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A PRACTICAL MANUAL ON

SEA WATER DISTILLATION.

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ON

SEA WATER DISTILLATION,

WITH A DESCRIPTION OF THE NECESSARY MACHINERY FOR THE PROCESS.

BY

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WITH NUMEROUS ILLUSTRATIONS.

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PREFACE.

In this Manual on the subject of the Distillation of sea water and other impure waters, so as to procure Pure Water for drinking purposes, and indeed for any other purpose for which pure water may be required, I have endeavoured first to explain the abstract principle of the process, and then to give some practical idea of the machinery that is required.

With regard to the *Principle* of distillation, in order to explain this properly, I have found it necessary to treat of the fundamental subjects, **Water, Steam,** and **Fuel.** I have then endeavoured to show that the cost of obtaining distilled water (*i.e.*, the amount of fuel used in the process) is, in point of fact, but a debit and credit account of the *heat* that is used, in other words, an account of the heat *given* and *returned* from first to last.

With regard to the *Machinery,* I give a general explanation of the different systems under which various types of apparatus operate, so far as they are all governed by the laws of nature, on the three cardinal points above alluded to; but to give in detail the construction of the various types supplied is quite beyond the object of this book. If further information is required as to any particular variety of apparatus, application should be made to the maker for his pamphlet dealing with the same.

To a considerable extent I have been obliged to base the details I have given on personal experience in the construction and working of this class of machinery, as there is not, so far as I am aware, any publication which deals with this subject with anything approaching exhaustiveness.

Much technical phraseology is naturally involved in giving a scientific explanation of this subject, but I have tried to put the same in as simple language as possible, hoping thus to make the book not only useful and interesting to experienced engineers, but also easily intelligible to students, and indeed to anyone desirous of obtaining some information concerning distillation.

The Tables I have given may be considered somewhat diffusive, but this amplification is due to my desire to assist possible research under more or less novel conditions.

In conclusion, I feel that some apology should come from me to the engineering profession, for this attempt to deal with a subject which is theirs, when my profession is an entirely different one.

F. NORMANDY.

2 Plowden Buildings,
Temple, E.C., *November*, 1909.

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CORRIGENDA.

PAGE.

10, 2nd line up, *for* "of various types" *read* "for various uses."

32, 12th line up, *for* "2 lbs." *read* "½ lb."

60, Table H, last column, 7th line down, *for* "11·34" *read* "13·14."

96, after Table L, *add* "see also Appendix."

153, 3rd line down, for the words "the poles of a powerfully charged magnet" *read* "the electrodes of a high tension alternating-current circuit."

168, after "Fig. 21" *add* "("Normandy" design)."

197, under Table N, *insert* "(see also Appendix)."

SEA WATER DISTILLATION.

CHAPTER I.

GENERAL OUTLINE AND DESCRIPTION OF DISTILLATION.

Distillation Explained.

1. DISTILLATION, as applied to sea water, is a process in which the water contained in sea water is converted into steam or vapour by the action of heat, which is absorbed, and such steam or vapour, thus generated, is then reconverted into water, by having its heat abstracted and absorbed by some cooling agent, say cold sea water. The water only is affected by its conversion into steam or vapour, and its reconversion into water. The sea water thus has its saline matter separated from the ordinary water. The steam produced is simply water in its pure and gaseous state, and as soon as its heat (usually called its latent heat) is abstracted from it, it liquefies or becomes water again, or what is called distilled water.

2. The process of sea water distillation, therefore, involves two distinct operations, viz. :—First, Vaporisation, or the conversion of the water from a liquid to a gaseous state ; and secondly, Liquefaction, or the reconversion of the vapour from a gaseous to a liquid state. By the above process the saline matter and all non-volatile substances

are separated and left to remain in the sea water operated upon, so as to increase its strength by the amount of saline matter so left.

Decomposition Distinguished.

3. It is important to bear in mind that **distillation** is a totally different thing from **decomposition.** In the process of the distillation of sea water, the steam that is generated from the water is still really water, but in a very finely divided state—that is, a collection of minute particles of water—the composition of which is still the two gases hydrogen and oxygen, in the same proportion to each other—*i.e.*, two atoms of hydrogen to one of oxygen, which combine to form water. To reunite these two gases when once separated, condensation, as above alluded to, is of no avail; heat, in the form of ignition, is needed to recombine these two gases, and then the reunion takes place with explosive force, but not imparting heat, as will be seen when we are dealing with fuels.

Principle of Distillation.

4. The whole principle which underlies this process of distillation is, that the amount of heat required to convert a given quantity of water into vapour is returned as soon as that vapour is reconverted into water again. The object of the following pages is to explain this matter in detail, as applied to the distillation of sea water.

Note.—As distillation can only remove or separate from sea water such substances as are not vaporisable—*e.g.*, its saline matter—it follows that water that is greasy, or water that contains objectionable matter, if vaporisable, will not be freed of such matter by distillation. Vapour from the oil or grease will come over with the steam. But, on the other hand, although the vapours alluded to coming over with the steam may be objectionable to the taste, the process of evaporation may have the effect of destroying all poisonous matter.

Filtration.

5. Filtration, although capable of separating substances that may be mechanically suspended in water, is not efficient in removing any saline matter dissolved therein, and although the saline matter can be removed by chemical agency, distillation is the only really practical manner in which pure water or fresh water can be procured from sea water.

"Evaporators" and "Boilers."

6. The term "*Evaporator*" is usually applied to an apparatus where the heat used for generating steam or vapour from the sea water is derived from steam heat. Where such heat is otherwise supplied—say by the combustion of coal, or wood, or oil, or any kind of fire, the term "Boiler" is generally applied. In the Board of Trade Rules evaporators are practically subject to the same rules in the details of construction as boilers.

Use of Distilling Machinery.

7. Sea-water distilling machinery is largely used, not only at sea on steam ships, but also on land, the apparatus being placed either on shore, so as to deal with the adjacent sea water, or it is placed more inland, the purpose being to deal with water whose impurities are such as to render it objectionable for the purposes it is required for.

(*a*) Use on Steam Ships.

8. For steam ships generally, there are two purposes for which water distilled from the sea is required. *First*, Fresh water is obviously required for the drinking purposes of the crew and passengers, for although a supply of fresh water may be carried on board, and replenished when calling at different ports, still this is not sufficient to satisfy requirements. *Secondly*, And this is hardly a less important requirement for pure water on board ship, is its production to make up for loss of distilled water by waste in its use for feeding the water-tube boilers on board.

Drinking Water—Quantity.

9. The quantity of fresh water considered sufficient for drinking purposes and other usual requirements naturally varies a good deal according to circumstances, and it is difficult to give a rule applicable to all cases. A first-class Battleship in H.M. service, having a crew of, say, 500 men, is allowed about 12 tons of fresh water per twenty-four hours for drinking purposes, &c. For large Ocean Liners, about 3,000 to 5,000 gallons per twenty-four hours is not an uncommon supply of fresh water to be allowed.

Loss of Fresh Water on Ships.

10. The exhaust steam from the engines on board is condensed by surface condensers, and such water is returned to the boiler feed tanks; but distilling apparatus is required to make up loss by leakage.

This loss of fresh water on steam ships has been variously estimated as amounting to something like 8 tons (about 1,800 gallons) per twenty-four hours per 1,000

I.H.P. in H.M. ships. The Committee appointed on the subject of Naval Boilers in the service reported that as much as 6 tons per twenty-four hours per 1,000 I.H.P. was a fair estimate of the loss of fresh water.

(*b*) Use on Land.

11. For **Land use**, distilling machinery is mostly required for procuring drinking water, and such machinery is usually installed near the sea shore at points of the globe where pure fresh water is in great demand. But land apparatus is often used for producing pure water for other purposes, as already said—namely, for industrial uses—and in that case the system of working the distilling machinery can be advantageously varied so as to be adapted to the rather different conditions prevailing on land from what exist on board ship. Thus, on a steam ship there is necessarily a dearth of available space, as compared with a land station; again, on a steam ship the only heat available is steam heat, whilst on land it is possible to have a suitable boiler, with a coal fire, for supplying the initial heat required for distillation. By this means multiple distillation apparatus (treated of in Chapter XI.), although difficult to carry out satisfactorily on a steam ship, can be installed on land with the greatest ease and advantage. The water thus produced can also be produced as it is required, for it is sometimes difficult to store a large supply of water, and at the same time keep it fit for drinking purposes.

12. The purposes for which distilled water is produced on land are as follows:—For drinking (when the distilled water is usually filtered and aërated, so as to make it agreeable to the taste as well as pure), and for indust-

rial purposes (when filtration and absence of aëration are not only unnecessary but indeed objectionable), such as the feeding of water-tube boilers, the manufacture of mineral waters—*i.e.*, in connection with mineral water making machinery, making ice, and in connection with accumulators and storage batteries at electrical generating stations, laundries, &c. These are the principal uses for distilled water.

13. The distilled water is made, not only from sea water, but also from any water that has saline matter dissolved in quantities that make the quality of such water objectionable for the use it is required.

General Object of this Book.

14. The object of this work, being intended to give some practical information regarding the distillation of sea water and impure water, it is now proposed to describe in detail the various parts of a distilling apparatus, first as ordinarily in use in *steam ships*—that is, not only in H.M. service, but on liners and yachts—and then to describe the types of distilling machinery mostly used on *land*, where the conditions of working are somewhat different from those prevailing on steam ships.

CHAPTER II.

TYPES OF DISTILLING APPARATUS.

(*a*) For Steam Ships.

Description of Double Distilling Apparatus.

1. For steam ships, the usual class of distilling machinery is what is known as *Double Distilling* apparatus. This class of apparatus consists of an Evaporator with a Distiller (or Distilling Condenser, as it is sometimes called). These are the main parts of the apparatus. The steam from the boiler, or exhaust steam pipes on board, is supplied to the evaporator so as to enable it to generate an extra or gained supply of steam from the sea water it evaporates, and such steam is conducted into the distilling condenser, where it is condensed into pure distilled water.

The Filter and Steam Pump.

2. To complete the distiller, and to render the distilled water palatable, a filter is included, and (although not always necessary, as will be shown further on) a steam pump is included, the functions of which are to force the circulation water through the distilling condenser, and to pump away the brine from the evaporator, also to pump the drinking water produced to where desired. Such brine has to be cooled and diluted, and then pumped out to sea, as it would be objectionable for it to run into the bilge of the ship.

Evaporator Feed Pump.

3. A force pump is sometimes also required to feed the evaporator—that is, when it works under pressure—otherwise the evaporator feed may be allowed to gravitate into the evaporator without the need of forcing it in by means of a special pump. The fresh-water pump usually takes the water from the filter and forces it into the drinking water tanks, but this distilled water can be diverted from the filter, and be run or pumped elsewhere to add to the boiler feed-water if desired.

Gained Steam—Discharge of.

4. At one time it was customary for the evaporator on board to discharge its gained steam—that is, the steam or vapour it has generated from sea water—direct into the surface condenser on board, instead of into the distilling condenser as above described. This, as will be shown hereafter, requires more or less special appliances, as the surface condenser is worked *under* atmospheric pressure more or less variable, whereas the distilling condenser ordinarily works at atmospheric pressure.

Fixing above and below Water Line.

5. From the above summary description of a double distiller as used on steam ships, it will be seen that a rather different system of working may be adopted, according as the apparatus is placed either *above* the sea water line—that is to say, placed on an upper deck—or is placed *below* the sea water line, say in the engine-room.

6. In the first case the fresh water, as it is produced, can flow into a tank alongside of, or just below, the apparatus, and then pipes may be laid for the fresh water

to be distributed about the ship as may be desired. Again, for the same reason, the brine, instead of having to be diluted and cooled and then pumped out to sea, may be allowed to gravitate away from the apparatus (as it leaves the evaporator) out to sea without any necessity of cooling, or diluting, or pumping.

7. On liners the circulating pump is often dispensed with, as the sanitary pump on board is used to supply the circulation water, so that the distilling apparatus thus reverts to its main elements—viz., the evaporator and distilling condenser—with its filter (if water of the best quality for drinking is required). The Board of Trade Rules provide for this.

On H.M. Ships.

8. On H.M. Ships it would not be expedient to place the distilling apparatus on an upper deck, where such important machinery might be shot away in action. It is, therefore, invariably fixed, not only in the engine room, but also in the protected part of the ship, hence the necessity of the various auxiliary parts above referred to, including also such accessories as feed-water regulators and heaters, to obtain as far as possible automatic working, and economy of fuel.

Duplicate Sets.

9. To the above, it may be added that on H.M. ships it is usual to have duplicate sets of distilling machinery, working on the lines above referred to. These sets are made, not only of the same power, but in duplicate, so that any part of one set may be correspondingly used in the other set. For convenience these two sets are placed

one in each engine-room—that is, one on the starboard side and the other on the port side.

Note.—The above description of the Double Distiller for use on *steam ships* is intended for the present to be a mere outline of the type ordinarily used at sea. The various parts referred to will, later on, be dealt with in detail, and the system of working be more thoroughly explained.

(*b*) For Land Stations.

10. For land apparatus the double distillation type, working very much in the same manner as just explained for ships, may be used, but besides apparatus of double distillation type, there is the type usually called single distillation, which is *less* economical of fuel than the double distillation (if fuel economy is not required), whilst there are types, usually referred to as Treble, Quadruple, and Multiple distillation, which are considerably more economical of fuel than the Double distillation apparatus. These will be described more fully later on.

Uses for Land Apparatus.

11. The uses to which distilling machinery on land is put are very numerous. Large installations, generally of the multiple distillation type, are most common abroad, where the apparatus is placed on the sea shore. The sea water is pumped up from the sea, and is then converted into fresh water, mostly for drinking, but the production of pure water from sea water, or from other water impregnated more or less with saline matter, is obtained from distilling machinery of various types. Thus at places like Aden, the sea water is distilled into fresh

water for the use of passing steam ships, either for drinking purposes or for storage for feeding the boilers on board, and for this latter purpose the fresh water has to be *absolutely pure* to meet the exigencies of the water-tube boilers. (For further uses see p. 5.)

Small Apparatus.

12. The need of very pure water is also felt at electrical generating stations, as the ordinary town water is very unsatisfactory for use in connection with accumulators or storage batteries. The quantity of absolutely pure water required is, however, so small that the distilling machinery suitable for the purpose has to be reduced to the proportions capable of yielding as little as 20 to 30 gallons daily. This is, however, met by having a small double distiller, worked off the steam of any boiler that is available. If there is no ordinary boiler available, then the distilling apparatus has to make its own steam by means of a miniature boiler, or steam generator, working with a distilling condenser, the former being worked by the heat obtained from an ordinary gas stove of suitable size to generate the quantity of steam required.

13. The above type of small distiller can also be worked by a gas or oil stove for producing pure cold drinking water from water that is not considered sufficiently pure for such purpose.

Automatic Working.

14. These very small distilling plants, whether worked with the steam from a boiler, or adapted to working with a gas or oil stove, are generally made to work *automatically*, as the necessity of having someone deputed to give

constant attention to the working and manipulation of the apparatus would entail expense and trouble that might be objected to for so small a supply of water. This type of apparatus will be referred to more in detail later on.

Quality of Water Produced.

15. Before leaving the present general review of the purposes for which distilling machinery is used, it is well to say a few words regarding its purity, as there are grades of quality, some being good enough for one purpose, but not for others. Pure water means water that is absolutely pure, but a very small amount of saline matter may be carried over with the steam, by what is termed *priming*, so that distilled water, passable for drinking purposes—that is, not containing sufficient saline matter to condemn it for such use—might be considered very objectionable if the distilled water is required for, say, feeding water-tube boilers, or for use in connection with accumulators, where water of absolute purity is required.

16. The composition of sea water is more fully dealt with in the next chapter, but we must just anticipate matters slightly, for the purpose of dealing with the quality of the distilled water after its saline matter has been separated. This saline matter will be found to be, for the most part, chlorides generally, and particularly chloride of sodium, or common salt.

Qualitative Analysis.

Testing for Saline Matter.

17. The test for chlorides is nitrate of silver, acidified with nitric acid. The chlorine attacks the silver, with

the result that an insoluble white precipitate is at once formed, varying in quantity according to the amount of chlorine (that is, chloride of sodium) present. The other salts found in sea water are mostly salts of calcium (lime) and magnesium, in combination with sulphuric acid so as to form sulphate of lime (plaster of Paris), and sulphate of magnesia. The former of these, the lime salt, is usually detected by the application of oxalate of ammonia, which also produces a white precipitate called oxalate of lime. The latter salt, sulphate of magnesia, is detected by the application of oxalate of ammonia, so as to first precipitate the lime salts: after filtering off this first precipitate, the addition of a few drops of liquid ammonia and hypophosphate of soda, will throw down a further white precipitate, which will indicate the presence of magnesium.

Comparative Qualities.

18. To give an idea of the comparative qualities of water from their appearance, after testing with nitrate of silver, Table A is subjoined. It is supposed that a specimen of distilled water is presented in an ordinary test tube, filled, say, three parts full of the distilled water to be tested. Having first acidified the specimen with a little nitric acid, let one drop of nitrate of silver (of 5 per cent. strength) fall into the water in the test tube. If chlorine is present, a white precipitate will be formed, varying from the slightest cloudiness to a heavy white mass.

Note.—It should be observed that this precipitate will be somewhat different in character, according as the water tested is *cold* or *hot*. If the specimen of distilled water in the test tube is *cold*, the chloride of silver will be observable in a streaky white precipitate of a more or less forked nature, whilst if the water tested is *hot*, the precipitate will have a more cloudy or woolly appearance. This test is a very delicate one, and should be carefully conducted to avoid misapprehension. A tumbler of water apparently perfectly pure after adding a few drops of nitrate of silver to it will, if merely stirred round with the finger, show signs of salinity from the saltness due to the trifling perspiration on the finger being washed off by running it through the water.

TABLE A.

Degree of Salinity. No.	Appearance of Water after Treatment with Nitrate of Silver (5 per cent. strength).
1.	Absolute purity. No trace of any bluish tint or discoloration by adding one drop of nitrate of silver.
2.	Very slightest blue discoloration.
3.	Bluish, but only slightly so.
4.	Bluish to slight white clouds or streaks.
5.	Slight cloudy precipitate, about equal to a specimen of ordinary town water.
6.	Cloudy, rather more than with ordinary London water.
7.	Rather heavy white clouds.
8.	Heavy white clouds and white matter falling to the bottom of the test tube. The water examined would have a slight taste of salt.
9.	Heavy white precipitate falling quickly to the bottom of the test tube. Another specimen, if tasted, would be decidedly salt.
10.	Ordinary sea water. A drop of nitrate of silver would be instantly coated with the chloride of silver, and drop like a stone to the bottom of the test tube.

Note.—When tasting any of the specimens above referred to, it should be pointed out that nitrate of silver is highly poisonous, so that a specimen treated with the silver nitrate should NOT, of course, be tasted.

19. For ordinary drinking water purposes a salinity

equal to No. 4 or 5 would not be objectionable, but for use in water-tube boilers, and other purposes where pure water is needed, No. 1 should be obtained ; not even No. 2 is now accepted as a satisfactory state of purity.

20. The nitrate of silver test has been explained, as it affords a means of ascertaining the presence of chlorides in solution, which, as will be seen when the chapter on "Sea Water" is read, is the predominating salt, especially chloride of sodium (common salt). But as common salt is easily soluble in water its presence, on evaporating surfaces, is not so objectionable as the lime salts, which are very slightly soluble in water, and, therefore, adhere to the evaporating surfaces very pertinaciously, and have to be scraped off or chipped off, or disengaged from the surfaces by the most approved means possible.

Testing for Lime.

21. As to lime, the test is as follows :—Add a few drops of oxalate of ammonia to a specimen in a test tube. A white precipitate falling indicates the presence of calcium. Six grains per gallon (*i.e.*, 9 per 100,000 parts) give a turbidity, and 16 grains per gallon (*i.e.*, 23 per 100,000 parts) give considerable turbidity.

Quantitative Analysis.

22. The testing can be carried further—that is, by *quantitative* analysis—by which means the exact amount of saline impurity can be ascertained.

Hard and Soft Water.

23. Water is familiarly spoken of as being *hard* or *soft*, as indicated by its action on soap. Water containing salts of calcium or magnesium produce a curdling effect

when mixing with the fatty acid in soap. Soft water not containing these salts dissolves the soap without any curdling action. Often boiling hard water will be sufficient to reduce its hardness. A hard water can also be softened by the admixture of lime water, or of carbonate of soda. The measure of hardness is often indicated by the number of degrees of hardness. One degree of hardness is 1 grain of saline matter per gallon.

Note.—In laundries the use of distilled water thus increases the efficiency of the soap used, and consequently reduces the quantity requirable for hard water.

Important Points regarding Sea Water Distillation.

24. From the general outline that has been given as to the distillation of sea water, it is apparent that the subject is closely involved in the composition and nature of *sea water* and impure water generally, as well as the properties and nature of *steam*, and the subject of *heat*. Therefore, before dealing with the parts of a distilling apparatus in detail, the next three chapters will be devoted to **Sea Water**, **Steam**, and **Fuels** generally.

CHAPTER III.

COMPOSITION OF SEA WATER.

Generally.

1. The word " sea " is usually applied indiscriminately to the open sea, so as to include the Ocean, while " Sea " and "Sea Water " are usually applied to every large area of salt water, however and wherever situated. For dealing with this water in a treatise on its distillation it is necessary to divide the subject of sea water into " ocean water " and " inland sea water," the latter including such large areas of water as the Mediterranean, the Baltic, and other extensive seas, which are either large inland lakes, or so land-locked as to be of a different character from the ocean.

(*a*) Ocean Water—Its Composition.

2. Ocean water is fairly uniform in its composition—*i.e.*, the quantity of saline matter it contains is not only fairly uniform in its proportion to the water it is dissolved in, but the salts (especially those which are most in evidence) are fairly uniform in their proportions amongst themselves.

3. The actual water in ocean water or in sea water is, of course, always the same. As already mentioned in an earlier part of this book, water is composed

of the two gases, hydrogen and oxygen, in the proportion of 2 atoms of hydrogen (whose atomic weight is 1) to 1 atom of oxygen (whose atomic weight is 16), so that, weight for weight, water (H_2O) is composed of 1 part of hydrogen and 8 parts of oxygen. These gases are chemically combined in this ratio, whether the combination is in a solid state (ice), a liquid state (water), or a gaseous state (steam), and the absorption of heat changes the state of this combination of the two elements which may be solid, liquid, or gaseous; whilst the loss of heat exactly reverses the operation—*i.e.*, changes it from steam to water, then to ice, without changing its composition.

4. The saline matter of all seas and oceans consists mostly of what is commonly called salt—that is, common salt, chemically called chloride of sodium, or muriate of soda, as it used to be commercially called. But although this is the predominating salt, many others are more or less strongly in evidence, whilst there are traces of a still larger number of other salts. The "bay-salt" of commerce is the saline matter of the sea water evaporated at a very low heat, and the brine or concentrated form of sea water is also known under the name of "bittern."

Note.—The information we have respecting the composition of sea water is mostly derived from the researches of eminent analysts, such as Schweitzer, Usiglio, Dittmar, and others. There is also the very elaborate paper by Forchhammer in the *R. S. Phil. Trans.* (1865). The reports of the investigations made by the officers of H.M.S. "Challenger" also give much information on this subject.

5. From these reports we find that besides the presence

of common salt, to which is attributable the saline taste of sea water, there are sulphates of lime and magnesia, these being the most in evidence, but there are also traces, more or less pronounced, of a large number of other salts, including salts of aluminium, iron, lithium, bromine, zinc, and even the precious metals, silver and gold. These precious metals are, however, present in such small proportions that any hope of extracting the free metal with financial success is very chimerical. It has, however, been considered with some seriousness, and the plan of operations suggested was to deal with the brine escaping from large distilling installations, such as exist at Aden and elsewhere. By the further evaporation of the brine, it was proposed either to get salt crystals, or a very concentrated solution of brine that could then be treated with chemicals, so as to obtain the free metals. Up to the present, however, it would appear that the cost of treating the saline matter in sea water, with a view to obtaining gold, is out of all proportion to the very small quantity of gold derivable from carrying out the process. Sea water, or brine, otherwise called bittern, is used as a source for obtaining bromine.

Ordinary Saline Matter.

6. For practical purposes of sea water distillation, all salts, other than those that are present in appreciable quantities, may be ignored. The following Table B gives the analysis of a specimen of sea water taken from the English Channel, which was selected as an average sample of sea water.

TABLE B.—PERCENTAGE COMPOSITION OF (ENGLISH CHANNEL) SEA WATER

Chloride of sodium (common salt),	2·806	3·248
„ magnesium,	0·366	
„ potassium,	0·076	
Sulphate of magnesia,	0·23	0·37
„ lime,	0·14	
Carbonate of lime,	0·003	0·006
Bromide of calcium,	0·003	
		3·624
Traces of a great many other salts,		0·003
Total saline matter,		3·627
Ordinary water,		96·373
Sea water,		100·000

Taking the above saline matter only, the percentage would be as follows :—

		Per cent.
Chloride of sodium,	2·806 =	77·3
„ magnesium,	0·366 =	10·1
„ potassium,	0·076 =	2·1
Sulphate of magnesia,	0·230 =	6·3
„ lime,	0·140 =	3·8
	3·618 =	99·6
Sundries,	0·009	0·4
Total saline matter	3·627 =	100·0

7. Faraday's analysis of sea water was 32 parts of saline matter in 1,000 parts of sea water, and in that proportion the analysis was as follows :—

25	parts of	muriate of soda (common salt).
3	,,	muriate of magnesia.
2	,,	sulphate of magnesia (Epsom salts).
1	,,	sulphate of lime (plaster of Paris).
1	,,	sundries.
32	,,	saline matter.
968	,,	ordinary water.
1,000	parts—Total.	

8. Dr. Tidy found that sea water at Margate (at high tide) contained :—

	Per cent.
Total solids,	3·343
Chlorine,	1·7705
Lime,	0·035
Magnesium,	0·205
Silica,	0·0004
Hardness,	0·564

9. The Rivers' Pollution Committee found that sea water contained approximately as follows :—

Free and saline ammonia,	A trace.
Total solids,	3·893 per cent.
Chlorine,	1·975 ,,

10. From a large number of specimens of ocean water, taken at various points of the world, it was found that the total salts averaged 3·5 per cent., ranging from 3·7 in *torrid* regions to 3·2 in *frigid* regions, and that water from a depth is not quite so saline as that at the surface. These results are what one would expect—viz.,

that on the surface, in the tropics, the sea water being more subject to evaporation, would make it salter. Ocean water may, therefore, be accepted as containing 3·5 per cent. of saline matter, of which about 3 per cent. consists of chlorides.

11. All the above analyses show the great preponderance of chlorides and sulphates, especially the former, in the shape of common salt. Table B also shows that the percentage of saline matter in sea water is about 3·6 per cent., of which chlorides constitute about 3·25 per cent.

Note.—The specific gravity of the actual salt in sea water may be taken at 2·24. The specific gravity of sea water (containing, say, $\frac{1}{32}$ of saline matter) would be 1·031. A *saturated* solution of salt and water will, when cold, hold about 36 per cent. of salt and, when at boiling point (226° F.), about 40 per cent. of salt. This equals a salinity ranging from about $\frac{11}{32}$ to $\frac{12}{32}$ and a specific gravity of 1·32 to 1·35. See also Table C on p. 26.

Salinometer Test.

12. When it is intended to ascertain the strength of sea water, or of brine, with the use of the salinometer, it is usual to deal with a specimen at a temperature of 200° F.,* but as water expands by being heated, it is obvious that a cubic foot of sea water at 60° will weigh more, as it is denser, than a cubic foot of water at 200°, and this has to be allowed for when taking the record of the salinometer, as hereafter explained.

A short Table (C C) on p. 26 gives the weight of water at various temperatures, ranging from 40° (the tem-

* Unless otherwise indicated, temperature is always expressed in Fahrenheit degrees in this work.

perature at which it may be taken to be at about its maximum density) up to 212°, its boiling point.

13. If, therefore, sea water containing $\frac{1}{32}$ of saline matter has been evaporated so as to reduce it to one-half —*i.e.*, in every 32 lbs. of sea water 16 lbs. of water have been evaporated—there will be left 16 lbs. of brine, with the same quantity of saline matter in it as was in the original 32 lbs. of sea water, thus making the 16 lbs. of brine double the strength of the 32 lbs. of sea water, which is called $\frac{2}{32}$ "density." The $\frac{1}{32}$ would equal about 3·12 per cent. of saline matter, and $\frac{2}{32}$ would equal about 6·25 per cent. of saline matter.

If $\frac{2}{3}$ of the 32 lbs. of sea water are boiled away, the remaining $\frac{1}{3}$ will contain the saline matter originally contained in the 32 lbs., and make this $\frac{1}{3}$ brine three times the strength of the original 32 lbs. of sea water, so that its salinity becomes $\frac{3}{32}$.

14. Sometimes the "density" of sea water is said to be $\frac{1}{33}$, meaning that 1 lb. of saline matter in every 33 lbs. of sea water, or 32 lbs. of ordinary water plus 1 lb. of saline matter, making a total of 33 lbs. But $\frac{1}{32}$ (meaning $\frac{1}{32}$ greater weight than the same volume) is the accepted proportion of salt in sea water, although neither $\frac{1}{32}$ nor $\frac{1}{33}$ quite accords with the accepted percentage of saline matter in sea water—namely, 3·5—for 3·5 per cent. equals between $\frac{1}{28}$ and $\frac{1}{29}$, whilst $\frac{1}{32}$ equals 3·125 per cent., and $\frac{1}{33}$ equals 3·03 per cent. However, the matter must rest as it stands now. Faraday's analysis of sea water containing 32 parts of saline matter per 1,000 parts of sea water, or 3·2 per cent., is certainly nearer $\frac{1}{32}$ than 35 per 1,000, or 3·5 per cent., which is now fixed on as the amount of saline matter in sea water.

15. The prevalent method of denoting the strength or

salinity of sea water and brine by 32nds of "density" (which is how it is commonly expressed) may be made clearer by the following illustration. Fig. 1 shows a hollow cube, the inside dimensions of which are 1 square foot at its base, and extending upwards for rather more than 1 foot. If pure water be now poured in, so that the quantity reaches to the height of 1 foot, we have obviously 1 cubic foot of pure water. If some insoluble matter (say sand) be added to this 1 cubic foot of water, the water will be displaced to the same extent as the volume of the sand that is added, and will rise to a cor-

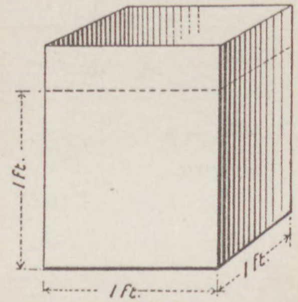


Fig. 1.

responding height above the 1 foot level. If, however, instead of sand, common salt (which is soluble in water) be added to the cubic foot of water, this will make no difference in the level of the water by displacement, but as additional substance has been added, the addition must manifest itself somehow, and it does so by making the same volume of water more saline and denser by the quantity of salt that has been added and become dissolved in the water. The saline water is still, therefore, only 1 cubic foot in volume, but its mass and its weight are increased. If double the quantity of salt be added, the volume would not be increased. In fact, however much salt be added (until the solution becomes saturated, and will dissolve no more), its volume will remain the same, although its density, salinity, and weight will be increased according to the quantity of salt that is added. If the quantity of salt added be in the proportion of $\frac{1}{32}$, or $\frac{2}{32}$, or $\frac{3}{32}$, the "density" and weight will be $1\frac{1}{32}$, $1\frac{2}{32}$, $1\frac{3}{32}$, as the case may be, but the volume of 1 cubic foot will still remain the same.

"Density" and "Salinity."

16. The foregoing observations on the strength of sea water and brines lead one to enquire as to whether "density" is the most appropriate term to use for conveying the meaning of the degree of brine strength.

17. When sea water or brine on being tested is said to have a "density" of $\frac{1}{32}$, $\frac{2}{32}$, $\frac{3}{32}$, as the case may be, the meaning is that in a given quantity (*i.e.*, weight) of the salt water there is the above proportion ($\frac{1}{32}$, $\frac{2}{32}$, or $\frac{3}{32}$, as the case may be) of saline matter dissolved in it. This would be its degree of "salinity," and consequently this proportion would be the same whatever the temperature of the specimen tested may be.

A "density" of $\frac{1}{32}$, or $\frac{2}{32}$, or $\frac{3}{32}$ does not, therefore, correctly denote the state of things, for if 1 cubic foot of salt water contains 2 lbs. (practically $\frac{1}{32}$) of saline matter massed in it, then the salt water would be correctly described as having a "density" of $1\frac{1}{32}$; or if 4 lbs. of salt are massed in it, then a density of $1\frac{2}{32}$, and so on; or, instead of 32nds, a "density" of 1·04, 1·062, 1·094, as the case may be. Again, a salinometer does not record "density." It records its buoyancy in water at a temperature of 200° F., and its relative buoyancy in water at the same temperature (200° F.) containing proportions of salt dissolved in it varying from 1 to 3 parts

TABLE C.—Boiling Point and Specific Gravity of Brine at various Strengths.

Salinity (in 32nds) of Saline Matter.	Temperature at Boiling Point. °F.	Specific Gravity.
1	213·2	1·029
2	214·4	1·058
3	215·5	1·087
4	216·7	1·116
5	217·9	1·145
6	219·1	1·174
7	220·3	1·203
8	221·5	1·232
9	222·7	1·261
10	223·8	1·290
11	225·0	1·319
12 (Saturation).	226·1	1·348

TABLE CC.—Comparative Weight of Sea Water and Brines at various Temperatures and Strengths of Salinity.

Temperature. °F.	Weight of 1 Cubic Foot (in pounds avdp.).				
	Distilled Water.	Sea Water. Strength.		Brines. Strength.	
		3·5 per cent.	$\frac{1}{32}$	$\frac{2}{32}$	$\frac{3}{32}$
40	62·41	64·60	64·36	66·31	68·26
60	62·33	64·48	64·3	66·22	68·17
80	62·16	64·30	64·11	66·06	68·01
100	61·93	64·07	63·90	65·83	67·78
120	61·64	63·82	63·59	65·54	67·47
140	61·32	63·49	63·30	65·28	67·25
160	60·93	63·07	62·90	64·83	66·78
180	60·51	62·20	62·46	64·41	66·36
200	60·06	62·10	62·05	63·69	65·91
212	59·83	62·00	61·64	63·45	65·26

TABLE D.—Approximate Comparative Volumes and Weights of Fresh Water and [Sea Water].

Fresh Water. [Sea Water.]	Imperial Gallons.	Cubic Feet.	Cubic Inches.	Tons or Cubic Metre (approx.).	Pounds (avdp.).	Litres.	U.S.A. Gallons.
1 Imp. gall., . .	1 [1]	0·160 [0·160]	277·27 [277·27]	0·0044 [0·00458]	10 [10·32]	4·543 [4·543]	1·2 [1·2]
1 Cubic foot, . .	6·232 [6·232]	1 [1]	1728 [1728]	0·0279 [0·0285]	62·4 [64]	28·37 [28·37]	7·476 [7·476]
1 Cubic inch, . .	..	..	1 [1]	..	0·036 [0·037]	0·016 [0·016]	0·0043 [0·0043]
1 Ton (1 cub. metre—approx.), . . .	224 [217]	35·9 [34·8]	..	1 [1]	2240 [2240]	1000 [1000]	268·8 [260]
1 Pound (avdp.), .	0·1 [0·07]	0·016 [0·0156]	27·727 [28·0]	0·00044 [0·00044]	1 [1]	0·454 [0·444]	0·12 [0·116]
1 Litre, . . .	0·22 [0·22]	0·0353 [0·0353]	61·5 [61·5]	0·001 [0·00125]	2·24 [2·296]	1 [1]	0·264 [0·264]
1 U.S.A. gall., . .	0·83 [0·83]	0·133 [0·133]	231 [231]	0·0037 [0·0038]	8·33 [8·58]	3·8 [3·9]	1 [1]

in 32 parts. A salinometer, in short, is an instrument for measuring the "salinity" of sea water or brine. It will also record the "density" of the sea water or brine; but this is a different thing from "salinity," and the figures that record the latter will not be the same as will record the former. $\frac{1}{32}$, $\frac{2}{32}$, $\frac{3}{32}$ cannot be either the "density" or the "specific gravity"; it is the "salinity."

Other Properties of Sea Water.

18. Sea water has a rather higher boiling point than ordinary fresh water, which is 212° F. Sea water boils at about 213° F. But, for ordinary purposes, in a practical treatise of the present description, 212° may be assumed to be the boiling point of sea water.

19. As there are various slight differences between sea water and fresh water, Tables C and D have been added, giving many useful notes concerning water generally.

(*b*) Inland Seas.

20. Up to the present we have been dealing with ocean water, which we find is practically the same all over the world, and whatever difference there is, is really due to climatic influences.

But in different parts of the world there are large areas of water, away from the ocean, such as inland or land-locked seas, lakes, river-mouths, &c., whose salinity is different from that of the ocean. Thus the Mediterranean, practically a huge lake, whose water is altogether unlike that of the ocean in appearance, has a salinity of 4 per cent.—*i.e.*, somewhat salter than the ocean. Then take the Red Sea, another large land-locked sea, having a salinity of 4 per cent. These two seas are almost completely shut in, and have a salinity of 4 per cent., whilst in the Suez Canal, which connects the two, the water has been found to have a salinity of 5 per cent., which is higher than in either sea. Then take the Baltic, a sea not nearly so land-locked as the above two seas, and its density is less than the above two seas, and less even than the ocean, as the Baltic has a salinity of only 3 per cent. The Black Sea and the Caspian Sea have a very much less density than the ocean. The Caspian Sea—that is, the open part of that sea—has a salinity of only $1\frac{1}{2}$ per cent., but an adjacent gulf (called Kara Borgas) has the enormous density of 28 per cent. of saline matter. Take again the Dead Sea, whose density is very great, having about 22 per cent. of saline matter in solution.

21. It appears strange that in two seas like the Caspian and the Dead Seas, the Caspian (in its open part) should have a density so slight, whilst the Dead Sea has a density so great. These two seas are not very far distant from each other, or very different in latitude, and both have large rivers pouring into them, yet they are very different in their composition, or rather *strength*, for the extra salinity in the Dead Sea, and in the side lake (Kara Borgas) of the Caspian is practically all common salt, or chloride of sodium.

22. These comparisons of salinity will be found useful in estimating what feed water has to be provided when working a sea-water distilling apparatus, as will be shown later on, when dealing with the apparatus in detail.

(c) Salt Wells.

23. Besides distillation of the water from inland seas, distilling apparatus is sometimes required for distilling well water in districts—*e.g.*, in Australia—when the

only water, and not overmuch in quantity, is obtainable from wells. This well water varies a good deal in its salinity, it being sometimes only brackish, whilst at others it is exceedingly salt. Distilling apparatus, when required for dealing with this class of water, has to be adjusted to meet the salinity of such water.

CHAPTER IV.

STEAM.

Generally.

1. In sea water distillation (especially in the type of it usually called "multiple" or "compound" distillation), a knowledge of the properties of steam (such as its heating power under various pressures) is essential.

2. Steam is a gas or vapour obtained from water by the action of heat, and the amount of heat required to convert a given weight of water into steam is *absorbed* by the steam or vapour in the operation of being thus converted from water into steam. On being re-converted or transformed back again into water, it is capable of imparting, to another substance, the exact amount of heat it absorbed when it was converted into steam. This is so in *theory*, but in *practice* it is impossible to avoid some waste of heat. *Waste*, however, must not be confused with a *loss*, for nothing is really lost; it is only that the heat absorbed by the steam, instead of being returned in its entirety to the cooling medium presented to it for that purpose either leaks away in other directions, or is not accounted for in some way or other; this is easily understood, but cannot be prevented. A perfect realisation of what theoretically takes place in nature is never wholly possible.

Note.—Steam is a perfectly transparent colourless gas. What is seen issuing from boiling water like a white cloud, usually called (and often thought to be) steam, is really not steam at all but fine particles of water, caused by the steam coming in contact with colder surrounding air, and becoming condensed thereby.

Properties of Steam.

3. The opposite Table gives the properties of saturated steam. By "saturated" is meant that condition or state of the steam when it is on the point of re-conversion into water by the slightest decrease in its temperature, or increase in its pressure, as each of these changes will cause the steam to be re-converted into water again.

Note.—This Table has been given in rather extensive form, as it will be found necessary (especially when dealing with multiple distillation) to examine different pressures somewhat closely.

TABLE E.—Properties of Saturated Steam.

P. (net) = *Pressure* in pounds per square inch, excluding the atmosphere. Every 2 lbs. pressure per square inch, below atmosphere = about 1 inch head of mercury per barometer.

S.H. = *Sensible Heat—i.e.*, temperature by Fahrenheit thermometer scale.

L.H. = *Latent Heat—i.e.*, the units of heat required to convert 1 lb. of water into 1 lb. of steam.

T.H. = *Total Heat—i.e.*, the latent heat + the sensible heat (from 32° F.).

S.V. = *Specific Volume—i.e.*, the number of (say) cubic feet of steam converted from 1 cubic foot of water.

W. = *Weight—i.e.*, of 1 cubic foot of steam (lbs. avdp.).

P. (gross) = *Pressure*, including the atmosphere.

P. (Net).	S.H. Fahr.	L.H.	T.H.	S.V.	W.	P. (Gross.)	S.H. Cent.
- 14	90·4	1051·1	1109·5	28,740	0·00217	0·7	..
- 13	120·3	1030·3	1118·6	12,480	0·00500	1·7	..
- 12	137·5	1018·3	1123·9	8,080	0·00800	2·7	..
- 11	149·8	1009·7	1127·6	6,009	0·01038	3·7	..
- 10	159·7	1002·8	1130·7	4,799	0·01300	4·7	..
- 9	167·9	997·0	1133·2	4,003	0·01558	5·7	..
- 8	174·9	992·1	1135·3	3,439	0·01814	6·7	..
- 7	181·1	987·8	1137·2	3,010	0·0292	7·7	..
- 6	186·7	983·9	1138·9	2,690	0·02319	8·7	..
- 5	191·8	980·3	1140·4	2,428	0·02568	9·7	..
- 4	196·4	977·1	1141·9	2,215	0·02817	10·7	..
- 3	200·7	974·0	1143·2	2,036	0·03063	11·7	..
- 2	204·7	971·2	1144·4	1,886	0·03307	12·7	..
- 1	208·5	968·5	1145·5	1,755	0·03553	13·7	..
Atmosphere	212	966·1	1146·6	1,643	0·0379	14·7	- 17·78
1	215·3	963·8	1147·6	1,544	0·04039	15·7	- 17·23
2	218·5	961·5	1148·6	1,457	0·04280	16·7	- 16·67
3	221·5	959·4	1149·5	1,380	0·04521	17·7	- 16·11
4	224·4	957·3	1150·4	1,310	0·04761	18·7	- 15·56
5	227·1	955·4	1151·2	1,248	0·05000	19·7	- 15
6	229·8	953·5	1152·0	1,191	0·05238	20·7	- 14·45
7	232·3	951·8	1152·8	1,139	0·05475	21·7	- 13·89
8	234·7	950·1	1153·5	1,092	0·05712	22·7	- 13·34
9	237·1	948·4	1154·3	1,049	0·05949	23·7	- 12·78
10	239·4	946·7	1155·0	1,009	0·06184	24·7	- 12·23
11	241·6	945·2	1155·6	971·8	0·06419	25·7	- 11·67
12	243·7	943·7	1156·3	937·5	0·06654	26·7	- 11·11
13	245·8	942·2	1156·9	905·7	0·06888	27·7	- 10·56
14	247·8	940·8	1157·5	876·0	0·07122	28·7	- 10
15	249·7	939·4	1158·1	818·2	0·07355	29·7	- 9·45
16	251·6	938·1	1158·7	822·2	0·07587	30·7	- 8·89
17	253·5	936·8	1159·3	797·8	0·07819	31·7	- 8·34
18	255·3	935·5	1159·8	774·9	0·08050	32·7	- 7·78
19	257·0	934·3	1160·3	753·2	0·08282	33·7	- 7·23
20	258·7	933·1	1160·9	732·8	0·08513	34·7	- 6·67
25	266·7	927·4	1163·3	645·7	0·09661	39·7	- 3·89
30	273·9	922·3	1165·5	577·6	0·1080	44·7	- 1·11
35	280·5	917·6	1167·5	522·8	0·1193	49·7	- 1·67
40	286·6	913·2	1169·4	477·7	0·1335	54·7	4·45
45	292·3	909·1	1171·5	440	0·1417	59·7	7·23
50	297·5	905·5	1172·7	408	0·1529	64·7	10
55	302·5	901·8	1174·2	380·4	0·1639	69·7	12·78
60	307·2	898·5	1175·6	356·4	0·1750	74·7	15·56
65	311·6	895·3	1177·0	335·4	0·1860	79·7	18·34
70	315·8	892·3	1178·3	316·7	0·1969	84·7	21·11
75	319·9	889·3	1179·5	300·1	0·2078	89·7	23·89
80	323·8	886·5	1180·7	285·2	0·2187	94·7	26·67
85	327·4	883·9	1181·8	271·7	0·2295	99·7	29·45

P. (Net).	S.H. Fahr.	L.H.	T.H.	S.V.	W.	P. (Gross.)	S.H. Cent.
90	331·0	881·3	1182·9	259·5	0·2404	104·7	32·23
95	334·4	878·9	1183·9	248·4	0·2511	109·7	35
100	337·7	876·5	1184·9	238·2	0·2619	114·7	37·78
110	343·9	872·0	1186·8	220·1	0·2833	124·7	43·34
120	349·8	867·8	1188·6	204·8	0·3046	134·7	48·89
130	355·4	863·7	1190·3	191·5	0·3258	144·7	54·45
140	360·6	859·9	1191·9	179·8	0·3469	154·7	60
150	365·6	856·3	1193·5	169·5	0·3680	164·7	65·56
160	370·4	852·8	1194·9	160·4	0·3889	174·7	71·11
170	374·9	849·5	1196·3	152·2	0·4098	184·7	76·67
180	379·3	846·3	1197·6	144·8	0·4307	194·7	82·23
190	383·5	843·2	1198·8	138·2	0·4514	204·7	87·78
200	387·5	840·3	1200·1	132.1	0·4721	214·7	93·34
225	397·0	833·4	1203·1	119.2	0·5230	239·7	107·23
250	405·7	826·9	1205·8	108·6	0·5744	264·7	121·11
275	413·9	820·9	1208·3	99·7	0·6258	289·7	135
300	421·5	815·3	1210·6	92·3	0·6766	314·7	148·89
325	428·6	810·1	1212·7	85·8	0·7268	339·7	162·78
350	435·4	805·0	1214·8	80·3	0·7770	364·7	176·67
400	447·9	795·7	1218·6	71·2	0·8764	414·7	204·45
500	469·9	779·2	1225·3	58·1	1·0741	514·7	260

Table E is explainable as follows :—

(1) In the *first* column is stated the *net* pressure of steam in lbs. per square inch—that is, the pressure of the steam *ex*clusive of, or above, the weight of the atmosphere. The *gross* pressure—that is, the pressure *in*clusive of the atmosphere—is given in the seventh column.

(2) In the *second* column will be found the "sensible" heat of steam—that is, its temperature (by the thermometer) whilst it continues to be steam—*i.e.*, in a gaseous state—and is in reality its "gaseous" heat at different pressures.

(3) In the *third* column will be found the "latent" heat of steam—that is, the heat that steam is capable of emitting when ceasing to be gaseous it returns to the liquid state—and is in reality its "liquescent" heat at different pressures.

(4) In the *fourth* column is stated the "total" heat of steam—that is, the total number of heat units required to raise 1 lb. of water from 32° (freezing point) to boiling point, *plus* the heat required to convert that 1 lb. of water into 1 lb. weight of steam at different pressures.

(5) In the *fifth* column is given the "specific volume" or density of steam—that is, the ratio in volume between 1 cubic foot of water and the number of cubic feet of steam that it is convertible into at the particular pressure indicated.

(6) In the *sixth* column is given the weight (in lbs. avoirdupois) of 1 cubic foot of steam at the particular pressure.

Heat—Measurement of.

4. Heat, although only the condition of a substance, is capable of measurement just as much as the substance itself is, with regard to its weight or its volume. A thermometer hanging in the air and recording, say 60°, on being plunged into water records, say 40°, shows that the condition of the air as regards temperature is 20° hotter than the water. But if a given weight of any substance, say 1 lb. of that water, has a certain amount of heat imparted to it, which raised it from 39° to 40°, the 1° of heat thus absorbed, and capable of returning to some other substance, affords a means of standardising the condition of any substance as regards the heat it is capable of absorbing from or imparting to any other substance. This heat standard is called in this country a thermal unit.

5. **A thermal unit,** usually referred to as one B.T.U. (British Thermal Unit), is the specific heat required to

raise the temperature of 1 lb. of pure water at 39·1° one degree (*i.e.*, to 40·1°). This is about the temperature at which water is at its greatest density—*i.e.*, when the 1 lb. of water has the smallest volume. But, although 39·1° is the specified temperature, practically any other temperature holds good for ordinary calculations; sometimes the B.T.U. is based on a temperature of 60° as being ordinary summer temperature, instead of 39°, as above referred to.

Note.—The thermal unit in France is called a "Calorie," and is further described as a "grande calorie" or a "petite calorie," the former being the heat required to raise the temperature of 1 *kilogramme* of water from 4° C. to 5° C., whilst the latter ("petite calorie") is the heat required to raise the temperature of 1 *gramme* of water from 4° to 5° C. From this it will be seen that the British thermal unit (B.T.U.) equals 0·252 (or, more accurately, 0·251996) "grande calorie," or 252 "petites calories."

Metrical System.

6. In France and on the Continent, where the metrical system is used, the pressures are often indicated by the number of atmospheres or kilogrammes per square metre. The following short Table will, therefore, be useful when pressures are mentioned in foreign terms:—

TABLE F (on page opposite).

A. = Atmosphere (*i.e.*, 29·9 inches of mercury) at ocean level, per barometer—Allow 0·1″ reduction for every 260 feet of ascent.

P. = Pounds per square inch.

K.M. = Kilos. per square metre.

H. = Head of water per square inch in feet high.

A.	P.	K.M.	H.
1	14·7	10,333	33·9
2	29·4	20,666	67·8
3	44·1	30,999	101·7
4	58·8	41,332	135·6
5	73·5	51,665	169·5
6	88·2	61,998	203·4
7	102·9	72,331	237·3
8	117·6	82,664	271·2
9	132·3	92,997	305·1
10	147·0	103,330	339·0

The Theory of Evaporation.

7. If 1 lb. of water at, say, 60° (which is about ordinary summer temperature), is heated up to boiling point (212°), and is then converted into 1 lb. weight of steam at atmospheric pressure, the following number of heat units will be absorbed :—

First, there will be the heat required to raise the 1 lb. of water to boiling point—viz., 212° - 60° = 152°—then there will be 966 units to convert it into steam. This will make a total of 1,118 units absorbed by the steam in this operation. If, however, the 1 lb. of water is evaporated at a pressure of, say, 10 lbs. above atmospheric pressure, under which condition the temperature of the boiling point is 239° and the latent heat is 946, there will then be required 239 - 60 = 179 + 946 = 1,125 units of heat.

In the first case the calculation is—

212 - 60 = 152 units of sensible heat } at atmospheric
966 ,, latent heat } pressure.

1,118 units (total) heat.

In the second case it is—

239 - 60 = 179 units of sensible heat	}	10 lbs. (net)
946 units of latent heat		pressure.
1,125 units (total) heat.		

8. From a study of Table E it will be seen that as the pressures rise the *sensible* heat *in*creases, whilst the *latent* heat *de*creases, so that the total heat is consequently not very much affected. It will thus be observed that, for practical purposes, the total heat required (or the fuel consumed) to generate steam will not vary greatly whatever may be the pressure at which such steam is generated, because the pressure obtained can be kept up with very little augmentation of heat expense.

Note.—This state of things has a most important bearing in the distillation of sea water, especially when the distilling apparatus is of the multiple or compound type.

9. To illustrate this, for the purpose of understanding what takes place in distillation, Fig. 2 shows a vessel (E) with a Bunsen gas burner (G) under it. Let us suppose that 1 lb. of water is put in the vessel (open at top), and its temperature is, say, 60°, as indicated by a thermometer placed in the water. On lighting the gas the temperature of the water will gradually rise, and will continue to do so till the temperature of 212° is reached. Then the water will boil, and will continue to do so, but the thermometer will record no more heat, whether its bulb is put in the water or in the steam rising therefrom, because it can only record the *sensible* heat.

10. The water keeps on boiling, whilst the gas is still burning, and steam keeps on being given off at the open

end of the vessel ; and the water in the vessel gradually diminishes until it has all boiled away. Now, what has taken place is this. The heat from the gas flame was first utilised in raising the temperature of the water from 60° to 212°—that is, 152° (and took a certain amount of time to do that), the gas flame then continued to give out the same heat, but such heat was no longer sensible,

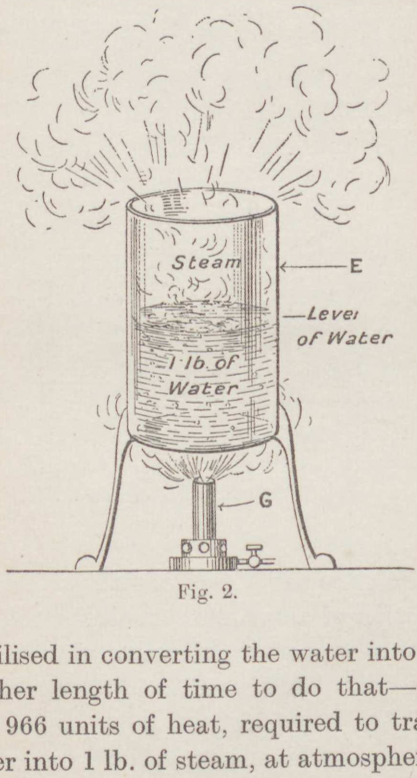


Fig. 2.

as it was utilised in converting the water into steam (and took a further length of time to do that—*i.e.*, by imparting the 966 units of heat, required to transform the 1 lb. of water into 1 lb. of steam, at atmospheric pressure.

11. Of course a great quantity of heat was lost in this rather crude experiment—that is, a great *waste* of heat occurred in the consumption of gas, as some of the heat

was never transferred to the water at all, but went outside the vessel into space. However, the waste of heat, whatever it was, may be taken to be at about the same rate during the whole time the gas flame was in use, so that if it took 3 minutes to warm up the 1 lb. of water from 60° to 212°, it would take about 19 minutes to transform the whole of the 1 lb. of water into steam, so as to leave the vessel empty. Thus, as 152 : 966 :: 3 : 19 minutes. For the same reason, if it took, say, x cubic feet of gas

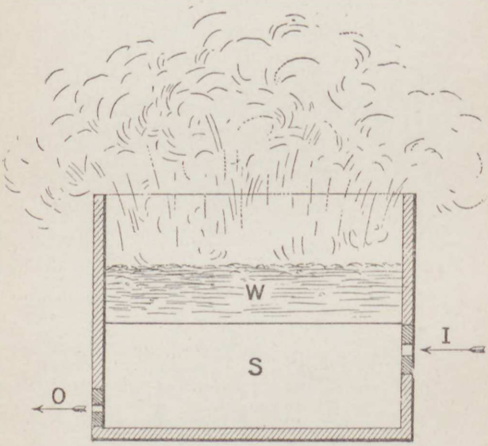


Fig. 3.

to impart the necessary heat of 152°, it would require the consumption of about 6·3 x cubic feet of gas to complete the operation of transforming the entire 1 lb. of water into steam. Thus, as 152 : 966 :: x cubic feet : 6·3 x cubic feet.

12. Let us carry this matter a little further. Suppose that the vessel, Fig. 3, open at the top, has 1 lb. of water (W) in the upper compartment, and is heated, not by a gas burner, but by pressure steam in the lower

compartment (S), the steam being admitted at I at, say, 25 lbs. pressure to the square inch, O being the drain or escape for the water as the steam condenses. The following results will be obtained :—

13. The heat imparted by the steam—that is, its sensible heat—will be brought into contact with the colder water above, the steam (S) will give up its latent heat, which the water (W) will at once absorb, and carry it away as steam, ready to re-deliver it back to any cold substance that is presented to it, and then reduce itself back again to water. The surface of the partition between S and W would have to be larger than when a gas burner was used ; but, given a surface large enough, the results will be the same.

14. From the foregoing experiment, the following points are to be noted :—Here a certain area or surface was exposed, on one side to the heat of steam, and on the other side to a certain quantity of water. The steam and water surfaces being in contact with the separating plate, the sensible heat (266°) from the pressure steam was imparted to the water above it, which absorbed such heat, and caused the steam (S) to be at once converted into water. The steam, at the same time, gave out its latent heat, and also occupied a considerably less space as water than it did as steam (the specific volume at that pressure being 645—*i.e.*, the steam occupied 645 times the space it occupies as water). The moment, therefore, that liquefaction took place, the space, thus free, was instantly occupied by more steam at 25 lbs. pressure, and this process was continually going on until the entire 1 lb. of water (W) was converted into steam.

15. It is, therefore, clear from this, that the heat

imparted (after heating the water up to its boiling point) was carried off by the steam into space.

It is also clear that the steam (S), having a temperature of 266°, was presented to the surface of the partition under the water, and the steam thus continually supplied to replace what was liquefied, at the same time continually giving up its latent heat of 927 B.T.U. until the whole of the 1 lb. of water (W) was converted into steam, which required 966 B.T.U. It is also clear that the steam (S), by giving up its latent heat as above described, and becoming water, escaped at O with a temperature of 266° still left in it.

16. To carry this point a little further still. Suppose the vessel is closed at the top, so as to enable a pressure being exerted inside the vessel (an outlet for such pressure steam being provided on the cover, controlled if required by a valve or cock). Suppose, also, provision is made for feeding water into the vessel, as it is gradually boiled away; and, lastly, suppose that the vessel is provided with a coil or worm placed inside, and the interior of the coil supplied with pressure steam.

17. Fig. 4 shows the apparatus now referred to, which may be recognised as a crude design of an ordinary evaporator, with a coil. C is the steam inlet to coil, E is the escape for the vapour, A is the feed inlet for replacing the water as it is gradually boiled away, B is the outlet for the brine, and D is for the discharge of the condensed steam from inside the coils, and F is the steam-room.

18. Suppose, now, the new steam generated inside the vessel, usually called secondary steam (to distinguish it from the steam inside the coil, usually called primary steam) is led into a condenser, and by the agency of cold

water such secondary steam is again reduced to a state of water. This secondary steam or vapour in the operation of being transformed or re-converted into water, will return the latent heat it absorbed, when, as water, it was converted into steam.

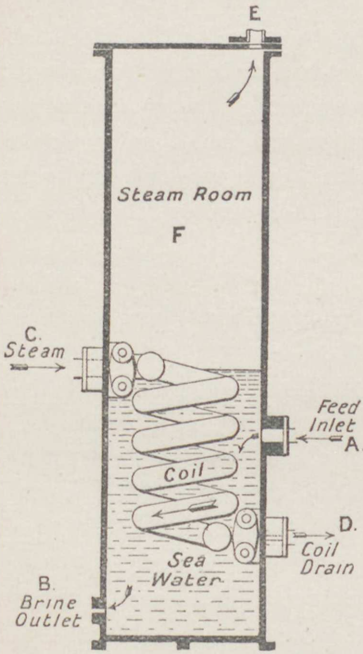


Fig. 4.

Primary and Secondary Steam.

19. The primary steam which was supplied to the interior of the coil, in the same manner, by imparting its heat to the water surrounding the coil, has itself, in the same way, been reduced to a state of water (primary water). If during a given period of time, therefore, the

primary water, thus resulting, is measured against the *secondary* water resulting from the condensation of the secondary steam, we have at once the proportion of the one to the other, which represents the *economy* of the process ; because the primary steam was necessarily obtained by the agency of fuel (say coal). One has really, therefore, to consider the weight of coal or other fuel required first to obtain a sufficiency of primary steam to produce the secondary steam. Such secondary steam is consequently termed (as its name would imply) *gained* steam—*i.e.*, extra to the *primary* steam directly obtained by the consumption of coal or other fuel.

Compound Distillation.

20. From the foregoing explanation, it will be gathered that the relationship between *primary* and *secondary* steam is such that by raising the pressure of the primary steam, and then getting a pressure on the secondary steam, this new steam may in its turn be used as primary steam to another evaporator, working on the same lines, and thus be the means of obtaining a further supply of gained steam, which will also be obtained for the same consumption of fuel, because we have seen that it takes practically the same amount of heat—that is, fuel consumed—to generate steam at any pressure.

Note.—The pursuance of this matter leads to an explanation of multiple distillation, which is best dealt with later on under the title of "Multiple Distillation."

The Heat of Primary Steam at Varying Pressures.

21. We have now to compare the effect of different pressures of *primary* steam, supplied to the interior of a coil, all other conditions being the same. The pressures

we propose to compare are 10 lbs., 25 lbs., and 75 lbs. to the square inch.

First.—Take a primary steam pressure of 10 lbs. per square inch inside the coil. We find, by the foregoing Table E, that its *sensible* heat is 239°, and that this is 27° above 212°, the temperature of the boiling sea water outside the coil, and that the *latent* heat of this primary steam at this pressure is 946 units. If there is this pressure of steam inside the coil, and the water outside of the coil is at a temperature of 212°, and has to be converted into steam at ordinary atmospheric pressure, the latent heat required for this purpose will be as 946 : 966 :: 1 : 1·021, or 946 × 1·02, which equals 964 units. The primary steam will also have been converted into 1 lb. of primary water, which will then escape, with a temperature of 239°, the sensible heat of the steam at 10 lbs. pressure.

Secondly.—Take a pressure of 25 lbs. per square inch. This, by Table E, is shown to have a *sensible* heat of 266°, which is 54° above 212°, the boiling point of the water outside of the coil. The *latent* heat required to convert it into steam is still 966°. As the latent heat of the primary steam at a pressure of 25 lbs. per square inch is 927 units, the latent heat, therefore, required to convert the 1 lb. of boiling water into steam will be as 927 : 966 :: 1 : 1·042, or 927 × 1·042, which equals 964.

Thirdly.—Take primary steam at 75 lbs. pressure, the temperature of which is 320°—that is, 108° above 212°—and the *latent* heat of such primary steam 889°. To provide the 966 units of heat to convert the 1 lb. of boiling water into steam), the 889 units of latent heat must be multiplied by 1·087, which equals 966 (as 889 : 966 :: 1 : 1·087).

22. From the above three cases, the following points should be noted :—

First.—That in all three cases there was *out*side the coil the same "sensible" heat of 212°, and the same "latent" heat of 966 units, that being the heat required to convert the 1 lb. of water into steam at atmospheric pressure.

Secondly.—That in all three cases the heat *in*side the coils was different—that is, the "sensible" heat not only *in*creased as each pressure got higher, but got higher in the ratio of 1, 2, and 4, as regards the amount of sensible heat above that outside the coil. Thus—

Sensible heat of	10 lbs.	pres. steam	=239 - 212=	27 units
,,	25 lbs.	,,	=266 - 212=	54 ,,
,,	75 lbs.	,,	=320 - 212=108	,,

so that 54 is double 27, and 108 is double 54.

Thirdly.—That in all three cases the "latent" heat, *in*side the coil, *de*creased as each pressure got higher, and decreased in nearly the ratio of 1, 2, and 4, as regards the latent heat outside the coil. Thus—

Latent heat of	10 lbs.	pres. steam	=966 - 946=20	units.
,,	25 lbs.	,,	=966 - 927=39	,,
,,	75 lbs.	,,	=966 - 889=77	,,

i.e., 39 is (nearly) double 20, and 77 is (nearly) double 39.

23. The outcome of the foregoing observations is that the primary steam is capable, as we should expect in theory, and as we find in practice, of imparting its "sensible" heat in proportion to its intensity above that of sea water, to which it imparts its heat. Therefore (other conditions being kept to), steam at 25 lbs. pressure is capable of evaporating (in point of time) twice as much

sea water as steam at 10 lbs. pressure will do, and steam at 75 lbs. pressure will (in point of time) evaporate twice as much sea water as steam at 25 lbs. pressure will do.

24. Therefore, with the same amount of coil surface for each case, the 25 lbs. pressure steam will be able to evaporate 2 lbs. of water in the same time that the 10 lbs. pressure steam would take to evaporate 1 lb., and the steam at 75 lbs. pressure will be able to evaporate 4 lbs. of water in the same time as it would take the steam at 25 lbs. pressure to evaporate the 2 lbs. of water. Or, put in another way, it would take the above pressures of 25 lbs. and 75 lbs. half and quarter of the time it takes the steam at 10 lbs. pressure to evaporate 1 lb. of water. This is due to the proportionate *intensity* of the heat of the steam (at each of the above pressures) above that of the sea water it has to evaporate.

25. In comparing the *economy* of the above three pressures of steam—viz., 10 lbs., 25 lbs., and 75 lbs. pressure—the latent heat required *in*side the coil has to be kept up so as to be sufficient to meet the latent heat required to evaporate the water *out*side the coil, so that the ratio in each case will be as follows :—

As 946 : 966 :: 1 lb. (weight) of steam	: 1·021	in case	(1)
As 927 : 966 :: 1 ,, ,,	: 1·042	,,	(2)
As 889 : 966 :: 1 ,, ,,	: 1·087	,,	(3)

which is the same *ratio* of 1, 2 and 4.

Sensible Heat in Primary Water.

26. It must not be forgotten that there is sensible heat still remaining in the primary *water* produced *in*side the coil, after the latent heat has been abstracted, and that this has not yet been counted. When this is taken into

account the above multipliers will not be required. Thus—

1st case, .	946	units of latent heat.
Add, .	27	units sensible heat (239 – 212 = 27).
	973	B.T.U., total.
2nd case, .	927	units of latent heat.
Add, .	54	units sensible heat (266 – 212 = 54).
	981	B.T.U., total.
3rd case, .	889	units of latent heat.
Add, .	108	units sensible heat (320 – 212 = 108).
	997	B.T.U., total.

Feed Temperature.

27. It must be borne in mind that in the above calculations no allowance has been made for waste of heat, nor for the heat required to heat the feed-water up to the boiling point. The object has been to show as clearly as possible the efficiency of various pressures, without being obscured by minor details.

28. In practice, the feed is $1\frac{1}{2}$ times the evaporation, and its temperature (as it enters the evaporator) about 150° or more, so that to meet these conditions an adjustment is necessary. Thus, the feed, being half as much again as the evaporation, there is, first of all, a quantity of $1\frac{1}{2}$ lbs. of water to be heated up from 150° to 212°, *i.e.*, $62 \times 1\frac{1}{2} = 93$ units + 966 (latent heat) = 1,059 units, in each case, instead of only 966 units, the heat

stated as required for *out*side the coils. This will, however, be more exhaustively dealt with in Chapter VI.

Condensation.

29. What has been said above with regard to *evaporation* of steam applies equally (though conversely) to its *condensation.* Thus, the secondary steam, escaping from the evaporator at a temperature of 212° of sensible heat, is also charged with its latent heat of 966 units. If this steam has to be condensed into water, a sufficient quantity of circulation water must be supplied, not only to absorb this latent heat, in order to condense this secondary steam into secondary water, at the temperature of 212°, but also sufficient circulation water to cool such boiling hot water down from 212° to whatever temperature is specified. This matter will, however, be more fully dealt with when the chapter on the Distilling Condenser is reached.

Note.—The rule that the amount of heat used to convert a specific quantity of water into steam is precisely the same as the amount of heat that is imparted when that steam is re-converted into water, is simply the axiom propounded by Carnot, which is, in practice, as follows :—Any substance transformed from one physical state to another, and then re-converted to its original state, so as to be identical therewith, the heat it has after re-conversion is precisely the same as it originally had. So that 1 lb. of water, at a specific temperature converted into steam, and then re-converted into 1 lb. of water at its original temperature, all the heat spent in the conversion into steam is recovered when the steam is re-converted into water at its original temperature. This is, of course, ignoring waste of heat during the process.

Compound Distillation.

30. The above observations have been confined to a constant pressure (that of the atmosphere) outside of the coils. It will, however, be found, when we consider compound or multiple distillation, that the rules above given are equally applicable when the outside pressure is varied.

Pressures below Atmospheric Pressure.

31. Hitherto *secondary pressures*, more or less low, have been dealt with. It is true, they have been very low, but they have been at or just above *atmospheric pressure*. It is, however, possible to evaporate at what is *called* a *vacuum* or *minus* pressure, often described as so many inches of mercury—that is, taking the height of 30 inches of mercury as counterbalancing the atmosphere. As atmospheric pressure is equal to 14·7 lbs. per square inch, every $\frac{1}{2}$ lb. per square inch below the atmosphere would, therefore, equal about 1 inch in a column of mercury. Table E., on p. 33 (in the first column) gives the properties of steam at such negative pressures.

Note.—The term "vacuum" is frequently used as being *any* pressure below that of the atmosphere at ocean level. It would be less confusing if a pressure which is *below* that of ordinary atmospheric pressure were referred to by another name than that of a *vacuum*. If water is converted into steam in an *open* vessel at ocean level, the evaporation will take place at what is called atmospheric pressure, so that the temperature of the water when boiling will be at 212°, and the specific volume of the steam will be 1,643. If, however, that open vessel be taken to a considerable altitude above ocean level, the water will boil below 212°, and the specific volume of the steam will be correspondingly greater. There is clearly no *vacuum* in either case. Yet, if the vessel be closed, instead of open, and the water made to boil at the same low temperature as when boiling in an open vessel at an altitude, by drawing away the steam by the action of a condenser and air pump, the evaporator is said to work at a vacuum, whereas it is only working at a specific pressure below ordinary atmospheric pressure. In both cases the upper part of the vessel is entirely filled with steam, but in the one case the steam is *denser* than in the other—that is, its specific volume varies according as the load is added to or taken from off the water that is being evaporated, and the temperature corresponds with the pressure, whatever it may be.

Note.—The boiling point at altitudes may be taken as 1° F. less than 212° for every 590 feet of ascent.

32. The object of this slight digression was only to make the subject of pressures *above* and *below* that of the atmosphere at ocean level easily understood, and it would be more convenient if all pressures were understood, as being above the weight of the atmosphere at the level of the ocean, unless denoted by a *minus* indication, to be below atmospheric weight. There would then be no confusion of ideas as to the condition of things when pressures are above or below atmospheric pressure. The same rules equally apply in both cases, and calculations with regard to sensible heat, latent heat, and total heat at different pressures are ascertainable by exactly the same process, and by reference to the Table E (p. 33) of the properties of saturated steam.

33. It will, therefore, be seen that as the pressure be-

comes lower, over the water from which the secondary steam is being evaporated, the lower may be the pressure of the primary steam to generate it. Thus with, say, the utmost *minus* pressure that can be obtained (even down to a vacuum, when water will boil at below 80° F.), if the water outside the coil is made to boil by a suitable pressure of steam inside the coil, there is no reason for not carrying the system of evaporation by steam heat thus far—that is, if it can be done advantageously in practice. The subject is, however, better dealt with in Chapter VI., which explains the evaporator in detail. Some evaporators are arranged for a primary pressure of, say, 6 to 8 lbs. per square inch with a *minus* pressure indicated by 8 to 10 inches for the secondary pressure, whilst in others the primary pressure is less, say, 4 to 6 lbs. per square inch, and a correspondingly lower pressure for the generating of the secondary steam outside the coil. This will be referred to again later on.

34. Having treated of "Steam" and its properties, generally, before dealing with the evaporator, which both uses and generates more of it, it is well first to treat of "Fuel" by which the initial heat is obtained to produce the *primary* steam.

CHAPTER V.

FUELS.

General Remarks.

1. As the cost of obtaining the primary steam is involved in the economy of a distilling apparatus, it is well to consider the subject of fuel; its importance is most clearly manifested in the distillation of sea water, when carried out by means of compound or multiple distillation. The most usual fuels are coal, coke, wood, petroleum, and gas. Therefore, one has a variety of fuel, in a state or condition that is either solid or liquid, or gaseous. As coal is the fuel that is most common, we will begin with coal and coke.

Note.—The experiments of Dulong show that 1 lb. of carbon is capable of emitting 12,906 B.T.U. when burnt, and that 1 lb. of hydrogen when consumed is capable of emitting 62,535 B.T.U. Therefore, the heat that various fuels of this class (hydrocarbons) are able to emit is the proportion in which these two combustibles are combined with each other. If, however, oxygen is also present *in the fuel* it will neutralise the hydrogen also present to the extent that it is combinable with that gas in forming water. Water consists of 2 atoms of hydrogen to 1 atom of oxygen, and as the atomic weight of oxygen is 16, whilst that of hydrogen is 1, it follows that in water oxygen has a preponderance of 8 to 1 over hydrogen as regards weight. Therefore, the quantity of hydrogen must have deducted from it $\frac{1}{8}$ of the quantity of oxygen present, and the surplus hydrogen only can be counted for giving heat. (See paragraph 26, on page 66.)

(*a*) Coal and Coke.

2. The composition of coal, according to the analysis of Péclet and others, is, approximately, as follows :—

		Coal.	Coke.
Carbon, per cent.,	. .	80·40	85
Hydrogen, ,,	. .	5·19	0
Oxygen, ,,	. .	7·87	0
Nitrogen, ,,	. .	2·46	0
		95·92	85
Refuse (ashes),	. . say	4·08	15
Total,	. . .	100·00	100

According to the foregoing analysis, therefore, 1 lb. of coal should be capable, when burnt, of yielding heat as under. (Coke is simply 85 × 12,906 = 10,970 B.T.U.) :—

		B.T.U.
Carbon, . . .	0·804 (*i.e.*, 80·4%) × 12,906 =	10,376
Hydrogen,	0·05190	
Less,	0·00984 used with its oxygen to form water (0·0787 ÷ 8 = 0·00984).	
	0·04206 surplus hydrogen × 62,535 =	2,732
B.T.U. obtainable from 1 lb. of coal . . . =		13,108

Coal exists in many varieties. The most important are :—

Anthracite class, which is almost pure carbon, and with this class may be included the hard Welsh steam coal. When burnt, the heat of this class of coal is very intense.

Bituminous coal, which may be more or less *hard*, so as to be suitable to some extent for the same uses as the anthracite coal, or more or less *soft*, when it borders on a gas-making coal.

Cannel coal, which is used almost exclusively for gas-making.

3. Coal varies considerably in its heating capacity—that is, its heat-giving power. The heat capacity is usually specified by the number of units of heat it is capable of emitting per lb. consumed—that is, the number of units (B.T.U.) 1 lb. of coal is capable of imparting to water, so as to convert a proportionate weight (say in lbs.) of water into steam.

4. We know that to convert 1 lb. of water into steam at 212°, at atmospheric pressure, it requires 966 B.T.U. Therefore, if a certain quality of coal is capable of converting 10 lbs. of water (in ordinary working of a boiler), the calorific effect of such coal may be stated to be 9,660 (*i.e.*, $966 \times 10 = 9660$). Of course, experiments with coal scientifically conducted may show a considerably higher efficiency, and the theoretical heating capacity may be, and in point of fact is, specified at about 30 to 50 per cent. more, but this cannot be realised in the ordinary working of a boiler, however economically the working in practice may be. By scientific experiments, made with something like 100 specimens of coal—English,

Welsh, and Scotch—conducted by Playfair and De La Beche, we are told that the average heat obtained amounted to 13,000 B.T.U. per lb. of coal. This is by calorimeter.

5. In a series of *practical* experiments made with the consumption of coal whilst working a boiler, conducted by H.M. Commissioners, some little while back, it was found as follows :—

Kind of Coal.	B.T.U. per lb.	Lbs. of Water Vaporisable at Atmospheric Pressure at 212°
Welsh, ...	8,800	9·0
Newcastle, ...	8,000	8·0
Lancashire, ...	7,700	8·0
Scotch, ...	7,450	7·7
Derbyshire, ...	7,400	7·5

Note.—All the above experiments appear to have been obtained whilst working with a *small Cornish boiler of 7 H.P.* With a boiler larger and more up-to-date the results would have been increased about 10 to 12 per cent. These different coals have been detailed here, because it will be found, when we come to the chapter on Multiple Distillation, that the quality of the fuel is a very important question.

The opposite Table (G) gives the heating power of various descriptions of coal, and of other fuels, as compared with Welsh coal.

Note.—Column (*a*) is approximate only, because the reports given of the heat obtained from fuels of the same description vary somewhat.

TABLE G.—WELSH COAL COMPARED WITH OTHER COMBUSTIBLES.

Col. (*a*) — Comparative Heating Power of various fuels.
„ (*b*) — Comparative Weights of fuel to give the same heat.

Description of Fuel.	(*a*).	(*b*).
WELSH coal, ...	1·000	1·000
Newcastle coal, ...	0·916	1·091
Derbyshire coal, ...	0·9	1·111
Lancashire coal, ...	0·9	1·111
Scotch coal, ...	0·913	1·095
Yorkshire coal, ...	0·915	1·091
Coke, ...	0·71	1·408
Charcoal, ...	0·779	1·285
Patent fuel, ...	1·5	0·83
Wood (dry and hard), ...	0·42	2·381
Petroleum, ...	1·29	0·775
Alcohol (spirits of wine), ...	0·97	1·032
Town gas (30 cf. = 1 lb.), ...	1·385	0·7

Note.—One ton of coal produces 1 chaldron of coke; and approximately 1 ton equals 1½ chaldrons.

One ton of loose coal averages about 45 cubic feet, and a chaldron of coke averages 75 cubic feet.

(*b*) Patent Fuels.

6. Besides coal, there are various mixtures of coal dust with coal tar, &c., known as patent fuels. The heating power of these mixtures varies a good deal, much depending upon the class of coal used in the mixture. These fuels are usually in the shape of briquettes, which can be broken up and used as required.

(*c*) Wood and (*d*) Petroleum.

7. It is not uncommon to have boilers fired with wood or petroleum, especially abroad, where coal is more costly. The Table (G) just given, shows that wood is consider-

ably less powerful than coal in giving heat, whilst petroleum is a good deal more so.

8. *Wood* fuel entirely depends on its dryness, and its closeness or density, for its power of giving heat, as the composition does not vary. In India, larch or *Casuarina* plantations are cultivated to supply wood fuel. The heating power of wood is about half to a third that of the same *weight* of coal.

Note.—The heating power of wood may be taken as follows :—One lb. of perfectly dry wood contains 0·51 of carbon, whilst the residue, 0·47, consists of hydrogen, 0·053, and oxygen, 0·417. In the process of combustion this 0·47 of hydrogen and oxygen must be ignored, as they combine so as to form water. Thus we have—

		B.T.U.
Carbon, ...	0·51 × 12,906 =	6,582
Hydrogen, .	0·053	
Less, .	0·052 used with oxygen to form water (0·417 ÷ 8 = 0·052).	
	0·001 surplus × 62,535 . (say) =	62
B.T.U. obtainable from 1 lb. of dry wood . .	=	6,644

The prolonged experiments of Péclet in wood combustion in a practical way show that from about 3,500 to 5,500 B.T.U. is the heat obtainable per lb. of wood of *ordinary dryness*. 3,500 B.T.U. seem rather *low*, whilst 5,500 B.T.U. seem rather *high* in practice. The effect of moisture in wood can be demonstrated as follows by dealing with 1 lb. of wood having, say, 20 per cent. of moisture, which is ordinary dryness.

		B.T.U.
One pound of dry wood, as above, ...	=	6,644
If there is 20 per cent. of moisture, *first* deduct 20 per cent. of 6,644	=	1,329
		5,315
From this must then be deducted 20 per cent. of 966, for the latent heat absorbable by the moisture being converted into steam during the combustion of the wood (20 per cent. of 966 = 193)	=	193
Heat given from ordinarily dry wood (*i.e.*, with 20 per cent. of moisture)	=	5,122

9. *Petroleum* is now coming a good deal into use for boiler work. It is convenient, but furnaces have to be specially constructed for its use—that is, the liquid fuel has to be injected into the furnace. Its heat-giving power is about 30 to 50 per cent. more than the same weight of coal, and may be calculated with the assistance of Table I, on p. 61.

10. In Seaton and Rounthwaite's *Pocket-book of Marine Engineering* is given the following classification of various descriptions of coal, and these are further compared with wood and petroleum. The following Table H, based thereon, shows that Welsh coal has the greatest heat-giving power amongst the coals, but that petroleum has about 25 per cent. more heating power than the best Welsh coal. This, it may be added, is the theoretical heat power in B.T.U. per lb. of fuel. In actual practice

—*i.e.*, in boiler working—these heating capacities may be reduced by 30 to 40 per cent. in ordinary work.

TABLE H.

Description of Fuel.	Total Heat Units of Combustion (B.T.U.)	Pounds Evaporated at 212°.
Welsh steam coal, average, . . .	15,564	16·11
Newcastle, average, ...	14,820	15·34
Derbyshire, ,, ...	13,860	14·34
S. Yorkshire, ,, ...	14,296	14·80
Lancashire, ,, ...	13,918	14·40
Scotch, ,, ...	14,164	14·65
Coal (a mean of 37 specimens of various descriptions), ...	13,006	11·34
Coke, ...	10,970	11·35
Charcoal, ...	12,000	12·42
Wood (dry), ...	6,582	6·81
Wood (ordinary), ...	5,265	5·45
Peat (fairly dry), ...	8,736 to 9,951	9 to 10·3
,, (ordinary), ...	7,151	
Petroleum—American (ordinary crude),	20,240	20·95
,, Refuse, ...	19,240	20·00
,, Caucasian (crude), . .	20,138	20·83
Town gas, about	18,000	18·73

Note.—To this Table H may be added the heat of combustion of alcohol (spirits of wine), which, when *pure*, has a heat-giving power of about 12,000 B.T.U. for every 1 lb. of alcohol (sp. gr., 0·79) consumed. About $12\frac{1}{2}$ lbs. of alcohol would go to the gallon, and, therefore, 1 gallon of alcohol would be able to impart about 150,000 B.T.U. (= 12,000 B.T.U. per 1 lb.), but the spirits of wine of commerce contains from 15 to 20 per cent. of water, so that its heating power would have to be correspondingly lowered in the same proportion—*i.e.*, 15 to 20 per cent. less than 12,000 B.T.U. per lb. The heating power of alcohol may be taken as about equal to that of coal (weight for weight).

TABLE I.—COMPOSITION OF VARIOUS COMBUSTIBLES, AS GIVEN BY PÉCLET AND OTHERS (PERCENTAGES).

Component Parts.	Coal.	Coke.	Wood (Dry).	Peat (Dry).	Petroleum Paraffin (Oil).	Alcohol. Pure Spirits of Wine.
Carbon,	80·40	85	51	58	85·22	52·0
Oxygen,	7·87	..	41·7	31	..	34·3
Hydrogen,	5·19	..	5·3	6	14·78	13·7
Nitrogen,	2·46	..	..	..	..	..
	95·92	85	98·0	95	100·00	100·0
Ashes or refuse,	4·08	15	2·0	5	..	..
Total,	100·00	100	100·0	100	100·00	100·0
The approximate heating power per 1 lb. is as follows :—						
B.T.U. (Table H).	15,600	11,000	6,600	7,200	20,000	12,000

(*e*) Coal Gas.

11. We have hitherto considered various kinds of fuel, both *solid* and *liquid ;* now, let us briefly notice *gas* as a fuel.

12. Coal gas is really the only gas we need consider, as no other is so readily provided for our use for heating purposes, and it is, of course, only as regards its heating power that we need concern ourselves, in dealing with its use for distillation purposes. *Petroleum* is sometimes volatilised by an apparatus which is adapted for household use, and the vapour thus produced is mixed with various proportions of air, so as to be used either for lighting or for heating purposes. A further description of the apparatus may be obtained on application to the makers of this class of apparatus. *Acetylene* is also a gas that is made by an apparatus suitable for a house-

hold. Particulars thereof may be obtained on application to the makers of the apparatus.

13. When it is necessary to produce distilled water in only very small quantities, and at intervals—*e.g.*, for use in a large household for drinking water, or for electrical generating stations in connection with accumulators or storage batteries—gas affords a very handy means of supplying the heat needed to evaporate water that is too saline or otherwise impure for such uses. It can be turned on and off at pleasure, so that the initial cost of gas, as compared with coal, is very much diminished when this is taken into consideration. A coal fire would be too small for such a purpose, and would require keeping up, while oil, with its wick and constant cleaning of the lamp, is not so convenient as gas. The arrangement of a small distilling plant heated by gas will be described later on in Chapter X.

14. Town gas, as manufactured by the various gas companies, is supplied at a rate varying from 2s. 6d. to 3s. per 1,000 cubic feet.

15. The specific gravity of coal gas is 0·45 (air being 1), and the weight of 1,000 cubic feet of gas is, therefore, about 33 lbs. One thousand cubic feet of gas has a heat giving power of about 570,000 to 600,000 B.T.U., and 1,000 cubic feet of gas is produced by about 0·095 to 0·1 ton of average coal, or, put conversely, 1 ton of coal will yield about 9,500 to 10,000 cubic feet of gas. Much, of course, depends upon the kind of coal used.

Composition of Gas.

16. Coal gas is obtained by the destructive distillation of coal, and its composition (by volume) is approximately as follows :—

	Per cent.
Hydrogen, ...	54
Hydrocarbons (marsh gas, &c.), . .	35
Carbon monoxide, ...	6
Sundries, mostly nitrogen, . . .	5
	100

When coal gas is mixed with air, in the proportion of 1 of gas to from 4 to 14 of air, the mixture will explode on being ignited. The most highly explosive proportion is 1 of gas to 8 of air.

Gas Pressure.

17. The average pressure of town gas, as supplied by the gas companies to houses, is from 1 to 3 inches head of water, or about 0·037 to 0·111 lb. per square inch. Therefore, when describing the amount of gas consumed by a particular gas stove, it is usually intended that the pressure at mid-day is meant, unless otherwise stated.

18. The following short Table gives approximately the proportionate amount of gas passed at different pressures.

TABLE J.—Gas Pressures.

If a pressure of 1″ head of water passes 1 cub. ft. of gas through a given burner in a given time—

Then,	,,	1½″	,,	1·2	,,	through the same.
,,	,,	2″	,,	1·4	,,	,,
,,	,,	2½″	,,	1·6	,,	,,
,,	,,	3″	,,	1·8	,,	,,

19. As the mode of measuring gas (by the 1,000 cubic feet) is not always fully understood, the following explanation is here given. For measuring purposes, every cubic foot of gas is taken to be at the pressure of the atmosphere, so that when gas is passing through the

meter (its pressure, whether equal to 3 inches head of water, or only 1 inch head of water, is immaterial) the consumer is charged for the number of cubic feet at atmospheric pressure. Thus, say that after the gas has passed through the meter it is allowed to escape into an inverted receiver, open at the bottom, the interior dimensions of which are 10 feet by 10 feet by 10 feet high, equalling 1,000 cubic feet. Gas, being about half the weight of air, will rise in the inverted receiver, and fill it with gas, the air being expelled downwards, and in a short time we shall have 1,000 cubic feet of gas at atmospheric pressure. This is the rate at which the gas is charged for. If the gas entered the receiver with a pressure of, say, 3 inches head of water behind it, it would obviously fill the receiver in a shorter time than if the pressure behind the gas was only 1 inch head of water, but the quantity would be the same. It may be taken that the volume of the gas is practically unaffected by the ordinary pressure of supply in town mains.

20. A simple manner of ascertaining the pressure of the gas is to take a piece of india-rubber tube, having a short piece (say 6 inches) of glass tube at one end. If the rubber end is then put on an unlighted gas burner, and the glass tube dipped into a tumbler of water, the gas (when passing into the glass tube) will depress the water for, say, 3 inches out of the glass tube below the level in tumbler, and this will show there is a pressure of 3 inches head of water.

Note.—Before leaving the subject of gas, it may be interesting to compare its cost as against that of coal. For this purpose it is necessary to compare their following heating powers.

Heating Power of Gas.

21. We have just seen that 1,000 cubic feet of gas will impart 600,000 B.T.U., and as 1,000 cubic feet weigh 33 lbs., that makes 18,181 B.T.U. per lb. of gas. We have also seen that 1 ton of coal is capable of imparting, theoretically, $13,000 \times 2,240 = 29,120,000$ B.T.U. of heat, but in practice about $7,000 \times 2,240 = 15,680,000$. Therefore, as 600,000 : 15,680,000 :: 3s. : 79s., or say £4, to obtain the 15,680,000 B.T.U., which 1 ton of coal is capable of imparting for about 25s.

22. This difference of cost between using gas and coal is, however, counterbalanced by the great reduction in the waste of heat, for gas can be lighted and turned off as occasion may require, but a coal fire has to be started for some time before it is used, and is giving out heat to no purpose long after it is required ; besides, a very large quantity of heat goes away into space, all the time the coal fire is in use.

23. Of course, the saving would not be obtained in the case of a large-sized boiler, working continuously and steadily for several hours. A coal fire would then be much more economical than gas, but in the case of a small generator that may be required to be worked for short periods, to meet special requirements, the use of gas would be far more economical and convenient than a coal fire.

(*f*) Recapitulation.

24. The most important point to be noted, so far as distillation is concerned, is the comparison between the heat required for water to become vaporised, and the heat that is procurable from the fuel used for that pur-

pose. Thus, if 1 lb. of water at a certain temperature requires, say, 1,000 B.T.U. to convert it into 1 lb. weight of steam, and 1 lb. of a particular fuel is capable of imparting, say, 10,000 B.T.U. when burnt, the *ratio* will be *one* of fuel to *ten* of distilled water.

Heat from Coal, &c.

25. It should be mentioned that the results obtained by Dulong (stated on p. 53) are not quite the same as those of some other analysts. Thus in burning hydrogen no more than 39,000 to 42,000 B.T.U. have been obtained, against Dulong's 62,535 B.T.U., by some analysts, whilst other reports practically agree with Dulong's analysis.

Economy of Working.

26. The "economy" of working distilling machinery is the amount of distilled water that can be produced by the fuel used or consumed—*i.e.*, weight for weight. There are, therefore, two points to consider—1st, the efficiency of the distilling apparatus, and 2nd, the heating power of the fuel. The heating power of various fuels has just been dealt with in this chapter, the efficiency of the distilling machinery will be dealt with as we consider the different types of apparatus.

CHAPTER VI.

THE EVAPORATOR.

(A) General Outline—Steam Coil.

1. The term evaporator, as before-mentioned, is mostly applied to an apparatus which generates steam from sea water by the agency of *steam* heat, as distinguished from *fire*. Evaporators, therefore, are constructed with a coil or other form of heating surface, so arranged that steam, of a desired pressure, shall pass into the coil and then give out its heat to the surrounding sea water contained in a shell or casing. The steam inside the coil (called for convenience "primary" steam) in the act of giving up its heat, is itself condensed into "primary water," whilst the sea water is evaporated into steam (called for convenience "secondary" steam), and the saline matter is left behind.

2. Only a suitable part of the sea water is evaporated, and the portion that is not evaporated (usually called "brine") is thus rendered stronger by the salinity of that portion which has been evaporated.

3. These are the main outlines of an evaporator, but connected with this is the method of supplying such primary steam to best advantage—*i.e.*, as to its pressure, and as to the discharge of the primary water from the interior of the coil, also as to the best manner of feeding and brining the evaporator, and many other points of a like nature, as to which various makers of evaporators have their own system. On main points, however, their

opinions do not, in fact cannot, vary much, as all are governed by the laws of nature—*e.g.*, the nature and properties of sea water as well as the properties of steam, which we have had under consideration, necessarily apply to all types of evaporators, although different makers may have their own special way of carrying out the details of their own make of evaporator.

Steam Pressure—Inside and Outside the Coil.

4. We have seen that the production, in a specified time, is increased or diminished according as the primary steam pressure (inside the coil) is raised or lowered, and that the back pressure (outside the coil) has the reverse effect—viz., that as the secondary, or back pressure, rises, so the production of secondary steam falls ; and as the back pressure lowers, so the production of secondary steam rises, the " primary " pressure, of course, being the same in both cases.

Use of Exhaust Steam in Coils.

5. A pressure of 20 lbs. per square inch inside the coil is suitable, when working with exhaust steam limited to 25 lbs. pressure in the exhaust steam pipes on board a large ship, such as a cruiser or battleship. When, however, the evaporator is placed on smaller ships, such as a destroyer or torpedo boat, it is found better to take the primary steam direct from the boiler at a considerably higher pressure. The secondary steam can then be raised to a pressure varying from, say, ½ lb. to 15 lbs. per sq. inch.

6. On ocean liners, yachts, and ordinary steam ships, boiler steam is invariably supplied to the evaporator, which generates its secondary steam mostly at or about atmospheric pressure. This, as will be shown later on,

is a much more simple and convenient form of working distilling apparatus.

7. The difficulty attending the use of exhaust steam for working the evaporator is its very unsteady pressure. It is not much used in ships of the mercantile marine for this very reason, and live boiler steam is the usual steam (primary) supplied to the evaporator.

Economy of Using Exhaust Steam.

8. The pressure of the primary steam supplied to the inside of the coil thus varies according to circumstances. Where there is plenty of steam available, of a low pressure, say from the exhaust steam pipe on a steam ship, it is evidently better to use the heat in this exhaust steam than to take live steam from a boiler working at a high pressure. Therefore, where there is exhaust steam not exceeding, say, 25 lbs. to the square inch, and there is ample space for the corresponding size of evaporator (which we shall see requires to be made larger), and arrangements are made to compensate for the varying pressure of the exhaust steam, it is more economical to use such exhaust steam.

Economy Generally.

9. The *economy* of working distilling apparatus (or rather the evaporator) is the proportion that exists between the amount of secondary, or gained, steam that is produced to the consumption of primary steam, weight for weight. By consumption of primary steam is meant the weight of primary steam that is re-converted into water in the operation of giving its latent heat for evaporating the sea water, and thus generating the secondary steam.

10. *Economy* is, therefore, a totally different matter from the evaporative power of an evaporator as against *time*, which we have just been considering with regard to the amount of heating surface required. Although large evaporators are naturally rather more economical than small ones, as relatively less heat is wasted, the primary steam required for a large production of secondary steam, or a small one, is proportionately the same. Thus, if it takes, say, 1·2 *lbs.* of primary steam to obtain 1 *lb.* of secondary steam (irrespective of the time taken in the operation), it will take 1·2 *tons* of primary steam to produce 1 *ton* of secondary steam, no matter what may be the amount of heating surface in operation, provided the type of apparatus and all the other conditions of working are kept to.

Note.—In specifying the economy of multiple distilling machinery, where the proportion of distilled water to coal consumption is specified, it is usual to state the economy as being so many lbs. (or tons) of water per 1 lb. (or ton) of coal.

11. Thus, take the three cases before referred to, and first take the case where the primary pressure is at 10 lbs. per square inch. Every lb. of the $1\frac{1}{2}$ tons of feed-water will have to be heated from, say, 100° to 212°, and then $\frac{2}{3}$ of the $1\frac{1}{2}$ tons (*i.e.*, 1 ton) will have to be converted into steam. This will, therefore, require heat as follows :—

168 units of sensible heat to heat up the feed-water

$(212 - 100 \times 1\frac{1}{2} = 168)$.

966 units of latent heat for evaporation.

1,134 B.T.U. (total) to be found (per lb. evaporated).

To meet this requirement, we have primary steam at 10 lbs. pressure, with a latent heat of 946 units and a sensible heat of 239°, so that (if no advantage is taken of the heat left in the primary water after the primary steam has imparted its latent heat) we shall have an economy of 1,134 ÷ 946 = 1·2—that is, 1·2 economy. If, however, we utilise the heat left in the primary water from 239° down to, say, 212°—that is, use 27° of it (239° - 212° = 27°)—the economy will then be improved as follows:—

946 the latent heat of steam at 10 lbs. pressure.
27 the sensible heat left in the primary water (239 - 212 = 27).

973 B.T.U. total heat.

So that 1,134 ÷ 973 = 1·166—*i.e.*, 1·166 economy. Or, if the sensible heat left in the primary water is further used, so as to reduce it from 239 to, say, 150, the economy will be further improved as follows:—

946 the latent heat as before (10 lbs. pressure).
89 the sensible heat left in the primary water (239 - 150 = 89).

1,035 B.T.U. total heat.

So that the economy will then be 1,134 ÷ 1,035 = 1·096 —*i.e.*, 1·096 economy, or 1·096 lbs. (weight) of primary steam to obtain 1 lb. (weight) of secondary steam.

12. Now, take the primary steam at 25 lbs. pressure, and compare it with the 10 lbs. pressure in last section. There will still be the 168° of sensible heat to provide for, also the latent heat of 966° also, making a total, as

before, of 1,134 units. But as the primary pressure is now 25 lbs. per square inch, with a latent heat of 927 units, the economy will be 1,134 ÷ 927 = 1·22, assuming that the sensible heat still left in the primary water is wasted ; but if it is not wasted and is used (say for feed-water heating) so as to reduce it to, say, 150°, then the economy will be as follows :—

927 the latent heat of the primary steam at 25 lbs. pressure.
116 the sensible heat left in the primary water after reducing it to 150° (266 - 150 = 116).

1,043 B.T.U. total.

The economy will then be 1,134 ÷ 1,043 = 1·087—*i.e.*, 1·087 economy, or 1·087 lbs. of primary steam to obtain 1 lb. of secondary or gained steam.

13. If, lastly, the primary pressure is at 75 lbs. per square inch, the economy will work out as follows :—

There will be the 1,134 units to provide for, as before. Then to meet this requirement we shall have as follows :— 888 the latent heat of the steam at 75 lbs. pressure, and if no use is made of the sensible heat, 277° left in the primary water, the economy will be 1·277—*i.e.*, 1,134 ÷ 888. If, however, the heat in the primary water is used, so as to lower it from 320° down to, say, 150°, the economy will then be as follows :—

888 the latent heat, as before.
170 the sensible heat (320 - 150 = 170).

1,058 B.T.U. total.

So that the economy will then be 1,134 ÷ 1·058 = 1·07, *i.e.*, 1·07 lbs. of primary steam to obtain 1 lb. of gained steam (weight for weight).

14. From the above calculations it will be seen that the *economy* of working at various primary pressures is not very different, if none of the heat is wasted, or not accounted for. The variation of primary pressure, however, makes an enormous difference in the *time* production.

Economy of Low Pressures.

15. Up to the present, we have been treating of various primary pressures working with the same secondary pressure at or just above that of the atmosphere. This is undoubtedly the most convenient pressure inside the evaporator. But sometimes it is desired to reduce the pressure outside the coil to a *minus* pressure—*i.e.*, some lbs. below the weight of atmosphere, so that when working at what is called a vacuum, the sea water will boil at a lower temperature, and will do so rather more economically with a lower primary steam pressure than by evaporating the sea water at atmospheric pressure.

16. There is a saving of heat by working at low pressures—that is to say, it is more economical to work with a low primary pressure than with a high primary pressure, and, consequently, with a low secondary pressure than a high secondary pressure. A larger amount of surface may be required, but that is not the point now; economy is being regarded, and the question is how much.

17. If the two primary pressures, 10 lbs. and 25 lbs., be compared, the latent heat of the former being 946 B.T.U., and of the latter 927 B.T.U., the economy would appear to be simply—as 946 : 927 :: 100 : 98—viz., 2 per cent. gained in economy. But it must not be forgotten that

there is still heat in the *primary water* draining from the coils, which is generally cooled down to below 150°, so that the heat in such primary water (from the point at which it was converted into water) down to, say, 100°, is available for heating the feed from, say, 100°, and this should, therefore, be taken into account in a comparison of the economy.

Note.—In practice the feed-water is not heated quite up to the boiling point, nor is the primary water discharged quite at the same temperature as the initial temperature of the feed (100°).

18. We will, therefore, compare three typical cases, as follows :—

(*a*) { Primary pressure, 75 lbs. per square inch.
  Secondary pressure, 25 lbs ,,

(*b*) { Primary pressure, 25 lbs. ,,
  Secondary pressure, 0 lb. ,,

(*c*) { Primary pressure, 10 lbs. ,,
  Secondary pressure, – 6 lbs. ,,
  (12″ of mercury).

1st. Take the *secondary* heat *required.*

In case (*a*) the secondary heat required is as follows :—

249	B.T.U.	For heating the feed-water from 100° to 266° = 166°, and as the quantity is $1\frac{1}{2}$ the evaporation, this would be $266 - 100 \times 1\frac{1}{2} = 249$ B.T.U.
927	,,	Latent heat to evaporate 1 lb. of water at 25 lbs. pressure.
1,176	,,	Total heat *required.*

In case (*b*) the secondary heat required is as follows :—

168	B.T.U.	For heating feed ($212-100\times 1\frac{1}{2}=168$).
966	,,	Latent heat to evaporate 1 lb. of water at atmospheric pressure.
1,134	,,	Total heat *required*.

In case (*c*) the secondary heat required is as follows :—

130	B.T.U.	To heat feed ($187-100\times 1\frac{1}{2}=130$).
984	,,	Latent heat to evaporate at − 6 lbs. (12″ mercury).
1,114	,,	Total heat *required*.

2nd. Now take the *primary* heat available.

In case (*a*) the *primary* heat is as follows :—

888	B.T.U.	The latent heat (at 75 lbs. pressure).
220	,,	The sensible heat remaining ($320-100=220$).
1,108	,,	Total heat *available*.

In case (*b*) the *primary* heat is as follows :—

927	B.T.U.	Latent heat (at 25 lbs. pressure).
166	,,	Sensible heat left ($266-100=166$).
1,093	,,	Total heat *available*.

In case (*c*) the *primary* heat is as follows :—

946	B.T.U.	Latent heat (at 10 lbs. pressure).
139	,,	Sensible heat left ($239-100=139$).
1,085	,,	Total heat *available*.

Therefore, the economy of the above three cases would work out and compare as follows :—

In case (*a*) { Primary pressure = 75 lbs. per sq. in.
Secondary ,, = 25 lbs. ,,

As 1,108 : 1,176 :: 1 : 1·061 economy.

In case (*b*) { Primary pressure = 25 lbs. per sq. in.
Secondary ,, = (atmospheric).

As 1,093 : 1,134 :: 1 : 1·037 economy.

In case (*c*) { Primary pressure = 10 lbs. per sq. in.
Secondary ,, = – 6 lbs. ,,
(12″ of mercury).

As 1,085 : 1,114 :: 1 : 1·026 economy.

19. The saving or economy is, therefore, greatest in (*a*) and least in (*c*), but the difference is not even theoretically very great, and a good many tons of coal would have to be burnt before a really appreciable saving would be manifested in practice.

Note.—No allowance has here been made for *waste* of heat in actual working—*i.e.*, for the heat lost with the discharged brine, and by radiation. The waste would be increased by irregularity of working, so that what is gained in theory would be lost in practice.

In a properly designed apparatus, which utilises to best advantage the heat it works with, the pressure worked at makes but little difference in the *economy* obtained. Indeed, if a substantial economy were shown by working at low pressures it would conflict with the law of nature that the heat required to raise a given quantity of water from a given temperature to its boiling point (*i.e.*, the sensible heat), and then to convert such quantity of water into steam (*i.e.*, the latent heat), is approximately the same at any pressure such steam is generated, or in other words, the "sensible" heat *plus* the "latent" heat almost equal the same total heat, at any pressure. (See Table E, p. 33; also *Note* on p. 49.)

The above economy is, of course, quite a different matter from the economy that is obtained by multiple distillation, which is treated of in the chapter on Multiple Distillation.

Steady Ebullition.

20. The secondary steam, at whatever pressure it is generated, should rise steadily from the surface of the sea water, and not in gulps, otherwise there will be a tendency to priming—*i.e.*, particles of sea water being blown up with the secondary steam, and carried over with it, so as to impair the good quality of the water condensed from the secondary steam. Baffles are sometimes fitted in the steam room to prevent priming, such baffles being of various designs to arrest these particles of sea water, and bring them down again into the sea water. More will be said as to this when the subject of "brine area" or "steam delivery area" is dealt with.

Secondary Steam Valve.

21. The pipe from the evaporator leading the secondary steam away to be condensed is sometimes fitted with a valve. The object of this valve is to regulate the flow of secondary steam, where there is a *minus* pressure in the condenser. Or such valve may be used to shut off altogether the secondary steam, so as to get up a pressure in the evaporator casing for the purpose of blowing away the brine at intervals, if required. This will, however,

be again referred to when dealing with the subject of "brine discharge." When the feeding and brining take place inwards and outwards by a constant flow, automatically worked, there would appear to be no need for this valve on the secondary steam pipe, but where the arrangement is for the brine to be blown out rapidly at intervals, then the valve would be necessary to perform this operation.

Safety Valve.

22. When an evaporator is designed for working with a pressure inside the casing above that of the atmosphere, it should be provided with a safety valve of sufficient size and load to prevent a greater pressure being possibly obtained than is sufficient to meet all emergencies. The Board of Trade rules make this obligatory, and so do Admiralty requirements.

(B) Gas-heated Steam Generators.

23. In the foregoing part of this chapter evaporators worked by *steam* heat only have been dealt with, and although a little digressive, we may here just refer to that class of evaporators which are worked by the heat of a gas stove or oil lamp, instead of by steam heat. When fire is used as a heating agent the term boiler is generally used, but a boiler is generally a much larger affair than is required for the particular purpose in view—viz., the production of distilled water of exceptional purity in very small quantities, not more in fact than a few gallons per day. Under such circumstances, gas is undoubtedly the most convenient form of supplying this almost miniature type of distilling plant required.

24. The details of this small type of apparatus, call it a boiler, evaporator, generator, or what you like, will be gone into in a subsequent chapter, when we deal with the working of the apparatus generally, after having explained all its parts. This small apparatus is complete in itself—that is, it includes a small distilling condenser, and, when required for producing drinking water, a small filter. The water is thus produced, not only of special purity, but also cold and of the best quality for drinking. The apparatus is suitable for domestic use.

(C) Heating Surface—Generally.

25. It will now be convenient to pass on to the subject of coil or tube surface—that is, the amount of heating surface required for certain productions under certain conditions of working. This is affected by the pressure of the steam inside the coil, perhaps more than by anything else.

26. It will be remembered that the *intensity* of steam heat—*i.e.*, the sensible heat of steam *in*creases and *de*creases, according as the pressure rises and falls. The higher the pressure, the hotter (sensibly) is the steam, in its gaseous state, and this *in*crease or *de*crease, as the case may be, of "sensible" heat is counterbalanced by a *de*crease or *in*crease of the "latent" heat that is emitted as the steam is reduced into a state of water. On the amount of "sensible" heat of the steam inside the coil, above the sensible heat of the sea water outside the coil, depends the amount of coil surface that is required.

27. To explain this, with a view to showing how to calculate the amount of heating surface, it is best to start with a *basis*, or a certain state or condition of things, thus :—

(*a*) A fixed pressure outside the coils, say $\frac{1}{4}$ lb. per square inch. Practically atmospheric pressure.

(*b*) A fixed proportion of evaporation and brine to the feed-water, say, from every $1\frac{1}{2}$ lbs. of feed-water supplied, 1 lb. is to be evaporated and $\frac{1}{2}$ lb. brine, making the brine $\frac{3}{32}$ in salinity.

(*c*) A fixed time for the evaporation, say 1 lb. of gained steam to be generated per hour (*i.e.*, $\frac{2}{3}$ of the feed).

(*d*) A fixed temperature for the inlet feed-water, say 150°.

28. Suppose we compare the three primary pressures of 10 lbs., 25 lbs., and 75 lbs. per square inch, working upon the basis mentioned in the preceding section. Different makers of evaporators have different rules to work by for estimating the square feet of surface required for a given evaporation in a given period of time. Much may influence them in arriving at what they consider a proper surface. Thus they may, and probably do, take into consideration what quantity of water has been evaporated by their evaporator on experimental occasions. Various matters have to be considered besides the bare question of the pressure of the steam inside the coils to settle the amount of coil surface to allow for a specified output of gained steam, and no rule can be fixed to apply to every kind of evaporator that is made. Experience can alone guide one as to the proper amount of surface, or square feet of coil surface, as it is usually termed.

29. Let us, therefore, assume that in the case above given, with a particular make of evaporator, the conditions of working are as specified in section 27, and that 1 ton of steam has to be generated from, say, $1\frac{1}{2}$ tons of sea water per hour, and for the purpose of com-

paring the effect of the three primary pressures, let us first take the primary pressure of 25 lbs. per square inch, which has a "sensible" heat of 266° (*i.e.*, 54° above 212°, the temperature of the sea water outside the coils).

30. Say also that, from experience of a particular make of evaporator, it has been found that x square feet of heating surface (*i.e.*, outer coil surface) suffices for evaporating the required quantity of 1 ton per hour, with the specified primary steam—that is, with primary steam 54° hotter (sensibly) than the boiling sea water outside the coils.

31. Now, take for comparison a primary steam of 10 lbs. pressure, whose sensible heat is 239°—*i.e.*, only 27° hotter than 212°, the temperature of the boiling sea water outside the coil. It is clear that to generate the same amount of secondary steam—viz., 1 ton in the hour—double the surface will be required, so that for this primary pressure of 10 lbs. we shall require a surface of $2x$ (whatever x may be), as the intensity of the heat presented to the coil surface (27°) is only half what it was with 25 lbs. pressure (viz., 54°).

32. For the same reason, if the primary pressure is raised to, say, 75 lbs., the temperature of such steam being 320°, or 108° hotter than 212°, the temperature of the secondary steam—all conditions remaining the same—as 108° is double the intensity of the heat of the steam at 25 lbs. pressure, the heating surface can be halved, and is, therefore, only $\frac{1}{2}x$.

33. This is carried out in practice, so that whatever number of square feet of surface is allowed for a pressure inside the coil of 25 lbs. per square inch, double that amount must be allowed, if the evaporator is to have a

pressure of only 10 lbs. per square inch inside the coil, other conditions being the same.

34. Having a fixed basis to work with—that is, say a surface of x square feet per ton of evaporation per hour, when the primary and secondary pressures are, say, 25 lbs. for the former, and practically zero for the latter—there is no difficulty in calculating what surface would be required for a pressure *on the secondary steam* greater or less than the atmosphere.

35. Thus, say the primary pressure is 25 lbs. per square inch, and the secondary pressure is, say, 10 lbs. per square inch, it will be seen that the excess heat of the primary steam over that of the secondary steam is the same as when the primary steam was at 10 lbs. pressure, and the secondary steam at a pressure of, say, $\frac{1}{4}$ lb. per square inch (viz., 27°), so that x surface would do in either case, other conditions remaining the same.

36. If evaporators are worked with a primary steam pressure suitable for secondary steam generated below atmospheric pressure, the heating surface has to be calculated in the same way according to circumstances.

Probably, taking all circumstances into consideration, the most convenient pressures to take, for ordinary working, are about 20 lbs. pressure for the primary steam, and $\frac{1}{4}$ to $\frac{1}{2}$ lb. pressure for the secondary steam—when one evaporator only is brought into requisition. This is when *exhaust* steam is being used inside the coils. If *live* steam is used, then the 20 lbs. pressure may be considerably increased.

37. The relationship of pressures inside and outside the coils is a subject which needs much consideration in *multiple* distillation, where it will be seen there are two, three, or more evaporators linked together, so that the

secondary steam of one evaporator becomes the primary steam of the next, and the secondary steam of the second evaporator becomes the tertiary steam of the third evaporator, and so on, as long as the successive distillations are carried. As, however, each successive distillation is less in degree than the preceding one, a limit is soon reached. The matter will, however, be more fully dealt with in the chapter on "Multiple Distillation."

Form of Heating Surfaces.

38. To proceed with the usual type of evaporator—that is, one that is heated by steam inside a coil—we will now deal with the form and shape of such coils or tubes.

39. Evaporator makers differ very considerably in the form of surface they prefer, and there have been considerable changes made in the construction of these surfaces from the earliest type of evaporators made.

40. Until about fifteen or twenty years ago, the only form of evaporating surface used was a sheaf or nest of tubes placed vertically, see Fig. 5, the primary steam entering at A, and after doing its work inside the tubes, the primary water thus formed fell into a bottom pan, and was blown away at B. These vertical tubes T were expanded in gun-metal tube plates at top and bottom, and a cap, C, to which the steam inlet at A was connected, was fitted at the upper end. The primary steam distributed itself inside the tubes, where it was condensed into primary water, by transferring its latent heat to sea water outside these tubes.

41. In these early days there was very little provision made for cleaning these surfaces. A very small mud door, D, was fitted to the lower end of the casing, through

which scaling tools had to be inserted, to scrape off as much of the deposit as possible for the time being, until the cylinder or casing could be lifted off, to give better access to the tubes. This did fairly well for land stations, where there was plenty of space above and around, but on board ship, with little or no head room, a better arrangement for cleaning was soon found necessary.

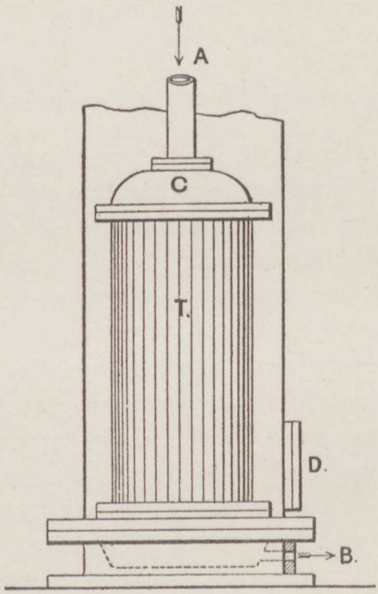


Fig. 5.

42. An improvement came about in a type of evaporator fitted with long U-shaped tubes, see Figs. 6 and 6*a*. These U-shaped tubes were fitted so as to be capable of being drawn out of the evaporator casing, along with the door. The casing was in the form of a horizontal cylinder. and the door placed on the front end.

43. This type of evaporator was worked with boiler

steam, and the secondary steam was generated at a pressure varying from 10 to 15 lbs. per square inch. This

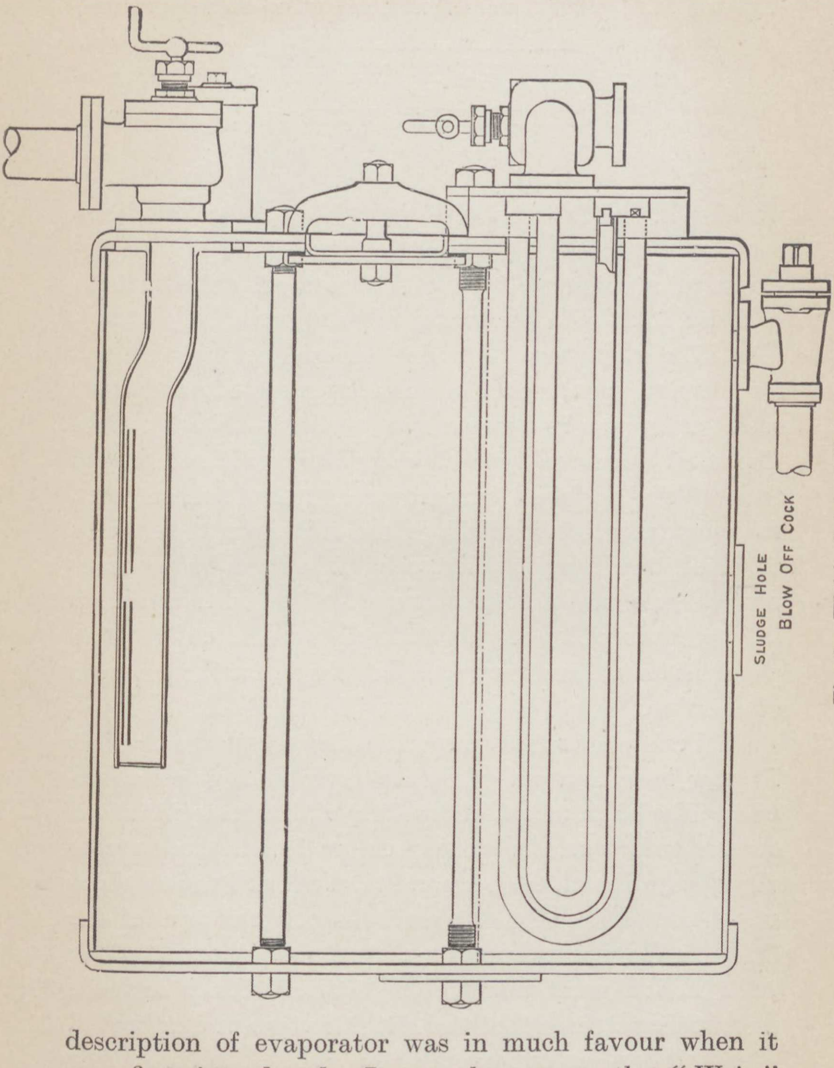


Fig. 6.—Weir's Original Evaporator.

description of evaporator was in much favour when it was first introduced. It was known as the "Weir" evaporator, and in 1889 and 1890 (under the Naval Defence Act) a very large number of cruisers and battleships of H.M. Navy were fitted with these evaporators,

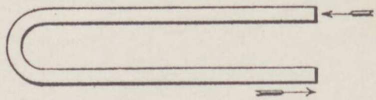


Fig. 6a.

working in combination with the "Normandy" distilling condenser. Messrs. Weir have, however, since then introduced a different type of evaporator, with vertical cylinder fitted with horizontal tubes or coils.

44. The advantage of having an easily removable coil for cleaning purposes was soon appreciated, and very soon further improvements were made in this direction. The most approved type of evaporator which succeeded the "Weir" original evaporator appears to have been the evaporator introduced by Caird & Rayner, the novelty of which was in having the coils in the form of a volute, placed horizontally in the casing, and fitted to the door, so that by opening the door the coils came out all of a piece therewith, and were then detachable for the purposes of cleaning.

45. Perhaps the most important feature of the Caird & Rayner invention was that the pressure inside the coil was utilised as a means of cracking off the scale deposited on the outer surface. The pressure had a tendency to slightly straighten the coil, and thus effected the cracking off of the scale. Fig. 7 shows the original type of the Caird & Rayner evaporator, introduced about 1891 or 1892, and a great many ships of H.M. Navy and the mercantile marine were fitted with this type of evaporator. Fig. 8 shows an improvement on this. The coils being

no longer fitted to the door. In the "Weir" evaporator the tubes or coils are also now placed horizontally, and run somewhat differently. The more recent "Normandy" type has horizontal tubes running somewhat differently from a volute. Numerous other evapor-

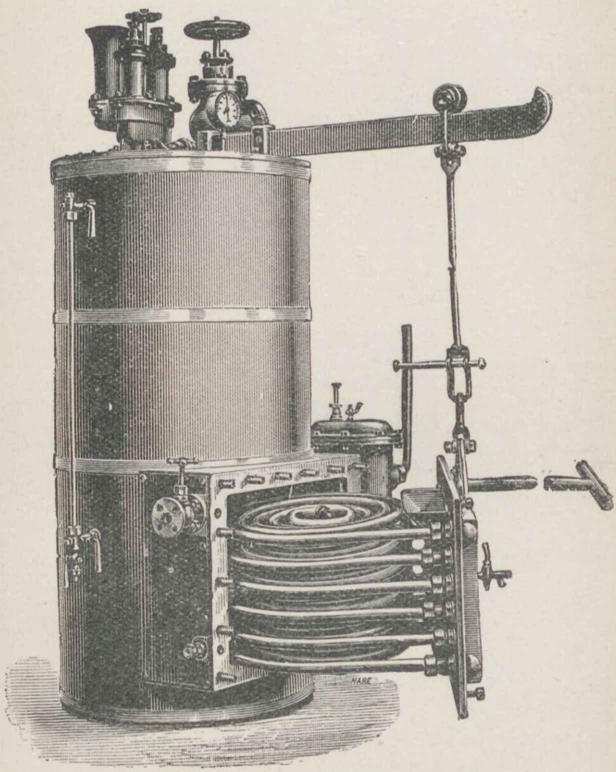


Fig. 7.—Caird & Rayner Evaporator—Old.

ators are also made with the tubes or coils running in various ways.

The object in all of these various methods of fitting the heating surface is to get as much surface into as little space as possible, and for such heating surfaces to be as effective as possible when fitted inside the casing, as will be referred to shortly.

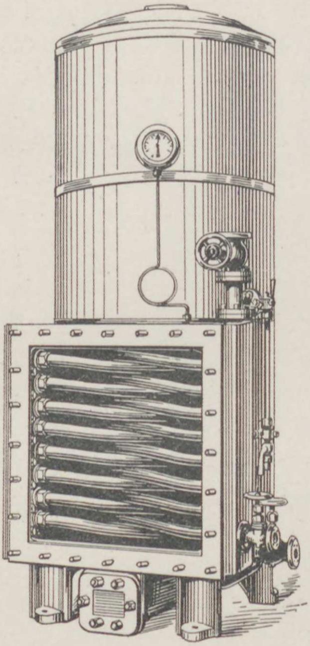


Fig. 8.—Caird & Rayner Evaporator—New.

46. The foregoing diagrams are not intended to show the details of any particular make of evaporator, but to indicate the strides made as each novelty of type became introduced. If further details of these, or of any other make of evaporator are desired, application should be made to the makers.

47. Since the above types of heating surfaces have been introduced countless types, more or less like these already mentioned, have been placed in the market or advertised. Thus, coils are made in the form of a volute, either horizontally or vertically fitted to the casing (and it may here be noted that fitting the coil to the door is somewhat discountenanced), some coils are made zig-zag, or with various contortions, according to the fancy of the makers.

48. The type of heating surface or coil that is really best is the one that satisfies most completely all the requirements of practical working, and these requirements may be shortly summarised as follows :—

1st. The heating surface required should occupy the minimum of space.

2nd. The coil or tube surface should be capable of being easily freed from scale.

3rd. The coils should be light and easy to handle, remove, and replace.

4th. The joints must be tight and durable, and when the coils have to be removed, must be easily broken and remade.

5th. All the coil joints should be exposed to view when tested either by water or by steam.

6th. The coils should allow the primary water to leave the inner coil surface easily, without lying there, as this deadens its heating power by preventing the access of steam to it.

49. The above points are perhaps the most important to keep in view when arranging for the heating surface of an evaporator, so as to give the greatest satisfaction in

working; these points may be supplemented by the following observations :—

(1) The volute-shaped coil would appear to be the best for cracking off the scale as it accumulates.

(2) The original vertical straight tube would appear to be the best for allowing the primary water to get away from the inside of the heating surface.

(3) Most makers prefer the primary steam to enter at the top of the coil, and the primary water to drain away at the bottom, so as to be helped by gravitation. This is not, however, obligatory, as the primary water will always be blown forward by the primary steam, whether the coil (in volute shape) is placed vertically or horizontally.

(4) The coil in volute, when lying horizontally, accommodates itself better to the cylindrical casing.

(5) Again, it is better for the coils to be similar and distributed in sets of eight or ten each than to be grouped in one sheaf or nest. Lightness and ease of cleaning are at once obtained by having the coils separate.

(7) The coils should be interchangeable.

50. The foregoing description of various types of heating surface is not, as already stated, intended to be exhaustive, there being a great number of designs of heating surface, more or less alike in their description, and more or less favoured. The object was to show the gradual improvements made in evaporative surfaces on the original straight and vertical sheaf of tubes shown in Fig. 5. First, there came the horizontal U-shaped tubes grouped together in one sheaf or nest; then the circular or volute-shaped coils, also grouped together and fitted to the inside of the cleaning door; then the same class of coils, but not

always in the form of a volute, nor grouped together, but each item of surface (some 8 to 10 items) separately fitted to the inside of the evaporator-casing, instead of to the inside of the door. A short description has also been given of the most material points requiring consideration in the various types of heating surfaces put in evaporators.

51. It is now usual to describe the heating surface of the evaporator (and, indeed, the cooling surface of the condenser) by the number of square feet of the outside surface of the coils or tubes used. As this is the subject of calculation, the following Table K gives the outside surface (in square feet) of various diameters of tube per foot length.

TABLE K.—Outer Surface in Square Feet of Tubes per 1 foot Length.

Outer Diam. of Tubes in Inches.	0	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
0	..	0·0327	0·0654	0·0982	0·1309	0·1636	0·1963	0·2291
1	0·2618	0·2945	0·3272	0·3600	0·3927	0·4254	0·4581	0·4909
2	0·5236	0·5563	0·5890	0·6218	0·6545	0·6872	0·7200	0·7527
3	0·7854	0·8181	0·8508	0·8836	0·9163	0·9490	0·9817	1·0145
4	1·0472	1·0799	1·1126	1·1454	1·1781	1·2108	1·2435	1·2763
5	1·3090	1·3417	1·3744	1·4072	1·4399	1·4726	1·5053	1·5381

Size and Thickness of Coils.

52. The size or diameter of the coil is also an important matter. Tubes that are small are apt to have a more adherent scale than tubes of large diameter, as the expansion and contraction of the outer circumference when at work is greater in the large diameter, which enables it therefore to crack off the scale. Another reason for preferring a large diameter is that it reduces the length

required to provide the amount of surface deemed necessary. The larger tube is also more rigid, and, therefore, less liable to be bent. The larger tube also allows the water inside to escape more freely.

53. Perhaps it is best to fix on a diameter of, say, $1\frac{1}{2}$ inches when the tubes are about 10 to 12 feet long, and say, $2\frac{1}{2}$ inches if the tubes are in about 20 feet lengths. The size of the coil, however, may differ with various makers, according to the shape and manner in which the coils are fitted.

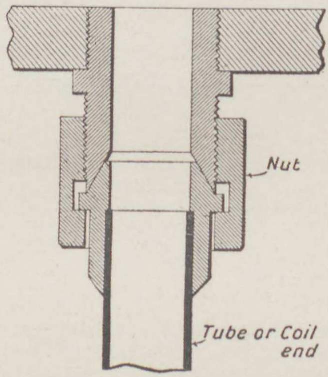


Fig. 9.

54. Whatever may be the size of the coil, it is most important that the tube or coil—that is, each item—should be in one piece solid drawn throughout. It is also most important that the joints at the end of each item—that is, the steam and water ends of the coils—should be sound, reliable, and durable, yet easily broken and re-made. An effective joint is made by expanding the tubes in gun-metal elbows or end pieces, then for these end pieces to be screwed into the casing where the steam and water pockets are. Such a joint is of the same class as an ordinary union joint (see Fig. 9).

Instead of having one large nut as shown, which is bulky in a large coil, the joint may be equally well made with a flange with studs and bolts in the ordinary way. See also Fig. 9*a*, which makes a good and effective joint.

T is the tube or coil expanded in a gun-metal casting, and on each side of "steam inlet" a stud and nut will secure all to the evaporator.

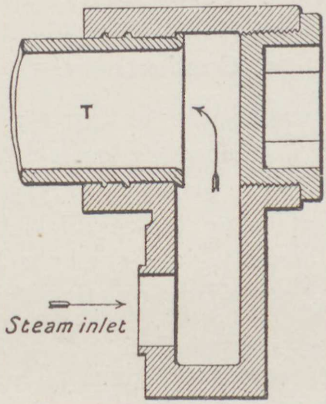


Fig. 9*a*.

55. The thickness of the coil is usually from, say, $\frac{1}{8}$ inch thick in small tubes, to $\frac{3}{16}$ inch in tubes of larger diameter. The usual rule is for evaporator tubes to be not less than 0·104 inch thick for tubes of 1 inch bore or under, and not less than 0·128 inch for tubes exceeding 1 inch bore. Although it is often desired to make the bends in the coils as sharp as possible, $\frac{3}{16}$ inch thickness is not perhaps too much to allow for the curving or bending process that the coils have to be subjected to. It is important to remember that the tube of each coil should be one entire piece, and not be made in two or more lengths.

Material Used for Coils—Copper and Brass.

56. The material used for the coils is either copper or brass tube, solid drawn, and the complete set of coils, fitted in place, are usually required to be sound under a test pressure of about double the maximum boiler pressure. Other metals are never used, but of the two (copper and brass), the former has many advantages over the latter, which may be pointed out as follows:—

1. Conductivity.

57. *First*, the conductivity of heat through copper is a great deal better than through brass. From the experiments of Péclet, with plates of various substances, of 1 foot square surface by 1 inch thick, he recorded the amount of heat (in units during one hour) passing through these plates (the two surfaces differing 1° in temperature) as follows:—

A copper plate passed 515 units of heat in the hour, whilst a zinc plate similar in size and thickness passed only 225 units of heat.

58. If, therefore, we have a composite plate made in parts, the thickness being $\frac{7}{10}$ inch of copper and $\frac{3}{10}$ inch of zinc, we should have a composite plate representing the proportions of brass (70 per cent. copper + 30 per cent. zinc), and one would expect this composite plate, if experimented upon like the other two separate plates (copper and zinc) to pass heat through it as follows—viz., $515 \times 0{\cdot}7 = 360{\cdot}5$ units, and $225 \times 0{\cdot}3 = 67{\cdot}5$, and that $360{\cdot}5 + 67{\cdot}5 = 428$ units would be the heat passing through brass, as against 515 units passing through copper, the ratio being—As 428 : 515 :: 1 : 1·2.

The proportion or ratio of effectiveness between the two metals, copper and brass, shows that copper is about 20 per cent. better than brass, so that from the foregoing figures one would expect that it would require about 20 per cent. more heating surface if made of brass than of copper. A brass plate made of an alloy of 70 per cent. of copper and 30 per cent. of zinc does not appear in the list of metals experimented on, but in actual practice with distilling machinery it has been found that a copper sheaf has about 15 to 20 per cent. more effectiveness than a precisely similar sheaf of brass tubes. Therefore, it may be said that a copper coil has practically about 20 per cent. more effectiveness than if the coil were made of brass, and, consequently, if copper is used instead of brass, about 20 per cent. less surface will be found sufficient for the same work. The metals copper and brass, are usually left to the choice of the evaporator-maker in Admiralty specifications, copper is usually selected for the heating surfaces of the evaporator.

Note.—It should be noted that the above comparison in the passage of heat through the two metals is not at all in the same ratio as what is usually termed the conductivity of heat by metals. The following Table L gives the ordinary conductivity of heat by various metals, and if copper and brass be compared in that list it will be seen that whilst copper is placed at 73·6 per cent., brass is placed at 24 per cent. This would lead one to suppose that copper is about three times as effective as brass, which is not at all borne out as regards the passage of heat through these metals as shown in practice.

TABLE L.—Conductivity of various Metals.

	Ratio.	B.T.U.	
Silver,	100	..	Heat passed through a plate 1 in. thick, per sq. ft., per hour. (See § 57, page 94.)
Copper,	74·0	515	
Gold,	53·0	..	
Zinc,	28·1	225	
Brass,	24·0	428	
Tin,	15·0	..	
Iron,	12·0	233	
Lead,	9·0	113	
Platinum,	8·0	..	
German silver,	6·0	..	

2. Galvanic Action.

59. *Secondly*, the composition of brass predisposes this metal to galvanic action, when used in a distilling apparatus. The two metals, copper and zinc, of which brass is composed, are the positive and negative poles of a galvanic battery, thus predisposing the zinc to decompose, whilst the gases oxygen and hydrogen are given off at the poles so long as the galvanic action is going on. Brass tubes are always required to be tinned, inside and out, when used either for evaporator or distiller coils, and a very small percentage of tin is specified as part of the admixture. Zinc plates are also ordered to be fixed to the interior of the casing, in order that the galvanic action may act on these zinc plates or blocks, and not on parts of the evaporator. But in spite of it all, brass tubes do perish quicker than copper.

60. The usual way in which such galvanic action shows itself is by the brass tubes becoming pitted by small holes, through which a pin or needle can be readily passed from outside right through the tube, with the result of course, that they cease to be either steam or water-tight, as the case may be. If more tin could be added to the alloy, the above objection might be reduced, but this cannot be done, as to put more than 1 per cent. of tin

in the alloy makes it impossible to solid-draw it into tubes.

61. Therefore, taking all matters into consideration, copper would appear to be the best material of all for evaporator coils. There is no need to tin the coils, either inside or out, if the primary water is condensed from the exhaust steam on board, which is greasy, and is returned to the boiler, but if the primary water is used (as in land apparatus) for drinking purposes, the interior of the evaporator coils should be tinned.

Evaporative Surfaces—How Fitted.

62. The coil, whether copper or brass, is either brazed or expanded into the end pieces, which are fitted to the casing as already shown. If the tube ends are brazed into these end pieces, the same will have to be made of brazing metal, but if the tube ends are expanded into the end pieces, then the same are made of gun-metal. The latter is by far the best work, as gun-metal is stiffer and better than brazing metal. If the tube ends are expanded in, they should be softened so as to facilitate expansion.

63. The joint made between the end pieces and the casing has already been shown in Figs. 9 and 9*a*. The joint is made by having a spigot or cone on the tube end or casting which fits into the hole in the pocket, and the joint is then tightened up by means of either one large nut, somewhat like an ordinary union joint (see Fig. 9), or the joint may be tightened up like an ordinary flange with a couple of nuts with studs (Fig. 9*a*). These studs are best made of phosphor bronze or manganese bronze, these metals being stiffer than gun-metal. It is not,

however, necessary to make the small elbows of this metal, as a good gun-metal casting will be found easier to make, and give greater satisfaction.

64. If the coil ends are expanded into the gun-metal elbows, a couple of small grooves inside the elbow socket (as shown in Fig. 9*a*) will make a tighter fit when expanded. A screw or thread is sometimes put instead of grooves, but this does not make such a tight joint as the grooves, which will stand a test pressure without the chance of leaking round the thread.

Coil Drain.

65. Before leaving the subject of the evaporator coils, a few words are necessary to explain the action of the coil drain.

66. As the primary steam inside the coils is condensed into water when giving out its latent heat for the purpose of generating steam from the water outside the coils, this primary water is blown away at the end of the coils, and the coil drain is usually a cock with a by-pass of suitable size for passing water only, as blowing away primary steam would be very wasteful.

67. This by-pass must not, however, be too small, otherwise the primary water would not escape freely, and the coils would become water-logged, and their heating power very considerably reduced. The exact size of the hole for the by-pass depends on the pressure inside the coil, and the quantity of water that has to escape, and can only be determined by experience.

68. It is important to note that the primary water is practically at the same pressure and, therefore, of the same temperature as the " sensible " heat of the primary

steam *inside* the coils, so that if used for heating the feed-water it has this amount of sensible heat to impart. This will be reverted to when dealing with the feed-water heater.

(D) The Evaporator Shell or Casing.

69. Having treated of the surfaces of the evaporator, the casing or shell, as it is sometimes called, may now be dealt with. In shape it varies according to the form of coil that is fitted inside it. The evaporator casing is usually cylindrical and vertical, and the coils are fitted inside to the lower part, the upper part being devoted to the steam-room or space.

(*a*) Steam-Room.

70. The steam-room should be of sufficient diameter and height to allow the steam or vapour generated from the sea water in the lower part of the casing to escape easily, without risk of priming—that is, without carrying over any particles of sea water with it. This point requires some consideration, as the sea water is in a somewhat violent state of ebullition, and if the space over the boiling brine is too contracted, the brine will rise and froth up, and eventually be carried over with the steam, so that the distilled water, when tested, will be found to contain more or less salt.

71. The question of what is a sufficient steam space to allow is to a very great extent determined by experience, much depending upon the form of the casing, the position of the coil, and the pressure under which the sea water is being evaporated, and quantity evaporated.

72. In theory, if water is being evaporated under high pressure, the steam delivered should be in smaller bubbles

than when evaporated at a low pressure, and one would, therefore, be inclined to allow a steam-room somewhat in proportion to the specific volume of the steam evaporated. This, however, would not at all guide one in practice, for take the two pressures of 10 lbs. per square inch, whose steam has a specific volume of 1,009, and 75 lbs. pressure, whose steam has a specific volume of 300, the steam space for the former pressure would be rather over three times the space of the latter, which is not at all in accordance with what is found requisite in practice. It is, therefore, safer to take the steam space from precedent, when it will be found to approximate itself somewhat as follows :—

The diameter of the evaporator casing—*i.e.*, the area of the brine surface—will be about in proportion to the weight of steam evaporated in point of time, the pressure under which it is evaporated not making very much difference; it is the *quantity* of evaporation that is important as regards the area at the brine level. The height of the steam space, on the other hand, does not vary very much with the amount of steam evaporated in point of time, provided a certain minimum height is allowed in all cases. But here again the practice of putting baffles upsets the making of any general or inflexible rule that will apply to all cases.

Note.—The arrangement of these baffles requires great care, for if placed unsuitably, they may in fact increase the priming by causing a further contraction of the delivery area.

73. In very small evaporators—*i.e.*, where the production, in point of time, is very small, say 2 or 3 gallons per hour—the diameter of the casing would become absurdly small, if it was estimated in proportion to the

yield by large evaporators for the same time ; therefore, a minimum should be adopted before the proportion is worked out.

To facilitate the understanding of this subject, suppose the diameters of two evaporators have to be determined, one for generating steam at the hourly rate of 1,000 lbs., the other of 20 lbs. Assume that the area at the brine level is 400 square inches, which would make the diameter of the shell $22\frac{1}{2}$ inches. By the rule of proportion 1,000 : 20 :: 400 : 8. The diameter of a shell with an area of 8 square inches would be barely $3\frac{1}{2}$ inches, an absurd dimension for an evaporator. A minimum diameter should be fixed, so that the *ratio* would cause the small evaporator to be of a suitable diameter.

(*b*) Material of Casing.

74. Undoubtedly the best material is gun-metal—that is, an alloy of copper and tin—the proportion of tin being between 10 and 12 per cent., and that of zinc 2 per cent. or less. This is Admiralty quality, and evaporator casings, especially the lower part containing the sea water, should be made of it. The steam-room is sometimes made of iron or steel galvanised, as also are the base and cover, but it is best for the entire evaporator to be made of gun-metal, as the corrosion is very great. When iron or steel is used it must be extra thick, in order to allow for the wear that sets in very quickly. Under these circumstances steel or iron casings become heavy and expensive, and are, then, not nearly so reliable as gun-metal. The upper part or steam-room may be made of copper, if preferred. It may be mentioned that quite small evaporators may be made of galvanised cast iron.

(*c*) Zinc Plates.

75. To preserve the casings of evaporators, zinc plates are sometimes fitted inside the casings, in order to take the galvanic action ; but they do not appear to be needed in casings made of gun-metal. These zinc blocks, as already stated in a former page, very soon corrode away and require some care in replacing, for if badly fixed they may be worse than useless. The gun-metal parts of an evaporator have been known to last for a considerable number of years without showing any signs whatever of perishing.

(*d*) Fittings and Mountings.

76. The usual fittings on the evaporator are as follows :—A *steam valve* for regulating the steam supplied to the interior of the coil. A *coil drain—i.e.*, a valve or cock for opening or closing the passage—for the escape of primary water condensed inside the coil. A *feed inlet*, which may, or may not, have a non-return valve, according as the feed-water is to enter, or not, against pressure inside the casing. A *filling pipe and cock* for quickly charging the evaporator with feed-water to start with. A *brine outlet* for the brine to discharge either into a brine receiver or elsewhere. A secondary *steam pipe* on the top of the evaporator, fitted with a *valve*, for getting up a pressure in the casing when desired. A *pressure gauge* for indicating the pressure of the steam inside the coils. Another *pressure gauge*, to indicate the pressure inside the casing. A *water gauge*, for indicating the brine level inside the casing. A *safety valve*, when pressure is got up inside the casing. A *test cock*, for use with the salinometer. A *large door*, facing the coils or evaporating surfaces, for

enabling the joints to be readily seen, and the coils to be easily detached and replaced when the door is taken off. A *smaller door*, fitted below the large door, for raking out the scale that falls from the coil.

77. A good deal of scale will also be found to adhere to the inner surface of the casing itself. This deposit, although it is well to remove it, has little influence in reducing the output of the evaporator, as the casing or, at anyrate, the actual shell is not an evaporating surface, but the surface of the steam pocket cast on the shell helps evaporation.

1. Steam Inlet.

78. The inlet steam valve requires but little comment. It should be of the best make, and of ample size for admitting a proper supply of steam to the coils. The inlet to the coils or to steam pocket can be made of suitable size to admit only sufficient steam (when the full steam pressure is in the pipe leading to the evaporator) for the maximum pressure specified for the coils. By this means, if the coils are removed, as a specified condition, and the primary steam is allowed to fill the casing, a smaller safety valve can be used for the evaporator casing.

2. Secondary Steam Pipe.

79. This pipe carries the secondary steam, as it is generated by the evaporator, to the distilling condenser. It should be large enough to carry off such steam, without causing any back pressure, for the *maximum* output of gained or secondary steam.

80. When the evaporator is working at atmospheric pressure, or just above atmospheric pressure, it is con-

venient to have the entry to the steam pipe governed by an orifice of suitable size, so that the pressure of the secondary steam inside the evaporator casing may be recorded on a water pressure gauge, and the height the water as forced up may be made to record the quantity of steam that is passing through the orifice. A water pressure gauge is best for this purpose, as an ordinary steam gauge is not accurate for such very low pressures.

3. Pressure Gauges.

81. The two pressure gauges placed on the evaporator are to indicate the pressures of (1) the primary steam *in*side the coils, and (2) the secondary steam *out*side the coils. The primary steam gauge is the usual Bourdon type, and on its face should be indicated the maximum working pressure. For the secondary steam, if the evaporator works only at atmospheric pressure or just above it, the best and simplest type of gauge is an ordinary water pressure gauge, which records very slight variations in low pressures more accurately than an ordinary steam gauge. If there is to be a vacuum (more or less great) inside the casing, the vapour gauge is often of the compound type—that is, for secondary pressures above and below that of the atmosphere.

4. Safety Valve.

82. The safety valve or valves fitted to the evaporator shell give relief when pressure is increased in the evaporator casing for blowing away the brine, or when the casing is tested with all the coils removed and the primary steam allowed to fill the casing. The removal of the coils, as a test, prevents any risk if the coils get leaky, or damaged.

5. The Coil Drain.

83. The use of this is explained in paragraphs 66 and 67.

6. The Feed Inlet.

84. The feed inlet is placed at various parts of the casing. Sometimes high up, sometimes low down. The best place is probably at a point that enables the feed-water either to flow in or be pumped in, as near as possible to the centre of the ebullition, because there it is more likely to mix up well with the sea water that is boiling, and the salinity of the whole body of brine in the casing thus kept more uniform. It is also well to place the feed inlet on the opposite side to the brine discharge, so as to prevent the feed-water passing away with the brine before it has been sufficiently evaporated, as this would render the brine stronger than it need be. The manner of heating the feed, and of regulating it, will be dealt with later on.

7. Filling Pipe and Cock.

85. This is for charging the evaporator with sea water quickly to start with, and thus avoid the tedious process of filling it slowly by means of the feed-box or regulator. The filling pipe should not, however, be used as a substitute for the proper method of feeding the evaporator. This should be left to the automatic work of the feed regulator, but in case of emergency this filling pipe might be used temporarily to feed the evaporator, its regulation being then done by hand.

8. Brine Discharge.

86. This outlet should be placed as far away as possible from the feed inlet, and the brine should be taken from the lower part of the casing, preferably up an internal dip pipe to the level of the surface of the brine, where it is then discharged into a receiver, and diluted and cooled there. Or it can be allowed to flow away, or be blown away, according to circumstances. All brine pipes should be of ample size, as the furring of them soon takes place; if these pipes are made too small they will get choked.

9. The Water Level Gauge.

87. This gauge is usually placed on the evaporator casing to indicate the level of the brine inside. When the evaporator is working automatically at, or about, atmospheric pressure, the brine automatically keeps at a proper level, thus enabling the brine to overflow into the receiver. This water gauge, therefore, indicates the actual level of the brine when depressed by the slightly varying pressure inside the casing, and is gradually forced up the dip pipe, so that the level in the water gauge can be read with the rise in the secondary pressure gauge on the steam-room, the depression of the former being practically the same as the rise of the latter.

10. Test Cock.

88. This small cock is placed on some convenient part of the evaporator shell, generally at about half the depth of the brine. It is used in connection with the salinometer for testing the strength—*i.e.*, the salinity—of the brine. In some cases the attendant in charge adopts this means

for regulating the feed, altering the feed-cock by guess work till he gets a strength of brine that he considers shows a proper amount of feed. This method has the advantage of being simple, but such a system of regulating the feed is somewhat risky. The amount of feed supplied is pure guess work, and should he leave his work, for only a short period of time, he may return to find his evaporator either filled with water, or the feed supply so insufficient that the evaporator is salted up, and practically useless, until it is opened out and cleaned.

89. A description of the salinometer and the mode of using it are as follows :—

The salinometer is a small float, made either of metal or glass, so weighted that it sinks to varying depths when placed in liquids of different densities. Fig. 10 shows an ordinary salinometer, 8 to 10 inches long. The central bulb is hollow, so as to make the instrument buoyant, and the small bulb at the bottom (W) is an adjusted weight, or poise, so that when the salinometer is placed in the saline liquid to be tested, it will sink deeply if the density is slight, but less so when the density or specific gravity of the liquid increases. The figures 1, 2, 3, 4, placed on the upper stem are intended to denote $\frac{1}{32}$, $\frac{2}{32}$, $\frac{3}{32}$, $\frac{4}{32}$. By putting the salinometer in brine drawn from the test cock, if its salinity is $\frac{3}{32}$, the salinometer will sink down to the figure 3 on its stem.

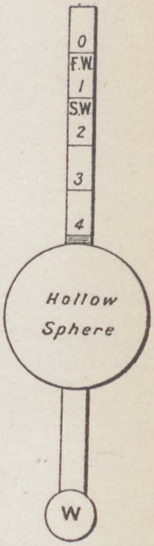


Fig. 10.

The brine to be tested must be at the temperature of 200°, which experience shows to be the most convenient. If this temperature is not kept to, the strength denoted by the salinometer is altogether delusive, as will be seen by referring to Table C C, p. 26.

Note.—If the brine to be tested has a temperature lower than 200°, the reading of the salinometer requires adjustment. Thus, with brine at 200°, the salinometer will indicate $\frac{2}{32}$, whereas at 180° the reading will be $\frac{2 \cdot 25}{32}$, and at 160° it will be $\frac{2 \cdot 5}{32}$, although the actual strength is $\frac{2}{32}$.

The figure 0 is the line the salinometer will sink to if put in fresh water (at 200°). These salinometers do not usually record a greater salinity than $\frac{4}{32}$, at which point there is usually a danger signal, to show the salinity is too great to be safe.

Note.—In connection with the use of the salinometer, the part of Chapter III. dealing with "Density" and "Salinity" should be read. A salinometer is really an instrument for ascertaining the "salinity" of the water it is placed in—*i.e.*, to show its buoyancy as compared with that of ordinary water. Specific gravity is the weight of a substance in comparison with an equal volume of distilled water at a temperature of 60°. The salinometer really indicates the relative buoyancy of salt water as compared with that of ordinary water at 200°. The salinometer is a delicate instrument, and if the bulb or hollow sphere is bruised, or the metal is allowed to be covered with scale, its accuracy in recording salinity will be much impaired. It should also be mentioned that salinometers are not always correct. They have been known to vary considerably when three or four salinometers of different makers have been put in the same solution at the same temperature.

(*e*) Lagging.

90. Finally, the evaporator casing should be covered or lagged with a good non-conductor, so as to avoid waste of heat by radiation.

(*f*) Construction Generally.

91. Generally, the evaporator in all its parts and in all its fittings should be supplied with everything of the best materials and workmanship. The wear and tear of an evaporator is very great, and if cheap and faulty, or inefficient work is used, the probability is that in a short time the evaporator will be put out of use by some trivial breakdown, necessitating repair.

(E) Feed.

1. Quantity.

92. After many years of trials, the best *quantity* of feed has been found to be one and a-half times the evaporation, which gives a brine salinity of $\frac{3}{32}$.

From this it will be seen that if the gained distilled water is measured against the brine discharged, its quantity will be twice the brine, or the brine one-half the gained water, whichever way it is taken. In official trials, the brine is measured so as to be one-half the evaporation; then it is known that the specified salinity of the brine is correct, and that the feed is what it should be in quantity.

93. The above, of course, applies only to ocean water of the usual strength of about 3·5 per cent. of saline matter. If the water is exceptionally strong, or the reverse (as mentioned in the Chapter on "Sea Water"), allowance must be made for this, by increasing the feed if it is over

strong, or reducing it if it is abnormally weak to start with.

94. Sometimes, again, the water to be operated on is fresh water, but not sufficiently pure for special requirements. In this case the feed quantity can be shortened very considerably.

95. It has already been shown that water which contains polluted or greasy matter, indeed any impurity that will vaporise and come over with the steam, cannot be distilled so as to generate pure steam for condensation into pure water. Put shortly, distillation only separates from salt-water substances that are not vaporisable, such as the saline matter it contains. On the other hand, although polluted matter may be contained in the water to be distilled, so as to make the distilled water unpleasant for drinking purposes, the operation of boiling may destroy all matter dangerous to health.

2. Feed Regulation.

96. There are many ways of regulating the quantity of feed-water to the evaporator. The feed is usually taken from the upper part of the distiller casing—that is, from the circulation water just before it is discharged, and is to some extent hot, as already explained. Therefore, a simple manner of regulating a fixed amount of feed-water, sufficient when the evaporator is generating steam to its maximum power, is to have a feed-box with a float in it, arranged so that as it rises with the water entering the box, the float rises and cuts off the inflow of water. The water in the box then flows away through a small hole of suitable size at the bottom of the box, so that the constant level kept over this hole regulates

the amount of water that runs through the hole. As this feed-water runs into the evaporator the quantity is fixed by the maximum amount of sea water evaporated. This is, of course, if the evaporator is working at atmospheric pressure. If it is working at a pressure, then the feed-water, instead of being allowed to run into the evaporator, must be pumped in.

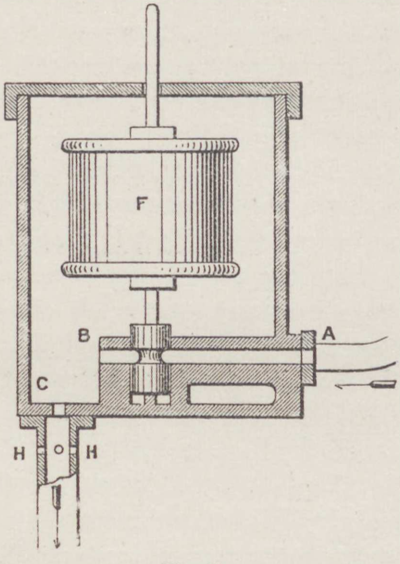


Fig. 11.

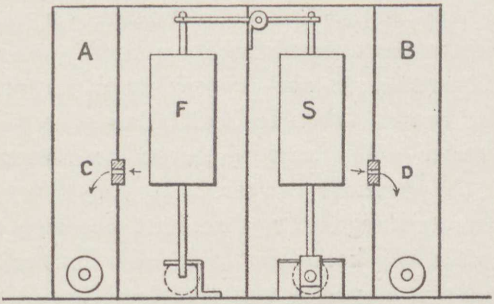
97. This type of feed regulator fixes the uniform amount of feed-water; but it does not vary its quantity, so as to be always in proportion to the amount of evaporation that is taking place inside the evaporator, unless the inlet cock to the feed-box is manipulated by hand so as to keep the water at a lower level. Fig. 11 shows a feed-box described in § 96. The feed-water enters the feed-box at (A), and its passage into the box at (B) is

controlled by the spindle end of the float (F), which rises as the water rises in excess of what flows away at (C). The hole (C) is of suitable size for letting out a proper quantity of water, when the level is at a height regulated by the controlling effect of the float. As the water flowing from (C) would, by its gravitation, or by pump action, have a drawing effect on the water in the box over the hole (C), small holes (H) are provided to prevent any such action. These holes (H) also act as a means for inspecting the flow of water running through hole (C), which should be in a steady, unbroken column or stream of water when a proper flow of water is taking place.

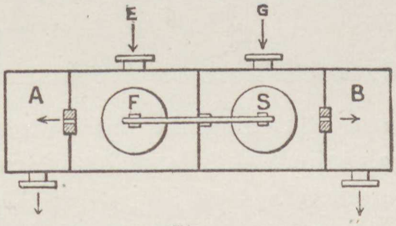
98. The type of feed box in Fig. 11 is, however, designed for passing a fixed quantity of water, irrespective of the amount of feed-water that is evaporated. If it is desired to regulate the feed so as to be always in due proportion to the evaporation, it is advantageous to have a feed regulator of the type shown in Fig. 12, which consists of two boxes with a pair of balance floats (F) and (S). As the distilled water enters at (E) and gradually fills the box with (F) float in it, the float is thus raised, and as it rises, it gradually depresses the float (S), thus causing it to gradually open (by means of a piston valve) the inlet (G) for admission of sea water. When the fresh water and sea water rise to a certain height these waters respectively run out into side boxes (A) and (B) through orifices (C) and (D), in quantities depending upon the height the levels are above these orifices. The fresh water continuing to rise in the (F) float box thus constantly regulates the sea water entering the box with the (S) float in it, so that the sea water leaving the side box (B) is always in due proportion to the fresh water leaving the side box (A). The action of this type of regulator is

automatic and immediate—*i.e.*, the moment the slightest variation takes place in the flow of fresh water into the box, with (F) float in it, the action of (F) float is instantly communicated to (S) float, which *increases* or *reduces* the flow of sea water in box with (S) float, to suit the fresh water production (see also *Appendix*).

99. The fresh water from the side box (A) and the sea water from the side box (B) are respectively drawn away



Elevation.



Plan.

Fig. 12.

by pumps, the former to drinking water tanks, the latter to feed the evaporator. In "multiple" distillation, as will be seen presently, this type of feed regulator (automatic in its working) regulates the supply to *several evaporators*, each with a different evaporative power, as well as the feed to a boiler, whose adjusted feed is more important than that of the evaporators.

100. In steam ships, where the steam for the evaporator is taken directly from the boiler, a feed regulator of this description (Fig. 12) is not so much needed as when the steam is taken from the exhaust steam pipes, because the former steam has steady pressure, but the exhaust steam is at all manner of pressures, and the production of secondary water consequently variable; therefore, an automatic feed regulator would be far more useful. On the other hand, if the feed-water is made very hot before being fed into the evaporator, its quantity, or rather its excess of quantity, is not of very much importance, as little or no heat is taken to heat it, and the quantity of *primary* water will therefore never be abnormally in excess of the secondary water.

101. The feed regulator, therefore, has two objects—*first*, it constantly keeps the brine at a proper strength, and *secondly*, it obviates waste of heat by an excessive feed, when the production of gained water is reduced.

Materials Used for Regulator.

102. The boxes containing the floats are usually made of cast iron galvanised, when large, but if small they may be made of gun-metal.

The floats are usually made of copper tinned, and should be tested to see they are water-tight. The fittings, such as the branches and the castings for the ferrule holes, should be of gun-metal.

The feed regulator is also fitted with two gauge glasses, one to each float box, so that the levels of the sea water and fresh water can be seen without opening the lid.

The feed regulator is usually covered with a hinged lid, which should be kept closed, so as to prevent substances falling in which might interfere with its action.

103. It should be borne in mind that the feed inlet to the regulator has often a considerable head of water over it (say 30 feet), and precautions should be taken to prevent this pressure overcoming the action of the regulator. There is usually a cock on the feed pipe leading to the regulator for this purpose.

3. Temperature—Heaters.

104. It has been shown that the quantity of the feed enters into the question of the economy of the evaporator, but the *temperature* of the feed is also important, indeed more so than the quantity, for if the feed is very hot the quantity is relatively of less consequence.

105. There are two ways of imparting heat to the feed-water by utilising heat that would otherwise be wasted or thrown away.

(1) One way is to utilise the *latent* heat yielded by the *secondary* steam when converted into water.

(2) The other way is to utilise the *sensible* heat of the *primary* water as it is blown from the coil drain, the temperature of which is practically the same as that of the steam before it was converted into water.

106. Take method (1) first—that is, by using the latent heat imparted by the secondary steam to the circulation water passing through the distilling condenser. Although a description of the distilling condenser has not yet been reached, it can easily be realised that by taking part of the circulation water from the *upper* part of the distiller casing, the heat (which would otherwise be wasted by going away with the discharged circulation water) can be

reclaimed, and thus be used for heating the feed-water. It is, however, advisable not to allow these distiller tubes to do too much heating work, for by taking the circulation water from too low a point the upper part of the distiller tubes will get covered with scale to an objectionable extent.

107. Fig. 13 explains the first method of heating the feed-water by means of the secondary steam. It will be

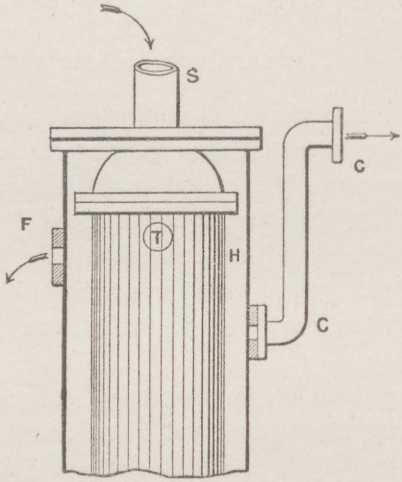


Fig. 13.

seen that the outlet circulation water is discharged at lower (C), a point rather lower down than (F), at which the feed-water is taken. The result of this is, that a body of circulation water is held up at (H), between (F) and (C), and there continues to receive more heat from the secondary steam entering at (S) than is imparted to the bulk of the circulation water that escapes at upper (C). This extra heating of the circulation water at (H) causes the tubes (T) to become more covered with scale than would happen lower down in the sheaf. This method is, therefore, good for heating up the feed-water to a small extent, say up to 120° or 130°.

108. Method (2) of heating the feed-water—viz., by using the sensible heat still remaining in the primary water, after the latent heat of the primary steam has been abstracted from it for evaporation purposes—can be effected as follows :—This heat can be utilised by means of a heater of usual type—*i.e.*, a nest of tubes inside a casing, the hot primary water going through the tubes, and imparting its heat to the feed-water going through the casing surrounding the tubes.

109. Fig. 14 shows the type of heater in question. The hot primary water enters the heater at (P), and passes through the tubes (T), escaping at the bottom outlet for return to the boiler. The feed-water enters at (F.I.) into the casing, surrounds the hot tubes which impart to it the heat of the primary water inside them, and finally the heated feed-water escapes at (F.O.) to run into (or be pumped into) the evaporator casing.

Many other types of heaters can be designed, but Fig. 14 shows a simple design which has been found to work well.

Note.—It should be noted that as much heat as possible should be abstracted from the primary water, as such water goes back to the hot well or elsewhere for return to the boiler.

110. The actual heat that is used, in the above way, to heat the feed-water may be arrived at as follows :—

Suppose 1 ton of distilled water—*i.e.*, gained water—has to be produced per hour, and that the primary steam pressure is to be 25 lbs. (whose *sensible* heat = 266° F., and whose latent heat = 927 B.T.U.). The feed-water supply is to be $1\frac{1}{2}$ tons per hour, and is to be heated from 120°, at which it leaves the distilling condenser, to 212° as it leaves the heater. The heat transferred under the foregoing conditions is as follows :—

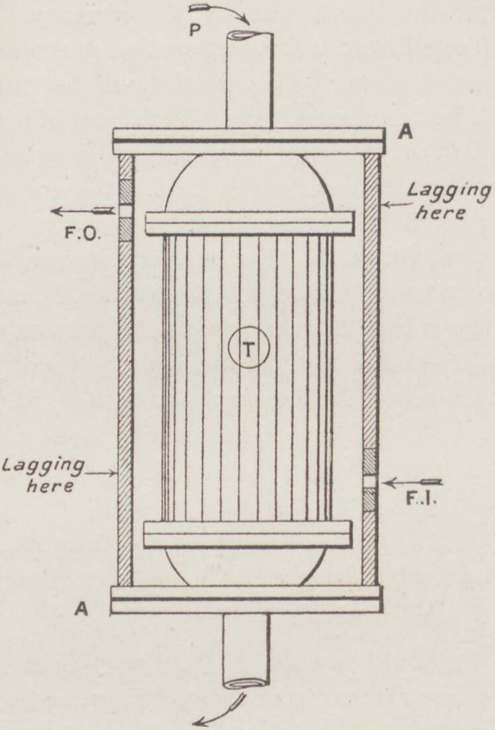


Fig. 14.

138 units, for heating each lb. of the feed from 120° to 212° ($212-120=92\times 1\frac{1}{2}=138$)—sensible heat.

966 units, for converting 1 lb. of feed-water into steam—latent heat.

1,104 units, *required* per lb. of feed-water.

To meet the above requirement, the heat *available* is—

927 units, for every lb. of primary steam converted into water—latent heat.

116 units, for cooling down the primary water from 266 to 150—sensible heat.

1,043 units, *available*.

Therefore, as 1,043 : 1,104 :: 1 : 1·06 (nearly)—*i.e.*, 1·06 lbs. of primary steam will be converted into primary water for the production of every lb. of gained water, and the primary water will leave the heater at 150°.

111. But if the feed-water had not been heated by using the 116 units out of the primary water heat, the economy would have been as follows :—As 927 : 1,104 :: 1 : 1·19—*i.e.*, 1·19 lbs. of primary water for every lb. weight of gained steam produced.

112. The economy of 1·06 is, of course, ideal, as no allowance is made for waste of heat by radiation, which is considerable, especially if the evaporators (during trials) are not lagged on the outside of the casing, a recent condition sometimes imposed (but the reason of it is difficult to account for).

113. The economy, in actual practice, will, therefore, be more than 1·06, and the specified limit imposed by the Admiralty of 1·2 will be much nearer actual results than the ideal of 1·06.

Heaters, Lagging of—Position.

114. The heater should be lagged on the outside, and such lagging may consist of the same material used for the evaporator shell, and the heater should be placed close to the evaporator, where it is fed, so that the feed-water

can enter at the bottom part of the heater casing, rise up in between the tubes, and escape at the upper part of the shell into the evaporator. The feed-water can run or be pumped through the heater as may be arranged. The primary water should be blown into the heater tubes, preferably at the top end, so as to force itself downwards, imparting its heat to the feed-water as the primary water passes to the lower outlet of the sheaf, which should be connected to the pipe leading it to the feed-tank, or where else desired.

Economy on Steam Ships.

115. On steam ships the only way in which the *economy* of a distilling apparatus can be counted is by measuring the weight of primary water against the weight of the secondary water produced. By doing this the coal consumption is indirectly got at, because we know that the heat absorbed to convert every lb. of water into 1 lb. of primary steam is the same (waste excepted) as the heat that the 1 lb. of primary steam will impart on its being re-converted into primary water. Therefore, if 1 lb. of coal will yield 10 lbs. weight of primary steam, and it takes 1·2 lbs. of primary steam to evaporate 1 lb. of gained steam, the 1 lb. of coal will yield the following proportion of gained steam :—As 1·2 : 1 :: 10 : 8·33—*i.e.*, 8·33 lbs. of gained steam per 1 lb. of coal. In "multiple" distillation this *ratio* of water to coal will be dealt with more exhaustively.

116. It should also be noted that the economy of using "exhaust" steam instead of "live" boiler steam is further enhanced by the fact that the exhaust steam has done its work—*i.e.*, it has no further useful purpose, but simply goes into, and out of the surface condenser as so

much distilled water. The further use of such exhaust steam in an evaporator coil is, therefore, not a waste of coal fuel, in the manner that the alternative use of *live* steam would be, as such extra live steam would be converted into primary water without having done any previous work.

Note.—To ascertain the economy, it is necessary to see exactly what amount of heat (say per hour) is supplied to the evaporator in the way of primary steam, and then how much is used, and how much is returned by the coil drain, or rather how much, after the primary water has left the heater.

Heater Surface.

117. The amount of surface put in a heater differs amongst makers according to the type of heater used, the heat given to the feed, and the temperature at which the discharged primary water is to be. These and other considerations make it impossible to give an inflexible rule for the amount of surface. It is sufficient to say that the heating surface of the heater will always have some relation to the evaporative surface of the evaporator. But this great distinction must be kept in view—viz., that in the evaporator coil, the heat that is imparted is the "latent" heat of the primary steam yielded when reduced to water, whilst the heat that is imparted in the heater coil is only the "sensible" heat left in the primary water which has just become liquefied, and, therefore, deprived of the latent heat that was available in the primary steam. Roughly speaking, the "sensible" heat thus available in the heater coil is about one-eighth of the "latent" heat that was imparted in the evaporator coil. It must be borne

in mind, also that the heater coil has not to convert feed-water into steam, but simply to raise its temperature a few degrees.

118. In settling the amount of surface for the heater, it must be remembered that only primary *water* is to be used for heating purposes. No primary steam should be allowed to pass along with the primary water, as no benefit will thereby be derived. It is true the heater will be made more effective, but then this will only be done by robbing the evaporator of the primary steam thus used in the heater, and such primary steam would be very much better employed in evaporative work—*i.e.*, by converting sea water into *steam* by its *latent heat*, than using some of this latent heat in heating up the feed-water.

Feed Heater—Its Construction.

119. The heater is best constructed with a shell, composed either of steel or gun-metal. The position of the heater is best vertical, so that the two waters—viz., the feed-water on the one hand, and primary water on the other—are able to flow, or can be forced, evenly through the heater. The primary water inlet—*i.e.*, from the coil drain—would appear to be best placed at the top of the heater, and the feed-water inlet at the lower end of the casing. This might be reversed by making the primary water enter at the bottom of the heater and the feed-water at the top, but the former would appear to be preferable.

120. The heating surfaces can be made of straight tubes or coils, and the material should be solid-drawn copper; if the tubes are expanded into tube plates, gun-metal of Admiralty quality should be used for the plates. The tubes, and all parts through which the primary

water has to pass, should be proved to the same pressure as that applied to the evaporator coils.

(F) The Brine.

121. Closely allied to the subject of the feed-water is that of the brine—that is, the remnant of the feed after a proper quantity of water has been evaporated from it for condensation into distilled water.

122. There are several points to be considered with regard to the brine formed during sea water distillation, and these will be dealt with separately. The most important of them are as follows : —

(1) Its *strength*.
(2) Its *deposit* on the heating surfaces.
(3) Its *area* at its surface or level.
(4) Its *level* in the evaporator.
(5) Its *discharge* from the evaporator.
(6) Its *condition* when boiling under pressure.
(7) Its *dilution*.

(1) Its Strength.

123. This has been partly explained in Chapter III.

124. When dealing with feed-water, it was shown that the quantity of feed was such as to provide for a brine strength equal to three times that of sea water—viz., $\frac{3}{32}$ strength—the same being obtained by feeding in $\frac{3}{3}$, so as to provide for $\frac{2}{3}$ evaporation and $\frac{1}{3}$ brine, the brine thereby acquiring the salinity of the entire quantity of the sea water fed into the evaporator.

125. In official trials it is usual to weigh the brine produced, to see that it actually is half the weight of the water produced. This is undoubtedly the surest way to

ascertain strength of the brine, but in practice—that is, in the general working of the apparatus when at sea—it is usual to take the salinity of the water drawn from the test cock by the salinometer, as explained in Sections 88 and 89.

126. Although the salinometer test for brine strength is resorted to, it is not an infallible test, and no very satisfactory system of regulating the feed can be effected by relying solely on it.

If the test cock is placed too close to the feed inlet, some portion of the specimen taken may be weaker than the brine generally, and be, in fact, only a specimen of heated feed-water. The inlet feed-water should be tested at 200°, in order to see what strength of the sea water is being fed into the evaporator.

127. The objection generally made to over strong brine is that it is supposed to deposit more scale on the coils than brine at $\frac{3}{32}$. But if 3 lbs. of sea water are fed into the evaporator, and 2 lbs. are evaporated, the remaining 1 lb. should have the same salinity as the 3 lbs. originally fed in, and a certain amount of the saline matter (chiefly the lime) will adhere to the surface. If, however, instead of 3 lbs., only $2\frac{3}{4}$ lbs. are fed in, and 2 lbs. boiled away as before, then the $\frac{3}{4}$ lb. of brine will have all the saline matter of the $2\frac{3}{4}$ lbs. of feed, so that why more scale should be deposited on the coils would require explanation.

128. Not very long since it was argued that the coils became more dirty owing to *excessive* feed, as more saline matter passed through the evaporator, and therefore more came in contact with the coils. This would seem more rational. Perhaps the extra scale (if any) with a short feed is due to the fact that as the brine becomes denser its boiling point gets higher, and causes its scale

to adhere more strongly to the surfaces. Be that as it may, whether $\frac{3}{32}$, or $\frac{4}{32}$ or a higher salinity is better theoretically than $\frac{3}{32}$, it has had many trials under varying conditions, and $\frac{3}{32}$ has been decided on as the best strength to work with.

129. It may be observed that with a high salinity there is a greater risk of salting up, if the evaporator is fed casually by hand.

It has also been found that brine, when made very strong, is rather apt to boil explosively, and shoot itself up in a rather objectionable manner.

Another objection to working with very strong brine is that if priming sets in—that is, if small particles of brine are blown over with the steam—such priming will be stronger or rather more saline, and, consequently, make the distilled water more impure than if the priming had come from a weak brine.

130. On the other hand, brine of high strength has the advantage of increasing the economy, as less heat is wasted with the brine discharged from a short feed.

(2) Deposit on the Heating Surfaces.

131. As the major portion of the saline matter is common salt, which is easily soluble in water, it is not this which gives the trouble in the deposit of scale on the heating surfaces. It is the *lime* salts, which are but little soluble in water, and adhere to the heating surfaces. The deposit on the heating surfaces is of a somewhat different character according as the sea water has been boiled under high or low pressure—that is, the deposit adhering to the heating surfaces, when the boiling is under a high pressure, is hard and refractory, sometimes almost like porcelain, whilst when the boiling is at a low pressure, the scale is

comparatively soft and crumbly, so as to be easily removable with the fingers. This is an advantage for double distillation where one evaporator is used, but in multiple distillation, when several evaporators are linked together, pressure steam must be used.

132. Scaling tools, for removing the scale from the coils, are usually supplied with the evaporator. These are of various forms and shapes, suited to the form and design of coil that is fitted in the evaporator. But a good deal of the scale can be removed by the expansion and contraction of the coils. A good plan is to empty out the boiling brine, then fill up quickly with cold sea water, and allow the water to stay in some little time. This will be found to very much loosen the scale, and make it more easy to remove when the coils are taken out to be cleaned.

(3) Brine Area.

133. Before dealing with the brine level, or the brine discharge, it is more convenient to deal with the brine area—that is, the area of its surface or steam delivery area. This is a very important matter in connection with the subject of priming, for if the steam delivery area is insufficient for the amount of steam that has to be evaporated from the sea water, frothing up will commence, and accumulate till it reaches the evaporator cover, and be carried over with the steam into the distiller, causing the fresh water to be salted so as to be quite useless, at anyrate, for such purposes as feeding water-tube boilers. When dealing with the size of the steam-room this subject was touched upon, but it is necessary to say a few words more here.

134. This matter of a sufficient delivery area can be illustrated by comparing the boiling of ordinary water in a narrow test tube and in an open beaker. Fill a test tube about half full of water, and hold it over a Bunsen gas flame. When the water boils the ebullition will be very violent, and probably be sufficient to shoot the water out of the test tube. Next, fill a small beaker about half full of water, hold it over the same flame, and it will boil quietly, without anything like the agitation that was seen when using the test tube. This difference is due to the small area on the top of the water in the test tube, as compared with that in the beaker. In the test tube there was not sufficient area for the steam that was being generated to deliver itself freely, and the consequence was that the water was shot out by the steam being unable to get through to the surface. As the beaker had sufficient area for its steam to escape, the delivery was quiet, without any sudden discharge of boiling water.

135. Applying this to the area of the brine in an evaporator, it shows that it is a most important point to have a sufficient surface area for the gentle delivery of the steam.

136. To a small extent this delivery area is affected by the pressure over the brine, because when under high pressure the same weight of steam has a smaller volume, and, therefore, a smaller area should be sufficient for the amount of water that is being evaporated ; below atmospheric pressure, the same weight of steam would have a larger volume.

The question of more or less pressure has, however, less effect on the sufficiency of brine area than one would expect.

137. The exact amount of brine area for a given output of steam is difficult to determine, as so many considera-

tions affect it—*e.g.*, the different construction of evaporators; thus in some the tubes are large, as also the water space between them, while in others the coils are small and compact, and the intervening water space less. Moreover, it must be remembered that the smaller evaporators require a proportionally larger brine surface than do large evaporators. Experience is the only reliable guide as to what is a sufficient brine area. Probably every evaporator maker has a different rule to apply to his evaporator, and his rule would not apply to another maker's evaporator. (See also "Steam-Room," p. 99.)

138. Some makers find they can reduce the brine area by the use of *baffles* placed in the steam-room. This cannot be regarded as wholly satisfactory. If the brine area is not sufficient priming will set in, and baffles will not be of much use. The Admiralty had a rule that baffles were not to be used. The form of baffles that are used are very diverse. Some are placed low down, near the surface of the brine, whilst others are placed high up, near the outlet of the steam.

(4) Brine Level.

139. The best level for the brine, when the evaporator is at work, has also been a subject of much consideration. With the vertical sheaf of tubes (originally the only form of evaporating surface in use), the best brine level was found to be about three-quarters of the distance up the sheaf—that is to say, the sheaf was immersed in the brine to the extent of three-fourths of its height. The object of this was to allow the upper part of the tube surface to deal with the froth as it rose from the boiling brine, and thus lessen any priming action. Now that the evapor-

ating surfaces have assumed various shapes and forms, the brine level has to be adjusted by experience, so that the greatest effect can be obtained without causing priming to set in.

140. In this respect, coils, when they are laid horizontally, do not act in quite the same way as a vertical sheaf of tubes. Thus, in the vertical sheaf, the only method of stopping a tendency to prime is to lower the level of the brine until the priming ceases. To such an extent does the brine have to be lowered that, when dealing with some sea waters, the level has to be reduced to less than half its usual height before any primary steam can be turned into the sheaf. A set of horizontal coils, however, shows that if they are entirely immersed in the brine, a tendency to priming is created, that this tendency decreases as the level of the brine is lowered, and that when the level gets too low priming begins again.

141. Numerous experiments have been made to ascertain what is the best level to work at, with the present form of separate coils (usually lying more or less horizontally in the brine). Apparently it is that at which the top coil only is not immersed, which would indicate that the top coil has the effect both of dealing with the frothy matter at the top of the brine surface, and possibly acting also as a baffle. All the coils appear, however, to do their work equally, if one may judge from the amount of scale deposited on the coils when they are taken out to be cleaned.

142. As it is important to keep the brine level steady, an automatic discharge, which compels the brine to escape at a constant level, is a great advantage; for no amount of care and watching can possibly ensure so steady a level.

(5) Brine Discharge.

143. The brine discharge, by which the brine level is governed, will now be dealt with.

144. The brine discharge may be either constant or intermittent. By *constant* is meant a gradual escape of the brine, and by *intermittent* a sudden emptying away of the entire brine from time to time ; on board ship it appears to be at the commencement of each watch. In the interval the brine level is kept by hand—that is, by partially opening the brine cock, according to the indications of the gauge glass and salinometer.

145. The advantage of an automatic *constant* discharge of brine is manifest. There is no objetcion to turning out all the brine periodically, but using the brine cock so as to work to a level that requires careful adjustment is naturally less efficient than a brine discharge that automatically regulates the brine level. It is stated to answer all right when the risk is pointed out. If so, it would hardly appear necessary to have expensive appliances to regulate the feed, and so many conditions specified, if this important matter is left to a casual feeding of the evaporator by hand.

146. The brine discharge, when the evaporator is working with a secondary pressure (that is, a pressure in the steam-room) at or just above that of the atmosphere, can be arranged as shown in Fig. 15, which represents an evaporator with casing (E)—the coils are not shown, so as not to interfere with the explanation of the brine level—and pipe (P), which rises from near the bottom of the casing to the outlet (B). The feed-water enters at (F), and the secondary steam evaporated therefrom escapes at (S) through a small hole of a size suitable to

keep the pressure of the secondary steam at about $\frac{1}{4}$ lb. per square inch (equal approximately to 6 inches head of water). When the pressure inside the casing is at $\frac{1}{4}$ lb. per square inch, the brine in the casing will be forced up pipe (P) until it reaches about 6 inches above the brine level, and the brine level depressed to that at which it balances the pressure in the steam-room, while the brine is constantly discharged at (B). By this means the brine level is kept constant at (L); if the height of the

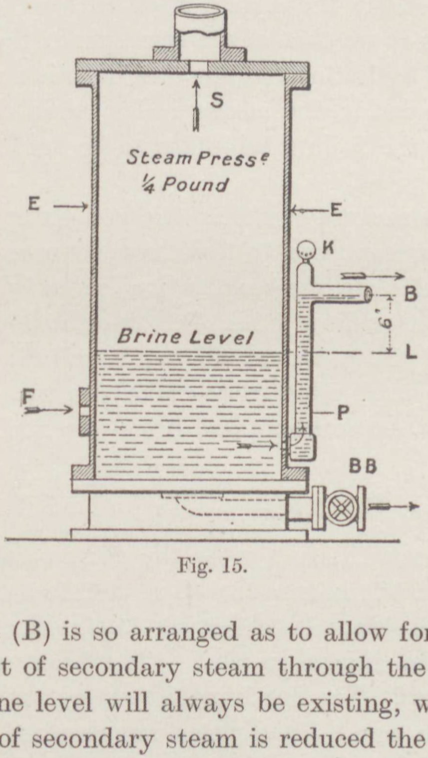


Fig. 15.

brine outlet (B) is so arranged as to allow for the maximum output of secondary steam through the hole (S), a suitable brine level will always be existing, whilst if the production of secondary steam is reduced the brine level would rise, but the risk of priming is then lessened by the diminished evaporation. A large blow off is provided at (BB), for use when desired. (K) is an air knob to prevent syphoning action.

(6) Boiling under Pressure.

147. This automatic arrangement is, of course, possible only with a pressure in the steam-room about equal to that of the atmosphere. If the evaporator is working with either a pressure much above the atmosphere, or considerably below it, other arrangements have to be made for the brine discharge. Thus, if there is a pressure in the casing above that of the atmosphere, the brine can be got rid of by letting the pressure blow it away, but if the pressure inside the casing is less than that of the atmosphere, the boiling brine has to be drawn out by a pump.

148. Some makers combine the feed pump and brine pump in due proportion to their respective requirements. This is useful when the evaporation is steady, but if the evaporation exceeds or is less than two-thirds of the feed, the speed of the pump would require altering, or some other arrangement adopted to make all three—that is to say, the feed, evaporation, and brine—proportionate.

(7) Brine Dilution—(*a*) Method of Diluting.

149. Formerly, it used to be the custom for the brine to be allowed to run into the bilge, or into a tank at the bottom of the ship, with which the ship's brine pump was connected and always at work. The brine was got rid of in this way. The hot brine, however, was considered objectionable, and a brine pump was required to be part of the distilling apparatus.

150. *Cooling* and *diluting* the brine after its discharge

from the evaporator casing is necessary when it has to be pumped away. There are several methods for arranging the supply of the cooling and dilution water. It is usual to take such water from the circulation water, either from the pipe leading the circulation water to the distiller, or from the lower part of the distiller casing before the water has become warm, and for this dilution water to be led into the brine receiver, and there mixed with the hot brine coming into the receiver, or to the valve box of the pump, or any other means that are suitable. Different evaporator makers have their own method of discharging the brine, as also of cooling and diluting it. Information on these points may be gained by reading their descriptive pamphlets.

(*b*) Quantity of Dilution Water.

151. The quantity of cooling and dilution water is usually that which reduces the brine to about half its density—that is, from $\frac{3}{32}$ to $\frac{1 \cdot 5}{32}$—and cooled down to 150° or lower. Therefore, if the quantity of the cooling water is made equal to the evaporation, that will be equal to double the quantity of the brine, and the above requirements will be satisfied. If the evaporation fluctuates, so as to be lowered much below half its maximum, then the feed (if not automatically regulated to suit the lowered production) will be increased. The pump will then have more to do, and should therefore be made amply large. If, however, the feed is regulated to suit the evaporation, however much it may fluctuate, then the brine will be proportionately lower, and the dilution water unchanged in rate of supply.

152. The least complicated way of dealing with the

brine is to let it flow out of the evaporator into a receiver, into which the cooling and diluting water (sufficient for the maximum amount of brine) also flows, and for a pump large enough to draw all away.

General Remarks.

153. Fig. 16 shows generally the most important details of a "Normandy" type of evaporator grouped together.

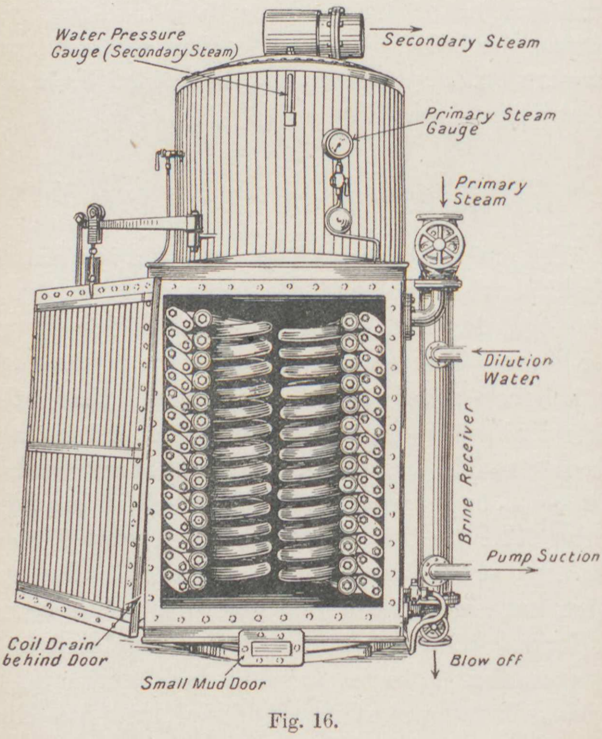


Fig. 16.

CHAPTER VII.

THE DISTILLING CONDENSER.

1. By *distilling condenser* is meant the condenser that is annexed to the evaporator. This is different from the surface condensers used for condensing engines.

2. The distilling condenser is generally used for two purposes—*first*, to condense all or part of the gained or secondary steam received from the evaporator into pure distilled water (more or less warm) to make up for the loss of the boiler *feed-water*, or, *secondly*, to condense part or all of such evaporator steam into cold fresh water for *drinking* purposes.

(*a*) Warm Feed-Water Production.

3. Fig. 17 shows a distiller for yielding *warm* water. The secondary steam or vapour from the evaporator enters the distilling condenser at (A), and its passage into the tubes (T) is sometimes controlled by a valve. The steam or vapour thus admitted is condensed (by the surrounding cold water) into warm distilled water, which escapes at the outlet (B). The circulation sea water enters the distiller casing at (C), fills the casing, and surrounds the tubes ; after condensing the secondary steam or vapour inside the tubes, it finally escapes at the outlet (D) in a more or less heated state. The feed-water can be taken from the branch (F), which may be placed a little higher than the circulation outlet, so that the feed-

water is made somewhat hotter than the discharged circulation water. The lower branch (G) is for a pipe for filling the evaporator, or for supplying the dilution water for the brine. Both this pipe and pipe from (F) should be controlled by cocks.

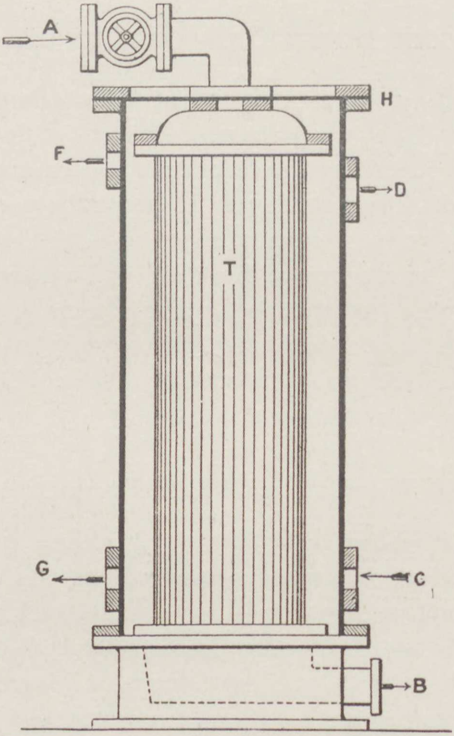


Fig. 17.

The Gained Steam.

4. To deal, first, with the secondary steam or vapour admitted into the distiller tubes. The most important point for consideration is the *pressure* at which the secondary steam or vapour is admitted into the distiller tubes.

It may be admitted (1) *at*, (2) *below*, or (3) *above*, the ordinary atmospheric pressure. The most convenient pressure is (1). In this case the gained steam at ordinary atmospheric pressure simply enters the tubes at the ordinary atmospheric pressure (valve at (A) is really not a necessity), is condensed into water, which falls into the bottom pan, and flows to where it is desired. In case (2), if the secondary steam or vapour enters the tubes *below* atmospheric pressure, a pump must be used to suck away the water from (B), which causes a sucking action at (A), so that the valve at (A) will have to be regulated by hand, as the low pressure inside the tubes (T) varies. In case (3) also the valve at (A) will need occasional regulation, and a valve will be needed at (B) to keep up the pressure in the tubes (T). Put shortly, the system of working at ordinary atmospheric pressure, as in case (1), accommodates itself at once to an automatic working between evaporator and distiller, which can hardly be said of cases (2) and (3).

5. When the distilled water is required for boiler feed, it is usually specified that it shall be delivered from the apparatus at a temperature not exceeding 150°, otherwise it could not be satisfactorily measured.

(*b*) For Cold Distilled Water—Drinking Water.

6. Let us now examine the type of distiller required to produce the distilled water *cold*.

7. It differs from the distiller for feed-water chiefly in the form of surface—that is to say, a cooling surface has to be added for cooling the water. This may be conveniently provided by having a set of cooling tubes placed under the condensing tubes, as shown in Fig. 18.

Here the secondary steam entering at (S) is condensed in the upper tubes, and the hot distilled water, as it drops from the inside of the condensing tubes, falls into the lower tubes, which become filled with water up to half way in the middle chamber (M). The water rises to this level as the fresh water rises from the bottom chamber (B) up the fresh-water pipe (F), the outlet of which is

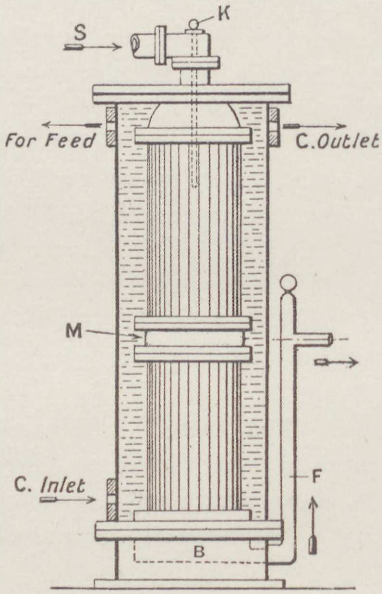


Fig. 18.

on a level with the fresh water in the middle chamber. The circulation water, as before, enters at the lower branch (C inlet), and escapes at the upper branch (C outlet). The feed-water for the evaporator is at another outlet near the top. Branches for filling and diluting can also be placed near the bottom.

Note.—By taking the fresh water in the manner just shown, it is got at its coldest, as it rises up pipe (F) direct from the bottom pan (B).

8. The following slight addition is needed to make the distiller work properly when the lower sheaf of tubes forms part of the apparatus ; it consists of a breathing knob to vent pipe (K), which allows the excess air to escape, when it comes over with the secondary steam at (S), by passing up the central tube and out into the atmosphere. In the distiller for producing warm water, the distilled water can escape freely from the bottom pan, and the air can pass along with it, but in the cold water producing distiller the lower tubes are filled with water, and there is no such means for the air to escape.

9. The distilled water produced by the distiller (Figs. 17, 18) flows, or is pumped away, as may be arranged. If the water is warm for feeding boilers, and an automatic feed regulator is included with the apparatus, the distilled water gravitates into the fresh water box of the feed regulator, and as it flows from the regulating box to the adjacent box, the water may flow or be pumped to where desired. If the distilled water is produced cold, it flows from the fresh water pipe (F) to a filter (described later on), then through the feed regulator, from which it flows or is pumped to where desired.

1. The Circulation Water.

10. The secondary steam passing from the evaporator into the distilling condenser has to be condensed. Cold sea water, being ready to hand, naturally suggests itself. Not only is the sea water the readiest, but it is also by far the most efficient medium that could be obtained for

the purpose required—viz., that of abstracting the latent heat of the steam.

11. There is only one other medium which suggests itself for cooling purposes, ready to hand, and that is the air. This, however, as a cooling medium, is out of the question, for the following reasons :—*First*, its weight, as compared with that of water, would necessitate an enormous amount of surface. Thus, 1 cubic foot of air, at normal pressure, weighs 0·071 lb., as against 64 lbs., the weight of 1 cubic foot of sea water, so that, to begin with, one would require about 100 times more surface with air than with water. *Secondly*, apart from the inferiority of weight, is its inferiority in specific heat. Air has only a specific heat of 0·238 when at a constant pressure, and only 0·169 when at a constant volume. So that when comparing what is required for using air instead of water as a cooling medium, both these inferiorities, as compared with water, would have to be allowed for.

Note.—Specific heat, it may not be out of place to observe, is the capacity for heat which a substance has as compared with the same weight of water. Thus if the amount of heat required to raise 1 lb. of water 1° (39·1° to 40·1° F.) is one unit (1 B.T.U.), it would take only 0·238 B.T.U. to heat 1 lb. of air (if kept at the same pressure), or 0·163 B.T.U. to heat 1 lb. of air (if kept at the same volume), the above being the heat capacity, or power of *absorbing* heat which air has ; its power of *emitting* heat would therefore be in the same ratio (reversed) with regard to water.

12. The following short Table of a few substances with their specific heat given (according to Petit, Dulong, and others) may be found useful :—

TABLE M.—SPECIFIC HEAT OF VARIOUS SUBSTANCES.

(Equal Weights).—Water (at 39°) being 1.

SOLIDS.

Ice,	0·5040
Magnesium,	0·2500
Aluminium,	0·2185
Brickwork (about),	0·2000
Glass,	0·1970
Cast Iron,	0·1268
Steel,	0·1175
Wrought Iron,	0·1138
Nickel,	0·1086
Copper,	0·0944
Zinc,	0·0820
Brass (70% copper and 30% zinc),	0·0939
Tin,	0·0562
Silver,	0·0557
Platinum,	0·0330
Gold,	0·0320
Lead,	0·0314

LIQUIDS.

Water,	1·0000
Alcohol,	0·6588
Mercury,	0·0330
Oil,	0·3096

GASES.

Hydrogen (constant pressure),	3·4046
— (constant volume),	2·4096
Coal Gas (constant pressure),	0·5929
— (constant volume),	0·4683
Air (at constant pressure),	0·2380
— (at constant volume),	0·1620
Steam (at constant pressure),	0·4750
— (at constant volume),	0·3640

13. The *quantity* of circulation water required to condense steam to water, and if necessary, to cool the hot distilled water (in connection with the tube surface in

contact therewith) must be such that the circulation, as it passes in between the tubes, is able to absorb all the *latent* heat of the steam or vapour inside the tubes, and further to reduce its temperature when condensed.

14. Suppose, therefore, that per hour 1 ton (2,240 lbs.) of steam has to be condensed into water—*i.e.*, hot water at 212°—and that such water has to be cooled to 150°; and that the circulation water is to enter the distiller at not less than 75°. Each pound of secondary steam (at atmospheric pressure) must part with 966 B.T.U. to the circulation water, in order to be reduced to a liquid. If, therefore, the circulation water is specified to have an inlet temperature of 75°, and it is convenient for such circulation water to be discharged at, say, 125°, a difference of 50° between its inlet and outlet (125 – 75=50), the proportion of circulation water to the condensed secondary steam will be as follows :—

As 50 : 966 :: 1 : 19·3 tons of circulation water to 1 ton of gained steam.

If, however, the distilled water is cooled down from 212° to 90° (15° above 75°, the inlet temperature of the circulation water), then the ratio will be as follows :—

As 50 : 966+212 – 90=1,088 :: 1 : 21·8 tons (nearly) of circulation to 1 ton of distilled water.

15. If 145° is the temperature of the circulation water at its outlet, the ratios will be—

As 145 – 75=70 : 966 :: 1 : 13·8 tons of circulation to 1 of distilled water, or

As 145 – 75=70 : 966+212 – 90 = 1,088 :: 1 : 15·5 tons of circulation to 1 of distilled water at 90°.

16. In the ordinary surface condenser for condensing the exhaust steam from the engine, the usual allowance is 30 lbs. of circulation water per 1 lb. weight of steam. This would, therefore, involve a larger circulation pump and a smaller amount of surface than above given. Some condenser makers arrange their condensers to work with less circulation water, say 18 to 1. Other makers allow 25 to 1, which is a still greater allowance of circulation water than is stated above for a distilling condenser. Books of reference give other ratios, such as so many units of heat per square foot of surface, but this depends much on circumstances, such as the nature of the cooling surface, its material and thickness, the temperature at which the circulation water enters and leaves, &c.

2. Surface—Condensing and Cooling.

17. The surface to be allowed per square foot depends on so many considerations, that no rule is applicable to all cases. The surface must be sufficient to allow the circulation water to abstract all the latent heat of the secondary steam, and the heat necessary to cool the water produced to the desired temperature.

18. Condenser makers have different rules to work by for the surface they allow. Some makers allow more circulation water, in order to reduce the surface area, and, consequently, the size of the condenser, but this requires a larger pump. Others reverse this, and allow plenty of surface and a reduced circulation.

19. Sometimes an allowance of 1 square foot of surface (brass tubes) is allowed per 25 lbs. weight of steam, on the assumption that the circulation water is 30 times that of the steam ($30 \times 25 = 750$ lbs. of circulation water), and its inlet temperature is 60°.

20. Sometimes the surface allowed for the surface condenser is as follows :—One square foot of brass tube (18 I.S.W.G.) surface per 30 lbs. of steam at a temperature of 212° to 30 lbs. of water at about 100°, with the circulation of 900 lbs. of sea water entering at about 50°, and discharged at about 90°. This would be for ordinary climates, but if the sea water used for the circulation is in the tropics then the surface allowed is 1 square foot per 16 to 20 lbs. of steam to be condensed.

Note.—This works out as follows :—

966 units of latent heat in the steam,
112 degrees cooled down (212 − 100 = 112).

1,078 (total) × 30 = 33,040 units of heat imparted by the steam.

90° temperature of outlet circulation.
50° ,, inlet ,,

40° (difference) × 900 = 36,000 units.

That is to say, 33,040 units imparted to, and 36,000 units of heat absorbed by the circulation water; which about balances the heat *given* and *received*. If the surface allowed is 1 square foot per 16 or 20 lbs. of water, other conditions being the same, it gives almost double the surface to be allowed for tropical climates.

3. Dilution and Feed-Water Allowance.

21. As it is usual to take water for *diluting* the brine from the *lower* part of the distiller casing, and more circulation water from the *upper* part of the casing for evaporator feeding, the total quantity of these two waters should

not be omitted in estimating the amount of circulation water required.

Construction of the Distiller.

(*a*) *The Coils or Tubes.*

22. The tubes are best made of solid-drawn copper. Some makers use brass instead of copper, but whether copper or brass is used, the tubes are tinned both inside and out.

23. What has been said in a former chapter when comparing the use of the two metals, copper and brass, for the heating surfaces of the evaporator applies equally to the condensing and cooling surfaces of the distilling condenser. The preference of copper to brass is based on the two following considerations :—

(1) The lessened liability to galvanic action in the copper tubes.

(2) The higher conductivity of heat of copper tubes.

With regard to (1), the galvanic action that takes place in brass tubes when used in a distiller has been very noticeable. Such action is usually manifested by the tubes becoming perforated by small holes, no larger than pin holes, through which the circulation water will enter, and of course, spoil the distilled water as soon as it is produced. Another way in which this galvanic action is manifested, is that the tube ends protruding through the gun-metal tube plate, beyond their expansion therein, have been known to waste away at the joint, so that short ends drop off into the middle chamber (M) in Fig. 18. This can only be accounted for by galvanic action.

Similar sheaves of *copper* tubes show no such inclination to perish.

Note.—It is thought advantageous to have brass tube plates and brass tubes, so as to have all of same metal; but copper tubes with gun-metal plates would seem to offer practically the same advantages.

(2) With regard to the conductivity of the two metals, what has already been said when dealing with the heating surfaces of the evaporator need not be repeated here, to show that a copper sheaf is about 20 per cent. more effective than a similar sheaf made of brass tubes (see p. 96).

24. The form of the surfaces varies with distiller makers. The most usual form is that of a set of tubes (copper or brass, as the case may be) either straight or coiled, but still of ordinary pipe shape. This is the most usual, but some makers prefer tubes that are flattened either at specified distances, or in such a manner as they think most scientific.

25. The size of tubes usually put in distilling condensers is $\frac{5}{8}$ or $\frac{3}{4}$ inch in outer diameter, and the thickness 18 I.S.W.G. The tubes (tinned throughout) are best expanded in the plates.

The test pressure is usually 30, 40, or 50 lbs. per square inch.

26. The space between the tubes varies from about $\frac{15}{16}$ inch, in small size tubes, to $1\frac{1}{4}$ inch, in tubes of larger diameter. The object, of course, is to put the tubes as close together as possible, in order to get the maximum of surface in the minimum of space, consistent with the water circulating freely, and the easy removal of the scale formed outside the tubes.

(*b*) *The Casing.*

27. The casing enveloping the tube surfaces is best made of sheet copper. If weight and space are not objected to, the casing can be made of cast iron or steel plate, in the former the corrosion is less. It is usual to galvanise the casings if iron or steel. This acts as a preservative, and when iron or steel is used it is customary to fix zinc blocks at suitable parts of the casing, to divert the galvanic action from the casing. These zinc blocks should, however (as said in a former part of this book with regard to evaporator casings), be carefully fitted—*i.e.*, clean metal to metal—or the danger sought to be obviated may be aggravated.

28. The *cover* of the distiller may consist of a single piece of thin sheet copper, gripped between the flange of the casing and an iron ring, as shown at H in Fig. 17 (p. 136). This arrangement has the advantage of superseding an expansion joint for the tube sheaves.

29. The distiller casing, usually cylindrical, is generally subjected to a test pressure of 40 to 50 lbs. per square inch. It is usual to make the shell in halves or sections for convenience of taking apart in confined places—that is, if the casing has considerable height.

(*c*) *Fittings for the Distiller.*

30. The usual fittings are as follows :—

(1) A *steam valve* (if required for the mode of working). This is required (1st) if the distiller receives pressure steam from the evaporator, or (2nd) if the distiller is made to work at a *minus* pressure, *i.e.*, less than the atmosphere under normal conditions, inside the tubes. If the distiller is intended for working in 1st way only—

that is, by taking the steam from the evaporator at ordinary atmospheric pressure—no steam valve is really required with automatic working.

(2) A *feed cock* and *pipe*, fitted to the upper part of the distiller casing, and leading warm water to the feed regulator or feed box, as the case may be. The feed cock, in case of emergency, may be used for regulating, by hand, the feed supply to the evaporator, but it is, of course, preferable to let the feed regulator or feed box do this. The feed cock is also useful for regulating, or rather mitigating, any excessive pressure that may be due to a head of water over this feed supply. Such pressure may be considerable if the apparatus is placed low down in a large ship, and might overpower the float in the feed regulator, if not controlled by the feed cock on the distiller.

(3) A *filling cock* and *pipe*, fitted to the lower part of the distiller casing. This is for charging the evaporator quickly with sea water as occasion may require.

(4) The *dilution* cock may be fitted to the same branch as the filling pipe is, in order that the same supply may be used for filling and for diluting.

(5) A *valve* on the circulation inlet may be fitted if desired, but no valve, other than a non-return one, should be fitted on the circulation discharge pipe.

(6) A *relief valve* is sometimes fitted on the casing, so that if any stoppage takes place in the free passage of the circulation water through the distiller, the continued action of the pump will do no injury.

(7) An *air pipe* or *vent* is fitted to the upper sheaf of tubes (the condensing tubes), for allowing the excess air to escape from these tubes. This air pipe or breathing pipe can be conveniently fitted to the top of the secondary

steam pipe, so that it can be made to pass down the central tube, and thus allow the excess air to escape instead of it accumulating in the upper tubes, which stops their proper action (see Fig. 18, p. 138).

(8) *Strainers* should be fitted to the circulation inlet, and to the feed supply, and these pipes should be of ample size. The strainers are to prevent foreign substances getting in with the circulation water, which might interfere with the proper working of the apparatus. In modern ships, more care is taken than used to be the case. The pump used to draw water direct from the sea with no strainer, and the consequence was that all sorts of substances were drawn in with the circulation; for instance, small fish got drawn in, and distillers have been known to become filled with fish bones as the result.

General Remarks.

31. Generally, with regard to the construction of the distiller, too much attention cannot be paid to the necessity of having all parts made of the best materials and workmanship, and small details carried out, otherwise an apparatus may give trouble by the inefficiency of some detail which may be difficult to locate.

CHAPTER VIII.

(*a*) THE FILTER; (*b*) THE STEAM PUMP; (*c*) THE CONNECTIONS; (*d*) SPARE GEAR; (*e*) CLEANING ARRANGEMENTS; (*f*) BOARD OF TRADE RULES.

(*a*) The Filter.

1. THE filter is an important item where distilled water of the best quality for drinking is required. A water may be pure, yet unpalatable. The mawkish and insipid taste of distilled water is too well known to need description. This insipidity is entirely removable by proper aëration and filtration of the distilled water.

2. Animal charcoal is used for rendering (aërated) distilled water palatable, but to be effective its relative volume must be large.

3. Distilling apparatus for producing drinking water should include a filter. It adds rather to the bulk of the plant, but on land the apparatus may be made more capacious than that for a steam ship.

4. For the filter to be effective the distilled water should be *well aërated*—that is, well impregnated with air. When any water is heated the air in solution is driven off long before it boils. This may be seen by putting a little ordinary cold water in a test tube, and holding the tube over a gas flame. In a moment or two small bubbles will be seen adhering to the sides of the

tube, and will gradually disengage themselves. Or again, if cold water be put into an ordinary glass jug and brought into a warm room bubbles will soon appear on the inside of the glass. This is owing to air being discharged as the temperature rises, until at the boiling point (212°) the water is almost free from air, and consequently boiled water has a different taste. The action of the filter on non-aërated distilled water is imperfect.

5. The action of the charcoal appears to be catalytic—that is, it oxidises the trace of gaseous organic matter or empyreuma passing over with the steam, which thus taints the distilled water. Whatever may be the action of the animal charcoal, it unmistakably converts unpalatable distilled water, into water equal in taste and appearance to water obtained from the best natural sources.

When the charcoal is first used a slight trace of ammonia may sometimes be detected, but this will soon pass away on continuing the use of the charcoal.

6. The filter can be made of any shape, provided the water is distributed evenly and does not run in currents. The quantity of charcoal used should not be less than about 4 cubic feet per ton of water filtered per hour.

7. The filter may be made in the form shown in Fig. 19, which represents a cylindrical tank, with a partition (P), so as to cause the unfiltered water entering at (I) to pass evenly down one compartment and up the other to its outlet at (O). Perforated gratings on the top of the charcoal in each compartment keep the charcoal in place, and the proper distribution of the water flows through it. The knobs (K) are to let air escape.

8. The animal charcoal when used for distilled water will retain its effect for a very long time. Care should

be taken to prevent any grease or lubrication from the pump contaminating the water. This might happen if the distilled water is pumped into the filter, and the filtered water allowed to gravitate away. It should also be noted that red lead must be avoided in making joints that are in connection with the distilled water, as the water would be fouled by the oily matter, which is not removable by the filter.

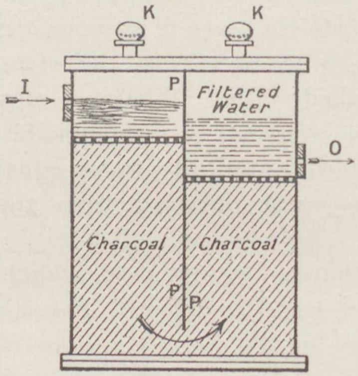


Fig. 19.

Note.—Before leaving this subject, a few words may not be out of place with reference to the process of purifying water by ozone. Ozone is an allotropic and denser form of the gas oxygen—*i.e.*, it is oxygen in a somewhat different atomic state. Thus, nascent oxygen is in the form of one atom or molecule, the oxygen in the air is in a double atomic form, and ozone, of which there is a small quantity also in the atmosphere, is in a triple atomic form. Ozone has a strong tendency to oxidise, and therefore consume organic matter, so as to make it a powerful oxidiser. By this process, which is given more in detail in the *Times* Supplement of 4th August, 1909, ozone is obtained in large quantities by means of the silent discharge of electricity which passes between the poles of a powerfully charged magnet. The process appears to be recommended in combination with filtration. Whether it will be useful in removing the taint and odour of distilled water remains to be seen.

(*b*) The Steam Pump.

9. The steam pump, usually included with the distilling apparatus, is made to combine several functions; it generally acts (1) for circulation, (2) for fresh water, and (3) for brine, thus making it of triple-function. The evaporator feed may be supplied to the evaporator by gravitation, but if the evaporator is working at a pressure, there must be another pump (4) to force in the feed-water.

10. In Admiralty ships it is now the practice to divide the pumps of each set of distilling apparatus into two machines—viz., one machine consisting of the *circulation* and *fresh-water pump*, while the other machine deals with the *evaporator feed* and *brine*. This is a suitable arrangement, as the brine and feed-waters can thus be kept at a constant ratio.

11. The Board of Trade rules require that the circulation pump should be available as a fire-pump in case of emergency.

12. The pumps should be of the best make throughout. All parts coming in contact with water, such as valves, valve-boxes, plungers, and barrels, should be of Admiralty quality gun-metal. It is well to allow a good margin for the capacity of all the pumps. The pumps should be fitted with suitable relief valves, and air vessels of specified capacity—that is to say, twice the capacity of the pump.

13. It is usual to test the pumps as follows :—The steam cylinders and all parts subject to boiler pressure are proved to about 450 lbs. per square inch. The circulation pump to 50 lbs. per square inch. The force pumps generally to about 200 lbs. per square inch.

14. The pumps supplied for land distilling apparatus are practically on the same principle, but they will be referred to more in detail when the subject of multiple distilling apparatus is dealt with, the type of apparatus best suited for land work.

15. The steam to drive the pumps comes from the boilers on board, and as the exhaust steam usually goes into the exhaust steam pipe, the pump should be arranged to work with a back pressure of about 25 lbs. per square inch on the exhaust.

(c) The Connections.

16. It is usual for the distilling apparatus to include all the fittings, mountings, and connecting pipes. All pipes for steam and water are brought up to the branches. A drawing is usually sent to the builders of the ship, or contractors for the main or auxiliary engines, as the case may be, for them to provide the necessary space for the apparatus on board.

17. It is well to bear in mind that the pipes leading to and from the apparatus must be of proper size—that is, not too small—*e.g.*, two pipes must not run into one of the same size, at some distance from the apparatus, as this might create a back pressure, and cause troubles and difficulties, sometimes not very easy to trace.

18. All connecting pipes should be made of copper as usual, and all pipes through which brine passes should be

of ample size to compensate for the furring up which inevitably occurs. Steel pipes are now sometimes used.

19. The pipes through which the drinking water passes should be tinned inside.

(*d*) Spare Gear.

20. Spare gear may be divided into two lots—*First*, such articles as are required to work the apparatus in the ordinary way—*e.g.*, spanners, interchangeable coils (for convenience when the dirty tubes are being cleaned), &c.; and *secondly*, such articles as may be considered requisite to replace parts that are subject to much use and wear—*e.g.*, the moving parts of the pump, &c.

21. On Government ships the spare gear is somewhat considerable, as will be seen from the list, which is substantially as follows :—

For the *Pump*.—Practically all the moving parts are duplicated in the spare gear, and these have to be fitted in place and worked when viewed by the inspecting officer, who generally also inspects the original moving parts under working conditions.

For the *Evaporator*.—A complete set of heating surfaces is required ready for replacing the set already in the evaporator. All the coils and the separate parts of coils must be interchangeable. A spare coil drain is also sometimes specified.

For the *Distilling Condenser*.—The spare gear includes a set of cooling surfaces. The surfaces are usually fitted in gun-metal plates, so that the whole sheaf of tubes may replace the sheaf already in the distiller. Sometimes, however, the whole sheaf is not required, but simply a spare set of loose tubes.

For the *Heater*.—The usual requirement is a set of coils, ready for fixing in place.

22. For passenger ships and emigrant ships the spare gear is specified by the Regulations of the Board of Trade, and a list may be seen in Seaton and Rounthwaite's *Pocket-book*.

(*e*) Cleaning the Apparatus.

23. During work, the evaporator coils are constantly accumulating and shedding scale. This scale may be raked out through a small mud door, until it is convenient to open out the apparatus for cleaning purposes.

24. To clean evaporator coils—First shut off the primary steam valve, and run off *all hot brine* by the brine valve; then fill up again rapidly with cold water by opening the filling cock, and re-admit primary steam to the coils. This will loosen the scale left on the coils. Then empty again as before.

25. Next unbolt and swing off the large cleaning door by its tackle (when provided). Then detach coils separately.

26. Take off small door, and rake out deposits.

27. After cleaning coils, replace them, and, before closing up, test joints, which should be all visible, under pressure.

28. The evaporating coils are generally separately detachable, and are readily cleaned and replaced interchangeably. In a very small apparatus there is generally only one coil to remove.

29. The passages for the *primary* steam into the evaporator and the outlet for the primary water to coil drain should be carefully cleaned.

30. It is well to keep clean the holes in the feed box, or feed regulator, so that the sea water may pass freely, and without diminution, through them. If gratings are used, as they should be, to strain off impurities, these gratings should also be cleaned. The floats should also be seen to work properly, and not be sticking in the spindles or guides owing to an accumulation of dirt.

31. The evaporator *casing* is not an evaporating surface, and it is not necessary to clean off the scale too frequently. Scraping it off tends to wear out the casing.

Board of Trade Rules.

32. The following is a summary of the rules of the Board of Trade regarding the distilling machinery on board ships :—

33. Where in evaporators, generators, feed make ups, &c., pressure is an essential feature in the process of evaporation, whether such evaporation is produced by heat from coal, gas, steam, or otherwise, the strength, quality of material, and method of construction must be in accordance with the regulations for steam boilers, and they should be examined by the official surveyor on each occasion the vessel is surveyed for passenger certificate, in the same manner as other boilers on board the vessel. All the fittings and mountings of such evaporators should also correspond with the fittings specified for a steam boiler.

34. If the evaporator shell is made of steel plates, all the rules apply just as in the case of the construction of a steam boiler. It is impossible here to deal with all these requirements ; reference should be made to a book like Seaton and Rounthwaite's *Pocket-book* for de-

tailed information as to the rules regarding the construction of *boilers*.

35. The Board of Trade additional rules also provide that the distilling apparatus on board emigrant ships should be taken to pieces every voyage, unless the ship is one holding a passenger certificate, when this opening out of the apparatus is required once every six months at least. The tubes or coils are also to be tested to twice the pressure at which the safety valve is loaded, or twice the highest working pressure of the boiler from which the apparatus can be worked. After putting the apparatus together again, it is to be tested as to its capability of producing its proper quantity. The boiler referred to is (in the absence of an evaporator) a donkey boiler on board the emigrant ship, for the purpose of supplying steam to the distilling condenser. The rules regarding boilers generally apply to these small boilers.

36. The water produced is to be cool, pure, and fit to drink immediately it is drawn from the filter of the apparatus. The apparatus must include a filter charged with animal charcoal, and the charcoal should be taken out, cleansed, or renewed every voyage, except in cases of ships holding passenger certificates, in which the taking out of the charcoal may be taken out not oftener than once every six months. A capable man is required to be in charge of the apparatus.

37. The steam for working the apparatus must not be taken from the main boiler (this would appear to mean that the main boiler steam must not be condensed for drinking water purposes), and no exhaust steam should go into the condenser if the steam is greasy, and the boiler of the apparatus must not be filled or fed with water from the surface condensers, nor the apparatus be fitted with

grease cocks. The presence of zinc in such boilers is considered objectionable.

38. A relief valve is required on the distiller casing for the escape of the circulation water, if necessary; and if the casings of the apparatus cannot stand boiler pressure, there should be a safety valve fitted between the steam pipe and the apparatus.

39. A list of tools and materials is included in the rules, the principal items of which are as follows :—

Stoking tools } (that is, for a donkey boiler, if
Set of fire bars } supplied).

Scaling tools.

Spanners.

A double charge of animal charcoal.

Salinometers (two made of glass) and brine pot for use therewith.

40. Besides the Board of Trade Rules there are various other regulations applicable to boilers, which would also apply to evaporators working under pressure. These regulations principally are those issued by the (1) Admiralty, (2) Lloyds, and (3) Bureau Veritas. These are also to be found in Seaton & Rounthwaite's *Pocket-Book.*

CHAPTER IX.

THE WORKING OF A DISTILLING APPARATUS.

Ordinary Ship Double Distiller.

1. An evaporator is simply a boiler worked by steam; consequently it has a much greater evaporating surface and power than a boiler of the same size heated by coal fire, whilst the quantity of water operated on is only a small fraction of that in a fire-heated boiler of the same evaporative capacity.

2. As the quantity of water in an evaporator is relatively small, and its evaporative surface proportionally so large, it is highly important to make sure that the evaporator is working steadily—*i.e.*, that its brine level is steady—in order to avoid any risk of the water being entirely evaporated off, or of the evaporator being deluged with water, either of which events will happen if reliance is placed on a man in charge adjusting the feed and brining by hand. In the first case, the evaporator will salt up; in the other, priming will occur and spoil the distilled water. These difficulties may arise in a few moments.

3. The feed-water having to be fed in such large quantities, and the evaporation being so large from comparatively so small a volume of sea water undergoing the operation, and the proper amount of brine discharge being so important, it has been found that an effective arrangement for *automatically* feeding and brining can alone give satisfaction.

Directions for Working.

4. The following details explain the (automatic) working of the apparatus (Fig. 20) in actual use, and includes a description of all the parts :—

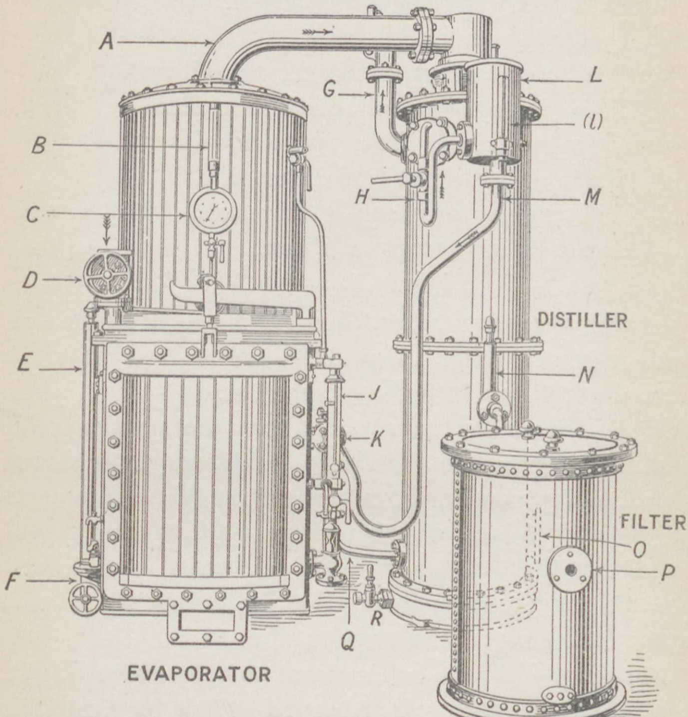


Fig. 20.—" Normandy " Double Distiller (see also Appendix).

A, [Gained steam pipe.

B, Water pressure gauge to show pressure (about atmospheric) in evaporator casing.

C, Steam gauge to show pressure in coils.

D, Steam valve, for starting evaporator.

E, Brine pipe, for brine discharge (constant action).

F, Brine blow-off valve (to empty evaporator).

G, Circulation discharge.
H, Feed pipe and cock, to feed box from distiller.
J, Water level gauge.
K, Feed inlet to evaporator.
L, Feed box (ordinary adjustment).
(*l*), Gauge glass on feed box.
M, Feed pipe to evaporator (from feed box).
N, Fresh water pipe from distiller to filter.
O, Circulation inlet (from pump not shown).
P, Fresh water outlet from filter.
Q, Filling pipe, for charging evaporator with sea water.
R, Drain cock to empty distiller.

In this apparatus a feed box (L) is shown instead of a feed regulator (Fig. 12, p. 113). The feed gravitates from the feed box into the evaporator.

First.—Start the pump (to about the speed specified it should work at) so as to pass circulation water through the distilling condenser, entering it at (O) and escaping at (G), and as soon as this is done use the filling pipe (Q) to charge the evaporator with sea water, and then let the ordinary feeding take place by means of the automatic feed box (L) or regulator (Fig. 12, p. 113).

Secondly.—Let the boiler steam pass, by valve (D), into the evaporator coils. It is best to do this very gradually, and as soon as an adequate pressure is obtained in the evaporator casing, generally about 3 to 6 inches head of water, indicated by water pressure gauge (B), then let the apparatus work at this, and pass its gained steam through pipe (A) into the distiller tubes.

Thirdly.—The water produced will soon flow from the fresh water pipe (N) into the feed regulator, if there is one (Fig. 12, p. 113), thereby regulating the feed ; and the brine will thus adjust itself so as to be in due proportion to the fresh water. If a filter is part of the apparatus, the fresh water will pass through the filter on its way to the feed regulator.

Fourthly.—The pumps will now draw away the fresh water and the regulated feed water, delivering the former to where desired, and the latter to the evaporator casing.

Trial Sheet.

5. A Form for entering the usual particulars required by Government is given below. For Government trials it is necessary to provide proper measuring tanks, in order to show the quantity of gained water produced, the weight of primary steam used, and the brine discharged, in compliance with the specification. All materials have first to be tested to the satisfaction of the inspector or overseer, and all parts of the apparatus have to be proved and passed in compliance with the terms of the specification. No distinction is made with regard to the long standing of any makers. All are treated in the same manner.

6. In the case of private contracts—that is, with regard to distilling apparatus supplied to private firms—the inspection is not nearly so strict, satisfaction being felt by specifying that the makers are to supply the distilling apparatus so as to meet the Board of Trade requirements, and the trial of the apparatus is more or less formal, according to the confidence in the makers that are supplying the distilling apparatus.

Note.—Official trials are usually conducted under the following conditions :—

(1) Primary Steam Pressure—25 lbs. per square inch

OFFICIAL TRIAL

OF DOUBLE DISTILLING APPARATUS No...............

MAKER'S NAME,..

Time.		Pressures.				Temperatures, Fah.							Speed of Pump (Revs. or Strokes per Min.)	Quantities Measured (Gallons).					Remarks.		
Date of Trial.	Time of Trial.	On Steam Valve of Evaporator (lbs.).	Inside Coils of Evaporator (lbs.).	Inside Casing (Water, inches).	Inside Heater Coils (lbs.).	Primary Water.	Secondary Water.	Diluted Brine.	Dilution Water.	Outlet Circulation.	Inlet Circulation.	Distilled Water.		Primary Water.	Secondary Water.	Feed Water.	Brine.	Dilution Water.	Brine Salinity in 32nds.	Economy of Primary Steam.	Nitrate of Sil. Test.
	Say																				
	A.M.																				
	10.0																				
	10.15																				
	10.30																				
	&c.																				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22

General report on trial—

in the pipe supplying exhaust steam to the evaporator, and 150 lbs. pressure in the pipe supplying steam to the pump. This is on large ships. On small ships the evaporator receives live steam.

(2) Secondary Steam Pressure—0·5 lb. per square inch in evaporator case is led into the distiller. The distiller is, however, required to work sometimes below atmospheric pressure, and the vacuum or *minus* pressure in the distiller into which the secondary steam is discharged may then amount to 18 inches.

(3) Pump Speed—Piston is not to travel more than 100 feet per minute, nor make more than 60 double strokes per minute, and crank revolutions not more than 60 per minute.

(4) Evaporator to be charged and fed with sea, or salt, water at a "density" of $\frac{1}{32}$. (See observations, p. 25.)

(5) The brine in the evaporator to have a "density" between $\frac{2}{32}$ and $\frac{3}{32}$. (See observations, p. 25.)

(6) The brine to be discharged at least 30 feet above the bottom of the evaporator. This is on large ships.

(7) The water diluting the brine must be at least twice the quantity of the brine.

(8) The temperature of the condensed primary steam is not to exceed 150° when it is discharged from the apparatus. That would mean *after* its heat has been used in the evaporator feed-water heater.

(9) The circulation water is not to have any head over the suction—*i.e.*, it is not to flow into, but be sucked up by the pump.

(10) The inlet circulation water is to have a temperature of 85°.

(11) The evaporators are not to be lagged during the trials.

(12) Duration of Trial—Four consecutive hours on the above conditions, with a production of 10 per cent. more than ordinary output specified; and during the trial there must be no altering of the steam valves or feed inlet, nor any manipulation of the automatic feed.

This margin (10 *per cent.*) is sometimes increased to 20 *per cent.* for trial before delivery, and 10 *per cent.* on subsequent trial when the apparatus is fixed on board ready for use.

Note.—In H.M. ships of cruiser and battleship type, it is usual to have a combination of two evaporators working with one distilling condenser. This saves space, but the arrangement is not so simple as a single evaporator working with its own distiller.

General Observations.

7. For ordinary working of a double distiller, an atmospheric pressure for the *gained* steam is clearly preferable to a *minus* pressure or *vacuum*. Perhaps the strongest argument in support of this is, that whereas a few years back, specifications required the double distiller to work always at a *considerable minus* pressure, now specify that practically atmospheric pressure is to be the condition for *normal* working. Where, however, the latter system (*i.e.*, a vacuum) is specified it is always complied with.

CHAPTER X.

GAS AND OIL STOVES FOR EVAPORATORS.

1. Before considering the multiple distilling apparatus, a few words may be devoted to the use of gas and oil stoves in distilling on land—*e.g.*, in houses or industrial establishments. This type of distilling apparatus is necessarily very small—*i.e.*, suited for a small supply of water, say 1 or 2 gallons per hour ; but this small quantity is produced very pure, as the steam is usually generated from water that is impregnated with only small quantities of chalk or other impurities, yet sufficient to make such water objectionable in many cases, either for drinking purposes, or industrially, where absolutely pure water is required. The distilled water can be filtered so as to render it agreeable to the taste, but for use with accumulators it is best unfiltered. Fig. 21 (p. 168) shows an apparatus of the above description complete with a filter.

2. A small apparatus of this kind must necessarily be worked automatically ; otherwise it would soon get out of order, or require an inordinately expensive attendance.

3. The working of the apparatus represented in Fig. 21 is as follows :—

(1) When the gas at (A) is ignited, the impure water in the generator over it is boiled and converted into pure steam. This steam passes over, by pipe (C), into the tubes inside the distilling condenser (D), where it is condensed into pure distilled water, which flows away at (E).

(2) A suitably regulated quantity of feed water automatically passes at (B) into the generator, and the excess is discharged, also automatically, at (F). The feed-water at (B) is taken from the circulation water as it passes through the condenser.

(3) This circulation water (which may be taken from

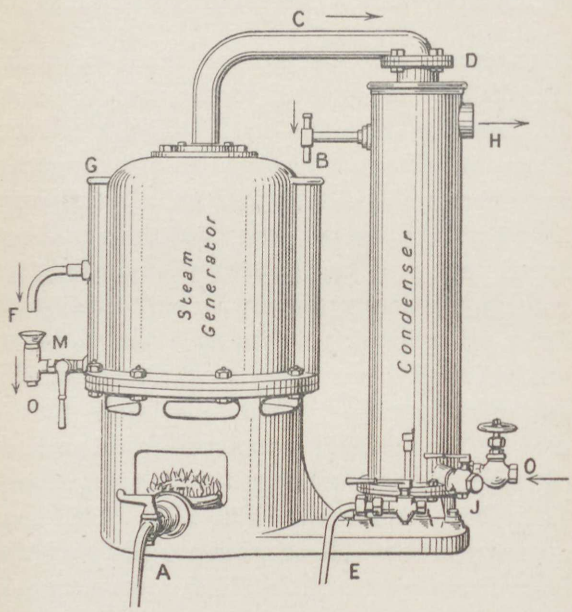


Fig. 21.

the main) enters at (O), surrounds the tubes inside the distilling condenser (thereby condensing the steam inside of them into distilled water), and then passes out to waste at the point (H).

(4) The opening (G) affords a means of charging the generator with water to start working with. The generator is emptied by the cock (M).

(5) The circulation water can be drained out at (J) when leaving off work.

(6) The pure water escaping at (E) is usually warm for industrial purposes, but when required for drinking, is cooled and rendered palatable by being passed through a suitable filter placed under (E).

4. The consumption of gas during work may be ascertained as follows :—

(1) In Chapter V. on "Fuels" it was shown that town gas was capable of imparting heat at the rate of 570,000 to 600,000 B.T.U. per 1,000 cubic feet of gas consumption. Therefore, to heat 1 lb. of water from, say, 60° to boiling point (212°) would require 152° (212 - 60 = 152), to which must be added the latent heat which has to be absorbed by that pound of water to convert it into steam ; hence, a total of 1,018 B.T.U. (152 + 966 = 1,018) of heat is required to produce 1 lb. weight of steam. Every 1,000 cubic feet of gas will, therefore, evaporate from 560 to 588 lbs. of water into the same weight of steam, which can then be re-converted into the same quantity of distilled water. At 3s. per 1,000 cubic feet, the cost of obtaining 500 lbs. of distilled water (*i.e.*, 50 gallons) would be about 0·7 of 1d., which is rather less than ¾d. per gallon.

(2) In the foregoing calculation, no allowance whatever is made for unavoidable loss, or rather waste of heat—that is, gas consumed that has not imparted its heat to the work it was put to. It is difficult to estimate what that waste is, but assuming it reaches the large amount of 40 to 50 per cent., the cost of producing the above distilled water would still not exceed 1½d. per gallon.

OIL STOVES.

5. An oil stove can be fitted to the small distilling apparatus above described. A wickless one is preferable, convenient forms of which are now made, but none give so *immediate* and *constant* and *continued* a supply as can be obtained by just turning on and off of a gas tap.

Note.—The quantity of oil required may be ascertained by reference to the Chapter on "Fuels."

CHAPTER XI.

MULTIPLE DISTILLATION.

(A) GENERAL PRINCIPLES.

1. IN the foregoing chapters we have been considering sea water distillation in its simplest form—*i.e.*, the *evaporation* or *conversion* of the water contained in sea water into steam, and the *condensation* or *re-conversion* of such steam into pure water. This is what is called *single* distillation. We have also considered the subject in a slightly extended form—viz., that of *double* distillation—for the purpose of steam ships, by the introduction of an evaporator, but the evaporator has been used more in the nature of a boiler—*i.e.*, a boiler worked by steam heat instead of the ordinary furnace usual with boilers. The gained steam, or steam generated by the evaporator has alone been counted for use, and the heat imparted by the primary steam by its re-conversion into water has been counted against the quantity of sea water evaporated, much as one would count the weight of coal consumed by a boiler against the weight of water evaporated. Up to the present we have not regarded double distillation (which is the *first step* in multiple or compound distillation) in the light of so much distilled water—*i.e.*, primary and secondary water combined—as the emanation of so much fuel consumed.

2. It is proposed now to deal with "compound" or "multiple" distillation, which accommodates itself to

use on land by having successive distillations—that is, a series of distillations linked together by means of the introduction of evaporators between the boiler (in which the fuel is consumed, and the initial steam is produced), and the condenser, in which the final steam is condensed.

3. The successive distillations are best named by the number of distillations carried out. Thus, a boiler simply discharging its steam into a condenser is obviously a single-process distillation, and is termed "single" distillation. The introduction of one evaporator between the boiler and the condenser involves two distillations (1st, the boiler, and 2nd, the evaporator), so as to make a double process of distillation, which is consequently termed "double" distillation; the introduction of two evaporators with the boiler so linked as to produce three successive distillations is termed "treble" distillation, and so on, according to the number of distillations.

Properties of Steam Reconsidered.

4. On considering the various types of distilling apparatus, it will be seen that the properties of steam apply to multiple distillation in the same way as they do to the double distiller of the steam ship, both as regards *time*, *rate*, and *economy* of production—*i.e.*, as against fuel consumed.

5. It should, however, be mentioned that although the distilling machinery supplied by various makers may differ somewhat in matters of detail, as to manner of construction, &c., yet on matters of principle, all are naturally governed alike. Thus, the properties of steam, as to its pressure, and heat, necessarily govern all systems of

multiple distillation; yet one maker may carry the system of successive distillations farther than another, or the feed-water may be differently heated or fed in, or the brine differently discharged, and other points of detail might be mentioned; but these really only affect the arrangement and construction of the apparatus.

Note.—As it is obviously impossible to give in detail the construction of every make of distiller and form of apparatus, the *system* or *theory* of multiple distillation will alone be explained, and the reader must apply the same to whatever type of apparatus he is interested in.

Suitability and Purpose.

6. The apparatus for multiple distillation is most suitable for large plants or installations, where a considerable amount of pure water has to be produced daily. Where, therefore, the daily (24 hours) production is, say, over 10 tons of water as a minimum, the apparatus for multiple distillation can always be regarded as suitable, on account of the great saving of coal. It also follows that the larger the daily requirement is, the more extended may be the type of multiple distillation adopted.

7. The following may be taken as a rough guide—*i.e.*, where the fuel, say coal, is at normal price, or very cheap, or abundant—as there is no advantage in incurring a large outlay on an apparatus, highly economical in its system of working (for every extension of compound distillation necessarily makes the apparatus more expensive), when an apparatus less economical in its system of working will answer the purpose.

8. For a production up to, say, 10 tons of water per day (24 hours) the double distillation type will probably be sufficient (except in cases where the price of fuel is very high).

For productions above 10 tons and up to, say, 50 tons daily, the treble distillation would be suitable. The simplicity of only three successive distillations will, however, often induce one to carry the installation of treble distilling apparatus up to 80 or even 100 tons of water daily. For productions over the above requirements, quadruple, quintuple, or even higher grades of multiple distillation may be suggested. Multiple distillation cannot, however, be continued with advantage to an unlimited extent.

9. It will be seen shortly that after carrying multiple distillation to a certain point, the increased gain of water becomes so small, the boiler so large, and the initial pressure so high, that the addition of more evaporators cannot be usefully continued.

Gained Water.

10. The term "gained" water is usually applied to the distilled water obtained by the evaporation of sea water by means of an evaporator (on board ship) to distinguish it from the greasy fresh water (condensed boiler steam) used by the evaporator—*i.e.*, the primary steam when it is re-converted into primary water by the abstraction of its latent heat. Such primary water has to be kept separate from the gained water, in order to be returned to the boiler for re-evaporation.

11. In the double distiller on a steam ship the primary steam, being always greasy, is only used as an initial

heating medium to the evaporator, but on a land apparatus, where boiler water does not acquire a greasy taint, the whole of the water, whether produced by the boiler or by the evaporators, can be mixed together, and counted as the production obtained by the coal or other fuel consumed. In land apparatus, therefore, the primary water is included with the gained water.

12. In some types of *land* distilling machinery the primary water is still returned to the boiler, and only the water distilled from the steam generated by the evaporators is counted. By this means the boiler is fed with fresh water instead of sea water, but the difference in the economy of working (*i.e.*, the amount of drinking water produced against the amount of coal consumed, weight for weight, is necessarily very much less than when the boiler is fed with sea water), and all the distilled water (including boiler evaporation) is counted against the amount of coal consumed (weight for weight, as before). Not only is the economy a good deal less (how much less will be shown presently), but the apparatus will have to be considerably larger, and consequently more expensive for the daily amount of water required, if the boiler distillation is retained, and not included in the general output per day.

13. Therefore, for the present purpose of explaining the principles of multiple distillation, it is proposed to assume that the boiler, like the evaporators, is fed with the same class of sea water, and that the water distilled from the boiler and evaporators, and the condensed steam or vapour from evaporation are mixed, and the total output counted against the coal that has been consumed to obtain it.

(B) SUCCESSIVE DISTILLATIONS.

14. Assume that 1 ton of coal will evaporate 10 tons of water with the boiler used in a given time. The 10 tons of steam thus produced, if led into a condenser, would obviously be re-converted into 10 tons of distilled water, so that the 10 tons of distilled water would be produced by 1 ton of coal, or, put in the usual form of calculation, 1 lb. of coal yields 10 lbs. of distilled water (weight for weight).

(1) Single Distillation.

15. The above simple form of distillation is commonly called "single distillation," and the condenser receiving the boiler steam is called the "distilling condenser." (The condenser of every distilling apparatus is usually called a "distilling condenser," in order to distinguish it from a surface condenser.) The boiler steam may be at any pressure that is convenient. Suppose the boiler pressure is 25 lbs. per square inch, which (as steam) has a "sensible" heat of 266°, and on liquefaction yields 927 B.T.U.; say also the water fed into the boiler has an initial temperature of 200°, and that its quantity is $1\frac{1}{2}$ times that of the evaporation of 10 tons. The heat required, per pound, is then :—

99 B.T.U. ($266 - 200 = 66 \times 1\frac{1}{2} = 99$).
966 ,, of latent heat.

1,065 B.T.U. *per lb.* of water evaporated.

As there are 22,400 lbs. in 10 tons of steam, $1{,}065 \times 22{,}400 = 23{,}856{,}000$ B.T.U., the quantity of heat needed. A ton of good Welsh steam coal is equal to the requirement, if yielding 10,650 B.T.U. per lb. (see Chap. v.), which would (under the conditions specified) yield 10 tons of steam by single distillation, an economy of 10 to 1 (weight for weight).

Note.—The quality of the coal—that is, its heat-giving power—is, of course, an important factor, because if the coal gave only 8,000 B.T.U. per lb., the weight of coal required would be as 8,000 : 10,650 :: 1 : 1·33 tons ; or, put in another way, the *evaporation* for the same weight of coal consumed would be as 10,650 : 8,000 :: 1 : 0·75 ton. The yield, therefore, will vary with the quality of the fuel.

(2) Double Distillation.

16. Now, compare the above fuel cost of working single distillation with the more economical type of *double* distillation, where one evaporator is interposed between the boiler and the condenser, and so connected up that the boiler or primary steam, instead of going directly into the condenser, where 1,065 B.T.U. were simply absorbed by the cooling water, and carried away to waste, now goes into the coils of an evaporator, and is thus able to generate a new supply of steam or vapour, which is called secondary or gained steam or vapour. The result is that the boiler steam works at the same pressure, and with the same *sensible* and *latent* heat, but the latent heat is now utilised in creating a new supply of secondary steam, amounting to about 80 per cent. of its weight, as already pointed out in the chapter on "Steam" ; and the production of extra or gained water is as follows :—

The 1 ton of coal imparts the same quantity of heat (*i.e.*, the same number of B.T.U.) for every lb. of the 10 tons of water converted into steam, but the 10 tons of primary steam (at 25 lbs.), by being re-converted into primary water in the evaporator tubes, imparts its latent heat of 927 B.T.U., which is about 87 per cent. of 1,065 (but which, owing to inevitable losses, may be reduced to about 80 per cent. in practice), thus giving—

10,650 B.T.U., as before (for the 1 ton of coal).
8,520 B.T.U.—*i.e.*, 80 per cent. of 10,650.

19,170 B.T.U. (total) obtained by the consumption of 1 ton of coal, imparting 10,650 B.T.U.

So that double distillation yields a ratio of 18 to 1 (*i.e.*, 18 tons of water per 1 ton of coal) instead of 10 to 1 in the case of single distillation. Thus—

As 10,650 : 19,170 : : 1 : 1·8, and 1·8 × 10 = 18 tons of water.

(3) Treble Distillation.

17. By interposing a second evaporator, the boiler, 1st evaporator, and 2nd evaporator are linked together into what is called treble distillation.

Boiler Pressure.

18. In this case the initial pressure in the boiler must be increased; assume it to be 75 lbs. per square inch. The pressure in the 1st evaporator and 2nd evaporator coils will then be intermediate between the primary pressure of 75 lbs. per square inch, and the final pressure (which call the tertiary pressure) at or near zero. What the working pressure is inside the coils of the 2nd evaporator and in the casing of the 1st evaporator will be considered presently, but by the extension of principle, the gain of distilled water per ton of coal will be as follows :—

Primary water (for 1 ton of coal), .	10 tons.
Secondary water, 80 per cent. of 10 tons (free of coal), ...	8 ,,
Tertiary water, 80 per cent. of 8 tons (also free of coal), ...	6·4 ,,
Total water (for the 1 ton of coal),	24·4 tons.

(4) Quadruple Distillation.

19. Obviously by extending the principle—*i.e.*, by adding a *third* evaporator—an additional 80 per cent. of 6·4 or 5·12 tons is distilled. This would be quadruple distillation. By adding a *fourth* evaporator the yield is 80 per cent. of 5·12 tons or 4·036. This would be Quintuple distillation. A *fifth* evaporator would yield 80 per cent. of 4·036 or 3·276 tons, and be Sextuple distillation.

Economy Comparison.

20. These progressive gains from 1 ton may be summarised as follows :—

SINGLE Distillation	= 10	tons.	
Add, . .	8	,,	(80% of 10 tons).
DOUBLE Distillation	= 18	,,	
Add, . .	6·4	,,	(80% of 8 tons).
TREBLE Distillation	= 24·4	,,	
Add, . .	5·12	,,	(80% of 6·4 tons).
QUADRUPLE Distillation	= 29·52	,,	
Add, . .	4·096	,,	(80% of 5·12 tons).
QUINTUPLE Distillation	= 33·616	,,	
Add, . .	3·276	,,	(80% of 4·096 tons).
SEXTUPLE Distillation	= 36·8928	,,	all from 1 ton of coal.

Boiler Pressure.

21. To obtain, however, the advantage of multiple distillation, the pressure of the initial steam—that is, the boiler steam pressure—must be *in*creased or the final pressure be *de*creased, as each evaporator is added, and the intermediate pressures—that is to say, the pressures in the steam-room or casing of each evaporator—will follow in a gradually diminishing rate from the initial pressure to the final pressure. Thus, in *Treble* distillation the intermediate pressure, between 75 lbs. of primary pressure in boiler, and zero (or thereabouts) in the 2nd evaporator casing, would be that corresponding to the pressure at the temperature about half-way between the initial and final temperatures of the steam. The temperature of steam at 75 lbs. pressure is 320°, which is 108° above 212°, so that 54 units (or ½ of 108) would be about midway. Therefore, if 54 be taken off 320°, or 54 be added on to 212°, the result would be 266°, at which temperature we find steam would have a pressure of 25 lbs. per square inch; so that in treble distillation the primary pressure might be 75 lbs. *primary* pressure, 25 lbs. *secondary*, and the *tertiary* pressure zero or ¼ lb. per square inch.

Limitation of System.

22. Theoretically, the principle of multiple distillation may be carried on indefinitely ; but, as will be observed, the gain soon reaches proportions negligible in practice.

23. At each successive stage—that is, with every evaporator added—the pressures must be increased or readjusted. The primary pressure must be *in*creased, or the final pressure *de*creased, to suit the necessity of having the same difference in temperature between that

of the steam inside the coils of each evaporator and the water outside such coils. Thus, in the foregoing explanation the difference (at each stage) is 54° of temperature —*i.e.*, the difference in the "sensible" heat of the generating steam *in*side of the coil and of the generated steam *out*side of the coil is 54°, the primary pressure of 75 lbs. per square inch having a *net* temperature of 54° (320 – 266 = 54) above the secondary pressure, and the secondary pressure of 25 lbs. a *net* temperature of 54° (266 – 212 = 54) above that of the tertiary pressure. The evaporators should, therefore, be constructed—*i.e.*, provided with a heating surface—on the above basis. If, however, this basis is altered to suit requirements, the construction must be altered accordingly. The heating surface may be *de*creased if the temperature difference is more than 54°, but *in*creased if less, according to the rule already explained—viz., that the amount of evaporator heating surface is governed by the amount that the sensible heat of the steam inside the coils is above that of the steam or water (which is the same), outside of the coils.

24. From the above observations it will be seen that a practical limit is soon found whether the pressures be *in*creased or *de*creased, as the *maximum* primary pressure and the *minimum* final pressure available are soon reached. The practical result of these considerations is to avoid carrying the principle beyond the limits dictated by practical economy, as the cost of the plant increases with every evaporator added, while the advantage gained with each lessens. The quadruple distilling apparatus, which is capable of producing about 30 tons of water to the ton of coal, working steadily and easily, will be found to be a good limit. Beyond this point, the actual *return* for the *outlay* is a doubtful advantage.

Economy and Time Productions.

25. It cannot be too often repeated that the *economical* working of an apparatus is a totally different thing from its productive power in point of time. The yield of a fixed quantity in a fixed *time* may be the same for any type of distiller, but the economy varies with each evaporator added, and is dependent, therefore, wholly on the type of apparatus at work. Generally, the same apparatus will show the same economy whether its time production is large or small. The larger the apparatus (or, to put it strictly, the larger the boiler) the more economically will the whole apparatus work.

Summary of Types.

26. The following points may be summarised in comparing the various types of distilling apparatus as the multiple effect is gradually increased :—

First.—That as every evaporator is added, in order to get more distilled water for the same weight of primary steam—that is, indirectly, the same coal consumption—the primary pressure must be gradually *increased*, or the final pressure must be *reduced*.

Secondly.—That the lower the pressure is (from first to last) the more must be the evaporator heating surface. Thus if, in treble distillation, the initial pressure is 75 lbs. and the final zero, the heating surface must be greater if such initial pressure is, say, only 50 lbs. per square inch.

Thirdly.—That at each successive distillation, although the total production is more, each distillation produces less. Thus, although in double distillation the total production is more than in single distillation, yet the secondary water is less than the primary water, and in treble distillation, although the total production is more than in double distillation, yet the tertiary water is less in quantity than the secondary water, and so on.

Fourthly.—That although at *each* successive distillation the production is less in degree (though more in total), the evaporators all have the same amount of heating surface. Thus, in quadruple distillation, although the 3rd evaporator affords only a gain of 5·2 tons, as against 8 tons by the 1st evaporator, both evaporators have the same evaporative surface.

Fifthly.—That the combined or joint production (in point of time) of *all* the evaporators in multiple distillation is about the same as the production would be if only one of the evaporators were used and worked with the same pressures (initial and final) as the multiple distilling apparatus. *Uniform* evaporators are understood.

Note.—To make this point clear—say that in treble distillation the primary water is 10 tons in a fixed time, and that the gained water (secondary and tertiary) in the same time is 14·4, making a total mixed production of 24·4 tons in the given time, and that the initial pressure (boiler steam) is 75 lbs. per square inch, and the final pressure in the 2nd evaporator casing is $\frac{1}{4}$ lb. If, instead of the evaporators being coupled together, the boiler steam at 75 lbs. pressure went into the 1st evaporator, and the pressure in that evaporator casing is reduced to $\frac{1}{4}$ lb., while the 2nd evaporator is cut out altogether, then the existing surface of the 1st evaporator, with 75 lbs. steam pressure inside the coil, would be capable of producing the 24·4 tons (in the same time); but the proportion of primary and secondary water would then be—

13·6	primary water (from 1·36 tons of coal).
10·8	secondary water (80 per cent.).
24·4	total, in a given time.

Instead of, as in treble distillation—

10·0	primary water (from 1 ton of coal).
8·0	secondary water (80 per cent.).
6·4	tertiary water (80 per cent. of 8).
24·4	total, in same time.

Note.—This is perhaps as good a way of demonstrating the difference between production in point of *time*, and production in point of *economy*, as can be given. Thus, in point of *time*, the total production (whether by double or treble distillation) is 24·4 tons, and this may be the work of, say, ten hours, so that in 100 hours the total production would obviously be 244 tons of water; but in point of *economy*, the production of every 24·4 tons of water would, in double distillation, be obtained by the consumption of 1·36 tons of coal, whilst in treble distillation every 24·4 tons of water would be obtained by the consumption of only 1 ton of coal, no matter whether the time during the apparatus is at work is 10 hours or 100 hours, or 1,000 hours. The *rate* of water production per ton of coal would be the same irrespective of time, and in, say, a 1,000 hours' working, whatever weight of *water* is actually recorded, the weight of *coal* consumed would (in double distillation) be in the ratio of 24·4 to 1·36, which equals 18 of water to 1 of coal, whilst in treble distillation the coal consumed would be in ratio of 24·4 of water to 1 of coal. Therefore, if in 1,000 hours' working the actual production of water was 500,000 gallons of water = 2,237 tons (500,000 ÷ 224 = 2,237), then the coal consumed in producing the 2,237 tons of water would be as follows :—

2,237 ÷ 18 = 124 tons (about) of coal (in double distillation).

2,237 ÷ 24·4 = 92 tons (nearly) of coal (in treble distillation) ;

So that a saving of about 32 tons of coal (124 − 92 = 32), about 25 per cent., would be obtained in producing 2,237 tons of water if treble distillation apparatus is used instead of double distillation apparatus.

27. By this method of calculation the *actual* saving by the use of any type of apparatus can be ascertained, and it will then be possible to judge how far the extension of multiple distillation can be carried advantageously for practical purposes.

Diminishing Economy.

28. The economy (or amount of fuel saved by the process of multiplying evaporators) is greatest in double distillation stage, in the *first* evaporator—*i.e.*, the first evaporator is the most effective—while the effectiveness of any evaporator beyond the fourth is scarcely remunerative, when the increased cost of the apparatus is taken into account.

Note.—Sometimes the boiler, instead of being fed with the same impure water that is in process of distillation, is fed with distilled water—*i.e.*, the *primary* water—or part of the total output is used as feed for the boiler. This arrangement will keep the boiler free from scale, but the loss will be very great, as it uses the water available for purposes other than feeding the boiler. The reduction will, in fact, be the loss of the 10 tons of water from the ton of coal consumed, thus—

In double distillation there will be only			8 instead of		18 tons.
,, treble	,,	,,	14·4	,,	24·4 ,,
,, quadruple	,,	,,	19·52	,,	29·52,,
,, quintuple	,,	,,	26·6	,,	36·6 ,,
,, sextuple	,,	,,	27·9	,,	37·9 ,,

This reduction is absolutely unnecessary if a suitable boiler, worked with sea water, forms part of the apparatus.

Right Boiler Pressure—Economy of.

29. From what has been said on the subject of boiler pressure, it will be observed that the most economical boiler pressure is one that is *sufficient*, but not excessive, for the lower the working pressure is the greater is the economy. Such a pressure is preferable to a higher one requiring the partial closing of the boiler steam valve.

Pump Steam.

30. It must not be forgotten that the above economy is calculated exclusive of the steam required to drive the pump. The pump is a necessary part of the apparatus, and is generally used for nothing else. This pump has to do a good deal of work—*e.g.*, it has (1) to pump circulation water through the condenser, for the purpose of condensing the steam and cooling the water down to a suit-

able drinking water temperature; (2) to feed the boiler and each evaporator; and, often, (3) to force the drinking water produced to a height above or to a distance from the apparatus. This requires considerable steam power, and the steam utilised for these purposes should obviously be included in the working cost of the apparatus. If statements of high economy are made without counting the coal used in providing steam to drive the pump (or, indeed, to provide any source of heat used by the apparatus), such statements are entirely delusive.

31. The method of dealing with the pump steam and exhaust will be noticed in the section on the pump, but meanwhile it may be stated that the requisite steam for driving the pump of a multiple distilling apparatus will amount to about 15 per cent. of the boiler steam used, so that if we take 10 tons of steam as the boiler evaporation by 1 ton of coal, then 25 per cent. of this 10 tons will leave $7\frac{1}{2}$ tons available for all evaporation purposes, and if worked out on the same lines already stated will make a considerable reduction at each stage or type of distillation.

Note.—It will be seen, however, that although the steam used to drive the pump is a large item in itself, yet if the exhaust steam is properly utilised in the working of the apparatus, this expenditure of steam on the pump may be very considerably retrieved. This will be shown later on.

Specified Economy.

32. It should be clearly understood that the true economy of working an apparatus is the ratio that exists between the weight of water yielded by the apparatus and the weight of coal consumed by it. Therefore, only such

distilled water as is delivered for use outside the apparatus can be reckoned in the output. On the other hand, any extraneous heat used for obtaining steam for the pump annexed to the apparatus, or for heating the feed-water supplied to the apparatus, should be added to the coal account. These points are mentioned, as it is very easy to be misled.

Note.—In all cases where the economy of a distilling apparatus is specified as so many lbs. of water distilled by 1 lb. of coal, the specification should make it clear (1) that in the working of the apparatus heat from no other source is used, and (2) that the water counted is all available for use outside the apparatus. This is perhaps more important than is at first sight apparent. Thus, to say 20 tons of water produced per ton of coal consumed may be strictly correct, yet if production is taken in the narrow sense of water distilled, the steam used by the pump may be ignored as not coming within the above wording, whilst the primary water, if returned to boiler and not available for use outside the apparatus, might still be held to come within the description of water produced by distillation. Again, as will be seen presently, by starting a short trial with a high boiler pressure, and finishing off with a very much lower one, an extraordinary economy can be shown. In all these cases the true economy effected can only be ascertained after a long run with the apparatus, when the actual weight of coal used can be measured to a pound, and the actual quantity of distilled water actually delivered from the apparatus (for *extraneous* use) counted to a gallon; then it will be seen to what extent the specified economy is real.

Dirty Surfaces—Economy Reduced.

33. The economy of an apparatus is very much affected by the condition in which the surfaces are in—*i.e.*, as to the scale deposited on them—especially on the boiler heating surfaces, because, as such scale forms on the boiler heating surface, the heat from the fire is prevented from passing to the water, and instead, goes up the boiler chimney unused.

34. Scale accumulating on the evaporator surfaces, although it reduces the evaporative power (*i.e.*, in point of time), does not affect the economy to anything like the extent that scale formed on the heating surfaces of the boiler does. The reason is that when scale forms on the evaporator surfaces, the evaporative power is reduced, and consequently less *gained* water produced, but then less *primary* steam is used in proportion, so that the economy is not very much affected, as the proportion of water yield to coal consumption is about the same.

35. To compensate for the boiler surfaces getting dirty, a greater pressure has to be got up. If, therefore, the boiler is started at its utmost capacity and pressure, the pressure cannot be increased as the surfaces get dirty, and the result is that the initial large production can only be kept up for a short time. It is sometimes said that it is better to lose heat by making short runs of work and then to clean the surfaces, than to continue working with dirty surfaces. This view may be advanced and supported by argument, but in practice it is found that the cost of working is less by running the apparatus as long as possible without stopping it for cleaning purposes.

Margin of Power Advisable.

36. The most satisfactory way to provide for the inevitable loss of power, owing to the gradual deposit on the heating surfaces, seems to be to treat the production of the apparatus against time as being only about $\frac{3}{4}$ of its maximum capacity, and the economy stated to be about $\frac{4}{5}$ of what the maximum capacity of the apparatus is. Or, put shortly, the apparatus should be capable of a margin of about 40 to 50 per cent. extra on trial with clean surfaces for a short trial, say of a few hours' duration, and the economy about 15 to 20 per cent. more at such trial than is specified as the ordinary output of the apparatus. By this means the apparatus may be worked for some considerable time easily and steadily—that is, by beginning with a low boiler pressure, and gradually working up as the heating surfaces get dirty, so that at the end of the run, say three or four weeks (night and day), the apparatus will be found to have made an average output of the specified quantity per day, and an average also of the specified economy.

Note.—At the end of a run of this duration, one can tell to a pound the weight of coal that has been consumed by working the apparatus, and to a gallon the quantity of water produced thereby, whilst in short runs and repeated stoppages the ascertainment of the coal consumed must be largely guess work.

37. Evaporator makers are always endeavouring to lessen the loss of power due to the formation of deposits on the heating surfaces by making them easier to clean, by adding substances to the sea water, and by other devices. Much has been said for and against all of them,

but the actual results obtained after continued working of the apparatus are the only reliable test of its value.

(C) DETAILED DESCRIPTION OF LAND APPARATUS.

(*a*) THE BOILER—Generally.

38. The boiler, being of predominant importance, will be dealt with first.

39. The boiler intended to work with a sea-water feed is the only kind that calls for notice in this treatise.

40. The *first* thing to be considered is the type of boiler best suited for sea water distillation. As on steam ships distilling apparatus is worked by the greasy steam on board, which, after use, is returned as so much greasy water, the boiler (as part of the distilling apparatus) is of much the same type as that used on *land*.

1. Type of Boiler.

41. Water-tube boilers, in which the water is evaporated inside the tubes, are obviously not suited for sea water distilling machinery; such a boiler can only be worked if fed with the returned *primary water*, but this involves the loss of economy already pointed out.

42. The boiler best suited for this purpose is the tank boiler of Cornish or Lancashire type, the former up to a certain size, say 5 to 6 feet in diameter, and the latter of a diameter exceeding 6 feet. A large Lancashire boiler is, of course, more economical in its working than a small one, and the same may be said of the Cornish type, which is also always rather less economical of fuel than the Lancashire boiler of the same power with its double flues.

43. For large installations, boilers of Lancashire or Cornish type are best, but if absolutely necessary, a boiler

of *vertical* type can be used. Its economy is, however, considerably less than that of the Cornish type of boiler. The vertical boiler will consume about 20 to 25 per cent. more coal for an equal evaporative power. The Cornish or Lancashire type of boiler requires to be set in brick-work, the vertical does not.

44. Whatever type is used, it is well to avoid cross tubes, and, in fact, all internal work, as far as possible, that will get incrusted with scale. All interior appliances should be arranged so as to avoid difficulties in cleaning off the scale. The flue or flues of the boiler should not be fitted too close to the bottom, as the passage between the bottom of the shell and the tube is readily filled with deposit.

2. The Size of the Boiler.

45. The proper size of the boiler to suit multiple distillation for a specified production and specified type of apparatus—*i.e.*, whether single, double, treble, or quadruple distillation—is a matter to be looked at from different standpoints. Some makers advocate larger boilers than others do for the same work. To have the same size boiler for salt feed as for fresh feed would obviously be erroneous, because no allowance would be made for the extra feed required for a sea-water feed, nor for the gradual loss of power caused by the heating surfaces getting furred over.

46. In estimating the size and power of a boiler for a set of distilling apparatus, the *quantity* of *primary* water contributed, and the steam *pressure* needed, must first be determined, having regard to the succeeding pressures in the evaporators; and due allowance must be made for the *quantity* and temperature of the boiler feed.

Never be niggardly in the size of the boiler. It is far better for the boiler to be too large than too small. A liberal margin will always be gratefully remembered by the attendant in charge of the apparatus.

47. Therefore, in settling upon the size of the boiler, one must be guided by precedent as to former plants supplied. The following instance will show how the size of a boiler is arrived at for a *treble* distilling apparatus producing, say, 40 tons of water per day (24 hours), which is (approximately) 400 gallons per hour.

In treble distillation it has been shown that the *ratio* of water produced is as follows :—

10	of primary water	=	41	per cent.
8	of secondary water	=	32·8	,,
6·4	of tertiary water	=	26·2	,,
24·4	total . . .	=	100·0	,,

So that the primary water (*i.e.*, the evaporation from the boiler) will be theoretically 41 per cent. of 400 gallons per hour, which equals 164 gallons ; this divided by 6·24 = 26 (nearly) cubic feet or H.P. It is, however, better to avoid H.P. estimates, and to base the calculation on the number of *pounds* of water to be evaporated per hour. In the present case this would be 1,640 lbs., and the working pressure be, say, 80 to 100 lbs., but in settling the boiler for other types the working pressure would be somewhat different.

48. As a salt-water feed is under consideration, allowance must be made for (1) extra feed, to allow a proper blow off of brine ; and (2) loss of power due to scaling of heating surfaces.

49. Assume, first, that a boiler is required for producing the above total evaporation of say 4,000 lbs. weight of steam per hour.

(1) If the plant consists of a *single distilling condenser* and boiler only, the steam pressure of the boiler need not be very high. The total heat is nearly the same as any pressure, but being rather less at low pressure, it is obviously inexpedient to work at a higher steam pressure than is sufficient to let the steam pass through pipes of ordinary size. For single distillation, a maximum boiler pressure of 50 lbs. will be sufficient, say 25 to 50 lbs. pressure. The size of the boiler will have to be equal to an evaporation of 4,000 lbs. of water per hour, and Table N, on p. 197, will be a guide.

(2) For *double* distillation also, the pressure need not be very high. Thus, say the primary steam to the evaporator has about 30 to 60 lbs. per square inch pressure. That would in ordinary cases be sufficient. The size of the boiler should be such as will yield $\frac{10}{18}$ of the total production. So that if 4,000 lbs. of distilled water is the required quantity per hour, the boiler must evaporate $\frac{10}{18}$ of 4,000 lbs. = 2,222 lbs. per hour.

(3) For *treble* distillation the boiler working pressure should be somewhat higher, say 50 to 80 lbs. The size of the boiler may be ascertained by the following Table N (p. 197), and the amount of sea water to be evaporated by the boiler will be $\frac{10}{24}$ of the total output. In the present case, therefore, $\frac{10}{24}$ of 4,000 lbs. will equal 1,666 lbs. of sea water to be evaporated by the boiler, and a suitable size of boiler may be selected from Table N.

(4) For *quadruple* distillation the primary or boiler pressure may be 80 to 100 lbs. per square inch. The size of boiler may be settled in the same way as before,

but taking its evaporative power at $\frac{10}{30}$ of the total output, then $\frac{10}{30}$ of 4,000 = 1,333 lbs. to be evaporated per hour.

(5) For *quintuple* and *sextuple* distillation the primary or boiler pressure should be 150 lbs. per square inch or more. The size of the boiler would be ascertainable in the same way as before—*i.e.*, by taking the proportion of boiler evaporation to the total output.

Economy Involved.

Note.—The economy one is able to obtain from a distilling plant depends very much on the size and type of boiler selected. It should be borne in mind that a small boiler is less economical of fuel than a large boiler, and that a vertical boiler is less economical of fuel than a boiler of Cornish or Lancashire type. For a consumption of 1 lb. of coal a large Lancashire will evaporate 10 lbs. of water, whereas a small Cornish or a large vertical boiler will evaporate only about 7 to 8 lbs., and a small vertical boiler only 4 to 5 lbs. of water; in other words, large boilers are about 20 to 25 per cent. more economical than small boilers, and Cornish and Lancashire boilers about 20 to 25 per cent. more economical of fuel than boilers of vertical type.

50. In all these types it is well to remember that it is always best to work at the lowest boiler pressure possible, with the steam valve full open, and not at an excessive pressure with the valve partly open.

51. The above working pressures are perhaps not applicable to every type or system of multiple distillation; but with the system explained more in detail in these pages, the working for types of apparatus ranging from

single distillation to sextuple distillation, the pressures given will be found to work very well.

3. Heating Surface of Boiler.

52. A good boiler maker will allow the correct amount of *heating surface* for the boiler power required, so that in this respect, and in the arrangement of the flues, a boiler maker's experience will perhaps be amply sufficient to provide for the most economical construction of boiler for the purpose of distillation. If a special kind of fuel other than coal is to be used, such as wood or petroleum, that information will have to be communicated to the boiler maker.

4. Grate Area.

53. The question of *grate area* is proportionate to the heating surface allowed. Therefore, this matter, as well as the heating surface, is best left to the boiler maker, after notifying to him the evaporative power, and class of fuel to be used.

54. The question of fuel used for generating steam has been dealt with in Chapter v. The grate will vary a good deal in shape and area, according to the description of fuel used. Wood fuel will require a considerably larger grate area than coal, and petroleum would require a furnace specially adapted for its use.

Evaporative Power of Boiler.

55. It will be found most convenient, and indeed less likely to lead to a misunderstanding, if the evaporative power required is stated in lbs. of water to be evaporated per hour, and the quantity and temperature of the feed

stated. The expression "horse-power" is sometimes misunderstood.

56. The following Table N, giving a list of boilers (Cornish and Lancashire type) suitable for sea water evaporation, which has been found to answer well after many years' use. The coal consumption is given *without* multiple effect.

TABLE N.

Evaporation from Sea Water, in Practice (lbs. per Hour).	Size of Boiler. Diam. × Length. Ft. In. × Ft.	Heating Surface in Sq. Ft.	Grate Surface for Coal in Sq. Ft.	Coal Consumed per Hour, Lbs.	Approx. Weight Boilers of 100 Lbs. W.P. Tons Avdp.
480	3·8 × 12	148	6·5	60	2·5
630	4·6 × 12	186	7·2	80	3·1
720	4·6 × 15	216	8·5	85	3·7
850	4·9 × 15	246	10	90	4·1
1,000	4·9 × 18	292	11	105	5
1,100	5·0 × 20	323	12	110	5·5
1,300	5·6 × 21	373	13·5	134	6·9
1,500	5·6 × 24	420	15	150	7·9
1,700	5·9 × 26	476	17	170	9·4
1,900	6 × 22	481	19	190	9·5
2,200	6·3 × 24	558	22	220	10·25
2,580	6·6 × 26	656	25	255	12·0
2,820	6·9 × 28	725	28	280	12·85
3,100	7 × 30	800	31	310	15·25
3,300	7·6 × 30	853	33	330	19·25
3,600	8 × 30	924	36	360	21·0
4,000	8·6 × 30	962	40	400	23·0
4,500	8·6 × 35	1,116	45	450	25·0

5. Boiler Fittings.

57. The usual fittings and mountings included are as follows :—

(1) A pair of safety valves (usually weight and lever type) fitted to the top of the steam dome.

(2) A steam valve in combination with the safety valves (1).

(3) A water gauge for indicating the water level.
(4) Test cocks (if required) for same purpose.
(5) A steam gauge.
(6) A feed check valve.
(7) A blow-off cock.
(8) An air cock at the highest point of boiler.

58. These fittings are always included with the boiler, and are usually detailed in the boiler specification. The heating surface and grate surface are also specified. Such parts as furnace doors, soot doors, dampers, &c., also a spare set of fire bars, should be included, and supplied with the boiler.

Note.—Boiler makers of repute will supply detailed drawings of the boiler they offer. It is an excellent plan, when ordering a boiler, to specify that its construction shall be under the supervision of a Boiler Insurance Office. Thus, the Ocean Accident Corporation (for quite a small fee) undertake to supervise the construction of a boiler, and see that the construction answers all rules and regulations. A certificate given by an insurance office of repute will always be taken as sufficient to show such regulations have been complied with. The details of boiler construction required by the Board of Trade, Bureau Veritas, Lloyds, and Admiralty will be found in Seaton and Rounthwaite's *Pocket-book*.

6. The Chimney.

59. The *chimney* is usually considered an extra, but it should be supplied, and, if the chimney is an iron structure, guy chains also. In the matter of size and height of chimney, this is usually left to the boiler maker to

estimate, according to type of boiler and the nature of fuel used.

7. Boiler Setting.

60. The brickwork material for setting the boiler is usually supplied, according to the quantities made out by the boiler maker, who will also supply complete drawings and estimates for setting the boiler. Such matters as wall plates, and iron work generally connected with the setting of the boiler are not, as a rule, included with the boiler. These are extras, but all that is required to make the boiler and setting complete should be supplied or offered.

8. Weight—Shipping Particulars.

61. When tendering for the apparatus, including a boiler, *approximate shipping particulars* are generally asked for and given for the boiler separately. The shipping particulars include, first, the *lifting weight* of the boiler, and, secondly, the *measured* weight of the boiler, on the basis of 40 cubic feet to the ton. The ship-owner charging on the highest figure. The boiler makers are always ready to give this information if applied to.

Rules for Working the Boiler.

62. The following few rules may be found useful as a guide for working the boiler supplying steam to a sea-water distilling apparatus.

(1) The boiler should be used for supplying steam to the distilling apparatus only, otherwise the feed-water will not be regulated properly.

(2) All exposed parts of the boiler and steam and feed pipes should be lagged, so as to avoid waste of heat.

Fire doors should be kept shut, and the steam pressure regulated by careful use of the dampers. Steam should not blow off to waste at the safety valve.

(3) The boiler should not be worked at an unnecessarily high pressure. The pressure of steam should not be more than sufficient to supply the evaporator with steam when the steam valve is full open—that is, the pressure of the steam in the boiler should not be very much above that inside the first evaporator coils. A little extra pressure may be needed to drive the pump.

(4) In prolonged runs of a distilling apparatus, it will be found that the pressure of the boiler will be low at first, and that it will require to be gradually increased as the scale deposits on the heating surfaces.

(5) The level of water should be kept as steady as possible. Blowing off too much brine and filling up with feed to make up is wasteful. The feed regulator should be designed to give a feed in proportionate excess of the evaporation, so that there will be a constant discharge of brine if the blow-off cock is carefully regulated.

(6) Once a day the safety valves should be just lifted by hand to see they are acting properly.

(*b*) THE EVAPORATOR—1. Heating Surface.

63. What has been already said as to evaporators (Chap. vi.)—viz., as to their heating surface, brine, and other details regarding double distillation—applies to multiple evaporation just as minutely.

64. The heating surface has to be calculated, as was shown, for a pressure *in*side the coils counteracted by a lower pressure (more or less great) *out*side the coils—*i.e.*, the difference in temperature is taken between the sens-

ible (or gaseous) heat of the steam (at its particular pressure) inside the coils, and that of the sea water outside the coils, which is continuously absorbing a sufficiency of latent heat to convert it into steam; whilst the steam inside the coils is being continuously converted into water, and more steam of same pressure (and, therefore, temperature) is being supplied inside the coils to meet the requirement outside the coils.

Uniformity of Surface.

65. The evaporator surfaces should be the same in all the evaporators, to allow for the proportionate falling off of power as the pressure is gradually lowered at each successive distillation. This is required by the rule that as the steam pressure (and, therefore, heat) inside the coil is lowered, or counteracted by a pressure (and, therefore, heat) outside the coil, so must the coil surface be proportionately increased, to do the same amount of work (see pp. 46, 47).

Extent of Surface.

66. The exact amount of surface depends, as we have seen, upon the quantity of water to be evaporated in a given time, and the temperature and quantity of feed-water that is presented to be heated up to boiling point, also the pressure of steam inside of the coil.

2. Safety Valve.

67. As all the evaporators (except the final one, which discharges its steam into the distilling condenser, or rather, as will be seen, into the heaters) have to work at a pressure, more or less high, they should each have a

suitable *safety valve* on the cover, loaded to the maximum pressure attainable in the casing.

3. Pressure Gauge.

68. It is also convenient to have a *steam gauge* on the first evaporator, showing the pressure inside the coils, and a suitable pressure gauge on the final evaporator steam-room, for indicating the pressure of the final steam before it is discharged. If the final evaporator is working at a pressure below the atmosphere, a vacuum gauge should be fitted.

4. Starting Valve.

69. A *starting valve* should be fitted for the primary steam, as it enters the first evaporator coils, but as the gained steam, afterwards generated, works directly from evaporator to evaporator, there is no need for any steam valve for the entry of the steam to each of the other evaporators. The steam (*i.e.*, the gained steam) generated outside the coils of each evaporator may be connected direct to the steam inlet to coils of the following evaporator, as the gained steam of the first evaporator becomes the primary steam of the second evaporator, and the gained steam of the second evaporator becomes the primary steam of the third evaporator, and so on, till the final evaporator is reached, which works at atmospheric pressure, or to as much below it as it is thought expedient to carry the successive distillations.

5. Water Gauge. 6. Blow-off.

70. Each evaporator should also be fitted with a *water gauge*, to indicate the brine level in the evaporator. The brine of each pressure evaporator may be blown from the

evaporator casing into one common pipe, and led into the discharged circulation water. The brine discharge from each evaporator should be controlled by a suitable valve or cock with an index to work to, and as the pressure can be made very steady, the brine cocks or valves are very soon set, and will require very little attention afterwards. A large brine valve is also fitted for emptying out the brine quickly when desired.

7. Coil Drain.

71. The waters discharged from the coil drain of each evaporator are collected in one common pipe leading to the heater, and are utilised in heating the feed-water, as will be explained later on when dealing with the heaters (p. 206). No cock or valve is needed for the coil drain in multiple distillation.

8. Evaporator Casings.

72. As the evaporators in multiple distillation have to work at a pressure more or less great, the casings should be made strong enough to stand a test pressure of at least double the working pressure. Gun-metal casings are the best for wear, and for standing the pressure required. The final evaporator, working at atmospheric pressure or thereabouts, may be made of cast iron, but it should be proved to about 20 to 30 lbs. pressure.

(c) THE DISTILLING CONDENSER.

73. What has been already said about the distiller in Chap. vii. regarding an ordinary double distiller condenser on a steam ship applies to the distiller of a multiple distilling apparatus, subject to the following important observations.

Surfaces—Condensing and Cooling.

(1) Cooling Surface.

74. For producing *cold* drinking water, it will be remembered, there were two sets or sheaves of surfaces, one above the other (see Fig. 18, p. 138), and that in double distilling apparatus the *lower* tube surface—that is, the set of tubes used for cooling the distilled water—varied according to the quantity of water to be cooled. Thus, if the secondary water only, just produced in the upper set of tubes, has to be cooled, the cooling surface has to be calculated for the quantity of such secondary water only, but if the *primary* water from evaporator coil drain is mixed with the secondary water, the surfacing of the cooling tubes must be sufficient to deal with both waters.

Such cooling surface will obviously have to be increased in the same proportion as the economy of the *primary* water is to that of the *secondary* water. So that, if x square feet of cooling surface is sufficient for the secondary water only, this x surface will have to be $x + (x \times 1{\cdot}2) = 2{\cdot}2x$, total, if the economy is 1·2. If the economy is 1·25, then the surface of the cooling tubes will have to be $x + (x \times 1{\cdot}25) = 2{\cdot}25x$, total.

75. This rule has to be given effect to in all types of multiple distillation, as the cooling surface must be equal to deal with the total production of all the water. The cooling surface is, therefore, *increased* at each successive distillation.

(2) Condensing Surface.

76. The above rule, however, applies to the distiller *cooling* surface only, for it is observable that only the water *increases* at each successive distillation—*i.e.*, with

regard to cooling requirements. The steam at each distillation is condensed inside the evaporator coils, so that the only condensing duty that has to be done by the distiller is to deal with the steam that is generated by the *final* evaporator, and this, as we have seen, gets less and less as each evaporator is added.

77. We, therefore, have a rule, as follows, viz. :—That at each successive distillation the distiller *condensing* surface *decreases*, whilst the distiller *cooling* surface *increases*, and that they respectively *de*crease and *in*crease in the same proportion.

78. The distilling condenser surfaces for *condensing* and *cooling* would, therefore, respectively *de*crease and *in*crease, as in Table O below—*i.e.*, assuming an increase of 80 per cent. of gained water at each successive distillation.

TABLE O.

Type of Distillation.	Distilling Condenser.	
	Cooling Surface.	*Condensing* Surface.
Single Distillation, ...	x sq. ft.	y sq. ft.
Double ,, ...	1·8 x	0·8 y
Treble ,, ...	2·44 x	0·64 y
Quadruple ,, ...	2·95 x	0·512 y
Quintuple ,, ...	3·36 x	0·409 y
Sextuple ,, ...	3·69 x	0·327 y

79. The above surfaces are given for theoretical requirements, but it is always wise not to cut down surfaces too close. Experience from what takes place with different types and makes of machinery can alone be a guide as to the margin that is advisable to allow. The condensing surface will be assisted by the action of the

heaters, which it will be convenient to deal with next, before dealing with the filter, the feed regulator, and the pump.

(*d*) FEED HEATERS.

80. In multiple distillation apparatus on land (where there is plenty of space available, including head-room over the apparatus), it is convenient to place the feed-water heaters over the centre line of the apparatus. There are, of course, various ways of placing the heaters. A convenient method of fitting them is as follows :—

The *first* heater (nearest to the boiler) is the boiler feed heater. In close succession usually follow—the second heater, which heats the feed-water for the first evaporator, the third heater, which heats the feed to the second evaporator, and so on, for as many evaporators as are linked together. The arrangement of feed-water heaters for a treble distilling apparatus is shown in Fig. 22.

81. These heaters are connected together at top and at bottom by common pipes. The top pipe (A) is for steam and the bottom pipe (B) for the water resulting from the condensation of the steam. The feed-water is pumped into each heater casing at the lower part, at (F), (F), (F), in each of the three heaters. After circulating between the tubes within each heater, the feed-water passes out from the first heater to the boiler, from the second heater to the first evaporator, and from the third heater to the second evaporator.

82. The temperature of these three feed-waters is raised by the heat derived from three sources, (1) the exhaust steam from the pump, which can impart its *latent* heat ; (2) the vapour or steam from the final evaporator, in which the *latent* heat of the steam is also used ; and (3)

the hot water collected from the coil drains, where the latent heat of the steam has already been abstracted by the evaporator tubes, but which has still left the *sensible* heat that the steam had. These are led into the top pipe (A) over the heaters. The first two, (1) and (2), being steam, give out their latent heat to the feed-water as such

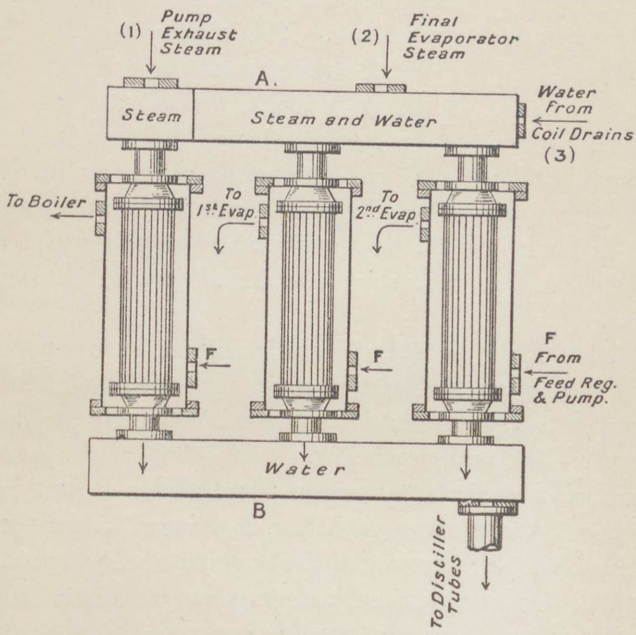


Fig. 22.

steam passes down into the tubes of the heater, and the waters of (3), together with any steam that may have escaped through the coil drain, and all three, (1), (2), and (3), after thus imparting their heat to the feed-water surrounding the tubes, are collected in the lower pipe (B), and then gravitate into the distiller tubes.

83. It will be observed that in this arrangement the exhaust steam from the pump is made to go into the boiler feed heater. This is done with a view to use the higher pressure and, consequently, hotter steam available for feeding water into the boiler at the highest temperature possible. Steam from (2) being at a lower pressure, and consequently lower temperature, does well enough to heat the feed to the evaporators. The upper pipe (A) is best partitioned off, so that the pressure of the exhaust steam can be kept up, whilst it is inside the tubes of the first heater. When the two steams, (1) and (2), have imparted their latent heat, and are converted into water, then all the waters (or condensed steams) go into the bottom pipe (B), and run into the condenser tubes, together with any steam that has not been condensed inside the heater tubes.

84. It will be seen that by utilising the exhaust steam from the pump, the heat of the steam used to drive the pump is to a great extent retrieved. The steam to the pump is high-pressure boiler steam—that is, the hottest steam of the whole apparatus—and to waste or misuse such heat would make, as before-mentioned, a very great difference in the economy of the working of the apparatus.

85. If the pump exhaust steam were led direct to the distiller tubes, some heat would be saved, but the saving would be less, as this mode of using the exhaust steam would, in fact, be single distillation only (with its lowest grade of economy), whereas by using the exhaust steam for heating the boiler feed, the heat of such steam is transferred to the boiler, and is thus indirectly given a multiple effect instead of only a single effect.

86. The pump exhaust may, however, be otherwise used to good purpose, thus (1) instead of this exhaust steam

being used to heat the boiler feed, it may be sent into the coils of the first evaporator, giving it a direct multiple effect. If this arrangement is made, a reducing valve must be placed on the boiler primary steam to the first evaporator, or the back pressure on the pump exhaust will stop the pump. Or, (2) this exhaust steam after passing into the tubes of the first heater may be made to continue on into the evaporator coils of the first evaporator, the water formed by condensation in the heater tubes going along with it. This has the advantage of profitably using any uncondensed exhaust steam that has passed through the tubes of the first heater unused—*i.e.*, unconverted into water—and, therefore, still having some latent heat to dispose of. (3) Or the pump exhaust may be led direct into the coils of the *second* evaporator, along with the secondary steam from the first evaporator. This has its merits, but it also has a rather disturbing effect on the ratios of pressure and production in the various stages of distillation. It, however, gives to the pump exhaust multiple effect, but its effect is one grade lower than that of the boiler steam.

Note.—Perhaps the most convenient way (although not quite so economical) is for the pump exhaust to heat the boiler feed, as first suggested.

Construction of Heater.

87. The construction of a heater has already been explained in pp. 115-122, and the construction of the heaters for multiple distilling apparatus is substantially the same, but it must be borne in mind that the feed-waters respectively passing through their heater shells are at a higher pressure than in the case of double distiller on a steam ship, where the feed-water may enter the evaporator

casing at practically no pressure at all. The heater shells and interior tube surfaces should be proved to not less than double the maximum working pressure, whatever that may be in each heater.

Surface of Heater.

88. The amount of surface for the heaters is calculated somewhat in the same manner as that already shown for calculating the amount of surface for evaporator and distiller coils or tubes. The amount of heat available in units per lb. weight of steam and water passing through the tubes is first ascertained, and then the weight of feed-water (in lbs.) that requires to be heated; the ratio of the one to the other will enable an estimate to be made of the temperature that each lb. of feed-water will be raised to by its being placed so as to absorb the heat passing through the tubes. The extent of the surface is then estimated on that basis, according to such rules as may have been arrived at by experience with the type of heater used.

Materials used for Heaters.

89. The actual surfaces of the heaters are conveniently made of solid-drawn copper tubes. It is well to have the tubes spaced not too close together, as the operation of cleaning has to be considered. The interior of the tubes should be proved to double the maximum working pressure.

90. The tubes are best expanded into gun-metal tube plates, much in the same way as the tubes are fixed in a distilling condenser.

91. The casing or shell of the heater is made of gun-metal, or copper, or steel, as may be desired. The covers

can be made of cast iron, or they can be made much in the same way as the distiller covers are made—*i.e.*, of a thin sheet of copper gripped between the flange of the casing and a ring outside (see Fig. 13, p. 116, and Fig. 14, p. 118).

(*e*) THE FEED REGULATOR.

92. The operation of the feed regulator for regulating the feed of the evaporator in a *double distilling apparatus* has already been explained in p. 113. In that case the only feed-water regulated was that of the evaporator. By the automatic action of balance floats, the evaporator feed-water was regulated so as to be constantly kept in due proportion to the production of the gained distilled water, thus causing the brine of the evaporator to be kept at a uniform salinity, whatever may be the rate of production of the distilled water.

93. The feed regulator suitable for multiple distillation is merely an extension of this principle. Thus, in multiple distillation, not one, but two or more evaporators have to be fed in due proportion to their respective evaporations; and the boiler also can be fed in this manner with sea water without any trouble, so as to keep the brine salinity invariable.

94. In the double distiller feed regulator (see Fig. 12, p. 113) the balance floats regulate the feed for one evaporator only. Fig. 23 shows that the sea water entering at (SW) into the compartment may be controlled by the float (S), so as to be equal to the total feed-water of the boiler and all the evaporators collectively. When this has been regulated by the action of the two floats (S) and (F), the sea water, from the box with (S) float, can be run out into channel (C), and from this channel it may

be correctly distributed to the boxes for (B)—*i.e.*, boiler feed; (1E)—*i.e.*, for the first evaporator feed; and (2E) —*i.e.*, for the second evaporator feed—and so on with as many extra boxes as there are evaporators to feed. The escape from these boxes is shown by the outlet arrows.

It is convenient to have a gauge glass on each box (F) and (S) to show that the head of water is about the same in each box.

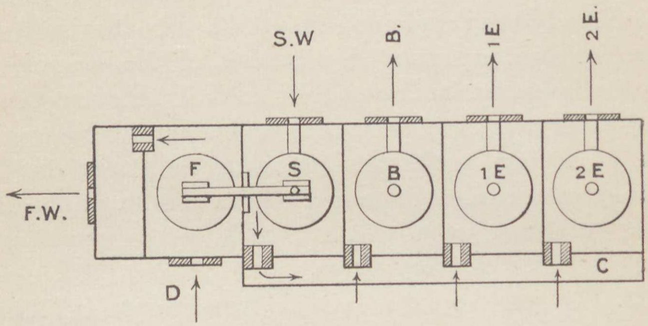


Fig. 23.

95. Pump suctions may be connected to these outlets, so that the severally regulated feed-waters may be pumped to where required. The distilled water, after having done its duty by regulating the total feed-water in due proportion to the distilled water produced, escapes, as shown by outlet arrow (F.W.), to where desired, generally to a tank, or, if desired, a pump suction pipe may be connected to this branch for delivery at a distance or a height above the apparatus.

The fresh water enters (F) box at (D) as indicated by the arrow. It is usually supplied from filter outlet.

96. Other types of feed-water regulators can, of course, be devised, but the chief objects should be to have the

several feeds automatically regulated, and the brine densities in the boiler and each evaporator thus kept uniform.

97. It is important that the pump, whilst drawing away the various feed-waters from these various compartments, should avoid drawing air, for any air drawn through the feed pump would find its way into the boiler, or the coils of the evaporators, and cause the apparatus to work less easily than if nothing but water were fed in. This may be guarded against by having floats in each of these compartments, so fitted as to close the pump suctions by their sinking action when the water gets below the level of the suction pipe end.

(*f*) THE PUMP.

Its Functions.

98. The pump usually supplied with the apparatus has three distinct functions :—

First.—It circulates the sea water through the distilling condenser.

Secondly.—It supplies the feed-water to the various parts of the apparatus that generate steam—that is to say, to the boiler and each evaporator, all of which have separate pumps, but the whole is combined in one machine, as a rule.

Thirdly.—It pumps away the fresh water that is produced.

1. Circulation Pump.

99. As to the *circulation* pump, what has been said at p. 153, when dealing with the distilling condenser as to the quantity of circulation water required must be considered in calculating the size of this pump to meet those

requirements, and the same may be said with regard to the capacity of the other pumps—*i.e.*, for the fresh water and the feed-pumps. It is always well to have plenty of margin as to capacity, so as not to necessitate driving the pump at an excessive speed.

The steam cylinder of the pump should be made amply large so that the net working pressure may be kept low.

Its Lubrication.

100. As the exhaust steam from the pump is utilised by being re-converted into water, and its latent heat not wasted, the water thus produced, and included in the general output of drinking water, should not be greasy or oily. It is well, therefore, to avoid greasy lubrication as far as possible. There is a natural desire of all engineers in charge of machinery to oil the steam cylinder and the plungers, in fact, all parts where there is any friction. Now, to put oil or grease inside the steam cylinders would at once manifest itself in the exhaust steam, and then in the water condensed from it. If a steam pump is well made, the cylinder may be so constructed that oil and grease are unnecessary, and, by leaving the cylinder unlagged, the slight condensation of the steam inside the cylinder acts as a lubricant. Pumps made on this system have been known to work well for many years. The piston-rod may be lubricated with oil, as the small quantity of oil getting into the cylinder is not sufficient to taint the exhaust steam, but the plungers should not be oiled ; a well constructed and suitable pump has water channels round the plungers for water to replace oil as a lubricant.

Economy Effected by using Pump Exhaust.

101. The pump is driven by the high-pressure steam coming direct from the boiler, therefore, the most economical and convenient manner of saving or retrieving the heat that is used is to let the exhaust steam impart its latent heat, either inside the first evaporator coils, or to the boiler feed-water (which requires to be made as hot as possible), and to let the water or the condensed exhaust steam go into the distilling condenser to be cooled along with the rest of the drinking water produced. The arrangement has already been explained, and need not be repeated here.

102. If the pump exhaust steam, instead of heating the boiler feed-water, is conducted back into the steam pipe leading the primary steam to the first evaporator, a non-return steam valve should be placed on the main or primary steam pipe to the apparatus, at a convenient place between the point where the live steam branches off to the pump and the point where the pump exhaust pipe rejoins the main steam pipe. By this means the non-return valve can be adjusted so as to reduce the pressure of the primary steam to the first evaporator sufficiently, so as not to overpower the exhaust steam or cause too great a back pressure upon the pump. This, however, involves the pressure in the boiler being kept somewhat higher than is necessary, in order to have a sufficient excess of pressure for driving the pump.

2. Feed-Water Pump.

103. The pumps, when drawing the regulated feed-water from the various compartments of the feed regulator, are prevented from sucking in air, by the arrangement of

floats in the feed regulator, which automatically close or control the pump suction when the level gets to a point that would allow air to be drawn in with the water, which would interfere with working of the apparatus.

104. The feed pumps, after drawing the feeds from their respective compartments of the feed regulator, pumps them through their respective feed-water heaters, and then to their ultimate destination.

3. Fresh-Water Pump.

105. The fresh-water pump is usually made suitable for pumping the fresh water produced to the height or distance desired.

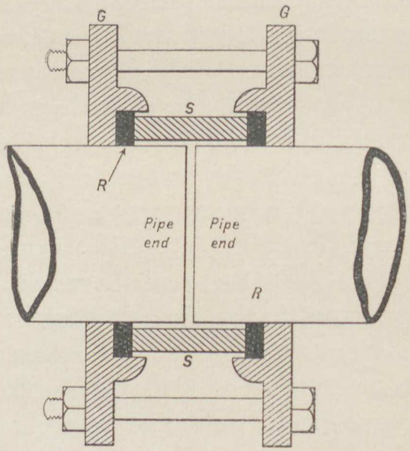


Fig. 24.—Dr. Normandy's Joint.

Circulation Pump—Strainers.

106. The delivery of the circulation water is at the bottom of the distilling condenser direct; the suction end is usually protected by a cage or strainer, so as to prevent foreign substances being drawn into the pump

and condenser casing, as such substances might find their way into the feed regulator, and interfere with its proper action.

Suction Pipe.

107. The suction pipe for the circulation pump, in a large apparatus, is of large bore, and very often is of considerable length, with many joints in it. It is important that such pipe should be sound, and not liable to leakage, as air drawn in at a faulty joint will cause an insufficient supply of circulation water, and the whole apparatus may be disorganised until the leaking joint has been discovered and made good.

108. A joint which has been found good after many years of use is shown in Fig. 24. It has the advantage of being non-rigid. GG are glands, S is a sleeve, RR rubber rings, all encircling pipe ends.

(*g*) THE FILTER.

109. The effect and construction of the filter have already been explained (p. 150). It should be placed between the distilling condenser and feed regulator, to deal with the distilled water as it passes from the former to the latter.

(*h*) SPARE GEAR.

110. The spare gear usually includes—a set of fire-bars for the boiler, a set of heating surfaces (interchangeable) for each evaporator, the same for each heater, and a complete sheaf of condensing and cooling surfaces for the distilling condenser. Also spanners, &c.

(*i*) CONNECTIONS.

111. The apparatus and boiler should include all fittings and connections between all the parts. It is also useful to

include a reasonable run of pipe for suction to the pump, and for the delivery of fresh water from the apparatus.

(j) INSTRUCTIONS FOR WORKING THE APPARATUS.

112. The following general rules for working a *treble* distilling apparatus are stated shortly, but this is always given in very much fuller detail by the makers when they supply their own class or type of apparatus.

(1) First of all, the boiler should be filled with sea water, the fire lighted, and steam got up just enough for working the pump.

(2) The pump should then be started, and as soon as the circulation water passes through the condenser, the evaporators should be filled with sea water by means of the filling pipe, and as soon as a proper level has been obtained in the evaporators, the quick means of charging the evaporators with sea water should cease, and the feeding be left to the feed regulator to deal with.

(3) The boiler steam may now be admitted to the first evaporator coils, and, if necessary, the steam valve and starting valve for the pump adjusted with each other, so that the pump goes at its proper speed.

(4) In a short time the sea water in the first evaporator will boil, and the steam generated therefrom will then pass into the coils of the second evaporator, and also generate steam therefrom, which will pass up into the heater tubes, and thus be utilised in heating the various feed-waters on their way to their respective destinations.

(5) The apparatus being in full work, it is necessary to see that the boiler pressure is not too high, as only sufficient pressure is needed to obtain the production specified, with the boiler steam valve full open.

(6) It will probably take about half-an-hour for an

apparatus to settle down properly to work, and all parts to be heated properly. As soon as this happens, the trial may be commenced against weighed coals, or such other fuel as is specified.

(7) In recording the production, it may here again be repeated that the production of the apparatus in point of time is a totally different thing from the production as regards consumption of fuel. An apparatus may be capable of producing quantities having a very wide range in point of time, and yet all may practically be equally economical. On the other hand, several types of apparatus may all be capable of practically the same output of water, in point of time, yet be immensely different in their rate of economy.

113. Fig. 25 shows the important parts of a *treble* distillation apparatus. The boiler, the pump, the automatic feed regulator, and the filter are shown elsewhere.

The following parts (some at the back of the apparatus not visible) may be indicated as follows :—

A, Steam pipe from the boiler.

B, Steam pipe leading to the pump.

C, Steam valve for letting the primary steam into the first evaporator.

D, Secondary steam from first evaporator shell to second evaporator coils.

E, Feed pipe from heater to first evaporator.

F, Tertiary steam from second evaporator shell to all three feed-water heaters.

G, Feed-water pipe from heater to second evaporator.

H, Tertiary steam (uncondensed by heaters) and the condensed steam from coil drains to distiller.

J, Circulation inlet to distiller.
K, Feed-water pipe from heater to boiler.
L, Circulation outlet. Feed branch is at back.
M, Pressure gauge, for inside coil pressure.
N, Pressure gauge, for inside steam room pressure.
O, Water pressure gauge, final steam room.

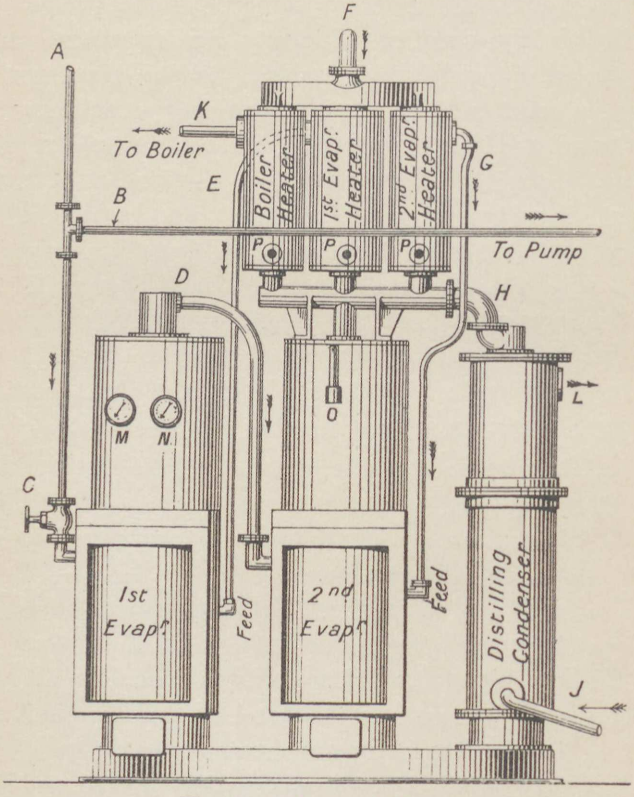


Fig. 25.—"Normandy" type.

The brines from first and second evaporators escape from the base, and are conducted into the circulation discharge from the top of the distilling condenser.

TRIAL FORM—SUITABLE FOR A TREBLE DISTILLING APPARATUS.

(If Quadruple Distillation, Columns for a third Evaporator, following the second Evaporator, are required).

OFFICIAL TRIAL

OF DISTILLING APPARATUS No......................

MAKER'S NAME,...

Time.		Pressures.			Temperature (Degrees Fah.).				Levels (Inches).							Coals.		
Date of Trial.	Time of Trial.	Boiler (lbs.).	1st Evaporator (in Shell, lbs.)	2nd Evaporator (in Shell, inches).	Circulation (Outlet).	Circulation (Inlet).	Fresh Water	Rise of Temperature. Cols. 7 and 8.	Boiler.	1st Evaporator.	2nd Evaporator.	Feed Reg. (Fresh Water).	Feed Reg. (Salt Water).	Pump Revs. per Min.	Drinking Water (Gallons).	Consumed (lbs.).	Time at which each lot is fed in, see Rule (4).	REMARKS. 1. Economy. 2. Nit. Silver Test. 3. Steadiness of Working. 4. Generally.
	Say A.M.																	1..................
	10.0																	2. ....
	10.15																	3..................
	10.30																	4..................
	&c.																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

The fresh water produced rises from a pipe at the base of the distilling condenser, and is conducted into the filter in very much the same way as indicated in (N) in Fig. 20.

The pressure gauges on first and second evaporators are the same as (A) and (B) in Fig. 20, whilst the first evaporator has two gauges, one for the coil pressure and the other for the pressure in the casing.

Note.—By using Col. 2 as suggested, a record of every 15 minutes is obtained, thus testing the steady working of the apparatus.

Form of Trial Sheet.

114. The foregoing form for recording the results of the trial of multiple distilling machinery will indicate the various points of importance. The following rules must be observed, otherwise the trial is more or less valueless.

RULES (for Trial Workings).

(1) All measuring appliances, such as tanks, steam gauges, thermometers, salinometers, &c., should be accurate, and of approved make.

(2) The record of the trial should commence from the time when the apparatus is in full operation. In a specially strict trial, the fires should then be drawn and re-lighted with weighed fuel (coal, &c., including the firewood, also cinders drawn out). This involves hardly a momentary fall in the production, but it is necessary, to avoid dispute as to the condition of the fire when finishing, as compared with what it was when starting the trial.

(3) When concluding the trial, the following state of things should be the same as when the trial commenced

—viz., the boiler pressure, the water level in boiler and in each evaporator, and the speed of the pump should all be as at starting—otherwise the trial will not be of much value. This applies most to the boiler pressure being the same (certainly not lower) when the trial ends, for if the boiler pressure is less at finish than at start, an obvious advantage is given to the apparatus, which it cannot maintain in general working. In a short trial, the temporary advantage cannot be spread over a sufficient length of time to minimise it.

Note.—The advantage gained by thus working the boiler is the uncounted supply (*before* commencing the trial) of the amount of coal used for getting up steam, from the low pressure recorded at finish to the higher pressure at which the trial commenced. This spread over a *short* trial would be of considerable value, and the shorter the trial, the more pronounced would be the saving ; therefore, an economy based on such a record would be somewhat misleading, as a quantity of coal is used to advantage without being counted.

(4) As it is very easy to get into a state of confusion as to the quantity of coal actually consumed, a good way of recording the same is to have several lots of coal (if coal is the fuel used) weighed out in separate lots of, say, 100 or 200 lbs. each, and to keep a double record (1) of the quantity taken from each lot, and (2) the quantity when the last shovelful of coal is put into the boiler furnace.

(5) At the conclusion of the trial the total weight of *water* delivered should be taken as against the weight of the *coal* consumed, and the latter should include the

weight of cinders again withdrawn from the furnace; and the weight of ashes collected during the continuance of the trial *deducted*. If the ash weighs about 4 per cent. of the coal used, it shows the quality of the coal is good; but if, say, 10 per cent. of ash exists, it shows the quality of the coal is not very good. See Chapter v. on fuels on this point, also with regard to the various descriptions of coal that may be used.

(6) The apparatus should work with steady regularity during the trial, and yield a fairly steady output of water with a steady consumption of fuel every hour, and the boiler pressure should be steady (not decreasing). If the output is irregular, it is a sign that the apparatus or the trial is not satisfactory, and is not likely to give satisfaction in after use.

Conclusion.—Although the principles of distillation will ever remain unchanged, the details may require amplification and revision, as time goes on and the necessity of pure water becomes more and more an essential to meet requirements both for drinking purposes and for industries generally. The author would, therefore, welcome criticism and suggestions made, but hopes he may be excused if he is unable at all times to enter into correspondence on the subject.

APPENDICES.

(Appendix to page 66.)

The Chapter on "Fuels" mentions a few combustibles that suggest themselves for use with sea water distilling machinery. The heating powers attributed to them are to some extent approximate, yet quite near enough a guide to compare their heating capacities when working this class of machinery. If greater accuracy is desired, reference should be made to the *Treatise on Heat*, by Mr. T. Box, in whose book will also be found fuller information on fuels and on heat generally.

(Appendix to page 96.)

With regard to Table L—Péclet, in his *Traite de la Chaleur*, gives the rule that when a substance with parallel surfaces (*i.e.*, of uniform thickness) has a constant flow of heat passing through it, with a constant difference of temperature between the two surfaces, such flow is in inverse *ratio* to the distance the two surfaces are apart (*i.e.*, to its thickness). Péclet then gives the following formula :—

Let M = Amount of heat passed through in a specified time (*i.e.*, units of heat).

t = Temperature of one surface.

t' = Temperature of other surface.
e = Thickness, or distance apart, of surfaces.
C = Conductibility of the substance (*i.e.*, the value of M for $t - t'$).

Then—
$$M = \frac{C\,(t - t')}{e}.$$

In his treatise, Péclet says that Biot, in 1816, verified this formula by experiment, and that later (1836) Despretz made further experiments confirming Biot. Péclet, however, casts doubt on the foregoing experiments, saying they were obtained under circumstances rather too special to be practical; he, therefore, in 1841, made very exhaustive experiments dealing with substances (mostly bad conductors of heat), and the results (converted into English equivalents for convenience) will be found in "Box on Heat."

With respect to the passage of heat through metals, Péclet gives the following *ratio* as the results of the earlier experiments of Biot and Despretz, but, for practical purposes, it will be found safer to go by the Table given on p. 96.*

Gold (as standard),	1,000
Platinum,	981
Silver,	973
Copper,	898
Iron,	374
Zinc,	363
Tin,	303
Lead,	179

* Where silver is given as the standard.

(Appendix to page 113.)

The feed, evaporation, and brine all hang together very closely; the distilled water being evaporated from the feed and the brine being what is afterwards left. Both the distilled water and the brine, therefore, offer themselves as agents for regulating the feed as to its quantity. Fig. 12 shows how the output of *distilled water* may be applied to this use. It has the following points which make it preferable to using brine for this purpose, viz.:—It is cold, or cooler than the brine, and it is also fresh, and therefore free from a disposition to cause incrustation on the float and other parts with which it comes into contact. If it becomes difficult to pass the distilled water into the feed regulator the brine has to be used, and, if due provision is made for the heat and impurity of the brine, a regulator somewhat on the same lines as shown in Fig. 12 can be adapted to the use of brine instead of the distilled water.

When, however, the *brine* is to be used in the feed regulator, it must be kept in view that (with a constant feed) the discharge of *brine increases* as the output of *distilled water decreases*. Therefore, the function of the brine in the regulator would be to shorten the feed supply as the brine tends to be excessive. The *feed*, *evaporation*, and *brine* will then all three be constantly kept in due proportion to one another.

(Appendix to page 161.)

The "Normandy" Double Distiller, shown in Fig. 20 (p. 161), has its evaporator coils designed to meet all the requirements detailed on p. 89 (sec. 48), as far as possible. Fig. 16 on. p. 134 shows the evaporator with door off, and coils exposed to view.

(Appendix to page 172.)

Péclet, in his treatise on *Heat* (3rd ed., 1860), dates the introduction of multiple distillation in 1829. After saying that the heat obtained by a primary distillation can be used for producing successive distillations—*i.e.*, as the steam condenses it emits exactly the same amount of heat it absorbed for its formation—and that, consequently, if there was no loss of heat, multiple distillation might be carried on indefinitely. He then says the principles of multiple distillation were (as far as he knows) first applied in practice by M. Pecqueur in a patent granted to him in 1829, and further patents were taken out in 1834 and 1849. He also points out that, whilst multiple distillation is applicable to land apparatus, double distillation is most suitable for use on ships.

(Appendix to page 197.)

The table on the next page is another List of Boilers (Cornish and Lancashire) which will be found useful.

With regard to the size of the boiler, it is important that the *diameter* and *length* should be in due proportion to each other. If the length is too little, the heat (from the products of combustion), after passing through the boiler flues, would reach the chimney too soon, and waste of heat would consequently result ; whilst, if the length is too great, there is a loss of heat by radiation from the unnecessary length of the boiler shell. A well-proportioned boiler is, therefore, better arrived at by experience than by resorting to calculations based on theory. These remarks may be said to apply not only to the dimensions of the boiler itself, but also to its heating surface and grate area, and indeed the size of the chimney.

Size Dia. × Length.	Grate Area. Width × Length.	Grate Area. Sq. Ft.	Heating Surface. Sq. Ft.	Approximate Weight. Tons.
CORNISH.	(One Flue.)			(80 lbs. w.p.)
4′ 0″ × 9′ 0″	2′ 0″ × 3′ 6″	7·0	135	3.0
4′ 0″ × 12′ 0″	2′ 0″ × 4′ 0″	8·0	170	3·6
4′ 6″ × 12′ 0″	2′ 3″ × 4′ 0″	9·0	190	4·0
4′ 6″ × 15′ 0″	2′ 3″ × 4′ 6″	10·1	230	4·8
5′ 0″ × 12′ 0″	2′ 6″ × 4′ 0″	10·0	210	4·7
5′ 0″ × 15′ 0″	2′ 6″ × 4′ 6″	11·25	255	5·45
5′ 0″ × 18′ 0″	2′ 6″ × 5′ 0″	12·5	305	6·25
5′ 0″ × 21′ 0″	2′ 6″ × 5′ 6″	13·75	355	7·0
5′ 6″ × 18′ 0″	2′ 9″ × 5′ 0″	13·75	350	7·1
5′ 6″ × 21′ 0″	2′ 9″ × 5′ 6″	15·1	410	7·9
5′ 6″ × 24′ 0″	2′ 9″ × 6′ 0″	16·5	470	8·7
6′ 0″ × 18′ 0″	3′ 0″ × 5′ 0″	15·0	370	7·6
6′ 0″ × 21′ 0″	3′ 0″ × 5′ 6″	16·5	435	8·5
6′ 0″ × 24′ 0″	3′ 0″ × 6′ 0″	18·0	500	9·5
LANCASHIRE.	(Two Flues, each.)	(Both Furnaces.)	(Total.)	(100 lbs. w.p.)
6′ 6″ × 18′ 0″	2′ 6″ × 4′ 6″	22·5	420	11·5
6′ 6″ × 21′ 0″	2′ 6″ × 5′ 0″	25	493	12·6
6′ 6″ × 24′ 0″	2′ 6″ × 5′ 6″	27·5	564	13·8
6′ 6″ × 27′ 0″	2′ 6″ × 6′ 0″	30	633	15·0
7′ 0″ × 21′ 0″	2′ 9″ × 5′ 0″	27·5	541	13·6
7′ 0″ × 24′ 0″	2′ 9″ × 5′ 6″	30·2	620	15·1
7′ 0″ × 27′ 0″	2′ 9″ × 6′ 0″	33	595	16·6
7′ 0″ × 30′ 0″	2′ 9″ × 6′ 6″	35	775	18
7′ 6″ × 21′ 0″	3′ 0″ × 5′ 0″	30	585	15·6
7′ 6″ × 24′ 0″	3′ 0″ × 5′ 6″	33	673	17·2
7′ 6″ × 27′ 0″	3′ 0″ × 6′ 0″	36	752	19
7′ 6″ × 30′ 0″	3′ 0″ × 6′ 6″	39	839	20·5
8′ 0″ × 21′ 0″	3′ 3″ × 5′ 0″	32·5	626	17·4
8′ 0″ × 24′ 0″	3′ 3″ × 6′ 6″	35·7	719	19·2
8′ 0″ × 27′ 0″	3′ 3″ × 6′ 0″	39	805	21
8′ 0″ × 30′ 0″	3′ 3″ × 6′ 6″	43	900	23

The *width* of grate (*i.e.*, each furnace) may be taken as the diameter of each flue, whilst the *length* of grate is the length of the fire-bars.

The theory of combustion in a boiler is that about 50 per cent. of the total heat given out by the fuel is directly transferred to and absorbed by the boiler parts enveloping the burning mass, so that all this *radiant* heat is utilised. (Some experts say 70 per cent. of the heat is thus imported.) The remaining 50 per cent. of the heat given off is transferred to the air admitted to the furnace to support combustion. This latter heat, therefore, passes through the flues, and what is not absorbed passes away, and is lost up the chimney. Hence it is necessary for these flues to be long enough to abstract as much heat as possible before the chimney is reached, but not too long, as it entails extra length of boiler, and a corresponding loss of heat by radiation from its exterior surface. A correct balance between the two extremes is gained by experience only. A properly proportioned boiler is essential to an economical distilling apparatus.

If, therefore, coal is taken as capable of imparting, say, 13,000 B.T.U. per lb., 6,500 B.T.U. (*i.e.*, 50 per cent.) will be directly imparted as radiant heat, and none of this will be wasted; but the balance, 6,500 (*i.e.*, the remaining 50 per cent.), which has to travel along the flues, will have a large proportion of unused heat when he chimney is reached. Thus, if in practice, only 10,000 B.T.U. are used out of the 13,000 B.T.U., which is approximately the heat required to evaporate 10 lbs. of water (see p. 66), it would show that the remaining 3,000 B.T.U. (13,000 − 10,000 = 3,000) are lost by radiation or gone up the chimney; *i.e.*, instead of the balance 6,500 B.T.U. being also utilised, only 3,500 B.T.U. are used, the remaining 3,000 B.T.U. being wasted. Hence the necessity of a properly proportioned boiler to minimise the loss inevitably caused, either by heat uselessly going up the chimney or by radiation, by the boiler being too long to effectively retrieve any part of such loss.

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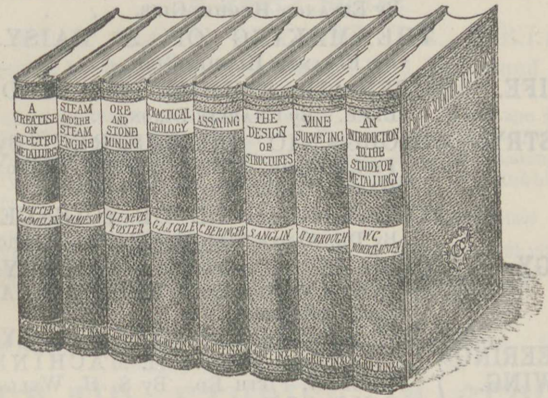

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