FLEET REPLENISHMENT SHIPS

BY

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Introduction

R.F.A.s *Resource* and *Regent* are the first ships to have been specially designed as Fleet Replenishment Ships. They will supply items of armament or naval stores which are critical to operations in war to a mixed task force.

They will also carry victualling stores, mainly for supply to those ships of lower endurance levels, a range of general mess and canteen stores and a limited stock of medical dressings and survival kits.

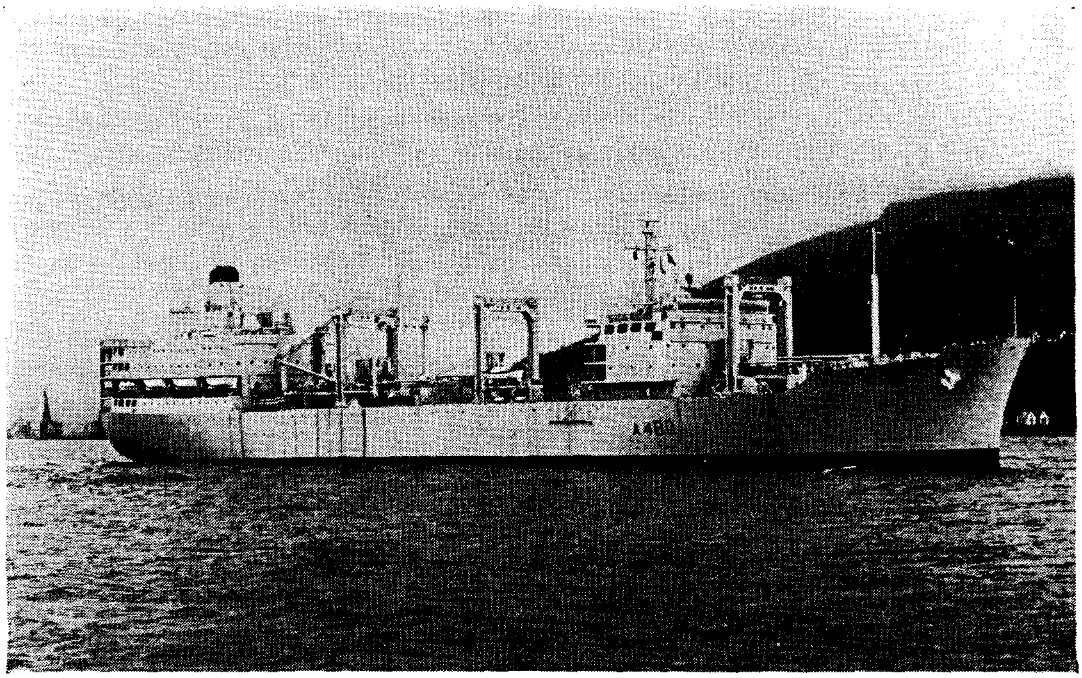

FIG. 1—R.F.A. 'RESOURCE'

The type numbers for these ships were AEFS 01 and 02 (Auxiliary, Explosives, Food and Stores).

Designed by D.G. Ships for D.A.S., the ships are manned and managed as Royal Fleet Auxiliaries.

Historical

In view of the importance of these ships to the Fleet, and the valuable nature of the cargo to be carried, it was agreed that full warship standards of shockproofing and NBCD should be applied, and furthermore, because of certain advantages, they should be single screw ships. The machinery standard and power required necessitated the development of a new set of machinery.

At the same time as the preliminary design for these ships was being investigated, a new class of Fleet Replenishment Tankers came under consideration. These would also be single-screw ships but with approximately 25 per cent more shaft horse power than the replenishment ships. Because of the advantages of saving in design time, design costs being spread over more ships and numerous ship running advantages, it was decided that one design of machinery would be developed which would be suitable for both types of ships.

Early in 1960 an order was placed with Y-ARD to carry out a design investigation into the most suitable machinery installation for the replenishment ships. The investigation was to proceed along the lines of steam turbine machinery of about 20,000 shp on a single screw and also that a 25,000 shp turbine installation might be required for a tanker and that a derated version of this machinery was to be used for the replenishment ship. Reliability of machinery and equipment and ease of access and maintenance was considered of paramount importance. The machinery installation to be designed along merchant lines, to comply with the requirements of Lloyds Register of Shipping, the Ministry of Transport (Board of Trade) and of D.G. Ships, General Requirements for Machinery (Engineering).

Late in 1960 the order on Y-ARD was extended to cover the building of a 1 in. to the foot scale model of the machinery arrangement, a sub-contract with

AEI for the design of main turbines, gearing and condensers and a sub-contract with Messrs. Foster Wheeler for the design study of main boilers.

Advance orders were placed late in 1961 with AEI for the supply of the main propulsion machinery followed early in 1962 with advance orders for the remaining Admiralty Supply Items, i.e., turbo and Diesel alternators, FFO service pumps, main feed pumps and main circulating water pumps; all these for the first ship of the class. Similar advance orders were placed for the second ship early in 1963.

By this time it had been decided not to proceed with the tanker design.

In mid-1963, Scott's tender was accepted for the construction and completion in 33 months of the leading ship and Harland and Wolff's tender accepted for the second ship for completion in 36 months. After a number of delays both ships entered service in June, 1967.

Hull—General

Structure

The vessels are designed with a bulbous bow, Hogner stern and marina rudder. The hull is of all-welded construction with four decks between the weather deck and the tank top, a poop aft and a bridge amidships. The ships have been built under special survey to Lloyds Register highest class for foreign service and the hulls strengthened for navigation in light ice conditions.

There are seven holds, each of which have four or five flats. A helicopter hangar to house one helicopter is built in the after superstructure.

Replenishment Arrangements

Alongside embarking and disembarking of stores can be done by twelve 5 to 10-ton derricks. Replenishment at sea arrangements comprise 2 and 4-ton positions and light jackstay port and starboard.

The two-ton positions are fitted with fixed high points but the design of gantries has provided for the future fitting of movable high points. The four-ton rig is a prototype design.

Arrangements are fitted for the reception of FFO at one point each side.

Vertical replenishment by means of a helicopter is provided at the after end. Helicopter servicing facilities are fitted, comprising workshops for radio, engine, hydraulics and electrical systems.

Complement

The ships complement includes an officer and ratings from the R.N. for the helicopter.

Accommodation is to best commercial practice and to latest requirements of the Board of Trade, being entirely cabin accommodation. The junior R.N. ratings are accommodated in multi-berth cabins. Additional accommodation for war complement is achieved by 'doubling up' in crews' cabins.

NBCD

NBCD arrangements are to R.N. standards including NBCD headquarters fitted with fire and smoke alarms and indicators, etc. and a prewetting system.

Mechanical smoke-making apparatus is fitted to meet Lloyds safety requirements.

Machinery—General

It was agreed to proceed with the design of machinery on the basis of initial steam conditions of approximately 600 lb/sq in., 850 degrees F, these conditions being the most advanced at the time in service in the R.N.

The machinery is designed to develop full power in seas of 85 degrees F and

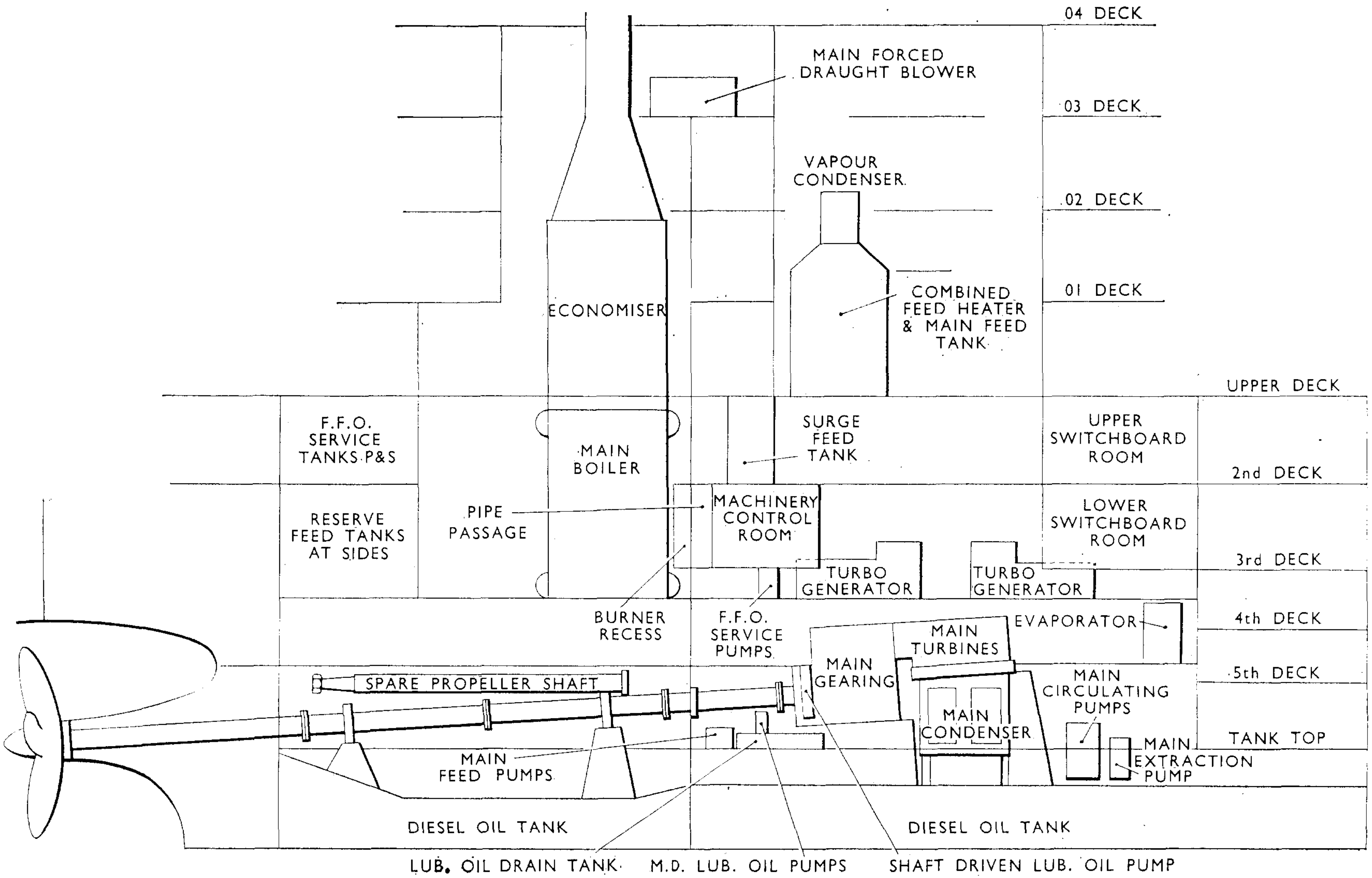

FIG. 2—MACHINERY ARRANGEMENT

for a total working life of 150,000 hours with the steam plant running at full power, which corresponds to an estimated running life of 30 years.

In order that the machinery installation should be capable of operating when flooded up to the level of the underside of the main turbine shafts, as in naval practice, all main propulsion motor-driven auxiliaries, with the exception of the FFO service pumps which are above the submersibility level, are of the vertical spindle type fitted with air bell motors, including the turbo alternators circulating water pumps which, although the main machines are fitted high up, are themselves located low down in the ship.

As time was not available for the building of a full-scale mock up of the machinery arrangements, the use of which undoubtedly brings to light unexpected regions of congestion, etc., the necessary clauses were written into the machinery specification to allow the Naval Engineer Overseers the latitude and authority to get the details of the machinery installation put right, which in a first of Class ship built under fixed-price contract would have meant delays while Board approval was obtained on every occasion where adjustments were required.

Main Machinery

It was decided to design the steam turbine machinery for 20,000 shp and obtain the increased power required for the tanker design by means of a by-pass arrangement. In both applications the main engines would be capable of operating at main shaft speeds up to 15 per cent above designed full power propeller shaft speed.

The arrangement consists of a two-cylinder cross-compound steam turbine driving through double-reduction gearing, with a two-pass surface condenser of the regenerative type, with tubes arranged with their axes horizontally athwartships, underslung from the LP turbine. To meet Lloyds rules, portable pipes and a valve are provided which enable either the LP or the HP turbine to be run at reduced power while the other turbine, if damaged, is isolated. An Aspinall type emergency overspeed governor is fitted and arranged to close an emergency shut-off valve in the event of maximum-designed ahead shaft speed being exceeded. The emergency valve will also close if there is excessive axial displacement of turbine rotors.

The astern element consists of a two-row Curtis stage and two impulse stages situated at the forward end of the low pressure ahead turbine. The LP ahead and the astern turbines have a common exhaust opening.

During the continuous astern trial at sea, the astern turbine was run for nearly 4 hours before the critical temperature in the later stages of the LP turbine due to windage, attained a steady value below the maximum permissible. In view of the almost complete inability of these ships to steer while running astern, this trial, which was carried out in the Firth of Clyde was no mean navigational feat.

The single flow LP turbine, which is a departure from previous naval practice, has 10 stages, the last row of blades being 18 inches high on a mean diameter of 63 inches running at a maximum speed of 3,500 rpm. These blades are longer than any used previously in recent marine geared steam turbine installations but have been used in similar form for many years in land turbines.

The HP top half cylinder has an integral steam chest containing three nozzle control valves. The first two valves supply groups of nozzles in the top half cylinders, while the third valve supplies steam to a single group of nozzles in the bottom half cylinder through internal passages and not via external pipes as adopted in previous designs. In the *Resource* the HP turbine horizontal joint leaked badly during sea trials and subsequent examination revealed that the Foliac jointing had been 'scrubbed clean' between the nozzle chamber connecting hole and the wheel case and gland pocket, indicating steam blow, and exhibited a crazy paving pattern between the 'hole' and the outer edge of the joint, also indicating steam tracking. Straight-edge readings showed an area of shallow depression around each connecting hole. One theory is that the metal in the area of the 'hole' heats more rapidly and to a higher temperature than the rest of the adjacent joint metal and, as it cannot expand freely, the metal around these holes is slightly crushed. Thus when the turbine cylinder comes up to a more uniform temperature, or when cold, a small gap is formed round the hole. The joint was remade with manganesite diluted with boiled oil with the addition of a little of Newsons Fibrene. No further leakage has so far been experienced.

The main gearing is of the single helical, dual tandem, articulated type, with hard pinion and hobbed and shaved 'soft' wheels. The pinions for the first ship were nitrided after being hobbed and shaved, because of a national lack of grinding capacity of the size required at the time of manufacture. The pinions for the second ship were surface hardened and ground and the ahead tooth flank profiles provided with end relief in accordance with general practice. End relief could not be applied with the nitrided procedure. The gears in the second ship proved extremely noisy when going ahead during sea trials and the pinions were subsequently reground to eliminate the tip and end relief and the noise level thereby reduced.

Excessive vibration in the gearing was experienced at high revolutions in both ships. The main thrust block is fitted with thrust measuring equipment and in the first ship this was subsequently converted, temporarily for trial, to a resonance changer. Trials with the resonance changer in use showed that the vibrations could be reduced by stiffening the front covers of the gearcases, and this course of action proved satisfactory.

During the sea trials of the second ship a minor explosion occurred in the gear case. Subsequent examination revealed that an assembly space ring approximately $4\frac{1}{2}$ inches internal diameter of $\frac{3}{4}$-inch square section was fitted as a push fit in the turning gear clutch end of the LP pinion and had not been removed after balancing and before assembly of the gearing. This ring had become loose during manoeuvring and fouled the stationary female portion of the turning gear. About two-thirds of the ring, in two pieces, was found inside the male end of the coupling and the remaining piece of the ring was found in bottom of the gear case. The sheared off bolt ends and nuts were also found in the bottom of the gear case. It was most fortunate that none of these items had passed through the gearing, as it is certain that the ship, in a totally unmanoeuvrable state, would have been driven ashore by wind and sea, as the weather conditions were too severe for tugs to approach the ship.

Two single-speed motor-driven circulating water pumps operating in parallel jointly supply the main condensers and lubricating oil coolers. For convenience and to provide the maximum integrity of the circulating water system, one pump has been fitted on each side of the ship, one with a high and one with a low suction.

A noise-reduced five-bladed propeller for agouti is installed.

Machinery Auxiliary Systems

The propulsion auxiliary systems generally follow accepted mercantile marine practice. The feed system, however, is simpler than might be expected in a merchant ship and the forced lubrication system follows naval trends.

The main feed pumps and the harbour service feed pumps are driven by back-pressure turbines, the former being the Weirs water lubricated bearing type.

These water lubricated bearings are protected under conditions of low feed demand and shut valve operation by providing a continuous flow of water through the pump and bearings by a light load by-pass to the deaerator inlet. In order to safeguard the bearings should a 'blackout' occur, an emergency supply of lubricating water from a battery powered, electrical switch operated MD pump can be effected.

The Venturi governors fitted to the main feed pumps, basically of similar design to those fitted to the TWL pumps in frigates, were most unsatisfactory during the early sea trials of the first of class. The steam valve of this governor had a single edge controlling the flow through the ports and the failure of the governor was attributed to the magnitude of the dynamic steam forces increasing beyond a critical value. Fitting a modified valve with two edges eliminated the troubles.

All other rotating auxiliaries are motor driven.

Feed Systems

Water in the main condenser sump is controlled at a nominally constant level by a float-operated discharge control valve in the extraction pump and air ejector discharge line. The extraction pumps of the turbo-generators, which have similar condenser float control arrangements, also discharge into the main feed line to the deaerator. The main feed pump draws directly from the main feed tank and separate automatic make-up and overflow arrangements are not required on the main and turbo generator condensers. The feed water storage between the low and high water levels in the feed tank is the equivalent of the maximum expected surge in the system plus the expected water losses during one watch. The stand-by main feed pump is connected to the working surge feed tank. Separate main and auxiliary feed discharge lines are provided each supplying both boilers in parallel.

Lubricating Oil System

This is the Swedish system with two motor driven pumps sitting on top of the drain tank, the combined capacity being equal to the full power requirements of the main engines and gearing. Another pump is driven from the main gearing and is also capable of meeting the full power requirements of the main engines and gearing.

The design envisages that at all powers the main gear driven pump would be in use together with one of the motor-driven pumps, with the remaining motor-driven pump stand-by on automatic cut-in. At low power the gear-driven pump will take part of the output from the motor-driven pump, the remainder going direct to the main engines and gearing. As the propeller shaft revolutions increase, the gear-driven pump takes more of the output from the individual pump until at just over half-power it will absorb the whole output. Above half-power the shaft-driven pump will take additional oil direct from the drain tank.

A system of non-return valves are fitted to enable the shaft-driven pump to be operable when the engines are going astern.

To meet the wishes of DFMT who operate the ships, an emergency gravity feed system with constant sight flow indication, has been installed. To meet Lloyds Regulations a pressure trip is fitted in the lubricating oil system which in the event of low lubricating oil pressure will close the emergency shut-off valve in the main steam supply to the main engines.

Fuel System

The system is generally in accordance with normal mercantile practice. Two main FFO pumps each capable of supplying both boilers at full power take suction from two service tanks, each of which hold enough fuel for 12 hours' supply at full power on both boilers.

The pumps are two-speed motor driven self-priming positive displacement pumps. A pressure control valve is operable from the machinery control room for controlling the discharge pressure of each pump at any desired value between the limits of the boiler burning equipment and capable of by-passing, through a cooler back to the service tank, the total putput from the pump when it is running at its higher running speed and handling heavy fuel at a low discharge pressure. The pumps can be used on dieso.

Main Boilers

The boiler installation consists of two Foster Wheeler ESD type double-cased marine boilers with superheaters, by-pass economizers for superheat control and economizers. Because of the comparatively high harbour load the installation of an auxiliary boiler was not justified. To avoid congestion of pipework the superheater outlets, main mountings, soot blowers, etc., are located at the after end of the boiler or the end remote from the engine room and MCR.

In view of the likelihood of steaming at high powers as compared with a naval vessel, the economizers were designed to provide a reasonably low full evaporation gas outlet temperature thereby maintaining a suitable boiler efficiency.

The requirements for NBCD are met by the adoption of simplex burners in a simple design of register developed by AMEE for remote manual operation. This is achieved from wing compartments of the MCR by means of a single connection from each register which operates the burner and associated air slide together. Steam purging equipment is fitted to the burners.

The boiler water level gauges and the feed regulators are fitted in the engine room above the MCR. The feed regulators were originally Copes two-element type, which, after unsatisfactory installation aspects had been rectified, proved fairly satisfactory in operation. However, DFMT were unhappy with this type of regulator and after completion of the ships, they were replaced by Weirs Robot single-element type.

Also to meet the requirements of DFMT a Stephens boiler water low level alarm was installed associated with a valve in the FFO supply line, which will close the oil supply to the sprayers in the event of the boiler water approaching a dangerously low level.

Motor driven two-speed blowers with inlet vane control operated from the MCR are fitted.

Electric Generating Plant

AC power supply system 440 volts, 60-cycle 3-phase installation. Four in No. Allens 1000 kW turbo alternators are fitted in the upper wings of the engine room. A 300 kW Diesel alternator is fitted forward below the bridge structure for emergency salvage load at sea and for harbour use when the boilers are shut down. In view, however, of the nature of the cargo carried these ships will normally only shut down boilers for refit and docking.

Distilling Machinery

Two sets of evaporators are fitted. They are of the submerged flexible element type by Caird and Rayner and an improved version of the plants fitted in the GM destroyers. They had been installed in the first ship of the class when the Board of Trade raised objections. Their rules laid down that all distilled water intended for cooking and drinking purposes should be effectively chlorinated and any surfaces or pipes made of copper in contact with steam or distilled water should be tinned. As regards chlorination, the shipbuilders fitted Electric-Katadyn sterilizing units which are acceptable to the BOT as an alternative to

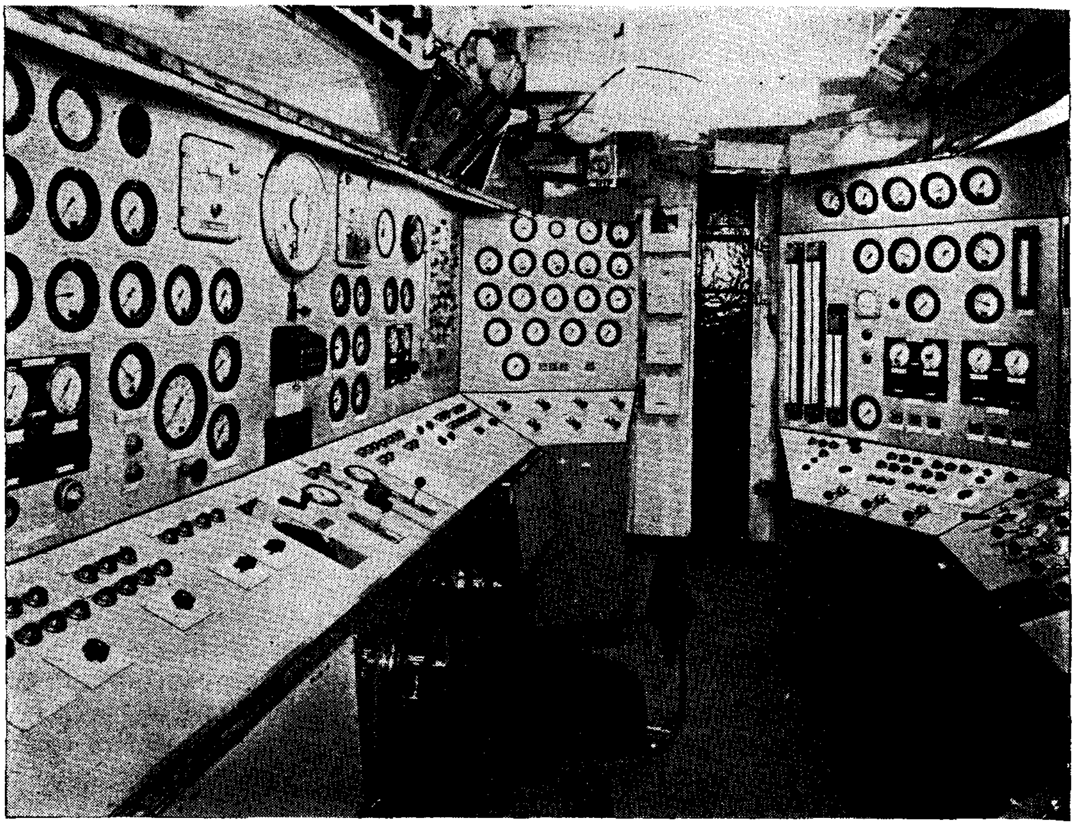

FIG. 3—MACHINERY CONTROL ROOM

chlorination. It is interesting to note, however, that this process was investigated by DME in 1962 and it was found that it is not possible to use this system if the conductivity of the distillate is below 20/25 micromhos. The plants in these ships give a purity of less than 4·5 micromhos!

The shells of the evaporators and the heat exchangers and the 8 in. vapour outlet pipes for the 2nd effect evaporator to the feed heater condenser are made from copper and to carry out tinning of these plants would have necessitated complete removal of the plants from the ship with consequent delay in completion. Tinning of copper surfaces was discontinued in R.N. ships in 1942 and after discussions with the BOT they agreed that tinning would not be insisted upon subject to the distillate not having a copper content in excess of 1 mg/litre. Samples were taken from the plants fitted in two GM destroyers as well as those in the two RFAs and these showed that the copper pick-up was well within the limit imposed.

Machinery Control

The MCR is situated in the after end of the engine room and is provided with wings port and starboard, enclosing the boiler burner operating position as mentioned under 'Main Boilers'.

The arrangement of controls permits operation of the main machinery and associated auxiliaries throughout the full range of power ahead and astern, after local preparation to the stand-by condition, i.e., when the machinery is ready in all respects to move the ship. Control is by air-operated Telektron motors and rod gearing. The console for the main engine and associated auxiliaries face the console for the boilers and their auxiliaries, with the console operators back to back. Automatic control of superheater steam, FFO and lubricating oil temperature, and exhaust and saturated steam pressures are provided.

Observations

The specified full power shp was never developed during sea trials because the ships were in the trials displacement condition—some 2,500 tons lighter than the standard displacement—and only 70 per cent full power was required to drive the ships at designed full power shaft revolutions. For the full power trials therefore the main machinery was run at a speed approaching the 15 per cent overspeed trip speed, with the attendant risk of tripping out the main turbines by variations in shaft revolution caused by helm and weather.

The most serious design defect concerns the main turbine automatic steam isolating valve. This is a Hopkinson type and shuts automatically for any one of six reasons: overspeed of either HP or LP turbine, excessive differential expansion of HP or LP turbine, low lubricating oil pressure or low vacuum. This valve, once tripped, will shut off steam to both ahead and astern turbines and can only be re-opened by hand.

The disadvantage of having only one such design of valve fitted for both ahead and astern turbines was illustrated on two occasions during the sea trials of the first of class:

(*a*) While changing over boilers for full output trial on each boiler, the starboard boiler primed. Both starboard turbo alternators were on the board and both failed with consequent total loss of electric power. The stopping of both motor-driven forced lubrication pumps resulted in the automatic isolating valve shutting due to loss of lubricating oil pressure. It was approximately 4 minutes before the ahead nozzle control valves were shut and the isolating valve re-opened to enable astern steam to be available to check shaft rotation.

(*b*) When working up to full power astern, the astern nozzle valve seized open at 70 shaft revs. The automatic valve was shut and the main turbine maintained at slow speed astern by use of the isolating valve by-pass valve while the astern nozzle valve was worked on and eventually freed.

This unsatisfactory arrangement will be modified during ships first refit by installing a Cockburn self-closing and emergency valve on the main steam line to ahead turbines and utilizing the Hopkinson, without its emergency connection, as a guard valve on the steam supply to the astern turbine. The Cockburn valve will automatically reopen when the cause of the trip, i.e. low lubricating oil pressure, etc., has been restored.