Y.E.A.D.I. PROTOTYPE TRIALS

BY

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The Yarrow—English Electric—Admiralty design of prototype steam plant, which has been installed for trials at Pametrada, comprises a 30,000 H.P. single shaft set of steam turbine machinery coupled to a water dynamometer capable of absorbing both the full ahead and astern power. The layout of the installation has been developed by Pametrada in accordance with the overall design and specification prepared by the Yarrow Admiralty Research Department (Y.A.R.D.), who, in turn, have followed the requirements laid down by the Engineer-in-Chief's Department. The main objects of the trials are to prove the design of all the components and to determine the efficiency of the boiler and the main engine over the full range of power. In addition, it is hoped to develop a reliable system both of remote servo-manual, and of fully automatic, boiler control suitable for use at sea.

The following is a brief description of the machinery and an outline of the arrangements for carrying out trials.

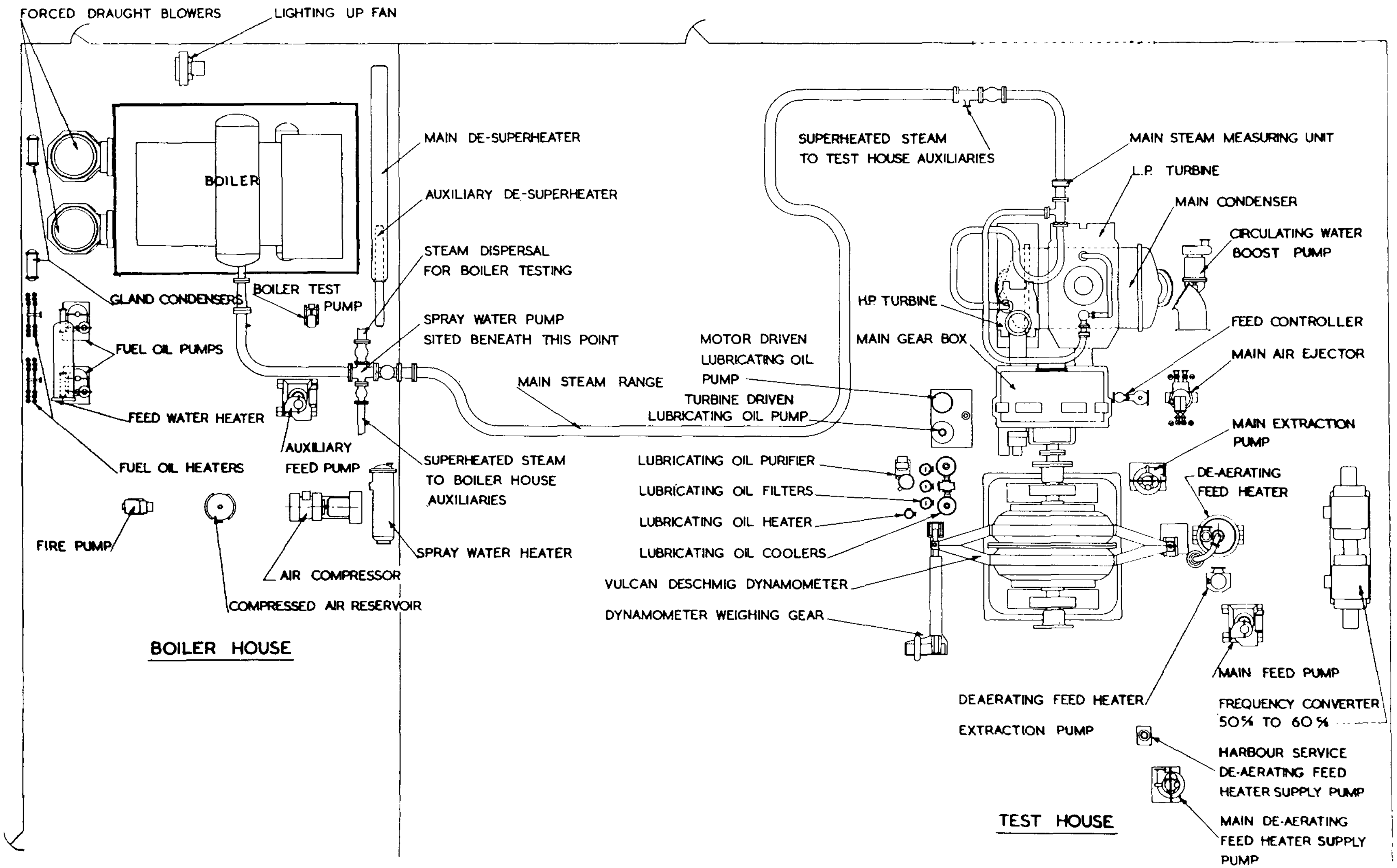
General

The layout of the machinery is shown in FIG. 1. The boiler and its auxiliaries are contained in a separate boiler house and steam is supplied through an all-welded steam pipe to the main engines which are located in the test house. This layout is peculiar to Pametrada and bears no relation to any that might exist in a ship.

The exhaust from the L.P. turbine is condensed in an underslung athwartship condenser supplied with cooling water from the River Tyne through a separate pump house on the jetty. Cooling water for the brake is also taken from the same source. All the steam auxiliaries are supplied from the Y.E.A.D.I. boiler and the electric auxiliaries are provided with 60 cycle A.C. from a rotary converter.

Boiler

The boiler is illustrated in FIG. 2, and in principle is a larger version of the Y.100 boiler which, in conjunction with the Y.100 main machinery, has been fitted in the *Blackwood* & *Whitby* Class frigates and in the Canadian destroyer escorts. The boiler was designed and manufactured by Messrs. Babcock & Wilcox Limited and is of the two drum single furnace type, capable of over 300,000 lb evaporation per hour. It has selectable superheat control by means of dampers which enable the amount of gas passing through the superheater to be varied. The boiler itself is enclosed in a steel box which represents a compartment in a ship designed to accept atomic contamination, all controls being outside the box. At Pametrada the controls are grouped into two control rooms, one in the boiler room itself and the other remote from both the boiler and the main engines. Air is supplied to the boiler box by two axial blowers which are capable of providing a draught loss of up to 80 in W.G. at full power. Fuel is supplied to the boiler through nine spill burners which give a turndown of as much as 25 : 1. This means, in practice, that it will be possible to steam



MACHINERY ARRANGEMENT.

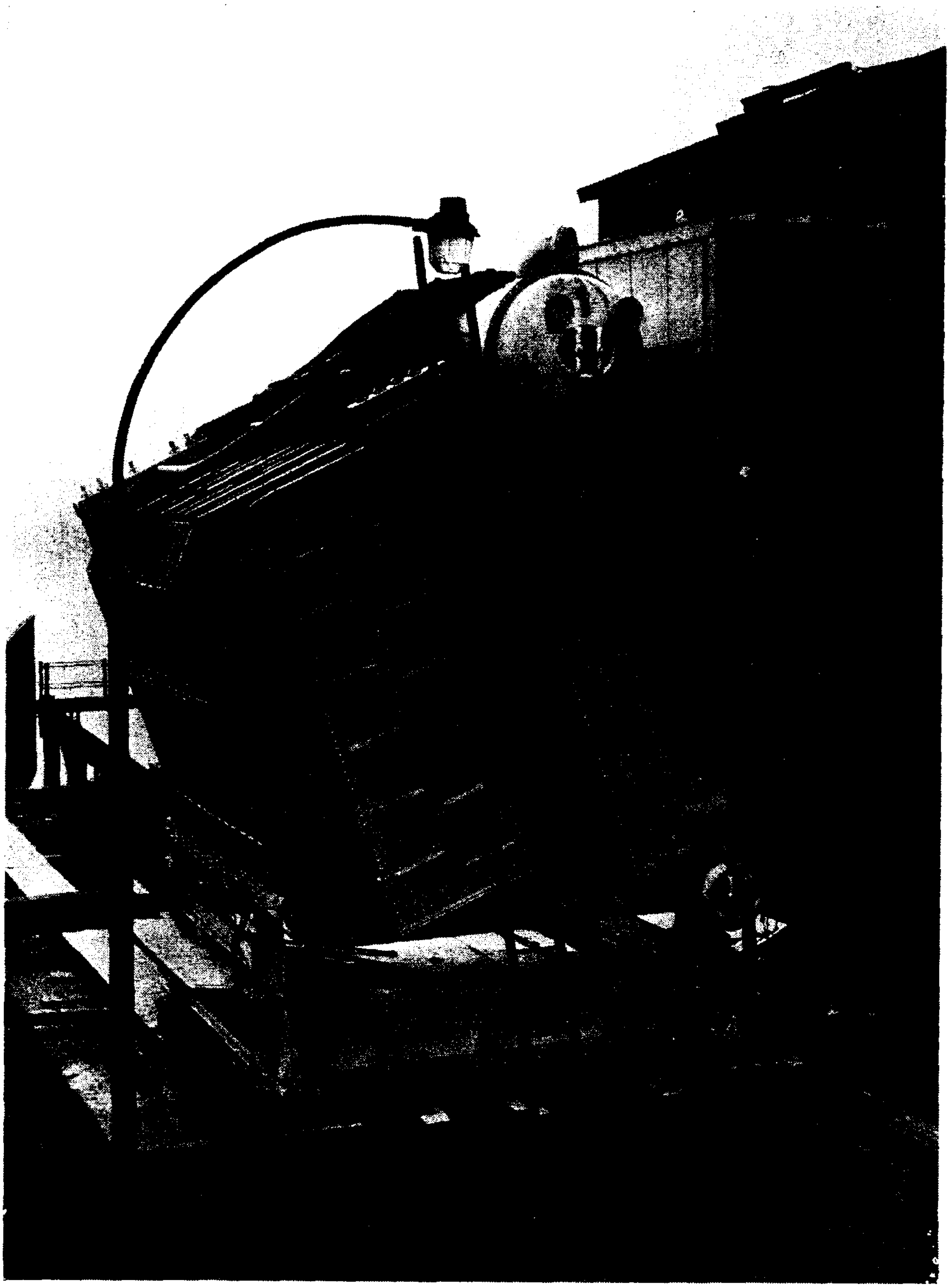


Fig. 2

the boiler from the stand-by condition to full power without putting on or taking off sprayers, an essential for control room operation.

Each of the two banks of four sprayers is supplied by its own turbine driven fuel pump and each pump is subdivided into two, the supply pump drawing from the main fuel tanks and delivering, through the oil fuel heaters, to the service pump which then discharges hot oil to the boiler at a pressure of up to 800 lb/sq in. The spill returns between the two pumps. Although both pumps are geared from the same turbine, the speed of the supply pump is

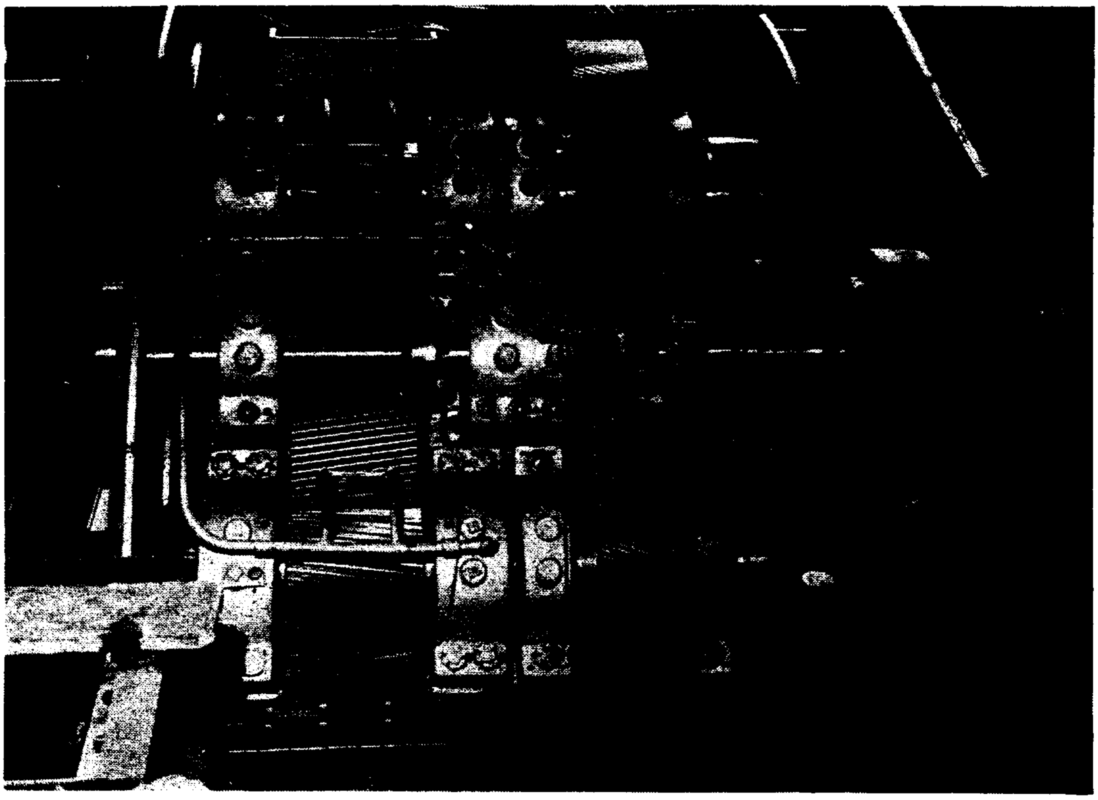


FIG. 3

slower than that of the service pump in order to match the different nature of their duties.

There are two identical feed pumps installed at Pametrada, one in the test house, the other in the boiler house ; each pump is capable of supplying the boiler at full power. The pumps are of the vertical type in which a small impulse turbine is geared down to a multi-stage centrifugal pump which discharges at 840 lb/sq in. to the boiler.

Main Turbines and Condenser

The main turbines, designed and manufactured by the English Electric Co· Ltd. are similar in general arrangement to those in H.M.S. *Decoy* and H.M.S. *Diana*, except for the steam conditions which have been increased to 700 lb/sq in, 950°F at 20 per cent power. Above 60 per cent power the temperature is reduced to 850°F. The main turbines are designed for maximum efficiency at about 20 per cent power, but a low water rate over the entire power range is assured by the use of nozzle control valves, rather than the throttle valve of pre-war design. Although the circulating water is delivered to the main condenser by the two electrically driven pumps on the jetty there is, in addition, a steam driven circulating water pump in the test house which permits re-circulation to take place and so enables tropical conditions to be simulated, i.e. the condenser inlet temperature can be raised to 85°F. The water velocity through the condenser at full power is of the order of 10 ft/sec.

Gearing and Lubricating Oil System

The main gearing consists of a set of case hardened and ground double reduction single helical gears with an overall reduction ratio of about 40 : 1 for the H.P. and 30 : 1 for the L.P. turbine. They have been designed and manufactured by Messrs Vickers-Armstrongs Limited and are the first set of case hardened and ground gears to be made in this country for marine purposes.

The full power loading of the teeth is roughly four times that employed in machinery now at sea and nearly twice that employed in Y.100.

The lubricating oil system is of conventional design, the two pumps, one motor and one steam being immersed in the L.O. tank in order to avoid loss of suction due to air leakage. The pumps discharge through a magnetic strainer, fine gauze filters, and thence through conventional L.O. coolers to the turbine and the gearing bearings. The pumps are fitted with the usual cut-ins which enable either the steam or the electric pump to be used as stand-by. Various methods of L.O. temperature control are being tried in an effort to establish the best arrangement for ship use, the object being to reduce as far as possible the loss which occurs due to churning cold oil in the bearings. Easily replaceable, steel-backed thin shell bearings are to be tried in due course.

Trials will also include over-torquing to simulate conditions occurring during rapid manœuvring at sea, and a point of interest here is that the nature of water brakes is such that over-torquing can only be achieved to a very limited extent by adjusting the brake control. It is therefore necessary to remove one half of the locked train of gears, so doubling the load on the other half. FIG. 3 shows the H.P. train of gears, the drive being through a quill shaft to the H.P. pinion, which carries the turning gear dog-clutch, and through the primary wheels to the secondary pinions and thence to the main wheel. The thrust block is integral with the gearcase and is mounted on the after end.

Feed System

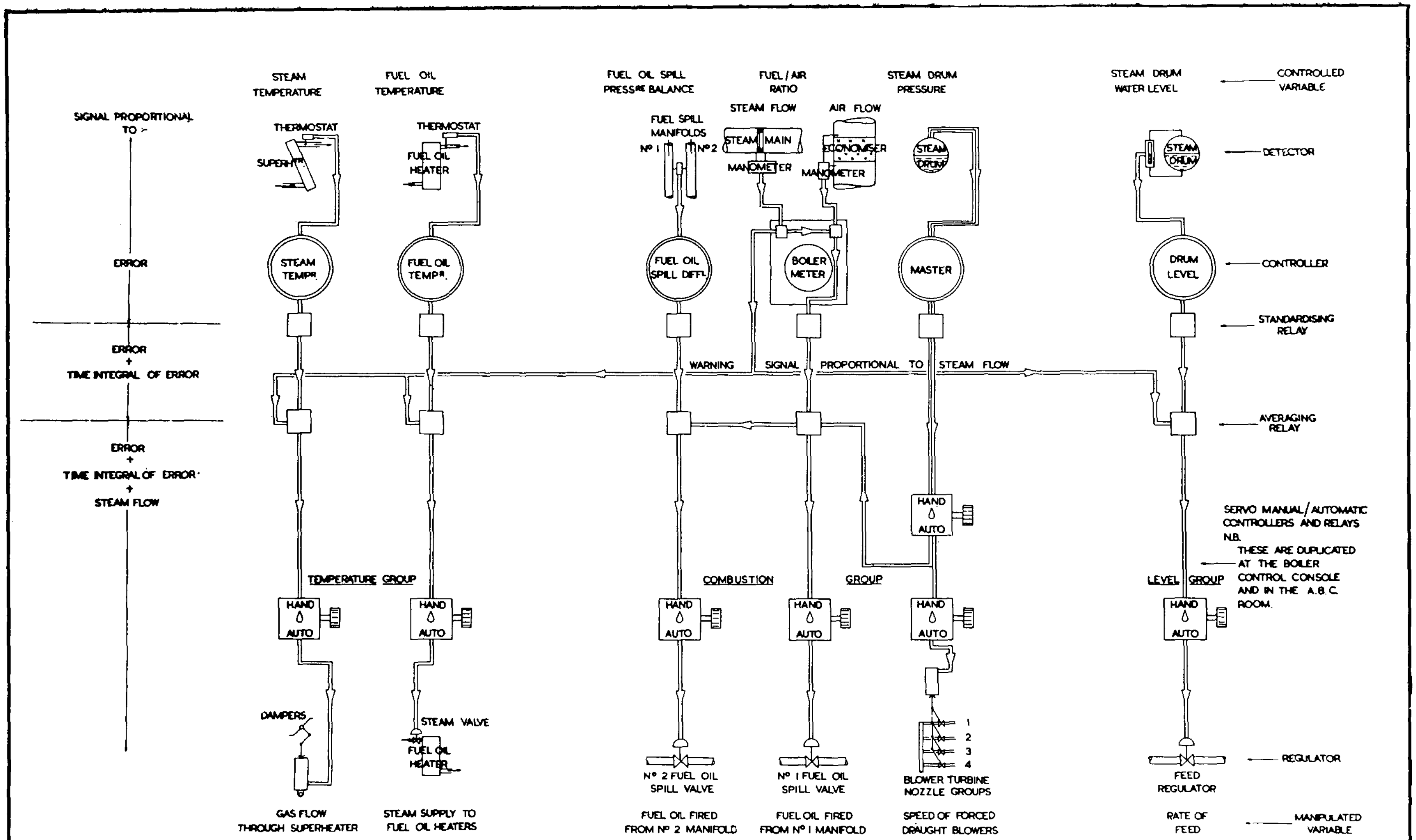
The feed system in Y.E.A.D.I. is of conventional design and centres round a standard feed controller, make-up feed being added from the condenser in the usual way. In addition, however, a deaerator has been fitted which removes air in the feed water not already taken out by the condenser and at the same time provides the required amount of feed heating. A high pressure feed heater is not used in this installation. Trials are to be carried out to determine the minimum size of deaerator necessary for the required degree of deaeration and feed heat. The extraction pump and feed pump arrangements are very similar to those employed in existing ships, but the feed regulator is operated by compressed air and obtains advance information of a change in water level from the change in steam flow rate. Other types of feed regulators are to be tried out in due course.

Boiler Trials

One of the difficulties experienced during the Y.100 trials was caused by the dependence of the boiler on the main engines. If for any reason the main engines were out of action then trials on the boiler could not be carried out. For the Y.E.A.D.I. installation a condenser from a *Weapon* Class destroyer has been erected on the jetty and boiler steam can be led directly into this condenser, thus enabling independent boiler trials to be carried out at any time. The *Weapon's* condenser has its own set of auxiliaries and is entirely independent from the rest of the Y.E.A.D.I. system. It is expected that the condenser will operate at atmospheric pressure when the heat transfer rate should be high enough to permit the full output of the boiler to be condensed. The steam from the boiler is desuperheated before entering the *Weapon's* condenser in order to avoid overheating the condenser casing and the top part of the tube nest. Relief valves are fitted in case of circulating water failure.

Automatic Control System

One of the novel features of the Y.E.A.D.I. installation is the comprehensive system of automatic boiler control that has been fitted for trial, both in a



AUTOMATIC BOILER CONTROL SYSTEM.

FIG. 4

remote control room and in the boiler house. In order to gain some experience as quickly as possible, it was decided to fit a system of conventional power station controls, after which a set more suitable for use at sea would be designed and tried out if the results proved sufficiently promising.

The principle of the present automatic control system is shown in FIG. 4 and it will be observed that the common function is the warning signal taken from the change of steam flow. In conjunction with the air flow signal, the steam flow is used to regulate the oil fuel supply, so keeping the air/fuel ratio constant. In addition, it passes advance information to the feed regulator, to the oil fuel heaters and to the superheater control before the local sensing elements of these various systems have had time to notice the change for themselves. The object of such an arrangement is to reduce the inevitable time lag associated with any thermal sensing element. By turning a knob, it is possible, at any time, to control any of the variables independently by hand and one of the objects of these trials is to establish the convenience or otherwise of a purely servo-manual control system.

Instrumentation

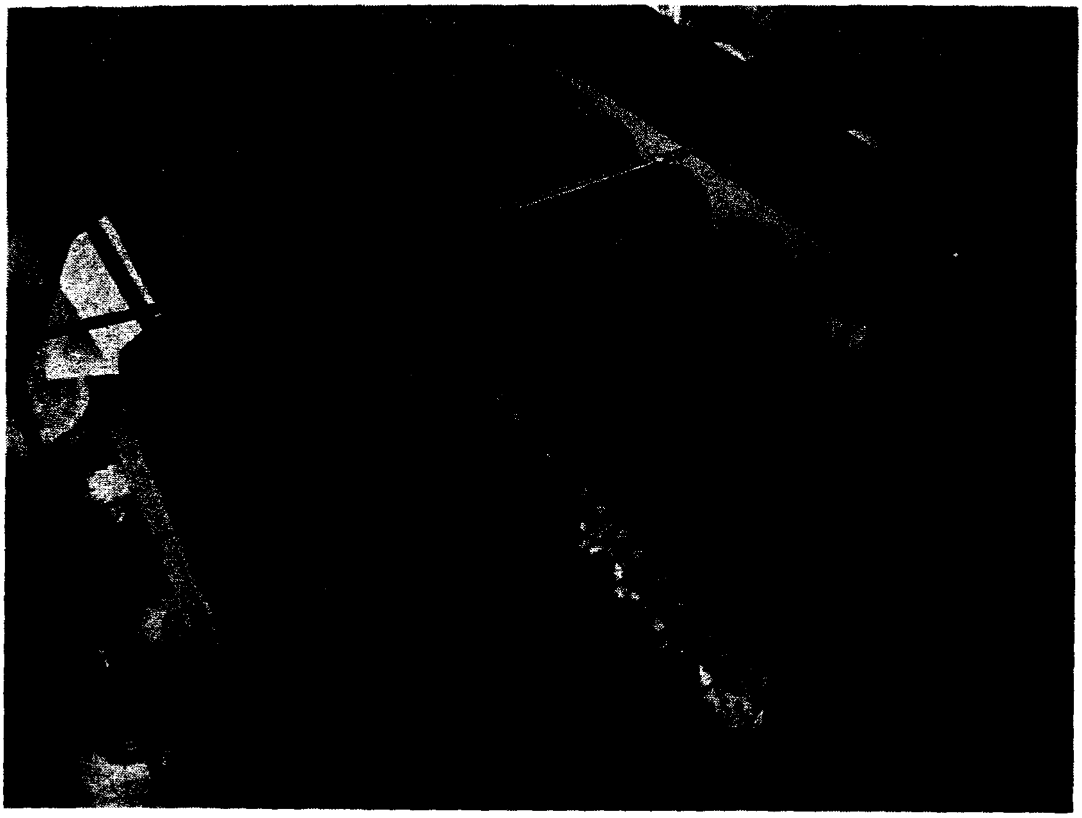
Before any of the quantities required for a full discussion of the behaviour of the marine steam turbine set can be measured, a very full and comprehensive system of instrumentation is necessary. In fact, over 700 separate quantities have to be measured in Y.E.A.D.I. The space required for the instrumentation involved is one of the reasons why extensive trials of main machinery are best carried out on shore as it would be very difficult to find the necessary space in a modern warship, and even more difficult to arrange for accurate calibration before and after each major trial.

It is usually possible to measure each of the various quantities in several different ways, the particular method employed being determined by the accuracy required. The preferred method of liquid measurement is by weigh-tank, since it is the least subject to doubt about possible calibration or reading errors. Moreover, it can be arranged to give any required degree of accuracy. However, on some systems it is not always convenient or even possible to use a weigh-tank and other means, such as a British Standard Orifice or one of the several types of flowmeters, have to be employed instead. Wherever possible secondary instruments of this sort are calibrated in place against a weigh-tank.

Pressures are usually measured by standard test gauges of known accuracy, although in some cases mercury manometers are used for flow measurement across an orifice. A steel ball floating on the mercury enables the level to be determined by magnetic means when high pressures necessitate the use of stainless steel U-tubes.

Temperatures are measured by thermocouples connected to recording instruments which register up to 12 temperatures at four second intervals on a slowly moving paper roll. In the case of turbine rotor bore thermocouples, the leads have to be taken away via a set of slip rings and these can give rise to stray currents that may upset the readings. This effect can be minimized by making all the rings the same diameter and providing air cooling.

To know the dilation of the H.P. rotor bore as the turbine speed increases is a matter of considerable importance to the designer, as it would enable the actual stress at the rotor bore to be compared with theoretical stress. An attempt is being made to measure this increase directly in the case of the Y.E.A.D.I., H.P. turbine by means of an instrument in which a ray of light is reflected from a set of three mirrors inside the rotor bore and describes a circle on a fixed screen as the turbine rotates. The diameter of the circle is a measure of the increase in the diameter of the bore.



Boiler Control Position

Method of Carrying Out the Trials

The most important work incurred by any trial is that which is done before and after the trial takes place. Any major trial is a very expensive matter and it is essential to determine in advance what readings are required and then to ensure that they are taken during the trial. Moreover, all the instruments must be calibrated in advance and again at the end of the trial, and all factors which might influence the results must be noted or eliminated. It has been found in practice that two or three trials in one week are all that can be managed economically.

As far as possible only one thing is tried at a time. To take an obvious example it would be rash to experiment with the main feed pump during a main turbine consumption trial, for if by any chance the feed pump should fail the main trial would have to be abandoned. Much information of a general nature can be obtained about the behaviour of various auxiliaries during a major trial, but the principal aim must never be overlooked otherwise a day's steaming may result in no useful information whatever.

A trial loses much of its value unless it is reported accurately and adequately. Corrections must be applied to many of the pressure gauge readings and allowances made for variations in ambient temperature and pressure. In a consumption trial, even the temperature of the lubricating oil can affect the result considerably and, should it vary from the agreed figure, allowances must be made.

Reports and Conclusions

Trials cannot be of much use until the results have been made known to all the interested parties. These normally include the Admiralty, Y.A.R.D. and specialist establishments such as A.F.E.S., Haslar, Pametrada, and the manufacturers directly concerned. Moreover, the sooner a report is issued in draft form, the easier it is to obtain general agreement as to the construction to be placed on the results. In practice, this apparently simple matter is complicated by the fact that the designer of the machine or system under test has a natural tendency to applaud results which agree with theory as a fine piece of scientific evidence, while condemning those that differ as being fraught with errors of instrumentation and observation. The trials team, on the other hand, are more likely to take the view that, while theory is often a matter of opinion, the results are there for all to see and cannot be denied or ignored.

In the case of Y.E.A.D.I., a system of interim reports ensures that the information, arising from any individual trial, is not delayed until all the trials on that particular machine or system have been completed, and the resulting discussion and verification of detail ensures that very little of any importance is overlooked. The final report is consequently a fair and unbiased account of what actually took place, and this, after all, is the object of the exercise.