U. S COAST GUARD
HERITAGE CLASS PATROL BOAT
PROTOTYPE CONSTRUCTION

By
LTJG D. R. Bird
CDR T. J. Collins, III
Mr. Fred Fisher
CAPT W. M. Simpson, Jr

LTJG David R. Bird, U. S. Coast Guard, is currently a member of the Heritage Class Prototype Project Resident Office, serving as Technical and Administrative Assistant to the Project Resident Officer. He received a Bachelor's Degree from the U.S. Coast Guard Academy in 1987 and subsequently completed the Student Engineering Program aboard the USCGC VIGILANT/USCGC RELIANCE.

CDR Thomas J. Collins III, U. S. Coast Guard, is currently the Heritage Class Prototype Project Resident Officer. Previously he served as Chief, Inspection and Repair Division at the WHEC FRAM Resident Inspectors Office in Seattle, Wa. He has served aboard the USCGC BOUTWELL as the Engineer Officer and the USCGC BURTON ISLAND and WESTWIND as an Engineering Duty Officer. He has had assignments at the Coast Guard Academy as an associate professor in the Marine Engineering Division and at the Coast Guard Yard as Ship Superintendent / New Construction Deputy Project Officer. CDR Collins is a graduate of the Coast Guard Academy and holds graduate degrees from the University of Michigan. He is a member of the Society of Naval Architects and Marine Engineers, American Society of Mechanical Engineers and American Society of Naval Engineers.

Frederick W. Fisher is a production superintendent at the Coast Guard Yard and is currently assigned as Project Director for the Heritage Class prototype construction project. Mr. Fisher has been with the Yard for over 32 years having progressed through the working and supervisory ranks of the structural shop and managerial positions within the Industrial Department. His work has ranged from construction of the 40 - ft UTB to the 210 - ft MEC. Mr. Fisher undertook studies at the Catonsville Community College and George Washington University. He is a member of the National Association of Superintendents of Naval Shore Establishments.

Capt. William M. Simpson, Jr., U.S. Coast Guard, is currently the Coast Guard Project Manager for Patrol Boat Acquisition. Previously he has served as Chief of the Engineering Division in the Thirteenth Coast Guard District and as Commanding Officer at Resident Inspector Office, Lockport, Louisiana. He has had assignments in the Naval Engineering Division at Coast Guard Headquarters, in the Engineering Department at the Coast Guard Academy and in the Merchant Marine Technical office in New York. He served as a deck officer on USCGC OWASCO and USCGC KIMBALL. He has degrees from the Coast Guard Academy and Massachusetts Institute of Technology.

ABSTRACT

A prototype Heritage Class patrol boat, USCGC LEOPOLD, is being constructed at the U. S. Coast Guard Yard in Curtis Bay, Maryland. It will be 120 feet long and will have a top speed of 30 knots. It will have two diesel engines driving fixed pitch propellers in partial tunnels with reduction gear trolling valves to provide slow speed capability. It will have a multi-chine deep-V steel hull with an aluminum deckhouse. The prototype hull is being built upside down as a single unit. Because light weight is critical to meet the desired speed and draft, extensive weight control is being exercised during the detail design and construction. Innovative steps are being taken to purchase the lightest possible components while complying with the Federal Acquisition Regulations (FAR). As a part of the prototype construction phase, the design is being reviewed for possible production producibility improvements. When completed in the late spring of 1992, the prototype is due to undergo a 17 month test and evaluation period. After the design is validated by the test and evaluation period, a commercial contract will be awarded for the construction of a yet to be determined number of Heritage Class patrol boats.

INTRODUCTION

The U. S. Coast Guard operates a fleet of patrol boats which are homeported in all 50 states, Puerto Rico, Guam and St. Thomas. Over half this fleet currently consists of 82 foot patrol boats which were constructed during the period 1960-1968 and will be in need of replacement in the near future. To fill at least a part of the need to replace existing patrol boats, the Coast Guard has developed a new design for a 120 foot patrol boat and a prototype is being constructed at the Coast Guard Yard. In anticipation of the need for replacement patrol boats, the conceptual design, for what was originally known as the Memorial Class and has now been re-designated the Heritage Class, was completed in 1985 and was reported in reference [1]. The design was further refined and developed by Coast Guard Headquarters Naval Engineering Division with assistance from NKF Engineering, Inc., and a project order was issued to the Coast Guard Yard, Curtis Bay, Md. for the detail design and construction of one prototype Heritage Class 120 foot patrol boat. Significant changes from the concept design include the incorporation of partial propeller tunnels to reduce draft, the elimination of mine countermeasures (degaussing) and redesign of the deckhouse.

MISSION REQUIREMENTS

The Heritage Class 120 foot patrol boat will be required to perform multi-mission patrols of coastal waters, within 100 miles to shore, with an unsupported endurance of five (5) days. This requirement assumes 110 hours underway at a best economical speed of at least 10 kts plus 10 hours at a minimum speed of 30 kts in calm seas while retaining 10% usable fuel reserve. Specific missions may require operating out to 200 miles or more from shore. Primary mission requirements include Enforcement of Laws and Treaties, Defense Operations, and Search and Rescue. Secondary mission requirements include Marine Environmental Response, Recreational Boating Safety, and Port Safety and Security. It must be able to carry out it's missions in ten (10) foot sea conditions, and be able to operate at a reduced performance level in 25 foot seas and 60 knot winds. Two compartment damaged stability performance requirements in accordance with U. S. Navy Design Data Sheet 079, Stability and Buoyancy of U S Naval Surface Ships, is required. Accommodations are required for a crew of 18 personnel, mixed male and female, with two spare racks and lockers. The patrol boat must be capable of towing vessels up to 500 tons displacement and have the capacity to intercept, overtake and maintain hot pursuit of waterborne craft normally used for illicit operations. Vessel shall have pilothouse and bridgewing conning stations with maximum visibility around the horizon and alongside, fore and aft, and astern. A small boat launch and recovery system, safely operable in sea state 5, is required to facilitate the boarding and rendering of assistance to sailing and powered boats. The Heritage shall carry suitable armament for exerting force while conducting Enforcement of Laws and Treaties duties. Space and weight reservations will be maintained for additional weapons systems that may be placed on board to meet future requirements for military operations. A self-defense capability from chemical, biological and radiological contaminants shall be provided for within operating and living spaces. The Heritage will have a dedicated, Tempest approved (MIL-STD-1680B), Radio Room which will provide the communications and surveillance capability to act as On-Scene-Commander, and communicate and operate with other Coast Guard and DOD vessels, aircraft and shore units. Weight and space reservations will also be maintained for additional communications and surveillance equipment which may be required in the future. In addition, full electronic navigational capabilities are required. Design criteria shall incorporate an approximate cutter service life of 25 years with a mid-life major repair availability, at which time outdated or unsupportable equipment will be replaced.

GENERAL DESCRIPTION

The principal design characteristics and hull dimensions are listed in Table 1. A general discussion of the hull form development is provided in Reference [1]. The prototype hull is a multi-chine deep-V steel hull. The hull form was specified by the conceptual designers and no changes were permitted during the detail design. The hull form developed for the Heritage Class is depicted in Figures 1 and 2. This hull form was selected because it provided the best combination of resistance and seakeeping characteristics for the mission requirements. Minimum resistance was desired at the maximum continuous speed in order to reduce the size and weight of the propulsion system and total fuel capacity required. The conceptual designers determined that as the slenderness ratio increased the resistance decreased, however, minimum beam is limited by stability requirements and arrangement considerations. The double chine hull form was selected since it provided an effective means to resolve these conflicting requirements. The narrow, lower chine beam favors lower resistance and the wider upper chine satisfies the stability and arrangement requirements. In addition, the narrow beam of the lower chine and the high deadrise tend to reduce vertical accelerations. The deadrise angle at the transom is approximately 15 degrees and gradually increases to 65 degrees at station 1. The deadrise at station 5 is 20 degrees. The forward section shapes above the upper chine are concave to deflect the bow spray and increase the fullness of the above water bow form. The forward extension of the upper chine will further increase the bow fullness and limit slamming. Reference [1] provides detail information on the previous hull form discussion.

The Coast Guard required that the appendage draft not exceed seven (7) feet and desired for it to be 6.5 ft or less. To meet the draft requirements the conceptual designers elected to use partial tunnels to reduce the distance the propellers protruded below the baseline. By utilizing the partial tunnels a reasonable propeller diameter could be used while maintaining a proper tip-to-hull clearance. An insufficient propeller diameter reduces propulsive efficiency and insufficient tip clearance will cause undesirable noise and vibration. Currently, the designed 48 inch propeller will extend below the baseline by 18 inches which results in a full load appendage draft of 6.4 ft while maintaining an adequate tip clearance of approximately 12.5% of propeller diameter. The tunnel depth is approximately 34% of the tunnel diameter at the propeller disc section. The current tunnel design is being reviewed in an effort to possibly improve the design for the Heritage Class production effort. Thus far it has been determined that if the tunnel edges were rounded in lieu of the current sharp edge design, that the overall propulsive efficiency could be improved.

The General Arrangement drawings are shown in Figures 3 through Figure 8. Reference [1] provides a general discussion on the conceptual development of the general arrangements. Operational requirements, habitability, producibility and access for personnel and equipment maintenance were considered during the development. The attached general arrangement drawings will provide the reader with the basic arrangement of the vessel and therefore will not be discussed herein. However, the following comments are warranted:

(a) The deckhouse structure has been modified since the conceptual design to provide 360 degree visibility around the horizon from the pilothouse and bridgewing conning stations.
(b) The patrol boat has a dedicated, Tempest approved (MIL-STD-1680), Radio Room which provides the communications and surveillance capabilities required to perform as an On-Scene-Commander, and communicate and operate with other Coast Guard and DOD vessels, aircraft and shore units.
(c) The patrol boat has a dedicated Law Enforcement Center.
(d) The patrol boat has a separate compartment (Aux. Machinery Room) for the Ship Service Diesel Generators, Distribution Switchboard and auxiliary machinery and equipment. Other Coast Guard patrol boats have this equipment in the main engine room.
(e) There is fore and aft access to the main deck from the pilothouse and bridgewings.
(f) The Rigid Hull Inflatable Boat, RHIB, can be launched from the starboard side only. The port boat crane was eliminated to save weight.
(g) The crew berthing compartments are located between frames 7 and 16. The berthing area is out of the normal personnel traffic patterns and is forward to limit the effects of the high ambient noise and vibration levels that will be present in the after machinery areas. Also the berthing areas are not too far forward and therefore will not be subject to the extreme vertical accelerations in the bow area.
(h) The arrangement of the crew berthing areas and sanitary spaces facilitate having a male and female crew.

PROPULSION SYSTEM

The major components of the Heritage Prototype propulsion system are: two (2) MTU 16V396TB94 diesel engines; each engine driving a non-controllable pitch propeller through a ZF BW-755 hydraulically actuated reverse reduction gear (which is equipped with a trolling valve for slow speed operations) and a solid, continuous shaft; and an integrated control, monitoring and alarm system. MTU of North America, Inc. (MTU NA) has been contracted by the Coast Guard to provide the detail design for the propulsion system and the integrated control, monitoring and alarm system. Along with the detail design, MTU NA will be providing the propulsion system machinery and major components from the engines to the propellers, inclusive. In addition MTU NA will be providing the main components for the integrated propulsion control, monitoring and alarm system.

Two propeller designs have been developed for the Heritage Prototype. The first is a 4 bladed standard series propeller with a diameter of 47.24 inches which provides a propulsive efficiency of 0.596 and a hull interaction efficiency of 0.90. The other is a 5 bladed hybrid propeller with a diameter of 48.00 inches which provides a propulsive efficiency of 0.62 and a hull interaction efficiency of 0.888. The hybrid propeller is designed to supercavitate outboard of the transition radius at $r/R = .666$ and subcavitate inboard of that radius.

The BHP required at the engine continuous power rating to obtain a minimum of 28.0 kts at trial load, sea state zero, is 2,525 HP for the designed standard propeller and 2,427 HP for the hybrid propeller design. The total EHP required for 28.0 kts at trial load, sea state zero, is 3,010 HP. The BHP required at the engine intermittent power rating to obtain a minimum of 30.0 kts at trial load, sea state zero, is 2,886 HP for the designed standard propeller and 2,775 for the hybrid propeller design. The total EHP required for 30.0 kts at trial load, sea state zero, is 3,440 HP. The MTU engine passed the 1000 HR endurance test in accordance with MIL-E-64455, Military Specification for Diesel Engine Rating, for a continuous BHP rating of 2642 HP @ 2040 RPM and a intermittent BHP rating of 2903 HP @ 2040 RPM. The MTU engine has a commercial rating of 3433 BHP. The overall mechanical efficiency of the power train from the engine output to the aft side of the shaft strut is estimated at 0.97.

The ZF BW-755 hydraulically actuated reverse reduction gear will have a gear ratio of 2.548 : 1.0. This gear was developed by ZF specifically for use with the MTU 16V396 series engine. In order to permit slow speed operations, the reduction gear will be equipped with a trolling valve. A trolling valve is a device used to vary oil pressure to the clutch, thus allowing the clutch faces to slip, thereby reducing the output RPM. Trolling valves are capable of reducing the output shaft speed from approximately 30 to 75 percent of the full locked-up condition. However, the slipping clutch will create additional heat which must be dissipated by the gears' lube oil system, therefore, the gears lube oil coolers will have increased capacity. The Heritage Prototype will have a trolling mode shaft speed range between 70 and 260 SRPM which relates to a vessel speed range of 2.8 kts to 9.5 kts. The normal mode operation (clutch fully locked-up and the engine speed varying from 600 ERPM to 2040 ERPM) shaft speed range will be from 235 SRPM to 800 SRPM which relates to a vessel speed of 9.0 kts to at least 30 kts. There is a 25 SRPM overlap between the trolling and normal operation modes. The control system logic being designed will account for this overlap and will provide for a smooth transition between the two modes of operation both in the increasing speed and decreasing speed direction maintaining the full speed range as usable.

The stainless steel propulsion shaft is a single piece between the reduction gear and the propeller. It penetrates the hull through a tube welded to the hull structure. A mechanical shaft seal is fitted to the inboard end of the tube and a water lubricated bearing is fitted to the outboard end. The shaft is 4.5 inches in diameter and approximately 24 ft in length. Shaft ends will be machined to a 30 : 1 taper on both ends to receive a hydraulically mounted shaft coupling and propeller. The tapers on both ends of the shaft will be identical to facilitate end-for-ending the shaft if the need arises. The aft end of the shaft will be supported just forward of the propeller by a water lubricated bearing mounted in a boss on a single arm shaft strut.

STEERING AND STABILIZATION SYSTEM

Steering shall be accomplished by a full follow-up / non-follow-up digital-hydraulic system capable of actuation by the following methods:

(a) Full Follow-up helm lever located on the bridge console
(b) Non-Follow-up jog lever located on the bridge console
(c) Autopilot system, controls located on the Pilothouse console
(d) Rudder Roll Stabilization System, controls located on the Pilothouse console

An independent mechanical system will be installed in the lazarette to allow for emergency steering of the vessel with the hydraulic system inoperative. The system will be designed for operation by one person.

The steering hydraulic gear will be powered by two diesel-generator set driven hydraulic pumps. Each hydraulic pump will be capable of providing 100% of the maximum required hydraulic power. The steering system is a hydraulic powered, inclined clevis type system. One double acting, single ended, cylinder will be provided for each rudder and the rudders will be connected with a mechanical linkage. Each cylinder will be arranged to permit steering of both rudders at a reduced capacity if one of the cylinders is disabled. The system is designed to move the rudders at a rate of 9.3 degrees per second or from a hard-over to hard-over (28 degrees port to 28 degrees starboard) in 6 seconds at maximum rudder torque of 16,000 ft lbs. The system will also move the rudder at a speed of 15 degrees per second for rudder roll stabilization. The rudders will be positioned as shown on Figure 9.

Rudder Roll Stabilization will be accomplished by a Roll-Nix System. The operating principle of the Roll-Nix system is based on the concept of opposing the roll moment created by the movement of the rudder to the roll moment created by the waves. The Roll-Nix system is designed for steady course keeping and minor course corections. When major steering orders are given by the autopilot or helmsman, Roll-Nix is automatically turned off. Once the rudder command is decreased again, Roll-Nix is automatically turned on again. This feature is required in order to ensure that the original rudder command will not be modified in situations that call for rapid, major changes in course. Maximum roll dampening is desired, however, as a minimum, reduced roll motions of at least 20 percent in a seaway with significant wave height of 3 feet (sea state 3 or higher) from the beam direction at craft speeds between 10 to 20 knots is required. The Rudder Roll Stabilization System shall be independent of the crafts other steering systems. Failure or removal of the Rudder Roll Stabilization System will not result in a loss of steering, nor make any other steering system component inoperative.

The detail design of the Steering and Rudder Roll Stabilization System for the Heritage Prototype is in the early stages of development.

POWER GENERATION AND DISTRIBUTION

Ship service electrical power will be provided by two diesel powered generator sets, located in the Aux. Machinery Room (AMR), each capable of supporting the normal ship service electrical load. The diesel engines will be Caterpillar 3304BT, four cylinder, 135 horsepower engines which will draw air from within the AMR and their exhausts will be through the transom. The generators will be Kato/Reliance, 99 KW (123.7 KVA) generators (power factor of 0.8) providing 450 VAC, 3 Phase, 60 Hertz, 159 amps. Both diesel prime movers will also drive a hydraulic pump for the steering and rudder roll stabilization system.

The Electrical Load Analysis, which has not been finalized, was developed under the guidance of the Naval Sea Systems Command Design Data Sheet 310-1, Electrical System Load and Power Analysis for Surface Ships, and load factors based on Coast Guard patrol boat experience. The current estimated electrical loads are:

At Anchor....................51.6 KW (64.5 KVA)
Normal Cruising..............56.8 KW (71.0 KVA)
Warm Climate Cruising........43.6 KW (54.5 KVA)
Cold Climate Cruising........60.0 KW (75.0 KVA)
Shore Power Requirements.....45.7 KW (57.1 KVA)

The generators being placed on the prototype are more than capable of providing the ship service electrical load requirements plus the required twenty (20) percent growth factor which is not included in the above loads. The selected Diesel Generator Sets were selected because they, and all associated procurement technical documentation, were readily available in the Coast Guard supply system. The detail design and construction effort and schedule benefited from the selection of these readily available Diesel Generator Sets. Generators for the production cutters will be selected based on the production design electrical load analysis and information obtained during the prototype's test and evaluation period.

Ship service power distribution will be from the Ship Service Distribution Switchboard located in the AMR to:

(a) four 440 VAC power distribution panels. (located in the AMR, Main Engine Room, Mess Deck and Main Deck Passage)
(b) a 75 KVA 440V/115V 3 phase transformer bank which feeds the Power and Lighting Load Center Panel, located in the AMR, which feeds four Power and Lighting Distribution Panels, an Electronic Power Distribution Panel in the Radio Room, the normal 115 VAC feed to the Uninterrupted Power Supply Unit (UPS) and two spare breakers.
(c) the two control panels for the two fire pumps
(d) the two control panels for the main propulsion engine jacket water heaters
(e) the two control panels for the HVAC system
(f) two spare breakers

The SPS 64 surface search radar will receive power from a dedicated power panel in the Radio Room which is feed from the Main Deck Passage 440 VAC distribution panel.

The prototype will be provided with a five (5) KVA UPS Unit which will be supplied 115 VAC power from the Power and Lighting Load Center Panel during normal power operations. The UPS Unit will supply power to the 115 VAC Normal/Emergency Power Distribution Panel and the 24 VDC Normal/Emergency Power Distribution Panel via two (2) 1.5 KW AC/DC converters. In the event of the loss of normal power, the UPS backup batteries will provide DC power to the UPS which will invert the power to 115 VAC and continue to supply power to the 115 VAC Normal/Emergency Power Distribution Panel and the 24 VDC Normal/Emergency Power Distribution Panel. If normal power cannot be restored in a timely manner, the main propulsion engines are fitted with alternators which will provide 115 VAC power to the UPS via a manual transfer switch and four 1.0 KVA inverters. The following are items that can be energized from the emergency power system:

(a) Navigation Light Panel
(b) Gyrocompass
(c) General Announcing System
(d) HF and VHF-FM Communications Equipment
(e) Propulsion Control System
(f) Central Alarm and Monitoring System and CO2 Pre-discharge Alarm
(g) Ship's Whistle
(h) Loran C Equipment
(i) Radio Room Door Entry Alarm

CENTRAL ALARM MONITORING SYSTEM

The Heritage Prototype will have a Central Alarm and Monitoring System (CAMS) that will provide an integrated system of remote instrumentation display, constant alarm monitoring and event recording in both scheduled and demand modes for major operating parameters and alarms of the following equipment/systems:

(a) Propulsion Engine Fuel Management (port and starboard) which will monitor engine speed, craft speed and fuel rate. (no alarms required)
(b) Main Propulsion Engine and Reduction Gear Status (port and starboard) which will monitor fifteen (15) parameters of which nine (9) will also have alarm settings.
(c) Steering and Rudder Roll Stabilization System which will monitor sixteen (16) parameters of which eleven (11) will also have alarm settings.
(d) Ship Service Diesel/Generator Status (port and starboard) which will monitor eleven (11) parameters of which five (5) will also have alarm settings.
(e) Zone Status for seven (7) Fire and Smoke Detection Zones with an alarm if there is trouble in any one of the zones

(f) Flooding Detection and alarm for all the compartments shown on the Hold Level Arrangement (Figure 8) with the exception of the Forepeak.
(g) Status and alarm for the High Temperature sensor in the magazine and the status of the magazine sprinkler system.
(h) CO2 Release alarm status for both the Main Engine Room and the Aux. Machinery Room.
(i) Sewage System Overboard Discharge warning indication.
(j) Status of level and high level alarm for all fuel tanks and both potable water tanks.

Each parameter sensor will be connected to a dedicated input circuit located in one of three data remote units. Two data remote units are in the Aux. Machinery Room (AMR) and one is in the Main Engine Room. The data remotes will communicate with the Central Unit (main processor), which is located in the Law Enforcement Center. The Central Unit will interface with the two operator stations, one located in the AMR and the other located at the Pilothouse console. Each station will be equipped with a color video monitor, an operator's keyboard, and a printer. The video monitor on the pilothouse console will have an all red display mode for use at night. The CAMS electrical power is supplied by the 24 VDC normal/emergency distribution power panel.

Processed data for each major piece of equipment, machinery and system is displayed in page format on the operator's video display and there is a dedicated key on the keyboard for each page that can be displayed. Parameters will be displayed in both analog bar graph and digital format. Operators, using an operator's keyboard, will be able to select the displayed pages and edit the monitored parameters and alarms. Alarm acknowledgment and status will be controlled through the operator's keyboard. Alarm status of individual pages will be indicated through the illumination of the operator's keyboard keys, an audible alarm will sound and an alarm summary page will be displayed with the item in alarm status being highlighted. The displayed data can be printed at each operator's station.

PRIMARY AUXILIARY SYSTEMS AND EQUIPMENT

Below is a summary of the primary auxiliary equipment to be installed aboard LEOPOLD. An attempt has been made to familiarize the reader with the significant systems that will be found aboard the Heritage Class Prototype. Some of the equipment listed below has already been procured, and some is still pending design development, therefore some systems are subject to change.

Collective Protection System: A gas tight envelope is being incorporated into the design of the LEOPOLD which will protect the crew from airborne Chemical, Biological and Radiological (CBR) contaminants. This gas tight envelope, or zone, is bounded by the structure of the vessel as follows:

(a) The platform deck from the watertight bulkheads at frame 4 aft to frame 19 which includes the crew and CPO berthing areas, Messdeck, and Galley

(b) The Law Enforcement Center, Air Lock, Radio Room, CO and XO Staterooms, and Fan Room, on the main deck

(c) The Pilothouse on the 01 deck

Note that this zone is comprised of all the living spaces and command/control spaces aboard LEOPOLD. Machinery spaces are not included. See Figure 10 for an illustration of this zone.

The grouping of components that provides this protection is termed the Collective Protection System (CPS). The CPS is composed of specially equipped exhaust and supply fans, air filters, and pressure sensors that are integrated to provide a pressurized zone, free of CBR contaminants. The zone is served by one supply and one exhaust fan, equipped with electrically actuated dampers for regulating air flow. When the system is off, these fans provide normal air flow within the CPS zone. When the system is turned on via a master control located in the Pilothouse, dampers downstream of the supply fan and exhaust fan are actuated to raise pressure within the zone to between 2.0 and 2.5 inches of water, relative to atmospheric pressure. A series of high efficiency particulate and charcoal activated filters are located in the Fan Room between the supply vent from atmosphere and the supply fan to remove contaminants. To allow personnel movement from the CPS zone to the weather decks, an Air Lock will be provided leading from the Law Enforcement Center to the main deck. This air-swept chamber has its own control system for initiating, timing and regulating a purge cycle when used.

Heating Ventilation and Air Conditioning: Heating and cooling aboard LEOPOLD will be provided by a reverse cycle system utilizing freon. Heating/cooling expansion coil units will be located in all inhabited spaces with the exception of machinery spaces. The temperature in manned spaces will be a maximum of 80 degrees under cooling conditions, and a minimum of 65 degrees under heating conditions. The minimum temperature of machinery spaces will not be less than 45 degrees with a maximum of 95 degrees. These conditions must be met under ambient conditions of 10 and 110 degrees F. The Main Engine Room, Auxiliary Machinery Room, Lazarette, and Pump Room will be provided ventilation via forced exhaust and natural supply arrangement. Other spaces, with the exception of the CPS Zone, will be provided with natural supply and exhaust ventilation. Supplemental electric heaters have been provided in the sanitary spaces and the machinery spaces.

Installed Damage Control Systems: LEOPOLD has several installed damage control/fire detection systems. The firemain, supplied by two 440 VAC 195 GPM pumps, feeds five fire stations, three on the main deck outside the deckhouse structure, one on the Messdeck and one in the Main Engine Room. The firemain also provides water for a magazine sprinkling system and the pressure for its hydraulically actuated controls. Lastly, it feeds a water washdown system for use in a CBR environment to decontaminate all topside surfaces exposed to the atmosphere. The firemain, which is dry when not in use, can be segregated into a fore and aft sections for survivability purposes.

A fixed CO_2 system will be installed aboard LEOPOLD with discharge nozzles in the Engine Room and the Aux. Machinery Room for protection of one space or the other. A single bank of three, 75 lb CO_2 bottles will be mounted in the Lazarette. If activated, all three bottles will be discharged into the Main Engine Room, or two bottles will be dischared into the Auxiliary Machinery Room with one left for reserve. Two manual N_2 actuators will be provided for each of the spaces protected, one for each will be located in the Pilothouse with another one in the compartment immediately forward of the space protected. The discharged CO_2 will actuate shutdown switches for the Ship Service Diesel Generators or the Main Diesel Engines and the ventilation system for the space being flooded.

An integrated heat and smoke detection system will also be installed. The LEOPOLD will be divided into seven fire zones which will be outfitted with ionization smoke detectors in most compartments plus heat sensors in the Auxiliary Machinery Room and Engine Room. The thermal detectors will be set to activate alarms at 130 degrees F, or when a temperature increase of 1.8 degrees per minute is detected. Upon activation, a horn and strobe light will be activated in or near the zones protected to alert personnel of fire. A Fire Detection System Control Cabinet located on the Messdeck will also be equipped with a bell which will activate when any of the sensors detect an alarm condition or a detector failure. This cabinet also supplies input to the Central Alarm Monitoring System when a sensor is activated for a fire smoke condition.

Deck Equipment/Machinery: LEOPOLD will be outfitted with an electro-mechanical crane primarily for launching and retrieving the outboard powered 5.4 meter Rigid Hull Inflatable Boat (RHIB). The crane will be capable of lifting a working load of 1800 lbs at a rate of 40 ft/min. This load is based on an estimated load consisting of the RHIB and two crewmembers. The crane will be capable rotating through an arc of 285 degrees. Two other deck machinery/equipment systems are as follows:

(a) For raising the anchor, a capstan will be installed on the forecastle. The 440 VAC capstan will be capable of 1700 lbs. of line pull at a rate of 28 ft/min.

(b) For conducting towing operations, a towing bitt will be installed on the main deck aft with a towing rail 39 inches above the main deck at centerline, rimming the after section of the vessel to prevent the towing hawser from fouling on deck equipment and stability purposes. Stops will be provided to limit the swing of the hawser 60 degrees to port or starboard of centerline. A reel for stowing 900 ft of 4 inch double braided nylon towing hawser will be mounted in the Lazarette.
Layout of the main deck can be seen in Figure 6.

Potable Water System: LEOPOLD will have the ability to make potable water by means of two, 400 gallon/day reverse osmosis watermakers. Potable water will be stored in two aluminum 400 gallon tanks located in the Lazarette. A bromination system will be installed for water purification.

Fuel System: Fuel storage of approximately 7500 gallons is divided among five separate tanks. Two storage tanks are located in the Auxiliary Machinery Room and three service tanks are located immediately forward of the Main Engine Room under the Galley.
Capacities of these tanks are as follows:

<u>Storage Tanks</u>
3-25-1-F...........2203 gal
3-25-2-F...........2203 gal

<u>Service Tanks</u>
3-16-1-F...........631 gal
3-16-2-F...........631 gal
3-16-0-F...........631 gal

Transfer of fuel between the tanks, or for recirculation through a filter coalescer will be accomplished by means of a 35 GPM transfer pump. A deck fill connection, recessed into the deckhouse structure, will be located at frame 19 and an at-sea refueling station will be located on the forecastle, also recessed into the deckhouse structure. The fuel filling system will be capable of receiving fuel at a rate of 250 GPM. The 35 GPM fuel transfer pump may also be used to pump fuel out of the vessel through the deck connections.

Hull Cathodic Protection: An impressed current cathodic protection system will be employed to protect the underwater portion of the hull from corrosion.

Vacuum Flush System: The shipboard vacuum sewage collection, holding and transfer system will serve five toilets throughout the vessel. Vacuum in the piping for transporting waste will be generated by ejection of sewage through and eductor nozzle into the 425 gallon capacity, stainless steel storage tank. The dual purpose sewage ejector pump will automatically cycle as needed, recirculating waste already in the tank to maintain a vacuum in the piping system. When the holding tank fills, an alarm will sound indicating the need to pump the contents off the vessel. With the proper alignment of valves, the sewage ejector pump will also serve to pump sewage overboard or to shore facilities.

Oily Water Separator: An oily water separator (OWS) will be installed for separating oil from bilge water. This OWS will be capable of filtering 2 gallons per minute and purifying the water to 15 PPM or less prior to dumping it overboard. Oil will be pumped to the dirty oil tank.

ARMAMENT PACKAGE

LEOPOLD will be armed with one 25 MM gun, mounted on the forecastle at frame 4. The gun mount and supporting structure have been designed for replacement of the 25 MM gun with a 30 MM gun with minimal modifications. Two .50 cal machine guns may be mounted in three firing locations, one centerline aft braced against the towing rail, and two on the 01 Deck just behind the Pilothouse, one port and one starboard . The two M60 machine guns may be mounted in the same locations as the .50 cal machine guns. See Figures 5 and 6 for deck layouts. Ammunition storage for these weapons will be provided in the Magazine and ready service lockers mounted near the weapons. Small arms will be stowed in locking gun racks in the Law Enforcement Center. A total of 8.15 tons is reserved for future ordnance systems growth. The main deck, aft of the deckhouse structure has been designed and strengthened for future placement of four Penguin missile box launchers. See Table 2 for a summary of armament.

ELECTRONICS PACKAGE

A key difference between LEOPOLD and other Coast Guard Patrol Boats is the fact that it has a designated radio room that will be constructed in accordance with MIL-STD-1680B (TEMPEST) requirements. Hence, LEOPOLD will be capable of transmitting and receiving secure record communications which will significantly improve communications abilities with other units of the CG, Navy and other federal agencies. It is anticipated that follow on HERITAGE Class Patrol Boats will be improved with integrated, state-of-the-art electronics. A reserve growth margin of 0.92 LTons is reserved for electronics systems. A summary of the major electronics/command and surveillance capabilities is provided in Table 3.

WEIGHT CONTROL AND REDUCTION

The Accepted Weight Estimate and subsequent Quarterly Weight Reports for the LEOPOLD construction effort are compiled using the Navy Ship Work Breakdown Structure (SWBS) for grouping of system weights. Each item is listed by an appropriate SWBS number and has its corresponding vertical, longitudinal and transverse centers of gravity in tabular form. Additionally, each item's weight is noted as being estimated, calculated or actual.

In addition to the SWBS item breakdown, the reports and estimates include margins as listed below:

(a) Builder's Margin.....2% of Lightship........2.54 Tons
(b) Design Margins, varies from 1% to 4% depending on SWBS group, total of each......3.85 Tons
(c) Government Furnished Equipment Margin.......1.00 Ton

These figures are taken from the Accepted Weight Estimate of 11 Sep 90 and have been partially depleted since that time.

The weight report also contains reserves for future growth as listed below:

(a) Ordnance Future Growth Margin..............10.00 Tons
(b) Electronics Future Growth Margin........... 2.00 Tons

These reserves were originally in the Contract Design Specifications for LEOPOLD, however, significant design changes have been required since the conceptual design that have warranted some depletion of these reserves. Table 4 provides a summary of weight activity from the initial Accepted Weight Estimate of 12 Nov 89 to the most current Quarterly Weight Report of 10 Apr 91. Due to the significant weight reduction as a result of the propulsion system selection, a Revised Accepted Weight Estimate was developed.

Upon completion, LEOPOLD must not have a list of greater than one half degree from the vertical at the lightship, half load and full load conditions. The vessel must not be trimmed more than one half degree (approx. six inches) from the horizontal at the lightship, half load and full load conditions. No ballasting will be allowed to meet these requirements. A summary of vessel hydrostatics as of 10 Apr 91 is provided in Table 5.

Reduction of weight from initial weight estimates has been a collective Coast Guard effort. In the interest of reducing weight, some significant design changes have been made from the conceptual design of LEOPOLD, some examples are listed below:

(a) The requirement for a Secondary Propulsion System consisting of a power take off from one of the Ships Service Diesel Generators for slow speed propulsion was deleted in favor of a trolling valve in the reduction gear.

(b) Deletion of the port electro-mechanical crane for launching and retrieving the RHIB.

(c) The selection of a propulsion system that is significantly lighter in weight than that anticipated in the conceptual design phase.

(d) The decision to delete the degaussing system

These major configuration changes, coupled with smaller weight savings during the detail design effort which are too numerous to list, are responsible for reducing the weight of the vessel to its current weight.

Control of weight growth is being accomplished by several means. A Weight Control Program has been developed by the YARD, providing guidance on controlling and accounting for weights on the LEOPOLD construction project.

A key component of this program is a strict accounting system to track all weights of shipboard systems and components. As detail design progresses, calculated weights are determined from drawings and recorded as such on bills of material. After being procured, actual weights of equipment and materials weighing over five lbs are captured by scale weighing. As this calculated and actual weight data is determined, it is then incorporated into the weight data base and published in subsequent Quarterly Weight Reports. Scale weighing of structural components is currently being performed to further add more accurate information to the weight data base. In the 10 Apr 91 Quarterly Weight Report, 11% of the line items were actual weights, 30% were calculated and 58% were still listed as estimated. For items that have been overlooked in the estimating process, or are heavier than estimated, weight is deducted from the appropriate margin. If weight savings are realized on equipment or materials, margins are neither increased nor restored to their original value. The result will instead be a lighter vessel.

Another area where weight is being controlled is through the procurement process. Limiting weights are assigned to the equipment being procured for installation aboard LEOPOLD. Vendors must meet or beat the maximum weight allowed in order to be considered. Vendors are also required to conduct scale weighing of items greater than 20 lbs, provide certified weight reports for products supplied.

QUALITY ASSURANCE

The Coast Guard YARD has been tasked with providing an inspection system for the construction of LEOPOLD that is in accordance with MIL-I-45208A, "Inspection Requirements". This document provides the framework for an inspection system which will assure that all supplies and services offered for acceptance by the YARD conform to contract requirements, (i.e. approved drawings and specifications.) The requirements of MIL-I-45208A also apply to subcontractors or vendors supplying goods or services to the YARD for this project. In order to establish a comprehensive system of documented inspections, the YARD has developed a Quality Assurance (QA) Plan which incorporates all Quality Assurance requirements of the project order for the construction of LEOPOLD. This QA Plan provides clear, complete and current instructions for inspection of end result items or, when end result inspections are difficult or impossible to conduct, special procedures have been developed at discrete, key points as a construction process progresses. These Quality Control Inspection Procedures (QCIPs) form the backbone of the YARD's QA Plan for construction of the Heritage Prototype. Some key components of the quality assurance system at the YARD are:

(a) Detailed procedures for inspection of materials/work performed throughout the construction effort, ranging from

(b) receipt inspections as material is received and stored at Supply Center Curtis Bay up through installation of material and equipment by YARD industrial shops

(c) Detailed instructions for documenting all inspections and what corrective action steps to take if nonconforming material is discovered

(d) Procedures for marking the inspection status of all materials and equipment once it has entered the CG YARD grounds

(e) Strict requirements for the control of drawings, including special procedures for rapidly processing and approving minor adjustments to drawings that have already been released to production

(f) A procedure and welder qualification system, certified by an independent Laboratory

(g) Non destructive testing of welds using dye-penetrant, and radiographic methods. 100% of all welds will be visually inspected.

Overall, the QA Plan prescribes inspection requirements from the time when materials are received at Supply Center Curtis Bay to the time they are installed. As entire systems are completed, a separate system of test memos will be invoked to measure performance and conformance with design specifications. The YARD will conduct a series of dockside and builder's trials to ensure that the vessel meets all requirements specified in the contract. Lastly, the Coast Guard will assemble an independent Pre-Acceptance Trial Board to evaluate the vessel's conformance with specifications and will determine LEOPOLD's readiness for commissioning into service.

STRUCTURE

The hull is being constructed of ASTM A-607, Grade 50 high strength low alloy steel having 50,000 psi yield strength and 65,000 psi ultimate strength.

The structure was designed to minimize weight while maintaining a 25 year service life. Flat stock design thickness was determined to be 3/16 inch for bottom shell, 11 GA for side shell, 1/8 inch for main deck, 12 GA for bulkheads and tank top, 9 and 10 GA for the transom, 3/8 inch for the keel, 1/4 inch for the shell around the tunnels and 5/16 inch for the propeller tunnels.

Since plate and sheet are typically rolled with the thickness variation all over the nominal, routine procurement would have resulted in an unknown and possibly substantial weight gain. To preclude this, our specifications included a + or - .005 inch thickness tolerance for the 3/16 inch and the 1/8 inch steel so that the mean would be at or close to nominal. These two thicknesses were the only items of sufficient quantity to warrant a mill run which was necessary to obtain the special tolerances. We also learned that our requirements could only be provided in sheet - thereby limiting the maximum width obtainable to 60 inches vs. the greater dimensions possible in plate.

Detailed design requirements also include angle shapes having unequal leg size to further minimize weight. Commercially available sizes were obtained and then cut down to the desired dimension. Flat bar longitudinal members were designed having scallops at the shell connection for weight reduction and maintenance purposes; these were cut out of sheet using the newly acquired CNC marking and burning machine (which will be discussed in greater detail later). Scallops in angle shapes were made using a punch and die on a hydraulic press.

The superstructure is being constructed of 5086 H116 aluminum plate and 5086 H111 aluminum shapes. Component thickness is designed to be 1/8 inch plate for the main to 01 deck house and 10 guage for the pilot house. The house front, main to 01 deck, is to be 5/32 inch plate. Variations in angle size up to 2 1/2 inch x 2 inch x 3/16 inch thick and some flat bar will be used for stiffening. The steel hull and aluminum superstructure will be joined using a 3/8 inch x 3/4 inch explosively bonded transition joint such as DETACOUPLE.

LOFTING/CUTTING

The conditions facing us as we embarked on this new construction project were:

- (a) a need to upgrade our existing oxy-acetylene/plasma cutting capability which operated on the pantograph principle
- (b) loss of lofting and templating talent
- (c) loss of lofting & templating facility
- (d) a desire to improve speed, accuracy and quality of both the lofting/templating and the marking/cutting of metals
- (e) a desire to acquire a state of the art capability.

Having first made the decision to replace the existing cutting machine for strictly facility improvement reasons, we then opted to incorporate the features needed to mark and cut out hull and superstructure components using software to be programmed by a commercial source.

- (a) We developed a specification for a computerized numerical control marking and cutting machine having both oxy-acetylene and plasma capabilities; it was solicited competitively in August-September 1989 and a contract awarded 27 September 1989. An ESAB machine, model G X M-1600, was installed in March 1990 and put into operation in April 1990.
- (b) A statement of work was developed for the needed lofting and templating software, solicited competitively and awarded to Maritime Design, Incorporated of Jacksonville, Florida in October 1989.

Throughout the work accomplished thus far we have recognized the close interaction needed between the detailed designers, the lofting/templating programmers and shop personnel and are pursuing the acquiring of in-house programming capability for future projects.

ERECTION

Our concerns in determining where and how to build the boat were:

- (a) maximum use of indoor construction facility
- (b) the likely order in which we would obtain metals
- (c) transporting the hull from the construction area to the abrasive blast area to a pier side final construction and launch location
- (d) the likely design schedule for defining hull components, e.g. - engine girders
- (e) accessibility to the areas of the hull for fitting and welding
- (f) ease of grit removal after the abrasive blasting
- (g) the complexity associated with structural details dictated by the upright or inverted position in which the boat would be built, e.g. the size and shape of cutouts in transverse members for longitudinals
- (h) design and construction of a bent system upon which the boat would be aligned and built
- (i) proper erection and weld sequencing
- (j) needed addition or change in facilities
- (k) one off vs. multi-unit construction.

After consideration of the different concerns we determined the most effective and economical approach would be to extend floor space and build the boat within the structural fabricating shop in an inverted position.

With engineering resources devoted early on to specify long lead time equipment and materials and to develop a design weight estimate, we turned to outside sources for the development of the erection and weld sequencing plan. We engaged the services of Scientific Management and Associates and NDI to meet with YARD engineering, shop and staff personnel to outline general objectives and to then develop the plan.

To date we have been able to follow the plan with one exception caused by later than expected receipt of lofting software. The deviation has been assessed by NDI and determined to be acceptable. Alignment of the hull components and distortion due to weld are well within permissible tolerance.

ROLL OVER AND LAUNCH

Having made the earlier decision to build the boat in an inverted position within the structural fabricating building our concerns focused on: a) weight handling capabilities, in-house and externally available, b) dimensional considerations within the building, i.e. - overall available height, desired distance under the main deck for fitting, welding and transport trailer access, c) retrieval of the boat after launching, d) available land area and terrain adjacent to the launch site, e) location of and provision for abrasive blasting of the hull, f) pier loading limitations.

Commercial A & E services were again employed to design and engineer a bent system upon which the boat would be built and an additional structure within which the boat would be turned upright and placed in the water.

KEY ELEVATION, figure (12), shows the rough outline of the bent system. The forward and aft sections are removable, the aft - to permit trailer access to the mid section which will be used in the transport/turning operation and the fwd - to eliminate unneeded weight after construction. Figure (13) shows the fixed mid section. Upon completion of construction the forward and aft sections will be removed as well as the mid section structure inboard of the WF 36 X 160.

The Key Elevation, figure (14), shows the structure outline between bulkhead 9 and 25 which makes up the turning rig. Figures (15), (16) and (17) show the construction details and dimensions of the turning rings. Figure (18) shows the calculated turning over distance to be approximately 40'-3".

Our plan is to remove the boat from the construction area on or about 20 May 1991 and move it to a location in between the shop and the pier location where the superstructure and major equipment will be installed. At the intermediate location a containment barrier will be erected and the boat will be abrasively blasted and prime painted. Upon completion, the remaining portion of the turning rings will be installed and the boat rolled over to an upright position at the location where land based work will be completed.

Further modification will be made to the structure so that it can be used to lift the boat and place it in the water using a floating crane in November of 1991.

SCHEDULING AND PROCUREMENT

The scheduling tool in use at the YARD was dependent upon the mainframe computer. Reaction time was very slow and downtimes were frequent. We wanted to improve in this regard and also use the software that was being promoted as the desired standard throughout the Coast Guard. We selected Super Project Expert software for use on Unisys B20 series computers.

We have made several iterations to date which have caused us to change the cutter delivery date from the original goal of August 1991 to March of 1992. This slip was driven by manufacturing time frames for commercially obtained equipment and materials, detailed design and engineering time frames dictated by available in-house and A & E resources, and administrative lead times required for procurement.

The procurement and engineering efforts create a linear succession of events which ultimately determine the construction and cutter delivery dates. The initial engineering specifications obtain specific technical details through equipment buys; this information in turn permits further detailed engineering and in turn additional equipment buys. Adherence to the Federal Acquisition Regulations further adds time to the procurement process by ensuring that measures are taken to achieve competition.

An important objective throughout the procurement process has been the obtaining of the lightest weight equipment and materials within practical limitations. A $5 per pound evaluation factor based on fuel savings over the service life of the cutter was established by Commandant G-AWP to be used during the solicitation and selection processes. Weight management has been made possible through actual weighing of items at the manufacturer's facility or upon receipt at the YARD.

NOISE CONTROL

The Contract Design Specification requires that NAVY Standard noise criteria be met in category A12 for the pilothouse, A3 for the galley, law enforcement center, mess room, radio room and B for the CO SR, XO SR, CPO SR, and crew berthing.

David Taylor Research Center in Annapolis was tasked with proposing noise treatments. Noise levels were predicted using the procedures outlined in the Combatant Craft Noise Reduction Handbook (NAVSEA S9073-AU-HBK-010) which indicated a structureborne noise problem approximately 10dB over the allowable level in the mess deck and galley areas in the 125 - 250 HZ frequency ranges.

The suggested solution to the problem was to rubber mount the platform deck which would include the tank tops between FR-16-19. European shipyards have used rubber mounts with success in attaching superstructures to main deck to reduce structureborne noise. An innovative seal was proposed that would have insured tank integrity, but this idea was discarded due to the complications involved in installation below the main deck and an estimated increase of 450 lbs. More traditional treatments were discussed and the final treatments selected are as follows:

(a) The sheathing of the galley forward of bulkhead 19 will be offset by 3 inches and mounted using rubber grommets to form a resiliently mounted secondary partition between the engine room and galley.
(b) All galley sheathing will be resiliently mounted to reduce airborne sound transmission.
(c) Three inches of fibrous glass felt, MIL-I-22023D will be applied to the side shell between frames 13-19. Two inches will be applied to the side shell elsewhere except in the forepeak tank. Two inches of POLYMIDE foam, DOD-I-24688, will be applied in the engine room, auxiliary machinery room and lazarette to save weight. Insulation will be faced with fibrous glass cloth in the living spaces and TUFFSKIN 1613 or equal in the machinery spaces.
(d) The overhead of the pump room and the main deck overhead will be treated with POLYMIDE Foam DOD-I-24688. This treatment will also be applied to the entire superstructure except for the fan room.
(e) The fan room will be treated with two inches fibrous glass felt, MIL-I-22023D type II, mass loaded vinyl sheet, followed by two more inches of fibrous glass felt, type III.
(f) The mess deck and galley (FR 13-19) deck covering will be MIL-M-15562-F Type 1 rubber, with a rubber underlayment to further attenuate structureborne noise.
(g) A lightweight PRC deck material will be used in the lower berthing area and carpet will be installed in the CO/XO Staterooms.
(h) The main engines, reduction gears and other rotating machinery that is normally operating will be mounted on isolation mounts.
(i) Other rotating machinery will be treated using Distributed Isolation Material (DIM).

A noise survey will be conducted after the described installations have been completed and identified "short circuits" will be corrected where possible.

The use of a cutconstrained damping treatment over the propellers has been discussed. This is a weight intensive treatment that may be considered depending on the results of the noise survey and sea trials.

The YARD's original total weight estimate for insulation and noise treatment amounted to approximately 3200 pounds of which approximately 1300 pounds was for lead loaded vinyl. This was based on the use of lightweight solimide foam throughout the ship; installation of the fibrous glass has resulted in an increase in weight, however, this has been offset by deletion of some lead loaded vinyl treatments. The YARD has succeeded in meeting the weight estimate.

As in most patrol boat design there is a fine line between noise treatment and weight impact. The YARD has carefully selected the treatments for the optimum envelope given weight considerations and is confident the prescribed criteria will be met.

TEST AND EVALUATION

LEOPOLD will undergo the normal cycle of builders trials and acceptance trials. These trials will be run by the Coast Guard Yard, just as would be done by a commercial shipyard for a naval vessel. The acceptance trials will be witnessed by a board of officers representing operational, maintenance and engineering interests. Based on the evaluation of the acceptance board, the boat will be accepted from the Coast Guard Yard and turned over to its crew for operation during a 17 month test and evaluation period. There will be an initial 7 month technical evaluation period followed by up to an 11 month operational evaluation period.

Following initial shakedown and training at Curtis Bay, LEOPOLD will proceed to its homeport in Portsmouth, VA to begin the technical evaluation period. The technical evaluation will be conducted by personnel from the Coast Guard Research and Development Center (R&DC) which is in Groton, CT. The technical evaluation period will be used to expand and supplement the data gathered during builder's and acceptance trials. The result will be a full set of technical data including speed and fuel consumption in calm water and in a seaway. Seakeeping will be evaluated with and without the rudder stabilization in operation. Side-by-side seakeeping trials with an Island Class patrol boat are planned to give an objective comparison of the relative seakeeping of the two designs. The bottom plating of LEOPOLD will be instrumented to measure the stresses at speed in a seaway. Towing, small boat launch and retrieve and machine gun mounts will also be evaluated for technical acceptability. The boat will be run through an electronic range to measure electronic propagation and through a de-perming range to check its magnetic signature. All of the systems will be tested during the technical evaluation period and the availability and maintainability observed during the period will be noted.

After the performance of LEOPOLD is validated during the technical evaluation, the U.S. Navy Commander, Operational Test and Evaluation Force (COMOPTEVFOR) will evaluate the operational performance. COMOPTEVFOR will evaluate the suitability of LEOPOLD to perform as required in what the Coast Guard calls the Sponsors Requirement Document (SRD). COMOPTEVFOR personnel will observe the operation of LEOPOLD by a typical Coast Guard crew under representative conditions. This period will include operational employments in Norfolk, the New York/New Jersey/New England areas and the Florida/Caribbean areas.

Results of both the technical evaluation and the operational evaluation will be documented in formal reports by the R&D Center and COMOPTEVFOR. These reports will be used as input to the Transportation Acquisition Review Council (TSARC) which will be asked to approve production of the Heritage Class patrol boats (As a part of the Office of Management and Budget Circular A-109 requirements, production approval is Key Decision Point 4 which is required prior to the start of unlimited production).

PRODUCTION

Following production approval from the Department of Transportation, proposals will be solicited from industry for production of Heritage Class patrol boats. A specification and a complete set of construction drawings will be provided by the government with a limited number of drawings such as the lines and general arrangement drawings being contract drawings. The remaining drawings will be for guidance only, but, if the contractor chooses to depart from the construction used in LEOPOLD, the contractor will be responsible to provide at least equal performance, both operational and life-cycle. Thus the contractor could use different main engines, as an example, but would be responsible to provide at least equal speed with no overall growth in boat weight or life-cycle fuel and maintenance costs.

The Coast Guard could eventually acquire up to 47 Heritage Class patrol boats. There is an established need for 96 patrol boats. Upon completion of the present Navy contract with Bollinger Machine Shop and Shipyard, the Coast Guard will have 49 Island Class patrol boats. That will leave a total of 44 82' patrol boats and 3 SES patrol boats which must be replaced within the next 5 to 10 years. The Coast Guard has initiated a request through the budget process to begin investigating the possibility of use of a smaller patrol boat, particularly in locations where the current 82 footer berthing facilities would not accommodate the larger Heritage Class without expensive upgrades. It is thus possible that the 47 needed replacement patrol boats will be a mix of Heritage Class and a class of smaller patrol boats.

Production funding for the Heritage Class will be sought through the normal budget process. Production at the rate of 11 or 12 boats per year is anticipated with the split between initial award quantity and outyear options being driven by budget realities.

As a way to improve the Heritage Class production patrol boats, several efforts are underway concurrent with the prototype construction. Naval Sea Combat Systems Engineering Station, Norfolk (NAVSEACOMBATSYSENGSTA) is reviewing the design to identify possible changes which would improve the producibility of the Heritage Class design. They are looking to identify those design features which could be changed to ease fabrication. They are also looking for things which might be a barrier to modern, production line techniques such as zone outfitting. The Coast Guard Research and Development Center is looking for possible design changes which might improve mission performance and/or reduce life-cycle costs. Possible examples include such things as crew reductions by use of prepared meals and an automated bridge. They are also looking at the possibility of using newer, lighter weight materials in certain applications and are studying the small boat launch and retrieval system. Prospective changes with a high probability of payback will be incorporated into the production design or possibly offered as an option to the production contractor.

CONCLUSION

USCGC Leopold, the Heritage Class patrol boat prototype is being constructed at the Coast Guard Yard and will be used to validate a new design which exploits the advantages of the multi-chine planing hull form developed by the US Navy. The design provides a very capable patrol boat with a durable and robust steel hull and a flexible propulsion system allowing continuous operations from 3 knots to 28 knots. Special attention is being given to weight control in the design and construction of the prototype to ensure the required performance is attained. Novel features which are being incorporated to meet performance requirements include rudder-roll stabilization, partial propeller tunnels and special noise control treatments. The prototype will be used to validate the design and confirm the required operational capabilities. As compared to the 110 foot Island Class patrol boats the Heritage Class patrol boats are expected to provide a softer ride in a head sea, a structure which is more resistant to damage and easier to repair and a collective protection system for operation in chemical, biological and radiological environments. After successful test and evaluation of the prototype, an as yet undetermined number of Heritage Class patrol boats will be produced to replace existing Coast Guard patrol boats which are reaching and, in some cases, exceeding their service life.

ACKNOWLEDGMENTS

The authors would like to recognize all of the people who have contributed to the important task of designing and building a new class of patrol boats for Coast Guard service. It is not possible to list all of the individuals involved, but we would like to acknowledge the contributions of the Coast Guard Yard, Coast Guard Supply Center Curtis Bay, Coast Guard Headquarters Offices of Acquisition, Engineering and Operations, Coast Guard Research and Development Center, Coast Guard Academy, U.S. Navy COMOPTEVFOR, NAVSEACOMBATSYSENGSTA, U.S. Naval Academy Hydromechanics Laboratory, David Taylor Research Center at Annapolis, NKF Engineering, Inc., Stevens Institute of Technology Davidson Laboratory, NDI, Inc., the venders and contractors who are providing detail design, materials and equipment for USCGC LEOPOLD and many other technical and industry personnel who have commented and contributed to the design development. Without doubt, all of the people involved in the Heritage Class development and production will be able to look with pride on the service to our Nation and to humanity performed in the years ahead by this new class of Coast Guard Cutters.

REFERENCES

[1] Cohen, S. H., Ghosh, D., Dodge, W. B., and McEachen, W., "Conceptual Design of an Offshore Patrol Boat", American Society of Naval Engineers Journal, Vol. 99, No. 1, January 1987.

TABLES & FIGURES INDEX

TABLE 1. PRINCIPAL CHARACTERISTICS

Length, overall	120.2 ft
Length between perpendiculars	110.0 ft
Beam, maximum overall	22.6 ft
Displacement, full load	162.4 LT
Displacement, trial load	154.35 LT
Freeboard, FP, to bulwark	10.5 ft
Freeboard, AP, to main deck edge	6.7 ft
Depth	12.0 ft
Mast Height above baseline	46 ft 3 in
Frame spacing throughout	3 ft 6 in
Draft, appendage, full load	6.4 ft
Draft, appendage, trial load	6.2 ft
Speed requirements at trial load, sea state zero:	
Minimum required speed	3.0 knots
Minimum speed at engine continuous power rating	28.0 knots
Minimum speed at engine intermittent power rating	30.0 knots
Endurance	5.0 days
Range, 10 hrs @ 30 kts plus 110 hrs at 9 kts	1290 NM
(note: maintaining a 19% fuel reserve)	
Range, maintaining a 10% fuel reserve	1430 NM
Accomodations, crew	18 male/female
Accomodations, spare	2 male/female
Total fuel tank capacity	7,750 gals
Fuel capacity required to meet range requirements	5,400 gals
Potable water capacity	800 gals
Watermaker capacity per day (2ea @ 400 g/day)	800 gals
MT1"	30.5 Ft Tons
TPI	3.23 Tons/inch

TABLE 2. LIST OF ARMAMENT

HUGHES 25 MM M242 AUTOMATIC CANNON

M2HB FLEX .50 CALIBER MACHINE GUNS (TWO EACH WITH THREE FIRING LOCATIONS)

M60 7.62 MACHINE GUNS (TWO EACH, FIRING LOCATIONS ARE INTERCHANGEABLE WITH THE .50 CALIBER FIRING LOCATIONS)

VARIOUS SMALL ARMS (9 MM PISTOLS, M16 RIFLES, RIOT SHOTGUN)

MAGAZINE FOR 25 MM, .50 CAL AND M60 AMMO

READY SERVICE LOCKERS FOR 25 MM, .50 CAL AMMO AND PYROTECHNICS

8.15 LTONS RESERVED FOR FUTURE ARMAMENT GROWTH

CURRENT 25 MM CANNON FOUNDATION AND SUPPORT STRUCTURE IS DESIGNED FOR FUTURE REPLACEMENT WITH A 30 MM GUN

AFT MAIN DECK STRUCTURE DESIGNED FOR FUTURE INSTALLATION OF FOUR PENGUIN MISSILE BOX LAUNCHERS
(TWO LAUNCHERS EACH ON BOTH THE PORT AND STARBOARD SIDES)

TABLE 3. **LIST OF MAJOR EEE EQUIPMENT**

HF RADIO COMMUNICATIONS

UHF RADIO COMMUNICATIONS

VHF-FM RADIO COMMUNICATIONS

SECURE VOICE COMMUNICATIONS

SECURE RECORD COMMUNICATIONS

IFF TRANSPONDER SET

DEPTHFINDER

WIND SPEED AND DIRECTION INDICATOR

DOPPLER SPEED LOG

GYROCOMPASS

RADIO DIRECTION FINDERS
(ONE FOR HF/MF, ONE FOR VHF/FM)

RADIO FREQUENCY NAVIGATION EQUIPMENT:
LORAN C
SATELLITE NAVIGATION
OMEGA

SURFACE SEARCH RADAR

1.92 LTONS ARE RESERVED FOR FUTURE ELECTRONICS SYSTEMS GROWTH

TABLE 4. SWBS WEIGHT INFORMATION

SWBS GROUP/ MARGINS/RESERVES	WEIGHTS IN LTONS ACCEPTED WEIGHT EST. 11/12/89	REVISED ACCEPTED WEIGHT EST. 9/11/90	QUARTERLY WEIGHT REPORT • 4/10/91
100 HULL STRUCT.	45.03	44.72	43.77
200 PROPULSION	28.90	22.99	24.13
300 ELECTRIC PLANT	10.81	10.81	10.38
400 COMMAND/SURV.	3.44	3.4	2.55
500 AUXILIARY SYS.	18.05	18.05	17.87
600 OUTFIT + FURN.	19.19	19.19	19.81
700 ARMAMENT	1.85	1.85	2.19
VAR. LOAD ITEMS	35.14	26.34	26.6
DESIGN MARGINS	3.61	3.85	1.56
BUILDERS MARGIN	2.54	2.54	2.54
EEE FUTURE GROWTH MARGIN	2.00	2.00	1.92
ORDNANCE FUTURE GROWTH MARGIN	9.08	9.08	8.15
GFE MARGIN	1.00	1.00	0.92
TOTAL (LTONS)	179.63	165.83	162.38

TABLE 5. HYDROSTATIC SUMMARY

CONDITION	FULL LOAD	HALF LOAD	TRIAL LOAD	MINOP
DISPLACEMENT(TONS)	162.4	150.6	154.4	147.6
KM (FT)	14.0	14.3	14.2	14.6
VCG (FT)	8.0	8.3	8.3	8.4
FREE SURF.COR.(FT)	0.1	0.1	0.1	0.1
GM, CORR(FT)	5.9	5.9	5.8	6.1
LCB (FT AFT AMIDSHIP)	10.7	10.8	10.7	10.8
LCF (FT AFT AMIDSHIP)	9.2	9.5	9.3	9.6
LCG (FT AFT AMIDSHIP)	10.9	9.9	9.9	9.5
TRIM (FT)	-0.1 AFT	0.4 FWD	0.4 FWD	0.5 FWD
DRAFT FWD(FT)	4.8	4.9	5.0	4.9
DRAFT AFT (FT)	4.9	4.5	4.7	4.4
DRAFT MEAN (FT)	4.9	4.7	4.8	4.6
DRAFT, APPENDAGE (FT)	6.4	6.0	6.2	5.9
TCG (FT)	-0.001 PORT	-0.008 PORT	-0.008 PORT	-0.012 PORT
LIST (DEG)	0.0 PORT	-0.1 PORT	-0.1 PORT	-0.1 PORT

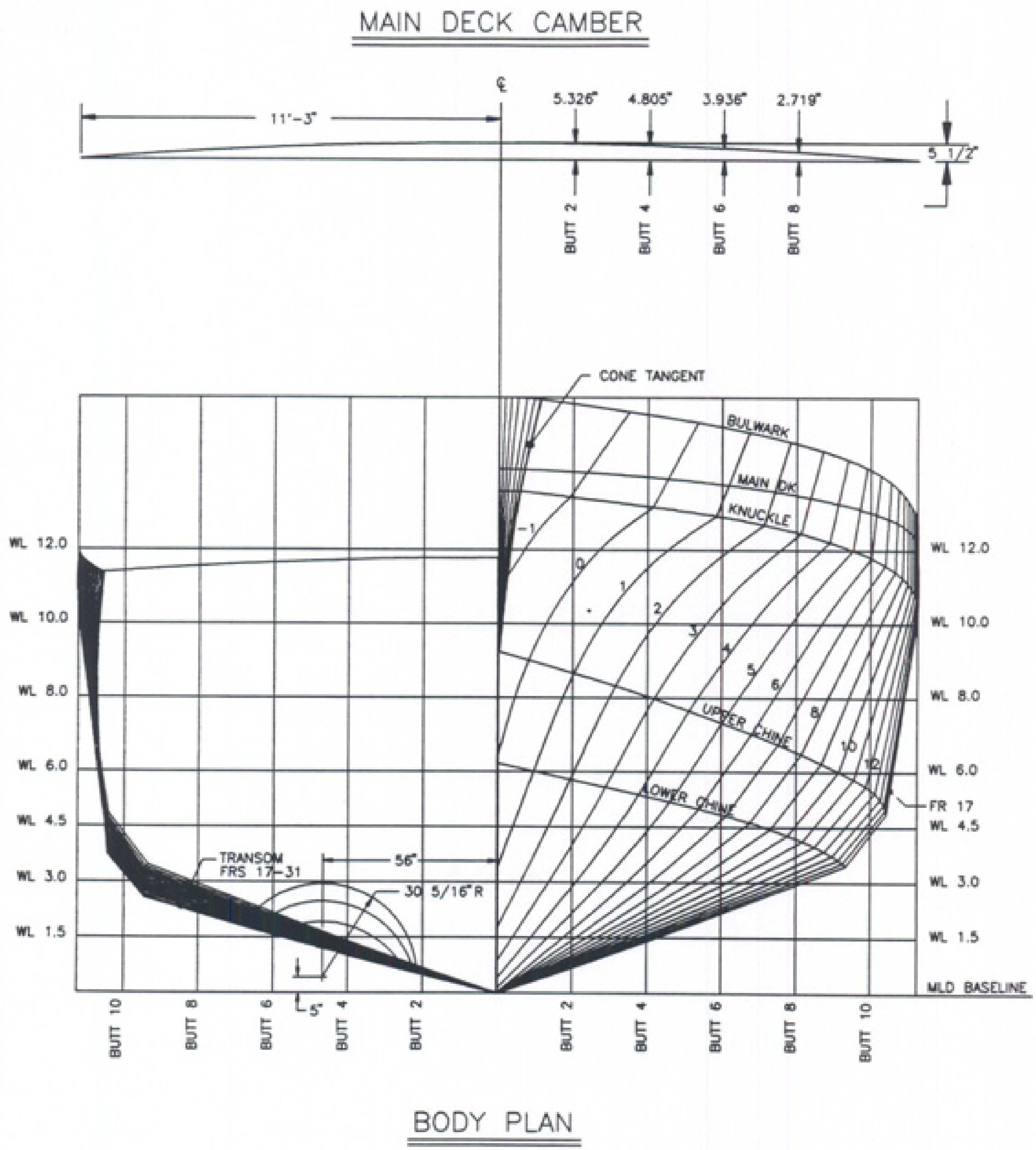

MAIN DECK CAMBER
℄
5.326"
4.805"
3.936"
2.719"
11'-3"
5 1/2"
BUTT 2
BUTT 4
BUTT 6
BUTT 8
CONE TANGENT
BULWARK
MAIN DK
KNUCKLE
-1
0
1
2
3
4
5
6
8
10
12
UPPER CHINE
LOWER CHINE
FR 17
WL 12.0
WL 10.0
WL 8.0
WL 6.0
WL 4.5
WL 3.0
WL 1.5
MLD BASELINE
TRANSOM
FRS 17-31
56"
30 5/16" R
5"
BUTT 10
BUTT 8
BUTT 6
BUTT 4
BUTT 2
BUTT 2
BUTT 4
BUTT 6
BUTT 8
BUTT 10
BODY PLAN

FIGURE 1

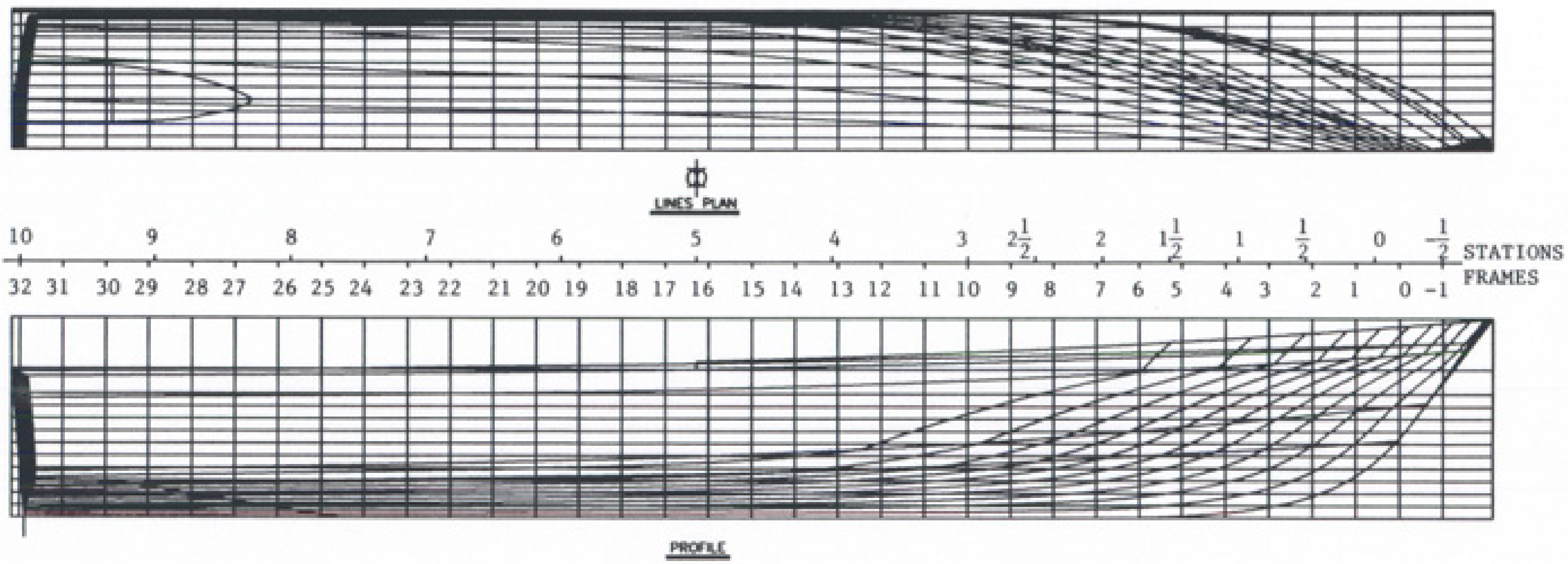

LINES PLAN
10 9 8 7 6 5 4 3 2½ 2 1½ 1 ½ 0 −½ STATIONS
32 31 30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1 FRAMES
PROFILE

FIGURE 2

OUTBOARD PROFILE

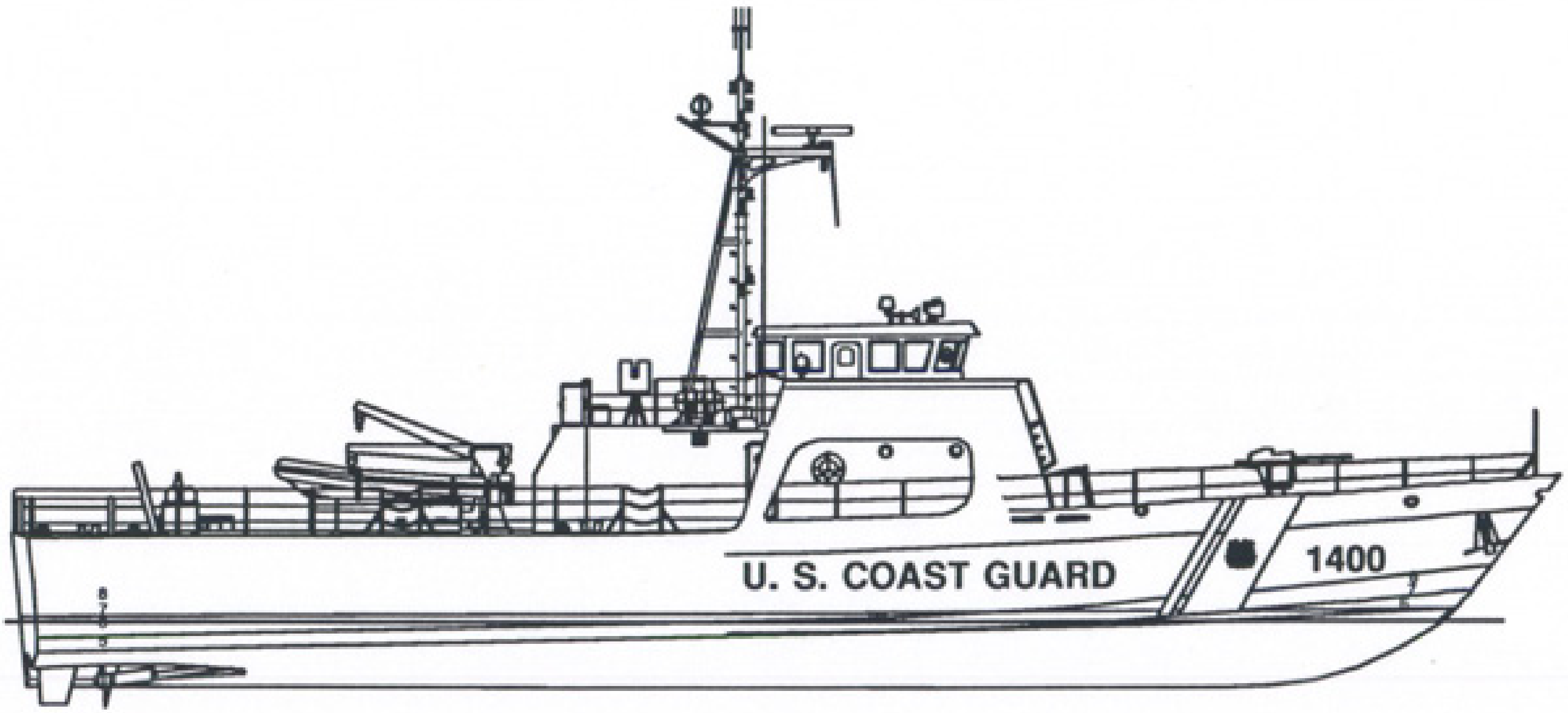


FIGURE 3

INBOARD PROFILE

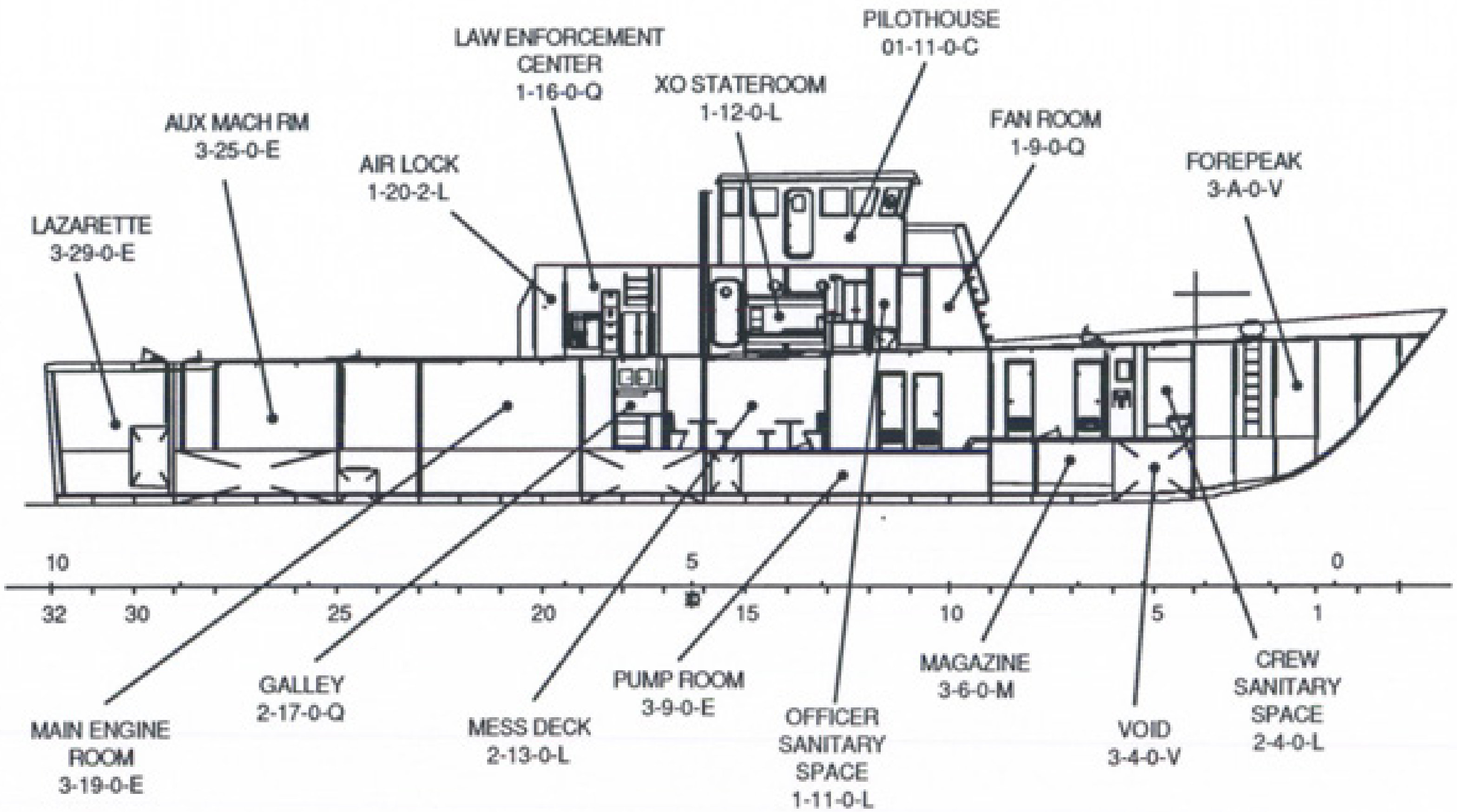


FIGURE 4

01 DECK ARRANGEMENT

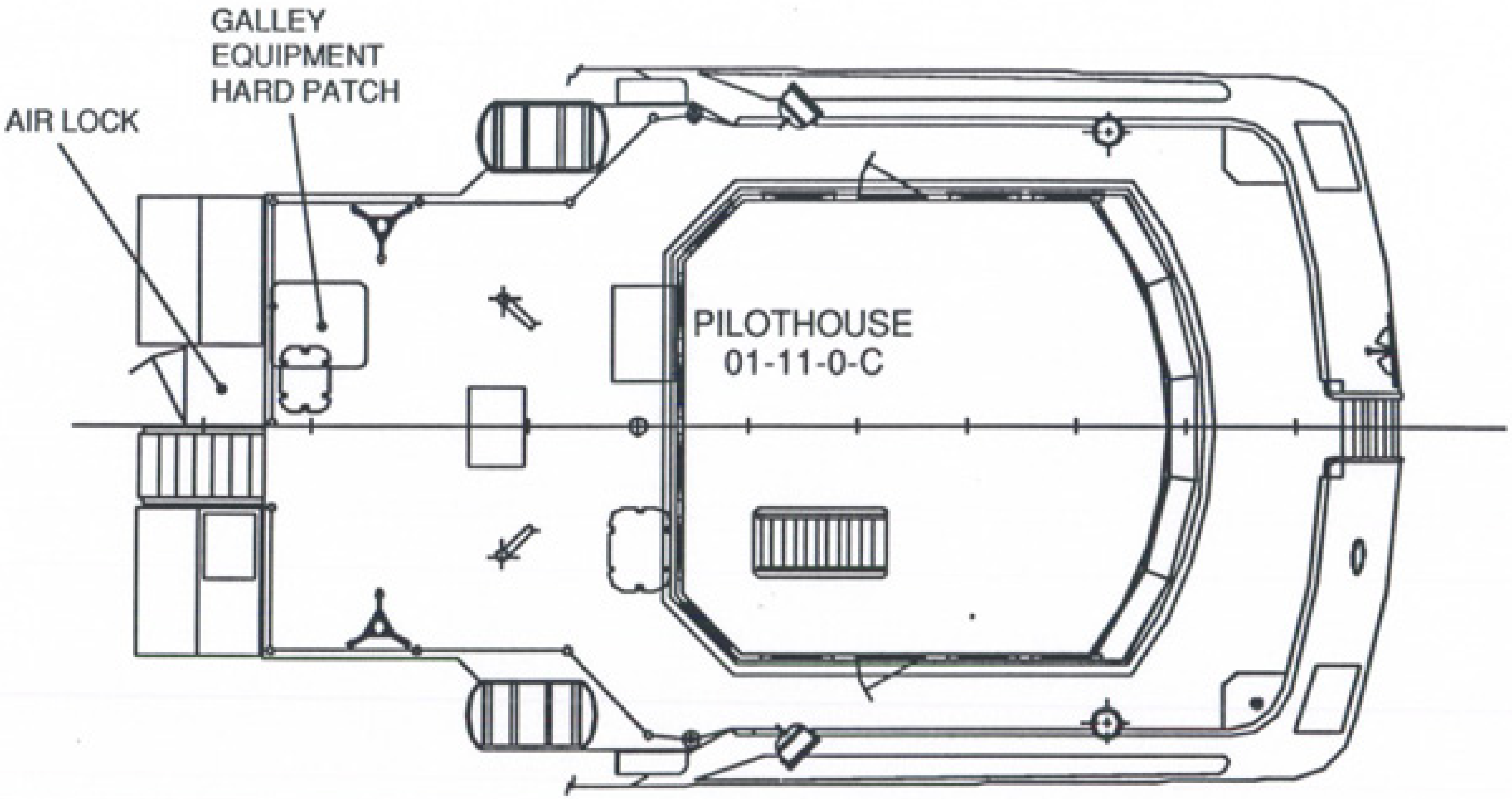


FIGURE 5

MAIN DECK ARRANGEMENT

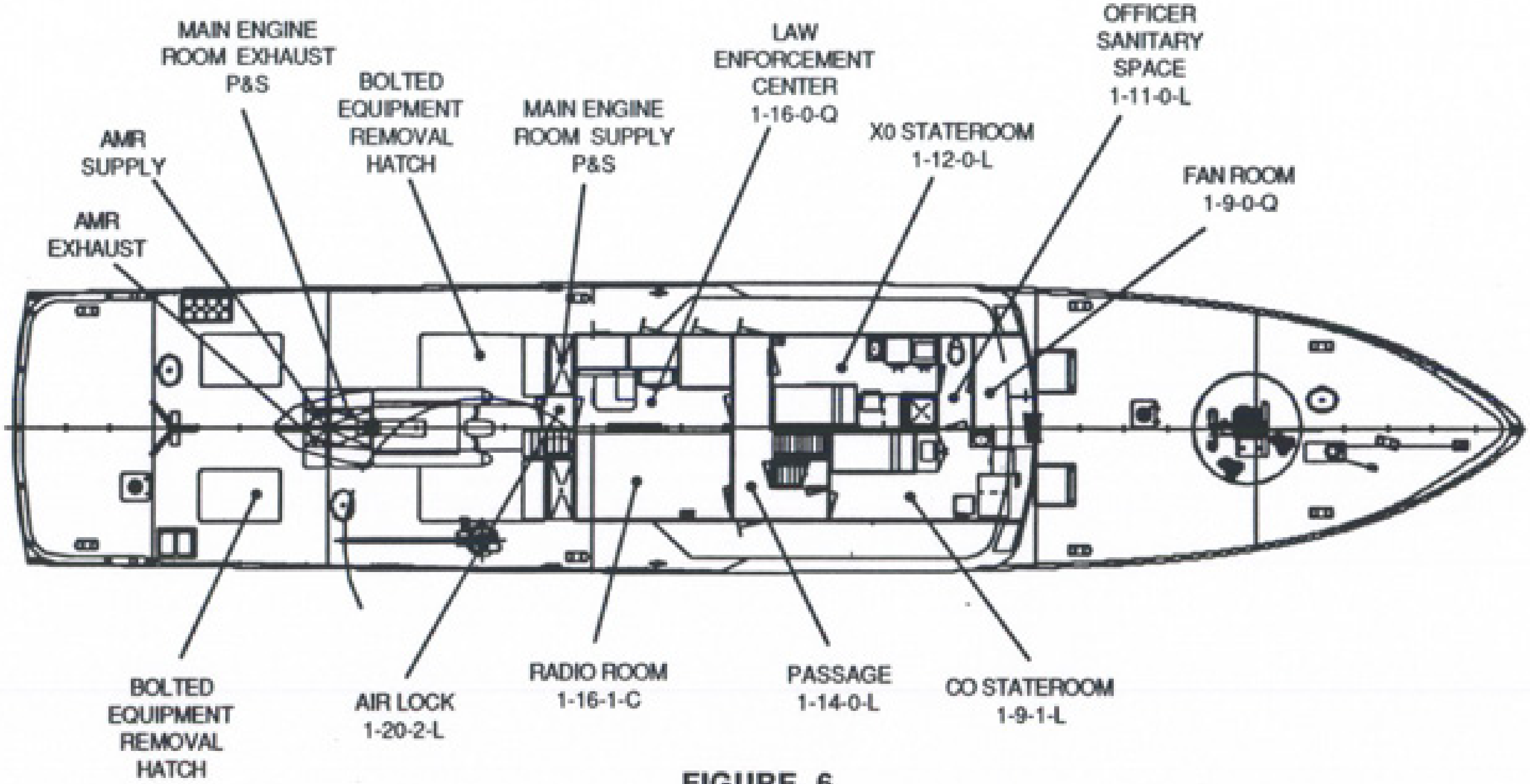


FIGURE 6

PLATFORM DECK

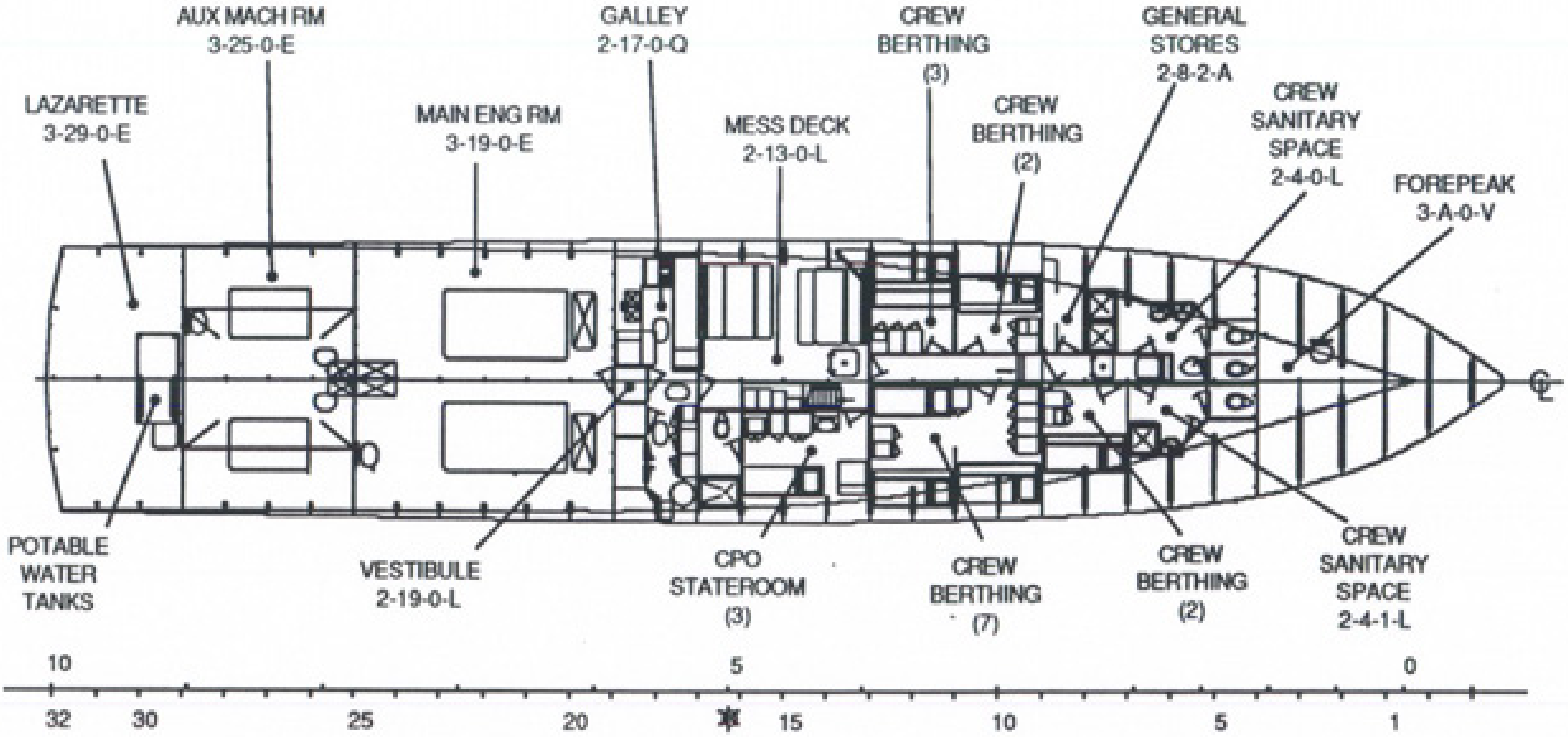


FIGURE 7

HOLD LEVEL

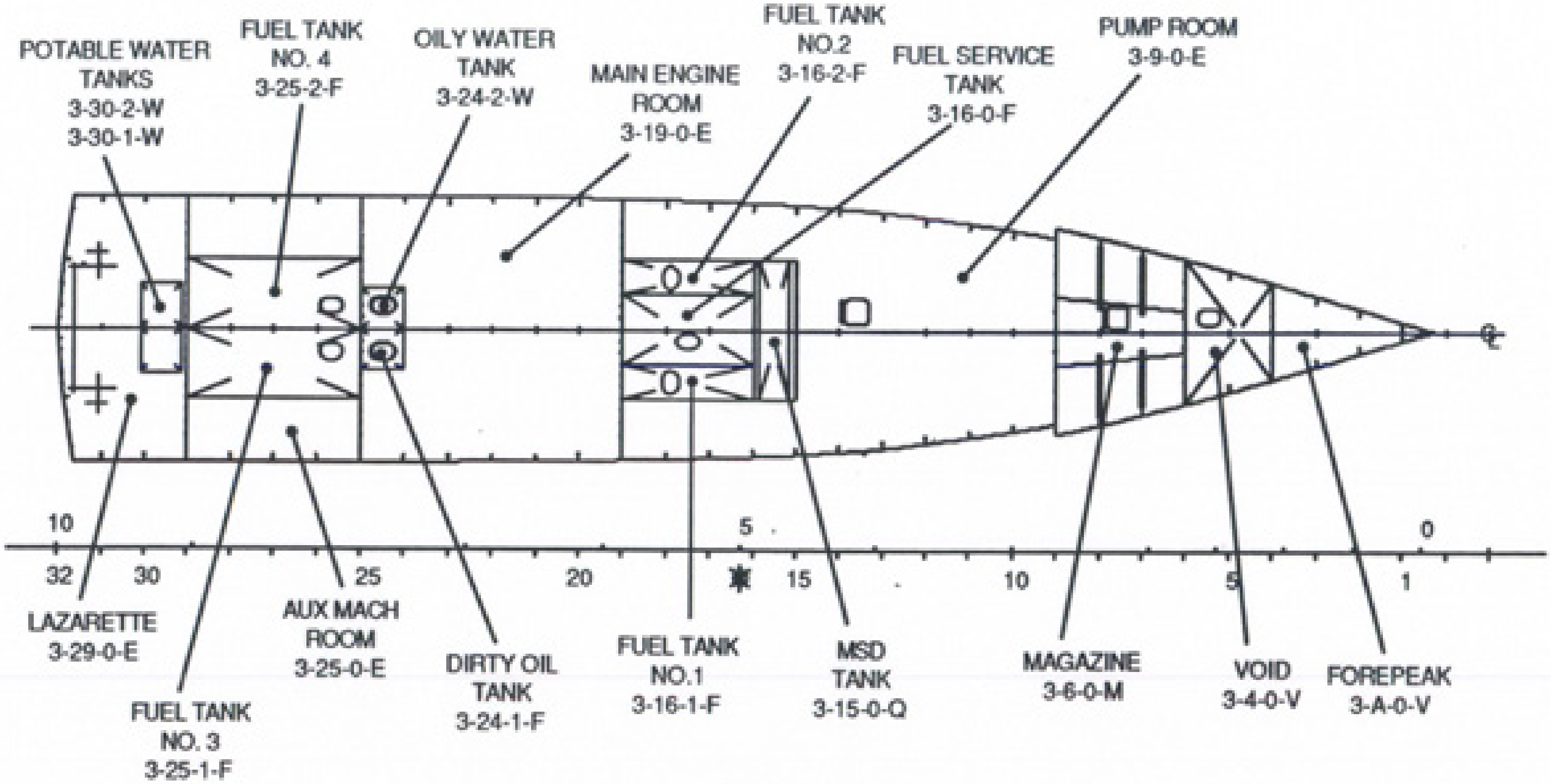
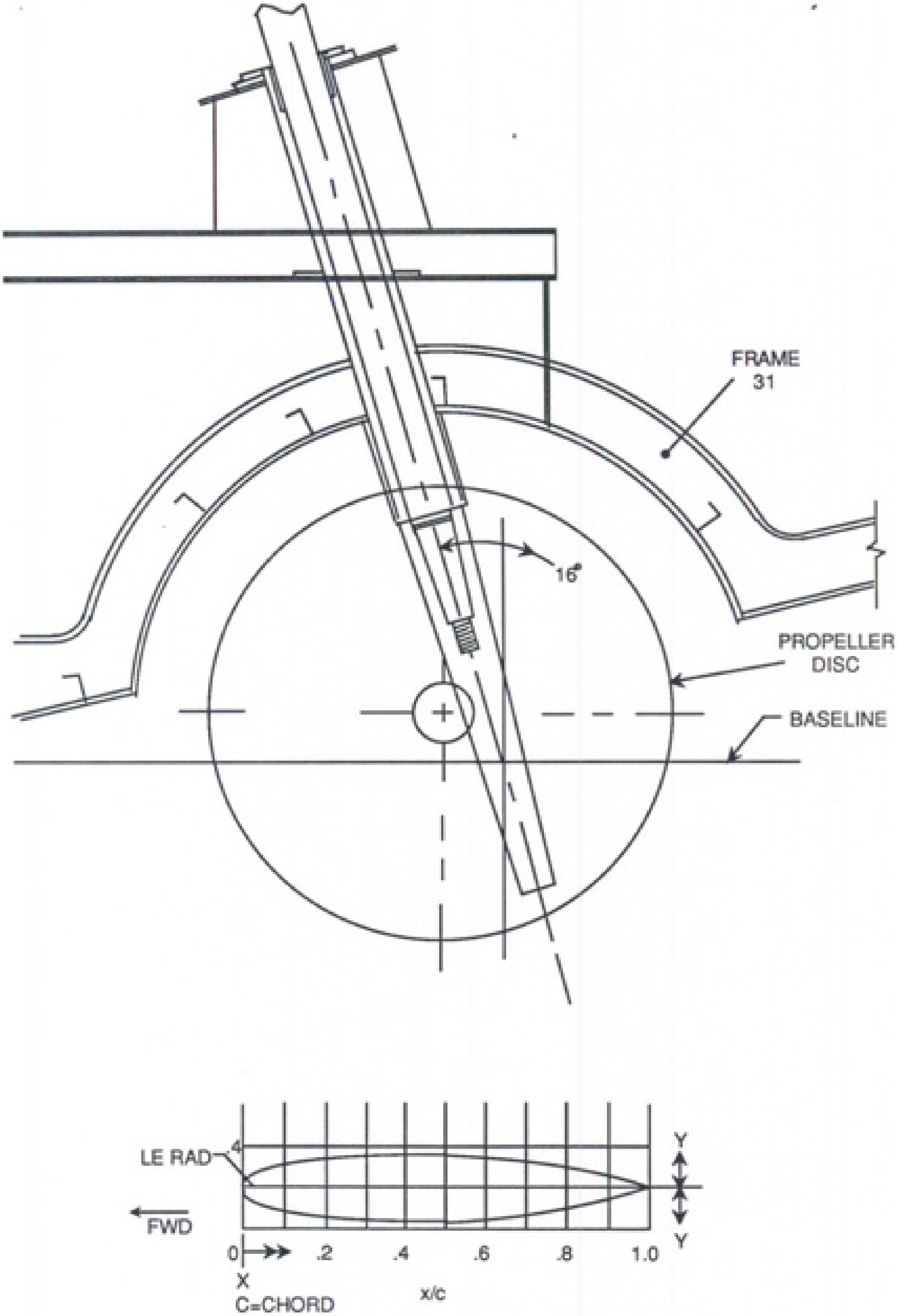


FIGURE 8



FRAME
31
16°
PROPELLER
DISC
BASELINE
LE RAD
4
FWD
Y
Y
0
.2
.4
.6
.8
1.0
X
C=CHORD
x/c

FIGURE 9

COLLECTIVE PROTECTION SYSTEM ZONE

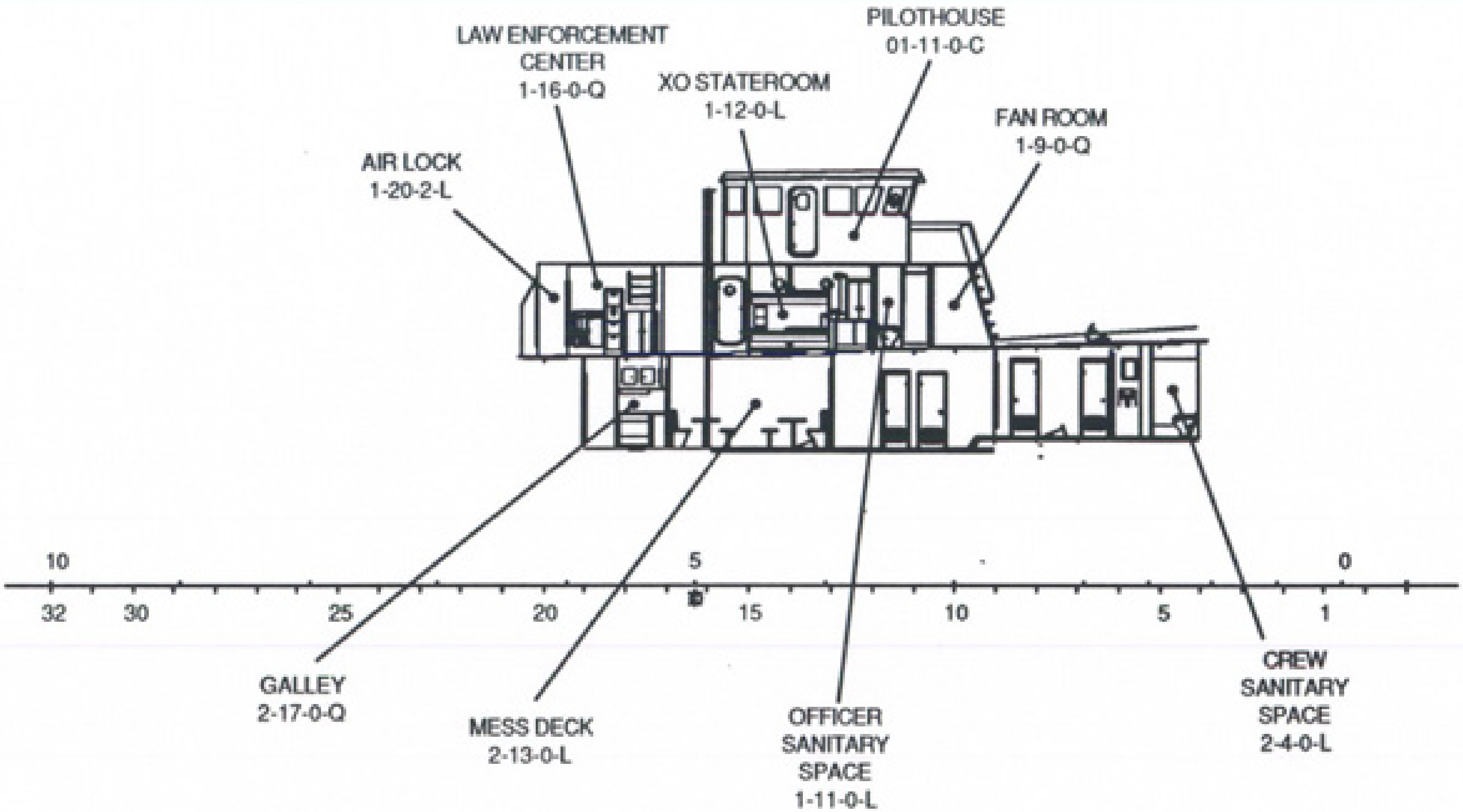
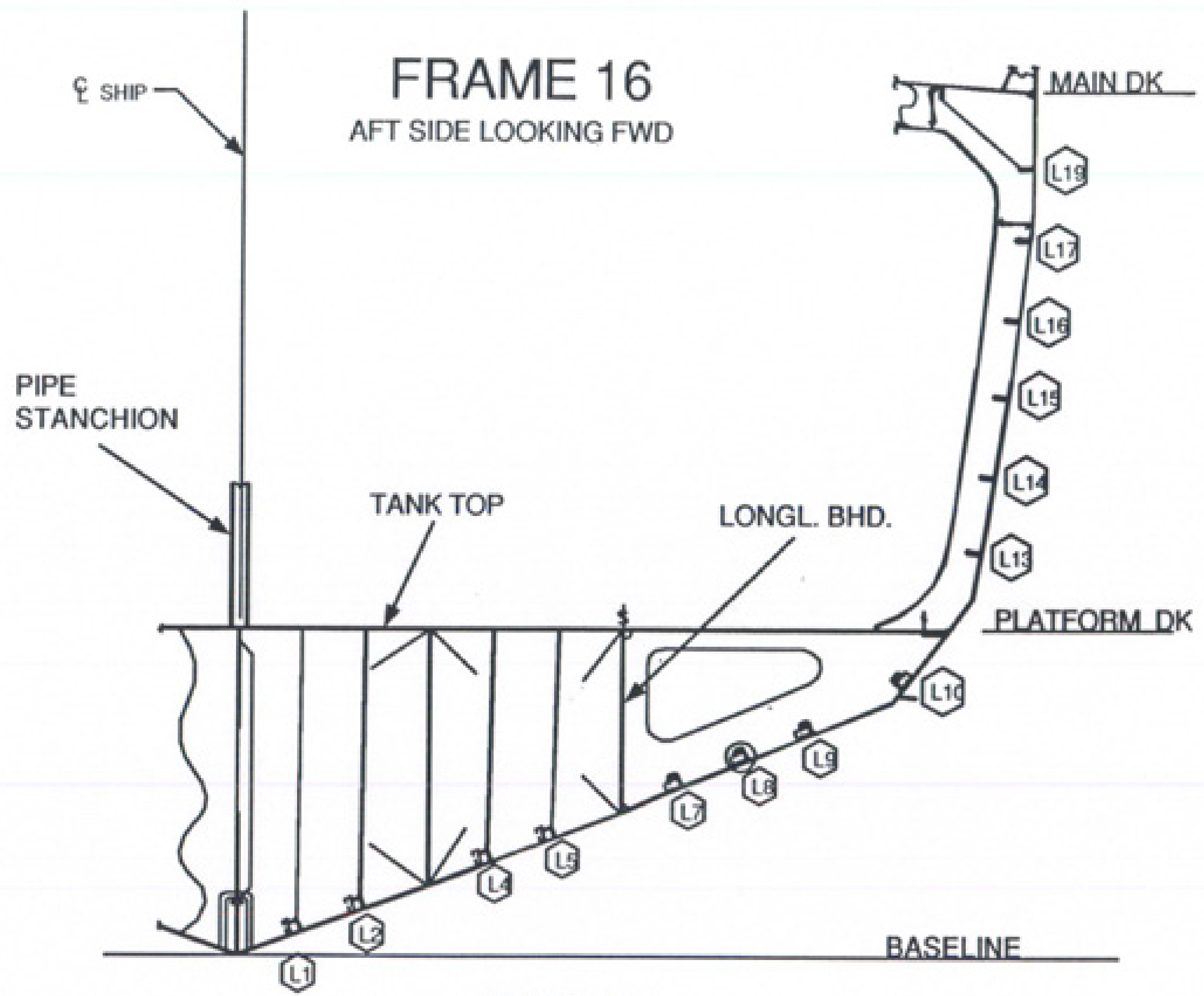


FIGURE 10



FRAME 16
AFT SIDE LOOKING FWD
℄ SHIP
PIPE
STANCHION
TANK TOP
LONGL. BHD.
MAIN DK
PLATFORM DK
BASELINE
L19
L17
L16
L15
L14
L13
L10
L9
L8
L7
L5
L4
L2
L1

FIGURE 11

KEY ELEVATION

BOAT/PLATFORM ASSY

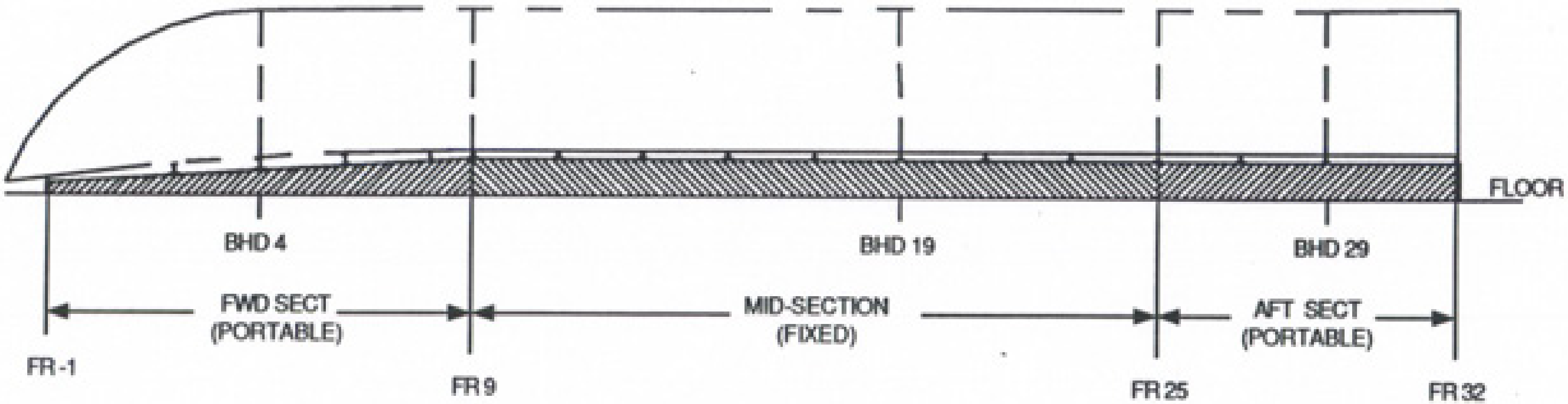
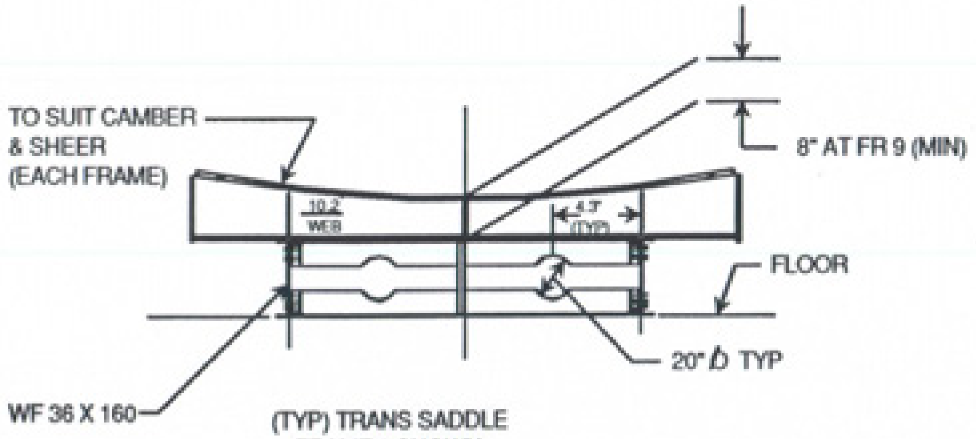
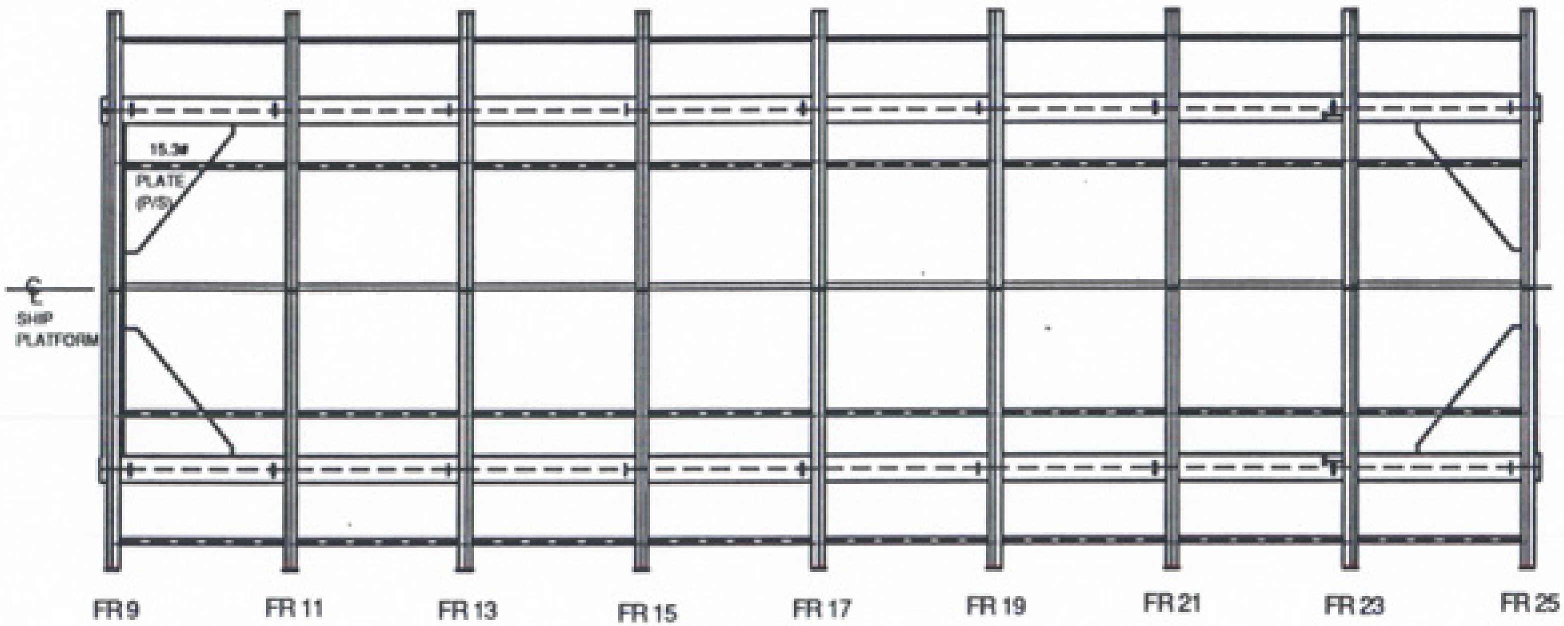


FIGURE 12



(TYP) TRANS SADDLE
FRAME 9 SHOWN
OTHERS SIMILAR



MID SECTION
(FIXED)

FIGURE 13

KEY ELEVATION

PLATFORM/TURNING RING ASSEMBLY

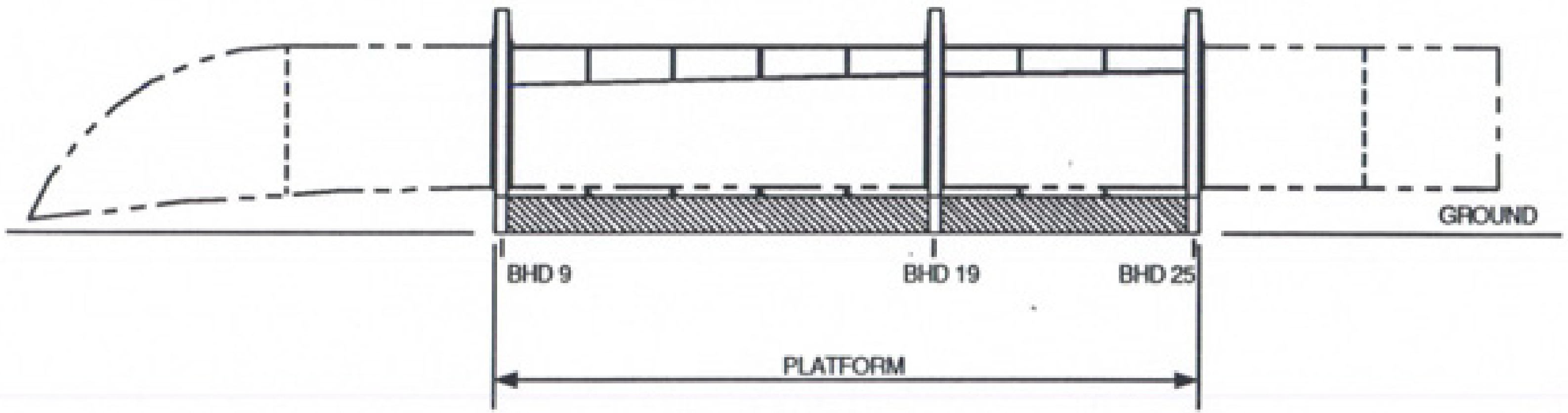


FIGURE 14

TURNING RING BHD 9

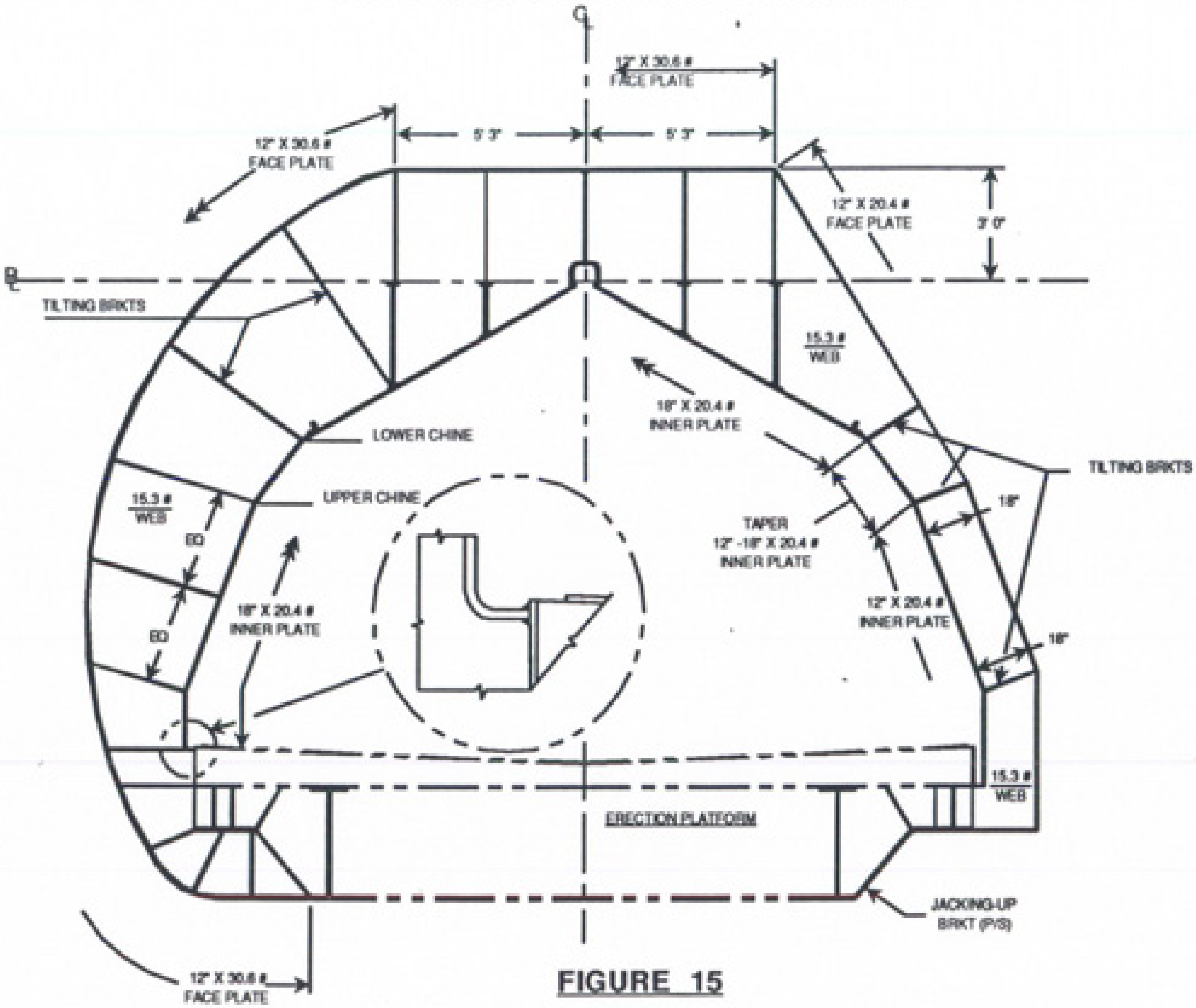


FIGURE 15

TURNING RING BHD 19

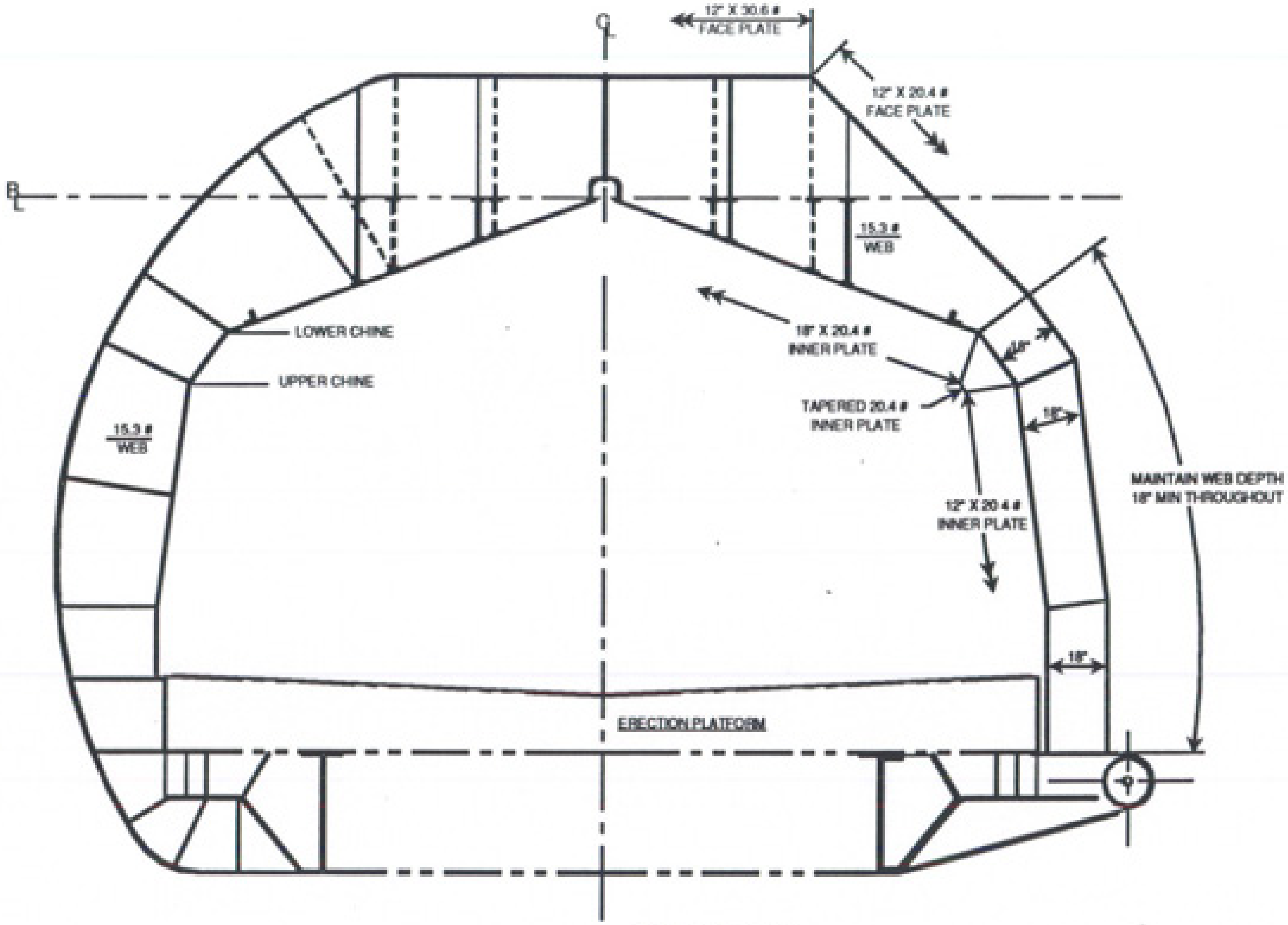


FIGURE 16

TURNING RING BHD 25

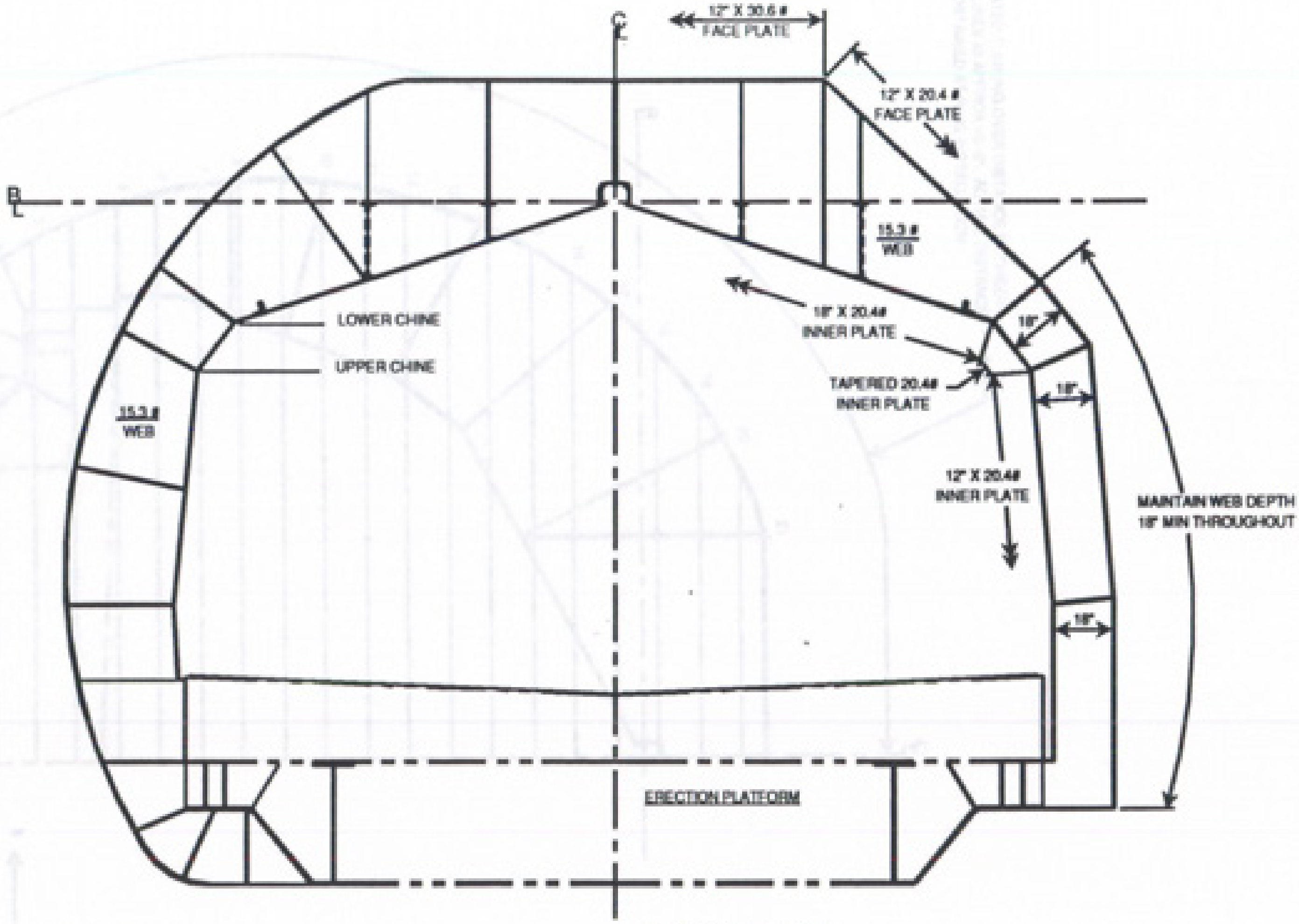


FIGURE 17