THE DEVELOPMENT AND DESIGN OF CONDENSERS AND CONDENSING PLANT

Some developments in design have taken place since this subject was reviewed in Papers on Engineering Subjects No. 8, and the following notes are intended to be read in conjunction with that article.

Main Condensers.—In the design of condensers at present being fitted the following objects have been kept in view in planning the arrangement of the tubes in the nest :—

(*a*) A good spread of steam over the whole of the cooling surface.
(*b*) Good penetration of the steam into the tube nest.
(*c*) Contact between the steam and condensate to secure a regenerative effect.
(*d*) A short path for air extraction which is not in opposition to the direction of movement of the condensing steam.
(*e*) Adequate cooling of the vapour to be handled by the air ejectors.

As pointed out in the previous article on this subject, the length and width of the condenser is to some extent dependent upon the design and size of the L.P. turbine. A further factor which influences the design is the minimum free suction head necessary at the full output of the water extraction pump. This imposes a limit upon the depth of the condenser tube, but as previously shown, the reduced pressure drop consequent upon a reduction in the length of the vapour path more than offsets any resultant decrease in heat transmission. It also generally necessitates placing the top row of tubes closer to the turbine exhaust orifice than is desirable from the point of view of steam spread referred to below.

In modern designs the L.P. turbine is generally two flow. In such cases, where the exhaust steam enters the condenser at each end, difficulty is naturally experienced in obtaining an even spread of steam over the whole surface of the tubes at the top of the condenser. Whenever possible large holes are cut in the diaphragm plates to allow passage for the steam in a longitudinal direction and in some designs holes are cut between every tube, while in others a central portion at the top of the plates is entirely cut away.

Good penetration of the steam into the tube nest is desirable for several reasons. There are three methods by which it is commonly effected, and these may be used separately or in conjunction. They are :—

(1) Omission of tubes in order to form lanes into the tube nest or at the sides of the nest to give steam access to the outer tubes. Sometimes a wide central lane is provided which extends from top to bottom of the condenser.

(2) The fitting of more widely pitched tubes at positions where the steam first impinges on the nest.

(3) Arrangement of the pitch lines so that the disposition of the rows of tubes tends to have some directional influence on the course of the steam.

The adoption of lanes into the nest and the omission of tubes at the upper corners has, in addition to providing a greater surface for steam entry with a reduction of film loss, the advantage of reducing the vapour velocity and resistance to flow.

The wide central lane right through the nest while possessing the above advantages and also the important one of allowing the entering exhaust steam to come into direct contact with the condensate, has the serious disadvantage of imposing no impedance to the flow of steam at the centre of the nest at each end where exhaust steam issues from the turbine. This is to some extent detrimental to a good spread of steam over the whole top surface of the condenser. A wide bay at the top of the nest, devoid of tubes, but not extending completely through the nest, possesses the advantage of giving the steam more space to reach the centre of the condenser below the turbine steam inlet belt.

Increasing the pitch of the tubes towards the top of the nest has the advantage of reducing vapour velocity, but by itself does not increase the area exposed to steam entry. Encouraging results have, however, been obtained with condensers where no lanes have been fitted, but the pitch of the tubes increased towards the top.

The value of the relative position of each tube to its neighbour from the point of view of directional flow is indeterminate, but in shore plants where the tubes are arranged to minimise the effects of dripping condensate very satisfactory results have been obtained. Attempts have been made in some naval designs to reduce the dripping effect by fitting sloping baffies in the nest to act as catchments for the drips.

From a thermo-dynamic aspect it is of considerable importance that the temperature of the condensate should be as little below that of the turbine exhaust as possible. The shorter the steam path and the lower the drop in pressure across the nest the smaller will this difference of temperature be. By arranging that the exhaust steam has direct contact with the condensate a regenerative effect is secured, and the condensate temperature raised. Modern condensers are frequently arranged with this object in view.

The wide central lane devoid of tubes, which is a feature of many of the latest naval condensers, is designed for this purpose. In the condenser fitted in the after engine room of one of the latest cruisers the same effect is obtained by the disposition of the steam inlets.

It is also possible that the mean direction of steam flow in relation to the rain of condensing water has some influence upon the condensate temperature.

Naturallly the shorter the path which has to be taken by the air and vapour drawn away by the ejectors, the lower the resistance will be and the higher will be the vacuum which can be maintained in the shell. A further factor which influences this is the mean direction of air extraction in relation to the condensing rain, there being more resistance to overcome if the air path is in opposition to the rain than if it is in a transverse direction.

As pointed out in the previous article the cooling tubes for the air and vapour to be handled by the ejectors are an integral part of the condenser separated from the rest of the tube nest by baffles. It is important that the tubes fill the space well, leaving no gaps through which the air can short circuit. The ends of these baffles are often turned up to catch the condensing water from the tubes above and only allowing it to fall close to each diaphragm plate.

Figs. 1-7 show the arrangement of tubes in several modern naval and mercantile condensers. The general features referred to above can be readily picked out, and it will be seen that no hard and fast standard has yet been reached, nor is this desirable in the present state of knowledge.

Air Ejectors.—The three stage sea water cooled ejector, which was the type fitted in earlier modern ships, was mentioned in the article previously referred to. A further article on this subject appears in Papers on Engineering Subjects No. 12. As pointed out there the condensate cooled two-stage ejector has superseded other types in naval work. There are, however, one or two disadvantages attendant upon its use which may be mentioned.

The manufacture of the two stage ejector is rather more complicated than that of the three stage type. In the first designs fitted in the Service some difficulty was experienced in maintaining tight joints between the spray cooling chamber and the parts under vacuum. Early difficulties have, however, been largely overcome.

With both types it is desirable to arrange that the air suction leads are as direct as possible, and in addition to this requirement the position of the condensate cooled ejector is dependent upon the relative positions of the water extraction and main feed pumps. It may not always be easy to arrange a suitable position.

Under normal conditions for a given performance the modern three stage condensate cooled ejector uses less steam than the corresponding two stage type. The latter, however, shows advantages in air extraction capacity when the temperature of the cooling medium is increased as, for instance, under tropical conditions. For this reason it is preferred as it is under these conditions that there is most difficulty in maintaining satisfactory vacuum.

Sea water cooled ejectors possess the great advantage that the temperature of the cooling medium, and hence the vacuum which the ejector can maintain, is independent of the absolute pressure in the condenser, but on the other hand they add an additional potential source of leakage of salt water into the feed system. With condensate cooled ejectors an air leak in the system has a cumulative effect, since the resultant loss of vacuum in the condenser engenders a rise in condensate temperature with a consequent fall in the vacuum maintained by the ejector.

Water Extraction Pumps.—The use of motor and turbine driven extraction pumps for removing the condensate from the condenser and supplying it to the eed pumps is now general except in small ships.

These pumps are of a constant speed type and have a flat characteristic. In the case of the turbine-driven pumps a speed governor is fitted. In addition to their being of ample capacity to supply all demands likely to be made on the feed pump, it is necessary that they should be able to produce this output with a minimum head of water over the suction branch. In modern designs where space is very limited this is of the utmost importance, and the latest pumps require a much smaller head than their forerunners. The design of these pumps is discussed in the article on Rotary Pumps in Papers on Engineering Subjects No. 13.

Main Circulating Pumps and Systems.—In destroyers, where no inner bottom is fitted it is possible to arrange the inlets for the main circulators at such an angle that the change of direction of the circulating water passing through the system is small with a resulting low resistance to flow. The use of sluice valves for main inlets and discharges is also of assistance in this direction. It is possible to fit scoops below the inlets so that the use of the circulators is only necessary at low powers, when standing by, going astern or manœuvring. This system is frequently used abroad, but has not been adopted in our Service on account of the interference with ship form and other complications resulting from its use. By suitable design of the ships bottom immediately before the inlets it is possible to steam at speeds up to 30 knots in destroyers without steam being admitted to the main circulators.

The introduction of the axial flow pump referred to in Papers on Engineering Subjects No. 13, promises further improvement in this respect.

In ships with double bottoms a certain amount can be done by careful consideration of the shape and position of the main inlets and circulating pumps. The use of sluice valves has been more widely adopted and the shape of the condenser doors receives careful attention so that the inflowing water is well distributed over the tube plate.

The reintroduction of gunmetal condenser doors eliminates the heavy wear and tear from the corrosion associated with ferrous material and the much greater resistance of cupro-nickel tubes to corrosion facilitates the change.

Endeavour is always made to provide sight doors above the level of the highest tubes for the purposes of Canterbury testing condensers, but the proximity of the cross girder for the turbine seatings does not always make this possible.

A new type of ferrule and packing has recently been introduced. These are known as Wilkie tube fittings, John Crane process. The new packing provides a more certain and more durable joint than the linen gromet, and also offers certain advantages on the score of weight. In addition a better entry for the water is provided, and eddies at the inlet end of the tubes are reduced. They possess the further advantage that less time for packing tubes is required than with Admiralty pattern ferrules. Their construction is apparent from Fig. 8.

Closed Feed Controller.—As mentioned in previous articles the designed level of water in the condenser is maintained by the controller. It will be appreciated, however, that the designed levels can only be obtained under conditions of list, heel or rolling if the controller placed on the fore and aft centre line of the condenser. This is not generally practicable and the controller is usually placed on the inboard side of the condenser. Care must be taken that, with any reasonable amount of list or roll the water level will not reach the air suction baffles in the condenser, thus blanking the air ejector suction on one side. With this in view wash plates are fitted running for and aft in the condenser well.

It is of equal importance to arrange that if it is not possible to place the extraction pumps on the same fore and aft centre line as the controller the actual head over the pump suction orifice is sufficient for full power conditions under any reasonable amount of heel and trim. In this connection where space is very cramped, by choosing suitable positions for the controller and extraction pumps, advantage can be taken of the average trim of the ship, which in nearly all warships is by the stern.

In general the machinery is so arranged that the use of the main condensers is not necessary in harbour. Auxiliary condensers are not fitted, the small amount of auxiliary exhaust being dealt with by the feed heaters and any surplus taken by the drain coolers.

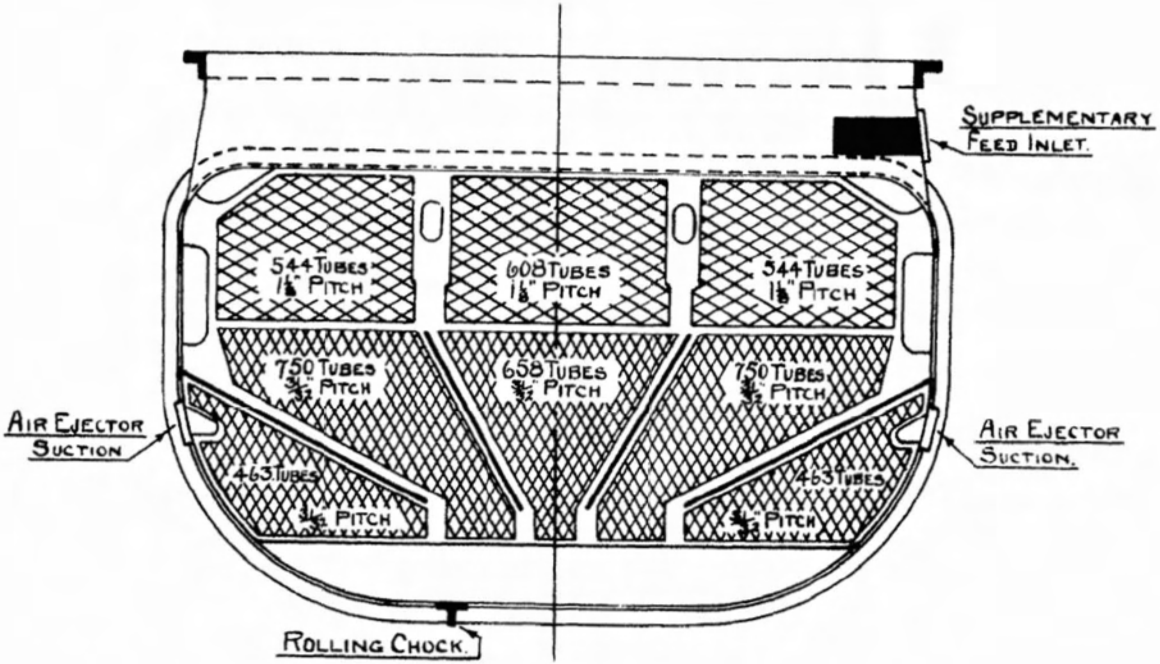


Fig. I.

(587)17213'10024.1600.6/33 Gp921.C&RLtd

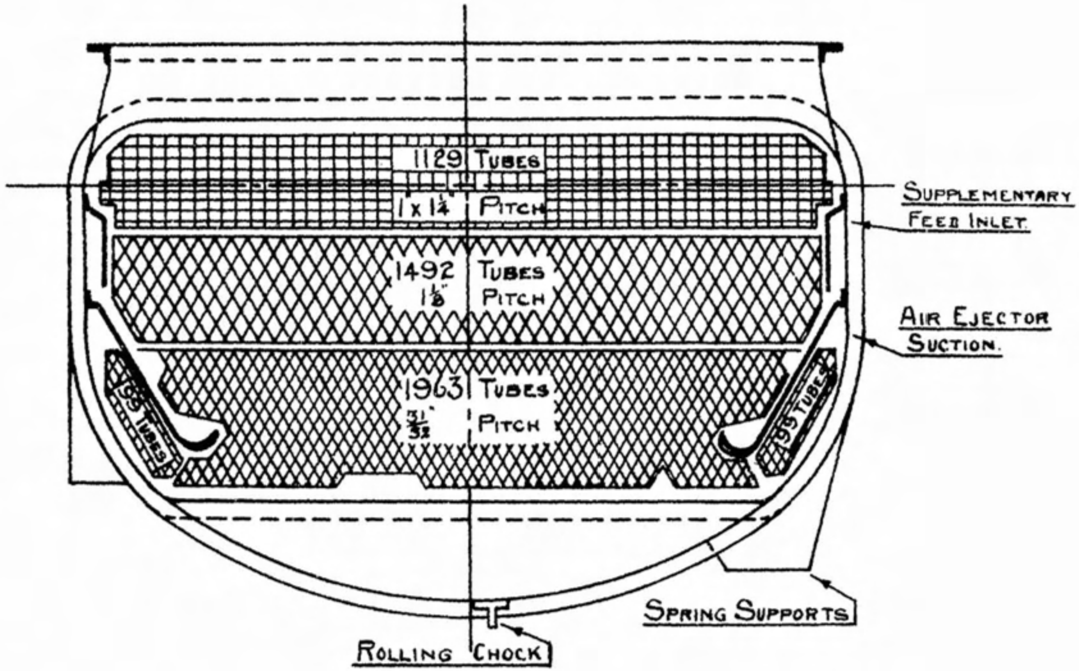

1129 Tubes
1" x 1¼" Pitch
1492 Tubes
1⅛" Pitch
1963 Tubes
31/32" Pitch
99 Tubes
99 Tubes
Supplementary Feed Inlet.
Air Ejector Suction.
Spring Supports
Rolling Chock

Fig. II.

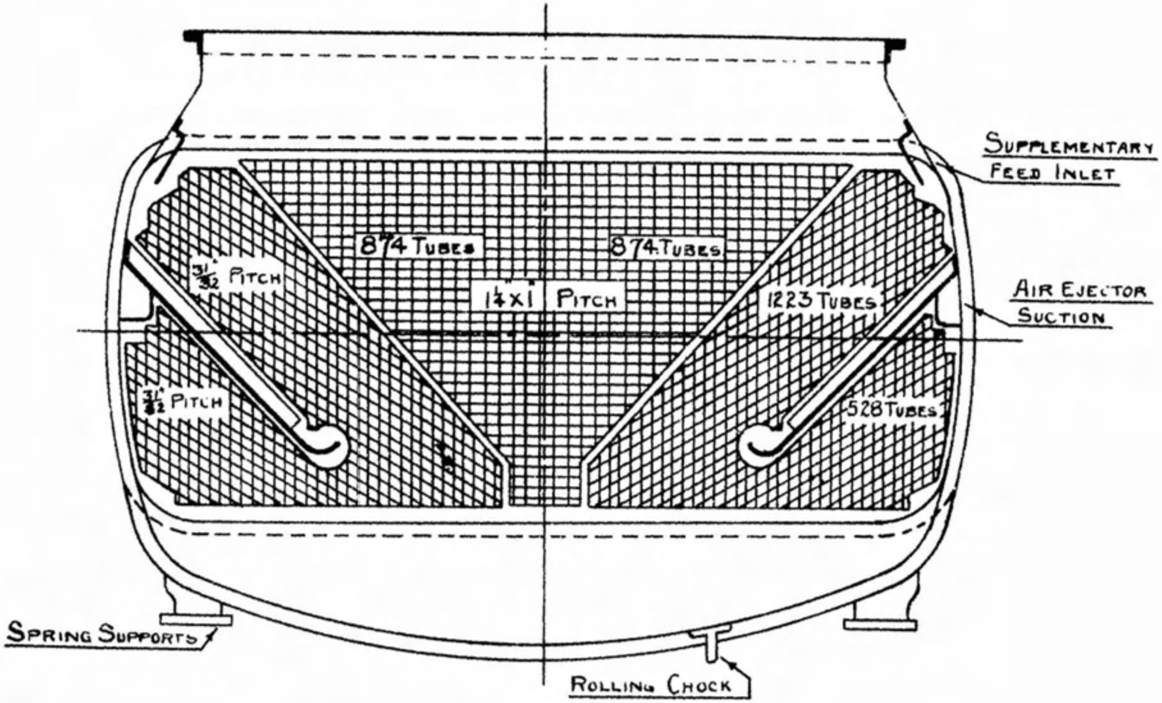
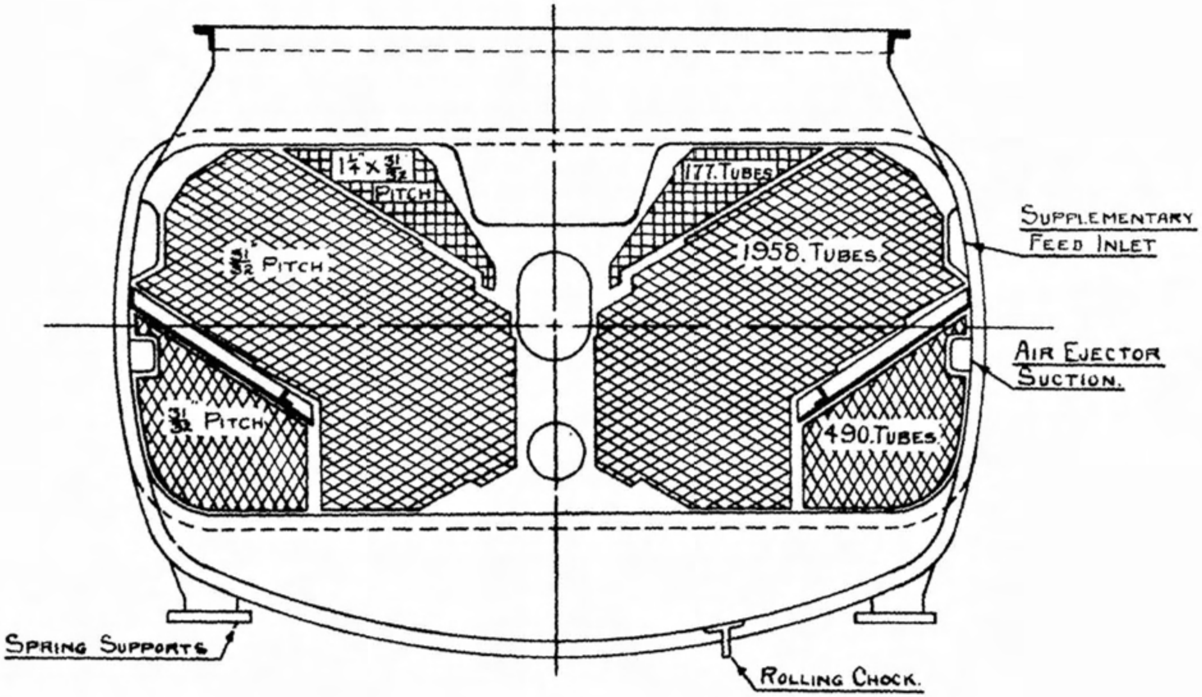

Supplementary
Feed Inlet
874 Tubes
874 Tubes
$\frac{31}{32}$" Pitch
$1\frac{1}{4}$"x1" Pitch
1223 Tubes
Air Ejector
Suction
$\frac{31}{32}$" Pitch
528 Tubes
Spring Supports
Rolling Chock

Fig III



1¼" x 31/32 Pitch
177. Tubes
31/32 Pitch
1958. Tubes
Supplementary Feed Inlet
Air Ejector Suction.
31/32" Pitch
490. Tubes.
Spring Supports
Rolling Chock.

Fig. IV

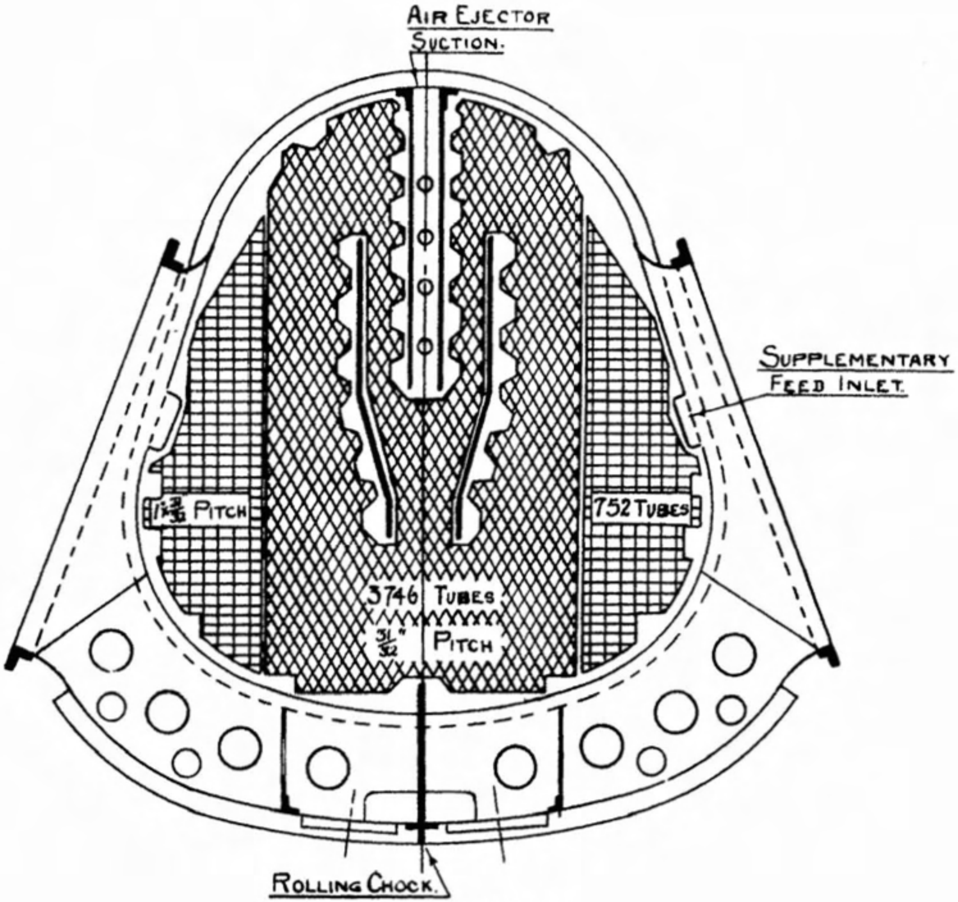

AIR EJECTOR SUCTION.
SUPPLEMENTARY FEED INLET.
1 3/32" PITCH
752 TUBES
3746 TUBES
31/32" PITCH
ROLLING CHOCK.

FIG. V.

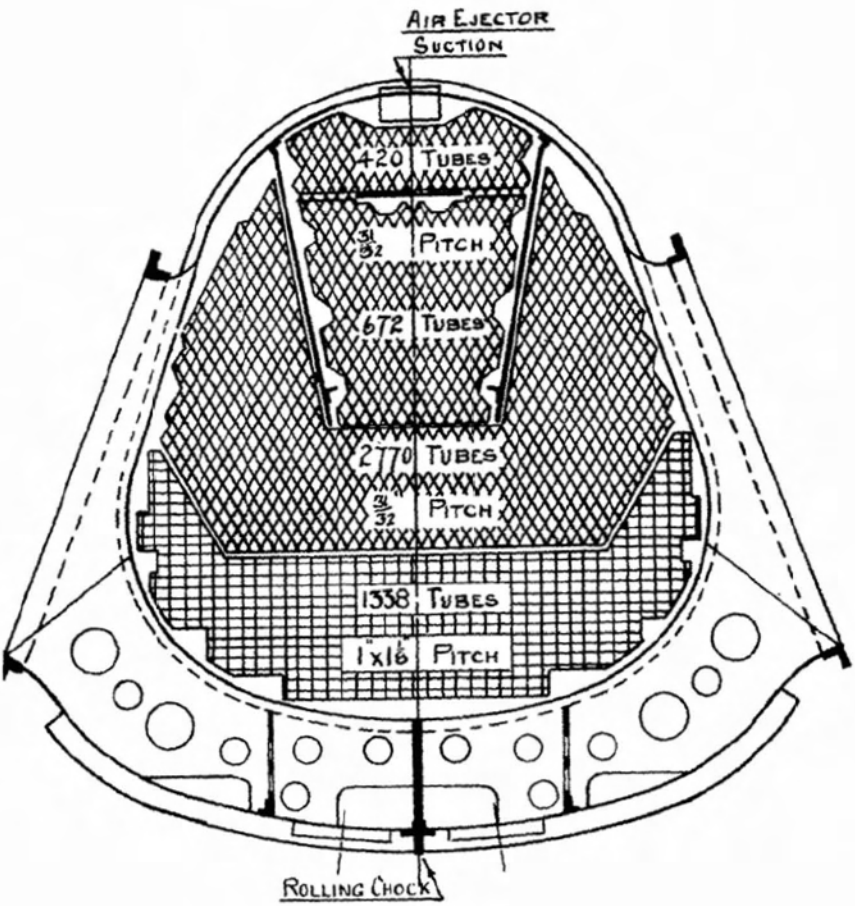

AIR EJECTOR SUCTION
420 TUBES
31/32" PITCH
672 TUBES
2770 TUBES
31/32" PITCH
1338 TUBES
1"x1 1/8" PITCH
ROLLING CHOCK

FIG. VI

FOR "BAUER-WACH" INSTALLATION.

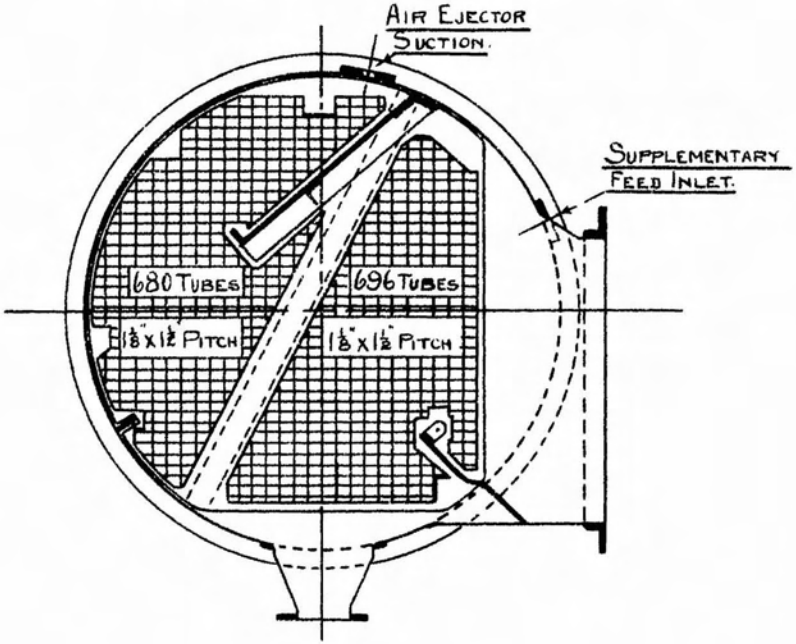


FIG. VII

"CRANE" PACKING.

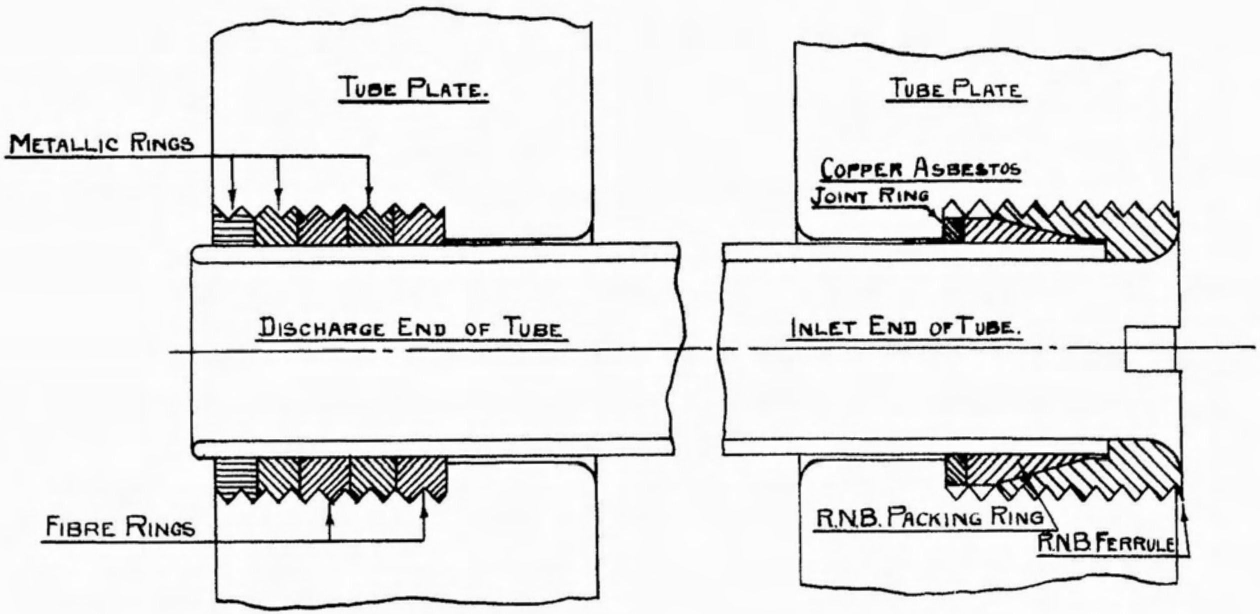


FIG VIII.