A MARINE INSTALLATION EMPLOYING HIGH PRESSURE STEAM. S.S. "KING GEORGE V."

The trend of progress in all marine power installations has ever been in the direction of improved economy without the addition of weight or sacrifice of reliability. As has been pointed out in previous issues of Papers on Engineering Subjects, the obvious direction in which to seek improved economy lies in extending the temperature range over which heat can be taken from the working fluid and transformed into energy. Limitations of weight and space, however, forbid any material lowering of the temperature of the exhaust steam, while the upper limit of temperature at the inlet to the turbines is defined by metallurgical considerations.

Fortunately there remains a third avenue for possible progress, and that is by raising the initial pressure of the steam without exceeding the maximum permissible temperature.

The curves given on Fig. I indicate the theoretical improvement

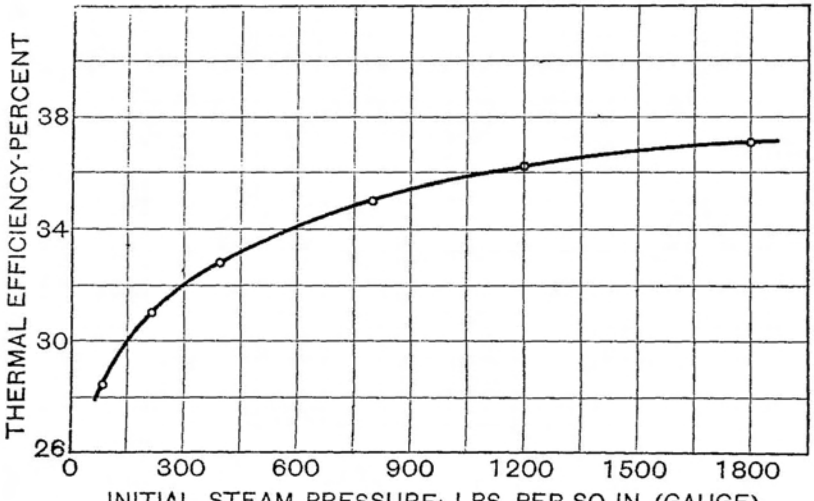


Fig. 1.

to be expected in a perfect steam turbine as the initial pressure is raised progressively, while maintaining a constant steam temperature of 750° F.

Fig. II shows the measured overall efficiency of a number of Parsons Turbines, taken from carefully conducted trials. These results substantiate the theoretical figures as far as moderate increases of pressure are concerned and do much to justify the efficiencies predicted with yet higher pressures. It may, however, be remarked that the properties of steam at pressures above 300 lbs. are but scantily explored, and on this account there is an element of doubt regarding the accuracy of any predictions that can be made in the present state of our knowledge. Experiments are being made in several countries with super-high pressure installations, and it is only a question of time before more accurate data is obtainable.

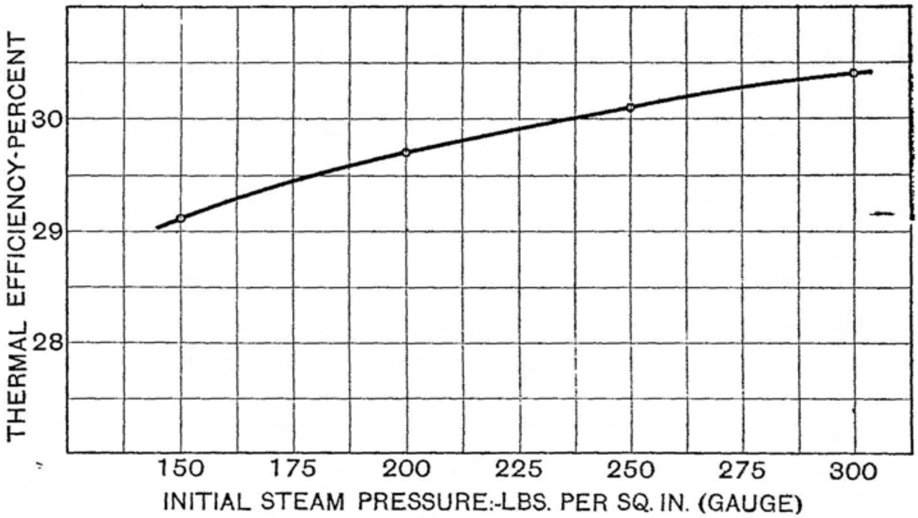


FIG. 2.

It must be appreciated that in practice the overall gain will be modified by slightly lower boiler efficiency, by increased work on the feed pumps and by higher leakage losses throughout the system. Success with high steam pressures will depend primarily upon these points, and it is with a view to obtaining practical data that the machinery installation described in this article was designed.

S.S. " King George V " is a Clyde River Steamer of 3,500 S.H.P. and a designed speed of 20 knots. Although, in view of the short duration of each run and of the considerable amount of manœuvring to be expected on service, this type of vessel may not be an ideal one in which to demonstrate the economy to be anticipated with higher steam pressure, yet for the purpose of obtaining information regarding the operation and upkeep of such an installation the type of vessel chosen offers many advantages.

The installation has been described in some detail in the technical press and this article will be mainly confined to some of the more interesting points observed on trials of the machinery.

The propelling machinery comprises two Yarrow land type boilers, in combination with two sets of geared Parsons turbines. Steam is generated at 550 lbs. pressure and superheated to 750° F., being utilised first in a high-pressure turbine of the reaction type in which it is expanded from about 510 lbs. per sq. inch down to about 220 lbs. per sq. inch and 650° F. temperature. The exhaust steam from the single H.P. turbine is then admitted in the normal way to the first turbine (1st I.P.) of each of two sets of three turbines, which are connected by single reduction gearing to the two propeller shafts : the H.P. turbine is connected in tandem to the 1st I.P. on the port shaft. The reduction is from 6,000 r.p.m. for the first two turbines of each set and 3,000 r.p.m. for the L.P. turbines, to about 570 r.p.m. on the propeller shafts, the total S.H.P. developed at these revolutions being about 3,500.

Astern turbines are provided in the 1st I.P. and L.P. casings in the usual manner.

It will be seen that for manœuvring ahead or astern the two shafts are necessarily run with an initial pressure of 200 lbs., and nozzles are fitted in the manœuvring steam pipes to effect the reduction to this pressure. Special non-return valves are fitted in the connection between the H.P. ahead and the two 1st I.P. turbines, in order to simplify the handling of the engines.

The ahead blading is entirely of the reaction type, Monel metal being employed in all except the L.P. turbines in view of the high steam temperatures. End tightened blading is employed in the H.P. and I.P. turbines in order to minimise leakage, a point of exceptional importance in the H.P. turbine where the blade heights are extremely small. Very ample radial clearances are thus provided in the blading, and the effects of slight distortion due to inequalities of temperature should therefore not be of importance.

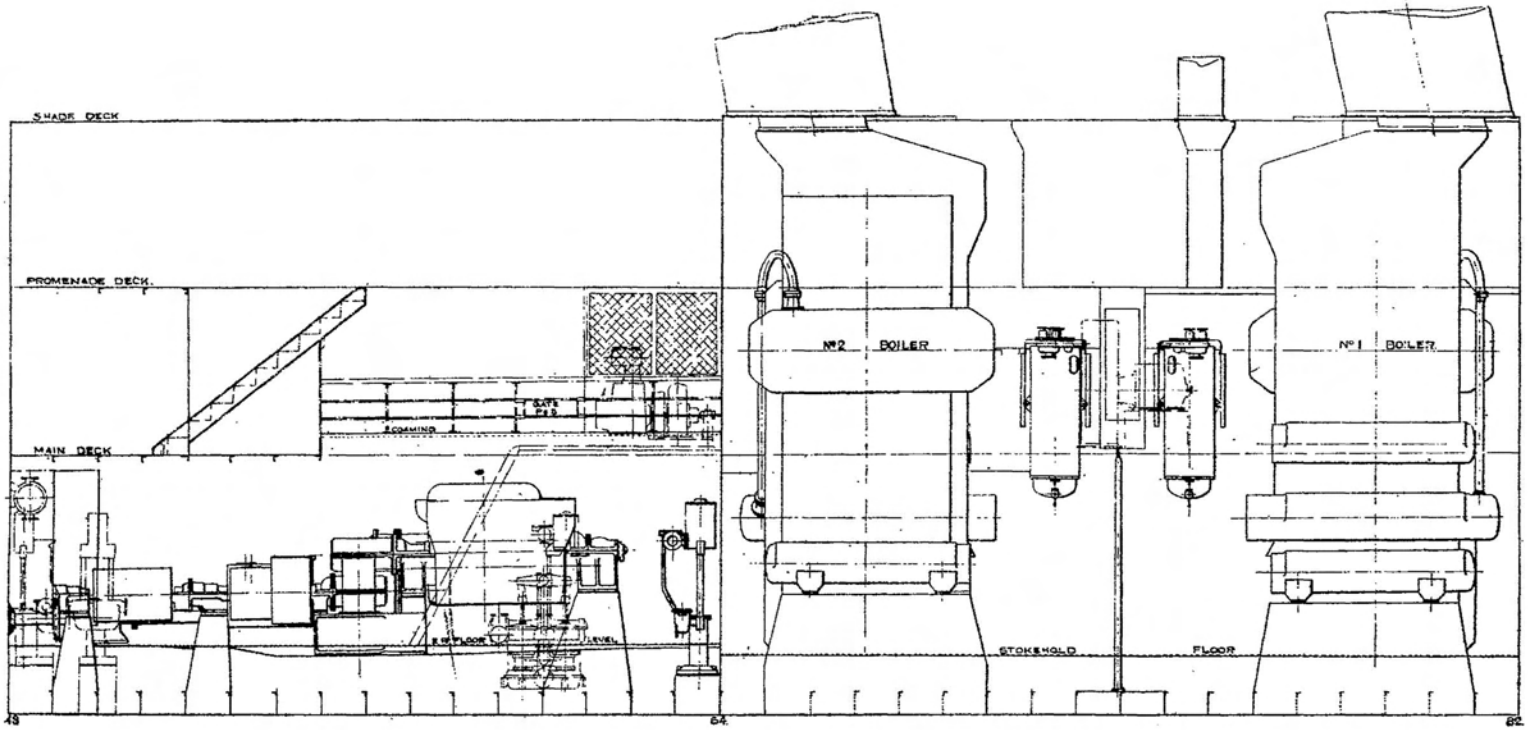
Boilers.—These are of the Yarrow land type, an air preheater and a superheater being located in the uptake which is ranged on one side of the boiler only : heat is conveyed to the tubes on the other side of the boiler mainly by radiation, the proportion of fire row surface to generating surface being considerably greater than is usual in Naval boilers.

The reason for adopting this single flow type of boiler is merely one of convenience, the ship arrangement being somewhat better than if the more usual type, with gases passing equally through both sides of the tube nest, was employed.

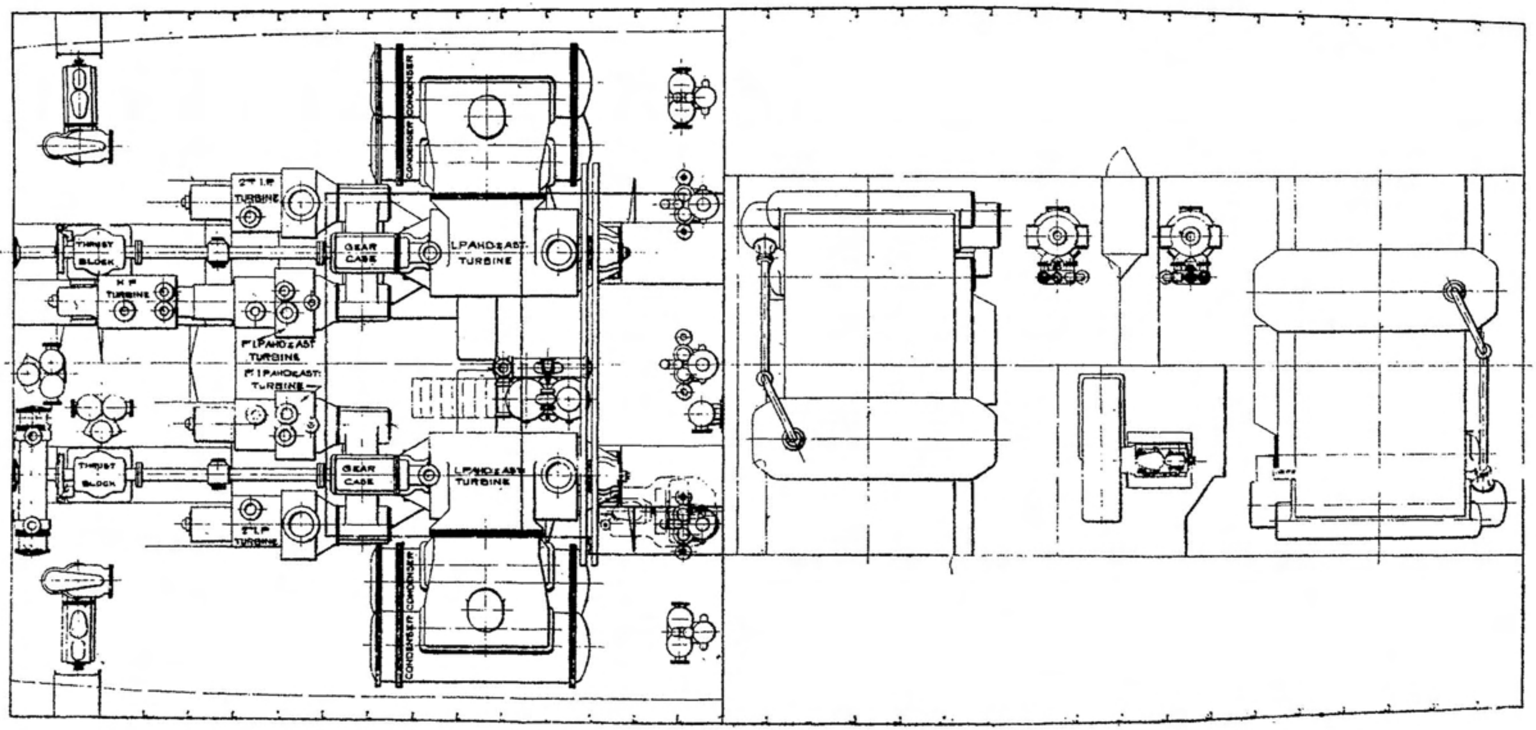
The air for combustion is supplied from a closed stokehold to an outer casing on the front of the boiler, thence to the air preheater and down a further double casing at the back of the boiler into the closed ash pit. This arrangement reduces the loss of heat by radiation and further tends towards cooler stokeholds and better conditions of working for the furnace brickwork. The air heater surface in each boiler is 2,200 sq. feet.

Each boiler has a total heating surface of 3,420 sq. feet, of which 870 sq. feet is superheating surface; it will thus be seen that the total heating surface excluding superheaters is 5,100 sq. feet for 3,500 S.H.P., a higher proportion than is usually permissible in Naval work owing to weight restrictions.

The design of the boiler is remarkable for the almost entire absence of rivetted and bolted joints : in the steam drum there are no rivetted joints at all, while the water and superheater drums are also made solid with the exception of front end plates which are secured by circumferential rivetted joints.



SHADE DECK
PROMENADE DECK.
MAIN DECK
COAMING
GATE
Nº2 BOILER
Nº1 BOILER
STOKEHOLD
FLOOR
LEVEL
49
64
82



ARRANGEMENT OF MACHINERY & BOILERS.

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Ma[illegible] & Sons [illegible]

Safety valves are fitted on the superheater only and are of Messrs. Cockburn's high-lift type set to 575 lbs. per sq. inch, the test pressure of the boiler being 913 lbs.

The main stop valves are fitted with monel metal spindles, valves and seats.

Feed Water Heaters.—A feed heater of the surface type, designed to operate with auxiliary exhaust steam at about 15 lbs. pressure, is fitted to heat the feed water up to 200° F.

An additional high pressure heater fed with steam tapped off from the turbines is provided, the final feed temperature being in the order of 300° F.

Auxiliary Steam System.—Steam for the auxiliary engines is taken from the outlet side of the superheater with the object of ensuring a flow through the tubes of the latter at all times.

In order to reduce the temperature of the auxiliary steam to one suitable for the operation of reciprocating engines, the steam pipe is led through the water in the steam drum to a decalorising tank, whence it enters the auxiliary steam range through a reducing valve set at 215 lbs. per sq. inch.

Condensers.—Two condensers are installed to each set of turbines, these condensers being provided with shut off " doors " both on steam and circulating water sides, to enable a leak to be dealt with while the vessel is still underway.

This point is one which has received considerable attention, the importance of maintaining the purity of the feed water in an installation of this type being fully realised. Evaporators are fitted to obviate the use of undistilled shore water and continuous indicating electrically operated salinity detectors are fitted on the condensate suctions and on the feed discharges.

The air and feed pumps are of the normal Weir reciprocating type, the auxiliary feed pump being fitted with a connection for use as an auxiliary air pump.

Steam Pipes.—All high pressure steam pipes are of solid drawn steel, the flanges being screwed on by means of a vanishing thread and the end of the thread at the face of the flange sealed by electric welding. The scantlings of the flanges are particularly generous, so as to avoid the possibility of any distortion. Joints are all metal to metal with bolts of large diameter, screwed with " plus " threads.

Expansion of the steam pipes is provided for by means of bends, expansion joints beng entirely avoided.

Preliminary Trials of the Machinery.—Trials of the machinery under way were successfully carried out in September 1926, after which the vessel proceeded on service.

As would be expected from the successful use of high pressure superheated steam in land installations no major difficulties were experienced during these trials, but some minor difficulties and departures from the designed figures were, however, experienced, and brief reference to these may be of interest.

(i) The temperature of the superheated steam both initially and throughout the subsequent stages in its expansion down to the first I.P., as shown by the distant reading pyrometers, was considerably above the designed figure, being about 800–820° F. at the boilers and 795–810° at the H.P. turbine. It should be added that there appears to have been some doubt regarding the reliability of the actual instrument in use.

While no damage from the use of these high steam temperatures is anticipated, it is probable that some reduction in superheating tube area will be made in order to bring the superheat down to the design figure of 750° F.

(ii) Due to the high temperature of the air delivered from the air preheater, considerable burning away of the furnace door baffles was experienced; other furnace fittings will probably be similarly affected after a comparatively short life.

The temperature of the boiler room was high, but not excessive.

The damage to the furnace doors can, of course, be remedied by fitting fire brick protectors, but the trouble is undoubtedly accentuated by the fact that an air supply at the back of the boiler impinges directly on to these fittings.

(iii) On account of the somewhat inadequate lagging of the heated parts of the boilers and machinery, the temperatures of the machinery spaces were high and radiation losses probably excessive.

The cramped nature of these spaces in a vessel of this type no doubt accentuated the effect referred to, but it is evident that special consideration is required to the question of providing efficient lagging in all marine installations employing steam at very high temperatures.

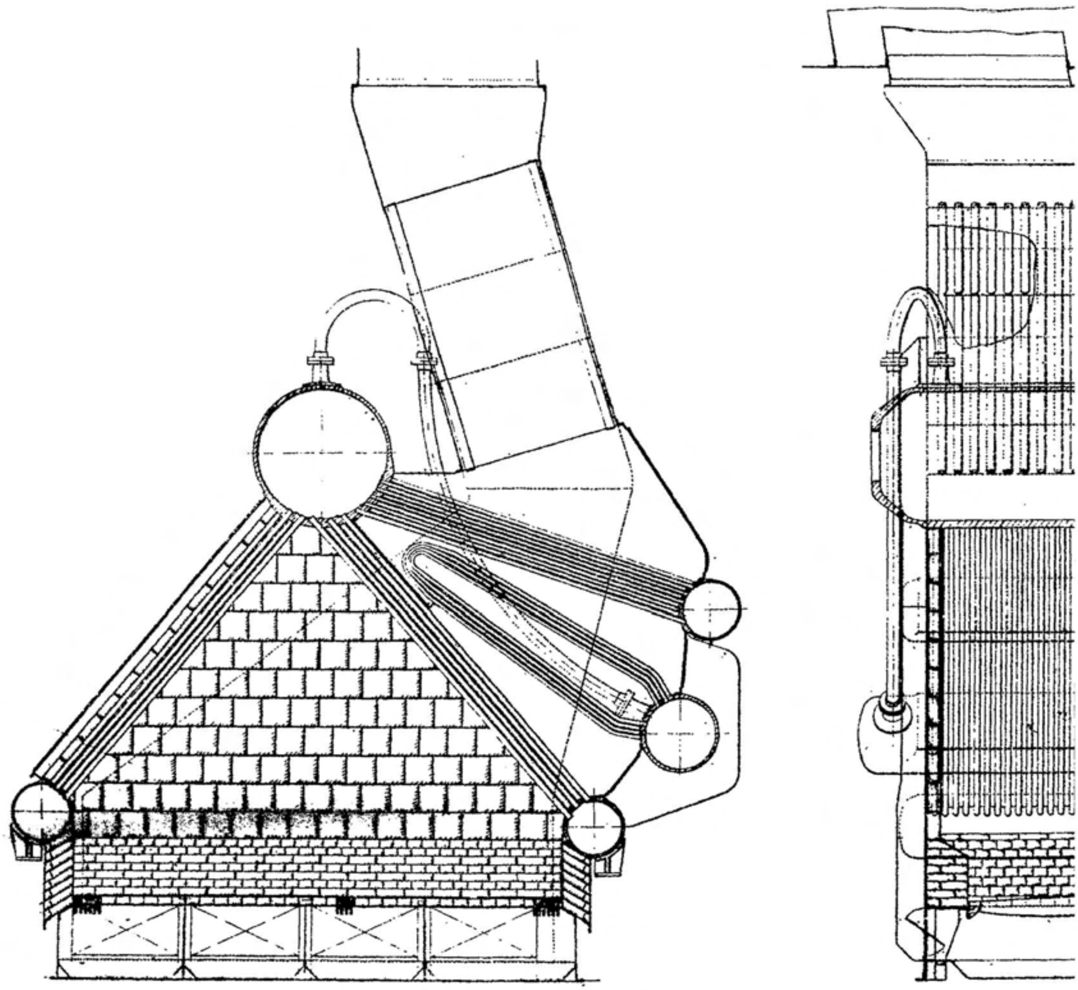
(iv) Difficulties were experienced in warming up of the H.P. turbine, due to differences in expansion between the rotor and casing, and the design of the gland and dummy packings had to be re-considered in the light of this fact.

(v) The turbine drain pipes were of inadequate strength in some cases to withstand the pressures to which they are liable to be subjected.

(vi) Some slight difficulty was experienced due to gland leakage, but this was only a matter of adjustment, which was rendered difficult on account of the confined space.

(vii) The absence of a stop valve on the steam supply to the superheater has on occasion led to the filling up of the latter as the boiler cooled down.

(viii) No leaky joints, except minor leaks in the feed system were noted; it may be observed, however, that the machinery was in new condition and, in view of the widespread interest displayed in the installation, it is probable that more than ordinary care was taken over details.



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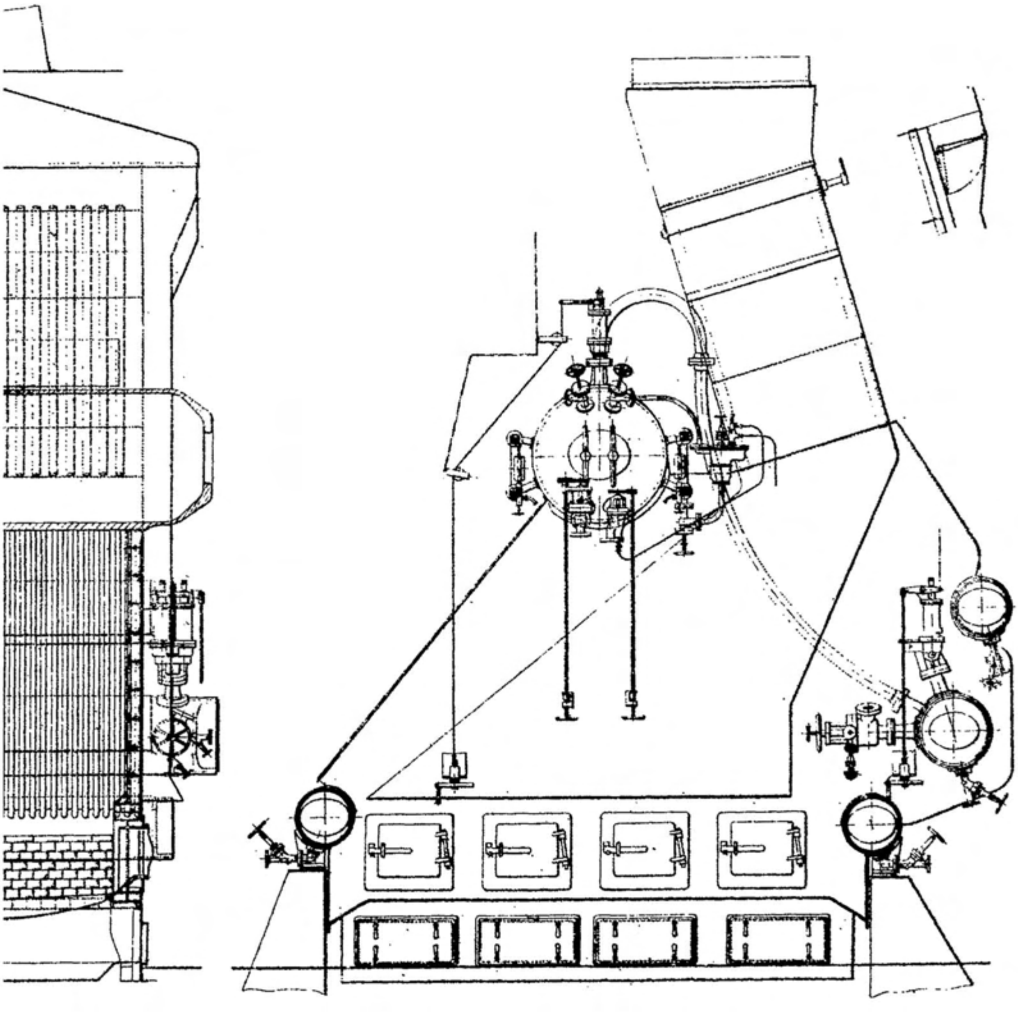
ARRANGEMENT



OF BOILERS.

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On the trials referred to no attempt was made to obtain data of any description, the object being merely to demonstrate the behaviour of the machinery under normal operating conditions.

At the conclusion of the summer season consumption trials were carried out in order to corroborate (or otherwise) the claims which have been made as to the economy which is obtainable by the use of high pressure, highly superheated steam. Full information regarding these further trials will be published at a later date, together with reports of the working of the machinery on extended service.

The results of this most interesting experiment are, however, such as to confirm the opinion that there are no insuperable difficulties in the manufacture and operation of an installation of this type. Whether the increased weight and cost will be sufficiently compensated for by improved economy yet remains to be proved; from this point of view it is to be regretted that the design of the installation was not such as to enable direct figures to be obtained regarding the effect of the high pressure and superheat only, uncomplicated by economies due to preheating of the air supply and to special feed heating devices.