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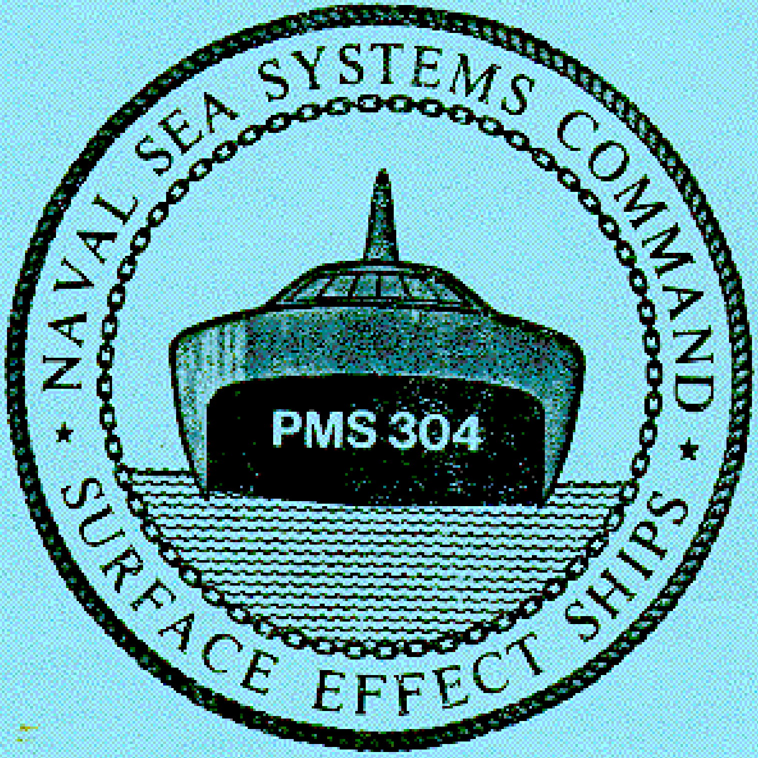
120

COASTAL
SURFACE EFFECT SHIP
CSES

TECHNICAL REPORT



SURFACE EFFECT SHIP ACQUISITION PROJECT
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C.

VOLUME I - TECHNICAL SUMMARY

CSES STUDY

December 1980

ABSTRACT

A 400 Long Ton Surface Effect Ship concept design developed to fulfill postulated United States Navy requirements is described. The ship design presented accommodates a particular combat suite having Harpoon missiles, the Oto Melara gun and a close in weapons system (CIWS) considered suitable for a coastal craft, though other combat system elements could be fitted with very little design change. Provision is made for the landing, fueling and launching of a helicopter. Performance capabilities are shown and the technical risk assessment of the design presented. The design represents a concept capable of fleet introduction by the mid 1980's.

The report is produced in two volumes. Volume I is the Technical Report presenting the ship's principal characteristics, performance, and description of the main subsystems. Volume II is a Cost Report presenting cost summary, cost details, basic construction cost estimating rationale, schedule, manpower distributions and appendices. The Cost Report also contains estimates for the lead ship, the first production ship, and a follow-on production for a total production of seven (7) ships.

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1 INTRODUCTION

The 400 Ton Coastal Surface Effect Ship (CSES) is an advanced naval vehicle capable of early fleet introduction. The assumed mission of the ship is to augment the main surface forces, particularly in the Mediterranean and the narrow seas and inlets of the Atlantic and Pacific in a surface warfare role. The capabilities of the ship as presented include surface and air surveillance and the detection and attack of enemy forces. The CSES has an all weather capability, a significant speed advantage over conventional craft combined with long range and good performance capability in high sea states. In line with the postulated coastal duties a mission time of five (5) days has been assumed, but as with many other surface effect ship designs, it has the ability to embark fuel in excess of the full load displacement (FLD) so that occasional extended voyages may be made without refueling.

The notable performance of this ship arises from the characteristics of SES that operate on an air cushion which provides effective lift to drag ratios at a given design speed higher than conventional ships. The CSES operates at a cushion length to beam ratio (L/B) of 5.0. With this L/B, the ship operates only in the sub-hump mode thereby overcoming the hump transit problems of both low L/B SES and hydrofoils. This L/B was selected so that the desired speed, range and payload could be achieved with adeqrate roll stability and maneuverability. The CSES has been designed so that it has a hullborne capability which provides extended range at an acceptable speed.

Although the design is advanced it is based on the use of materials and systems presently available and fully tested. This gives confidence in the low technical risk assessment and produces the least costly product to meet the operational objectives.

The technical and production planning material in this report is based on 14 years of technology pursuits, test and evaluation, production analysis, manufacture of large surface effect craft, and a wealth of corporate knowledge and expertise residing in the United States Navy Surface Effect Ships Project Office (SESPO) and the David W. Taylor Naval Ship Research and Development Center (DTNSRDC).

2 REPORT SUMMARY

2.1 STUDY OBJECTIVES

The CSES has been configured to perform the following military missions:

- Offensive operations against surface combatants and craft
- Surveillance, patrol and blockade in coastal and inland sea areas
- Screening (except ASW-space provided)
- Special operation

In addition to fulfilling its military mission, the CSES has the following design objectives:

- Speed advantage over conventional ships
- Good range at economical speed
- Low cost
- Low risk
- Minimum manning
- Maximum payload capability

With the above objectives as guidelines a 400 Long Ton 180 Foot Surface Effect Ship evolved having a 60 long ton payload capability. Simplified plan and elevation views are shown in Figure 2.1-1 with the principal characteristics listed in Table 2.1-i. The predicted performance is in Table 2.1-ii and a typical combat suite considered adequate to meet mission requirements is listed in Table 2.1-iii.

2.2 STUDY RESULTS

The twin screw CSES shown in Figure 2.1-1, when gas turbine propelled, on cushion, and at full load displacement (FLD), achieves 53 knots in a sea state 0 (SS-0). When utilizing the secondary diesel propulsion system and hullborne, its range is 4000 nautical miles (nm) at 16 knots. This performance far exceeds the capability of existing coastal ships.

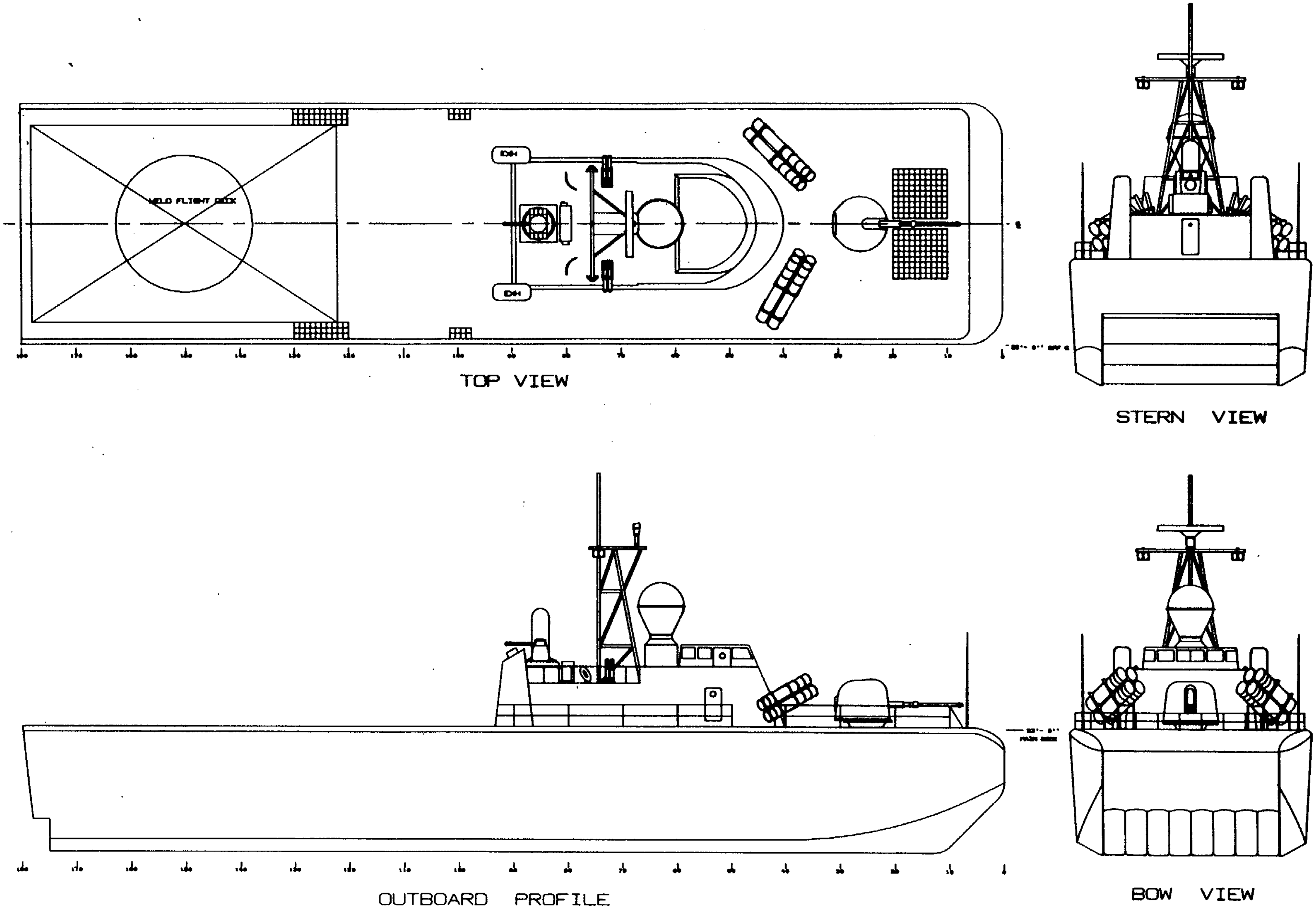


FIGURE 2.1-1

COASTAL SURFACE EFFECT SHIP PLAN AND ELEVATION VIEWS

COASTAL SURFACE EFFECT SHIP PRINCIPAL CHARACTERISTICS

WEIGHTS:

Full Load Dispacement (FLD) (LT)	400
Light Ship (LT)	277
Fuel 96 LT & Payload 60 LT	156

DIMENSIONS:

Length Overall (FT)		180
Beam Overall (FT)		44
Cushion Length/Beam Ratio		5
Wet Deck Height (FT)		13
Nominal Cushion Pressure (PSF)		157
Effective Cushion Length (FT)		160
Effective Cushion Beam (FT)		32
W/S	FLD	2.45
	CLD 500	3.08

POWER PLANTS:

Propulsion (CODOG)	Two Allison 570-K (6445 Continuous SHP) Gas Turbine
Lift Engines	*Four MTU 8V331 (870 SHP) Diesels - Similar to Fit in PHM
Lift Fans	Four Mixed Flow Fans
Propulsors	Two 8 Foot Diameter Fixed Pitch Propellers

CONSTRUCTION:

Structures	Welded Aluminum with Fiberglass Superstructure
Seals	Two Dimensional Bag and Finger
Electrical	Three 200 KW Gas Turbine Generators
Steering	Twin Rudder, Differential Thurst Reversal with the Propellers

CREW ACCOMMODATIONS:

Crew	33 Officers & Men
Accommodations	33 Berths

*Two of the Diesels may be used for Propulsion when off cushion and for lift when on cushion

TABLE 2.1-i

PERFORMANCE FLD = 400 TONS

SPEED KNOTS

ON CUSHION			
MAXIMUM POWER		CONTINUOUS POWER	
SS-0	SS-3	SS-0	SS-3
57	43	53	41

OFF CUSHION (DIESELS)	
CONTINUOUS POWER	
SS-0	SS-3
16	15

RANGE NM (96 LT FUEL)

CONDITION	MAXIMUM RANGE	RANGE AT MAXIMUM AVERAGE SPEED
ON CUSHION		
SS-0	2050 NM @ 25 KNOTS	1600 NM @ 53 KNOTS
SS-3	1750 NM @ 25 KNOTS	1250 NM @ 40 KNOTS
OFF CUSHION		
SS-0	4000 NM @ 16 KNOTS	-----

TABLE 2.1-ii

TYPICAL COMBAT SUITE

EIGHT (8) HARPOON MISSILES

MK 75 76MM OTO MELARA GUN

MK 95 GUN FIRE CONTROL SYSTEM (GFCS)

CLOSE-IN WEAPON SYSTEM (CIWS)

AUTOMATED COMBAT INFORMATION CENTER (CIC)
  - o Two (2) Displays - One (1) Computer

ENHANCED PHM COMMUNICATION SUITE
  - o Link 11 and 14

HELO PAD
  - o Lamps III
  - o Fueling

ELECTRONIC SUPPORT MEASURES (ESM) SLQ-32

TABLE 2.1-iii

Throughout the design, every effort has been made to keep costs and risks as low as possible. This has been achieved largely by considering only materials and equipments which are available now and that have been fully tested; and by simplifying the design. For example, the proven 5456 aluminum alloy is specified for hull structure rather than the experimental C19 aluminum, even though the latter because of its higher yield strength would have resulted in a lighter structure. Fixed pitch propellers have been specified in the design. These are readily available, simpler and considerably cheaper than controllable pitch propellers which would have been more efficient overall.

Organizational level maintenance has been kept low by deferring as much as possible to the intermediate level which can then be undertaken between missions. This has the advantage of enabling the ship to be complemented for its operational needs and not its maintenance requirements, so allowing a smaller crew than might normally be expected. Where possible also, "state of the art" remote and automatic operation of machinery has been fitted. This contributes significantly to the minimum crew concept.

It is anticipated that the CSES will function on an eighteen (18) month operational cycle followed by a forty-five (45) day regular overhaul (ROH) period. Similar to that available to the PHM, intermediate level maintenance support by a Maintenance/ Logistics Support Group (MLSG) is planned for periods throughout the 18 month employment.

Ship availability has been enhanced and overhaul time reduced to a minimum by including in the machinery design layouts, maintenance envelopes for all machinery to ensure easy access, and removal routes for critical equipments. This enables a component/module replacement strategy to be implemented.

The Combat System of the CSES uses subsystems which have been approved for service use, or are in current procurement for other ships or ship classes. It was a design requirement that normal procedures be used to install these equipments and therefore consideration was taken to insure that unique characteristics were identified. No developmental systems are identified in the baseline design except for the collision avoidance system which was adapted from the high speed ship collision avoidance and navigation system (AN/SSQ-87(V)) scheduled for Operational and Technical Evaluation in 1981.

2.3 SHIP DESCRIPTION

Figure 2.1-1 presents a simplified plan and elevation of the CSES showing the hull shape and proposed combat suite.

2.3.1 Operational Propulsion Modes

The ship can operate in either of two modes - cushionborne or hullborne. The performance at FLD is shown in Table 2.1-ii. Operation in higher sea states up to SS-5 is possible with survivability to SS-9.

When cushionborne the CSES is powered by two Allison 570K(6445 SHP) gas turbines with the lift power provided by MTU(870 SHP) diesels. Four diesels are fitted to drive the four mixed flow lift fans though all of these would only be necessary in maximum sea states or for maximum speeds.

In the hullborne mode, the machinery plant is designed so that either one or both of the two after lift fan diesels would provide the propulsive power. Thus, these diesels have a dual role providing power for lift when cushionborne, and propulsion when hullborne. In addition the propulsive power could be supplied by either or both gas turbines.

2.3.2 Combat System

The combat system shown in Table 2.1-iii is typical of what can be fitted in the CSES hull, and is considered adequate to meet mission requirements.

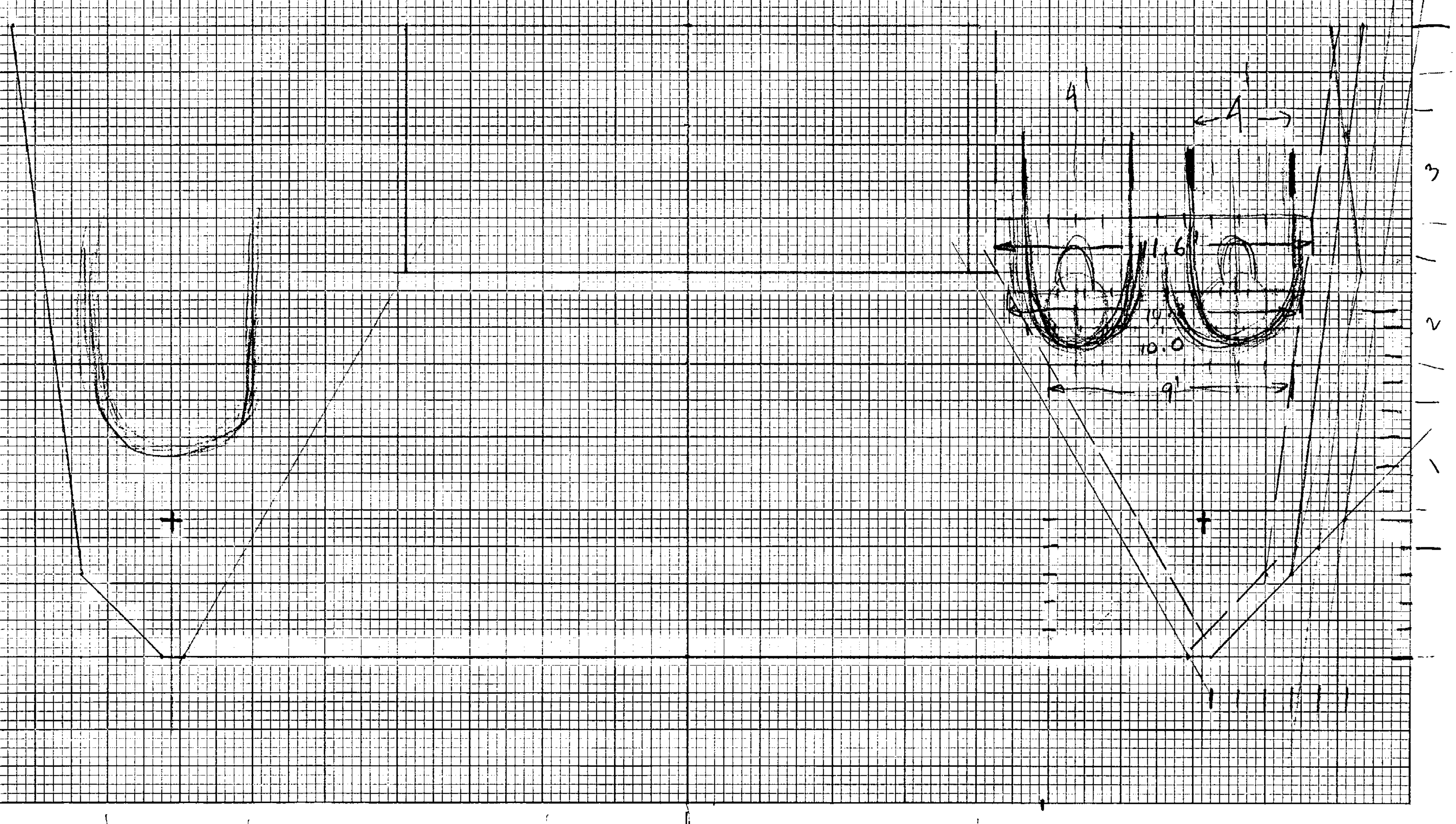
Surface engagements against patrol craft and small boats would utilize the 76mm gun, controlled by the MK 92 Mod 1 fire control system; and with HARPOON, the ship has the capability to engage surface targets using radar or over-the-horizon targeting sensors (i.e., AN/SLQ-32) or Link 11.

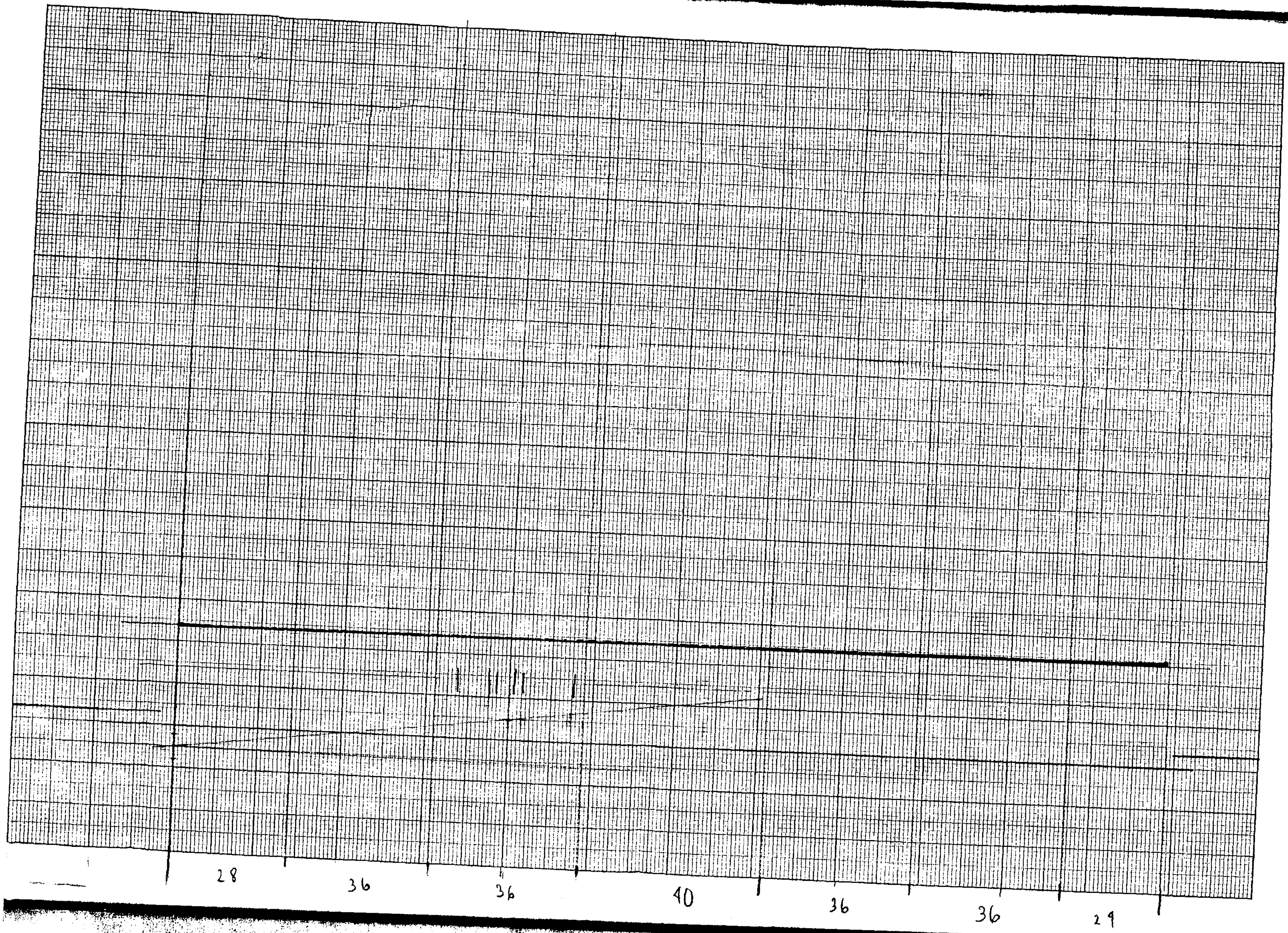
Air targets also can be engaged by the 76mm gun as well as with the close-in weapons system (CIWS). The CIWS, the primary anti-ship missile defense (ASMD), provides close-in terminal defense against anti-ship missiles or manned aircraft making low level passes over the ship.

3/16" = 1'

RR SPCY

AL 570's

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Although not fitted with a hanger or repair facilities, the CSES has a helicopter pad with the ability to embark, fuel and launch the LAMPS III Sikorsky SH-60B. In addition, space is available for developmental high performance sonars.

2.3.3 Other Systems

The ship is provided with a Navigation and Collision Avoidance System (NAVCAS), an Exterior and Interior Communications System, and a Ship Control System. Electrical power is provided by three 200KW, 440 volt, gas turbine generators two of which can meet the full battle load. Auxiliary machinery, including pumping systems, distilling plants, sewage disposal system and air conditioning are installed in the sidehulls.

2.3.4 Fire Protection

Fire protection is a major element of the CSES damage control system. Protection is provided by an integrated active and passive system designed to protect specific spaces and areas of high fire probability. The major function of the passive fire protection system is to protect the aluminum ship structure until the active system is brought into play. Passive fire insulation is installed in spaces presenting a high fire threat which are unmanned a considerable percentage of the time. These include the machinery spaces which are treated on the decks, bulkheads and overheads.

The active fire protection system provides fire detection and fire extinguishing. Detection is accomplished by early warning ionization and overheat detectors. The liquid fuel fire hazard spaces are protected by automatic detection and rapid automatic extinguishment. Each gas turbine engine, lift machinery, auxiliary and electrical compartment is protected by a distributing Halon 1301 system. An aqueous film forming foam (AFFF) system serves as a back up for the main machinery and auxiliary compartments and as the primary protection for the helicopter landing platform. The CSES firemain supplies seawater to fire plug hose stations and the magazine sprinkling system. Halon 1211 portable, lightweight fire extinguishers are provided for manual use.

2.3.5 Ship Delivery

The CSES design is based upon hydrodynamic data, performance prediction techniques, structural system, propulsion systems, lift fans, cushion seals, and ship control technology previously developed within the scope of the SES Program. As a result, the technology selected for this point design is readily available and has been subjected to considerable testing and/or operation within the scope of the SES Development Program or within other ship programs. There is therefore no R&D necessary before contract design work and the preparation of a request for proposal (RFP) could commence. Given the go ahead it is estimated that these could be completed within nine months.

The RFP would be for the design, construction, and delivery of a lead CSES with an option for follow-on ships.

The detail design and construction of the first CSES, including long lead time for certain installations has been estimated to take thirty (30) months.

The ship could therefore easily be introduced to the fleet by the mid 1980's.

2.3.6 Weight Estimates

Preliminary calculations for the CSES show the weight estimate in long tons (LT) split into the various SWBS groups as shown in Table 2.3-i.

WEIGHT ESTIMATES

SWBS	ITEM	LONG TONS
100	Structure	98.4
200	Propulsion	23.8
300	Electric	11.6
400	Command and Surveillance	17.6
500	Auxiliary	26.1
567	Lift System	18.0
600	Outfit and Furnishings	25.0
700	Combat Systems	22.7
	Design & Construction Margins	36.2
	Light Ship	279.4
	Variable Load - Ammunition	20.1
	- Personnel	4.5
		26.7
	FLD without Fuel	304
	Variable Load - Fuel	96
	Total FLD 400 Long Tons	

TABLE 2.3-i

3 SHIP ARRANGEMENTS

3.1 CONFIGURATION AND TANKAGE

The 180 foot long coastal SES design is efficiently arranged with the catamaran hull shape offering unique opportunities for efficient ship systems layout. The fuel and water tanks are located in the double bottom of each side hull which gives tankage of 8000 cubic feet available to handle over 140 LT of fuel plus potable and ballast water.

Having tankage segregated in each sidehull decreases the chances of overall contamination and so increases the reliability of the fuel system. The use of interconnecting piping and isolation valves enables fuel from either sidehull to be used for port or starboard services.

3.2 WATERTIGHT INTEGRITY

The watertight integrity is maintained by watertight bulkheads in each sidehull spaced every 30 feet. These thirty foot compartments, in addition to a collision bulkhead 10 feet aft of the bow, provide a full 2 compartment damage stability capability. The V-lines do not penetrate the 2nd deck, however the watertight bulkheads are extended up to the main deck to further improve the combat survivability of the ship. This enables the CSES to survive damage along the entire length of the bottom of one sidehull and still be able to return to port under the power provided by the machinery in the other sidehull.

3.3 MACHINERY ARRANGEMENT

The main propulsion machinery is located on the third deck within each sidehull between watertight bulkheads at 90 and 120 foot stations. Nine (9) foot wide spaces provide easy access to the main engines for service, repair and removal.

Auxiliary machinery spaces are located on the third deck aft of the main machinery spaces and on the second deck above both the main machinery and lower auxiliary spaces between stations 90 and 150. These spaces contain over 2000 square feet of useful area in 8 rectangular shaped spaces.

Four more compartments are dedicated to the lift system. Two are located forward on the second deck in the bow between stations 10 and 20 where they have minimal impact on the ships general arrangements. The two remaining lift fans are positioned on the third deck aft. Six-hundred forty (640) square feet of deck space is utilized by the lift system to provide a total machinery space area of 2700 square feet.

Separating the main machinery in each sidehull adds some extra weight to the distributive supporting systems, but this is offset by the gain in reliability and the increased survivability from the damage viewpoint due to the wide segregation of the plants. Also the wide propeller spacing significantly improves maneuverability and ship control.

The location of the main machinery aft of station 90 enables easy vertical removal paths for all machinery aft of the superstructure without interfering with other ship equipment and also results in a short drive shaft length of only 70 feet. The catamaran shape of the sidehulls and the location of the machinery low in these hulls provides a shaft inclination of only 4 degrees and allows the installation of the propellers on the transom. This eliminates the need for exposing the shafting and propellers beneath the hulls and in turn eliminates appendage drag resulting in as much as 10 to 15 percent higher performance than conventional arrangements. This arrangement was successfully demonstrated both on the SES 100B and in recent model tests on the DD963 for improved destroyer efficiency. An additional benefit associated with this propeller installation is the increased component life resulting from the elimination of salt water corrosion of the shafting and bearings. The propellers themselves are located so as to permit maintenence and removal without drydocking the ship and are protected from foreign object damage by the sidehulls and the rudders which are located forward of the propellers.

3.4 SHIP CONTROL POSITIONS

The CIC, IC and Gyro rooms totaling 540 square feet are located directly below the superstructure which extends from station 40 to 90. Immediately above in the superstructure are the radar space, communications center, MK 92 Fire Control System Space and the CO's stateroom totaling 1180 square feet. This places the command in close proximity to ship control and ship combat spaces. Table 3.4-i compares the CSES with several current Navy ships and shows that it has the space associated with combatants many times its displacement. This could be of value with todays weapons systems and complex electronic systems becoming larger and making most monohulls volume limited. The central control station and both machinery and damage control central are located aft of station 90 on the second deck.

COMMAND AND CONTROL SPACES COMPARISION

SPACE DESCRIPTION	FFG7 SQ FT	PCG SQ FT	PHM SQ FT	CSES SQ FT
PILOT HOUSE & CHART ROOM	366	244	149	199
COMBAT INFORMATION CENTER	850	483		450
INTERIOR COMMUNICATION & GYRO ROOM	200	75	388	90
MK 92 FIRE CONTROL SYSTEM/AIR NAVIGATION/ ELECTROMAGNETIC COUNTERMEASURES, ETC.	336	154		158
COMMUNICATION CENTER	432	187	81	100
RADAR ROOM	1024	266	151	242
SONAR EQUIPMENT ROOM	180	252	NONE	600
RADIO ROOM	280		NONE	
FUTURE GROWTH	NONE	NONE	NONE	665
TOTAL COMMAND & CONTROL	3668	1661	769	2379

TABLE 3.4-i

3.5 ARRANGEMENT FLEXIBILITY

The entire space on the second deck aft of station 20 to the transom at station 180 which measures 160 x 44 x 10 feet can be laid out variously to suit mission requirements. The layout illustrated in Figure 3.5-1 is one typical arrangement. but all arrangements can be made clean and functional due to the lack of volume restraints that are so typical of most modern ships. For example the CSES has more than 2.5 times the internal volume of the PHM which has both a higher installed horsepower and lower top speed and range. This large, efficiently arranged CSES has 60 LT of payload compared to 35 LT of the PHM to arrange on this deck and in the 1300 square feet of superstructure. The resulting CSES payload transport efficiency (Wp x V/P) at full power cruise speed is 1.4 compared with 0.7 for the PHM.

A further example of the spaciousness of this ship can be made by noting that the CSES has approximately the same internal volume as the Saudi Arabian 245 foot 800 LT FLD PCG. It is noteworthy that with half the PCG displacement the CSES has a better range at double the speed of the PCG. The CSES also has a large air capable landing deck aft which can accommodate the LAMPS MK III helicopter. This is the smallest known combatant design with these capabilities.

Referring to Figure 3.5-1 an important feature of the 44 foot wide 2nd deck is the provision of two fore and aft passageways located 9 feet off the centerline to port and starboard. These two passageways provide redundant convenient access to all operational and combat stations. The 1320 foot area aft of station 150 to the transom is currently unassigned and is reserved for future growth. It could accommodate other combat suites or expanded helicopter support facilities.

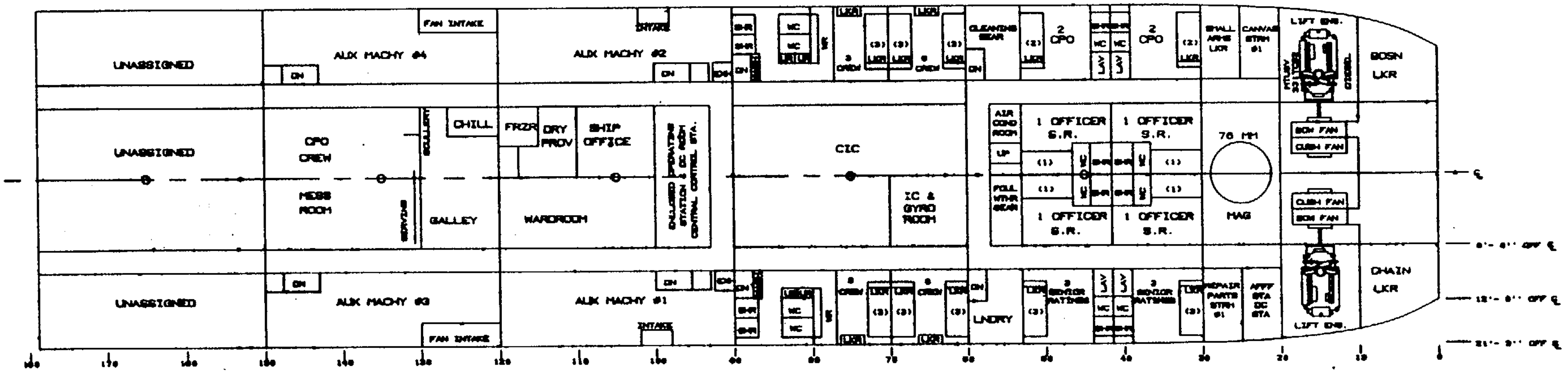
Just aft of the forward lift fans is the 76 mm ready service magazine; this directly supports the Oto Melara gun on the main deck above. It also serves as an effective noise barrier between the lift fans and the berthing areas that are immediately aft of the watertight bulkhead at station 30.

The aft location of the machinery leaves the entire 3rd deck forward of station 90 free for mission payload or crew recreation spaces etc. The drawing Figure 3.5-1 indicate but one of many possible uses of this extra 1000 square feet of space. The catamaran hulls provide a significant amount of useable volume amounting to 27,000 cubic feet.

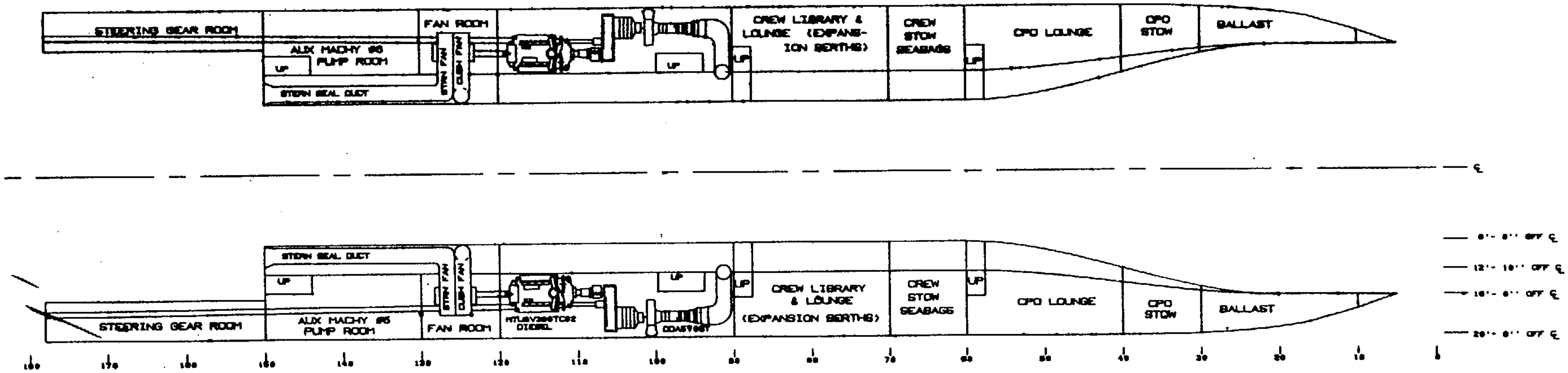
3.6 ACCOMMODATION SPACES

The primary living and operations deck of the CSES is on the second deck. It contains over 6000 square feet of fully useful 10 foot high deck space in addition to the 1200 square feet of auxiliary machinery spaces described above for a total of 101,000 cubic feet. The 44 foot beam of the ship is fully realized over the entire length of this deck except for the very first 10 feet at the bow that contains basic stowage and chain lockers. The next 10 feet between stations 10 and 20 is dedicated to the two diesel powered lift fans that discharge directly into the bow seal and cushion thereby eliminating long space wasting air distribution ducts.

Accommodation for officers consists of four adjacent single staterooms with 88 square feet per man, with convenient access to the CIC and upper decks. These rooms provide more than twice the square footage per officer than the PHM and PCG and each could be converted to two man staterooms if required.



SECOND DECK (13 FEET ABL)



THIRD DECK (6 FEET ABL)

FIGURE 3.5-1

TYPICAL ARRANGEMENT - SECOND AND THIRD DECK

Two CPO two-man staterooms to port and two senior enlisted men 3 man state rooms to starboard are located outboard of the officers accommodation between stations 30 and 60. Each set of staterooms share a common sanitary space. The CPO spaces provide 47 square feet per man. The remaining crew is quartered outboard of each passageway between stations 60 and 90 in six man berth areas with 17 square feet per man.

Baggage spaces, crew and CPO lounges are arranged below on the third deck to provide convenient access from the berthing areas. 400 square feet of baggage stowage space is provided. These spaces compare favorably with the DD963, and FFG-7 standards as summarized in Table 3.6-i and are considerably less cramped than most monohull gunboats and corvettes.

HABITABILITY SPACES COMPARISON

SPACE DESCRIPTION	FFG7 SQ FT	PCG SQ FT	PHM SQ FT	CSES SQ FT
COMMANDING OFFICERS STATEROOM & BATH	210	132	75	131
EXECUTIVE STATEROOM & BATH	165	NONE	NONE	NONE
OFFICERS STATEROOMS	775	332	151	334
CPO STATEROOMS	470	NONE	97	190
CREW BERTHING	3000	606	274	530
OFFICERS WASHROOM, WATERCLOSET, SHOWERROOM	100	42		80
CPO WASHROOM, WATERCLOSET, SHOWERROOM	72	NONE	80	40
CREW WASHROOM, WATERCLOSET, SHOWERROOM	500	110		270
WARDROOM	340	210	NONE	180
CPO MESS	228	NONE	NONE	NONE
ENLISTED MESS	1172	368	188	360
CPO LOUNGE	135	NONE	NONE	350
ENLISTED LOUNGE	610	NONE	NONE	400
SCULLERY	110	24	NONE	14
GALLEY	540	150	90	145
DRY PROVISION STOREROOM	190	42	NONE	53
FREEZER	140	65	NONE	25
CHILL STOREROOM	155	59	NONE	21
LAUNDRY SPACE	115	50	NONE	60
SHIP SERVICE OFFICE	255	80	NONE	90
CREW BAGGAGE STOREROOM	130	NONE	97	400
TOTAL HABITABILITY SPACES	9412	2270	1052	3673
HABITABILITY SPACE/MAN	50.9	40.5	50.1	111.3

TABLE 3.6-i

3.7 DOMESTIC SERVICE

The remaining space to bulkhead 120 is occupied with the wardroom, ships office and galley provisions. The galley is located directly aft of this bulkhead between the wardroom and the crew mess room. Table 3.7-i summarizes these spaces on a per man basis for several ships and shows the high habitability standards of the CSES.

HABITABILITY DENSITY COMPARISON PER CREWMAN IN SQUARE FEET/MAN

	COMPLEMENTS*			
SPACE DESCRIPTION	FFG7 185	PCG 56	PHM 21	CSES 33
COMMANDING OFFICERS STATEROOM & BATH	210	132	75	131
EXECUTIVE STATEROOM & BATH	165	NONE	NONE	NONE
OFFICERS STATEROOMS	52	55	38	84
CPO STATEROOMS	32	NONE	24	48
CREW BERTHING	20	12	23	22
OFFICERS WASHROOM, WATERCLOSET, SHOWERROOM	7	7	NONE	20
CPO WASHROOM, WATERCLOSET, SHOWERROOM	5	NONE	NONE	10
CREW WASHROOM, WATERCLOSET, SHOWERROOM	3	2	4	11
WARDROOM	8	30	NONE	36
CPO MESS	15	NONE	NONE	NONE
ENLISTED MESS	20	8	12	13
CPO LOUNGE	9	NONE	NONE	88
ENLISTED LOUNGE	4	NONE	NONE	17
SCULLERY	0.6	0.4	NONE	0.4
GALLEY	3	3	4	4
DRY PROVISION STOREROOM	1	1	NONE	2
FREEZER	1	1	NONE	1
CHILL STOREROOM	1	1	NONE	1
LAUNDRY SPACE	1	1	NONE	2
SHIP SERVICE OFFICE	1	1	NONE	3
CREW BAGGAGE STOREROOM	1	NONE	5	12

*Complement Breakdown:

FFG7: 17 Officers - 15 CPO's - 153 Enlisted
PCG : 7 Officers - 0 CPO's - 49 Enlisted
PHM : 5 Officers - 4 CPO's - 12 Enlisted
CSES: 5 Officers - 4 CPO's - 24 Enlisted

TABLE 3.7-i

4 SHIP PERFORMANCE

4.1 GENERAL

The performance relationships given in this section are for a ship designed to 400 LT FLD carrying a total of 96 LT burnable fuel. The displacement is that applicable to normal coastal operations compatible with its five-day mission requirement. Should the need arise, say for an occasional extended voyage, the range of the ship can be significantly extended without an undue speed penalty by providing additional fuel -- this ability to embark fuel such that the ship is above its normal FLD is a feature of many surface effect ships. The performance of the ship is presented in one performance table and 13 graphs.

The graphical data include both cushionborne and hullborne operations at various propulsive power levels. Power variation, while cushionborne, is achieved by operating the gas turbines either singly or in combination at the power setting of 6500 shp maximum continuous (MCP) per unit, or 7170 shp maximum intermittent (MIP) per unit. Hullborne operation is achieved with these same gas turbines or by using one or two diesel engines that are also used for stern lift fans during cushionborne operations. Each diesel is rated at 870 shp normal or 1065 shp maximum.

In general, the CSES at FLD has a dash capability of 57 knots and 43 knots in SS-0 and SS-3 respectively, and a maximum continuous speed of 53 knots and 41 knots in the same respective sea states. In the hullborne mode, the ship at normal diesel rating, has an average speed of 16 knots in SS-0 and 15 knots in SS-3. Using maximum diesel power the speeds are 17 and 16 knots in the same sea states. Higher hullborne speeds are attainable with the gas turbines. Summarized performance characteristics are presented in Tables 4.1-i and 4.1-ii.

CSES PERFORMANCE - CUSHIONBORNE (2 GAS TURBINE OPERATION)

		SEA STATE 0		SEA STATE 3	
INITIAL DISPLACEMENT (LT)	AVAILABLE FUEL (LT)	SPEED KNOTS	RANGE NM	SPEED KNOTS	RANGE NM
400	96	53	1650	-	-
400	96	40	1650	40	1300
400	96	25	2150	25	1850
350	46	50	780	45	640
350	46	25	1040	25	900

TABLE 4.1-i

CSES PERFORMANCE - HULLBORNE (2 DIESEL OPERATION)

		SEA STATE 0		SEA STATE 3	
INITIAL DISPLACEMENT (LT)	AVAILABLE FUEL (LT)	SPEED KNOTS	RANGE NM	SPEED KNOTS	RANGE NM
400	96	16	3900	-	-
400	96	15	4200	15	3800
400	96	12	5100	12	4600
350	46	16	1950	-	-
350	46	12	2600	12	2400

TABLE 4.1-ii

Estimates of full-scale drag, shown in Figures 4.1-1 and 4.1-2, have been derived from test data of an L/B = 5 model. Although the model is not identical with the proposed design, the data obtained has been modified by accepted analytical methods that have been previously verified by other extensive model tests and full scale correlation.

The optimum lift power associated with the drag curves is shown in Figure 4.1-3 as functions of speed. It can be seen that there is surplus lift power available for ride control throughout the CSES operating envelope as required in higher sea states.

4.2 THRUST, DRAG AND SPEED

4.2.1 Cushionborne

Figure 4.1-1 shows drag curves in SS-0 for FLD and for two other displacements. It should be noted that the distinctive high primary hump drag typical of low L/B ships no longer exists for this higher L/B ship. There is a secondary hump in the 15 knot region but this is mild so that no difficulty exists in accelerating over the full range of speed up to maximum. The elimination of the high primary hump drag provides two important advantages over other high speed ships including low L/B SES and hydrofoils:

a. the propulsion system whether waterjet or propeller does not have to provide high, low speed thrust for accelerating through hump.

b. in high sea states both low L/B SES and hydrofoils experience some difficulty in becoming respectively cushionborne over hump or foilborne due to additional hump drag from the large waves. The CSES operating always below hump speed does not have this difficulty and the additional drag in high sea states effects its speed only incrementally.

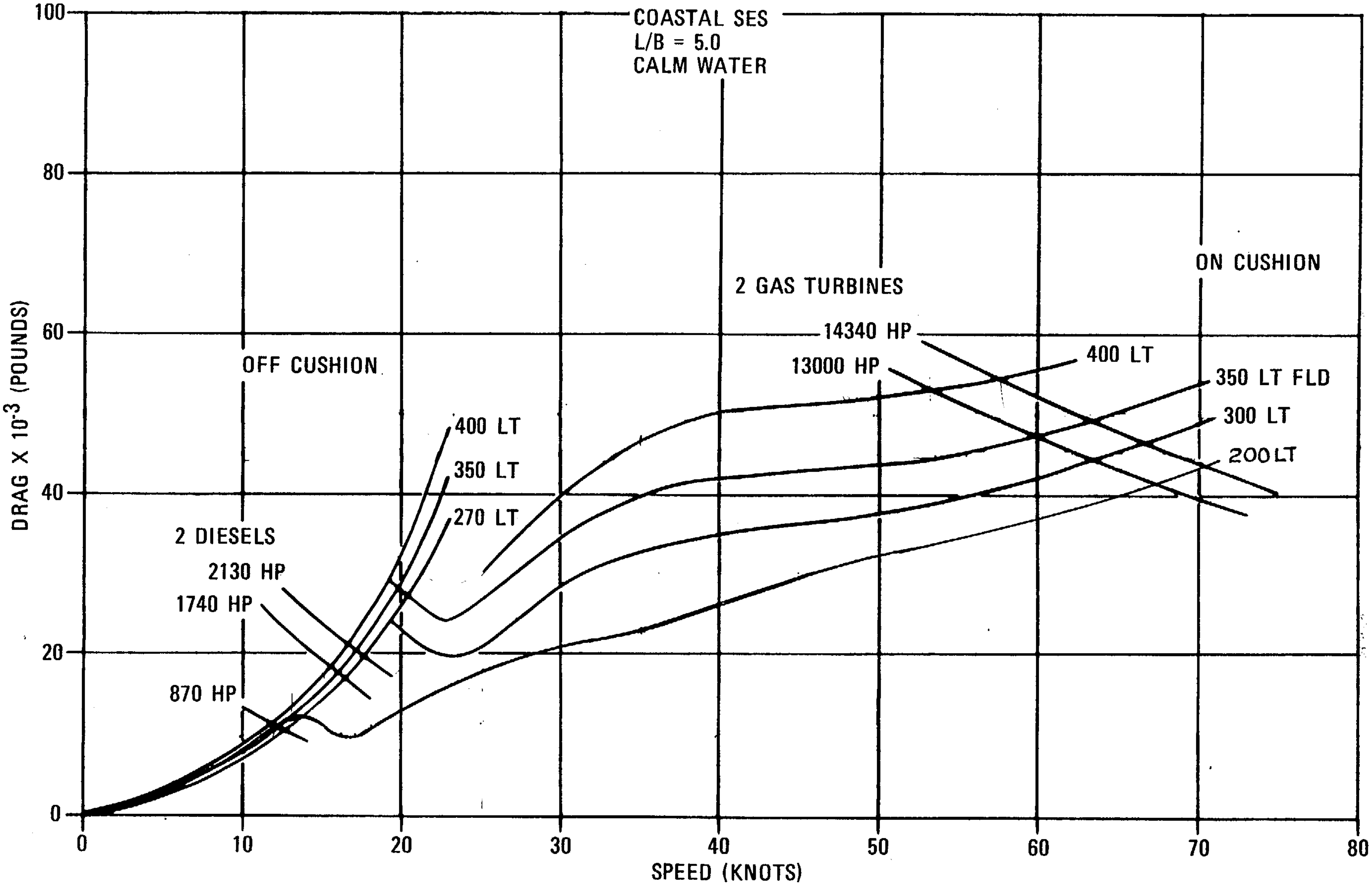


FIGURE 4.1-1
CALM WATER DRAG VERSUS SPEED

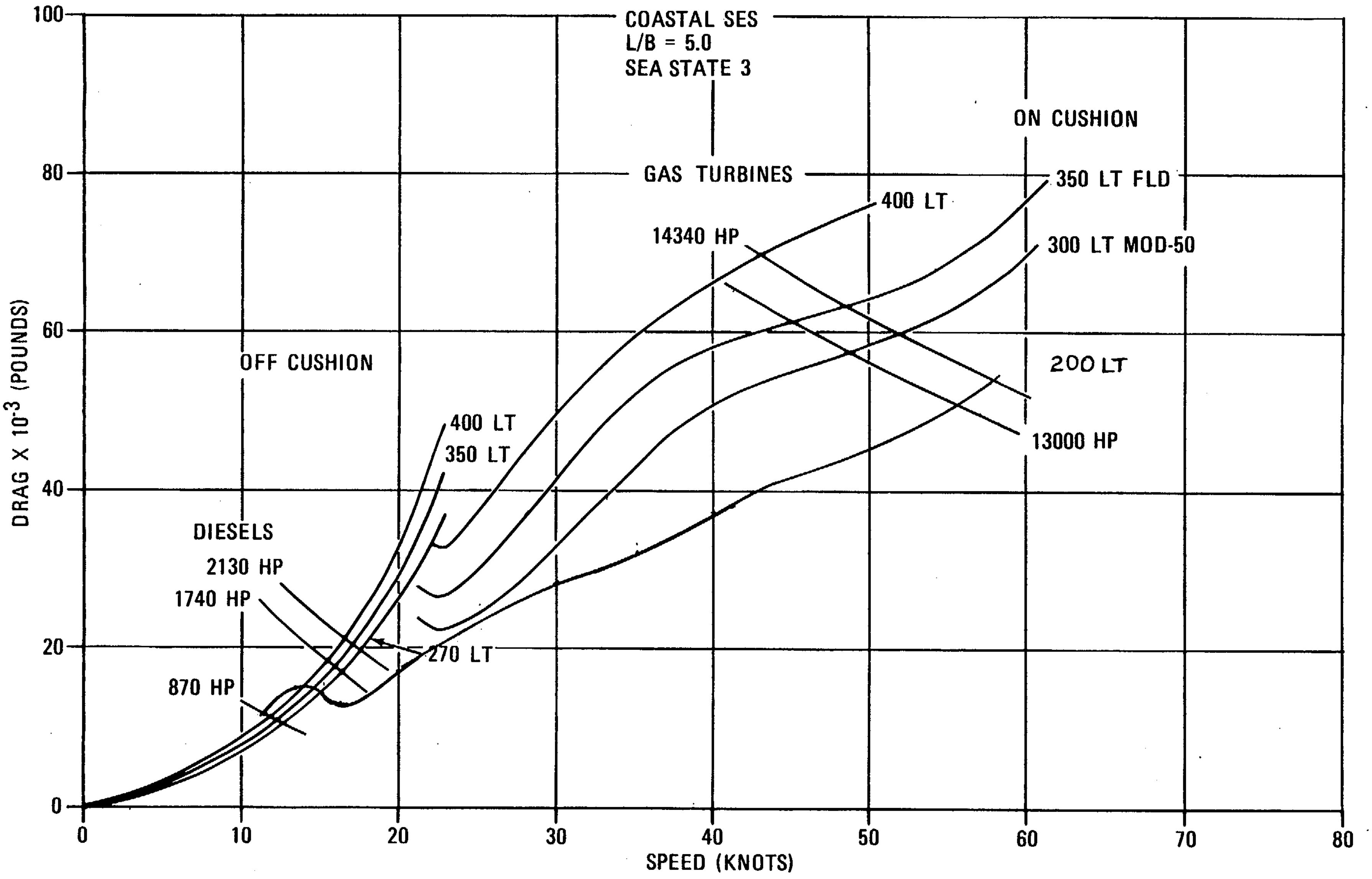


FIGURE 4.1-2
SEA STATE-3 DRAG VERSUS SPEED

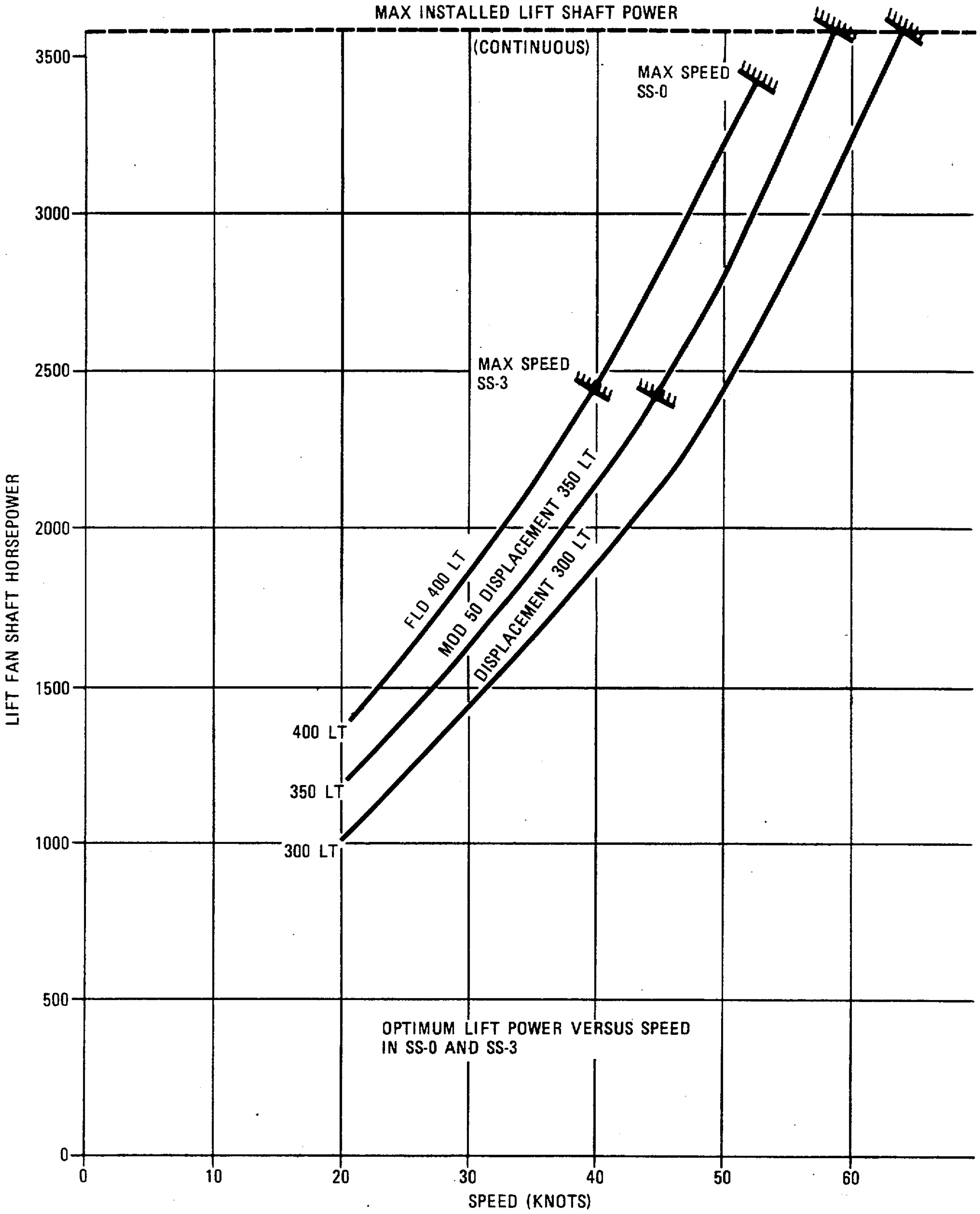


FIGURE 4.1-3
OPTIMUM LIFT POWER VERSUS SPEED

Thrust curves are presented for the total gas turbine powers of 13,000 hp (MCP) and 14340 hp (MIP). The curves show the characteristic performance trait of SES, namely the speed variation with displacement. For 13,000 shp (MCP) at FLD the maximum speed is 53 knots. After burning half this fuel the speed will have increased to 60 knots, while after burning off the remaining fuel the speed will have further increased to 63 knots. The corresponding dash speed variation at 14,340 shp (MIP) is from 57 to 66 knots.

The performance in SS-3, 4.0 feet significant wave height, is shown in Figure 4.1-2. At MCP the maximum speed is 41 knots at FLD with a variation from 41 to 48 knots at displacements of 400 LT and 300 LT, respectively. The corresponding dash speeds are 43 knots at FLD with a variation to 52 knots as fuel burns off.

The effects of higher sea state have not yet been examined in detail. However, testing of other manned and model SES has shown a consistent speed change with sea states in proportion to the significant wave height. Confirming model tests to precisely determine drag at sea states other than zero and three will be an integral part of the next stage of design.

4.2.2 Hullborne

Figures 4.1-1 and 4.1-2 show the off cushion drags for calm water and SS-3, respectively. Curves are shown for FLD and lighter conditions. As might be expected for the hullborne mode, which is similar to that of conventional ships, the variation in drag due to both displacement and SS-3 is less severe than for the cushionborne mode. As shown in Table 4.1-ii, the speeds at FLD using two diesels, total power of 1740, is 16 and 15 knots in SS-0 and SS-3, respectively. With one diesel at 870 shp a speed of approximately 12 knots in both sea states is achievable.

4.2.3 Transport Efficiency

When transport efficiency (Displacement x Velocity/Total Power) is computed for the CSES as a function of ship speed, the improvement to be gained in SES effectiveness by designing for high L/B (sub-hump operation) and propellors is demonstrated. Transport efficiencies of over 12 at 25 knots to about 9 at 50 knots are attained for full load displacement (400 LT). It can thus be seen when compared with published data (e.g., ANVCE Volume II) that the high speed transport efficiencies of high length-to-beam SES will be large compared to that of other types of advanced ships of comparable size.

4.3 RANGE AND SPEED

4.3.1 Cushionborne

Range, speed and endurance relationships are presented for propulsive powers up to 13,000 shp. Figures 4.3-1 and 4.3-2 show curves of range versus speed in SS-0 and SS-3, respectively, from 20 knots to maximum speed. Data has not been solidly plotted between 20 and 25 knots because of the option of operating in either the hullborne or cushionborne modes; however, it may be safely assumed that at least down to 20 knots the cushionborne range will increase. It can also be seen that for those different sea states shown, the maximum range occurs at 20 knots. Variations in range with speed are noticeable but not dramatic. Thus, in SS-0 range decreases

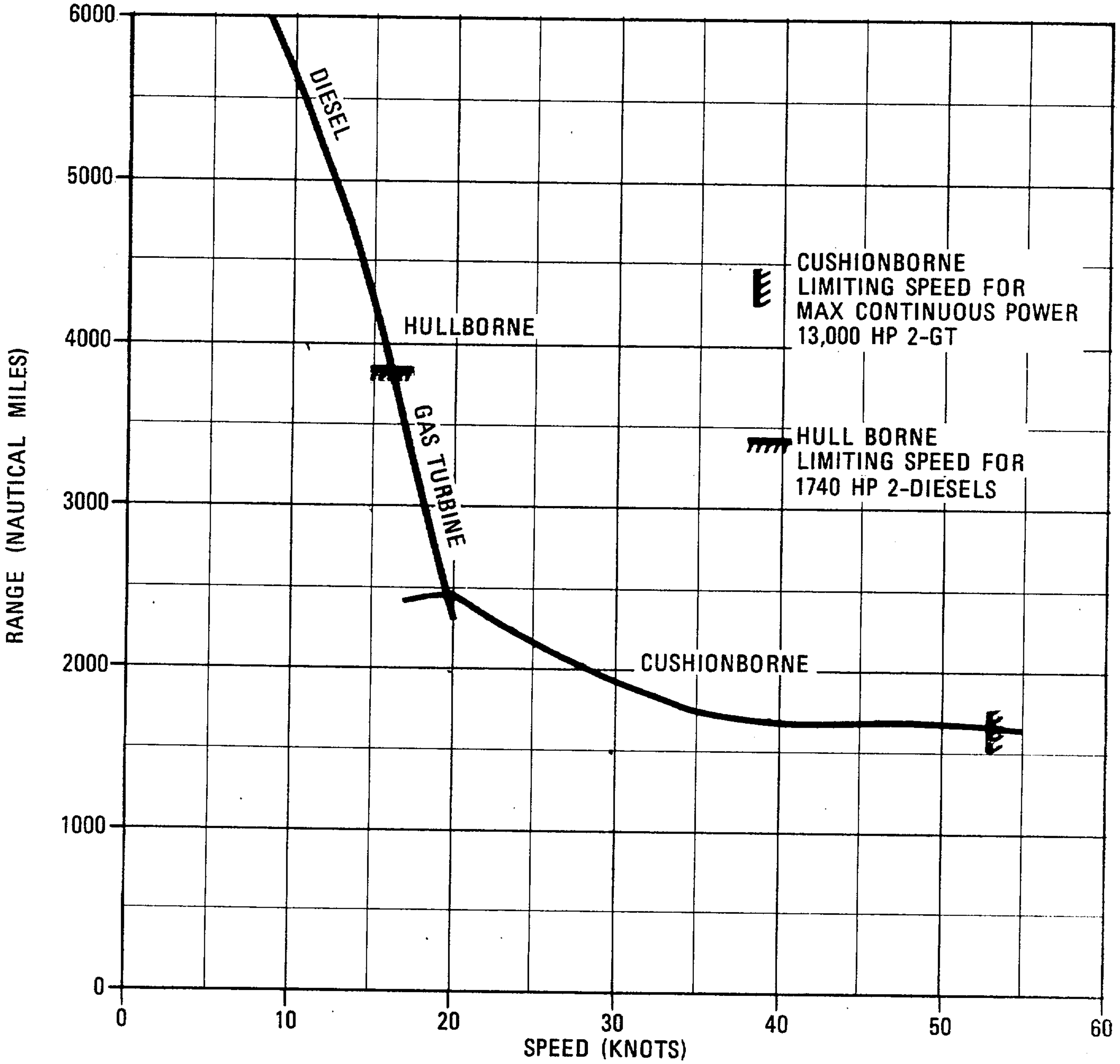


FIGURE 4.3-1
COASTAL SES (400 LT DISPLACEMENT 96 LT-FUEL)
SEA STATE 0 RANGE VS SPEED

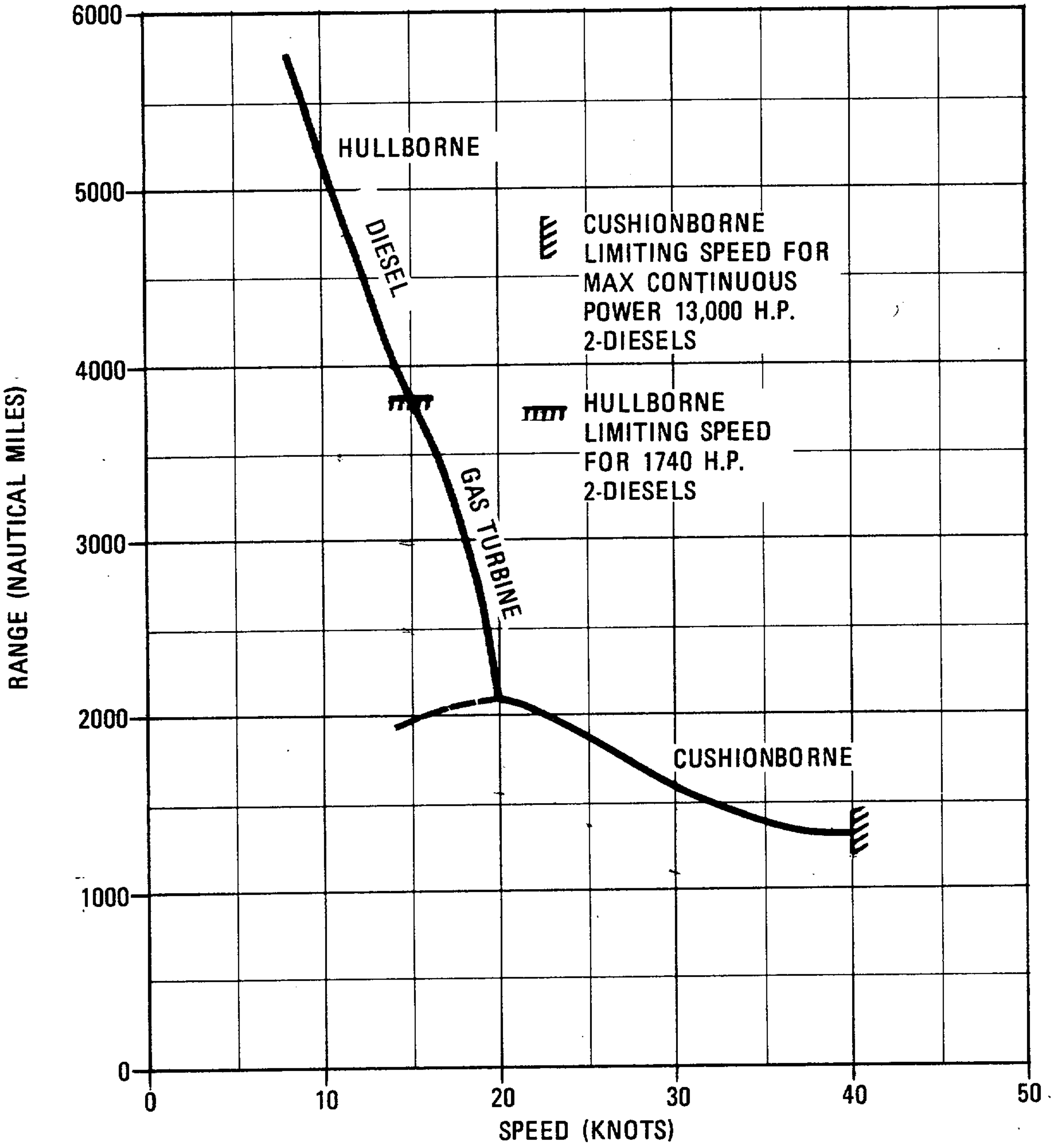


FIGURE 4.3-2
COASTAL SES (400 LT DISPLACEMENT 96 LT-FUEL)
SEA STATE-3 RANGE VS SPEED

as speed increases from 20 to 40 knots but then is essentially unchanged as the speed increases to maximum. For FLD in SS-0 the change is from 2400 nm at 20 knots to 1650 nm at 53 knots. The effect of increasing sea state to SS-3 reduces range by a relatively small amount; for example at FLD and 20 knots the range decreases by only 300 nm. These cushionborne ranges at high speed together with the considerable range at low speeds in the hullborne mode (see paragraph 4.3.2 below) are compatible with the requirements of typical coastal scenarios of five-day mission duration.

Figures 4.3-3 and 4.3-4 show curves giving the relationship between fuel remaining and distance travelled for the cushionborne mode for SS-0 and SS-3. For clarity, the curves are given only for speeds of 25 knots and speeds at MCP. Curves for other cushionborne speeds fall between those shown. Figure 4.3-5 shows curves of endurance for the range of cushionborne speeds from 25 knots upwards for the same displacements and sea states as in the previous curves.

4.3.2 Hullborne

Figures 4.3-1 and 4.3-2 show also hullborne range versus speed in SS-0 and SS-3 respectively. Comparison of the two figures show relatively small effects due to sea state. Thus at FLD (400 LT) the range in SS-0 at continuous diesel power (1740 hp) is 3900 nm at a maximum speed of 16 knots. In SS-3 the maximum speed is 15 knots with a corresponding range of 3800 nm i.e., a decrease of 2.5 percent due to change in sea state. At 12 knots a range of 5100 nm can be achieved reducing to 4600 nm in SS-3 i.e., a reduction of 12 percent.

Figures 4.3-6 and 4.3-7 give the relationship between fuel remaining and distance travelled in the hullborne mode for SS-0 and SS-3. Two speeds are given for each case, 12 knots and the maximum speed available with two diesels at 1740 shp. It will be noted that although the drag at 12 knots is approximately half that at 16 knots, the range is not doubled. This is because at the lower speed, the fuel for hotel load becomes more significant.

Figure 4.3-8 gives endurance versus speed for the same sea states and FLD as above. The minimum endurance shown (FLD = 400 LT and SS-3) is 240 hours (10 days) at 15 knots which easily exceeds the five day endurance stipulated in the requirements.

4.4 MANEUVERABILITY

Preliminary calculations show that the CSES will have turning characteristics cushionborne comparable to or better than those of equivalent conventional ships. The propellers located in the two sidewalls are very widely spaced compared with those in a conventional hull of similar size and a significant amount of turning moment can be provided by their differential thrust in addition to that given by rudders. Using rudders only, it is estimated that with an area per side of 8-10 square feet, the turning diameter will be of the order of 3000 feet at 25 knots. Propeller differential thrust will reduce this turning circle further. Precise rudder size has not yet been selected but will be determined during the next stage of the design.

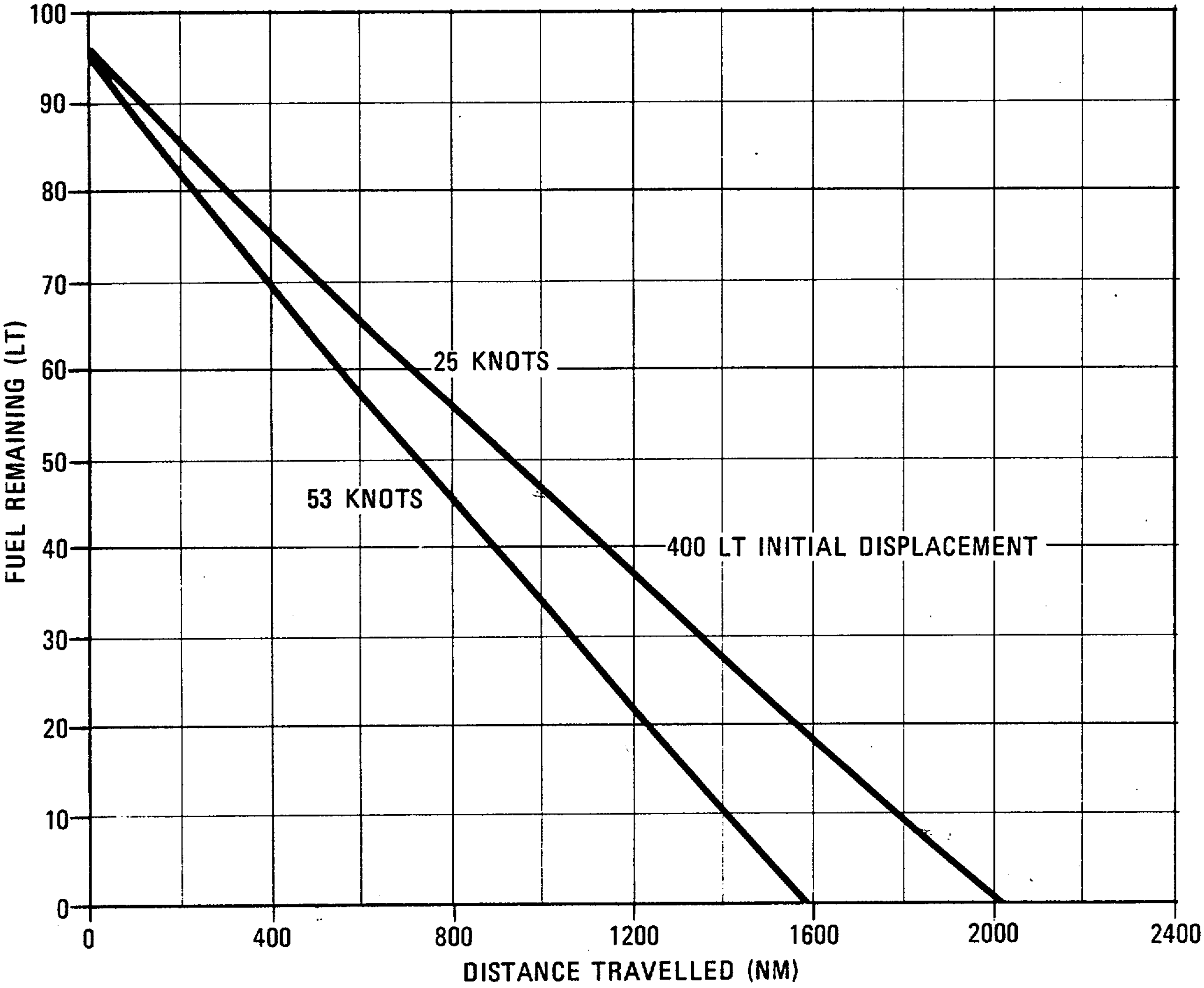


FIGURE 4.3-3
FUEL REMAINING VERSUS CALM WATER
CUSHIONBORNE DISTANCE TRAVELED

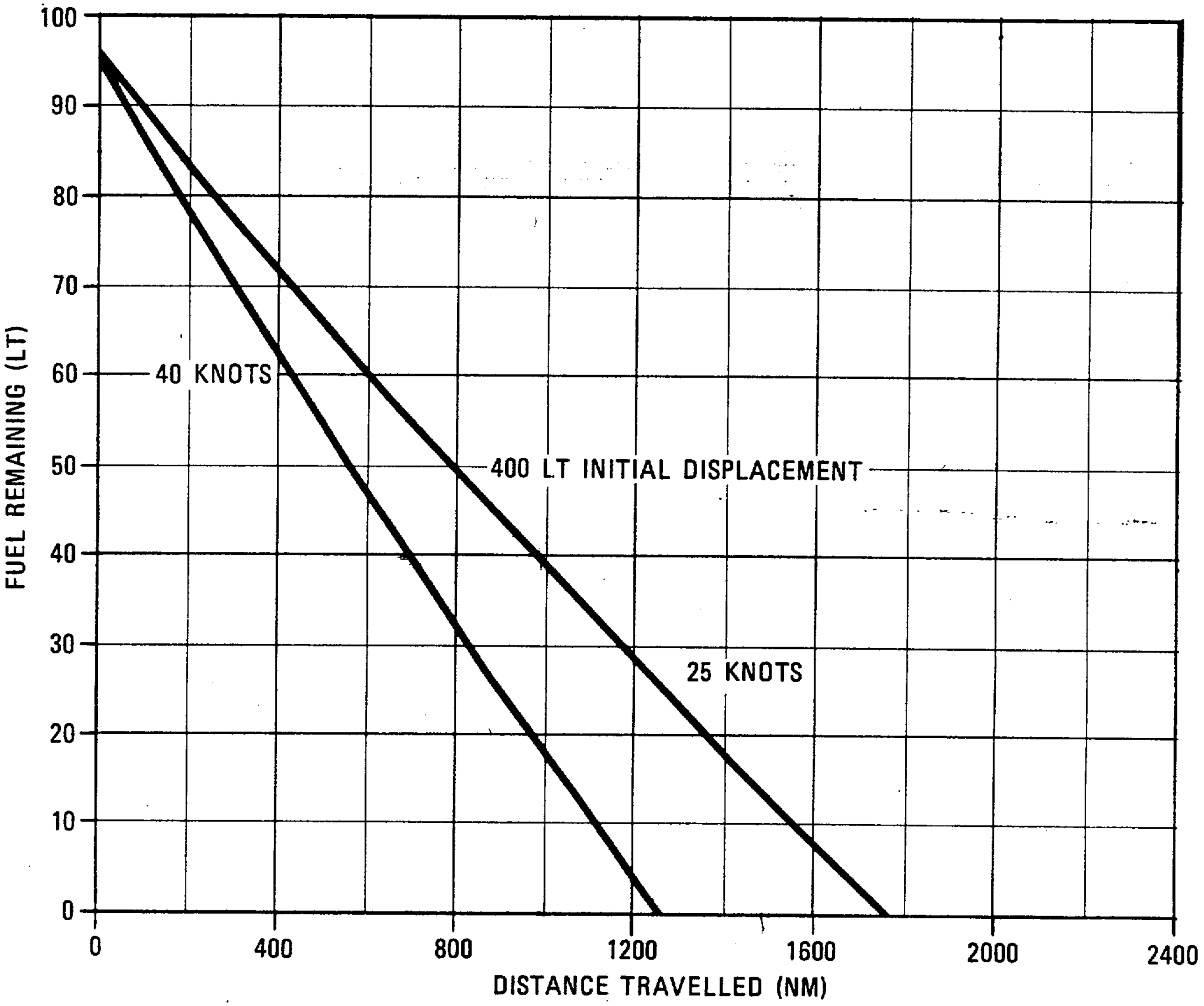


FIGURE 4.3-4
FUEL REMAINING VS
SS-3 CUSHIONBORNE DISTANCE TRAVELED

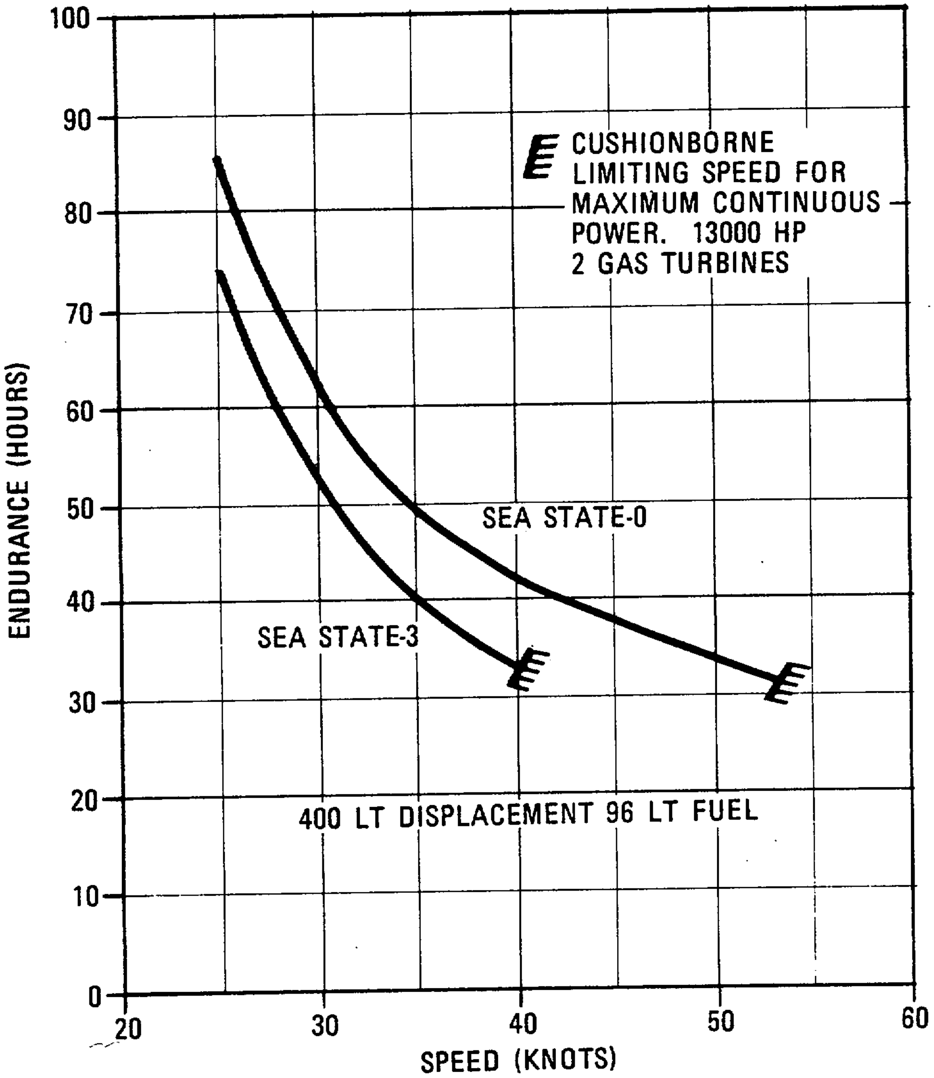


FIGURE 4.3-5
CUSHIONBORNE ENDURANCE VS SPEED

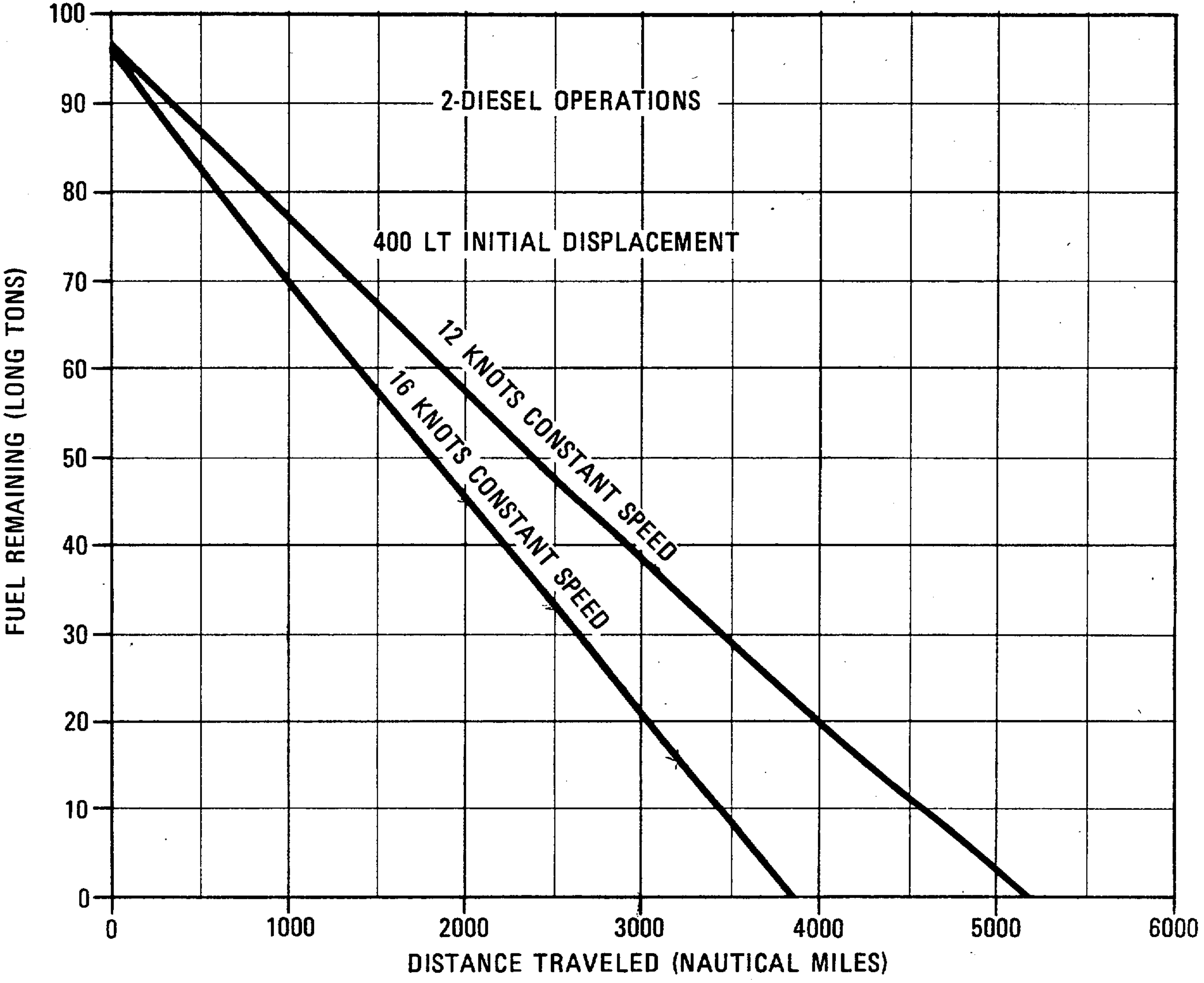


FIGURE 4.3-6
COASTAL SES HULLBORNE SEA STATE-0
FUEL REMAINING VS DISTANCE TRAVELED

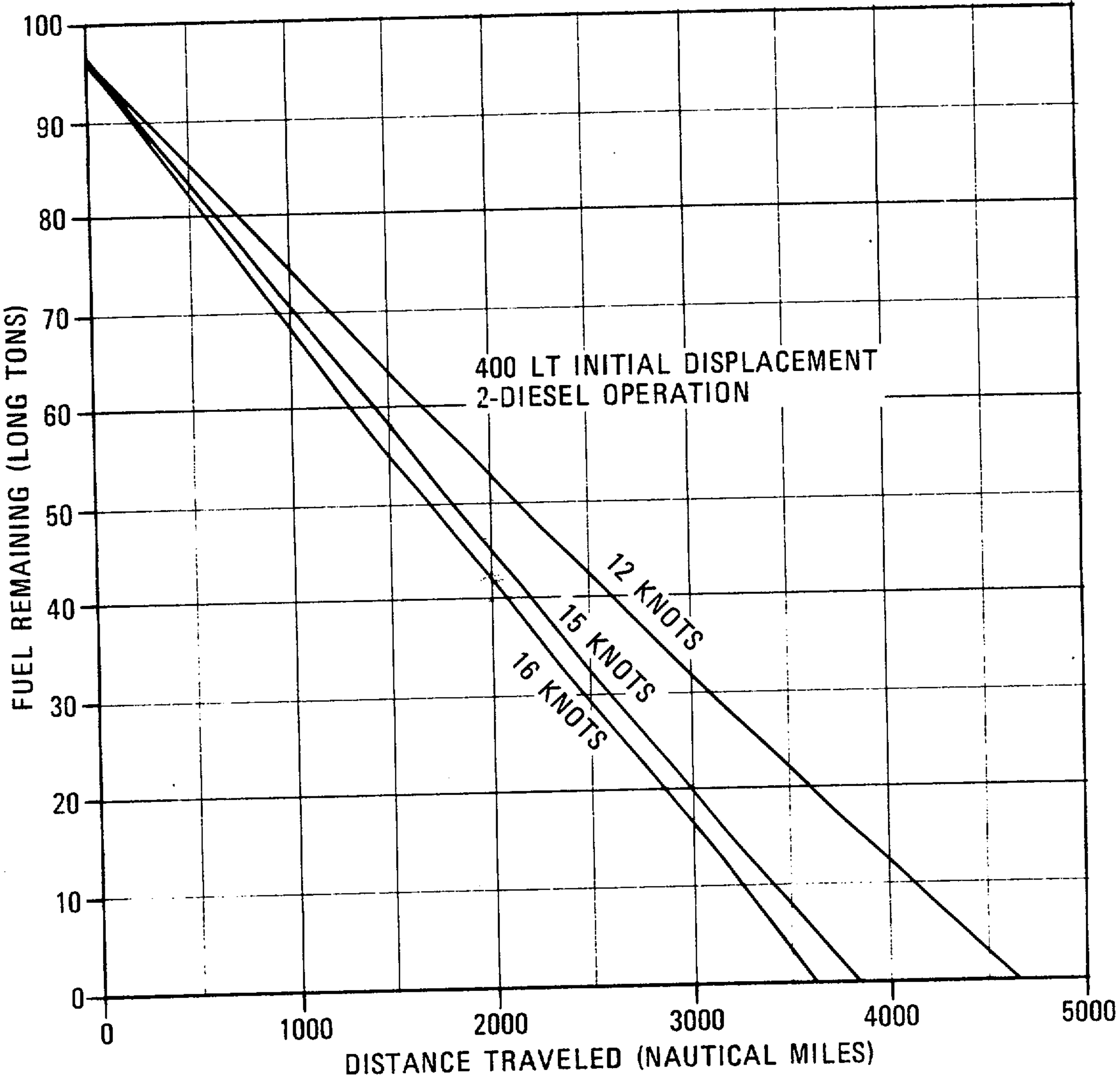


FIGURE 4.3-7
COASTAL SES HULLBORNE SEA STATE-3
FUEL REMAINING VS DISTANCE TRAVELED

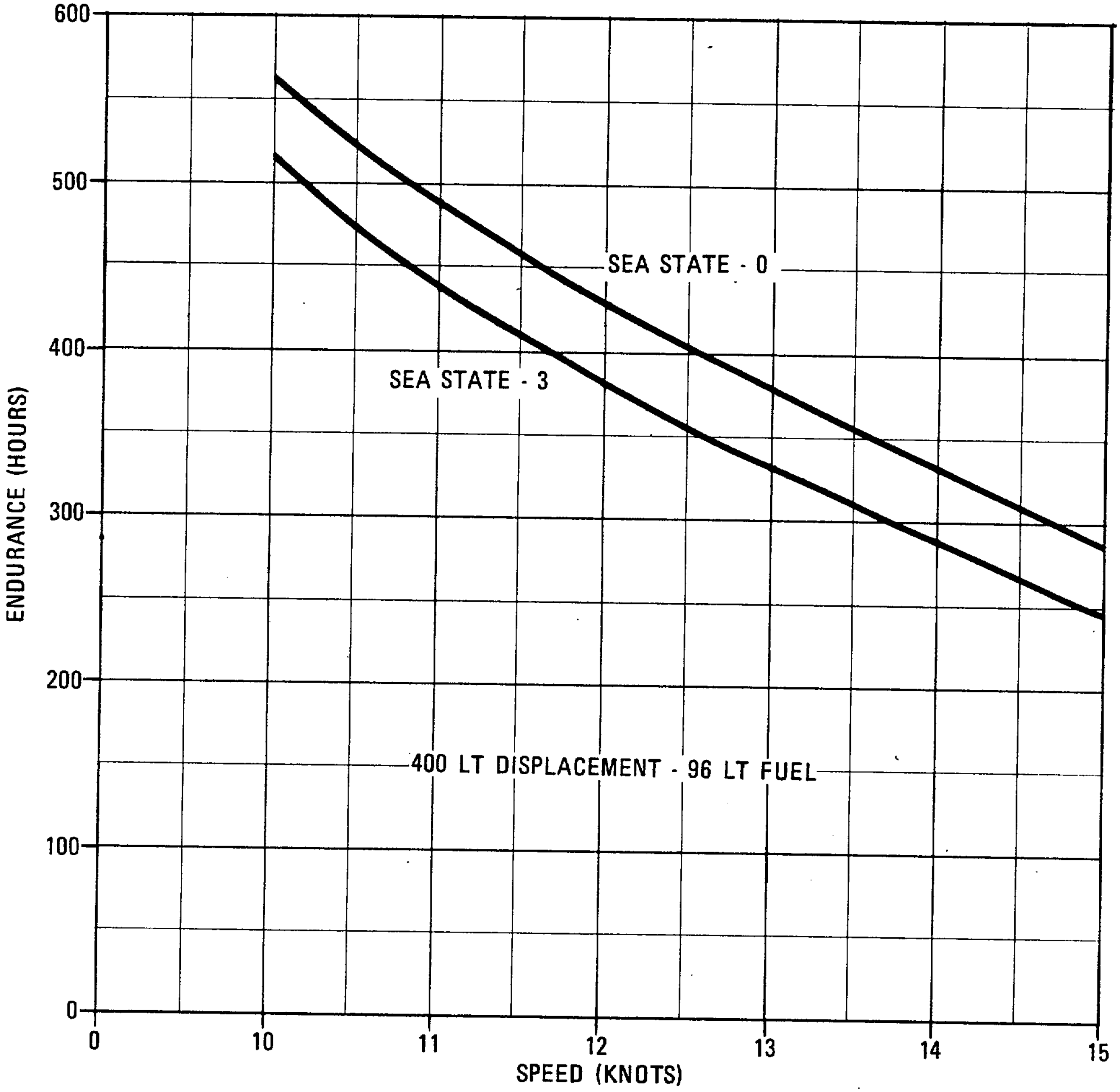


FIGURE 4.3-8
COASTAL SES HULLBORNE ENDURANCE VS SPEED

For the hullborne mode and for docking, the differential and reversing capability of the propellers ensure that under normal circumstance the ship has excellent low speed maneuverability.

4.5 STABILITY

The intact and damage stability investigation of the CSES is based on the requirements of NAVSEA DDS 079-1. Computations used for another high L/B design were adapted to the CSES. A number of different loading conditions which cover the full range of payload/fuel combinations were considered.

4.5.1 Intact Stability

Calculations show that the intact stability far exceeds Navy requirements. The physical explanation for this is that the "catamaran" arrangement of the CSES produces considerable roll stiffness. Thus, for a 100 knot beam wind, roll angle is in the range of 1 - 2 degrees. For the worst loading case considered, the range of positive stability exceeds 60 degrees. It is considered that the range of stability combined with the high roll stiffness is sufficient to ensure a safe ship in any envisioned operational sea state.

4.5.2 Stability in Damaged Condition

Damage stability was examined for the two conditions of longitudinal damage specified in DDS 079-1 Part III, namely, a shell opening equal in length to 15 percent of the design water line length with 50 percent penetration, and a shell opening equal to 50 percent of the design water line length with transverse extent to the first inboard longitudinal bulkhead (no less than 10 percent of the beam). The two conditions were considered in conjunction with various payload/fuel combinations. For all cases considered, the ship satisfied the NAVSEA criteria. The margin line in the forward and after sections of the CSES will be sufficient to result in a satisfactory damage stability for all specified cases.

4.6 MOTIONS AND RIDE QUALITY

The ride quality and motion predictions over the operational envelope of the CSES are considered to be fully satisfactory. It is predicted that, at speed, the CSES ride quality will be better than or comparable to that experienced by conventional Navy ships of similar size. In fact, the CSES ride will be significantly better when operating at the same speed as conventional ships.

The CSES motions predictions are based on data backed by extensive experimental and analytic activities directed by the SES Program Office over the past twelve years. These activities include full scale manned tests of the SES 100A, SES 100B and XR-1 testcraft both with and without ride control, sub-scale model tow tank tests to support ride quality and motions predictions for the above manned testcraft as well as for the larger 2KSES and 3KSES. In parallel with the above, numerous analytical tools have been developed and validated including a sophistocated Six-Degree-of-Freedom motions digital computer simulation. Additional supportive information concerning SES ride quality in a seaway has been provided by the commercial Bell-Halter BH-110 SES which has been operated extensively in the Gulf of Mexico and the Atlantic for the past two years. This 110 foot, 107 ton SES has operated in 8 to 10 foot waves at speeds near 30 knots without adverse effects on crew or equipment.

The cushionborne motions of the CSES in sea states have been determined principally by analyzing the data from tests on a manned testcraft (XR-1D) that is specifically equipped and instrumented for studying motions and ride control. These tests determined experimentally, the estimated heave and pitch motions of the CSES both without and with ride control at various speeds and sea states. Figure 4.6-1 illustrates the sea states in which the CSES is intended to operate and for which XR-1D at sea trials data are applicable. It shows that quarter scale XR-1D operations have been conducted in equivalent CSES sea state 7 with significant wave heights of 28 feet.

Figure 4.6-2 shows three sets of curves. One is a set of four giving the criteria developed by SESPO and shows the limiting vertical accelerations in the principal frequencies of interest relative to motion sickness and extended duration. The second set consists of one curve developed by ANVCE for the 4 hour limit. The third set consists of the data derived from the aforementioned tests and correspond to 60 knots speed in SS-3. It is seen that without ride control the accelerations in the 0.5 - 1.5 Hz region slightly exceed the SESPO 4 hour limit but falls well within the ANVCE limit. With ride control the accelerations are consistant with long term habitability. Figures 4.6-3, 4.6-4 and 4.6-5 indicate the degree of modulation of vertical accelerations in the CSES provided by the ride control system, in terms of power spectral density, while operating at 50 to 60 knots in Sea States 3, 4 and 5 head seas respectively. The intensity of these worst case vertical motions can be substantially reduced by lowering ship speed or by turning slightly away from head-seas.

Based on this analysis of the XR-1D data, and earlier successful operations of the manned XR-5 at 25 knots in sea states with significant wave heights greater than the wet deck height of the craft, without a ride control system, it is concluded that the CSES will have attractive ride qualities in all seas and that ride control will not be required in Sea State 4 or below.

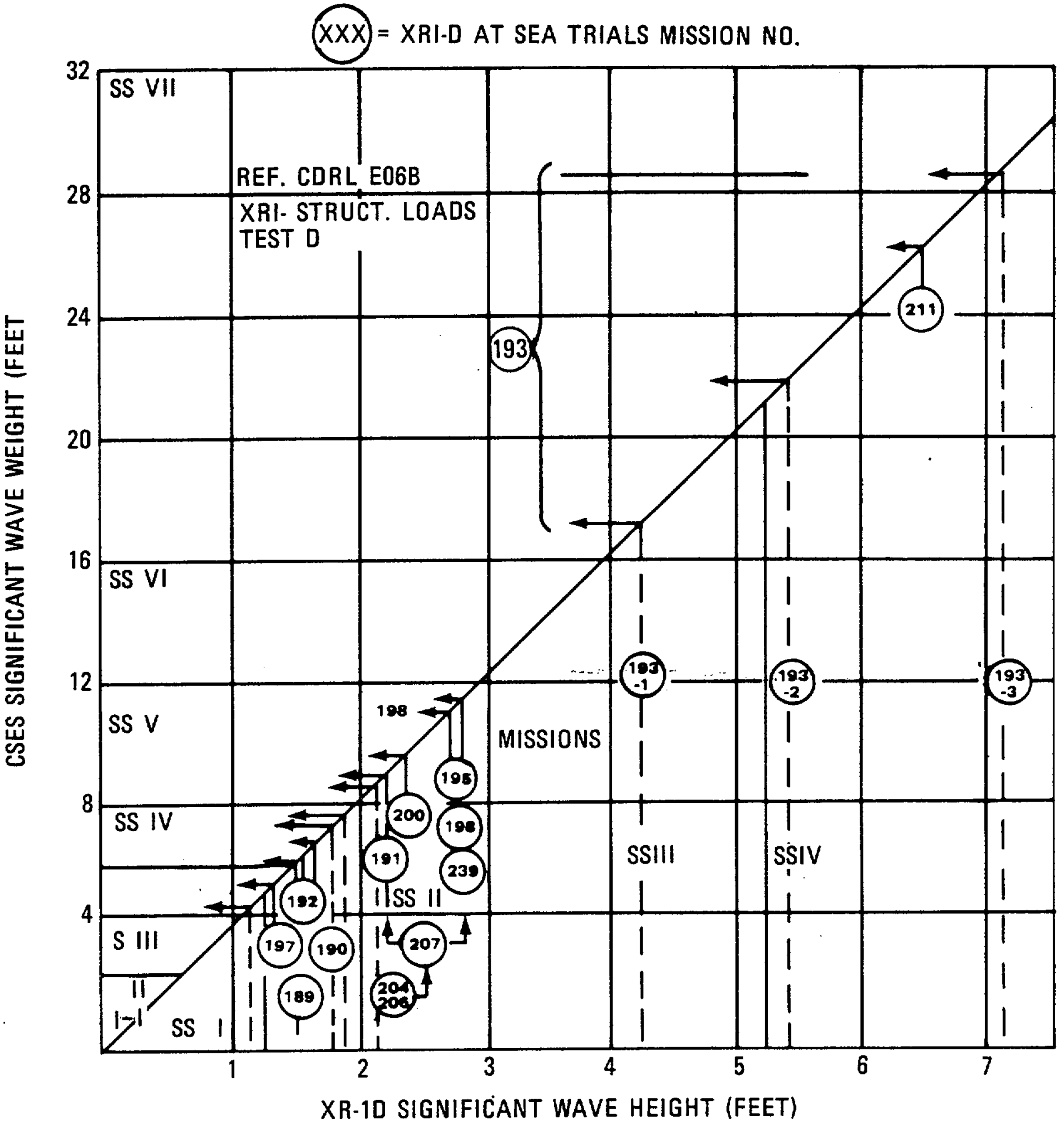


FIGURE 4.6-1
SEA STATE EQUIVALENTS XR-1D – CSES

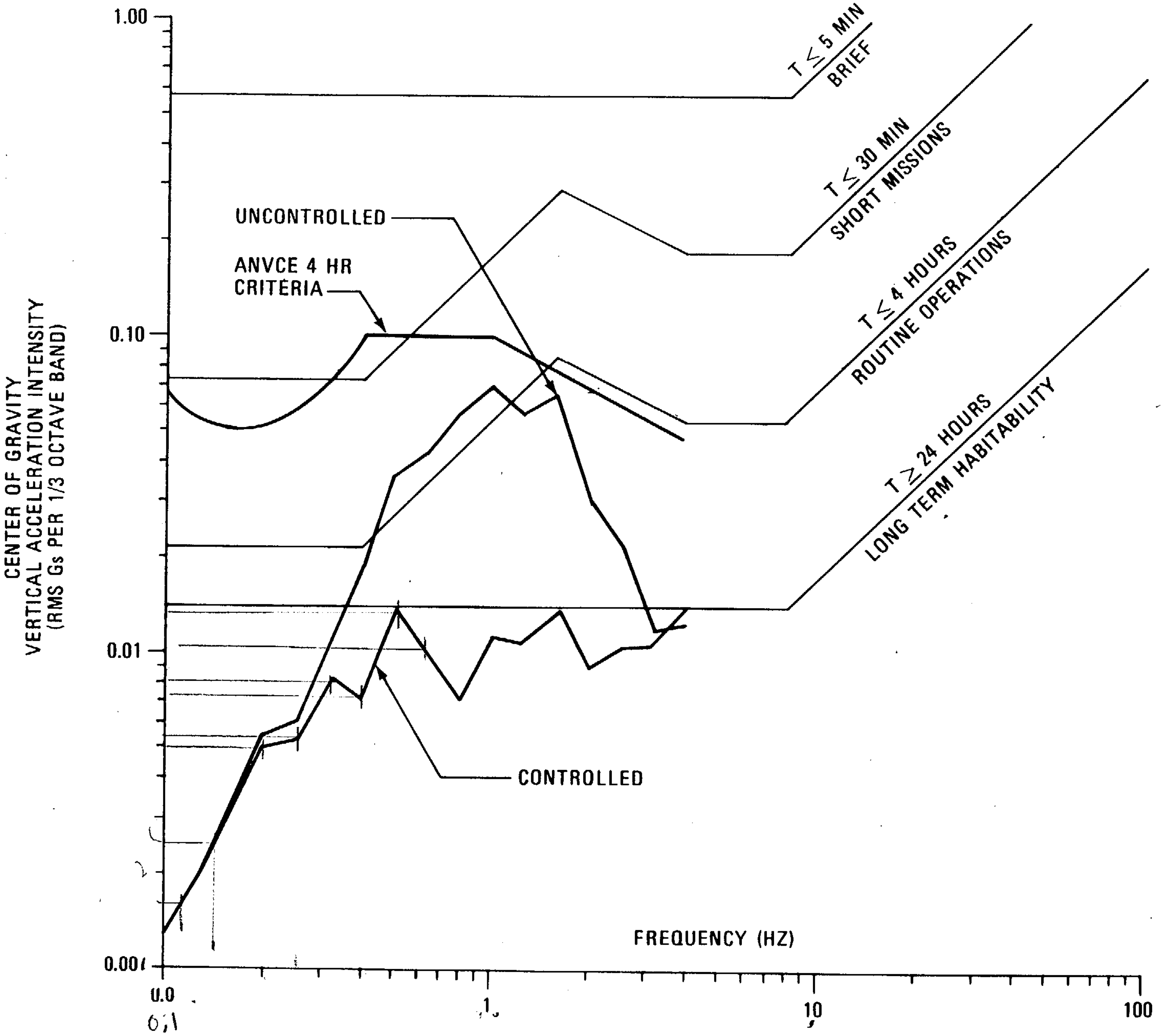


FIGURE 4.6-2
CSES ACCELERATION VERSUS FREQUENCY(SEA STATE-3 – 60 KNOTS)

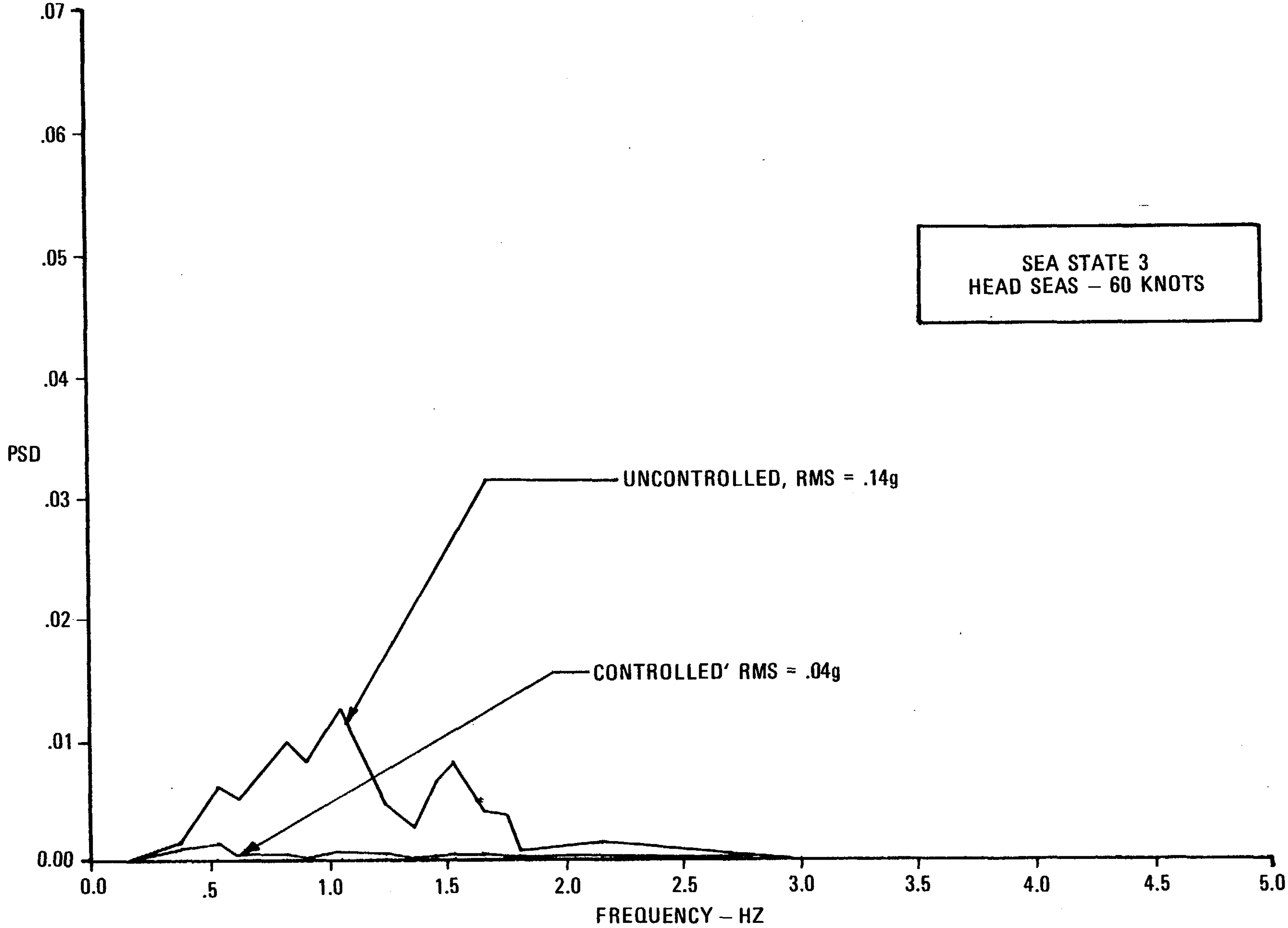


FIGURE 4.6-3
60 KNOTS POWER SPECTRAL DENSITY VERSUS FREQUENCY SEA STATE-3

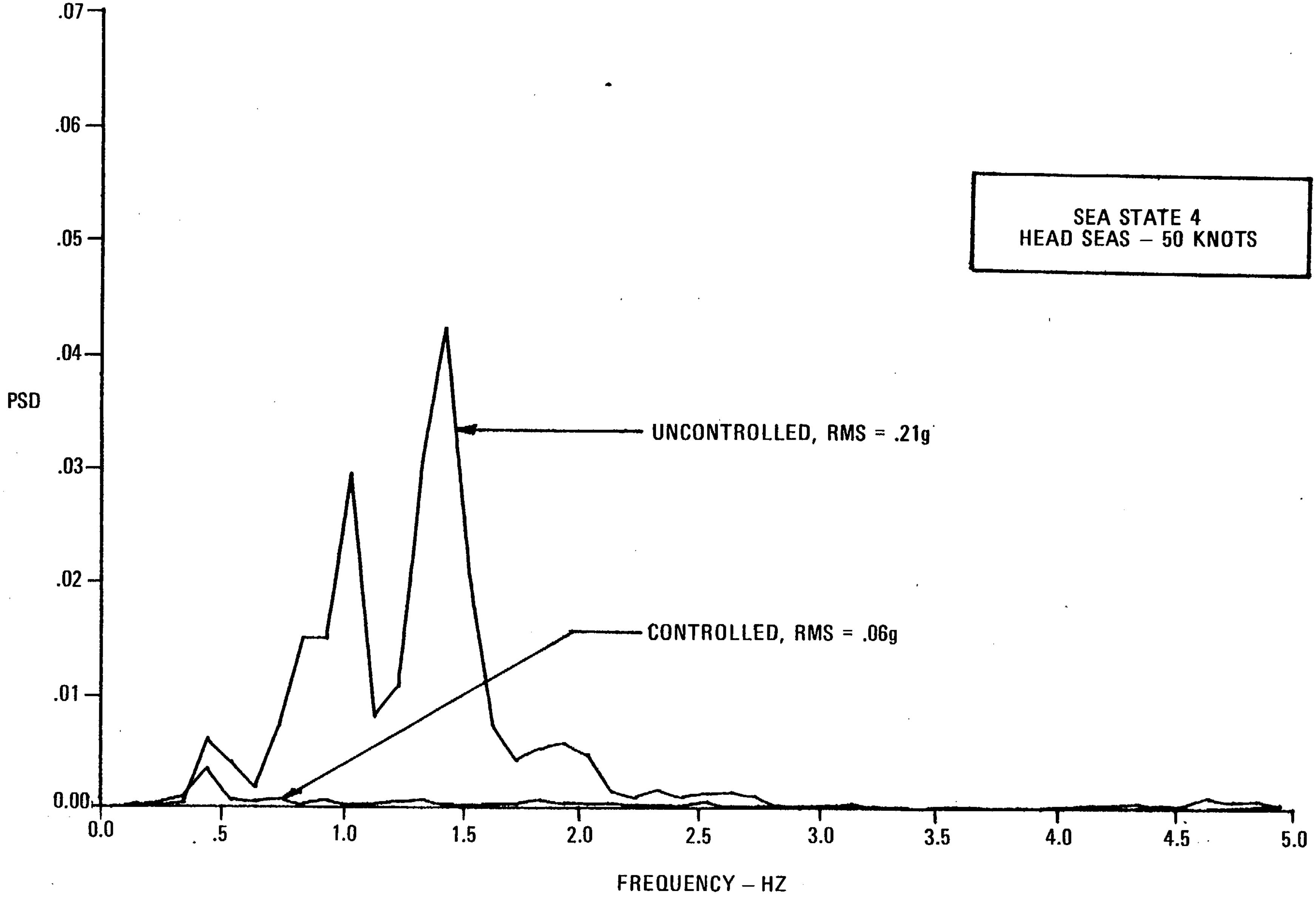


FIGURE 4.6-4
50 KNOTS POWER SPECTRAL DENSITY VERSUS FREQUENCY SEA STATE-4

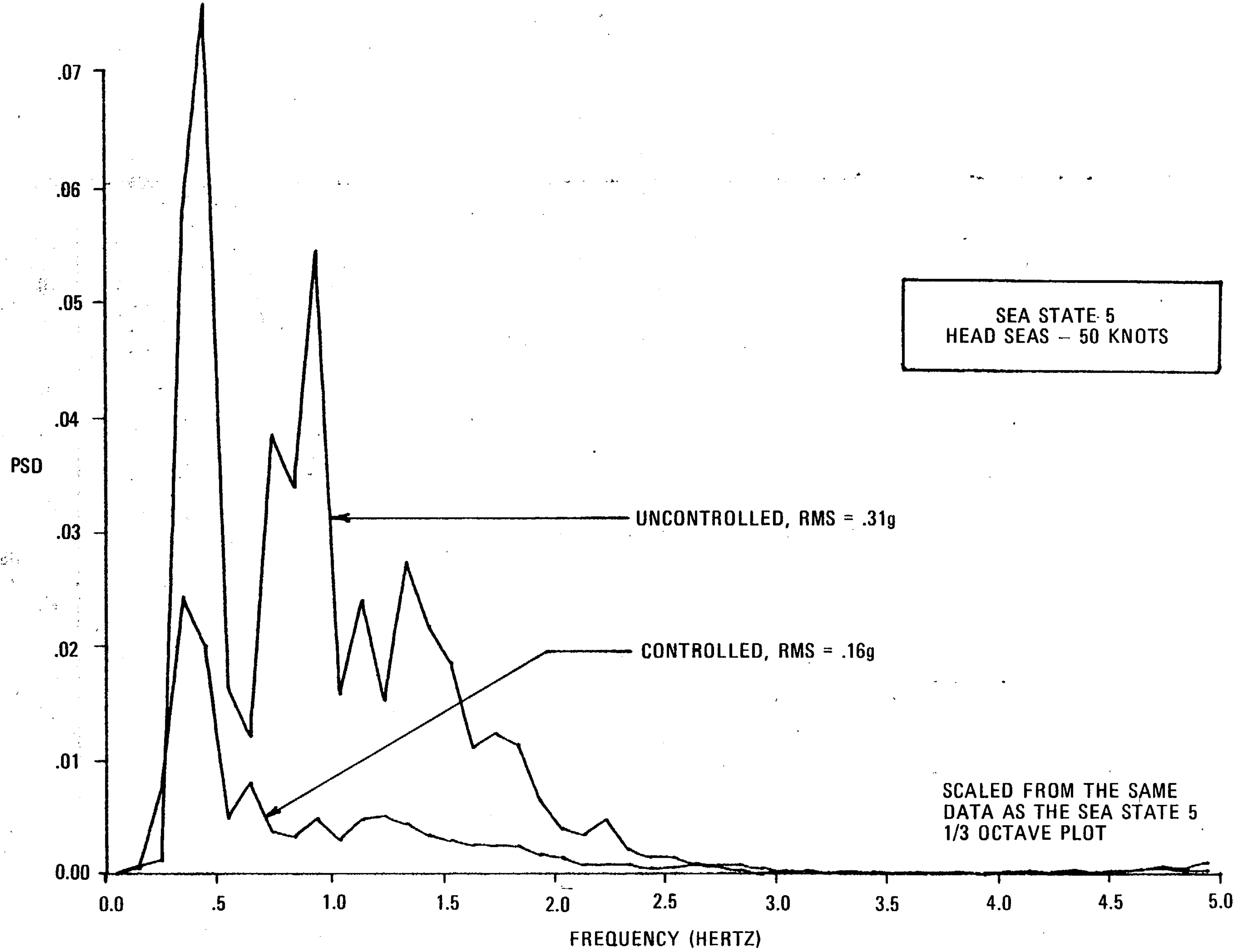


FIGURE 4.6-5
50 KNOTS POWER SPECTRAL DENSITY VERSUS FREQUENCY SEA STATE-5

5 SUBSYSTEM DESCRIPTION

5.1 HULL STRUCTURE

5.1.1 Structural Arrangement

The cross-sections representing typical CSES frame and transverse bulkhead structures are shown in Figures 5.1-1 a and b.

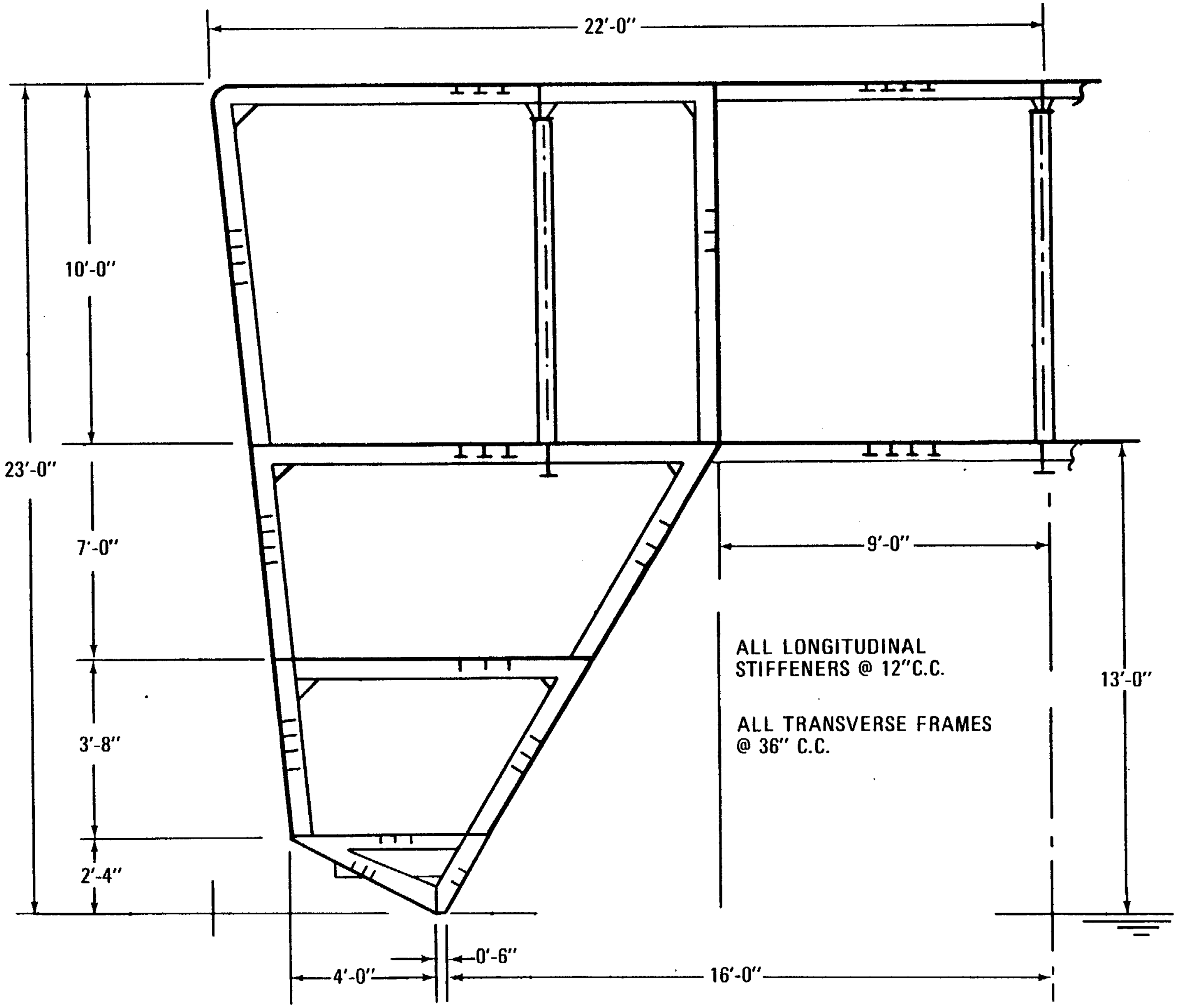
The hull is an all-welded, marine grade aluminum alloy structure consisting of a box-like centerbody with integral catamaran-like rigid sidehulls. The sidehulls are faired for proper hydrodynamic performance. At fore and aft locations the sidehulls and centerbody form rectangular openings which are compatible with the bow and stern seals arrangements. The sidehulls serve as end closures for the transverse cushion seals and relieve the critical seam stresses. The sidehulls are designed to provide sufficient volume to accommodate CSES fuel, much of the machinery and enough buoyancy to place the bottom of the second deck approximately 6 feet above the water when the craft is hullborne. This 6 foot clearance and the 30 degree bow ramp angle tend to reduce critical hullborne slamming loads and result in a more efficient overall hull configuration, and lower structural weight.

The basic building block of the hull structure is the longitudinally stiffened panel supported by integral transverse frames, Figure 5.1-2. This basic arrangement is maintained throughout the majority of the ship structure. In the bow area Figure 5.2-1a, however, the transverse frames are eliminated and longitudinal stiffners increased in size in order to withstand high slamming pressures. This results in approximately a 20 percent (about 1.4 LT) increase in the weight of the bow section. The disadvantage of weight increase is offset by lower fabrication costs due to improved accessibility and weldability of the bow structure.

The second deck structure in fore and aft areas is stiffened using an arrangement similar to the one shown in Figure 5.1-2 except that stiffeners and frames are located on the "wet" side of the deck and the stanchions are located internally. The longitudinal girders distribute slamming pressures to the adjacent frames and transverse bulkheads and provide a more efficient structural arrangement. This arrangement also makes the deck structure easier to fabricate, inspect and repair, and tends to lower local slamming pressures. Lightweight removable panels are installed at the seal/deck interface areas to provide a smooth surface and prevent seal material damage due to contact with the frames and stiffeners. This second deck stiffener arrangement has no effect on CSES performance in the cushionborne mode, but during hullborne operation in high sea states results in a small increase in drag, when the deck bottom is occasionally wetted by high waves.

5.1.2 Operational Envelopes

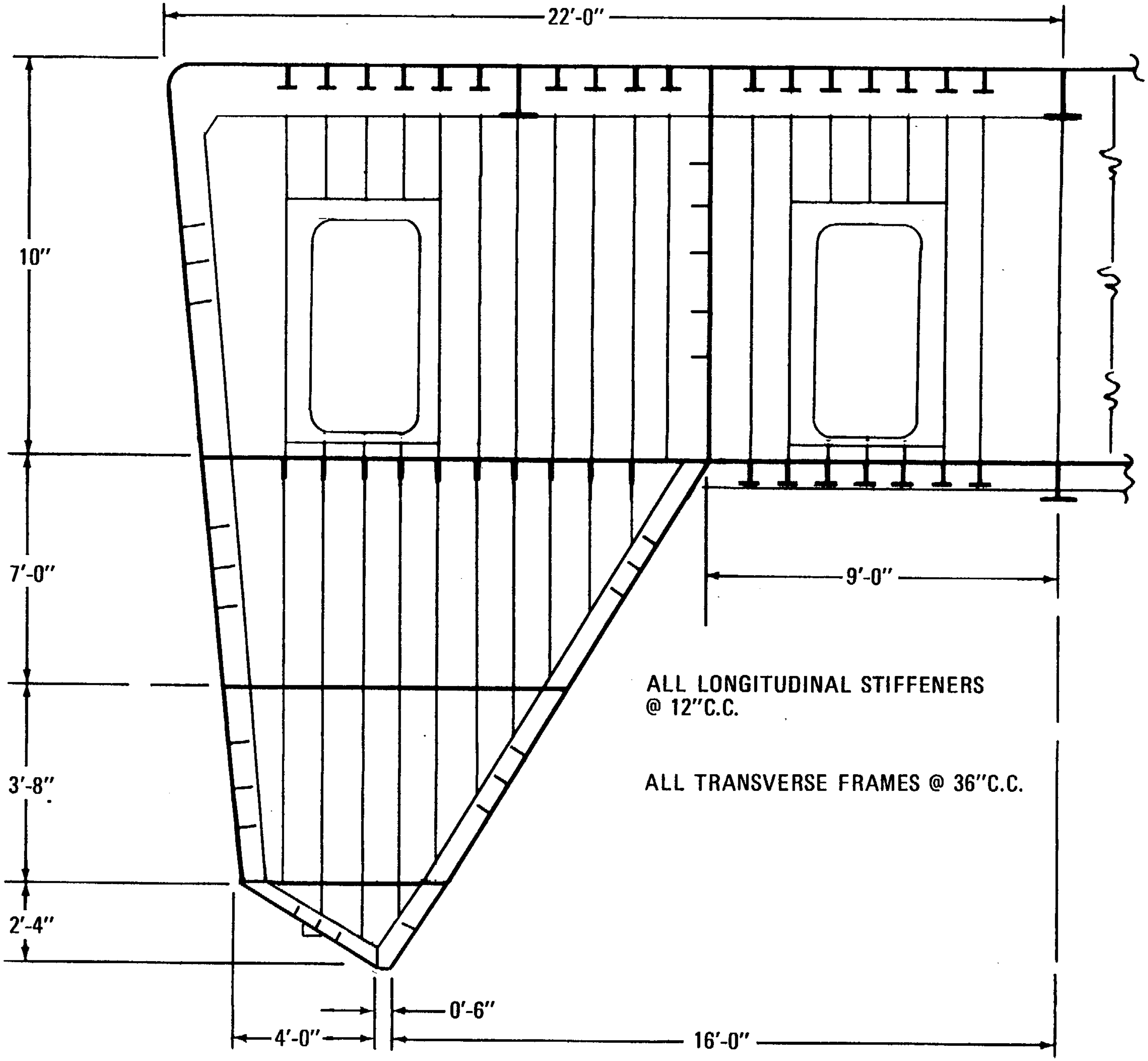
The CSES is designed to operate in coastal waters and narrow seas of the Atlantic and Pacific. The operational life of the craft is twenty years, of which it is estimated that 35 percent will be spent at sea within the performance envelope provided in Table 5.1-i. Of these, approximately 2/3 of the operations will be cushionborne and 1/3 hullborne.



ALL LONGITUDINAL STIFFENERS @ 12"C.C.

ALL TRANSVERSE FRAMES @ 36" C.C.

FIGURE 5.1-1 a
TYPICAL MIDSHIP FRAME SECTION



ALL LONGITUDINAL STIFFENERS @ 12"C.C.

ALL TRANSVERSE FRAMES @ 36"C.C.

FIGURE 5.1-1b
TYPICAL TRANSVERSE BULKHEAD

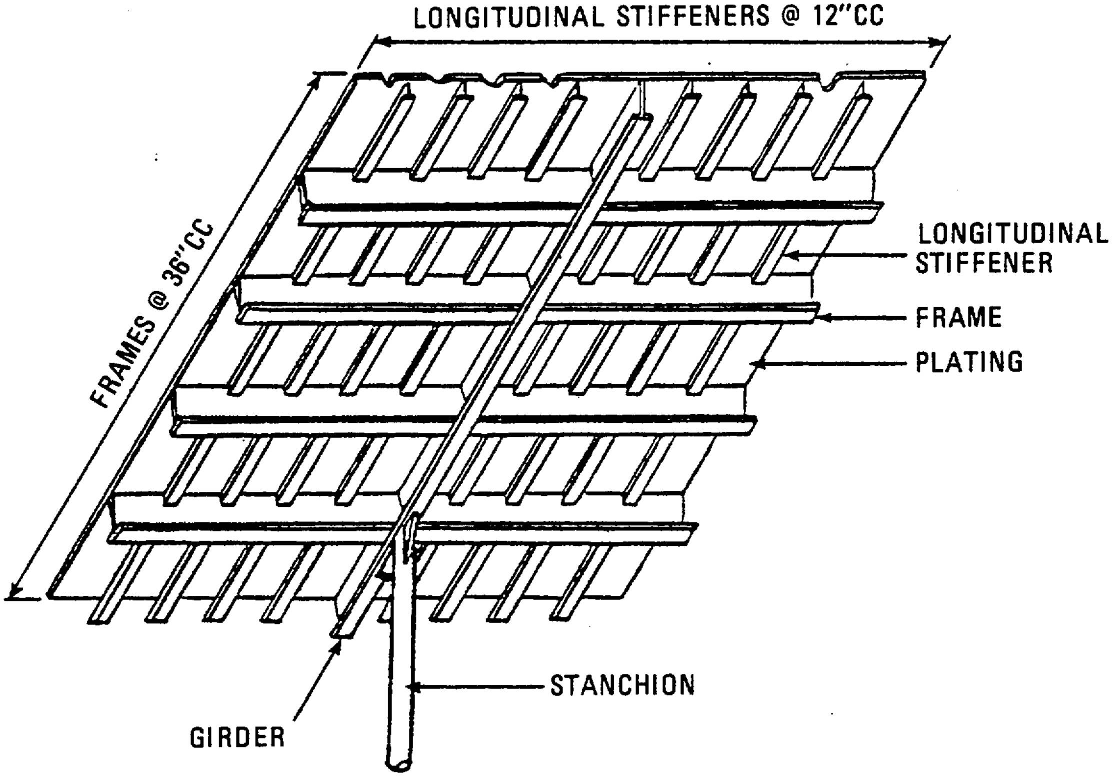


FIGURE 5.1-2
TYPICAL STIFFENED PANEL STRUCTURAL ARRANGEMENT

CSES PERFORMANCE ENVELOPE

OPERATIONAL MODE		SEA STATE	V_K (Kt)	HEADING
I	Cushionborne	0	57 Knots	Any
II	Cushionborne	6	TBD*	Any
III	Hullborne	3	20 Knots	Any
IV**	Hullborne	6-7	2-3 Knots	Any

*Forward velocity should be adjusted to obtain same loads as hullborne conditions IV

**Partial cushion operation may be used to reduce loads

TABLE 5.1-i

5.1.3 Structural Design Criteria

The loads criteria for this craft are based on tests conducted with a length-to-beam (L/B = 5) model in the David Taylor Naval Ship Research and Development Center (DTNSRDC) towing tank. All test were with the model in the hullborne mode. Previous experiments with the 3KSES structural models, have shown that hullborne hull girder loads are more severe than cushionborne loads and therefore govern the design.

Figures 5.1-3 a and b show test data and Weibull statistical distribution curve fit, which were used to extrapolate the loads to the desired probability of 0.999. This value may be interpreted as a one-in-a-thousand chance that the hull girder design loads will be exceeded in the course of the 20 year life of the ship. From the characteristics of the CSES hull it is considered that the maximum loads will occur somewhere in sea state 6 - mid 7 wave height range. Wave heights higher than twenty feet will not produce an appreciable increase in hull girder loads because of reduction of slamming intensities and lower wave induced loads. This is due to "contouring" effect which occurs when the wave lengths corresponding to this wave height become longer than the length of the craft which then mainly follows the wave slopes and frequency so that intensity of slamming is diminished. Since the test environment was limited to approximately 11 feet high significant wave (CSES scale), the loads shown on Figure 5.1-3 were increased by 50 percent to account for higher (Mid Sea State 7) waves. Figure 5.1-4 summarizes the CSES hull design criteria.

The slamming pressure envelopes shown on Figure 5.1-4 are based on manned SES test data specifically XR-1C hullborne tests. These pressures are generally in consonance with the design pressures used in 100 Ton SES design and recently in Bell-Halter craft structural modifications. Safety factors specified in Figure 5.1-4 are based on risk analyses performed under the 3KSES program and account for uncertainties related to the variables associated with loads, materials, analysis and fabrication. Conservatism is provided by using the minimum rather than the average material properties which are 10 - 15 percent higher.

NOTE 1: MEASURED AND EXTRAPOLATED HULL GIRDER LOADS AT FORWARD 1/4 POINT OF L/B = 5 MODEL

OBSERVED DATA ————

WEIBULL DISTRIBUTION – – – –

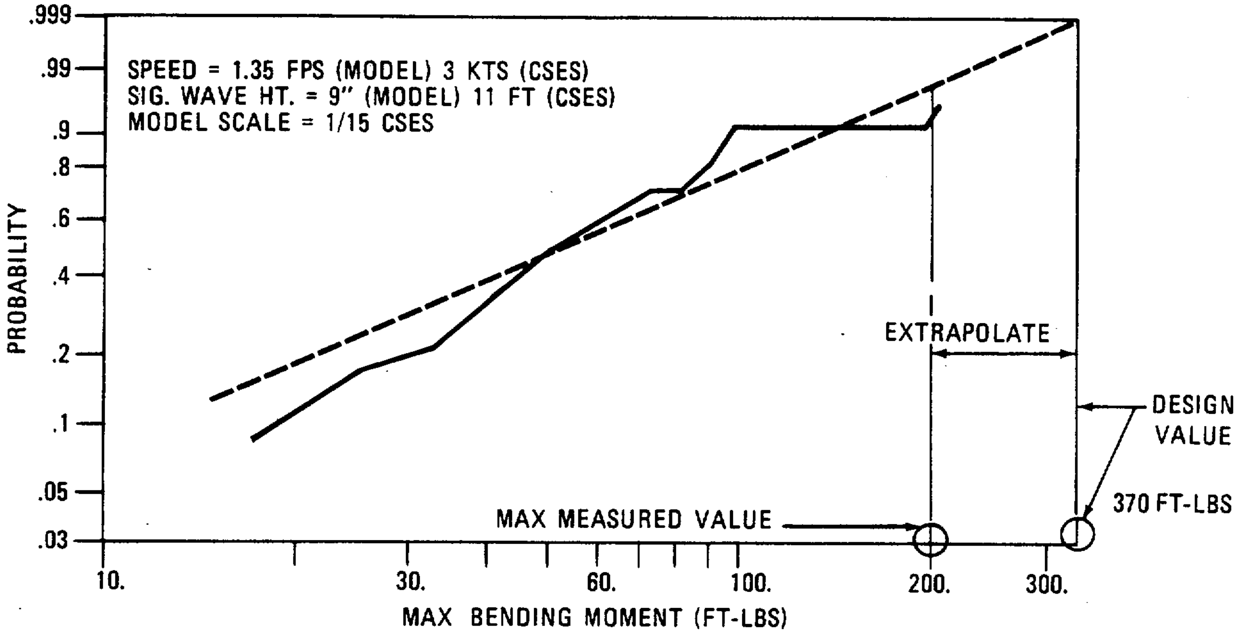


FIGURE 5.1-3 a
PROBABILITY VERSUS MAXIMUM SHEAR

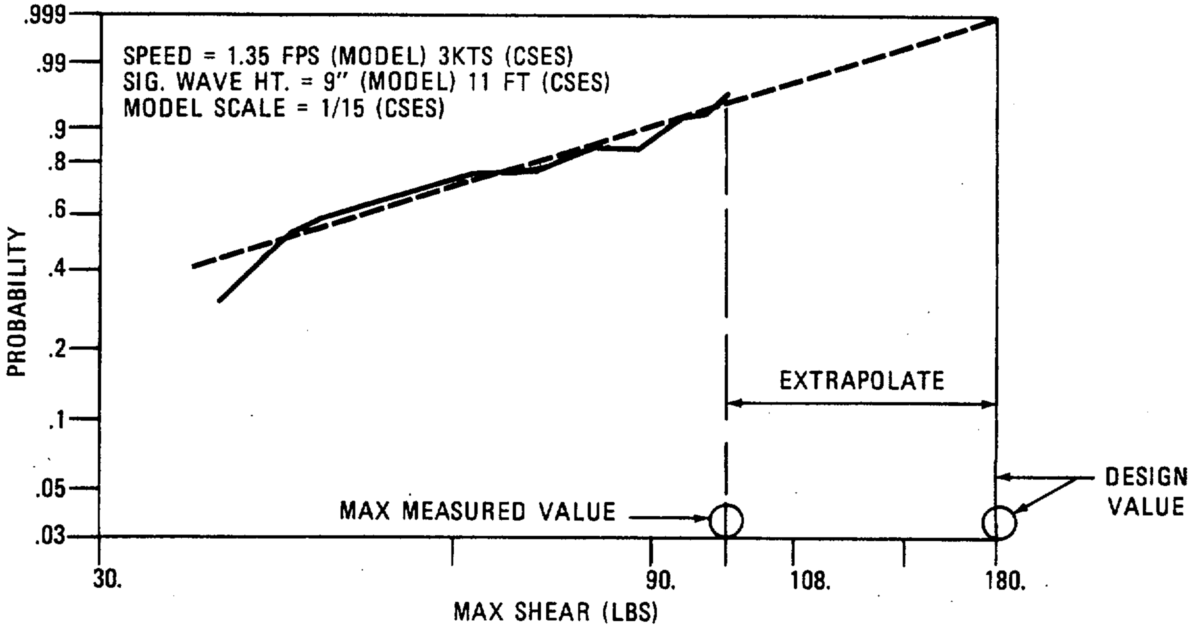


FIGURE 5.1-3b
PROBABILITY VERSUS MAXIMUM SHEAR

FIGURE 5.1-3
WEIBULL STATISTICAL DISTRIBUTION CURVES

NOTES:

1 HULLBORNE & CUSHIONBORNE HULL GIRDER LOADS ASSUMED EQUAL

2 SLAM PRESSURES ARE NOT COMBINED WITH HULL GIRDER LOADS

3 LOCAL LOADS (OTHER THAN SLAMMING) ARE COMBINED WITH HULL GIRDER LOADS

4 LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE)
150 PSF (LIVING, OFFICE SPACES)
200 PSF (MACHINERY SPACES)

5 HOGGING BENDING MOMENT IS ONE-THIRD (1/3) OF SAG MOMENT

6 USE 70% OF SLAM PRESSURE FOR FRAME DESIGN

SAFETY FACTORS	YIELD	ULT.
HULLBORNE + LOCAL LOADS	1.2	1.5
CUSHIONBORNE + LOCAL LOADS	1.2	1.5
*SLAMMING PRESSURES	1.0	1.2

*PERMANENT SET TO A MAXIMUM OF PLATE THICKNESS IS ALLOWED

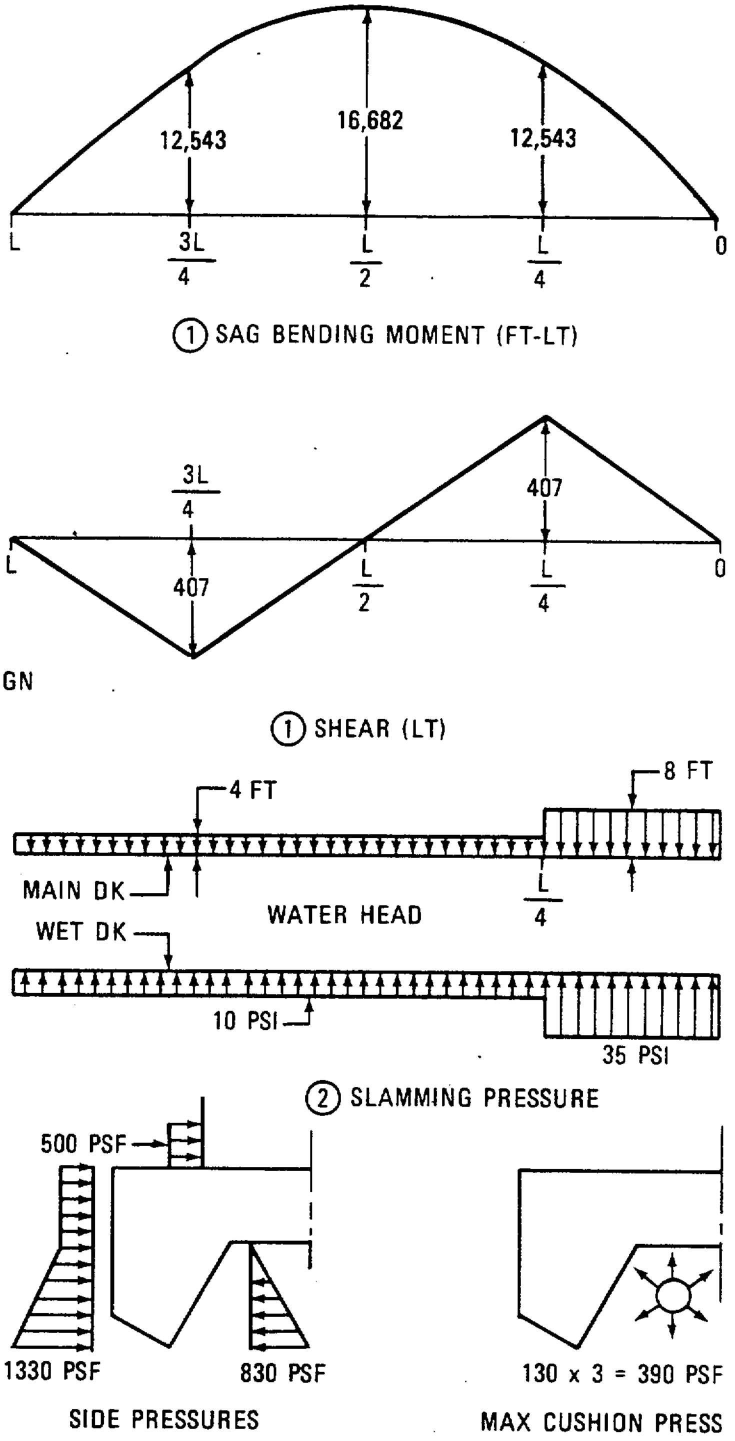


FIGURE 5.1-4
CSES HULL DESIGN CRITERIA

5.1.4 Hull Materials

Candidate materials for the hull structure are summarized in Table 5.1-ii.

CANDIDATE MATERIALS - HULL STRUCTURE

	STEEL		ALUMINUM		
	HY 100	HY 130	5086	5083	*5456
*Hull Weight	1.57	1.51	1.17	1.08	1.00
*Hull Cost	0.50	0.70	.95	.98	1.00

*Weight and Cost relative to 5456 aluminum

TABLE 5.1-ii

Minimum welded mechanical properties for the candidate materials are presented in Table 5.1-iii.

CANDIDATE MATERIALS - WELDED MECHANICAL PROPERTIES

MATERIAL	TENSION		COMPRESSION	SHEAR	
ALUMINUM ALLOYS:	ULTIMATE (ksi)	YIELD (ksi)	YIELD (ksi)	ULTIMATE (ksi)	YIELD (ksi)
Plate 5086-H116	35	19	18	21	11
Extrusion 5086-H111	35	18	17	21	10
Plate 5083-H116	40	24	23	24	14
Extrusion 5083-H111	39	21	20	23	12
Plate 5456-H116	42	26	24	25	15
Extrusion 5456-H111	41	24	22	24	14

TABLE 5.1-iii

Another potential candidate material, not shown in the table above, is C-19 aluminum alloy with a welded yield strength approximately 35 percent higher than the baseline CSES hull material i.e., 5456 aluminum. C-19 alloy is still in the development stage and although attractive, is not considered in the present study. This alloy offers almost 15 LT reduction in CSES hull weight and when available will be considered for follow-on CSES and other SES constructions.

Of the candidate materials, 5083 and 5456 marine grade weldable alloys are rated best suited for CSES hull structure due to low weight, reasonable cost and good mechanical and corrosion resistance properties. 5456 aluminum has been selected as the preferred material. 5086 aluminum has 19 percent lower strength-to-weight ratio as compared to the other two alloys and would result in slightly heavier structure.

All aluminum structures are easily damaged by fire, they must therefore be insulated to keep temperatures below 400 degrees F. Typical passive fire insulation is shown in Figure 5.1-5. This insulation technique will be used in selected areas of high potential fire loading e.g., machinery spaces.

The deckhouse structure will be either all aluminum or constructed from glass reinforced plastic (GRP) sandwich panels bolted to either aluminum or GRP frames as shown in Figure 5.1-6. GRP panels were successfully utilized in the construction of the deckhouses of the USS Southland (DD-743), USS Fletcher (DDR-870) and SES 100A. Although GRP panels are more expensive than aluminum panels, the overall installation and life cycle costs of the GRP paneled deckhouse would be lower. Also GRP structures have better fire, thermal and acoustical insulation properties and greater fatigue resistance than a comparible welded aluminum construction. It is estimated that the weight of the deckhouse constructed from GRP panels and aluminum frames would be about 7 - 10 percent lighter than the comparable all aluminum structure. Greater weight savings could be achieved with fiberglass frames (about 25 percent) but the cost would be much higher than with an aluminum frame assembly. At present, GRP panels supported by aluminum frames are considered a reasonable compromise for CSES deckhouse structure.

5.1.5 Fabrication Considerations

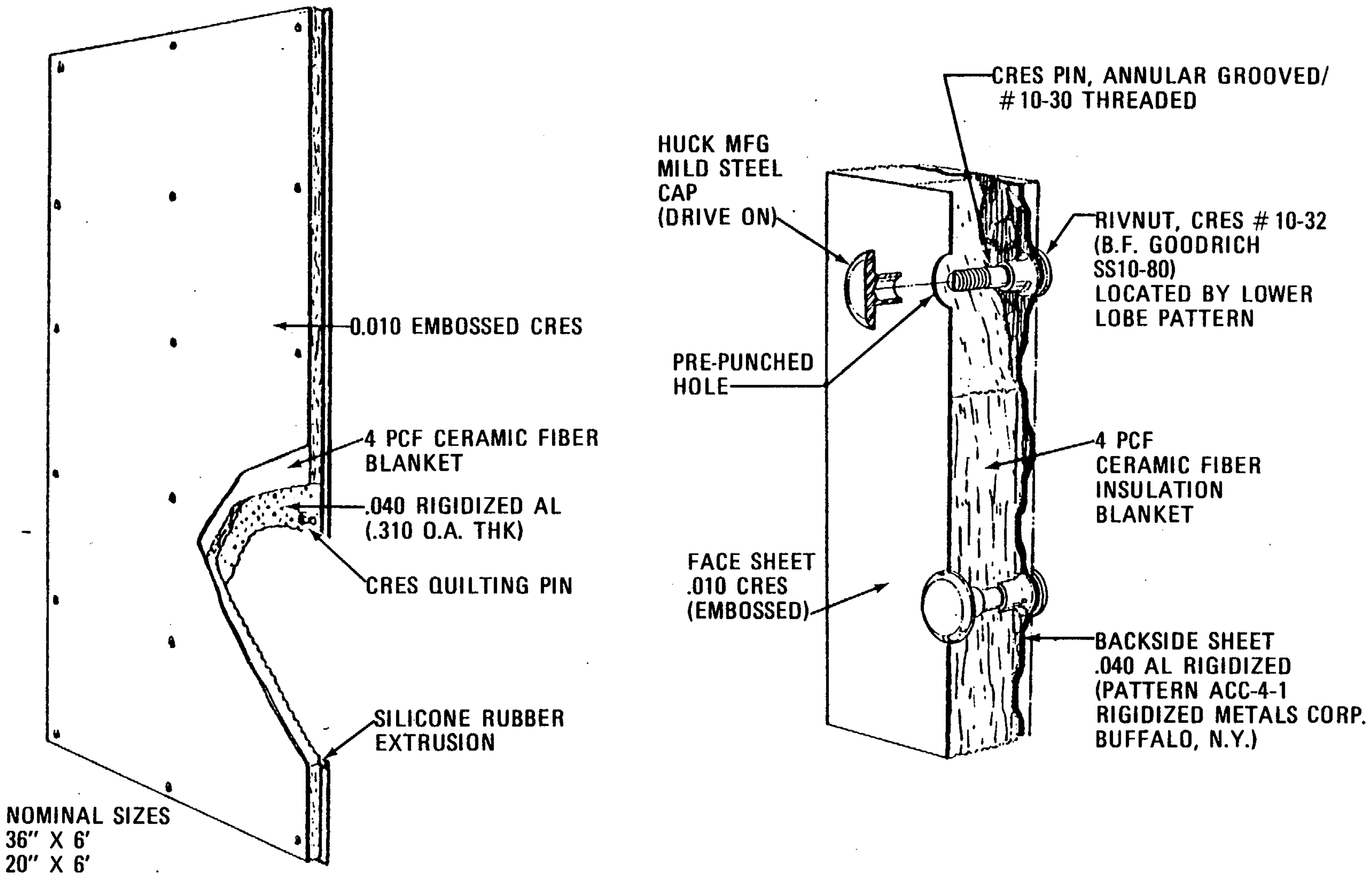
5.1.5.1 General Provisions

The fabrication costs and hull weight are greatly influenced by the choice of minimum material gages. These gages control the design of relatively lightly loaded panels which comprise a significant portion of the CSES structure. The savings in weight and material costs provided by thinner material must be traded against the increased difficulties in welding, distortion control and greater skill and care required to avoid "burn-throughs".

Minimum gages shown in Figure 5.1-7 represent the thinnest or smallest sizes used in the CSES structure. Selection of these gages is based on trade-off studies performed under the 3KSES program.

The influence of stiffener and frame spacing on the cost and weight of stiffened aluminum panels was studied extensively by means of a special computerized optimization program. It was determined that 12 inch stiffener and 36 inch frame spacings represent a good compromise between fabrication cost and structural weight.

Trade-off studies have indicated that the flat bar stiffener is the most economical for many hull areas at a slightly heavier weight. The flat bar stiffeners are cut from the plating and therefore have higher yield strength and are less expensive and more readily available than comparable "T" shape extrusions. The flatbars, however, are inherently less stable than "T" shapes which are more efficient in high pressure areas. The CSES hull utilizes both "T" and flat bars which provides the best arrangement from the standpoint of weight, ease of fabrication and structural strength.



A) STANDARD PANEL(S)

B) DETAIL - QUILTING PIN INSTALLATION

FIGURE 5.1-5
TYPICAL FIRE INSULATION BLANKET

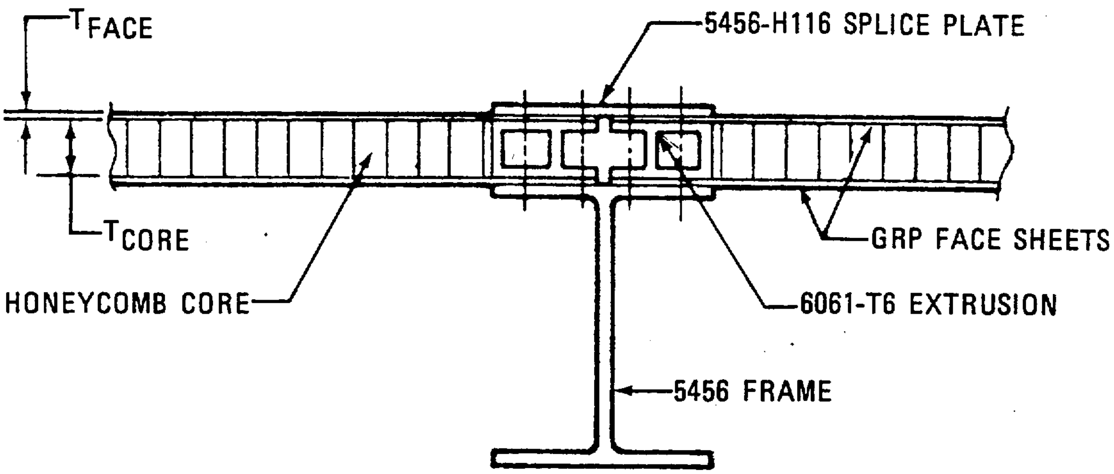


FIGURE 5.1-6A
GRP SANDWICH PANEL SUPPORTED BY ALUMINUM FRAME

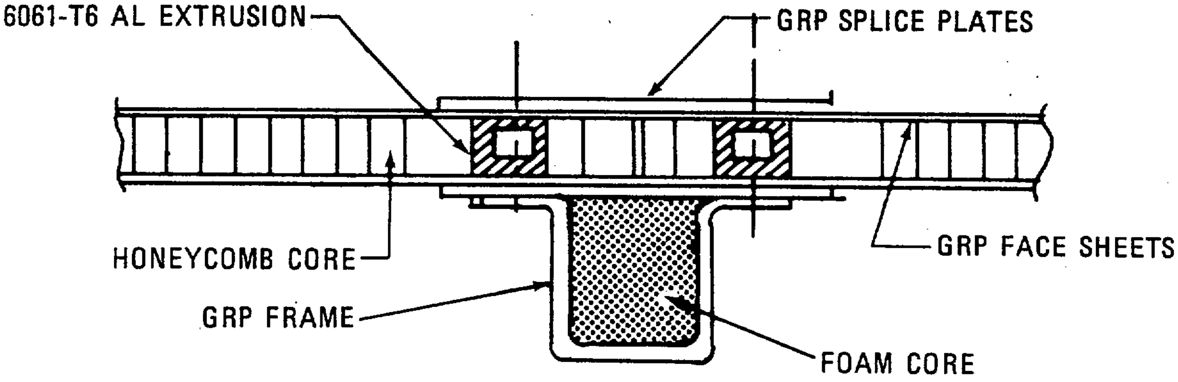
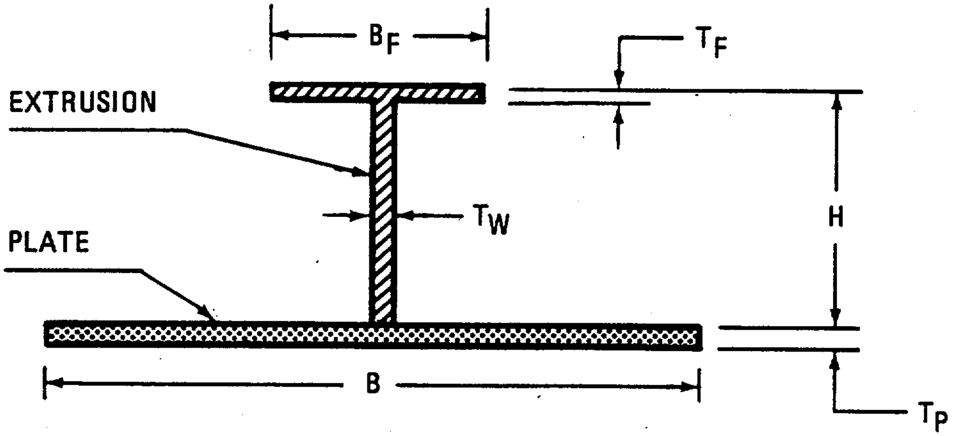


FIGURE 5.1-6B
GRP SANDWICH PANEL SUPPORTED BY GRP FRAME

FIGURE 5.1-6
DECKHOUSE GRP STRUCTUAL DETAILS



T_P = {0.150" (INTERIOR)
{0.180" (EXTERIOR)
T_F = 0.100"
T_W = 0.100"
H = 2.50"
B_F = 1.65"
B = 10"-12"C.C.

FIGURE 5.1-7
MINIMUM GAGE AND EXTRUSION DIMENSIONS

The primary fabrication method for aluminum hull construction is manual gas-metal-arc (GMA) welding, which is relatively fast and requires low capital cost of equipment and reasonable welder skill.

The difficulties encountered in thin aluminum GMA welding, are: a) producing consistently good welds, b) controlling distortion, c) preventing degradation in fatigue performance due to repeated weld repairs. These difficulties are mainly due to lack of proper control with manual welding and can be practically eliminated through use of automated welding equipment.

5.1.5.2 Alternative Welding Methods

Manual welding can be greatly reduced by the use of robot welders such as developed by Unimation Industry in Sweden. The Swedish Kocum shipyard estimated a 50 percent cost saving for specific steel weld joints using this method. It is estimated that the saving for aluminum will be similar. Due to high cost of this equipment it can be considered only for five or more CSES's. For a single prototype CSES, a majority of the welding will be semi-automatic and manual.

The most successful fully automatic welding machine is currently used by Boeing Marine Systems, Seattle, Washington to produce 12 x 40 foot stiffened panels for Patrol Hydrofoil Missileship (PHM). An alternative to the Boeing type equipment is a mechanised hand-held GMA welding gun which automatically controls the gun attitude and rate of travel. This technique was successfully used during SES-100A hull modifications and during construction of the fabrication module and panels for 3KSES program. Two types of this equipment, Pacer for butt welds and Wiggler for fillet welds were successfully used in the SES program.

Other techniques suitable for aluminum welding include: gas tungsten arc (GTA), plasma arc (PA) and electron beam (EB) welding. GTA welding is slow and useful mainly in weld repair operations. PA welding is being used for Roland missile construction. It is fast and significantly reduces distortion and improves weld quality. The main drawback is the lack of shipyard experience in PA welding. EB welding provides excellent quality welds but require vacuum chambers which limit the size of the workpiece. Existing electron EB chambers can accommodate up to 4 feet x 8 feet size panels. The need for maintaining a vacuum around the area welded and the high capital cost are the disadvantages associated with this technique.

A special weld-forging method developed by Alforge Company appears attractive. It is capable of producing low distortion high quality welds at less than 50 percent of the cost of conventionally welded panels. The Alforge welded aluminum panels have been successfully used in the construction of dump truck bodies. The possible drawback of this method is availability of aluminum extrusions. The panels welded by the existing Alforge equipment cannot exceed the maximum 8 foot width which limits their use to transverse bulkheads of the CSES.

5.1.5.3 CSES Hull Construction

The CSES hull design is inherently suitable for automated welding. Most of the structure consists of flat two dimensional elements and repeatable structural subassemblies. These characteristics suggest a modular construction approach where the hull is assembled from smaller structural subassemblies (modules), fabricated in sheltered, controlled environment from automatically welded stiffened panels. This approach will be used in CSES hull construction. By locating the wet deck stiffeners and frames on the external "wet" side of the 2nd deck, the welder's access to stiffener and frame connections is improved and fabrication, inspection and maintenance costs are significantly reduced. It is estimated that more than 75 percent of CSES hull welds may be deposited by fully automatic or semi-automatic equipment.

Manual welding is still necessary in joining transverse frames to longitudinal stiffeners and for joining hull structure subassemblies. The use of flat bar stiffeners, which do not require collar plates considerably reduces the extent of manual welding and simplifies welding operations. Also, the majority of CSES hull structural details are designed to provide good access to the weld areas, further minimizing manual welding problems. To improve the fatigue strength of the CSES structure, weld contour grinding and brush peening will be used. This procedure will be applied to critical high stress welds and to selected weld repair areas. The brush peening technique was developed under the 3KSES program and demonstrated on SES 100A where old waterjet foundation welds were successfully repaired and brush peened.

5.1.6 Structural Weight Breakdown

Detailed SWBS Group 100 breakdown and percentages of total structure are presented in Table 5.1-iv.

WEIGHT OF STRUCTURE SWBS GROUP 100
INCLUDING MILL TOLERANCES AND WELD MATERIAL

WEIGHT GROUP	DESCRIPTION	WEIGHT LT	% TOTAL STRUCTURE
110	Shell & Support Structure	50.1	50.9
120	Hull Structure Transverse Bulkheads	10.1	10.3
130	Hull Decks	21.5	21.9
140	Hull Machinery Flats & Platform	2.8	2.9
150	Deck House Structure	8.2	8.3
160	Special Structures	2.2	2.2
170	Masts, King Post & Service Platform	1.5	1.5
180	Foundations	2.0	2.0
100	Hull Structure, Total	98.4	100

TABLE 5.1-iv

5.1.7 Structural Risk Assessment

Structural risks associated with any ship structure including the CSES can be generally related to the hull strength. Hull strength is dependent on an accurate assessment of materials, fabrication and loads variables.

The information on materials has been derived from a large number of small specimen tests and in the case of 5456 aluminum, it has been supplemented by extensive data derived from testing stiffened panels and structural joints as part of the 3KSES program. There are now sufficient data to adequately account for material variables so that the risk associated with this area is minimal.

Fabrication may introduce distortions and misalignments which will affect buckling strength of the hull structure. For economical and technological reasons fabrication defects cannot be totally eliminated and are tolerated as long as they remain within certain bounds dictated by strength requirements and fabrication costs. The effects of fabrication tolerances on structural strength can be determined with a reasonable accuracy and properly accounted for in the structural design criteria. Experience with 100 Ton SES hulls and several small fabrication modules have demonstrated that reasonable tolerance requirements can be met or exceeded. The risk of underestimating the effects of fabrication variables on hull strength is considered small.

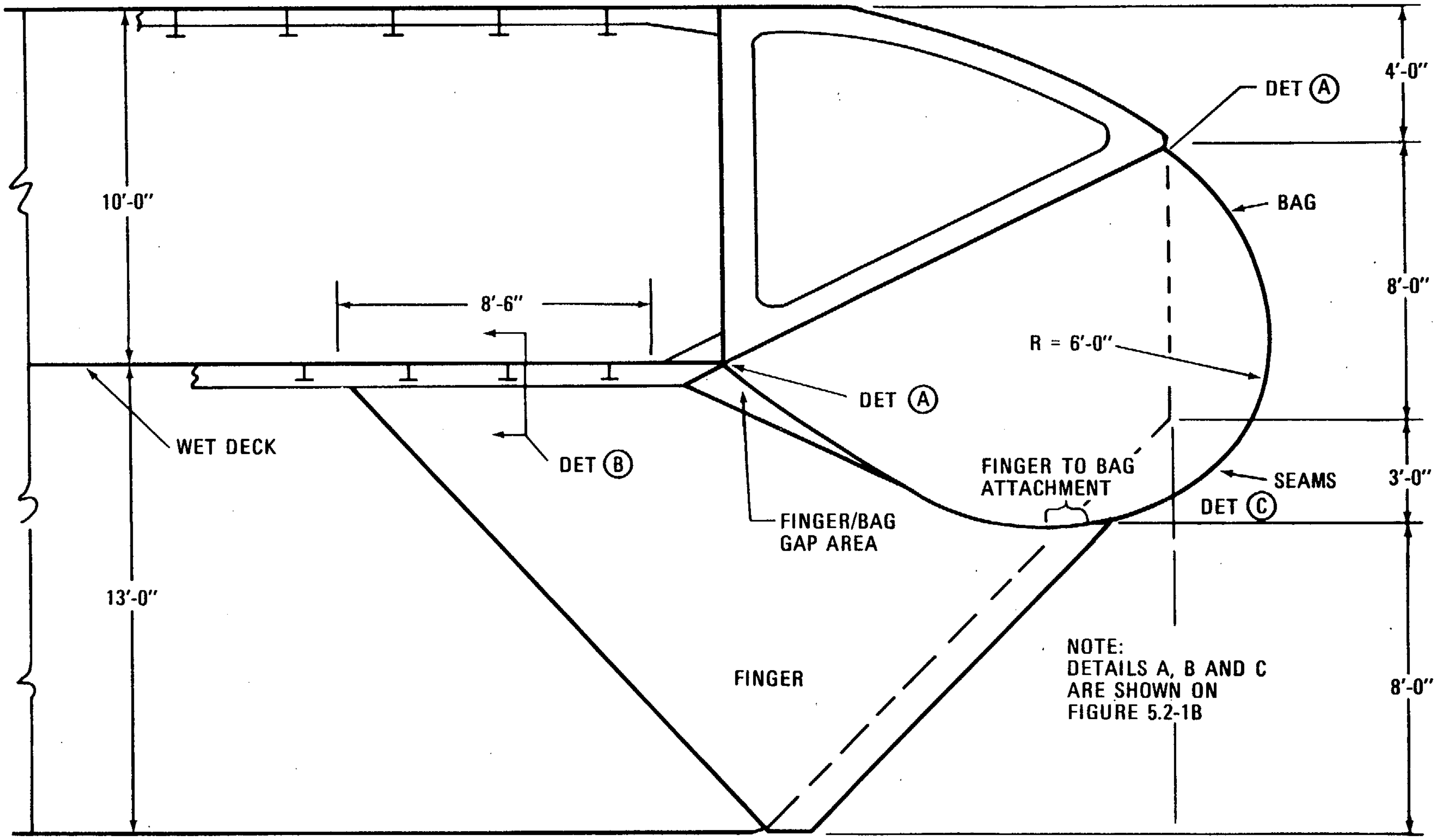
Because of the random nature of the sea environment it is not possible to make a categorial statement that the design loads will not be exceeded during the lifetime of the ship. There is always a chance that the ship will experience loads higher than for which it was designed. In the case of the CSES, the risk of exceeding the maximum design loads is limited to 0.001 (probability of survival 0.999), i.e., during twenty years, one-in-a-thousand CSES structures may encounter the loads which would exceed the design loads. The load variables for CSES has been accurately evaluated using structural model testing techniques and computerized loads analyses developed from extensive experimental and analytical studies done under the 3KSES program. This variable risk level is regarded as acceptable, particularly since the consequence of such an event would be limited mainly to local buckling of the main deck structure, and would not seriously jeopardize the overall integrity of the ship.

5.2 SEAL STRUCTURE

5.2.1 Seal Description

The CSES seals and some of the structural details are shown on Figures 5.2-1a and b and 5.2-2 . These seals represent an extension of the technology successfully demonstrated on many ACV and SES craft including the SES-100B and more recently the Bell Halter commercial SES. There is a wealth of materials fabrication and performance data generated under 3KSES and ACV programs, which is readily applicable to these types of seals.

The main structural features of the CSES seals are described as follows:



NOTE:
DETAILS A, B AND C
ARE SHOWN ON
FIGURE 5.2-1B

FIGURE 5.2-1A
BOW SEAL SIDEVIEW SECTION

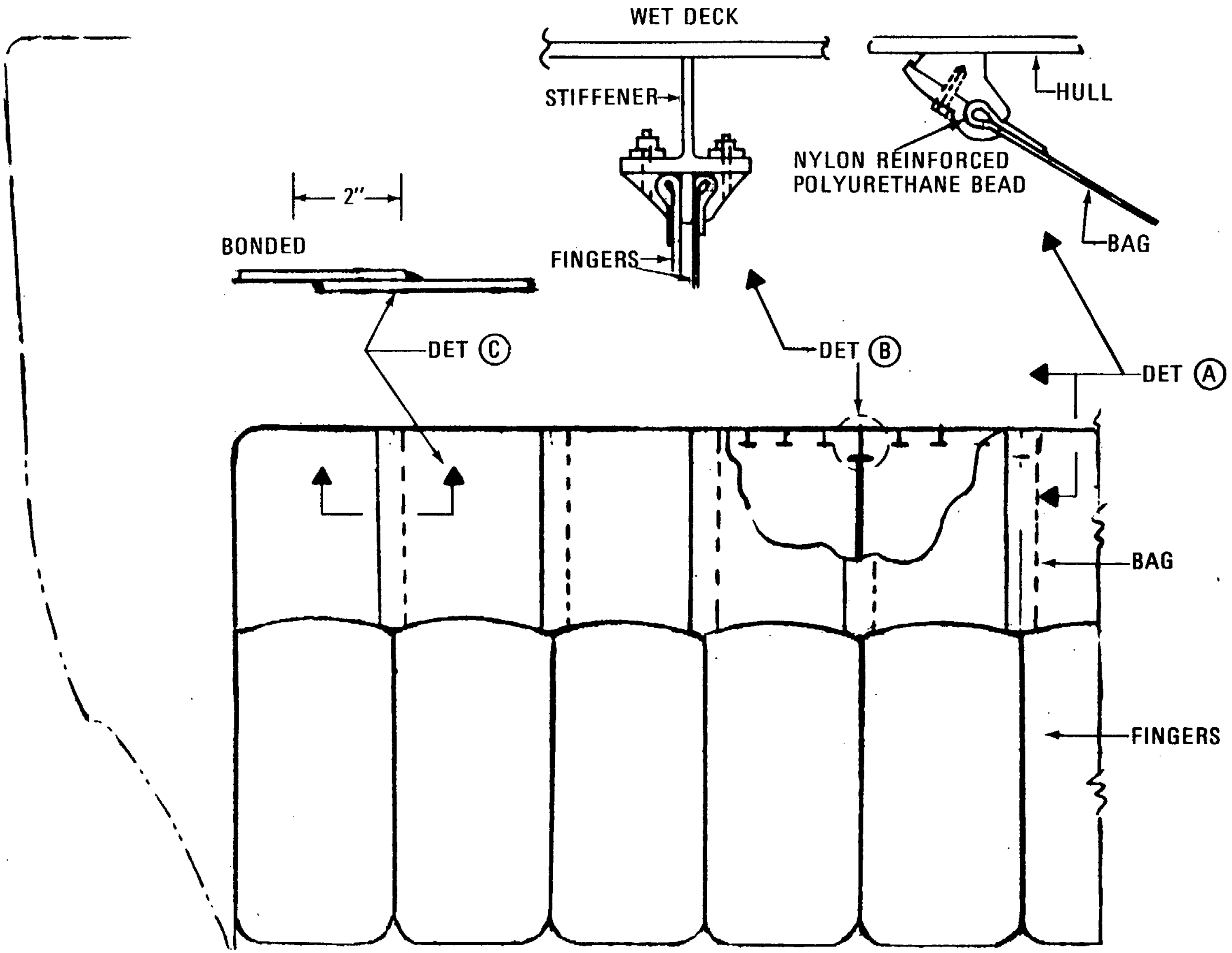


FIGURE 5.2-1B
BOW SEAL FRONT VIEW

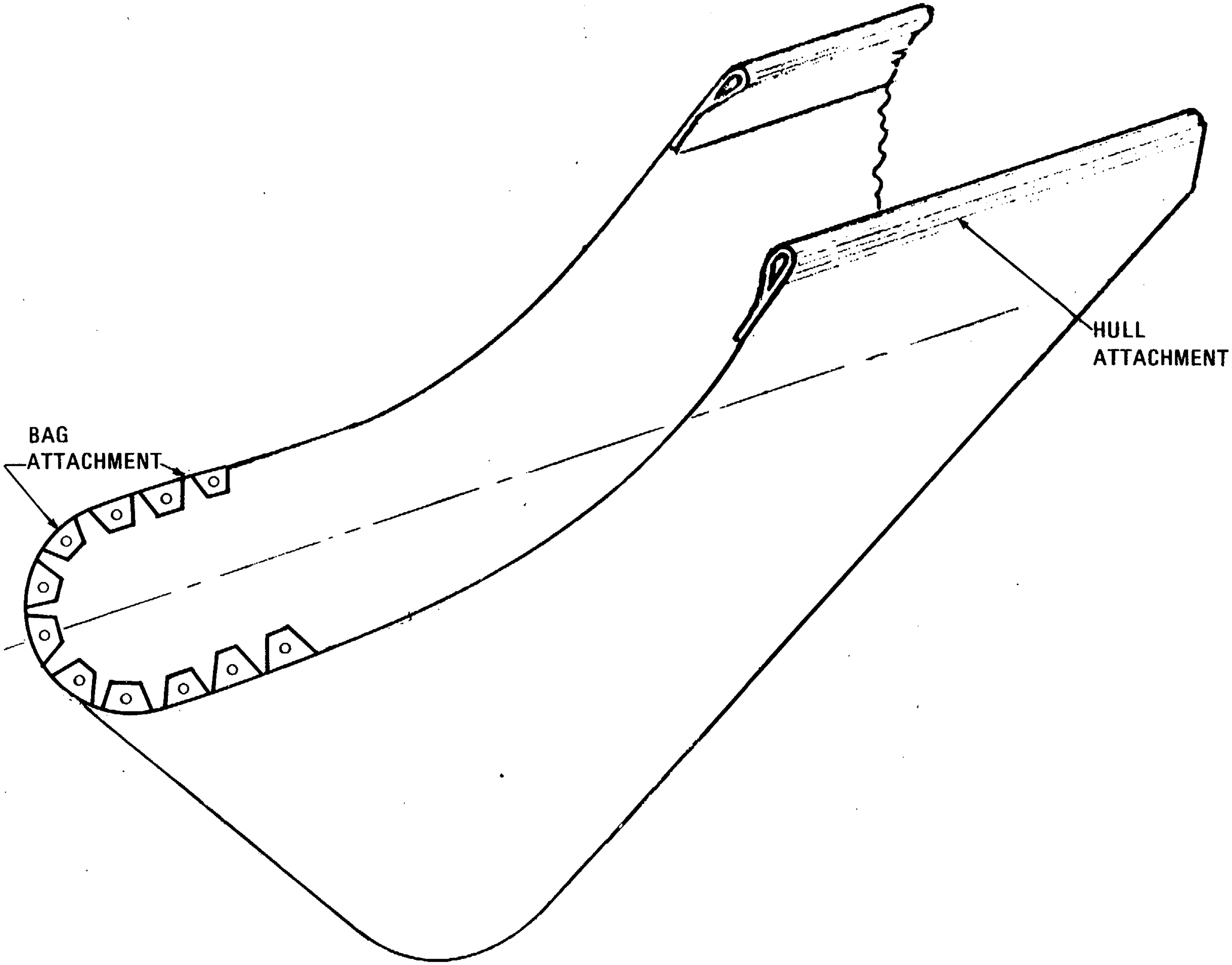


FIGURE 5.2-2
SEAL FINGER

a. Bow Seal. This seal Figure 5.2-1a and b is a simplification of the SES-100B type seal. The toroidal shape SES-100B bow seal bag is replaced with a simple cylindrical, "straight across" bag. This bag shape offers advantages of design simplicity, low seam stresses and repeatability of finger configurations. The front and the tails of the fingers are respectively connected to the lower portion of the bow bag and to the wet deck stiffeners by means of detachable mechanical connectors which allow easy replacement of the fingers. The finger design shown in Figure 5.2-2 allows most of the finger pressure load to be absorbed by the hard structure. This arrangement results in lower stresses in finger-to-bag joints which improves their fatigue performance and resistance to tear. The alternative to "bag- and finger-" seal described above, is an "all finger" bow seal such as used on the Bell-Halter (B-H) craft. This seal is simpler and lighter than the "bag- and finger-" seal but requires more hull structure for the finger attachments. In the case of the CSES, the hull length would have to be increased 10 - 15 feet to accommodate the B-H type seal, resulting in 8 - 10 LT additional hull weight. This was less efficient so the design was not pursued as an option.

b. Stern Seal. This seal Figure 5.2-3 is similar to the one successfully used on the SES-100B craft. It consists of a simple 3 lobe "straight across" bag attached to the wet deck structure. The lobe radii and the number of lobes are dictated by the stiffeness requirement of the stern seal, i.e., smaller lobe radii and larger number of lobes, result in "softer" more readily deformable seal. The seal is equipped with vertical diaphragms for geometry control and dynamic stability. Adequate drain holes are provided to remove the entrained bag water when the seal is inflated.

5.2.2 Seal Loads

The seals are designed to withstand loads engendered by the operational conditions summarized in Table 5.1-i. The critical design load is produced by a rapid bow bag contact with waves, which results in pressure increases such as exemplified by Figure 5.2-4 which shows cushion pressures measured during SES-100B rough water test. For the CSES bow seal, this load corresponds to three times the cushion pressure, i.e., 3 x 135 = 405 psf. The required safety factor (SF) for this load is 4.0. This value was used for the 3KSES bag and finger seals and accounts for material strength variables (SF = 2.0) and material degradation due to fatigue and environmental effects. Calculations have indicated that the existing 1000 pounds-per-lineal inch (pli) fabrics are more than adequate to satisfy CSES seal material strength requirements. The fabric in this strength range have been used on various Air Cushion and SES craft and provided good performance and adequate tear strength. Other loads such as drag forces in high seas, forces due to entrained water in the bag, were determined to be less critical than the overpressure loads and are adequately covered by the large safety factor. The stern seal is designed using materials and hard structure connections identical with the bow seal. Because of inherently milder operational environment and low stresses, the stern seal will have ample capability to withstand the operational environment loads.

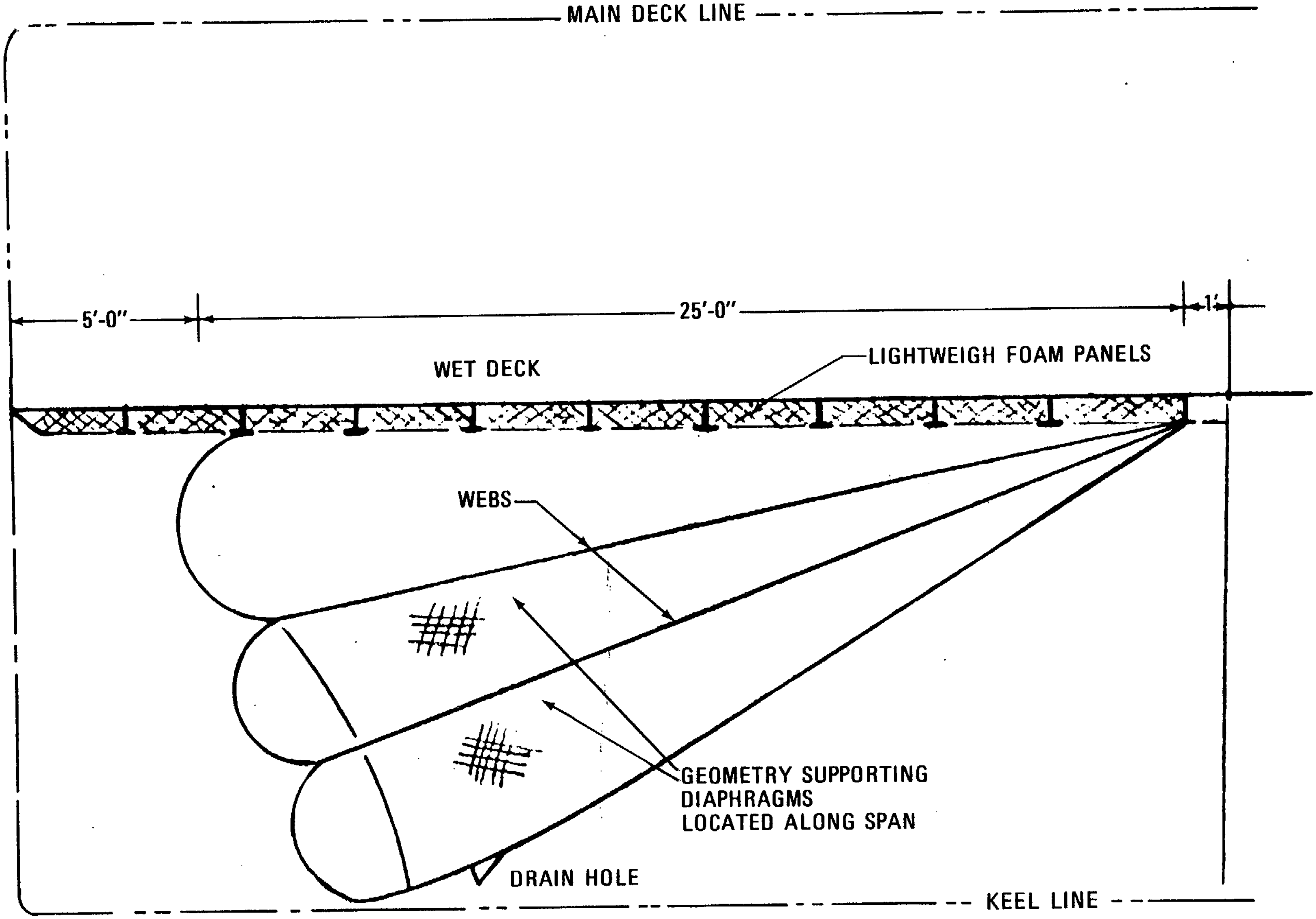


FIGURE 5.2-3
STERN SEAL

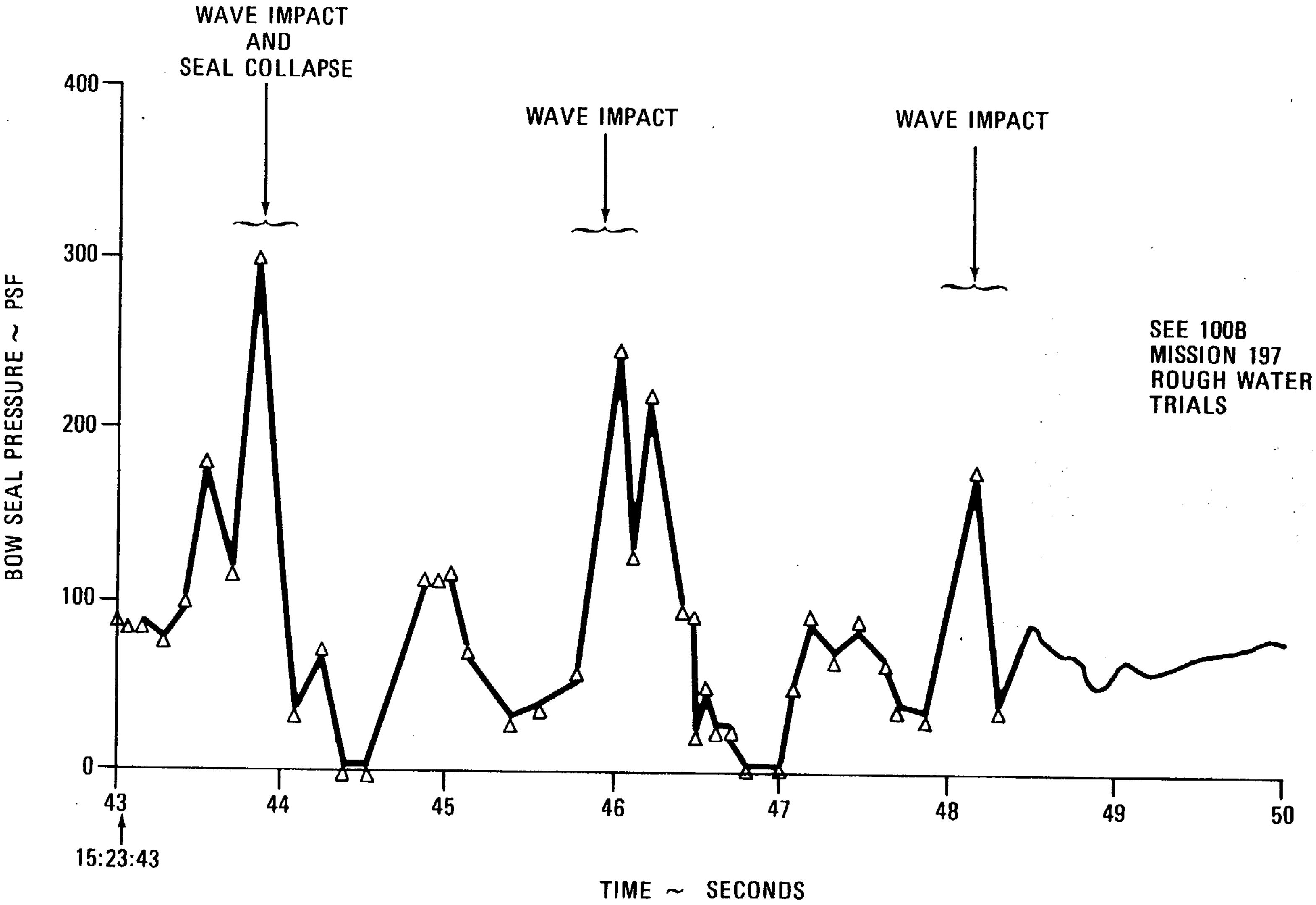


FIGURE 5.2-4
SES 100B BOW SEAL PRESSURE TIME HISTORY

5.2.3 Seal Materials

Both bow and stern seals are constructed from commercially available elastomer coated fabric panels. The width of these panels is limited to 54 inches although panels up to 20 feet width may be obtained by special order to manufacturers equipped with carpet weaving machinery. Although wider panels have an advantage of fewer seam joints and lower bag fabrication costs and seal weight, their cost is much higher than the 54 inch wide materials and their delivery time is longer. Additionally, the bag constructed from the narrower panels has a built-in tear-stopper feature in the form of bonded seams which join the adjacent panels together.

Table 5.2-i summarizes the strength characteristics of the coated fabric materials specified in CSES seals. The values in the table are based on bag and finger material tests performed by Bell Aerospace Company under the 2KSES program. The selected coatings are derived from more than 10 years of development work and offer the best combination of durability and flexural fatigue strength.

STRENGTH CHARACTERISTICS OF BAG MATERIALS SELECTED FOR CSES SEALS

MATERIAL CHARACTERISTIC		BAG	FINGERS
Fabric Type		Nylon 3 x 3 Basket	Nylon 3 x 4 Basket
Fabric Weight		23.2 oz/yd^2	30 oz/yd^2
Coating		Neoprene base rubber	Natural rubber/ cis-polybutadiene
Tie-Coat		Neoprene base adhesive	Neoprene base adhesive
Material Weight		90 oz/yd^2	135 oz/yd^2
Tensile Strength			
Dry	- Warp	1260 pli	1600 pli
	- Fill	1280 pli	1690 pli
Wet	- Warp	1100 pli	-
	- Fill	-	
Tear Strength		430 pound	500 pli

TABLE 5.2-i

Other materials used in CSES seal construction include CRES bolts and aluminum clamps used for connecting seal to the hull structure and for joining fingers to the bag. Teflon inserts and other insulating materials are used in the dissimilar metal interfaces to prevent galvanic corrosion.

5.2.4 Seal Weight Breakdown

Table 5.2-ii provides bow and stern seal weight estimates based on 54 inch wide fabric panels and 2 inch single overlap seam joints. The full weight breakdown for the lift system is shown in Table 5.4-iii.

CSES SEAL WEIGHTS BREAKDOWN

BOW SEAL COMPONENT	WEIGHT (LBS)	STERN SEAL COMPONENT	WEIGHT (LBS)
*BAG (coated fabric)		*BAG (coated fabric)	
Lobe panels	321	Lobe panels	1811
End Caps	78	End Caps	26
Apron	39	Vertical web (set of five)	444
**FINGERS (coated fabric)			
Set of eight (8)	1563		
ATTACHMENT CLAMPS (Aluminum)		ATTACHMENT CLAMPS (Aluminum)	
Bag-to-hull	221	Bag-to-hull	260
Finger-to-hull	587		
Finger-to-bag	181		
TOTAL:	2990	TOTAL:	2541
MISCELLANEOUS 5%:	150	MISCELLANEOUS 5%:	127
BOW SEAL:	3140	STERN SEAL:	2668

*Bag fabric weight = 90 oz/sq. yd.

**Finger fabric weight = 135 oz/sq. yd.

TABLE 5.2-ii

5.2.5 Seal Risk Assessment

Risk assessment of seals generally can be related to two requirements: (1) adequate strength, and (2) adequate life. The risk of not meeting the first requirement is small since the CSES seals are provided with generous safety margins and use proven design features. Experience shows that the risk of failing to meet life requirements, is primarily related to seal elements in frequent contact with the water i.e., tips of the fingers and lower portions of the stern bag. Even though finger wear cannot be completely eliminated, the rate of wear can be maintained at an acceptable level by taking advantage of recent advancements in seal material and by using flagellation suppressors, such as nylon stiffening cables integrated into finger material. Test data have shown that in addition to material variables, the finger life is dependent on speed, cushion pressure and finger geometry such as finger diameters and incidence angle. The CSES seal finger geometry is selected to provide a good balance between performance and durability. The CSES speed is modest as compared to 80 - 100 knots specified for 3KSES finger. It is anticipated that finger life will be sufficient to provide 800 - 1000 hours of good performance at speeds above 35 knots. At lower speeds finger life will be much greater. Stern bag wear is usually quite small and can be further reduced by the use of fiber glass sheathing or sacrificial elastomer layers at the bottom of the lower lobe. However, for the CSES stern seal the anticipated wear will be small and bag modifications are unnecessary. In the past, seals were occasionally damaged by the hard mechanical fasteners rubbing and chafing the adjacent soft seal fabric. The damage occurred mainly at the seam joints. Risk of this self-inflicted damage in CSES seal is minimized by reducing the number of mechanical fasteners and, by shrouding metallic elements in rubber.

5.3 PROPULSION SYSTEM

5.3.1 Propulsion System Description

The CSES propulsion system consists of two independent combined diesel/gas turbine (CODOG) plants, one in each sidehull powering an eight foot diameter fixed pitch propeller.

Propulsion plant design philosophy is based on simplicity and maximum use of commercially available and existing proven components. This approach is evidenced by the selection of the MTU 8V331 diesel engine, a widely used marine engine which provides hullborne propulsive power in the PHM Hydrofoil, and the Detroit Diesel Allison Division (DDAD) 570-K gas turbine, a second generation unit offering good performance and economy in the 2000 to 7000 shp range. The gearbox is a CODOG version of a reduction/reversing unit designed specifically for the DDAD model 570 gas turbine by the Cincinnati Gear Company. These propulsion plants, powering readily obtained fixed pitch propellers, and using diesel fuel marine (DFM), (MIL-F-16884) provide the CSES with the flexibility to select operating combinations for efficient and economical performance throughout the ship's operating envelope.

5.3.2 Propulsion System Arrangement

Figure 5.3-1 illustrates the general arrangement of the propulsion plant in each sidehull. Figure 5.3-2 shows the CODOG installation in greater detail. The selected arrangement provides compact and efficient installation which allows full input power of either gas turbine or diesel in either forward or reverse direction.

During gas turbine operation, power to each 8 foot diameter propeller is provided by a DDAD 570-K gas turbine via turbine coupling, epicyclic reduction gearbox, syncronous self-shifting (SSS) clutch, hydraulic reversing clutch, pinion and bullgear, shafting, bearings and thrust block. The overall reduction ratio of the gas turbine drive train is 23.00/1.

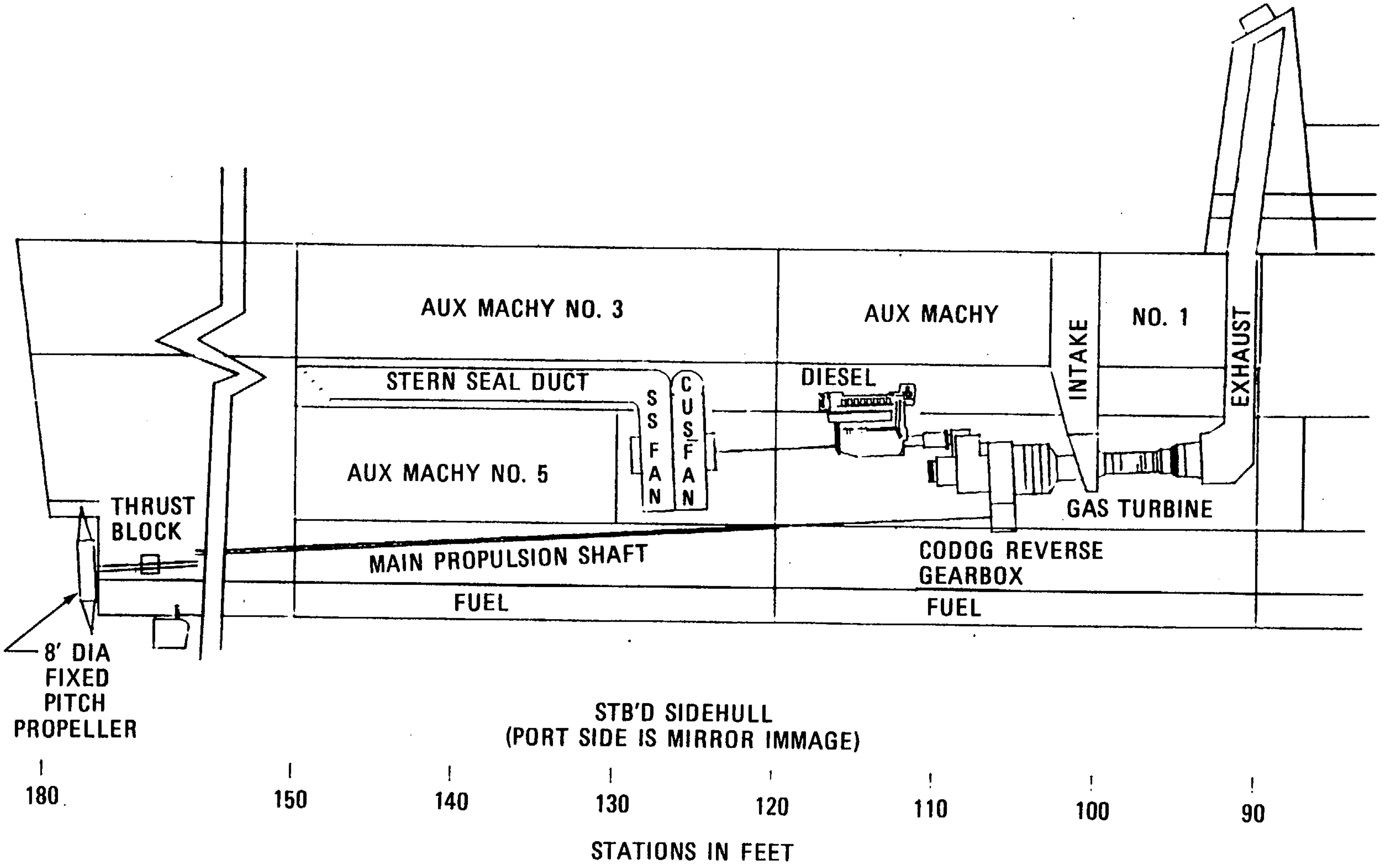
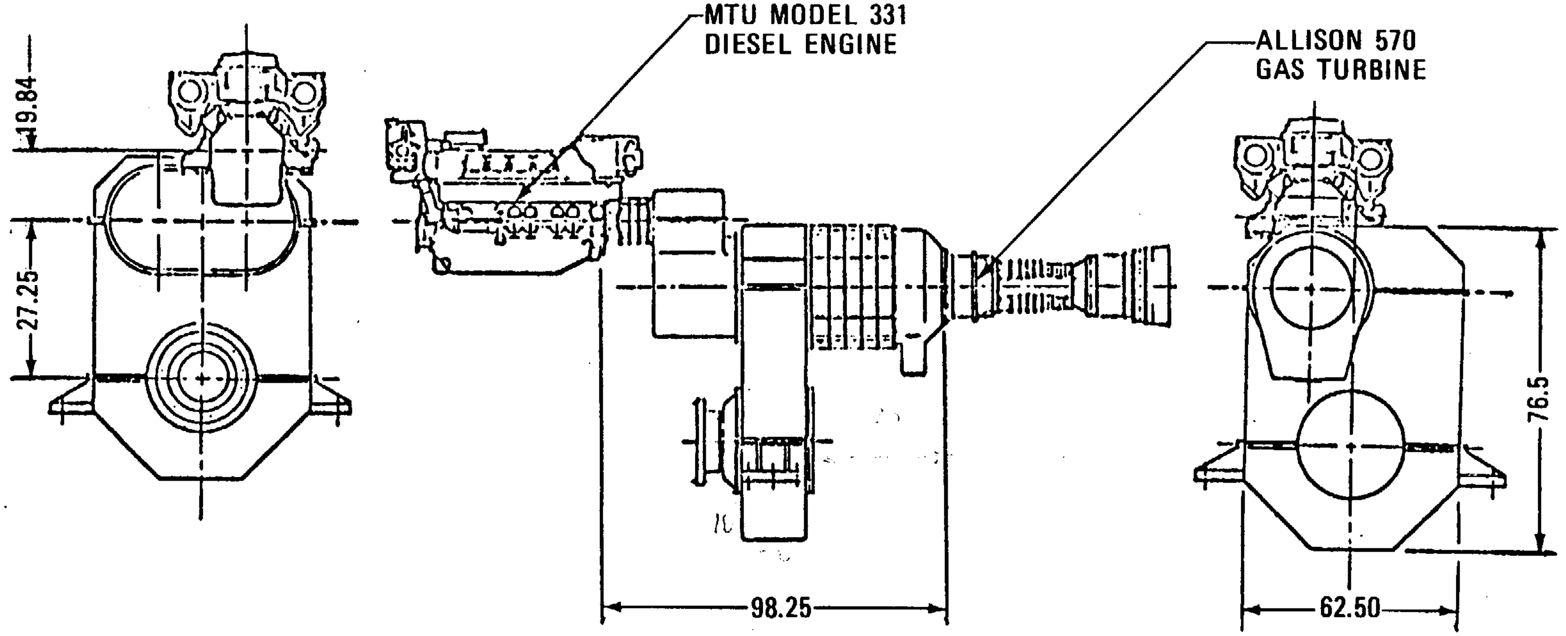


FIGURE 5.3-1
PROPULSION PLANT ARRANGEMENT



COASTAL SES. CODOG/REVERSE GEAR			
	INPUT SPEED	INPUT POWER	OUTPUT SPEED
GAS TURBINE	11,500 RPM	7000 HP	500 RPM
DIESEL	2,200 RPM	870 HP	207 RPM
CINCINNATI GEAR	PART NUMBER 26-0500-03467		

FIGURE 5.3-2
CODOG ASSEMBLY

For diesel operation, power is transmitted via a torsional damping flexible coupling, SSS clutch, input pinion, hydraulic reversing clutch, pinion and bullgear. The reduction ratio provided for diesel operation is 10.63/1. Each stern seal lift fan is driven from the opposite end of the diesel through a clutch which is normally disengaged during off cushion diesel propulsion operation. This diesel engine is carried under the lift system for inventory and weight and balance purposes.

5.3.3 Machinery Characteristics

5.3.3.1 Gas Turbine System

Several marine gas turbine engines in the 5 - 7000 shp range were considered for powering the CSES. In addition to the DDAD 570-K, the Garrett 1E-990 at 6300 shp; the General Electric LM-500 at 5500 shp; and the Rolls Royce Tyne RMIC at 5340 shp were examined. Based on a trade-off considering power, fuel consumption, speed, weight and size; the DDAD 570-K was selected as the engine best suited overall to meet the requirments for the CSES.

The 570-K marine gas turbine, manufactured by Detroit Diesel Allison, is a low-volume, high power-to-weight propulsion system Figure 5.3-3. The engine is rated at 6445 shp continuous and 7170 shp intermittant and is capable of maintaining minimum specific fuel consumption over a wide range of horsepower settings. The engine has been well proved industrially and for marine application has successfully completed an 1100 hour salt injestion test to Navy specifications.

Design and development of the 570-K engine began in the late 1960's. The basic engine design, materials, and modular construction are the results of product improvements which have been made to the Allison 501 Turboshaft engine which has been in production for more than 20 years.

The 570-K differs from the 501 Turboshaft in two major areas:

a. It employs a full annular combustor to accommodate the greater gas volume.

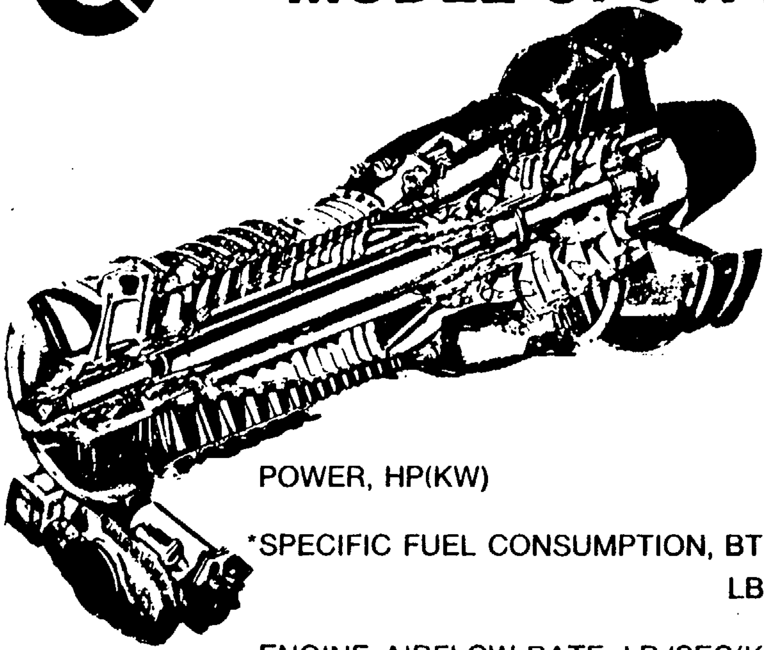
b. The compressor is equipped with variable geometry to reduce the part load fuel consumption rate.

The engine is of modular construction. It consists of five separable modules which include the compressor, combustor, gas generator turbine, power turbine, and accessory gearbox. The modules are designed to facilitate on-the-job replacement.

The 570-K employs a thirteen-stage axial flow compressor which produces a 12.1:1 compression ratio. The inlet guide vanes and the first five stator vanes are of the variable action type. The setting angle of the stator vanes are modulated through hydraulically operated variable geometric linkage in response to a scheduled electronic control signal.

The 570-K has a relatively flat specific fuel consumption curve. This flat curve makes the 570-K an excellent engine for power installations where the load varies. In addition, Detroit Diesel Allison has demonstrated a better-than-average thermal efficiency for this simple cycle engine in the lower power output ranges Figure 5.3-4.

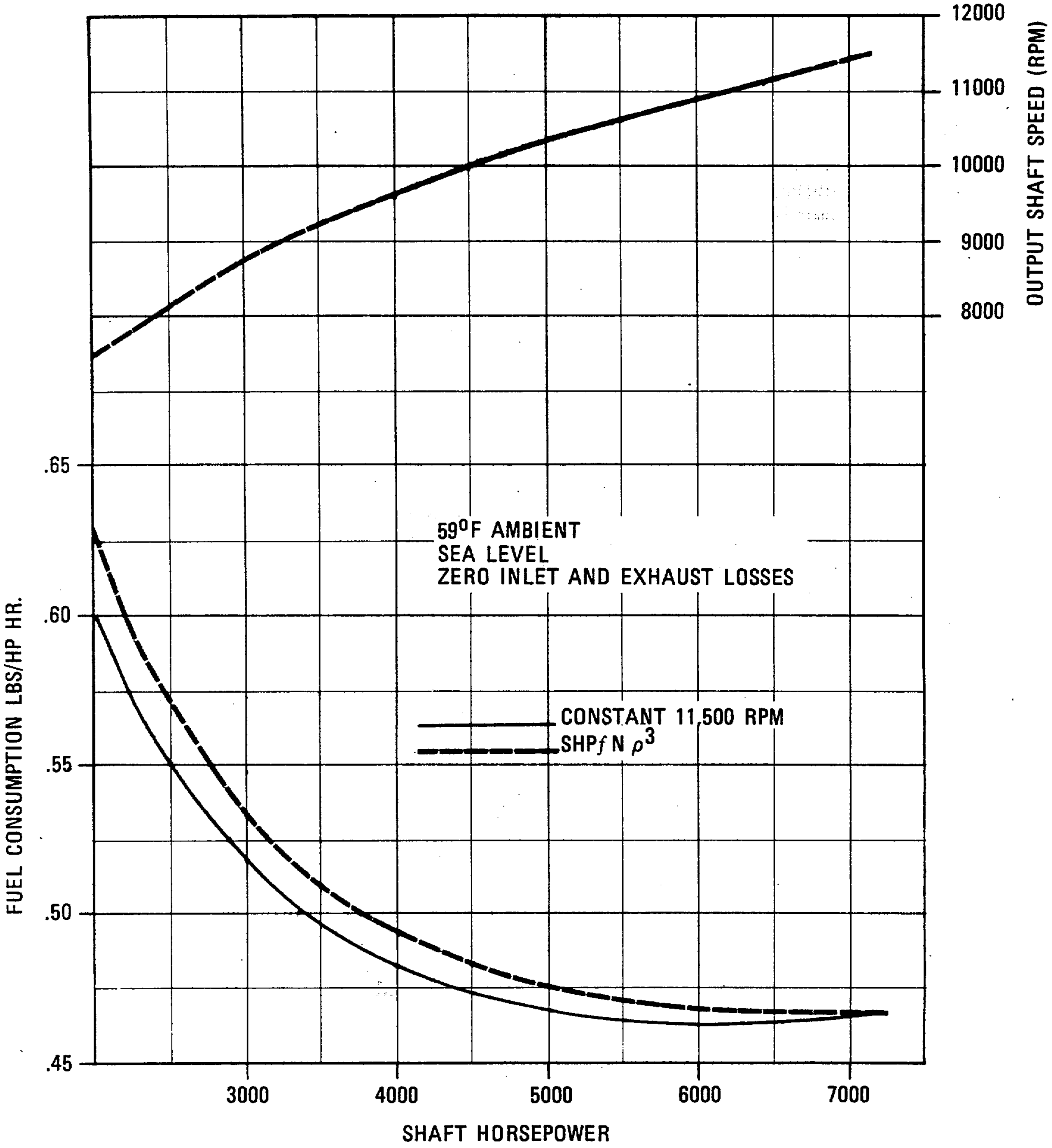
MODEL 570-K PERFORMANCE



	INTERMITTENT	CONTINUOUS
POWER, HP(KW)	7170(5347)	6445(4806)
*SPECIFIC FUEL CONSUMPTION, BTU/HP-HR	8510	8473
LB/HP-HR(mg/w-Hr)	.462(281)	.460(280)
ENGINE AIRFLOW RATE, LB/SEC(Kg/SEC)	42.8(19.4)	41(18.6)
MEASURED GAS TEMPERATURE, °F(°C)	1562(850)	1477(803)
POWER TURBINE OUTPUT SPEED, RPM	11,500	11,500
GAS GENERATOR SPEED, RPM	14,722	14,281

LHV = (8,400 BTU/LB(10,200 Kcal/Kg)

FIGURE 5.3-3
DETROIT DIESEL ALLISON GAS TURBINE



DETROIT DIESEL ALLISON MODEL 570K GAS TURBINE

FIGURE 5.3-4
GAS TURBINE SPECIFIC FUEL CONSUMPTION

The 570-K is fitted with an integrated electronic engine control system and fuel control valve. The system provides complete automatic starting and shutdown sequencing. It also provides a complete electronic fuel control, including power turbine and gas generator speed governing, closed loop temperature acceleration control, open loop acceleration fuel limiting, steady-state temperature control and deceleration control.

The system has a dual channel engine temperature monitor and speed monitors for the power turbine and gas generator shafts. Complete malfunction monitoring is also provided along with automatic compressor variable geometry control.

The gas generator turbine is an air-cooled, two-stage, axial-flow unit consisting of a single major stationary subassembly and the turbine rotor assembly. The power turbine is also a two-stage, axial-flow unit, gas coupled to the gas generator turbine. The power turbine drives the output shaft at the front of the engine. Direction of rotation is clockwise, viewed from the rear, and output speed is 11,500 rpm at rated power turbine speed. The gas producer speed is variable and depends on power selection with a maximum of 15,000 rpm.

5.3.3.2 Diesel System

A diesel engine located aft in each sidehull can power either a stern seal fan or a propulsion drive train through the CODOG transmission system. The diesel selected is the MTU 8V331, the same engine that provides hullborne propulsion power in the PHM Hydrofoil. This marine engine is rated at 870 shp continuous at 2180 rpm and is capable of full power transmission from either end of the engine. The two hour rating is 950 shp at 2250 rpm.

Other diesel engines, both American and foreign are available in the required power and speed ranges for this application but the MTU 8V331 was selected because of its overall suitability and proven marine performance.

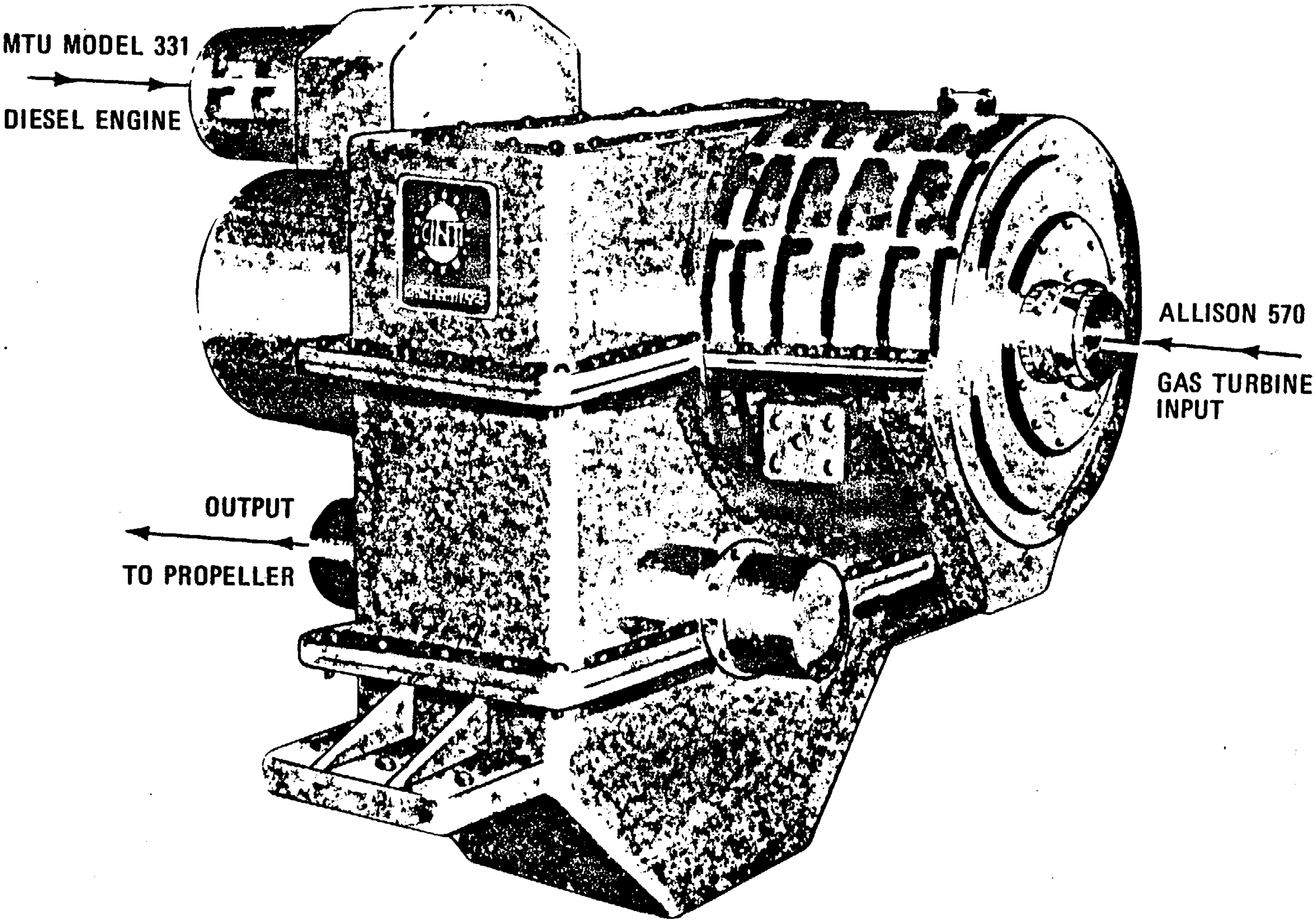
The model 331 diesel is based on design concepts which make it particularly suitable for fast high-performance vessels. Over 2500 of the 331 model engine have been built and more than 1200 of these are employed in high speed water craft. This provides an exceptional operational experience base for this choice of diesel.

The engine is of short stroke design (155 mm) with rated speeds from 2100 to 2400 rpm. Design features include 90 degree V arrangement, direct injection, exhaust turbocharging, and internal charge air cooling with intercooler incorporated in the engine water circuit. The engine uses electric starting and has a dry weight of 2.3 LT.

5.3.3.3 Transmission System

A reversing reduction gear system based upon an existing design has been selected for the CSES. The unit is illustrated externally in Figure 5.3-5.

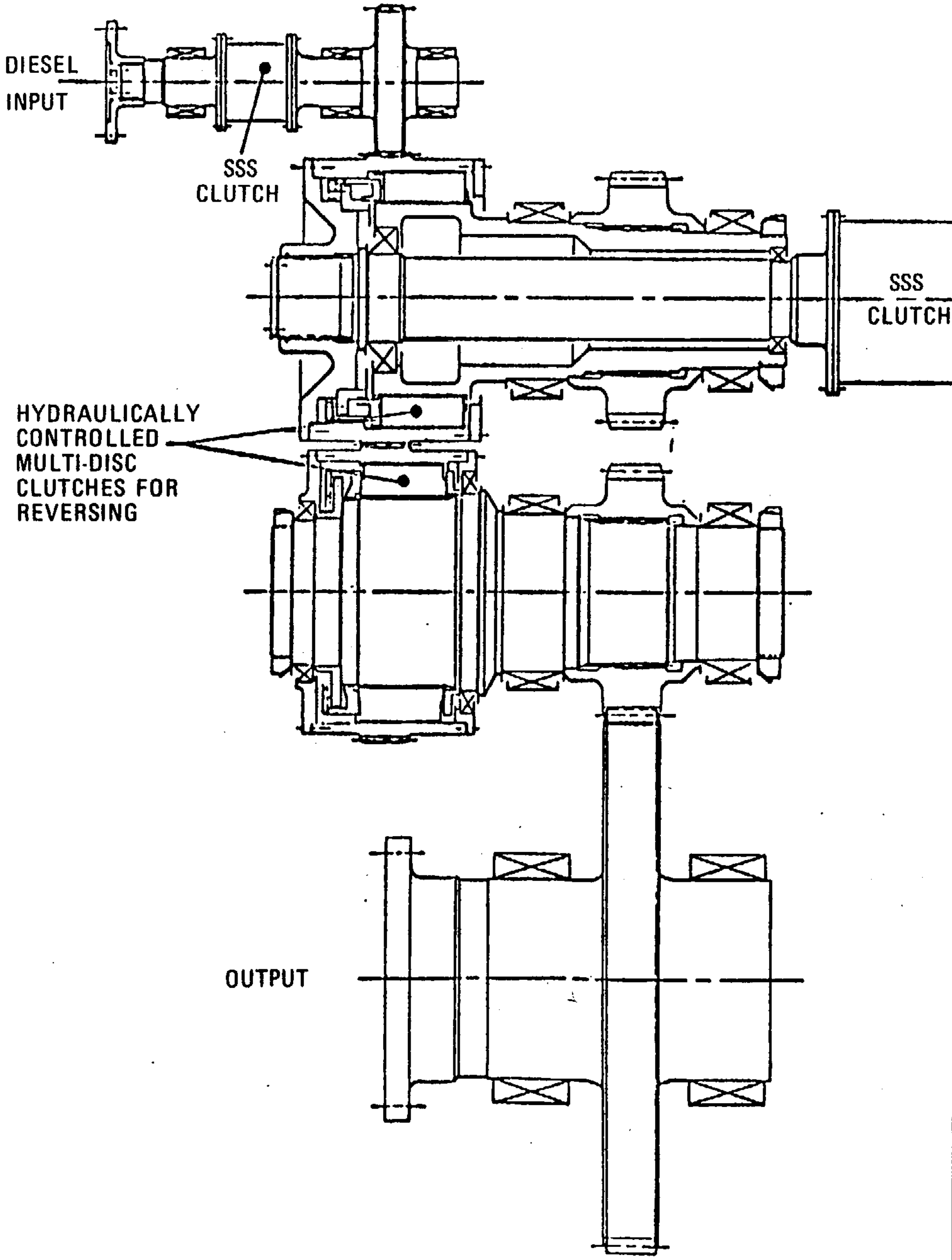
A cross section of the transmission is shown in Figure 5.3-6 which shows the reverse gear arrangement. The reversing parallel shaft gearbox section is an established concept utilizing multi-disc viscous oil shear clutches to provide the reverse mode of operations. Since the shift from forward to reverse is accomplished by the

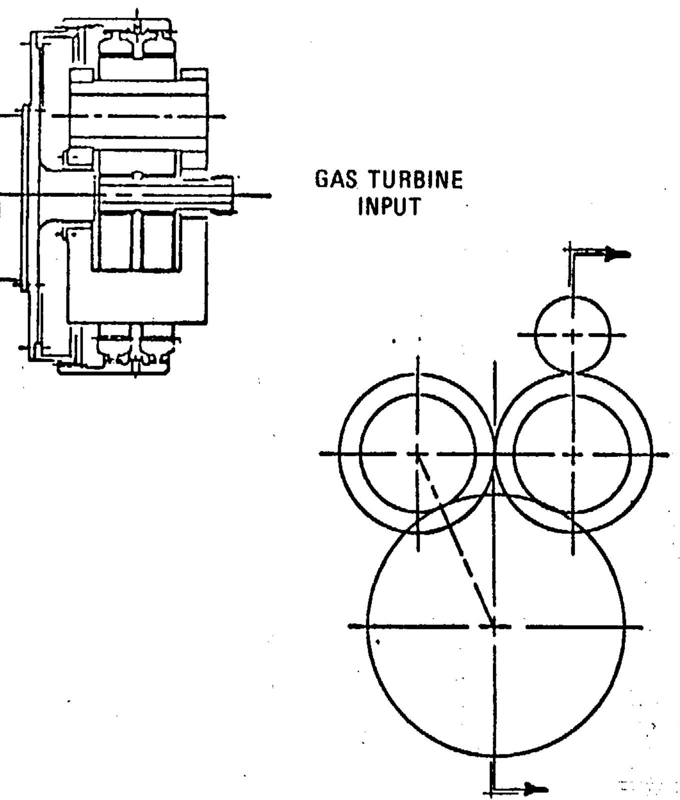


THE CINCINNATI GEAR COMPANY

CODOG/REVERSE GEAR CINTI ASSEMBLY NUMBER 26-0500-03467

FIGURE 5.3-5
CODOG/REVERSE GEAR





COASTAL PATROL REVERSE GEAR			
	INPUT SPEED	INPUT POWER	OUTPUT SPEED
GAS TURBINE	11,500 RPM	7000 HP	500 RPM
DIESEL	2,200 RPM	870 HP	207 RPM
CINTI	PART NUMBER 26-0500-03467		

FIGURE 5.3-6
CODOG/REVERSE GEAR CROSS SECTION

multi-disc clutches, no sliding gear meshes are required and the control system for reversing is therefore greatly simplified. The system design allows full input power of either gas turbine or diesel in either forward or reverse direction. This feature allows the gearbox to be installed in either the port or starboard sidehull and provide counter rotating propellers.

The initial high speed reduction from the gas turbine is through a proven Stoeckicht epicyclic design. In this design, free floating sun and annulus gears insure complete load equalization among three planets. The gear case carries only torque since gear separating and axial loads cancel out with the epicyclic design. Overall, a very compact, lightweight, reliable planetary reduction is provided.

The reversing parallel shaft gearbox section is designed to low K-Factor and unit loads which results in low risk and long reliable operating life. Bending and durability stresses are within accepted industry and American Gear Manufacturers Association (AGMA) allowable high performance marine standards.

During diesel engine operation power is transmitted to the diesel input SSS clutch via an Eaton/Geislinger torsional coupling to damp torsionual vibrations induced by the diesel (the SSS clutch is equipped with a lock-out mode for diesel start-up). Power is then transmitted through the input pinion, reversing clutch, pinion and bullgear, and shafting to the 8 foot diameter fixed pitch propeller. Appropriate shaft bearings, thrust block and stuffing box are fitted.

During gas turbine operation power is transmitted via the epicyclic reduction unit, SSS clutch, pionion, reversing clutch, pinion and bullgear. In this mode, the pinion on the diesel engine side idles, thereby releasing the SSS clutch on the diesel side and disconnecting the diesel engine.

From a maintainability viewpoint the vertical offset arrangement fitted allows output/thrust block clearance and accessibility. Servicibility is also enhanced by the modular building block design concept of the system. The turbine SSS clutch with lock-out allows gas turbine operation without gearbox rotation for field service or the performance of checks.

The gas turbine reduction ratio is 23.00/1 with an output speed of 500 rpm; the diesel reduction ratio is 10.63/1 with an output speed of 207 rpm. The gearbox efficiency is 94 percent and it's dry weight 11,800 lbs.

5.3.3.4 Propulsor System

Propulsor selection was influenced by the requirements for low cost, high efficiency in both hullborne and cushionborne modes of operation, and for ruggedness and simplicity of the design. Fixed pitch propellers are therefore specified. Should more efficient low speed performance be required in the future, controllable pitch propellers could be retrofitted.

A parametric propeller design study was performed utilizing a computer design program developed for the SES Project Office in 1979. Basically, the program combines linearized supercavitating foil theory with supercavitating momentum and cascade theories backed by extensive model tests. Blade section strength is calculated by a curved beam analysis, and section characteristics are continually adjusted until a satisfactory combination of structural integrity and hydrodynamic performance is achieved.

Results of the parametric study indicate that for the installed CODOG system, an 8-foot diameter fixed pitch propeller with a maximum rotative speed of 500 RPM will achieve required performance over the craft operating range. This propeller has the following characteristics:

Number of Blades	4
Effective Aspect Ratio (EAR)	0.60
Skew	15 degree
Maximum Stress	15000 psi (fatigue limit)

Nickel Aluminum Bronze (NIBRAL) was selected for the propeller blades because of the extensive experience with this material in marine propulsors. The propeller is sufficiently small so as not to pose any manufacturing problems. The estimated hydrodynamic performance of this propeller is shown in Figure 5.3-7, where thrust coefficient (KT) and efficiency (η) are functions of advance ratio (J). These estimates are based on a 50 percent propeller submergence level at top speed (design point) and with a fully submerged propeller for low speed conditions. For partially submerged operation the propeller hub and the upper half of the propeller disk function in the "shadow" of the transom. Similar to the SES 100B, this is achieved through proper design of sidehull geometry to obtain effective full propeller submergence or partial submergence when desired. This can be achieved by varying the streamlines of the local water flow through mechanical or hydrodynamic arrangements. The method of achieving this will be determined during the next stage of the design.

5.3.3.5 Combustion Air Intake

The air inlet openings for the gas turbines are located on the weather deck on each side of the ship just aft of the deck house. Sea water and moisture separation is provided by 3 stage demisters. For de-icing purposes, a small percentage of hot gas turbine exhaust gases can be run through a heat exchanger which is part of the weather deck inlets. The gases having warmed the intakes are injected into the free stream of inlet air. Sound suppression panel assemblies in the intake duct reduce engine noise. Demister modules remove moisture and other contaminants in the air. Bypass doors are included in the demister assembly to prevent blockage during icing conditions. Aluminum honeycomb panels on all duct walls provide smooth airflow surfaces and additional sound suppression.

5.3.3.6 Exhaust Gas Uptakes

Engine exhaust gases pass from the engine collector through a transitioning elbow and into the exhaust gas assembly. The assembly stack rises vertically exhausting through port and starboard stacks at the aft end of the superstructure. The duct is round in cross-section. Concentric sound suppressors are installed in the vertical duct. The entire system is insulated.

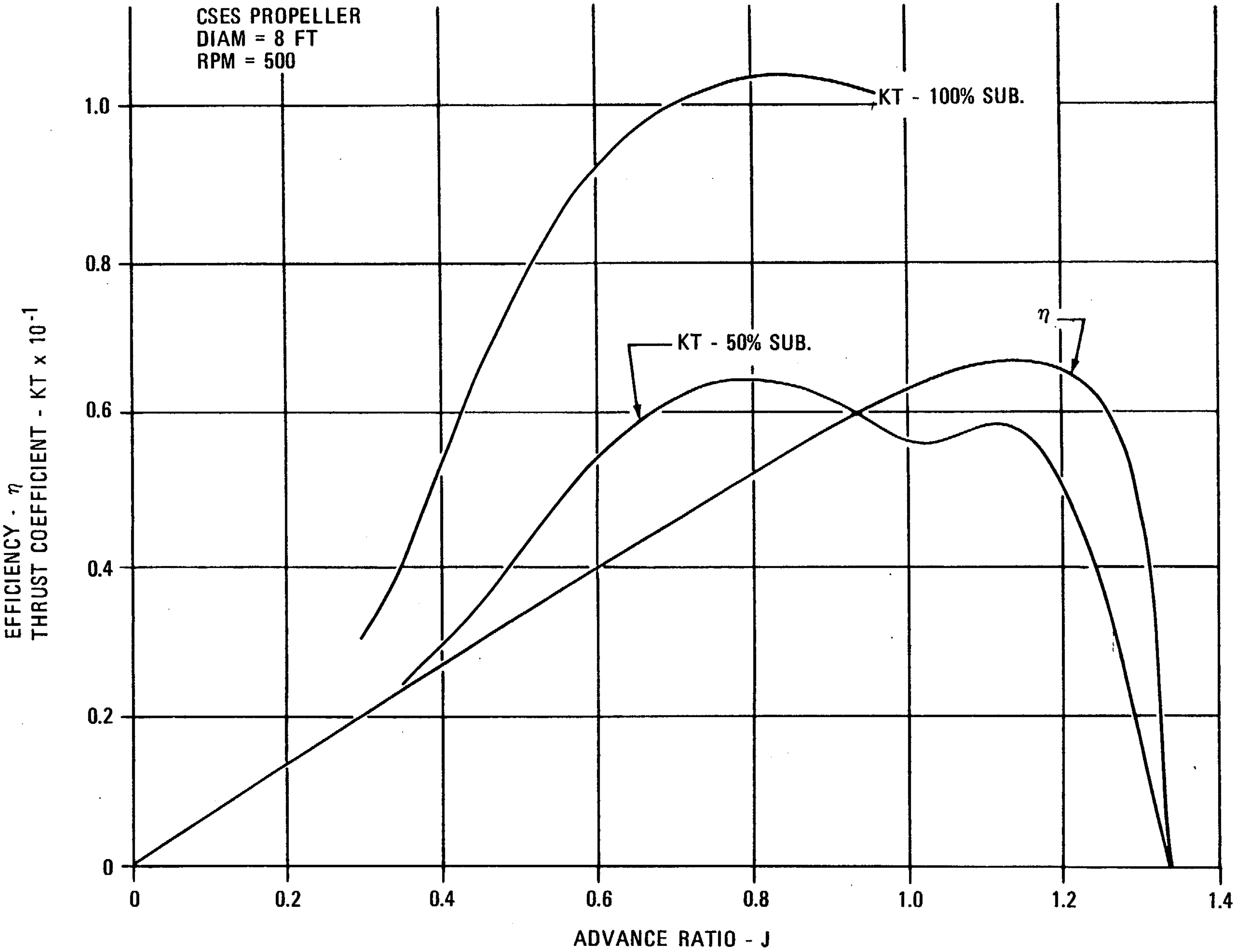


FIGURE 5.3-7
PROPELLER CURVES

5.3.3.7 Propulsion Lube Oil System

Each propulsion engine has an independent lubrication system. Detail requirements for the system are specified by the engine manufacturer. Independent lubrication systems service the port and starboard propulsor thrust bearings, gearboxes, and driveline shaft/bearing modules. MIL-L-17331G (2190-TEP) lube oil is used, which provides sufficient viscosity for the journal and roller bearings. System flow requirements are based on removal of all friction heat from the components with a maximum oil temperature rise of 40 degrees F. The reservoir is sized for one minute residence time and includes electrical heaters to warm the oil to 90 degrees F prior to propulsor operation. The supply pump has excess capacity. The heat exchanger is sized to keep oil temperature below 125 degrees F. An auxiliary electric motor-driven pump is used for pre and postlube as well as emergency backup.

5.3.4 Propulsion System Operation

The propulsion system is operated as a subset of the ship control system. Control is maintained from either the central control position or the bridge. Performance monitoring and evaluation of principal propulsion machinery elements can be undertaken from the central control position and machinery compartments are normally unmanned during operation.

5.3.4.1 Hullborne Operation

Hullborne and partial cushion operations at speeds up to 15 knots can be performed using diesel engines of the CODOG systems to drive the propellers. Automatic SSS clutch actuators disengage the gas turbine engines and engage the diesel engines to the combining reduction gearboxes to drive the propeller shafts and disengage the diesels from the stern seal lift fans. Diesels are normally used for the hullborne mode, thus providing economical low speed operation. It is possible, however, to operate hullborne with one or both of the Allison 570 gas turbine engines. Dockside and low speed maneuvering is accomplished by use of rudders, propeller reversal and/or RPM control.

5.3.4.2 Hump Transition

The high cushion length to beam ratio of the CSES places the primary drag hump above the maximum speed of the CSES. A relatively mild secondary drag hump is encountered at about 18 knots. Secondary hump transition is therefore readily accomplished in response to a high power command. Secondary hump transition is possible with full cushion, partial cushion, or can be avoided by remaining hullborne until over 18 knots.

5.3.4.3 High Speed Cruise Operation

High speed cruise operation is the operational domain defined by maximum continuous gas turbine power operation at displacements from full load displacement to light ship condition in the full cushion mode.

The CSES may be operated in either a maximum speed mode or maximum range mode. The former is based upon use of the maximum continuous horsepower available to achieve minimum time between two geographical locations within the available range. The maximum range mode of high speed cruise provides the speed profile for maximum available range and is achieved by continuous or incremental adjustment of lift power and propulsion power to maximize the specific range (nm per LT of fuel) at all particular displacements and sea conditions.

5.3.5 Propulsion Weight Breakdown

Propulsion system weights by subdivisions of SWBS Group 200 weight are presented in Table 5.3-i.

WEIGHT OF PROPULSION PLANT - SWBS GROUP 200

SWBS GROUP	ITEM	WEIGHT
234	Propulsion Turbines	1.2
241	Reduction Gearing	10.5
242	Clutches and Couplings	0.8
243	Shafting	2.2
244	Bearings	1.4
245	Propellers	3.6
251	Combustion Air System	0.8
252	Propulsion Control	0.4
259	Exhaust System	0.8
261	Fuel Service	0.2
262	Lube Oil Service	0.6
298	Operating Fluids	1.2
299	Repair Parts	0.1
	Total Propulsion System	23.8

TABLE 5.3-i

5.3.6 Propulsion System Risk Assessment

The conservative approach used in this design ensures that the propulsion system technical risk is sufficiently low so as not to place any constraints on CSES construction.

The Allison 570 prime mover is marine (salt) qualified, with a rapidly increasing industrial experience base. The MTU marine diesel engine is in use world wide. The Cincinnati Gear reduction gear is of conservative, state-of-the-art design. The simple, fixed pitch propeller installation ensures very high reliability.

Overall, the CSES propulsion installation risk is evaluated as low. The installation involves no more technical difficulty than other modern conventional monohull ship propulsion plants.

5.4 LIFT SYSTEM

5.4.1 Lift System Description

The lift system consists of four independent sets of lift machinery, air distribution elements, ride control equipment and bow and stern seals. As indicated in Figure 5.4-1, the lift machinery is arranged in both sidehulls at the stern and in the bow to form independent redundant air supply systems for the bow seal, air cushion and stern seal. The two forward fans supply the bow seal and the cushion; and the aft fans supply the stern seal and the cushion with lift air.

Each set consists of an Aerophysics, Incorporated Rotating Diffuser (RD) Double Width Double Inlet (DWDI) fan with radially placed Inlet Guide Vanes (IGVs). Power is supplied to each lift fan by one MTU 8V331TC82 870 HP diesel engine with appropriate gearbox. No cross-connection exists between the four sets of lift machinery.

The aft two sets of lift machinery are located one in each sidehull near the stern seal, and serve dual functions. During low power propulsion operations these diesel engines supply input power to the CODOG propulsion transmission system through appropriate clutches and couplings. The diesels can simultaneously drive both the stern fans and propellers.

The fan intakes are vertical trunks to the main deck and terminate with a personnel and debris safety screen/barrier.

5.4.2 Lift System Arrangement

Figure 5.4-2 illustrates one of the four lift system machinery sets installed in the CSES. These four sets, together with appropriate ducting, valving, bow and stern seals, and controls, comprise the lift system.

5.4.3 Lift System Components and Characteristics

5.4.3.1 Prime Movers

The MTU 8V331TC82 marine diesel engine is described in Section 5.3.3.2.

5.4.3.2 Gearbox

Lift gearboxes provide speed reduction and power transmission from the diesel engines to the lift fans. Preliminary design arrangements and calculations have been performed. The design is simple and conservative with a low gear ratio of 1.23 to 1. The gearbox assembly includes the following components:

a. Gearing of helical design of modified involute form machined from non-welded CEVM 9310 forgings

b. Single input shaft with flanged coupling driving through parallel shafting and associated gears to a single output shaft with flanged couplings

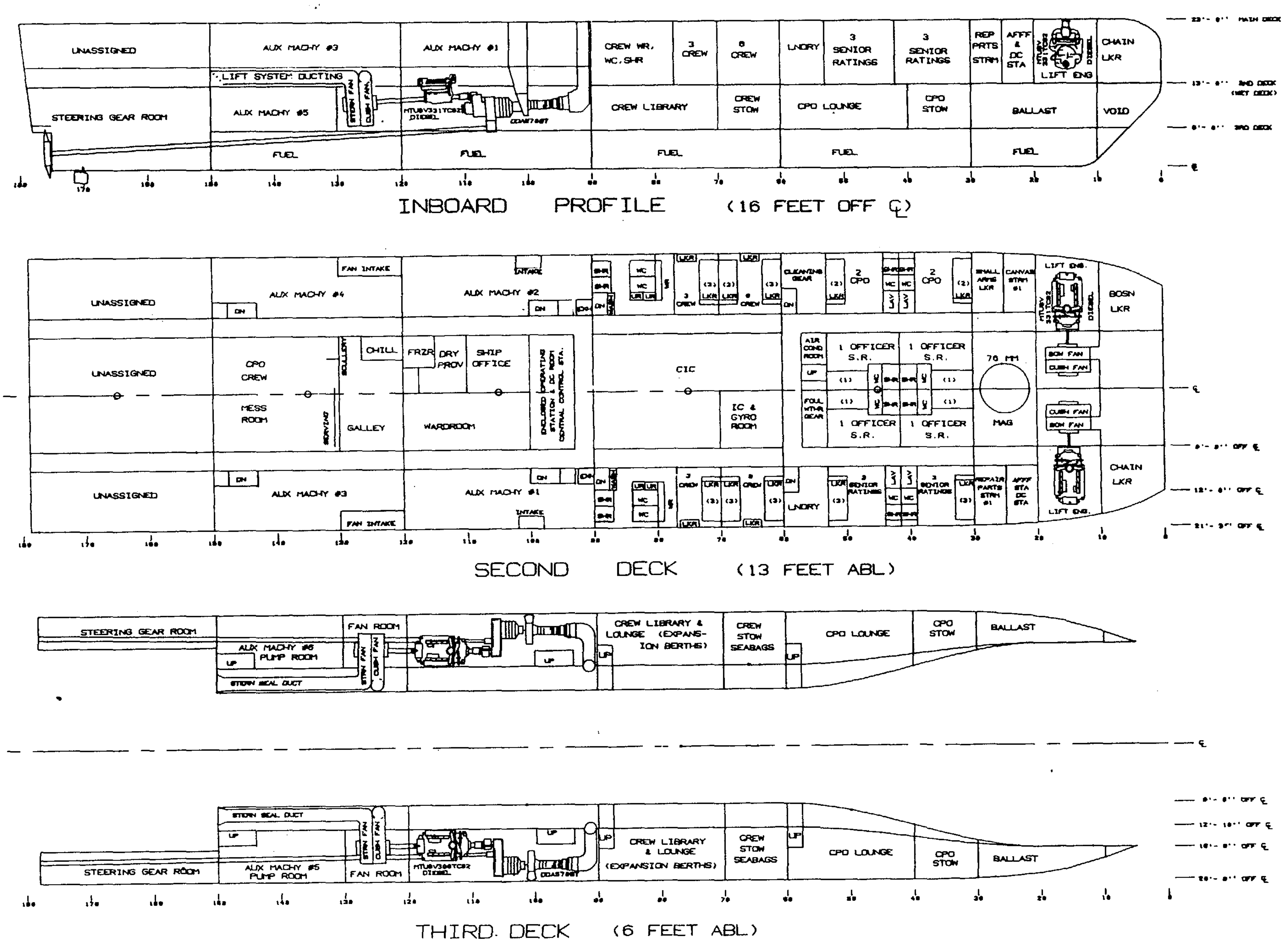


FIGURE 5.4-1

LIFT SYSTEM

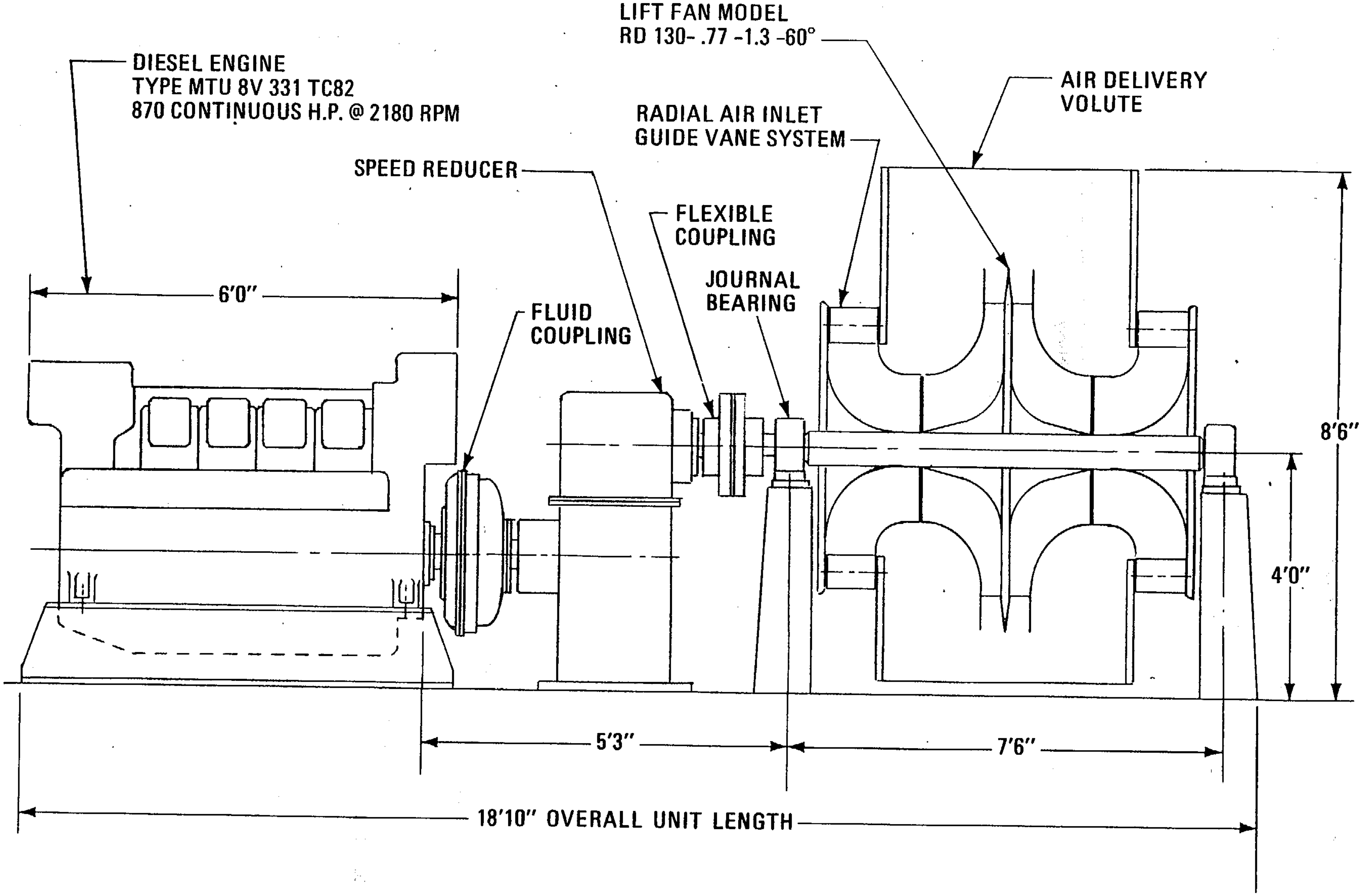


FIGURE 5.4-2.
LIFT SYSTEM MACHINERY SET

c. Housing or casing enclosing all gears (mounting and lifting provisions included)

d. Two auxiliary gear driven output shafts and mounting provisions for two hydraulic pumps located on the output side of the housing.

e. An attached shaft lock brake for the lift power transmission system with a torque capacity of 15,000 in-lbs on the input shaft

f. Installed gear driven displacement type oil pumps (supply and scavenge). The supply pump provides sufficient capacity for lubrication of the gearbox plus the fan driven by the gearbox

g. Integral instrumentation for all critical parameters.

The accessory drive is designed as a self contained, detachable gearbox. It can be removed and replaced without disassembly of the pumps or gears. Bearings, removeable sumps, oil shields, brakes, and many other small components are interchangeable. Where possible, parts are unitized to eliminate joints that might fret or sustain assembly or operating damage. Design allowables used in rotating components are below the crack propagation threshold and/or below infinite life fatigue limits to ensure against material failures.

The gearbox is capable of carrying and sustaining all variable, unidirectional loads, including an additional overload factor of 2.0 for a life of at least 45,000 hours. The power efficiency of the gearbox has been calculated to be 98.0 percent. This efficiency does not include accessory power.

5.4.3.3 Lift Fan

Lift fans provide the airflow and pressure to the air cushion and seals for aerostatic support of the ship compatible with cushionborne performance. Each fan is a double suction double discharge rotating diffuser type fan. All design performance requirements are met by four fans having a diameter at the blade trailing edge of approximately 3.85 feet, or 117 cm.

The Aerophysics, Incorporated rotating diffuser (RD) fan shown in Figures 5.4-3 has been successfully used for many years in industrial applications, and has been selected for the CSES. Figure 5.4-4 is a side view sketch of the CSES fan and diesel engine. Use of the RD fan on air cushion supported platforms was first investigated in studies sponsored by the U. S. Army in the mid 1960s. These included the design, fabrication, and spin testing of a 5.5 foot diameter lightweight fan constructed entirely of aluminum using aircraft type riveted construction. Following these early investigations, development of the RD fan was extended to very large sizes, Figure 5.4-5. Under the 3KSES contract, the detailed design of a lightweight lift fan was completed. The fan was under full-scale construction when the 3KSES program was terminated. In addition, dynamic tests of a large scale model RD fan were completed at the David Taylor Naval Research and Development Center (DTNSRDC). These tests included evaluation of the fan's performance in the unsteady SES marine environment. The conclusion drawn from the DTNSRDC tests was that the behavior of the RD fans is well suited for the SES environment.

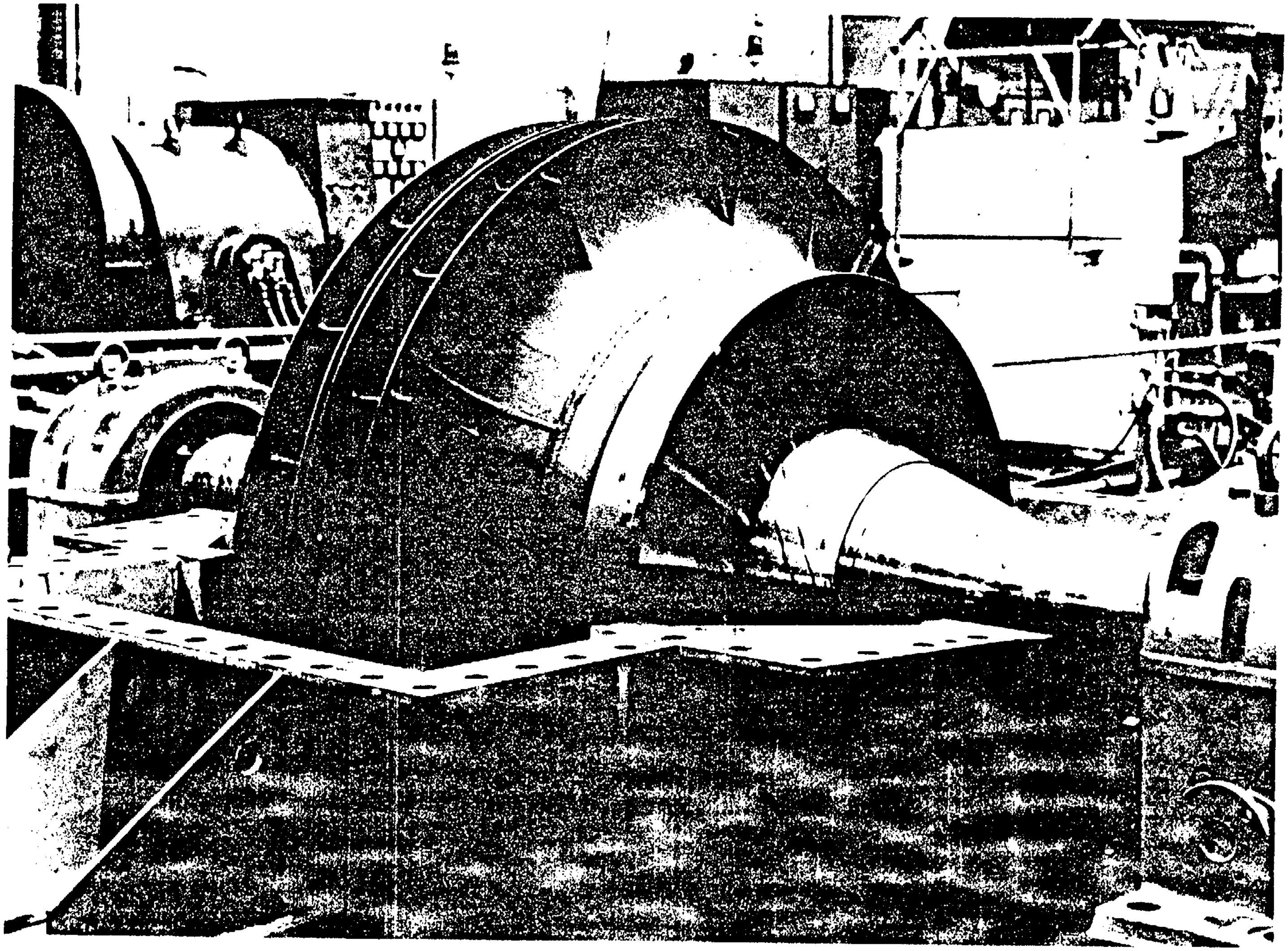


FIGURE 5.4-3
AEROPHYSICS INCORPORATED ROTATING DIFFUSER FAN

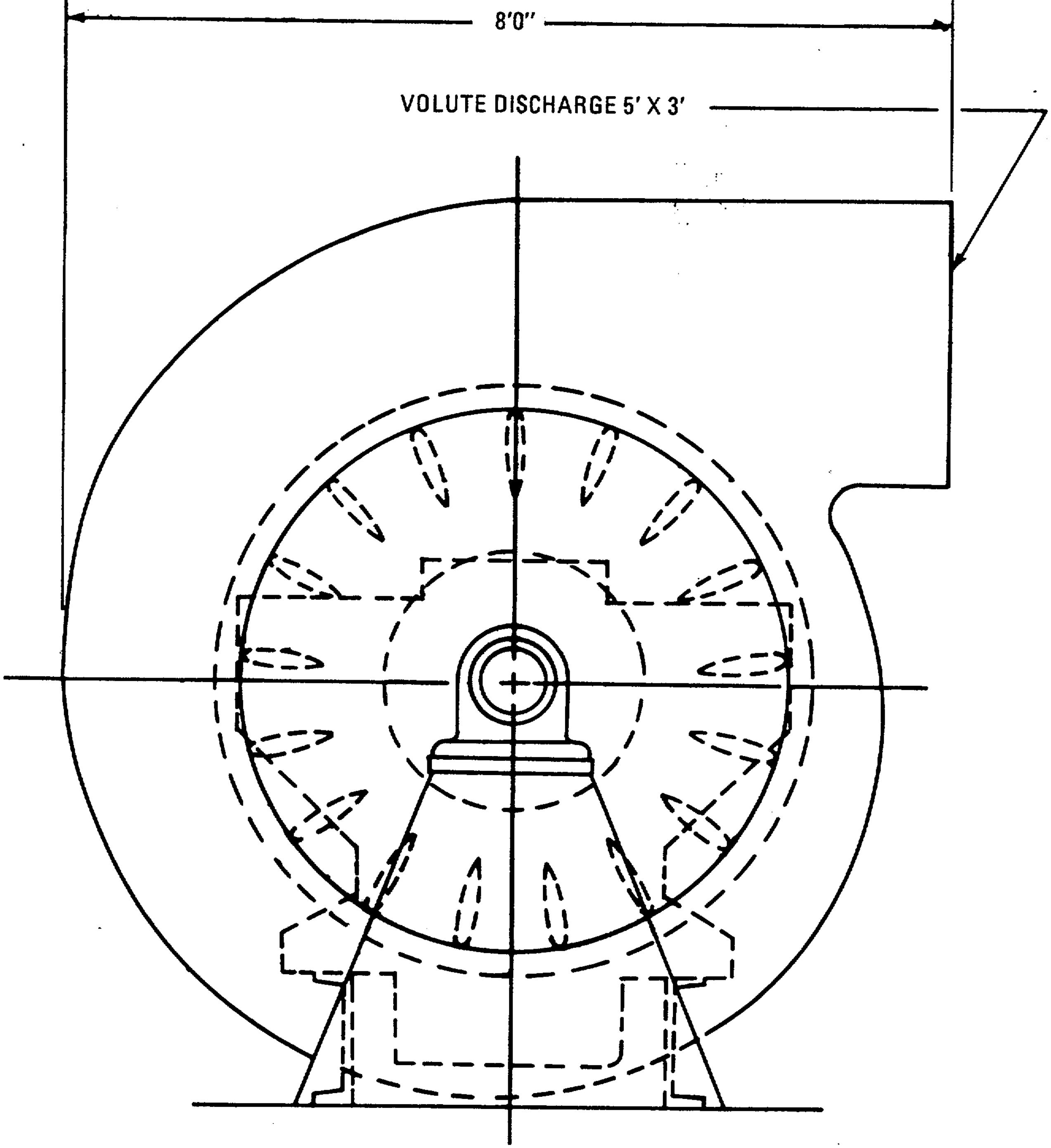


FIGURE 5.4-4.
CSES LIFT FAN – SIDE VIEW
WITH DIESEL ENGINE

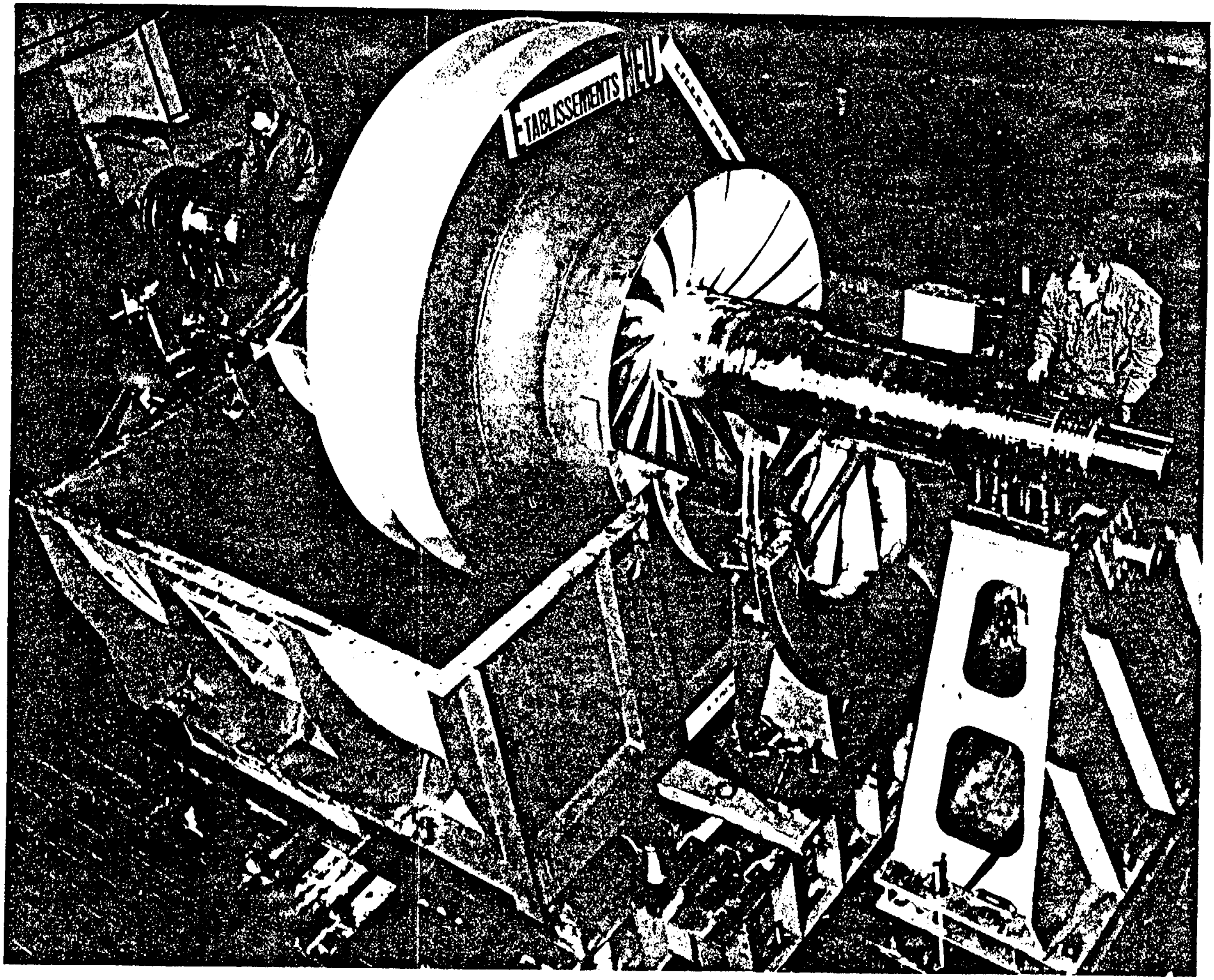


FIGURE 5.4-5
LARGE INDUSTRIAL ROTATING DIFFUSER FAN DURING ASSEMBLY

The RD lift fan for the CSES is of an existing design that has been in operation since 1974. Performance data was obtained from direct full scale measurements utilizing an approved ASTM code tester. Fan data is complete, including flow variations achieved with the radially installed inlet guide vanes. Tables 5.4-i and 5.4-ii detail the CSES fan's operating range of pressure and flow at CSES displacements of 350 and 400 LT respectively. The fan is capable of lifting the CSES by operating at pressures to 220 PSF. Figure 5.4-6 shows the measured fan operating map complete with the effects of IGVs. The pressure versus flow curve is smooth with no positive slope regions to cause instabilities or stalling. Efficiencies of 86 percent are achieved. Note the wide range of performance above 80 percent efficiency.

LIFT SYSTEM PERFORMANCE REQUIREMENTS - (350 LT)

SUB-SYSTEM	SEALS	CUSHION
NO. OF DWDI RD LIFT FANS	2	2
NO. OF INLETS	4	4
HORSE POWER AVAILABLE/INLET	435	435
P_S STATIC, PSF	140	127
P_T TOTAL, PSF	154	140
DELIVERED FLOW/INLET, CFS	1320	1452
TOTAL FLOW IN CUSHION, CFS	--	5810
TOTAL FLOW IN BOTH SEALS, CFS	5280	--
TOTAL FLOW/SHIP, CFS	11,090	
C_{Pt}, TOTAL PRESSURE COEFFICIENT	.061	.056
C_d, FLOW COEFFICIENT	.420	.460
N_t, TOTAL EFFICIENCY	.860	.850
IGV BLADE SETTING, DEGREES	0	0
SLOPE OF PERFORMANCE CURVE	STABLE	STABLE
TIP SPEED, FT/SECOND	362	362
RPM, ENGINE - FAN	1990 - 1620	
GEAR RATIO REQUIRED	1.23 to 1	

TABLE 5.4-i

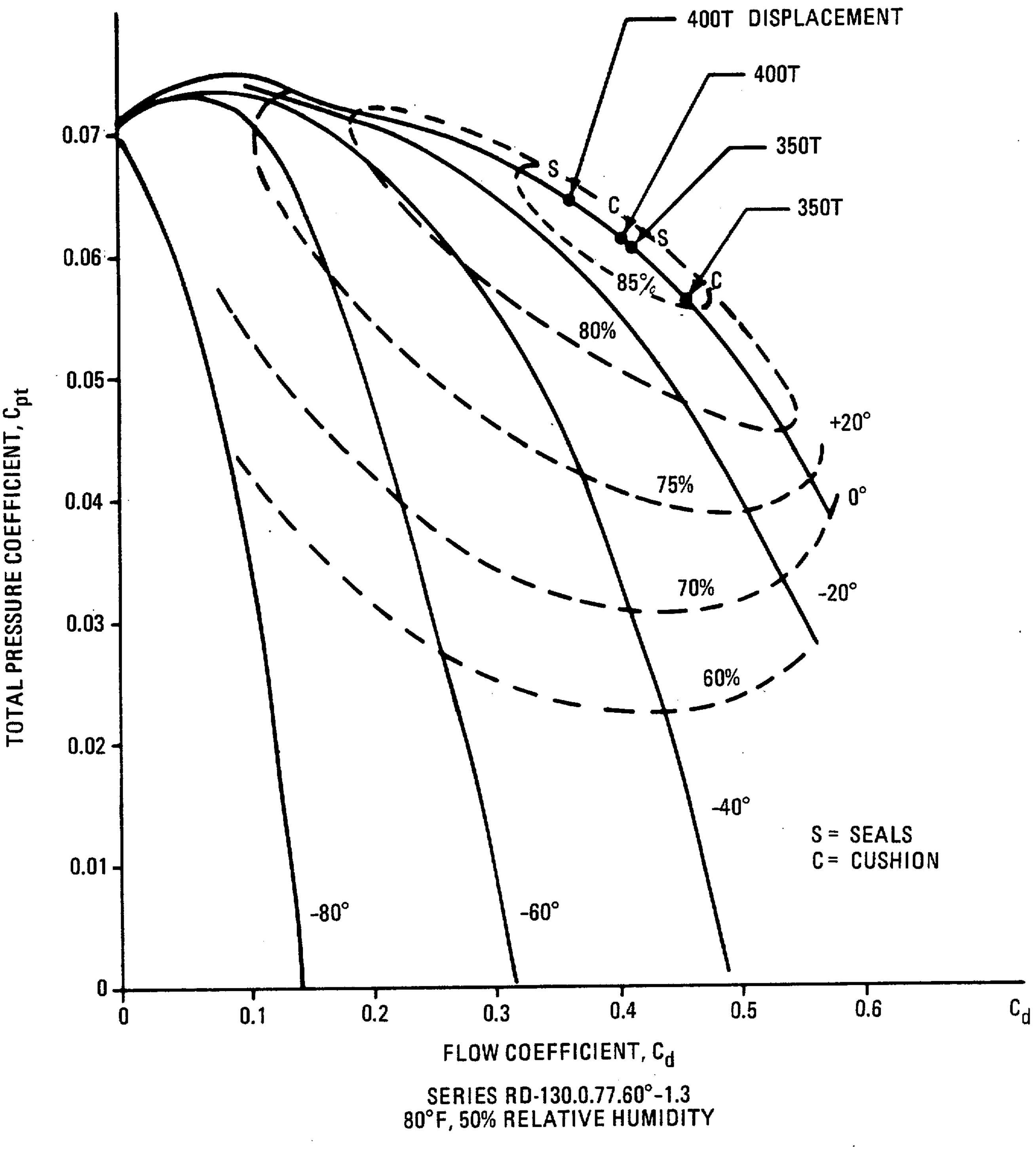


FIGURE 5.4-6
PERFORMANCE OF CSES
FULL SIZE ROTATING DIFFUSER FAN

LIFT SYSTEM PERFORMANCE REQUIREMENTS - (400 LT)

SUB-SYSTEM	SEALS	CUSHION
NO. OF DWDI RD LIFT FANS	2	2
NO. OF INLETS	4	4
HORSE POWER AVAILABLE/INLET	475	475
P_S STATIC, PSF	164	149
P_T TOTAL, PSF	180	164
DELIVERED FLOW/INLET, CFS	1233	1354
TOTAL FLOW IN CUSHION, CFS	--	5416
TOTAL FLOW IN BOTH SEALS, CFS	4934	--
TOTAL FLOW/SHIP, CFS	10350	
C_{Pt}, TOTAL PRESSURE COEFFICIENT	.065	.062
C_d, FLOW COEFFICIENT	.370	.414
N_t, TOTAL EFFICIENCY	.860	.860
IGV BLADE SETTING, DEGREES	0	0
SLOPE OF PERFORMANCE CURVE	STABLE	STABLE
TIP SPEED, FT/SECOND	380	385
RPM, ENGINE - FAN	2100 - 1710	2080 - 1685
GEAR RATIO REQUIRED	1.23 to 1	

TABLE 5.4-ii

The fan incorporates a centrifugal discharge impeller with an integral axial inducer inlet. The center disk and outer shrouds extend some 30 percent beyond the blade trailing edges to form the rotating diffuser air passage. Blades are flat plates rather than airfoil blades and are installed axially in the inlet portion. The flat plate blades facilitate economical construction and long life. The fan volute is a conventional rectangular volute. The fan inlet is directly coupled to a high efficiency ram recovery inlet duct. Inlet guide vanes are arranged in a radial torus in this duct. This configuration results in a shorter overall length in comparison to a fan configured with axial inlet guide vanes. The inlet caisson configuration also results in a quieter fan, as shown by noise level measurements in Figure 5.4-7 for a tip speed of 528 Ft/Sec. The CSES fan noise levels at 385 Ft/Sec are below the ISO 80 decibel level for non-ear protected spaces.

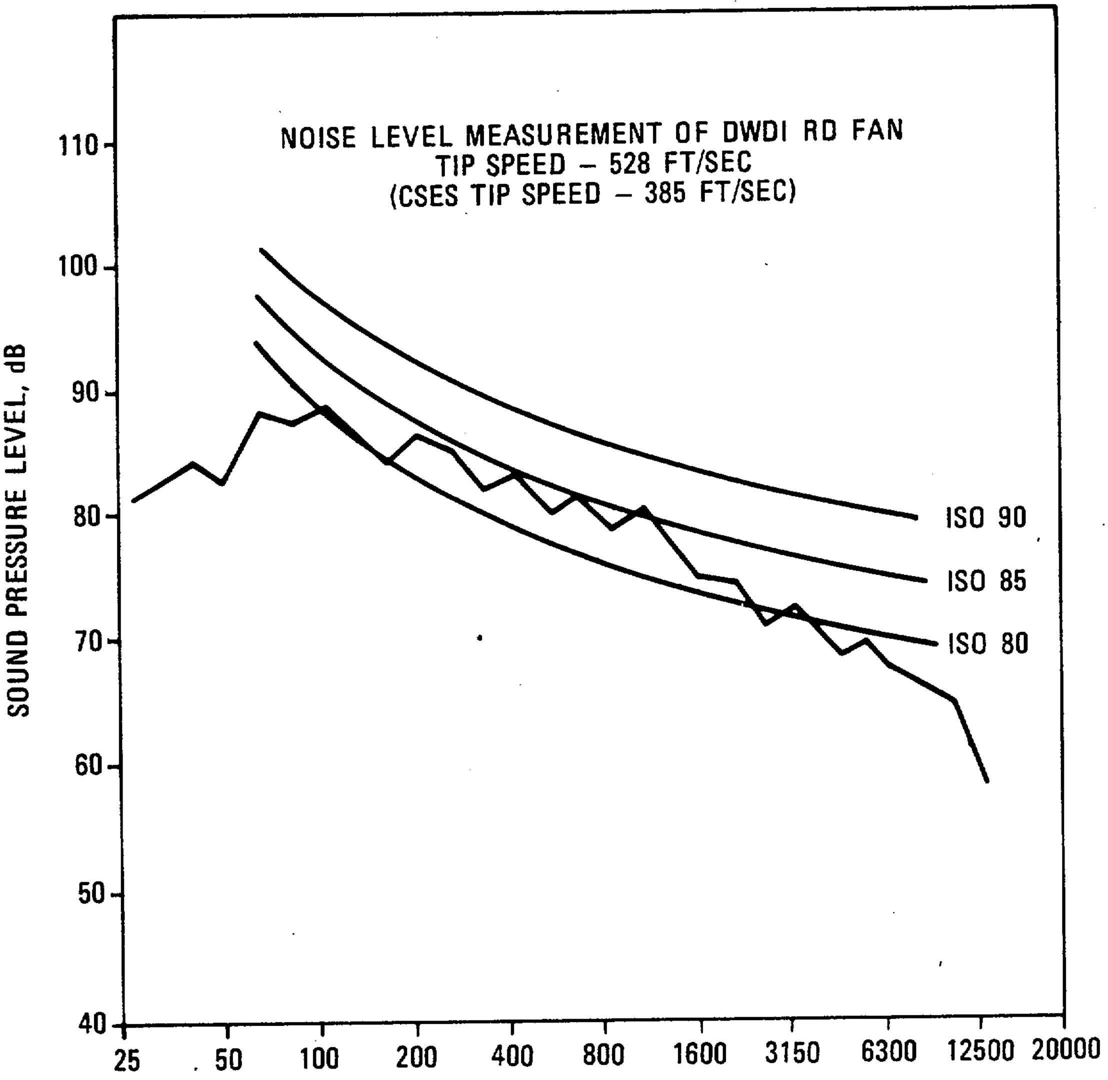
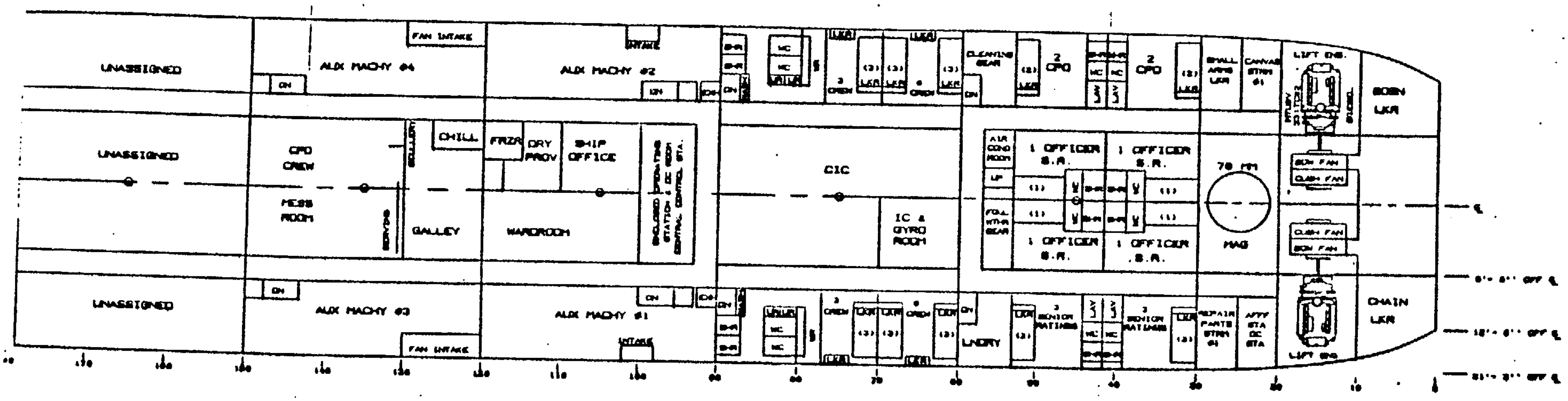
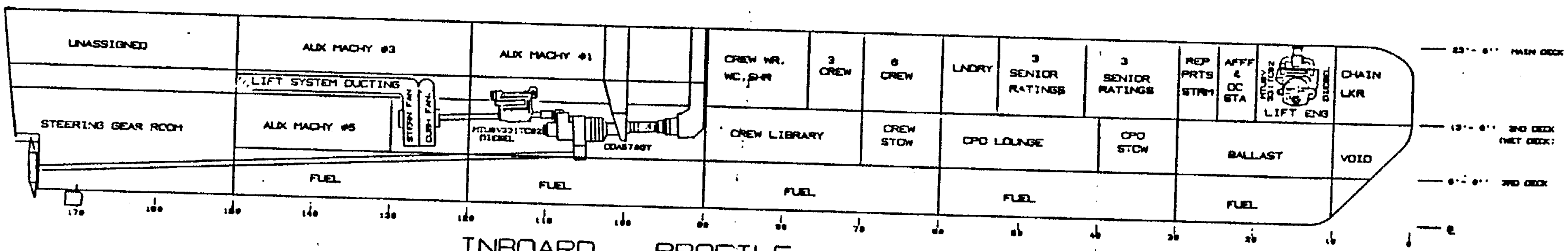


FIGURE 5.4-7.
FAN NOISE CHARACTERISTICS



SECOND DECK (13 FEET ABL)

FIGURE A-7
COASTAL SES SECOND DECK GENERAL ARRANGEMENT



INBOARD PROFILE (16 FEET OFF ℄)

FIGURE A-5
COASTAL SES INBOARD PROFILE

An available industrial type fan can be utilized since the CSES can accommodate this type fan both space and weight-wise, and at the same time provides the required pressures and flows. This fact, together with the extensive operating history of this type of fan (over 3,000,000 hours) provides the CSES with a development risk-free lift fan.

5.4.3.4 Lift Air Intake System

Intake air to the four lift fan sets is taken in through a large volume air trunk system that passes upward from the intake plenum through to a flush intake grill and valve entry on the ship main deck. Where the air trunk passes through the main deck level, grilled openings and air balance valves are provided in the overhead portion of the interior auxiliary machinery spaces. The intake lift fan air is also used as the source for the ship's machinery space ventilation.

The lift fan and diesel engine comprise a unified module in an essentially air tight compartment fed from above by the inlet air trunk. The volume and clearances of this plenum allow free air flow into the inlet guide vane system. Any water that might enter the topside intake would settle in this room and be discharged overboard through the deck drainage system. The placement of engine, gearbox, and other drive train elements within this volume allows for a secondary cooling air flow over these elements. Like the uptake, this room is structured to resist lower than atmospheric pressure.

5.4.3.5 Lift Air Distribution System

The lift air intake and distribution system accepts incoming ambient air at the weather deck and routes it to the lift fans, and then to the cushion and seals. In order to regulate the stern seal pressure relative to the cushion pressure, a transfer duct with a control valve between the stern seal and cushion augments fixed orifices in the stern seal. The lift air intake and distribution system also provide airborne noise attenuation for the lift fan inlets. Shut-off and ride control valves in the distribution ducts down stream of each fan forestall flooding of the fans when the ship is off-cushion in high seas, prevent back flow from the cushion or seal if the fan is shut down during on-cushion operation and modulate airflow to control cushion pressure in high seas to maintain good ride quality in conjuction with the IGV's.

5.4.4 Lift System Operation

The lift system is operated and monitored from the central control console and bridge as part of the propulsion control system (see paragraph 4.3.4). Machinery control and performance monitoring devices provide the means for control of individual fans and flow distribution devices and provide performance and condition monitoring of principal lift system elements. The lift system spaces are unmanned during operation.

The ship can operate on-cushion with any combination of the four fans. Maximum system efficiency at high speed and in rough seas is achieved with all four fans. This flexibility ensures almost 100 percent lift system availability. Even the loss of three fans increases ship drag by only 20 percent, which reduces top speed by approximately 10 knots. Secondary hump transition is possible with full-cushion, partial-cushion and can be avoided by remaining hullborne until over 18 knots before going on cushion, and is therefore independent of fan performance.

5.4.5 Lift System Weight Breakdown

Estimated weight of lift system components is presented in Table 5.4-iii. The total lift system weight is 18 LT.

WEIGHT OF LIFT SYSTEM - SWBS GROUP 567

LIFT SYSTEM	WEIGHT LT
MTU-8V331 TC 82 DIESEL ENGINES (4) (Includes intake/exhaust system, fuel and lube systems, cooling water system, mounts and electronics)	10.24
LIFT FANS (4)	2.55
GEARS, SHAFTS, SUPPORTS, MOUNTS (4)	1.73
AIR DISTRIBUTION DUCTS AND VALVES	.91
BOW SEAL	1.40
STERN SEAL	1.20
TOTAL LIFT SYSTEM	18.03

TABLE 5.4-iii

5.4.6 Lift System Machinery Risk Assessment

Overall, the risk associated with the lift system machinery is assessed to be low as indicated below and as supported in the preceeding text.

Engines -	No risk. Engines are currently in production and military marine use.
Transmission -	Low risk. Gearbox detail design is straight forward. The low power and reduction ratio keeps the system lightweight, simple and within several manufacturers' stock series. Performance estimates will be verified by test of first unit.
Lift Fans -	Low risk. Rotating diffuser fans have been operated extensively at duty points that exceed those required for the CSES. Successful operation has demonstrated their reliability. Centrifugal and mixed flow fans produced by other manufacturers are also available with efficienies of up to 80 percent.
Lift Air Distribution - System	No risk. This is a straight-forward detail design task.

5.5 ELECTRICAL SYSTEMS

5.5.1 Electrical Power Requirements

The sizing of the electrical generators is based on meeting the following requirements:

a. power to be available to meet the full battle load

b. instantaneous availability of an alternate power source for vital circuits.

c. a margin for further growth, and

d. a 50 percent redundancy for generation.

Because of the similarity in size, weapon suite and auxiliary equipments, the CSES electrical load estimates are based on the PHM Electrical load analysis. The ship service battle load for the PHM is 175 KW. For the CSES this load has been factored by 1.3 to allow for the greater area, volume and crew size. Also an additional 37 KW has been included to provide power for the Close-In-Weapons System (CIWS) which is not installed in the PHM. This results in an estimated battle condition combined electrical load of 265 KW for the CSES. In addition, growth margin of 30 percent has been applied resulting in a combined electrical power requirement of 344 KW for the CSES.

5.5.2 Electrical System Description

The CSES electrical system is modelled after the PHM system, scaled upward to meet the CSES electric load requirements. The system provides alternating and direct current power for normal ship's use, for engine cranking and for emergency.

Power generation is provided by three Airesearch Model ME 831-800 gas turbines driving three Westinghouse 200 KW, 400 Hz, 440 volts generators. One or two of the generators provide primary alternating current power dependent on the operating electrical load. The third generator is available on a standby basis. Emergency power is supplied by the lift system diesel engine generators and by batteries to provide 28 volt direct current power for emergency radio, ship control system and emergency lights.

Power conversion to handle the 60 Hz loads is provided by three 400 Hz/60 Hz frequency converters, two units for primary conversion and the third for standby. The two on-line generators each supply a separate switchboard which also serves as a central point for power distribution. A tie bus between the main switchboard buses allows the generators to supply the ships system individually, split plant, or in parallel. The third generator may be connected to either switchboard. In order to insure maximum continuity of service, the design of the electric plant is based on split plant operation. Parallel operation of the ship service generators is also provided. Conversion equipment is provided to convert 400 Hz AC power to DC for ship service DC loads and for automatic battery charging. The electric plant will be monitored and operated from the central control station console.

5.5.3 Electrical System Weight Breakdown

Electrical system weights by subdivisions of SWBS Group 300 weight are presented in Table 5.5-i.

WEIGHTS OF ELECTRICAL SYSTEM - SWBS GROUP 300

SWBS	ITEM	WEIGHT LT
311	Ship Service Power Generation	4.64
313	Batteries and Service Facility	0.45
314	Power Conversion System	0.94
315	Shore Power Receptacle	0.03
321	Ship Service Power Cable	2.57
322	Switch Gear and Panels	1.24
331	Light Distribution	0.12
332	Light Fixtures	1.30
333	Switches, Receptacles and Outlets	0.12
398	Electrical Plant Operating Fluids	0.12
399	Electrical Plant Repair Parts & Tools	0.04
	TOTAL ELECTRICAL SYSTEM	11.57

TABLE 5.5-i

5.5.4 Electrical System Risk Assessment

Electrical system design is based upon the PHM electrical system. The gas turbines which power the ship's service power units have been qualified in accordance with MIL-E-17341. All PHM ship service electrical equipment is suitable for marine use and vibration levels and is compatible with all operating fluids. No technical risk or special development is anticipated therefore for this area.

5.6 COMBAT SYSTEM

The Coastal Surface Effect Ship (CSES) is intended to augment the main surface forces, particularly in the Mediterranean and the narrow seas and inlets of the Atlantic and Pacific in a surface warfare role. Capabilities of the CSES include surface and air surveillance, and detection and attack of enemy forces. The CSES will have all weather capability, a significant speed advantage over conventional craft, and long range and good performance capability in high sea states. It is expected that the maximum duration of any mission will be five days.

5.6.1 Combat System Description

Air targets can be detected by the Fire Control System FCS MK 92/Mod 1, the ASMD/EW ESM Suite AN/SLQ-32(V)2, CIWS Radar, and in the case of low flyers, the surface search radar AN/SPS-64. Target identification is performed using the AIMS MK 12 IFF System and the AN/SLQ-32(V)2 (for active RF emitters). Air targets can be engaged by the 76mm gun and the CIWS system. The CIWS, the primary anti-ship missile defense (ASMD) system for the CSES, provides close-in terminal defense against anti-ship missiles or manned aircraft making low level passes over the ship. The 76mm gun would supplement CIWS in ASMD and provide limited capability for engaging multiple closing targets or aircraft making dive bombing or rocket attacks outside CIWS range. A passive terminal defense is provided by the MK 36 decoy launcher using chaff and other decoys now under development to deflect radar homing or other types of anti-ship missiles.

For the surface warfare function, the CSES would have an engagement capability against patrol craft and small boats using the 76mm gun controlled by the MK 92 MOD 1 FCS. With HARPOON the CSES would have a capability to engage surface targets using radar or over-the-horizon targeting sensors (i.e., AN/SLQ-32) or LINK 11. The MK 92 Mod 1 Fire Control System would perform air search, surface search (supplementing AN/SPS-64), target tracking and weapon control.

The Command and Control system to support the warfare area functions is an austere version of that used for FFG-7 and slightly more sophisticated than the PHM. The Command and Control system would be oriented to AAW/ASUW self-defense as reflected by the organization and reduced number of consoles. LINK 11 affords an automatic exchange of data with other surface combatants, and provides a source for targeting data against surface targets. This will provide an additional capability for ASMD through a heads-up warning of potential closing air targets, and permits command to optimize the use of all AAW systems.

5.6.2 Combat System Elements

This section provides a summary description of the varied elements of the CSES Combat System (SWBS Groups 4 and 7).

5.6.2.1 Radar Set AN/SPS-64(V)

The AN/SPS-64(V) is the surface search and navigation radar. It is a two dimensional (azimuth and range) radar set designed for surface search with a potential secondary capability of anti-ship-missile (ASM) and low-flyer detection. The Collision Avoidance System AN/SSQ-87(V) (currently under development for PHM-1) will use this radar as the primary sensor. The concept shown in Figure 5.6-1 is an adaption of this system.

5.6.2.2 Shipboard AIMS MK XII IFF System

The Shipboard AIMS MK XII IFF System provides a means of identifying radar targets. Aircraft or ships carry transponders that, when enabled, automatically respond to RF coded signals. These responses are encoded to provide identification for IFF, but are generally used for transmitting emergency and altitude information for traffic control, and emergency signals for search and rescue purposes.

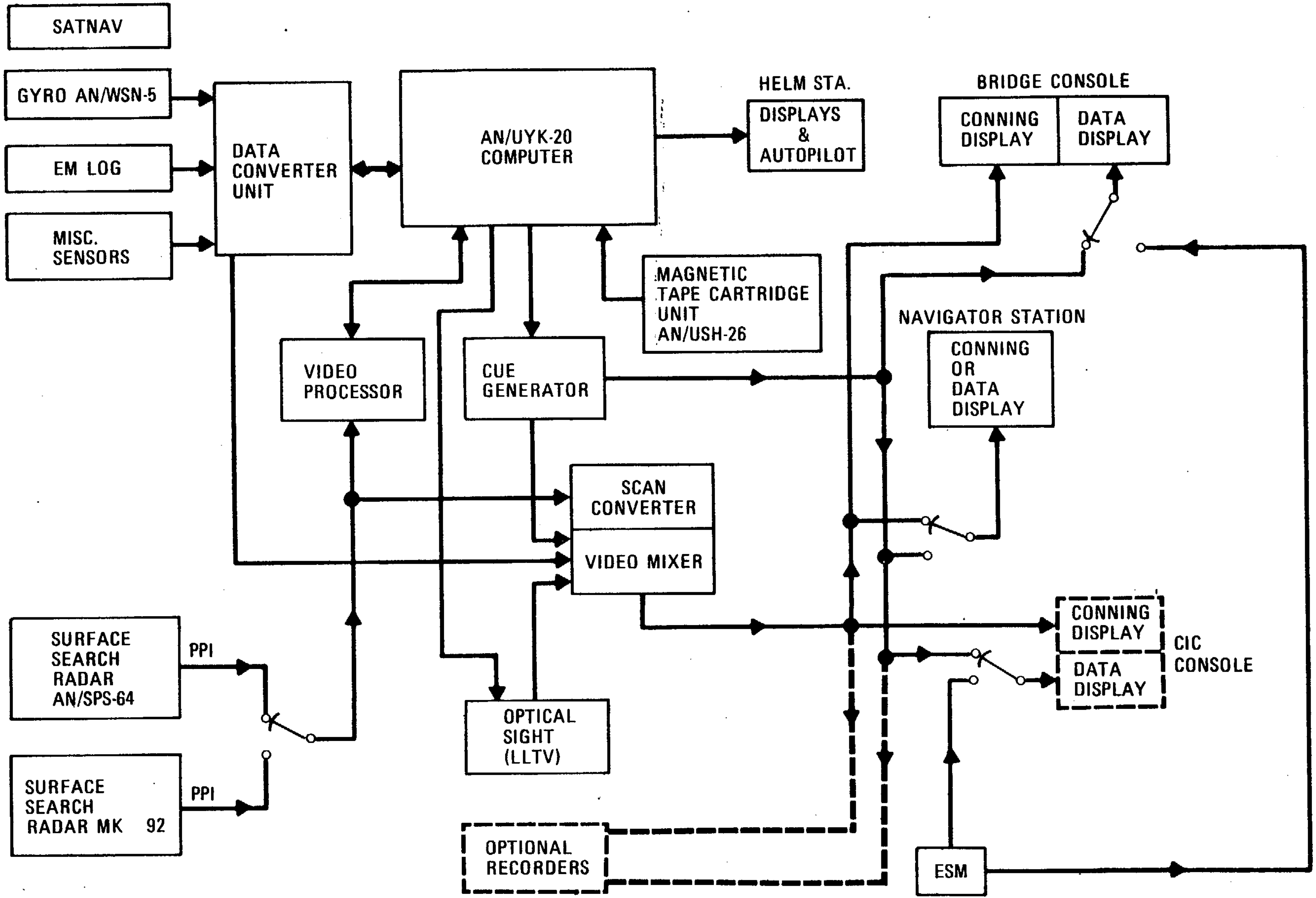


FIGURE 5.6-1
MODIFIED COLLISION AVOIDANCE SYSTEMS (AN/SSQ-87)

The AIMS MK XII IFF System consists of:

- Two interrogators UPX-25(V)4
- Transponder set AN/UPX-28(V)2
- Radar test set AN/UPM-137A

One interrogator is associated with the MK 92 FCS combined antenna system (CAS) and the other with the AN/SPS-64(V) radar antenna. IFF video decoders are provided on the consoles in CIC to actuate the interrogators and present IFF returns.

A crypto-computer is provided with each of the two interrogators and the transponder. The crypto-computer controls encoding of transponder responses, interrogator inquiries and decoding of interrogator returns to implement the crypto-secure identification feature of the AIMS MK XII.

The active video decoders require synchronous sweep data from the associated display for proper operation. A standard interface would be employed for the video decoders mounted on the AN/UYQ-21(V) consoles.

The AIMS transponder group consists of the AN/UPX-28(V)2 Transponder Set with the associated C-628Z/APX control. It uses a omnidirectional antenna for receiving interrogations and transmitted responses. A radar test set having a separate AS-177B/UPX antenna is used to test the Transponder Set. The transponder operation is automatic when enabled, except for the supression gates to prevent the transponder from replying to ownship interrogations.

5.6.2.3 Countermeasures Set AN/SLQ-32(V)

Countermeasures Set AN/SLQ-32(V)2 is a shipboard system designed to provide Electronic Support Measures (ESM), automatic signal processing and analysis and Electronic Countermeasures (ECM) capabilities. The system can detect, identify and measure direction of arrival for RF emitters in the frequency range of 0.6 to 17G Hz. The system incorporates a display console with a polar situation display of emitters and the track history of emitters when requested. The system can operate in automatic, semi-automatic or manual modes. The operators also provide the primary control for the Decoy Launching System MK 36 MOD 1 through a firing panel mounted on the console. This system is pictorially laid out in Figure 5.6-2.

5.6.2.4 Command, Control and Communications (C^3)

The Command, Control and Communications elements of the CSES Combat System consists of equipment, software programs, operator, operations and procedures associated with the collection and evaluation of combat information and sensor data, dissemination of targets with engagement orders to the weapon systems. The primary function of C^3 is coordinating all ship's resources into an integrated combat system. C^3 provides Command the capability to assess and evaluate tactical data on an orderly basis, make logical decisions with regard to the current threat environment, and exercise effective control over the combat system.

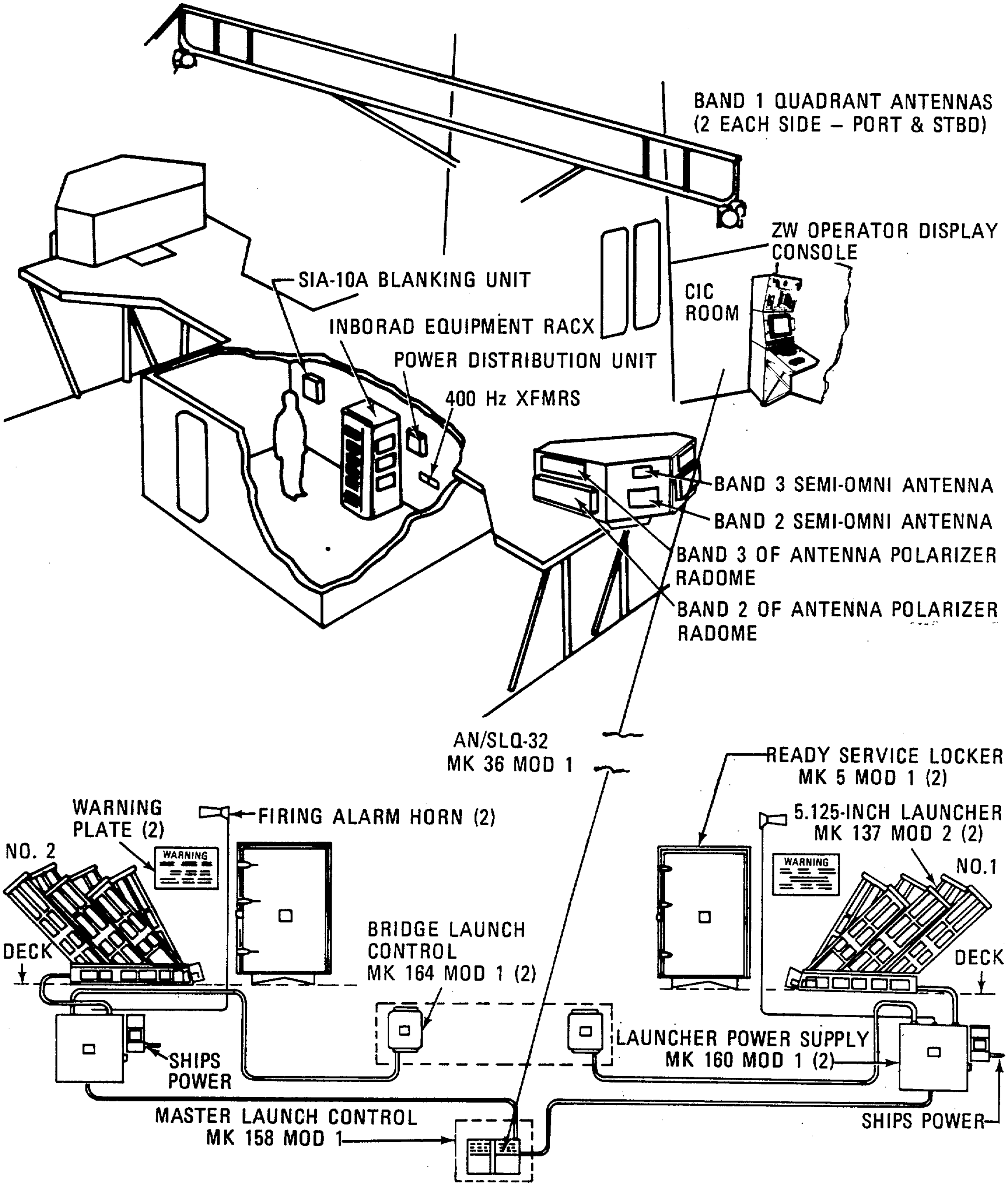


FIGURE 5.6-2
ELECTRONIC COUNTERMEASURES SET (AN/SLQ-32) AND
LAUNCHING SYSTEM (MK 36 MOD 1)

The principal components of Command, Control and Communication are the display group, computer processing system, ships support equipment (navigation, ship's data), and communication (external, internal).

5.6.2.4.1 Display Group

The Display Group consists of displays, support equipments and software programs which provide the interface between sensors, armament systems, data processing system and operators. The Display Group includes UYQ-21 displays (Navy standard), Fire Control System displays (MK 92-WCC1), Radar Indicators, Central Equipment Group, Radar Switchboards, Radar Video Processor, Signal Data Converter, Common Data Buffer, Video Signal Simulator, Signal Blanker and a Keyset.

5.6.2.4.1.1 AN/UYQ-21 Standard Display Console

The Standard Display Console can accommodate a variety of entry and control panel types for tailoring to the requirements of a given application. The configurations are made up of a number of standard panels.

5.6.2.4.1.2 MK 92 - Weapon Control Console (WCC)

Weapon Control Console (WCC), part of the FCS MK 92 MOD 1, provides the air and surface operator function. An A-scope provides the capability to monitor the acquisition and tracking of air targets along with markers showing minimum and maximum firing ranges for target being tracked. The operator also makes target kill or survival entries as appropriate for air engagements. The surface track-while-scan operator is responsible for the detection, tracking and engaging surface targets. The operator performs kill assessments along with control of HARPOON Control-Indicator Panel. A B-scope provides for monitoring surface tracking.

The PPI provides simultaneous display of radar video, IFF data, and track symbols. Radar video is selectable from the MK 92 radar or AN/SPS-64 surface search radar. See Figure 5.6-3 for a diagram of the complete MK 92 Mod 1 system which is further discussed in 5.6.2.8.

5.6.2.4.1.3 Radar Indicator

A Radar Indicator (AN/SPA-25) provides a two coordinate display of targets detected by the selected radar source. The radar indicator is physically located in CIC, and provides a range variation from 1 to 300 miles.

5.6.2.4.1.4 Central Equipment Group (CEG)

The Central Equipment Group (CEG) is normally used with a UYA-4 Display Group. The AN/UYQ-21 Display Group requires a similar equipment for sensor data conversion and provides a good conceptual representation of the space, weight and cost required.

5.6.2.4.1.5 Radar Switchboards

The Display Group uses a Radar Data Distribution Switchboard and a Radar Signal Distribution Switchboard. The Radar Data Distribution Switchboard provides for the selective distribution of radar and IFF/SIF data from the ship's sensors to the

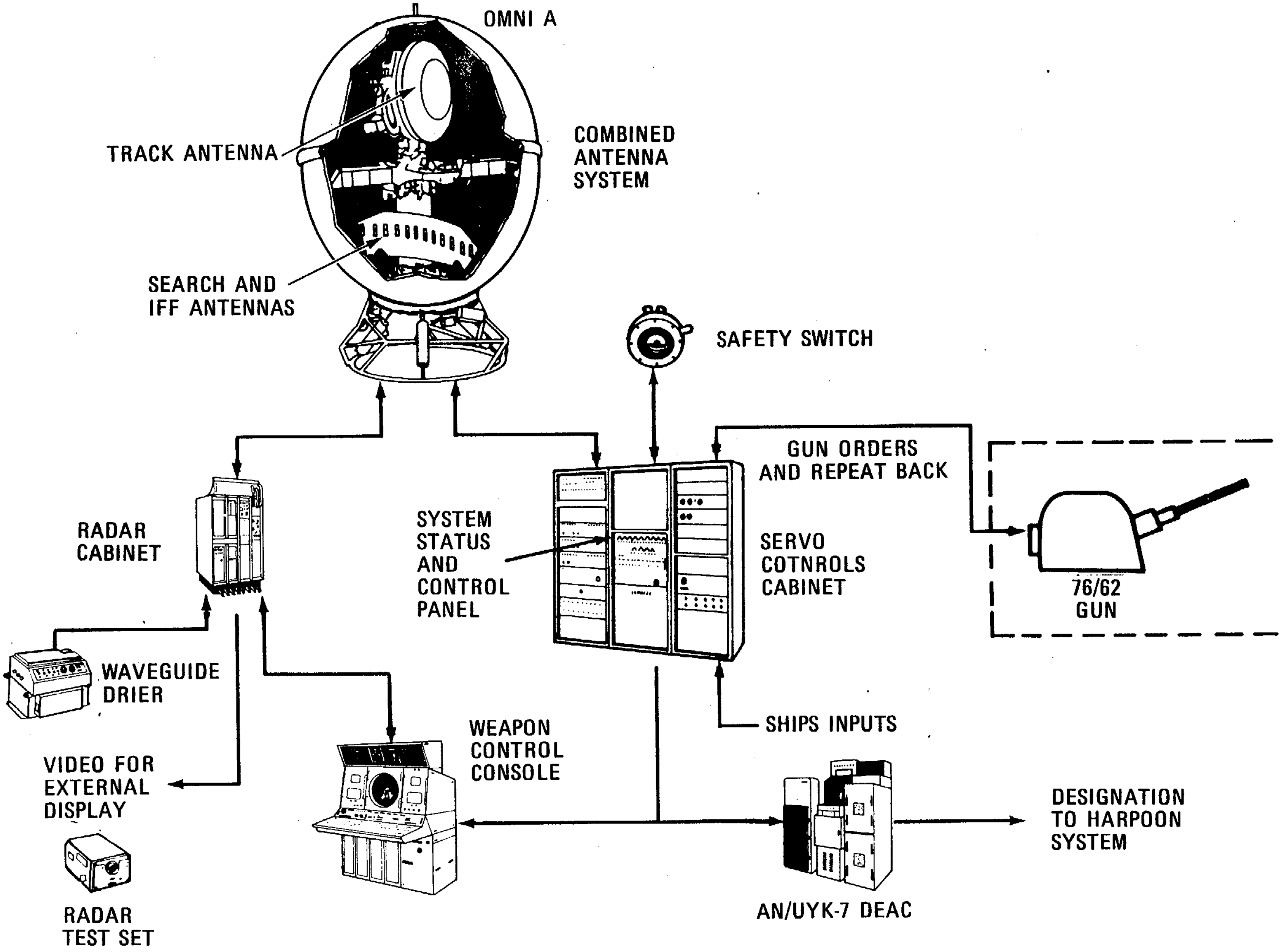


FIGURE 5.6-3
FIRE CONTROL SYSTEM (MK 92 SYSTEM MOD-1)

consoles of the display group. Each display console operator can select the data source he wishes. The Radar Signal Distribution Switchboard is used to distribute radar and IFF/SIF data to the radar indicators AN/SPA-25 and the FCS MK 92 MOD 1 WCC1 console, and the adapted collision avoidance system AN/SSQ-87(V).

5.6.2.4.1.6 Radar Video Processor (RVP)

The Radar Video Processor provides for the processing and data transfer required to present composite video to the display consoles.

5.6.2.4.1.7 Signal Data Converter (SDC)

The Signal Data Converter (SDC) provides the conversion of analog ship parameter data to a digital format for entry into the computer. Target bearing and elevation is also converted from a digital format to analog form in designation to weapons. The SDC is also used to multiplex low bandwidth data inputs to the computer.

5.6.2.4.1.8 Common Data Buffer (CDB)

The Common Data Buffer (CDB) is used to distribute data from multiple computers to multiple display group channels.

5.6.2.4.1.9 Video Signal Simulator (VSS)

The Video Signal Simulator (VSS) is used to test, calibrate, and determine system accuracy of display equipment and their operators by simulating tactical situations under computer control.

5.6.2.4.1.10 Signal Blanker

The Signal Blanker prevents interference from occuring between combat system sensors and the EW system. The unit disables the EW receivers during active radar transmission.

5.6.2.4.1.11 Keyset

The Keyset is used by the EW operator in entering EW contact data into the computer.

5.6.2.4.2 Computer Processing Group

The Computer Processing Group includes a single bay AN/UYK-7 general purpose computer, Input/Output Console, Cartridge Magnetic Tape Unit, Combat System Switchboard, Computer Control and Computer Logic Unit Test Set.

The Command and Control (C&C) software for the CSES performs the coordination of the combat system elements. Data is maintained, evaluated and disseminated by the C&C software functions. These functions, which are described below, may exist as a separate module or several may be combined into single modules depending upon the philosophy of the final design.

5.6.2.4.2.1 Command and Control (C&C) Software

The C&C software consist of programs executed in the single bay UYK-7 computers. The computer program has an executive and support function module providing initialization, scheduling, interrupt processing, I/O handling, error processing, intercomputer data processing, peripheral data processing, and consolidating common data, mathematical functions and conversion routines.

The following functions are provided by the Command and Control Software:

a. Tracking

b. Threat Evaluation and Weapon Assignment (TEWA)

c. Engagement

d. Display

e. Ownship position keeping

f. RADAR Video Processor (RVP)

g. LINK 11

h. Electronic Warfare (EW)

5.6.2.4.3 AN/UYK-7 Computer (1 Bay)

The single bay UYK-7 Computer consists of the following modules:

- Central Processor Unit - Processes and executes instructions
- Memory Unit (Three, each of 16, 384 words of 32 bits each) - Storage of data and instructions
- Input/Output Controller - Controls I/O transfer between peripherals via I/O adapter
- Input/Output Adapter - Interfaces the I/O Controller to the peripherals
- Power Supply - Provides operating power
- Operator Panel - Full local computer control for monitoring and test purposes.

5.6.2.4.4 Computer Control Panel

The Computer Control Panel provides remote operational control of AN/UYK-7 computer.

5.6.2.4.5 Computer Logic Unit Test Set

The test set provides a means of monitoring and exercising the computer for operability testing. It also provides fault isolation during maintenance.

5.6.2.4.6 Input/Output Console

The Input/Output Console is a OJ-172. It provides the following Input/Output capabilities:

- Teletype keyboard and printer
- Paper tape reader and punch
- Magnetic tape recorder/reproducer

5.6.2.4.7 Cartridge Magnetic Tape Unit (CMTU)

The Cartridge Magnetic Tape Unit (CMTU) is used for storing the operational program, data bases and off line system modules as required.

5.6.2.4.8 Combat System Switchboard

The Combat System Switchboard consists of three functional sections: Power Distribution Section, a Digital Switching Section and a Control and Status Section. Each section contains appropriate electrical electronic hardware required to support its associated function.

5.6.2.5 Ship's Support Equipment

The Ship's Support Equipment consists of navigational and ship's data equipment.

5.6.2.5.1 Navigation Equipment

The Navigation Equipment consists of the Satellite Navigation (SATNAV), AN/WRN-5 Dead Reckoning (DR) system, EM Log and gyro compass.

5.6.2.5.2 Satellite Navigation (SATNAV)

The Satellite Navigation system, which is a world-wide all-weather system, provides the CSES with the capability of obtaining accurate periodic fixes (hourly, day or night).

5.6.2.5.3 Electromagnetic (EM) Log

The Electromagnetic (EM) Log equipment consists essentially of a rodmeter and indicator transmitter by which ship's speed is provided.

5.6.2.5.4 Gyrocompass

The AN/WSN-5 Gyrocompass provides own ship heading and position to the navigation system, and a dead reckoned position independent of outside assistance at all times.

5.6.2.5.5 Ship's Data Equipment

The Ship's Data Equipment consists of the Gyrocompass (previously identified), Wind Monitoring Equipment, and Depth Indicator. The Gyrocompass provides roll and pitch data for stabilization of Surveillance, Fire Control equipment and the ship control system. The Wind Monitoring Equipment provides wind direction and speed to respective indicators.

5.6.2.6 Communications

The CSES communication equipment consists of external and internal communication systems which provide command the capability to carry out the ship's assigned missions.

5.6.2.6.1 External Communication

The External Communication system provides the exchange of information between own ship and other ships, aircraft, shore stations or shorebased units. The Communication system includes visual means, Radio Teletype (RATT), Radio Telephone (non-secure and secure) and Radio Net for external communications. The Visual Means of communication includes flaghoist, semaphore and flashing lights. Visual means are generally most used during daylight hours. The Radio Teletype communication systems sends and receives messages in radio central. The systems consist of Simplex, Duplex and Broadcast channels as required. The Radio Telephone systems provide voice (non-secure, secure) communications in HF, VHF and UHF frequency bands. These systems are the primary means of external communications because of their convenience, speed and simplicity of operation. The Automated Radio Net (LINK 11) is an organization of two or more stations capable of direct computer to computer communication on a common channel and being controlled by one of the stations. Table 5.6-i provides a set of requirements and a typical installation is provided in Figure 5.6-4.

5.6.2.6.2 Internal Communication

The Internal Communication systems provide the exchange of information between two or more stations within a ship. The communication systems consist of the following:

a. Sound-Powered Telephones. The Sound-Powered Phone System links stations throughout a ship, such as ship control, weapons control, bridge and lookouts.

b. Dial Telephones. The Dial Telephone System, which is primarily an administrative circuit, provides selected communication among the ship stations, and when in port, between the ship and the shore system. The system provides direct control to the calling station.

c. Inter-Communication (Intercom) System. The Intercom System provides two-way communication between stations. The Combat Information Announcing System (Circuit 20MC), and Captain's Command Announcing System (Circuit 21MC) would be installed.

d. General Announcing System. The General Announcing System is used to broadcast information to a number of stations simultaneously.

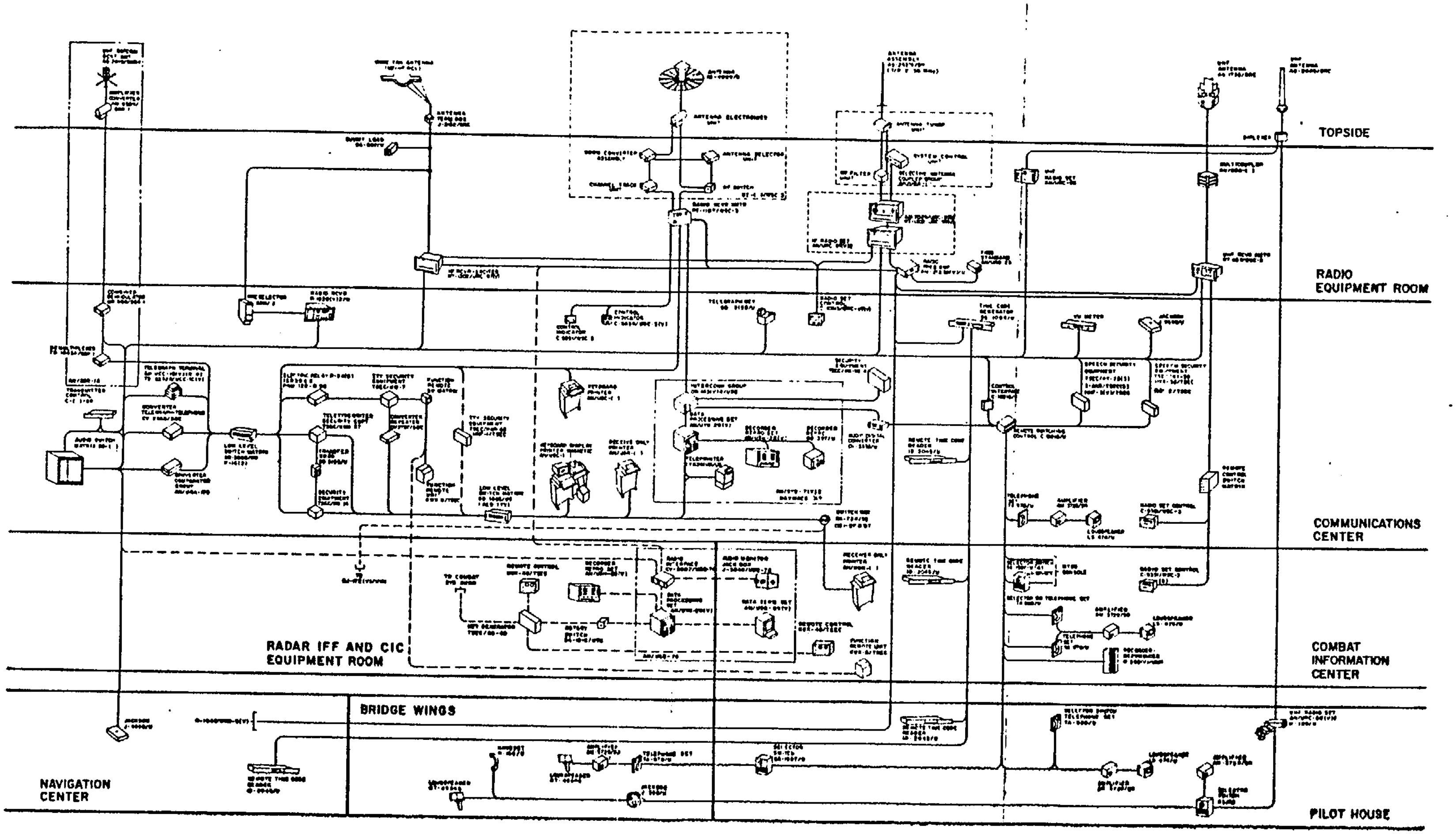


FIGURE 5.8-4
EXTERIOR COMMUNICATION SYSTEM

e. Closed-Circuit Television. The Closed-Circuit Television System is used to transmit video from the HELO platform to a TV monitor in the bridge.

EXTERNAL COMMUNICATION REQUIREMENTS

RADIO TRANSMITTING/TRANSCEIVER FACILITIES			QUANTITY
2.0	- 30	MHZ All Emissions (1KW)	2
115	- 156	MHZ A3	1
156	- 162	MHZ F3	1
225	- 400	MHZ A3/F3	4
225	- 400	MHZ Satellite Transceiver	1
RADIO RECEIVING FACILITIES			
0.5	- 30	MHZ A1, A2, A3, F1	1
2.0	- 30	MHZ All Emissions	2
115	- 156	MHZ A3	1
225	- 400	MHZ Satellite Broadcast	1
TERMINAL SYSTEMS			
"B"	-	SC Simplex AFTS RATT	1
"C"	-	Duplex AFTS RATT	1
"G"	-	SC Duplex RFCS RATT	1
"N"	-	MC BCST AFTS RATT (4 CHANNEL)	1
"R"	-	V/UHF SC Secure Voice (Wideband)	3
"S"	-	HF SC Secure Voice (Narrowband)	1
"VV"	-	SC Simplex AFTS/RFCS RATT (Non-secure)	1
	-	UHF Satellite Secure Voice (Narrowband)	1
Link 11	-	NTDS (S&W)	1
Link 14	-	SC BCST RFCS RATT NTDS (Receive) (S&W)	1
SPECIAL FACILITIES			
Relay Device			1
Manual Message Handling			1
AN/URQ-23 Frequency Standard			1
CSS			1

TABLE 5.6-i

5.6.2.7 Harpoon Launchers

Two HARPOON canister launchers are to be installed. Each launcher as shown in Figure 5.6-5 contains four HARPOON missiles.

5.6.2.8 Fire Control Systems MK 92 MOD 1

The MK 92 Mod 1 is a lightweight gunfire control system whose functions include air and surface target detection and tracking, identification, and engagement with the 76mm/62 Gun Mount MK 75. The system includes the components illustrated in Figure 5.6-3.

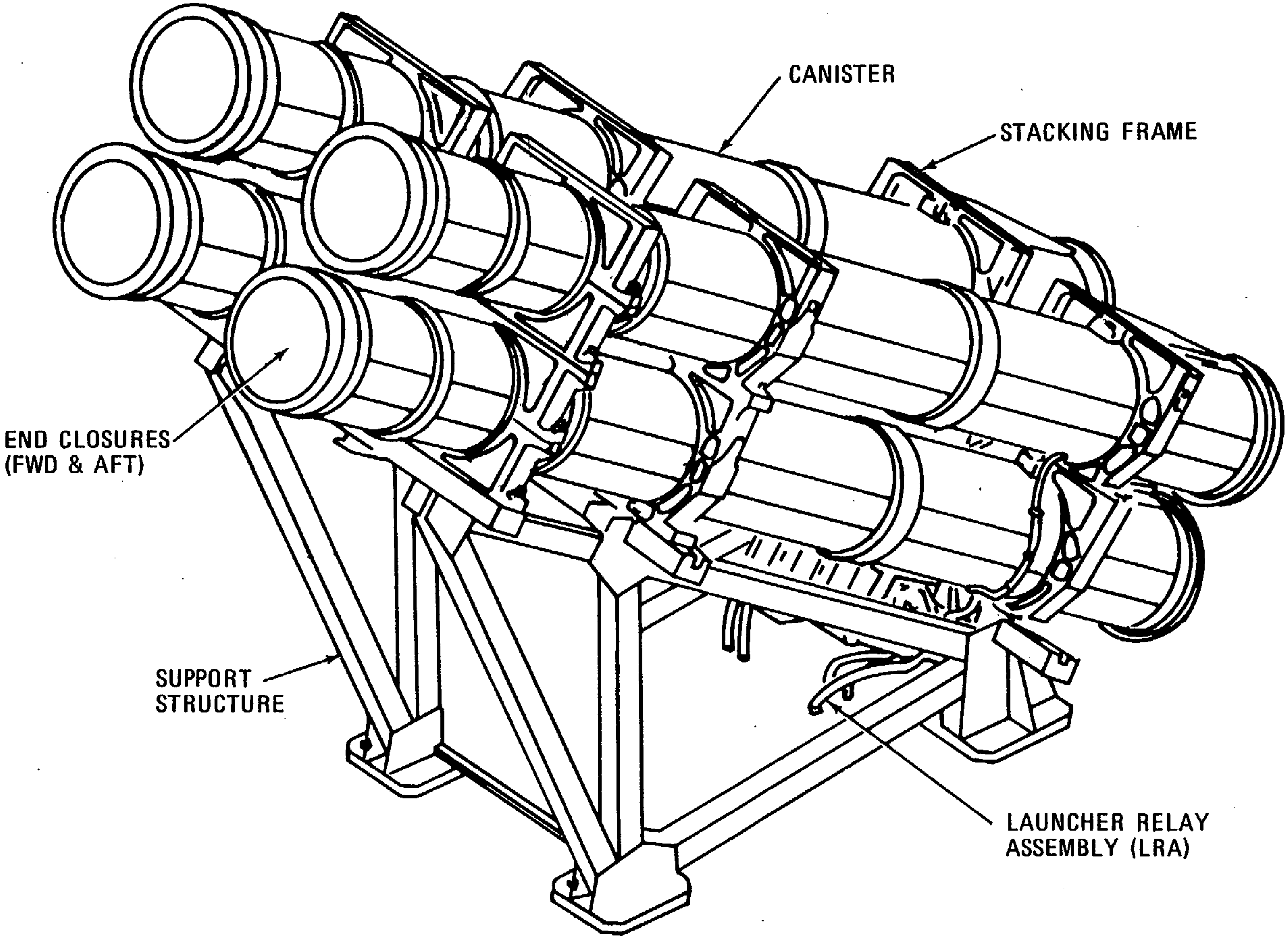


FIGURE 5.6-5
HARPOON CANISTER LAUNCHER

The combined antenna system incorporates a three coordinate air tracking radar antenna, a two coordinate surface or low altitude air tracking radar antenna, and directional and omni-directional antenna of the AIMS MK XII IFF system.

The Weapon Control Console (WCC) has PPI, A scope, and B scope displays for target video, an evaluation display and keyboard for target information display and a control panel for radar and weapon control. The single bay AN/UYK-7 computer and DEAC are part of the central computer system described previously.

The FCS MK 92 MOD 1 provides one air engagement channel, two surface track-while-scan engagement channels, and gun control. It has a limited capability with one surface channel to engage non-radar targets using dead reckon or grid-reference modes.

5.6.2.9 76mm/62 Gun Mount MK 75

The MK 75 gun mount shown in Figure 5.6-6 includes a water cooled 76mm/62 caliber gun, fiberglass shield, an automatic loader, automatic hoist, and open below decks magazine. It is controlled by the FCS MK 92 MOD 1, and can fire several types of service and test ammunition including IR, radar proximity and point detonating projectiles.

5.6.2.10 CIWS MK 15 MOD 1

CIWS MK 15 MOD 1 is an autonomous weapon system that provides search, detection, declaration (threat evaluation), acquisition, track, firing and target destruction. CIWS uses closed-loop spotting to simultaneously measure both the target location and the relative projectile location and update the fire control solution to reduce any difference to zero. In this way, CIWS automatically and continuously directs the stream of projectiles onto the target throughout the firing period. CIWS MK 15 MOD 1 is composed of the major components shown in Figure 5.6-7.

5.6.2.11 Decoy Launching System MK 36 MOD 1

The Decoy Launching System MK 36 MOD 1 is a deck-mounted, mortar-launched, chaff countermeasure system used against a variety of threats. The purpose of the system is to project chaff aloft at specified distances from a ship for the purpose of confusing enemy guidance and fire control systems. Operationally, the launch system is controlled from a special panel on the AN/SLQ-32(V), and is dependent upon information provided by the ship's detection and threat analysis equipment.

The system shown in Figure 5.6-3 consists of two deck-mounted launchers, each with its own power supply, two bridge control panels, and a master control panel in CIC. Energizing and firing is usually done from the master control panel; however, the bridge control panel provides displays for loading and maintenance and is capable of firing in an emergency. A ready service locker with a capacity of 20 chaff rounds is provided for each launcher.

The ASMD/EW Decoy Launching System MK 36 MOD 1 is operated via the AN/SLQ-32(V) Display and Control Console (OJ-446/SLQ-32(V)). The authorization to dispatch chaff depends on the information provided by the ship's detection and threat analysis equipment. The Decoy Launching System also has bridge launching control for emergency deployment of chaff.

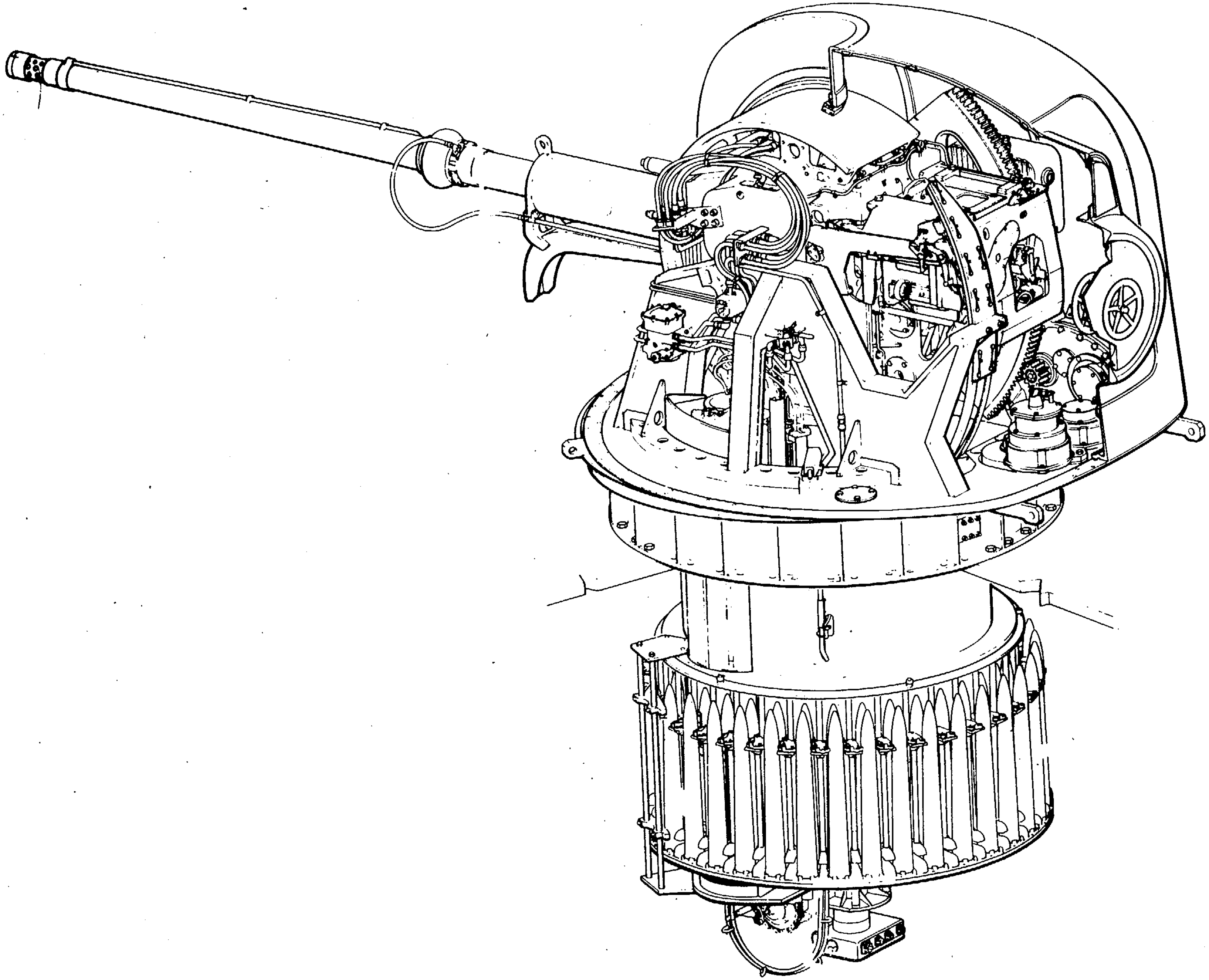


FIGURE 5.6-6
76mm/62 GUN MOUNT, MARK 75 OVERALL VIEW WITH SHIELD SECTIONED

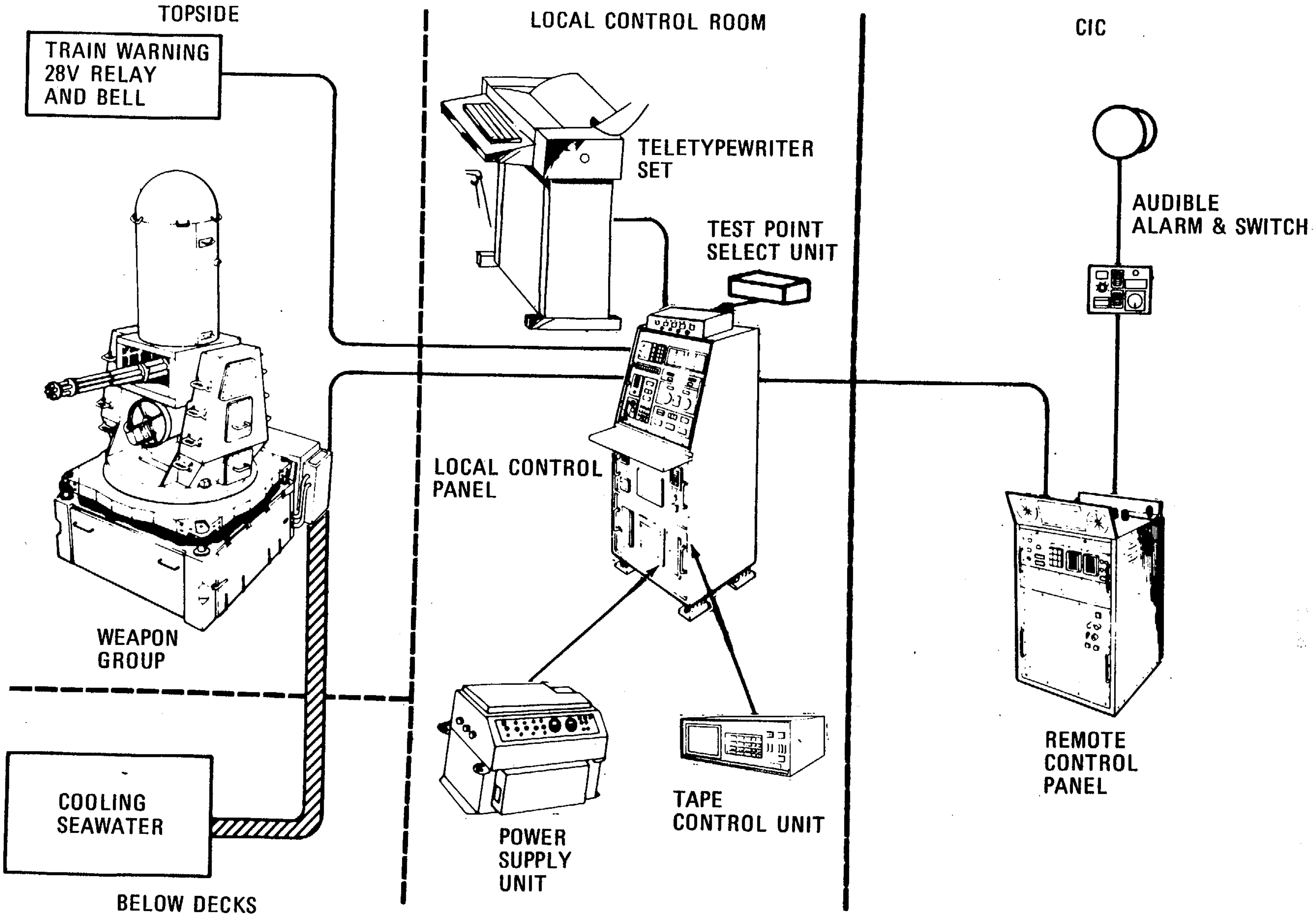


FIGURE 5.6-7
CLOSE IN WEAPON SUPPORT INSTALLATION (MK 15 MOD-1)

5.6.2.12 Aircraft Systems

Several aircraft may be accommodated for landing and fueling on the CSES:

SIKORSKY SH-60B (LAMPS III)
KAMAN SH-2F (LAMPS I)
SIKORSKY SH-3H/3D
WESTLAND LYNX HAS MK 2

5.6.2.13 Ship Control System (SCS)

The SCS provides the means for initiation and control of ship maneuvers from the Pilot House and for the engineering plant monitoring and control from the Central Control Station (CCS). Certain interior communications systems are integral with this concept including:

a. Tank level indicators
b. Equipment monitors
c. Salinity indicators
d. Warning and alarms systems

5.6.3 Combat System Weights Breakdown

Combat System weights are presented in Table 5.6-ii for SWBS Group 400, Table 5.6-iii for SWBS Group 700 and Table 5.6-iv for Variable Loads.

WEIGHT OF COMBAT SYSTEM - SWBS GROUP 400

SWBS	ITEM	WEIGHT LT
410	Command & Control	2.44
420	Navigation	1.08
430	Interior Communication	1.58
440	Exterior Communication	4.18
450	Surveillance (Surface)	.34
460	Surveillance (Underwater)	.12
470	Countermeasures	2.28
480	Fire Control System	3.73
490	Special Purpose	1.80
	TOTAL COMBAT SYSTEM	17.55

TABLE 5.6-ii

WEIGHT OF COMBAT SYSTEM - SWBS GROUP 700

SWBS	ITEM	WEIGHT LT
710	Gun Systems	19.79
720	Missile Systems	2.62
760	Small Arms	.16
700	Armament	22.73

TABLE 5.6-iii

WEIGHT OF COMBAT SYSTEM - VARIABLE LOADS

F21	Ammunition	18.5
F25	Ordnance Repair Parts	.10
F27	Pyrotechnics	1.54
	TOTAL	20.14

TABLE 5.6-iv

5.7 AUXILIARY SYSTEMS

5.7.1 Auxiliary Systems Description

The auxiliary systems consist of the machinery, piping, and ducting required to support other ship systems. They include, as well as normal ship hotel services, fluid distribution, fire extinguishing, underway replenishment, mechanical handling and anchors and mooring systems.

5.7.2 Auxiliary Systems Arrangement

The majority of the auxiliary machinery is located in the sidehulls between bulkheads 90 and 150. These auxiliary machinery rooms contain major functional equipment such as the fuel distribution manifold and pumping systems, distilling plant, sea water pumps, sewage disposal system and air conditioning machinery. There is no central refrigeration machinery since the ship will be fitted with electric refrigerator and freezer units.

5.7.3 Auxiliary Systems Characteristics

Significant characteristics of the auxiliary systems are described briefly in the following subparagraphs.

5.7.3.1 Climate Control System

This system consists of compartment heating, ventilation and air conditioning (HVAC); and machinery spaces ventilation and heating.

All cabins, mess deck, lounges, CIC, electronic spaces, offices, commissary, sanitary, and control spaces are air conditioned by two outside air condition units, multizone units and room terminal units (Anton Kaeser). The air conditioner machinery is located in the auxiliary machinery room.

All air conditioned spaces are heated by means of electric resistance heaters included within the terminal units. All other spaces will be heated either by individual units or units incorporated in the ventilation ducting.

Machinery space ventilation for the main propulsion and auxiliary machinery rooms will be independent of the primary ventilation system and will be provided by the lift systems intake valving and by electric fans when the lift system is not in operation.

Below the main deck, ducts will have watertight closures at main transverse bulkheads and at penetrating points in the main deck.

5.7.3.2 Seawater Systems

A combined firemain, sprinkler and diesel engine cooling system is provided by eight 210 gpm, 150 psi pumps, four in each sidewall. Each has its own sea chest and pump riser leading to a common ring main on the wet deck with branches to the superstructure, helicopter landing area, and to the machinery deck. Cooling water for the diesel engines and heat exchanger is taken from the pump risers at the machinery flat level. This arrangement provides for the magazine sprinkling system also.

Acqueous Film Forming Foam (AFFF) to extinguish flamable liquids fire is provided in the machinery and auxiliary room spaces. AFFF outlets at the helicopter landing area are provided in accordance with Helicopter Facilities Bulletin No. 1c.

The system also includes the plumbing drainage from sanitary, food preparation, and other spaces containing plumbing fixtures.

5.7.3.3 Fresh Water Systems

Fresh water production and stowage is sized for a 33 man crew. The system also provides for window washing, 76mm gun flushing and gas turbine washdown. Two desalinators, vapor compression type distillers, with a capacity of 600 gallons per day each are provided. Hot water is provided by electric hot water heaters.

Fresh water stowage tanks of 1200 gallon capacity are provided for domestic use and additional 500 gallon tankage is provided for gas turbine washing.

5.7.3.4 Fuels and Lubricants Systems

The fuel system provides control of the fuel distribution in the ship's storage tanks, together with purification of and delivery to the fuel consuming machinery. The system is designed for use of diesel fuel marine (DFM), although JP-5 is interchangeable and can be used. The system is controlled from the Central Control Station. The ship's fuel system consists of two electrically-driven main fuel pumps with filter coalescer systems for processing fuel taken from the storage tanks and transferred to the clean fuel oil service tanks. Fuel taken from service tanks is delivered to each engine by an engine-dedicated delivery pump.

The main fuel pumps are also used for fuel transfer between storage tanks for ship trim control purposes. Appropriate valving provides for direct transfer when the pumps are functioning in this mode.

Aviation JP-5 for helicopter refueling is stored in dedicated tankage of 10 ton capacity. Separate service tank, pump and filter separators are also provided in accordance with Helicopter Facilities Bulletin No, 1d. A connection from the aviation JP-5 system is provided for emergency transfer of JP-5 to the ship fuel service tanks by means of the ship fuel transfer system. A locked closed stop-check valve and a line blind valve are used at this connection.

Contaminated discharge from the filter coalescer systems is delivered to a waste oil tank for subsequent discharge to a disposal service facility. An oil and water separator ensures that condensate of seepage water discharged overboard satisfies environmental requirements. A stripping system is provided with service to all fuel tanks.

There are dedicated lubrication systems for:

a. Each gas turbine;

b. Each diesel engine;

c. Each pair of propulsion reduction gear and propeller shaft bearing sets;

d. Each set of lift fans and lift transmissions.

Oil cooling is provided by heat exchangers with cooling water supplied from the seawater system.

5.7.3.5 Air, Gas and Miscellaneous Fluids

The air, gas, and miscellaneous fluid systems consist of low pressure compressed air, high pressure compressed air, fire extinguishing and hydraulic fluid systems. The ship's service air system is provided by an electrically driven 125 psi air compressor, which has its own associated filter, dehydrator, and accumulator elements. Distribution is provided to each deck, machinery space and the workshop.

Starting air for the main propulsion gas turbines is provided by two auxiliary power units situated one each in the port and starboard main propulsion machinery spaces which are cross connected for redundancy (diesels are electric start).

Fixed flooding Halon systems are the primary fire extinguishing systems for the propulsion, lift, electrical and auxiliary machinery rooms. Halon gas bottles sufficient to supply a 6 to 7 percent concentration by volume for individual spaces are provided. Halon extinguishing is also provided for each gas turbine compartment.

Two motor driven hydraulic pumps deliver nominal 3000 psi hydraulic power to a ship service hydraulic system. Principle hydraulic users include the davits, winches, anchor retraction, lift system duct valving and ride control devices.

5.7.3.6 Ship Control System

A control console is provided in the Pilot House that includes the primary maneuvering controls and display for the helmsman and operating controls and displays for conning and monitoring ship operation for the OOD.

Steering is provided by dual hydraulic-electric systems, port and starboard, providing the signal to two hydraulic pumps which are sited aft, one in each sidehull. The pumps, which are driven by a continuous rated electric motor, control the two rudders with a conventional steering feedback system.

For emergency operation, a secondary steering position for each rudder is provided at the hydraulic pumps; order for steering angle being passed by sound powered telephone from the Pilot House.

Steering also can be augmented by differential thrust accomplished through propeller reversal and by propulsor speed control.

5.7.3.7 Replenishment At-Sea Systems

The CSES is equipped to refuel at-sea as well as transfer cargo and personnel.

Refueling is accomplished, on either port or starboard sides, by means of a 2 1/2 inch hose rig with saddles and trollies and span line supplied by the fueling ship. Fueling rate is 6000 gallons per hour.

Cargo and personnel transfer will be performed via highline rigging from port or starboard side. Interface hardware and line handling equipment for accepting messenger lines, inhaul lines and the highline rigging is provided. A lightweight one-man platform is installed aft of the mast to serve as a working platform for rigging connections for cargo/personnel transfer.

Vertrep is accomplished using the helicopter landing deck aft of the deckhouse.

5.7.3.8 Mechanical Handling Systems

These systems comprise anchor handling and mooring and stowing.

One Danforth anchor is provided with 900 feet of nylon rope.

A hydraulic capstan will handle the anchor line, and the anchor will be lowered and hoisted using a davit at the deck edge. The same capstan will handle the mooring lines.

5.7.3.9 Boat Handling and Stowage

Two 25-man and two 7-man inflatable boats will be stowed on the main deck, one each portside and one each starboard side, to accommodate the crew and embarked passengers. Stowage racks will be designed to provide either manual or hydrostatic release.

5.7.3.10 Pollution Control

Sewage drainage of sanitary waste is transferred to a GATX evaporator. The solid contents of the evaporator effluent will be transferred to a shore facility or will be dumped overboard when at sea.

A compactor will package the domestic trash for disposal in port or sinkable overboard when beyond the 50-mile limit.

A suitable commercial type garbage grinder is provided for the galley.

5.7.4 Auxiliary System Weight Breakdown

The weight breakdown of the auxiliary subsystems is presented in Table 5.7-i.

5.7.5 Auxiliary System Risk Assessment

All auxiliary systems selected are within the present state-of-the-art. Most are derived from PHM design and application to provide a sound basis for performance and weight estimates. No development effort or technical risk is envisioned.

5.8 OUTFIT AND FURNISHINGS

5.8.1 Summary Description

Outfit and furnishings include material, equipment, and furnishings not included elsewhere in the Ship Work Breakdown Structure, but necessary to provide human support and complete the functional use of spaces and areas. Major areas of outfit and furnishings are:

a. Ship Fittings
b. Hull Compartmentation
c. Preservatives and Coatings
d. Spaces - Living, Service, Working, and Storage

5.8.2 Outfit and Furnishings Arrangements

Figures 5.8-1 and 5.8-2 show plan layouts for crew accommodations, working and storage spaces. Officers berthing spaces are located on the second deck and provide quick access to operational spaces. Crew living spaces are arranged on the second deck and are adjacent to sanitary, messing, service, and relaxation areas.

AUXILIARY SYSTEMS WEIGHT - SWBS GROUP 500

SWBS	ITEM	WEIGHT (LT)
511	Compartment Heating	0.30
512	Ventilation	0.80
513	Machinery Spaces Ventilation	0.60
514	Air Conditioning	4.96
521	Firemain and Flushing	3.70
522	Sprinkler	
523	Washdown	
524	Auxiliary Seawater	
526	Scuppers and Drains	0.02
528	Plumbing Drainage	1.10
531	Distilling Plant	1.67
533	Potable Water	1.01
541	Ship Fuel & Lube Stowage & Handling	1.82
551	Compressed Air	0.44
555	Fire Extinguishing	2.28
556	Hydraulic Fluid	2.18
561	Steering	0.27
562	Rudder	0.27
568	Maneuvering	0.15
571	Replenishment At-Sea	0.25
581	Anchor & Stowage	0.85
582	Mooring & Towing	
583	Boat Handling & Stowage	0.54
593	Environmental Pollution	1.01
594	Special Auxiliarys Support Hardware	0.18
595	Auxiliary Systems Integration	1.34
599	Auxiliary System Parts & Tools	0.38
	TOTAL AUXILIARY SYSTEMS	26.12

TABLE 5.7-i

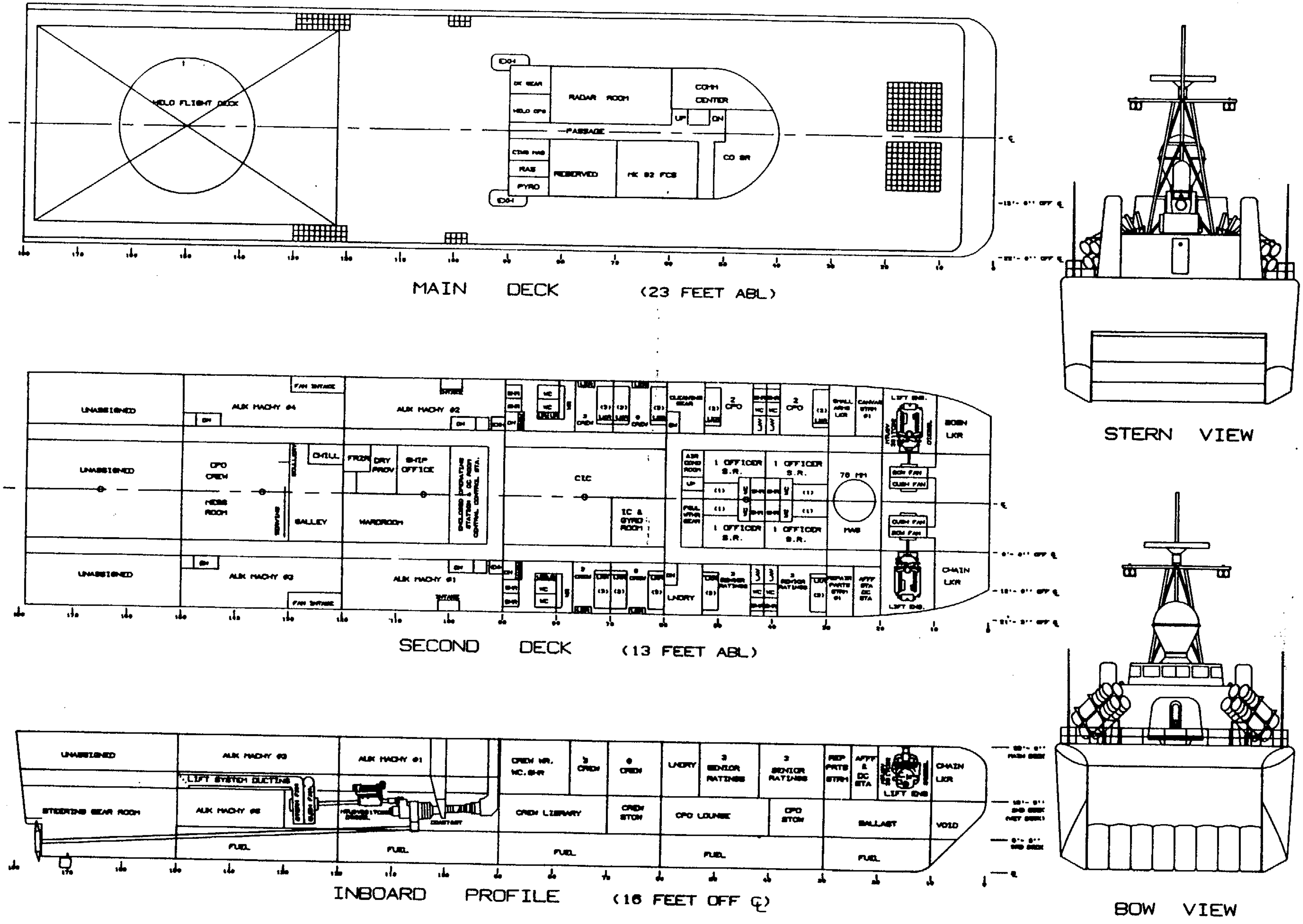
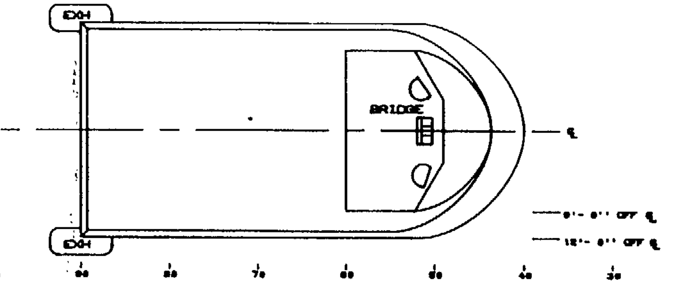
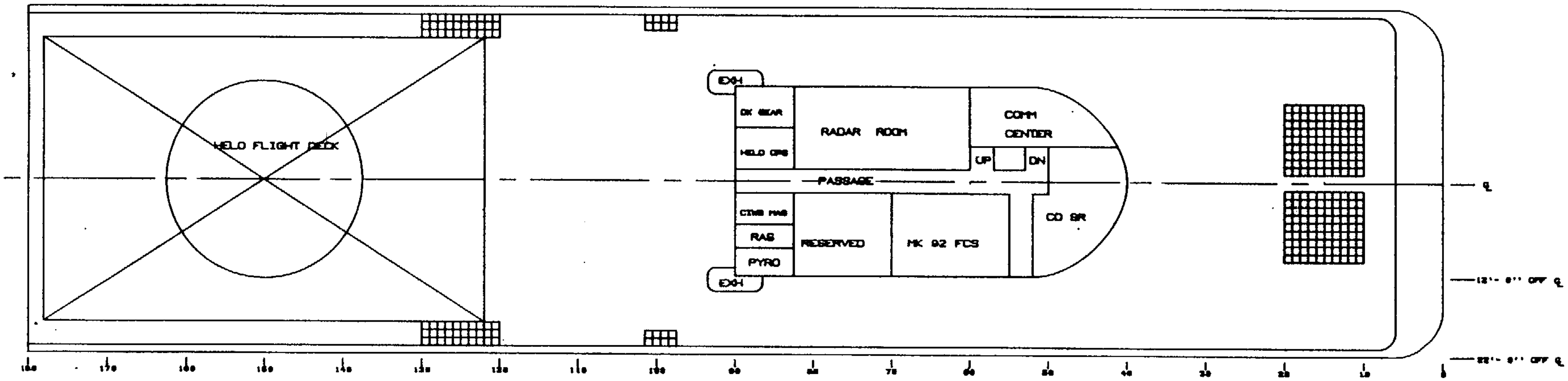


FIGURE 5.8-1

CREW ACCOMMODATIONS - GENERAL ARRANGEMENTS BETWEEN DECKS



01 LEVEL (31 FEET ABL)



MAIN DECK (23 FEET ABL)

FIGURE 5.8-2

GENERAL ARRANGEMENT DECK HOUSE

The pilot house and navigation room are located on the 01 level, the communications center is arranged on the main deck. The Combat Information Center (CIC) is situated on the second deck.

Storage spaces for flammable liquids, spares, provisions, small arms, general and ship stores are located on the third deck.

5.8.3 Outfit and Furnishings Weight

Table 5.8-i provides estimated weights of outfit and furnishings for SWBS Group 600. Weights for the Coastal SES were derived from outfit and furnishings as used in the 3KSES, the Saudi Naval Expansion Program's Patrol Chaser Missile (PCG), and the Patrol Hydrofoil Missile (PHM).

WEIGHT OF OUTFIT AND FURNISHINGS - SWBS GROUP 600

SWBS	ITEM	WEIGHT LT
611	Hull Fittings	0.60
612	Rails, Stanchions, Lifelines	0.81
613	Rigging & Canvas	0.15
621	Non-Structural Bulkheads	1.44
622	Floor Plates & Gratings	0.78
623	Ladders	0.31
624	Non-Structural Closures	0.51
625	Airports, Fixed Portlights, Windows	0.31
631	Painting	2.34
633	Cathodic Protection	0.04
634	Deck Covering	1.02
635	Hull Insulation	2.44
637	Sheathing	1.25
638	Refrigerated Spaces	0.46
641	Living Spaces - Officer	1.26
642	Living Spaces - CPO	1.0
643	Living Spaces - Enlisted	1.58
644	Sanitary Spaces & Fixtures	1.70
651	Commissary Spaces	2.90
652	Medical Spaces	0.17
655	Laundry Spaces	0.20
661	Offices	0.10
662	Machinery Control Centers Furnishings	0.06
663	Electronics Control Centers Furnishings	0.06
664	Damage Control Stations	0.91
665	Workshops	-
671	Lockers & Special Stowage	0.20
672	Storerooms & Issue Rooms	2.30
698	Operating Fluids	0.10
699	Repair Parts	-
	TOTAL OUTFIT & FURNISHINGS	25.0

TABLE 5.8-i

6. MANNING AND HABITABILITY

6.1 MANNING CONCEPT

The operational manning objective of the Coastal SES (CSES) is directed toward minimum shipboard manning. Organizational and intermediate maintenance requirements as well as logistic and administrative support functions will be performed by a separate Maintenance and Logistic Support Group (MLSG). The on board personnel will perform primarily operator functions but are required to be of a sufficiently high skill (rate/rating) level so as to be capable of effecting minor operational repairs to safety and mission essential equipment. The primary concepts required to achieve the minimum manning objective are:

a. Use of minimum essential crew required to safely operate the ship's systems and equipments consistent with the expected mission profile.

b. Utilize "state-of-the-art" remote and automatic operation of machinery.

c. Utilize condition monitoring systems in mission essential electronics and machinery.

d. Limit the use of "new" and "unique" equipments.

e. Adopt standard accepted engineering/ship construction techniques and utilize common ship construction materials.

f. Defer all maintenance actions for in-port accomplishment by the MLSG.

g. Install redundant system capacity to minimize mission impact of failed equipment.

h. Conduct a Maintenance Engineering Analysis (MEA), Level of Repair Analysis (LOR), and Reliability Centered Maintenance Analysis (RCM) to identify and validate maintenance requirements.

i. Implement a component/module replacement strategy for operational and corrective maintenance and repair of critical equipments.

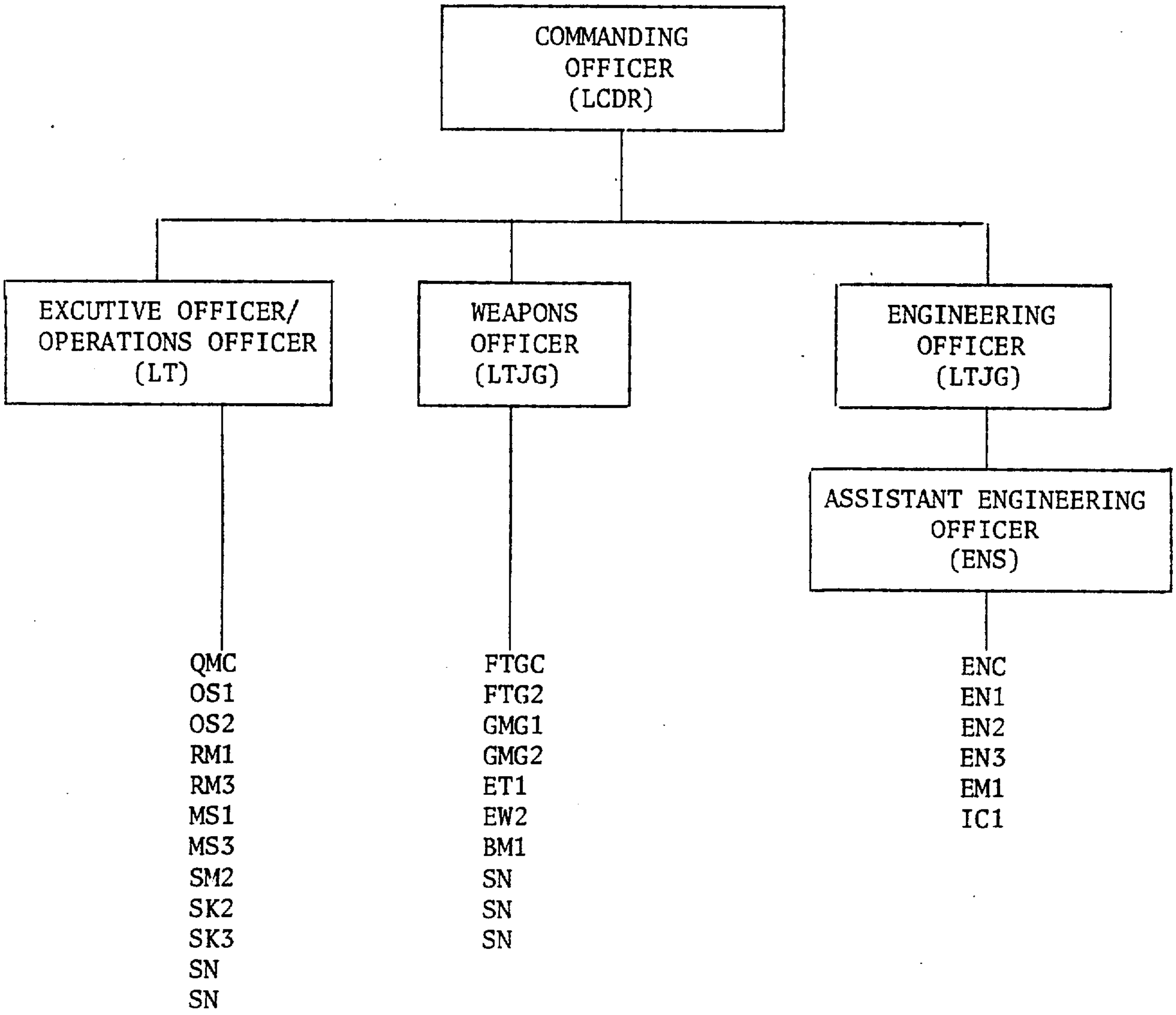
Adopting an objective of minimum operational manning requires understanding and acceptance of manpower/watchstation utilization which does not conform fully with standard Navy manning policy, practice and some "traditional requirements". Example of this are:

a. Assignment of one lookout vice two for Condition III watches.

b. Using one Signalman (SM) on an on-call basis for Condition III.

Acceptance of these procedures is not without precedence. However, an evaluation of trade-offs such as cost, endurance (personnel), and safety will be further evaluated in follow-on design stages.

The preliminary shipboard organization is shown in Figure 6.1-1. Projected Condition I and III watchstations are shown in Tables 6.1-i and 6.1-ii. Table 6.1-iii provides the variable loads weight estimate.



Officers - 1	Officers - 1	Officers - 2
Enlisted - 12	Enlisted - 10	Enlisted - 6

TOTAL: OFFICERS - 5

ENLISTED - 28

SHIPBOARD ORGANIZATION

FIGURE 6.1-1

CSES CONDITION I WATCHSTATIONS

SHIP CONTROL

1. Commanding Officer
2. Ship Control Officer (SCO)
3. Ship Control Petty Officer (SCPO)
4. Navigator
5. Signalman
6. Lookout
7. Lookout

INFORMATION CONTROL

8. Tactical Action Officer (TAO)
9. CIC Supervisor
10. Radar Operator
11. ECM Console Operator
12. Radio Supervisor
13. Radio Operator

WEAPONS CONTROL

14. Weapons Liaison Officer (WLO)
15. 76mm Console Operator
16. 76mm Ammo Handler
17. 76mm Ammo Handler
18. MK 92 FCS Engagement Controller
19. MK 92 Missile Control Console Operator

CENTRAL CONTROL

20. Engineering Officer of the Watch (EOOW)
21. Assistant EOOW (AEOOW)
22. Engine/Auxiliary Watch

DAMAGE CONTROL

23. Damage Control Assistant (DCA)
24. DC Plotter
25. Repair Party Leader
26. Scene Leader
27. Investigator/OBA
28. Nozzleman/OBA
29. No. 1 Hoseman
30. No. 2 Hoseman
31. Electrical Repairman
32. Repairman
33. Repairman

TABLE 6.1-i

CSES CONDITION III WATCHSTATIONS

SHIP CONTROL

1. SCO
2. SCPO
3. Lookout

INFORMATION CONTROL

4. CIC Supervisor
5. Radar Operator
6. Radio Operator

WEAPONS CONTROL

7. CIWS Console Operator

CENTRAL CONTROL

8. EOOW
9. Sounding & Security

Total Condition III Requirements

WATCHSTATIONS (3 x 9)	27
CO & XO	2
SUPPORT	4
TOTAL	33

TABLE 6.1-ii

VARIABLE LOADS WEIGHT ESTIMATE*

PERSONNEL	POUNDS PER MAN
Officers	400
CPOs	330
Enlisted	230

Weight Allowances (Crew & Effects)

PERSONNEL	QTY	WEIGHT
Officers	5	2,000
CPOs	3	990
Enlisted	25	5,750
	33	8,740 LB = 3.90 LT

Weight Allocation for Provisions, Personal Stores, and General Stores

PROVISIONS	POUNDS PER MAN PER DAY
Dry	3.20
Freeze	1.11
Chill	1.65
Clothing & Small Stores	.07
Ship's Store	.08
General Stores	1.06
	7.89

For 5-Day Mission:

33 Men x 5 Days x 7.89 LBS/MAN/DAY = 1,302 LBS
= 0.58 LT

*In accordance with Naval Ships Technical Manual 1 March 1974, Chapter 9290 Paragraph 173.1

TABLE 6.1-iii

6.2 HABITABILITY

Preliminary design of habitability arrangements for the CSES was performed during this phase for the purpose of establishing and evaluating area and volume requirements and investigating the impact of sizing on auxiliary equipments and outfit and furnishings. General habitability arrangements were prepared utilizing requirements identified in OPNAVINST 9640 of 13 October 1979. The General Arrangements are depicted in Figures 5.8-1 and 5.8-2. The design goals and considerations were as follows:

a. Provide comfortable and utilitarian crew accommodations.

b. Provide logical and functional arrangement of working and machinery spaces.

c. Allocate sufficient space for the ship's subsystems.

d. Provide for optimum utility of the communication systems and weapons systems.

e. Provide the ability to limit progressive flooding.

Key elements of the ship's arrangement as they relate to these five areas are discussed below.

a. Crew Accommodations. Crew living spaces are located amidship in the outboard compartments on the second deck. This location is good for noise isolation and is adjacent to sanitary, service and relaxation areas. Officer berthing areas are located also on the second deck inboard and provide ready access to operational spaces as well as messing and lounge areas.

b. Working Spaces. The ship's operational stations and working spaces are located to provide a degree of isolation from messing and berthing areas. The pilot house, CIC, communications center and office spaces are arranged to allow for functional separation while retaining the convenience of adjacency. Engineering spaces have been located fore and aft in the sidehulls for noise level considerations, functional requirements, and centralization.

c. Location of Ship's Subsystems. Figures 5.8-1 and 5.8-2 show the location of major subsystems. Some key features of this arrangement are (1) the location of engineering systems in the sidehulls with the exception of auxiliary areas on the 2nd deck; (2) consolidation of ship's machinery on the third deck to isolate noise sources; (3) full utilization of sidehull space for provisions, spare parts, and general stowage; and (5) reserved space for addition of future systems.

d. Command and Control. The view from the pilot house is maximized in all quarters to support ship control. The location of the Close-in Weapon System (CIWS) offers maximum weapon arcs-of-fire and isolation (and hence safety) for ship's personnel. The adjacency of the command spaces allows swift and efficient passage between compartments. Most antennae will be located on the single mast, reducing the hazard from electromagnetic radiation while providing maximum coverage.

e. Flooding Prevention. The transverse and longitudinal watertight bulkheads are spaced to limit flooding caused by hull damage. The primary transverse watertight bulkheads are 10, 30, 60, 90, 120 and 150. The watertight longitudinal bulkheads are the longitudinal bulkheads 9 feet outboard of the centerline to port and starboard.

7 LOGISTICS CONSIDERATIONS

7.1 MAINTENANCE AND MAINTAINABILITY CONCEPT

The ship system incorporates provisions which maximize equipment utilization and defer requirements for at-sea maintenance to in-port accomplishment. The maintenance concept for meeting the objectives and availability goal of the CSES is to: (1) perform limited operational and corrective maintenance on critical equipments only and program other maintenance for in-port availabilities. This concept de-emphasizes maintenance at the organizational (shipboard) level and emphasizes an organizational /intermediate level role by the Maintenance and Logistic Support Group (MLSG).

For design purposes, particular emphasis was given to: (1) maximum use of existing equipment items to permit use of standard maintenance procedures and supply support; (2) use of performance and condition monitoring for detecting failures in critical equipments; (3) provision for equipment accessibility to support a component and module replacement strategy; and (4) provision of redundant systems to minimize impact of single system failures. The replacement strategy includes scheduled replacement, replacement on condition, and replacement at failure depending on the subsystem and equipment criticalities.

Major maintenance actions will be accomplished by the MLSG and ashore maintenance activities during periodic upkeep and maintenance availabilities in accordance with ship utilization schedules. These maintenance activities will perform all facilities maintenance (FM), preventive maintenance (PM), and corrective maintenance (CM), that is beyond the capability of ship personnel.

Built-in test equipment (BITE) will be used for critical ship electronics and control system. Mechanical and electronic test equipment will be provided for (other) system measurements. Special purpose tools and test equipment as well as standard tools will be provided as ship's tool items.

No personnel will be assigned for the sole purpose of performing maintenance. Operational maintenance performed by the crew will be in accordance with the ship systems operational maintenance requirements. Condition monitoring equipment will be installed in mission essential systems. Corrective maintenance actions will be performed to maintain safety and mission critical equipment in an operational state and will be accomplished through replacement of defective or degraded subassemblies within equipments or through replacement of the equipments themselves. Arrangement design will ensure adequate accessibility to equipments for maintenance without necessitating secondary structure rip-out or equipment removal.

Regular overhauls are to be minimized by intensive use of the upkeep periods as maintenance availabilities. Dry-docking will be accomplished primarily to provide for major emergency repairs and ship alterations. Equipment removal routes have been established for transverse and vertical movements of large equipments, such as propulsion and lift engines in order to preclude structural rip-outs or removal of other equipments.

Employment of a replace-before-failure maintenance strategy in conjunction with a reduced manning philosophy requires that a significant number of equipments be removed for rotable pool replacement and off-ship repair/refurbishment. The manning concept is discussed in Section 6.1 of this report.

7.1.1 Levels of Maintenance

The CSES Maintenance Concept employs three levels of maintenance - organizational, intermediate, and depot. These maintenance levels are summarized and discussed below.

a. Organizational-Level Maintenance is the routine maintenance that will be performed by the MLSG assisted by the CSES crew. Certain organizational level tasks, such as daily PM actions that cannot be scheduled for inport periods and emergency mission Corrective Maintenance (CM) actions, will be performed at sea. Underway maintenance will be performed using only the standard test equipment and tools that will be carried aboard the CSES (in combination with BITE). Government Furnished Equipment (GFE) was designed for use on ships with standard maintenance capability, and the CSES maintenance concept has been adjusted to accommodate the maintainability features of these systems and equipments, primarily by shifting organizational tasks to the MLSG in port. The on-board repair parts will be limited in number and variety. They will consist, for the most part, of replacing fuses, bulbs, and critical modules/parts.

b. Intermediate-Level Maintenance consists of repair of certain defective equipment modules, and shipboard equipment maintenance or repair beyond the capability of the CSES crew. Intermediate-level maintenance will normally be conducted by the MLSG personnel. The MLSG will provide diagnostic skills, special skills, special tools, test equipment, technical documentation, and other maintenance resources not available aboard the CSES. On occasion, it may be necessary for MLSG personnel to go aboard to perform fault isolation under actual operating conditions. The MLSG will provide corrective maintenance and support requirements for the following:

    (1) Weapon system repairs and module replacement

    (2) Command, Control, Communications, and Navigation (CCCN) equipment checkout, repair and module replacement

    (3) Hydraulic subsystem checkout and repair

    (4) Electrical tests and repairs

    (5) Marine gas turbine inspection and limited repair and replacement

    (6) Auxiliary machinery repairs and replacement

    (7) Minor hull repairs

The CSES will receive nearly all intermediate-level logistic support from the MLSG facility in port.

c. Depot Level Maintenance will be conducted at a ship repair facility, at a Naval or private shipyard, or at the shipbuilder's facilities. The work accomplished at the depot will be major repairs, modifications, rework, and maintenance tasks beyound the scope of the MLSG intermediate-level capability. The type of work to be accomplished at the depot will be identified in a Maintenance Engineering Analysis (MEA) and Level of Repair (LOR) Analysis.

7.2 SUPPLY SUPPORT CONCEPT

The objective of supply support (spares provisioning) is to provide the resources required to support the maintenance philosophy in order to obtain an operational readiness condition capable of meeting ship availability requirements. To this end the spare parts objectives for the CSES are:

a. Emphasize design utilization of standard ("off-the-shelf") components/equipments.

b. Utilize a component/module replacement strategy in determining stockage criteria for range and depth.

c. Onboard spares and repair parts determination will be based on a 5 day expected usage for mission essential systems and insurance stockage limited to items which are vital to primary mission and safety requirements.

d. Shore based spares will be directed toward long lead time and unique items and will support the progressive overhaul strategy. Impact of new requirements on the supply system is to be minimized.

e. Prioritize identified spares and repair parts by mission criticality, safety, and skill capability for utilization to further establish onboard requirements as well as MLSG stockage levels.

7.3 RELIABILITY AND AVAILABILITY

CSES reliability and availability must be high because of the reduced manning and because the maintenance and support concept as well as the mission profile minimize the possibility for at sea maintenance. Equipment maintenance will be primarily scheduled for in port availability periods. Redundancy will assure continuous operation by having parallel equipment in operation or by placing back-up equipment on line. Automatic monitoring systems will be used to indicate equipment malfunctions due to the limited number of watch station personnel.

To the greatest degree possible, ship systems with established records in fleet marine usage will be used. Specifically, systems requiring high reliability and availability and so selected are:

a. Propulsion System. Primary propulsive power is provided by two gas turbine engines proven industrially and marine qualified for salt injestion to Navy specifications. Propulsive power may also be provided by two of the lift system marine diesels engines for ship low speed operations. Gas turbine or diesel operation can be performed in either the hullborne or cushionborne mode.

The port and starboard propulsion plants including prime movers, CODOG reduction units, shafting and fixed pitch propellers, are completely independent. Either plant is capable of providing the ship propulsion as required for off, partial or full cushion operation; thus providing redundancy and flexibility of operation.

Conventional marine machinery design practices relative to gearing, bearings, shafting and related equipment have been applied. Selection of rugged, simplistic fixed-pitch propellers and proven marine diesel engines further enhances the reliability and low-risk design characteristics of the propulsion system.

b. Electric Plant. Highly reliable generators proven components, and multiple switchboards are included.

c. Command and Surveillance. Redundant modules and plug-in replacements are included. To the greatest degree possible, equipment has been called out generically to assure that the most reliable components will be used.

d. Lift System. Off-cushion the ship will operate like any displacement ship. All equipment has been selected for high reliability and off-the-shelf availability. Fan power is generated by proven diesels through in-line-drive transmission. One diesel/transmission for each fan.

The bow seals will be similar to those found on the SES-100B. Seal reliability will be improved through ease of maintainability as the CSES seal will be two dimensional rather than three, as in the SES-100B. Additional reliability will be gained as the ship speeds are well below those considered critical to seal finger wear.

e. Auxiliary Systems. All systems are off-the-shelf with parallel or standby redundancy.

f. Combat System. CSES will employ the same combat system as the PHM.

7.3.1 Reliability and Availability Assessment Program

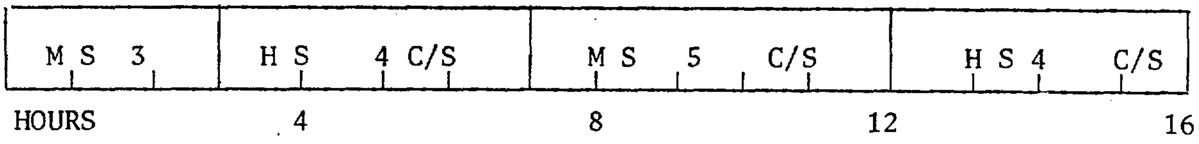
Reliability and availability assessment and indices will be provided for all ship systems and subsystems that will be considered as necessary to the on-going operation of the ship. In addition, all systems below the necessary level will be analyzed at a lower level of indenture to develop an overall set of indices for the ship. An early assessment of those systems considered necessary to the on-going operation of the ship, as well as other systems, will allow for a clear determination of just what values these indices should have, and which systems require effort to make them acceptable, with a level of confidence that will be high and traceable.

A building block approach will be used to develop, first, the system indices and finally those of the platform. Reliability Block Diagrams (RBD's) will be constructed for each system. These will be enforced by Failure Mode Effects and Criticality Analyses (FEMCA) which will describe the impact of equipment or system failure on the basis of frequency of failure and criticality.

Failure mode frequency guidance is found in MIL-STD-1629, as revised, while criticality will be ajudged from DOD-STD-2101(OS). Specifically two levels of criticality will be used in this effort, they are:

- o <u>Critical Failure</u> - a failure which results in the inability of the ship to complete its assigned mission without shipboard or depot repairs. Shipboard repairs are defined as those for which the crew has inherent expertise, tools, spare, and repair parts readily available.
- o <u>Major Failure</u> - a failure which results in the degradation of the ships functional performance, but does not preclude the ship from completing its assigned mission.

Mission timelines, covering the four separate operations of the CSES have been developed and included as Figure 7.3-1 through 7.3-4. They cover the 16 hour sortie, 75 hour normal patrol, 120 hour transit and 120 hour generalized patrol. For each operation reliability shall be determined based on mission duration.



MS 16 - 32 KNOTS

HS 33 - 48 KNOTS

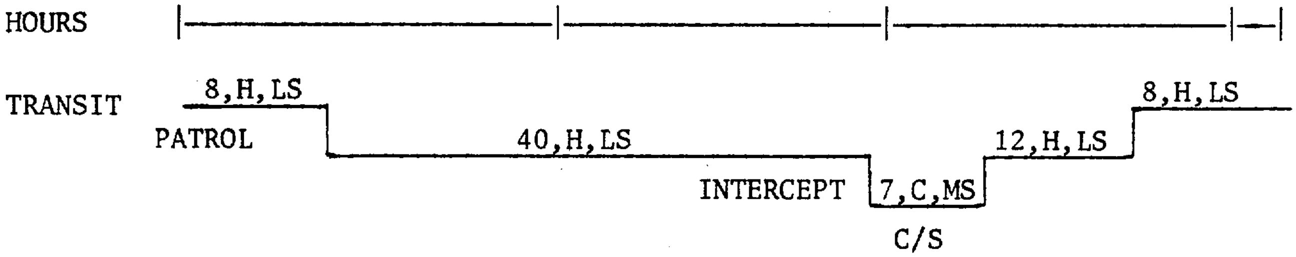
C/S Combat System In Use

ASSESSMENT:

RELIABILITY, AVAILABILITY

<u>CSES SORTIE MISSION - 16 HOURS - CONDITION I</u>

FIGURE 7.3-1



C = CUSHIONBORNE

H = HULLBORNE

LS = 0 - 15 KNOTS

MS = 16 - 32 KNOTS

C/S = Combat System In Use

ASSESSMENT:

RELIABILITY, AVAILABILITY

<u>CSES NORMAL PATROL - 75 HOURS</u>

FIGURE 7.3-2

120 HOURS LOW SPEED (0 - 15 KNOTS)

ALL SYSTEMS IN USE EXCEPT LIFT AND COMBAT SYSTEM

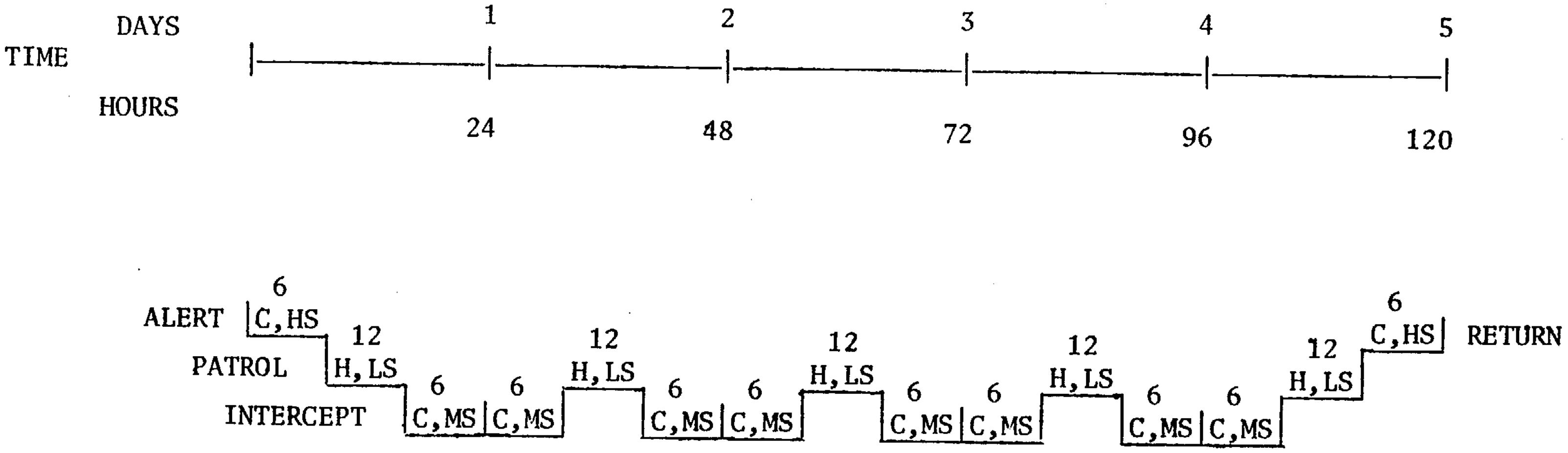
ASSESSMENT:

RELIABILITY, AVAILABILITY

<u>CSES TRANSIT - 120 HOURS</u>

FIGURE 7.3-3

5 DAYS - 120 HOURS - CONDITION III



C = CUSHIONBORNE
H = HULLBORNE
LS = 0 - 15 KNOTS
MS = 16 - 32 KNOTS
HS = 33 - 48 KNOTS

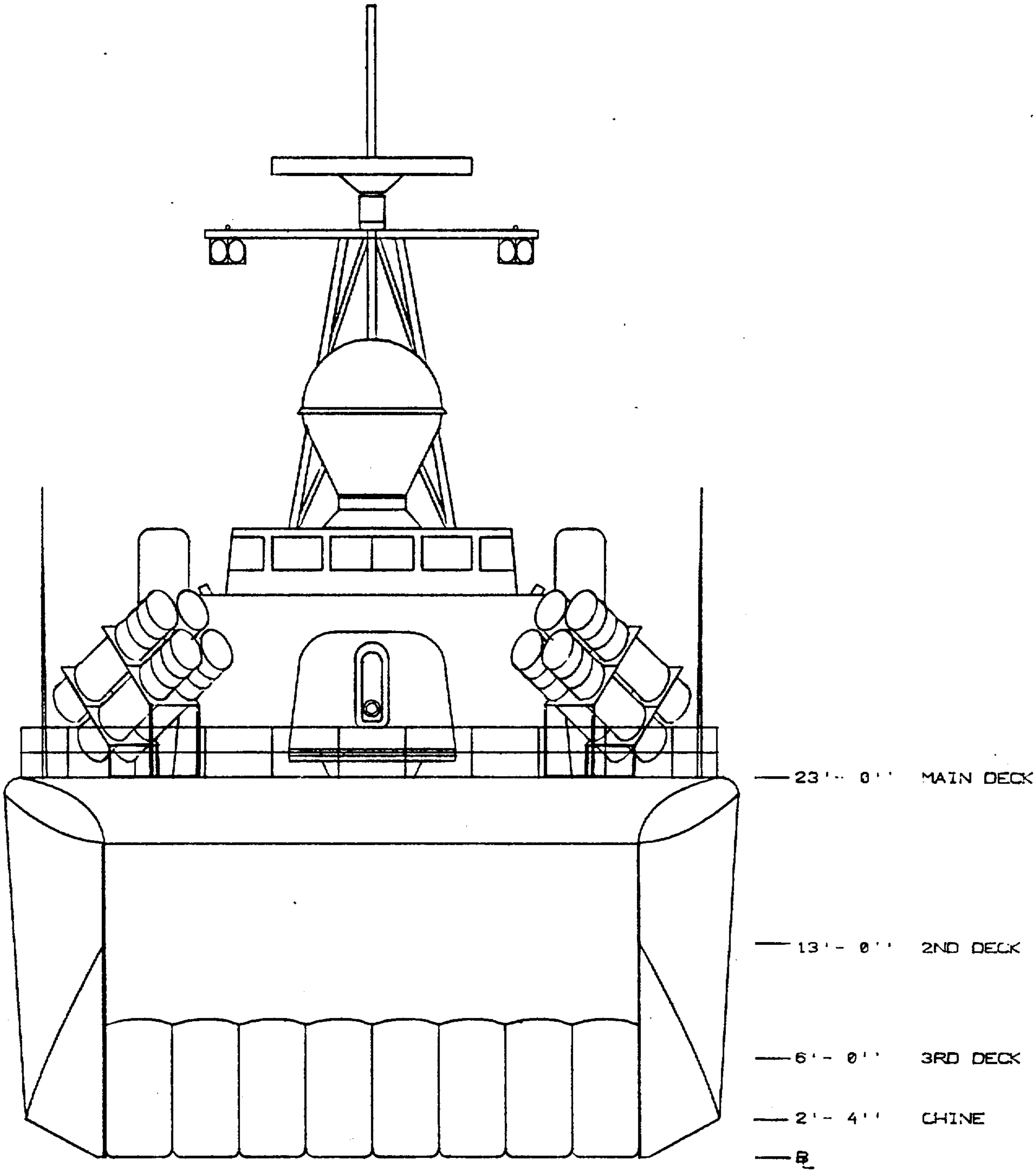
COMBAT SYSTEM IN USE DURING INTERCEPT PERIODS

ASSESSMENT:

RELIABILITY, AVAILABILITY

CSES GENERALIZED PATROL

FIGURE 7.3-4



BOW VIEW

FIGURE A-1
COASTAL SES BOW VIEW

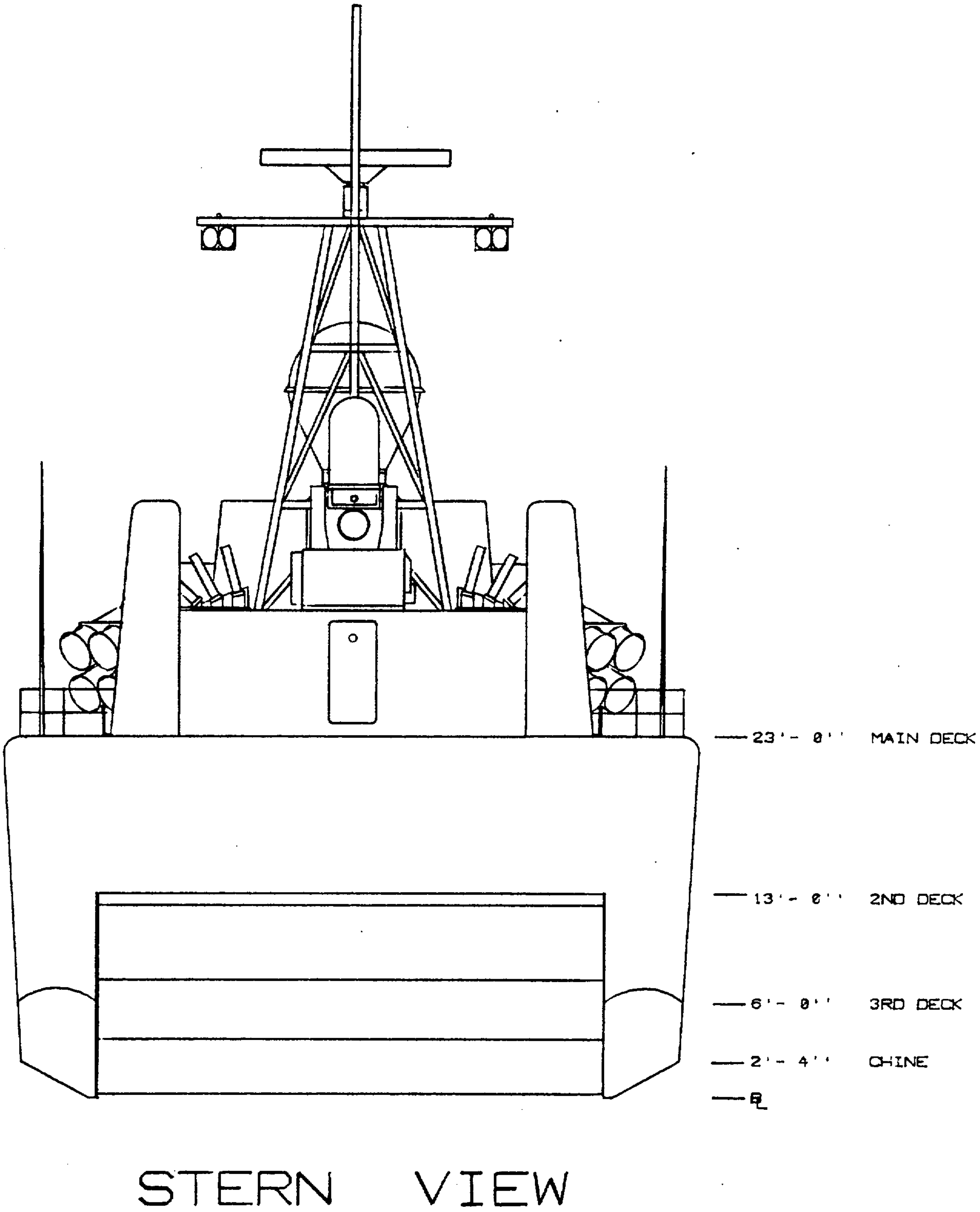


FIGURE A-2
COASTAL SES STERN VIEW

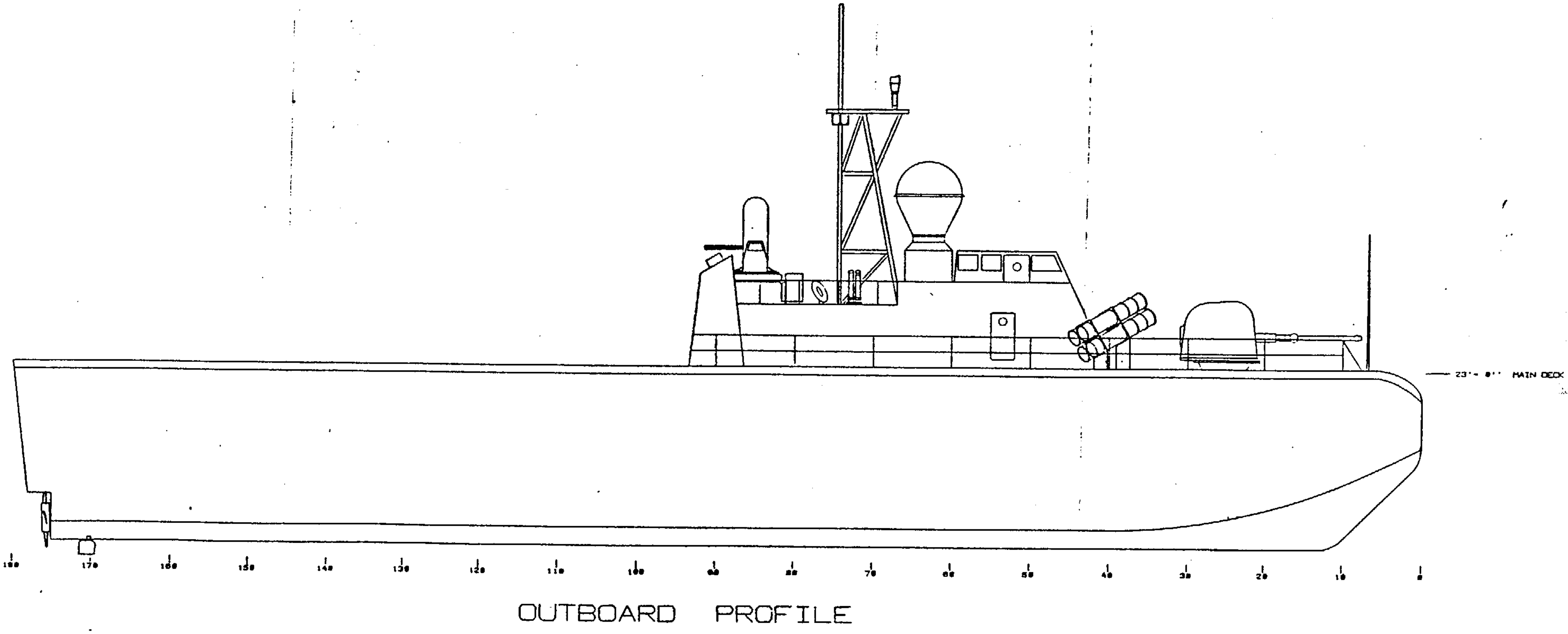
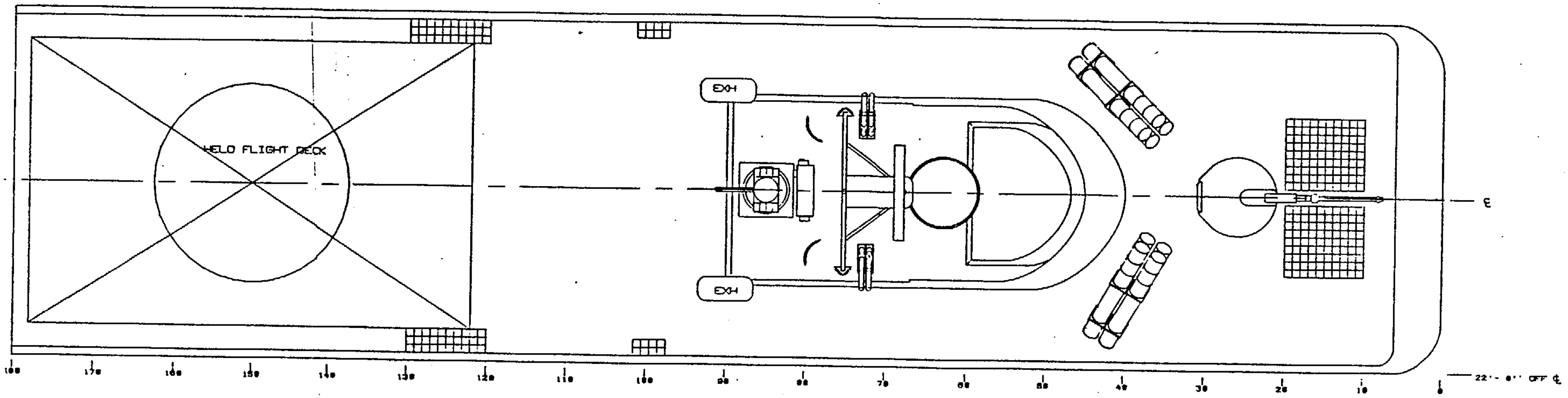


FIGURE A-3
COASTAL SES OUTBOARD PROFILE



TOP VIEW

FIGURE A-4
COASTAL SES TOP VIEW

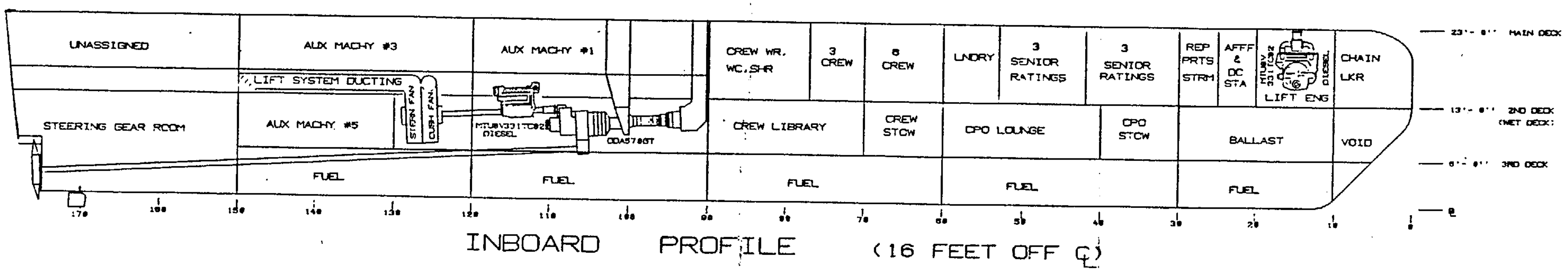
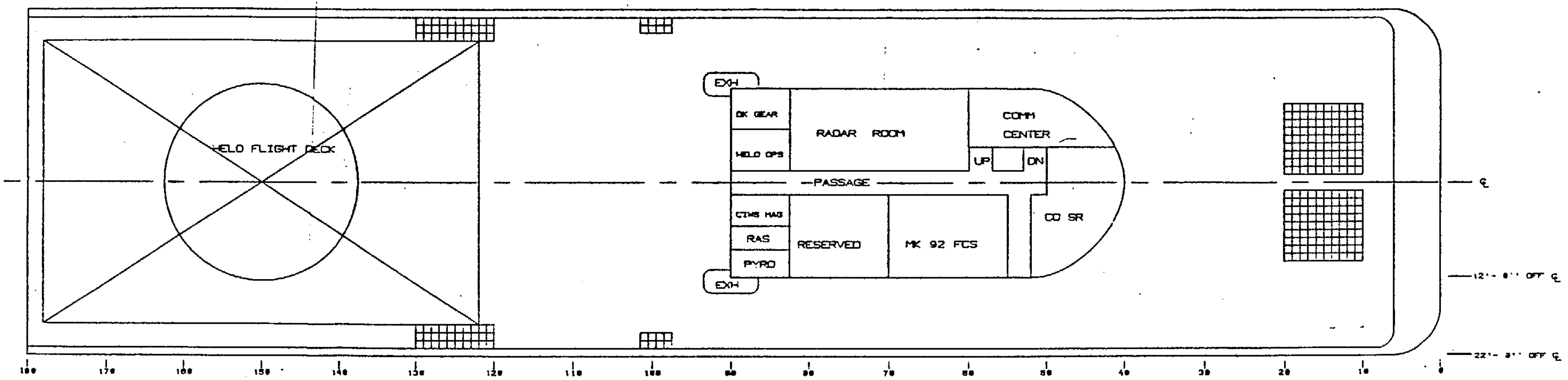
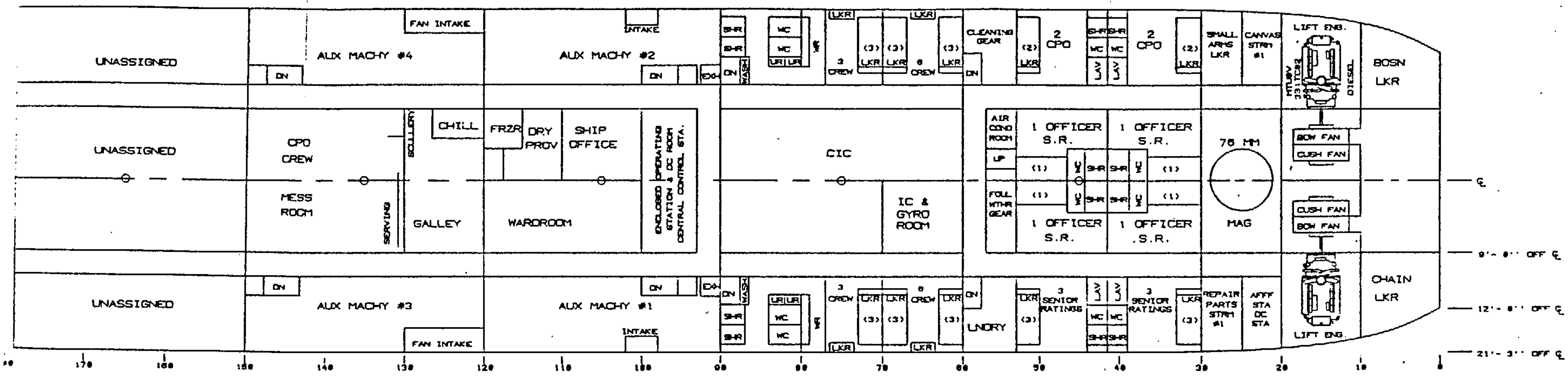


FIGURE A-5
COASTAL SES INBOARD PROFILE



MAIN DECK (23 FEET ABL)

FIGURE A-6
COASTAL SES MAIN DECK GENERAL ARRANGEMENT



SECOND DECK (13 FEET ABL)

FIGURE A-7
COASTAL SES SECOND DECK GENERAL ARRANGEMENT

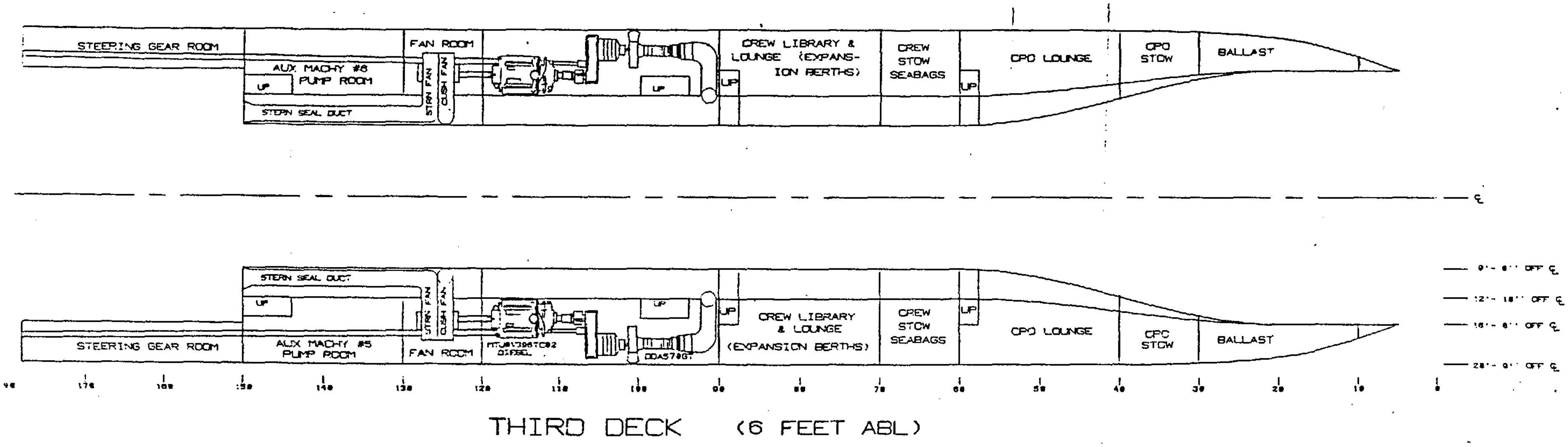


FIGURE A-8
COASTAL SES THIRD DECK GENERAL ARRANGEMENT

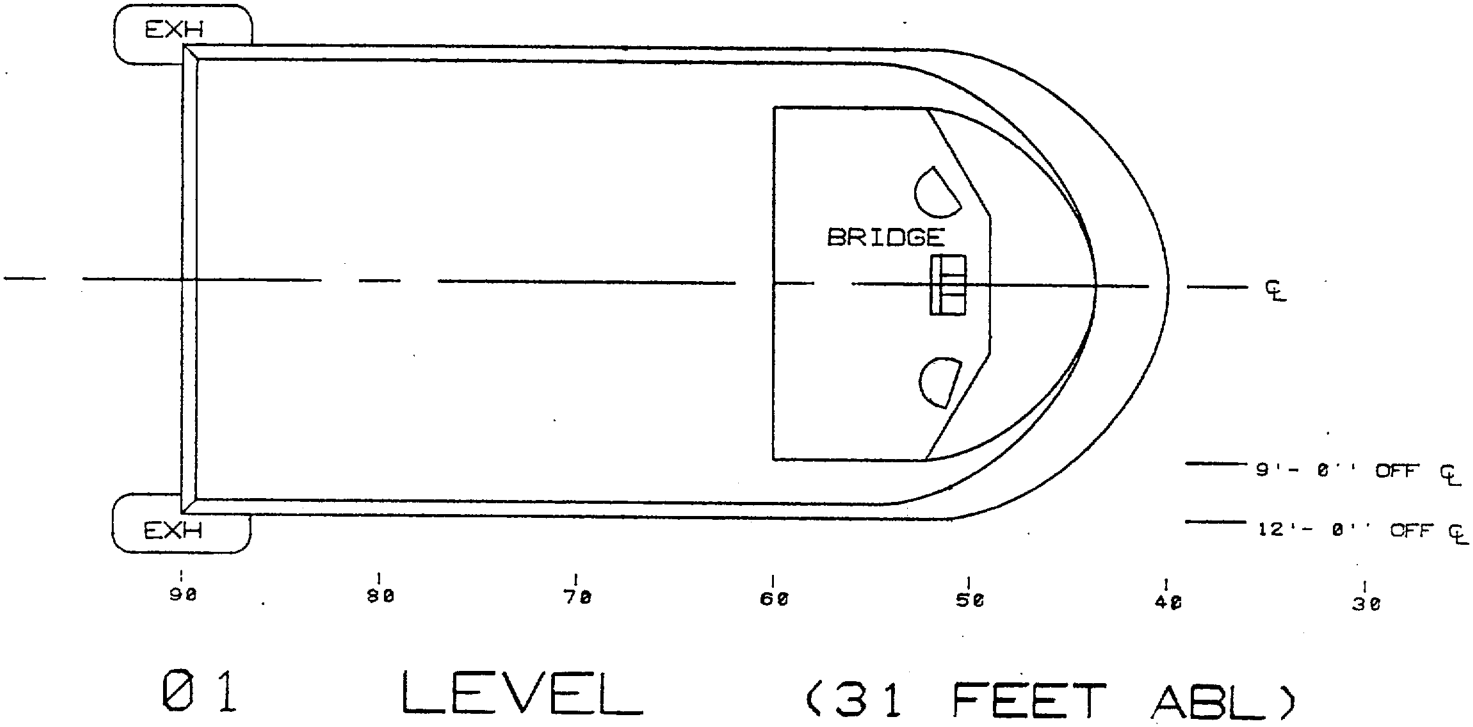


FIGURE A-9

COASTAL SES 01 LEVEL GENERAL ARRANGEMENT