'HAVOC'—DAMAGE REPAIR INSTRUCTIONAL UNIT (DRIU)

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ABSTRACT

The DRIU consists of typical ship compartments over three decks, and can list or roll to 15° either side. Flooding and other damage incidents are dealt with under realistic and stressful conditions.

Introduction

The ability of a warship to survive, once damaged, depends to a large extent on the efficiency, expertise and confidence of the ship's company and in particular of the damage repair teams. Operation CORPORATE in 1982 clearly demonstrated the need for more realistic and stressful damage repair training than could be provided by existing facilities. As a result, approval was given in January 1985 for the provision of a new generation of damage repair trainers, the first of them to be sited at H.M.S. *Raleigh* at Torpoint in Cornwall. It is known as the DRIU, denoting Damage Repair Instructional Unit.

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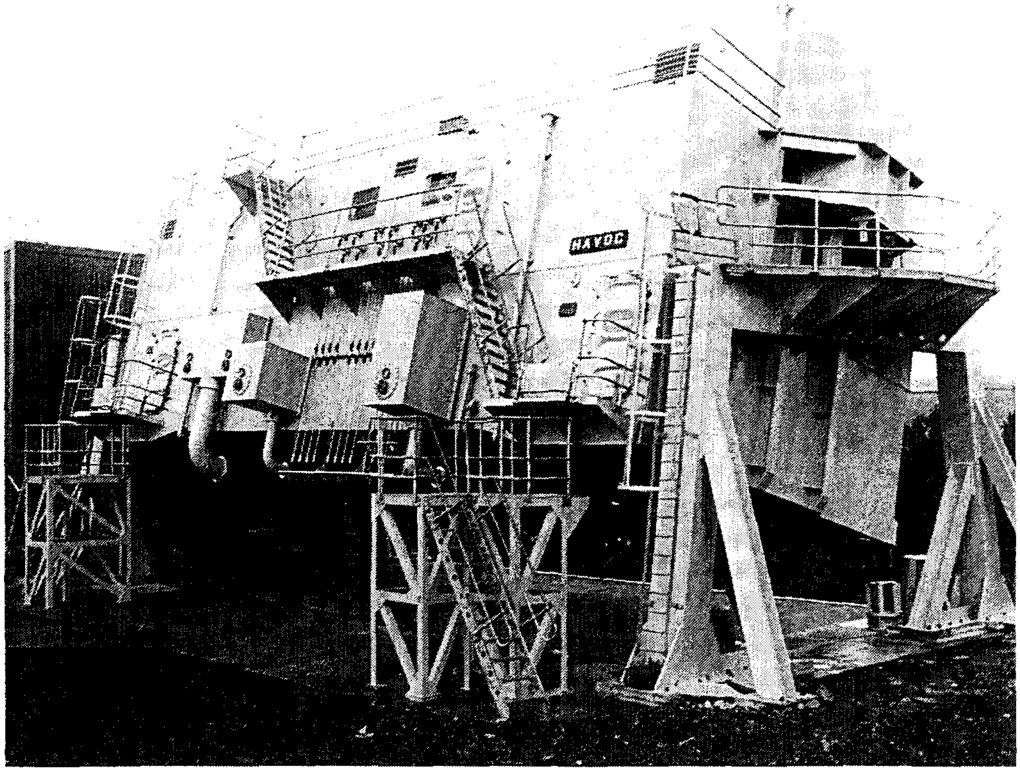

FIG. 1—'HAVOC' HEELED 15° TO PORT

The unit was completed in December 1986 (FIG. 1), and was officially accepted into service and named 'HAVOC' by Mr R. Freeman, M.P., the Parliamentary Under Secretary of State for the Armed Forces in January 1987. Three further units are planned, at other sites.

Description

The DRIU is designed to provide damage control and repair training for both ship and submarine teams by simulating action damage under realistic conditions. The unit has the ability to move about its longitudinal axis to a maximum of 15° to port or starboard. This motion is intended to represent the roll of a ship at sea or the list and loll conditions as a result of flooding. To permit this motion the DRIU structure is suspended from portal frame supports positioned at either end of the longitudinal axis. The rolling motion is provided by two horizontally opposed hydraulic actuators fitted at one end of the unit.

The DRIU consists of a number of typical ship compartments arranged over three deck levels with subdividing watertight bulkheads. Built and fitted out to current R.N. standards, the systems include high pressure sea water (HPSW) main, electrical power, lighting and emergency circuits, emergency breathing air (EBS) and internal communications facilities. These compartments also have various forms of damage incidents built into them, with water being supplied from an external header tank. In addition to these ship-like compartments there are further compartments, set aside for the instructional staff and operators of the unit. A second structure, the Pump Room is adjacent to the DRIU and contains at ground floor level the equipment necessary to provide the required hydraulic, electrical and water services for the DRIU. At first floor level is mounted the water header tank.

Construction and Layout

The DRIU is 14·64 m long, 6·7 m wide and 8·86 m high, and its approximate weight when fully operational is 190 tonnes, including 91 tonnes of water that may be in compartments or systems.

It is constructed generally from 5 mm and 10 mm thick mild steel plate and from long stalk tee bars ranging in size from 25 mm × 76 mm to 76 mm × 152 mm. In high stress areas such as the trunnion bearing plate, the scantlings are much larger. The unit is of all welded construction except for two horizontal bolted connections 150 mm above 2 Deck and 100 mm above 1 Deck. These connections were necessary in order to facilitate ease of breakdown for transportation from the shipyard to the site.

The unit is supported at each end by a main bearing assembly. This comprises a stub shaft (1355 mm long × 340 mm diameter) supported by two end brackets which are bolted to an extension of the trunnion bearing plate. A double spherical roller bearing (600 mm diameter and 243 mm wide), mounted in a bearing housing bolted on top of the frame, supports the stub shaft. The main bearing assembly at the Pump Room end of the DRIU is fixed longitudinally, while the main bearing at the opposite end is a 'sliding' bearing and is designed to accept any small structural deflection of the unit.

The beam and leg sections of the support portal frames are fabricated box sections, and two I-section struts are fitted at each leg. The bottoms of the legs and struts are tied by means of a common base plate which is secured with bolts embedded within the prepared concrete foundations. The support portal frame legs at the Pump Room end are also fitted with clevis brackets for securing one end of the hydraulic actuators.

TABLE I—*DRIU layout*

Deck Level	*Compartment*
1 Deck (weather deck)	Lobby*
	Re-entry Fire Party Post
2 Deck	Staff Observation Point*
	Senior Rates Mess/Casualty Handling
	First Aid Post
	Fire and Repair Party Post
	Staff Control Room*
	Ventilation Fan Chamber
	Workshop
	Passageway
3 Deck	Entry/Escape Lobby*
	Generator Compartment
	Junior Rates Mess Deck
	Fire Pump Compartment
	Lobby
	Viewing Area*
	Aux Machinery Space

* These compartments are for the use of the instructional staff.

The structures of the DRIU and ground support portal frames have been designed to take account of the dynamic loading caused by the rolling of the structure and the sloshing effects of the water within the flooded compartments. In addition, wind, snow and ice loadings have been superimposed on the structure.

As the unit represents a midship section of a warship it has been given lettered sections K, L, M, and N, which run from frames 26 to 41. The compartments on each deck are listed in TABLE I and shown in FIG. 2.

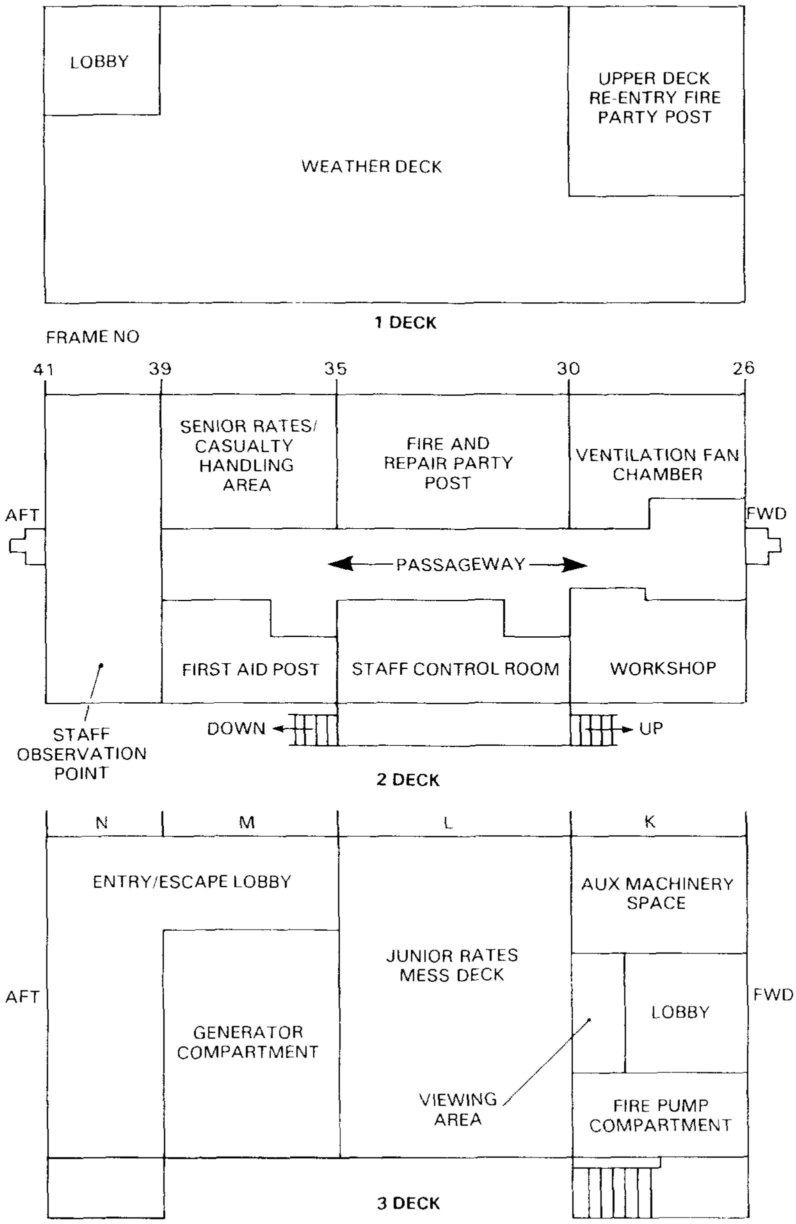

FIG. 2—DRIU COMPARTMENT LAYOUT

The unit is provided with some of the systems and equipment normally found in a ship (FIG. 3). These include HPSW main, fire pump, fixed eductor system, electrical power, emergency electrical runs, normal and emergency lighting circuits, emergency breathing system, sound powered telephones, and ventilation system.

The unit includes a number of the lessons learned in the Falklands experience. Smoke curtains have been fitted in the main passageway at each main watertight door to maintain a smoke boundary. Emergency life support apparatus (ELSA) has been distributed throughout the unit. Photoluminescent coatings are used on signs for escape routes, hatches, ladders, and positions for ELSA and breathing apparatus stowage. A 're-entry' Fire Party Post has been fitted on the weather deck. It contains the full range of fire-fighting equipment to facilitate a re-entry to the decks below, including the Hathaway HMD7 portable diesel fire pump.

Situated in the Staff Control Room on 2 Deck is the Staff Control Console (FIG. 4). This provides a centralized control position for the co-ordination of exercise routines, and for control and surveillance of machinery and communications associated with the DRIU and Pump Room. The console comprises three separate cubicle assemblies, known as bays, bolted together to form a composite unit. Bay 1 houses the broadcast system and includes a tape deck so that simulated battle noises can be broadcast. Bay 2 serves as the central control position for the control and surveillance of the electrical services, including lighting, heating, ventilation, flooding and drainage systems. Bay 3 serves as the central control position for the hydraulic system.

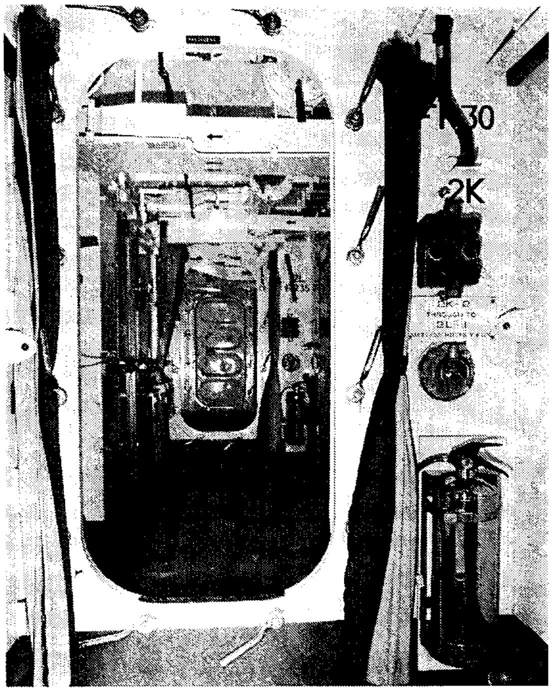

FIG. 3—2 DECK PASSAGEWAY

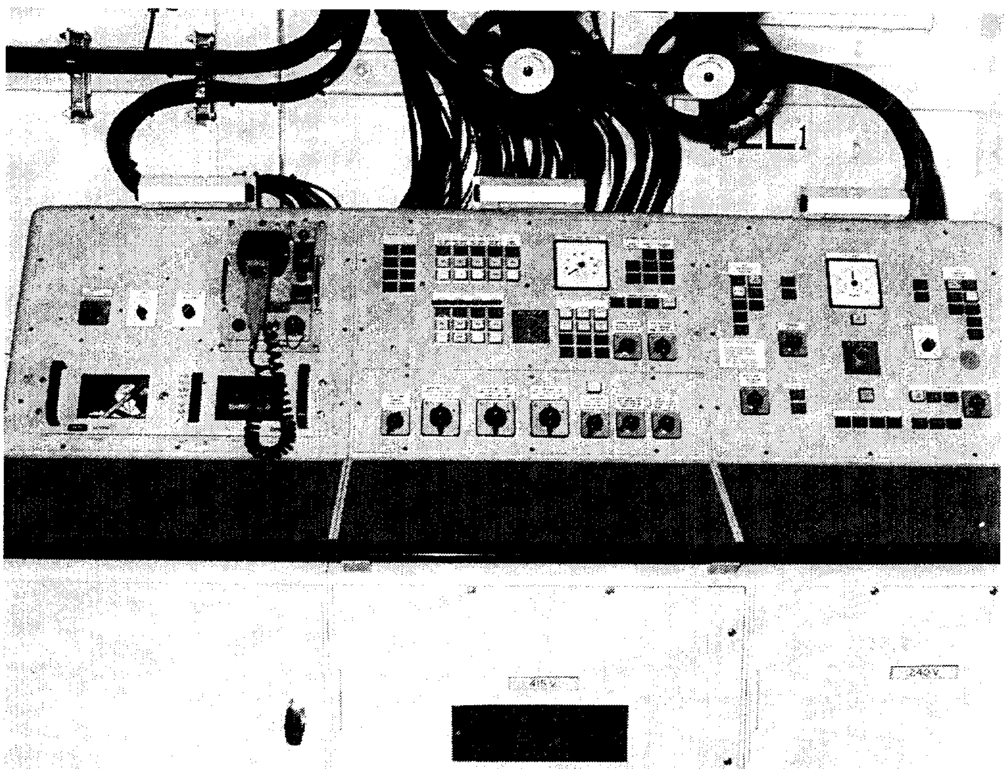

FIG. 4—STAFF CONTROL CONSOLE; FROM LEFT TO RIGHT, BAY 1, BAY 2 AND BAY 3

Hydraulic and Hydraulic Control Systems

A feature of the DRIU is its ability to roll and/or heel from 0 degrees to 15 degrees either side of the vertical. This motion is accomplished by means of a hydraulic power pack, situated in the Pump Room, driving a pair of horizontally opposed hydraulic rams. A closed loop electro-hydraulic control system provides control and surveillance of the hydraulic power pack from the Staff Control Console.

Hydraulic System

The hydraulic system has been designed to provide a torque of 130 tonne-metres at a system pressure of 245 bar. It comprises a hydraulic power pack (FIG. 5) and two hydraulic ram assemblies (FIG. 6). Power for the transmission system is provided by one of two motor-driven variable delivery pumps mounted on the hydraulic power pack frame. Only one pump is necessary to develop the required hydraulic power to move the DRIU in either the automatic or the manual mode, the second pump remaining in a non-running stand-by role.

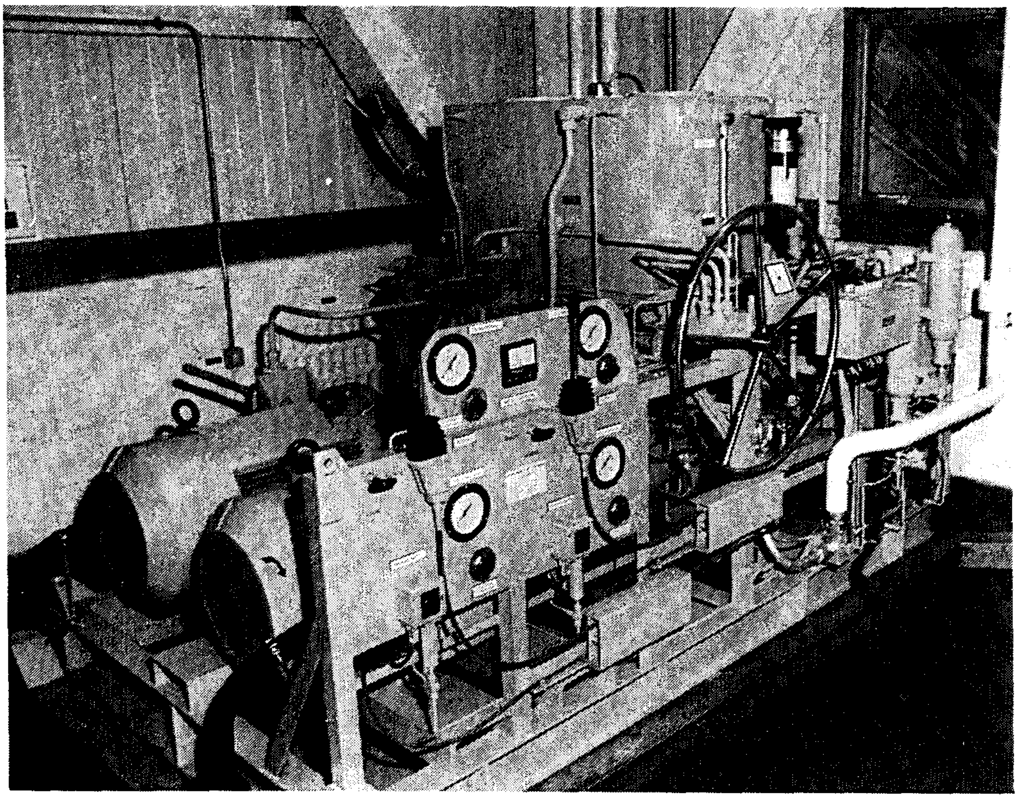

FIG. 5—HYDRAULIC POWER PACK

Control of the DRIU movement in the automatic mode is via a pre-programmed system controller located in Bay 3 of the Staff Control Console. Commands from the operator's control console and feedback signals from the hydraulic system are processed by the system controller. The system controller then generates a command signal which goes to an electro-hydraulic servo valve. The servo valve controls the hydraulic pump which delivers hydraulic oil to the ram assembly.

Control of the DRIU movement in the manual mode is by means of control levers mounted on the hydraulic power pack which, when engaged, enable the output of the hydraulic pump to be controlled. In the event of an electrical failure, a wheel-driven hand pump can be used to restore the DRIU to the vertical position by moving the hydraulic rams directly.

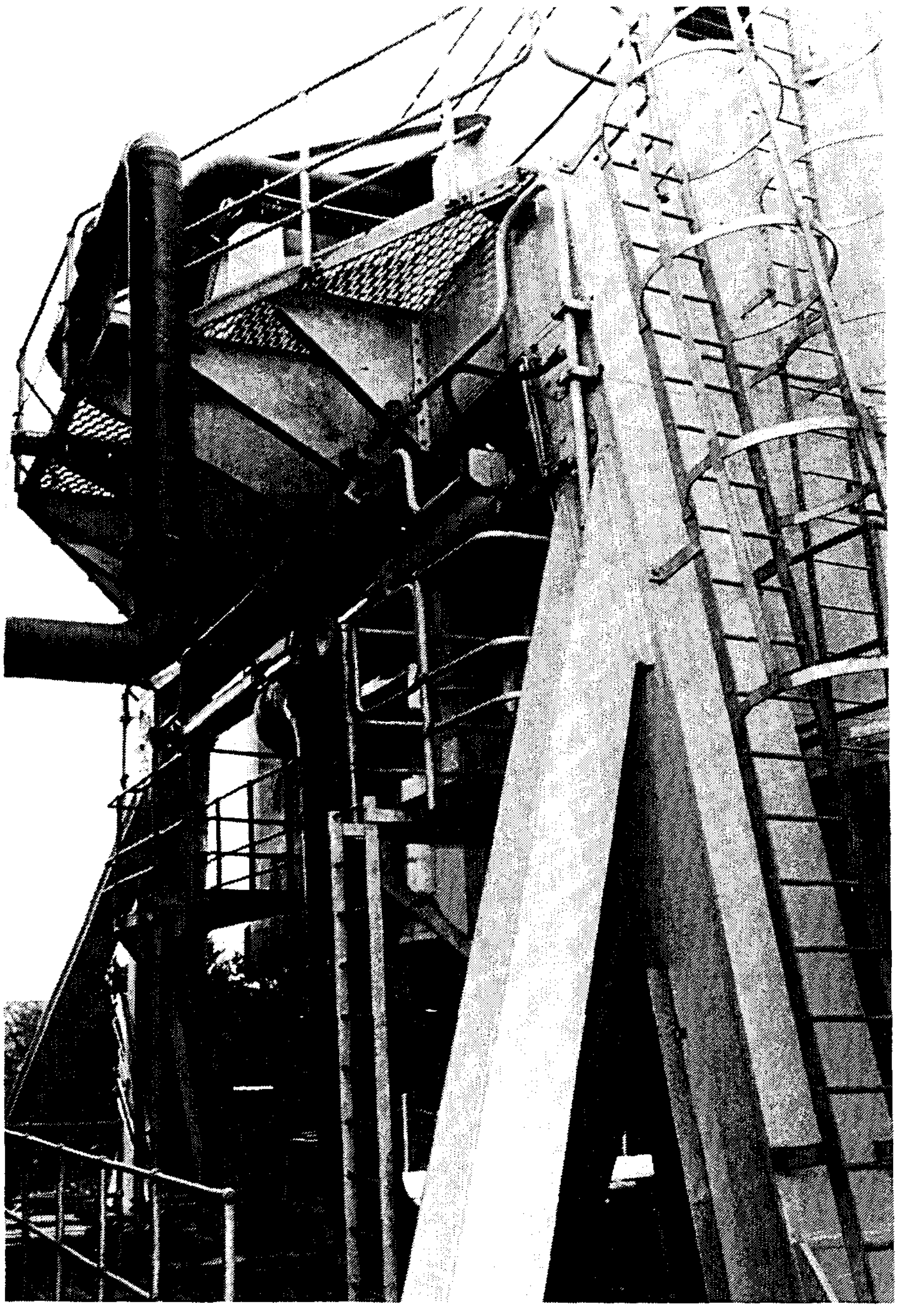

FIG. 6—DRIU SEEN FROM PUMP ROOM END. NOTE THE HYDRAULIC RAMS AT MID HEIGHT

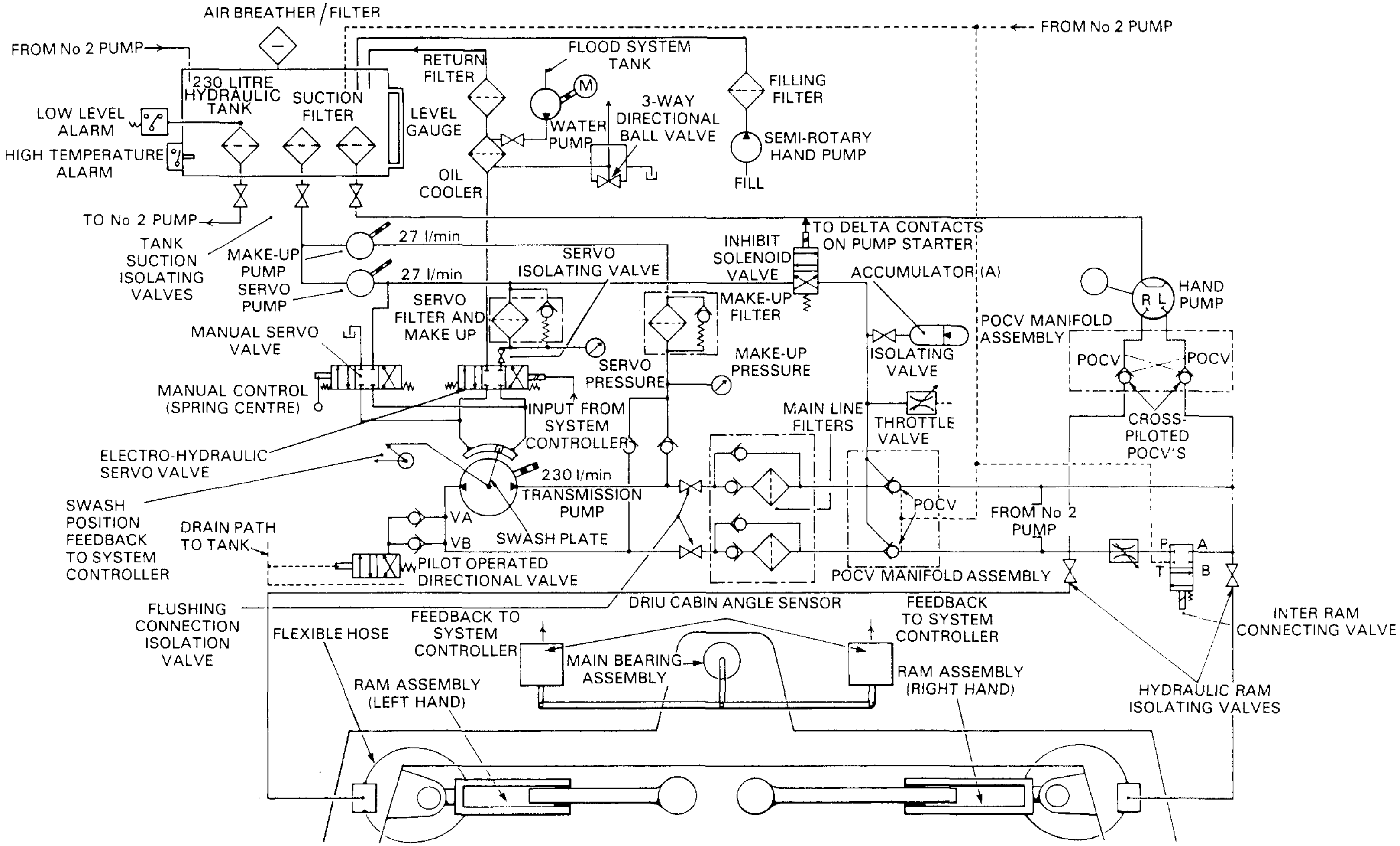

FIG. 7—HYDRAULIC SYSTEM

System Operation

FIG. 7 shows the hydraulic system utilizing No. 1 pump only. The hydraulic supply from No. 2 pump is connected to the main pilot-operated check valve (POCV) manifold assembly mounted on the portal frame structure that supports the DRIU. The hydraulic pump assembly, which is horizontally mounted, comprises an axial piston transmission pump, a servo pump and a make-up pump, housed within a common casing and driven by the same electric motor. The transmission pump delivers oil under pressure to the hydraulic rams; the servo pump supplies the electro-hydraulic servo valve (and the manual servo valve) and thence to the transmission pump swash plate; and the make-up pump replenishes the transmission pump's supply lines under load conditions and also provides a constant flow of cooling oil through the pump casing. Both the servo and make-up pumps are supplied with oil via suction filters from a common hydraulic tank mounted on the upper section of the power pack frame.

From the transmission pump, oil is delivered to the hydraulic ram assemblies via 6 micron main line filters, a POCV manifold and ram isolating valves. An oil cooler is fitted in the return line from the transmission pump casing to the hydraulic tank. The water circulating through the oil cooler is supplied from a water pump, mounted on the power pack frame, which takes its suction from the Pump Room header tank.

The main POCV manifold assembly is common to both systems. The main POCVs ensure that the rams are hydraulically locked in their selected positions when the transmission pump swash plate is at zero pump angle. These POCVs are piloted open by the servo pressure of the hydraulic pump in use. In addition a pair of cross-piloted POCVs permit the flow of oil from the wheel-driven hand pump to the rams when required.

Included in the POCV manifold block assembly is an electrically controlled inter-ram connecting valve. This valve is operated from the operator's console and will bring the DRIU to its vertical position in the event of motorized pump or system failure, by equalizing the oil pressure between the right-hand and left-hand rams.

The transmission pump rate and direction of motion of the rams are determined by the position of the swash plate. This position is itself controlled hydraulically by means of the electro-hydraulic servo valve which receives electrical command signals from the system controller. Should the electrical control system fail, then the swash plate position can be manually operated by means of the manual servo valve.

A pilot operated directional valve (PODV) piloted from the accumulator (A) is fitted in the transmission circuit (pilot line not shown in FIG. 7). The purpose of this valve is to provide a drain path to the tank from either side of the swash plate (one side only shown in FIG. 7) via connections VA and VB. This ensures that the swash plate is in a neutral position on pump start-up.

An 'inhibit' solenoid valve controlled by the hydraulic pump starter is fitted in the servo transmission line to the main POCVs and the accumulator. This valve is not opened until the delta contact in the hydraulic pump motor starter closes, thus ensuring that:

(*a*) the pump is destroked when started;

(*b*) the POCVs are not opened until the pump is on zero swash angle and therefore the DRIU will not move.

The starters for the hydraulic pump motors and their associated cooling water pump motors are housed within common cabinets and situated in the Pump Room. The control circuits of each system are electrically interlocked to ensure that both pumps start and stop simultaneously.

The hydraulic rams (FIG. 6) which control the DRIU movement are of the single-acting type. Each ram is 200 mm diameter, and has a nominal stroke of 1215 mm. Progressive hydraulic cushioning is applied as the ram retracts into its last 115 mm of stroke. The ram and the cylinder are each suspended in self-lubricating spherical bearings and are positioned in a near horizontal line. The cylinder ends are fixed to the vertical legs on the after portal frame and the ram ends to the DRIU structure.

The rams operate as an opposite pair. Hydraulic oil from the high pressure side of the transmission extends one ram thereby driving the DRIU, and at the same time retracting the opposite ram. Hydraulic oil displaced by the retracting ram returns to the low pressure side of the transmission. Systematic pressure and exhaust to the rams results in a smooth sinusoidal motion being imparted to the DRIU.

Hydraulic Control System

The control and surveillance of the hydraulic system is performed from the operator's console (Bay 3) of the Staff Control Console (FIG. 4). The system comprises a system controller, feedback transmitters and sensors and allows the DRIU to be automatically controlled so that its angular position varies sinusoidally with time, with a limiting angular displacement of ± 15 degrees from vertical, a maximum angular velocity of 5 degrees/sec and an acceleration of 1·5 degrees/sec^2. The DRIU may also be positioned under manual control to any angle within the range ± 20 degrees from vertical. The hydraulic control system is shown in FIG. 8.

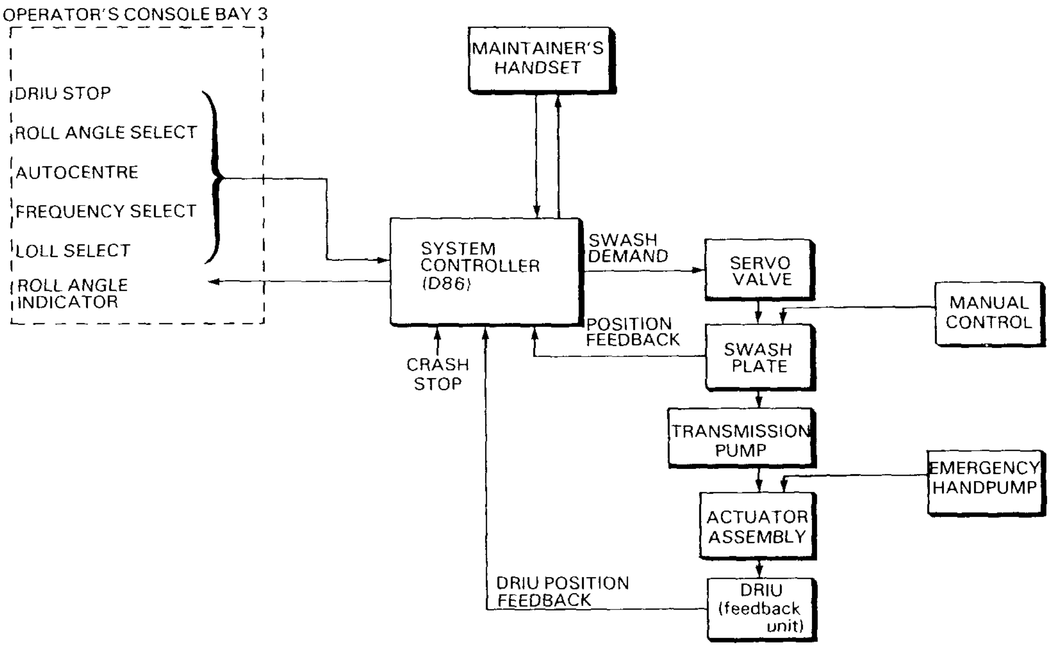

FIG. 8—HYDRAULIC CONTROL SYSTEM

The system controller receives input control signals from the operator's console and surveillance information from the sensors, and it sends commands to the hydraulic system electro-hydraulic servo valve, and to indicators on the Staff Control Console.

Controls associated with the motion of the DRIU are Loll Angle Select, Roll Angle Select and Frequency Select. Motion may be stopped by the use of the DRIU Stop command, and the Autocentre command returns the DRIU to zero degrees of heel from a stationary position.

The system controller is programmed to respond to input signals so that the DRIU motion does not exceed its design parameters. The program takes the form of a control schedule. This schedule processes the combined command and surveillance input signals to produce command and demand output signals. The system controller also interfaces and activates the Crash Stop procedures.

The amplitudes of the input signals dictate the level of the swash demand output signal which controls the flow of hydraulic oil through the electro-hydraulic servo valve to position the swash plate and hence to activate the transmission pump and rams. A feedback potentiometer moves relative to the swash plate angle and, in conjunction with the DRIU angle feedback transmitter, completes the electrical servo loop controlling pump displacement. If the system controller receives an input signal that calls upon the DRIU to exceed its design parameters as incorporated into the control schedule, it will issue commands at the maximum permitted level.

Limit switches housed within the DRIU cabin angle sensors operate in the automatic mode when the DRIU angle exceeds 16 degrees to port or starboard. Operation of either of these limit switches causes the system controller to revert to a failsafe condition and sends a stop command to the hydraulic pump motor. The DRIU is then brought to a controlled halt.

In the event of a genuine emergency situation arising there are four crash-stop pushbuttons which are located throughout the DRIU for use by the instructional staff. Pressing the pushbutton causes the following actions:

(*a*) Heeling motion ceases.
(*b*) Motorized drain valves in flooded compartments open.
(*c*) Supplies to lighting circuits in exercise areas are restored.
(*d*) Ventilation exhaust system is started.

The system controller and its associated sub-assemblies are located within Bay 3 of the Staff Control Console. It utilizes an advanced microprocessor-based system designed to perform the following functions:

(*a*) Monitor operator commands from Bay 3 control console.
(*b*) Interpret these commands and output them as machinery control signals to the hydraulic system in use.
(*c*) Monitor operational status signals from the hydraulic system in use, and also signals within the system controller.
(*d*) Control and interlock the movement of the DRIU cabin in response to (*a*), (*b*) and (*c*) above.
(*e*) Interpret signals from the hydraulic systems and operate indicators and alarms located on Bay 3 control console.

The system controller employed to control the hydraulic system is a standard D86 rack assembly, fitted with the following printed circuit boards (PCBs) and diagnostic fault/failure aids:

1 Processor II PCB
2 mixed input/output PCBs
1 diagnostic PCB
1 maintainer's handset
3 filter boards.

The Processor II PCB provides the processing power for the system controller. Within its memory is stored the control schedule for the DRIU. The memory also includes an area of Electrically Erasable Programmable Read Only Memory (EEPROM) which allows the operator to modify certain elements of the system.

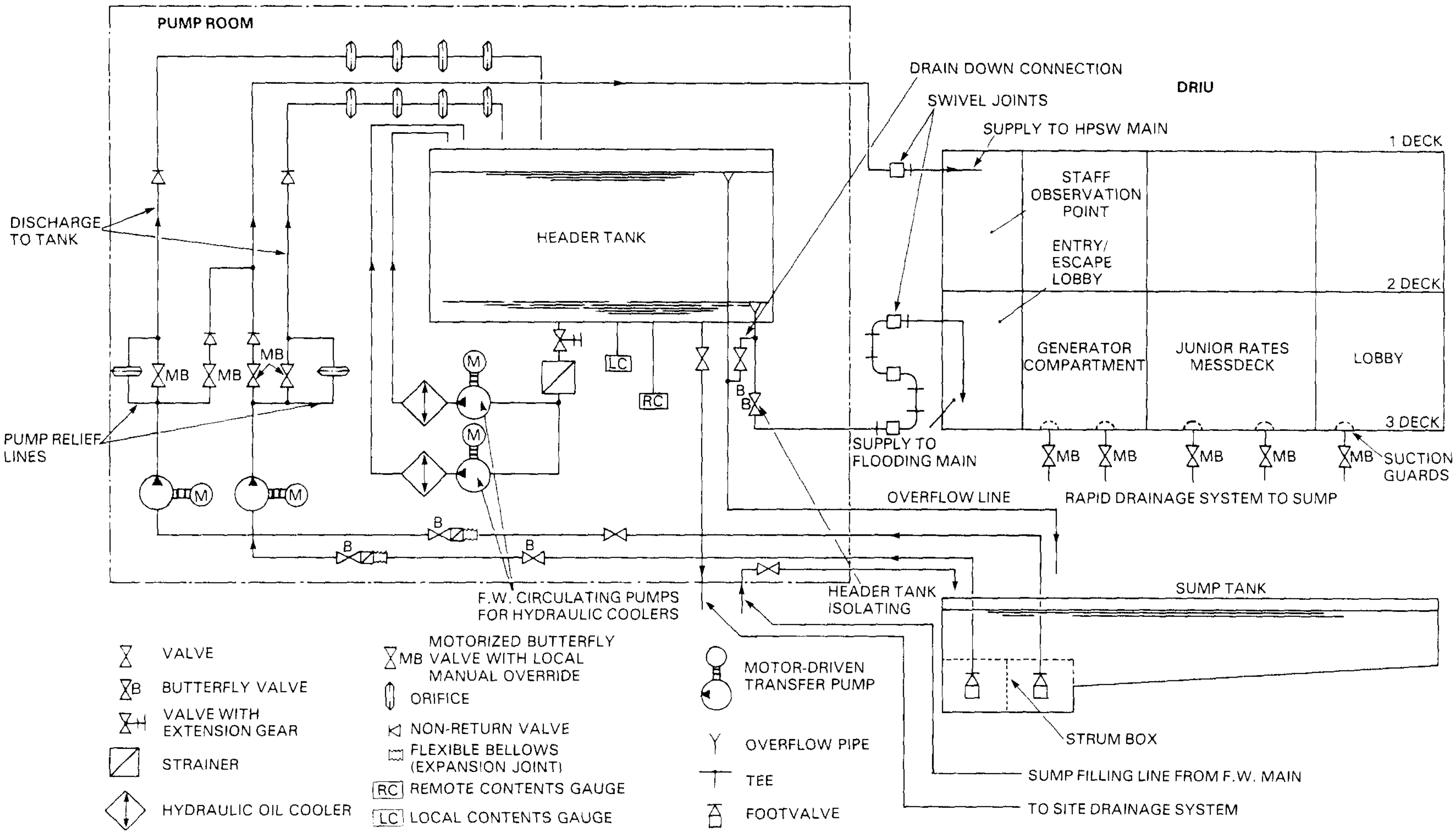

FIG. 9—PUMPING AND DRAINAGE SYSTEM

The mixed input/output PCBs enable the processor to interface with the external control system. The PCBs provide all necessary digital and analogue input/output channels.

The diagnostic PCB continually monitors the operation of key parameters within the D86 to determine if a detectable fault/failure exists within the system. An audible alarm and illuminated indicators on the operator's console indicate the fault/failure status.

The maintainer's handset is a portable unit which plugs into the Processor II PCB. It is primarily a diagnostic aid to assist the operator to identify faults within the system controller. A keyboard on the handset permits the operator to enter commands to the system controller and monitor the response on an alpha-numeric display. The handset can also be used to change certain parameters within the system controller.

Signals to and from the diagnostic PCB and each input/output PCB are routed through the filter boards to remove unwanted internal/external noise.

The system controller program takes the form of a control schedule and is stored in the memory of the Processor II PCB. The program contains all software which controls or responds to the following functions:

- DRIU cabin movement.
- system self-check.
- system sensors and interlocks.
- fault and failure sequences.
- alarm handling.
- operator control facilities.
- lamp test.
- maintainer's handset.

Water Systems

The water system can be divided into three sub-systems, namely:

- Pumping and Drainage System.
- Flooding System.
- DRIU HPSW System.

Fresh water is used throughout, to reduce the effects of corrosion.

Pumping and Drainage System

This system, shown diagrammatically in FIG. 9, provides the means of supplying water to both the Flooding and HPSW sub-systems and of removing flood water from the DRIU. The system consists of a sump tank, a header tank, and transfer pumps. The drainage system contains a series of motorized valves located in those compartments on 3 Deck that can be subjected to flooding incidents. These valves drain water to the sump tank which is below ground level beneath the DRIU structure.

The header tank is above the Pump Room. Its purpose is to provide a source of water to any of the ship's structure damage incidents via the flooding sub-system to represent a pressure head of between 1·8 m to 3·7 m below an imaginary water line. The header tank is filled from the sump tank via one of the two transfer pumps, and it discharges, via a locally operated isolating valve, to the flooding sub-system. In addition, the header tank supplies water to the hydraulic system cooling water circulating pumps. The header tank is equipped with transmitters for both local and remote reading contents indicators, and has a working capacity of 125 tonnes.

The transfer pump duty is to transfer water from the sump tank to fill the header tank and to pressurize the DRIU HPSW system. Two transfer pumps are provided, either of which can be selected to fulfil this duty. The pumps are motor-driven self-priming centrifugal pumps, capable of 150 tonnes/hour against a discharge pressure of 6·9 bar. They are in the Pump Room and are horizontally mounted. The pump suction is taken from the sump tank via a foot valve, isolating valves and a strainer. A flexible bellows is located between the strainer and the suction pipe to cater for vibration transmitted by the pump. The pump discharge is controlled by motorized valves which can be operated locally but are normally operated remotely from the Staff Control Console. Pump by-pass lines are provided to maintain a flow of cooling water through the pump when they are running against closed discharge valves.

To permit rapid drainage of the flood water that could be present in major flood compartments on 3 Deck, five motorized butterfly valves are fitted which discharge the flood water to the sump tank via short drain pipes. All of these drain valves can be operated both locally and remotely from the Staff Control Console. The major flooding compartments when full of flood water will hold approx 80 tonnes of water, and this can be fully drained down within 60 seconds.

Flooding System

The flooding system consists of a flooding main which distributes water to the various flooding boxes that simulate damage to the ship's structure. Water from the header tank is supplied under gravity to the flooding system via a locally operated valve and a 300 mm diameter swivel joint assembly. The valves which control the flow of water in the flooding main itself, and to the flooding boxes, are remotely operated from the Staff Control Room by rod gearing. In total, eleven flooding incidents are available to the instructor, ranging from extensive ship side damage to small splinter holes, distorted hatches, and stretched bolts on manhole covers. During training exercises about 91 tonnes of water may be required for the various damage incidents.

In addition to the supplies to the flooding boxes, the flooding main provides a suction via a standpipe, for the portable pumps on the upper deck and 2 Deck passageway and a supply to the fire pump which is installed in the Fire Pump Compartment on 3 Deck.

DRIU Sea Water System

This system (FIG. 10) represents the ship's HPSW main and it distributes water to all the fire hydrants, and to all six of the HPSW main damage incidents. The sea water main also provides water to a fixed eductor located in the Fire Pump Compartment. The sea water main may be pressurized to 6·9 bar by means of one of the two transfer pumps located in the Pump Room. Provision also exists for drawing pressure from the fire pump on 3 Deck and from one of the emergency portable pumps on the upper deck. The fire pump is a vertically mounted motor-driven unit with a local starter panel and has a capacity of 110 tonnes/hour. Two emergency portable pumps are provided, the Godiva and the Rover Gas Turbine, which take their suction from a standpipe on the upper deck.

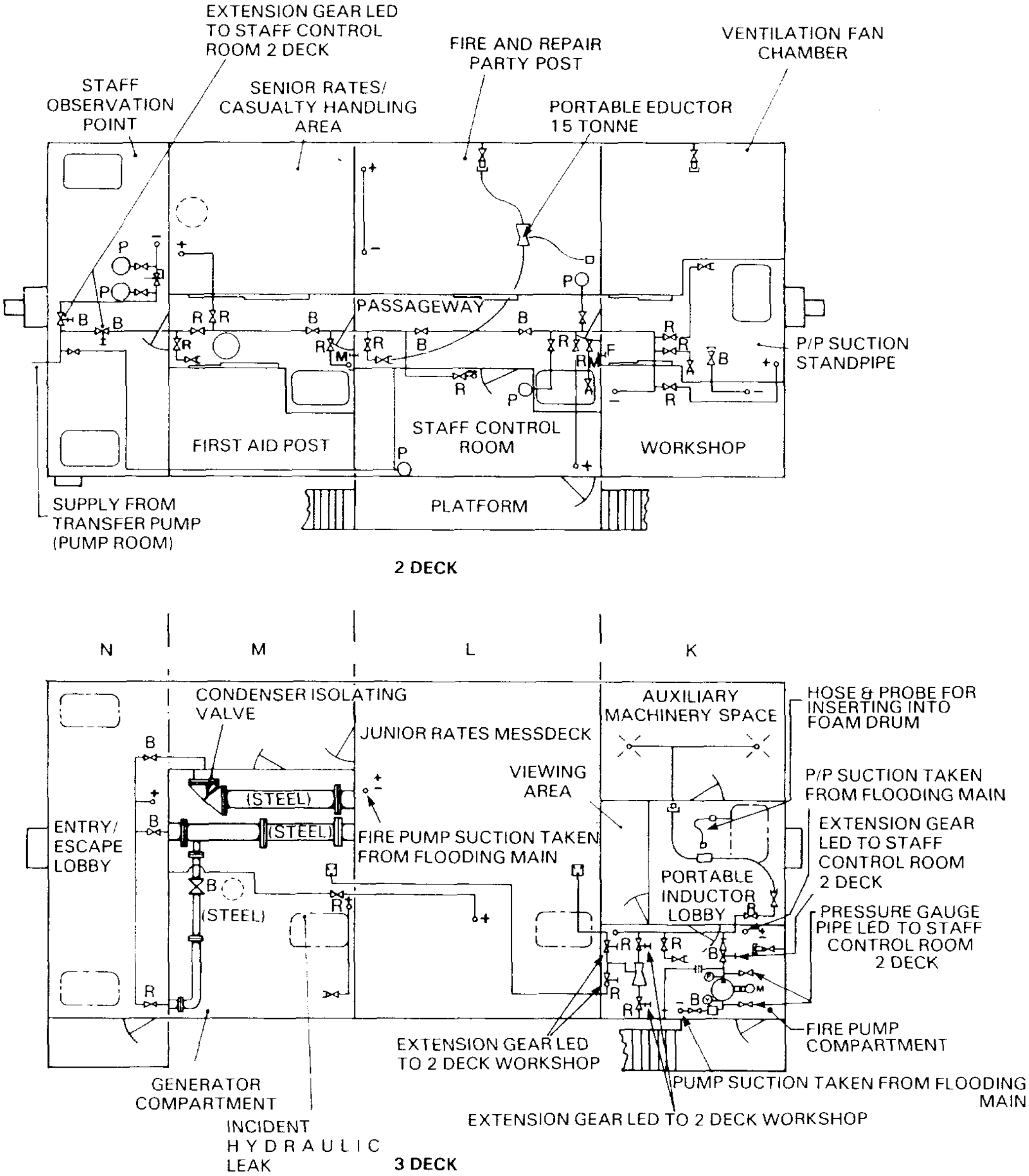

FIG. 10—HPSW SYSTEM ON 2 AND 3 DECKS
B: butterfly valve
R: rotary ball valve

Electrical and Communication Systems

Control and surveillance of the electrical services associated with the DRIU and Pump Room is from the centre bay of the Staff Control Console (FIG. 4). These services include, lighting, heating, ventilation, flooding and drainage systems. In addition, the power supplies to the portable pump sockets and the emergency cable runs located on 2 and 3 decks are controlled from this bay.

Electrical power for the DRIU and Pump Room services is derived from a local sub-station supply of 415 V 50 Hz 3 phase and neutral supplying two distribution panels situated in the Pump Room (FIG. 11). One panel distributes a maintained (amber) supply to both DRIU and Pump Room services. The second panel distributes a non-maintained supply to a motor generator set, and those services that are necessary to bring the DRIU to an operational state. The motor generator, a 300 kVA set, situated in the Pump Room converts the supply to 440 V 60 Hz.

In addition to normal electrical safety features, residual current circuit devices are fitted in the electrical supplies to the training areas. These devices will trip when line to earth current exceeds 30 mA.

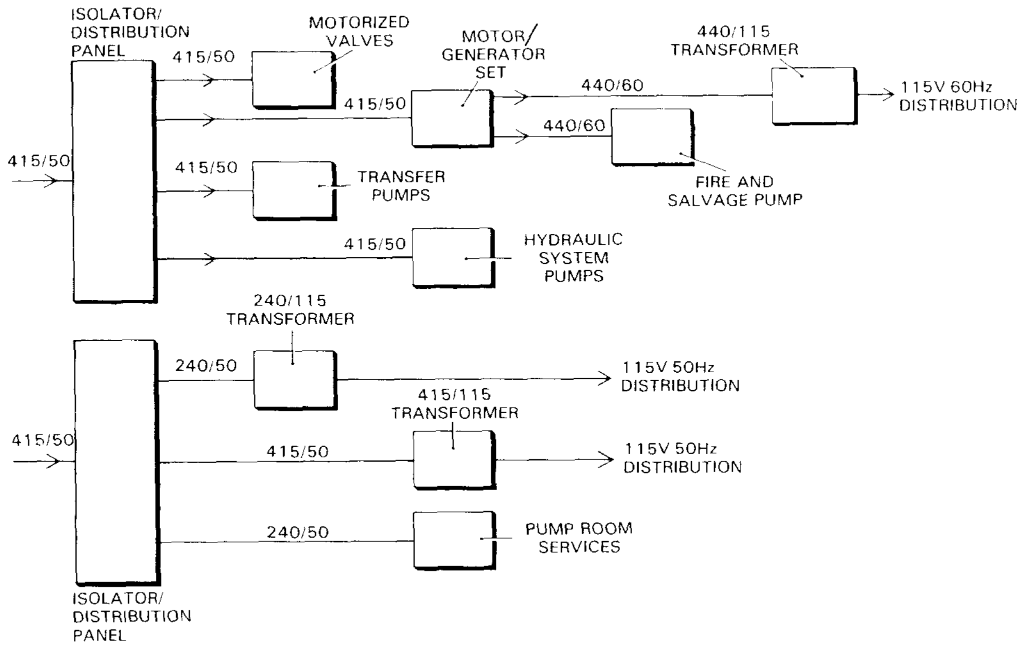

FIG. 11—ELECTRICAL SERVICES

The major components of the Broadcast System are located in Bay 1 of the Staff Control Console. The top section of the cubicle houses a broadcast microphone station, and a tape deck. The bottom section houses the amplifiers, power supply unit and a relay and alarm unit. The remainder of the system comprises outstation microphone control units and loudspeakers dispersed throughout the DRIU.

Conclusion

The DRIU at H.M.S. *Raleigh* will provide, for the Plymouth Command Area, a modern training facility for progressive training in damage control and repair under realistic and stressful conditions in various damage scenarios.

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