

# **SYSTEM DESCRIPTION**

**Ben Franklin**

**GRUMMAN AIRCRAFT ENGINEERING CORPORATION**

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GRUMMAN AIRCRAFT ENGINEERING CORPORATION

BEN FRANKLIN

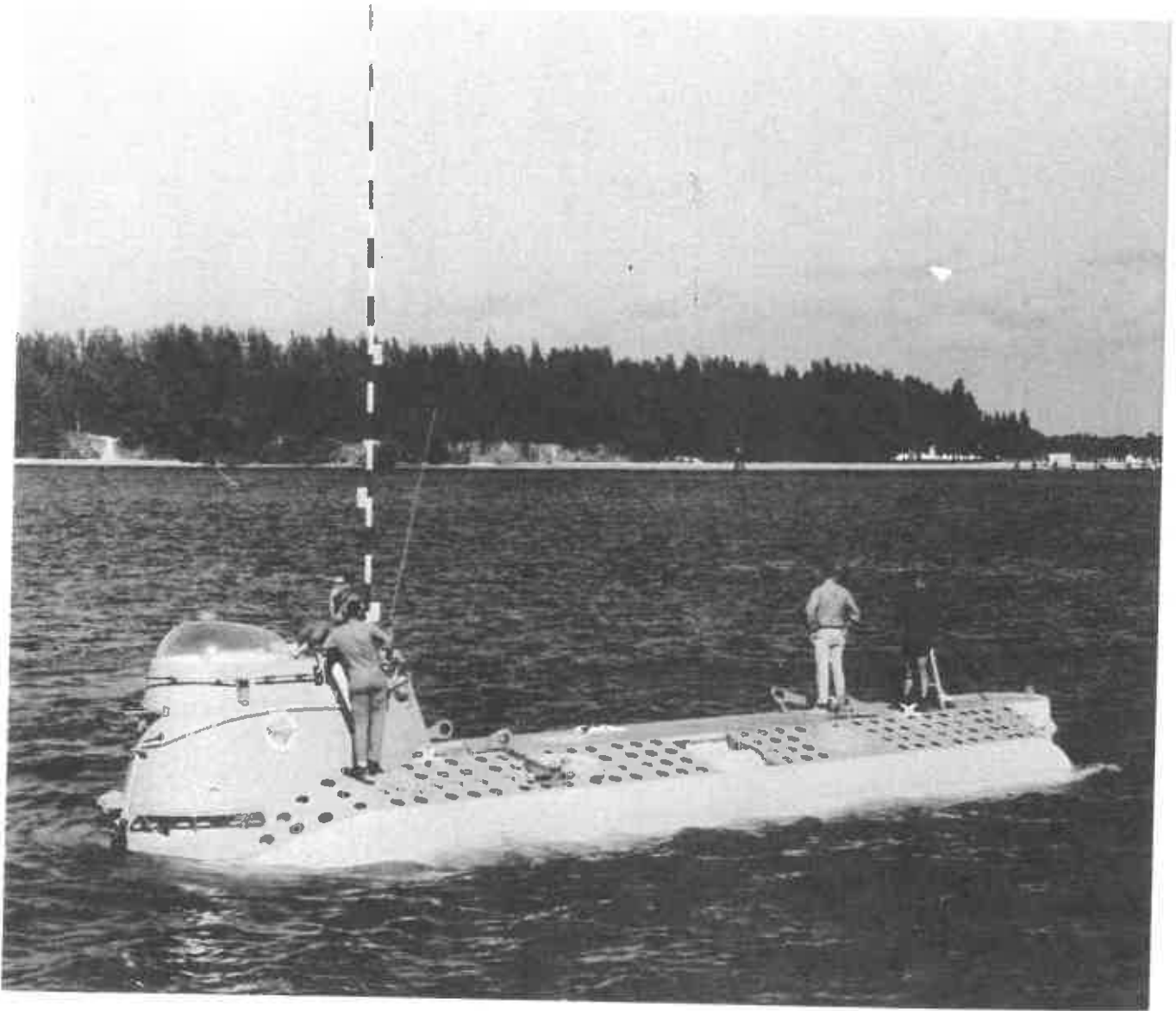
BRIEF SYSTEMS DESCRIPTION

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95  
96  
97  
98  
99  
100

TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
1	BEN FRANKLIN Characteristics	1-1
1.0	HULL	
1.1	Pressure Hull	1-1
1.2	Hull Flange	1-2
1.3	Surface Finish	1-2
1.4	Hull Penetrator Castings	1-3
1.5	Access Hatches	1-3
1.6	Low Pressure Seal	1-4
1.7	Hatch Mechanism	1-4
1.8	Deblocking Screw	1-4
1.9	Emergency Access	1-5
1.10	View Ports	1-5
1.11	External Salvage Valves	1-6
2.0	HULL SUPERSTRUCTURE AND FITTINGS	
2.1	Sail	2-1
2.2	Hull Pedestals	2-3
2.3	Deck and Supports	2-4
2.4	Motor Guards	2-4
2.5	Lifting Points and Sling	2-4
2.6	Towing Bridle	2-5
2.7	Hull Brackets	2-5
2.8	Battery Housing	2-5
3.0	BALLAST AND TRIM TANKS	
3.1	Main Ballast	3-1
3.1.1	Main Ballast Tanks	3-1
3.1.2	Solenoid Vent Valves	3-3
3.1.3	Salt Water Sensors	3-4
3.1.4	External Blow	3-4
3.1.5	Lights	3-5
3.1.6	Plugs	3-5
3.2	Variable Ballast Tanks	3-5
3.3	Shot Ballast System	3-6
3.3.1	Shot Ballast Tanks	3-6
3.3.2	Dribble System	3-7
3.3.3	Metering	3-8
3.3.4	Timer and Shot Level Indicator	3-9
3.3.5	Emergency Shot Ballast	3-9
3.4	Trim Tanks	3-10
3.5	Lead Ballast	3-12

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
4.0	PNEUMATIC SYSTEM	
4.1	Air Storage	4-1
4.1.1	High Pressure Air Storage	4-2
4.1.2	High Pressure Air Charging	4-3
4.2	Hull Venting	4-4
4.3	Distribution	4-4
4.4	Main Ballast Blow and Vent	4-5
4.5	Variable Ballast Blow and Vent	4-6
4.6	SAS Circuit	4-7
5.0	HYDRAULIC SYSTEM	
5.1	Hydraulic Pump	
5.2	Reservoir	5-2
5.3	Circuit Selector Valve	5-2
5.4	Pressure Accumulator	5-3
5.5	Adjustable Pressure Control Valve	5-3
5.6	Hydraulic Pressure Alarm	5-3
5.7	Filters	5-3
5.8	SAS Lines	5-4
5.9	Pipelines and Hose	5-4
6.0	ELECTRICAL POWER AND DISTRIBUTION	
6.1	Main Battery	
6.1.1	Main Batteries	6-1
6.1.2	Specifics - Main Battery	6-1
6.2	Emergency Battery	6-2
6.2.1	Emergency Battery	6-3
6.2.2	Specifics - Emergency Battery	6-4
6.3	Battery Chargers	6-4
6.3.1	Underwater Charging	6-4
6.3.2	Service Charging	6-5
6.4	Battery Venting and Compensation	6-5
6.4.1	Manifold	6-5
6.4.2	Reservoir	6-6
6.4.3	Venting	6-7
6.5	Distribution System	6-7
6.5.1	External Wiring	6-8
6.5.2	Mode Switch	6-9
6.5.3	B1 Battery Selector Switch	6-10
6.5.4	Emergency/Shore Power Switch	6-12
6.5.5	Charge Isolation Switch	6-12
6.5.6	TOPAZ Inverters	6-13
6.5.7	Basic Loads	6-13
		6-14

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
7.0	PROPULSION AND STEERING	
7.1	Pilot's Console	7-1
7.2	Propulsion Panel	7-1
7.2.1	Throttles	7-1
7.2.2	Depress Elevate Lever	7-2
7.2.3	SAME/OFF/OPPOSITE Switches	7-2
7.2.4	Other Dials	7-3
7.2.5	Toggle Switches	7-3
7.2.6	Main Power Switch	7-3
7.2.7	Emergency Shutdown Switch	7-3
7.3	Propulsion System Inverters	7-3
7.3.1	Main Propulsion Inverters	7-3
7.3.2	Specifics on Main Inverters	7-4
7.3.3	Inverters for Positioning Motors	7-5
7.3.4	Specifics for Positioning Inverters	7-5
7.3.5	Position Inverter Selector Switch	7-5
7.3.6	Propulsion Inverter Selector	7-6
7.4	Propulsion Motors	7-6
7.4.1	Rotor with Propeller Shaft	7-6
7.4.2	Stator with 3-Phase Windings	7-8
7.4.3	Rotor Bearings	7-8
7.4.4	Propeller Shaft Bearing	7-9
7.4.5	Shaft Seal	7-9
7.4.6	Thrust Bearing	7-9
7.4.7	Insulation and Corrosion Protection	7-9
7.4.8	RFM Transmitter	7-10
7.4.9	Technical Data - 25 hp Motor	7-10
7.4.10	Technical Data - 0.5 hp Motor	7-11
7.4.11	Technical Data - Propeller	7-12
7.5	Steering	7-12
7.5.1	Specifics on Steering Motor	7-13
7.5.2	Specifics on Rudder	7-13
8.0	INSTRUMENTATION AND ELECTRONICS	
8.1	Sensor Circuits	
8.1.1	Salt Water Sensors	8-1
8.1.2	Hydraulic Pressure Alarm	8-1
8.1.3	Shot Dribble System	8-2

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
8.2	Compass/Turn and Bank Indicator	8-2
8.2.1	Magnetic Compass	8-2
8.2.2	Directional Gyro	8-3
8.2.3	Turn and Bank Indicator	8-3
8.3	Chronometer	8-3
8.4	Temperature Sensors	8-3
8.5	Depth Sensors	8-4
8.6	Depth Recorder	8-4
8.7	Depth Gauges	8-4
8.8	Radio	8-4
8.9	Intercom	8-5
8.10	Phone - Sound Powered	8-5
8.11	Underwater Telephone	8-5
8.12	Fathometer	8-6
8.13	CITM Sonar	8-7
8.14	Pinger	8-8
8.15	Periscope T.V.	8-9
8.16	Underwater T.V.	8-9
8.17	Battery Monitoring	8-10
8.17.1	Ampere Hour Meters	8-10
8.17.2	Voltmeter	8-10
8.17.3	Ground Detection	8-10
9.0	LIFE SUPPORT	
9.1	CO-2 Removal System	9-1
9.2	Oxygen Supply and Regulation	9-2
9.3	Temperature Control	9-3
9.4	Humidity Control	9-3
9.5	Atmospheric Pressure	9-3
9.6	Contaminants Removal	9-4
9.7	Waste Management System	9-6
9.8	Contaminant Detection	9-7
9.9	Atmosphere Exchange System	9-8
9.10	Potable Water System	9-8
10.0	EXTERIOR LIGHTING	
10.1	Navigation Lights	
10.2	Underwater Lamps	10-1
10.3	Thallium Iodide Lights	10-2
		10-3

TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
11.0	SAS AND SIMILAR EQUIPMENT	
11.1	Outer SAS Hatch	11-1
11.2	SAS Chamber	11-2
11.3	Inner SAS Hatch	11-2
11.4	SAS Servo Motor	11-2
12.0	HULL PENETRATIONS	
12.1	Pipe Penetrators	12-1
12.2	Blank Plugs	12-2
12.3	Single Pole Electrical Penetrator	12-2
12.4	Multiple Electrical Penetrator	12-3
12.5	DTMB Penetrator	12-4
12.6	MIL Spec. Penetrators	12-4
13.0	CRITICAL VALVES AND PIPING	
13.1	Pipe Size and Material	13-1
13.2	Color Code	13-2
13.3	Argus Hull Valves	13-2
13.3.1	Stainless Valve	13-3
13.3.2	Standard Valve	13-3
13.4	Globe Valve	13-3
13.5	Flange Fitting	13-4
13.6	Ermeto Fitting	13-4
14.0	DAMAGE CONTROL AND EMERGENCY	
14.1	Fire Fighting	14-1
14.2	Smoke Removal	14-1
14.3	Bilge Pump	14-1
14.4	D.C. Bag	14-2
14.5	Emergency Lights	14-2
14.6	Emergency Breathing	14-2



TABLE OF CONTENTS (Continued)

<u>Illustrations</u>	<u>Title</u>	<u>Page</u>
Figure 1-1	Pressure Hull	1-7
Figure 1-2	Hull Frame	1-8
Figure 1-3	Hull Flange	1-8
Figure 1-4	Reinforcement	1-9
Figure 1-5	General Arrangement (A91B1003)	1-10/11
Figure 2-1	Front View (PX15-2015)	2-6/7
Figure 3-1	MBT Stiffener	3-13
Figure 3-2	Electromagnetic Shot Valve	3-13
Figure 3-3	Trim System	3-14
Figure 3-4	VBT - Regleur (PX15-7002)	3-15/16
Figure 4-1	Pneumatic Schematic (PX15-7001)	4-8/9
Figure 5-1	Hydraulic Schematic (PX15-6001)	5-6/7
Figure 6-1	Electrona Battery	6-21
Figure 6-2	Battery Arrangement (PX15-5507)	6-23/24
Figure 6-3	Manifold System	6-25
Figure 6-4	Vent Valve (A91H1000)	6-27/28
Figure 6-5	Basic Electrical System	6-29
Figure 6-6	1 mm Wire Connectors	6-30
Figure 6-7	Modification to Vent Valve	6-31
Figure 7-1	Photograph of Pilot's Panel	7-14
Figure 8-1	Resistance Nomogram	8-12
Figure 9-1	Schematic	9-9/10
Figure 10-1	Exterior Lighting	10-4
Figure 10-2	Light	10-5
Figure 12-1	Penetration Casting	12-6
Figure 12-2	Blank Plug	12-7
Figure 12-3	Electrical Penetrator (95 mm)	12-9/10
Figure 12-4	Electrical Penetrator (Motor)	12-11/12
Figure 12-5	Multi Conductor Penetrator	12-13
Figure 13-1	Ermeto Fitting	13-5

TABLE OF CONTENTS (Continued)

<u>Tables</u>	<u>Title</u>	<u>Page</u>
Table 6-1	Battery Cell Groupings	
Table 6-2	Mode Switch	6-15
Table 6-3	110 V DC Bus Loads	6-16
Table 6-4	28 V DC Bus Loads	6-17
Table 6-5	110 V AC Bus Loads	6-18
		6-20

BEN FRANKLIN CHARACTERISTICS

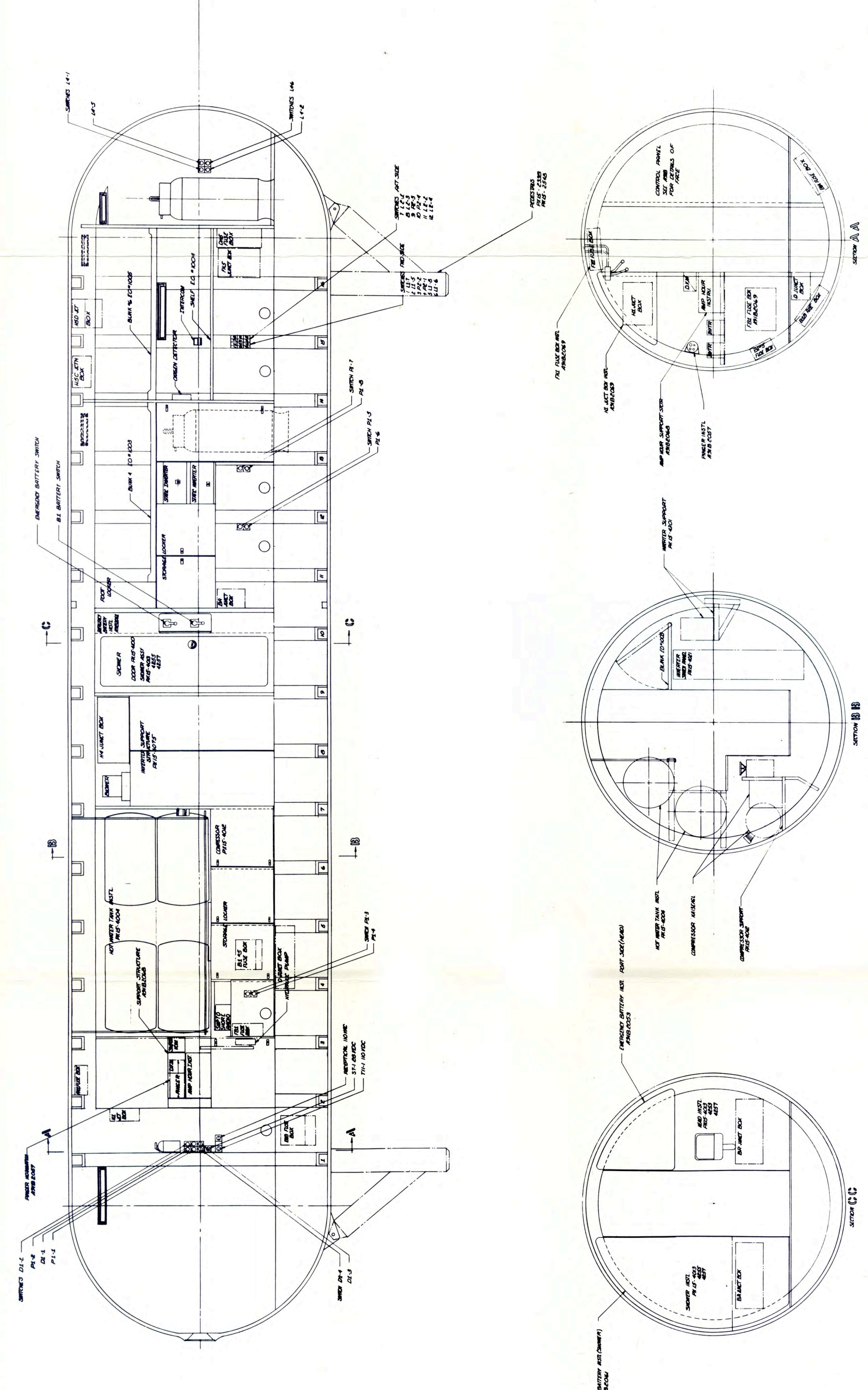
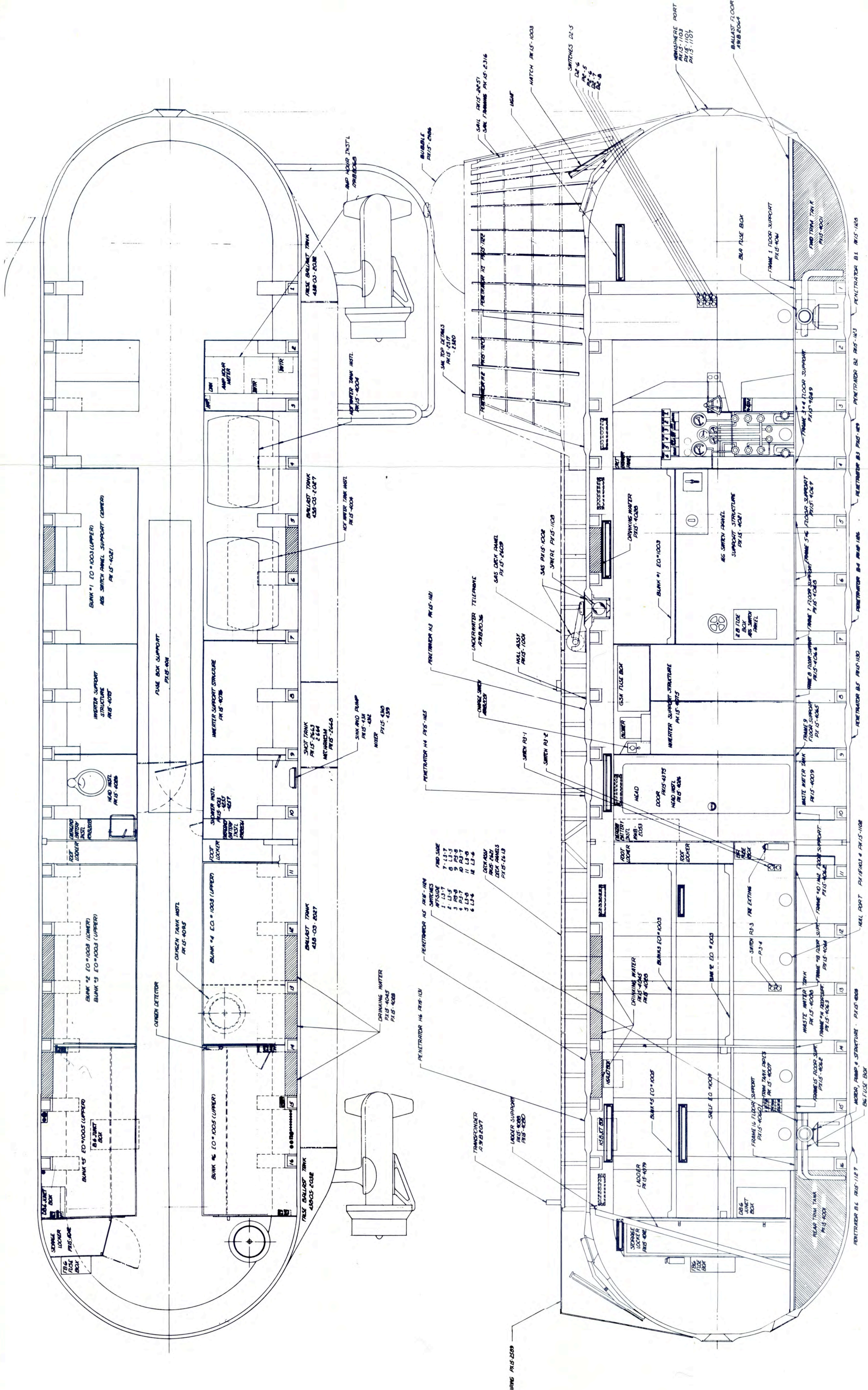
Gross Weight	147.35 short tons
Net Weight	142.95 tons (1200 lb)
Internal Volume	3769.7 cu. ft.
Length	48 ft.
O.D. of Pressure Hull	10.33 ft.
Beam (over ballast tanks)	13 ft 4 in.
Beam (including motors)	18 ft. 6 in.
Beam (including motor guards)	20 ft.
Height	21 ft. (to top of sail)
Draft	14'
Access	Two 30" hatches
Maximum Operational Depth	2000 ft.
Collapse Depth	4000 ft. +
Battery Power	750 KWH (10 hr. rate)
Propulsion	Four 25 h.p., 3 phase, variable frequency motors
Power Conversion	Two variable frequency (60 KVA) solid state inverters for propulsion  Two fixed frequency (3 KVA) solid state inverters for rotating propulsion motors 360°  Two 110 VAC solid state inverters for various on-board equipment
Visibility	29 viewports

Potable Water	188 gallons hot water 380 gallons cold water
Total Life Support	6 men for 4 weeks with a 2 week reserve
Emergency Ballast	6 tons of steel shot
Maximum Ascent Rate (Calculated)	One-shot ballast tank - 180 ft/min Two-shot ballast tanks - 257 ft/min With motors - 2 meters/sec
Normal Descent Rate	1.4 ft/sec (calculated)
Maximum Submerged Speed	4 knots
On Surface Time from Full Ahead to Stopped Using All Back Full	20 seconds
Endurance (calculated) 8 hrs at hull speed	2 KTS 2 motors - 0.126 naut. mi/KWH 3 KTS 2 motors - 0.074 naut. mi/KWH
Thrust	1000 lbs per motor (nominal max)
Trim and List Angles (calculated)	Normal Trim $\pm 10^\circ$ - Emergency Trim $\pm 25^\circ$ Normal List $0^\circ$ - Emergency max List $\pm 17.6^\circ$
Submerged BG	10.3 inches



Figure 1-1 Interior View

Figure i-2 Inboard Profile



SECTION 1.0 - HULL

1.1 Pressure Hull - The pressure hull, 48 feet long by 10.33 feet o.d., is cylindrical in shape with both ends capped by hemispheres. The empty hull has an inside capacity of 3769.7 cu. ft. The end hemispheres are made up of seven pieces; six Welmonil steel plates hot formed, sized and welded to a single shallow dished end cap (Figure I-1). The Welmonil steel was manufactured by HOAG, Oberhausen, Germany. The complete cylindrical section is made in two sections joined 29 feet from the extremity of the forward hemisphere at mating machined flanges. These cylindrical portions are made from Aldur Steel - 55/68 D, manufactured by Voest, Linz, Austria. The cylindrical sections use six sub-assemblies welded together. Four sub-assemblies comprise the forward section and two make up the cylinder aft of the joint (Figure I-3). Both Aldur (77,800 psi yield) and Welmonil (71,500 psi yield) steels exhibit excellent mechanical qualities characterized by high resistance to cleavage fracture, high notch toughness, excellent weldability and high yield point. For welding, the hull sections were preheated to 150°C and maintained at that temperature until the weld on that section was completed. Welding of the hemispheres was all manual while the cylinders were welded using automatic techniques.

The pressure hull itself is 1-3/8" thick reinforced by hollow structural rings equally spaced at 27-1/2" center to center, along the inside of the cylinder. These structural rings are rectangular in cross section and have a web thickness of .790 inches with a cap of 1.25 inches (Fig. 1-2).

During assembly, the rings for each section were spaced exactly as required on a special tool. The rolled welded cylinder was heated and slipped over the rings. While temperature at each ring/cylinder joint was maintained and carefully monitored, the rings were welded in place. At the completion of fabrication at the Giovanola Brothers Plant in Monthey, Switzerland, the entire hull was stress relieved in an oven.

1.2 Hull Flange - To form the hull flanges, a 1.97 inch thick Aldur steel ring was welded on the end of each hull section. They were later machined to a thickness of 1.25 inches with a shoulder projecting from the aft section into a seat on the forward section. This was provided to transfer shear loads at the joint. The bending loads are transmitted by (60) MS 20016 standard bolts evenly spaced around the flange (Figure I-3). An "O" ring groove was machined in the forward flange to accept a 9 mm (approximately) diameter neoprene ring. High pressure sealing is accomplished by the metal to metal fit of the two machined flanges faces. These faces are forced tighter together as external submerged pressures are exerted on the hull. The neoprene "O" ring acts as a low pressure seal and was sized to occupy about 90% of the "O" ring groove to prevent sea water corrosion of the groove.

1.3 Surface Finish (Paint) - The entire surface of the hull was sand-blasted and painted with Galvazinc, a two-component primer manufactured by Jallut SA, Bussigny, Switzerland. The primer is composed of a polyamide epoxy resin, powdered zinc and an aromatic solvent. After a second coat of the same paint, two coats of Super Jaltonit Special White was



applied. This paint is composed of polyamide epoxy with titanium dioxide, zinc oxide and aromatic solvent. Finally, the hull was given a coat of Super Jaltonit Special White anti-fouling paint containing a high percentage of (Tri-N-Butylzinnoxid).

1.4 Hull Penetrator Castings - The hull penetrator castings for viewports and access hatches through which the hull penetrations for all pipes and cables pass, were manufactured by Georges Fisher SA, Schaffhouse, Switzerland. Figure I-4 shows a typical hull reinforced section.

The plan view of a typical reinforcement is lemon shaped with a raised circular center about 5-1/2 inches (140 mm) thick. Castings for pipes and cables are bored with either 17 or 19 holes to allow various combinations of electrical, pneumatic and hydraulic system hull penetrators.

Three sizes of hull penetrations have been drilled into the castings.

- o 20 mm Dia.
- o 24 mm Dia.
- o 38 mm Dia.

1.5 Access Hatches - Access hatch castings are of necessity larger in area than those for viewports and other hull penetrations. The hatch openings are virtually 30 inch discs cut out of a reinforced section welded to the hull. The hatches are seated in a conical opening in order to seal when under pressure. Identical access hatches are located in the bow and stern hemispheres. Each hatch opens outwards and is centered over the fore-and-aft line of the hull with five springs for counterbalancing. In the center, a conical plexiglass window (or viewport) is held in position by a retaining ring, bolted into the cast steel hatch.

On the centerline, a DIN 582 steel eye-ring is welded to the hatch to provide a grip for opening from the outside.

1.6 Low Pressure Seal - Around the outer circumference of the hatch is a steel ring held in place with screws. On the underside of this ring is a rubber gasket that overlaps the hatch opening thereby producing a low pressure seal.

1.7 Hatch Mechanism - Hatches are designed to close by their own weight and to be held firmly closed by external pressures. They can be opened in surface condition by normal manual pressure on the underside, counter-balanced by five adjustable tension springs. For locking the hatch shut, two dogs are used. A simple lever-gear arrangement moves the dogs into place. When in the raised position, the hatch (forward only) is held open by a latch connected to the sail by a stainless steel cable. The hatch can be held shut by a strongback (normally stowed in the sail). The strongback fits against the hatch and sail and is forced into position by a screw mechanism that lengthens it.

1.8 Deblocking Screw - In some instances, it may not be possible to open the hatch from inside the boat. To provide the necessary leverage, a simple device is used. On the fore-and-aft centerline, a steel block is welded to the inside of the hull with a plate bored to take two internal wrenching bolts. One bolt holds the plate in place, the other bolt bears on the underside of the hatch and when tightened, provides the pressure to open the hatch.

1.9 Emergency Access - Both hatches are fitted with a device to enable them to be opened from the outside. The device consists of an outer ring bolted to the hatch around the viewport. This outer ring overlaps an inner split ring that actually holds the viewport in place. The inner ring is slotted and the outer ring has ears extending upward to act as fulcrum points for a pry-bar. The specially designed pry-bar is slipped into one of the slots to remove the inner ring. Removal of the viewport is then accomplished by lifting with a suction cup (a screw driver is also provided for leverage). The hatch mechanism can then be actuated by reaching in through the viewport. All of the emergency tools (pry-bar, screw driver and suction cup, are stowed in the sail).

1.10 Viewports - Plexiglass windows, manufactured by Isoplex AG, Zurich, Switzerland, are used in 30 locations throughout the vessel. All are similar in construction except that those in the SAS are smaller. The ports are conical in shape and fitted into machined surfaces cut in reinforced hull sections. The viewports, 3.15 inches deep, provide a 90° field of vision and are held in place by a steel retaining ring flush with the outer surface of the hull. Flat-head M6 screws hold the ring in place.

To prevent corrosion of the machined hull surface seating the viewport, the surface was painted with Phos-Pho-Neal (a phosphoric acid coating) and Laminar X500 Green Primer (a zinc chromate). The surface was then covered with Lubriplate grease (130-AA, L-702). To prevent moisture from reaching the machined surface from inside the boat, a rubbery material (Pro-Seal 890) was applied where the hull contacts the plexiglass.

1.11 External Salvage Valves - Located in penetrator casting H1 and H6, these valves are used to provide air for breathing purposes if the boat is disabled on the bottom.

Outside the boat is located a Jamesbury HT36,1 ball valve with a CPV female fitting identical to that used on the pneumatic system (air charge and external MBT blow). It is plugged with a CPV SIT-7 and is normally shut on RIG FOR DIVE. Inside the boat is another Jamesbury ball valve normally open on RIG FOR DIVE. In case of emergency, a diver can remove the plug, connect a male fitting (same as that used on the pneumatic system), open the ball valve and introduce breathing air. Of course the after valve (in H-6) would have to be rigged as a vent. The valve in H1 is located under the deck and has a reach rod extending up through. A special wrench for rotating the reach rod is mounted on a bracket in the sail.

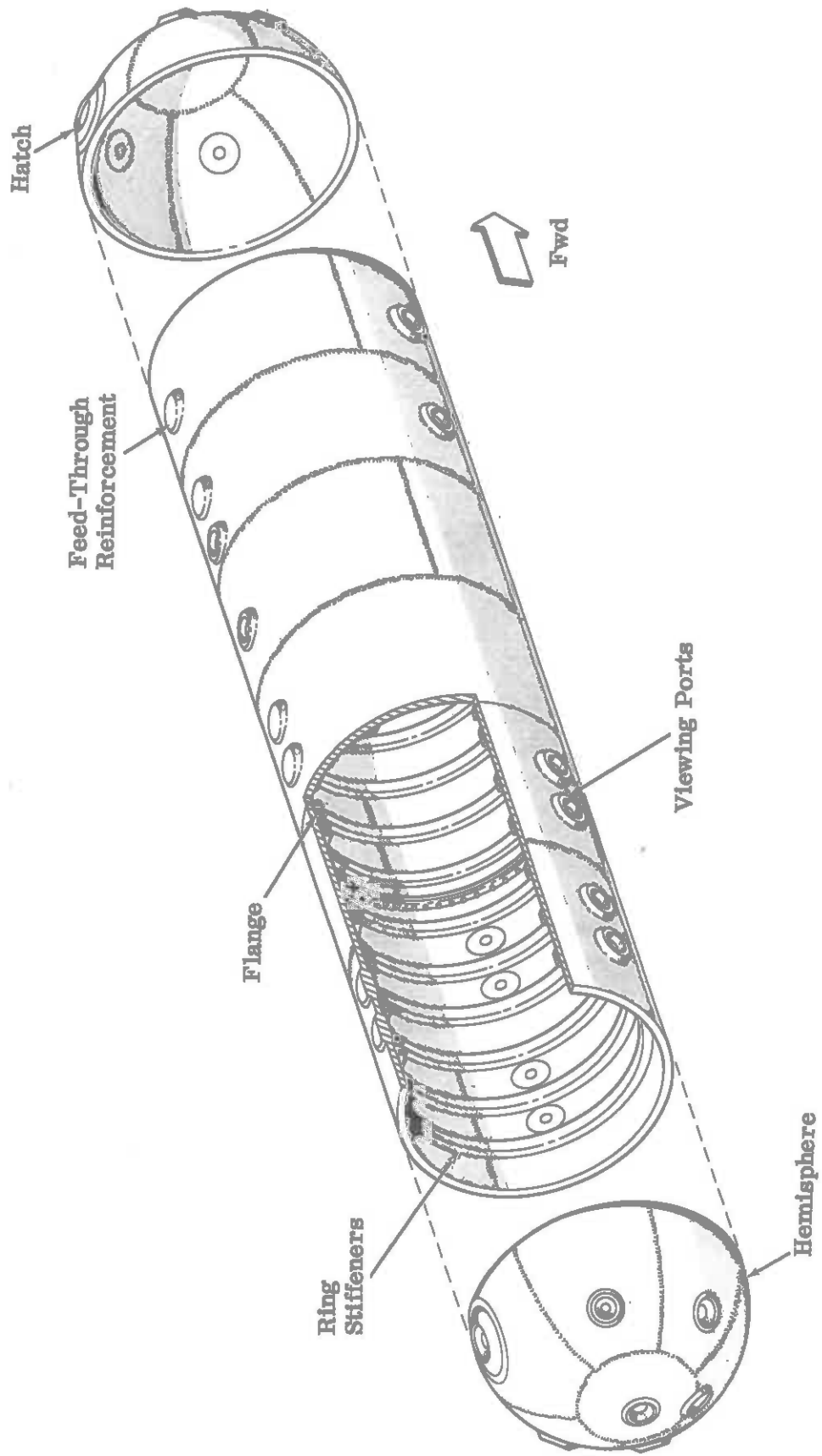


Figure 1-1 Pressure Hull

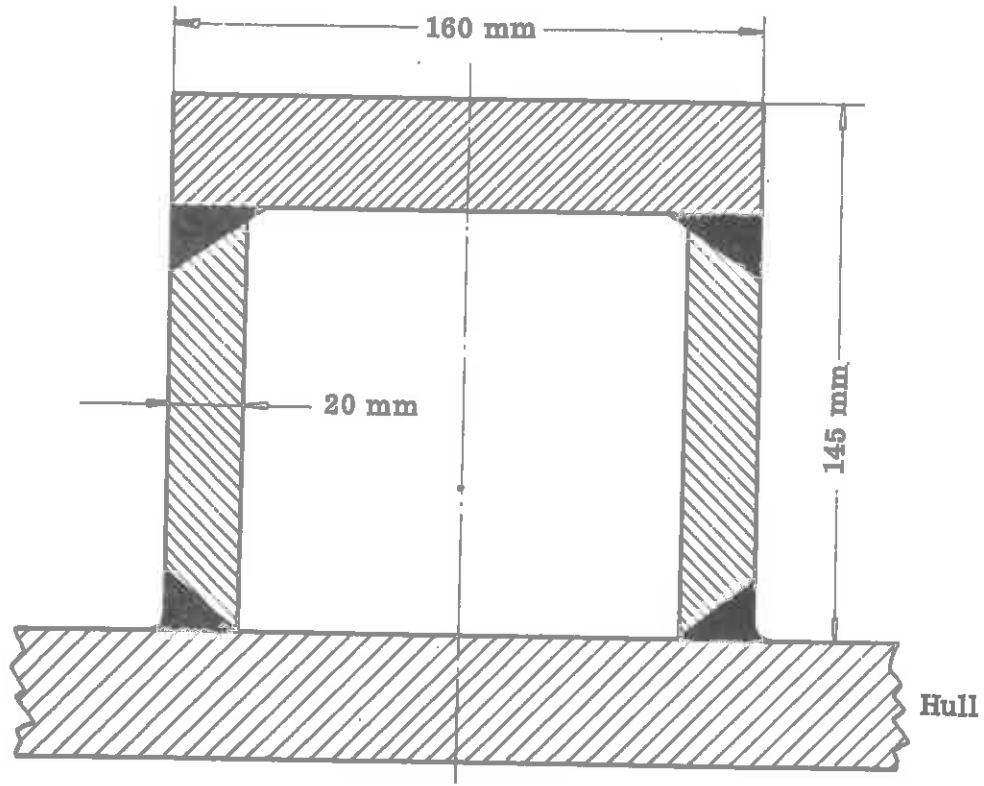


Figure 1-2 Hull Frame

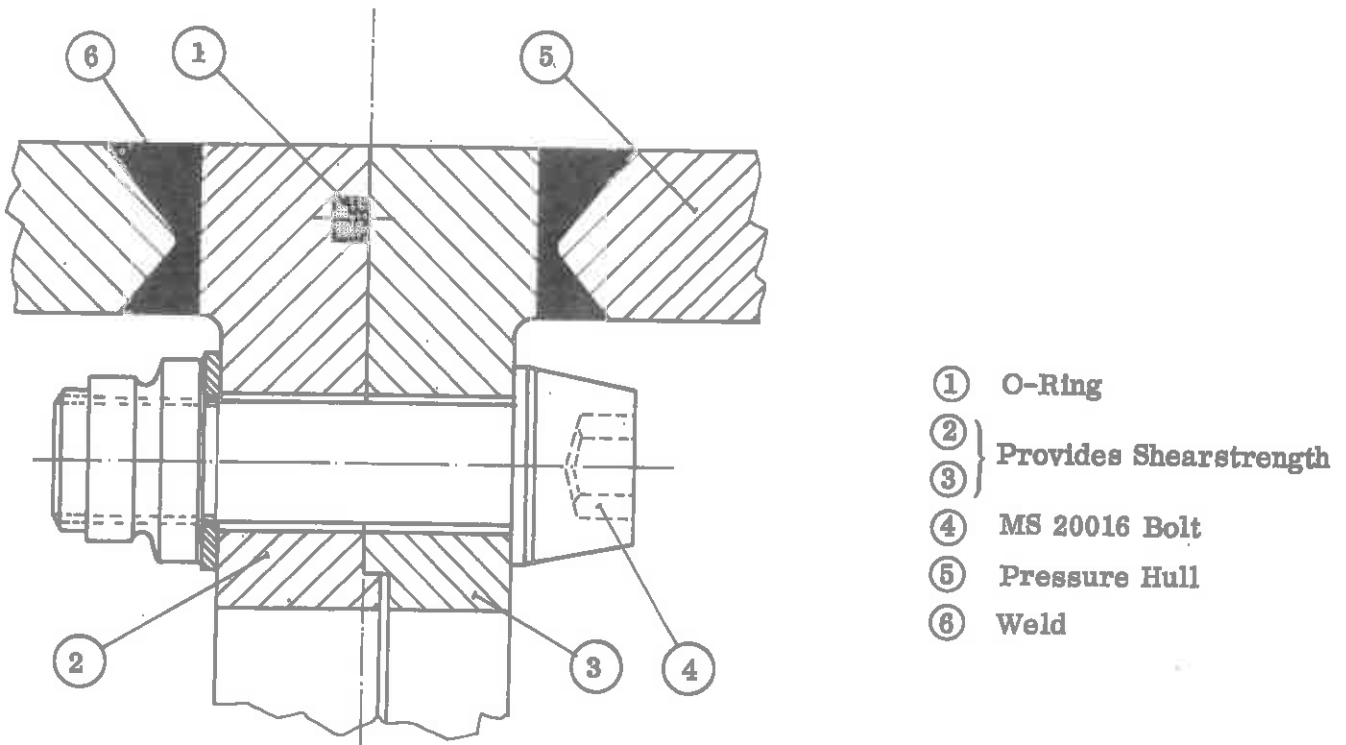
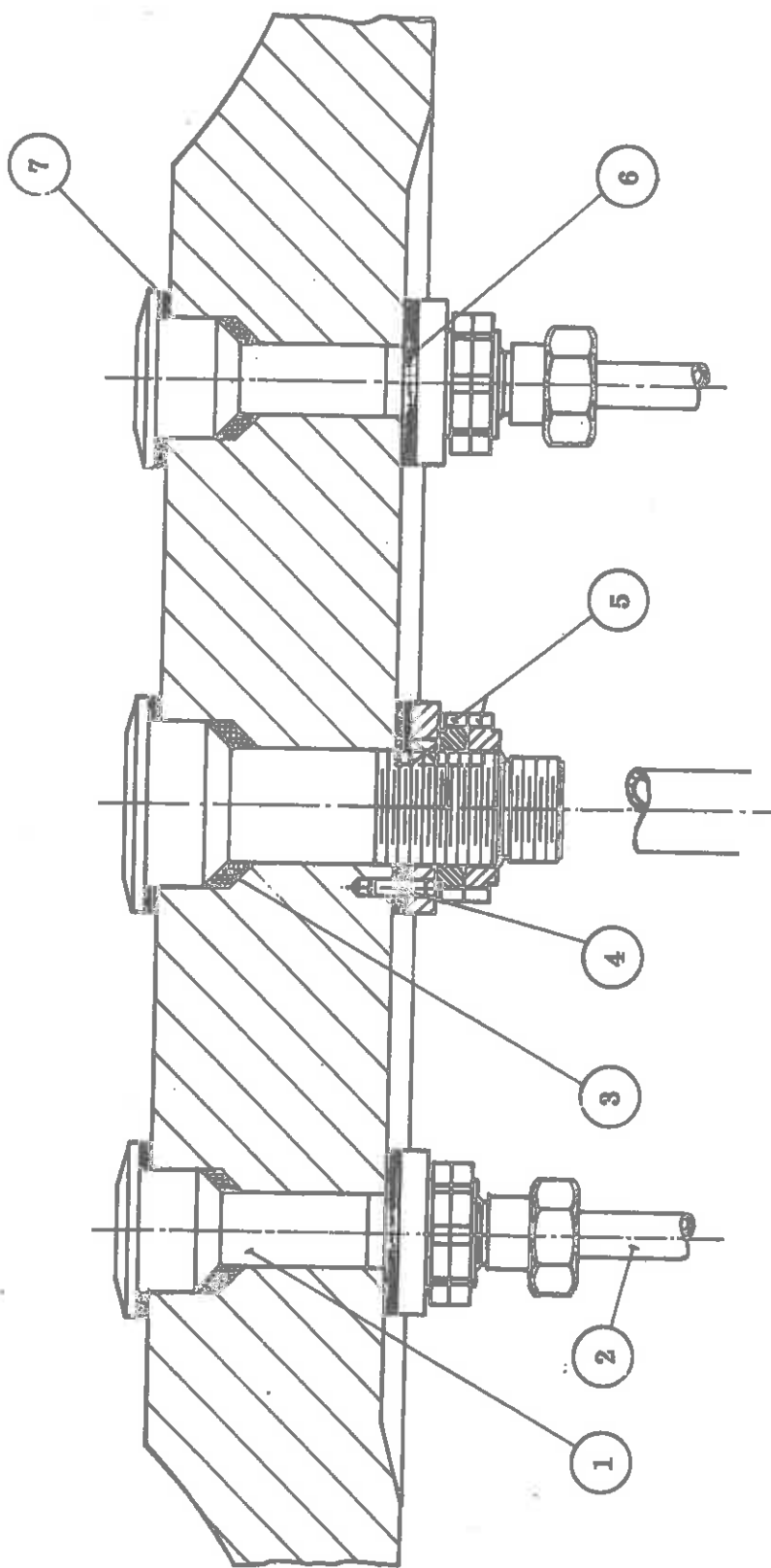


Figure 1-3 Hull Flange



1. Penetrator
2. Pipe to Hull Valve
3. Plexiglass High Pressure Seal
4. Holding Screw - Several of These in a Circular Pattern for Large Pipe Penetrators
5. Holding Nut
6. Interior Gasket

Figure 1-4 Reinforcement





## SECTION 2.0 - HULL SUPERSTRUCTURE AND FITTINGS

To satisfy requirements for surface operations, maintenance and exterior equipment, a superstructure and special fittings were installed. These components consist of:

- o Sail
- o Hull Pedestals
- o Deck and Supports
- o Motor Guards
- o Lifting Points and Sling
- o Tow Cable Shackle Points
- o Hull Brackets and Mooring Cleat Foundations
- o Battery Housing (keel)
- o Safety Line Tripod Mast

2.1 Sail - A fiberglass sail (designed for 1000 psf) is mounted well forward on the hull. The sail, beside being a station for surface maneuvering houses:

- o Pry bar, suction cup, screwdriver for hatch viewport removal
- o Brackets (4) for heaving lines
- o Sound powered phone connections and brackets (2)
- o Hatch Closure device (external) and hold open latch
- o Valve handle for external salvage valve
- o Lighting mast (strobe, submarine identification, anchor, masthead lights - surface operations only)
- o H.F. Radio Antenna
- o T.V. Periscope

- o Magnetic Master Compass Transmitter
- o Temperature sensor
- o Obstacle avoidance sonar
- o Screens for VBT outboard vents, SAS flood, and hull vent
- o Depth Sensor Oil reservoir (external pressure sensing)

The sail has been designed to minimize exposure of crew members during surface operations. It is high enough to give full protection and good visibility through the use of a molded plexiglass dome mounted to the lip in the sail structure. It also protects the boat from flooding when the forward hatch is opened on the surface. Just aft of the bubble is a hatch that is normally shut during at sea operations.

When the boat dives or surfaces the sail is completely flooded or drained through a series of valves and one-way scuppers. Just prior to diving, two 3" dia. PVC ball valve flood ports are opened. This allows water to flood the sail from under the deck. A plexiglass vent in the sail bubble allows air to escape. Upon surfacing of the boat, drainage is accomplished through the use of two one-way scuppers located at the lowest area of the sail. These scuppers are simple hinged plates that shut with external water pressure.

Fabrication of the sail was done by Andre Perreten, Lausanne, Switzerland. It was molded in two halves of glass reinforced epoxy. Thickness of the skin varies from approximately 7/8 inch at the lower edge tapering upward to approximately 3/8 inch at the top. The structure was strengthened by the addition of a large number of fiberglass stiffeners. These stiffeners

were bonded to the outer skin and the entire structure was further improved by the hand layup of several layers of glass cloth over the skin and onto the stiffeners.

Mounting of the sail to the hull is accomplished by bolting through the fiberglass structure into a series of mounting brackets that were welded to the hull prior to heat treatment. Sealing of the sail to the hull is accomplished by the use of a gasket like material called Coast Pro-Seal 890. This material was packed by hand along the area where the sail is bolted to the hull and also along the fiberglass protection around the after hatch.

2.2 Hull Pedestals - Fitted to the underside of the fore and aft hemisphere are four pedestals located in pairs filled with lead shot. These form an under-carriage so that BEN FRANKLIN can be supported while in dry dock without the use of special fixtures. The pedestals extend just below the forward fairing and battery housing. They are fabricated of 10-3/4 inch OD X .365 inch wall pipe welded together with a bearing plate on the bottom. Pedestals are located below frames (1) and (16) and are bolted to hull attachments. One pair of attachments is welded to the hemisphere and one pair is welded to the hull cylinder. Sixteen one inch OD (160 KSI HT) bolts secure the pedestal at the hemisphere and 1-1/2 inch special hollow pins hold the pedestal support that slants (back/forward) from the pedestal acting as a brace. If a severe collision occurs, the pedestals were designed to fail at the point where they are bolted to the hull, thereby preventing rupture of the pressure hull. The entire assembly can be removed.

2.3 Deck and Supports - Running fore and aft along the top of the hull is a walking deck. The deck affords a working area along the length of the boat and also provides protection for piping, wiring and equipment located below it. A life line of stainless steel cable runs from the aft port of the sail to a steel tripod located just forward of the aft hatch.

The deck structure itself (designed for 1000 psf) was fabricated of welded carbon steel structural sections. The assembly was mounted by bolts onto upright brackets welded to the pressure hull. The deck structure contains several zinc plates for anodic protection.

The entire steel structure is covered by fiberglass panels bolted to the framework. A series of panels running fore-and-aft on both sides serve as fairings. These panels mount to steel angle plates welded to the deck structure itself and slant down to another angle mounted to the tops of the main ballast tanks.

2.4 Motor Guards - Allowing freedom of rotation but still offering protection against buffeting, a simple tubular welded frame protects the submerged motor casing from damage and from entanglement with underwater cables.

The guards are constructed from seamless steel tubing that is bolted into sockets welded to the hull.

2.5 Lifting Points and Sling - For lifting during drydocking, shipment or any transportation, four heavy duty fittings are welded to the outside of the cylindrical section of hull over frames (3) and (14). These fittings are made from ALDUR 55-68 steel with an ultimate strength of 4-1/2 times the gross weight of the vehicle.

Two projecting lugs have holes through which passes an 88 mm diameter pin with a convenient handle. These lifting pins are installed only when in use and are removed for normal operations.

2.6 Towing Bridle - Two rigs are provided with one permanently mounted forward. The bridle is shackled to the boat at two towing lugs that are welded to the boat at the leading edge of the motor guards. Nylon rope (1-1/4" dia.) is used for all three sections of the bridle.

2.7 Hull Brackets - All hull brackets (mild 37-12 steel) are welded to the pressure hull. The brackets are located in specific positions necessary for mounting normal hull fittings and also to allow for any new equipment that may be added.

2.8 Battery Housing - (Keel) - The 376 batteries are housed in a keel structure that is attached to the bottom of the hull. Each battery is contained in its own compartment. Reference Fig. 6-2 for the battery arrangement.

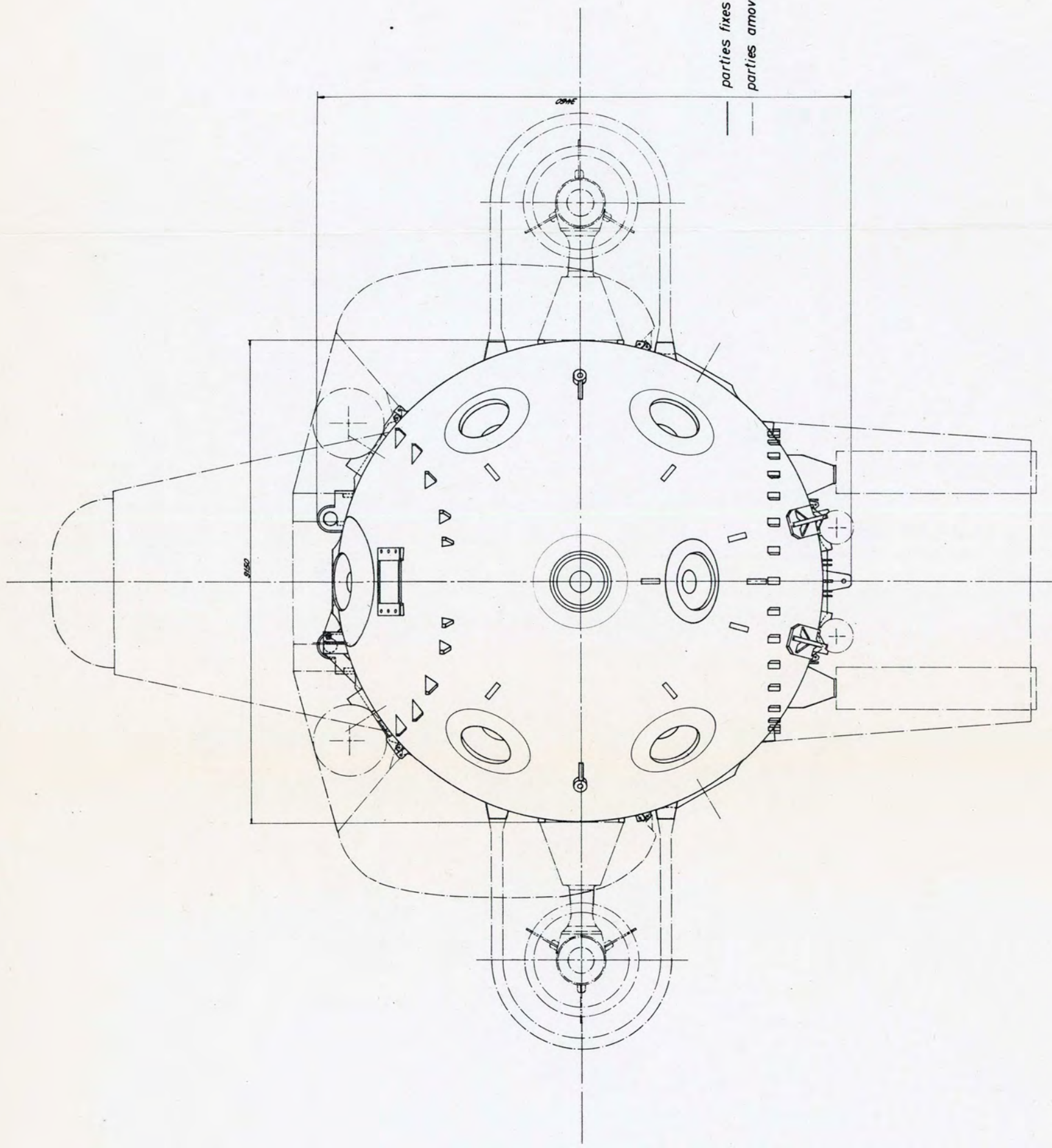


Figure 2-1      Front View

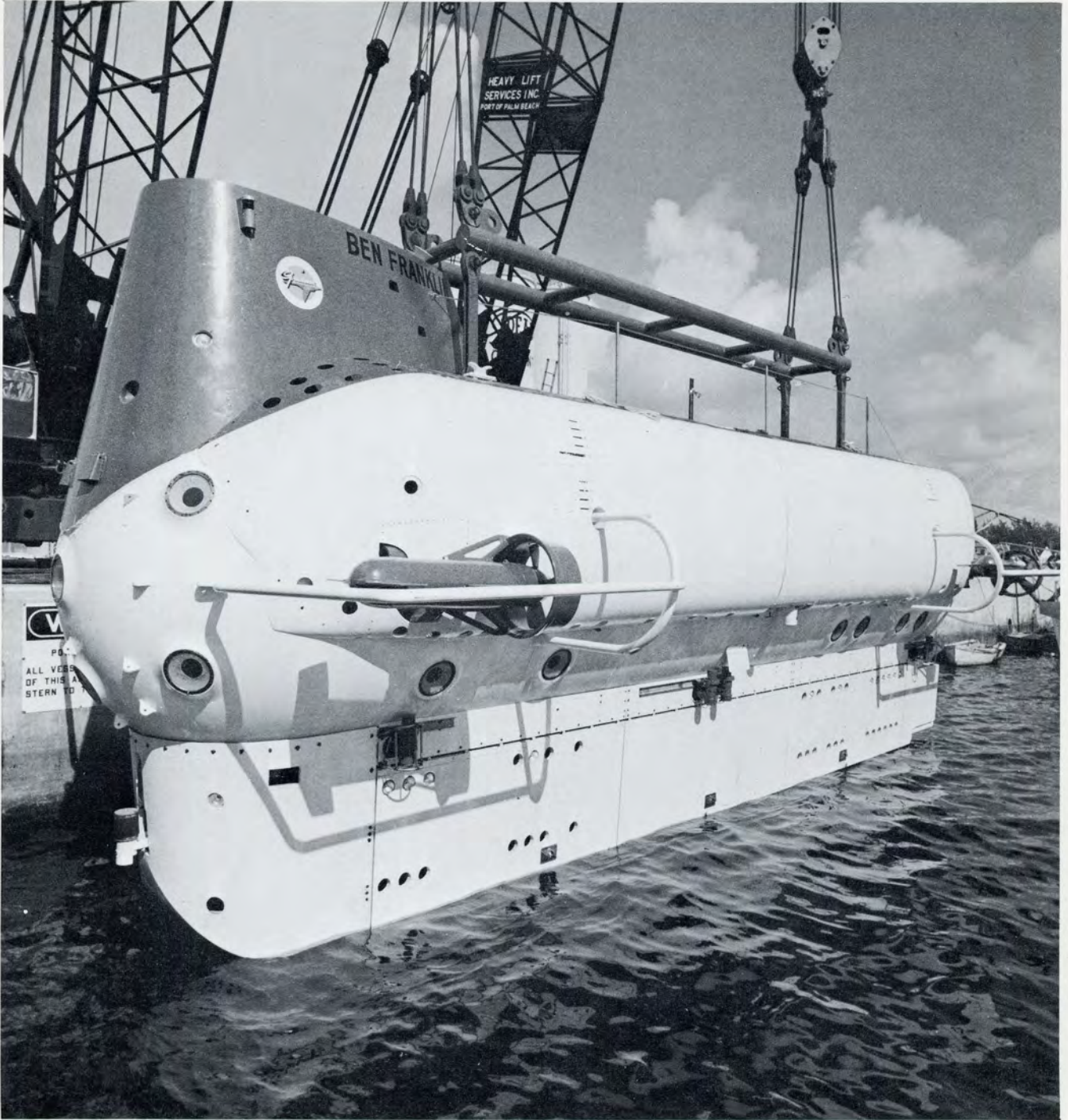
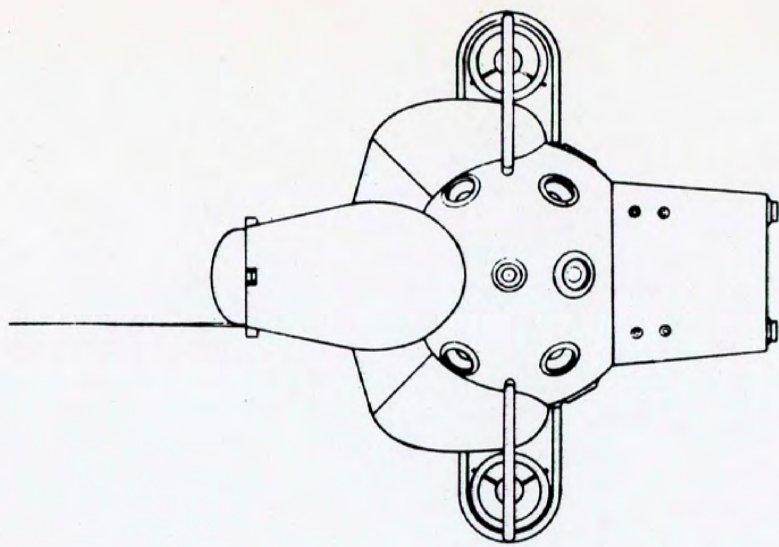
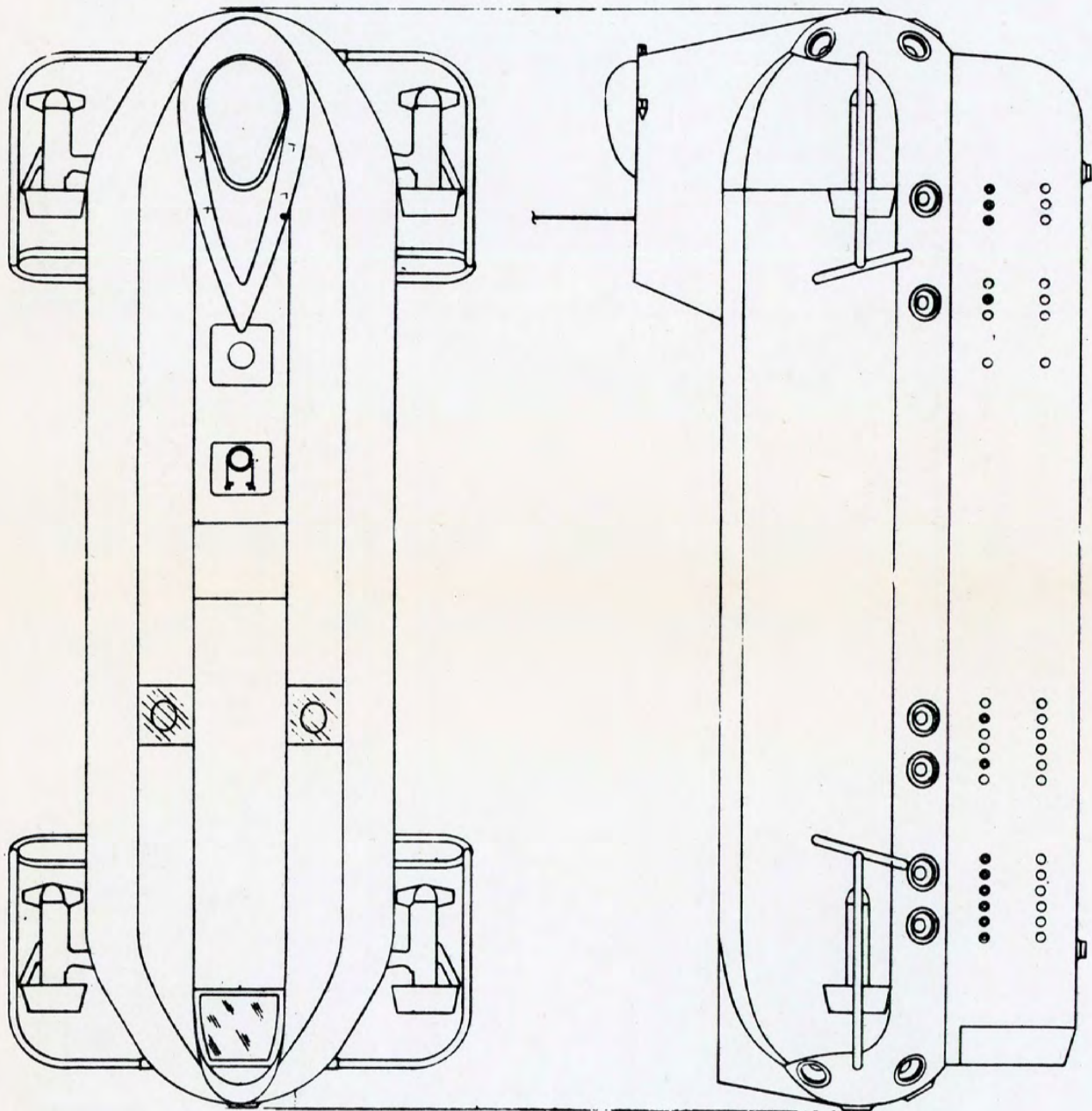


Figure 2-2 Ben Franklin Launch



0 100 200

APPROX. SCALE IN INCHES

Figure 2-3 General Arrangement -  
Ben Franklin



### SECTION 3.0 - BALLAST AND TRIM TANKS

The ballast system aboard the BEN FRANKLIN can be divided into four main subsystems:

- o Main ballast (162 cubic feet per tank) - 4 tanks
- o Variable ballast (12.3 cubic feet, 788 pounds salt water per tank) - 2 tanks
- o Shot ballast (3 tons of shot per tank)- 2 tanks
- o Trim (49.5 cubic feet, 3,087 pounds of fresh water per tank).  
2 tanks

Other changes in ballast can be accomplished through the use of lead or syntactic foam.

#### 3.1 Main Ballast -

3.1.1 Main Ballast Tanks - Adequate freeboard for surface maneuvering and the ingress and egress of personnel is provided by four main ballast tanks. These tanks, when dry, provide sufficient buoyant force to give the boat approximately 18 inches of surface freeboard under normal operating conditions (approximately 41,500 pounds of positive buoyancy). In order to dive the boat these tanks are flooded by venting the entrapped air from the tanks and allowing water to flow into them through open flood ports located at the bottom of each tank (six ports per tank, 4-1/2" in diameter). When the main ballast tanks are fully flooded, the boat should be in a state of approximate natural buoyancy at or very near the surface. At this point the addition of any more ballast will cause the boat to dive.

The main ballast tanks are located in pairs on the port and starboard sides of the boat, tanks one and three to starboard and tanks two and four to port. They are constructed of laminated polyester and fiberglass approximately 1/4 to 3/8 inches thick. Additional strength is provided each tank by eleven fiberglass ribs spaced along the length of the tank and filled with syntactic foam (Epocast 1310, Mod I) (Figure 3-1). The fabrication of the tanks was done by Lunn Laminates, Inc., Wyandanch, New York.

Mounting to the hull is accomplished by the use of several ears bonded to the tank and stabilized by rivets and cement which are mated to fittings welded to the hull.

A manhole is provided in the upper section of each tank for the purpose of inspecting the tank interior, piping, cable runs, and the MBT vent valves. The manhole cover is bolted in place and sealed with a rubber gasket. Each cover is provided with an AN-816-4 stainless test fitting.

The tanks were designed to take 1000 psf. wave slap with a factor of safety of two and an allowable delta P across the tank wall of 3 psi. For this reason the tanks are normally blown when the boat is on or near the surface. Although the quantity of high pressure air carried aboard the boat is not enough to blow the tanks dry at 2000 feet, it is enough to blow to 50% of the tank capacity (for an emergency ascent only). As the vehicle ascends, the air in the tanks expands and forces additional water out the open flood ports. As mentioned before, each tank is free flooding, when vented, through six 4-1/2 inch diameter openings in its bottom.

Flooding of a tank or tanks can be stopped by closing the solenoid operated vent valve located at the top of each one.

3.1.2 Solenoid Vent Valves - To flood the MB tanks, electrically operated vent valves are used. These valves are located on the rear top of each main ballast tank (total 4 valves) and for this reason it is advisable to flood with a slight down angle to prevent air pockets from forming. The operation of the valves is controlled from inside the boat using a switching mechanism to electrically operate a solenoid located in the valve. The valves are normally closed and must be energized to open, thereby providing fail safe operation. Hand installed plugs are placed over each vent when rigging for surface.

The valve body and moving parts are machined from 316 stainless steel. The seating ring is machined Teflon and it is held in the closed position by an Inconel X-750 spring.

The valve will operate in sea water (temperature range 0°F to 120°F) on 18-28 volt D.C. power with a flow rate of 180 std.cu.ft/min. at sea level. These valves are connected to the 28 volt D.C. bus.

The valves can be rapidly changed by separating the connectors and removing six 5/16-24 screws which hold the valve to its seat on the tank top. The electrical connection is made using Marsh and Marine type connectors.

Accidental flooding is prevented by an interlock system and a key operated switch.

To flood the MB tanks, a switch on the pilot's console activates the valve solenoid. The solenoid overcomes the pressure exerted by the spring holding the valve closed and the inside piston moves up off its seat allowing a free flow of air from the tank top. The tank rapidly floods through the open ports located in the tank bottom. When a tank is full, an indicator light goes on and the pilot releases the activate switch.

With the solenoid deenergized, a spring with 50 pounds of force, moves the piston back on its seat, closing the tank. With the valve shut, the MB tank is ready for blowing. Note - the valves will shut at any point during tank venting by the release of the switch on the pilot's console so that flooding can be stopped and the tanks blown dry.

Automatic blowing of the tanks is also accomplished by a safety device included in the pneumatic system which actuates if the boat accidentally descends below 2200 feet (see Section 4 for details).

3.1.3 Salt Water Sensors - Two electrically operated 28 V.D.C. sensors, supplied by an amplifier connected to the 110 A.C. bus, monitor water state in each tank. The sensors are mounted in the center of each tank, one at the bottom and one at the top. They indicate when a tank is full, or nearly empty. When both lights are out the tank is dry.

3.1.4 External Blow - Each tank also has an external blow connection on its rear top (same as vent connection). This allows the tank to be blown on the surface or submerged, using an external source of air.

3.1.5 Lights - Recessed into the bottom of each main ballast tank are a series of flood lights of either 150 or 650 watt halogen lamps (see Section 10, Exterior Lighting). The lamps are mounted in a fiberglass recessed tube cemented into place in the tank. The wiring for these lamps runs along the bottom wall of the tank in a closed free flooded tube molded in place. This tube or conduit is attached to each lamp housing so that the wiring leads from the conduit to lamp housing without entering the tank.

3.1.6 Plugs - The flood ports at the bottom of the main ballast tanks may be sealed with special plugs. The plugs are similar to large capacity vacuum flask stoppers made of steel plates and a rubber insert. They may be installed when the boat is surfaced to prevent flooding of the tanks due to leaks. Installation is accomplished by divers swimming down below the boat, inserting the plugs and tightening the wing nut on the assembly.

3.2 Variable Ballast Tanks - The two variable ballast tanks aboard the BEN FRANKLIN are externally mounted hard tanks. Each tank is mounted below the pressure hull and has a capacity of approximately 790 pounds of sea water. Refer to PX15-7002 for a drawing of the "Regleur".

The tanks are fabricated from carbon steel heavy wall pipe (219 mm outer diameter by 10 mm wall) and are considered to be "pressure vessels". They

run the full length of the boat on port and starboard sides (37 feet long) and are mounted to the hull by a series of steel straps lined with neoprene. The straps are bolted to fittings welded to the hull which are also neoprene coated. Each tank is capped on its ends by a machined steel plate held in place by a series of bolts. The tanks are restrained from fore and aft motion by a fitting bolted to the rear flange of each tank and attached to brackets welded to the hull. The tank interior is painted with a vinyl primer and topcoat. Outside, the tank is painted exactly the same as the hull. The lines for blowing and flooding the tanks pass through the steel end plates, up through steel tubing and into and out of the hull (see Pneumatic System, Section 4).

The sea connections for the VBT flood/drain lines are located under the pilot's viewport just above the upper row of batteries. Filters are located at each of the two flood/drain lines. The outboard vents, after leaving penetrator casting H-2, connect to PVC tubing which leads to the rear section of the sail. Two filters, stainless steel tubes with holes covered with a plastic screen, prevent clogging of the vents. Each filter has two lines - one filter is for the two VBT outboard vents, the other filter is for the hull vent, and for the SAS flood/drain line.

### 3.3 Shot Ballast System -

3.3.1 Shot Ballast Tanks - Separating the two main ballast tanks to port and starboard are the shot ballast tanks. They follow the same hull contours as the main ballast tanks. Each shot ballast tank is filled with steel shot up to a point about 4 inches below the water line. The tanks are free flooding and always open to the sea - to pressure compensate the

tanks and to prevent rusting of the shot into an unmanageable agglomeration. When completely immersed in sea water, the corrosive action on the shot is minimized and the granules remain free. Shot used aboard the boat is Globe Steel S-780C.

Each shot ballast tank is fixed to the sides of the hull by similar attachments to those on the main ballast tanks but with elongated bolt holes designed to allow for any play which occurs during expansion and compression of the pressure hull. The tanks are constructed of sheet steel supported internally by steel truss frames. They were manufactured by Giovanola Brothers.

The shot ballast system has two functions - to adjust the buoyancy of the boat by metering out shot through a specially designed electromagnetic valve and to provide six tons of buoyancy (6,372 lbs. per tank) in an emergency by rapidly dropping all of the shot (release of hydraulic pressure on a piston opens a large door at the bottom of the shot ballast tank):

3.3.2 Metered Shot Drop System - This system is an electrically controlled means for dropping small quantities of shot for the purpose of reducing the weight of the boat. It consists of two electromagnetic valves - one for each shot tank. Each valve has two sets of coils - 110 V.D.C. and 28 V.D.C. Refer to Figure 3-2.

The 110 V.D.C. holding coils are made up of soft iron cores which can be permanently magnetized by coils when supplied by 110 V.D.C. These "magnetic valves" are used to hold the soft iron shot in the shot ballast tanks when permanently magnetized and the power removed. This is accomplished when the shot ballast becomes magnetized in the "throat" of the valve.

The valve can be demagnetized to release its hold on the shot by cycling  $\pm$  110 V.D.C. voltage through progressing voltage dropping resistors.

Dropping the voltage and cycling both the plus and minus values through the coils, the cores (soft iron of valve and soft iron shot) become totally demagnetized since any residual magnetic effects are erased in this manner.

The 28 V.D.C. metering coils are essentially electromagnets which are used to control the flow of the flow of the soft iron shot through the "valves." This is accomplished when the 110 V.D.C. "coils" are demagnetized and the 28 V.D.C. "coils" are de-energized. Flow of shot is stopped when the full 28 volts direct current is used to energize the electromagnet and the soft iron shot in the "valve's" throat is magnetized. This condition can be maintained when the voltage is reduced to 14 volts D.C.

3.3.3 Metering - The electric metering system, used to measure the amount of shot in each of the two tanks, port and starboard, is made up of a transformer which is vertically oriented in each tank. The primary coils are excited by 20 VAC which has been stepped down via transformer from the 110 VAC Bus. The secondaries of the metering transformer are returned into the boat and terminated into voltmeters. The voltage recorded on the meter is directly proportional to the amount of shot in the tank,



since the level of shot represents the amount of mutual coupling between the two coils and hence the induced voltage on the secondary.

3.3.4 Timer and Shot Level Indicator - A specially constructed timer by Longines Watch Company, is installed in the pilot's console. This timer consists of two stop watches each connected to one of the shot ballast circuits. The timer automatically starts and stops as shot ballast is metered out of each hopper. The quantity of shot jettisoned is simply calculated by time units as 4.4 lbs. (2 kg) of shot falls through the valve per second. This operation is controlled by the pilot. One push on the button on the pilot's console is approximately equivalent to one half second or 2.2 lbs. (1 kg) of iron shot.

3.3.5. Emergency Shot Ballast - This system was installed to provide a quick release of ballast in case of flooding or some other emergency requiring rapid surfacing or extra buoyancy. From PX15 6001 (Hydraulic Schematic) it can be seen that hydraulic pressure ( $140 \text{ Kg cm}^2$ ) is built up in the accumulator which in turn holds a port and starboard hydraulic piston in a position that prevents a trap door at the bottom of each tank from opening. By opening a valve that allows the hydraulic fluid to return to the reservoir, hydraulic pressure is released on the piston which in turn allows the trap door to open. (The weight of the shot causes the piston to move to the opposite end of the cylinder when hydraulic pressure is released). The trap door, hinged on the opposite side, allows the shot to drop rapidly. If a piston fails to move due to corrosion or some other reason, hydraulic fluid can be forced to the opposite side of the piston to

provide an additional force. By operating valves A - D in rapid succession, the entire operation, including power to the opposite side of the piston, is accomplished.

The double acting piston was manufactured by HYDRO-LINE in Switzerland (Model N2UD 1.5 6812011) and modified for use aboard the BEN FRANKLIN. Seals at each end of the piston prevent sea water from entering the cylinder. Around the rod is fitted a stainless cylinder or sleeve capped with a rubber boot. The cylinder is packed solid with grease and the boot can move in and out slightly with sea pressure. This end of the piston is untouched by sea water and cannot corrode.

Prior to getting the boat underway or just prior to diving if the boat has been towed for several days, the trap door/piston mechanism should be tested. This can be accomplished by having a diver install a special screw fitting in each tank that holds the trap door in place. The piston is then moved by applying power in the opposite side of the cylinder and a diver can observe whether or not the piston retracts.

3.4 Trim Tanks - During underwater operation, changes in pitch are necessary either to make closer inspection of terrain through fore and aft viewport, to compensate for movement of personnel or equipment, or to compensate for weight changes in water and waste tanks. To achieve or correct longitudinal stability, water is transferred between two trim tanks. Refer to Figure 3-3.

One tank forward and one aft are located inside the bottom of the hemispheres at either end of the pressure hull. Each tank has a capacity of 50 cubic feet (3100 pounds of fresh water).

The trim tanks extend from the inside of the forward and aft hemispheres of the pressure hull ending at frames 1 and 16 and the base of each tank is formed by the inside contour of the hull. Steel plate sections are welded to form the upper surface of the trim tanks. A vertical wall, at the aft end of the forward tank and forward of the aft tank, is made of one 3 mm steel plate welded flush to the interior edge of frame 1 and 16. Centered in this wall is a manhole for inspection.

Enough water to fill one tank completely is carried during missions. This is sufficient to produce approximately a  $10^{\circ}$  angle, which is the equivalent of placing 5 men at one end of the vessel.

The forward trim tank has a filling hole in the top, closed by a threaded plug. Both tanks are linked by a polyethylene pipe running vertically and along the top of the hull interior forming an air venting system. The polyethylene pipe is joined to metal tubes located on the top of each trim tank. Each metal tube has a valve for air release.

When water is pumped from either tank it vents through the overhead pipe into the opposite tank. Trim water moves through two polyethylene pipes running fore and aft down the port side of the boat and connected to Jabsco trim pumps.

The trim pumps, Jabsco Model 10490, ball-bearing, self-priming pump, are mounted on brackets bolted to blocks welded to the hull. The pumps are turned by electric motors and controlled at the pilot's station. Each pump operates in one direction only. They are connected to the 110 volt D.C. bus and run at 1750 rpm (2 hp) with a capacity of 84 gallons per minute.

The forward trim tank has a manometer connection for reading the percentage of water. The gage is located at the pilot's console and connected to the tank via tubing. A small plunger next to the gage is pulled out to let air in a cylinder. The plunger is then pushed, forcing air into the manometer and bottom of the trim tank. The amount of back pressure forced into the manometer depends on how deep the water level is in the tank.

3.5 Lead Balast - In order to reach unladen diving trim, lead ballast has been added to the boat as follows:

Hull Pedestals

Forward Starboard	842 lbs. of shot
Forward Port	838 lbs. of shot
Aft Starboard	850 lbs. of shot
Aft Port	861 lbs. of shot

Trim Tanks (1-9/16 inch thick sections of lead)

Forward	4277 lbs.
Aft	3650 lbs.

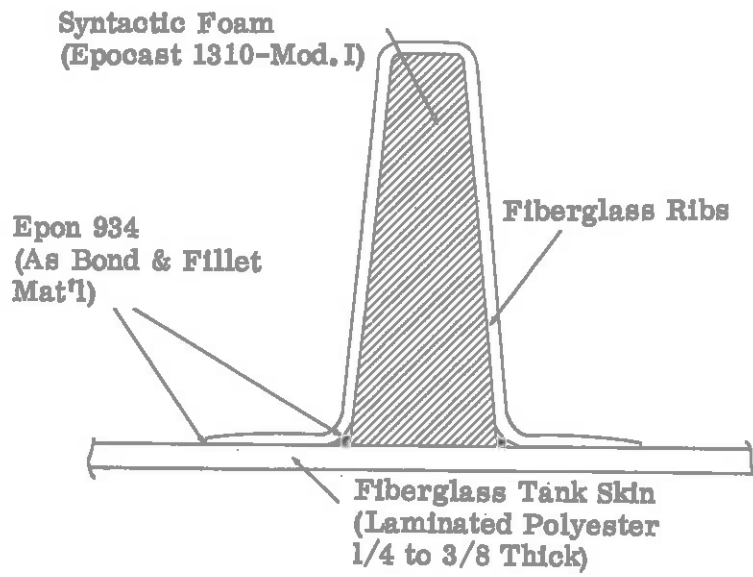


Figure 3-1 MBT Stiffner

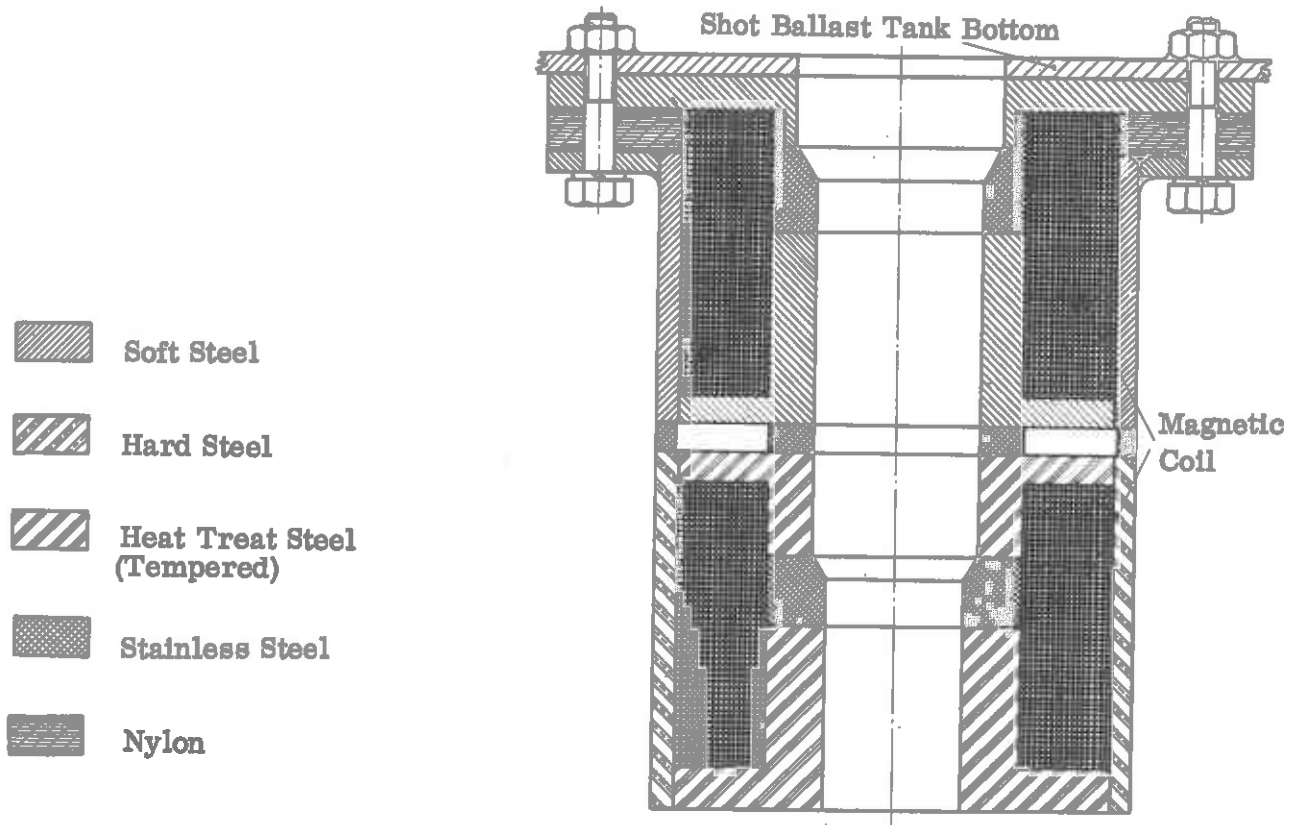


Figure 3-2 Electromagnetic Shot Valve

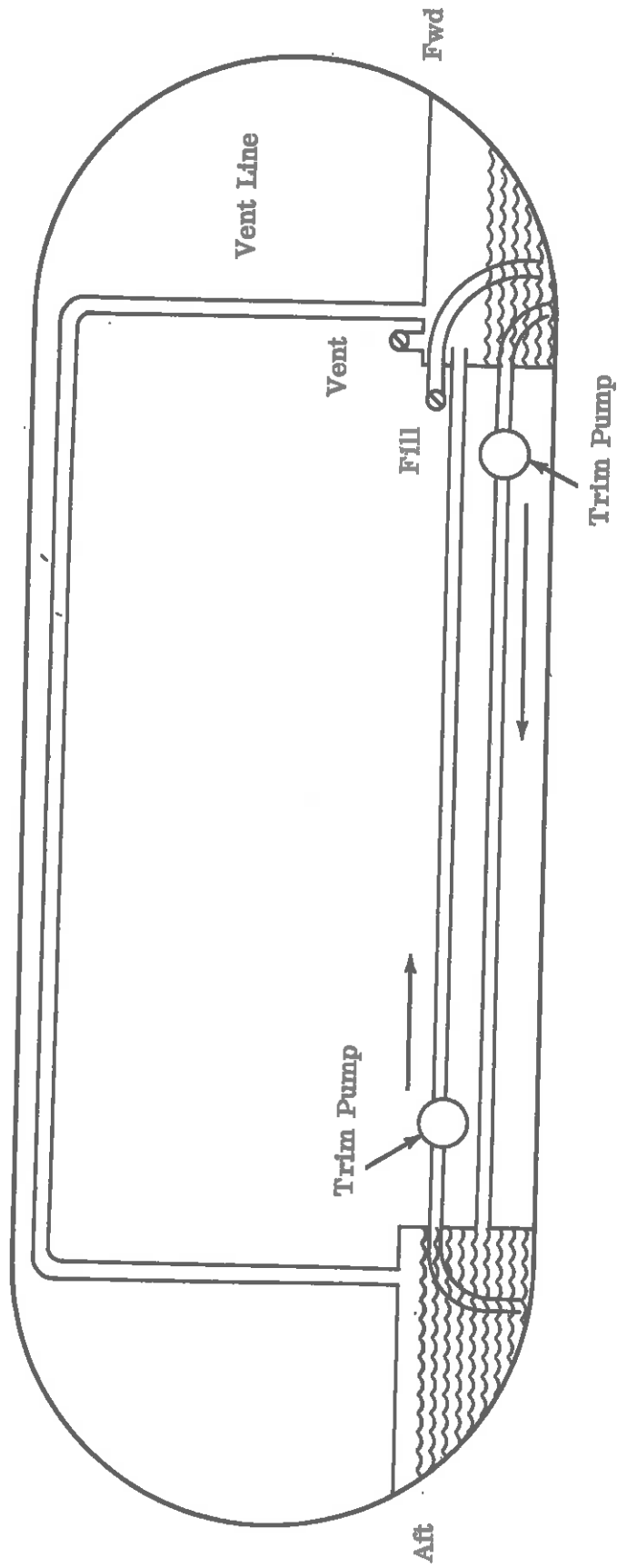


Figure 3-3 Trim System





## SECTION 4.0 - PNEUMATIC SYSTEM

The Pneumatic System aboard the PX-15 can be divided into four circuits:

- o System high pressure air storage, fill, vent and distribution
- o Main Ballast Blow and Vent
- o Variable Ballast Blow and Vent
- o Sas Circuit

The Pneumatic Schematic is presented in PX15 7001 and should be referred to while reading this section. For a detailed discussion of critical piping, hull penetrators and valves, see Sections 12 and 13.

4.1 Air Storage - Compressed air is stored aboard in steel tanks. From these storage tanks, high pressure air enters the system through hull penetrators, quick acting hull valves, and piping which runs to a pressure reducer (Victor GD 90 B). Here the air pressure is reduced from 200 kg/cm<sup>2</sup> to 100 kg/cm<sup>2</sup> (2844 psi to 1422 psi) before it is distributed throughout the vehicle. The low pressure side of the system (100 kg/cm<sup>2</sup>) is protected by a relief valve set for 110 kg/cm<sup>2</sup>. In an emergency, this relief valve and pressure reducer can be by-passed and high pressure air fed directly into Main Ballast Blow, Variable Ballast Blow and to the SAS. The entire system\* is capable of accepting maximum system pressure (200 kg/cm<sup>2</sup>).

\* The Main Ballast Blow system may be pressurized to 200 kg/cm<sup>2</sup> upstream only of the hull valves, to prevent the possibility of overpressurizing the Main Ballast Tanks.



4.1.1 High Pressure Air Storage - High pressure air is stored in six air flasks - U. S. Steel compressed gas flasks designed for Class 3000 service (per specification MIL-F-22606B). Three size flasks are used, 7 cu. ft., 10 cu. ft. and 21 cu. ft., mounted port and starboard, in pairs, on the top of the boat below the sloping deck. On the starboard side are flasks 1 (21 cu. ft.), 3 (7 cu. ft.) and 5 (10 cu. ft.) and to port are tanks 2 (21 cu. ft.), 4 (7 cu. ft.) and 6 (10 cu. ft.). When filled, the 21 cu. ft. flasks hold 262 lbs. of air; the 10 cu. ft. flasks hold 125 lbs. of air and the 7 cu. ft. flasks hold 88 lbs. of air - a total of 950 pounds. The total capacity of the system when fully charged is 76 cu. ft. at 2500 psi. If all this air was bled into the hull, six atmospheres would be added to give a pressure of 105 psi. This figure assumes that the internal hull volume has been reduced by 30% due to installed equipment. Each flask is piped through its own hull valve, (Argus ball valve), pressure gage and control valve all grouped near the pilot's station. The lines are manifolded together where they then feed through a single line to a pressure reducer. The tanks are mounted on brackets welded to the hull and held in place by neoprene lined steel straps. These straps are secured by a tightening nut and locknut arrangement fitted to the hull brackets. Stainless steel cables on each end of the flasks prevent fore and aft movement.

All high pressure air enters the hull through six penetrators at reinforcement (H-2). located topside forward between frame 3 and 4.

4.1.2 High Pressure Air Charging - The pneumatic system is charged in two ways:

- o External source of H.P. air

The normal method of charging the high pressure air flasks is through an external filling connection located near hull reinforcement (H-1) inside the sail between frames (1) and (2). Here high pressure air from some external source (dockside compressors) passes through the filling system and into the tanks. An additional connection is available inside the boat for charging the system should it be desired.

CPV Fitting - Both the internal air charging fitting and external air charging fitting (penetrator casting B-1) are female CPV 50 N-4.

The male fitting, CPV 2-12 UN, is normally stowed in the support van.

The system is designed to operate at pressures up to 6000 psi.

4.2 Hull Venting - During the course of test operations, cabin pressure may build up due to venting VBT's inboard, oxygen buildup or temperature changes.

It is possible to equalize this internal pressure to ambient pressure at the surface, before opening the hatch via a hull air vent. This vent is simply an open line running through a control valve, hull valve, penetrator and out to a screened fitting. This line passes through the hull at reinforcement (H-2). Venting the hull may also be accomplished through the SAS or the variable ballast piping.

4.3 Distribution - Once the high pressure air flows into the boat and through the pressure reducer it is directed through piping to the various circuits of the system. All normal internal piping in the pneumatic system is carbon steel except for lines which carry sea water are stainless steel. All fittings used for these internal lines down stream of the hull valves are standard Ermeto fittings.

4.4 Main Ballast Blow and Vent - The main ballast circuit is tied into the pneumatic system at the pilot's station. Here, an individual line running from the distribution circuit branches into two lines. These two lines each contain a simple control valve which supplies 100 kg/cm<sup>2</sup> air to a pair of main ballast tanks. The piping after the control valve is again split into two lines, each feeding to a hull valve and out through a penetrator at reinforcement (H-2). Once outside the hull the lines run through a check valve then out to a diaphragm (pressure restriction) and into a main ballast tank.

At the end of this line provision has been made to allow an external source of air to be hooked into each tank on an individual basis. The fitting located on each MBT blow line is a CPV 50N-4 female. It receives the CPV fitting with a 2-12 UN male thread, the same fitting used for external salvage valves and both air charging connections. The blow lines enter the tank tops aft and just below the vent valve. The electrically controlled vent valve ties into the tank at the same location through a special elbow fitting. For a complete discussion of this vent valve see Section 3.

Built into the Main Ballast Blow and Vent circuit is an emergency circuit which has been designed to blow the tanks if the vehicle drops below its operating depth. This circuit is automatic and requires only that the hull valves and two small valves be open downstream of the reducer. All valves are located just behind the panel directly aft of the pilot's seat. Operation of this circuit is simple and positive. As the boat passes its

operational depth, pressure is sensed in the oil filled gage line. This is transmitted to a pressure sensitive valve which opens at 2200 feet allowing  $100 \text{ kg/cm}^2$  air to flow from the distribution line into the Main Ballast Tank blow line downstream of the manual blow control valves. As the ambient sea pressure is reduced (when the boat starts to ascend) the valve closes (at 1400 ft.) halting the supply of air to the tanks. The air in the tanks continues to expand as the boat rises and forces water out through the tank flood ports. If the ascent is not halted, the boat will surface. A schematic of this circuit is included in the overall pneumatic system schematic.

4.5 Variable Ballast Blow and Vent - The variable ballast circuit uses  $100 \text{ kg/cm}^2$  supplied through the pneumatic distribution circuit. A "Tee" fitting breaks the variable distribution circuit into two halves. One half services the port variable ballast tank while the other half services the starboard variable ballast tank. Both sides are identical.

Lines lead out of the variable ballast tank at one end. They pass from the tank through a hull penetrator, a hull valve, a control valve, back out through another hull valve, a penetrator and to a screened fitting. This is the variable ballast tank flood and blow line. The entire line and all its fittings and valves are stainless steel. On the opposite end of the tank the blow line enters. This line picks up one side of the "tee" in the boat. It follows down through a control valve, hull valve, penetrator, then out to the tank. A pressure gage monitors the pressure on this line. Split off this line, just upstream of the pressure

gage, is an inboard vent line. The vent line is controlled by a hand valve which, when opened, shows whether or not the variable ballast tank is flooded.

These tanks may also be vented overboard through a second line which runs from the inboard vent line. The outboard vent line breaks out from the inboard vent line just upstream of the inboard vent control valve. It passes through its own control valve up to the top of the boat through a hull valve and on out through a penetrator and screen.

All variable ballast blow and flood lines passing into or out of the boat pass through the pressure hull at reinforcement (B-2) located below the deck level forward between frames (3) and (4). The outboard vent lines pass out of the hull at reinforcement H-2. All control valves are located at the pilot's station.

4.6 SAS Circuit - Downstream of the pressure reducer, a line branches out of the main pneumatic distribution circuit and leads to the SAS. This line, 12 mm in diameter, runs from a "tee" in the main line through a control valve and a check valve, then up into the SAS chamber.

On the line is a pressure gage (and a cut off valve) to monitor pressure in the SAS chamber plus an additional line and valve to allow venting of the SAS into the boat. Blowing and flooding of the SAS is accomplished through a line which leads from the bottom of the chamber through a control valve, hull valve, penetrator (at reinforcement H-2) and out to the sea through a screened fitting.

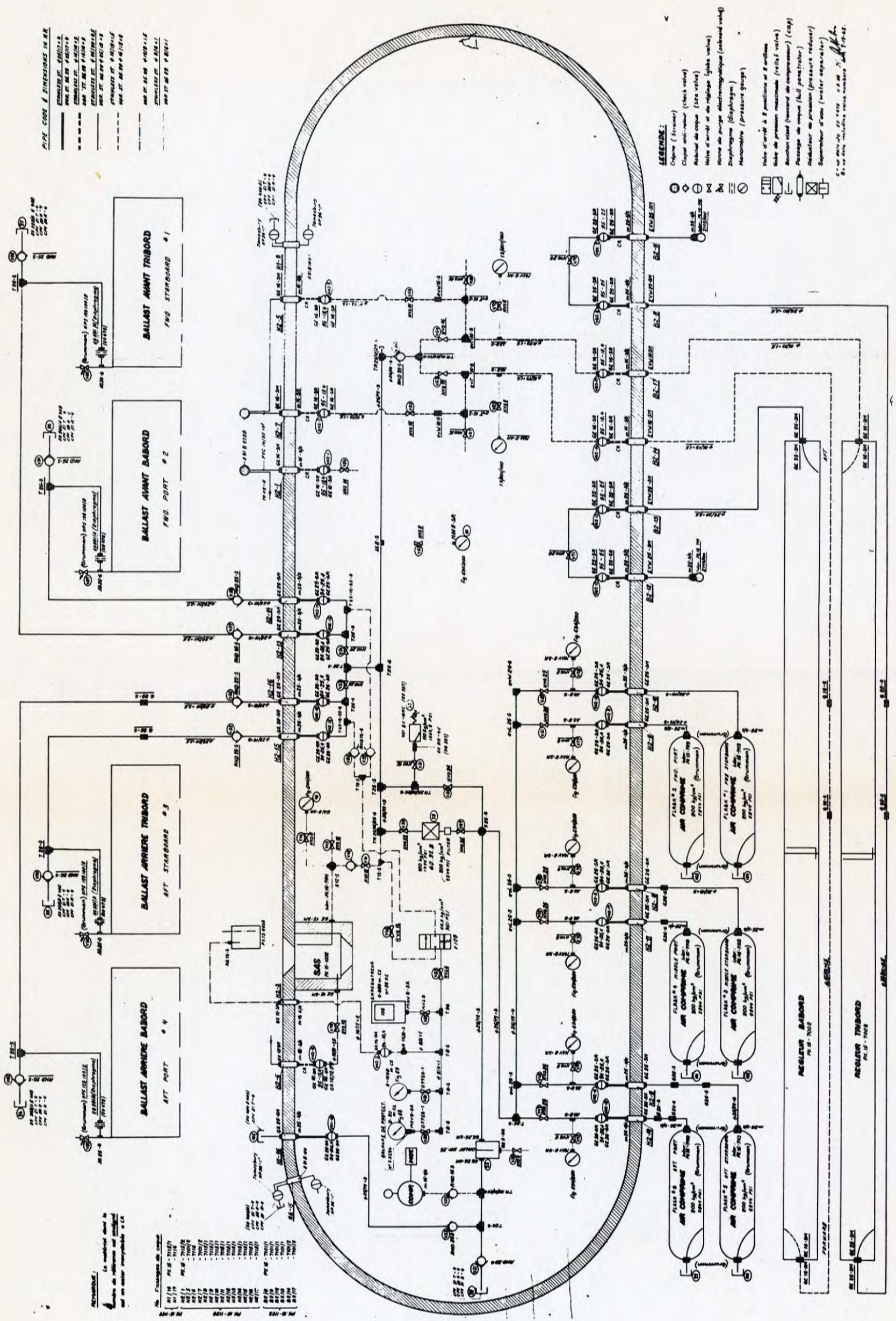


Figure 4-1 Pneumatic Schematic

## SECTION 5.0 - HYDRAULIC SYSTEM

The PX-15 hydraulic system has two main functions:

- o To open and shut the SAS chamber.
- o To ensure that pressure is maintained in the shot ballast emergency drop system.

All components in this system are manually controlled. The major system components are:

- o Hydraulic pump
- o Reservoir
- o Circuit selector valve
- o Pressure accumulator
- o Adjustable pressure control valve
- o Hydraulic pressure alarm
- o SAS lines
- o Lines, gages, fittings, etc.

A hydraulic reservoir is located in the equipment cabinet across from the pilot's console. Oil is drawn from the reservoir by a lever-operated hand pump. From the hydraulic pump, fluid is sent to the circuit selector valve. In the line leading to this valve a "Tee"-coupling leads to the adjustable pressure control valve which ports oil back to the reservoir if the set pressure is exceeded.



The circuit selector valve ports oil to either the SAS circuit or to the emergency shot ballast circuit. In the line leading to the shot ballast circuit is a hydraulic accumulator, normally set at  $140 \text{ kg/cm}^2$ . This accumulator maintains pressure in the shot ballast system at all times. The accumulator circuit is fitted with an adjustable pressure alarm with an electrical buzzer sounding when pressure drops below the set level in the shot ballast circuit.

The circuit leading from the selector valve to the SAS is normally not pressurized. This line leads to the SAS hatch valve which ports oil to the motor for opening or shutting the SAS hatch. Pressure to operate the SAS is provided by operating the hydraulic pump.

5.1 Hydraulic Pump - The pump in the system is a Greer Aircraft Emergency Hand Pump. It is fitted with a line filter at the pump outlet.

5.2 Reservoir - A welded aluminum tank (approx. .5 cu.ft.) is located just above the hydraulic hand pump. This tank contains the oil reserve for the hydraulic system. Lines to the hand pump enter the bottom of the reservoir. The hydraulic return line also runs into the tank at the top through an oil filter. The oil used in the system is Shell Tellus 927.

- 5.3 Circuit Selector Valve (Type HB2RA15/301 G/N) - This valve, located at the pilot's console is used to direct the output of the hydraulic pump to either the SAS motor or hydraulic accumulator (emergency shot ballast circuit). It will normally be in the emergency shot ballast position. The valve was manufactured by Ardie-Werk GmbH, Nuremburg, West Germany.
- 5.4 Pressure Accumulator (Type MPB) - Mounted in the hydraulic line after a non-return check valve is the pressure accumulator. This accumulator maintains pressure on the line to the emergency shot ballast release. It has a capacity of  $150 \text{ kg/cm}^2$  maximum and it holds 2.5 liters of oil. The accumulator is located under the pilot's console, below the deck level. It was manufactured by Olaer France, S.A., Colombes, France. Time required to charge the accumulator by hand is approximately 10 minutes.
- 5.5 Adjustable Pressure Control Valve (Type MVV15-5 OND) - This valve is located near the hand pump and is used as a relief valve in the system. Relief pressure is set at  $142 \text{ kg/cm}^2$ . When this pressure is reached, the output of the hand pump is fed back to the reservoir. The valve is an Ozone Metal Products AN6245B4 MIL-V-5527.
- 5.6 Hydraulic Pressure Alarm - This alarm consists of a pressure sensor that measures hydraulic pressure downstream of the accumulator. When the pressure falls below a set level (set by a key switch), an alarm sounds and a light goes on. The alarm is normally set at  $130 \text{ kg/cm}^2$ .

5.7 Filters - A Gesto type EN3OMS is used in the system and is located in the return line just prior to entering the reservoir. A line filter (Waterman INT. EL 48005 481-3) is located at the output of the pump.

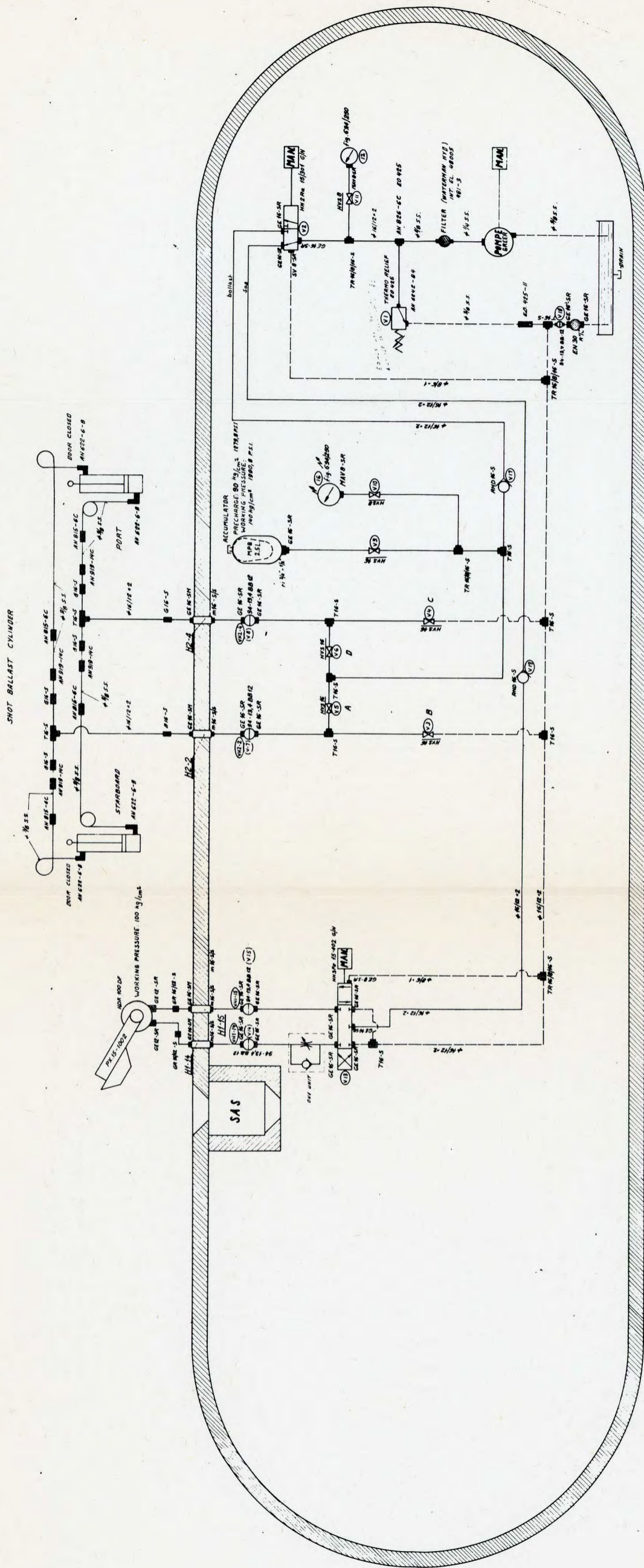
5.8 SAS Lines - The SAS outer hatch is operated by hydraulic power. This power is supplied by the hand pump and is directed by a two position valve to the SAS port motor. This valve is located just forward of the SAS itself in the overhead on the starboard side of the boat and was manufactured in Germany by Ardie-Werk GmbH. The outer hatch itself is opened or closed by a Sudhydraulic Marktoberdorf, Type 100 hydraulic motor made in West Germany. (See Section 7 for details of the SAS motor).

5.9 Pipelines and Hose - Seamless 35.29 carbon steel pipelines (16 mm x 2 mm) are used for pressure lines and main return circuit. The pressure outlet line from the pump is 8 mm x 1 mm as is the pump feedback to reservoir, feedback from the 2-position selector valve, and SAS lock control valve. Pump fluid return lines to the reservoir are 10 mm x 1 mm.

All pipes are joined by conventional ERMETO pipe-thread straight through, elbow, tee, cross and reducer fittings. These are made by ERMETO ARMATUREN GMBH+ WINDELBLEICHE+ BIELEFELD, West Germany.

All piping going to the outside of the boat have individual hull penetrators and hull valves. These penetrators are located at reinforcement H-1 (for the SAS) and H-2 (for the shot ballast).

Standard aircraft 3/8 stainless steel tubing with a wall thickness of .040 are used for the connections to the shot ballast cylinders on the outside of the boat. A loop is formed in each line at the cylinder to allow for movement of the cylinder during actuation.



PIPE CODE  
 ——— CIRCUIT UNDER PRESSURE  
 - - - RETURN CIRCUIT

No Passages de coque

PK 15-1120	H1/14	PK 15 - 7115/2
	H1/15	- 7115/2
	H2/2	
PK 15-1120	H2/4	PK 15 - 7115/2

Figure 5-1 Hydraulic Schematic

## SECTION 6.0 - ELECTRICAL POWER AND DISTRIBUTION

### 6.1 Main Battery -

6.1.1 Main Batteries - Batteries for BEN FRANKLIN were constructed by Electrona in Boudry, Switzerland. The cells are a lead acid type (Electrona RPHLOS) with cases made specially for the BEN FRANKLIN. Each cell, located in the keel area, is exposed to sea water and therefore compensated for sea pressure. The cells are mounted horizontally at an angle of 3°. They are held in a keel pigeon hole with a stainless steel retainer which forces them against a rubber pad at the back of the pigeon hole. The electrical connections between the cells are made with 95 mm<sup>2</sup> flexible cable ending in plugs that are insulated from sea water. At the end of each cell is a reservoir which contains approximately 2 liters of acid and 8 decliters of oil. The front of the reservoir is plexiglass marked so that electrolyte levels can be checked. Since the oil is colored with a dye additive, the level of electrolyte can be read at the interface with the oil in the reservoir. The reservoir is also fitted with a connection to a common manifold for gas venting and compensation. A removal plug on the reservoir is used for taking gravities and adding distilled water when required.

The batteries can be fully charged in 13 hours on land or while the boat is on the surface of water. When charging the batteries hydrogen gas is formed and about 53.5 cubic centimeters of distilled water are consumed. However, with a reserve of 2 liters of electrolyte, it is possible to charge about 30 times without adding water. Hydrogen gas is another problem.

Most of the generated hydrogen escapes, however 600-800 cm<sup>3</sup> of gas remains trapped in the cells six hours after charge. This quantity of gas affects the submerged stability of the boat since it is compressed upon submerging thereby causing the boat to become heavy. When ascending in the water, the gas expands causing the boat to become light - therefore the vehicle will tend to be unstable at depths down to about 100 meters and stable ( the gas will be in solution) at depths greater than 100 meters. While on discharge, hydrogen is also formed and is freed from solution at .5 atmospheres.

Refer to Table 6-1 for battery configuration. Figure 6-1 shows the construction of its cell and Figure 6-2 (PX15 5507) shows the battery arrangement in the keel.

#### 6.1.2 Specifics - Main Battery

- o 1000 AH at 10 hr. rate (100 amps)
- o 750 AH at 3 hr. rate (250 amps)
- o Total capacity 750 KWH
- o 1.260 specific gravity when charged
- o 1.120 specific gravity when discharged
- o Low voltage 1.75 V at 10 hr. rate

- o Low voltage 1.7 V at 3 hr. rate
- o 2.8 liters (oil and electrolyte) in each reservoir
- o Lifetime 650 cycles in 3 years
- o 30 cycles between watering
- o Battery jar hard rubber
- o Battery weight approximately 160 lbs.
- o Dimensions approx. 201 mm wide x 535 mm long x 231 mm high
- o Maximum operating attitude 45°

In order to monitor the state of the battery, a recording ampere hour system is installed adjacent to the pilot station.

## 6.2 Emergency Battery -

6.2.1 Emergency Batteries - In the event that main battery power is interrupted, 14 C & D Battery Co., DCUA, 13 calcium grid, lead acid batteries are provided to power the 28 V DC bus. The cells are located in sealed compartments aft of the shower and toilet. The lead calcium type battery is particularly suitable for submarine use since the amount of hydrogen given off during discharge is too small to measure. Each cell provides 2.2 volts giving a total of 31 volts. A Model ARF 28 A3D charger (115 V 60 Hz) is used to charge the cells.



### 6.2.2 Specifics Emergency Battery (C&D cell DCUA 13)

- o 168 AH per cell x 30 V = 5 KWH
- o Cell size 10-3/4" x 6-3/8" x 7-3/8"
- o Weight 38 lbs each
- o Cell voltage averages 1.75 to 2.20 volts over rated life (24.5 to 31 volts for 14 cell system)
- o Operating temp. 0°F to 140°F
- o Fully charged specific gravity about 1.300
- o 8 hrs. to 1.75 volts (168 AH)

6.3 Battery Chargers- The charging installation, located in the support van along with the air compressors, is composed of eight automatically controlled rectifiers divided in three groups:

Group 1 - 2 chargers for 84 cells each (168V)

Group 2 - 3 chargers for 56 cells each (112V)

Group 3 - 3 chargers for 14 cells each (28V)

The rectifiers are mounted in eight cabinets of approximately the same size. Cooling is accomplished by natural convection - cool air enters the bottom and leaves at the top. In the upper part of each charger is located a voltmeter, ammeter, ampere hour meter and recording voltmeter. A key operated switch is provided for choosing the charging program. Input power is 440 V AC.

Two charging programs can be set into the chargers - underwater charging (while boat is in the water) and service charging (while the boat is on land).

6.3.1 Underwater Charging - This program permits the full charge of the battery in a relatively short time (about 13 hours) producing a minimum of gas formation. More rapid charging may cause a carry-over of sulphuric acid.

6.3.2 Service Charging - This program differs from the underwater program by a smaller charging current of the second step. The program is somewhat longer since water pressure is not available to prevent acid carry-over. In addition to this, a lower charge current is necessary in order to prevent a temperature increase of over 95°.

In addition to the eight chargers already mentioned, a single cell charger is provided to charge from one to six cells simultaneously. Input power is 110 V AC.

6.4 Battery Venting and Compensation - Since all of the main batteries are located outside of the pressure hull, a method is provided to prevent them from being crushed by sea water pressure - a compensation system. In addition to this, a means is also provided to allow for the escape of hydrogen gas produced in each cell. The gas venting and sea water compensation systems are joined together into one integrated system.

Briefly, each battery cell has a riser tube leading from its reservoir to a manifold located above the keel. The manifold is connected to a large fiberglass reservoir located forward of the keel. The reservoir is open to sea and therefore sea pressure is transmitted from the reservoir to the manifold to each cell. There are five manifolds (3 starboard and 2 port) and each one has two vent valves which allow for the escape of hydrogen gas. A more detailed explanation follows.

6.4.1 Manifold - The manifold system is divided into five sections basically following the electrical grouping of the cells. The headers are fabricated from 100 mm ID x 5 mm wall rigid Polyethelene with a screw cap on each lid for cleaning. Each battery cell is connected to a manifold header with a nylon reinforced 14 mm ID transparent P.V.C. flexible hose and special P.V.C. fittings. The hose is fitted onto the header and connected to each cell with a union type fitting and neoprene gasket. Where the hose connects to the header, a tailpiece is provided that extends more than halfway into the header. This prevents sea water from entering a cell if the relief valve fails (the salt water will proceed forward into the main reservoir). Refer to Figure 6-3.

Each manifold header is connected to the top of the main reservoir with a nylon reinforced flexible transparent P.V.C. tube 38 mm I.D. x 5 mm wall. A curved trap located where the tube connects to the header is provided to catch sea water and can easily be inspected by a diver. Presently, the entire system contains 1481 liters of MARCOL 70 mineral oil, dyed orange in color.

6.4.2 Reservoir - The main compensating reservoir (955 liters or 252 gal.) is constructed of 10 mm thick fiberglass reinforced with steel. To compensate it with sea water, a 4" dia. P.V.C. tube, open to sea at the top of the reservoir, extends down to within a few millimeters of the bottom. The upper opening of this tube is even with the level of oil in the gas vent valves that are located in each end of the headers. The reservoir contains an oil filling connection, drain plug and four salt water sensors. The sensors are located on the aft end of the reservoir and are used to indicate the level of salt water. They read normal (20 gal. of s.w.); 1/2 full (80 gal. of s.w.); 3/4 full (150 gal. of s.w.); and full (about 220 gal. of s.w.). Normally only one light will be on. However, as the boat descends, other lights will light up due to salt water entering the reservoir. This additional salt water enters because of the compressibility of oil and the entrapped gas in each cell (about .6 liters per cell). At 200 feet approximately 520 liters of salt water enters the reservoir which will result in three of the sensor lights indicating on.

6.4.3 Venting - There are 10 hydrogen gas relief valves in the system - one at each end of a header. The purpose of the valves is to allow for the escape of hydrogen from the battery cells without allowing sea water to enter the system.

Gas that builds up in a battery cell travels up the riser tube to a header and then to a vent valve where it is released to sea. The gas enters the bottom of the valve and builds up in pressure. At a certain point, the float assembly (2 PVC coated spheres joined together) is forced downward in the oil thereby opening a port which allows the gas to escape into the upper (sea water filled) body. If the float does not move downward, a cracking pressure of about 2 psi will move the poppet seat to allow gas to pass. The port is surrounded by an inverted cup device and when the pressure inside the cup increases, it pushes the gas down under the lip letting gas bubbles enter the sea water. The upper and lower valve bodies are constructed of PVC and are bolted together at a flange joint. In the bottom of each valve is a salt water sensor and also a tube leading down to a stainless steel reservoir. If salt water enters the valve, it will travel down to this small reservoir (2-1/2" diam. by 6" long). Before a sensor would light up, salt water would have to fill the reservoir and its line to the bottom of the valve. Any salt water build up beyond the sensor would probably enter a header and proceed down through one of the lines leading to the main reservoir. Refer to Figure 6-4 (A91H1000).

6.5 Distribution System - Prior to entering the hull, current from the cells flows via molded neoprene connectors 95 mm<sup>2</sup> cable and then through Shawmut 400 amp fuses that are potted into the cable runs with a special epoxy system. The fuses are installed to protect the penetrators in case of a possible short. Tests show that they fail in 50 seconds with 1000 amps of current. From the fuses,

the 38 lengths of 95 mm<sup>2</sup> cable pass into the hull via 38 penetrators and then into large fuse boxes under the walking deck near the penetrators. There are 34 fuses located in 4 boxes in this area - one for each side (+ and -) of a battery cell string. Four additional fuses are located in another box adjacent to the shower. All are 250 amp fuses except for the 160 amp fuses of the D battery. From the fuse boxes, the cables lead into a multicircuit switch (MODE Switch) in the main AEG distribution panel. The mode switch in turn feeds power to the propulsion system, 110 VDC bus, and 28 VDC bus. There are four distribution modes plus one for battery charge plus off positions. Refer to Figure 6-5 and Table 6-2.

For battery charging, 16 charge cables are led from the support van to the mode switch via penetrator H-3. Two shore power cables (for 28 VDC bus only) also enter at H-3. Shore power and emergency power are fed to the 28 VDC bus by the Emergency Shore Power switch.

6.5.1 External Wiring - The 95 mm<sup>2</sup> external wire (batteries to hull penetrators) is R.E. Huber Co. (Swiss) Type 3 GWO. It is stranded copper wire with a double insulation - butyl and hypalon. All connections are molded neoprene and specially designed. All other external wiring is 1 mm<sup>2</sup> Cossonay with a thermo-plastic insulator and "Gyrlon" jacket with a 3.0 mm O.D. This wire is gradually being replaced by a new wire with solid hypalon insulation (.185 "OD"). Pleuger position motor wire is larger than 1 mm<sup>2</sup> and in order to pass through penetrators it is spliced (epoxy potted) to three 1 mm<sup>2</sup> wires and fed through three small penetrators in series. Connectors for this wire are a Piccard design similar to Marsh and Marine type as shown in Figure 6-6.

6.5.2. Mode Switch - Located on the main distribution panel is a multi-stack gear driven Kraus and Naimer C type switch. The contacts are rated at 200 amps (continuous) with surge capability to 1400 amps. Before operating the switch, appropriate circuits should be secured because normal operating procedure reduces switching surges to less than 50 amps. The mode switch is used to choose one of five main power distribution systems. Mode 0 is the off mode and is located between each of the five active modes. In order to keep battery groups at approximately the same capacity, it is recommended that while underway the propulsion system be shifted from four to two motor operations daily.

In order to understand the functions of the mode switch, the following is tabulated.

#### M O D E S W I T C H

##### Mode #1

<u>Battery Group</u>	<u>Use</u>
A1 & A2	- Supply port inverter and both position motor inverters
B & C	- Supply starboard inverter and 110 VDC bus
D	- Supplies 28 VDC bus

## Mode #2

<u>Battery Group</u>	<u>Use</u>
A1 & A2	- Supply starboard inverter
B & C	- Supply port inverter, both position motor inverters, and 110 VDC bus
D	- Supplies 28 VDC bus

## Mode #3 (Two motor operations)

<u>Battery Group</u>	<u>Use</u>
A1 & A2	- Supply starboard inverter and both position motor inverters
B1	- Supplies 110 VDC or 28 VDC bus
B2	- Supplies 110 VDC bus
C & D	- Supply 28 VDC bus

## Mode #4 (Two motor operations)

<u>Battery Group</u>	<u>Use</u>
A1 & A2	- Supply port inverter and both position inverters
B1	- Supplies 110 VDC or 28 VDC bus
B2	- Supplies 110 VDC bus
C & D	- Supply 28 VDC bus

## Mode #5 (Battery charge)

- NOTE: (1) B-1 battery switch must be in 112 volt position for modes 1, 2, or 5.
- (2) B-1 battery switch may be in 112 volt or 28 volt position for modes 3 and 4.



6.5.3 B-1 Battery Selector Switch - This switch is located amidships and is used to select one of two battery cell combinations for the B1 battery group. In one position, B1 is configured in 14 cell strings to produce 28 volts. This configuration may be used only when operating in modes 3 or 4 (two motor operation) and provides additional capacity for the 28 volt bus. In the other position, B1 is arranged in 28 cell groups connected in series to provide a 112 volt output. This configuration can be used at any time. The switch is rated at 50 amps during a switching function.

NOTE: If the mode switch is OFF and the B1 battery switch is on the 28 VDC bus, there is power on the 28 VDC bus.

6.5.4 Emergency/Shore Power Switch - Located amidships, this switch has four positions - off, normal, shore power, and emergency.

- |           |   |
|-----------|---|
| Off       | - Isolates all batteries from 28 VDC bus  |
| Normal    | - 28 VDC from Mode Switch connected to 28 VDC bus   |
| Emergency | - Isolates B1, C and D batteries from 28 VDC bus. Supplies 28 VDC bus from emergency batteries. |
| Shore     | - Isolates all batteries from 28 VDC bus and supplies shore power to the 28 VDC bus.            |

- NOTE:
- (1) It is not necessary to shift the mode switch to OFF when using the Emergency/Shore Power switch.
  - (2) Circuits on the 28 VDC bus are secured when shifting to and from shore power or emergency power.
  - (3) The switch can handle up to 100 amps during a switching function.

6.5.5 Charge Isolation Switch - Eleven (1) of the battery charging cables that enter the hull through a penetrator go directly to the mode switch and therefore when the mode switch is in any mode except 5, the charge penetrators are isolated from the system. Five wires lead to a separate charge isolation switch. This switch electrically isolates the D battery group from the charging penetrators when the battery is not on charge.

6.5.6 TOPAZ Inverters - Two TOPAZ (Model 500 GW) Solid State inverters are installed aboard the BEN FRANKLIN to power the 110 V.A.C. bus. A cooling fan is provided to improve reliability.

#### Specifications

Input Voltage	22 to 30 VDC
Current	6 to 30 amps
Power	0 to 500 VA
Waveform	Sine wave with less than 6% total harmonic distortion

Frequency	60 cycles <u>±</u> 1 cycle
Protection	Fused and current limited
Operating Temp.	-20 to +50°C
Weight	Approx. 65 lbs.

The inverters are operated from a switch at the pilot's console - an ON/OFF switch for each TOPAZ inverter - C5 and C6. In addition, a selector switch is provided to determine what circuits are supplied from each inverter.

<u>Inverter</u>	<u>Switch Position</u>		
	1	2	3
C5	110 VAC bus	both	OFF
C6	Life Support	OFF	both

6.5.7 Basic Loads - There are five basic loads supplied from the distribution system

- (1) Port 60 Kva Propulsion Inverter
- (2) Starboard 60 Kva Propulsion Inverter
- (3) Position Inverters and Propulsion Switching
- (4) 110 VDC bus
- (5) 28 VDC bus

Refer to Figure 6-5.

The loads that are part of the propulsion system (1, 2, and 3) are covered in Section 7.0. Tabulations of the 110 VDC bus loads and the 28 VDC bus loads are given in Table 6-3, Table 6-4, and Table 6-5.

TABLE 6-1

<u>Group</u>	<u>No. of Cells</u>	<u>Voltage</u>	<u>KWH</u>
A1	28 cells) 28 cells) - 84 cells 28 cells)	168 volts	168 KWH
A2	28 cells) 28 cells) - 84 cells 28 cells)	$\frac{168}{336}$ volts 336 volts (A1 + A2)	168 KWH
B1	14 cells) 14 cells) 14 cells) - 56 cells 14 cells)	112 volts or 28 volts	112 KWH
B2	28 cells) 28 cells) - 56 cells	112 volts	112 KWH
C	14 cells) 14 cells) 14 cells) - 56 cells 14 cells)	$\frac{112}{336}$ volts 336 volts (B1 + B2 + C)	112 KWH
D	14 cells) 14 cells) - 42 cells 14 cells)	28 volts	$\frac{84}{756}$ KWH 756 KWH

3 7 8

TABLE 6-2  
MODE SWITCH

## Mode #1

A1 & A2	-	Supply port inverter and both position motor inverters
B & C	-	Supply starboard inverter and 110 V.D.C. bus
D	-	Supplies 28 V.D.C. bus

## Mode #2

A1 & A2	-	Supply starboard inverter
B & C	-	Supply port inverter, both position motor inverters, and 110 V.D.C. bus
D	-	Supplies 28 V.D.C. bus

## Mode #3 (Two motor operations)

A1 & A2	-	Supply starboard inverter and both position motor inverters
B1	-	Supplies 110 V.D.C. or 28 V.D.C. bus
B2	-	Supplies 110 V.D.C. bus
C & D	-	Supply 28 V.D.C. bus

## Mode #4 (Two motor operations)

A1 & A2	-	Supply port inverter and both position inverters
B1	-	Supplies 110 V.D.C. or 28 V.D.C. bus
B2	-	Supplies 110 V.D.C. bus
C & D	-	Supply 28 V.D.C. bus

## Mode #5 (Battery charge)

TABLE 6-3110V DC BUS LOADS110 Volt DC Bus

- o 650 watt projectors
- o Shot valve holding coil
- o Trim system motors
- o Air compressor
- o Rudder limit switches
- o Hot plate
- o Hot water heaters
- o Convenience Outlets

TABLE 6-428V DC BUS LOADS28 Volt DC Bus

- o Rudder sensors
- o Salt water detector lights
- o MBT vent valves
- o Shot metering coil
- o Emergency lights (charging)
- o TOPAZ inverters (2)
- o Underwater telephone
- o Radio
- o Fathometer
- o TV (2)
- o Pinger
- o 150 watt projectors
- o Internal lighting
- o Navigation - compass, turn and bank, etc.
- o Hydraulic accumulator alarm
- o Shot demagnetizing alarm
- o Electrical outlets
- o Running lights
- o Strobe light
- o Submarine ident. light

TABLE 6-4 (Continued)28 Volt DC Bus - Continued

- o Temp. sensors (ext.)
- o Pilot panel lights
- o Horn
- o Obstacle avoidance sonnar (CTFM)
- o Battery monitoring panel (inverter for ampere hour meter and digital voltmeter)



TABLE 6-5110 Volt AC Bus (From TOPAZ Inverters)

- o Rudder indicator switch
- o Convenience outlets
- o Toilet - macerator and blower
- o Containment removal system
- o Teledyne/solenoid for LOX tanks
- o Salt water sensors (MBT levels and battery vent valves/reservoir)
- o Thallium iodide lights
- o Pan and tilt for TV
- o Shot ballast level indicating system

## NOTE:

Hot water heaters are powered by an external 110V AC source and are not normally powered by the boat systems AC or DC.

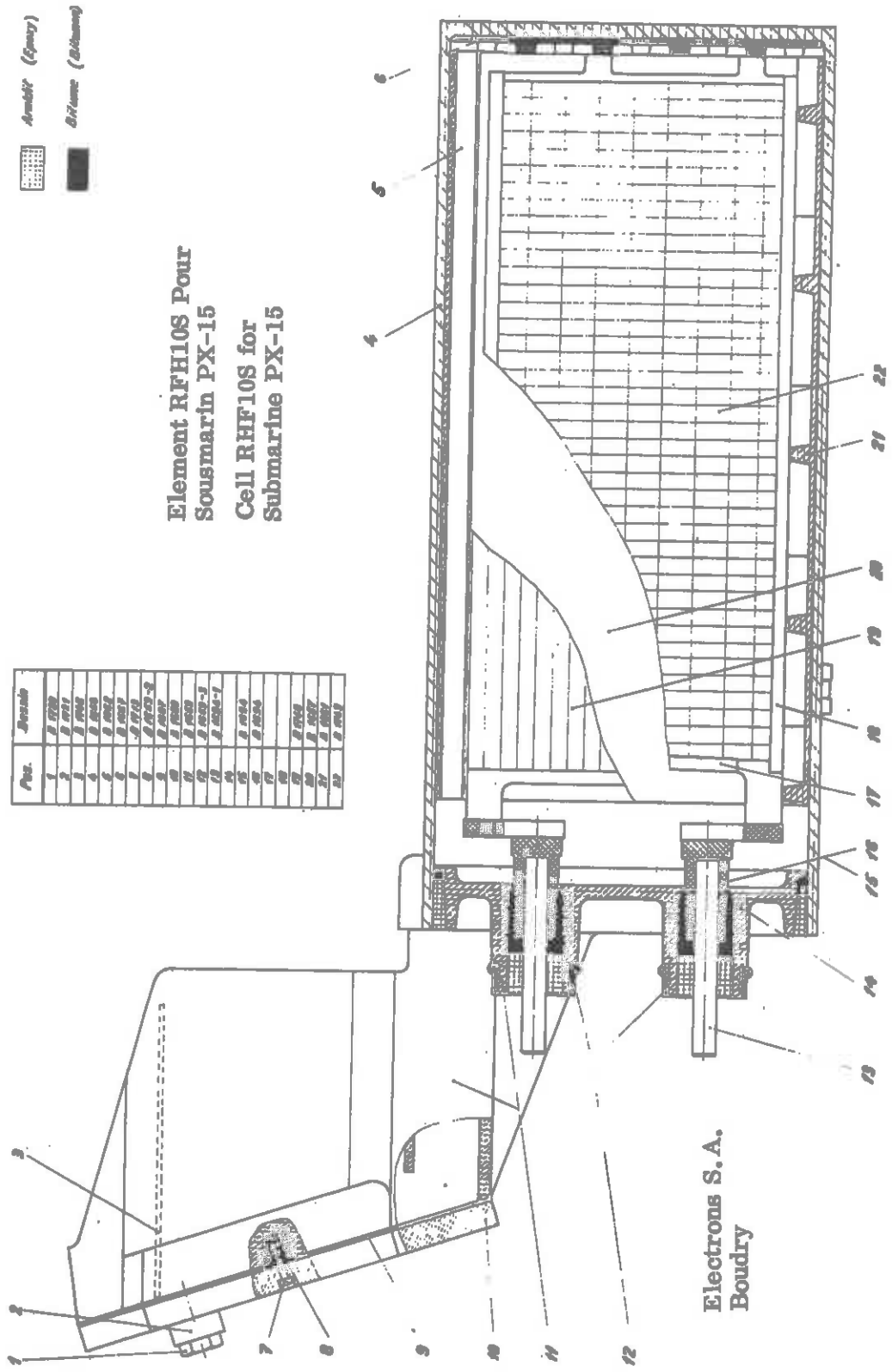
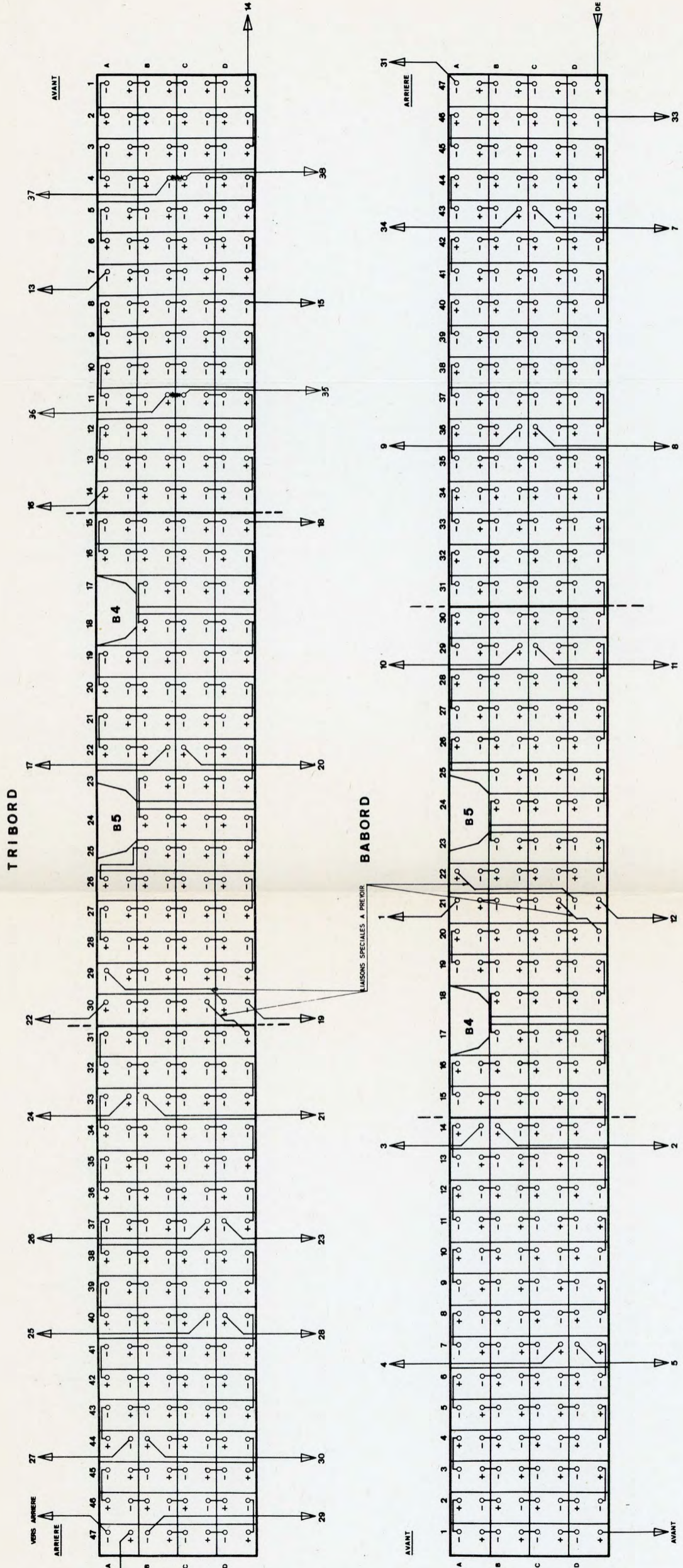
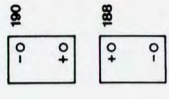


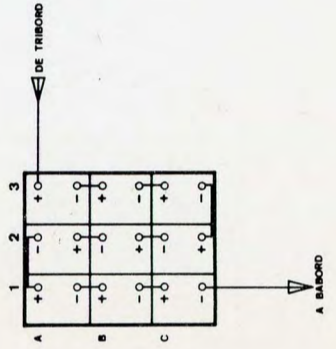
Figure 6-1 Electrona Battery



POUR DISTRIBUTION (VOIR PLAN RENFORT DE COQUE)  
 B4 - 12 15  
 B5 - 18 24



ARRIERE



AVANT

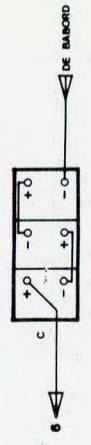


Figure 6-2 Battery Arrangement

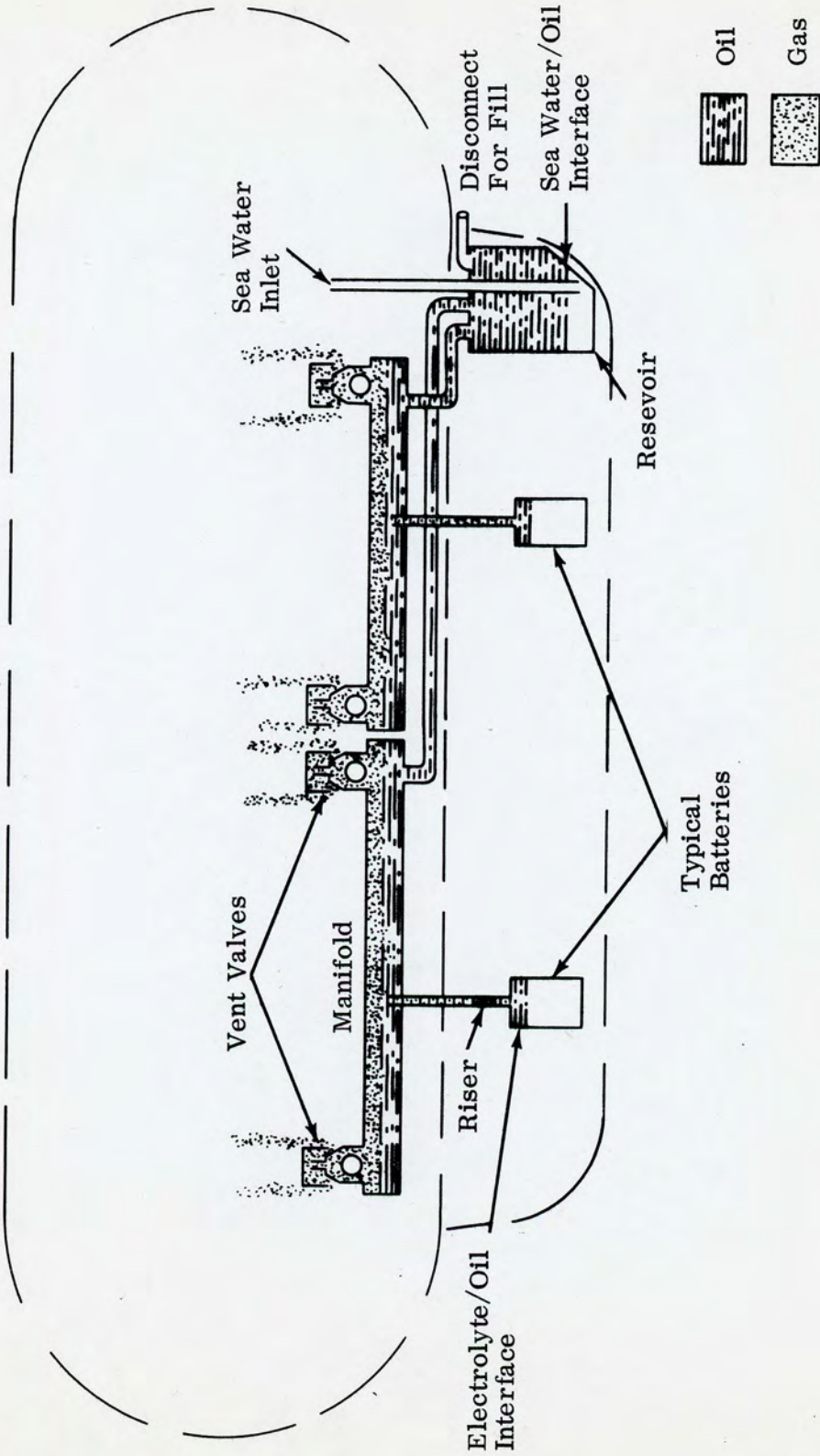
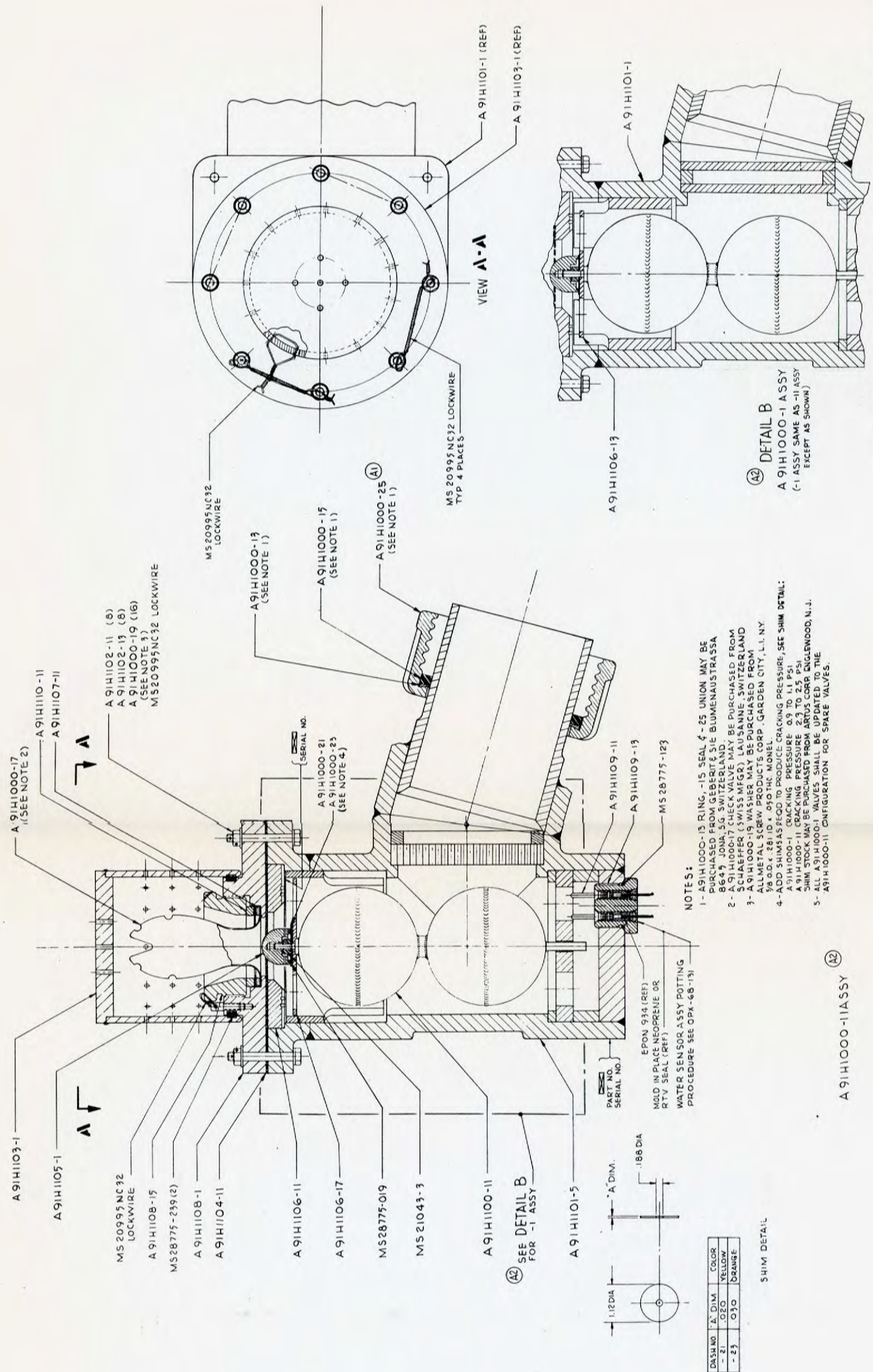


Figure 6-3 Manifold System



- NOTES:
- 1- A91H1000-13 RING, -15 SEAL & -25 UNION MAY BE PURCHASED FROM GEBERIT & SIE BLUMENAUSTRASSA 8649 JONA, SG, SWITZERLAND
  - 2- A 91H1000-17 CHECK VALVE MAY BE PURCHASED FROM SCHAEFFER (SWISS MFGR) LAUSANNE, SWITZERLAND
  - 3- A 91H1000-19 WASHER MAY BE PURCHASED FROM ALLMETAL SCREW PRODUCTS, CORP. GARDEN CITY, L.I. NY. 1/8" OD x .281 ID x .050 THK MODEL
  - 4- ADD SHIMS AS FOLLOWS TO PRODUCE CRACKING PRESSURE, SEE SHIM DETAIL:  
 A 91H1000-11 CRACKING PRESSURE 0.9 TO 2.5 PSI  
 A 91H1000-13 CRACKING PRESSURE 0.9 TO 2.5 PSI  
 SHIM STOCK MAY BE PURCHASED FROM ARTUS CORP. ENGLEWOOD, N.J.
  - 5- ALL A91H1000-1 VALVES SHALL BE UPDATED TO THE A91H1000-11 CONFIGURATION FOR SPARE VALVES.

DASH NO	A DIM	COLOR
- 21	0.20	YELLOW
- 23	0.30	ORANGE

SHIM DETAIL

A 91H1000-11 ASSY

FOR PARTS LIST, USAGE DATA, & DWG SH STATUS, SEE DOCUMENT SAME NUMBER PREFIXED PL

Figure 6-4 Vent Valve

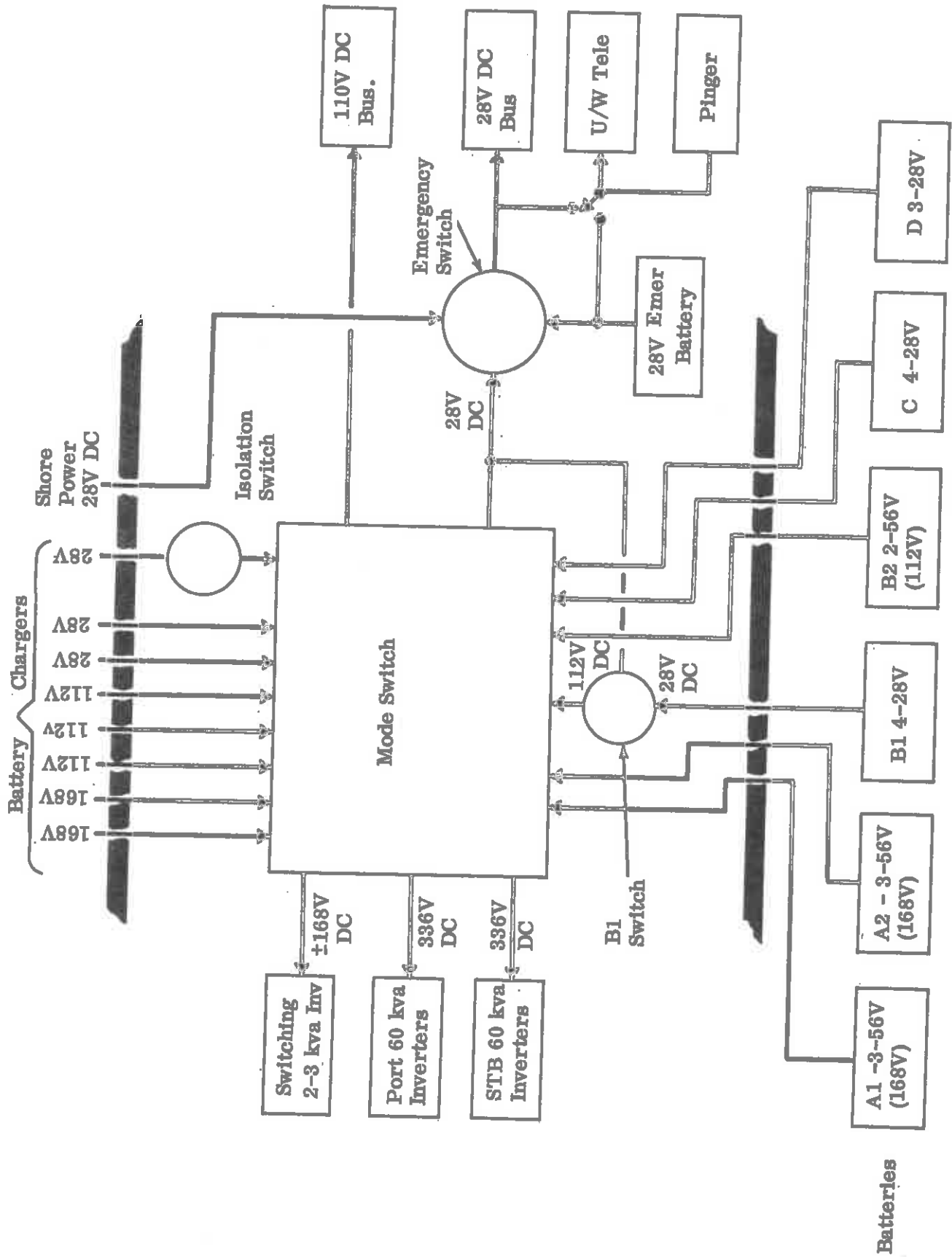


Figure 6-5 Basic Electrical System

Neoprene Plug Molded to Boston Insulated Wire - Hygalon Jacket Cable

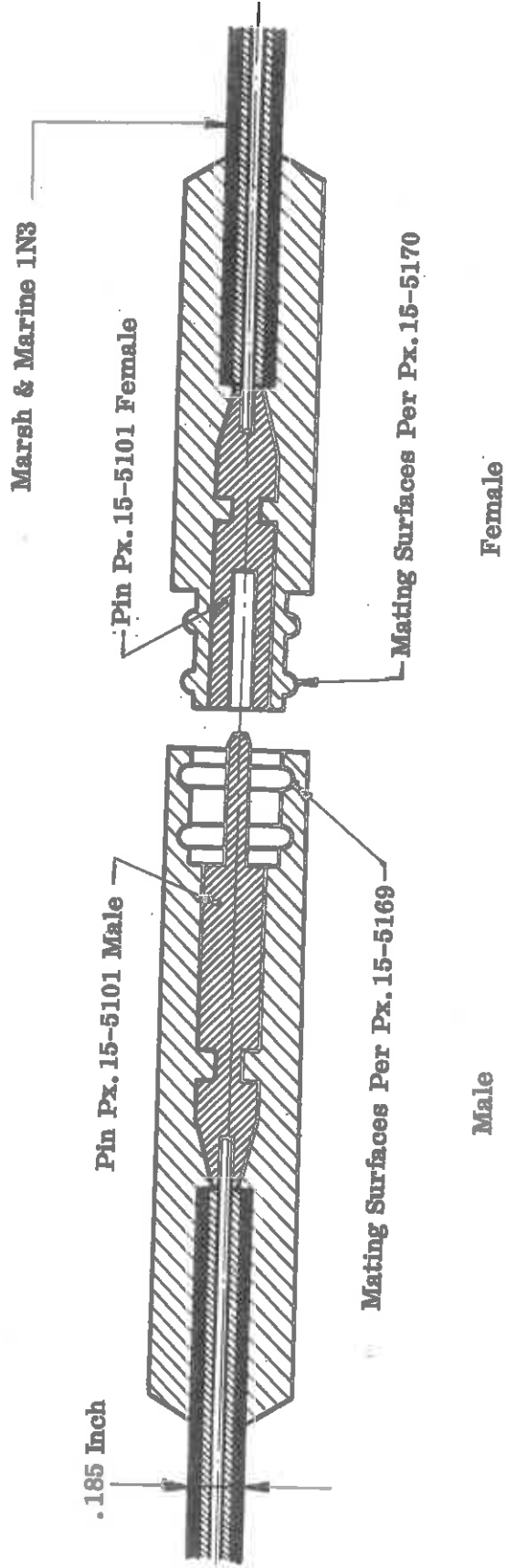


Figure 6-6 1 mm Wire Connectors



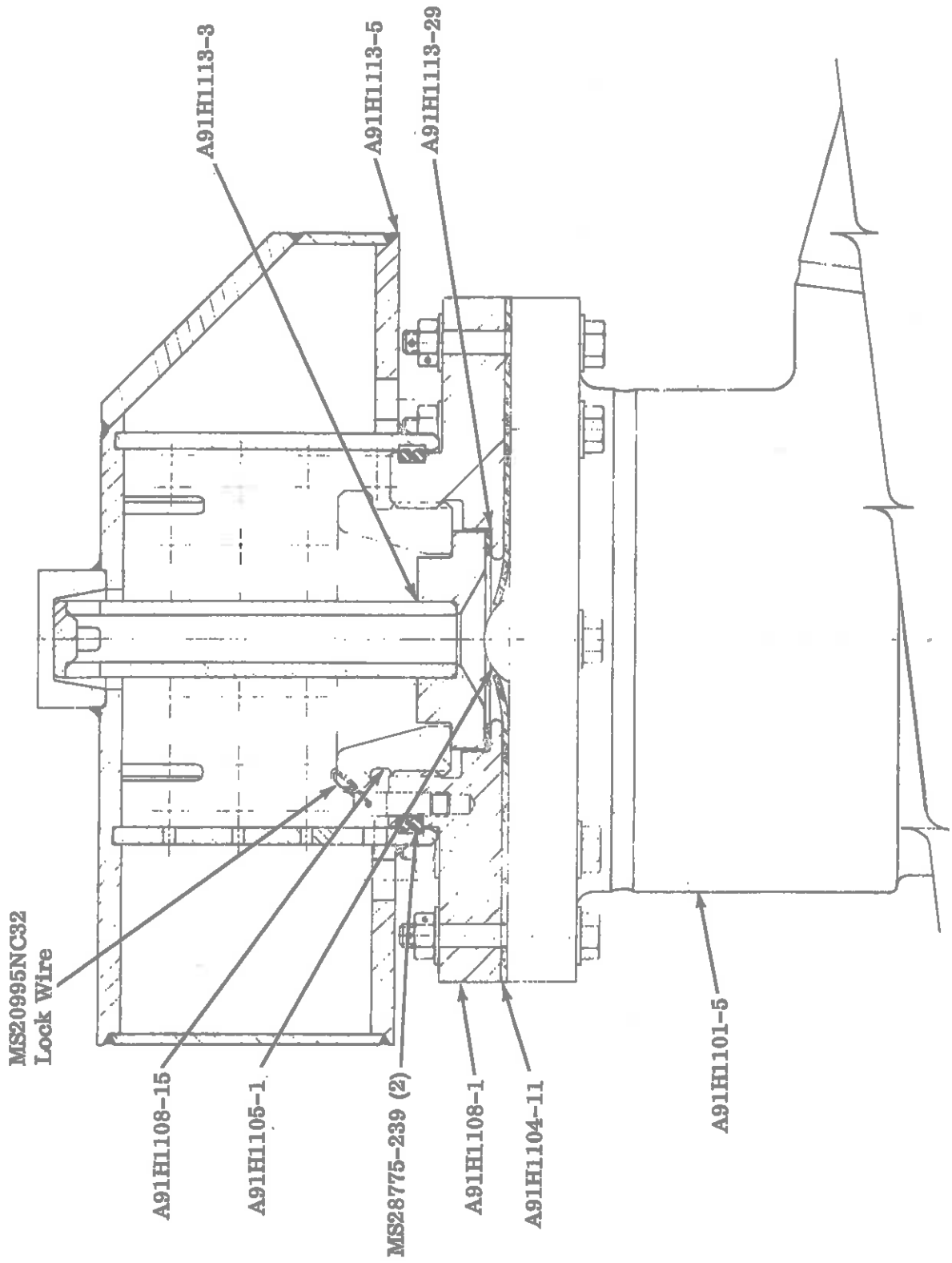


Figure 6-7 Vent Valve Modification



## SECTION 7.0 - PROPULSION AND STEERING

7.1 Pilot's Console (AEG) - This equipment contains all the necessary instruments and controls for operating the vessel. Refer to the photograph Figure 7-1.

7.2 Propulsion Panel - Built by AEG the panel is located directly in front of the pilot's seat.

The batteries normally provide 336 volts to two 60 KVA inverters for propulsion.

Each inverter powers one or two 25 h.p propulsion motors with speed varied by changing the frequency and voltage. The batteries also supply two 3 KVA inverters which in turn provide power to index the orientation of the propulsion motors. The rotation motors (4) are .5 h.p each.

7.2.1 Throttles - There are two "throttles" used to control the output of each 60 KVA inverter. Selection of throttle/motor combination is accomplished with the Propulsion Inverter Selector. Normally, in Mode 1 (turn mode) the starboard throttle controls the starboard motors and the port throttle controls the port motors. In Mode 2 (cruise mode) the starboard throttle controls the two aft motors and the port throttle controls the two forward motors. When the Propulsion Inverter Selector is shifted from vertical to the

horizontal position, the port throttle controls the starboard or rear motors and the starboard throttle controls the port or forward motors (depending upon whether in cruise or turn mode). A detent is at the center throttle setting to indicate the stop position. Tachometers are provided for each motor and provide readings from 0 to maximum RPM (720).

7.2.2 Depress/Elevate Level - Two levers (joysticks) are used for motor positioning. The forward lever controls the forward motors and the rear lever controls the rear motors. Normally the forward joystick directs power from the forward 3 KVA inverter and the aft joystick the aft 3 KVA inverter. This can be reversed by shifting the Position Inverter Selector to the horizontal position. A dial is provided for each motor indicating its position.

7.2.3 SAME/OFF/OPPOSITE Switches - One of these switches is provided for each motor. In the "SAME" position, a motor operates as directed by the throttle. If the OPPOSITE position is selected, the motor will operate opposite to the throttle setting. In order to operate this switch; the throttle must first be at the OFF position and the propeller completely stopped. When in the OFF position the motor will not operate. One propulsion inverter may be used to operate one or two motors.

7.2.4 Other Dials - In addition to the motor position indicators and tachometers, the panel has an ammeter indicating current to each 60 KVA inverter and a voltmeter indicating voltage to each 60 KVA inverter. When battery voltage to an inverter drops to 300 volts, the throttle should not be operated beyond the 1/2 speed position. If battery voltage to an inverter drops below 260 volts, the inverter will automatically shut down.

7.2.5 Toggle Switches - At the top right hand corner of the panel are four toggle switches. These switches are used to energize the two propulsion and two motor positioning inverters.

7.2.6 Main Power Switch - This switch energizes the panel and can be operated only when the key (below the power switch) is in the ON position. The key prevents accidental operation of the propulsion system.

7.2.7 Emergency Shutdown Switch - In case of emergency, the panel and inverters (4) can be secured by pressing this switch. It is located above the main power switch.

7.3 Propulsion System Inverters - The BEN FRANKLIN propulsion system consists of four propulsion motor units, each consisting of a reversible 25 h.p. AC squirrel cage induction motor driving its own propeller and complete with an integral 0.5 h.p. reversible positioning motor used to rotate the propulsion motors up to 350°. The inverters for energizing the

main propulsion motors are designed to supply continuously variable frequency and voltage for variable speed and reversing operation. The inverters for energizing the position motors operate at a constant frequency and voltage. Each inverter supplies one or two motors. The propulsion inverters are mounted either side of the passageway just aft of the main distribution panel. The port throttle controls the port inverter and the starboard throttle controls the starboard inverter. The two positioning motor inverters are located behind the main AEG distribution panel in line parallel with the hull. The forward inverter is normally controlled by the forward lever (pilot's panel) and the aft inverter by the aft lever. This combination can be reversed in case of a casualty. All four of these inverters were manufactured by AEG of Hamburg, Germany.

7.3.1 Main Propulsion Inverters - The variable frequency propulsion inverters consist of three inverter power sections, one filter condenser section, one choke coil filter section, control and regulation section, three over-current sections, frequency setting control, and cooling fans. The output frequency and voltage is continuously variable over the full range of 3-50 Hz by means of a single lever (throttle) on the pilot's console. The output voltage is proportional to frequency and the inverter is arranged for rapid reversing and jogging from both forward and reverse positions of the control throttle. Reversing motors from full power forward to full power reverse requires 27 seconds. Overcurrent protection circuitry prevents damage from overcurrent at both the input and output sections.

### 7.3.2 Specifics on Main Propulsion Inverters -

Voltage input	336 to 260 V (inverters will not operate at input voltages less than 260 V)
Current input	190 A
Inverter output	65-220 volts 3 phase 3 - 50 Hz $I_{eff} = 160$ A (max.) Power = 62 KVA at .75 pf active power 46 KW Efficiency - 94% for motor output of 25 hp 78% for motor output of 5 hp
Cooling	Blower (2 speed) If blower fails, motors can be operated up to a maximum of 400 r.p.m.

7.3.3 Inverters for Positioning (Rotation) Motors - The two fixed frequency inverters provide a square wave output using a transformer center tap connection with silicon controlled rectifiers. They are arranged to permit reversing of the Pleuger type H5-S-10-4 positioning motors. Overcurrent circuitry is provided to protect against damage from overcurrents at both the input and the output sections.

### 7.3.4 Specifics for Positioning Inverters -

Full load rated output	3 KVA
Efficiency	85%
Cooling	Passive
Voltage input	168 V (Nominal)
Voltage input	135 V (Minimum)
Input current	30 A
Output volt	168 V (Nominal, 60 Hz) (Square wave)
Output volt	135 Minimum 60 Hz S.W.
Output current	30 A (Max.)

7.3.5 Position Inverter Selector - Located adjacent to the mode switch. This switch is used to direct the output of the two 3 KVA inverters. This switch should only be operated when the rotation motors are secured.

7.3.6 Propulsion Inverter Selector - Located in the main distribution panel. The ZA switch is used to direct the output of the two 60 KVA inverters. Throttle must be off before ZA can be operated.

7.4 General Description of Propulsion Motors - The propulsion plant of BEN FRANKLIN consists of 4 propulsion units, each of them composed of a Fleuger submersible propulsion motor, type AE 16-4-25, with a 4-bladed bronze propeller, a thrust nozzle and 2 stabilizing fins to compensate the hydraulic forces in case of diagonal flow. The motor is streamlined by fairings that are made of fiber glass reinforced resin. Both the current supply cables and the two cables of the RPM-transmitter, which is installed into the motor near the front shaft end, come out of the motor underneath the front fair water cap and go to the pressure resistant cable connections which are outside the motor and protected by a plastic rail. The motor is completely filled with a water antifreeze solution. The solution serves as cooling for the windings, lubrication for the soft rubber journal bearings and axial bearing, and pressure compensation underwater pressure which has access to the interior of the motor via a compensating diaphragm. The submersible propulsion motor is flanged to the hollow shaft of the training gear. The training gear is designed as a two-stage worm gear with a total transmission ratio of

1 : 1200. The worms, the worm wheels, and the rotatable shaft move in roller bearings. Lubrication is secured by a high-efficiency lub. oil with which the gear housing is completely filled. At the training gear, too, the underwater pressure is equalized by means of a compensating diaphragm. Both the gear housing and the propulsion unit connection column are designed as bending beams and transmit the forces, resulting from the weight and the propeller thrust, to the hull. The training gear is driven by a Pleuger positioning motor, type H5-S-10-4. This motor is also filled with a water/anti-freeze solution and pressure-compensated by a diaphragm. Its capacity of 0.5 HP at 1720 RPM is transmitted to the training gear by means of a claw coupling. All shaft bushings are sealed with shaft sealing rings. The training gear allows an upward and downward turning movement of  $180^{\circ}$  each. The total range of turning over  $350^{\circ}$  is limited by 2 micro-switches which are mounted into oil-filled and pressure-compensated housings. The turning position is given to the position indicator, which is installed inside the boat, by means of a multi-turn potentiometer, also fitted into an oil-filled, pressure-compensated casing. The multi-turn potentiometer, as well as the two micro-switches are fastened to a cover at the back of the gear housing. The turning of the rotatable shaft is transmitted to the multi-turn potentiometer with a gear ratio of 1:10. The micro-switches are operated by controllable trip cams. The training gear has no mechanical end-stop.

The cables coming from the propulsion motor go through the hollow rotatable shaft to the back of the gear housing and are fixed here by means of a clamp. During the  $180^{\circ}$  turning in either direction the cable bunch is twisted without any significant mechanical strain. The cables are also fastened to the gear housing together with the cables of the training motor by means of a connecting strip.

7.4.1 Rotor With Propeller Shaft - The rotor consisting of laminations, short circuit rods, short circuit rings and balance rings, is mounted onto the hollow shaft. The trunnions of the hollow shaft are made of stainless steel. The torque is transmitted from the hollow shaft to the propeller shaft by a shrink fit connection. The propeller shaft end with propeller is supported by a sea-water lubricated shaft bearing. All radial loads affecting the propeller are taken up by this bearing, thus being kept away from the two rotor bearings.

7.4.2 Stator With 3-Phase Winding and Connected Cable - The stator laminations, fixed in the stator casing, are protected by a special corrosion proofing treatment. The stator slots, housing the motor windings, are sheathed with insulating linings. The winding coil bends protruding from the stator front faces, are conveniently cooled by the circulating water inside the motor. The winding ends are connected to the flexible rubber insulated power cable. Inside the motor, the cables are fastened by cable clamps. The connections between cable and winding ends are insulated and made water-proof by vulcanization.



- 7.4.3 Rotor Bearings - The two rotor bearing housings are fixed at both ends of the stator tube. The rubber bearing bushings are pressed into the bearing housing.
- 7.4.4 Propeller Shaft Bearing - The propeller shaft bearing housing is flanged to the corresponding rotor bearing housing.
- 7.4.5 Shaft Seal - The shaft sealing is mounted to the propeller bearing housing and is flexibly supported to absorb oscillations of propeller shaft. The main purpose of the sealing is to prevent entrance of sea water and impurities into the motor.
- 7.4.6 Thrust Bearing - The thrust bearing is located at the motor end opposite to the propeller, and consists of a thrust bearing block and two thrust bearing rings. Depending on the respective sense of rotation, the corresponding thrust bearing takes up the axial thrust, transmitting it to the motor frame.
- 7.4.7 Insulation and Corrosion Protection - The insulation of the electric cable is sea-water resistant. All other parts of the motor exposed to sea-water are either made of stainless steel, or protected by a patented treatment using synthetic resin at high enamelling temperatures.

7.4.8 RPM-Transmitter - The RPM-transmission takes place via a magnet wheel, two coils and a moving-coil instrument. Permanent magnets are attached to the circumference of the magnet wheel which is made of hard-PVC and mounted to the thrust bearing block. The coils are offset against one another by  $120^\circ$  and are fastened to the lower part of the motor. If the active rudder motor is running, the magnets of the magnet wheel pass through the poles of the iron core of the coil and generate in the coil an A.C. current. With the help of condensers and a rectifier this A.C. current is changed to D.C. current and displayed on the RPM-indicator.

#### 7.4.9 Technical Data - Propulsion Motor, 25 HP -

Motor: Design: Submersible threephase A.C. motor, water cooled, water lubricated single cage rotor:

Type: AE 16-4-25

##### Nominal Characteristics:

Output	N = 25	SHP
Speed	n = 710	RPM
Frequency	f = 50	c/s
Voltage	$U_n = 220$	volts
Power Factor	cos = 0.74	
Efficiency	= 80	%
Current	$I_n = 85$	amps

##### Starting Characteristics at 100 % $U_n$ :

Locked rotor current	$I_l = 340$	% $I_n$
Locked rotor power factor	cos = 0.36	
Starting torque	$M_s = 100$	% $M_{nom}$
Starting time	t = 0.5	sec.

Cables: Type: Submersible, rubber-coated and insulated

Number of leads	$z = 3$	
Cross section per lead	$q = 25$	sq. mm
Outside dia. per lead	$d_1 = 15 \text{ mm} = 0.6 \text{ in.}$	
Length per lead	$l = 3.3 \text{ m} = 10 \text{ ft.}$	

#### 7.4.10 Technical Data - Position Motor, 0.5 HP

Motor: Design: Submersible single-phase A.C. motor, water cooled, water lubricated, single cage rotor.

Starting condenser: 400 M F

Permanent condenser: 120 M F

Type H5 S 10-4

#### Nominal Characteristics:

Output	$N = 0.5$	SHP
Speed	$n = 1750$	RPM
Frequency	$f = 60$	c/s
Voltage	$U_n = 115-60$	volts
		(rectangular form)
Power Factor	$\cos = 0.5$	(Mean)
Efficiency	$= \text{ca. } 60$	%
Current	$I_n = 8.55-10.0$	amps

#### Starting Characteristics at 128 Volts:

Locked rotor current	$I_1 = 18.9$	amps
Locked rotor power factor	$\cos = 0.35$	
Starting torque	$M_s = 27$	cm kp
Starting time	$t = 0.1$	sec.

Cables: Type: Submersible, rubber-coated and insulated

Number of leads	$z = 3$	
Cross section per lead	$q = 2.5$	sq. mm
Outside dia. per lead	$d_1 = 8 \text{ mm} = 0.31 \text{ in.}$	
Length per lead	$l = 3.3 \text{ m} = 10 \text{ ft.}$	

## 7.4.11 Technical Data - Propeller -

4 Blades	Shrouded
Diameter	720 mm (28.35 in.)
Blade thickness	11 mm (.44 in.)
Hub diameter	185 mm
Weight	40 Kg
Material	Bronze
Max. RPM	720
Tip clearance	5 mm

7.5 Steering - The steering system consists of two rudders acting together aft of the battery housing, an electric motor located between the rudders and a control switch at the pilot's console. The motor operates in each direction and moves the rudder from left  $40^{\circ}$  to right  $40^{\circ}$ . Magnetic sensor switches stop the motor at the full rudder position and indicate this with a light at the console. A third sensing switch indicates (at the console) when the rudder is in the amidships position.

Normal steering is accomplished by differential operation of the propulsion system.

#### 7.5.1 Specifics on Steering Motor -

Motor:	Horsepower	0.34
	R.P.M.	8 (shaft)
	Power	0.25 KW
	Power Supply	110 V 30 cps (from 3 KVA inverter - switch on main distribution panel chooses inverter)
	Compensation	Oil, bladder, (TURBO OIL 33)
	Penetrator Used	B-6 (9 1 mm wires, spliced together in groups of 3)

#### 7.5.2 Specifics on Rudder -

	Number	2
	Area	1521 sq. in. each
	Total Effective Area	1521 sq. in
	Deflection	40° either side of amidships

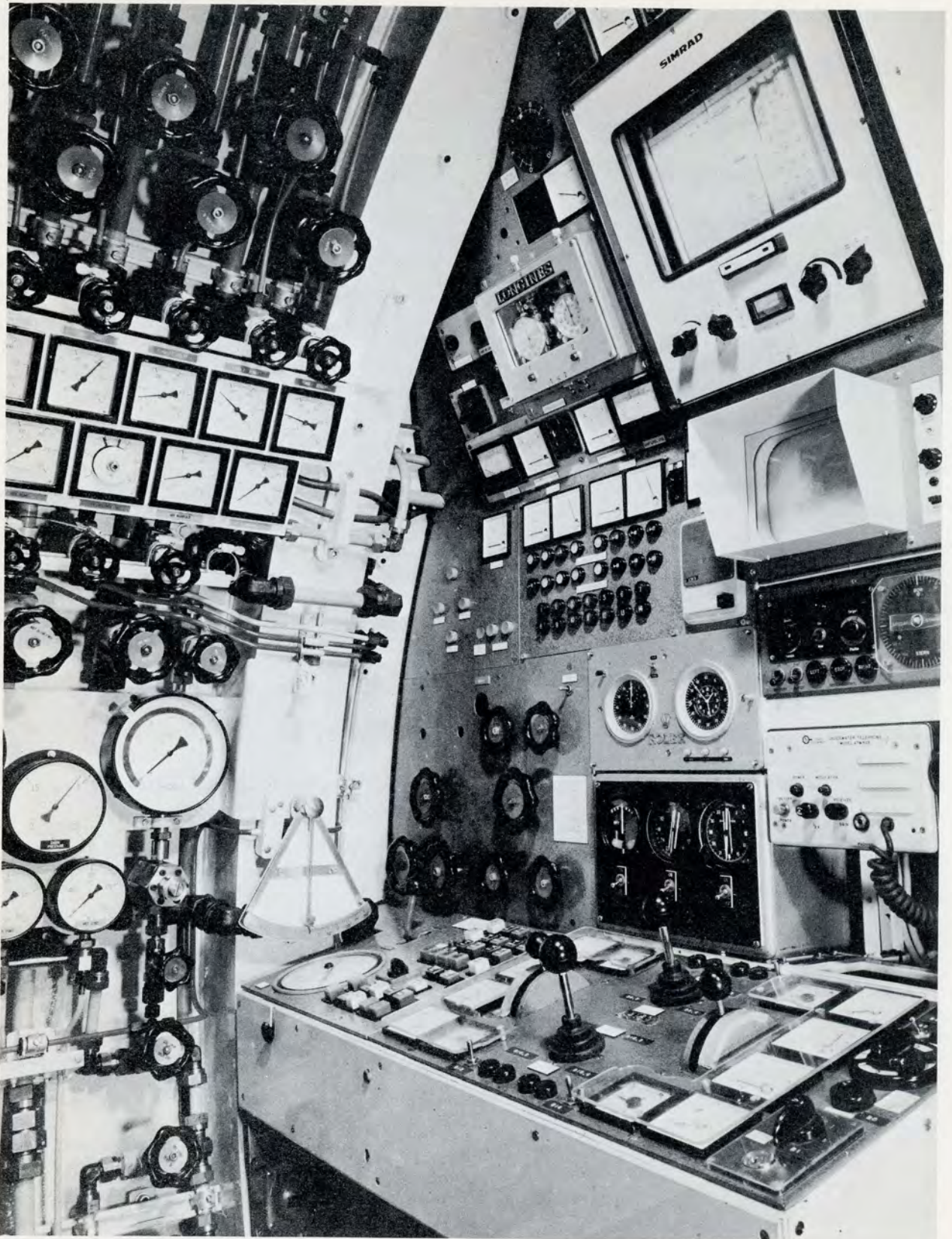


Figure 7-1 Pilots Panel

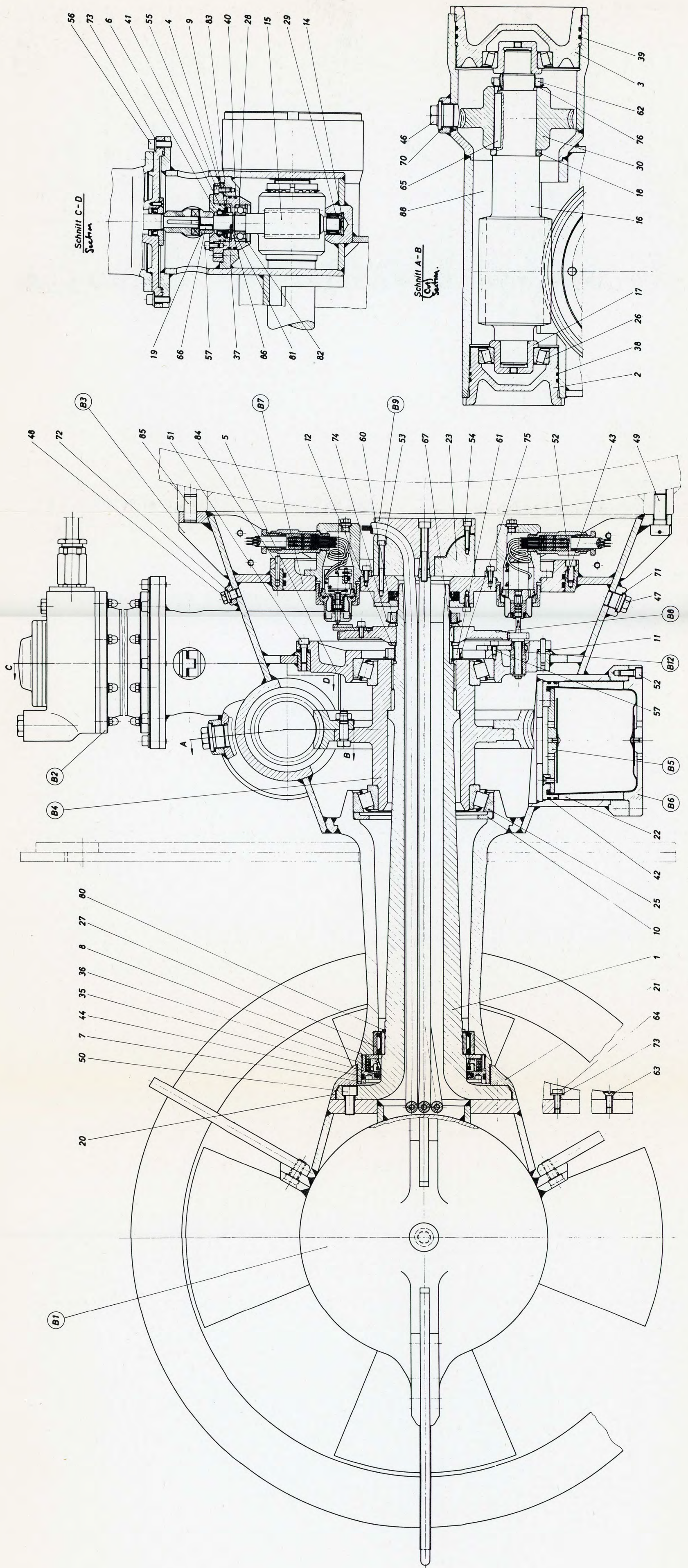


Figure 7-2 25 HP Motor Section

## SECTION 8.0 - INSTRUMENTATION & ELECTRONICS

The following equipments are part of the basic submersible systems. Additional equipments will be added as required by the missions planned.

8.1 Sensor Circuits - This system consists of the salt water sensors, hydraulic pressure alarm and the demagnetizing current alarm.

8.1.1 Salt Water Sensors - These sensors are located as follows:

- 1) MBT's - There are two sensors in each tank upper and lower. The upper indicates when the tank is full and the lower indicates the tank is partially full. If both lights are off, the tank is empty.
- 2) Battery Manifold Reservoir - indicate salt water level at four points: Normal, 1/2 full, 3/4 full, full.
- 3) Battery Vent Valve - Each vent valve has an indicator that is energized when salt water has filled the vent valve reservoirs, line to the valve and bottom of the valve. The sensors are actually located in the bottom of the vent valve.



8.1.2 Hydraulic Pressure Alarm - The hydraulic pressure gage located downstream of the accumulator has a device set to indicate when pressure drops below a set value. The indicator is an audio alarm and light.

8.1.3 Shot Dribble System - When the shot ballast is being held by the 28V DC dribble system, a loss of 28V current to the coils will be indicated by an audio alarm and warning light.

8.2 Compass/Turn and Bank Indicator/Gyro - This equipment, standard aircraft gear, consists of three indicators - turn and bank, gyro compass, and remote reading magnetic compass. The system is designed to operate at voltages of 22.5 to 31.5 at 0° to 35°C at a saturated humidity level.

8.2.1 Magnetic Compass (magnesyne) - Located in the sail, this equipment is supplied with 400 Hz, 26 volt, 3 phase power from a static inverter (Ministor RIC-327) in the indicator panel at the pilot's console. Input to the inverter is 28 VDC. The remote reading indicator at the pilot's console should not deviate more than 2° from the master compass in the sail. A compensator is provided for the purpose of reducing compass deviations on north-south and east-west headings. The compensator is adjusted with a single screw. With the transmitter heading north, a slight turn of the north-south compensator

screw off the zero position in a clockwise direction will cause a rotation of the indicator pointer in a clockwise position. With the transmitter heading east, a slight turn of the east-west compensator screw off the zero position in a clockwise direction will cause a rotation of the indicator pointer in the clockwise direction.

8.2.2 Directional Gyro - This component, Type IUN 1272 (equivalent to Sperry Type T514), operates at 30 v 800 cps 3 phase power supplied by a Ministor CV330A-27 inverter. The inverter is supplied with 28 VDC. The gyro must be reset approximately every 15 minutes from the magnesyn compass.

8.2.3 Turn and Bank Indicator - This aircraft indicator is used to provide roll and rate of turn information. It requires a 40 second warm-up.

8.3 Chronometer - A specially designed chronometer based on an electronic timepiece is installed directly above the propulsion panel. This battery operated clock/timer, supplied by Rolex of Geneva, was designed for an accuracy of 100th of a second per 24 hours.

8.4 Temperature Sensors - Two sensors are installed - one on the upper port side of the sail and one where the keel joins the hull - port side forward. An indicator on the pilot's console can be switched to read either sensor. The sensor

consists of a fine wire of known resistance. Temperature causes the resistance to change and this is calibrated to read temperature.

8.5 Depth Sensors - Located under the TV periscope mast in the sail, a two liter reservoir provides an interface between sea water and hydraulic oil. Sea pressure is transmitted via hydraulic lines to penetrator reinforcement B-2 and to three depth gauges - shallow, deep and recording. The system uses MARCOL 70 mineral oil.

8.6 Depth Recorder - A recording depth gauge is provided just behind the pilot's seat. The gauge operates between 0 and 800 meters and is powered by a wind-up motor 8-day clock. Two indicators are provided - an ink recorder (depth versus time) and a dial presenting actual depth. The equipment used aboard the BEN FRANKLIN is Model 89 RE built by HAENNI S.A. of Jegenstorf, Switzerland.

8.7 Depth Gauges - Two depth gauges are provided in addition to the recording gauge - a shallow and a deep gauge. Both indicate sea pressure (depth) at the centerline of the hull.

8.8 Radio - A Simpson 150-A radio telephone is installed for use with a C/P Shakespeare 9-foot fiberglass whip antenna. A multi-wire type penetrator is used for this system.

## Brief Description:

Channels	8 (crystal controlled)
Frequency Range	2 to 5 mc
Power Supply	28 V DC
Transmitter Power	150 Watts
Power Output	96 Watts
Current Drain	Receive: 2.5 amps Transmit: 30 amps
Weight	31 pounds

8.9 Intercom - A simple battery powered system is provided throughout the boat.

Unit Locations: Pilot's Console

Amidship

AFT

8.10 Sail - Pilot's Console Phone Circuit - Two sound powered telephone circuits are provided for communications between the sail (bridge) and pilot's console. Normally, handsets are connected to one circuit and full headsets to the other.

8.11 Underwater Telephone - One Straza ATM-503 is provided at the pilots' console. It can be switched to a vertical transducer located on deck amidships or a horizontal transducer just below the forward hemisphere. The Straza ATM-503 is a single

side band, suppressed carrier, underwater telephone which operates in a frequency range of from 8.3 to 10.7 KC. It is compatible with the Navy AN/UQ-1 and AN/PQC (diver held) underwater sound communication set and has a range of over 7500 yards. The unit is small and contains transistorized circuits mounted in plug in circuit boards.

Quick reference data:

Primary power - 24-28 VDC, 13 watts max (transmitting)

Power to transducer - 5 Watts

Carrier frequency - 8.087 KC (KHz)

Range - 7500 yds.

Horizontal directivity pattern - Omnidirectional

Vertical directivity pattern - 50° beam width

8.12 Fathometer - A SIMRAD (Oslo, Norway) model EP2BN fathometer is mounted on the pilot's console. Two transducers are located in the forward part of the battery housing (chin mount), one directed downward and one directed forward. The forward looking transducer provides an auxiliary obstacle avoidance capability.

Reference data:

Power Supply - 24 V DC

Power Consumption - 80 watts

Time per paper roll - 70 hours

Frequency - 38.5 KC

Weight - 30 Kg

Scale ranges -	<u>Feet</u>	<u>Fathoms</u>
	0-240	0-240
	180-420	180-420
	360-600	360-600

Motor/Converter - Type GW<sub>2</sub>4360

8.13 CTFM Sonar - For obstacle avoidance, the BEN FRANKLIN has been provided with a Straza model 500. The equipment consists of a projector and hydrophone (both mounted on the forward upper part of the sail). The circuitry is completely transistorized and the equipment is designed to operate at unlimited depth by the use of oil filled pressure compensation techniques. The Sonar unit consists of a training mechanism projector, receiving hydrophone, Sonar unit, display unit, and analyzer.

The display unit (PPI unit) is monitored visually to detect and view returns from underwater objects lying in a volume  $\pm 7.5$  degrees vertically and  $\pm 90$  degrees horizontally about the longitudinal axis of the vehicle at ranges of 10 to 1500 yards. In addition, an aural signal is available to enable the operator to monitor the target return signals by means of a speaker or headset.

#### 8.14 Pinger (Underwater Acoustic Tracking & Ranging System) -

This system allows the support vessel to determine the direction and range to the BEN FRANKLIN. The equipment consists of a transponder-pinger, receiver antenna, and readout module.

The transponder transducer is located on the main deck near the after hatch. The transponder, upon command of the support vessel, transmits an acoustic signal into the water through an omnidirectional transducer-preamplifier. The readout module is self-contained, battery operated, and has a meter readout for range.

Separate frequencies are used to separate the tracking pulse from the ranging pulse.

From inside the submarine, the transponder can be energized to send a continuous or momentary signal. The transponder however, would normally be set in the OFF position from which it can be energized upon command of the tracking station on the support vessel.

8.15 Topside TV - A Grundig-Electronic Fernange FA30 closed circuit television set is provided for use as a simple periscope system. The camera is located on top of a mast in the sail and the console is located at the pilot's console. A rotation motor is located in the base of the mast and is controlled from a switch at the console. The equipment is transistorized and operates with a power supply of 24 Volts DC. It will operate in a temperature range of  $-15^{\circ}\text{C}$  to  $40^{\circ}\text{C}$  ( $5^{\circ}\text{F}$  to  $104^{\circ}\text{F}$ ) with a power consumption of 25VA.

8.16 Underwater TV - The Hydro Products Model TC303 "Hydro Eye II" television system, mounted just forward of the keel, is a complete self-contained camera, designed specifically for underwater applications. The system is composed of the camera, LQ10 Thallium Iodide lights, Model TM8-C Conrac monitor with power supply, remote focus control, and Model RP-3 pan and tilt unit. The pan and tilt unit is a remote controlled



manipulator operated from a joy stick aboard the submarine  
 It develops 18 foot pounds of torque to accommodate a heavy  
 load in strong currents.

8.17 Battery Monitoring Panel - This compact system includes  
 the necessary meters for monitoring the state of each battery  
 string (14 or 28 cells)

Ampere hour meters (counters)

Digital Voltmeter

System for detecting ground currents

8.17.1 Ampere Hour Meters - There are 6 meters to read: A1,  
 A2, B1, B2, C and D batteries. Full capacity for each battery group is  
 1000 AH except for the D group which is 3000 AH. The equip-  
 ment is accurate to 0.1% and was manufactured by ACROMAG -  
 series 1300 integrator. Power for the meters is provided by a  
 110 V AC built-in inverter fed from the 28 V DC bus.

8.17.2 Voltmeter - In order to read the voltage of each  
 battery string (14 or 28 cells) a digital voltmeter Model 353  
 is included in the panel. The equipment operates off the 100  
 V AC power and has a built-in inverter fed from the 28 V DC bus.

8.17.3. Ground Selection - Ground readings on all external equip-  
 ments except the battery system is accomplished by using a meg-  
 ohm meter. The system for measuring grounds on the battery  
 system uses a precision resistor and digital volt meter to

measure battery string voltage and voltages to ground. The precision resistor is used in parallel with the digital voltmeter to load the ground circuit. The measured string voltage (E), voltage to ground from the positive leg (Vp) and voltage to ground from the negative leg (Vn) are used with the Nomogram of Fig 8-1 to determine resistance to ground (Rt). Any low values of Rt can be calculated using the formula given.

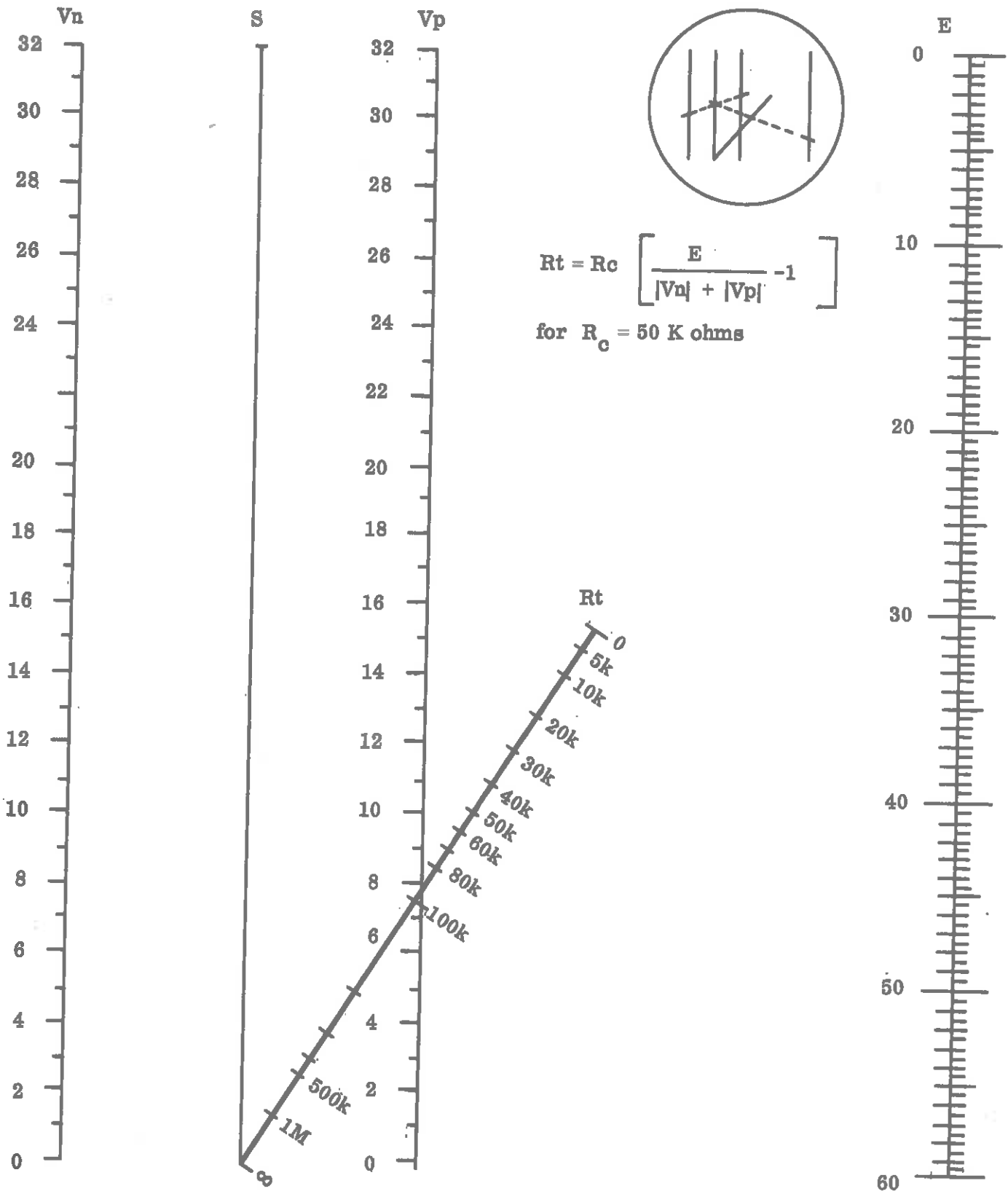


Figure 8-1 Resistance Nomogram

## SECTION 9.0 LIFE SUPPORT

9.1 CO<sub>2</sub> Removal System - Carbon dioxide removal is accomplished passively by absorption on LiOH panels strategically located throughout the vehicle. Diffusive and natural convection currents circulate the atmosphere through the panels. Three portable blowers are included as part of the system to be used to aid in circulation during those periods in which natural convection is not adequate.

Each panel contains more than enough LiOH to remove the CO<sub>2</sub> generated by one man per day, however, because of panel surface limitations, (CO<sub>2</sub> removal rate per panel ( $\text{g}^{\text{m}}$  CO<sub>2</sub>/hr) is roughly 1/3 the generation rate per man ( $\text{g}^{\text{m}}$  CO<sub>2</sub>/hr)) it is necessary to expose 3 panels per man. Thus for a six man crew it is necessary to expose 18 fresh panels, which will last approximately 3 days before needing replacement. The panels are located throughout the vehicle.

Once the vessel is sealed, CO<sub>2</sub> readings must be taken every 4 hours. Normal CO<sub>2</sub> buildup may reach the 1 - 1.5% range. This level may vary reaching a maximum when crew activities are highest, and a minimum when activities are lowest.

CO<sub>2</sub> readings are to be made with the Dwyer Analyser. This instrument should be checked daily with the Fyrite Analyzer and a CO<sub>2</sub> Drager tube. Operating instructions for these instruments

are found in the Life Support System Operational Manual as well as in the equipment carrying case.

When CO<sub>2</sub> levels reach 1.75% and remain in this range for a minimum of 4 hours (2 readings) LiOH panels should be changed. This should represent an average panel exposure time of 3 days. Again, care in preventing panel dusting should be exercised when removing the old panels and mounting new ones. Used panels are to be replaced in their original plastic bags.

9.2 Oxygen Supply & Regulation - Oxygen for the PX-15 is stored as a cryogenic liquid in two standard Linde LC-3GL cylinders each of which holds up to 250 pounds of O<sub>2</sub>. Operation of the system requires that O<sub>2</sub> consumption be greater than normal O<sub>2</sub> boiloff to prevent a hazardous buildup in O<sub>2</sub> partial pressure. Because normal boiloff is approximately 3.75 lb/tank/day, two tanks should be used only when four or more crew members are on board. For less than a four man crew only one tank should be used.

9.3 Temperature Control: (Gulf Stream Drift) - Because of moderate Gulfstream temperatures (average water temperature 15°C (59°F), temperature control for the PX-15's maiden mission is passive. Using the sea as a heat sink, bare sections of the hull's interior surface will conduct heat out of the vessel. Internal temperatures have been estimated to range between 63°F and 83°F for corresponding sea water temperatures of 50°F and 70°F. The average vehicle temperature is anticipated to be 73°F.

These numbers are based on a sedentary activity level for the crew and an average power drain of approximately 250 watts by the internal electrical equipment.

9.4 Humidity Control - Humidity control is accomplished passively by allowing moisture to condense on the bare sections of the hull interior. Thus relative humidity (RH) becomes a function of the temperature difference between the inner hull and the vehicle interior. A 10 degree difference yields a RH of approximately 70 percent, 13 degrees - 65% and 15 degrees - 60%. As the moisture is condensed, on the hull it runs into a catch trough that carries it into the waste water storage tank. A small dehumidifier is available on board for use as required. A back-up supply of desiccant (silica-gel) is also available to absorb moisture.

9.5 Atmospheric Pressure - The internal pressure of the PX-15 will be maintained at approximately sea level conditions (14.7 psia). However under normal operating conditions, the internal pressure may vary from a low of 13.5 psia to a high of 16 psia.

These changes can be expected when the sea level temperature (when bottoming up) varies a great (30°F) from vehicle interior temperature. Slight pressure changes 10 - 25 mmHg can be incurred by normal variations in O<sub>2</sub>, CO<sub>2</sub>, and H<sub>2</sub>O partial pressure. Pressure is indicated by a helicoid compound pressure gage. (15 psia -0-30 inches Hg vacuum)

9.6 Contaminants Removal - Contaminant removal for the PX-15 is accomplished in the following manner:

- o Continuous passive removal of contaminants by LiOH and activated charcoal, both of which are provided in the CO<sub>2</sub> removal panels.
- o Intermittant active removal of contaminants by the odor removal (purafil) cartridge in the toilet.
- o Periodic active removal by the portable contaminant removal system (operated as needed)

CO<sub>2</sub> Removal Panels

LiOH (lithium Hydroxide)

Activated Charcoal

Toilet Odor Removal Cartridge

Purafil

Portable Contaminant Removal System Cannisters

#18 Activated Charcoal

Kalite  
Hopcalite  
Acamite

#19 Activated Charcoal

Purafil

#20 Activated Charcoal

Hopcalite

Contaminants removed by each of the above are the following:

- o LiOH in addition to its primary function of removing CO<sub>2</sub> will also remove acid gases such as HCl and H<sub>2</sub>S.
- o Activated Charcoal - A small quantity of activated charcoal is provided along with the LiOH in the CO<sub>2</sub> scrubbing panel and in each of the portable contaminant removal system cannisters. It absorbs organic vapors, odors and ammonia.
- o Purafil - This material is pelletized activated alumina impregnated with potassium permanganate. It is found in the toilet odor removal cartridge and cannister #19. Purafil will remove odors, organic vapors, organic acids, phenols, sulphides, and oxides of nitrogen.
- o Hopcalite - This substance is found in portable contami-



removal cannisters #18 and #20. It is a catalyst and has a primary function of oxidizing CO to CO<sub>2</sub> (also handles aldehydes, alcohols, etc.)

- o Acamite - Found in portable contaminant removal cannister #18, absorbs alkaline gases (NH<sub>3</sub>) and also acts as a drier.
- o Kalite - Found in portable contaminant removal cannister #18, absorbs acid gases (HCl, H<sub>2</sub>S, etc.)

9.7 Waste Management System - The waste management system chemically treats and stores metabolic wastes onboard the vessel. A schematic of the system is presented in Figure 9-1. Waste wash waters from the sink and shower are collected in a waste wash water storage tank from which flush water is drawn for the toilet. As the toilet is flushed, germicide is automatically metered into the exit stream. The wastes then enter a macerator where they are simultaneously pulverized and thoroughly mixed with the germicide. The treated wastes are held in the macerator between toilet uses. It is during this period that biological organisms are inactivated. Wastes are then pumped from the macerator into the waste storage tank where they remain until the tank is cleaned.

Toilet odors are handled by a blower which draws air through a cannister filled with purafil. Storage tank odors are handled by a vent line that feeds into the odor removal cannister.

Two waste tanks are installed - a "mini waste tank" and "waste storage" tank. The mini waste tank collects water from the three sinks and shower. This tank stows the water for use in flushing the toilet. The waste storage tank is used to stow human waste received from the chlorinator.

The wash water storage tank is to be initially primed with 10-15 gallons of fresh water. At the conclusion of a mission, the tank is cleaned out.

9.8 Contaminant Detection - Trace contaminant detection of the PX-15 is accomplished with Drager type gas detector tubes, a method requiring no power. Forty different tubes, many of which detect more than one contaminant, will be used. Measurements are made by breaking the tips off the tube and inserting them into a hand operated bellows pump.

Pumping a specific number of times for each contaminant, air is drawn through the chemical filled calibrated tube. The chemical discolours lengthwise proportionally to the contaminants concentration in the atmosphere.

Gaseous contaminants certain to appear in the atmosphere of the PX-15 are those resulting from the crew's metabolic processes. In addition to the metabolic contaminants it is possible that other trace contaminants may be generated by on-board equipment, surface finishes, lubricants, etc.

9.9 Atmosphere Exchange System - The function of the atmosphere exchange system is to purge the vehicle atmosphere and replenish with fresh air. The system consists of a portable blower to which is attached approximately 30 feet of flexible ducting.

The system is to be used when:

- o Smoke due to a fire or insulation breakdown has filled the vehicle.
- o The CO<sub>2</sub> level has reached 3.0 percent.
- o The O<sub>2</sub> partial pressure has reached a hazardous level (above 25%).
- o A trace contaminant level has built up and cannot be removed by the contaminant removal system.

9.10 Potable Water System - The potable water supply consists of both hot and cold water. The cold water is stored in four saddle tanks each of which hold approximately 95 gallons and the hot water is stored in four super insulated tanks each of which hold 50 gallons. The tanks are initially filled with cold fresh water from dockside. Two inline filters remove gross particles and bacteria. A second bacterial filtering is performed as the water is drawn from the cold water tanks by another filter on the cold water discharge line. Hot water is prepared by using the electric immersion heaters in the insulated tanks.

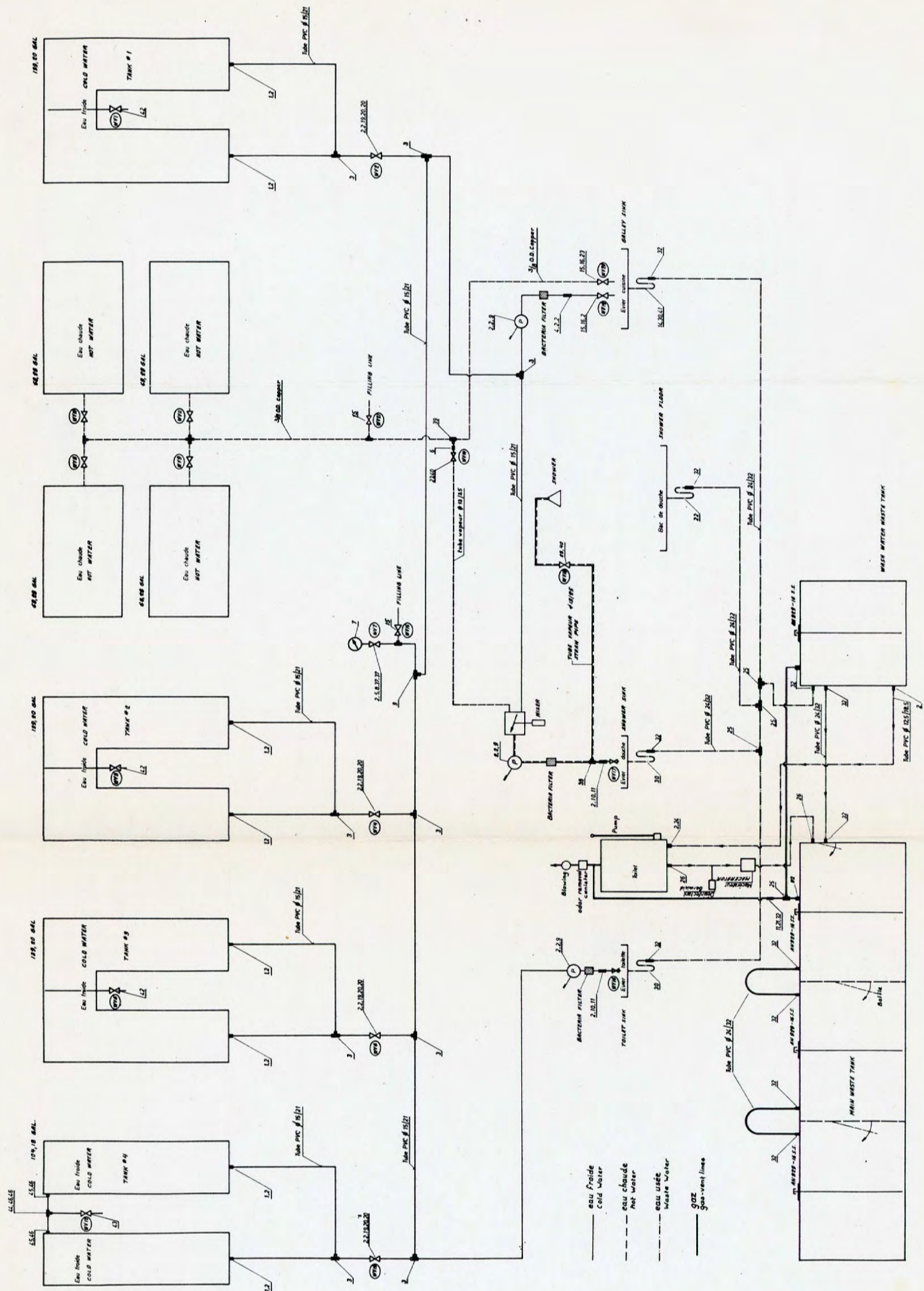


Figure 9-1 Life Support Schematic

## SECTION 10.0 - EXTERIOR LIGHTING

Lighting outside the hull is arranged mainly for underwater observation and color photography. The light source consists of forty 650 watt floodlights, (110 Volt D.C.) and thirty-four 150 watt (28 Volt D.C.) floodlights located in the underside of the MB tanks, the battery housing under the hull, in the sail and in the faring between the superstructure deck, main ballast tanks and shot ballast tanks. Three thallium iodide lights are provided for the underwater TV. If the boat is considered identical on port and starboard sides, the arrangement of the exterior lighting can be seen in Figure 10-1.

The side panels of all battery housing sections are provided with plugged holes which may be opened for the installation of further projectors or for the rearrangement of existing floodlights.

10.1 Navigation Lights - The port and starboard running lights are located on the sail and the stern light is located on the main deck aft of the hatch. These three lights use the same pressure proof bulbs as the 28 Volt 150 watt projectors. All other navigation lights are not pressure proof and are located on a portable mast that fits on the starboard side of the sail just forward of the sail access hatch. This mast, normally stowed inside the boat, is in the shape of a cross and constructed of anodized aluminum. The lights, 28 Volt, are plugged in individually where the mast is mounted in the sail. The following lights are fixed to the mast:

- o Xenon Flasher light (an emergency light to be used if the submarine is lost.
- o a rotating amber beacon (submarine identification light)
- o standard masthead light.
- o standard anchor light.

10.2 Underwater Lamps - These lights were designed to economize on weight and to ensure pressure resistance. High pressure seals use a conical shape (rubber) and "O" rings are used to provide low pressure sealing. The lamp bulb is protected by a glass tube with a hemispheric outside end, seated in a rubber seal. The whole lamp assembly is contained in a strong body casting which is screwed together.

Refer to Figure 10-2.

Connections in the base of the lampholder are designed to fit the rubber connections which are the same type used in the multi-electrical hull penetrators. The hollow base is filled with Araldite epoxy to prevent water penetration.

All floodlights are protected by fiberglass back covers which cover the lamp fitting in main ballast tanks and battery housings.

Lamp bulbs used are Osram 64640, 24V 150 watt, and Osram 64535 115-120V, 650 watt. Color temperature of the bulbs at rated

voltage make them ideally suited for underwater color photography.

10.3 Thallium Iodide Lights - Three of these Hydro Products lights are installed, two on the forward hemisphere for visual observation and one in the chin mount as part of the underwater TV system. These 250 watt green lights are equivalent to 2000 watt incandescent projectors since green light penetrates sea water most efficiently. Operating depth maximum is 8000 feet and input power is 110V A.C. (60 cps). A warm-up time of 7 minutes is required and the operating life is in excess of 5000 hours.

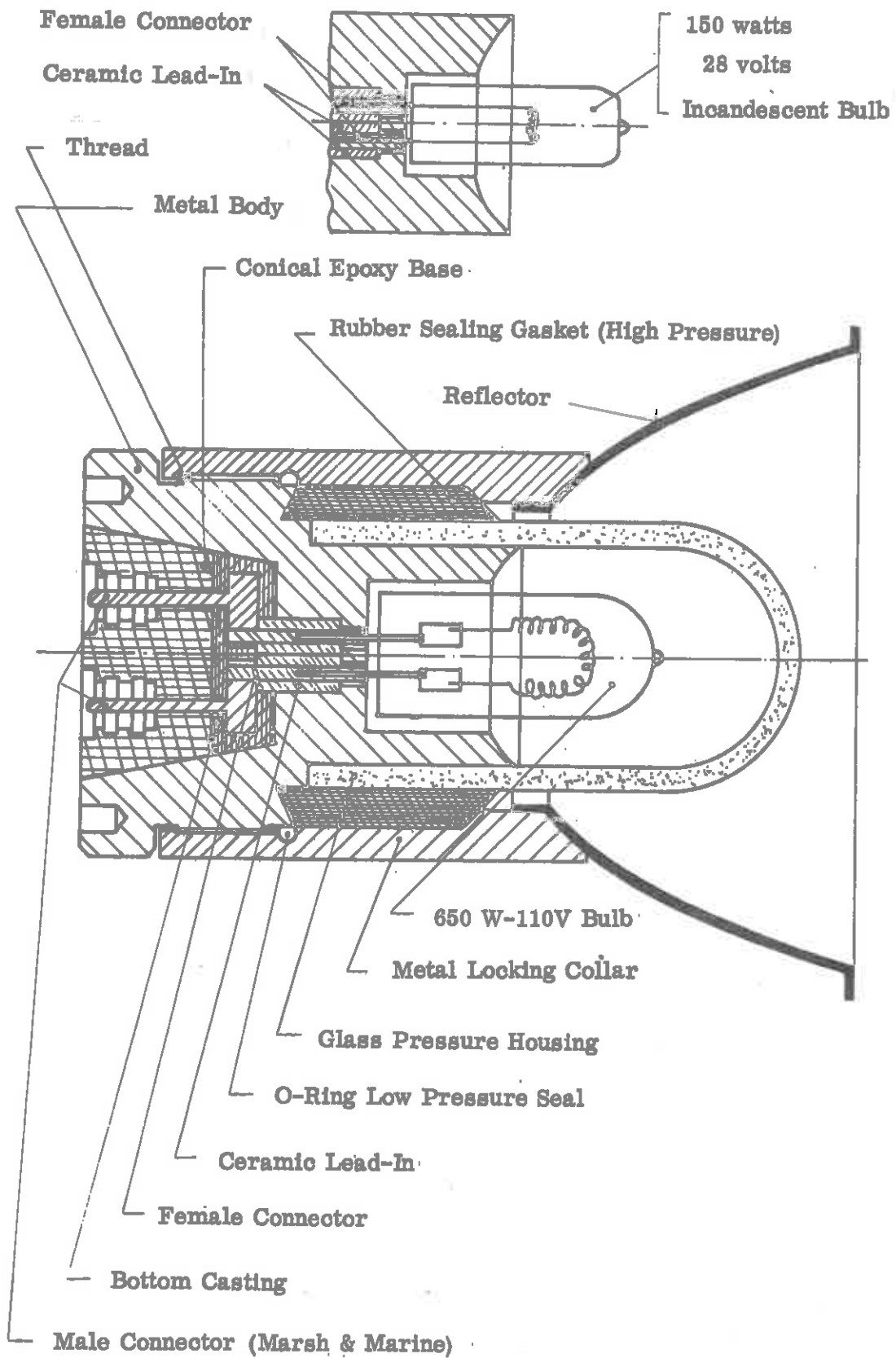


Figure 10-2 Light



External Locations of Lighting Additions to Piccard Lighting (Navoceano Not Shown)

Notes:

- I Ten (10) 250 Watt Halogen Lamps Coded 250 W H Located as Shown  
Part No.: LQ 5 (Hydro-Products Q-1)
- II Six (6) 500 Watt Halogen Lamps Coded 500 W H  
Part No.: LQ 10 (Hydro-Products Q-1)
- III Three (3) 1000 Watt Halogen Lamps (1000 W H)  
Part No.: LQ 1000 (Hydro-Products Q-1)
- IV Three (3) 350 Watt Thallium Iodide (TI)  
Part No.: LT6 (Hydro-Products)
- V Two (2) 1000 W Mixed Gas Arc Lights (MG)  
Part No.: HB 1000 (Luminetics "Hydro Blaze")

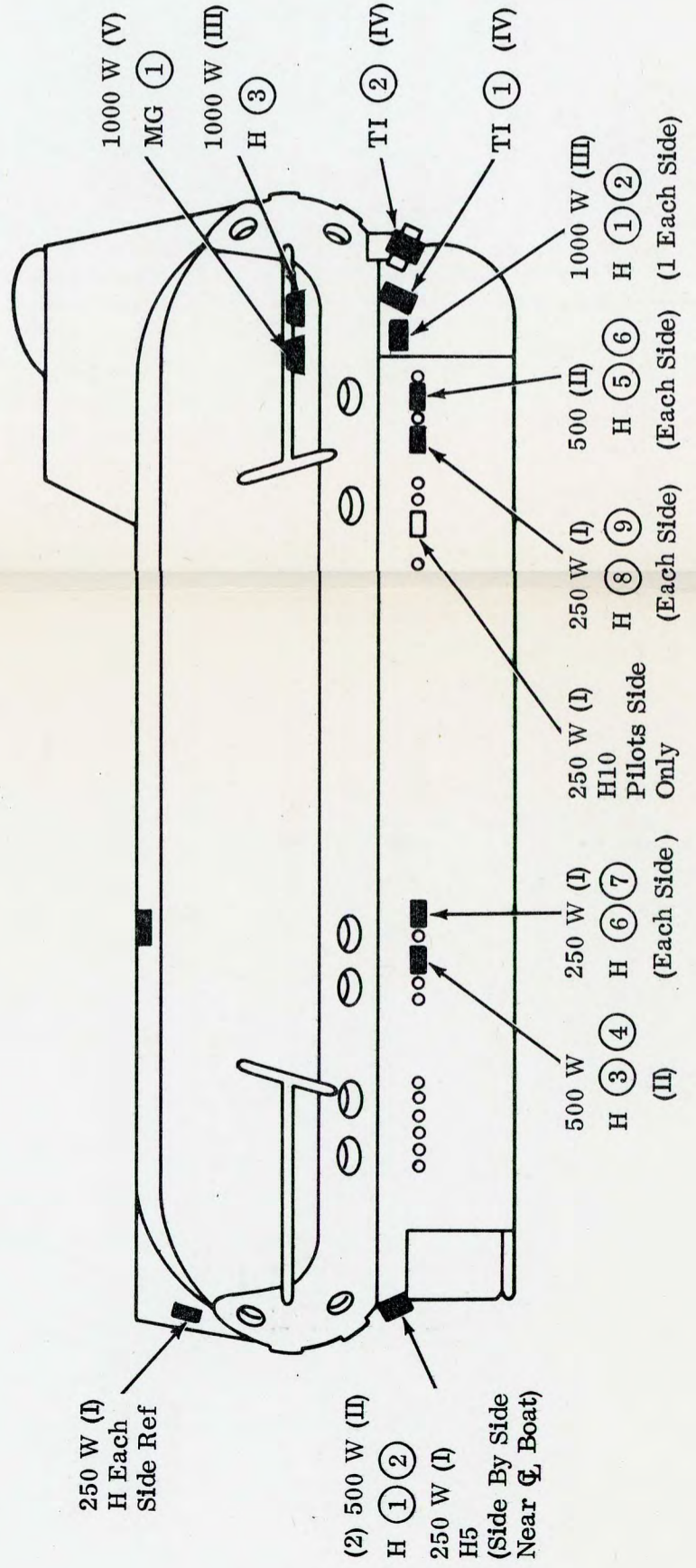
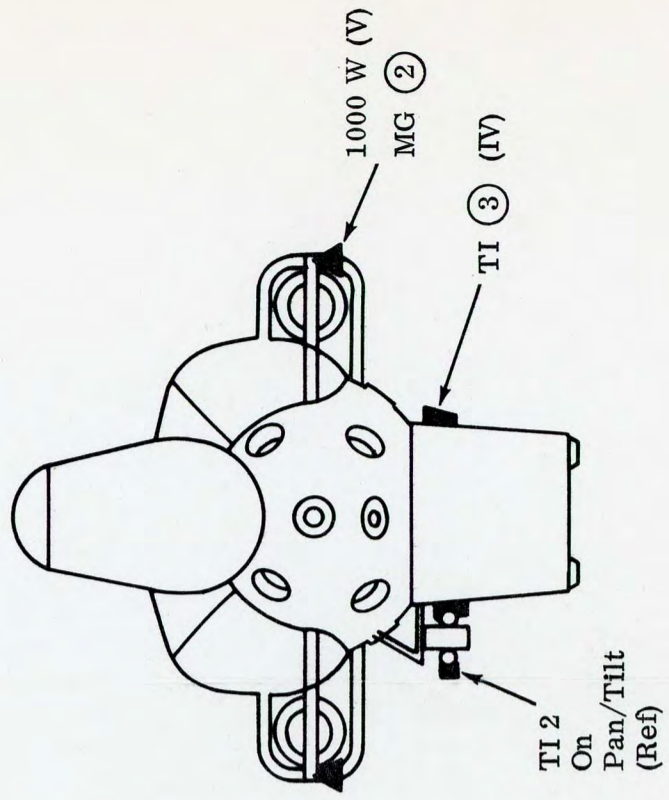
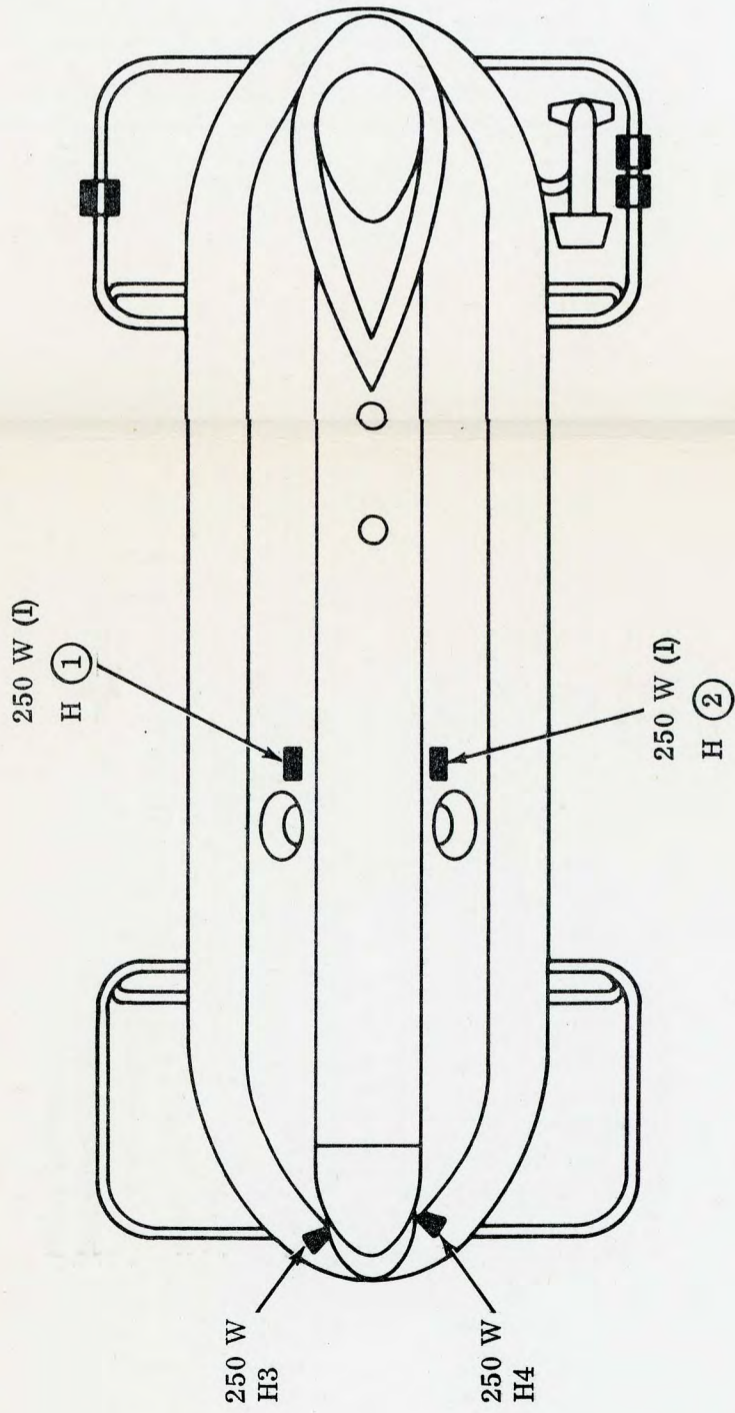


Figure 10-1 Lighting-External Locations

## SECTION 11.0 SAS AND SIMILAR EQUIPMENT

The designation SAS has been adopted from the French word "le sas" currently used as an idiom for an air lock or vestibule in French-speaking countries and is used as a reference during the construction of BEN FRANKLIN.

This small lock is used to send spheres with biological or water samples, rolls of film, recorder paper rolls, written messages or other articles to the surface. The metal spheres are approximately 5 inches in diameter and are made in two halves. A sphere is placed in a frame bolted to the SAS inboard hatch, the SAS flooded and the outside hull hatch opened by the hydraulic servo-motor. The sphere then rises to the surface, the outer hatch shut, and the chamber is blown dry with the air system.

11.1 Outer SAS Hatch - The SAS is located at the top of the hull between frames 6 and 7 and is set into a hull penetrator casting. The SAS hatch is a circular port - 310 mm outer face diameter - 150 mm inner, of cast steel and machined with conical edges to fit the conical opening of the hull casting. A small plexiglass view port is held into the hatch by a circular retaining steel ring recessed into the hatch cover with two "O" rings. Over each of these rubber seals, a steel Tecalto nipple is screwed into the metal ring for non-soluble grease packing. The inner diameter of the SAS hatch is 150 mm to allow for the passage of the spherical containers.

11.2 SAS Chamber - The chamber itself is a 244.5 mmx 20 mm wall pipe 110 mm long with flanges welded at top and bottom. An "O" ring is seated in the flange, the whole unit being bolted to the hull casting. The bottom flange is threaded to take the inner SAS hatch and has an inside diameter of 197 mm and finished with a curved surface for ease of drainage and cleaning. A drain hole at an angle of 15° to the horizontal base is joined by an Ermeto coupling to a drainage pipe. Inside, a vertical stand pipe, 96 mm long, is joined to the pneumatic system for blowing the SAS with compressed air.

11.3 Inner SAS Hatch - The hatch in the bottom of the SAS chamber is a circular steel fitting 36 mm thick, 200 mm in diameter threaded on the outside of the circular center piece to form a tight screw fit also with a O-ring seal. The center is machined out to take another plexiglass view port to permit checking on the inside of the chamber when flooded. To secure the plexiglass cone, as in the outer hatch, a retaining ring with an O-ring is held in place with 18 (4.2 mm) bolts. One Tecalto M6 steel nipple supplies the O-ring with nonsoluble grease.

Inside the SAS, the sphere is placed into a frame consisting of four vertical guide rods riveted into a circular base plate and bolted into the upper side of the inner hatch. Guide rods are in two sections, screwed together thereby retaining a metal ring which supports the sphere.

11.4 SAS Servo-Motor - Located outside the pressure hull above the SAS is a Hypramag HDK 100 servo-motor manufactured by Sudhydraulic, Marketoberdorf, W. Germany, which is used to open and shut the SAS outer hatch.

The motor is connected to the Hydraulic System via steel pipes through a hull penetrator casting. This hydraulic system circuit is normally kept at zero pressure. To operate the SAS hatch a selector lever on the pilot's console is moved to the SAS position. Another selector lever located next to the inner SAS hatch is placed in the open or shut position as appropriate. Hydraulic pressure to operate the SAS hatch is then provided by the hydraulic pump to the right of the pilot's console.

## SECTION 12.0 HULL PENETRATIONS

Along the top and bottom of the cylindrical section of the hull are strengthened sections - lemon shaped thickened castings welded to the basic hull. Seventeen or nineteen holes were machined in each casting in order to allow the passage of piping, single pole electrical cables, multi-electrical wire penetrators, and any special penetrators for items such as strain gages and TV cables. Refer to Fig. 12-1 for a typical casting. All of the penetrators make use of two seals-a flat neoprene rubber gasket for low pressure seal and a conical plexiglass insert for high pressure. The neoprene rubber gasket is compressed by a nut on the inside of the hull that holds the penetrator in place.

12.1 Pipe Penetrators - There are two sizes of pipe penetrators - 26 mm and 38 mm O.D. (12 mm and 19 mm I.D.) for approximately 3/8" and 3/4" pipe sizes. Carbon Steel is used for penetrators carrying sea water. A conical high pressure plexiglass seal is used to keep the penetrator watertight. Low pressure sealing is accomplished with a rubber gasket outside the boat.

Another rubber gasket is used on the inside of the hull where it is held in place by a nut which also holds the penetrator. The inside (hull interior) of each pipe penetrator is constructed to accept a flange fitting with O-ring to prevent sea water from coming into contact with pipe threads. On the outside (hull exterior) of each pipe penetrator, Ermeto (compression type) fittings are used. Refer to Fig. 12-1.

12.2 Blank Plugs - Several penetrations in the casting are not in use and are filled with a steel plug. Other than being solid, the plug is similar in construction to other penetrations. Refer to Fig. 12-2.

12.3 Single Pole Electrical Penetrator - For battery cables, main water cables, battery charging, and short power, a specially designed penetrator is used (refer to figure 12-3). The penetrator is basically a 13 mm dia. copper rod 215 mm long with a bronze machined collar on the outboard end. The rod is inserted in a plexiglass sleeve and the rod and plexiglass are placed inside a steel penetrator insert. The end of the insert is threaded and held in place in the interior of the boat. Two conical plexiglass surfaces provide a high pressure seal - one on the interface of the machined collar and penetrator insert and the other between the insert and penetrator hole. Other seals are as follows:

- o A flat rubber gasket between the hull and the penetrator insert (low pressure seal).
- o The bronze machined collar is covered with neoprene. The interface between this neoprene cover and the penetrator insert is a seal.
- o In the case of the battery penetrator, a neoprene boot (see figure 12-3) provides an additional seal for the entire outboard side of the penetrator.

The penetrator illustrated is used for battery cables, battery charging, and shore power. Figure 12-3 shows that the cable fits straight in to the penetrator. The end of the copper in the cable is flared around the pointed stud in the female connector which in turn mates with the male copper rod. The exterior of the penetrator is then covered with a neoprene boot. Connections to the main motor penetrators are made up the same as the intercell connectors. (See Figure 12-4)

12.4 Multiple Electrical Penetrator - For all circuits other than propulsion, battery cables, TV coax and strain gages, a specially designed penetrator is used. This unit is basically a steel shell (or insert) that is designed to carry (19) 1 mm<sup>2</sup> wires arranged in two concentric circles. Inserted into the outer shell of the penetrator is a neoprene plug with holes to hold one half of standard Marsh and Marine connectors (press fit into place). The 1 mm<sup>2</sup> wires are soldered to the connectors, knotted to prevent their flow into the hull and are fed through the penetrator which is then filled with epoxy. The Marsh and Marine connectors are filled with silicone

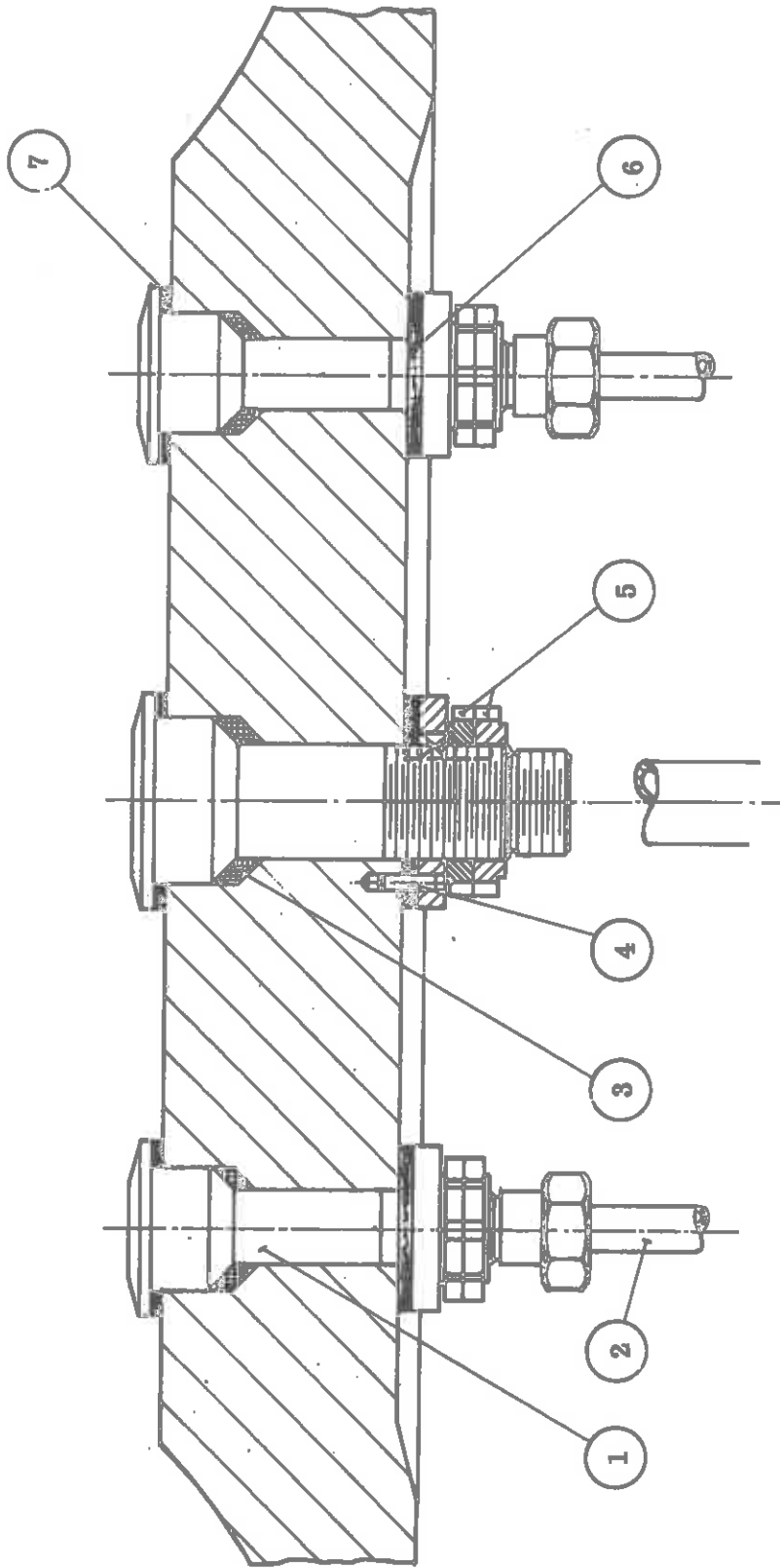
grease and sealed by the O-ring shape of the female end. The penetrator is held in place by a nut on the inside of the hull and is sealed by the same method as the other penetrators -- neoprene gasket for low pressure and cone shaped plexiglass for high pressure. Refer to Fig. 12-5.

12.5 DTMB (David Taylor Model Basin) - For the strain gage wires used aboard the BEN FRANKLIN, a DTMB penetrator has been modified to fit into existing hull penetrations. Eighty-four holes are drilled into a steel compression plug which leads the wires into holes drilled in a neoprene seal. The neoprene seal is a flat disc 5/8" in thickness that is squeezed down to 1/2" by the compression plug. This produces an extremely effective watertight seal around each wire. The wires are then fed thru the penetrator insert into the hull. The insert is filled with epoxy. The penetrator is held in place by a retainer ring which squeezes on an interior rubber gasket. Small screws hold the ring in place. Low and high pressure sealing is accomplished in the same manner as the other penetrators.

12.6 Mil-Spec-Multi Wire Penetrators - Standard receptacles and plugs per MIL.C-24217 are utilized with a typical penetrator adaptor for the "periscope" t.v. system and scientific equipment feed throughs. The receptacles are 316L Stainless steel, welded to 316L Stainless adaptors to form a penetrator unit.



The t.v. system uses a 37 pin, #16 AWG unit and all other units are 24 pin, #16 AWG. Adaptors for the 24 pin unit are made for both the 38 mm hydraulic fitting and the standard 20 mm electrical fitting, allowing use of any available penetrator casting. The plugs and receptacles are manufactured by Viking Industries and welded by Viking to adaptors manufactured by Grumman.



- 1. Penetrator
- 2. Pipe to Hull Valve
- 3. Plexiglass High Pressure Seal
- 4. Holding Screw - Several of These in a Circular Pattern for Large Pipe Penetrators
- 5. Holding Nut
- 6. Interior Gasket

Figure 12-1 Piping Penetrators

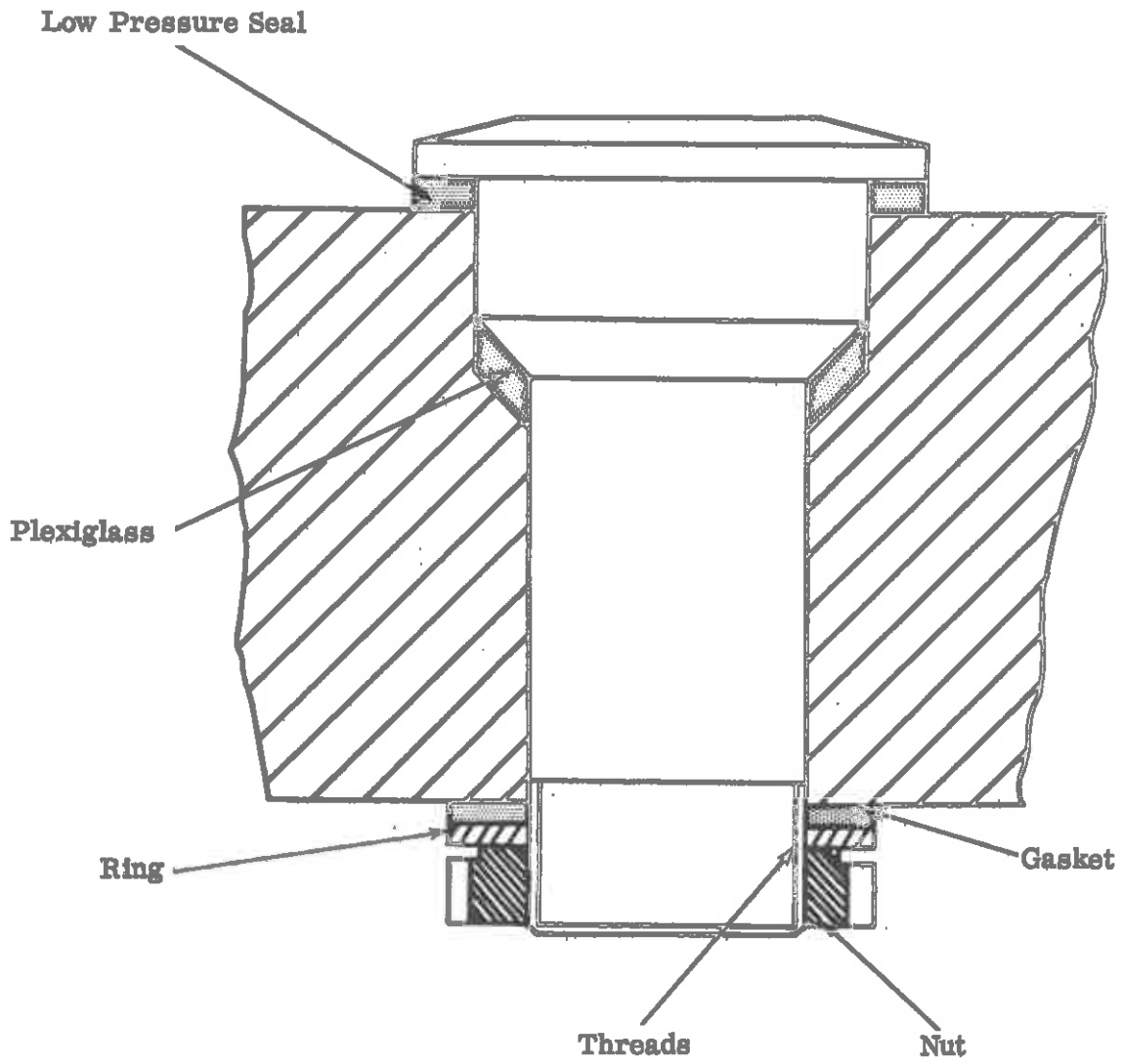
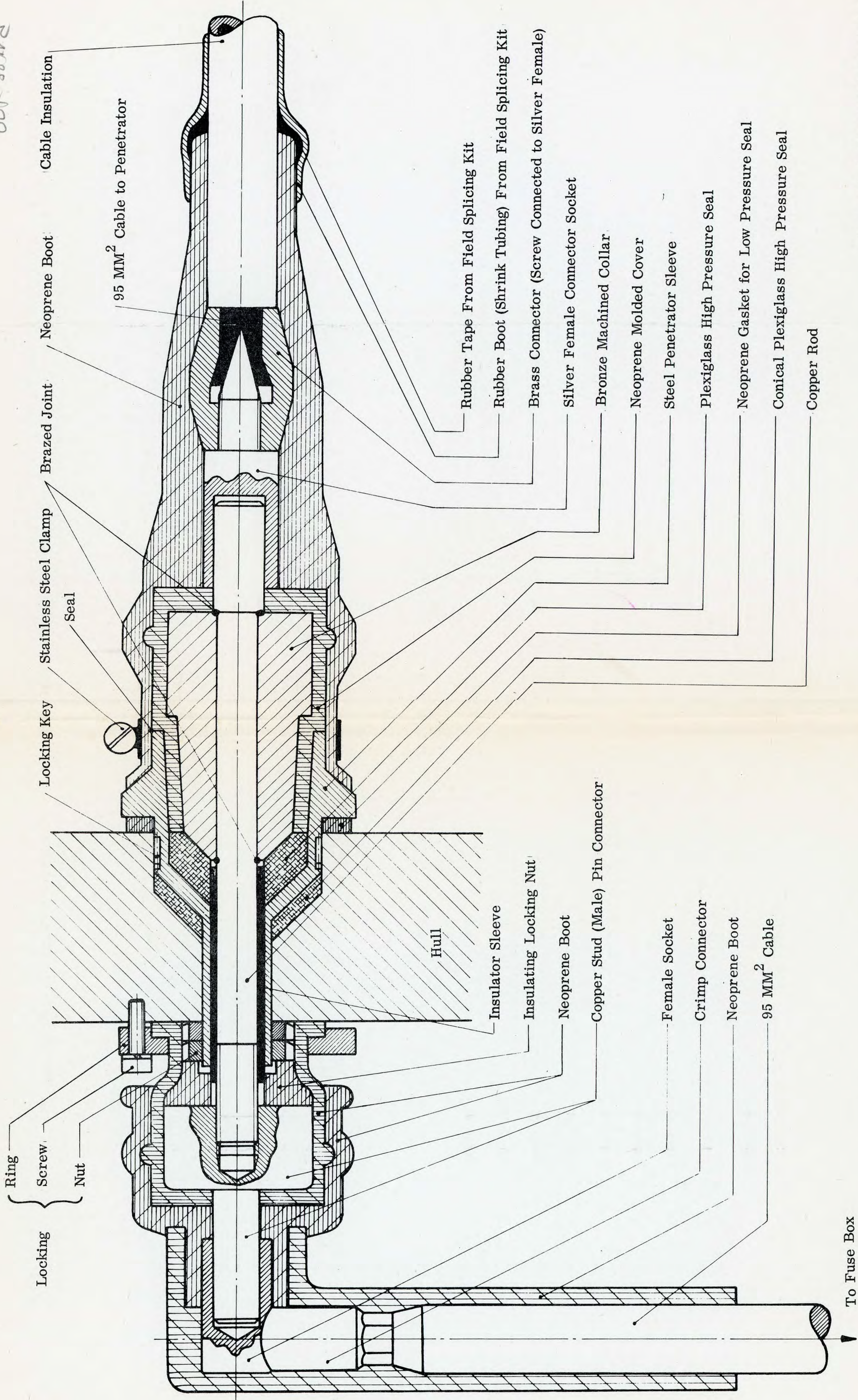


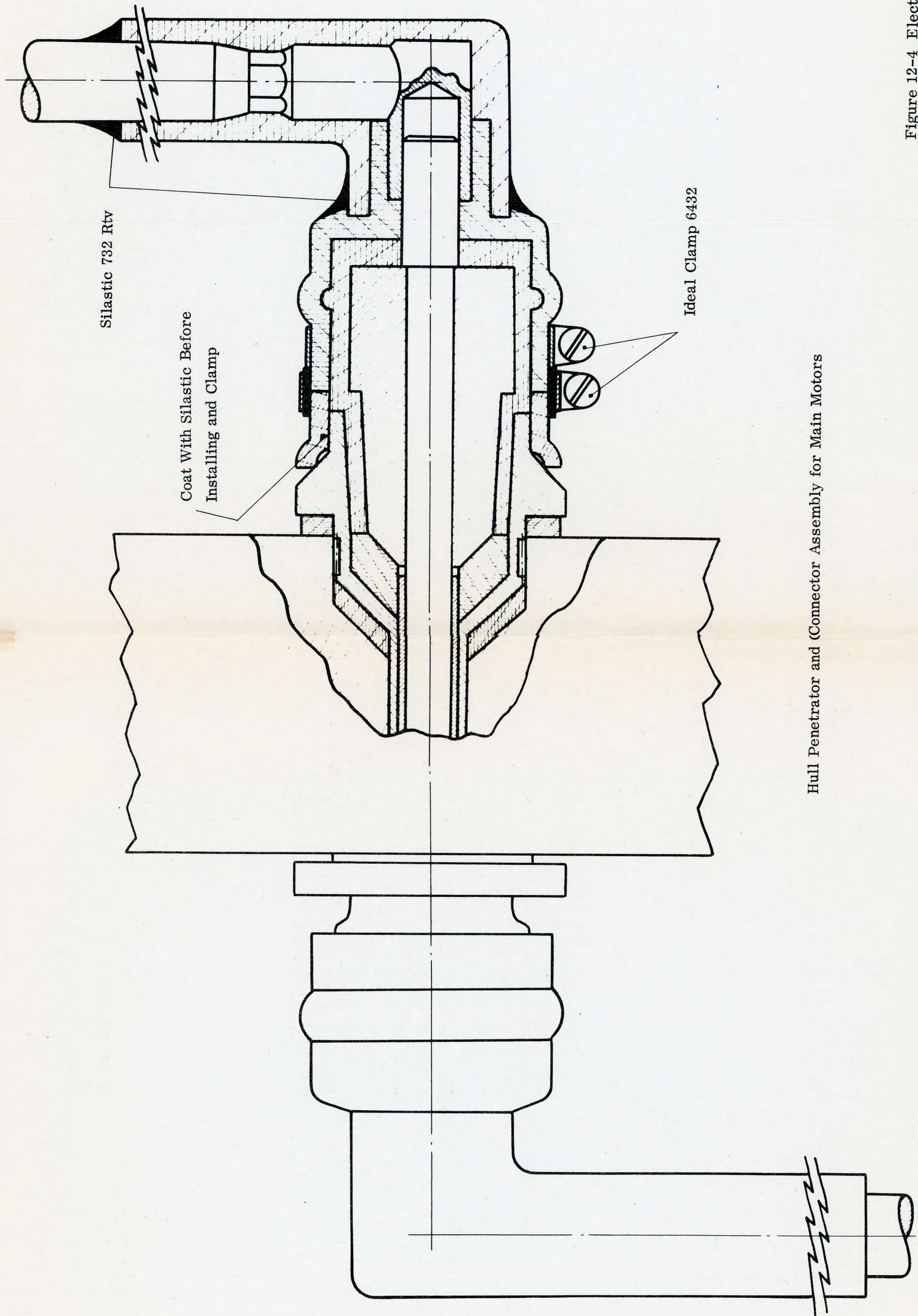
Figure 12-2 Blank Plug

out board



To Fuse Box

Figure 12-3 Electrical Penetrator (95 mm)



Hull Penetrator and Connector Assembly for Main Motors

Figure 12-4 Electrical Penetrator (Motor)

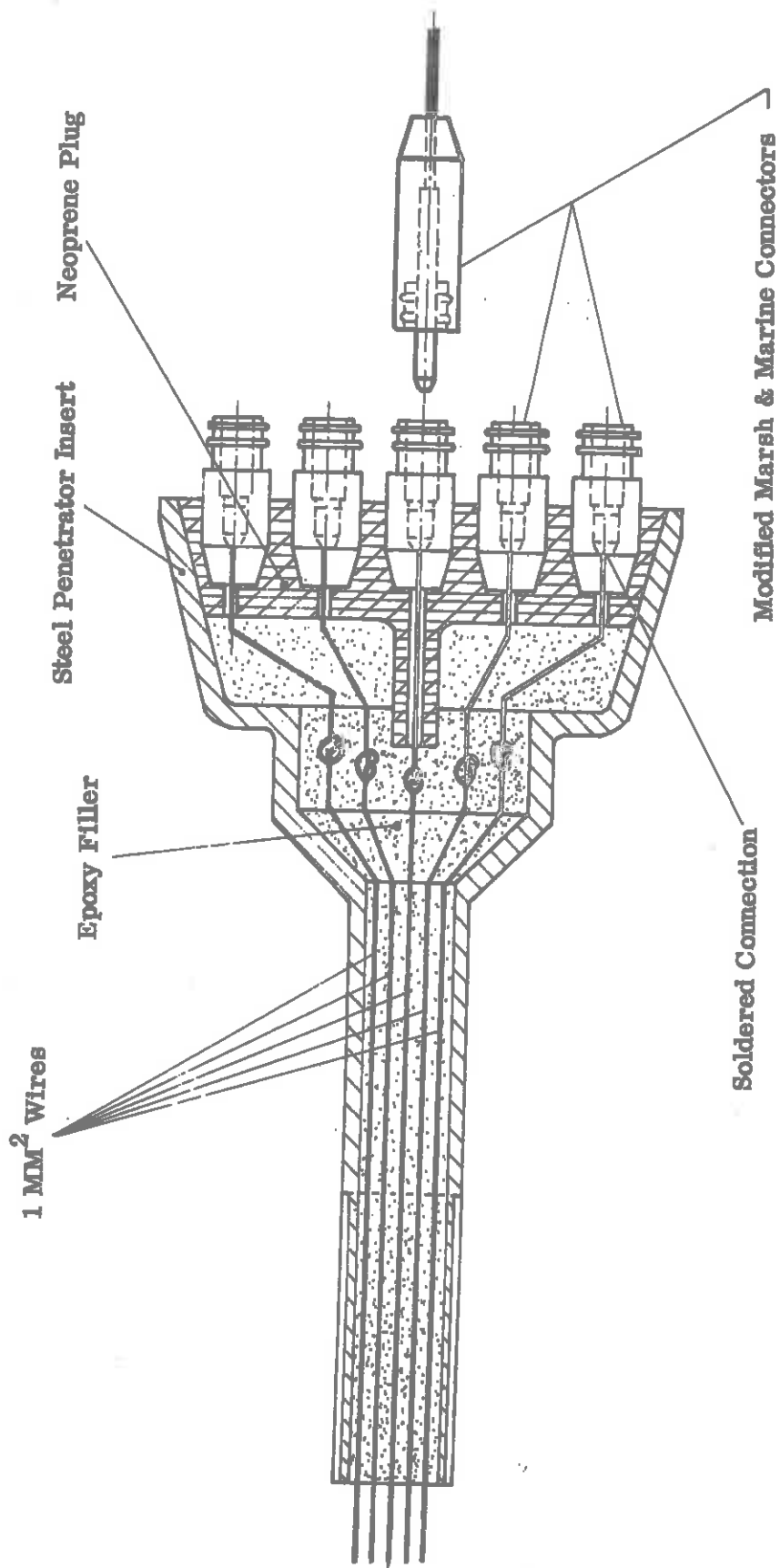


Figure 12-5 Multi Conductor Penetrator

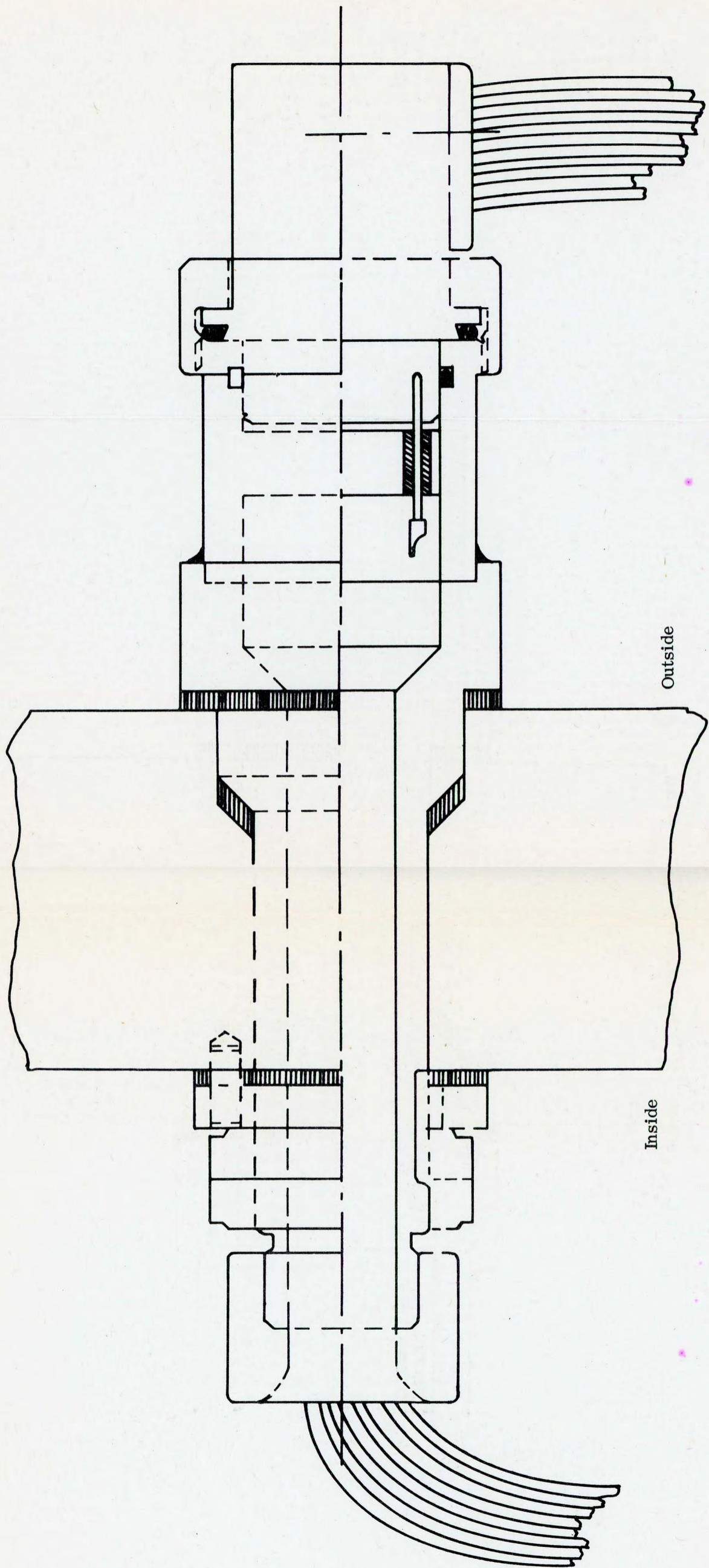


Figure 12-6 Mil Spec Penetrator

### SECTION 13.0 CRITICAL VALVES AND PIPING

From each pipe penetrator, a section of pipe runs to a hull valve. The pipe has welded to each end a flange fitting with an O-ring to prevent sea water from coming in contact with pipe threads. This pipe section is flange fitted to a penetrator and a hull valve. From the hull valve thru the remainder of a piping system, Ermeto fittings are used for all piping joints. Pipe sizes from penetrators to hull valve are approximately 3/4" and 3/8" nominal schedule 80 pipe.

13.1 Pipe Size and Material - There are three pipe materials used for major systems throughout the boat:

316L Stainless - Schedule 80 (heavy wall) used between penetrator and hull valve for all sea systems (pipe internally subject to sea water).

Size: 26.7 OD x 3.9 mm (3/4" nom. sch. 80 pipe)

17.1 OD x 3.0 mm (3/8" nom. sch. 80 pipe)

35.29 Carbon Steel - Schedule 80 equivalent used between penetrator and hull valve for air and hydraulic systems.

Size: 25.0 OD x 4.0 mm

16.0 OD x 3.0 mm



304 Stainless - Standard wall thickness pipe for sea systems.

Used with Ermeto fittings.

Size: 25.0 OD x 2.5 mm

16.0 OD x 1.5 mm

8.0 OD x 1.0 mm

35.29 Carbon Steel - Standard wall thickness pipe for air and hydraulic systems. Used with Ermeto fittings.

Size: 25.0 OD x 3.0 mm

16.0 OD x 2.0 mm

12.0 OD x 1.5 mm

8.0 OD x 1.0 mm

13.2 Color Code - The following color code is used for piping systems throughout the boat:

2844# air - dark grey

1422# air - light grey

oxygen - green

hydraulics - yellow

salt water - blue

fresh water - cold water - clear  
hot water - black

13.3 ARGUS Model BK Ball Hull Valves - Two type ball valves are used -- stainless for sea systems and standard for air and hydraulics. The valves are basically for 3/4" and 3/8" nominal pipe sizes and move from

open to closed with 1/4 turn on the handle. Both types of valves were manufactured by Neve Argus Gesellschaft, Ettlingen, Goethestrab 15, West Germany.

13.3.1 Stainless (316L) Valve - This hull valve was modified for use in sea water under high pressure. The valve body was enlarged slightly and constructed in a manner to prevent salt water from reaching threaded connections. An O-ring is used at each end where the valve is coupled to a pipe. This new valve is called type SBK. For 3/8" size, burst pressure is 800-900 kg/cm<sup>2</sup> (11,400-12,800 psi) and for 3/4" size, burst pressure is 700-800 kg/cm<sup>2</sup> (10,000-11,400 psi).

13.3.2 Standard Valve - This hull valve is made of carbon steel.

Body - 9S20K steel

Stem - MS58F44 steel

Ball - Chrome plated brass

Seat - Bronze

13.4 Globe Valves - All other valves used in sea, air, and hydraulic systems are globe valves manufactured by Voss GmbH, West Germany, and distributed by Hypramag, Zurich, Switzerland. They were modified by adding special inserts - an O-ring protected valve stem and teflon surface plug on the end of the stem. Stainless steel valves are used for sea systems (models HVS 25 and HVS 16). Low grade stainless steel is used for air and hydraulic (models HVS 8, 12, 16, 25). The globe valves are designed to operate

from 250 kg/cm<sup>2</sup> to 400 kg/cm<sup>2</sup> (3560 psi to 5700 psi) (depending on size) with a factor of safety of 4.

13.5 Flange Fittings - Each section of pipe between a penetrator and hull valve has flange fittings welded at each end. These fittings have an O-ring to prevent sea water from corroding pipe threads. They were manufactured by Giovanola Freres, S.A., Monthey, Switzerland.

13.6 Ermeto Fittings - Pipe systems downstream of the hull valves use Ermeto compression fittings. These fittings are designed for a maximum pressure of 400 kg/cm<sup>2</sup> (5700 psi) with a factor of safety of 4. For sea systems, stainless Ermeto fittings are used and for other (air, hydraulic), carbon steel is used. Refer to Fig. 13-1.

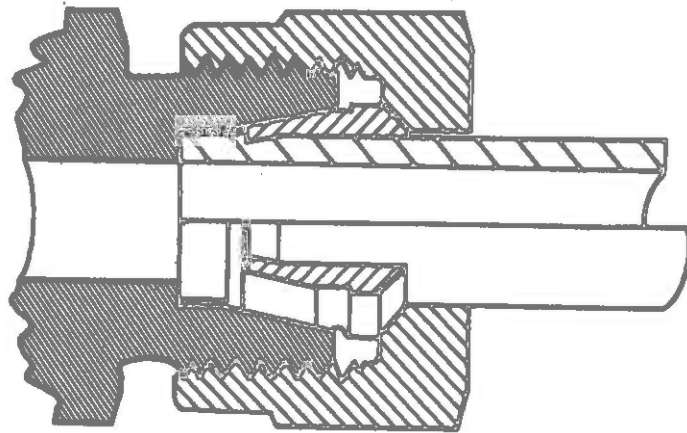


Figure 13-1 Ermeto Fitting

SECTION 14.0 DAMAGE CONTROL AND EMERGENCY EQUIPMENT

14.1 Fire Fighting - Dry powder fire extinguishers are located in the following positions:

- (1) Forward hemisphere
- (2) Aft hemisphere
- (3) Amidships

Each extinguisher has five pounds of siliconized, non-toxic, dry powder. To operate, squeeze grip and direct spray at base of fire.

NOTE: Sheets, pillows, pillow cases, mattresses, bunk curtains and crew uniforms (coveralls), are made of non-flammable material.

14.2 Smoke Removal - For the purposes of removing smoke, the boat is equipped with a portable exhaust blower and flexible exhaust hose. To operate, place the blower as close to the main concentration of smoke as possible. Rig the exhaust hose to discharge smoke outside of the sail (via the upper hatch).

Specifics:

Blower - 500 c.f.m. capacity

G.E. Motor - 1/4 H.P.  
24 Volt D.C.  
10.6 Amps  
1725 RPM

14.3 Portable Bilge Pump - This pump is a standard marine hand pump (plastic) that has a long enough discharge line to reach from any bilge area to the shower.

14.4 D.C. Bag (Damage Control) - This canvas bag contains:

- o Fiberglass pipe patching kit
- o Epoxy (general purpose)
- o Pipe patching clamps
- o Emergency flares and smokes
- o Marlin line
- o Duck-seal

14.5 Emergency Lights - These six lights are wired into the mode switch and light when 28 Volt D.C. power is lost. They can be removed from their holders for use as flashlights and are located throughout the boat in strategic areas. When in port with the mode switch on zero, the lights must be removed from the circuit or they will be on and operating off their 1.5 Volt NI-CAD batteries. A switch is provided for this purpose. When on the line, the lights will be constantly on Charge (power from 28 Volt D.C. bus). In addition to these, 3 scuba lanterns are provided for use during submerged escape.

14.6 Emergency Breathing - A set of six oxygen breathing apparatus are available as required. These are manufactured by chemox. In addition to this, a set of six Drager mixed gas (he/O<sub>2</sub>) diving apparatus is provided for emergency use.

14.7 Emergency Tool Box - A tool box is provided to effect emergency repairs. The box contains an assortment of metric as well as standard tools.

14.8 Fuse Pullers - A set of fuse pullers compatible with all sizes of fuses used in the boat is provided.