SPEY INSTALLATION FOR TRIALS AT R.A.E.

BY

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Introduction

During the 1970s prolonged endurance trials of the aero-derived marine Tyne and Marine Olympus engines were conducted in the Admiralty Test House at the National Gas Turbine Establishment (NGTE) Pyestock, now part of the Royal Aircraft Establishment (RAE). The valuable results obtained from these successful trials strongly supported the case for similar trials of the new SM1A Marine Spey[1], then under development. Plans for a Spey test installation at Pyestock were therefore put in hand.

The Admiralty Test House

The Admiralty Test House (FIG. 1) was completed in 1952 for development testing of gas turbines for the Royal Navy. The building is 100 ft (30·5 m)

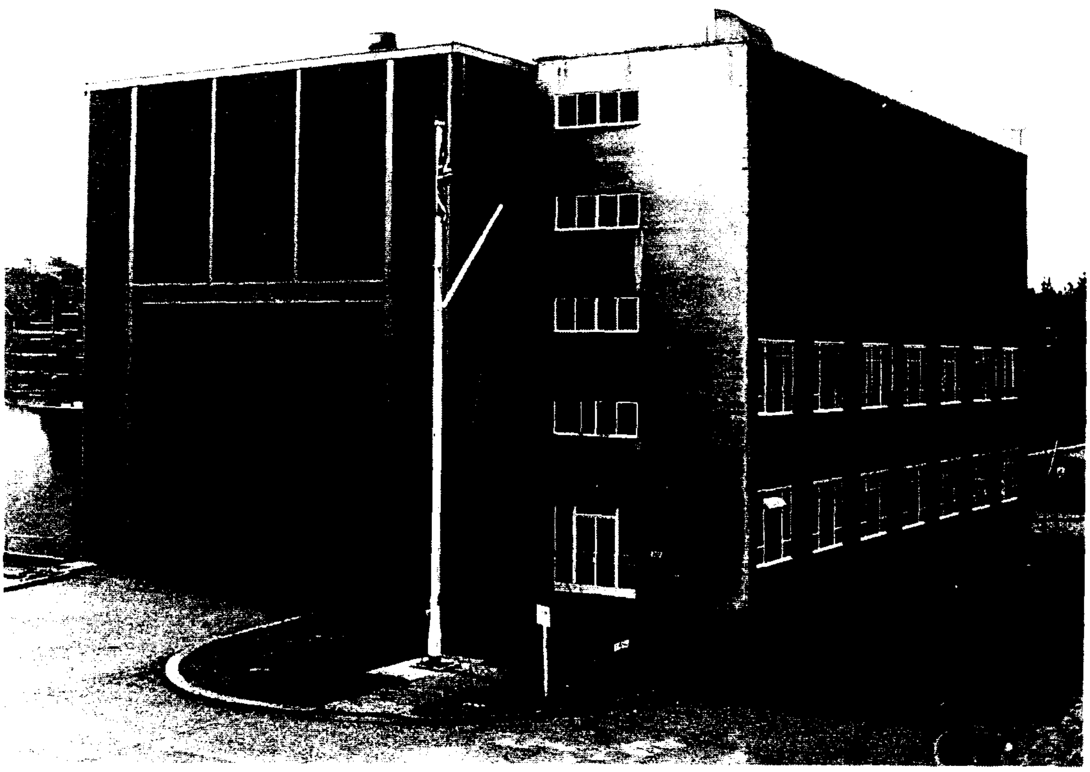

FIG. 1—THE ADMIRALTY TEST HOUSE FROM THE NORTH-WEST

by 94 ft (28·6 m) in plan, and 50 ft (15·2 m) high. The test hall itself (FIG. 2) is 40 ft (12·2 m) wide and accommodates a single test bed 73 ft (22·3 m) long by 10 ft (3·05 m) wide, constructed of heavily reinforced concrete 6 ft (1·8 m) deep. Water systems for dynamometers are provided, with main and emergency reservoirs, two induced-draught cooling towers, and pumps, all located close by (FIG. 3).

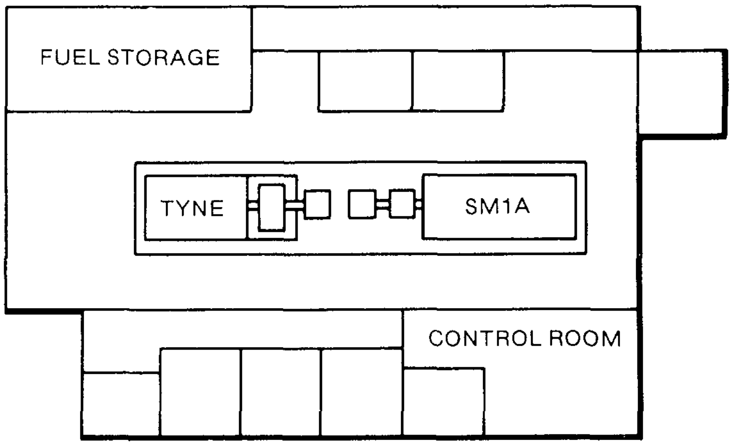

FIG. 2—PLAN OF THE ADMIRALTY TEST HOUSE

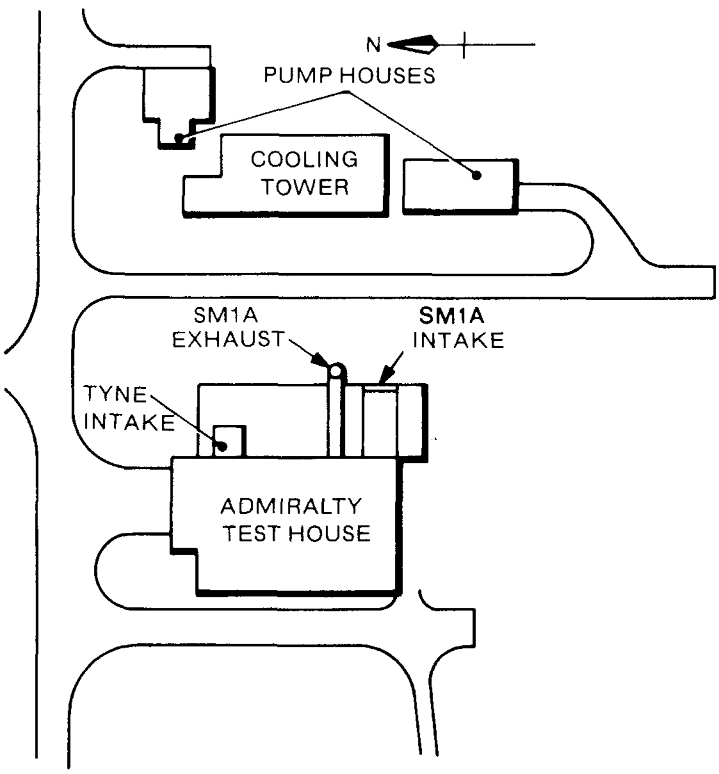

FIG. 3—ADMIRALTY TEST HOUSE AND ASSOCIATED SERVICES

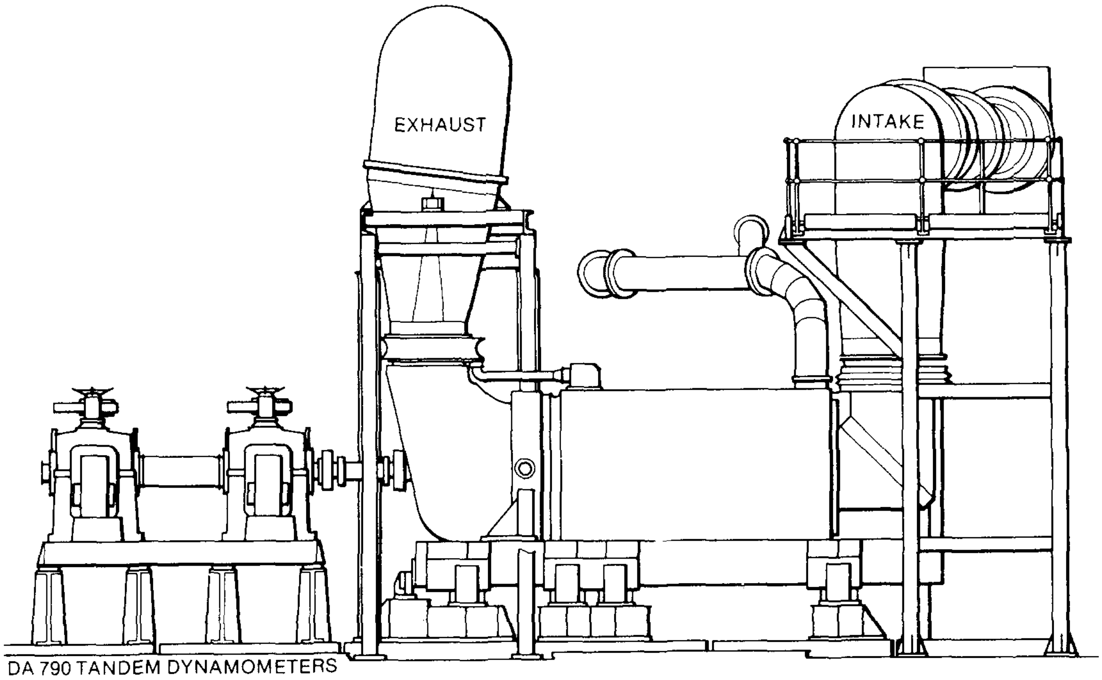

FIG. 4—SM1A TRIALS INSTALLATION

Overall Installation Design

Comparatively little design and manufacture was needed to convert the Olympus installation for the SM1A (FIG. 4). There were three main areas of design:

(*a*) module mounting arrangements;
(*b*) intake and exhaust ducting;
(*c*) remote controls and instrumentation.

Other design areas were comparatively straightforward:

(*a*) module ventilation supply;
(*b*) lubricating oil for power turbine;
(*c*) electrical and compressed air supplies;
(*d*) access platforms;
(*e*) vents and drains;
(*f*) Special Service Air Bleed (SSAB) dump system.

It was decided to use the tandem DA 790 EH dynamometers without alteration to their position, and therefore without any change to connected supplies and services, thus saving considerable work. It was also decided to use the Olympus torque tube, and this fixed the position of the SM1A module on the test bed.

The Olympus intake system included coarse filtration and splitter silencers, and was entirely suitable for the SM1A. The exhaust system also was suitable, and incorporated a detuner. Both systems were large and heavy, and any alteration in their position would have been difficult and expensive. It was decided to use them without alteration. These decisions resulted in some problems in connecting up the module intake and exhaust ducting, discussed later.

Module Mounting Arrangements

The SM1A module is supported by four pairs of combined vertical/horizontal mounts (FIGS. 5 and 6) and it is located at the power turbine end by a pair of ram and rake stops. The module is mounted on rubber shock/vibration mounts in the same way as ship installations; however shock-absorbing devices have been omitted, since these have no effect on the vibration characteristics of the installation and are not relevant to the planned trials.

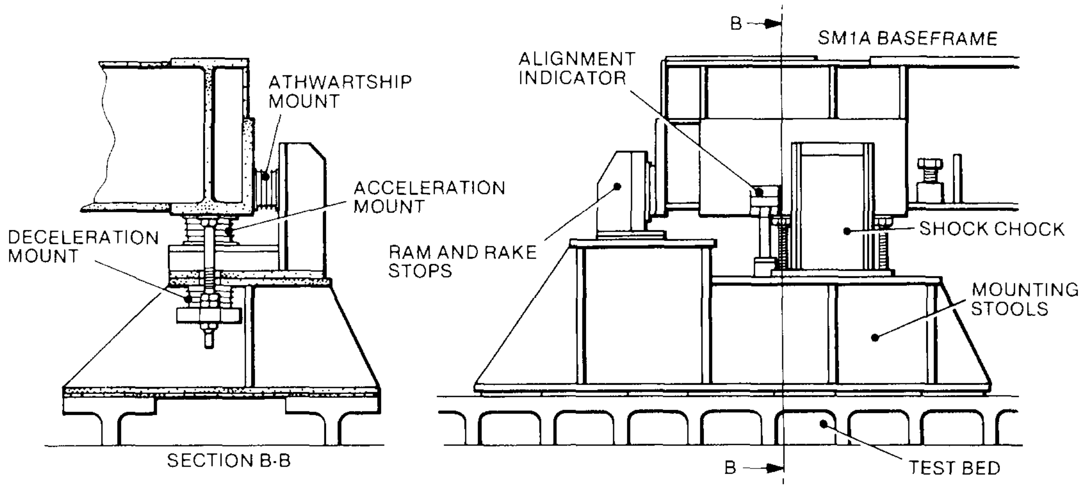

FIG. 5—SM1A MOUNTINGS

The procedure for mounting and aligning the module was based on the ship installation procedure, but required alteration mainly to allow for bolted assembly of mounting chocks and stools on the test bed, instead of chocks welded directly to engine bearers on the ship's seatings.

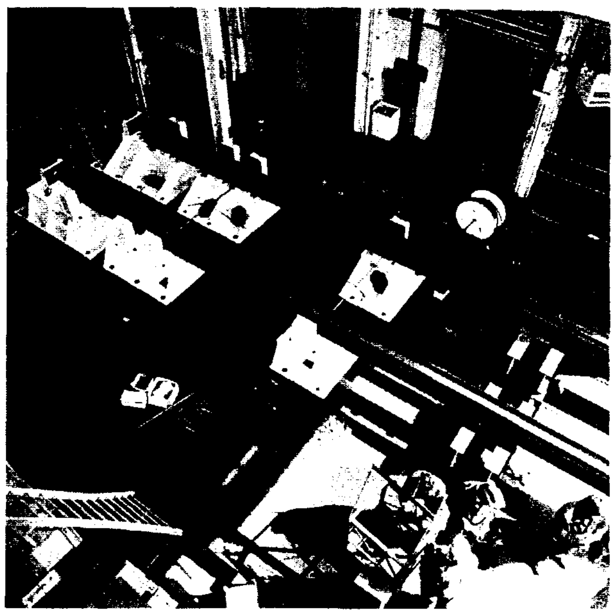

FIG. 6—SM1A MOUNTING STOOLS

The power turbine is connected to the dynamometer by a 41 in. (1041 mm) torque tube with two flexible membrane couplings. The alignment procedure was drawn up by the engine manufacturer, on the basis that at full power the power turbine and dynamometer shafts would be in alignment, with the membrane couplings in an optimum position. The procedure took into account:

(*a*) shaft bearing lift and rotational climb;

(*b*) dynamometer trunnion lift;

(*c*) axial float between thrust faces;

(*d*) thermal growth;

(*e*) vertical and transverse loading on rubber mounts.

The loading on rubber mounts was based on static weight distribution, and modified by torque reaction and ducting thrusts at full power. Mounts used for vertical acceleration under shock and for athwartships location were individually pre-calibrated, and the calculated compressions took into account primary creep, which occurs over the first 48 hours under load.

The required vertical and horizontal offsets when cold were established using lining-up telescope equipment, including right-angled eyepiece, mirror target, and light. Four alignment indicators were secured at the corners of the module baseframe to record the datum full power condition, for subsequent lining up after routine replacement of mounts and for periodical checking.

Air Intake

The arrangement of the engine air intake is shown in FIGS. 4 and 7. Air enters the engine module through a right-angled cascade bend, similar to arrangements for the Tyne and Olympus. However as a result of overall design decisions described above, the SM1A cascade centre is displaced 3½ ft (1 m) from the centre of the Olympus cascade on which the test house intake system was designed. It was decided to angle the horizontal ducting by 14° to accommodate this discrepancy. The plenum chamber from which air enters the ducting is 15 ft (4.6 m) square, and the boundaries were therefore far enough from the duct to eliminate any possibility of flow distortion. The two cascade bends provided further insurance against flow distortion which they have the property of eliminating almost completely.

A venturi airflow meter manufactured in fibreglass is fitted at entry to the ducting. This was designed in accordance with British Standards 726(1957) and 1042 Part 1 (1981), and has a throat diameter of 36 in. (915 mm). Transition to the full 4 ft 8 in. (1·4 m) diameter duct size is made in two diffuser stages in the horizontal section.

The Olympus intake plenum chamber had been constructed ten years before on timber frames, and was packed with rockwool insulation between galvanized sheeting. A survey revealed that the test house roof had leaked, resulting in some rotting of timber and in severe oxidation of the lining. Extensive refurbishment was therefore needed, which included replacement of the roof by marine ply covered with waterproofing membrane, replacement of the rotted support frames and insulation, and representation of the lining.

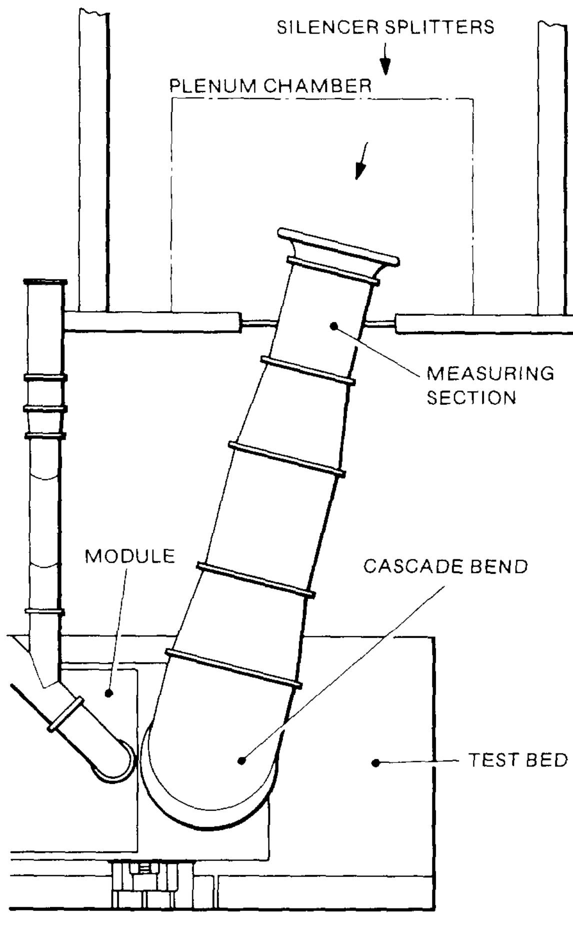

FIG. 7—SM1A INTAKE—PLAN

Exhaust

The arrangement of the exhaust system is shown in Figure 4. Exhaust gas leaves the rectangular power turbine volute exhaust duct, passes through a vertical transition section and is then turned to the horizontal direction by a cascade elbow. The horizontal duct incorporates the detuner already referred to, and is returned to the vertical direction by a second cascade elbow connected to the stack. The entire system was surveyed, and found to be in good condition. Some minor cracking of cascade vanes was repaired by welding after cleaning and sealing, and surfaces were represerved.

Using the old Olympus exhaust system and torque tube resulted in a problem with the SM1A arrangement, because differences in volute design resulted in a 1 ft (0·3 m) difference between the rectangular volute centre lines. This was overcome by rotating the first cascade elbow through 8°, giving a vertical transition section with wall angles within a limiting design figure of 10°, imposed by considerations of flow breakaway. This was particularly important on the forward side because the volute eduction system for module ventilation derives its suction from that side of the flexible bellows.

The flexible bellows is of the non-metallic type originally tested at Pyestock, and used for the Olympus engines in the INVINCIBLE Class aircraft carriers. It consists of layers of ceramic fibre, graphite-impregnated woven glass fibre, viton-coated glass cloth, and fluorocarbon membrane, supported by stainless steel mesh.

Remote Controls and Instrumentation

SM1A operation is regulated by a fuel system controller (FSC) comprising a hydromechanical unit with direct manual throttle for local control in emergency, operated by an electronic controller for starting and power alteration. The electronic system has full authority over acceleration, deceleration, power and speed, and provides safe working limits for the engine, taking account of ambient conditions. It includes a comprehensive self-monitoring capability and built-in test equipment. Two fuel system controllers have been operated at RAE, West Drayton, in a propulsion controls simulator for over 7000 hours without failure. Associated with the FSC is an electronic system for providing the required starting and stopping and power demand signals from either local or remote control stations, and a signal conditioning system for local and remote instrumentation.

The remote control position in the Admiralty Test House (FIG. 8) does not attempt to duplicate a ship installation, though it incorporates some ship components such as the remote power demand transmitter, and displays the same information and warning signals as a ship panel. It also includes additional interlocks and trips for test house systems such as power turbine oil supply and brake water, which are provided by a programmable logic controller. Dynamometer controls and instrumentation for the operator have been included in a section of the main panel for convenience.

Data Logger

An automatic data logging system had been installed in the Admiralty Test House in 1975; this processed data collected from voltage sensors, status sensors, and frequency channels, which under computer programme control stored, manipulated, or displayed the processed data. The equipment was the Compulog II system based on a PAC II 32 k memory central processing unit (CPU), using FORTRAN II language.

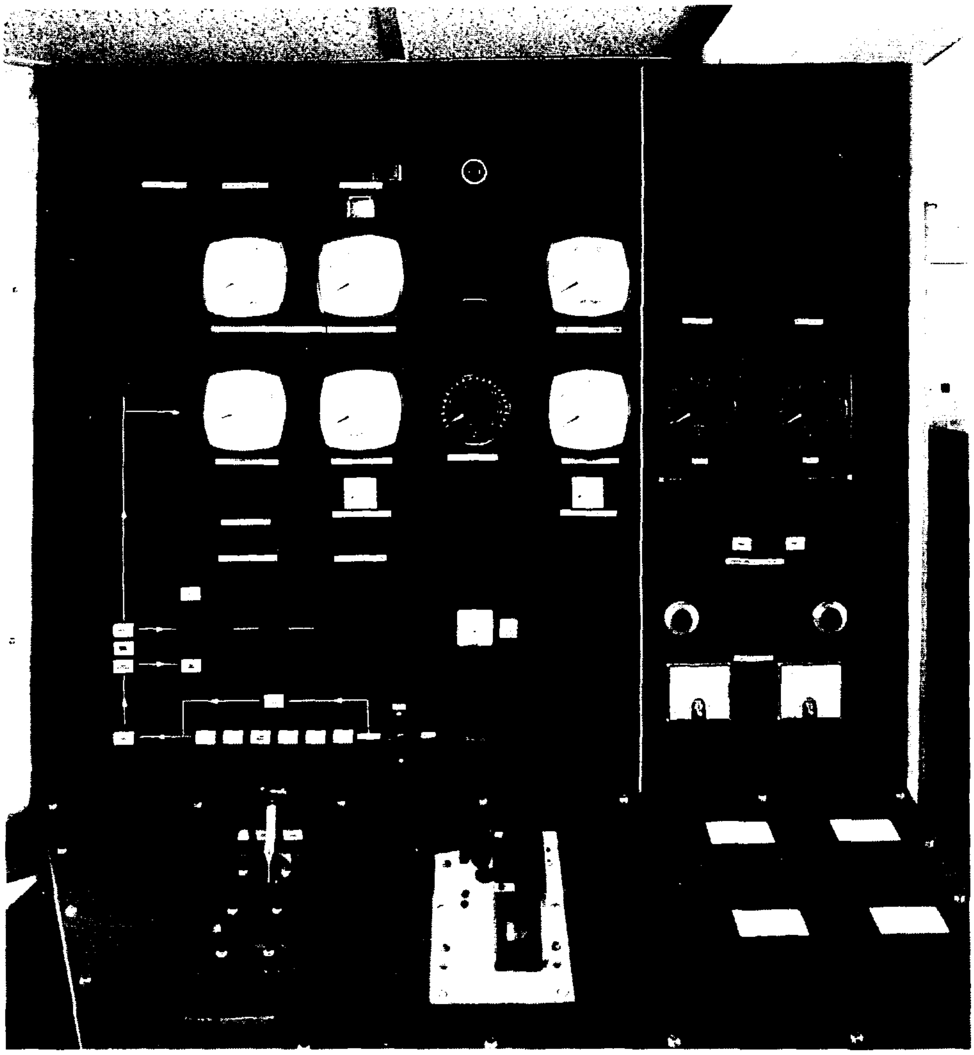

Fig. 8—Remote control panel

This system suffered some limitations: it was unable to perform simultaneous tasks, programme editing was cumbersome, and output peripheral equipment was limited in its speed and accuracy. Experience had shown an increasing need for rapid reading and processing during trials involving transients. In addition, the equipment was already obsolescent and suffered from scarcity of replacement parts. Although a number of improvements had been incorporated over the years, the decision to proceed with the SM1A clearly indicated the need for a fundamental review of data logger facilities.

It was decided to replace the CPU by a Compulog III system using a Fortran IV or Basic compiler, with two cartridge disk storage systems having an additional 96k memory capacity. The input/output peripherals were replaced by more modern items, such as a visual display unit in place of teletype, a cartridge tape unit for back-up in place of paper tape punch and reader, and a line printer with graph plotting mode facility. This updating of the data logger has greatly enhanced its flexibility by providing quick and accurate speeds of response, increased storage capacity, and a much more satisfactory mode of operation.

Module Shipping Route

A problem emerged when arrangements for shipping the SM1A module on to the test bed were considered. The maximum safe working load of the overhead crane is 20 tons, but the module weight without the GTCU is 23·4 tons. There was no acceptable way to bring the weight below 20 tons, and space in the test hall prevented the use of a portable crane. It was decided to pull the module on to the test bed on rails supported by a special structure 5 ft (1·5 m) high outside the south wall of the test house (FIG. 9).

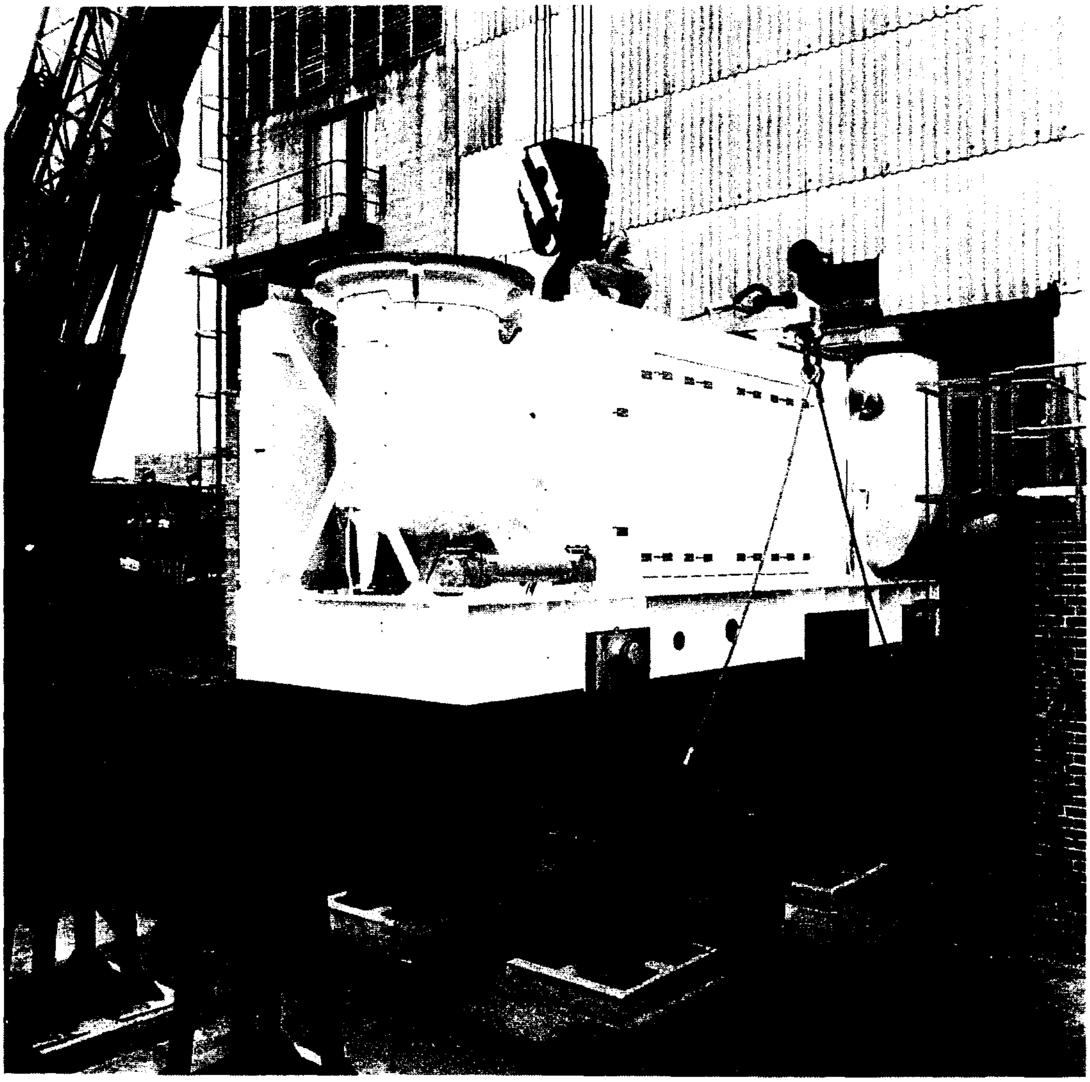

FIG. 9—SHIPPING THE MODULE INTO THE TEST HOUSE

There were two complications: firstly the concrete hardstanding on that side was not strong enough to support such a weight, and secondly the route was blocked by a vertical steel beam, which formed part of the support for the temporary wall structure. The first problem was solved by constructing eight concrete support plinths for the rail stools. The second problem was tackled by making the lower section of the vertical beam portable and stiffening the remaining wall structure by welding in a horizontal lintel. A large number of electrical cables were rerun 4 ft (1·2 m) higher to clear the entrance; existing doors were removed, and external corrugated panels and internal linings were removed to provide an opening large enough for the module.

Programme

An outline of the installation programme is shown in FIG. 10, which covers the two-year period between completing the Olympus trials and removing that engine in early 1982, and starting the SM1A trials at the end of 1983.

Planning and design work for the scheme finally chosen had started in the second half of 1980, and by 1982 the majority of drawing work and some manufacture had already been completed. The installation work was divided into seven phases as shown, linked to major milestones in the programme.

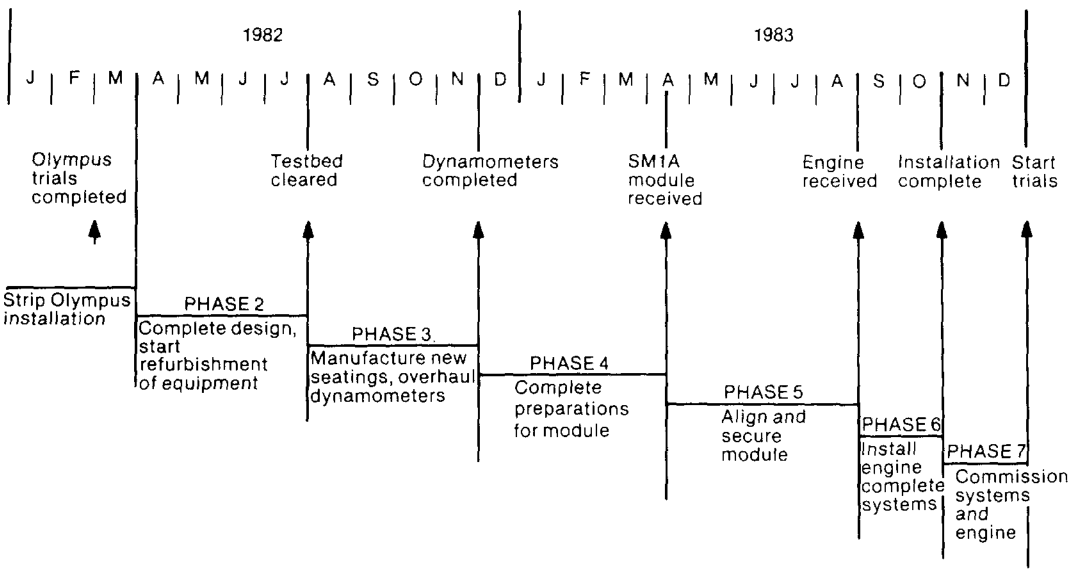

FIG. 10—SM1A INSTALLATION PROGRAMME

The SM1A module was received from the manufacturer (Rolls-Royce Ltd., Ansty) in April 1983, by which time the dynamometers and engine seatings had been mounted and aligned on the test bed, and the structure and rails for shipping the module and the modified south wall entrance had been completed. By mid-July, the module had been aligned to the dynamometers and was supported on rubber mountings. The engine was commissioned early in 1984.

Note

Any views expressed are the author's, and do not necessarily express those of the Ministry of Defence.

Reference
1. Colby, R.F.D.: Marine Spey (SM1A) introduction into service; *Journal of Naval Engineering*, vol. 28, no. 1, pp. 15–23.