TEST INSTALLATION FOR THE SM1A MARINE SPEY AT RAE (PYESTOCK)

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SYNOPSIS

When full development of the SM1A started in 1977, plans were drawn up for an installation in the Admiralty Test House at Pyestock, for trials similar to those carried out there for the Marine Tyne and Olympus. This paper describes the design and construction of the installation, associated work to update the existing test house services and systems, and refers to alternative plans which were considered.

INTRODUCTION

During the 1970's 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 Pyestock (NGTE), 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, then under development for future propulsion requirements in the Royal Navy and other navies. When full development started in 1977, plans for a test installation at Pyestock were put in hand; this paper describes the design and construction of this facility.

THE ADMIRALTY TEST HOUSE

The Admiralty Test House (ATH) was completed in 1952 for development testing of gas turbines for the Royal Navy. It is illustrated in Figures 1 and 2. The building is 100 ft (30.5 m) by 94 ft (28.6 m) in plan and 50 ft (15.2 m) high. The South wall was constructed on a temporary basis to allow the building to be extended easily at a later date if required, and the land to the South was left vacant accordingly; this was to prove significant for the SM1A installation.

The test hall itself is 40 ft (12.2 m) wide and accommodates a single test bed 73 ft (22.1 m) long by 10 ft (3.0 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 located in adjacent buildings.

INITIAL PLANNING

When plans for the SM1A installation were started in 1977, the test bed was completely occupied by a RMIA Marine Tyne and a TM3B Marine Olympus. Future requirements for these engines were considered, to see if the SM1A could be substituted.

For the Tyne, there was a firm programme of important trials to prove the recently uprated RMIC design which had just started, which was likely to occupy a further five years at least. For the Olympus the programme was less firm, but it included important trials of smoke-reduced combustors and other trials to validate improvements over prolonged periods. It was concluded that these installations should be retained throughout the 1980's, and therefore a new test
installation would have to be constructed for the SM1A. It was also concluded the simultaneous running of at least two engines should be possible. It was decided to take advantage of the ability to extend the test house provided in the original design, and to construct an extension housing a separate test bed for the SM1A, complete with the services required for the test installation, and a separate control room. It was decided also to take the opportunity to extend the office accommodation and other facilities for staff.

The decision to provide new services for the SM1A installation had further advantages, because those for the Tyne and Olympus were then over twenty five years old. With the prospect of several years of SM1A testing ahead it was preferable to start with new systems, rather than embark on major refurbishment of existing systems which could cause serious interference with Tyne and Olympus trials.

The design was carried out in detail by the Property Services Agency (Department of the Environment), and is illustrated in Figure 3. The extension, although connected to the original building, was designed to be structurally independent to minimise loading on the existing structure. New environmental protection standards made it necessary to design for exhaust discharge no less than 100 ft above ground level.

The air intake for the Tyne had been taken through the South wall when the installation was built in 1972, and this clearly had to be renewed before the ATH could be extended on that side. A revised intake system was constructed during a break in the trials programme in 1981, incorporating coarse filtration and silencing, which took air from the East side of the ATH. The opportunity was taken to improve salt aerosol injection and sampling arrangements provided for simulating a marine environment during endurance trials.

**ENERGY RECOVERY SCHEME**

It was originally intended to dissipate the SM1A power by high speed hydraulic dynamometers, as used in existing test installations, with a new water system having normal and emergency reservoirs, cooling tower and pumps. However there was a growing awareness that trials over several thousands of hours for a 17,000 HP (12.1 MW) engine would use a very large quantity of expensive fuel. As part of general energy conservation studies at NGTE, it was decided to investigate an energy recovery system in which electrical power could be generated for site services, thereby reducing the cost of imported electricity.

The proposed system consisted of a 14 MW AC generator driven by the SM1A power turbine through an epicyclic gearbox. The output would be rectified, and then passed through three-phase fired thyristors supplying output transformers, which in turn would feed the Establishment 11 kV grid.

It was considered that this system would meet trial requirements for controlling the power turbine speed/power characteristics, that it would respond quickly enough to meet rapid power changes and that it would have acceptable reliability. A similar system, though of lower power, was already under construction at NGTE for energy recovery from a marine diesel engine test bed.

The possible savings of the proposed scheme depended upon a simple comparison of the capital costs with those for the conventional dynamometer system, and consideration of compensating savings in electrical power for the establishment over the period of trials. It was estimated that on balance capital cost would increase by 5%. The value of electricity saved amounted to approximately £100 per running hour, and this would recover the increased capital cost within two years of operation. The change in design would delay completion for three months, but there was sufficient margin in the programme, and a change to the electrical energy recovery scheme was generally accepted as worthwhile in view of the significant cost savings.

**TEST BED RAKE**

A significant feature of Ship Department requirements for the SM1A test installation was to mount the engine at a rake of 80° nose-down. The intention was to reproduce a ship arrangement where an
engine would drive forwards into the main transmission gearbox, such as in all Marine Tyne installations. This could possibly reveal problems in areas such as hearing oil scavenge and engine drains which would not otherwise emerge until a first ship installation. Such problems were considered less likely in a nose-up installation, which would be closer to operation of an engine in an aircraft during climb. The requirement would result in a test installation with the engine loading equipment - whether a brake or a generator some 15 ft (4.6 m) above the bed due to the length of the module. In the absence of any evidence of problems in Tyne installations in service, it was decided that the significant extra cost and difficulties involved were not worthwhile, and the requirement was deleted.

In these circumstances justification for retaining the Olympus installation at NGTE was closely re-examined. This installation was then the only satisfactory test facility for Olympus module/power turbine/ancillary problems, and its future depended particularly on possible problems in those areas, there being no shortage of jet test beds for engine change units. It was concluded that there would be no further requirements for the facility on completion of the current programme towards the end of 1981.

The way was therefore open to convert the test bed occupied by the Olympus for the SMIA after 1981, avoiding the need to construct the building extension and new services. This would save considerable cost, but there were some disadvantages:

- a. systems would require major refurbishment, which could interfere with Tyne trials.
- b. installation of the SMIA in the existing test hall would be delayed by Tyne trials.
- c. office accommodation and other facilities for staff would remain restricted.

The electrical energy recovery scheme was also re-examined. The ability to utilise the Olympus dynamometers for the SMIA tipped the financial balance clearly in favour of that scheme, and the extra capital cost of the electrical scheme could not then be recovered within the first two years of operation. Constraints imposed by using the existing test bed would have introduced technical problems, such as the accommodation of static electrical equipment and the length required for the gearbox/generator unit. With considerable disappointment, the electrical energy recovery scheme was abandoned. On the positive side, use of the Olympus dynamometers removed a possible limitation which might have applied to testing the SMIA at a greatly increased rating at a later stage.

OVERALL INSTALLATION DESIGN

Comparatively little design and manufacture was needed to convert the Olympus installation for the SMIA, and this was a further attraction of the scheme. There were three main areas of design:-

- module mounting arrangements
- intake and exhaust ducting
- remote controls and instrumentation

Other design areas were comparatively straightforward:-

- module ventilation supply
- lubricating oil for power turbine
electrical and compressed air supplies
access platforms
vents and drains
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, saving considerable work. It was also decided to use the Olympus torque tube, and this fixed the position of the SMIA module on the test bed. The Olympus intake system included coarse filtration and splitter silencers, and was entirely suitable for the SMIA. 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 SMIA module is supported by four pairs of combined vertical/horizontal mounts, and it is located at the power turbine end by a pair of ram and rako 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.
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.

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:

- shaft bearing lift and rotational climb
- dynamometer trunion lift
- axial float between thrust faces
- thermal growth
- 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 Figures 5 and 8. 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 center is displaced 32 ft (1 m) from the center 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, 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 galvanised sheeting. A survey revealed that the roof had leaked, and as a result some timber had rotted and there had been 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 rotted support frames and insulation, and represervation of the lining.

EXHAUST

The arrangement of the exhaust system is shown in Figure 5. 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.

The decision to use the 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 center 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 suction 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 and viton impregnated woven glass fibre 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 controller also limits values of shaft speed and turbine temperature, and trips the engine if these are exceeded. It includes a comprehensive self-monitoring capacity and built-in test equipment. Two fuel system controllers have been operated at the associated naval machinery evaluation centre 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 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
DATA LOGGER

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

This system suffered some limitations; it was unable to perform simultaneous tasks, program 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.

The updating of the data logger has greatly enhanced its flexiblility by providing quick and accurate speeds of response, increased storage capacity and a much more satisfactory mode of operation.

UPDATING ATH SYSTEMS

As already mentioned, ATH systems were generally over twenty five years old, and required major refurbishment and modernisation to give reliable service for SM1A trials over many more years. The main systems concerned were:-

i. dynamometers and electronic/hydraulic controls
ii. cooling tower and brake water systems
iii. electrical services
iv. fuel storage and supply
v. high pressure compressed air

The tandem DA790 EH dynamometers had given good service for some 5000 hours of Olympus testing over the previous seven years, and it was prudent to take the opportunity to carry out a major overhaul at the makers works, including the hydraulic operating power pack. Upgrading modifications were incorporated, including a new hydraulic motor with "fail set" brake for the butterfly control valve. Both dynamometer shafts were replaced, due to erosion and the extent of previous repair actions on the original shafts. The electronic dynamometer controls were to include a temperature monitoring system, and to change the propeller cube law operating profile to suit the likely SM1A ship applications.

Extensive repairs to the cooling tower were needed. The internal wooden slats and channels had deteriorated considerably over the years, and were stripped out and replaced by modern design components manufactured of plastic. Reinforced concrete structure had experienced surface spalling and cracking; the surfaces were cleaned by high pressure water jets, repaired and rescaled. Splash trays, wooden walkways and doors, and galvanised handrails were all replaced. The induced draught fan, of 20 ft diameter, its driving motor and gearbox were overhauled, as were the cooling tower and dynamometer supply pumps.

In the original electrical installation there was a standby direct current diesel generator for providing essential services in the event of AC main supply failure. This was for DC pumps to maintain lubricating oil supply during the run-down and cooling of machinery following tripping. Under normal conditions these were supplied by AC/DC conversion machinery. The system was modernised by replacement with an AC equipment, including a compact diesel generator set. Two mercury arc rectifiers, a motor/generator set and switchgear were removed, making available valuable extra space. Emergency lighting in the control room was replaced, and flame-proof lighting was installed in the fuel tank room to reduce fire risk.

The fuel system had been extensively modified over the years to cater for many different gas turbines, and its arrangement was complicated and illogical and pumps were approaching the end of their useful life. Pipework was mostly mild steel, and there had been some contamination of fuel with rust. It was decided to rationalise the system layout to replace it in stainless steel with modern valves, to fit two new pumps and a coalescer filter. Further improvements in the safety of the fuel tank room were carried out; the ability of the sunken floor to contain fuel spillage was improved, and a sump and pump were fitted. The fuel storage tanks, of 25,000 gallons capacity, were cleaned and recalibrated, and the automatic fire extinguishing system was overhauled.
The high pressure air system also had been extensively modified over the years and incorporated many obsolete components. The main compressor was at least 40 years old, it was unreliable and was becoming difficult to repair. This was replaced by a type TC4 HP compressor, pipework was rearranged and renewed in cupro-nickel with modern fittings and connections.

Apart from work to update the main systems, there was extensive work to refurbish other areas. In the air compressor room, new cladding and improved ventilation were needed, and in the main control room the ceiling acoustic tiles were replaced. Obsolete wiring and redundant instrumentation such as liquid manometers were stripped out. A new fire alarm system was fitted throughout the test house.

The original plan to build an ATH extension with new systems for the SM1A would have been more satisfactory, but extensive refurbishment and modernisation of the existing plant and systems will give a satisfactory test installation for at least 10 years, and this should be adequate to meet the requirements of the testing programme.

MODULE SHIPPING ROUTE

A problem emerged when arrangements for shipping the SM1A module onto the test bed were considered. The maximum safe working load of the the overhead crane is 20 tons, but the module weight without the engine is 25 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 onto the test bed on rails supported by a special structure 5 ft (1.5 m) high outside the South wall of 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 there was a vertical steel beam in way of the route, 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, stiffening the remaining wall structure.

FIG. 10 SHIPPING THE MODULE

1982

[Olympus trials completed]

[Testbed cleared]

[Dynamometers completed]

[SM1A module received]

[Engine installation complete]

[Start trials]

1983

[PHASE 1]

[Strip Olympus installation]

[PHASE 2]

[Complete design, start refurbishment of equipment]

[PHASE 3]

[Manufacture new seatings, overhaul dynamoseters]

[PHASE 4]

[Complete preparations for module]

[PHASE 5]

[Align and secure module]

[PHASE 6]

[Install engine complete systems]

[PHASE 7]

[Commission systems and engine]

FIG. 11 SM1A INSTALLATION PROGRAMME
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.

Considerable work and ingenuity were needed to provide a satisfactory and safe shipping route for the SM1A module, due to the limitations imposed by the crane capacity and space available in the test hall.

PROGRAMME

An outline of the installation programme is shown in Figure 11, 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.

As described earlier, 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.

The SM1A module was received from the manufacturer (Rolls-Royce Ltd Ansty) on 14 April 1983, by which time the dynamometers and engine seatings had been mounted and aligned on the test bed, the structure and rails for shipping the module and the South wall entrance had been completed. By mid-July, the module had been aligned to the dynamometers and was supported on rubber mountings. At the time of going to press (August 1983), engine build is approaching completion at Ansty and delivery is expected shortly. It is planned to complete the installation and commission the engine by the end of 1983.

CONCLUSION

The provision of the SM1A test installation at Pystock started with plans for an ideal solution, which would have provided a tailor-made installation and extra facilities for the foreseeable future. In the event, the installation provided has some shortcomings and limited life, but it will meet the requirements for trials over many years to come, and adapting an existing installation has proved to be an interesting and worthwhile challenge which has saved design and manufacturing resources and cost.

NOTE

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