BOEING

FSCM NO. 81205

THIS DOCUMENT IS:

CONTROLLED BY PHM PRELIMINARY DESIGN, H-7301

ALL REVISIONS TO THIS DOCUMENT SHALL BE APPROVED BY THE ABOVE ORGANIZATION PRIOR TO RELEASE.

PREPARED UNDER
- CONTRACT NO.
- X IR&D
- OTHER

PREPARED ON DOCUMENT NO. D312-80946-2

FILED UNDER MODEL PHM

TITLE IMPROVED AND ENLARGED VARIANTS OF THE PHM 3 SERIES PATROL COMBATANT MISSILE (HYDROFOIL)

ORIGINAL RELEASE DATE 31 OCTOBER 1983

ISSUE NO. TO DATE

THIS DOCUMENT SHALL NOT BE EXPORTED EXCEPT UNDER DEPARTMENT OF STATE, OFFICE OF MUNITIONS LICENSE

ADDITIONAL LIMITATIONS IMPOSED ON THIS DOCUMENT WILL BE FOUND ON A SEPARATE LIMITATIONS SHEET.

PREPARED BY D.S. Olling R.G. Merritt H.D. Thomas

CHECKED BY

SUPERVISED BY R.G. Merritt H-7301

APPROVED BY R.G. Merritt H-7301

SIGNATURE ORGN DATE

DO 6000 2160 REV 9/82

ABSTRACT

The purpose of this document is to describe the PHM-Extended Hullborne Range (PHM-EHR) and the enlarged Model 928-78 variants of the PHM 3 Series ships. This document also provides a description of these ships, their configuration, ship's systems, mission capabilities and equipment, manning, and performance.

KEY WORDS

PHM 3 SERIES
EXTENDED HULLBORNE RANGE (EHR)
HYDROFOIL
MODEL 928-78
PATROL COMBATANT MISSILE (HYDROFOIL)
PERFORMANCE

TABLE OF CONTENTS

SECTION	TITLE	PAGE
1.0	INTRODUCTION	6
2.0	SUMMARY	11
3.0	PHM-EXTENDED HULLBORNE RANGE	12
3.1	SHIP CONFIGURATION	12
3.2	MISSION EQUIPMENT AND MANNING	16
3.3	SHIP PERFORMANCE	20
4.0	GROWTH PHM — MODEL 928-78	26
4.1	SHIP GENERAL DESCRIPTION	26
4.2	MISSION EQUIPMENT ALTERNATIVES	36
4.3	MANNING	37
4.4	SHIP PERFORMANCE	39
	REFERENCES	49

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.0-1	Squadron Comparisons (Five Ship Squadron)	7
3.1-1	Outdrive Assembly and Installation	14
3.1-2	Ship Service Power Unit Installation	15
3.2-1	PHM 3 Series CIC Arrangement	19
3.3-1	PHM-EHR Hullborne Range Capabilities	22
3.3-2	PHM-EHR Foilborne Range Capabilities	24
3.3-3	PHM-EHR Calm Water Thrust Margins	24
3.3-4	Range Capability, Mixed Hullborne-Foilborne Operation, Optimum Speed Strategy	25
4.1-1	Model 928-78 Exterior Arrangement	27
4.1-2	Model 928-78 Deckhouse Plan	31
4.1-3	Model 928-78 Platform Deck	31
4.1-4	Electrical System Functional Diagram	34
4.4-1	Model 928-78 Hullborne Power Requirements	41
4.4-2	Model 928-78 Hullborne Range Capability	41
4.4-3	7LM 2500 Maximum Horsepower	44
4.4-4	Model 928-78 Takeoff and Foilborne Drag	45
4.4-5	Model 928-78 Foilborne Range Capability	45
4.4-6	Model 928-78 Time Available for Hullborne Sonar Search, Mixed Hullborne-Foilborne Operation, ASW Mission	47
4.4-7	Model 928-78 Mission Profile Effect on Range Capability	48

LIST OF TABLES

TABLE	TITLE	PAGE
3.1-1	Range Extension Options Weight Summary	17
3.2-1	Mission Equipment	18
3.2-2	Manning	21
4.1-1	Model 928-78 General Characteristics and Principal Subsystems	28
4.1-2	Model 928-78 Weight Summary	30
4.4-1	MTU Series 331TC80 Marine Diesel Weight Summary	40
4.4-2	Model 928-78 Propeller Characteristics	40

1.0 INTRODUCTION

PHM is a well developed and tested ship system. Lessons learned from both construction and operation of the lead ship, USS Pegasus, have been incorporated into the production ship design. Many elements of the ship have been specifically designed to facilitate production. Detail manufacturing planning, tooling, and production management systems consistent with efficient rate production have been completed. Progression of five ships through the major tool positions demonstrated the effectiveness of the production design and process, and production learning has been achieved.

PHM is a cost effective ship in antisurface warfare (ASUW) missions. Analyses based on the PHM 3 Series design show that PHM can rapidly intercept and carry out a coordinated attack against seaborne threats. Eight surface-to-surface missiles and a 76-mm gun give the PHM a surface firepower capability comparable to the new construction destroyers (DD) and frigates (FF). Speed, maneuverability, and size make the PHM an extremely difficult target for aircraft and surface combatants. With a small underwater profile, a foilborne PHM is almost impossible to hit with a torpedo.

PHM is significantly more effective than lower speed conventional ships in surface barrier and choke point control missions and in trailing other ships including visual inspection. To provide the equivalent surface offensive capability, PHM can be over four times as cost effective as a DD and twice as cost effective as a FF (Figure 1.0-1). The PHMs require considerably fewer crew and support personnel, and their fuel usage is significantly more economical than large displacement ships. These studies are developed in reference 1.

PHM has the seakeeping ability to operate in the coastal or ocean areas anywhere in the world. The ship can operate foilborne at speeds over 40 knots more than 95 percent of the time in the North Atlantic Ocean, and over 98 percent of the time in the North Sea. A comparison study of the ride response of 300-ton conventional fast patrol boats, 3,000-ton destroyers and PHMs shows that PHM crew members

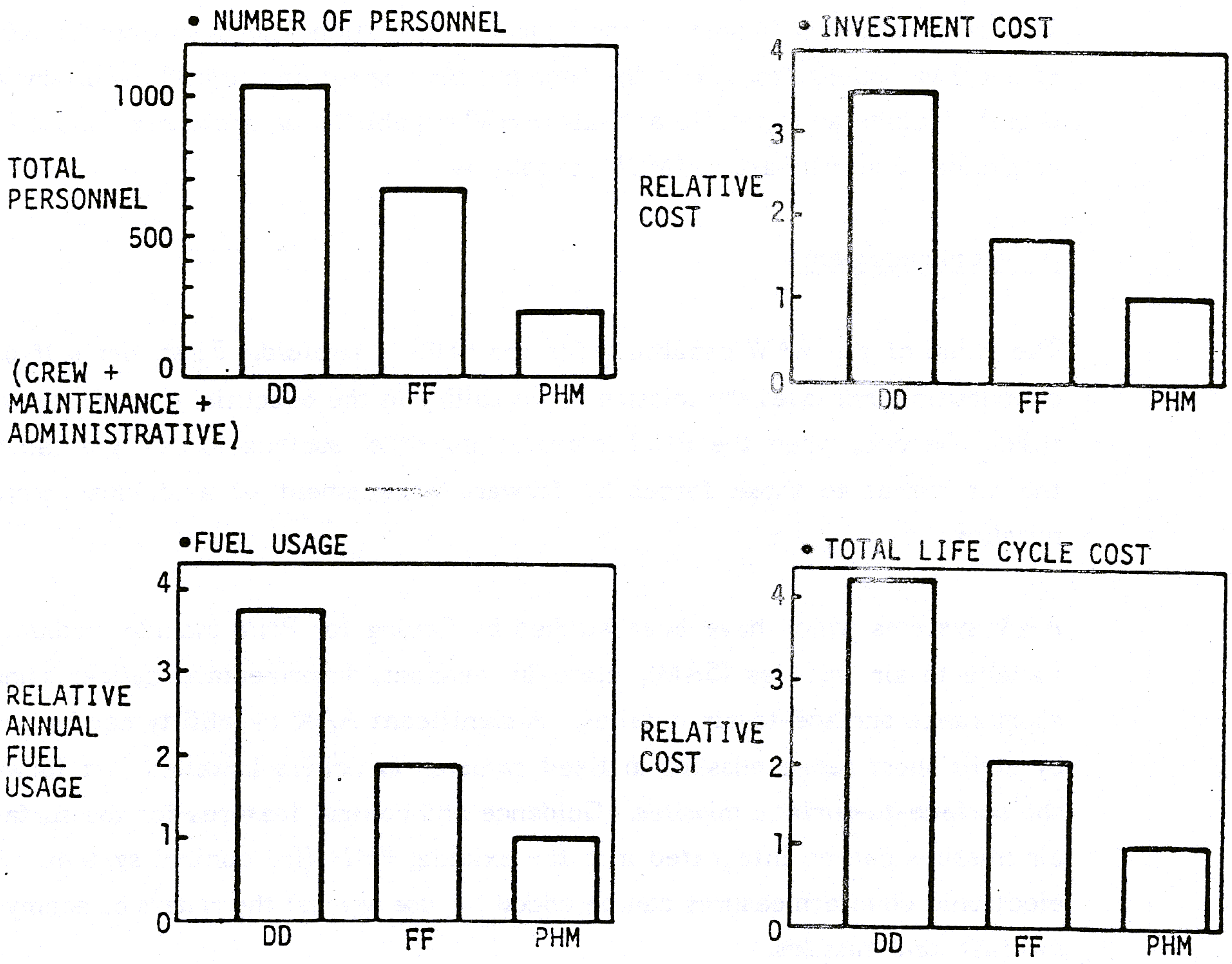

FIGURE 1.0-1: SQUADRON COMPARISONS (FIVE SHIP SQUADRON)

can retain their working proficiency for significantly longer periods in high sea states. In the hullborne mode, the PHM's ride quality approximates that of the destroyer. Details are shown in reference 1.

PHM has considerable potential for mission growth both through modification of her military payload and by alterations to enhance ship performance. Increased ship range and endurance have been shown to be readily achievable, reference 2. This is particularly important for hullborne operation where, in over 13,500 hours of underway operation, 3/4 of the time has been spent on the hull. Military growth options include an expanded anti-air (AAW) capability, an addition of an ASW suite, or a mine countermeasures (MCM) capability.

AAW Enhancement

The value of the AAW capability for the PHM is twofold. First, her self-defense contribution increases the mission survivability in the execution of surface warfare tasks. Second, when the PHM is protecting other surface forces, she can reduce the air threat to those forces by forward engagement of attacking aircraft or missiles.

AAW systems which have been studied by Boeing for PHM include medium range surface-to-air missiles (SAM), close-in weapons, intermediate caliber guns, and short range surface-to-air missiles. A significant AAW capability can be provided by eight short range missiles in fixed canister launchers installed just forward of the surface-to-surface missiles. Guidance and control features for the surface-to-air missiles can be integrated into the existing PHM fire control system. Active electronic countermeasures can be added for use against the radars of enemy ships, aircraft, and missiles.

One tactic considered is the deployment of PHM in the tattletale or trailing position within a few miles of the enemy cruise missile ships. The speed and maneuver capabilities of the PHM enable her to maintain an optimal position from which to fire SAMs at cruise missiles launched by the enemy. In addition, it is estimated that the PHM can move close enough to strike the enemy ship with surface-to-surface missiles before midcourse guidance commands can be sent to the cruise missiles.

ASW Capability

PHMs can be equipped for an Antisubmarine Warfare (ASW) mission and integrated into a group with conventional ASW ships. The PHM can be used as a pouncer to deliver weapons against a submarine contact held by another ship such as a DD.

Tests have proven that hydrofoils can launch torpedoes while foilborne. Configuration analysis has proven that PHM can be modified to carry torpedoes in deck tubes located forward of the surface-to-surface missile installation.

MCM Capability

The modern mine, especially of the influence type, has become a very sophisticated piece of equipment which requires sophisticated systems to counter it. The influence mine can be programmed to react to the pressure, acoustic, and magnetic (PAM) signatures of an overpassing ship, to any one of the signatures or to any combination, and to detonate for a single-count or multi-count of ships.

Mine countermeasures by sweeping offer a higher productivity (defined as area covered per hour) than hunting/neutralization to quickly open and keep open shipping channels through mine fields. In minesweeping the signatures of a ship are simulated with different devices. The pressure signature is most difficult to simulate with an acceptable low risk to the minesweeper.

Naval Coastal System Center's (NCSC) prediction, that hydrofoils positioned in a certain formation relative to each other can generate a pressure signature which can be recognized by a pressure mine set for conventional ships, has been evaluated by testing. The point of recognition of the signature is astern of the hydrofoils which are moving away at foilborne speed.

The PHM possesses some unique features which can provide a MCM capability to sweep mines if properly utilized. Adding sweepgear for acoustic and magnetic mines, a minesweeper is achieved which will improve the capability to sweep influence mines of the pressure-acoustic-magnetic (PAM) combination.

Document Content

This document describes the ships most appropriate for any future production procurement. The first squadrons would be identical to the PHM 3 Series except for changes to the hullborne propulsion system and the Ship's Service Power Unit (SSPU) to significantly increase the unrefueled hullborne endurance by 200-300 percent, increase the maximum hullborne speed to 13 knots, and increase the foilborne range by 8 percent. The performance improvement is achieved with a full load displacement growth of 6 metric tons (2.5 percent) to 247 metric tons.

The next squadrons would incorporate changes and growth in PHM which would utilize the full power capability of the LM 2500 gas turbine engine. On PHM 3, this engine is limited to an output of 17,000 metric horsepower which is sufficient to meet all performance specifications. However, the full power capability of the LM 2500, approximately 27,000 metric horsepower, is sufficient to power a ship of at least 300 metric tons displacement.

The larger ship, compatible with the 300-ton displacement, is created by merely adding 4 meters length to the PHM 3 hull at midship. Most of the ship's systems are identical to PHM 3 with, in some cases, minor changes to accommodate the larger spaces or longer runs. The deckhouse is extended to the full width of the main deck. As a result, additional space and increased useful load are possible with a minimum amount of redesign and relocation of major equipment items. This additional space and weight is used to improve habitability through expanded living and duty spaces, add deck area, improve the payload capability and increase the fuel loading. Again the hullborne propulsion with propeller outdrive units and diesel power for the Ship's Service Power Units produce significant improvements in the hullborne performance.

2.0 SUMMARY

PHM 1 is an extremely capable well tested ship which has, in effect, served as a prototype for the PHM 3 Series ships. Much knowledge was gained during the PHM 1 construction and during its operations resulting in many changes in the design and construction of the PHM 3 series. If additional PHM-type ships are procured other changes can be made to greatly improve the ship's performance. Using the PHM as a building block, two different configurations are presented: i.e. extended hullborne range (PHM-EHR) and an enlarged variant of PHM, Boeing Model 928-78.

The PHM-EHR uses the existing ship and changes only its hullborne propulsion system and the prime mover for one of the Ship's Service Power Units (SSPU). This, in effect, improves the efficiency of the propulsion system and reduces the fuel consumption of the SSPU. Although these changes increase the ship's displacement by six metric tons, they improve the unrefueled hullborne endurance by 200-300 percent, increase the maximum hullborne speed by two knots, and increase the foilborne range by eight percent.

The Model 928-78 builds even further on the PHM 3 Series ship. By using the horsepower available from the ship's foilborne engine, a General Electric 7LM2500, a major increase in ship size can be attained. Initial studies indicate that the ship would be four meters longer and about sixty tons heavier. Preliminary configuration and system designs and performance predictions have been made. The foilborne range will increase to about 1.7 times over that predicted for PHM 3, the optimum speed hullborne range will increase up to 7 times over that predicted. The hullborne speed, with larger engines, increased to approximately 15 knots. The additional space from the longer hull and full width deckhouse improve habitabiity, add deck area, improve payload capability and increase fuel loading.

3.0 PHM-EXTENDED HULLBORNE RANGE

3.1 Ship Configuration

The ship configuration described herein is the PHM 3 Series ship as defined in reference 7 with changes to the hullborne propulsion system and the Ship's Service Power Unit (SSPU) to increase hullborne endurance. These changes are the result of a number of preliminary design studies aimed at increasing the effectiveness and flexibility of this class of ships. The following options are the most effective of the means studied for increasing the unrefueled hullborne endurance, references 1 and 2.

a. Increasing the amount of fuel carried.

b. Replacing the hullborne waterjets with retractable propeller outdrives.

c. Substituting a diesel-driven Ships Service Power Unit (SSPU) for one of the existing gas turbine-driven units.

The first option can be achieved by adding fuel tankage, i.e., making modifications to the hull at the expense of redesign and relocation of auxiliary systems and equipment presently located in the hull voids. Without redesign, an additional 2.7 metric tons of fuel can be carried by filling the existing tanks to maximum usable capacity and operating with a 3-ton increase in full load displacement. This produces approximately a 6 percent increase in both foilborne and hullborne range. The option of adding significant fixed tankage to PHM 3 is feasible but is not pursued further in this discussion because of the need to relocate auxiliary equipment now occupying the available voids.

The second option exploits the greater efficiency of propellers at low speed, allowing more efficient fuel utilization and increasing the maximum hullborne speed with the existing installed horsepower. Since these propellers are retracted during foilborne operation, there is no appreciable change in foilborne range capability. This option, illustrated in Figure 3.1-1, requires minimal development because of experience gained from High Point (PCH 1) and Plainview (AGEH 1) outdrive designs.

Boeing Marine Systems has been examining the feasibility of hullborne propeller drives developed specifically for PHM since 1975. A preliminary design study of a number of propeller drive configurations is presented in reference 3. This study concludes that an outdrive arrangement is the most practical and trouble-free configuration. A more refined outdrive design was developed for a proposed U.S. Coast Guard version of the PHM 3 Series. This outdrive is described in reference 4. The range obtained with these outdrives is approximately 20 percent greater than with waterjets and the maximum hullborne speed is 2-3 knots greater.

The third option, the substitution of a diesel-driven SSPU for one of the gas turbine-driven units, significantly increases hullborne range. Currently, at the average power demand, the gas turbine-driven SSPU accounts for 30 to 70 percent of the total hullborne fuel consumption, depending on ship speed. The greater economy of the diesel reduces the fuel required for power generation by a factor of 3, i.e., from 122 kg per hour to 37 kg per hour. As shown below, this has a large impact on hullborne range and endurance. Because the foilborne propulsion fuel consumption is much greater, this reduction has a much smaller effect on the total foilborne fuel usage rate. This modification will increase foilborne range by about 3 percent when using the nominal PHM 3 fuel load of 47.2 metric tons or 9 percent when combined with filling the existing tanks to 49.9 metric tons of fuel.

This third option requires minimal ship redesign. The basic modification involves replacing SSPU No. 1, located in Auxiliary Machinery Room No. 1 on the main deck, with an MTU 6V331TC82 diesel-driven SSPU. The driven accessories are identical. This diesel also has substantial commonality with the two MTU hullborne diesels. The second gas turbine SSPU is retained. Figure 3.1-2 shows the new arrangement of Auxiliary Machinery Room No. 1 and the location of the SSPU in the ship.

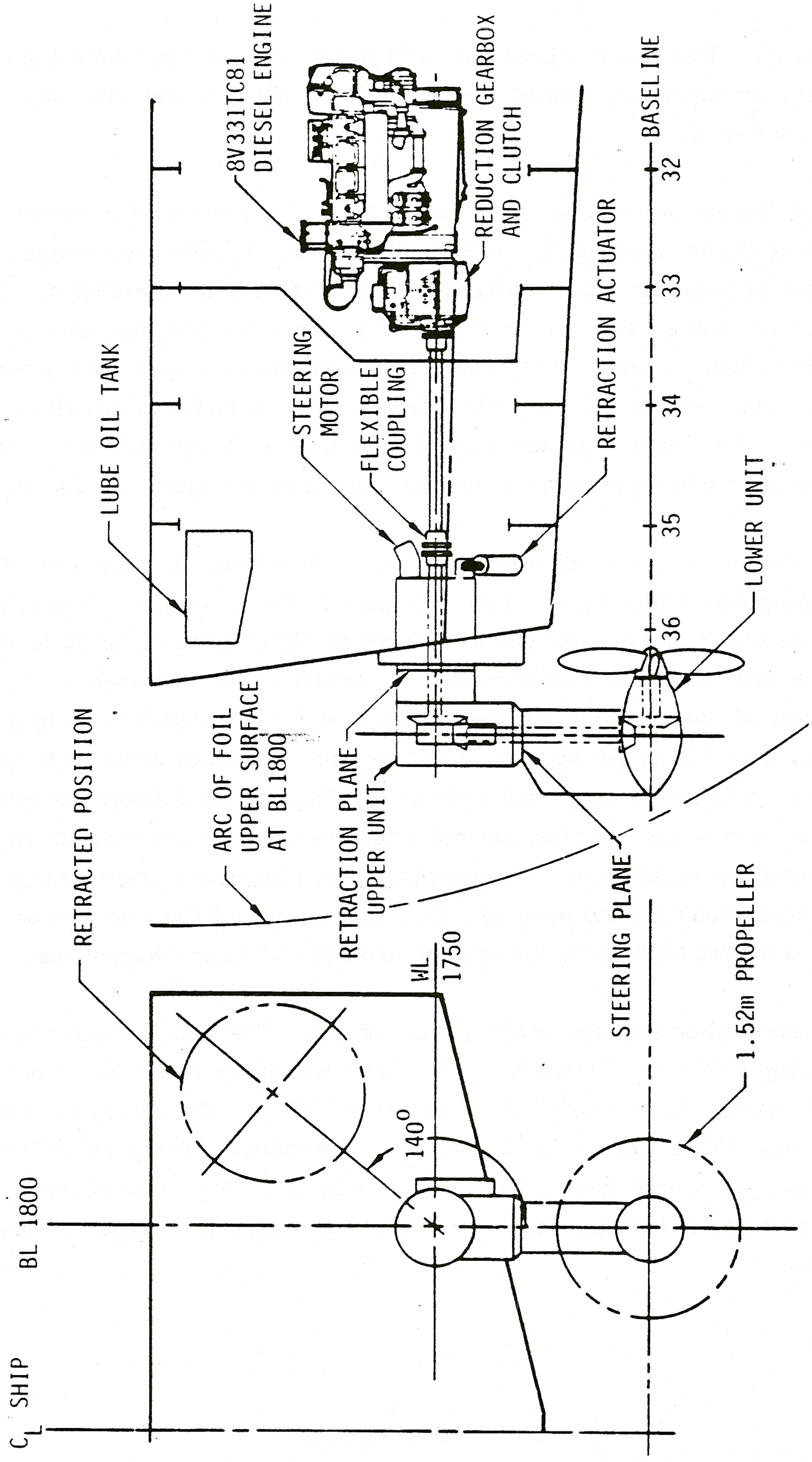

FIGURE 3.1-1: OUTDRIVE ASSEMBLY AND INSTALLATION

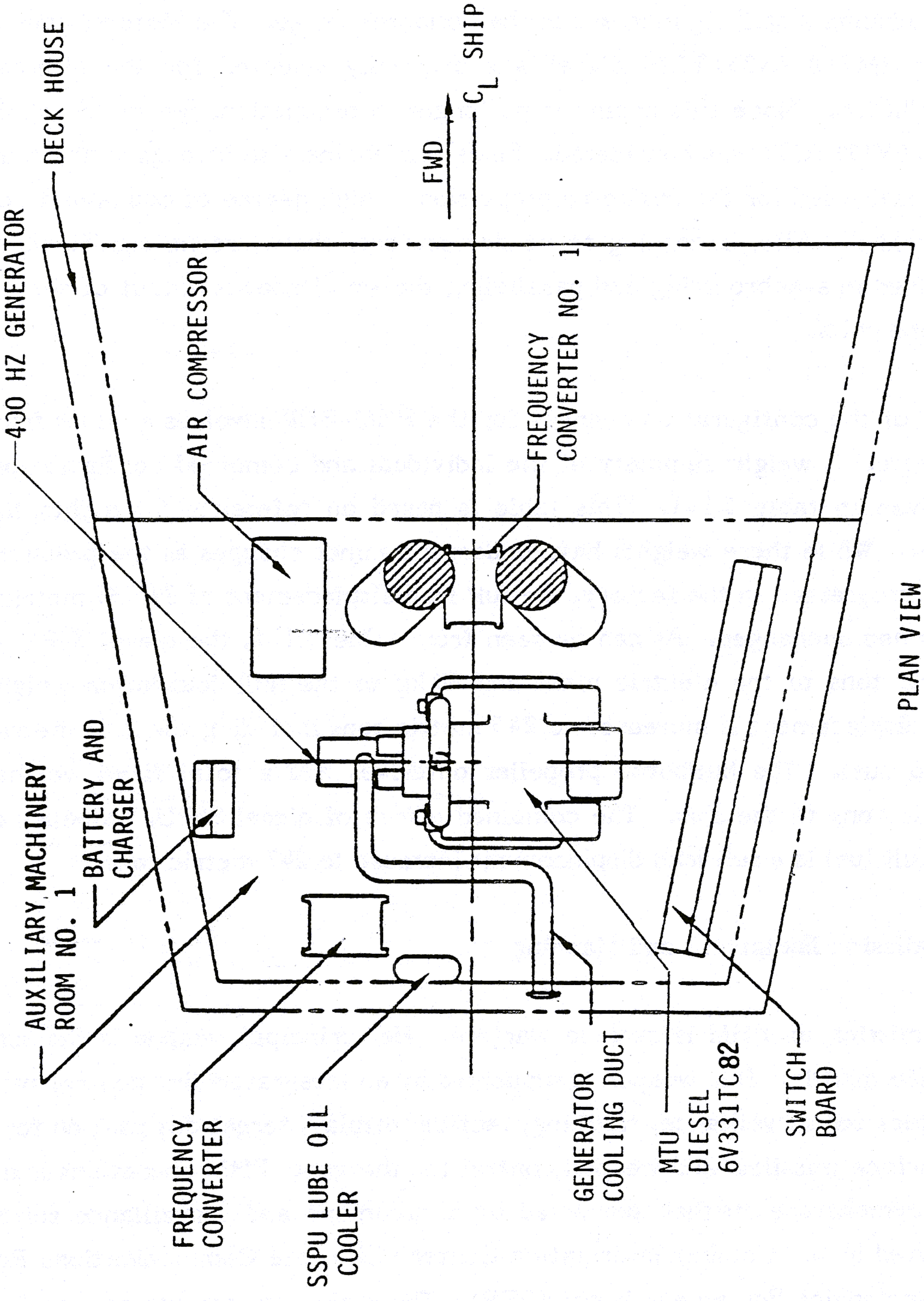

FIGURE 3.1-2: SHIP SERVICE POWER UNIT INSTALLATION

The feasibility of replacing one of the gas turbine-powered SSPUs with a diesel-driven unit delivering the same power was established in reference 5. The greater economy of the diesel reduces the fuel required for power generation by a factor of 3, producing a striking increase in the hullborne range. The Motoren-und Turbinen-Union (MTU) 6V331TC70 diesel was originally selected for the alternate SSPU installation. Since this engine is no longer in production, use of the similar sized MTU 6V331TC82 was considered. Since this engine also belongs to the same family of diesels used for the hullborne propulsion, a high degree of equipment commonality exists. Also, according to vendor sources, there are no significant problems involved in synchronizing and paralleling the simultaneous output of the diesel and turbine units.

Each of the configuration changes for the PHM-EHR involves a minor fixed weight increase. A weight summary of the individual and combined configuration options is given in table 3.1-1. This table is based on reference 6 weights for PHM 3 Series. While these weights have undergone minor changes as the production ships have progressed in the factory, the full load displacement of 241.39 metric tons has remained unchanged. As can be seen from table 3.1-1, the diesel SSPU adds 1.16 metric tons to the electric plant and 60 kg to the hull foundation weights. Full load displacement is increased to 245 metric tons including the 2.71 metric tons of added fuel. The hullborne propeller outdrives add a total fixed weight of 1.87 metric tons to the ship. The combined effect of diesel SSPU, propeller outdrives and full fuel is a full load displacement increase to 247 metric tons.

3.2 Mission Equipment and Manning

The mission of PHM is surface warfare. Her principal weapon is the surface-to-surface missile. This weapon is supported by an integrated fire control system that provides for surveillance, tracking, tactical display, target designation for surface-to-surface missiles, and weapon control for the gun. PHM operations and tactical employment are further supported by a command and surveillance suite accommodated in the Combat Information Center (CIC), the Communications Room, and an Electronics Equipment Room (EER). The major equipments are summarized in table 3.2-1. The general arrangement of the CIC is shown in figure 3.2-1.

TABLE 3.1-1: RANGE EXTENSION OPTIONS WEIGHT SUMMARY

(ALL WEIGHTS IN METRIC TONS)

WBS	DESCRIPTION	PHM 3 (UNMODIFIED) (1)		DIESEL SSPU VERSION (2)		PROPELLER OUTDRIVE VERSION (3)		DIESEL SSPU + PROPELLER OUTDRIVE VERSION (2) & (3)	
		NOMINAL FUEL LOAD	CAPACITY FUEL LOAD	NOMINAL FUEL LOAD	CAPACITY FUEL LOAD	NOMINAL FUEL LOAD	CAPACITY FUEL LOAD	NOMINAL FUEL LOAD	CAPACITY FUEL LOAD
100	HULL STRUCTURE	47.67	47.67	47.73	47.73	47.63	47.63	47.70	47.70
200	PROPULSION PLANT	25.91	25.91	25.91	25.91	27.79	27.79	27.79	27.79
300	ELECTRIC PLANT	7.30	7.30	8.46	8.46	7.30	7.30	8.46	8.46
400	COMMAND AND SURVEILLANCE	10.53	10.53	10.53	10.53	10.53	10.53	10.53	10.53
500	AUXILIARY SYSTEMS	53.49	53.49	53.49	53.49	53.52	53.52	53.52	53.52
600	OUTFIT AND FURNISHINGS	14.64	14.64	14.64	14.64	14.64	14.64	14.64	14.64
700	ARMAMENT	9.53	9.53	9.53	9.53	9.53	9.53	9.53	9.53
	LIGHTSHIP LESS MARGINS	169.06	169.06	170.29	170.29	170.94	170.94	172.17	172.17
	MARGINS	6.45	6.45	6.45	6.45	6.45	6.45	6.45	6.45
	LIGHTSHIP	175.52	175.52	176.74	176.74	177.39	177.39	178.62	178.62
	FULL LOAD LOADS LESS FUEL	18.67	18.67	18.67	18.67	18.67	18.67	18.67	18.67
	FUEL	47.20	49.91	47.20	49.91	47.20	49.91	47.20	49.91
	FULL LOAD DISPLACEMENT	241.39	244.10	242.61	245.32	243.26	245.97	244.49	247.20
	FOILBORNE WATER	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42
	LESS FOIL AND STRUT BUOYANCY	-6.23	-6.23	-6.23	-6.23	-6.23	-6.23	-6.23	-6.23
	CRUISE DYNAMIC LIFT	243.58	246.29	244.80	247.51	245.45	248.16	246.68	249.39
	50% FUEL DISPLACEMENT	217.79	219.15	219.01	220.37	219.66	221.02	220.89	222.25
	50% FUEL CRUISE DYNAMIC LIFT	219.98	221.34	221.20	222.56	221.85	223.21	223.08	224.44
	OVERLOAD AT 100% FUEL	------	2.71	1.22	3.93	1.87	4.58	3.10	5.81

SOURCES: (1) D312-80314-2, "QUARTERLY WEIGHT REPORT, PHM 3 SERIES", APRIL 1978
(2) D312-80910-1, "SUITABILITY OF A DIESEL DRIVEN SHIP SERVICE POWER UNIT FOR PHM", AUGUST 1975
(3) D312-80917-1, "HULLBORNE PROPELLER DRIVES FOR PHM VARIANTS", OCTOBER 1976

TABLE 3.2-1

MISSION EQUIPMENT

ARMAMENT:	(1)	76mm/62 cal. Oto Melara Gun
	(2)	Surface-to-Surface Missile Canister Launchers
	(2)	4.4-inch Chaff Launchers
AMMUNITION:	(400)	76 mm Rounds
	(8)	Surface-to-Surface Missiles
	(24)	Chaff Cartridges
		Small Arms, Ammunition and Pyrotechnics

COMMAND AND SURVEILLANCE:

Command and Control:	(2)	Radar Displays
Navigation:	(1)	AN/SRN-17 OMEGA
	(1)	SMA 3TM20-H Radar
	(1)	PL41E Gyrocompass and Vertical Reference
	(1)	UL-100-3 Underwater Log
	(1)	DE-723D Depth Sounder
	(1)	Wind Speed and Detection System (Type F)
	(1)	Dead-Reckoning Tracer
Interior Communications:	(1)	MCS 2000 Intercom, Announcing and Alarm System
Exterior Communications:	(1)	VHF Transceiver
	(2)	UHF Transceivers
	(2)	HF Transceivers
	(1)	Radio Teletype System
Surveillance:	(1)	IFF System
Countermeasures:		Rapid Bloom Off-board Chaff
		ESM (Weight, Space, Power Reservations)
Fire Control:		Gun Fire Control System
		Surface-to-Surface Ship Command-Launch Control Set

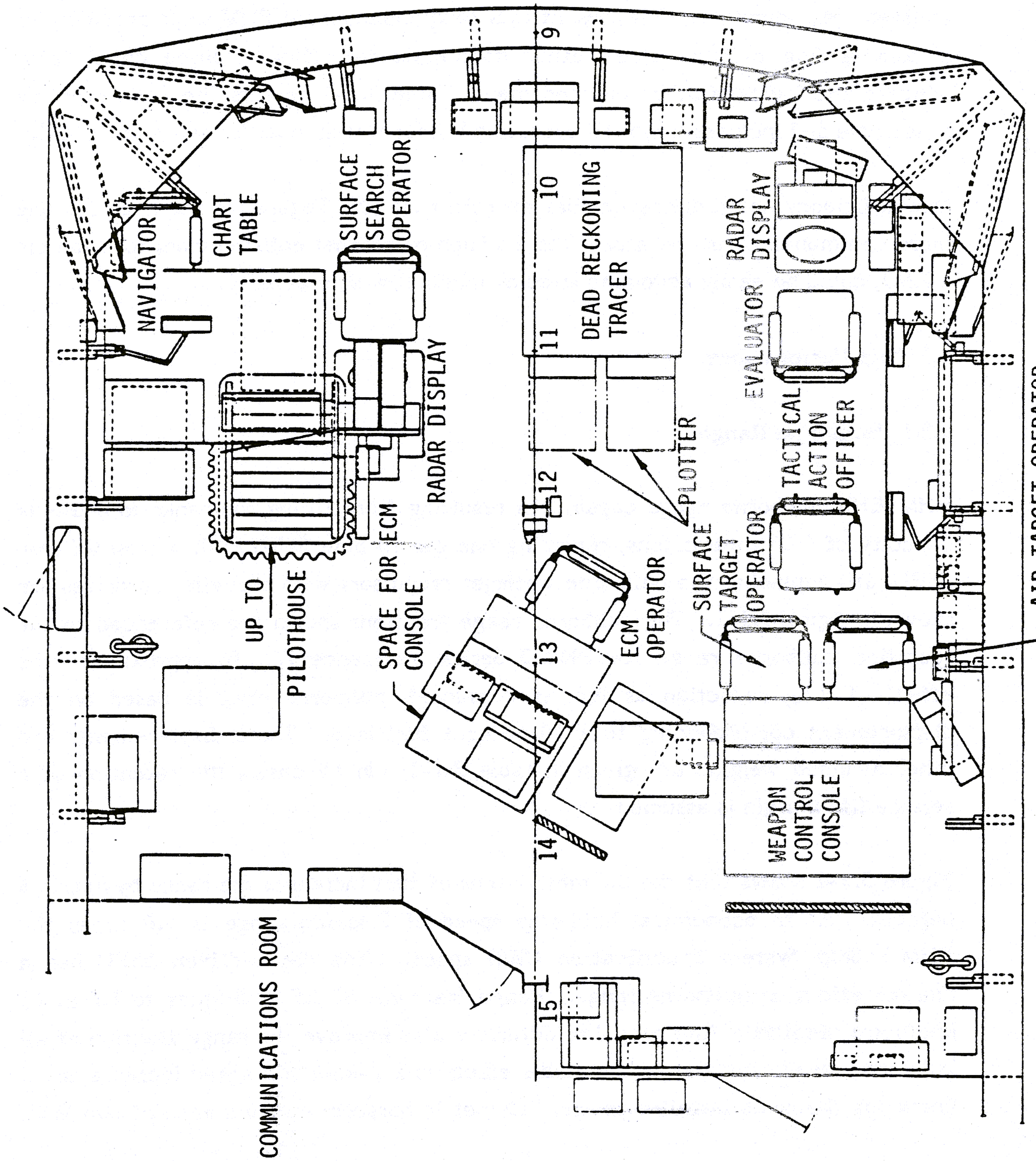

FIGURE 3.2-1: PHM 3 SERIES CIC ARRANGEMENT

USS Pegasus (PHM 1) and the PHM 3 Series ships have the capability to house a total of 24 personnel. Accommodations are available for one commanding officer, four other commissioned officers, four chief petty officers and fifteen other enlisted crew members. The present U.S. Navy manning for PHM ships provides for a commanding officer, three other commissioned officers, three chief petty officers and fourteen other enlisted men. Table 3.2-2 depicts the PHM crew by billet title and includes a typical operating bill (or watch, quarter and station bill).

One deficiency noted during combat exercises on USS Pegasus is the need for one more communications operator. The addition of another enlisted man, for example a RM3, could be easily accommodated at minimal weight penalty.

3.3 Ship Performance

3.3.1 Hullborne Range

PHM-EHR hullborne range capabilties resulting from filling the tanks to a usable capacity of 49.9 metric tons, replacing one gas turbine SSPU with a diesel-driven SSPU, and replacing the hullborne waterjet propulsors with propeller outdrives are shown in figure 3.3-1. The hullborne range fractions shown are referenced to the specified hullborne range for PHM 3 Series, reference 7. To approximate the effect of drag reduction as fuel is consumed, hullborne drag is based on the displacement corresponding to a 50 percent fuel load. These displacements and other assumed weights are given in table 3.1-1. In all cases, the retention of a service life margin is assumed.

Figure 3.3-1 shows that the 2.7 metric tons of fuel increases the range by nearly 6 percent. At an economical hullborne speed of 8 knots, range is 1.6 times the PHM 3 Ship System Specification (SSS) speed. The diesel-driven SSPU has a marked effect on hullborne range. Range fractions of 2.9 at 8 knots to 1.6 at 11 knots are obtained. The propeller outdrives also improve the range fraction at all hullborne speeds, but the most notable effect is a 2-knot top speed increase to 13 knots for the same installed power, 815 metric horsepower from each of two MTU

TABLE 3.2-2: MANNING

OPERATING BILL		
BILLET	GENERAL QUARTERS	WARTIME CRUISING
LCDR	COMMANDING OFFICER	COMMANDING OFFICER
LT	TACTICAL ACTION OFFICER	EVALUATOR
LTJG	EVALUATOR	EVALUATOR
LTJG	OFFICER OF THE DECK	OFFICER OF THE DECK
QMC	NAVIGATOR	OFFICER OF THE DECK
FTG1	SURFACE TARGET	SURFACE TARGET
ENC	ENGINEER'S OPERATING STATION	ENGINEER'S OPERATING STATION
FTG2	AIR TARGET	SURFACE TARGET
GMG1	LOADER I	HELMSMAN
BM2	HELMSMAN	HELMSMAN
OS1	SURFACE SEARCH	SURFACE SEARCH
ET2	PLOTTER II	--
RM2	COMMUNICATIONS OPERATOR	--
EN1	DAMAGE CONTROL CENTRAL	ENGINEER'S OPERATING STATION
EM2	DAMAGE CONTROL I	ELECTRONIC SUPPORT STATION
EN3	DAMAGE CONTROL II	PLOTTER I
IC2	DAMAGE CONTROL III	PLOTTER I
OS2	PLOTTER I	LOOKOUT
MS2	LOOKOUT	--
EW3	ELECTRONIC SUPPORT MEASURES	ELECTRONIC SUPPORT MEASURES
ICFN	LOADER II	

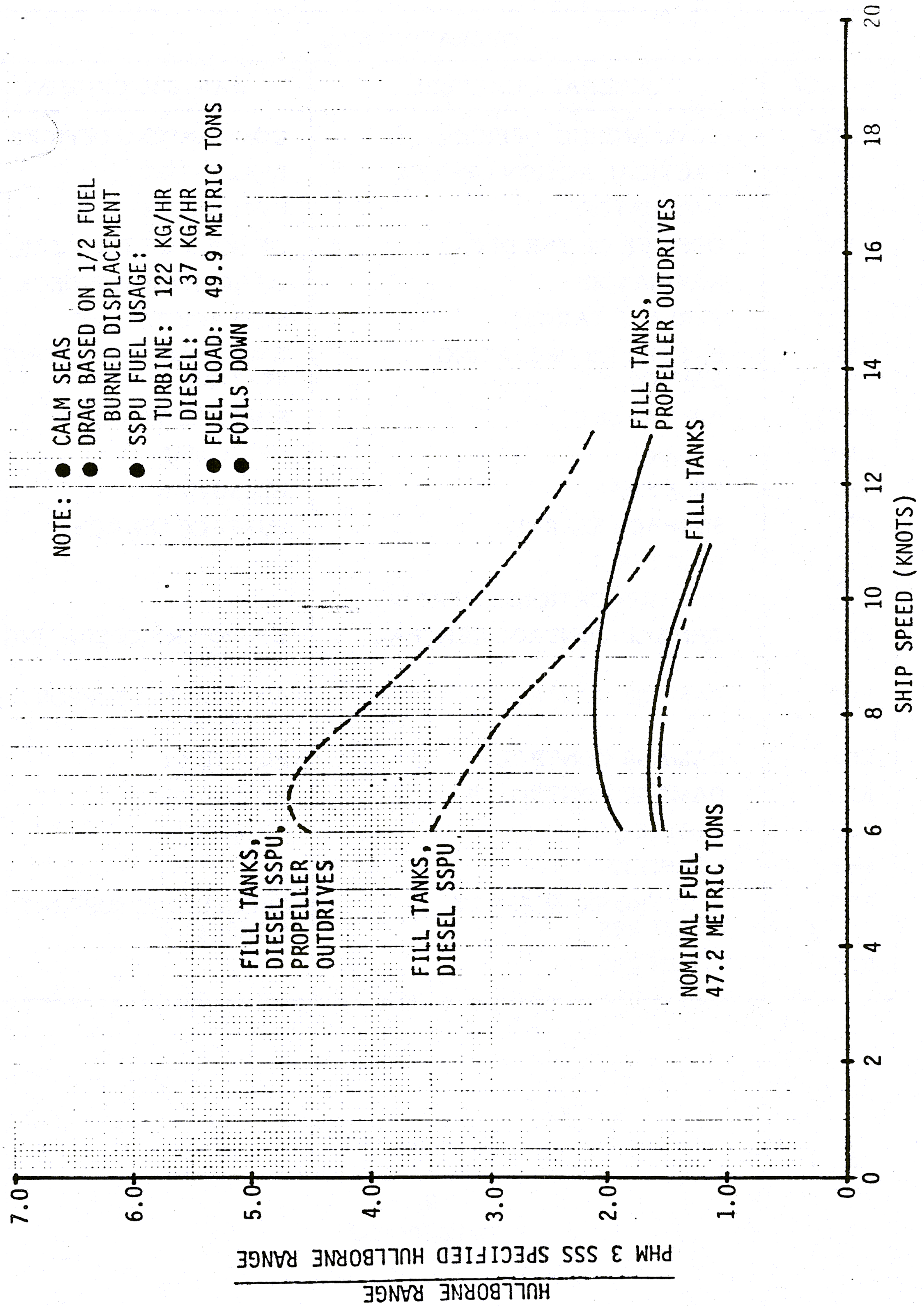

FIGURE 3.3-1 PHM-EHR HULLBORNE RANGE CAPABILITIES

8V331TC81 diesel engines. The combined effect on hullborne range of all three improvements is remarkable. Hullborne range fractions of 4.1 at 8 knots to 2.1 at 13 knots (a speed not achievable on PHM 3) are confidently predicted.

3.3.2 Foilborne Range

PHM-EHR foilborne range capabilities resulting from the hullborne range extension options are shown in figure 3.3-2. These ranges were based on the drag associated with the dynamic lift resulting from a 50 percent fuel load. Range fractions and ship speed are referenced to the PHM 3 SSS values in reference 7. Filling the tanks increases the foilborne range by approximately 5.5 percent. Using a diesel-driven SSPU to supply power during the foilborne phase also reduces the foilborne fuel usage and increases the range by another 3.5 percent. The addition of the propeller outdrives increases the cruise dynamic lift required and consequently the drag, causing a 1 percent loss of foilborne range.

One impact of operating at a heavier full load displacement than PHM 3 is the reduction of the takeoff thrust margin. Figure 3.3-3 shows the estimated calm water takeoff margin for a range of displacements extending into the overload region. These results indicate that the full load displacement of 247 metric tons still gives the ship a takeoff thrust margin of over 20 percent.

3.3.3 Mixed Hullborne-Foilborne Operation

The additional hullborne capability described in section 3.3.1 will also improve the effectiveness of PHM-EHR when operating with other ships in either a task force situation, or in surveillance and trailing missions. Conventional ships transit at speeds between PHM's maximum hullborne speed and minimum foilborne speed. To maintain the same speed of advance, PHM must alternate between the hullborne and foilborne modes. Reducing the hullborne fuel consumption increases both total range and endurance. As a result, the frequency of refueling can be reduced, expanding the time PHM is available for performing her assigned tasks.

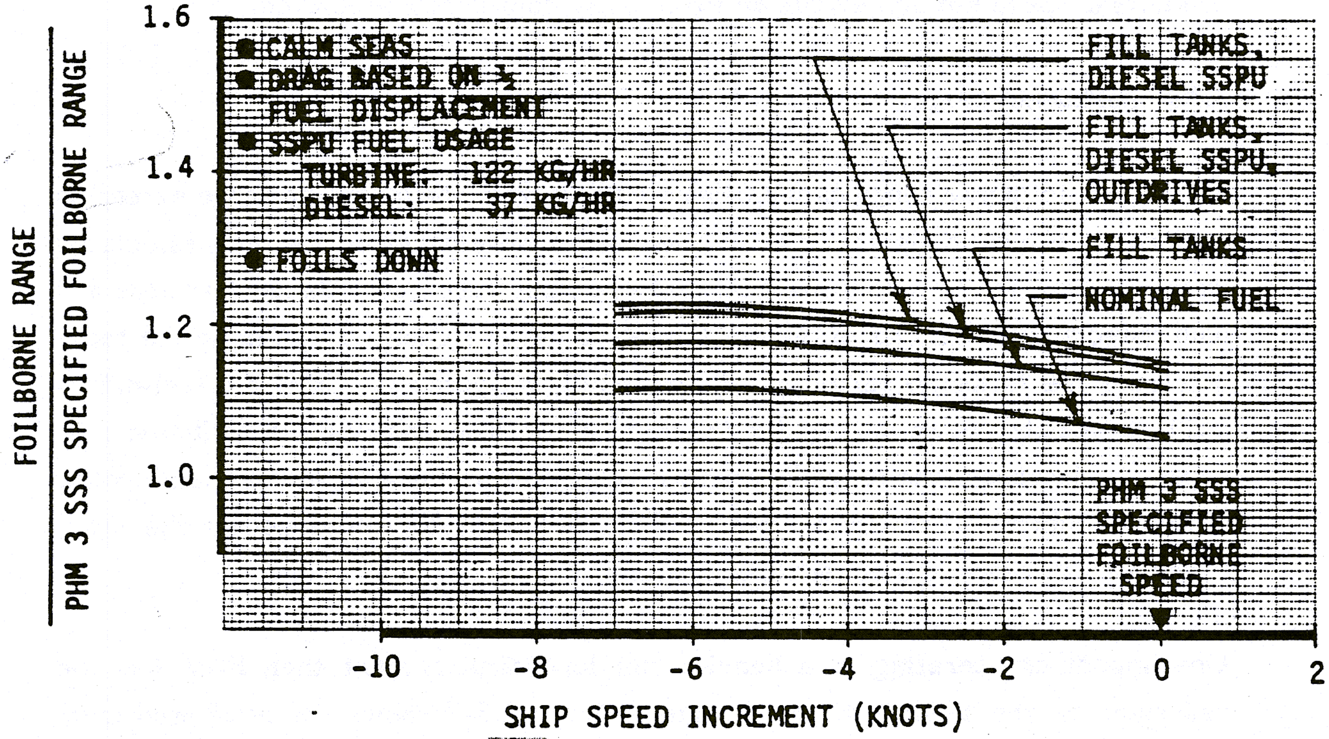

FIGURE 3.3-2: PHM-EHR FOILBORNE RANGE CAPABILITIES

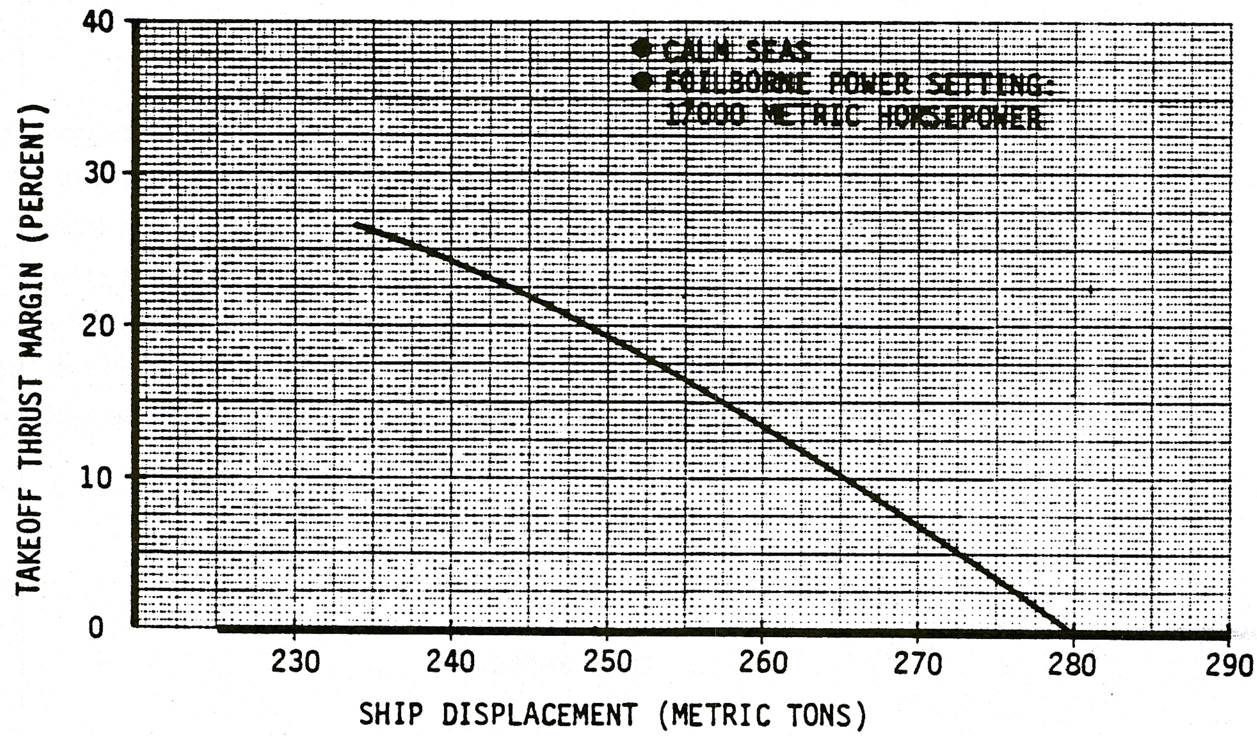

FIGURE 3.3-3: PHM-EHR CALM WATER THRUST MARGINS

By selecting the hullborne and foilborne speeds correctly, the average fuel flow in mixed hullborne-foilborne operation can be minimized. Range capabilities based on the use of these "optimum" speeds are shown in figure 3.3-4. While the use of propellers alone does not increase the range in straight hullborne operation as much as the diesel SSPU, the higher speed capability permits a longer period of hullborne operation to acquire a specific average speed. This results in greater range between 10 and 20 knots.

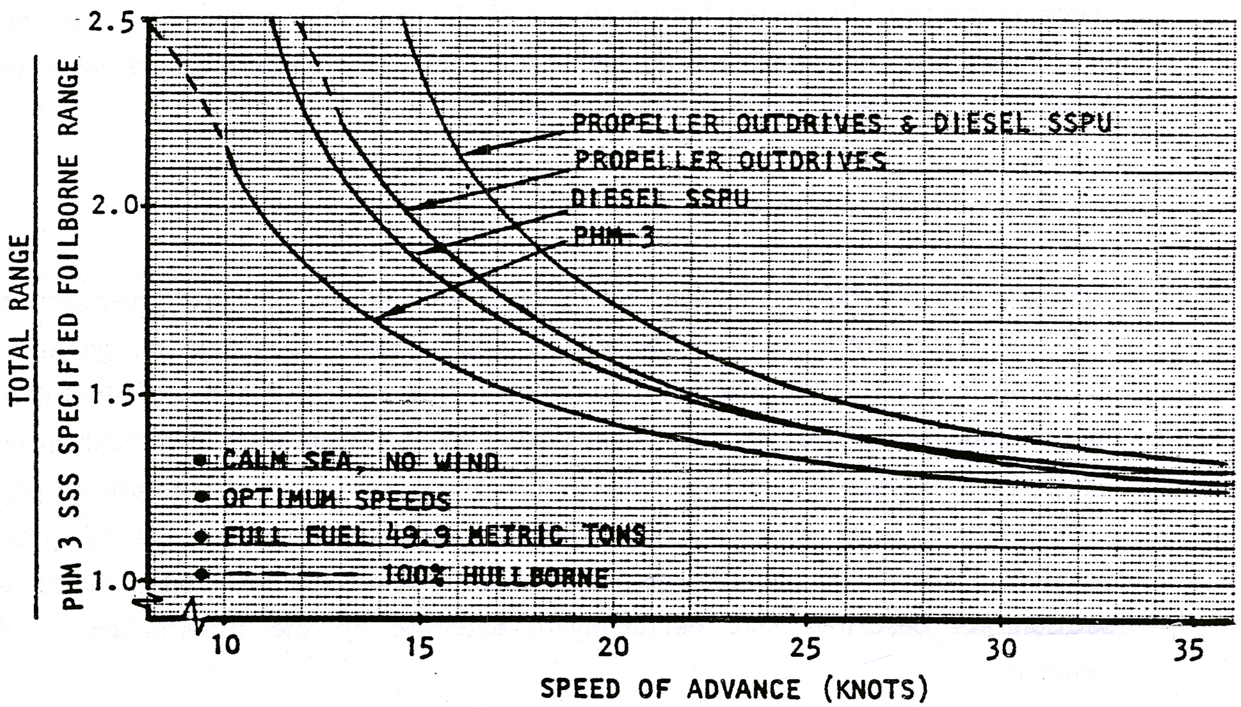

FIGURE 3.3-4: RANGE CAPABILITY, MIXED HULLBORNE-FOILBORNE OPERATION, OPTIMUM SPEED STRATEGY

4.0 GROWTH PHM—MODEL 928-78

The ship described in this section is an enlarged, improved version of the PHM 3 Series hydrofoil. Boeing Marine Systems has been conducting feasibility and conceptual design studies of this growth variant since 1975 using its Independent Research and Development funds. For identification purposes, this growth PHM is designated Model 928-78. This ship was created initially to improve crew habitability and to allow the use of more of the power available in the LM 2500 gas turbine. As the Model 928-78 evolved, more and more improvements such as increased range, increased hullborne speed, increased internal space for mission equipment and increased usable deckspace for weapons and sensors were postulated. The results of the preliminary studies are presented herein.

4.1 Ship General Description

The ship, Model 928-78, as stated before is an enlarged improved version of the PHM 3 Series hydrofoil. Although no ship system specification governs the construction of this specific ship, guidance for performance and technical requirements and generalities on the construction of this ship were obtained from the PHM 3 Series Ship System specification, reference 7. This ship is presented as a basic platform in which a variety of weapon and or sensor systems can be installed. Sections 4.2 and 4.3 provide descriptions of mission systems and manning while section 4.4 describes ship performance affected by the installation of these systems.

4.1.1 Ship Configuration

The Model 928-78 is a submerged foil hydrofoil, propelled foilborne by a waterjet and hullborne by two retractable propeller outdrives. The basic ship is shown in exterior arrangement, figure 4.1-1. The general characteristics and principal subsystems are listed in table 4.1-1. The principal subsystems, primarily expanded variants of the PHM 3 Series systems, are discussed in detail in later sections.

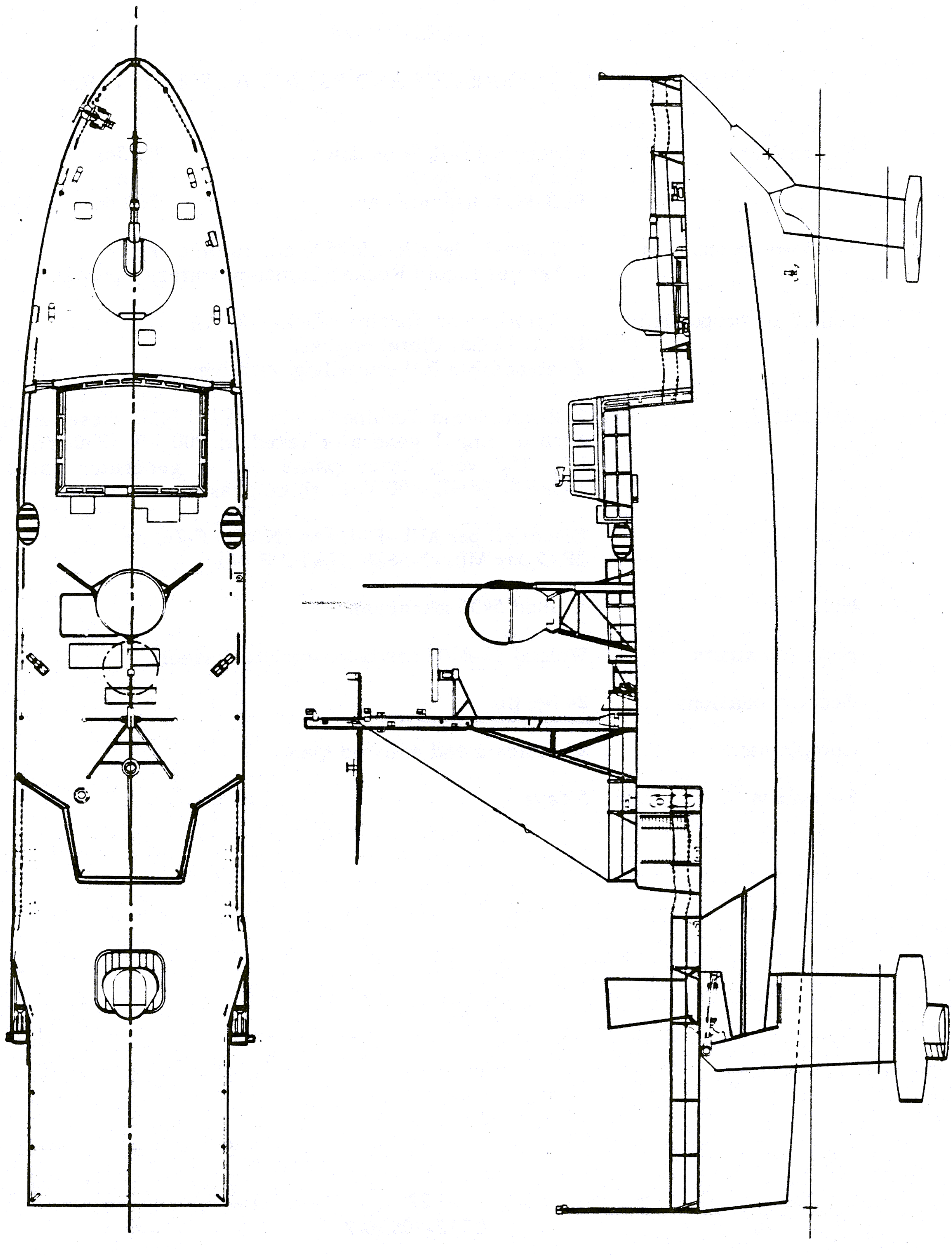

FIGURE 4.1-1: MODEL 928-78 EXTERIOR ARRANGEMENT

TABLE 4.1-1

MODEL 928-78

GENERAL CHARACTERISTICS AND PRINCIPAL SUBSYSTEMS

Dimensions	Length overall, foils down	44.5m
	Beam, main deck	8.6m
	Full-load displacement	300 metric tons
Foilborne propulsion	1 General Electric LM2500 gas turbine engine 1 Aerojet Liquid Rocket Company waterjet propulsor	
Hullborne propulsion	2 Motoren-und Turbinen-Union (MTU) 12 V331TC81 diesel engines 2 retractable full swivelling outdrives	
Electrical	2 Motoren-und Turbinen-Union 6V331TC82 diesel engines, each driving 1 generator rated at 200 kW (250kVA), 400 Hz, 450 volt, three phase and 1 generator rated at 100kVA, 60HZ, 450 Volt, three phase	
Fuel	Diesel oil per MIL-F-16884 (NATO F-76) or JP-5 per MIL-J-5624 (NATO F-44)	
Hull	Welded 5456 aluminum	
Foils and struts	Welded 17-4PH corrosion-resistant steel	
Accommodations	24 berths	
Complement	21 officers and enlisted men	
Provisions	5 days	

A weight summary for the basic ship is listed in table 4.1-2. The ship's payload is considered to include mission equipment which is listed in the weight summary under groups 400 and 700. The ship's mission load is defined as a sum of payload, crew, provisions, water and fuel.

The platform deck plan and main deck plan are shown in figures 4.1-2 and 4.1-3, respectively. The hull is arranged with most machinery in the after three, normally unmanned, watertight compartments. Machinery noise is attenuated to provide acceptable noise levels in the living areas on the platform deck and the operating stations. The Bridge and Engineer's Operating Station are highly automated for ease of operation and for system troubleshooting. Watertight bulkheads are located to satisfy a two-compartment flooding standard.

The deckhouse, figure 4.1-3, includes the Combat Information Center (CIC), Communications Room, Electronics Equipment Room, the Commanding Officer's Stateroom, the Engineer's Operating Station (EOS), and Auxiliary Machinery Room No. 1. All operating spaces are air-conditioned.

Control of the ship is accomplished in the Pilot House on the 01 level where three stations are provided.

The ship has 4 separate fuel tanks all located in the hold below the platform deck. The fuel oil tanks have usable capacity (95 percent of full capacity) of 77.2 tons.

4.1.2 Hull

The hull of the Model 928-78 is an extended PHM 3 hull. Four meters are added ahead of the machinery space bulkhead (BHD 21 on PHM 3). The ships lines are refaired from frame 18 to new frame 25. The hull form is identical to PHM from frame 18 forward and from frame 25 aft. Obviously the longitudinal strength of the hull will have to be increased because of its increased length. The compartmentation of the ship is changed to account for the increased length and

TABLE 4.1-2 MODEL 929-78 WEIGHT SUMMARY

WBS	DESCRIPTION	WEIGHT METRIC TONS
100	HULL STRUCTURE	52.6
200	PROPULSION PLANT	38.0
300	ELECTRIC PLANT	9.3
400	COMMAND AND SURVEILLANCE	10.5
500	AUXILIARY SYSTEMS	61.6
600	OUTFIT AND FINISHINGS	14.6
700	ARMAMENT	8.8*
	LIGHTSHIP LESS MARGINS	195.4
	MARGINS	8.4
	LIGHTSHIP	203.8
	FULL LOAD LOADS LESS FUEL	19.0
	FUEL	77.2
	FULL LOAD DISPLACEMENT	300.0
	FOILBORNE WATER	11.3
	LESS FOIL AND STRUT BUOYANCY	-6.8
	CRUISE DYNAMIC LIFT	304.5
	50% FUEL DISPLACEMENT	261.4
	50% FUEL CRUISE DYNAMIC FUEL	265.9

*ONLY CONTAINS WEIGHT ALLOWANCE FOR 76-mm GUN AND SMALL ARMS

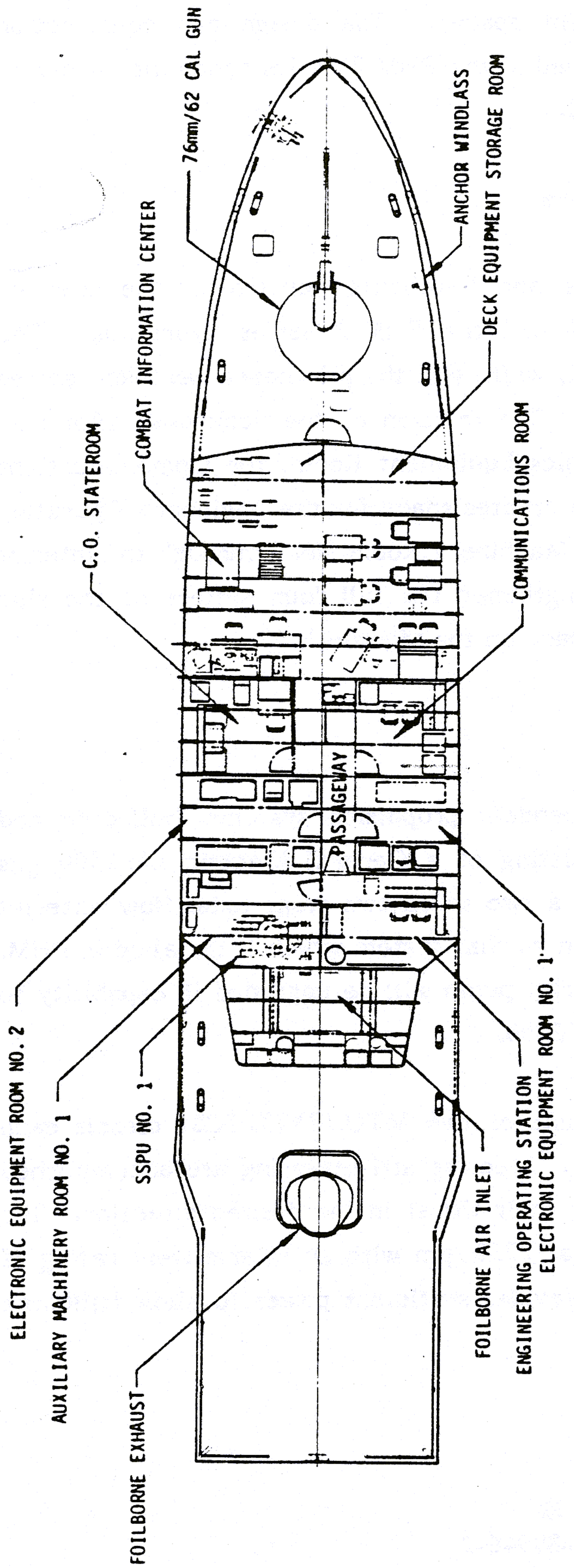

FIGURE 4.1-2: MODEL 928-78 DECKHOUSE PLAN

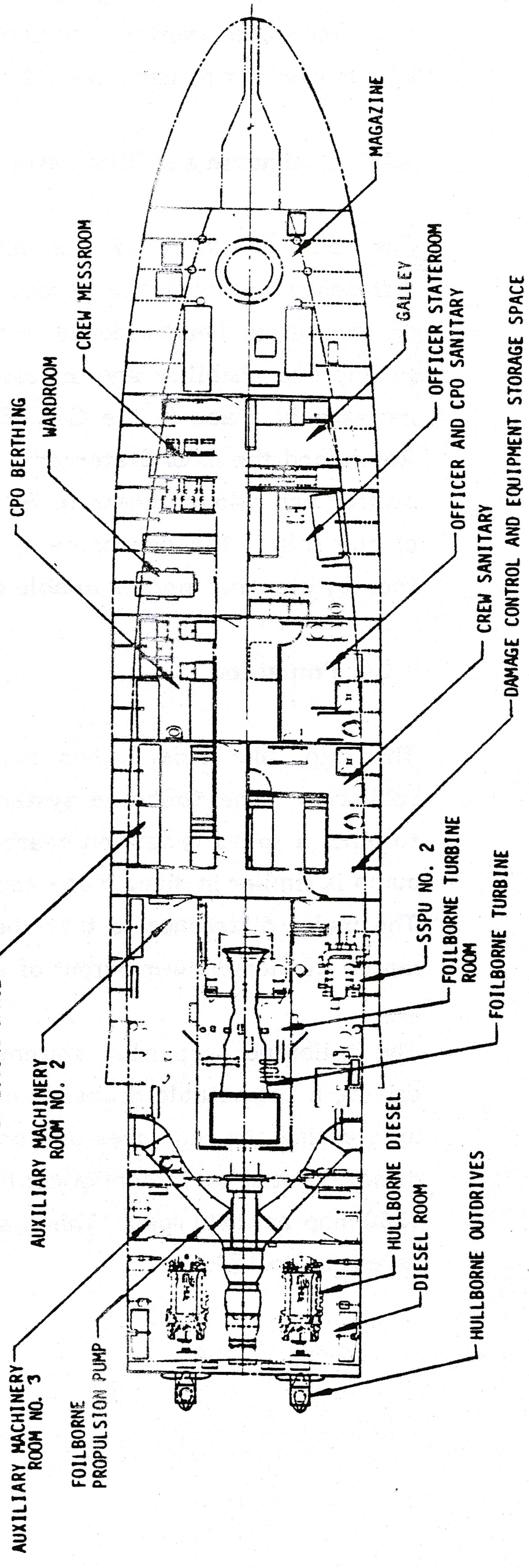

FIGURE 4.1-3: MODEL 927-78 PLATFORM DECK

rearrangement of living and equipment spaces. The design and construction techniques used and the experience gained in the PHM 3 Series production program will be used for construction of this hull.

4.1.3 Deckhouse and Pilothouse Structure

The reconfiguration of the deckhouse and pilothouse constitutes the greatest difference between the Model 928-78 and the PHM 3 Series hydrofoils. The deckhouse has been widened to full hull width and the pilothouse has been revised to improve visibility and accessibility. The revision of the deckhouse allows an increase in space in the CIC, Electronics Equipment Room, the Communications Room, and the C.O. Stateroom. It also creates space for the Engineer's Operating Station and allows access to Auxiliary Machinery Room No. 1 through the interior of the ship. The deckhouse is not lengthened the full four meters of the ship thereby creating more available deck space on the afterdeck.

4.1.4 Propulsion

The ship, like PHM 3, has two independent propulsion systems, hullborne and foilborne. The foilborne system consisting of a General Electric LM 2500 gas turbine, a speed reduction gearbox and a two speed-two stage axial flow waterjet pump is similar in size, shape and weight to that system which is installed in PHM. The major difference is that the waterjet pump will be upgraded in capability to match the horsepower output of the LM 2500.

The hullborne propulsion systems consists of two MTU 12V331TC81 diesels each driving a retractable propeller outdrive. Steering and reversing are accomplished by steering the outdrives and orienting their thrust in the desired direction. The diesel is rated at 1200 mhp continuous at 2260 rpm with an intermittent rating of 1360 mhp at 2340 rpm. This system provides sufficient power to allow hullborne speeds up to 15 knots.

4.1.5 Electrical System

The electrical system proposed for the Model 928-78 generates, distributes, and controls the ship's electrical power. Two 450-volt a.c., 400Hz, 3-phase and two 450-volt a.c. 60Hz, 3-phase generators driven by redundant Ship's Service Power Units (SSPU) provide power to the ship's electrical equipment. Each of these SSPUs has the capability to provide the entire ship's electrical requirements. Switchboards and distribution panels distribute and control the electrical output. Transformers and inverters convert a portion of the generator output to lower a.c. and d.c. voltages. Two shore power receptacles are provided to receive power from shore installations or other ships. Controls for the Electrical System are in the EOS.

All d.c. voltage is supplied from two battery chargers paralleled with two battery sets. The chargers supply normal ship d.c. power requirements and maintain the battery sets at specified charge levels. Battery power is used for SSPU startup and to supply emergency power upon loss of a charger. Emergency d.c. generators are located on the ship's hullborne propulsion diesels.

A block diagram of the electrical generation and distribution system is shown on figure 4.1-4.

The SSPUs vary from PHM 3 in that both are diesel-driven and that both gearboxes would be modified to accommodate 60Hz generators.

The electrical distribution system will allow 450-volt, 60 Hz, 3-phase shore power to be used to drive the 60Hz generator as a motor to produce 400Hz power. Other 60Hz requirements would be directly distributed from shore power.

SSPU No. 1 is installed in the relocated Auxiliary Machinery Room No. 1 on the main deck in the deckhouse. SSPU No. 2 is an identical unit located on the starboard side of the ship on the Platform deck in Auxiliary Machinery Room No. 2.

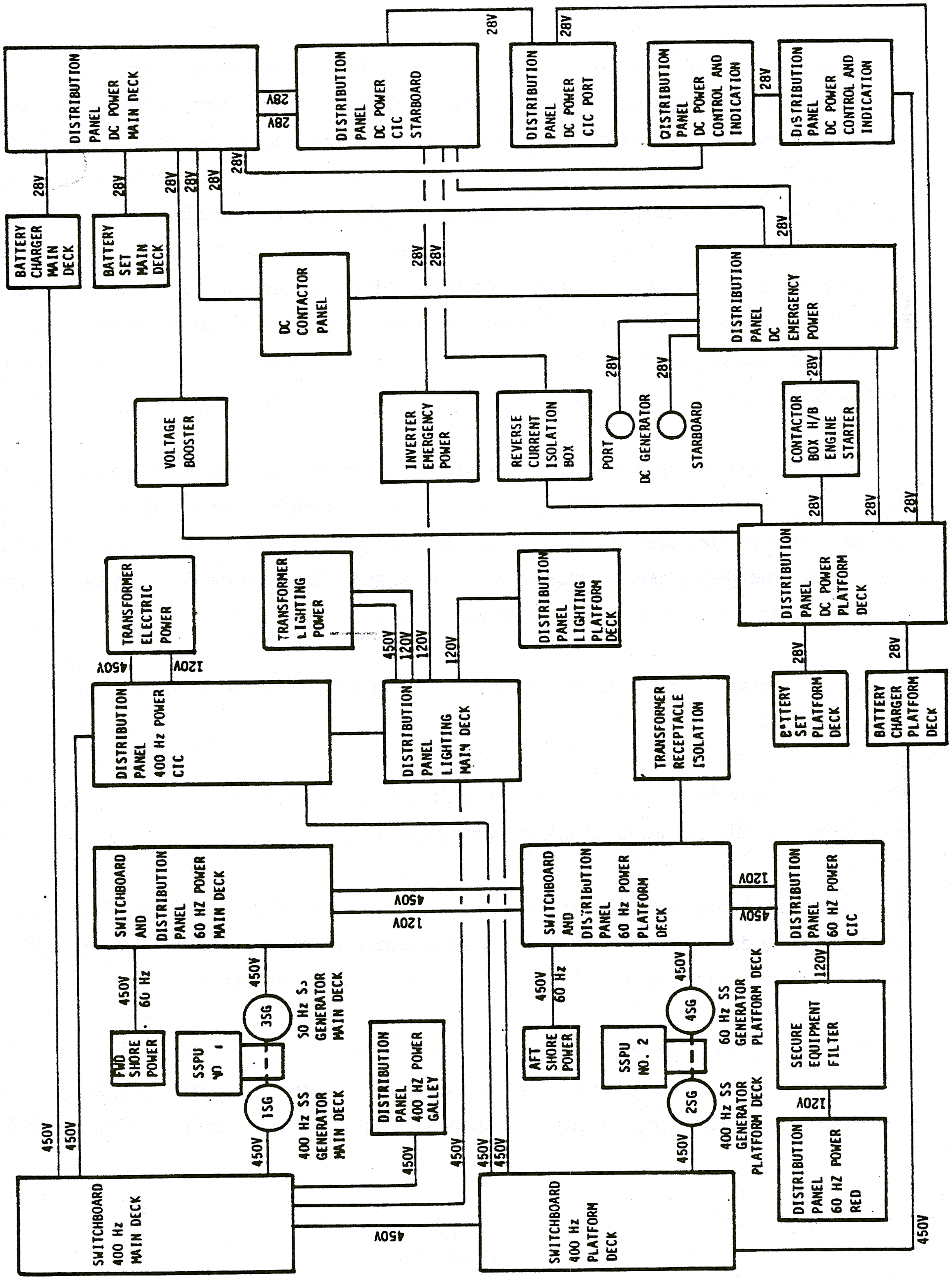

FIGURE 4.1-4: ELECTRICAL SYSTEM FUNCTIONAL DIAGRAM

The prime mover is a Motoren-und Turbinen-Union Model 6V331TC82 six cylinder diesel engine. The engine is rated at 515 mhp at 2000 rpm (continuous operation). This engine is of the same family as the hullborne propulsion engines (Model 12V331TC81).

The 400Hz generator is a brushless Westinghouse 450-volt, 3-phase, 250-kva unit. A generator control unit controls and protects generator circuits and ship loads. The 60Hz generator is a 100-kva unit that produces 450-volt, 60Hz, 3-phase power. The generator is sized to act as a motor to drive the 400Hz generator.

4.1.6 Auxiliary Systems

The auxiliary systems on the ship consist of environmental control; sea water; fresh water; fuel and lube oil handling and storage; air, gas and miscellaneous fluids; ship control; material handling; mechanical handling; and special purpose systems. All of these systems will remain essentially the same as in the PHM 3 Series except that their capabilities will be increased to match the slightly larger requirements of the Model 928-78 ship. The control system will have to be modified to allow the control and retraction of the propeller outdrive. The fuel tankage of the Model 928-78 has been increased to hold 77.2 metric tons.

4.1.7 Lift System

The Model 928-78 lift system, like the PHM 3 system, is a fully submerged canard configuration system. The forward foil will be tapered with an aft sweep to its leading edge. The configuration of the aft system will be similar to that of the PHM 3 series but the planform of the foil has not as yet been configured. The actual size and hydrodynamic shape of the foils will be determined when the weight and balance of the ship and its systems are more exactly known.

4.1.8 Outfit and Furnishings

Outfit and furnishings include those items attached to or stowed in the hull for personnel accommodations and safety. These items include lifelines, handrails, ladders, doors, safety tracks, cleats, and chocks. It also includes berthing spaces, food preparation spaces, messing areas, and sanitary spaces. The ship has berthing capability for one commanding officer, four other officers, four chief petty officers and fifteen other enlisted personnel. These spaces have all been increased in size to improve habitability. A wardroom with the capability to seat five officers has been added, and the crew messroom has been increased in size to allow the seating of twelve persons at one sitting. An additional sanitary space has been added, doubling the shower and lavatory accommodations. A washer and dryer are included for crew use.

4.2 Mission Equipment Alternatives

The mission equipment for PHM consists of a number of stand-alone subsystems with a minimal degree of functional integration. Operational experience suggests several areas where improvements might be made, especially in the command and surveillance area. To facilitate operation in a battle group and to exploit more fully the effectiveness of the Surface-to-Surface Missile Weapon System it is proposed that the basic PHM command and control and communication segments be upgraded. Increased tactical communication capabilities are needed, and a more fully integrated command and control suite is proposed.

In the conceptual suites for alternative missions it is proposed to make use of available multipurpose equipments to the maximum practicable extent. Accordingly, a standard display console should be used for command and control, countermeasures, and surveillance display and control applications. This assures compatibility with a tactical data system and data link.

For enhanced effectiveness on all missions a limited tactical data system is proposed. This includes a radio data link on either HF or UHF and standard display consoles for the Evaluator and Surface Search Operator. The High Speed Ships Collision Avoidance and Navigation System (HICANS) performs functions essential to ships such as PHM. HICANS functions could be implemented in elements of the tactical data system should that prove advantageous.

It is proposed that the basic PHM communication suite be augmented with 2 MF/HF receivers, 1 UHF SATCOM receiver, 2 more UHF (LOS) transceivers, and full SATCOM capability for the existing UHF SATCOM/LOS transceiver. Data Link modems should be provided for 1 existing HF transceiver and 1 existing UHF transceiver. Two teletypewriters and a General Address Reading Device (GARD) will support Fleet Broadcast and Task Force or Task Group Common circuit requirements.

The increased size of the deckhouse provides sufficient room in the CIC to accommodate additional control and display consoles to support increased or alternative mission capability. Space allocated to the unattended electronic equipment is considerably greater than in PHM 3, thus providing both improved access for maintenance and the accommodation of additional equipment.

No specific proposal is made with respect to improvements that might be made in intersystem cabling. However, to realize the capability for rapid reconfiguration for alternate missions some form of data multiplexing would be quite advantageous. Prior studies have shown also that cost and weight savings can be realized with this approach.

4.3 Manning

The complement of PHM 3 Series is 21, viz., 4 officers, 3 CPOs, and 14 petty officers and non-rated men. Experience in USS Pegasus has shown a need for an additional radioman to support sustained operation in a fleet environment. In the proposed Model 928-78 the communication suite has been augmented to improve the ship's ability to operate in the command and control structure of the battle group. Accordingly it is proposed that the complement be increased by adding one RMC and one RM3.

For alternate missions it is anticipated that different skills will be needed as well, possibly, as added personnel. However, the proposed command and surveillance suite makes extensive use of general purpose consoles and computer-aided processing and display. This should reduce the need for the 2 plotters at the DRT (one of whom alternates as HICANS operator) and make them available for alternate tasks. In the case of an ASW mission it is considered useful to add a fifth officer to serve as ASW officer and man the ASW engagement console at General Quarters. A sonarman (SO1) would be added as ASW sensor operator.

4.4 Ship Performance

Model 928-78, as described in Section 4.1, incorporates all of those desirable features that were found beneficial in improving the performance of PHM-EHR. These features include propeller outdrives for higher speed, more efficient hullborne operation, and diesel SSPUs for lower fuel consumption power-generation. Tankage size has been increased to accommodate a total usable fuel capacity of 77.2 metric tons.

The weight breakdown for Model 928-78, table 4.1-2, shows the that full load displacement has grown from 247 to 300 metric tons. The weight breakdown is for a basic ship with only the 76-mm gun and small arms contained in the WBS 700 series. The mission load, i.e., the sum of payload (a portion of WBS 400, WBS 700, and full load loads) and fuel is 112.8 metric tons. As shown in the preceding sections, alternative missions can be accommodated by changes (usually additions) in mission equipment. This can be achieved by reducing the fuel loading. The ship performance presented in this section is that performance resulting from utilizing the mission load growth as fuel. Alternative missions therefore imply somewhat lesser ranges and endurance.

4.4.1 Hullborne Range

Because the MTU 331TC80 series diesel engines have nearly identical specific fuel consumption characteristics, the primary effect on hullborne range is engine weight. Estimated installed engine weights for 6, 8, and 12 cylinder MTU diesels are shown in table 4.4-1. Both engine weight and fuel consumption data are from reference 8. If the fuel were to be increased by the 1969 kg weight increment of the 12 cylinder engine over the 8 cylinder engine, the effect on hullborne range would be about 2.5 percent. On the other hand, the lesser power of the 8 cylinder engines would reduce maximum hullborne speed capability. Figure 4.4-1 shows the hullborne power required to achieve various ship speeds. The MTU 12V331TC80 engine is predicted to achieve a maximum hullborne speed of 15.2 knots while the 8 cylinder engine results in 13.5 knots. For a baseline design consideration, the 12

TABLE 4.4-1
MTU SERIES 331TC80 MARINE DIESEL
WEIGHT SUMMARY

(Weight in Kilograms)

ITEM	6 CYL.	8 CYL.	12 CYL.
BASIC ENGINE	1515	1810	2690
ENGINE ACCESSORIES	215.7	251.7	331.2
REDUCTION GEARS	509.5	509.5	534.5
TOTAL PER ENGINE	2276.2	2571.2	3555.7
INCREMENT REFERENCED TO 8 CYL. (PER ENGINE)	-295.0	0.0	984.5
2 ENGINE INCREMENT	-590.0	0.0	1969.0

TABLE 4.4-2 MODEL 928-78 PROPELLER CHARACTERISTICS

PARENT DESIGN:	DWTMB NO. 3227
NUMBER OF BLADES:	4
EXPANDED AREA RATIO:	0.50
MEAN WIDTH RATIO:	0.273
BLADE THICKNESS FRACTION:	VARIABLE
PITCH-DIAMETER RATIO: (AT 0.7 R)	0.87
DIAMETER:	1.676 METERS (5.5 FEET)

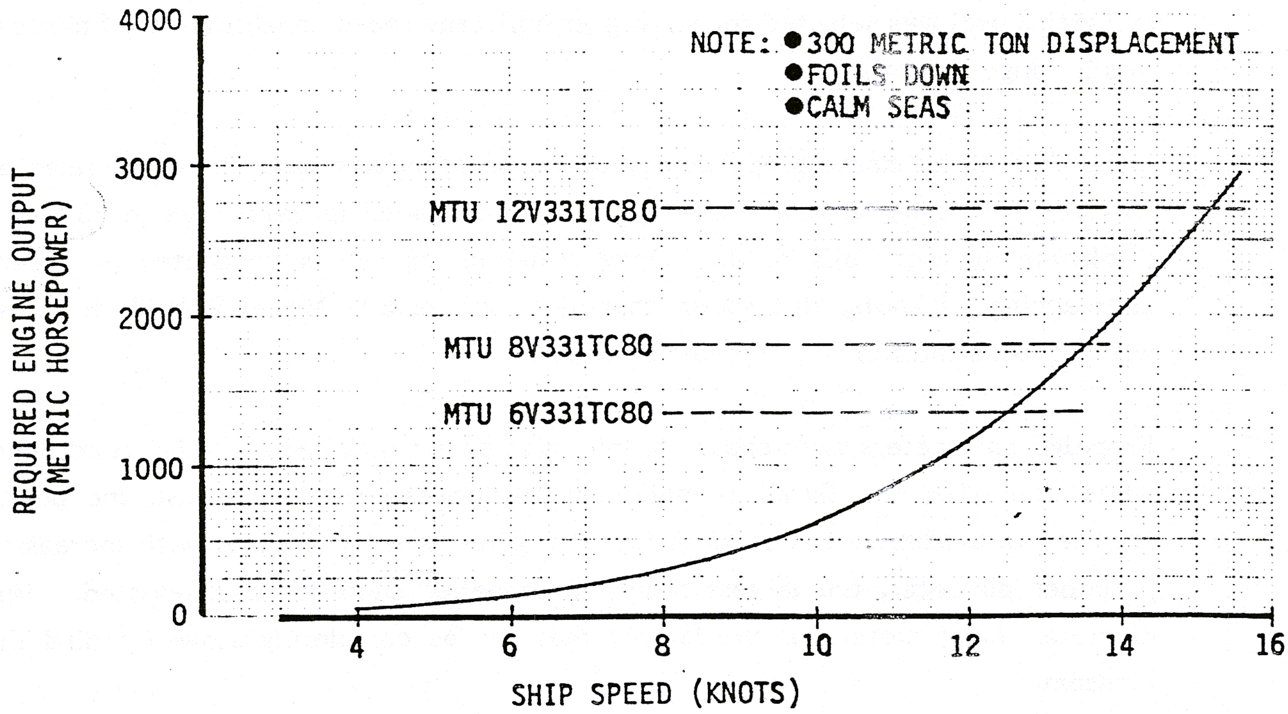

FIGURE 4.4-1: MODEL 928-78 HULLBORNE POWER REQUIREMENTS

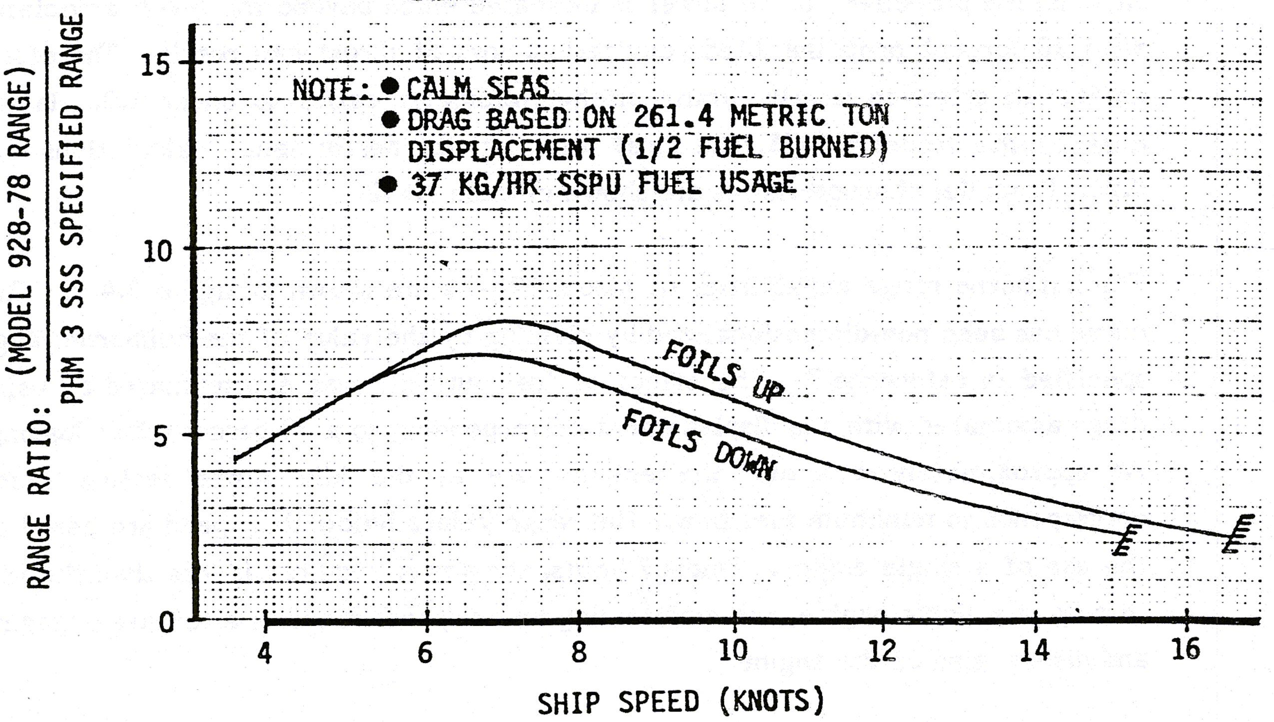

FIGURE 4.4-2: MODEL 928-78 HULLBORNE RANGE CAPABILITY

cylinder diesel was selected for the higher hullborne speed capability at 2.5 percent loss in range potential.

Model 928-78 hullborne propulsion system characteristics were therefore selected to meet the design goal of achieving a 15-knot speed in calm seas at full load displacement with foils down. Since refueling at sea is conducted at speeds approaching 15 knots, this speed capability will enable Model 928-78 to refuel without using the foilborne propulsion engine.

Propeller parameters were chosen to minimize power required at design conditions, while satisfying the Burril propeller cavitation criterion. Because the power required to produce a specified thrust at a given speed decreases with increasing propeller diameter, the largest practical propeller diameter was selected. This diameter, 1.676 meters, is the largest that can be completely stowed behind the transom.

The power required is minimized by using the highest practical pitch-to-diameter ratio on the propeller. If the power is increased much beyond the levels associated with 10 percent propeller blade cavitation, loss of thrust can result. Therefore, cavitation criterion usually limits pitch-to-diameter ratios to under 1.0. In the case of the Model 928-78, the final selection for performance calculations was 0.90. Propeller characteristics are shown in table 4.4-2.

The hullborne range capabilities of Model 928-78 are shown in figure 4.4-2. This curve has been non-dimensionalized by dividing by the value of the hullborne range specified in reference 7. The effect of fuel burn-off was approximated by using drags associated with the displacement corresponding to a 50 percent fuel loading. At approximately 8 knots, the engines are at the idle power setting which corresponds to minimum fuel flow. The range values below this speed are based on the use of a single engine. Below 7 knots, the power required is less than the idle setting of a single engine, and maintaining lower speeds requires alternate engaging and disengaging of the engine.

4.4.2 Foilborne Range

The basis for increasing the full load displacement, the size and the range of the PHM is the utilization of the full power capability of the LM 2500 gas turbine engine. While informal discussions with the General Electric Co., manufacturer of the LM 2500 engine, indicate a growth capability to at least 30,000 horsepower, the latest published data on the engine is contained in reference 9. The power capability on a continuous basis as a function of ambient air temperature (OAT) is shown in figure 4.4-3. The peak power capability with realistic inlet and exhaust losses is predicted to be 28,400 metric horsepower at 92^{o}F. For the basic Model 928-78 design studies, a continuous power level of 24,120 metric horsepower was assumed. This is about 85 percent of the peak power capability and is independent of OAT. At this time, it seems reasonable to assume that further studies, combined with inputs from the engine manufacturer, will support a full load displacement somewhat greater than the 300-ton displacement assumed for the Model 928-78.

Figure 4.4-4 shows the takeoff and foilborne drag characteristics and the maximum thrust capability for Model 928-78. A propulsion duct lower elbow area of 0.229 m^2 and the LM 2500 continuous power rating of 24,120 metric horsepower was assumed. Pump cavitation limits shown on this figure correspond to an inducer suction specific speed of 24,400 (English units). At full load displacement, the thrust margin is 14 percent compared to the 22 percent demonstrated by PHM 1. Foil cavitation and an associated drag rise is expected at the higher foilborne speeds. Model 928-78 foilborne range capability is presented in figure 4.4-5. Range values were non-dimensionalized by dividing by the foilborne range specified for PHM 3 in reference 7. Ship speed is expressed as an increment based on the PHM 3 speed also specified in this reference.

4.4.3 Mission Profile Effects on Range Performance

The Model 928-78 provides a considerable hullborne range and foilborne range increase over the PHM 3 and PHM-EHR, particularly if all of the increase in

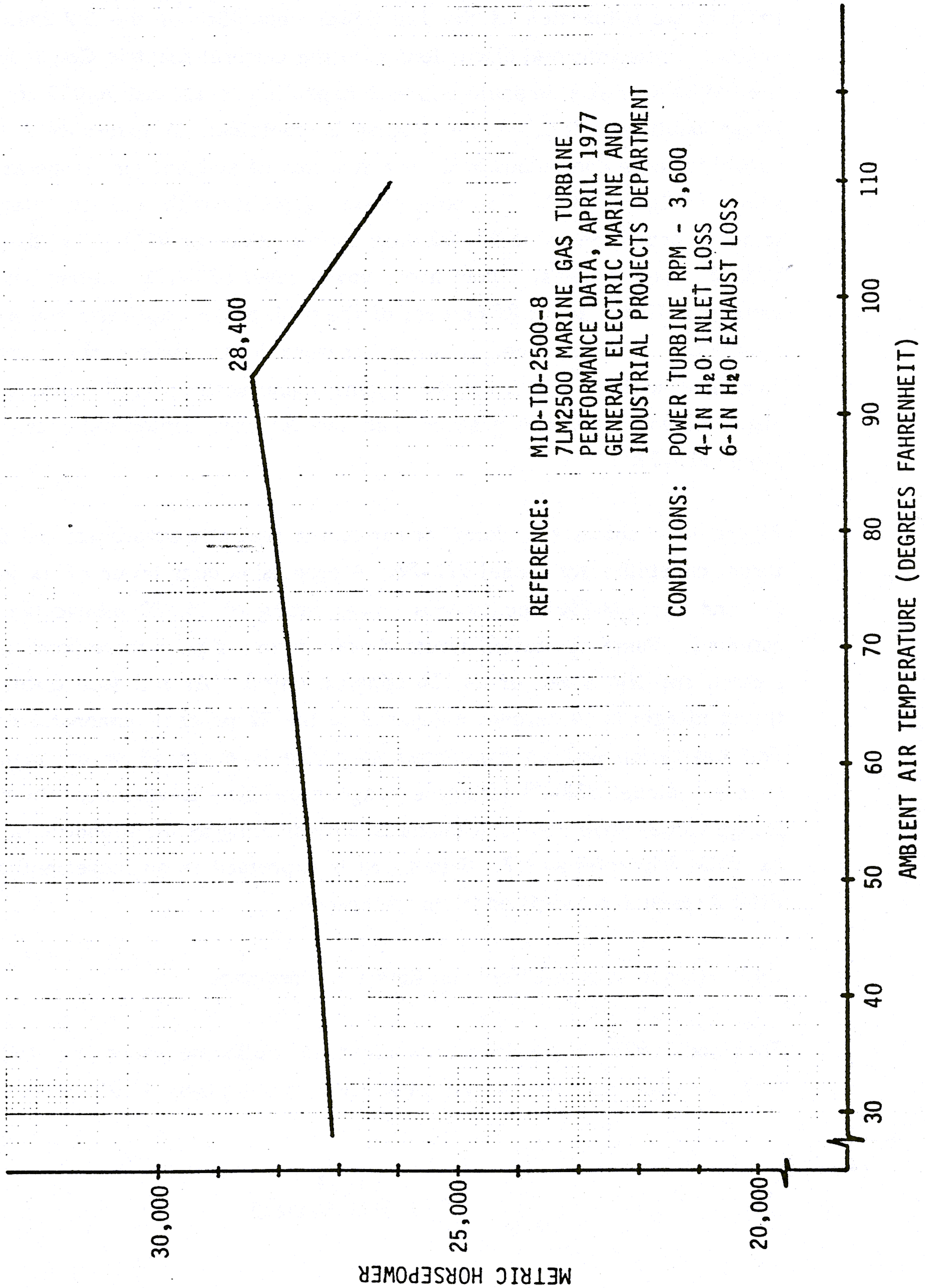

FIGURE 4.4-3 7LM2500 MAX M HORSEPOWER

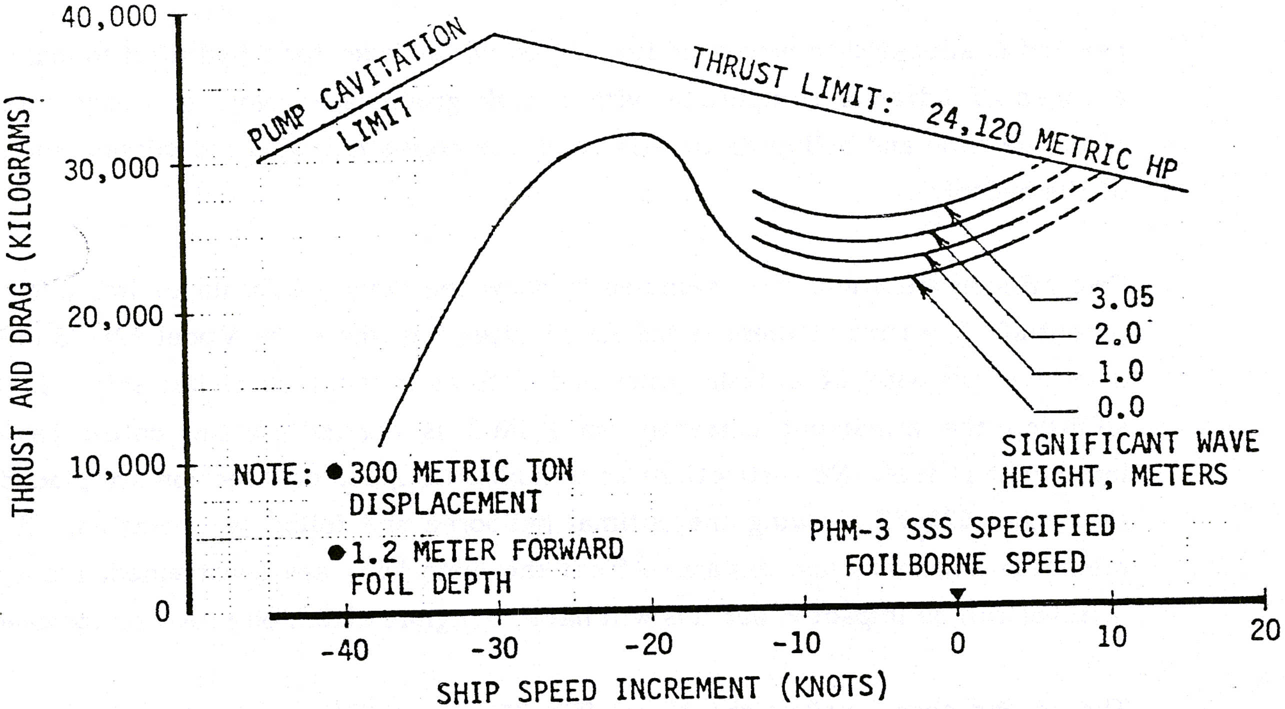

FIGURE 4.4-4: MODEL 928-78 TAKEOFF AND FOILBORNE DRAG

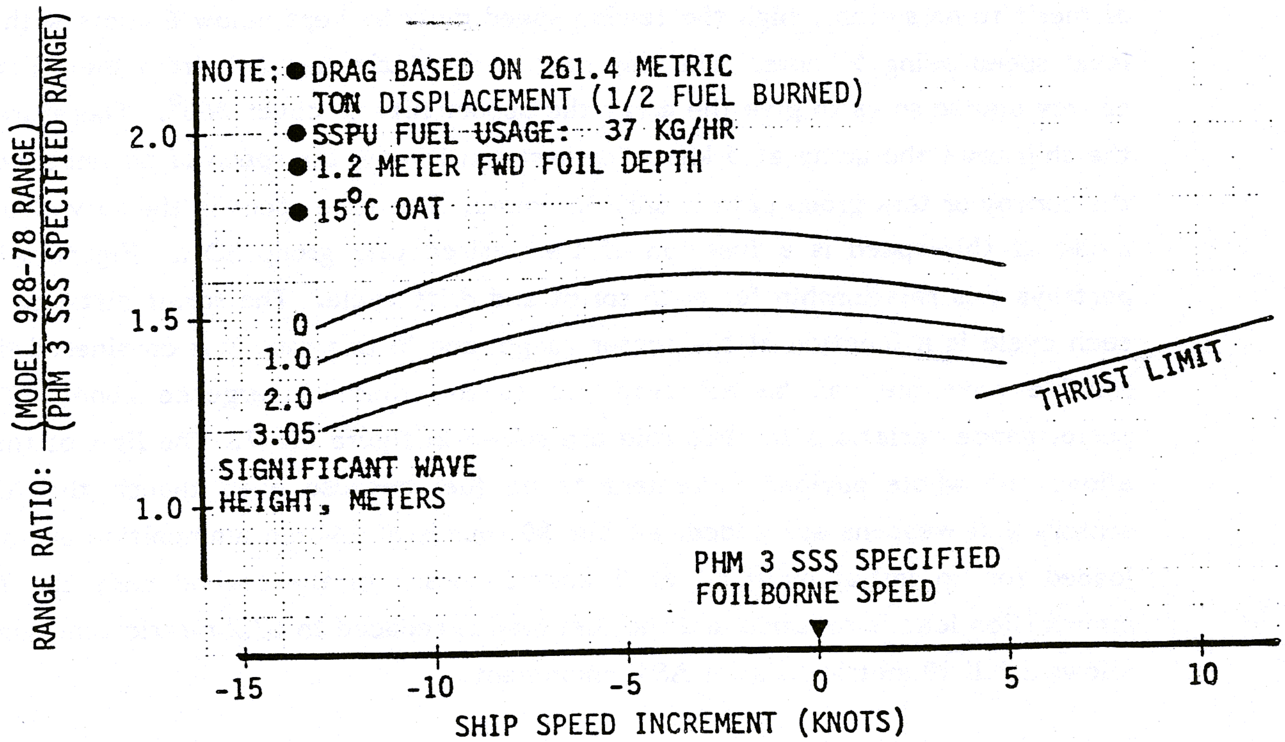

FIGURE 4.4-5: MODEL 928-78 FOILBORNE RANGE CAPABILITY

payload is allocated to increased fuel capacity. In order for a hydrofoil to maintain a speed of advance compatible with a task group or convoy, a proper mix of foilborne time and hullborne time is employed consistent with the mission and role of the hydrofoil.

Two mission situations are examined to show the range performance improvement potential. The first of these is the ASUW situation where the Model 928-78 moves into the vanguard of a task group and acts as a scout or picket ship. In this situation the armament currently on PHM 3 is carried so the entire payload increment is fuel. No restrictions as to hullborne speed or direction are placed on the Model 928-78 allowing the optimal hullborne and foilborne operation. If the minimum and maximum distances from the main body are constrained, the cycle interval will be impacted but this will have negligible effect on range performance.

The second case involves the Model 928-78 in an ASW escort role (outer screen) where the employment of the Depressed Towed Array Sonar (DTAS) places speed and direction constraints on the ship when hullborne. In order for the array figure of merit to be suitably high the towing speed must be kept below 6 knots with an ideal speed being 5 knots. The ship runs in a 45° zig-zag path from the primary convoy course so as to give the array the opportunity to cover 360°. Therefore if the ship tows the array at 5 knots for best sensitivity, the speed of advance along the convoy or task group path is only 3.5 knots. The time spent in the surveillance mode at this speed is a function of the desired task group SOA. Figure 4.4-6 portrays this relationship for each sprint and drift cycle. The sprint distance for each cycle is a function of the sensor range, and in this case it is considered that reliable coverage can be achieved out to the first convergence zone. Two performance variations for this role are shown in figure 4.4-7. The first of these allows the whole payload increment to be fuel because even though the ASW sensors and weapons are added, all but 80 rounds of 76-mm ammunition are off-loaded for an initial overload of 3 metric tons. In the second case the full ammunition load is retained and the fuel load is reduced to 67.2 metric tons which allows a full 10 metric tons for ASW equipment.

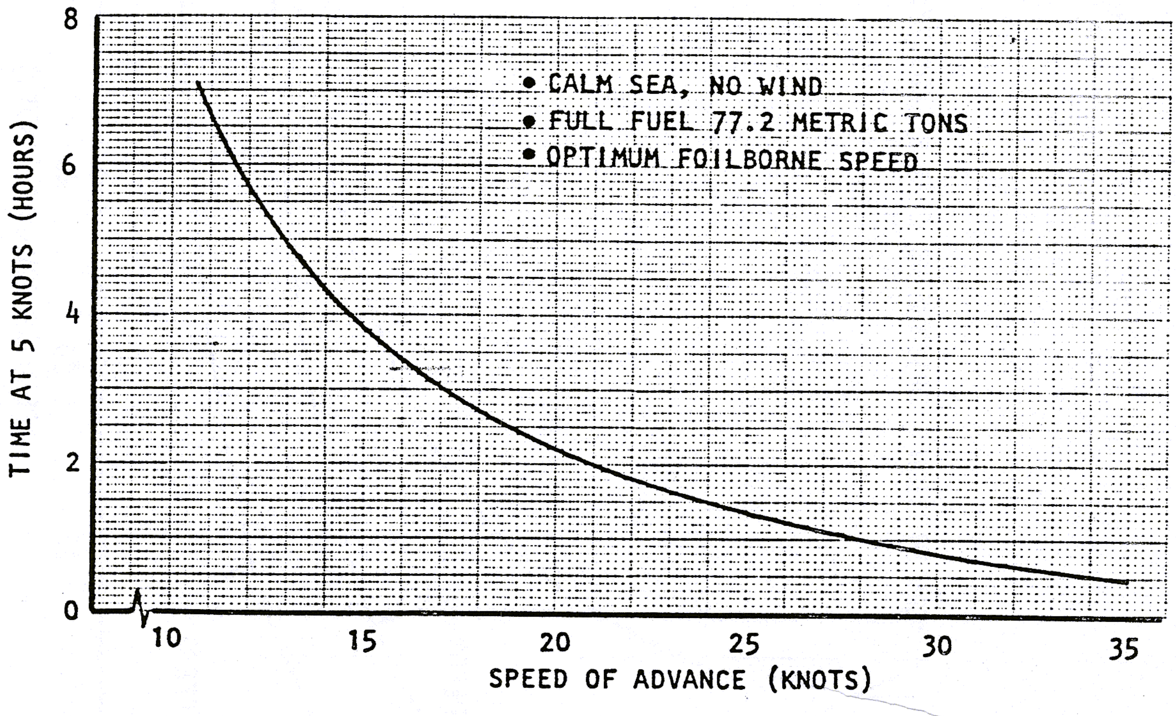

FIGURE 4.4-6: MODEL 928-78 TIME AVAILABLE FOR HULLBORNE SONAR SEARCH, MIXED HULLBORNE-FOILBORNE OPERATION, ASW MISSION

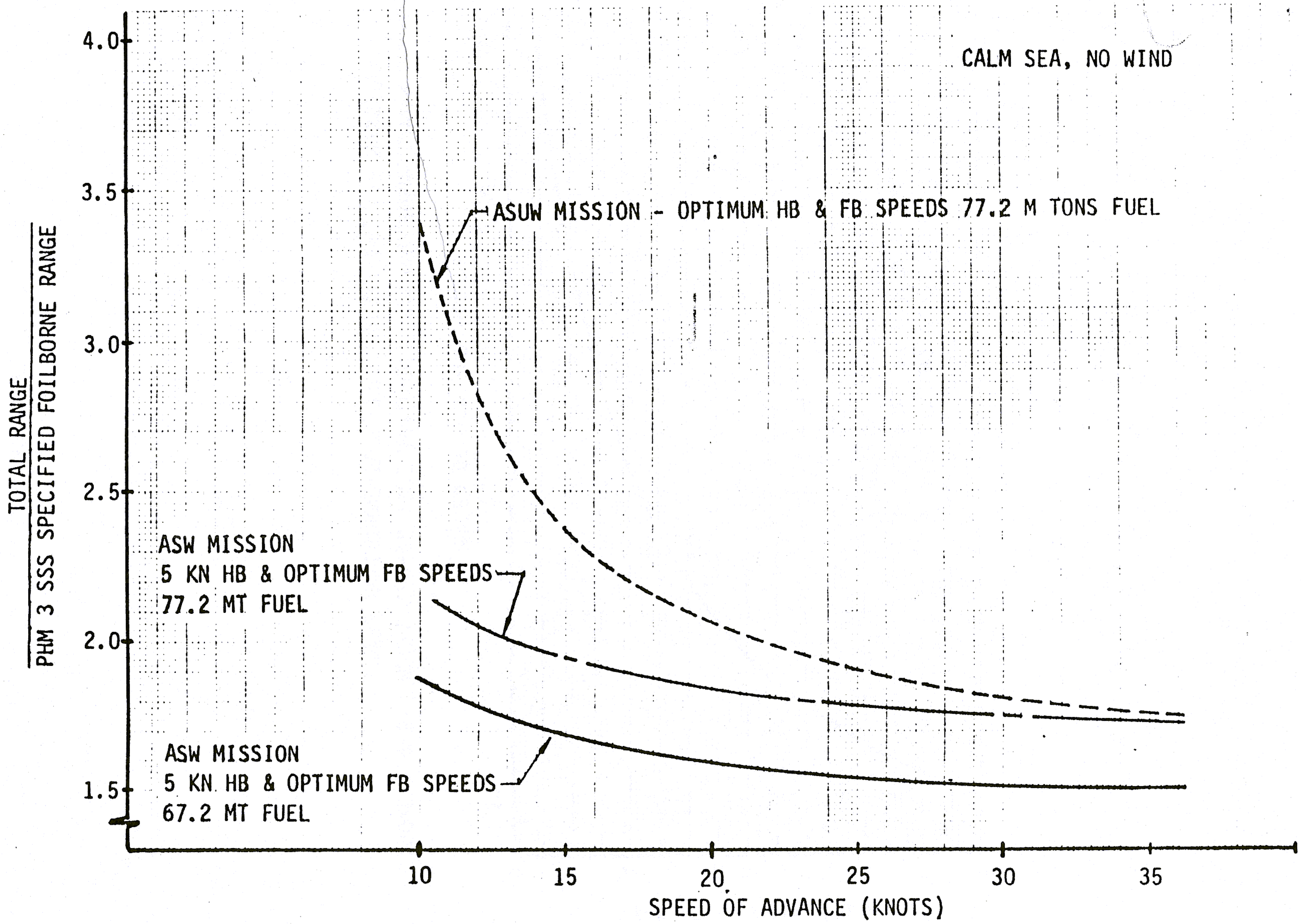

FIGURE 4.4-7: MODEL 928-78 MISSION PROFILE EFFECT ON RANGE CAPABILITY

REFERENCES

1. Boeing Document D312-80938-1, "A Patrol Hydrofoil Missile Ship for Naval Forces," Revision A, February 25, 1980.

2. Boeing Document D312-080931-1, "An Independent World-Wide Transit Capability for the PHM 3 Series Ships," Revision A, October 12, 1978.

3. Boeing Document D312-80917-1, "Hullborne Propeller Drives for PHM Variants," October 5, 1976.

4. Boeing Document D312-80925-3, "Boeing Model 928-77A — Patrol Hydrofoil Cutter, WPHC, Ship and Subsystem Description," August 3, 1977.

5. Boeing Document D312-80910-1, "Suitability of a Diesel Driven Ship Service Power Unit for PHM," August 6, 1975.

6. Boeing Document D312-80314-2, "Quarterly Weight Report, PHM 3 Series," April 1978.

7. S9PHM-00-SPN-020/(c) PHM-1 CL, "Ship System Specifications for Building Patrol Combatant Missile (Hydrofoil), PHM 1 Class (PHM 3 Series)," Addendum, November 30, 1977.

8. VSP 08024 (521E)b, "MTU Series 331 Marine Diesel Engines," Motoren-und Turbinen-Union.

9. MID-TD-2500-8, "7LM 2500 Marine Gas Turbine Performance Data," General Electric Marine and Industrial Products Dept., April 1977.

ACTIVE SHEET RECORD

SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR	ADDED SHEETS SHEET NO.	REV LTR
1						31					
2						32					
3						33					
4						34					
5						35					
6						36					
7						37					
8						38					
9						39					
10						40					
11						41					
12						42					
13						43					
14						44					
15						45					
16						46					
17						47					
18						48					
19						49					
20						50					
21						51					
22											
23											
24											
25											
26											
27											
28											
29											
30											

DO 6000 2155 ORIG. 4/71

REVISIONS

LTR	DESCRIPTION	DATE	APPROVAL