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The Modern Condenser, Main and Auxiliary, with all necessary Pumps and Appliances connected therewith.

BY "HELIX" (Mr. C. P. Tanner, Graduate).

THE modern condenser for sea-going purposes is now essentially a surface condenser. The two main objects of this condenser is firstly, to reduce the final back pressure, hence increasing the total power, and secondly, to return the condensed steam as feed-water to the boilers. The chief arrangements of an ordinary condenser for a sea-going cargo steamer are shown in Fig. I.

As with all parts of a marine engine, those of the Admiralty are superior, and more costly than those of the mercantile marine. For the purposes of the latter, the condenser shell is usually cast iron or mild steel. In the Admiralty, nearly the whole condenser is made of gunmetal, though this is not always essential for the best results. Fig. I. shows a cylindrical condenser. The shell is of mild steel, and at each end of this a flange is attached, and against these, gunmetal tube plates are jointed; while outside these the end-covers are fixed. The tube plates are usually about 1in. thick, and have an enormous number of holes bored in them, through which the tubes pass;

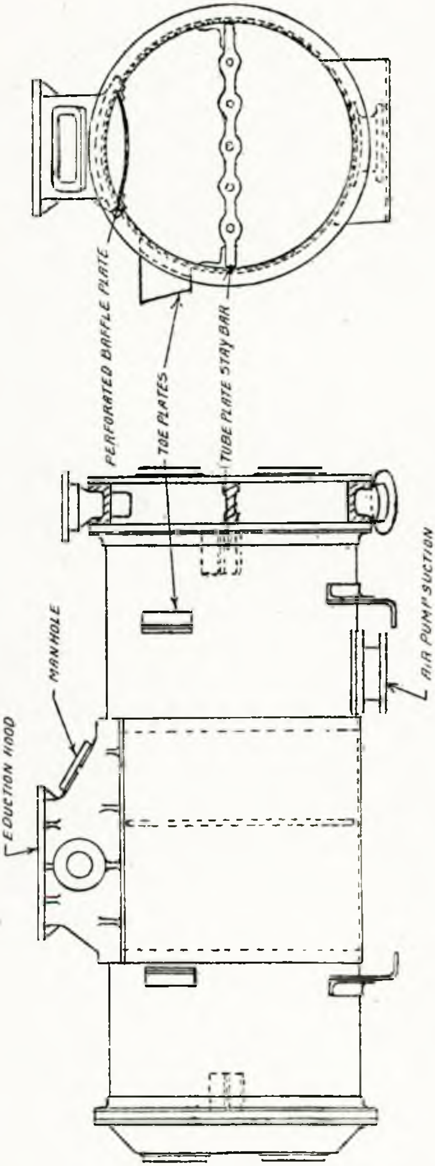

PERFORATED BAFFLE PLATE
TOE PLATES
TUBE PLATE STAY BAR
MANHOLE
EDUCTION HOOD
AIR PUMP SUCTION

Fig. 1.

in large condensers they number several thousands. The tubes are usually $\frac{3}{4}$in. external diameter, sometimes $\frac{5}{8}$in., and are made of gunmetal of special composition. Fig. II. shows a section of the jointing for the tube plate and end-covers. Fig. III. gives a section of part of a tube plate which explains itself.

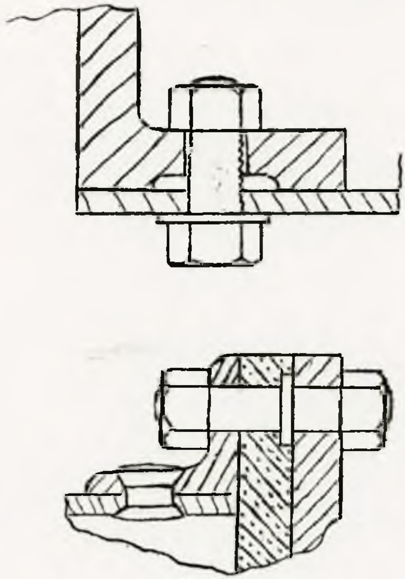


Fig. II.

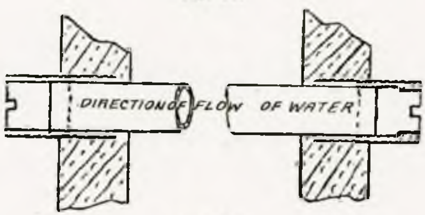


Fig. III.

The ferrule is of gunmetal, and the packing of cotton. An open ferrule is placed at the end where the water enters the tube, and a reduced one where it leaves. The tubes connect the end spaces, and by this means the circulating water passes from one space to the other. The exhaust steam is led from the L.P. cylinder by the main eduction pipe to the space in the condenser surrounding the tubes. Thus we get steam on the external and water on the internal sides of the tubes. In Fig. I.

the circulating water enters by main inlet, through the inlet valve, hence to the centrifugal pump. From here it is discharged to one end space, passing through the tubes to the other space, and returning again through the higher row of tubes.

A division plate is fitted horizontally at the water-end, and this prevents the water short circuiting. It has thus to follow the direction of the arrows, and finally is discharged overboard by the main outlet. The end-covers are shaped as shown, in order to deflect the water equally over the tube plate, so that each tube shall do an equal amount of cooling. Small hand holes are fitted to the end-covers for examination of, and repairs to the tube ends. The covers should have webs cast on them for strengthening purposes.

Protecting plates, now almost invariably made of mild steel are fitted on the water side of the condenser, in electrical contact with the tube plates, to prevent corrosion of the tubes and tube plates. A weed trap is fitted close to the inlet, and this prevents blocking up of the tubes, and can be cleared conveniently. A simpler method is to have a grating fitted over the inlet, only this cannot be cleaned at sea, except by reversal of the circulation. After leaving the cylinders the course of the steam is as follows: it first enters the condenser by the top. Nearly always the momentum of the steam is broken by a baffle plate; this is a perforated sheet of steel or cast iron, and is attached to the sides of the condenser. The steam, after passing round and through this plate, comes in contact with the tubes, is condensed to water, and falls to the bottom, whence it is drained to the air pump suction, and from there to the air pump. The usual fittings to a main condenser are as follows:—

On the top, usually in the saddle:

The main eduction pipe from the L.P. cylinder;

Exhausts from the reversing engine and main circulating engines;

Automatic separator drains, and supplementary drains, with drain from the L.P. cylinder;

Exhaust from main feed-pumps and the various pumps which are in use whilst the main engines are at work, including the dynamo engine exhaust.

At the bottom:

The air pump suction;

Connection with reserve tanks to make up feed-water loss, with various other fittings given later on.

The tube plates require staying against the external pressure, and this is effected by placing rods instead of tubes at suitable intervals, which take all the stress off the tubes. When the condenser is of any great length a support plate is fitted nearly midway between the tube plates. This plate is marked off from the tube plates, and holes are bored with a small clearance for the tubes. It is then set up in position by attaching it to the shell. The reason for fitting the stay plate off the centre is to prevent the vibrations of the tubes from synchronising on each side, and so increasing their intensity.

The chief of the improved condensers which have been brought out lately are the "Weir-Uniflux," the Morison, "Contraflo," and the Normand, Condenser.

The "Weir-Uniflux" is triangular or heart-shaped in cross-section, the chief feature being that there are no training or collecting plates. Practically no importance is attached to the deposit of water on the sides of the tubes, and the steam enters through an enormous eduction pipe taking up almost the complete top of the condenser. Fig. IV. shows a freehand sketch of

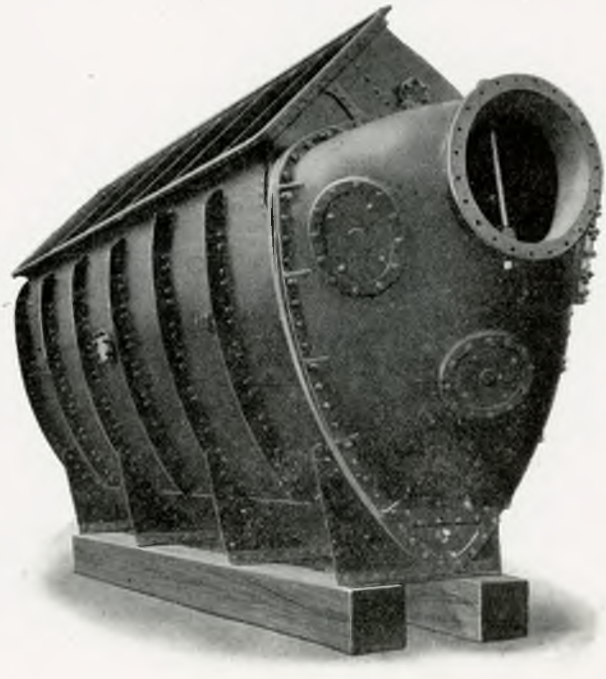


Fig. IV.

this type of condenser. When the steam enters this it is condensed by contact with the tubes, through which circulating water is flowing, and the water drops down to the side of the shell and drains to the bottom. As the steam descends more is condensed, and its volume is decreased, and the cross-section area of the condenser is diminished proportionally. Although there is a great advantage in having no guide-plates, the shape of the condenser is not economical for space, and the shell requires considerable staying to resist external pressure.

In contradistinction to the "Weir-Uniflux," the Morison condenser has several guide-plates. In Fig. V. a cross-sectional

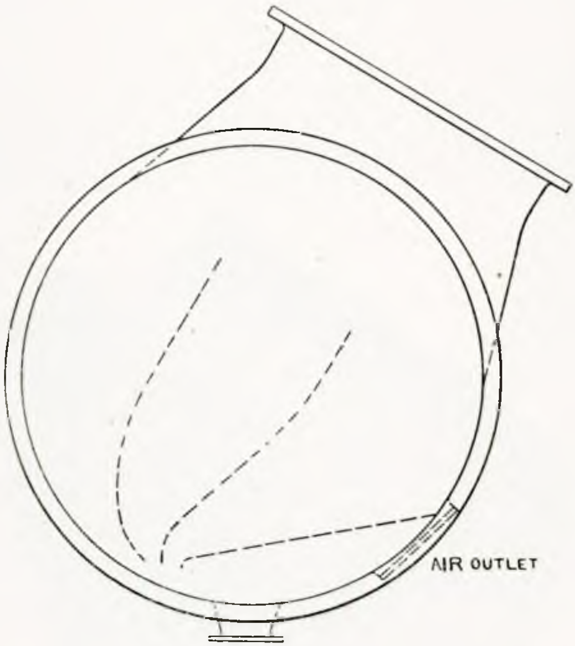


Fig. V.

view of the latter is shown, in which the three guide-plates may be seen. The chief object aimed at is that immediately steam is condensed to water it is collected and drained away to the air pump suction. In this way a high temperature is given to the feed. The shape is usually cylindrical and so needs little staying.

Fig. VI. shows a "Contraflo" condenser in part section, with a feed temperature regulating valve fitted. The shape is similar to the Uniflux, but there are several guide-plates. Most of the steam is condensed and drained on to the plates (A and B). From here the water drains down through (F) to the regulating valve, where it can either be sent direct to the air pump, or back to the condenser (at E). From (E) the water flows up through (G), and out to the air pump suction with the rest of the air and vapour.

The "Normand" Condenser is distinct from the rest in that there is no packing at the tube ends. The entire shell and tubes are curved to a certain radius, and the tubes are expanded into the tube plates. In this way expansion effects due to heat are taken up by the curvature, and there is no packing trouble or leaky glands; in fact it only leaks when the tubes have deteriorated. It can be re-tubed in about a quarter of the time, and the total cost is about half that of an ordinary one of the same capacity with cotton cord packing and glands.

The latest alterations in condensers are in those used in connection with turbines. Both in reciprocating engines and turbines, the final back pressure, and thus the vacuum gained, has an important effect on the efficiency obtained. With the reciprocating engine, however, when a fairly high vacuum, about 27 inches of mercury is obtained; any increase in this vacuum makes very little difference in the efficiency. In a turbine this is quite different, and thus the extra cost in obtaining a vacuum of 29 or 29·5 inches is more than compensated for by the extra increase in power. One difficulty in getting an effective vacuum is the resistance offered to the steam by its friction in going from the exhaust to the condenser. This is almost eliminated by making the eduction pipe extremely large in cross-section, and very short. The most important factor, though, is the air, which leaks through the joints and any little holes in the castings. It is also present in the feed-water, and is set free in the condenser and ruins the vacuum.

Therefore the whole efficiency of the condenser depends on that of the air pump. This pump should be as small as possible, so that little power only should be required to drive it. From this it may be seen that all possible means must be taken to ensure against leakage of air into the condenser, especially with turbines.

If the temperature and pressure of the steam at the condenser inlet be taken they will be found to correspond to those given in the steam tables. The pressure at the air pump suction is practically the same, but the temperature is considerably lower. Now the pressure at the air pump suction is due to the partial pressures of the air and steam present. Thus, if the temperatures of the steam at the inlet and suction be taken and the corresponding pressures determined, the difference gives that pressure due to the air. By having thermometers at the inlet and suction, an approximate gauge of the air present can be formed.

The presence of air also has the effect of "blanketing" the tubes, that is, it reduces the total conductivity of the tube. From these facts the extreme importance of the absence of air is seen, and such inventions as steam-packed glands, etc., have been made solely for this object. Since turbines have come in with their demand for high vacua in the condensers (about 29·5in.) many improvements have been made.

The chief of these are:

The wet and dry air pump;
The augmenter condenser;
The scoop system of circulation.

The wet and dry air pump was invented by Weir, and consists of two separate pumps, usually driven by the same engine. One of these pumps takes off the air and vapour, and the other takes the water and any remaining vapour. Fig. VIII. gives a diagrammatic sketch of a Weir's "Dual" Air Pump, with an injection water cooler.

The wet pump is always directly beneath the cylinder of the engine driving the pumps, as this has all the heavy work, and the dry air pump is worked from a pair of links in connection with the wet pump.

Only one connection is made to the condenser, but a branch pipe is let off to the dry air pump suction. The pipe line is so fitted that all the water goes to the wet pump. The pumps are usually fitted with the three-valve system, and each pump has a separate suction, the dry pump discharging through A to the wet pump below the head valves.

The dry pump has water for sealing the valves and making the working parts air-tight, and this is taken from the hot-well of the wet pump at B. When starting up B is opened and enough water admitted. After this the water goes through the injection water cooler and is pumped up to the dry air pump hot-well, when it is again returned to the cooler. The air and vapour are discharged through the spring-loaded valve C, which is set to maintain about 20 inches in the dry pump hot-well. The wet pump discharges the whole, the water going to the feed, and the air escaping.

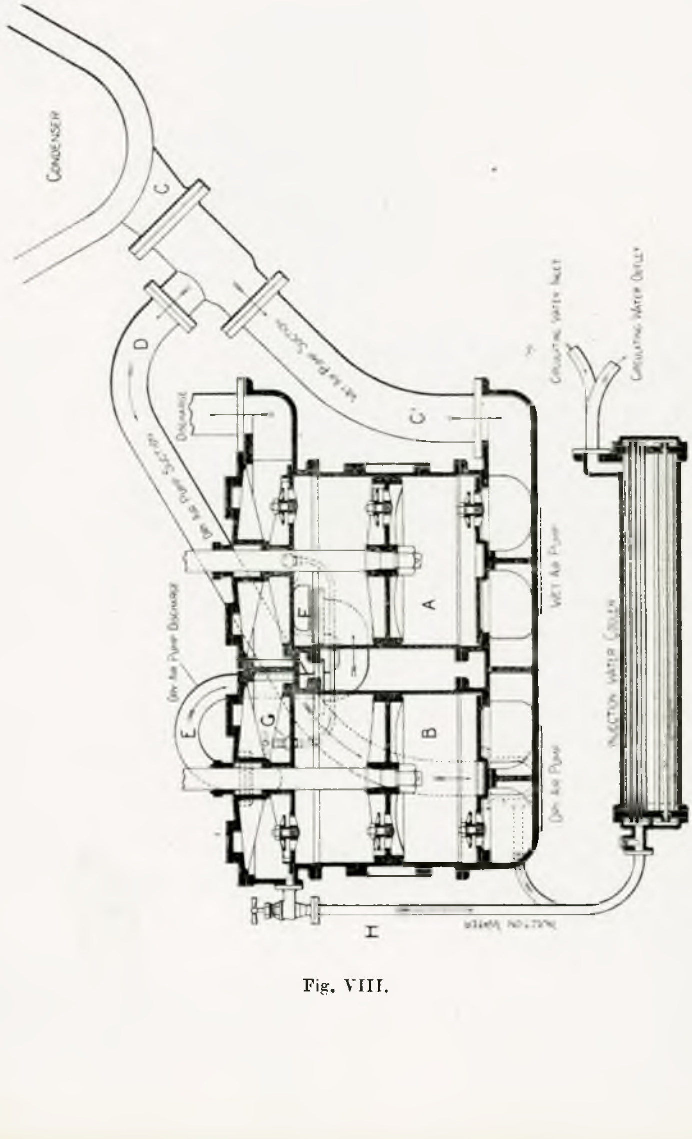
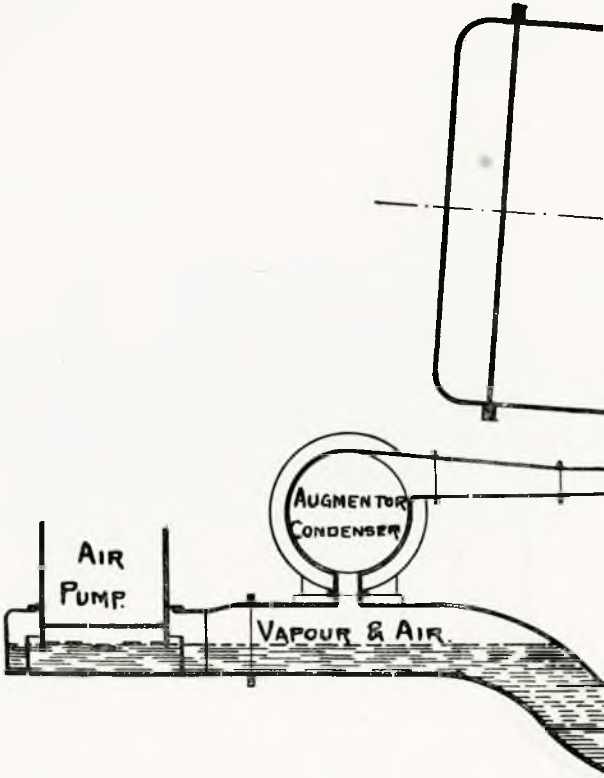


Fig. VIII.

Fig. IX. shows a "Vacuum Augmenter" fitted to a condenser. This has been invented by Sir C. A. Parsons, and is used in connection with his turbines. The main condenser is usually tilted as shown, and has two outlets fitted. One takes off the air and vapour and the other drains away the water. The condenser and air pump are so arranged that the air pump inlet is about four feet below the lowest part of the condenser, and therefore the pressure at the inlet is about two inches of mercury greater than that in the condenser. Now, with a vacuum of 28 ins. it can be seen that the pressure at the inlet will be double that in the condenser. Therefore any air will occupy half the volume and so an air pump will carry off twice as much air as it would under ordinary conditions. As the diagram shows, an outlet is made at A and this carries off the air and vapour by means of the steam jet and nozzle. The steam and air pass through an augmenter condenser and this lowers their temperature, and they pass down to the air pump suction and are drawn off there as usual.

The scoop system of circulation is perhaps, under some conditions, the most efficient, although under others it is very troublesome. Instead of the ordinary circulating inlet, a lip projects on the aft side of the hole, and the suction line from the inlet to the condenser is sloped inwards so that the motion of the ship forward induces a flow of water through the condenser in the opposite direction, without the aid of a circulating pump. When going astern the circulation is maintained by having the outward delivery sloped in the opposite way to the inlet, and then the circulation is reversed, and the outlet becomes the inlet. Small circulating pumps are used when warming the engine up, and when going at very slow speeds. Usually the pumps are made too small, and when the engines are being continually reversed the circulation is not good, and the vacuum decreases. With efficient pumps this method is extremely good, for as the speed of the ship increases and hence the amount of steam used, the quantity of water passing through the condenser increases in proportion. Contrary to most opinions, the lip has little retarding effect on the speed of the ship, and if the suction and delivery lines are well designed the lip can be made extremely small.


AUGMENTOR CONDENSER
AIR PUMP.
VAPOUR & AIR.

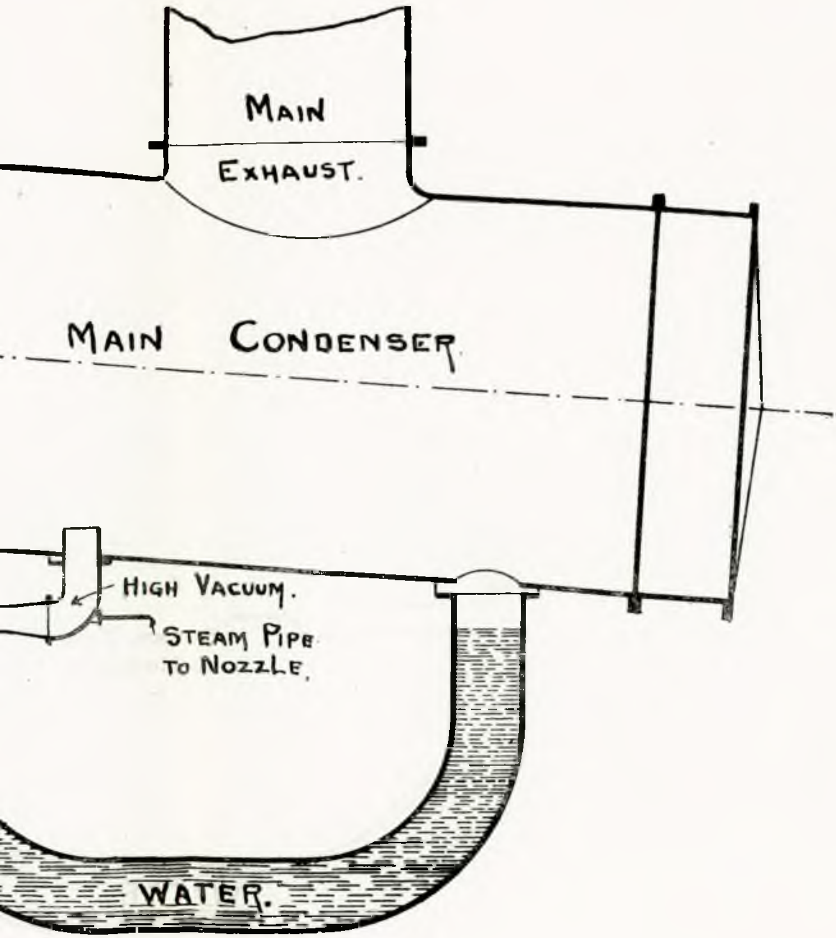

MAIN
EXHAUST.
MAIN CONDENSER
HIGH VACUUM.
STEAM PIPE
TO NOZZLE.
WATER.

Fig. IX.

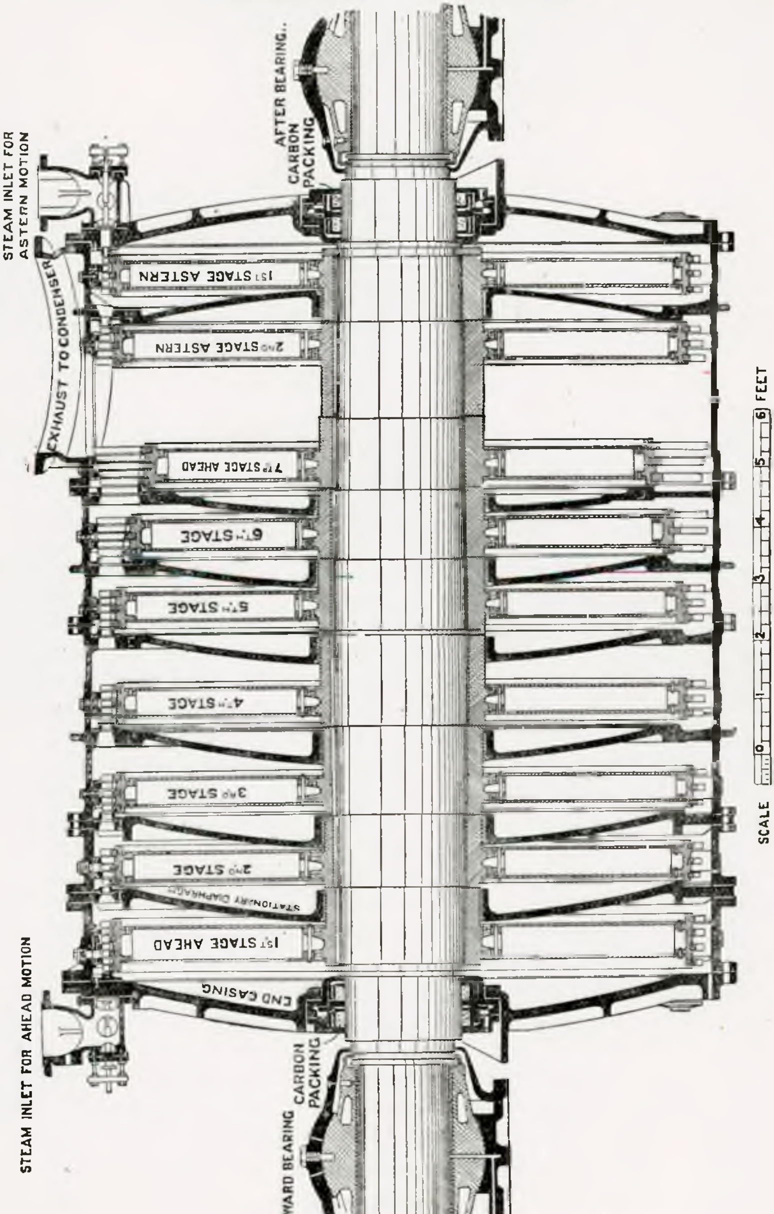
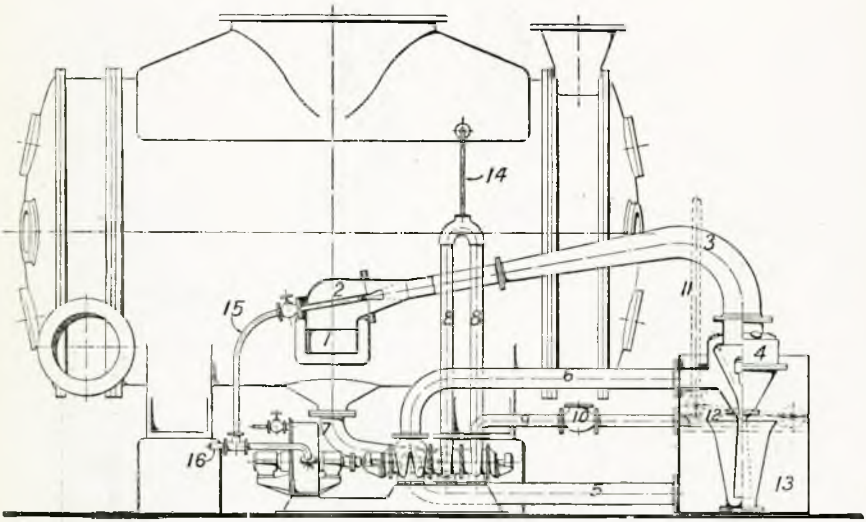

STEAM INLET FOR ASTERN MOTION
AFTER BEARING.
CARBON PACKING
EXHAUST TO CONDENSER
1ST STAGE ASTERN
2ND STAGE ASTERN
7TH STAGE AHEAD
6TH STAGE
5TH STAGE
4TH STAGE
3RD STAGE
2ND STAGE
STATIONARY DIAPHRAGM
1ST STAGE AHEAD
END CASING
STEAM INLET FOR AHEAD MOTION
CARBON PACKING
FORWARD BEARING
SCALE
0
1
2
3
4
5
6
FEET

Fig. IXa.



The Kinetic Air Pump is also another modern improvement. The principle is first to mix air and uncondensed vapour with steam, and then extract it by a high velocity water jet. The sketch, with its notes needs little explanation. The water used for the Kinetic water jet is condensed steam, and this, in condensing the jet steam, has its temperature raised before going to the feed tank. The water is withdrawn from the condenser by two pumps, known as the " head " pump and the pressure pump. The head pump is designed to work with an extremely small head on the suction side, and it discharges into a stand-pipe. The latter is connected to the suction of the " pressure " pump, and so this pump has a natural head and discharges against atmospheric pressure. By this method the pumps can be placed only a few inches below the condenser bottom, which is a great advantage in some ships.

Another pump is the Leblanc Air Pump, this however, like most other pumps of its kind is affected greatly by the temperature of the sealing water and various other conditions. The most common pump for ordinary work is Edwards' Pump, which is too well-known to need explanation. Many air pumps are now worked from independent turbine engines.

Some other fittings to the condenser are given below :—

A vacuum guage to show height of vacuum, usually combined pressure and vacuum guage.

A supplementary feed, which usually consists of a small copper pipe joining the water side of the condenser to the steam side, and can be used in emergency to make up feed losses by turning on a cock.

Thermometer sockets are fitted at various places, such as the inlet and suction on the steam side, as mentioned before, and also at the inlet and outlet of the circulating water.

The fittings on an auxiliary condenser are much the same. They consist of a combined pressure and vacuum guage; the auxiliary exhaust pipe; exhausts from the auxiliary air pump and one main circulating engine; pipe conveying the gained steam from the evaporator for feed-water make-up. This is usually fitted to the main condenser also—exhausts from steering and dynamo engines; the air pump suction; drains from the H.P. and M.P. cylinders and casings; drain from primary steam of the evaporator coils.

The circulating pumps are nearly always of the centrifugal types, and this is too well-known to need explanation. The general tendency is to have these pumps driven by independent engines, as with most of the other pumps, and these engines are usually small turbines, although the main engines may be of the reciprocating type.

We are indebted to the courtesy of the following firms for the loan of blocks to illustrate the figures and specialities referred to in the essay, and we have pleasure in giving this acknowledgment:—Messrs. G. and J. Weir, Richardsons, Westgarth & Co., Sir Chas. Parsons & Co.; the publishers, Messrs. McMillan & Co., Chas. Griffin & Co.; also to the authors of the volumes published by the last two firms named, viz., Messrs. Tompkins & A. E. Seaton.—J.A.