No. 12

RECENT DEVELOPMENTS IN THE DESIGN OF MACHINERY FOR DESTROYERS

Objects of the Designers.—" Consistent with seaworthiness, a destroyer should be designed so that it can be constructed as easily and cheaply as possible." As far as the machinery is concerned, this means that saving of weight and space, ease of control and saving of upkeep are requirements of paramount importance, and that, to further these ends, some loss of economy and lack of protection and sub-division must be accepted.

A destroyer's machinery is designed with the smallest possible margin over safe working figures, and it is the constant aim of the designer to approach these figures as closely as possible without overstepping the mark.

This paper is intended to describe how the machinery of the A to H class has been developed with the above objects in view.

General Trend of Design.—Table I shows particulars of post-war destroyers compared with the V and W classes. All reference to ships with special fittings, such as " Ambuscade," " Acheron," " Decoy " and " Grenville " has been omitted from this table, and figures for endurance, although comparable with each other, are not accurate for sea-going conditions.

The outstanding features of the above designs will be described briefly in order to lead up to details of the latest machinery.

(*a*) **V and W Classes. (Generally.)**—Three boilers were fitted in two boiler rooms, and these generated dry and saturated steam at 250 lb./in.^{2}.

The majority of vessels have Brown-Curtis geared H.P. and L.P. turbines and reciprocating auxiliary machinery. Generally speaking this machinery is simple and easy to handle. Its performance is, however, inferior to more recent designs as regards weight and space, and the reciprocating auxiliary machinery requires an excessive amount of upkeep. The condenser performance has fallen off badly on service. due to scaling of the tubes, and a vacuum as low as 23" to 24" on a full power trial is not an uncommon feature in these vessels, whose full speed is correspondingly reduced. In some cases where descaling has been carried out a vacuum of 27" has been attained. Trouble has also been experienced due to vibration of the rims of turbine wheels which causes fracture and stripping of blading.

TABLE 1.

Ship.	V. and W.	A. and B.	Sague-nay.	C. and D.	E.	F.	G and H.	Amphion. 1 Unit.
S.H.P.	27,000	34,000	32,000	36,000	36,000	36,000	34,000	36,000
Steam pressure	250	300	300	300	300	300	300	350
Steam temperature	406	580	422	600	622	642	640	635
Machinery weight, lbs./S.H.P.	35·2	33·3	34	32·7	31·8	30·8	31·3	40·7
Length of machinery spaces—								
No. 1 B.R.	45 ft. 6 in. (No. 1 and No. 2)	28 ft.	26 ft.	28 ft.	26 ft.	26 ft.	24 ft. 6 in.	After Unit 56 ft. (No. 1, No. 2 and No. 3)
No. 2 B.R.		46 ft. (No. 2 and No. 3)	46 ft. (No. 2 and No. 3)	46 ft. (No. 2 and No. 3)	24 ft.	24 ft.	21 ft. 9 in.	
No. 3 B.R.	27 ft. 3 in.				24 ft.	24 ft.	21 ft. 9 in.	
E.R.	51 ft.	50 ft.	52 ft.	50 ft.	52 ft.	52 ft.	49 ft. 9 in.	46 ft.
Total	123 ft. 9 in.	124 ft.	124 ft.	124 ft.	126 ft.	126 ft.	117 ft. 9 in.	102 ft.
E.R. complement	28	30	30	30	34	34	34	Half Comp. 81
Fuel carried	370	450	440	470	470	470	455	1800
Endurance at 2500 S.H.P. ..	4100	5500	5750	5750	6430	6700	5950	—

(*b*) **A, B and C and D Classes.**—Three boilers were fitted in two boiler rooms as before, but the working pressure was increased to 300 lb./in.^{2} and superheated steam was introduced to improve the machinery performance generally.

The new oil fuel sprayers and open fronts were first fitted in the B class, and an appreciable gain in efficiency resulted.

The turbines were Parsons impulse-reaction type, the H.P. being fitted with a two-row impulse wheel and three reaction stages to give economy when cruising. Fig. 2 shows a diagram of a D class H.P. turbine.

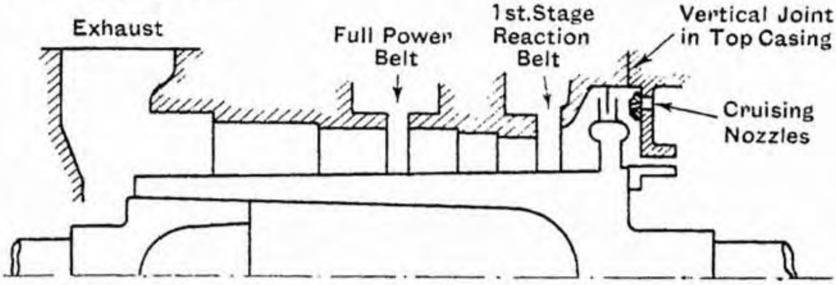


FIG. 2.
D Class. H.P. Turbine Basis Plan.

The L.P. turbines were of double flow type with the astern turbine at the forward end.

It was originally intended to by-pass all the cruising stages when proceeding at full power and to admit steam direct to the full power belt. The A class completed satisfactory trials and ran for a short period at sea under these conditions. Trouble soon appeared, however, due to churning of stagnant steam in the cruising stages when the full power valves were open, and, although this was overcome in vessels already under construction by arranging for a definite minimum drop of pressure to be maintained between the inlet and the full power belt, it was decided at that time to fit separate cruising turbines in the new designs.

(*c*) **"Saguenay" and "Skeena."**—Built for the R.C.N. contemporary with the B class but using saturated steam. Cruising turbines were fitted to give the same endurance at low powers as contemporary ships.

(*d*) **E and F Classes.**—Cruising turbines and mechanical clutches were fitted (*see* Fig. 3).

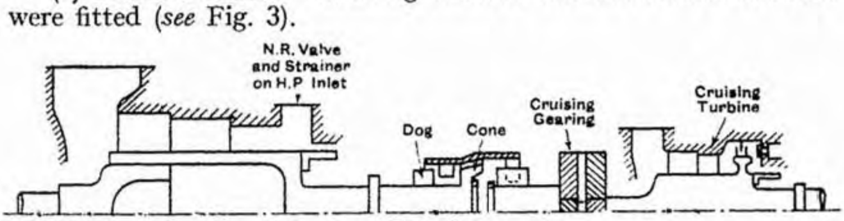


FIG. 3.
Cruising and H.P. Basis Plan. E and F Classes.

The water-tight subdivision was improved, at the expense of some increase in length and engine room complement, by fitting a single boiler in each of three boiler rooms.

In order to reduce the extra space required for this arrangement, it was intended originally to provide a portable plate in the bulkhead between Nos. 2 and 3 boiler rooms for the withdrawal of the superheaters, but it was found by a full scale experiment in the shops that, to renew any superheater tube, it was only necessary to withdraw the header far enough to obtain a distance equal to a whole tube length between the tube support and the back of the boiler room. It will be seen from Fig. 4 that this not only saves

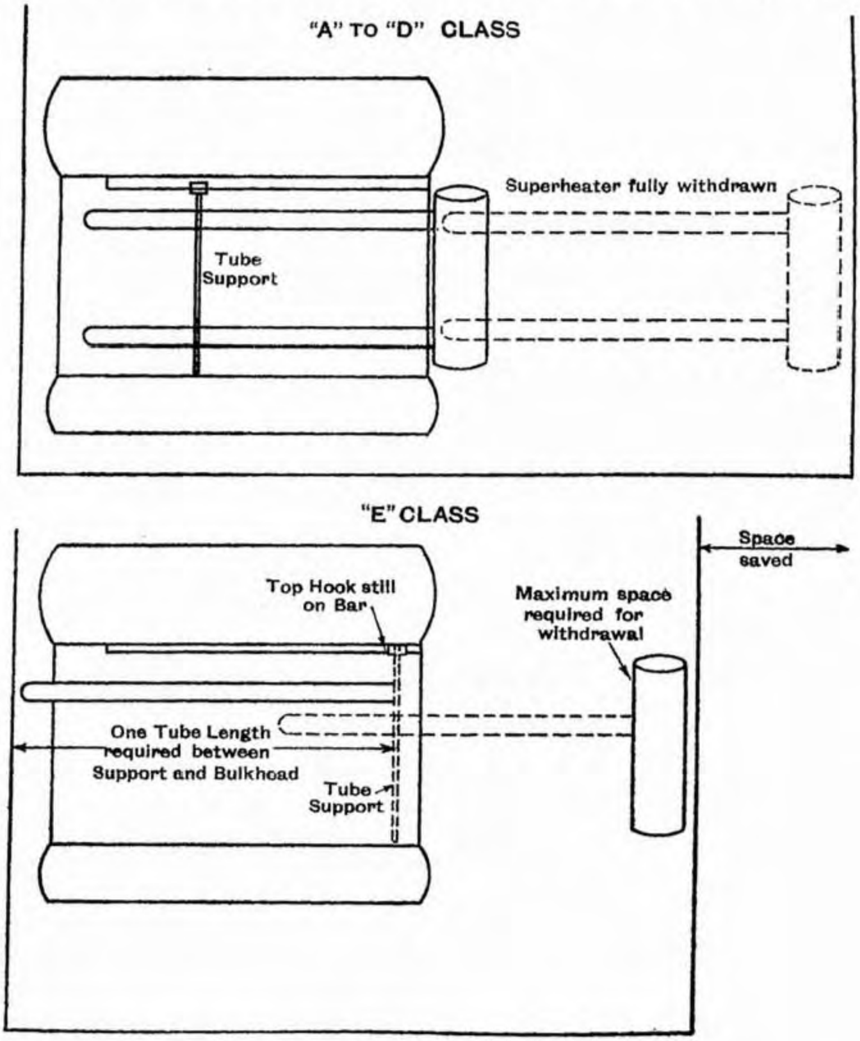


FIG. 4
Superheater Withdrawal.

in boiler room length, but considerably simplifies the operation of renewal of superheater tubes, making it unnecessary to withdraw the tube support from the carrier bar on the boiler drum.

Two vessels of the E class and all the F and later classes are fitted with closed feed.

(*e*) **G and H Classes.**—Study of the details of cruising turbines, clutches, and the accompanying fittings in the E and F classes showed that these were unduly complicated for use in destroyers, and in the G and later classes, economy at low power was obtained by fitting a two-row impulse wheel, a number of groups of nozzles at the forward end of the H.P. turbine, and fixed blades arranged over an arc in the top casing opposite the cruising nozzles only. (*see* Fig. 5).

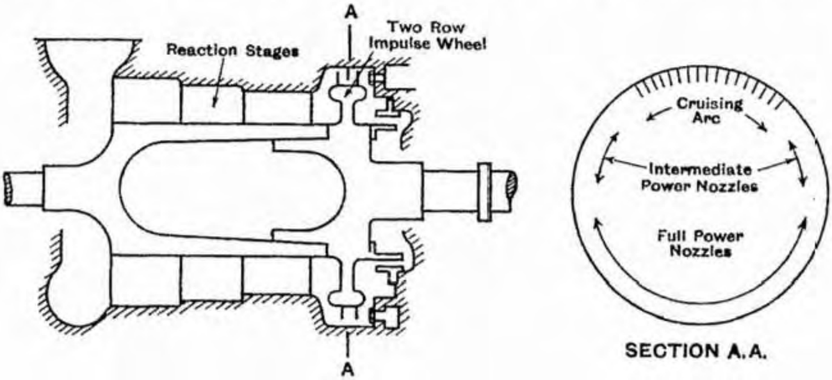


FIG. 5.

G Class. H.P. Basis Plan.

At high powers the cruising nozzles are shut off and steam enters the nozzles remote from the fixed blades, in effect making the impulse wheel a single bladed wheel only. It is an essential feature of this design that there is a flow of steam through all the moving blades at all powers to avoid overheating due to vane friction.

In the G class, rearrangement of the engine room machinery, consequent on the omission of the cruising turbines, together with the saving in space required for superheater withdrawal effected in the E class, gave an appreciable saving in the overall length of machinery spaces and hence in length and displacement of the ship itself, thus enabling the S.H.P. to be reduced.

Details of Design.—Having dealt briefly with the main features of post-war designs, it is now proposed to describe some details of the construction of individual items.

(1) Boilers.—Table VI shows particulars of three drum boilers of Admiralty type fitted in the latest destroyers.

TABLE VI.

Ship.	D.	E.	F.	G.
Total S.H.P.	36,000	36,000	36,000	34,000
Superheat °F.	180	200	220	220
Rate of forcing—				
(i) Lbs. oil/ft.² wall area/hour ..	39	39	42	44½
(ii) Lbs. oil/ft.² total heating surface/hour	1·21	1·20	1·25	1·07
Generator surface	7670	7750	7370	7150
Superheater surface	1120	1270	1244	1200
Rows of tubes	17	18	19	19
Boiler efficiency at full power ..	75	76·7	76·5	76

In all cases the fire row tubes are 1¾ ins. diameter, and the two row superheaters are fitted behind the fifth row generator tubes. In the F class and later, the diameter of the generator tubes outside the superheater was reduced to 1 in. in order to allow an increased number of rows to be fitted with the standard boiler drums. By this means, increase in weight was avoided, while at the same time maintaining the boiler efficiency which tends to fall off at the increased rates of forcing.

The tubes are so arranged that one spare tube of any given diameter is suitable to replace any tube of that diameter in the boiler, the lengths of the ends being adjusted as requisite.

The axes of all boilers are inclined at 2½° to the keel to allow for the squat of the ship at full power. The superheater tubes of boilers facing aft are specially sloped to ensure drainage with the ship at normal trim.

(2) Boiler Drums.—In the E class, solid forged steam and water drums were fitted to compensate for the extra weight expended upon cruising turbines. It was anticipated that a saving in weight of about 1½ tons per boiler would result, but in practice it was not found possible to machine the forgings sufficiently accurately, and in " Exmouth," the only vessel where a direct comparison is available, the boiler with riveted drums is about 2 cwt. lighter than those with forged drums. The forged drums also involved considerable extra cost, and the field of supply is restricted.

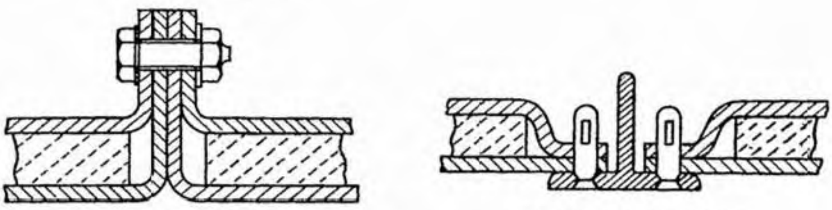
In view of this, the F class and later boilers have riveted drums. The drum ends are riveted in all cases, as a solid forged end leads to difficulties with the manholes and requires extra length. It is of interest to note that in some of the E class, the drum ends were given a slight shrink by immersing the drum in hot water before fitting and riveting the ends.

(3) Boiler Casings.—In designing boiler casings great attention has been paid to :—

(i) The arrangement of brickwork to protect all parts of the casing from direct radiant heat from the furnace, and at the same time allow of easy renewal by standard and, if possible, uncut bricks. It has been found that any part of the casing that is visible from inside the furnace, will become red hot at full power.

(ii) The arrangement of inspection doors to facilitate external cleaning of tubes. With this object in view, the casings of the G class and later vessels have been built on a frame of Tee-bars to which they are attached by cotters. Fig. 7 shows the difference between the two types of joint.

Hinged inspection doors are fitted at the bottom of the side casings, and doors with cotters are provided for inspection of superheater tubes where these enter the headers.



OLD TYPE CASING JOINT. NEW TYPE CASING JOINT.

FIG. 7.

(iii) The avoidance of large flat pieces of casing which lack rigidity and therefore may cause pulsation.

(iv) The provision of portable plates round the bottom of the outer funnel (H class) for preservation and cleaning of the inner casing, as it has been found that serious wastage occurs here after a period of service.

(4) Superheaters.—The type of superheater has been unchanged since the A class, the tubes being rolled into the header and supported at about two-thirds of their length from the header by some form of comb. The weight of the header is taken by a strap bolted to a bracket riveted to the steam drum, while at the bottom, a foot rests freely on a rail riveted to the water drum, which serves also as a rest for the bottom end of the tube support (Fig. 8).

Considerable trouble has been experienced due to steam leakage at the superheater tube ends, as the resultant moisture held by soot lodged locally causes rapid wastage of the tubes at this point. In this connection it is reasonable to suppose that the superheater header attains a temperature about halfway between that of superheated and saturated steam. The temperature of the tubes will differ in either leg, the inlet or saturated leg tending to a temperature somewhat above saturation point and the outlet or superheated leg to something above the superheat temperature. The leakage referred to above took place mainly at the outlet ends when these were arranged nearer to the furnace. The temperature difference results in a compression of the tube sufficient to cause distortion due to creep, which eventually results in leakage. Since the heat flow through the leg remote from the furnace is less than that in the near leg, an improvement in conditions may be brought about by arranging the superheated leg remote from the

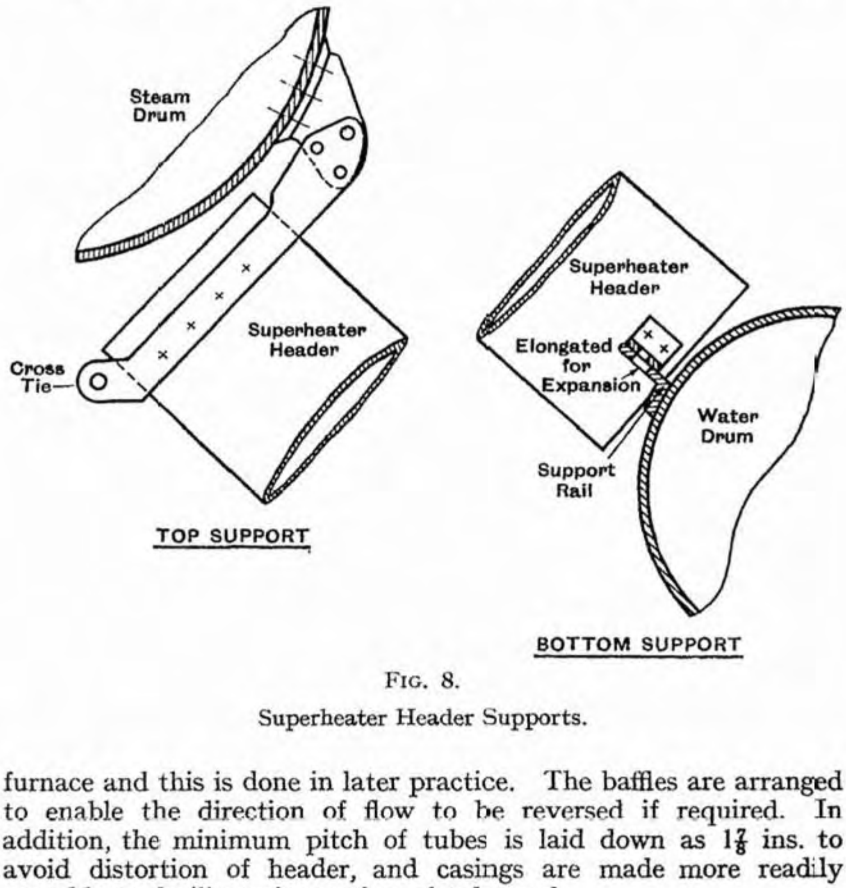


Fig. 8.

Superheater Header Supports.

furnace and this is done in later practice. The baffles are arranged to enable the direction of flow to be reversed if required. In addition, the minimum pitch of tubes is laid down as $1\frac{7}{8}$ ins. to avoid distortion of header, and casings are made more readily portable to facilitate inspection of tube ends.

Up to the present, superheater tubes have been made of mild steel, but steam temperatures are now approaching a limit beyond which this material is not satisfactory and tubes of molybdenum steel are being tried with the object of exploring the possibilities of further increases in temperature.

Tube supports are made of special heat resisting steel. The original design consisted of a number of shaped fingers held between

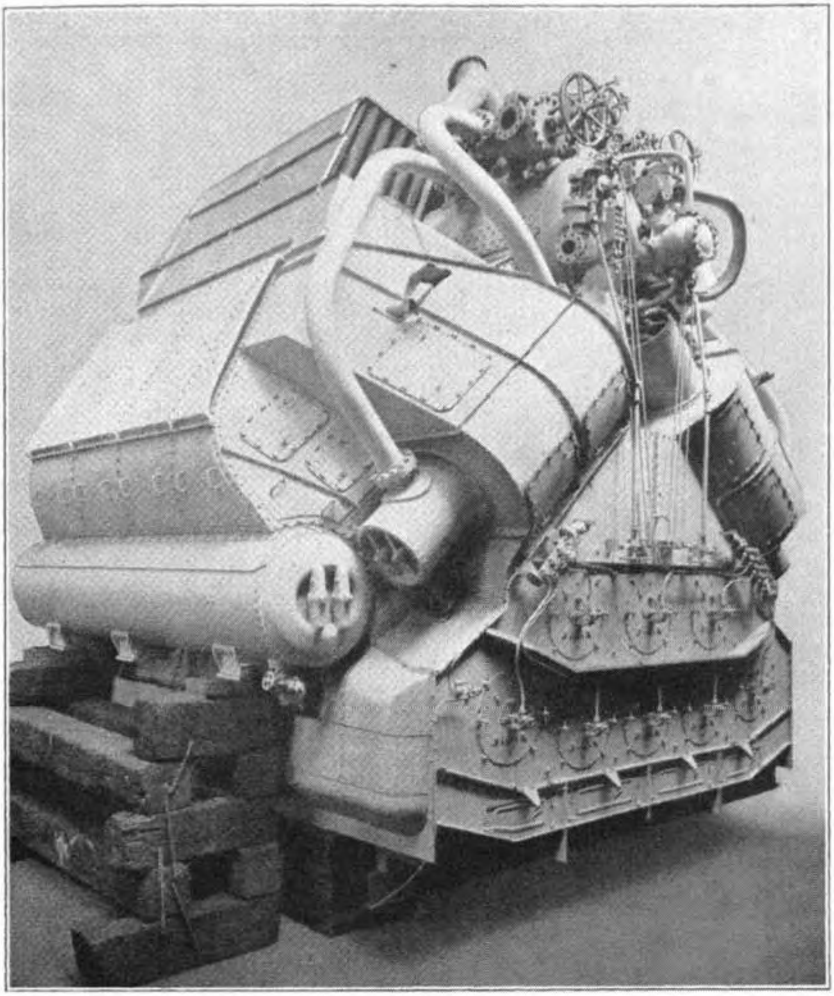


FIG. 10.
H.M.S. Decoy Boiler.

Note.—(1) Main Stop Valves on steam drum
(2) Complicated casings round superheater headers
(3) Contraflo type feed regulator

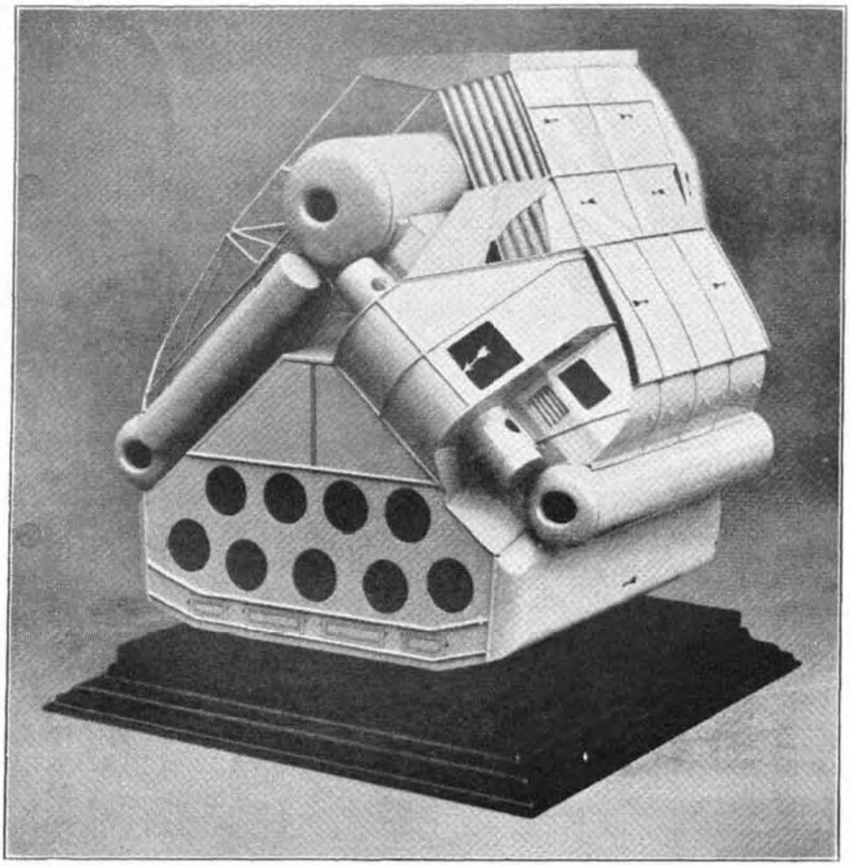


FIG. 11.

Model of Air Casings—H.M.S. Decoy Boiler two central plates to which the hook was bolted. Trouble was experienced due to overheating and stretching of these central plates which allowed the top finger to slip clear, and in one case this became jammed between two generator tubes (Fig. 9).

In the E class and later vessels, each support is made from a solid plate, dished in the centre for rigidity.

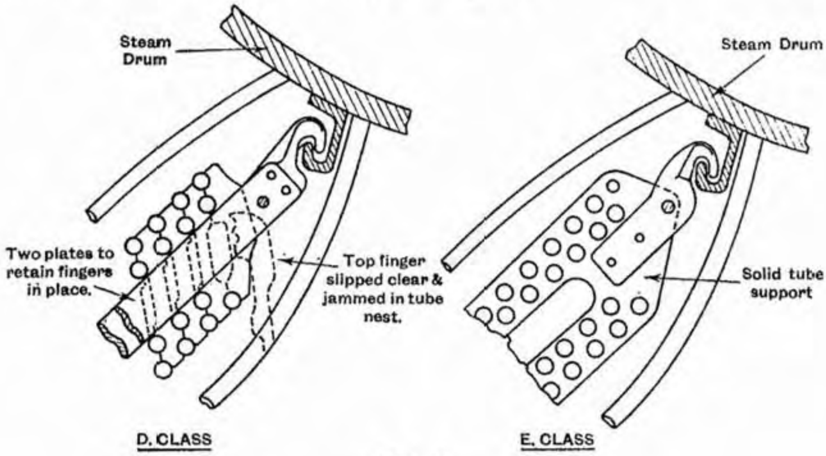


FIG. 9.

Superheater Tube Supports.

(5) **Special Boilers** (*see also* Article No. 3 of this Issue).—In addition to the standard design, a number of experimental boilers have been fitted in sea-going vessels.

(*a*) Standard boilers with air preheaters in H.M.S. "Decoy" and "Hunter." Fig. 10 shows one of the boilers fitted in H.M.S. "Decoy," and Fig. 11 shows the direction of air and gas flow indicated by a model.

Full records were taken for one boiler only during the trials, but owing to difficulty in taking good average temperature readings the results were not of very great value. The boiler dimensions are the same as the remainder of the D class and the addition of air preheaters resulted in a gain of 3½ per cent. in boiler efficiency at full power. The boiler rooms are remarkably cool compared to the remainder of the class, and the single air control tubes fitted to the sprayers are much easier to operate than the four flaps fitted in the open type fronts.

In spite of these advantages, preheaters, although in general use in cruisers, are not very suitable for use in destroyers for the following reasons :—

(1) Additional weight (about 3 tons per boiler) which comes high up in the ship and raises the centre of gravity of the machinery, which is an important point owing to heavy deck weights.

(2) Limited headroom leads to difficulty owing to the uptakes fouling the fore and aft strength girders of the ship. This point is illustrated in Fig. 12, showing standard and preheater boilers fitted into the boiler room of a destroyer.

(3) The air casings under the brickpans make it necessary to raise the boiler as a whole, thus further raising the centre of gravity. Alternatively, the furnace volume has to be reduced.

(4) Complicated air casings lead to difficulty with external cleaning of tubes and preservation of ship's structure. The photograph, Fig. 10, showing one of the boilers fitted in H.M.S. " Decoy " illustrates this point.

(5) Front and back casings increase the overall length of the boiler.

(6) About 50 per cent. extra fan power required.

(*b*) *Yarrow Five-drum Type Boiler.*—This type of boiler, illustrated in Fig. 13, is fitted in H.M.S. " Grenville," built by Messrs. Yarrow. The boilers are side fired and the steam drums are offset about 2 ft. from the centre line of the ship, being staggered to keep the ship on an even keel. This arrangement enabled the length of the ship to be reduced by about 7 ft. compared to the standard design, but there were considerable difficulties in working out the details and, as it was found impossible to design an arrangement of corrugated steam pipes of sufficient size to pass the steam required, it was necessary to fit balanced expansion joints, earlier designs of which have proved unsatisfactory in other naval vessels using superheated steam.

The " Grenville " design, however, has been satisfactory on service but requires maintenance by both ship's staff and dockyard as opposed to no maintenance with the corrugated pipe. There were also difficulties in fixing upon a control position in the boiler room in full view of the boiler mountings which were screened by the boiler room access.

Fig. 14 shows this boiler fitted into the boiler room, the auxiliary machinery being in front of the sprayers.

The superheater has six rows of tubes and transverse baffles are arranged to give three passes to the steam. The superheater and upper water drum are carried in cradles attached to the lower water drum and to the boiler casing. Air preheaters are fitted, the air being passed through the tubes. This simplifies the problem of supporting the preheater tube plate, but presents difficulty in external cleaning of preheater tubes. During trials it became evident that the water circulation was not satisfactory and large downcomers had to be fitted as shown dotted in Fig. 13.

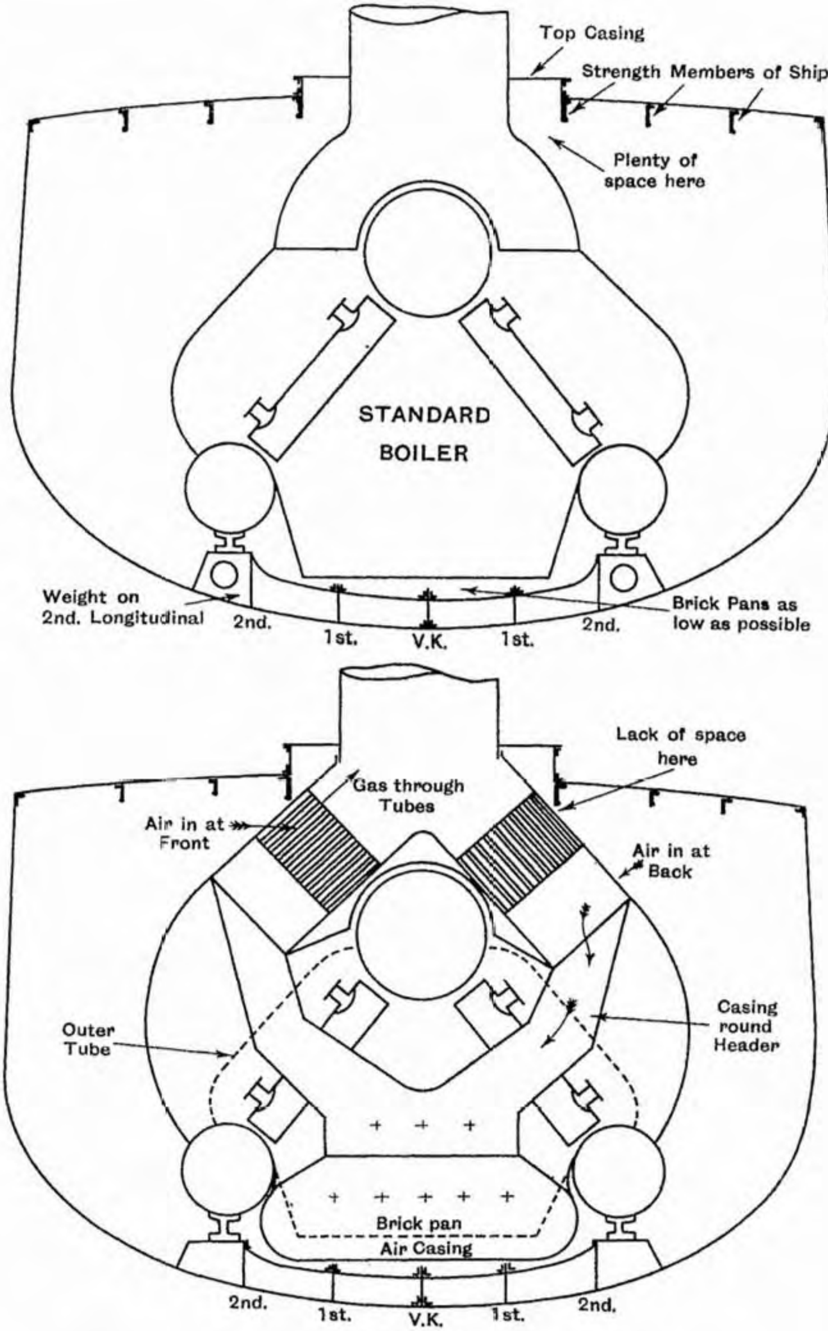


FIG. 12.

Diagram showing difficulty in fitting Air Preheaters in Destroyers.

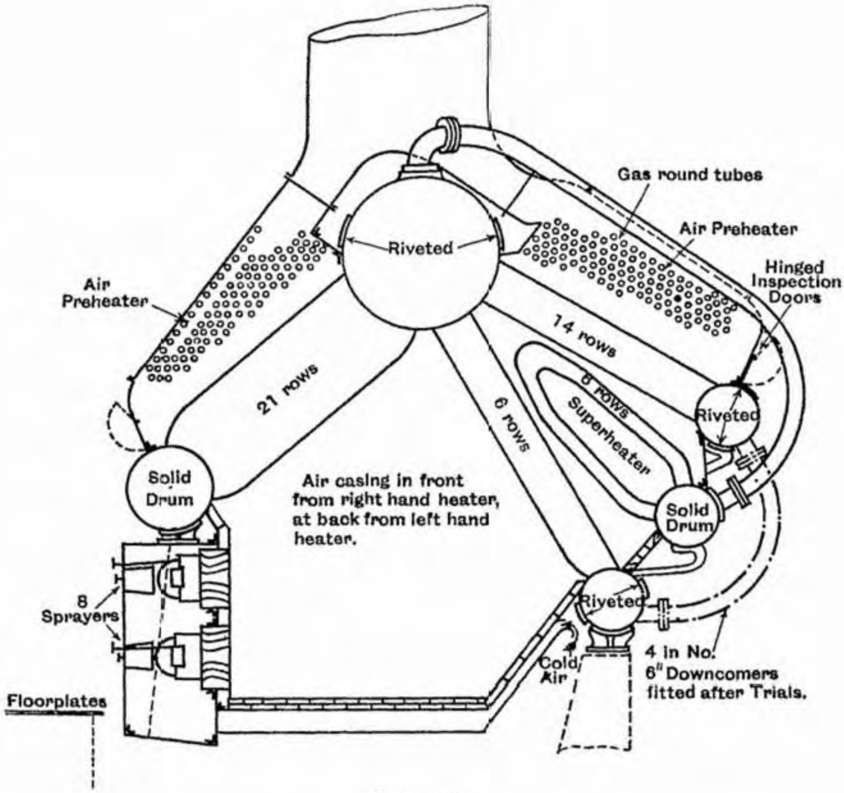
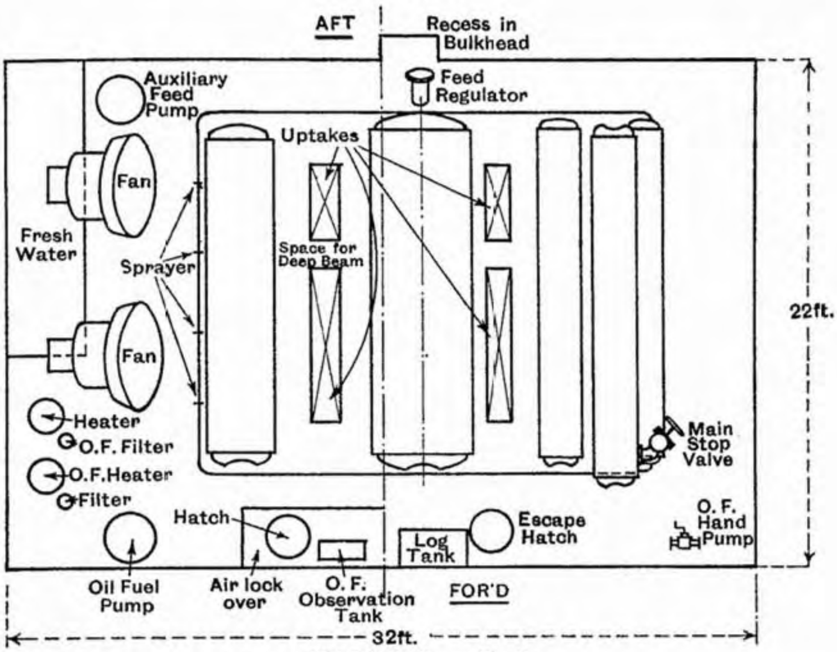


FIG. 13.

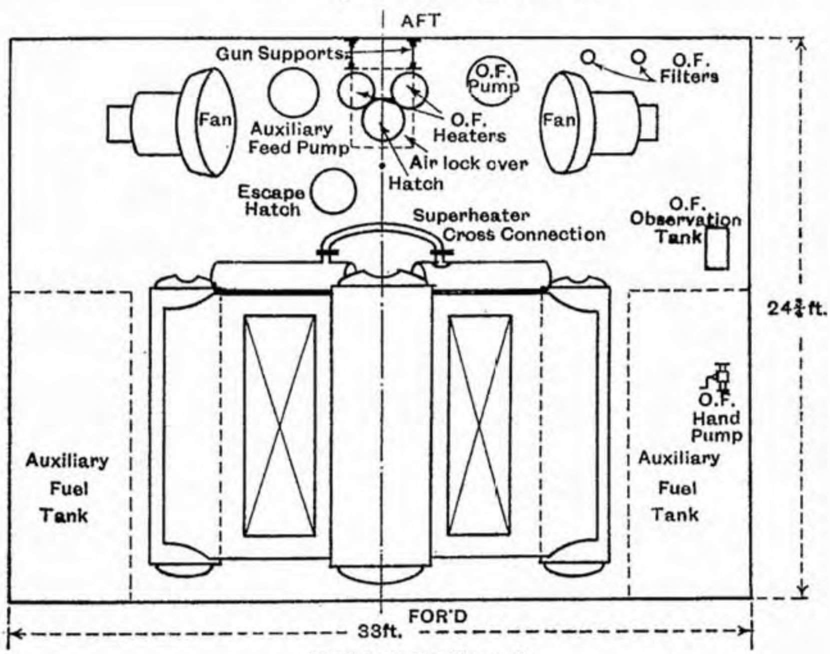
Yarrow 5-drum Boiler. H.M.S. "Grenville."

BOILER DETAILS

	"Grenville."	Admiralty Type G Class.
Generating surface	7,900 ft.^{2}	7,150 ft.^{2}
Superheater surface	2,000 ft.^{2}	1,200 ft.^{2}
Preheater surface	2,200 ft.^{2}	—
Weight (water at W)	66¾ tons	48 tons
Evaporation	129,000 lbs./hr.	110,000 lbs./hr.
Boiler efficiency at F.P.	74 per cent. (trial) 78½ per cent. (design)	76 per cent.



H.M.S. " Grenville."
Machinery Arrangement No. 1 B.R.



H.M.S. " Faulknor."
Machinery Arrangement No. 2 B.R.

FIG. 14.

(*c*) *Thornycroft Boiler.*—One boiler of this type is fitted in H.M.S. "Grafton." It has three drums and an Admiralty type superheater, but the length of the fire row tubes has been increased considerably compared to a standard boiler by lowering the water pockets, and the length of the boiler itself has been correspondingly reduced.

Another feature is the water wall fitted at the back between the steam and water drums (*see* Fig. 15). The object of this is to improve the efficiency of the boiler and to increase its output. Difficulties may be experienced when renewing back brickwork, as bricks have to be bolted to the panels of the casing before these are placed in position.

(*d*) *Johnson Boiler.*—One Johnson boiler (Figs. 16, 17, 18) is fitted in H.M.S. "Hyperion." High claims were made for the original boiler of this type which was intended for H.M.S. "Exmouth" but these were not fulfilled owing to circulation difficulties. It also suffers from the disadvantage that the whole of the weight is concentrated on the vertical keel of the ship which has to be made as low as possible to keep the uptakes clear of the deck beams and is therefore heavier than normal.

The heavy steam drum without good lateral support is also unsuitable for a destroyer on account of rolling, and heavy channel girders are carried from the steam drum to the second longitudinal to form a side support.

The great advantage of the boiler is the small amount of brickwork, which reduces upkeep. The weight is slightly greater than a standard H class boiler.

A new type of superheater tube is also being tried in this Johnson boiler (*see* Fig. 19).

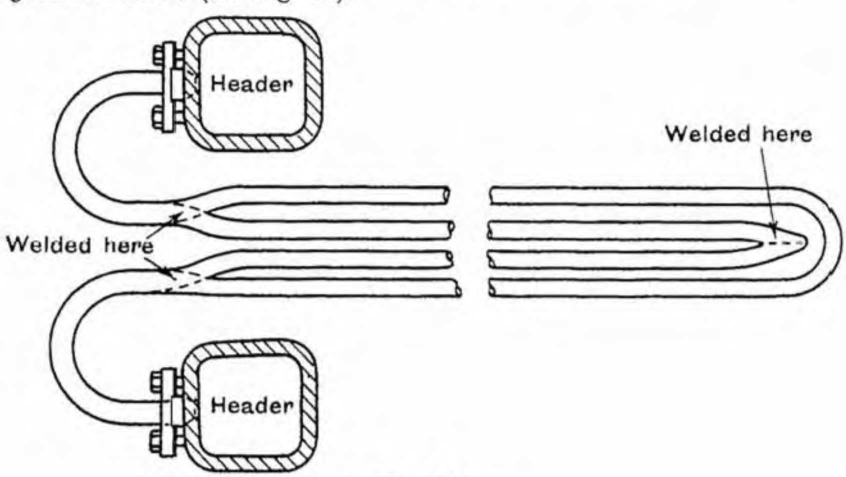


Fig. 19.

M.L.S. (Melesco) Superheater Tube.

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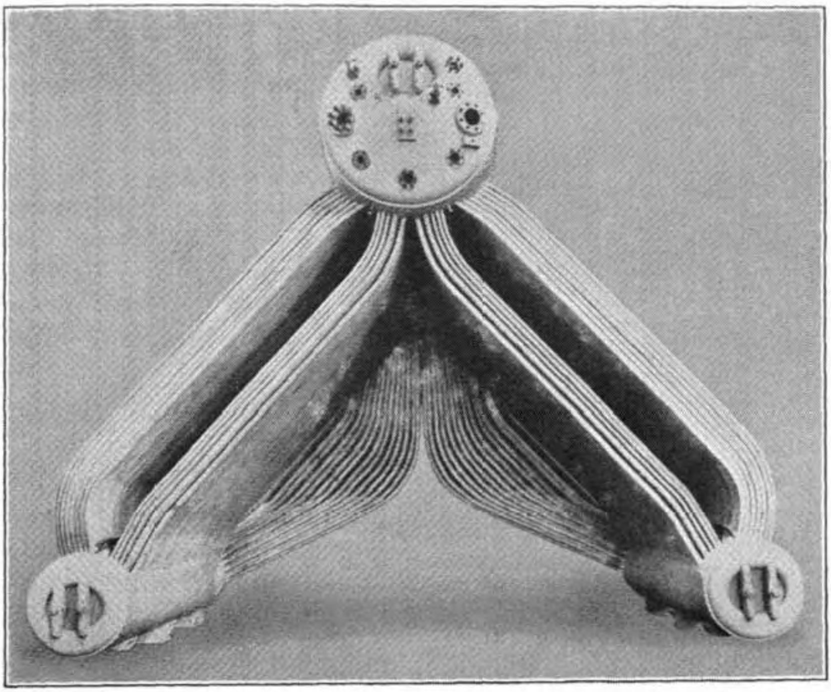


Fig. 15.

H.M.S. Grafton—Special Thornycroft Boiler.

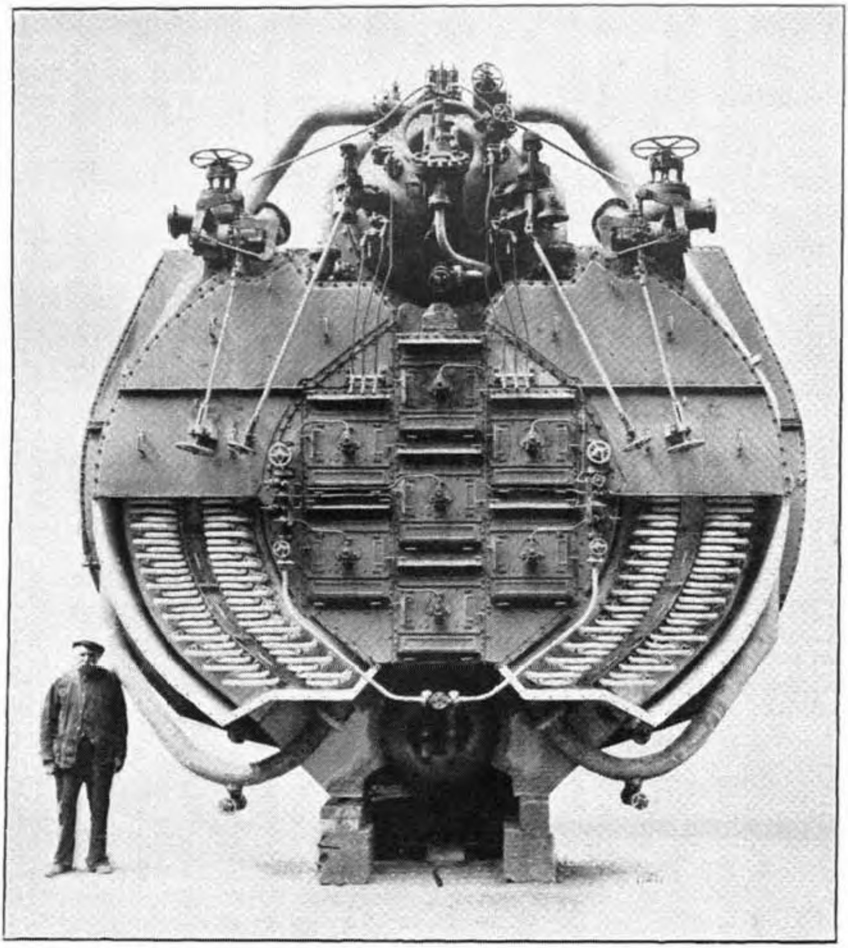


Fig. 16.

H.M.S. Hyperion—Johnson Boiler.

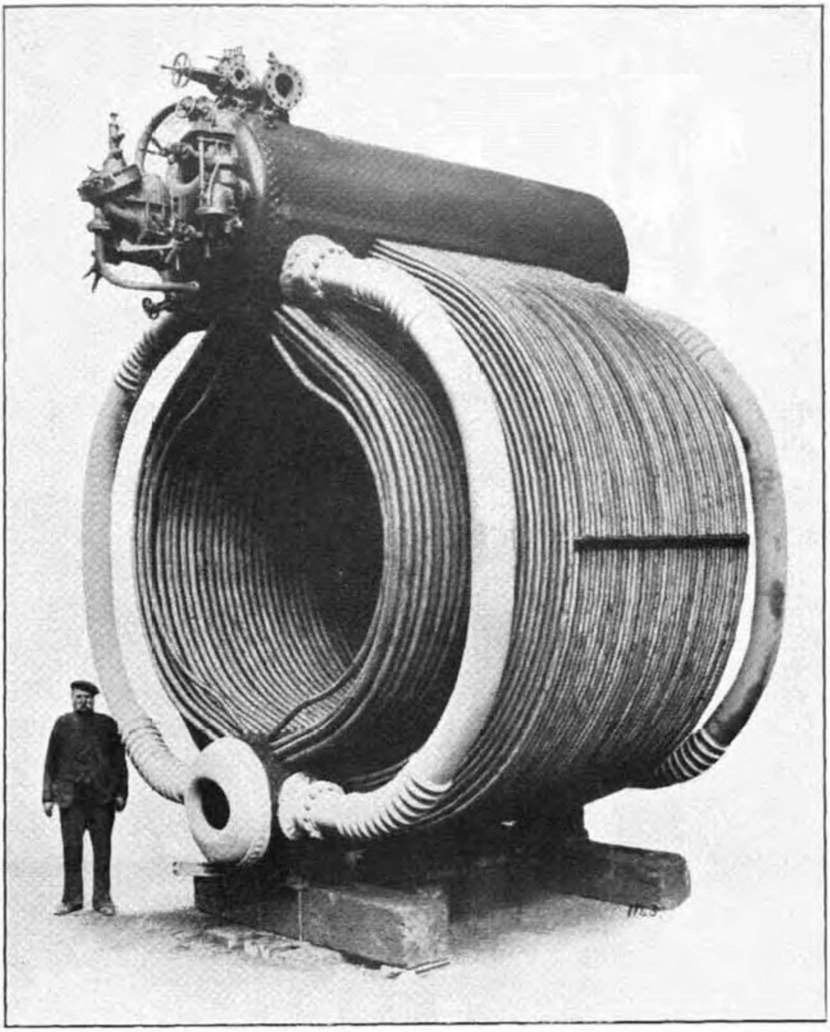


Fig. 17.

H.M.S. Hyperion—Johnson Boiler.

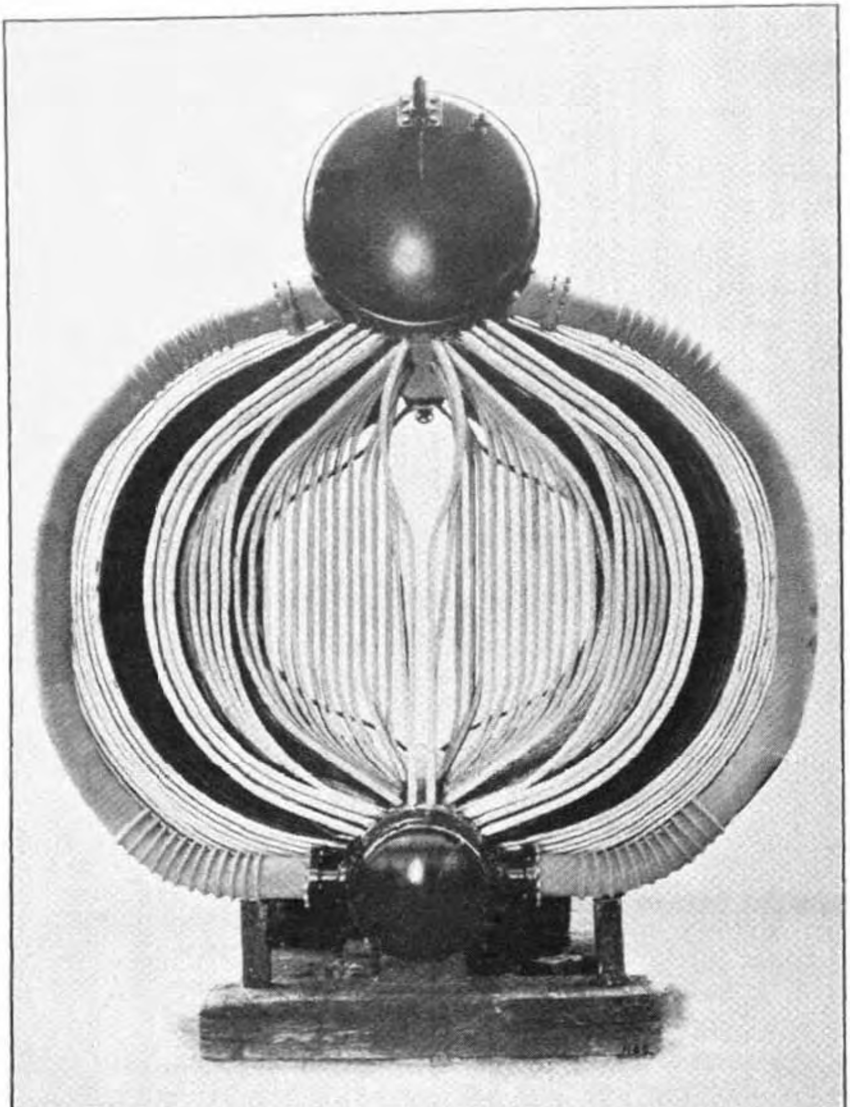


Fig. 18.

H.M.S. Hyperion—Johnson Boiler.

Its main features are :—

(i) The welded construction which reduces very considerably the distance between the inner tubes of the element and also halves the number of joints to be made between the tubes and the headers.

(ii) The method of securing the tubes to the headers by means of strongbacks, which it is hoped will avoid the troubles due to leakage experienced in ordinary superheaters, and will also simplify the renewal of tubes. Experience with these joints has so far been satisfactory.

(6) Boiler Mountings.—The arrangement and details of many boiler mountings have been altered with a view to improving accessibility. The main stop valves are mounted directly on the superheater headers and the valves are ordinary screw down valves, the casting being arranged to reduce pressure drop as far as possible. A main stop valve of the parallel slide type has been fitted for trial.

Safety valves were redesigned for the E class to eliminate the possibility of leakage at the internal joint between the cage and the casting, and are now fitted to the superheaters only, behind the main stop valves. Two pilot valves to operate the safety valves are fitted on the steam drum and arranged to lift at different pressures. Each pilot valve will operate both main safety valves. This is necessary to ensure the maintenance of a flow of steam through both superheaters should the safety valves lift.

As a further precaution, to cover the possibility of a block in the control lead between the steam drum and the safety valves, a whistle alarm set to blow at about 320 lb./in.^{2} is provided on the steam drum.

(7) Feed Regulators.—The adoption of turbo driven feed pumps in the D class made much greater demands on the automatic feed regulators and the Contraflo type was fitted in these vessels. One of these regulators is shown in Fig. 10 mounted on "Decoy's" boiler. They are satisfactory but somewhat cumbersome for a destroyer and in the E class and later the Steadiflow regulator was fitted.

The essential difference between the two types is shown diagrammatically (*see* Fig. 20). It will be seen that extreme accuracy is essential in construction of the Steadiflow type to ensure that the needle valves and piston are a good fit. This point was not sufficiently realized at first and in consequence considerable trouble occurred during trials of the E class. In both the above regulators the leak off is led to the main feed tank. This results in a waste of heat, and a modified type of Steadiflow regulator with leak off to the boiler has been tried. This design is being adopted in new construction.

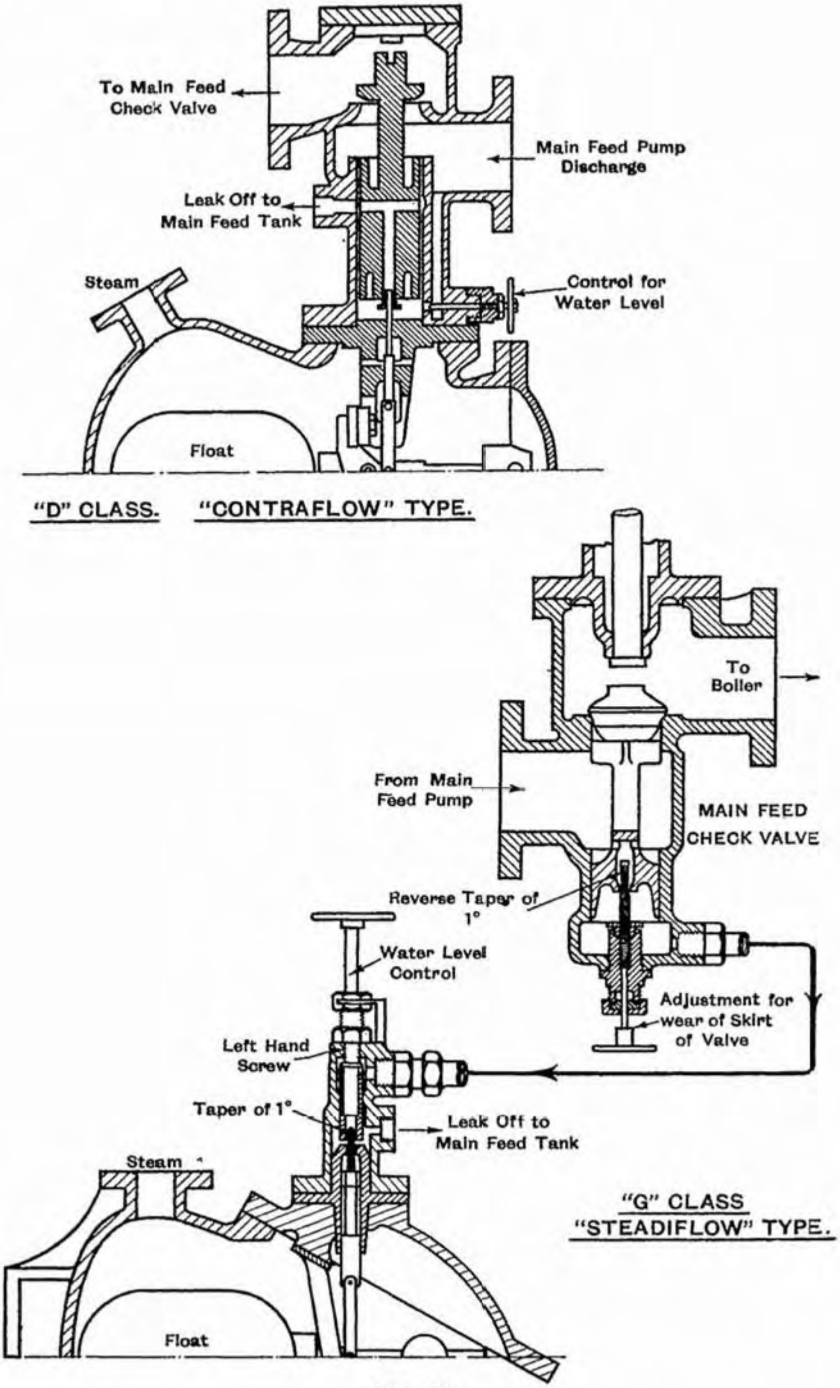


FIG. 20.
Feed Regulators.

(8) Internal Fittings.—The slots in internal steam pipes and feed pipes have been spaced to ensure an even flow of steam and distribution of water along the drum, and satisfactory trials of many vessels have been carried out with internal steam pipes omitted altogether.

A circulation augmentor in the form of a coffer dam in the steam drum was fitted for experiment behind the fifth row of generator tubes in an F class destroyer, and rates of forcing approximately 50 per cent. above the normal full power for prolonged periods were reached without the slightest damage to the boiler. (*See also* article No. 2 of this Issue.) Circulation augmentors are now being fitted generally in new construction.

Trials are also being made to see what effect the complete omission of zinc slabs has upon the life of the boiler.

(9) Sirenettes.—Considerable trouble has been experienced at intervals with these fittings, and the solution has been retarded by difficulties in carrying out full scale experiments of sufficient duration. The principal difficulty has been caused by leakage of steam to the underneath side of the rotor, which causes considerable upward thrust leading to wear of thrust surfaces and eventual fouling of the rotor and casing.

After extensive experiments a modified design was produced in which the upward thrust has been reduced to a very low figure. The new sirenettes were fitted in the G class and no further trouble has been experienced.

Fig. 21 shows the old and the modified types.

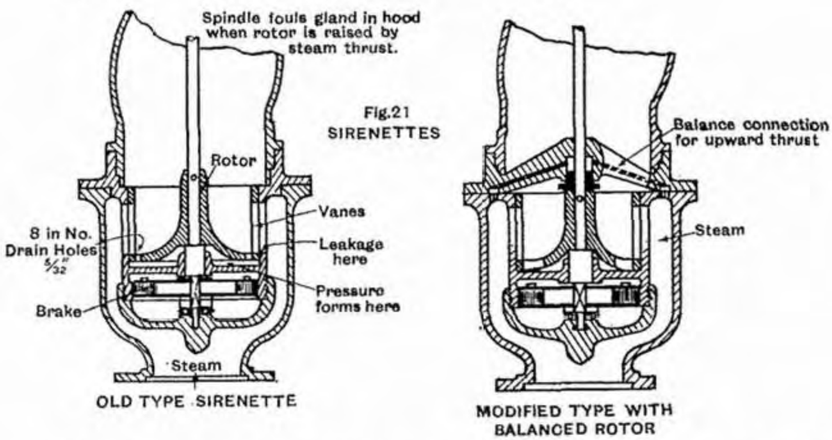


Fig.21 SIRENETTES

(10) Turbines.—The main features of the turbines have already been described and the construction of the H.P. and cruising rotors are indicated in Figs. 2, 3 and 5. The whole H.P. casing is of cast steel and in the A to D classes the top halves are made in two portions with a vertical joint at the impulse wheel. Considerable trouble was experienced with leakage from these vertical joints, and the top halves of all the later turbines are cast in one piece. In the E and F classes the forward feet are also cast integral with the bottom half casings.

The H.P. reaction blading is of the end-tightened type and is made either of monel metal or stainless iron. The latter material is cheaper, but the operation of brazing the roots of the blades has given some trouble. Briefly the process is as follows :—

The blades are thoroughly cleaned, then built up into segments on formers, the roots being secured either by a root wire or in the case of stainless iron blades, by running a small line of welding along their base. They are then dipped into the brazing bath. After cleaning, serrations are machined on the roots and the blades are fitted to the rotors, being secured at the sides by mild steel locking pieces (*see* Fig. 22).

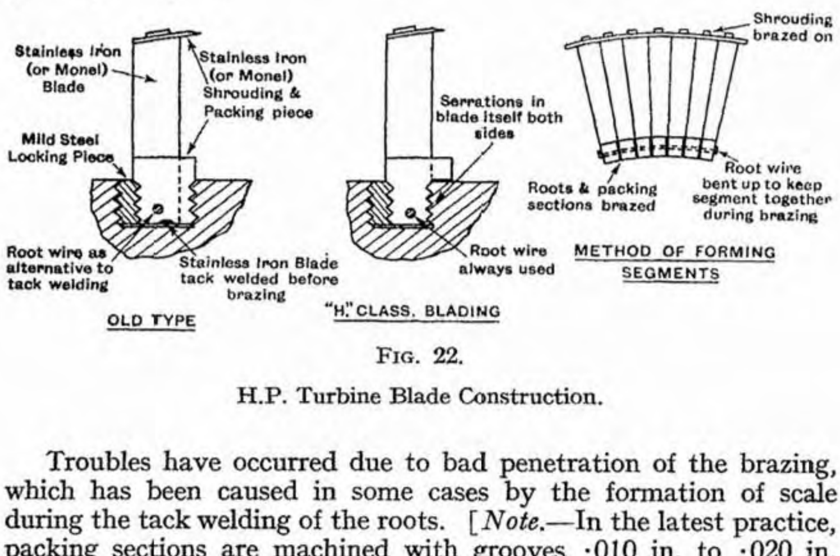


FIG. 22.

H.P. Turbine Blade Construction.

Troubles have occurred due to bad penetration of the brazing, which has been caused in some cases by the formation of scale during the tack welding of the roots. [*Note.*—In the latest practice, packing sections are machined with grooves ·010 in. to ·020 in. deep on front and back to ensure penetration of brazing metal.]

(11) L.P. Turbines.—L.P. turbines are of double flow type with the astern turbines at the forward end and the condensers underslung. The construction of both rotor and casing was fundamentally altered in the E class and later destroyers (*see* Fig. 23). This alteration has resulted in saving of weight of about 5½ tons per ship. It has been objected that the conical construction of the E class casing is liable to lead to fouling of the blade tips if any differential expansion occurs between rotor and casing, but in theory at least, the blades would foul axially by touching the adjacent row of fixed blading before the radial clearance was absorbed, as is shown by the diagram of a typical case, Fig. 23.

In some cases however, fouling of blade tips has occurred in the forward flow and the indications are that local distortion of the casing may in part be the cause as well as differential axial expansion.

All L.P. casings are of cast iron and the astern portions are cast steel.

Up to the D class, the L.P. blading was of the individual type, the blades being of hard drawn brass. In the E class and later, segmental construction was introduced, the blading being exactly similar in dimensions to previous designs. This led to several interesting difficulties, the first of which was caused by the closing in of the blade passages of the first few rows of the L.P. turbines by

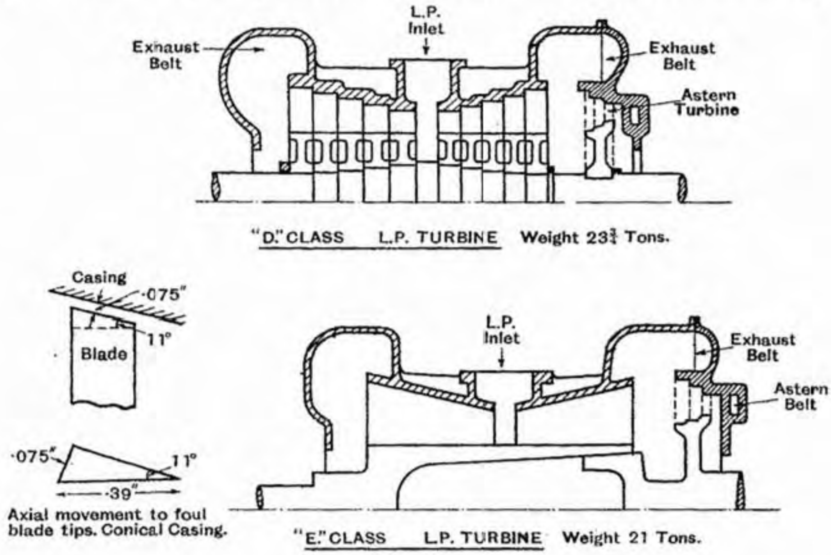


FIG. 23.

the clamps used to hold the segments during the operation of machining the serrations on the roots. This resulted in excessive L.P. receiver pressures at full power and trials were postponed until the areas between the blades had been corrected.

The second and more serious trouble occurred in the last few stages of the rotor and was not discovered until the F class shop trials. As a result of several failures during the overspeed trials, it was found that the operation of brazing the roots of the segments had annealed the hard drawn brass blades, and that these were being stressed beyond their yield point. The last four rows of blades in all L.P. rotors of the F and G classes were thereupon replaced by stainless iron blades. The stresses in the blades in the rest of the turbine are well below the yield point of the original material so that replacement was not essential. In the H and later classes, stainless iron blades are used throughout.

As a general rule, all impulse blading is of A.T.V., but trials are being made with other materials which offer high resistance to erosion.

(12) Impulse Turbines.—The only turbines of this type fitted in standard post-war destroyers are the H.P. turbines in two A and two B class destroyers. These turbines were fitted in conjunction with standard Parsons type L.P. turbines. Trouble occurred due to vibration of the eighth stage wheel during "Acasta's" trials and these were replaced by wheels with stiffer rims and wider blades. Further trouble of a similar description appeared in the seventh stage wheels of "Basilisk" and after about five years running "Acasta" and "Achates" also developed defects in the seventh stage blading.

In "Fortune" and "Foxhound" Messrs. John Brown fitted H.P. turbines with three impulse wheels, the remainder being reaction blading of the ordinary type. Arrangements were made to by-pass some of the steam past the first and second wheels at full power, while economy at low power, almost equal to that of the other vessels of the class fitted with cruising turbines, was obtained by fitting suitable groups of nozzles.

Fig. 24 shows a diagrammatic arrangement of this turbine. It will be noted that it was necessary to fit a vertical joint in each half of the casing to facilitate machining. This feature is a bad one and may lead to leaky joints.

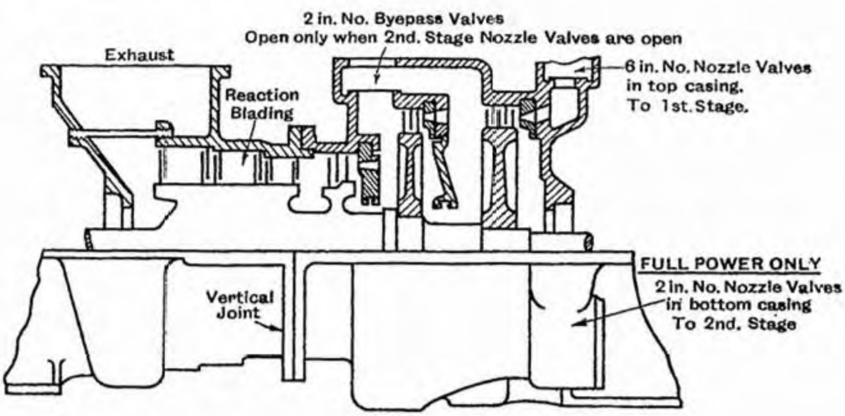


FIG. 24.

H.M.S. "Fortune." H.P. Basis Plan.

Trials of these vessels were very successful except for a certain amount of vibration of the H.P. turbines at full power, which either caused or was caused by fracture of a number of the carbon glands into small pieces. No other defects, however, ensued.

The great disadvantage of this design for a destroyer with its small watch-keeping complement is the large number of nozzle and by-pass valves, amounting to 20 in each vessel, which have to be operated at varying speeds.

(13) Cruising Turbines and Clutches.—The cruising turbines fitted in the E and F classes are similar in construction to the H.P.'s except that the rotors are solid forgings (*see* Fig. 3).

The clutches (Fig. 25) are of the mechanical type and are arranged so that the turbines can be clutched up and declutched with the vessel under way. The full power revolutions of the cruising turbine

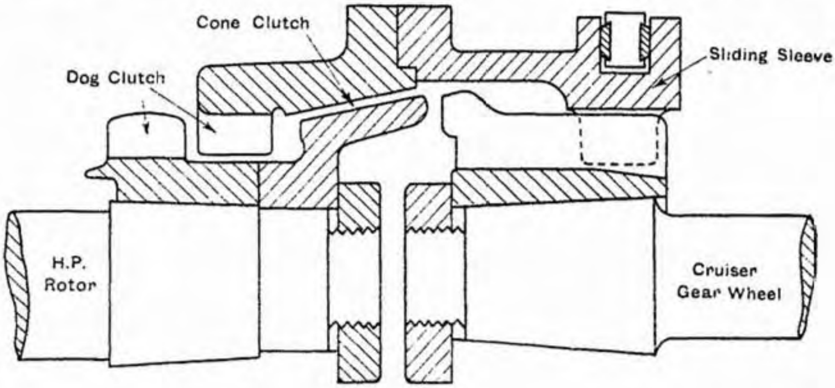


FIG. 25.
Diagram of E and F Class Cruising Clutch.

corresponds to about 188 r.p.m. on the main shaft, but the turbine and gearing are so designed that they can be trailed in vacua up to 280 r.p.m. of the main shaft, should a rapid increase of speed be required before they can be unclutched.

A synchronizing indicator, consisting of a differential driven from either side of the clutch, is provided for use when clutching up. The cruising turbine is speeded up until this pointer is steady, and the clutch is then engaged by putting the lever first over to the friction cone to bring the two shafts exactly into synchronism and then engaging the dog clutch.

An Aspinall emergency governor worked from the forced lubrication system is provided on the cruising turbine. This is, however, a somewhat complicated fitting and is of doubtful utility with a mechanically operated clutch. With an oil operated clutch it is an essential safeguard.

(14) Gearing.—In the E and earlier classes, the gear wheels and pinions had double helical involute teeth, and a centre bearing was fitted to each pinion to reduce the deflection due to bending of the pinions. Trials were made with new shapes of teeth in " Crescent "

(V.B.B.) and "Delight" (A.A.), and as these proved satisfactory the F class and subsequent vessels have been fitted with the new tooth shapes. Details of these teeth will be found in "Papers on Engineering Subjects" No. 14. Their introduction enabled the width of the gear face to be reduced considerably on account of higher permissible loading per inch length of pinion and in consequence, it was found possible to omit the centre pinion bearings. These modifications resulted in savings amounting to about 8 tons per ship in the gears and gear case.

Experiments are also being carried out in certain vessels to to find the effect of lightening the gear wheels by reducing the thickness of the rim and plates.

(15) Gear Case.—Fundamental alterations in the construction of the gear cases have been made in the G class and later vessels. Fig. 26 shows a diagram of these alterations. It will be noted that the gear case is now reduced in thickness and cast in one piece with an aluminium cover over the whole (*see* Fig. 26.)

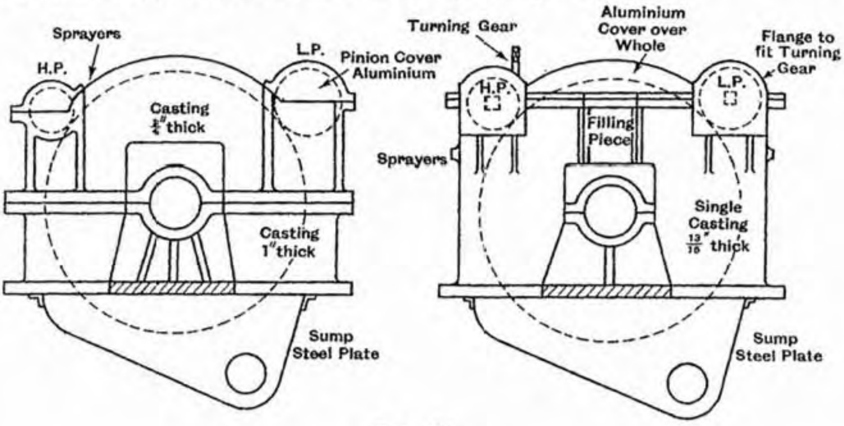


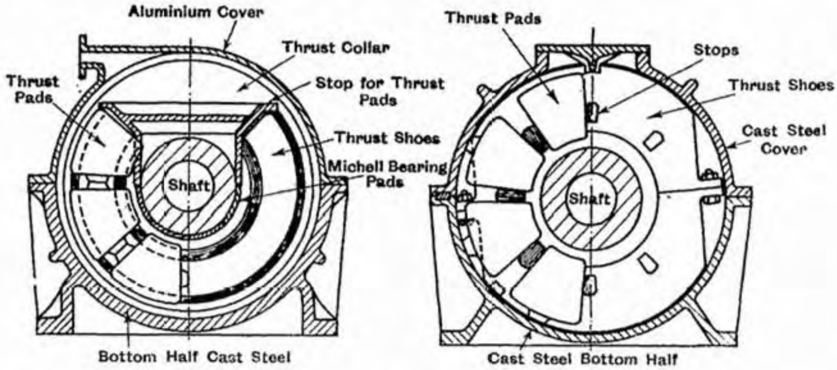
FIG. 26.
Gear Case Design Alterations.

It will be noticed that filling pieces have been fitted to enable the gear wheel to be removed and the turning gear is now fitted to one of the pinions instead of on the main shaft. This is lighter and easier to handle.

In the H class, the lubricating oil sprayer rail is cast in the gear case itself. By this means and by eliminating redundant webs on the casting, the amount of cleaning required has been considerably reduced.

The drive for the revolution counters is now taken off the forward end of the L.P. turbines instead of from the gear wheel. This alteration involves a small error of the order of $\frac{1}{4}$ per cent. in the reading of shaft revolutions on account of the presence of the hunting tooth on the main gear wheel.

(16) Thrust Blocks.—A new type of thrust block was introduced in the B class. The thrust pads are now carried in a U-shaped steel forging which rests on the bottom half of the casting only. The top half is a light aluminium cover. Fig. 27 illustrates the difference between the two types.



G Class. A Class.

FIG. 27.
Main Thrust Blocks.

In H.M.S. "Grenville" the bottom half of the main thrust block is cast in one with the gear case. This leads to a danger of the propeller thrust being taken by the gear case casting, although it saves space. The thrust collar is also solid with the gear wheel hub. This necessitates the provision of a small thrust surface in the plummer blocks for use when trailing, but saves the weight of one shaft coupling.

(17) Plummer Blocks.—The increased length of the A class propeller shafting compared to V's necessitated fitting plummer blocks. These are self-lubricating, and in the F class and later destroyers water cooling has been omitted, the castings being provided with a number of fins to assist air cooling.

(18) Shafting, etc.—Considerable trouble was experienced during some of the F class trials due to sudden overheating of the shaft bulkhead glands. This caused considerable whipping of the shaft, damaged the stuffing boxes, and in some cases scored and slightly bent the shafts themselves. The trouble in all cases occurred at about 300 r.p.m. and was thought to be due to slight bending of the hull as the squat became more pronounced, *i.e.*, as the stern became more waterborne at high power. It is hoped to overcome this difficulty by the development of a new design of gland which will be fitted in a new construction destroyer for trial.

Trials have been carried out with "Cutless Rubber" lined A bracket bearings with a view to reducing vibration and saving renewals. These bearings are lubricated by salt water, and being of rubber should never be touched with oil. Their behaviour during extended trials has been satisfactory, the only point of note being a curious squeaking as the shaft started from rest.

The objection to this type of bearing from a naval point of view is that of re-rubbering the bush when the clearance becomes excessive, as, at the moment, only one firm in this country has developed the necessary vulcanising process, whereas the re-wooding or re-metalling of normal types presents no difficulties. The supply of spare rubbered bushes is not considered expedient at the moment and alternative methods of repair are under consideration.

Considerable trouble has been experienced in older vessels due to rapid grooving of propeller shafts in way of the stern glands. This is thought to be started in the first place by corrosion and roughening of the shaft under the gland, which tears new packing, and leads to leakage and excessive tightening up. A finger piece has been provided in the G class so that the wear down of the inner stern tube bearing can be measured without unpacking the gland so frequently.

New types of oil lubricated stern tube bearings, developed in sloops, are now being tried in destroyers. In these designs, oil tightness at both inboard and outboard ends is maintained by a special form of gland which obviates wear of the shafts.

(19) Closed Feed System.—The system was adopted in destroyers mainly because it provided the most convenient method of employing rotary extraction and feed pumps, which have the following advantages compared to reciprocating pumps :—

(1) Saving of weight and space (*see* Table XXVIII).

(2) Saving of upkeep.

(3) Possibility of using superheated steam.

The requirements of rotary pumps also led to the development of automatic float gear for condensers and to the perfecting of boiler automatics so that the present feed system as fitted in destroyers requires far less attention than the old system.

TABLE XXVIII.—COMPARISON OF WEIGHTS OF FEED SYSTEMS.

C Class. Open Feed System.	Cwts.	G Class. Closed Feed System.	Cwts.
2 air pumps and augmentors	141½	2 extraction pumps	35½
6 main feed pumps (reciprocating)	106	2 air ejectors	26
		2 main feed pumps	52
		2 float controllers	7½
	247½		121

Saving per ship, 6·3 tons.

The requirements for which a closed feed system in a destroyer is designed are as follows :—

(*a*) The main feed pump delivers the full output of all boilers at full power plus a margin of 30 per cent. for emergencies.
(*b*) The two extraction pumps between them must be capable of supplying the full requirements of the main feed pump under all conditions, otherwise the feed pump will run short of water and, being pressure governed, will race and trip.
(*c*) The make-up ports in the feed controller must be capable of passing the full requirements of the extraction pumps from the main feed tank to the condenser for use in case steam is suddenly shut off when proceeding at full power.
(*d*) The overflow ports must be capable of passing sufficient water from the condensers to the main feed tank to prevent the level in the condenser rising unduly when speed is increased suddenly.
(*e*) The automatic feed regulators must be designed, in conjunction with the feed discharge system, to pass the feed required for full power +30 per cent. to each boiler with the feed check valve fully open. The discharge pressure of the main feed pump can be adjusted slightly to asist with this latter requirement.
(*f*) The air ejectors must be capable of maintaining the specified vacuum.
(*g*) The system is also required to be worked at low powers with one extraction pump and one ejector only in action.

In fulfilling the above requirements the greatest difficulty is to maintain an adequate suction head at the eye of the extraction pump under all conditions of heel and trim. Until recently, extraction pumps which would work satisfactorily at the low suction heads available in destroyers had not been designed, but Messrs. Drysdale & Weir have now produced a pump which gives the whole output required with a suction head of as low as 10 ins.

Fig. 29 shows the output of this type of pump when working against a 28-in. vacuum with condensate at the corresponding temperature.

Let us now consider the effect of heel upon the performance of this pump. In destroyers the closed feed system is designed to work at full power at maximum angles of heel of 16° either way. This gives ample margin over the figures of heel recorded when turning at full speed.

Case 1 : *Two pumps in use. Ship at* 16° *heel.*—Suppose the pumps are placed at the centre lines of each condenser, the effect of

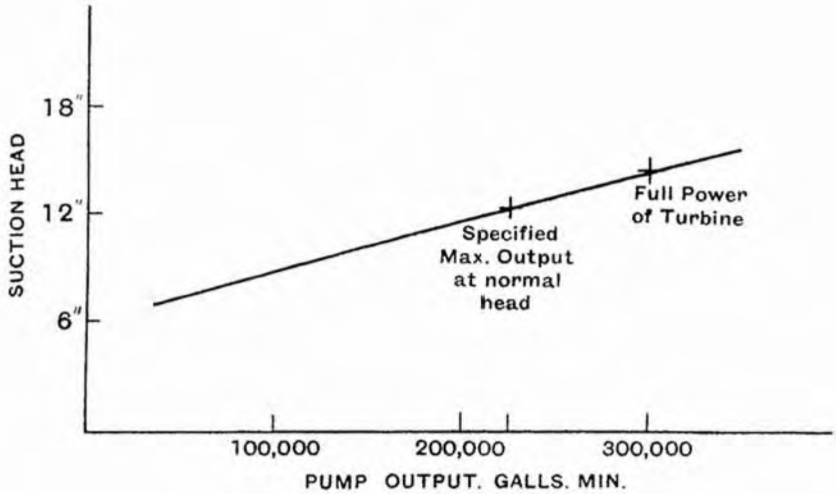


FIG. 29.

Output of Extraction Pump at Constant Speed.

heel will be to reduce the available suction head very slightly, but if they are placed at the centre line of the ship, at the same distance above the outer bottom as previously, the suction head on the low pump will be reduced and that on the high pump increased under heel (*see* Fig. 30).

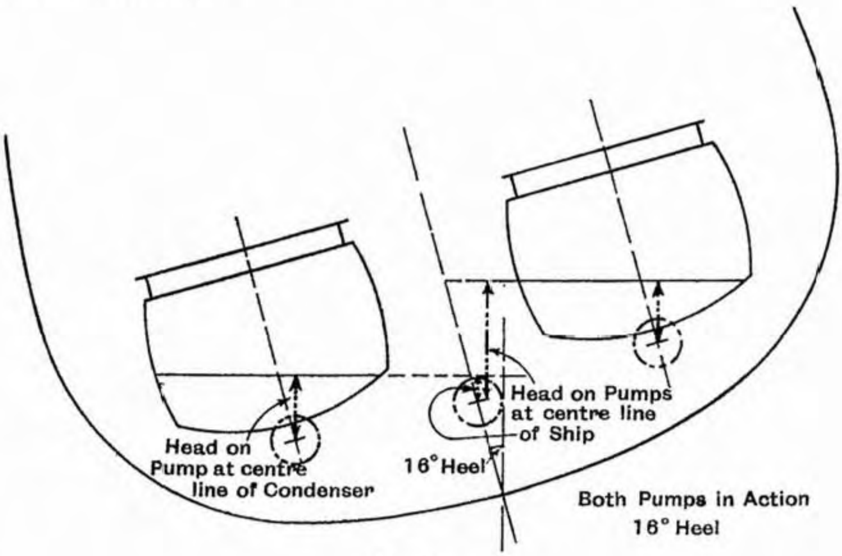


FIG. 30.

Effect of Position of Pump on Available Head.

It will be readily seen that, in the case of pumps on the centre line of the ship, the reduced output capacity of the " low side " pump must be such that, when combined with the increased output of the "high side" pump, the maximum requirement of the feed pump can be met, the limit of capacity of the " high side " pump being set by the power of the driving turbine.

Case 2: *One pump in use. Ship at* 7° *heel.*—Under these conditions only one feed controller is used, to prevent the system hunting, and as the amount of water required is small, the question of suction head does not arise. There is, however, a danger of flooding the opposite condenser to such an extent that the air cooling nest baffles become waterlogged, in which case the ejectors will pick up water and the vacuum will be lost. Fig. 31 indicates

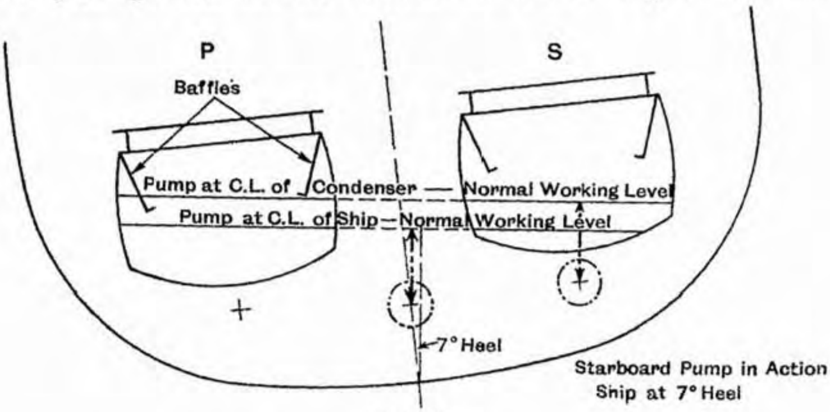


FIG. 31.
Effect of Position of Pump on Flooding Baffles.

the effect of the position of the extraction pump in this matter and it will be seen that under low power conditions the best position for this pump is at the centre line of the vessel.

Case 3: *Effect of trim at high power.*—It is not generally realized that a destroyer trims about 8 ft. by the stern at full power. The resultant effect upon the feed system is appreciable and leads to a danger of flooding the bottom condenser tubes at the after end.

We have therefore to choose a mean position for the extraction pump such that it will give its full output under all conditions and at the same time will not flood the air cooling nests or condenser tubes, although some flooding of the latter is inevitable under certain conditions of heel. The pump must also clear the ship's framing and be reasonably accessible for examination and repair.

The rapidly tapering section of the ship, together with the gear case seats, make it impossible to fit the pumps at the after end of the condenser and they are therefore fitted at the forward end, usually about 2 ft. off the centre line of the condenser. The float control boxes are fitted as nearly as possible on the centre lines of the pumps.

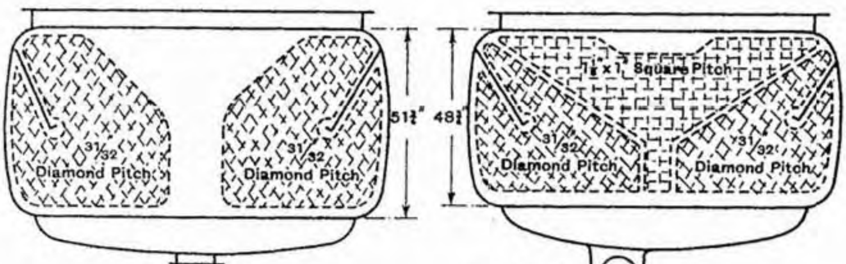
In the F class they were on top of the reserve feed tank and separate from the pumps, but in the G and later classes they are attached at the back of the pumps themselves (*see* Fig. 32).

In the diagrams referred to above, the water level in the condensers has been assumed to be stable under all conditions, and surge baffles are fitted inside the condenser sump to assist in this direction, but when turning at high speed these conditions obviously do not apply and the water will tend to bank up on one side of the condenser. To guard against loss of suction under this condition, an emergency suction is led from the main feed tank to the main feed pump with a light " plate type " non-return valve, which is normally kept closed by the pressure of the extraction pump discharge.

(20) **Air Ejectors.**—Three-stage salt water cooled air ejectors are fitted in destroyers, as these are not only smaller and lighter than the condensate cooled type, but permit of a much more convenient arrangement and are easier to manipulate, in that failure of an extraction pump does not affect their performance. On the other hand, they waste heat and are a possible source of contamination of the feed water.

(21) **Condensers.**—From the foregoing it will be seen that in destroyers with closed feed it is most desirable to reduce the depth of the condenser tube plate as much as possible in order to give sufficient suction head for the extraction pumps. For the A to E classes the majority of condensers were of the regenerative type with a large lane down the centre of the tube nest, the total tube surface being varied in accordance with the horse-power.

In the F class, however, the central lane was filled in with widely spaced tubes transferred from the bottom of the nest thus decreasing the depth of the tube plate and improving the suction head over the extraction pumps. (*See* Fig. 33.) The effect of this improvement was, however, largely discounted by the increased pressure drop



" Electra " and " Encounter."   F Class.

Fig. 33.

Condenser Tube Plates.

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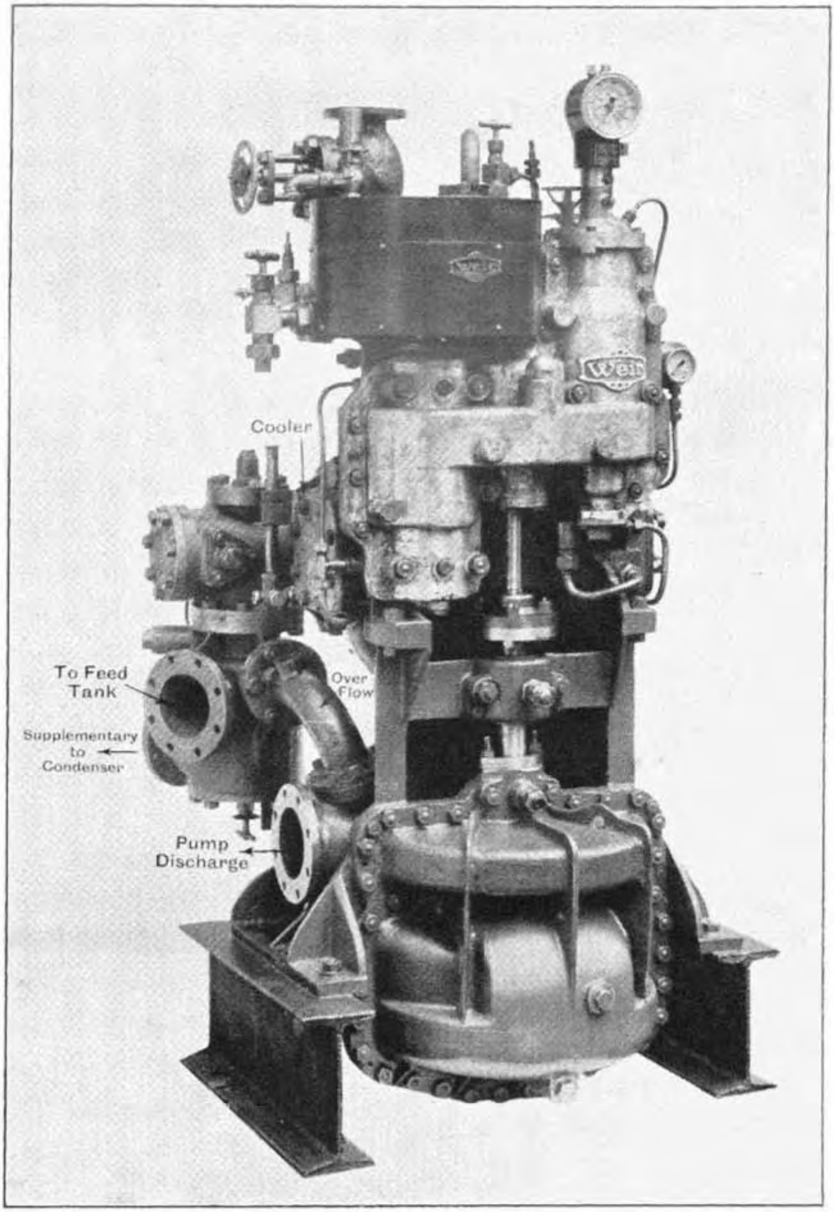

FIG. 32.

Extraction Pump and Feed Controller.

across the tube nest, which increased the vacuum required at the air pump suction, but it also led to slight undercooling of the condensate which had a beneficial effect on the performance of the extraction pumps.

Further experiments are being carried out in G and H class vessels with a view to reducing the pressure drop across the tube nest and at the same time retaining the slight undercooling effect.

After many experiments to find a more suitable material than drawn brass, copper nickel has been specified for all condenser and cooler tubes since the B class and no failures in material have yet occurred. John Crane's tube packing, which was described in Issue No. 14 of these Papers, was first fitted to the E class condensers, but considerable trouble was experienced owing to faulty tapping of the holes in the tube-plate which did not allow the ferrules to be screwed in far enough to make a satisfactory joint on the back washers. (*See* Fig. 34.) Other defects were caused by bad fitting

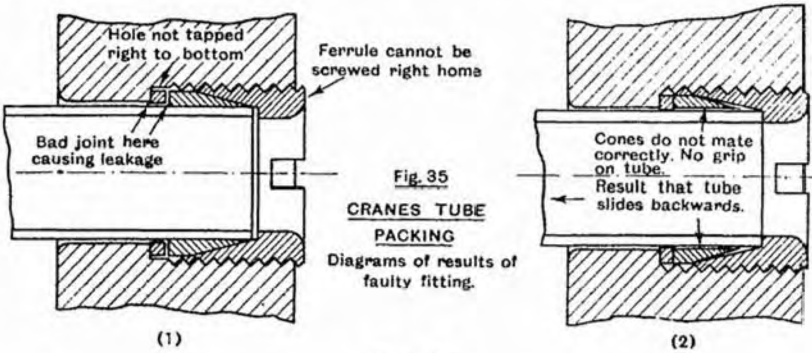

FIG. 34.

of the male and female cones so that the tubes were not properly gripped by the male cone and gradually vibrated back.

Correct fitting and resultant satisfactory service are being obtained by more rigid inspection during manufacture.

(22) Circulating Pumps.—Circulating water supply to the condensers is arranged by taking advantage of the scoop action of the water in a specially shaped inlet pipe. External scoops are not fitted. Auxiliary outlets are fitted from the top of the after doors to improve circulation in the top tubes.

This system has been in use since the A class destroyers, but with vertical spindle centrifugal circulators full advantage could not be taken of the scoop effect as difficulties arose over trailing the circulators. There was also very natural aversion to shutting steam off the circulator turbines on account of the possibility of a sudden call for manœuvring of the main engines.

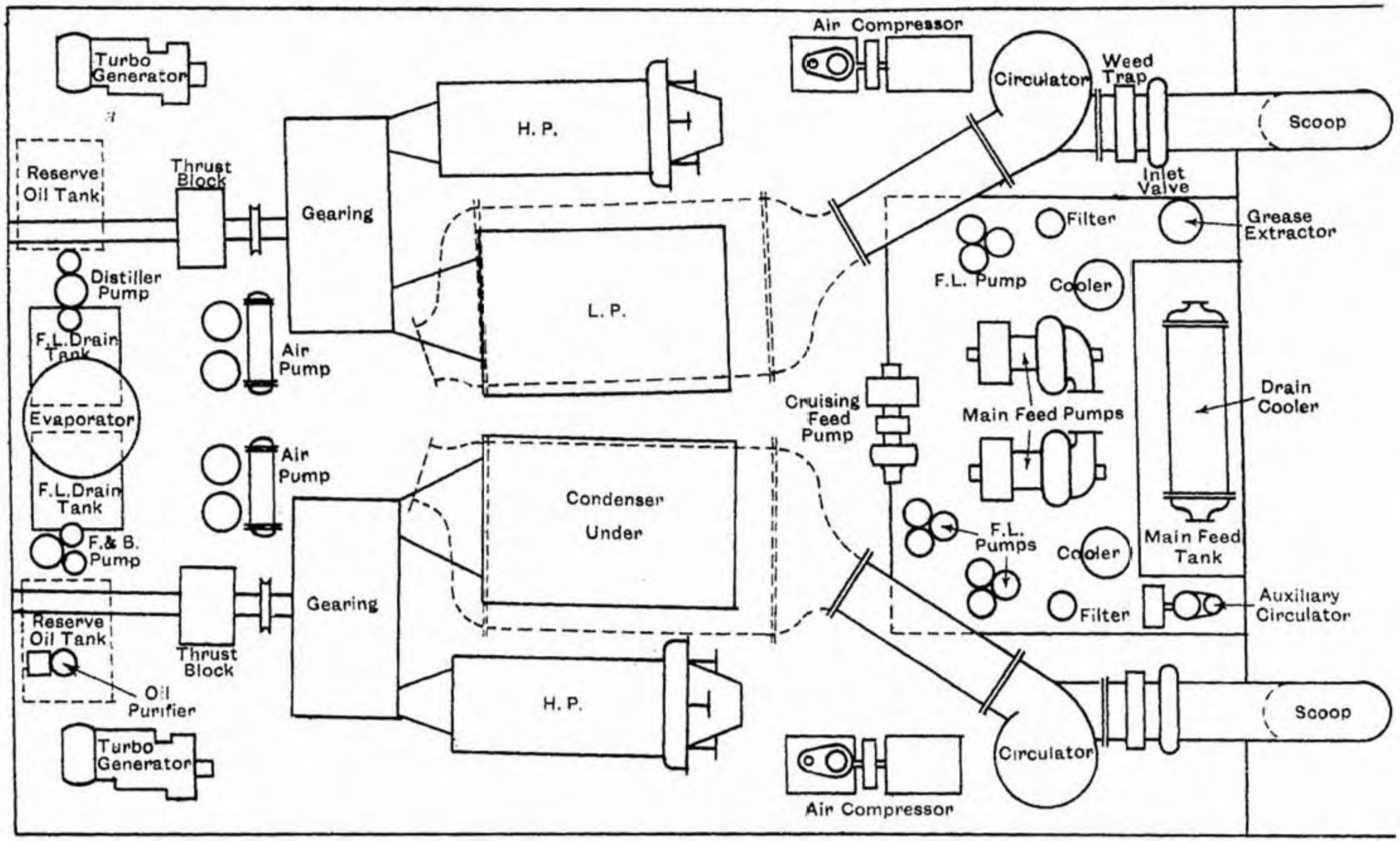

FIG. 36.

D Class.. Engine Room Arrangement.

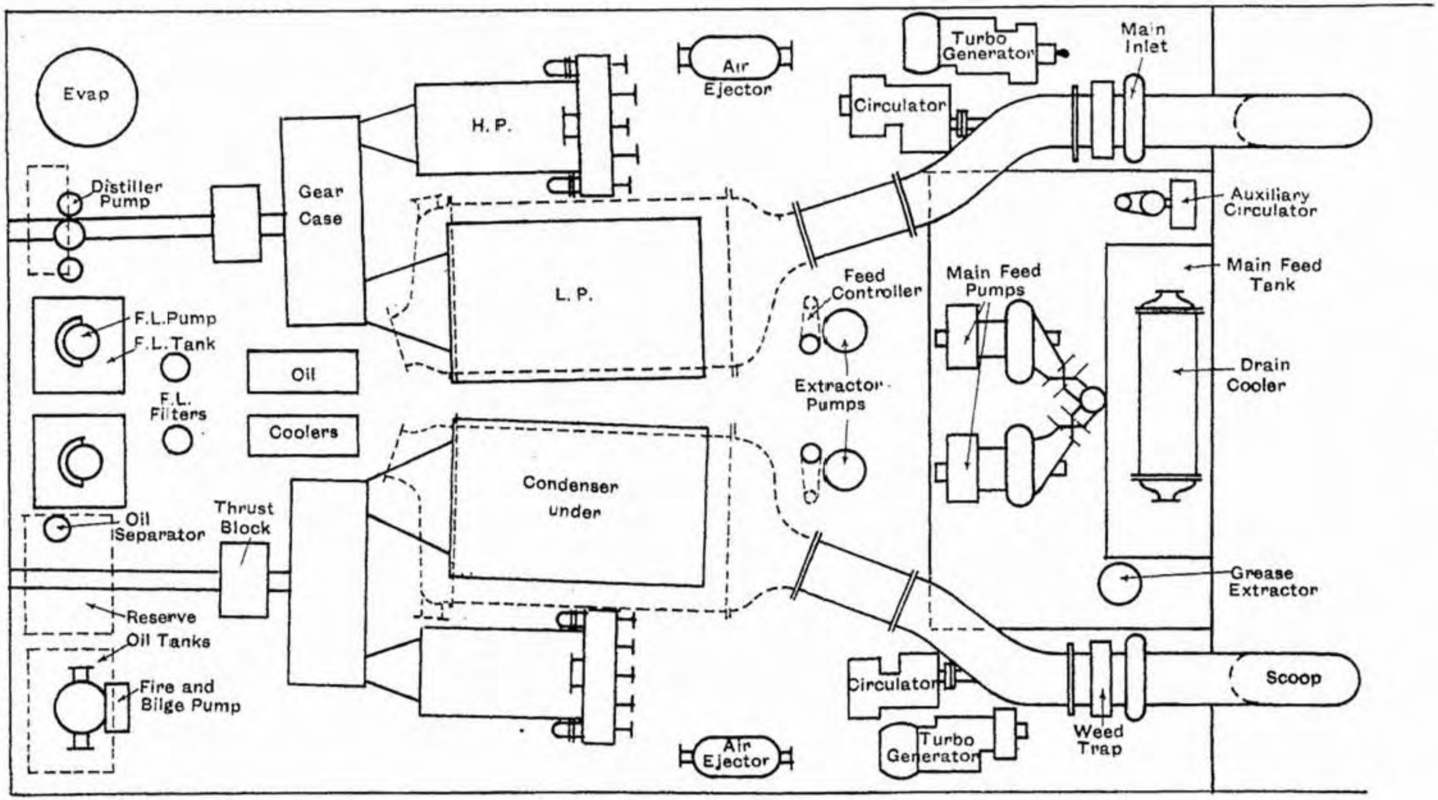

FIG. 37.
G Class. Engine Room Arrangement.

The introduction of the axial flow type of circulators (Fig. 35), which were fitted for trial in H.M.S. " Decoy " and " Delight," has overcome these objections and this type is fitted in all E class and later vessels.

The low trailing loss in these circulators enables them to be trailed at all speeds up to practically full power, and some vessels have carried out their full-power trials with circulators trailing without appreciable loss of vacuum. Special provision is made for rapid starting of the circulators in emergency and the turbines are kept warm while trailing by the use of a small by-pass on the steam valve.

In the latest types, the impeller bearings are lined with " Cutless Rubber " similar to the " A " bracket bearings, an object in this case, in addition to that of reduction of wear and maintenance, being to eliminate the necessity for grease lubrication with the accompanying danger of fouling the condenser tubes.

(23) General Arrangement of Machinery.—Large variations in the machinery arrangement of a destroyer are not possible without adding greatly to weight and space required. Arrangements with two engine rooms and with alternate engine and boiler rooms have been attempted on paper, but the very considerable increase in the length of machinery spaces together with the increased engine room complement which would be required have made them impossible in a vessel of only 1,500 tons displacement.

The requirements of gear case drainage and head of water at the extraction pump suction are the principal factors affecting the position of the main engines.

In the arrangement of auxiliary machinery, however, large alterations have been made in the latest engine rooms with the idea of reducing the length and resistance of the various pipe systems and thus saving weight and space.

Comparison of the D and G class engine room arrangements (Figs. 36 and 37) will show what has been done in this respect.

The ship's framing under the forced lubrication tanks is necessarily inaccessible until the tanks have been lifted, and in the G class arrangements are made for this being readily achieved by the provision of lifting gear and by keeping all pipes clear of the tank tops. The forced lubrication pumps are fitted directly on the tanks.

Cooling water for the following auxiliaries is taken from the inboard side of the main circulators :—F.L. oil coolers, air ejectors and dynamos which, it will be noted, are now fitted at the forward end of the engine room. In all cases care has been taken to reduce all bends in the pipe leads.

The inlet and discharge valves for these auxiliaries are of a streamline type to improve the flow of water (*see* Fig. 38).

The arrangement of boiler room machinery offers less scope for alteration, but care has been taken to keep pipes and fittings clear

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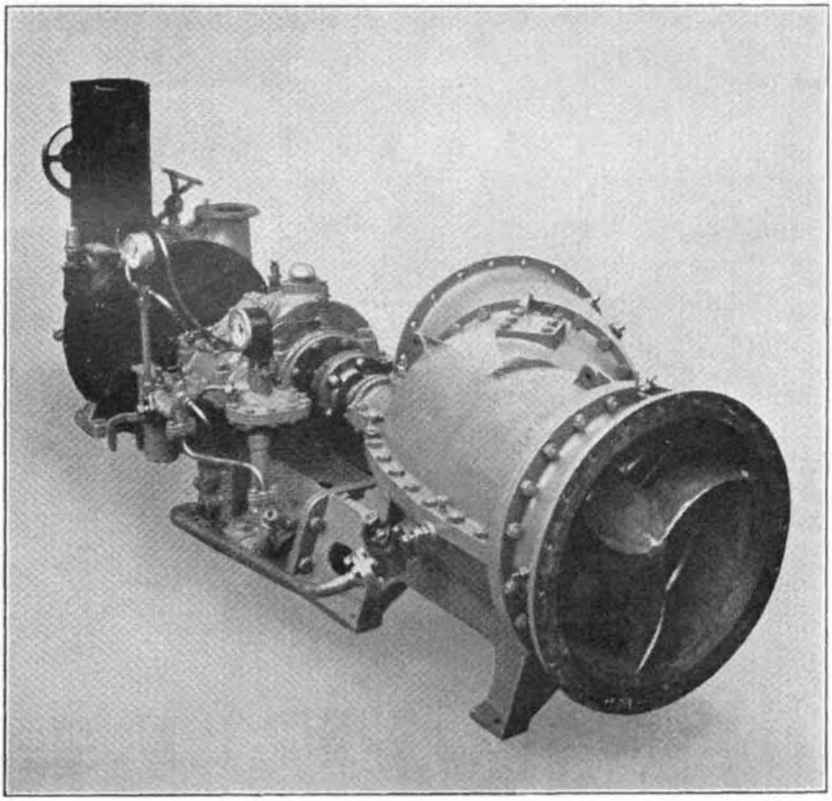

FIG. 35.

Drysdale Axial Flow Circulator.

of the superheater withdrawal space and, as already mentioned, boiler mountings have as far as possible been removed from the top of the steam drum and made more accessible.

Particular attention is paid to the provision of a central control position in each boiler room from which all gauges are readily visible and the oil fuel pump can be controlled. Extension spindles to fan and heater master valves are provided at this position.

A single feed heater is fitted in the after boiler room, and is of such a size that it will condense all the available exhaust steam down to very low powers. A nozzle plate is fitted in the feed heater drain which restricts the flow to the drain cooler and allows the heater to function without attention from the watchkeepers.

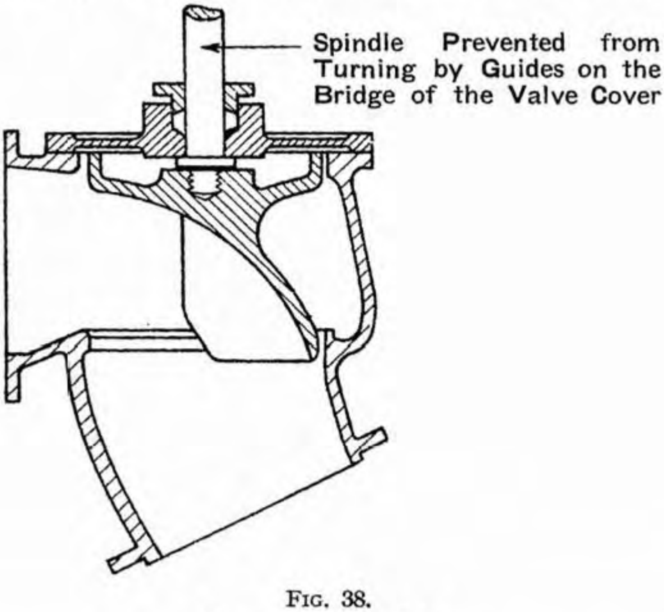

FIG. 38.
Stream Sea Inlet Valve.

The air compressors are fitted on each side of the after boiler room.

Auxiliary fuel tanks have been omitted in the G class, except in No. 2 boiler room, in order to reduce top weight and the Diesel oil tank is now recessed into Nos. 3 and 4 main oil tanks at the forward boiler room bulkhead.

A Diesel generator is fitted in the forward boiler room.

(24) Arrangement of Steam Pipes.—Fig. 39 shows the arrangement of main and auxiliary steam pipes in recent destroyers. The main stop valves are of the plain screw-down type and are fitted on each superheater header. There are small cross connection pipes

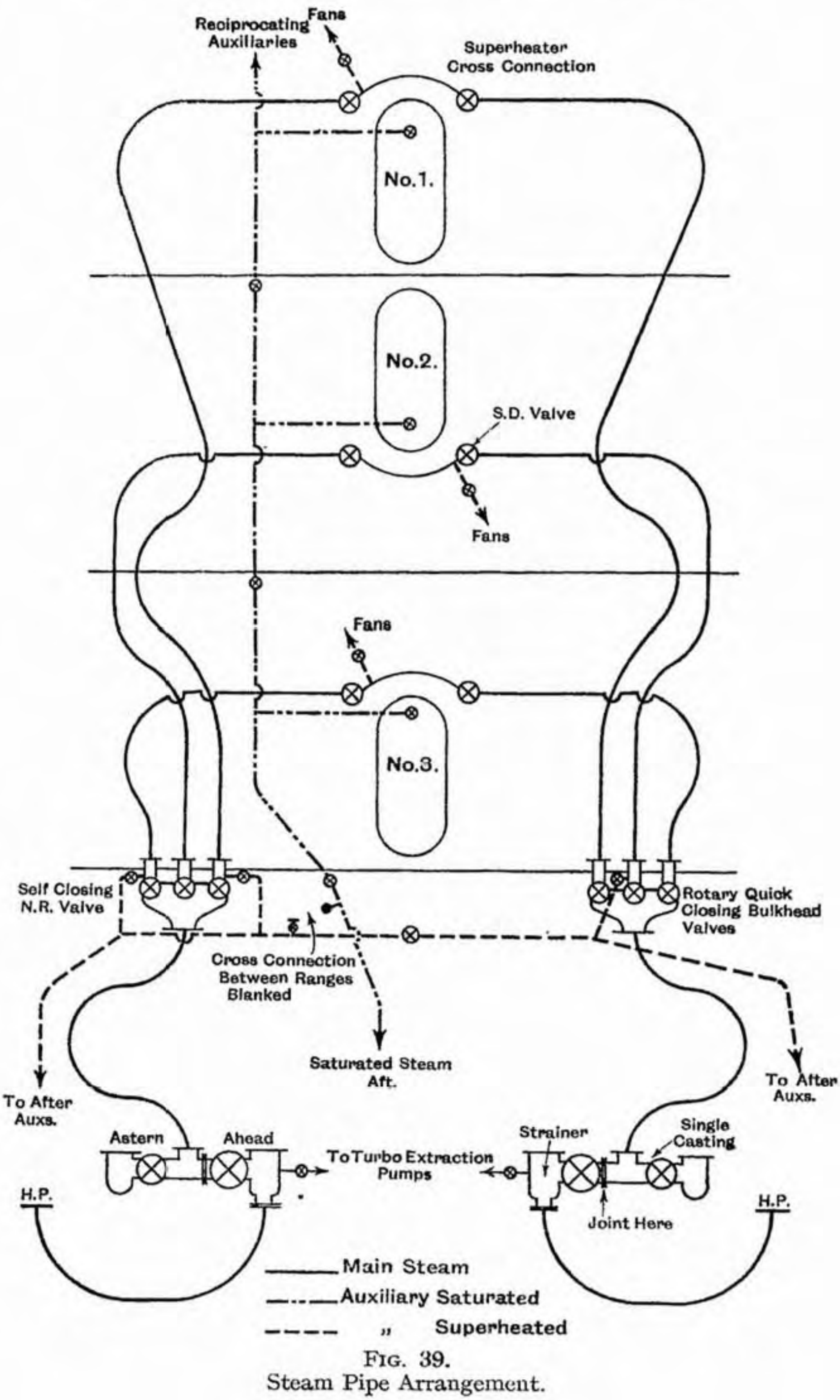

Fig. 39.
Steam Pipe Arrangement.

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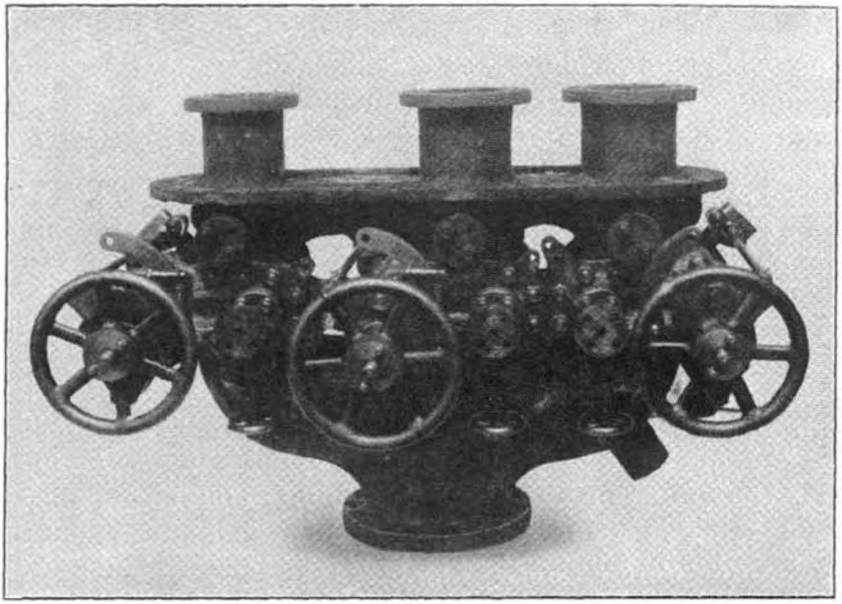

FIG. 40.

Rotary Quick-closing Bulkhead Valves.

between the outlet sides of the superheaters in order to maintain a flow of steam through the superheater tubes if one stop valve is closed.

The auxiliary bulkhead valves are of the self-closing non-return type.

The main bulkhead valves are mostly of Cockburn rotary slide type (*see* Fig. 40), but trials are being carried out with other types of parallel slide valves. The bulkhead valves are quick closing only, with two emergency levers in the engine room and two on the upper deck. They have to be opened by hand and are not self-closing.

This means that if a boiler room main steam pipe is carried away in action, the whole main steam supply has to be shut off at the engine room bulkhead by the emergency gear. Auxiliary steam is maintained from two of the three auxiliary bulkhead valves, while the third, that in connection with the damaged lead, closes automatically due to the reduction of pressure in that lead. The damaged lead is readily detectable by means of pressure gauges in the engine room and main steam supply from the undamaged leads can be restored by opening up the appropriate main valves individually. As it is not possible, owing to limitations of weight and space, to provide a complete unit system in a destroyer, this disadvantage must be accepted until a reliable and simple type of self-closing gear for the rotary bulkhead valves can be obtained.

In the C and D classes, leakage of the main steam joints was experienced at the tee piece adjoining the main regulating valves. This was caused by the collection of water over the joints when the manœuvring valves were shut. In later vessels this was overcome by casting the tee piece in one with the astern manœuvring valve, and leading steam from the ahead strainer (boiler side of valve) to the extraction pumps, thus ensuring a continuous flow of steam over the remaining joint under all conditions. The flanges on these and other fittings subjected to steam thrusts were also thickened about 30 per cent. above the normal figure.

Expansion of main steam pipes is taken by corrugated lengths of bent and straight pipes. The latter were introduced in order to shorten the length of lead and so reduce the pressure drop from the boilers to the engines at full power. This pressure drop is as high as 50 lb./in.^{2} and presents a formidable problem as, if pipes are made larger to reduce the loss, they have to be made thicker and therefore stiffer which entails longer pipes with more bends to give flexibility. The greatest care is therefore necessary in designing the valves and fittings on the main steam system to reduce resistance to flow. The pipes from the various boilers are of slightly different diameter in order to equalize the pressure drop.

Corrugated bent pipes were first fitted for trial in H.M.S. " Amazon " and these are being watched carefully with a view to detecting any signs of corrosion fatigue in the corrugations.

(25) Auxiliary Machinery.—Reciprocating auxiliaries have been replaced by turbo-driven units in the majority of cases. These were necessarily in an undeveloped state at first and have been modified in the later designs with the object of improving accessibility and facilitating handling under way. The auxiliaries will be taken in turn from the forward end of the ship and a brief reference made to the principal alterations in each case.

(26) Capstans.—Up to the C class, a single cable holder was fitted with the capstan engine on the mess deck, but in the D class, a new design was introduced with twin cable holders and the capstan engine on the upper deck. The first design was unsatisfactory in minor details and gave much trouble in upkeep, but in the later designs the engines were enclosed in a watertight box and the various parts stiffened up. The result has proved most satisfactory. Messrs. Clarke and Chapman carried out the development of this design, but other makers are now coming forward with similar engines. An experimental type has been introduced by Messrs. Reid in which the clutch is incorporated in the cable holder instead of being fitted on the worm shaft.

A further experiment is being made with a turbo hydraulic capstan consisting of a turbine and " A " end in the boiler room with the " B " end on the foc'sle. The drawback to this type is the extra weight entailed by the hydraulic transmission system, but it should give much finer control and, with the disappearance of other auxiliaries requiring saturated steam, it will be difficult to defend the retention of a separate steam system for the capstan and paravane winches only.

(27) Fans.—Geared turbo fans have been fitted in all post-war destroyers. Diffusers are fitted all round the fan discharge to distribute the air evenly in the boiler rooms and, so effective are these fittings, that the watchkeeping positions become extremely hot at low powers and special ventilation shutters have to be fitted. As a direct result, in the latest destroyers all fans revolve in the same direction in order to reduce the requirements of spares. Previously, those on different sides of the ship were handed in order to distribute the air supply over the whole of the boiler front.

The majority of fans are supplied by Messrs. W. H. Allen, but some are made by Messrs. Yarrow. The latter are direct driven and the power unit embodies an arrangement of " buckets " instead of the normal type of turbine blades.

Messrs. Allen have now developed a direct driven fan with a steam consumption very little inferior to their geared type. Fig. 41 shows this unit which has been fitted experimentally in two H class vessels.

Another fitting developed in connection with fans is the self closing shutter (Fig. 42). The object of this is to prevent the

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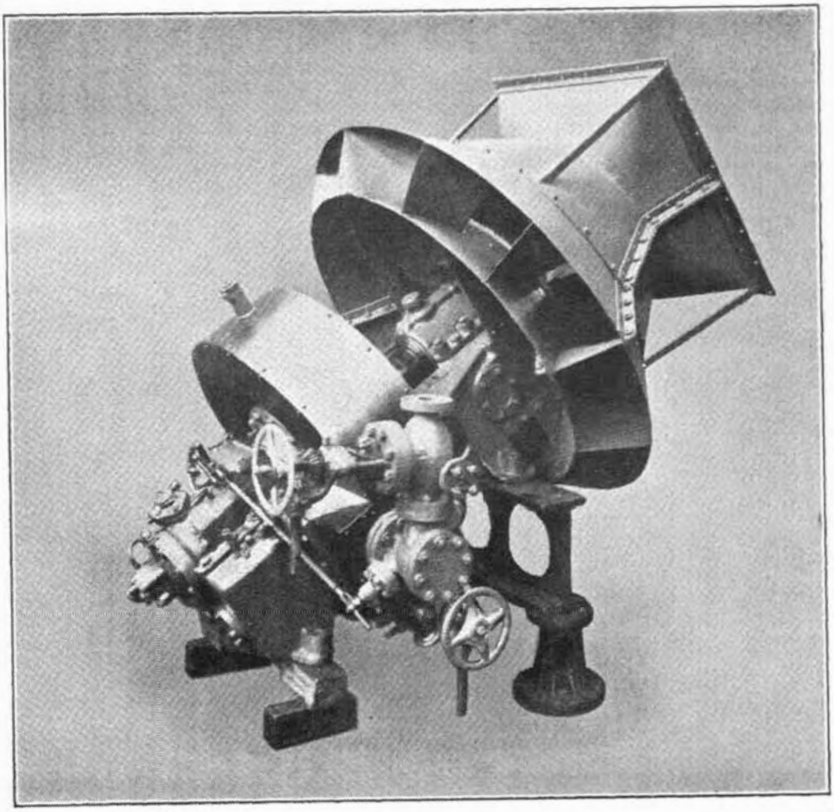

FIG. 41.
Allen Direct Drive Fan.

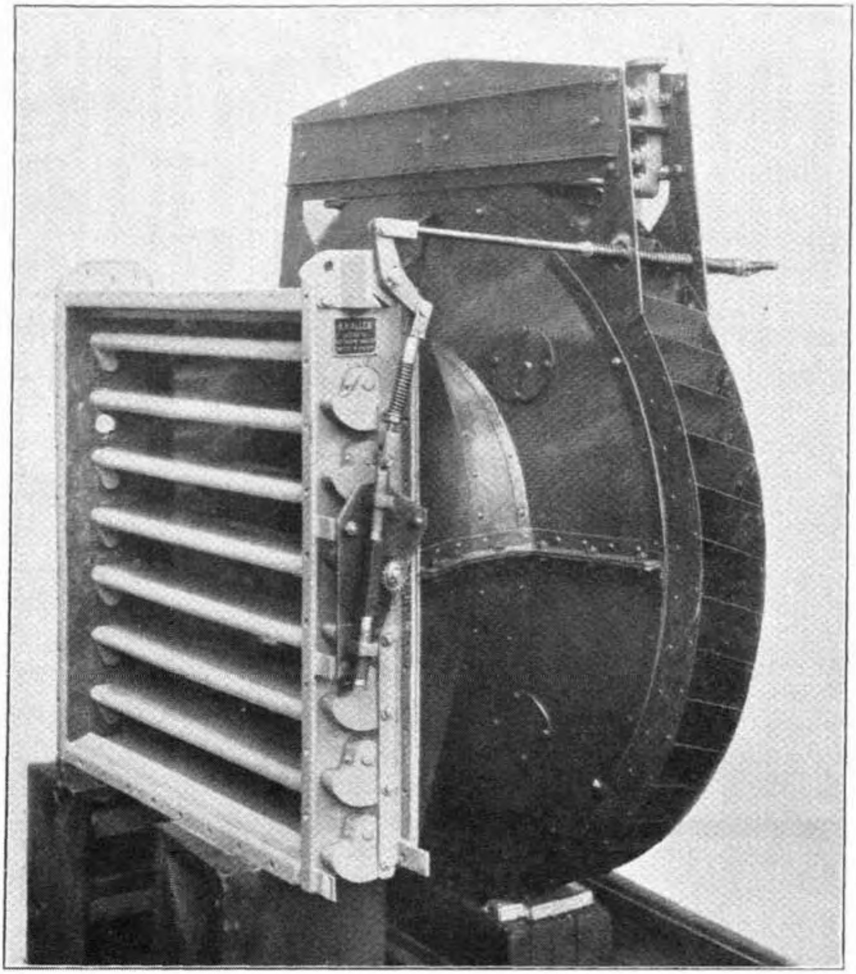

Fig. 42.
Self-closing Shutter.

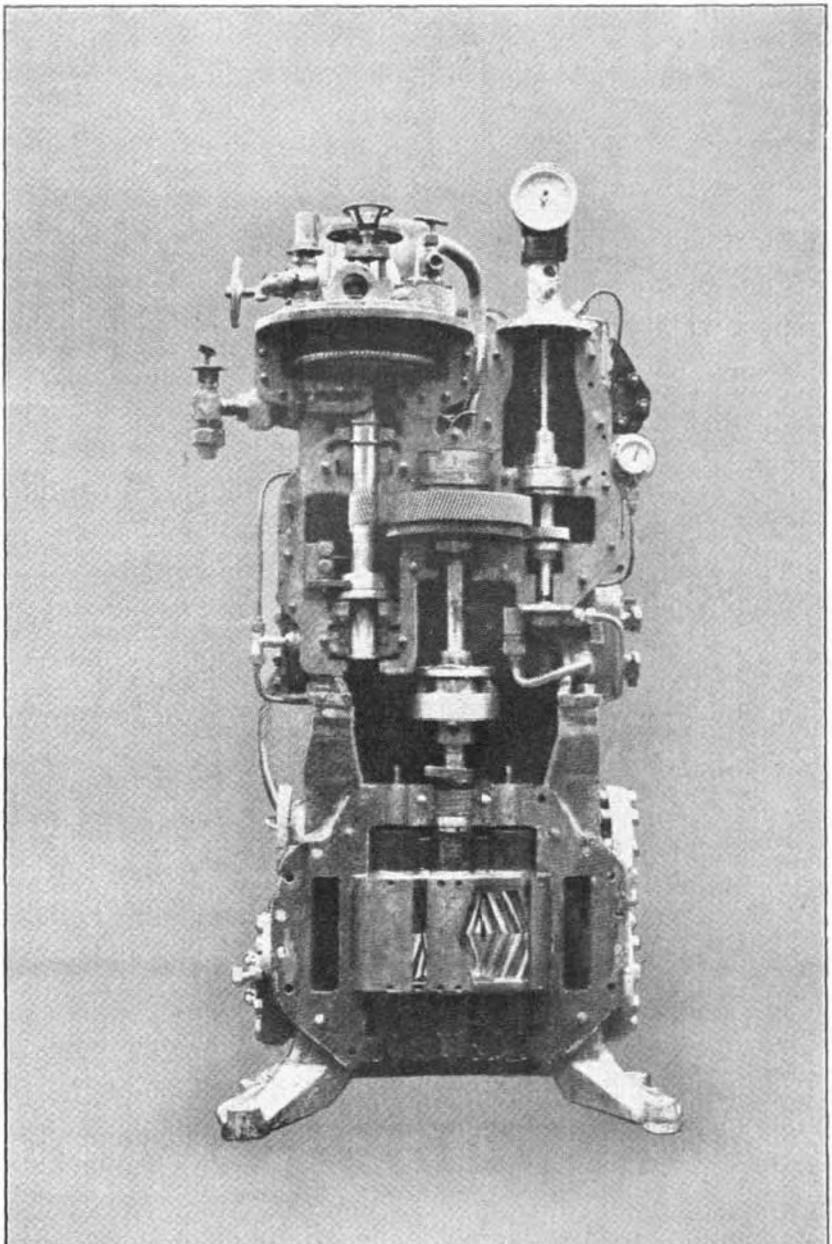

Fig. 43.

"Vertoil" Forced Lubrication Pump.

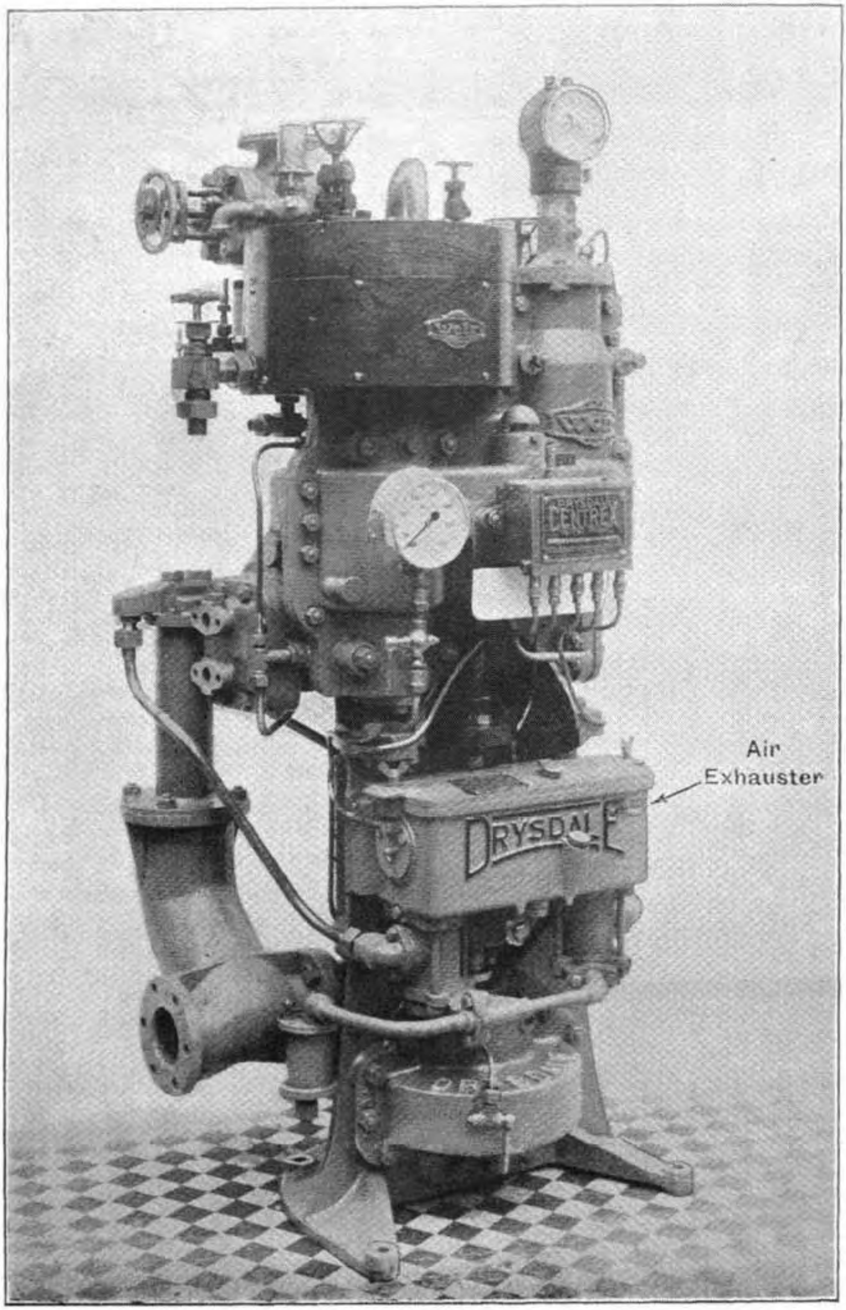

FIG. 44.

"Centrex" Fire and Bilge Pump

escape of air from the boiler room if a fan trips. It also facilitates starting up a second fan.

(28) **Auxiliary Feed and Oil Fuel Pumps.**—The design of these has not altered and the old type Weir's reciprocating pumps are still in use. A new type of shuttle has been tried experimentally for use with superheated steam. A turbo driven oil fuel pump is also under trial and has proved satisfactory. Similar units have been fitted in cruisers. While a saturated steam range has to be kept for other purposes there is little point in fitting these turbo driven units which are heavier than the reciprocating pumps.

(29) **Air Compressors.**—The standard designs of these are still of the compound reciprocating type but speeds have been increased to 500 r.p.m. and an experimental unit running at 700 r.p.m. has been fitted. Turbo driven units are also being tried in two G class vessels.

(30) **Main Feed Pumps.**—Up to the C class, these were of reciprocating type and were fitted in the boiler rooms. In the D class, turbo feed pumps were fitted with an open feed system. Each main pump delivered sufficient feed for full power plus 30 per cent. and there was in addition a cruising feed pump. These pumps were all fitted in the engine room.

Some trouble occurred due to bad alignment of some of the D class pumps which caused bent and scored spindles, and in one case the impeller was badly out of hydraulic balance. Minor alterations to stiffen up the design were made in the later classes and have proved satisfactory. The cruising feed pump was omitted in the E class and provision made for using the auxiliary pumps at low powers. In order to provide a standby with this arrangement, the main feed pumps are now arranged with a rapid starting valve at the platform level. All valves on the pump and turbine are kept open except this steam valve, which is fitted with a small by-pass to keep the pipe drained and the turbine warm.

(31) **Forced Lubrication Pumps.**—Up to the D class, three of the old type of reciprocating pumps were fitted. In the E class, a geared turbo driven unit driving a rotary displacement pump at about 1,250 r.p.m. was introduced. Fig. 43 shows this unit with the covers of pump and turbine removed. The turbine is a special unit developed by Messrs. Weir and is suitable for a very wide range of turbo auxiliaries, the different speed requirements being catered for by fitting varying sizes of gear wheels. Experimental direct driven forced lubrication pumps with a speed of up to 2,000 r.p.m. are also being tried.

(32) **Fire and Bilge Pumps.**—Turbo driven fire and bilge pumps were first introduced in the E class. The turbine is of Weir's standard type, mentioned above, and the pump is of the impeller type, an air exhauster being provided (*see* Fig. 44).

(33) Extraction Pumps.—These superseded the Paragon Air Pumps in the F class vessels. The Drysdale pumps have two impellers in series with water entering the top and bottom eyes of the lower impeller. They are driven by the Weir standard unit.

Experimental pumps produced by Messrs. Allen are being tried in two of the H class. The great difficulty with these pumps is to get stable running with low suction heads and with the condensate very near the temperature corresponding to the condenser vacuum. At the smallest increase in vacuum at the pump eye some of the water will boil and so upset the suction. This in turn leads to hunting which it is difficult for the turbine governors to control when the pumps are running in parallel.

(34) Distiller Pumps.—Distiller pumps are normally of reciprocating type but an experimental turbo driven unit (Fig. 45) is being tried.

Recording salinometers are also being tried with a view to keeping a permanent check on the purity of the make up feed.

(35) Turbo Generators.—There are in use four different makes of these auxiliaries, which call for no special comment. An experimental unit driven by a worm and wormwheel instead of by helical gearing is under trial. The ultimate object is to develop a unit with the turbine shaft vertical in order to save floor space, but the experimental unit has both shafts horizontal.

(36) Lubricating Oil Separators.—These are fitted with permanent connections to the main forced lubrication drain tanks and are intended to be in constant use at sea. In the G class, a small tank is supplied near the separator for accommodating dirty oil from the turbo auxiliaries.

(37) Forced Lubrication Coolers.—The standard type of Serck oil cooler is fitted in all ships and is most satisfactory. In the later vessels the oil inlet, discharge and by-pass valves are cast in the cooler body which is of aluminium.

A new type of cooler made by the Premier Radiator Company is being tried in one H class vessel. The main feature of this design is the provision of fins on the tubes to improve the cooling effect. There are, however, considerable difficulties in the construction of a suitable unit of this type which has yet to prove itself.

(38) Distant Reading Level Indicators.—Distant reading level indicators of the pneumercator type are fitted to the forced lubrication drain tanks and led to the starting platform. So far, the type adopted has been somewhat unreliable and is therefore of doubtful utility.

(39) Forced Lubrication Filters.—The standard filter is of the Auto Klean type. Experimental units of the Lolos type are, however, under trial. These consist of a number of light cages with pieces of fine wire wound round at a standard distance apart.

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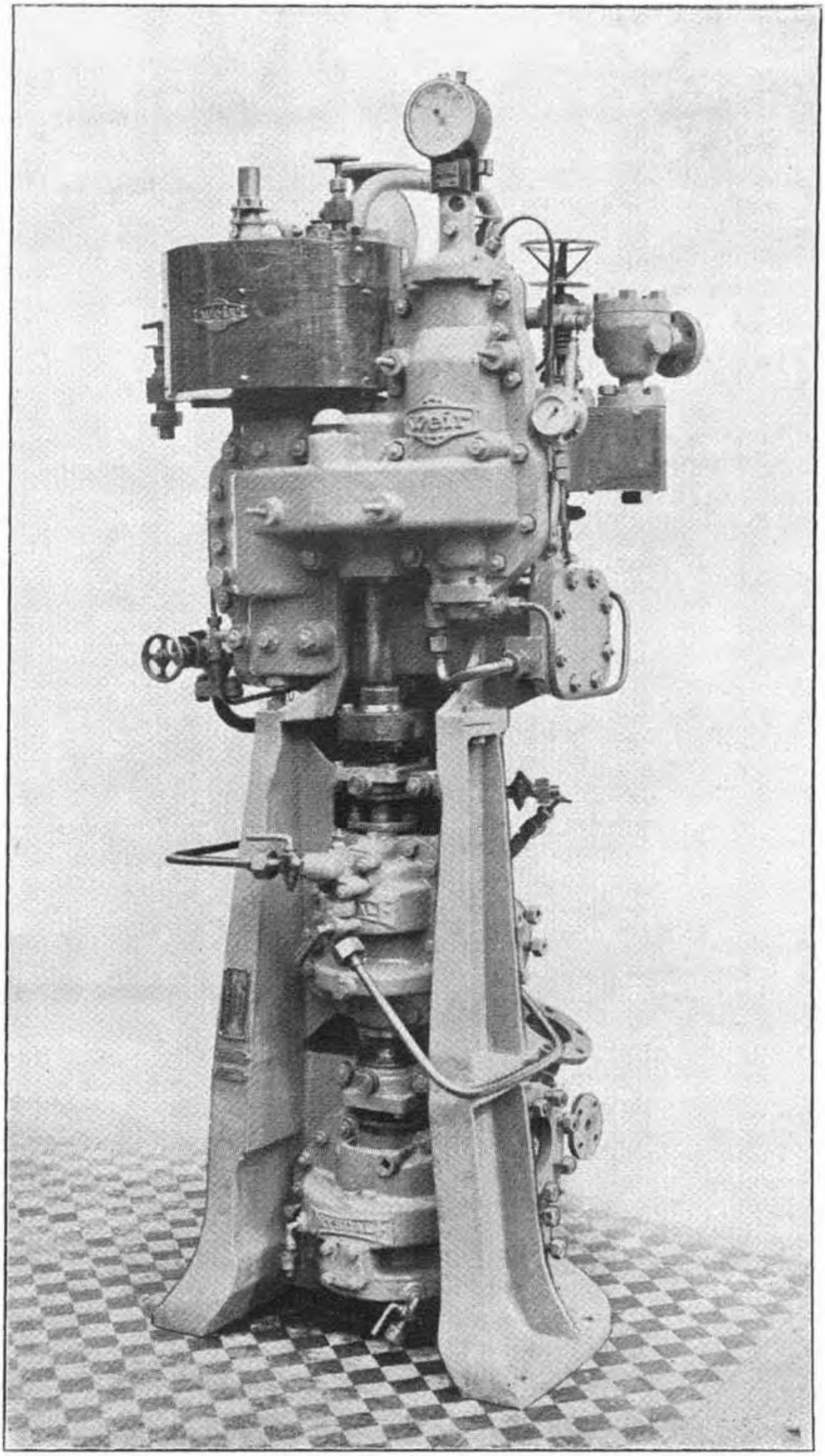

FIG. 45.
Combined Evaporator Pump.

The oil is filtered between adjacent coils of wire, the advantage being a much larger filtering surface in a given space compared to the standard type.

(40) Boiler Filling Pump.—A small electrically driven pump weighing only about 80 lbs., complete with motor, has recently been provided for pumping up boilers in all destroyers of A and later classes. Provision is made for transporting it between the boiler rooms and suitable hose connections are provided on the auxiliary feed suction pipe. The output is only 2 tons per hour, but it was not possible to improve on this without a large increase in the weight of the motor and the provision of a starter.

In the G class, a small oil pump has been provided for use in conjunction with the same motor when lighting up. This extra requirement limits the speed of the motor, and therefore the output of the water pump, and is unlikely to be repeated.

(41) Steering Gear.—An electro hydraulic type of gear has been used since the A class, but in the E class it was re-designed, the cylinders and rams being fitted athwartships in order to save length.

Conclusion.—The above somewhat lengthy description shows that practically every item of machinery design has been under review during the last few years with the objects of reducing weight and bulk and increasing ease of handling and maintenance. This process has been facilitated by a small but steady building programme.

A paper of this kind is necessarily incomplete and a number of items have been omitted. In particular, no mention has been made of H.M.S. " Acheron," an experimental design working at 500 lb./in.^{2} boiler pressure and 750° F. steam temperature. Experience in this vessel has shown that there are no inherent disadvantages in working at these high pressures except that the number of turbines required complicates the arrangement of pipes and seatings, and entails large loss of feed water and increased work in operation, due to the number of glands. Experiments are, however, being made with an automatic system of gland control with a view to overcoming the latter disadvantage.

An increase in propeller revolutions, although most desirable from the point of view of the main machinery, since it would reduce the dimensions of the main gearing or alternatively allow an increase in speed of main turbines, is not at present practicable on account of the rapid fall in propeller efficiency at higher speeds. It has been estimated that an increase of shaft speed to 450 r.p.m. would require an additional 10 per cent. on the S.H.P. to give the propulsive effect at present obtained at 350 r.p.m. It seems, therefore, that, for the present, the main principles of the G class design are likely to be repeated.

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