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ADVANCED NAVAL VEHICLES CONCEPTS EVALUATION
(ANVCE)

LEVEL II

POINT DESIGN REPORT FOR
SES 3 (U)

Final Rohr SES 3

[redacted]

Prepared by

ROHR MARINE, INC.

393 299

31 DECEMBER 1976

[redacted]

Classified by: CNO (OP-96)

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Declassified on: 31 December 1982

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Advanced Naval Vehicles Concepts Evaluation
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Parametrics and Point Designs	SES Point Design	Seal/Sidehull Design
	Advanced Concept SES	1990-2000 IOC SES
	Medium Air Capable SES (See Reverse Side)	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the point design of a 3600 long ton (35.87 M ton 3657 metric ton), waterjet-propelled, Medium Air Capable, Surface Effect Ship (SES) that meets the far term requirements of the Office of Advanced Naval Vehicle Concepts Evaluation (ANVCE). The SES-3 point design is a combatant SES that is a logical progression from today's technology.

The SES-3 point design is described in overall terms of General Detection,

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Vehicle Performance, Maneuvering, Range, Payload, Weights, Volumes, Stability, Geometric-Form, and Ride Quality. Subsystems further described are Structures; Propulsion; Electrical; Command, Control, and Communications; Auxiliary; Outfitting and Furnishing; and Combat System. The report also includes sections addressing logistic Considerations; Survivability and Vulnerability; and Technical Risk.

The SES-3 point design is shown to be a cost-effective, minimum risk and high performance means of satisfying ANVCE requirements. An alternate point design utilizing semi-submerged, supercavitating propellers is also described in an Appendix to the report.

19. Cont'd.

SES Performance
SES Subsystem Design
SES Survivability/Vulnerability
SES Supportability/Availability
Combat System
Waterjet SES
Propeller SES

[redacted]

ADVANCED NAVAL VEHICLES CONCEPTS EVALUATION
(ANVCE)

POINT DESIGN REPORT FOR
SES 3 (U)

FINAL TECHNICAL REPORT

31 December 1976

Prepared Under
CONTRACT NO. N00024-74-C-0924
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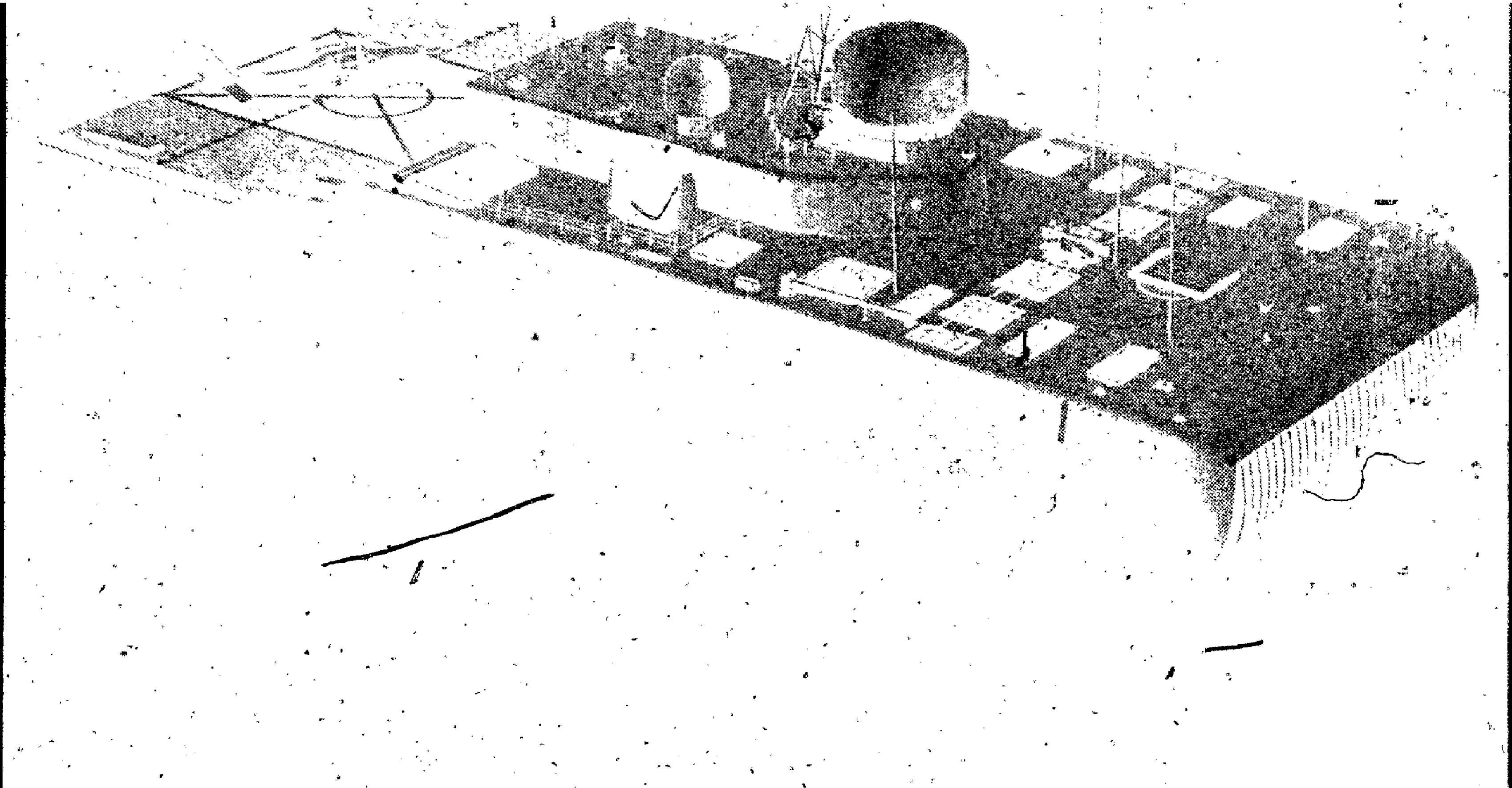

ANVCE Far Term SES

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ABSTRACT

(U) The report describes the point design of a 3600-long ton (35.87 mega-Newton), waterjet-propelled, Surface Effect Ship (SES) that meets tbe far term requirements of the Office of Advanced Naval Vehicle Concepts Evaluation (ANVCE). The point design is a weaponized, fully combatant SES that is a logical progression from today's technology.

(U) The SES point design is described in overall rerms of General Description, Vehicle Performance, Maneuvering, Range, Payload, Weights, Volumes, Stability, Geometric-Form, and Ride Quality. Subsystems further described are Structures: Propulsion; Electical Command, Control, and Communications; Auxiliary; Outfitting and Furnishings; and Combat System. The report also includes sections addressing Logistic Considerations; Survivability and Vulnerability; and Technical Risk.

(U) The far term point design SES is shown to be a cost-effective, minimum risk, and high performance means of satisfying ANVCE requirements. An alternate point design utilizing semi-submerged propellers is also described in a separate Appendix to the report.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

LIST OF ILLUSTRATIONS (Continued)

Figure Number ... Page

LIST OF ILLUSTRATIONS (Continued)

* In SECRET Supplement to This Document

LIST OF TABLES

LIST OF TABLES (Continued)

Table Number | Page

1/ INTRODUCTION

(U) This report describes the point design of a far term (1980-1990 calendar year time period) Surface Effect Ship (SES) for the Office of Advanced Naval Vehicle Concept Evaluation (ANVCE). The "SES-3" point design has been developed in accordance with Modification P00017 to Contract N00024-74-C-0924 under the auspices of the SES Project Office (PMS-304).

(U)The data in this report are for a weaponized combat ship with a full load displacement (FLD) of 3600 LT (35,870 kN). The far term SES is an extrapolation from a near term SES point design described in the "ANVCE Design Summary Report (Near Term)", a CONFIDENTIAL Final Technical Report of Rohr Marine, Inc., dated 15 November 1976. The near term SES, in turn, employed 3KSES data that were originally submitted in response to RFP N00024-76-5342(S). The far term ANVCE SES was developed in accordance with a Rohr-proposed revision of 25 October 1976 to ANVCE WP-006, "Top Level Requirements for a 3000-Ton Surface Effects Ship in the 1990 Year Time Frame (Far Term)," an ANVCE-originated CONFIDENTIAL working paper dated 2 September 1976.

(U) The basic 3KSES design from which the near and far term ANVCE SES's were developed was documented in Rohr Industries, Inc., "Technical Proposal for Design and Construction of a Large Surface Effect Ship," in five (5) volumes consisting of 34 books and 16 appendices, dated 19 July 1976, CONFIDENTIAL, as amended by the "'Best and Final Proposal for the Design

(U) and Construction of a 3,000-Ton Surface Effect Ship, Volume I - Management and Technical Change Summary," dated 12 October 1976 (with four (4) appendices). The far term SES design is a fully combatant ship, while the near term SES and prior 3KSES designs were basically combatant test prototype ships.

(U) To support the Maintenance Concepts specified in the far term ANVCE Top Level Requirement document, the ship system design incorporates provisions that maximize equipment utilization and minimize requirements for at-sea maintenance. Condition monitoring equipment is installed to identify incipient equipment failures in combat, propulsion, lift, electrical, auxiliary and other mission essential systems.

(U) The ship system design provides for fast and positive fault localization/isolation compatible with the replace and restore modularization concept. Corrective maintenance actions are performed by the ship's crew to maintain the mission essential systems in an operational state and are accomplished primarily by replace-and-restore.

(U) To support this concept, ship system design incorporates, to the extent practicable, built-in test equipment and fault localization/isolation monitoring that identifies the defective module to be replaced; this maximizes use of rotatable pool equipment/components. One result of this application of automated monitoring and fault isolation is a greatly improved ship operating profile featuring very high availability.

(U) A typical operating profile was developed for the far term SES and is displayed as Figure 1-1. It is shown for the first 10 years of service with depot modernization continuing into the eleventh year of a minimum 20-year service life. To comply with the established policy for the conduct of test and evaluation by the Navy Department in the acquisition of defense systems, as set forth in OPNAV Instruction 3960.10 dated 22 October 1975, Year 1 of the profile allows for a six-month period to conduct continuing phases of operational Test and Evaluation on the lead

(U) ship of a class so as to rapidly reduce risks and thereby minimize the need for modification to follow-on ships. For the follow-on ships of the same class, this six-month period would be rescheduled as a normal deployment period. The abbreviations used in this operating profile include:

- POM - Preparation for Overseas Movement
- Lv/Upk - Leave and Upkeep
- Ref. Tra - Refresher Training

(U) The Type Training preceding and the Maintenance Availabilities following each deployment period are required with the minimized ship's manning recommended for the far term ANVCE SES.

(U) The far term SES design is presented in the format specified in the Office of Advanced Naval Vehicle Concept Evaluation (ANVCE) Working Paper WP-005A, "Point Design Description," dated 13 August 1976. The terms "far term ANVCE point design" and "1980-1990 time frame" SES are used synonymously throughout the report to refer to the same "SES-3" design concept.

(U) In addition to that required by the ANVCE WP-005A formatting, Appendices B and C were introduced for the purpose of separately grouping the foldout drawings and equipment data sheets.

(U) Appendix D follows the same WP-OOSA format in presenting the propeller-driven alternate SES point design as that for the parent basic report, but with "D" prefixes added to each section and subsection. A new D.5 section was added to show the differences in Design Process for the propeller-driven alternate SES point design from that for the waterjet-propelled SES (otherwise shown in Appendix A to the parent report).

(U) A separately bound and published SECRET supplement to the report contains infrared ship signature data. The use of this supplement permitted the basic report to be published as a CONFIDENTIAL document.

(U) This report contains the following major sections (subsections are delineated in more detail in the table of contents) as specified in **ANVCE WP-005A:**

Section No.	Content
1/	**Introduction**
2/	**Vehicle** General Description
2.1	Principal Characteristics
2.2	Vehicle Performance
2.3	Ship Subsystem Descriptions
2.4	**Survivability** and Vulnerability
3/	Logistic Considerations
3.1	Reliability and Availability
3.2	Maintenance Concepts
3.3	Overhaul Concept
3.4	Supply Support Concept
3.5	Human Engineering
3.6	System Safety
4/	Technical Risk Assessment
Appendices	
A	Design Process
B	Drawings and Diagrams
C	Equipment Data Sheets
D	Propeller-Driven Alternate Design
Supplement	(SECRET -- Under Separate Cover)
1	Ship Infrared Signature Data

(U) The far term point design is described in English, as well as in SI **(metric)** units of measurement. The point design was developed with English units as the primary standard of measurement. SI conversions shown in the text within parentheses conform to American National Standard **(ANS)** 2210.1 "Standard for Metric Practice," published February 1976 by the American Society for Testing and Materials (ASTM) as Standard No, E380-76. The ANS Z210.1/ASTM E380-76 standard has been approved by the Department of Defense and its use stipulated by the ANVCE Project Office.

(U) Rohr Marine, Inc., has defined ship displacements in the following terms:

- Full Load Displacement (FLD) is approximately 3600 long tons (35,870 kN) and characterizes a ship complete and ready for service in every respect. (FLD is equivalent to the full load vehicle weight, W, specified in ANVCE WP-002A).
- Mean Operating Displacement (MOD) is primarily characterized for two conditions:
  - MOD-50; A complete and loaded ship ready for service in every respect with 50% usable fuel.
  - MOD-10; A minimum loading condition for maximum speed operation in any sea state where the ship was complete and ready for service in every respect with 10% usable fuel.
- Light Ship Displacement (LSD) is a complete and empty ship with all operating fluids (SWBS X98) encompassing SWBS Groups 100 through 700 plus margins, but without fuel. (LSD is equivalent' to WE, the empty weight specified in ANVCE WP-002A.)
- Empty Ship Displacement (ESD) is the same as LSD except that unusable fuel (tailpipe allowance) and all other loads groups are included.

(U) A variety of performance and design data were developed in relation to these displacement definitions and have been referenced in the sections that follow.

MOS YR.	1	2	3	4	5	6	7	8	9	10	11	12
1	FITTING OUT	READY FOR SEA (RFS) SHAKEDOWN			POST SHAKEDOWN AVAIL. (PSA)		OPERATIONAL EVALUATION (LEAD SHIP ONLY) OR DEPLOYMENT					
2	TYPE TRAINING			POM	DEPLOYMENT (4 MOS.)				LV/UPK	MAINT. AVAIL.		TYPE T.
3	TYPE T. & POM		DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL.	TYPE TRAINING	
4	POM	DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL. (DEPOT)			RFS
5	REF. TRA.	TYPE TRAINING & POM			DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL.
6	TYPE TRAINING & POM			DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL.	TYPE T.
7	TYPE T. & POM		DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL. (DEPOT)		RFS
8	REF. TRA.	TYPE TRAINING & POM			DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL.
9	TYPE TRAINING & POM			DEPLOYMENT (6 MOS.)						LV/UPK	MAINT. AVAIL.	TYPE T.
10	TYPE T. & POM		DEPLOYMENT (6 MOS.)						DEPOT LEVEL MODERNIZATION (CONTINUES INTO 11th YEAR)			

Figure 1-1 (U). 10 Year Typical Operating Profile (U)

2 / VEHICLE GENERAL DESCRIPTION

(U) 2.1 PRINCIPAL CHARACTERISTICS

[redacted] **2.1.1** SUMMARY -- The Far Term Point Design SES illustrated in Figure 2.1-1 is a warship designed for high speed operation in an open ocean environment. The ship meets the specified range capability and carries a more significant military payload than the near term SES. The design is based on the use of GE LM5000 gas turbines which, with 50,000 hp (37.28 MW) maximum continuous power (MCP) and improved fuel economy, permit carrying a payload to a greater range, compared to the near term SES. Primary mission areas are anti-submarine warfare (ASW), surface warfare (SUW), and anti-air warfare (AAW) in the defense of fleet elements. Characteristics are summarized in Table 2.1-1.

(U) The following subsections describe the ANVCE Far Term Point Design SES in detail -- Section 2.2 outlines Vehicle Performance, Section 2.3 contains ship subsystem descriptions, and Section 2.4 provides survivability and vulnerability information.

(U) The point design, in the on-cushion mode, operates on the captured air bubble principle to reduce hydrodynamic drag and achieve high speeds. In the off-cushion mode, it operates as a displacement hull. The ship is capable of maneuvering in both modes including turning, accelerating, decelerating, and backing, and can also hover in the on-cushion mode.

[redacted] The principal ship dimensions are shown in Figure 2.1-2. The 266.26 feet (81.15 m) length overall and 108 feet (32.92 m) maximum beam satisfy the volumetric and performance requirements. Themaximumbeam permits transiting the ma and Suaa Canals, within the explicit scenario assumption th he United States of America will continue to exercise its sovereign ver the Panama Canal Zone into the 1990's. Effective cushion dimensions are 221 feet (67.36 m) length and 85 feet (25.91 m) beam. A cushion height of 18 feet (5.49 m) was selected to ease ship motions and structural loads in Sea State 6. The full load displacement is 3,600 long tons (35,870.5 kN) including all contract margins and fuel load. Table 2.3-1 shows the principal characteristics of the design and Table 2.1-2 shows the key differences between the far term and the near term SES concepts.

Table 2.1-1 (C). Principal Characteristics of the Far Term 3000 LT Point Design SES (U) (Sheet 1 of 4)

OPERATION: . . . . Warship with primary missions of ASW, SUW and AAW in defense of fleet elements.

DIMENSIONS:

o Length Overall (LOA) ft (m)	266.25	(81.15)
0 Maximum Beam, ft (a)	108.00	(32.92)
o Wet Deck Height (above baseline • ML). ft (m)	16.00	(5.49)
o cushion Area, ft ^{2} (m^2)	18,785.00	(1.745.13)
o Effective Cushion Length, ft (m)	221.00	(67.36)
o Main Deck Height (ABL), ft (m)	40.00	(12.19)
o Sidehull Fence Depth (BBL), ft. (m)	3.33	(1.02)
o Stabilizer Fin Depth (BBL), ft (a)	10.39	(3.17)
o Hullborne Design Waterline (ABL), ft (m)	22.10	(6.74)
o Maximum Navigating Draft, ft (m)	52.49	(9.90)

POWER PLANTS:

0 Propulsion Engines	Four (4) General Electric (GE) LM5000
o Propulsors	Four (4) Aerojet Liquid Rocket Co. (ALRC) Waterjet Pumps
o Lift Engines	Two (2) GE LM5000 (Derated)
o Lift Fans	Six (6) ALRC Centrifugal, Variable Geometry

CREW AND COMPLEMENT:

0 Vehicle	11 Officer, 12 CPO, 101 Enlisted
o Secondary-Vehicles (Helicopters/RPV's)	6 Officer, 1 CPO, 10 Enlisted

SYSTEMS:

0 structure	All aluminum (5456). welded structure consisting of longitudinally stiffened plate supported by transverse web frames.
o Electrical	Independent 1000 kW, 60 Hz and 2000 kW, 400 Hz subsystems, each powered by independent Gas Turbine Generator Sets, Type If Power.
0 steering	Thrust vectoring, differential thrust. and thrust reversal with the outboard waterjet pumps only: same except thrust reversal by reverse rotation or reverse pitch propellers on alternate propeller-driven design.
o Propulsion	Dual waterjet propulsors in each sidehull, driven by in-line gee turbines through separate reduction gear trains. Pump feed in each sidehull is from fixed inlets. An alternate propulsor system uses a single semi-submerged, supercavitating propeller in each sidehull, driven by dual gas turbines through reduction gear trains or an optimal electric power transmission system. (Performance and weights for the propeller drive contained in this table are for a mechanical transmission system.)
o Lift	Three (3) centrifugal, variable geometry fans in each sidehull, driven by a single gas turbine through reduction gear.

Table 2.1-1 (C). Principal Characteristics of the Far Term 3000 LT Point Design SES (U) (Sheet 2 of 4)

SYSTEMS (CONTINUED):

o Seal	Advanced, two-dimensional, planing bow and stern seals, enclosed between sidehulls. The stern seal is passive and incorporates vent valve (ride control) features.
o Ship Integrated Control	Closed loop control for steering, propulsion and lift systems. Automatic control of ride (lift fans and/or vent valve). Performance and fault monitoring of auxiliary, electric plant, and distribution systems. Centralized ship damage control and integrated navigation and collision avoidance.
o Outfit and Furnishings	Hull compartmentation, access and safety conforming to Navy standards with generous habitability provisions.
o Auxiliaries:	
o Heating, Ventilating and Air Conditioning (HVAC)	600 Hz powered, axial flow fan, packaged air conditioning (A/C) plants with dual-due: mixing boxes.
o Refrigeration	Two (2) 600 Hz, powered centrifugal, packaged refrigeration plants.
o Firemain and Auxiliary Seawater	Open loop, horizontal system capable of 1600 gpm (0.10 m^3/s) at 125 psi (861.86 kPa).
o Scupper and Deck Drains	Standard gravity drainage system utilizing glass reinforced plastic (GRP) piping.
o Plumbing Drains (Soil and Waste)	Vacuum assisted collection discharged to holding tank.
o Main Drain	Combines pumps and eductors for main machinery space dewatering and bilge water removal.
o Secondary Drain	Seawater actuated eductors for miscellaneous drainage of spaces not served by main drain system.
o Potable and Fresh Water	Upgraded shipboard system operated to minimize storage with GRP piping used extensively.
o Cooling Water and Auxiliary Fresh Water Cooling	Two (2) systems (Freon and seawater cooled) are provided. Closed loop design meets Navy standards.
o Fuel Oil	Provides for filling, storage transfer and purification Of n-5 fuel for ship use.
o Aviation Fuel	Two (2) JP-5 furl service tanks, filled from ship's storage through filter coalescers for helicopter service.
o Compressed Air	Low pressure air from engine bleed and high pressure air from separate compressor are provided.
o Nitrogen	Charging system is capable of supplying 70 to 3,000 psig (0.48 to 20.68 MPa) of oil free nitrogen.
o Fire Extinguishing	Consists of high capacity AFFF, fixed flooding halon and high expansion foam.
o Hydraulic	Closed 4,000 psig (27.6 MPa) system capable of delivering 246 gpm (0.016 m^3/s).

Table 2.1-1 (C). Principal Characteristics of the Far Term 3000 LT Point Design SES (U) (Sheet 3 of 4)

Auxiliaries (Continued)

o Replenishment at Sea (RAS)	VERTREP area, port/starboard alongside RAS for fuel, potable water, weapons and stores. A vertical flow conveyor is provided for rapid strikedown.
o Anchoring.	3,000 Lb. (13.31 kN) Danforth anchor end associated cable winch.
o Mooring and Towing	Three (3) capstans, bite. chocks, and towing padeyes.
o Boat Handling and Stowage.	Six (6) 25-man life rafts and an outboard motor driven, inflatable rescue craft with handling davit.

WEIGHTS:	Waterjet-Propelled	Propeller-Driven
o Full Load Displacement (FLD) (LT; MN; *)	3.600; 35.87; 3,658	3.600; 35.87; 3,658
o Empty Weight (Lightship + Margins) (LT; MN; *)	2.064: 20.57; 2.097	2,093; 20.86: 2.126
o Fuel Weight (Capacity) (LT; MN; *)	2,049; 20.42; 2,082	2,047; 26.42: 2,082
o Usable Fuel at FLD (LT; MN; *)	1.217; 12.13; 1,236	1,188; 11.84; 1,207
o Unusable Fuel(1) at FLD (LT; EM; *)	65; 0.64: 66	65: 0.64; 66
o Other Load (LT; MN; ●)	253: 2.52; 257	233; 2.52: 257
o Fuel Volume (Capacity) (ft^3; m^3)	90,247; 2.56	90,247; 2.56

MOBILITY/PERFORMANCE SUMMARY:	Waterjet-Propelled		Propcllar-Driven	
o Cushion Pressure at MOD-50 (psf, kPa)	342.0	(16.38)	342.0	(16.38)
o Maximum Speed in Calm Water (knots; m/s) at MCP and FLD	106.0	(54.5)	112.0	(57.6)
o Maximum Speed at 3.94 ft (1.20 m) Significant Wave Height and FLD (knots; m/s)	98.0	(50.4)	100.0	(51.49)
o Hump Margin at 3.94 ft (1.20 m) Significant Wave Height, NOD-50 end MIP (%)	80.0	(80.0)	28.0	(28.0)
o Best Range Speed, Calm Water (Kts; m/s)	98.0	(50.41)	92.0	(47.32)
o Best Range speed at 4.59 ft (1.4 m) Significant Wave Height (knots; m/s)	92.0	(47.32)	95.0	(28.9)
o Tim co Accelerate to Cruise Speed in Calm Water at MOD-50 (s)	100.0	(180.0)	115.0	(115.0)
o Time to Accelerate to Max Speed at MOD-50 in Calm Water (s)(2)	360.0	(360.0)	145.0	(145.0)
o Time to Decelerate from Max Speed to 0 at MOD-50 in Calm Water (s)	52.0	(52.0)	50.0	(50.0)
o Stopping Distance from Hex Speed et HOD-50 in Calm Water (ft; km)	3.460.0	(105.51	3,450	(1052)
o Turn Radius et MOD-50, 50 knots (25.8 m/s) speed (ft; km)	4,000.0	(1.221	4,000	0.22)
o Range at 4.59 ft. (1.4 m) Significant Wave Height (nm; km)	3,500.0	(648.2)	3,639	(1052)
o Endurance (Hours) at Speed for Best Range and 4.59 ft. (1.4 m) Significant Wave Height	37.5	(37.5)	36.0	(36.0)

(1) Per ANVCE Specification (2% deep tank, 5% flat tank.)

(2) MIP applied in last minute of acceleration to avoid an asymptotic approach to maximum speed.

* non-SI Metric Tons

Table 2.1-1 [redacted] Principal Characteristics of the Far Term 3000 LT Point Design SES (U) (Sheet 4 of 4)

COMBAT SYSTEM:	Qty	System
o Armament	1	Advanced Lightweight TWS PCS
	1	MK74 MOD XX PCS
	1	Advanced Vertical Missile Launching System (72 cells)
	40	AMRM Multimode Cannister Missile
	16	HARPOON MXX Cannister Missile
	16	ASW Standoff Weapon Cannister Missile
	1	Advanced Self-Defense Missile Launcher (24 sells)
	24	Advanced Self-Defense Missile
	4	Improved MK48 Torpedo in Ejection Launch Container
o Underwater, *Surface and Air* Surveillance and Ew	1	Advanced Dual Band 2D Long Range Radar
	1	Advanced 2D Short Range Radar
	1	3D Rotating Phased Array Radar
	1	ASMD EW MKXX System
	1	APRAP Sonar System
	1	Deployed Linear Array System (6 arrays)
	1	Towed Array with Depressor System
	1	ERAPS Rocket Launcher System
	26	EBAPS Rocket Launched
	10	ERAPS
	200	Type A Sonobuoys
	10	Type B Sonobuous
o Command/Control/Communication and Navigation(3)	1	ANVCE Medium Air Capable Ship System
o Secondary Sub-Vehicle.		
o Sub-Vehicles	2	LAMPS MKXX Helicopters
	12	Standard Ship Launched RPV
o Sub-Vehicle Armament	36	Advanced Lightweight Torpedo

(3) Medium Air Capable Ship System in accordance with Revision 1. dated 19 October 1976, ANVCE Combat System support; Data for Point Designs.

Table 2.1-2 ([redacted]). Key Feature Comparison -- Near and Far Term SES (U)
(Sheet 1 of 2)

NEAR TERM SES	FAR TERM SES
DIMENSIONS: Both SES's have basically the same overall hull and superstructure dimensions. The only exceptions in the far term SES are (I) that the forward structure terminala on the main deck are one frame further aft at frame 53, (2) that the mast structure above the 03 level is an open space frame featuring a single platform 90.5 feet (27.58 m) ABL with the forward legs of the mast at frame 28, and (3) that a new transverse bulkhead is incorporated co divide vertical missile rooms at frame 7. Finally. the far term SES does not utilize a raised platform coaming around all lift fan air inlets and incorporates a new (raised coaming) combustion air inlet for improved performance.	
FULL LOAD DISPLACEMENT: o 3000 LT (29.89 MN or 3048 *)	o 3600 LT (35.67 MN or 3658 *)
SYSTEMS: o Four (4) General Electric (GE) LM2500 or four (4) Turbo Marine FT-9A-2A gas turbines for propulsion o Four (4) Aerojet Liquid Rocket Co. (ALRC) Waterjet Pumps o Four (4) reduction gear trains o One (1) variable roof ramp, semi-flush rectilinear inlet per sidehull with bifurcated duct	o Four (4) GE LM5000 gas turbines for propulsion o Four (4) uprated near term SES (ALRC) Waterjet Pumps o Four (4) reduction gear trains o One (1) fixed orifice, semi-flush cylindrical inlet par sidehull with bifurcatad duct
LIFT SYSTEM: o Two (2) GE LX500 gas turbines to drive the lift fans o Three (3) ALRC centrifugal. variable geometry fans in each sidehull o Non-interchangeable reduction gear trains (port and starboard) o Active Bow and Stern planning seals o Independent vent valve ride control subsystem (air dump from cushion)	o Two (2) derated GE LM5000 engines to drive the lift fans o Three (3) ALRC uprated near term SES centrifugal, variable geometry fans in each sidehull o Interchangeable reduction gear trains (pore and starboard) o Active planning bow seal. Passive planning stern seal o Integrated vent valve ride control subsystem (air dump from stern seal)
STRUCTURES: o All aluminum (5456) welded, stiffened plate structure with no design requirement for ballistic protection or shock hardening	o All aluminum (5456) welded, [illegible]d plate structure with spaced armor
ELECTRIC PLANT: o Three (3) 375 kW, 60 Hz GTG's and rhrec (3) 375 kW, 400 Hz GTG's, interconnected in a ring bus system	o Two (2) 500 kW, 60 Hz GTG's and four (4) 500 kW, 400 Hz GTG's, interconnected in a ring bus system

* non-SI metric tons

Table 2.1-2 (C). Key Feature Comparison -- Near and Far Term SES (U) (Sheet 2 of 2)

STEERING: Steering is identical for both Near and Far Term SES's.	
SHIP INTEGRATED CONTROL: o Closed loop control for propulsion, lift and steering; automatic control of ride (lift fan (VG) and/or vent valves); performance and Fault monitoring of auxiliary and electric plant distribution systems; centralized ship damage control and integrated navigation and collision avoidance: hardwired IC system	o Upgraded Near Term SES system (e.g., increased microprocessing utilization and improved LSI technology); fully multiplexed data status and signal distribution with redundant battle damage paths (wire with growth to fiberoptic); fully multiplexed IC system (voice and ship entertainment) with redundant battle damage paths (wire with growth to fiberoptic)
OUTFIT AND FURNISHINGS: o Traditional approach to O&F berthing and messing systems o Panel system integrating passive fire, thermal and acoustic protection in all spaces	o Increased use of lightweight and advanced concept berthing and messing systems o Panel system integrating passive fire, thermal and acoustic protection in all spaces with added ballistic protection in selected spaces
AUXILIARIES : Basic Far Term SES Auxiliary Systems are identical to those of the Near Term SES with the following exceptions: 0 Higher operating pressure in compressed air and hydraulic subsystems 0 . Reverse osmosis, lightweight desalinization plant 0 The Underway Replenishment Systems have been expended to facilitate along-side replenishment of all cannister missiles, ship and aircraft launched torpedoes, dispensed ASW sensors, ships provision and stores. The far term SES provides full capabilities for along-side fueling, VERTREP of munitions, stores and provisions, and HIFR facilities for ownship or other helicopters	
CREW AND COMPLEMENT: o Total 125	o Total 141
SECONDARY VEHICLES: o Two (2) SH-3H Helicopter, OR One (1) AV-EB V/STOL 0 Space Reservation for ten (16) mini-RPV's	o Two (2) LAMPS MKXX Helicopters o Twelve (12) Standard Ship Launched Mini-RPV's
COMBAT SYSTEM: o LSES TLR System (2B May 1976)	o ANVCE Medium Air Capable SES Suite (5 November 1976)

(U) 2.1.2 **GENERAL ARRANGEMENT DRAWINGS** — The general arrangement drawings of the ship are contained in Appendix B. Topside combat system locations are shown on the drawings. The drawings are:

- Outboard Profile
- Inboard Profile
- 01 Level and Above
- Main Deck
- Second Deck
- Third Deck
- Wet Deck
- Transverse Section
- Sidehull Inboard Profile
- Bow and Stern Views

(U) In lieu of a "Tank Arrangements and Tank Capacities" drawing, the pertinent information is contained in Table 2.1-3. These data are presented in both English and SI units and include near term SES values for comparative purposes. The differences in tankage for the far term SES are in the fuel trim and storage tanks numbered 13 through 15 which have increased capacities.

(U) The drawings are grouped in Appendix B, Section B.l, for consistency of report format and the benefit of the reader. These drawings are completely up to date and definitive; they take precedence in those cases where minor discrepancies may be found in supporting drawings used elsewhere in this report.

Table 2.1-3 (U). Tank Arrangements and Capacities

(a) Near Term SES with 1,823.7 LT (18,171.4 kN) Total Fuel Capacity (U)

TANK	LOCATION		CAPACITY	LCG FROM 80
	DECK	FRAMES	(LT) (kN)	(FT) (m)
FUEL TRIM AND STORAGE: NO. 1	S/HULL	0-14	88.9 885.8	218.30 66.54
NO. 2	S/HULL	0-14	88.9 885.8	218.30 66.54
NO. 3	WET	0-7	84.3 840.0	228.25 69.57
NO. 4	WET	0-7	84.3 840.0	228.25 69.57
NO. 5	S/HULL	14-28	90.0 896.8	176.61 53.83
NO. 6	S/HULL	14-28	90.0 896.8	176.61 53.83
NO. 7	WET	14-28	52.1 519.1	177.00 53.95
NO. 8	WET	14-28	52.1 519.1	177.00 53.95
NO. 9	S/HULL	28-42	94.6 942.6	134.88 41.11
NO. 10	S/HULL	28-42	94.6 942.6	134.88 41.11
NO. 11	WET	28-42	52.1 519.1	135.00 41.15
NO. 12	WET	28-42	52.1 519.1	135.00 41.15
NO. 13	WET	70-78	59.5 592.9	18.00 5.49
NO. 14	WET	76-78	40.9 407.5	6.57 2.00
NO. 15	WET	67-80	40.9 407.5	6.57 2.00
TOTAL			1,065.3 10,614.7	158.38 48.27
FUEL STORAGE: NO. 1	S/HULL	42-56	182.0 1,813.5	92.83 28.29
NO. 2	S/HULL	42-56	182.0 1,813.5	92.83 28.29
NO. 3	WET	42-56	52.1 519.1	93.00 28.35
NO. 4	WET	42-56	52.1 519.1	93.00 28.35
TOTAL			468.2 4,665.2	92.87 28.31
FUEL SERVICE: NO: 1	WET	42½-55½	145.1 1,445.8	93.00 28.35
NO. 2	WET	42½-55½	145.1 1,445.8	93.00 28.35
TOTAL			290.2 2,891.6	93.00 28.35
HELICOPTER & RPV SERVICE: NO. 1	WET	58-63	7.6 75.73	58.50 17.83
NO. 2	WET	58-63	7.6 75.73	58.50 17.83
TOTAL			15.2 151.46	58.50 17.83

Table 2.1-3 (U). Tank Arrangements and Capacities

(b) Far Term SES with 1,999 LT (19,918 kN) Total Fuel Capacity (U)

TANK	LOCATION		CAPACITY (LT) (kN)	LCG FROM 80 (FT) (m)
	DECK	FRAMES		
FUEL TRIM AND STORAGE: NO. 1	S/HULL	0-14	88.9 885.8	218.30 66.54
NO. 2	S/HULL	0-14	88.9 885.8	218.30 66.54
NO. 3	WET	0-7	84.3 840.0	228.25 69.57
NO. 4	WET	0-7	84.3 840.0	228.25 69.57
NO. 5	S/HULL	14-28	90.0 896.8	176.61 53.83
NO. 6	S/HULL	14-28	90.0 896.8	176.61 53.83
NO. 7	WET	14-28	52.1 519.1	177.00 53.95
NO. 8	WET	14-28	52.1 519.1	177.00 53.95
NO. 9	S/HULL	28-42	94.6 942.6	134.88 41.11
NO. 10	S/HULL	28-42	94.6 942.6	134.88 41.11
NO. 11	WET	28-42	52.1 519.1	135.00 41.15
NO. 12	WET	28-42	52.1 519.1	135.00 41.15
NO. 13	WET	67-76	67.0 667.6	25.50 7.77
NO. 14	WET	67-80	117.2 1,167.8	18.00 5.49
NO. 15	WET	67-80	117.2 1,167.8	18.00 5.49
TOTAL			1,225.4 12,210.0	141.21 43.04
FUEL STORAGE: NO. 1	S/HULL	42-56	182.0 1,813.5	92.83 28.29
NO. 2	S/HULL	42-56	182.0 1,813.5	92.83 28.29
NO. 3	WET	42-56	52.1 519.1	93.00 28.35
NO. 4	WET	42-56	52.1 519.1	93.00 28.35
TOTAL			468.2 4,665.2	92.87 28.31
FUEL SERVICE: NO. 1	WET	42½-55½	145.1 1,445.8	93.00 28.35
NO. 2	WET	42½-55½	145.1 1,445.8	93.00 28.35
TOTAL			290.2 2,891.6	93.00 28.35
HELICOPTER & RPV SERVICE: NO. 1	WET	58-63	7.6 75.73	58.50 17.83
NO. 2	WET	58-63	7.6 75.73	58.50 17.83
TOTAL			15.2 151.46	58.50 17.83

(C) 2.1.3 COMBAT SYSTEM **DRAWINGS** -- Weapons and **sensor** coverage on the near term SES are shown on drawings contained in Appendix B, Section B.4. The drawings illustrate coverage for:

- Advanced Dual Band 2D Long Range Radar
- Advanced 2D Surface Search Radar
- 3D Rotating Phased Array Radar
- Advanced Lightweight TWS FCS
- MK 74 MOD XX FCS
- IR Sensor ASMD EW MK XX
- Rocket Projected ERAPS Launcher
- SATCOM AS-3018/WSC-3

(U) The drawings are grouped in Appendix B for consistency of report format and the benefit of the reader.

(U) 2.1.4 SHIP INTERFACES AND SIZING

(U) 2.1.4.1 Ship Interfaces -- The far term SES is designed to functionally interface with other U.S. Navy ships, craft, shore commands and aircraft during operational deployment, and with Navy and other logistic facilities for support. The primary physical interface characteristics of the ship are:

- Vertical underway replenishment (VERTREP) with the capability for rapid strike down.
- Underway alongside fuel, potable water, munitions and stores replenishment (CONTREP).
- In-flight refueling of helicopters (HIFR).
- Capability of being towed.
- Capability of receiving support services, including power, water, fuel and replenishment stores, when secured to a shore facility.
- Capability for precision anchoring in depths not exceeding 40 fathoms (73.15 m).
- Mooring system to provide means for mooring alongside a pier or ship.
- Provide fuel and oil for helicopters and RPV's.
- Capability of maintaining visual and radio communication with other ships, aircraft, and shore facilities.

(U) 2.1.4.2 Far Term SES Sizing -- The full load displacement and performance for the Far Term SES was based on the 1980-1990 time period technology projections shown in Table 2.1-4. The technology date for these projections was 30 June 1987. Waterjet propulsors were selected as the thrusting units for the sizing study. Projections were made for open cycle marine gas turbine fuel consumption, waterjet propulsor efficiency and total ship drag. The finally selected size was reached by an iterative process.

(U) The initial projections of ship weight, made by summing the projections in each 100 level SWBS element, were used to project an upper bound for range calculations. Drag forces were determined for ship weights between 2200 (21,920 kN) and 4000 long tons (39,854 kN). Figure 2.1-3 shows range vs. displacement for the near term ship with its corresponding drag projections. The effect of ship length extensions of 14 (4.27 m) and 23 feet (8.53 m) are shown. The length increases were investigated in anticipation of space and volume requirements imposed by the expanded weapons suite.

[redacted] The results show increases in maximum displacement required to attain the range goal of 3500 nm (6482 km) with increased cushion length-to-beam (L/B) ratio. The L/B = 2.6 ship has lower fuel consumption than longer versions studied. The added impact of increased lightship weight with increased L/B was not considered. Installation studies showed that the near term ship size with an 85 foot (25.91 m) cushion beam and a 221 foot (67.36 m) cushion length (L/B = 2.6) provided sufficient space and volume to accommodate the far term weapons suite and no further study of ship size increase was required. Thus, the far term ship has the same principal dimensions as the near term ship but operates at a higher FLD and with increased payload and fuel weights.

[redacted] Figure 2.1-4 shows the effect of displacement on range for the L/B = 2.6 ship. Results are presented for SS3 ($H_{1/3}$ = 4.6 ft. (1.4 m) with the current drag prediction and with an anticipated 10 percent overall drag reduction available in far term SES operation. The anticipated drag reduction is projected on the basis of tow tank tests of full keel length performance fences, further seal drag improvements, sidehull refinements, and an aerodynamic improvement beyond the topside arrangement shown elsewhere in this report. The results show that the required ship maximum displacement is 3560 long tons (35,470 kN) to achieve a range of 3500 nm (6482 km) for an empty weight of 2451 long tons (24,420 kN).

[redacted] The results include projections that are based upon anticipated technology improvements in the 1980-1990 calendar year time period for waterjct propulsor and open cycle marine gas turbines. The projected pump efficiency of 0.90 compares with a current 0.886 value. The LM5000 engines, operating in the 50,000 hp (37.29 MW) category, have a projected specific fuel consumption of 0.32 lb/hp•h (1.91 N/kWh) compared with a current 0.36 lb/hp•h (2.15 N/kWh) value. The sizing reaulted in the selection of 3600 Long Tons (35,869 kN) as the basis for detailed study of various ship systems, Final thrust, drag, power and payload information are presented in Section 2.2.1 and 2.2.3. The final ship weight summary is presented in Section 2.2.4.

Table 2.1-4[redacted]. SES Technology Projections (U)

PARAMETER	EXPECTED VALUE NEAR TERM SES (1985 IOC)	EXPECTED VALUE FAR TERM SES (1995 IOC)	TYPICAL PERCENT INCREASE (1985) to (1995)
Structural Weight Fraction, W_{STR}/W_G	0.268	0.256	-4.5
Specific Fuel **Consumption, lb/hp-h (N/kWh)**	0.40 (2.39)	0.32 (1.91)	-20.0
Miscellaneous Weight: **Weight$^{(1)}$ Fraction, W_{MISC}/W_G**	0.117	0.110	-6.0
Propulsion System **Efficiency (Waterjet)**	53	60	+13.0
Propulaion system Efficiency (Propeller)	N/A	70	--
Lift System Efficiency (Static)$^{(2)}$	0.761	0.792	+4.1
Sidehull Dreg, **Ratio, $D_{SH}/W_G$$^{(3)}$**	0.28	0.25	-12.0
Appendage Drag, Ratio, $D_{APP}/W_G$$^{(3)}$	0.14	0.12	-15.0
Seal Drag, Ratio, $D_{SEAL}/W_G$$^{(3)}$	0.04	0.04	0
Aerodynamic Drag$^{(4)}$ Coefficient, C_{D_A}	0.39	0.33	-18.0
Seal Leakage (Equiv. Airgap ft^2 (m^2)	370 (34.37)	340 (31.59)	-9.0

(1) Includes electric, seals, furnishings less payload and auxiliaries less payload and lift.
(2) As defined in Section A.2.6.
(3) At 100 knots (51.44 m/s) speed and with projected improvements.
(4) Based on frontal area.

NO DRAG REDUCTION

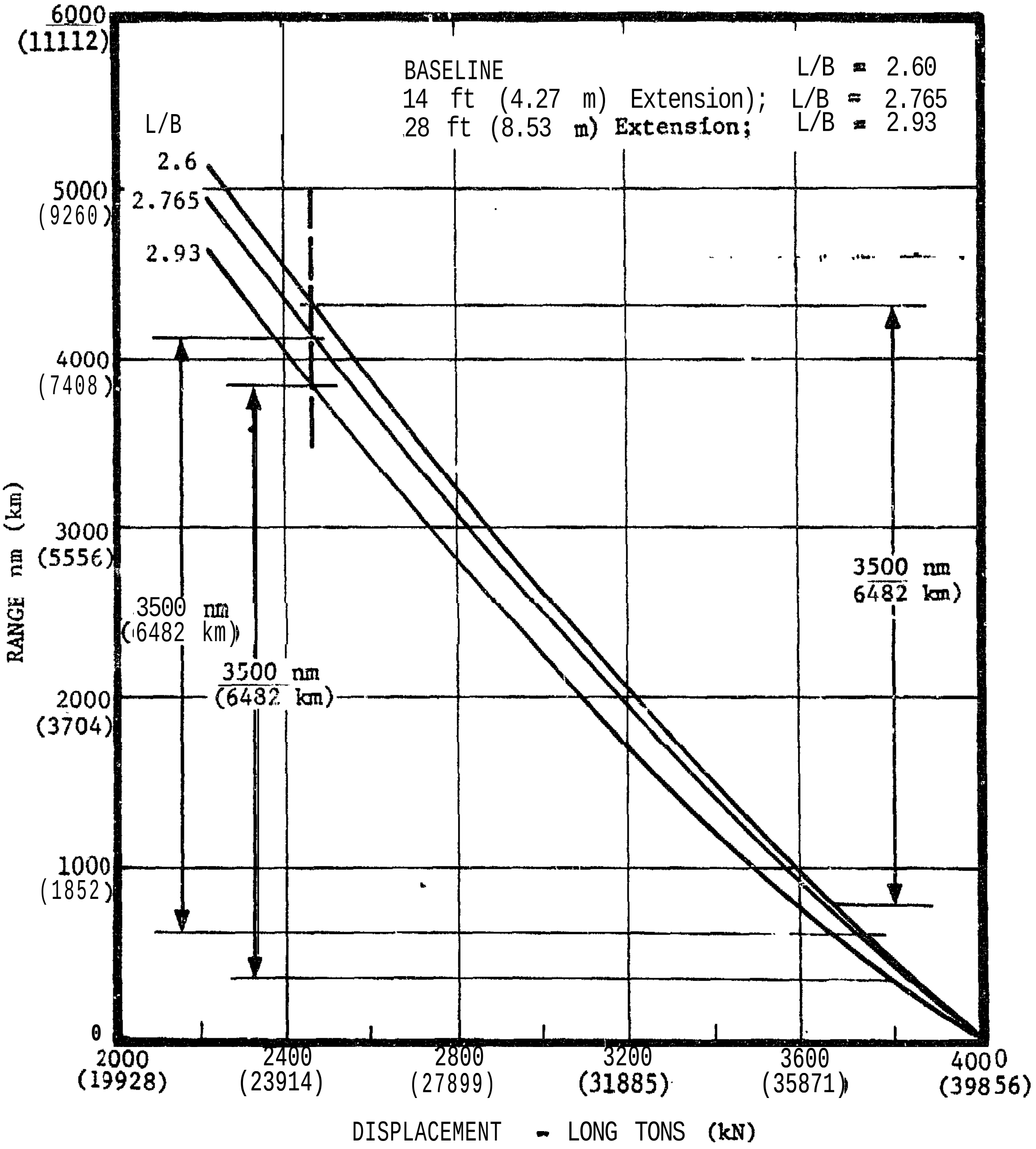


Figure 2.1-3 [redacted]: Effect of Cushion Length-to-Beam Ratio on Far Term SES Maximum Displacement and Range on a 1976 Performance Basis (U)

$H_{1/3}$ = 4.6 FT (1.2 m)
SFC = .32 lb/hp·h (1.91 N/kWh)
η PUMP = 0.90
L/B = 2.6
Propulsion hp (W) per engine = 50,000 (37.29 mn)

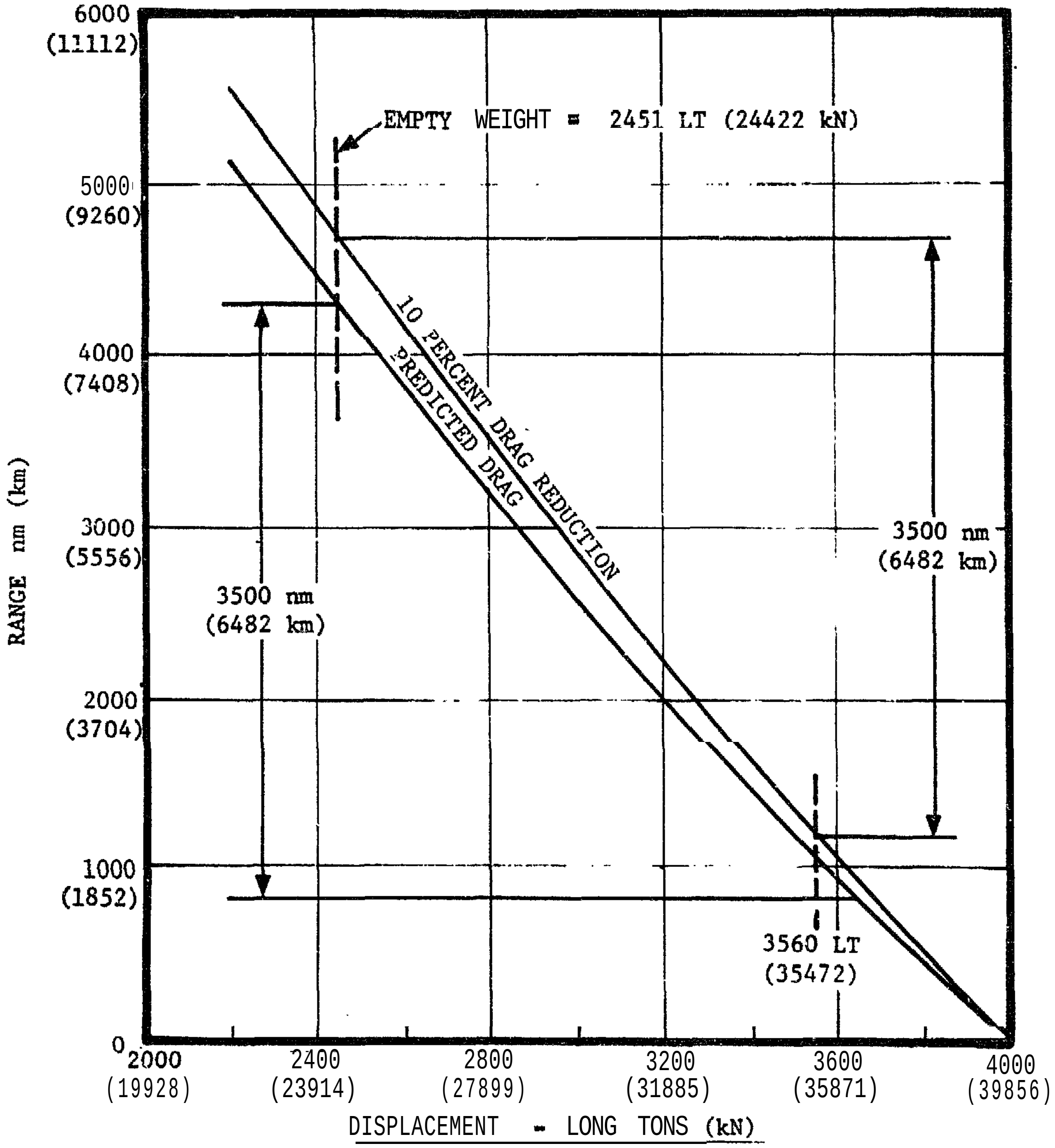


Figure 2.1-4 [redacted]: Effect of Displacement or Far Term SES Range Performance with 1980-1990 Year Time Period Drag Levels (U)

(U) 2.2 VEHICLE PERFORMANCE

(U) 2.2.1 THRUST, DRAG, AND POWER -- Figure 2.2.1-l presents the predicted drag/displacement ratios for the far term SES, as a function of ship speed and significant wave height at Full Load Displacement (FLD). Performance is shown with the ride control system off, and with the ride control system operating at a level sufficient to meet or better the Rohr ride criteria shown in Figure 2.2.1-2. The figure also shows the ANVCE ride criteria specified in the TLR (W-006) as a dashed line which is more restrictive in the 0.1 to 1.0 Hz region. Ride control is not required to meet either criteria for significant wave heights equal to or less than 4.6 ft (1.4 m). In addition, a plot illustrating the speed dependent character of the drag components is presented in Figure 2.2.1-3. These data reflect an assumed 10 percent reduction in drag for the 1980 to 1990 time frame on the basis of projected improvements due to full-keel-length fences and both seals and sidehull refinements. The analytic prediction methodology is based on techniques which have been validated and enhanced by correlation with model test data. While no allowance was made for marine fouling, a 1.0 mil surface finish was assumed for all hydrodynamically wetted surfaces. The available thrust is plotted in Figure 2.2.1-4 as a function of speed.

(U) Figure 2.2.1-5 presents the propulsion system efficiency of the far term SES versus speed and significant wave height. These data are based on the assumption that the propulsion power could be set at that level necessary to maintain a constant speed,

(U) The propulsion system efficiencies were based upon an SFC value of 0.32, as read at a 60,000 hp (44.76 MW) value from the open cycle marine gas turbine curve for the year 2000 in Figure 3 of ANVCE WP-011, initial issue of 31 August 1976 (the latest revision available at Rohr). Re-examination at a 50,000 hp (37.30 MW) value resulted in a SFC of 0.325. A 1987 year value found by interpolation between 0.325 and 0.360 for year 2000 and 1980, respectively, is 0.345. Range corrections within the

(U) accuracies of the results can be readily made by multiplying the quoted ranges of this report by the ratio of a chosen SFC to the 5.32 value used in the predictions.

(U) Propulsion efficiencies are defined as the ratio of the product of thrust required times craft speed divided by the propulsion power required. The thrust required is the total of the SES aerodynamic and hydrodynamic drag force without installed drag forces due to the propulsion system which are taken as a deduction from total thrust. The propulsion power required is the gross power available from the engines before any deductions are made for gear box, pump, nozzle, or other losses.

(U) The transport efficiency of the far term SES as a function of speed and significant wave height is shown in Figure 2.2.1-6. In accordance with the definitions presented in ANVCE WP-002, dated 2 April 1976, transport efficiency was defined by:

$$\frac{\text{Full Load Displacement (3655 LT; 35,870.0 kN)} \times \text{Speed (Independent Variable)}}{\text{Total Power Required at Half Fuel (3526 LT; 30,146.2 kN) Condition}}$$

(U) Figure 2.2.1-7 presents the maximum speed performance versus significant wave height for the FLD condition. These predictions are based on the ride-control-off data, Figures 2.2.1-l and 2.2.1-S. In all asea, maximum speed is limited by the thrust avail&&,_--

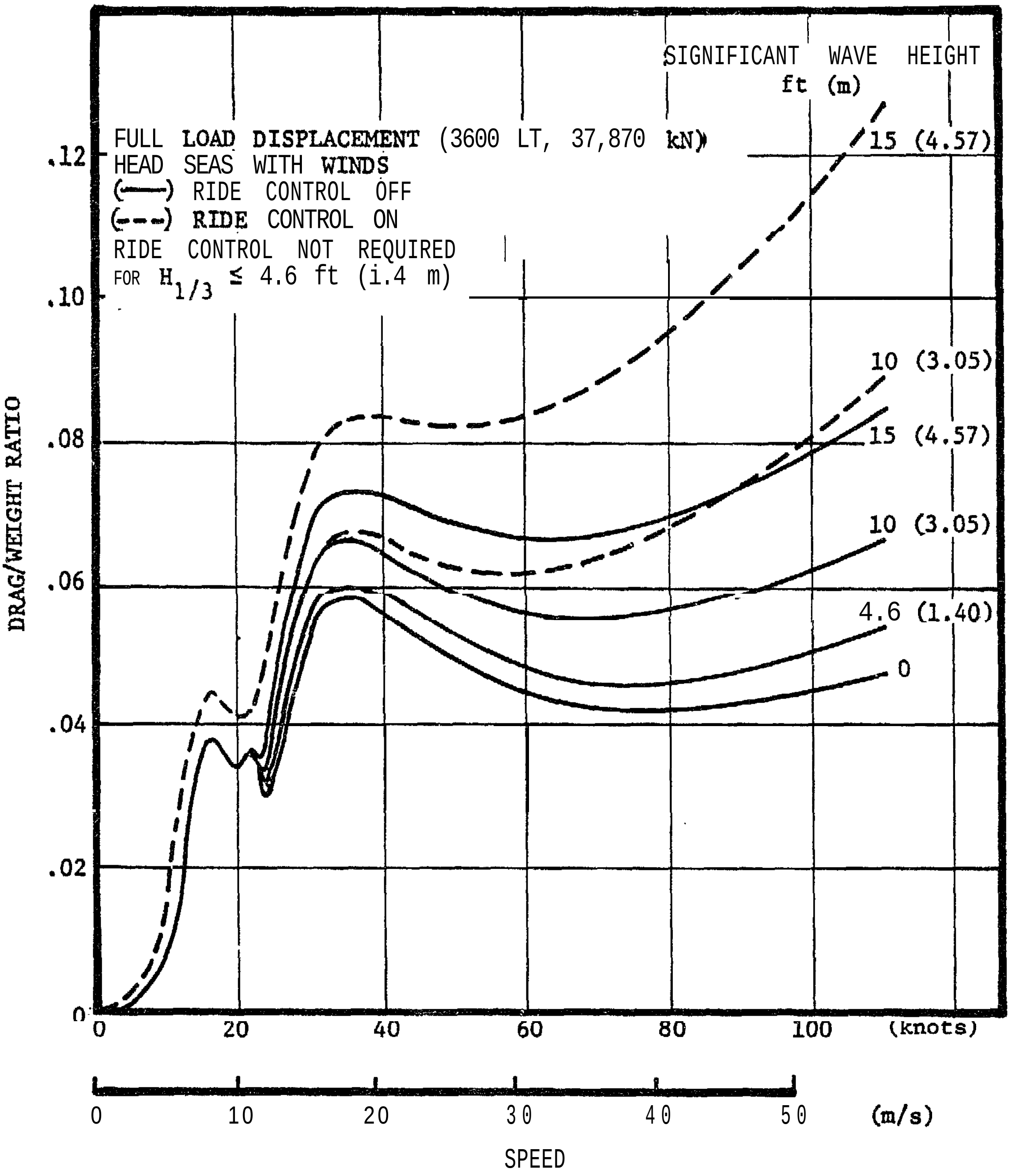


Figure 2.2.1-1 ([redacted]): Far Term SES Drag/Weight Ratio Versus Speed and Significant Wave Height (U)

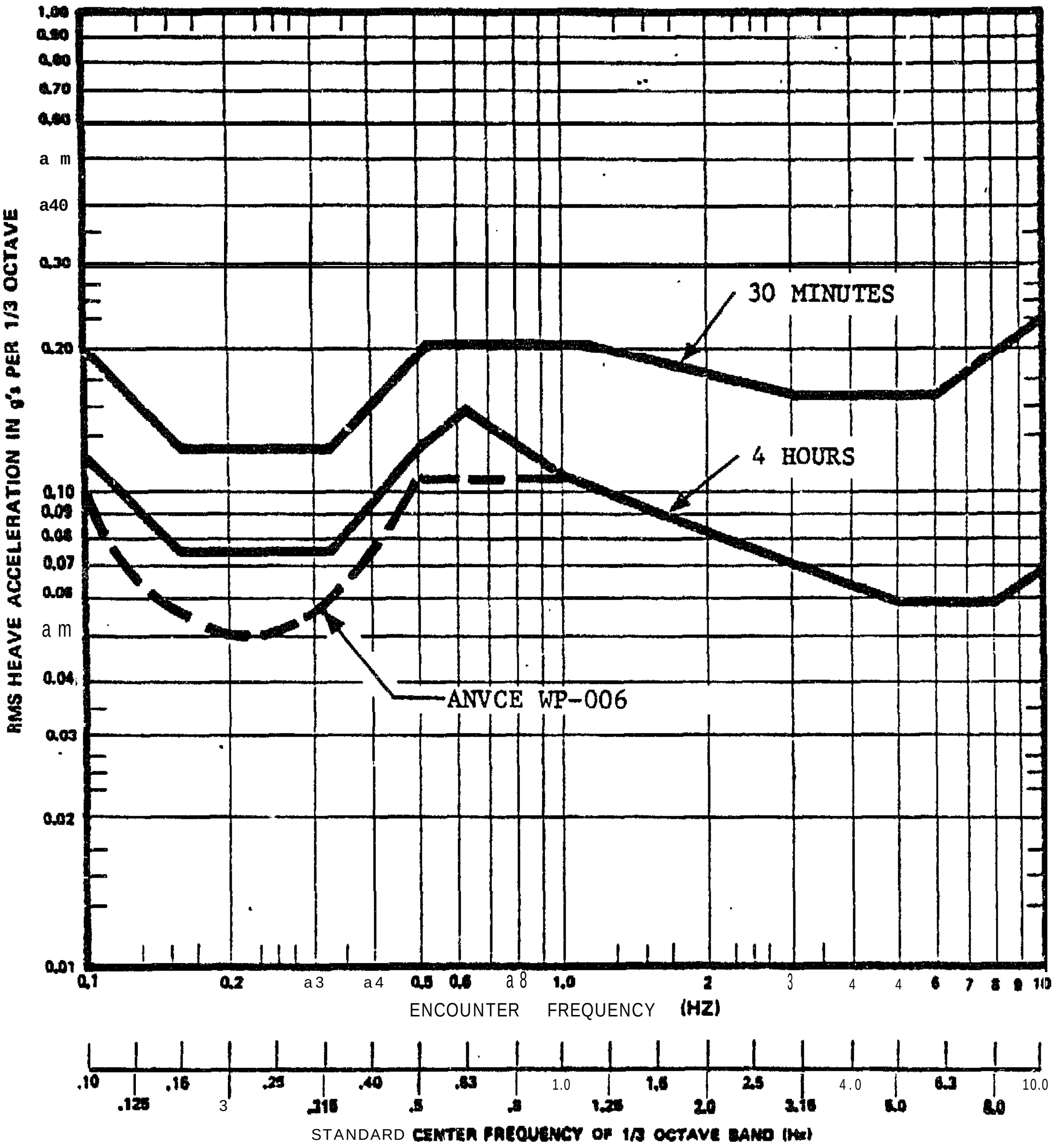


Figure 2.2.1-2 (U): Rohr SES Heave Acceleration Ride Criteria (U)

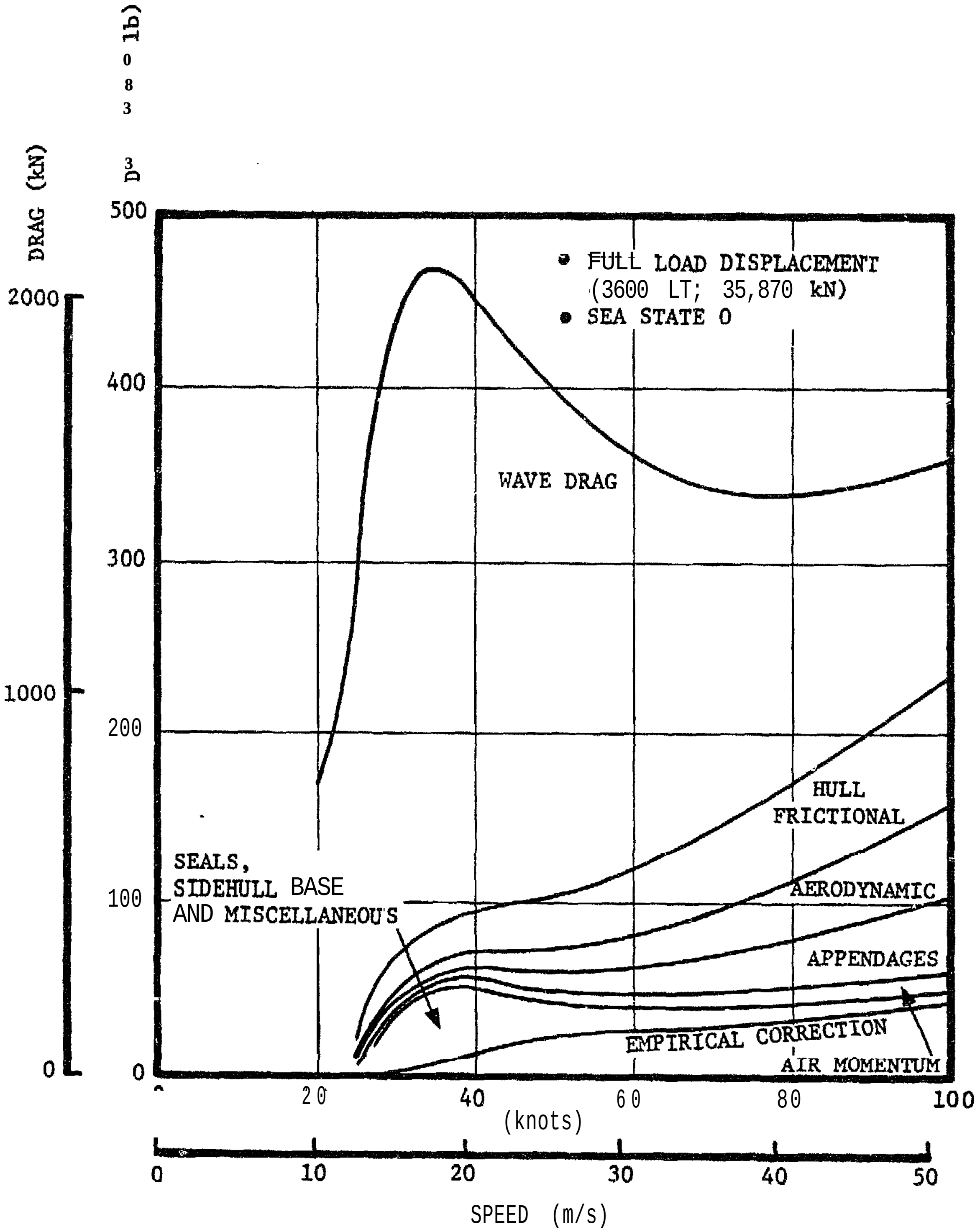


Figure 2.2.1-3 ~~(C)~~: Far Term SES Drag Breakdown (U)

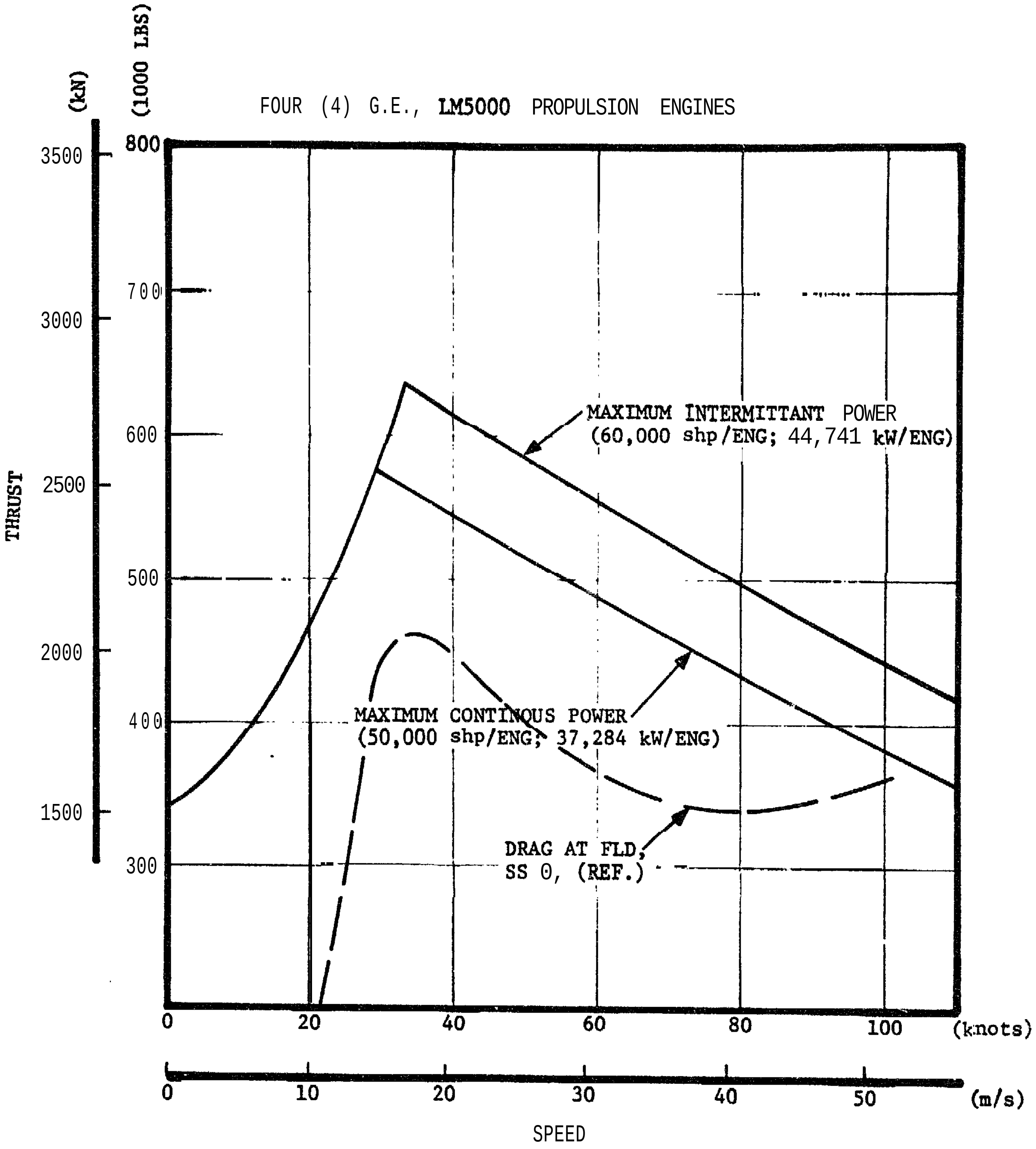


Figure 2.2.1-4 [redacted]: Far Term SES Available Thrust Versus Speed (U)

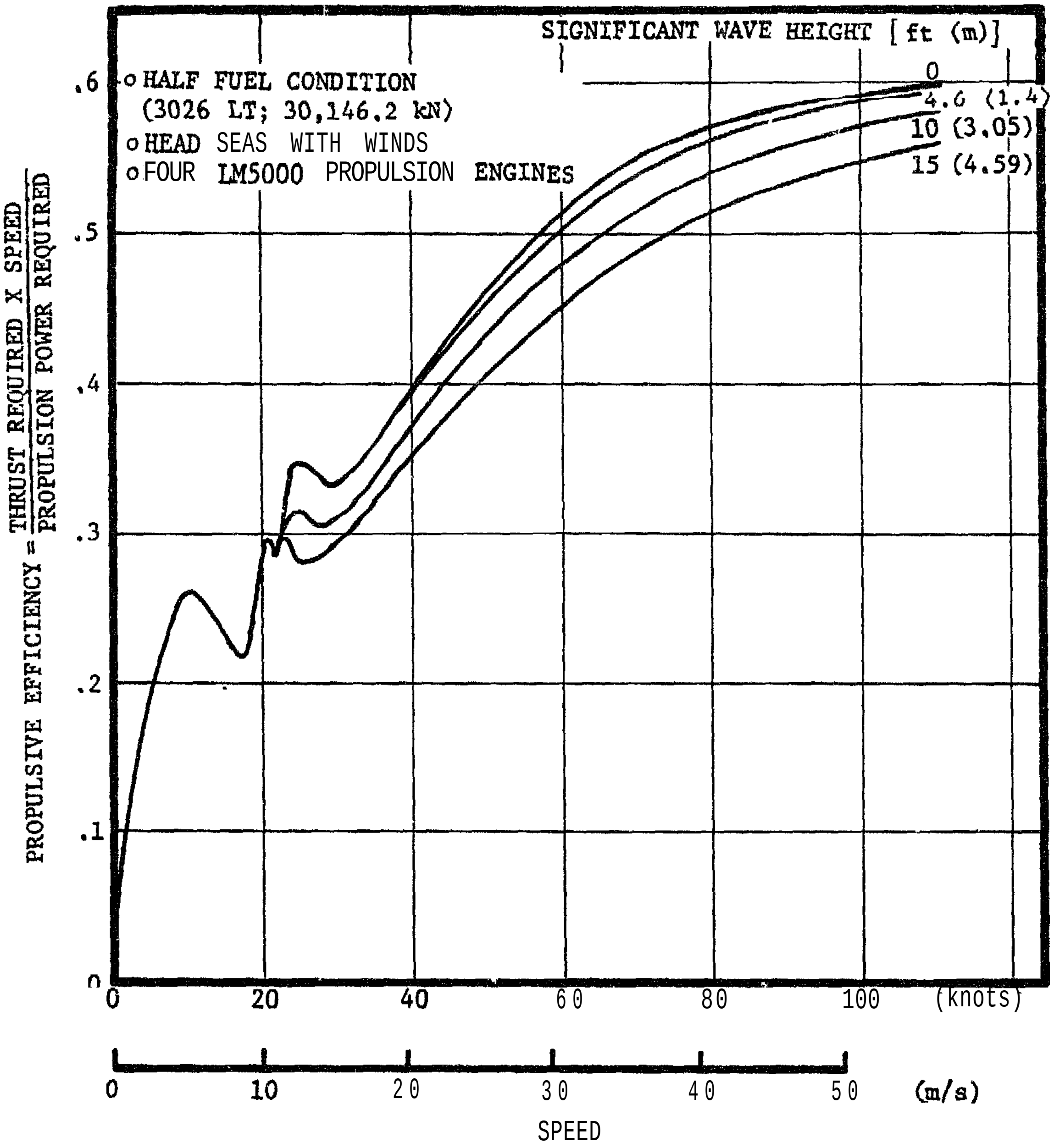
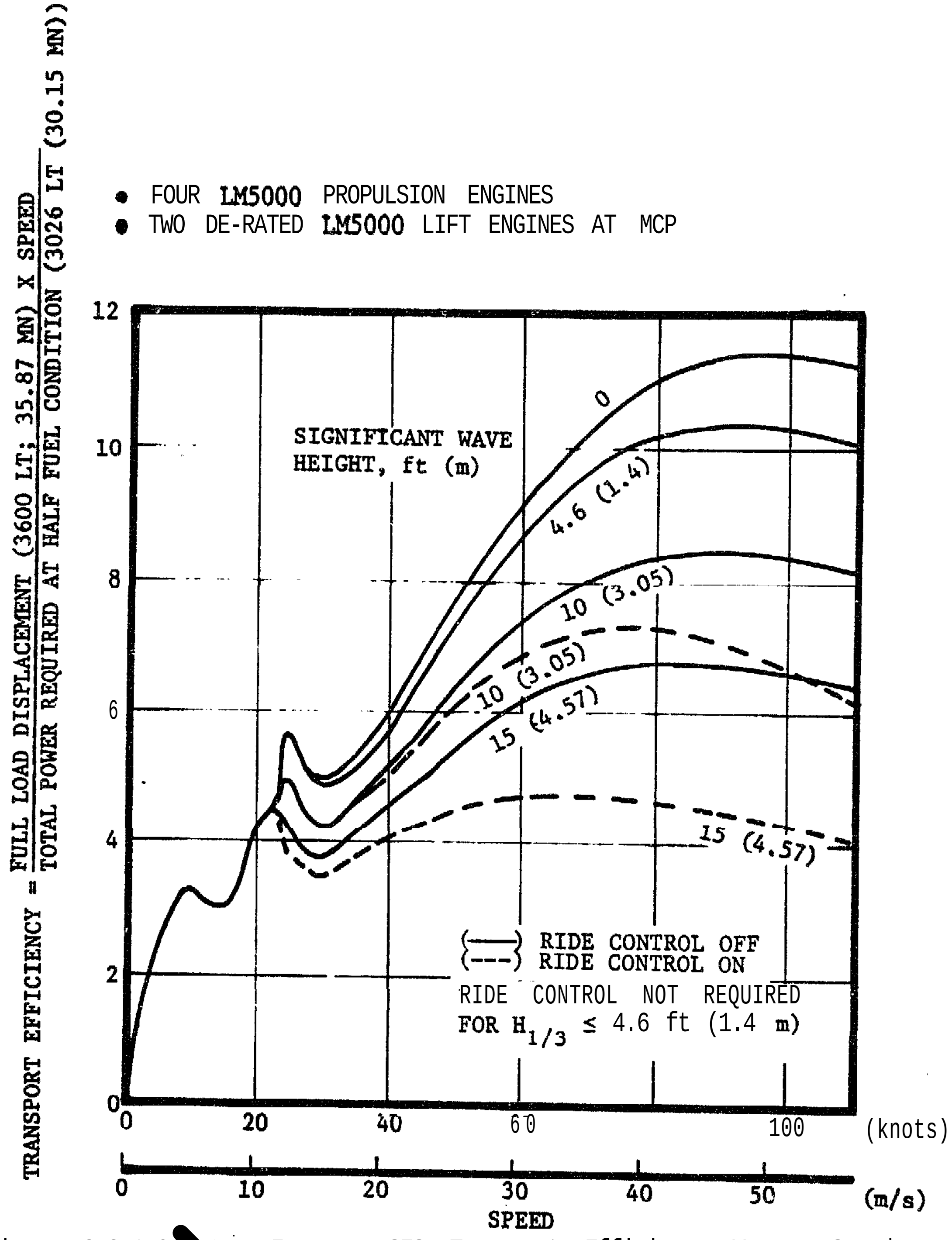


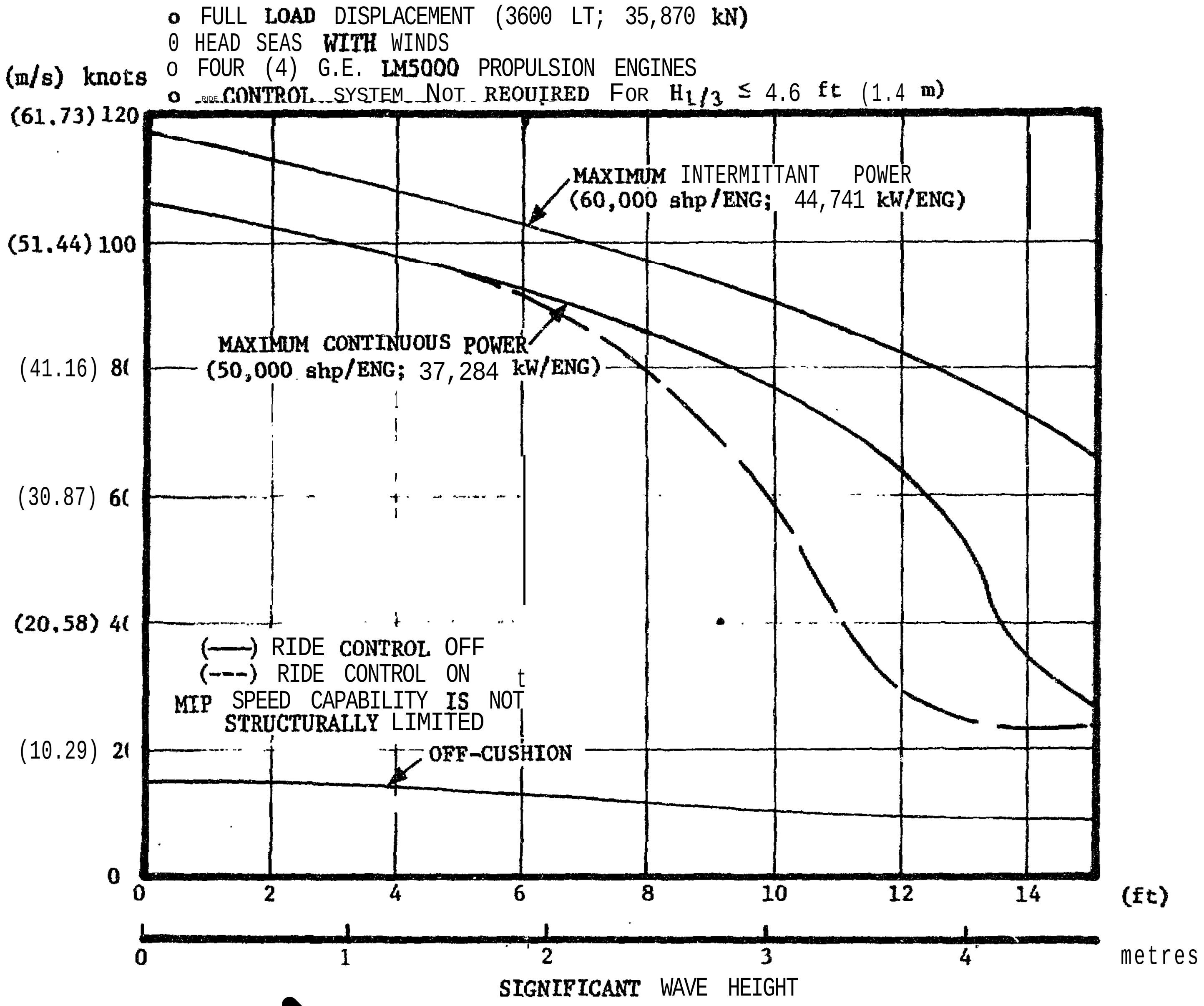
Figure 2.2.1-5 ~~(C)~~: Far Term SES Propulsive Efficiency Versus Speed and Sea State (U)



- FOUR LM5000 PROPULSION ENGINES
- TWO DE-RATED LM5000 LIFT ENGINES AT MCP

RIDE CONTROL NOT REQUIRED FOR $H_{1/3} \leq$ 4.6 ft (1.4 m)

Figure 2.2.1-6 ~~(C)~~. Far Term SES Transport Efficiency Versus Speed (U)



- FULL LOAD DISPLACEMENT (3600 LT; 35,870 kN)
- HEAD SEAS WITH WINDS
- FOUR (4) G.E. LM5000 PROPULSION ENGINES
- RIDE CONTROL SYSTEM NOT REQUIRED FOR $H_{1/3} \leq$ 4.6 ft (1.4 m)

(——) RIDE CONTROL OFF
(---) RIDE CONTROL ON

MIP SPEED CAPABILITY IS NOT STRUCTURALLY LIMITED

Figure 2.2.1-7 [redacted]: Far Term SES Maximum Speed Versus Significant Wave Height (U)

(U) 2.2.2 **MANEUVERING** -- The steady state turn performance of the far term SES configured with four GE LM5000 propulsion engines is shown in Figures 2.2.2-1 and 2.2.2-2. These data are for the craft in calm water and at a half fuel load condition. The turn performance is based on steady state turns using combined thrust vectoring and differential thrust. For initial speeds above 50 knots (25.7 m/s), the turns are preceeded by a deceleration to 50 knots (25.7 m/s) to reduce turn radii. The turns are limited by the maximum drift angle limits of Figure 2.2.5-22. These drift angle limits represent the steering capability below 35 knots (18 m/s) and safety constraints at and above 35 knots (18 m/s).

(U) Figure 2.2.2-3 presents the acceleration times from a standing start as a function of speed and significant wave height. These maneuvers were computed on the basis that both the lift and propulsion engines are set at Maximum Continuous Power (MCP) and that the bow seal is partly retracted while transiting hump. At low speeds, however, the power levels were limited to those imposed by cavitation limits of the waterjet pumps. The use of Maximum Intermittent Power (MIP) during the last minute of the acceleration maneuver would avoid an asymptotic approach to maximum speed.

(U) Figures 2.2.2-4 and 2.2.2-S present the deceleration performance as a function of speed and significant wave height. These maneuvers were accomplished by:

- Engaging the thrust reversers (available only on the outboard propulsion engines)
- Applying MIP to the outboard propulsion engines
- Reducing the inboard engine power to "idle"
- Retracting the stern seal

(U) These procedures cause the ship to decelerate in a bow up attitude and thereby avoid the possibility of undesirable pitch motions. Engagement of the thrust **reversers requires** 3.0 seconds. The remaining emergency stopping procedures are effected **during** this time interval.

- MOD-50 CONDITION (3026 LT; 30,146.2 kN)
- COMBINED THRUST VECTORING AND DIFFERENTIAL THRUST
- SIGNIFICANT WAVE HT = 0
- NO WIND

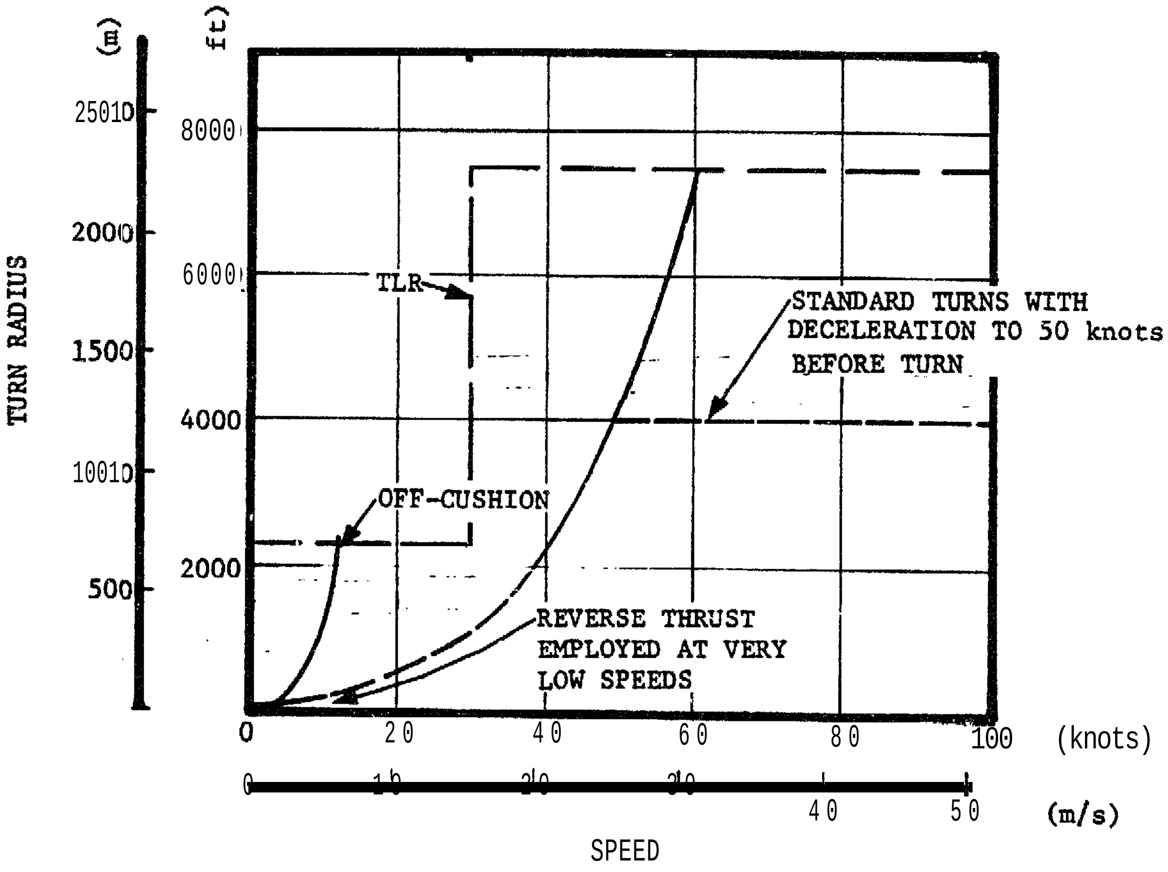


Figure 2.2.2-1 (U): Far Term SES Turn Radius Versus Speed (U)

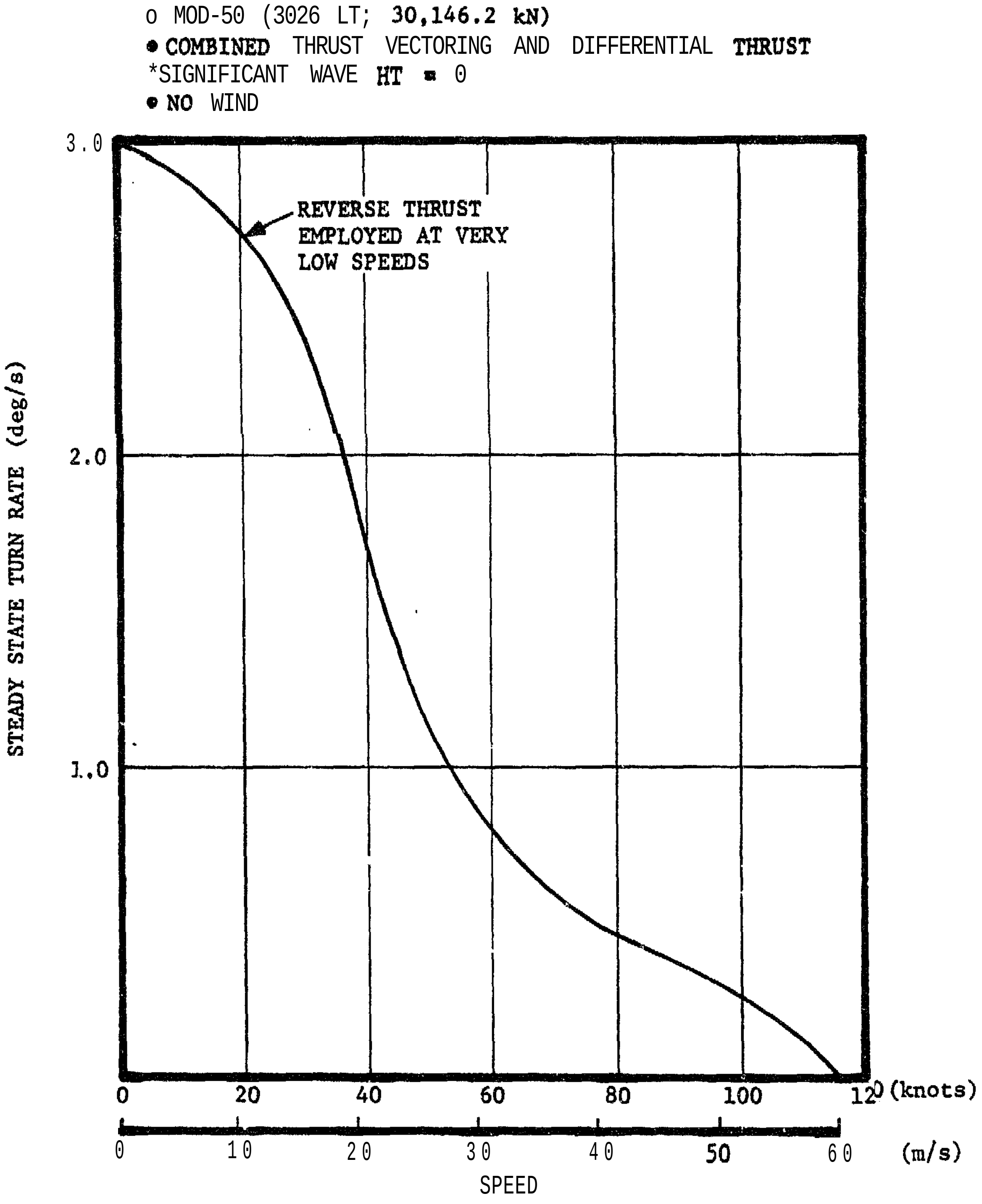


Figure 2.2.2-2 (U): Far Term SES Steady State Turn Rate Versus Speed (U)

[redacted]

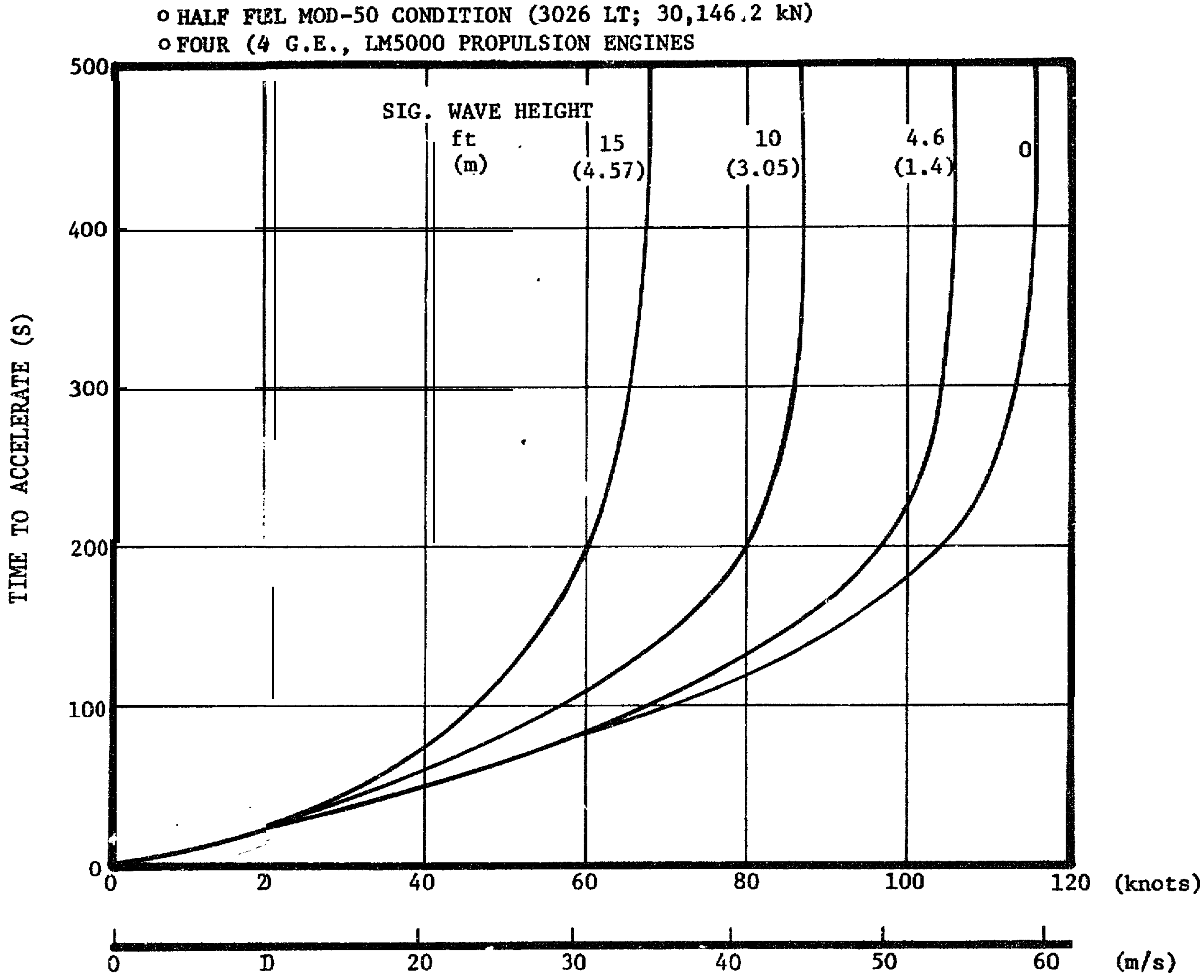


Figure 2.2.2- [redacted]: ANVCE Far Term SES Time to Accelerate Versus Speed (U)

[redacted]

[redacted]

- HALF FUEL CONDITION (3026 LT; 30,146.2 kN)
- HEAD SEAS WITH WINDS
- FOUR (4) G.E., LM5000 PROPULSION ENGINES
- TWO (2) DE-RATED LM5000 LIFT ENGINES

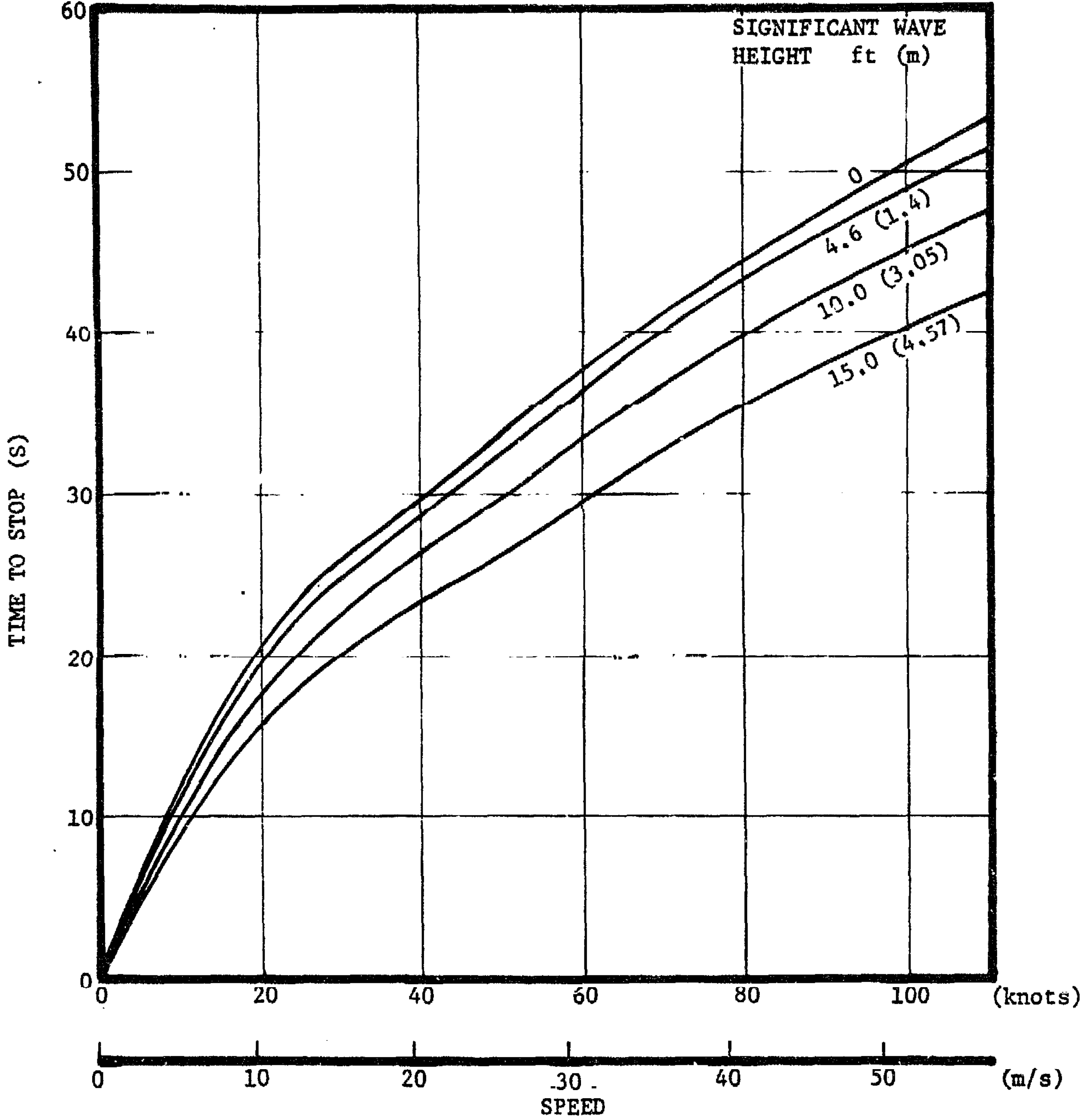


Figure 2.2.2-4 [redacted]: Far Term SES Time to Stop Versus Speed (U)

[redacted]

[redacted]

- o **HALF** FUEL CONDITION **(3026 LT; 30,146.2 kN)**
- o **HEAD** SEAS WITH WINDS
- o **FOUR (4)** G.E., **LM5000** PROPULSION ENGINES
- o TWO **(2)** DE-RATED **LM5000** LXFT ENGINES

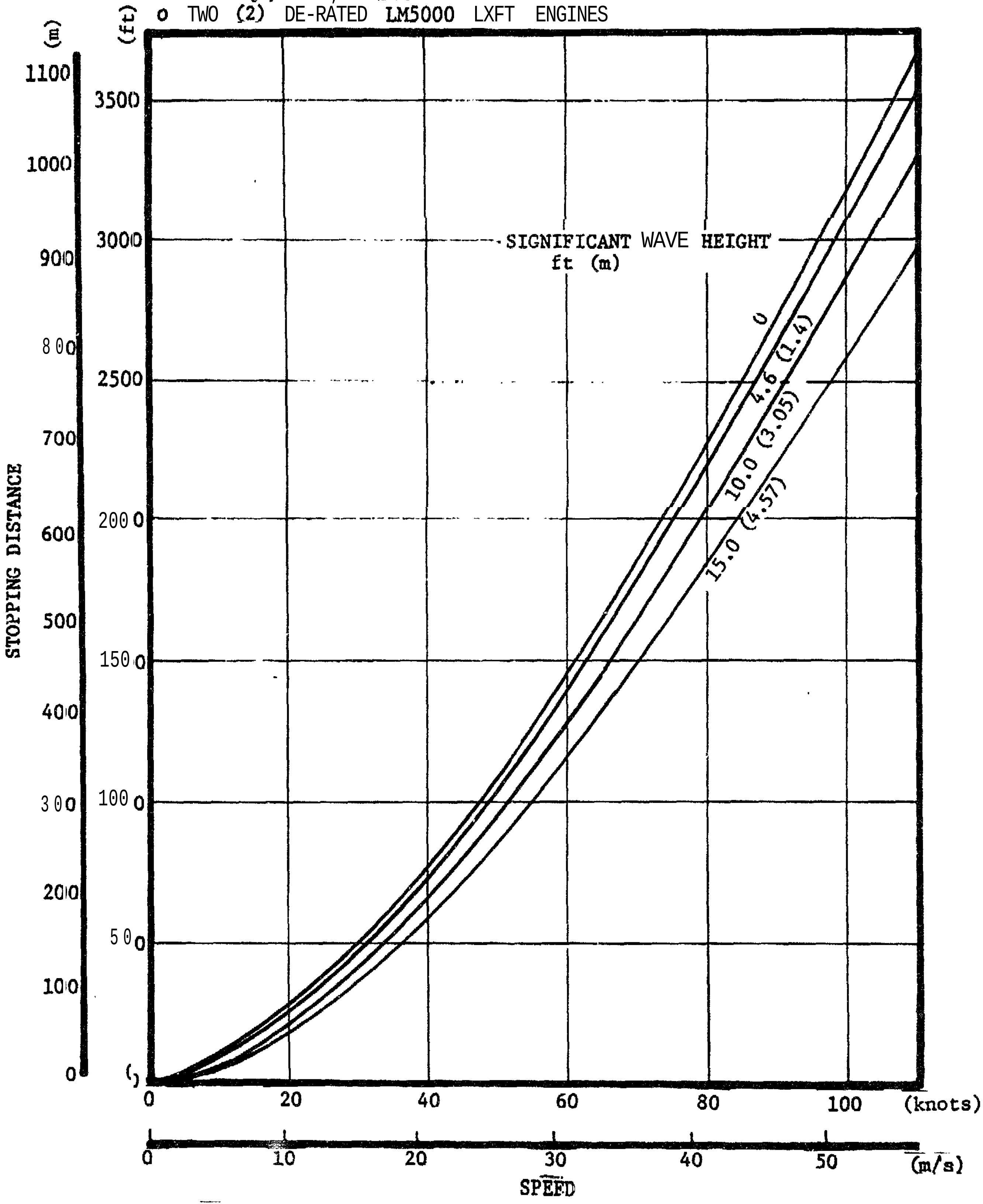


Figure 2.2.2-5 (C): Far Term SES Stopping Distance Versus Speed (U)

[redacted]

(U) 2.2.3 RANGE AND PAYLOAD -- The far term ANVCE SES meets the required range with the specified payload and GE LM5000 engines as shown in Figure 2.2.3-1. Range is computed by integrating speed and fuel rate over the interval from full load displacement (FLD) to the near empty weight of lightship displacement plus unusable fuel.

(U) The range and endurance characteristics, as presented in Figures 2.2.3-1 through 2.2.3-4, are influenced by speed, significant wave height and payload. The characteristics are shown with the ride control system off and with the ride control system operating at a level sufficient to meet or better the Rohr ride criteria. These data are based on the MOD-50 resistance data, the propulsion system efficiencies presented in Figure 2.2.1-5, and a specific fuel consumption of 0.32 lb/hp˙h (1.915 kN/Wh). The corresponding fuel consumption rates are shown in Figure 2.2.3-4.

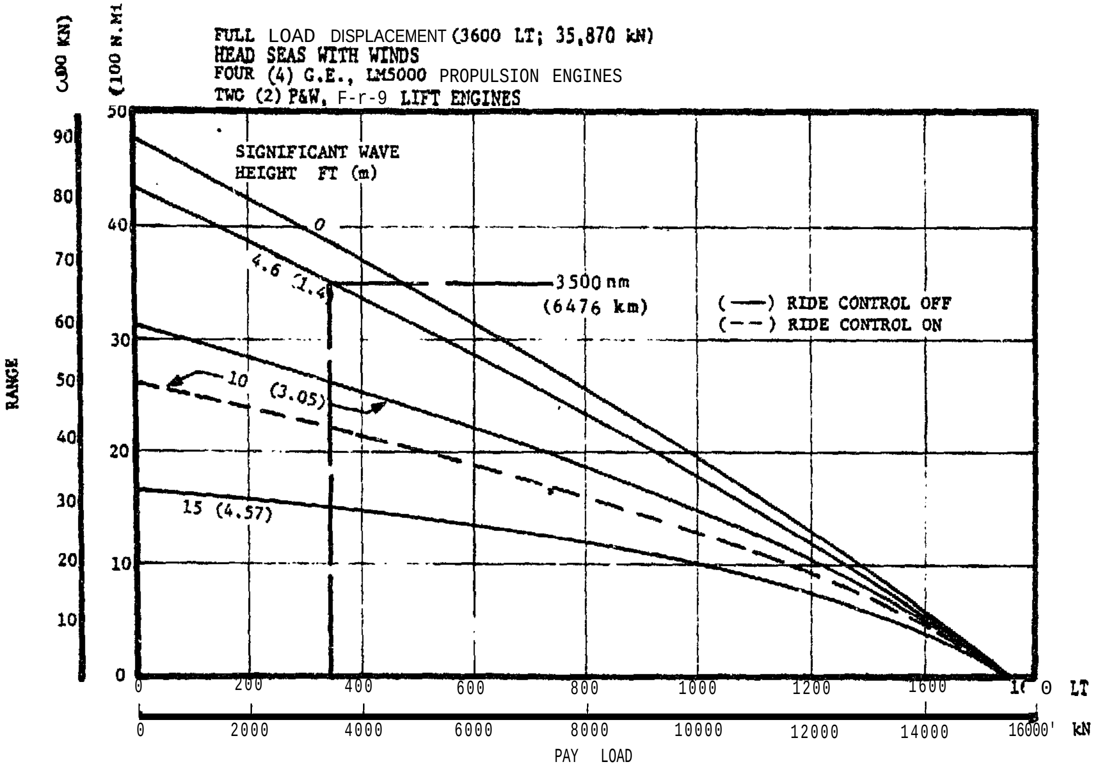


Figure 2.2.3-1 ([redacted]): Far Term SES Range Versus Payload (U)

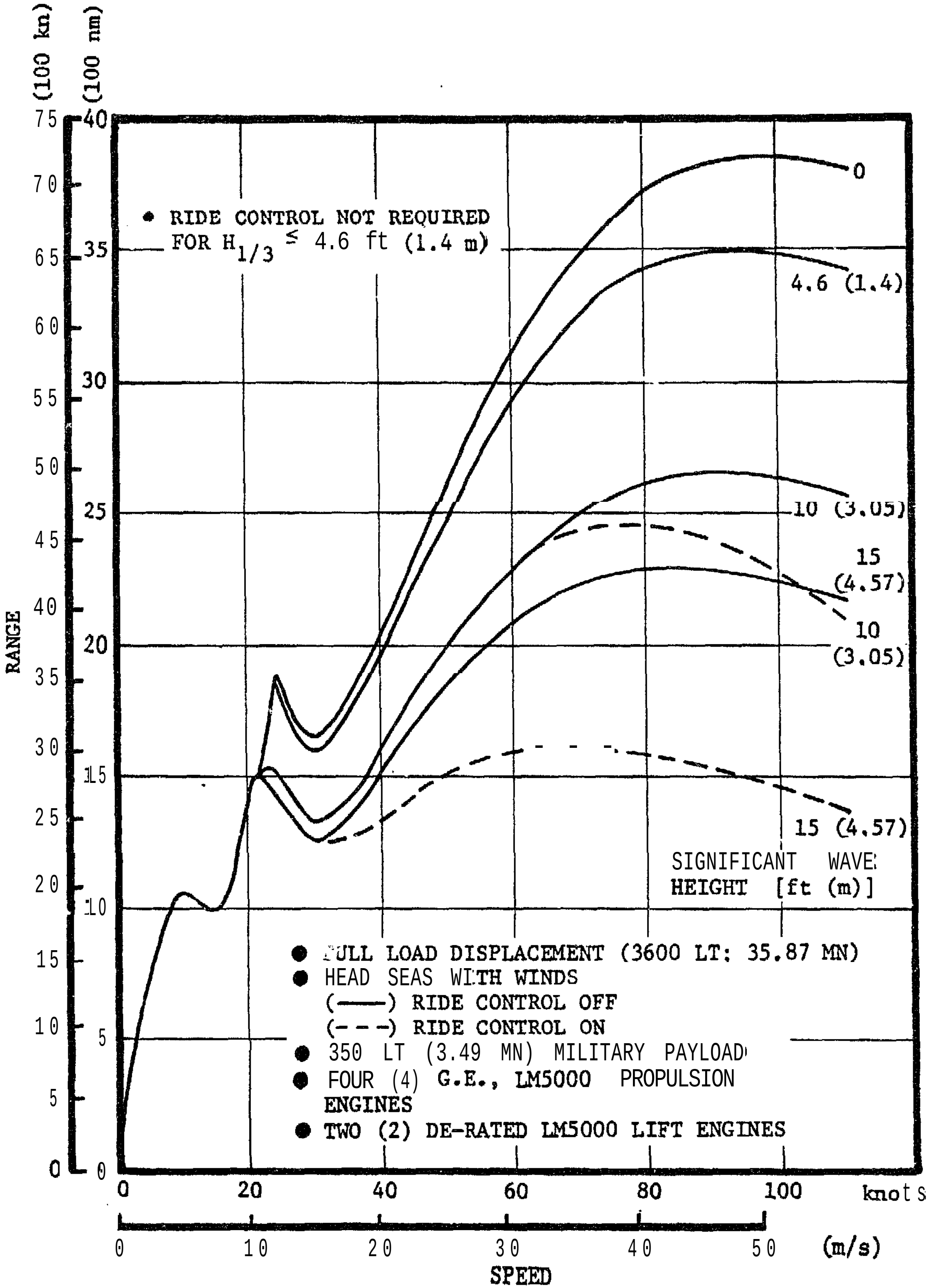


Figure 2.2.3-2 ~~(C)~~: Far Term SES Range Versus Speed (U)

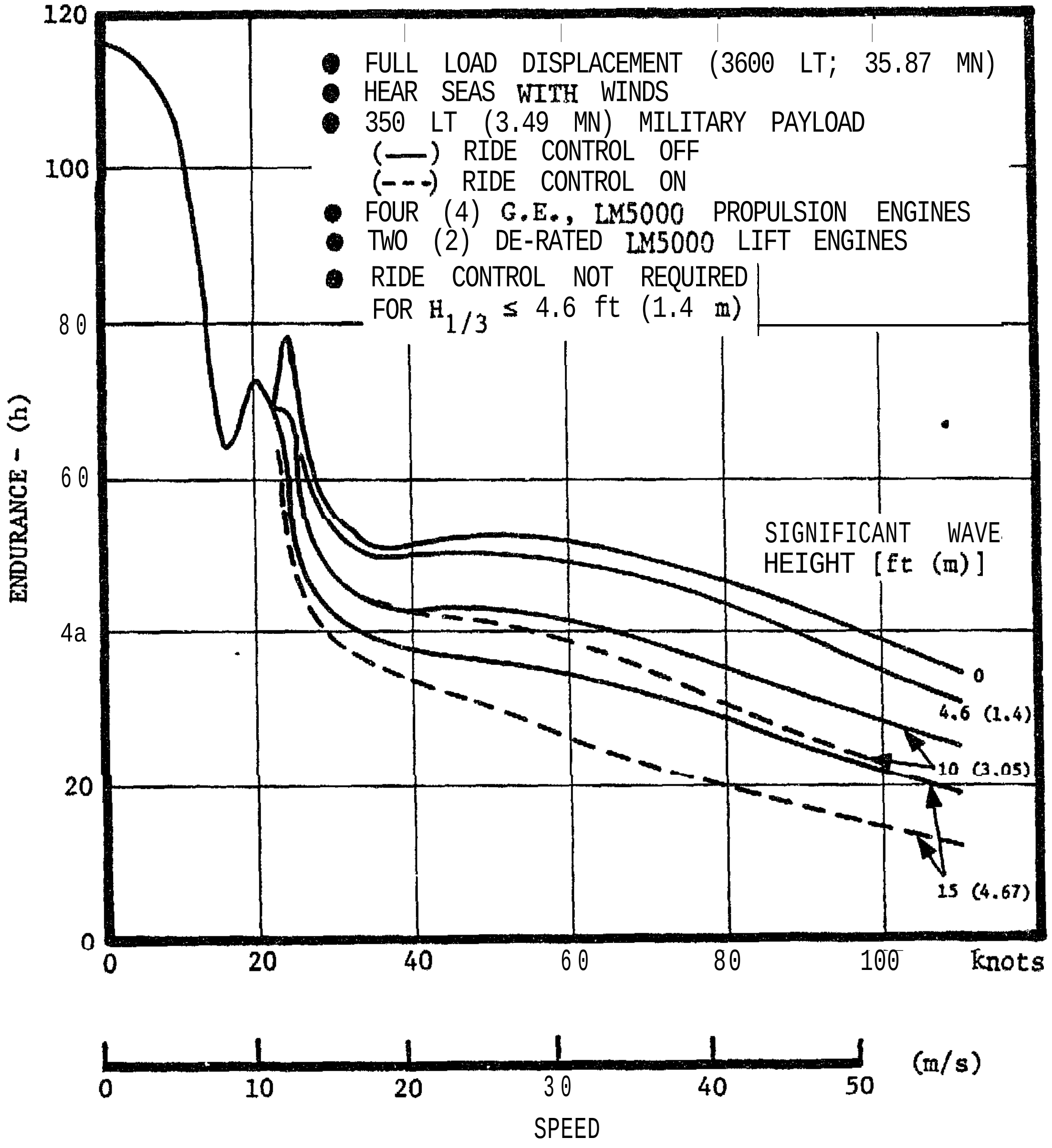


Figure 2.2.3-3 ~~(C)~~: Far Term SES Endurance at Various Speeds and Significant Wave Heights (U)

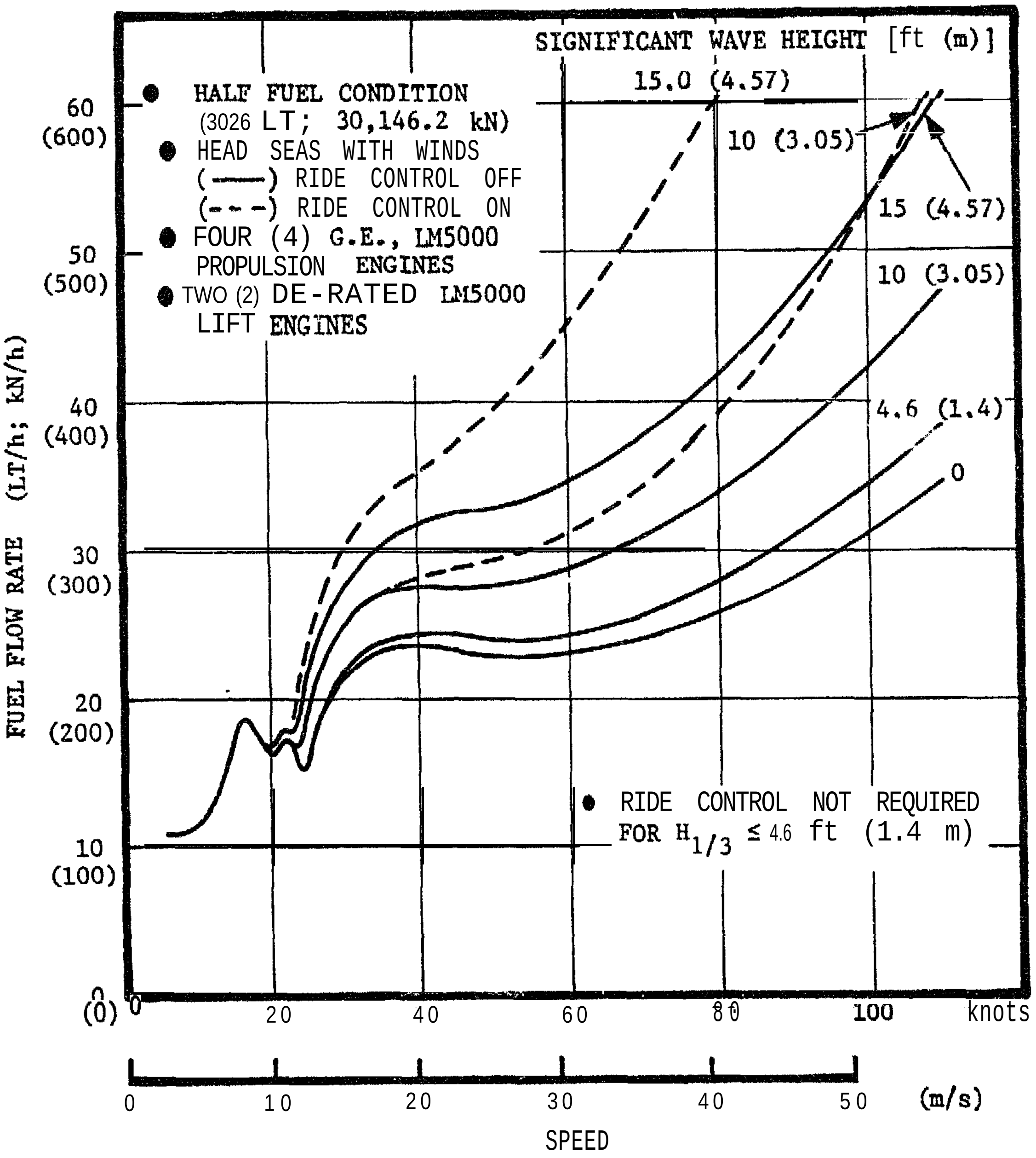


Figure 2.2.3-4 ([redacted]): Far Term SES Fuel Consumption Versus Speed (U)

(U) 2.2.4 WEIGHT AND VOLUME SUMMARY -- A summery of the light ship weight, variable load, contract margins and full load weight of the ANVCE far term SES is presented in Table 2.2.4-1. The summary represents the results of parametric studies, design iterations, and trade-off investigations performed during the ANVCE far term SES design effort.

(U) The ship volume summary is presented in Table 2.2.4-2. The internal volume is occupied by the principal categories of machinery, equipment and personnel.

(U) The design light ship, the total of SWBS groups 100 through 700, i's the displacement of the ship ready for sea in every respect, but excluding all variable load items such as crew, stores, ordnance, and fuel. Operating fluids such as lube oil, hydraulic fluid, and entrained water in the inlet and propulsor are included in the design light ship. The variable load items include the 141 man crew; provisions and effects, stores and spares for a 15-day mission; ordnance; both ship and aircraft fuel; and fresh water for the ship when operating at FLD.

Table 2.2.4-1 **(U):** Weight Summary with LM5000 Engines (U)

SWBS GROUP	WEIGHT			
	LONG TONS*	SHORT TONS*	METRIC TONS*	KILONEWTONS
100: HULL STRUCTURE	948	1062	963	9446
zoo: PROPULSION PLANT	213	239	216	2122
300: ELECTRICAL PLANT	66	74	67	658
400: COMMAND AND SURVEILLANCE	74	83	75	737
500: AUXILIARY SYSTEMS	3.16	130	118	1156
567: -Lift System	122	137	124	1216
600: OUTFIT AND FURNISHINGS	193	216	196	1923
700: ARMAMENT	63	71	64	628
PRELIMINARY, CONTRACT DESIGN AND BUILDERS MARGIN	269	301	273	2680
EMPTY WEIGHT (LIGHT SHIP)	2064	2312	2097	20 566
FOO: LOADS:				
Crews	16	18	16	159
Provisions	10	11	10	100
Stores		5	4	40
Fresh Water	2:	24	21	209
Ordnance -- Main Vehicle	164	184	167	1634
-- Sub-Vehicle	15	17	15	149
Sub-Vehicle	24	27	24	239
Fuel	1282	1434	1304	12 774
FULL LOAD WRIGHT	3600	4032	3658	35 870

*Non-SI

TABLE 2.2.4-2 (U): VOLUME SUMMARY (U)

FUNCTION	INTERNAL VOLUME[(1)]	
	CUBIC FEET	CUBIC METERS
Main Propulsion (including main machinery box, uptakes, shafting)	119,034	3,371
Lift System	109,881	3,112
Personnel (including living, messing and all personnel support and storage)	108,454	3,071
Auxiliary and Electrical (machinery spaces other than main propulsion and lift outside main machinery box)	100,962	2,859
Payload (internal volume only)	165,841	4,697
Other (including passageways, maintenance spaces and all other spaces not included in above).	128,777	3,647
TOTAL ENCLOSED VOLUME	732,949	20,758

(1) Total enclosed volume does not include tanks and other innerbottom spaces below third deck, or helo landing and any weather decks.

(U) 2.2.5 STABILITY -- The hullborne and cushionborne stability of the far term SES was addressed for both zero speed and underway conditions. The results show that the SES has adequate stability to meet the required operating ranges of speed, sea state and displacement.

(U) 2.2.5.1 Stability at Zero Speed, Hullborne -- The hullborne stability at zero speed has been evaluated in accordance with the Navy criteria of acceptability cited in Section A.2.11.2 in relation to intact and damaged stability characteristics.

(U) 2.2.5.1.1 Hullborne Intact Stability -- The far term ANVCE SES has the identical hull form and principal dimensions as those for the near term design. The far term SES, however, operates at a higher FLD (3600 LT or 3568.32 cu.m.). The static stability at zero speed was addressed for the near term SES by development of cross-curves of stability for a suitable range of ship displacement and for a range of heel angles from 0 through 90 degrees. The SES has a positive range of stability from 0 to 80 degrees as shown in Figure 2.2.5-3 and in Tables 2.2.5-1 and 2.2.5-2. Based on these near term SET results, it is concluded that the far term SES meets the intact stability criteria.

(U) 2.2.5.1.2 Stability in Damaged Condition -- The fundamental adequacy of the SES with respect to reserve buoyancy and stability under conditions of hull damage in an open ocean environment has been addressed for the Navy criteria. The analysis for limiting displacements of the far term SES with respect to shell-to-shell flooding shows that the FLD condition is acceptable within a range of logitudinal centers of gravity bounded by 117.5 ft. (35.81 m) to 123.5 ft. (37.64 m) aft of the forward perpendicular. Figure 2.2.5.1 depicts the range of operational displacements combined with acceptable boundaries of longitudinal centers of gravity.

(U) Based on the results derived from stability studies for the near term SES, it is concluded that the heel angle due to unsymmetrical flooding will not exceed 15 degrees (maximum allowable) and the criteria of adequate stability in damaged condition can be met with adequate margins.

(U) 2.2.5.2 Static Stability Underway

(U) 2.2.5.2.1 Off-Cushion Stability Underway -- Predicted off-cushion static pitch and roll stabflity characteristics for the ANVCE far term SES are presented in Figures 2.2.5-2 and 2.2.5-3, respectively. The ship has positive static stability with pitch and roll restoring gradients of approximately 99 x 10^6 ft-lb/degree (134.23 x 10^6 N·m degree) and 22 x 10^6 ft-lb/degree (29.83 x 10^6 N·m/degree), respectively. In the off-cushion mode, the SES is statically unstable in yaw but dynamically stable, thus providing satisfactory course keeping characteristics as influenced by the ship's ride control system in a seaway.

(U) 2.2.5.2.2 On-Cushion Static Stability Underway -- The predicted on-cushion static stability data presented next show that the ANVCE far term SES has positive stability in roll, pitch and yaw within the operational trim range. Pitch, yaw, and roll stability are respectively shown at 40, 60 and 80 knots (20.58, 30.87 and 41.16 m/s). The stability characteristics shown are for a nominal MOD-50 condition.

(U) The positive on-cushion pitch stability of the SES at 40, 60 and 80 knots (20.58, 30.87 and 31.16 m/s> is shown in Figure 2.2.5-4. Predictions are plotted with zero moment occurring at the nominal pitch trim attitude for each speed. Speed variation at a constant weight primarily alters the minimum-drag pitch attitude. These predictions were derived by Froude scaling hydrodynamic model test data without other correction. Positive static stability is indicated by the negative gradients of the moments with their corresponding attitudes.

(U) The average pitch restoring moment is approximately 18 x 10^6 ft-lb/degree (24.40 x 10^6 N·m/degree) for all speeds shown. The minimum gradient of about 8 x 10^6 ft-lb/degree (10.85 N·m/degree) occurs on the curve for 40 knots (20.58 m/s>.

(U) The yaw stability characteristics are shown in Figure 2.2.5-5 for three (3) pitch attitudes. Positive static yaw stability is shown for all conditions except the high speed, negative pitch case (80 knots (41.14 m/s) and -1 degree trim). However, extrapolation of the dynamic stability indicates that the SES will be dynamically stable, in the directional sense, to greater bow down pitch angles. In actual operation, such extreme bow down trim attitudes are beyond the currently predicted failure mode value of minus 0.5 degree. Strong pitch restoring moments ensure such a rapid return to nominal attitudes that little yaw divergence is possible, even under failure mode conditions.

(U) The positive on-cushion roll stability of the far term SES at 40, 60 and 80 knots (20.58, 30.87 and 41.16 m/s) is shown in Figure 2.2.5-6. Predictions are plotted for nominal pitch attitudes at each speed. The roll restoring moment gradients vary slightly with speed and ship attitude. The principal roll restoring moments are due to the sidehull design.

(U) Two of the more significant features which contribute to the excellent stability characteristics of the ANVCE far term SES are the seal and sidehull designs. The Rohr advanced planing seals maintain their geometric integrity at all times, even in high sea states. The advanced planing seal design increases the effective cushion length as a direct function of bow immersion; as the bow goes down, the effective cushion length boundary moves forward, providing additional pitch and roll restoring moments. The design therefore precludes slope reversal in the pitch stability curve ("pitch clicks"), or catastrophic plow-in characteristics exhibited by other type seal designs at bow down attitudes.

(U) The design stiffness of the seals is a careful balance between stability requirements and ride quality. The Rohr design provides a degree of stiffness which maintains adequate roll and pitch stability while providing good ride qualities.

(U) The sidehull forward sections contribute additional pitch and roll restoring moments at bow down attitudes. This effect is obtained by designing the bow stem to match the bow seal contour. In addition, the stem angle minimizes destablizing moments at bow down attitudes. The low (45 degree) deadrise angle of the sidehull design provides better pitch and roll stability than higher deadrise sidehull configurations.

(U) 2.2.5.3 Dynamic Stability Underway

(U) 2.2.5.3.1 Heading Stability -- With normal operational trim, and somewhat beyond it, the ship will be dynamically stable as shown by Figures 2.2.5-7 and 2.2.5-8 for the MOD 50 condition at 60 and 80 knots, respectively. Even at a representative failure-mode trim of -0.5 degrees, the ship has an excellent margin of dynamic stability.

(U) 2.2.5.3.2 Pitch Attitude Excursions -- Figure 2.2.5-9 presents the significant pitch excursions with speed for two weights, each in two sea conditions. These characteristics are based upon analytic modeling of the veritical plane dynamics of the ship in a random sea.

(U) 2.2.5.3.3 Roll Attitude Excursions -- The roll excursions are based upon hydrodynamic model testing in the DTNSRDC maneuvering basin. The RMS roll excursions are given with speed at several sea states, for five relative headings to the seas (Figures 2.2.5-10 through 2.2.5-12).

(U) 2.2.5.3.4 Damping Characteristics in Calm Water -- The times to half amplitude for pitch, heave, yaw-sway, and roll motions are given as functions of speed in Figure 2.2.5-13.

(U) 2.2.5.3.5 Drift Angle Limits -- The drift angle boundaries are shown in Figure 2.2.5-14. Below hump speed, the maximum drift angles are proscribed by steering control power. At and above hump speed, drift angles are limited by stability considerations. The curve includes a 20 percent safety margin. The limiting values are based on data obtained from scale model tests in the DTNSRDC towing tank. The desired amount of roll into turns was determined on the basis of inlet broaching studies and the drift angle limit line was determined from this relationship and the roll-drift boundaries at various speeds.

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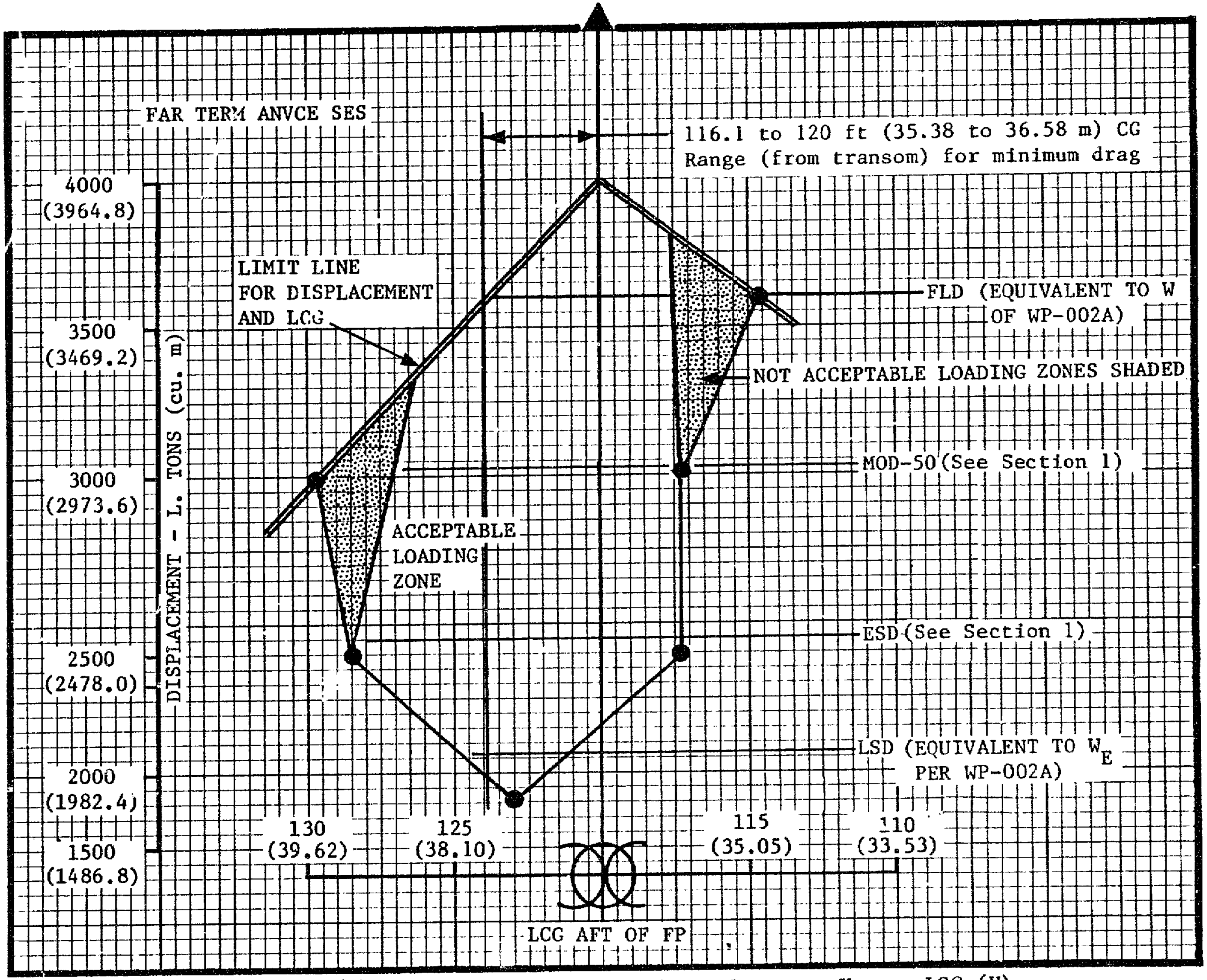


Figure 2.2.5-1(C). Operational Range and Displacement Versus LCG (U)

[redacted]

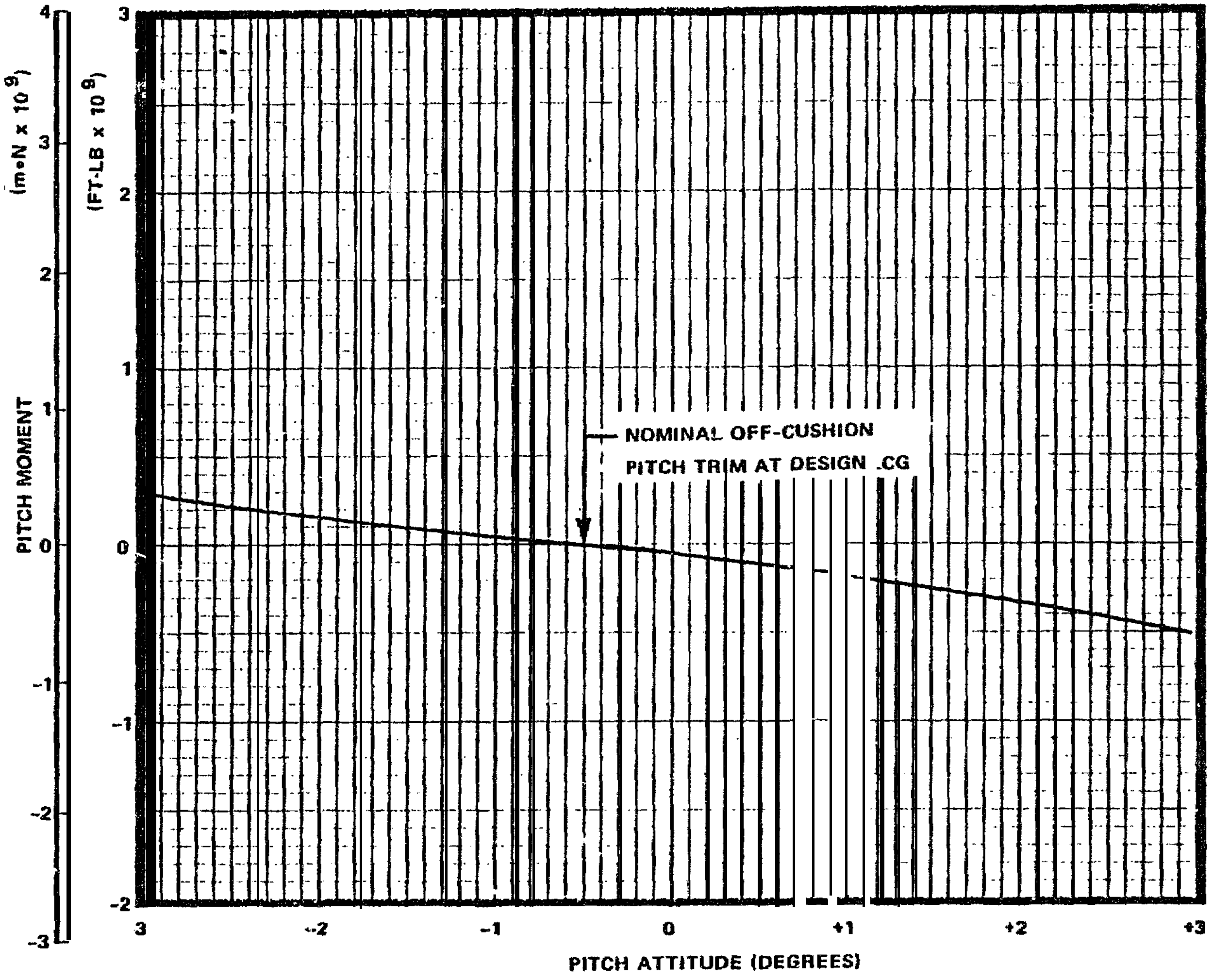


Figure 2.2.5-2 (U): Off-Cushion Static Pitch Stability, 30 Percent Fuel Condition (U)

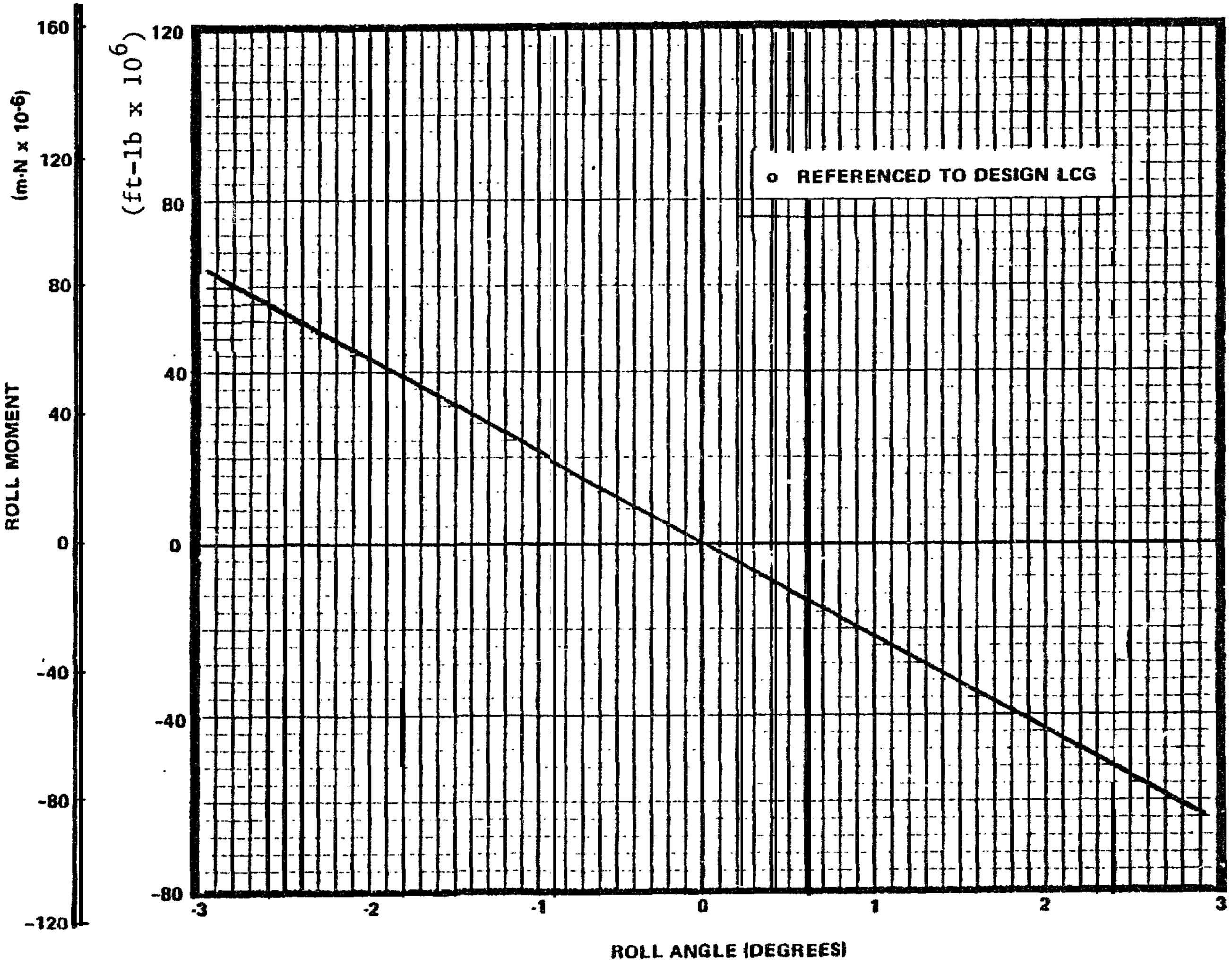


Figure 2.2.5-3 (U)= Off-Cushion Static Roll Stability, 30 Percent Fuel Condition (U)

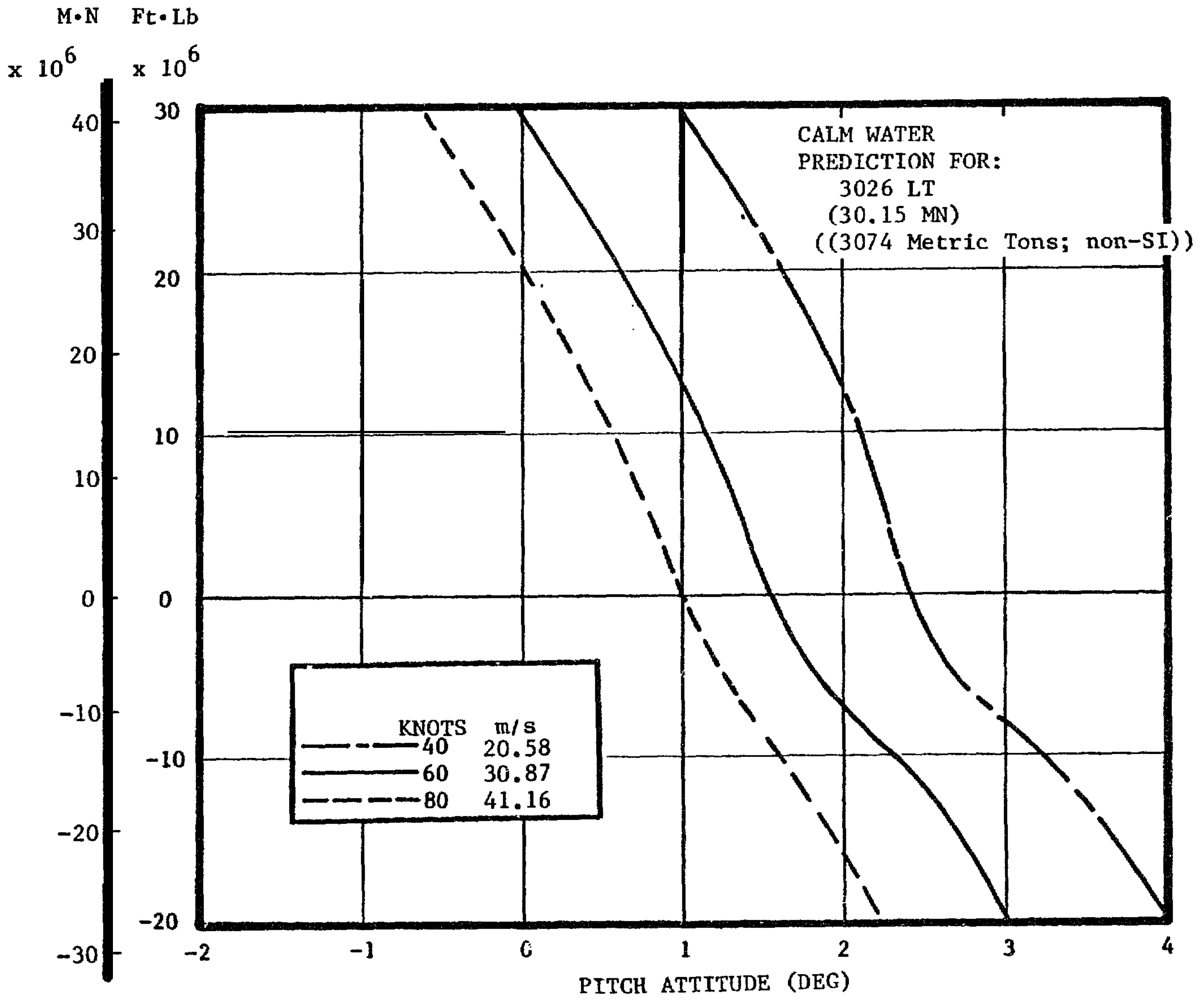


Figure 2.2.5-4 (U): Static Pitch Stability at MOD 50 (3026 LT; 30.15 MN)

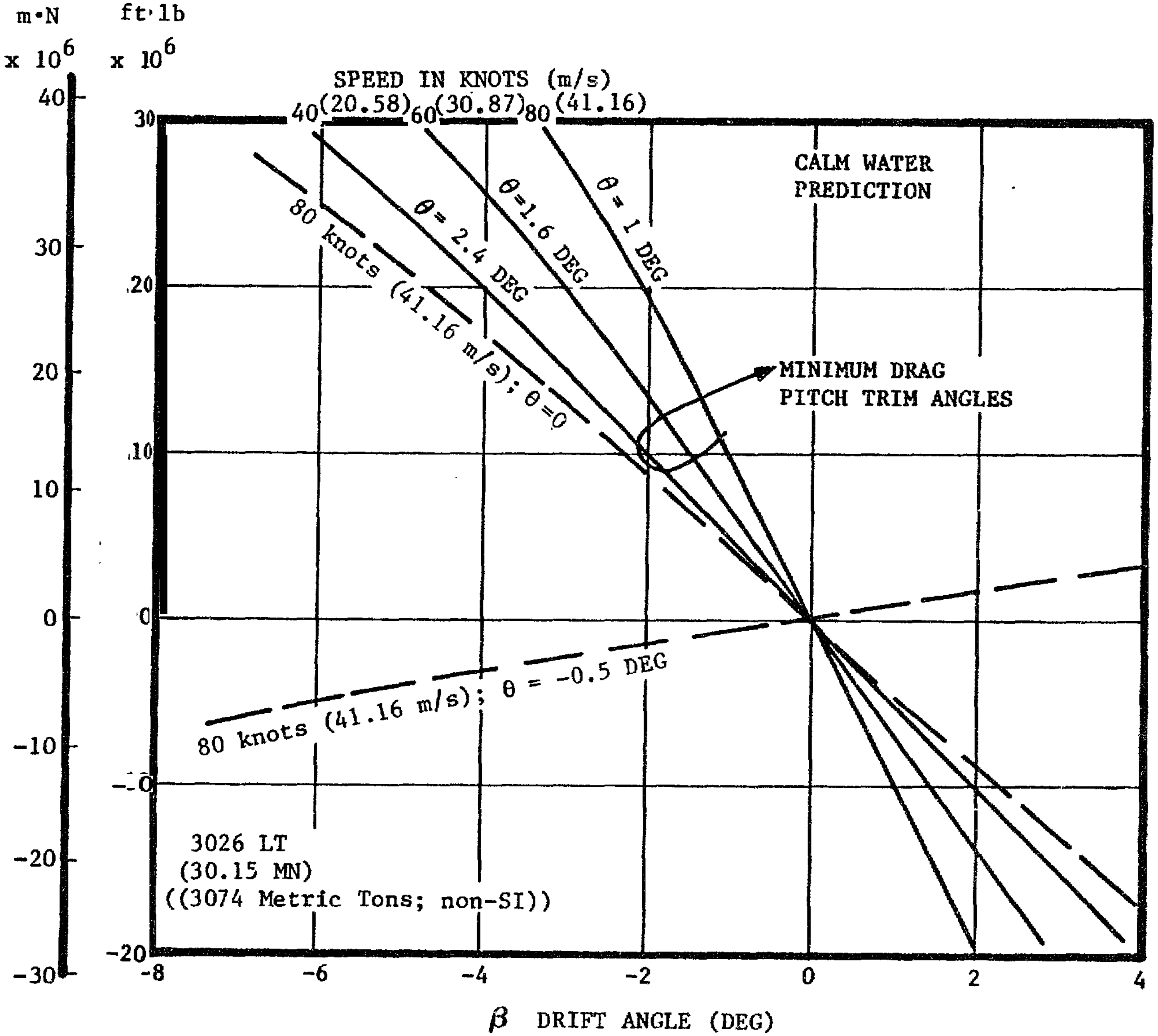


Figure 2.2.5-5 (U): Static Yaw Stability at MOD 50 (U)

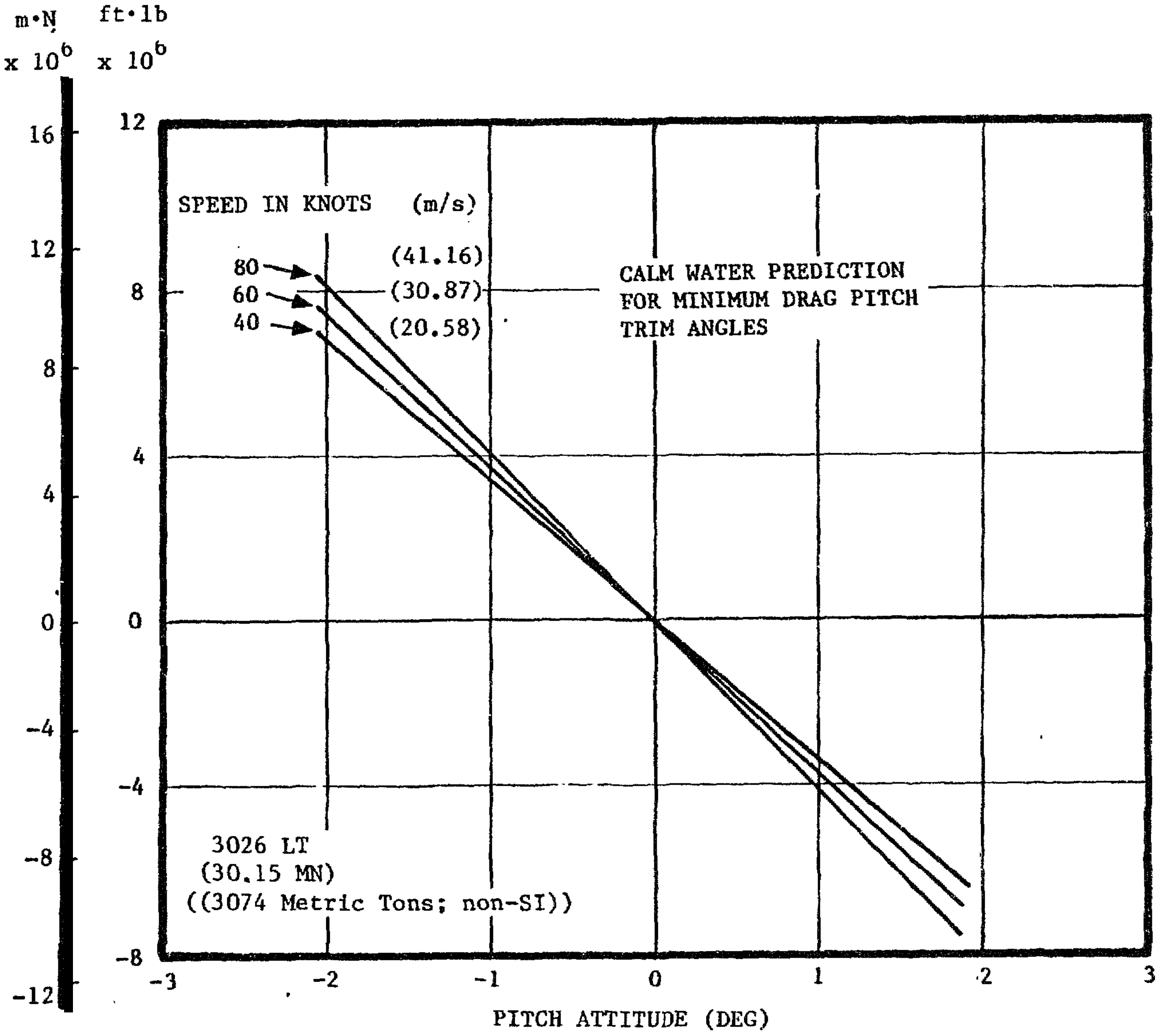


Figure 2.2.5-6 (U): Static Roll Stability Prediction at MOD 50 (U)

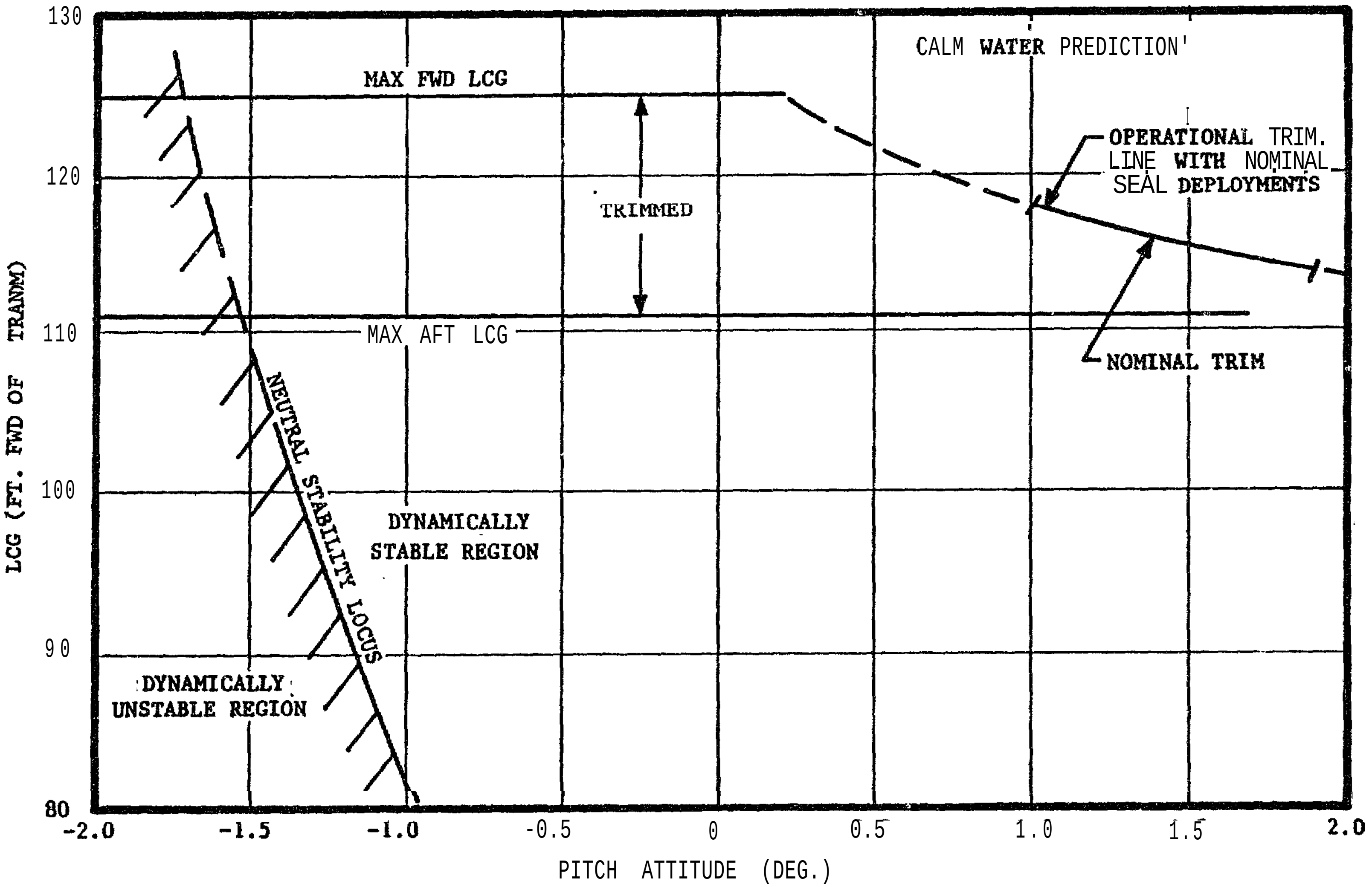


Figure 2.2.5-7 (U): Dynamic Heading Stability at a MOD-50 Condition and a Speed of 60 Knots (30.87 m/s) (U)

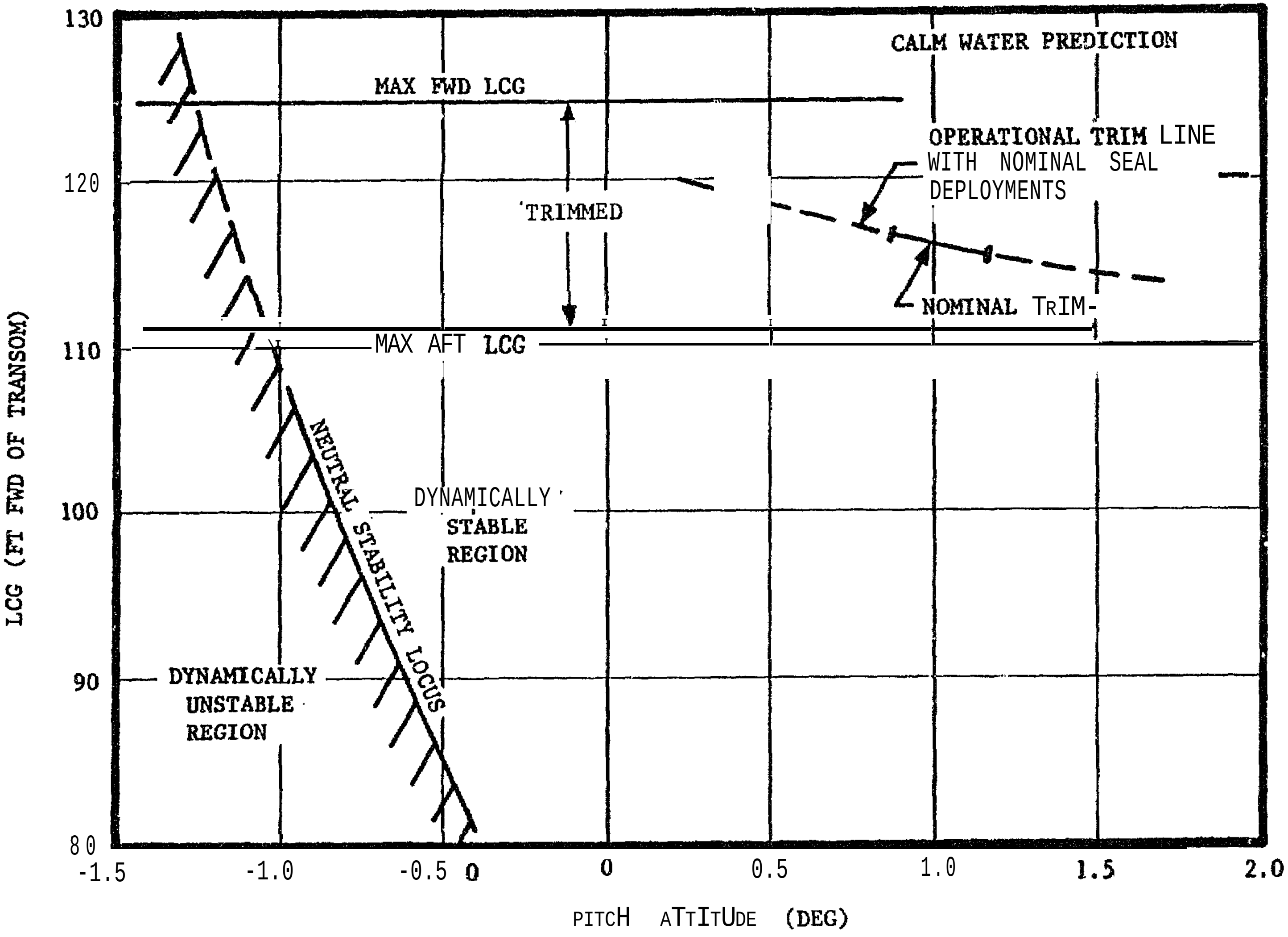


Figure 2.2.5-8 (U): Dynamic Heading Stability at a MOD-50 Condition and a Speed of 80 Knots (41.16 m/s> (U)

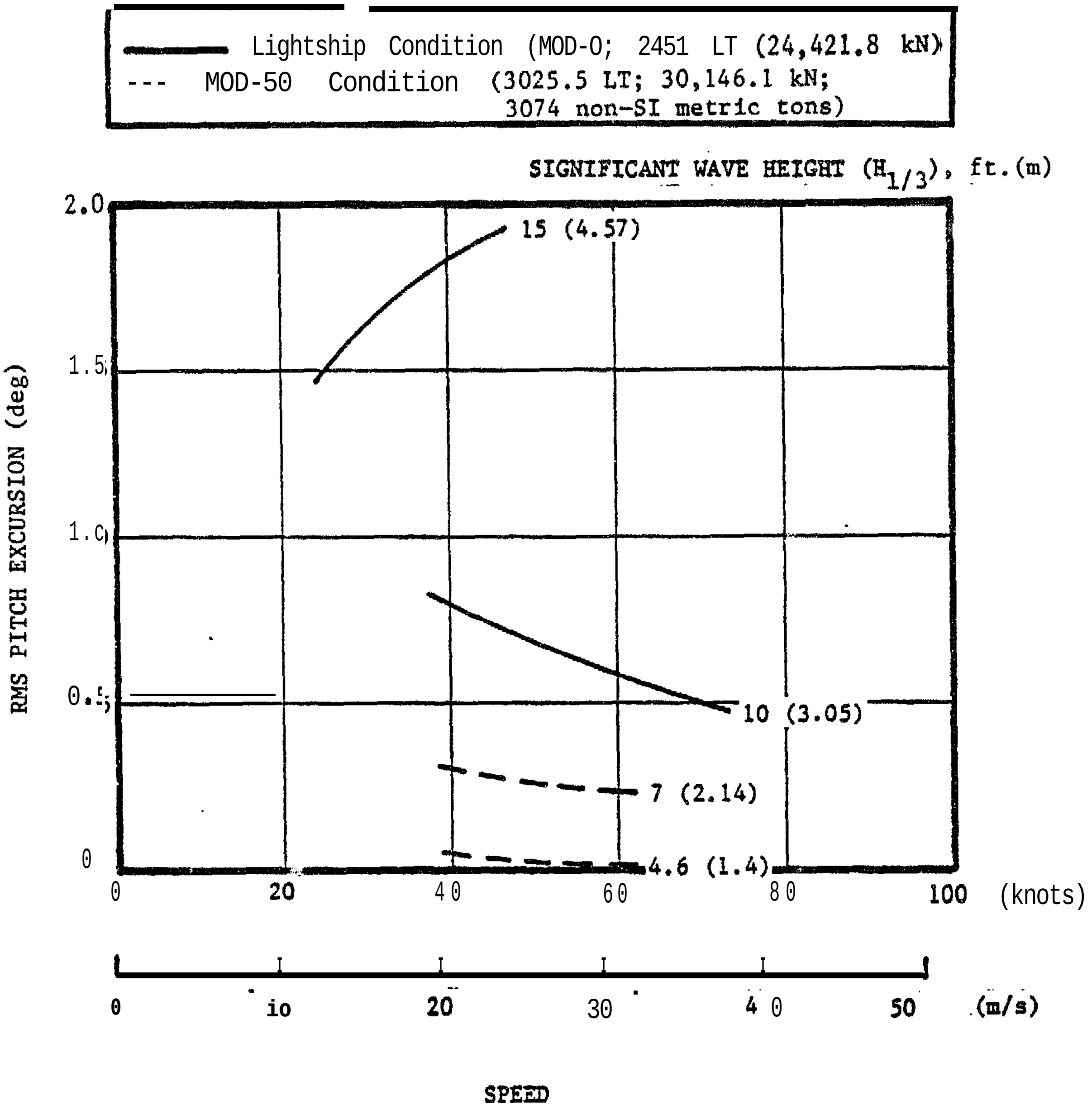


Figure 2.2.5-9 (U): Pitch Deviation Versus Speed in Head Seas (U)

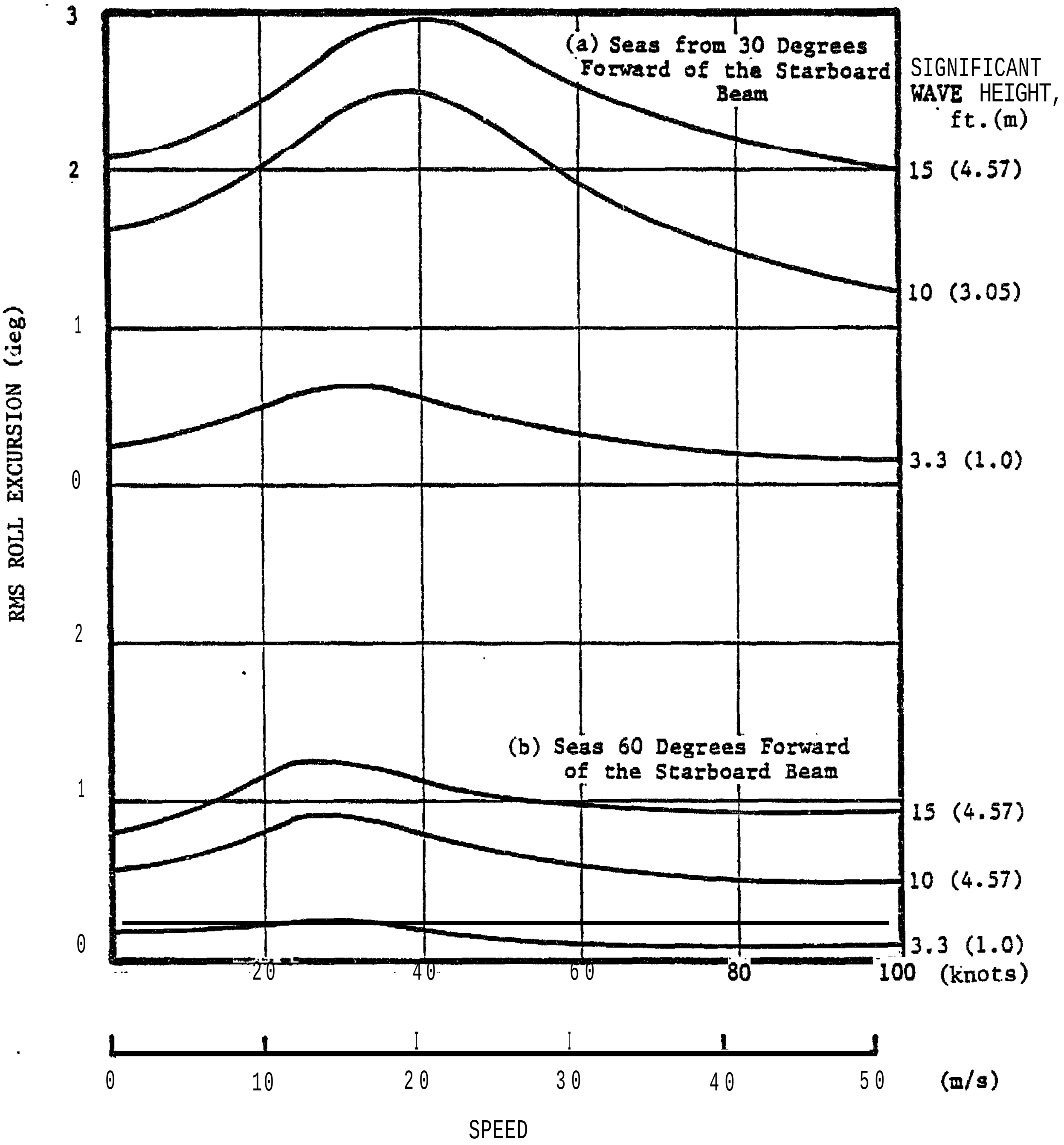


Figure 2.2.5-10 (U): Roll Deviation Versus Speed - Seas From 30 and 60 Degrees Forward of Starboard Beam (U)

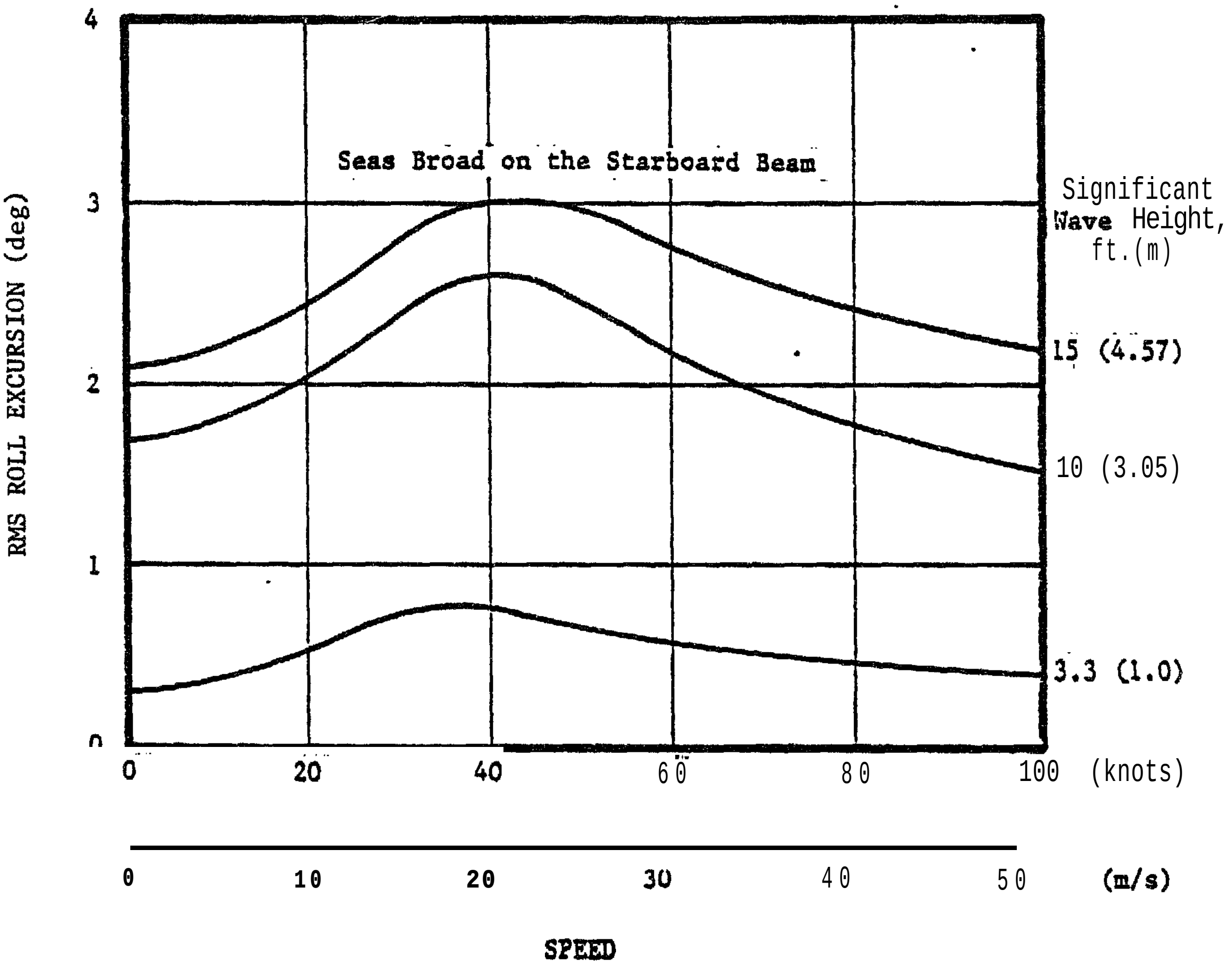


Figure 2.2.5-11 (U): Roll Deviation Versus Speed - Seas Broad on the Starboard Beam (U)

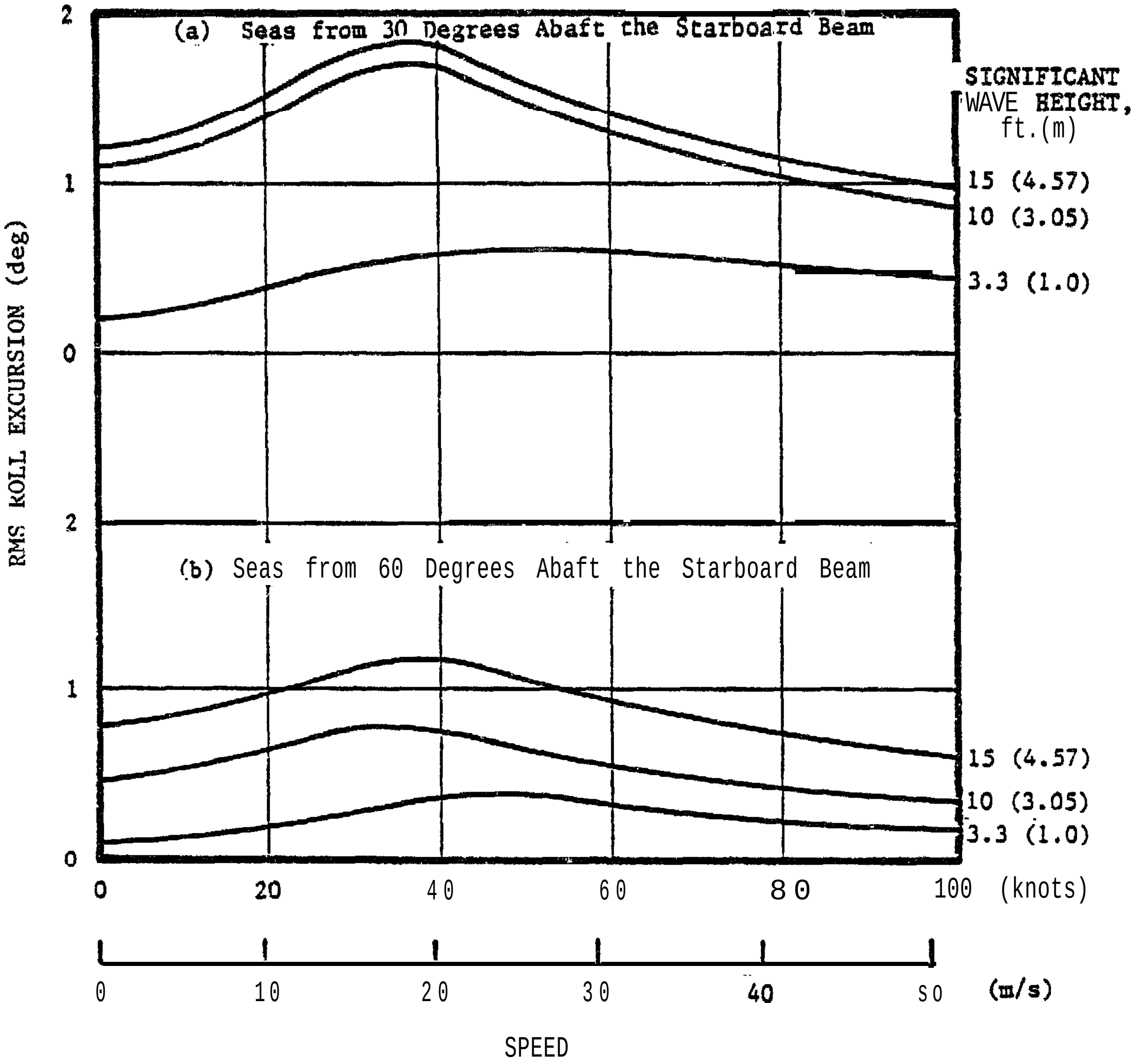


Figure 2.2.5-12 (U): Roll Deviation Versus Speed - Seas From 30 and 60 Degrees Abaft The Starboard Beam (U)

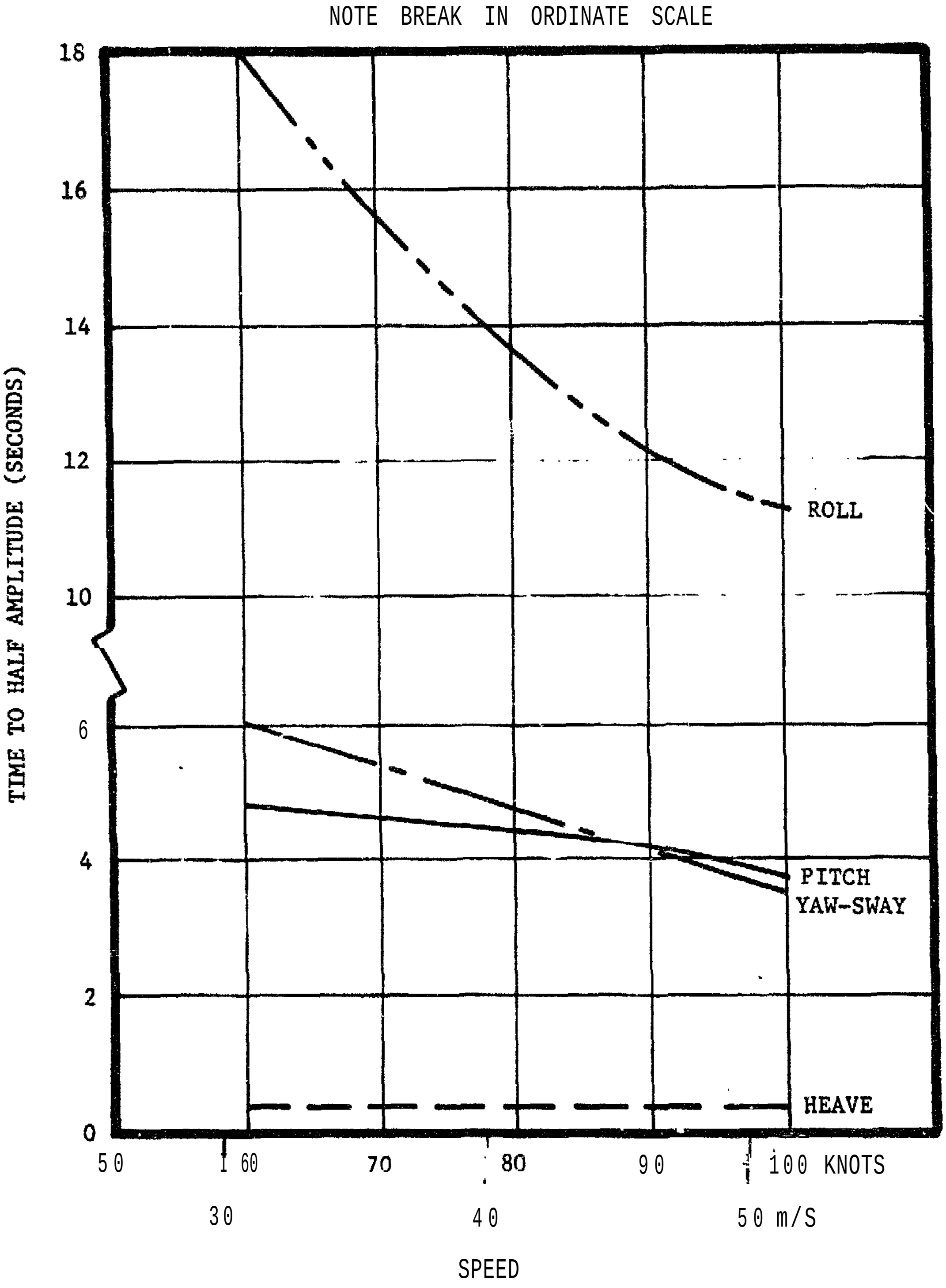


Figure 2.2.5-13 (U): Time to Half Amplitude in Calm Water **(U)**

MOD-50 (Half Fuel) Condition
calm Water, On-Cushion

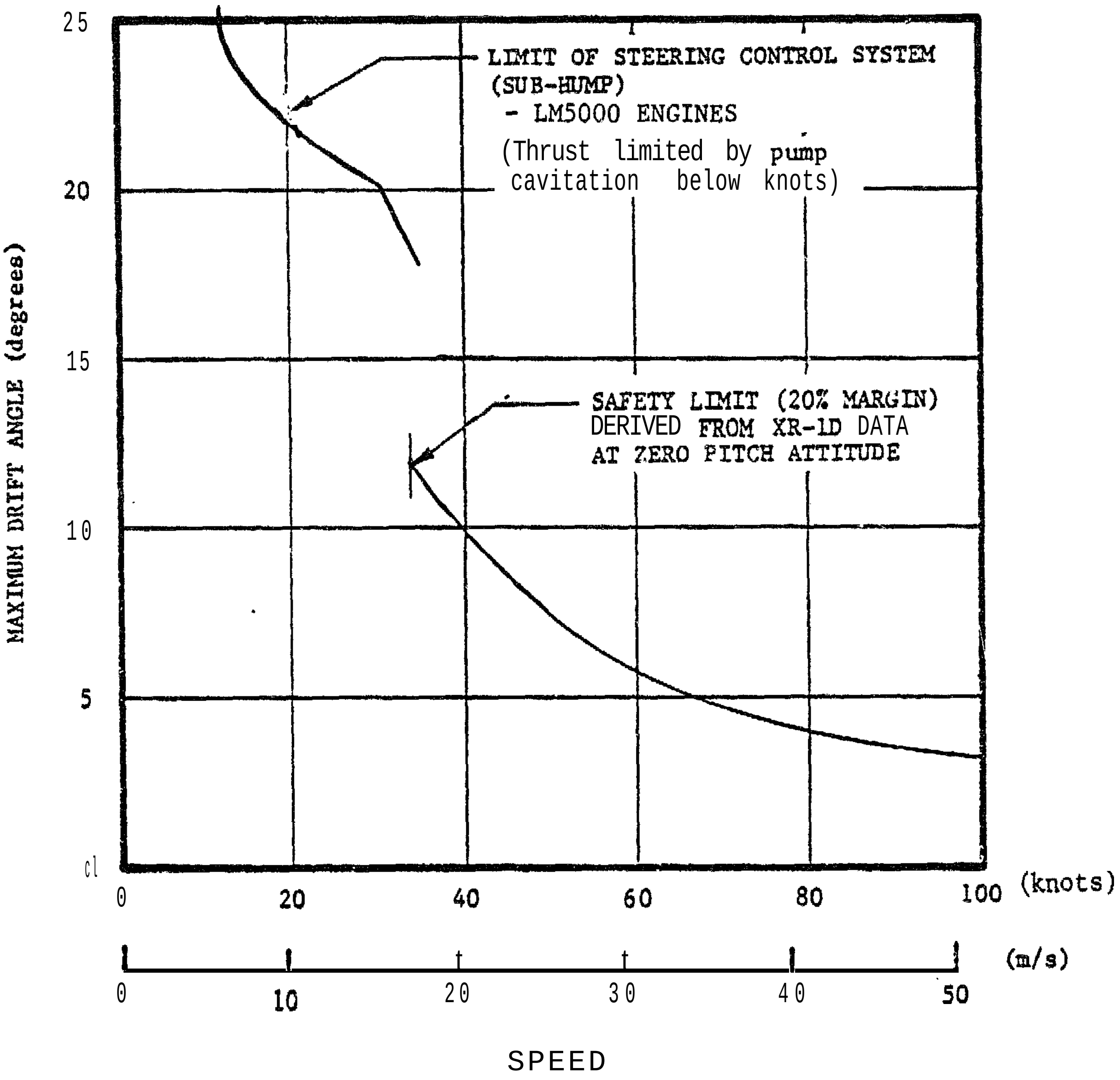


Figure 2.2.5-14 (U): Drift Angle Limit Versus Speed (U)

(U) 2.2.6 GEOMETRIC FORM -- The geometric form of the far term SES is described by the hull lines and the control surface drawings of this section.

(U) 2.2.6.1 Hull Geometry -- The selection of the hull form is based on judicious compromises between overall hullborne and cushionbarne performance; structural strength; manufacturing economy; volumetric. requirements; combat suite; safety, survivability and efficiency of ship operations. The net result is shown in the lines drawing presented in Appendix B and shown in this section at reduced size as Figure 2.2.6-l. The principal hydrostatic and hydrodynamic parameter values are shown in Table 2.2.6-1.

(U) The sidehull geometry is based on the effects of deadrise and ventilation cutouts on the overall hydrostatic and hydrodynamic performance parameters, bow seal interface, waterjet inlet configuration and structural strength requirements. Hydrodynamic drag considerations have influenced the choise of a slender body sidehull concept.

(U) The full-length sidehulls enclose the sides of the bow seal, decreasing seal vulnerability to damage as compared with exposed bag and finger seal systems on partial-length sidehulls. The full length sidehulls, in combination with planing type bow and stern seals, provide significantly lower drag forces, superior pitch stability characteristics and greater ship safety in all sea states as compared to partial length sidehulls with wrap-around seals. The full length sidehull vertical inner face also permits a simple bow seal/sidehull interface and allows the use of a two dimensional, modularized bow seal system.

(U) 2.2.6.2 Principal Dimensions -- The principal dimensions, as related to the proportions and form characteristics of the sidehulls and the centerbody, are based on the following considerations:

- Provision for the required cushion area in conjunction with space requirements for main propulsion machineries and waterjet inlets..' The Panama Canal transit requirement established the maximum beam of 108 ft. (32.918 m). The trace of the maximum beam follows 4 ft. (1.219 m) above the upper chine and is canted inboard to the main deck and 01 level. The nominal tumblehome at Station 10 is 3 ft. 7 in. (1.092 m).

- The overall length of 266 ft. 3 in, (81.153 m) was established from rhe maximization of performance parameters as related to cushion length to beam ratio, bow and stern seal geometry design, overall utility, and volumetric requirements.
- The wet deck height was selected at 18 ft. (5.486 m) above baseline to minimize wetdeck slamming and cushion induced dynamic response. This distance is increased to about 21 ft (6.4 m) by the keel-length fences rhroughout most of the ship's length. The wet deck is horizontal except forward of Station 4 where it ramps upward to minimize pitch induced slam loads and to provide a flat interface with the forward seal in its retracted position.
- The selection of main deck height at 40 ft. 0 in. (12.192 m) above baseline was based on requirements of hull girder strength, reserve buoyancy in damage situations, and overall volumetric and apace demands. This permits a three deck arrangement that allows ample interior space for machinery systems, habitability, and a full length inner bottom. The high main deck also provides a drier environment for engine air intakes and for helicopter operation, relative to lower main deck configurations that were evaluated.

(U) 2.2.6.3 Control Surfaces -- The baseline design of the far term ANVCE SES incorporates two stern-mounted stabilizing fins, port and starboard, canted 28 deg. 'inboard from the bottom of the fence, as shown in the Lines Drawing of Appendix B and Figure 2.2.6-1. Fin section geometry is shown in Figure 2.2.6-2.

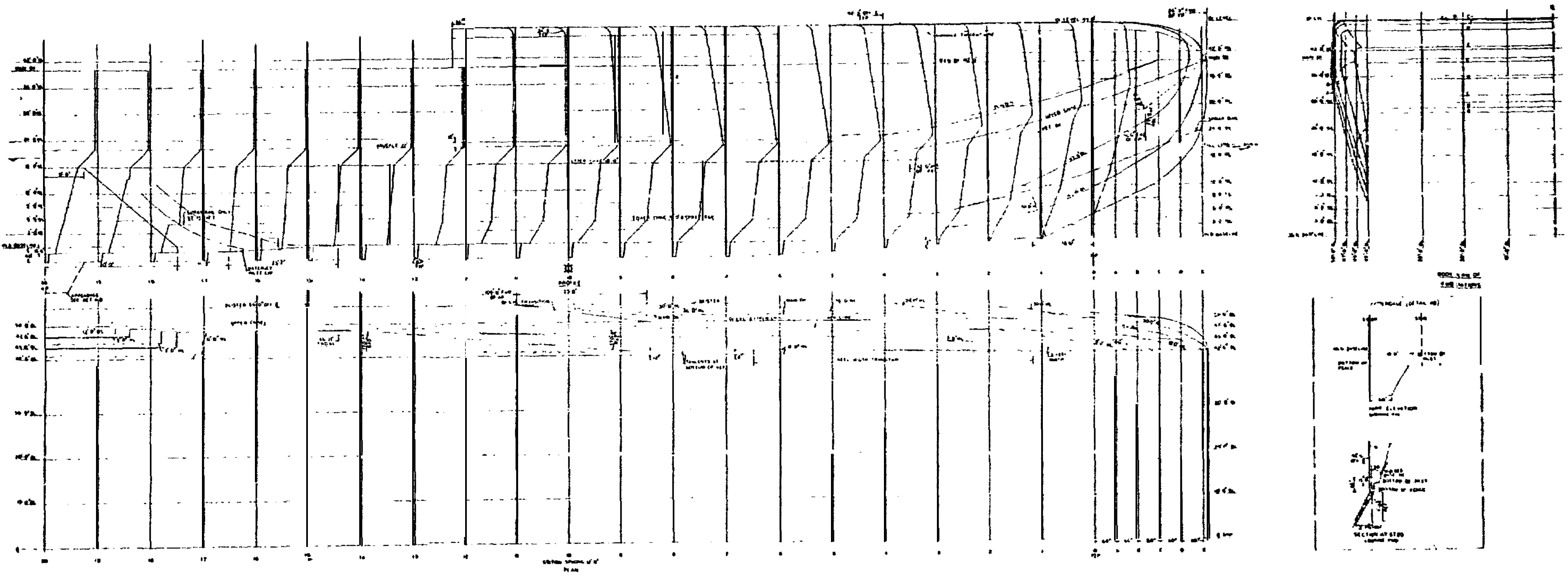


Figure 2.2.6-1 (U). Far Term SES Hull Lines (U).

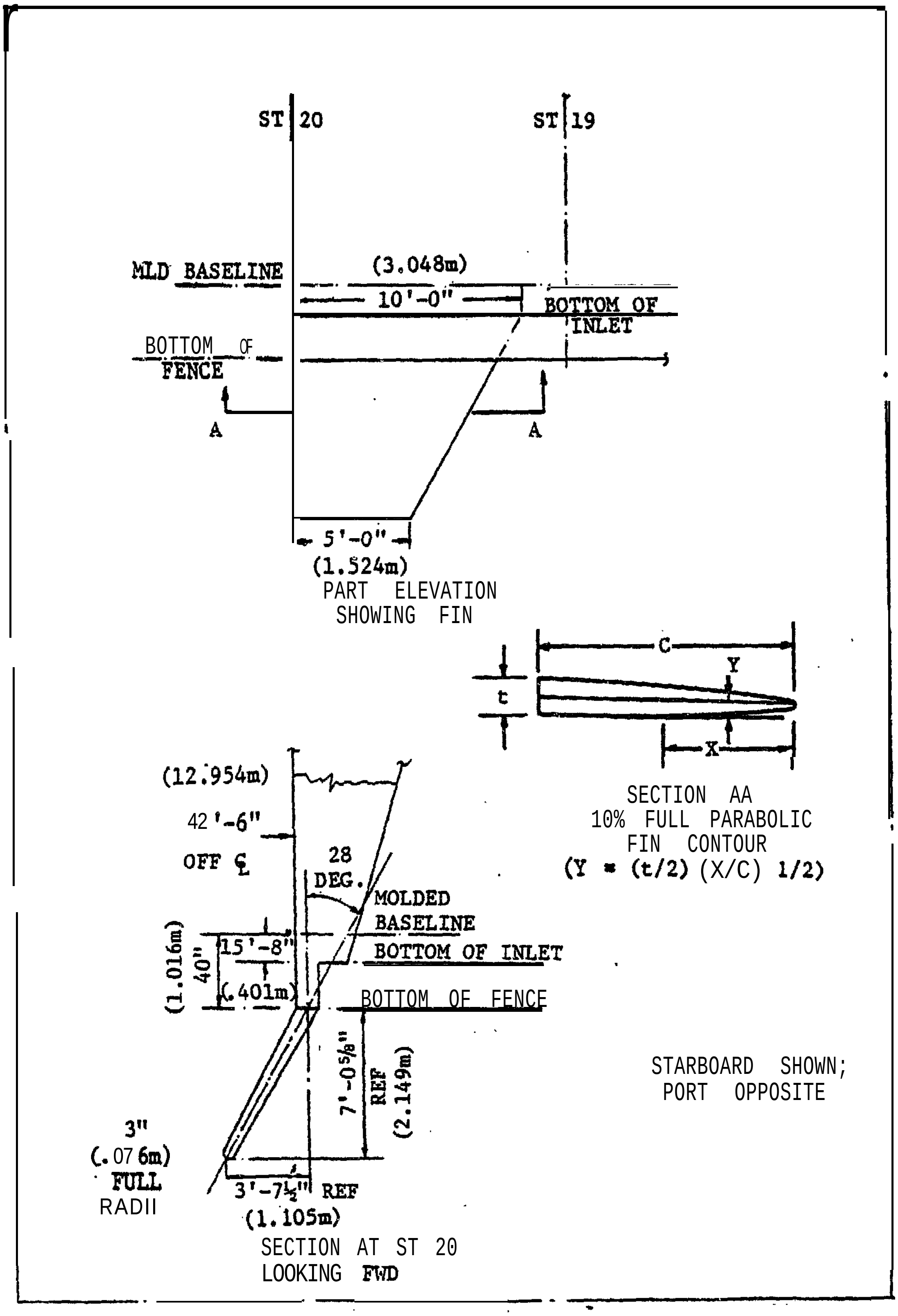


Figure 2.2.6-2 (U): Baseline Stabilizer Fin Geometry (U).

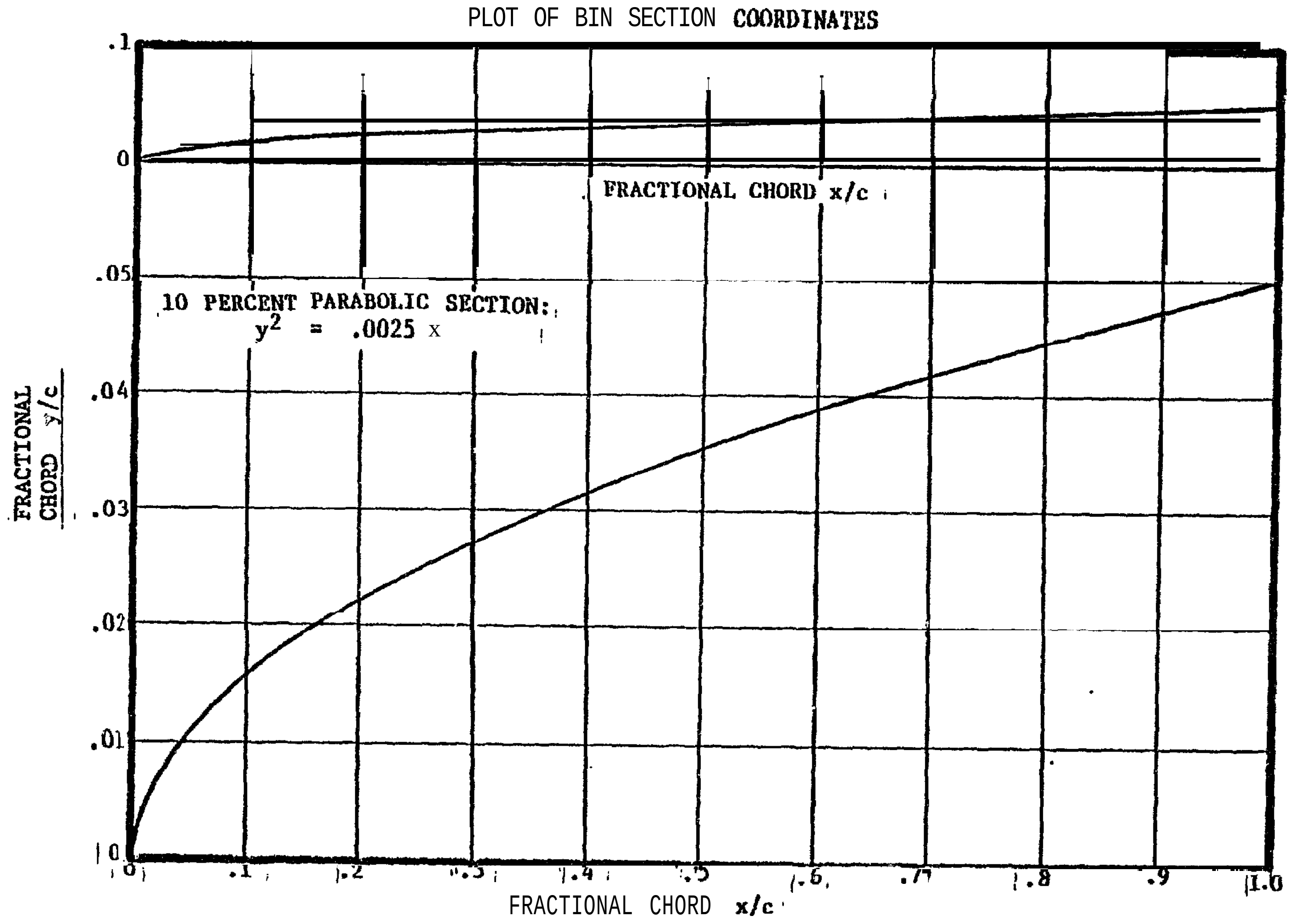


Figure 2.2.6-3 *(U)*: Fin Section Geometry (U).

Table 2.2.6-1(U); Principal Hydrostatic and Hydrodynamic Parameter Values (U)

PRINCIPAL HYDROSTATIC PARAMETERS (OFF CUSHION)	Near Term	Far Term
Mean Draft	= -- (--)	22.1 (6.74)
Block Coefficient (C_b), Full Load	= 0.1662	0.2176
Prismatic Coefficient (Pc), Full Load	= 0.8341	0.8051
Wetted Surface, Full Load, ft^2 (m^2)	= 49,931 (4,546)	52,981 (4,922)
Transverse KM, Full Load, ft (m)	= 175.68 (53.55)	151.75 (46.25)
Vertical Center of Buoyancy (KB), ft (m)	= 14.80 (4.51)	15.98 (4.86)
Tons per Inch Immersion, TPI (RN/m)	= 41.04 (16.01)	38.18 (14.89)
Longitudinal Center of Flotation (LCF), From FP, ft (m)	= 137.11 (41.79)	136.56 (41.62)
PRINCIPAL HYDRODYNAMIC PARAMETERS (ON CUSHION)		
Cushion Length, ft (m)	= 221 (67.36)	
Cushion Beam, ft (m)	= 85 (25.91)	
Cushion Height, ft (m)	= 18 (5.48)	
Longitudinal Center of Gravity Fwd of Transom, ft (m)	= 118 (35.89)	
Cushion Length/Beam	= 2.60	
Cushion Beam/Height	= 4.72	

ρ_{SW} = 1.025 Metric Ton/m^3

(U) 2.2.7 RIDE QUALITY

(U) 2.2.7.1 Far Term SES Ride Criteria -- Far term SES high speed operation in high sea states can result in vertical motion modes not previously experienced by man over long periods of time. While considerable data exist on vibratory effects upon man, the heave acceleration environment of the SES centers in the 0.1 to 0.5 Hz portion of the frequency regime for which characterizing data are sparse and where sea sickness may be increased. In addition, certain higher resonances are predicted between 1 Hz and 5 Hz in the range where human physical performance capability is better documented.

(U) The primary purpose of developing a ride criteria is to establish the motion limits that can be tolerated by operations, maintenance and off-duty crew for specific mission durations. The importance of these criteria is to ensure a reasonable level of operating efficiency if craft motions are maintained at or below the limits.

(U) The curves illustrated in Figure 2.2.7-l were established from a comprehensive literature search by overlaying graphical data representing human performance decrement studies. The search encompassed hundreds of previous motion studies, experiments and simulations related to the adverse effects of vibratory environments on human performance, These data form the data base for the ride criteria, categorized by specific task type and correlated by rms g's versus the center frequencies of the one-third octave band. Although considerable vibration data and criteria exist above 1 Hz, very little is available to describe the effects on humans between 0.1 and 1 Hz. This is the most important region of the ride criteria since the predicted SES heave acceleration environment tends to center in this portion of the frequency regime.

(U) Although the data points cover vastly different conditions and show varying degrees of performance or motion sickness, trends were established for short term and long term conditions. Trend lines were compared with all other data points and with previously developed habitability criteria to establish firm ride criteria.

(U) The present ride criteria represent 30 minute and 4 hour duration tolerance limits for adapted crews with ten to twenty percent expected performance decrement. In the frequency region of 0.1 to 0.5 Hz, ten percent of the crew could be expected to have some motion sickness. The actual task performance decrement of the ten percent displaying sickness might mean slower performance, increased errors or complete non-performance of assigned duties.

(U) The identification of the kind and level of performance decrement expected must consider the specific tasks to be performed. The reduced tolerance between 1.0 and-10 Hz refers primarily to precision manual tasks such as plotting or tracking. The operation of a decimal input device (with proper arm support and restraints) would suffer no performance decrement at motion levels near or even slightly above the ride criteria curves.

(U) 2.2.7.2 Far Term SES Ride Quality -- Figures 2.2.7-2 through 2.2.7-9 present the narrowband frequency spectra of the heave acceleration levels for the far term ship at MOD-50 (3025.5 LT, 30,146.1 kN) with the ride control system both on and off. In order to comply with the Rohr ride criteria, it is predicted that a ride control system (RCS) is not required in sea states zero to three. Above sea state three, the RCS (described in Section 2.3.5.2) effectively limits the ship motion and meets the Rohr ride criteria at the C.G. and pilot house for all speeds, weights and sea states in the operational envelope.

(U) Rohr's SES ride quality is substantially better than required for crew comfort or performance of precision tasks.

(U) The ride control system is designed to meet the Rohr ride criteria with the maximum possible steady state air flow in order to optimize the top speed performance of the ship. Better ride quality could be obtained at the sacrifice of ship speed performance by reducing the steady state flow in order to dedicate more air flow to ride control. All ship performance speeds are quoted for the LM5000 engines.

The ride control results are based on realistic constraints on available air flow and system stability. The primary ride control effectors are the variable geometry feature of the lift fans. For the extreme sea state 6 conditions, the passive stern seal vent valves are used for additional control in the tandem or push-pull mode.

(U) Figures 2.2.7-2 through 2.2.7-5 show the predicted heave acceleration for the far term ship at various sea states and speeds. Uncontrolled ship motions penetrate the four hour curve in the performance decrement range and Figures 2.2.7-3 through 2.2.7-S also extend beyond the four hour criteria limits in the motion sickness range. The addition of the Rohr ride control system improves the ride quality to an acceptable level as shown in the figures, This capability allows operation of the far term ship into higher sea state/speeds when necessary for short to medium time periods for special operational needs (e.g., outrun storms, combat, etc.).

(U) Figure 2.2.7-6 illustrates a high speed (80 knots, 41.2 m/s) low sea state condition where ride control is not used. Ride quality is well within the established ride criteria for long duration ship operation,

(U) Figure 2.2.7-7 shows bow heave acceleration for high sea states/speeds which exceed the 30 minute rfde criteria. However, bow accelerations are more severe than elsewhere and there are no permanently inhabited spaces in this area. Exposure to these severe conditions, which occur only with near head seas, can be minimized by relatively minor adjustments to the ship's course or speed except for that one percent of the total ship life which would most likely occur under operational conditions when it is least possible to significantly alter course or speed.

(U) Figure 2.2.7-8 shows the low sea state example for the bow acceleration. Even without ride control, long duration operation is acceptable.

(U) The Far Term SES studies were made at the MOD-50 condition, Sensitivity studies have shown that, for a given length-to-beam ratio, the overall heave acceleration response is not appreciably affected as the weight varies from the light ship to the full load weight condition.

(U) 'Lateral acceleration plots, Figures 2.2.7-9 through 2.2.7-12, show very low levels and fall well below the MIL-STD-1472B or ISO criteria curves for lateral acceleration. No impact is expected on ride quality due to the low levels of lateral acceleration. Figure 2.2.7-13 is a plot of the standard deviation on lateral acceleration versus heading to sea for several vehicle locations. This data corresponds to 'the plots in Figures 2.2.7-9 through 2.2.7-12.

(U) Table 2.2.7-l shows the typical power expended to control the ride for several speed/wave height combinations. This power is the total added "cost" due to ride control, and includes the added lift system power as well as the added propulsion system power due to the increased drag that is caused by reduced steady state air flow.

(U) Table 2.2.7-2 lists typical frequency and damping ratios predicted for the ship's basic heave and pitch modes for several speeds in calm water and a ship weight of 2800 L.T. (27,899.2 kN).

(U) Figure 2.2.7-14 is a plot of the standard deviation on c.g. heave acceleration as a function of ship's heading at 60 knots (30.9 m/s) and significant wave height of 6.9 feet (2.1 m) with and without ride control. This figure shows the dramatic improvement obtained by changing the ship's course relative to the seas.

(U) Figures 2.2.7-15 and 2.2.7-16 are plots of the standard deviations on bow, c.g. and stern heave accelerations and c.g. heave position as a function of ship speed for head seas, with and without ride control.

(U) Figures 2.2.7-17 and 2.2.7-18 are plots of the predicted number of exceedances per second as a function of the c.g. heave acceleration level for several speed/wave height combinations in head seas, with and without ride control. These exceedances were computed using the assumptions for stationary and ergodic Gaussian zero-mean random processes.

Table 2.2.7-1(U). **Typical** Power Expended for Ride Control (MOD-50 Condition)(U)

SHIP SPEED (KNOTS)(m/s)	SIGNIFICANT WAVE HEIGHT (FT)(m)	INCREASED SHP (kW) OR CHANGE IN SHP (kW) DUE TO RIDE CONTROL
40 (20.58)	15 (4.57)	41,000 (30,600)
60 (30.87)	10 (3.05)	22,700 (16,927)
70 (36.01)	10 (3.05)	29,500 (22,000)

Table 2.2.7-2(U). Typical Pitch and Heave Frequency and Damping Ratios (U)

SHIP SPEED (KNOTS) (m/s)	FREQUENCY (Hz)/DAMPING RATIO	
	PITCH	HEAVE
40 (20.58)	.19/.22	.65/.28
60 (30.87)	.20/.20	.66/.29
80 (41.16)	.21/.16	.68/.31

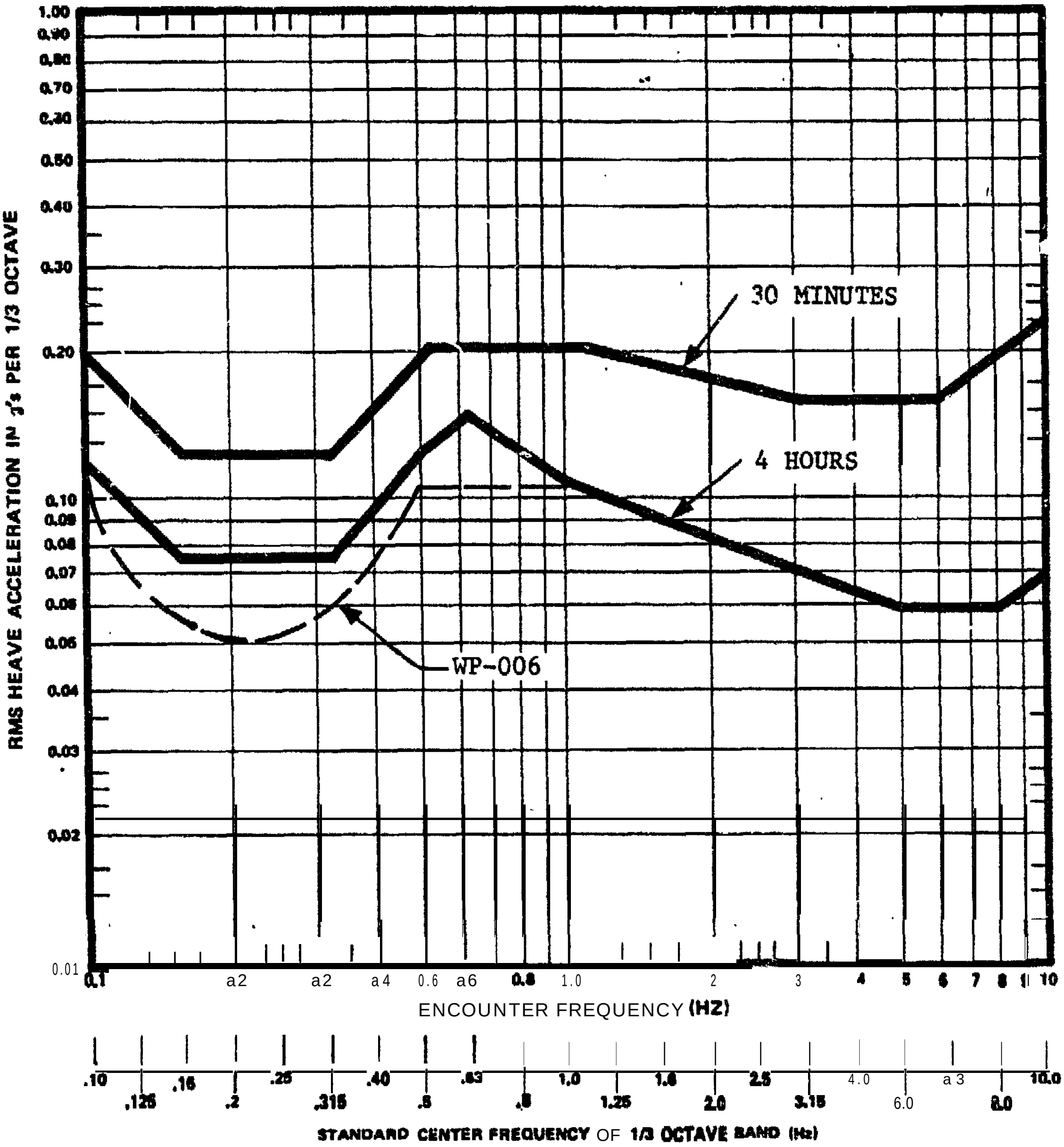


Figure 2.2.7-1(U). Rohr Heave Acceleration Ride Criteria(U)

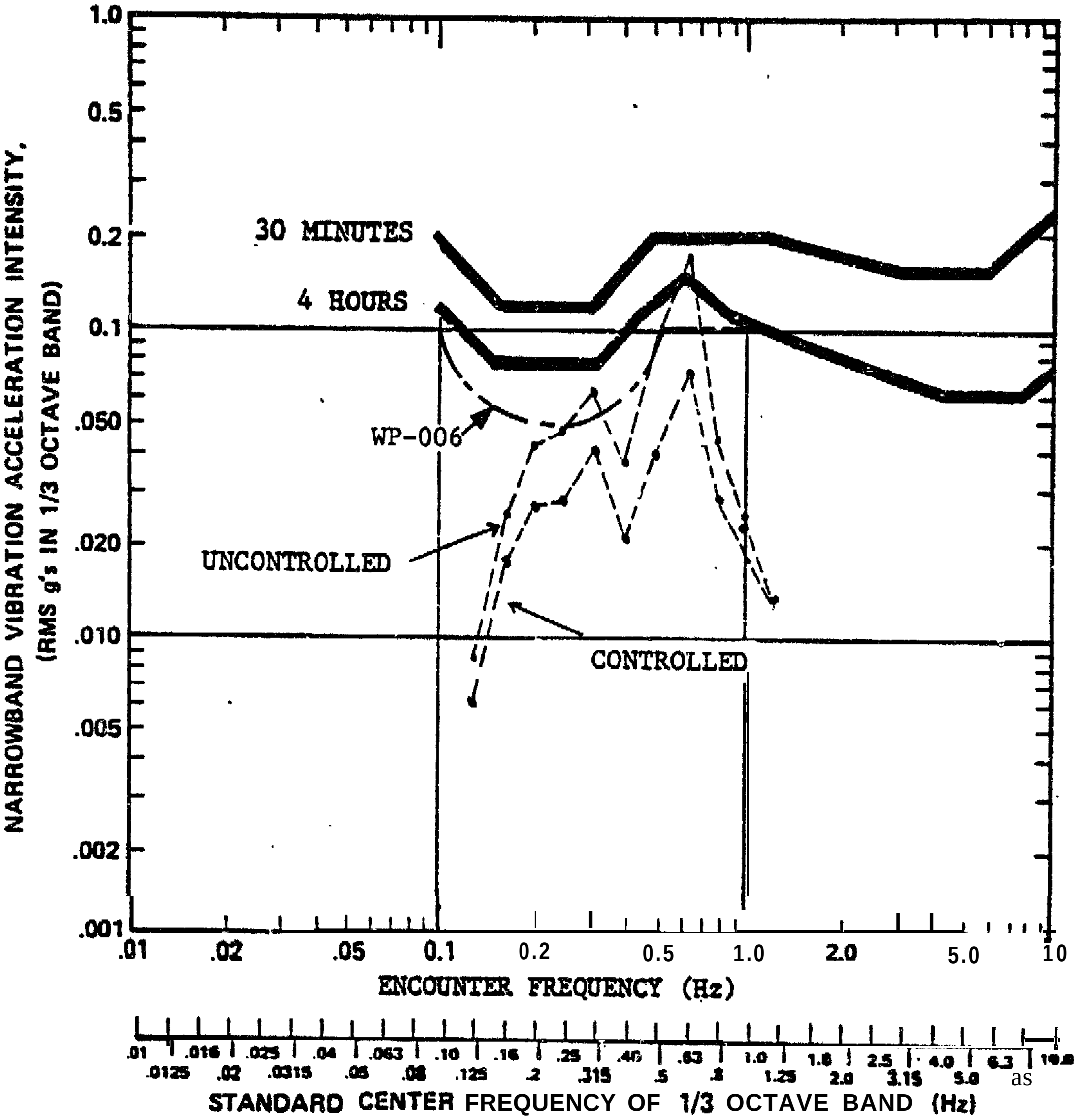


Figure 2.2.7-2(U). CG Heave Acceleration Versus Rohr Ride Criteria -- 40 knots (20.58 m/s), $H_{1/3}$ = 15 ft (4.57 m), Head Seas and the MOD-SO Condition (U)

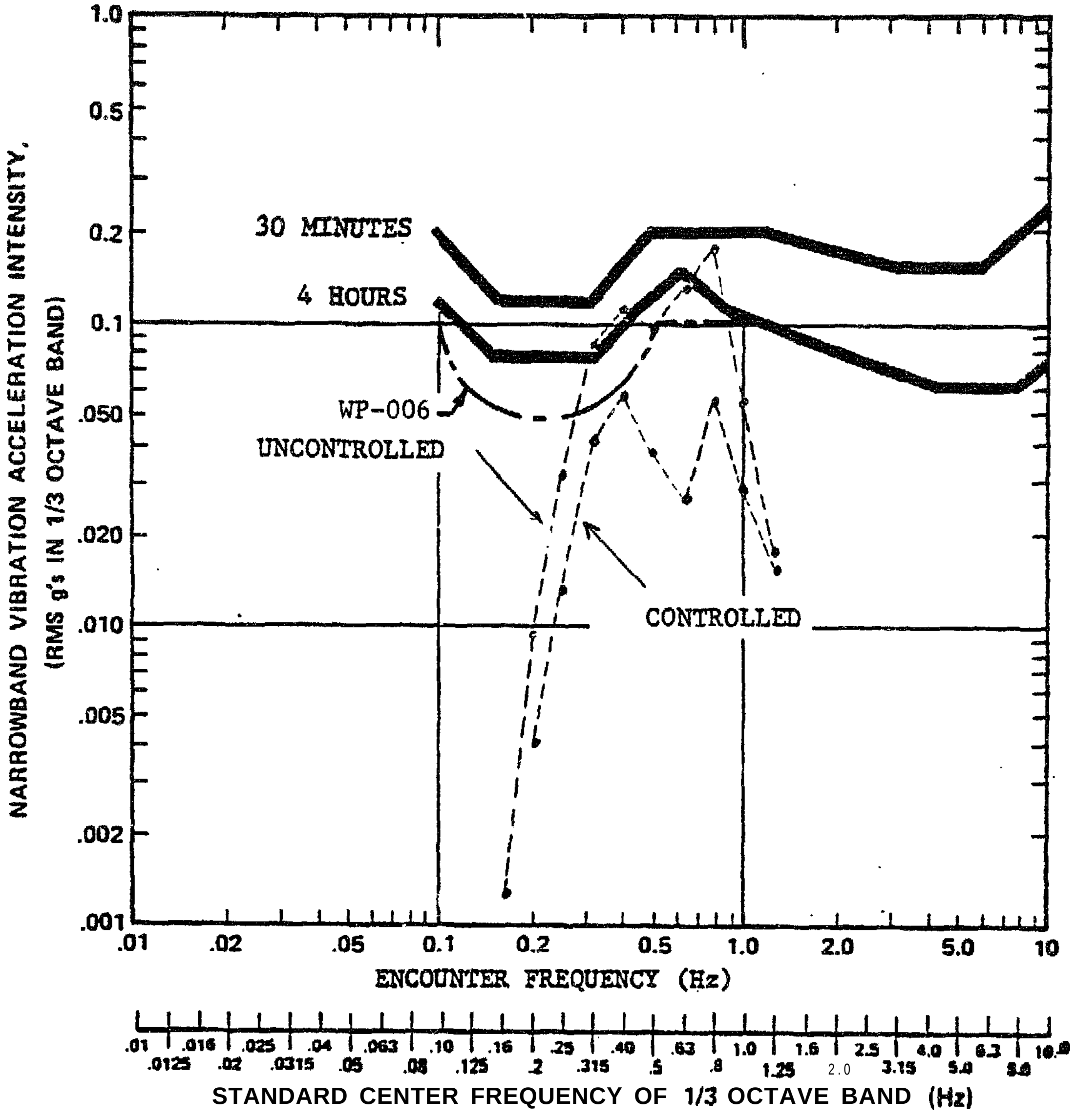


Figure 2.2.7-3(U). CG Heave Acceleration Versus Rohr Ride Criteria -- 60 knots (30.87 m/s>, $H_{1/3}$ = 10 ft (3.05 m), Head Seas and the MOD-50 Condition (U)

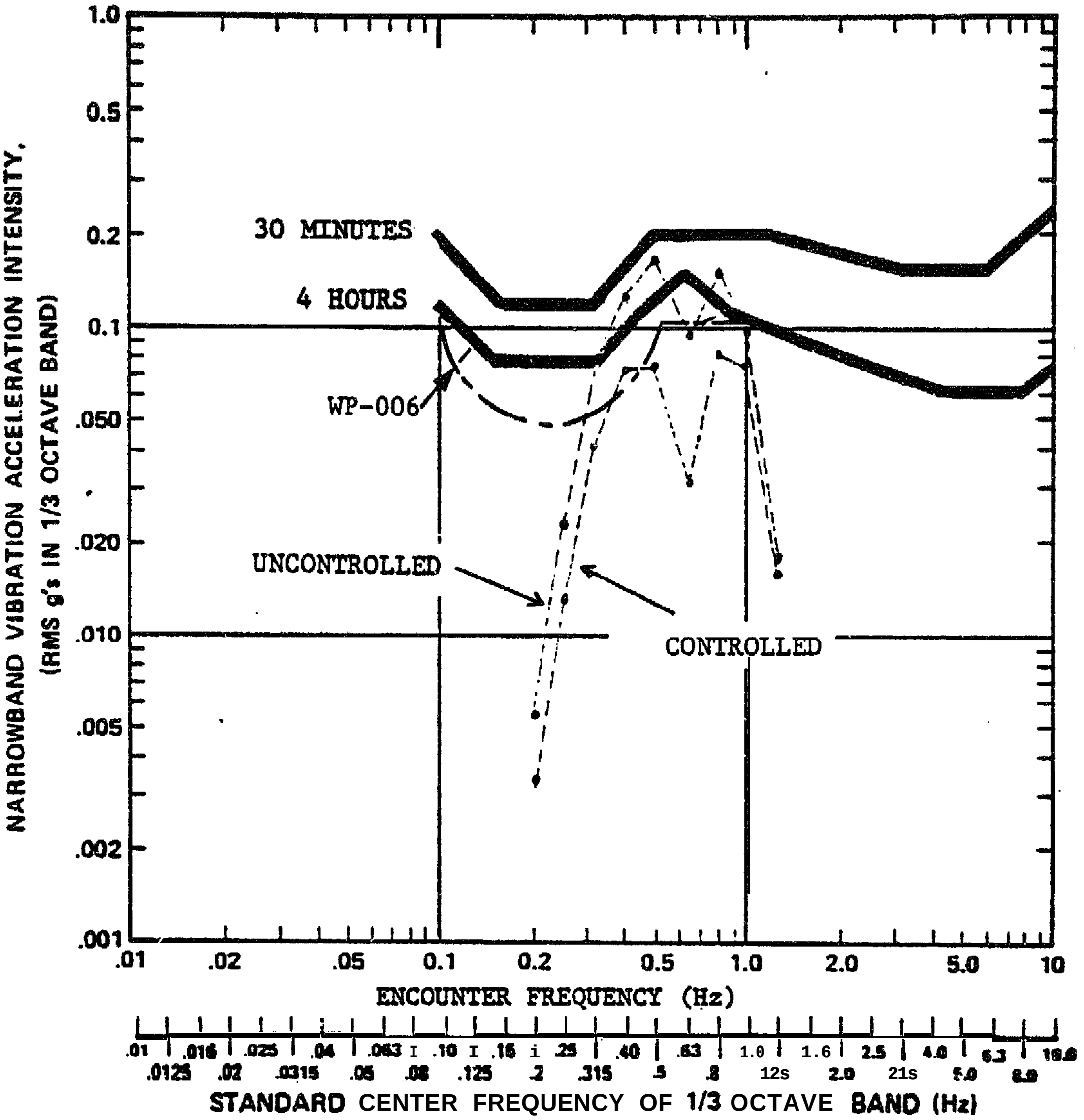


Figure 2.2.7-4(U). **CG Heave** Acceleration Versus Rohr Ride Criteria -- 70 knots (36.01 m/s), $H_{1/3}$ = 10 ft (3.05 m), Head Seas and the MOD-50 Condition (U)

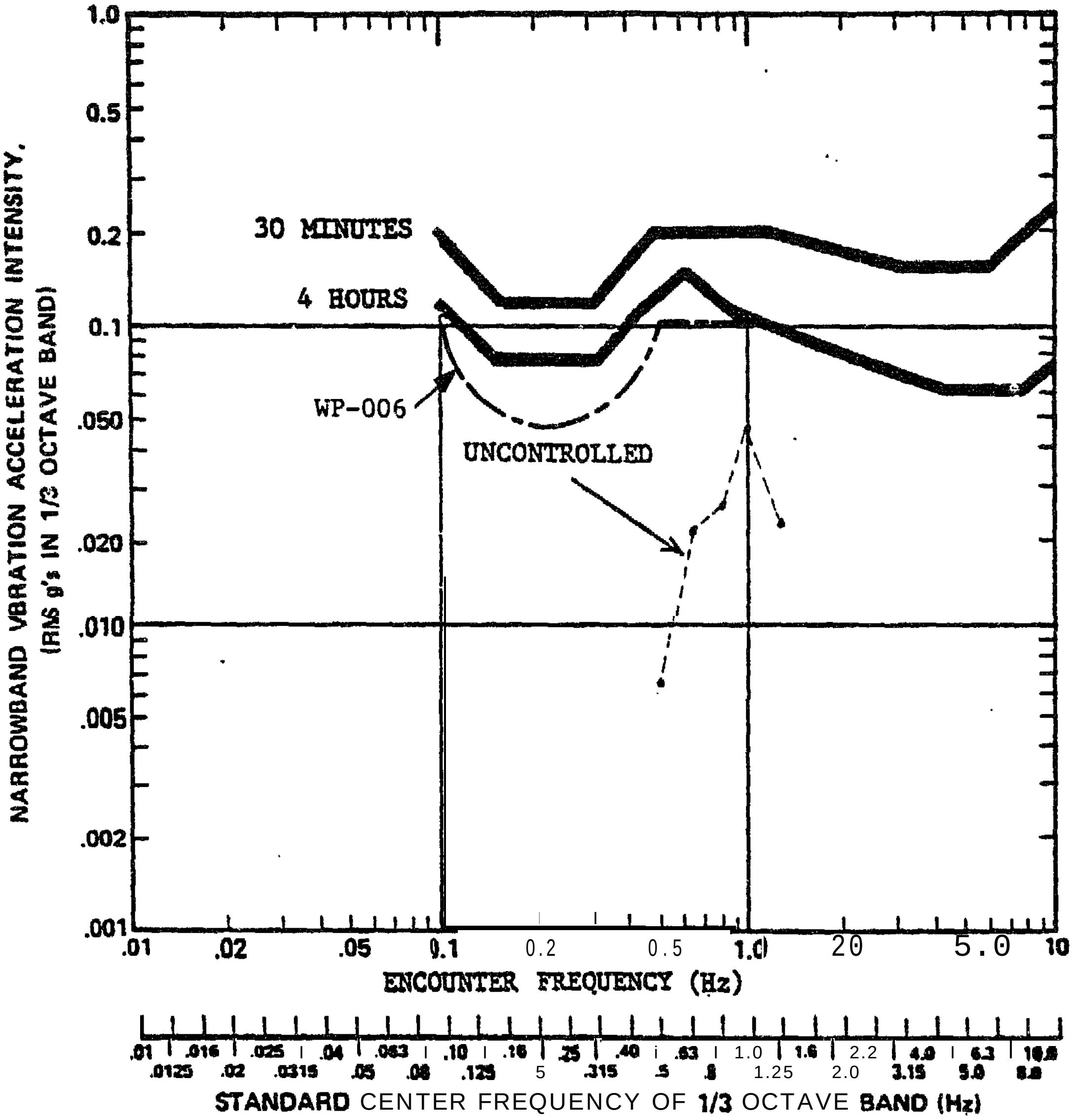


Figure 2.2.7-5(U). CG Heave Acceleration Versus Rohr Ride Criteria -- 80 knots (41.16 m/s), $H_{1/3}$ = 3.3 ft (1.0 m), Head Seas and the MOD-50 Condition (U)

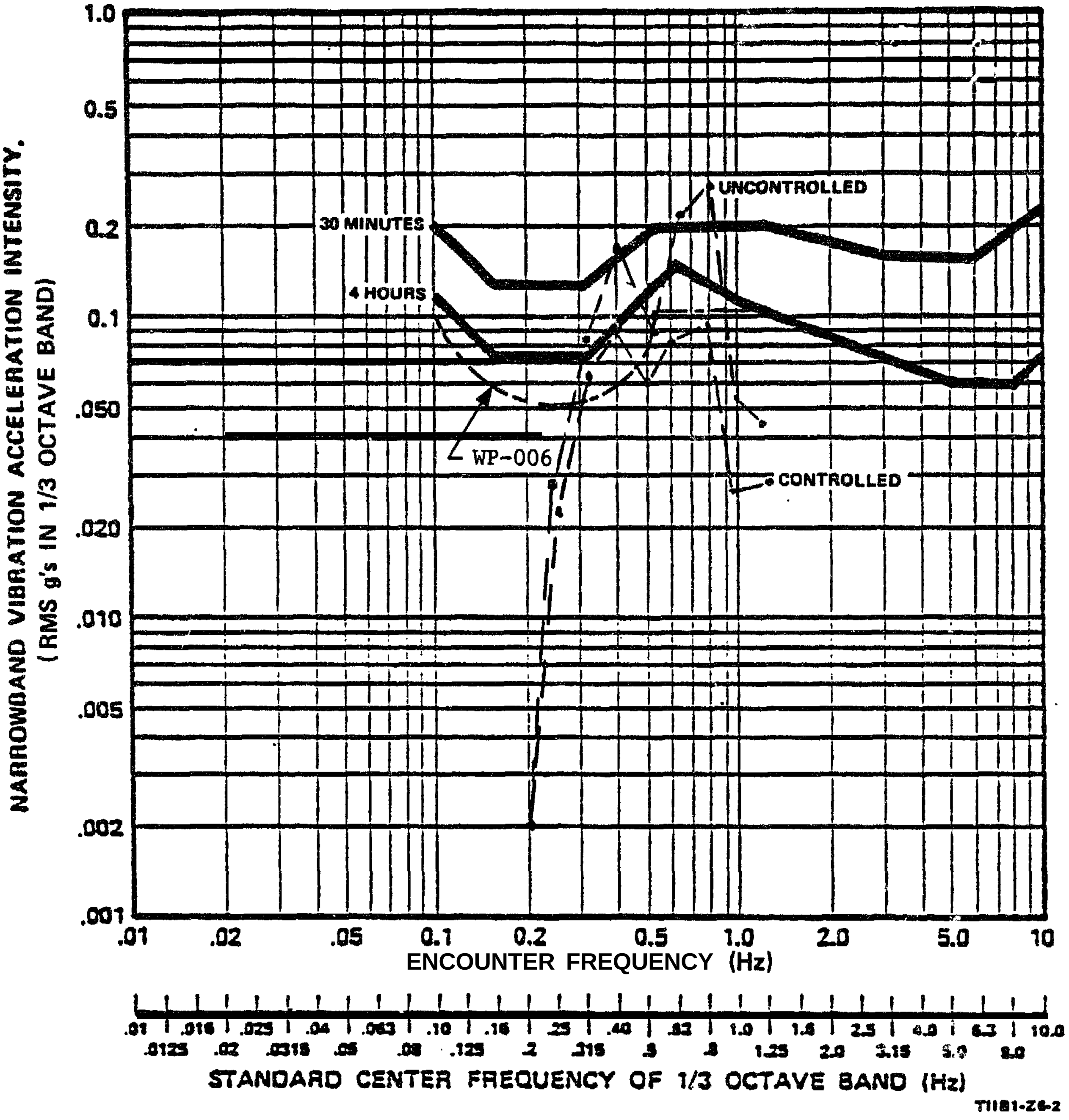


Figure 2.2,7-6(U). Bow Heave Acceleration Versus Rohr Ride Criteria -- 60 knots (30.87 m/s>, $H_{1/3}$ = 7 ft (2.1 m), Head Seas and the MOD-50 Condition (U)

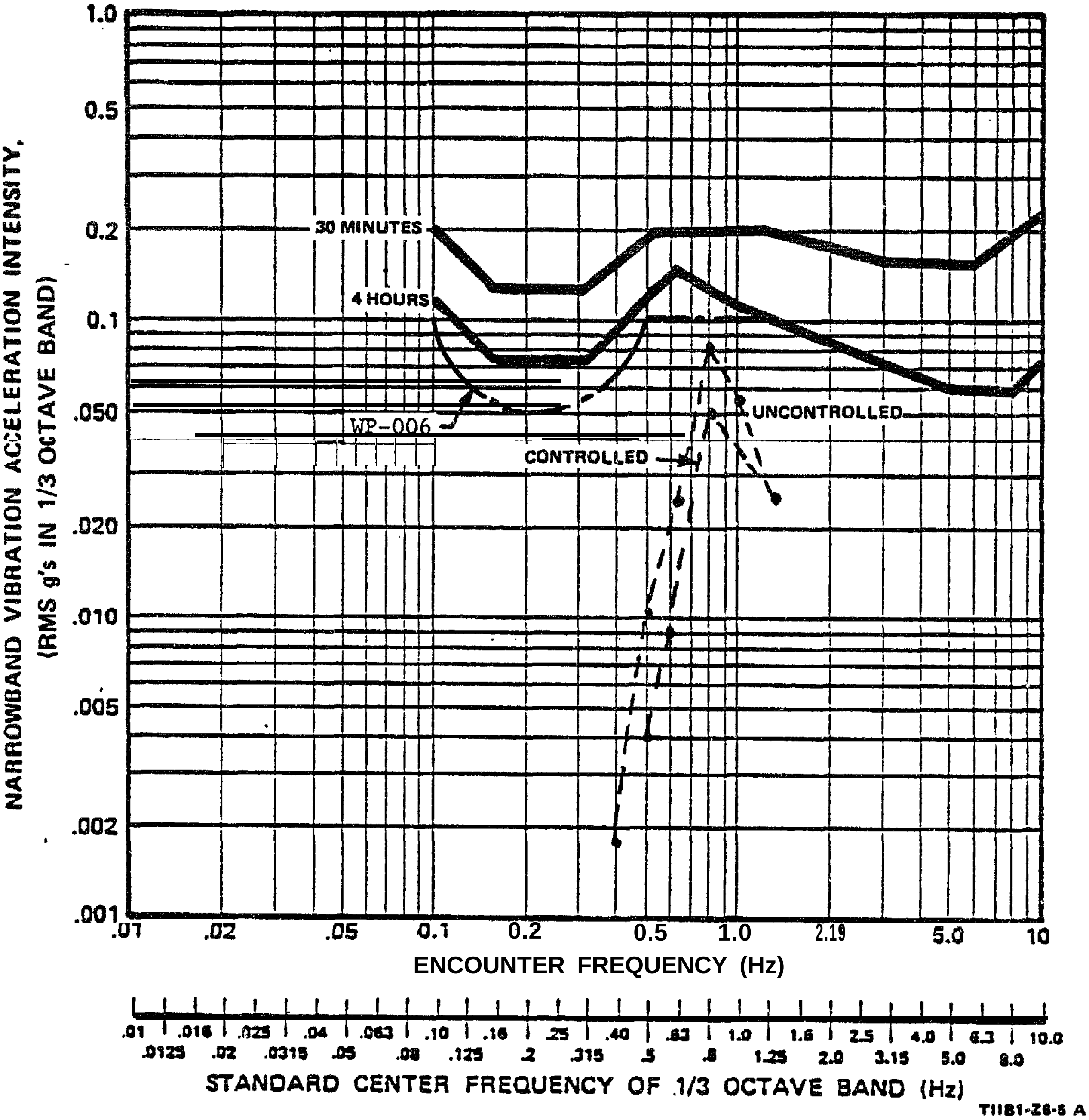


Figure 2.2.7-7(U). Bow Heave Acceleration Versus Rohr Ride Criteria -- 70 knots (36.01 m/s), $H_{1/3}$ = 3.3 ft (1.0 m), Head Seas and the MOD-50 Condition (U)

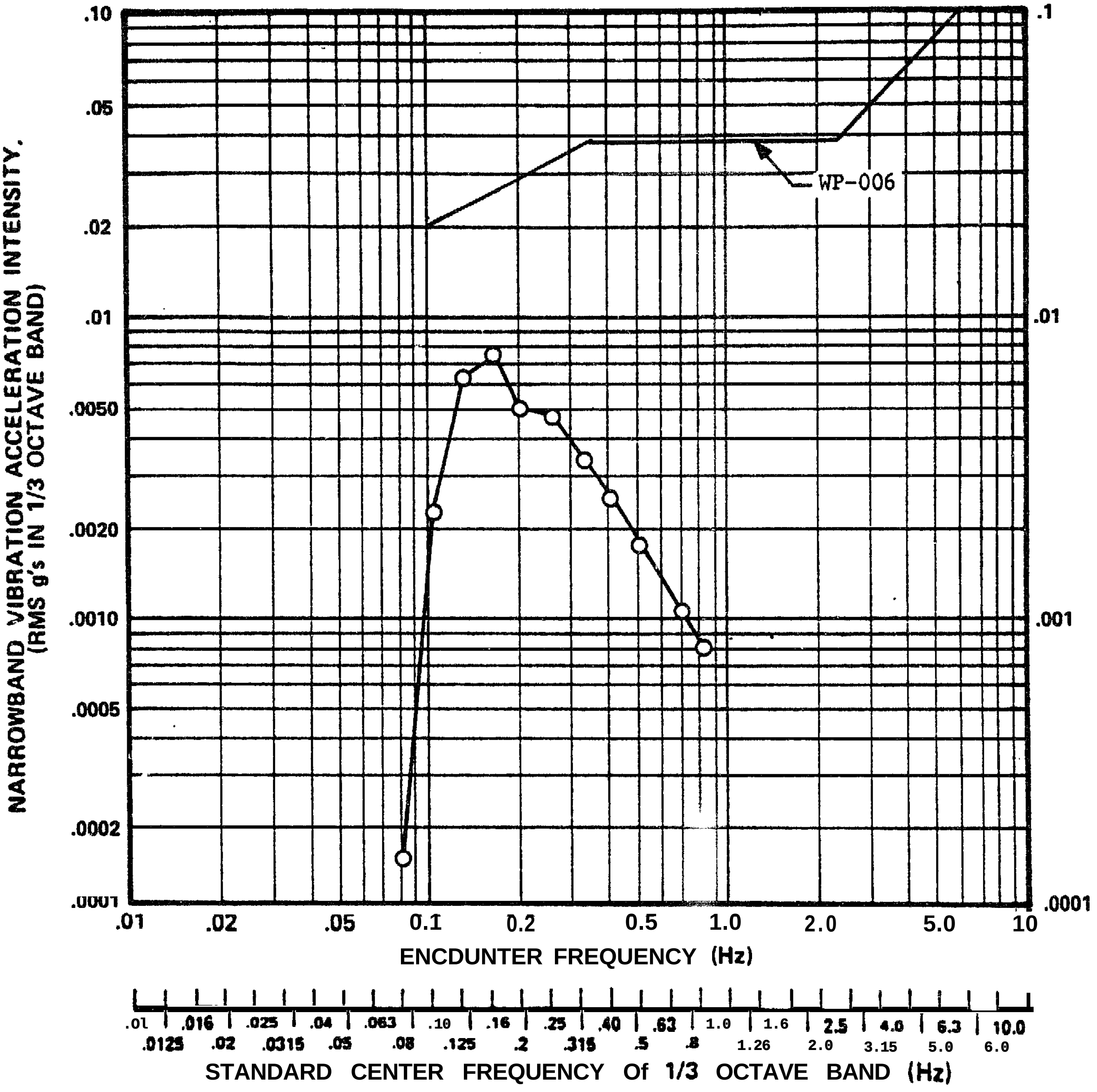


Figure 2.2.7-8(U). CG Lateral Acceleration Versus Encounter Frequency -- 60 knots (30.87 m/s), $H_{1/3}$ = 6.9 ft (2.1 m), Beam Seas, MOD-50 Condition, Insensitive to Ride Control (U)

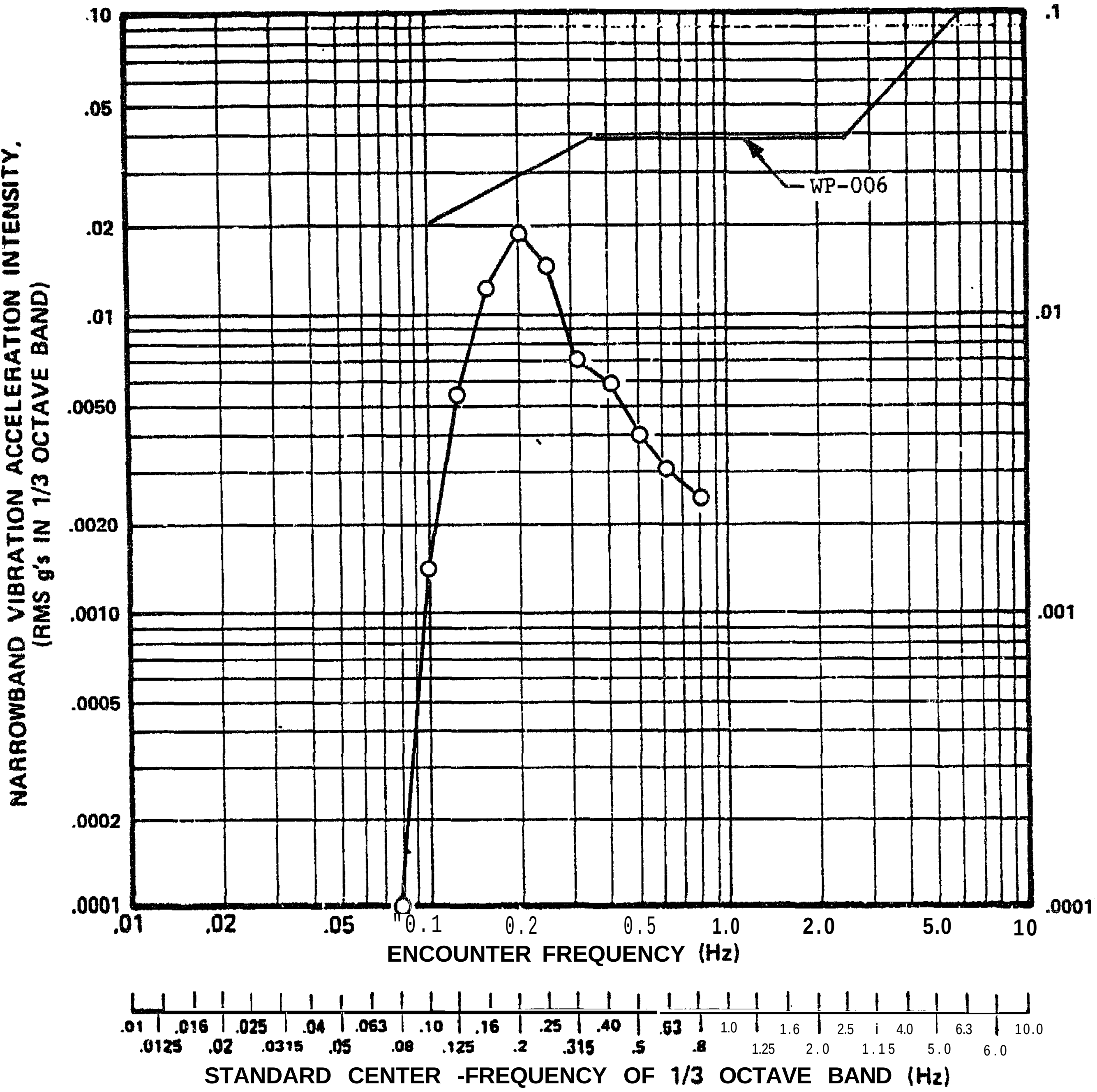


Figure 2.2.7-9 (U). Bow Lateral Acceleration Versus Encounter Frequency -- 60 knots (30.87 m/s), $H_{1/3}$ = 6.9 ft (2.1 m), Beam Seas, MOD-50 Condition, Insensitive to Ride Control (U)

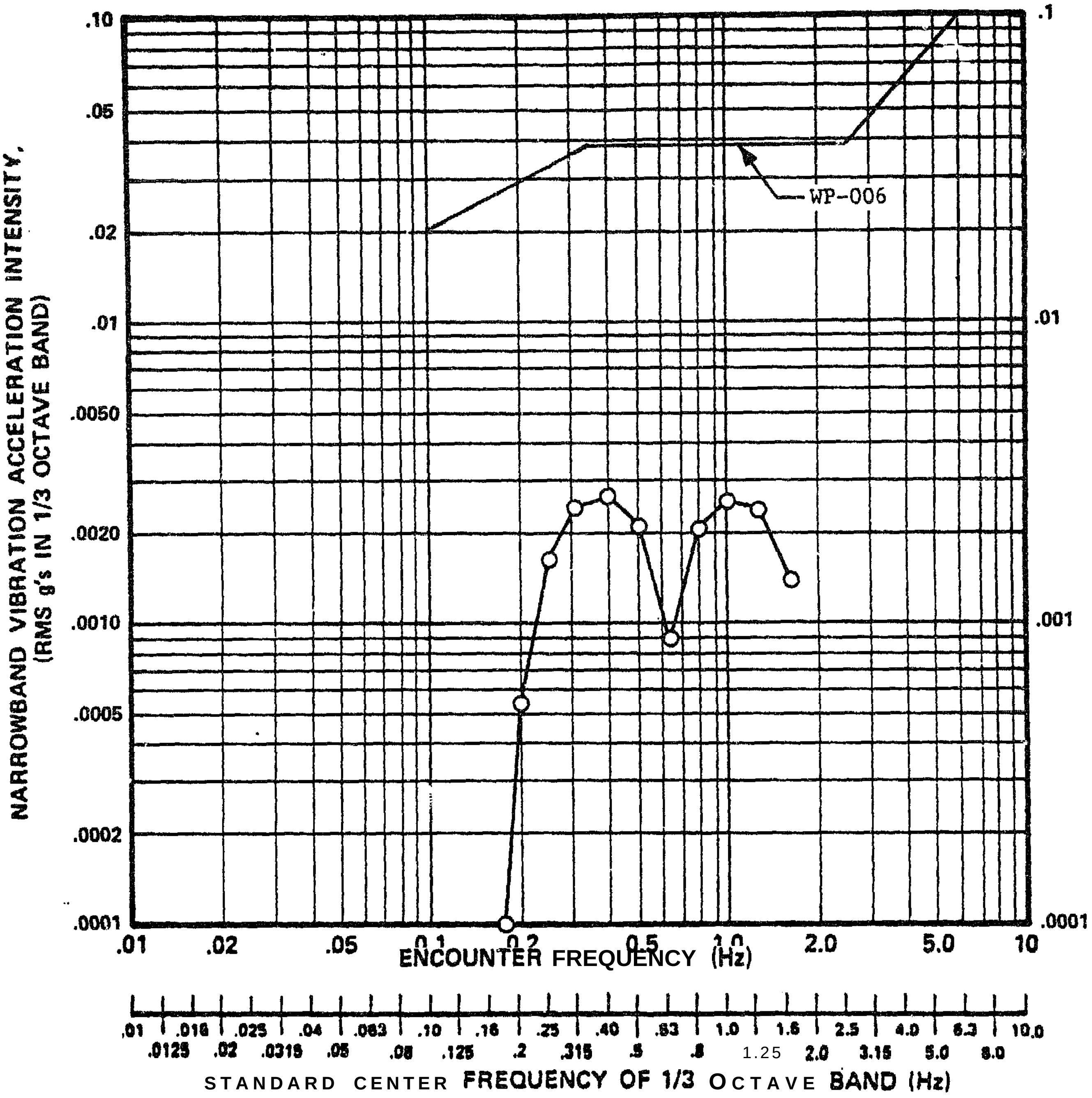


Figure 2.2.7-10(U). CG Lateral Acceleration Versus Encounter Frequency -- 60 knots (30.87 m/s), $H_{1/3}$ = 6.9 ft (2.1 m), Sea Heading Broad on the Bow, MOD-50 Condition, Insensitive to Ride Control (U)

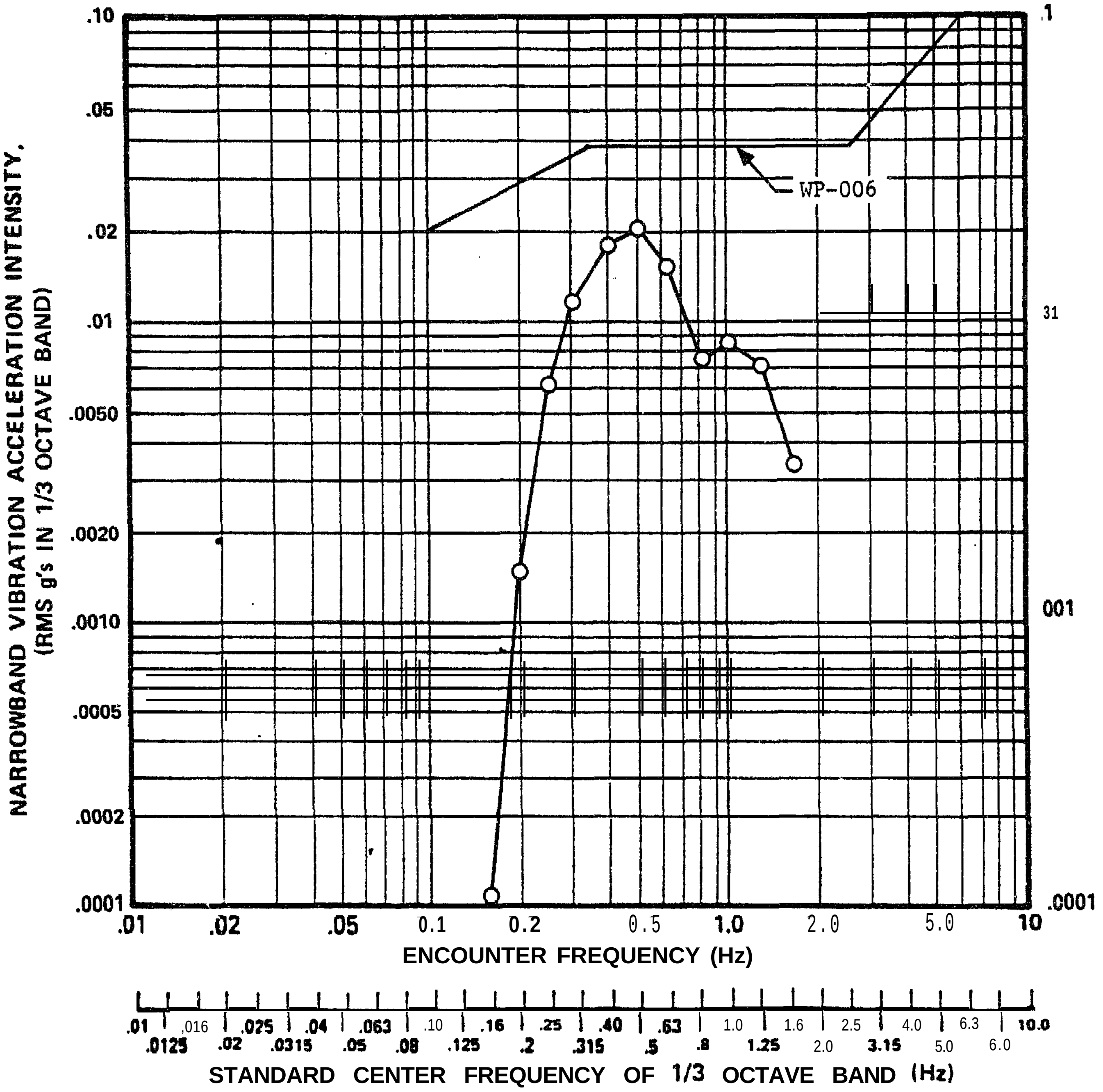


Figure 2.2.7-11(U). Bow Lateral Acceleration Versus Encounter Frequency -- 60 knots (30.87 m/s), $H_{1/3}$ = 6.9 ft (2.1 m), Sea Heading Broad on the Bow, MOD-50 Condition, Insensitive to Ride Control (U)

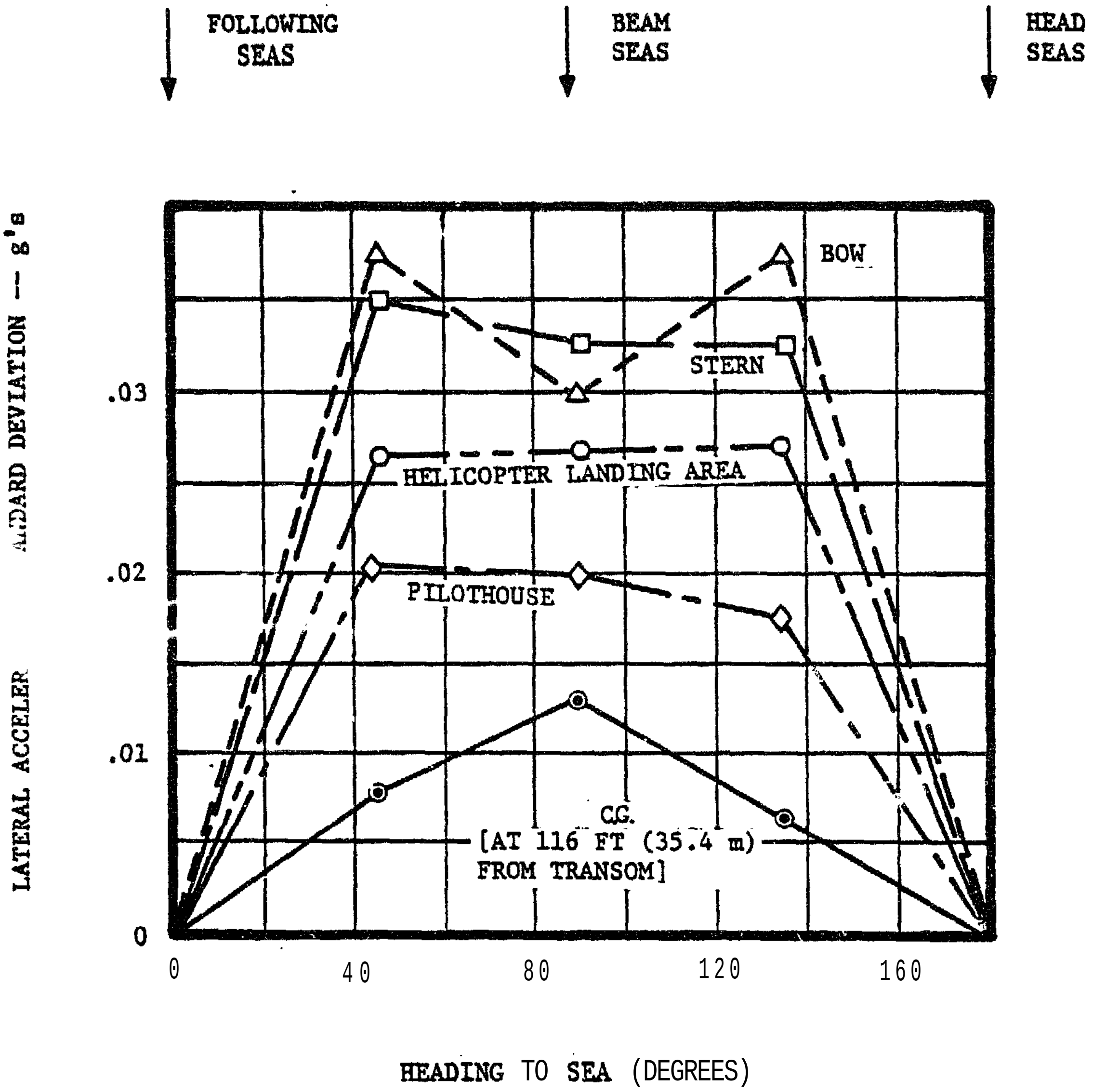


Figure 2.2.7-12(U) **Lateral Acceleration** Standard Deviation Versus Heading to Sea -- 60 knots (30.87 m/s), $H_{1/3}$ = 6.9 ft (2.1 m) MOD-50 Condition, Insensitive to Ride Control (U)

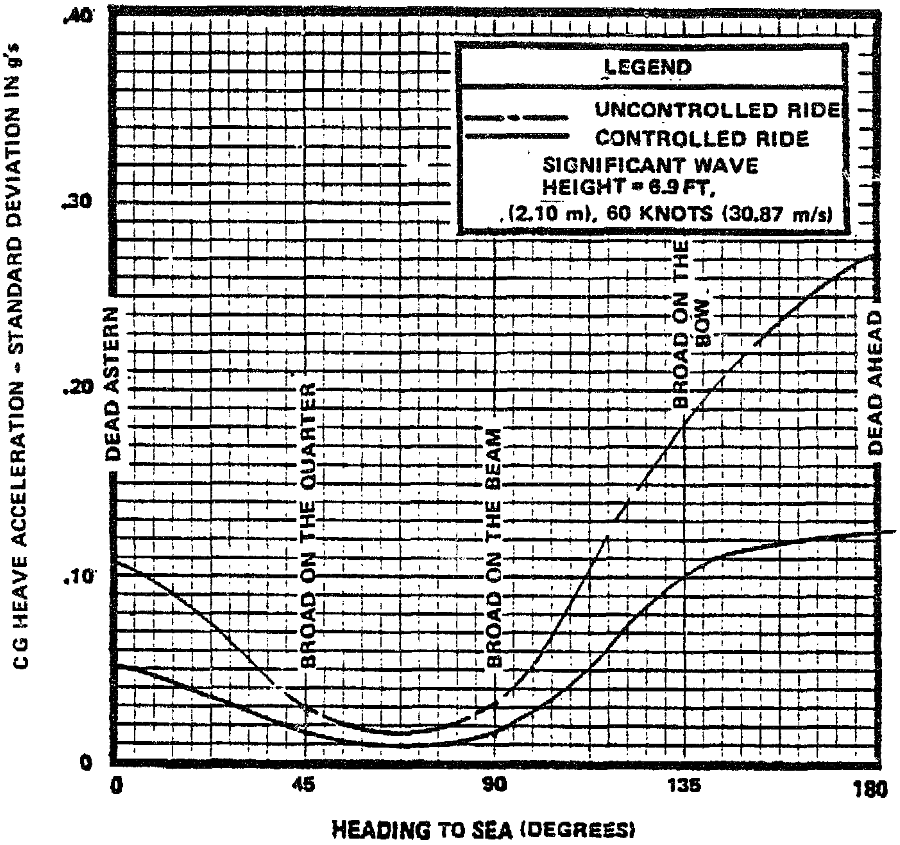
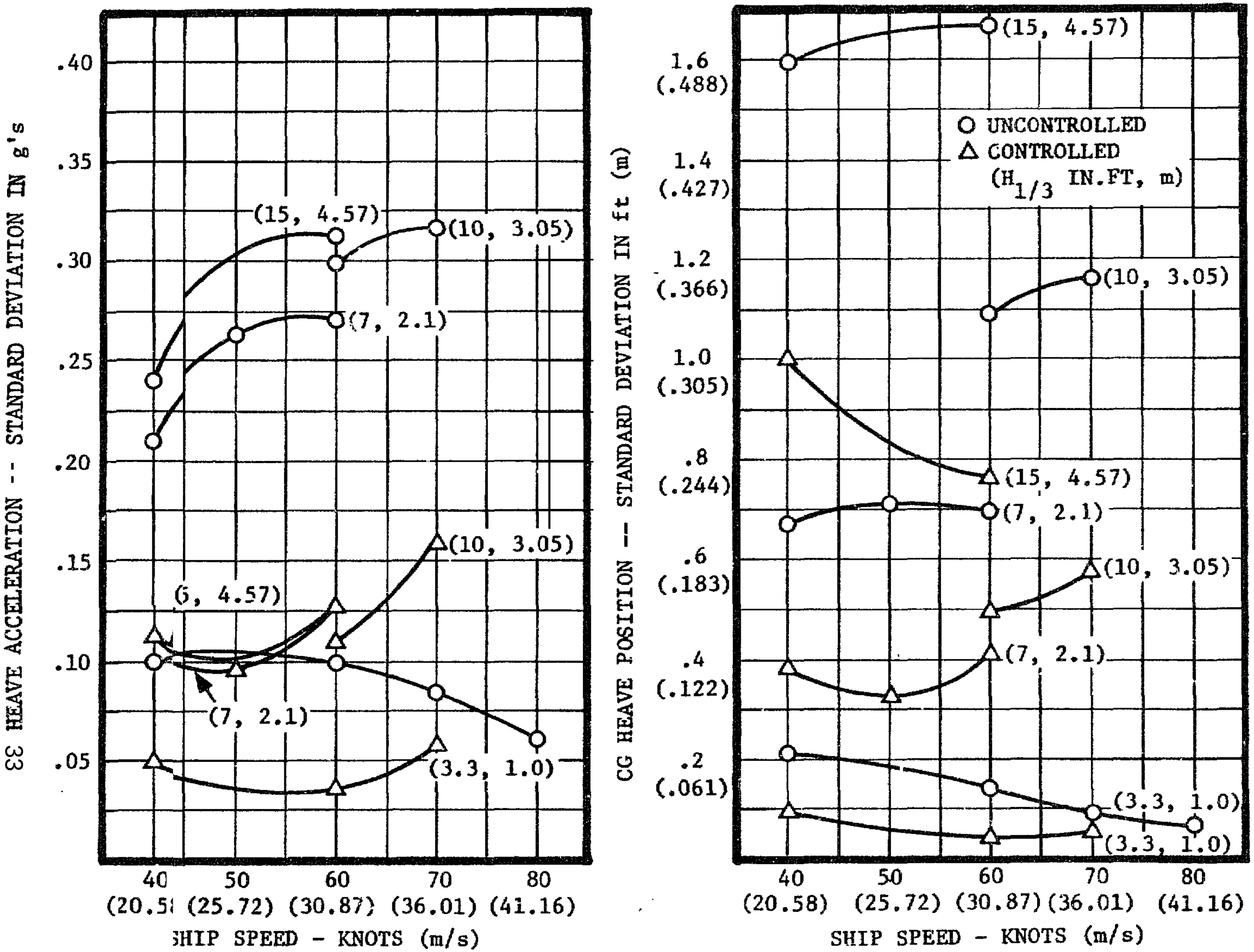


Figure 2.2.7-13(U). CG Heave Acceleration Standard Deviation Versus Heading to Sea (MOD-50 Condition) (U)



igure 2.2.7-14(U). CG Heave Acceleration and Position Standard Deviations Versus Ship Speed (Head Seas and MOD-50 Condition) (U)

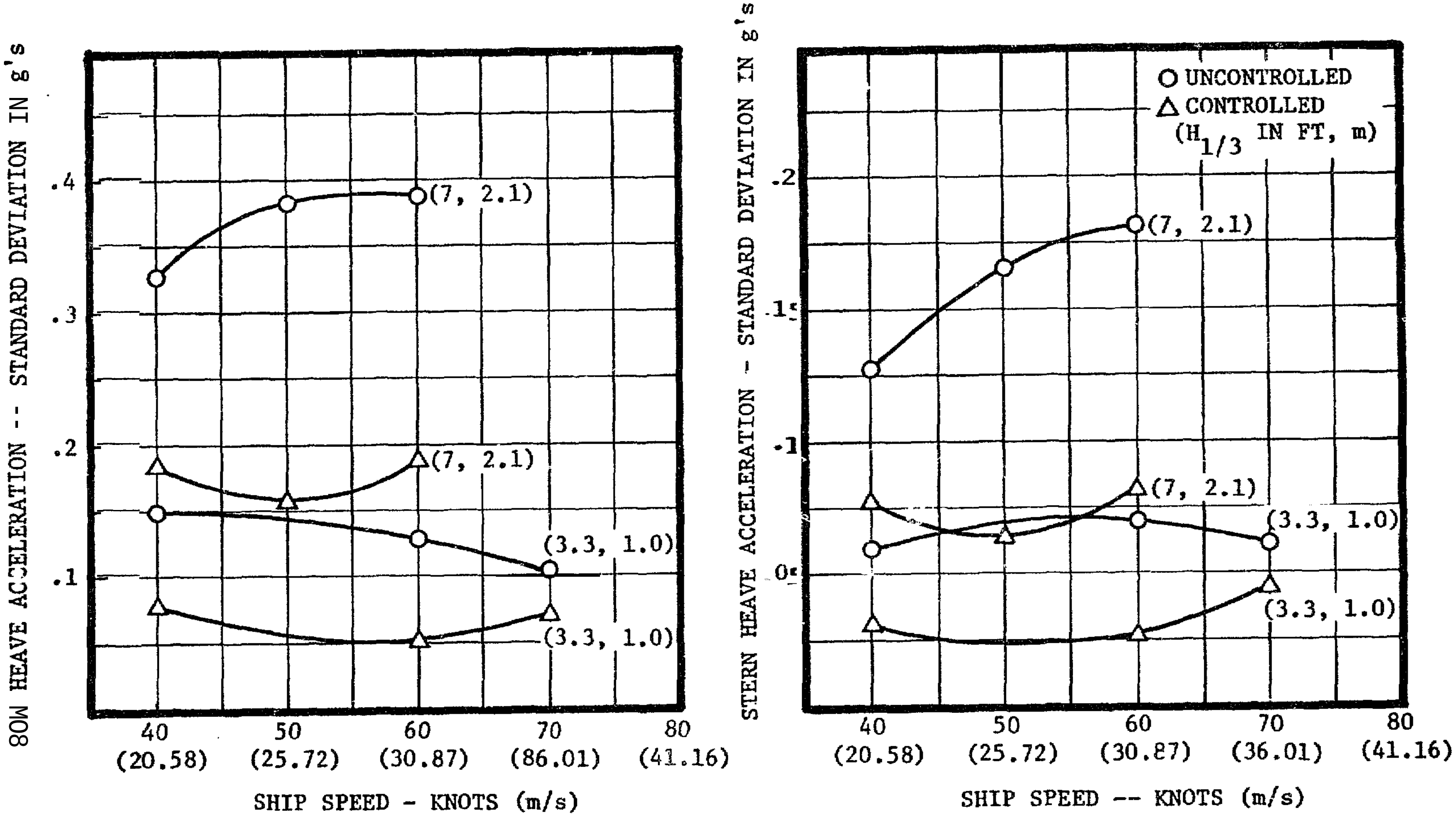


Figure 2.2.7-15 (U). Bow and Stern Heave Acceleration Standard Deviations in g's Versus Ship Speed (Head Seas and MOD-50 Condition) (U)

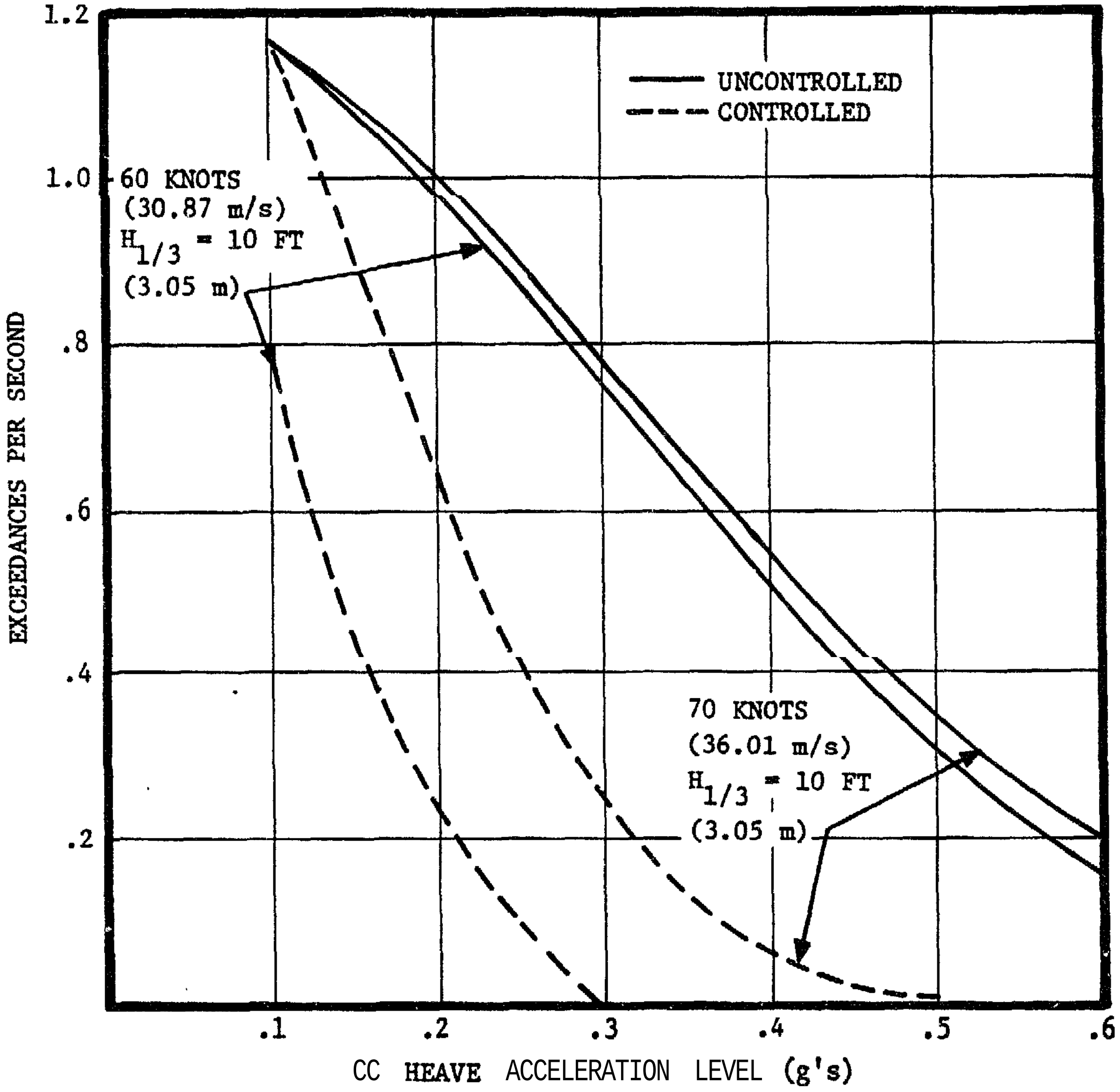


Figure 2.2.7-16 (U). Exceedances per Second Versus CG Heave Acceleration Level for Head Seas and the MOD-50 Condition, $H_{1/3}$ = 10 ft (3.05 m) (U)

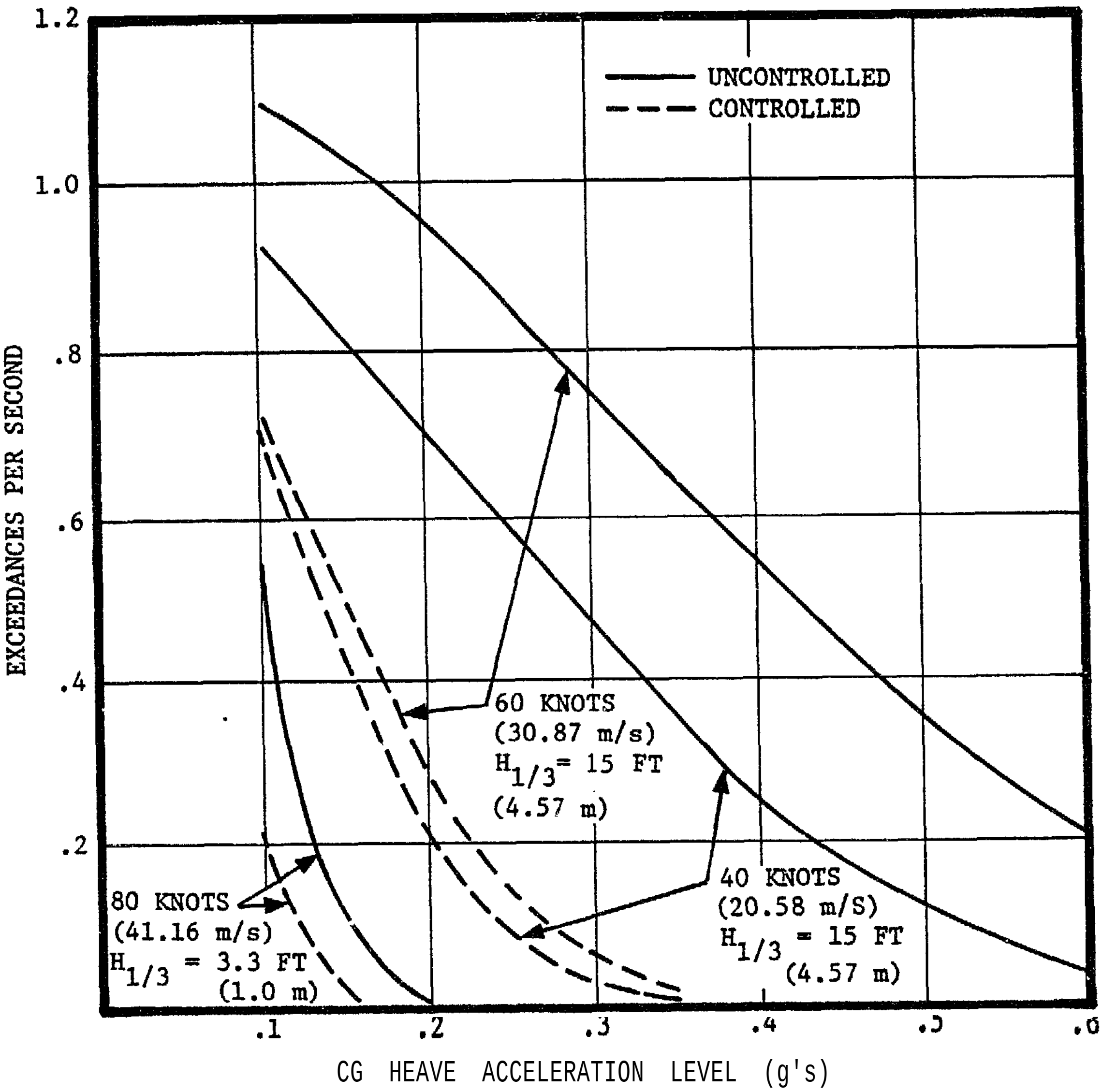


Figure 2.2.7-17 (U). Exceedances per Second Versus CG Heave Acceleration Level for Head Seas and the MOD-50 Condition, $H_{1/3}$ = 15 ft (4.57 m) and 3.3 ft (1.0 m) (U)

(U) 2.2.8 MANNING -- The manning'presected herein delineates the minimum quantitative and qualitative personnel essential to the operation, maintenance, and support of the far term SES under stated missions, conditions of readiness and configuration. These requirements are termed Organizational Manning and were developed in general accordance with the "Guide to the Preparation of Ship's Manning," Document OPNAV 10P-23. The developed manpower requirements are sufficient for performing all operational, organizational, maintenance, administration, and support tasks required for the far term SES.

(U) The organizational manning requirements developed for the far term SES are as follows:

	Officers	CPO	Other Enlisted	TOTAL
Vehicle (Ship}	7	7	36	50
Vehicle (Combat System)	4	5	64	73
Secondary Vehicle Team	6	1	10	17
TOTAL	17	13	110	140

(U) Table 2.2.8-1 displays the manning requirements in the prescribed format.

Table 2.2.8-1. Manning Requirements

VEHICLE

OFFICERS	CPO	OTHER ENLISTED				
Commanding	BMC	1 BM3	2 ETR3	1 GMM2	2 MS2	3 RM2
Executive	EMC	1 DS1	2 ETN3	2 GMM3	2 MS3	3 RM3
Operations	ETC	2 DS2	1 EW1	1 TM2	3 OS1	
Communications	FTCS	2 DS3	1 EW2	3 GS1	3 OS2	1 SK3
1st Lieutenant	GSCS	3 EM2	1 EW3	1 GS3	3 OS3	1 YN1
Combat Systems	MSC	1 EM3	1 FTM1	1 GSFN	3 OSSN	1YN3
Asst. Combat Sys.	OSCS	1 EN1	1 FTG1	1 HT1	1 STG1	8 SN
Elec. Material	HMC	1 EN2	3 FTM2	1 HT2	2 STG2	1 FN
Missile	QMC	1 ENFN	1 FTG2	1 HTFN	3 STG3	1 AT2
Engineer	RMC	2 ET1	3 FTM3	1 IC1	1 SM2	1 AX2
Damage Cont. Asst.	SKC	1 ETN2	1 FTG3	1 IC2	2 QM3	1 AMH1
	ATC	1 ETR2	1 GMM1	1 ICFN	1 QMSN	1 AMS2
				1 ADJ1	1 ADJ3	
11	12	100				

SECONDARY VEHICLE

Helicopter Pilot	ADJC	1 ADJ1	
Helicopter Pilot		1 AMH1	
Helicopter Co-Pilot		1 AMH3	
Helicopter Co-Pilot		1 AMS1	
Crewman		1 AT1	
Crewman		1 AT3	
		1 AE1	1 AO2
		1 AX2	1 AN
06	01	10	

TOTAL COMPLEMENT

17	13	110

GRAND TOTAL: 140

(U) 2.3 SHIP SUBSYSTEM DESCRIPTIONS

(U) 2.3.1 STRUCTURE

(U) 2.3.1.1 Summary Description -- The twin, full cushion length sidehulls of the far term SES are designed to be aerodynamically and hydrodynamically clean, and to contribute to good stability, maneuverability and performance characteristics. The ship houses the required weapon suite within its three major decks and provides an operational air capability, The survivability and reliability of the structural system are consistent with a 20-year life requirement and a much greater anticipated service life.

(U) The hull structure includes the shell plating, framing, structural bulkheads, decks, superstructure , structural closures, mast and foundations. The functional requirements of the hull structural system are: (1) to provide a watertight envelope which houses all other subsystems, (2) to provide a structurally sound platform suitable to the performance goals of the craft, (3) to provide an envelope that can be conditioned for crew comfort and utility, and (4) to provide a platform for aircraft and weapon system operations.

(U) The hull structural configuration was derived by considering overall hullborne and cushionborne performance, manufacturing economy, functional space requirements, combat suite, habitability, survivability and safety within the overall constraint of meeting mission requirements. It is designed to provide a realistic balance between minimum weight, structural reliability and construction cost.

(u) The far term SES hull is subjected to a wide variety of loading conditions, including impact loads, while operating at high speed. These loads would normally require a conservative, heavy structure; however, far term SES performance requirements dictate a more sophisticated and lightweight structure. For convenience, structural loads are subdivided into Primary and Local load categories. Combinations of these categories provide the

(U) basis for the development of structural design.

(U) Primary loads are defined as those loads affecting the entire hull structural girder. These include overall hull bending, torsion and shear resulting from ship weight, and hull buoyancy distributions when the ship is off-cushion or from a wave impact when the ship is traveling at high speed on cushion.

(U) Local loads are those applied over limited portions of the hull structure, such as loads resulting from hydrostatic or hydrodynamic pressure, deck burden, foundation and topside icing.

(U) The hull bending, torsion, and shear that result from weight and buoyancy distributions when off cushion, and wave impact loads when transiting at high speed on cushion were investigated. The NASTRAN and multi-cell girder load distribution programs established internal loads for stress analysis. A plate stiffener analysis computer program was used for the stress analysis of all major structural areas. Loads considered were those due to hull bending, torsion, pressures, drydocking and equipment,

(U) Scantling design requires a balance between structural weight and ease of fabrication, without sacrificing structural integrity. The scantlings were designed through the use of a computerized optimization program to vary frame, stiffener, and plate sizing with frame and stiffener spacing and provide comparisons of the resultant structural weight and the associated fabrication costs. A frame spacing of 3 feet (0.91 m) with 10 inch (0.25 m) stiffener spacing was selected. In lightly loaded areas of the ship, such as superstructure, the frame and stiffener spacings were increased to provide light weight and enhance ease of fabrication.

(U) Hull structure optimization has provided a basis for optimum structural design of scantlings, wetdeck height, wetdeck ramp angle, full length sidehulls, and keel length fences. The structure optimization has been instrumental in design decisions relating to the square bow far term SES.

(U) The main hull girder is composed of a centerbody and two rigid sidehulls, The main, second, third and wetdecks, as well as seven (7) longitudinal bulkheads, comprise generally continuous longitudinal members which contribute to the section modulus over the entire length. All stiffeners on these members, as well as shell plating stiffeners, run longitudinally.

(U) Bulkhead and deck penetrations are minimal, enhancing structural continuity. This result is a compromise between the location of structural bulkheads and the arrangement of machinery, equipment, and weapons systems, Minimizing the number of bulkhead and deck penetrations reduces the associated structural weight penalties which occur when primary load paths are interrupted and internal loads are redistributed through use of secondary load paths. Trusses are used to retain overall load carrying capability wherever large penetrations exist.

(U) The hangar and pilot house structure located above the weather deck is assigned a secondary structural role and does not carry primary hull bending or hull torsion. As a consequence, the hangar is designed with a six foot (1.83 m) frame spacing and a 16 inch (0.41 m) stiffener spacing.

(U) The hull transverse frames are relatively large aluminum extruded tees welded to the deck plates. These members function as beam sections to span across openings between decks and form the vertical frame columns. These members are capable of reacting axial, shear, and moment loads in the plane of the frame. The sidehull and innerbottom frames are designed as an open truss configuration. These trusses react the locally applied hydrodynamic pressures and function integrally with the non trussed portion of the transverse frame. Stiffened webs are used in place of the trusses to accommodate tank boundaries,'foundations or local load conditions. Reactions to the bow seal and stern seal loadings are concentrated at locally reinforced transverse frames at the wetdeck level.

(U) Transverse bulkheads are spaced at 42 feet (12.80 m) intervals, with the exception of the aft most compartment where a 30 feet (9.14 m) spacing

(U) is used to accommodate the propulsion machinery. These bulkheads are all watertight. Vertically oriented tee members are spaced at 10 inches (254 mm) on center. The longitudinal bulkheads are sized to resist primary loads, flooding loads and drydocking loads. Stiffeners are arranged 10 inches (254 mm) on center, nominally,

(U) Figures 2.3.1-1 through 2.3.1-5 show the major structural differences between the Near and Far Term ships. Frame joints have been simplified, flat bar stringers are used in place of tee stringers, and tubular truss members are used in the sidehull, This provides a simpler and less costly manufacturing sequence.

(U) The all-welded aluminum hull structure is designed for ease of fabrication, for minimum weight, and to provide structural integrity under all loading conditions. Marine grade weldable 5456-H116/117 aluminum alloy was selected for the major portion of the hull structure because of mechanical, corrosion, manufacturing, and cost considerations. The H117 temper is free of continuous grain boundary networks which would be susceptible to exfoliation or severe intergranular corrosion in a marine environment.

(U) Material "S" allowables were used for'the stress analysis in all areas regardless of whether or not welds were located near the area of the analysis. The yield strength used for analysis was determined from a lo-inch (254 mm) extensometer spanning a transverse butt-weld joint. The yield strength indicated by the extensometer data is closely representative of an effective panel yield strength and has been adopted for usage by the Aluminum Association. This yield strength has also been substantiated by panel testing, When actual extensometer data were used for predicting panel buckling strength, the predicted values closely approximated the actual values, being one to six percent below the actual strengths.

(U) The basic ship structure would be fabricated in twenty (20) major structural assemblies including two (2) stabilizer fins (P&S) and the mast. All fabrication, subassembly, and assembly of the structures, from receipt of plate and extrusion until the assemblies are ready to be transported to a building basin for erection, would be performed indoors in a controlled environment. A 139,000 feet^2 (12,913.5 m^2) Marine Assembly Facility would be required. Operations have been planned and sequenced to maximize down-hand and automatic welding such that no overhead welding is required prior to erection of the hull structure. Final assembly and erection would be accomplished outdoors in a building basin. Overhead welding required during erection would be less than two (2) percent of the total lineal footage of welding on the ship.

(U) Erection of the hull in the building basin would proceed from the stern forward. This erection sequence was selected after reviewing outfitting density and erection sequences to determine that sequence which provides the longest possible span for the highest density area of the ship with respect to outfitting and system testing,

(U) 2.3.1.2 Structural Arrangement -- The drawings that define the far term SES structure are contained in appendix B, Section B.2. The following drawings are included:

- o Main Deck Plating
- o Longitudinal Bulkhead
- o Transverse Bulkheads
- o Transverse Frame

(U) 2.3.1.3 Key Structural Features -- Outstanding characteristics of the far term SES include the size and shape of the hull, seal interface, and structural arrangement of primary memebrs. The design is characterized as an exceptionally clean ship with smooth flowing lines.

(U) The functional design of the ship provides minimum air turbulence for helicopter operations while the minimum motion characteristics of the ship enhance the ability of helicopters to take-off and land,

(U) The physical constraints of the hull structure require that the craft have a beam of 108 feet (32.92 m) or less, a full load displacement of approximately 3600 tons (35,870 kN), and be capable of housing all required subsystems. Physical dimensions developed from parametric trade-offs established the following dimensions:

- Overall length of 266 feet 3 inches (81.15 m)
- Wet deck height of 18 feet (5.49 m)
- Wet deck ramp angle of 13.7 degrees
- Minimum main deck height of 40 feet above keel (12.19 m)

(U) The internal geometry of the hull structure was optimized with respect to the following, as illustrated in Figure 2.3.1-l:

- Stiffener spacing of 10 inches (0.25 m)
- Frame spacing of 3 feet (0.91 m)
- Transverse bulkheads spaced at 42 feet (12.80 m) intervals (aft bulkhead at 30 feet (9.14 m))
- Longitudinal bulkheads at approximately 14 feet (4.27 m) spacing
- Between deck height of 9 feet (2.74 m)
- Third deck height above keel - 22 feet (6.71 m)
- Second deck height above keel - 31 feet (9.45 m)
- Main deck height above keel - 40 feet (12.19 m)
- 01 deck at 49 feet (14.54 m)
- 02 deck at 60 feet (18.29 m)

(U) 2.3.1.4 Structural Weight Breakdown -- The structural weight breakdown of the hull and superstructure is shown in Table 2.3.1-1:

Table 2.3.1-1 (U) Structural Weight Breakdown (U)

SWBS SUBGROUP	WEIGHT			
	LT	kN	*	% of total
Shell Pl & Trans Fr	436.42	4348.5	443.35	46.1
Long & Trans Bkds	165.54	1649.4	168.17	17.5
Decks	184.01	1833.5	186.93	19.4
Superstructure	29.70	295.9	30.17	3.1
Struct Closures	19.10	190.3	19.40	2.0
Mast	2.78	27.7	2.82	0.3
Foundations	110.16	1097.6	111.91	11.6
TOTAL	947.71	9442.9	962.75	100.0

* non-SI metric tons

(U) 2.3.1.5 Structural Technical Risk **Assessment** -- The hull of the far term SES is designed to realistic worst case loading conditions which are forecast to occur within the ship lifetime. These structural loads were obtained from an extensive Rohr **2KSES/3KSES** model testing and analytical loads development program. The **structural** materials are primarily commercially produced aluminum alloys which have been utilized in existing Navy ships, such as the PHM and SES **100B.** The baseline design configuration features conventional built-up plate-stiffener combinations, a conventional ship framing system, and state-of-the-art welding and producibility details to **minimize** construction problems, Consequently, structure of the far term SES is producible, competitive with respect to cost, and represents an optimum design configuration for **performance** of the specified mission.

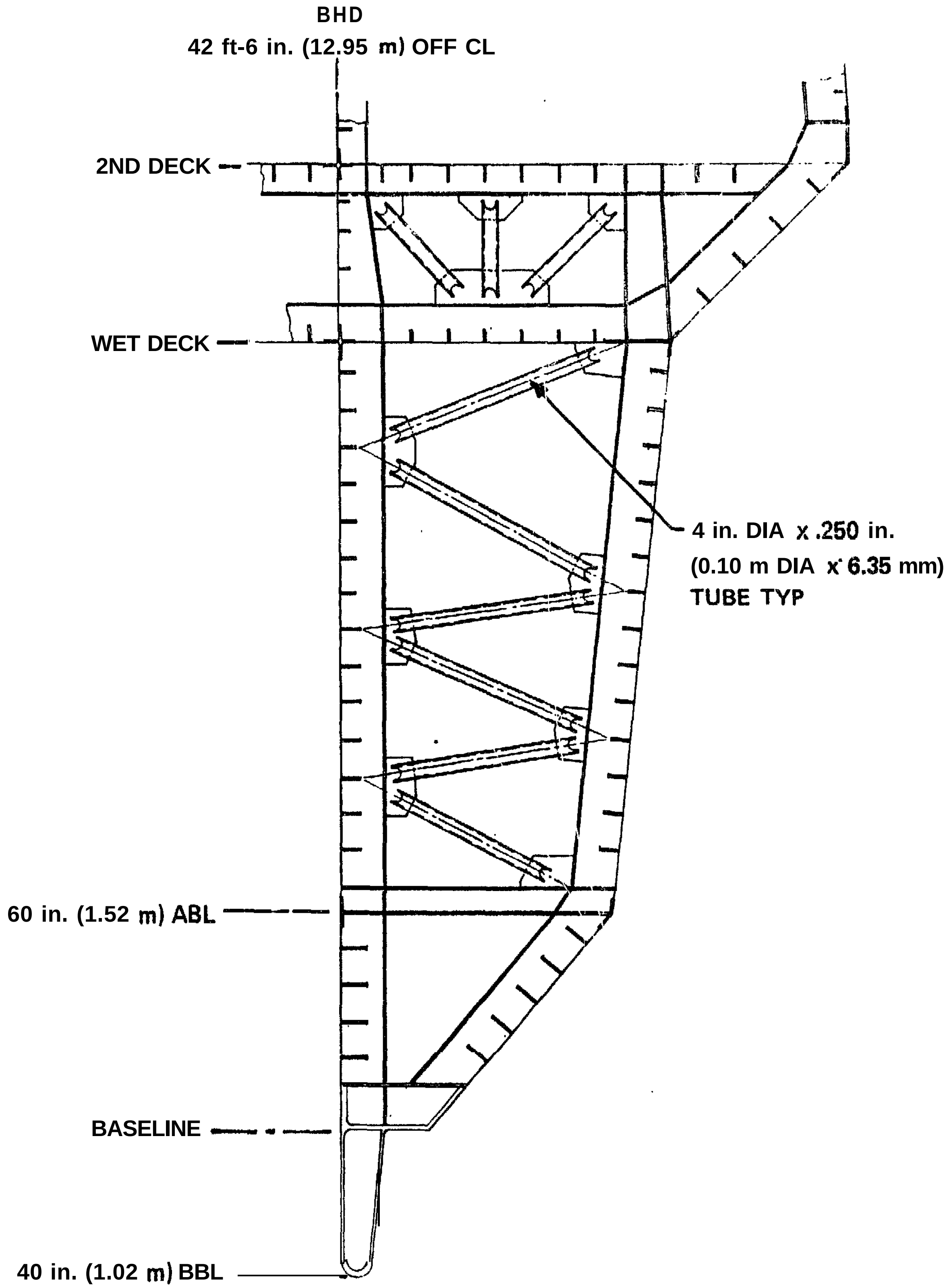


Figure 2.3.1-1 (U). Truss Concept at Sidehull - FR 15 & Aft (U).

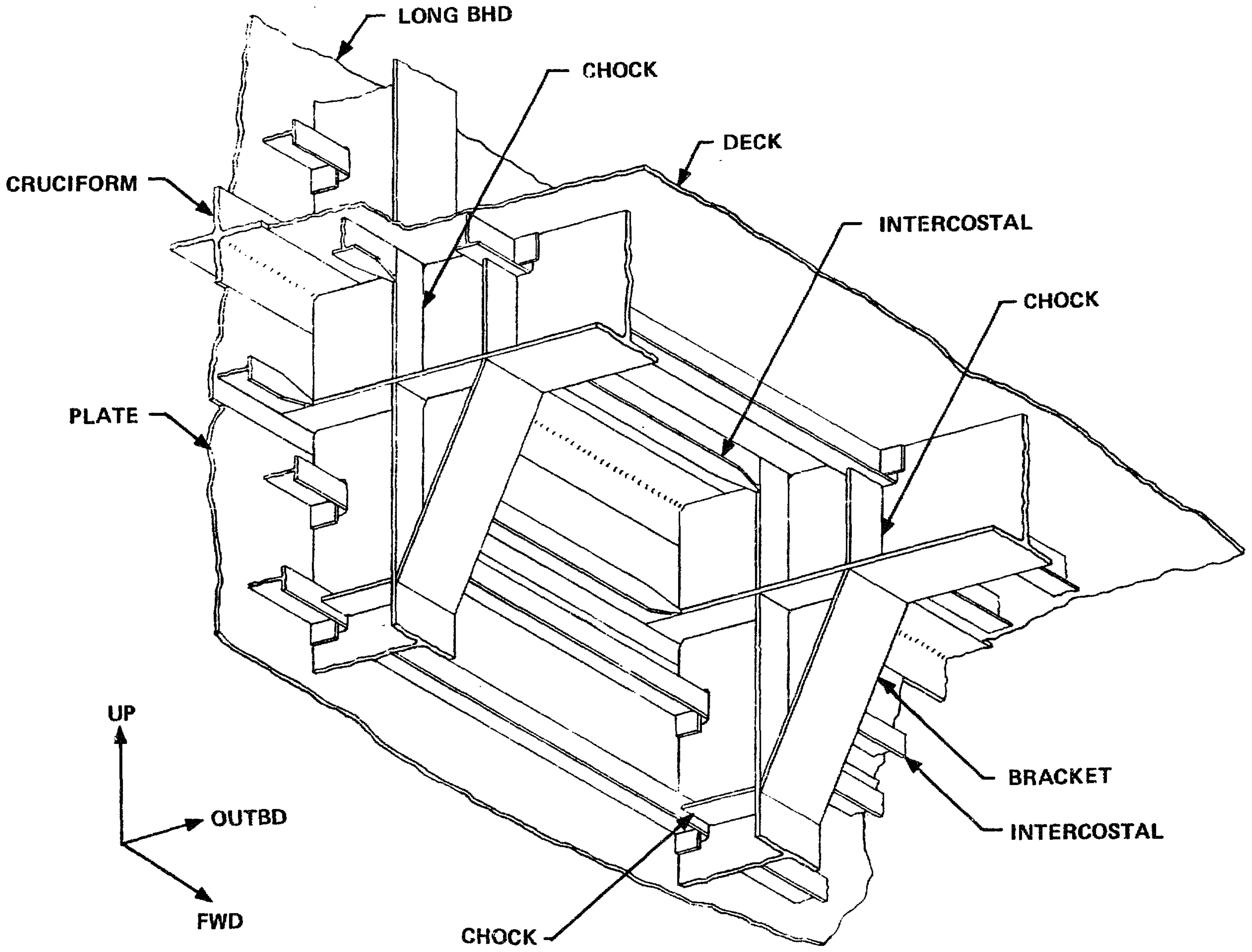


Figure 2.3.1-2 (U). Near Term Frame Joint Example (U).

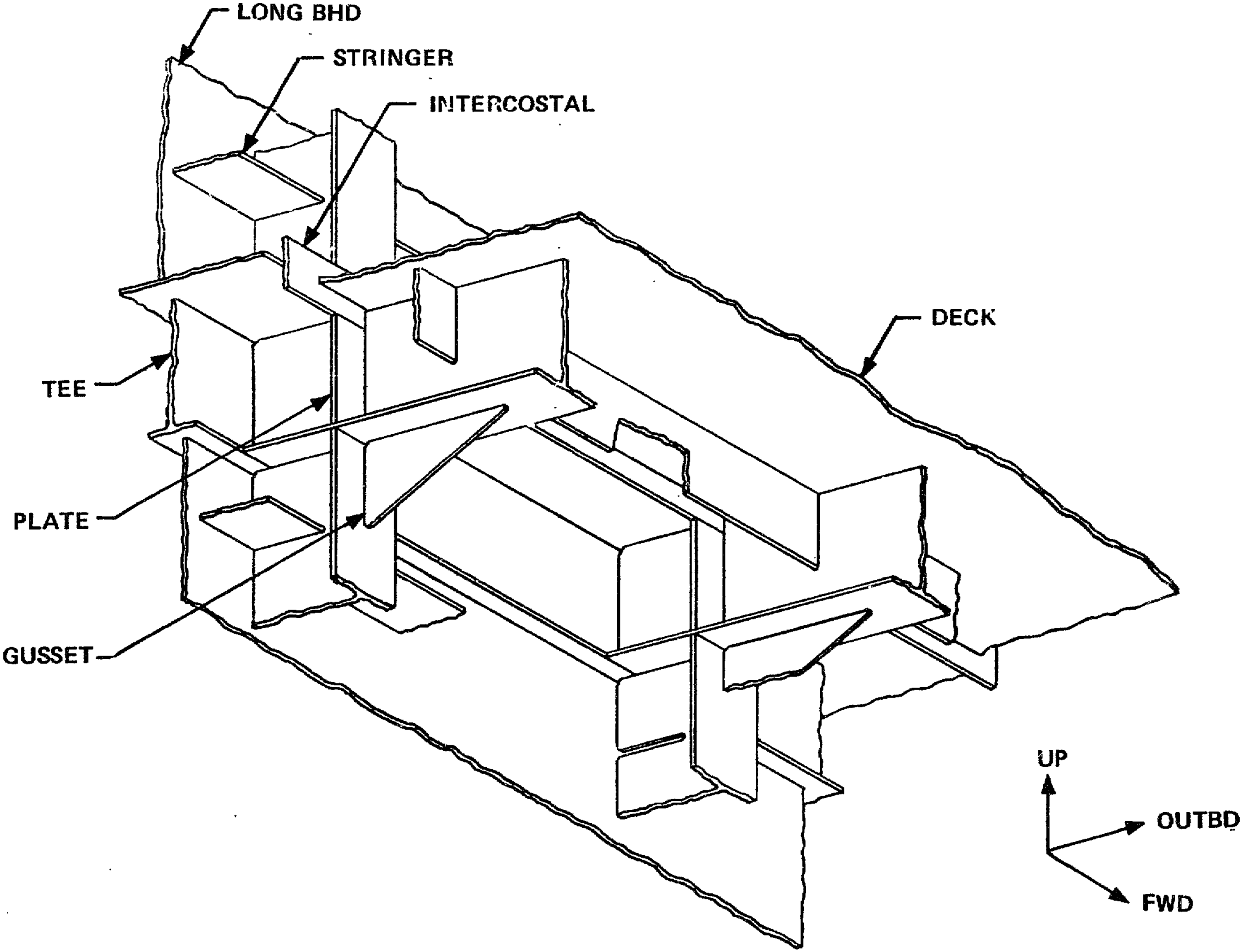


Figure 2.3.1-3 (U). Far Term Frame Joint Example (U).

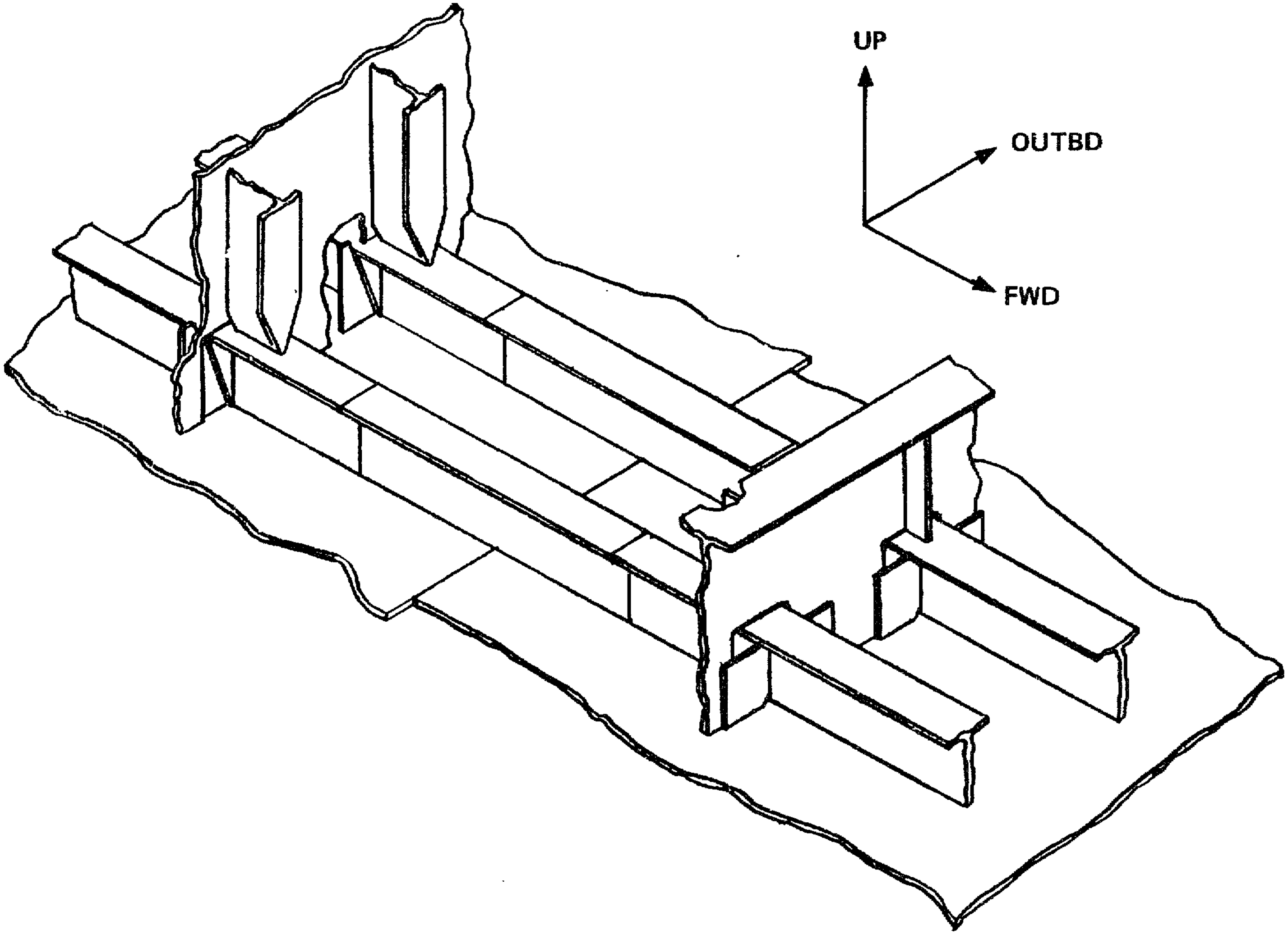


Figure 2.3.1-4 (U). Near Term Tee Stringer U).

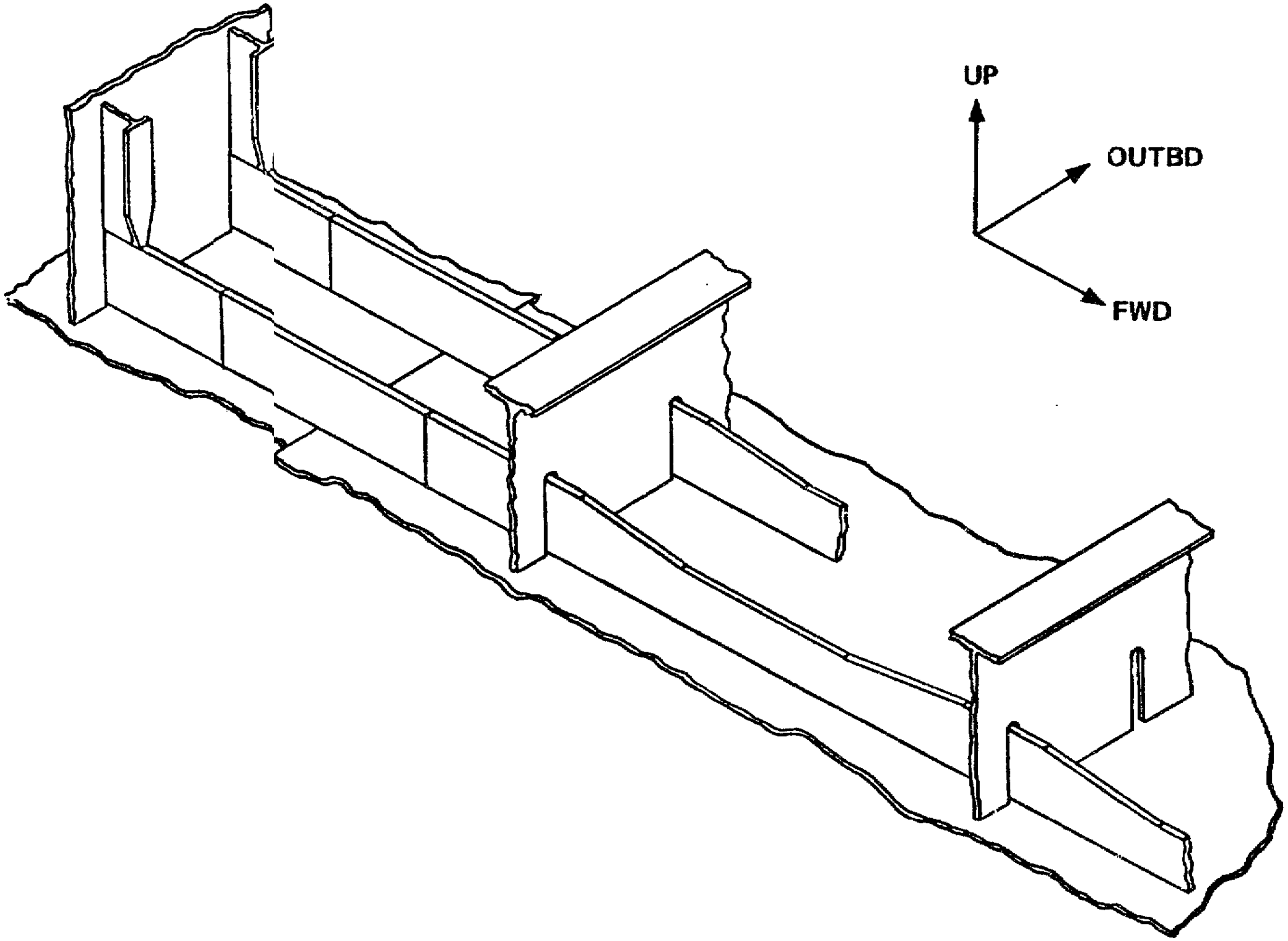


Figure 2.3.-5 (U). Far Term Haunched Flat Bar Stringer (U).

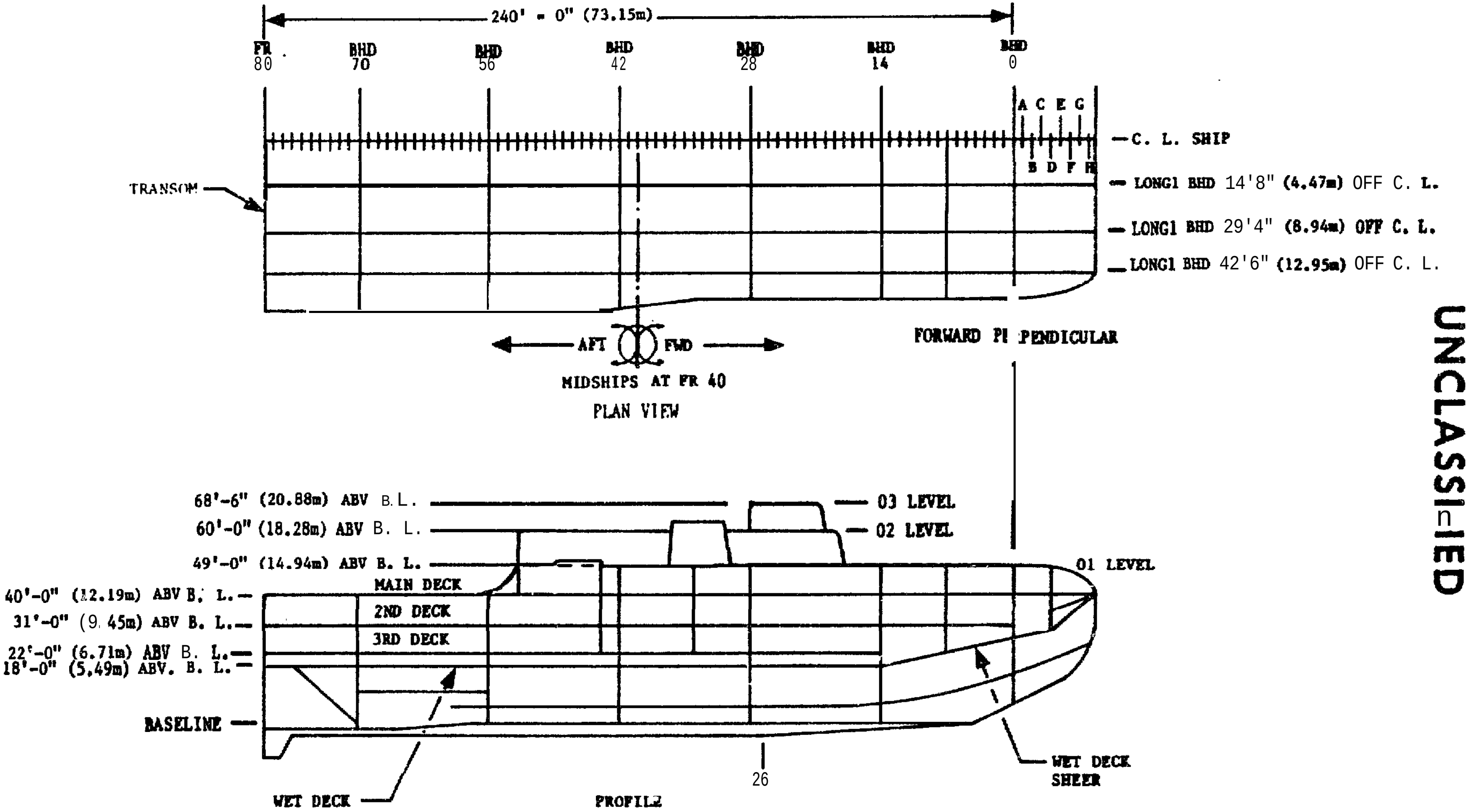


Figure 2.3.1-6 **(U)** Far Term SES Structural Arrangement **(U)**

(U) 2.3.2 PROPULSION -- The far term SES is powered by a **waterjet** propulsion plant. Its principle is the conversion of that mechanical energy supplied by the gas turbine-driven **waterjet** pumps into kinetic energy, by increasing the velocity of the seawater inducted at the water jet seawater inlets and ejected through the **waterjet pump** exit **nozzles.** The general arrangement is shown on Figure 2.3.2-l.

(U) The SWBS breakdown of the propulsion plant is:

- Gas turbine system (234)
- Transmission system (242, 243, 244)
- **Waterj** et propulsor system (247)
- Combustion air intake system (251)
- Exhaust gas uptake system (259)
- Lube oil system (262)

(U) 2.3.2.1 Summary Description

(U) **2.3.2.1.1** Gas Turbine System -- A total of four (4) gas turbines, each driving a **waterjet** propulsor, are utilized in the far term SES propulsion plant. The four (4) turbines are arranged in pairs of two (2): one (1) pair is located on the starboard side of the ship and the other pair is located on the port side. Each gas turbine is operationally independent of the others.

(U) The baseline propulsion gas turbine for the far term SES is the LM5000 gas turbine, each of which is capable of delivering 50,000 continuous shaft horsepower (37,284 kW), and 60,000 **intermittent** shaft horsepower (44,741 kW).

(U) The LM5000 marine gas turbine is derived from the CF6-50 commercial turbofan engines used on the DC-10-30, A300B and B747 aircraft. The LM5000 also uses technology derived from the design and operation of its predecessor, the LM2500 marine gas turbine presently in service with the U. S. Navy on the DD 963 class destroyers. The LM5000 gas generator is a two-shaft design consisting of a five-stage low pressure (LP) compressor; a fourteen-stage high pressure (HP) compressor; an annular axial swirler combustor; a two-stage air cooled HP turbine; a single-stage LP turbine; coaxial shafts and associated gearboxes controls and accessories. The LM5000 power turbine has three stages and is a low stress design.

(U) 2.3.2.1.2 Transmission System -- This system consists of the propulsion shafting, shaft flanges, shaft bearings with mounting structure, flexible couplings and torque meters, Each of the four transmission systems connect a propulsion gas turbine to a waterjet propulsor reduction gearbox input flange. The shaft, flanges, bearings, seals and bearing housing form the shaft/bearing module which is installed (or replaced) as a unit. Figure 2.3.2-2 illustrates the arrangement, The reduction gearbox is described in the waterjet propulsor system description.

(U) 2.3.2.1.3 Waterjet Propulsor System -- The waterjet propulsor system consists of the integral reduction gearboxes and waterjet pumps, instrumentation, mounting links, steering sleeves with hydraulic actuators, waterjet pump inlet flex joints, thrust reversers with hydraulic actuators, transom flexible seals, waterjet pump priming systems, attached lube oil pumps with minor lube oil system components and piping, seawater inlets, seawater intake diffusers and bifurcated ducts. A nozzle closure valve and a thrust bearing are contained within each waterjet pump. A shaft brake is attached to each reduction gearbox.
reduction gearbox.

(U) Each reduction gearbox (four (4) total) contains necessary gearing to reduce the input speed and divide the power between the two (2) waterjet pump rotors which run at different speeds. The propulsor assembly gearbox details and gear train are shown in Figures 2.3.2-3 and 2.3.2-4.

CU) 2.3.2.1.3.1 **Waterjet** Propulsor Assembly -- The **waterjet** propulsor is a two-stage, two-speed design based on the hydraulically similar **PHM** and **3KSES** propulsors. The first stage is an inducer designed to produce a sufficiently high head rise at low suction (cavitating) conditions to permit the second stage impeller to operate at high rotation speeds without cavitation, The power split between the inducer and impeller is approximately **30:70.** The inducer rotates at about **1/4** engine speed, the impeller at about double this. The propulsor assembly is shown in Figure 2.3.2-5.

(U) 2.3.2.1.3.2 **Waterjet** Inlet -- Seawater for the four (4) **waterjet** propulsars is taken **aboard** through two fixed area, round duct inlets as shown in Figures 2.3.2-6 and 2.3.2-7. One inlet in each **sidehull** serves the two **waterjet** pumps also located in each sidehull. The sidehulls are enlarged through **fairings** from their nominal cross-sections to accommodate the inlets.

(U) The round duct, fixed area inlets are the result of weight, performance, and drag force trade-offs. The new inlets have the advantages of no moving parts, actuators, and no flexible roof or lip mechanisms, The inlets will perform adequately at all ship environmental conditions and operate within the cavitation limit boundaries defined by various combinations of speed, power, and induced failure modes. The **waterjet** inlet duct contains an abrupt expansion at the juncture of the end of the diffuser with the bifurcated duct section. The abrupt expansion is the result of trade-offs of curved diffuser losses vs abrupt expansion losses with the associated weight considerations.

(U) The water flow through each **sidehull** inlet passes into the diffuser section of the inlet duct and is distributed through a duct bifurcation of the two pumps. Water flows through the inlets by combination of pump action and ship forward motion, at a rate determined by the ship and pump speed. The curved diffusers then turn and raise the water to the pumps through the bifurcated ducts. An abrupt expansion is used at the

(U) entrance to the bifurcated ducts. Each bifurcated duct is constant area, symmetrical and has integral turning vanes.

(U) The waterjet inlet geometry with round ducts and circular arc inlet lips is based on aerodynamic test results that are reported in Program Extension Task (PET) No. 8.1 of the PET Final Report now published (see section A.5.11). Further testing for drag forces, cavitation effects, and recovery performance will be accomplished by hydrodynamic tests now planned for completion within the first 12 months of the 3KSES contract.

(U) 2.3.2.1.3.3 Steering and Reverser System -- Each waterjet propulsor has an associated steering sleeve and the two outboard propulsors have thrust reversers. The discharge water from each pump's single fixed-area nozzle passes coaxially through a flexible seal at the transom, and subsequently through a swiveling steering sleeve mounted on the transom. The steering sleeve deflects the waterjet to generate side forces on the ship. Each sleeve is hydraulically actuated, utilizing the ship hydraulic system,' and is instrumented to permit position monitoring.

(U) The thrust reversers direct the waterjets in a forward direction. In operation, they are pivoted into the water streams by controllable position actuators. During reverse thrust operation, the high-velocity water is redirected forward, down, and slightly outboard to minimize spray and hazard to aearby objects. The thrust reversers are variable position to give full forward through full reverse thrust on the outboard waterjets.

(U) 2.3.2.1.4 Combustion Air Intake System -- The intern21 configuration of the combustion air intake system and the location of the demister banks, acoustic panels, gas turbine plenums, air heating system, and external opening of the air inlet area shown in Figure 2.3.2-8. A section of a potential demister development (charged droplet scrubber) is sketched in Figure 2.3.2.9. The features of the intake design which reduce salt spray are the coaming projecting above the 01 level; the vertical portion of the intake which requires the air to turn 90 degrees to enter the demister banks; and the-drainage sump at the third deck level.

(U) The intake contains sound supression panels in three locations to attenuate engine noise to acceptable levels. The panels in the section between the 01 level and main deck are comprisedof six inch (0.15 m) spaced perforated panels, installed in the athwartship direction. Thin aluminum splitters between the panels form six inch (0.15 m) rectangular ducts.

(U) Anti-icing, de-icing, and pre-heating of the intake system for the engines is accomplished by recirculation and mixing of lift engine exhaust gas at the weather inlet on each side of the ship, as is shown schematically in Figure 2.3.2-9, Each combustion air intake system supplies air to one lift engine, two propulsion engines, gas turbine generators, and the gas turbine cooling systems.

(U) 2.3.2.1.5 Exhaust Gas Uptake System -- This system consists of the exhaust ducts (including supports and insulation) which are routed from the propulsion gas turbines to the transom, where the combustion products are exhausted: The design incorporates a water trap at the transom to provide stern wave protection. Each exhaust duct is acoustically treated to attenuate noise and insulated to protect surrounding structure.

(U) 2.3.2.1.6 Propulsion Lube Gil System -- This system provides lubrication for the bearings in the transmission system and for the waterjet propulsor assembly. The reduction gear system is of the dry sump type and carries driven pressure and scavenge pumps. The lube oil system upstream of the mechanically driven pressure pump, and downstream of the mechanically driven scavenge pump, is defined as the propulsion lube oil system. Each propulsion drive train has its own dedicated propulsion lube oil system (four total). The lubricant used is 2190 TEP per MIL-L-17331 (although synthetic oil requires further consideration in detail design to provide commonality with the engine oil, to reduce maintenance, and further simplify the design).

(U) 2.3.2.1.7 Propulsion System Condition Monitoring and Fault Isolation -- The propulsion system will be condition monitored with an automated sensing and display system. Changes in measured propulsion component parameters (engine, pump, gearbox, etc.) are related to changes in component performance which are caused by physical propulsion component faults such as erosion, corrosion, fouling, dirt build up, foreign object damage, worn seals, excessive tip clearance or plugged fuel nozzles. Comparison of performance in real time values to the baseline data provides short term monitoring and subsequent out-of-limits conditions. If a parameter exceeds a normal level limit, all parameters associated with the out-of-limit condition will be recorded and displayed. Additionally, by tape recording the changes in parameters at set intervals, an off line time plot of long term changes is established which provides prognostication (trending) capability. The condition monitoring and fault isolation system is applied to all critical propulsion system components,

(U) 2.3.2.2 Operation

2.3.2.2-I Start-Up -- The gas turbine propulsion engines are pneumatically started from the electrical system gas turbine generator which provides compressed air for starting one engine. The start air system cross connects all propulsion and lift engines; any one engine can start another by supplying bleed air from its compressor into the system. The start control sequence is automatic but manual start controls provisions are provided for back up. Each gas turbine engine can be started and ready to deliver power in approximately 90 seconds.

(U) The waterjet propulsors are above the ship off-cushion waterline and thus require priming. Priming is accomplished in these successive steps: apply transmission brake to prevent rotation of the dry pump; shut nozzle closure; supply auxiliary water to rubber bearings; operate the air ejector that connects to both pump pairs; and when pumps are primed, water then covers the pump inducer centerline.

(U) The brake is then released and the pump rotated enough to produce a static head of about 15 feet (4.57 m) H_2O. When the nozzle closure is opened, the pump begins to deliver water, the ejector system and auxiliary water supply are shut off and the priming is completed. The features of the priming system are shown on Figure 2.3.2-10.

(U) 2.3.2.2.2 Low Speed -- Low shfp speed operation of the propulsion plant requires the ship to be in the off-cushion mode to reduce the possibility of broaching which could unprime the propulsors. Additionally, with the ship off-cushion, inlet head to the pump inducer is maximized to reduce suction specific speed. The steering sleeves and reverser may be configured to give low speed forward, astern, turning and sway translation of the ship for undocking and maneuvering in a seaway. The power level is limited by the suction specific speed limit of the propulsors to reduce possible cavitation erosion of the pump components.

(U) The seals are extended to a height/speed schedule when above 10 knots (5.14 m/s) ship speed to avoid operation at high pump suction specific speeds.

(U) 2.3.2.2.3 Hump Transition -- Hump transition requires the use of high power settings and, in the case of a heavily loaded ship and/or high sea state, may require use of the intermittent power level to produce the desired margin of thrust over drag. Suction specific speed limitations are not present at trans-hump speeds.

(U) Ship heading control will require use of a combination of differential thrust, asymmetrical throttle settings on the propulsion engines, and thrust vector control with the steering sleeves. The ship's control system automatically determines the required combination and the mix of control forces that provides heading control with minimum fuel consumption.

(U) 2.3.2.2.4 High Speed **Cruise** -- At cruise conditions, throttle settings for steady state **conditions** are maintained by the propulsion control system,

(U) 2.3.2.3 Machinery **Characteristics** -- The machinery characteristics are presented in Tables 2.3.2-l through 2.3.2-4.

(U) 2.3.2.4 Arrangements -- The drawings and sketches **depicting** the far term SES propulsion system are contained in Section 2.3.2.1.

(U) 2.3.2.5 Propulsion System Weights -- Weights within the propulsion system SWBS 200 are shown in **Table** 2.3.2-5.

(U) 2.3.2.6 **Propulsion** System Technical Risk Summary -- The propulsion system is projected to perform safely with high confidence and minimum risk. The following are supporting statements.

(U) Engines -- The **GE LM5000** gas turbine engine is derived from the **CF6-50** commercial gas turbine and uses technology from the **LM2500** marine gas turbine currently in service with the U. S. Navy. The **LM2500** itself was derived from the TF39 military gag **turbine** and the **CF6** commercial gas turbine.

(U) Transmission -- The propulsion transmission system is designed to transmit all anticipated alternating and continuous torques between the propulsion engine and the propulsor assembly without failure over a **20-year** life span with specified overhaul of the life limited components; to have not more than 10 percent failures prior to the scheduled overhaul period of 5,000 hours minimum (10,000 hours goal) for the life limited components; to withstand a limit torque of **1,612,590** inch pounds (182.198 **kN.m) without** degradation of performance or failure; and to eliminate any critical speed (of any component) **which** is less than 125 percent of the system maximum operating speed (4,690 **rpm).**

(U) Waterjets -- The propulsor is hydraulically similar to the PHM pump now in operation. Comprehensive model tests have already been successfully conducted for the 40,000 SW (29,828 kW) propulsor (for the 3KSES propulsor). The waterjet inlet has been extensively tested with models and with similar inlets of the operational SES-100A and XR-1 test-craft. The installation design of the waterjet propulsor assembly will withstand all anticipated input powers, thrusts and external loads due to ship accelerations and equipment malfunctions without failure for a 20-year design life and with specified overhaul. The waterjet seawater inlet duct system is optimized to improve performance, cavitation characteristics, drag and structural weight on the basis of substantial analysis and model testing.

(U) The propulsion lube oil system, combustion air intake system, and exhaust gas uptake system are typical of present gas turbine ship installations. All components are presently available and proven in service. For the combustion air inlet, anti-ice protection by exhaust gas mixing is the accepted method of General Electric, Pratt and Whitney, and Garrett.

Table 2.3.2-1 (U). LM5000 Engine Characteristics (U)

Item	Characteristics	
Turbine Inlet Temperature - °F (°C)	2,400	(1,316)
Air Flow - lb/Sec (N/Sec)	305	(1,357)
Dry Weight - lbs (kN)	19,750	(8,965)
Compression Ratio at Max. rpm	31:1	
SFC - lb/hp.h (N/kWh)	.32	(1.91)
Max. Power at Sea Level - hp at 80°F (kW at 27°C)	60,000	(44,742)
No, of LP Compressor Stages	5	
No. of HP Compressor Stages	14	
No. of HP Turbine Stages	2	
No. of LP Turbine Stages	1	
No, of Power Turbine Stages	3	
No. of Combustors	1	
Combustor Type	Annular	
Length-inch (m)	328	(8.33)
Diameter (Max) - inch (m)	106	(2.69)

Table 2.3.2-2 (U) Reduction Gear and Transmission (U) Characteristics

ITEM	CHARACTERISTICS
Reduction Gear	
Speed (Max)	4690 rpm
Power (Max)	60,000 shp (44742 kW)
Weight (Dry)	9,900 lb (44.04 kN)
Length	76 inch (1.93 m)
Width	59.50 inch (1.51 m)
Lubricant	2190 TEP per Mil-L-17331
Gears	Double-Helical 9310 steel one-piece pinion and shaft welded gears.
Ratio	
First stage	4.359
Second stage	2.0508
Bearings	Journal, Babbit Lined
Gear Case	Cast Aluminum A356-T6
Transmission	
Length	138 inch (3.50 m)
Diameter	22 inch (0.56 m)
Bearings	Fwd - Duplex ball thinwall Aft - Roller thinwall
Shaft and Flanges	4340 forgings
Flexible Coupling	Double diaphragm+ 0.50 degree misalignment capability
Torquemeter	Acurex Strain type

Table 2.3.2-3 (U). **Waterjet** Propulsor Characteristics (U)

ITEM	CHARACTERISTICS	
Speed	4,690 rpm	
Power	60,000 shp	(44,742 kW)
Weight (wet)	22,703 lb	(100.98 kN)
Length	203 inch	(5.16 m)
Height	70 inch	(1.78 m)
Diameter	49.5 inch	(1.26 m)
Efficiency* (incls. transmission)	90%	
Headrise*	1,352 ft H_2O	(412.1 m H_2O)
Flow Rate*	152,376 gpm	(12.914 m^3/sec)
Gross Thrust*	204,698 lb	(910.496 kN)
Nozzle Diameter	17.52 inch	(0.45 m)
Speed Inducer*	1,076 rpm	
Speed Impeller*	2,287 rpm	
Suction Specific Speed Limit	30,000 at Inducer Centerline	

*Values at rpm and power quoted and total inlet head of 163.6 ft H_2O (49.9 m H_2O).

Table 2.3.2-4 (U). Waterjet Inlet (U)

ITEM	CHARACTERISTIC	
Width Forward of Lip	4 ft	(1.22 m)
Inlet Area of Lip	12.77 ft^2	1.186 m^2
Maximum Diffuser Area	14.80 ft^2	1.375 m^2
Lip Angle to Vertical	22 deg Forward at Top	
Lip External Angle	15.50 deg	
Drop Fraction	-0.06	
Bifurcation	Equal Legs with Turning Vanes	
Maximum Flow Rate	409,396 gpm	(25.828 m^3/s)

Table 2.3.2-5 (U). **SWBS** 200 Propulsion System Weights (U)

SWBS Subgroup	Weight			
	LT	kN	*	% of Total
Gas Turbines	39.57	394.2	40.20	18.6
Reduction Gears	17.68	176.1	17.96	8.3
Couplings	1.06	10.56	1.08	.5
Shafting	-1.79	17.83	1.82	.8
Shaft Bearings	0,90	8.97	0.91	.4
Waterjet Propulsors (Includes **waterjet** inlet)	42.33	421.73	43.00	19.8
Combustion Air System	28.33	282.25	28.78	13.3
Control System	0.46	4.58	0.47	.2
Uptakes	26.18	260.83	26.60	12.3
Fuel Service System	0.11	1.10	0.11	.1
Lube Oil System	3.80	37.85	3.86	1.8
Operating Fluids	50.60	504.13	51.39	23.7
Repair Parts	0.44	4.38	0.45	.2
TOTAL	213.25	2124.61	216.63	100.0

* non-SI metric tons

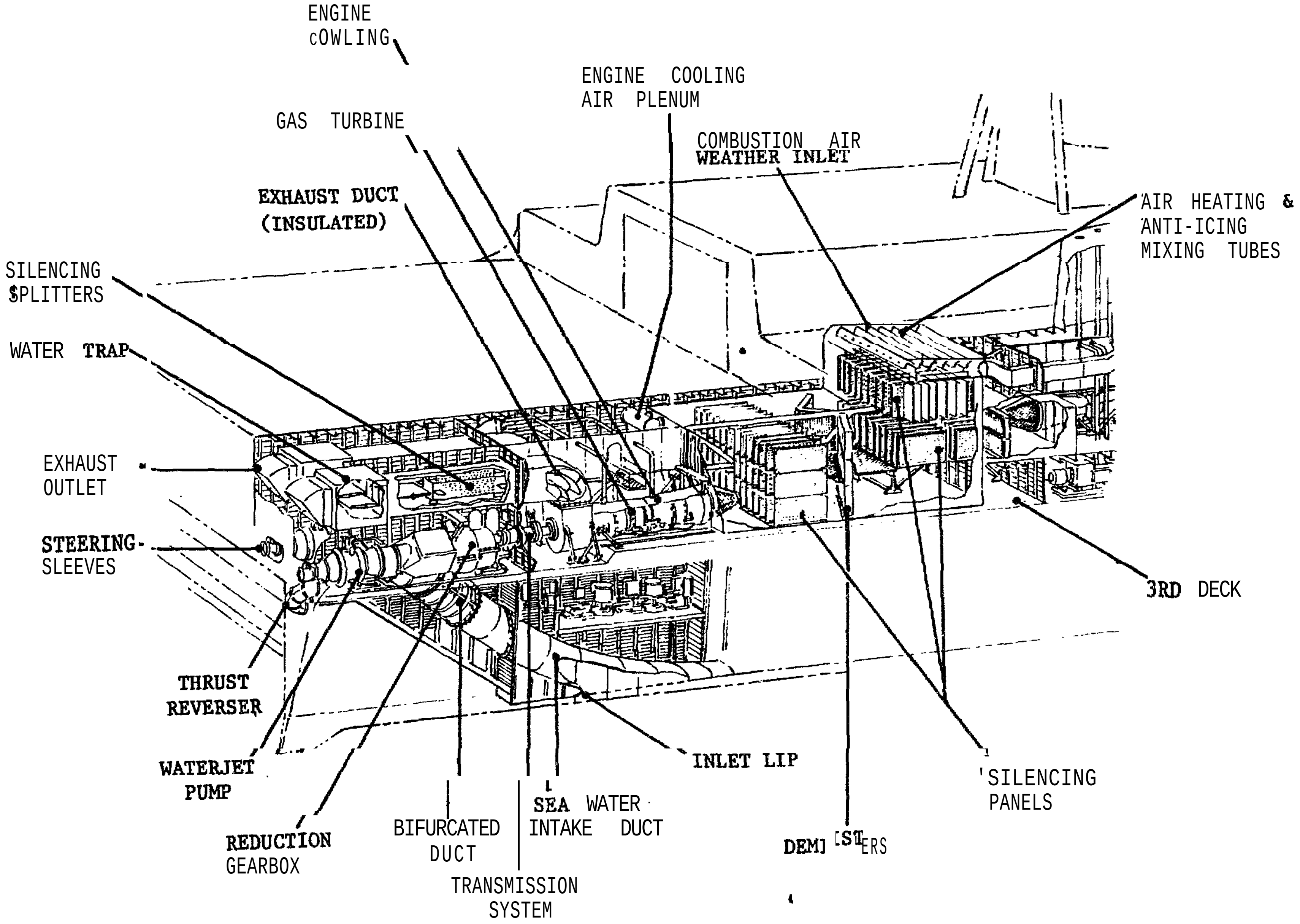


Figure 2.3.2-1 **(U):** Propulsion Plant General Arrangement, Starboard Side Only **(U)**

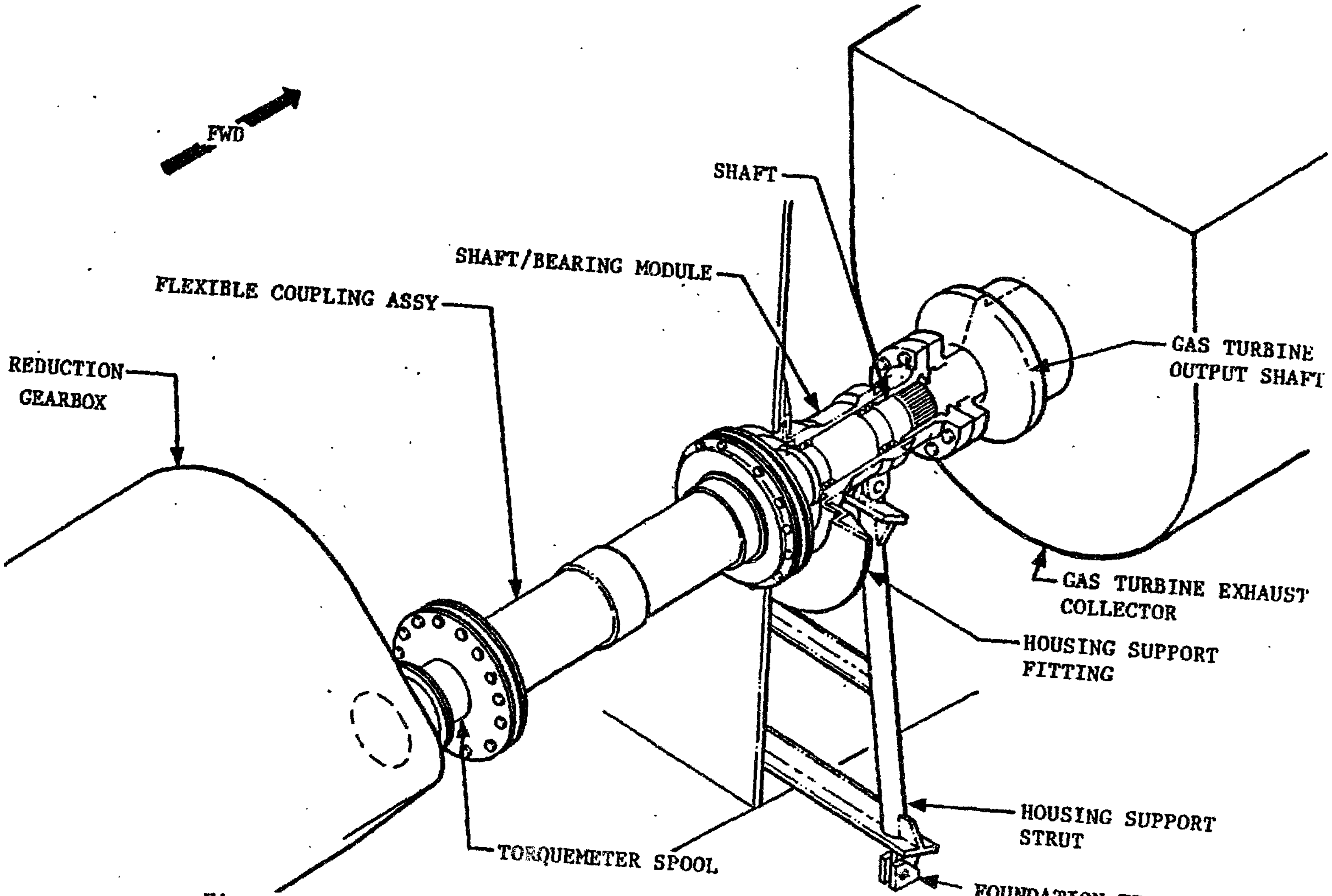


Figure 2.3.2-2. (U) Typical Propulsion Transmission System (U)

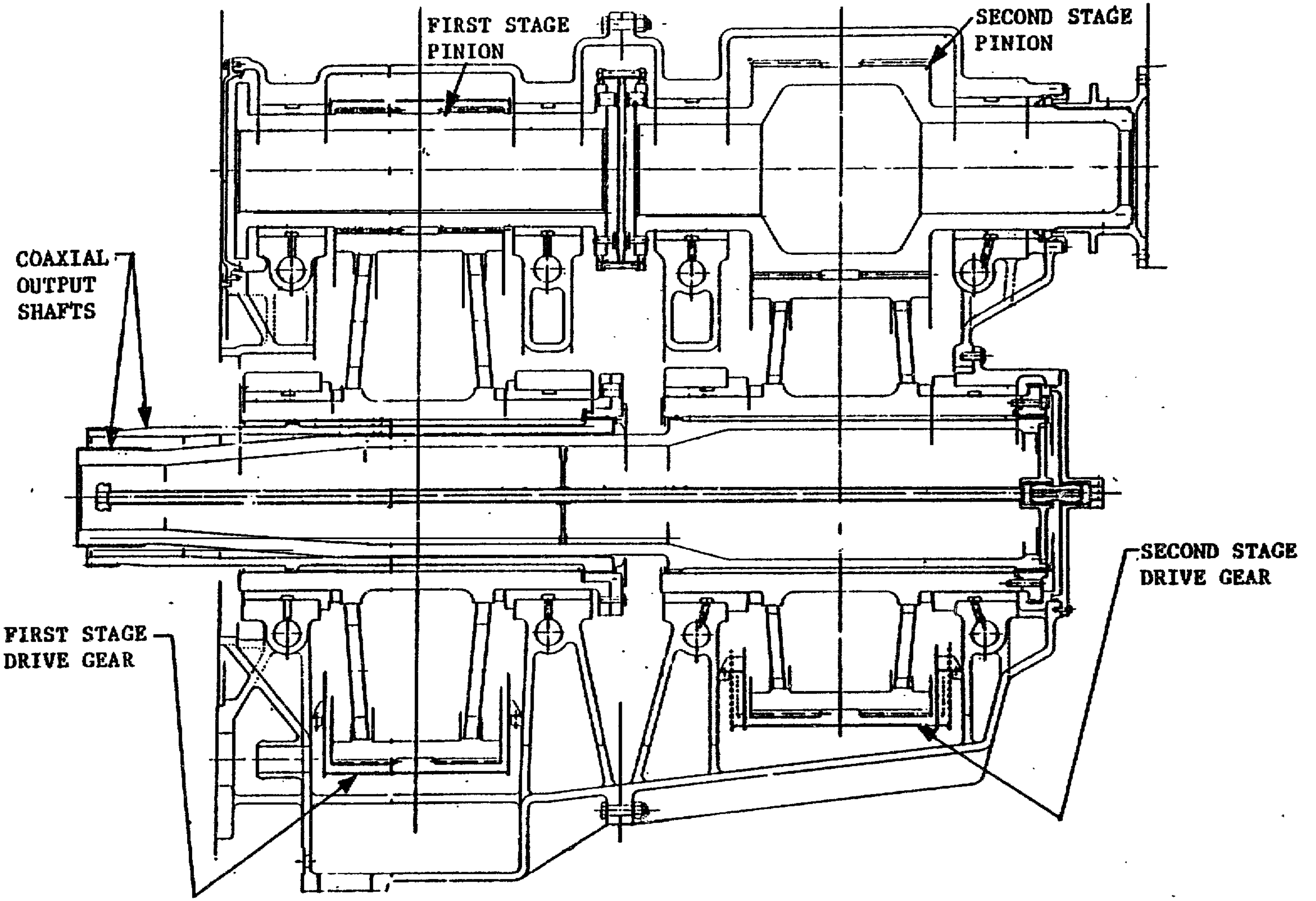


Figure 2.3.2-3. (U) Propulsor Assembly Gearbox Arrangement (U)

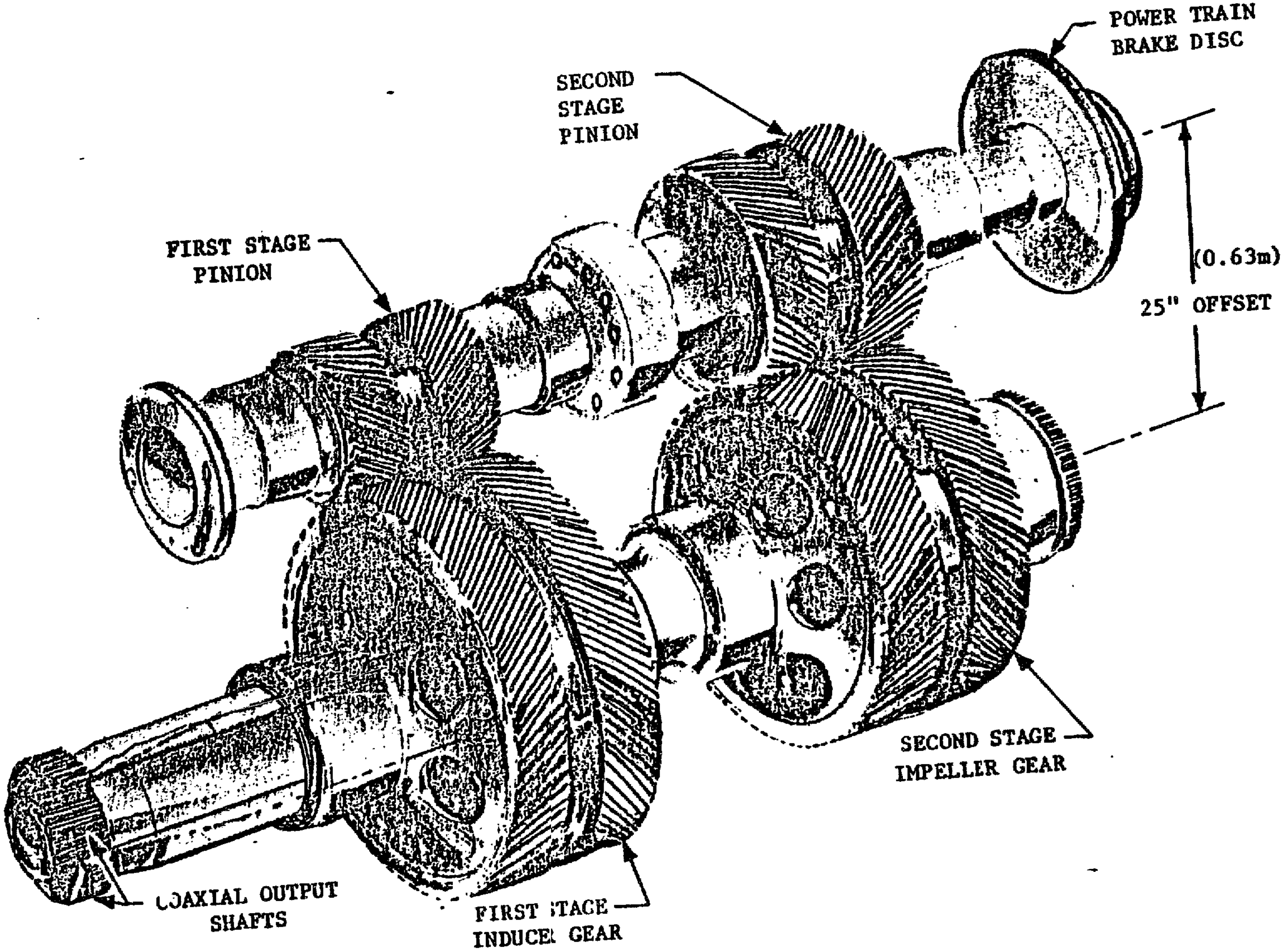


Figure 2.3.2-4 (U): Propulsor Assembly Gear Train (U)

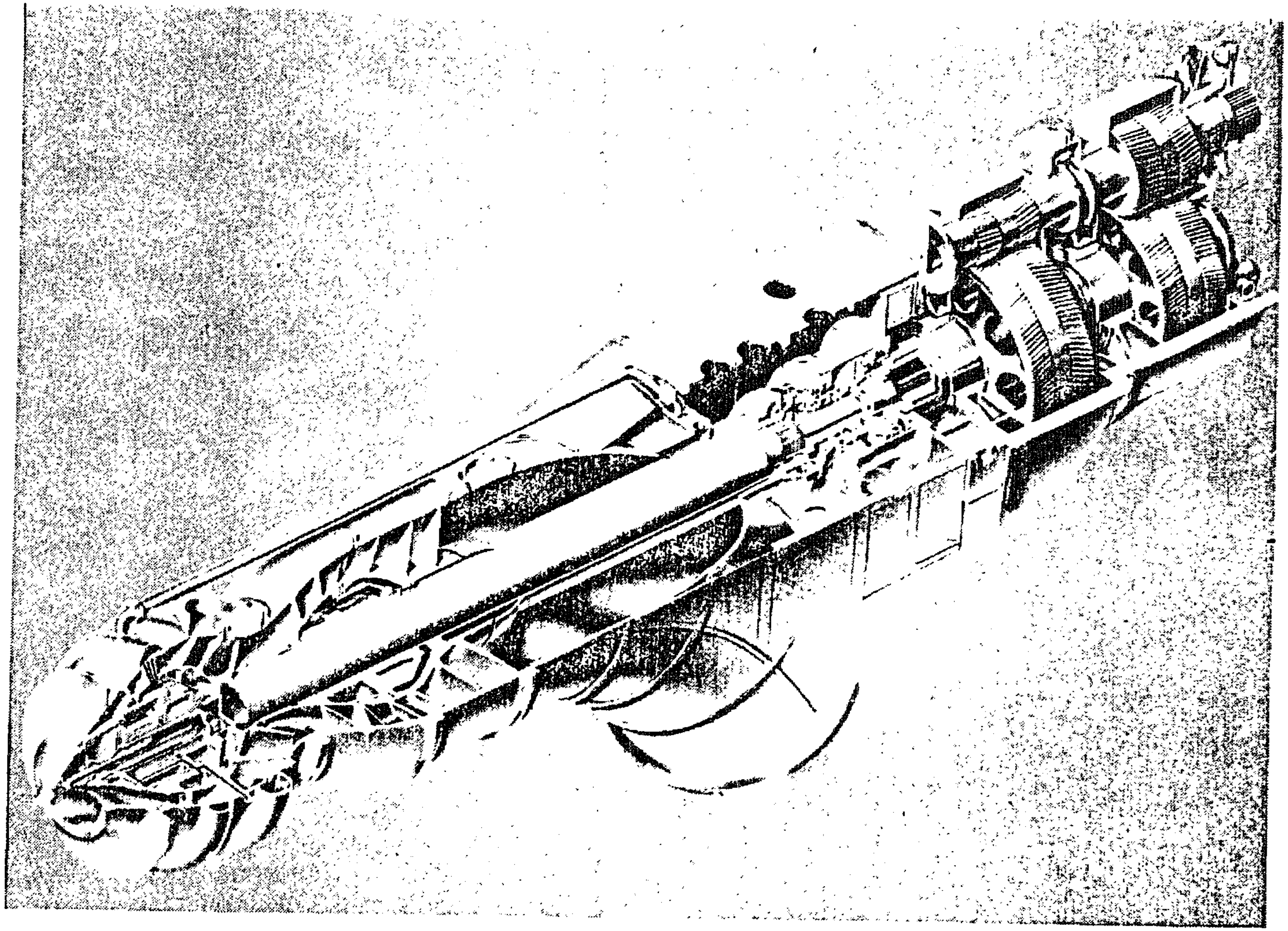


Figure 2.3.2-5 (U): Waterjet Propulsor Assembly U)

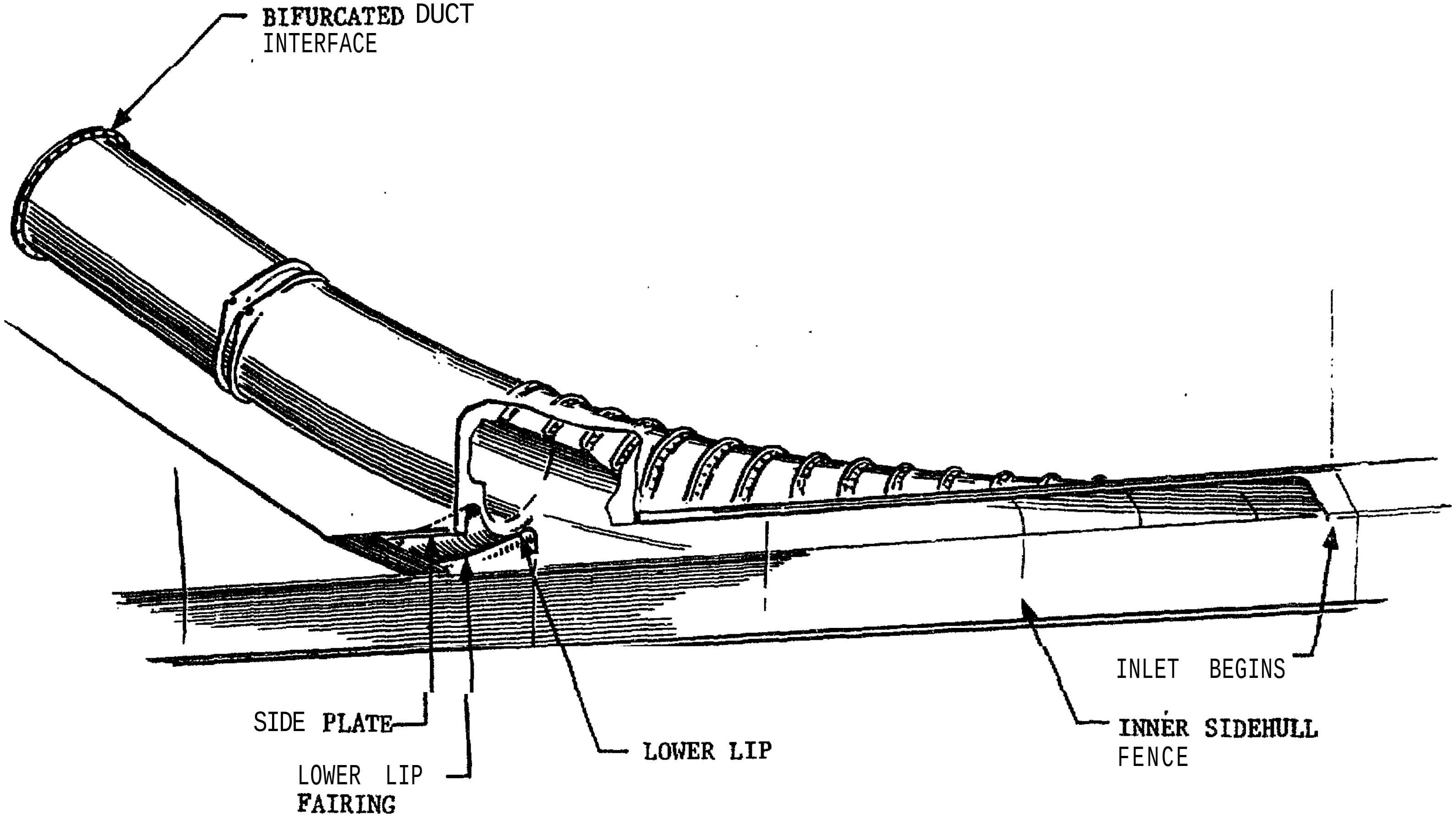


Figure 2.3.2-6 (U). Far Term SES Round Duct Waterjet Inlet (U)

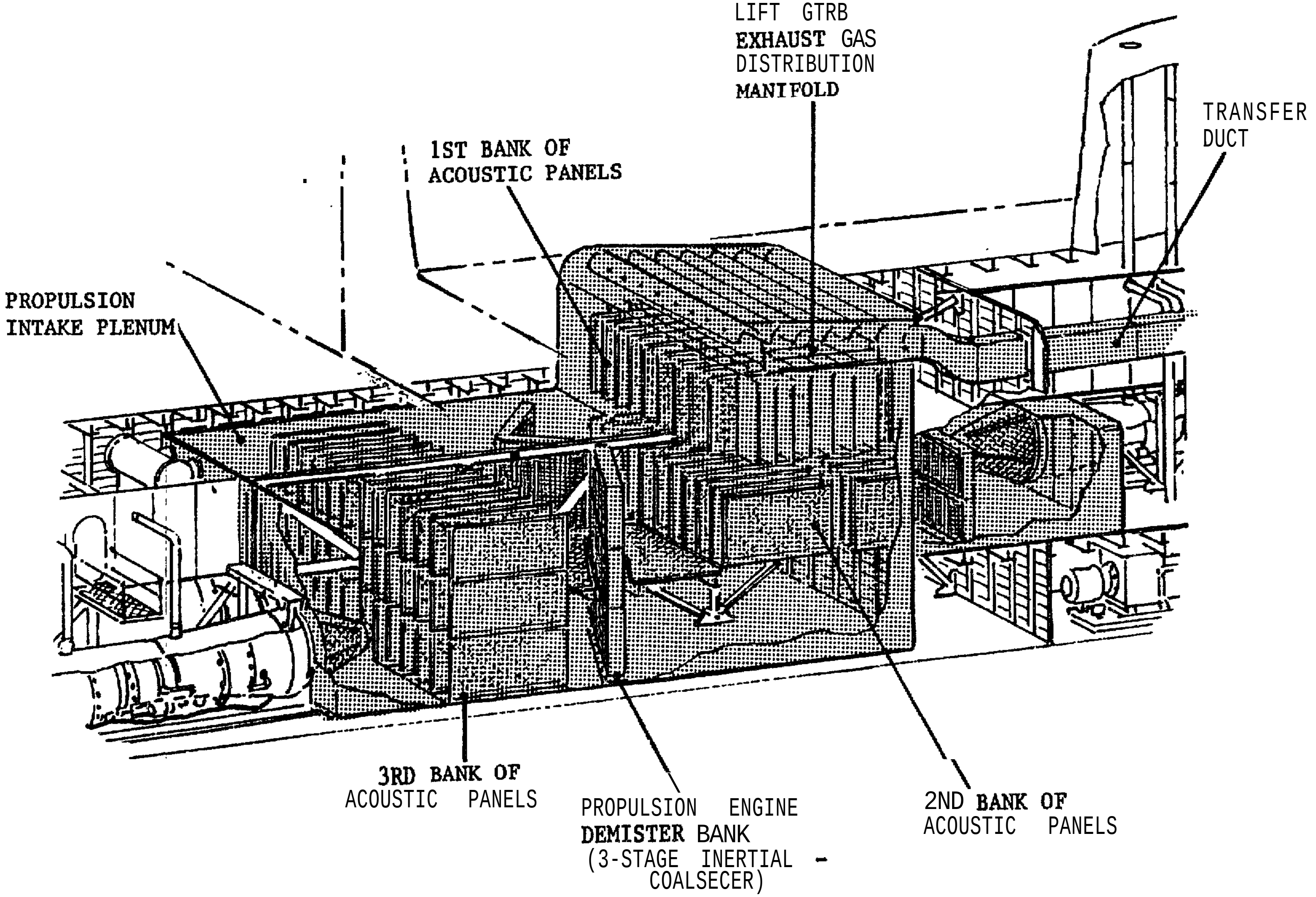


Figure 2.3.2-7 (U): Combustion Air Intake System Arrangement (U)

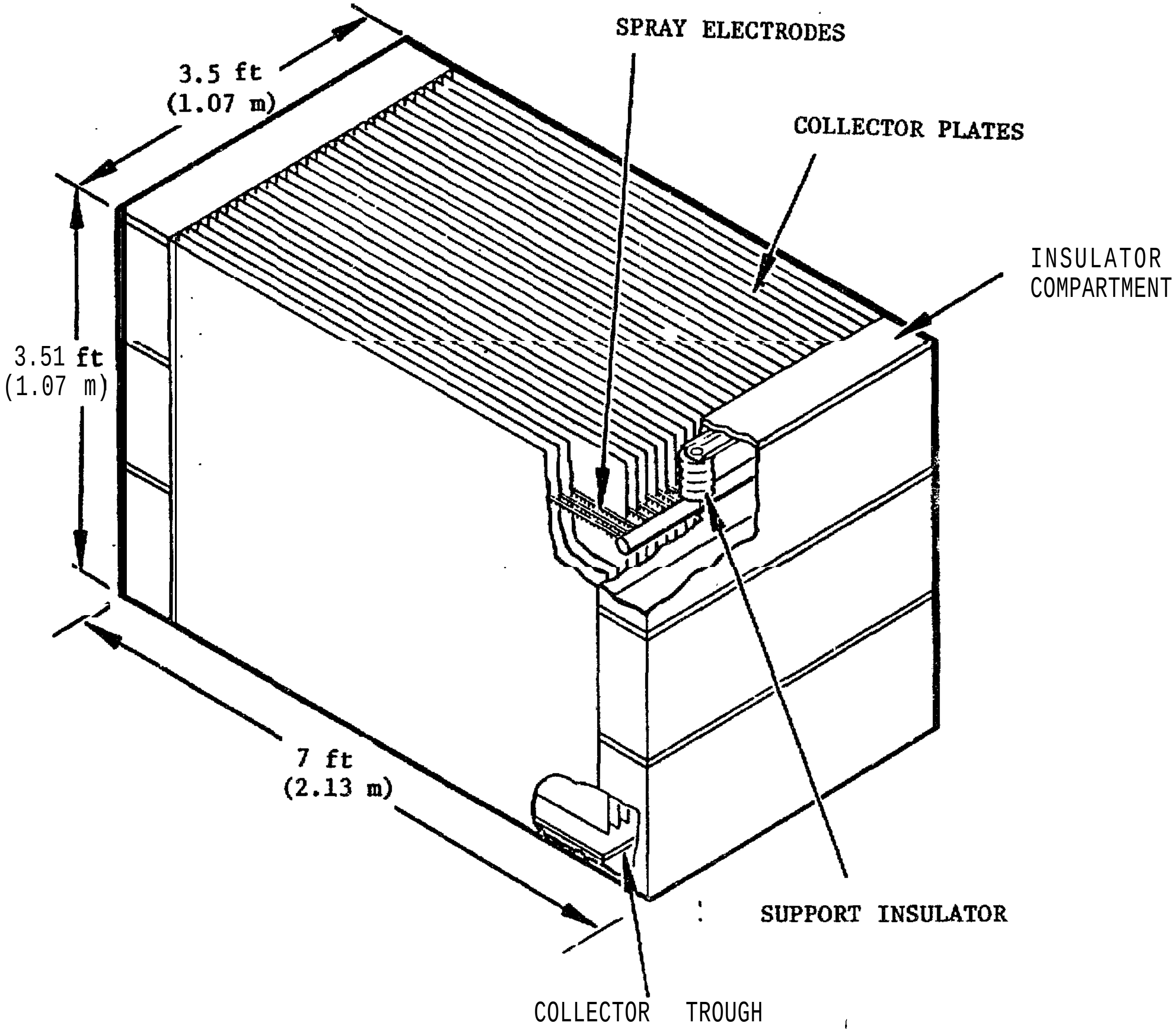


Figure 2.3.2-8 **(U):** Two-Stage Charged Droplet Scrubber Module **(U)**

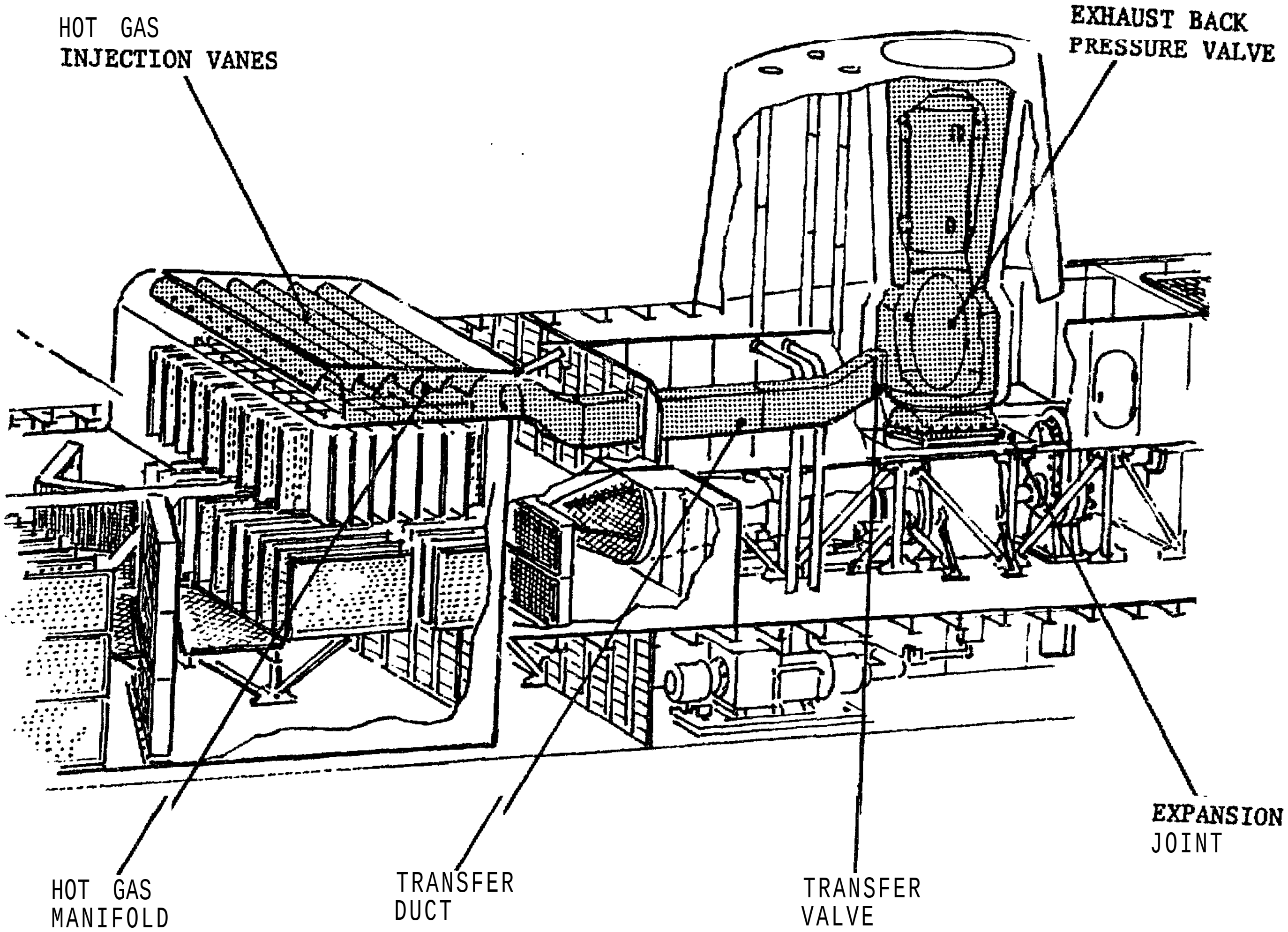


Figure 2.3.2-9 **(U)**: Anti-Icing and Intake Air Heating System **(U)**

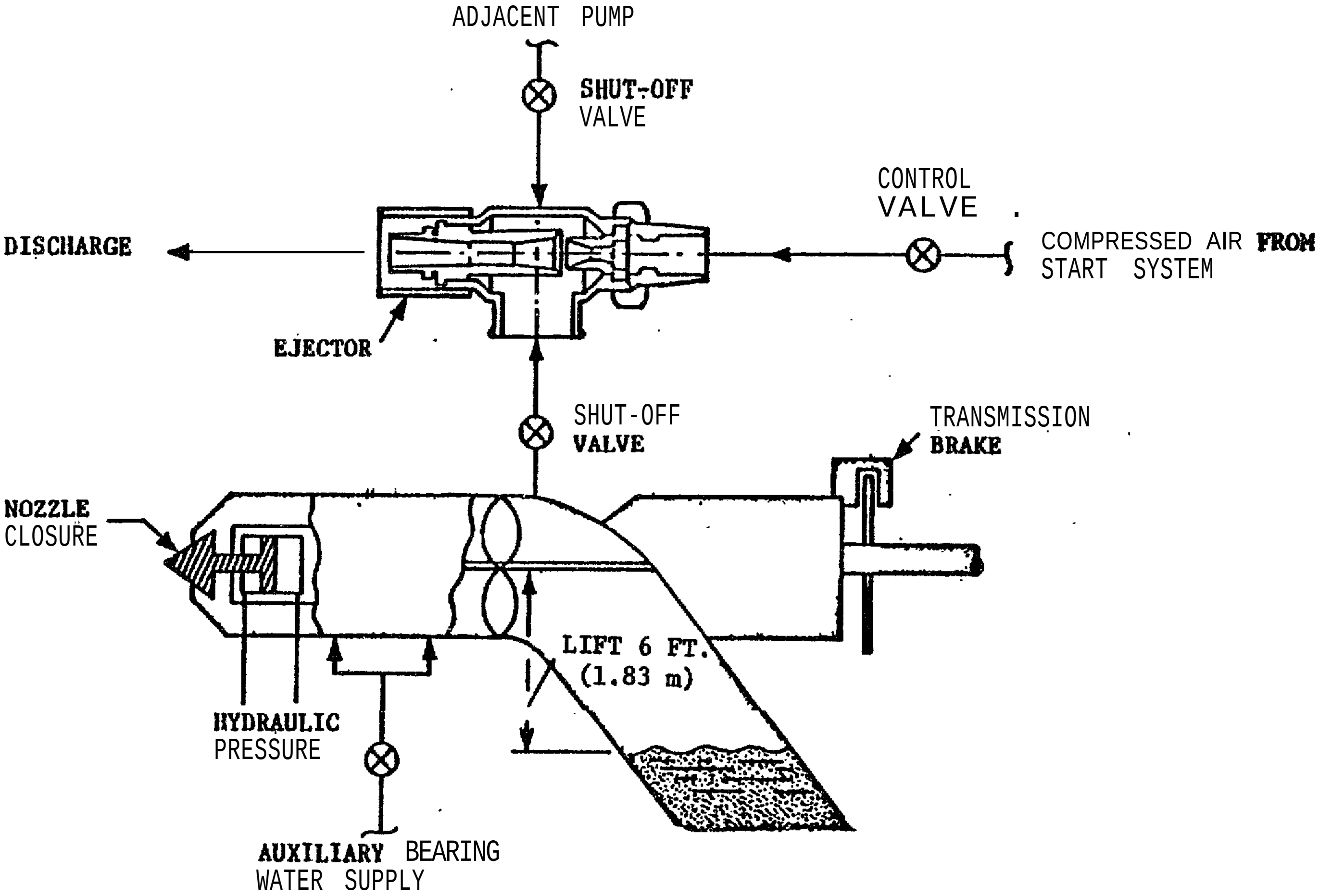


Figure 2.3.2-10 **(U):** Propulsor Priming System Schematic, Port and Starboard (U)

(U) 2.3.3 ELECTRICAL SYSTEM

(U) 2.3.3.1 Summary of Key Features — Primary 450 Volts power for the far term SES is generated at 60 Hz and 400 Hz frequencies by six gas turbine generator (GTG) sets. Two (2) identical GTGs rated 500 kW, 60 Hz and four (4) identical GTGs rated 500 kW, 400 Hz provide a total system capacity of 3,000 kW. All six (6) GTGs are driven by Garrett uprated ME 831-800 turbines.

(U) The distribution system is arranged to provide an operational choice of ring-bus or split-plant operation. Six (6) ship service switchboards are provided, four (4) for 400 Hz service and two (2) for 60 Hz service.

(U) The lighting arrangement is based upon dividing the ship into four (4) lighting zones or "cubes". Three cubes comprise the internal illumination distribution system, while the fourth cube services the specialized needs of the helicopter hangar and landing lights. Lights throughout the ship are predominantly of the fluorescent type and are energized by the 400 Hz system.

(U) Estimated electrical loading of the two primary power systems are 350 kW of 60 Hz power and 850 kW of 400 Hz power. This system provides adequate power with margins of 30 percent to 40 percent, with one generator in each system non-operating.

(U) Electrical power wiring is copper with lightweight insulation.

(U) 2.3.3.2 Electrical System General Schematic -- An electrical system general schematic is shown in Figure 2.3.3-l. This shows the complete independence of the two primary power systems (60 Hz and 400 Hz) from each other. Each generator, both 60 Hz and 400 Hz, has an associated switchboard located in the same room with its generator. The locations of the generators have been made so that the units for either system are dispersed one from the other.

(U) Shore connections for both 400 Hz and the 60 Hz systems are made at connector receptacles located near the centerline on the 02 level. Inter-locking is provided between the shore connection and the switchboard-mounted shore power circuit breaker to prohibit make-or-break of the shore connection under load.

(U) 2.3.3.3 Electrical System General Arrangement -- Six GTG sets are installed in four different rooms, separated from each other by at least two water-tight bulkheads. GTG Rooms 1 and 2 are symmetrically arranged and located on the third deck at the outboard extremes of the ship, as illustrated in Figure 2.3.3-2. Figure 2.3.3-2 also shows the location of the two GTGs (one 60 Hz and one 400 Hz) within each room.

(U) GTG Rooms 3 and 4 are located port and starboard on the main deck, just forward of the combustion air inlet plenum, They are symmetrically arranged with each containing one 400 Hz GTG and its associated switchboard, battery and battery charger , as shown in Figure 2.3.3-3. The GTG prime movers are Garrett ME 831-800 gas turbines with a direct cooled first stage stator. This uprating permits an electrical generator rated 500 kW. The gas turbine is the same overall design and size of the present ME 831 engine, which has four million hours of operational experience.

(U) In addition to the 60 Hz GTG use of the same gas turbine as the 400 Hz GTG, the other major components (such as the fuel system, lube system, and governors) differ very little between the two power frequency systems. The gearboxes are fundamentally identical except for the output gears which provide shaft speeds of 1800 rpm for the 60 Hz generator and 8000 rpm for the 400 Hz generator.

(U) Each GTG set comprises a gas turbine, reduction gear, generator, governor, fuel system, self-contained lube system, enclosure and control system. Figure 2.3.3-4 and 2.3.3-5 show the turbine prime mover major components, envelope, and weight for the 60 Hz and 400 Hz units, respectively.

(U) Each GTG is equipped with an electrical starter operating from its own dedicated 24 V DC battery system. This arrangement ensures very high starting reliability, positively guaranteeing "blackship" starts.

(U) Combustion air supplied to the GTGs is drawn from the same inlet plenum that supplies the lift and propulsion engines. This air needs no further treatment before entering the gas turbine. Exhaust gas is ducted independently for each turbine and passes through silencers before exiting to the atmosphere.

(U) Bleed air is extracted from the ME 831-800 compressor. This source of compressed air constitutes a cost and weight effective means for starting the lift or propulsion gas turbine engines. The maximum air bleed rate is 104 lb/s (7.71 N/S) from each turbine, if operating without electrical load. To accommodate the large quantity of air required for starting, all six GTGs will be running and sharing the electrical loads and all six will be simultaneously bleed to provide the required air supply.

(U) The 400 Hz and the 60 Hz distribution switchboards are identical in construction. Typical outline dimensions are shown in Figure 2.3.3-6. Local control devices and instrumentation for GTGs are provided within a control cabinet located on the GTG. Switchboards are of the freestanding, dead front type, constructed with aluminum framing and sheeting. Access space is provided at both front and rear of each switchboard. All devices for the remote control and monitoring of the switchboards are conveniently terminated at terminal boards in the rear of the switchboard to facilitate connection of the ship's cables. Reverse power protection for the generator sets is provided within the switchboards.

(U) 2.3.3.4 Key Electrical System Information -- A block diagram depicting the functional integration of the electrical system is shown in Figure 2.3.3-7. The power generation system provides all anticipated ship service primary and secondary electrical power with minimum weight, minimum development risk and maximum assurance of required performance, reliability, and flexibility. Both the 60 Hz and 400 **Hz** systems generate power at 450 **V,** 3 phaae, ungrounded delta. Power quality meats or exceeds the requirements for Type II power per **MIL-STD-1399/103.**

(U) In addition to driving the 60 and 400 **Hz** generators, the ME **831-800** gas turbines provide bleed air for starting the propulsion and lift engines and also provide a small amount of continuous bleed air for the ship's compressed air system.

(U) The far term SES' operating loads are approximately **70** percent on the 400 Hz system and 30 percent on the 60 Hz system. The ship's 400 Hz operating loads are distributed evenly among the four 400 Hz switchboards, each of **which** serves consumers located nearest to the particular switchboard. Each switchboard is connected to the other switchboards by bus ties which form a ring bus arrangement.

(U) Three of the four generating plants are generally connected to the ring bus arrangement for all operating modes, allowing the fourth unit to be in a standby mode. Generators may be added or deleted as the power demand dictates when operating with the ring bus system.

(U) The 60 **Hz** power distribution system is similar to the 400 Hz system.

(U) A lighting system provides adequate and reliable illumination in all areas of the ship, regardless of operating mode or condition. Special and detail lighting **is** provided for specific tasks. The lighting fixture arrangement is spaced to provide prescribed levels of working surface illumination, as well as uniform, shadow free illumination services throughout the ship, as follows:

- General white illumination in all spaces.
- Detail illumination according to work task.
- Low-level, red-band illumination for darkened ship.
- Two levels of blue-band lighting in the Combat Operations Center.

- Automatic and manual battery operated battle lanterns.
- Helicopter platform visual landing aid and **VERTREP** platform illumination for night operation.
- Navigation and running lights.

(U) Advancements in the use of 400 Hz lighting fixtures, coupled with their non-flicker characteristics, indicate that the 400 Hz power system will be used for lighting throughout the ship.

(U) The system utilizes the Navy concept of dividing the ship into vertical, volumes, each approximately a cube, for optimum distribution. The ship is divided into four cubes. One cube is dedicated to the helicopter landing area and supporting lighting. The remaining three cubes are divided into the forward, middle and aft portions of the ship. The lighting distribution system is fed from the four 400 Hz switchboards. Each of the three ship cubes contains two transformer banks fed from different switchboards. One transformer bank in each cube receives two separate power sources via a two-way automatic bus transfer, for supplying power to all areas containing vital lighting, The other transformer bank in the cube receives power from one switchboard. Figure 2.3.3-8 illustrates this arrangement.

(U) Lighting fixtures are designed to provide satisfactory illumination with optimum operational economy and minimum maintenance. 400 Hz fluorescent lighting is used predominantly wherever feasible, owing to its superior lighting qualities and lower power consumption. Incandescent lighting is utilized only where a suitable fluorescent fixture is not available.

(U) Circuit breakers used in the switchboard are of the proven reliable MIL-Spec type. Molded case AQB type circuit breakers are used within the distribution system to achieve reduced system weight and cost. The AQB type bus tie and shore power circuit breakers are equipped with motor operated devices to enable remote operation. The generator circuit breakers are ACB type.

(U) Each circuit breaker has been selected to provide adequate protection in the event of a fault. A sequenced opening of breakers will occur with the generator breaker operating last. Should distribution circuit breakers open, manual resetting of the breakers is required as a safety feature to ensure that the fault or overload is first removed. Selected breakers may be remotely opened for damage-control purposes but manual reset is required. Large power consumers are fed directly from switchboards while smaller consumers are routed to power distribution panels located throughout the ship. Transformers are located in close proximity to distribution panels for loads requiring voltages other than generated voltage. Voltage and frequency monitors (VFM) are provided where required for protection of 400 Hz electronics.

(U) An estimated load under the most demanding condition is approximately 350 kW of 60 Hz power and 850 kW of 400 Hz power. Therefore, the normal operating configuration requires one 60 Hz and three 400 Hz generators to be running, leaving one of each type in reserve. These off-line reserve generators are automatically started when required, and are thus functionally equivalent to conventional "emergency" generators,

(U) GTG sets and associated switchboards are arranged for remote control and monitoring and for limited local control. Automatic and manual controls are provided for remotely paralleling the two 60 Hz generators and for remotely paralleling the four 400 Hz generators. Both the 60 Hz and 400 Hz systems are equipped with voltage and frequency trim controls, load shedding, load sharing, malfunction shutdown, overload controls, and warning alarms.

(U) Condition monitoring and fault isolation are handled automatically on the far term SES. All vital conditions on the GTG's are monitored continuously. When normal conditions are exceeded and reach a pre-established limit, a warning alarm is activated and the parameter is automatically recorded. Warning alarms are used for those conditions where prompt action by the operator may eliminate the problem and permit continued operation. Should a condition occur which will result in damage to the GTG, an automatic manfunction shutdown is initiated and its parameters are recorded. Automatic start up of au off-line GTG is initiated whenever a warning alarm or a malfunction shutdown occurs.

(U) The control systems provide corrective measures for sustained overload or a generator failure. These provisions include automatic start of an off-line generator and automatic paralleling with the system bus. In the event of failure of an on-line generator, an automatic load shedding scheme protects the remaining vital loads. Manual reset of breakers is required following load shedding as a safety precaution. Sustained generator overloads activate an automatic sequence to start up and parallel an off-line generator. Failure or malfunction of an operating generator also results in immediate automatic start-up and parallel operation of an off-line generator and automatic shedding of non-vital consumers. The system provides ample capacity for accross line motor starting of the largest motors currently identified or anticipated for consumers.

(U) Two power sources are supplied for all vital loads. The lighting, "Circle W" ventilation, electronics, fire pumps and ship's control receive normal power from one switchboard and an alternate supply from a different switchboard via a bus transfer device located near the using equipment. Other vital consumers are supplied from a different switchboard for each element of a vital equipment pair, to assure continuity of service. Thus, in the event of a failure or casualty of the power supply to any vital load, all that system's generators or switchboard (60 Hz or 400 Hz) would have to fail to create a total loss of power.

(U) In the event of an emergency condition where power cabling has been damaged, casualty power cables are supplied at various locations in the ship.

(U) Electric Plant Weight Breakdown -- Table 2.3.3-l shows the estimated percentage weights of the major equipments and components of the electrical system.

(U) 2.3.3.6 Electrical System Technical Risk Assessment — The electrical system provides high confidence that the requirements for electrical power will be completely met, regardless of operating condition. The associated trade-off studies (1) provide assurance that the baseline system can be implemented with off-the-shelf equipment at low cost. This system features six generators, of which only four are required to supply the maximum load. This offers advantages over other configurations (which depend on a smaller number of larger generators) that include:

- A turbine or switchboard failure has less impact on total power generation capability.
- Major components are smaller and easier to remove for depot repair or replacement.
- Smaller GTG envelope and smaller exhaust piping allows greater installation arrangement flexibility.
- Set enclosures are smaller and easier to remove in confined GTG rooms.
- A reserve GTG can readily be provided for each power frequency.

(U) The system proposed for incorporation in the ANVCE far term SES is based on the increased use of 400 Hz power for lighting, motors, command and surveillance and other general equipments for shipboard use. Power generation is derived from uprated ME 831-800 gas turbines with a direct cooled first stage stator. In the time frame projected for this ship, these equipments should be standard off-the-shelf items, and the overall system is considered to have a minimum risk.

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(1) Megerle, R., "Ships Service Trade-Off Study Report," Rohr Industries; Inc., Document No. D300S00301, dated 23 December 1975.

Table 2.3.3-l (U). SWBS 300 Electric Plant Weight Breakdown (U)

SWBS SUBGROUP	WEIGHT			
	LT	kN	*	% of total
Gas Turbine Generator Sets	14.19	141.36	14.43	29.5
Battery and Equipment	0.94	9.34	0.96	1.9
Transformers	3.00	29.92	3.05	6.2
Cable	9.71	96.79	9.86	20.1
Swtich Gear, Panel's, Fixtures	11.70	116.61	11.87	24.2
Lighting Equipment	2.00	19.93	2.03	4.2
Turbine Support	6.72	66.96	6.83	13.9
Total	48.26	480.91	49.03	100.0

* non-SI metric tons

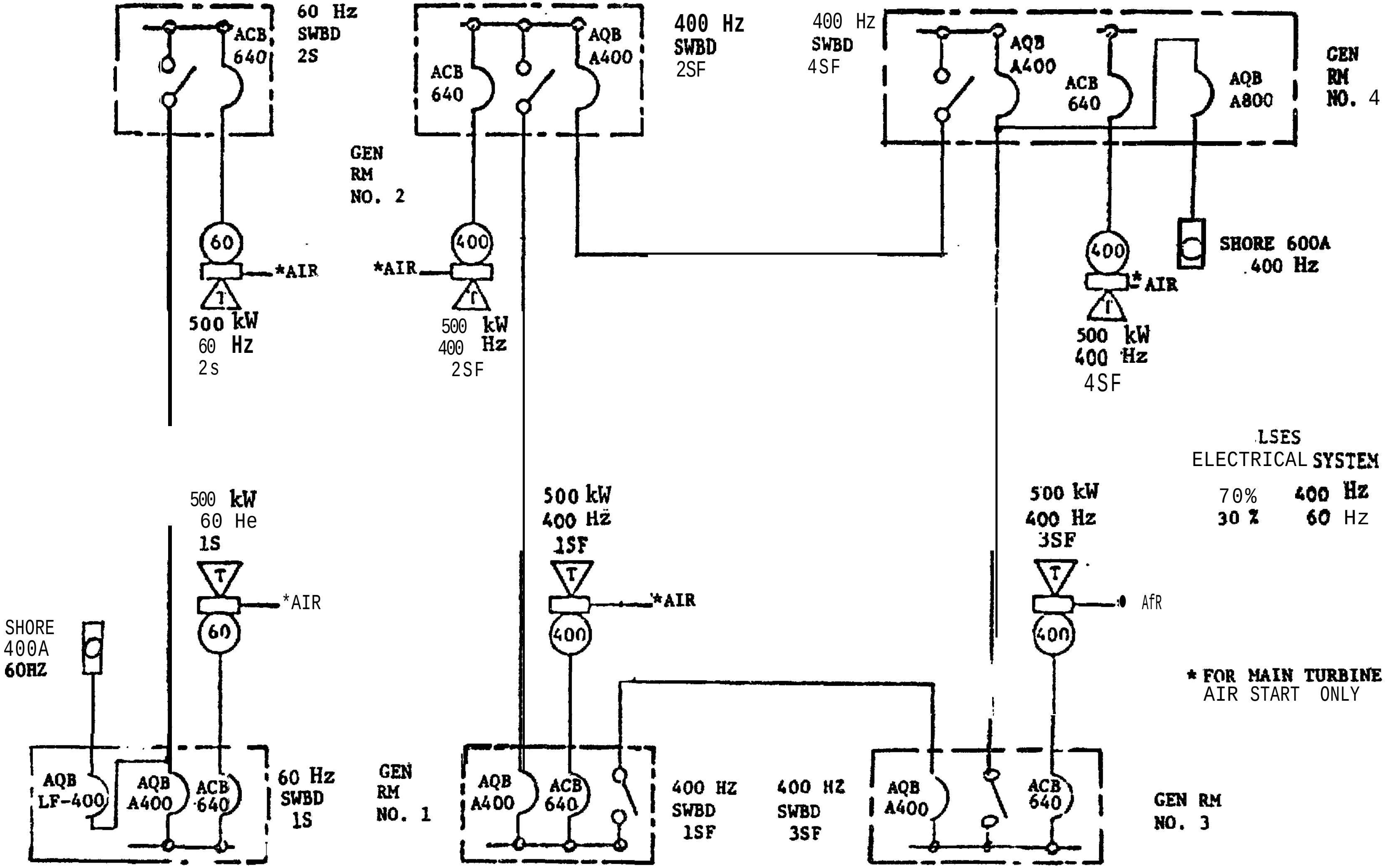


Figure 2.3.3-1 (U). Electrical System General Arrangement **Schematic,** Illustrating Flexibility and Availability Provided by Multiple **GTG's** and Ring Bus Interconnection of Switchboards (U)

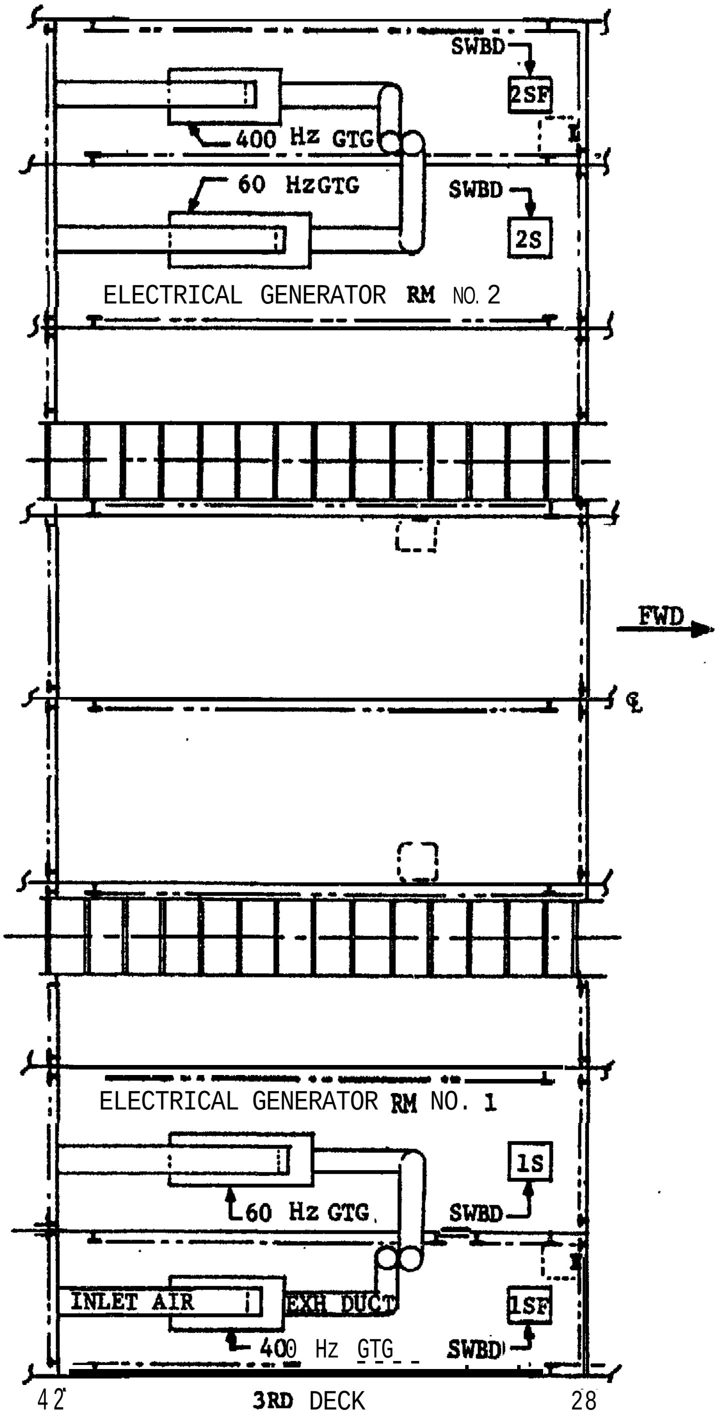
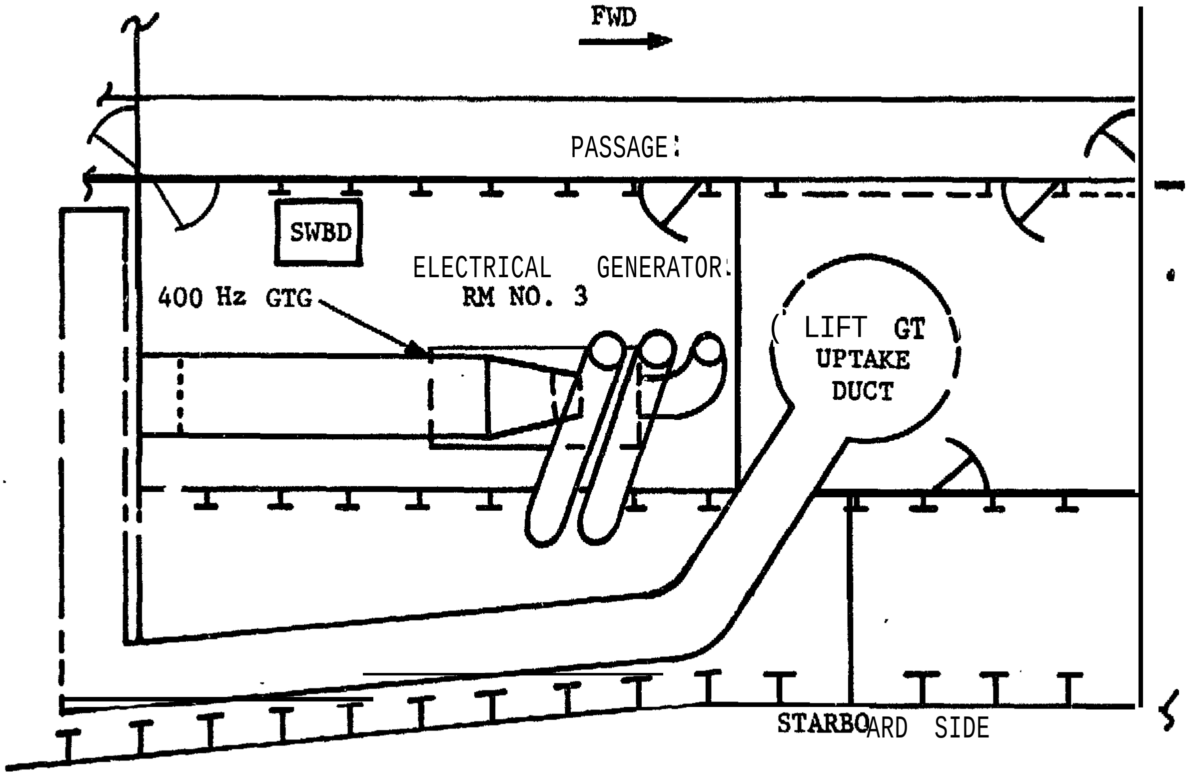


Figure 2.3.3-2 (U): Electrical Generator Rooms 1 & 2 (U)



PLAN VIEW MAIN DECK

Note: Generator Room No. 4 is Symmetrical and Located on Port Side.

Figure 2.3.3-3 (U): Electrical Generator Room No. 3 (U)

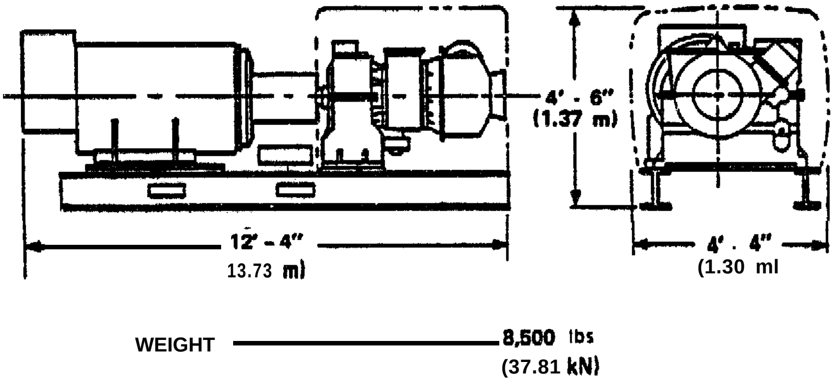


Figure 2.3.3-4 (U). The 60 Hz Gas Turbine Generator Set(U)

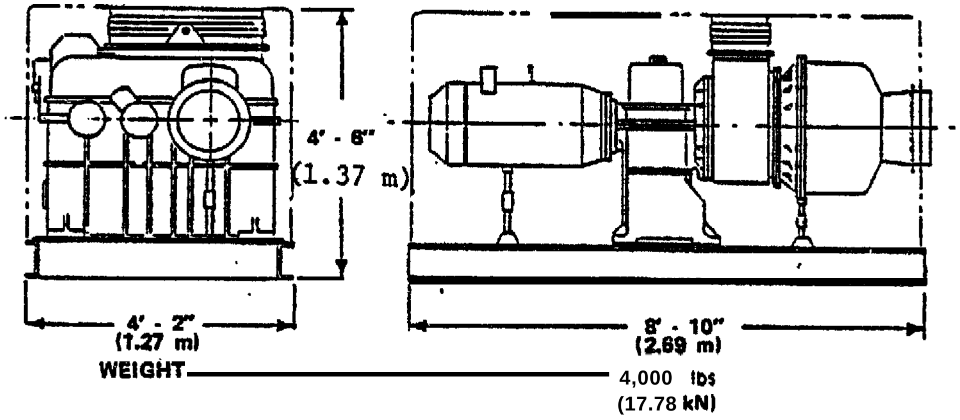


Figure 2.3.3-5 (U): The 400 Hz Gas Turbine Generator Set (U)

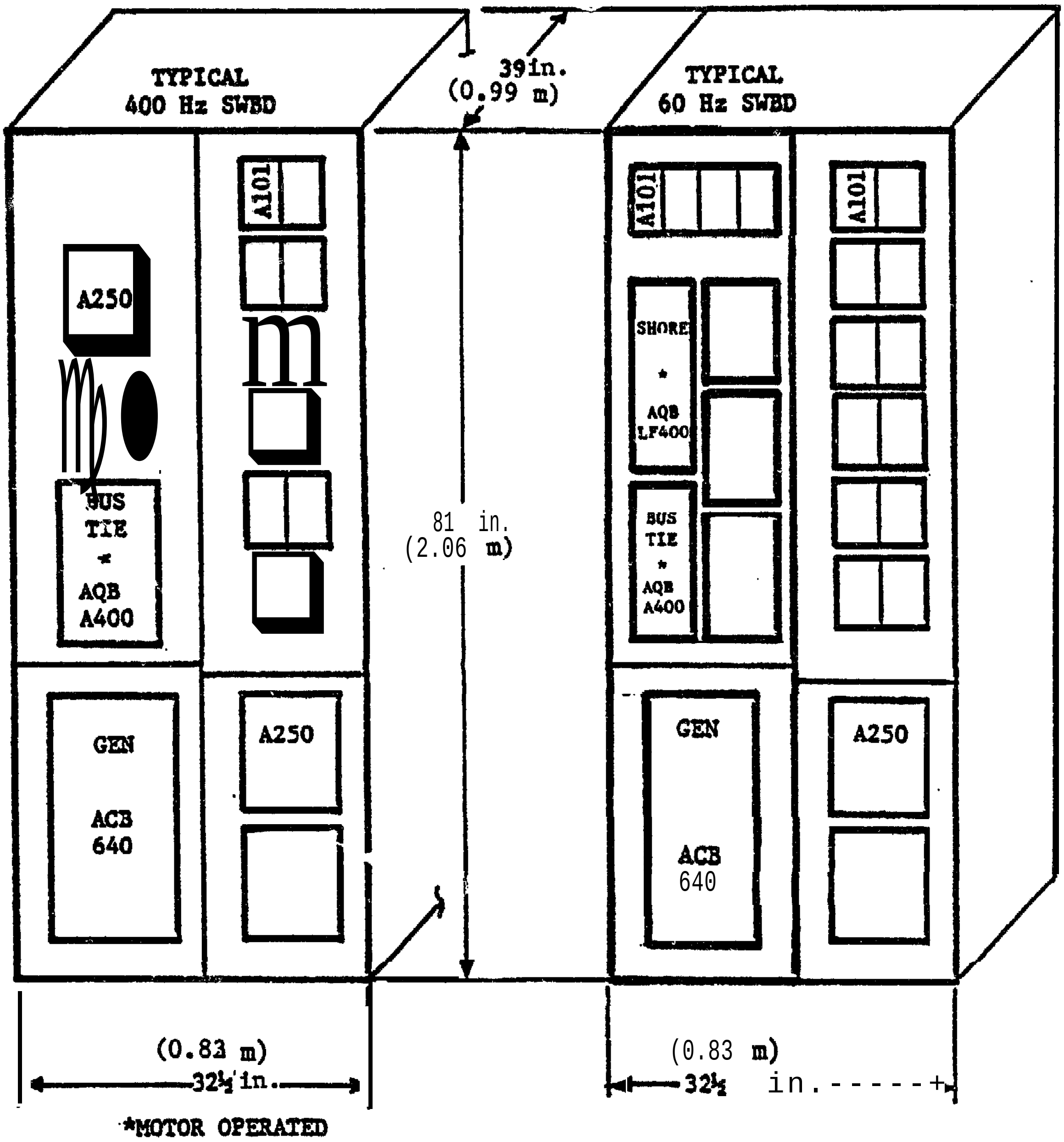


Figure 2.3.3-6 (U): Switchboard Arrangement {Typical) (U)

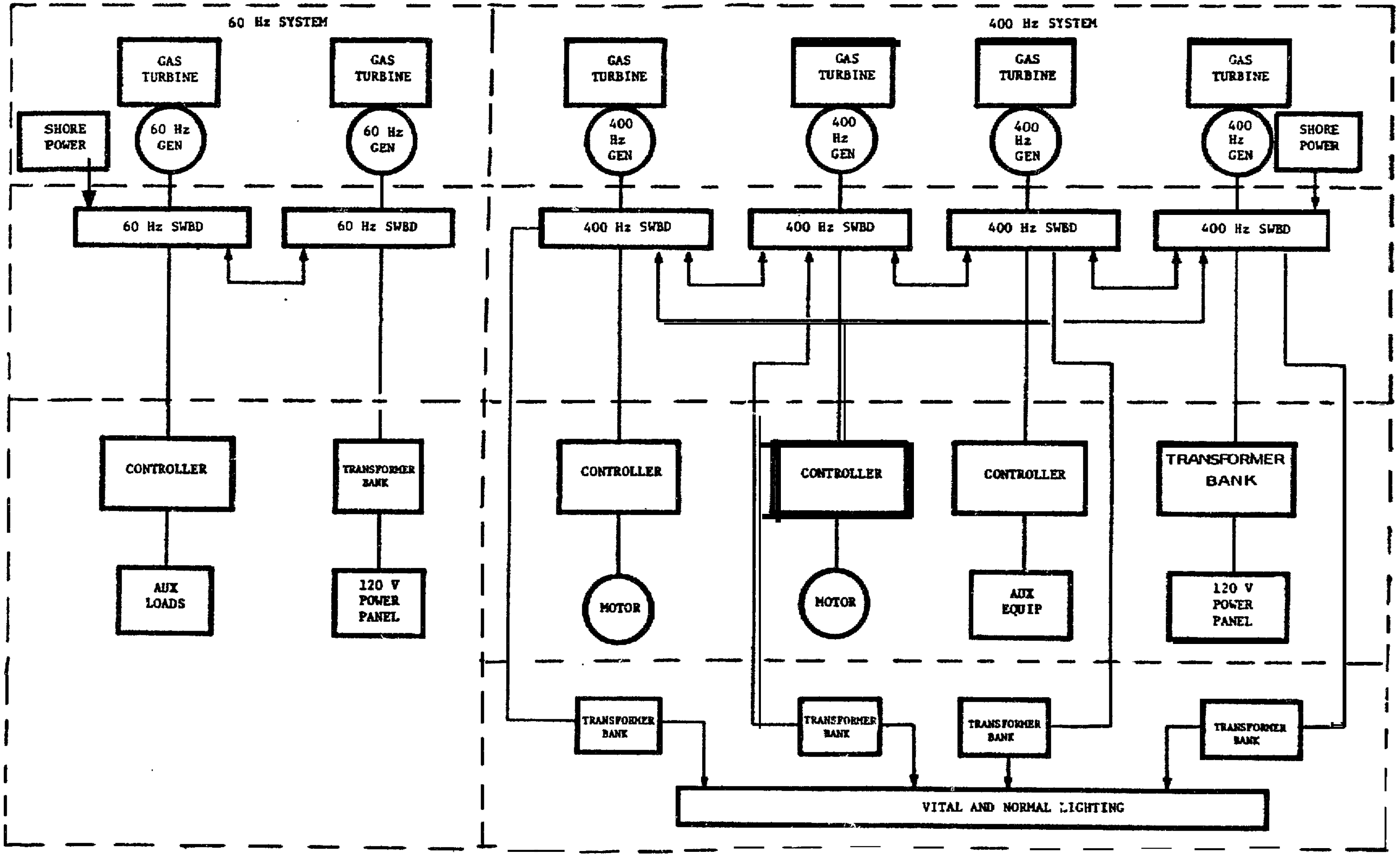


Figure 2.3.3-7 (U). Electrical Plant Functional Block Diagram Illustrating Independent 400 Hz and 60 Hz Systems and Ring Bus Arrangement which Precludes Total Loss of Power (U)

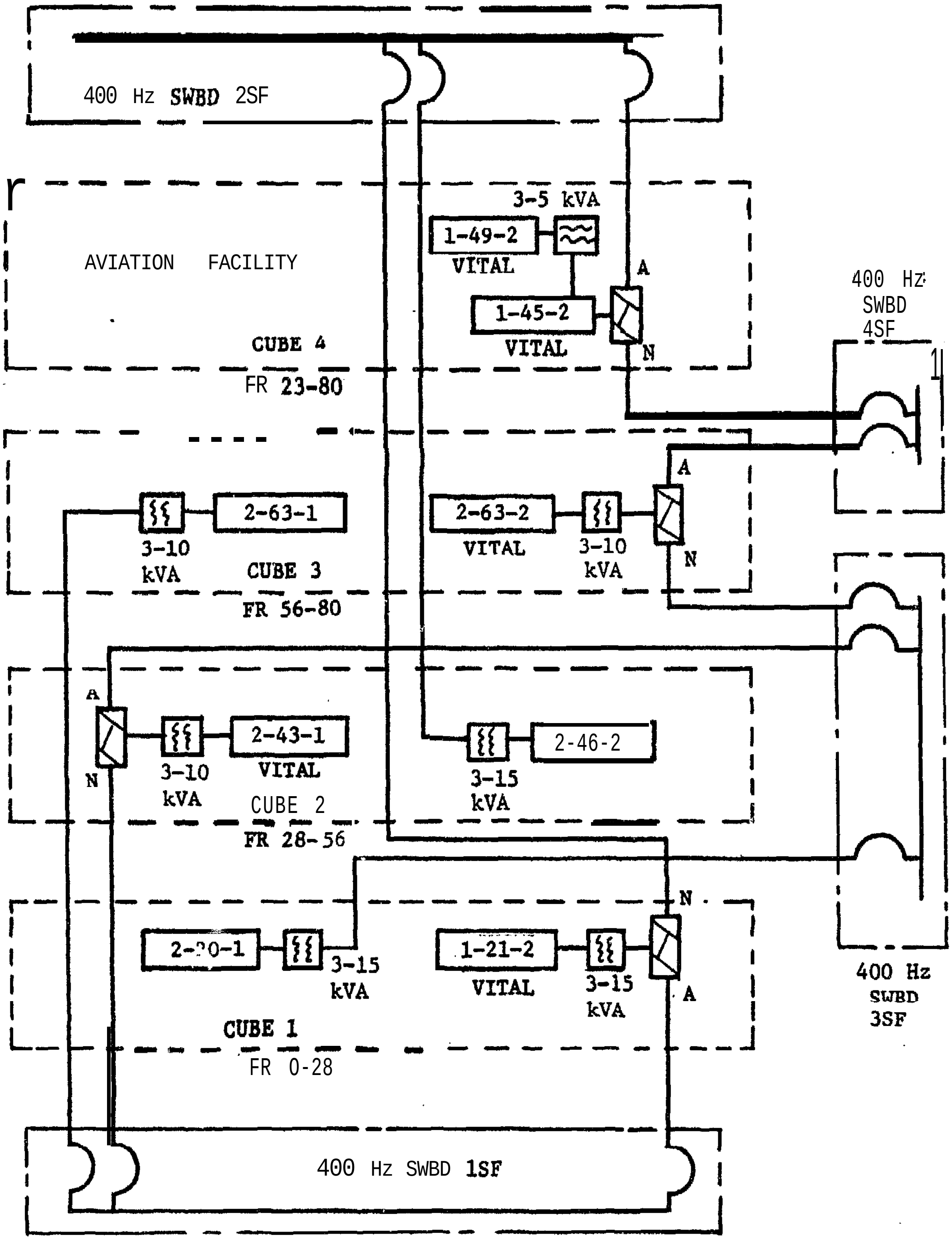


Figure 2.3.3-8 (U). Lighting System, One - Line Diagram (U)

2.3.4 COMMAND, CONTROL AND COMMUNICATIONS (C^3)

(U) **2.3.4.1** Summary Description -- C^3 functions are accomplished by subsystems and equipments arranged and integrated to optimize the collection, evaluation, display, and dissemination of data and intelligence supporting command and control. The C^3 system includes equipments for:

- Display
- Data Processing
- Navigation and Collision avoidance
- Interior communications
- Exterior communications

(U) The C^3 system interfaces with Combat System elements for underwater, surface and air surveillance, as well as Combat System fire control and weapons elements.

(U) Worldwide navigation capability and continuous absolute and relative position as well as ship's speed, heading, drift angle and attitude, are provided by the navigation system. The navigation system includes the hardware and data processing necessary to receive and integrate signals from an inertial navigation system (SHIPS-G-5683; TYPE II), and from Omega (SRN-17) and satallite radio navigation (AN/WRN-5; SATNAV).

(U) The surrounding surface environment is monitored to provide the capability to sense and quantitatively measure potential collision situations. The collision avoidance subsystem displays the surface situation and computes trial evasive maneuvers so that the ship may safely avoid predicted areas of danger. Navigation aids, shoal locations, and other significant data are stored for display as a synthetic map which includes radar-derived data as an aid in coastline, harbor, river, and shoal area piloting.

(U) **2.3.4.2** List of C^3 Equipment -- The list of C^3 equipment is contained in Appendix C. Interior Communications and Navigation Equipment are separately identified. The list itemizes equipment physical characteristics, weight and ship services requirementa.

(U) Collection, evaluation, display and dissemination of information relative to the friendly and enemy environment, and control of sensors and weapons is centralized in a Combat Operating Center (COC) on the main deck. Equipment and operator stations are arranged on the basis of functional adjacency requirements to improve reaction time and permit positive control. over weapons and sensors in accordance with enclosure (2) to ANVCE Combat System Support; Data for Point Designs, Rev., 1, 19 October 1976.

(U) The COC arrangement permits evaluation of the air, surface or subsurface environment from a centralized station. The COC operators exercise control of all weapons, sensors and displays and keep the commanding officer apprised of the tactical situation.

(U) A sonar equipment room is also on the main deck providing accommodations for equipment listed in Enclosure (5) to ANVCE Combat System Support; Data for Point Designs, Rev. 1, 19 October 1976.

(U) Multiple path exterior communications are provided, and communications equipment is arranged functionally in a manner consistent with minimum manning. Transmitter receiver groups and remote control-devices are centrally located in the communication center adjacent to the COC in accordance with Enclosure (3) to ANVCE Combat System Support; Data for Point Designs, Rev. 1, 19 October 1976.

(U) 2.3.4.3 C^3 System Weights -- Table 2.3.4-1 delineates the weights of major C^3 subsystems.

Table 2.3.4-1 (U): SWBS 400 C^3 Subsystems Weights (U)

SWBS SUBGROUP	WEIGHT			
	LT	kN	*	% OF TOTAL
Command & Control System	7.14	71.1	7.25	23.2
Navigation System	3.54	35.3	3.60	11.5
Interior Communications .	15.54	154.8	15.78	50.5
Exterior Communications	4.54	45.2	4.61	14.8
TOTAL	30.76	306.4	31.24	100.0

* non-SI metric tons

(U) 2.3.4.4 C^3 System General Arrangements -- C^3 system arrangements of the ANVCE Far Term Point Design SES are shown in the General Arrangement Drawings in Appendix B: No. AVA802003, 01 Level and Above and No. AVA802004, Main Deck.

(U) The drawings are grouped in the Appendix for consistency of report format and the benefit of the reader.

(U) 2.3.4.5 **C^3 Risk Assessment -- Only** Navigation and IC Systems were evaluated in terms of risks. The remainder of C^3 systems are comprised of equipment specified by ANVCE supporting documentation and are assumed to have acceptable risks for far term SES design application.

(U) Navigation and collision avoidance equipment were selected from Navy inventory items to meet the accuracy, reliability and special requirements of the far term SES. The interior communication system (IC) equipment group provides the means and methods for directing functions within the far term SES, other than for weapons control, by the transmission and reception of orders and the exchange of information by electrical and audible means.

(U) The IC equipment group also provides audio and television entertainment. The IC system will be an advanced version of the Shipboard Data Multiplex System now in development and test. It will have expanded capability beyond the distribution of periodic and aperiodic synchro, analog, digital, discrete and telegraphic signal data. Also included are the switching, queing and transmission of voice communication.

(U) Since the Navigation and Collision Avoidance Systems (CAS) are comprised almost entirely of government nomenclatured equipments, there is low technical risk in its implementation. The Advanced 2D Surface Search Radar will serve a dual function'on the far term SES. In addition to surface surveillance, it will be the primary sensor for collision avoidance functions. Some modifications to the AN/APS-116 radar constitute the principal departure from nomenclatured equipment. There is low technical risk involved in developing the required NAVCAS computer programs. The CAS consists of the following elements:

a. CAS control and display.

b. AN/APS-116M Collision Avoidance Radar (Advanced 2D Surface Search Radar) Subsystem with its own dedicated control unit.

c. CAS data processor and computer programs (AN/UYK-20(V)).

d. CAS water depth sensor.

e. CAS map data storage.

f. Low light level television.

g. Radar Beacon.

(U) 2.3.5 **AUXILIARY SYSTEMS** -- Innovations pertaining to auxiliary systems are assumed for the far term SES. These include the use of: (1) readily available exotic materials and joining techniques to reduce piping weight, (2) higher system pressures to reduce systems weight, (3) reverse osmosis systems for converting seawater into fresh water with an associated weight reduction over the present distillers, and (4) waste heat management.

(U) The prevailing state-of-the-art will be adapted in regard to piping materials and joining techniques. Tubes and pipes of the lightest weight commercially available for the particular fluid service will be selected. Pipe and tube joining techniques will be specified that result in lowest maintenance.

(U) Such high pressure systems as compressed air and hydraulic may be operated at higher than 3000 psig (20.68 mPa) system pressures, assuming: ready availability of the required components.

(U) Reverse osmosis is contemplated for the desalination units. This decreases the weight and the cost per gallon of distillate over conventional vapor compression distillers which depend on heat energy to generate a change of state during the desalination process, The main advances are in increased life of filters and decreased salinity of the output. A 35 percent reduction in weight and power required are anticipated as compared to that for the near term SES, resulting in a unit weight of 2400 lb (10,675 N) and a total power requirement of 50 kW. Additional weight reductions will be obtained by advancements expected in light weight piping-and valve materials.

(U) The far term SES is the same size as the near term SES. The increased exhaust gas energy of the LM5000 could provide the energy now supplied by the gas turbine-driven generating equipment through use of a "bottoming" Rankine cycle engine to drive the rotating electrical generating equipment. This would provide both direct space heating and the generation of the total

(U) electrical requirements without the use of added energy. Of course, start-up, survivability, and vulnerability requirements will result in the installation of at least two gas turbine-driven electrical generators.

(U) The baseline far term SES does not include this system; however, the trades involved are promising and should be further studied in the detail design plan of any far term SES Program.

(U) The recovery of waste heat from the main propulsion engines, lift engines and auxiliary electric power engines will be more attractive in the 1985-1995 time period because of the improvement in gas-side heat transfer coefficients and a reduction in weight and size of heat exchanger equipment. The facility for the manufacture of serrated heat exchanger fins with light weight material and the improvement of fin density without fouling penalties appears possible in this time period. The use of titanium for tube and header fabrication will decrease the weight of all elements of the heat recovery system.

(U) Lightweight heat exchangers designed to recover exhaust gas energy with a minimum effect on engine performance can be coupled to a vapor turbine directly connected to the main propulsor shaft. The turbine design could reflect the latest technology in light weight, high strength materials so that such items as the turbine case and wheel would have considerably less weight. Welded tubing instead of flanged connections, titanium valves, solid state controls and lightweight-pumps will all serve to reduce the Rankine system installed weight. The savings in fuel alone should offset any weight and cost penalties accrued by the use of the heat recovery system.

(U) 2.3.5.1 Auxiliary System Less Lift System -- The auxiliary systems would be developed for the ANVCE operational environment with performance, reliability and low weight as primary objectives. The location of major equipment for the auxiliary systems is shown in Dwg. No. AVA 802006 in Appendix B. A listing of pumping equipment, filter separators, and manifolds: is shown in Table 2.3.5-l.

(U) 2.3.5.1.1 Climate Control System -- The Climate Control System consists of the compartment heating, ventilation, and air conditioning (HVAC) system; machinery space ventilation; and the ship stores refrigeration system.

(U) Heating, Ventilation and Air Conditioning (HVAC) -- The HVAC System provides conditioned air to various spaces and/or major equipment throughout the ship. The system combines electrical resistance heating, mechanical fresh air supply and exhaust, and recirculating air conditioning: The system employs 400 Hz electric motor-powered, packaged air conditioning plants and 400 Hz electric motor-driven axial flow fans.

(U) Machinery Space Ventilation -- Thirteen air supply systems supply 100 percent summer cycle outside air to all auxiliary machinery rooms, electrical generator rooms, lift fan rooms, lift fan- engine rooms, and main propulsion engine rooms. There are no duct preheaters for heating air in winter cycle.

(U) Refrigeration System -- Two separate 400 Hz motor-driven centrifugal, packaged-type refrigeration plants are provided for ship stores refrigeration. Each refrigeration machine supplies Freon to the cooling coils in the freezer and chiller spaces. One unit maintains the required temperatures for both spaces during normal. operation with redundancy provided by the second machine; two refrigeration machines are used for pull-down.

(U) 2.3.5.1.2 Seawater Systems -- The seawater systems consist of all seawater supply and drainage systems. These include firemain sprinkling, auxiliary seawater, scuppers and deck drains, plumbing drains and drainage systems.

(U) Firemain and Auxiliary Seawater System -- The seawater services are furnished by a single combined firemain and auxiliary seawater

1-10

(U) system. The system is arranged as a firemain for damage control and separated into fire and auxiliary service functions at the respective required pressures. Four each centrifugal pumps are used, each capable of a delivery of 400 gpm (0.025 m^3/s) at 125 psig (0.862 kPa).

(U) [illegible] **Scuppers** and Deck Drains -- The scuppers and deck drains consist of all space deck drains at and above the second deck. Space deck drains (with GRP piping) from wet spaces and fan rooms are combined and directed overboard via scuppet valves. The overboards are located on the third deck above the full-load waterline to reduce drag.

(U) [illegible] **Plumbing Drains** -- The plumbing drains are vacuum-assisted and collect soil wastes from water closets and urinals, and waste drains from showers, lavatories, sinks, laundry, galley, and scullery. The drains lead to a vacuum collection tank from which wastes either discharge overboard or are directed to the collecting, holding and transfer tank (CHT). Connections are prdvided for discharge to shore receiving facilities.

(U) [illegible] **Drainage System** -- The drainage system consists of a main and secondary drainage system which provides the drainage for the machinery spaces and other spaces on and below the third deck. 500 gpm (0.0315 m^3/s) main drainage eductors are provided for the propulsion engine rooms and the waterjet pump rooms. Eductor actuating water is provfded by the firemain and auxiliary seawater system. Discharge is overboard above the full-load off-cushion waterline to reduce drag.

(U) 2.3.5.1.3 Fresh Water Systems -- Fresh water systems include the desalination units, the potable water system, and the fresh water supply and distribution system. The desalination units are the reverse osmosis type supplying 30 gallons per day (gpd) (0.0000013 m^3/s) per man with a 10 percent growth capacity plus 40 gpd (0.00000175 m^3/s) for windshield wash, 125 gpd (0.00000548 m^3/s) for helicopter service, and capacity for auxiliary fresh water cooling make-up.

(U) Two potable water pumps (duty and standby) are furnished, each sized to adequately serve the ship's hotel services plus the hangar and helicopter service. The hot water system includes two 100-gal. (0.379 m^3) storage tanks and a recirculation pump. Two potable water storage tanks with level and interconnect controls are provided.

(U) The fresh water supply and distribution system includes the demineralized water storage tank, a single wash water pump for the engine(s) and windshield wash, an automatic additive feed system, and a hot water storage tank. The storage tank is electrically heated.[1] The fresh water system provides water to the air conditioning plant(s) and make-up water for the electronic water cooling system. Shore fill connections provide potable and fresh water tank replenishment.

(U) Two electronic cooling water systems are provided: the cooling water system (Freon-cooled) and the auxiliary fresh water cooling system (sea-water-cooled). These systems may be complemented by heat pipes or other heat dissipating elements whose development in the future might make such innovations attractive.

(U) 2.3.5.1.4 Fuels and Lubricants Systems

(U) Fuel Systems -- The far term SES is geometrically similar to the near term SES, and the concept of fuel tanks with three different dedicated functions is maintained. The three functions are: (1) trim and storage tanks, (2) storage tanks, and (3) service tanks for both aviation and SES operation.

(U) The propulsion and lift engines are GE-LM5000 with larger fuel demands so the-pumping equipment from service tank to engines is larger, thus making it possible to use only one type and size pump for trimming, transferring

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[1] This could be replaced by a steam-powered, minimum-storage, quick-recovery heater should the ship utilize a waste heat recovery system providing the necessary steam.

and feeding the engines, facilitating the logistics for the pumping equipment.

(U) The geometric arrangement of tanks is maintained, so the distribution system will be quite similar to that for the near term SES. The grouping of tanks by an intelligent combination of valves and pumps through manifolds allows full automatic and remote control of the trimming and transfer and produces redundancy by allowing each manifold to transfer fuel from any tank to any tank, including the possibility of more rapid transfer of fuel by coupling pumps in parallel.

(U) By 1990, the selection of tubing materials will be improved. Apart from stainless steel ARMCO 2169 and titanium used today in aircraft, the possibility of extra-thin wall tubing (metallic or otherwise) reinforced radially with graphite or boron fibers must be considered. Mechanical connections would be used only for components, while tube-to-tube connections would be by welding or bonding, depending on the tubing selected.

(u) Clustering of fittings were avoided, and where fittings are used and penetrations are made, the products stress reliability and use of proven products of the aerospace, petrochemical and processing industries. This provides a lighter and highly efficient system that is easy to manufacture and maintain.

(U) The fuel storage tanks are quite deep and permit fuel and water separation. The proper suction level should be selected and, if there is no possibility of installing the pumps at discrete locations in the sidehulls, the pumps should be changed to immersed type or to vertical turbine pumps of the deep well or wet pit type as used in the petrochemical industry. All pumps should be equipped with vortex spoiler-type suction to permit maximum utilization of the tanks.

(U) Filter/separators of advanced design and with high dirt-holding capacity and automatic water drains should be installed in the incoming lines to the service tanks and in the lines between service tanks and gas turbine engines and aviation service tanks.

(U) Fuel transfer from the aviation service tanks to aircraft is through units similar to those at airports or specially designed for the refueling of turbo-powered helicopters. Monitoring devices for fuel quality will assure absolute stoppage of contamination in case of failure of the filter/separator media.

(U) The selection of different combinations of new membranes and filter materials will produce extremely light filters of high efficiency that could be housed in titanium shells,

(U) Full redundancy will be attained with a redundant transfer system incorporating two pumps per service tank, each capable of feeding the'complete demand of the GT engines and GTG's.

(U) Fueling of the ship will be provided at port and starboard fill stations utilizing seven-inch (0.18 m) probe receivers, each capable of 3000 gpm (0.189 m^3/s).

(U) Lubrication System -- The lubrication system for the propulsion gas turbines is furnished by the engine manufacturer. It includes an oil storage and conditioning system for each engine so that they function independently. A fuel oil cooler is provided to remove the requirement for seawater to cool the oil, which eliminates the piping and additional seawater necessary to remove the heat rejected to the oil. The energy thereby recovered by the fuel increases the efficiency of the overall thermodynamic cycle.

(U) The lubricating oil specified for the gas turbine engines is in accordance with Military designation MIL-L-7808 or MIL-L-23699.

(U) The propulsor assembly gearbox and transmission shaft bearings are lubricated by separate pressure and scavenge pumps with individual reservoirs and oil conditioning systems. The oil conditioning systems consist of a filter deaerator and a heat exchanger cooled by seawater. The close proximity of the heat exchanger to the waterjet pump reduces the seawater piping requirement. Since the water used has already performed its function in the propulsor, there is no additional water pumping load requirement for cooling. The water is obtained from the propulsor's second stage cavity.

(U) The reservoir in this system contains internal baffles and trays to enhance deaeration and to perform the venting function. Venting through the reservoir instead of the gearbox precludes air leakage into the gearbox.

(U) An electrically driven pre-lube pump is provided for both starting and back-up operation, especially during low speed conditions when the direct drive mechanical pumps are at a low flow and pressure operating point.

(U) There is no central oil system provided for the propulsion, gearbox and transmission systems. Independent lubrication and oil. conditioners are imcorporated in each of the GT engine-powered electric generators.

(U) To improve reliability and reduce syetem weight, welded tubing connections are used wherever possible in lieu of flanges. The lubrication system features are listed in Table 2.3.5-2.

(U) 2.3.5.1.5 Air, Gas and Miscellaneous Fluids -- The air, gas and miscellaneous fluids consists of compressed air systems, nitrogen system, fire extinguishing systems, and hydraulic fluid systems.

(U) Compressed Air Systems -- Both low pressure and high pressure systems are provided. The low pressure compressed air system is furnished by bleed air from the GTG's and main propulsion and lift gas turbine engines. The low pressure compressed air system consists of ship's service, control air, and starting air systems. The pertinent compressed air rates are:

	Flow Rate scfm (m^3/s)	Pressure, PSIG(MPa)	Temperature °F (°C) Max.
Engine Starting	2,580 (1.22)	45 (0.31) Min.	450 (232.2)
Ship Service	100)0.047)	90-116 (0.62-0.78)	110 (43.3)

(U) A high pressure air system is provided for charging the RPV launcher. A nominal 3000 psig (20.68 MPa), 6 scfm (0.0028 m^3/s) compressor, dehydrator and air flasks are used for this particular launch activity.

(U) Nitrogen System -- A nitrogen system is provided for helicopter services. The nitrogen charging station in the hangar consists of five cylinders and a variable regulator capable of supplying 70 to 3000 psig (0.48 to 20.68 MPa) of oil-free nitrogen for helicopter tire inflation and other services.

(U) Fire Extinguishing Systems -- The fire extinguishing systems on the ship consist of AFFF, Halon (FE 1301) fixed flooding systems, high-expansion foam, and portable Halon extinguishers, A high capacity AFFF proportioning system is provided for the helicopter hangar and landing area. A fixed sprinkling system is provided for the hangar and two hose stations are provided port and starboard on the landing platform.

(U) Fixed flooding Halon systems which meet the requirements of NFPA No. 12A are the primary fire extinguishing systems for propulsion engine rooms, lift fan engine rooms, auxiliary machinery rooms, waterjet pump room, and electrical generator rooms.

(U) A high expansion (Hi-X) foam system is provided as a secondary (backup) system for the Halon fixed flooding systems. Port, starboard, and amidships proportioning units are supplied from the firemain system.

(U) Hydraulic System -- The subsystems requiring hydraulic power are located port and starboard, forward and aft. Smaller hydraulic power supplies dedicated to certain hydraulically actuated equipment can then be used. This avoids the need for large diameter rube and pipe runs throughout the length of the ship. Hydraulic pumps are dirven by propulsion and lift fan engine gearboxes, by small electric motors, or by waste heat recovery turbines. Each pump is furnished with a relatively small pressurized reservoir, heat exchanger, filters and required valving.

(U) Operating pressures of greater than 3,000 psig (20.68 MPa) will be permissible due to the anticipated availability of qualified components in the 4000 to 6000 psig (27.6 to 41.4 MPa) range. This reduces component and line sizes and effects a lower system weight. Further weight decreases result from the aforementioned elimination of long tube runs and the availability of higher strength tubing in the required sizes. Hydraulic fluid in accordance with MIL-H-83282 is specified in the 1980-1990 time period as a replacement. The pertinent subsystem flow rates are:

	Pump Flow/Pump		System Oper. Press.		Reservoir Size	
	gpm	(m^3/s)	Psig	(MPa)	gal.	(m^3)
Motor-driven Pump System (2)	18	(0.00114)	4000	(27.6)	6	(0.0273)
Propulsion Eng. Pump System (2)	35	(0.0022)	4000	(27.6)	10	(0.0455)
Lift Engine Pump System (2)	70	(0.0044)	4000	(27.6)	18	(0.0818)

(U) 2.3.5.1.6 Underway Replenishment System -- The Underway Replenishment System comprises the Replanishment-at-Sea System; the Ship Stores, Personnel, Weapons and Equipment Handling; Monorail System; Missile Handling; and Miscellaneous Equipment. Replenishment-at-sea will be provided by VERTREP and alongside refueling and replenishment. A combined VRRTREP, HIFR helicopter landing area is provided on the main deck aft of the hangar, and alongside replenishment stations are provided on the 01 Level aft of the exhaust stacks, port and starboard.

(U) Stores, Personnel, Weapons and Equipment Handling -- Strike-'down is simplified by arrangement of magazines, storerooms and refrigerated spaces on the main and second deck for ease of access. Handling on the main deck is by hand pallet trucks, package truck, and manual means. Materials struck down to the second deck will be conveyed by a vertical conveyor, located starboard. A stores handling area is provided on the second deck. The co-location of galley and refrigerated spaces eliminates the need for a dumbwaiter.

(U) Monorail.System -- An electrified monorail system with approximately a 6000-pound capacity (26,689.3 N) is located under the 02 Level to further simplify and expedite strikedown. The system will be capable of transferring material between the port and starboard UNREP stations, transportation and stowage of the Advanced Lightweight Torpedoes (ALWT), handling of RPV's and associated equipment, delivery of stores to the vertical conveyor, and helicopter maintenance.

(U) Missile Handling -- Two hydraulically operated cranes with telescopic booms and a low stowage profile are provided for missile handling. The basic extension and load capacity is 74,000 pounds at 10 feet (106,757.2 N at 3.048 m). The cranes are located to take the missiles from the UNREP stations and either deliver them to the weapon loader forward of the pilot house on the 01 Level or physically load the Advanced Self-Defense Missiles into the launching tubes. The cranes are also utilized in handling cargo and weapons in port. The arrangement of the cranes and the above monorail system is depicted on Dwg. AVA 802003, Appendix B. A weapon loader as specified in Rev. 1, dated 19 October 1976 of ANVCE Combat System Support; Data for Point Designs (ANVCE Combat System Portable Handling Equipment Requirements) has been provided for loading the AMRM multi-mode, ASW stand-off and Harpoon MkXX missiles.

(U) Miscellaneous Equipment -- One Handling Dolly MK74, MOD 1 and a dolly adapter MK 137 MOD 0 for loading the ALWT onto the helicopter are supplied. Also provided are two pallet trucks for stores handling; one container sling MK 109; MOD 0; four torpedo slings MK 102, MOD 0; and two weapons handling slings MK 99, MOD 0 for weapons handling. These equipment items are coded A, C. F, H. I and P in Table l-l of the ANVCE Combat System Portable Handling Equipment Requirements.

(U) 2.3.5.1.7 Mechanical Handling Systems -- The mechanical handling systems are the anchor handling, mooring and towing, boat handling, hangar door, and the helicopter securing and traversing system. The basic Anchor Handling System meets the requirements of anchoring with a 70-knot (360.1 m/s) wind velocity, a 4-knot (20.58 m/s) current velocity, and in 40 fathoms (73.15 m) water depth. A single anchor of the Danforth-Hi-Tensile type was selected on the basis of the recommended criteria.

(U) Three line-handling capstans constitute the Mooring and Towing System, provided to facilitate mooring alongside piers and other ships.

(U) Boat Handling Facilities consist of abandon-ship equipment and an inflatable hard-bottom boat for use during helicopter operations and for man overboard recovery. Ten MK-V inflatable CO2 15-man life rafts are provided in' standard containers on the 01 Level outboard of the hangar.

(U) Horizontally deployed hangar doors are used that consist of vertical hinged panels which travel on horizontal tracks. The doors are mounted under constant tension by spring-loaded lower roller bearings that apply tension to upper roller bearings. Door operation is by an electric motor and gearbox drive.

(U) The Canadian **Beartrap** System is currently being developed for Helicopter Securing and Traversing. This system employs a messenger winch attached to the helicopter to retrieve a variable tension cable from the ship. The tension is increased as the landing gear contacts the ship and the **beartrap** device is activated to engage a probe attached to the underside of the fuselage. The helicopter is then secured and the entire **beartrap** device can be moved into the hangar with the helicopter attached.

(U) 2.3.5.1.8 Special Purpose Systems -- The Special Purpose Systems consist only of the Environmental Pollution Control System. The Environmental Pollution Control System is concerned primarily with the solid and liquid wastes produced by the ship. The primary item is the Collecting, Holding and Transfer (CHT) tank which collects all plumbing and fresh water drains. The holding tank is sized to accommodate one day's waste. A sewage pump is used to discharge waste from the vacuum collection tank to the CHT. This same pump (a standby pump is provided) is used to discharge the CHT to a shore connection.

(U) Garbage is ground and flushed, via the vacuum collection tank, to the CHT. Solid trash is treated by compaction and retained aboard for disposal at a shore facility.

(U) Contaminated oil drains (fuel, lube oil, helicopter defuel, stripping lines, etc.) are discharged into a waste oil tank. They are pumped to shore facilities by waste oil drain pump.

(U) 2.3.5.1.9 Auxiliary System Weight Breakdown -- Table 2.3.5-3 shows the weight breakdown of the major equipments and components of the auxiliary system.

(U) 2.3.5.1.10 Auxiliary System Risk Assessment -- The auxiliary systems utilize components, subsystems and machinery that have established operational characteristics, will be readily available, and require no development. There should be no cost, schedule or technical risk.

(U) 2.3.5.1.11 Condition Monitoring and Fault Isolation -- Key to the minimization of technical risk and maximization of ship availability is condition monitoring and fault isolation. The Auxiliary Subsystems incorporate certain instrumentation for condition monitoring and fault isolation as next discussed:

o Potable and Fresh Water Systems

Desalination Units -- Each reverse osmosis (RO) unit produces potable water with a total dissolved solids content of less than 500 ppm from seawater having a concentration of approximately' 37,000 ppm. Pre-treatment with electrolytically generated chlorine combined with ultrafiltration and ultraviolet purification assures hygienic purity of the water and minimizes the permeate rate decline of the RO unit in extended operation. If the conductivity of the effluent rises beyond a selected limit to indicate membrane damage, the unit is automatically shut down, and a light alerts the control station. In addition, a turbidity sensing unit automatically shuts down the unit if allowable limits are exceeded.

Potable Water System -- Water level indication for the two potable storage tanks and the fresh water storage tank is provided. Alarms indicate low and high water level extremes and excessive hot water temperatures. Automatic start-up of the standby pump takes place when the system pressure is too low.

Electronic Cooling -- The chilled water temperature provides a basic measure of the correct system operation; monitoring of the pressure indicates water line(s) integrity. Automatic system shut-off is provided (and indication thereof) for zero pressures.

Pollution Control Systems -- Wastewater and waste oil level-sensing and display is-provided for the collection, holding and transfer tank; the waste water drain tank; and the waste oil drain tank.

- Seawater -- Normal monitoring of seawater flow and pressure is sufficient for ship operations during all conditions.

- Fuel Oil -- Normal monitoring of pressure and/or flow are sufficient to identify incipient failures in this fully redundant subsystem.

- Lubrication System -- Oil pressure, temperature, and reservoir level for each propulsion engine are monitored at the engine control panel. The propulscr gearbox oil pressures and temperatures for each drive unit are indicated. In the event of low-pressures, an alarm warning sounds and the pre-lube pump is actuated. A light at the appropriate monitoring station indicates that the pre-lube pump is on or off. The seawater supply into the lube oil heat exchanger is monitored by a pressure transducer.

- Compressed Air -- The engine bleed air temperature downstream of the heat exchanger is monitored by use of pressure transducers with readout on the control console to ascertain that the bleed air is kept below 450°F for engine starters. Each engine starter valve is position monitored with a position open or closed indication= A pressure transducer on the service air receiver indicates the adequate pressure range for service air usage.

- Hydraulic System - The hydraulic fluid system pressure is continuously monitored by a pressure transducer with readout on a control console meter. The hydraulic pumps are provided with pressure switches that activate lights on the control console if a pump malfunctions.

  Each hydraulic subsystem has flow fuses activated by losses of fluid due to any major leak in a particular line. The hydraulic fluid temperature is monitored. If the temperature exceeds 150°F (normal operating temperature range is 100 to 120°F), it will indicate heat exchanger or seawater control valve malfunction. A temperature transducer at each heat exchanger continuously monitors the fluid temperatures with readouts on control console meters.

  The pressurized reservoirs have local fluid volume indicators to show low fluid levels and remote readout on the control console. Each hydraulic fluid filter is provided with a pressure differential activated by pressure drops beyond a specified limit. The pump inlet filters are provided with pressure differential transducers with remote readout on a control console to indicate bypass mode operation of the filter.

Table 2.3.5 -1 **(U).** List of Pumping Equipment, Filter Separators, and Manifolds (U)

a) <u>**Pumping** Equipment</u>

Item	Quantity	Flow gpm (m^3/s)	Press psi(mPa)	Power Reg. hp/Kw	Type	Driver Power	
Trim	4	400(.0252)	65 (0.448)	24(17.9)	Cent.	400Hz	440V
Transfer	2	400(.0252)	65 (o.448)	24(17.9)	Vert.Tur.	"	"
Service	4	400(.0252)	65 (0.448)	24(17.9)	Cent.	"	"
Helo Serv.	2	50(.0031)	65 (0.448)	3.5(2.6)	Cent.	"	"

b) <u>Filter Separators</u>

Item	Quantity	Flow gpm (m^3/s	Press Rating psi(mPa)	Driver Power	
Transfer	2	400(.0252)	200(1.38)	400Hz	220V
Service	2	400(.0252)	200(1.38)	"	"
Helo Serv.	2	50(.0031)	200(1.38)	"	"

c) <u>Manifolds</u>(1)

Item	Quantity	Press psi(mPa)	Driver Power, VDC
Trim	4	200(1.38)	28
Transfer	2	200(1.38)	28
Service	2	200(1.38)	28
Helo Serv.	1	200(1.38)	28

(1) Manifolds include valves with operating times of 3 seconds

Table 2.3.5 -2 (u). **LM5000** Propulsion System Gears, Transmission and **Waterjet** Pump Lube Oil System **(U)**

Number of Systems: 4

Maximum Power Rating per System: 50,000 hp (37,285 **kW)**

Lubricant Type: MIL-L-17331

Maximum Heat Rejected per System: 42,440 **btu/min.** (745.78 **kW)**

Maximum Lube Flow/System: 233 gpm (0.0147 m^3/s)

Heat Exchanger: Secondary Surface - Liquid to Liquid

Number/System: 2 in parallel

Cooling Media: Seawater

Source: Second-stage cavity, propulsor

Maximum **Seawater** ΔP across Heat Exchanger: 0.4 psi (2.758 **kPa)**

Auxiliary Pump Capacity at 4000 **rpm:** 100 **gpm** @ 100 psi (0.00631 m^3/s @ 68.9 Pa) press. side/200 **gpm** (0.01262 m^3/s) scavenge side

Dwell Time, Seconds: 40

Auxiliary Pump Driver: 400 Hz, 12.5 hp (9.32 **kW)**

Table 2.3.5-3 (U): SWBS 500 (less 567)
Auxiliary System
Weight Breakdown (U)

SWBS Subsystem	Weight			
	LT	kN	*	% of Total
HVAC	16.63	165.7	16.89	14.4
Sea Water	18.41	183.4	18.70	15.4
Fresh Water	8.59	85.6	8.73	7.4
Fuel and Lubrication Handling & Storage	10.79	107.5	10.96	9.3
Air, Gas & Fluid	18.72	186.5	19.02	16.2
Mech. Handling	22.01	219.3	22.36	19.0
Special. Purpose	12.78	127.3	12.98	11.1
Miscellaneous	7.63	76.0	7.75	6.6
TOTAL	115.56	1,151.4	117.39	100.0

* non-SI metric tons

(U) 2.3.5.2 Lift System

2.3.5.2.1 Air Distribution Summary Description -- Lift system air distribution consists of two sets of lift machinery and ride control equipment schematically shown in Figure 2.3.5.2-l. Each set of lift machinery is arranged in an in-line configuration, one set on each side of the ship. Power for each set of lift machinery is supplied by an LM5000 gas turbine engine. The required power and speed is delivered to the lift fans via the lift power transmission system which consists of the reduction gear unit, shafting and associated components. The lift fans draw air through inlets on the ship's deck, and discharge into spearate and independent air distribution ducts. The forward fan on each side of the ship supplies air to the bow seal, the center fan supplies the cushion, and the aft fan also discharges into the cushion. Each fan duct is supplied with a shut-off valve to prevent back flow when the fan is not operating.

(U) 2.3.5.2.2 Seal Summary Description -- The design for the advanced planing bow seal and the passive planning stern seal utilizes a series of flexibly connected fiberglass planers at the water interface. An elastomer pressure bag provides the closure necessary for air containment in both the bow and stern seal applications and provides the necessary force to contour the bow seal. These planing seals are a new, improved concept in SES seals that combine excellent low drag performance with rugged, high wear resistance qualities. The excellent wear resistance of the planing seals is exemplified by the high speed water impact erosion resistance of the glass reinforced plastic (GRP) elements, which is greater than the resistance of the rubberized fabric material of common bag and finger seals. The advanced planing seals also perform the normal and vital functions of containing the air in the cushion, contributing to ship ride quality, and providing pitch and roll restoring forces to the ship.

(U) The success of the advanced planing bow seal in model and manned craft testing has provided a high degree of confidence in the design concept. Commercially available materials have been specified throughout during initial design phases. This policy has provided reliability and performance predictability. Future refinements in materials technology and the increased use of state-of-the-art materials, particularly in the field of reinforced plastics, will greatly improve the strength to weight ratio and, consequently, the total life expectancy of seal components. These improvements will be implemented into the design in such a manner as to preserve the high reliability and performance characteristics.

(U) Considerable success has been obtained with small scale models of the passive stern seal system. The results have indicated that full scale development of a passive stern seal will yield many weight and system complexity improvements. The passive seal will require no ducting and will thus provide weight and structural benefits by the elimination of control valving and the necessity for duct penetration of transverse bulkheads. The performance of the passive seal will add a self-regulating characteristic to the operation of the craft; the seal will be more responsive to surface irregularities and will thus provide reduced drag and improve craft performance profile, Much of the technology advancement inherent in the near term SES seals will be incorporated into the passive seal design. Materials of construction and manufacturing methods will benefit from bow seal improvements that may be implemented as technology improves sufficiently to provide the same high degree of reliability as that for'the near term SES design.

(U) 2.3.5.2.3 Condition Monitoring and Fault Isolation Lift System -- The lift system will be condition monitored with an automated sensing and display system. Changes in measured lift system parameters are related to changes in component performance which further relates to component faults such as erosion, corrosion, fouling, foreign object damage and worn seals, bearings, etc. Comparison of performance to baseline data provides near term monitoring and subsequent out-of-limits conditions. If a parameter is not within operating range, all parameters associated with the fault parameter will be recorded and/or displayed. Component fault prognostication capability will be developed by "off the line" component static measurements which will be recorded at established intervals. The combined "on and off the line" component sensing systems will provide high operational reliability with a programed down time to occur during scheduled overhaul periods.

(U) 2.3.5.2.4 General Arrangement -- The air distribution and seals are arranged as shown in Figure 2.3.5.2-2. Component details of the air distribution and seals combined system are discussed in the following paragraphs.

(U) Power Units -- Two gas turbines, each driving three VG fans through a reduction gearbox, are utilized in the SES lift system. One gas turbine is located on the starboard side of the ship and the other on the port side. Each gas turbine is independent of the other and can deliver 40,000 hp (29.84 MW) continuous shaft power and 48,000 hp (35.81 MW) intermittent shaft power. The link mounting system is identical to that used for the propulsion plant LM5000 gas turbines.

(U) Power Transmission System -- The power transmission system begins at the flange which connects the power turbine to the reduction gearbox shaft. A disc type brake is mounted on the gearbox at the input shaft. At the output side of the reduction gearbox, a torsionmeter is installed. Two diaphragm type flexible couplings are installed between the torsionmeter

(U) (gearbox output shaft) and the first lift fan, one at each end of the shaft. The driven power to the fan rotor is picked up through the integral fan couplers. The integral fan couplers are those sections of drive shaft within, and integral to, the fans which permit decoupling of any fan. Flange couplings are used at each end of the fan through-shaft to connect to the drive shaft. A length of shafting and two shaft bearing support5 with associated couplings are situated between the fan couplers of the second and third fans. Seals are provided where the lift shaft penetrates watertight bulkheads. The transmission systems are interchangeable port and starboard.

(U) The lift reduction gearbox is a parallel shaft, 36 inch **(0.81m)** vertical drop box dasign with an overall reduction ratio of 2.22 to 1. The gearing is external double helical of involute form and is case hardened and ground to **AGMA** quality 12 or better, The gear case is an aluminum casting. Identical gear boxes are used for both port and starboard lift systems.

(U) The power transmission system for each set of lift fans is designed to transmit a maximum of 48,000 hp (35.81 MW) from the gas turbine through the reduction gears to the lift fans. The system is designed to accommodate a maximum input shaft speed of 4,000 rpm from the turbine and a maximum output shaft speed of 1,800 rpm from the reduction gear to the fans.

(U) Lift Fans -- *The* Lift *and* Ride Control System uses a total of six lift fans. The fans are symmetrically located, three port and three starboard,. with each group positioned in line on a common shaft.

(U) All of the lift fans are **identical,centrifugal** type, with an 87 inch **(2.21m)** diameter rotor, a housing, and variable geometry elements. **They** incorporate a double axial inlet design, airfoil shaped radial blades, constant velocity volute housings, and a single circular discharge. The variable geometry fan elements provide modulation of the air flow

(U) for ride control purposes. The fan is shown in Figure 2.3.5.2-3.

(U) Included in the fan envelope are the self-contained rotor decoupler, rotor bearings and coaxial line shafting that permit independent decoupling of any fan while operating under any design load. The mechanisms additionally provide for remotely activated recoupling of fans from an at-rest condition.

(U) Lift Ducting -- The lift air is delivered through vertical short ducts to the bow seal and to the cushion area. The bow and cushion air ducts are' short, conical sections which act as diffusers to reduce high velocity losses. The incorporation of a passive stern seal. system has eliminated the need for a stern seal pressure differential and thereby the associated delivery duct to the stern seal. No transverse bulkhead penetration is required.

(U) All supply ducts have hydraulically operated butterfly type shut-off valves located near the fans. The shut-off valves prevent back flow from the pressurized cushhon if a fan is not operating for any reason.

(U) Lift Air Intakes -- The lift fan inlets supply atmospheric air to the lift fans for pressurization and subsequent distribution into the cushion, bow seal and stern seal. Five openings are provided in the deck, port and starboard, to supply air for each group of three fans. The intake openings are positioned directly above the lift fan bellmouths as shown in Figure 2.3.5.2.4 Four of the inlets- are 12.2 feet (3.72m) wide by 7.0 feet (2.15m) long; the fifth inlet, which supplies the adjacent inlets of the mid and aft fans is 12.2 feet (3.72m) wide by 14.0 feet (4.29m) long.

(U) Passive Stern Seal -- The passive stern seal system uses lift fans ducted directly into the cushion. The stern seal is inflated only by means of the cushion and does not require a separate fan or source of inflation. Pressure losses due to long ducts leading to the stern seal are therefore avoided, leaving these spaces available for fuel or additional payload on the third deck. Higher flow rates into the cushion at the same fan flow are due to reduced back pressure. The optimum location of the lift fans, however, should be in the proximity of the bow seal, since induction effects (particularly at high speeds and in rough seas) cause a pressure distribution buildup in the aft cushion which is alleviated by such forward fan loctions.

(U) The mechanism of wave pumping is largest when the cushion length is in multiples of 0.5, 1.5, 2.5, 3.5, etc., of the wave length. At multiples of 1, 2, 3, 4, etc., the wave pumping contribution of the waves traversing the cushion is zero. The vent valve interconnecting the stern seal with the atmosphere monitors the passive stern seal such as to stabilize the cushion pressure during wave pumping. Preliminary studies have shown that a vent valve opening rate of 100 ft^2/s (9.29 m^2/s) results in substantial heave alleviation of the resulting motion.

(U) The most critical condition of ship dynamics relative to the passive stern seal response is in a low sea state five head sea at 85 knots (43.72 m/s) with a significant wave height of 5.0 ft (1.52 m), a wave length of 155 ft (47.24m), and a relative wave speed of 171.73 fps (52.34 m/s). This is a condition of maximum wave pumping that results in the highest amplitude-frequency related response of the passive stern seal. With lower wave heights and higher speeds, the low amplitudes and high frequency rates allow the seal to provide ample cyclic gaps without impairment of ship performance, as the pressure variations tend to level out (due to the wave). In higher waves, reduced ship speeds allow the passive stern seal ample time to recover.

(U) The passive stern seal geometry is shown in Figure 2.3.5.2-5. The design incorporates the following additional features:

Stern seal drain area = 10 ft^2 (0.93 m^2)
Stern seal maximum control (dump) valve area = 40 ft^2 (3.72 m^2)
Dump valve rate of opening/closing = 100 ft^2/s (9.29 m^2/s)
Weight of planer = 11,000 lbs. (48.93 kN)
Miscellaneous cushion leakage = 30 ft^2 (2.79 m^2)

(U) The cited values pertain to nominal (enlarged) ANVCE fan speed seetings equivalent to that for the 3KSES fan at 1868 rpm, with fully open variable geometry and a maximum backflow area per fan of 28 ft^2 (2.60 m^2). The combined bow/stern seal system has a 221 ft (67.36 m) cushion length, an 85 ft (25.91 m) cushion beam, and a cushion length-to-beam ratio of 2.60.

(U) The passive stern seal geometry is capable of meeting the far term ANVCE requirements with a stern seal-to-cushion by-pass area of 300 ft^2 (28.87 m^2). A substantial heave alleviation effect is achieved by the vent-valve controlled passive stern seal, Forces experienced by the seal are well within the state-of-the-art and ship dynamics are projected to be within acceptable bounds.

(U) Figure 2.3.5.2-7 provides the Rohr passive stern seal design characteristic geometry. The passive stern seal is mounted to a flat wet deck. The lobes are held by tension straps and a geometry strap attached integral to the wet deck. A series of gussets are attached to the wet deck to provide a large opening between the planer attachment and the wet deck. A deflector plate ahead of these gussets prevents direct entry of water into the stern seal due to wave action but allows entry of air (the lighter medium). The planer is attached to the gussets (and thereby to the wet deck). The heart of the passive seal is the compression strut, attached to the planer and the geometry

(U) A **fairing** is provided around the openings to eliminate the ship boundary layer air and surface water flowing on the deck from entering the fan air inlets. The inlet design incorporates aerodynamic turning vanes to direct the air flow downward into the fan rooms. The vanes permit recapture of about half the air velocity head across the deck. An electrical **heating** system is incorporated in the vanes to provide **anti-**icing capability. The vane walls of each flow passage are treated to provide the necessary sound attenuation.

(U) Ride Control System -- The ride control system integrates the variable geometry lift fans, the stern seal vent valves and their associated actuators **with** appropriate ship motion sensors and the controller electronics into an active system. The total active system modulates the bow seal and cushion airflows to reduce the ship's heave accelerations to an acceptable level. The primary ride control system uses the variable geometry fans to control airflow. Vent valves are provided to expand the flow range available in high seas and to provide maximum versatility for RCS development,

(U) The variable geometry component of **the** fans is hydraulically operated and located in the fan inlets. When fully closed, the fan flow is reduced to less than 10 percent of design point conditions. The frequency response bandwidth of the sleeve actuating system is 0 to 5 Hz.

(U) Advanced Planing Bow Seal -- The advanced planing bow seal is illustrated in Figure 2.3.5.2-5. Geometry of the seal is given in Figure 2.3.5.2-6. The seal consists **of** four main elements which are described as follows.

(U) An elastomer pressure bag is attached to the bow at the 40 foot **(12.19m)** waterline and normally extends aft in a continuous circular arc and connects to the wet deck. The bag is configured of eight identical modules with elastomer end caps at the **sidehull** interfaces. The bag and end caps provide a flexible structure which contains the bow seal air while minimizing water ingress into the seal. The aft loop of the bow bag contains slotted openings of fixed width to provide controlled air flow between the seal and the cushion and to assure rapid water drainage.

(U) The planer/stay portion of the seal consists of thirty-two (32) modules across the beam of the craft. These planer/stay modules are constructed of glass reinforced plastic (GRP) and are attached to the wet deck at the 40 foot (12.19m) waterline. The upper forward portion, or stay, has relatively low stiffness allowing it to conform to the curvature of the forward portion of the bow bag. Near the lowest portion of the bow bag loop, the stays widen and are joined together by flexible sealing strips to form a continuous fiberglass planer surface.

(U) A 31-inch wide tapered GRP feather edge is attached to the trailing end of each bow seal planer module. This feather edge, having increased flexibility is used to attenuate the effective wave impact on the seal, assist in cushion sealing and improve the seakeeping capability of the craft.

(U) Each planer is supported by a geometry strap and a retract strap. The strap provides mid span support and geometric control of the planer through the full range of sea states. The geometry strap normally carries a tension load due to the cushion pressure acting on the planers, but may be unloaded for a short duration when encountering high waves at a higher velocity.

(U) A seal retract strap is attached to the retraction reel recessed inside the hull and extends down to an attachment at the aft edge of each planer. The straps provide for full retraction of the seals against the wet deck for off-cushion operation and also for adjustments and trimming of the seals for minimum drag during hump transit, partial-cushion and full-cushion operation.

(U) The 32 straps pass through slots in the wet deck structure, and over sheaves, before attachment to the retraction reel drums. Provision is made at each drum for unlimited strap length adjustment. Locks at the retraction drive outputs prevent inadvertent seal extension by high loadings. The drive units allow for high and low speed seal retraction, low speed extending adjustment, and the rapid free-wheeling extension associated with the craft going on-cushion.

(U) strap. The arrangement forms a four bar linkage with the base and the compression strut angled to the wet deck.

(U) Stay elements are attached to the wet deck and extend the depth of the sidehull. The Rohr design features a series of connected planer strips and a compression strut geometry that allows the planer to deform both longitudinally (vertical motion) and laterally (differential vertical motion or lateral bending) for beam sea wave compliance. Thirty-two such elements span the beam of the craft and provide a forward member of a 4-bar linkage arrangement.

(U) A three-lobed bellows bag is attached at the wet deck and to short stiff force members attached by pin joint fittings to the lower aft termination of the stay elements. This arrangement is stabilized by a cable running from the bellows bag/force member terminus to the wet deck. This cable, aligned parallel to the stay element, completes the 4-bar linkage.

(U) The bellows bag is built in modular sections and is fabricated of the same nylon/elastomer material as the bow seal bag. Holes are located along the lower lobe of the bellows bag and sized to permit rapid drainage of water. The three-lobe bellows is optimum for seal spring rate requirements and for tensile loading in the membrane.

(U) Convolute tension cables are connected between the wet deck and the junctions of the lobes of the bellows bag to maintain the geometry of the bellows bag through the entire deflection of the seal. Retract straps are attached to each planer near the planer's trailing edge and are connected to the retract system reel in a manner similar to the bow seal system. The stern seal retraction system is similar to the bow system.

(U) 2.3.5.2.5 Tabulation of Key Parameters -- The key parameters of the lift system are presented in Tables 2.3.5.2-1, Lift System Physical Parameters, Table 2.3.5.2-2, Lift System Point Design, Table 2.3.5.2-3 and Table 2.3.5.2-4.

(U) 2.3.5.2.6 Lift System Weight Breakdown -- Table 2.3.5.2-5 shows the weight of each major lift system subsystem and each subsystem's percentage of the Lift System total,

(U) 2.3.5.2.7 Lift System Technical Risk -- The total lift system risk depends upon the individual component risks. Considering the diversification of functions and the number of components included in the lift system (lift air machinery, ride control elements, seals), the overall risk is based on the relative importance of each function. To further, reduce risk, commonality between the starboard and port lift systems was established by using identical gear boxes (3 ft. (0.81m)) with no opposite hand rotation. The result is that the starboard lift equipment can be interchanged with that on the port side.

- Lift Gas Turbine Engine System -- The LM5000 gas turbine engine is derived from the CF6-50 commercial gas turbine and the LM2500 marine gas turbine (which is currently in service with the U. S. Navy). The LM5000 lift gas turbine engine has been derated from the propulsion LM5000 rating by renozzling the gas generator. Otherwise, the lift and propulsion GT's are identical.
- Power Transmission System -- Reduction gear and gear box designs employ proven technology utilized for marine applications. The transmission system arrangement and component selection are proven and within the present state-of-the-art. The transmission system is identical for port and starboard lift systems. There is no apparent development risk for this system.
- Variable Geometry Fan -- The variable geometry fan concept has been proven feasible by test at a number of scaled sizes. Especially significant is the use of the 3K 1/4 scale ALRC lift fans with VG feature on the XR-1 testcraft. The far term SES fan is a growth fan of the 3KSES sized by "affinity laws" and standard industry procedures. The fan design must be verified in terms of full-size material strength and fluid requirements and integrative ramifications.
- Duct Configuration -- The analysis of the lift system duct configurations predicts the pressure losses with a high degree of confidence. The construction uses proven marine/aircraft concepts.

(U)

- Lift Air' Inlet -- The analysis supporting the lift inlet design is based on the use of existing aerodynamic flow concepts. The materials and the shaping of the turning vanes are well within the current technology of the marine/aircraft industry.
- Ride Control Valves -- The ride control valves are a type similar to that used successfully in the 100A program. Proven off-the-shelf type components are used throughout the system. To further improve reliability, the mechanism is a simple straight-forward linkage design similar to aircraft linkage systems that are presently in use.

Table 2.3.5.2-1 (U): Lift System Physical Parameters (U) (Sheet I of 3)

	UNITS		VALUES	
	ENGLISH	(SI)	ENGLISH	(SI)
1. Engine - **LM5000,** 2 Required				
Design Rotational Speed	rpm	(r/s)	4,000	(418.88)
Maximum Continuous Power (MCP)	hp	(kW)	40,000	(29,840-0)
Specific Fuel Consumption (SFC)	lb/shp-h	(kN/kW-h)	0.32	(1.91)
Maximum Intermittent Power **(MIP)**	hp	(kW)	48,000	**(35,808.0)**
Volume	ft^3	(m^3)	2,294	(64.959)
Basic Engine Weight	lb	(kN)	**19,750**	**(87.852)**
2. **Reduction** Unit With Brake, 2 Req.				
Power Capacity	hp	(kW)	48,000	**(35,808.0)**
Gear Ratio			2.22	
Cear **Type:** Single Reduction, **Dougle Helical** Involute Tooth				
Volume	ft^3	(m^3)	203	(5.748)
Weight Port	lb	(kN)	5,900	**(26.244)**
Weight Starboard	lb	(kN)	3,762	(16.734)
3. Lift Fans (ALRC) 6 Required				
Type: Centrifugal, Dual Inlet, Constant Velocity Volute, Variable Geometry, Decoupling Device				
Rotor Diameter	in	(m)	87.0	(2.210)
Rotational Speed	rpm	(r/s)	1,461	(156.45)
Tip Velocity	ft/s	(m/s)	567	(172.8)

Table 2.3.5.2-1 **(U):** Lift System Physical Parameters (U) (Sheet 2 of 3)

	UNITS		UNITS	
	ENGLISH	**(SI)**	**ENGLISH**	**(SI)**
3. Lift Fans (ALRC) Continued				
Design **Head** Rise	**psf**	**(kPa)**	436	(208.8)
Design Flow	**cfs**	**(m^3/s)**	10,000	(283.169)
Peak Efficiency, Fan Percent			83.5	
Specific Speed, $N_S = \frac{NQ^{1/2}}{H^{3/4}}$			156	
Exit Diameter'	in	**(m)**	103.75	(2.63525)
Design Exit Velocity	**ft/s**	**(m/s)**	170	(51.82)
Maximum Rotational Speed	**rpm**	**(r/s)**	1,800	(188.50)
Maximum Flow (Approximate)	cfs	**(m^3/s)**	13,000	(368.119)
Maximum Power	**hp**	**(kW)**	13,000	**(9,698.00)**
Volume	**ft^3**	m^3	2,980	(908.40)
Weight	**lb**	KN	12,200	(54.2683)
4. Transfer Shafting				
Total Length (1) Per Ship	**ft**	**(m)**	98	(29.9)
Total Weight (4)	**lb**	**(kN)**	13,900	(61.830)
5. Districution Ducting				
Total Length (3) Per Ship	ft	**(m)**	40	(12.2)
Total Weight (4)	lb	**(kN)**	**7,737**	(34.416)

Table 2.3.5.2-l **(U):** Lift System Physical Parameters **(U)** (Sheet 3 of **3)**

	UNITS		**VALUES**	
	ENGLISH	**(SI)**	ENGLISH,	**(SI)**
6. Fan Inlets				
Type: Flush Horizontal with Acoustic Turning Vanes.				
Velocity **Ratio (IVR)** at 80 Knots (41.16 m/s); Free Stream/Inlet Velocity			**.70**	
Weight	lb	**(kN)**	13,101	**(58,276)**

(1) Total length from gear box interface to last fan. Fan internal shafting not **included.**

(2) Includes shafting **flex** couplings and bearing pedestals.

(3) Includes ride control **ducting.**

(4) Includes flex coupling and values.

Table 2.3.5.2-2 (U): Lift System Point Design (U)

Ship Weight:	LT (MN)	3600	(35.87)
Weve Height $H_{1/3}$:	ft (m)	4.6	(1.40)
Ship Speed:	knots (m/s)	80	(41.2)
Pressures:	psf (kPa)		
Bow :		401	(19.20)
cushion :		385	(18.43)
Total -Flow Rate:	cfs (m^3/s)	60,000	(1,699.01)
Lift System Efficiency:	%	79.2	79.2
Duct Losses:	psf (kPa)		
[illegible]		30	(1.44)
Cushion:		31	(1.48)
Fan Parameters:			
Speed:	rpm	1,500	(157.08)
Total Shaft Power	hp (kW)	51,727	(38,588.4)
Flow:	cfs (m^3/s)		
Bow:		19,290	(546.23)
Cushion:		40,710	(1,152.78)
Engine Parameters (LM5000)			
Speed:	rpm	3,333	(349.03)
Total Brake Power	hp (kW)	53,034	(39,563.4)
Total Fuel Flow	lbs/h (N/s)	19,729	(24.377)
SFC	$\frac{\text{lbs}}{\text{bhp-h}}$ $\left(\frac{\text{N}}{\text{kW-Hr}}\right)$	0.372	(2.218)

Table 2.3.5.2-J **(U):** Seals Design Load Parameters (U)

1. BOW SEALLOADS

ELEMENT	**DESIGN[1] FACTOR (MINIMUM)**	**NOMINAL WORKING LOADS**	**MAXIMUM LOADS**
Wet Deck Stay Attachment	2	**3,588 lbs/ft (146,083 N/m)**	**17,044 lbs/ft (258,864 N/m)**
Fwd Wet Deck Bag Attachment	**1.5**	**781 lbs/ft (11,395 N/m)**	24,605 **lbs/ft (358,823 N/m)**
Aft Wet Deck Bag Attachment	**1.5**	**485 lbs/ft (7,162 N/m)**	16,916 **lbs/ft (246,692 N/m)**
Geometry Strap	2	2,690 **lbs/strap** (11,957 N/strap)	55,120 **lbs/strap** (246,060 N/strap)
Retract Strap	2	1,281 **lbs/strap** (5,700 N/strap)	4,900 **lbs/strap** (21,960 N/strap)
Module-to-Module Joint	**2.0**	435 **lbs/ft** (6,397 N/m)	1,250 **lbs/ft** (18,205 N/m)
Planer-to-Planer	**2.0**	1,200 **lbs/ft** (17,520 N/m)	6,407 **lbs/ft** (93,542 N/m)

[1] **Maximum** load multiplied by **its** respective design **factor** is the ultimate design load.

Table 2.3.5.2-3 **(U):** Seals Design Load Parametars (Continued) (U)

2. STERN SEALLOADS

ELEMENT	**DESIGN FACTOR (MINIMUM)** (1)	**NOMINAL WORKING LOADS**	**MAXIMUM LOADS**
Planer Attachment to Wet Deck	2	909 lbs/ft (13,443 N/m)	8,650 lbs/ft (126,000 N/m)
Geometry Strap	-	1820 lbs/strap (8,100 N/strap)	55,120 lbs/strap (245,314 N/strap)
Wet Deck Attachment, Geometry Strap	1.5	1,845 lbs (8,200 N)	56,388 lbs (251,183 N)
Convolute Cable	2	10,800 lbs/cable (47,937 N/cable)	20,107 lbs/cable (89,322 N/cable)
Retract Strap	2	11,534 lbs/strap (51,262 N/strap)	50,685 lbs/strap (285,551 N/strap)
Stern Bag Wet Deck Attachment	1.5	1,068 lbs/ft (15,570 N/m)	16,916 lbs/ft (247,332 N/m)
Planer-to-Planer Joint	2.0	1,282 lbs/ft (18,717 N/m)	6,407 lbs/ft (93,542 N/m)

(1) Maximum load multiplied by its respective design factor is the: ultimate design load.

Table 2.3.5.2-4 **(U):** Seal Materials Physical Properties (U)

Planer Materials — Gloss Reinforced Fabric	**UNITS** **English** **%**	**(SI)** **%**	**VALUES**[1] **English**	**(SI)**
Generic Materials				
S-Type Glare				
Epoxy **Resin**				
Resin Content				
Tensile Strength	10^3psi	10^4Pa	32	(32)
Longitudinal			140	(671)
Transverse			120	(578)
Flexible Strength	10^3psi	10^4Pa		
Longitudinal			180	(875)
Transverse			156	(748)
Flexural Modulus	10^6psi	10^7pa		
Longitudinal			4.6	(21.0)
Transverse			3.7	(17.7)
Pressure Bag Materials — Elastomer Coated Fabric				
Generic Materials				
Nylon Fabric				
Neoprene Elastomer				
Tensile Strength	lbs / inch	(N/m)		
Warp			2,000	350,000
Fill			1,800	310,000
Elongation, Ultimate	%	%		
Warp			53	53
Fill			72	72
Pressure Bag Materials — Elastomer Coated Fabric	**UNITS** **English**	**(SI)**	**VALUES** **English**	**(SI)**
Weight	oz/sq. yd	(kg/m^2)	90	3.05
Coating Adhesion	lbs/inch	(N/m)		
Warp			80	13,300
Fill			70	12,000
Gage	inches	(m)	0.100	0.00254

(1) Values for 0/90 degree eleven ply laminates

Table 2.3.5.2-5 (U). SWBS 567 Lift System Weight Breakdown (U)

SWBS SUBSYSTEM	WEIGHT			
	LT	kN	*	% of total
Engines	26.98	268.8	27.41	22.1
Gearboxes	5.27	52.5	5.35	4.3
Lift Fans	32.68	325.6	33.20	26.7
Shafting	6.21	61.9	6.31	5.1
Ducting	3.28	32.7	3.33	2.7
Seals	32.13	320.1	32.63	26.3
Miscellaneous	15.57	155.1	15.82	12.7
TOTAL	122.12	1,217.7	124.05	100.0

* non-SI metric tons

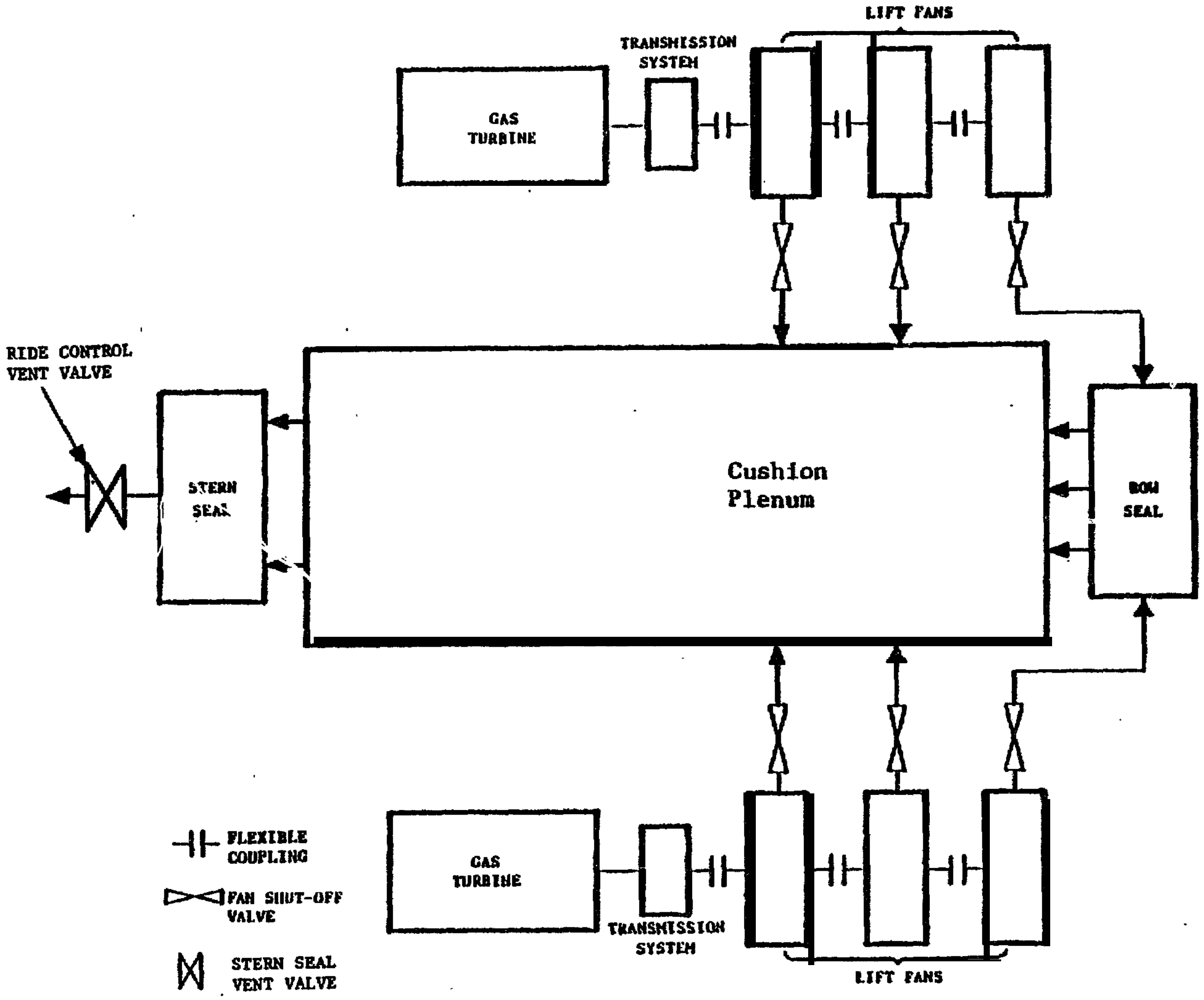


Figure 2.3.5.2-1 (U): Lift System Air Distribution Schematic (U)

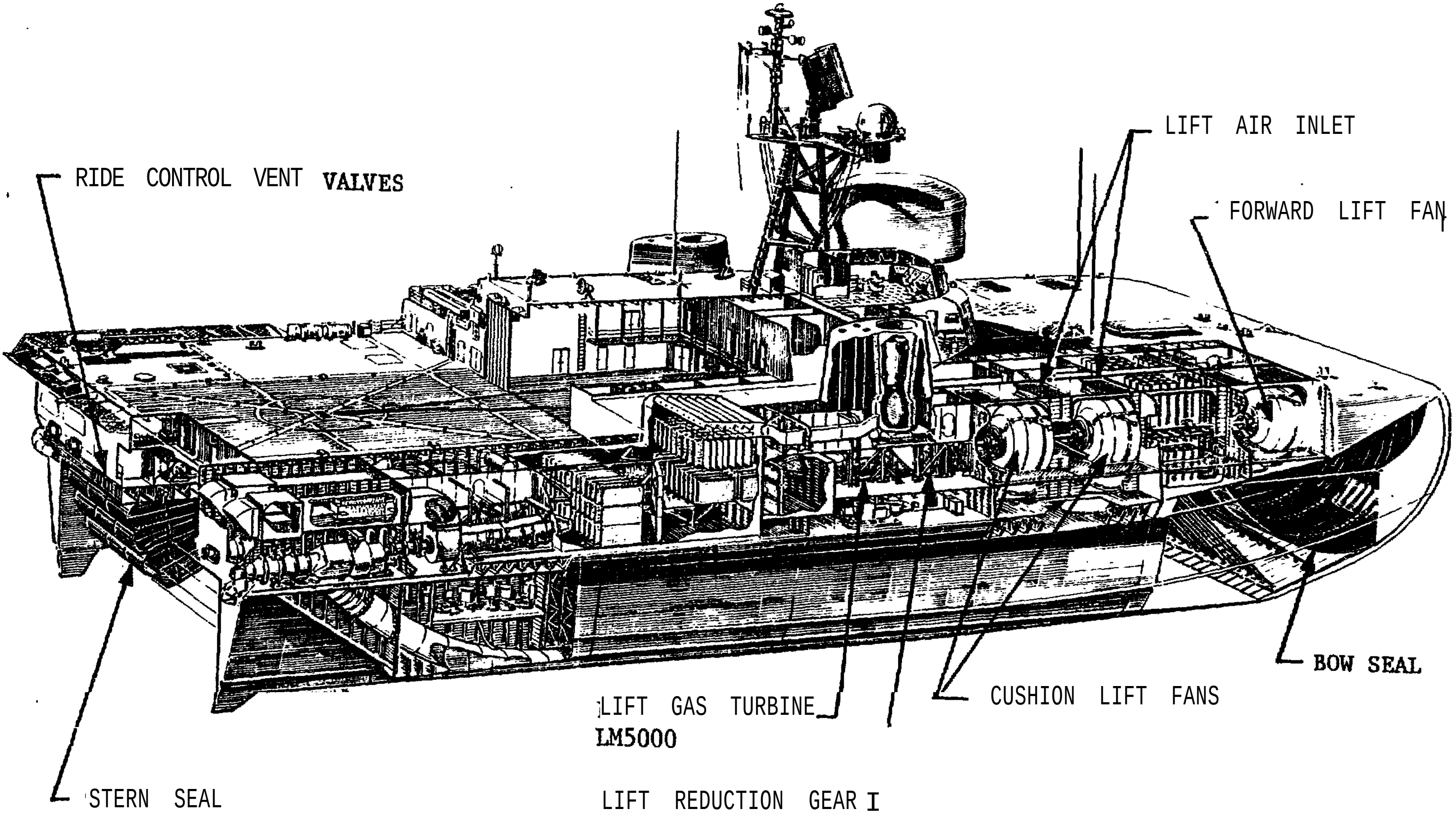
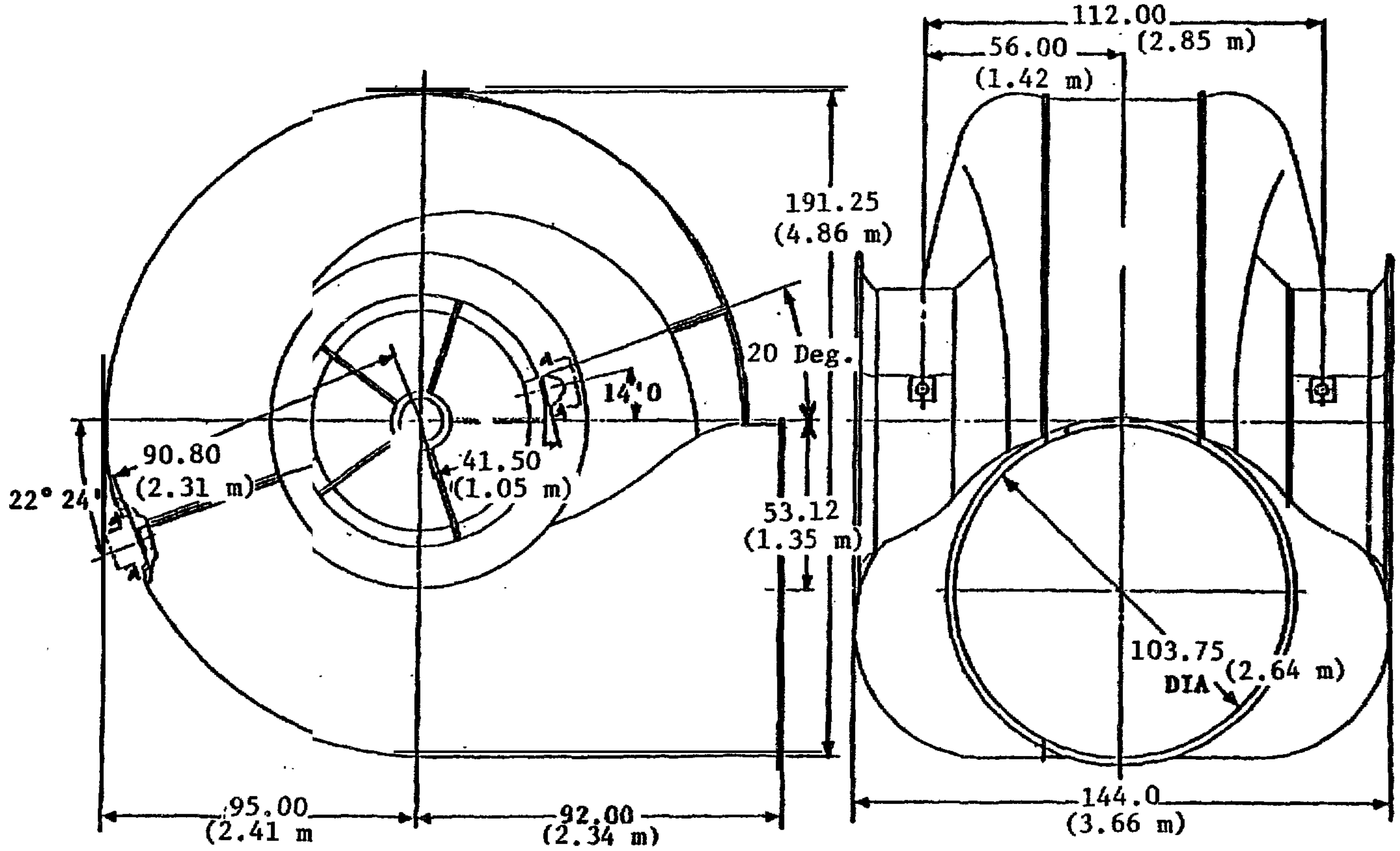


Figure 2.3.5.2-2 (U): SES Lift System Arrangement (U)



Notes: 1. Drawing not to scale.

2. All dimensions in inches (m) or as noted.

Figure 2.3.5.2-3 (U): Lift Fan Envelope - 87 Inch (2.21 m) Diameter Rotor (U)

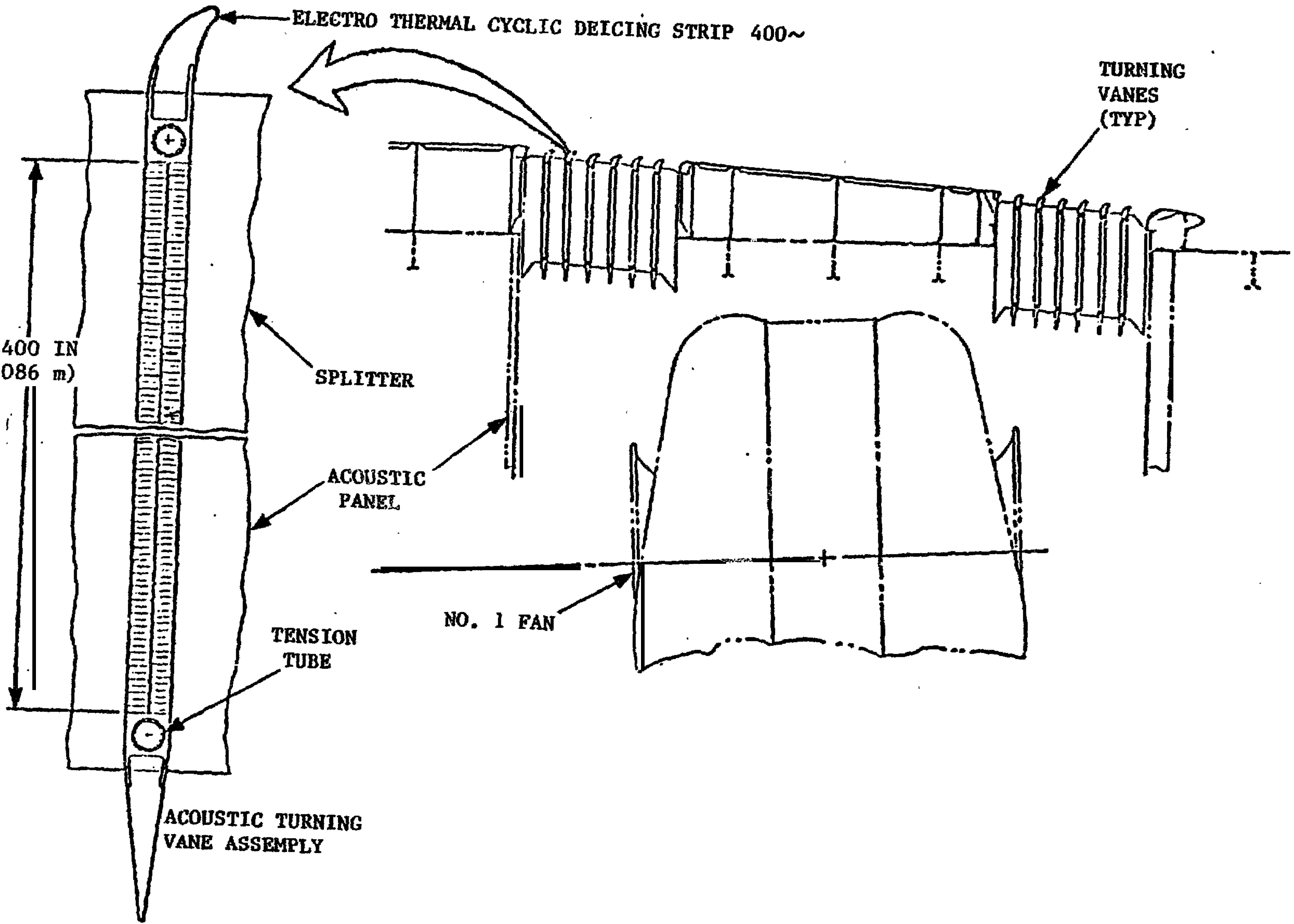


Figure 2.3.5.2-4 (U) Lift Fan Inlet and Turning Vanes (U)

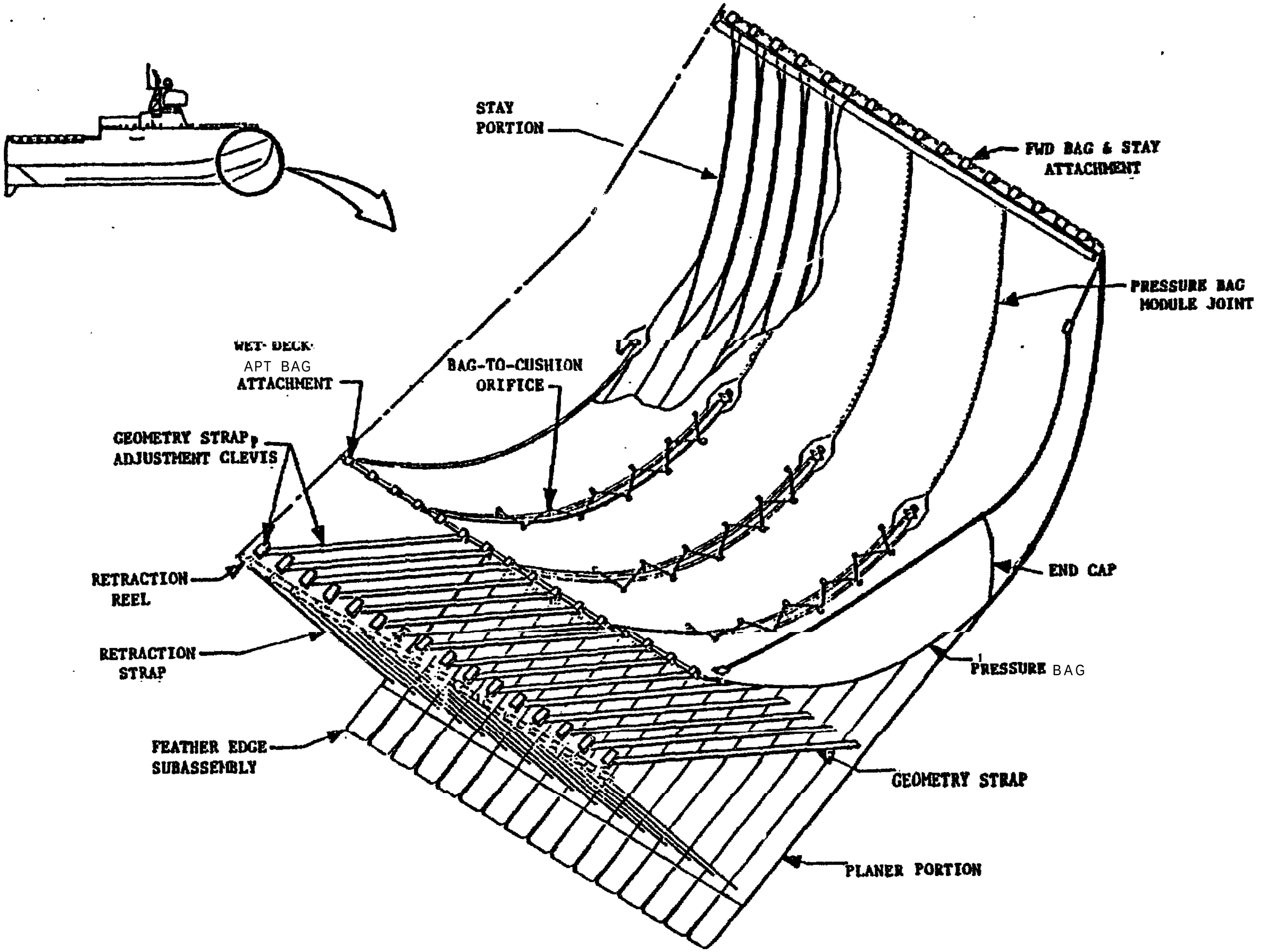


Figure 2.3.5.2-5 **(U)**: Advanced Planing Bow Seal **(U)**

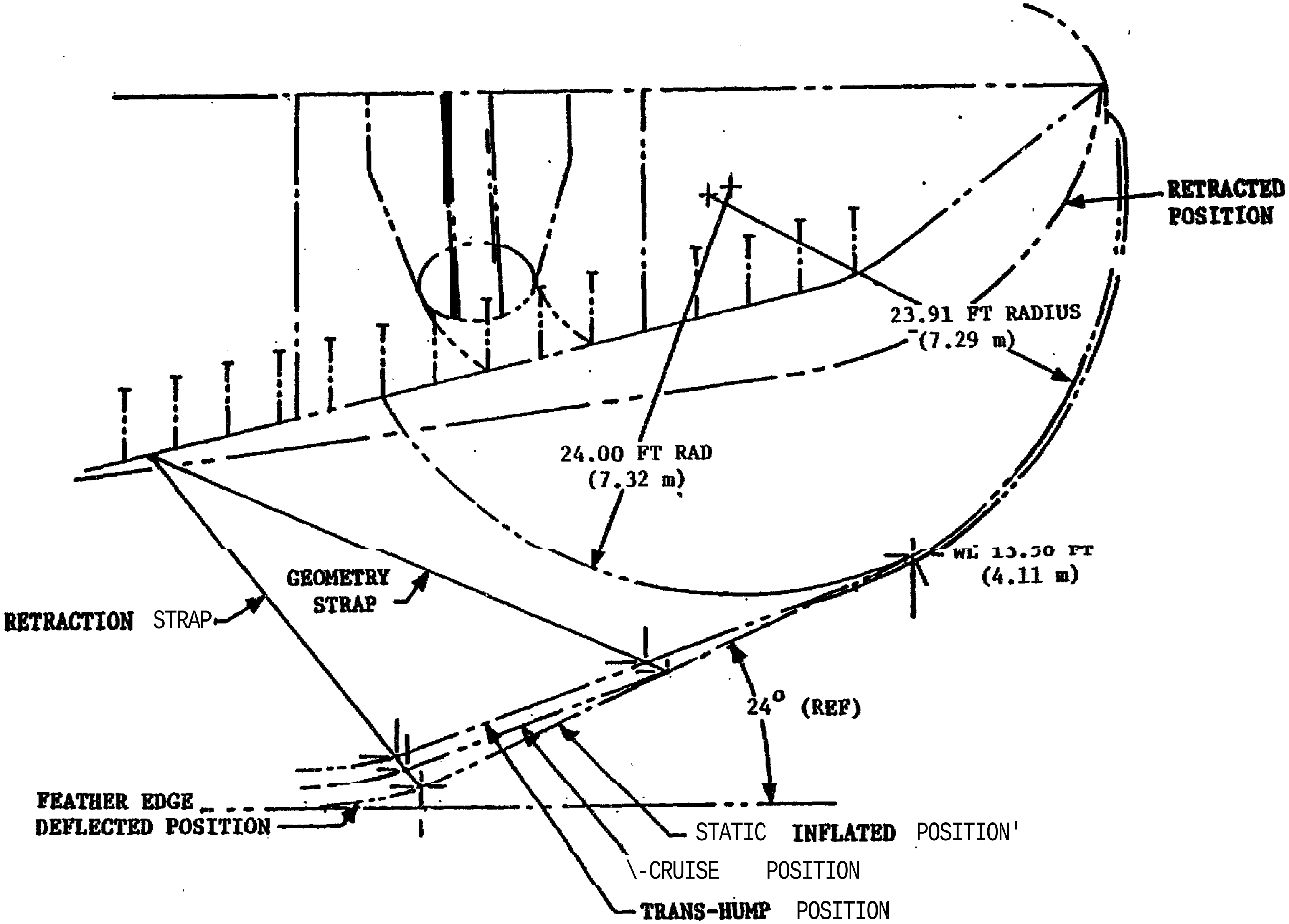


Figure 2.3.5.2-6 **(U):** Advanced Planing Bow Seal Geometry **(U)**

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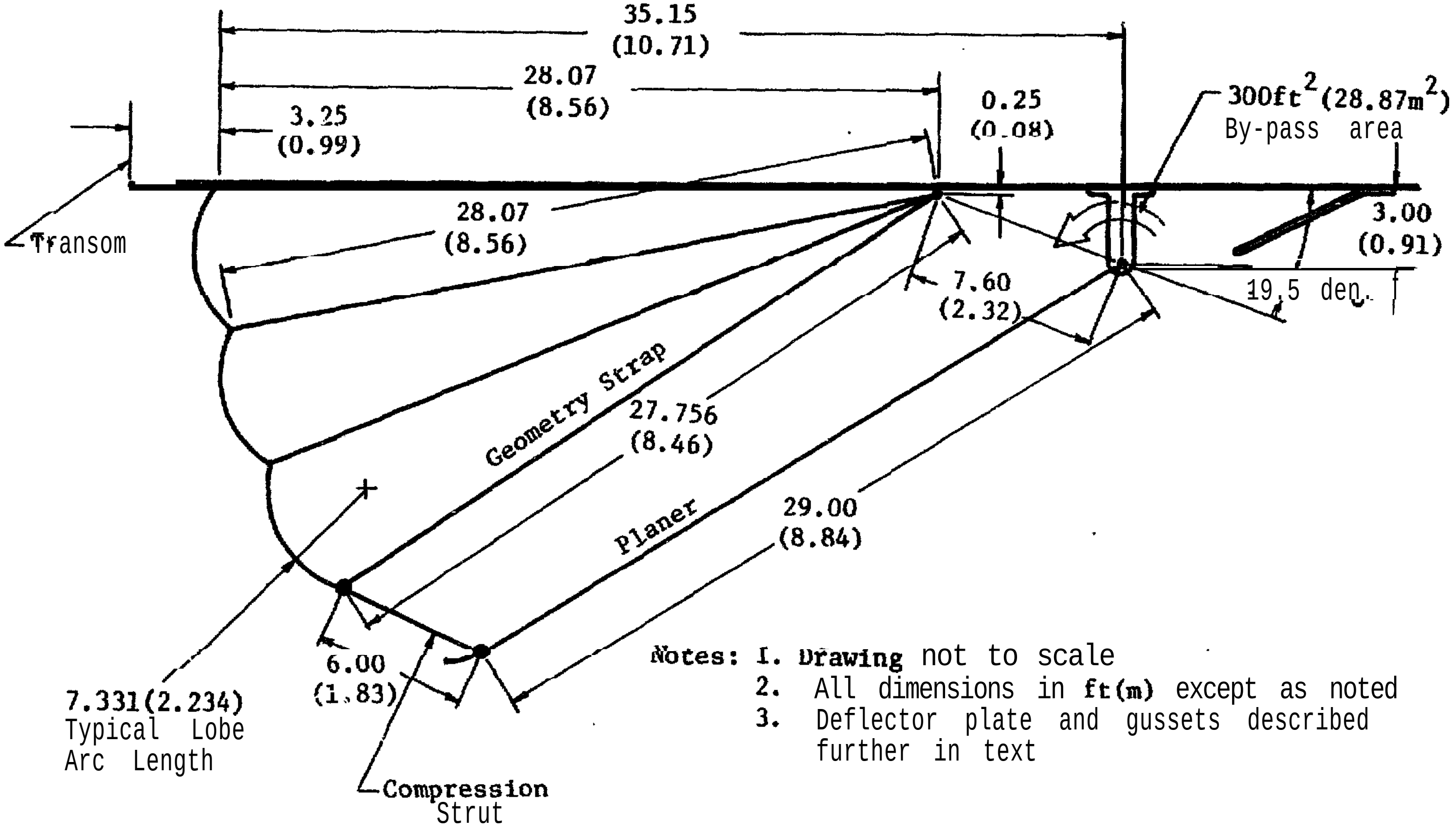

Notes: 1. Drawing not to scale
2. All dimensions in ft(m) except as noted
3. Deflector plate and gussets described further in text

Figure 2.3.5.2-7 (U). Fan Term SES Passive Stern Seal Geometry (U)

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(U) 2.3.6 OUTFITTING AND FURNISHINGS

(U) 2.3.6.1 Key Features of O & F System -- Outfit and furnishings (0 & F) is composed of a number subsystems whose functional requirements include providing (1) habitable living and functional working spaces for the ship's crew, (2) safety features and fittings such as rails and lifelines, (3) ease of access to the working and living spaces, (4) protection against abrasion or galvanic corrosion for the hull structure, (5) insulation to provide passive thermal, fire and acoustic protection and (6) storage and service spaces as required for the ship and its crew to perform their mission. All O&F subsystems conform to General Specifications for Ships of the U.S. Navy, OPNAVINST 9330.7A (proposed), and Habitability Manual N.S. 0933-005-0010.

(U) 2.3.6.1.1 Habitability -- The Rohr proposed revision of 25 October 1976 to the far term ANVCE WP-006 specifies a minimal standard of 494 ft^3 (14.0 m^3) gross volume per man for personnel living space. The near term SES with a crew of 125 provided an allocation of 555 ft^3 (15.73 m^3) per man. The far term SES with an enlarged crew of 141 provides an allocation of 637 ft^3 (18.03 m^3) per man or about 1.3 times the minimum ANVCE WP-006 requirement.

(U) Table 2.3.6-1 shows a detailed breakdown of habitability space allocations by compartment. Crew living spaces are compartmented with a maximum of 12 men to a compartment. CPO living spaces are compartmented with a maximum of five men to a compartment. Officers staterooms are double occupancy except that the Commanding Officer and Executive Officer each have single, separate staterooms.

(U) The furniture is constructed of molded non-flammable plastic. The berths each have controllable ventilating air outlets, directable reading lights and phone jacks with channel selectors. Drawers and doors are built into the berths for stowage of personal effects. See also Section 3.5.3.

(U) Messing areas are located within a convenient distance of respective crew living **spaces.** Cross-traffic has been avoided. **The** galley **is** centrally located to serve the crew from one side **and** the **CPO and commissioned** officers from the other, again **eliminating** cross-traffic;

(U) Minimum galley equipment is required since most provisions will **be** pre-prepared and the majority of the cooking will be with micro-wave ovens.

(U) Recreation areas are **also located** within a convenient distance of the respective crew living spaces. The habitability spaces are all located on the second deck and the watch stations are readily accessible for all hands.

(U) The crew's lounge is located adjacent to the crew's mess and the crew's Recreation Room and Library are located on the third deck to isolate these areas from routine traffic and noise.

(U) 2.3.6.1.2 Stowage --'Dry provisions, chill storage and freeze storage are located next to the galley. The vertical **conveyor** is located within a few steps of the galley and each storage area. Supply Department storerooms and spare parts storerooms were located in areas of the ship convenient to users (e.g., repair shops).

(U) Deck gear lockers are located near each mooring and **towing** station. This provides convenience for stowing deck gear and facilitates keeping the decks **clear** at all times.

(U) 2.3.6.2 Estimated Percentage Weight Breakdown -- Table **2.3.6-2 shows** the estimated weight percentage of the major components of the O&F System.

(Sheet 1 of 2)

Table 2.3.6-l (U). Far Term SES Habitability Space Allocations (U).

COMPARTMENT	COMPARTMENT NO.	VOLUME	
		ft^3	m^3
1 LEVEL:			
CO Stateroom	01-18-0-L	2,618.0	74.12
CO Cabin	01-19-1-L	1,078.0	30.52
CO Bath	01-23-3-L	396.0	11.21
Water Closet	01-23-1-L	222.8	6.30
AIN DECK:			
Water Closet	l-32-4-L	486.0	13.76
ND DECK:			
Crew Living Space	2-77-2-L	1,174.5	33.25
Crew Living Space	2-77-l-L	1,174.5	33.25
Crew Living Space	2-70-4-L	1,368.0	38.73
Crew Living Space	2-70-3-L	1,368.0	38.73
Crew Living Space	2-70-2-L	1,858.5	52.61
Crew Living Space	2-70-1-L	1,858.5	52.61
Crew Living Space	2-56-4-L	1,530.0	43.31
Crew Living Space	2-56-3-L	1,530.0	43.31
Crew Living Space	2-56-2-L	2,340.0	66.24
Crew Living Space	2-56-l-L	2,340.0	66.24
Crew WR, WC & SHR	2-64-4-L	1,080.0	30.60
Crew WR, WC & SHR	2-64-3-L	1,080.0	30.60
Crew Lounge	2-47-4-L	2,070.0	58.60
Crew Messroom	2-42-2-L	4,950.0	140.13
Galley	2-42-l-Q	4,950.0	140.13
Officer Lounge	2-34-2-L	2,286.0	64.72
Wardroom	2-34-l-L	3,240.0	91.72
Pantry	2-39-l-Q	1,134.0	32.10
CPO Mess	2-34-l-L	1,890.0	53.51
CPO Lounge	2-34-3-L	2,286.0	64.72
CPO Living Space	2-28-0-L	7,056.0	199.76
CPO WR, WC, & SHR	2-28-1-L	1,260.0	35.67
Medical Treatment Room	2-22-6-L	1,620.0	45.86
Medical Berthing	2-17-2-L	810.0	22.93

(Sheet 2 of 2)

Table 2.3.6-l (U). Far Term SES Habitability Space Allocations (U)

COMPARTMENT	COMPARTMENT NO.	VOLUME	
		ft^3	m^3
2ND DECK (Cont'd):			
Officer SR	2-22-4-L	1,260.0	35.67
Officer SR	2-22-1-L	1,260.0	35.67
Officer SR	2-22-3-L	1,260.0	35.67
Officer SR	2-14-4-L	1,260.0	35.67
Officer SR	2-14-2-L	1,260.0	35.67
Officer SR	2-14-1-L	1,260.0	35.67
Officer SR	2-14-3-L	1,260.0	35.67
Officer SR	2-14-5-L	1,260.0	35.67
Officer WR & WC	2-22-2-L	1,260.0	35.67
Exec Officer	2-22-5-L	1,440.0	40.77
Exec Office & P.O.	2-7-0-Q	5,490.0	155.42
3RD DECK:			
Crew Baggage	3-59-2-Q	1,805.6	51.12
Ship Store	3-63-3-Q	1,431.0	40.51
CPO Baggage	3-62-l-Q	3,564.0	100.90
Officer Baggage	3-56-3-Q	965.3	27.33
Crew Lounge/Library	3-42-4-L	5,507.5	155.92
Barber Shop	3-18-2-Q	1,260.0	35.67
Athletic Gear StRm	3-14-4-A	1,122.2	31.77
TOTAL		89,820.0	2,542.80

Table 2.3.6-2. (U) SWBS 600 Outfit and Furnishings System Weight Breakdown (U)

SWBS SUBSYSTEM	WEIGHT			
	LT	kN	*	% of Total
Ship Fittings	4.03	40.2	4.09	2.1
Hull Compartments	18.10	180.3	18.39	9.4
Preservation and Coverings	29.23	291.2	29.70	15.1
Hull Insulation	100.29	999.3	101.87	52.0
Furnishings	40.79	406.4	41.44	21.1
Miscellaneous	0.56	5.6	0.57	0.3
TOTAL	193.00	1,923.0	196.06	100.0

* non-St, metric tons

(U) 2.3.6.3 O&F Arrangement Drawings -- Arrangements of O&F subsystems are shown in the drawings contained in Appendix B, Subsection B.l.

(U) 2.3.6.4 Outfit and Furnishings Risk Assessment -- The fittings, furnishings, coatings, and outfit items used on the ANVCE far term SES possess proven shipboard capability and are not peculiar to the SES. Passive fire protection system concepts have been proven by an extensive test program. Consequently, the risk involved is considered minimal and is no greater than that of the outfit and furnishings subsystems of conventional Navy Surface Ships.

(U) 2.3.7 COMBAT SYSTEM -- The combat systems of the **ANVCE** Far Term Point Design SES consist of systems that provide a capability in anti-submarine warfare (ASW), anti-air warfare (AAW), and surface warfare **(SUW)** naval missions. These equipments are listed in Appendix C which contains weight, volume, geometry, and service requirements for each item.

(U) The combat systems comprise subsystems for underwater, air and surface surveillance. The subsystems consist of surface and air search **radar's,** EW systems, towed and dipping sonar devices, and both rocket projected and ship dispensed **sonobuoys. Space** allocations are shown in Table 2.3.7-1.

~~(C)~~ An advanced lightweight Track-While-Scan **(TWS)** FCS and ME74 Mod XX FCS are provided for surface-to-air weapons. Surface-to-air and point defense **weapons** consist of vertically launched AMRM Multimode Missiles and Advanced Self Defense Missiles. The anti-shipping weapons are Harpoon MKXX and **MK48** torpedoes. The **ASW** self-defense and offensive weapons are advanced lightweight torpedoes and ASW standoff **weapons. Weapons** and sonobuoy delivery for offensive **ASW** operations is accomplished by LAMPS **MKXX** helicopter. The LAMPS **MKXX** helicopter can also deliver Harpoon weapons for SUW (space reservation only), Accommodations have been made for applications of twelve standard ship- launched **mini-RPV's** for SUW target localization and weapon terminal guidance, as well as for relaying sonobuoy field telemetry data.

~~(C)~~ 2.3.7.1 Surveillance -- Air surveillance is provided by an Advanced Dual Band 2D Long Range Radar and a 3D Rotating Phased Array Radar. Surface Surveillance is accomplished by an Advanced **2D** Surface Search Radar which serves a dual function as it is also the-primary sensor for the far term SES collision avoidance and navigation system.

~~(C)~~ An ASMD EW **MKXX** system provides a passive surface and air surveillance capability for long range active emitter detection and threat classification. The system also includes an **IR** sensor for threat correlation and passive threat detection and classification. Finally, the system provides an active, as well as passive (chaff) threat deception capability..

[redacted] Underwater surveillance is provided by APRAPS, Deployed Linear Arrays, a towed array with depressor rocket projected ERAPS and ERAPS Type A and Type B dispensed sonobuoys. The LAMPS MKXX helicopter is used for emplanting sonobuoy fields. Sonobuoy data link is via UHF telemetry.

[redacted] 2.3.7.2 Armament -- Armament includes surface-to-air missiles, surface-to-surface missiles, missile launching systems, air drop and over-the-side launched torpedoes, small arms, and pyrotechnic devices. Stowage facilities are also provided. Armament missile systems are controlled by the fire control system elements of Command and Surveillance. Torpedoes are controlled by underwater fire control elements,

[redacted] An Advanced Vertical Launching Missile System (AVLMS) with 72 cells is provided for AMRM Multimode, Harpoon MKXX and ASW standoff weapon missiles. A separate Advanced Self Defense Missile Launcher (24 cells) is provided for Advanced Self Defense Missiles.

(U) Armament provides the ship with weapons and a means for delivery of those weapons to counter air, surface, and subsurface threats with provisions for the following:

- 16 environmentally sealed and protected Harpoon MKXX missiles carried in the AVLMS. The missile cannisters are armored.
- 40 environmentally sealed and protected AMRM multimode missiles carried in the AVLMS. The missile cannisters are armored,
- 16 environmentally sealed and protected ASW standoff weapon missiles carried in the AVLMS. The missile cannisters are armored.
- Four environmentally sealed and protected MK48 ejection launched cannister torpedoes for ship launch. The torpedo cannisters are armored.
- 24 environmentally sealed and protected advanced self defense missiles in the advanced self defense missile launcher systems. The missile cannisters are armored.

(U)
- 36 advanced lightweight torpedoes for LAMPS MKXX helicopter launch.
- Miscellaneous ordnance and small arms.

(U) 2.3.7.3 List of Combat System Equipment -- The list of combat system equipment (non-variable load items) is contained in Appendix C. The list itemizes equipment physical characteristics, weight, and ship services requirements.

(U) 2.3.7.4 Combat System and Military Payload Weights -- Table 2.3.7-2 presents the weights of major components within the combat system and includes variable load elements. Table 2.3.7-3 shows military payload weights (C^3 + Combat System) in accordance with ANVCE WP-002 definitions.

(U) 2.3.7.5 Combat System General Arrangements -- The arrangements of the far term SES Combat Systems are shown in drawings contained in Appendix B, Section B.1 and B.7. The coverage of the weapons and sensors are shown on the figures contained in Appendix B, Section B.2.

(U) 2.3.7.6 Combat System Risk Assessment -- The specified combat weapons and sensors suite is entirely defined by the ANVCE Project Office and has the minimal risk associated with evolutionary development of far term combat systems.

Table 2.3.7-1 (U). **Combat** System Space Allocation (U).
(Sheet 1 of 2)

COMPARTMENT - System Description	**BELOW DECK ENVELOPE ft^2 (m^2)**	**LOCATION**	**EQPT DK AREA ft^2 (m^2)**	**TOTAL DK AREA ft^2 (m^2)**	**ACTUAL EQPT/DK AREA RATIO**
RDR EQPT RM #1 Advanced Dual **Band 2D Long Range Radar**	145.0 (134.7)	01-23-4-C	145 (13.47)	289 (26.85)	1.99
RDR EQPT RM #2 MK 74 MOD XX **Signal Data** Converter Transmitter **Group** **Computer**	100.0 (92.9) 4.4 (.41) 17.2 (1.6) 10.3 (.96)	01-29-3-C (2)	32 (2.97)	103.5 (9.62)	3.23
RDR EQPT RM #3 Advanced Dual **Band 2D Long Range Radar** **ALWTWSFC**	 25.0 (2.3) 10.0 (.93)	01-29-4-C	35 (3.25)	103.5 (9.62)	2.96
RDR EQPT RM #4 **3D Rotating Phased Array**	350.0 (32.52)	1-14-2-C	350 (32.52)	779.6 (72.42)	2.23
EW EQPT RM Advanced **EW Suite MK XX**	60.0 (5.57)	02-26-0-C	20$^{(3)}$ (1.86)	50 (4.65)	2.5
LINEAR TOWED ARRAY (1)		3-70-2-Q	42 (3.9)	350 (32.52)	8.33
PASSIVE TOWED ARRAY (1)		3-70-1-Q	90 (8.36)	350 (32.52)	3.89
APRAP/SONAR ROOM (1)		3-17-2-Q	150 (13.94)	482 (44.78)	3.21
SONAR EQPT ROOM (4)		1-7-1-C	64 (5.95)	180 (16.72)	2.81

Table 2.3.7-1 **(U).** Combat System Space Allocation **(U).**
(Sheet 2 of 2)

COMPARTMENT - System Description	**BELOW DECK ENVELOPE ft^2 (m^2)**	**LOCATION**	**EQPT DK AREA ft^2 (m^2)**	**TOTAL DK AREA ft^2 (m^2)**	**ACTUAL EQPT/DK AREA RATIO**
ERAPS ROOM		1-7-3-Q	37.5 (3.48)	140 (13.0)	3.73
SONOBUOY LOCKER		1-38-1-Q	35 (3.25)	70 (6.5)	2.0

(1) ANVCE Combat System Data Sheets, **Vol.** II, 30 June 1976.

(2) **Weapons** Sytems Handbook, **NAVSEA** OD **40313,** dated 1 January 1975; It is assumed that 100.0 ft^2 (92.2 m^2) envelope refers to total deck area.

(3) AN/SLQ-30 (V-3) DPEW .
54104-MA76-14-3 dtd Feb 76

(4) ANVCE Data System Support, Data for Point Designs, Enclosure 5, Rev. 1, 19 October 1976, **SEA-6112E/RCH**

NOTE: Assumed that equipment is removable from the front for access and maintenance.

Table **2.3.7-2** (U). Combat System Weight Breakdown **(U)**

SWBS	SWBS SUBSYSTEM	WEIGHT			
		LT	kN	*	% of Total
400	Surveillance	32.31	321.9	32.82	30.2
400	ECM & Fire Control	9.69	96.6	9.84	9.1
700	Missiles & Rockets	50.67	504.9	51.48	47.4
700	**Torpedoes**	0.67	6.7	0.68	0.6
700	Small Arms & Pyro.	0.35	3.5	0.36	0.3
700	Cargo Munitions	11.80	117.6	11.99	11.0
700	Aviation-related **Weapons**	1.53	15.2	1.55	1.4
	TOTAL	107.02	1066.3	108.72	100.0

* non-SI metric tons

Table 2.3.7-3 (U). **Military** Payload Weights (U)

SWBS	SWBS Subsystem	WEIGHT		
		LT	kN	*
400 less 420 & 430	C&S less Navigation and Internal Communication	54.65	544.5	55.52
700	Armament	63.37	631.4	64.38
F21-27	Ordnance	180.00	1,793.5	182.85
F42	JP-5 Helicopter Fuel	24.55	244.6	24.94
	TOTAL MILITARY PAYLOAD	322.57	3,214.1	327.69

* non-SI metric tons

(U) 2.4 SURVIVABILITY AND VULNERABILITY (S/V)

S/V relates to the capability of the far term design to carry out a combat mission in a hostile environment. Though survivability and vulnerability Interrelate to a large extent, vulnerability of the ship is determined primarily by its signature while survivability is determined by the hardness designed into the ship. Improvements in S/V are brought about by signature suppression and by hardening to withstand battle damage. The S/V features of the ANVCE design are discussed next under the headings of signature and hardness.

(U) 2.4.1 SIGNATURE CHARACTERISTICS

(U) 2.4.1.1 Radar Cross Section (0.3 to 18 GHz) -- Radar cross section data not available and not provided,

(U) 2.4.1.2 Microwave Signature -- Microwave signature data not available and not provided.

[redacted] 2.4.1.3 Infrared Signature -- The infrared radiation signature is a measure of the heat emitted by a ship relative to the background radiation level. The detectability of ship by infrared devices is dominated by the hot spots created by engine exhausts. The far term SES maximum detectability is from the stern where the four propulsion engines exhaust and only the stern signature was analyzed.

[redacted]) The stern signature is created by the four propulsion exhaust duct exits. For the purpose of calculating the configuration factor between the exhaust exit and the detector, each exit was treated as a disk radiating at the exhaust duct temperature of 910° F (487.8' C). The signature was calculated for the 3 to 5 and 8 to 12 micron wavelength bands, and atmospheric attenuation due to the presence of water vapor and carbon dioxide was included. Since the exhaust ducts of a turbine engine have an emissivity of near unity, an emissivity of one was assumed for this analysis.

~~(C)~~ The radiant emittance of a source in a wavelength band is given by:

$$W = F \tau a \sigma T^4 \qquad (1)$$

where

τ = Transmittance through the atmosphere

F = Geometric configuration factor

a = Percent emittance in the wavelength band

σ = Stefan-Boltzmann constant

T = Absolute temperature of the source

As the distance from the source to the detector increases, both the geometric configuration factor and the atmospheric transmittance decrease. The radiant emittance of the far term SES as a function of distance directly aft in both the 3 to 5 and 8 to 12 micron wavelength bands is shown on Figure 2.4-1 for the Secret Supplement to this report. The 8 to 12 micron band has a much steeper slope due to the effect of atmospheric attenuation in this band. As a constant radius arc is followed from the ship centerline, the geometric configuration factor decreases as the angle increases until the sidehull masks the engine exhaust exits at 90 degrees.

~~(C)~~ Figures 2.4-2 through 2.4-5, also contained in the Secret supplement of this report, show that the signature along that arc at a distance of 5, 10, 30 and 50 nautical miles (9.26, 18.52, 55.56 and 92.60 km). The radiant emittance in the 8 to 12 micron band is zero at 30 and 50 nautical miles due to the effect of atmospheric attenuation.

(U) Figures 2.4-1 through 2.4-5 are contained in the SECRET Supplement to this report. The unclassified titles of the figures are:

Figure 2.4-1 (S): IR Signature Directly Aft at Zero Azimuth Angle (U)

Figure 2.4-2 (S): IR Signature 5 Nautical Miles (9.26 km) Aft of Ship and at Zero Azimuth Angle (U)

Figure 2.4-3 (S): IR Signature 10 Nautical Miles (18.52 tan) Aft of Ship and at Zero Azimuth Angle (U)

Figure 2.4-4 (S): IR Signature 30 Nautical Miles (55.56 km) Aft of Ship at Zero Azimuth Angle in the 3-5 Micron Band (U)

Figure 2.4-5 (S): IR Signature 50 Nautical Miles (92.60 km) Aft of Ship in the 3-5 Micron Band (U)

(U) 2.4.1.4 Visibility -- Visual detection of the 1990 SES by the unaided eye is influenced by various factors. Firstly is the ship's vertical height (114 ft; 34.75 m) and secondly, its contrast ratio to the background. In calculating the maximum detection range for this ship, it was assumed that the ocean was relatively calm and the atmospheric condition clear. Using a 90 percent probability of detection, Figure 2.4-6 indicates that a visual angle of 1.2 minutes of arc (0.02 deg) is required. Therefore, the maximum detection detection range was determined through the use of the following expression:

$$D = \frac{L}{2 \tan [1/2\ VA]} \qquad (2)$$

where

D = range (ft; m)
L = vertical height (ft; m)
VA = visual angle (degrees)

Therefore substituting the measures for vertical height and visual angle :

$$D = \frac{114}{2\ \text{ten}\ [(1/2)\ (.02\ \text{deg})\ ]} = \frac{114}{0.349 \times 10^{-3}} =$$

$$= 326{,}585\ \text{ft or } 53.71\ \text{nautical miles } (100.20\ \text{km})$$

The far term SES would be detectable 90 percent of the time at the cited range. Obviously, a change to a lower contrast ratio, a reduction in vertical height, or poor atmospheric conditions such as rain or fog will significantly reduce the detectability.

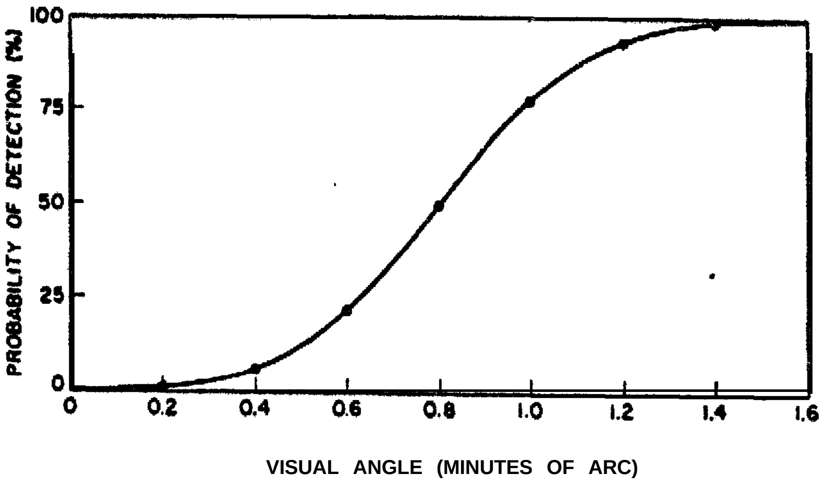

Figure 2.4-6 **(U).** Probability of Detection Versus Visual Angle **(U)**

[redacted] **2.4.1.5** Acoustic Signature **--** The airborne radiated noise signature comes primarily from the engine combustion air inlets, propulsion exhausts and lift fan air inlets. The total signature at a distance of 1 **metre would** be approximately 100 **dB** re **20μPa** in the 250 Hz band. Including spreading and **absorption a 45 dB** sound pressure level **in** the 250 Hz band will be reached at approximately 500 metres.

(U) Target strength, **dB** at a 1 yard (0.9144 **m),** is shown in Table 2.4-C and the underwater radiated noise signature **(dB** re **1μPa)** is shown in **Table** 2.4-2.

[redacted] The far term point design SES probably has a distinctive **line** spectra at **approximately** 500 **Hz.** This relates to the blade passage frequency of the **lift** fans. The acoustic signature will probably show directionality abeam and abaft the waterjets. ,

[redacted] Airborne radiated noise signature may be reduced by treating the **combustion** inlet, propulsion exhaust, and fan inlets **with** additional splitters. Underwater radiated noise signature may be reduced by suitably treating the engine and fan mountings. This will reduce [redacted] distinct spectral lines, but will virtually do nothing to reduce the overall level in any given 1/3 octave band, since most of the energy in any band results from the impingement of the watetjet stream on the ocean's surface.

Table 2.4-1 [redacted]: Estimated Target Strength (dB) (U)

ASPECT SHIP CONDITION	BEAM	STERN/BOW
On Cushion	15	2
Off Cushion	20	10

Table 2.4-2 (C): Estimated Underwater Radiated Noise Signature (dB re 1μPa @ 1 metre) (U)

	SHIP SPEED			
"INTENSITY"	10 knots (5.14 m/s)	50 knots (25.72 m/s)	80 knots ((41.14 m/s)	120 knots (61.74 m/s)
"Intensity" of Highest Line (0-100 Hz)	180	174	168	160
"Intensity" of Highest Line (≥100 Hz)	170	164	158	150
"Intensity" of 1/3 Octave Band 2kHz	180	175	170	160

2.4.2 HARDNESS

[redacted] **2.4.2.1** SUMMARY -- The far term SES must be designed to survive in the hostile environments encountered by a combatant ship. Therefore, vulnerability must be addressed with respect to both surface and underwater threats. The surface weapon threats used as a guidance for survivability vary from a .30 caliber armor piercing (AP) ball delivered by small arms fire to conventional high explosive projectiles, 23-180 mm, delivered by naval guns, aircraft cannon or rockets, and anti-ship missiles. Underwater threats considered are high explosive mines and torpedoes,

[redacted] The type of threat encounter can be a near miss, contact, or penetration and detonation inside the ship. For this evaluation only the following types of threats and encounters were considered:

a, Projectile threat from a .30 caliber ball (AP).

b. Near miss from a 5"/54 high explosive shell.

c. Near miss from a 500 lb. (2.22 kn) high explosive mine.

All topside threats are assumed to come from a broadside azimuth with the hit locations occurring over the midships half of the ship. The 5"/54 shell will detonate approximately 18.5 ft (5.64m) above the 02 level along the ship centerline. The .30 caliber projectile threat will be assumed to impact at 0 degrees obliquity on any vertical plate and 60 degrees obliquity on any horizontal plate. The underwater mine threat is assumed to occur over the aft one-third of the underwater portion of the ship.

(U) The output from an explosive detonation is a function of the amount and type of explosive and the location of the detonation relative to the ship. This output includes blast pressures, primary fragments, secondary fragments and shock. For surface blasts it is assumed that the standoff distance is great enough that blast pressures will not rupture shell plating skin panels. Therefore the ballistic effects of fragmentation will be the primary design parameter for protection features.

[redacted] The areas to be protected against projectile and fragmentation damage are:

a. All magazines
b. Propulsion and Lift Systems
c. Electric Generator Rooms
d. Pilot House
e. Communications and Combat Operations Center
f. Radar Equipment Rooms

[redacted] In most cases it is not possible or practical to allocate ship spaces based primarily on survivability considerations. However, where possible, equipment is arranged to utilize surrounding spaces and compartments for shielding. The remaining protection will be provided by a spaced armor configuration shown in Figures 2.4.2-7 and 2.4.2-S. In addition, all missiles are assumed to be housed in armored cannisters; the gas turbine engines incorporate armored features into the engine cowlings; and the lift fan inner housings utilize composite armor materials, The vital spaces to be protected are shown in Appendix B-3. These areas will have full overhead protection. All exposed vertical plates will also have full protection. Interior bulkheads will not be armored. Existing plate and fire protection panels are considered adequate since the shell plating around these areas is heavily armored.

[redacted] 2.4.2.2 ARMOR DESCRIPTION -- The spaced armor configuration is a combination of heavy aluminum plating and an inner barrier that utilizes an existing insulation panel design. The two barriers are approximately 12 inches apart. This concept uses the basic hull structure and passive fire protection system. No new systems are required; only modifications to existing systems. The result is a very efficient design with a minimal weight penalty.

([redacted]) The hull plating is 5456 **H116/117** marine grade aluminum alloy., It possesses excellent ductility and toughness and **is** relatively insensitive to stress corrosion. **Research** and development has shown this *to* be a good fragment-resisting armor material. Therefore the ship plating has been increased in thickness locally to provide **a** 7 to 10 psf (335.16 to 478.80 N/m^2) area1 density and is designed to absorb the initial impact of shell fragments. Tests conducted by the Army Materials and Mechanics Research Center **(AMMRC)** have shows that this amount of material will provide protection levels as shown in Table 2.4-3.

Table 2.4-3 **(C):** Protection Ballistic Limit (V_{50}) Provided by **10** psf (478.89 N/m^2) Plating

Simulated Fragment Size			**Caliber Equivalent**	**Impact Angle**	**V_{50} Protection Ballistic Limit**	
Grains	**Ounces**	**Newtons**		**Degrees**	**ft/s**	**(m/s)**
44	**0.10**	**0.028**	**0.30**	**0**	**2400–4350**	**731.52–1325.88**
147	**0.33**	**0.092**	**0.45**	**0**	**2300**	**701.04**
207	**0.47**	**0.131**	**0.50**	**0**	**1800**	**548.64**
207	**0.47**	**0.131**	**0.50**	**30**	**2150**	**655.32**
207	0.47	0.131	0.50	45	2600	792.48
830	1.88	0.523	20 mm	50	1600	487.68
830	1.88	0.523	20 mm	60	2000	609.60

(U) The protection ballistic limit **(V_{50})** is defined as the striking velocity at which 50 percent of the fragments can be expected to fully penetrate the plate. Any impact which remains imbedded in the plate or **passes** through with insufficient energy remaining to pierce an 0.020 **in.(5** mm) thick **2024-T3** aluminum witness plate six inches (0.152 mm) behind the target is considered a partial penetration only.

[redacted] Calculations for the weight and distribution of primary fragments from a theoretical 5"/54 shell indicate that 95.7 percent of all fragments will be less than 830 grains (0.523 N) and 65 percent less than 241 grains (0.152 N) with the initial fragment velocity at the point of detonation equal to 3900 feet per second (1188.72 m/sec) maximum.

[redacted] This initial fragment velocity will decrease as the distance to impact increases. Therefore, the striking velocities will be less than 3900 feet per second (1188.72 N).

[redacted] Also, it is assumed that not all fragments will have the high initial velocity. For a detonation 18.5 feet (5.64 m) above the 02 level and an average fragment of 241 grains (0.152 N), the maximum impact velocities that can be expected are shown in Table 2.4-4.

Table 2.4-4 (C) . Fragment Impact Velocity Versus 'Standoff Distance (U)

Location	Distance from Detonation Point		Impact Velocity/ Initial Velocity	Impact Velocity	
	Feet	(Metres)		ft/s	(m/s)
02 Level	20	6.10	0.88	3430	1045.46
01 Level	30	9.14	0.85	3315	1010.41
Main Deck	40	12.19	0.82	3200	975.36

[redacted] Comparing the theoretical 5"/54 shell fragments and velocities to the AMMRC test data it can be expected that at least 50 percent of the smaller fragments will not penetrate the shell plating. Also, a large percentage of fragments striking at high angles of impact will not penetrate. Those framents that do penetrate the first barrier will have lost some kinetic energy. Assuming a 50 percent energy loss, no fragment mass breakup, and a maximum impact velocity as shown above, the fragments that do penetrate will impact the inner barrier at a velocity of approximately 1600-1715 feet per second (487.68-522.73 m/sec). This inner barrier must now absorb the remaining kinetic energy.

[redacted] The outer barrier horizontal plating is designed to this fragment threat. Vertical plates will not be exposed to direct impact from shell fragments; they will however be subject to direct impact from 0.30 caliber projectiles. Therefore all vital spaces will employ the same spaced armor protection philosophy on exposed vertical plates.

[redacted] The outer plating is designed to absorb the initial impact of the 0.30 caliber projectile. It is set at 7-10 psf (335.16 to 478.80 N/m^2) areal density which corresponds to a thickness of 0.50-0.75 inch (13 - 19 mm). The AMMRC test data for aluminum panels of this size has demonstrated protective capabilities as shown in Table 2.4-5.

Table 2.4-5 (C). Protection Ballistic Limit (V_{50}) for .30 Caliber Projectile (U)

Areal Density		**Impact Angle**	**V_{50} Protection Ballistic Limit**	
PSF	**(N/m^2)**	**Degrees**	**ft/s**	**(m/s)**
7	335.16	0	1270	387.10
7	335.16	30	1420	432.82
7	335.16	45	1730	527.30
7	335.16	60	2660	810.77
10	478.80	0	1540	469.39
10	478.80	30	1780	542.54
10	478.80	45	2160	658.37
10	478.80	60	3180	969.26

[redacted] The actual impact velocity of a .30 caliber projectile is approximately 2125 feet per second (647.7 m/sec). Then based on the above test results the 10 psf (478.80 N/m^2) plate will be very effective in dissipating a portion of the kinetic energy of the initial impact. Now, with similar assumptions as made previously on energy losses, it can be estimated that those projectiles penetrating the outer barrier will have a velocity at impact on the inner barrier of approximately 1000 feet per second (304.8 m/sec).

[redacted] The inner barrier must now be designed for the following threats:

Overhead	Fragment ≃ 241 grains
	Impact Velocity ≃ 1700 feet per second (516.16 m/sec)
Side	**Projectile** .30 cal
	Impact Velocity ≃ 1000 feet per second (304.8 m/sec)

[redacted] This barrier uses a modified passive fire protection insulation panel. The existing panels utilized an 0.015 inch (0.4 mm) titanium face sheet on the compartment surface and an 0.020 inch (0.5 mm) aluminum face sheet on the bulkhead side with 1.00 inch (25 mm) of fiberfrax felt filler material. The modified panel uses an 0.025 inch (0.64 mm) titanium face sheet on the compartment side and 15 plies of Kevlar as a face sheet on the structure side with a 1.00 inch (25 mm) fiberfrax felt filler material. This panel now serves the dual function of passive fire protection and inner barrier armor plating. The Kevlar is an organic material and has relatively poor flammability and toxic gas emission characteristics. However, the panel is designed so that the Kevlar is thermally protected from a fire threat by the fiberfrax and therefore will not reach combustion temperatures. The materials exposed to the fire are inorganic which makes the panel very efficient from a fire protection consideration.

[redacted] AMMRC has conducted tests using Kevlar (also known as Fiber B) fabric. It is a high modulus (20 million psi, 137.895 x 10^9 Pa), high strength (350,000 to 500,000 psi, 2.413 x 10^9 to 3.447 x 10^9 Pa), low density (1.45 g/cc) fiber. Results of tests with Kevlar showed that a 15 oz/ft^2 (44.89 N/m^2) areal density panel will provide a Protection Ballistic Limit (V_{50}) of 1450 feet per second (441.96 m/sec) for a 44 grain (0.028 N) fragment.

[redacted] Tests have also been conducted using nylon felt material. Fiberfrax felt will behave in a similar fashion, The nylon felt of areal density equal to 5 ox/ft^2 (14.963 N/m^2) will provide a Protection Ballistic Limit (V_{50}) of 700 feet per second (213.36 m/sec) for a 44 grain (0.028 N) fragment or about 60 percent that of Kevlar.

[redacted] The Kevlar face sheet will stop most high speed fragments that have penetrated the outer barrier and the fiberfrax filler materials should absorb the remaining energy. For those fragments or projectiles which have a large mess and high initial impact velocities, any remaining kinetic energy will be absorbed by the titanium face sheet or the fragment will have spent all kinetic energy in penetrating the entire spaced armor system.

(U) The spaced armor concept uses materials and areal densities which have been tested and proved to be very effective in preventing penetration of small fragments and projectiles. Working in conjunction with this armor concept is a highly sophisticated self defense system which is expected to prevent encounters with more serious weapon threats. In the-extreme case where very large mass and high kinetic energy fragments do impact the ship, this spaced armor system will absorb a high portion of fragment energy. The judicious arrangement of equipment and the internal structural bulkheads, fire and acoustic panels, and equipment consoles will be more than adequate to prsvent serious damage to vital systems.

[redacted] Finally, all weapons continers and critical machinery will be provided a failsafe protection capability. The missile cannisters, rocket projected ERAPS cannisters, and MK 48 torpedo cannisters will have a 15-ply Kevlar sheet bonded to the cannister. Likewise, the fan inner housing will be provided with this Kevlar sheet. However, due to the increased danger of fire in engine rooms a material with superior fire resistant characteristics will be used on engine cowlings. Propulsion and lift engines will have a face sheet added to the outer surface [redacted]) of the insulation panels. This sheet is 5 plys of continuous ceramic fibers (3M-AB-312) with a fire retarded resin. The material has a tensile strength of 135,000 psi (931 x 10^6 N/m^2) and a density of .073 pounds/in.^{3} (2.09 g/cc^3).

[redacted] The weight increase in the various structural areas due to the addition of ballistic protection is shown in Table 2.4-6.

Table 2.4-6 [redacted]. Structural Weight Increase (SWBS 100) for Ballistic Protection (U)

Location	Horizontal Plating			Vertical Plating			Total Weight		
	LT	kN	*	LT	kN	*	LT	kN	*
03 Level	1.14	-11.36	1.16	2.07	20.63	2.10	13.76	137.11	13.98
02 Level	6.06	60.38	6.16	4.49	44.74	4.56			
01 Level	17.12	170.58	17.39	--	—	—	17.12	170.58	17.39
Main Deck	5.55	55.30	5.64	—	—	—	5.55	55.30	5.64
Shell Plating	--	--	--	17.86	177.96	18.14	17.86	177.96	18.14

* non-SI Metric Tons

[redacted] The weight increase in insulation panels due to the requirements of ballistic protection is shown in Table 2.4-7.

Table 2.4-7 [redacted] Insulation Panel Weight Increase (SWBS 600) for Ballistic Protection (U)

	Area (Ft^2)						Weight		
	Overhead		Side		Total				
Location	ft^2	(m^2)	ft^2	(m^2)	ft^2	(m^2)	LT	kN	*
03 Level	313	29.08	569	52.86	882	81.94	0.39	3.89	0.40
02 Level	1663	154.50	1232	114.46	2895	268.95	1.29	12.85	1.31
01 Level	9717	902.74			9717	902.74	4.34	43.24	4.41
Main Deck	3600	334.45			3500	334.45	1.61	16.04	1.64
Shell Plating	—	—	8829	820.24	8829	820.24	6.63	66.06	6.74

* non-SI metric tons

(U) 2.4.2.3 Shock Hardening Considerations -- Combat reliability and survivability under attack has been considered with respect to the fundamental structural adequacy of the far term SES. Hull hardening requirements and keel shock criteria have been specifically addressed, consistent with the degree of detail that can be provided within the scope of this feasibility design study.

[redacted] With respect to underwater explosive loads, hull damage is distinguished from damage to machinery and equipment. For primary hull structural members affecting overall ship seaworthiness, stresses corresponding to attenuated peak shock factors is limited to the elastic range. For machinery installation components vital to performance, mechanical ruggedness requirements were adopted in the form of static equivalent vertical design acceleration levels. For exterior subsurface plating exposed to direct impact of blast pressure, protection is accomplished through energy absorption and dissipation by accepting local plastic deformation of hull plating.

[redacted] For the cushionborne operational mode the affects of two conventional weapon threats were considered: 250 pound (112 N) torpedo contact detonations uniformly distributed over the after-one-third of the underwater portion of a sidehull; and underbottom or sidehull standoff detonation of 500 pound (2224 N) fused mines or torpedoes. For contact hits, local structure is sacrificed and an effective keel shock factor of three-tenths was considered locally. For near miss underwater explostions, TNT charge weights were assumed to be approximately fifty percent of the warhead weight and standoff distances were assumed consistent with a keel shock factor of three-tenths. In all cases, the interaction of the SES cushion and the blast was assumed, to result in a decoupling affect corresponding to an interface coefficient of two tenths. This approach to the shock analysis of the far term ANVE is consistent with the findings of Working Paper WP-013.

[redacted] Weight of the hull structure was estimated for the inertia load profile of Figure 2.4-9 and is summarized in Table 2.3.1.1.

Specified factors of safety of 1.15 and 1.50 were considered for the shock loading case.

(U) Methods of shipboard shock mounting are available depending on specific applications and include spatial arrangements allowing excursions of fixed equipment, shock damping isolators for mitigation of effects of foundation rotational and translational excitation, resilient mountings, and damping devices. Such approaches will be utilized (based upon more detailed investigation) throughout the design as appropriate.

[redacted] Difficulties in achieving armor protection sufficient to preclude loss of cushion pressure, flow to the propulsion system or mission capability are expected for broadside azimuth weapon assaults in the vicinity of the waterjet inlets.

(U) Comprehensive theoretical and detailed empirical evaluation of high explosive bubble pulse effects such as transient decay times, resonant vibration, interaction phenomena for air and water-backed stiffened plating, and probabilistic criteria exceed the scope of this study.

[redacted] 2.4.2.4 **Ownship Weapon Effects** -- The protection that is provided for the main deck against the blast/heat from the vertical missiles consists of 0.25 in. (2.64 mm) thick fiberglass layup having 25 percent by weight phenolic resin. The phenolic/glass layup will be fabricated as a rectangular panel having a cutout to suit the deck cutouts for the missiles. The panels will be bonded to the deck with a high [redacted] temperature phenolic adhesive and will function as reusable heat shield tiles similar to the heat shield tile application on the space shuttle,

[redacted] Although the exhaust products of the missiles include large concentrations of abrasive alumina and HCl, the impingement time during a normal launch will be brief and it is not expected to cause appreciable damage to the insulation. Therefore, many launches can be made without refurbishment. An attractive feature of the tile concept is the ease with which the tiles can be replaced when refurbishment is necessary.

(U) 2.4.2.5 Control of Fire/Flooding after Battle Damage -- The major feature of the damage control system utilized for control of fire and flooding are redundancy and separation of the active fire protection components for the control of fire and utilization of water tight bulkheads for the control of flooding.

(U) The fire detection system consists of automatic, semi-automatic and visual responses. The ship has been divided into discrete fire zones depending on the level of potential fire hazards; e.g., main machinery spaces are considered a more hazardous fire zone than crews' berthing areas. All machinery spaces have three separate detection devices, ionization, thermal, and visual (remote T.V.). These detection devices are in turn powered by separate means and are wired in parallel. All responses are monitored in a central station provided at the damage control console. This system would then have to incur three simultaneous failures to be rendered ineffective. In addition, critical areas throughout the ship, such as ships communication center, are provided with individual detection systems that have battery powered back-up detection and automatic fire suppression.

(U) The fire extinguishing systems consists of total flood Halon 1301, high expansion foam systems, AFFF (aqueous film forming foam) systems, T.A.U. (twin agent units), sea water sprinkling and fire plugs, portable Halon 1211, dry chemical and light water extinguishers. The type of fire protection provided for each area of the ship was desinged to match the potential fire hazard of that area. The helicopter landing area, for example, is provided with AFFF hose stations, sea water fire plugs, portable extinguishers, and T.A.U. station. The main machinery spaces have total flooding Halon 1301 systems for a first line of defense backed-up by high expansion foam systems for rapid extinguishment. In addition, each gas turbine engine has its own enclosure which is provided with a main and secondary supply of Halon, independent from the space in which they are located. The living spaces have portable Halon cylinders which are located outside of the space they serve to protect against damage from the potential source of the fire.

(u) Two or more high expansion foam generators are provided within each machinery compartment to provide redundancy. High expansion foam systems are divided into three separate groups, one port and starboard, and one amidships. Therefore, loss of a port or starboard system through attack or damage will not affect the other systems. Additionally, the high expansion foam and AFFF proportioners are balanced pressure diaphram operated, rely only on firemain pressure and are therefore void of any electrical malfunction problems. Likewise, the high expansion foam generators are water driven and supplied with an external source of air.

(U) The heart of the foam systems is the firemain supply system. The supply of seawater to each proportioner is from the firemain header located above the damage control deck. The firemain system is a horizontal open loop system which is fed by four firemain pumps, two located low in each sidehull. Any one fire pump is sufficient to supply fire protection to any one of the foam proportioners. In addition, the discharge of the firemain pumps are cross connected, allowing for isolation of any portion of the firemain without interfering with the fire protection systems.

(U) In addition to 011 of the systems above, seawater fireplugs have been provided in discrete locations to assist in suppression of Class A fires, and to provide a path of exit from the craft.

(U) The possibility of rendering the extinguishing mediums ineffective are extremely low by the use of the diversified fire protection systems.

(U) The utilization of water tight bulkheads to control flooding is addressed in Section 2.2.5.1.2, Stability in Damaged Condition.

(U) 2.4.2.6 Passive Fire Protection -- A fire protection system is necessary as an element of damage control and must incorporate within the system both active and passive means. The active fire protection system is described in-2.3.5. The passive fire protection system is designed to protect the primary structure until the active system is brought into play.

(U) For the design of the fire protection system, the ship spaces were grouped into two major classifications: Group 1, liquid fuel fire hazard **speaces;** and Group 2, solid combustible fire hazard spaces. In addition to fire protection for these spaces, passive fire protection is provided for the torpedo and small arms magazines.

(U) 2.4.2.6.1 Group 1 -- Liquid Fuel Fire Hazard Spaces -- Group 1 consists of all engine rooms, auxiliary machinery spaces, gas turbine generator rooms and the helicopter hangar.

(U) Passive fire protection for bulkheads and overhead structures for all Group 1 spaces are provided by a ceramic fibrous felt sandwich panel.

(U) Panel Design -- The panel (see Figure 2.4-10) consists of one inch (2.54 mm) thick refractory fiber felt of four (4) lb_f/ft^3 (192.46 N/m^3) density (Carborundum Fiberfrax felt or equivalent) between 0.015 inch (.38 mm) titanium front face sheet and 0.020 inch (.51 mm) aluminum, narine grade, back face sheet.. Number 6 CRES screws and nuts are employed on a lo-inch (254 mm) grid pattern to hold the face sheets together.

(U) Close-Out members of the panel are 0.015 inch (.38 mm) titaniumchannels with 1/2 inch (12.7 mm) flanges seam welded to the front face sheet and riveted to the back face sheet.

(U) Panel Attachment -- The panels are attached to the structure by screw attachment with #6 CRES screws to 0.06 inch x 0.5 inch x 1.0 inch (1.52 mm) strips. The aluminum strips are attached to the structure by adhesive bonding with an adhesive modified with a fire retardant. The panels are spaced from the primary structure with a 1/4 inch (6.4 mm) air gap.

(U) Panel Joints -- Panel joints (see Figure 2.4-11) are sealed from vapor penetration as well as heat pen&ration by sandwiching the panel ends between two strips of refractory fiber felt which are compressed between the 0.060 in.(1.52 mm) aluminum strip at the back of the joint and a 0.030 inch (.76 mm) CRES strip at the front or fire threat side of the joint. Comer joints are similarly sealed with 0.060 inch (1.52 mm) aluminum angles and 0.030 inch (.76 mm) CRES angles which are used as comer trim. Wicking would be prevented by inserting the panels in aluminum channels which are adhesive bonded to the deck with a fire retarded adhesive. A silicone sealant would then be used to seal the panel in the channel.

(U) Decks -- The decks in Group 1 areas are protected with a 0.25 inch (6.35 mm) thick ceramic fiber moist felt insulation (Refractory Products Company WRP-X-AQ or equivalent). It is a moldable fibrous ceramic felt in an inorganic colloidal silica binder and has a density of 15 lb/ft^3 (717.99 N/m^3). The felt is packed in plastic bags during shipment and storage to prevent drying. After adhesive bonding the felt to the deck, it is allowed to air dry and harden. The felt is bonded to the deck with an air-setting ceramic cement (Carborundum QF-180 or equivalent), which has a layer thickness of 0.010 inch (.25 mm). After air drying, the felt is faced with fiberglass cloth impregnated with a fire retarded epoxy resin. The cloth is an 1800 plain weave with a weight of 10 oz/yd^2 (3.33 N/m^2). The epoxy resin is room temperature curing (Shell Epon 934 modified with fire retardant agents or equivalent).

(U) Stanchions, Penetrations end Ladders -- Stanchions are protected by wrapping with 0.750 inch (19 mm) thickness of the moldable fiber moist felt insulation. The moist felt is bonded to the stanchion with ceramic cement. The moist felt is overlapped 1.5 inch (38.1 mm) to prevent a direct path to the protected member. All penetrations are sealed to prevent passage of vapors. Where the penetration member is exposed to a fire hazard, it would be protected from structural collapse with moist felt insulation and/or intumescent paint. Ladders would be fabricated from corrosion resistant steel.

(U) 2.4.2.6.2 Group 2 -- Solid Combustible Fire Hazard Spaces -- Group 2 consists of all electronic spaces, living spaces and command centers.

Passive fire protection for bulkhead and overhead structure for all 'Group 2 spaces is provided by a refractory fiber felt sandwich panel similar to the panels used for Group 1 spaces but with a panel thickness of 0.5 inch (12.7 mm).

(U) The decks are protected with deck covering underlay material and tile or carpeting in these spaces. Stanchions, penetrations and ladders would be treated as described for Group 1.

(U) 2.4.2.6.3 Magazines -- The passive fire protection for the magazine is one inch (25.4 mm) thick lightweight glass thermal insulation on the interior surfaces of the compartments and 0.5 inch (12.2 mm) thick fire protection panels on the exterior surfaces of the compartments.

[redacted] 2.4.2.7 Risk Assessment -- The spaced armor concept employed on the far term ANVCE SES uses state-of-the-art armor materials and draws on considerable test data available for the performance.. of these materials when exposed to ballistic threats, The weight of material used for protection is in agreement with what the Navy considers adequate and in many cases exceeds the Navy estimates. In addition to this compartment protection system, critical machinery and weapons are provided a failsafe capability with the addition of protective features on those components. All armor systems utilize the existing structure and are producible. Therefore, the system represents the optimum design configuration for performance of the specified survivability/vulnerability goals.

The weight impact on all ship systems is summarized in Table 2.4.8. This includes weight additions for ballistic hardening and shock resistance.

Table 2.4.8 ~~(C)~~. Far Term SES Armor and Shock Hardening Allowances (U)

SWBS No.	Group	Weight LT	 kN	 *	Percentages SWBS Group	 Ship
100	Hull Structure	79.71	794.2	80.98	8.4	2.2
200	Propulsion	3.91	39.0	3.97	1.8	0.1
300	Electrical	2.32	23.1	2.36	3.5	0.1
400 (1)	Comm & Surveill	—	—	—	—	—
500	Auxiliaries	1.16	11.6	1.18	1.0	--
567	Lift System	2.57	25.6	2.61	2.1	0.1
600	O & F	14.0	139.5	14.22	7.3	0.4
700 (1)	Armament	---			—	—
LIGHTSHIP TOTALS		103.67	1033.0	105.32	5.8	2.9
MOO MARGINS		15.55	154.9	15.79	5.98	0.4
SHIP TOTALS		119.22	1187.9	121.11	3.3	3.3

* non-SI metric ton

(1) Groups 400 and 700 are primarily government furnished material; therefore, the associated Armor and Shock Hardening weight penalties are unknown.

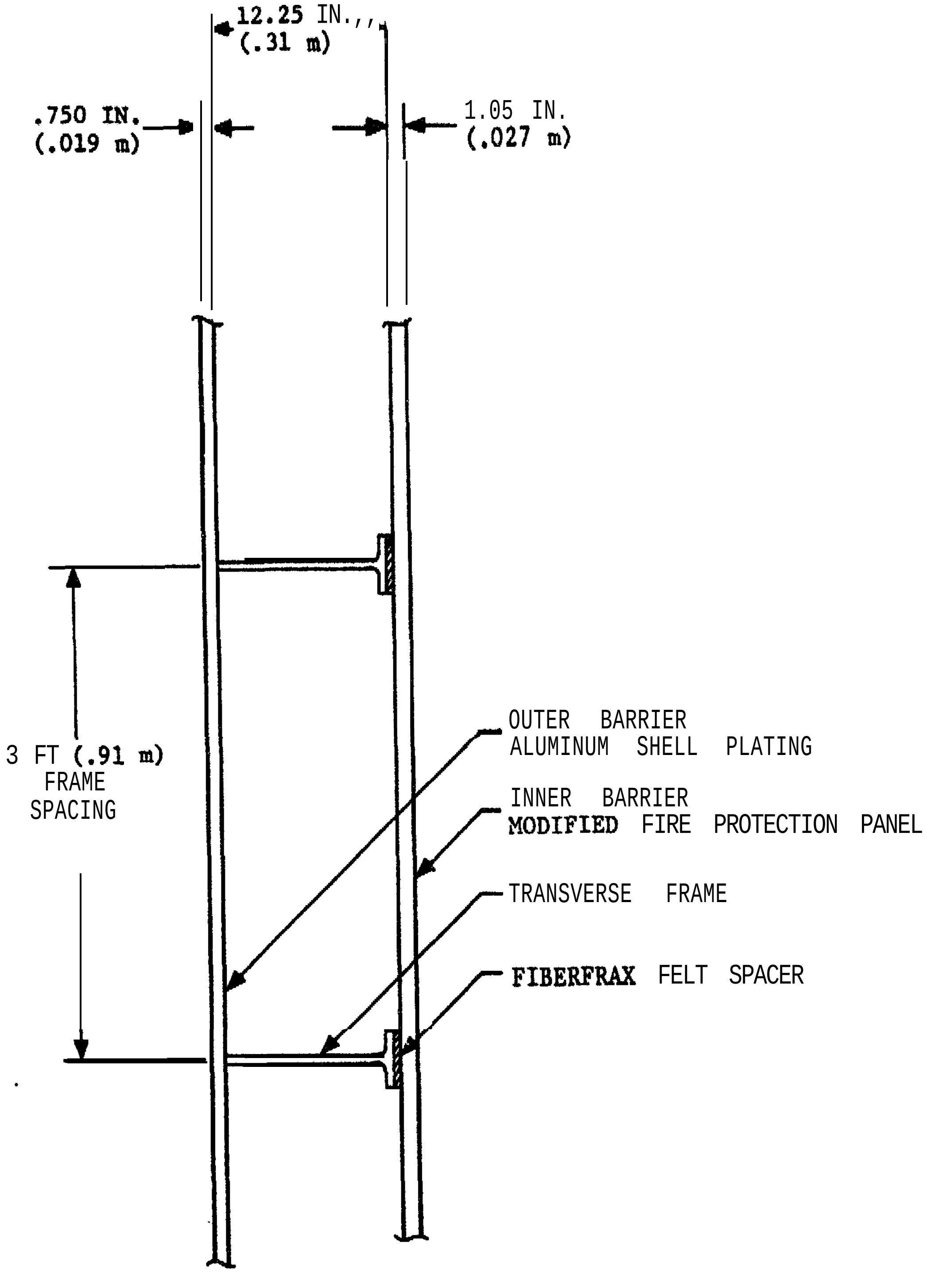

Figure 2.4-7 (C). Far Term SES Spaced Armor Concept (U).

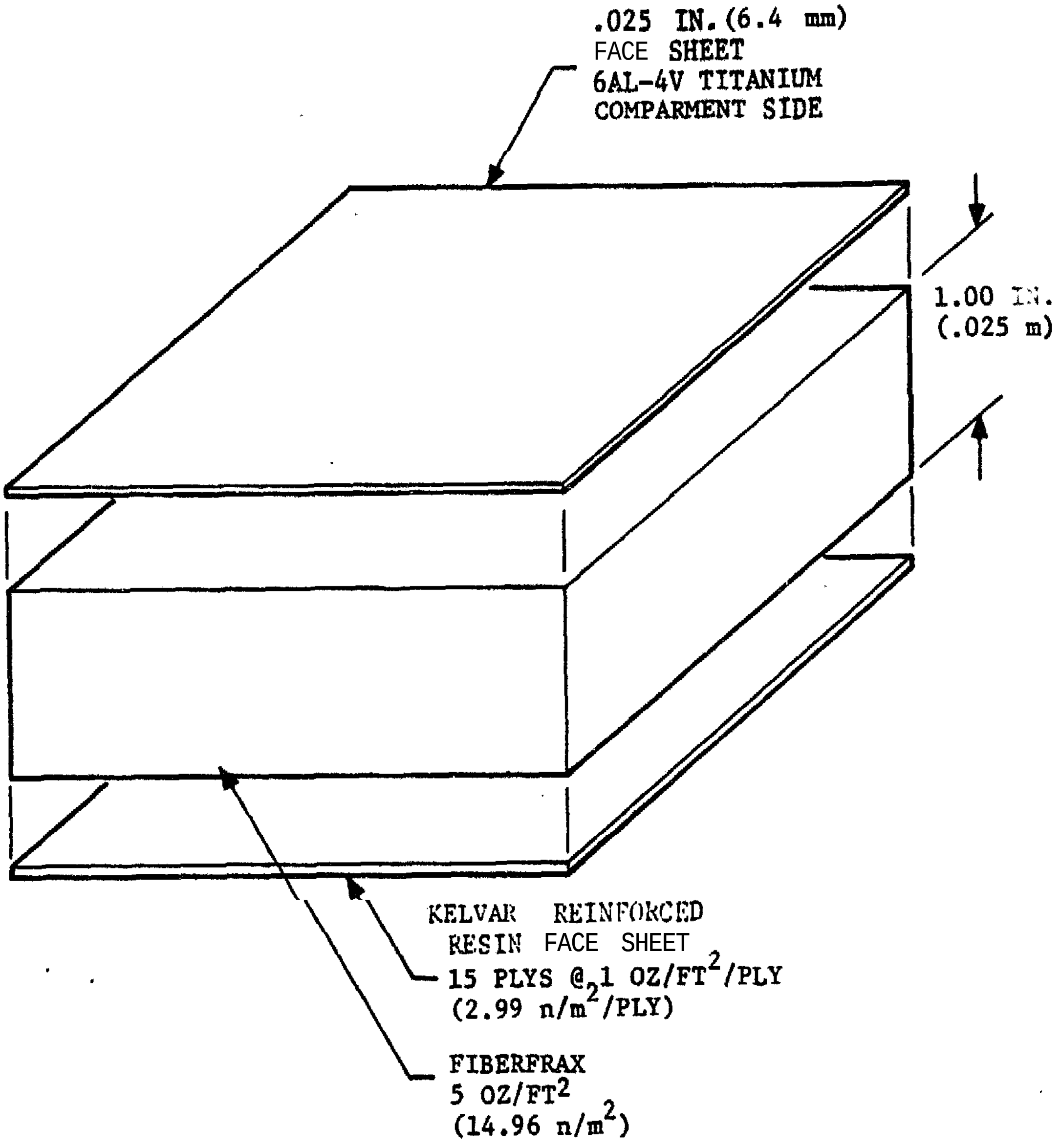

Figure 2.4-8 (U). Inner Barrier Panels (U)

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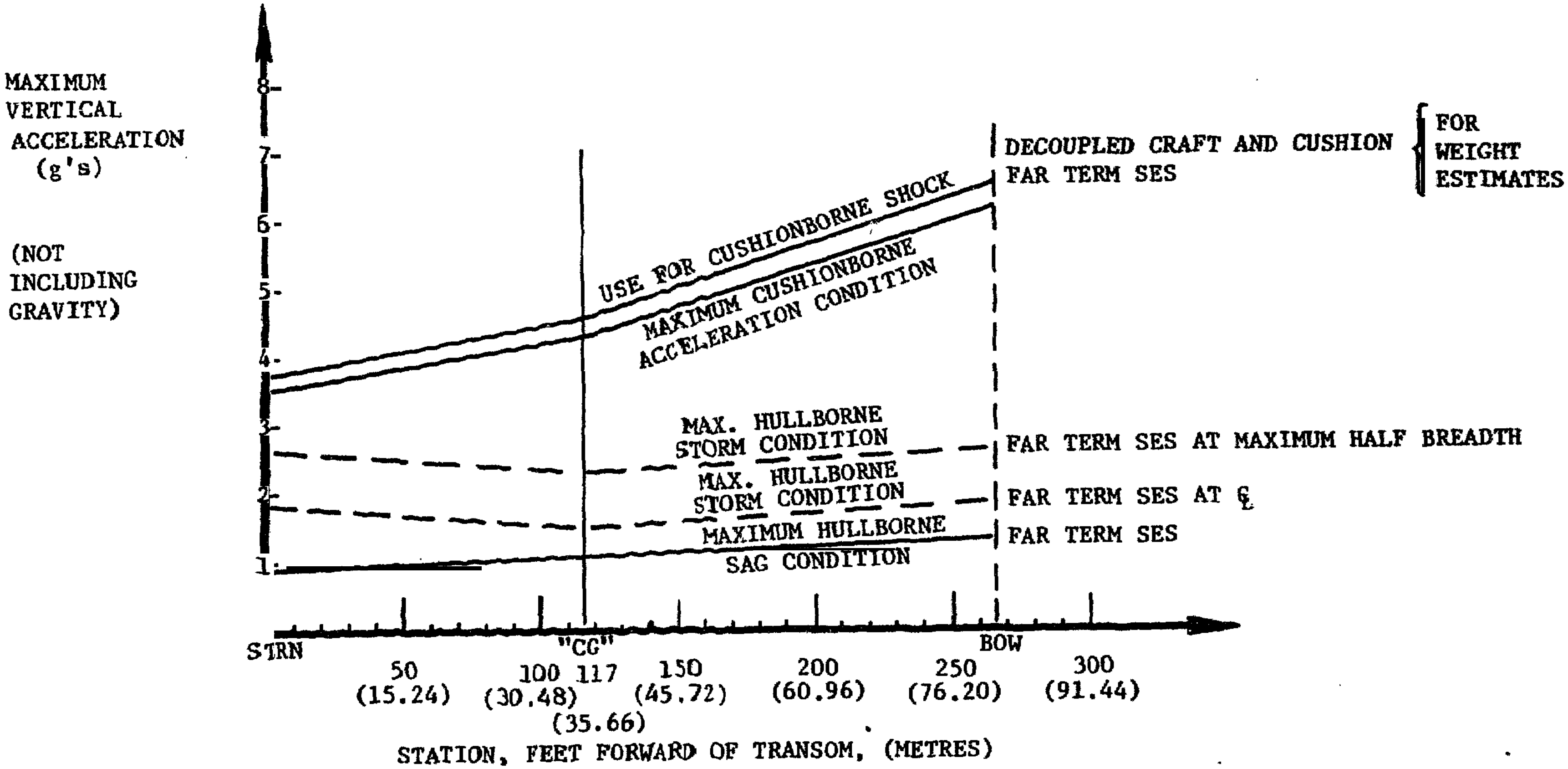

Igure 2.4-9 [redacted]. Shock Factors Adopted for Equipment and Machinery (U)

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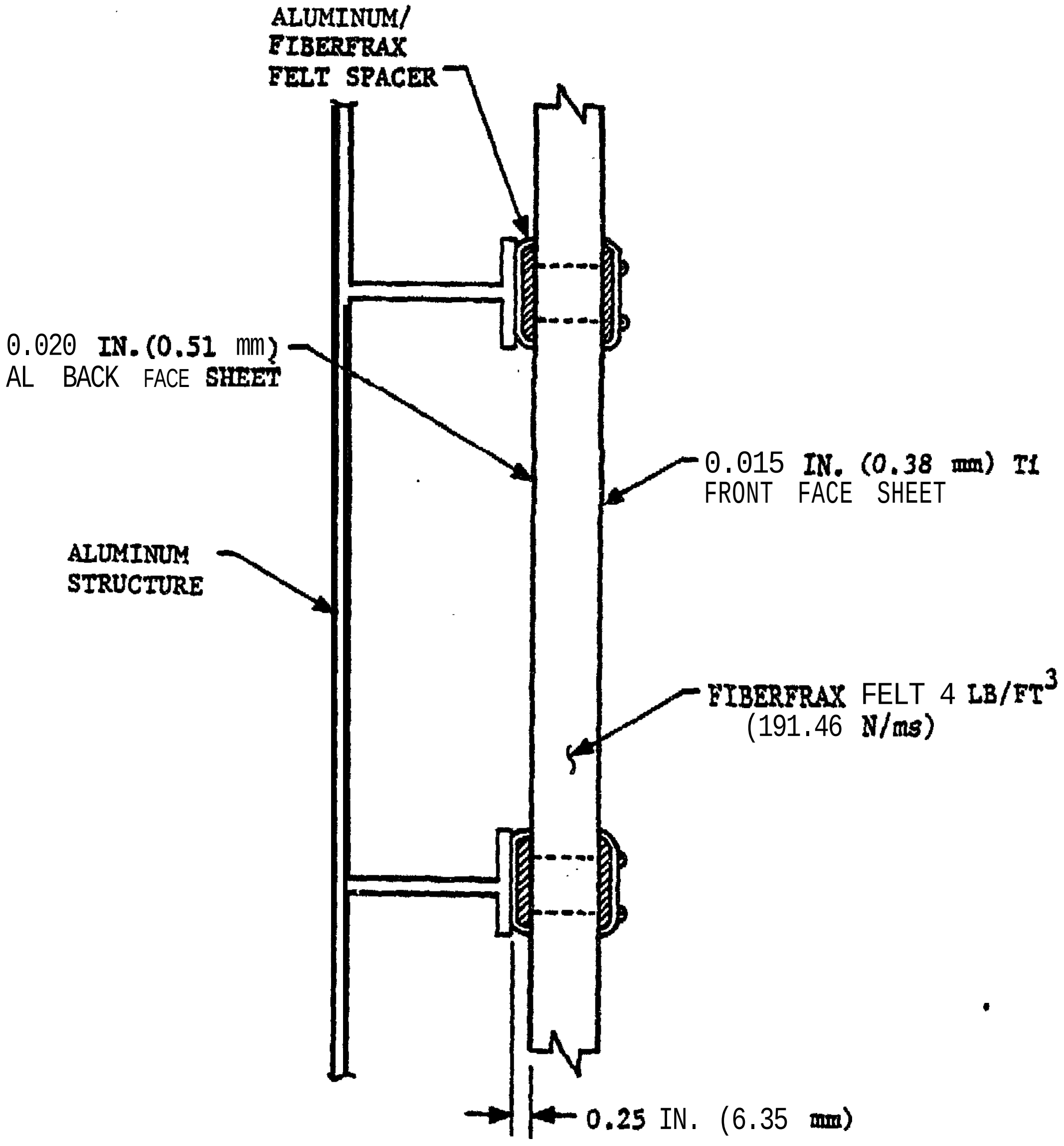
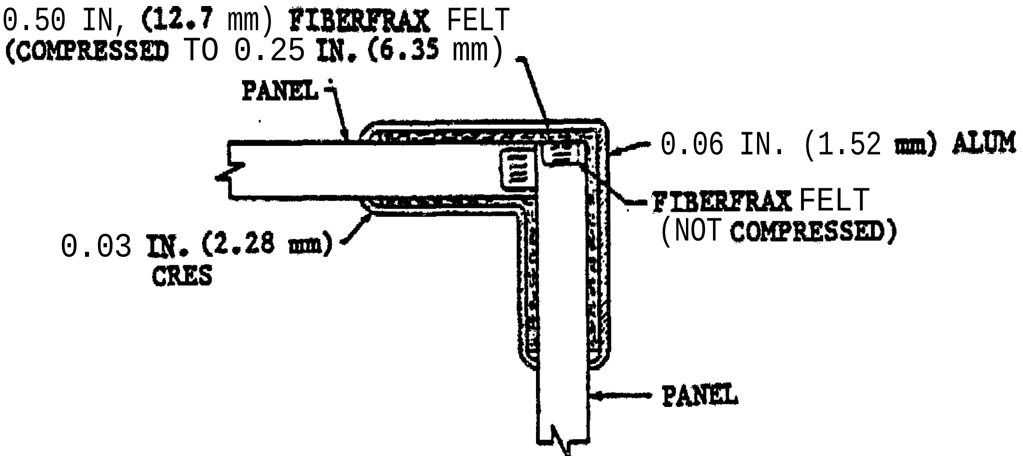
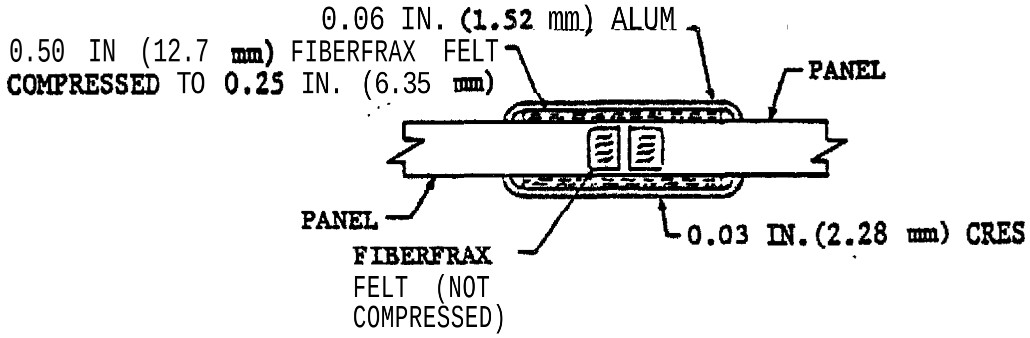


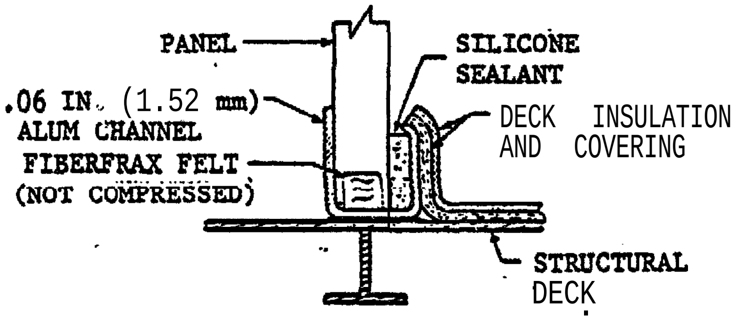
Figure 2.4-10 (U): Insulation Panel Design (U)



a) CORNER JOINT AND BULKHEAD PANEL TO OVERHEAD PANEL JOINT



b) PANEL TO PANEL JOINT



c) BULKHEAD PANEL TO DECK JOINT

Figure 2.4-11 (U): Panel Joints Designs to Prevent Vapor Leakage in a JP-5, Fuel Fire (U)

3 / LOGISTIC CONSIDERATIONS

(U) The principal logistic elements contributing to the far term ANVCE SES design baseline are maintenance planning, supply support, ship manning, training, technical publications and support system requirements. Interdependently and interacting with other requirements, these elements affect ship sizing, light ship weight, variable load weight, and inherent design capabilities for performing selected missions. The overall approach to logistics will support the far term ANVCE SES design, construction and fleet use.

(U) The support system provides the logistic support resources required to maintain the ship in an operational readiness condition capable of meeting the availability requirement of the missions. The logistic support resources include personnel and training, initial and back up inventory of spares and repair parts, industrial support facilities (intermediate and depot support levels) and common/peculiar support equipment (intermediate and depot repair shops). These logistics elements are displayed in the support system block diagram, Figure 3-1. The support system is compatible to the maximum degree possible with U.S. Navy and other existing logistics support activities.

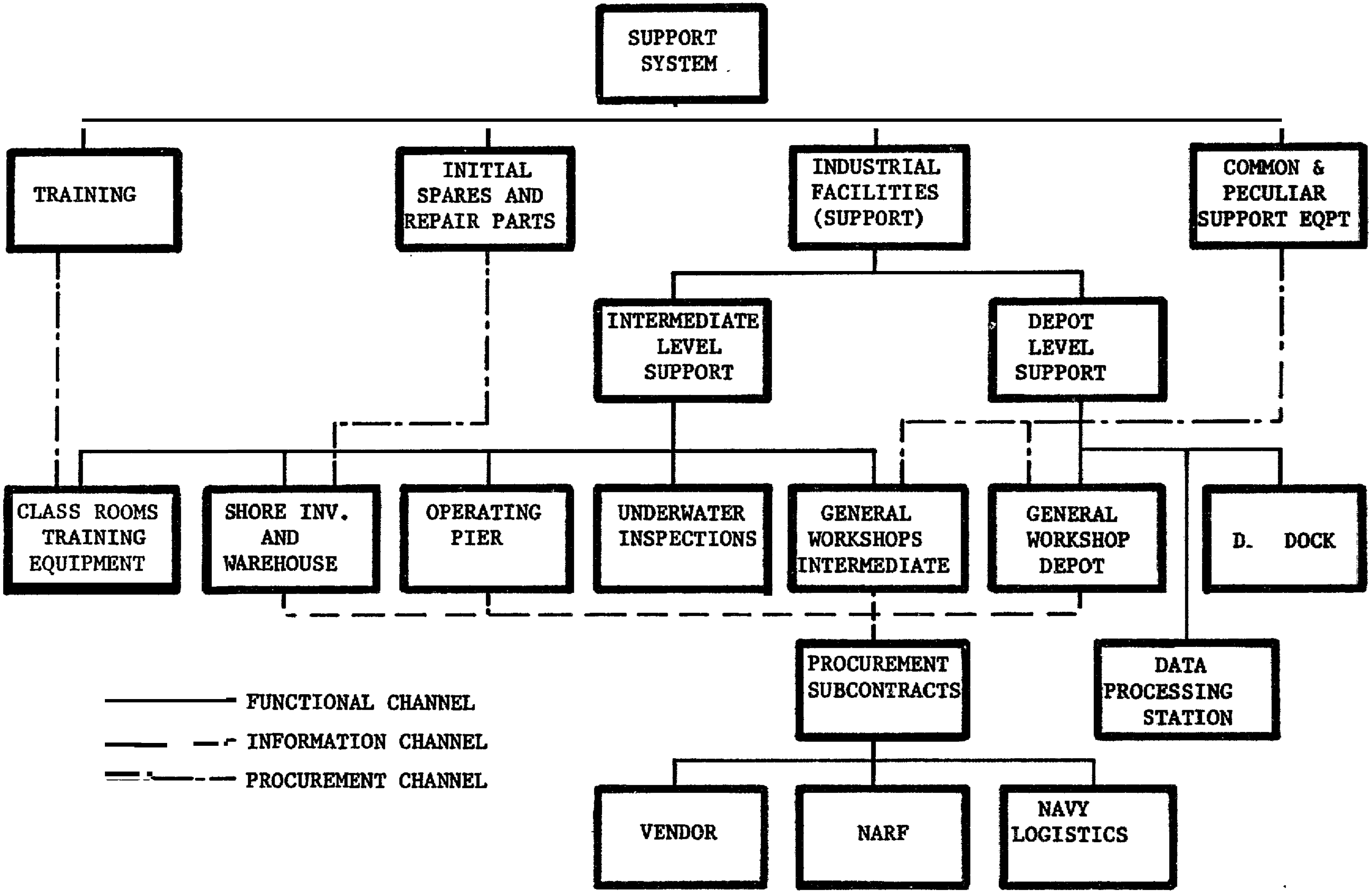


Figure 3-1 (U). Support System Block Diagram (U)

(U) 3.1 RELIABILITY AND AVAILABILITY

Since Rohr Marine Incorporated is not conducting the Supportability/Availability analysas (WP-008)(1), availability block diagrams **are not** a Part of this report; however, subsystem availability predictions applicable to the far term ANVCE **SES** are a part of this report, In addition, MTBF and **MTTR** data for major components of Surface Effect Ship Subaystams are listed in Paragraph 3.1.3 along with a utilization factor.

(U) 3.1.1 SES UTILIZATION -- This subparagraph topic is not addressed inasmuch as a scenario has not been derived for the **15-day** mission.

(U) 3.1.2 SES SYSTEM AND SUBSYSTEM -- The predicted availability for the far term SES is shown in Table 3.1-1. The predictions are based on a **15-day** mission per the TLR. Availability is defined as the ratio of mission uptime to total at sea time scheduled for the mission.

Table 3.1-l **(U).** Par Term SES Availability Prediction (U)

Subsystem	Availability Prediction
Hull Structures	0.9960
Propulsion Plant	0.9710
Electric Plant	0.9990
Command and Surveillance	0.9860
Auxiliary System	0.9900
Lift system	0.9820
ANVCE SES Ship (Far Term)	0.93

(U) (1) This is the understanding derived from the 20 September 1976 meeting at PMS-304. The information submitted in this report presents data used in Rohr Marfne Incorporated RMA analysis.

(U) The predicted availability for the ANVCE SES is high due to:

a. Propulsion Plant - Redundant components are contained in the lubrication system for the transmission system. LM5000 gas turbine and propulsor will have more operating experience by 1990 that will improve their reliability. Redundancy: 2 of 4 power trains is acceptable for the sub-hump and off-cushion speed regimes.

b. Electric Plant - Redundancy: 2 of 3 gas turbine generators are required at sea for 400 Hz and 60 Hz power. Most electrical equipments contain proven components. Vital loads receive power from 1 of 2 switchboards,

c. Command and Surveillance - For availability purposes, the maneuvering and navigational functions are our only concern. For these functions redundancy and modularization for ease of maintenance provide high availability.

d. Auxiliary System - Redundancy utilizing proven components is the basis for high availability of the auxiliary systems. Maintainability is achieved through accessibility and use of light weight moderate size components.

e. Lift system - Redundancy: 1 of 2 banks of three fans each are adequate for sub-hump operation and a portion of post-hump operation. High reliability of the stay stiffened planing seal due to pre-operational checkouts which screen out potential mission failures. All seal components can feasibly be replaced without dry-docking - a big plus for maintainability. The lift transmission is a simple in-line shaft design without complex gear ratios or right angle drives.

(U) The availability predictions listed in Table 3.1-l are relative to a mature design. Furthermore, these predictions are for a ship maintained in accordance with the Maintenance Concept outlined in Paragraph 3.2. The combat functions have not been considered in computing these predicted availabilities.

(U) It is realized that an availability prediction for a far term ANVCE SES should include the combat functions; however, this would require a mission time line and scenario which are not now available. Therefore, the ANVCE SES combat system availability is not predicted.

(U) 3.1.3 MAJOR COMPONENT BLOCKS - MTBF AND MTTR DATA -- The reliability and maintainability data in Tables 3.X.3-1 through 3.1.3-6 list mission essential equipments. Not listed are equipment in the combat system with the exception of those functions required for maneuvering and navigation. Many of the MTBFs in this list show improved MTBFs over the near term ANVCE SES data due to anticipated reliability growth for those components where improvement is expected, Although many of the MTTR will be reduced by design improvement and a learning curve, this knowledge has not been factored into the data, The equipment R & M data are listed by subsystem with the following definitions applying:

EQUIPMENT - Major equipment group of function

MTBF - Mean Time Between Failure

MTTR - Mean Time to Repair or Restore (the times listed include a 501% allowance for conditions at sea)

UTIL - Utilization Factor. That portion of time that the item is in use during the mission,

NR Non-Repairable at sea.

Table 3.1.3-l (u). Propulsion Plant MTBF and MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Combustion Air Supply Heating (NR)	11,500	5.0	0.5
Combustion Air Supply	24,400	1.5	1.0
Combustion Air Supply (NR)	81,300	5.0	1.0
Gas Turbine - LM5000			
Gas Turbine (NR) - LM5000			
GTRB Lube Oil Cooler	90,000	4.5	1.0
GTRB Lube Oil Filter - Supply	60,000	4.5	1.0
GTRB Lube Oil Filter - Scavenge	60,000	4.5	1.0
Flex Coupling (NR)	72,780	4.0	1.0
Tongue Meter	10,000	1.5	1.0
Shafting & Bearings (NR)	11,600	6.0	1.0
Thrust Reverser	6,150	6.0	0.1
Propulsor (NR)	11,000	8.0	1.0
Waterjet - Steering	6,150	6.0	1.0
Exhaust Duct	62,000	4.5	1.0
Exhaust Duct (NR)	300,000	15.0	1.0
GTRB Cooling Blower	18,250	2.25	1.0
Lube Oil Pump - Pressure	21,800	3.0	1.0
Att. Lube Oil Pump - Press.	34,500	4.5	1.0
Lube Oil Pump - Scavenge	21,800	3.0	1.0
Att. Lube Oil Pump - Scavenge	34,500	4.5	1.0
Lube Oil Filter/Separator	30,000	4.5	1.0
Lube Oil Control Manifold	46,730	3.0	1.0
Lube Oil Cooler	45,000	4.5	1.0
Vacuum Pump	18,250	2.25	1.0
Inlet Sensors & Control	5,000	1.5	1.0
Inlet Ramp Actuator	6,100	3.7	1.0
Inlet - Misc.	91,000	3.0	1.0
Inlet (NR)	45,000	15.0	1.0
Propulsion System - Misc.	10,000	3.0	1.0
Sensors for System Control	10,000	1.5	1.0

Table 3.1.3-2 (U). Electric Plant MTBF and MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Engine Air Supply	70,000	1.5	1.0
Gas Turbine Generator 60 Hz	14,000	3.0	1.0
Gas Turbine Generator 60 Hz (NR)	21,000	8.0	1.0
Gae Turbine Lube Oil Cooler	90,000	4.5	1.0
Exhaust Duct (NR)	26,000	5.8	1.0
60 Hz Switchboard	645,000	1.5	1.0
60 Hz Power Panel	173,580	1.5	1.0
60 Hz Transformer	1,000,000	1.5	1.0
400 Hz Switchboard	645,000	1.5	1.0
400 Hz Power Panel	173,580	1.5	1.0
400 Hz Transformer	1,000,000	1.5	1.0
Cooling Fan	18,250	2.25	1.0
Lighting Vital Spaces * (each light)	1,000,000	1.5	1.0
Gas Turbine Generator 400 Hz	17,000	3.0	1.0
Gas Turbine Generator 400 Hz (NR)	25,000	8.0	1.0
28 VDC Rectifier	36,000	1.5	1.0
28 VDC Distribution Box	28,930	1.5	1.0
28 VDC Power Panel	43,395	1.5	1.0

*Each light receptacle contains redundant flourescent tubes, MTBF = 20,000

Table 3.1.3-3 (U). Command & Surveillance Navigation 6
Collision Avoidance MTBF and MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Anti-Clutter Collision Avoidance Radar	2,400	4.5	1.0
Anti-Clutter Collision Avoidance Radar (Advanced 2D Surface Search Radar (NR))	22,000	3.0	1.0
Collision Avoidance Computer AN/UYK-20	4,400	0.4	1.0
Navigation Computer AN/UYK-20	4,400	0.4	1.0
Navigation Data Switchboard	2,000	1.5	1.0
SAT-NAV	1,100	0.75	1.0
OMEGA	3,300	1.5	1.0
Inertial Nav	12,000	1.0	1.0
Gyro (Types 1 and II)	12,000	1.0	1.0
Depth Sounder AN/UQN-4	12,500	0.75	0.5
Doppler Speed Sensor	2,200	1.5	1.0
Interior Communications	44,000	1.5	1.0
HF Transceiver	2,400	0.5	1.0
UHF Transceiver	4,600	0.6	1.0
VHF Transceiver	5,500	0.5	0.1
VHF Antenna (NR)	25,000	2.0	1.0
Transfer Switchboard	35,000	0.7	1.0

Table 3.1.3-4 (U). Command & Surveillance Ship Controls MTBF and MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Wheel	5,000	1.5	1.0
Autopilot	1,666	1.0	1.0
Propulsion Power Lever Actuator	5,000	1.0	1.0
Lift Throttle	5,000	1.0	1.0
Lift Control (Ship's Control Console and Propulsion Control Console)	5,000	1.0	1.0
Autopilot Control Display Unit	5,000	1.0	1.0
Navigation - Collision Avoidance Display	4,000	1.0	1.0
Central Processing Unit	4,400	1.0	1.0
Fire Protection Controls	1,000	1.0	1.0
Electric System Control	1,000	1.0	1.0
Fuel Management Control	1,000	1.0	1.0
Auxiliaries Control	1,000	1.0	1.0
Power Supply	90,000	1.5	1.0
PPI Display	8,800	3.0	1.0
PPI Display (NR)	8,800	3.0	1.0
Commanding Officer Communications Console	50,000	1.0	1.0
Ship's Control Console - Monitoring	10,000	1.0	1.0
Propulsion Control Console - Monitoring	10,000	1.0	1.0

Table 3.1.3-5 (U). Auxiliary System MTBF AND MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Air Conditioning Unit	12,650	4.0	0.5
Recirculating Fan	13,880	3.0	1.0
Mixing Box	38,080	3.0	1.0
Supply Fen	18,250	3.0	1.0
Exhaust Fan	18,250	3.0	1.0
Supply Fan - Machinery Space	18,250	3.0	1.0
Exhaust Fan - Machinery Space	18,250	3.0	1.0
Fire Pump (NR)	10,500	8.0	1.0
Distiller	3,400	4.0	1.0
Distiller (NR)	10,000	9.8	1.0
Pump - Potable Water	15,150	3.0	0.5
Pump - F.W. Transfer	15,150	6.0	1.0
Pump - Coolant, Electronic	15,150	4.5	1.0
Demineralizer	32,860	4.4	1.0
Heat Exchanger	90,000	4.5	1.0
Valve, Temp. Control	11,700	3.0	1.0
Pump, Fuel Transfer	3,760	4.5	0.3
Pump, Fuel Service	3,760	4.5	1.0
Pump, Fuel Trim	3,760	4.5	0.5
F.O. Filter	60,000	4.5	1.0
Manifold, Fuel	10,000	3.0	0.75
Heat Exchanger	90,000	4.5	1.0
Mass Flow Multiplier	50,000	4.5	0.1
Valve, Motbr Operated	20,000	3.0	0.05
Regulator, Air	46,730	3.0	0.05
Air, Receiver	16,700	4.5	1.0
Hydraulic Pump - Att.	15,000	3.0	1.0
Hydraulic Pump - Motor Drive	10,500	3.0	1.0
Filter, Hydraulic	60,000	4.5	1.0
Cooler, Hydraulic	90.000	4.5	1.0
Control, Hydraulic System	50,000	4.5	1.0

Table 3.1.3-5 (U). Auxiliary System MTBF and MTTR Data (Continued) (U)

EQUIPMENT	MTBF	MTTR	UTIL
Regulator, Hydraulic Resevoir	23,365	3.0	1.0
Anchor Windlass (NR)	3,350	5.0	0.05
Capstan Mooring (NR)	3,350	5.0	0.05
Fuel Probe-Receiver	50,000	3.0	0.10
Pollution Control System	10,000	3.0	1.0
Hangar Door - Actuation	10,000	4.5	0.05
Hangar Door - Manual	10,000	4.5	0.05
Sensors for System Control	10,000	1.5	1.0
Auxiliaries - Misc.	5,000	3.0	1.0
Fire Detection	2,000	1.0	1.0

Table 3.1.3-6 (U). Lift System MTBF and MTTR Data (U)

EQUIPMENT	MTBF	MTTR	UTIL
Gas Turbine - LM5000			
Gas Turbine (NR) - LM5000			
GTRB Cooling Blower	18,250	2.2s	1.0
GTRB Lube Oil Cooler	90,000	4.5	1.0
GTRB Lube Oil Filter - Supply	60,000	4.5	1.0
GTRB Lube Oil Filter - Scavenge	60,000	4.5	1.0
Torsionmeter	10,000	1.5	1.0
Exhaust Duct (NR)	26,000	5.8	1.0
Reduction Gear (NR)	188,000	8.0	1.0
Pump - Lube Oil Pressure	21,800	3.0	1.0
Pump - Lube Oil Pressure - Attached	34,500	4.5	1.0
Pump - Lube Oil Scavenge	21,800	3.0	1.0
Pump - Lube Oil Scavenge - Attached	34,500	4.5	1.0
Filter Separator - Lube Oil	30,000	4.5	1.0
Control Manifold - Lube Oil	46,730	3.0	1.0
Lube Oil Cooler	90,000	4.5	1.0
Vacuum Pump	18,250	2.25	1.0
Shafting & Bearings (NR)	41,000	6.0	1.0
Demister	23,200	1.5	1.0
Lift Fan	48,000	3.0	1.0
Lift Fan (NR)	14,000	18.0	1.0
Shut Off Control Valve	5,900	4.5	1.0
Control - Ride Control Valves	10,000	3.0	0.1
Ride Control Valve	5,900	4.5	0.1
Bow Seal (NR)	12,000	4.3	1.0
Stern Seal (NR)	12,000	4.7	1.0
Bow Seal Retract	9,120	4.5	0.05
Control - Bow Seal Ret.	5,000	1.5	0.05
Stern Seal Retract	9,120	4.5	0.05
Control - Stern Seal Ret.	5,000	1.5	0.05
Misc. Valves & Piping	10,000	1.5	1.0
Sensors for System Control	10,000	1.5	1.0
Transfer Valves	5,900	4.5	1.0

(U) 3.2 MAINTENANCE CONCEPTS

In consonance with the TLR[1], the maintenance concept for meeting the objectives and availability goal of the far term SES is to: (1) perform the preventive/corrective maintenance on critical equipment onboard; (2) accomplish the emergency repair of non-critical equipments with helicopter provided (VERTREP) augmentation from the intermediate level support resources; and (3) defer/schedule all non-essential equipments/ components maintenance for in-port availabilities. For design purposes, particular emphasis was given to: (1) maximization of the use of existing and projected Navy equipments to permit use of standard maintenance procedures and supply support; (2) use of performance/ condition monitoring for detecting incipient failures for critical equipments; and (3) provisions for equipment accessibility to support a component/module replacement strategy. The replacement strategy includes scheduled replacement, replacement on condition, and replacement at failure depending on the subsystem/equipment criticality.

(U) If forward bases are available in the 1990s (such as Rota, Spain, Guam, or Diego Garcia), the far term SES could be located at these bases for more immediate availability to conduct forward area operations. One of the strengths of the SES, however, is that even without such forward bases, it can reach a crisis scene in a matter of a couple of days from CONUS bases.

(U) Therefore, the maintenance concept in support of far term SES availability and mission is based on a number of objectives and constraints.

(U) The maintenance objectives of the far term SES are:

- Support the SES in the achievement of assigned missions while assuring safety of ship and personnel, and meeting availability requirements.
- Use the inherent maintenance capability of operator personnel.
- Minimize shipboard maintenance manning.

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(1) Rohr-proposed modification of 25 October 1976.

(U)

- Minimize "at sea" repair to the vital and critical equipments and components.
- Minimize ship carried weight of logistic resources.
- Use the most cost-effective distribution of effort between shipboard and off-ship maintenance.
- Use helicopter service (VERTREP) to provide logistics resources not carried on board, i.e., personnel skills, special tools and test equipment, spares, etc.
- Use the replace and restore concept to the maximum, vice piece-part repair.
- Provide adequate accessibility for servicing to minimize secondary removals/replacements.
- Maximize the use of existing and projected Navy equipments to permit use of standard maintenance procedures and supply support. Navy rotatable pool stocks will be used as applicable.
- Achieve incremental subsystem overhaul by maintenance actions and scheduled replacement of subsystems accessories and related auxiliaries consistent with the major item replacement cycle.

(U) The maintenance constraints placed on the far term SES are:

- Accomplish both preventive and corrective maintenance actions, to the maximum extent possible, while in port.
- In view of the perennial need to minimize ship weight, a single item weight limitation of 160 lbs (711.72 N), will relegate a few "potentially repairable at sea" maintenance tasks (on critical equipments) to a non-repairable at sea category.
- At sea maintenance shall be limited to that required, consistent with ship speeds and sea states.

(U) 3.2.1 INTERMEDIATE LEVEL SUPPORT -- Intermediate Maintenance Activity (IMA), either ashore or afloat, will be required by the far term SES. Existing repair bases and fleet tenders will incorporate certain skills and capabilities that go beyond their needs for supporting other naval units, (example - seal and lift fan repairs). However, the weapons, electronics, hull and machinery IMA requirements should not differ significantly from other types of combatants that will exist in the 1990s.

(U) IMA's will accomplish PM not within the capacity of the ship's crew. The IMA will provide condition monitoring services not otherwise within the capabilities of the monitoring equipment aboard ship, during upkeep or Maintenance Availabilities of the ship. Intermediate-level maintenance for the far term SES will include support from shore based and afloat Intermediate Maintenance Activities.

(U) 3.2.1.1 Shore Based Intermediate Facilities -- The shore based intermediate level support will provide the following types of facilities to meet the operating, maintenance, training and supply support requirements of the far term SES:

a. Operating pier -- will provide for safe and efficient mooring of the ship for servicing, maintenance and/or testing, The mooring provisions will be designed to be specifically compatible with the ship. An unobstructed access and a sufficient depth of water are required. Bits and chocks will provide the capability of withstanding wind loading up to 100 knots (51.44 m/s). Compatible dockside fittings for fueling/defueling, fresh water, compressed air, 60 and 400 Hz electrical power and telephone connections to the SES will be provided. Crane services for loading/unloading equipments/components and materials, gangways and/or ramps for personnel access/egress will be provided.

(U) Emptying the collecting/holding tanks (CHT) of sewage and other liquid wastes will be accomplished by appropriate sludge barges and receiving vehicles. Solid trash (compaction) disposal will be provided.

b. Intermediate level maintenance shops/capability such as:

(1) Ship **fitters/welding/pipefitters**

(2) Mechanical - pumps/auxiliary **machinery**

(3) Electrical - generators/switchboards

(4) Electronics/test instrumentation

(5) Underwater inspection/repair support shop including photographic service

(6) Operational computer program maintenance

c. Training classrooms including the necessary training equipments (devices, simulators, etc.), test equipment, materials and tools for each required training station.

d. Supply warehousing and storerooms

e. The administrative space, personnel, furnishing and equipments necessary to coordinate the logistics resource support, including the planning and scheduling of the resupply services to support the SES while at sea. Support shall be provided for logistics resources not carried on board (i.e. personnel skills, special tools and test equipment, spares, etc.)

(U) 3.2.1.2 Afloat Intermediate Facilities -- The afloat intermediate level activity will provide the following types of maintenance shop/capability support:

a. Ship **fitters/welding/pipefitters**

b. Mechanical - pumps/auxiliary machinery

c. Electrical - generators/switchboards

d. Electronics/teat instrumentation

e. Underwater inspection/repair support shop, including photographic service.

f. Replenishment of material requirements

(U) 3.2.2 **DEPOT** LEVEL SUPPORT -- Depot-level support maintenance of the far term **SES** will include the **following:**

a. Preserving the underwater body and maintaining sea-connected tanks, valves, pipes, and fittings.

b. Performing repairs requiring heavy lift capability and special tools and test equipment (examples: **bow/stern** seals, radar antennas, gas turbines, **waterjet** propulsor, electrical generators).

c. Removing, installing, and testing certain equipments identified as stock rotating spare items (examples: main propulsion and lift gas turbines).

d. Stocking and repairing designated stock rotating spares items at selected depot maintenance activities.

e. Stocking and issuing of system level stocks.

(U) The depot level support will provide a dry dock and the necessary work shops for systems/equipments for overhaul and/or repair beyond the capability of the intermediate maintenance activity. The depot level support will provide general workshops and dry dock facilities and services.

(U) 3.2.2.1 General Workshops -- Depot level maintenance shops/ capability will provide maintenance for the waterjet propulsor, lift fans, seals, structural/welding, computers, consoles and related electronics, and gas turbine generatore. A Naval Rework Facility is required for gas turbine engine maintenance. Overhaul points for communications, sensors, computers, displays, and related electronics must be designated. A facility, either Government or Contractor, is required for the maintenance of operational computer programs.

(U) 3.2.2.2 Drydock -- A aafe and efficient facility capable of drydocking the ship. Cranes, temporary power, compressed air, fresh water, salt water, firemain, sewage collection and disposal shall be available at the dock site.

(U) 3.3 OVERHAUL CONCEPT

Regular overhauls, as now understood, are to be eliminated by intensive use of the upkeep periods as maintenance availabilities. The far term SES will employ the concept of progressive overhaul. Equipment replacement and alteration will be accomplished progressively during relatively frequent maintenance availability. periods of short duration. Dry-docking will be accomplished, primarily to provide for major emergency repairs and/or ship alterations. The ship system will be designed to be capable of incremental overhaul of its subsystems and subsystem accessories and related auxiliaries. Operational usage and schedule replacement will be consistent with the major item replacement schedule.

(U) 3.3.1 SCHEDULING -- The scheduling of maintenance availabilities shall be in general accordance with the 10 year operating profile (Section 1) exhibited in the Rohr-proposed TLR. A one month maintenance availability following each deployment will be conducted except that one additional month (two months total) will be provided after every third deployment for Depot level assistance. A Depot level moderization period is scheduled after 10 years operations.

(U) 3.3.2 PIPELINE REQUIREMENTS -- No unusual pipeline requirements are anticipated and the existing Navy pipeline service is considered satisfactory for the far rerm SES.

(U) 3.3.3 SHIPYARD OVERHAUL FACILITIES -- See Section 3.2.2 for description of recommended shipyard overhaul facilities to satisfy the requirements of the far term SES.

(U) 3.3.4 LAN&BASED TEST FACILITIES -- The Land-Based Test facility designated for the development of the far term SES operational-computer programs will be capable of supporting the computer programs maintenance. Requirements are delineated in Sections 3.2.1 and 3.2.2.

(U) 3.3.5 MAINTENANCE PROGRAM INTERFACE -- (Not provided).

(U) 3.4 SUPPLY SUPPORT CONCEPT

The sizing of far term SES storerooms, commissary system and other supply spaces are constrained by design requirements and indirectly by the maintenance concept and the personnel requirements. Within the permissible volumetric and weight limits, the far term SES design provides the necessary supply support capability. The design supports the requirements for 10 and 15-day missions in accordance with the TLR, A salient design consideration is the frequency of underway replenishment, including helicopter (VERTREP) delivery of required logistics resources, and the requirement for underway refueling,

(U) The supply support concept provides material support for the assigned missions. The support includes initial outfitting of provisions, medical supplies and spares and repair parts as well as replenishment. The support provides an adequate allowance of onboard material to fully support the operational organizational maintenance needs of the ship and of the embarked aviation detachment. Allowance lists will provide for the subassemblies and modules required to support the ship's most demanding mission. A far term SES Coordinated Ships Allowance List (COSAL) will reflect the onboard allowances of material required for this ship.

The following is a list of specific requirements for provisioning and stowage space for the onboard allowances for the far term SES.

TYPE	DAYS ENDURANCE
Dry Provisions	30
Chilled Provisions	15
Frozen Provisions	30
Repair Parts/Equipment Related Consumables	30
Non-Equipment Related Consumables	30
Ships Store Stocks	30
Medical Stores	30
Aviation Support Spares	30

(U) The supply concept provides for the fitting out of the far term SES. It provides for the material to be assembled in a shore warehouse prior to loading on board. The loading of spares and repair parts and equipage will be kept to a minimum consistent with space and weight constraints, necessary to support availability and mission requirements. Tailored loads of support for specific missions will be utilized.

(U) Replenishment for all repairables, consumables, and spares will be provided through Underway Replenishment Groups at sea and through normal resupply methods in port. Maximum utilization of in-port delivery for all repairables, consumables, and spares, will be planned. Supply requirements, for at sea emergencies, will be met by the utilization of helicopter delivers (VERTREP).

(U) 3.4.1 MODIFICATIONS TO MOBILE LOGISTIC SUPPORT FORCE SHIPS -- The far term SES requires the existence of a Fleet Tender (1), either as a part of the Mobile Logistic Support Force or as an integral part of the SES Task Force. This Fleet Tender will serve as the second echelon for maintenance and supply support of the far term SES. This Fleet Tender shall also provide administration/legal services not included within the far term SES manning complement. In addition, it shall have trained personnel that can augment the far term SES crew to accomplish both corrective and preventive maintenance beyond the capability of SES ship's company, It shall also be capable of providing the logistic resources, by helicopter if required, to assist in the maintenance of non-mission critical as well as mission critical equipment/components on the far term SES. The capability to provide on-call service to the far term SES shall be available to provide logistics resources not carried on board, i.e, personnel skills, special tools and test equipment, spares and repair parts. The frequency of flights and duration thereof shall be a function of the specific combat mission being conducted.

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(1) With flank speed capability of about 30 knots (15.43 m/s).

(U) 3.4.2 UNIQUE SHORE FACILITIES -- There are no known unique shore facilities required for the far term SES except to provide those intermediate maintenance and supply functions ashore similar to those services provided by the Fleet Tender or its equivalent.

(U) 3.4.3 UNIQUE REPLENISHMENT TECHNIQUES -- Resupply of provisions, consumables, spares, and expendable ordnance will be a scheduled function performed by Mobile Logistic Support Forces and Underway Replenishment Groups and will be dictated by operational readiness requirements as set forth by the Fleet Commander.

(U) At-Sea replenishment will be provided by Underway Replenishment Groups via UNREP and VERTREP methods. The capability for rapid receipt, strike-down, and stowage of replenished items and rapid off-ship movement of retrograde items (rotatable pool Items, reusable containers, and other repairables) is provided in the far term SES.

(U) The far term SES design does provide for the rapid receipt, strike-down, and stowage of replenishment items and for the rapid movement off-ship of retrograde material by VERTRRP and UNREP methods. To this end, appropriate handling equipment (monorails, chain hoists, conveyors, davits, dollies,, etc.) and access hatches, passageways, and doors are provided to accommodate material transfer with minimum delay and disruption to the ship's operational commitments.

(U) Replenishment shall normally be accomplished by VERTREP. This shall include providing urgently required spares and repair parts to restore mission critical subsystems, equipments and components. Rapid replenishment of critical aviation spares and repair parts shall also be provided by VERTRRP. The rate of replenishment by VRRTREP is estimated at 100 short tons per hour (0.89 MN/h) for provisions, spares and repair parts, Ordnance material shall be replenished in a manner which permits safe handling and minimizes the possibility of damage or creates a personnel safety hazard. VRRTREP can be used to distinct advantage by eliminating the

(U) approach, hookup and disconnect time required in alongside transfer. This is particularly true during small scale replenishment's when less than approximately 75 short tons (0.67 MN or 68 non-SI metric tons) are to be transferred. Based on data in NWP 38 (D), Replenishment at Sea, and utilizing one UH-46 Helicopter, or its equivalent, an estimated daylight transfer rate of up to approximately 100 ST (0.89 MN or 91 non-SI metric tons) per hour can be anticipated. Night delivery rates will be lower since night cargo pickup and delivery requires increased care and precision.

(U) Replenishment of JP-5 fuel shall be accomplished by connected replenishment (CONREP). This replenishment shall be available from ships within the Task Force which shall permit rapid and frequent refueling. Refueling of helicopters shall be accomplished using on-deck or airborne refueling (HIFR) techniques. The fuel utilized shall be available from ships tank and shall be appropriately filtered to assure safety of flight. Fuel will be transferred to service tanks prior to accomplishing refueling.

(U) 3.4.4 UNIQUE SUPPLY SUPPORT PROCEDURES -- The concept of minimizing onboard maintenance with the resultant reduction in spares and' repair parts carried as a part of the far term SES allowances will require a different type of distribution of system stocks. The Tender Allowance List for the Fast Fleet Tender and for the equivalent Intermediate Support Activity will contain a greater range of items to be carried, including rotatable pool items and bit and piece repair Parts. Employment of a replace-and-restore maintenance strategy on the far term SES in conjunction with a minimum manning philosophy requires that a 'significant number of equipment/components be removed for rotatable pool replacement and off-ship repair/refurbishment at the Fleet Tender or shore based Intermediate Support Activity.

(U) Based on the anticipated missions for the far term SES, specific attention must be directed to a comparison of the results of the analysis of failures as reported by the Maintenance Data Collection System and that data reported as usage via the Navy Supply System. This comparison

(U) should provide an insight to the true material requirements and permit' a more cost effective reprocurement fiscal expenditure. In addition, it should permit the proper allocation of the right spares and repair parts at the appropriate maintenance level.

(U) 3.5 HUMAN ENGINEERING

The human engineering effort on the 1990 point design encompassed three basic areas: (1) design of major workstations; (2) maintenance access; and (3) habitability criteria.

(U) 3.5.1 DESIGN OF WORKSTATIONS -- The pilothouse, chart room and Combat Operations Center (COC) were analyzed with regard to man-machine interfaces and functional adjacencies between operating personnel. The pilot house and COC, as conceived in the 1990 point design, are equipped with highly integrated display-control consoles to allow minimum manning at these stations. These workstations have also been designed for seated operations to ensure a high level of operability in all sea states and at all ship speeds.

(U) 3.5.2 MAINTENANCE ACCESS -- All ship spaces and equipments within these spaces were examined to determine if sufficient space had been allocated for both corrective and preventative maintenance. The analysis revealed that all proposed 1990 baseline subsystems and equipments can be installed, serviced and removed with a minimum of effort. Particular attention was given to the waterjet propulsors, propulsion gas turbines, lift gas turbines and the lift fans with regard to maintenance removal requirements.

(U) 3.5.3 HABITABILITY AND RIDE **CONTROL** -- The point design was compared with the habitability criteria stated in OPNAVINST 9330.78, guidelines provided in the habitability Manual, N.S. 0933-005-8010 and numerous industry advanced design studies. The space allocations for crew living areas meet-or exceed those requirements for berthing, sanitation spaces, recreation spaces, galley and messing. The crew living areas occupy a single deck to minimize the need for crew members to move about the ship whether on- or off-duty. Design features provided include: (1) all off-duty crew spaces are on the same level to minimize the use of ladders; (2) within the constraints of **crew/CPO** officer off-duty separation, the best possible adjacency between mess rooms, recreation rooms, and berthing spaces, has been provided; (3) sanitary spaces are located within the living spaces.

(U) Improvements over earlier design configurations include all new furnishings of molded plastic. More built-ins were used that feature ease of cleaning, added floor space, less weight, and lower noise levels for lounge and berthing spaces. Individual room or space control of air conditioning, light and earphones is provided in personal areas. Molded furnishings also improve safety with smooth edges and better impact surfaces.

After considering a number of alternative approaches, present conventional wash/dry capability is still the best overall choice. Wash and wear jumpsuit clothing is recommended *for* all on-board use.

(U) Noise/thermal separation between living and machinery spaces ensures a more comfortable off-duty crew environment. Off-duty spaces are separated from machinery spaces/engine rooms by passageways, storerooms or other effective noise and thermal barriers. This lessens ship weight allocation for insulation material while improving habitability,

(U) In analyzing potential reduction of work tasks, a reasonably full schedule of planned duty, personal support and recreation tasks should improve crew tolerance for motion sickness and overall stress. The ride quality to be expected by the crew at higher sea states, in combination with higher ship speeds, was examined. Large amplitude vertical accelerations (see Section 2.2.7 Ride Quality) can exceed human tolerance levels to a point where human performance can be affected. To ensure that human performance is not degraded, ride criteria limits were developed and used to verify the adequacy of the ride control system in limiting vertical accelerations within the operational sea state and speed envelope.

(U) Safety features for maintaining control of body motions underway include: safety/shoulder harness restraining devices for seated and sleeping positions, arm restraints for console operators, padded barriers, railings and hand holds for walking and standing functions, non-skid deck surfaces, and head protective gear. Non-critical maintenance activities are minimal while underway in high sea states to minimize personnel injury from random vertical accelerations.

(U) 3.6 SYSTEM SAFETY

The primary intent of safety program requirements is the elimination or control of hararde inherent in the design and in the operation of the SES in its environment. Particular attention has been given to safe ship survival in any singular hardware malfunction of the lift, propulsion, steering, reversing, or sidehull damage from foreign objects, regardless of sea state, -speed, displacement, or maneuver at the time of the casualty. Equal importance is given to safe survival of personnel functional capacities and preclusion from injury during any operational or maintenance phase.

(U) 3.6.1 PRELIMINARY HAZARDS ANALYSIS -- The entire ship design was reviewed for gross hazard failure modes. Design characteristics singularly relevant to the SES were given emphasis. A major effort was placed on hull arrangement and structures, lift system, seals, waterjet pump, fire protection integration, operation and maintenance hazards, selected control aspects, and outfit and furnishings,

(U) 3.6.2 DAMAGE CONTROL -- The safety of the 1990 SES will be enhanced with the addition of a centralized damage control system. This system will provide the necessary sensor status information, ship layouts and damage control maps, so that a single watch-stander has the capability to monitor and control all damage situations that are likely to occur. The system's computer is programmed to evaluate and prioritize each alarm situation and then determine the most effective damage control response. These step-by-step actions will be displayed to the Damage Control Officer (DCO) for implementation.

(U) 3.6.3 FIRE PROTECTION -- A significant safety feature of this ship is the incorporation of an integrated fire/smoke detection and extinguishing system. This system utilizes information supplied from the sensors located within every ship compartment. This ensures

(U) that all fire, smoke or explosion hazards are detected quickly and that appropriate control responses can be implemented rapidly to minimize ship damage or personnel injury. Various extinguishing methods available within each compartment include optimal mixes of freon, HI-RX foam, AFFF or salt water that depend on the compartment's fire load. Upon the activation of an alarm, each extinguishment system will be automatically deployed or remotely activated by the DCO.

(U) 3.6.4 ANTENNA LOCATIONS -- The radar antenna8 were located to maximize efficiency and, at the same time, eliminate radiation hazards (RADHAZ) to personnel working on the weather deck or helicopter landing platform. Only one radar, the Mark 74 Mod (XX) fire control illuminator, could cause a RADHAZ problem, if accidentally activated while personnel were occupying the signal flag station just aft of the pilothouse. Since this situation has a low probability of occurrence, it is deemed adequate to place warning signs, visual and audible alarms on all signal flag station access doors to warn personnel of this potential hazard.

(U) 3.6.5 ORDNANCE STOWAGE -- The ordnance stowage areas were located adjacent to the hangar, so that these storage areas are easily accessible during UNREP and continguous to the helicopter and launcher tubes for loading. In addition, all stowage areas are protected by IR sensors activating multiple fire extinguishing systems.

(U) Vertical missiles are located forward of the pilothouse. All missiles are contained within a metal canister to eliminate HERO problems and is serviced and replenished via a tracked missile loader system to enhance safety during missile handling operations.

(U) 3.6.6 UNREP SAFETY -- Due to the requirement to safely and rapidly transfer stores and ordnance during UNREP, it was necessary to provide handling aids, cranes and elevators as part of the fär term SES design. Special features, such as torpedo dollies and missile loaders, facilitate

(U) movement of ordnance from the staging area to the stowage compartments. An elevator located adjacent to the hangar allows the crew to rapidly strikedown palletized stores below decks. Weather deck personnel working on the **UNREP** detail are protected from falling hazards around inlets and along deck edges via a combination of portable guard rails and quick disconnect life lines.. In addition, non-skid coatings are applied to the weather deck to improve footing where personnel are engaged in **UNREP** activities.

(U) 3.6.7 HELICOPTER CONTROL STATION -- The helicopter control station is located at the port side of the Helicopter Hangar at the mezzanine level. This provides greater visibility and a safer location in the event of a helicopter crash or platform fire. **Emergency** egress to the 01 level is readily available in the event of a hangar fire.

4 / TECHNICAL RISK ASSESSMENT

(U) One of the design objectives has been to incorporate standard practices and parts to the maximum degree. Equipments developed and available from existing Government inventory have been preferred over new equipments to be developed. Qualification by extension of existing designs has been used to the extent practicable in lieu of development of new items,

(U) The ship configuration is a viable concept and can be developed with minor or acceptable levels of risk. Furthermore, the far term ANVCE SES has been configured to accept further design alternatives which may enhance ship performance, utility and reliability. The overall technical risk is assessed as follows:

(U) Hull Structure --. The hull is designed to realistic worst case loading conditions forecast to occur within the ship lifetime. The hull materials are commercially produced aluminum alloys which have been utilized to existing Navy ships; such as the PHM and SES-100B, and newer materials which in the 1980 - 1990 time frame will have equivalent experience. The baseline configuration is conventional with state-of-the-art details to minimize construction risk. The hull-as presently configured is producible, cost effective, and adequate to perform the specified mission.

(U) Propulsion System -- The LM 5000 engines were chosen an the basis of ANVCE-specified requirements and advanced developmental status. The transmission design features high state-of-the-art reliability and performance. The wacerjet propulsor and inlet design has been optimized on the basis of extensive analysis and sub-scale tests. All other components are typical-of PHM, SES-100A, and XR-1D practice, are presently available and proven in service.

(U) Electrical System -- The baseline system design can be implemented with off-the-shelf equipment. The design is low risk, cost effective, and will provide satisfactory and reliable performance with high confidence.

(U) Command, Control, and Communication (C^3) -- The C^3 systems are comprised almost entirely of Government Nomenclatured Equipments with attendant low risk in their use. The only potential risk is HF communications during on and off cusion ship operations that would effect the antenna ground plane. The risk associated with other C^3 equipment is low or well within the state-of-the-art and absorbed by substantial, funded ongoing programs.

(U) Lift System -- The FT-9 gas turbine is in an advanced developmental status. Lift fan development is based on extensive subscale testing. The other elements of the air distribution system are typical of present gas turbine ship installations and within the present state-of-the-art. The advanced bow and stern planing seals have proved highly successful in sub-scale tests. While there are no historical research or performance data on this particular SES application, full-scale loads analysis and materials selection indicates that all considerations are within the state-of-the-art.

(U) Outfit and Furnishings **(O&F)** -- Nearly every item in the O&F system is a proven shipboard item not peculiar to the SES. The risk is equivalent to that of O&F on conventional Navy ships. Passive thermal/fire and acoustic protection systems are based on extensive testing and material evaluations. The risks associated with their application will be minimal.

(U) Combat System -- The risk is that associated with *outgoing* Government development of the combat system equipments. The interface design risk is low.

APPENDIXA

DESIGN PROCESS

APPENDIX A

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE Or' CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

APPENDIX A

DESIGN PROCESS

(U) The various far term ANVCE Point Designs will be arrived at from different technology bases. Different standards, criteria and assumptions' are used because of the different program offices and other Navy organizations involved. For example, structural safety factors between different vehicles are not the same' weight **margins** are frequently different and different ambient conditions may be assumed in quoting engine performance.

(U) The far term SES point design concept outlined in this report adheres, wherever practicable, for consistency to information provided in such ANVCE documents as:

ANVCE Primary Documentation

- Rohr proposed WP-006 - dated 25 October 1976 - "Top Level Requirements in a **3000-Ton** Surface Effect Ship in the 1990 year Time Frame (Far Term) **(U) CONFIDENTIAL"**
- WP-010 - dated 27 August 1976 - "Environmental Conditions"
- WP-008 - dated 20 August 1976 - "Supportability/Availability"
- WP-007 - dated 30 July 1976 - "Point Design Guidance"
- **WP-005A** - dated 13 August 1976 - "Point Design Description"
- WP-002 - dated 2 April 1976 - "Definition of Terms"

- WP-013 - dated 10 September 1976 - "Survivability/Vulnerability Methodology"
- WP-011 - dated 1 September 1976 - "Standard Power Plant Characteristics for Advanced Naval Vehicles in the 1980-2000 Time Period", (Marked up copy of 31 August 1976 version)

ANVCE Supplementary Documentation

- "Design Standards for Surface Point Designs, Revision A", ANVCE Memorandum 90-76, dated 10 August 1976.
- Marked-up Revision to Appendix A of Rohr proposed WP-006, Received from PMS-304 on 5 November 1976.
- "ANVCE Combat System Support, Data for Point Design" SEA-6112E/RCH, dated 15 September 1976 with Revision, dated 19 October 1976, with enclosures (1), (2), (3), (4), and (5); all received from PMS-304 on 5 November 1976.
- "ANVCE Combat System Data Sheets for AAW, ASW and SSW (U)", Vol I and II, dated 30 June 1976, SECRET; Selected Data Sheets from a Revision 2, dated 30 September 1976, were also received on 11 November 1976 for MK 74 MOD XX FCS, Advanced Dual-Band 2-D Long Range Radar, Advanced T-W-S FCS System, 2-D Short Range Search Radar, Advanced Vertical Launching System, Advanced AMRM Multi-Mode Missile, Harpoon MK XX Missile, and ASW Standoff with ALWT Missile.
- "Guidelines and Assumptions", submitted by Rohr on 27 October 1976; received 5 November 1976 from PMS-304 in annotated form.

(U) The dates shown for the cited documents are those for the versions available at Rohr on 23 October 1976 except as noted. No other document revisions after this date were received or are reflected in the present study results.

(U) WP-005A was used as the basis for the data developed in this report and was assumed as having precedence over other stated documentation requirements in cases of conflict. As a further aid to making proper evaluation of the far term SES point design presented in this report, this Appendix

(U) provides a basis for the insight needed into the design approach, criteria, philosophy and trade studies used in arriving at the design.

(U) This Appendix collects in summary form those pieces of information needed to identify the source of data and the design process used. Section D.5 of Appendix D contains comparable information respecting the alternate, propeller-driven far term SES point design concept.

(U) A.1 APPROACH

For a basic vehicle configuration and the major subsystems, several methods of establishing characteristics exist. They may be classified into three groups:

- **Scaling** -- projection of characteristics based on **ratioing** up or down from a chosen vehicle
- Modification -- **development** of characteristics based on small changes to an existing vehicle
- Synthesis- development of characteristics based on design data, parametric analysis and theoretical investigations

(U) The approach primarily used for the Rohr version of the ANVCE far term SES Point design is modification to the Rohr ANVCE near term SES design. This design is, in turn, based **upon scaling** of appropriate model and testcraft data, as well as upon synthesis as just defined. The specific approaches in each disciplinary area are next identified and presented in concise form.

(U) A.2 DESIGN CRITERIA

Those pertinent design criteria, standards and assumptions used in the Point Design are provided In the following areas: hull structure, propulsion, electrical plant, command and surveillance, auxiliary systems, lift system, outfit and furnishings, armament, load conditions, weight margins, and vehicle. Tabular forms and references are used as appropriate in the sections that follow for each of these areas.

(U) A.2.1 HULL STRUCTURE -- Load Conditions were developed that correspond to a number of operational definitions. The selected loading conditions are the result for a ship operating over a 20-year life anywhere within its operational envelope.

(U) The following load conditions are considered "operational" and the required safety factors used when applying these loads are 1.30 on the minimum yield strength and 1.80 on the ultimate strength:

- Load Condition 1 -- Cushionborne, Operational - This condition is based on on-cushion operation anywhere within the operational envelope. There are no heading or speed restrictions.
- Load Conditian 2 -- Hullborne, Low Sea State - This condition represents hullborne operation (entirely off-cushion) in sea states 5 and below. There are no heading or speed restrictions.
- Load Condition 3 -- Partial Cushion, High Sea State - This Condition is for partial-cushion operation (not entirely off-cushion) in sea states 6 and above. There are no heading or speed restrictions.

(U) The following load conditions were considered as emergencies due to system(s) failures. Because the ship is in an emergency mode, operational.. maneuvers to alleviate loads and motions would be deemed appropriate. The

(U) safety factors used for the following two conditions are 1.0 based upon the minimum yield strength and 1.50 based upon the ultimate strength:

- Load Condition 4 -- Hullborne/Lift System Failure in High Sea States - This condition is for a lift system failure in sea states 6 and above. Headings within 45 degrees of head seas are not considered, but there is no restriction on speed.
- Load Condition 5 -- Hullborne/Lift and Propulsion Failure in High Sea States - This condition is for lift and propulsion system failures in sea states 6 and above. Speed is considered to be zero, but there is no restriction upon heading.

(U) For ship damage with subsequent flooding, the safety factor applied was 1.20 on the minimum ultimate strength. No safety factor is used for yield strength since the ship would already have suffered structural damage; therefore, local yielding was permissible.

- Load Condition 6 -- Damaged Ship - This condition is for the ship suffering maximum damage (two compartments flooded). Still water bending moments are considered along with hydrostatic loads due to flooding to the "V-Lines".

(U) The following factors of safety were used when investigating far term SES survivability and vulnerability: (i.e. battle damage conditions):

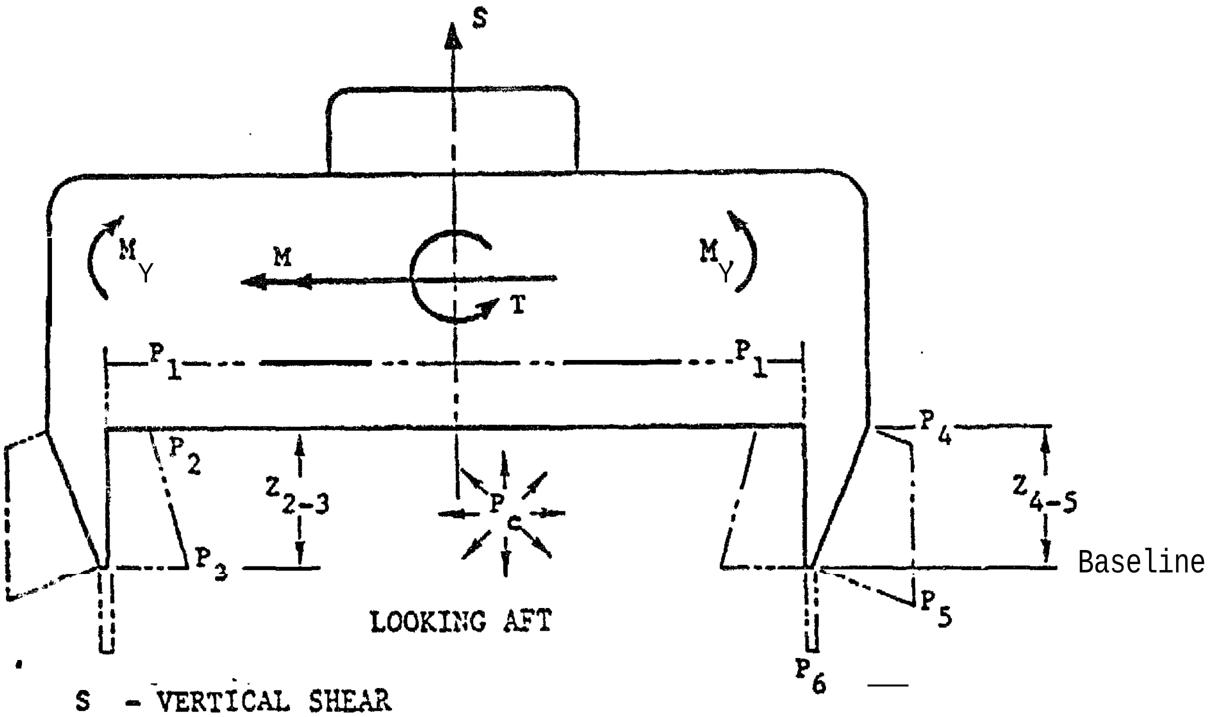
- 1.15 based upon minimum yield strength
- 1.50 based upon minimum ultimate strength

(U) The far term SES hull structure is designed to the predicted maximum once per lifetime loads that the ship will experience in a twenty-year life, These loads are not considered singly since those sea and weather conditions which produce the most severe loads, such as longitudinal bending, also produce other associated loads, such as shear, torsion and those due to hydrodynamic pressure forces. Figure A.2.1-1 presents the load nomenclature and definitions used in the descriptions of the structural load

(U) conditions which follow. Figure 19.2.1-2 presents the maximum cushionborne bending moment and the associated shear, hydrodynamic pressures and vertical accelerations resulting from operations in load condition 1.

(U) The maximum bending moments resulting from the conditions of C&es 2, 3 and 4 are presented in Figures A.2.1-3, A.2.1-4, and A.2.1-5, respectively. The loads resulting from Case 5 were found to be significantly less than those of Load Case 4, and are not presented. The many possible damage conditions of Load Case 6 are too numerous and complex to discuss in this document. However, the hydrostatic heads associated with flooding to the V-lines were the loads which determined the scantlings of many structural elements.

(U) Fatigue Considerations -- A well established fatigue life (FATLF) computer program, along with accelerated time and fatigue testing of full scale welded panels, was used for verification of the endurance capabilities of the ship structure. Basic joint design, along with controlled and scheduled welding and an in-service failure prevention plan, will assure a safe operational lifetime.



S - VERTICAL SHEAR
T - TORSION
M - BENDING MOMENT (POSITIVE MOMENT INDICATES UPPER DECKS IN COMPRESSION)
M_Y - TRANSVERSE BENDING MOMENT (POSITIVE MOMENT INDICATES UPPER DECKS IN COMPRESSION)

Figure **A.2.1-1 (U):** Loads Nomenclature and Reference System (U).

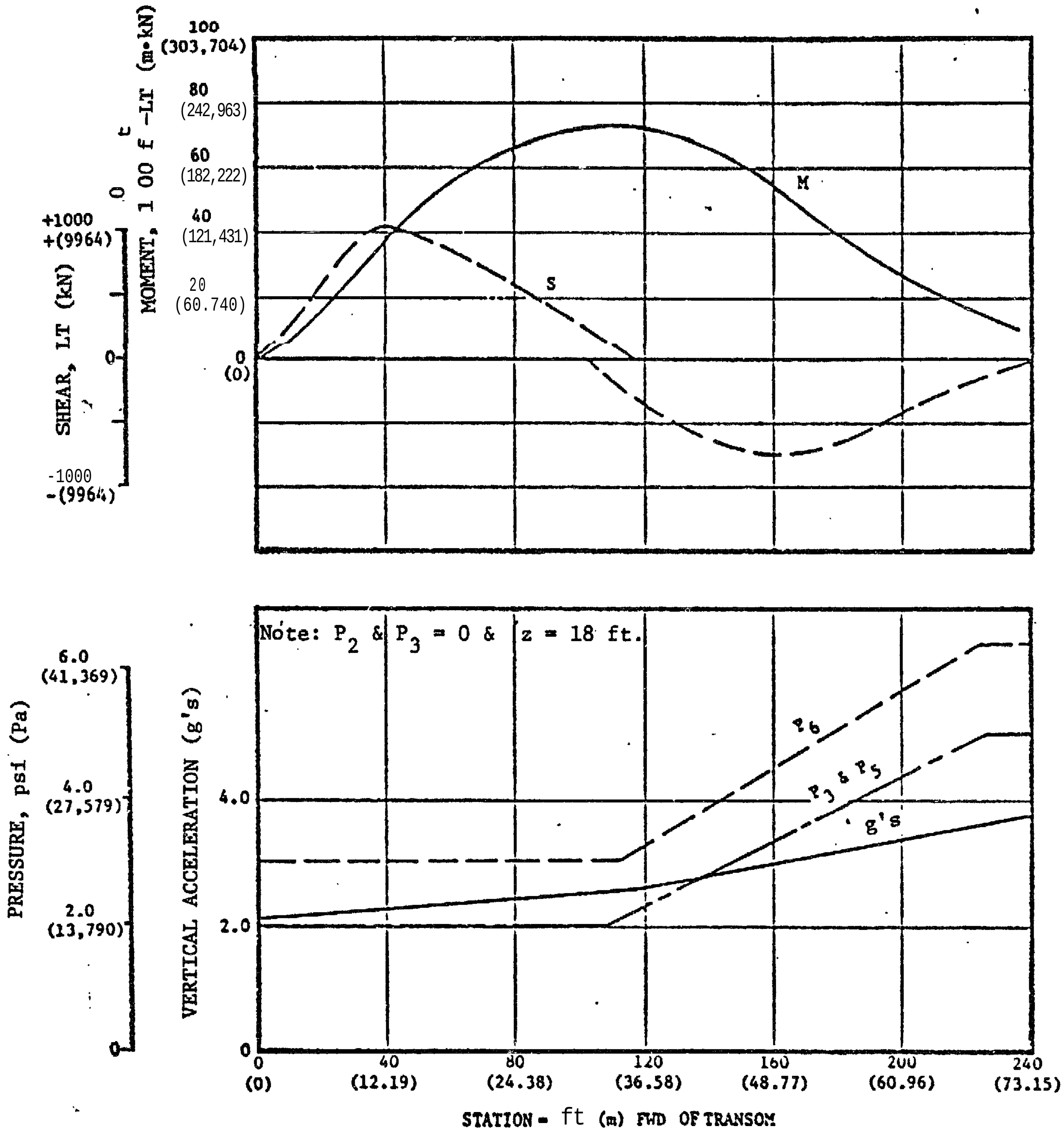


Figure A.2.1-2 (U): Maximum Bending Moments with Corresponding Shear Loads, Hydrodynamic Pressures, and Vertical Accelerations Resulting from Load Condition 1 (U).

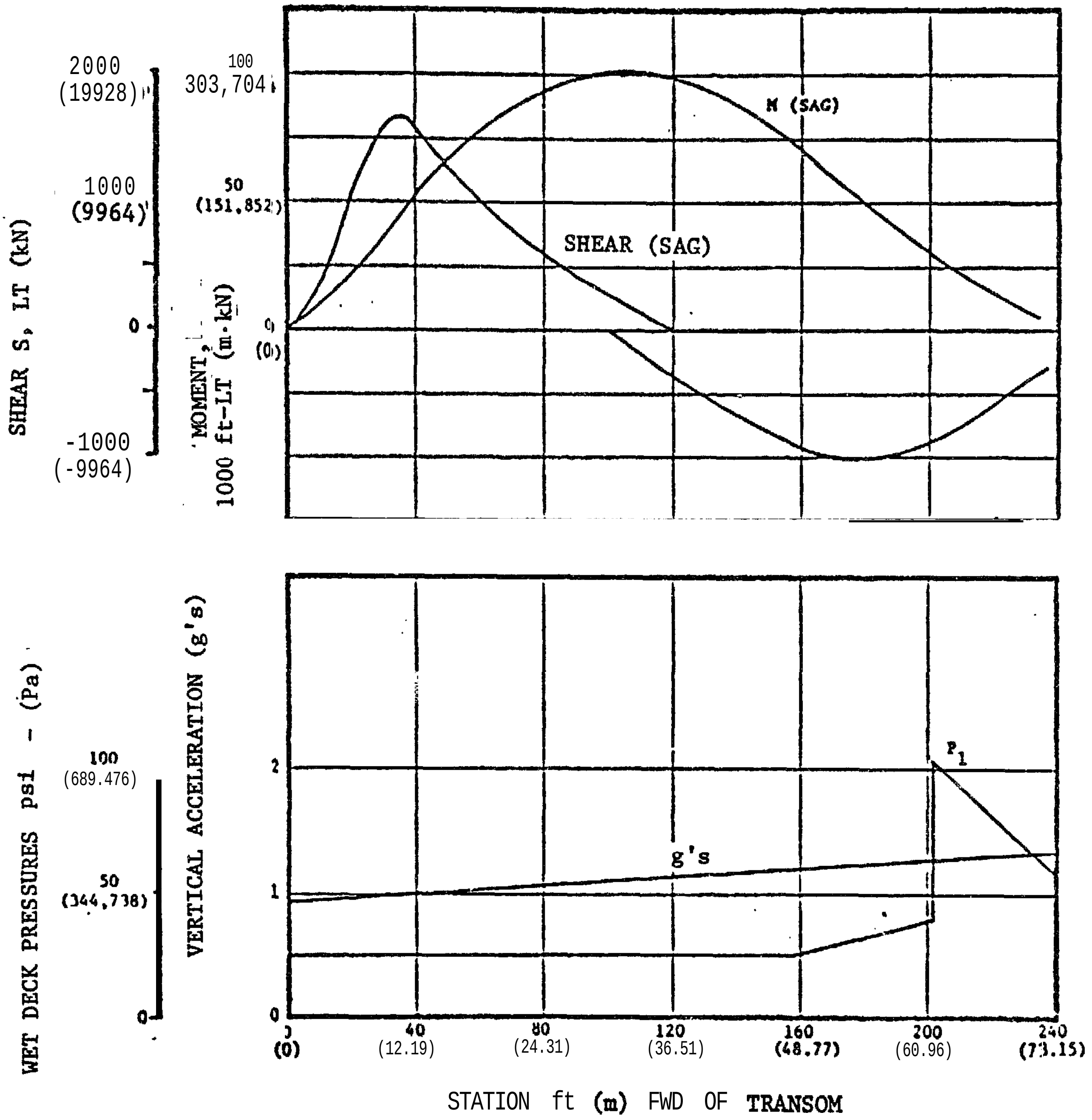


Figure **A.2.1-3 (U):** Maximum Bending Moments **with** Corresponding Shear Loads, Hydrodynamic Pressures, and Vertical Accelerations Resulting from Load Condition 2 (U).

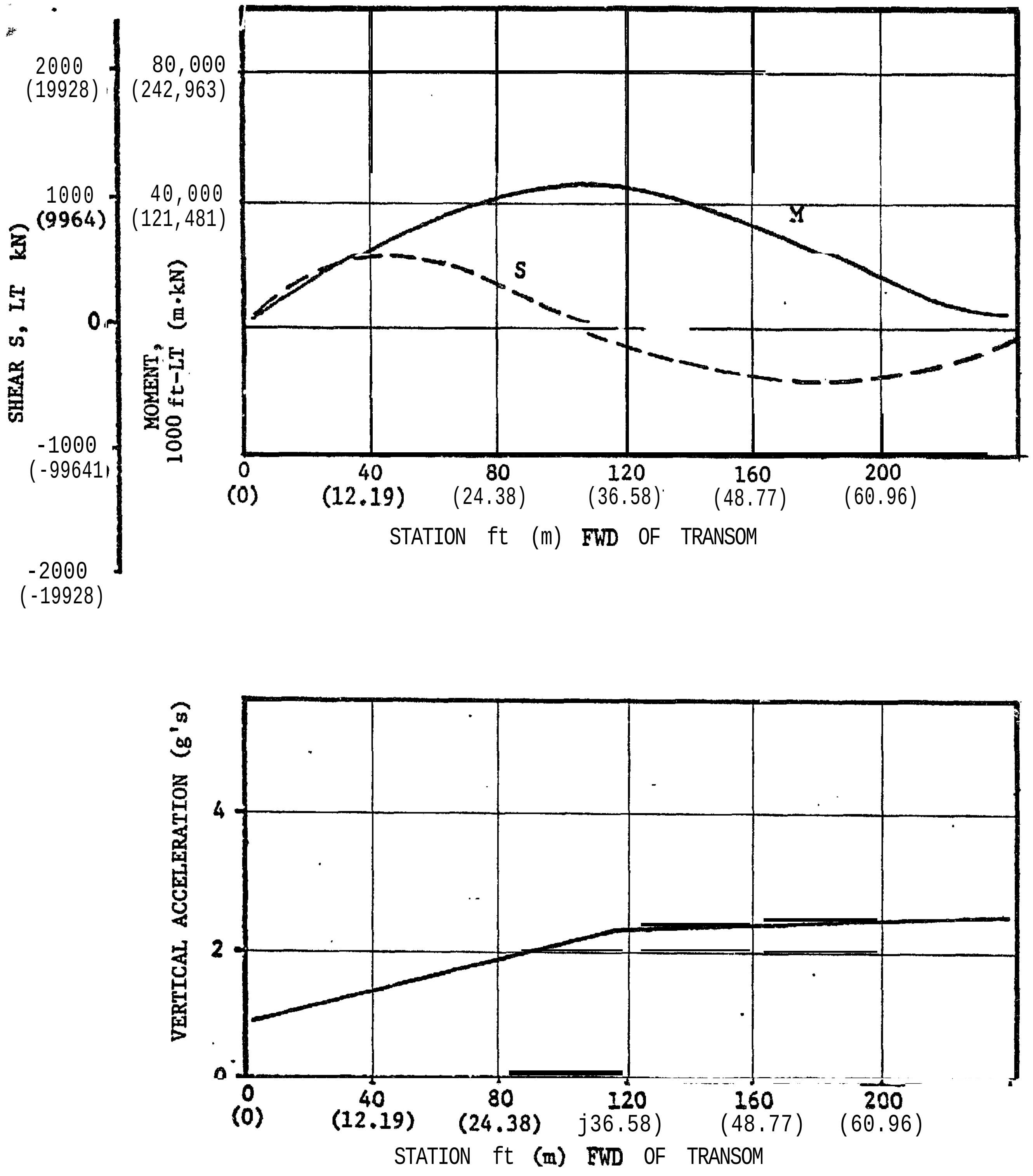
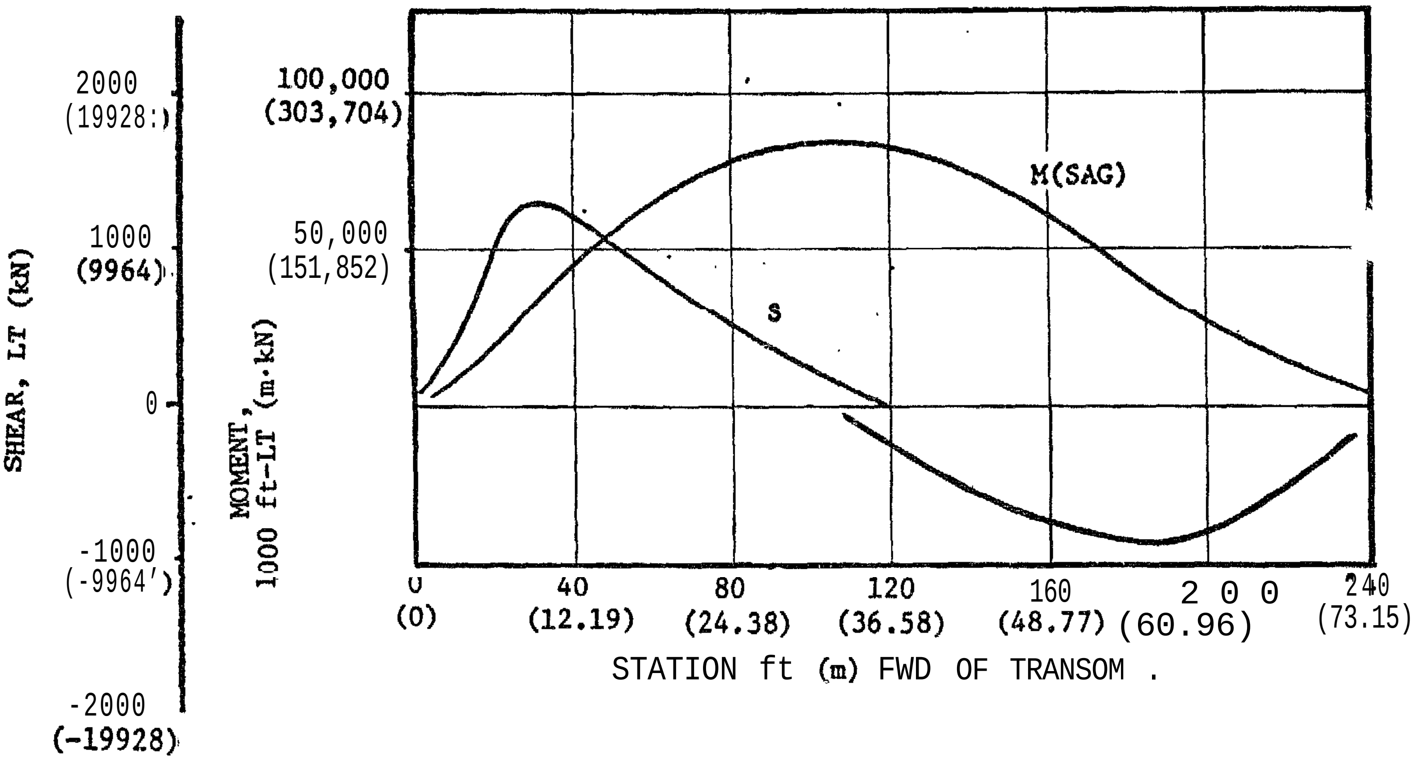


Figure **A.2.1-4** (U): Maximum Bending Moments with Corresponding Shear Loads, and Vertical Accelerations Resulting from Load Condition 3 (U).



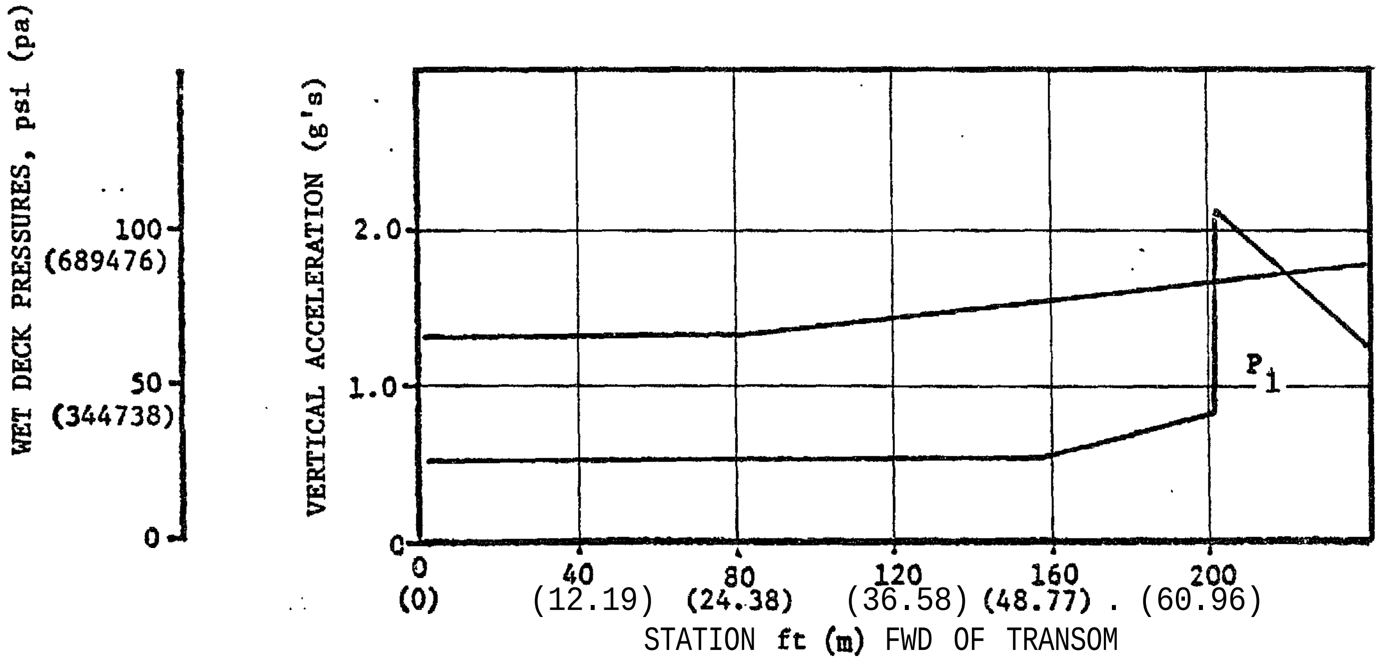


Figure **A.2.1.-5** (U): Maximum Bending Moments with Corresponding **Shear** Loads, Hydrodynamic Pressures, and Vertical Accelerations **Resulting** from Load Case 4 **(U).**

(U) A.2.2 PROPULSION

(U) **A.2.2.1** General Design Criteria -- General design criteria for the far term SES propulsion system includes maximization of performance, reliability, maintainability and simplicity. Specific design criteria applied to the point design are:

- All machinery accessible for maintenance off-cushion without dry-docking. No corrosive air/water interfaces.
- Short, straight drive shafts with no alignment and vibration problems. Flexible couplings to absorb dynamic misalignments.
- Overspeed gas turbine engine control for protection against propulsion inlet air ingestion without complete engine shutdown.
- Non-redundant link mounted propulsion components. The link mounted propulsor has less deflection than a gun mount, This simplified alignment, steering, and reversing interface and reduces vibration problems.
- Low loss combustion air inlet system designed for 4.0 inches (0.10m) H_2O loss for the LM5000 installation. Sufficient internal flow area is available to install a charged droplet scrubber moisture separator operhting at a face velocity of 20 feet/second (6.1 m/second). The total salt ingestion goal is 0.00136 ppm with a projected water wash interval of 450 hours. The combustion air inlet has the capability to withstand a 4 foot (1.22 m) wave of green water on the 01 level without demister flooding and resultant breakthrough. There is sufficient volume forward of the engine bellmouths to reduce pre-swirl and counter-swirl to less than 5 and 12 degrees, respectively, and to keep distortion below 10 percent.
- Low loss propulsion exhausts - the design criteria for sizing the exhausts is based on obtaining maximum net thrust to the ship with low weight, back pressure, fuel consumption, and jet thrust within limit of 7 inches (0.18 m) H_2O.
- Acoustically treated intake and exhaust to meet Navy Category E requirements on the flight deck.

(U)
- Anti-icing system designed to provide protection to -20°F (-28.9°C).
- Engine cowlings designed to limit potential personnel contact areas to 125°F (51.7°C).
- Propulsion inlets designed to provide cavitation-free operation to ship speeds exceeding the maximum ANVCE specified speed. Symmetrically configured bifurcated duct for low water velocity distortion into the pumps.
- Fixed area waterjet inlets for reliability, maintainability, and optimum performance.

(U) A.2.2.1.1 **Waterjet Pump Size Selection** -- The waterjet pump selected for the far term SES is the ALRC two-stage, two-speed pump of the 3RSES. To check this selection, a waterjet pump sizing study was made to determine whether an increased size pump would provide a ship range improvement. The study was based on a maximum ship displacement of 3600 LT (35,868 kN).

(U) The study considered the effects of improved propulsive coefficient with increased pump size and the corresponding propulsion system weight increase with increased pump size. The results are shown graphically on Figure A.2.2-1.

(U) A.2.2.1.2 Pump Size -- The pump inducer diameter was selected as characteristic of the pump size. Table A.2.2-1 shows the pump (propulsor) characteristics as they are influenced by pump inducer diameter. The diameter was increased in steps of 5 inches (0.127 m) from the ALRC inducer diameter of 44.6 inch (1.133 m) up to a diameter of 60 inches (1.524 m), The assumed flow and headrise coefficients were consistent with the selected ALRC two-stage, two-speed pump.

(U) Each pump size (inducer diameter) was evaluated to obtain the propulsive coefficient, PC, at 70 knots (36.01 m/s) ship speed and an effective

(U) thrust (4 pumps) of 295,000 lbf (2939.1 kN. PC is defined as:

$$PC = \frac{\text{Effective Thrust} \times \text{Ship Velocity}}{\text{Input Power}}$$

The other assumptions of this study were: 1) a constant waterjet inlet area of 14 ft^2 (1.3 m^2) and 2) a maximum pump efficiency of 0.90.

(U) A.2.2.1.3 Propulsion Weights -- Incremental weight increases were estimated for the propulsion system and associated hull foundations to reflect increases in pump inducer diameter. Table A.2.2-2 shows the weight increases for the waterjet propulsor which include reduction gear, waterjet inlets, entrained water (working fluid), propulsors and inlet mountings and foundations. The steering and reversing systems are also included in the waterjet propulsor weights. The estimates are shown in Figure A.2.2-1.

(U) A.2.2.1.4 Effect of Pump Size on Ship Range -- The effect of diameter on propulsive coefficient and propulsion system added weight are shown in Figure A.2.2-1. The effect on range is based on a 3600 LT (35,868 kN) initial weight and increased empty weights (reduced fuel load). The design full load of 3600 tons (35,868 kN) was used for all pump sizes to compare ships with the same damage stability criteria as specified by the U. S. Navy Reference DDS-079-E. The combination of Improved propulsive coefficient and increased empty weight counteract to show the effect of diameter on range as a very flat curve with no distinct improvement as pump size is increased. The pump size selected, therefore, has an inducer diameter of 44.6 inches (1.13 m) which is the same size as the near term SES propulsor.

Table A.2.2-1 (U). Propulsar Characteristics for Various Inducer Diameters (U)

Conditions --	Ship Velocity	70 knots (36.01 m/s)
	Inlet Area	14 ft^2 (1.3 in^2)
	Pump Efficiency	0.90
	Effective Thrust	295,000 lbf (2939.1 kN)
	Propulsor Configuration	ALRC two-speed, two-stage

Pump Inducer Diam. in. (m)	44.6 (1.133)	50 (1.27)	55 (1.397)	60 (1.524)
Turbine Power hp (kW)	29,148 (21,708)	28,048 (20,889)	27,147 (20,218)	26,663 (19,857)
Inducer Gear Ratio	4.359	4.942	5.793	6.697
Pump Flow gpm (m^3/s)	122,356 (7.719)	136,905 (8.677)	156,119 (9.850)	170,570 (10.761)
Pump Head Rise ft (m)	817 (249)	704 (214.6)	597 (182)	537 (163.7)
Jet Velocity ft/s (m/s)	246.5 (75.1)	231.2 (70.5)	215.9 (65.8)	205.2 (62.5)
Propulsion Coeff.	.549	.571	.590	.601

Table A.2.2-2 (U). Incremental Propulsion System Weight Increases for Increased Pump Inducer Diameters(1) (U)

ITEM	PUMP INDUCER DIAMETER INCH (m)			
	44.6 (1.133)	50 (1.27)	55 (1.397)	60 (1.524)
Waterjet Propulsor (Wet)	0	15.93 (157.7)	30.04 (299.3)	48.34 (481.6)
Watekjet Inlet Structure	0	2.79 (27.8)	6.94 (69.1)	10.43 (103.9)
Inlet Entrained Water	0	8.52 (84.9)	21.25 (211.7)	31.92 (318.0)
Propulsion Mounts and Foundations	0	1.64 (16.3)	4.78 (47.6)	7.95 (79.2)
Incremental Weight	0	i-28.88 (228.0)	+63.01 (627.8)	+98.64 (982.8)
15% Margin	0	+4.32 (43.0)	+9.45 (94.2)	+14.80 (147.5)
Total Incremental Weight	0	+33.2 (330.9)	+72.46 (721.9)	+113.44 (1130.2)

(1) All weights in LT (kN)

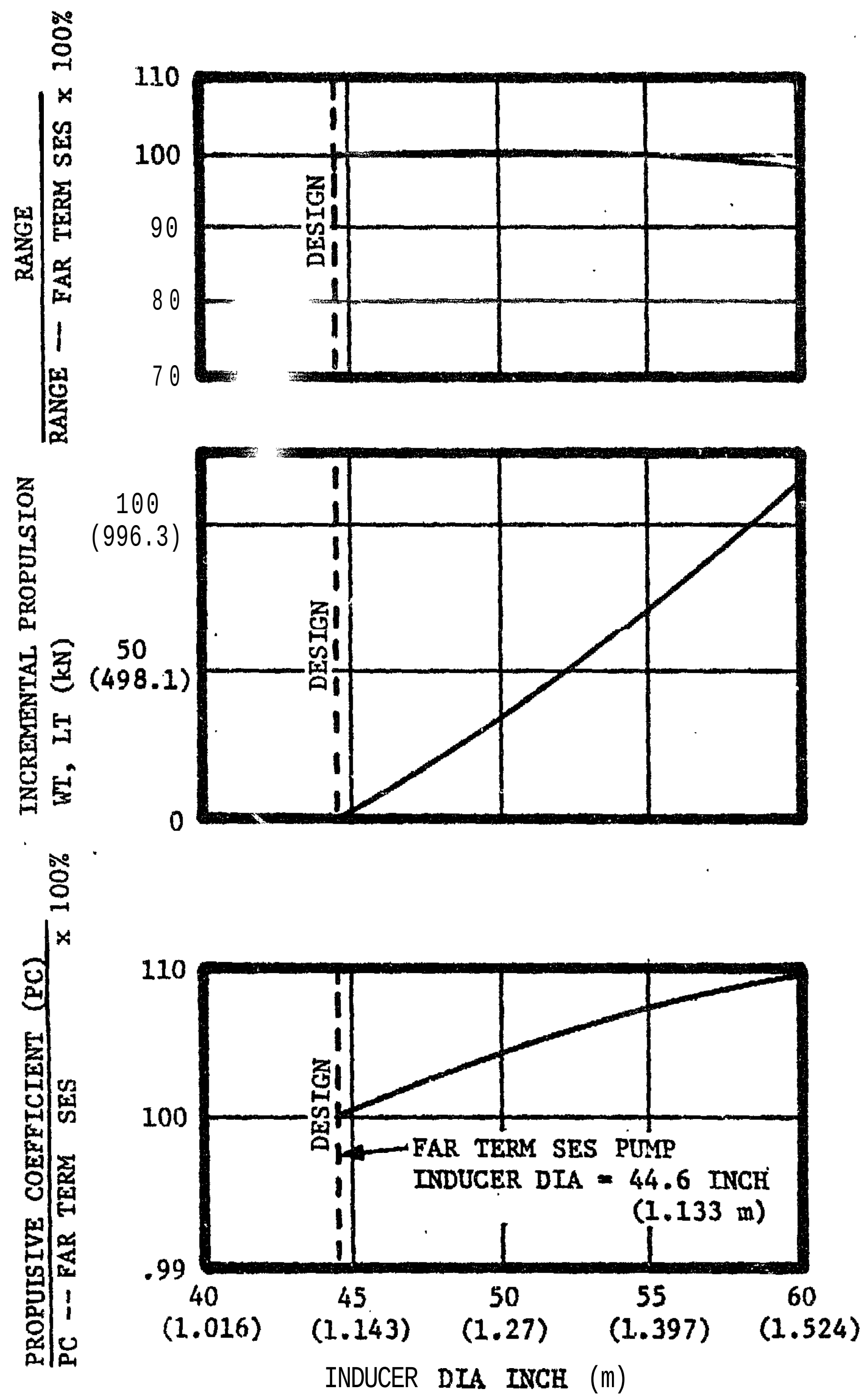


Figure A.2.2-1 (U). Effect of Pump Inducer Diameter on Propulsive Coefficient, Propulsion Weight and Range (U)

(U) A.2.3 ELECTRIC PLANT -- The far term SES Electric Plant design has been guided and controlled by a set of design criteria, standards, and a system design philosophy, collectively oriented toward the design of an uncomplicated and flexible system featuring minimum weight, cost, and fuel consumption. The current design highlights the following:

- Adequate generated power, measured by operating margins, off-line reserves, and power quality
- Weight and envelope minimization
- Environmental compatibility
- Minimal technical risk
- Interface compatibility with ship structure
- Adequate RMA and Safety considerations
- Use of proven components where practicable
- Use of standard Navy design precepts for the power distribution system

(U) The system design philosophy emphasizes the criticality of a continuous source of electrical power, with judicious minimization of system weight, envelope size, and cost of components and installation. Every effort is made to strike a proper balance between innovative and traditional design. Modernization to include superior materials or components is encouraged, particularly where significant benefits accrue in reduced life-cycle costs, enhanced safety, or performance improvements. New and revised standards will be used in the far term design methodology to ensure suitability for Navy use and compatability with the anticipated marine environment. Among present standards used were:

MILITARY SPECIFICATIONS AND STANDARDS

MIL-E-917	Electric Power Equipment, Basic Requirements (Naval Shipboard Use)
MIL-STD-454	Standard General Requirements for Electronic Equipment

MIL-STD-1399/ 103	Interface Standard for Shipboard Systems Section 103 Electric Power, Alternating Current
MIL-S-16036	Switchgear, Power, Naval Shipboard
MIL-C-17361	Circuit Breakers, Air, Electric, Insulated Enclosure (Shipboard Use)
MIL-C-17587	Circuit Breakers, Air, Electric, Open Frame Removable Assembly (Shipboard Use)
MIL-C-17588	Circuit Breakers (Automatic - ALB) and Switch, Toggle (Circuit Breaker, Non-Automatic - NLB), Air, Insulated Enclosure, 125 Volts and Below, AC or DC, Naval Shipboard
MIL-G-3124	Generator, Alternating Current, 60-Cycle (Naval Shipboard Use)
MIL-G-21480	Generator System, 400 Hz AC, Aircraft
MIL-G-22077	Generator Sets, Gas Turbine, Direct-and Alternating-Current, Naval Shipboard Use
0902-001-5000	General Specifications for Ships of the U. S. Navy (GSS); Naval Sea Systems Command (NAVSEA)
DDS-300-2	Design Data Sheet, AC Fault Current Calculations
DDS-311-3	Design Data Sheet, Ship Service Electric Power System, Application and Coordination of Protective Devices
DDS-304-2	Electrical Cables, Rating and Characteristics
DDS-311-2	Design Data Sheet, Voltage Regulation for AC Ship Service Electric Power Systems

(U) A.2.4 COMMAND AND SURVEILLANCE -- The Combat System, including command and surveillance was dictated by the Top Level Requirements Document. Equipment lists were provided by the U.S. Navy. Selected additions for Collision Avoidance, Navigation and Piloting have been noted and are separately identified as desirable on the basis of the near term SES design.

(U) A.2.5 AUXILIARY SYSTEMS

(U) A.2.5.1 AIR CONDITIONING -- Requirements for the far term SES air conditioning system are:

- The decentralization of the air conditioning system by dividing the load in small serviced areas, and by using the fan rooms to accommodate the cooling/heating/fan integral units.
- Replacement of the chilled water system by straight air and hot-cold mixing boxes, and selection of lightweight foam type reinforced materials for ducting.
- Existence of state-of-the-art components already qualified by commercial and/or military requirements and in actual operation.

The results foreseen are:

- Pseudo redundancy, since failure of one unit will bring only fractional failure to the subsystem.
- Weight savings inherent to aircraft components.
- Energy savings by proper management and more efficient equipment.
- Reliable system by the use of qualified components.

(U) A.2.5.2 LUBE SYSTEM -- A number of subsystems on board require lubrication. The prime thermal drivers for propulsion and lift and the electric power generating units will be self-contained; others like propulsion gearing, power transmission, waterjet pump and lift gearing, fans and power transmission require dedicated lube subsystems.

(U) The concept of a single centralized lube system versus multiple, dedicated systems was analyzed on the basis of: weight, cross contamination, cooling requirements, length of lines and bulkhead penetrations involved, reliability, and redundancy. The multiple, dedicated systems design was chosen.

(U) The standard way of using cooling seawater is acceptable only if it does not demand extra loading on the seawater subsystem, as for propulsion gear-pump units where water is available from the waterjet pump (second-stage cavity). The lift system employs air as cooling media, and the location of the heat exchanged (oil to air) can be established at either the inlet or outlet of fans.

(U) Pre- and post-operation lube oil, circulation is provided, as well as standby lubrication to assist main lube pump in low speed operation. The aeration of lube oil is considered and the quality of lube oil is closely controlled. High holding capacity for particulate contamination and dewatering (vacuum plus coalescers) filters is inherent in the use of advanced practices and state-of-the-art components. The closed lube system was chosen over alternate schemes compared.

(U) Short coupled lines are used, as exemplified by advanced systems used in other industries (petrochemical), and the clustering of fittings and components was replaced by functional manifolds. The material for transmission lines is compatible with that for gears and bearings, and reflects low weight, fatigue strength compatibility and ease of handling. The lines are supported by resilient mounts.

(U) The results of this approach are enhanced system functioning, weight savings, energy savings (by using cooling media already available), and improved reliability by use of qualified components, practices in other industries, and application of naval operation experience.

(U) A.2.5.3 SEAWATER SYSTEM -- An integrated seawater system serves firemain, seawater service and sprinkling functions with an appreciable weight reduction. Additional weight savings were effected by installation of an open horizontal loop, i.e., elimination of the wet weight cross connection.

(U) Installation of GRP piping for seawater, auxiliary system and wet firemain removes corrosion problems and effects weight savings of approximately one-third, compared to that for an equivalent copper-nickel system. Components to be used are readily available and qualified for marine use.

(U) A.2.5.4 POTABLE AND FRESH WATER SYSTEMS -- Generation of potable and fresh water from seawater requires selection of the desalination process, i.e., reverse osmosis versus one of the several types of distilling processes. The inability of presently available reverse osmosis units to meet the salinity requirements of the general ship specifications prohibited its use.

(U) The trade-off of potable and fresh water systems involved investigation of components and configurations possessing potential weight savings. This led to the selection of vacuum-assisted water closets and low water demand showers. The resulting weight reduction is due to the reduced quantity of water collected and stored via the drainage system and the reduced pumping capacity requirement. Further weight reduction was obtained with GRP piping.

(U) A three-distiller configuration to reduce the stored potable water tonnage was investigated. Each unit was capable of supplying the ship's daily demand, and the tank tonnage was reduced by one-third of the required 40 GPM (25.24 mm^3/s) per accommodation. The fresh water storage tonnage. was reduced by restricting the utilization of fresh water (demineralized) to gas turbine engine washing and to make-up water for the auxiliary fresh water electronic cooling system.

(U) The selection of electrical power (in lieu of gas or steam) was made upon its ready availability. The 400 Hz supply was selected for all pump motors, on the basis of weight savings over 60 Hz types.

(U) A.2.5.5 DISTILLING PLANT -- The selection of the type and capacity of distilling plant(s) requires consideration of ease of maintenance and operation, quantity and form of energy available, and the fresh water requirements. The three basic types of distillers for naval ships are vapor compression, submerged tube, and flash. Each was evaluated in the trade process of optimal design selection.

(U) A.2.5.6 FUEL SYSTEM -- The fuel. system performs the following functions: provides fuel of proper quality to all the thermal drivers for propulsion, lift, and electric power generation; provides CG location management by using fuel transfer as a means of trimming; provides storage and service of fuel for the aircraft on board.

(U) Designated tanks are established for: trimming and storage, storage, service for on board equipment, and service for aircraft. The need of interconnecting tanks for functional operation dictates the use of multiple controls and a well planned distribution system that provides redundancy. Fluid lines with mechanically assembled joints of well known reliability are used in sections which may need to be removed and replaced; otherwise, butt weld connections are used, Proliferation of connections is avoided by use of functional manifolds. Due to high flow conditions, valves must have defined times for the close-to-open or open-to-close cycles to avoid hammering. Lines are supported by resilient mounts to avoid premature fatigue and undue noise or vibration coupling. Underway fueling is in agreement with naval practice.

(U) The quality of the fuel is closely controlled by use of high capacity filters for particulate contamination and water removal in lines between storage tanks and service tanks, and between service tanks and thermal driver units or aircraft.

(U) The results are: weight savings, by a judicious selection of components and materials, and reliability by the use of redundancy and qualified components.

(U) **A.2.5.7.** **COMPRESSED** AIR SYSTEM — The compressed air system permits propulsion and lift turbine starting. It supplies air for actuation of back pressure valves, exhaust gas transfer valves and propulsion engine exhaust doors, and for miscellaneous uses as required. Weight reduction of the compressed air system was acheived by starting the **GTG's** by electric battery power. Several tons of high pressure charged air bottles were thereby eliminated. Practically all of the compressed **air** system components would be **selected** from available **and qualified lightweight** components.

(U) A.2.5.8 FIRS EXTINGUISHING SYSTEM — A trade-off study was made to provide the design criteria and rationale for selection of the best flooding extinguishing agent. CO_2 and **Halon** 1301 extinguishing systems were compared, and a **Halon** 1301 system was found to require less weight and to discharge in a much shorter time as shown here:

Agent	Compartment	Quantity of Agent	Total Discharge Time	Weight	Toxicity Class
CO_2	5000 ft^3 (850 m^3)	250 lb (1.11 kN)	90 sec	825 lb (3.67 kN)	5a
Halon 1301	5000 ft^3 (850 m^3)	141 lb (627 N)	10 sec	263 lb (1.17 kN)	6

(U) A.2.5.9 HYDRAULIC **SYSTEM** -- The choice of hydraulically-powered actuators/motors in lieu of either electrical. or pneumatic equipment included weight, performance, cost, compatibility of design, installation and environment factors in each application. A trade-off study indicated a weight saving of several tons by employing hydraulically-powered equipment. The studies resulted in selection of the following system features:

- Hydraulic Fluid: MTL-H-83282 was selected due to its ability to be operated at fluid temperatures up to 400°F (204°C); it is a synthesized hydrocarbon fluid that is interchangeable with MIL-H-5606.
- System Pressure: 3000 psi (20.68 kPa) is recommended as the system pressure; it is the most widely used high pressure, and consequently, a great variety of qualified components are marketed from which to choose.
- Optimum Fluid Temperature: A fluid system temperature between 100 to 130°F (54°C) is recommended for stable fluid operation.
- Pump Selection: Variable displacement constant pressure pumps of aircraft type were selected for lightweight and input horsepower economics proportionate to flow rate.
- Reservoir : Pressurized reservoirs (bootstrap type) are substantially lighter and require less stored fluid (fluid weight alone is reduced by 1600 lbs (7117 N) minimum). These reservoirs are sized to deliver the required pump inlet pressure and maintain the entire return system pressurized which avoids external contamination.
- Rigid Tubing: CRES 304 is the selected material; it is readily available in the required diameters, relatively easy to bend and weld, and is appreciably less costly than tubing made from 21Cr-6Ni-9Mg. Welding was selected in preference to the use of fittings in the interest of

(U) minimizing leakage. Welding is also preferred to brazing on the basis of fabrication and inspection considerations.

- Flexible Tubing: Flexible tubing is Teflon-lined to avoid static charges and dirt contamination associated with rubber (which also "sluffs off" particles which can dam servo valves).
- Cleanliness and Filtration: Hydraulic fluid cleanliness must oe enforced, fluid must be purchased to Class 1, components must be clean to Class 2 prior to installation, and the entire system must be maintained at Class 3 by adequate on-board filtration.

(U) A.2.5.10 POLLUTION CONTROL -- The pollution control systems are for wastewater and oil. Wastewater includes sewage (human body wastes, blackwater, soil lines) and sanitary (or gray) water, which includes shower, laundry and galley water). The selection of a marine sanitation device includes evaluating the regulations, technical and operational factors, installation, and maintenance, and the cost of the system.

(U) A weight trade-off analysis for the marine sanitation device was made on the basis of a one-day operational period to disclose a weight saving through use of a no-discharge type compared to a flow-through type. A waste oil tank, sized for a 15-day mission provides storage of collected waste oil from machinery and equipment drains for subsequent disposal at a shore facility, thereby conforming to the zero oil discharge regulation.

(U) A.2.6 LIFT SYSTEM

(U) A.2.6.1 AIR MANAGEMENT -- The design criteria applied to the development of the far term SES lift system air management concept were:

- The total nominal cushion flow rate at low sea states, to be 60,000 CFS (1699 m^3/s).
- The cushion pressure for a 3KSES point design would be 425 PSF (20.35 kPa).
- Approximately 1/3 of total air supply to be delivered to the bow seal and 2/3 to the cushion.
- System efficiency shall be at least 75 percent, defined as

  $$\frac{(P_c \times Q)/550}{\text{bhp}} \times 100, \text{ in English units}$$

  where P_c = cushion pressure at rated design
  Q = total cushion flow
  bhp= prime mover horsepower output
- All machinery should be capable of withstanding the following ship acceleration levels in g's: 6 up, 4 down, 2 forward, 3 aft and 0.5 thwartships.
- The lift system should have a minimum availability factor of 0.9285. Availability is defined as the ratio of mission uptime to total planned mission length.
- Machinery spaces would be acoustically treated to meet categories A through H.
- All lift machinery should be capable of withstanding a cushion-borne underwater explosion that results in 6 g vertical acceleration.
- Lift equipment will be blast protected to a degree compatible with surrounding structure in order that the energy of a foreign object will be absorbed before impact with either of the two vital machinery components: 1) the gas turbine engine core and controls and 2) the fan rotor assembly.

(U)

- Aircraft structural design practices would be applied to the design of machinery components in a marine environment with the goal of producing high strength--to-weight ratio components with a correspondingly high reliability.
- Mechanical vibration requiremeats for all ship machinery and equipment would be in accordance with Section .073c of the GSS.

(U) In support of these criteria, thirty-three separate component specifications were developed to govern the lift system design.

(U) A.2.6.2 SEALS SYSTEM DESIGN CRITERIA

(U) A.2.6.2.1 General -- The design of the Far Term SES advanced bow seal is based on the same 2KSES/LSES configuration successfully tested in the 1/30-scale tow tank model test series LOL-4, SIT-7, and NSRDC-7 (LSES). The results of these tests are reported in the "1/30-scale 2KSES LOL-4 and SIT-7 Seals System Verification Tests, Test Data Analysis and Correlation Report", Rohr Industries, Inc., Document No. DL7/L8S00G06. The l/30-scale model bow seal provided information on seal system weight, planer stiffness and configuration tolerances permitted in the full scale design.

(U) The far term SES passive stern seal is a unique Rohr concept that operates purely on cushion pressure and requires no additional source of inflation. It is particularly attractive for the ANVCE vehicle since the additional space generally required for ducting can be utilized for additional fuel and/or desired payload. The design of the far term SES passive stern seal is based on the'configuration successfully tested in the 1/30-scale 2-D water tunnel model (CIT-2) test series and in the SIT-6 tow tank test series. The former supported the anti-flooding/de-flooding characteristics of the passive stern seal concept from full-cushion to near wet-deck immersions at high speeds. The latter supported the operational performance of the passive stern seal up to mid-sea-state-six simulated conditions. It demonstrated successful performance, in the purely passive mode, from the flooded off-cushion condition transitioning under simulated craft acceleration to the full cushion-borne mode and up to the maximum velocity of the craft. Program Extension Task 25 of the 3KSES program provides a 2-dimensional computer study of the passive stern seal system. This study supports the heave alleviation qualities of this novel concept and provides calculations of the internal forces within the seal during rough sea passage. The computer program was employed, using the most critical ANVCE SES wave pumping condition:

Ship speed = 85 knots (4.37 m/s), head seas, Low Sea State 5.

(U) The result of the study showed a 6:1 heave alleviation ratio (wave height-to-rigid system CG heave response) and demonstrated that the internal seal loads resulting from this critical condition are well within the state-of-the-art.

Seals Deployment Sequence -- The transition from the off-cushion to the full cushion mode must take place such that the universal depth of the propulsor inlet is programmed with craft speed for optimum performance. The passive stern seal allows this transition to take place with a minimum of pitch excursions merely by controlling the lift fan rpm. This feature simplifies the transition mode in that intermediate down-stops on the bow and stern seal are no long a necessity. The off-cushion to cushion-borne transition was demonstrated in a tow tank simulation during the SIT-6 test series.

Pertinent references on the passive stern seal system are as follows:

"Test Report, Water Tunnel (CIT-2) Square Bow Seal Test," Rohr Industries, Inc., Document No. DL7SOOE, F01, 23 December 1975.

"Test Report, Bow Seal Hydrodynamics and Motions l/30-scale Square Bow Seals (SIT-6)," Rohr Industries, Inc., Document No. DL7SOOF04,.19 September 1975.

"Program Extension Task (PET) 25, Passive Stern Seal Conceptual Study," part of the PET Report now in publication.

"Users' Guide - Program SESPSFLT, a 2DOF Time-based program Employing the Passive Stern Seal," Rohr Industries, Inc., Report No. AP2-004785, November 1976.

Far Term ANVCE, "2-Degrees of Freedom Performance with the Passive Seal System at High Speeds and High Sea States, " Rohr Industries, Inc., Report No. AP8-000229, December 1976.

(U) A.2.6.2.2 Operational Criteria -- The seals have been tested and evaluated at substate conditions throughout these operational modes:

1. "Off Cushion", seals stowed for slow speed operation in the hullborne mode.
2. "Transition to full cushion", with seals partially deployed and high bag-to-cushion ratios.

(U) 3. "On Cushion", seals fully deployed with optimum bag-to-cushion ratios with evaluation at selected sea conditions with the operational envelope.

4. "Seakeeping", seals partially deployed with reduced cushion pressure.

(U) A.2.6.2.3 Seal Design Criteria -- The seals design was developed within requirements which include:

- sealing of the cushion with a minimum drag and minimal leakage of cushion air;
- design for a minor influence upon ship pitching motion in the absence of ride control;
- in concert with ride control devices, reduces bow and CG accelerations to a level compatible with ride quality requirements; and
- exhibit lateral compliance while operating in waves other than those dead ahead or astern.

(U) The seals are of modular design with the flexible seal material modules separated by tear inhibiting attachment fittings to reduce seal vulnerability. They are designed to minimize water ingress into the pneumatic bags and to provide for the rapid drainage of water that enters the bag. Standardization was emphasized in all portions of the design. Seal system weight was minimized with total design weight Less than the following:

	Maximum Acceptable	Target
Bow Seal; lb (N)	33,000 (147,000)	25,000 (111,000)
Stern Seal, lb (N)	32,000 (142,000)	25,000 (111,000)

(U) Attachment fittings were designed to minimize weight, be simple to remove and replace, to minimize structural fatigue of the flexible seal. pressure bag material, to resist. the effects of the marine environment, and (between hard structure and fabric) to be designed such that rubbing and impacting between the two structures is minimized to reduce wear.

(U) Further constraints included requirements that any seal system operational failure mode would not result in an unsafe ship operating condition and that retraction would be provided for off and partial cushion operation.

The result is seal systems that feature ease of maintenance, repair and replacement with simple tooling and procedures in drydock, at dockside, and at sea. Non-elastomeric surfaces were employed on the planing bow and stern seals at the seal water interface to minimize hydrodynamic drag and maximize seal service life. The major seal system components were designed to MTBF characteristics of:

Seal System Component	Minimum Acceptable	Target Service Life
Planing Surface at Seal/Water Interface	400 Operating Hours	100 hours at 80 knots (41.16 m/s)
Bag and Upper Loop Seal Structures .	1000 Operating Hours	2000 Operating Hours

(U) The tear strength of the coated fabric pressure bag material for the 3KSES was specified as a minimum of 300 pounds (1,333 N) with a target of 500 pounds (2,220 N), for tear propagation in the full direction. This strength requirement is not expected to increase significantly on the far term SES. As in the 3KSES, the tear strength is considered to be the controlling factor in the selection of the pressure bag material. The tensile strength of the pressure bag material will be at a minimum of 1000 pounds per inch (175,000 N/m) in the warp direction and 800 pounds per inch (140,000 N/m) in the fill direction. The pressure bag material is required to possess good environmental resistance, consistent with the seal system design specifications. The weight of the pressure bag material is minimized, consistent with the other requirements, with a maximum weight goal of 90 oz sq yd (29.93 N/m^2).

(U) The pressure bag material requirements included surviving 10^6 cycles at 20 percent of ultimate tensile strength in the warp direction (R=0.2); the goal was 10^6 cycles at 30 percent of ultimate tensile strength (R=0.2). Seams in the pressure bag material must meet the requirements for the coated fabric. The seams must also be relatively flexible and stiffness discontinuities in the joint minimized.

(U) The flexural fatigue strength of the glass reinforced plastic (GRP) planer material shall be a minimum of 90,000 psi (6.20 x 10^8 Pa) in the

(U) longitudinal direction and 85,000 psi (5.85 x 10^8 Pa) in the transverse direction. Target values are 135,000 psi (9.30 x 10^8 Pa) in the longitudinal direction and 105,000 psi (7.25 x 10^8 Pa) in the transverse direction.

(U) The maximum acceptable decrease in flexural fatigue strength of the planer material after aging in hot water shall be 18 percent. The target value is 12 percent. Tensile strength of the planer material shall be a minimum of 70,000 psi (4.83 x 10^8 Pa) in the longitudinal direction and 60,000 psi (4.14 x 10^8 Pa) in the transverse direction. The corresponding target values are 107,000 psi (7.38 x 10^8 Pa) and 90,000 psi (6.20 x 10^8 Pa). Tensile modules of the planer material shall be a minimum of 3.7 x 10^6 psi (2.5 x 10^{10} Pa) in the longitudinal direction and 3.4 x 10^6 psi (2.3 x 10^{10} Pa) in the transverse direction. The corresponding target values are 5.0 x 10^6 psi (3.4 x 10^{10} Pa) and 4.2 x 10^6 psi (2.9 x 10^{10} Pa).

(U) A.2.7 OUTFIT AND FURNISHINGS

(U) A.2.7.1 **HABITABILITY** -- The habitability standards should conform to or exceed General Specifications for Ships of the U.S. Navy and OPNAVINST 9330.7A (proposed). Crew accommodations are as follows (based on Combat System and Aviation Complement manning requirements incorporated in Rev. 1, dated 19 October 1976; Rev. 2, dated 29 October 1976, of ANVCE Combat System Support; Data for Point Designs and Rohr Developed manning for ship operation; and direction received at the Rohr briefing of 17 December 1976 to ANVCE):

	CREWBREAKDOWN			TOTAL BERTHS PROVIDED
	SHIP	COMBAT SYSTEM	AVIATION COMPLEMENT	
Enlisted	36	64	10	110
CPO	7	5	1	13
Officer	7	4	6	17
TOTAL	50	73	17	140

(U) A minimal space allocation per man of 494.4 ft^3 (14.0 m^3) governed all spaces directly related to personnel (e.g., berthing, food preparation and handling, sanitary, personnel administrative offices, medical and dental, laundry, post office, ship's store, recreation and personnel storerooms).

(U) A-2.7.2 PASSIVE FIRE PROTECTION -- The approach to passive fire protection system design was combined with the armoring requirements and is separately treated in Section A.2.0.2.

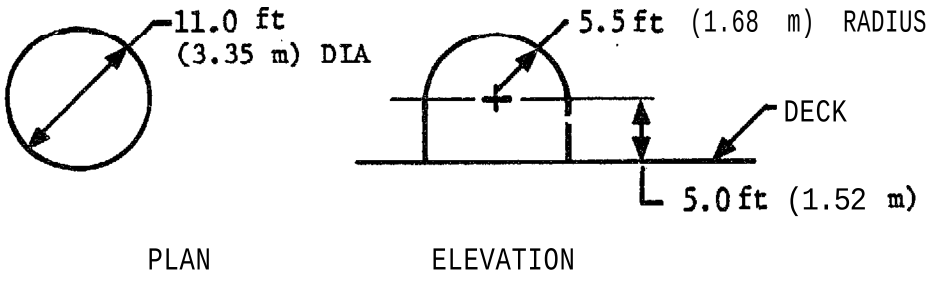
[redacted]) A.2.8 COMBAT SYSTEM AND SHIP HARDENING --

[redacted]) **A.2.8.1** Combat System -- All topside sensors and armament were required to have as great an unobstructed coverage envelope as practicable. The order of precedence for sensor coverage in descending order for the far term SES is:

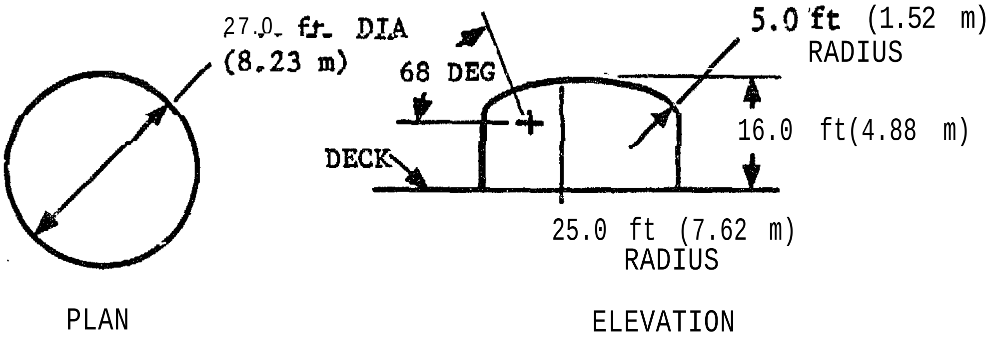
- TACAN
- ASMD EW MK XX System (SRS Antennas)
- 3D Phased Array Radar
- Advanced Lightweight Track-While-Scan Radar
- ASMD EW MK XX System (IR Sensor)
- Advanced 2D Short Range Search Radar (Collision Avoidance Radar)
- Advanced Dual Band 2D Long Range Radar
- ASMD EW MK XX System (TW/DECM Antennas)
- MK 74 Mod XX FCS

[redacted]) The far term ANVCE Combat Systems are as shown in Table A-2.8.1-1 with the following assumptions made for selected subsystems:

- The far term ANVCE SES has one FCS Mk74 Mod XX with a system weight of 20 kLbs (89 kN) that includes the radome weight. The antenna requires protection within a rigid wall radome shell whose external dimensions are:



(U) ● The advanced Dual Band 2D Long Range radar for the far term **ANVCE** SES has an antenna that is physically similar to the AN/SPS-49 antenna and a rigid wall radome shell with a total weight of 10.4 **kLbs** (42.26 RN). The principal dimensions of the radome are:



PLAN ELEVATION

(Revision 2, dated 30 September 1976, to the Combat System Data Sheets for AAW, ASW and SSW (U), Volume II, was received an 11 November 1976 and did not clarify the antenna configuration.)

● The Rotating Phased Array (**AEGIS** Derivative) antenna is configured as the AN/SPA-72 of the AN/SPS-52 system. No radome is required. The single face of the **angenna** is approximately 12 ft x 12 ft (3.66 m x 3.66 m) (AN/SPY-l) and is included at an angle of 18 degrees to its pedestal, Overall height is 15.0 ft (4.57 m). The weight of the Rotating Phased Array System is 25.4 **kLbs** (113 **kN).**

a The ASMD EW Mk XX suite is physically similar to the AN/SLQ-31 (V-3) system in terms of topside antennas, **IR** sensors, and chaff launcher equipments. The weight

(U) of the EW system is 3.7 kLbs (16.46 kN). Four chaff launchers are required. The variable load for the chaff launchers are:

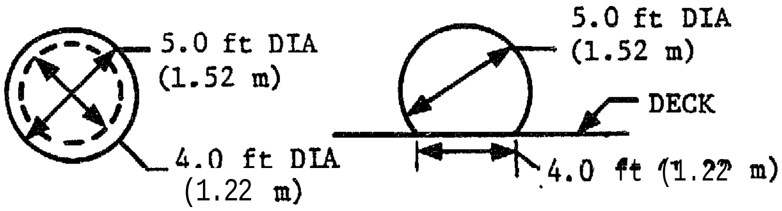
(1) Eight IR decoys -- at 40 lbs (178N)/decoy

(2) 32 chaff decoys at 40 lbs (178N)/decoy

(3) Four hybrid decoys at 50 lbs (222N)/decoy

(4) Four active decoys at 50 lbs (222N)/decoy

- The antenna for the Advanced Lightweight Track-While-Scan Fire Control System (ALTWSFCS) is similar to the Hughes FLEXAR electronically scanned I-band unit. The weight of a rigid wall radome shell is included, The shell has these principal dimensions:



PLAN ELEVATION

The total weight for the ALTWSFCS is 1700 lbs (7.56 kN).

- The 2D Short Range Search Radar is similar to the AN/APS-116 system proposed as a collision avoidance/surface search radar for the 3KSES. Weight of systems is 400 lbs (1.78 kN).

- An Advanced Vertical Launcher System Mk XX (AVLS) is a multipurpose system capable of handling and launching mixes of AMRM (Type A), Harpoon, Mk XX (Type A), and ASW Standoff (Type B) weapons. The total weight of a 72-cell installa- is 99.4 kLbs (442 kN), or approximately 1.38 kLbs

(U) (6.4 kN)/ cell, which includes blast deflectors, plenum connectors and cannister supports and attachments. The weights for the missile load are further defined in Table A.2.8.1-2.

e A notational concept for a LAMPS MK XX helicopter was developed to facilitate arrangements of helicopter hanger and landing platform spaces, The key dimensions for the helicopter are shown in Pigure A.2.8-1. The airframe is a composite of present Boeing and Sikorsky concepts for the UTTAS helicopter under consideration by the Navy for future LAMPS application. Landing platform arrangements conform to Bulletin 1C requirements for non-aviation ship facilities.

Table **A.2.8.1-1** ([redacted]). **Combat/Subvehicle** Systems(1) (U) (Page 1 of 2)

MISSION	FUNCTION	SYSTEM	QTY
AAW	**Search/Acquisition/ Track**	Advanced **Dual** Band **2D** 3D Long Range Radar	1
		Rotating Phased Array (AEGIS Deriv.)	1
		ASMD **EW MkXX**	1
	Fire Control **System**	Advanced Lightweight TWS FCS	1
		MK 74 Mod XX FCS	1
	Countermeasures/ Outboard Jamming	**ASMD** ED **MkXX**	1
		Chaff Decoy	32
		IR Decoy	8
		Hybrid Decoy	4
		Active Decoy	4
	Weapons/Launchers	Advanced Vertical Lchg Sys (72 cells)	1
		AMRM Multimode Advanced Self **Def. Msl. Lchg (24 cells)**	1
		Advanced Self Def. Msl	24
		AMRM Missiles	40
SUW	Search/Acquisition **Track**	Advanced 2D Short Range Search Radar	1
		3D Rotating Phased Array (AEGIS Deriv,)	1
		Advanced Lightweight TWC FCS	1
		ASMD EW MkXX	1
	Fire Control **System**	Advanced Lightweight TWS FCS	1
	Countermeasures/ Outboard Jamming	**None**	—
	Weapons/Launchers	Harpoon Mk XX	**16**

(1) List in accordance with 5 Nov 1976, Appendix A, Medium Air Capable SES Combat Suite

Table **A.2.8.1-1** ~~(C)~~. **Combat/Subvehicle** Systems **(U)**. (Page 2 of 2)

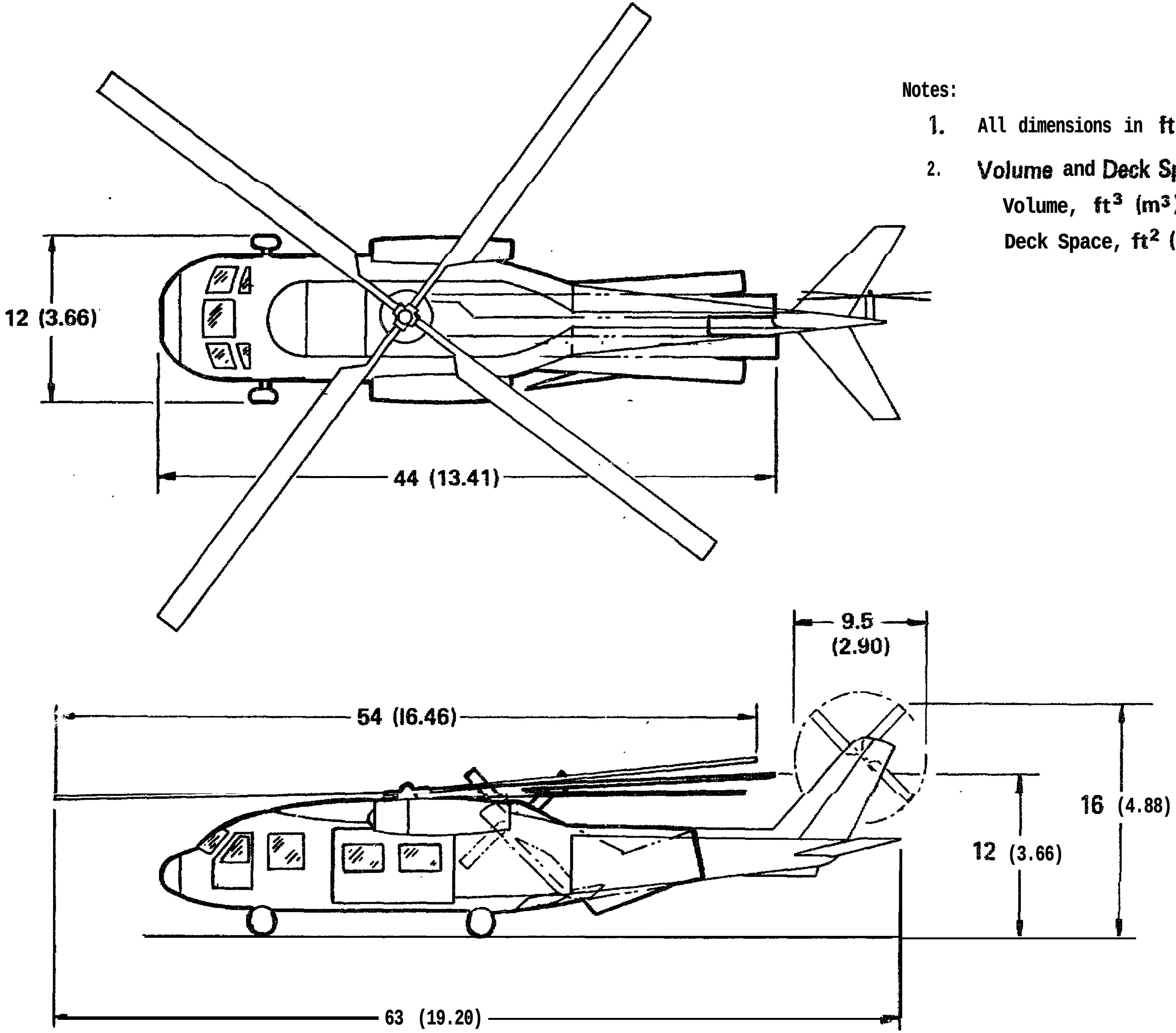
MISSION	FUNCTION	SYSTEM	QTY
ASW	**Search/Acquisition/ Track**	**APRAP**	1
		Deployed Linear Array	6
		Deployed Linear Array Hndlg	1
		Towed Array w/Depressor and Spare	
		ERAPS	10
		ERAPS Rocket Projectile	26
		ERAPS Lchr	1
		Sonobuoys — Type A	200
		Sonobuoys — Type B	10
		ASW Electronics	x
	Countermeasures	**None**	--
	Weapons/Launcher	ALWT	36
		Mk 48 Improved	4
		Mk 48 Ejection Launch **Container**	4
		ASW Standoff Wpn/ALWT	16
ASW/ AAW/ SUW	Command/Control/ **Comm/Navigation**	**ANVCE System**$^{(2)}$	x
ASW/ SUW/ MOB	**Aviation:**		
	Manned Subvehicles	LAMPS MkXX	2
		Spares and Support	x
	RPV Subvehicles	Standard Ship Launched RPV	12
		RPV **Lchr/Recovery** System	1
		Spares and Support	x
		Lchr/Recovery C^2 System	1
	Subvehicle Fuel	**JP-5 for 15-Day Mission**	x

(2) The C^3 system was as specified in Revision 1, dated 19 October 1976, Attachments 2, 3 and 5 to **ANVCE** Combat System Support Data for Point Designs.

Table A.2.8.1-2 (U). Missile/Missile Cannister Weights (U)

MISSILE TYPE	DESCRIPTION	MISSILE WT (klb/kN)	UNARMORED CANNISTER WT (klb/kN)	ARMORED(1) CANNISTER WT (klb/kN)
A	AMRM	1.99/8.85	1.69/7.52	1.99/8.85
A	Harpoon MkXX	1.45/6.45	1.69/7.52	1.99/8.85
B	ASW Standoff with ALWT	3.32/14.77	2.82/12.55	3.32/14.77

(1) Armored Cannister Weights were used for all missiles.



Notes:

1. All dimensions in ft (m)
2. Volume and Deck Space with stowed blades:

Volume, ft^3 (m^3)	6336 (179.32)
Deck Space, ft^2 (m^2)	628 (49.05)

Figure A.2.8.1-1 (U). ANVCE Far Term SES - Notational LAMPS MK XX Helicopter (U).

(U) A.2.8.2 PASSIVE FIRE PROTECTION — The design philosophy for treatment of spaces in Group 1 is based on prevention of primary aluminum structure from reaching 400° F (204° C) for a period of 15 minutes, The passive system is designed around an active fire protection system which will detect and extinguish a fire within 5 minutes maximum.

(U) The Fiberfrax panel system was selected for its superior performance relative to other lightweight systems considered. The methodology used to establish the insulation thickness is described in the following steps:

a. A computerized thermal analysis established the relationship between felt insulation thickness and temperature of the structure under fire conditions.

b. A full-scale JP-5 fuel fire test was conducted and the temperature distribution of the front face sheet of the insulation panels was monitored throughout the test.

(U) c. The temperature/time profile obtained during the test was used as an input to the thermal analysis, and temperature/time curves were obtained for several insulation thicknesses (see Figure A.2.8.2-1 and A.2.8.2-2).

d. From the curves of Figures A.2.8.2-1 and A.2.8.2-2, plots were made of insulation thickness versus time for the structure to reach 400° F (204° C) (See Figure A.2.8.2-3).

(U) Toxic gas emission characteristics of the insulation material were a prime consideration for Group 2 spaces. The concern stems from the direct threat to personnel and from restricted visibility along escape routes. The very low smoke and toxic gas emission propertfes of Fiberfrax made this material attractive to application in Group 2 spaces.

(U) The design approach to treatment of spaces in Group 2 is based on a modification of the fire loading concept described in the Society of Naval Architects and Marine Engineers (SNAME) Aluminum Fire Protection Guidelines, The fire loading of a space is a measure of the quantity of combustibles per unit deck area. It is expressed as pounds of wood per square foot with combustibles other than wood related to wood with a heat capacity of 8000 BTU/lb (1.86 x 107 J/kg). The methodology used to establish the amount of protection (insulation thickness) is described in the following steps:

a. Full scale fire tests were conducted with fire loadings of 12.5, 10, 7.5, 5 and 2.5 lbs mass of wood per square foot (61.0, 48.8, 36.6, 24.4 and 12.2 kilograms of wood per square meter).

b. The temperature/time profiles of the front face of the insulation panels during the tests were used as input to the thermal analysis computer program. Figure A.2.8.2-4 shows the temperature/time profiles for the various fire loadings.

c. The program output the temperature/time envelope of the aluminum structure for various amounts of insulation thickness. The maximum temperature of the structure with a given insulation thickness for each fire loading is plotted in Figures A.2.8.2-5 and A.2.8.2-6.

d. From the curves of Figures A-8.7.2-5 and A.8.7.2-6, plots were made of insulation thickness versus fire loading for one-side and two-side insulated structures (see Figure A.2.8.2-7).

e. The insulation thickness was selected from these curves. (Panel thicknesses in increments of 0.50 in. (12.75 mm) were selected for practical manufacturing and ready material availability.)

(U) The primary need in protecting magazines is to provide cooling when there is an adjacent fire hazard. Water sprinkling is the most efficient means to cool these spaces, Likewise, glass thermal insulation can be used more efficiently than refractory fibrous insulation in these spaces to prevent heat from entering.

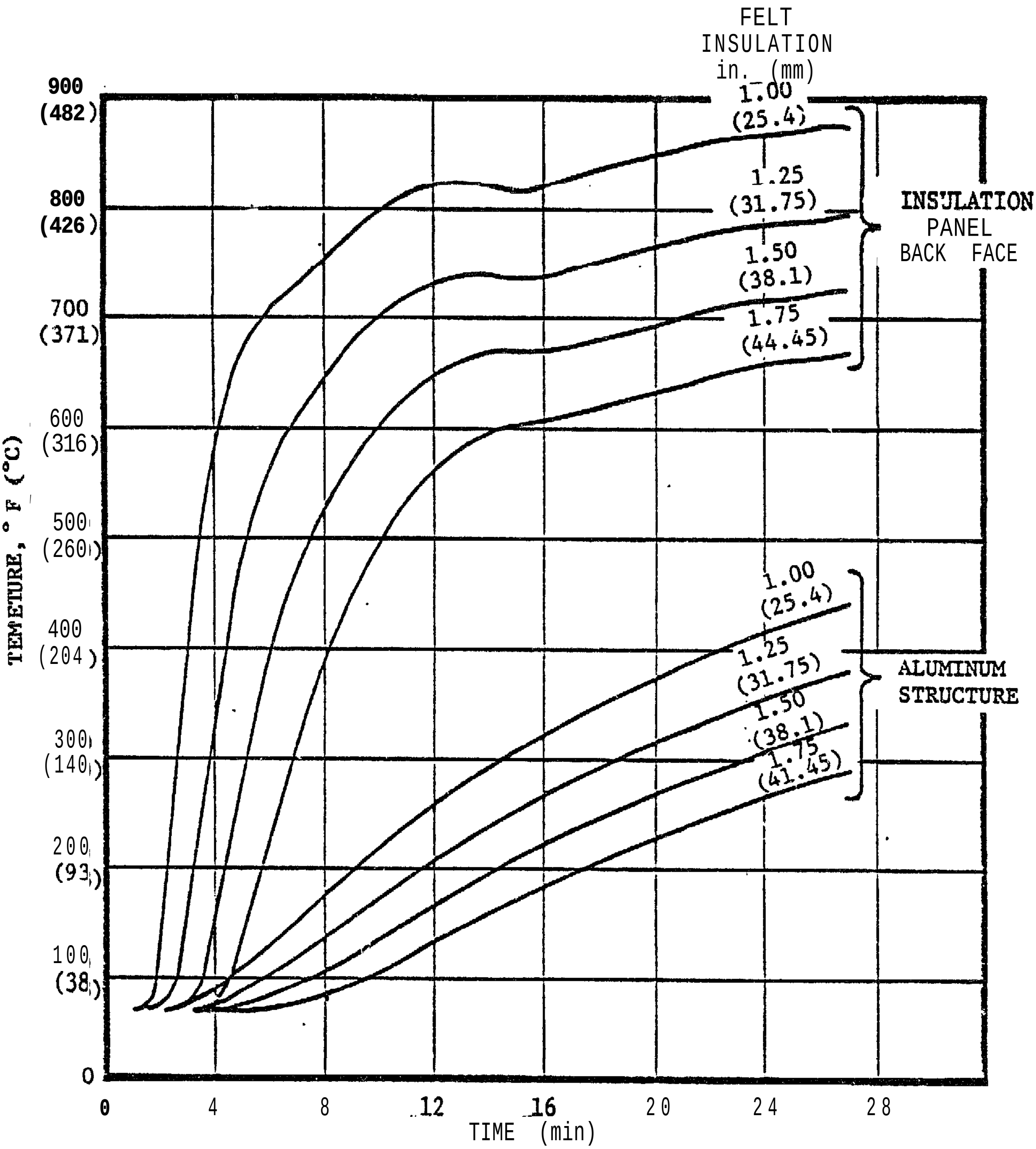


Figure A.2.8.2-1 (U): Temperature/Time Curves of Back Face of Insulation Panel and Aluminum Structure for Various Insulation Thicknesses in a JP-5 Fuel Fire (Structure Not Insulated on Far Side) (U)

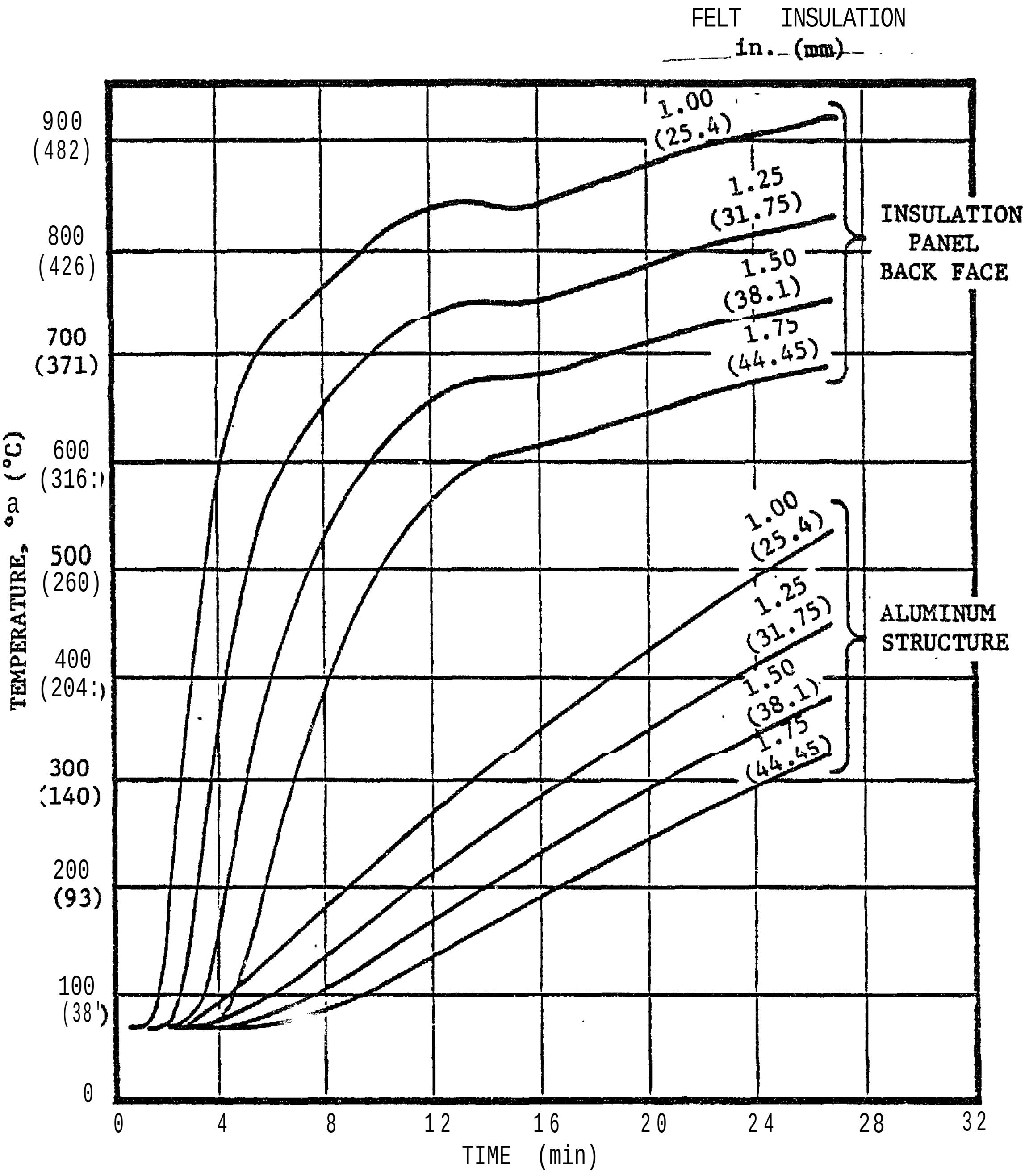


Figure A.2.8.2-2 (U): Temperature/Time Curves of Back Face of Insulation Panel and Aluminum Structure for Various Insulation **Thicknesses** in a YP-S Fuel Fire (Structure Insulated on Far Side) (U)

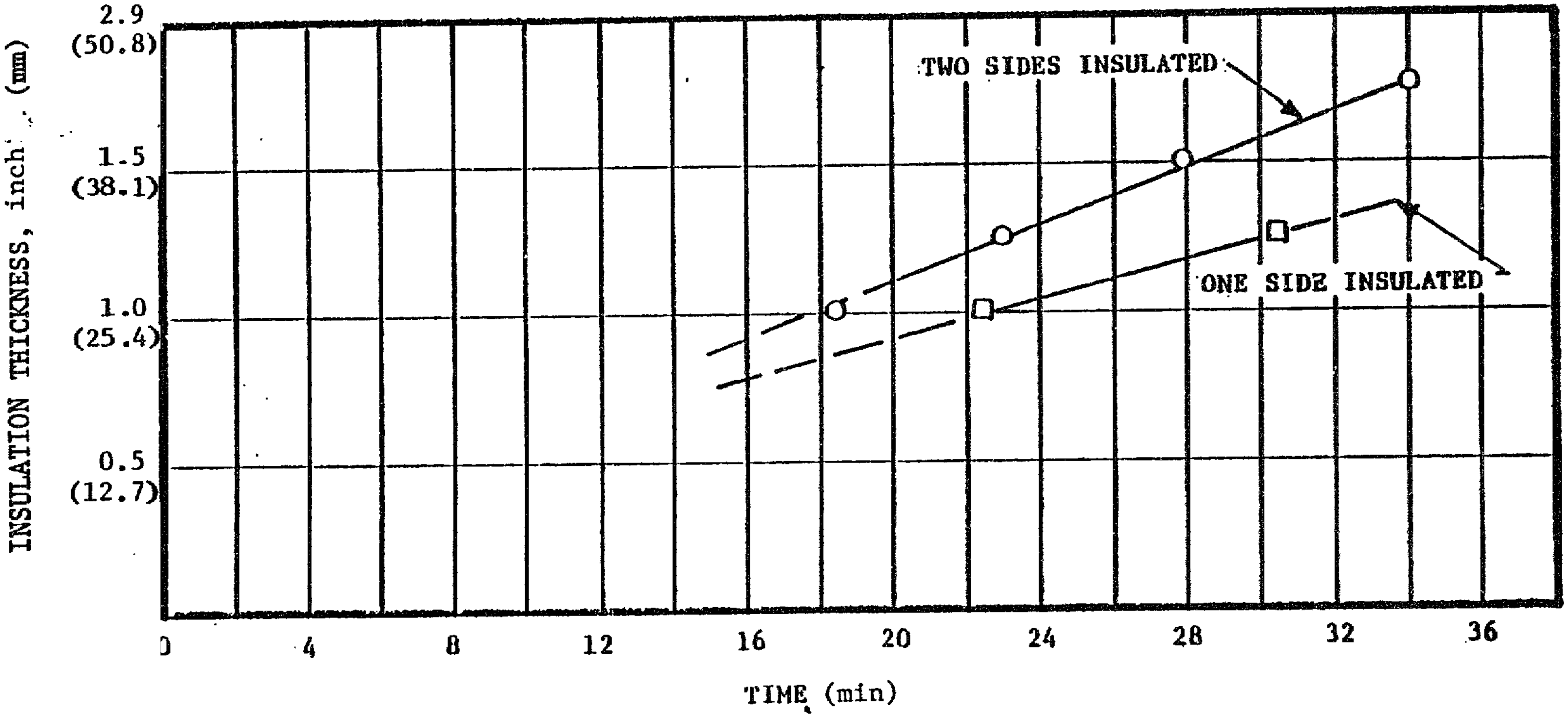


Figure A.2.8.2-3 (U): Insulation Thickness Vs Time for Aluminum Structure to Reach 400 Degrees F in JP-5 Fuel Fire (U)

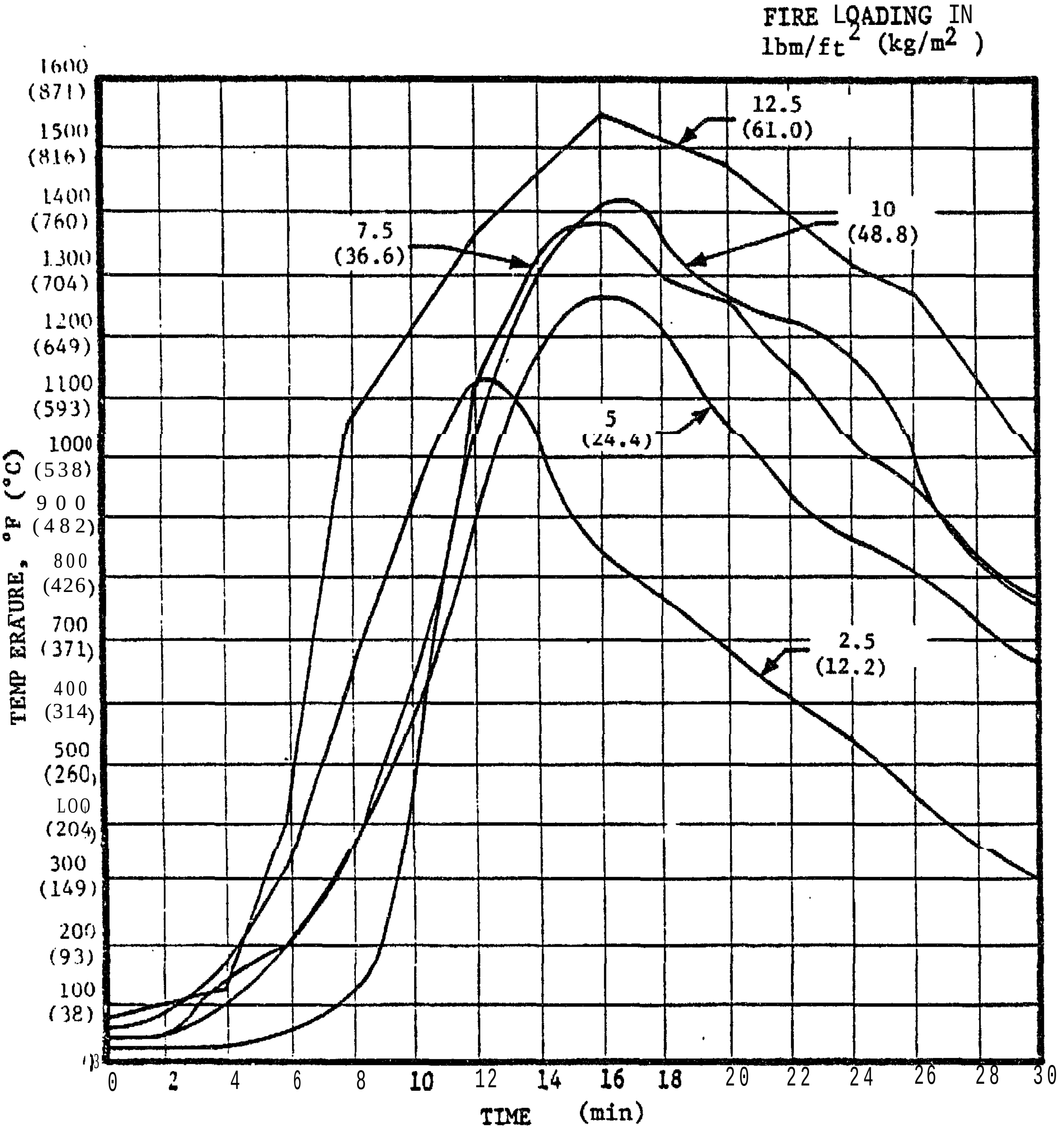


Figure A.2.8.2-4 (U): Temperature/Time Profiles on Front Face of Insulation Panels in Wood Crib Fires with Various Fire Loadings (U)

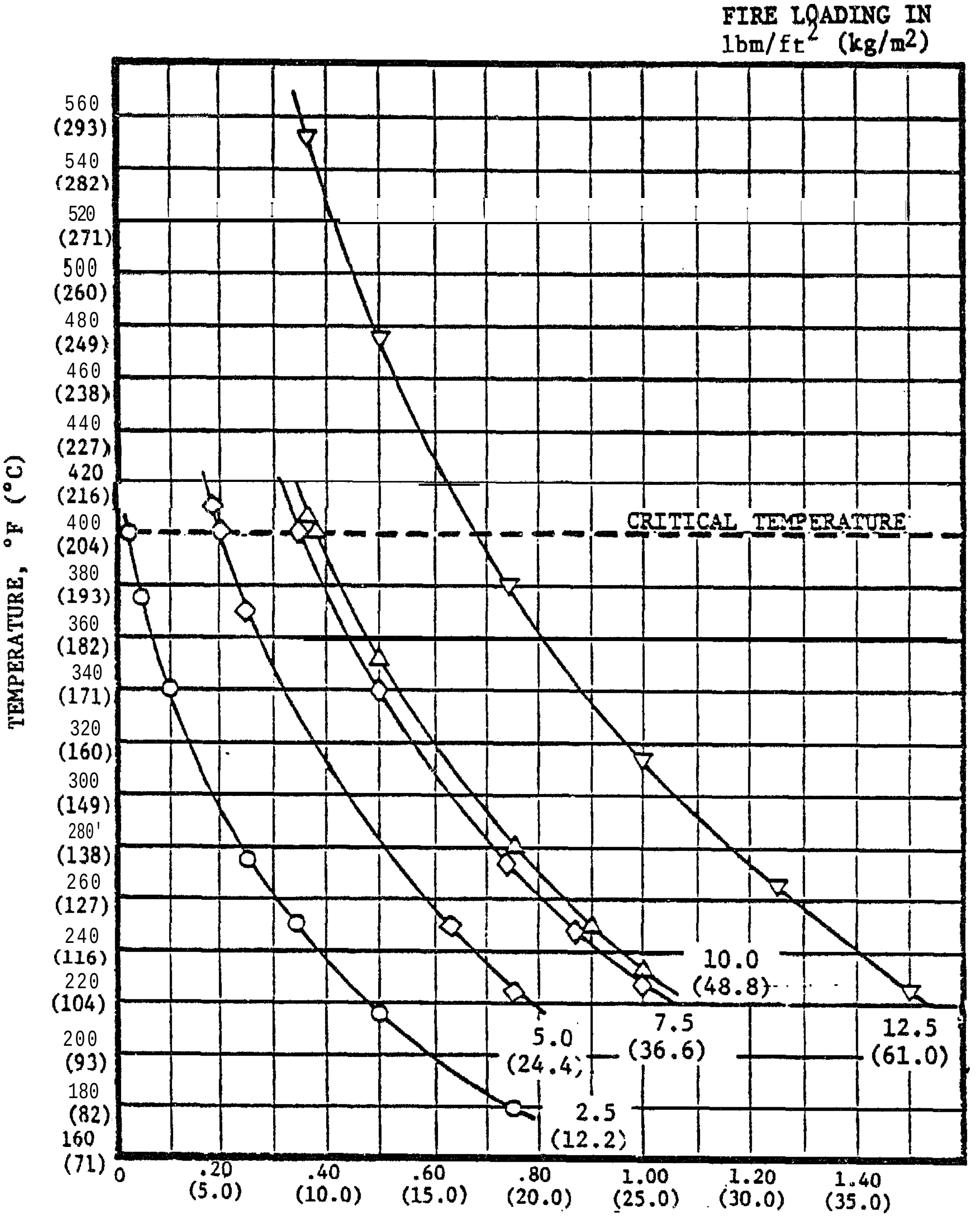


Figure A.2.8.2-5 (U): Maximum Temperature of Aluminum Structure Versus Insulation Thickness for Various Fire Loadings in Solid Combustibles Fires (Structure Insulated on Far Side) (U)

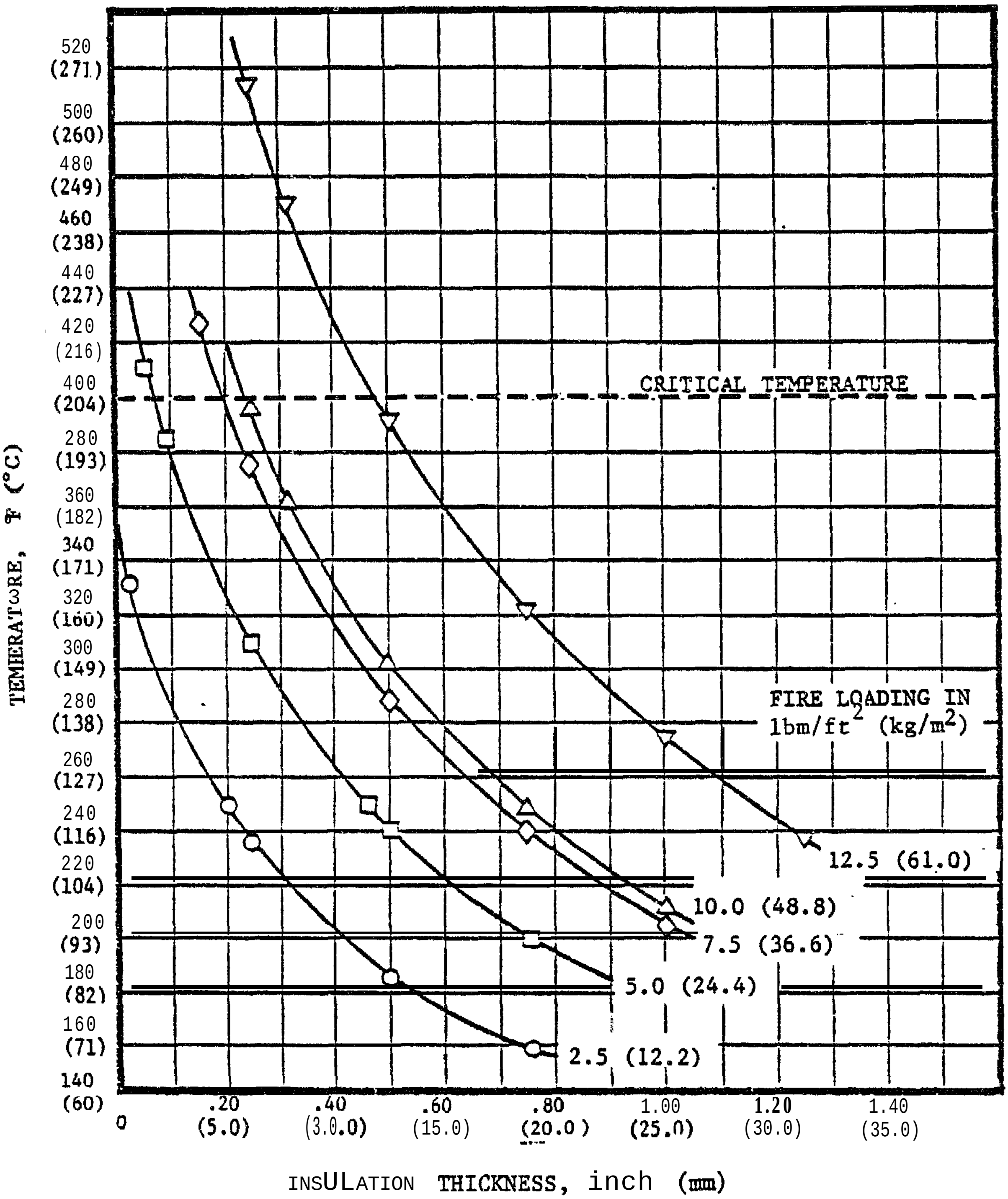


Figure A.2.8.2-6 (U): Maximum Temperature of Aluminum Structure Versus Insulation Thickness for Various Fire Loadings in Solid Combustibles. Fires (Structure Not Insulated on Far Side) (U)

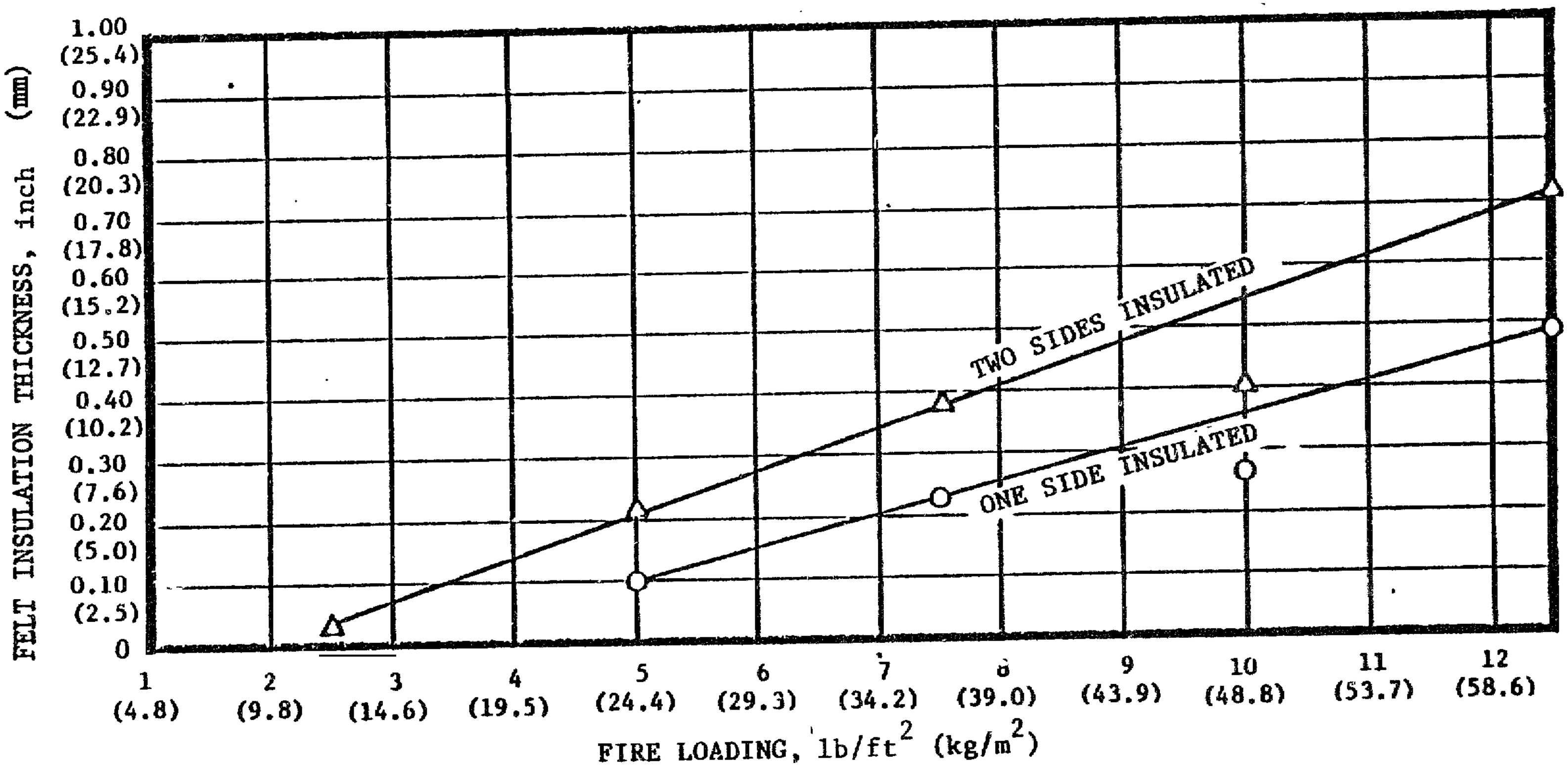


Figure A.2.8.2-7 (U): Felt Insulation Thickness Versus Fire Loading to Prevent Aluminum Structure from Exceeding 400 Degrees F (U)

[redacted]

A 2.8.3 HARDNESS

(U) The design threats which the far term SES can be expected to encounter are specified in Table 2.8.3-1, and the ballistic protection which must be provided is defined in Table 2.8.3-2.

(U) Table **A.2.8.3-1 (U).** Conventional **Weapons** Design Threats (U)

WEAPON TYPE	WARHEAD SIZE (HE) AND TYPE	DESIGN THREAT
Anti-Ship Missiles	Shaped Charge 1000 lbs (44488) Semi-Armor-Piercing 500 lbs (2224N)	1
Naval Guns	40-180mm Shells, HE and AP	2
Aircraft Cannon	23-37mm Projectiles, HE	3
Aircraft Rockets	50-150mm HE, AI?	4
Small Arms	.30 Caliber Ball and AP	5
Shore Rockets	Covered by Aircraft Rockets	6
Torpedoes	300 lb (1334N) and 600 lb (2669N) HE	7
Mines	400'lb (1779N) HE, Bottom and Contact	8
Limpets	50 lb (222N) Bulk and Shaped Charge	9

Table **A.2.8.3-2** ([redacted]). Ballistic Protection (U).

COMPARTMENT OR COMPONENT PROTECTED	THREATS PROTECTED AGAINST (Ref.: Table A.2.8.3-1
1. Magazines (prevention of mass detonation)	Projectile Threat 5 and Fragments from Near-Misses of Threats 2, 3, and 4
2. Propulsion and Fuel Systems (Vital Parts Only)	Same as above
3. Weapon System Components (Vital Parts Only)	Same as above
4. CIC (Vital Parts Only)	Same as above

[redacted]

(U) In addition to ballistic protection, shock resistance must be provided for near-miss underwater explosion attacks. A resulting keel shock factor of 0.3 or less must not inactivate components required for the following:

a. Propulsion, ship control, navigation, and replenishment at sea.

b. Command and control, and communications.

c. Surface, air, and underwater surveillance, countermeasures, fire control, firing or launching, and guidance of weapons.

d. Stowage, handling and reloading of weapons (also applicable to expendable ordnance while in stowage).

e. Launching, retrieving, fueling, defueling, rearming, handling, checkout, and maintenance of helicopters.

f. Casualty and damage control.

(U) Determination of this performance is based on Grade A shock tests (MIL-S-901), tests on Floating Shock Platform or analysis using DDS 072-l. Above performance to be determined in cushion mode for the SES.

(u) The methodology used to establish the level of ballistic protection is as follows: .

First, the following threats were assumed to govern the design:

5"/54 Shell (HE) Fragments - Horizontal Plating

.30 Caliber Ball (AP) Projectile - Vertical Plating

Next, the geometry and explosive content of the warhead was determined. A MK65 MOD 0 5"/54 shell was used as a guide. This projectile weights 57.3 lbs. (255N) and contains 7.9 lbs. (35N) of composition A-3 type explosive. The explosive container was assumed cylindrical with the following dimensions:

Length	12 inches (0.30 m)
Inside Diameter	3.76 inches (95.50 mm)
Thickness	0.62 inches (15.75mm)

(U) At this point it was necessary to define the standoff distance for a near-miss. This was assumed to be that distance at which a blast pressure and impulse loading due to the detonation of high explosive weapons is not critical to the structure. To determine this distance, the critical impulse load for a specific thickness of plate was caluclated using a method formulated by Robert Sewell and G. F. Kinney, "Response of Structures to Blast: A New Criterion." The actual blast loads were then assumed to be 1/3 of the critical impulse load. At this load some permanent plate deformation would occur, but failure would not result. Actual impulse loads were determined from NAVFAC P-397 "Structures to Resist the Effects of Accidental Explosion." A free air burst at sea level was assumed, and the pressure and impulse loads were determined for a range of standoff distances until the actual impulse equalled approximately 1/3 the critical impulse.

(U) For a 5"/54 shell the critical impulse and pressures for various plate thicknesses are shown in Table A,2.8.3-3

Table A.2.8.3-3 (U). Critical Blast Characteristics versus Plate Thickness (U)

Plate Thickness Inches (mm)	Critical Impulse psi-ms (Pa•s)	Critical Time ms	Minimum Pressure psi (kPa)
0.16 (4)	55.4 (382	0.71	78 (538)
0.25 (6.4)	86.5 (596)	0.45	192 (1324)
0.375 (9.5)	129.8 (895)	0.30	433 (2985)
0.50 (12.7)	173.0 (1193)	0.22	786 (5419)
0.75 (19.0)	259.5 (1789)	0.15	1730 (11,928)

(U) Table A.2.8.3-4 shows the actual blast impulse as a function of distance. For the far term ANVCE SES an average plate thickness of 0.25 inches (6.4mm) was assumed. The critical impulse for this plate is 86.5 psi-ms (596 Pa•s), and the standoff distance will be that distance which results in an actual impulse of ~ 29 psi-ms (200 Pa•s).

Table A.2.8.3-4 (U). Actual Blast Characteristics versus Standoff Distance (U)

STANDOFF DISTANCE		ACTUAL IMPULSE		ACTUAL PRESSURE	
FT	(m)	psi-ms	(Pa·s)	psi	(kPa)
10	(3.0)	78.0	(538)	108.5	(748)
18.5	(5.6)	36.0	(248)	2oio	(138)
20	(6.1)	32.8	(226)	16.6	(114)
25	(7.6)	25.4	(175)	11.0	(76)
30	(9.1)	19.0	(131)	7.1	(49)

(U) From Table A. 2.8.3-4 an impulse of 29 psi-ms corresponds to a standoff distance of ~ 22.5 ft (6.8 m).

(U) The primary fragment weights, distribution, and initial and striking velocities were then determined using methods presented in NAVFAC P-397. Fragment characteristics are dependent on the projectile geometry and the weight and type of explosive. Table A.2.8.3-5 'lists fragment characteristics for the notational 5"/54 shell,

(C) A spaced armor configuration was selected as the best approach to ballistic protection. This concept utilized existing ship structure and insulation panels. Test data obtained from the Army Materials and Mechanics Research Center report on Ballistic Technology of Lightweight Armor was used to determine the amount of plating and insulation panel face sheet beef-up required to absorb the kinetic energy of incoming fragments. The results are shown in Section 2.4.2.

Table A.2.8.3.-5 (U). Fragment Characteristics for a 5"/54 Shell (U)

PRIMARY FRAGMENT WT.		NO. WITH WT. GREATER THAN PRIM FRAG WT	AVERAGE FRAGWT.		INITIAL FRAG VEL.		FRAG STRIKING VEL.	
OZ.	(N)		oz.	(N)	fps	(m/s)	fps	(m/sec)
0.2209222	.98	560.	.33	1.47	3900	1189	3458	1054
0.4418445	1.96	263.	.55	2.45	↓	↓	3458	1054
0.6627667	2.94	147.	.77	3.43	↓	↓	3537	1078
0.8836889	3.91	90.	.99	4.40	↓	↓	3616	1102
1.1046104	4.89	58.	1.21	5.38	↓	↓	3635	1108
1.3255320	5.89	39.	1.43	6.36	↓	↓	3675	1120
1.5464535	6.89	27.	1.65	7.34	↓	↓	3694	1126
1.7673750	7.87	20.	1.87	8.32	↓	↓	3714	1132
1.9882965	8.85	14.	2.10	9.34	↓	↓	3734	1138
2.2092180	9.83	10.	2.31	10.28	↓	↓	↓	↓
2.4301395	10.81	8.	2.54	11.30	↓	↓	↓	↓
2.6510611	11.79	6.	2.76	12.28	↓	↓	↓	↓
2.8719826	12.77	4.	2.98	13.26	↓	↓	↓	↓
3.0929041	13.75	3.	3.20	14.23	↓	↓	↓	↓
3.3138256	14.72	2.	3.42	15.21	↓	↓	↓	↓
3.5347471	15.70	2.	3.64	16.19	↓	↓	↓	↓
3.7556686	16.73	1.	3.86	17.17	↓	↓	↓	↓
3.9765902	17.70	1.	4.08	18.15	↓	↓	↓	↓
4.1975117	18.68	1.	4.30	19.13	3900	1189	3734	1138
4.4184332	19.66	1.						

(U) A.2.8.4 References -- The following is a list of references used in the survivability/vulnerability investigation:

- "Top Level Requirements for a 3000-ton Surface Effects Ship in the 1990 Year Time Frame (Far Term)", Rohr-proposed revision of 25 October 1976 to the office of Advanced Naval Vehicles Concept Evaluation (ANVCE) Working Paper No. WP-006, dated 2 September 1976. CONFIDENTIAL
- "Survivability/Vulnerability Methodology", Advanced Naval Vehicles Concept Evaluation (ANVCE) Working Paper No. WP-013, Revision A, dated 15 November 1976.
- "Structures to Resist the Effects of Accidental Explosions", Department of the Navy Publication NAVFAC P-397, June 1969.
- Kinney, G. F., and Sewell, Robert G. S., "Response of Structures to-Blast: A New Criterion", Annals of the New York Academy of Sciences-, Volume 152, Art. 1: Prevention of and Protection Against Accidental Explosion of Munitions, Fuels and Other Hazardous Mixtures, 28 October 1968.
- Mascianica, Francis S., "Ballistic Technology of Lightweight Armor", Process Development Division, Army Materials and Mechanics Research Center (AMMRC) TF-73-47, November 1973.
- Keil, A. H., "The Response of Ships to Underwater Explosions", SNAME Transactions, November 1961.
- Harris, Cyril M. and Crede, Charles E., Shock and Vibration Handbook, McGraw-Hill Book Company, 1961.
- "Design of Foundations and Other Structures to Resist Shock Loading", Bureau of Ships DDS-9110-7, March 1964.
- "A Guide to the Design of Shock Resistant Naval Equipment", Bureau of Ships NAVSHIPS 250-660-30, July 1949.
- Harrington, R. C. and Vorus, W. S., "Dynamic Shock Analysis of Shipboard Equipment'", Marine Technology, October 1967.
- Hollycr, R. S., LCDR, USN, "Direct Shock-Wave Damage to Merchant Ships from Noncontact Underwater Explosions", SNAME Transactions, April 1959.

A.2.9 LOADS

(U) The weight allowances for variable load items were derived from Naval Ships Technical. Manual dated 1 March 1974, Chapter 9290, Paragraph 173.1, titled "Detailed Description of Conditions of Loading for Surface Ships." Paragraph 173.1(a) covers weight allocations for crew and effects as follows:

	Pounds (Newtons) Per Man
Officers (commissioned *or* warrant)	400 (1779)
Chief Petty Officers	330 (1468)
Other Enlisted Personnel	230 (1023)

(U) The ANVCE far-term TLR specifies a ship personnel complement of 17 officers, 13 chief petty officers and 110 enlisted men. The weight allowances then are:

		Weight	
Personnel	Qty	lbs.	(kN)
Officers	17	6,800	(30.24)
Non-Coms	13	4,290	(19.08)
Enlisted	110	25,300	(112.54)
TOTAL	140	36,390	(161.86)

(U) This 161.86 kN total corresponds to 16.25 long tons or 16.51 non-SI metric tons (F10).

(U) Paragraphs 173.1(c) and (d) of the referenced Technical Manual cover weight allocations for provisions, personnel stores, and general stores as follows:

Provisions	Pounds (Newtons) Per Man Per Day
Dry	3.20 (14.23)
Freeze	1.11 (4.94)
Chill	1.65 (7.34)
Clothing and Small Stores	0.07 (0.31)
Ship's Store	0.80 (3.56)
General Stores	1.06 (4.72)

(U)The ship provisions, personnel stores, and general stores using those provisioning allowances are:

- Dry Provisions 3.20 lbs/man/day x 30 days x 140 men = 13,440 lbs
- Freeze Provisions 1.11 lbs/man/day x 30 days x 140 men = 4,662 lbs
- Chill Provisions 1.65 lbs/man/day x 15 days x 140 men = 3.465 lbs
- Clothing & Small Stores 0.07 lbs/man/day x 30 days x 140 men = 294 lbs
- Ships Store 0.80 lbs/man/day x 30 days x 140 men = 3,360 lbs
- General Store 1.06 lbs/man/day x 30 days x 140 men = 4,452 lbs

29,713 lbs*

* 13,26 LT; 13.48 non-SI metric tons; or 132.17 kN

(U) A.2.10 WEIGHT MARGINS

(U) The ANVCE far-term ship weight margins were allocated according to the Rohr proposed modifications to the ANVCE far-term TLR (ANVCE-WP-006), dated 23 October 1976. Paragraph 3.9 specifies 15% of lightship displacement as ship weight margins for the ANVCE far-term ship.

(U) A.2.11 VEHICLE

(U) A.2.11.1 Payload Weight Breakdown -- The vehicle weight summary shown in Table A.2.11-1 details the far-term ship as defined in ANVCE-W-P-002, "Definition of Terms", dated 2 April 1976, Section III. The weight margins are included in the vehicle empty weights. This weight breakdown supports range and payload performance projections in Section 2.2.3.

Table A.2.11-1 (U): Vehicle Weight Summary (U)

SYMBOL	TITLE	LONG TONS	SHORT TONS	METRIC TONS	KILO-NEWTONS
W_E^1	Empty Weight Less Fixed Payload Items	1,940	2,173	1,971	19,330
W_C	Ship's Complement and Effects & Stores	30	34	31	299
W_P	Payload	327	366	332	3,258
W_F	Liquids	1,303	1,459	1,324	12,983
W	Vehicle Weight	3,600	4,032	3,658	35,870

(U) A.2.11.2 STABILITY AND RESERVE BUOYANCY -- The far term SES must survive, with margin, the operational hazards of the open ocean, as specified in the criteria of:

- Goldberg, L. L., Tucker, R. G., "Current Status of Stability and Buoyancy Criteria Used by the U. S. Navy for Advanced Marine Vehicles", Naval Engineers Journal, October 1975.
- Sarchin, T. H., Goldberg, L. L., "Stability and Buoyancy Criteria for U. S. Naval Surface Ships", Transactions of the SNAME(1), Volume 70, 1962.

(U) The freeboard and internal subdivision of the far term SES must be selected to satisfy the qualification of the criteria for reserve buoyancy and stability in terms of:

- Hullborne intact stability
- Reserve buoyancy under conditions of hull damage
- Damaged stability

(U) Analysis has demonstrated (Section 2.2.5) that the far term SES design would meet the Navy criteria established for Large SES's as set forth in the cited references for displacements in excess of 3000 tons.

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(1) Society of Naval Architects and Marine Engineers.

(U) A.2.12 MANNING

The Rohr developed manning presented herein delineates the minimum quantitative and qualitative personnel essential to the operation, maintenance, and support of the far term SES under stated missions, conditions of readiness and configuration. These requirements are termed Organizational Manning and were developed in general accordance with the "Guide to the Preparation of Ship's Manning," Document OPNAV 10P-23. The developed manpower requirements are sufficient for performing all operational, organizational, maintenance, administration, and support tasks required for the far term SES.

The planned use of the far term SES will be in accordance with direction provided in the Rohr developed Top Level Requirements (TLR) of 25 October 1976 (ANVCE WP-006).

(U) A.2.12.1 PROJECTED OPERATIONAL ENVIRONMENT — The following projected Operational Environment was established to develop Organizational Manning Requirements:

a. At sea in wartime

b. Capable of simultaneously performing all defensive and offensive functions while in Readiness Condition I,

c. Capable of performing other functions which are not required to be performed simultaneously.

d. Continuous Readiness Conditon III (three-section watch) at sea.

e. Capable of performing all maintenance for which ship's company is assigned responsibility.

f. Capable of performing in-port readiness requirements in peacetime on a six duty section basis.

(U) Required Operational Capabilities **(ROC) --** ROC have been developed for the far term SES and are contained in the Rohr developed TLR of 25 October 1976 (ANVCE WP-006). Organizational manning was derived from the ROC Projected Operational Environment and assumptions stated herein.

(U) **A.2.12.2** OPERATIONAL MANNING REQUIREMENTS -- Operational manning is the sum of quantitative and qualitative naval manpower needs to man essential operating stations during a specified condition of readiness. The operational manning requirement for a condition of readiness is expressed in terms of the related condition watch organization.

a. The minimum essential operational stations developed for the ANVCE SES are:

1) Readiness Condition I, manned on a o&section basis requires 109 operational stations.

2) Readiness Condition III, manned on a three-section basis required 18 operational stations (54 personnel). The minimum number of personnel required for Readiness Condition III is 140 (duty and watch).

3) Readiness Condition V, manned on the basis of a one-in-three watch rotation within each of six duty sections, requires five operational stations (90 personnel).

4) Flight quarters, manned on a one-section basis requires 44 operational stations,

(U) Based on the projected requirements displayed in this document, Readiness Condition III was selected as the operational requirement which would dictate the greatest operational manpower needs. No other Readiness Condition and Evaluations task will require a greater number' of personnel than that of Readiness Condition III. The following minimum required operational watch stations were developed for the purpose of determining the operational manning requirements for the far term SES and are displayed for Readiness Conditions I, III, and Flight Quarters:

Table **A.2.12.2-1** (U). Par **Term SES Operational** Watch Stations **(U)** Sheet 1 of 4

Title	Requirements			
	Minimum Skill	I	III	Flight Quarters
PILOT HOUSE				
Command Control	Officer	X		
OOD/Ship Control Officer	Officer	X	X	X
JOOD/Asst Ship Control Officer	Officer	X	X	X
Lookout, Starboard	SN	X	X	X
Lookout, Port	SN	X	X	X
Navigating Assistant	QM3	X	X	X
Visual Signalman	SM2	X		X
CHART ROOM				
Navigator	QM1	X		X
COMBAT OPERATIONS CENTER (COC)				
Tactical Action Officer	Officer	X		
TAO Console Operator	OS1	X		
System Monitor Coordinator	DS1	X		
Navigation Console Operator	OS3	X		X
Navigation Station No. 1	OS3	X		X
Navigation Station No. 2	OS3	X	X	X
Asst **TAO/AAW** Coordinator	Officer	X	X	
Radar Console Operator	FTG3	X		
AAW/EC (Area Defense) No. 1	FTM2	X		
Radar **Console Operator**	FTM3	X	X	
AAW/EC (Self Defense) No. 2	FTM2	X	X	
Electronic Warfare EC Operator	EW3	X	X	
ASMD-EW Console Operator	FTM3	X		
Assistant **TAO/SUW-ASW** Coordinator	Officer	X		X
Underwater EC Operator	STG2	X		
Surface/Sub-surface EC Operator	STG3	X	X	
Acoustic/ASAC Console Operator No. 1	OS3	X	X	
Acoustic/ASAC Console Operator No. 2	OS3	X		
Acoustic/ASAC Console Operator No. 3	OS3	X		
Acoustic/ASAC Console Operator No. 4	OS3	X		
Air Controller Console Operator	OS2	X		X
Surface EC Operator	OS2	X		
RPV (NAV) Console Operator	OS2	X	X	
RPV (PILOT) Console Operator	OS2	X	X	
Engineering Control Coordinator	GS1	X	X	X
Damage Control Coordinator	EPO1	X	X	X

Table **A.2.12.2-1(U).** Far Term SES Operational Watch Stations **(U)** Sheet 2 of 4

Title	Requirements			
	Minimum Skill	I	III	Flight Quarters
COMMUNICATIONS CENTER				
Communication System Supervisor	RM1	X		
ACCS/NAVMACS Console Operator	RM2	X	X	X
TT Operator/Clerk	RM3	X	X	X
HELO/RPV CONTROL STATION				
HCO/RPV Control Officer	Officer	X		X
Talker	SN	X		X
LANDING PLATFORM/HANGAR				
Pilot	Officer	X		X
Pilot	Officer	X		X
Co-Pilot	Officer	X		X
Co-Pilot	Officer	X		X
Crewman	Officer	X		X
Crewman	Officer	X		X
Plane Captain	APO3	X		X
Plane Captain	APO3	X		X
LSE/POINC HIFR	PO3	X		X
Talker	AN/SN	X		X
A/C Handler No. 1	AN/SN	X		X
A/C Handler No, 2	AN/SN	X		X
A/C Handler No. 3	AN/SN	X		X
A/C Handler No. 4	AN/SN	X		X
RPV Launch/Retrieve Supervisor	APO2	X		X
RPV Launch/Retrieve Crew	AN/SN	X		X
RPV Launch/Retrieve Crew	AN/SN	X		X
CRASH/RESCUE TEAM **(HANGAR)**				
Scene Leader	HT2/BM2 9555	X		X
Talker/Messenger	SN/AN/FN	X		X
Hotsuitman/Cutaway	SN/AN/FN	X		X
Hotsuitman/Cutaway	SN/AN/FN	X		X
AFFF Nozzleman No. 1	SN/AN/FN	X		X
AFFF Hoseman No. 1	SN/AN/FN	X		X
AFFF Nozzleman No. 2	SN/AN/FN	X		X
AFFF **Hoseman** No. 2	SN/AN/FN	X		X
Hospitalman	HM2	Located medical treatment room - "on call"		

Table A.2.12.2-1(U). Far Term SES Operational Watch Stations (U) Sheet 3 of 4

Title	Requirements			
	Minimum Skill	I	III	Flight Quarters
DAMAGE CONTROL TEAM NO. 1 (FWD REPAIR)				
Repair Party Leader	POC/9555	X		
Talker/Messenger	SN/FN	X		
Investigator/OBA	P03	X		
Investigator/OBA	PO3	X		
Scene Leader	PO2/9555	X		
Talker/Messenger	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
Auxiliary Equipment Repairman	EN3	X		
Electrical Repairman	EM3	X		
DAMAGE CONTROL TEAM NO. 2 (AFT REPAIR)				
Repair Party Leader	POC/9555	X		
Talker/Messenger	SN,'FN	X		
Investigator/OBA	P03	X		
Investigator/OBA	P03	X		
Scene Leader	P0219555	X		
Talker/Messenger	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
DC Repairman	SN/FN	X		
Auxiliary Equipment Repairman	EN3	X		
Electrical Repairman	EM3	X		
MACHINERY REPAIR TEAM (AFT REPAIR)				
Repair Party Leader	EPOC	X		
Talker/Messenger	FN	X		
Elec SWBD Operator/Repairman	EM3	X		
Elec SWBD Operator/Repairman	EM3	X		
Elec SWBD Operator/Repairman	EM3	X		
PLCC Operator Starboard/Repairman	GS2	X		
PLCC Operator Port/Repairman	GS2	X		
Machinery Room Patrol/Repairman	GSFN	X		
Machinery Room Patrol/Repairman	GSFN	X		

Table **A.2.12.2-1 (U).** Far Term **SES** Operational Watch Stations (U) Sheet 4 of 4

Title	Requirements			
	Minimum Skill	**I**	**III**	**Flight Quarters**
ELECTRONICS REPAIR **TEAM** (ELEX SHOP)				
Repair Party Leader	ELEX POC	X		
Electronics Repairman	ETR2	X		
Electronics Repairman	ETN2	X		
Electronics Repairman	DS2	X		
Electronics **Repairman**	IC2	X		
Electronics Repairman	GMM2	X		
Electronics Repairman	TM2	X		
BATTLE DRESSING (MEDICAL TREATMENT ROOM)				
Hospitalman	HM2	X		
First-aid Assistant	SN	X		
First-aid Assistant	SN	X		

(U) A.2.12.3 Maintenance Manning Requirements -- Maintenance Manning is the sum of quantitative and qualitative naval manpower needs to perform preventive, corrective, and facility maintenance on the far term SES and its component systems and equipment,

(U) The far term SES system design has incorporated provisions to minimize the requirements for "At Sea" maintenance. Its operation is essentially that of a "failure warning system" and is addressed under condition monitoring and fault isolation. The result is near-zero shipboard manning for maintenance purposes. When fully operational, underway maintenance will provide for minimum essential scheduled maintenance actions, restoration of equipment operation after failure by replacement of spare modules or assemblies. The far term SES maintenance plan otherwise conforms to the current 3M system insofar as practicable. The Intermediate Maintenance (IM) level facilities will be the primary support activity for the ANVCE SES.

(U) PREVENTIVE MAINTENANCE -- Preventive Maintenance (PM) is work accomplished in response to scheduled requirements. In quantitative terms, it is the total workload associated with the performance of maintenance actions, based on far term SES Maintenance Plan on vital and critical operational systems, equipments, or components that contribute to uninterrupted operation within designed characteristics.

(U) CORRECTIVE MAINTENANCE -- Corrective Maintenance (CM) is work accomplished on an unscheduled basis because of malfunction, failure or deterioration. In quantitative terms, it Is the workload associated, based on far term SES Maintenance Plan, with restoration of disabled systems, equipments, or components to an operational condition within predetermined tolerances and limitations.

(U) FACILITY MAINTENANCE -- Facility Maintenance (FM) is work accomplished to maintain cleanliness and to preserve the hull, superstructure, and all equipment against corrosion or deterioration. In quantitative terms, it is the workload associated with routine housekeeping actions, on the basis of the far term SES Maintenance Plan.

(U) MAINTENANCE PLAN -- The maintenance plan developed for the far term SES was utilized in the determination of maintenance manning requirements. This approach is described in Section 3.2 and is predicted on the availability of an Intermediate Maintenance Activity **(IMA)** embarked (Support Ship - e.g., Fleet Tender) and ashore at designated Naval Facilities. With the ability to move 3500 nm (6477 km) in a couple of days, the **IMA** could be provided by any of several existing major bases. The Fleet Tender is only required when the **SES's** are conducting prolonged operations in very remote areas of the world.

(U) SUPPORT MANNING REQUIREMENTS -- In the preparation of this report, only organizational manning is addressed. It is recognized that further analysis for the Intermediate Maintenance Activity **(IMA)**, within the Fleet Tender, must be developed.

(U) A.2.12.4 Manning Assumptions -- In **developing** the far term SES Organizational Manning, the following assumptions were made:

a. That the Navy Standard Workweek will be adhered to.

b. That all maintenance will be performed in accordance with the concept defined in Paragraph 3.2 of this report.

c. That Administrative Services support for records keeping and legal matters will be provided by the general purpose Fleet Tender, or by an advanced forward base.

d. That skill levels of required personnel **will** be held to the minimum consistent with performance of assigned tasks, provisions of adequate levels of supervision, and effective organization. To the maximum extent feasible, required manning shall be composed of presently available Navy skills as identified in the Manual of Navy Officer Classification (NAVPERS **15839)**, Manual of Qualifications for Advancement in Rating (NAVPERS 18068) and the Manual of Navy Enlisted Classification **(NAVPERS** 15015).

(U) e. That the following billets normally assigned as primary duties will be performed on a collateral basis:

(1) Chief Master at Arms

(2) Mess Deck Master at Arms

(3) Ship's 3-M Coordinator

(4) Librarian (On-Board Data Bank)

f. That the ship will not provide routine barber service. In the event the ship is underway for a longer period than 20 days, haircuts will be provided on an as-needed basis.

g. That the ship will not provide a separate ice cream bar. Provisions are made for soft ice cream as part of the serving line of the Commissary System.

h. That the laundry is self-service and provides for two loads per crew member per week. Each crew member is responsible for his own laundry tasks. A laundry crew will provide service for all ships linen and the Commanding Officer and Executive Officer,

i. That all bakery products will be purchased from commercial sources and/or provided through the Naval Supply System.

j. That the food service function is a centralized concept. Both the wardroom and CPO mess will subsist from the general mess.

k. That certain facilities which primarily provide services for the crew will have established hours of operation as indicated in Figure A.2.12-1.

Figure **A.2.12-1 (U).** Service Facilities Hours of Operation(U)

FACILITY	CONDITION III/IV	CONDITION V
Post Office		
Sale of stamps	1.00 hr. weekly	1.00 hr. weekly
Sale of money orders	1.00 hr. each payday	1.00 hr. each payday
Sick Bay		
Sick Call	2.00 **hrs.** daily	2.00 hrs. daily
Supply		
Storeroom Issues	2.00 hre. daily	2.00 hrs. daily
Ship's Store	2.00 hrs. daily	1.00 hr. daily
Ice Cream Bar	(part of commissary complex)	

(U) A.2.12.5 Administrative Organization -- The far term SES organization was developed to minimize the administrative workload and place each crew member in a functional area of responsibility to maximize his utility within the organization. The command organization is shown in Figure A.2.12-2 and the department functional organization is portrayed in Table A.2.12-1

(U) The recommended administrative organization for the far term SES is as follows:

Commanding Officer
Executive Officer

Operation Department
    0 Division

Combat Systems Department
    C Division

Engineering Department
    E Division

Aviation Department
    V Division

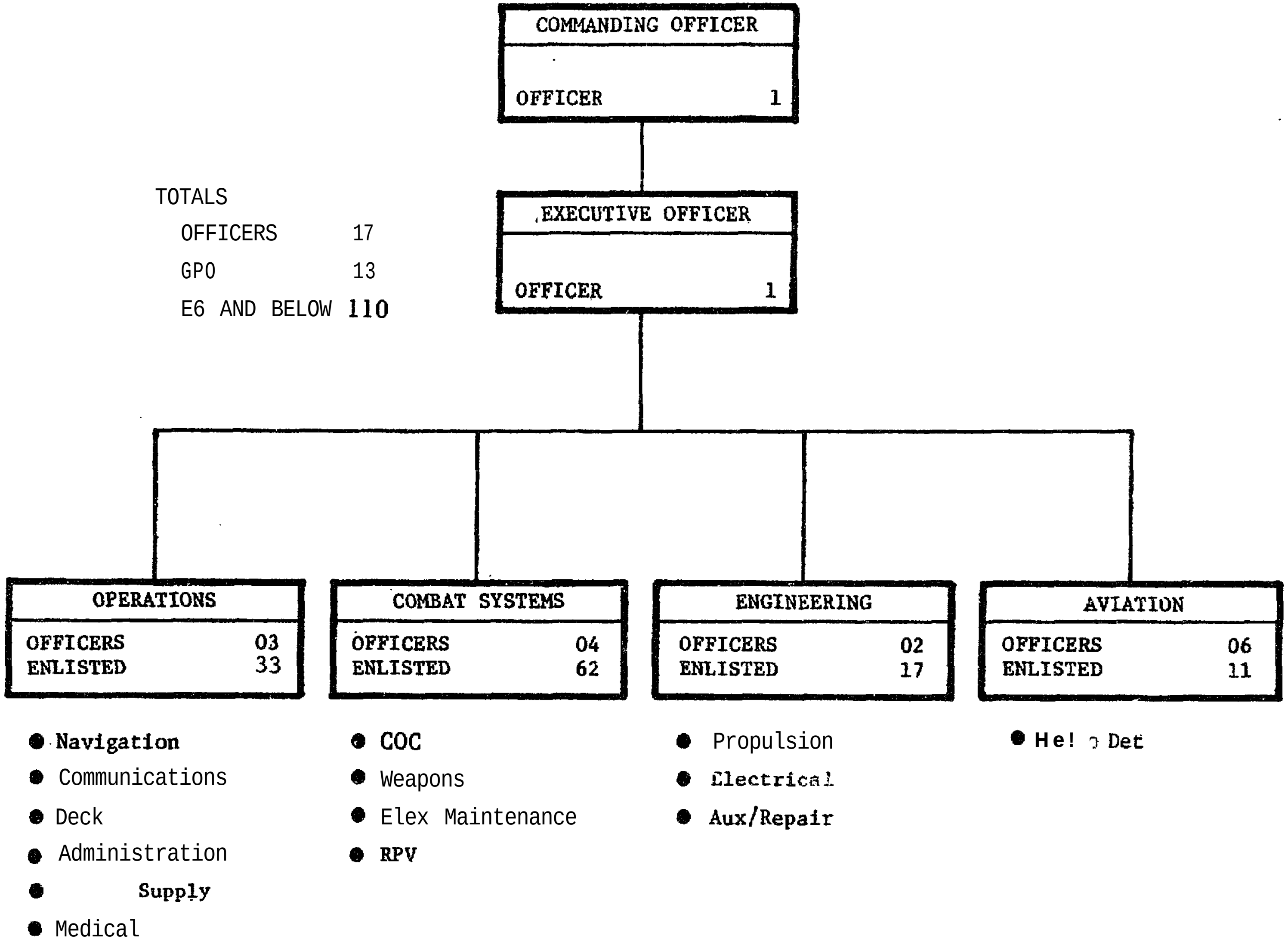

Figure A.2.12-2 (U): Far Term SES Command Organization (U)

Table A.2.12-1(U). Functional Organization Chart (U) Sheet 1 of 4

FUNCTION	RANK/RATE	NUMBER REQUIRED
Commanding Officer	CDR	01
Executive Officer	LCDR	01
OPERATIONS DEPARTMENT		
Operations Officer	LT	01
Communications		
Communications Officer	LTJG	01
	RM1	01
	RM2	03
	RM3	03
Deck		
First Lieutenant	LTJG	01
	BMC	01
	BM3	01
	SN	04
Navigation		
Navigator	QMC	01
	SM2	01
	QM3	02
	QMSN	01
Support		
Administration	YN1	01
	YN3	01
Medical	HMC	01
Supply	SKC	01
	SK3	01
Ship Service	SH3	01
Food Service	MSC	01
	MS2	02
	MS3	02
	SN	04
	FN	01

Table A.2.12-1(U). Functional Organization Chart (U) Sheet 2 of 4

FUNCTION	RANK/RATE	NUMBER REQUIRED
COMBAT SYSTEMS DEPARTMENT		
Combat Systems Officer	LT	01
Combat Operations Center		
Asst. Combat Systems Officer	LTJG	01
	OSCS	01
	OS1	03
	OS2	03
	OS3	03
	OSSN	03
Electronics Material Officer	LTJG	01
Computer maintenance	DS1	01
	DS2	02
	DS3	02
Radar/Comm Eqt Maintenance	ETC	01
	ET1	02
	ETR2	01
	ETR3	02
	ETN2	01
	ETN3	02
Electronic Warfare Opr/Maint	EW1	01
	EW2	01
	EW3	01
IC/Ship Control Eqt Maint.	IC1	01
	IC2	01
	ICFN	01
Sonar Eqt Opr/Maintenance	STG1	01
	STG2	02
	STG3	03

Table **A.2.12-1(U).** Functional Organization **Chart(U)** Sheet 3 of 4

FUNCTION	RANK/RATE	NUMBER REQUIRED
Missile Officer	LTJG	01
FC **Opr/Maintenance**	FTCS	01
	FTM1	01
	FTM2	03
	FTM3	03
	FTG1	01
	FTG2	01
	FTG3	01
Launcher/Handling eqt **Maint**	GMM1	01
	GMM2	01
	GMM3	02
	TM2	01
RPV Maintenance	ATC	01
	AT2	01
	AX2	01
	AMH1	01
	AMS2	01
	ADJ1	01
	ADJ3	01
ENGINEERING DEPARTMENT		
Engineer Officer	LT	01
Main Propulsion	GSCS	01
	GS1	03
	GS3	01
	GSFN	01
Electrical	EMC	01
	EM2	03
	EM3	01

Table A.2.12-1(U). Functional Organization Chart (U) Sheet 4 of 4

FUNCTION	RANK/RATE	NUMBER REQUIRED
Damage Control Assistant	LTJG	01
	HT1	01
	HT2	01
	HTFN	01
Auxiliaries	EN1	01
	EN2	01
	ENFN	01
AVIATION		
Flight Crews		
Pilot	LT	01
Pilot	LT	01
Co-Pilot	LTJG	01
Co-Pilot	LTJG	01
Crewman	LTJG	01
Crewman	LTJG	01
Maintenance	ADJC	01
	ADJ1	01
	AMH1	01
	AMH3	01
	AMS1	0f
	AT1	01
	AT3	01
	AE1	01
	AX2	01
	AO2	01
	AN	01

(U) A.2.12.6 summary -- The developed manpower requirements are sufficient for performing all operational, maintenance, and support tasks required for the far term SES. The **following significant** workload elements were utilized in determining the crew size and composition.

a. Operator Stations

(1) Readiness Conditions

(2) Evolutions (i.e. Flight Quarters, Replenishment)

(3) Automation of equipment/systems

(4) Ride Criteria

b. Maintenance Planning

(1) Routine identified

(2) Mission Critical

(3) Condition Monitoring/Built in test equipment

(4) Method of accomplishment

(5) Ride Criteria

c. support

(1) Shop sizing

(2) Storeroom capacities

(3) Tender/yard requirements

(4) Ride Criteria

(U) The organizational manning requirements developed for the far term SES are **as** follows:

	Officers	CPO	Other Enlisted	TOTAL,
Vehicle (Ship)	7	7	36	50
Vehicle (Combat System)	4	5	64	73
Secondary Vehicle Team	6	1	10	17
TOTAL	17	13	110	140

A.2.13 PERFORMANCE

The proposed 3600 LT (35.87 MN or 3657 non-SI metric tons) far term SES includes all of the fuel (for bothsship and helicopters), sensors, weapons and armor specified.(1) The basis upon which the far term SES design performance was developed is compared with the far term TLR specifications below:

DESIGN PARAMETER	FAR TERM TLR	ANVCE FAR TERM SES
Full Load Displacement (LT; MN; *)	None Specified	3600; 35.87; 3657
Mean Operating Displacement (LT; MN; *)	None Specified	3025.5; 30.15; 3074
Wind Speeds	Pierson Moskowitz Sea Spectra (no altitude gradient for winds)	
Tail Pipe (Trapped Fuel) Allowance (LT; MN; *)	64.6; 0.644; 65.63	64.6; 0.644; 65.63
Marine Fouling Allowances	1 Mil Surface Finish	
Ambient Temperatures - Air	80° F (26.67° C)	
Water	59° F (15° C)	

* non-SI metric tons.

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(1) "Top Level Requirements for a 3000 Ton Surface Effect Ship in the 1990 Time Frame (Far Term)", Advanced Naval Vehicles Concept Evaluation (ANVCE WP-006), Rohr Industries Proposed Modification, dated 25 October 1976.

(2) Mean Operating Displacement at 50% fuel load (LM5000 propulsion).

(U) Detailed comparisons between performance of ANVCE far term design and the TLR regarding speed, hump margin, acceleration and deceleration, turning range, and operation sea state performance are outlined in the following sections:

[redacted] A.2.13.1 SPEED -- At maximum continuous power, the maximum far term SES speed limit of 100 knots (51.4 m/s) can be met (or exceeded) in head seas of a 3 ft. significant wave height or below, while the 70 knot (36 m/s) cruise speed requirement can be attained in head seas as high as 11 ft. (3.3 m) significant wave heights.

[redacted] A.2.13.2 HUMP THRUST MARGIN -- As compared with the requirement for a 25% hump thrust margin over calm water drag, the far term SES has a 34% calm water hump margin at full load displacement, a 25% margin in a head sea of 6.5 ft. (1.98 m) significant wave height, and-no margin-in a head sea of 17 ft. (5.2 m) significant wave height.

(U) A.2.13.3 TURNING

A.2.13.3.1 Low Speed Maneuvering -- On- or off-cushion, ahead or astern, the ship has the ability to control heading for docking, undocking or low-speed maneuvering in a seaway. The low speed capability is comparable to that for the near term SES.

(U) A.2.13.3.2 Tactical Diameter -- The requirements are a maximum tactical diameter of 1500 yards (1371 m) at speeds below 30 knots (15.5 m/s) and 5000 yards (4572 m) when entering a turn at maximum speed. At a speed of 30 knots (15.4 m/s) in calm water, the far term SES is capable of turning with a 750 yard (686 m) tactical diameter while at speeds of 50 knots (25.7 m/s), at full load displacement and above, it is capable. of turning within a 2720 yard (2487 m) tactical diameter. Consequently, the far term SES betters these specified turning performance requirements by 100 and 84%, respectively.

[redacted] A-2.13.4 ACCELERATION AND DECELERATION -- At full load displacement, and all engines set at their maximum continuous power ratings, the far term SES is capable of accelerating in calm water from a standing start to a speed of 70 knots (36 m/s) in 102 seconds. This is 76 percent better than the specified 0 to 70 knots in 180 seconds at full power, which can be achieved in head seas as high as 12.5 ft. (3.81 m) significant height. Then, by engaging the thrust reversers, applying maximum intermittent power to the outboard propulsion engines, reducing the power to the inboard *engines* to idle, and retracting the stern seal, the ship can be decelerated from 70 knots (36.01 m/s) to a full stop in 620 yards (567 m). This is 0.62 of the specified 1000 yards (914 m) stopping range.

~~(C)~~ A.2.13.5 RANGE -- The specified range of 3500 nautical miles (6483 km) in head seas of 3.94 feet (1.2 m) significant wave height is met by the far term SES.

(U) A.2.13.6 MAXIMUM OPERATIONAL SEA STATE -- The speed-sea state operational envelope for the far term SES is shown on Figure A.2.13-1 for on-cushion ahead as well as on and off-cushion conditions. These limits are set by ship performance. The structural and ride quality limits are within these envelopes.

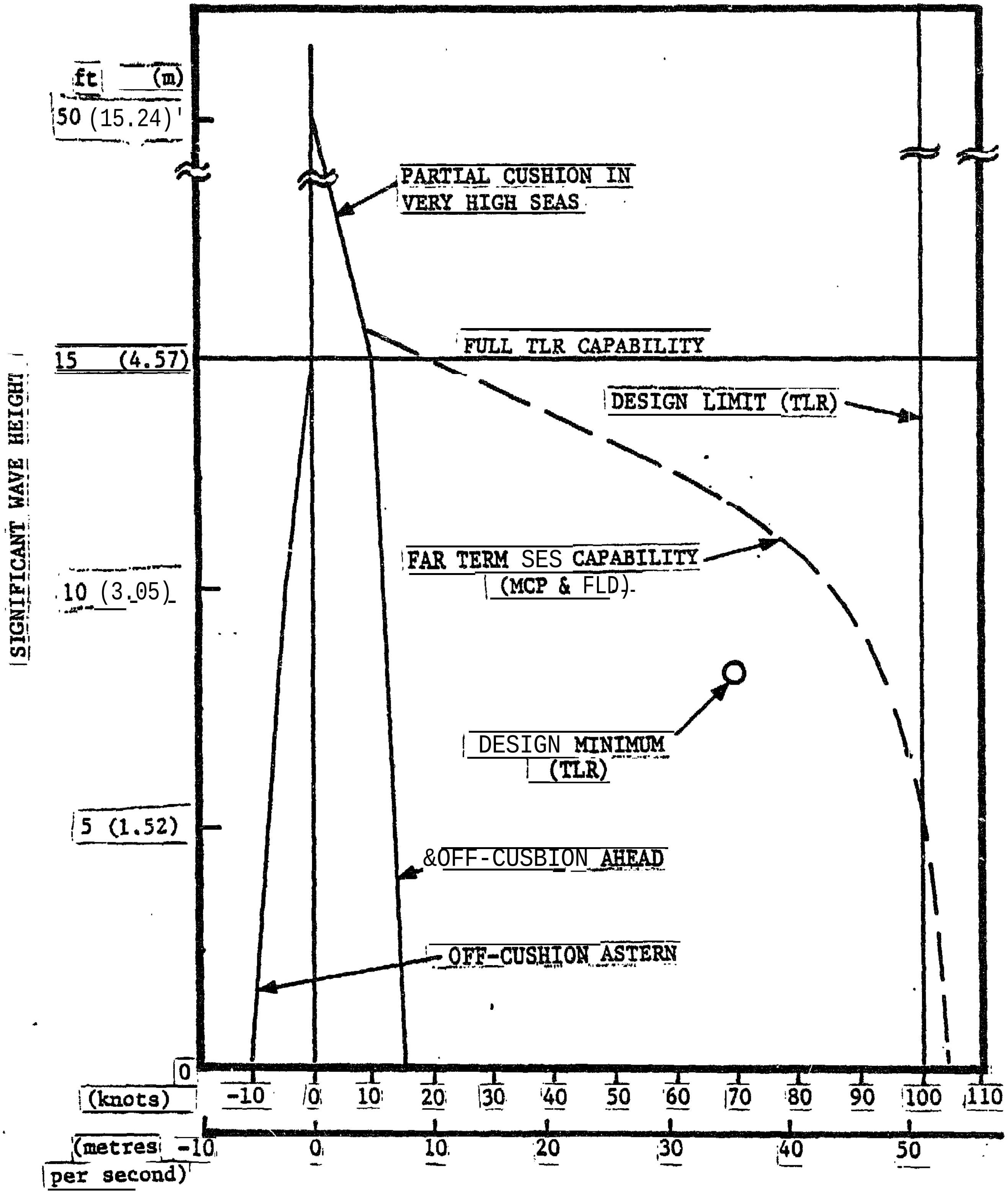


Figure A.2.13-1 (C): Far Term SES Operational Envelope - TLR Requirements/Capabilities (U)

(U) A.3 DESIGN PHILOSOPHY

(U) The overriding philosophy of the far term point design SES is design for a combat capability to fulfill a role as an operational fleet unit, Every design decision has supported this philosophy. The result is a balanced design in which no single feature is dominant. All subsystems and their components were accorded careful development and engineered to meet the specified Top Level Requirements (TLR).

(TJ) The ANVCE far term SES is a cost effective design, inhabited and operated by sailors, which provides superior performance, seaworthiness, and survivability in high sea states. The design philosophy is manifest in the ship's performance and subsystems design,

(U) The SES meets or betters Top Level Requirements for speed, range, and hump margin in all sea states at a full load displacement. It betters all requirements for turns. Translation and rotation maneuvers are easily made at zero and low forward speeds for docking, harbor operations, and certain tactical situations. It comes to a full stop from 70 knots (36.01 m/s) in 620 yards (567 m), 62% of that specified.

(U) The ride quality is much better than required for crew comfort and performance of precision tasks. The superior ride quality is maintained over the entire operational envelope and has been proven at sea. A destroyer (DD-963) cruising at 10 knots, sea state 5, meets the established 4 hour limits. The near term point design SES operating at 60 knots, sea state 5, easily meets and can exceed the same 4 hour ride criteria.

(U) The design is inherently stable. It is safely operable well beyond the limits of the operational requirements. It is functional in sea state 6.

(U) It is designed to survive hurricane conditions. Extensive digital computer simulation and 3,800 hours of tow tank testing confirmed the design as stable and safe.

(U) It is a habitable and highly maintainable ship due to careful attention given to functional space arrangements and by designing the ship with 9 foot (2.74 m) deck heights to assure adequate head room in all spaces where activity is required. Duty stations and living spaces are located away from noise and vibration producing machinery. All living spaces and messing areas are located for best ride quality and with least noise.

(U) The lift and ride control system is unique and effective. It is a proven system. The ride control system (RCS) attenuates vertical motions to levels within ride criteria limits.

(U) It utilizes an advanced planing seal concept which easily meets the tram-oceanic requirements of long life and high reliability. The seals are a marked advance in the state-of-the-art.

(U) The propulsion system is designed for operational use. It is a simple, proven system sized for growth. It is a symmetrical system port and starboard that is easily aligned and maintained.

(U) The far term point design SES incorporates an integrated ship control system which enables five (5) men to operate the ship in complete safety. It is designed for centralized operation, operational simplicity, full exploitation of the SES potential, and fail safe operation. Reliability and safety are fully integrated into the design.

(U) A.4 TRADE-OFF STUDIES

Many design variations were considered during the development of the far term SES point design. These required various trade-off studies in the general areas of ship configuration, subsystems, and performance.

(U) A.4.1 **CONFIGURATION TRADE-OFFS --** The far term SES is a full length sidehull ship with an effective length-to-beam (L/B) ratio of 2.60. The choice of full length sidehulls over partial length sidehulls was the result of trade studies that included consideration of parameters such as drag, static and dynamics stability, sea worthiness, seal design, maneuverability and structural weight fraction.

(U) The selected seals design resulted from trade-offs that considered the application of a two-dimensional, planing type seal, or a bag-and-finger type seal. Factors evaluated in the definition of the seal baseline included design simplicity, durability, response characteristics, high speed drag, performance and off--cushion drag penalties.

(U) Lateral directional stability at high yaw angles is provided by fixed ventral fins. The specification of these devices and their related fences are the results of trade-off studies considering various geometries and evaluating their drag, waterjet inlet broaching, and maneuvering performance.

(U) The configuration also includes semi-flush waterjet inlets and related ventilation cutouts. The location and geometry of the inlets and ventilation cutouts are the result of trade studies involving drag, weight, propulsion efficiency, and machinery location considerations.

(U) A number of trade-offs were made to determine the impacts of variatfon in bulkhead spacing, frame and stiffner spacing and number of decks within the hull. The considerations were optimization of the structural weight fraction while providing sufficient enclosed volume to accommodate the required ship company, machinery fuel, and specified military payload.

(U) A.4.2 KEY SUBSYSTEMS TRADE-OFFS

(U) A.4.2.1 Main Propulsion System -- Trade-offs for the propulsion machinery subsystem emphasized criteria which resulted in a design that provides optimum performance, low development risk, minimum complexity, high reliability, maximum protection from environmental elements, good habitability and replacement of most major components without drydock of the ship. The primary trade-off was between wsterjet propulsors and partially submerged, supercavitating propellers. Waterjets were chosen because they produce much lower noise and vibration levels, are less susceptible to damage by floating debris, have less complex transmission systems, can be maintained without drydock (except for some elements of the waterjet inlet), and can be acquired at lower cost and with less developmental risk.

(U) The propulsion system utilizes four LM5000 gas turbines. The TX.5000 engine has low fuel consumption, adequate power, and expected long life and high reliability.

(U) Other major trade-offs were in the propulsion machinery arrangement, combustion air system, and waterjet inlet, All propulsion components, except the waterjet inlet, are located above the wet deck to obtain good maintainability and minimize complexity. Use of seemingly available space in the sidehulls resulted in poor installations with disadvantages outweighing the marginal advantages in performance. Similarly, the combustion air system was generously sized to minimize engine power losses and maximize accessability, salt removal and noise suppression.

(U) The selected waterjet inlets are fixed orifice designs that provide superior cavitation and recovery performance, simplicity, and low drag.

(U) **A.4.2.2** Lift System -- An intensive parametric trade-off study of both axial, mixed flow and centrifugal fan8 resulted in the selection of dual inlet, single discharge, constant velocity volute, centrifugal fans because of their low weight, compact geometry, and favorable performance properties. A further trade-off resulted in consideration and rejection of two circulation control designs when compared to the fan concept. Circulation control was found relatively complex and not as advanced as tha technology for fans; a proven l/l-scale fan model was in operational. use.

(U) The far term fans were sized for the far term SES cushion pressure and flow parameters required to meet craft objectives. The near term SES would not provide the head rise required for the far term ship with any margin for overload. Therefore, a new fan was sized using "affinity laws" and industry standard design p&meters. The fan was designed with a radial wheel for higher head rise in a minimum envelope and with a discharge angle of 90 degrees. A pressure coefficient of 0.64 was selected which resulted in a wheel diameter of 87 inches (2.21 m). A flow coefficient of 0.475 was used to establish the impeller profile. The peak efficiency was established at 83.5 percent.

(U) The selection of the prime mover was based upon the fan power requirements and establishing commonality with the propulsion prime mover.

(U) Trade-off8 of various fan locations and their attendant shafting, gearboxes, and ducting complexity were performed. The result was a design featuring an identical lift system for port and starboard sides with identical gearboxes and horizontal fore and aft shafting. The transmission system utiliees a proven marine helical gear set (single reduction) which drops the fan shafting 3 feet (0.91 m) vertically to the prime mover shaft line.

(U) Ducting trade-offs are closely related to those for the power transmission. With fan locations and air delivery points established, further trade-offs determined the minimum weight ducting configuration with no common plenum or duct plenum, no duct air splitting and use of round ducts.

(U) The passive stern seal eliminated the long stern seal ducting. The fair-weather intake design resulted from trade-off studies concerning free stream pressure recovery, noise control, fabrication techniques, base drag, weight and water ingestion.

(U) The location and size of the stern seal vent valve was determined by the unique features of the passive stern seal. Due to the relatively small vent area required, the vent trunks are kept in the confines of the wet deck-third deck structure and venting is through the transom. The valves will be of modular design incorporating proven hydraulically-operated vanes similar to the Rohr 3KSES ride control valves. The valves are capable of operating at 2 Hz.

(U) The planing seal was selected for its demonstrated lower drag forces, improved wear resistance and the durability of glass reinforced plastic planar elements. The two-dimensional planing bow seal was selected along with the square bow/full length sidehull because together they offered a more simplified seal design, modularization of components, and improved seal maintainability and reliability.

(U) Modularization trade-offs were performed to optimize seal maintenance, to minimize loads and to assure high performance in a seaway. Components included were number and type of restraints (straps and cables) and quantity of planers and bag modules.

(U) Significant hardware and seal material trade-offs included comparisons of (1) straps and cables, (2) materials for planers, pressure bags, restraints, attachments, and modular joints and (3) planer-to-strap transition attachments. Key criteria in these trade-offs were weight, reliability, maintainability, ease of fabrication, and methods of design verification.

(U) A.4.2.3 Trade-Offs -- Trade-offs optimized the electric1 power generation and conversion subsystem design. The weight was reduced by almost 50 percent by increasing the use of 400 Hz power. The power requirements were adjusted through judicious selection of user equipment so that 400 Hz and 60 Hz power consumptions were equal. The weight savings resulted from the extensive use of 400 Hz generators and motors, which weight less than one-eighth as much as their 60 Hz counterparts.

(U) Direct generation of 400 Hz power by generators powered by aircraft-derivative turbines (in lieu of 60 to 400 Hz converters) was a principal factor in this accomplishment, While impressive weight savings at reasonable dollar cost were made, further conversion to 400 Hz usage would result in sharply increased costs, owing to the need for special equipment development.

(U) Trade-offs were made between GTG and equivalent diesel-powered generators, both with associated gear boxes, reduction gears, and other necessary equipment, and both operating at average ship electrical loads and with projected 1980 SFC's reflected in fuel flow rates. The results show that the break&en time for equal weights is at a mission duration of 25 days, beyond which diesel-powered generators show ever-increasing weight advantage with increasing mission duration. Comparable resuits with 30 percent over average load operation show a breakeven time of 20 days. The choice of GTG's therefore results in less weight for the anticipated SES-3 mission durations.

(U) A.4.2.4 AUXILIARIES -- Weight trade-offs were made of 12 air conditioning systems and equipment items. As a result of this study, a decentralized system was selected. This system divides the load into smaller serviced areas, each using packaged air conditioning units.

(U) Single centralized and multiple dedicated lube systems were analyzed on the basis of weight, cross contamination, cooling requirements, length of lines, bulkhead penetrations, reliability and redundancy. A multiple dedicated system was selected.

(U) The trade-offs for the potable and fresh water systems involved investigation of components and configurations possessing potential weight savings. Vacuum-assisted water closets and low water demand showers were selected. Weight was reduced through reduced quantities of collected and stored water via the drainage system and the reduced pumping capacity requirement. Further weight reduction was obtained by selecting advanced lightweight piping materials.

(U) A trade-off study was made to provide the design criteria and rationale for the most advantageous total flooding extinguishing agent. CO_2 and Halon 1301 extinguishing systems were compared and a Halon 1301 system was preferred over a CO_2 system for its lower weight and shorter discharge time.

(PI) Hydraulically-powered actuators, motors, and pumps were compared to electrical and pneumatic equipment on the basis of weight, cost, compatibility, installation requirements and operating environment. Trade-off comparisons indicated a weight saving of several tons by employing hydraulically-powered equipment. In some instances, the electric motor-driven actuators appeared so bulky and cumbersome as to be essentially impractical. In the case of high performance servo-driven devices such as the ride control valves, low inertia servo-motors with power ratings not readily obtainable would be required.

(U) A weight trade-off analysis for the marine sanitation device was made on the basis of a one-day operational period to disclose a weight saving through use of a no-discharge type compared to a flow-through type. A waste oil tank, sized for a 15-day mission provides storage of collected waste oil from machinery and equipment drains for subsequent disposal at a shore facility, thereby conforming to the zero oil discharge regulation.

(u) A.4.2.5 Outfitting, Furnishings, Survivability and Vulnerability -- Trade-offs were made for the insulation and protection (fire, thermal, acoustical and ballistic) of the aluminum structure. A rigid panel placed outside the frames was compared to a flexible blanket placed against the structure. The rigid panel design was selected because of:

- Ease of installation
- Reusability of panels after removal for inspection of structure
- Ease of modular panel replacement
- Elimination of separate sheathing and false ceilings
- Resistance to deterioration during normal shipboard use
- Efficient thermal protection of structure through utilization of an air gap between the panel and structure and a reflective surface facing the fire threat
- Elimination of insulating against fire for the cabling and piping systems.

(U) Contrariwise, the advantages of flexible blanket design are lower cost, slightly lower-weight, increased space and elimination of the hazard of fire penetration behind the insulation panel. However, the development of an effective and practical seal for panel joints to prevent fire penetration offset the advantages of flexible blanket design.

(U) The large amount of insulated and sheathed cabling and piping external to the flexible blanket design, coupled with the relatively close frame spacing of 3.0 ft (0.91 m), further minimized the increased space advantage of the flexible blanket design and imposed a weight and cost disadvantage.

(U) A.4.3 PERFORMANCE TRADE-OFFS -- Maximum performance of the selected design configuration was optimized with respect to:

a. Speed (at optimum trimmed attitude) with maximum continuous power.

b. Thrust/drag margin at hump speed with maximum intermittent power.

c. Range in head areas of 3.94 ft (1.2 m) significant wave height.

(U) Optimization of each of these performance factors involved selecting a best operating policy (i.e., the determination of operating trim and draft), lift system airflow settings, and seal adjustments within the latitude and constraints of the design. While this selection could be an n-dimensional optimization process of great complexity, only a limited number of major effects need be considered in practice. The key trade-offs are:

a. Trim and Draft for Least Drag -- Ship operating attitude for minimum drag is determined by comparing tank test data with analytically-derived relationships, The resulting policy is checked against system constraints to assure that the desired attitudes can be achieved with the available adjustments.

b. Lift System Optimization - Airflow distribution, pressure ratios and seal settings are optimized with empirical data in conjunction with analytical characterizations of the lift system. Individual policies for maximum speed (least drag) and maximum range are developed.

c. Optimum Cruise Speed - There is a speed and cushion air flow rate at which range is maximized for each vehicle weight between zero and 100 percent fuel. This speed is found recursively by a performance computer program that includes appropriate representation of drag, lift system, and propulsion system characteristics.

SECTION A.5

COMMENTS AND RESPONSES TO REVIEW OF SES-3 FINAL REPORT DRAFT

(U) The far term SES-3 point design concept was presented to ANVCE on 17 December 1976, at DTNSRDC, Carderock, Maryland. Formal comments were received by a Telecopier II copy of ANVCE letter PJM/dtw No. 178-6 dated 20 December 1976. The comments resulted in many, relatively small changes throughout the report. Formal responses to these comments are presented in this section.

(U) A.5.1 USE OF CS-19

COMMENT:

(U)' Because of the need to keep technology projections to as common a basis as possible all participants were asked to use the materials and material characteristics as documented in DTNSRDC Report MAT-74-18, "Material Information Profile." (See TLR Section 2.4.1)

(U)' CS-19 is currently under development at ALCOA. Since it is under development its properties cannot be stated with certainty (I believe there is some question as to the stress corrosion resistance of welded CS-19 plate, for example).' Possibly a variation of CS-19 may be more suitable and available by 1990.

(U)' Again, please use MAT-74-18 for material selection and if CS-19 is considered to provide a significant improvement in structural design, then provide the delta improvement in some tabular manner?'

RESPONSE:

(U) The weight delta is presently judged insignificant. Because of the relative importance of the structural data into the various computer mathematical models, assume that CS-19 materials are not used in the far term SES-3.

(U) A.5.2 ENGINE PERFORMANCE PROJECTION

COMMENT:

(U) "As you know, engine performance projection has been the downfall of many hardware projects, and it was felt that a common projection was needed for all ANVCE projected designs, This was done in ANVCE WP-011 "Standard Power Plant Characteristics for Advanced Naval Vehicles in the 1980-2000 Time Period." The curves in this Working Paper are mean values between future projections of P&W, GE and others. By using this common "ANVCE Standards" this would ensure that we were comparing concept differences as evidenced by differences in the platform and not due to individual projections of, say, engine performance projections.

(U) "Accordingly, as requested at the mid-term briefing please use the 1980 projection curve engine performance for far term SES performance. Note that engine envelopes and auxiliary equipment must be taken from projected engines but the performance is to be from WP-011."

RESPONSE:

(U) The propulsion system efficiencies were based upon an SFC value of 0.32, as read at a 60,000 hp (44.76 MW) value from the open cycle marine gas turbine curve for the year 2000 in Figure 3 of ANVCE WP-011, initial issue of 31 August 1976 (the latest revision available at Rohr). Re-examination at a 50,000 hp (37.30 MW) value resulted in a SFC of 0.325. A 1987 year value found by interpolation between 0.325 and 0.360 for year 2000 and 1980, respectively, is 0.345. Range corrections within the accuracies of the results can be readily made by multiplying the quoted ranges of this report by the ratio of a chosen SFC to the 0.32 value used in the predictions.

(U) Propulsion efficiencies are defined as the ratio of the product of thrust required times craft speed divided by the propulsion power required. The thrust required is the total of the SES aerodynamic and hydrodynamic drag forces without installed drag forces due to the propulsion

(U) system which are taken as a deduction from total thrust. The propulsion power required is the gross power available from the engines before any deductions are made for gearbox, pump, nozzle, or other losses.

(U) A.5.3 USE OF METRIC TONNES

COMMENT:

(U) "While the purity of "Newtons" is recognized from the SI System, a certain amount of common usage factors must be recognized in using the metric system. For example, the NATO countries which are on the metric system have agreed that for nautical use 'that speeds are quoted in "knots" and not "m/s" and that "tonnes" are acceptable measures of weight. Because of this common usage factor and the desire to minimize confusion as we ease into the metric system, it was decided early in the project to use "tonnes" in quoting weights, This was spelled out in ANVCE WP-002, Table 1, p.3 and clarified verbally at the mid-term."

RESPONSE:

(U) The "Standard for Metric Practice" (ASTM No. E380-76 and IEEE Standard No. 268-1975) has been approved for use by agencies of the Department of Defense and for listing in the DOD Index of Specifications and Standards, as well as being stipulated for use by ANVCE WP-002, Section II, wherein the units for force (Newtons) and mass (kilograms) are also cited. The latest revision at Rohr of WP-002 is the 2 April 1976, initial issue version received on 3 September 1976, and an identical copy received on 9 September 1976. Table 1 of Section II, however, cites deviations from SI usage in conversion examples of weight (force) units to both kilogram and "t" mass units, conformance to SI usage from horsepower to watts, and again deviations from SI usage to 'allowed and preferred" (but not required)" metric horsepower". Speed (p.5) has the m/s SI units correctly shown. Nowhere in WP-002 was required use of non-SI units specified. Section 3, "Application of the Metric System", of the ASTM No. E380-76 Standard specified the form of the metric system that is preferred for all applications. It states, in part, "...... the name 'ton' has been given to several large mass units that are widely used in commerce and technology -- the long ton

(U) of 2240 lb., the short ton of 2000 lb., and the metric ton of 1000 kg. (also called the 'tonne'). None of these terms are SI. The term metric ton should be restricted to commercial usage, and no prefixes should be used with it. Use of the term 'tonne' is deprecated". (Section 3.3.2) For such commercial usage, the Standard lists metric tons (t) in Table 2, "Units in Use with SI" (p. 15). Section 3.4.1.2 of the Standard is also pertinent to the application of SI units, It states, in part, 'In science and technology, the term 'weight of a body' has usually meant the force that.....would give it an acceleration equal to ths local acceleration of free fall.....it is important to use SI units properly by using kilograms for mass or Newtons for force".

(U) W'P-005 states (p. 1) that WP-002 shall be used "as a guide (for) both English and Metric Units", WP-005 adds confusion, however, by the example Table 2a "Weight Summary" (p. 7), which cites Short Tons and Metric Tons.

(U) The use of the ASTM No. E380-76 Standard in the present report follows the Rohr-submitted 'Guidelines and Assumptions" of 21 October 1976 in that:

a. WP-005 and WP-006 govern in the event of conflicts with other WP's.

b. The WP-006 version used is the Rohr-proposed modification of 25 October 1976.

c. All units are given in both English and SI equivalents.

d. Summary weight tables additionally provide both short and metric ton equivalents that follow the examples of Table 1 of WP-002 and Table 2a of WP-005.

(U) Subsystem weight tables were subsequently changed in the report as a result of an ANVCE requeet during the mid-term (17 December 1976) to include non-SI metric ton units in addition to that provided in the far term SES Final Report draft,

(U) NATO countries subscribing to the ASTM No, E380-76 Standard are cited among the forty-four (44) States that are members of "The International Bureau of Weights and Measures (BIPM) Metre Convention" as of 1 August 1975: Argentina, Australia, Austria, Brazil, Belgium, Bulgaria, Cameroon, Canada, Chile, Czechoslovakia, Denmark, Dominican Republic, Egypt, Federal Republic of Germany, Finland, France, German Democratic Republic, Hungary, India, Indonesia, Iran, Ireland, Italy, Japan, Korea, Mexico, The Netherlands, Norway, Pakistan, Poland, Portugal, Rumania, Spain, South Africa, Sweden, Switzerland, Thailand, Turkey, USSR, United Kingdom, USA, Uraguay, Venezuela, and Yugoslavia. Rohr is not aware of any agreement between the NATO countries that specifies exceptions to SI for nautical use. However, speeds are quoted in knots (English) and m/s (SI) as part of the dual dimensioning used throughout the report. "Tonnes" are not used, in conformance to the earlier cited deprecation in the Standard.

(U) A.5.4 HEAD WINDS AND SEA STATE

COMMENT :

(u) "There are several "standards" in use on winds and seas. These include the Marks Chart, Woods Hole Chart and the Oceanographic Chart - all slightly different. Most of these charts are old and do not have the advantage of the significant data collection techniques used in recent years. The Marks Chart, for example, assumes fully-arisen seas which is not a frequent occurrence for most scenarios.

(U) "The ANVCE criteria has been based on the Hogben and Lumb charts where the probability of certain significant wave heights occurring has been matched to the probability of certain winds occurring. It is felt that in that manner a more realistic representation of the most likely combination of wind and waves is included rather than the artificial assumption of fully arisen seas. It is asked that ANVCE WP-010 be used in quoting the sea state performance."

RESPONSE:

(u) Figure A.5.4-1 is a comparison of significant wave heights occurring with the winds presented in WP-011, the winds for the Pierson-Moskowitz (P-M) spectrum for the same WP-011 wave/wind frequencies of occurrence conditions, and the spectrum from which Rohr's (Mark's table) data were calculated.

(U) Since the Pierson-Moskowitz spectrum can be defined in terms of wind speed for each sea state, and since the significant wave height is related to the integral of the spectrum, a definite relationship exists between wind speed and significant wave height. This relationship can be expressed as:

$$H_{1/3} = (1.856 \times 10^{-2})(U_{K_{1/3}})^2,$$

for a percentage of occurrence of 13.5 percent.

(U) Using a Rayleigh distribution of:

$$U_K = \left[(\tfrac{1}{2}) \ln \frac{1}{P}\right]^{\frac{1}{2}} U_{K_{1/3}},$$

and the percent occurrence given in WP-011, provides the P-M curve in Figure A.5.4-1. These data embody the assumption of associated winds measured at a height of 28 feet (14.4 m) above the water surface. This curve closely approximates the curve with the UP-011 data at wave heights up to 30 feet (9.1 m).

(U) In comparison, similar data from Rohr's (Mark's Table) Table A.5.4-1 show a more severe wind-wave height combination than UP-011 up to wave heights of 10 feet (5.1 m). Therefore, the quoted SES performance speed and range performance values are conservative. Only in waves higher than 10 feet (5.1 m) are less performance values indicated and the differences are well within two percent.

Table A.5.4-1. WIND AND SEA SCALE FOR FULLY ARISEN SEA

SEA GENERAL		WIND (3)				SEA (3)								
SEA STATE (1)	DESCRIPTION (2)	(BEAUFORT) WINDFORCE	DESCRIPTION	RANGE (KNOTS)	WIND VELOCITY (KNOTS) (a)	WAVE HEIGHT FEET: AVERAGE	WAVE HEIGHT FEET: SIGNIFICANT	WAVE HEIGHT FEET: AVERAGE 1/10 HIGHEST	SIGNIFICANT RANGE OF PERIODS (SECONDS)	T_{max} (PERIOD OF MAXIMUM ENERGY OF SPECTRUM)	$\bar{T}$ (AVERAGE PERIOD)	$\bar{L}$ (AVERAGE WAVE LENGTH)	MINIMUM FETCH (NAUTICAL MILES)	MINIMUM DURATION (HOURS)
0	SEA LIKE A MIRROR.	0	CALM	LESS THAN 1	0	0	0	0	—	—	—	—	—	—
	RIPPLES WITH THE APPEARANCE OF SCALES ARE FORMED, BUT WITHOUT FOAM CRESTS.	1	LIGHT AIRS	1 – 3	2	0.05	0.08	0.10	UP TO 1.2 SEC.	0.7	0.5	10 IN.	5	18 MIN.
1	SMALL WAVELETS, STILL SHORT BUT MORE PRONOUNCED; CRESTS HAVE A GLASSY APPEARANCE, BUT DO NOT BREAK.	2	LIGHT BREEZE	4 – 6	5	0.18	0.29	0.37	0.4–2.8	2.0	1.4	6.7 FT	8	39 MIN
	LARGE WAVELETS, CRESTS BEGIN TO BREAK. FOAM Of GLASSY APPEARANCE PERHAPS SCATTERED WHITE HORSES.	3	GENTLE BREEZE	7–10	**8.5**	0.6	1.0	1.2	0.8–5.0	3.4	2.4	20	9.8	1.7 HRS
					10	0.88	1.4	1.8	1.0–6.0	4	2.9	27		2.4
2	SMALL WAVES, BECOMING LARGER; FAIRLY FREQUENT WHITE HORSES.	4	MODERATE BREEZE	11–16	12	1.4	2.2	2.8	1.0–7.0	4.8	3.4	40	18	3.8
					13.5	1.8	2.9	3.7	1.4–7.6	5.4	3.9	52	24	4.8
3					14	2.0	3.3	4.2	1.5–7.8	5.6	4.0	59.	28	5.2
					16	2.9	4.6	5.8	2.0–8.8	6.5	4.6	71	40	6.6
4	MODERATE WAVES TAKING A MORE PRONOUNCED LONG FORM; MANY WHITE HORSES ARE FORMED. (CHANCE Of SOME SPRAY).	5	FRESH BREEZE	17–21	18	3.8	6.1	7.8	2.5–10.0	7.2	5.1	90	55	8.3
					19	4.3	6.9	8.7	2.8–10.6	7.7	5.4	99	65	9.2
					20	5.0	8.0	10	3.0–11.1	8.1	5.7	111	75	10
5	LARGE WAVES BEGIN TO FORM; THE WHITE FOAM CRESTS ARE MORE EXTENSIVE EVERYWHERE. (PROBABLY SOME SPRAY).	6	STRONG BREEZE	22–27	22	6.4	10	13	3.4–12.2	8.9	6.3	134	100	12
					24	7.9	12	16	3.7–13.5	9.7	6.8	160	130	14
					24.5	8.2	13	17	3.8–13.6	9.9	7.0	164	140	15
6					26	9.6	15	20	4.0–14.5	10.5	7.4	188	180	17
	SEA HEAPS UP AND WHITE FOAM PROM BREAKING WAVES BEGINS TO BE BLOWN IN STREAKS ALONG THE DIRECTION OF THE WIND. (SPINDRIFT BEGINS TO BE SEEN).	7	MODERATE GALE	28–33	28	11	18	23	4.5–15.5	11.3	7.9	212	230	20
					30	14	22	28	4.7–16.7	12.1	8.6	250	280	23
					30.5	14	23	29	4.8–17.0	12.4	8.7	258	290	24
					32	16	26	33	5.0–17.5	12.9	9.1	285	340	27
7	MODERATELY HIGH WAVES OF GREATER LENGTH; EDGES Of CRESTS BREAK INTO SPINDRIFT. THE FOAM IS BLOWN IN WELL MARKED STREAKS ALONG THE DIRECTION Of THE WIND. SPRAY AFFECTS VISIBILITY.	8	FRESH GALE	34–40	34	19	30	38	5.5–18.5	13.6	9.7	322	420	30
					36	21	35	44	5.8–19.7	14.5	10.3	363	500	34
					37	23	37	46.7	6–20.5	14.9	10.5	376	530	37
					38	25	40	50	6.2–20.8	15.4	10.7	392	600	38
					40	28	45	58	6.5–21.7	16.1	11.4	444	710	42
8	HIGH WAVES. DENSE STREAKS OF FOAM ALONG THE DIRECTION OF THE WIND. SEA BEGINS TO ROLL. VISIBILITY AFFECTED.	9	STRONG GALE	41–47	42	31	50	64	7–23	17.0	12.0	492	830	47
					44	36	58	73	7–24.2	17.7	12.5	534	960	52
					46	40	64	81	7–25	18.6	13.1	590	1110	57
	VERY HIGH WAVES WITH LONG OVERHANGING CRESTS. THE RESULTING FOAM IS IN GREAT PATCHES AND IS BLOWN IN DENSE WHITE STREAKS ALONG THE DIRECTION OF THE WIND. ON THE WHOLE THE SURFACE Of THE SEA TAKES A WHITE APPEARANCE. THE ROLLING Of THE SEA BECOMES HEAVY AND SHOCK-LIKE. VISIBILITY IS AFFECTED.	10	WHOLE GALE *	48–55	48	44	71	90	7.5–26	19.4	13.8	650	1250	63
					50	49	78	99	7.5–27	20.2	14.3	700	1420	69
					51.1	52	83	106	8–28.2	20.8	14.7	736	1560	73
					52	54	87	110	8–28.5	21.0	14.8	750	1610	75
					54	59	95	121	8–29.5	21.8	15.4	810	1800	81
9	EXCEPTIONALLY HIGH WAVES (SMALL AND MEDIUM-SIZED SHIPS MIGHT FOR A LONG TIME BE LOST TO VIEW BEHIND THE WAVES.) THE SEA IS COMPLETELY COVERED WITH LONG WHITE PATCHES OF FOAM LYING ALONG THE DIRECTION Of THE WIND. EVERYWHERE THE EDGES OF THE WAVE CRESTS ARE BLOWN INTO FROTH. VISIBILITY AFFECTED.	11	STORM *	56–63	56	64	103	130	8.5–31	22.6	16.3	910	2100	88
					59.5	73	116	148	10–32	24	17.0	985	2500	101
	AIR FILLED WITH FOAM AND SPRAY. SEA COMPLETELY WHITE WITH DRIVING SPRAY; VISIBILITY VERY SERIOUSLY AFFECTED	12	HURRICANE *	64–71	>64	(b) ·80	(b) ·128	(b) ·164	10–(35)	(26)	(18)	~	~	~

NOTES

(a) A HEAVY BOX AROUND THIS VALUE MEANS THAT THE VALUES TABULATED ARE AT THE CENTER OF THE BEAUFORT RANGE.

(b) FOR SUCH HIGH WINDS, THE SEAS ARE CONFUSED. THE WAVE CRESTS SLOW Off, AND THE WATER AND THE AIR MIX.

REFERENCES

(1) MANUAL OF SEAMANSHIP, VOLUME II. ADMIRALTY, LONDON, H.M. STATIONERY OFFICE, 1952, pp. 717-718

(2) ENCYCLOPEDIA Of NAUTICAL KNOWLEDGE, W.A. McEWEN AND A.H. LEWIS. CORNELL MARITIME PRESS, CAMBRIDGE, MD., 1953, p. 483

(3) PRACTICAL METHODS FOR OBSERVING AND FORECASTING OCEAN WAVES, PIERSON, NEUMANN, JAMES. N.Y. UNIV. COLLEGE Of ENGIN. 1953.

* FOR HURRICANE WINDS (AND OFTEN WHOLE GALE AND STORM WINDS) REQUIRED DURATIONS AND FETCHES ARE RARELY ATTAINED. SEAS ARE THEREFORE NOT FULLY ARISEN.

Adapted from Material Originally Prepared by Wilbur Marks, David Taylor Model Basin, With Added Data by M. Shin.

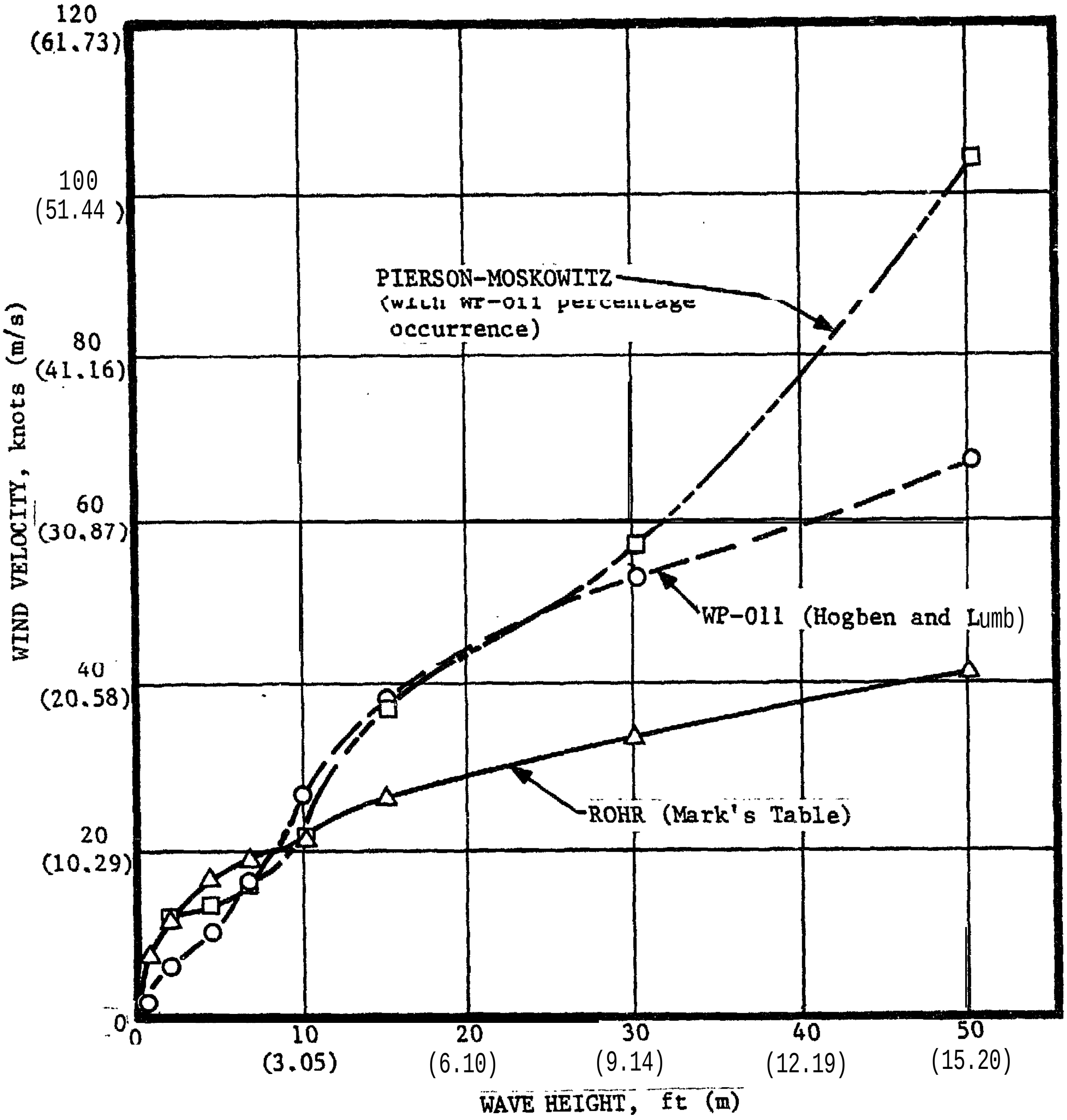


Figure A.5.4-1 (U). Sea State Definitions (U).

(U) A.5.5 PROPULSIVE EFFICIENCY

COMMENT:,

(U) "The most startling item that must have back-up presented is how has the **waterjet** achieved increasing efficiency at **120 knots** without running into cavitation boundaries and choking limits. Since it has taken years of development to make the **waterjet** function properly at 70 knots, this is a technical risk area that needs strong documentation.

(U) "As a corollary, it is noticed that a similar curve is presented for the near term SES design which further increases the risk. Is **this** the assumption for the LSES?

(U) "The definition of "thrust efficiency" on Figure 2.2.1-5(c) needs to be explained."

RESPONSE:

(U) The **waterjet** projected improvements to the far term time frame are based on current S-O-A technology results shown in the response Section A.5.11. Thrust efficiency is defined in the text of Section 2.2.1.

[redacted] **The** 60 percent propulsive efficiency is projected on the basis of the following propulsive coefficient (P.C.) definition:

$$\text{PC} = \frac{(\text{Drag}) \times (\text{Velocity})}{(\text{Engine Power}) \times 550 \times (\text{Transmission Efficiency})}$$

at a thrust/drag intersection. A typical point at 120 knots with 352,800 lbs drag force, an engine power of 53,909 hp and a transmission efficiency of 0.99, gives:

$$\text{PC} = \frac{(352{,}800)\times(120)\times(1.689)}{(53{,}909)\times(4)\times(550)\times(0.99)} = 0.609$$

[redacted] A 53,909 shp value is required to maintain 120 knots (Rohr **waterjet** program results). Based on engine power, the PC would be 0.609 (0.99) = 0.603.

[redacted] The inlet drag force for the SES-3 negative drop fraction inlet is based on pressure integration of aerodynamic model test data for a fixed area inlet with a 14 ft^2 area operating at an **IVR** of 0.255 and results in an inlet opening drag force projection of -11,153 lb (thrust direction). The inlet drag has yet to be confirmed. Drag and recovery tests in water of three inlet configurations *are* scheduled during the first year of the **3KSES** program to verify these preliminary wind tunnel results. If the inlet drag were zero, the resultant PC would be further reduced to 0.584.

[redacted] The 3KSES **variable** ramp roof inlet drag projection for the 0.5 drop fraction is approximately 15,500 lb. in the drag direction. If this projection **were** used, the PC would be reduced to 0.557. Other effects are the result of an overall ship drag reduction of 10 percent for the year 1987; These factors combined with an increase in pump efficiency from 88.6 to an estimated 90.0 percent were used to provide the projected results in Figure 2.2.1-S as presented.

(U) A.5.6 SPEED

COMMENT:

~~(C)~~ 'The TLR issued from the ANVCE Project Office established 70 knots as the required speed. Even if this were interpreted as "70 knots minimum", it still is a long way from designing a 106 knot ship - a 50 percent increase in speed with installed power ramifacations, even accounting for high propulsive efficiency, that is too excessive. It is felt that the costs associated with the spiralling increase in gross weight and power will adversely affect the evaluation. If it is too late to recycle the design back to the TLR requirements, it is requested that some delta effect calculation be made to show what a "70 knot SES" would have been,"

RESPONSE:

~~(C)~~ The TLR specified the speed as follows:

> "3.1.3 .SPEED -- Cruise speed shall be 70 knots (129.6 km/hr) minimum under the following conditions:
>
> Significant Wave Height 3.94 Ft (1.2 m)
> (Average of 1/3 Highest; Head Seas)
>
> Air Temperature 80°F (26.7°C)"

~~(C)~~ The TLR also specified the range as:

> "3.1.4 RANGE -- Range will be 3500 nautical miles (6482 km) minimum...."

under the same environmental conditions as just cited for speed.

[redacted]) There was no TLR paragraph which established 70 knots as any required speed, except as a minimum cruise speed. The consequence of higher transport efficiencies at speeds higher than 70 knots, the range requirement of 3500 nm, and the need to provide minimum ship displacement resulted in the present SES-3 design which meets the range requirement and exceeds the minimum speed requirement. Operation of the SES-3 at lesser speeds than stipulated for the ranges quoted will result in less range by the ratios of the resulting transport efficiencies to those used in the projections.

(U) A.S.7 RIDE QUALITY CRITERIA

COMMENT :

(U) The subject of ride quality will continue to be in debate for many years. Some groups say RMS g's in the 1/3 octave should be used, some say the complete octave should 'be used -- still others say RMS g is the wrong measure anyway. Most of the data collected to date is based on sinusoidal vibration under laboratory conditions, yet we know that the sea is a spectrum of random frequencies. Some limited tests show that "subjects" perform better under random vibration - other just as reliable data source8 show that they perform worse.

(U) The point is that while this subject is being worked (and the ANVCE . Project Office is doing this) a consistent set of criteria had to be levied on all designers for consistency. The ANVCE criteria is taken from the ISO curves for high frequency where "fatigue decreased proficiency" is probably the dominant factor and from the O'Hanlon and McCauley data for the low frequency where motion sickness is probably the dominant factor.

(U) It is asked that the criteria issued in the TLR be used for comparing data. If it is felt that you have prepared other criteria that would benefit ANVCE this would be most welcome to aid us in this complex issue.

(U) {It was agreed at the 17 December 1976 meeting that such a report done under contract to PMS-304 would be made available to OP-96V.)"

RESPONSE:

(U) Both the ANVCE and Rohr ride criteria are given in the report in Section 2.2.7. That section contains a brief description of extensive ride criteria studies made by Rohr that are summarized in:

> "Ride Criteria Study Final Analysis Report", Rohr Industries, Inc., Document No. DSWZ6S00D02, dated 26 February 1976 (CDRL No. S00D(Z-6); Rohr Data Bank No. AP2-004180.

(U) The report contains some 160 references and is the justification for preference of the Rohr ride criteria over others proposed as "standards", However, in presenting ride quality data, performance comparisons are shown with both ride criteria (Rohr and ANVCE specified).

(U) A.S.8 RIDE CONTROL POWER REQUIREMENTS

COMMENT :

(U)'Tables or curves of power requirements to suppress the ride to within the ride quality criteria limits need to be supplied for a set of consistent conditions.

(U)'Specifically, Table 2.2.7-1(U) provides power requirements for speed and wave height conditions different to the acceleration reductions shown in Figure 2.2.7-14(U). These need to be matched."

RESPONSE:

(u) The tabular power settings presented were revised in the body of the report to present consistency between the tabular values and the corresponding graphs. The power requirements are, in part, related to the lift fan design. The latest Rohr studies are reported in:

> "Lift Fans Commonality Tradeoff Study Report, Volumes 1 and 2", Rohr Industries, Inc., Document No, DL2S00301 (CDRL No. S003(L-2)A), dated 27 May 1975.

(U)The report contains tradeoff study results for three centrifugal type fans:

a. ALRC Lift Fan with variable geometry

b. Westinghouse Jet-Flap with variable geometry

c. NSRDC Circulation Control Fan

(U) A presentation was also made on SES lift fan characteristics by Aerojet Liquid Rocket Company (ALRC) to NSESPO (PMS-304) during September 1972 which compared centrifugal, mixed, and axial flow fan designs. A copy of this presentation has been separately sent to Mr. P. J. Mantle, ANVCE.

(U) A.5.9 MANNING

COMMENT:

(U)' ANVCE manning in the TLR was 140. The Rohr mannin[illegible] 141) needs to be revised."

RESPONSE:

(U) Per ANVCE direction at the 17 December 1976 meeting, one SH3 enlisted person was removed to meet the 140 ANVCE specified manning (in a TLR revision not available at Rohr).

(U) A further question at the 17 December 1976 meeting related to "comparable" FFG manning of 177 and to justification of the difference with respect to the Fleet Tender requirements incident to the Rohr Maintenance Support concept.

(U) With a limited amount of evaluation, a manning delta estimate has been developed- for the off-ship maintenance requirements. Considering the future state-of-the-art in shipboard maintenance, these are estimates of the required augmentation to the far term SES Ship Crew to accomplish maintenance on board which had been planned to be accomplished at the intermediate shore facility/tender.

(U) The off-ship maintenance requirements that are required for the far term SES in support of the Maintenance Concept depicted in Section 3.2 of this report, have been derived as the representative requirements if this maintenance were to be performed by the ship's crew. The representative estimates are those required utilizing the Navy Standard Workweek afloat, and within the guidance contained in the "Guide to the Preparation of Ship's Manning Documents", OPNAV 10P-23.

(U) These estimated manpower requirements,' when combined with the developed far term SES Organization Manning, as presented in Appendix A2.12,

(U) are sufficient for performing the organizational and that organizational level maintenance transferred to a intermediate level activity for accomplishment. These skills are not a one-for-one transfer to a tender/ashore activity for performance of the maintenance. The specific skill task requirement would be incorporated into the appropriate Intermediate Mainteannce Activity and, with all other parameters considered, a specific billet would be developed.

(U) The representative maintenance requirements are summarized with the organizational manning requirements as follows:

	OFFICERS	CPO	OTHER ENLISTED	TOTAL
Far Term SES Organizational Manning	17	13	110	140
Delta Vehicle (Ship)	01	02	23	26
Delta Vehicle (Combat System)	01	01	09	11
Delta Secondary Vehicle Team	0	0	0	0
TOTAL	19	16	142	177

(U) The onboard facilities (i.e., storerooms, maintenance shops, office spaces, and accommodations) have not been increased to accommodate the support requirements for this estimated maintenance increase.

(U) A.5.10 TURNING RADIUS

COMMENT:

(U)'A clarification is needed in Figure 2.2,2-1(U) as to the speed, Is it the speed entering the turn that goes with the radius quoted or the average speed in the turn? If it is the average speed, what are the entering and leaving speeds?'

RESPONSE:

(U) The speed shown is the speed entering the turn, not the average speed in. the turn. The speeds in the figure are steady-state equilibrium speeds maintained in the turn,

(U)A.5.11 WATERJET DESIGN

COMMENT:

(U)"It was agreed at the 17 December 2976 review that appendix material would be added to the final report to explain how a variable area inlet is not required for the far term SES."

RESPONSE:

(U)The fixed round duct watorjet inlet performance is based on wind tunnel test results reported in "Interim Summary Report", D002, dated 10 December 1976, pages 8-47 through 8-51, which was recently delivered to PMS-304. The incipient cavitation velocities were based on the minimum static pressures measured by static pressure taps located along the inlet ramp roof, internal lip, and external lip. Pressure coefficients (C_p) were formulated as shown in Figure 8.1-24C and equated to the incipient cavitation index number σ_i such that,

$$(-C_p) = \sigma_i$$

where,

$$\sigma_i = \frac{P_{S\infty} - P_{Svapor}}{q_c}$$

$P_{S\infty} = 2116.8$ psfa

$P_{Svapor} = 36.7$ psfa

and,

$$4\,, = \frac{\rho U_c^2}{2}(1.6878)^2$$

$\rho = 1.99$, mass density of sea water

$U_c =$ Incipient Cavitation speed - knots

Then,

$$U_c = \frac{(2116.8-36.7)2^{\frac{1}{2}}}{(1.6878)\ (-\rho C_p)^{\frac{1}{2}}} = \frac{27.0899}{(-C_p)^{\frac{1}{2}}}$$

(U)The minimum cavitation inception speed envelope was further **corrected** for submergence **depth to** result in Figure **8.1-24D.** Load **lines,** based on maximum propulsor efficiency, were superposed for 40,000 and 27,000 shaft horsepower as shown in this figure.

(U)**Pages** 8-47 through 8-51 of the aforementioned report show a load line for 60,000 shaft horsepower superposed in Figure **8.1-24D.** This was not included in the delivered report which was aimed at the **3KSES** for operation with **FT9** gas turbine engines. For 60,000 shaft horsepower, cavitation-free operation can **be** achieved at speeds between 14 and'103 knots. Below 14 knots, power must be reduced for **cavitation-**free operation. In the 1980-2000 calendar year time period, further **modifications** to the ramp and lip shapes could push the maximum speed **limit** into the 120 knot region.

(U)**Figure** 8.1-22 shows photographs of the l/20-scale round duct inlet tested in the wind tunnel at Rohr. It shows a portion of the inboard fence used to **provent** cushion **air** from being ingested by the inlet. Figure 8.1-23 shows the transition of the inlet cross-sectional geometry from the inlet ramp tangency point with the keel line into the round duct section.

(U)**The** November extension task required that a fixed area round duct inlet be fabricated for l/20-scale wind tunnel tests. The model has a full scale area of 14 square feet and included an inboard anti-air ingestion fence. Photographs of this inlet are shown in Figure 8.1-22. The inlet geometry is shown in Figure 8.1-23. (Note **in** the figure that:

1. **All** sections are rotated to vertical position and inlet duct CL is 27.36 in. from ship C_L (EL 45'6" full scale). ,
2. Duct sections are **circular** from Section N-N to interface with bifurcated duct.
3. Lower surface of lip is a conical surface of a cone with an included angle of 74½ degrees at the apex, as shown in Section P-P.

(U) 4. Lower lip center line contour from Section L-L to Section N-N is maintained ±50 degrees from C_L of duct (see Section L-L), then fairs linearly into side wall at horizontal line through duct C_L.)

(U)The results of testing the round duct inlet in the Rohr wind tunnel are shown in Figure 8.1-24. New ramp tangency point measurements were taken in the X and Y direction to account for sidehull fence effects. These were mass flow weighted to determine the average velocity in stream tubes ahead of the inlet for various IVR's. The loss coefficients shown in Figure 8.1-24B are based on these velocities at the ramp tangency point. They are quite low due to the effect of the thicker boundary layer. Figure 8.1-25 shows the graph of A_i X IVR versus $\bar{q}/q_\infty$ used in the calculation of total head at the ramp tangency point. The definition of loss coefficient by Rohr and other experimenters and the effects of boundary layer on them are discussed in Appendix A of the cited aforementioned report.

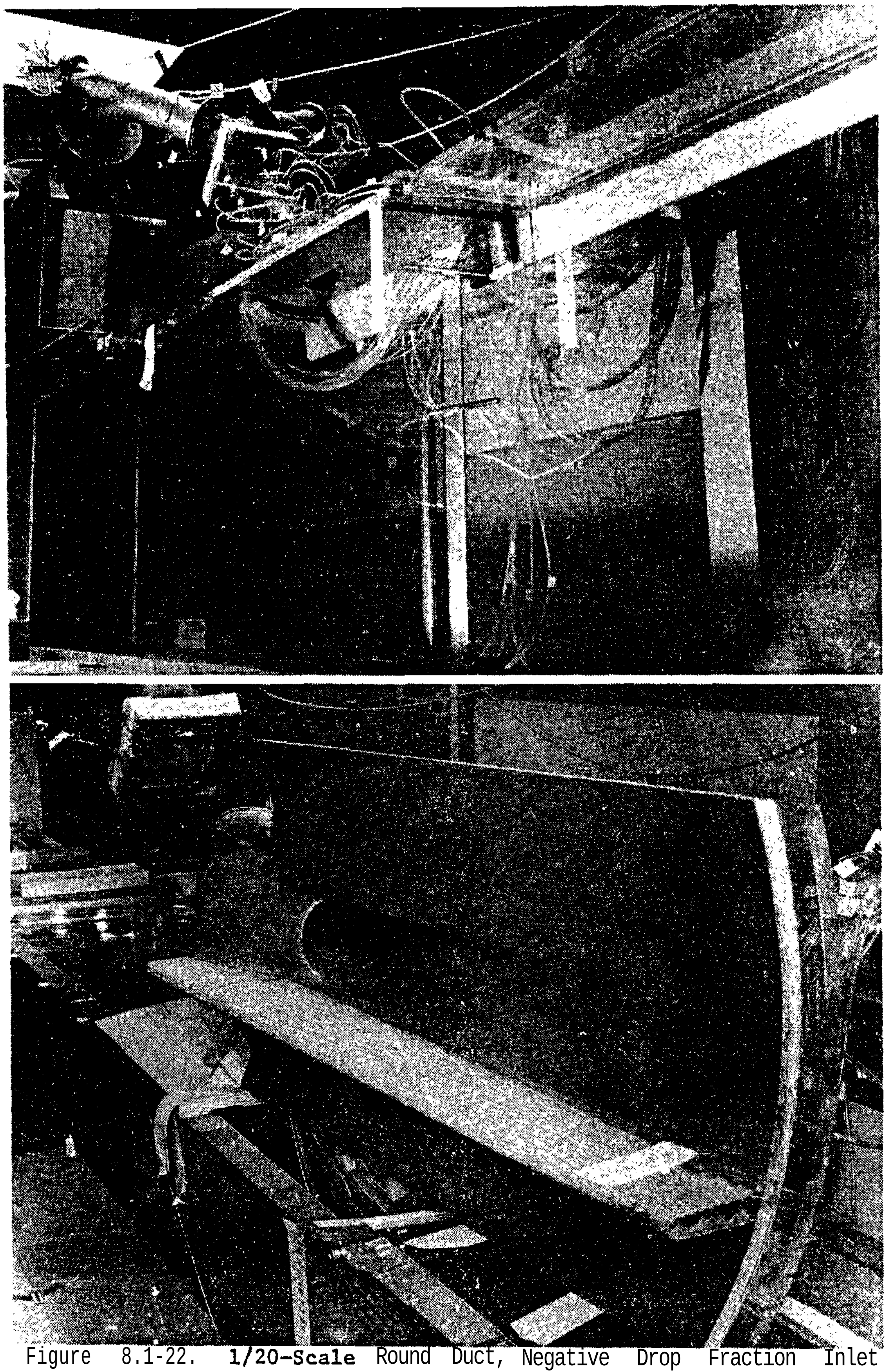
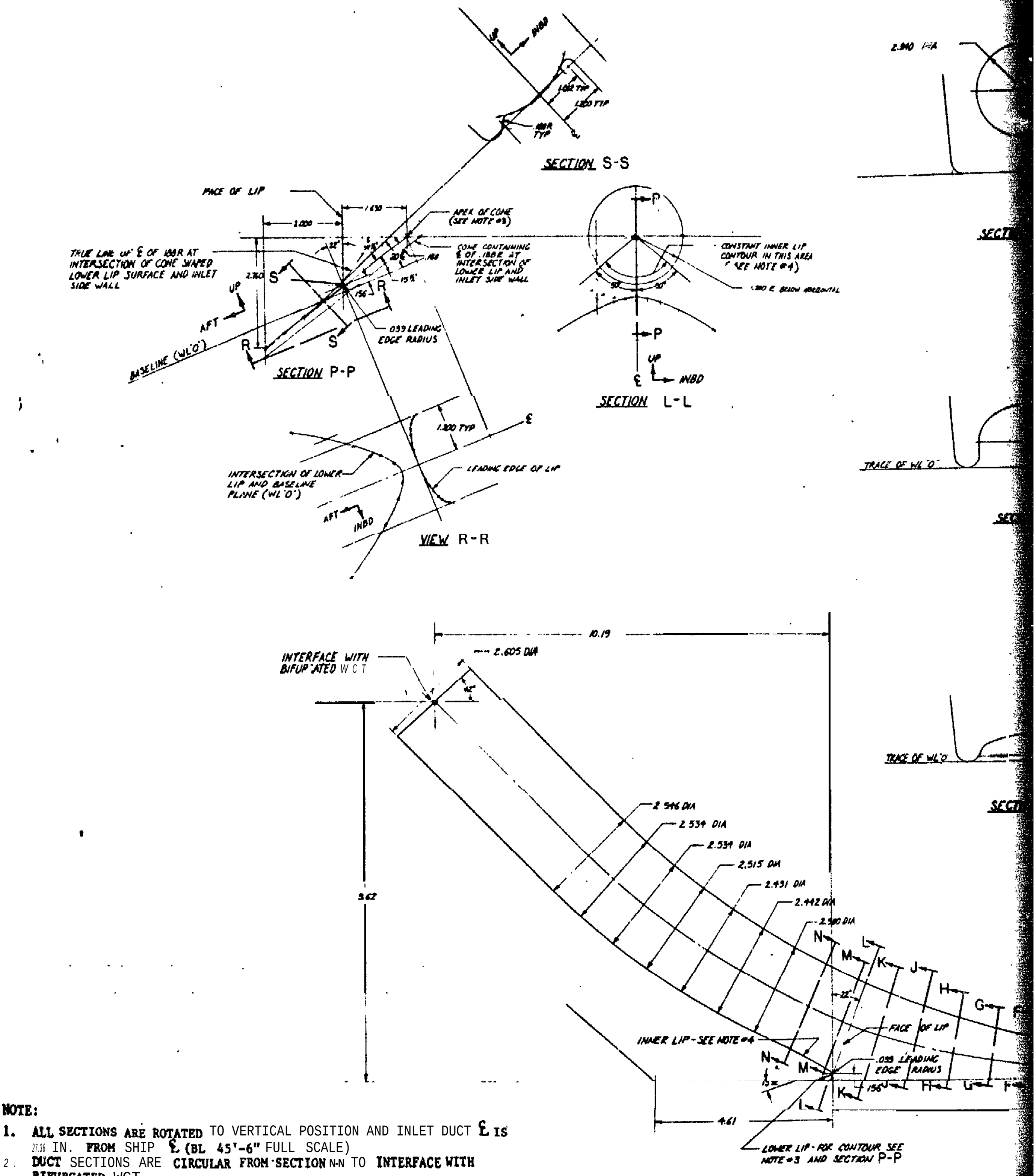


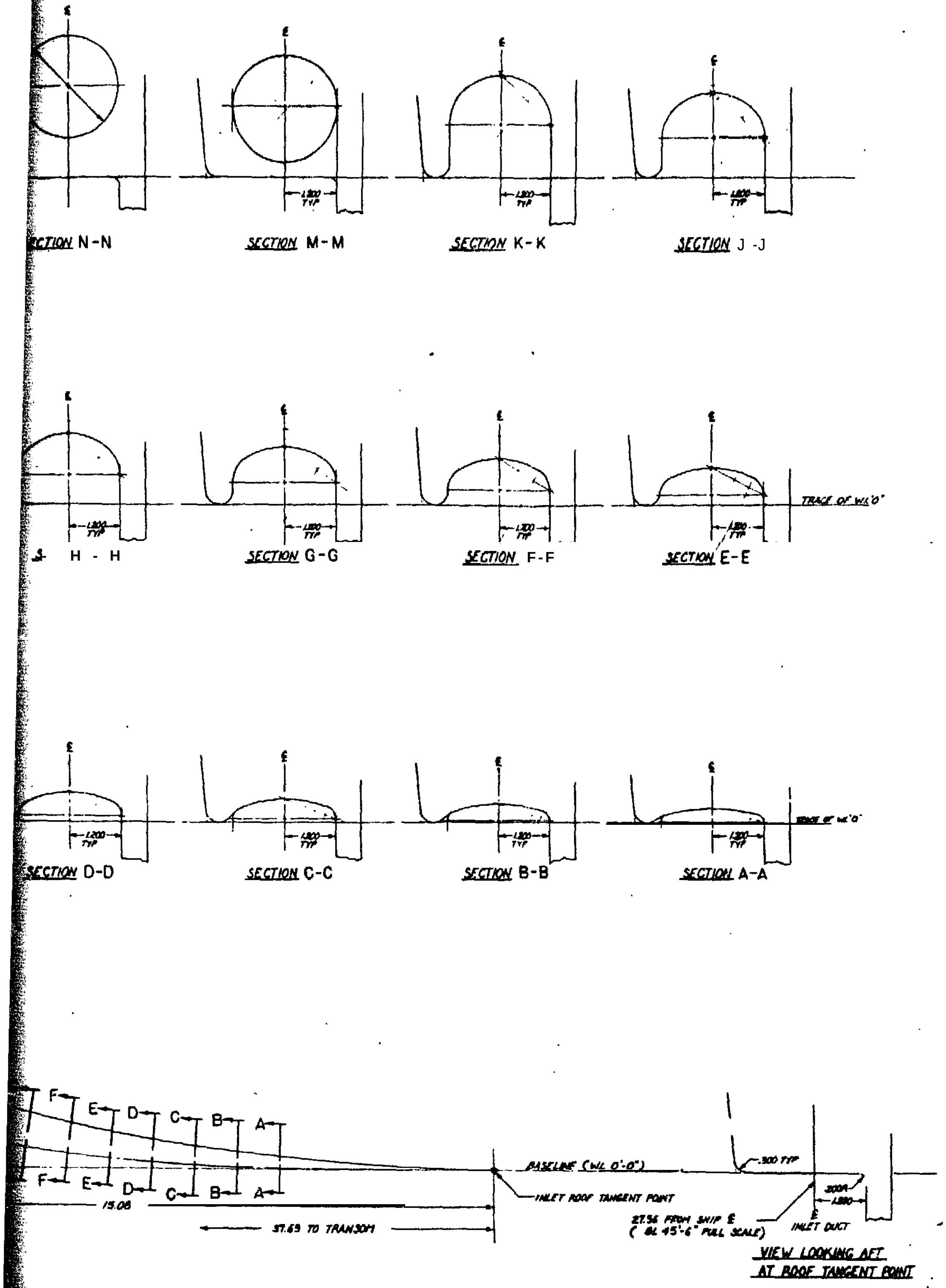
Figure 8.1-22. **1/20-Scale** Round Duct, Negative Drop Fraction Inlet Wind Tunnel Model



NOTE:

1. ALL SECTIONS ARE ROTATED TO VERTICAL POSITION AND INLET DUCT ℄ IS 27.36 IN. FROM SHIP ℄ (BL 45'-6" FULL SCALE)
2. DUCT SECTIONS ARE CIRCULAR FROM SECTION N-N TO INTERFACE WITH BIFURCATED WCT
3. LOWER SURFACE OF LIP IS A CONICAL SURFACE OF A CONE VITH AN INCLUDED ANGLE OF 741/2" AT THE APEX, AS SHOWN IN SECTION P-P
4. INNER LIP CENTER LINE CONTOUR FROM SECTION L-L TO SECTION N-N IS MAINTAINED ± 50 FROM ℄ OF DUCT (SEE SECTION L-L), THEN FAIRS LINEARLY INTO SIDE WALL AT HORIZONTAL LINE THRU DUCT ℄.

Figure 8.1-23 (U). Waterjet
Negativ



et Inlet Lines - Round Duct,
ve Drop Fraction

2

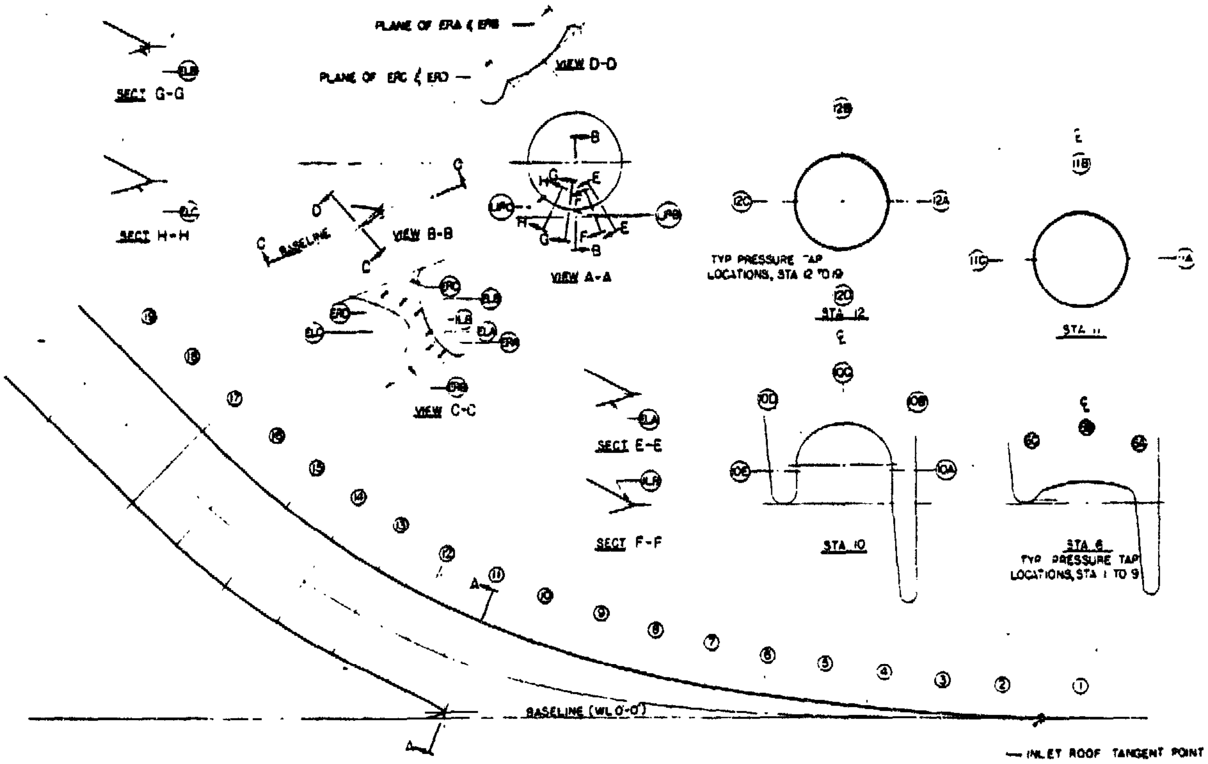


Figure 8.1-24A. **Waterjet** Inlet-Round Duct, Negative Drop Fraction

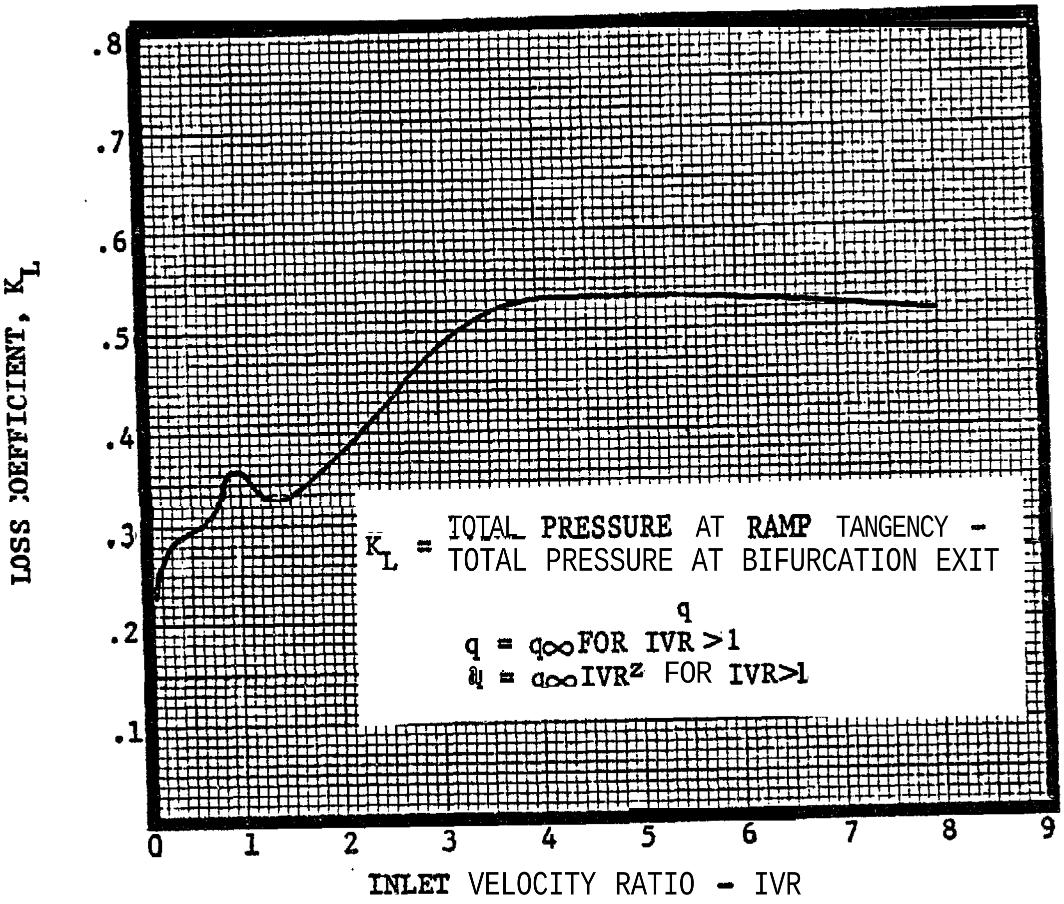


Figure 8.1-24B. Loss Coefficient Versus Inlet Velocity Ratio

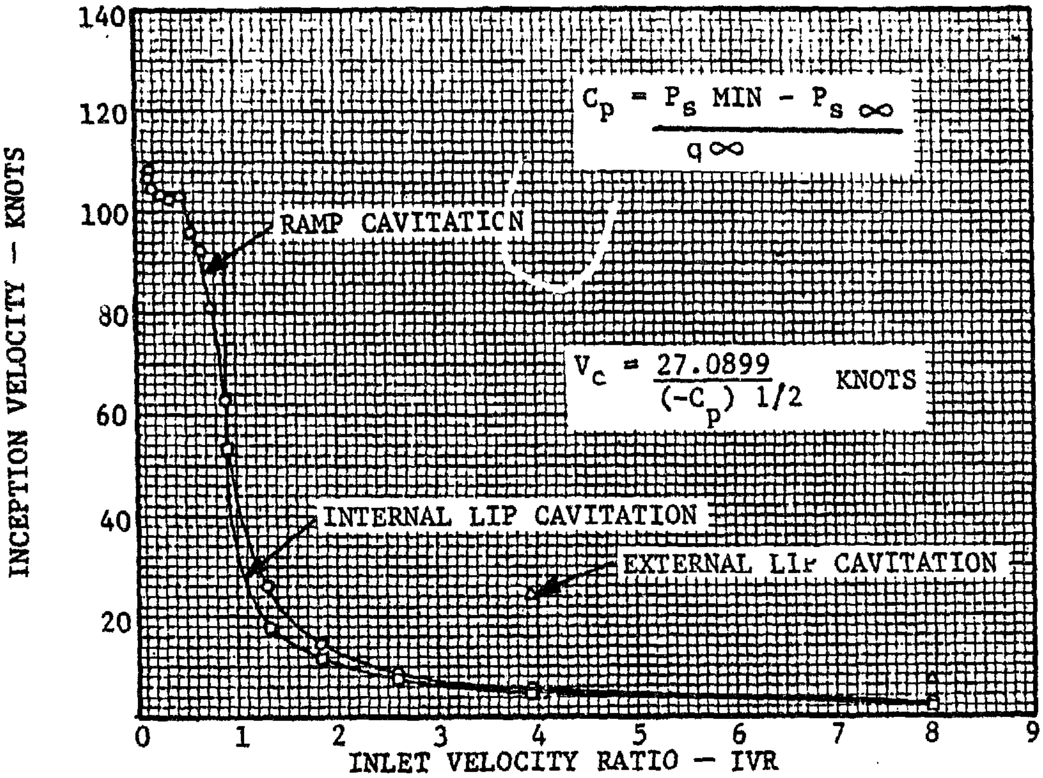


Figure 8.1-24C. Inlet Cavitation Inception Velocity

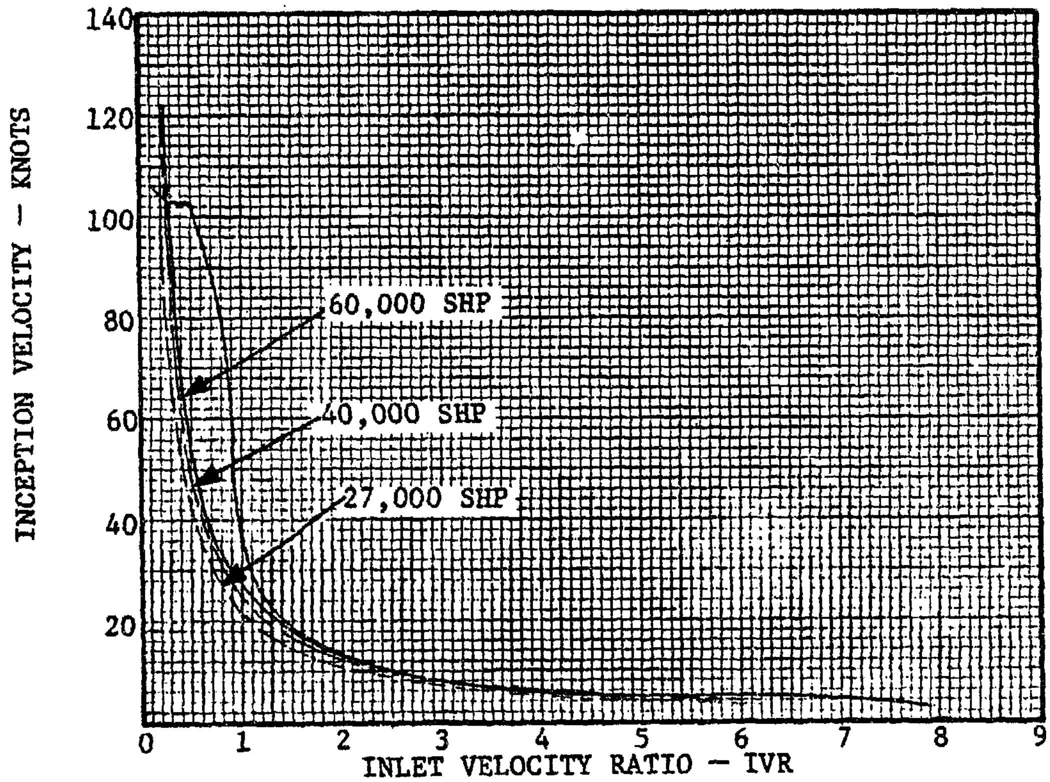


Figure 8.1-24D. Inlet Cavitation Inception Velocity Corrected for Submergence Depth, with Load Lines at Maximum Pump Efficiency

(U) A.5.12 OPERATIONAL ENVELOPE

COMMENT:

(u) " Figure 2.2.1-7(C) provided the performance envelope in wave height and speed as limited by the power and increased resistance for travelling in waves.

(U) " It was agreed that boundaries of (a) structural limits, and (b) ride quality limits would be superimposed on Figure 2.2.1-7(C).

(U) " Also, it looks like the 'metre scale' slipped on the Figure and needs to be checked."

RESPONSE:

(U) Ride control "on" and structural/seals limit lines were added to the figure. The metre scale was corrected.

(U) A.T.13 PROPELLER DRIVEN OPERATIONAL, ENVELOPE

COMMENT:

(U) "Something looks garbled on the vertical scale for expressing wave height and needs to be corrected."

RESPONSE:

(U) The semi-log plot was revised to show a background grid in the field of the graph.

(U) A.5.14 SEAL SYSTEM

COMMENT :

(U)"The planar bow (and stern) seal feature is a new feature and as presented did not show any testing substantiation. Current "bag and finger" seals have a low life, say 400-500 hours at 50 knots and considerably less projected for 80-100 knots. The planar seal was stated to have 10,000 hour lift (at 100 knots?). What testing, analysis or other information can be presented to give some measure of confidence in these projections? "

RESPONSE:

(U) The 10,000 hour life at 100 knots is for the glass reinforced plastic (GRP) components only. Other components of the seals, such as the bag material and the straps and cables, would probably have somewhat shorter lives.

(U) The projected GRP life is an extrapolation of the present state-of-the-art. The projection is based upon developments in materials technology and improvements in the stress analysis of the planer system. The primary development in GRP technology that is predicted is a decrease in the amount of strength lost after extended sea water immersion, (1) permitting the application of higher design allowables in the manufacture of the planers to result in a lower over-all weight, and (2) indicating that the planer will have a longer life, Improvements in the stress analysis, through the development of improved loads data, will result from the operation of manned SES's that use the advanced planing seals. The improved stress analysis also allows the design of lower weight planers or the prediction of longer life.

(U) The present 3KSES life estimate for the GRP planer elements is 2000 hours, assuming a 3KSES top level requirement (TLR) operational envelope. The 2000 hour estimate is considered to be conservative, and has been presented in Reference 1. An estimate of the 3KSES service life of the

(U) bag material is also presented in Reference 1. The estimates are based on engineering analysis of seal test results, design loads, the GRP seal material, and the design of the seals. Testing of a GRP feather edge (Reference 2) in the Navy Environmental Test Rig provided an important data point. A full seals feather edge was impacted with water at velocities between 80 and 90 knots for almost 150 hours with absolutely no apparent degradation. This is equivalent to many more operational hours with the TLR-defined operational time profile.

(U) Reference 1: "Final Bow and Stern Seals Inspection, Maintenance and Repair Procedures Reliability/Maintainability Report," Rohr Industries, Inc., Document No. DL6R00401A, (CDRL No. R004 (L-6) A; ID No. AP2-00 4413), dated 30 April 1976.

(U) Reference 2: "Seals Development Summary Report," Rohr Industries, Inc., Document No. D567S00701 (CDRL No. S007 (L-6, L-7, L-8, & H-9), ID No. AP2-00 4501), dated 28 May 1976.

(U) A.5.15 PROVISIONS

COMMENT:

(U) "The provisions table used by Rohr does not match that in the TLR issued by ANVCE Project Office. Please use the TLR table. If it is felt that the ANVCE requirement is too conservative please feel free to quote a delta weight increment for going to the shorter duration provisions. "

RESPONSE:

(U) The ANVCE provisions table is felt to be too conservative. A 30-day mission duration was used to save weight because the ship will have ample opportunity for replenishment in that time period. When the ANVCE requirements that differed from the Rohr provisions are modified to agree with the Rohr provisions allocations, the weight savings are as follows:

Provisions	MISSION DURATION (Days)		Weight Savings		
	ANVCE	ROHR	**	lbs	kN
Dry	60	30	6.09	13,440	59.78
Ship Stores	60	30	1.52	3,360	14.95
Medical Stores	180	30	Negl.*	Negl.*	Negl.*

* Medical stores weight saving is negligible due to the small amount of medical stores on board.

** non-SI metric tons

APPENDIX B

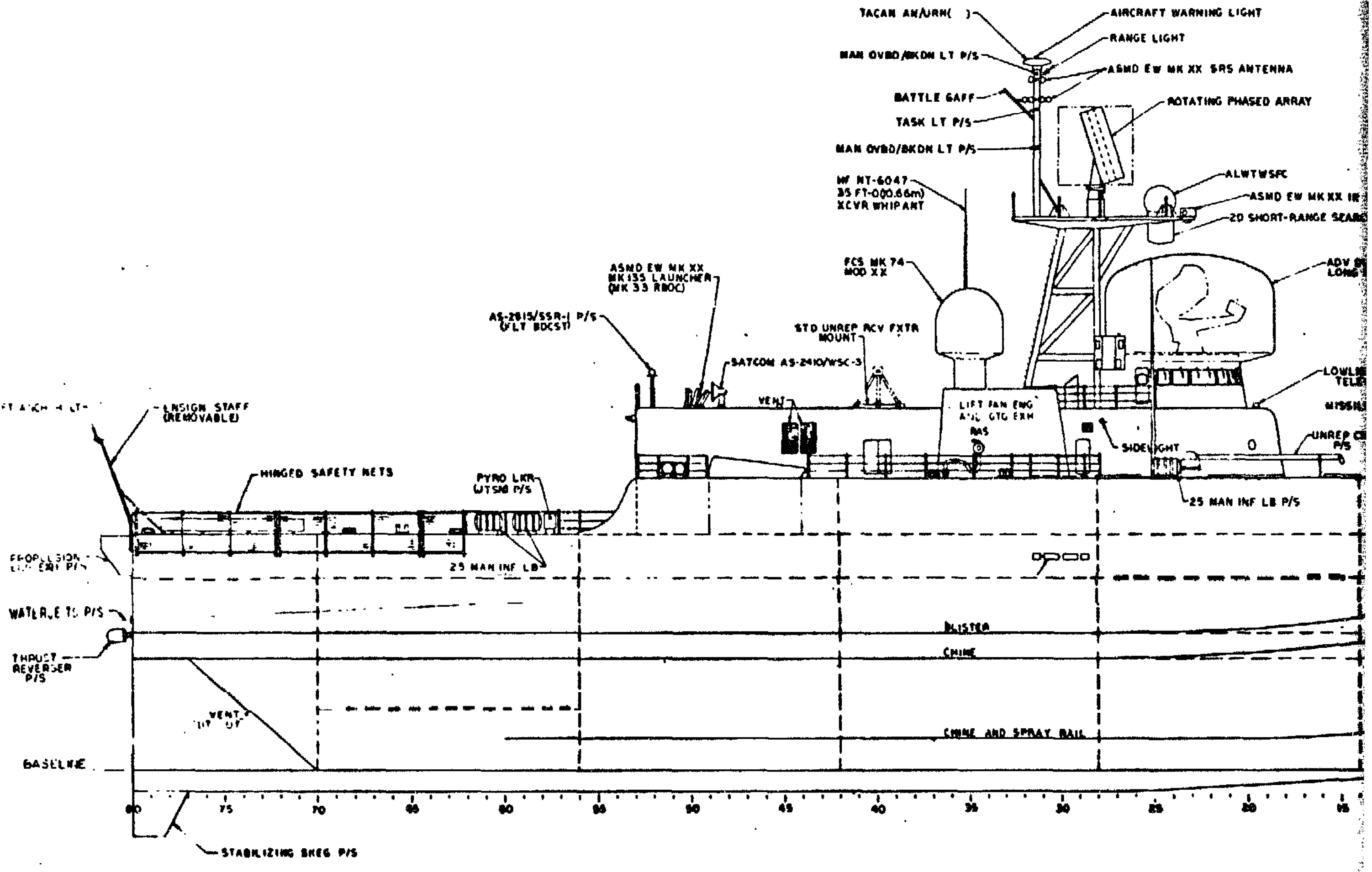
DRAWINGS AND DIAGRAMS

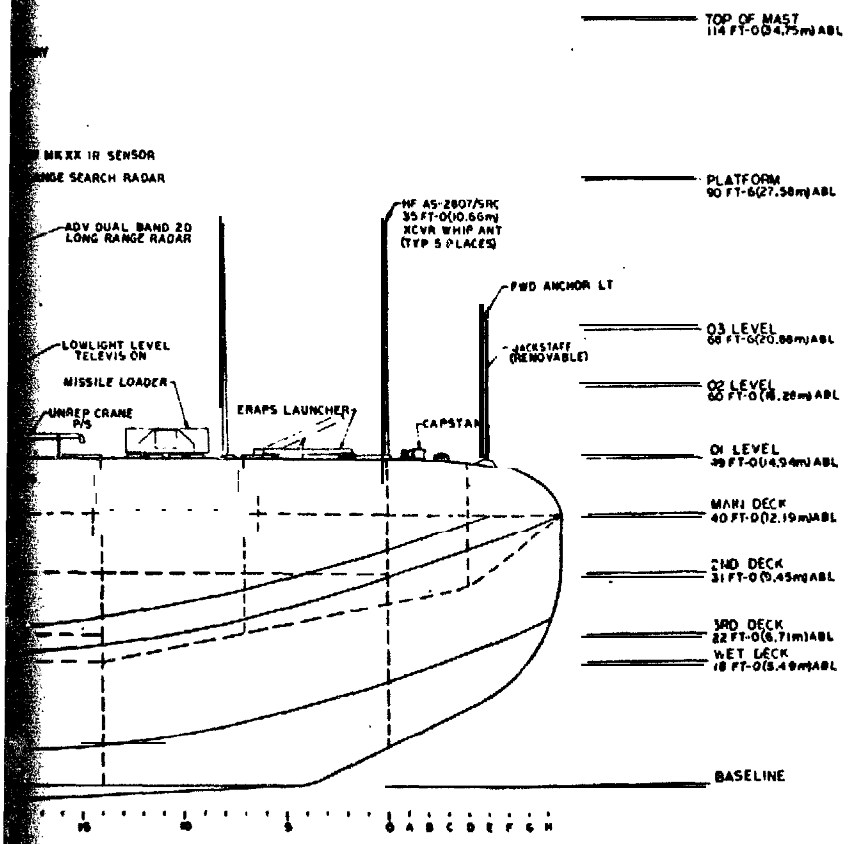
APPENDIX B

(U) B.1 GENERAL ARRANGEMENT DRAWINGS

(U) This section of Appendix B contains the general arrangement drawings for the far term ANVCE SES Point Design. These drawings are as follows:

G/A Title	Dwg. Ref.
Outboard Profile	AVA802001
Inboard Profile	AVA802002
01 Level and Above	AVA802003
Main Deck	AVA802004
Second Deck	AVA802005
Third Deck	AVA802006
Wet Deck	AVA802007
Transverse Section	AVA802008
Inboard Profile	AVA802009
Bow and Stern Views	AVA802010


TACAN AN/URN( )
AIRCRAFT WARNING LIGHT
RANGE LIGHT
MAN OVBD/BKDN LT P/S
ASMD EW MK XX SRS ANTENNA
BATTLE GAFF
ROTATING PHASED ARRAY
TASK LT P/S
MAN OVBD/BKDN LT P/S
HF NT-6047
35 FT-0(10.66m)
XCVR WHIP ANT
ALWTWSFC
ASMD EW MK XX IR
20 SHORT-RANGE SEAR
FCS MK 74
MOD XX
ADV
LONG
ASMD EW MK XX
MK 135 LAUNCHER
(MK 33 RBOC)
AS-2815/SSR-1 P/S
(FLT BDCST)
STD UNREP RCV FXTR
MOUNT
SATCOM AS-2410/WSC-3
LOWLI
TELE
MISSI
VENT
LIFT FAN ENG
AND GTG EXH
RAS
SIDELIGHT
UNREP C
P/S
AFT ANCH LT
ENSIGN STAFF
(REMOVABLE)
HINGED SAFETY NETS
PYRO LKR
WTSM P/S
25 MAN INF LB P/S
PROPULSION
 ENG EXH P/S
25 MAN INF LB
WATERJETS P/S
BLISTER
THRUST
REVERSER
P/S
CHINE
VENT
CHINE AND SPRAY RAIL
BASELINE
80
75
70
65
60
55
50
45
40
35
30
25
20
15
STABILIZING SKEG P/S



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9	AVA 802010		BOW AND STERN VIEW
8	AVA 802009		INBD PROFILE SILHOUETTE
7	AVA 802008		TRANSVERSE SECTION
6	AVA 802007		WET DECK
5	AVA 802006		THIRD DECK
4	AVA 802005		SECOND DECK
3	AVA 802004		MAIN DECK
2	AVA 802003		01 LEVEL AND ABOVE
1	AVA 802002	GENERAL ARRANGEMENT	INBOARD PROFILE

REFERENCES

MID LACINA

INDUSTRIES, INC SES DIVISION

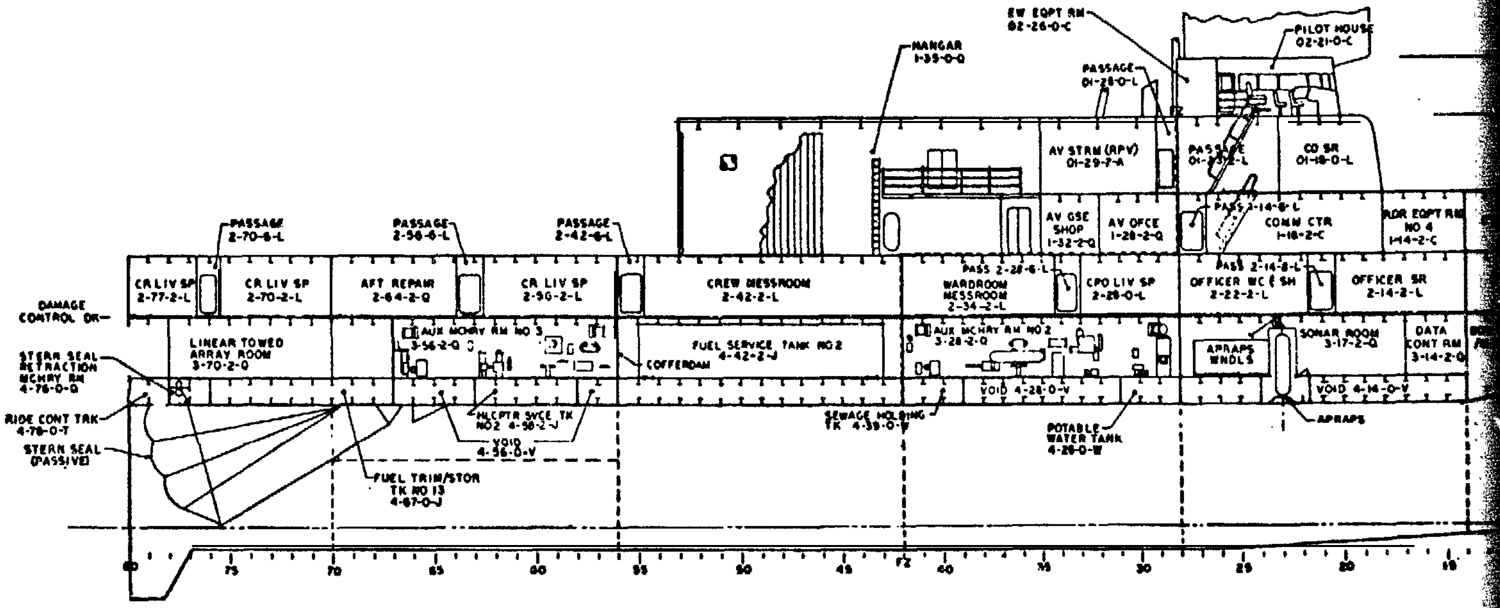
ANVCE
GENERAL ARRANGEMENT
OUTBOARD PROFILE

J AVA 802001

SCALE 1/8 = 12

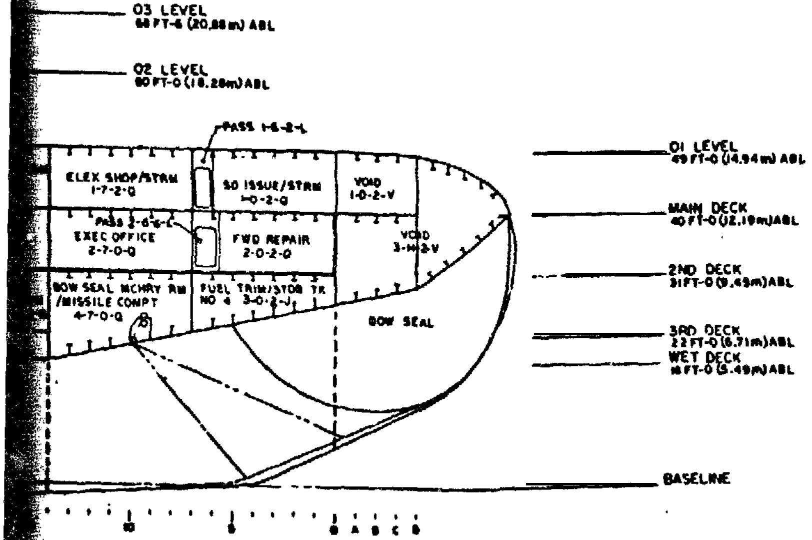
SHEET 1 OF 1

2



INBOARD PROFILE AT CENTERLINE

~~CONFIDENTIAL~~



NO	DWG NO	TITLE
9	AVA 802010	BOW & STERN VIEW
8	AVA 802009	INBD PROFILE-SIDEWALL
7	AVA 802008	TRANSVERSE SECTION
6	AVA 802007	WET DECK
5	AVA 802006	THIRD DECK
4	AVA 802005	SECOND DECK
3	AVA 802004	MAIN DECK
2	AVA 802003	01 LEVEL & ABOVE
1	AVA 802001	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

DRAWN RIO LACINA

[illegible] INDUSTRIES, INC. [illegible]

ANVCE
GENERAL ARRANGEMENT
INBOARD PROFILE

SIZE J
AVA 802002

SHEET 1 OF 1

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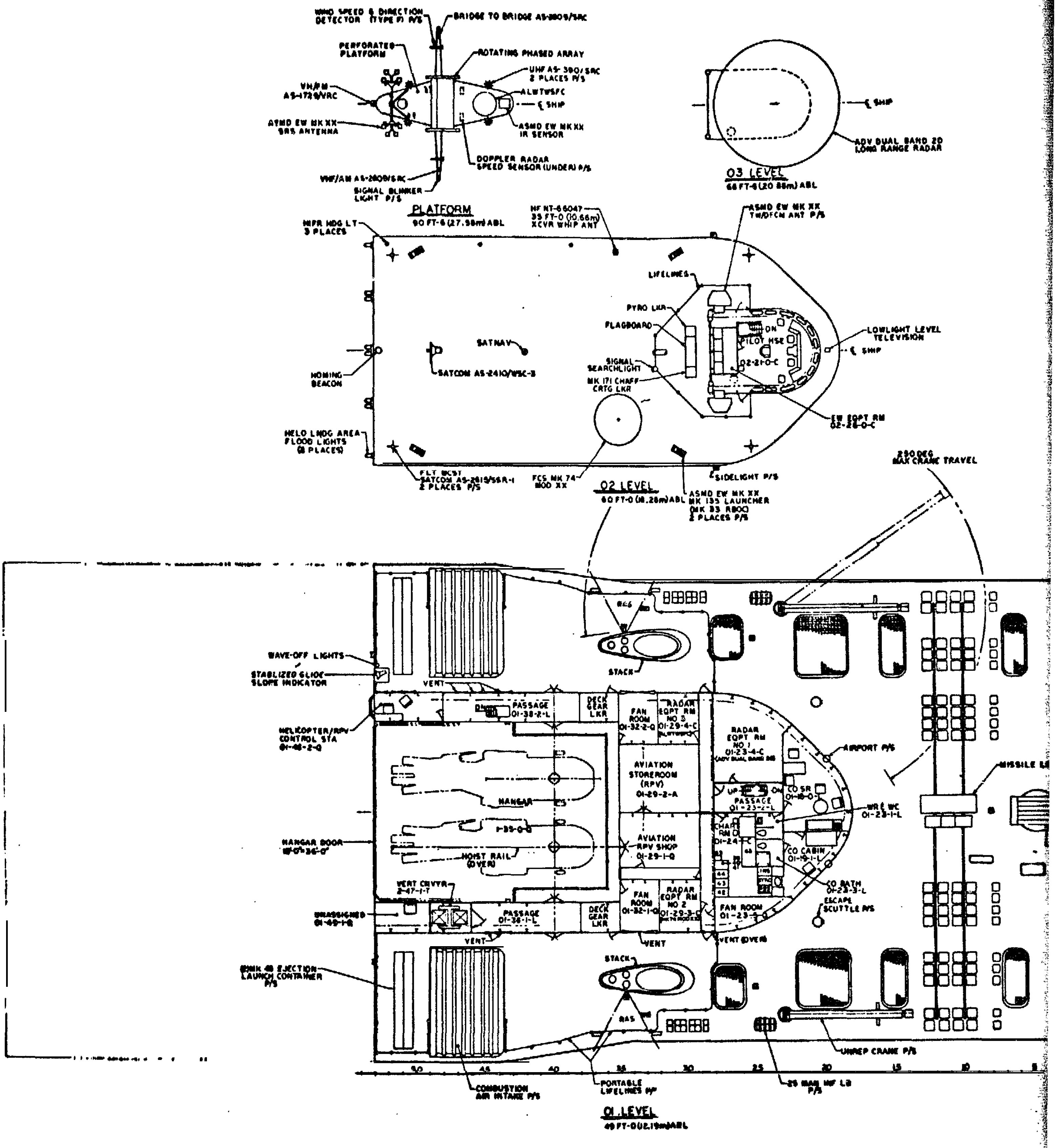
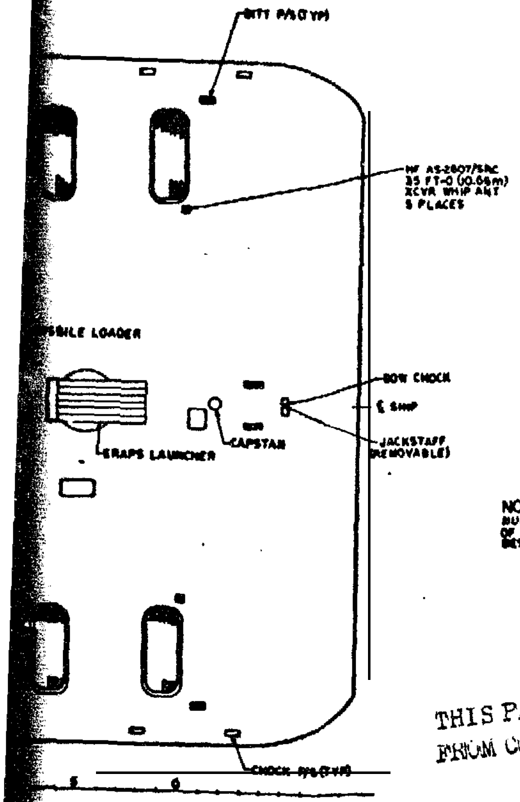
2


WIND SPEED & DIRECTION DETECTOR (TYPE F) P/S
BRIDGE TO BRIDGE AS-2809/SRC
PERFORATED PLATFORM
ROTATING PHASED ARRAY
UHF AS-390/SRC 2 PLACES P/S
VH/FM AS-1729/VRC
ALWTWS/FC
℄ SHIP
ATMD EW MK XX SRS ANTENNA
ASMD EW MK XX IR SENSOR
DOPPLER RADAR SPEED SENSOR (UNDER) P/S
VHF/AM AS-2809/SRC
SIGNAL BLINKER LIGHT P/S
PLATFORM
90 FT-6 (27.58m) ABL
℄ SHIP
ADV DUAL BAND 2D LONG RANGE RADAR
03 LEVEL
66 FT-6 (20.88m) ABL
HF NT-66047 35 FT-0 (10.66m) XCVR WHIP ANT
ASMD EW MK XX TW/DFCM ANT P/S
MFR HDG LT 3 PLACES
LIFELINES
PYRO LKR
FLAGBOARD
ON
PILOT HSE
02-21-0-C
LOWLIGHT LEVEL TELEVISION
℄ SHIP
SATNAV
SIGNAL SEARCHLIGHT
MK 171 CHAFF CRTG LKR
HOMING BEACON
SATCOM AS-2410/WSC-3
EW EQPT RM 02-28-0-C
HELO LNDG AREA FLOOD LIGHTS (8 PLACES)
FLT BCST SATCOM AS-2815/SSR-1 2 PLACES P/S
FCS MK 74 MOD XX
SIDELIGHT P/S
02 LEVEL
60 FT-0 (18.28m) ABL
ASMD EW MK XX MK 135 LAUNCHER (MK 33 RBOC) 2 PLACES P/S
290 DEG MAX CRANE TRAVEL
RAS
STACK
WAVE-OFF LIGHTS
STABLIZED GLIDE SLOPE INDICATOR
VENT
PASSAGE 01-38-2-L
DECK GEAR LKR
FAN ROOM 01-32-2-Q
RADAR EQPT RM NO 3 01-29-4-C
HELICOPTER/RPV CONTROL STA 01-46-2-Q
RADAR EQPT RM NO 1 01-23-4-C (ADV DUAL BAND 2D)
AIRPORT P/S
MISSILE L
AVIATION STOREROOM (RPV) 01-29-2-A
HANGAR
UP
ON
CO SR 01-18-0
PASSAGE 01-23-2-L
WR & WC 01-23-1-L
1-35-0-Q
HANGAR DOOR 18'-0" x 36'-0"
HOIST RAIL (OVER)
AVIATION RPV SHOP 01-29-1-Q
CHART RM 01-24-C
CO CABIN 01-19-1-L
VENT CRVYR 2-47-1-T
44
43
42
CO BATH 01-23-3-L
ESCAPE SCUTTLE P/S
UNASSIGNED 01-49-1-Q
PASSAGE 01-38-1-L
DECK GEAR LKR
FAN ROOM 01-32-1-Q
RADAR EQPT RM NO 2 01-29-3-C
FAN ROOM 01-23-5
VENT
VENT (OVER)
STACK
MK 48 EJECTION LAUNCH CONTAINER P/S
RAS
50
45
40
35
30
25
20
15
10
5
UNREP CRANE P/S
COMBUSTION AIR INTAKE P/S
PORTABLE LIFELINES P/S
25 MAN INF LR P/S
01 LEVEL
40 FT-0 (12.19m) ABL



NOTE:
NUMBERED EQUIPMENT IS PER REV 1 DATED 10-19-76 OF ANCVE COMBAT SYSTEM SUPPORT DATA FOR POINT DESIGNS FOR NAV & ELEK SUPPORT ROOM

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8	AVA802009	INBD PROFILE SIDE HULL
7	AVA802008	TRANSVERSE SECTION
6	AVA802007	WET DECK
5	AVA802006	THIRD DECK
4	AVA802005	SECOND DECK
3	AVA802004	MAIN DECK
2	AVA802002	INBOARD PROFILE ℄
1	AVA802001	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

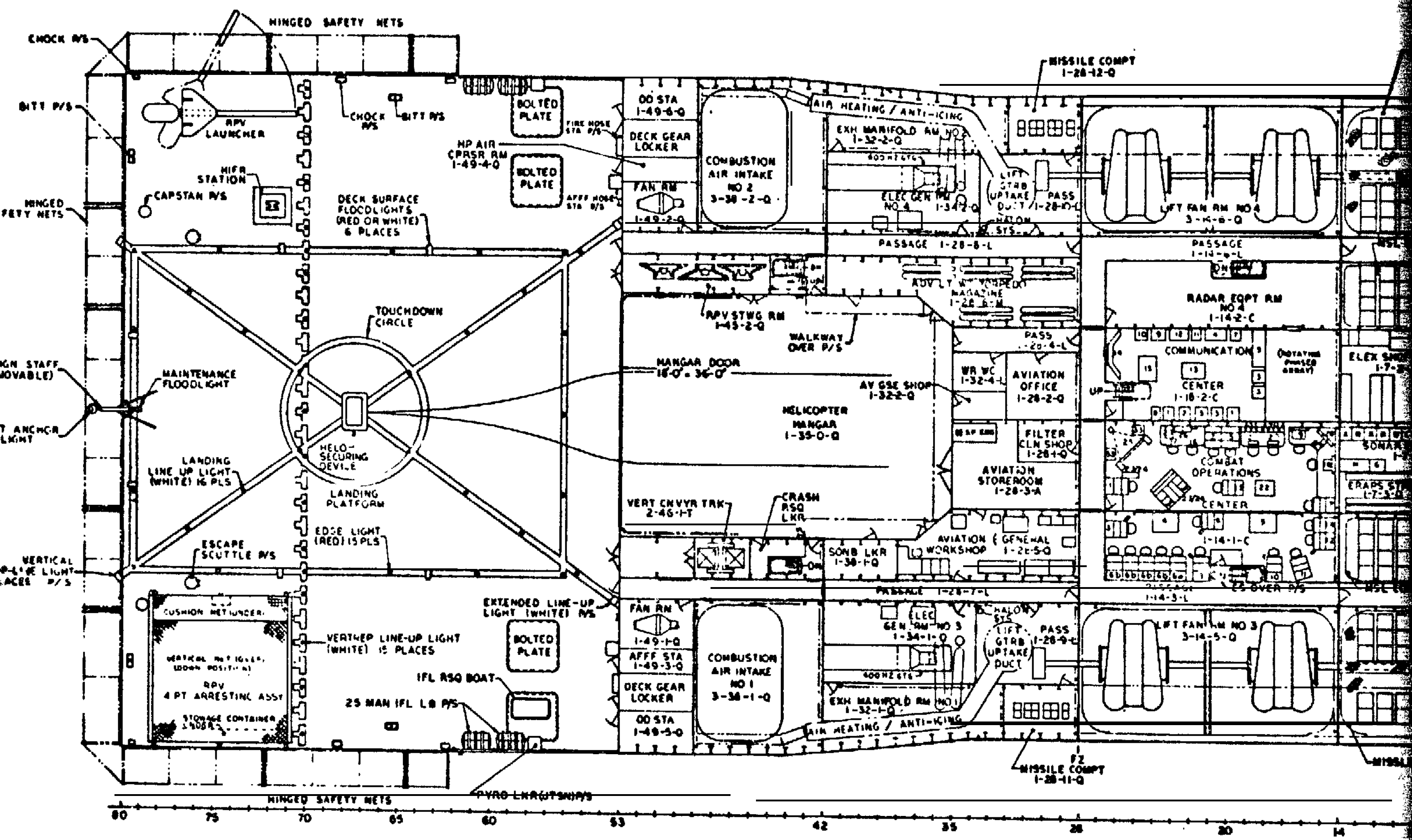
ANVCE
GENERAL ARRANGEMENT
01 LEVEL AND ABOVE

J

AVA 802003

SCALE 1/8 = 12

SHEET 1 OF 4



MAIN DECK
40 FT-0(12.19m)ABL

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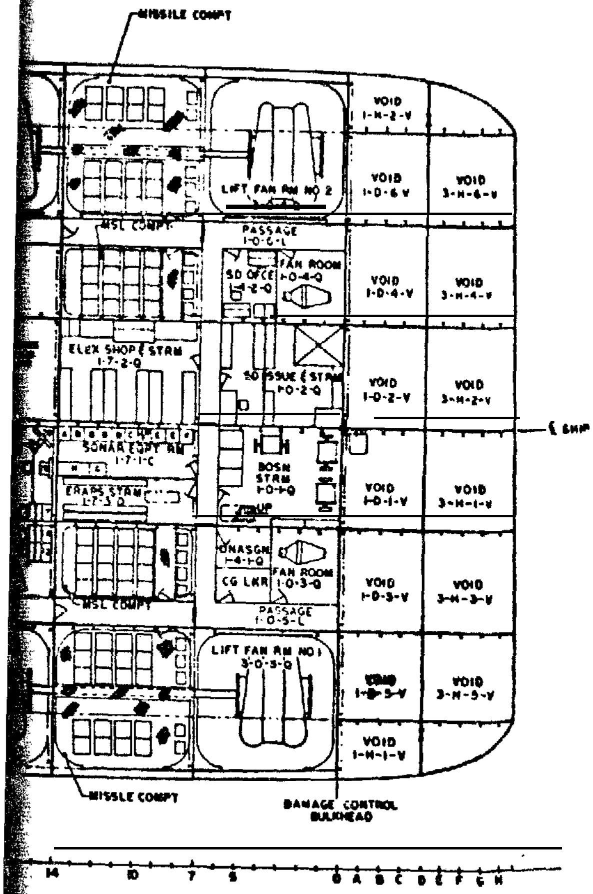

NOTE:
NUMBERED EQUIPMENT IS PER REV 1 DATED 10-19-76 OF ANVCE COMBAT SYSTEM SUPPORT; DATA FOR POINT DESIGNS FOR COC & COMM CENTER
SONAR EQUIPMENT DESIGNATION IS:

LETTER	EQPT TYPE	QTY
A	DATA LINK RCVR+SEL & DISTR	4
B	SIG CONDTN/DATA PRCS	4
C	ADV SIG PRCS	6
D	CRTG MAG TAPE UNIT	1
E	MASS MEMORY UNIT	2.25
F	COMPUTER (AN/UYK 20 MOD XI)	9
G	PWR DISTR CABINET	1
H	INTERFACE CONTROL UNIT	1
J	ARITH DGTL DISPLAY	1

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8	AVA 802009	INBD PROFILE SIDEHULL
7	AVA 802008	TRANSVERSE SECTION
6	AVA 802007	WET DECK
5	AVA 802006	THIRD DECK
4	AVA 802005	SECOND DECK
3	AVA 802003	01 LEVEL AND ABOVE
2	AVA 802002	INBOARD PROFILE ℄
1	AVA 802001	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

MID LACINA

ANVCE
GENERAL ARRANGEMENT
MAIN DECK

J 51561 AVA 802004

SHEET 1 OF 1

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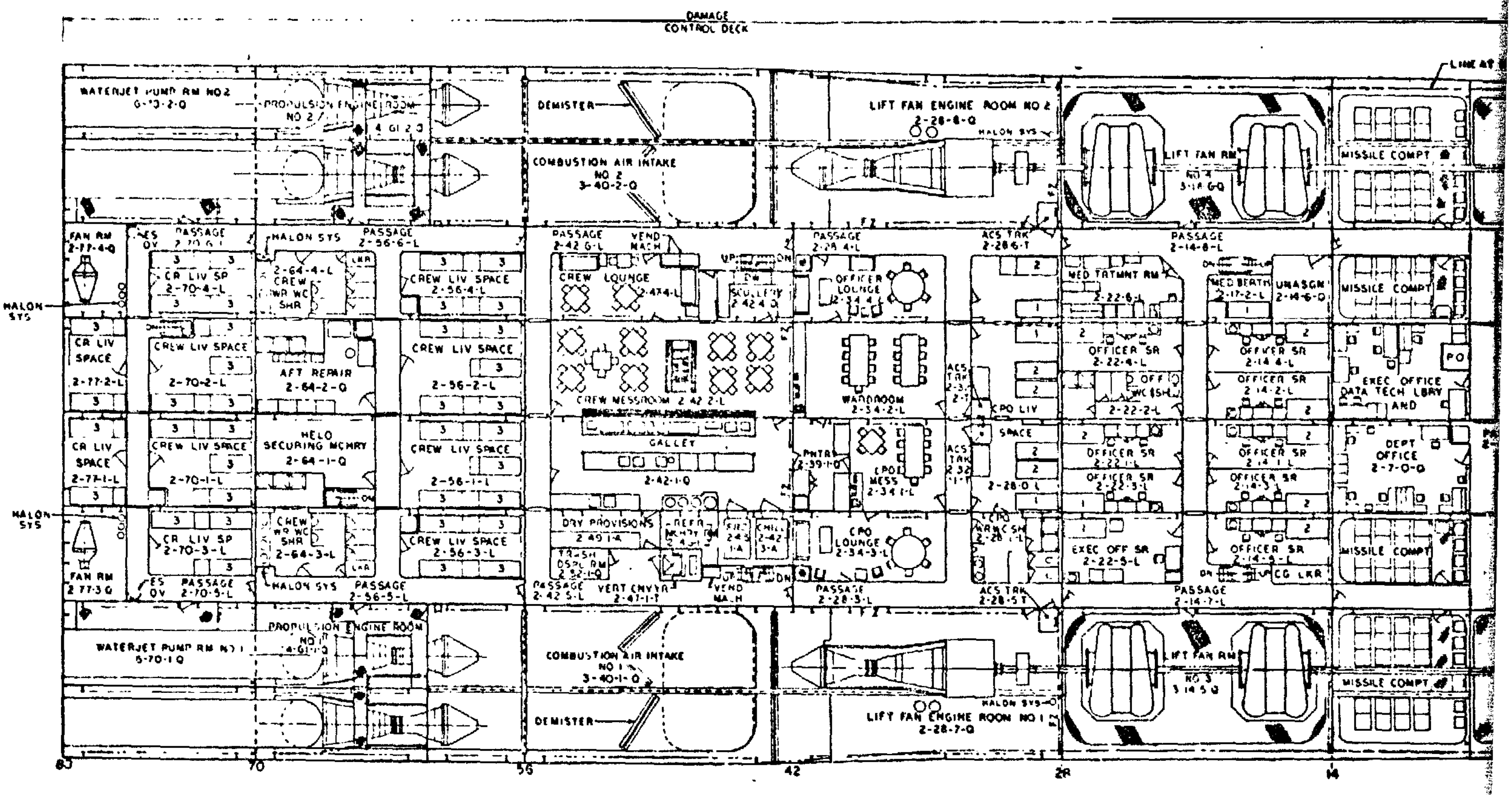
2



SECOND DECK
31 FT 0 ABL (9.45 m)
NO CAMBER
OR SHEER

9	AVA 802010		
8	AVA 802009		
7	AVA 802008		
6	AVA 802007		
5	AVA 802006		
4	AVA 802004		
3	AVA 802003		
2	AVA 802002		
1	AVA 802001	GENE	
NO	DWG NO		

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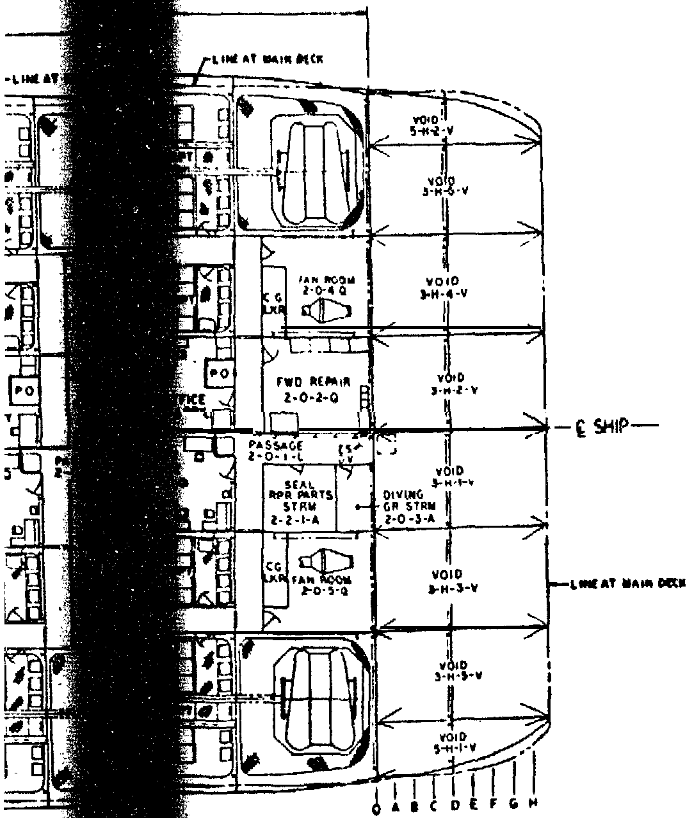


NOTE:

ALL DAMAGE CONTROL FUNCTIONS COORDINATED FROM CQC THE THREE SPECIAL PURPOSE CONSOLES CALLED OUT IN REV 1, 19 OCT 76 OF "ANVCE COMBAT SYSTEM SUPPORT; DATA FOR POINT DESIGNS" NOT INCLUDED AT FWD REPAIR AND AFT REPAIR (DAMAGE REPAIR TEAM NO 1 AND 2) LOCATIONS.

	BOW & STERN VIEW
	INBD PF SIDEHULL
	TRANSVERSE SECTION
	WET DECK
	THIRD DECK
	MAIN DECK
	01 LEVEL & ABOVE
	INBOARD PROFILE
GENERAL ARRANGEMENT	OUTBOARD PROFILE
TITLE	
REFERENCES	

GENER

MUSZYNSKI

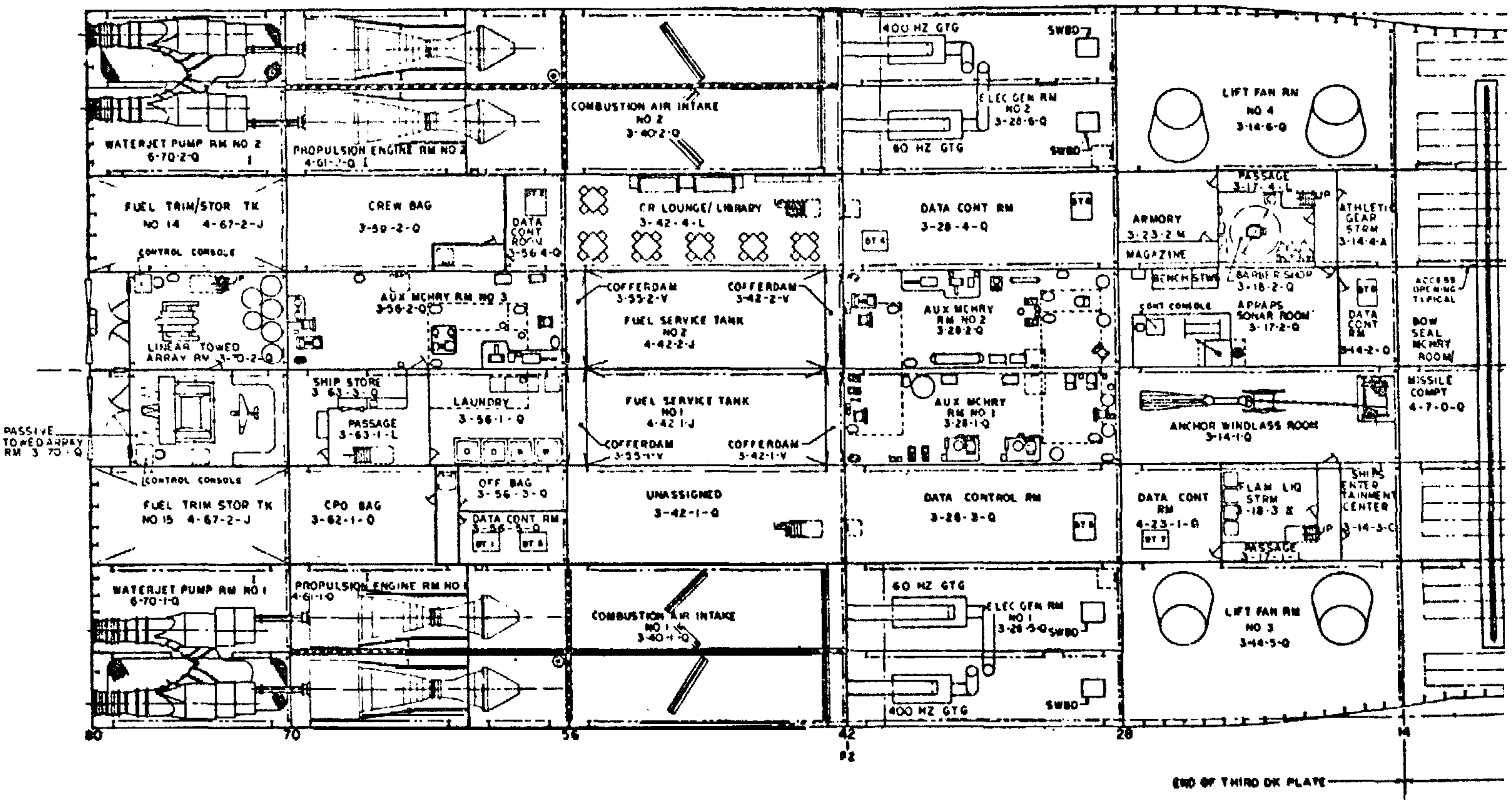
INDUSTRIES, INC. SES DIVISION

ANVCE
GENERAL ARRANGEMENT
SECOND DECK

J
51563
AVA 802005

~~CONFIDENTIAL~~

2



THIRD DECK
22 FT-0 ABL (6.71 m)
NO CAMBER

NO	DWG NO
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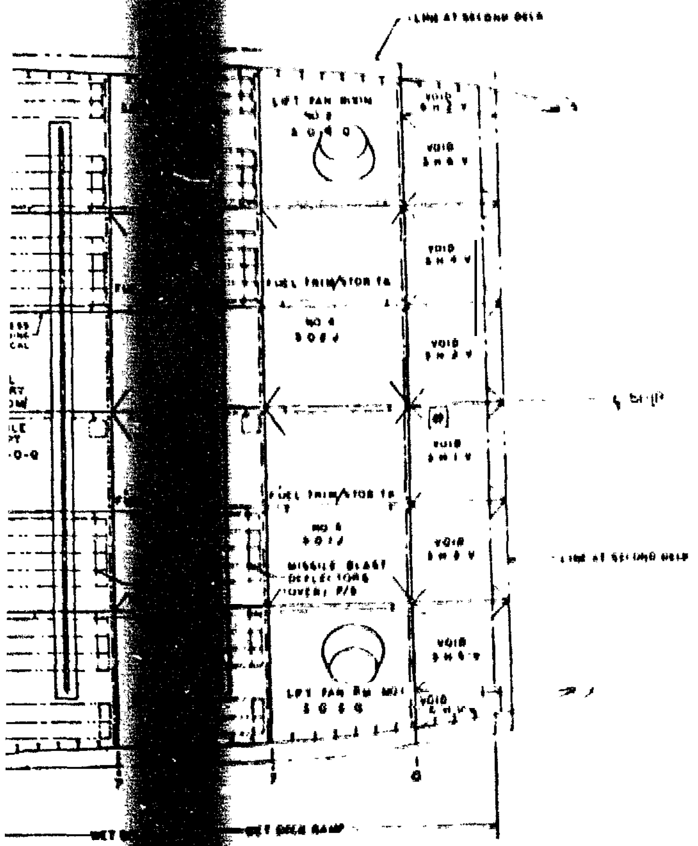
7	AVA 802008
6	AVA 802007
5	AVA 802005
4	AVA 802004
3	AVA 802003
2	AVA 802002
1	AVA 802001

~~CONFIDENTIAL~~



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DWG NO		TITLE
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802009		INBD PL SIDEHULL
802008		TRANSVERSE SECTION
802007		WET DECK
802005		SECOND DECK
802004		MAIN DECK
802003		01 LEVEL & ABOVE
802002		INBOARD PROFILE
802001	GENE	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

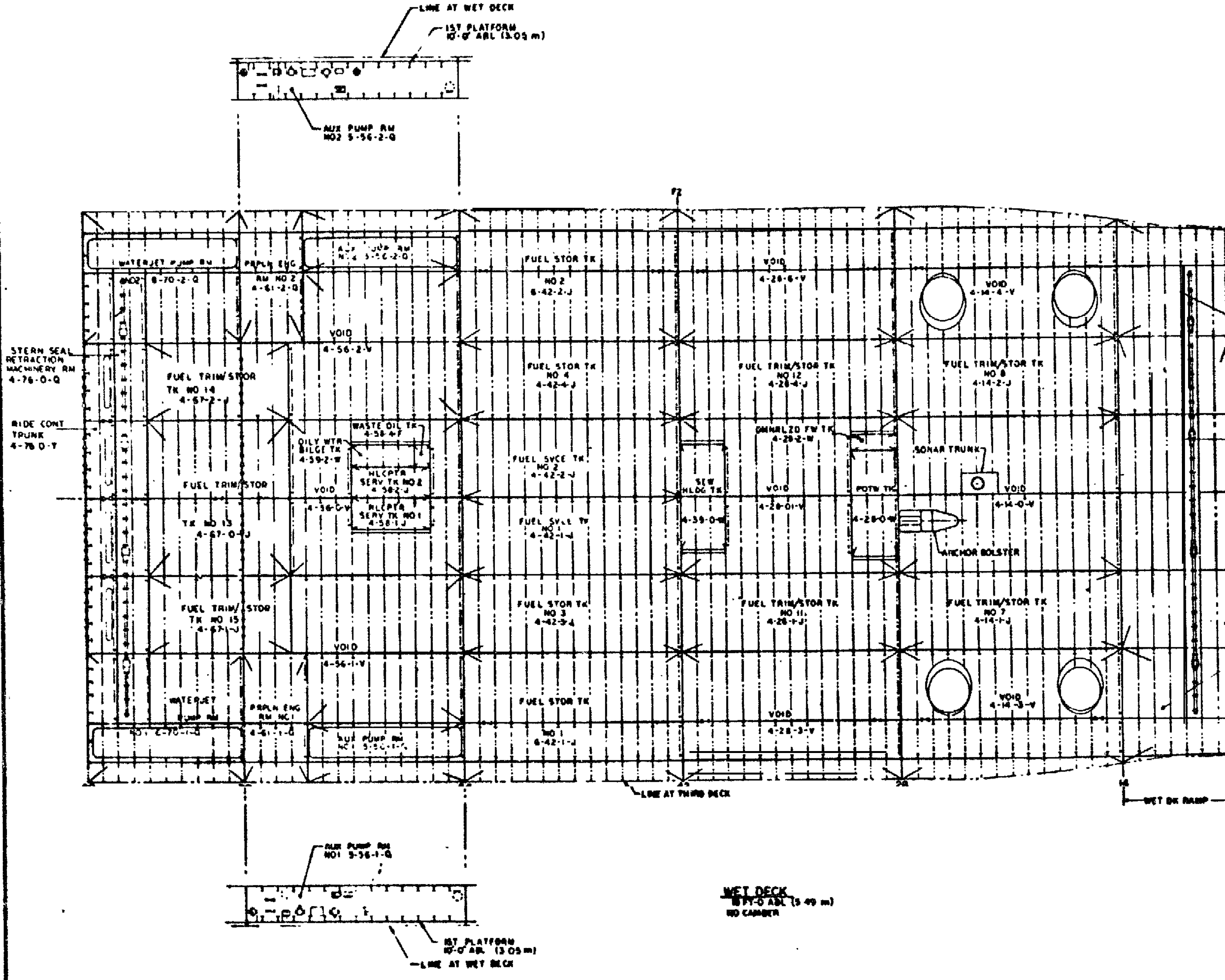
ANVCE
GENERAL ARRANGEMENT
THIRD DECK

J

A/A 802006

~~CONFIDENTIAL~~

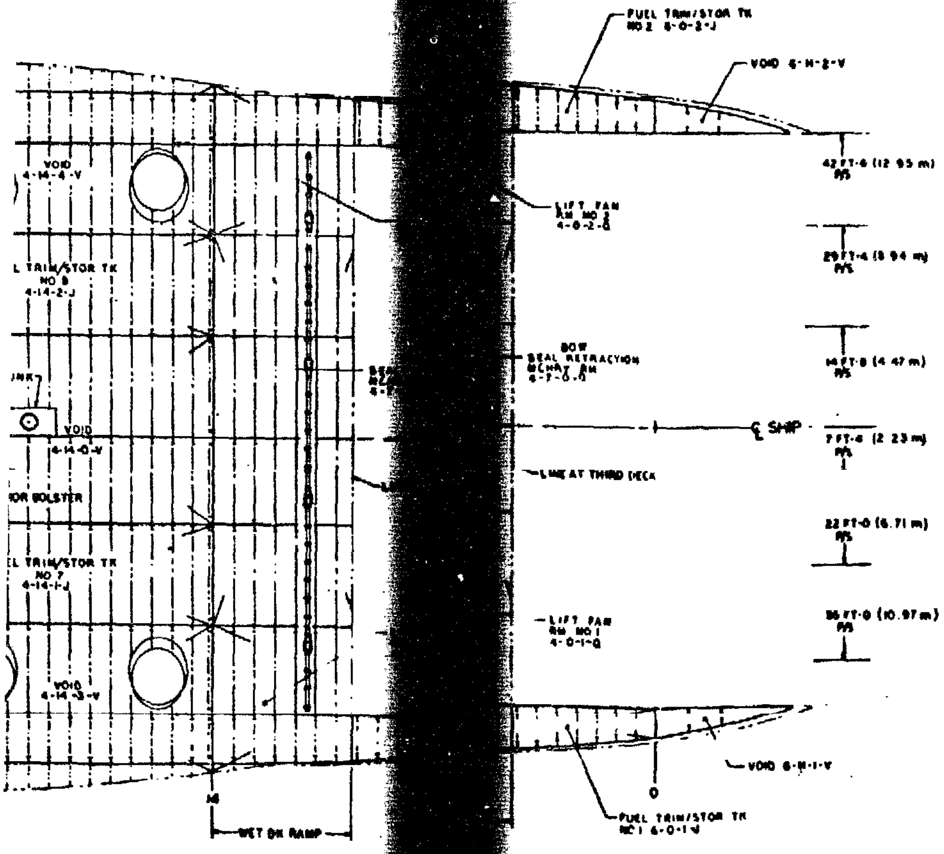
2



WET DECK
18 FT-0 ABL (5.49 m)
NO CAMBER

NO	DWG NO	
9	AVA802010	
8	AVA802009	
7	AVA802008	
6	AVA802006	
5	AVA802005	
4	AVA802004	
3	AVA802003	
2	AVA802002	
1	AVA802001	GE

~~CONFIDENTIAL~~



NO	DWG NO	TITLE
9	AVA802010	BOW & STERN VIEW
8	AVA802009	INBD PF. SIDEHULL
7	AVA802008	TRANSVERSE SECTION
6	AVA802006	THIRD DECK
5	AVA802005	SECOND DECK
4	AVA802004	MAIN DECK
3	AVA802003	01 LEVEL & ABOVE
2	AVA802002	INBOARD PROFILE
1	AVA802001	GENERA ERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

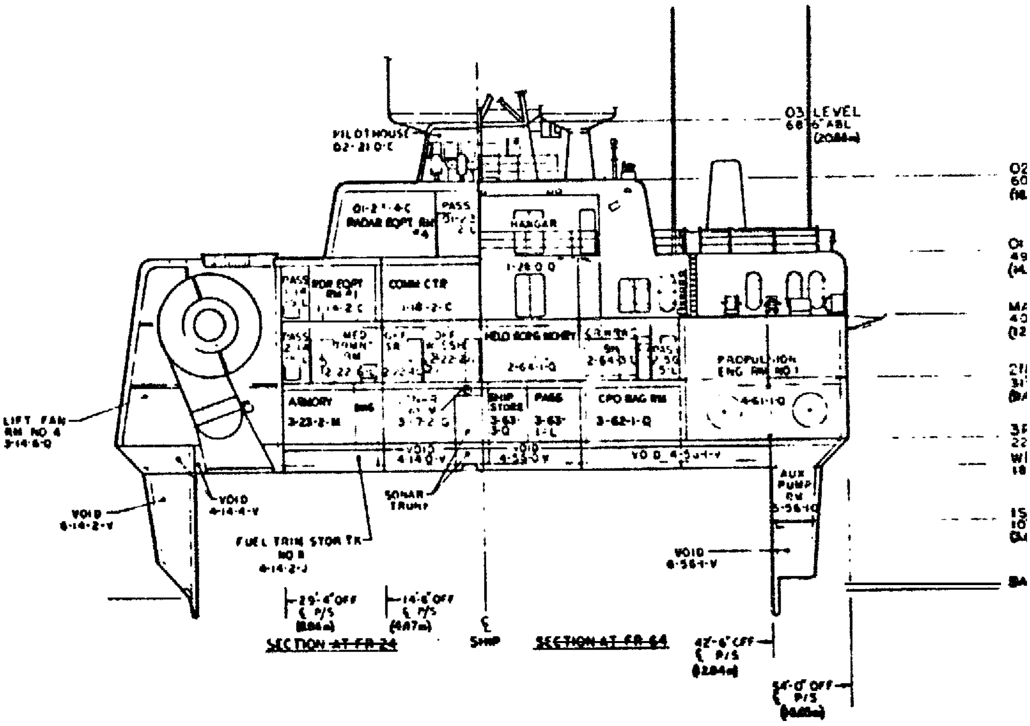
E. MURPHY

ANVCE
GENERAL ARRANGEMENT
WET DECK

J 51583 AVA 802007

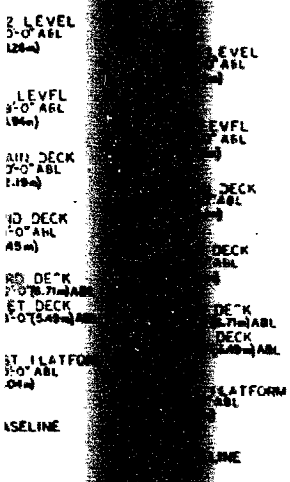
~~CONFIDENTIAL~~

2



TRANSVERSE SECTION
LOOKING FWD

~~CONFIDENTIAL~~



9	AVA 802010	BOW & STERN VIEW
8	AVA 802009	INBD PF SIDEHULL
7	AVA 802007	WET DECK
6	AVA 802006	THIRD DECK
5	AVA 802005	SECOND DECK
4	AVA 802004	MAIN DECK
3	AVA 802003	01 LEVEL & ABOVE
2	AVA 802002	INBOARD PROFILE
1	AVA 802001	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

ANVCE
GENERAL ARRANGEMENT
TRANSVERSE SECTION

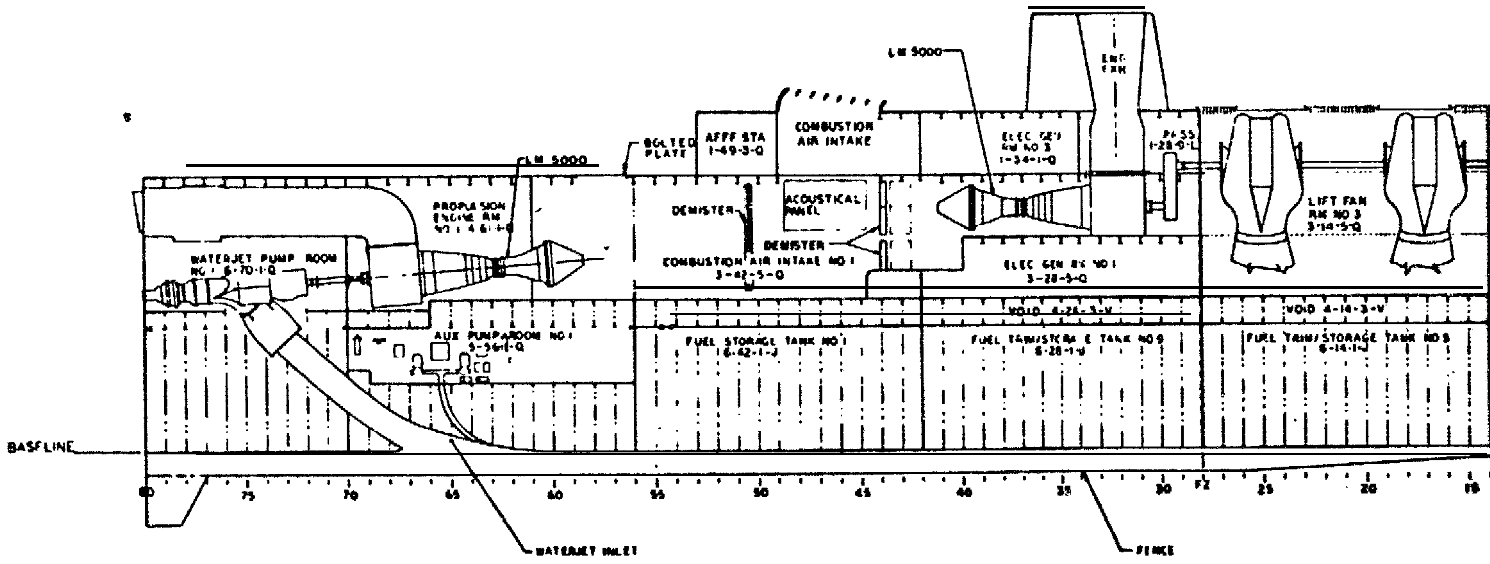
J 51563 ANA 802008

SCALE 1/8 = 1'

SHEET 1 OF 1

~~CONFIDENTIAL~~

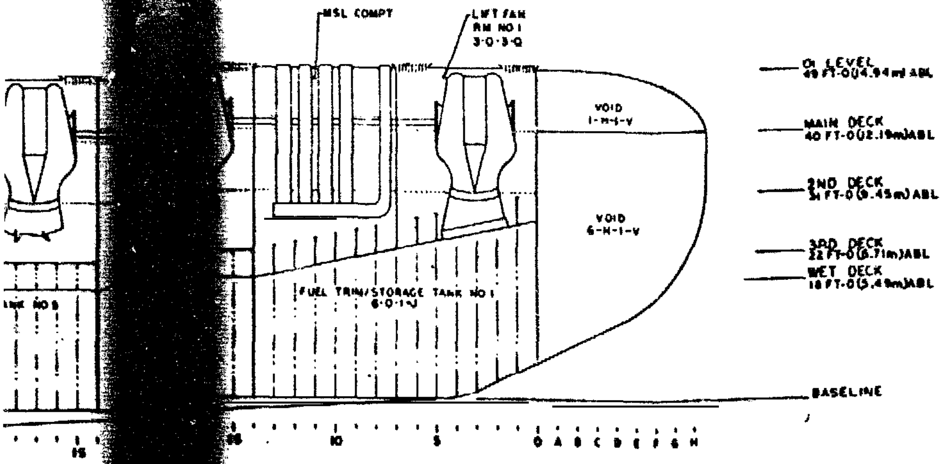
2



SIDE HULL INBO
STARBOARD SIDE LOO

BELOW 3RD DK SECT
APPROXIMATELY 44 FT-
ABOVE 3RD DK SECT
ACCORDING TC EQUIP

~~CONFIDENTIAL~~



HULL INBOA… …OARD PROFILE
…ARD SIDE LOOK… …LOOKING TO PORT

3RD DK SECTI… …SECTION PLANE IS
…MATELY 44 FT-… …FT-0(13.41m)OFF ℄ SHIP
3RD DK SECTI… …CTION PLANE VARIES
…ING TO EQUIP… …IPMENT SHOWN

THIS PAGE IS BEST QUALITY PRACTICABLE
FROM COPY FURNISHED TO DDC

NO	DWG NO	TITLE	
9	AVA802010		BOW AND STERN VIEW
8	AVA802008		TRANSVERSE SECTION
7	AVA802007		WET DECK
6	AVA802006		THIRD DECK
5	AVA802005		SECOND DECK
4	AVA802004		MAIN DECK
3	AVA802003		01 LEVEL AND ABOVE
2	AVA802002		INBOARD PROFILE ℄
1	AVA802001	GENERAL ARRANGEMENT	OUTBOARD PROFILE

REFERENCES

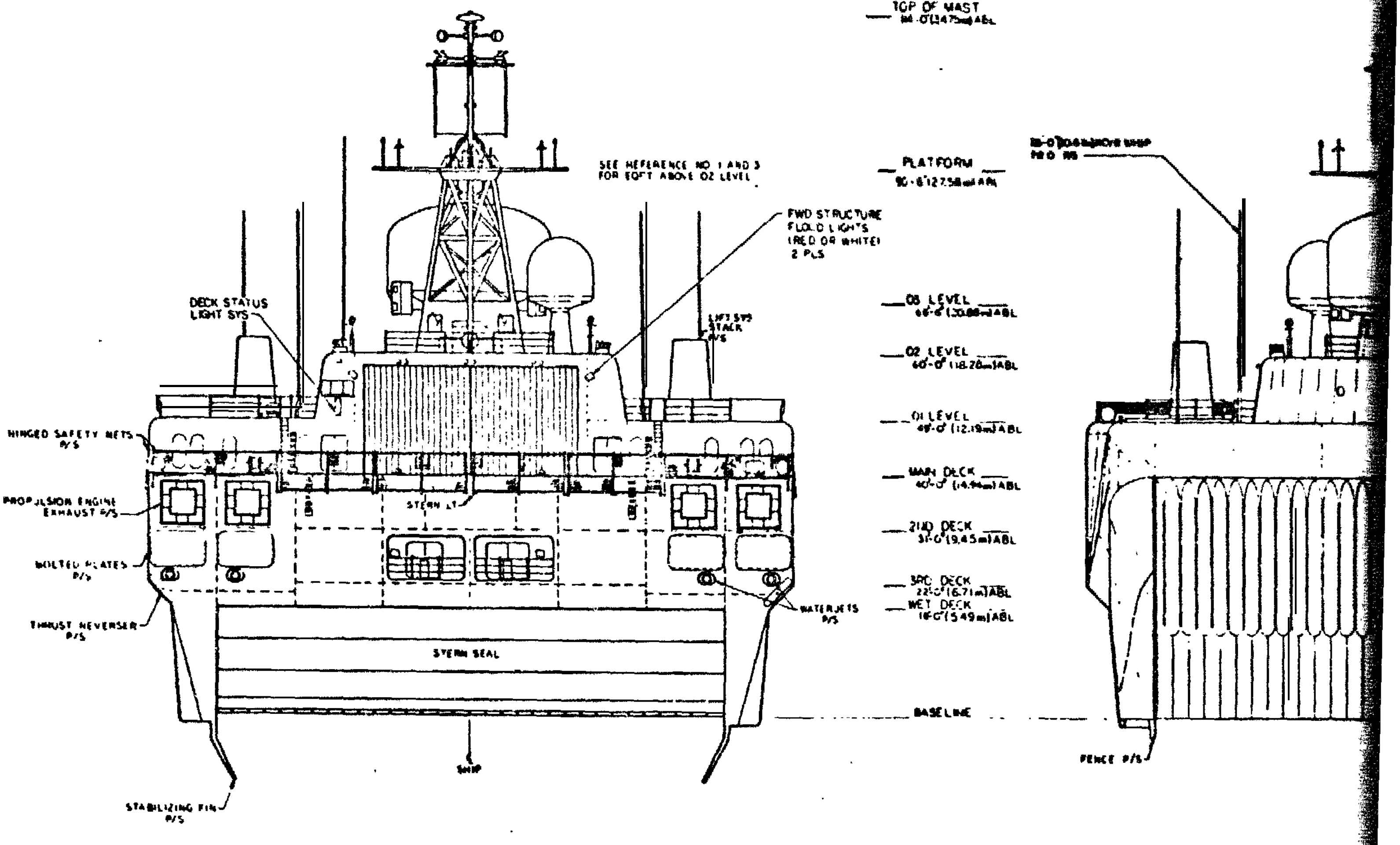
ANVCE
GENL ARR - SIDEHULL
INBOARD PROFILE

J

AVA 802009

1/8=12

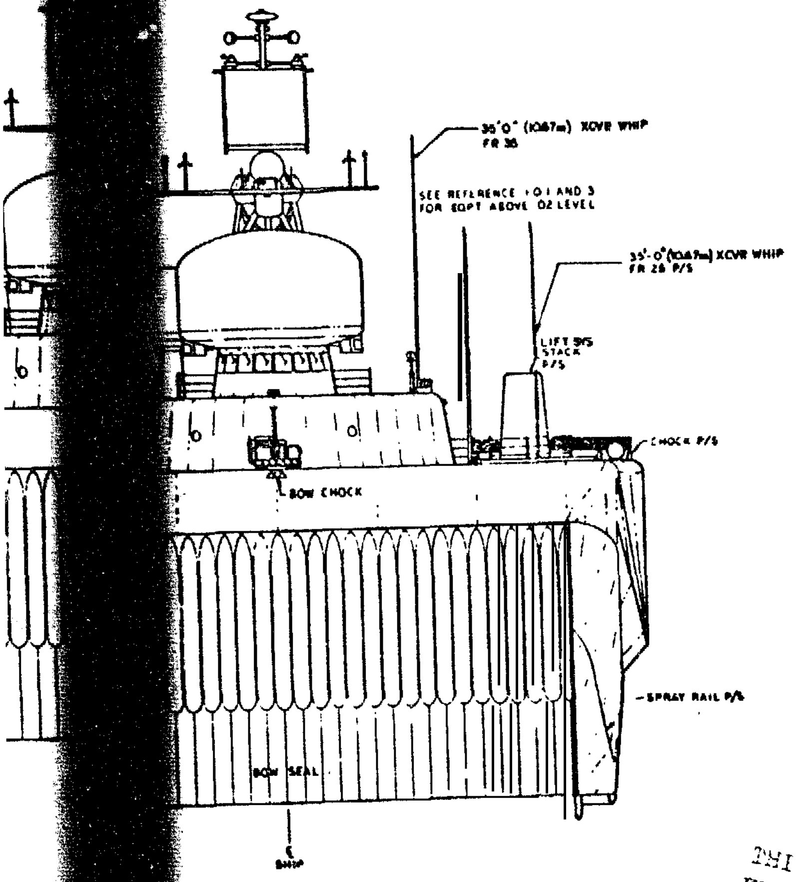
~~CONFIDENTIAL~~



STERN VIEW

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~



BOW VIEW

9	AVA802009		INBD PROFILE SIDEHULL
8	AVA802008		TRANSVERSE SECTION
7	AVA802007		WET DECK
6	AVA802006		THIRD DECK
5	AVA802005		SECOND DECK
4	AVA802004		MAIN DECK
3	AVA802003		01 LEVEL AND ABOVE
2	AVA802002		INBOARD PROFILE &
1	AVA802001	GENERAL ARRANGEMENT	OUTBOARD PROFILE

REFERENCES

ANVCE
GENERAL ARRANGEMENT
BOW & STERN VIEWS

J

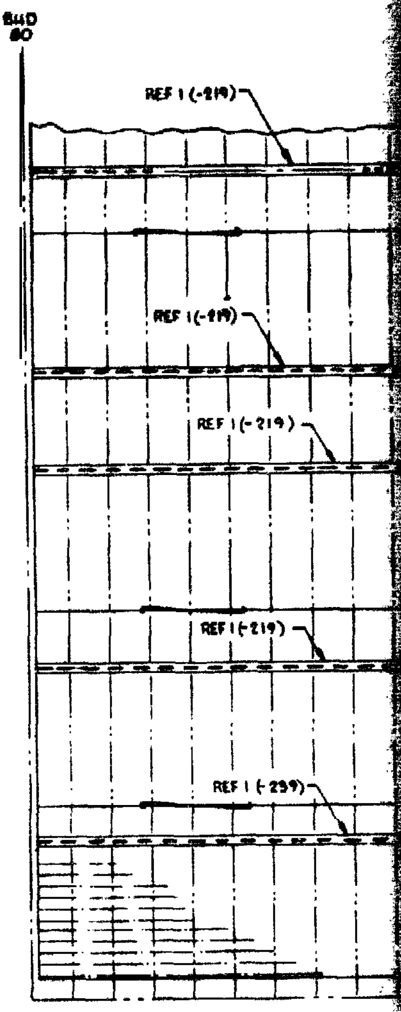
AVA 802010

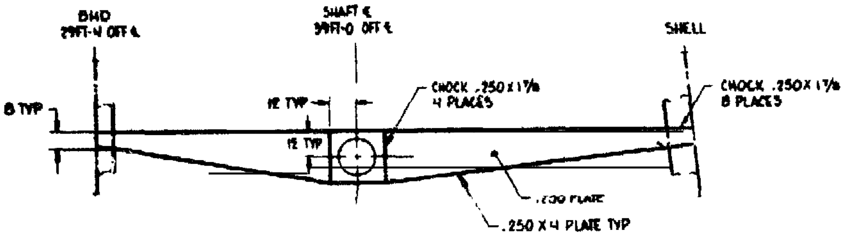
~~CONFIDENTIAL~~

(U) B.2 STRUCTURE DRAWINGS

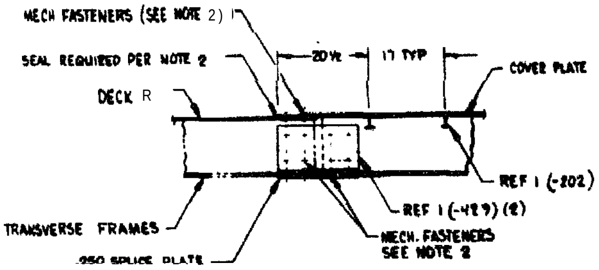
This section of Appendix B contains the structure drawings for the ANVCE far term SES Point Design. These drawings show the primary structure design philosophy which has not changed from the near term SES point design. Existing structural concepts will be utilized to accommodate new ship arrangements and heavier members or advanced materials will be used where loads are higher. These drawings are:

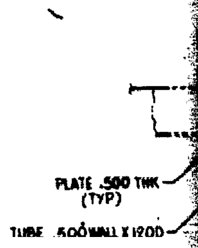
Title	Dwg. Ref.
Deck Plating - Main Deck	LL 131001
Bulkhead - Long CL	LL 121001
Transverse Bulkheads	LL 122001
Transverse Prams	LL 117001





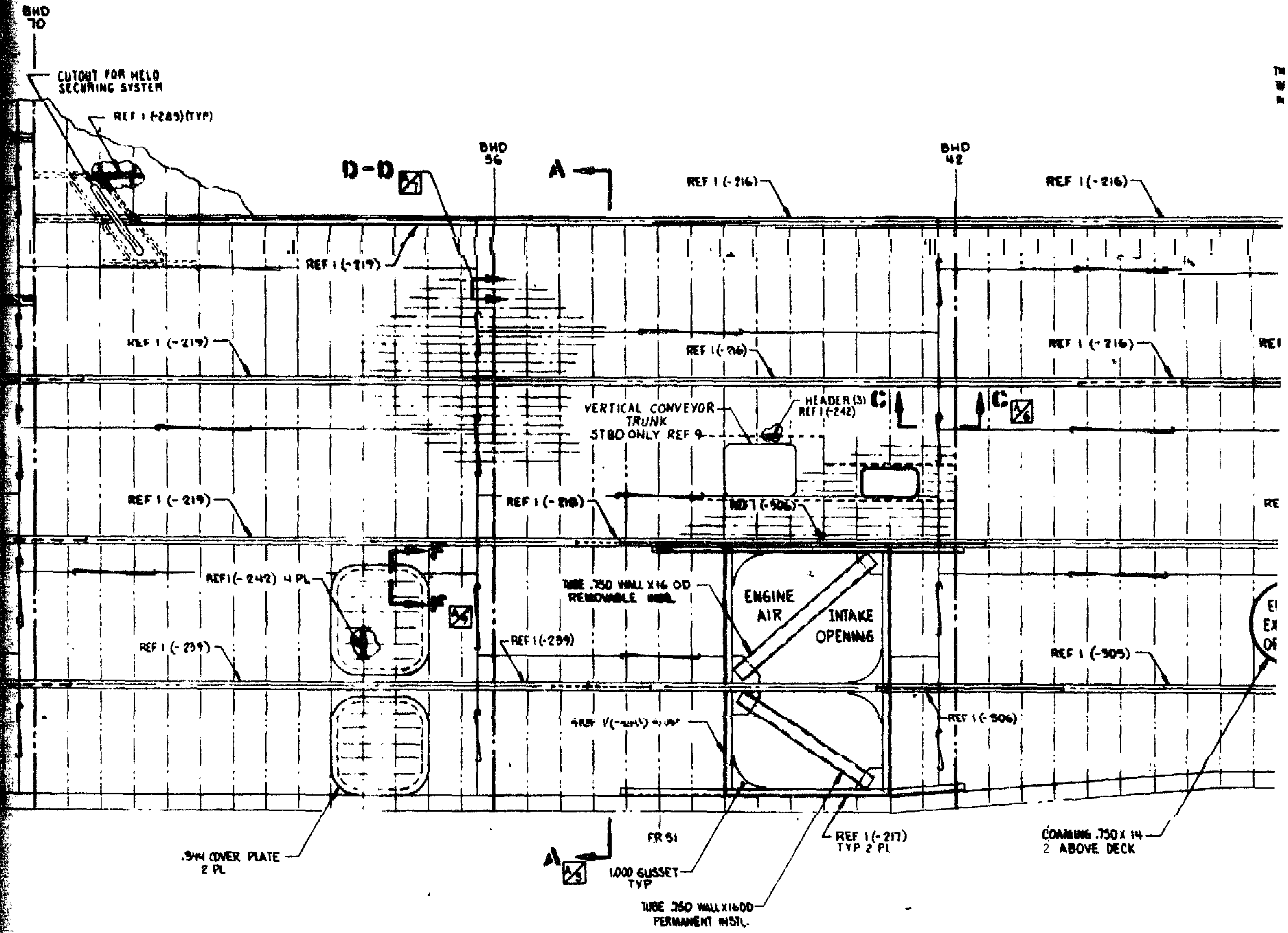
SECTION G - G
SCALE 1/2 = 12
ROTATED 90° CCW
FAN SHAFT SUPPORT FRAME TYP 2 PL
FOR 3 FAN CONFIGURATION ONLY

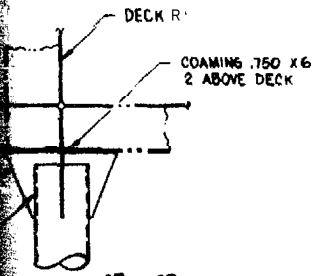




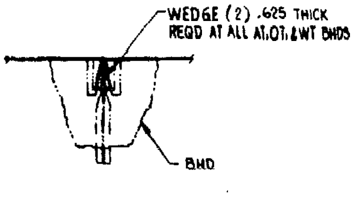
SECTION F - F
SCALE 1 = 12
ROTATED 90° CCW
TYP PLATE & FRAME SPLICE

UNCLASSIFIED

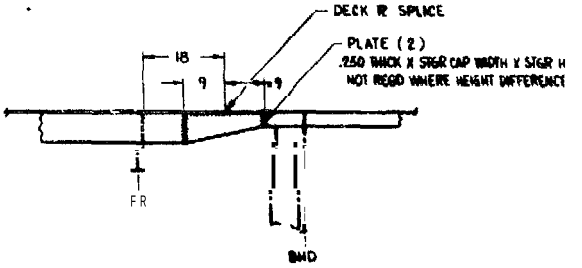




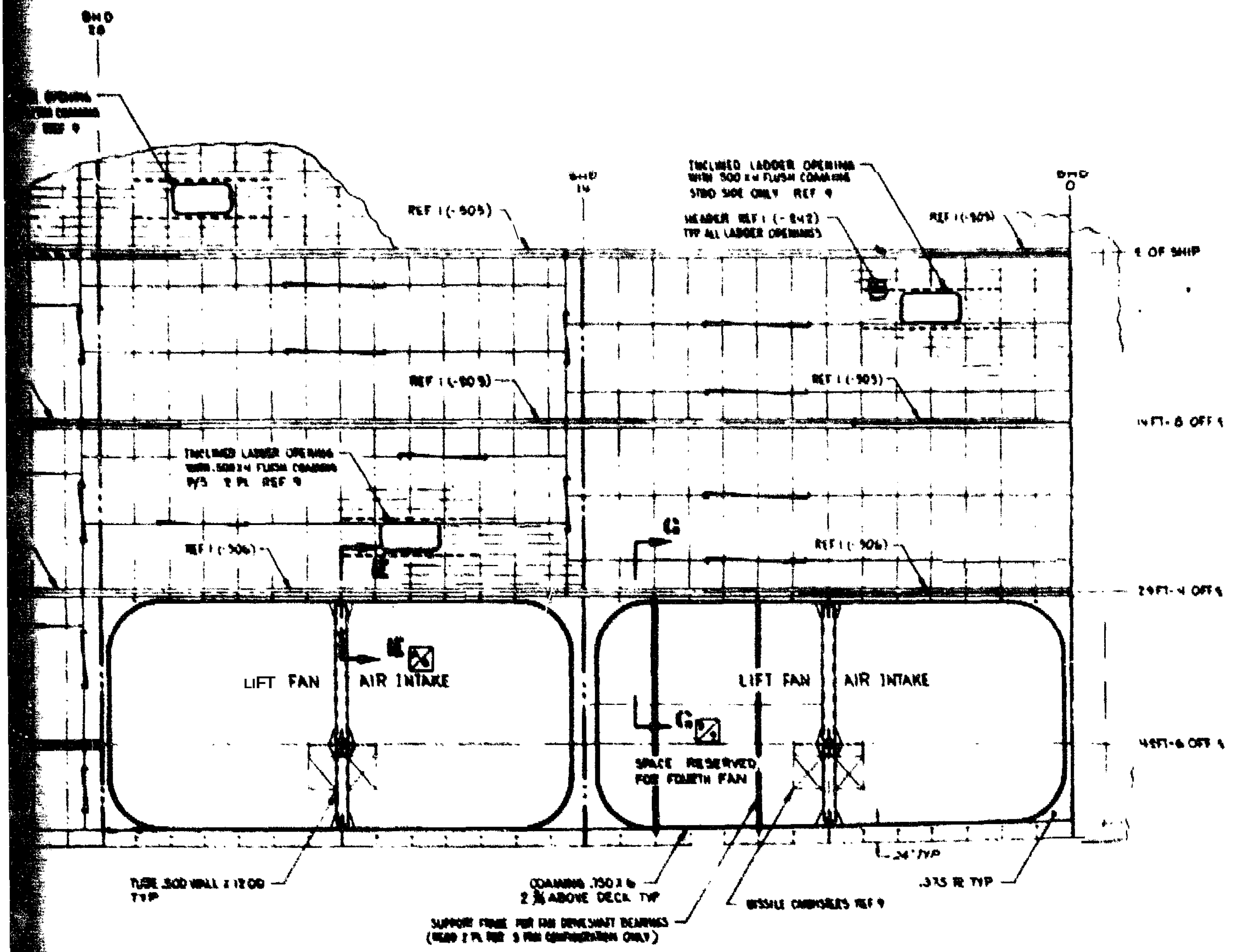
ECTION E - E
ALE 1=12

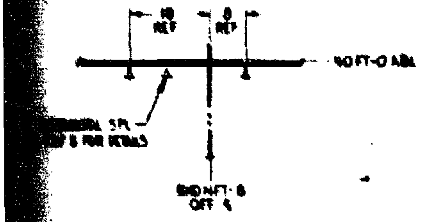


SECTION D - D
SCALE 1=12
ROTATED 90° CCW

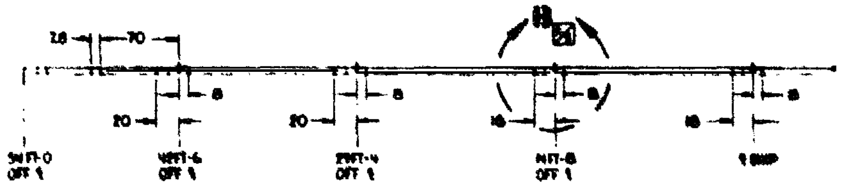


SECTION C - C
SCALE 1=12
TYP BUTT JOINT



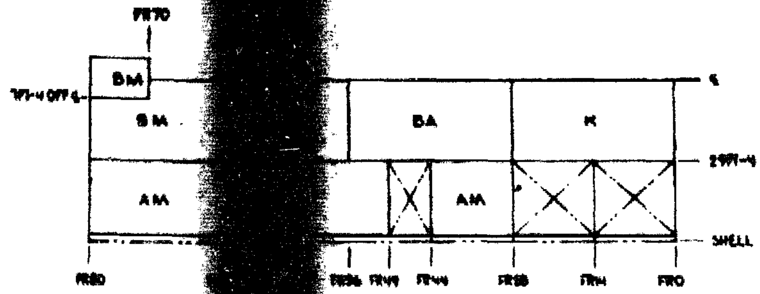


DETAIL B
SCALE 1=12



SECTION A-A
SCALE ¾=12
VIEW LOOKING AFT
ROTATED 90° CW

A REVISION [illegible] LOGGED



P[illegible] PLATING / STRINGER DIAGRAM

[illegible] FOR DETAILS OF PL & STGR SEE REF 2

SCALE - NONE

9. FOR LOCATION PROPORTION AND CLOSURE REQUIREMENTS OF ALL OPENINGS SEE REF 9

8. FILLET WELDS AROUND ENDS OF WELDED MEMBERS TO FORM CLOSED LOOP.

7. ABBREVIATIONS PER MIL-STD-12.

6. SEE DIAGRAM (ZONE D 2) FOR PLATING AND STRINGER COMBINATIONS.

5. STARBOARD SIDE SHOWN - PORT SIDE OPPOSITE EXCEPT AS NOTED.

4. FRAME SPACING 36in EXCEPT AS NOTED.

3. GENERAL STIFFENER SPACING 18in EXCEPT AS NOTED.

2. FABRICATE WELD AND INSPECT PER NAVSHIPS 0900-060-4010. (SEE 2KSES PROGRAM DIRECTIVES 500.12, 500.16, 500.19, 500.20)

1. MATERIAL: (SHEET & PLATE) 5456 AL ALY COND H116/H117 FOR THICKNESSES .188 AND ABOVE, COND H 32S FOR THICKNESSES BELOW .188, PER FED SPEC QQ-A-250/20. (EXTRUSIONS) 5456 AL ALY COND H111 PER FED SPEC QQ-A-200/7.

NOTES:

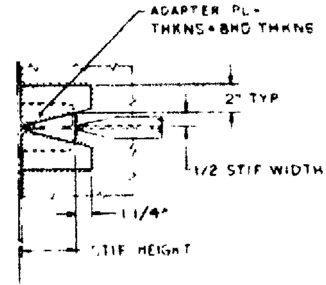
REF	DRAWING NO.	TITLE
9	LL 802004	GENERAL ARRANGEMENT MAIN DECK
8	LL 122001	BULKHEADS TRANSVERSE
7	LL 121004	BHD LONG 49FT-6 OFF ℄
6	LL 121001	BHD LONG CL
5	LL 117001	FRAMES TRANSVERSE
4	LL 111001	SHELL PLATING
3	LL-110001	BOW
2	LL 101005	PLATING/TEE TABULATION
1	LL 101004	STRL EXTRUSIONS

LSES DECK PLATING -
MAIN DECK

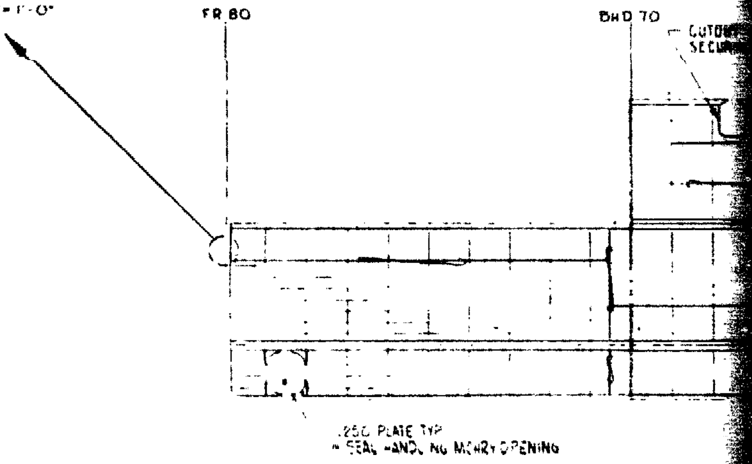
J LL131001

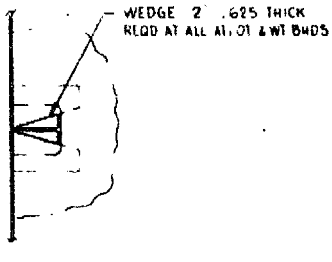
3

4

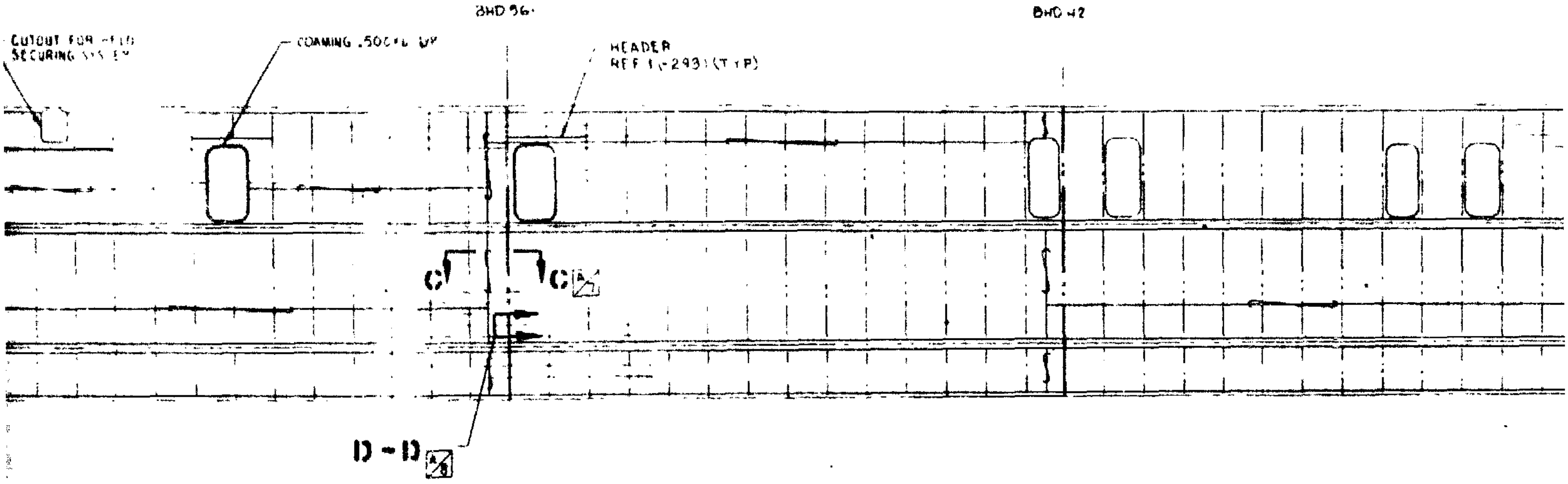


TYP WT STIF PEN
SCALE - 3" = 1'-0"





SECTION D - D 8/7
SCALE - NONE



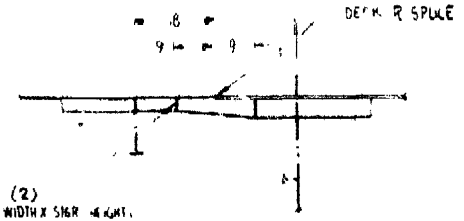
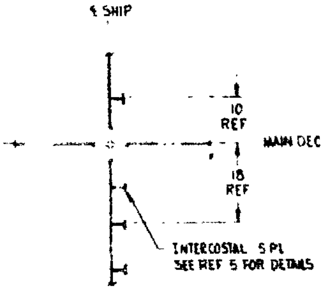


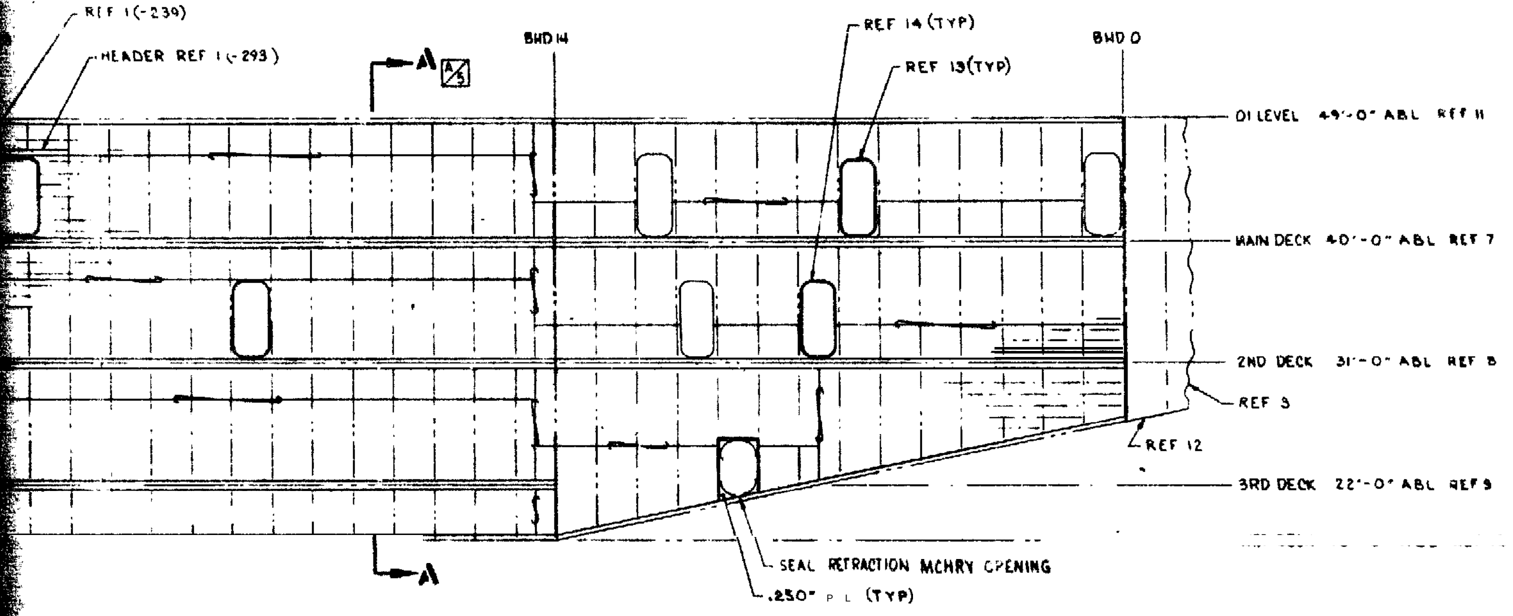
PLATE (2)
.250 THICK x STGR CAP WIDTH x STGR HEIGHT
NOT REQD WHERE HEIGHT DIFFERENCE IS 1/4 OR LESS

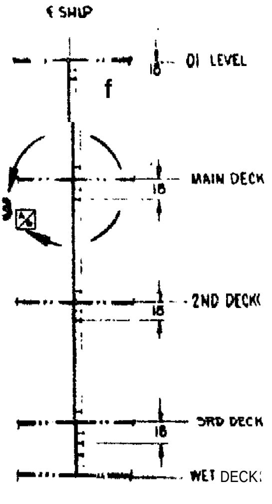
SECTION **C - C**
SCALE - NONE
TYP BUTT JOINT



DETAIL **B**
SCALE 1 = 12

51583	LL121001	A	1



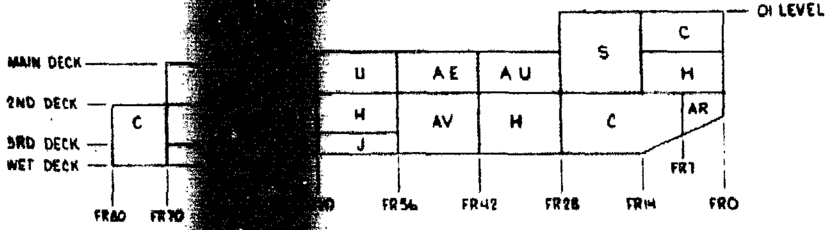


SECTION A-A C/4
SCALE - NONE

81963 LL121001 A 1

UNCLASSIFIED

A | REVISED PER ECO [illegible]



PL PLATING/STRINGER DIAGRAM

FO FOR DETAILS OF R & STGR SEE REF 2

SCALE - NONE

460

9. FOR LOCATION PROPORTION AND CLOSURE REQUIREMENTS OF ALL OPENINGS SEE REF 13&14

8. FILLET WELDS AROUND ENDS OF WELDED MEMBERS TO FORM CLOSED LOOP.

7. ABBREVIATIONS PER MIL-STD-12.

6. SEE DIAGRAM (ZONE D2) FOR PLATING AND STRINGER COMBINATIONS.

5. STARBOARD SIDE SHOWN - PORT SIDE OPPOSITE EXCEPT AS NOTED.

4. FRAME SPACING 56in EXCEPT AS NOTED.

3. GENERAL STIFFENER SPACING 10in EXCEPT AS NOTED.

2. FABRICATE WELD AND INSPECT PER NAVSHIPS 0900-060-4010. (SEE 2KSES PROGRAM DIRECTIVES 500.12, 500.16, 500.19, 500.20)

1. MATERIAL: (SHEET & PLATE) 5456 AL ALY COND H116/H117 FOR THICKNESSES .188 AND ABOVE, COND H323 FOR THICKNESSES BELOW .188, PER FED SPEC QQ-A-250/20. EXTRUSIONS 5456 AL ALY COND H111 PER FED SPEC QQ-A-200/7.

NOTES:

DOCUMENT RELEASE

14	LL802005	GEN ARRANGEMENT - 2ND DECK
13	LL802004	GEN ARRANGEMENT - MAIN DECK
12	LL802009	LSES HULL LINES
11	LL136001	DECK PLATING - 01 LEVEL
10	LL134001	DECK PLATING - WET DECK
9	LL133001	DECK PLATING - 3RD DECK
8	LL132001	DECK PLATING - 2ND DECK
7	LL131001	DECK PLATING - MAIN DECK
6	LL122001	BULKHEADS - TRANSVERSE
5	LL117001	FRAMES - TRANSVERSE
4	LL111001	SHELL PLATING
3	LL110001	BOW
2	LL101005	PLATING/TEE TABULATION
1	LL101004	EXTRUSIONS - STRUCTURAL
REF	DRAWING NO.	TITLE

J.A. JACOB

P.J.

LSES BULKHEAD -
LONG, CL

J | LL121001 | A

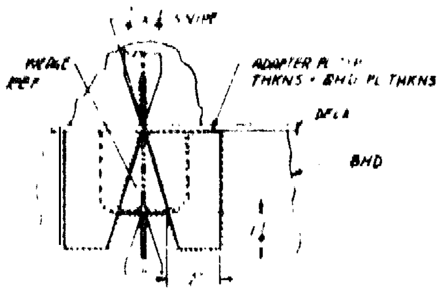
UNCLASSIFIED

3

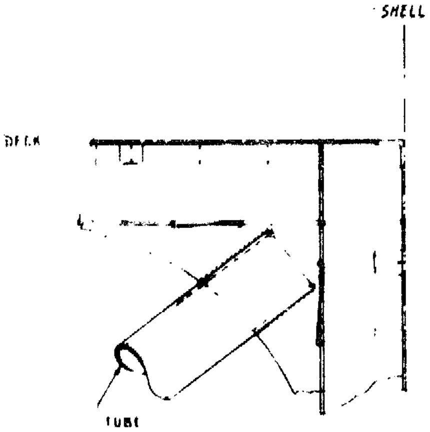
4

UNCLASSIFIED

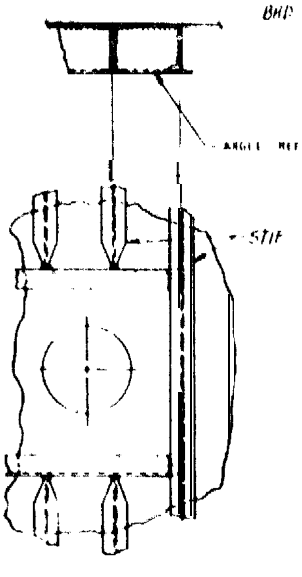
12 11 10



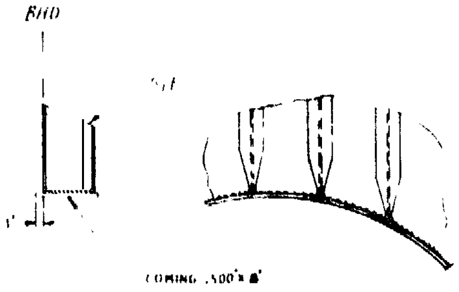
DETAIL **D** [A/5]
SCALE 3" = 1'
REQ'D AT ALL AT, DECK & WT LONG BHDS, SHELL & DECKS REF 14, 5, 6 & 7



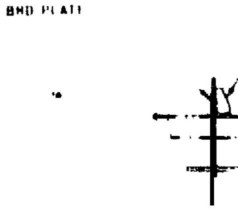
DETAIL **A** [D/6]
SCALE $1\frac{1}{2}$" = 1'-0"
(TYP TRUSS DETAIL)



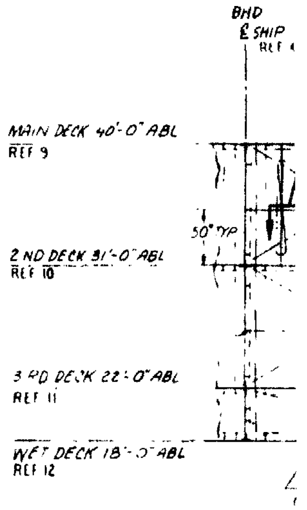
DETAIL **C** [A/7]
SCALE $1\frac{1}{2}$" = 1'-0"

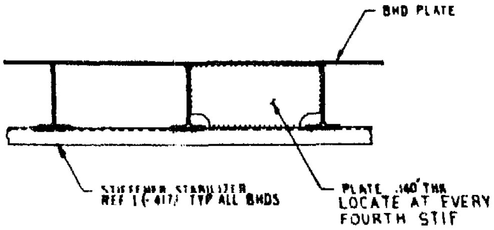


DETAIL **B** [C/5]
SCALE 1 1/2" = 1'-0"

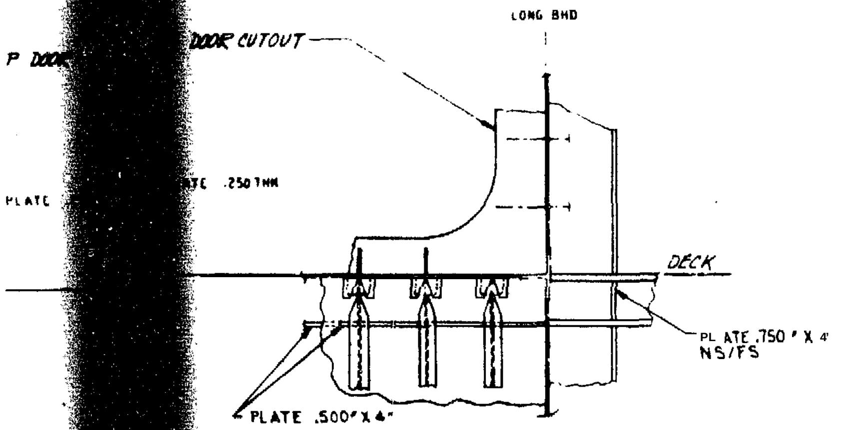


UNCLASSIFIED

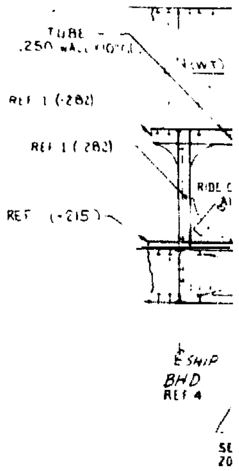




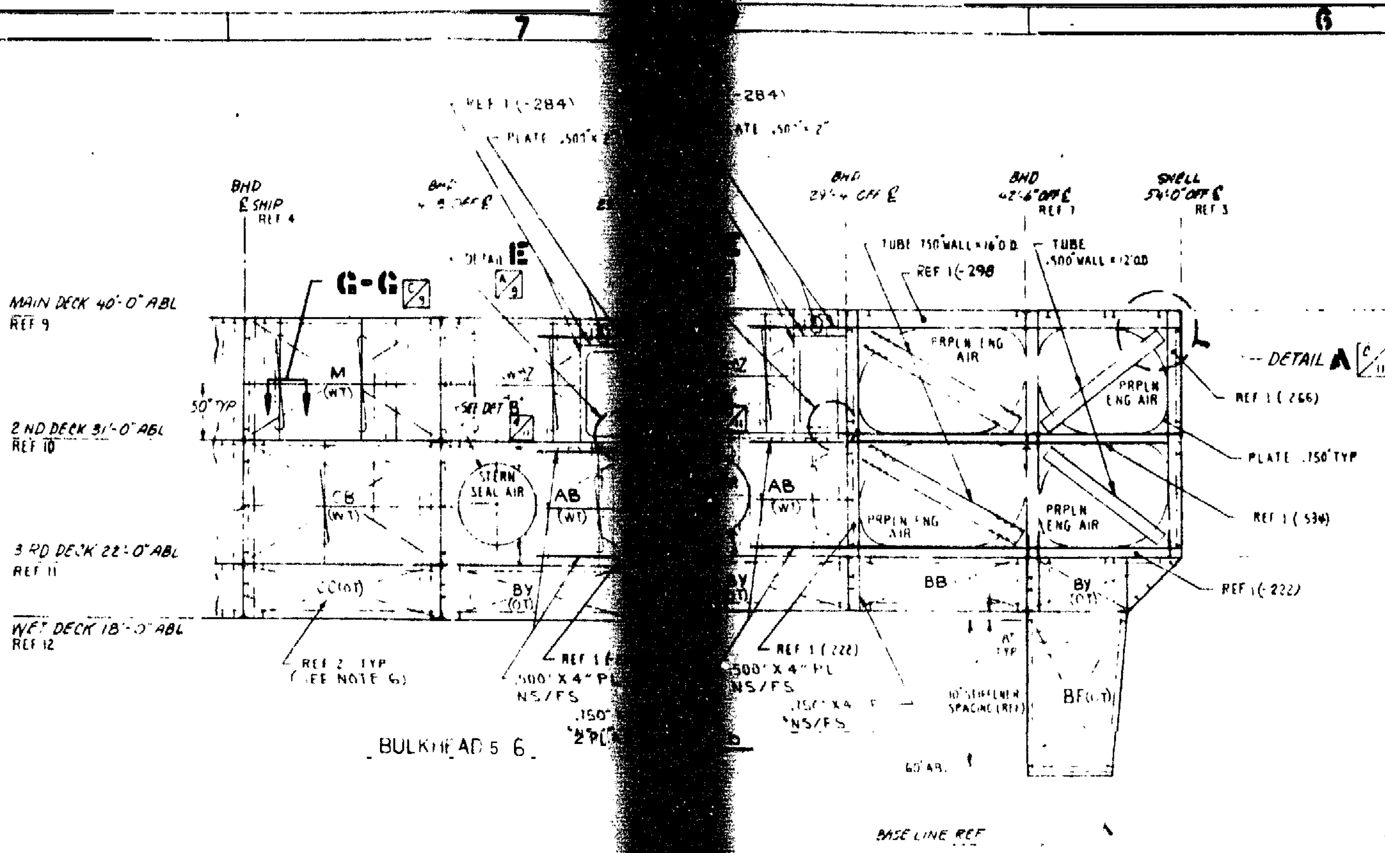
SECTION G-G D
SCALE 3" - 1'-0"



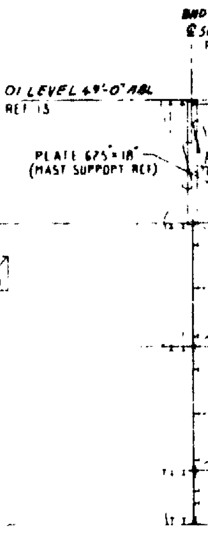
DETAIL E D 7
SCALE 1½" = 1'-0"

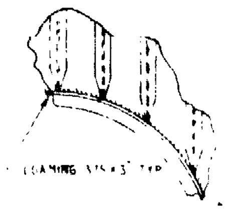


LL 122001 1

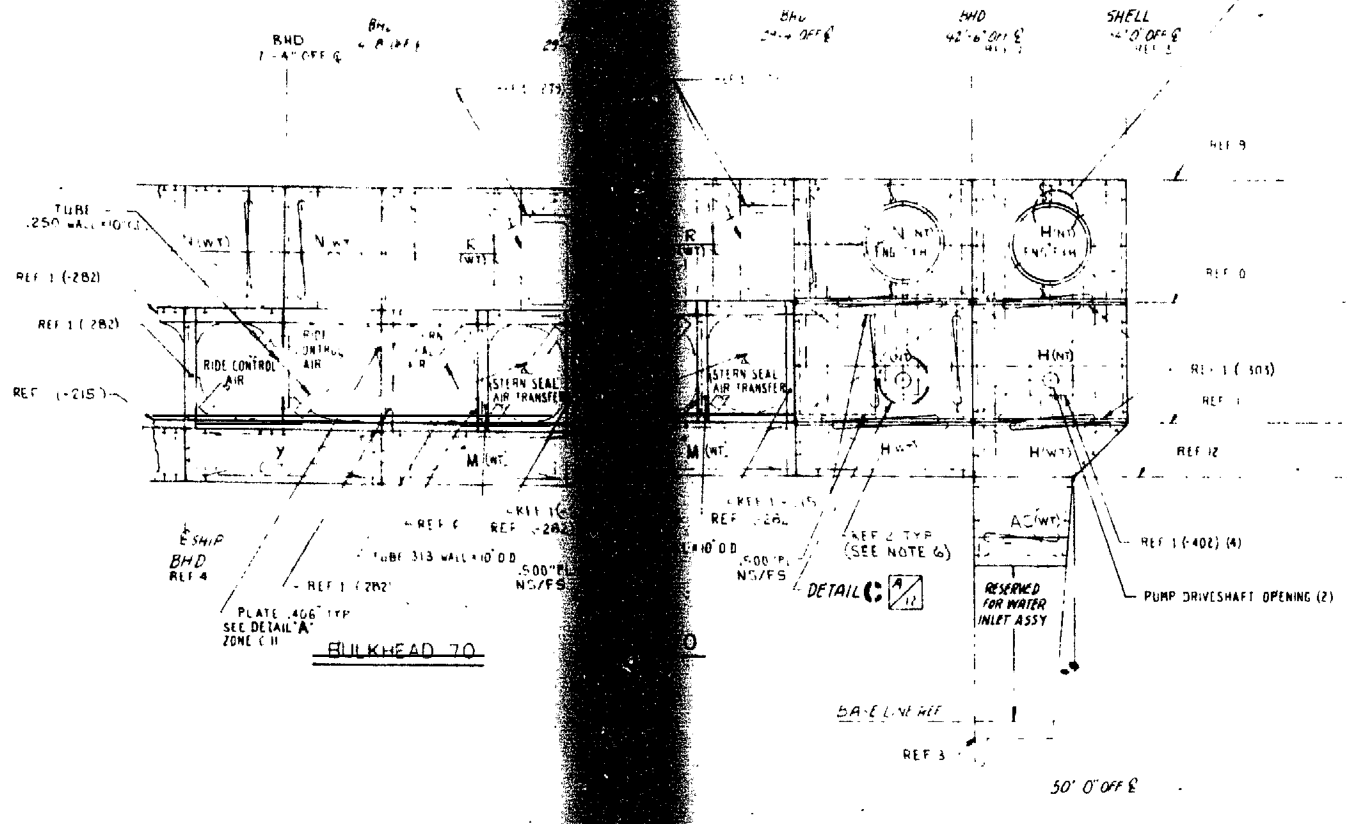


BULKHEAD 5 6





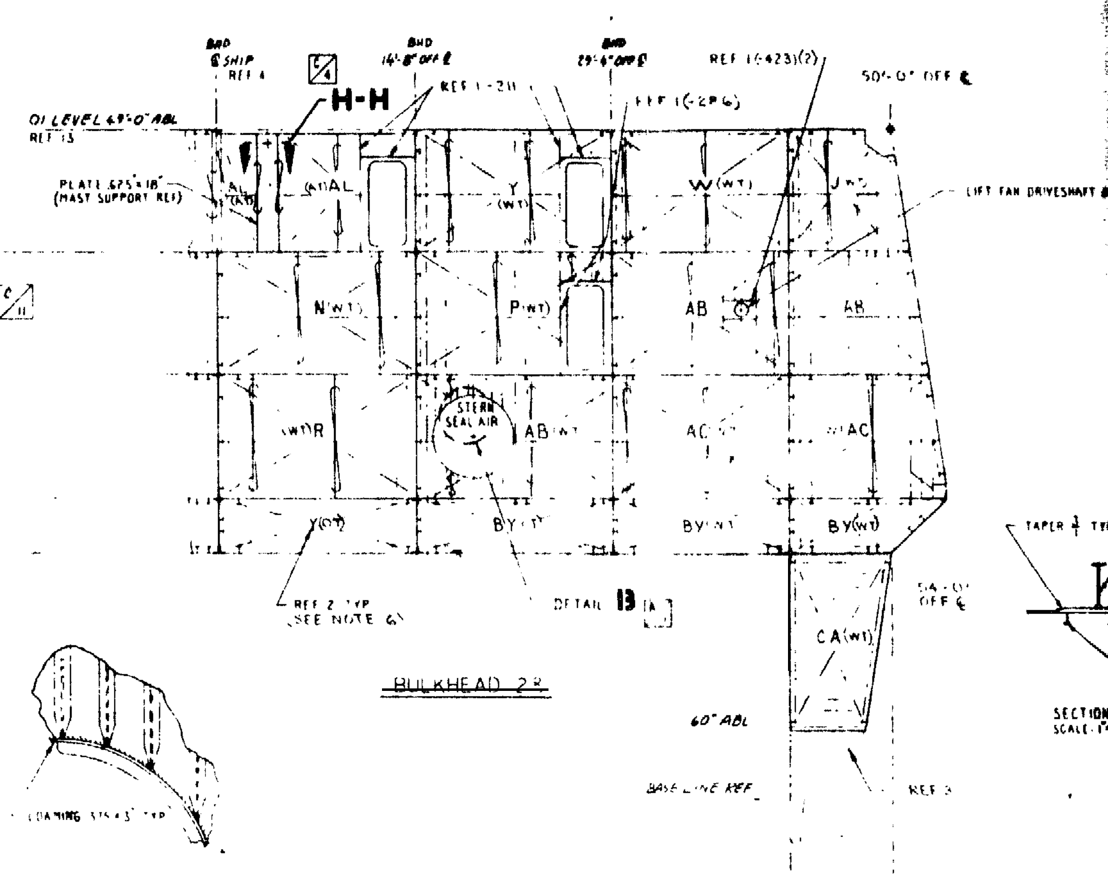
EXHAUST ... SCALE 1" ... 0"



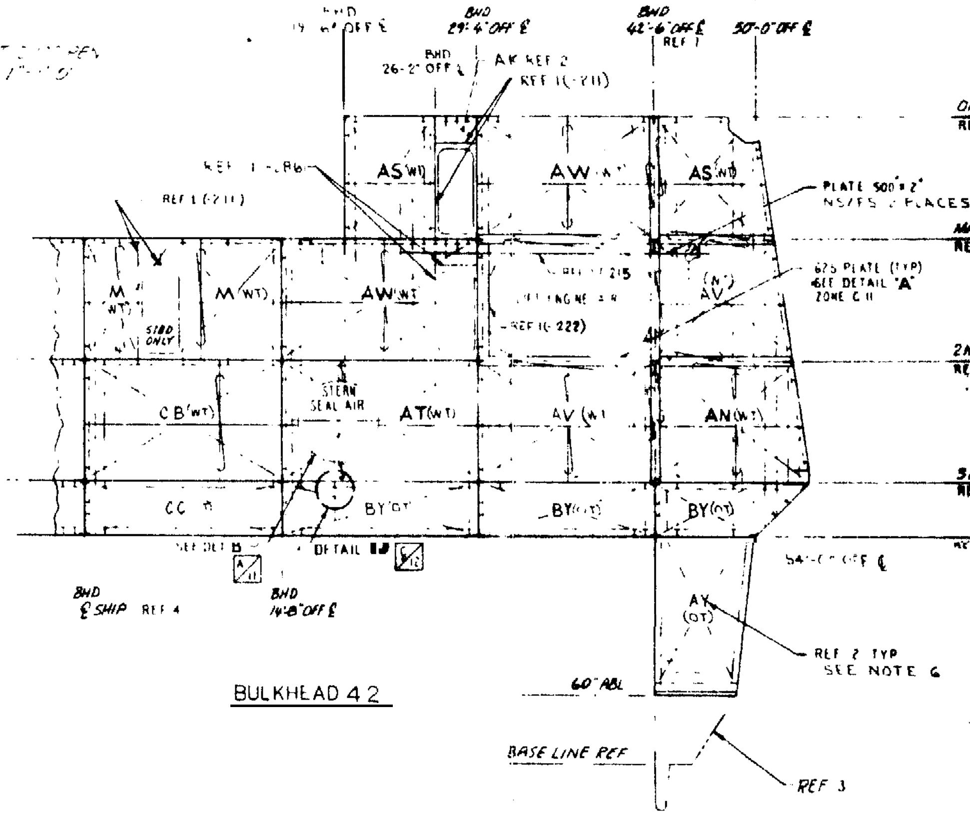
BULKHEAD 70

2

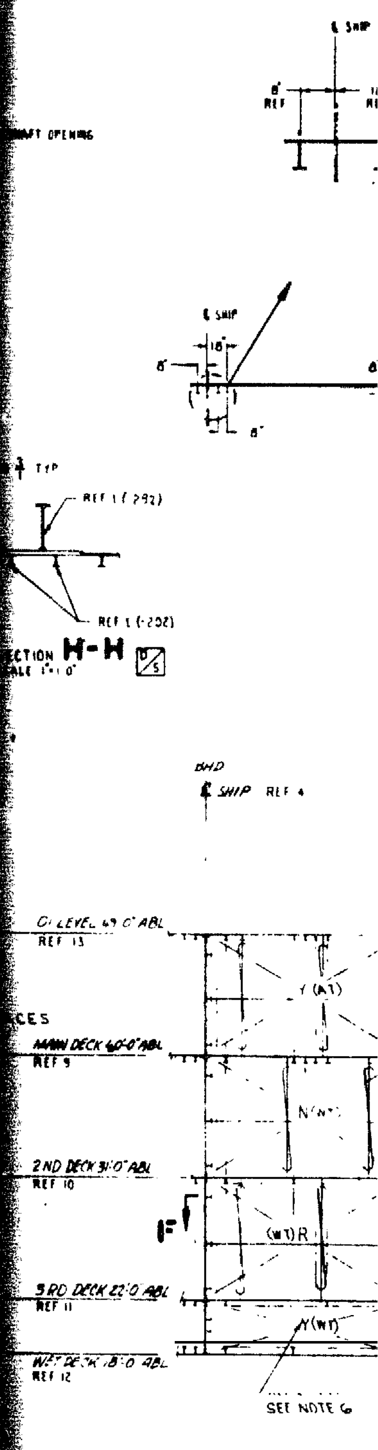
1



BULKHEAD 22



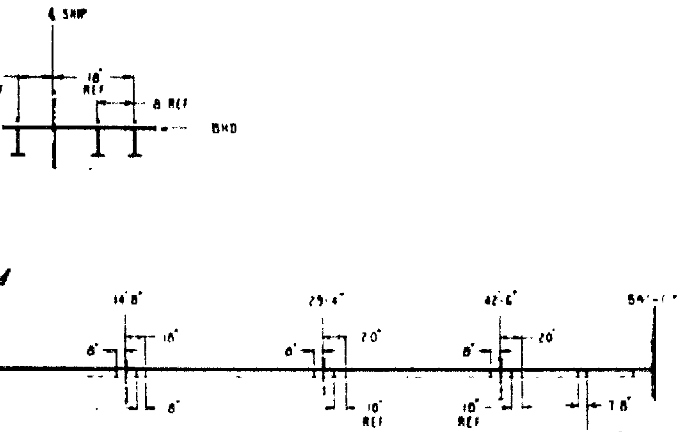
BULKHEAD 42



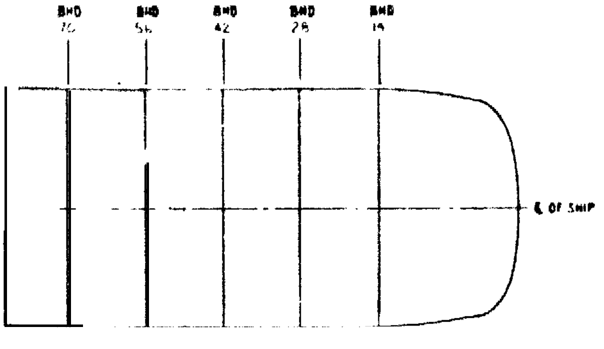
51563 LL122001 1

3

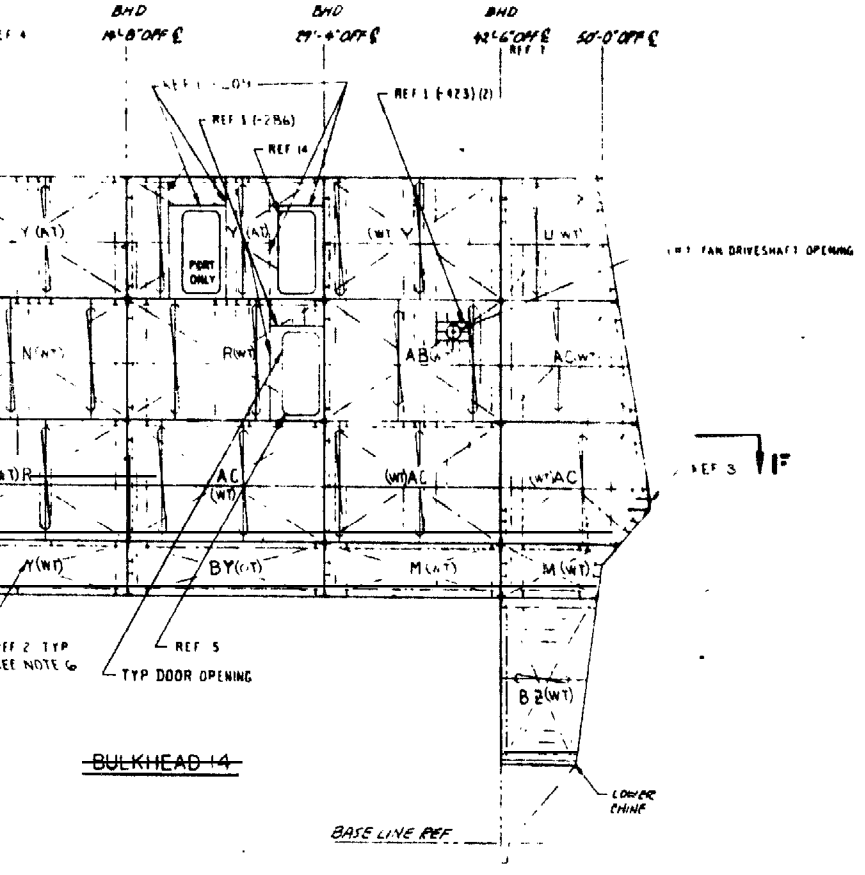
3 2



SECTION F-F B/5
TYP STIFFENER SPACING
ALL BHDS



ORIENTATION VIEW
SCALE: NONE



~~BULKHEAD 14~~

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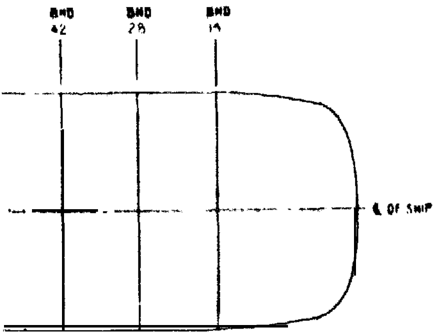
466

NO

17		
16		
15		
14	LL8[illegible]004	GEN ARRANGEMENT MAIN DECK
13	LL135001	DECK PLATING - 01 LEVEL
12	LL134001	DECK PLATING - WET DECK
11	LL133001	DECK PLATING - 3RD DECK
10	LL132001	DECK PLATING - 2ND DECK
9	LL131001	DECK PLATING - MAIN DECK
8	LL8[illegible]7	GEN ARRANGEMENT WET DECK
7	LL121004	BHD LONG 42'-6" OFF ℄
6	LL802006	GEN ARRANGEMENT 3RD DECK
5	LL802005	GEN ARRANGEMENT 2ND DECK
4	LL121001	BHD LONG ℄
3	LL111001	SHELL PLATING
2	LL101005	PLATING TEE TABULATION
1	LL101004	EXTRUSIONS - STRL

UN

4



ORIENTATION VIEW
SCALE: NONE

466

NOTES:

1. MATERIAL: (SHEET & PLATE) 5456 AL ALY COND H116/117 FOR THICKNESSES .188 AND ABOVE. COND H323 FOR THICKNESSES BELOW .188, PER FED SPEC QQ-A-250/20. (EXTRUSIONS) 5456 AL ALY COND H111 PER FED SPEC QQ-A-200/7.
2. FABRICATE, WELD AND INSPECT PER NAVSHIPS 0900-060-4010 (SEE 2KSES PROGRAM DIRECTIVES 500.12, 500.16, 500.19 & 500.20).
3. GENERAL STIFFENER SPACING 10" EXCEPT AS NOTED.
4. FRAME SPACING 36" EXCEPT AS NOTED.
5. STARBOARD SIDE SHOWN - PORT SIDE OPPOSITE EXCEPT AS NOTED.
6. SEE REF 2 TABULATION CODE IDENT N F/D FOR PLATING & STRINGER COMBINATIONS.
7. ABBREVIATIONS PER MIL-STD-12.
8. FILLET WELDS AROUND ENDS OF WELDED MEMBER TO FORM CLOSED LOOP.
9. FOR LOCATION, PROPORTION AND CLOSURE REQUIREMENTS OF ALL OPENINGS SEE REF 14, 15, 16 & 17.
10. FOR DETAILS OF PLATING & STRINGERS SEE REF 2.

DOCUMENT RELEASE

17		
16		
15		
14	LL6[illegible]004	GEN ARRANGEMENT MAIN DECK
13	LL135001	DECK PLATING - 01 LEVEL
12	LL134001	DECK PLATING - WET DECK
11	LL133001	DECK PLATING - 3RD DECK
10	LL132001	DECK PLATING - 2ND DECK
9	LL131001	DECK PLATING - MAIN DECK
8	LL802[illegible]7	GEN ARRANGEMENT WET DECK
7	LL121004	BHD LONG 42'-6" OFF ℄
6	LL802006	GEN ARRANGEMENT 3RD DECK
5	LL802005	GEN ARRANGEMENT 2ND DECK
4	LL121001	BHD LONG ℄
3	LL111001	SHELL PLATING
2	LL101005	PLATING TEE TABULATION
1	LL101004	EXTRUSIONS - STRL

A. MONTAGUE

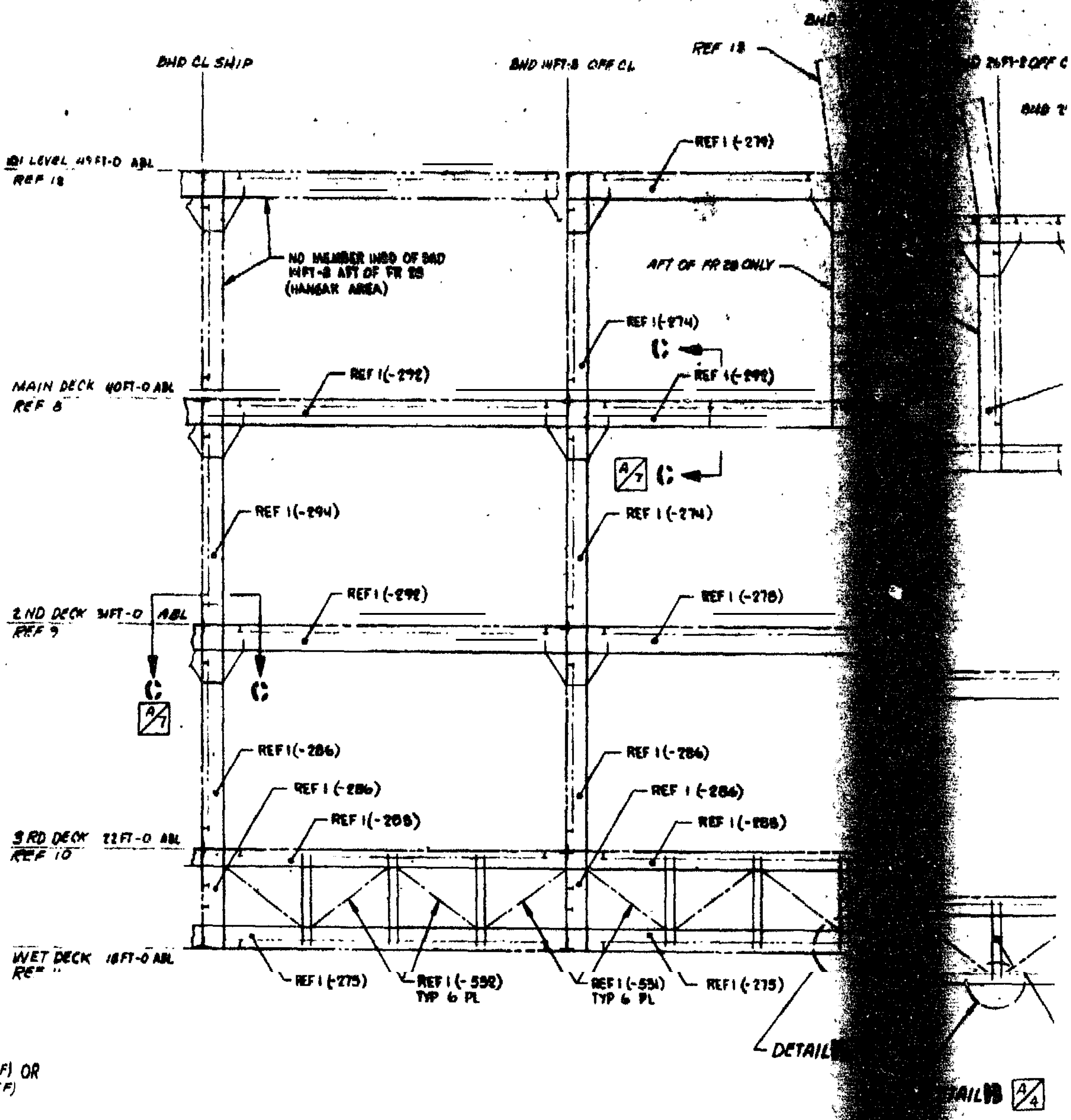
LSES
TRANSVERSE
BULKHEADS

J

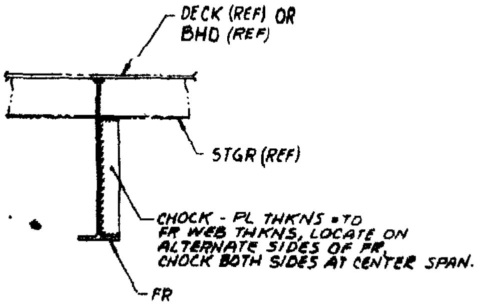
LL122001

4

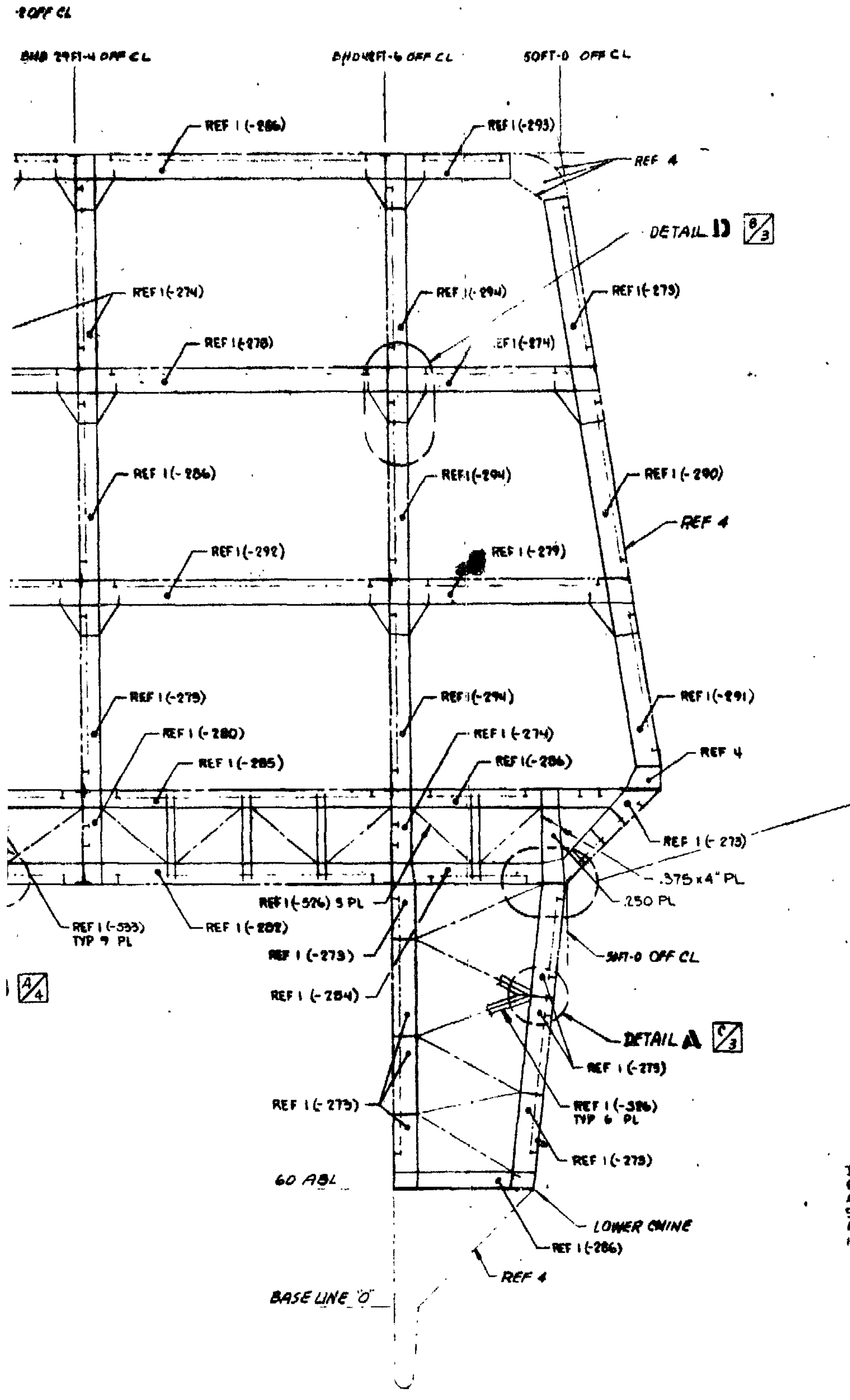
5

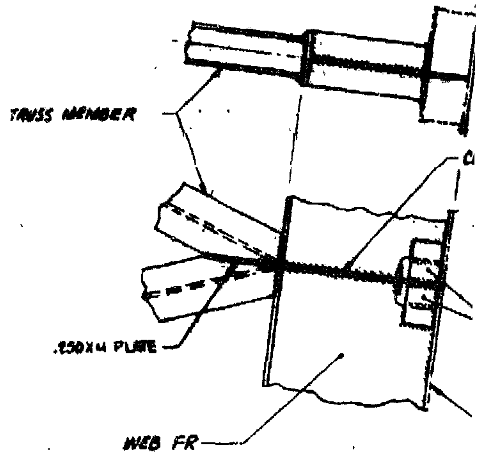


TRANSVERSE FRAMES
FR 32 SHOWN

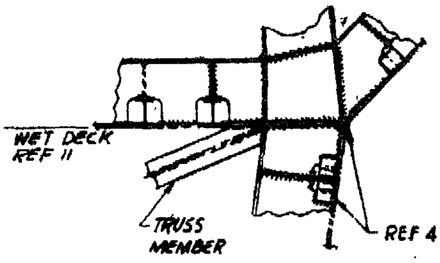


SECT. C-C C/7 C/6
SCALE: 3"=1'-0"
TYP ALL FRAMES





DETAIL A 8/4
TYP TRUSS/FR JOINT- S
SCALE: 3"=1'-0"

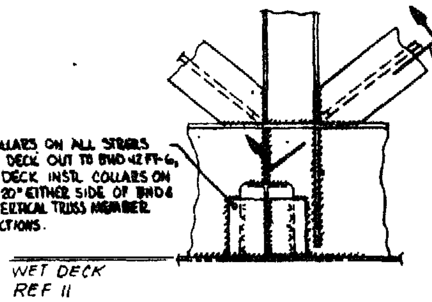


SCALE: 1½"=1'-0"

COLLA
=TO
INSTL COLLAR
20" EITHER
20" ABOVE
3RD STRGR

CH
TH
WE

BR
M/
GR

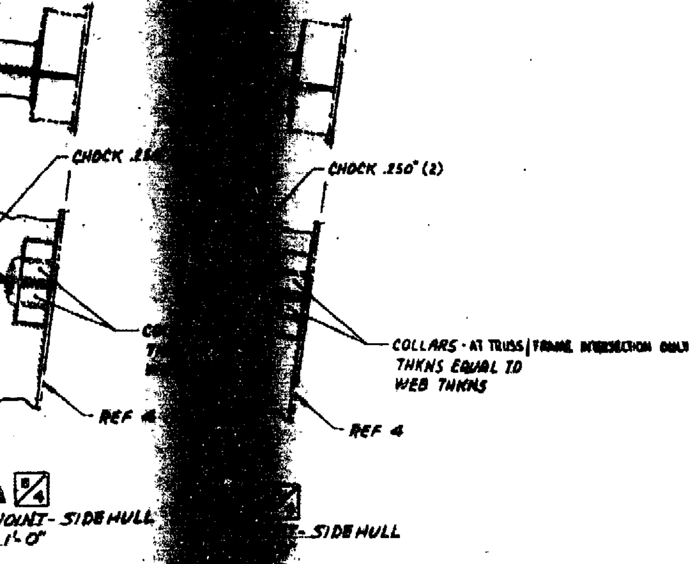


INSTL COLLARS ON ALL STRGRS ON WET DECK OUT TO BHD 42 FT-6, AT 3RD DECK INSTL COLLARS ON STRGRS 20" EITHER SIDE OF BHD 6 AT ALL VERTICAL TRUSS MEMBER INTERSECTIONS.

DETAIL B 8/6
SCALE: 3"=1'-0"

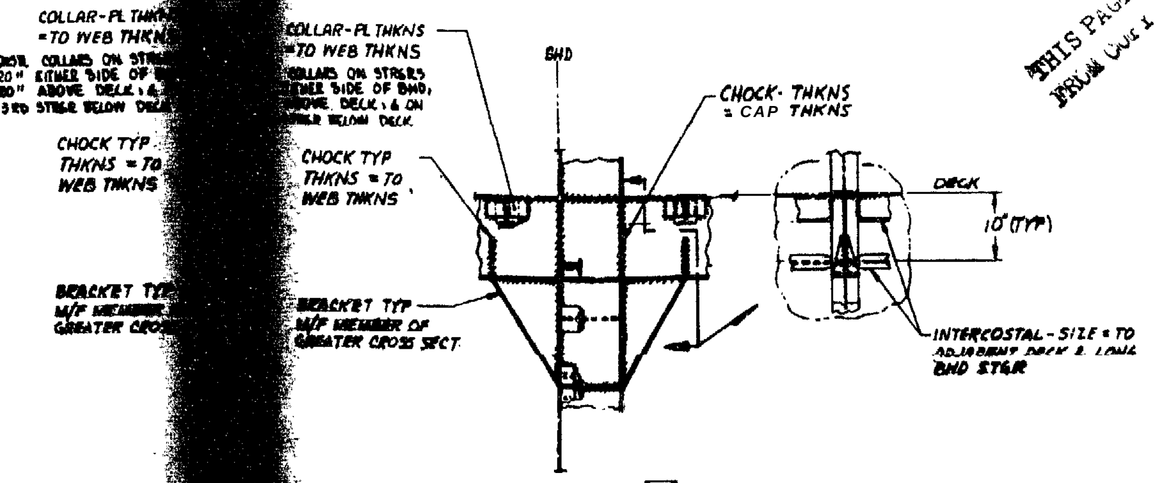
2

A INC ECO



JOINT- SIDE HULL
1'-0"

-SIDE HULL



DETAIL D $\frac{B}{4}$

SCALE: 1½"=1'-0"

TYP FRAME JOINTS ABOVE 3RD DECK

NOTES:

1. MATERIAL: (SHE
ALY COND H FE
AND ABOVE. CO
NESSES BELOW
QQ-A-250/20. (
ALY COND H111 PE

2. FABRICATE, WE
PER NAVSHIPS
(SEE 2KSES PRO
500.12, 500.16,

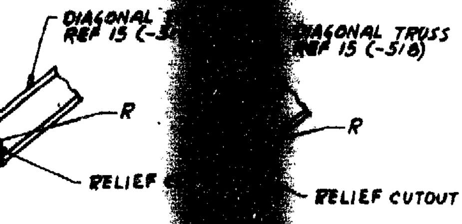
3. GENERAL STIF
10" EXCEPT AS

4. FRAME SPACIN
AS NOTED.

5. STARBOARD S
SIDE OPPOSIT

6. ABBREVIATION

7. FILLET WELDS
OF WELDED ME
CLOSED LOOP

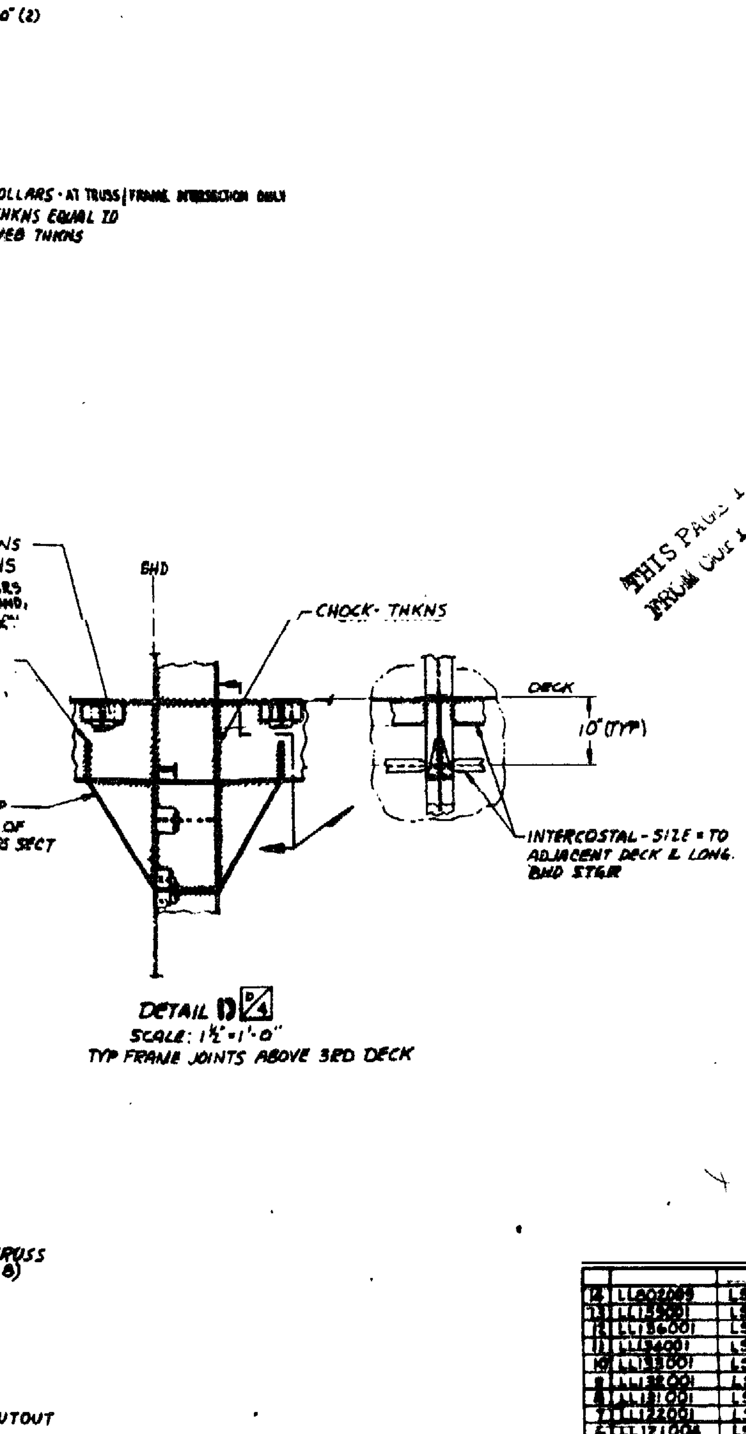


14	LL802089	LSES HULL LINES
13	LL1[illegible]5001	LSES SUPERSTRUCTURE
12	LL136001	LSES 01 LEVEL
11	LL134001	LSES WET DECK
10	LL133001	LSES 3RD DECK
9	LL132001	LSES 2ND DECK
8	LL131001	LSES MAIN DECK
7	LL122001	LSES TRANSVERSE BULKHEADS
6	LL121006	LSES 42'-6" LONG. BULKHEAD
5	LL121001	LSES CL LONGITUDINAL BULKHEAD
4	LL111001	LSES SHELL PLATING
3	LL110001	LSES BOW ASSEMBLY
2	LL[illegible]	LSES [illegible] - PLATING/[illegible]
1	LL[illegible]004	LSES EXTRUSIONS - STRUCTURAL
REF	DRAWING NO.	TITLE

J

UNC

A	INC ECO L00003



DETAIL D D/4
SCALE: 1½" = 1'-0"
TYP FRAME JOINTS ABOVE 3RD DECK

NOTES:

1. MATERIAL: (SHEET & PLATE) 5456 AL ALY COND H116 FOR THICKNESSES .188" AND ABOVE. COND H323 FOR THICKNESSES BELOW .188" PER FED SPEC QQ-A-250/20. (EXTRUSIONS) 5456 AL ALY COND H111 PER FED SPEC QQ-A-200/7.
2. FABRICATE, WELD AND INSPECT PER NAVSHIPS 0900-060-4010 (SEE 2KSES PROGRAM DIRECTIVES 500.12, 500.16, 500.19 & 500.20).
3. GENERAL STIFFENER SPACING 10" EXCEPT AS NOTED.
4. FRAME SPACING 86" EXCEPT AS NOTED.
5. STARBOARD SIDE SHOWN - PORT SIDE OPPOSITE EXCEPT AS NOTED.
6. ABBREVIATIONS PER MIL-STD-12.
7. FILLET WELDS AROUND ENDS OF WELDED MEMBERS TO FORM CLOSED LOOP.

14	LL602009	LSES HULL LINES
13	LL135001	LSES SUPERSTRUCTURE
12	LL136001	LSES 01 LEVEL
11	LL134001	LSES WET DECK
10	LL133001	LSES 3RD DECK
9	LL132001	LSES 2ND DECK
8	LL131001	LSES MAIN DECK
7	LL122001	LSES TRANSVERSE BULKHEADS
6	LL121006	LSES 42'-6" LONG. BULKHEAD
5	LL121001	LSES CL LONGITUDINAL BULKHEAD
4	LL111001	LSES SHELL PLATING
3	LL110001	LSES BOW ASSEMBLY
2	LL1[illegible]005	LSES [illegible] - PLATING / [illegible]
1	LL101004	LSES EXTRUSIONS - STRUCTURAL
ITEM	DRAWING NO.	TITLE

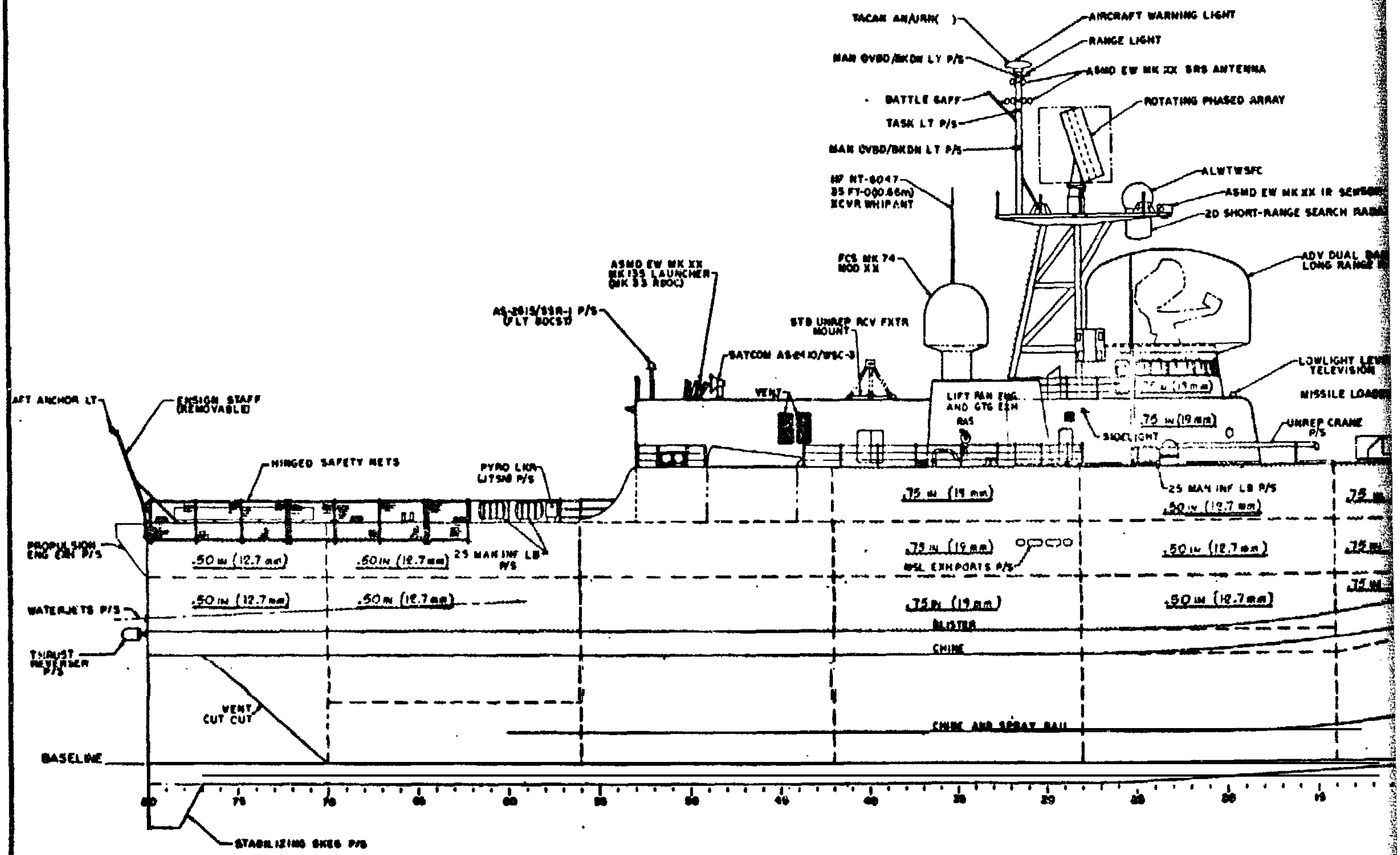
LSES TRANSVERSE FRAME

J | LL117001

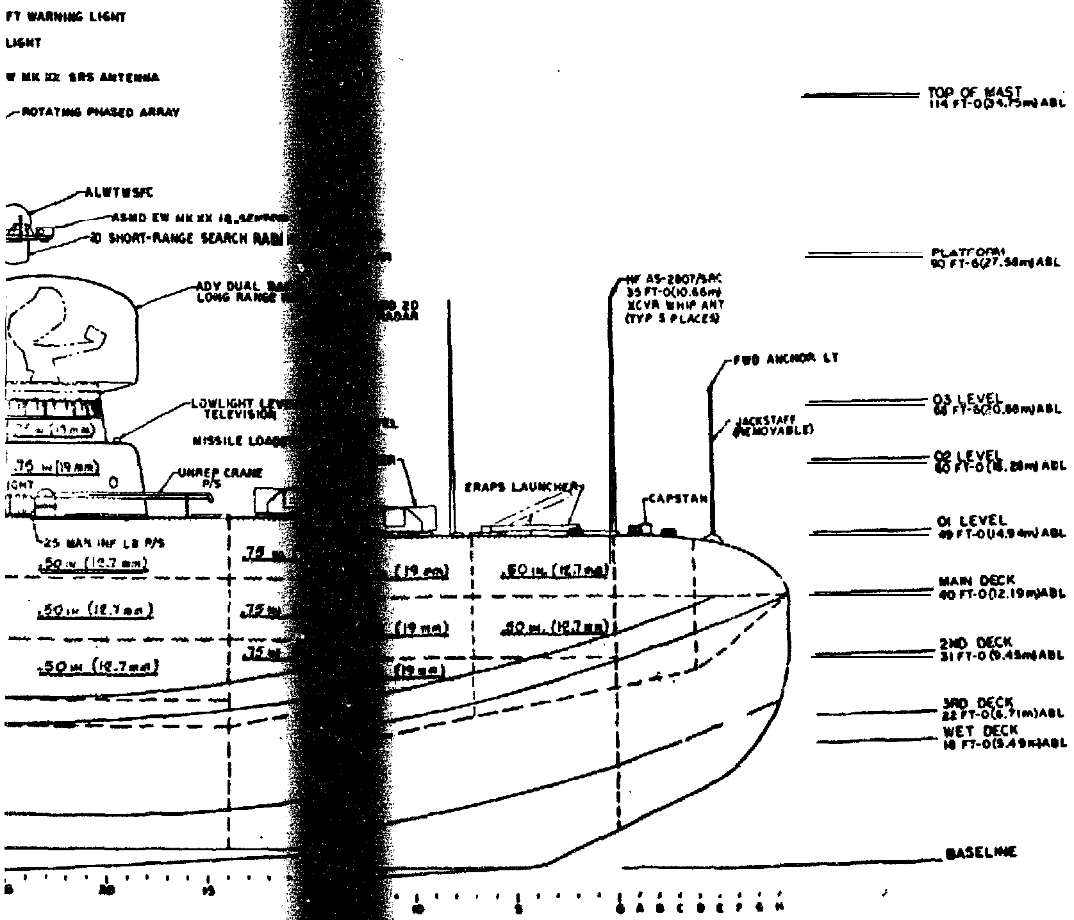
(U) B.3 ARMOR PROTECTION DRAWINGS

(U) This section of Appendix B contains Armor Protection Drawings for the far term ANVCE SES Point Design. These drawings are as follows:

Title	Dwg. Ref.
ANVCE Armor Protection - Shell Plating	AVA 111001
ANVCE Armor Protection - 01 Level and Above	AVA 111002
ANVCE Armor Protection - Main Deck	AVA 111003


TACAN AN/URN( )
AIRCRAFT WARNING LIGHT
RANGE LIGHT
MAN OVBD/BKDN LT P/S
ASMD EW MK XX SRS ANTENNA
BATTLE GAFF
ROTATING PHASED ARRAY
TASK LT P/S
MAN OVBD/BKDN LT P/S
ALWTWSFC
HF RT-6047
35 FT-0(10.66m)
XCVR WHIPANT
ASMD EW MK XX IR SEN
2D SHORT-RANGE SEARCH RA
FCS MK 74
MOD XX
ADV DUAL
LONG RANGE
ASMD EW MK XX
MK135 LAUNCHER
(MK 33 RBOC)
AS-2815/SSR-1 P/S
(FLT BDCST)
STD UNREP RCV FXTR
MOUNT
SATCOM AS-2410/WSC-3
LOWLIGHT LEV
TELEVISION
MISSILE LOA
VENT
LIFT FAN ENG.
AND GTG EXH
RAS
SIDELIGHT
UNREP CRANE
P/S
AFT ANCHOR LT
ENSIGN STAFF
(REMOVABLE)
HINGED SAFETY NETS
PYRO LKR
LITSNI P/S
25 MAN INF LB P/S
PROPULSION
ENG CRH P/S
.50 IN (12.7 mm)
.50 IN (12.7 mm)
25 MAN INF LB
P/S
.75 IN (19 mm)
.50 IN (12.7 mm)
.75 IN (19 mm)
.75 IN (19 mm)
MSL EXHPORTS P/S
.50 IN (12.7 mm)
WATERJETS P/S
.50 IN (12.7 mm)
.50 IN (12.7 mm)
.75 IN (19 mm)
.50 IN (12.7 mm)
BLISTER
THRUST
REVERSER
P/S
CHINE
VENT
CUT CUT
CHINE AND SPRAY RAIL
BASELINE
80
75
70
65
60
55
50
45
40
35
30
25
20
15
STABILIZING SKEG P/S

~~CONFIDENTIAL~~



▭ DESIGNATES AREAS PROVIDED BALLISTIC PROTECTION. PLATING SIZES ARE SHOWN ON THE FACE OF THE DRAWING.

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NO	DWG NO	TITLE			
9	AVA 802010				BOW AND STERN VIEW
8	AVA 802009				INBD PROFILE SIDEHULL
7	AVA 802008				TRANSVERSE SECTION
6	AVA 802007				WET DECK
5	AVA 802006				THIRD DECK
4	AVA 802005				SECOND DECK
3	AVA 802004				MAIN DECK
2	AVA 802003				01 LEVEL AND ABOVE
1	AVA 802002	GENERAL ARRANGEMENT			INBOARD PROFILE

REFERENCES

ANVCE
ARMOR PROTECTION
SHELL PLATING

J

AVA 111001

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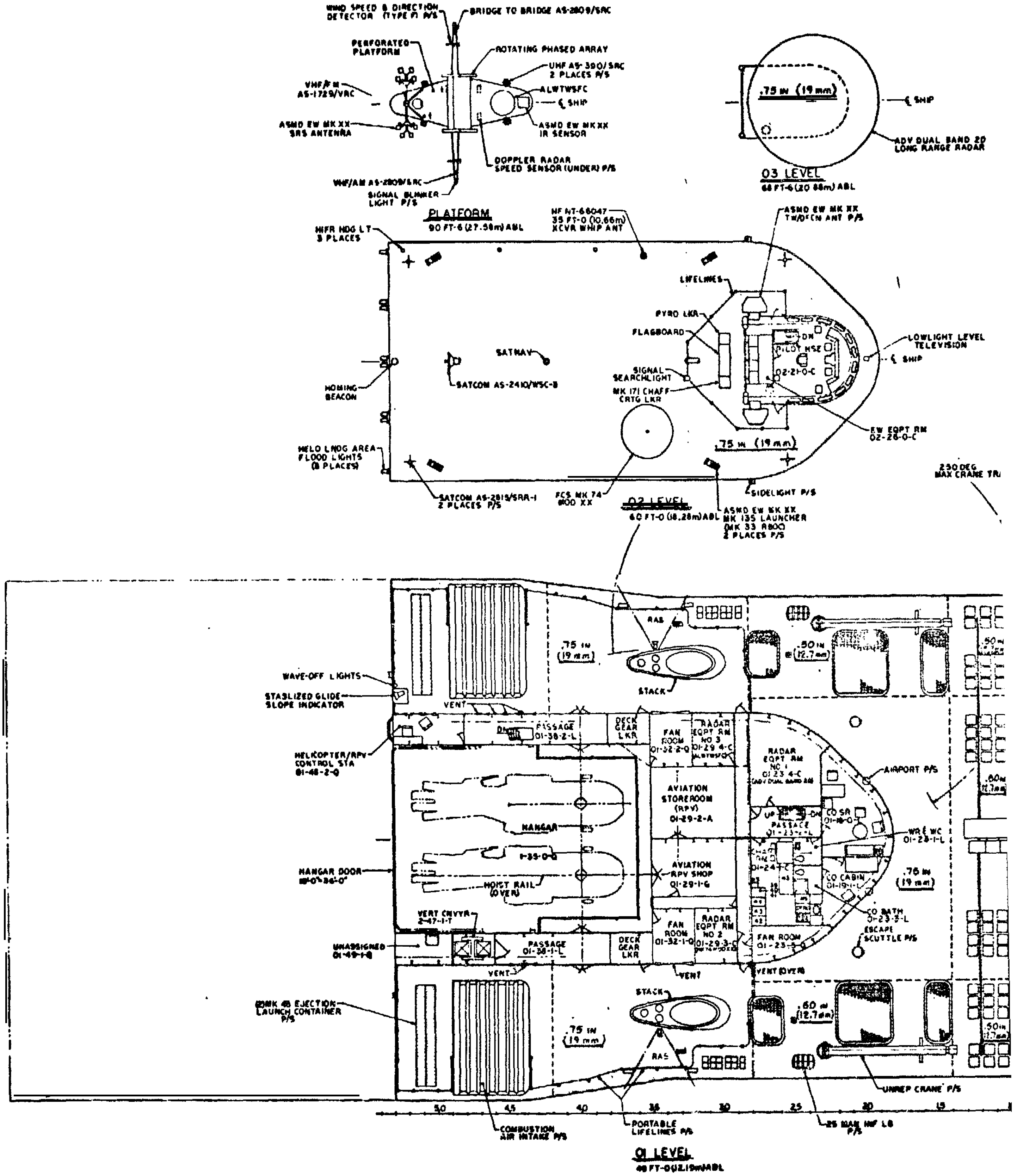
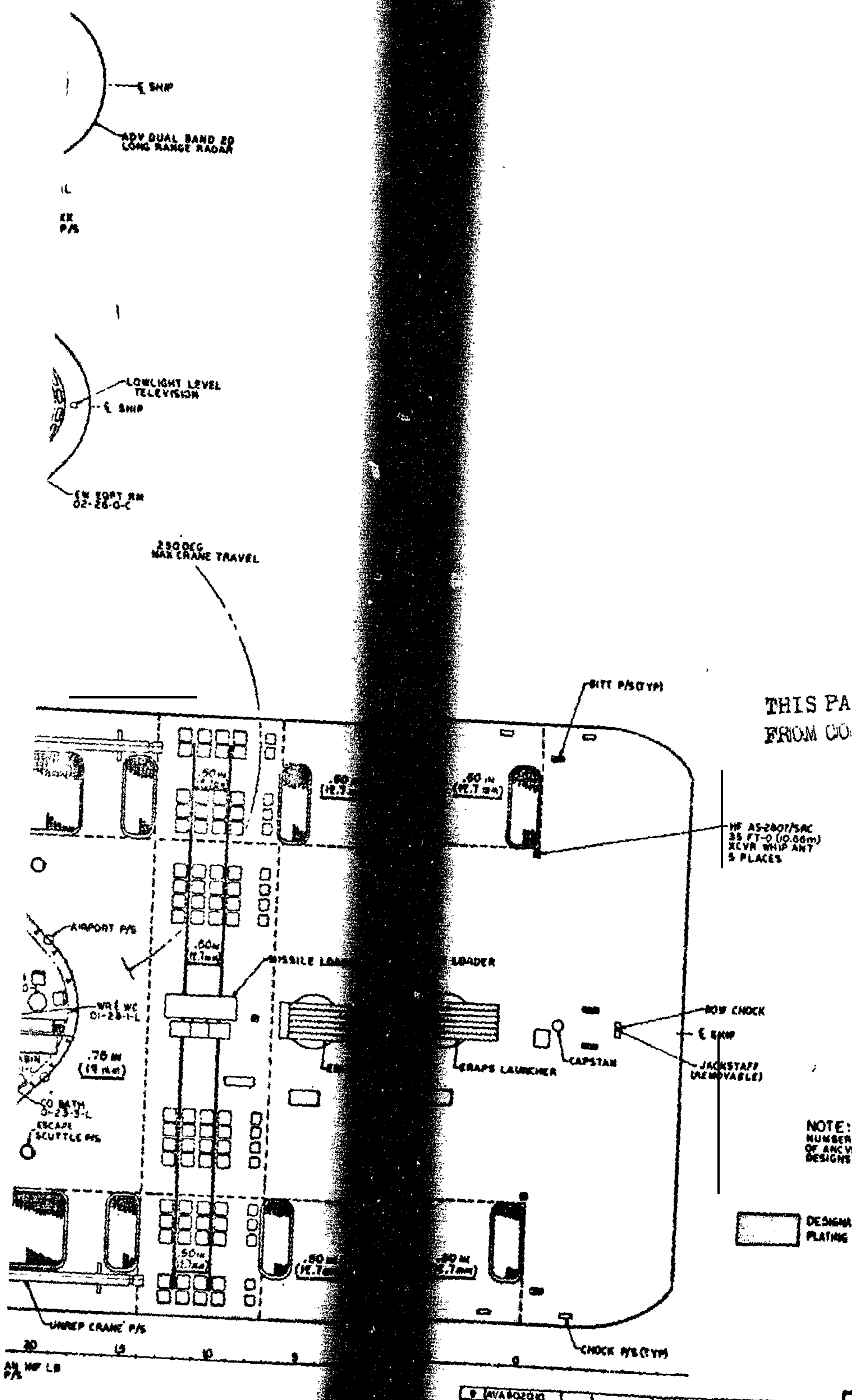

WIND SPEED & DIRECTION DETECTOR (TYPE F) P/S
BRIDGE TO BRIDGE AS-2809/SRC
PERFORATED PLATFORM
ROTATING PHASED ARRAY
UHF AS-390/SRC 2 PLACES P/S
VHF/FM AS-1729/VRC
ALWTWSFC
℄ SHIP
ASMD EW MK XX SRS ANTENNA
ASMD EW MK XX IR SENSOR
DOPPLER RADAR SPEED SENSOR (UNDER) P/S
VHF/AM AS-2809/SRC
SIGNAL BLINKER LIGHT P/S
PLATFORM
90 FT-6 (27.58m) ABL
.75 in (19 mm)
℄ SHIP
ADV DUAL BAND 2D LONG RANGE RADAR
03 LEVEL
68 FT-6 (20.88m) ABL
HF NT-66047 35 FT-0 (10.66m) XCVR WHIP ANT
ASMD EW MK XX TW/DECN ANT P/S
HIFR HDG LT 3 PLACES
LIFELINES
PYRO LKR
FLAGBOARD
SATNAV
SATCOM AS-2410/WSC-3
SIGNAL SEARCHLIGHT
MK 171 CHAFF CRTG LKR
HOMING BEACON
DN
PILOT HSE
02-21-0-C
LOWLIGHT LEVEL TELEVISION
℄ SHIP
EW EQPT RM 02-26-0-C
.75 in (19 mm)
HELO LNDG AREA FLOOD LIGHTS (8 PLACES)
SATCOM AS-2815/SRR-1 2 PLACES P/S
FCS MK 74 MOD XX
02 LEVEL
60 FT-0 (18.28m) ABL
ASMD EW MK XX MK 135 LAUNCHER (MK 33 RBOC) 2 PLACES P/S
SIDELIGHT P/S
230 DEG MAX CRANE TR
RAS
.75 in (19 mm)
STACK
.50 in (12.7 mm)
.50 in (12.7 mm)
WAVE-OFF LIGHTS
STABLIZED GLIDE SLOPE INDICATOR
VENT
DN
PASSAGE 01-38-2-L
DECK GEAR LKR
FAN ROOM 01-32-2-Q
RADAR EQPT RM NO 3 01-29-4-C
RADAR EQPT RM NO 1 01-23-4-C (ADV DUAL BAND RR)
HELICOPTER/RPV CONTROL STA 01-48-2-Q
AIRPORT P/S
.60 in (12.7 mm)
AVIATION STOREROOM (RPV) 01-29-2-A
HANGAR
UP
DN
PASSAGE 01-23-2-L
CO SR 01-18-0
WR & WC 01-23-1-L
1-39-0-Q
HANGAR DOOR 18'-0"×36'-0"
AVIATION RPV SHOP 01-29-1-G
01-24-C
CO CABIN 01-19-1-L
.75 in (19 mm)
HOIST RAIL (OVER)
VERT CNVYR 2-47-1-T
CO BATH 01-23-3-L
ESCAPE SCUTTLE P/S
UNASSIGNED 01-49-1-Q
PASSAGE 01-38-1-L
DECK GEAR LKR
FAN ROOM 01-32-1-Q
RADAR EQPT RM NO 2 01-29-3-C
FAN ROOM 01-23-5
VENT
VENT
VENT (OVER)
STACK
MK 48 EJECTION LAUNCH CONTAINER P/S
.75 in (19 mm)
.60 in (12.7 mm)
.50 in (12.7 mm)
RAS
UNREP CRANE P/S
50
45
40
35
30
25
20
15
COMBUSTION AIR INTAKE P/S
PORTABLE LIFELINES P/S
25 MAN HF LB P/S
01 LEVEL
40 FT-0 (12.19m) ABL

~~CONFIDENTIAL~~



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NOTE:
NUMBERED EQUIPMENT IS PER REV 1 DATED 10-19-76 OF ANCVE COMBAT SYSTEM SUPPORT DATA FOR POINT DESIGNS FOR NAV & ELEK SUPPORT ROOM

▭ DESIGNATES AREAS PROVIDED BALLISTIC PROTECTION. PLATING SIZES ARE SHOWN ON THE FACE OF THE DRAWING.

NO	DWG NO	TITLE
9	AVA802010	BOW AND STERN VIEW
8	AVA802009	INBD PROFILE SIDE HULL
7	AVA802008	TRANSVERSE SECTION
6	AVA802007	WET DECK
5	AVA802006	THIRD DECK
4	AVA802005	SECOND DECK
3	AVA802004	MAIN DECK
2	AVA802002	INBOARD PROFILE &
1	AVA802001	GENERAL ARRANGEMENT OUTBOARD PROFILE

REFERENCES

J.R. Jaggs

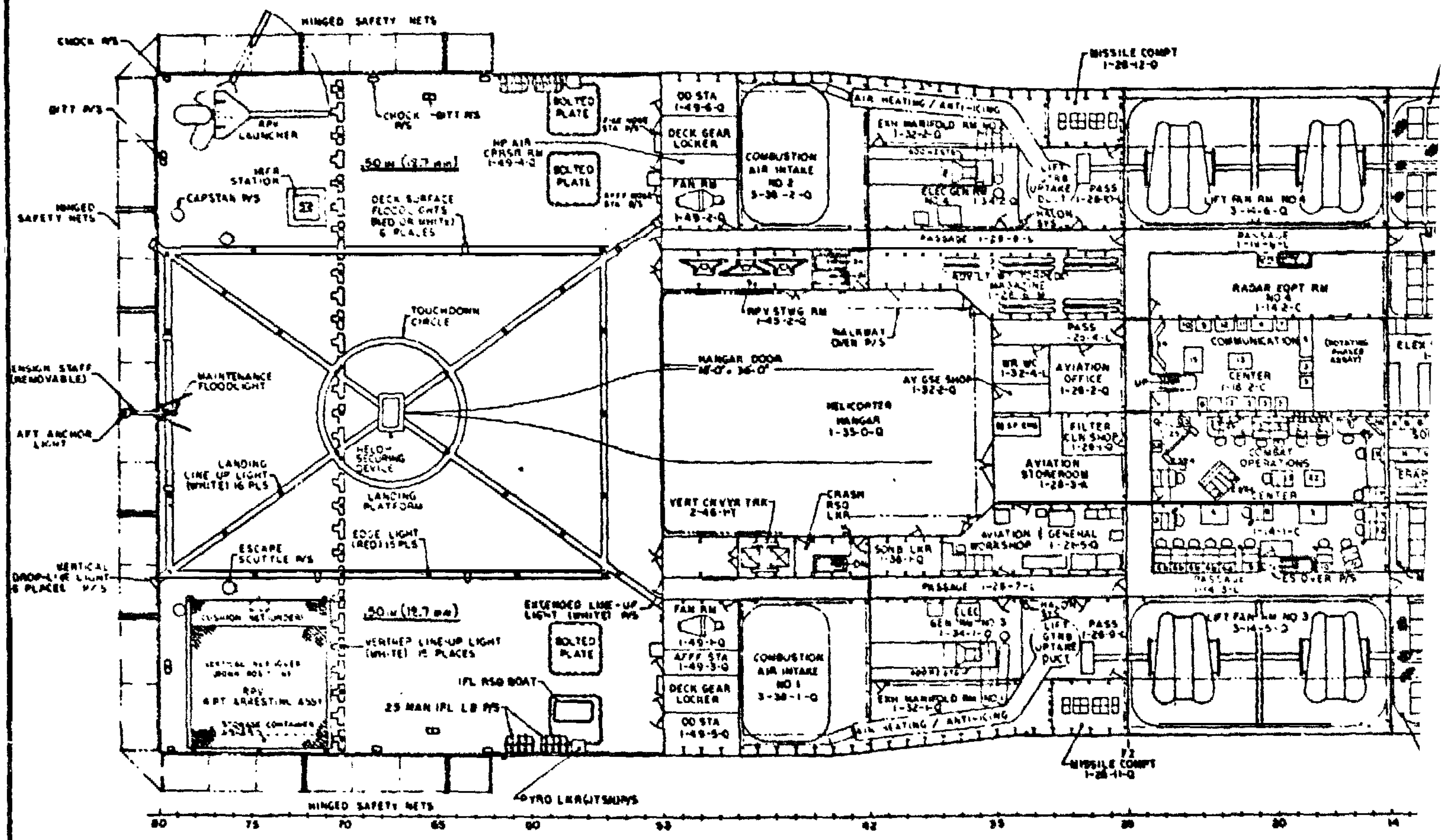
[illegible] INDUSTRIES, INC. [illegible] DIVISION

ANVCE
ARMOR PROTECTION
01 LEVEL AND ABOVE

J AVA 111002

SCALE 1/8 = 1'

~~CONFIDENTIAL~~



MAIN DECK
40 FT-0 (12.19m) ABL

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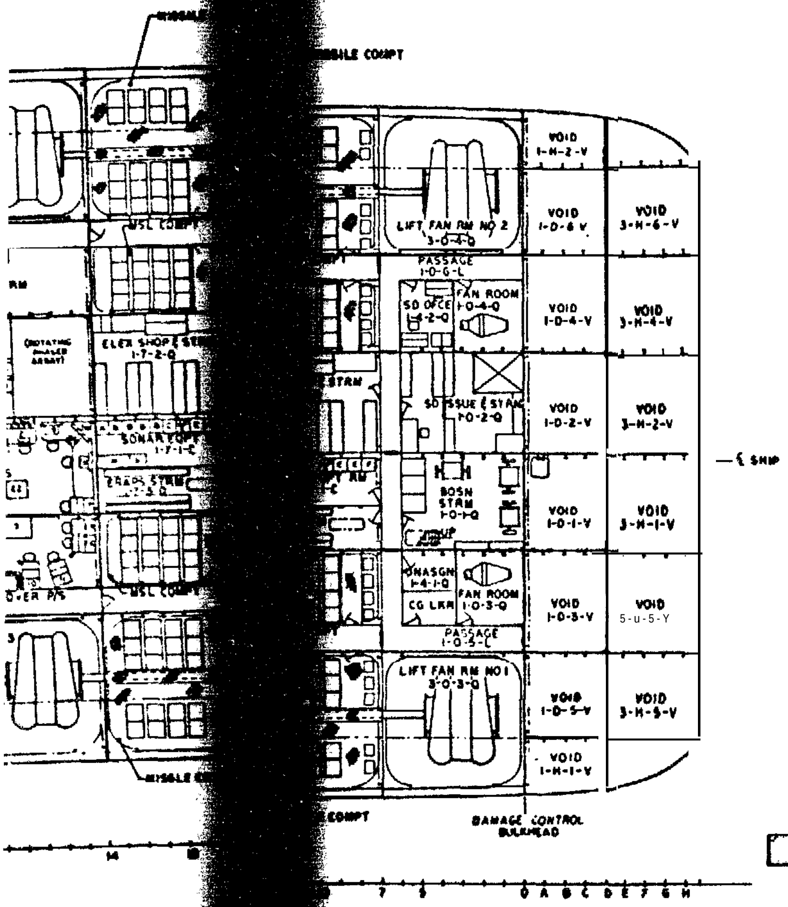

NOTE:
NUMBERED EQUIPMENT IS PER REV 1 DATED 10-19-76 OF ANVCE COMBAT SYSTEM SUPPORT; DATA FOR POINT DESIGNS FOR COC & COMM CENTER
SONAR EQUIPMENT DESIGNATION IS:

LETTER	EQPT TYPE	QTY
A	DATA LINK RCVR+SEL & DISTR	4
B	SIG CONDTN/DATA PRCS	4
C	ADV SIG PRCS	6
D	CRTG MAG TAPE UNIT	1
E	MASS MEMORY UNIT	2.25
F	COMPUTER (AN/UYK 20 MOD XI)	8
G	PWR DISTR CABINET	1
H	INTERFACE CONTROL UNIT	1
J	ARITH DGTL DISPLAY	1

▭ DESIGNATES AREAS PROVIDED BALLISTIC PROTECTION. PLATING SIZES ARE SHOWN ON THE FACE OF THE DRAWING. HELO LANDING PLATFORM IS PRESENTLY .50 in (12.7 mm) PLATING.

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NO.	DWG NO	TITLE	
9	AVA802010		BOW AND STERN VIEW
8	AVA802009		INBD PROFILE SIDEHULL
7	AVA802008		TRANSVERSE SECTION
6	AVA802007		WET DECK
5	AVA802006		THIRD DECK
4	AVA802005		SECOND DECK
3	AVA802003		01 LEVEL AND ABOVE
2	AVA802002		INBOARD PROFILE &
1	AVA802001	GENERAL ARRANGEMENT	OUTBOARD PROFILE

REFERENCES

ANVCE
ARMOR PROTECTION
MAIN DECK

J AVA 111003

~~CONFIDENTIAL~~

2

(U) B.4 SENSOR COVERAGE DRAWINGS

(U) This section of Appendix 3 contains coverage diagrams for the far term ANVCE SES Point Design sensors. These drawings are as follows:

Title	Dwg. Ref.
Advanced Dual Band 2D Long Range Radar - Azimuth Coverage	AVA 450001
Advanced Dual Band 2D Long Range Radar - Elevation Coverage	AVA 450002
Advanced 2D Surface Search Radar - Azimuth Coverage	AVA 450003
Advanced 2D Surface Search Radar - Elevation Coverage	AVA 450004
3D Rotating Phased Array Radar - Azimuth Coverage	AVA 450005
3D Rotating Phased Array Radar - Elevation Coverage	AVA 450006
Advanced Lightweight Track-While-Scan FCS - Azimuth Coverage	AVA 450007
Advanced Lightweight Track-While-Scan FCS - Elevation Coverage	AVA 450008
MK 74 Mod XX FCS - Azimuth Coverage	AVA 450009
MK 74 Mod XX FCS - Elevation Coverage	AVA 450010
IR Sensor ASMD EW MK XX - Azimuth Coverage	AVA 450011
IR Sensor ASMD EW MK XX - Elevation Coverage	AVA 450012

Title	Dwg. Ref.
ERAPS Launcher - Azimuth Coverage	AVA 450013
SATCOM AS-3018/WSC-3 - Azimuth Coverage	AVA 450015
SATCOM AS-3018/WSC-3 - Elevation Coverage	AVA 450016

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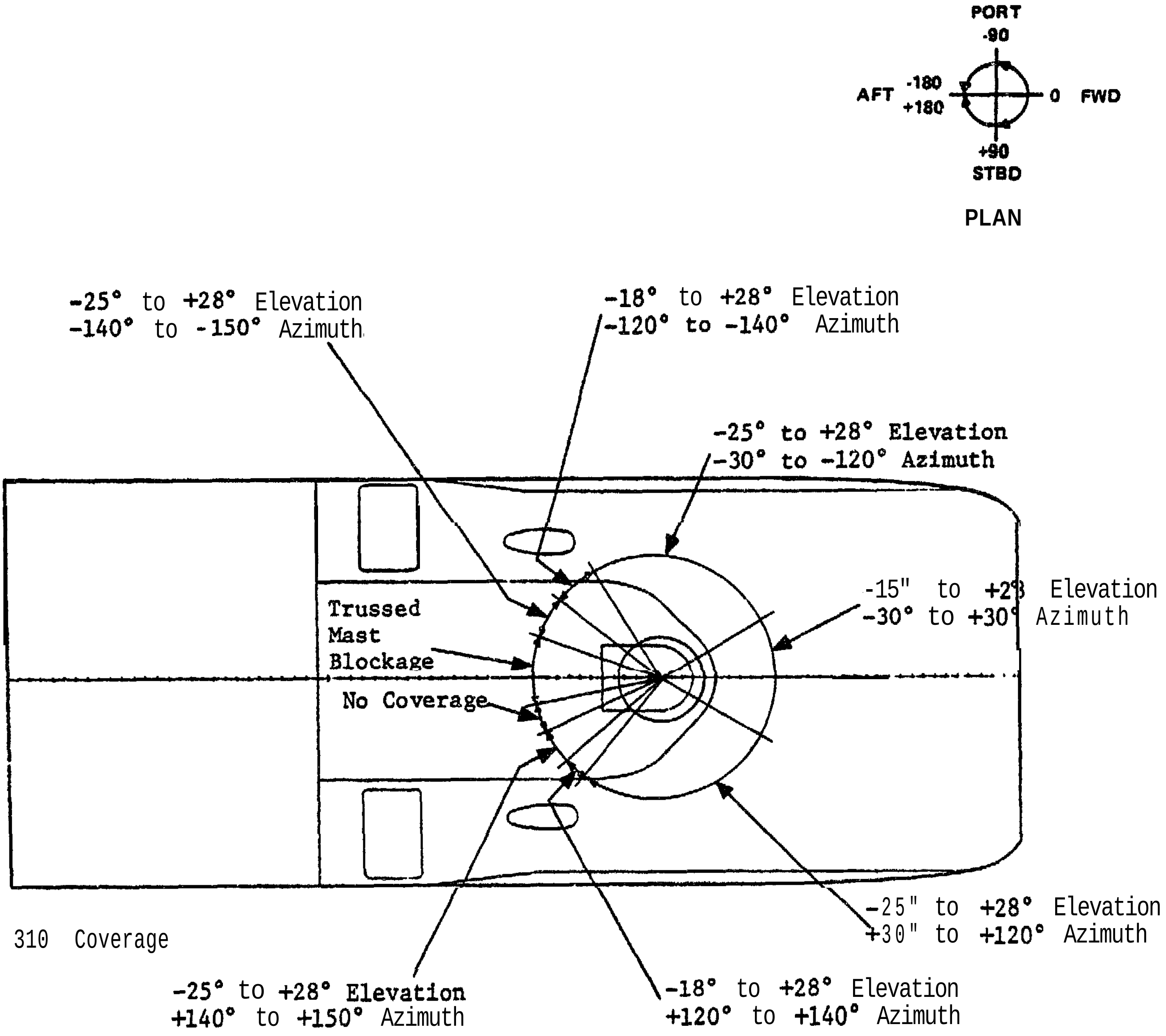


310 Coverage

NOTE: Coverage is shown as optical line of sight

ROHR INDUSTRIES, INC. SES DIVISION

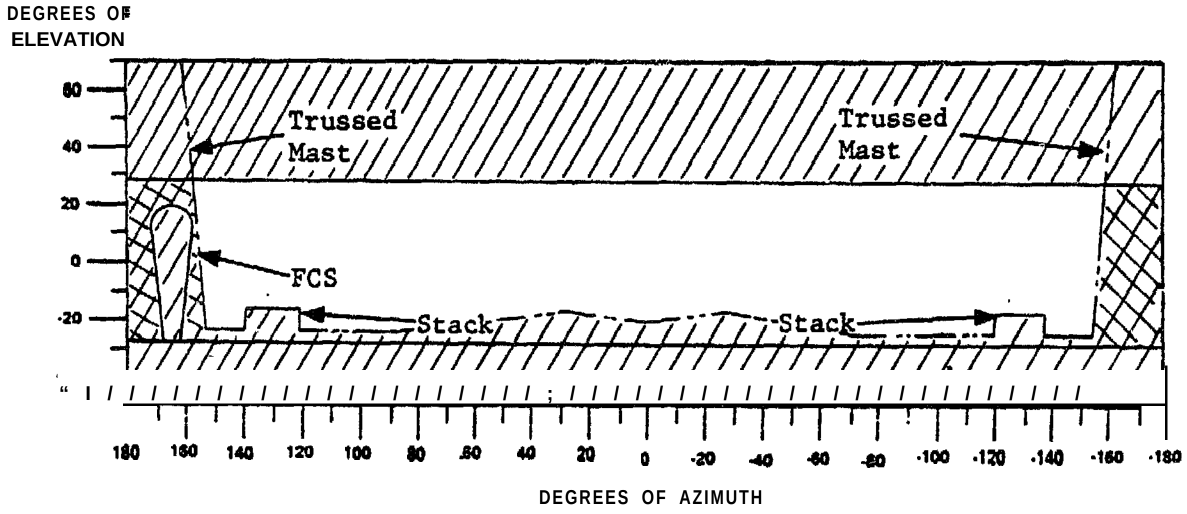
ADVANCED DUAL BAND
2D LONG RANGE RADAR
AZIMUTH COVERAGE

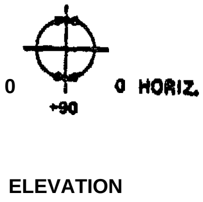
B23

DWG NO
AVA 450001

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~





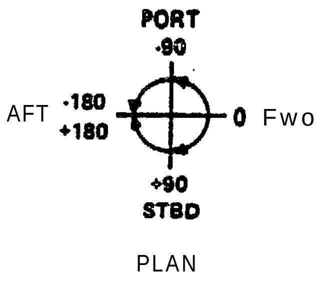
NOTE: Coverage is shown as optical line of sight

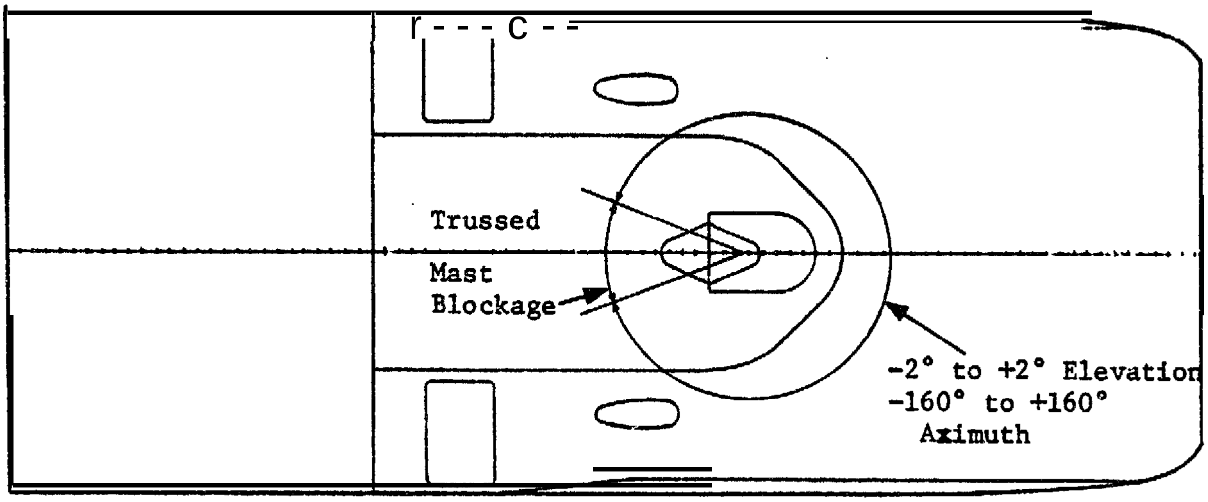
ROHR INDUSTRIES, INC. SES DIVISION

ADVANCED DUAL BAND
2D LONG RANGE RADAR
ELEVATION COVERAGE

DWG NO
AVA 450002

~~CONFIDENTIAL~~



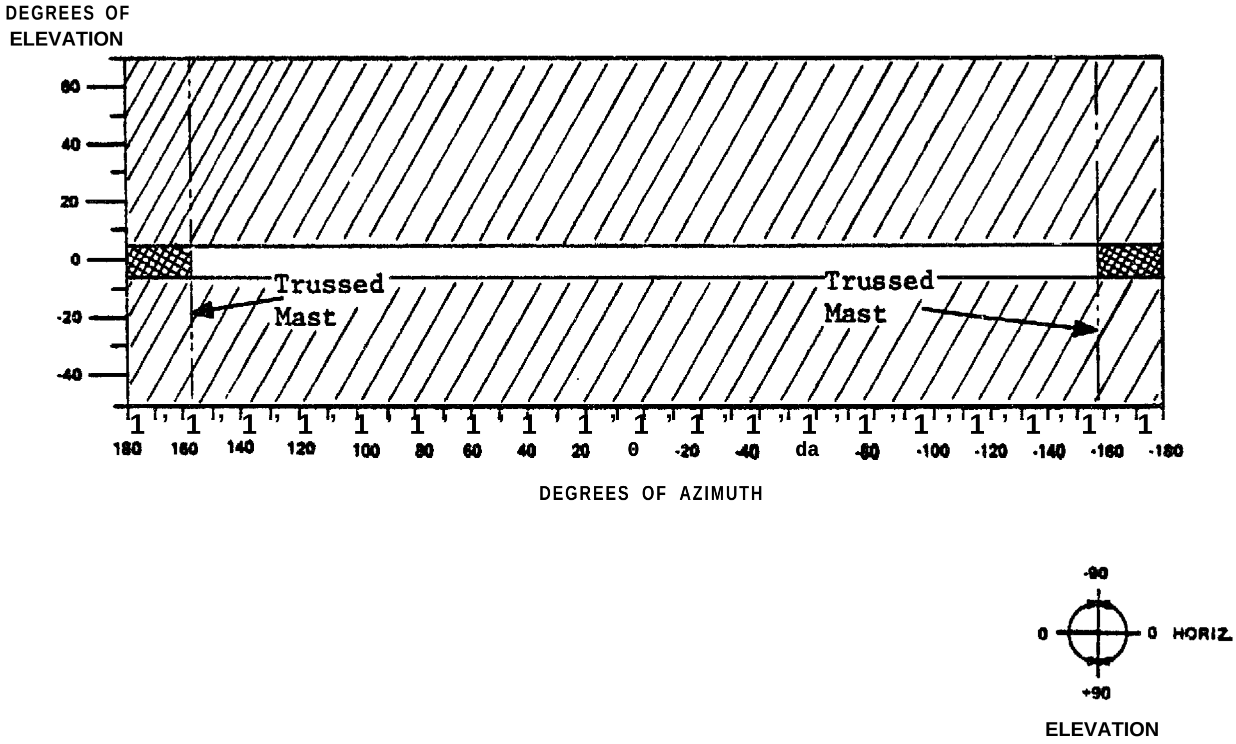


NOTE: Coverage is shown as optical line of sight.

ROHR INDUSTRIES, INC. SES DIVISION

ADVANCED 2D SURFACE SEARCH RADAR
AZIMUTH COVERAGE

DWG NO
AVA 450003

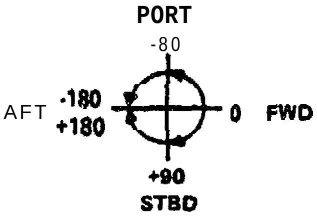


NOTE: Coverage is shown as optical line of sight.

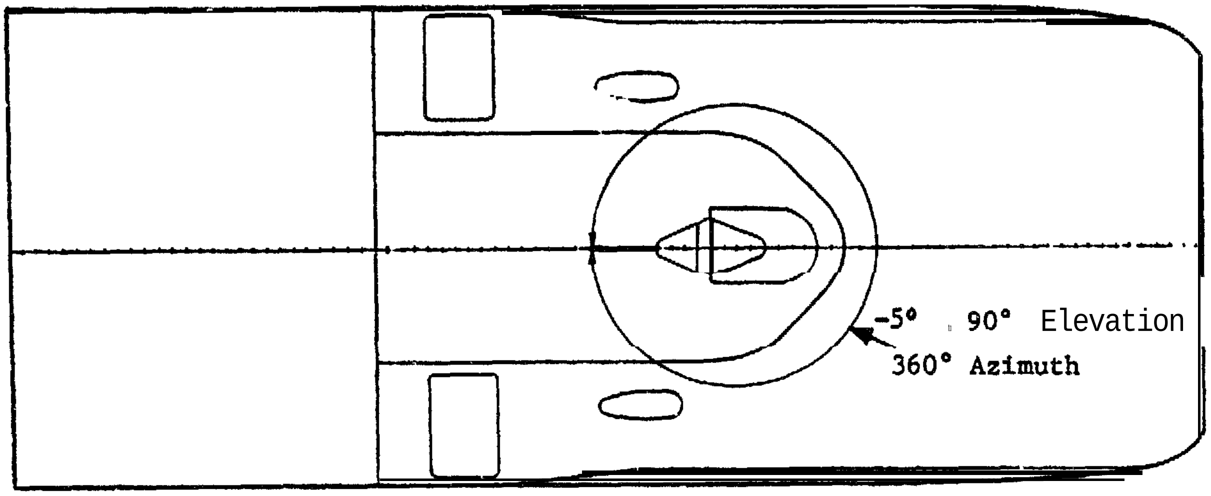
ROHR INDUSTRIES, INC. SES DIVISION

ADVANCED 2D SURFACE SEARCH RADAR
ELEVATION COVERAGE

DWG NO
AVA 450004



PLAN

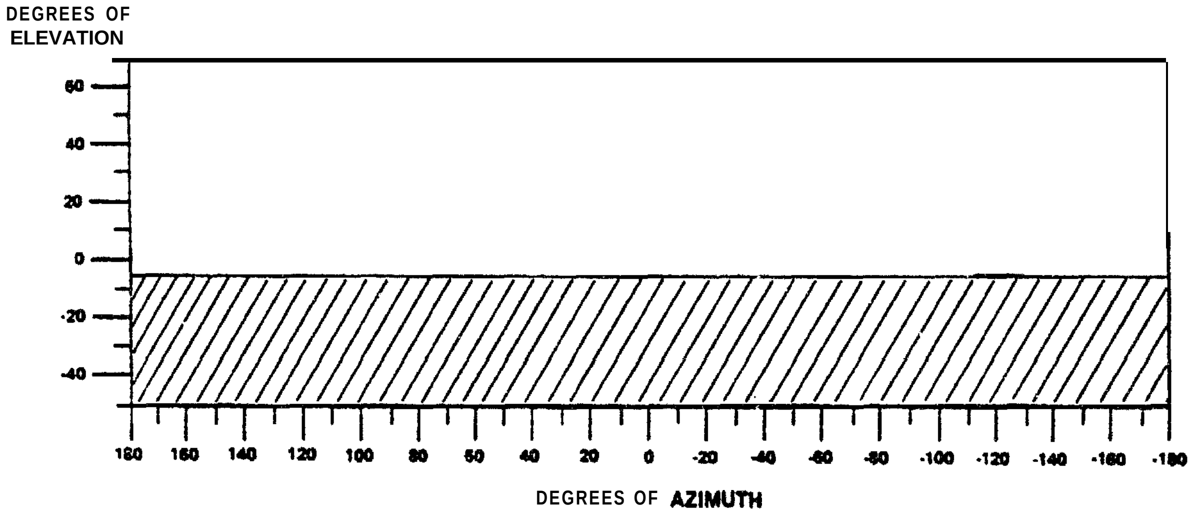


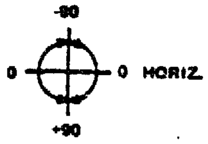
NOTE: Coverage is shown as optical line of sight.

ROHR INDUSTRIES, INC. SES DIVISION

3D ROTATING PHAZED ARRAY RADAR
AZIMUTH COVERAGE

DWG NO
AVA 450005





ELEVATION

NOTE: 1. Coverage is shown as optical line of sight.

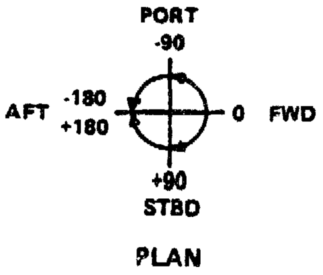
2. Negligible blockage from pole mast aft.

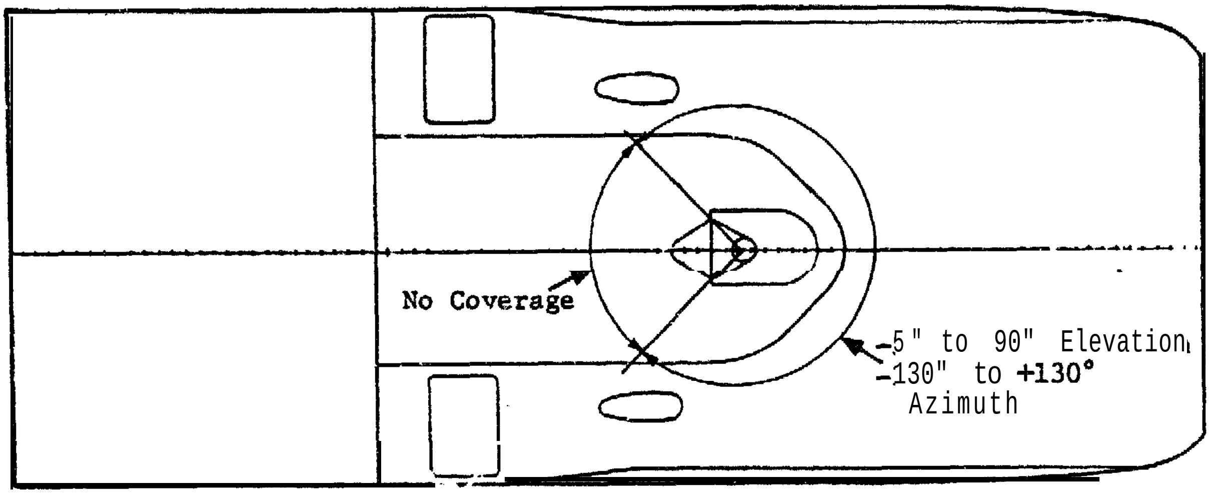
ROHR INDUSTRIES, INC. SES DIVISION

3D ROTATING PHAZED ARRAY RADAR
ELEVATION COVERAGE

DWG NO
AVA 450006

~~CONFIDENTIAL~~





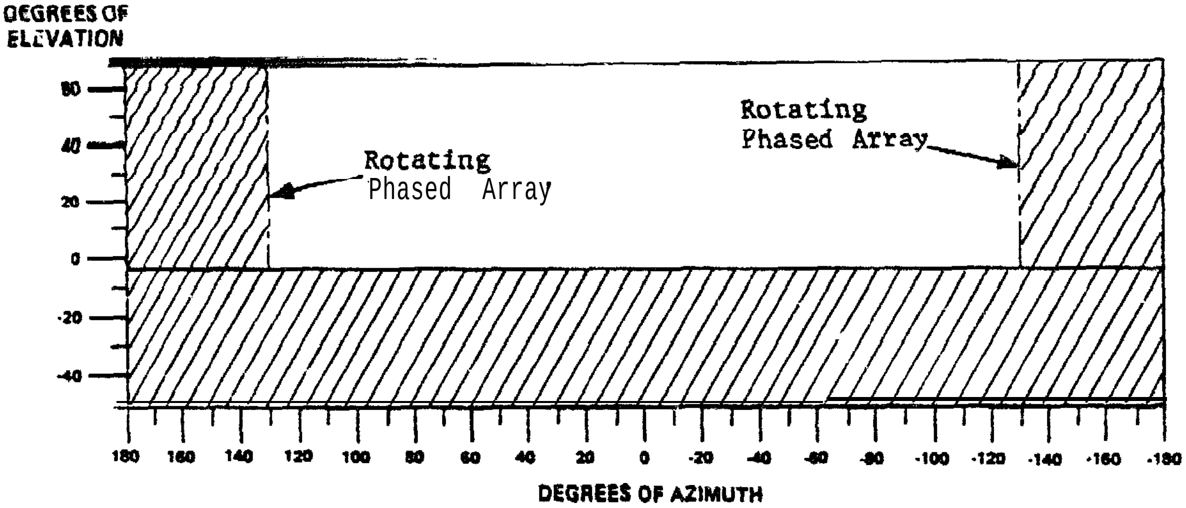
NOTE: Coverage is shown as optical line of sight.

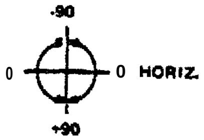
ROHR INDUSTRIES, INC. SES DIVISION

ADVANCED LIGHTWEIGHT TRACK-WHILE-SCAM FCS – AZIMUTH COVERAGE

DWG NO
AVA 450007

~~CONFIDENTIAL~~





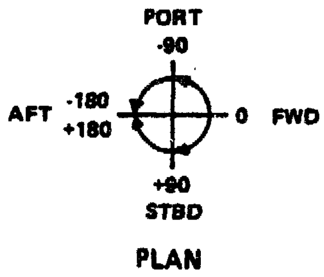
ELEVATION

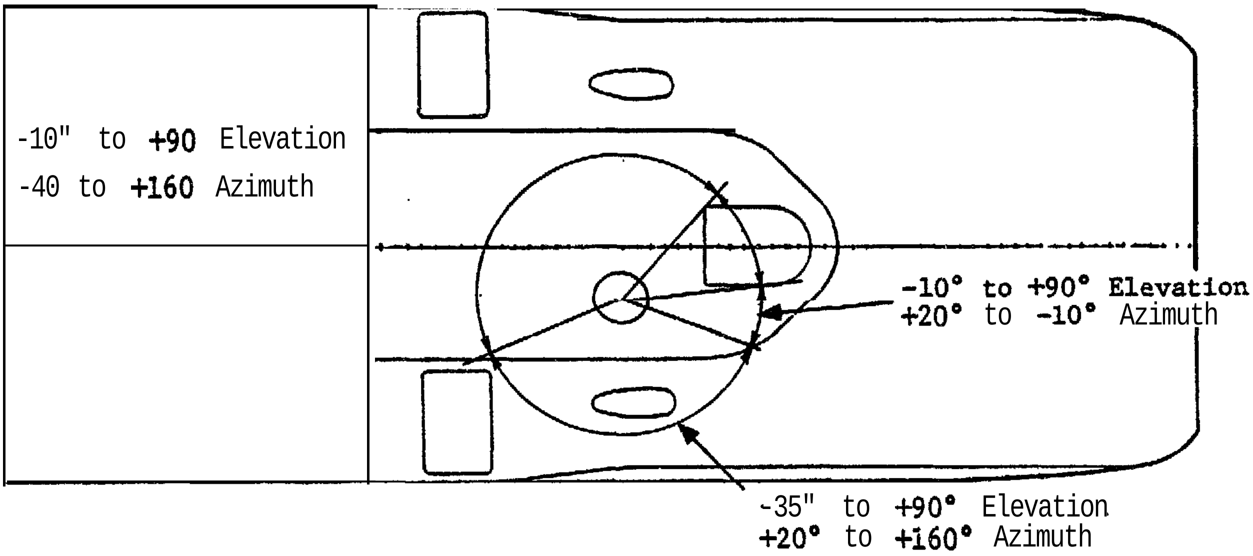
NOTE: Coverage is shown as optical line of sight.

ROHR INDUSTRIES, INC. SES **DIVISION**

ADVANCED LIGHTWEIGHT TRACK-WHILE-SCAN FCS – ELEVATION COVERAGE

DWG NO
AVA 450008





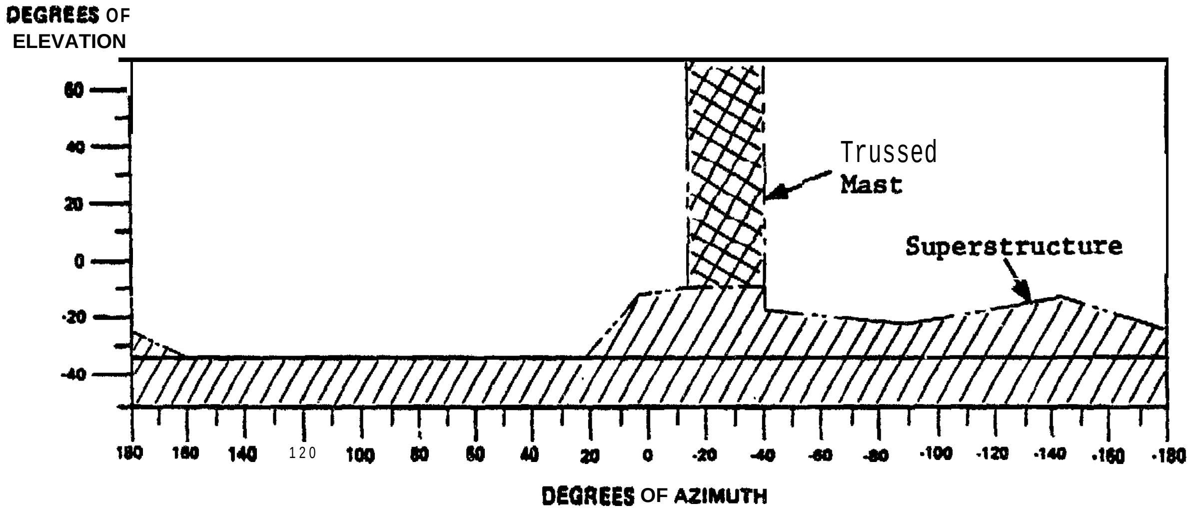
NOTE: Coverage is shown as optical line of sight.

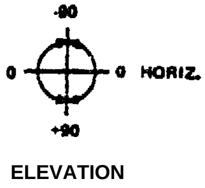
ROHR INDUSTRIES, INC. SES **DIVISION**

MK 74 MOD XX FCS – AZIMUTH COVERAGE

DWG NO
AVA 450009

~~CONFIDENTIAL~~





NOTE: Coverage is shown as optical line of sight.

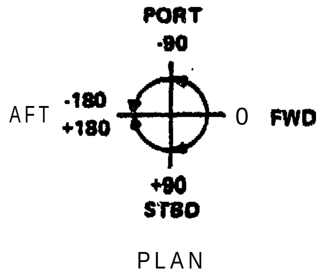
ROHR INDUSTRIES, INC. SES DIVISION

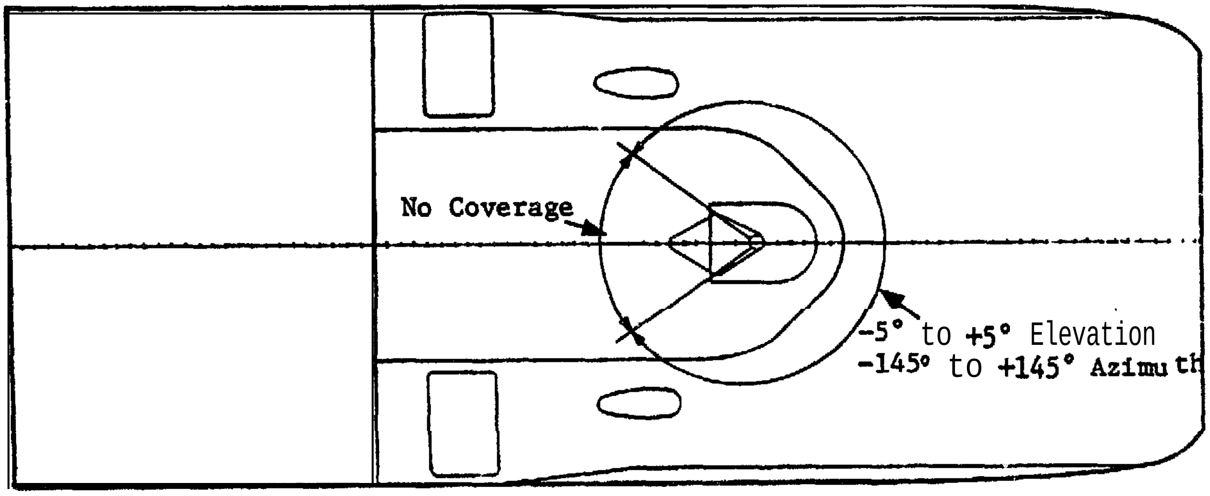
MK 74 MOD XX FCS – ELEVATION COVERAGE

DWG NO
AVA 450010

~~CONFIDENTIAL~~

~~CONFIDENTIAL~~





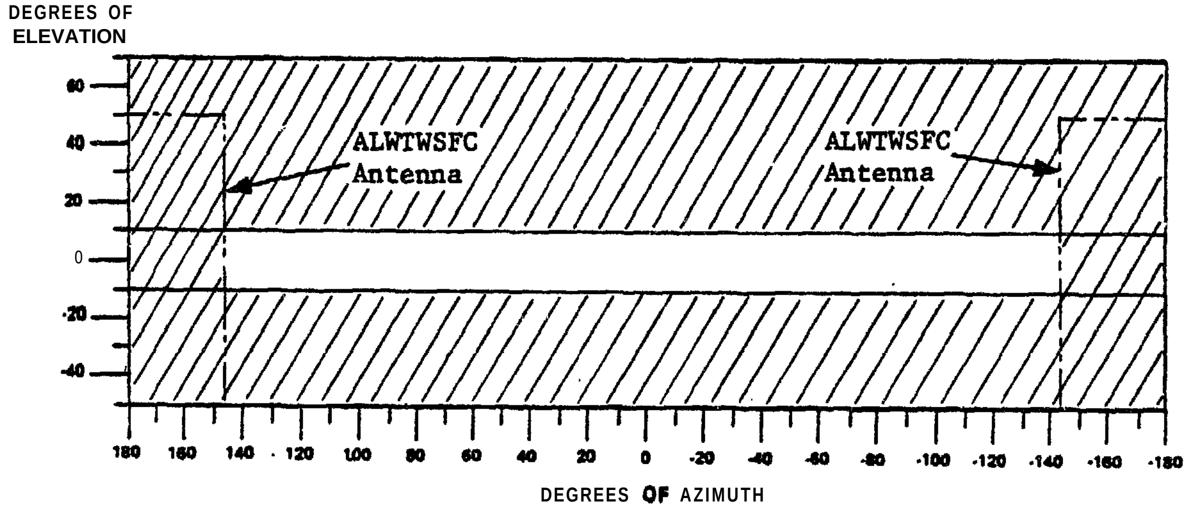
NOTE: Coverage is shown as optical line of sight.

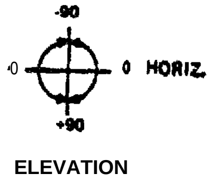
ROHR INDUSTRIES, INC. SES DIVISION

IR SENSOR ASMD EW MKXX
AZIMUTH COVERAGE

DWG NO
AVA 450011

~~CONFIDENTIAL~~



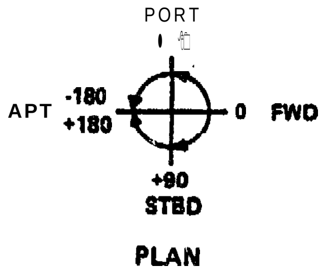


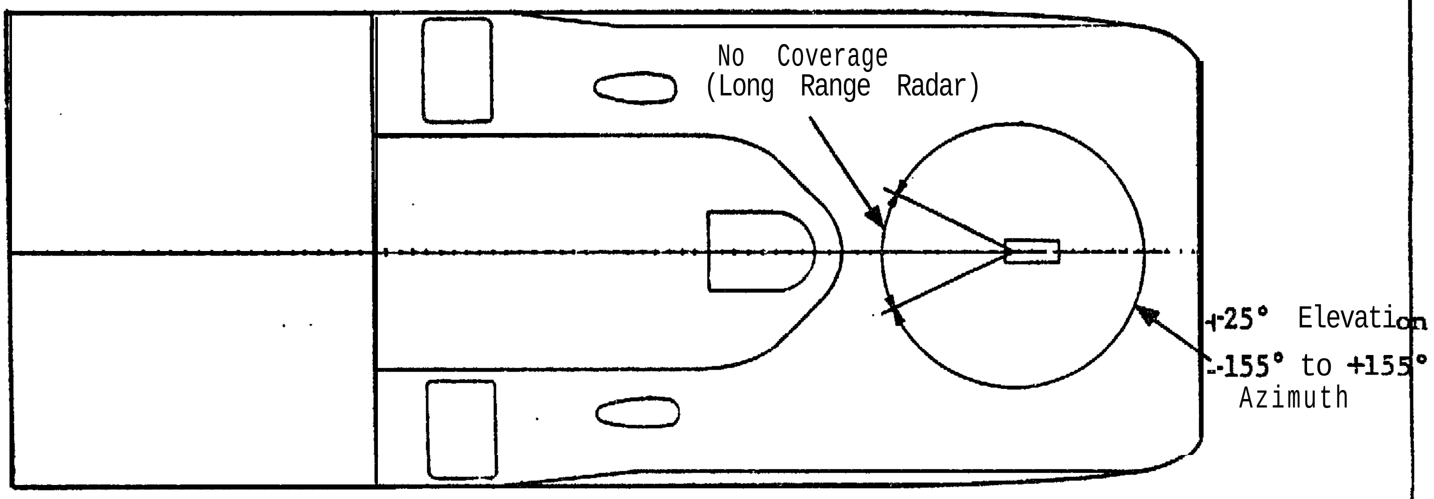
NOTE: Coverage is shown as optical line of sight.

ROHR INDUSTRIES, INC. SES DIVISION

IR SENSOR ASMD EW MKXX
ELEVATION COVERAGE

DWG NO
AVA 450012





NOTE: 1. Coverage is shown as optical line of sight.

2. Fixed Elevation Firing Angle (+25°).

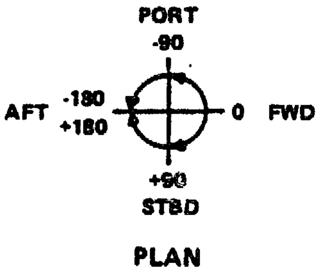
ROHR INDUSTRIES, INC. SES **DIVISION**

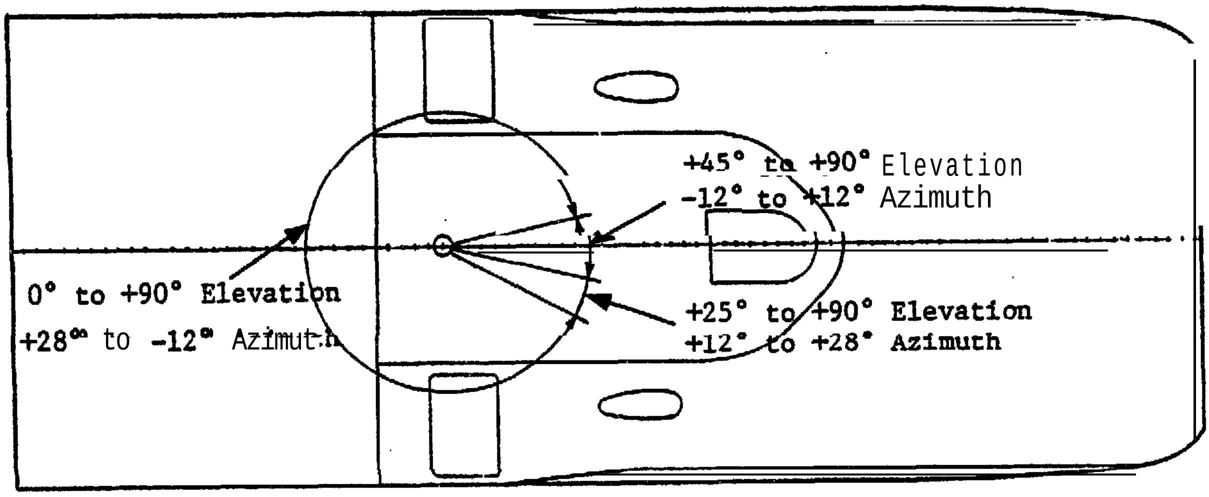
ERAPS LAUNCHER – AZIMUTH COVERAGE

B35

DWG NO AVA 450013

~~CONFIDENTIAL~~





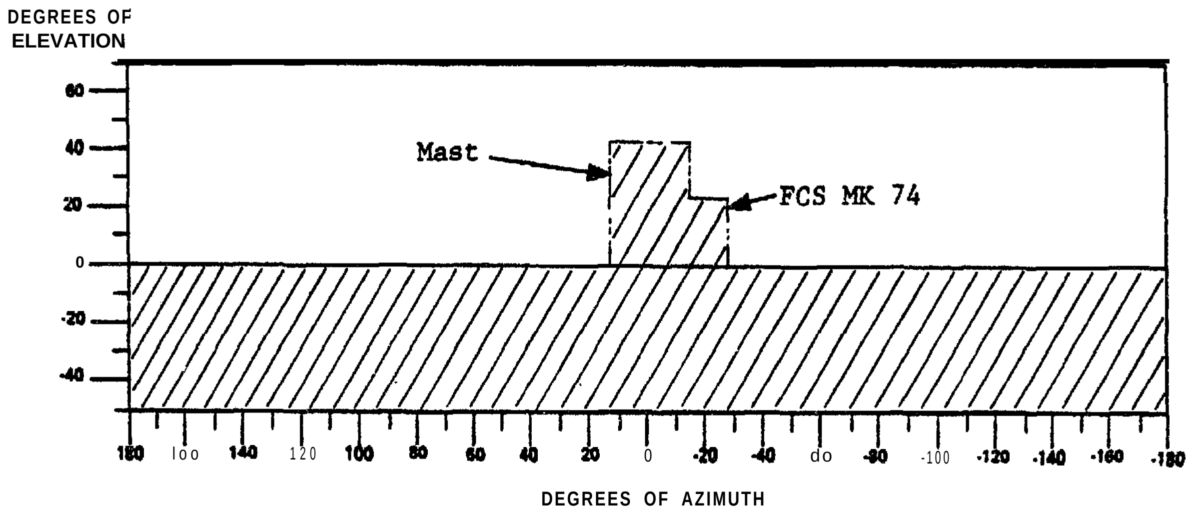
NOTE: Coverage is shown as optical line of sight.

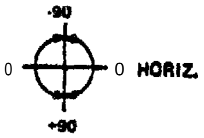
ROHR INDUSTRIES, INC. **SES DIVISION**

SATCOM AS-2410/WSC-3 – AZIMUTH COVERAGE

DWG NO
AVA 450015

~~CONFIDENTIAL~~





ELEVATION

NOTE: Coverage is shown as optical line of sight.

ROHR INDUSTRIES, INC. SES DIVISION

SATCOM AS-2410/WSC-3 — ELEVATION COVERAGE

DWG NO
AVA 460016

APPENDIX C

EQUIPMENT DATA SHEETS

APPENDIX C

ANVCE POINT DESIGN (FAR TERM)

AAW SUITE

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-10-60Hz	115V-30-60Hz	450V-30-60Hz	115V-10-400Hz	115V-30-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W		COOLING WATER FLOW GPM (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	ΔP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
Search/Acquisition/ Track	1	-										DECK SPACE ft² (m²)															
Advanced Dual Band 2D	1.1	1			90KVA						10,400 (46.2 kN)	Above DCK 555 (51.6) Below DCK 180 (16.7)						45 2839									Antenna 26 ft dia. (7.92 m) 8 ft height (2.44 m)
Rotating Phased Array (AEGIS Deri)	1.2	1			100KVA						25,400 (112.9 kN)	Above DCK 220 (20.4) Below DCK 350 (32.5)			40KW	40KW											Antenna 20' dia. (6.10 m)
ASMD EW MK XX	1.3	1			60KW						3,700 (16.5 kN)	Above DCK 100 (9.3) Below DCK 60 (5.6)			15KW	30KW											
Fire Control System	2	--																									
Advanced Lightweight TWS FCS	2.1	1			15KW						1,700 (7562)	Above DCK 10 (0.9) Below DCK 10 (0.9)						20 (1262)									
MK 74 MOD XX FCS	2.2	1			EST 40KW						20,000 (88.9 kN)	Above DCK 80 (7.4) Below DCK 100 (9.3)			20KW	30KW											
Counter-Measures/ Outboard Jamming	3	--																									
ASMD EW MK XX	3.1	--	REFER TO PARAGRAPH 1.3																								
Chaff Decoy	3.1.1	32	NO PWR REQD								1,300 (5783)																Variable Load
IR Decoy	3.1.2	8									300 (1334)																
Hybrid Decoy	3.1.3	4									200 (890)																
Active Decoy	3.1.4	4									200 (890)																

INSTALLATION DATA			ELECTRICAL POWER (TOTAL)														COOLING WATER					HYDRAULICS			AIR		
EQUIPMENT	EQPT. NO.	QUANTITY	115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED W	TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	WDP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
Weapons/Launchers	4												ft²	(m²)													
Advanced Vertical Launching System (72 cells)	4.1	1			240 KW					240 KW is primarily deicing	67,000 (298,031)	Above DCK Below DCK		420 (39) 420 (39)													64K BTU Heating Reqt.
AMRM Multi-Mode		40			Power Reqts. TBS						112,000 (498 kN)	Launched from Vertical Launhing System															Variable Load
Advanced Self Defense Missile Launching (24 cells)		1			Provided by FCS						8400 (39.4 kN)	Below DCK		360 (33)													
Advanced Self Defense Missile		24									9600 (42.7 kN)																Variable Load

ANVCE POINT DESIGN (FAR TERM)

SUW SUITE

INSTALLATION DATA			ELECTRICAL POWER (TOTAL)														COOLING WATER					HYDRAULICS			AIR		
EQUIPMENT	EQPT. NO.	QUANTITY	115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (cm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	MXDP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
Search/Acquisition/ Track	1	—																									
Adv 2% Short Range Search Radar	1.1	1					4700				400 1779	Above DCK Below DCK	35 ft³ (1 m³) 33 ft³ (1 m³)														
Rotating Phased Array (AEGIS Deriv)	1.2	1	Refer to AAW 1.2																								
Advanced Light-Weight TWS FCS	1.3	1	Refer to AAW 2.1																								
ASMD EW MK XX	1.4	1	Refer to AAW 1.3																								
Fire Control System	2	—																									
Advanced Light-Weight TWS FCS	2.1	1	Refer to AAW 2.1																								
Weapons/Launchers	3	—																									
Harpoon MK XX	3.1	16					25.6KVA	Warm up 16 Msls & Ripple Fire 8 Msls.			49000 (218 kN)	Launched from VLS.															Variable Load

ANVCE POINT DESIGN (FAR TERM)

ASW SUITE

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	COOLING WATER TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	MXDP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
Search/Acquisition/ Track	1	--																									
ARRAP	1.1	1						20 KW (Sensor) 25 KW (Winch)			12,800 (56.94 kN)																
Deployed Linear Array	1.2	6									9200 (41 kN)	Above DCK 324 ft² (30.10 m²) Below DCK 129 ft² (11.98 m²)															
Deployed Linear Array Handling	1.2.1	1	2 KW-Elex		20KW - Handling										EST 22 KW												
Towed Array W/ Depressor & Spare	1.3	1			10KW						8100 (36 kN)	Above DCK -- Below DCK 200 ft² (18.58 m²)					FW	100PM									
ERAPS	1.4.	10	Data Link 2KW								1800 (80 kN)	Above DCK -- Below DCK 30 ft² (2.79 m²)															Variable Load
ERAPS Rocket Projectile	1.4.1	26									13,000 (57.83 kN)	Above DCK 16 ft² (1.49 m²) Below DCK 50 ft² (4.65 m²)															Variable Load
ERAPS Lchr	1.4.2	1									3700 (16.45 kN)																
Sonobuoys	1.5										8000 (35.58 kN)	Below DCK 40 ft² (3.72 m²)															Variable Load
Sonobuoys Type A	1.5.1	200																									
Sonobuoys Type B	1.5.2	10									2300 (10.2 kN)																
ASW Electronics	1.6	--									15,200 (67.6 kN)																
Weapons/Launcher	2	--																									
ALWT	2.1	36			Hndlg Eqpt 2KW					Helo Dropped	25,200 (112.1 kN)	Below DCK 240 ft² (22.30 m²)															Variable Load
MK 48 Improved	2.2	4									13,700 (60.94 kN)	Below DCK 120 ft² (11.15 m²)															Variable Load
MK 48 Ejection Launch Container	2.3	4									4000 (17.8 kN)																
ASW Standoff Wpn/ALWT	2.4	16					11KVA				51,200 (227.75 kN)	Above DCK 110 ft² (10.22 m²) Below DCK 400 ft² (37.16 m²)															

ANVCE POINT DESIGN (FAR TERM)

COMMAND OPERATIONS CENTER (COC) SUITE

* Assumed Value (not specified in ANVCE Documents)

(1)

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	COOLING WATER TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	MKDP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
AN/UYQ-21 Tact Displ./Aux	1	1					2KVA			TAO Multi-Purpose CSL	600 (2669)	56.5 (1435)	29.0 (73.7)	39.5 (1003)		1800	CW										
AN/UYQ-21 Tactical Display	2	1					2KVA			Adaptive Battle Planning/Navig.	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
AN/UYQ-21 * Tact Display/Aux	3	1					2KVA			Surface/Subsurface FC	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										Not yet Reqd.
AN/UYQ-( ) MOD XX-8	4	1					300W			Surf/Subsurf Warfare Coord OSC	250 (1112)	40 (1016)	51 (1295)	36 (914)	150												
AN/UYQ-( ) MOD XX-8	5	1					300W			Asst TAO (AAW Warfare Coord OSC	250 (1112)	40 (1016)	51 (1295)	36 (914)	150												
AN/UYQ-21 * Tact Displ. Aux	6a	1					2KVA			UW Warfare EC Sonar target Track-CSL	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										Not yet Reqd.
AN/UYQ-21 Tact Displ/Aux	7	1					2KVA			Air Controller/ Engagement Cons.	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										Not yet Reqd.
AN/UYQ-21 Tactical Display/Aux	8	1					2KVA			Surf Warfare FC	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
Radar Set CSL *	9	1					2KVA			S.P. RDR (3D, APS-116, LPI) CSL	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										Not yet Reqd.
AN/UYQ-21 Tact * Display/Aux	10	1					2KVA			Anti-Air Warfare FC No. 1 (area)	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										Not yet Reqd.
Radar Set Console	11	1					2KVA			S.P. Adv Trk While-scan RDR CSL or TAS	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
AN/UYQ-21 Tactical Display/Aux	12	1					2KVA			AAW FC #2	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
AN/UYQ-21 Tactical Display	13	1					2KVA			EW FC	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
Special Operation Console (ASMD-EW [illegible]	14	1					2KVA			S.P. ASMD-EW CSL	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
AN/UYQ-(1)Special Console	15	1					2KVA			S.P. Sys Monit. CSL	600 (2669)	56.5 (1435)	29.0 (737)	39.5 (1003)		1800	CW										
Special Nav Station	16	1					500			S.P. Nav. Sta.	EST 1200 (5338)	60 (1524)	84 (2134)	40 (1016)	500												
Special Nav Console	17	1					500			S.P. Nav.Sta.	EST 1200 (5338)	60 (1524)	84 (2134)	40 (1016)	500												
AN/UYQ-21 Tactical Display	6b	4					8KVA			Acoustic/ASAC Display Console	2400 (10676)	56.5 (1435)	29.0 (737)	39.5 (1003)		7200											

UNCLASSIFIED

(2)

INSTALLATION DATA EQUIPMENT	EQPT NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	COOLING WATER TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	ΔP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
Special Purpose RPV Control Console	18	1					000			S.D. RPV Cont. CSL & DRO	1500 (6672)	(Includes item 28.(C²RDV)			6000	3000											
Special Purpose RPV Pilot Station	19	1					000			S.P. RPV Pilot Sta & Dro																	
Special Purpose Engineering Console	20	1					000			S.P. EMG-Cont CSL	2000 (8896)	61 (1549)	84 (2137)	40 (1016)	2000							WT and Size Based on 3KSES PCC, DCAC & ASVCE CIC Arr. DWG					
Special Purpose Damage Control Console	21	1					000			S.P. D.C. CSL																	
Data Processing Cabinet	22	1/2					100			S.P. Data Proc. Cab	60 (267)	14 (350)	19 (483)	19 (483)	1600												
AN/UYQ-( ) MOD XX-6 Module	23	2						5VDC 40W		Action/Data Entry Module	50 (222)	10 (254)	8 (203)	2 (51)	30												
AN/UYQ-( ) MOD XX-7 Module	24	2					100			Voice and Video Comm	50 (222)	10 (254)	8 (203)	2 (51)	40												
AN/UYQ-( ) MOD XX-9 Large Screen Display	25	1					300			Large Screen Display & TV Status Boards	(SCREEN 6 x 66) 50 (222)	9 (229)	16 (406)	25 (635)	150							Includes Projection Unit and Screen					
—	26	1					100			Global Posit. Sys Cont Set & DIG SHI	EST 75 (334)	EST 12 (305)	30 (762)	10 (254)													
—	27	1					100			Radar Cont. Set/PPI	EST 150 (667)	EST 12 (305)	15 (381)	15 (381)													
—	28	1					--			LLLTV & FLIR Monit. for RPV LCH/Rcvry	--	P/O	18 (457)	19 (483)													
AN/UYQ-( ) MOD X-7 Module	29	1					50				25 (111)	10 (254)	8 (203)	2 (51)	20												
—	30	1								Eng Cons TV Monit & Status Boards	—	P/O	20 (508)														
—	31	1								DC Cont CSL TV Monit., Status Boards & ALM Board	—	P/O	21 (533)														
AN/UYQ-( ) Signal Converter	33	2					000			Convert/Amplifier	EST 1000 (4448)	72 (1829)	24 (610)	17 (432)	2000												

UNCLASSIFIED

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	COOLING WATER TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	ΔP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
AN/WRN-5 Sat-Nav Receiver	39	1																									
AN/SRN-12 Omega Receiver	40	1																									
Global Positioning System Rcvr	41	1																									
Maintenance Unit	42	1																									
Remote Multiplexer	43	24																									
Area Multiplexer	44	3																									
Traffic Controller	45	1																									
Data Link Rcvr + Select & Distr.	46	4									600 (2669)	6.8 ft^3 (.19 m^3)															
Signal Conditioner/ Data Processor	47	4									5720 (25444)	27.1 ft^3 (.77 m^3)															
Adv. Signal Processor	48	6									1440 (6405)	5.7 ft^3 (.16 m^3)															
Arithmetic Digital Display	49	1									150 (667)	6.8 ft^3 (.19 m^3)															
Cartridge Magnetic Tape Unit	50	2									200 (890)	3.2 ft^3 (.09 m^3)															
Mass Memory Unit	51	2.25									3285 (14612)	36.2 ft^3 (1.03 m^3)															
AN/UYK-20 Mod XX Computer	52	8									1760 (7829)	3.7 ft^3 (.10 m^3)															
Power Distribution Cabinet	53	1									730 (3247)	18.4 ft^3 (.52 m^3)															
Interface Control Unit	43	1									1600 (7117)	53.3 ft^3 (1.51 m^3)															

ANVCE POINT DESIGN (FAR TERM)

COMMUNICATIONS SUITE

INSTALLATION DATA			ELECTRICAL POWER (TOTAL)														COOLING WATER					HYDRAULICS			AIR		
EQUIPMENT	EQPT. NO.	QUANTITY	115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	TYPE	FLOW gpm (cm^3/s)	PRESSURE psi (kPa)	TEMP IN °C	ΔP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm^3/s)	NOTES	PRESSURE psi (kPa)	VOLUME/FLOW ft^3/min (m^3/s)	NOTES
AN/WSC-3 SATCOM Transceiver	1	1	1500								148 (658)	12 (305)	19 (483)	22 (559)	100												
AS-2410/WSC-3 Antenna	2	1	No Power								225 (1001)	60 (1524)	48 (1219)	36 (914)													
AN/UYK-20 Processor	3	1	1000								220 (979)	80 (508)	24 (610)	19 (483)	000												
RD-[illegible](V)/U Mag Cassette Unit	4	4	1060								200 (890)	8 (203)	18 (457)	20 (508)	060												
RD-397(V)/U Paper Tape Reader Punch	5	1	265								150 (668)	41 (1041)	16 (406)	20 (508)	265												
TT-624/UG Medium Speed Printer	6	1	350								270 (1201)	28 (711)	18 (457)	42 (1067)	350												
AMF2-CM-43A Modem	7	1	250								100 (445)	10 (254)	17 (432)	18 (457)	250												
TSEC-KG-36 Crypto Device	8	1	36								27 (120)	10 (254)	6 (152)	22 (559)	36												
CRT Display Unit	9	4	1000								800 (3559)	20 (508)	19 (483)	24 (610)	000												
AM-653[illegible] Amplifier-Converter	10	4	No Power								52 (231)	6 (152)	8 (203)	6 (152)													
MD-[illegible] Combiner-Demodulator	11	1	65								81 (360)	10 (254)	18 (457)	17 (432)	5												
TD-1063 Demultiplexer	12	1	24								72 (320)	10 (254)	16 (406)	14 (356)	4												
TSEC-KG-36 Key Generator	13	1	50								110 (489)	10 (254)	6 (152)	22 (559)	0												
ACCS/NAVMACS Master ControlCns	14	1	500								450 (2002)	36 (914)	108 (2743)	24 (610)	50												
AN/SRA-12 Antenna Patch Panel	[illegible]	1	No Power								35 (156)	8 (203)	17 (432)	18 (457)													
CU-2007/SRR Highpass/Lowpass Filter	16	1	No Power								8 (36)	6 (152)	10 (254)	6 (152)													

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL) 115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	COOLING WATER TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	MXDP psig (kPa)	HYDRAULICS PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	AIR PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	NOTES
SB-2727/SRR Receiver Patch Panel	17	1	No Power								44 (195)	14 (357)	14 (357)	10 (254)													
SB-863/SRT Transmitter Patch Panel	18	1	No Power								74 (329)	25 (635)	13 (330)	14 (356)													
SB-1203/UG TTY Patch Panel (Black)	19	2	No Power								24 (107)	6 (152)	12 (305)	6 (152)													
SB-1210/UGQ TTY Patch-Panel (Red)	20	2	No Power								24 (107)	6 (152)	12 (305)	6 (152)													
AN/UCC-1 Modem	21	1	154								67 (298)	7 (178)	17 (432)	18 (457)	154												
AN/URA-17 FSK Converter	22	2	140								140 (623)	8 (203)	17 (432)	19 (483)	140												
AN/URQ-10 Frequency Standard	23	1				15					22 (98)	8 (203)	6 (152)	17 (432)	15												
TSEC/KY-8 Covered Voice Crypto	24	2	260								160 (712)	19 (483)	14 (356)	13 (330)	260												
TSEC/KW-7 Covered TTY Crypto	25	2	170								146 (649)	10 (254)	17 (432)	14 (356)	170												
TSEC/KWR-37 Covered BCST Crypto	26	2	640								293 (1303)	12 (305)	22 (559)	20 (508)	640												
TSEC/KW-14 Covered BCST Crypto	27	2	200								270 (1201)	10 (254)	17 (432)	26 (660)	200												
AN/UGC-25 Teletypewriter	28	1	65								50 (222)	12 (305)	17 (432)	10 (254)	50												
C-[illegible] ( )/UR Radio Set Cont. Remote (VHF/UHF)	29	4									160 (712)	8 (203)	10 (254)	17 (432)	40												
PP-2717A/UG Power Supply (RED TTY)	30	2	640								80 (356)	7 (178)	8 (203)	16 (406)	640												
PP-3494B/UG Power Supply (Black TTY)	31	2	640								44 (196)	8 (203)	10 (254)	10 (254)	640												
AN/UGC-6 Teletypewriter	32	1	197								230 (1023)	40 (1016)	36 (914)	19 (483)	123												

INSTALLATION DATA			ELECTRICAL POWER (TOTAL)														COOLING WATER					HYDRAULICS			AIR		
EQUIPMENT	EQPT. NO.	QUANTITY	115V-1Ø-60Hz	115V-3Ø-60Hz	450V-3Ø-60Hz	115V-1Ø-400Hz	115V-3Ø-400Hz	DC	TYPE	FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	HXDP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	PRESSURE psi (kPa)	VOLUME ft³/min (m³/s)	NOTES
JTIDS Command Terminal Unit	33	1											Includes Items 34 through 38														
Control Display Unit	34	1									10 (45)																
Power Amplifier Unit	35	1									28 (126)																
Transmitter-Receiver Unit	36	1									42 (187)																
Signal Processor Unit	37	1				400 Based on		Line 11			73 (325)	20 (508)	20 (508)	20 (508)	400												
Terminal Processor Unit	38	1									24 (107)																
AS-2012 Antenna	39	1	No Power								6 (27)																
TT-624/UG Medium Speed Printer	40	1	350								270 (1201)	28 (711)	30 (762)	44 (1118)	350												
AN/SSR-1 SATCOM Receiver	41	1	61								90 (400)	12 (305)	20 (508)	24 (610)	61												
AS-2815 Antenna	42	4	No Power								52 (231)	6 (152)	8 (203)	6 (152)													
AM-6534 Amplifier Converter	43	4	No Power								52 (231)																
AN/URC-80 Bridge-to-Bridge Transceiver	44	1				50					25 (111)	5 (127)	8 (203)	18 (457)	50												
AS-2855/SRC Antenna	45	1	No Power								8 (36)																
AN/URC-81 HF Transceiver	46	5									270 (1202)	46 (1168)	17 (432)	19 (483)	16,500												
MX-5316/UR Transmitter Adptr	47	5	175								100 (445)	8 (203)	10 (254)	16 (406)	175												
CU-938/URA-38 Antenna Cplrr	48	5	400								375 (1668)	7 (178)	19 (483)	18 (457)	300												

UNCLASSIFIED

INSTALLATION DATA EQUIPMENT	EQPT. NO.	QUANTITY	ELECTRICAL POWER (TOTAL)							FUNCTION								COOLING WATER				HYDRAULICS			AIR		NOTES
			115V-1Φ-60Hz	115V-3Φ-60Hz	440V-3Φ-60Hz	115V-1Φ-400Hz	115V-3Φ-400Hz	DC	TYPE		TOTAL WEIGHT lbs (N)	HEIGHT in (mm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	TYPE	FLOW gpm (cm³/s)	PRESSURE psi (kPa)	TEMP IN °C	HDDP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm³/s)	NOTES	PRESSURE psi (kPa)	VOLUME/FLOW ft³/min (m³/s)	
C-3698/URA-38 Antenna CPLR Control	49	5	P/C	CU-9386 URA-38							125 (556)	5 (129)	19 (483)	10 (254)													
AS-2807/SRC 35' Whip Antenna	50	5	No Power								850 (356)	35 ft. (10.7 m)															
AN/URC-86 VHF/AM Transceiver	51	1				50					80 (356)	24 (610)	17 (432)	19 (483)	50												
C-9060/UR Radio Set Control	52	1						28VDC 20			20 (89)	6 (152)	8 (203)	8 (203)	20												
CA-1079 ANT.	53	1	No Power								—																
AS-2809/SRC Antenna	54	1	No Power								8 (36)																
AN/URC-93 UHF Transceiver	55	4					2400				640 (2846)	46 (1168)	17 (432)	19 (483)	2400												
C-9359/URC Control Radio Set Antenna	56	1						28VDC 20			7 (31)	6 (152)	8 (203)	8 (203)	28												
AT-350/SRC Antenna	57	4	No Power								18 (80)																
AN/URR-67 HF Receiver	58	4						2400			240 (1068)	10 (254)	19 (483)	22 (559)	1000	1000	FW	1.5 (94.6)									
ST-66547 Antenna (35' Whip)	59	1	No Power								100 (445)	35 ft. (10.7 m)															
AN/VRC-46 VHF/FM Transceiver	60	1						600			78 (347)	6 (152)	16 (406)	13 (330)	600												
MX-1955A/SRC Control Adapter	61	1	35								30 (133)	8 (203)	17 (432)	19 (483)	35												
MX-6707/VRC Antenna Matching Unit	62	1	35								10 (45)	6 (152)	8 (203)	6 (152)	35												
AS-1729/VRC Antenna	63	1	No Power								15 (67)																

UNCLASSIFIED

ANVCE POINT DESIGN (FAR TERM)

AIRCRAFT SUITE

INSTALLATION DATA			ELECTRICAL POWER (TOTAL)																COOLING WATER				HYDRAULICS			AIR		
EQUIPMENT	EQPT. NO.	QUANTITY	115V-10-60Hz	115V-30-60Hz	450V-30-60Hz	115V-10-400Hz	115V-30-400Hz	DC	TYPE		FUNCTION	TOTAL WEIGHT lbs (N)	HEIGHT in (cm)	WIDTH in (mm)	DEPTH in (mm)	HEAT DISSIPATED (AIR) W	HEAT DISSIPATED (WATER) W	TYPE	FLOW gpm (cm^3/s)	PRESSURE psi (kPa)	TEMP IN °C	HHDP psig (kPa)	PRESSURE psi (kPa)	FLOW gpm (cm^3/s)	NOTES	PRESSURE psi (kPa)	VOLUME/FLOW ft^3/min (m^3/s)	NOTES
Subvehicles	1	--																										
Manned	1.1	--																										
LAMPS MKXX	-1.1.1	2					5KVA					40,000 (178 kN)	Above DCK 644 ft^2 (60 m^2) Below DCK 1136 ft^2 (105 m^2) DCK 1836 ft^2 (171 m^2)															Variable Load
Spares & Support	1.1.2	--										10,000 (45 kN)	Above DCK 7 ft^2 (.70 m^2) Below DCK 605 ft^2 (56 m^2)															
Fuel for 15 days (JP-5) (Helo & RPV)	1.1.3	--										55,000 (245 kN)				5070	6500											
RPV	1.2	--																										
Standard Ship Lchr RPV	1.2.1	12										3000 (13kN)																Variable Load
RPV Lchr/Recovery System	1.2.2	1			20KVA								Below DCK 95 ft^2 (8.8 m^2)			4000	3000											
Spares & Support	1.2.3	--									2100 (9.3 kN)																	Variable Load
Lchr/Recovery C^2 System	1.2.4	1	Power included in Lchr/Recovery System																									

APPENDIX D

PROPELLER-DRIVEN FAR TERM SES ALTERNATE POINT DESIGN

APPENDIX D

APPENDIX D

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

Table Number | Page

LIST OF TABLES (Continued)

D.1 INTRODUCTION

(U) The material in this Appendix presents the far term ANVCE SES propeller-driven alternate point design in the format specified in ANVCE Working Paper WP-005A in the addition of a prefix "D" for each section and the replacement of "Appendix A, Design Process" with Section D.5. Each section of this Appendix is treated as an incremental extension to sections of the parent document. The complete description of the propeller-driven alternate point design is therefore completed by direct reference to the parent document,

(U) This appendix describes a propeller-driven point design alternate to the waterjet-propelled SES concept of the parent report. Included in Section D.5 "Design Process" are the rationale and studies conducted to incorporate a propeller drive system that results in the fewest changes to the basic waterjet propelled ship.

(U) Two, 14 ft. (4.27 m) diameter, partially submerged, super cavitating propellers are incorporated in the propeller-driven far term SES alternate point design. The design with a single propeller in each sidehull was made with minimum changes to the far term waterjet-propelled SES. Trade-offs in'propulsive efficiency, weight, complexity and reliability are discussed in Section D.5.

(U) Propeller sizing is constrained by the cushion beam width, the width of the sidehull at the propeller centerline, and by the overall maximum ship width of 108 ft. (32.92 m). Other propeller driven configurations with 3, 4, 6 or 8 propellers per ship show potential performance gains but do not appear mechanically feasible for the twin sidehull far term SES.

(U) Both mechanical and electrical power transmission systems were compared. The mechanical system was chosen for the point design as more feasible

(U) within projections of the current state-of-the-art. It employs right angle drives to deliver power from engines mounted on the 3rd deck to the propellers installed with a small angle to the bottom of the sidehulls.

(U) The electrical transmission system option would use the same type of engine installation as the mechanical installation, In this optional arrangement, each gas turbine engine drives a super-conducting electric generator mounted on the 3rd deck. The electric generators supply power to super-conducting electric motors mounted low in each sidehull and with direct drive to the propellers.

(U) The mechanical transmission system requires a controllable, reversible pitch propeller to provide backing and maneuvering capability. The electric transmission option could employ a fixed pitch propeller, should it prove feasible, with backing and maneuvering capability provided by reversing the direction of rotation of the electric motor.

(U) Both the point design mechanical transmissions and optional electrical generators rotate at gas turbine rpm. The rpm reduction in the mechanical system is at the two stage epicyclic reduction gearbox mounted to the propeller thrust bearing assembly. The electrical system employs a motor operating at propeller rpm.

(U) Propulsion equipment not common to the waterjet and propeller far term SES propulsion system are described in this Appendix.

(U) D.2.0 VEHICLE GENERAL DESCRIPTION

(U) D.2.1 PRINCIPAL CHARACTERISTICS -- The principal characteristics of the propeller-driven SES alternate point design are shown in Section 2.1 of the parent document.

[redacted] D.2.1.1 SUMMARY -- The Far Term Point Design SES illustrated in Figure 2.1-1 is a warship designed for high speed operation in an open ocean environment. The ship has greater range capability and carries a more significant military payload than the near term SES. The design is based on the use of GE LM5000 gas turbines which, with 50,000 hp (37.28 MW) maximum continuous power (MCP) and improved fuel economy, permit carrying a higher payload to a greater range. Primary mission areas are anti-submarine warfare (ASW), surface Warfare (SUW), and anti-air warfare (AAW) in the defense of fleet elements. Characteristics of both the propeller-driven and waterjet-propelled ship are summarized in Table 2.1-1.

(U) The following subsections are primarily incremental extensions of Sections of the parent document -- Section D.2.2 outlines vehicle performance, Section D.2.3 contains ship subsystem descriptions, and Section D.2.4 provides survivability and vulnerability information,

(U) The point design, in the on-cushion mode, operates on the captured air bubble principle to reduce hydrodynamic drag and achieve high speeds. In the off-cushion mode, it operates as a displacement hull. The ship is capable of maneuvering in both modes including turning, accelerating, decelerating, and backing, and can also hover in the on-cushion mode.

[redacted] The principal ship dimensions are shown in Figure 2.1-2. The 266.25 feet (81.15 m) length overall and 108 feet (32.92 m) maximum beam satisfy the volumetric and performance requirements, The maximum beam permits transiting the Panama and Suez Canals, within the explicit scenario assumption that the United States of America will continue to exercise its sovereignty over the Panama Canal Zone into the 1990's.

(U) Effective cushion dimensions are 221 feet (67.36 m) length and 85 feet (25.91 m) beam. A cushion height of 18 feet (5.49 m) was selected to ease ship motions and structural loads in Sea State 6. The full load displacement is 3,600 LT (35.87 MN or 3,657 non-SI metric tons) including all contract margins and fuel load. Tables 2.1-1 and 2.1-2 of the parent document show the principal design characteristics and the key differences between the far term and the near term SES concepts.

(U) D.2.1.2 GENERAL ARRANGEMENT DRAWINGS -- The general arrangement drawings of the propeller-driven point design ship in Appendix B are the same as for the waterjet propelled ship, Topside combat system locations are shown on the drawings. The drawings are:

- Outboard Profile
- Inboard Profile
- 01 Level and Above
- Main Deck
- Second Deck
- Third Deck
- Wet Deck
- Transverse Section
- Sidehull Inboard Profile
- Bow and Stern Views

(U) D.2.1.3 COMBAT SYSTEM DRAWINGS -- There are no changes in the combat system for the propeller-driven alternate SES point design from those presented in Section 2.1.2.

(U) D.2.1.4 SHIP INTERFACES -- There are no significant changes in ship interfaces for the propeller-driven alternate SES point design from those presented in Section 2.1.4.

(U) D.2.2 VEHICLE PERFORMANCE

(U) D.2.2.1 THRUST, DRAG, AND POWER -- Figure D.2.2.1-1 presents the predicted drag/displacement ratios for the far term propeller-driven SES, as a function of ship speed and significant wave height at Full Load Displacement (FLD). Performance is shown with the ride control system off, and with the ride control system operating at a Level sufficient to meet or better the Rohr ride criteria shown in Figure D.2.2.1-2. In addition, a plot illustrating the speed dependent character of the drag components is presented in Figure D.2.2.1-3. There are no changes in the ship drag forces from the waterjet-propelled ship to the propeller-driven alternate. These drag data are based on analytic predictions which have been validated and enhanced by correlation with model test data. The far term SES drag reflects a ten percent drag reduction from the near term craft due to anticipated design improvements. While no allowance was made for marine fouling, a 1.0 mil surface finish was assumed for all hydrodynamically wetted surfaces.

(U) The available thrust is plotted in Figure D.2.2.1-4 as a function of speed. Figure D.2.2.1-5 presents the propulsive efficiency of the far term propeller-driven SES versus speed and significant wave height. These data are based on the assumption that the propulsion power could be set at that level necessary to maintain a constant speed.

(U) The transport efficiency of the far term propeller-driven SES as a function of speed and significant wave height is shown in Figure D.2.2.1-6. In accordance with the definitions presented in ANVCE WP-002, dated 2 April 1976, transport efficiency was defined by:

$$\frac{\text{Full Load Displacement (3600 LT; 35,870 kN)} \times \text{Speed (Independent Variable)}}{\text{Total Power Required at Half Fuel (3026 LT; 30,146.2 kN) Condition}}$$

(U) Figure D.2.2.1-7 presents the maximum speed capability versus significant wave height for the FLD condition. These predictions are based on the ride-control-off data presented in Figures D.2.2.1-1 and D.2.2.1-4. In all seas, maximum speed is limited by the thrust available.

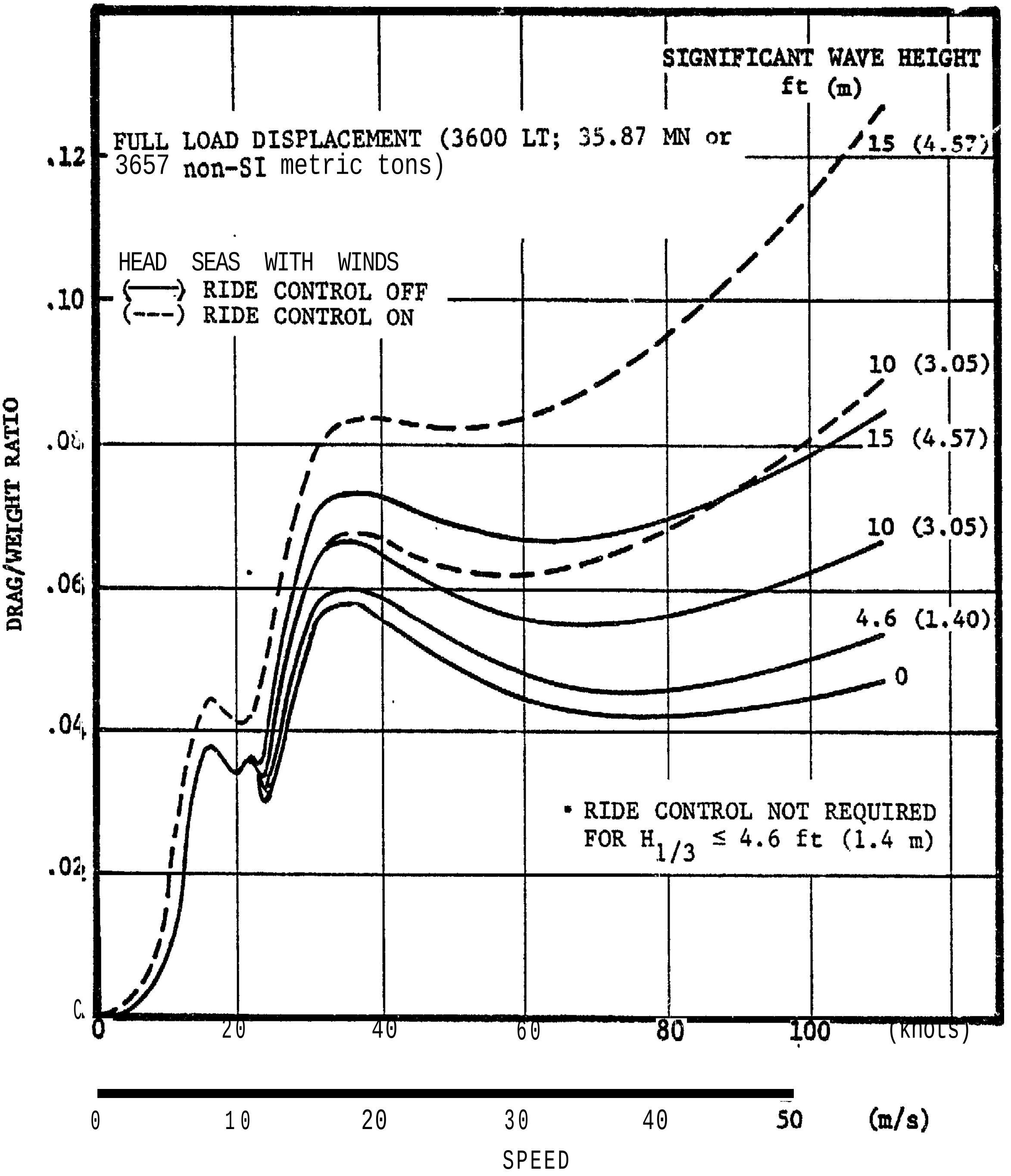


Figure D2.2.1-1 ([redacted]. Far Term SES (Propeller) Drag/Weight Ratio Versus Spsed and Sea State (U)

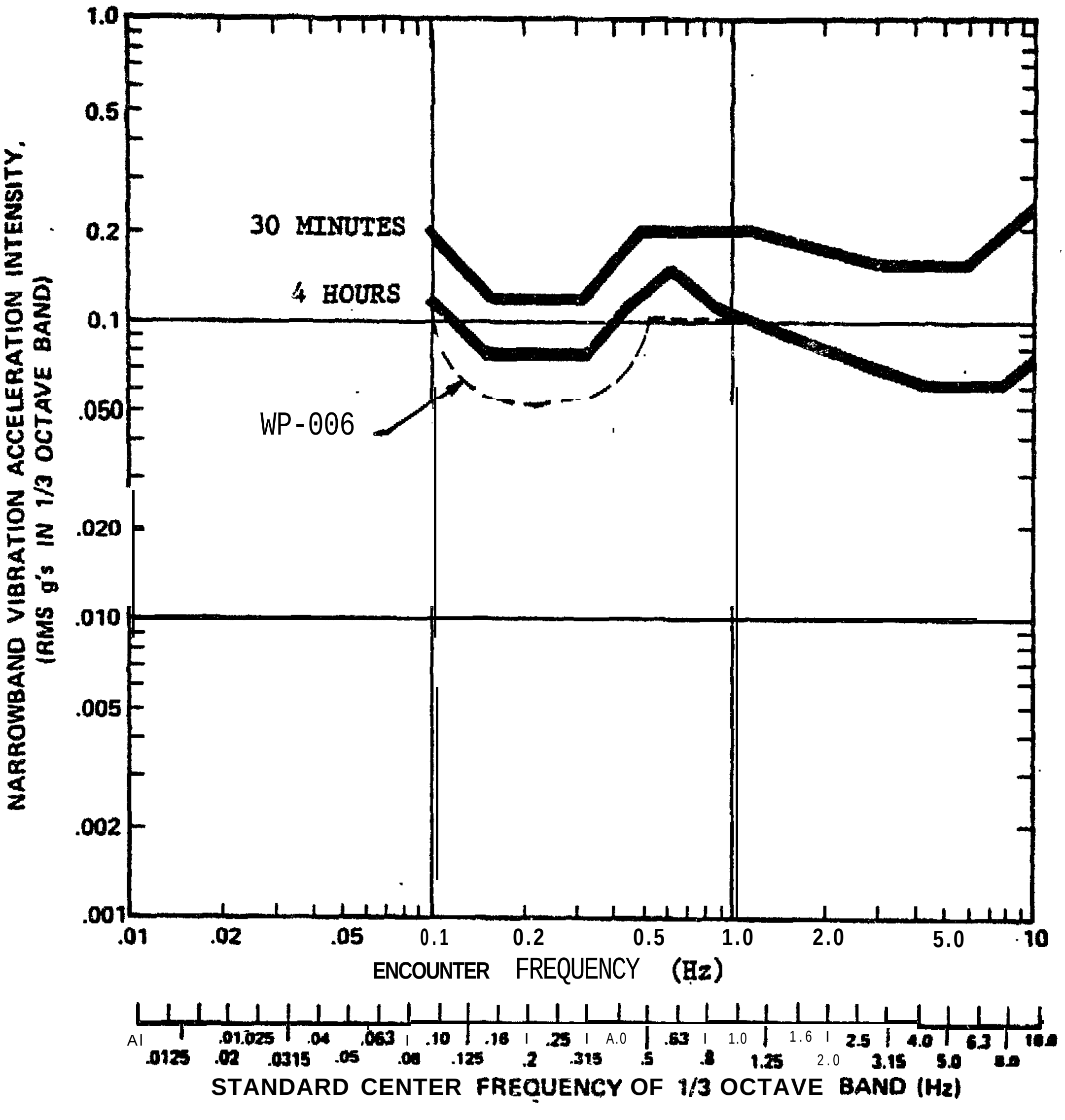


Figure D.2.2.1-2 (U). Rohr SES Heave Acceleration Ride Criteria (U)

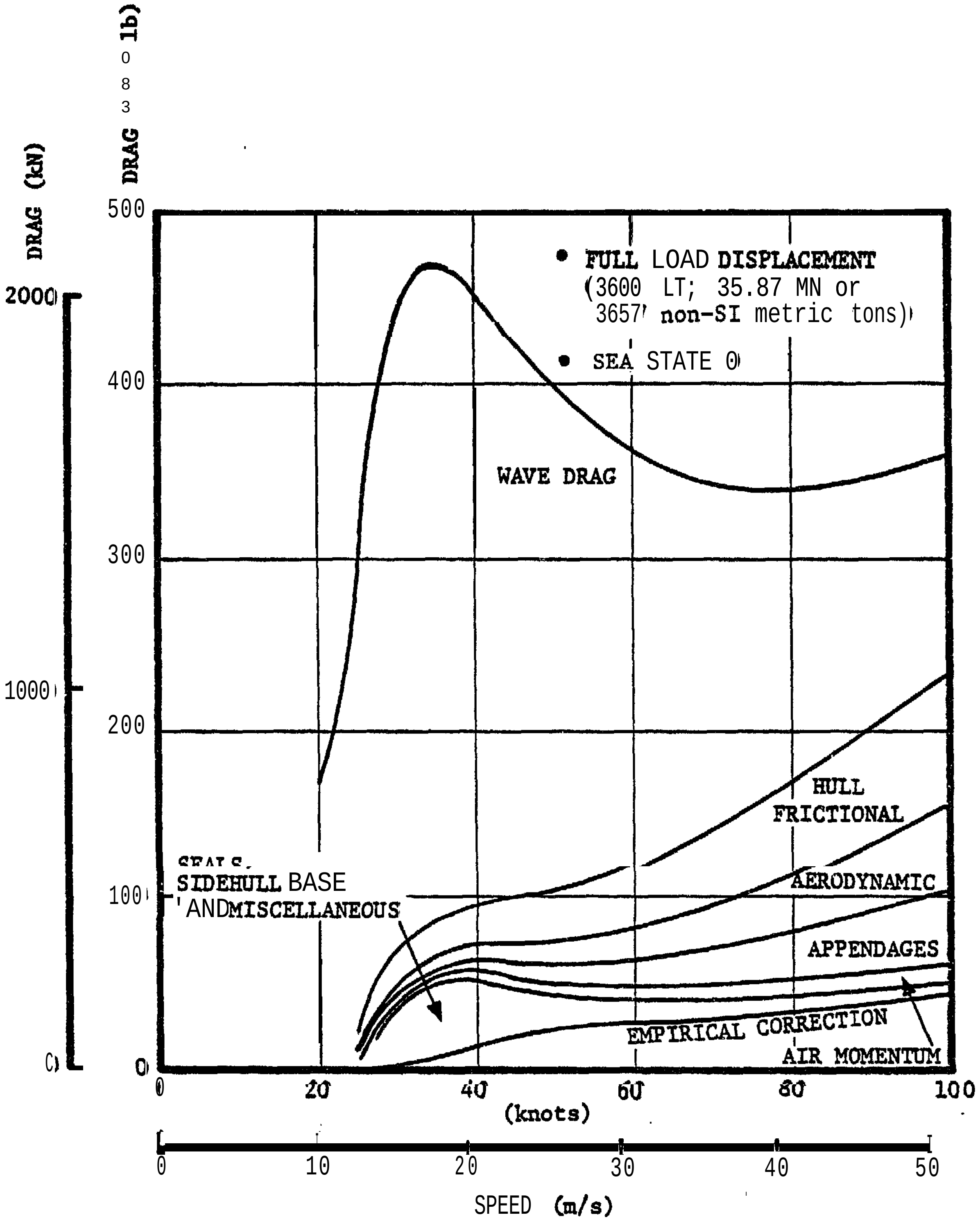


Figure 42.2.1-3 ~~(C)~~. Far Term SES (Propeller) Drag Breakdown (U)

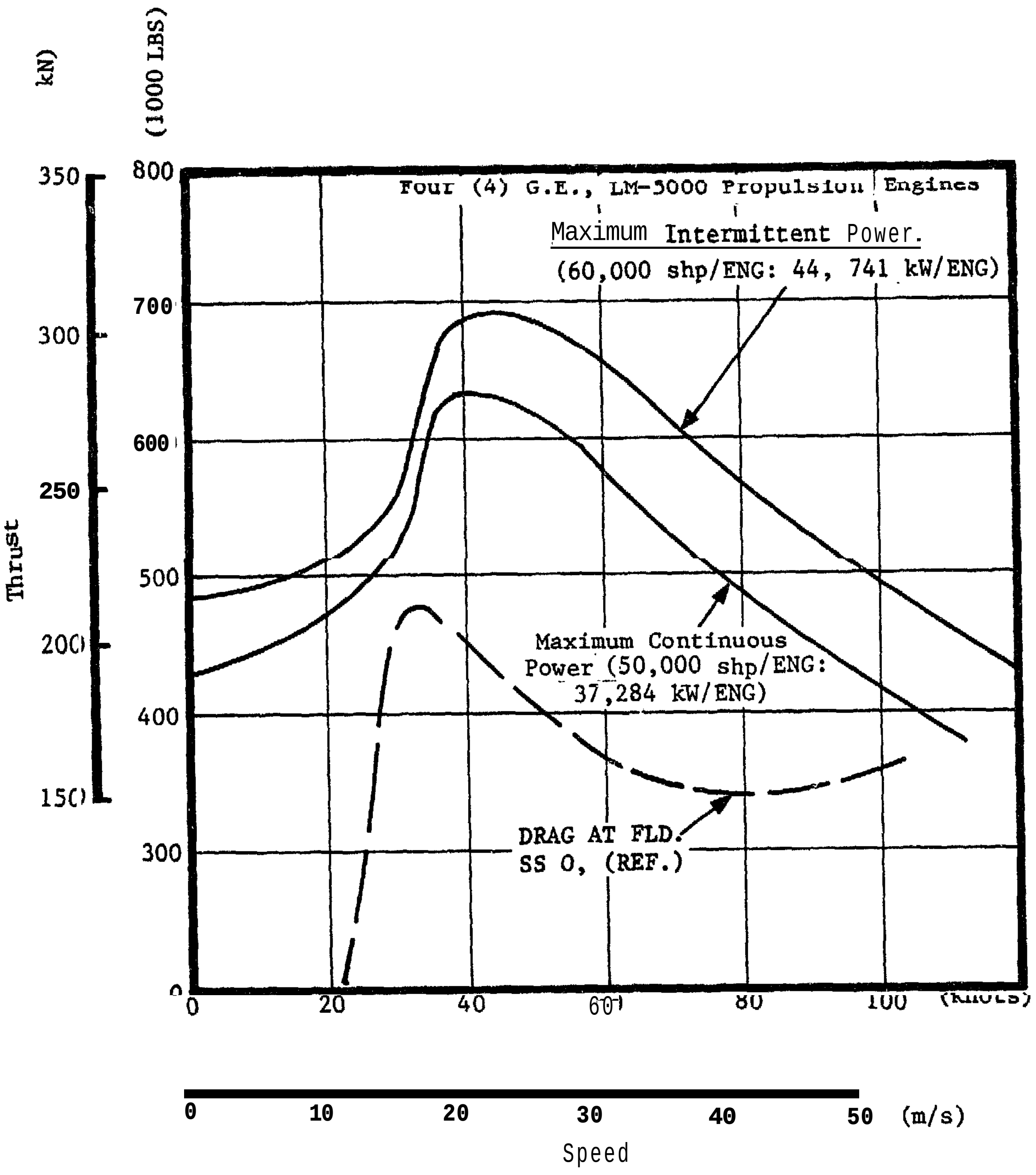


Figure D2.2.1-4 ([redacted] Far Term SES (Propeller) Available Thrust Versus Speed (U)

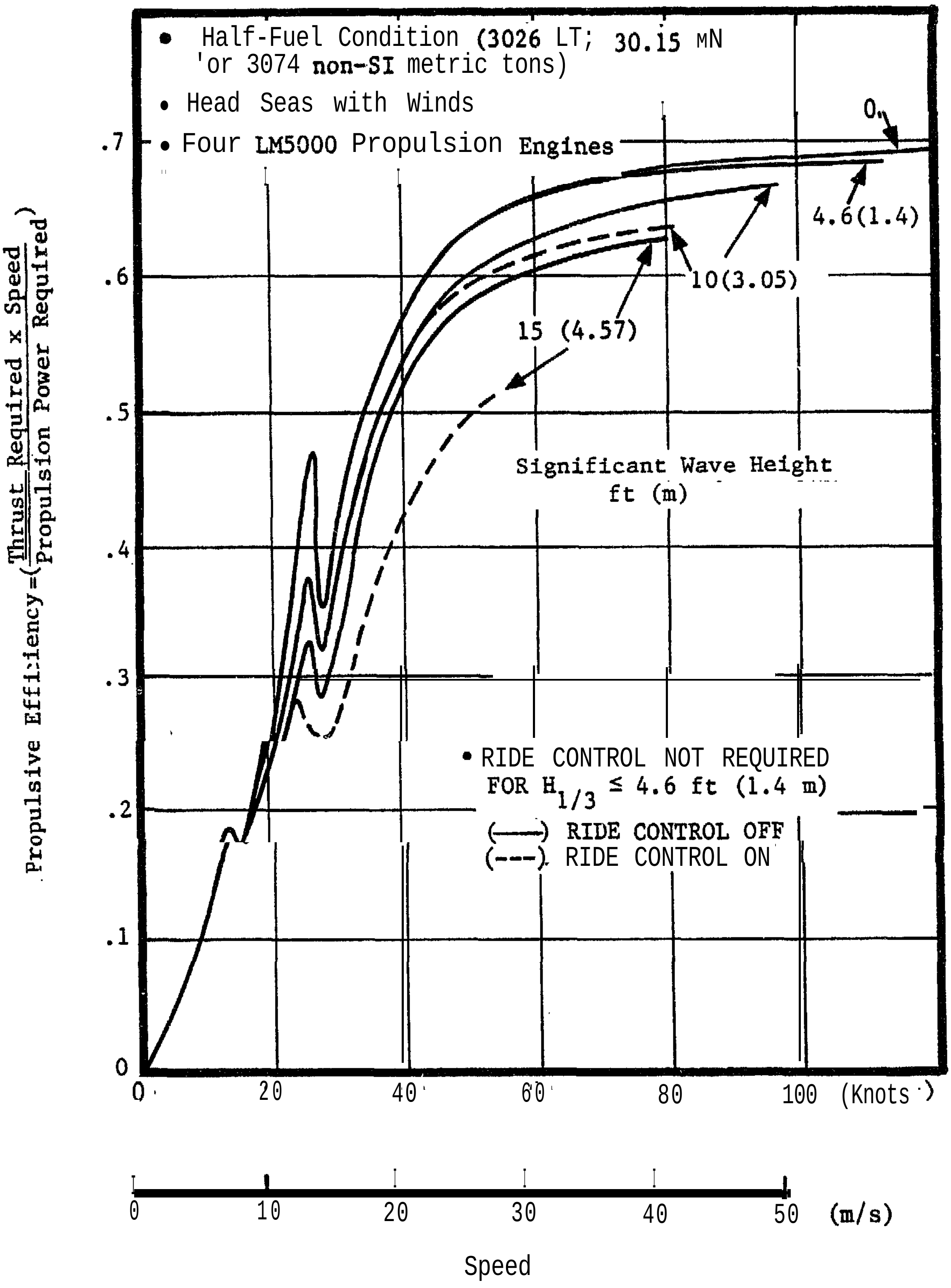
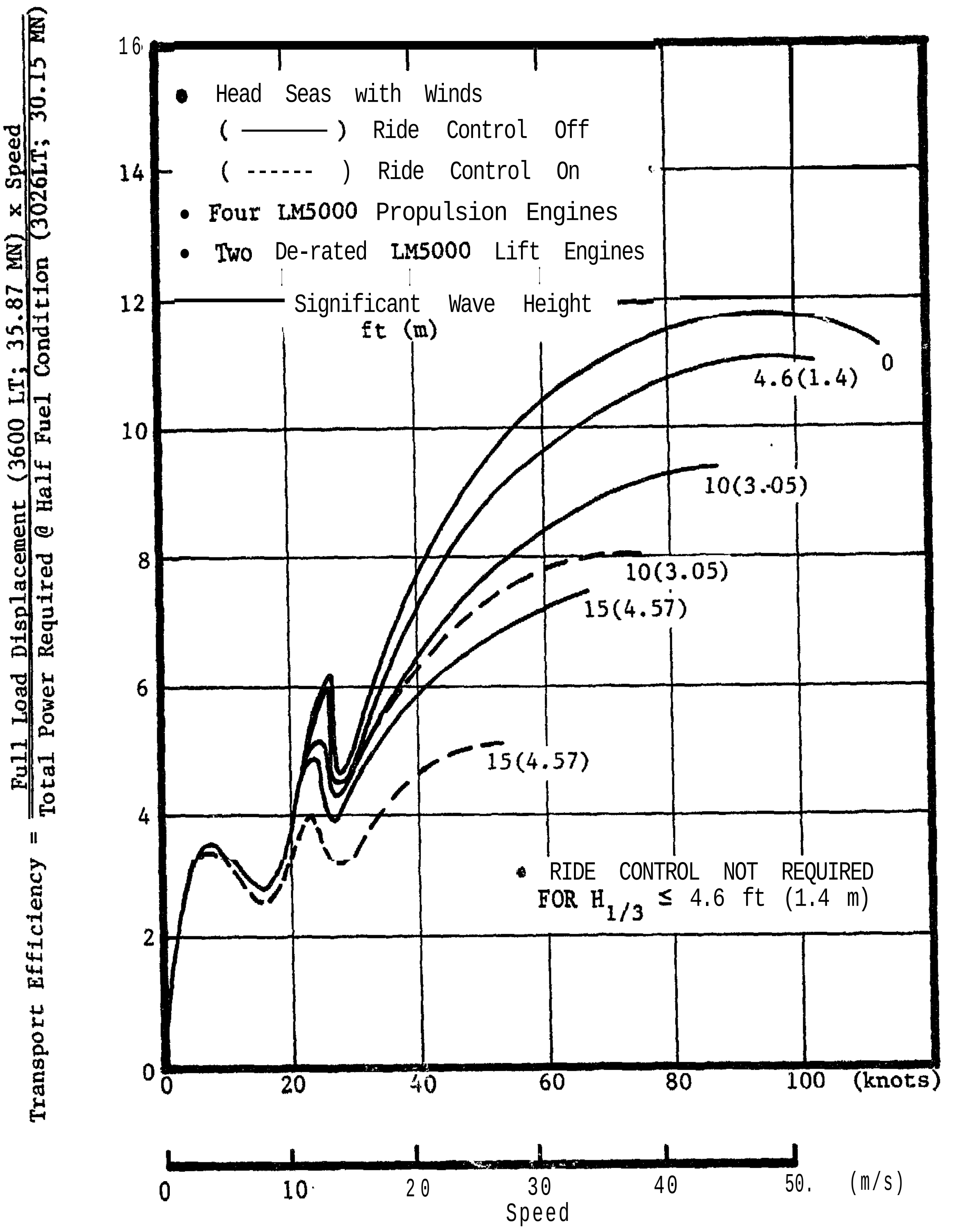


Figure D.2.2.1-5 ~~(C)~~ Far Term Propeller-Driven SES **Propulsive** Efficiency Versus Speed and Sea State (U)



'Figure D.2.2.1-6[redacted] Far Term Propeller - Driven SES Transport Efficiency Versus Speed (U)

- NO STRUCTURAL LIMIT WITH MCP

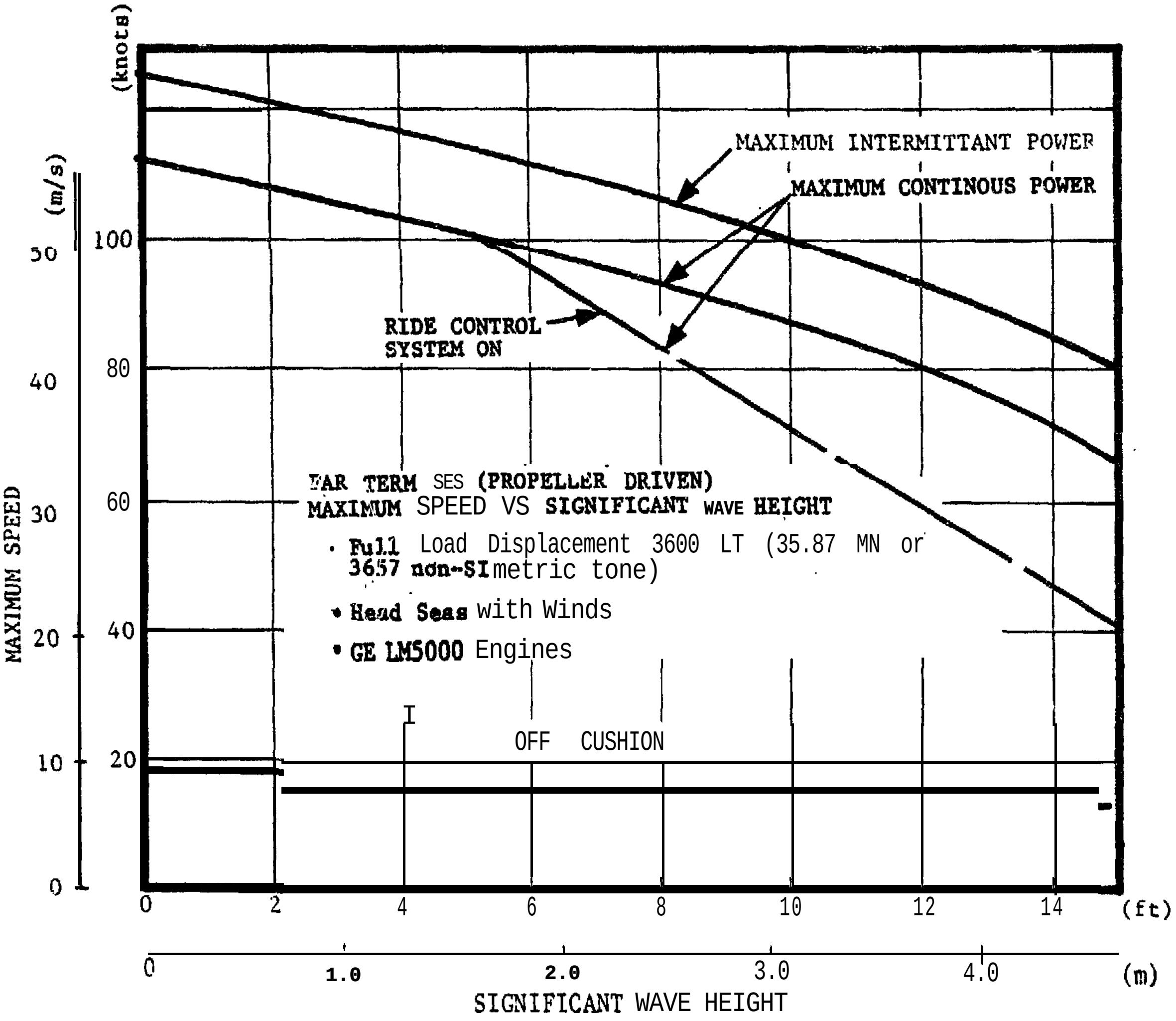


Figure D.2.2.1-7 [redacted]: Far Term **SES (Propeller-Driven)** Maximum Speed Versus Significant Wave Height (U)

(U)D.2.2.2 MANEUVERING

(U)D.2.2.2.1 Turn Performance -- The propeller-driven SES makes its turns through a combination of differential thrust control and steerable fin deflection. The moments produced by differential thrust control are due not only to the difference in propeller thrust between the port and starboard sides of the vessel but also by the difference in side forces on the two propellers. The side forces are generated by the propellers operating at semi-submerged conditions and also to operating the propellers in yaw as discussed later. Propeller rotation direction was selected such that the side forces generated by each propeller act outward from the vehicle. Thus the differential side force resulting from differential thrust on the two propellers increases the input yaw control moment.

(U) Operating the vessel at drift angles in turns results in propeller side forces which increase the yaw restoring moments of the vessel. The increases are increases in the static yaw stability which lower turn capability. However, the steady state turn radius achievable with the propeller-driven SES is better than that achievable with the waterjet-propelled craft. As an example, the steady state turn radius of the propeller-driven craft at 60 knots (30.9 m/s> is about 6600 ft (2012 m) vs. 7500 ft (22.86 m) for the waterjet-propelled craft.

(U) D.2.2.2.2 Propeller Failed Operation -- Heading control cannot be maintained in the event a propeller is inoperative as a result of damage to it or to its drive shaft. The steerable fins cannot generate sufficient yaw moments to counter the yaw moment due to thrust of the propeller on the opposite side, even if the inoperative propeller were jettisoned to eliminate its adverse yaw moment contribution due 'to drag. While heading control cannot be maintained with an inoperative propeller, the worst result is a safe turn at less than the maximum turn capability of the craft. Deployable emergency heading control devices would be evaluated to provide heading control with an out-of-service propeller.

(U) If a single propulsion engine or gearbox fails, the remaining engine/ gearbox on the side of the vessel incurring the failure would continue to drive the propeller. The SES can be operated in the failed condition at speeds above hump with the three remaining engines.

(U) Calm water operation of the craft at 3026 LT (30.15 MN or 3074 non-SI metric tons) can be achieved with only two engines, both operating at maximum continuous power. At this weight, the steerable fins can be used to steer the craft. Differential thrust is also available to provide additional yaw control moments, at speeds below the maximum speed for two engine operation.

(U) Three engine operation is required to achieve speeds above hump in calm water at 3600 LT (35.87 MN or 3657 non-SI metric tons). The adverse yaw moments due to assymetric thrust can be balanced through deflections of the steerable fins.

(U) D.2.2.2.3 Acceleration and Deceleration -- Figure D.2.2.2-3 presents the acceleration times from a standing start as a function of speed and significant wave height. These maneuvers were computed on the basis that both the lift and propulsion engines are set at Maximum Continuous Power (MCP) and that the bow seal is partly retracted while transiting hump. The use of Maximum Intermittent Power (MIP) during the last minute of the acceleration maneuver would avoid asymptotic approaches to maximum speed.

(U), Figures D.2.2.2-2 and D.2.2.2-3 present the deceleration performance as a function of speed and significant wave height. These maneuvers were accomplished by;

- Applying full propeller reverse pitch control
- Applying MIP to the propulsion engines
- Retracting the stern seal,

(U) These procedures cause the ship to decelerate in a bow up attitude and thereby avoid the possibility of undesirable pitch motions.

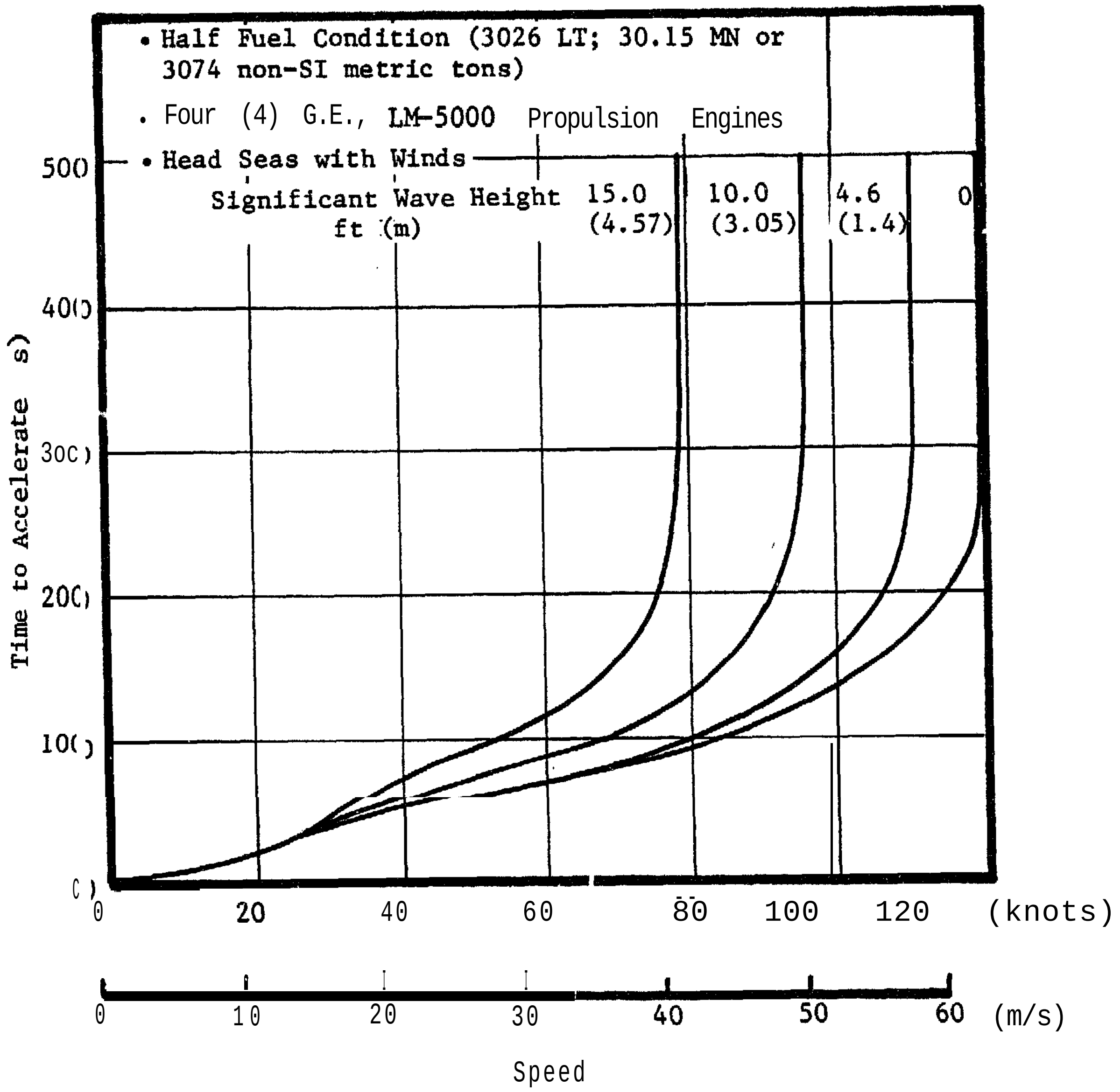


Figure D.2.2.2-1 (6): Far Term Propeller-Driven SES Time to Accelerate versus Speed (U)

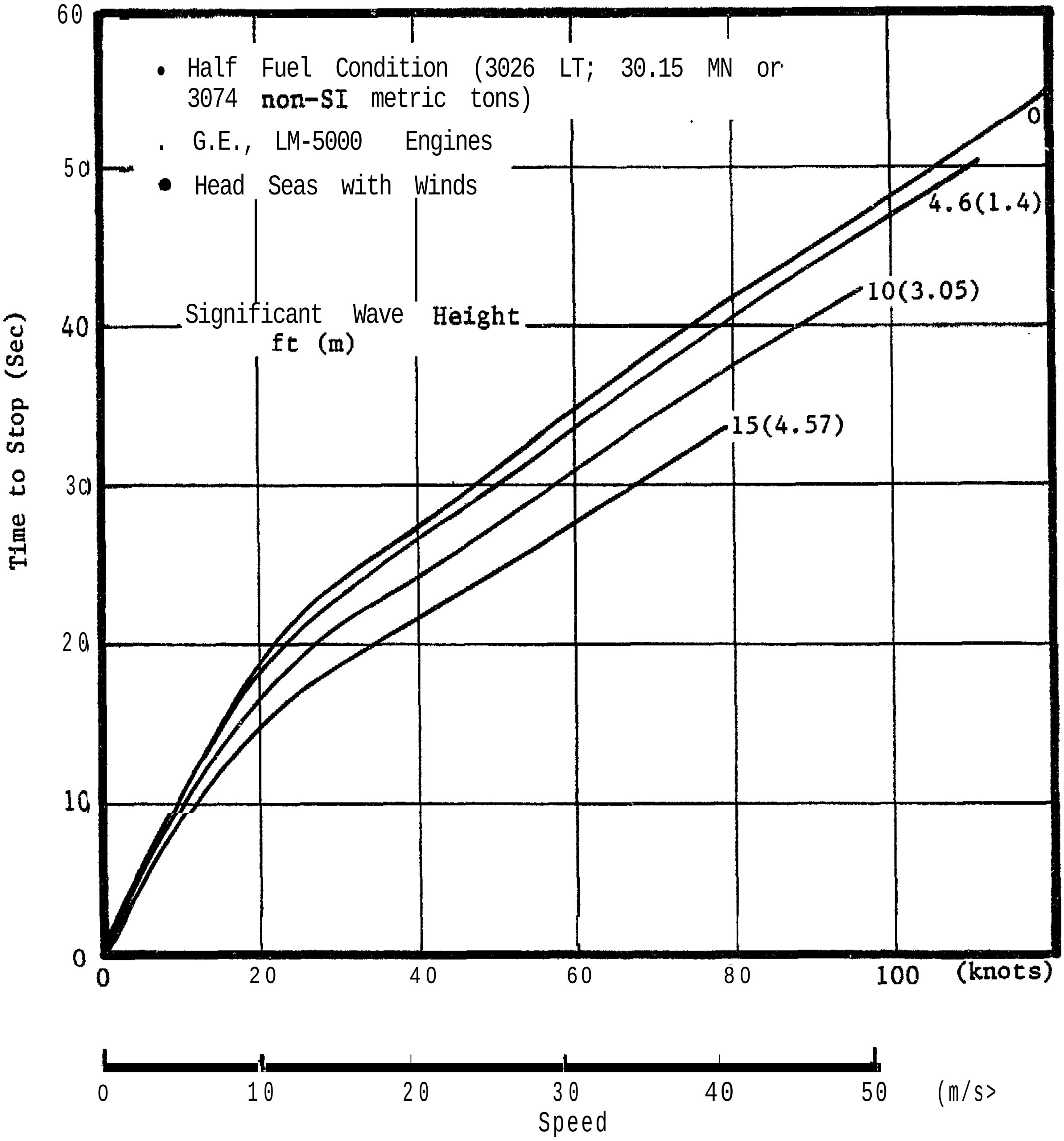


Figure D.2.2.2-2 [redacted] Far Term Propeller-Driven SES Time to Stop Versus Speed (U)

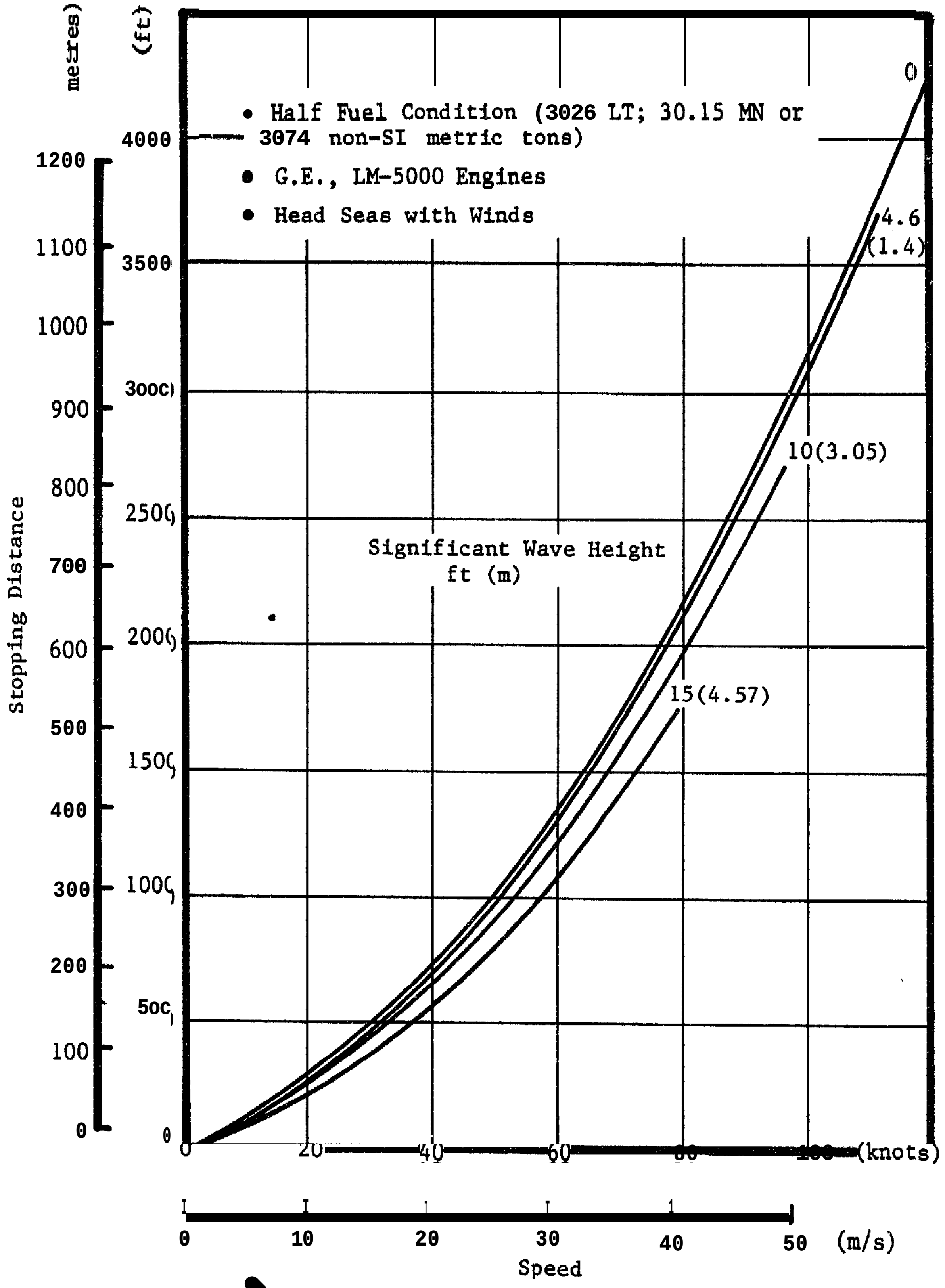


Figure D.2.2.2-3 [redacted]) Far Term Propeller-Driven SES Stopping Distance Versus Speed (U)

(U) D.2.2.3 RANGE AND PAYLOAD -- The propeller-driven far term ANVCE SES exceeds the required range in 4.6 ft (1.40 m) head seas with the GE LM5000 engines by 113 nm (209 km). The range, endurance characteristics and fuel consumption rates, as presented in Figures D.2.2.3-1 through D.2.2.3-4, are influenced by speed, significant wave height and payload. The characteristics are shown with the ride control system off and with the ride control system operating at a level sufficient to meet or better the Rohr ride criteria. These data are based on the MOD-50 resistance data, the propulsion system efficiencies presented in Figure D.2.2.1-5, and a specific fuel consumption of 0.32 lbs/HP-hr (1.915 kN/Wh).

[redacted]

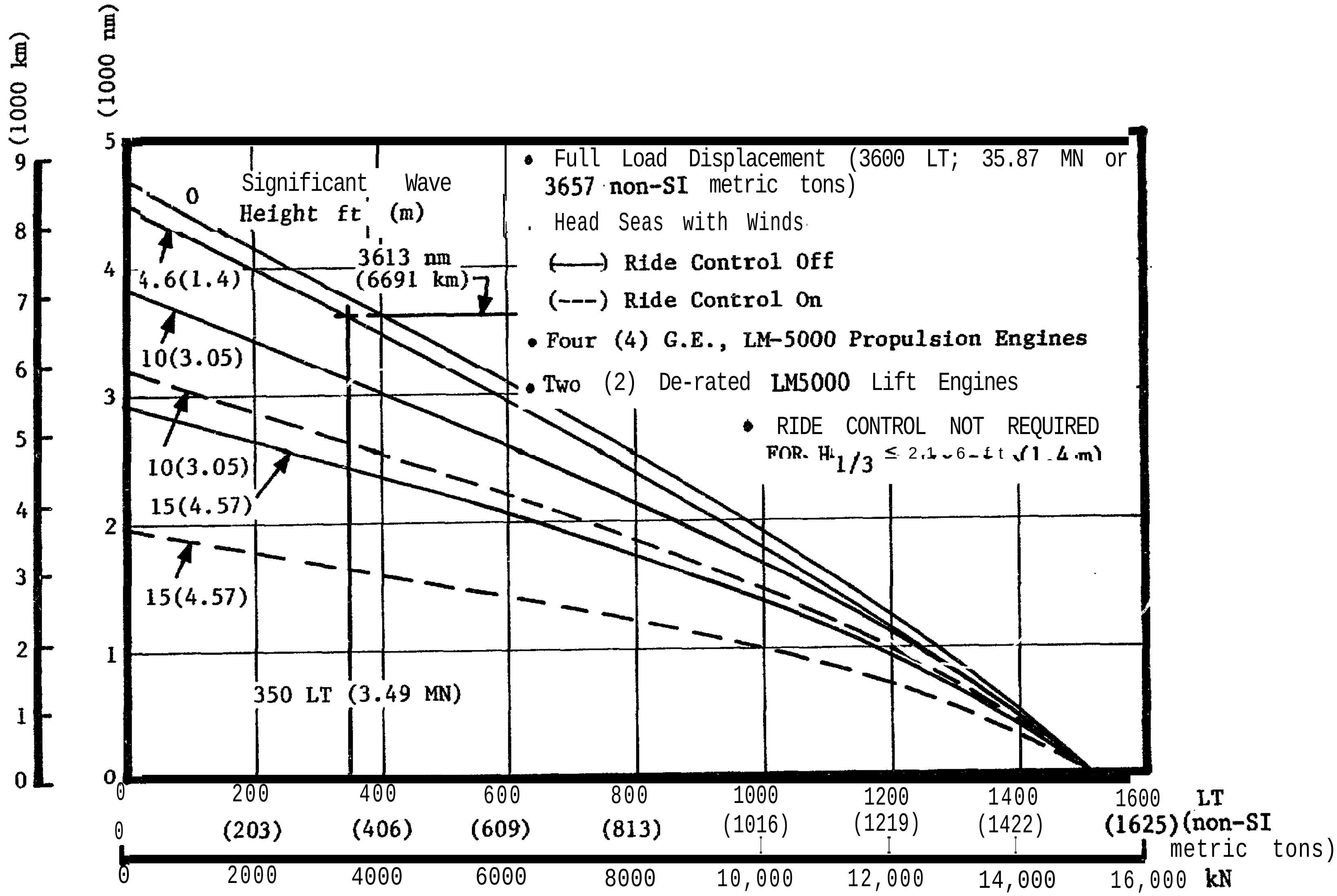


Figure D.2.2.3-1 [redacted] Far Term Propeller-Driven SES Range Versus Payload (U)

[redacted]

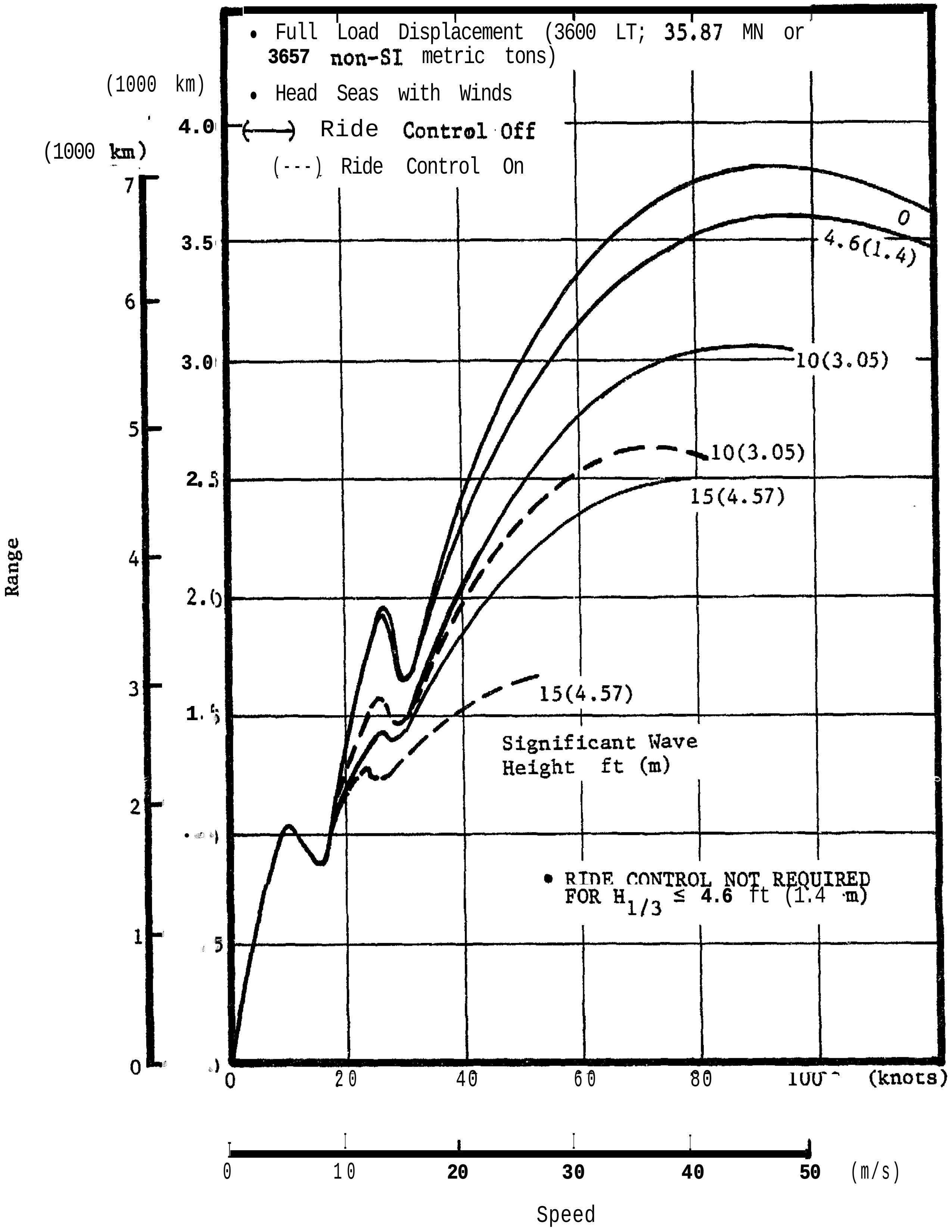


Figure D.2.2.3-2 (C) Far Term Propeller-Driven SES Range Versus Speed (U)

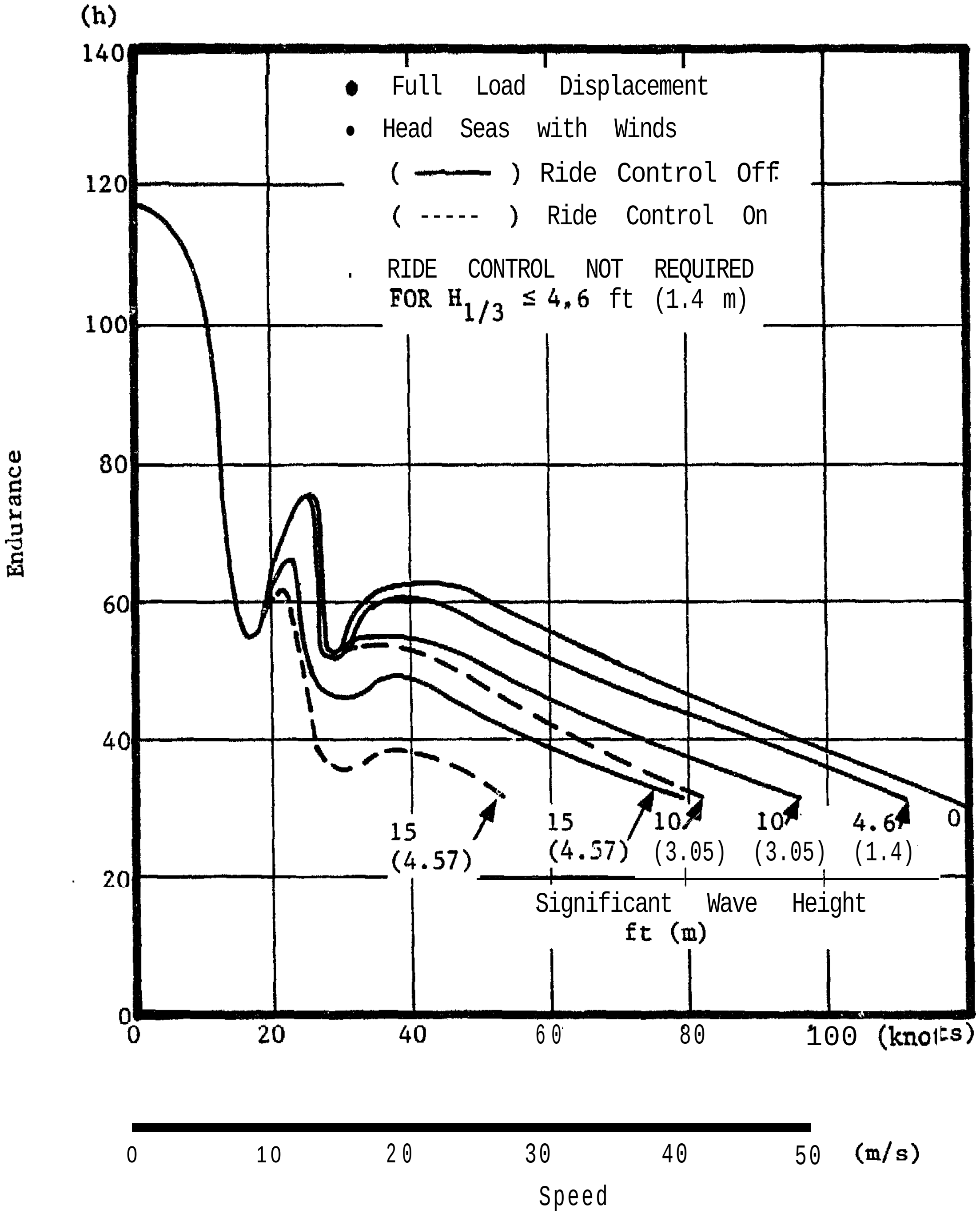


Figure D.2.2.3-3 [redacted] Far Term Propeller-Driven SES Endurance Versus Speed (U)

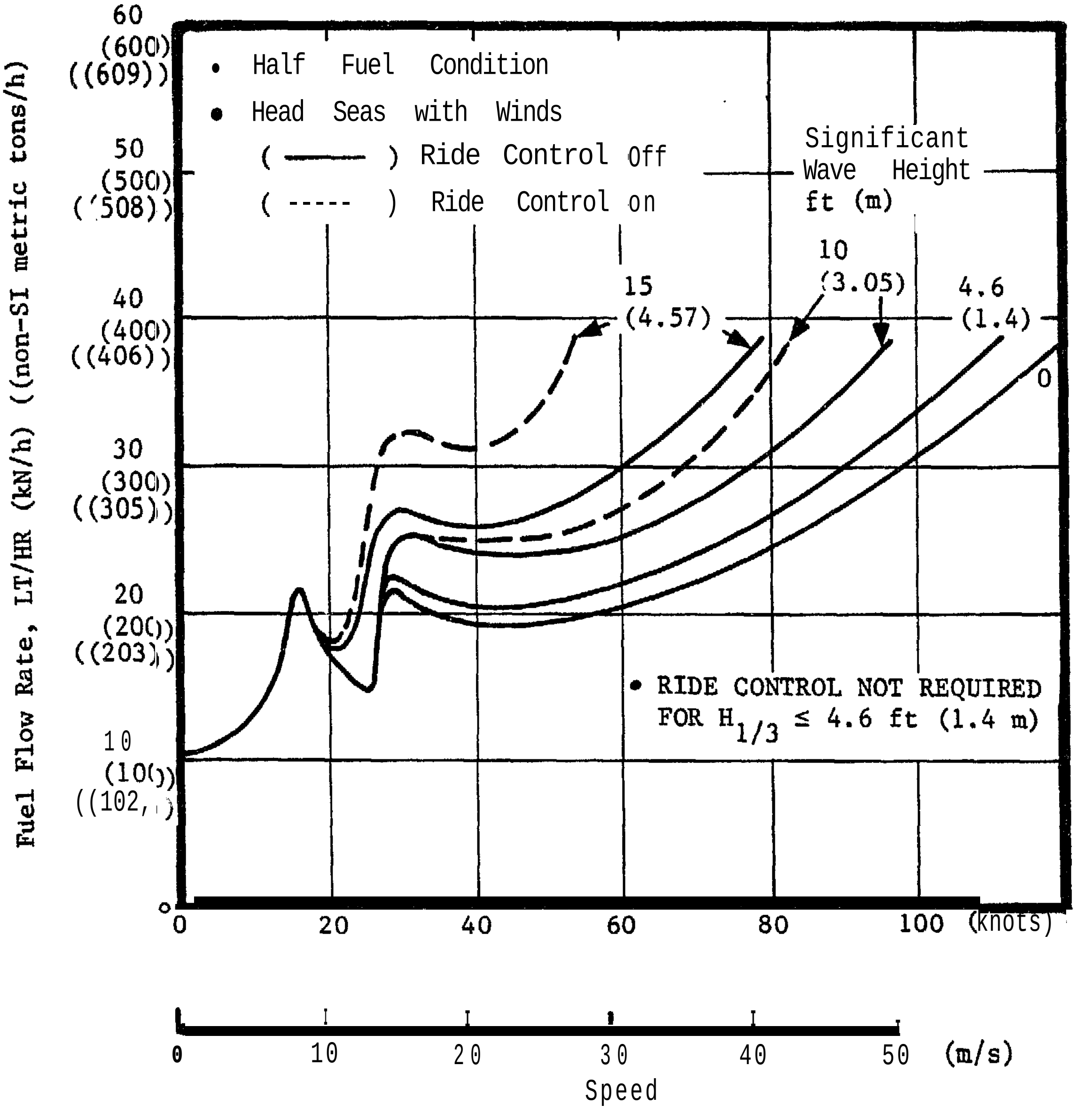


Figure D.2.2.3-4 (C) Far Term Propeller-Driven SES Fuel Consumption Versus Speed (U)

(U) D.2.2.4 WEIGHT AND VOLUME SUMMARY -- Summaries of the lightship weight, variable loads, contract margins and full load weight for the ANVCE far term propeller-driven SES point design and for optional electrical drives are presented in Tables D.2.2.4-1 and D.2.2.4-2.

The volume summary presented as Table D.2.2.4-3 is identical to that for the waterjet-propelled version. It is presented here to complete the weight and volume summary of the propeller-driven far-term SES.

Table **D.2.2.4-1 (U).** ANVCE Far--Term Propeller-Driven SES Alternate Point Design Weight Summary (Two Propellers and Mechanical Transmission)(U)

SWBS GROUP		**LONG TONS**	**SHORT TONS**	**METRIC TONS**	**KILO-NEWTONS**
100	Hull Structure	948	1062	963	9,446
200	Propulsion System	238	267	242	2,371
300	Electric System	66	74	67	658
400	command & Surveillance	74	83	75	737
500	Auxiliary Systems	116	130	118	1,156
567	Lift System	122	137	124	1,216
600	Outfit and Furnishings	193	216	196	1,923
700	**Armament**	63	71	64	628
Preliminary, Contract Design and Construction Margins		273	306	277	2,720
	Empty Weight (Lightship)	2093	2344	2127	20,855
Loads	Crew	16	16	16	159
	Provisions	10	11	10	100
	Stores	4	5	4	40
	Fresh Water	21	24	21	209
	Ordnance-Main Vehicle	164	184	167	1,634
	-Sub-Vehicle	15	17	15	149
	Sub-Vehicle	24	27	24	239
	Fuel	1253	1403	1273	12,485
	FULL LOAD **WEIGHT**	3600	4032	3658	35,870

Table D.2.2.4-2 (U). ANVCE Far-Term Propeller--Driven SES Alternate Point Design Option Weight Summary (Two Propellers and Electric Transmission)(U)

SWBS GROUP	LONG TONS	SHORT TONS	METRIC TONS	KILO-NEWTONS
100 Hull Structure	948	1062	963	9,446
200 Propulsion System	315	353	320	3,139
300 Electric System	66	74	67	658
400 Command and Surveillance	74	83	75	737
500 Auxiliary Systems	116	130	118	1,156
567 Lift System	122	137	124	1,216
600 Outfit and 'Furnishings	193	216	196	1,923
700 Armament	63	71	64	628
Preliminary, Contract Design and Construction Margins	285	319	290	2,840
Empty Weight (Lightship)	2,182	2,444	2.217	21,743
Loads				
Crew	16	18	16	159
Provisions	10	11	10	100
Stores	4	5	4	40
Fresh Water	21	24	21	209
Ordnance-Main Vehicle	164	184	167	1,634
-Sub-Vehicle	15	17	15	149
Sub-Vehicle	24	27	24	239
Fuel	1,164	1,201	1,184	11,597
FULL LOAD WEIGHT	3600	4032	3658	35,870

Table D.2.2.4-3 (U)

Volume Summary (U)

FUNCTION	INTERNAL VOLUME (1)	
	CUBIC FEET	CUBIC METERS
Main Propulsion (including main machinery box, uptakes, shafting)	119,034	3,371
Lift System	109,881	3,112
Personnel (including living, messing and all personnel support and storage)	104,454	2,958
Auxiliary and Electrical (machinery spaces other than main propulsion and lift outside main machinery boss)	100,962	2,859
Payload (internal volume only)	150,955	4,275
Other (including passageways, maintenance spaces and all other spaces not included in above)	147,663	4,182
TOTAL **ENCLOSED VOLUME**	732,949	20,758

(1) Total enclosed volume does not include tanks and other innerbottom spaces below third deck, or helo landing and any weather decks.

(U) D.2.2.5 STABILITY

(U) D.2.2.5.1 **Hullborne** Stability -- **Analysis** has demonstrated that the far term propeller-driven SES design meets the Navy criteria for Large **SES's** set forth In the references of Section **A.2.11.2** for displacements greater than 3000 LT (29.89 MN or 3048 non-SI metric tons).

(U) **D.2.2.5.2** Static Stability Underway

(U) **D.2.2.5.2.2** Off-Cushion -- The propellers slightly Increase stability in yaw. The restoring moments arise from the changes In the **propeller**-generated moment with changes In pitch attitude. The yaw effect is limited because the keel and fence tend to straighten the flow Into ail but that portion of the propeller disc below the fence. By comparison, waterjet-propelled craft do not experience this added stability because the pump blades do not see changes in their local angles-of-attack as the craft drift angle changes. The inlet flow is straightened by the fence such that the **reaction** forces and moments due to drift are a part of the hull-fence hydrodynamics. In pitch, that portion of the propeller disc overhanging the sldehull lines contributes to pitch stability, offsetting the **waterjet** inlet pitch restoring forces.

(U) **D.2.2.5.2.2** On-Cushion -- The propeller effects off-cushion are modified for the on-cushion condition. The propellers have reduced submersion at all but the lowest speeds or at reduced **cushion pressures.** At cruise speeds, with 50 percent submersion of the propellers, the pitch stabilizing moments of the propellers are reduced from that of the fully-immersed condition. However, only very small differences In the on-cushion yaw static stability between the **waterjet** and propeller ships are projected.

(U) D.2.2.5.3 Dynamic Stability Underway

(U) D.2.2.5.3.1 Heading Stability -- The change from waterjets to propellers is not expected to impact the dynamic stability to any significant degree. The yaw damping provided by the exit flow from the propellers is similar to that of the waterjet. Hence, Figures 2.2.5-7 and 2.2.5-8 apply to both versions.

(U) D.2.2.5.3.2 Pitch Attitude Excursions -- No significant change to the data of Figure 2.2.5-9 is expected.

(U) D.2.2.5.3.3 Roll Attitude Excursions -- The results shown on Figures 2.2.5-10 through 2.2.5-12 apply for the propeller-driven SES.

(U) D.2.2.5.3.4 Damping Characteristics in Calm Water -- The damping in pitch or yaw produced by the exit flow from a propeller is similar to that produced by a waterjet. Given equal momentum increases from either propulsion system, there are no differences in the damping produced by an angular velocity of the ship. With the slightly greater static stability in yaw of the propeller version, the frequencies increase slightly, but the times to half amplitude are the same,

(U) D.2.2.5.3.5 Drift Angle Limits -- The boundary shown on Figure 2.2.5-11 for above hump operations, established by stability considerations independent of the propulsion system, equally applies to the propeller-driven ship.

(U) D.2.2.6 GEOMETRIC FORM -- The use of propellers in lieu of waterjet propulsion requires insignificant changes to the hull form characteristics from those presented in Section 2.2.6; the changes are limited to changes in the aft sidehull geometry and are minor.

(U) D.2.2.7 RIDE QUALITY -- No significant changes in ride quality are expected from the propeller-driven alternate SES point design from those presented in Section 2.2.7.

(U) D.2.2.8 MANNING -- No changes in manning requirements are expected for the propeller-driven alternate SES point design from those presented in Section 2.2.8.

(U) D.2.3 SHIP SUBSYSTEM DESCRIPTION

(U) D.2.3.1 STRUCTURE

(U) D.2.3.1.1 Summary Description -- The use of a propeller drive system required the following structural changes.

a. Revise the pump rooms to eliminate pump machinery and foundations, and add foundations for electric motors, generators, and gear boxes.

b. Revise the sidehull by eliminating the ventilation cutout and increasing the width to accommodate propeller machinery,

c. Extend the auxiliary pump room deck in the sidehull to the transom for cryogenic equipment and to support the electric motors and generators.

d. Add foundations in the lower sidehull to mount the propeller and its machinery.

e. Eliminate the waterjet inlet structure and add a small water inlet to provide for machinery cooling and firemain water.

(U) To accommodate these changes the basic structural design philosophy was not changed. A stiffened skin and frame construction was used for shell plating. The stiffeners are at 10 inch (.25 m) spacing and the frames at 3 foot (.91 m) spacing. All transverse frames aft of frame 70 were increased in size to accommodate high local machinery and foundation loads. The sidehull plating and 42 ft-6 bulkhead plating was also increased to allow propeller thrust loads to be distributed into the hull.

(U) D.2.3.1.2 Structural Arrangement -- No structural arrangement drawings have been prepared for the propeller drive system. The design approach is the same as shown on the drawings in Appendix B, Section B.2 with scantlings increased as required for structural integrity.

(U) D.2.3.1.3 Key Structural Features -- The structural characteristics of the propeller driven far term SES are the same as the waterjet drive ship. The only difference is the increased width of the sidehull aft of frame 70. The width was increased 1 ft (.30 m) and faired into the baseline sidehull lines forward of frame 70.

(U) D.2.3.1.4 Structural Weight -- No weight change results from the use of a propeller system. The elimination of the water inlet duct, pump machinery, and all the corresponding foundations provides a major weight decrease. This weight savings is more than adequate to accommodate the addition of machinery and foundations for the propeller drive.

(U) D.2.3.2 PROPULSION SYSTEM

(U) D.2.3.2.1 Description -- The propeller-driven far term SES alternate point design is shown in Figures D.2.3.2-1 and D.2.3.2-2 for the point design mechanical transmission and for the optional electrical transmission, respectively. The two propellers rotate oppositely, outwards at the top. Propulsion equipment items common to the waterjet-propelled and propeller-driven far term SES include:

- Gas Turbines (SWBS 234)
- Combustion Air System (SWBS 251)
- Uptake System (SWBS 259).

(U) The propeller-driven far term SES propulsion equipment common to both the mechanical point design and electrical option transmission systems include the following:

- Thrust Bearing (SWBS 244)
- Propeller (SWBS 245)
- Pitch Change Mechanism (SWBS 245).

(U) The propeller-driven far term SES common equipment items are described in the following subsections. This is followed by a subsection describing equipment peculiar to each method of power transmission.

(U)D.2.3.2.2 Common Equipment

(U)D.2.3.2.2.1 Thrust Bearing -- This unit is designed to support the propeller overhang loads and resists propulsive thrust. Because the large propeller loads are coupled with a speed of 510 RPM, hydrodynamic bearings were chosen over rolling element bearings: rolling element bearings require special design, are sensitive to pulsating loads, and consequently have a short life expectancy.

(U)The propeller is supported radially at two places, near to the hub and near to the reduction gear. Each journal bearing has 10 Kingsbury type floating shoe hydrodynamic bearings pivoting on a ring in the housing.

Between the journal bearings lie the thrust bearings that react through a substantial thrust collar, integral with the shaft. The thrust collar. bearings are two sets of 12 self-aligning shoes of the Kingsbury type.

The oil film design pressure is 500 psi maximum (3447 kPa). Characteristics of this unit are shown in Table D.2.3.2-1.

(U)D.2.3.2.2.2 Propeller -- The propellers are 14 ft. (4.27 m) in diameter, eight-bladed, of super cavitating design and operate 50 percent submerged at high speed. The blade shape is indicated in Figure D.2.3.2-3. The blade contours exhibit modest skew and associated rake and have a discontinuous shape at the annex (hub) portion of the blade. The geometry includes reversing propeller pitch provisions, while the skew reduces the rate of blade loading during water entry and improves transfer of the blade bending load to the annex portion of the blade.

(U)The blades are retained in the hub by back-to-back spherical, angular roller bearings. A trunnion driven by the pitch change yoke is located on the end of each blade. The blades are sealed at the hub to prevent water entry. The material of the blades and hub is Ti-6Al-4V extra low interstitial (ELI) titanium alloy. Stainless steel liners are provided for wear and fretting resistance at the blade and hub interfaces.

(U)D.2.3.2.2.3 Pitch Change Mechanism -- The pitch change mechanism is based on aircraft propeller design practice. Pitch change is affected by movement of a servo controlled hydraulic piston attached to the pitch change yoke. Locking means are provided to prevent pitch changes in the event of hydraulic system failure.

Control signals to the servo valve are transmitted by a hollow rotating shaft which also carries the 3000 psi (20,682 kPa) hydraulic pressure supply, return, and lube oil supply.

(U)D.2.3.2.2.4 Shaft Inclination -- The 4.25 degrees inclination of the propeller shafts provides space to accommodate the thrust bearings and reduction gear boxes with a minimal enlargement of the sidehulls and minimum projections below the baseline (WL 0). The inclination is also used to provide the necessary propeller submersion for the anticipated operational conditions, (U)D.2.3.2.3 Peculiar Equipment

(U)D.2.3.2.3.1 Reduction Gear for Mechanical Configurations -- Engine shaft speed is reduced to propeller speed by the main reduction gear unit which has an overall reduction ratio of 9.2:1. The two-stage planetary unit is used for the application because of its light weight, high efficiency and, in particular, its compactness which permits it to be located within the envelope of the narrow sidehull and cantilevered from the thrust bearing. The characteristics of this gear are shown in Table D.2.3.2-2.

(U)D.2.3.2.3.2 Mechanical Drive Configuration Equipment -- The transmission concept shown in Figure D.2.3.2-4 consists of three upper spiral bevel gear and two lower units. Each spiral bevel gear has a dual load path such that each gear mesh is limited to 30,000 shp (22,371 kW) at a speed of 4690 rpm.

Each drive utilizes couplings between the gear units which drive into a common propeller input shaft. The couplings of the diaphragm type are state-of-the-art, Bendix type, double diaphragm units.

(U)D.2.3.2.3.3 Transfer Gears -- The input gear drives two transfer (idler) gears which, in turn, drive the output gear. The two idler gears are slightly bigger in diameter than either the input or output gears for gear tooth clearance.

(U)D.2.3.2.3.4 Gear Cases -- The gear cases are cast assemblies which carry rolling element bearings for rigidity and precise location of the gears.

(U)D.2.3.2.3.5 Bevel Gears -- The two spiral bevel gear units at the outputs of the gas turbines are reversed for the opposite side of the ship to give the opposite propeller rotation. The bevel gear pitch diameters are about 27 inches (0.686 m) and can be manufactured on present day equipment. The characteristics of the spiral bevel gears are shown in Table D.2.3.2-2.

(U) D.2.3.2.4 Propulsion System Weights -- The weights for the mechanical transmission of the propeller-driven far term SES point design are listed in Table D.2.3.2-3. The weights for the electrical transmission option are presented in Table D.2.3.2-4.

(U) D.2.3.2.5 Propulsion System Technical Risk -- The risk associated with large diameter propellers and with the optional electrical motor drives (Section D.2.3.3) is judged to be greater than that for the waterjet propulsion system. The propellers introduce the need for special handling in Panama Canal transit and increase the navigational draft. The projected high efficiencies for 14 ft (4.27 m) diameter propellers are based upon small scale test results which require verification; extensive development appears to be a requirement. A further discussion of additional risks is contained in Section D.4.

Table D.2.3.2-1(U). Propeller and Thrust Bearing Characteristics (U)

ITEM	CHARACTERISTIC
Propeller	
Speed (max)	510 rpm
Power (max)	124,410 shp (92,773 kW)
Diameter	14 ft (4.27 m)
No. of Blades	8
Skew Angle	10.0 degrees
Hub/Diameter Ratio	0.4
Weight	30,000 lbf (133.44 kN)
Pitch	Controllable - forward pitch for electric drive - reverse pitch for mechanical drive
Pitch Change Mechanism	Hydraulic - servo controlled
Material	6A1-4V Titanium ELI
Thrust Bearing	
Thrust (max)	600,000 lbf (2668.8 kN)
Diameter	4.8 ft (1.46 m)
Length	9.5 ft. (2.90 m)
Weight	57,000 lbf (253.536 kN)
Type	Kingsburg Floating Shoe Hvdrodvnamic Bearings

Table **D.2.3.2-2(U).** Reduction gear and Spiral Bevel Gear Characteristics (U)

ITEM	CHARACTERISTIC
Reduction Gear	
Input Speed **(max)**	4690 rpm
Power (max)	60000 shp (44742 **kW)**
Weight Dry	16000 **lbf** (71.168 **kN)**
Length	7 ft. (2.13 m)
Diameter	4 ft. (1.22 m)
Lubricant	2190 TEP per MIL-L-17331
Type and Ratio	Double epicyclic **9.2:1**
Gears	Double helical 9310 steel
Bearings	Journal - Babbit lined
Casing	Cast Aluminum **A356-T6**
Spiral Bevel Gears	
Speed @ power **(max)** per mesh	4690 rpm @ 30,000 shp **(22371 kW)**
Weight - Upper	**6900 lbf (30.691 kN)**
Weight - Lower	7200 **lbf (32.0[illegible]6 kN)**
No. Of Gears	**One** input, two idlers, one output
Length x Width	5.2 ft. (1.58 **m)** x 3.8 ft. (1.16 m)
Lubricant	2190 TEP per **MIL-L-17331**
Type, Ratio and Drive Angle	Spiral Bevel, **1:1,** 90 degrees
Gears	9310 steel
Bearings	Rolling element angular contact
Casing	Cast Aluminum **A356-T6**

Table D.2.3.2-3 (U). Propulsion System Weights for the Two Propellers and Mechanical Transmission Point Design (U)

SWBS NO.	SUBGROUP	WEIGHT			
		LT	kN	*	Percentage
234	Gas Turbines	39.57	394.2	40.20	16.6
241	Gears	-	-	-	-
241.1	Reduction Gears	14.29	142.4	14.52	6.0
241.2	Spiral Bevel Gears	31.34	312.2	31.84	13.1
242	Clutches and Couplings	5.18	51.6	5.26	2.2
243	Shafting	1.07	10.7	1.09	0.4
244	Thrust Bearing	50.89	507.0	51.70	21.3
245	Propellers	26.79	266.9	27.22	11.2
251	Combustion Air System	28.33	282.3	28.79	11.9
252	Control System	0.46	4.6	0.47	0.2
259	Uptakes	26.18	260.8	26.60	11.0
261	Fuel Service System	0.11	1.1	0.11	0.05
262	Lube Oil System	10.13	100.9	10.29	4.2
298	Operating Fluids	3.71	37.0	3.77	1.6
299	Repair Parts	0.44	4.4	0.45	0.2
200	Propulsion System	238.49	2376.1	242.28	100.0

* non-SI metric tons.

Table D.2.3.2-4 (U). Propulsion System Weights for the Two Propeller and Electrical Transmission Option (U)

SWBS NO.	SUBSYSTEM	WEIGHT			
		LT	kN	*	Percentage
234	Gas Turbines	39.57	394.2	40.20	12.6
235	Electrical Propulsion	-			--
235.1	Electrical Motors	31.25	311.3	31.75	9.9
235.2	Electrical Generators	23.21	231.2	23.58	7.4
235.3	**Gryogenic** System	20.18	201.1	20.50	6.4
235.4	Auxiliary Cooling Sys.	13.39	133.4	13.60	4.3
235.6	Cable	22.32	222.4	22.67	7.1
235.7	Switchgear	18.53	184.6	18.82	5.9
242	Couplings	2.30	22.9	2.34	0.7
243	Shafting	1.07	10.7	1.09	0.3
244	Thrust Bearing	50.89	507.0	51.69	16.2
245	Propellers	26.79	266.9	27.22	8.5
251	Combustion Air System	28.33	282.3	28.78	9.1
252	Control System	0.46	4.6	0.47	0.1
259	Uptakes	26.18	260.8	26.60	8.3
261	Fuel Service System	0.11	1.1	0.11	0.04
262	Lube Oil System	3.80	37.9	3.85	1.2
298	Operating Fluids	6.02	60.0	6.12	1.9
299	Repair Parts	0.44	4.4	0.45	0.1
200	Propulsion System	314.84	3136.8	319.84	100.0

* **non-SI** metric tons.

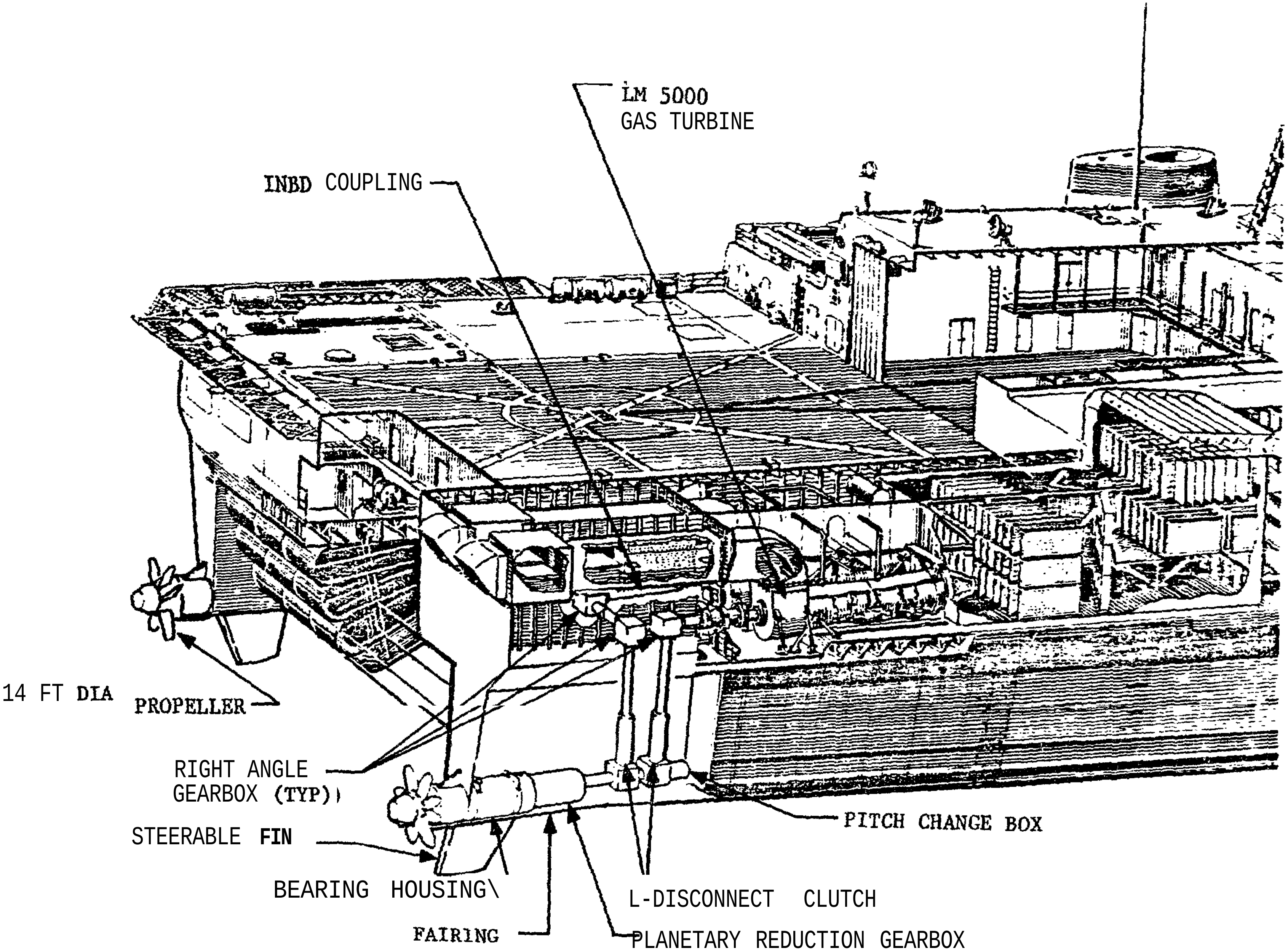


Figure D.2.3.2-1 (U). Mechanical Transmission for Propeller-Driven Alternate SES Point Design (U)

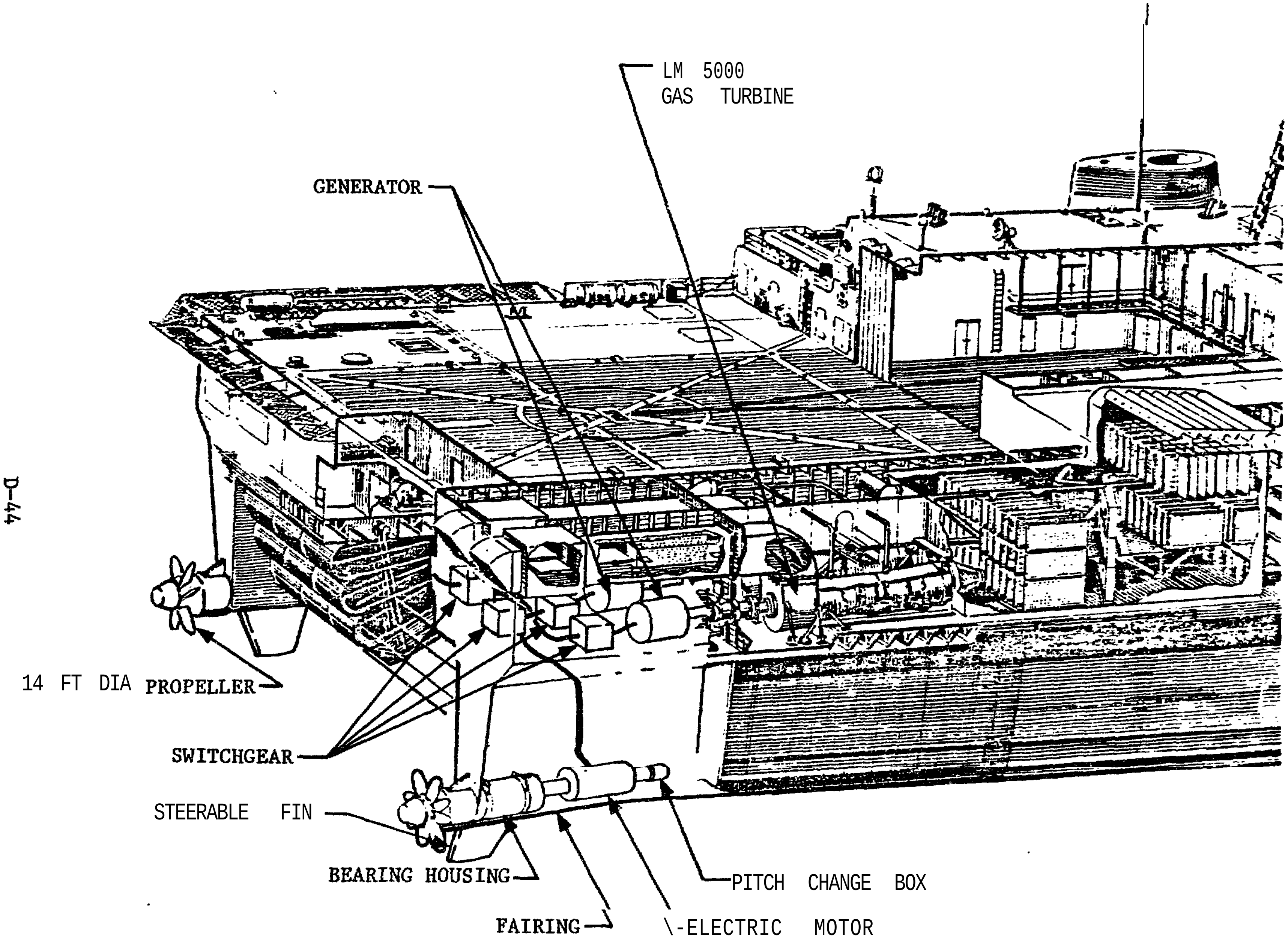


Figure D.2.3.2-2 (U). Electrical Transmission for Propeller-Driven Alternate SES Point Design (U)

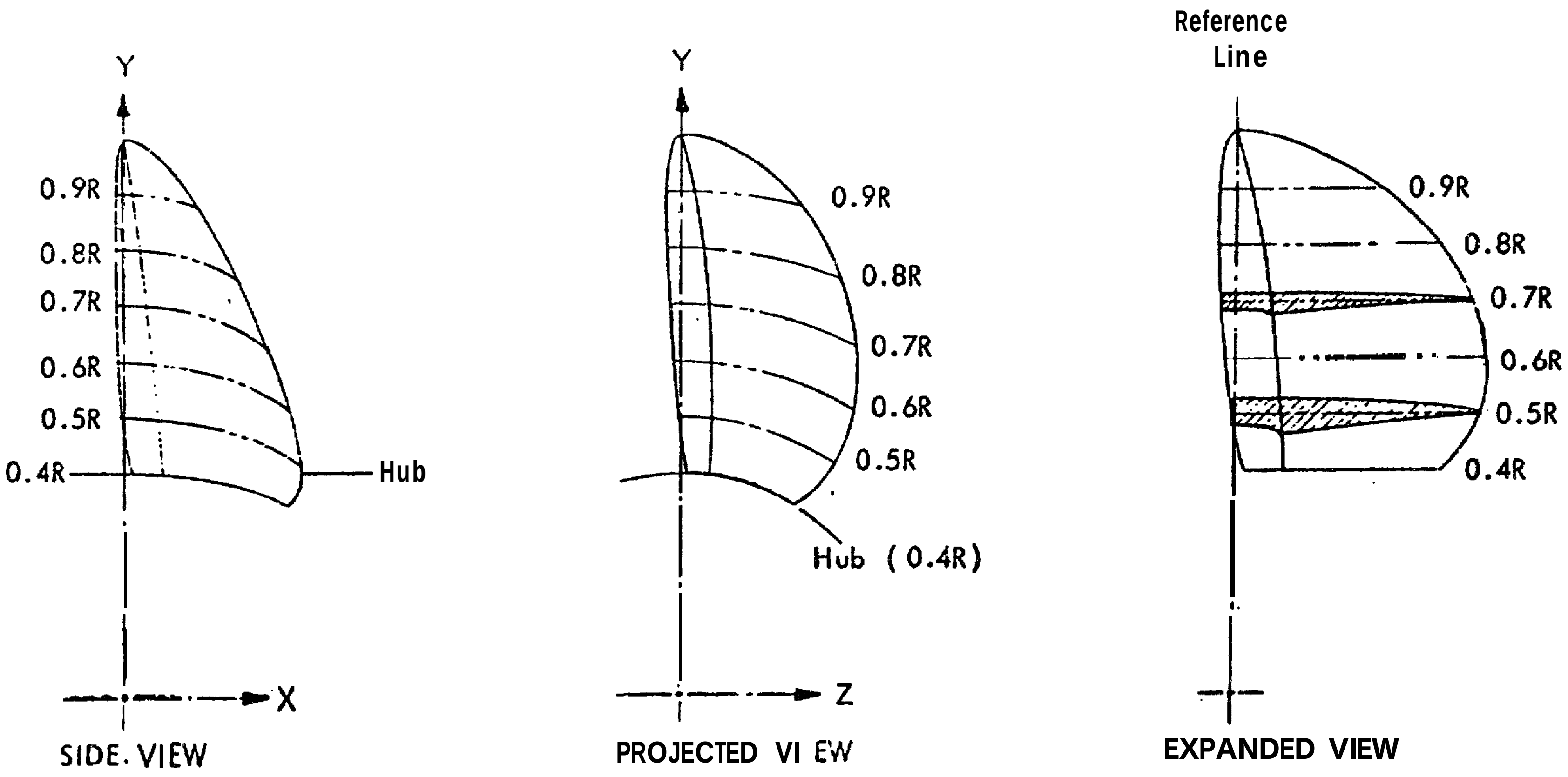


Figure D.2.3.2-3 (U). Propeller Blade Shape (U)

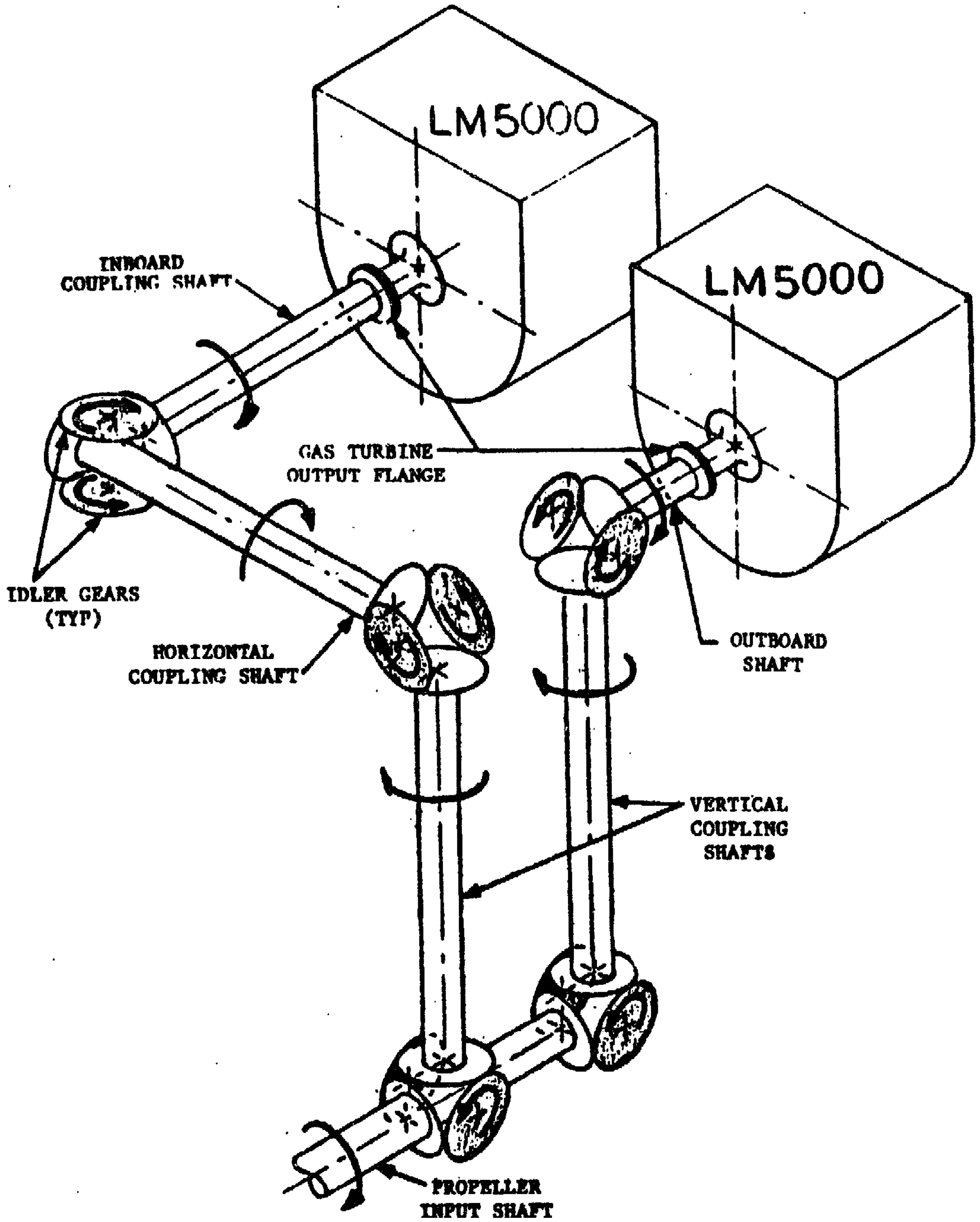


Figure D.2.3.2-4 (U). Dual Mesh Gear System (Spiral Bevel Gears) **(U)**

(U)D.2.3.3 Electrical Drive Option Equipment -- The far term SES with the electrical transmission option of the propulsion system requires an enlargement of the ship service (s/s) electrical system to accommodate the additional auxiliary equipment for the superconducting generators and motors. These auxiliaries include cryogenic systems, refrigeration systems, sodium-potassium systems, LN_2 storage, coolant systems and cover gas systems.

(U) D.2.3.3.1 Additional Generating Capacity -- Efficiency losses of 0.4 percent were projected for the electrical drive systems and 600 kW of additional generating capacity is therefore provided for cooling. One additional 500 kW, 400 Hz generator identical to the existing units is added to the system to accommodate this load with total system margins of 30 percent. This generator and its associated switchboard is located in one of the electrical generator rooms on the third deck.

(U)The electrical drive option equipment weighs 12,300 lbs. (54.71 kN or 5.58 non-SI metric tons) and consists of the generator, switchboard and associated hardware. The risk assessment for this S/S electrical system will be the same as that described in Section 4.3.

(U)D.2.3.3.2 Electric Transmission Option -- Four LM5000 gas turbines drive four superconducting generators which supply the electrical power for ship propulsion. Each generator is rated 60,000 hp (44,742 kW) with two generators operating in parallel to drive a 120,000 hp (89,484 kW) superconducting motor. Figure D.2.3.3-1 is a simplified representation of this system. Table D.2.3.3-1 lists the major characteristics of the generator and motor.

(U)The use of electric motor drives permits the propeller shaft speed to be regulated by varying the field voltage of the motors and generators. Reversal of the propeller for maneuvering can be accomplished electrically through appropriate switchgear.

(U) The sizes and weights shown for this equipment were extrapolated from data contained in Garrett Corporation Report #74-10565-l, "Superconducting Propulsion System and Ship Interface Study," prepared for the U.S. Naval Ships System Command in 1974. Additional data for updating the characteristics of the equipment for this system were obtained from NSRDC .

(U) D.2.3.3.3 Electrical System Technical Risk -- Compared to the waterjet-propelled version of the parent document, the electrical drive option for the far term SES introduces additional technical risk. The electrical propulsion option uses superconducting generators and motors. It requires cryogenic auxiliaires, liquid-metal brushes, cover gas systems and extremely high transmission currents. These are all relatively new development items and, when applied to 60,000 hp (44.742 MW) generators and 120,000 hp (89.484 MW) motors, will require much further development.

(u) Switchgear capable of handling currents in the 100,000 ampere range are not available today and will require extensive development to produce a simple switch capable of meeting these requirements, Various Navy programs are presently working on these problem areas and viable solutions can be expected by the 1995 calendar year established for initial operation of the far term SES.

Table D.2.3.3-1(U). Electrical System Component Characteristics (U)

SUPERCONDUCTING GENERATOR	
Rating	60,000 hp (44.742 MW)
Speed	4,400 rpm
Diameter	48 in (1.22 m)
Length	94 in (2.39 m)
Weight	13,000 lbf (57.82 kN or 5.90, non-SI metric tons)
SUPERCONDUCTING MOTOR	
Rating	120,000 hp (89.48 MW)
Speed	513 rpm
Casing Diameter	60 in (1.52 m)
Length	120 in (3.05 m)
Weight	35,000 lbf (155.7 kN or 15.88 non-SI metric tons)

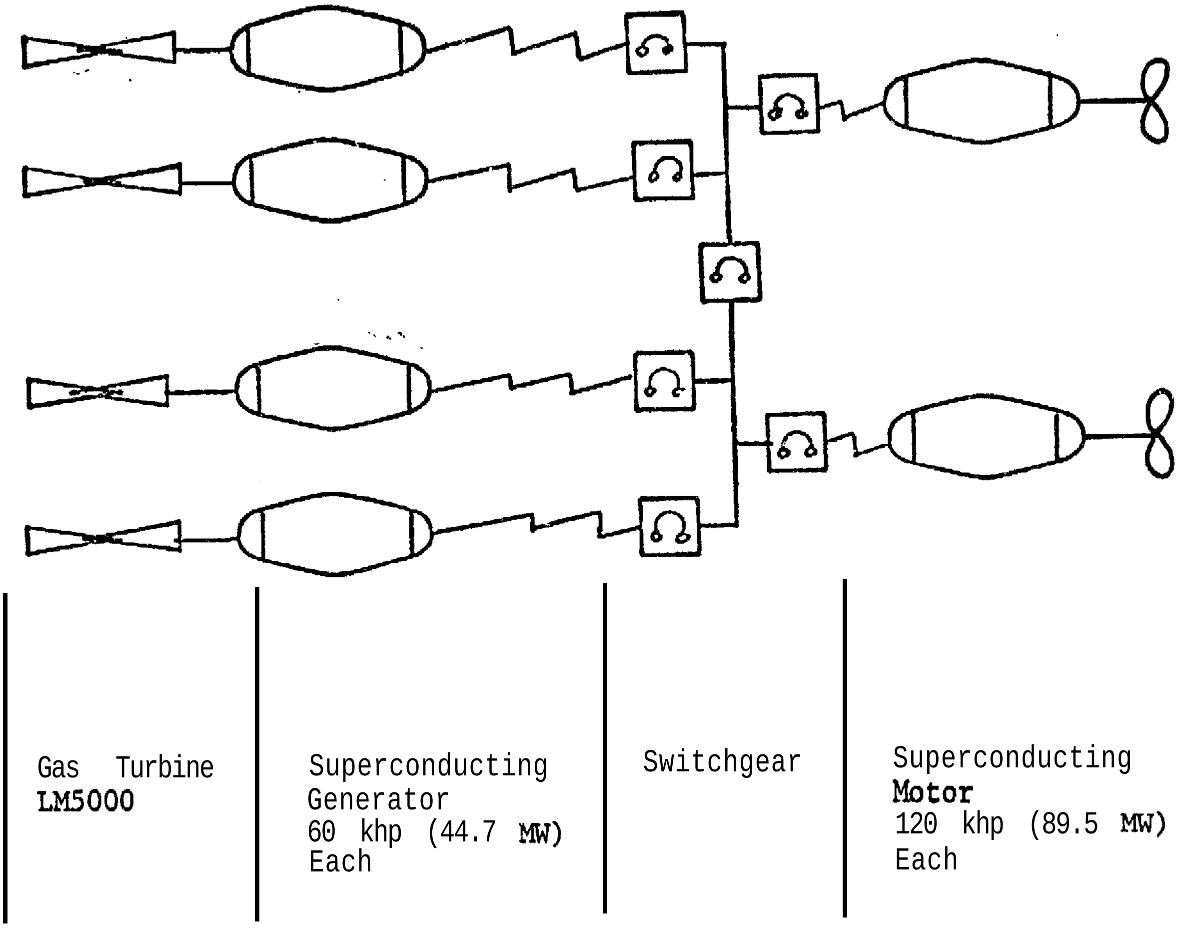


Figure D.2.3.3-1 (U): Simplified Representation of the Electric Propulsion Option (U)

(U) D.2.3.4 COMMAND, CONTROL AND COMMUNICATIONS (C3) -- No significant changes in command, control and communications equipment are expected for the propeller-driven alternate SES point design from those presented in Section 2.3.4.

(U) D.2.3.5 AUXILIARY SYSTEMS

(U) D.2.3.5.1 Auxiliary Systems less Lift System -- The propeller-driven craft compared to the **waterjet** engine-driven ship requires the following changes in the Auxiliary Subsystems:

(U) D.2.3.5.1.1 Hydraulic System -- The hydraulic subsystems for such **waterjet** features as nozzle vectoring, thrust reversing, ramp roof actuation and **waterjet** pump closure are deleted. Hydraulic subsystems for rudder and propeller pitch control are implemented with each having independent hydraulic power supplies.

(U) D.2.3.5.1.2 Compressed Air System -- The compressed air for **waterjet** pump priming is not required for the propeller propulsion system.

(U) **D.2.3.5.1.3** Seawater System -- Two seachests, one in both the port and starboard sidehulls, will be required for seawater pump suction with the elimination of the **waterjet** pump inlets.

(U) D.2.3.5.1.4 Lubrication System -- The propeller drive system with the **LM5000** engines uses three right angle gearboxes to transfer power from each inboard engine into a final reduction gear and through a thrust bearing to the propeller. The outboard engines each have two right angle gearboxes through which energy is transfered into a concentric shaft and then into the final reduction gear. Two gas turbines supply the motive force for one propeller.

(U) Water-cooled heat exchangers remove the heat generated by the right angle gearboxes. Each gearbox has its own cooler so that there are a total of twelve coolers, including the two required for the final reduction gear.

(U) The oil conditioning system for the gearboxes is completely independent. It consists of pressure and scavenge pumps located on the driven side of the gearboxes, together with a back-up pressure and scavenge pump

(U) driven by an electric motor. The back-up system also serves as a prelube supply for starting operations. Reservoirs, filter separators and filter deaerators are integral parts of the oil conditioning system. The water for the coolers is obtained from a fresh water cooling loop that exchanges heat with the surrounding seawater.

(U) D.2.3.5.2 Lift System -- No changes were made to the direct gear-driven lift system for the propeller-driven SES alternate point design. A study was performed to consider the use of superconductive motors to drive the lift machinery. Investigation revealed that a weight penalty of approximately six times the present reduction gear - shafting system would be incurred. (The superconductive system weight and horse-power relationships were projected by Garrett to the 1990 calendar year,) No great advantage of the electric system could be found to offset its weight penalty.

(U) D.2.3.6 OUTFITTING AND FURNISHINGS -- No significant changes in outfitting and furnishing requirements are expected for the propeller-driven alternate SES point design from those presented in Section 2.3.6.

(U) D.2.3.7 COMBAT SYSTEM -- No change in the combat system is expected for the propeller-driven alternate SES point design from those presented in Section 2.3.7. Potential changes to the propellers to mask or alter their noise characteristics and thereby enhance ship use in combat scenarios were not investigated.

(U) D.2.4 SURVIVABILITY AND VULNERABILITY

(U) The changes in survivability and vulnerability expected for the **propeller-driven** alternate SES point design from those presented in Sections 2.4, 2.4.1, and 2.4.2 relate to the exposed propellers. These appear more vulnerable than the **waterjet** system. No armor plating provisions have been made on the hull in the vicinity of the propellers and the propellers are unprotected.

(U) The only ship signature change relates to underwater acoustic noise.

(U) D.2.4.1.5 Acoustic Signature -- The underwater radiated noise signature of the propeller-driven far term SES is shown in Table D.2.4-1.

Table D.2.4-1(C). Estimated Underwater Radiated Noise Signature For Propeller Driven SES (U) (dB re 1 μPa @ 1 metre)

INTENSITY	SHIP SPEED			
	10 knots (5.14 m/s)	50 knots (25.72 m/s)	80 knots (41.19 m/s)	120 knots (61.79 m/s)
Intensity of Highest Line (0-100 Hz)	160	175	195	200
Intensity of Highest Line (100 Hz)	150	165	185	190
Intensity of 1/3 Octave band 2kHz	160	175	195	200

([redacted]) The acoustic signature at 1 kHz in a 1/3 octave band level in dB relative to 1 microPascal at 1 metre in the water is 196 dB (510 rpm, 92,773 kW).

([redacted])'The vehicle probably has a'distinctive line spectra at about 60 Hz because of the blade passage frequency of the propellers.

(U) D.3.0 Logistic Considerations

No significant changes in logistic considerations are expected for the propeller-driven alternate SES point design from those presented in Section 3.0.

(U)D.4.0 TECHNICAL RISK SUMMARY

(U)D.4.1 MAIN PROPULSION -- The G.E. LM5000 gas turbine engine is derived from the CF6-50 commercial gas turbine and uses technology from the LM2500 marine gas turbine currently in service with the U.S. Navy. The LM2500 itself was successfully derived from the TF-39 military gas turbine and the CF6 commercial gas turbine.

(U)D.4.2 MECHANICAL TRANSMISSION SYSTEM -- The mechanical propeller transmission system consists of five (5) right angled gear boxes per side. Each gearbox has 2 meshes to reduce the power to 30,000 hp (22,371 kW) per mesh. A gearbox transmitting 25,000 hp (18,642 kW) has been made and tested. It is projected that the gear technology will be extended in the 1990 time frame to include the development of 30,000 hp (22,371 kW) per mesh. Development is needed in the area of bearings, gear accuracy, and vibration analysis

(U)D.4.3 ELECTRICAL TRANSMISSION SYSTEM -- The electrical propulsion drive option for the far term SES stipulates the use of superconducting generators and motors. This requires cryogenic auxiliaries, liquid-metal brushes, cover gas systems, and very high transmission current densities. These are all relatively new and will require further development to apply to such very high power 60,000 hp (44.742 MW) generators and 120,000 hp (89.484 MW) motors.

(U)Switchgear capable of handling currents in the 100,000 ampere range are not available today and will require extensive development to produce a simple switch capable of meeting the requirements. Numerous Navy programs are presently working on these problem areas and viable solutions are expected with the time frame established for the far term SES.

(U) D.4.4 PROPELLER -- Partially submerged, supercavitating propellers of 14 foot (4.27 m) diameter were selected (one per sidehull). Performance predictions were based on design charts from "Experimental Results of Partially-Submerged Propeller 4281"' by R. **Hecker** and **A. Hendrican,** NSRDC Report 249-R-09, August 7, 1969, **One propeller** per **sidehull** is the simplest installation for the currently configured Far Term SES. Development is needed in the areas of blade root stresses and controllable pitch mechanisms. Development of emergency heading control devices for use in an inoperative propeller mode is also required; available SES 100B test data and analysis results would be used as applicable.

(U)D.4.5 PERFORMANCE -- The higher lightship weight of the propeller-driven far term SES (and the still higher weight of the electrical drive option) are combined with high propulsive efficiencies to result in projected performance improvements over the **waterjet-**propelled version. The higher top speed and greater range projections, however, are based on relatively large extrapolations from today's technology. The validity of these performance projections depends on adequately-funded development of propeller technology and large, cyrogenically cooled electrical motors.

(U) D.5 DESIGN PROCESS

(U) The various far term ANVCE Point Designs are arrived at from use of different technology bases, standards, criteria and assumptions. For consistency, the far term SES propeller-driven point design concept outlined in Appendix D adheres to information provided in the ANVCE documents cited in Appendix A.

(U) WP-005A was used as the primary basis for the data developed in this Appendix. As a further aid to making proper evaluation of the far term propeller-driven SES point design presented in the Appendix, Section D.5 provides a basis for the insight needed into the design approach, criteria, philosophy and trade studies used in arriving at the design. This section collects in summary form those pieces of information needed to identify the source of data and the design process used.

(U) D.5.1 APPROACH

For a basic vehicle configuration and the major subsystems, several methods of establishing characteristics exist. They may be classified into three groups:

- Scaling -- projection of characteristics based on ratioing or scaling up or down from a chosen vehicle or test-derived datum
- Modification -- development of characteristics based on small changes to an existing vehicle
- Synthesis -- development of characteristics based on design data, parametric analysis and theoretical investigations

(U) The approach primarily used for the Rohr version of the propeller-driven ANVCE Far Term SES Point Design is a modification to the Rohr ANVCE Far Term SES design. This design is, in turn, based upon scaling of appropriate model and testcraft data, as well as upon synthesis as just defined. The specific approaches in each disciplinary area are next identified and presented in concise form.

(U) A partially submerged supercavitating propeller was studied. The results indicated that a 14 foot (4.27 m), 8-bladed propeller was optimum for a two propeller installation -- one per sidehull. This size is also the largest allowed by physical constraints; the term "optimum" denotes minimum power required, taking into account the size constraints. The thrust envelope is given for the 14 foot (4.27 m) propeller with 60,000 to 120,000 shp (44.742 to 89.484 MW)/shaft.

(U) Performance predictions are based on available design charts* and study of up to 4, 6 and 8 propellers per ship. Power required is found to decrease with increased number of propellers -- especially at low speed. Further study is needed for judging installation arrangements with more than two propellers.

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* Design Charts Based on "Experimental Results of a Partially-Submerged Propeller 4281", by R. Hecker and A. Hendrican. NSRDC Report 249-H-09, 7 August 1969.

(U) Variable pitch propellers were selected for both the mechanical point design and electrical option drives. However, fixed-pitch propellers may be feasible for the electric drive; direction of rotation can be reversed with such a drive to provide ship backing. With a gas turbine-mechanical drive, a controllable pitch propeller is necessary.

(U)D.5.2 DESIGN CRITERIA

Those pertinent design criteria, standards and assumptions used in the Point Design are provided in the following areas: hull structure, propulsion, electrical plant, command and surveillance, auxiliary systems, lift system, outfit and furnishings, armament, load conditions, weight margins, and vehicle. Tabular forms and references are used as appropriate in the sections that follow for each of these areas.

(U) D.5.2.1 HULL STRUCTURE -- The Load Conditions are the result for a ship operating over a 20-year life anywhere within its operational envelope, There were no changes in anticipated loads from that shown in Sections 2.3.1 and A.2.1.

(U) D.5.2.2 PROPULSION -- Propeller calculations are based on the conditions listed in Table D.5.2-1.

Table D.5.2-1(C). Propeller Design Conditions (U)

Significant Wave Height		Speed		Drag		Thrust		Submergence
ft.	m	Knots	m/s	1000 lbs	MN	1000 lbs	MN	Percent(3)
0	0	35(1)	18.01	520	2,313	585(2)	2,602	100
0	0	70	36.01	367	1,632	367	1,632	50

(1) Hump drag speed
(2) Thrust is (1.25) x (Drag)
(3) Based on disc area

(U)Zero thrust deduction and wake fraction values are assumed.

(U)D.5.2.3 . ELECTRIC -- No changes except as shown in D.5.1.

(U)D.5.2.4 COMMAND AND CONTROL -- No changes.

(U)D.5.2.5 AUXILIARY SYSTEMS LESS LIFT -- The changes in the Auxiliary (Less Lift) Systems are shown in Section D.2.3.5.1 for the propeller-driven far term SES together with those changes to the propeller-related criteria. No significant changes were otherwise found in the design criteria for the propeller-driven alternate design from those presented in Section A.2.5.

(U)D.5.2.6 LIFT SYSTEM -- There are no significant changes in the lift system criteria for the propeller-driven alternate SES point design from those presented for the waterjet propulsion design.

(U)D.5.2.7 OUTFIT AND FURNISHINGS -- No changes from waterjet-propelled version.

(U)D.5.2.8 ARMAMENT -- No changes from waterjet-propelled version.

(U)D.5.2.9 LOADS -- No changes from waterjet-propelled version.

(U)D.5.2.10 WEIGHT MARGINS -- There are no significant changes in the weight margin design criteria for the propeller-driven alternate SES point design from that for the waberjet propulsion design.

(U)D.5.2.11 VEHICLE

(U)D.5.2.11.1 Payload Weight Breakdown -- The vehicle weight summaries shown in Tables D.5.2-2 and D.5.2-3 detail the far term ship as defined in ANVCE WP-002, "Definition of Terms", dated 2 April 1976, section III. Margins are included in the vehicle empty weights, These weight breakdowns support range and payload performance projections in Section D.2.2.3.

(U)D.5.2.12 MANNING -- No changes from waterjet-propelled version.

(U) D.5.2.13 PERFORMANCE

The 3600 LT (35.87 MN or 3657 non-SI metric ton) far term propeller-driven SES includes all of the fuel (for both ship and helicopters), sensors, weapons and armor specified. The basis upon which the performance was developed is compared with the far term TLR(1) as follows:

Design Parameter	Far Term TLR	ANVCE Far Term SES
Full Load Displacement (LT; MN; *) Mean Operating Displacement(2) (LT; MN; *)	None Specified None Specified	3600; 35.87; 3657 3026; 30.15; 3074
Wind Speeds	Pierson Moskowitz Sea Spectra (no altitude gradient for winds)	
Tail Pipe (Trapped Fuel) Allowance (LT; MN; *)	64.6; 0.644; 65.6	64.6; 0.644; 65.6
Marine Fouling Allowances	1 Mil Surface Finish	
Ambient Temperatures - Air Water	80°F (26.67°C) 59°F (15°C)	

* non-SI metric tons.

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(1) "Top Level Requirements for a 3000 Ton-Surface Effects Ship in the 1990 Time Frame (Far Term)", Office of Advanced Naval Vehicles Concept Evaluation (ANVCE WP-006), Rohr Industries Proposed Modification, dated 25 October 1976, CONFIDENTIAL.

(2) Mean Operating Displacement at 50% fuel load (LM5000 propulsion).

(U)The far term performance projections are based on wind speeds appropriate to the Pierson-Moskowitz sea spectra. The winds used for the far term SES calculations have no altitude gradient and deviate in magnitude from the winds called for in ANVCE WP-010 as follows:

Significant Wave Height		Pierson-Moskowitz Winds		ANVCE WP-010 Winds	
ft	(m)	knots	(m/s)	knots	(m/s)
4.6	(1.4)	16	(8.2)	10	(5.1)
10.0	(3.05)	22	(11.3)	26	(13.4)
15.0	(4.57)	26	(13.4)	38	(19.5)

(U)The effects on drag, speed, and range with use of the ANVCE winds instead of the winds associated with the Pierson-Moskowitz spectra for fully arisen seas is less than 2 percent. In seas with $H_{1/3}$ = 4.6 ft (1.4 m), the far term SES predicted performance is slightly better with the ANVCE winds. For a 15 ft (4.57 m) significant wave height, the SES performance is slightly worse with the ANVCE winds.

(U)Detailed comparisons between performance of the propeller-driven far term SES design and the TLR regarding speed, hump margin, acceleration and deceleration, turning, range, and operational Sea State performance are outlined in the following sections.

[redacted] D.5.2.13.1 Speed -- At maximum continuous power, the maximum far term SES speed requirement of 100 knots (51.4 m/s) can be met (or exceeded) by the propeller-driven version at full load displacement in head seas of a 5.5 ft (1.67 m) significant wave height or less, while the 70 knot (36 m/s) cruise speed requirement can be attained in head seas as high as 14.4 ft (4.39 m) significant wave height.

[redacted] D.5.2.13.2 Hump Thrust Margin -- As compared with the requirement for a 25 percent hump thrust margin over calm water drag, the propeller-driven far term SES has a 32 percent calm water hump margin at full load displacement, a 25 percent margin in a head sea of 5.4 ft (1.64 m) significant wave height, and no margin in a head sea of 16.7 ft (5.1 m) significant wave height.

(U) D.5.2.13.3 Turning

D.5.2.13.3.1 Low Speed Maneuvering -- On- or off-cushion, ahead or astern, the propeller-driven SES has the ability to control heading for docking, undocking or low-speed maneuvering in a seaway.

(U) D.5.2.13.3.2 Tactical Diameter -- The requirements are a maximum tactical diameter of 1500 yards (1371 m) at speeds below 30 knots (15.4 m/s) and 5000 yards (4572 m) when entering a turn at maximum speed. The propeller-driven SES turning capability is projected to be better than the waterjet-propelled version. The far term propeller-driven SES betters the specified turning requirement by at least 100 percent and 84 percent, respectively.

[redacted] D.5.2.13.4 Acceleration and Deceleration -- At the half-fuel (MOD-50) condition with all engines set at the maximum continuous power rating, the propeller-driven far term SES is capable of accelerating in calm water from a standing start to a speed of 70 knots (36 m/s) in 82 sec. This is 120 percent better than the specified 0 to 70 knots in 180 seconds at full power, which can be achieved in head seas as

(C) high as a 12.5 ft (3.81 m) significant wave height. Then, by engaging the propeller reverse-pitch controls, applying maximum intermittent power to the propulsion engines and retracting the stern seal, the ship can be decelerated from 70 knots (36.01 m/s) to a full stop in 580 yards (530 m). This is 58 percent of the specified 1000 yards (914 m) stopping distance.

(C) D.5.2.13.5 Range -- The propeller-driven far term SES betters the specified range of 3500 nautical miles (6482 km) in head seas of 3.94 ft (1.2 m) significant wave height by 113 nm (209 km).

(C) D.5.2.13.6 Maximum Operational Sea State -- The speed-sea state operational envelope for the propeller-driven far term SES is shown together with the envelope for the waterjet-propelled version in Figure D.5.2.13-1 for on-cushion ahead as well as on and off-cushion operation. These limits are set by ship performance; the structure and ride quality do not limit performance.

TABLE D.5.2-2

VEHICLE WEIGHT SUMMARY

TWO PROPELLERS AND MECHANICAL TRANSMISSION

SYMBOL	TITLE	LONG TONS*	SHORT TONS*	METRIC TONS*	KILO NEWTONS
WE	Empty weight less fixed payload items	1969	2205	2000	19,619
W_C	Ship's complement and effects and stores	30	34	31	299
W_P	Payload	327	366	332	3,258
W_F	Liquids	1274	1427	1295	12,694
W	Vehicle weight	3600	4032	3658	35,870

* non-SI

TABLE D.5.2-3

VEHICLE WEIGHT SUMMARY

TWO PROPELLERS AND ELECTRIC TRANSMISSION

SYMBOL	TITLE	LONG TONS *	SHORT TONS *	METRIC TONS*	KILO NEWTONS
W_E	Empty weight less fixed payload items	2058	2305	2090	20,507
W_C	Ship's complement and effects and stores	30	34	30	299
W_P	Payload	327	366	332	3,258
W_F	Liquids	1185	1327	1205	11,806
W	Vehicle weight	3600	4032	3658	35,870

* non-SI

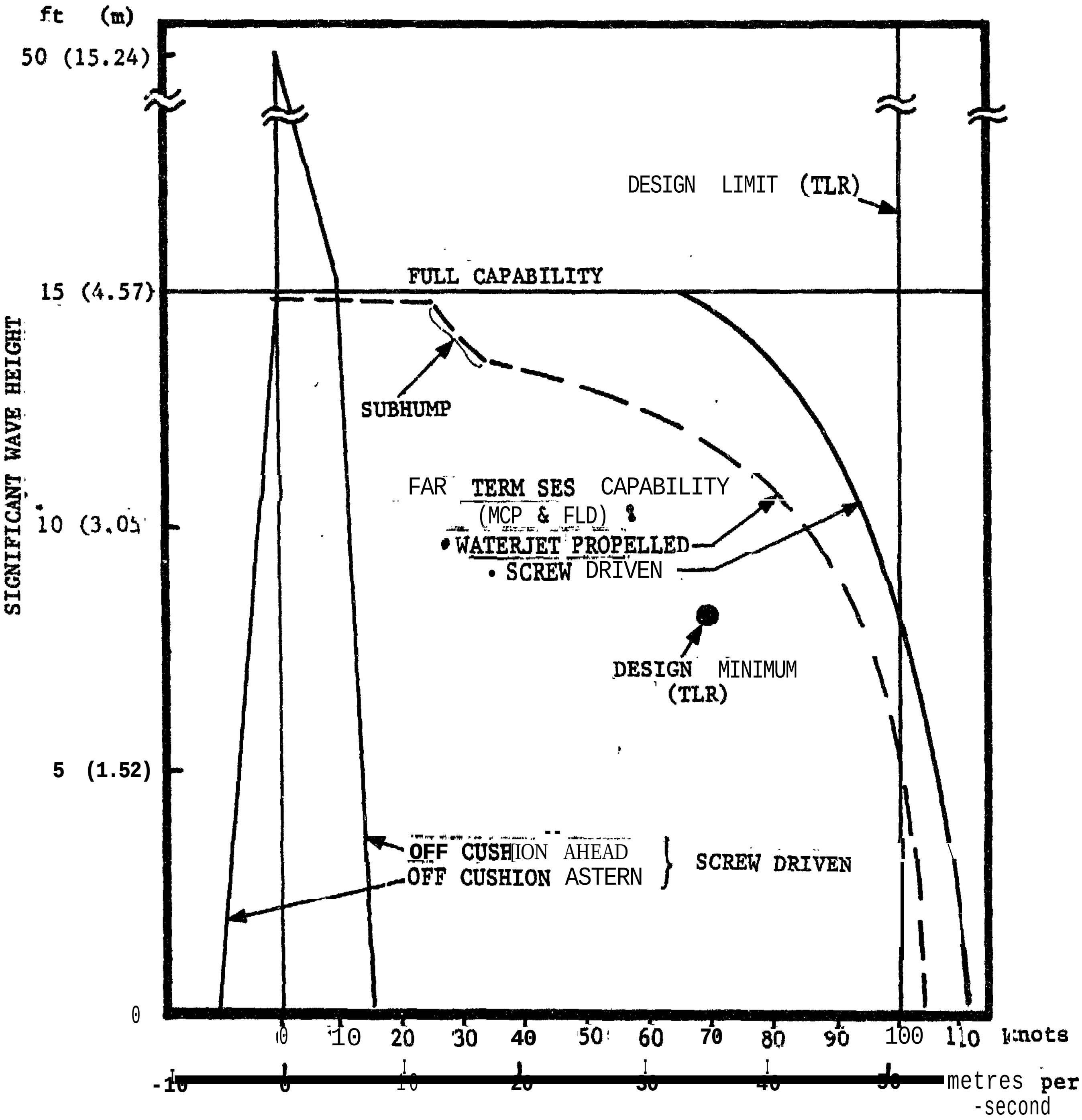

Figure D.5.2.13-1(~~C~~): Propeller-Driven Far Term SES Operational Envelope - TLR Requirements/Capabilities (U)

(U) D.5.3 DESIGN PHILOSOPHY

(U) The overriding philosophy of the far term pofnt design SES is design for a combat capability to fulfill a roll as an operational fleet unit. Every design decision has supported this philosophy. The result is a balanced design in which no single feature is dominant. All subsystems and their components were accorded careful development and engineered to meet the specified Top Level Requirements (TLR). There was no change from this philosophy in the development of the alternate propeller-driven far term SES concept.

(U) D.5.4 TRADE-OFF STUDIES

(U) **D.5.4.1 CONFIGURATION TRADE-OFFS** -- The configuration trade-off studies for the propeller-driven alternate far term SES point design are the same as those shown in Appendix A for the waterjet-propelled SES except for the propulsion-related subsystem trades shown next.

(U)D.5.4.2 KEY SUBSYSTEMS TRADE-OFFS

(U) D.5.4.2.1 Propulsion System Performance Tradeoffs

(U) D.5.4.2.1.1 Performance (Diameter and Required Shaft Horsepower) -- Results are given before describing the analysis method. Propeller selection for design conditions in Table D.5.2-1 consider performance versus blade diameter with 2, 4, 6 and 8 propellers per ship. The results at the 70 knots (36.01 m/s> conditions are:

- Engine shp and rpm versus propeller diameter, Figures D.5.4-1 and D.5.4-2.
- Corresponding propeller efficiencies, Figure D.5.4-3.

(U) Engine power (shp) is the power delivered to the propeller divided by a transmission efficiency of 0.957. The efficiency is assumed to be the same for either the mechanical or superconducting electrical drives.

The results at 35 knots (18.01 m/s) are:

- Engine shp versus propeller diameter for different propeller pitch-to-diameter ratios, Figure D.5.4-4.
- Corresponding propeller efficiencies, Figure D.5.4-4.

(U) Marked on all of these figures are the design condition points at either of the two speeds considered. (Table D.5.2-1.)

Symbols in Figures D.5.4-1 through D.5.4-4 are defined as follows:

K_T	Thrust coefficient, $\text{thrust}/\rho n^2 d^4$
J	Advance ratio, U/nd
η	Propeller efficiency, (thrust)x(ship speed)/(550xshp) in English units
U	Ship speed, knots (m/s)
n	Propeller rotational speed, rps
d	Propeller diameter, ft (m)
ρ	Water weight density, lb/ft^3 (N/m^3)
shp	Engine power, hp (W)
η_T	Power transmission efficiency

(U)Figures D.5.4-1 through D.5.4-4 for the 70 and 35 knots (36.01 and 18.01 m/s) conditions, respectively, were prepared from design chart data for propeller 4281. The off-design chart data were available only for 50 percent propeller submergence at 70 knots (36.01 m/s). For 100 percent submergence at 35 knots (18.01 m/s), the estimate is made by doubling the 50 percent values of K_T/J^2. Figure D.5.4-4 contains this correction. Available test data indicates that the thrust coefficient K_T may vary directly as submergence. Also, propeller efficiency tends to remain the same, since torque increases similarly. See data in "Marine Propulsion", A.S.M.E., O.E.D., Vol. 2, December 1976 (page 92). The method for using the chart data is next described. From Figures D.5.4-1 and D.5.4-4, the power required to propel the ship is obtained for the design conditions in Table D.5.2-1. These powers are summarized in Table D.5.4-1.

(U)Descriptions of Figures D.5.4-1 through D.5.4-3 follow. Values for the selected 14 foot (4.27 m) propeller are noted in each figure.

(U)**Figures** D.5.4-1, D.5.4-2 and D.5.4-3; 70 knot (36.01 m/s) case:

Power required per ship is shown in Figure D.5.4-1. Increasing propeller diameter and number of propellers are seen to reduce the power needed. The selected 14 foot (4.27 m) propeller is marked. Figures D.5.4-1, D.5.4-2 and D.5.4-3, prepared from Figure 4 of the design chart data for model 4281, show the line of "maximum efficiency for a constant C_T".

(U)Propeller efficiency data corresponding to each point in Figure D.5.4-1 are given in Figure D.5.4-3. Efficiency increases significantly with increasing number of propellers for a given diameter.

(U)Propeller pitch-to-diameter ratios (p/d)'s are also given in Figure D.5.4-3. The general trend for these ratios indicate that a p/d near 1.7 is a median value for any diameter.

(U)Figure D.5.4-4; 35 knot (18.01 m/s) case:

Power required per ship is shown'in Figure D.5.4-4. For a given p/d ratio, increasing propeller diameter and propeller number reduces the power needed, Figure D.5.4-4 was prepared directly from the propeller characteristic curves for model 4281 (Figures 25 through 27 of NSRDC Report 249-H-09). The maximum efficiency data for model 4281 (Figure 4 of the NSRDC Report) cannot be used at 35 knots (18.01 m/s) because the thrust coefficient range is much less than needed at that speed.

(U)D.5.4.2.1.2 Thrust Envelope for Selected Propeller -- The propeller thrust envelope is given and the calculation procedure described,

(U)Figure D.5.4-5 shows the optimum thrust envelope and pitch change schedule on the basis of two, 14 foot (4.27 m) diameter propellers. Lines of thrust versus velocity are shown with each line corresponding to a different engine power. The computational procedure is described later in this section. Table D.5.4-2 summarizes the selected propeller powering.

(U)Figure D.5.4-5 was prepared with model 4281 propeller data, 50 and 100 percent submergence at 100 and 35 knots (51.44 and 18.01 m/s) respectively, and submergence versus speed is shown in Figure D.5.4-6. Off-design model 4281 propeller data are available only for 50 percent submergence; thrust is corrected for each submergence, s, with the multiplication factor (s/.5). The transmission efficiency, η_T, is 0.957 at all speeds, and the propeller efficiency, η, is assumed unchanged with submergence.

(U)Thrust Envelope Calculation -- The procedure is calculation of Thrust, T, for a given engine power for specific propeller rps, n, and thrust coefficient, K_T. T is given by:

$$T = 2(\rho n^2 d^4 K_T)(s/.50) \qquad (D.5-1)$$

for two propellers. Submergence is given in Figure D.5.4-6.

(U)Thrust coefficient, K_T, follows from power input considerations described next. Engine shp is related to propeller character-ietic data (K_T and K_Q versus J), by the relation;

$$\text{shp} = 2\left[(2\pi\rho n^3 d^5 K_Q / (550\eta_T)\right] \bullet (s/.50) \qquad \text{(D.5-2)}$$

per shaft (2 engines). Equation **D.5-2** is used in the rearranged form:

$$\text{shp} = 2\left[\frac{2\pi\rho U^3 d^2}{550\eta_T} \times \frac{K_Q}{J^3}\right] \bullet (s/.50) \qquad \text{(D.5-3)}$$

(U)Equations **D.5-1** through **D.5-3** contain the ratio **s/.50** so that propeller efficiency, $\eta =$ **TU/P**, remains constant with submergence. Values of K_Q/J^3 versus advance ratio J for each blade pitch setting, p/d, can be prepared from model 4281 data for 50 percent submergence. From Equation **D.5-2**, the required value of K_Q/J^3 to absorb the power is:

$$K_Q/J^3 = (11\ \text{shp}/U^3 d^2 s) \qquad \text{(D.5-4)}$$

(U)For each ship speed, U, a K_Q/J^3 is calculated and the corresponding advance ratio, J, obtained from Table 5.4-3. The comparison of K_Q/J^3 values yields a different J for each pitch diameter ratio p/d in Table **D.5.4-3.** Propeller rps follows from:

$$n = U/(Jd),\ \text{rps} \qquad \text{(D.5-5)}$$

(U)Thrust coefficient, K_T, is read directly from model 4281 propeller data of K_T versus advance ratio; T follows from Equation **D.5-1.**

(U)Thrust computation between 0 and 35 knots (18.01 m/s) differs from the foregoing procedure due to a sparseness of propeller chart data for that speed region. The thrust curve in Figure **D.5.4-1** is extrapolated between computed thrusts at 0 and 35 knots (18.01 m/s). Zero speed thrust values, for the designated 100 percent submergence, are obtained as follows:

(U)At zero speed, the ratio of thrust-to-horsepower is:

$$\frac{T}{shp} = \frac{550}{2\pi n d} \times \frac{K_T}{K_Q} \times \eta_T \text{ ; per propeller} \qquad \text{(D.5-6)}$$

(U)The shp in equation **D.5-6** is a specified engine power per propeller shaft; power delivered to the propeller is η_T x shp.

(U)At zero speed ($J = 0$), the analysis uses $K_T = 0.02$ and $K_Q = 0.005$, based on 50 percent propeller submergence; these values occur at the last available data point, $J = 0.3$, for model 4281 with $p/d = 1.4$. The ratio K_T/K_Q is assumed the same, essentially, between $J = 0$ and $J = 0.3$. The curves of K_T and K_Q show only small changes with J in this region; K_T/K_Q is assumed the same between 50 to 100 percent submergence. A small pitch ratio, p/d, is required at low speed where efficiency is higher and $p/d = 1.4$ is the smallest value for which model 4281 data are available.

(U)Propeller rps, n, values needed for use of equation **D.5-6** are obtained from:

$$n = \frac{4690}{60}\left(\frac{shp}{60{,}000}\right)^{1/3} / \; 9.2 \qquad \text{(D.5-7)}$$

(U)Equation **D.5-7** follows from the cubic law **between** the power (per engine) and rpm; the nominal power condition being 60,000 shp (44.7 **MW)** at 4,690 engine rpm. There is a reduction gear ratio of 9.2 between engine and propeller. Equation **D.5-6,** for $d = 14$ ft (4.27 m), yields (for two propellers):

$$T = 200.5\ (shp/propeller)^{2/3} \qquad \text{(D.5-8)}$$

in English units.

(U)Table **D.5.4-4** lists **T/shp** (and **T/MW)** per propeller and total thrust on ship (2 propellers) for various engine powers, as obtained from equation **D.5-8.**

(U)D.5.4.2.1.3 Selection of Propeller Pitch and Thrust Versus Speed -- The procedure is illustrated with typical data. Figure D.5.4-3 shows thrust versus speed for propeller pitch-to-diameter ratios (p/d) of the model 4281 propeller data; engine power is 50,000 shp (37.29 MW) per engine or 200,000 shp (149.14 MW) total. Thrust at each speed generally increases with decreasing p/d. The maximum thrust enclosing the curves in Figure D.5.4-3 is selected for use in the thrust envelope of Figure D.5.4-1. Repetition of the foregoing method for different engine powers leads to the thrust envelope in Figure D.5.4-1.

(U)Selection of Propeller Pitch and Thrust Versus Speed -- The procedure is illustrated with typical data. Figure D.5.4-7 shows thrust versus speed for propeller pitch-to-diameter ratios (p/d) of the model 4281 propeller data; engine power is 50,000 shp (37.29 MW) per engine or 200,000 shp (149.14 MW) total. Thrust at each speed generally increases with decreasing p/d. The maximum thrust enclosing the curves in Figure D.5.4-7 is selected for use in the thrust envelope of Figure D.5.4-5. Repetition of the foregoing method for different engine powers leads to the thrust envelopes in Figure D.5.4-5.

(U)The extension of results for p/d = 1.4 for J > 0.6 uses the efficiency extrapolation given in the article "An Advanced Concept for Propeller-Driven Surface Effect Ships (SES)" by E. Butler, <u>Naval Engineers Journal,</u> October 1976; see Figure 17 therein.

(U)There is a p/d value schedule versus speed corresponding to each maximum thrust; such p/d values are noted in Figure D.5.4-1.

(U) D.5.4.2.1.4 Consideration of Calculation Uncertainties -- Computations are dependent on the available model 4281 propeller data for partially submerged conditions. Potential problems with data usage relate mainly to:

- Uncertainty of the ventilation and blade surface cavitation limits in the propeller data.
- The use of a proportionality constant to determine the effects of propeller submergence on performance.
- Extrapolation of propeller characteristic data (K_T, K_Q and η versus J) to high advance ratios.for p/d = 1.4.
- The need for Froude number corrections, if any, to those data for partial submergence. (Froude number in this case being based on propeller diameter.)

(U)The first three items were previously noted in the text. The technical projection is that continuing developments will yield propeller designs with the performance shown.

(U) D.5.4.2.2 Lift System -- Performance requirements of the lift system for the propeller-driven alternate SES point design are unchanged from the waterjet propulsion ship. Therefore no trade-offs were made for this propeller-driven ship study.

(U)D.5.4.2.3 Electrical System Trade Offs -- Two options exist for the propeller-driven ship, one using a mechanical drive and the other using an electrical generator and motor drive. There are no increased loads in the ship electrical system for the mechanical drive point design and, therefore, no changes are required from that electrical system described in paragraph 2.3.3. With the electrical propulsion option, using superconducting generators and motors, changes were required in the ship electrical system to accommodate the additional auxiliary equipment. Cryogenic systems, refrigeration systems, coolant systems and cover gas systems all consume additional electrical power with this option.

(U)A trade-off study showed that about 600 KW of additional load would be drawn by the supporting auxiliaires for the optional electrical drive. Power for these auxiliaires would be provided by the whips electrical system. This would require an additional GTG to maintain the required 30 percent margins.

(U) D.5.4.2.4 Auxiliaries -- There were no significant trade-off studies of auxiliaries for the propeller-driven alternate SES point design from those presented in Appendix A.4.2.4 for the waterjet propulsion design.

(U) D.5.4.2.5 Outfit and Furnishings -- There were no changes in Outfit and Furnishings from that presented in Appendix A and Section 2.3.6.

Table D.5.4-1[redacted]. Total Engine Power Required with Two **14-Foot** Propellers **(U)**

Significant Wave Height		**Speed**		**Total Engine Power (2)**		**rpm**	**Propeller Pitch-to-Diameter Ratio**
ft	**m**	**knots**	**m/s**	**shp**	**MW**		
0	0	35	18.01	(3) 193,000	143.9	426	1.4
3.9	1.2	70	36.01	130,000	96.9	415	1.65

(2) $\eta_T = 0.957$

(3) Includes 25 percent excess at hump speed

Table D.5.4-2[redacted]. Powering Conditions for Thrust Envelope with 4 Engines and 2 Propellers **(U)**

POWER/ENGINE		**POWER/PROPELLER**	
shp	Mw	shp	**MW**
30,000	22.37	60,000	**44.74** 44.74
40,000	29.83	80,000	59.66.
50,000	37.29	100,000	74.57
60,000	44.74	120,000	89.48

Table D.5.4-3(U). Rearranged Propeller Characteristic Data (Model 4281) for Calculating Advance Ratio at Each Power Input (U)

p/d→	1.4		1.8		2.2		2.6	
J	K_Q	K_Q/J^3	K_Q	K_Q/J^3	K_Q	K_Q/J^3	K_Q	K_Q/J^3
.4	.0064	.100						
.5	.0083	.0664	.0099	.0792				
.6	.0106	.0491	.0133	.0616	.0153	.0708	.0167	.0773
.8			.0192	.0375	.0247	.0482	.0275	.0537
1.0			.0220	.0200	.0308	.0308	.0365	.0365
1.2			.0208	.0120	.0325	.0188	.0418	.0242
1.4			.0188	.0068	.0311	.0113	.0432	.0157
1.6							.0412	.0101
1.8								
2.0								

Table D.5.4-4(C). Thrust Estimate at Zero Speed for 100% Submergence (U)

shp/propeller		T/shp, per propeller		Thrust, 2 propellers	
shp	MW	lbs/shp	kN/MW	lbs	kN
20,000	14.9	3.69	22.0	147,741	657
40,000	29.8	2.93	17.5	234,524	1043
60,000	44.7	2.56	15.3	307,313	1367
80,000	60.0	2.33	13.9	372,284	1656
100,000	74.6	2.16	12.9	431,997	1922
120,000	89.5	2.03	12.1	487,830	2170

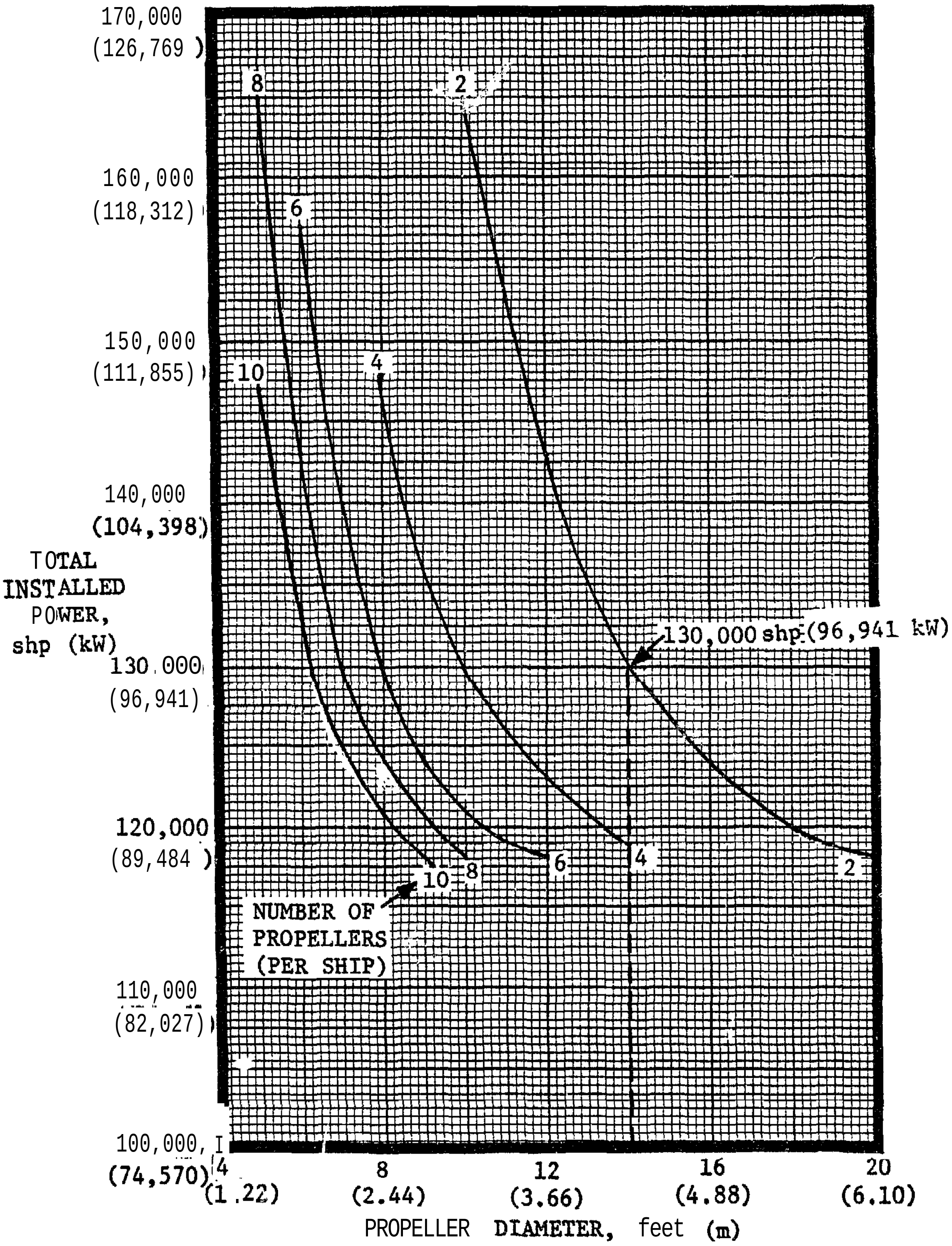

Figure D.5.4-1 (U). Total Power Required at 70 Knots (36.01 m/S) with a 50 Percent Submerged Propeller (U)

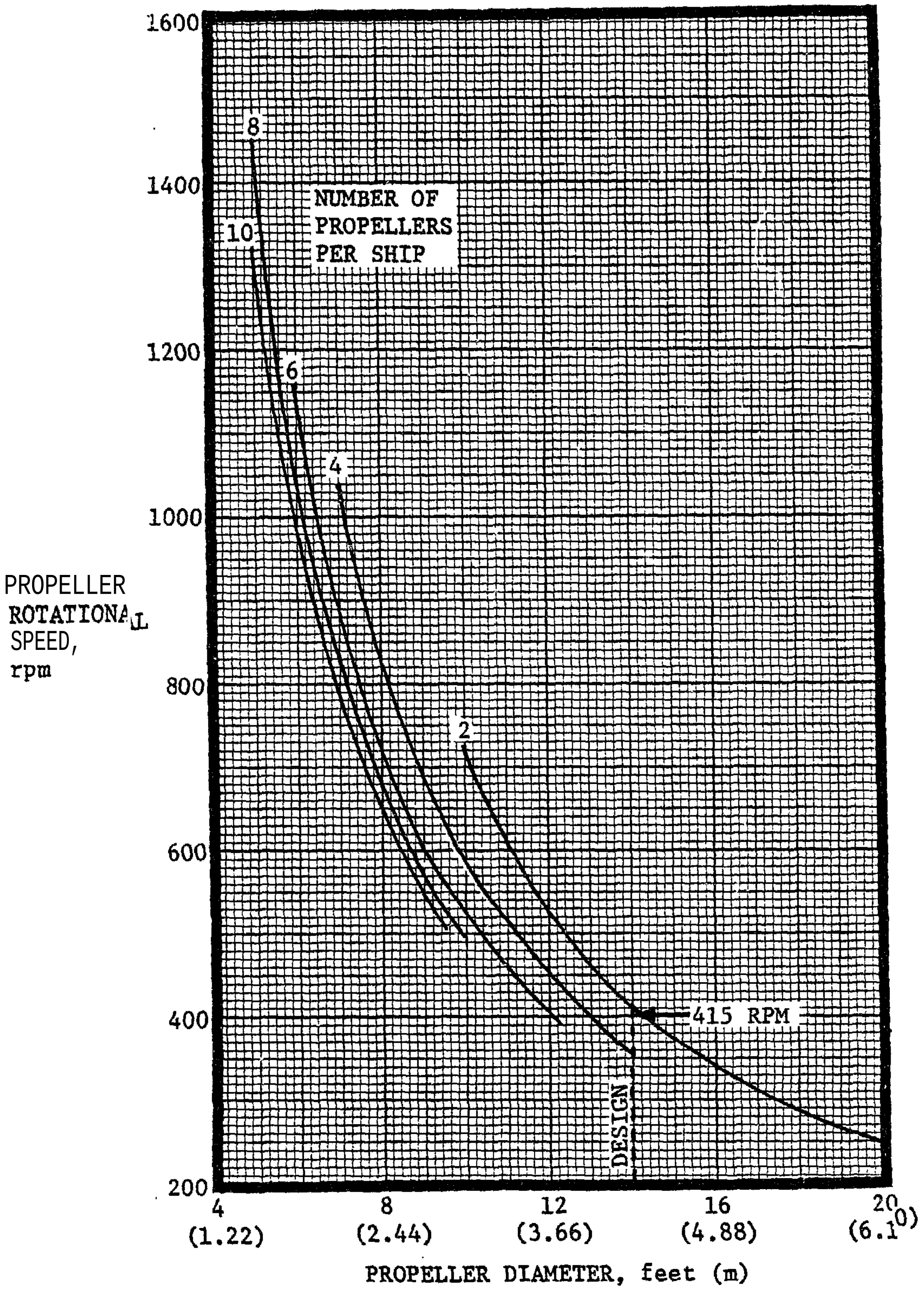

Figure D.5.4-2 (U). Propeller RPM Required at 70 Knots (36.01 m/s) with a 50 Percent Submerged Propeller (U)

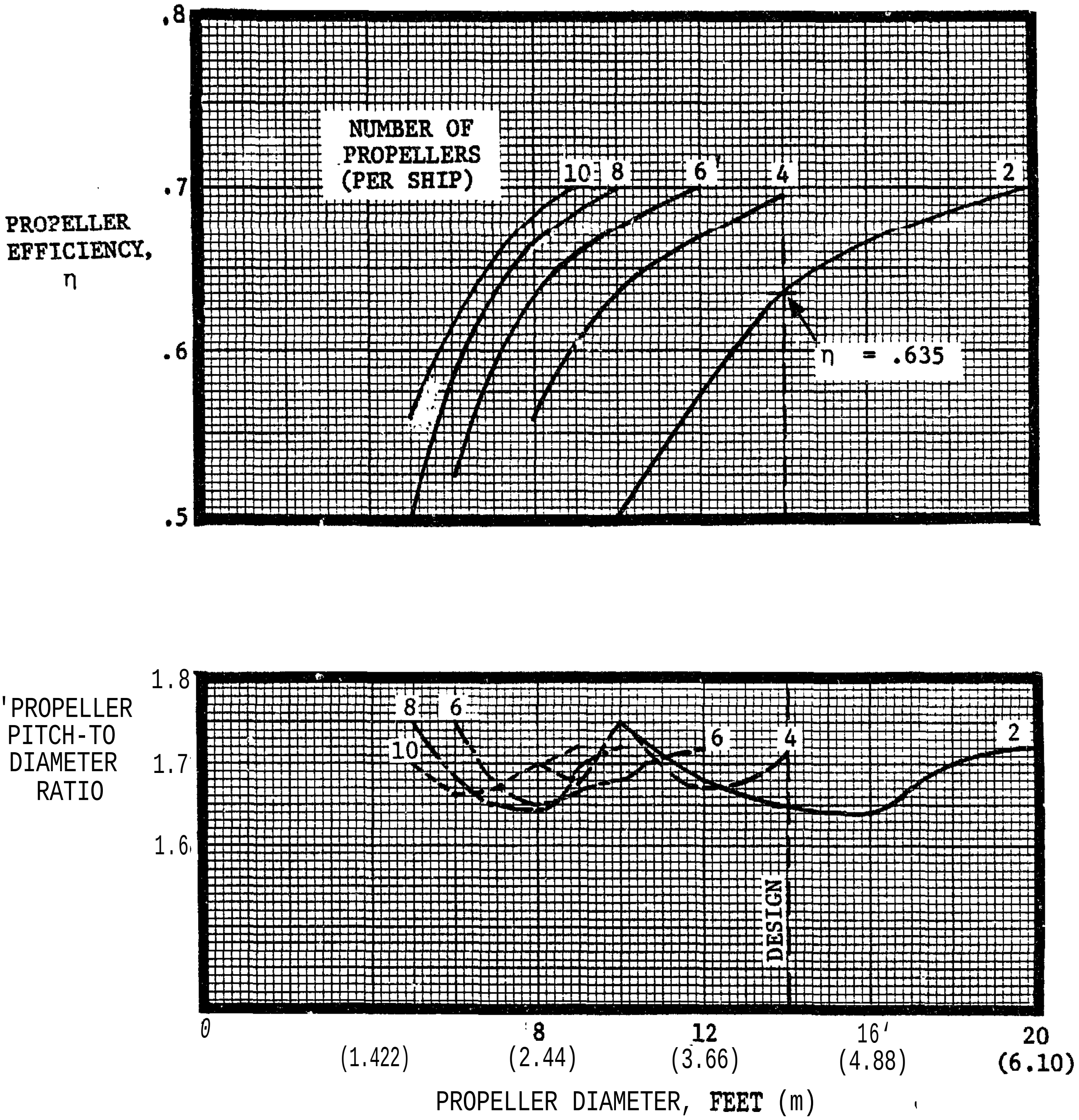

Figure D.5.4-3(U). Propeller Efficiency and Pitch at 70 Knots (36.01 m/s) *with* a 50 Percent Submerged Propeller (U)

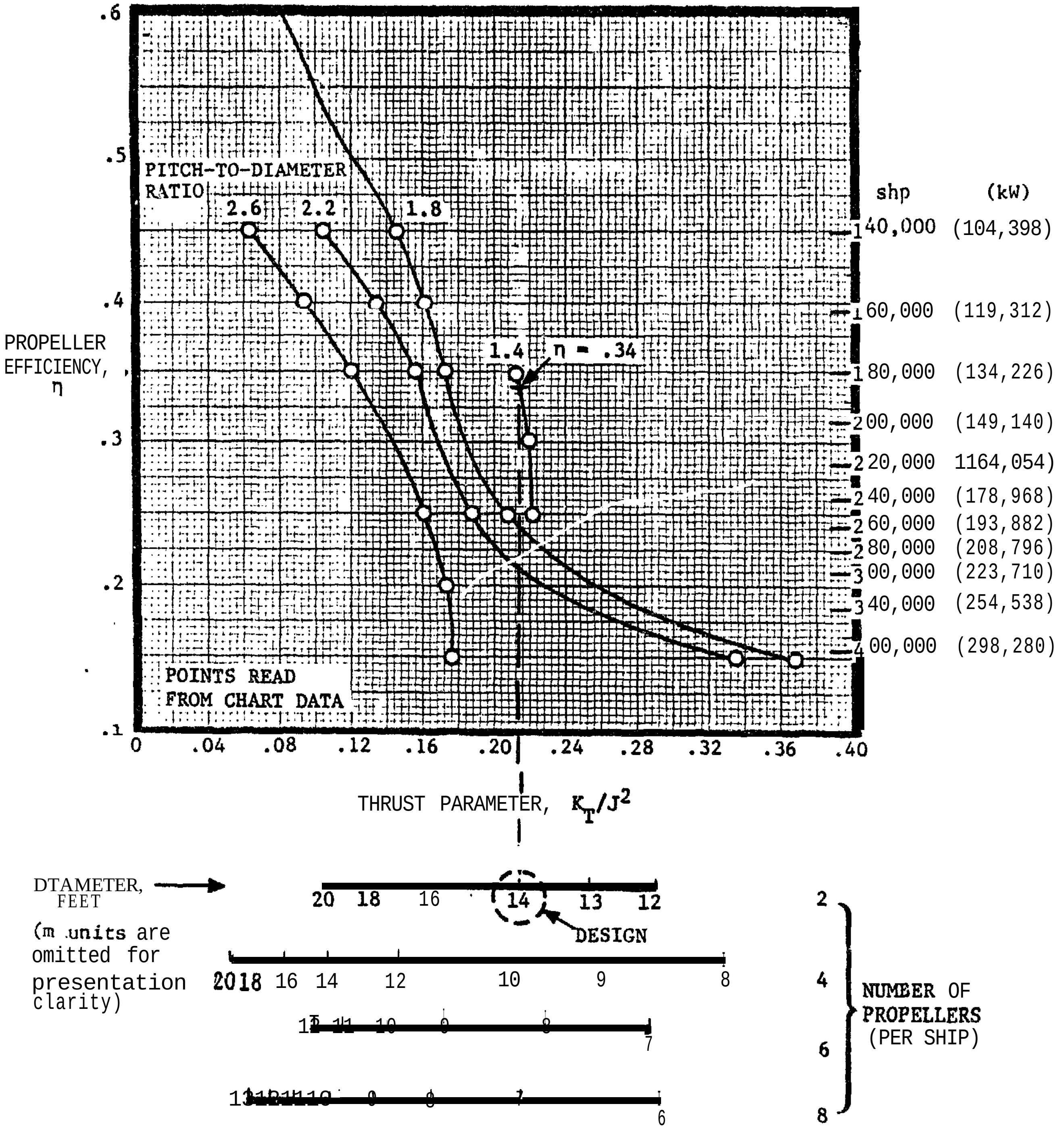

Figure D.5.4-4 (U). Total Power Required and Efficiency at 35 Knots (18.01 m/s) with a 100 Percent Propeller Submergence at Sea State 0 (U)

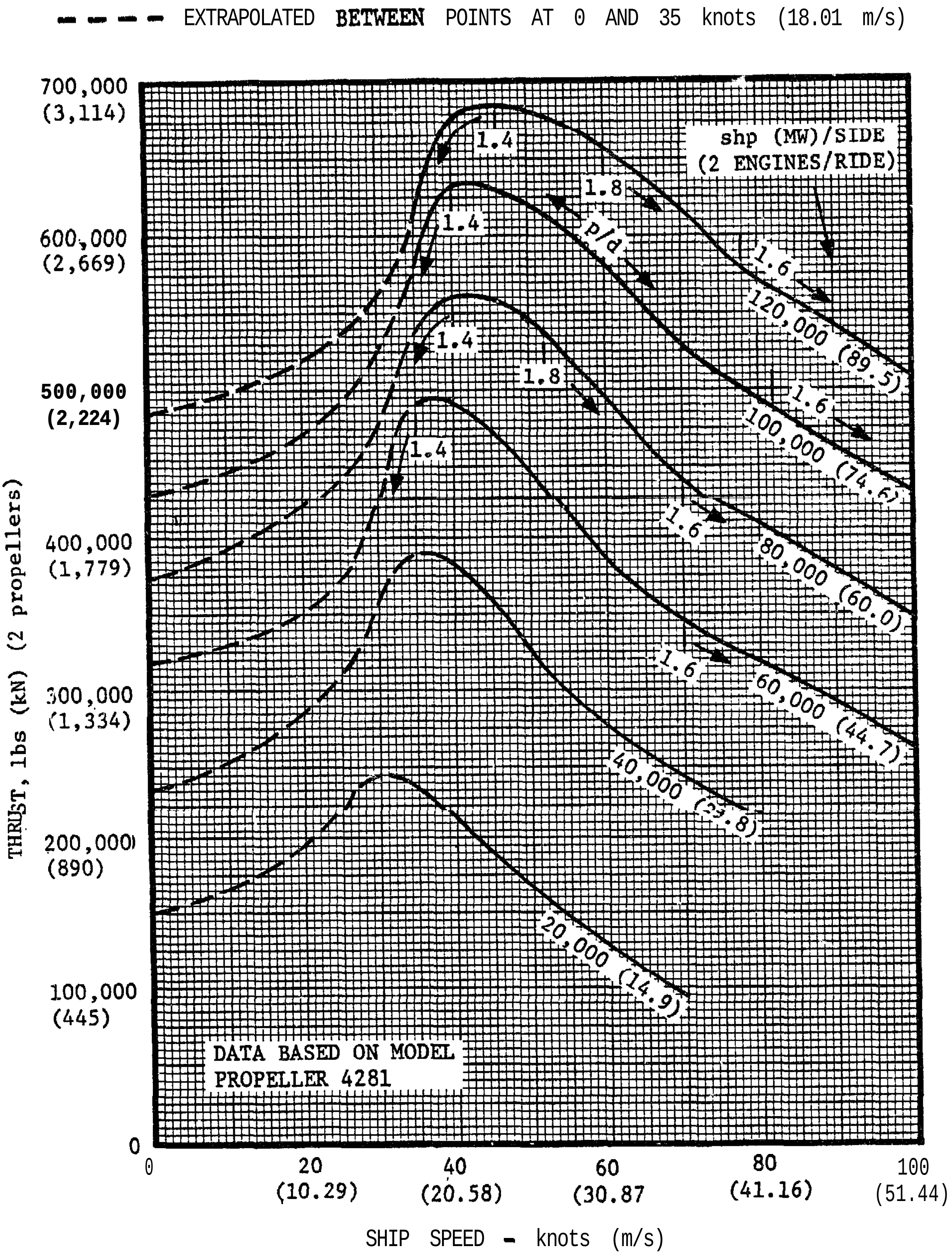

Figure D.5.4-5 (U). Optimum Thrust Envelope for Two 14 foot (4.27 m) Partially Submerged, Supercavitating Propellers (U)

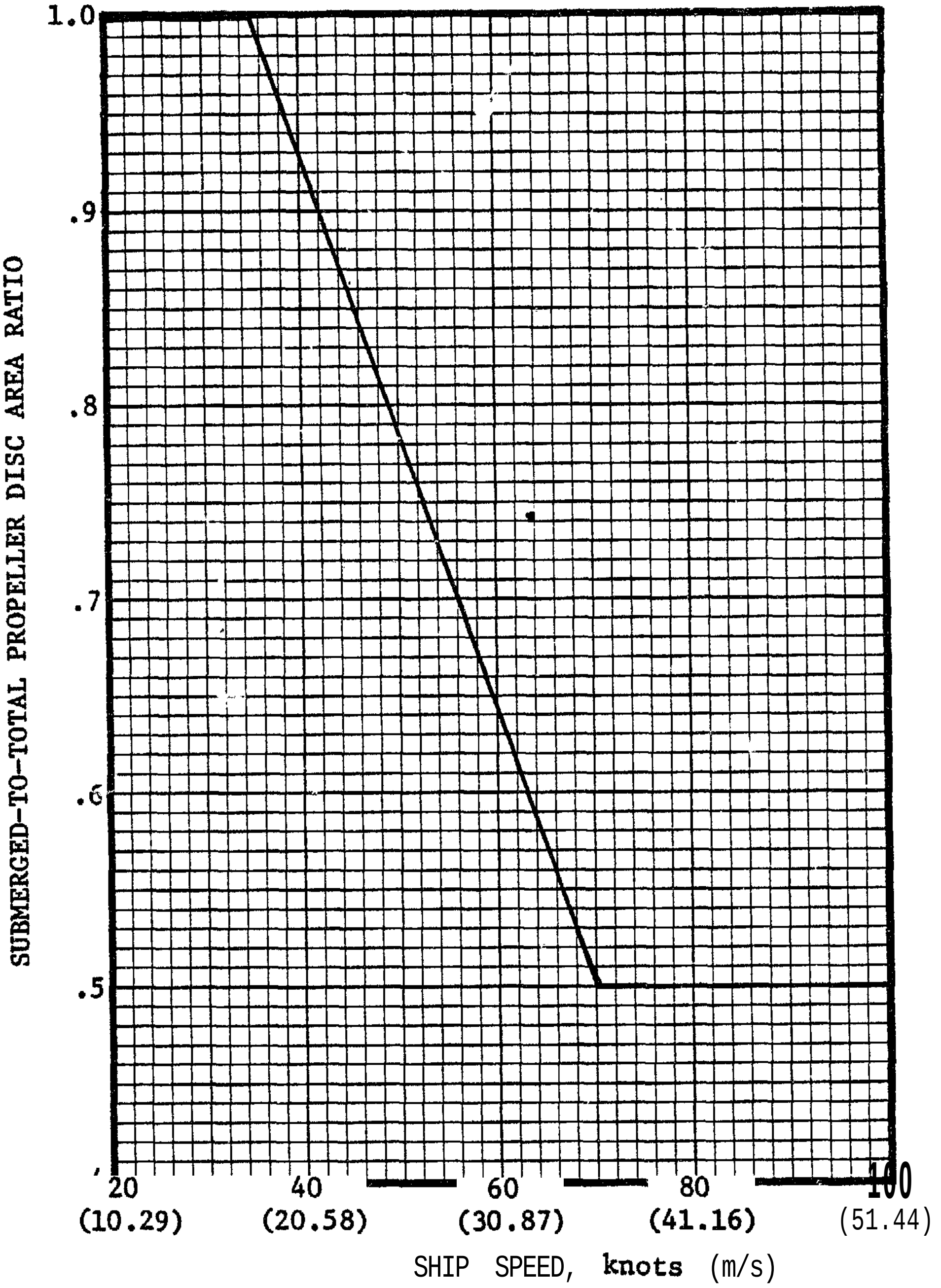

Figure D.5.4-6 (U). Propeller Submergence Ratio Versus Speed (U)

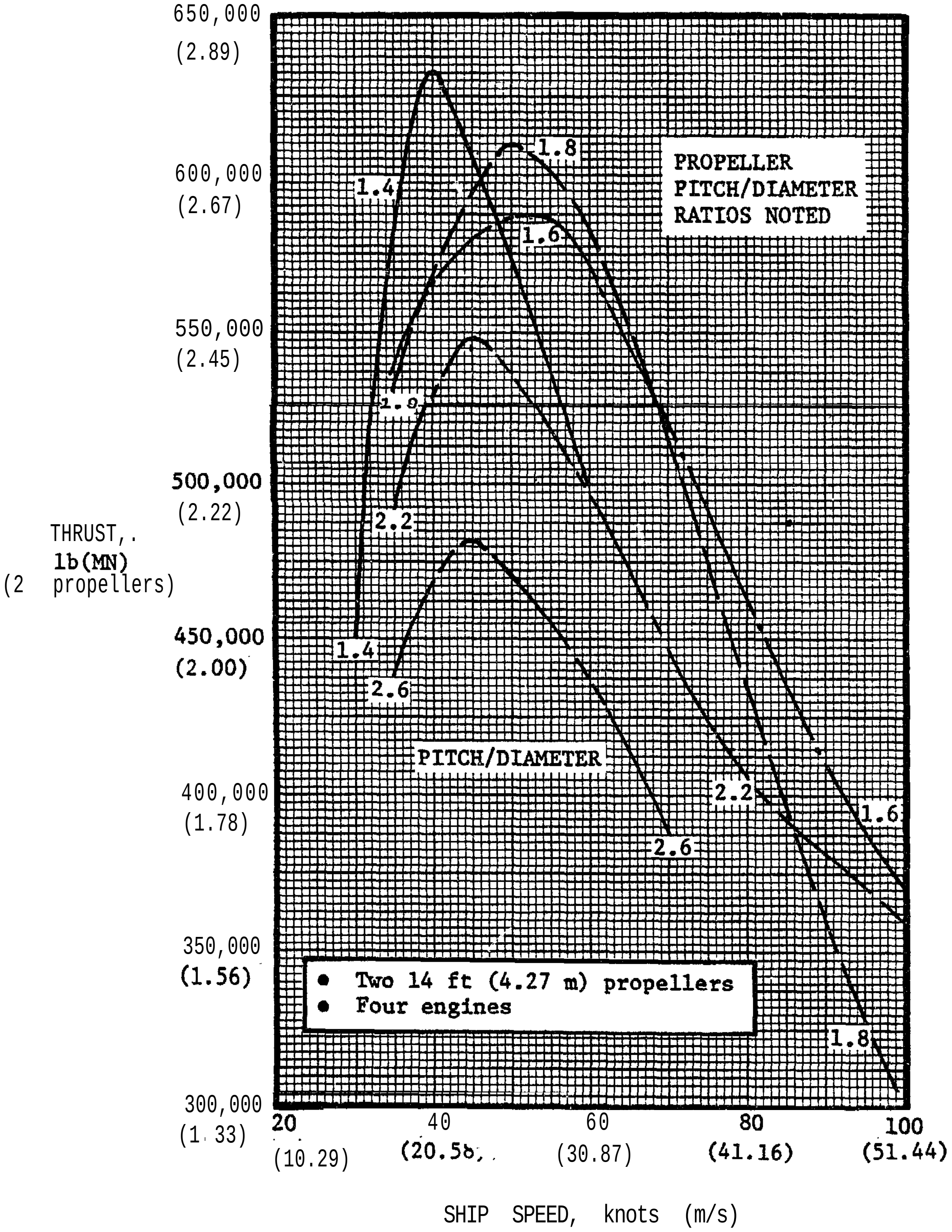

Figure D.5.4-7 (u). Variation of Propeller (2) Thrust with Speed and Pitch Setting for 100,000 shp (74.57 MW)/Shaft (U)