SUBMARINE MACHINERY INSTALLATION TEST ESTABLISHMENT

S.M.I.T.E.

BY

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Introduction

SMITE is the code name for the new submarine propulsion machinery testing facility at Barrow; the natural successor to ADEB—the Admiralty Development Establishment at Barrow—which was established in 1946, and where the hydrogen-peroxide-fuelled steam-turbine machinery of the E class submarines and all nuclear submarine propulsion machinery up to and including SSN11 were successfully erected and tested before installation in the vessels.

The need for a new test establishment arose because ADEB, sited on rented land away from the shipyard, was by 1970–1 a straggling complex of buildings and aging equipments at the limit of their economic development.

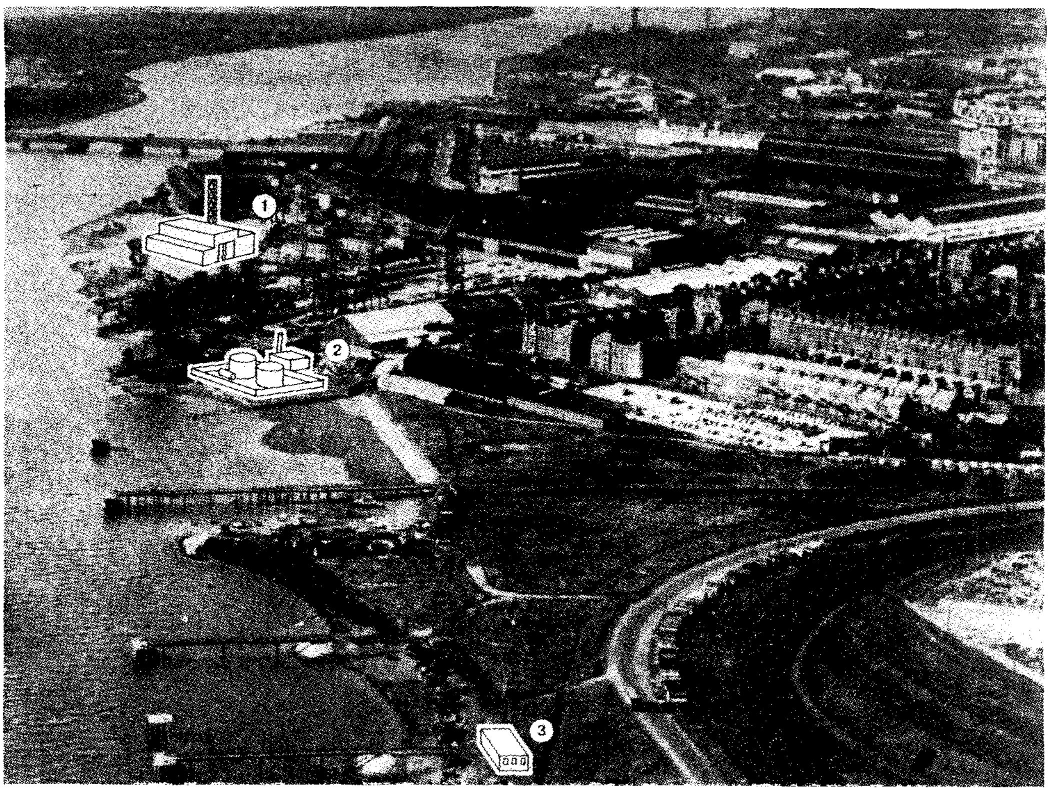

FIG. 1—GENERAL VIEW SHOWING LOCATION OF SMITE FACILITY
(1) Test facility (2) Tank farm (3) Pump house

ADEB was unsuited to meet the increased and more sophisticated demands of the third and fourth phases of nuclear machinery testing and development work due to begin in the late 1970's and extend through to the year 2000 and beyond.

In 1972, after consultations between MOD(N) and Vickers Ltd., including a design feasibility study, contracts were placed with the latter to design, build, commission and operate such a facility to cover the future requirements.

SMITE had been conceived, the confinement or build phase has been lengthy and not without its problems, the birth or commissioning proved to be exacting, particularly to the professional staff, but the future looks exciting and potentially rewarding across a wide range of machinery and equipment testing possibilities.

Design Concept

The designers were instructed to take account of the limitations of ADEB and create an economic design that would meet the requirements, the future operational parameters having been defined.

Areas of particular importance were considered to be:

(*a*) the need to locate the building close to the building slips to simplify the transfer of machinery to ship and to minimize the strip-down after testing;

(*b*) the provision of a focal point control room and communication centre containing adequate instrumentation and alarms to completely monitor and control all machinery trials;

(*c*) the provision of a computer, data bank, and information service to store and present the required information;

(*d*) a twin test-bed capability;

(*e*) adequate fuel storage and transfer arrangements to avoid frequent re-fuelling by road tanker;

(*f*) the need for management to have operational flexibility by making provision in key areas for future growth of systems and plant.

Design Problems

The following are a few of the more interesting design problems:

Cooling Water System

Operation under all states of the tide (which has a maximum astronomical range of 10·4m) required the pump house to be located at the deep water berth. Sampling of the water in the channel indicated that problems with silting and weed were unlikely to be great.

The distance between the pump house and the test facility called for remote operation of the cooling water pumps from the control room and consequently a complex control system. The system was designed to provide a constant head of 15m at the test house. As calculations showed that surge pressures of six times the normal working pressure could be produced in the pipeline in the event of power failure, surge vessels at the pump house and quick-closing valves at the discharge end of the system were fitted to limit such pressures to within the strength of the system.

Boiler Steam Conditions

To provide flexibility, the main boiler plant was designed to operate at two conditions (55 bar/399°C and 19 bar/377°C) and the plant can be controlled to match the steam pressure/flow characteristics of the submarine's steam generator. Spray-type attemperators (which can be removed) are installed to provide temperature control and enable dry saturated steam to be delivered to the turbines at low pressure.

Environmental

The North West Water Authority were concerned about the effect of the large quantities of warm effluent entering the Walney Channel from the cooling-water system. An environmental survey has been set up to monitor the effect on biological life in the channel and also to monitor the effect of chemicals used for dosing the water remaining in the cooling system when not in use.

Care has been taken to avoid pollution of the channel by fuel, lubricating oil, and hydraulic fluid used in the facility. Tilted plate interceptors have been provided at the storage facility and also for the floor and yard drainage at the test facility.

Planning consent was only granted on condition that noise levels were acceptable for the surrounding houses. A careful assessment and tests based on trials at ADEB show that this requirement should be met.

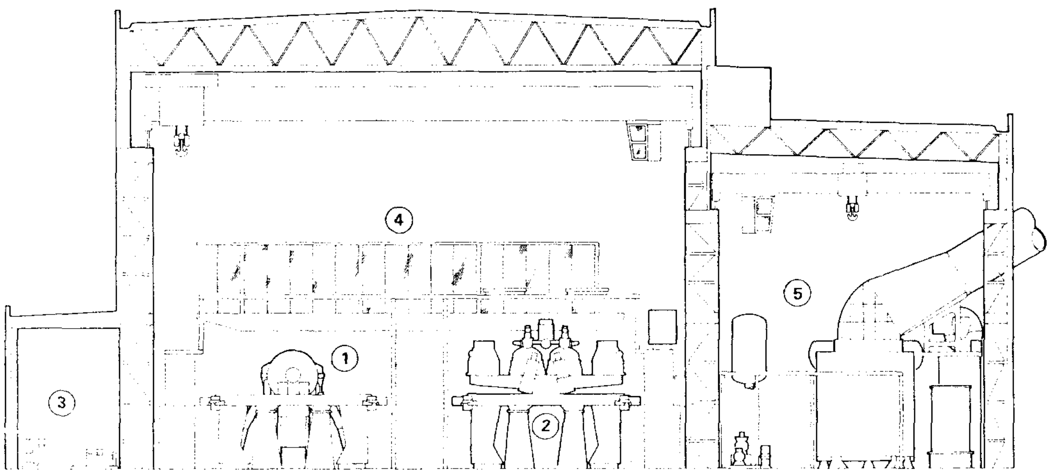

FIG. 3—SECTION OF SMITE FACILITY
(1) Dynamometer on No. 1 test bed
(2) Set of main machinery on No. 2 test bed
(3) Machine shop
(4) Control room windows
(5) Boiler house

Construction

The overall forecast of expenditure has grown almost entirely due to inflation from £4·9M at the time the site work started in the Summer of 1973 to £8·2M now. The office block was occupied by SMITE permanent staff in the Spring of 1976.

As the site for the complex was that of the old building berths which over the years had been filled in with excavation material, considerable piling was necessary to obtain adequate load-bearing capability. This was achieved by installing 434 concrete piles 13m long, each capable of carrying a working load of 60t.

The test house containing the two test beds is 52m long by 30m wide and 24m high. The building which is of steel construction is fitted with two 60t monobox overhead cranes capable of working in tandem at a height of 18m above the floor. Entrance doors 13m high allow access to the building over 50 per cent. of the end at any point.

An annexe on one side of the test building contains the boiler plant and the electrical and pump test areas, and has a 15t overhead crane. A machine shop is on the other side of the test building. The three-storey services block is at the end of the test house, advantage being taken of the ground sloping away to form a basement for the cooling-water pipe gallery, storage areas, and transformer bay.

Cooling-water System

The need to construct the intakes and cooling-water pump house at the deep water berth has already been mentioned under 'Design Problems'.

Six pumps were required to meet the full demand, and the pump suction design was checked by a model at various flows of water. Due to the poor ground conditions, the depth of construction had to be extended to 26m below ground to obtain a bearing in the underlying gravel. A concrete caisson method of construction was used but during the sinking the caisson developed a lean towards the channel of 1·8m. The contractor, however, managed to correct this to only 150mm out of plumb when the caisson was completed to the design depth.

The cooling-water mains are of welded steel lined with bitumen. These pipelines had to pass under the shipbuilding berths and the crane ramps to convey the water from the pump house to the test facility. The sections under the crane ramps were completed by thrust boring concrete pipes which act as sleeves for the steel mains.

An outfall capable of conveying the large volume of water across the foreshore without erosion had to be designed, the adequacy of which was checked by a test model. The foreshore below the outfall is protected by a carefully laid stone apron.

Fuel oil

An oil off-loading terminal was constructed in the channel at the deep-water berth, and two 3400t storage tanks with appropriate heating and pumping to convey the oil to the two 50t service tanks adjacent to the test facility were provided.

Access

A new concrete road capable of being used by the present 350t transporter and also future designs up to 600t was constructed to give access to the submarine building berths. The floor slab and the two test beds within the test house were also designed to take these weights.

Chimney

To meet the Clean Air Act, a large chimney was required for the boilers, and to achieve an economical height it was necessary to use individual flues for each boiler. The area available for construction with its densely-piled foundation was extremely cramped; and a design was developed consisting of a tubular-steel framework in which two 2800mm diameter main flues and a 600mm diameter auxiliary flue were suspended, the total height of the chimney structure being 72m.

Commissioning

The importance of having a fully-proven facility in advance of a submarine test programme was always recognized and arrangements were made to start commissioning all systems in December 1976, as soon as possible after the installation had been completed.

To achieve this, two high-duty dump condensers were installed so as to accept boiler steam from one boiler at a time up to maximum boiler rating. This arrangement allowed the boilers and their associated steam, feed, and fuel systems together with the electrical and control equipment to be adequately demonstrated under working conditions.

As sea-water cooling was required for the dump condensers during these boiler efficiency trials, the cooling-water pump house and associated systems were operationally proved. Fuel loading, handling and transfer facilities were also demonstrated.

All SMITE systems were tested and results recorded using test forms produced on a system basis which defined test parameters and requirements. These test forms were authorized by a Commissioning Group representing the Design Authority, Consulting Engineers, and SMITE. The rate of completing the work covered by these test forms provided a progress guide for reporting completeness of the overall facility.

This formal commissioning programme was justified as a number of deficiencies were highlighted and rectified, some of which although relatively minor in themselves would have been a major embarrassment if submarine machinery trials had been in progress.

SMITE

ORGANISATION CHART

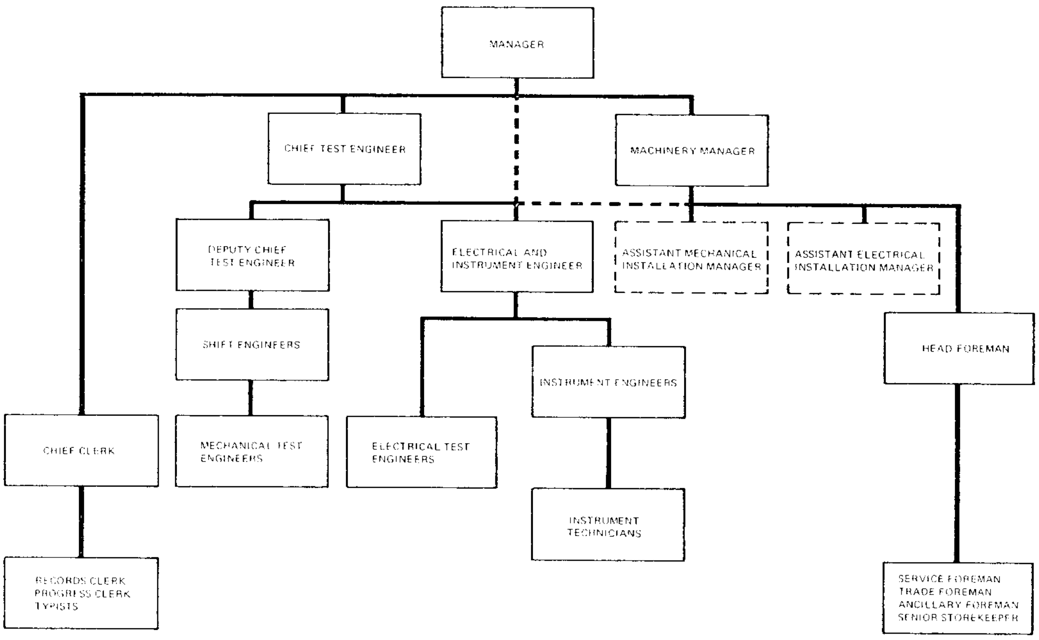

FIG. 4—SMITE ORGANIZATION CHART

General Aspects of Management

The overall management of SMITE is in accordance with the Operating and Maintenance (O & M) Agreement between MOD(N) and Vickers Ltd. This agreement which, subject to agreed changes, holds for twenty years details the responsibility of the SMITE Manager, who is responsible to the SMITE Director for technical and financial matters; it also indicates that the Company's specialist departments must always support the SMITE management as required. The MOD Project Officer will maintain close liaison with the SMITE Manager.

When problems of policy arise, particularly those of priority and allocation of resources, which cannot be resolved at local level within Vickers, a Board of Appeal comprising the MOD Project Manager, Vickers SMITE

Director, and Vickers Marine Engineering Manager has been constituted to make the necessary policy decisions.

The management structure (FIG. 4) shows that the organization is divided into two main areas:

(*a*) Testing and the technical management of the facility which is the responsibilty of the Chief Test Engineer.

(*b*) Works management, including installation, plant operation and maintenance, which is the responsibility of the Machinery Manager.

The Chief Test Engineer is also the Chairman of the SMITE Joint Test Group (JTG) and is able in this way to obtain agreed authorization for his programme of testing.

The quality assurance (QA)—in accordance with Vickers Quality Manual and Defence Standard 05–21—is the responsibility of the SMITE Machinery Manager supported by the SMITE QA Foreman who, through the Chief Inspector, is ultimately responsible to the VEB Quality Manager.

The Electrical and Instrument Engineer provides a technical co-ordination and support service for both specialities to the Chief Test Engineer and the Machinery Manager during installation and testing phases.

Support from the Vickers Shipbuilding Works, Barrow (VSB) Technical Departments is co-ordinated by a Liaison Engineer who provides a day-to-day link between SMITE and VSB, the latter of whom initiate the majority of design requirements and changes.

Entry to the establishment for all authorized personnel is past a permanent security guard in the foyer.

Scope of Test Facilities

Main Test House

The SMITE facility has as its main function the full-power testing of geared steam-turbine marine propulsion machinery and associated turbo generators, and, to support this primary role, ample supplies of steam, circulating water, and electrical power (50Hz, 60Hz, and d.c.) are available, together with means of absorbing and measuring the developed power, mechanical and electrical.

Steam is provided for test purposes by two test boilers at a flow rate up to a maximum of 226 000 kg/h at 55 bar and 400°C. Automatic attemperator/reducing valves produce the desired final steam conditions at the test bed; these are variable down to approximately 14 bar saturated steam.

Sea water is pumped from the Walney Channel at a present maximum flow rate of 58 000 l/min for circulating the main condensers, plus 29 000 l/min for dynamometer and heat exchanger circulation. The circulating water for the dynamometer is pumped from the sea-water main by booster pumps to an open 100t head tank, giving a static head of approximately 30m over the dynamometer. This arrangement allows the release of entrained air from the cooling water and gives a static inlet pressure to the dynamometer resulting in stable power absorption.

Electrical power supplies into the facility comprise:

(*a*) 50Hz from a single NWEB incomer at 6·6 kV transformed down to 415V in the SMITE transformer bay with a total capacity of 2 MVA.

(*b*) 60Hz from Vickers 60Hz ring main via two 50/60Hz frequency converters, total capacity 6 MVA, but the converters do not run in parallel. SMITE can be supplied from either machine via appropriate switching arrangements. Supply is also at 6·6 kV transformed in SMITE to 450V with total capacity of 2 MVA.

Electrical load-absorption tanks are provided for the main test beds, capable of absorbing 4000 kW. Half this load will normally be at 0·8 p.f.; the other half at unit p.f. Circuit breakers and switching arrangements are provided to allow the desired electrical loading to be selected for the machine on test.

The dynamometer at present available in the test bed is a Froude RFA18, capable of absorbing up to 30 000 hp at 140 to 278 rev/min in either direction of rotation. This machine will give automatic reversal of load with change of rotation and the load/speed relationship can be controlled either by the usual Froude system to give an approximation of propeller-law loading, or by the SMITE computer acting on the Froude control valve to give any desired curve of speed/power within the dynamometer capability.

To allow evaluation of the vibration pattern of machinery and mounting arrangements, the two main test beds are separately piled from the surrounding structure and each test-bed slab is isolated with a layer of vibration damping material. Each test-bed slab is 27m by 10m and can accommodate machinery weighing up to approximately 500t.

Pump Test Area

The pump test area has two 356mm bore high-pressure test loops suitable for test running of low-head, high-flow pumps operating at high background pressure. Each loop has a number of connections fitted with isolating valves to enable several different types of pump to be assembled and then test run when the loop is available. The loops are coated internally with a hard nylon material that is resistant to erosion and is inert in sea water.

A pressurizing pump is provided for raising loop background pressure and each loop includes several coils immersed in a large external water tank arranged to absorb and dissipate the heat put into the loop water by the pumps on test. Power supplies are available at 440V, 60Hz, 3-phase; total capacity 800A. A supply of filtered lubricating oil is available at up to 27 l/min, together with ample supplies of water for cooling purposes, supplied from a closed-loop fresh-water system.

A variable output pump can be valved into either test loop to be run in series with a pump on test and so provide it with varying inlet conditions. The loops are fully instrumented and all parameters can be monitored by the SMITE computer, the output from which can give pump test performance curves and typical log sheets in a form ready for binding in a test report.

Electrical Test Area

The electrical test area (16m × 8m) is designed for test of electrical equipment with a.c. for 60Hz and 400Hz applications and d.c. in the range 170 to 380V. This facility can handle large a.c./d.c. motor generator sets and is sufficiently flexible to cater for future designs. Power supplies and load equipment is available as follows:

(*a*) 1200 kVA, 60Hz, 440V, 3-phase;

(*b*) 7 kVA, 400Hz, 200V, 3-phase;

(*c*)* 2500Ah d.c., 175–380V from a full submarine battery with extra cells;

(*d*)* 180Ah d.c., 24V;

*Both d.c. systems are rectifier supported.

(*e*) Loading equipment: a.c. 450 kW, 0·8 p.f.
d.c. 480 kW.

The loadings of the kW tanks and reactive banks are adjustable in suitable increments. Other electrical supplies are available in other areas, e.g. 415V, 50Hz with a total capacity of 1200 kVA.

Other Services

Two high-duty marine condensers are available fitted with steam pressure breakdown cones containing a series of orifice plates and spray nozzles. Each of these condensers is capable of condensing 62 000 kg/h of steam at 12 bar and 368 °C. It is intended that these condensers will be installed in a permanent situation for use on tests requiring large steam flows with the associated dump steam capacity.

A hydraulic oil system delivering up to a maximum of 227 l/min of filtered oil at a pressure between 180 bar and 207 bar is piped to several locations around the test beds, each terminal point having isolating valves in the supply and return lines.

A high-pressure air system is provided on the test beds giving a supply of dry filtered air at 276 bar. This system has a compressor with an output of 2·05 m^3/min of free air and three storage bottles each with a capacity of 0·25 m^3. An extensive low-pressure instrument air system is installed; this includes two compressors, each capable of delivering 3·62 m^3/min of free air at a pressure of 5·5/6·9 bar. This air is also filtered and dried before being supplied to the system. Supplies are piped to manifolds in the boiler house, the test beds, and the instrument laboratory. A number of large cooling-water valves are also pneumatically operated by this system.

Planning, Execution, and Control of Trials

All trials carried out in SMITE will be under the jurisdiction of the SMITE JTG, comprising four engineers of whom the Chief Test Engineer is the chairman.

Test procedures will be produced by SMITE staff and agreed with the relevant design authorities before being offered to the JTG for approval and authorization. These test procedures will detail the preparation of systems, machinery, and test rigs, and also the method of achieving the objective of the trial and the parameters to be recorded.

Controls for machinery under test and remote controls for all plant required for machinery trials have been grouped in consoles located in a central control room. The main control position in this room overlooks the test beds and the engineer in charge has all essential controls close to hand. The visual display unit for the SMITE computer and the main sources of printed data, i.e. computer printer/plotter and Decca Isis typewriters, are sited at the control position.

The control room is double glazed and air conditioned. As the noise from the machinery is considerably attenuated before reaching the engineer in charge, a system of external microphones is provided to enable machinery noise to be monitored on a loudspeaker at the control position.

Communication between members of the shift crew and between SMITE and other departments is provided by three telephone systems, a UHF radio transceiver system and a public address system. This enables effective control of trials from the control position in the main control room.

The establishment is geared to deal rapidly with the provision of modifications to test rig and machinery needed to overcome problems found during testing. Appropriate changes to the test procedures can, in conjunction with the design authority, also be produced quickly.

Operating procedures will be produced to ensure the safe operation of test plant, test rigs, and machinery, and also giving details of emergency routines. In this respect, the requirements of the Health and Safety at Work Act 1974 have been borne in mind and all manufacturers' instructions are incorporated.

A rational system of planned maintenance will be implemented for all SMITE plant and equipment.

A 'Code of Practice' manual will be prepared by the SMITE staff incorporating all the foregoing procedures and with appropriate extracts from all regulations affecting SMITE and its operation.

Computer and Instrumentation

Instrumentation in the SMITE setting covers the computer and data loggers for data collection, processing, evaluation and control, with associated transducers for the measurement of physical properties, as well as conventional local and remote instrumentation. The appropriate maintenance and calibration facilities are, in the main, 'in house' in the SMITE instrument workshop and calibration laboratory.

ADEB experience showed the need for a flexible and adaptable instrumentation system capable of being extended to meet changing future requirements. It was decided that this was best met by a system based upon a mini-computer. A further consideration was that the opportunity should be taken to gain experience in the use of computer-based systems for inclusion in future submarine designs.

The methods of manipulating stored data lead naturally to one of the main improvements over the previous ADEB situation, i.e. the results of a particular trial will be available more rapidly.

In addition to the panels for control, display, and alarm purposes in the SMITE control room, the shift engineer has his own small console where control data and visual alarms for essential parameters are displayed. The shift engineer also has a simple means of calling up information from the computer (e.g. logs, plots, etc.) for display on a visual display unit (VDU).

The boiler control system, supplied by Bailey Meters, is completely pneumatic. Design features include:

(*a*) hand control of firing at the boiler front from the burner management panel;

(*b*) remote hand/auto control from the boiler panels in the control room;

(*c*) automatic control over flame turndown, effective over the range 15:1, and compensation for steam pressure over the whole range.

The boiler house is designed to be unmanned normally. The control room boiler panel is supplemented by inputs to one of the data loggers, so allowing the shift engineer to monitor the boiler channels on the VDU in the same way as the machinery under test.

To meet the instrumentation task, a specialized training programme for instrument engineers was started early. The instrument team will carry out computer and logger first-line repair and maintenance, backed up by adequate spare gear and support from the equipment manufacturers.

'In-house' calibration facilities are available to deal with the large number of items requiring either functional or full calibration checks. Primary laboratory standards are, however, checked by the appropriate section of the British Calibration Service. Calibration procedures are produced by SMITE staff and verified by the local MOD overseers.

Portable shipboard equipment can be calibrated or evaluated in the laboratory and the attached workshop as the power supplies likely to be found in a nuclear submarine have been built in.

Machinery Installation and Services Management

The Machinery Manager's function embraces the installation of machinery for testing as well as plant operation and maintenance. Mechanical and

SMITE

CHART SHOWING RELATIONSHIP WITHIN THE COMPANY

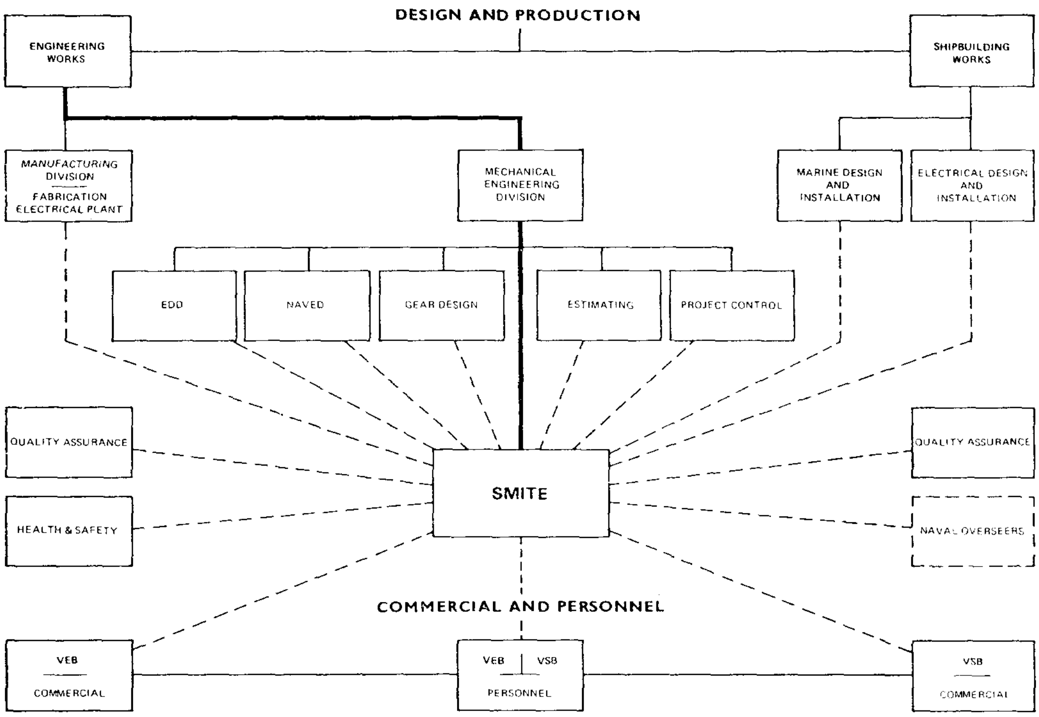

FIG. 5—CHART SHOWING RELATIONSHIP WITHIN THE COMPANY

Electrical Assistant Installation Managers are seconded to SMITE, and this will ensure co-operation between SMITE and the shipyard installation team. It has already been acknowledged that SMITE will be an excellent training ground for assistant managers, later to be made responsible for aspects of boat installation.

FIG. 5 shows the relationship of SMITE with the principal departments of the Company's engineering works (VEB) and shipbuilding works (VSB). Some of the departments most closely concerned with erection and maintenance work are:

(*a*) *Mechanical Engineering Division—VEB*: SMITE is part of this Division, which also includes the Noise and Vibration Engineering Department (NAVED)—providing technical expertise for noise and vibration analysis—and the Engineering Development Department (EDD)—responsible for the design of interface equipment, i.e. the link between machinery under test and the SMITE facility systems.

(*b*) *Marine Engineering Design and Drawing Office (MEDO)—VSB*: This office is responsible for the design and ordering of mechanical equipment for the machinery under test and also a major part of the SMITE mechanical plant.

(*c*) *Electrical Design and Drawing Office (EDO)—VSB*: This office is responsible for the design and ordering of electrical equipment for machinery under test and also SMITE electrical plant.

(*d*) *Quality Control and Assurance Departments (QC & QA)—VSB/VEB*: Day-to-day quality control and assurance services within SMITE are provided by the VEB QA organization, represented in SMITE by a QA Foreman directly responsible to the VEB Chief Inspector.

TABLE I—*SMITE personnel*

	Permanent Staff	*Total Installation Phase*	*Main Machinery Testing Phase*
Management	5	5	5
Supervision	3	7	7
Engineers	9	15	20
Skilled Tradesmen	12	70	45
Clerical Grades	7	7	7
Ancillaries*	8	28	22

* Includes crane drivers, slingers, storemen, and labourers.

Maintenance

The use of the periods of down time between trials to carry out maintenance will avoid the need for maintenance work outside normal working hours.

The Mechanical Services Foreman, supported by a small number of skilled tradesmen, will monitor and control day-to-day servicing. On-the-job training will be used to improve individual performance and to train additional personnel to supplement this team, which will also provide operational support to the test engineers during trials. Similarly, electrical maintenance will be carried out by the SMITE electrical team under the supervision of the Electrical Foreman.

Certain specialist skills, available in the Vickers Works and Plant Departments, will be used to carry out such maintenance as is beyond the capacity of the above mechanical and electrical teams.

SMITE has been provided with a small machine shop equipped with twelve general purpose machines, a marking-off table and tool store. The establishment also includes several specialized stores and a finished parts store where all parts for machinery erection and plant maintenance will be kept. Initiation of all spares ordering will be through the SMITE stores organization.

Equipment maintenance and spares ordering history sheets have been drawn up. The maintenance control numbers are directly related to the SMITE equipment inventory which is system based. All records, drawings, manufacturers manuals, and technical data will be kept in a Record Office manned full time.

A separate clean inspection area has been provided where accurate measurements and inspections can be carried out on equipment up to 700 kg weight. Although not temperature controlled, this room is sited so that it is not unduly affected by varying temperatures elsewhere. The shift inspector manning this room will be responsible to the SMITE QA foreman.

Conclusions

The SMITE facility is a comprehensive modern testing complex capable of dealing with the next generation of submarine machinery and meeting the associated development demands. The facility is now operational and SSN12 machinery is being erected with trials planned for early 1978.

SMITE possess a considerable steam, electrical, and pump testing capability with adequate back-up facilities, and can be clearly identified as a significant addition to the testing, development, and research arm of the MOD and Vickers Limited.