'BULLDOG' CLASS NEW PROPULSION CONTROL SYSTEM

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ABSTRACT

The existing mechanical controls of the BULLDOG Class are being replaced by a modern digital system. In addition to enhancing the performance of the operator's controls, the new system provides facilities to protect the propulsion machinery from overload, and to simplify maintenance by using an alpha-numeric maintainer's panel.

Introduction

As part of the life extension programme for the BULLDOG Class coastal survey vessels, extensive alterations to the bridge layout were required to accommodate the new surveying equipment. The bridge controls for the main engines had to be moved to the front of the bridge but the nature of the existing equipment made it impossible to reposition it. This provided an opportunity to replace the wear-prone mechanical controls and their associated linkages with a modern digital system.

The first new system underwent sea trials during the latter half of 1989. Two further systems have been built; one will have sea trials during 1990, and the third in 1991.

The Present System

The existing system consists of bridge and bridge wing levers, linked together by bicycle chains and rod gearing, driving a camshaft.

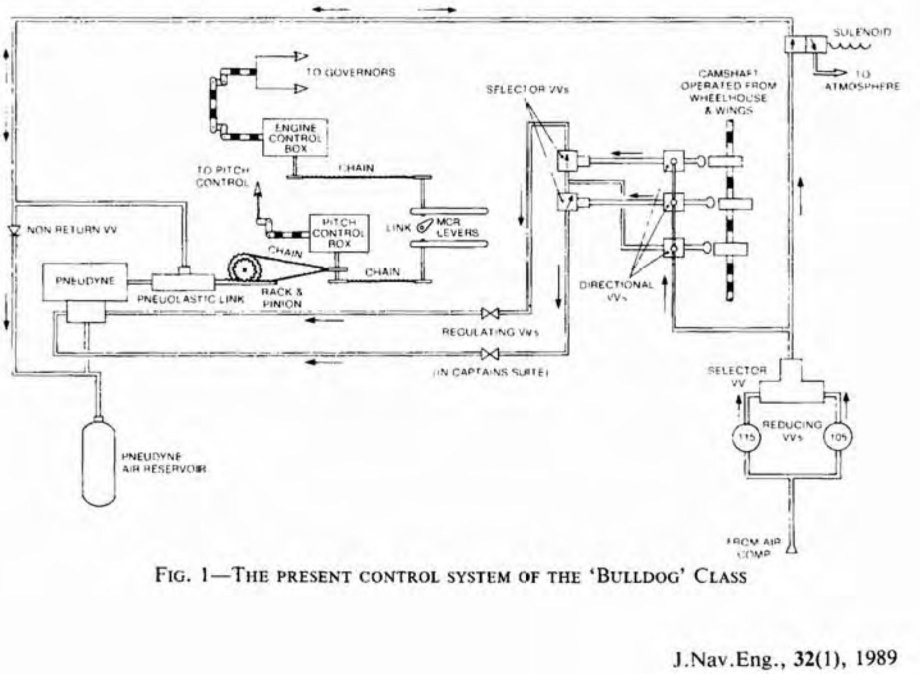

FIG. 1—THE PRESENT CONTROL SYSTEM OF THE 'BULLDOG' CLASS

FIG. 2—PRESENT BRIDGE CONTROL CONSOLE, SHOWING MECHANICAL LINKAGE

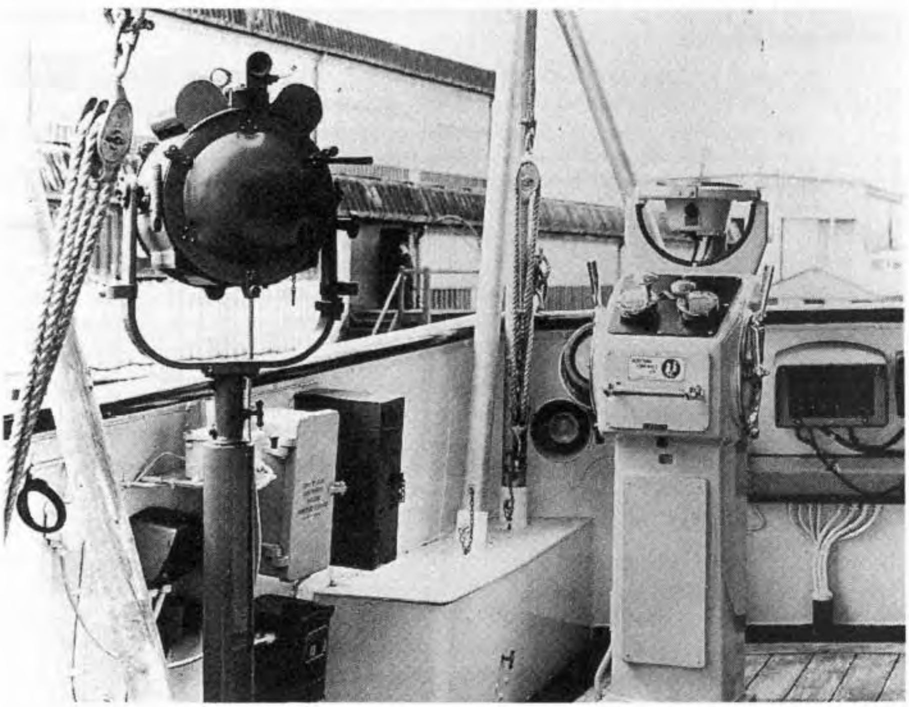

FIG. 3—PRESENT BRIDGE WING CONTROL PEDESTAL

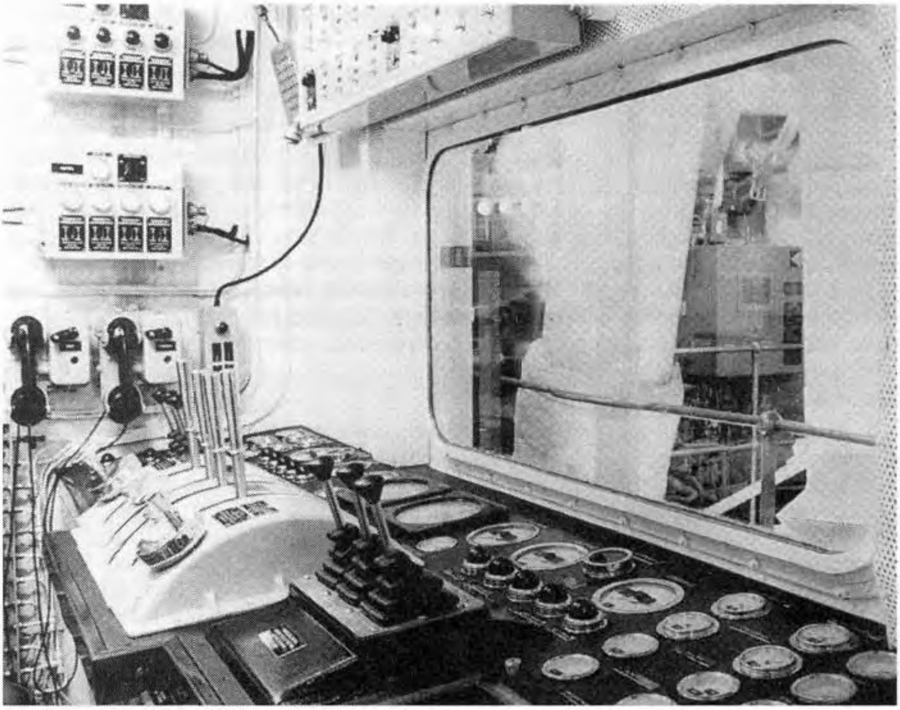

FIG. 4—PRESENT MCR CONTROL PANEL

The camshaft operates directional valves and, through a pneudyne and pneuolastic link, drives a rack and pinion, bicycle chains and bellcrank levers to actuate the pitch and engine controls. The Machinery Control Room (MCR) has separate levers for pitch and engine control, with a dog clutch connection between them which has to be made for the bridge to have engine and pitch control from a single lever. The MCR levers connect directly to the pitch and engine control positions via the familiar bicycle chains and bellcrank levers. This is shown diagrammatically in FIG. 1. Figs. 2, 3 and 4 show the bridge, bridge wing and MCR consoles respectively.

Current Problems

The bridge and bridge wing levers require a high maintenance effort to enable them to remain mechanically free, incidentally requiring the Captain's cabin deckhead to be dismantled at regular intervals.

Play in the chain and bellcrank drives makes the setting up of power-sharing between the inner and outer engines of each shaft virtually impossible; minor adjustments have to be made every time the Power Control Lever (PCL) lever is moved.

The original design also had some other serious shortcomings including:

(*a*) Telegraph system indication only; no reply except by an acknowledge bell.

(*b*) Diesel engines could only be started and stopped at the local position.

(*c*) Shaft brake could only be applied at the MCR position.

(*d*) Power-sharing achieved by balancing exhaust temperatures from local gauges which are not ideally positioned.

(*e*) All safe operation of the plant effected by operator drill. The bridge, which is normally in control, has no visibility of engine overload conditions.

The Way Ahead

Following a survey carried out by MOD in conjunction with ship and squadron staff, a Statement of Technical Requirement was produced to enable competitive tendering for a new system to be undertaken. Due regard was given to overcoming the shortcomings in the present system and providing safety features that protect the plant without operator involvement.

Four companies were then invited to tender. All four offered a digital solution and the Hawker Siddeley Dynamics Engineering (HSDE) tender was, after technical and financial appraisal, selected as successful.

Replacement Propulsion Control System

The new system was introduced to replace the original arrangement of direct mechanical linkages between the propulsion machinery and the operator's control levers, the limitations of which have just been discussed. The replacement system is based upon the Dynalec 5000 (D5000) digital control system developed by HSDE during the mid 1980s as a successor to the earlier all analogue D1000 systems. To date some thirty-six D5000-based systems have been installed. These include systems for Brazil (corvettes), Korea (corvettes, etc.), and Sweden (minehunters), in addition to the U.K. (BULLDOG) systems.

The general arrangement of the system is shown in FIG. 5. The propulsion equipment consists of two shafts with CP propellers, each shaft being driven by two Lister Blackstone ERS8M diesels, in a CODAD drive configuration.

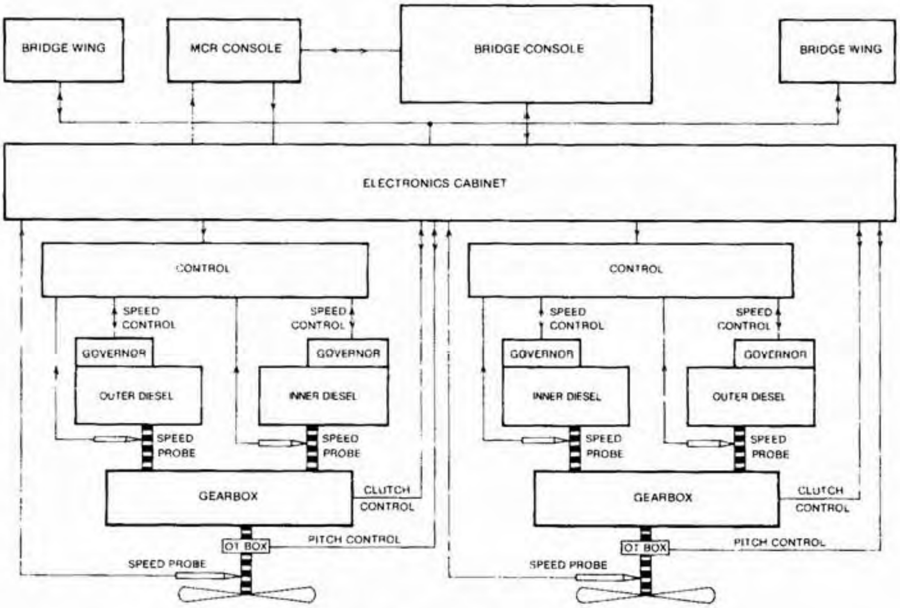

FIG. 5—NEW 'BULLDOG' CLASS CONTROL SYSTEM
OT: oil transfer

The main control system is supplemented by a servo-manual backup, with an additional facility for fully manual operation should this become necessary. Main control is based upon a D5000 processor module linked to a number of general purpose input/output modules. Unlike previous all analogue systems, these modules are not committed to specific system functions; system functionality is dependent upon the application software facilities provided. Servo-manual operation utilizes an additional independent processor module with its own associated input/output circuits.

The specific advantages offered by this new system are the provision of:

(*a*) a series of limit checks and interlocks to protect the propulsion machinery against overload conditions and to provide enhanced safety;

(*b*) a servo-manual fall-back control facility in the event of primary control failure;

(*c*) improved engine governing, with an automatic power-sharing capability between engines;

(*d*) a big improvement in control system reliability, and maintainability, through the use of modern digital equipment and a comprehensive maintenance support facility;

(*e*) adjustment-free electronic controls, in place of the wear-prone mechanical control linkages;

(*f*) a more effective man-machine interface—single lever automatic control leaving the operator free to concentrate on other ship functions;

(*g*) better feedback of propulsion system status to the operator.

Functional Overview

The new propulsion control system is designed to co-ordinate the propulsion machinery to provide the desired ship performance, whilst preventing unsafe operation and without exceeding the machinery stress limitations. To achieve this, the system provides automatic control of the two shafts, with their associated diesel engines and controllable pitch propeller. The automatic control functions include the clutches and shaft brakes, in addition to providing scheduled control of engines and propeller pitch. The system provides an approximately linear relationship between Power Control Lever position and ship speed.

Fully automatic control is available from the MCR and bridge level. Bridge level control also includes the bridge wings. The system provides automatic load sharing between the two engines on each shaft.

An independent back-up servo-manual system 'shadows' the main control system, to ensure that a smooth transfer of control occurs from automatic to servo-manual. Servo-manual control can be selected from the MCR, and will be automatically selected in the unlikely event of a failure of the automatic system. An emergency telegraph link provides a method of relaying propulsion orders to the MCR.

These functions are supplemented by a series of interlocks and protective mechanisms. The purpose of the interlocks is to prevent functions from being selected unless specific pre-requisites are met. The protective mechanisms control the propulsion machinery within its design limits, for example by controlling the maximum rate of change of engine power and propeller pitch.

In addition to providing these control functions, the system provides additional facilities for monitoring of machinery status, and gives warnings of abnormal conditions. A maintenance and diagnostic capability is provided via a maintainer's system monitoring panel.

Functional Details

Let us now look at the functions identified above in some more detail, to show some of the benefits over the original system.

Station in Control

Master control of the system resides with the MCR. A switch on the MCR control panel enables automatic control to be selected. Control transfer from MCR to bridge requires that an operator on the Bridge accepts control within a specified time period. Once bridge control is selected, any bridge station can select control from another. Status lamps show the current control position. The MCR can regain direct control at any time.

Discrepancies in PCL positions are normally insignificant, due to the 'electric shaft' system which links them together. If a discrepancy of greater than two degrees exists between the station in control and the MCR for five seconds or more, control reverts to the MCR. The original system had none of these safeguards.

Automatic Control

Once in automatic mode, the PCLs are the principal operator interface for the system. The PCLs are of the dual lever Stork-Kwant electric shaft type. This enables all four levers associated with each of the two shafts constantly to track each other in response to commands from the current operator's position. These levers provide the operator with scheduled control of the engine speed and propeller pitch.

Once the engines have been started, the operator can select and deselect the engines using four push buttons on the MCR, one for each engine. When an engine has been selected its respective button illuminates to show which engines are driving. An engine cannot be selected unless it is at idle. Engine selection causes the clutch to be engaged, ready for PCL control. Engine deselection disengages the clutches once the engine is at idle.

PCL movement away from the zero position in the ahead direction will progressively increase the propeller to design pitch, followed by a progressive increase in engine demand from idle to maximum. Moving the lever back to the zero position will provide the reverse sequence. The maximum allowable engine acceleration and pitch rate are automatically controlled within safe limits. Lever movement in the astern direction provides a mirror image of the same sequence.

The automatic control system will allow the PCLs to be moved in any manner, e.g. full ahead to full astern, without any risk to the propulsion machinery. In addition, the control system automatically imposes limits on the engine speed demand for single engine operation, and additionally if the sonar equipment is lowered (H.M.S. *Bulldog* only).

System Monitoring

Directly wired indicators are provided on both the MCR and bridge control panels to show propulsion system status and warnings. Lamp indication is provided for clutch engaged, shaft brakes, engine overload and control status. Analogue indications are provided for shaft speed and propeller pitch. The MCR also provides indication of the speed of each engine.

The bridge and MCR are linked by emergency and position order telegraphs. The position order telegraph gives a digital display of the required shaft speed as a percentage of full power. It is controlled by increment/decrement push buttons from the bridge. An acknowledgement facility is provided from MCR to bridge.

Servo-Manual Control

A switch on the MCR panel allows this mode to be selected by the operator. Manual selection in this way would be required to operate the propulsion machinery in an unusual manner, such as when towing. The emergency telegraph would then be used to transfer orders from bridge to MCR. Servo-manual also provides a backup to the automatic control system, should that system fail. Servo-manual would be automatically engaged in this case.

Engagement of servo-manual enables a set of increment/decrement push buttons on the MCR. One pair of buttons is provided for each control function. The servo-manual system operates independently of the automatic system and, when selected, it freezes the automatic system demand signals to ensure there is a smooth transition with no change in speed or pitch demand. The push-buttons can then be used to change the speed, pitch, clutch and brake status. Interlocks are provided to ensure that clutches cannot be engaged when the brakes are on, nor can brakes be applied whilst the clutches are engaged.

Engine Control

The new system has replaced the old Hartwell hydraulic governors with Heinzmann electronic governors. It now provides a load-sharing facility between the two engines on a shaft and enables the governor demand to be controlled automatically by the D5000 system. When loadsharing, one of the governors becomes a master, setting the same fuel rack position for the two engines on that shaft. The previous system did not have an automatic load-share capability; it relied instead upon the matching of engine temperatures, which was always difficult to achieve consistently in practice.

Clutches

The new system has replaced the lever-operated mechanisms with solenoid-operated hydraulic valves. The valves are controlled by either the automatic or servo-manual back-up, dependent upon which of these is in control. Interlocks prevent the clutches from being engaged when the shaft brakes are on.

Shaft Brakes

These too are now controlled by solenoid operated hydraulic valves. The valves are operated by push buttons on the MCR console. Interlocks ensure that the brakes cannot be applied until clutches are disengaged and the PCL is at zero.

Propeller Pitch Control

The original linkages have been replaced by a stepper motor driven actuator, which receives its position demand from automatic or manual, whichever is in control.

Maintenance and Diagnostics

The System Monitoring Panel contains a small keyboard with an associated alpha-numeric display. This is used for the display of system parameters and fault data, to assist maintenance and commissioning trials activities. Password protection is provided to prevent unauthorized access to these functions.

The New Equipment

The equipment necessary to provide this propulsion system upgrade includes the new control consoles/panels and a number of new sensors and actuators.

The new bridge console (FIG. 6) is a free-standing enclosure, with two functional panels. The vertical panel contains the propulsion machinery monitoring meters, the indicator lamps and the push-button controls. The smaller inclined desk panel includes the PCLs and the emergency telegraphs.

The bridge wing panels (FIG. 7) are drop-in replacements for the original bridge wing pedestal control panels. Each panel has a pair of PCLs, together with pitch and shaft speed indicators, and is sealed against spray to the IP65 environmental category.

FIG. 8 shows the MCR control panel which fits into the existing console. It contains a comprehensive suite of controls and indicators: PCLs, shaft

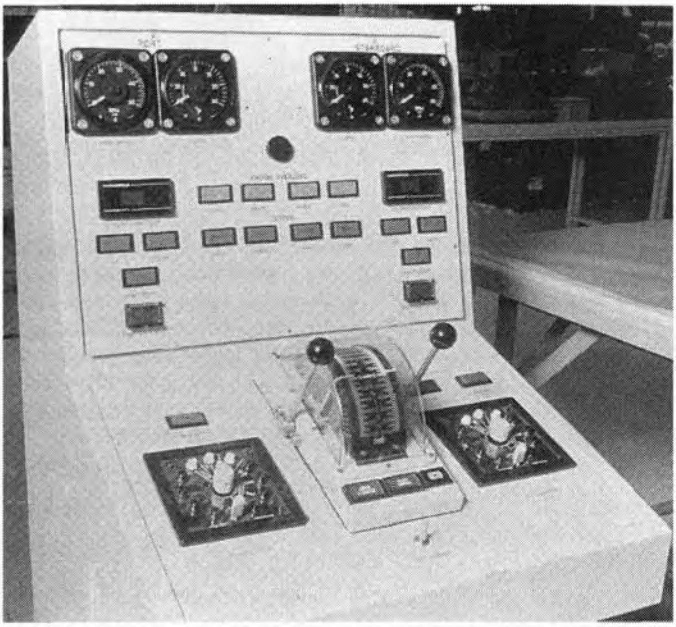

FIG. 6—NEW BRIDGE CONSOLE

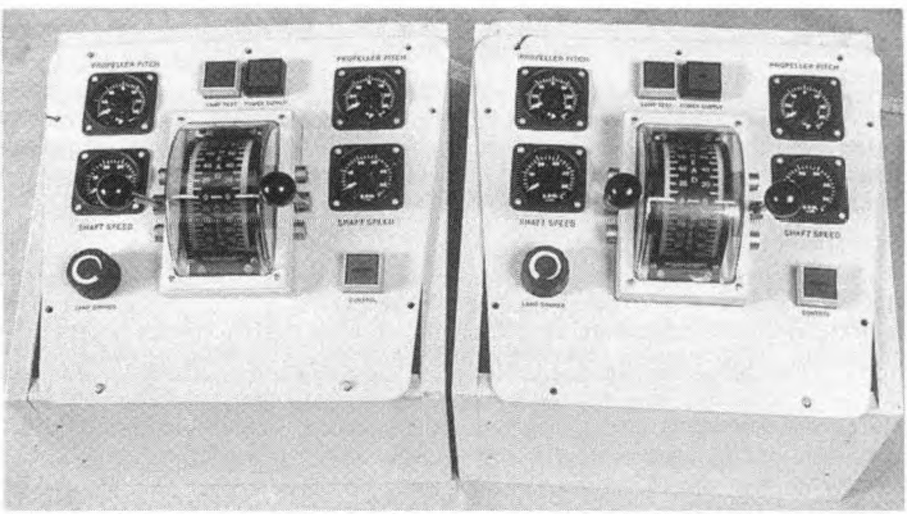

FIG. 7—NEW BRIDGE WING CONTROL PANELS (PORT AND STARBOARD)

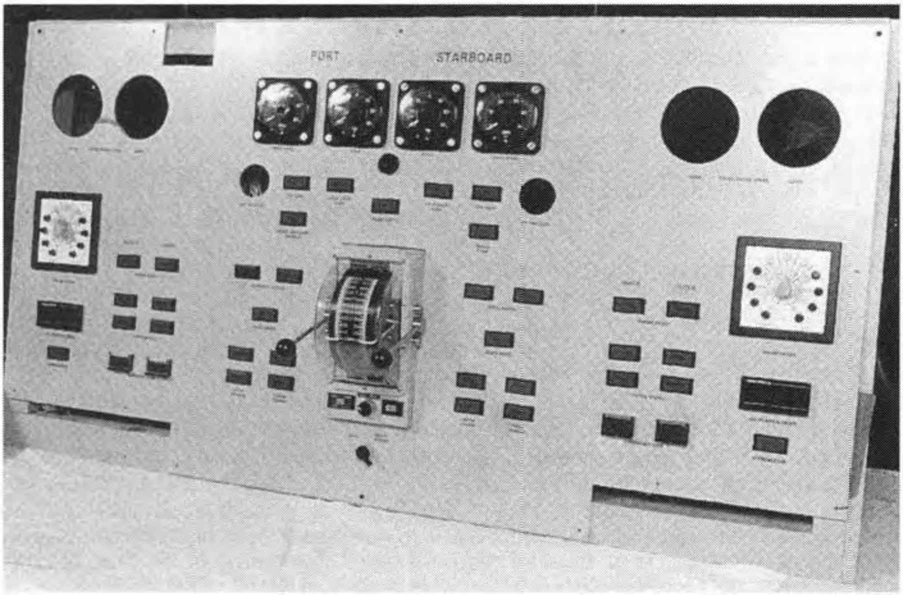

FIG. 8—NEW MCR CONTROL PANEL

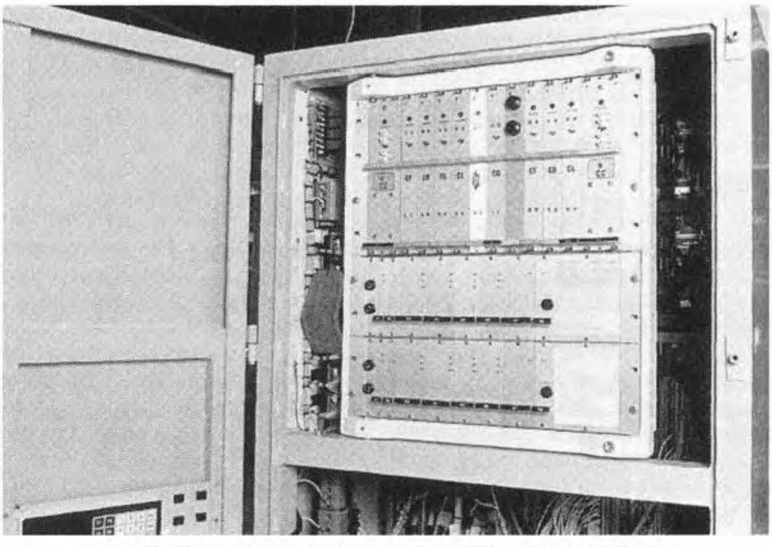

FIG. 9—ELECTRONICS CABINET OF THE NEW CONTROL SYSTEM

speed and propeller pitch instrumentation, engine speed indicators, telegraphs, servo-manual push-buttons, and indicator lamps.

A separate electronics cabinet (FIG. 9) houses the D5000 automatic and servo-manual control hardware. It includes the processors, I/O cards and power supplies. Stepper motor and solenoid driver hardware are also contained within this cabinet. In addition the system has shaft speed probes, solenoid valves, pressure switches, engine governors, and load-share hardware.

Acknowledgements

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