CONTROL AND SURVEILLANCE

OF

SURFACE SHIP MAIN PROPULSION MACHINERY

BY

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Introduction

The article reviews the reasons for the introduction of remote control and considers new factors which have arisen in this field, and follows with an account of the design philosophy. Basically, control and surveillance is undertaken from a Ship Control Centre from which extensions of the controls are led to the Bridge. Manual control is retained locally at the machinery installation as an alternative.

Pneumatic systems are no longer being fitted. Their place is taken by electronic systems interfacing with pneumatic and hydraulic power actuators. These newer systems have yet to be tried out at sea.

Development in surveillance involves revised techniques in watch-keeping and presentation of information.

Reasons for the Use of Remote Control

Apart from such devices as automatic feed regulators for steam generating plant, pressure governors, speed governors, and other localized control instruments, there was little automatic overall propulsion plant control equipment fitted in the Royal Navy before the advent of nuclear weapons. Whatever controls were fitted were operator supervised and manually adjusted to suit conditions prevailing from time to time. Nuclear fall out presented a severe problem to such a situation because huge quantities of air contaminated by radioactive particles would be ingested by the combustion systems of main propulsion plant with harmful effect on the watchkeepers. Similar hazards were presented by conditions of chemical and biological warfare. A pressing operational need for remote control of such machinery was thereby established and programmes of work to introduce effective remote control were started first with existing machinery and later with new designs.

Other factors which influenced the programme were:

(*a*) The predicted shortage of suitable manpower to serve at sea.

(*b*) Realization of the significant cost of manpower, arising from life-cycle costing of warships.

(*c*) The trend towards smaller ships containing relatively more equipment.

(*d*) Shorter reaction times encountered in modern plant, together with reduced safety factors in design.

(*e*) The need to establish a modern environment for engineering staff.

Philosophy

Early attempts at automation in warships had aroused considerable interest but had also illustrated the penalties, awaiting the unwary, of both unreliability and of increased technical maintenance manpower requirements. Above all, the ability to continue to fight the ship under conditions of action damage remained paramount. This has resulted, relevant to merchant ship practice, in making haste slowly. Even ignoring the factor of wartime damage, it still remains necessary to retain a sufficiently large complement to cope with the normal hazards of shipboard life—fire, flood, collision—as well as with potential plant failures. In this latter connection, it is realized that duplication or triplication of vital parts or even of only control systems is a heavy price to pay for increased reliability of operation. Clearly a balance between automation and human operation must be sought and achieved.

Generally speaking the balance achieved has avoided triplication and has made use of more than one propulsion shaft per ship, and/or more than one engine per shaft. This reduces the likelihood of overall plant failure from the point of view of both power and of control, and limits it in the first instance to a loss of one of two or one of four parallel systems. Within each system, levels of control are arranged to reduce the vulnerability of the control itself. FIG. 1 illustrates this philosophy: prime movers are shown as four blocks transmitting power into two transmissions each driving a separate propeller. Control is exercised from three alternative levels, starting at the bridge and feeding via the Ship Control Centre through the block labelled 'Programme' to the prime movers and transmission system. Local (Level 3) control is provided by separate inputs at the prime movers and transmission. Such a system permits a retreat from Level 1 via Level 2 to any part of Level 3 as circumstances dictate. The significance of the 'programme' is to relate the inputs from Level 1 or 2 to the various plant block characteristics in terms of amount, rate, and time so as to provide optimum performance and at the same time avoid damage to the plant. Level 3 involves no programme and depends for success on the intelligence, training, and correct drill of the operator. In some particular cases elementary mechanical interlocks are included even at this level.

It is relevant here to discuss more deeply the roles of Bridge and Ship Control Centre (SCC). In brief the Bridge Control involves only a feedback of output parameters to the operator, namely shaft speed and direction and ships speed through the water, and assumes correct operation of connected plant. The SCC control is provided with plant surveillance in terms of analogue gauges and preset level operated alarms and warnings as well as output parameters. Thus the SCC operator can observe plant behaviour, monitor the effect of control input and adjust it, if necessary, to avoid dangerous conditions. This should only be needed if the controlled machinery has become partially defective and is operating abnormally.

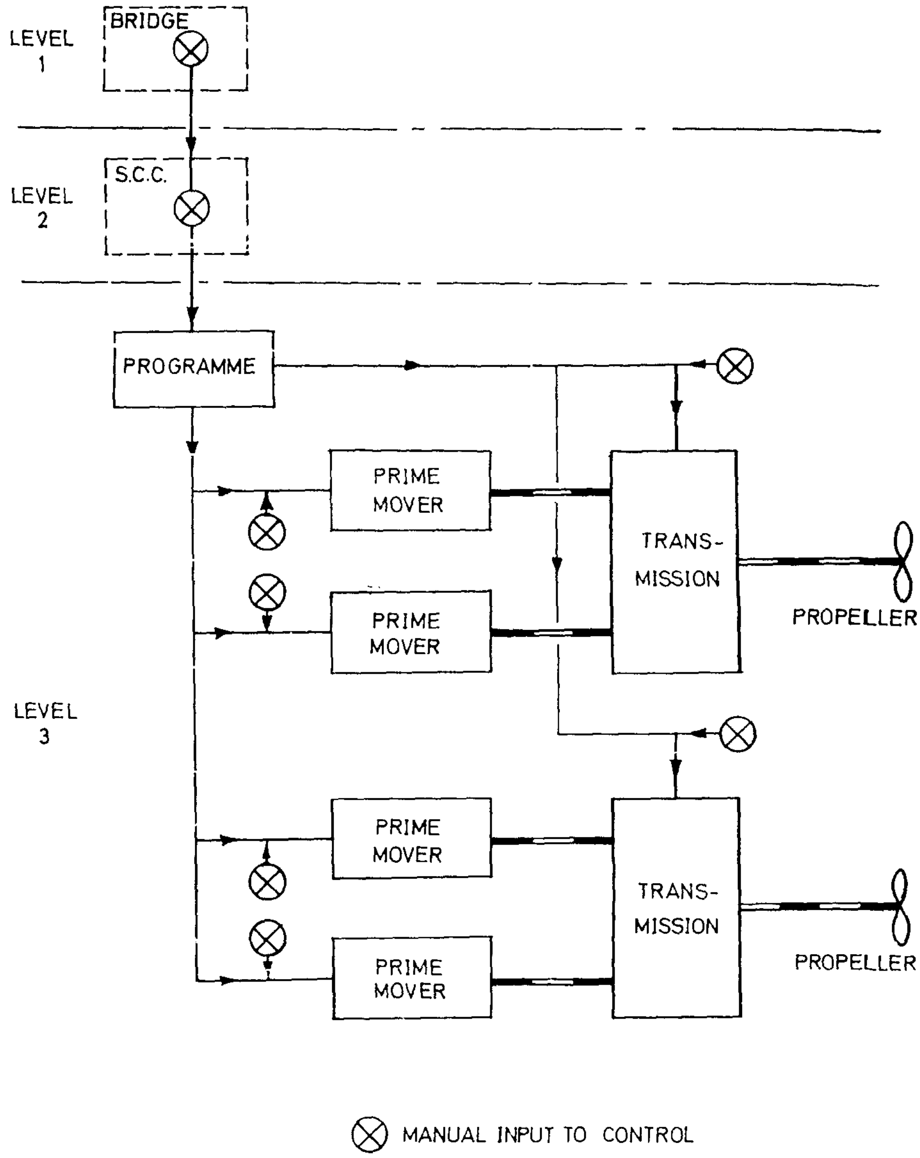

FIG. 1—PLANT AND PLANT CONTROL PHILOSOPHY

Local (Level 3) control is provided as the fallback position in the event of failure of the 'programme' or of the control links. More extensive instrumentation is in some cases provided at the local control position to permit safer manual operation. A slower reaction time to propulsion orders must be expected at this level of control, and it should be regarded only as a 'get-you-home' facility with limited manoeuvring capability.

Control Media

In the Royal Navy, the selection of the control medium was initially concerned with its suitability for steam propulsion plant. A pneumatic system was chosen for reasons of compatability with prevailing conditions in machinery spaces and boiler rooms and for its energy potential for powering the large number of actuators necessary for steam plant operation. To overcome the risk of electrical supply failure stopping the air compressor, bottled emergency air supplies were fitted. Such systems, obtained from various manufacturers, were fitted widely and operated satisfactorily.

The introduction of combined steam and gas (COSAG) plant added gas turbines to the existing types of steam installations. While retaining pneumatic controls, hydraulics were then employed to operate the fluid-couplings and clutches required to connect and disconnect the various prime movers to and from the reversing gear trains associated with these gas-turbines. The selection of hydraulics for this purpose was mainly associated with the need to provide positive positioning of these mechanisms at all times.

The subsequent advent of all gas turbine plant for propulsion then materially changed the factors influencing the selection of control media. Solid state electronics were now available and offered practical advantages in size and power requirements compared with their thermionic predecessors. Gas turbine plant requires a high degree of logic in controlled operation, but power actuation is reduced to a minimum on the turbine itself and in the transmission system. Solid state electronics is a most suitable medium for logic. It can be battery supported in emergency, is amenable to built-in testing by less expert diagnosticians, and repair by replacement is simplified. At this point, therefore, a change was made in the selected control medium, and a programme was started to develop an electronic control system interfacing with pneumatic and hydraulic actuators. Such systems are now being installed in new ships being built and are tailored to suit the operating characteristics of the plant concerned.

Surveillance Systems

The point has already been made that two kinds of surveillance presentation are provided in the SCC—analogue, and preset alarms and warning lamps. In the last of the COSAG installations, the control console became a very extensive unit incorporating large numbers of analogue gauges and requiring a considerable number of experienced watchkeepers for its operation. This console is illustrated at Fig. 2. H.M.S. *Bristol*, an experimental gas turbine installation, produced a smaller console but relatively large for a single screw vessel. The next design was for H.M.S. *Sheffield* and is the first of the solid state electronic systems—see Fig. 3. Analogue gauges are reduced to a minimum in number and backed up by 'alarm' and 'warning' windows illuminated to alert the operator to an abnormal condition. Alarms denote that an emergency has arisen endangering the equipment and, in most areas, indicates the action automatically initiated, e.g. to shut down plant or start alternatives. Warnings indicate and draw attention to an abnormal condition (not covered by an alarm) for which early remedial action is required. Auxiliary systems are covered by similar means but

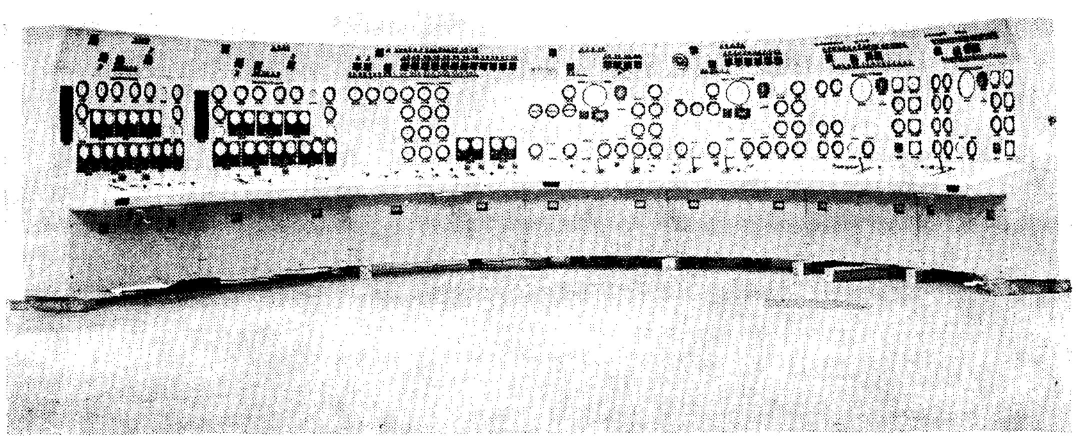

Fig. 2—Control console in H.M.S. 'Bristol'

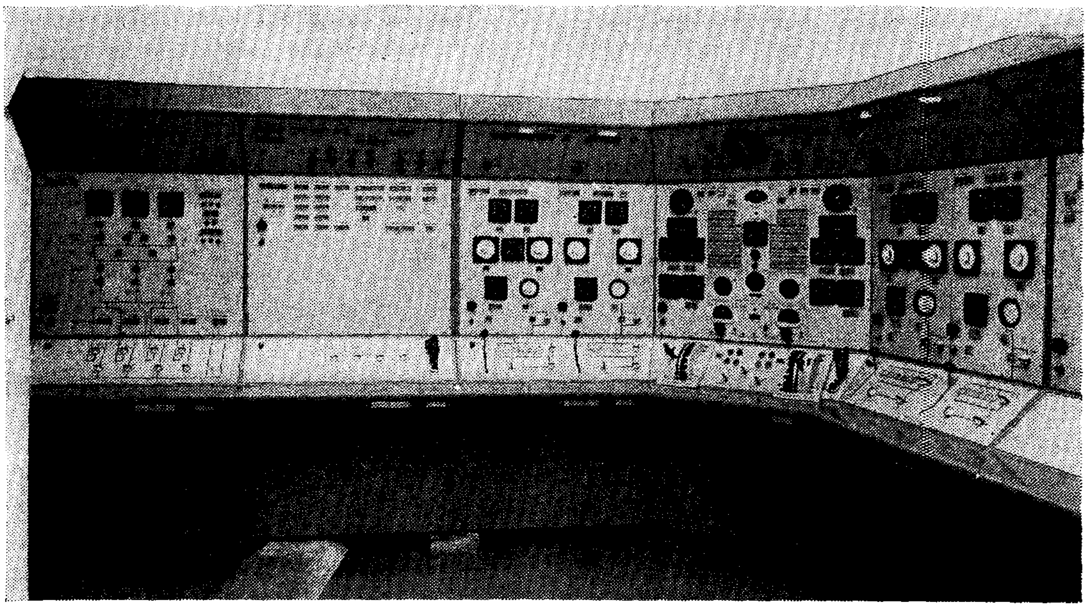

FIG. 3—CONTROL CONSOLE IN H.M.S. 'SHEFFIELD'

possess their own automatic watchkeeping panels; an alarm simply indicates automatic shut down, and the cause must then be diagnosed locally.

The system described no longer requires the operator to supervise gauges in the same way as formerly: he is alerted by flashing lamps and audible warnings which draw attention to the defective area. This change in concept introduces different factors in selection of skill and employment of watchkeepers. It permits the use of a 'shift' engineer leaving watchkeeping to a lower level of semi-skilled personnel.

The system does not incorporate automatic data logging, nor does it provide much to assist the watchkeeper in remembering the significance and geography of the plant. Subsequent design has progressed towards the use of mimic diagrams and automatic data logging. There is no doubt that mimics can provide a significant aid to operators of complex plant both in assessing operation and in deciding remedial action. Automatic data logging is an aid to providing accurate historical data showing trends, and releases manpower to perform tasks more intelligent than data collection alone. It may also reduce the manpower needed for continuous plant operation.

As usual, a balance has to be struck between cost of equipment and the alternative manpower. In a ship of frigate size, accommodation is at a premium, engineering staff is numerically limited, and it seems that the balance is in favour of automatic remote surveillance for propulsion and auxiliary machinery. In larger vessels there is a significant increase in generating capacity and auxiliaries resulting in an increase in the number of men visiting widely spread machinery compartments. Their task can, however, advantageously be eased by a judicious application of automatic remote surveillance with data logging.

Development State

The control equipment chosen for naval application is a development of the commercial Hawker Siddeley Dynamics Engineering Co. Ltd. modular electronic system. A programme to navalize the commercial modules was undertaken and has resulted in the system whose console is illustrated in FIG. 3.

The system has a single control lever per shaft input to actuate a frequency analogue servo system providing pulsed output to stepper motors. Related programmes for propeller pitch and gas turbine throttle opening are aimed at achieving an approximately linear relation between input lever position and shaft revolutions above that corresponding to turbine idling speed. To achieve slower ship speed, the propeller pitch is reduced and eventually reversed to provide astern power. Separate start/run/stop facilities are fitted for each of four engines together with smooth change-over between engines driving the same shaft. At the zero position of the control lever, a shaft brake can be applied by a sideways movement through a 'gate'. The system is designed on a 'fail-set' basis.

A series of standard modules is employed to perform the necessary functions, e.g. power supply, frequency comparitor, actuator drive, logic sequencing, surveillance, etc. These are 'plug-in' units fitted in chassis which are wired into the console.

A test and monitoring system is superimposed on the control system. This enables on-line testing of modules on a 'go/no-go' basis. Spare modules are kept at hand in case of failure. This system is designed for operator first-line maintenance, the operator being a propulsion engineering mechanic with minimal electrical training. Inter-module failures need more skilled electrical engineering expertise for diagnosis, and this is provided by the ship's electrical engineering staff. The console is designed for rear access which permits test and monitoring to proceed without disturbing the front panels.

Surveillance channels are wired individually, via appropriate modules, from sensor to warning light/acceptance switch. In the event of a pre-set limit being exceeded, the appropriate lamp flashes until the operator accepts it by depressing the lamp window when it remains illuminated until the parameter concerned returns to normal. Alarm lamps are red; warnings are yellow. Where state lamps are fitted, these are green. A test circuit is available to test each sub-system.

The first systems have now been built and tested at the factory. Most design areas were validated at factory test. However, some sub-systems were unsatisfactory and required correcting modifications to be generated, proved, and fitted; electrical interference was the main culprit. Installation is now proceeding. Setting to work will start later this year followed by sea trials.

Further Development

As already mentioned, there is now a greater use of automatic data logging. A survey of available equipment was made two to three years ago and, as a result, trials were carried out in H.M.S. *Hecate* and in a shore test facility using the commercial Decca ISIS 300 surveillance system. These trials have proved very satisfactory and a ship design, incorporating this warning equipment with the Hawker Siddeley Control and Alarm system, is now proceeding. The equipment also offers the advantage of reduced ship cabling as it employs multiplexing.

Apart from this basic system described above, work is also going on with the design of a modern d.c. servo system for application to control of propulsion machinery in smaller ships.

At the present time, no work is being done on the application of digital computers to the control of surface ship propulsion machinery in the Royal Navy. Progress in merchant ships in this field is, however, being followed with keen interest. As the cost of small computers gets less, this approach becomes more attractive.

Generally for all systems, sensors form a weak area in achieving satisfactorily reliable solutions and actuators do not present as wide a choice as is desirable. However ingenious the signal processing and however reliable the actual control programming may be, the system will only be as good as its input sensors and output actuators. All our experience at present indicates that there is much room for improvement in sensors and for development of actuators, particularly in the electrical field.