THE SEABED OPERATIONS VESSEL

A PROGRESS REPORT

BY

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Introduction

A previous *J.N.E.* article (Reference 1) described the Seabed Operations Vessel (SOV) towards the end of the Design Development Contract which had been placed with Scotts Shipbuilding Company Ltd. Since then Scotts has been awarded the Build Contract, and has metamorphosed into Scott Lithgow Ltd., and SOV has become H.M.S. *Challenger*. She was launched on 19 May 81, but remains 'The Sov' to the project teams involved. The procurement of her 'Weapon Systems' for navigation, dynamic positioning, and saturation diving is now well advanced, while the design of the towed unmanned submersible is almost complete.

This progress report on the ship half way through her build programme describes in greater detail the machinery control arrangements, and the approach adopted to the important issue of Diver Safety.

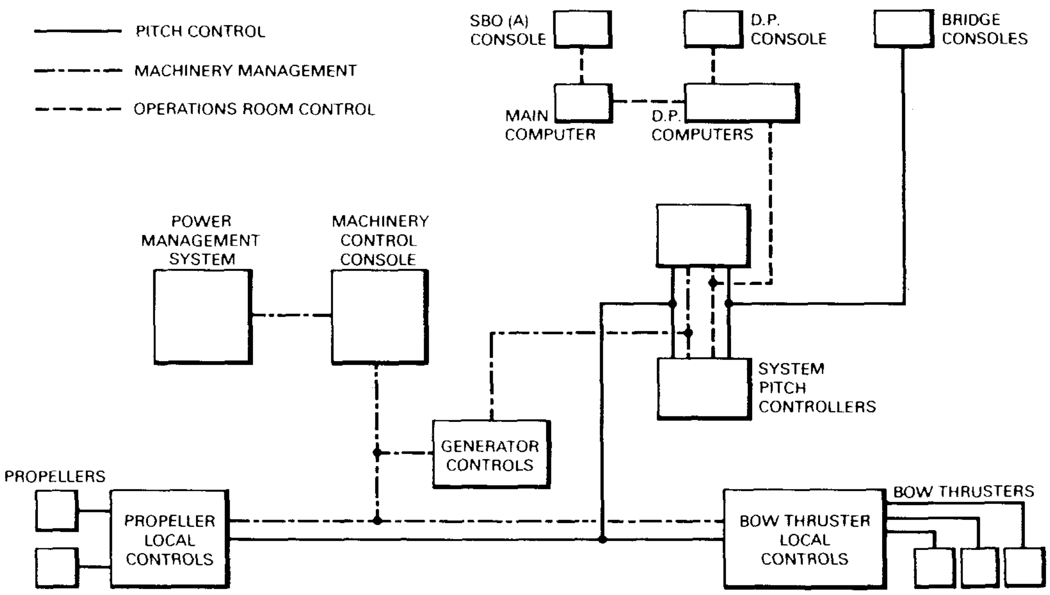

FIG. 1—MAIN MACHINERY CONTROL AND MANAGEMENT

Machinery Control and Management

Reference 1 outlined the machinery control principles adopted for SOV. The system is shown in more detail in FIG. 1. Because of the machinery plant design chosen, the control arrangements can be conveniently divided into two:

(*a*) pitch control,

(*b*) machinery management.

Pitch Control

Pitch control is centred round two positions, the bridge and the operations room. Normal control for passage and manoeuvring is from a quartermaster's (QM) console sited on the bridge, with associated consoles on the merchant style bridge wings for use during close manoeuvring.

The Officer of the Watch can transfer control to the operations room which allows computer-aided direction of the propulsion system using either the dynamic positioning (DP) console or the seabed operations (SBO(A)) console. This enables a number of pitch changing methods to be used ranging from fully automatic track following or hovering to emergency operator control by multidirectional joystick.

Commanded pitch reference signals are passed to a system pitch controller (SPC), via a suitable computer interface for operations room control. The SPC has the following functions:

(*a*) available power control,
(*b*) pitch reference control,
(*c*) command signal selection,
(*d*) control logic,
(*e*) monitoring and testing.

The processed reference signals are then channelled to the local electro-hydraulic sub-servo systems which provide mechanical actuation for the commercial design bow thrusters and propellers. Local control consoles contain sub-servo electrical components, and provide mounts for the hand controls, alarms, and gauges used in local operation. The SPC and the associated sub-servos and links are duplicated to give the high reliability necessary to meet diver safety requirements, as are the DP system equipments. On failure of one DP computer, a smooth changeover to the back-up computer system will occur. Similarly any failure within a SPC system will result in the other SPC system taking control. This matches the propulsor philosophy which states that, after the failure of one bow thruster and one propeller, the ship can still

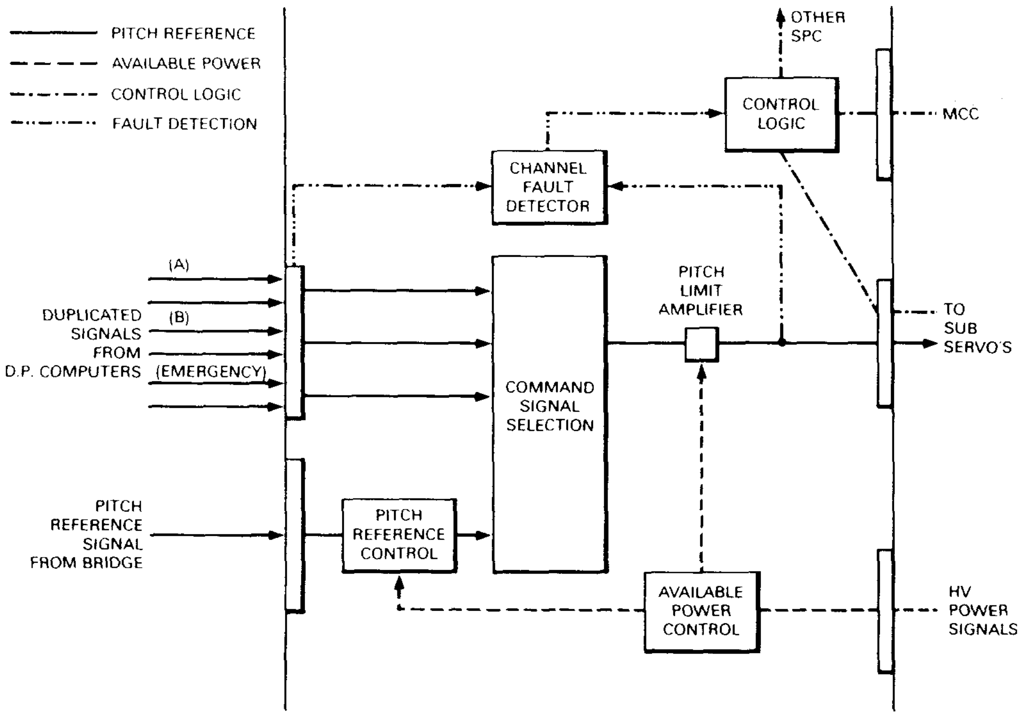

FIG. 2—SYSTEM PITCH CONTROLLER

maintain station in the most severe weather conditions under which divers could be deployed.

The SPC is built up from standard analogue components, using a minimum number of types of each. Its major functions are related as shown in FIG. 2. The pitch reference signal from the bridge is processed and limited by the SPC to prevent overloading of the drives, and to keep the power required within the capacity of the high voltage (HV) system. Detection of a fault within the SPC or its system channel drives causes the 'in control' SPC to relinquish control of the faulty channel to the other SPC. If the standby controller and all its drives are healthy, then complete changeover takes place. If any drive on the standby SPC is not healthy, further changeover is inhibited and both SPCs control in a 'quasi-mode'.

Available power control is exercised by comparison of signals indicating generator power available and HV loads, and the consequent generation of an excess power signal. When this signal falls below a set value, 'power limit' is introduced. Light overload causes a reduction in the pitch reference rail signals (see FIG. 3) so arranged as to leave the resultant propeller thrust direction unchanged, while its magnitude falls. Large overloads are 'crash limited' by the pitch limit amplifiers on each drive which preferentially reduce ahead/astern pitch before athwartships to maintain steerage.

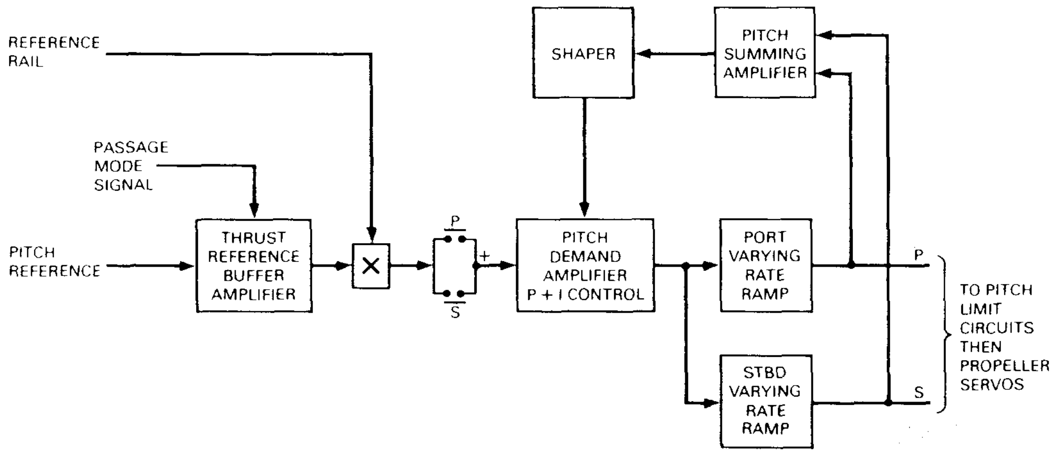

FIG. 3—SYSTEM PITCH CONTROLLER—TYPICAL PITCH CONTROL CIRCUIT PROPELLER STEERING PORT AND STARBOARD UNITS

Pitch control is divided into the following channels:

- bow thrusters (athwartships);
- port propeller speed (ahead and astern);
- starboard propeller speed (ahead and astern);
- both propellers steering (athwartships).

TABLE I—*QM console control modes*

Mode	*Bow*	*Stern*
Passage	Inop	Wheel
Manoeuvring	Lever	Lever
Auto Pilot	Inop	Course set on auto pilot

While port and starboard propeller speed pitches are controlled using levers on the QM console, athwartships thrust at bow and stern is subject to the various modes of control shown in TABLE I. These hand controls give thrust proportional to control movement in the athwartships direction, but ship speed proportional to throttle position for fore and aft power.

A functional diagram for a typical control channel (in this case propeller athwartships) within the SPC is shown in FIG. 3. The circuits provide correct proportioning of thrust between propellers if both are running. Varying ramps decrease the rates of change of pitch as pitch increases, and allow greater rates when pitch is being removed. The thrust reference buffer is limited to 30 per cent. of full pitch range when in 'passage' mode.

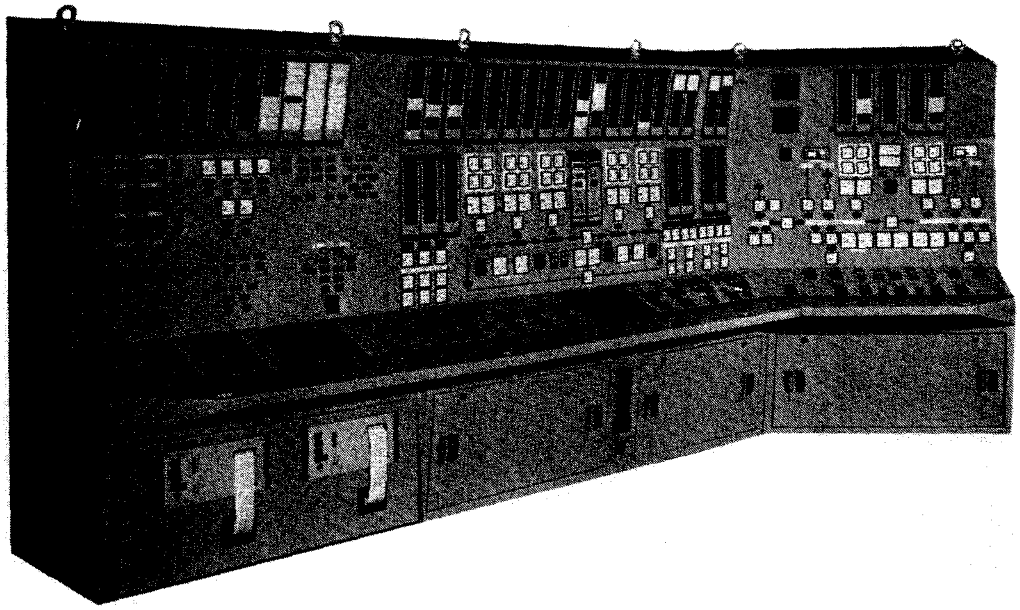

FIG. 4—MACHINERY CONTROL CONSOLE

Machinery Management

Management of machinery is directed from the machinery control room (MCR) in which is installed the machinery control console (MCC), shown in FIG. 4. The MCC provides the following facilities:

- start/stop of main and auxiliary machinery;
- limited control of the HV system (3·3 kV);
- full MV system control (440 V);
- surveillance and alarm of critical parameters;
- damage control.

The MCC is divided into three sections. The central area contains the displays and switches for the propulsion and HV systems and the associated ISIS alarms, arranged around a mimic of the distribution ring. The two end sections are 'MV' and 'damage control', the former mimicking the MV tree and harbour generators, the latter including auxiliary services.

In addition to automatic start, synchronization, and load share controls for generator sets, the MEOOW is assisted with the difficult task of balancing power supply and demand by an Intel 8085 microprocessor-based power management system (PMS). When required this will perform the following functions:

- starting/stopping main generator sets to suit kW and kVA load;
- starting/stopping bow thrusters to suit thrust requirements;
- changing propeller motors from low to high speed windings.

PMS operating margins are preset 'high' and 'low'. The former ensures that there is sufficient spare on-line generator capacity to satisfy diver safety reliability requirements. The MCC operator transfers control of machinery to the PMS by means of individual select switches on the MCC for each generator set, bow thruster, and propeller motor. The system hardware is contained in a cabinet in the MCR. The power management system will be a valuable operator backup and training aid, but it does not remove the overall authority of the MEOOW nor does it inhibit manual management of the systems involved.

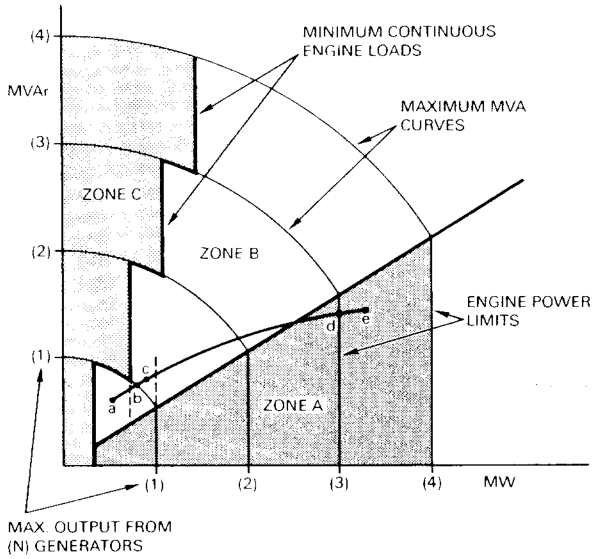

FIG. 5—TYPICAL GENERATOR LOAD VARIATION

The novel management problems presented by the SOV's systems are illustrated by the generator running requirement (FIG. 5). Zone A is kW limited by the engines maximum power, Zone B is MVA limited by the generators, and Zone C is restricted by engine low-load running considerations. Thus at start condition (a) for example, one generator set only is on-line. An increase in power to (c) requires a second set on load as insufficient kVA are available above (b). Further increase to (e) requires four generators by (d) to cope with the kW load. Reduction of power back to (a) would mean the shutting down of three sets to avoid low engine loads.

The MCR watchbill allows for one MEA 1 as MEOOW, assisted by a POMEM(M). Watchkeeper supervision of HV system operation should provide an interesting on-board training load for the MEO. A basic commercial course is being arranged for the first commission team.

Reliability and Diver Safety

Since one of *Challenger's* roles is to deploy saturation divers, very high standards of reliability are required for the systems concerned. These are the saturation diving system and the dynamic positioning arrangements, plus all the associated supplies and services. The need for a target reliability standard was recognized early in the design process. Thus a Diver Safety Reliability Target was formulated as an overall failure rate of better than 1 in 100 000 operational hours. The ship and weapon projects also agreed to utilize the resources of a single reliability consultant, either as main contractor or as a sub-contractor to the hardware designers as applicable, to ensure consistency of approach, and YARD Ltd. was chosen.

Designing for reliability is an iterative process of design, failure analysis, and reliability quantification—the extent being conditioned by the standards required, and the money available. SOV resources have been put into the following:

(*a*) design—use of:
- redundancy;
- proven design methods and designers;
- standard proven commercial equipment.

(*b*) failure analysis:
- FEA of critical systems during design;
- FMEA of complex design areas;
- FTA of final systems.

(*c*) quantification—use of:
- reliability block diagrams during preliminary studies;
- FMEA or FTA for final systems;
- FTA at whole ship level.

The techniques used, failure effects analysis (FEA), failure modes and effects analysis (FMEA), and fault tree analysis (FTA), are all well-known reliability methods.

In order to assess the acceptability of the target used, a study of comparative risks was undertaken. It was decided that the most helpful way of presenting risk would be as Annual Occupational Risk (AOR). The AOR is defined as the risk of death to an individual during one calendar year. This presentation allows some comparison to be made between the risks involved in similar occupations (e.g. SOV diver and North Sea commercial diver), and between those for completely unconnected activities (e.g. SOV diver and miner). While this type of analysis has dangers, since often data is unreliable or difficult to interpret, it is useful in assessing whether the right order of safety is being sought. TABLE II shows comparative figures.

TABLE II—*Comparative figures for annual occupational risk for SOV diver against other jobs*

Occupation	*Annual occupational risk*
SOV diver	20×10^{-4} per year
North Sea diver	50×10^{-4} per year
Trawler crewman	30×10^{-4} per year
Coal miner	5×10^{-4} per year
Merchant seaman	10×10^{-4} per year

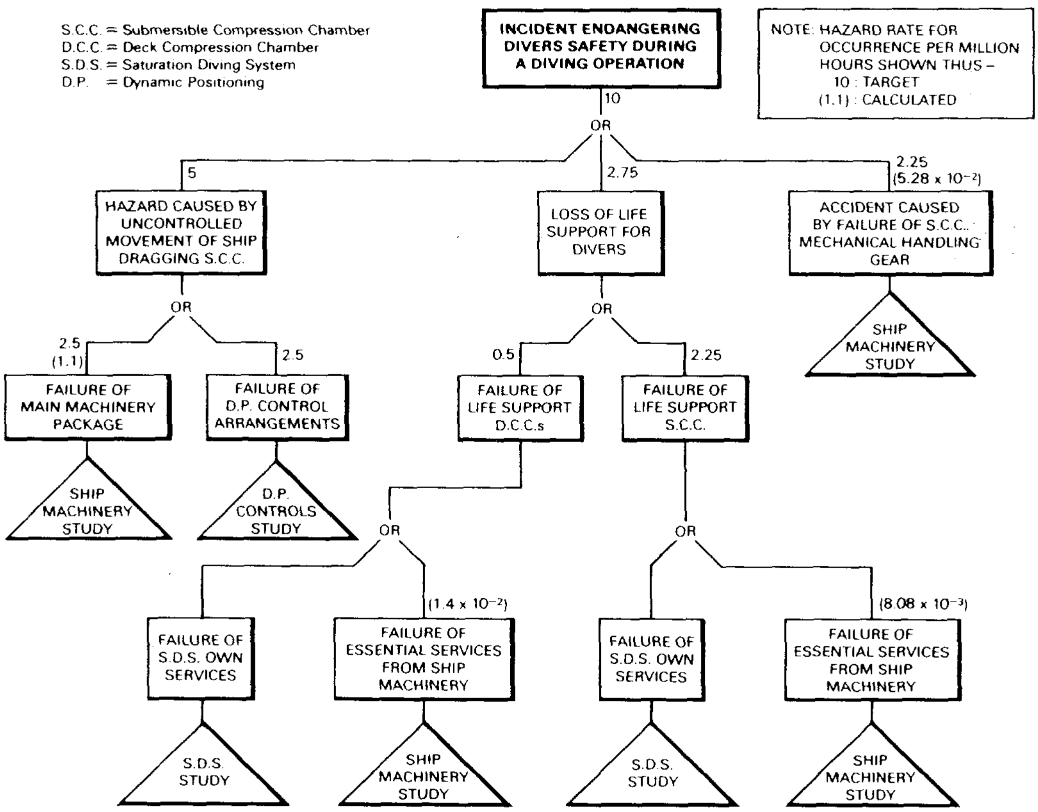

FIG. 6—TOP-LEVEL FAULT TREE FOR SOV HAZARDS THAT COULD LEAD TO AN INCIDENT ENDANGERING DIVERS' SAFETY

Because of the lack of laid-down target standards for commercial diving systems, assessment of hardware reliability standards is not easy. However, recent failure rate guidelines laid down by the Department of Energy for dynamically positioned support ships in Reference 2 are directly comparable with the SOV figure for DP arrangements, and a comparison is made in TABLE III

TABLE III—*Comparison of failure rates for DP arrangement*

Source	*Failure rate per 100 000 operational hours*
D of E guideline	1·0
SOV target	0·5

FIG. 6 is the highest level fault tree for SOV. On it is shown the breakdown of the overall reliability target between individual systems, and the separate reliability study areas are indicated. The predicted system failure rates so far calculated are also included, and it can be seen that they meet target requirements.

The Future

As the design problems diminish and this unique and sophisticated ship progresses towards the start of her acceptance programme, a number of management areas preoccupy Ship and Weapon Projects and MOD(N) Directorates. Of prime concern are the following questions:

(*a*) How can a full assessment of the highly integrated ship and weapon systems be carried through?

(*b*) What support arrangements can be provided in an environment of decreasing resources?

(*c*) What training in the novel systems fitted can be arranged for the ship's company in a world of OJT?

The future successful deployment of this powerful underwater operations tool rests upon the adequacy of the answers obtained. Unusually for an auxiliary vessel these answers should be of considerable interest to future major warship projects.

References

1. Pirquet, J. R. S., 'The Seabed Operations Vessel', *Journal of Naval Engineering*, Vol. 24, No. 3, pp. 304–320, December 1978.
2. Department of Energy Petroleum Engineering Division, 'Guidelines for the Specification and Operation of Dynamically Positioned Diving Support Vessels (1980)'.