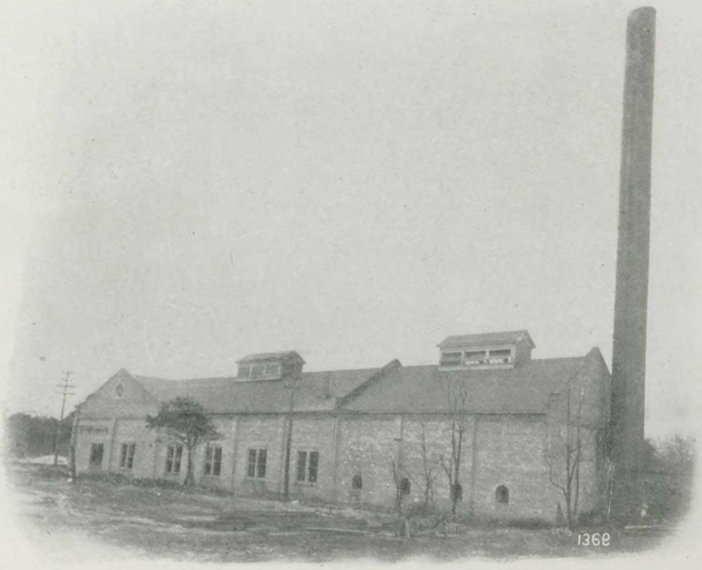
"We have had in use one of your air compressors for delivering water from deep wells since 1895; from that date to 1902 we were taking water from one well 255 feet deep; this well had a small natural flow, but the application of compressed air developed a flow equal to the body of the well, increasing the delivery many times.

"In 1902, we put in another 8-inch well and connected the air, and have the same result, maintaining the increased flow from ten to fourteen hours continuously each day; the forced flow from these wells has not diminished, in fact, we believe they are fully as strong as when we first began the use of air.

The First Municipal Air Lift Plant.

"The use and operation of compressed air in these wells have met the increased demand for water, and we will in time, if demand increases, put in another well.

"The only cost for repairs to the compressor since it was installed has been $1.25 for springs."



Water Works at Ocean Grove, N. J., where the Air Lift is in Successful Operation.

Reliability and Economy.

Reliability and economy—see how they figure in the experience of the Plattsmouth (Neb.) Water Company, according to the statement of T. H. Pollock, Superintendent and Secretary of that company:

"In the three years which we have used the air compressor system furnished by your company, we have had practically no expense whatever in the way of repairs.

"For several years previous to the installation of the air lift, we were obliged to do a great deal of night pumping in order to keep up the supply of water in our reservoirs, and during the winter months we had great difficulty in maintaining the supply, but since we installed the Ingersoll-Sergeant air compressor we have never had to pump a single night, using the compressor only from six to eight hours per day.

"We are using the air lift on five 8-inch wells, our only source of supply, and we are certain that the wells will produce as much, if not more, water than when we first began using them."

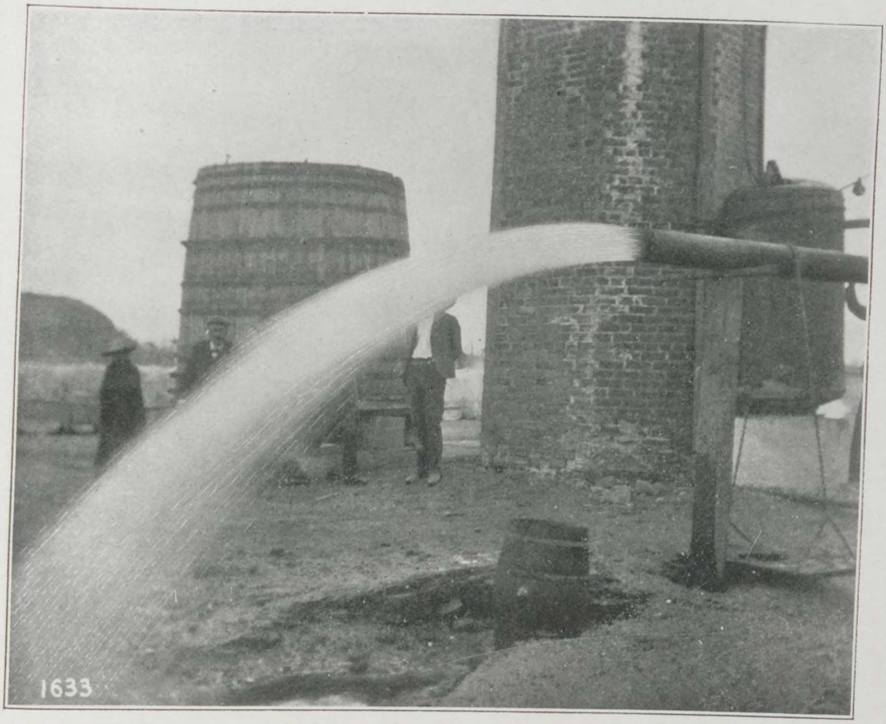
Natural Flow from an Artesian Well at a Mexican Cotton Plantation.

No Repairs in Four Years.

Houston, Tex., has found the Air Lift of great value. The Chief Engineer of its water company, John Crummy, says:

"This plant has been using water from artesian wells for city supply since 1888, the wells having a natural flow of from 100,000 to 1,000,000 gallons per 24 hours, according to their size and depth or strata from which they secure their supply. We are now using 35 such wells. In 1899, the rapid growth of the city having reached the capacity of these wells, we put in, after the trial of a small machine, a large Corliss compound piston inlet air compressor, piping the compressed air to the wells by common iron pipe. This plan at once increased the capacity of the wells, so that we had plenty of water.

"Though this machine has now been here for over four years, I am glad to say that we have no charges for repairs on our books against this engine up to date, and it is yet in splendid condition."



Flow from an Artesian Well at a Mexican Cotton Plantation, After the Installation of the Air Lift

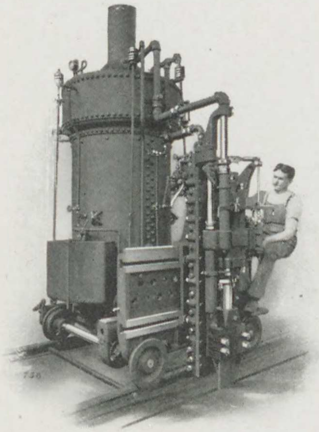
Double the Natural Flow.

From Zimmerman Davis, Secretary and Treasurer of the Charleston Light and Water Company, of Charleston, S. C., comes the following testimonial:

"We have been using your air lift in two deep artesian flowing wells for several years, and take pleasure in stating that by its use we obtain a daily increase of at least double the natural flow of the wells."

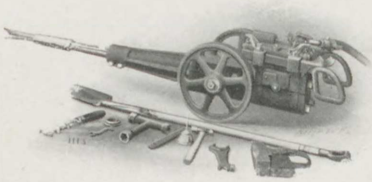
QUARRY AND COAL MINE MACHINERY

Quarry Machines



Track, "Broncho" and Undercutting Channelers. Gadders and Quarry Bars. For Granite, Marble, Sandstone and all Rocks. Steam and Air Driven.

Catalog No. 60



"New Ingersoll" Coal Cutters

Undercutting Pick Machines without a kick. Easiest on the runner. Economical of power and repairs.

Catalog No. 52

"Radialax" Coal Cutters

For shearing, undercutting and entry driving. Operated by compressed air.

Pamphlet No. 353

Rotary Coal Drills

Light, strong, portable, powerful.

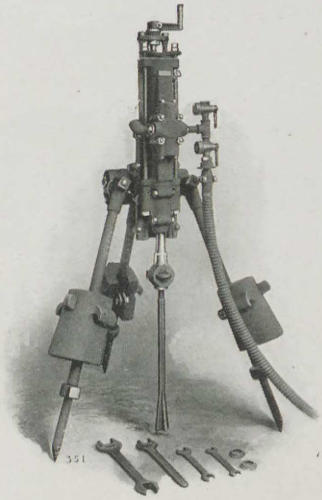
ROCK DRILLS

FOR

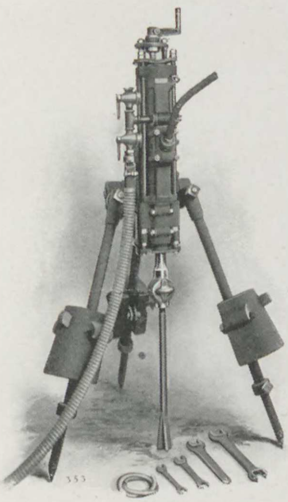
MINE, TUNNEL, QUARRY and CONTRACT

The Sergeant "Auxiliary Valve" Drill

The most powerful, effective and reliable drill for hard, medium or soft rock.



Catalog No. 43



The Sergeant "Arc Valve Tappet" Drill

The only successful application of the tappet principle. Especially adapted for the use of steam.

The "Little Jap" Hammer Drill

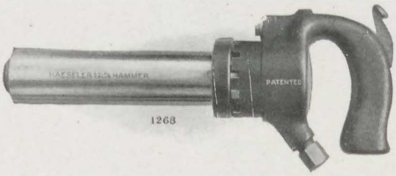
A Hand Machine

For sinking pop holes, drilling plug and feather holes, stoping, squaring up, cutting hitches, trimming walls, drilling anchor holes, and all light work of rock excavation.

Bulletin No. 2001

PNEUMATIC TOOLS

HAESELER
"AXIAL VALVE" HAMMERS

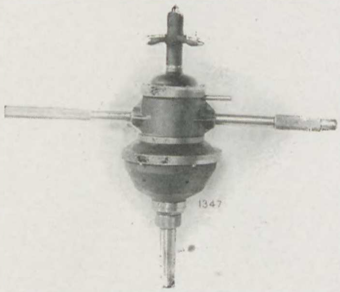


For

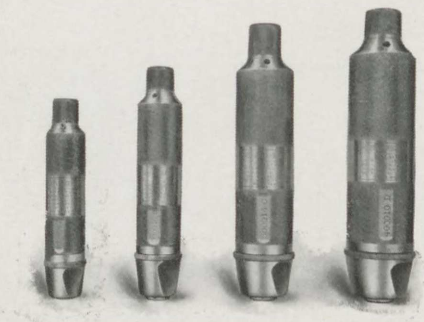
Chipping, riveting, calking, flue beading, etc., in shop, foundry, structural work and field.

Catalog No. 6

Haeseler Rotary Piston Drills



For drilling, boring, reaming, tapping, flue expanding and similar work.



Ingersoll-Sergeant Stone Tools

For every process of stone dressing and every grade of stone.

Bulletin No. 2004

Useful Information

for the

Engineer

Air Mains, Initial and Final Pressures.

45 Pounds Initial Gauge Pressure

Reduction of Final Pressure in 500 Feet

Diameter of Pipe Inches	1 Pound	2 Pounds	3 Pounds	5 Pounds	7 Pounds	9 Pounds	12 Pounds
1	14	20	24	30	34	37	40
1¼	26	36	44	54	62	68	74
1½	43	60	72	90	102	112	121
2	95	132	159	198	226	247	268
2½	172	239	287	358	409	446	484
3	281	390	470	585	667	728	791
3½	419	583	701	874	997	1080	1180
4	595	827	995	1240	1410	1540	1670
4½	806	1120	1340	1680	1910	2090	2270
5	1050	1470	1770	2200	2510	2740	2980
6	1690	2350	2820	3520	4020	4380	4760
7	2500	3480	4190	5220	5950	6500	7060
8	3520	4900	5890	7340	8370	9140	9930
9	4770	6630	7970	9930	11300	12300	13400
10	6240	8680	10400	13000	14800	16100	17600

60 Pounds Initial Gauge Pressure

Diameter of Pipe Inches	1 Pound	2 Pounds	3 Pounds	5 Pounds	7 Pounds	9 Pounds	12 Pounds
1	16	22	27	34	39	43	48
1¼	29	41	49	62	72	79	87
1½	48	67	81	102	117	129	143
2	107	149	180	226	259	286	315
2½	193	269	325	408	469	516	569
3	315	440	532	667	766	844	930
3½	471	657	794	996	1140	1260	1380
4	668	932	1120	1410	1620	1780	1970
4½	905	1260	1520	1910	2190	2420	2660
5	1180	1650	2000	2510	2880	3170	3500
6	1890	2650	3200	4010	4610	5080	5590
7	2810	3920	4740	5950	6840	7530	8290
8	3960	5520	6670	8370	9620	10500	11600
9	5350	7470	9020	11300	13000	14300	15700
10	7010	8710	11800	14800	17000	18700	20700

75 Pounds Initial Gauge Pressure

Reduction of Final Pressure in 500 Feet

Diameter of Pipe Inches	1 Pound	2 Pounds	3 Pounds	5 Pounds	7 Pounds	9 Pounds	12 Pounds
1	18	25	30	38	44	48	54
1¼	32	45	55	69	80	89	98
1½	53	74	90	113	131	145	161
2	117	164	199	251	289	320	356
2½	212	296	359	453	523	579	643
3	346	484	587	740	855	946	1050
3½	517	723	876	1100	1270	1410	1560
4	734	1020	1240	1560	1810	2000	2220
4½	994	1390	1680	2120	2450	2710	3010
5	1300	1820	2210	2780	3220	3560	3950
6	2080	2910	3530	4450	5140	5690	6320
7	3090	4320	5230	6600	7630	8440	9370
8	4350	6070	7360	9290	10700	11800	13100
9	5880	8220	9960	12500	14500	16000	17800
10	7710	10700	13000	16400	19000	21000	23300

90 Pounds Initial Gauge Pressure

Diameter of Pipe Inches	1 Pound	2 Pounds	3 Pounds	5 Pounds	7 Pounds	9 Pounds	12 Pounds
1	19	27	33	41	48	53	60
1¼	35	49	59	75	87	97	109
1½	57	80	97	123	143	159	178
2	127	178	215	273	316	351	394
2½	229	321	390	493	572	635	712
3	375	525	636	806	934	1030	1160
3½	560	784	950	1200	1390	1550	1730
4	794	1110	1340	1700	1980	2190	2460
4½	1070	1500	1820	2310	2680	2970	3330
5	1410	1970	2390	3030	3510	3900	4370
6	2250	3160	3830	4850	5620	6240	6990
7	3340	4680	5680	7190	8340	9260	10300
8	4700	6590	7990	10100	11700	13000	14500
9	6360	8930	10800	13600	15800	17600	19700
10	8340	11600	14100	17900	20700	23000	25800

Air Mains, Initial and Final Pressures.

Initial Gauge Pressure, 105 Pounds.

Diam. Pipe.	Reduction of Final Pressure in 500 Feet.						
	1 lb.	2 lbs.	3 lbs.	5 lbs.	7 lbs.	9 lbs.	12 lbs.
1 in.	20	29	37	44	52	58	65
1¼ "	37	52	68	81	94	105	118
1½ "	61	86	111	133	155	172	194
2 "	129	190	245	294	341	380	427
2½ "	245	344	443	531	617	687	772
3 "	401	562	724	867	1,000	1,120	1,260
3½ "	599	839	1,080	1,290	1,500	1,670	1,880
4 "	850	1,190	1,530	1,830	2,130	2,370	2,670
4½ "	1,150	1,610	2,070	2,480	2,890	3,220	3,610
5 "	1,510	2,110	2,720	3,260	3,790	4,220	4,750
6 "	2,410	3,380	4,350	5,220	6,070	6,760	7,590
7 "	3,580	5,010	6,460	7,740	8,990	10,000	11,200
8 "	5,030	7,050	9,080	10,800	12,600	14,000	15,800
9 "	6,810	9,540	12,200	14,700	17,100	19,000	21,400
10 "	8,920	12,500	16,100	19,200	22,400	24,900	28,000

Example.

It is required to deliver 2,000 cubic feet of equivalent free air at the end of a pipe line 1,500 feet long, the initial pressure being 60 pounds, and the loss of pressure not to exceed 10 pounds; what diameter of pipe must be used?

By table of 60 pounds initial pressure under 3 pounds loss, and opposite 5 inch diameter of pipe, we see that the delivery would be 2,000 cubic feet, so that for a pipe line 1,500 feet long, the loss of pressure would be about 3x1,500÷500=9 pounds. We say "about" 9 pounds, because the loss is not exactly proportional to the length, but nearly so when the basis of length is 500 feet.

Globe Valves, Tees and Elbows.

The reduction of pressure produced by globe valves is the same as that caused by the following additional lengths of straight pipe, as calculated by the formula:

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})}$$

Diameter of pipe	1	1½	2	2½	3	3½	4	5	6 inches
Additional length	2	4	7	10	13	16	20	28	36 feet

7	8	10	12	15	18	20	22	24 inches
44	53	70	88	115	143	162	181	200 feet

The reduction of pressure produced by elbows and tees is equal to two-thirds of that caused by globe valves. The following are the additional lengths of straight pipe to be taken into account for elbows and tees. For globe valves multiply by $\frac{3}{2}$:

Diameter of pipe	1	1½	2	2½	3	3½	4	5	6 inches
Additional length	2	3	5	7	9	11	13	19	24 feet

7	8	10	12	15	18	20	22	24 inches
30	35	47	59	77	96	108	120	134 feet

These additional lengths of pipe for globe valves, elbows and tees must be added in each case to the actual lengths of straight pipe. Thus, a 6-inch pipe, 500 feet long, with 1 globe valve, 2 elbows and 3 tees, would be equivalent to a straight pipe 500 + 36 + (2 x 24) + (3 x 24) = 656 feet long.

Table of Standard Dimensions of Wrought Iron Pipe.

Nominal Inside Diameter.	Actual Inside Diameter.	Actual Outside Diameter.	Internal Area Square Inches.	External Area Square Inches.	U. S. Gallon per Foot of Pipe.	Weight of Pipe per Lineal Foot.
Inches.	Inches.	Inches.	Sq. Inches.	Sq. Inches.	Gallons.	Pounds.
⅛	.270	.405	.057	.1288	.0029	.24
¼	.364	.540	.104	.2290	.0054	.42
⅜	.493	.675	.191	.3578	.0099	.56
½	.622	.840	.304	.554	.0158	.84
¾	.824	1.050	.533	.866	.0277	1.12
1	1.048	1.315	.861	1.358	.0447	1.67
1¼	1.380	1.660	1.496	2.164	.0777	2.24
1½	1.610	1.900	2.036	2.835	.1058	2.68
2	2.067	2.375	3.356	4.430	.1743	3.61
2½	2.468	2.875	4.780	6.492	.2483	5.74
3	3.067	3.500	7.383	9.621	.3835	7.54
3½	3.548	4.000	9.887	12.566	.5136	9.00
4	4.026	4.500	12.730	15.904	.6613	10.66
4½	4.508	5.000	15.961	19.635	.829	12.34
5	5.045	5.563	19.986	24.301	1.038	14.50
6	6.065	6.625	28.890	34.472	1.500	18.76
7	7.023	7.625	38.738	45.664	2.012	23.27
8	7.981	8.625	50.027	58.426	2.599	28.18
9	8.937	9.625	62.730	72.760	3.259	33.70
10	10.018	10.75	78.823	90.763	4.095	40.06
11	11.000	11.75	95.033	108.434	4.937	45.02
12	12.000	12.75	113.098	127.677	5.875	49.00
13	13.25	14	137.887	153.938	7.163	54.00
14	14.25	15	159.485	176.715	8.285	58.00
15	15.25	16	182.665	201.062	9.489	62.00

Standard Dimensions of Couplings for Steam, Gas and Water Pipe—Black and Galvanized.

Size of Pipe, Nominal, Inside Diameter.	Inside Diameter of Coupling.	Outside Diameter of Coupling.	Outside Area of Coupling.	Length of Coupling.	Thread per Inch of Screw.	Average Weight of Coupling in Pounds.
Inches.	Inches.	Inches.		Inches.		
⅛	11-32	19-32	.276	13-16	27	.031
¼	15-32	23-32	.405	15-16	18	.046
⅜	37-64	27-32	.559	1 1-16	18	.078
½	23-32	1	.785	1 5-16	14	.124
¾	63-64	1 21-64	1.382	1 9-16	14	.250
1	1 11-64	1 9-16	1.917	1 13-16	11½	.455
1¼	1½	1 61-64	2.953	2⅛	11½	.562
1½	1¾	2 7-32	3.832	2⅜	11½	.800
2	2 7-32	2¾	5.939	2⅝	11½	1.250
2½	2 21-32	3 9-32	8.419	2⅞	8	1.757
3	3¼	3 15-16	12.177	3⅛	8	2.625
3½	3 25-32	4 7-16	15.466	3⅝	8	4.000
4	4 17-64	5	19.635	3⅝	8	4.125
4½	4¾	5½	23.758	3⅝	8	4.875
5	5 9-32	6 7-32	30.347	4⅛	8	8.437
6	6 11-32	7 5-16	41.991	4⅛	8	10.625
7	7⅜	8 5-16	54.255	4⅛	8	11.270
8	8⅜	9 5-16	68.078	4⅝	8	15.150
9	9 7-16	10⅜	84.541	5⅛	8	17.820
10	10 7-16	11 21-32	106.688	6⅛	8	27.700
11	11 15-32	12 21-32	125.78	6⅛	8	33.250
12	12 7-16	13⅞	151.20	6⅛	8	43.187
13	13 11-16	15 1-16	178.16	6⅛	8	49.280
14	14 23-32	16⅜	210.60	6⅛	8	63.270
15	15 11-16	17⅜	237.10	6⅛	8	66.000

Contents in Cubic Feet and U. S. Gallons of Cylinders of Various Diameters, and One Foot in Length.

For 1 Foot in Length.			For 1 Foot in Length.			For 1 Foot in Length.		
Diameter in Inches.	Cubic Feet; also Area in Square Feet.	U. S. Gallons, 231 Cubic Inches.	Diameter in Inches.	Cubic Feet; also Area in Square Feet.	U. S. Gallons, 231 Cubic Inches.	Diameter in Inches.	Cubic Feet; also Area in Square Feet.	U. S. Gallons 231 Cubic Inches.
1	.0055	.0408	11¾	.7530	5.633	42	9.621	71.97
1¼	.0085	.0638	12	.7854	5.875	43	10.085	75.44
1½	.0123	.0918	12½	.8522	6.375	44	10.559	78.99
1¾	.0167	.1249	13	.9218	6.895	45	11.045	82.62
2	.0218	.1632	13½	.994	7.436	46	11.541	86.33
2¼	.0276	.2066	14	.069	7.997	47	12.048	90.13
2½	.0341	.2550	14½	1.147	8.578	48	12.566	94.00
2¾	.0412	.3085	15	1.227	9.180			
3	.0491	.3672	15½	1.310	9.801			
3¼	.0576	.4309	16	1.396	10.44			
3½	.0668	.4998	16½	1.485	11.11			
3¾	.0767	.5738	17	1.576	11.79			
4	.0873	.6528	17½	1.670	12.49			
4¼	.0985	.7369	18	1.768	13.22			
4½	.1134	.8263	18½	1.867	13.96			
4¾	.1231	.9206	19	1.969	14.73			
5	.1364	1.020	19½	2.074	15.51			
5¼	.1503	1.125	20	2.182	16.32			
5½	.1650	1.234	20½	2.292	17.15			
5¾	.1803	1.349	21	2.405	17.99			
6	.1963	1.469	21½	2.521	18.86			
6¼	.2131	1.594	22	2.640	19.75			
6½	.2304	1.724	22½	2.761	20.66			
6¾	.2485	1.859	23	2.885	21.58			
7	.2673	1.999	23½	3.012	22.53			
7¼	.2867	2.145	24	3.142	23.50			
7½	.3068	2.295	25	3.409	25.50			
7¾	.3276	2.45	26	3.687	27.58			
8	.3491	2.611	27	3.976	29.74			
8¼	.3712	2.777	28	4.276	31.99			
8½	.3941	2.948	29	4.587	34.31			
8¾	.4176	3.125	30	4.909	36.72			
9	.4418	3.305	31	5.241	39.21			
9¼	.4667	3.491	32	5.585	41.78			
9½	.4922	3.682	33	5.940	44.43			
9¾	.5185	3.879	34	6.305	47.16			
10	.5454	4.08	35	6.681	49.98			
10¼	.5730	4.286	36	7.069	52.88			
10½	.6013	4.498	37	7.467	55.86			
10¾	.6303	4.715	38	7.876	58.92			
11	.66	4.937	39	8.296	62.06			
11¼	.6903	5.164	40	8.727	65.28			
11½	.7213	5.396	41	9.168	68.58			

Friction of Water in Pipes.

Pressure in Pounds per Square Inch to be added for each 100 Feet of Clean Pipe.

Gallons per Min. Delivered	PIPE SIZES.											
	2	2½	3	3½	4	5	6	7	8	9	10	12
5	.04	.02	....	....	....	....	....	....	....	....	....	....
10	.12	.04	.02	....	....	....	....	....	....	....	....	....
15	.25	.08	.04	.02	....	....	....	....	....	....	....	....
20	.42	.14	.06	.03	....	....	....	....	....	....	....	....
25	.62	.21	.10	.04	.02	....	....	....	....	....	....	....
30	.91	.30	.13	.06	.03	....	....	....	....	....	....	....
35	1.22	.40	.17	.09	.05	.02	....	....	....	....	....	....
40	1.60	.53	.23	.11	.06	.02	....	....	....	....	....	....
45	1.99	.66	.28	.14	.07	.03	....	....	....	....	....	....
50	2.44	.81	.35	.17	.09	.04	....	....	....	....	....	....
60	3.50	1.17	.50	.24	.13	.05	.02	....	....	....	....	....
70	4.80	1.50	.60	.38	.19	.07	.03	....	....	....	....	....
75	5.32	1.80	.74	....	....	....	....	....	....	....	....	....
80	6.30	2.00	.90	.41	.23	.08	.03	....	....	....	....	....
90	7.80	2.58	1.10	.54	.26	.09	.04	....	....	....	....	....
100	9.46	3.20	1.31	.64	.33	.12	.05	.02	....	....	....	....
125	14.9	4.89	1.99	.96	.49	.17	.07	.03	....	....	....	....
150	21.2	7.00	2.85	1.35	.69	.25	.10	.04	....	....	....	....
175	28.1	9.46	3.85	1.82	.93	.34	.13	.05	....	....	....	....
200	37.5	12.47	5.02	2.38	1.22	.42	.17	.07	....	....	....	....
250	....	19.66	7.76	3.70	1.89	.65	.26	.12	.07	.04	.03	.01
300	....	28.06	11.2	5.04	2.66	.93	.37	.17	.09	.05	.04	....
350	....	....	15.2	7.10	3.65	1.26	.50	.23	.12	.07	.05	.02
400	....	....	19.5	9.25	4.73	1.61	.65	.30	.16	.09	.06	....
450	....	....	25.0	11.70	6.01	2.00	.81	.37	.20	.11	.07	.03
500	....	....	30.8	14.5	7.43	2.40	.96	.45	.25	.14	.09	.04
750	....	....	....	....	....	....	2.21	1.03	.53	.30	.18	.08
1000	....	....	....	....	....	....	3.88	1.80	.94	.53	.32	.13
1250	....	....	....	....	....	....	6.00	2.85	1.46	.82	.49	.20
1500	....	....	....	....	....	....	8.60	4.08	2.09	1.17	.70	.29

Table is based on Ellis' and Howland's Experiments. To find "Friction Head" in feet multiply figures by 2.3.

Friction of Water in Elbows.

Pressure in Pounds per Square Inch to be added for each Elbow.

Gallons per Min. Delivered	PIPE SIZES.										
	2	2½	3	3½	4	5	6	7	8	9	10	12
5												
10	.002	....	....	....	....	....	....	....	....	....	....	....
15	.006	.003	....	....	....	....	....	....	....	....	....	....
20	.014	.005	....	....	....	....	....	....	....	....	....	....
25	.025	.012	.005	....	....	....	....	....	....	....	....	....
30	.038	.02	.008	....	....	....	....	....	....	....	....	....
35	.055	.028	.011	....	....	....	....	....	....	....	....	....
40	.076	.037	.015	.009	....	....	....	....	....	....	....	....
45	.098	.049	.02	.011	.007	....	....	....	....	....	....	....
50	.125	.062	.026	.015	.009	....	....	....	....	....	....	....
60	.153	.08	.032	.017	.01	....	....	....	....	....	....	....
70	.22	.112	.044	.026	.015	.006	.003	....	....	....	....	....
75	.304	.148	.06	.035	.021	.009	.004	.002	....	....	....	....
80	.35	.172	.072	.04	.024	.01	.005	.003	....	....	....	....
90	.392	.196	.08	.044	.027	.012	.005	.003	....	....	....	....
100	.50	.248	.104	.06	.035	.014	.007	.004	....	....	....	....
125	.612	.32	.128	.068	.043	.017	.008	.005	.003	.002	....	....
150	.970	.48	.20	.112	.067	.027	.013	.007	.004	.003	.002	....
175	1.39	.685	.286	.16	.096	.039	.019	.01	.006	.004	.003	.001
200	1.90	.935	.390	.218	.132	.053	.026	.014	.009	.005	.004	.002
250	2.44	.128	.512	.272	.172	.068	.032	.02	.011	.007	.005	.002
300	3.86	1.91	.80	.446	.268	.109	.025	.029	.017	.011	.007	.004
350	5.56	2.74	1.14	.64	.384	.156	.076	.042	.025	.016	.01	.005
400	....	3.77	1.58	.88	.530	.215	.103	.057	.034	.022	.014	.007
450	....	5.12	2.05	1.09	.688	.272	.128	.08	.044	.028	.018	.009
500	....	6.20	2.58	1.45	.870	.352	.170	.094	.057	.036	.023	.011
750	....	7.64	3.20	1.78	1.07	.436	.208	.116	.068	.044	.028	.016
1000	....	....	....	....	2.42	.970	.470	.260	.156	.10	.063	.031
1250	....	....	....	....	4.28	1.74	.832	.464	.272	.176	.112	.064
1500	....	....	....	....	6.70	2.71	1.31	.728	.435	.276	.175	.086
	....	....	....	....	9.68	3.88	1.88	.84	.624	.40	.252	.124

Table is based on Weisbach's formula for very short bends, or with a radius equal to the radius of the pipe. To find "Friction Head" in feet multiply figures by 2.3.

RULES FOR CALCULATING PUMPS.

Rule 1.

To find the capacity of a double-acting pump: square the diameter of the water cylinder and for a single cylinder pump, multiply by 4; for a duplex pump multiply by 8; for a triplex pump multiply by 12; and for a quadruplex pump multiply by 16. This gives the discharge in gallons per minute at piston speed of 100 feet. For piston speed other than 100 feet, multiply the result secured as above by the ratio of the given speed to 100. Thus for speed of 80 feet, multiply by .8.

Rule 2.

To find the diameter of a double-acting pump to discharge the given volume of water: for single cylinder pumps divide the discharge in gallons by 4; for duplex pumps by 8; for triplex by 12; and for quadruplex by 16.

Extract the square root of the result so secured, giving the diameter in inches of the water cylinder of the pump which at 100 feet piston speed will deliver the required volume.

For piston speed other than 100 feet divide the discharge by the ratio of the given piston speed to 100 and proceed as above.

Rule 3.

To find the size of a pump to feed a given boiler: multiply the boiler horse power by 6 and divide the result by 100. This gives the required discharge of the pump in gallons per minute, and the size of the pump may then be found by Rule 2. *Boiler feed pumps should not run at a piston speed of more than 30 to 50 feet.*

Note.

The results secured by these rules are not exact but are sufficiently close for all practical purposes.

INDEX.

MAIL AND EXPRESS JOB PRINT
9-15 MURRAY ST., N. Y.

The Ingersoll-Sergeant Drill Co

Information Needed for Estimate on Air Lift Pumping Outfit

1. How many wells are to be pumped? ....

2. Entire depth:

No. 1...........ft. No. 2...........ft. No. 3...........ft. No. 4...........ft.

3. Inside diameter casing at top:

No. 1...........in. No. 2...........in. No. 3...........in. No. 4...........in.

4. If inside diameter is reduced, state at what depth below surface and to what diameter:

No. 1 at........ft. No. 2 at........ft. No. 3 at........ft. No. 4 at........ft.
to........in. to........in. to........in. to........in.

5. If any further reduction in diameters state fully below:

No. 1..

No. 2..

No. 3..

No. 4..

6. To what depth is well cased?

No. 1...........ft. No. 2...........ft. No. 3...........ft. No. 4...........ft.

Is casing air tight?...................... If not, where is leak?

7. What make, length, diameter and depth to strainers?

No. 1........ .... Bottom open or closed?..........................

No. 2........................ Bottom open or closed?.......... ....

No. 3........................ Bottom open or closed?..........................

No. 4........................ Bottom open or closed?..........................

8. How far below the surface does the water stand when not pumping?

No. 1...........ft. No. 2...........ft. No. 3...........ft. No. 4....... ....ft.

9. If well flows, how many gallons per minute at surface?

No. 1.........gals. No. 2.........gals. No. 3.........gals. No. 4.........gals.

10. What natural head or pressure do they have at surface when closed ?

No. 1........... lb. No. 2............lb. No 3............lb. No. 4............lb.

11. If wells have been pumped, at how many gallons per minute ?

No. 1.........gals. No. 2........ gals. No. 3.........gals. No. 4.........gals.

12. How far below the surface did the water level fall when giving the above quantity?

No. 1............ft. No. 2............ft. No. 3............ft. No. 4............ft.

13. At what depth below the surface is the water obtained?

No. 1............ft. No. 2............ft. No. 3............ft. No. 4............ft.

14. Was the pump used a suction, deep well or air lift?..............................

15. State all cylinder diameters, length of stroke, speed, and WHETHER DUPLEX or SINGLE: ....

16. How far above the ground surface do you wish to raise the water?..........ft.

17. How far horizontally from the well is it to be discharged?

No. 1............ft. No. 2............ft. No. 3............ft. No. 4............ft.

18. What horse-power of boiler can you spare and what steam pressure do you carry? ....H.P.....................lbs.

19. Can you use a belt-driven Air Compressor? ....
H. P. available? ....

20. What is the source of water supply; sand, gravel or rock? ....

21. How many gallons per minute do you require? ....gals.

22. When there are more than one well please make sketch showing location and distances, and write any other remarks on back of this sheet.

Name..

Address...

Date.............................. ....

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to........in. to........in. to........in. to........in.

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No. 4..

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