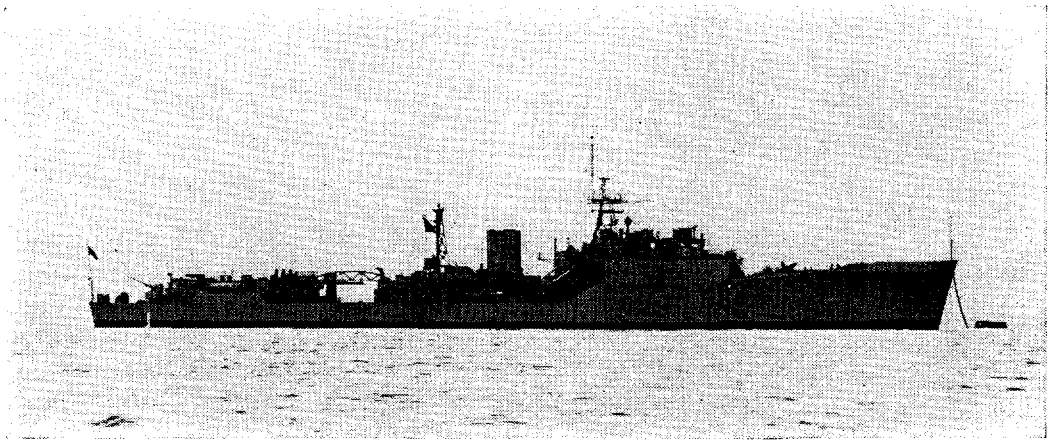

FIG. 1—H.M.S. 'EXMOUTH'

H.M.S. EXMOUTH CONVERSION

BY

J. R. CRUMP, B.SC., R.N.E.S.

Contrary to the belief apparently held by the more sensational of our daily newspapers, H.M.S. *Exmouth* is *not* to become the Royal Navy's first jet ship. Since the efficiency of the jet engine is largely dependent on minimizing the difference between vehicle and relative effluent gas speeds, this mode of propulsion is most unlikely ever to be adopted for a surface vessel, a point for which our long suffering dockyard personnel will probably be grateful!

The ship is, however, to be converted to all gas turbine propulsion machinery and the engines used are to be marinized forms of two well-proved aero-engines. The advantages of this type of engine in the continual struggle to build ships which will run longer and faster, carry more weapons and men to man them, spend longer than one day in every two (between long refits) at sea, require less and less maintenance and yet be economically viable on a decreasing Defence Budget have been expanded elsewhere* and are in any case widely known. Suffice to say that the object of the project is to prove the Bristol Siddeley Olympus gas turbine as a marine main propulsion engine, operated under the normal conditions obtaining in a typical frigate.

In approving the conversion, the Admiralty Board stipulated that the work was to be carried out coincident with a planned normal long refit and that when the ship was returned to service, her operational capability measured in terms of speed, endurance, manœuvring performance, noise, weaponry, shock resistance, etc., should be at least equal to a standard *Blackwood* Class frigate after the equivalent long refit.

*'Gas Turbines in the Royal Navy', Vol. 16, No. 2.

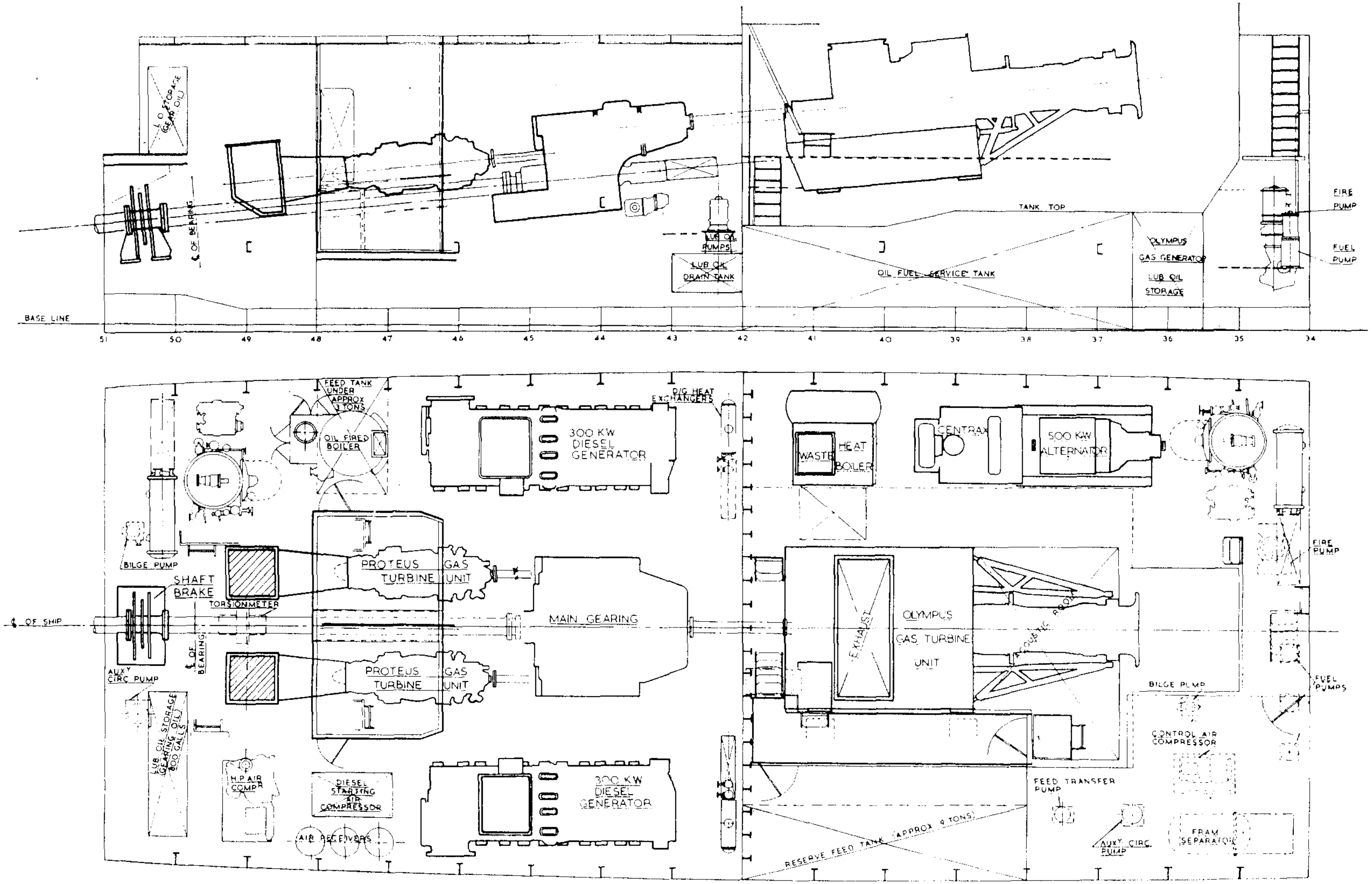

FIG. 2—NEW MACHINERY LAYOUT

Main Machinery

The two machinery spaces of the ship are to be completely gutted, leaving only the bulkheads and deckheads sensibly unaltered.

Three propulsion gas turbines will be installed: one Olympus TM 1 unit in the new forward engine room and two Proteus type 10M/533 in the after engine room (FIG. 2).

The need to provide suitable uptakes and downtakes for these engines has meant a complete re-design of the superstructure above the machinery compartments which will give the ship a most distinctive appearance. In place of the old square funnel, a squat deckhouse will contain the Olympus intake filters and silencer, the exhaust being carried by a new rounded funnel further aft than the original. Intakes and exhausts for both Proteus engines are combined in a single structure above the after engine room. The engine uptakes are not diffusers, since the high exhaust velocities are utilized to carry the gases clear of the ship.

The engines will drive into a single gearbox, sited well forward in the after engine room; a single screw is to be used and the present line of shaft and propeller blade centre line are to be retained. In order to provide reverse power a Kamewa controllable-pitch propeller is being fitted. This is a standard commercial design modified only for the Agouti noise reduction system. The necessary air is bled from the compressor of each main engine, the full requirement being met from any single unit.

The Olympus unit support system had already been developed for installation in the Type 82 destroyer and the principle underlying the mounting arrangement used for H.M.S. *Exmouth* has been to retain interchangeability of engines for these two applications. Two heavy steel girders bolted along each side of the power turbine carry the unit on a rigid/resilient mounting system; the gas generator is cantilevered from the power turbine casing by means of tubular steel frames which afford considerable shock attenuation and which are designed to swing clear to permit removal of the gas generator. Gas generator and power turbine are connected by a flexible duct.

The Proteus engines are mounted on heavy steel brackets cantilevered from the after end of the gearcase, rigid/resilient mountings again being used for shock protection. The engines are carried in cold rings giving four-point support around the engine centres.

The drive from the Olympus power turbine is transmitted through a Metaduct torque tube, incorporating Metastream flexible couplings, into the forward end of the gearcase, the torque tube cover being split into two sections and forming the watertight seal at the bulkhead. SSS clutches are included in the input shafts of all three engines. These are similar in design to those used for the DLGs and GP frigates and incorporate 'pawls-free' and 'locked-in' facilities; the former being essential to allow independent barring of the three power turbine rotors. Because of the similarity between the maximum power and speeds of the Olympus and of the *Blackwood* Class main steam turbine, it has been possible to retain certain elements common to the original gearbox for the Olympus gear train, mainwheel and thrust block. Thus double-reduction gears of the tandem locked-train type are used.

The Proteus engines are supplied complete with an epicyclic gearbox to give 1,000 r.p.m. output at full power and their transmissions are carried through Metastream couplings and quill shafts to the single-reduction pinion. This arrangement permits the engines to be close-coupled to the gearbox while allowing for displacement of their supports under shock.

Some redesign of the thrust block astern pads has been necessary due to the uni-directional rotation of the propeller shaft.

The forward end of the gearcase carries the oil distribution box for the C-P

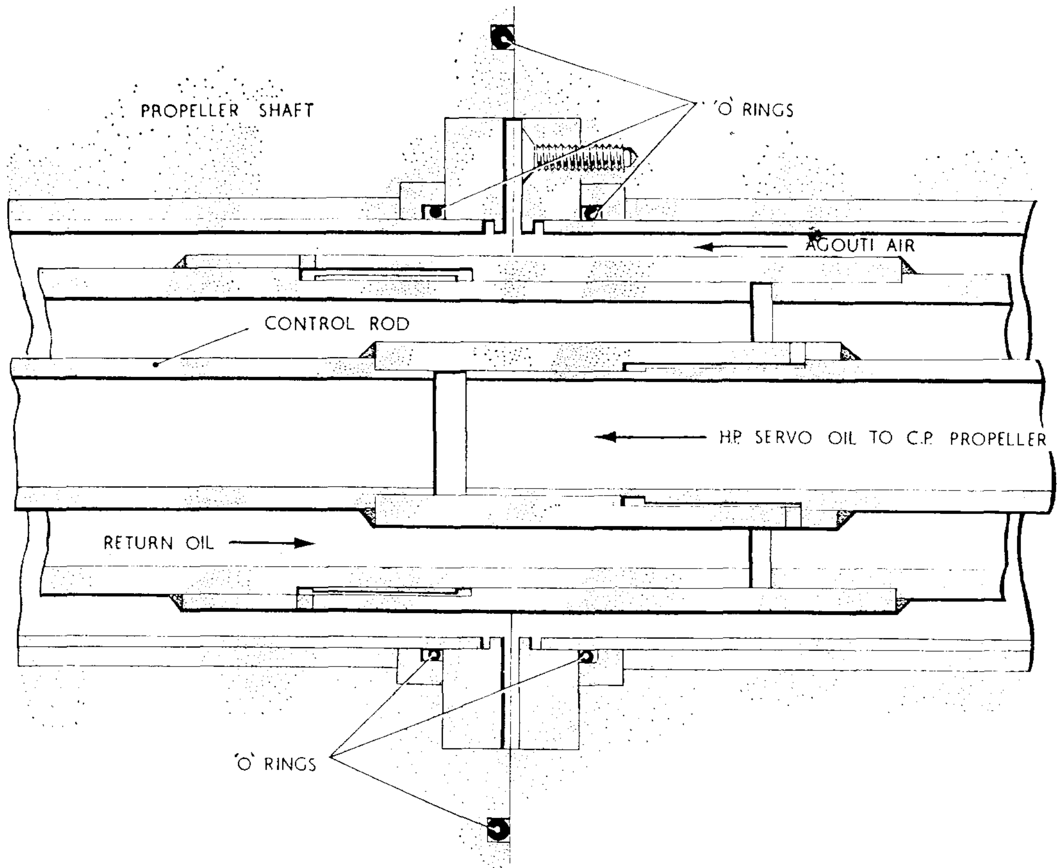

FIG. 3—CROSS-SECTION OF PROPELLER SHAFTING SHOWING JOINING OF CONTROL ROD, RETURN OIL AND AGOUTI AIR TUBES

propeller which also serves to introduce the Agouti air to the main shaft. Three concentric tubes pass down through the shaft; hydraulic oil, at about 500 lb/sq in., is carried in a central control rod, the axial position of which governs pitch; the oil acts on one side of a spring-loaded piston linked to lugs on the four blade carriers in the propeller hub and returns at 50 lb/sq in. between the control rod and the Agouti air tube (See FIG. 3).

Generating Machinery

One 500 kW Centrax CS 600/2 gas turbine alternator is provided in the forward engine room as the ship's primary generator. The engine is based on a commercial machine used by Area Electricity Boards and on order for the C.E.G.B. and G.P.O. Exhaust gas from the gas turbine is passed into a Babcock and Wilcox waste-heat boiler which is rated to produce about 4,500 lb/hr of saturated steam at 100 lb/sq in. when the generator is on full load (FIG. 4). An automatically controlled gas by-pass damper is fitted to regulate steam output and an electric feed heater increases the flexibility of the plant. By absorbing 50 kW of the generator output under part load conditions an additional 1,000 lb/hr of steam may be produced. Air for the boiler control is bled from the Centrax compressor.

Two 300 kW Paxman Type A12 YHAXZ Diesel generating sets (ex-H.M.S. *Yarmouth*) are being installed in the after engine room. Each machine will be fitted with a belt-driven compressor to supply air to the turbo-charger seals; this is required to prevent excessive rate of carbon build-up on the labyrinth seals during the anticipated sustained operation at low loads. It is hoped that it will be feasible to arrange remote starting of these sets.

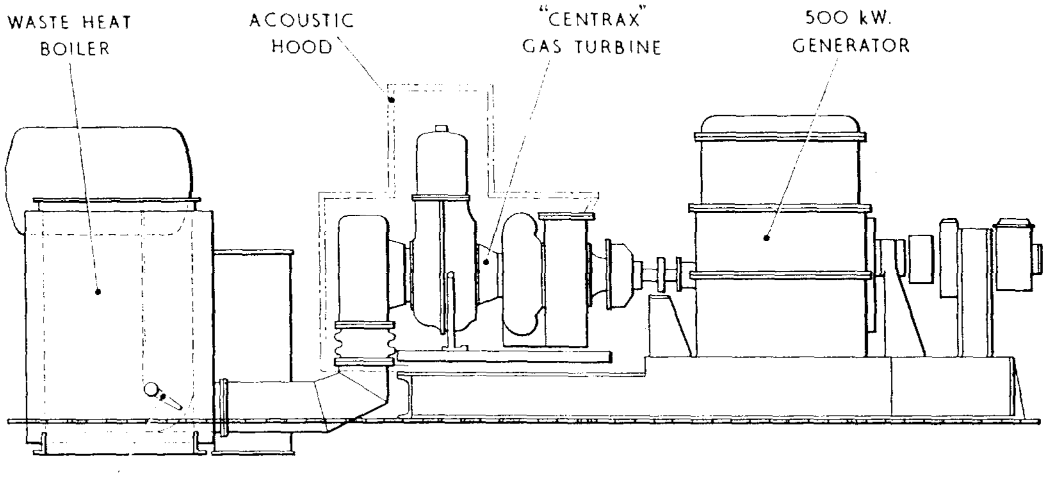

FIG. 4—CENTRAX GAS TURBINE/WASTE HEAT BOILER INSTALLATION

Although three quite independent generating sets are being fitted, under cruising conditions only the Centrax will be used and therefore electrical integrity cannot be guaranteed. For this reason separate pumps, shaft-driven from the main gearing, are being fitted to safeguard the vital services of lubricating oil, CP propeller hydraulic oil and main circulating sea water which will normally be sustained by motor-driven machines. In addition, fuel header tanks are provided to supply fuel automatically to the main engines on fall of boost pump discharge pressure, permitting steady-state operation together with a limited manœuvring capability during a complete loss of electric power.

Auxiliary Machinery

In selecting auxiliary machinery, preference has invariably been given to equipment well-proved in service elsewhere and wherever possible plant already fitted in the ship is being completely refitted and re-used.

A standard Stone-Vapor Type 4, 4,500 lb/hr oil-fired boiler located in the after engine room will provide steam when the Centrax is not in use.

The two existing Weir 25 ton/day submersed element evaporating plants are being retained, one in each engine room. These, like all other machinery, will be brought up to the latest modification state and will also be fitted with automatic dump valves and salinometers incorporating remote warning lights and chart recorders.

Two Reavell TC 3½, 40 cfm high pressure air compressors provide air for starting main engines and the usual services and seven 9·1 cu ft reservoirs provide ample storage capacity. In addition a Dunlop HO2 10 cfm compressor fulfils the salvage function.

There is a cross-connection between the HP air and the main engine control servo-air reservoir but a Williams and James 55 cfm machine will be the normal means of sustaining the latter at 100 lb/sq in.

A motor-driven 75 ton/hr Hamworthy Dolphin fire pump replaces the existing turbo-driven fire and bilge pump and firemain-operated bilge eductors will be fitted in each machinery compartment.

Noise Attenuation

In order to reduce noise in the machinery spaces, all three main engines are enclosed in acoustic rooms built within the two compartments, but of the Olympus only the gas generator portion is included. Ideally the power turbine

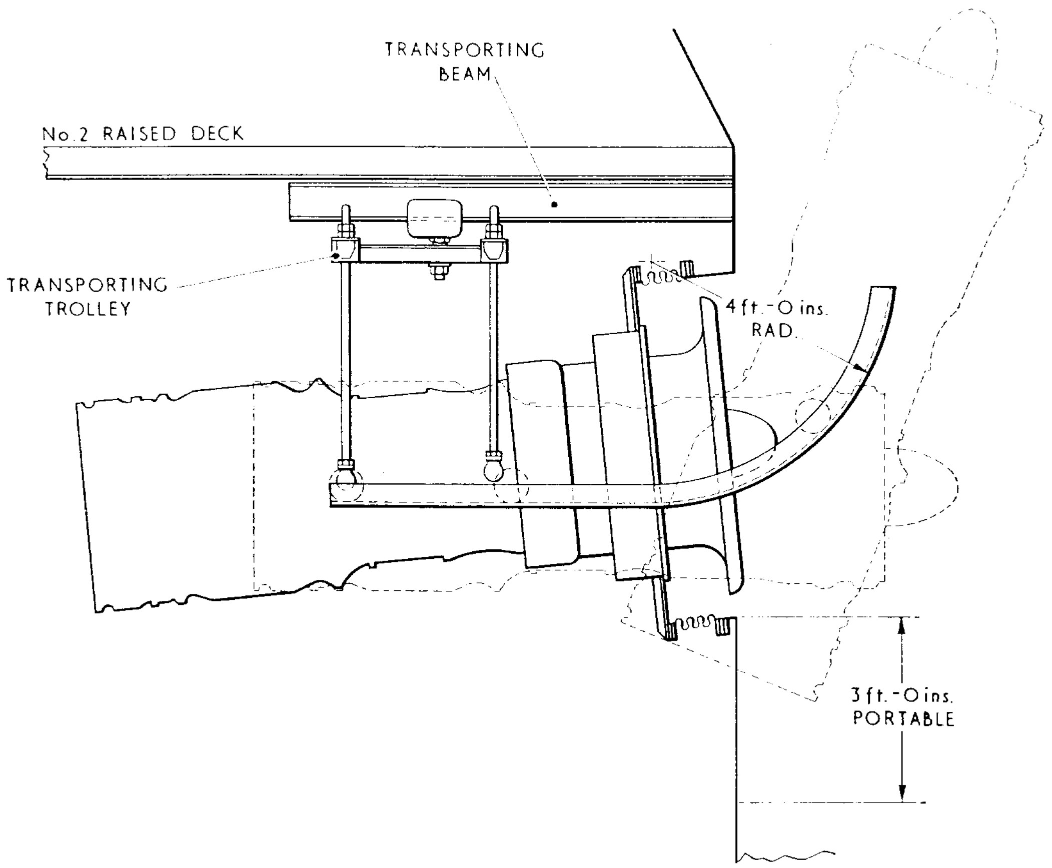

FIG. 5—METHOD OF REMOVING OLYMPUS GAS GENERATOR

would have been also enclosed but space considerations made this quite impracticable. The Olympus room is ventilated by supply and exhaust fans. In case of an electrical failure, a manually operated valve in the bulkhead with the inlet plenum chamber will allow cooling air to be drawn down both supply and exhaust trunks, through the acoustic room and into the engine.

The Proteus acoustic rooms are also the engine plenum chambers, air entering the compressors through a circumferential intake around the middle of the engines; no ventilation arrangements are therefore required.

An acoustic hood will be fitted over the Centrax gas turbine. Sections of this will be removable to permit access to the machine for maintenance and inspection purposes.

Acoustic absorption material (mineral-fibre resin-bonded slab) will be fitted around all bulkheads, ship's sides (down to the deep water line) and deckheads of both machinery spaces and this will be supplemented by acoustic damping plates in selected areas.

Air Inlet Systems

Each gas turbine air inlet is fitted with an arrangement of knitted mesh filters to limit the ingress of salt water and general dirt to the engine. The filters are of standard size and are arranged for ease of withdrawal and replacement; a fresh water spray system is built into each inlet hood. Emergency flaps are provided to enable the filters to be by-passed under severe icing conditions.

Splitter type silencers are fitted downstream of the filters in each gas turbine supply duct. These are arranged for easy removal as complete units.

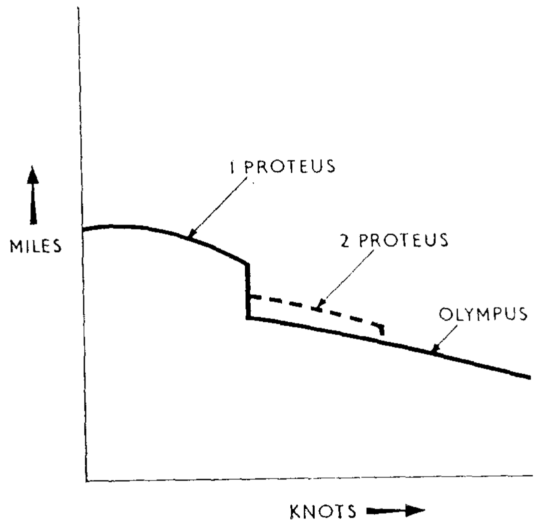

FIG. 6—COMPARISON OF ENDURANCE IN OLYMPUS AND PROTEUS ENGINES

Machinery Removal

Particular attention has been paid to providing good facilities for the rapid removal and replacement of the Proteus engines and Olympus gas generator. The units are lifted through their inlet trunks, the route being cleared in each case by the removal of a bolted cover plate and the appropriate silencer. The Proteus engines are detached from their cold ring supports and hoisted out in their horizontal attitude. The Olympus gas generator is carried away from the power turbine casing by a traveller running on a permanent track and turned through 90 degrees so that it enters the downtake vertically and nose-up. (FIG. 5.) A similar method has been tested for the Type 82 destroyer installation by a full-scale mock-up at Y-ARD (see p. 390). It should be possible to fit a main engine exchange unit within 24 hours.

Portable plates are provided in the two engine rooms for the removal of auxiliary machinery, including the Centrax gas turbine unit which like the main engines will invariably be 'overhauled-by-replacement'.

Mode of Operation

At high speed the Olympus engine will be used alone; in the lower power range, where the specific fuel consumption of the big gas turbine is poor, a single Proteus will normally be employed. Although the two Proteus engines may be used in combination, providing an excellent performance capability were the Olympus for any reason not available, there would be little economic advantage to be derived from habitual use of this mode in the middle speed range. (FIG. 6.) The Proteus engines cannot be used in combination with the Olympus.

In order that the full output of the two Proteus engines can be realized in combination, it has been necessary to compromise on the choice of reduction gear ratio. If this were arranged for maximum efficiency on one engine, then two engines would overspeed without anything like the full output being achieved. A sacrifice of only about $4\frac{1}{4}$ per cent in specific fuel consumption at 15 knots on one engine is involved in the choice of the lower reduction ratio, which is clearly worthwhile.

Control System

An air-conditioned combined switchboard and machinery control room is being built into the starboard side of the forward engine room. From here starting and control of the main engines will be exercised. A single lever sited on the Bridge will alternatively allow direct control by the Command of the power output of engines which have been previously started and engaged from the M.C.R.

Each engine is started by means of a 4-position uni-directional rotary control lever having the following functions:

Position 1—Stop: close high speed shut-off cock

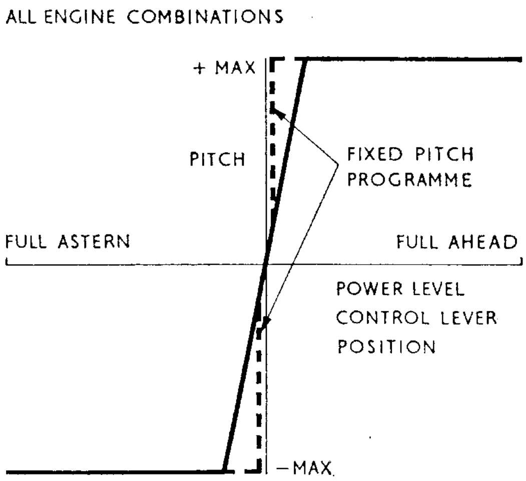

FIG. 7—PROPELLER PITCH PROGRAMME

Position 2—Prepare to start: move SSS clutch to 'ready to engage' position

Position 3—Start (and run): initiate starting cycle

Position 4—Prepare to stop: move SSS clutch to 'ready to disengage' position.

The lever is mechanically prevented from turning until the interlocks associated with the previous stage have been completed.

Once an engine has been run up, it may be selected by pressing one of five engine selector buttons, viz., Olympus, starboard Proteus, port Proteus, both Proteus, or cancel. The function of these is to bring the engine(s) under the control of the power level control lever and the control system then links the throttle of the engine(s) to the pitch of the CP propeller. The SSS clutch will not engage until the speed of the engine exceeds that of its input pinion and the engine acceleration during this phase will be limited.

Another engine may be started at any time and will remain at idling until selected. The system will be tuned to ensure the minimum of power interruption on changing engines. On being discarded by the engine selector buttons, an engine will remain clutched-in but idling until disengaged by moving the appropriate rotary control lever to Position 4; moving the lever to Position 1 will of course shut the engine down. An interlock will prevent overspeeding of a Proteus power turbine by the Olympus prior to disengagement of the Proteus clutch.

Computer calculations by Y-ARD demonstrated that, for practical purposes, maximum endurance would be obtained if the propeller pitch were kept constant at the full-ahead position for all forward speeds. However, it was also necessary to consider the manœuvring performance and here the stroking time of the propeller is important. From full-ahead to full-astern pitch this is approximately 20 seconds, so that a fixed-pitch programme would imply a delay of that order whenever a movement involving change of direction was ordered. Thus again a compromise was reached and the pitch/throttle programmes (a different one is required for each engine combination) arrange that pitch increases with power and shaft speed up to the point where full pitch is reached (FIG. 7); during this phase the engine throttles are controlled by a signal from the pitch servo. From then on the power is a function of shaft speed alone, the throttles being governed by a direct signal from the power level control lever. (FIG. 8.)

The control system and console, which will include a comprehensive range of instrumentation for main and auxiliary machinery, is being designed, manufactured and installed in the ship by Messrs. Bailey Meters & Controls Ltd.

Shaft Brake

When idling with the Olympus engine engaged, it has been estimated that the propeller shaft will rotate at about 86 r.p.m. It was essential therefore to provide a means of stopping the shaft and holding it at rest as the occasion demands. This has been achieved by the fitting of a disc type brake on to an extension of one secondary pinion shaft at the after end of the gearbox.

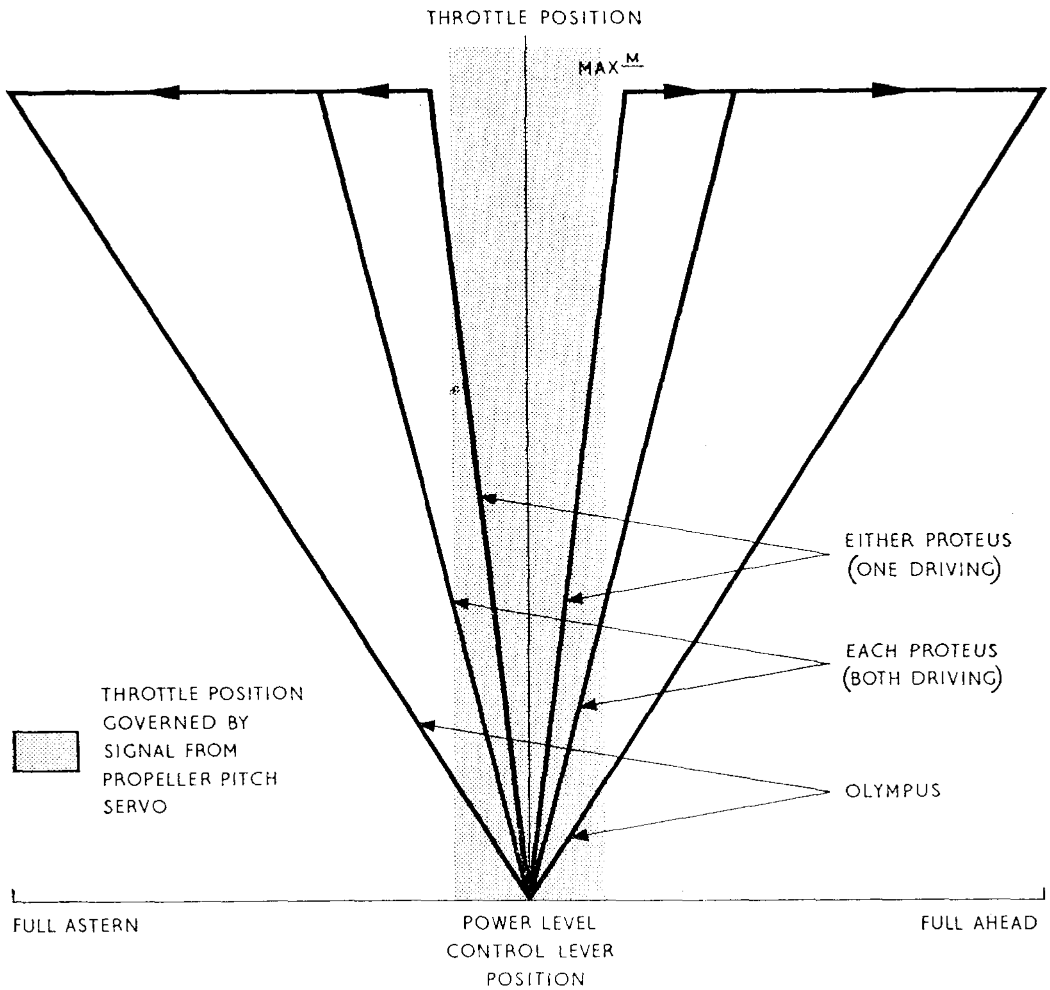

FIG. 8—THROTTLE PROGRAMMES

The brake, supplied by the Dunlop Rubber Co., has pneumatically actuated double calipers and its control is combined with the power level control lever. Interlocks prevent its operation unless all throttles are to idling, the shaft speed is below 86 r.p.m. and the main turning gear disengaged. It will not be used during normal manœuvring.

Lubricating Oils and Systems

The number of different oils carried on board has been kept to the minimum; even so three varieties are required.

The Proteus engines and Olympus gas generator have integral lubricating oil systems for which a synthetic oil, OX 38, is used. Since relatively small quantities will be needed and in order to ensure absolute cleanliness, this oil will be carried in one-gallon cans stowed in racks, from which it will be poured directly into the engine service tanks.

OEP-69 is used in the common main gearing and Olympus power turbine oil system for which the following pumps are provided:

Two full size motor-driven units (identical to the existing machine),

One unit driven from the main gearing at a speed which gives a margin of about 10 per cent on the full duty at full shaft speed; the pump end of this is interchangeable with those of the motor-driven machines.

The system is arranged so that the gear driven pump can be operated either in series or in parallel with a motor driven machine. Under cruising conditions, one motor-driven pump will normally be run, with the other set to automatic cut-in from a pressure switch. Two half-size sea-water cooled L.O. coolers are provided and the installation could operate up to about 50 per cent power on one.

For the Centrax, Diesel generators and C.P. propeller, hydraulic oil, OMD 112, is used.

Bridge Steering

In order to take full advantage of the Bridge engine-control facility, Bridge steering is also being fitted. An electric servo system is used and a commercial console, complete with auto-pilot will be installed in the centre of the fore-screen with the engine control lever alongside. An after power unit in the tiller flat is connected to the existing telemotor receiver linkage. The hydraulic system and existing wheelhouse will be retained, and changeover between the two positions simply effected by a linked isolating switch and by-pass valve.