021

MEDIUM DISPLACEMENT COMBATANT SURFACE EFFECT SHIP MDC

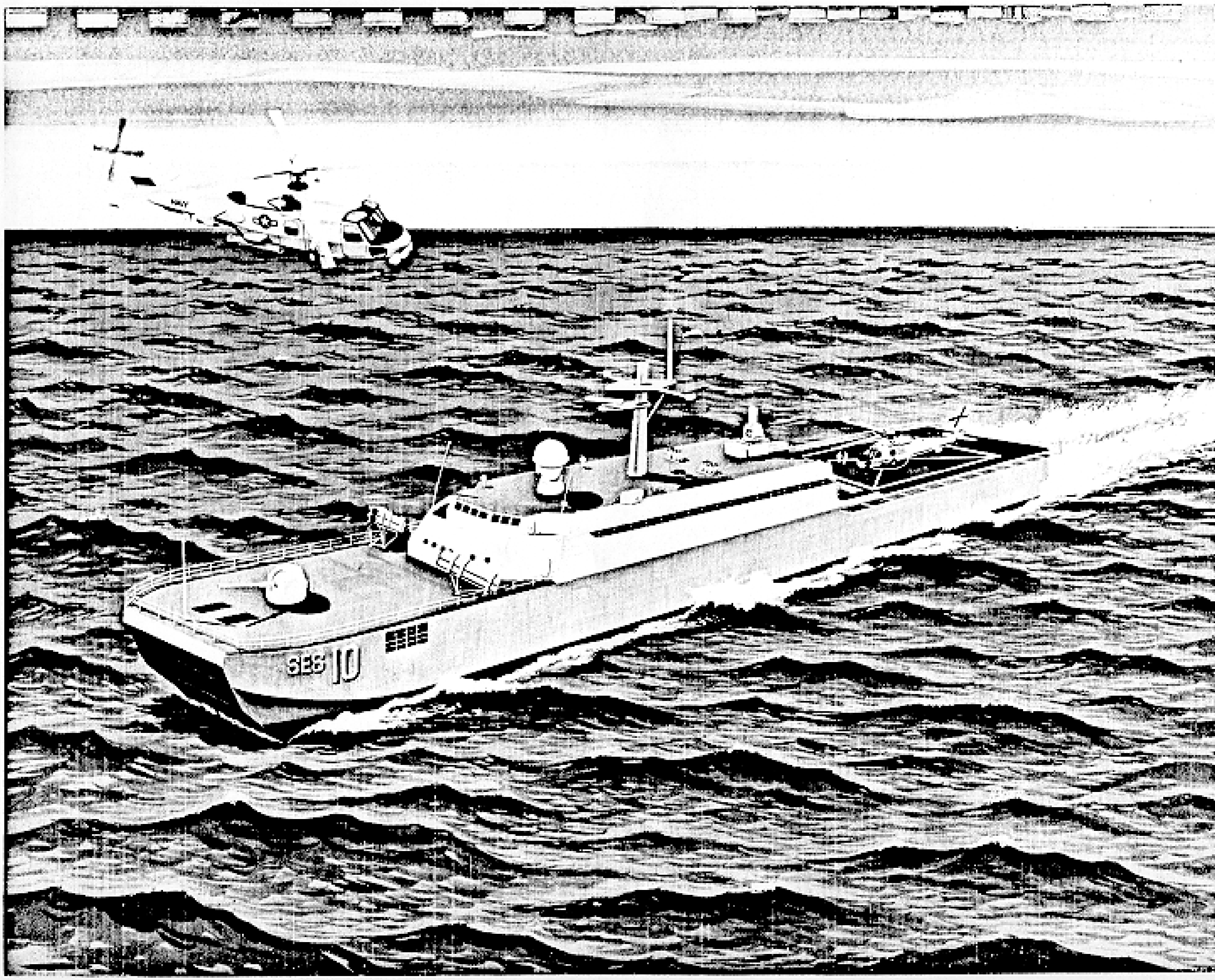
TECHNICAL REPORT

NAVAL SEA SYSTEMS COMMAND

PMS 304

SURFACE EFFECT SHIPS

SURFACE EFFECT SHIP ACQUISITION PROJECT
NAVAL SEA SYSTEMS COMMAND
WASHINGTON, D.C.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VOLUME I - TECHNICAL SUMMARY

MEDIUM DISPLACEMENT COMBATANT STUDY

APRIL 1981

ABSTRACT

A nominal 1000 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 ASW as its primary mission. For this the AN/SQR-19 towed sonar is fitted augmented by Lamps III helicopters. Surface and air targets can be engaged with Harpoon missiles, the Oto Melara gun and a close-in weapons system (CIWS). Other combat system elements could be fitted with very little design change. Performance capabilities are shown and the technical risk assessement 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 contains estimates for a first of class ship only.

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1 INTRODUCTION

The 1030 Ton Medium Displacement Combatant Surface Effect Ship (MDC) is an advanced naval vehicle capable of early fleet introduction. The assumed mission of the ship is to augment the main surface forces in an escort role, in the open ocean. The capabilities of the ship as presented include surface, subsurface, air surveillance, detection and attack of enemy forces. The MDC has an all weather capability, long range and good performance capability in high sea states, and a significant speed advantage over all other ships and submarines.

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 MDC is designed with a cushion length to beam ratio (L/B) of 7.52. 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 adequate roll stability and maneuverability. The MDC 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 which are 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 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 OBJECTIVES

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

- Search out, detect, localize and destroy submarines
- Offensive operations against surface combatants and craft
- Surveillance, patrol and blockade
- Special operations

In addition to fulfilling these military missions, the MDC has the following design objectives:

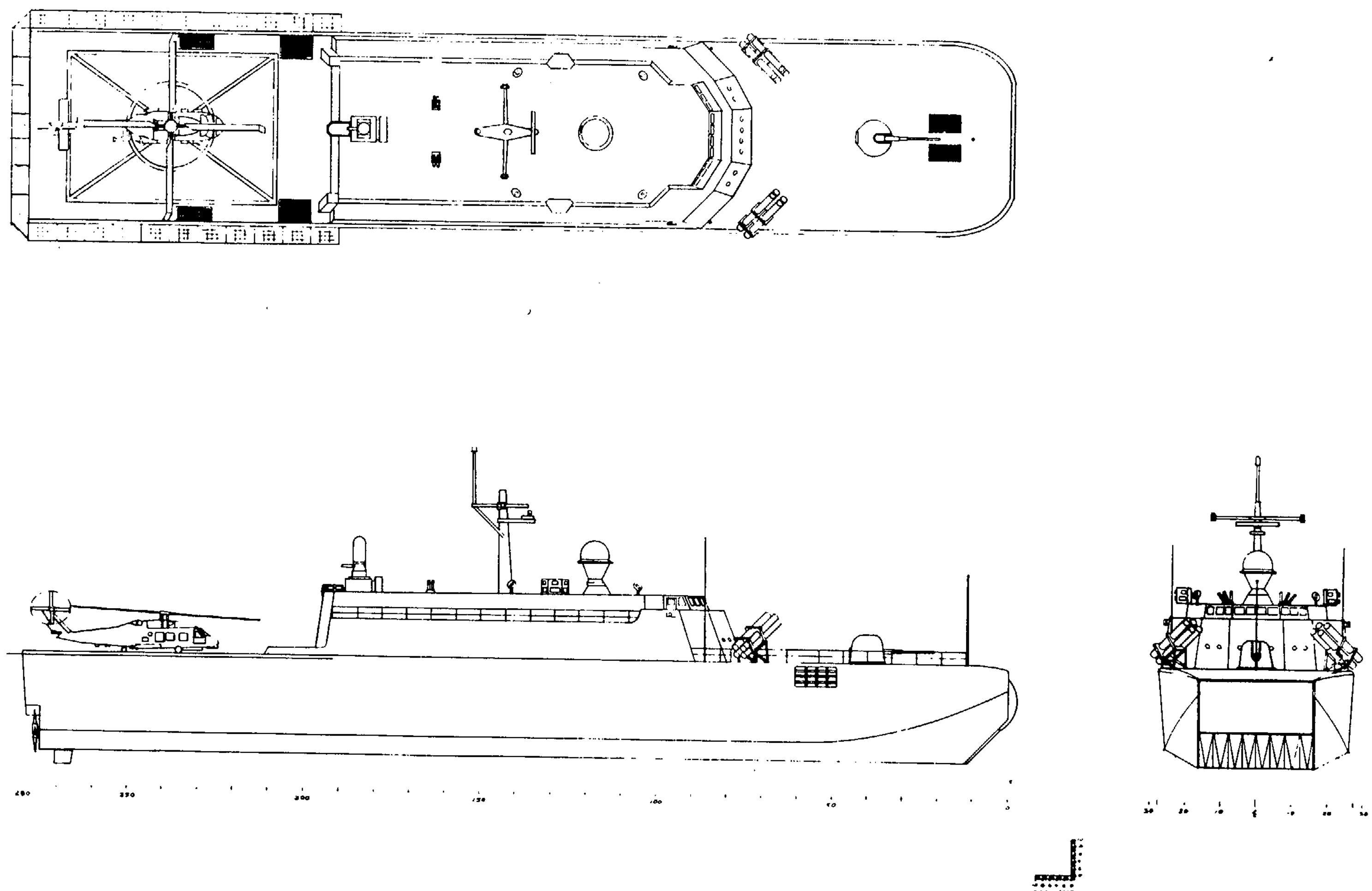
- Speed advantage over conventional ships
- Transoceanic range
- Independent Operations
- High Reliability and minimum manning
- Cost effectiveness coupled with low risk

With the above objectives as guidelines, a 1030 Long Ton 280 Foot Surface Effect Ship design has evolved with a 168 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 MDC when gas turbine propelled, on cushion, and at full load displacement (FLD), can achieve 53 knots in a sea state 0 (SS-0). When utilizing the secondary diesel propulsion system and hullborne, its range is 7000 nautical miles (nm) at 18 knots. This performance is compatible with the requirements for a ship operating as an outer ASW screen force.

The Combat System of the MDC employs subsystems which have been approved or are scheduled 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. 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.



MDC
FIGURE 2.1-1
PLAN AND ELEVATION VIEWS

MEDIUM DISPLACEMENT COMBATANT SURFACE EFFECT SHIP
PRINCIPAL CHARACTERISTICS

WEIGHTS:

Full Load Dispacement (FLD) (LT)	1030
Light Ship (LT)	676
Fuel 250 LT & Payload 168 LT	418

DIMENSIONS:

Length Overall (FT)	280
Beam Overall (FT)	55
Cushion Length/Beam Ratio	7.52
Wet Deck Height (FT)	20.5
Nominal Cushion Pressure (PSF)	239
Effective Cushion Length (FT)	252
Effective Cushion Beam (FT)	33.5

POWER PLANTS:

Propulsion (CODOG)	Four Allison 570-K (6445 Continuous SHP) Gas Turbines
Lift Engines	*Three SACM 195V12 CZSHR (2200 SHP) Diesels
Lift Fans	Six Aerophysics RD Fans
Propulsors	Two 12 1/2 Foot Diameter Controllable Pitch Propellers

CONSTRUCTION:

Structures	Welded Aluminum with Fiberglass Superstructure
Seals Bow:	Two Dimensional Bag and Finger
Stern:	Multi-lobe
Electrical	Three 500 KW Diesel Generators
Steering	Twin Rudder, Differential Thrust Reversal with the Propellers

CREW ACCOMMODATIONS:

Crew	99 Officers & Men
Accommodations	109 Berths

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

TABLE 2.1-i

MEDIUM DISPLACEMENT COMBATANT - SUMMARY OF PERFORMANCE

SPEED (KNOTS) - FLD

ON CUSHION

PROPULSIVE POWER (GAS TURBINES)	SEA STATE	LIFT POWER (DIESELS)	
		MAXIMUM	*OPTIMAL
MAXIMUM	SS-0	53	50
	SS-3	46	43
90% MAXIMUM	SS-0	-	47
	SS-3	-	41

*Lift Power for Maximum Range - See Text

OFF CUSHION

CONTINUOUS POWER		
SEA STATE	DIESEL	GAS TURBINE
SS-0	18	35
SS-3	17.5	30

RANGE (NM) - WITH 272.5 LT FUEL

CONDITION		RANGE	RANGE AT MAXIMUM AVERAGE SPEED
ON CUSHION	SS-0	2700* NM AT 47 KNOTS	2456 NM AT 53 KNOTS
90% MAXIMUM POWER	SS-3	2100* NM AT 41 KNOTS	2156 NM AT 46 KNOTS
OFF CUSHION	SS-0	7000 NM AT 18 KNOTS	-
	SS-3	6900 NM AT 17.5 KNOTS	-

*Maximum Range On Cushion

TABLE 2.1-ii

MEDIUM DISPLACEMENT COMBATANT TYPICAL COMBAT SUITE

AN/SQR-19 TACTAS
LAMPS III
MK 75 76MM OTO MELARA GUN
MK 92 GUN FIRE CONTROL SYSTEM (GFCS)
CLOSE-IN WEAPON SYSTEM (CIWS)
AUTOMATED COMBAT INFORMATION CENTER (CIC)
o Four (4) Displays - One (1) Computer
FRIGATE TYPE COMMUNICATION SUITE
o Link 11 and 14
AN/SLQ-32 ELECTRONIC COUNTERMEASURE SYSTEM (ECM)
EIGHT (8) HARPOON MISSILES

TABLE 2.1-iii

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.

2.3 SHIP DESCRIPTION

2.3.1 Ship Operational Modes

The ship can operate in either of two modes - cushionborne or hullborne.

When cushionborne the MDC is propelled by a maximum of four Allison 570K(6445 SHP) gas turbines with the lift power provided by three SACM (2200 SHP) diesels. These diesels are fitted to drive the six mixed flow lift fans. Simultaneous operation of the diesel engines is required only 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 can be supplied by the gas turbines.

It should be noted that because the design selected for this SES is of the high length to beam ratio type there is no large drag hump to overcome as in low length to beam ratio SES or in hydrofoils. There is therfore no problem in operating in the cushionborne mode however high the sea state. The SES can also readily become cushionborne from the hullborne mode.

2.3.2 Combat System

The combat system shown in Table 2.1-iii is typical of those systems that could be fitted in the MDC hull. The primary mission for which this suite is intended is ASW and is considered adequate to meet the postulated mission requirements. The MDC will use its AN/SQR-19 towed sonar for search augmented by the Lamps III to provide long range redetection, localization and destruction of submarines.

Surface engagements against patrol craft and small boats would use 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 weapon 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.

2.3.3 Maintenance Policy

Organizational level maintenance has been kept low by deferring as much as possible to the intermediate level which can be undertaken between missions. This has the advantage of enabling the ship to be manned for its operational needs rather than for maintenance requirements. This allows for a smaller crew than might normally be expected. Where possible "state of the art" remote and automatic operation of machinery has been fitted. In addition, multiple redundant subsystems have been incorporated in the design to increase overall ship availability. This contributes significantly to the minimum crew concept.

It is anticipated that the MDC will have progressive overhaul periods with incremental overhaul of equipments, subsystems and components.

2.3.4 Fire Protection

Fire protection is a major element of the MDC damage control system. Protection is provided by active and passive systems 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 which are unmanned a considerable percentage of the time and present a high fire threat. These include the machinery spaces which are treated on the decks, bulkheads and overheads.

The active fire protection system provides for fire detection and 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 and hangers as required by Helicopter Facilities Bulletin No. 1d. The MDC firemain supplies seawater to fire plug hose stations and the magazine sprinkling system. Halon 1211 portable, lightweight fire extinguishers are provided throughout for manual use.

2.3.5 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 500KW, 440 volt, diesel generators two of which can provide the full battle load. Auxiliary machinery, including pumping systems, distilling plants, sewage disposal system and air conditioning are installed in the sidehulls.

2.3.6 Ship Producibility

The MDC 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 Project. 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 little R&D necessary before contract design work and the preparation of a request for proposal (RFP) could commence.

2.3.7 Weight Estimates

A preliminary weight estimate in long tons (LT) split into the various SWBS groups is shown in Table 2.3-i.

MEDIUM DISPLACEMENT COMBATANT WEIGHT ESTIMATES

SWBS	ITEM	LONG TONS
100	Structure	276.7
119/ 248	Lift System	46.6
200	Propulsion	59.0
300	Electric	34.9
400	Command and Surveillance	57.7
500	Auxiliary (include RAST & Helo Services)	69.2
600	Outfit and Furnishings	61.9
700	Combat Systems	23.0
	Design & Construction Margins	47.0
	Light Ship	676.0
	Variable Load - ~~Disposable~~ Payload Fluids	14.0
	- Personnel & Stores	11.4
	- Fluids	6.2
	Lamps Support - 2 MK III Helos	11.6
	- F21, 22, 24, 26, 29	38.2
	- Helo Fuel (150 GPH) (100 LT Capacity Tanks)	22.5
	FLD without Fuel	779.9
	Variable Load - Fuel	250.0
	Total FLD 1029.9 Long Tons	

TABLE 2.3-i

3 SHIP ARRANGEMENT

3.1 CONFIGURATION

The 280 foot long MDC SES design has a catamaran hull shape offering unique opportunities for efficient ship systems layout. The catamaran hulls contain over 130,000 cubic feet of useable volume. The tank top in each sidehull in five (5) feet above the keel at the chine and serves as the fourth deck. The third decks are also in the sidehulls. These are sixteen (16) feet wide over most of their length and well suited to machinery and crew quarters. The second deck bridges the catamaran hulls, and together with the main deck serves as the primary structural box supporting the catamaran hull. It is fifty-five (55) feet wide over more than 90 percent of its length and is almost completely available for mission and habitability requirements. The superstructure is two levels high and extends the full width of the ship to provide the enclosed passageways necessary on a high speed ship. Superstructure length may be adjusted to suit special requirements. The MDC configuration lends itself to modular automated construction due to its extensive parallel middlebody and rectangular shape.

3.2 TANKAGE

The fuel and water tanks are located in the double bottom of each sidehull with tankage of 14000 cubic feet available to handle over 400 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.

3.3 WATERTIGHT INTEGRITY

The watertight integrity is maintained by transverse watertight bulkheads in each sidehull spaced every fifty (50) feet. These fifty foot compartments, in addition to a collision bulkhead twelve (12) feet aft of the bow, provide for a full two compartment damage stability capability in accordance with NAVSEA DDS 079-1, Part III. The V-lines do not penetrate the second deck, however the watertight bulkheads are extended up to the main deck outboard of the port and starboard longitudinal watertight bulkheads to further improve the combat survivability of the ship. This enables the MDC 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 with only a four (4) degree list.

3.4 MACHINERY ARRANGEMENT

The main propulsion machinery is located on the third and fourth decks within each sidehull between watertight bulkheads at the 195 and 245 foot stations. Sixteen (16) 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, on the fourth deck forward of the main machinery between stations 145 and 195, and above the main machinery on the second deck. These spaces contain 2600 square feet of useful area in eight (8) rectangular shaped spaces. One more compartment is dedicated to the forward lift system machinery set of two (2) lift fans. This is located forward on the second deck in the bow between stations 12 and 25 where it has minimal impact on the ship's general arrangements. The four remaining lift fans are positioned on the third deck in the main machinery spaces. One thousand (1000) square feet of deck space is utilized by the lift system to provide a total machinery space area of 4500 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 195 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 45 feet. The catamaran shape of the sidehulls and the location of the machinery low in these hulls provides a shaft inclination of only eight (8) degrees and allows for the installation of the propellers on the transom. This eliminates the need for exposing the shafting and propellers beneath the hulls and therefore 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 are located so as to permit maintenance 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.

3.5 SHIP CONTROL POSITIONS

The pilot house, chart house and radar room are all clustered together on the 01 level of the superstructure to provide for convenient conning of the ship. The officers quarters are situated immediately below the bridge to provide quick access to the pilot house and down to the combat information center (CIC), communications and radio spaces along with the MK 92 fire control system (FCS) and sonar spaces. These spaces are also conveniently grouped to provide for efficient operations. This separation of the CIC on the 2nd deck and the bridge by the main deck officers quarters enhances combat survivability with no loss in operational efficiency. Over 3000 square feet of space is devoted to command and control. The central control station which contains both the machinery and damage control central is located aft of station 245 on the second deck.

Table 3.5-i compares the space on the MDC with several current Navy ships and shows that it compares very favorably with other combatants.

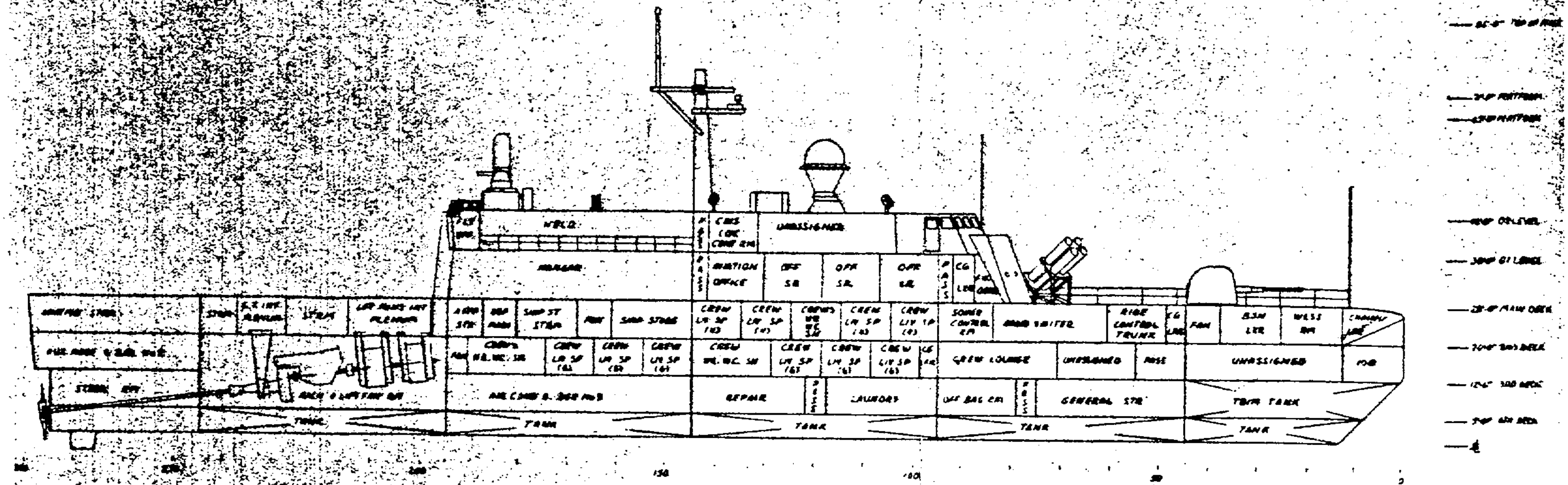
COMMAND AND CONTROL SPACES

SPACE DESCRIPTION	MDC SQUARE FEET	FFG7 SQUARE FEET	PCG SQUARE FEET	PHM SQUARE FEET
Pilot House	402	376	244	149
Chart Room	171	84	-	-
Combat Information Center (CIC)	600	817	483	388
Communication Center	450	456	187	81
Interior Communication & Gyro Room	231	326	70	-
Radar, IFF & CIC Equipment Space	762	984	266	151
Radio Transmitter Space	241	276	-	-
MK 92 Fire Control System, Air Navigation, ECM	357	276	154	-
CIWS Control Room	67	-	-	-
TACTAS Equipment Room	228	144	112	-
TACTAS Control Room	84	-	140	-
SONAR Control Space	115	187	98	-
MK 13 MOD 4 Missile Launcher Control	-	124	-	-
STIR Equipment Room	-	274	-	-
Helo Control Station	23	-	-	-
Central Control Station	562	642	150	95
Future Growth 01 level	452	-	-	-
Future Growth 2nd deck CIC	160	-	-	-
TOTALS	4905	4966	1904	864

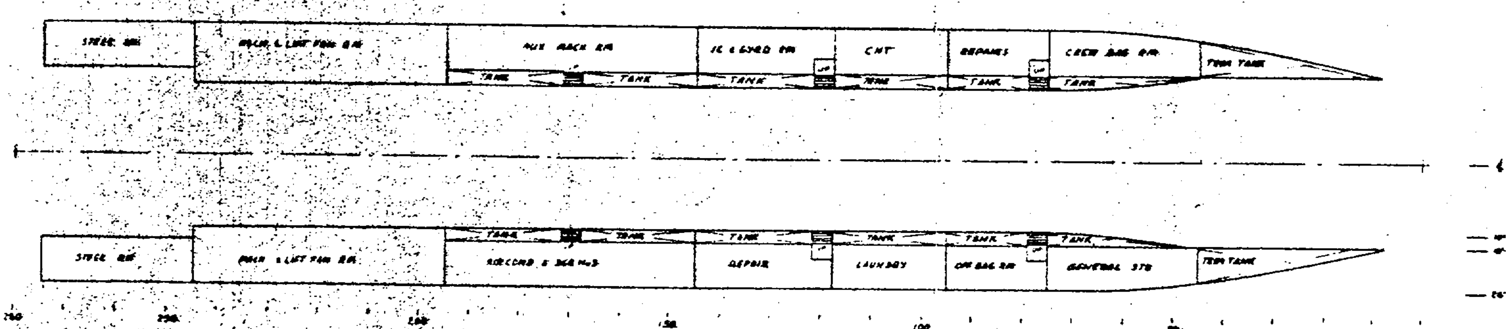
TABLE 3.5-i

3.6 ARRANGEMENT FLEXIBILITY

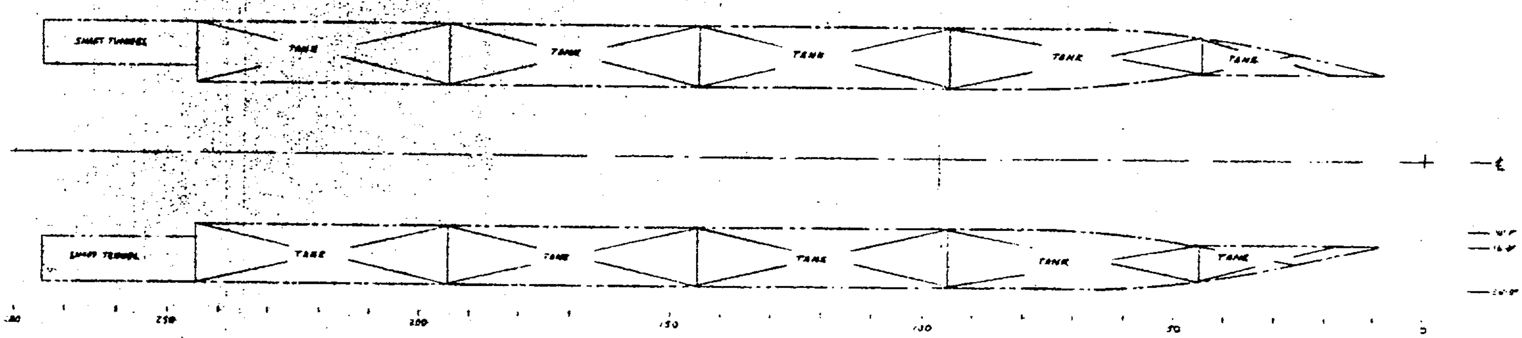
The entire space on the second deck aft of station 25 to the transom at station 280 which measures 255 x 55 x 8 feet can be arranged to suit various mission requirements. The layout illustrated in the plan and elevation views (Figures 3.6-1 and 3.6-2) is efficient for the installed system but other arrangements can also be made clean and functional due to the lack of volume restraints that are so typical of most modern ships. For example, the MDC has 1.8 times the internal volume per ton of displacement of the FFG-7 and 168 LT of payload as compared to 280 LT on the FFG-7 to arrange on this deck and in the 12000 square feet of superstructure. The resulting MDC payload transport efficiency (Wp x V/P) at full power cruise speed is 1.7 compared with 1.4 for the FFG-7.



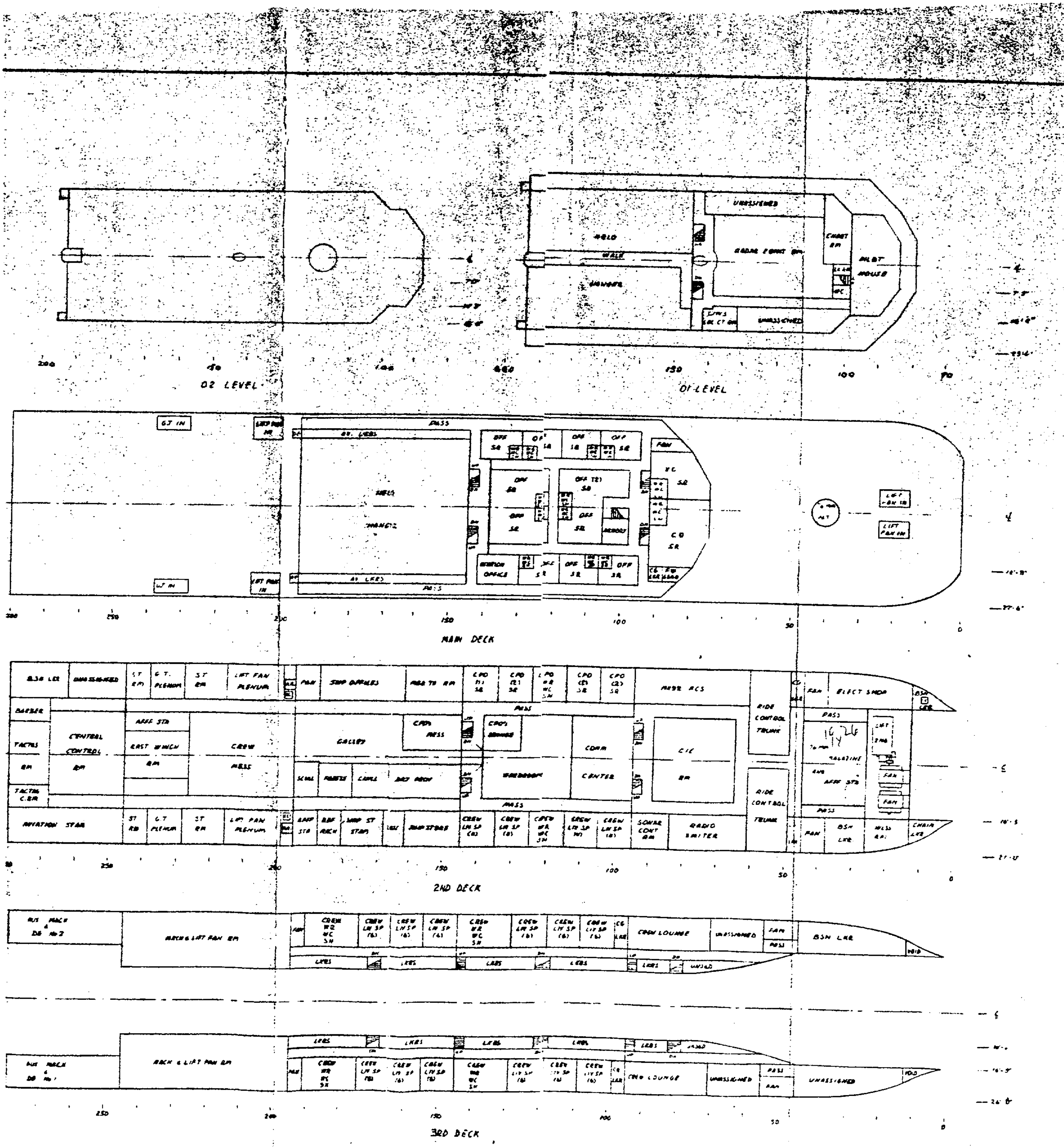
SIDEHULL INBOARD PROFILE
STARBOARD SIDE



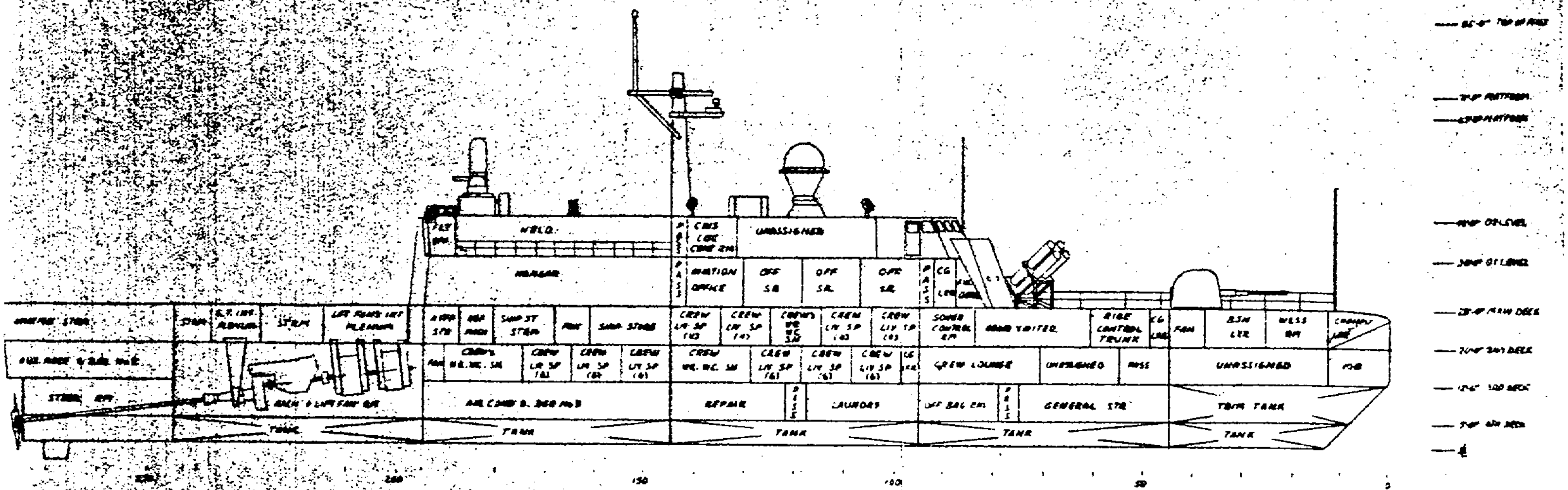
4TH DECK



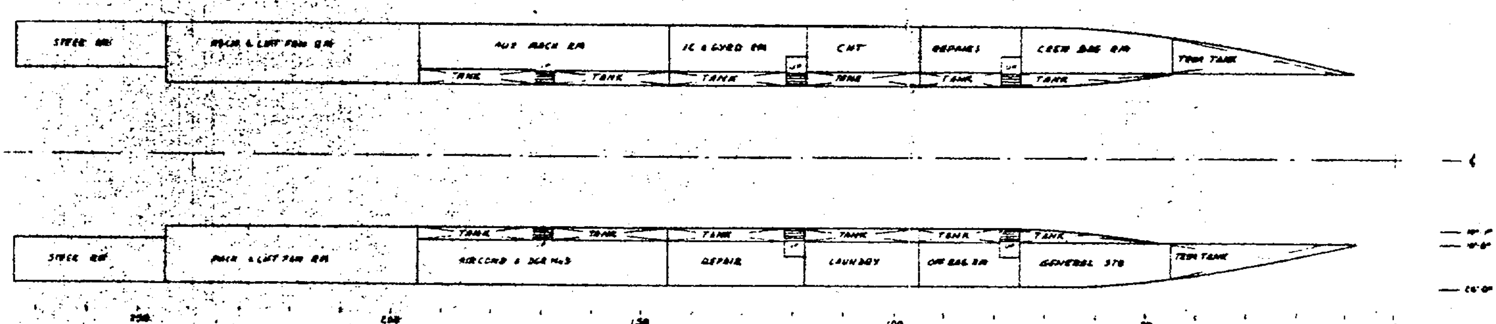
TANKS TOP



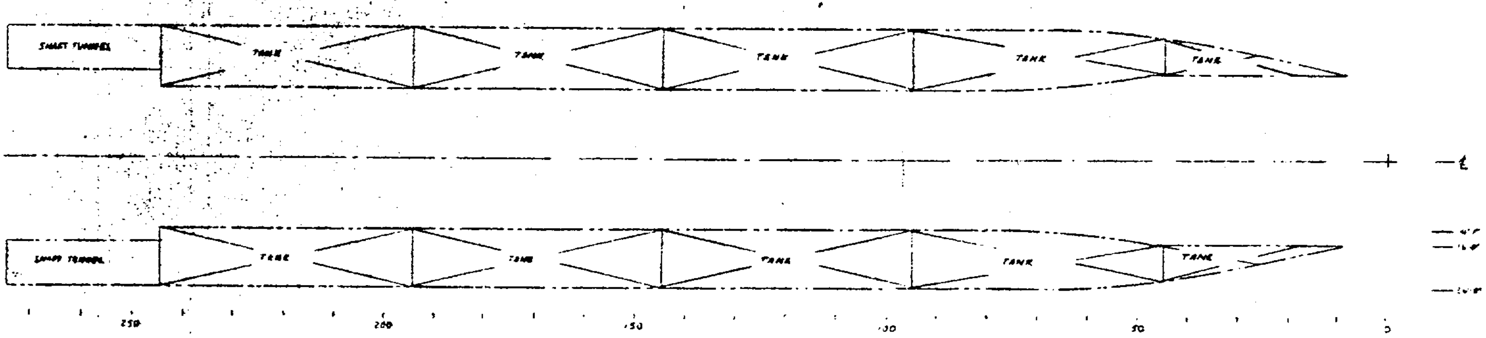
02 LEVEL
01 LEVEL
MAIN DECK
2ND DECK
3RD DECK



SIDEHULL INBOARD PROFILE
STARBOARD SIDE



4TH DECK



TANKS TOP

Referring again to the plan views an important feature of the 54 foot wide 2nd deck is the provision of two fore and aft passageways 12.5 feet off the centerline to port and starboard. These two passageways provide redundant convenient access to all operational and combat stations and significantly reduce internal ship noise reverberation. Four hundred and thirty (430) square feet is currently unassigned on this deck and is reserved for future growth. It could accommodate other combat suites. 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 CIC and Communications areas that are immediately aft of the bulkhead at station 62.

The aft location of the machinery leaves the entire 3rd deck forward of station 195 free for mission payload or crew spaces etc. The plan views indicate but one of many possible uses of this 5000 square feet of space. The fourth deck forward of station 145 contains an additional 3000 square feet of deck space.

3.7 ACCOMMODATION SPACES

The living spaces on the MDC make full utilization of the expansive deck areas inherent in all SES and meets the standards of OPNAVINST 9640.1 of 13 October 1979. As a result all crew members are quartered in cabins conveniently located for comfort and sound isolation as well as for quick access to operational stations. The officers are all located on the main deck in the forward half of the superstructure. All but the two most junior officers have single staterooms with self-contained sanitary facilities. These staterooms average 98 square feet per man and are clustered in a private officers country with direct access to the bridge and the combat control spaces. The non-commissioned officers (CPO) and senior enlisted personnel are quartered directly below the officers between stations 95 and 145 on the second decks. The CPO's are located outboard on the port side. They share two man staterooms averaging 60 square feet per man with a centrally located sanitary facility. The CPO lounge and CPO mess are located directly across the fore and aft passageway for direct access. On the starboard side four man bunkrooms are provided for the senior enlisted personnel. These spaces average 26 square feet per man and share a common centralized sanitary facility.

The remaining 72 crew accommodations are on the third deck between stations 95 and 191 below the CPO and senior enlisted personnel spaces. These enlisted personnel are berthed in six-man berthing spaces averaging 17 square feet per man. Four sanitary facilities are provided in convenient locations. Directly forward of this berthing area are large sized crew lounges in each sidehull.

The fourth deck contains baggage stowage, laundry facilities and storerooms for crew services.

3.8 DOMESTIC SERVICE

All food preparation and eating facilities are located in a single central area on the second deck's centerline between stations 113 and 225. This 110 foot long by 25 foot wide block has the galley in the middle with the CPO and Wardroom forward and the crew's mess aft. This shortens serving lines and separates officers and enlisted personnel eating facilities. The galley area contains extensive freeze, chill and dry provisions storerooms within the space for convenient access for daily use and close proximity to the main deck loading areas for fast reprovisioning. The ship's store and offices are located adjacent and outboard of these spaces to minimize personnel traffic into ship operations areas.

Table 3.8-i lists the square footage of each habitability area for the MDC and several other ships. On a per man basis the MDC allocates 44 percent more space to these services than the much larger FFG-7. Table 3.8-ii breaks down each space in terms of square feet per user. This shows the dramatic improvement in habitability density achieved on the MDC design.

HABITABILITY SPACES COMPARISON

SPACE DESCRIPTION	MDC SQ FT	FFG-7 SQ FT	PCG SQ FT	PHM SQ FT
COMMANDING OFFICERS STATEROOM & BATH	317	265	150	75
EXECUTIVE OFFICER'S STATEROOM & BATH	215	181	-	-
OFFICER'S STATEROOMS	1176	756	274	151
CPO STATEROOMS	420	487	-	97
SENIOR ENLISTED BUNKROOMS	420	-	-	-
ENLISTED MEN BERTHING	1428	2985	510	275
OFFICER WASHROOM, WATERCLOSET, SHOWERROOM	220	100	58	
CPO WASHROOM, WATERCLOSET, SHOWERROOM	105	125	-	80
CREW WASHROOM, WATERCLOSET, SHOWERROOM	745	494	119	
WARDROOM	524	510	210	-
CPO MESS	189	235	-	-
ENLISTED MESS	775	1172	358	190
GALLEY	551	581	136	90
SCULLERY	77	123	24	-
DRY PROVISIONS	210	277	42	30
FREEZER AND MACHINERY ROOM	156	105	60	-
CHILL STOREROOMS	157	116	60	-
CPO LOUNGE	126	141	-	-
CREW LOUNGE	500	556	36	-
SHIP STORE AND STOREROOM	304	195	-	-
MEDICAL TREATMENT	189	286	-	-
SHIP OFFICES	262	1120	82	-
BARBER SHOP	84	60	-	-
CREW LOCKERS	626	594	60	-
LAUNDRY	207	540	55	-
CREW BAGGAGE	260	92	-	97
OFFICER BAGGAGE	144	36	-	-
TOTAL HABITABILITY SPACES	10,387	12,128	2,234	1,085
HABITABILITY SPACE/MAN	95.3	72.2	38.5	51.7

TABLE 3.8-i

HABITABILITY DENSITY (SQUARE FEET PER USER)

SPACE DESCRIPTION	COMPLEMENTS* MDC 109	FFG-7 185	PCG 56	PHM 21
COMMANDING OFFICERS STATEROOM & BATH	317	265	150	75
EXECUTIVE OFFICER'S STATEROOM & BATH	215	181	-	-
OFFICER'S STATEROOMS	98	50	39	38
CPO STATEROOMS	60	32	-	24
SENIOR ENLISTED BUNKROOM	-	-	-	-
ENLISTED BERTHING	21	20	10	23
OFFICER WASHROOM, WATERCLOSET, SHOWERROOM	18	6.7	9.7	
CPO WASHROOM, WATERCLOSET, SHOWERROOM	15	8.3	-	4
CREW WASHROOM, WATERCLOSET, SHOWERROOM	8.5	3.2	2.3	
WARDROOM	37	34	30	-
CPO MESS	27	16	-	-
ENLISTED MESS	11	7.7	7.6	9.1
GALLEY	5.0	3.5	2.3	4.3
SCULLERY	0.7	0.7	.4	-
DRY PROVISIONS	1.9	1.5	.7	1.4
FREEZER AND MACHINERY ROOM	1.4	0.6	1.0	-
CHILL STOREROOMS	1.4	0.6	1.0	-
CPO LOUNGE	18.	9.4	-	-
CREW LOUNGE	6.9	3.6	.7	-
SHIP STORE AND STOREROOM	2.8	1.1	-	-
MEDICAL TREATMENT	1.7	1.5	-	-
SHIP OFFICES	2.4	6.0	1.4	-
BARBER SHOP	0.8	0.3	-	-
CREW LOCKERS	7.1	3.5	1.2	-
LAUNDRY	1.9	2.9	1.0	-
CREW BAGGAGE	2.7	0.5	-	4.6
OFFICER BAGGAGE	10.	6.1	-	-

*Complement Breakdown:

MDC :	14 Officers	-	7 CPO's	-	72 Enlisted plus 16 SR Enlisted
FFG-7:	17 Officers	-	15 CPO's	-	153 Enlisted
PCG :	7 Officers	-	0 CPO's	-	51 Enlisted
PHM :	5 Officers	-	4 CPO's	-	12 Enlisted

TABLE 3.8-ii

3.9 COMBAT SYSTEM ARRANGEMENT

The large rectangular shaped decks of the SES are well suited for carrying modern weapon systems. Table 3.9-i compares the space allocated for common weapons between the MDC and several other modern ships. The MDC allocates more deck space than the FFG-7 does for similar weapons. The large 55 foot ship beam is carried all the way from the bow to the transom. This wide transom allows a spacious 85 x 55 foot helicopter landing platform that leads directly to a large unobstructed 50 foot long hanger. The same wide deck forward provides ample space for two 4 cell Harpoon launchers and the 76 mm Oto Melara gun. Below decks the magazines and equipment spaces are located conveniently to their respective weapons and are of sufficient size to expedite handling and maintenance. The wide transom also provides an optimum TACTAS sonar installation. The inherent flexibility offered by the MDC hullform is further demonstrated by noting that with the removal of one Lamps MK III helicopter the MDC could add an extensive anti-air missile and radar system while still retaining an ASW capability.

COMBAT SYSTEM DECK AREAS

SPACE DESCRIPTION	MDC SQ FT	FFG-7 SQ FT	PCG SQ FT	PHM SQ FT
76 MM Oto MELARA MAGAZINE	520	596	364	314
CIWS 20 MM MAGAZINE	67	72	123	-
LAMPS MK III HELICOPTER HANGER	2040	1940	-	-
HELICOPTER OFFICE	96	54	-	-
HELICOPTER CONTROL STATION	23	37	-	-
HELICOPTER RAST SPACE	285	192	-	-
HELICOPTER REFUELING ROOM (ENGINE ROOM)	50	36	-	-
SONOBOUY STOREROOM NUMBER 1	127	75	-	-
SONOBOUY STOREROOM NUMBER 2	127	104	-	-
SMALL ARMS MAGAZINE	NONE	50	24	9
ARMORY	64	150	-	-
AVIATION STOREROOM	162	147	-	-
HELICOPTER SHOP	200	198	-	-
TOTALS	3761	3653	511	323

TABLE 3.9-i

3.10 ARRANGEMENT SUMMARY

With a total deck area of 50,000 square feet compared to 68,000 square feet for the 1.6 times longer FFG-7 it is clear that the SES configuration with its wide beam carried over its entire length is very space efficient. At the same time it should be noted that at 1030 LT displacement the MDC is less than one third the displacement of the frigate. This means that the SES is more weight sensitive than conventional monohulls. However, the SES higher lift to drag ratio results in a ship with higher speed and range for equal volume with less horsepower and about one-half the displacement. With careful control of weight, extensive modern high volume military payloads can be installed. Altogether, this combat suite arrangement provides an exciting new anti-submarine and anti-ship hunter killer with high speed and endurance in a small economically priced ship.

4 SHIP PERFORMANCE

4.1 GENERAL

The MDC has been sized and powered as a "blue water" ship capable of operation in all weathers in either cushionborne or hullborne modes.

The performance characteristics given are for a ship of 1030 LT FLD carrying a total of 272.5 LT burnable fuel of which 22.5 LT is normally reserved for helicopters. The presented data include both cushionborne and hullborne operations at various propulsive and lift power levels. Propulsion while cushionborne is achieved by operating the gas turbines either singly or in combination up to four at a power setting of 7170 shp maximum power (MP) per unit, or 6445 shp 90 percent maximum power per unit which is their continuous rating. The three diesel engines that power the lift fans can also be operated singly or in combination at different power levels. For maximum speed the diesel engines are operated at MP with the turbines also operating at their MP. At lower speeds the diesel engines are used at power levels such that in combination with the gas turbines the total combined power (i.e., effective drag) for any speed is minimized.

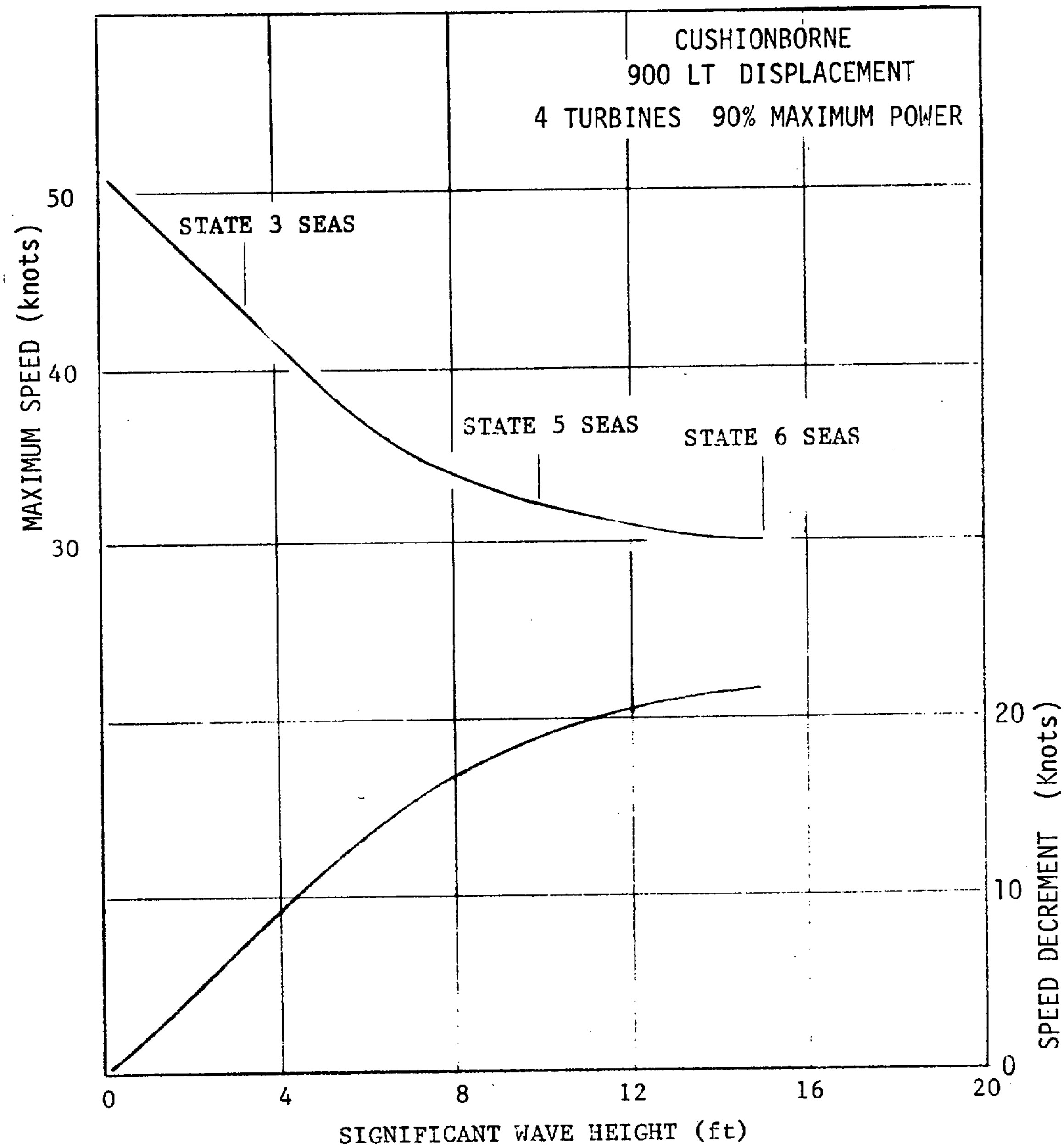
Hullborne propulsion may be achieved with one or two of the after diesel engines, which when cushionborne are used for the stern lift fans, or with the gas turbines. The gas turbines achieve higher hullborne speeds but are less fuel efficient. The diesel engines are rated at 2200 shp continuous or 2420 shp maximum.

The data presented below provides the speed, range and motions characteristics for various sea states. Speed is presented in Figure 4.1-1 as a function of sea state up to SS-6 for cushionborne operation. Detailed drag and thrust curves, Figure 4.1-2 and 4.1-3, are presented for two sea states 0 and 3 showing how the speeds were typically obtained for Figure 4.1-1. Data is also presented for the hullborne mode in Figures 4.1-2 and 4.1-3.

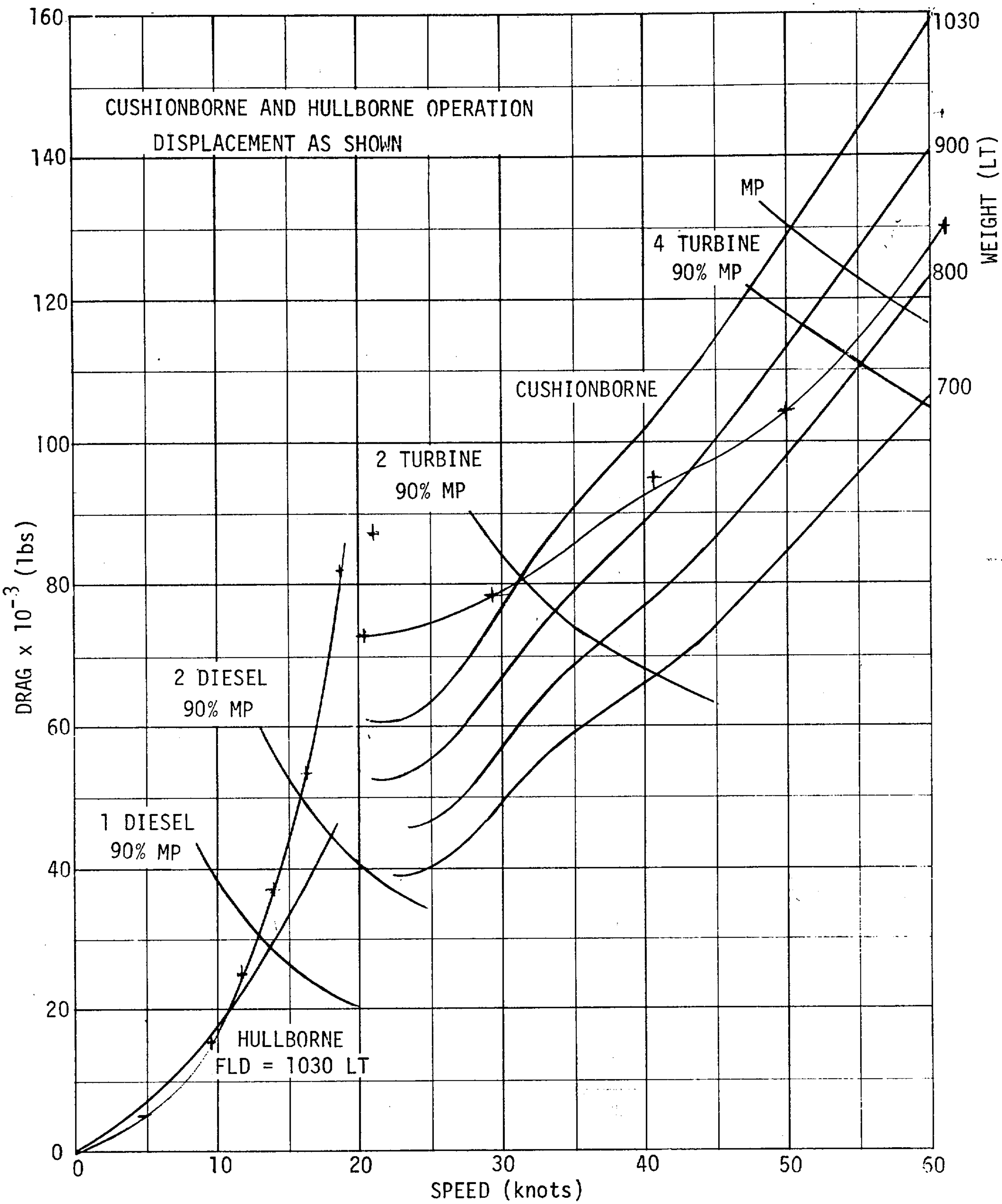
The range data presented in section 4.3 are for SS-0 and SS-3 as these were regarded as typical of what the ship would experience for much of its life. The motion data presented in section 4.4 are shown for SS-3 and SS-5.

Model tests of an MDC are scheduled for the spring of 1981. These are intended to validate the predictions presented in this report and to extend the data base where necessary.

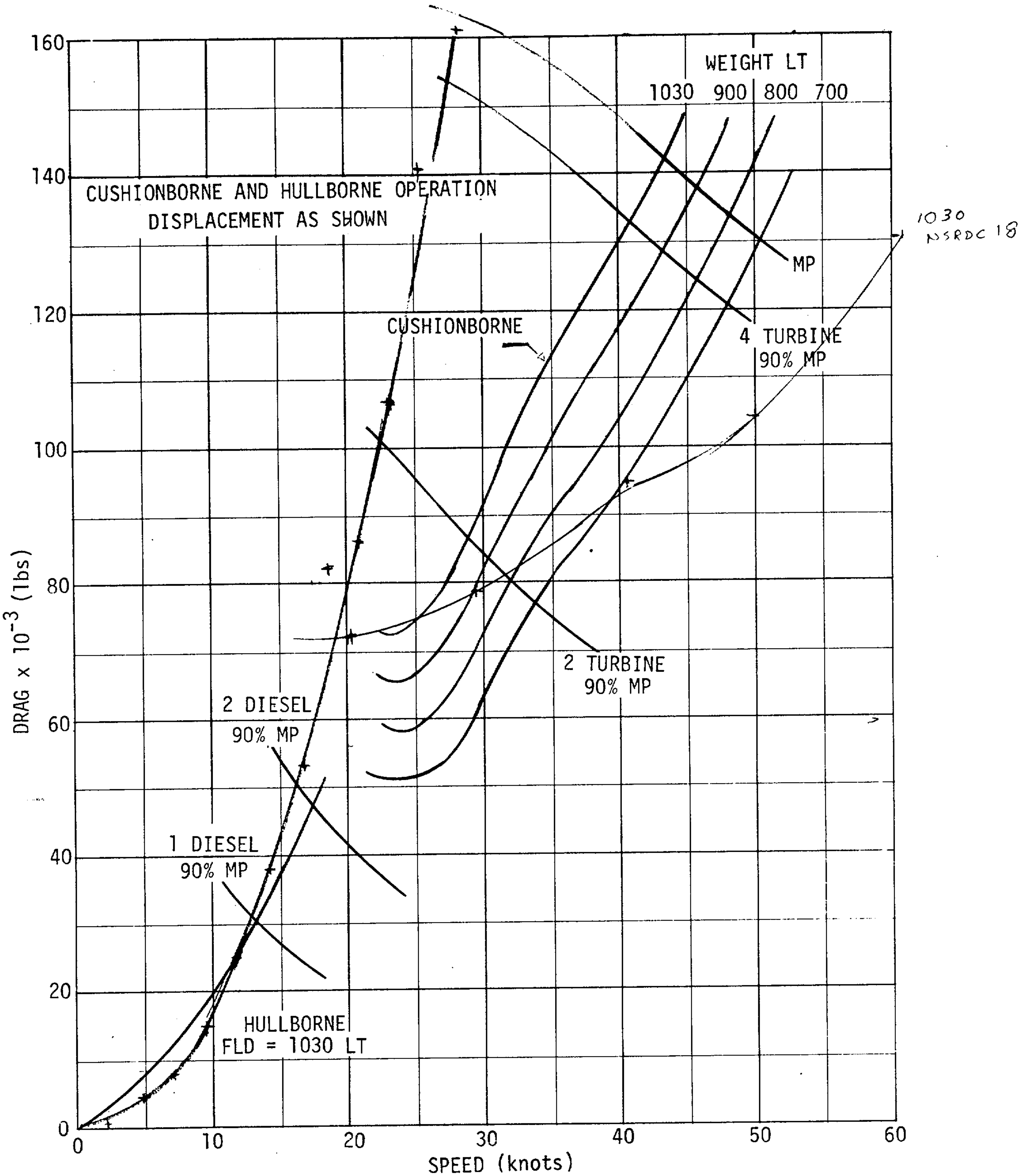
The estimates of full scale drag as shown in Figures 4.1-2 and 4.1-3 have been derived from model test data that were converted to full scale by previously verified analytical methods. The model tests were run so that full accounting could be made for both propulsion and lift power in estimating speeds and ranges. This was done by testing the model for each selected displacement and speed over a range of fan flows and measuring drag for each fan flow. Drag (proportional to propulsive power) reduces with increase of fan flow and is minimum for maximum fan flow Q_m as shown conceptually in Figure 4.1-4a. When however for a given speed, the propulsive and lift powers are summed, Figure 4.1-4a shows that for any speed there is a minimum value of total power at some optimum fan flow Q_o. The drag curves shown in Figures 4.1-2 and 4.1-3 are values of drag corresponding to respective values of Q_o and are



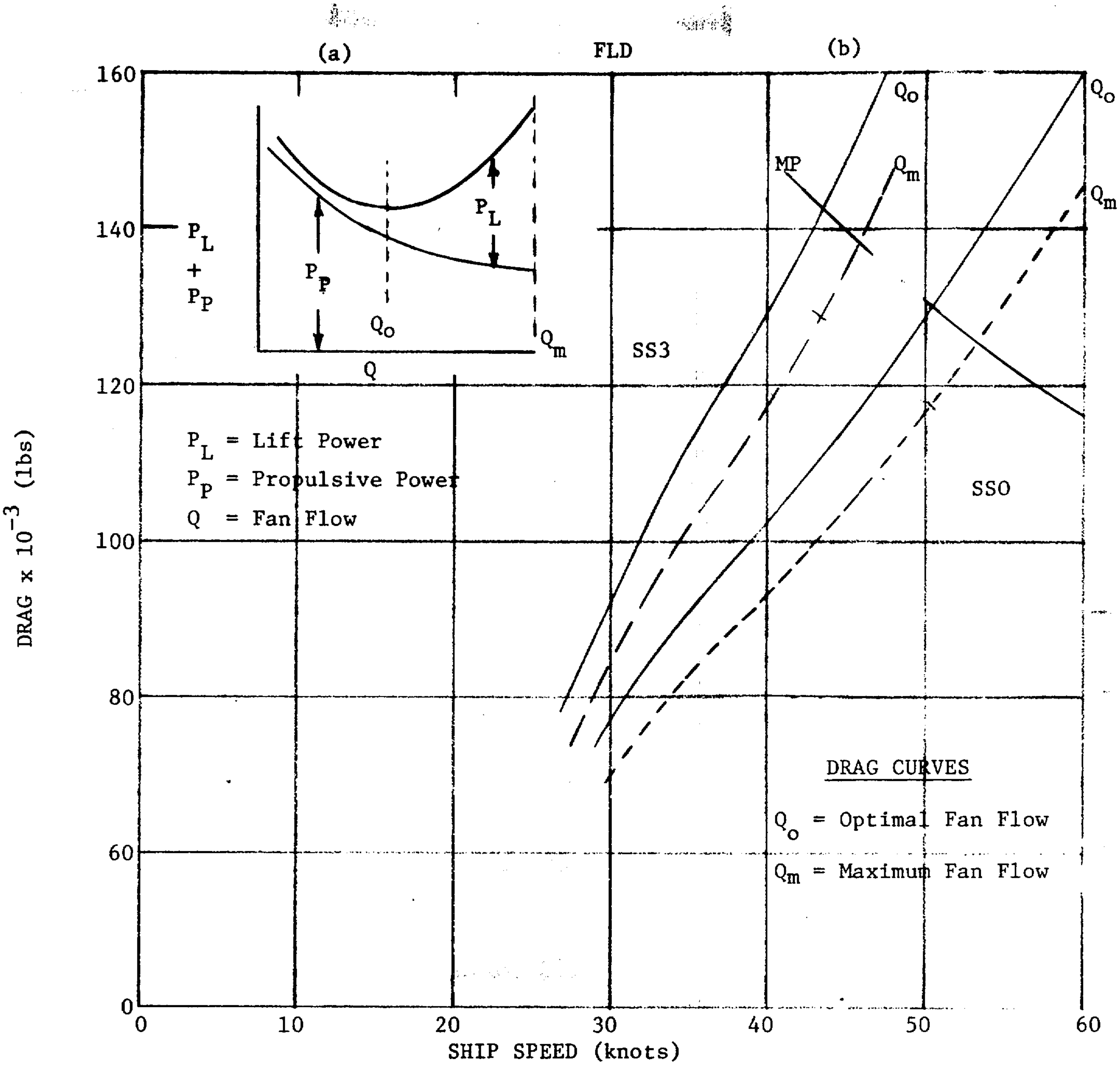
MDC
FIGURE 4.1-1
SPEED VERSUS SIGNIFICANT WAVE HEIGHT



MDC
FIGURE 4.1-2
DRAG VERSUS SPEED SEA STATE 0



MDC
FIGURE 4.1-3
DRAG VERSUS SPEED SEA STATE 3



MDC
FIGURE 4.1-4
EFFECT OF FAN FLOW ON DRAG

used for estimating maximum range values. The curves given in Figure 4.1-4b show the drag reduction to be expected when maximum fan flow is used at FLD in SS-0 and SS-3 and are used to obtain maximum speeds.

The thrust curves shown in Figures 4.1-2, 4.1-3 and 4.1-4 include the overall machinery system efficiency as shown in Figure 4.1-5 and applies equally to cushionborne and hullborne operation. The efficiency curve accounts for all mechanical and hydrodynamic losses in the system. The optimal lift horse power required at different speeds and displacement is given in Figure 4.1-6. It is seen that in the high speed 40 - 50 knot region the available horsepower is about double that actually required, this ratio increasing with decreasing ship speed. The surplus lift power can be used in low sea states for providing high speed dash capability or is available for use with a ride control system in higher sea states. The optimal fan flow rates corresponding to the power in Figure 4.1-6 are shown in Figure 4.1-7. These fan flow rates have been shown to depend only on beam width and are independent of displacement for the range of displacements considered.

4.2 THRUST, DRAG AND SPEED

4.2.1 Cushionborne

Figure 4.1-2 shows the drag curves for FLD and three other displacements in SS-0. The thrust curves shown are for MP and 90 percent MP using four turbines and 90 percent MP using two turbines. Since these drag curves are based on optimal lift power they are used largely for range calculations. The same remarks apply to Figure 4.1-3 that show drag curves for SS-3. Figure 4.1-4 shows that maximum speeds of 46 knots and 53 knots can be achieved in Sea State 3 and zero.

The effect of higher sea states upon speed is shown in Figure 4.1-1. The curve plotted is for a displacement of 900 ton and 90 percent full power, but the speed decrement due to the sea state is closely applicable to other displacements and powers. It is seen that the ship is capable of a speed of 30 knots in sea state 6.

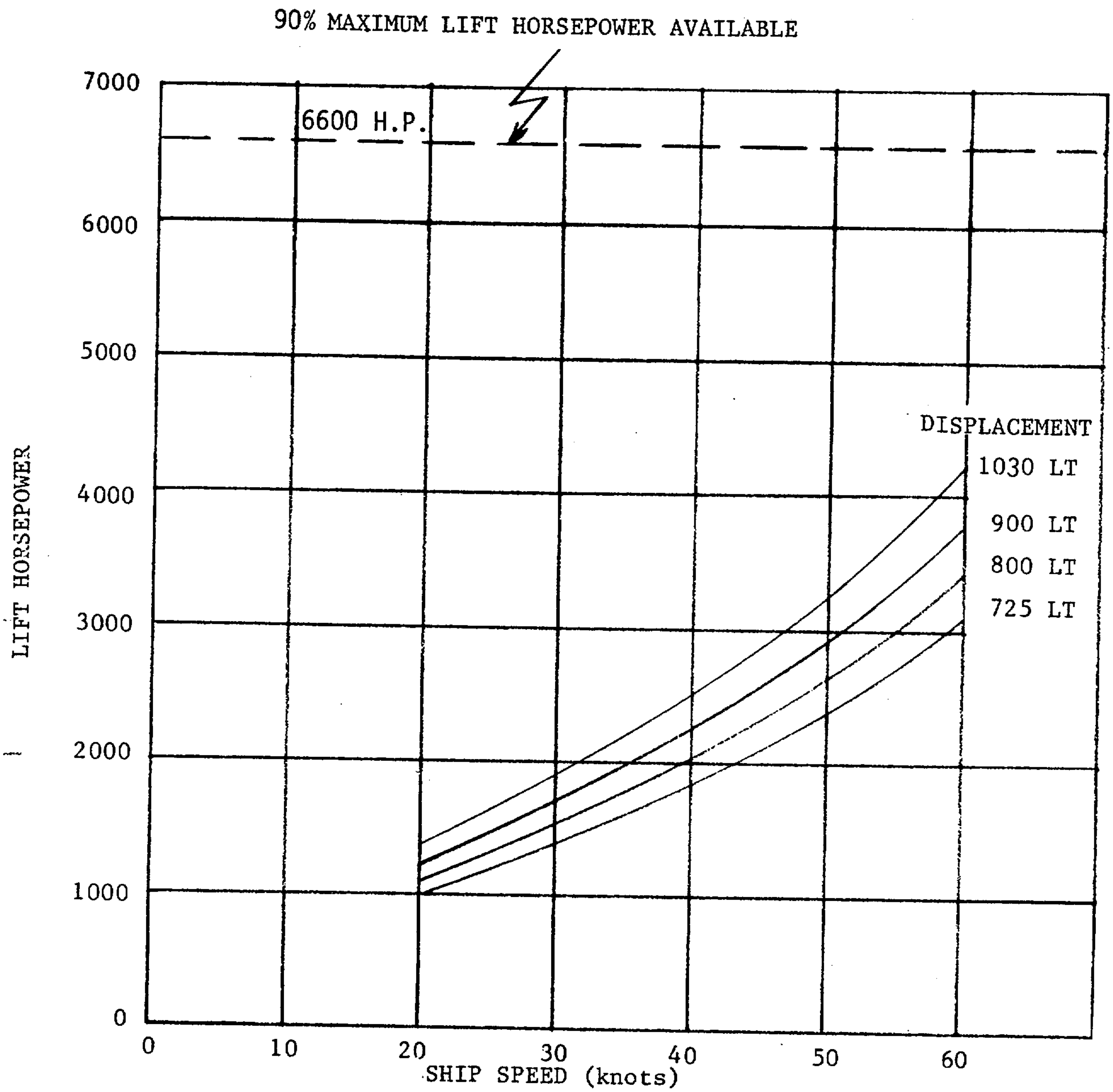
4.2.2 Hullborne

Hullborne drag curves for FLD in SS-0 and SS-3 are shown in Figures 4.1-2 and 4.1-3. Comparison of the two figures show relatively small effects due to sea state up to SS-3. Operation with two diesels at continuous power (total of 4400 shp) gives hullborne speeds of 18 knots and 17.5 knots in SS-0 and SS-3. With one diesel operating, the corresponding speeds are 13.5 and 13 knots.

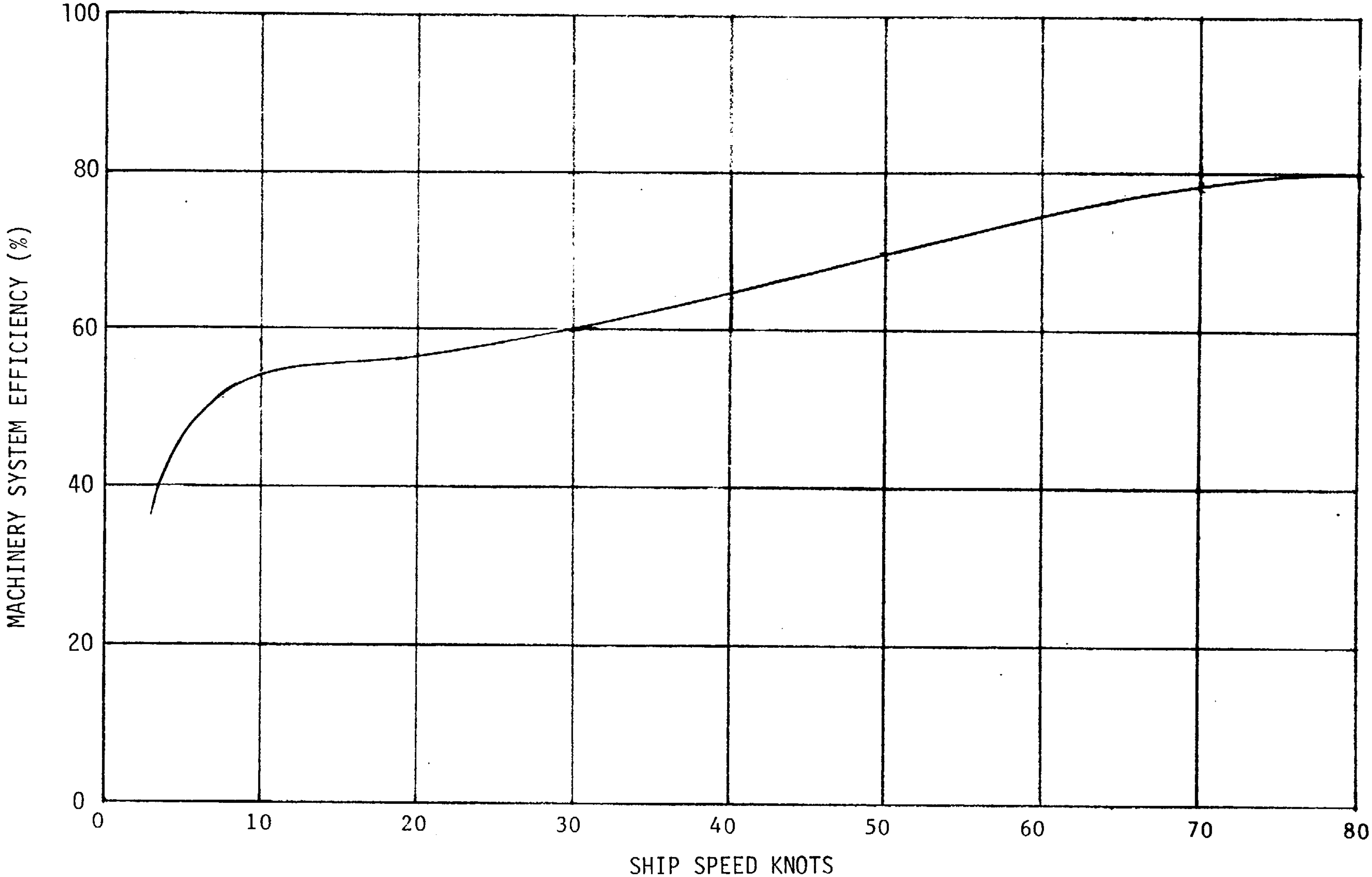
4.3 RANGE AND SPEED

4.3.1 Cushionborne

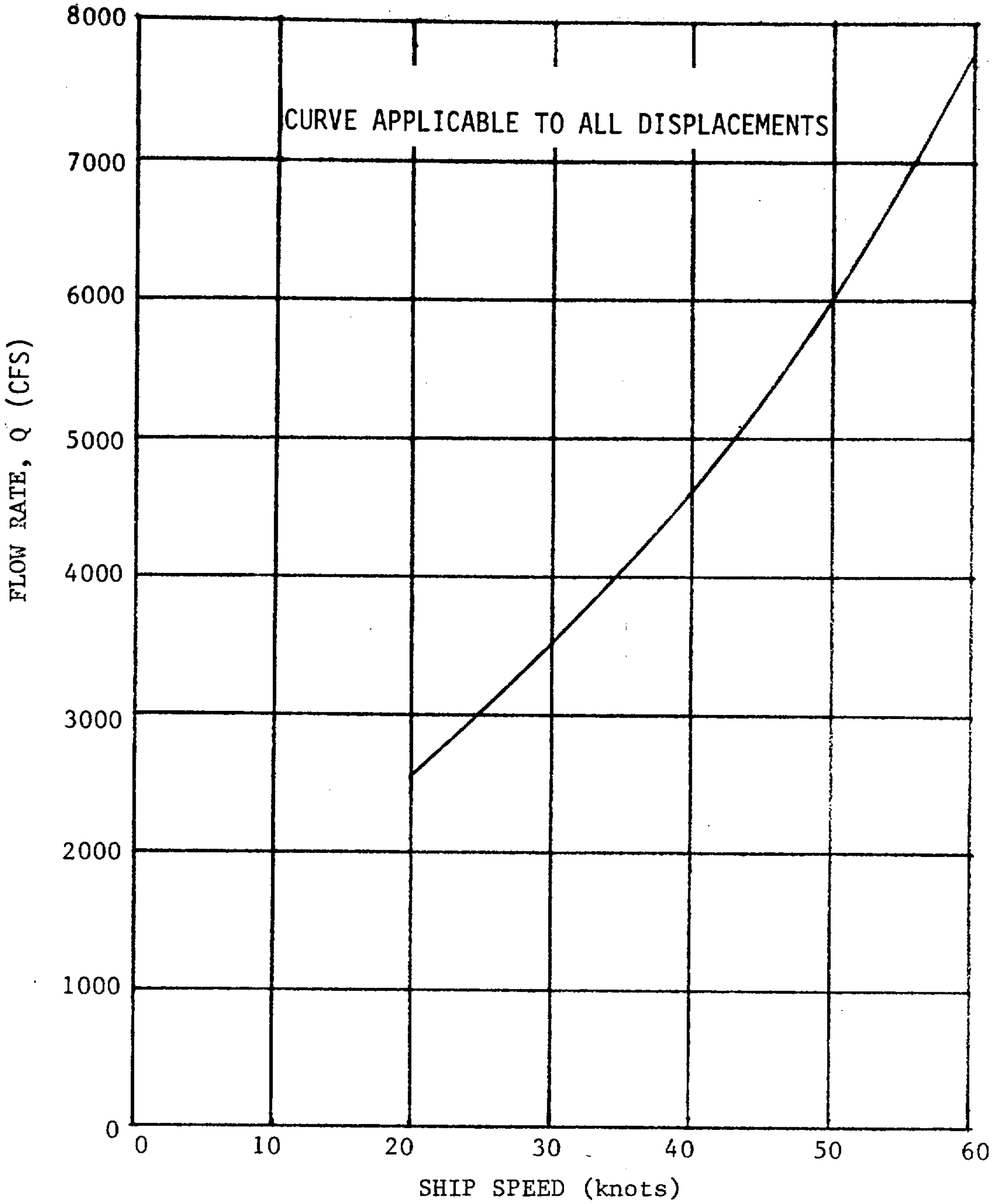
Range-speed relations for cushionborne operations in Sea State 0 and Sea State 3 are shown in the lower half of Figures 4.3-1 and 4.3-2. The curves shown are for constant speed, that is, as fuel is burned off, power is reduced so as to maintain the required speed. Operation at constant power would give increasing speed over the distance travelled as fuel burns off. Calculations for this case show that range as a function of average speed differs only slightly from the constant speed curves. The curves shown are plotted up to a maximum speed given by 90 percent MP,



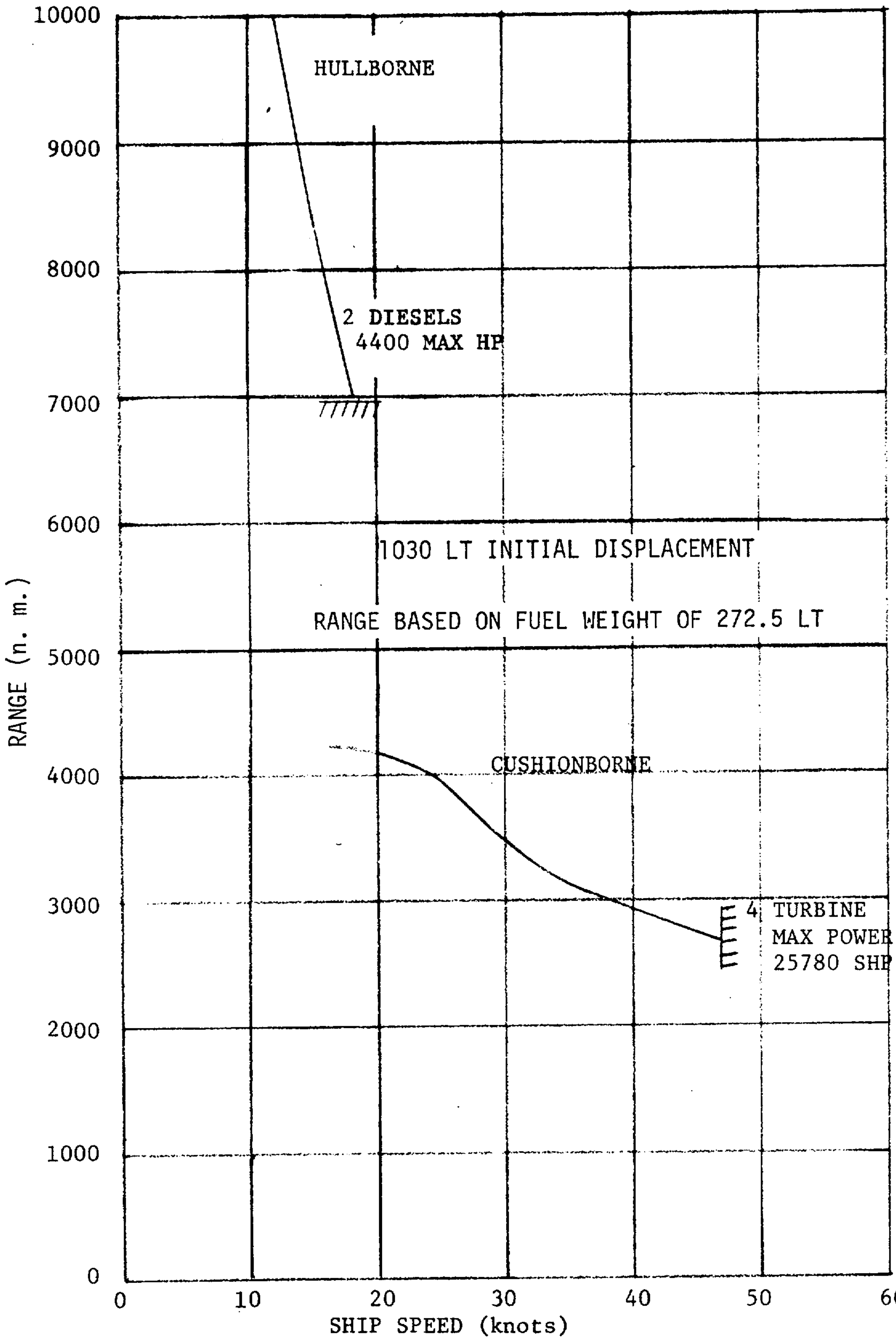
MDC
FIGURE 4.1-6
OPTIMAL LIFT HORSE POWER VERSUS SPEED



MDC
FIGURE 4.1-5
MACHINERY SYSTEM EFFICIENCY VERSUS SPEED

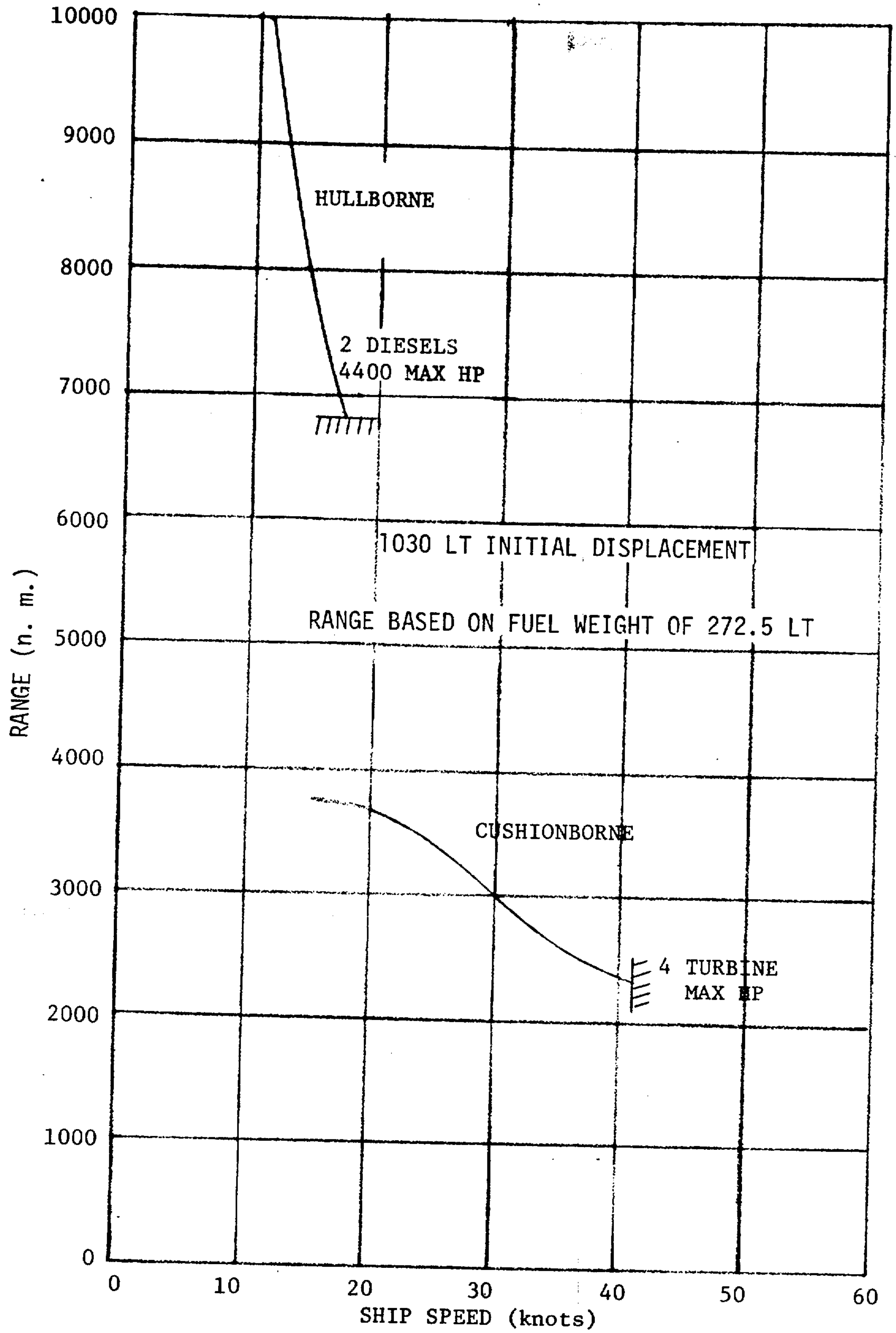


MDC
FIGURE 4.1-7
FAN FLOW RATE VERSUS SPEED



MDC
FIGURE 4.3-1

RANGE VERSUS SPEED SEA STATE 0



MDC
FIGURE 4.3-2
RANGE VERSUS SPEED SEA STATE 3

i.e., 2700 nm at 47 knots for SS-0 and 2310 nm at 41 knots for SS-3. The range at maximum average speed using maximum power is 2456 nm at 53 knots in SS-0 and 2156 nm at 46 knots for SS-3.

Figures 4.3-3 and 4.3-4 show curves of fuel remaining as a function of distance travelled for two representative speeds in SS-0 and SS-3. The higher speed was selected as being achievable using only 90 percent MP and optimal lift power. The lower speeds represent those close to maximum range for cushionborne operation.

Figure 4.3-5 shows the cushionborne endurance for 272.5 LT fuel in SS-0 and SS-3 and correspond to the range-speed curves of the previous figures.

When the ship is operating helicopters 22.5 tons of fuel is allocated for that purpose so that 250 tons only is available for the ship. The appropriate ranges for this amount of fuel are indicated in the figures. This applies also to the hullborne condition in paragraph 4.3.2.

4.3.2 Hullborne

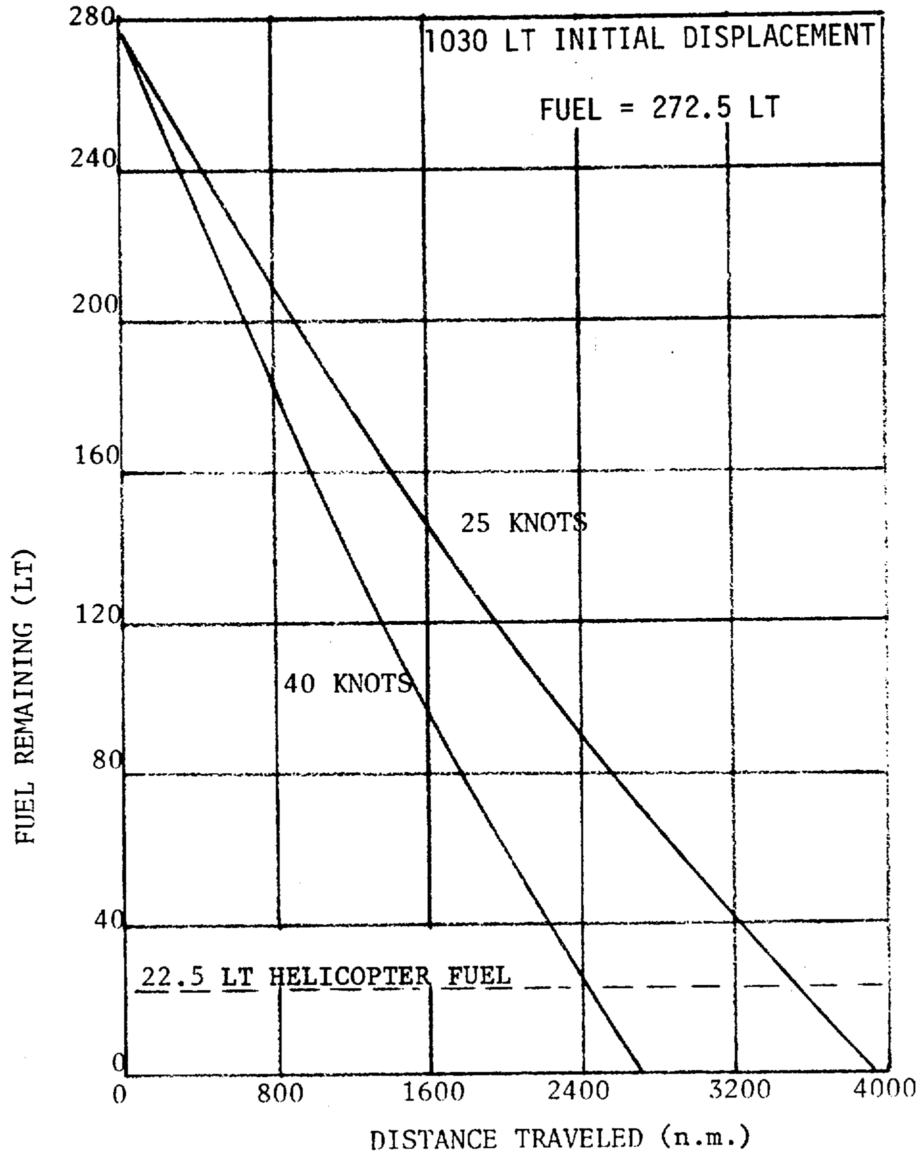
Range-speed relations for hullborne operations are shown in the upper half of Figures 4.3-1 and 4.3-2. These curves are similar to those of conventional or catamaran hulls. As with such hulls, the variation of speed with fuel burn off is small, unlike the variation in speed when operating cushionborne. The hullborne range using 272.5 LT fuel is 7000 nm at 18 knots in SS-0 and 6900 nm at 17-1/2 knots in SS-3 using two diesels at a total continuous horsepower of 4400. At lower powers the ranges are correspondingly larger. Figures 4.3-6 and 4.3-7 show curves of fuel remaining as a function of distance travelled for SS-0 and SS-3. The maximum fuel (initial starting conditions) shown is 272.5 LT. Figure 4.3-8 shows the endurance for hullborne operations in SS-0 and SS-3 with a maximum fuel weight of 272.5 LT.

4.4 MANEUVERABILITY

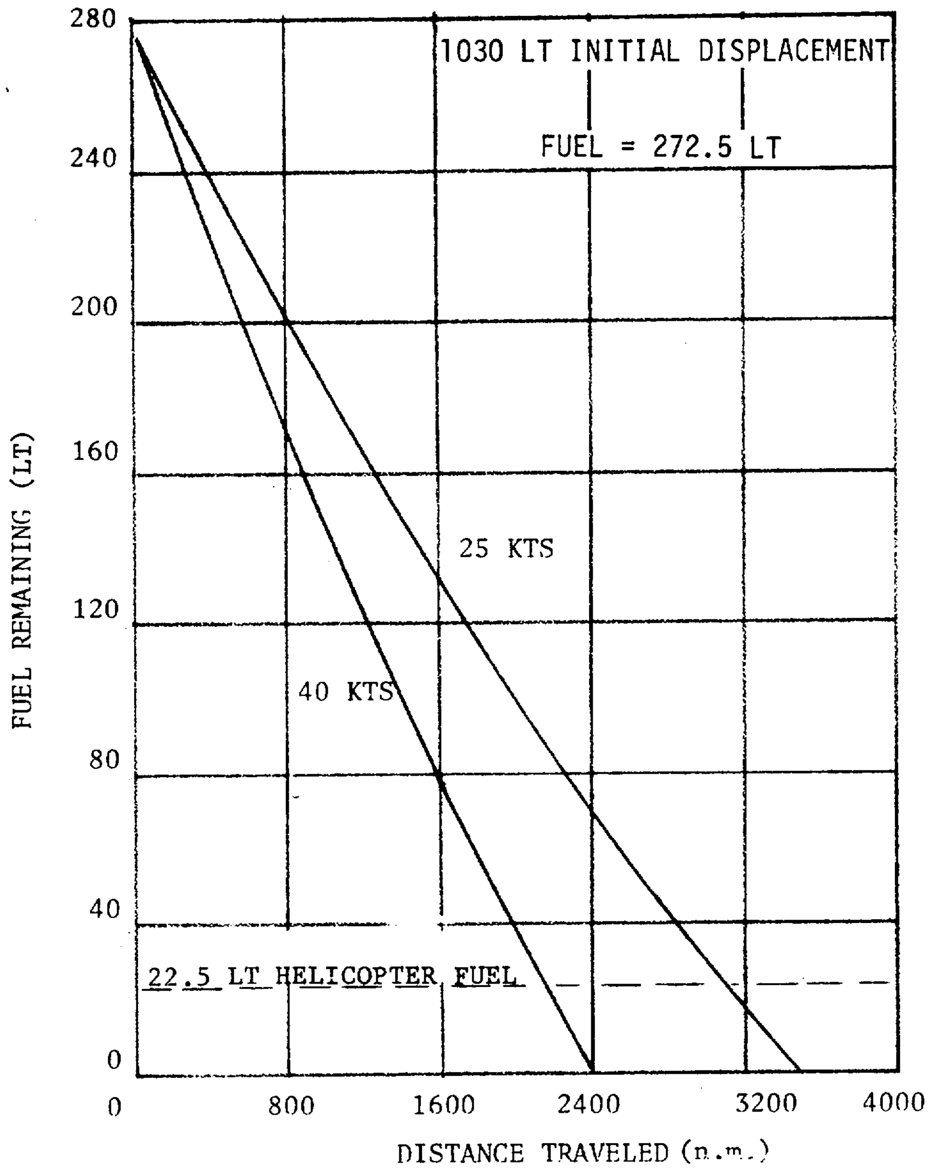
Preliminary calculations show that the MDC will have turning characteristics better than those of conventional ships of similar length. The controllable pitch propellers located in the two sidewalls are very widely spaced compared with those in a conventional hull of similar size and a significant amount of turning moment can be provided by their differential thrust in addition to that given by the rudders. Calculations using rudders only show that at 30 knots with a rudder area of 25 square feet the approximate turning diameter will be 6000 feet. More precise steering calculations will be performed at the next stage of design.

4.5 STABILITY

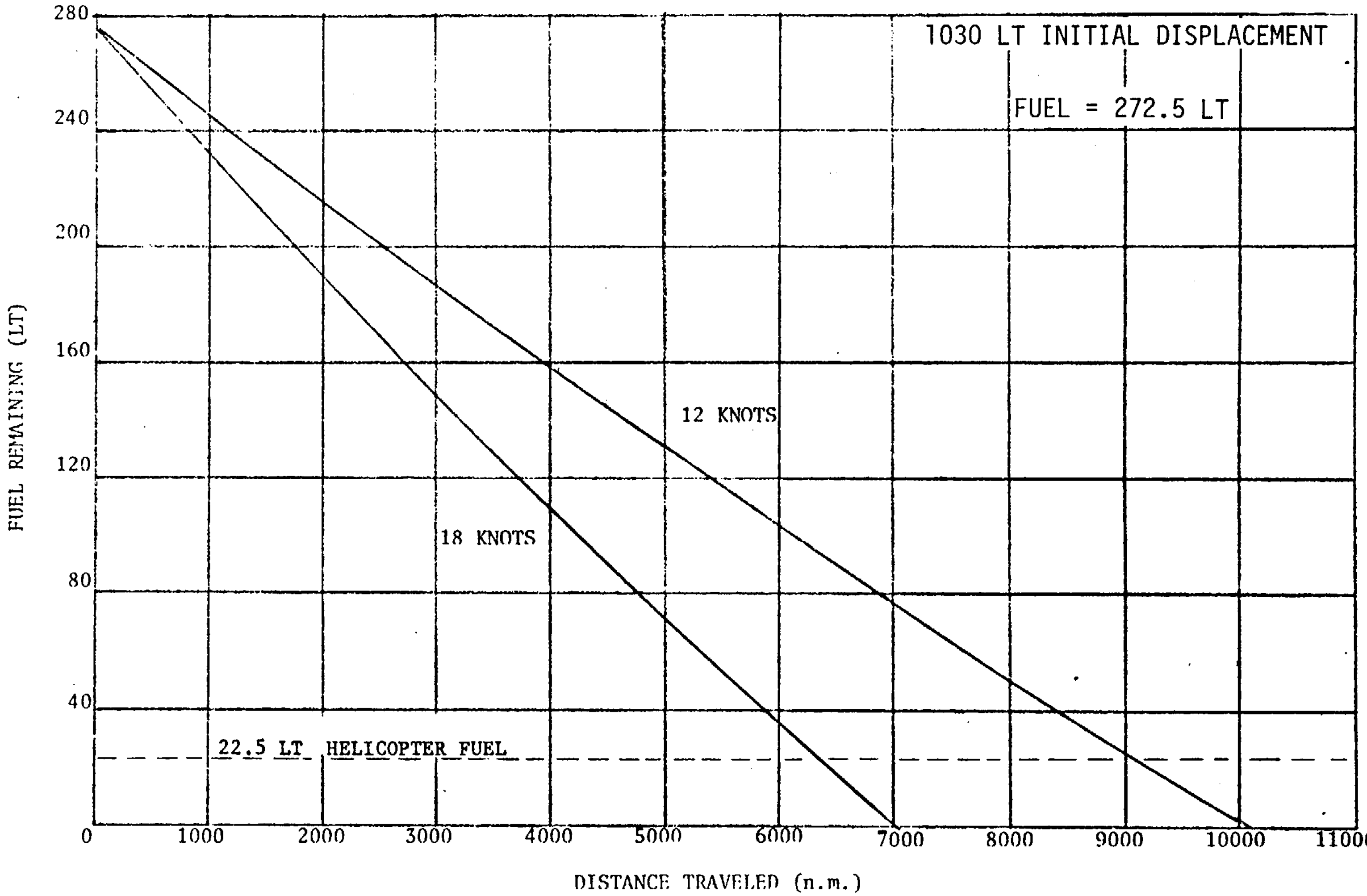
The intact and damage stability investigation has been based on the requirements of NAVSEA DDS 079-1. Computations were performed using a computer program known as ARC C4. Figure 4.5-1 illustrates the body plan used by the computer program. The program solves for values of roll angle, trim angle and draft so that the center of gravity is on the same vertical line as the center of buoyancy when the weight equals the buoyancy.



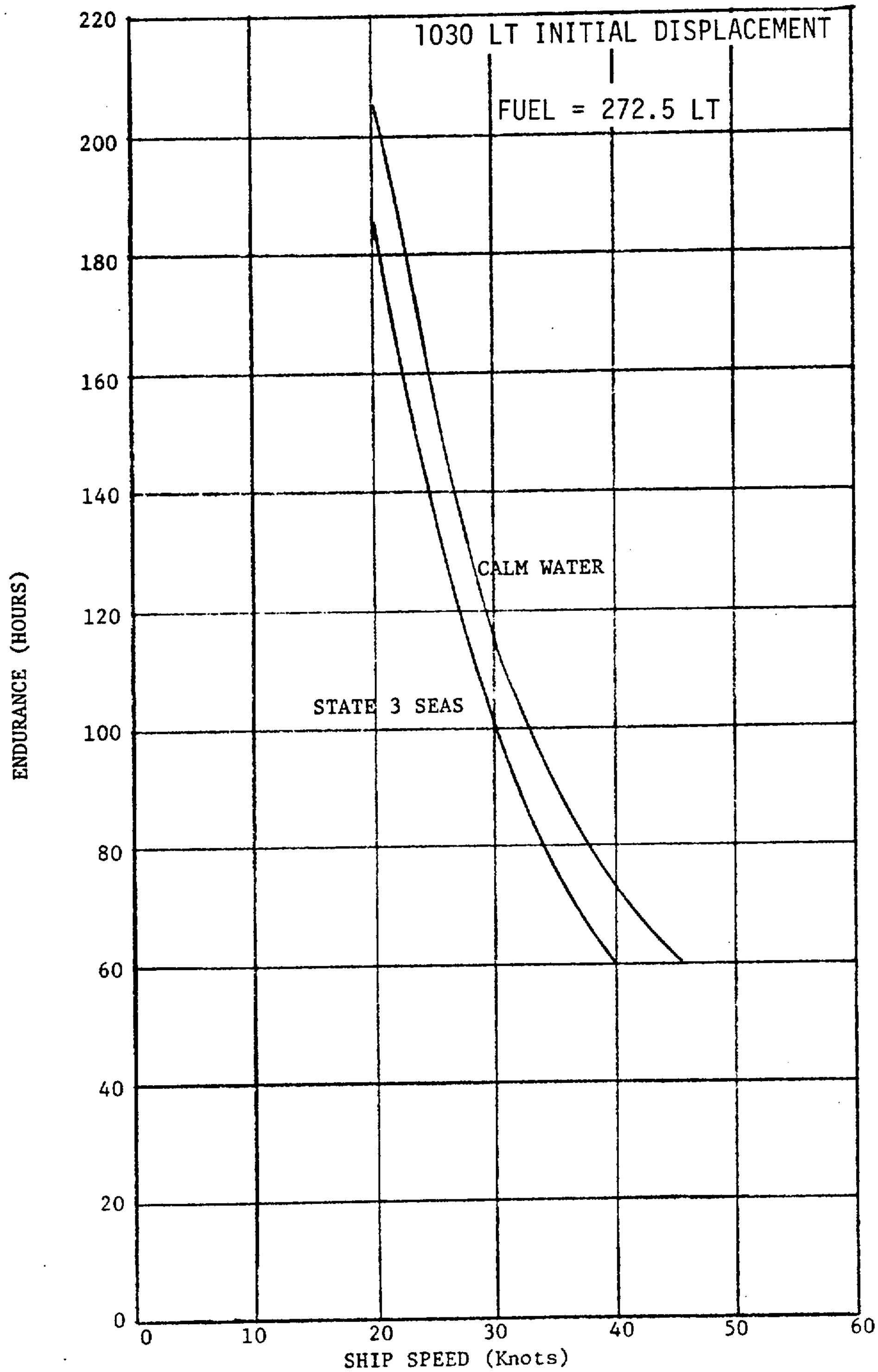
MDC
FIGURE 4.3-3
FUEL REMAINING VERSUS DISTANCE TRAVELED SEA STATE 0 CUSHIONBORNE



MDC
FIGURE 4.3-4
FUEL REMAINING VERSUS DISTANCE TRAVELED SEA STATE 3 CUSHIONBORNE



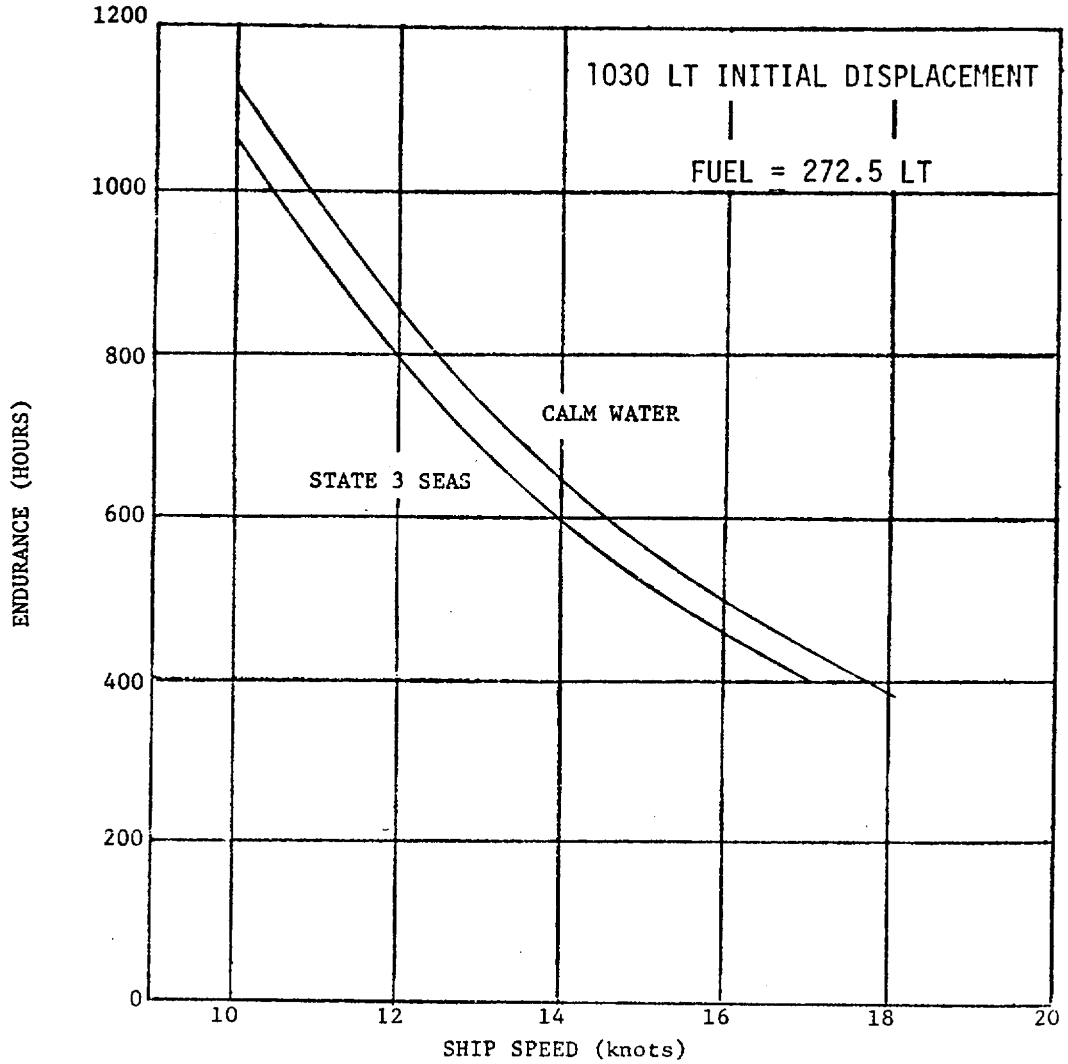
MDC
FIGURE 4.3-6
FUEL REMAINING VERSUS DISTANCE TRAVELED SEA STATE 0 HULLBORNE (DIESEL OPERATION)



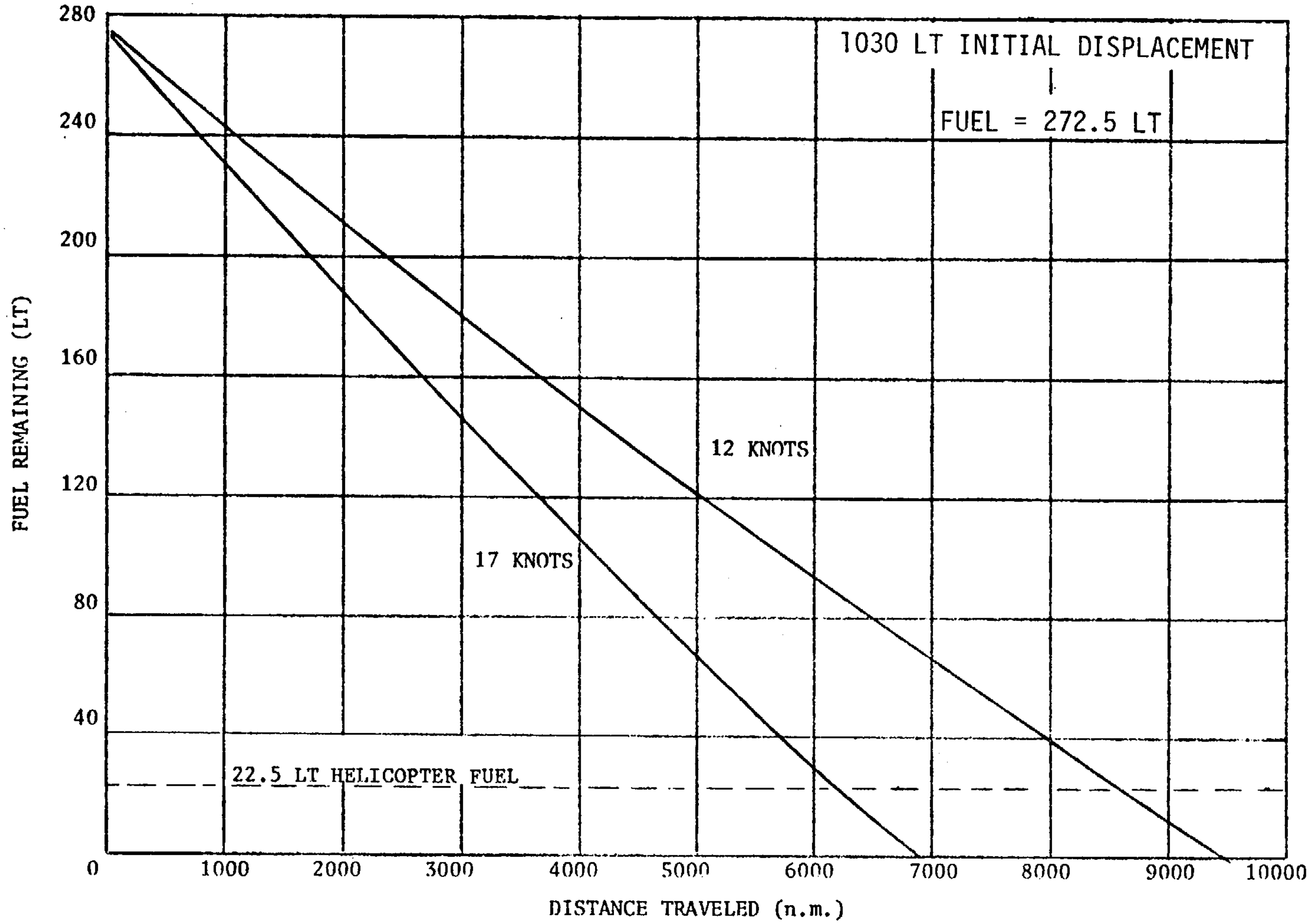
MDC

FIGURE 4.3-5

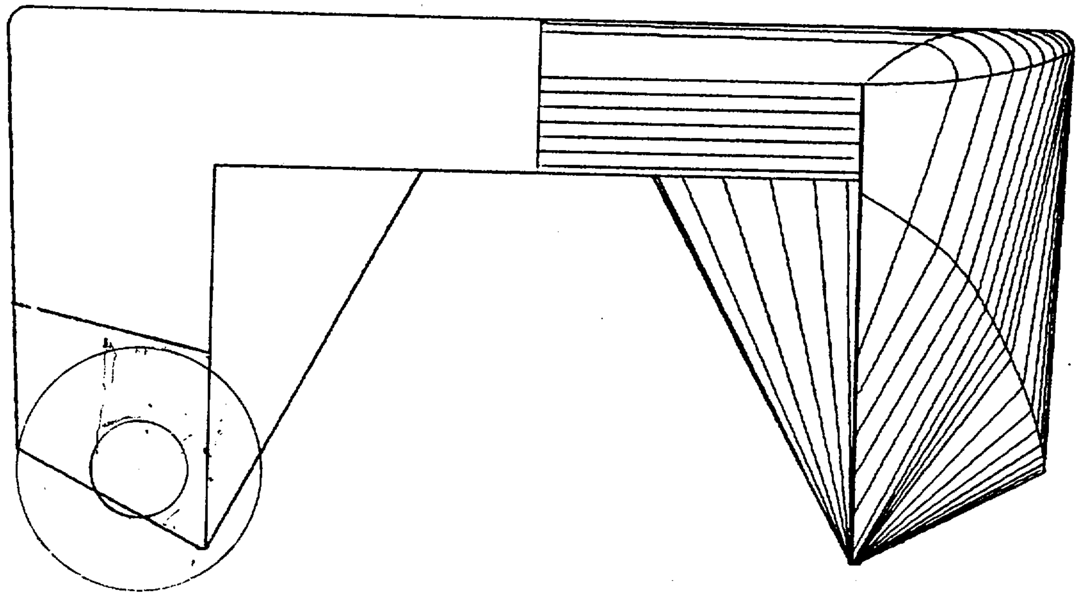
ENDURANCE VERSUS SPEED CUSHIONBORNE



MDC
FIGURE 4.3-8
SPEED VERSUS ENDURANCE HULLBORNE DIESEL



MDC
FIGURE 4.3-7
FUEL REMAINING VERSUS DISTANCE TRAVELED SEA STATE 3 HULLBORNE (DIESEL OPERATION)



MDC
FIGURE 4.5-1
BODY PLAN

4.5.1 Intact Stability

Calculations show that the intact stability for the MDC exceeds Navy requirements. The physical explanation for this is that the twin hull arrangement of the MDC produces considerable roll stiffness. Thus for a 100 knot beam wind, roll angle is of the order of 1 degree. For the worst loading case considered, the range of positive stability exceeds 60 degrees. This range of stability combined with the high roll stiffness is sufficient to ensure a safe ship in all sea states.

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 waterline 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. The two worst cases were found to be:

a. A shell opening extending from 35 feet forward of the stern to 235 feet, port side. This produced a roll to port of 18 degrees, 0.3 degrees trim up and 11.5 feet draft at the bow.

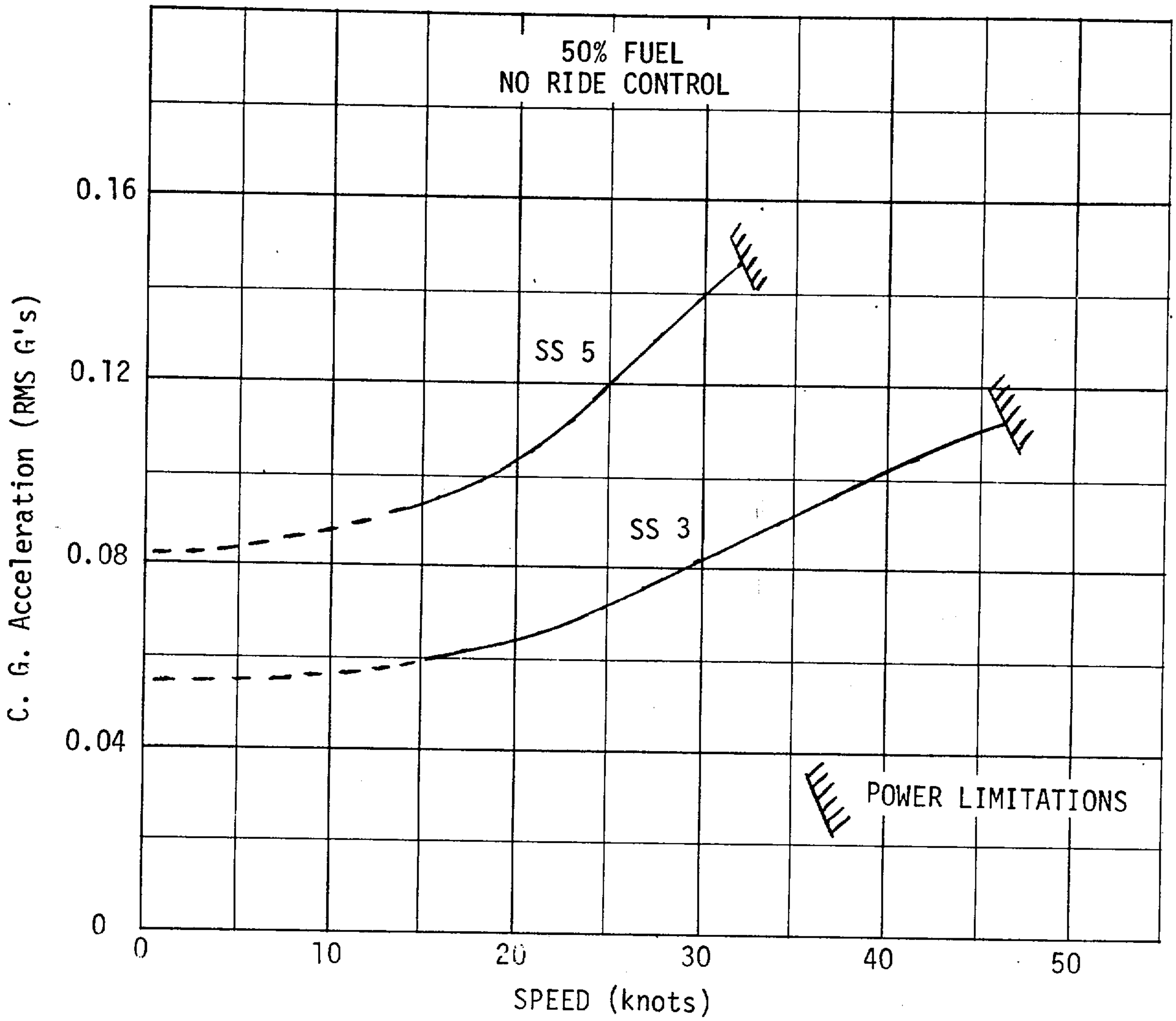
b. A shell opening extending from 85 feet to 280 feet port side giving a roll to port of 15.5 degrees, 2.5 degrees trim down and 17.5 feet draft at the bow. All other cases were less severe so that the damage stability for the MDC can be regarded as satisfactory.

4.6 MOTIONS

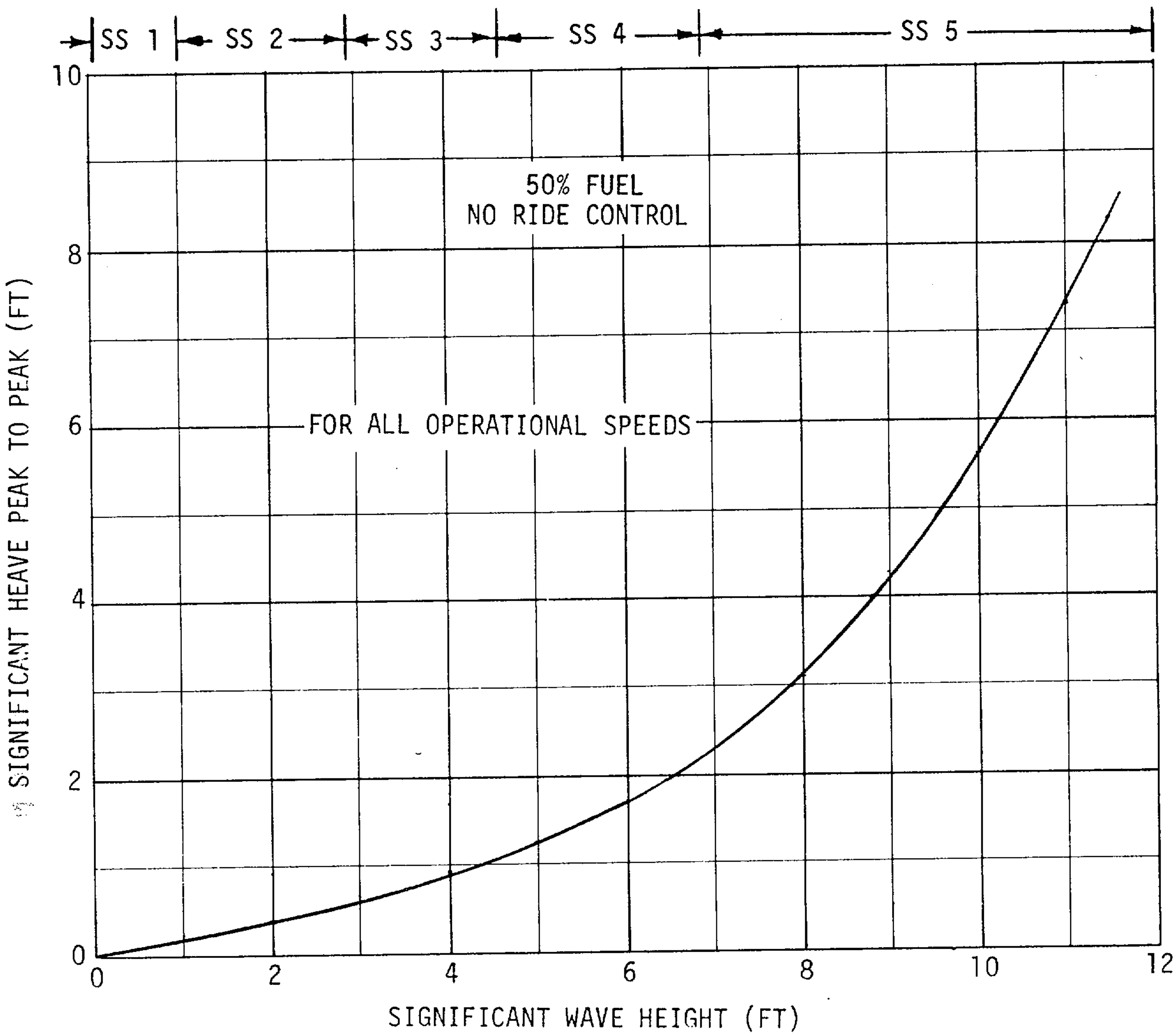
4.6.1 Cushionborne

Motions of the ship are presented in Figures 4.6-1 and 4.6-2. The curves presented have been extrapolated from a 1/15 scaled model that was tested in two scaled sea states SS-3 and SS-5 (head seas) at various speeds. Figure 4.6-1 shows the rms accelerations at the center of gravity of the ship (g's) as a function of speed. The limiting maximum speeds shown for each sea state were determined from the maximum thrust available. Figure 4.6-2 shows the significant heave (peak to peak) as a function of wave height. The relationship does not change significantly with speed; speed however does change the heave frequency. The results shown do not include the effect of ride control. Use of a ride control system would significantly reduce the accelerations shown by more than half in SS-3 and by a third in SS-5 and correspondingly change heave magnitude. Pitch data obtained from the moded tests showed that the significant pitch (peak to peak) in SS-3 was 1 degree and in SS-5 was 5 degrees with a standard deviation of 1 degree.

Based on the data given the ride in SS-3 is acceptable, even without ride control, over the full range of speed. The ride in SS-5 is more severe but is still regarded as acceptable up to 20 knots and moderately so up to the maximum speed shown. With ride control the ride in SS-5 would be acceptable at all speeds.



MDC
FIGURE 4.6-1
CENTER OF GRAVITY ACCELERATION VERSUS SPEED



MDC
FIGURE 4.6-2
SIGNIFICANT HEAVE VERSUS SIGNIFICANT WAVE HEIGHT

5 SUBSYSTEM DESCRIPTION

5.1 HULL STRUCTURE

5.1.1 Structural Arrangement

A typical MDC mid-ship section and bulkhead structural arrangements are shown in Figures 5.1-1 and 5.1-2.

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 seal arrangements. The sidehulls serve as end closures for the bow and stern seals and greatly reduce the critical seam stresses in the seal bags. The sidehulls are designed to provide sufficient buoyancy to elevate the wet deck approximately 11 feet above the mean water level when the ship is hullborne. This 11 foot clearance and the 30 degree bow ramp angle significantly reduce the intensity and frequency of hullborne slamming loads.

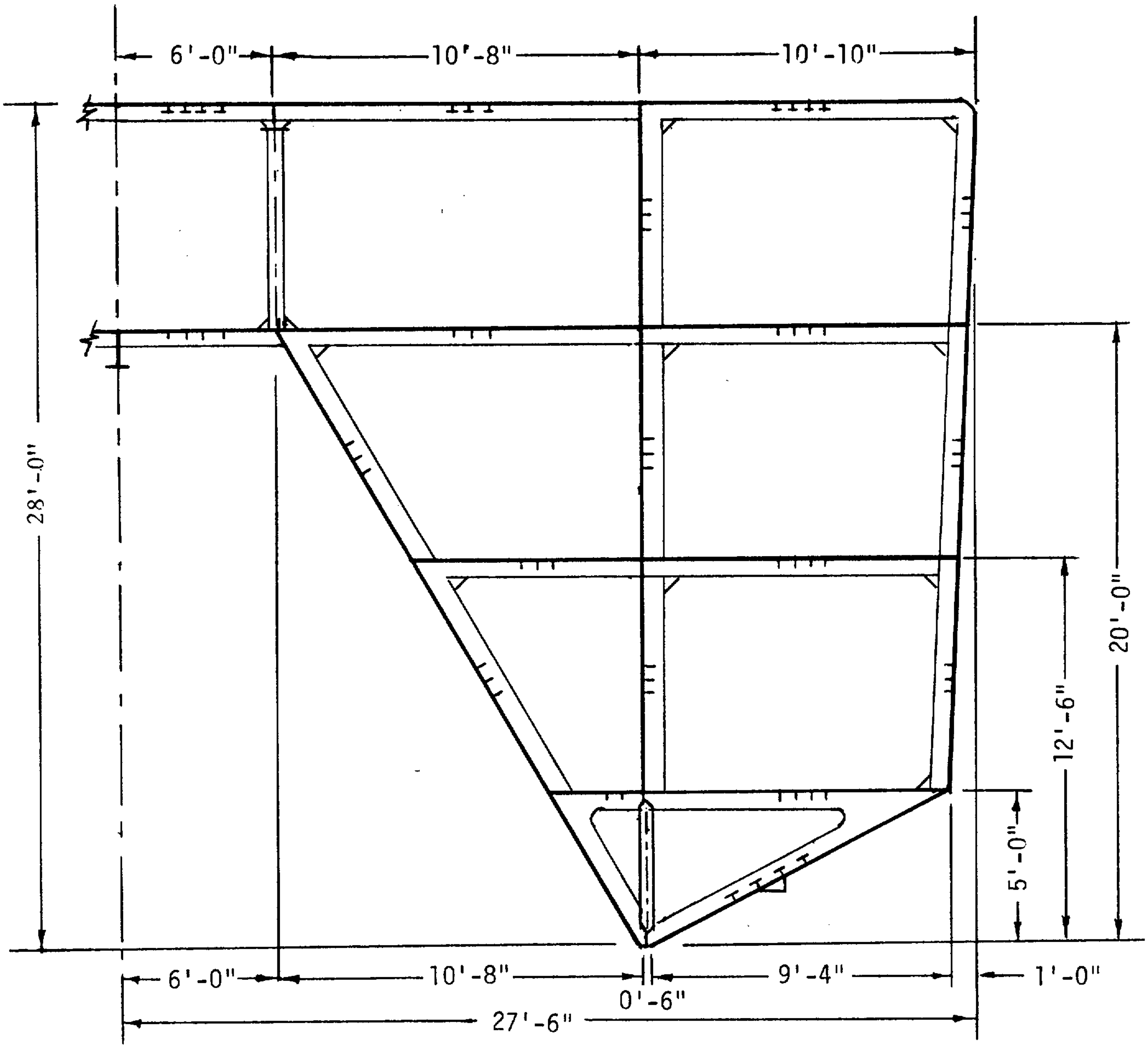
The basic element of the hull structure is a longitudinally stiffened panel supported by integral transverse frames, Figure 5.1-3. This arrangement is maintained throughout the majority of the MDC structure. Longitudinal stiffeners are either extruded or fabricated "T"s or flat bars cut from plating. Flatbars, as compared to "T" stiffners, offer advantages of a lower cost and greatly simplify joining longitudinal to transvers stiffners. However, flat bars are less efficient than "T" stiffners in resisting bending and buckling. Approximately 75 percent of all longitudinal stiffners in the MDC hull will be flat bars; the remainder will be "T" stiffners used in hull areas with high compressive and/or local bending loads. In the bow ramp area the transverse frame arrangement is changed to a longitudinal arrangement at 24 inch frame spacing. Although this results in approximately a 20 percent increase in the weight of the bow section, the accessibility and weldability of the bow structure considerably improves producibility.

A small increase in hullborne drag in high sea states due to the intermittent wetting of the external frames and stiffeners located on the flat portions of the wet deck is accepted. This arrangement eases the fabrication, inspection and repairs of the wet deck. The effect of this stiffening arrangement on cushionborne drag is negligible.

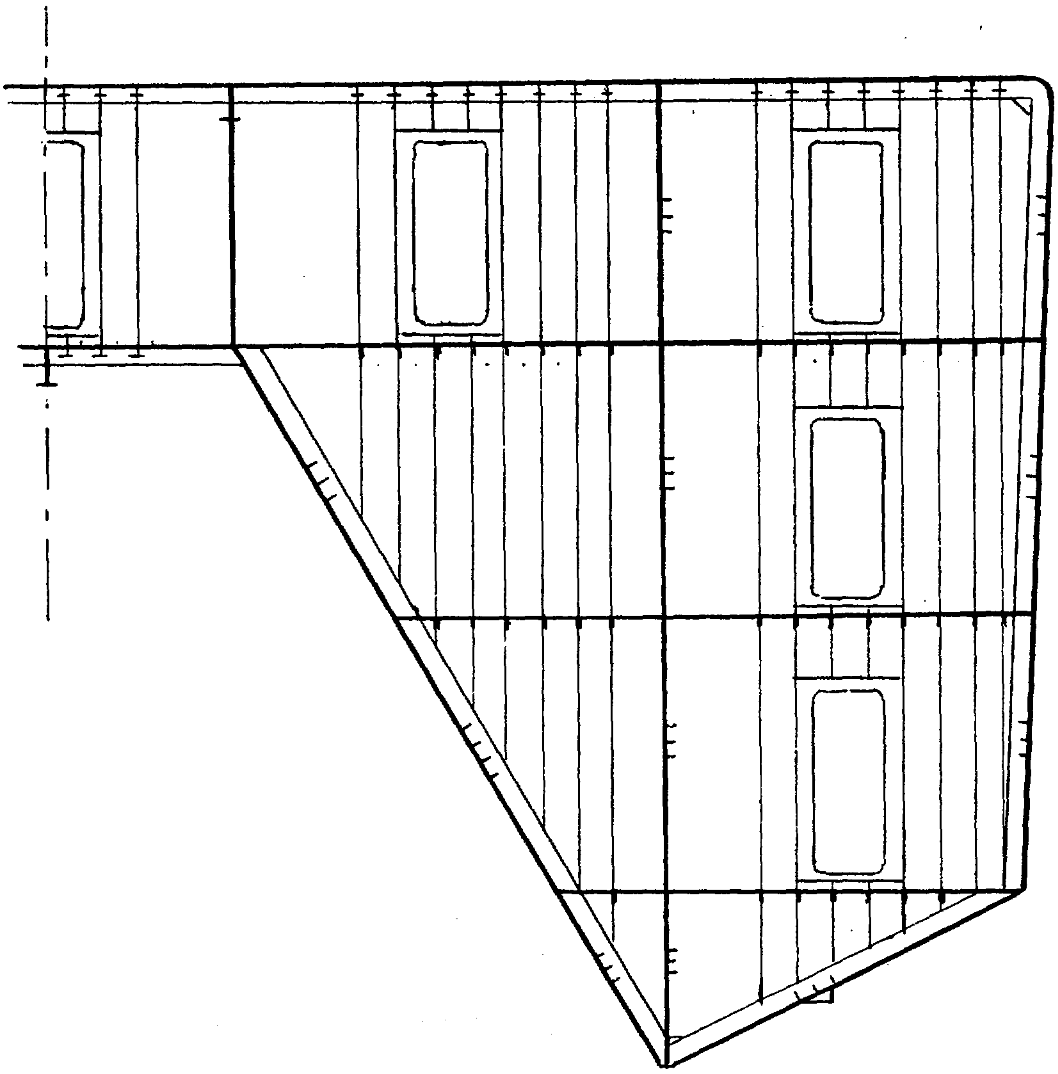
To prevent damage to the seal material by the edges of the stiffener flanges the space between stiffeners both forward and aft is filled with lightweight removable panels.

5.1.2 Operational Envelopes

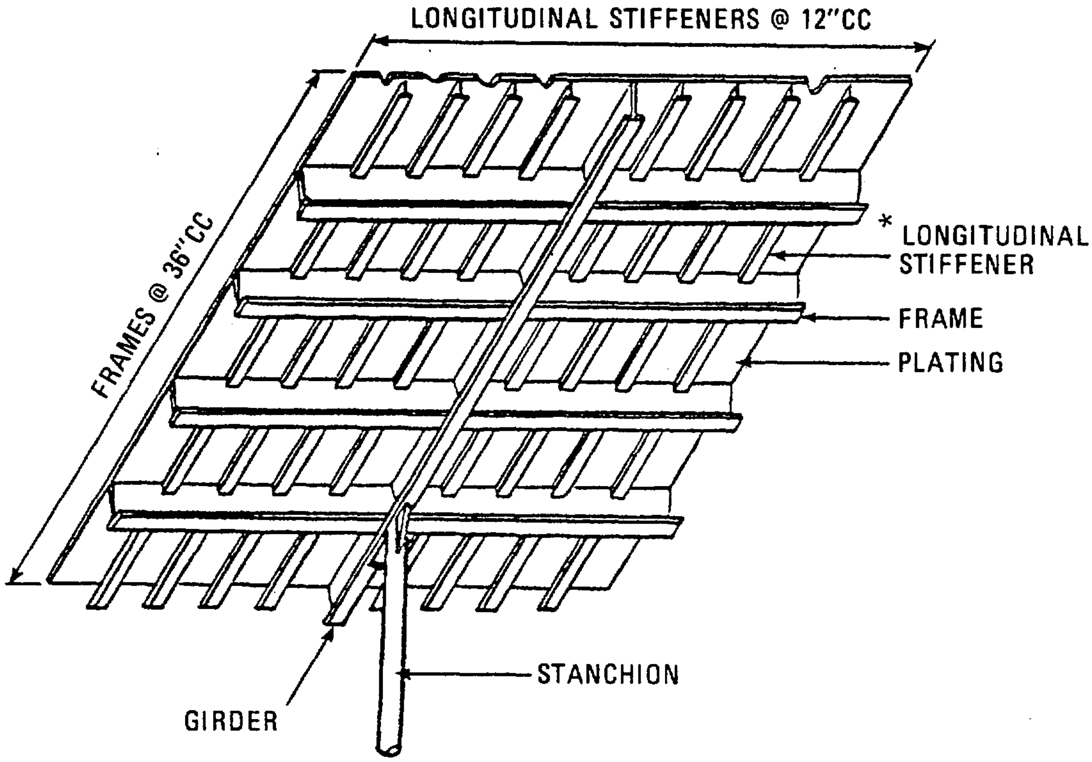
The MDC is designed to operate in the open ocean. The operational life of the craft is assumed to be twenty years, of which it is estimated that 35 percent will be spent at sea with approximately 2/3 of the operations cushionborne and 1/3 hullborne.



MDC
FIGURE 5.1-1
TYPICAL MIDSHIP FRAME SECTION



MDC
FIGURE 5.1-2
TYPICAL TRANSVERSE BULKHEAD



*"T" OR FLAT BARS WILL BE USED DEPENDING
ON LOCATION AND LOADS

MDC
FIGURE 5.1-3
TYPICAL STIFFENED PANEL STRUCTURAL ARRANGEMENT

5.1.3 Structural Design Criteria

The loads criteria for this craft are based on tests performed with a length-to-beam (L/B = 5) model performed in the David Taylor Naval Ship Research and Development Center (DTNSRDC) towing tank. All tests were with the hullborne model. 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 5.1-4a and 5.1-4b 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 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.

The extrapolated test data was scaled to MDC size using scale factors shown in Table 5.1-i.

SCALE FACTORS L/B 5 to 7.52 HULLBORNE

ITEM	SCALE FACTOR	VALUE
Length	λ_{HL}	26.4
Beam	λ_{HB}	15.5
Moment	$\lambda^3_{HL} \times \lambda_{HB}$	285000.0
Pressure	λ_{HL}	26.4
Shear	$\lambda^2_{HL} \times \lambda_{HB}$	10800.0

TABLE 5.1-i

The data shown in Figure 5.1-5 are based on the measurements taken at the forward quarter of the model. To obtain the maximum loads at the midship section these data were increased by 43 percent, and the aft quarter point were taken as 60 percent of the forward quarter point loads. The validity of these assumptions is supported by the 3KSES model test data and by more recent tests performed at Stevens Institute. The Stevens model measured loads at the forward and aft quarter points. The loads at the aft quarter point were lower than the forward quarter point suggesting that for L/B ratios higher than 5 the maximum bending moment envelope is skewed forward. This is reflected in the sagging moment envelope shown in Figure 5.1-5. This figure summarizes the hull design criteria used to estimate the MDC structural weight and strength. Not shown are the live loads which were taken from the Structural Design Manual for Naval Surface Ships (NAVSEA 0900-LP-097-4010, 15 December 1976).

The slamming pressure envelopes shown on Figure 5.1-5 are based on manned SES test data, specifically XR-1C hullborne tests. These pressures are generally in consonance with the design pressures used in the 100 Ton SES design and recently in

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

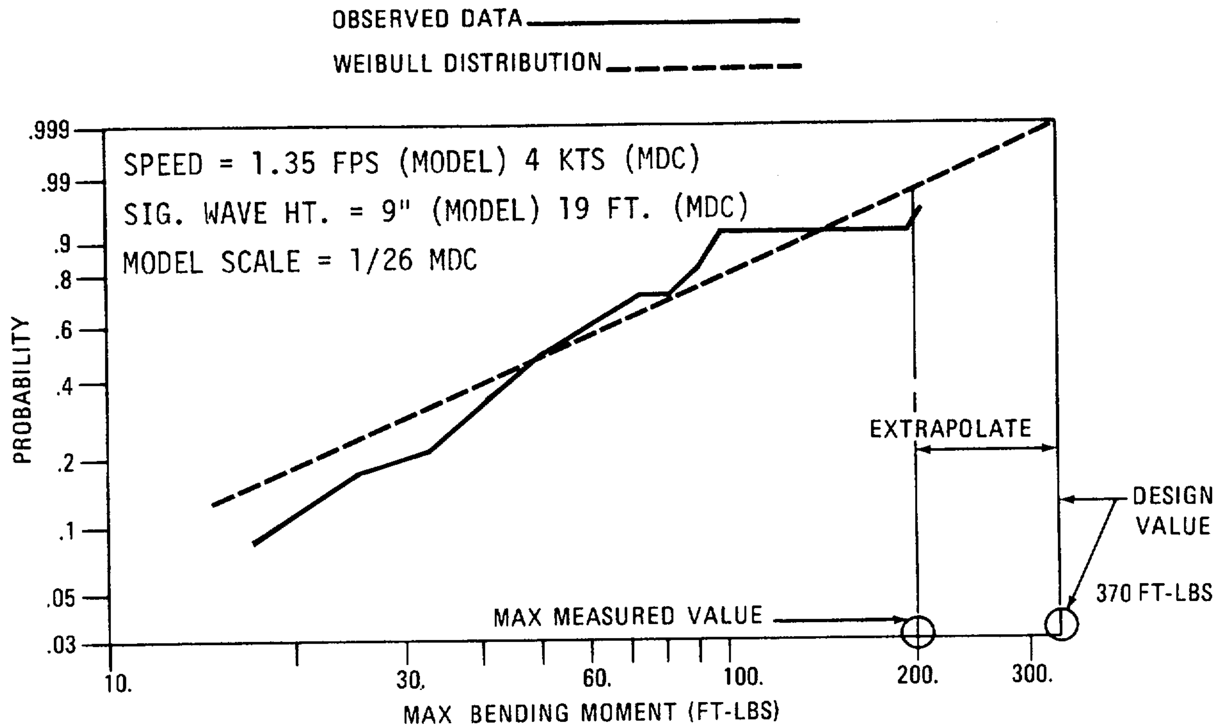


FIGURE 5.1-4a
PROBABILITY VERSUS MAXIMUM SHEAR

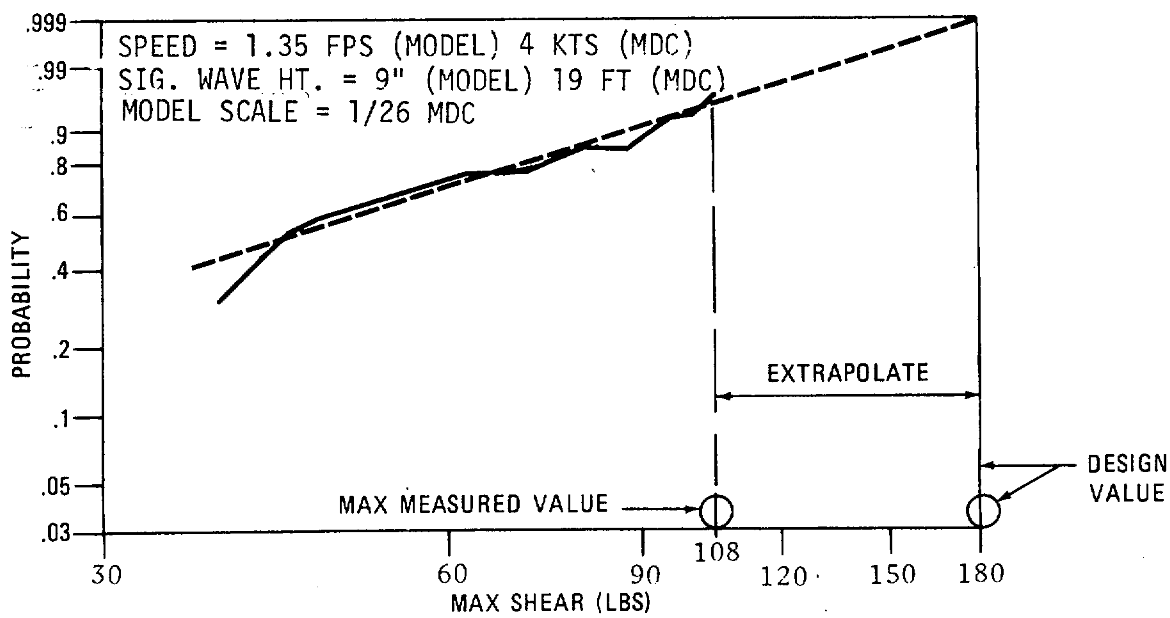


FIGURE 5.1-4b
PROBABILITY VERSUS MAXIMUM SHEAR

MDC
FIGURE 5.1-4

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

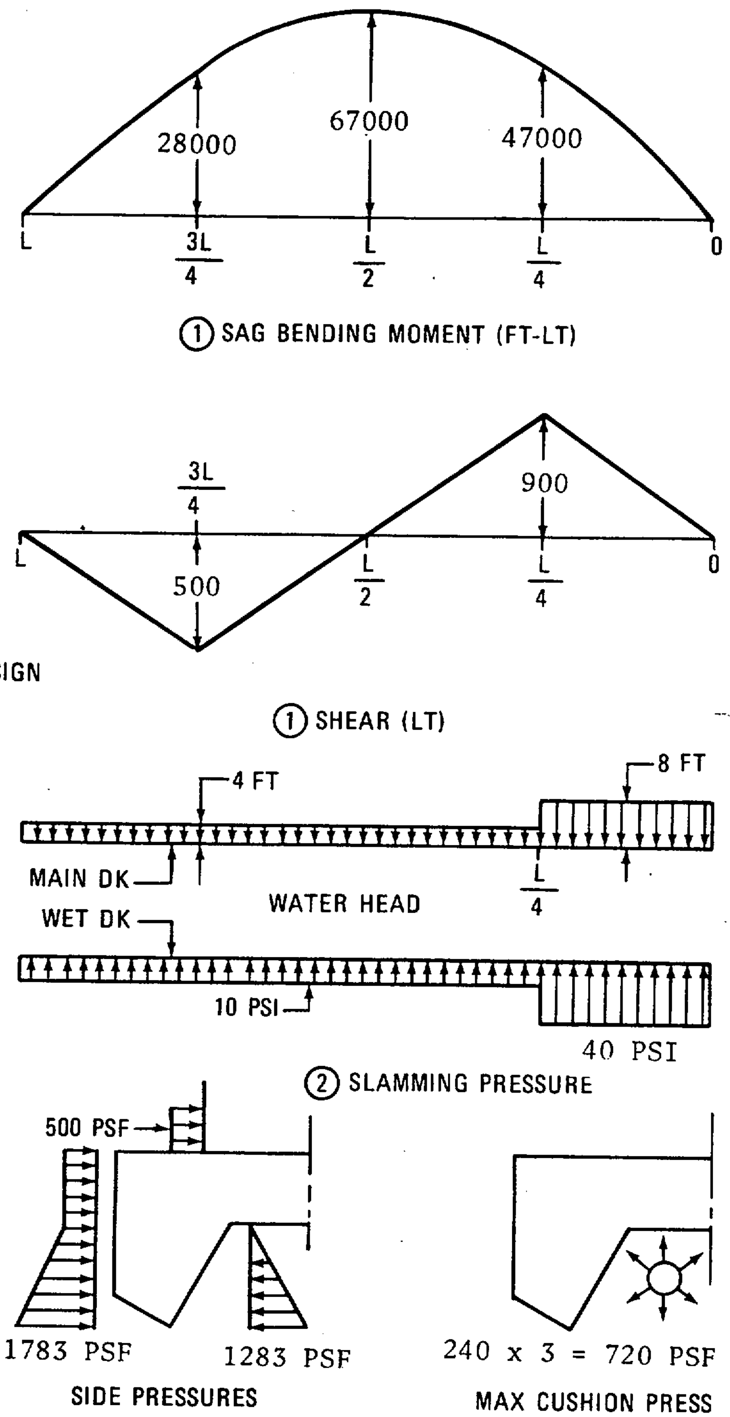
4 LOCAL LOADS INCLUDE DECK LIVE LOADS: 75 PSF (TOP OF DK HSE) 150 PSF (LIVING, OFFICE SPACES) 200 PSF (MACHINERY SPACES)

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



MDC
FIGURE 5.1-5
MDC HULL DESIGN CRITERIA

Bell-Halter craft structural modifications. Safety factors specified in Figure 5.1-5 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.

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

High Yield (HY) steel hulls are cheaper than aluminum and do not require fire protection. However, since for a ship of MDC size the majority of the hull plating is dictated by the minimum thickness requirement, which is the same for both aluminum and steel, i.e., 0.188 thickness; an MDC steel hull would be unacceptably heavy. For this reason high strength steels were eliminated as candidate materials.

Of the other candidate materials, 5083 and 5456 marine grade weldable alloys are rated best suited for MDC 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 5.1-6. This insulation technique will be used in selected areas of high potential fire loading e.g., machinery spaces.

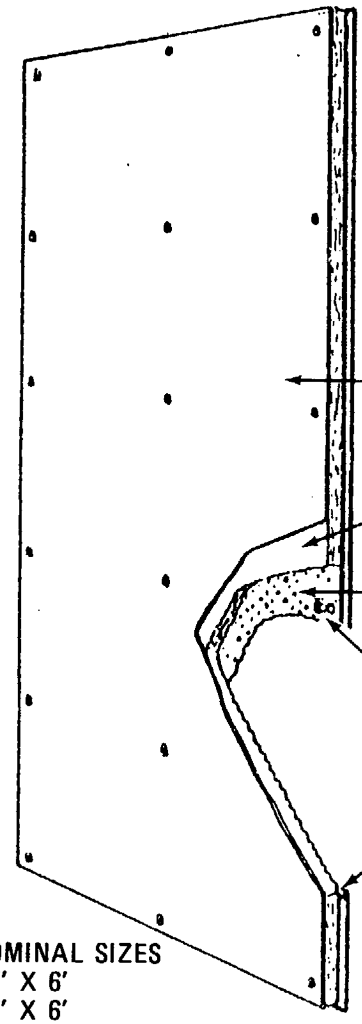
The deckhouse structure will be constructed from glass reinforced plastic (GRP) sandwich panels bolted to either aluminum or GRP frames as shown in Figure 5.1-7. GRP panels were successfully utilized in the construction of the deckhouses of the USS Southland (DD-743), USS Fletcher (DDR-870) and SES 100A. Although GRP panels are more expensive than aluminum panels, the overall installation and life cycle costs of the GRP paneled deckhouse will 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 MDC deckhouse structure.

CANDIDATE MATERIALS - WELDED MECHANICAL PROPERTIES

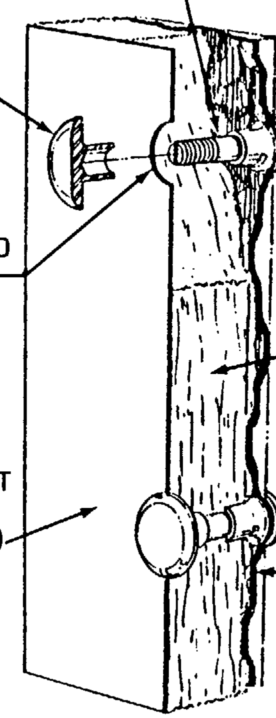
MATERIAL	TENSION		COMPRESSION	SHEAR	
HIGH YIELD STEELS:	ULTIMATE (ksi)	YIELD (ksi)	YIELD (ksi)	ULTIMATE (ksi)	YIELD (ksi)
Plate HY 100	120	100	100	72.0	60.0
Plate HY 130	150	130	130	90.0	78.0
ALUMINUM ALLOYS:					
Plate 5086-H116	35	19	18	21	11
Extrusion 5086-H111	35	18	17	21	10
Plate 5083-H116	40	24	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
Plate 5454-H32*	31	16	16	19	10
Extrusion 5454-H111	31	16	16	19	10

*Application of -H32 aluminum is restricted to the hull areas which are exposed to elevated temperatures

TABLE 5.1-iii



A) STANDARD PANEL(S)



B) DETAIL - QUILTING PIN INSTALLATION

MDC
FIGURE 5.1-6
TYPICAL FIRE INSULATION BLANKET

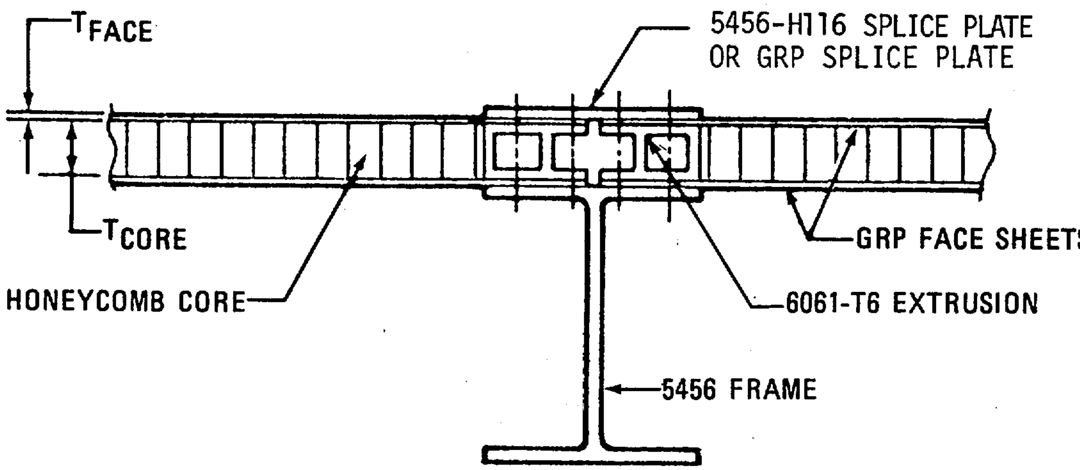


FIGURE 5.1-7a
GRP SANDWICH PANEL SUPPORTED BY ALUMINUM FRAME

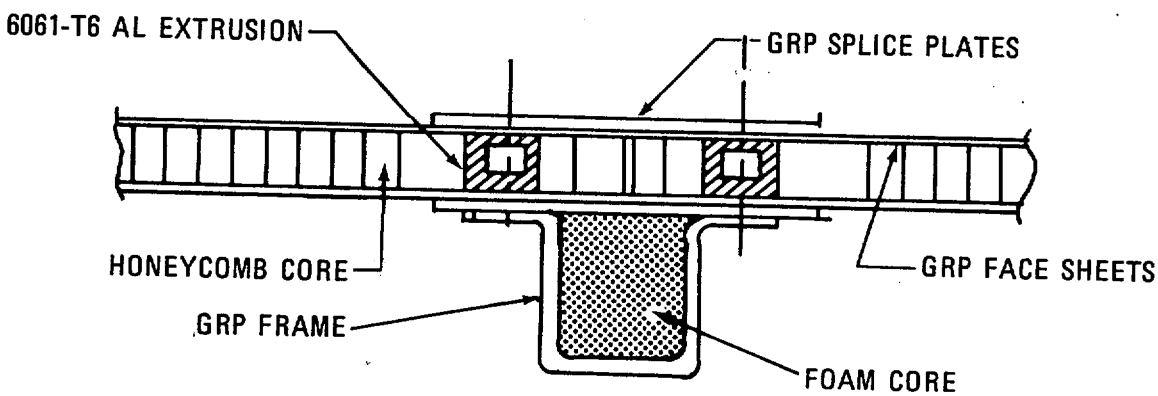


FIGURE 5.1-7b
GRP SANDWICH PANEL SUPPORTED BY GRP FRAME

MDC
FIGURE 5.1-7

DECKHOUSE GRP STRUCTURAL DETAILS

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 MDC 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 5.1-8 represent the thinnest or smallest sizes used in the MDC structure. Selection of these gages is based on trade-off studies and tests 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 MDC hull utilizes both "T" and flat bars which provides the best arrangement from the standpoint of weight, ease of fabrication and structural strength.

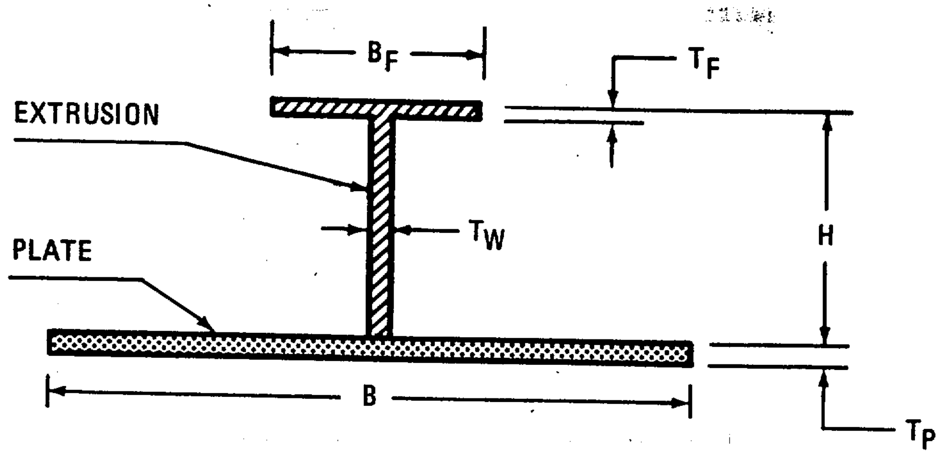
The primary fabrication method for aluminum hull construction is gas-metal-arc (GMA) welding, which is relatively fast and requires low capital cost of equipment and reasonable welder skill.

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.

In the USA 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 the Patrol Hydrofoil Missileship (PHM). This machine could be readily adapted for MDC stiffened panel construction. 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. Two types of mechanised hand-held weld guns are presently



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.

NOTE: WHEN FLAT BARS ARE USED IN LIEU OF THE DEPICTED "T" CONFIGURATION, THE MINIMUM BAR THICKNESS IS THE SAME AS THE PLATE T_P

MDC
FIGURE 5.1-8
MINIMUM GAGE AND EXTRUSTION DIMENSIONS

available: Pacer for butt welds and Wiggler for fillet welds. These equipments were successfully used during the SES-100A hull modifications and during construction of the fabrication module and panels for the 3KSES program.

Other techniques suitable for aluminum welding include: gas tungsten arc (GTA), plasma arc (PA) and electron beam (EB) welding. GTA welding is slow but well suited 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 the uncertain availability of the 5000 series aluminum extrusions. The panels welded by the existing Alforge equipment cannot exceed the maximum 8 foot width.

5.1.5.3 MDC Hull Construction

The MDC hull design is inherently suitable for automated welding because 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 the MDC 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 the MDC hull welds may be deposited by fully automatic or semi-automatic equipment.

Manual welding is 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 reduced the extent of manual welding and simplified welding operations. Also, the majority of MDC 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 MDC 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 the SES 100A where old waterjet foundation welds were successfully repaired and brush peened.

5.1.6 Structural Weight Breakdown

The MDC structure was divided into three sections representing the bow, middle and stern areas of the ship. Structure in each section was designed in accordance with the NAVSEA Design Data Sheet DDS 100-4 and NAVSEA Structural Manual 0900-LP-097-4010. The design loads and safety factors were as shown in Figure 5.1-5. Based on the designed scantlings, weight of each section including the transverse frames and bulkheads was determined and summed to provide the weight of the hull structure for SWBS Groups 110, 120, 130 and 140. The deckhouse structure, Group 150, was designed separately using DDS 100-4 design equations. Weight Groups 160, 170 and 180 were estimates from the 3KSES structural design. 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	118.2	42.7
120	Hull Structure Transverse Bulkheads	23.0	8.3
130	Hull Decks	64.2	23.2
140	Hull Machinery Flats & Platform	31.3	11.3
150	Deck House Structure	20.7	7.5
160	Special Structures	6.6	2.4
170	Masts, King Post & Service Platform	5.2	1.9
180	Foundations	7.5	2.7
100	TOTAL HULL STRUCTURE,	276.7	100%

TABLE 5.1-iv

5.1.7 Structural Risk Assessment

Structural risks associated with the MDC as with any ship structure 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 100 ton and 3KSES program. There are now sufficient data to adequately account for material variables so that the risk associated with this area is negligible.

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 under-estimating 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 categorical 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 MDC 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 MDC structures may encounter the loads which would exceed the design loads. This 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 jeopardize the overall integrity of the ship.

5.2 SEAL STRUCTURE

5.2.1 Seal Description

The MDC seals and some of the structural details are shown on Figures 5.2-1a and 5.2-1b. 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 MDC seals are described as follows:

a. Bow Seal. This seal Figure 5.2-1a and 5.2-1b 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 a simple design, low seam stresses and standardization of finger sizes and 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 detachable mechanical connectors for 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.

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

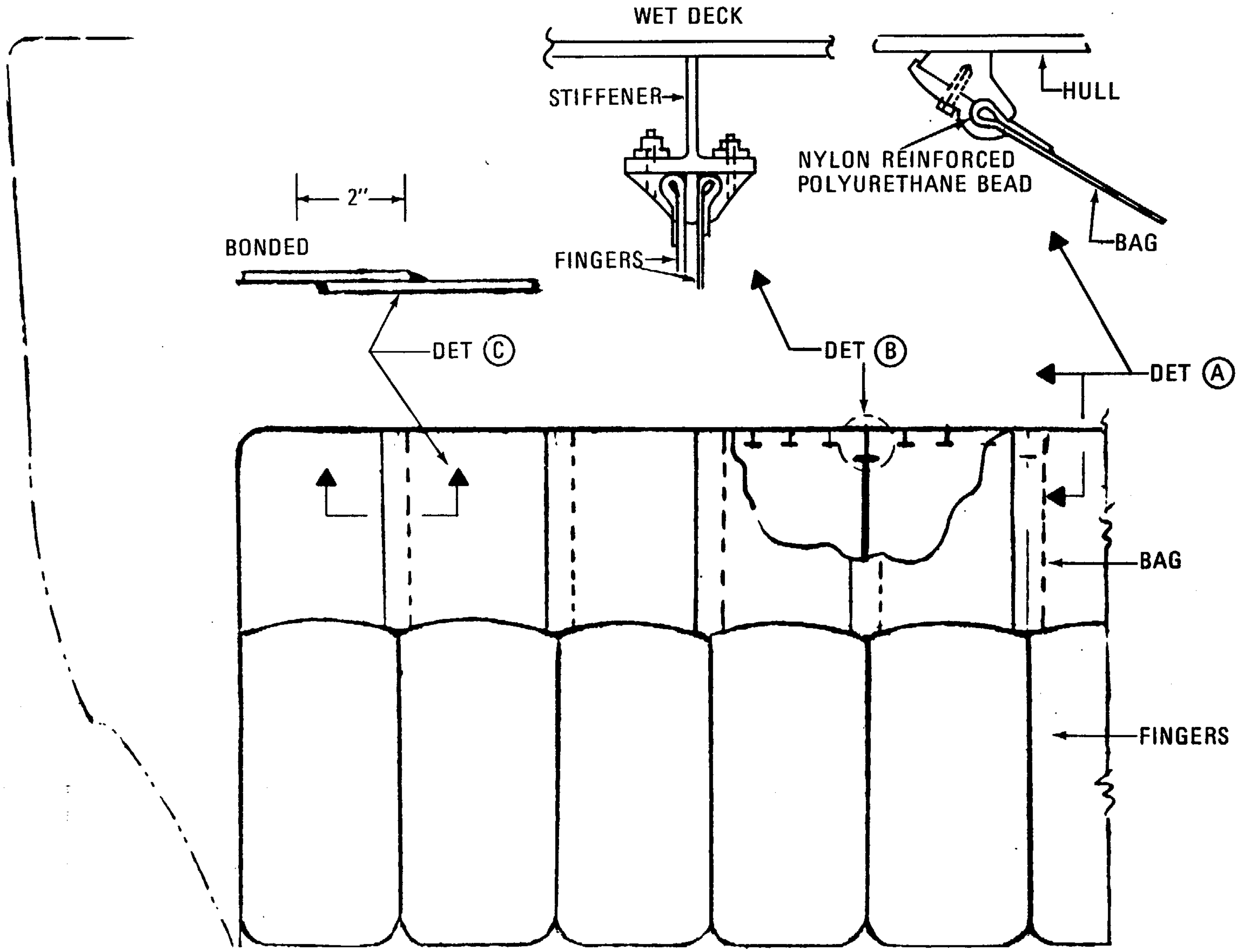


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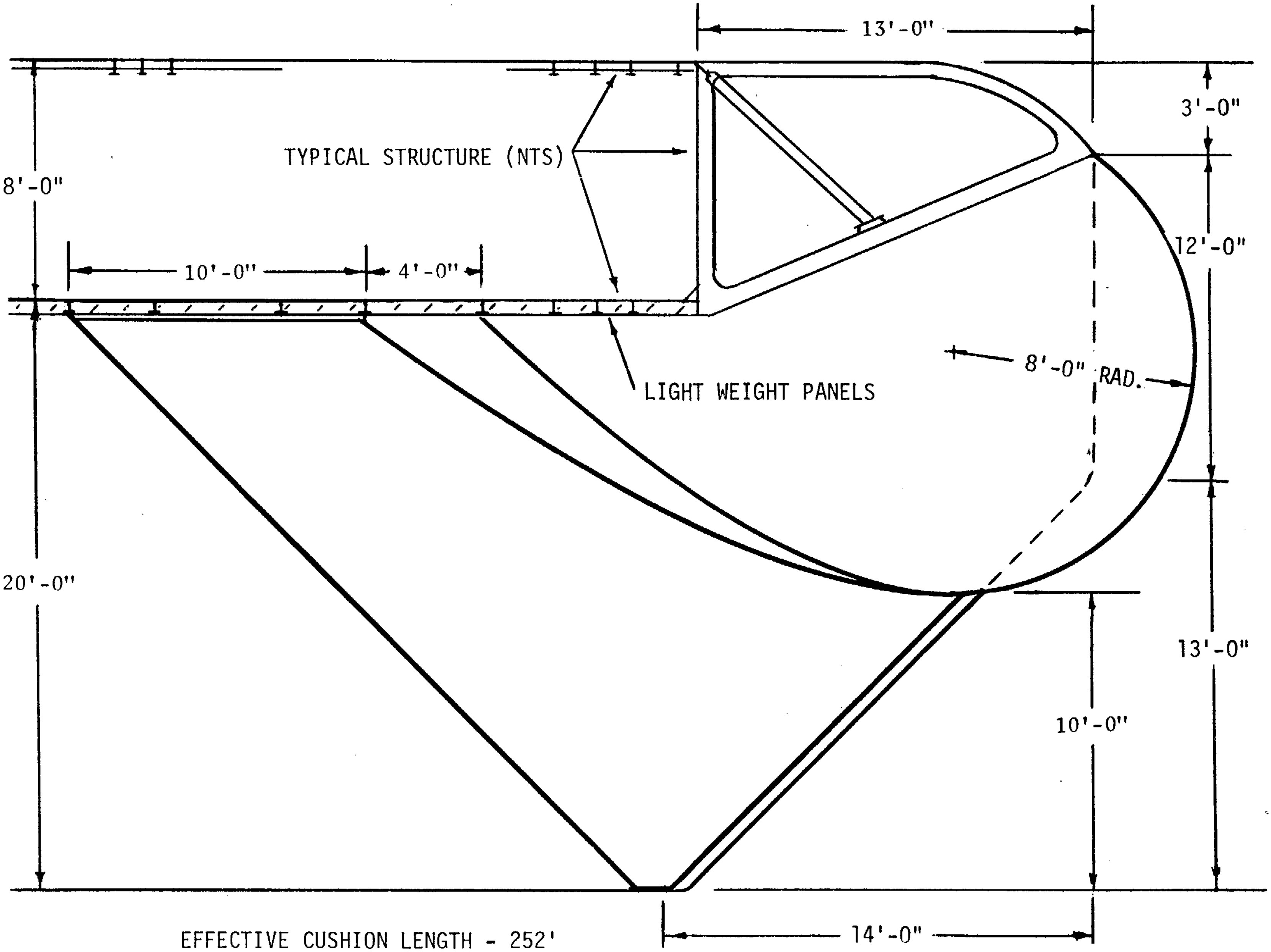
FIGURE 5.2-1b
BOW SEAL FRONT VIEW



EFFECTIVE CUSHION LENGTH - 252'

MDC

FIGURE 5.2-1a

BOW SEAL CENTER LINE CROSS SECTION

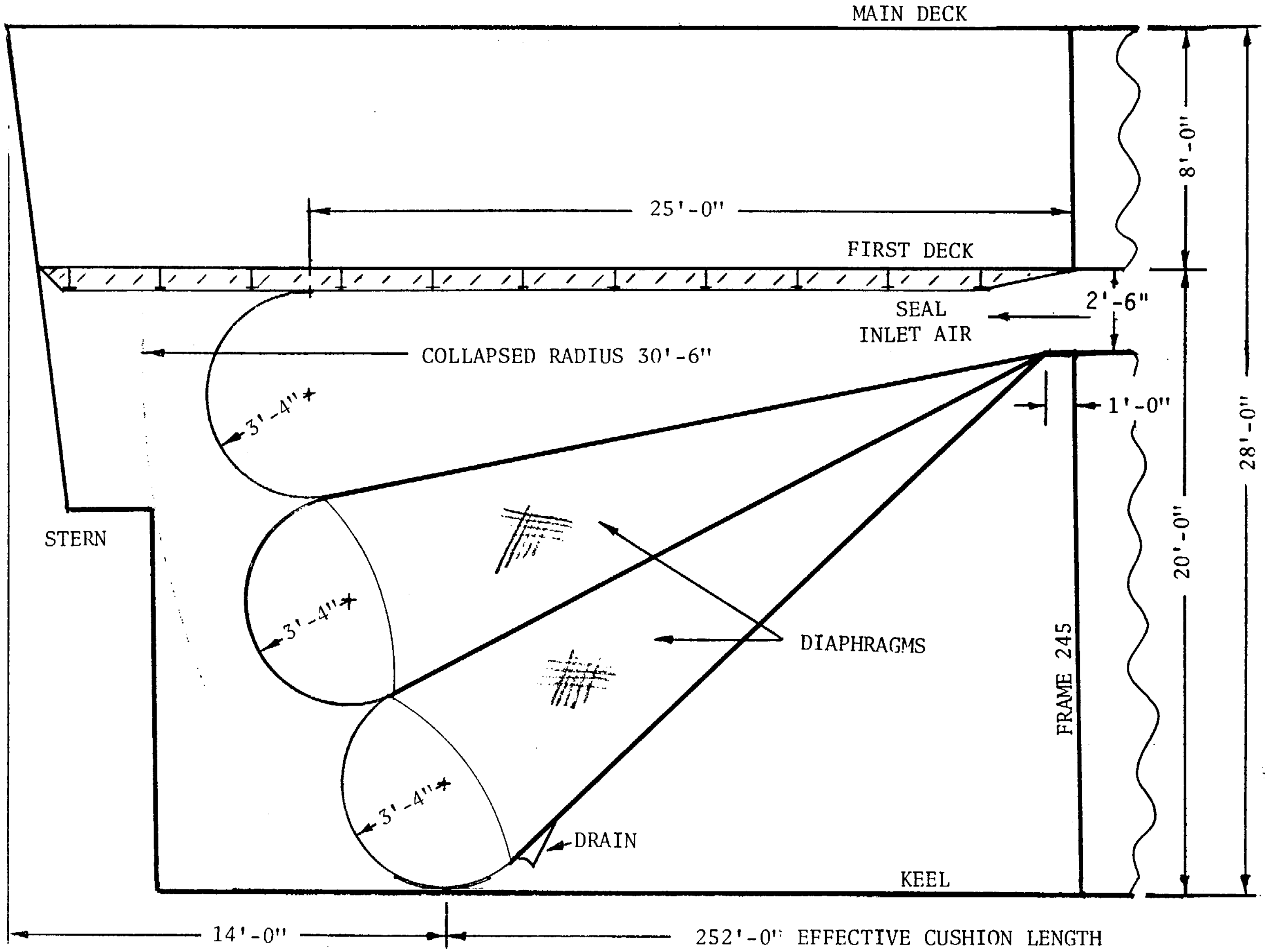


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FIGURE 5.2-3
STERN SEAL CROSS SECTION 14' FROM CENTERLINE

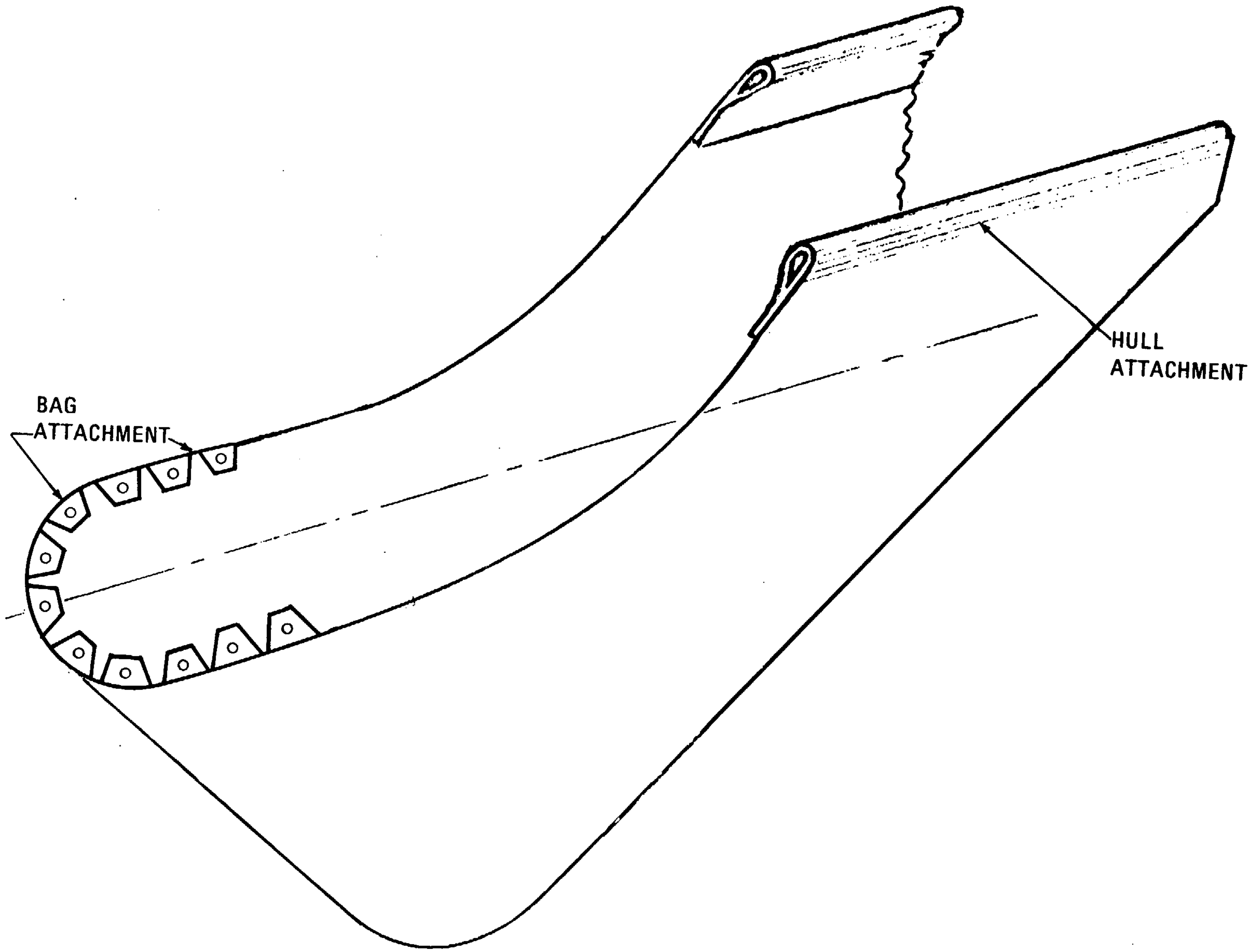

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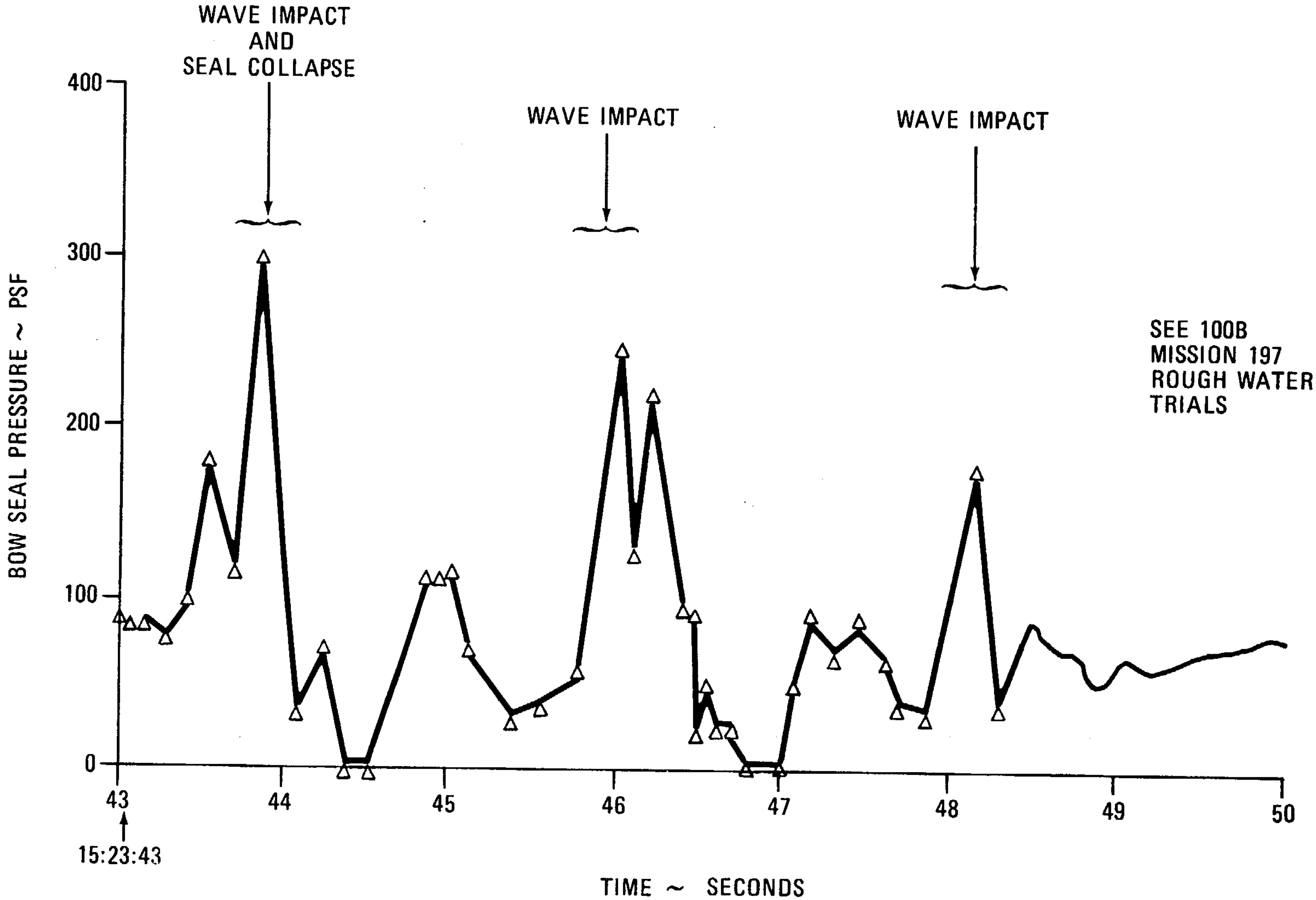
FIGURE 5.2-2
SEAL FINGER



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

"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 resulting from the operational performance envelope. 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 MDC bow seal, this load corresponds to three times the cushion pressure, i.e., 3 x 240 = 720 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 2000 pounds-per-lineal inch (pli) fabrics are more than adequate to satisfy MDC seal material strength requirements. The 2000 pli fabric is a readily available material and was produced and tested under the 2KSES and 3KSES program along with much heavier and stronger 4000 to 5000 pli materials 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 for the same pressure loads as the bow seal. Because of inherently milder operational environment and low stresses, the stern seal has an ample capability to withstand the operational environment loads.

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 MDC 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 under SES and ACV programs and offer the best combination of durability and flexural fatigue strength.

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

STRENGTH CHARACTERISTICS OF BAG MATERIALS SELECTED FOR MDC SEALS

MATERIAL CHARACTERISTIC	BAG BOW	BAG STERN	FINGERS
Fabric Type	Nylon 3 x 3 Basket	Nylon 3 x 3 Basket	Nylon 3 x 4 Basket
Fabric Weight	55 oz/yd^2	23.2 oz/yd^2	30 oz/yd^2
Coating	Neoprene base rubber	Neoprene base rubber	Natural rubber/ cis-polybutadiene
Tie-Coat	Neoprene base adhesive	Neoprene base base rubber	Neoprene base adhesive
Material Weight	170 oz/yd^2	90 oz/yd^2	135 oz/yd^2
Tensile Strength			
Dry - Warp	2400 pli	1240 pli	1600 pli
- Fill	2400 pli	1280 pli	1690 pli
Wet - Warp	1920 pli	1100 pli	1280 pli
- Fill	1920 pli	1100 pli	1350 pli
Tear Strength	1200 pli	500 pli	500 pli

TABLE 5.2-i

5.2.4 Seal Weight Breakdown

The bow and stern seals were designed using loads and safety factors indicated in paragraph 5.2.2. The calculations showed that the materials presented in Table 5.2-i satisfy the design requirements. The seal weights were determined by calculating the areas of coated fabric needed for the bow and stern bags and the bow fingers and converting these to weights using Table 5.2-i. The weight of attachments was estimated using existing SES-100B and Bell-Halter seal designs. 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-ii.

MDC SEAL WEIGHTS BREAKDOWN

BOW SEAL COMPONENT	WEIGHT (LBS)	STERN SEAL COMPONENT	WEIGHT (LBS)
BAG (coated fabric)		BAG (coated fabric)	
Lobe panels	1766	Lobe panels	2650
End Caps	238	End Caps	700
Apron	95	Vertical web (set of five)	80
FINGERS (coated fabric)			
Set of eight (8)	3060		
ATTACHMENT CLAMPS (Aluminum)		ATTACHMENT CLAMPS (Aluminum)	
Bag-to-hull	298	Bag-to-hull	400
Finger-to-hull	688		
Finger-to-bag	255		
TOTAL:	6400	TOTAL:	3830
MISCELLANEOUS 5%:	320	MISCELLANEOUS 5%:	200
BOW SEAL:	6720	STERN SEAL:	4030

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 MDC 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. These elements experience a gradual wear caused by rapid flagellation and repeated buckling of the seal material. Since the stern seal environment is less severe than that of the bow seal fingers, the stern seal material wear is generally slight in comparison and has a life expectancy of 5000 to 6000 hours. The life of the bow finger material is generally lower than the remainder of the bow seal requiring a more frequent finger replacement. 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 damping cables integrated into finger material. Test data have shown that the finger life is dependent on speed, cushion pressure and finger geometry such as finger diameter and incidence angle. The MDC seal finger geometry is selected to provide a good balance between performance and durability. The MDC speeds are modest as compared to the 80 - 100 knots speeds specified for the 3KSES finger. It is anticipated that finger life will be sufficient to provide at least 500 to 600 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. For the MDC 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 the MDC 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 MDC propulsion system consists of two independent combined diesel/gas turbine (CODOG) plants, one in each sidehull, each powering a 12.5 foot diameter controllable pitch propeller.

Propulsion plant design philosophy is based on simplicity and maximum use of comercially available and existing proven components. This approach is evidenced by the selection of the SACM 195 V12 CZSHR diesel engines, a widely used marine engine, and the Detroit Diesel Allison Division (DDAD) 570-K gas turbines, a second generation unit offering good performance and economy in the 2000 to 7000 shp range. The diesels provide lift when on cushion and are available to provide propulsive power when hullborne. The gearboxes are a CODOG version of an epicyclic reduction unit designed specifically for the DDAD model 570 gas turbine by the Cincinnati Gear Company. Each gearbox combines the inputs of two model 570 gas turbines, providing for either one or two gas turbine operation per shaft, or for one diesel operation. The propulsion plants, powering controllable pitch propellers, and using marine diesel fuel (DFM), (MIL-F-16884) provide the MDC 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. The selected arrangement provides compact and efficient installation which allows full input power for either gas turbine or diesel operation.

During gas turbine operation, power to each propeller is provided either by one or two gas turbines via turbine coupling, epicyclic reduction gearbox, syncronous self-shifting (SSS) clutch, input pinion, bullgear, shafting, bearings and thrust block. The overall reduction ratio of the gas turbine drive train is 38.26 to 1.

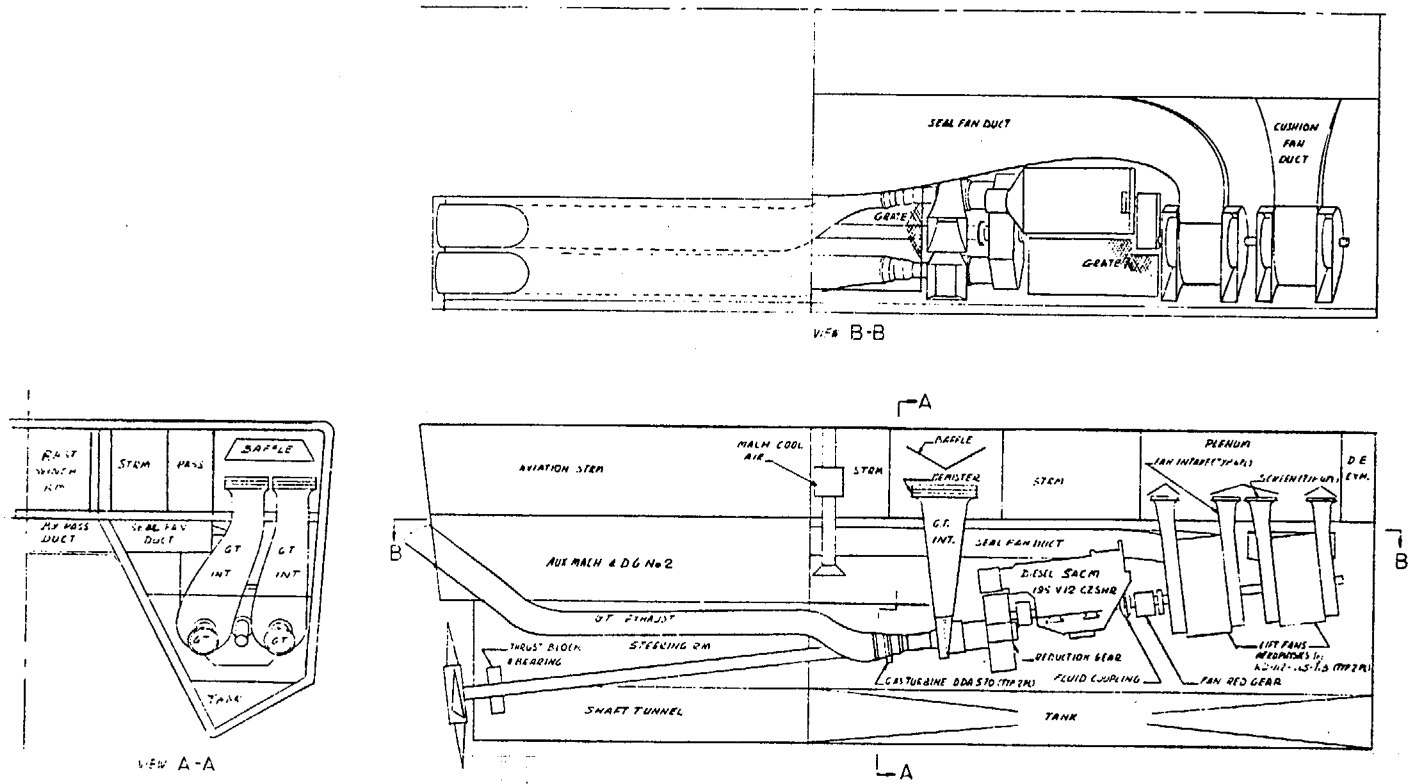


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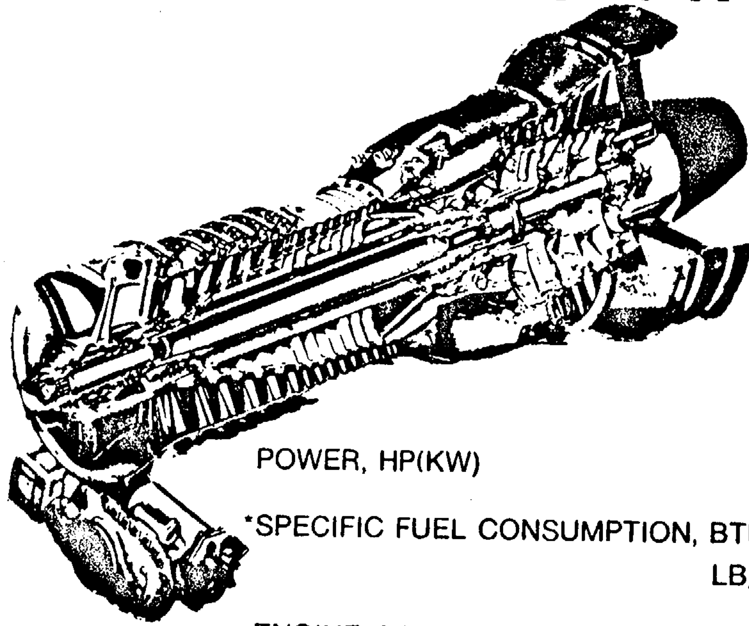
FIGURE 5.3-1
PROPULSION PLANT - GENERAL ARRANGEMENT

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)

MDC
FIGURE 5.3-2
DETROIT DIESEL ALLISON GAS TURBINE

For diesel operation, power is transmitted via a torsional damping flexible coupling, SSS clutch, input pinion, pinion and bullgear. The reduction ratio provided for diesel operation is 7.80. Two lift fans are driven from the opposite end of each diesel through a clutch which is normally disengaged during hullborne diesel propulsion operation. Although these diesel engines provide propulsive power, they are the primary lift system drivers and are 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 desired power range were considered for powering the MDC. In addition to the DDAD 570-K, the Garrett 1E-990, the General Electric LM-500, and the Rolls Royce Tyne RMIC and SM2B 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 MDC; although other engines might be used.

The model 570-K marine gas turbine, manufactured by Detroit Diesel Allison, is a low volume, high power-to-weight propulsion system, Figure 5.3-2. 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:

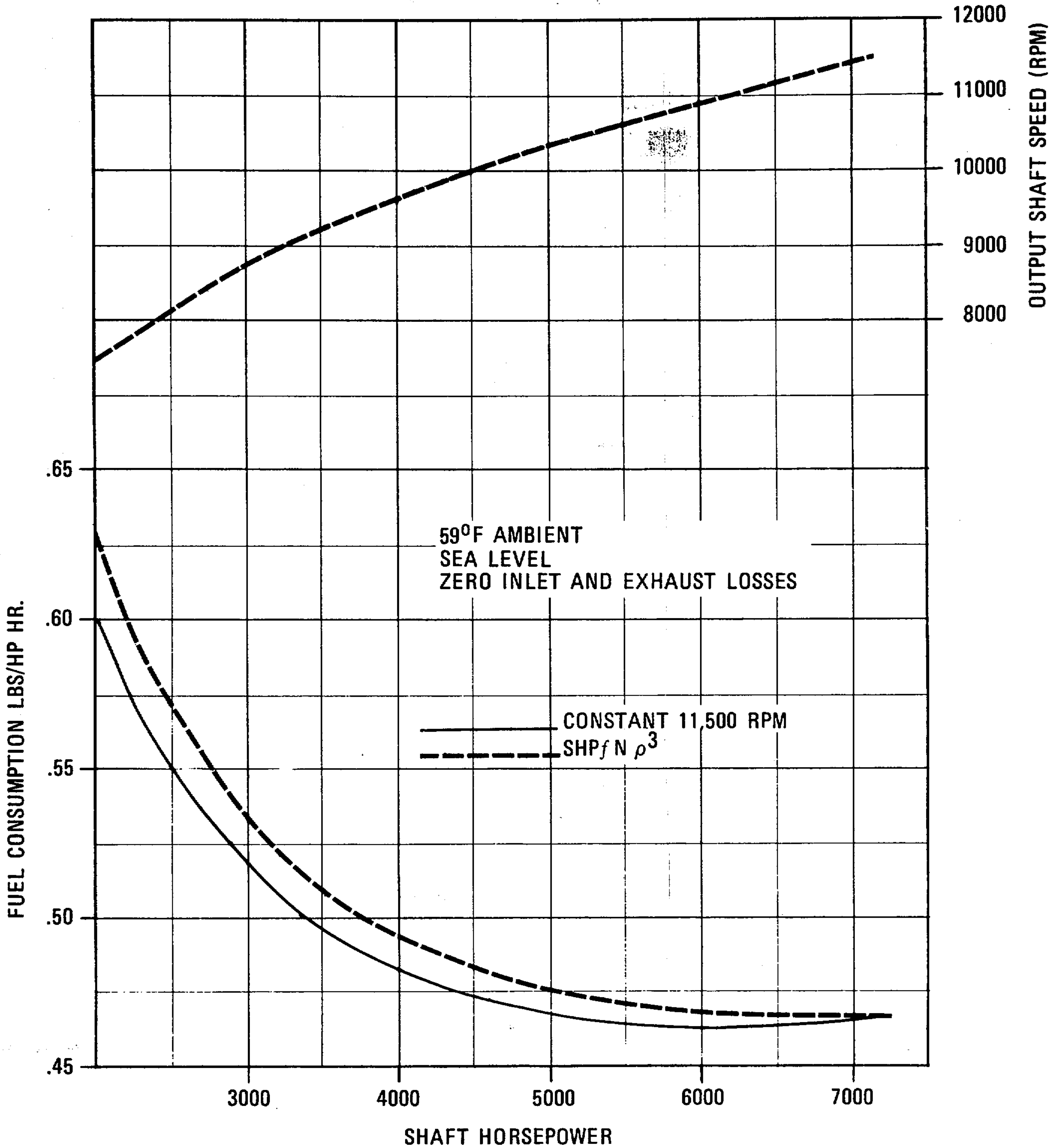
a. It employs a full annular combustor to accommodate the greater gas volume.

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 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. See Figure 5.3-3.

The 570-K engine 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



DETROIT DIESEL ALLISON MODEL 570K GAS TURBINE

MDC
FIGURE 5.3-3
GAS TURBINE SPECIFIC FUEL CONSUMPTION

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.

5.3.3.2 Diesel System

A diesel engine located in each sidehull powers either a pair of lift fans or a propulsion drive train through a CODOG transmission system. The diesels selected as best suited for the MDC are the SACM 195 V12 CZSHR or the MTU 12V 956 TB-82. Either engine may be used, however, the SACM engine will be shown in this design. The SACM 195 V12 engine is rated at 2200 shp continuous at 1560 rpm and is capable of full power transmission from either end of the engine. The two hour rating is 2420 shp at 1610 rpm. This engine is shown in Figure 5.3-4.

The model 195 V12 diesel is based on design concepts which make it suitable for high performance vessels. Over 150 of the 195 V12 model engine are in marine service and more than 300 SACM diesels are employed in military ships worldwide. Other diesel engines are available in the required power and speed ranges for this application but the SACM 195 V12 was selected because of its overall suitability for the MDC and its proven marine performance.

The engine is of short stroke design (195 mm bore, 180 mm stroke) with rated speeds from 1510 to 1660 rpm. Design features include 60 degree V arrangement, direct injection, exhaust turbocharging, and internal charge air cooling with intercoolers incorporated. The engine uses air starting and has a dry weight of 6.2 LT.

5.3.3.3 Transmission System

A CODOG reduction/combining gear system based upon existing design and technology has been selected for the MDC. 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 gear arrangement.

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 system is provided. This unit was designed specifically for use with the DDAD 570-K engine. Propeller counter-rotation is provided by using a planetary gear on the starboard side and star configuration on the port side.

The parallel shaft gearbox section is designed to low K-Factor and unit loads for 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.

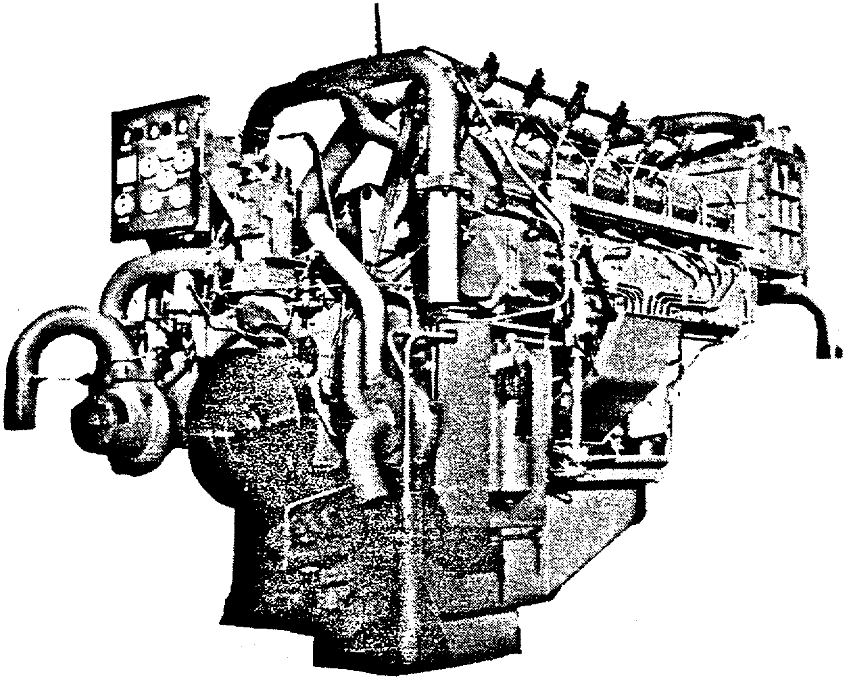


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FIGURE 5.3-4

SACM 195 V 12 CZSHR DIESEL ENGINES

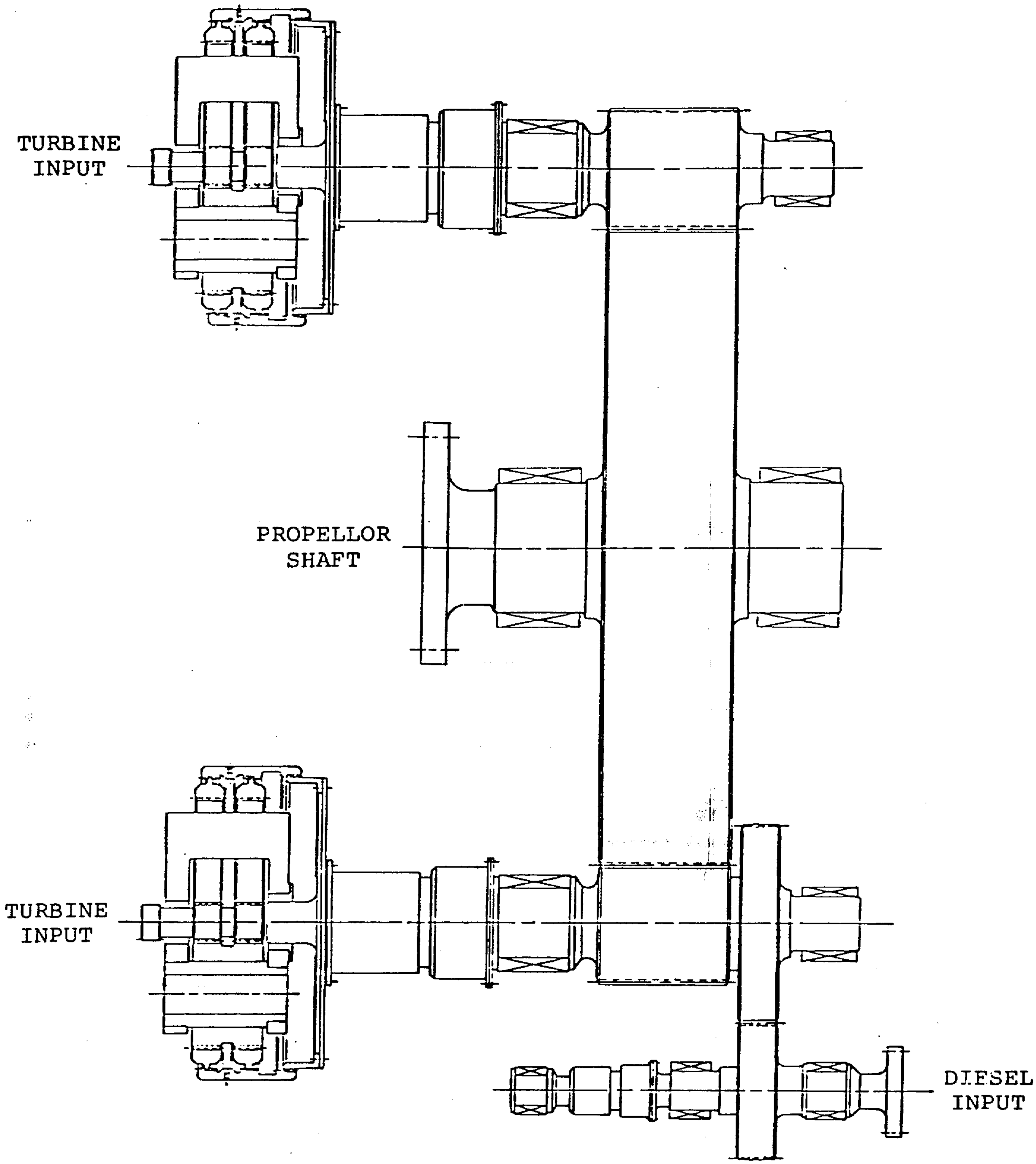

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FIGURE 5.3-6
CODOG TRANSMISSION CONFIGURATION

THE CINCINNATI GEAR COMPANY

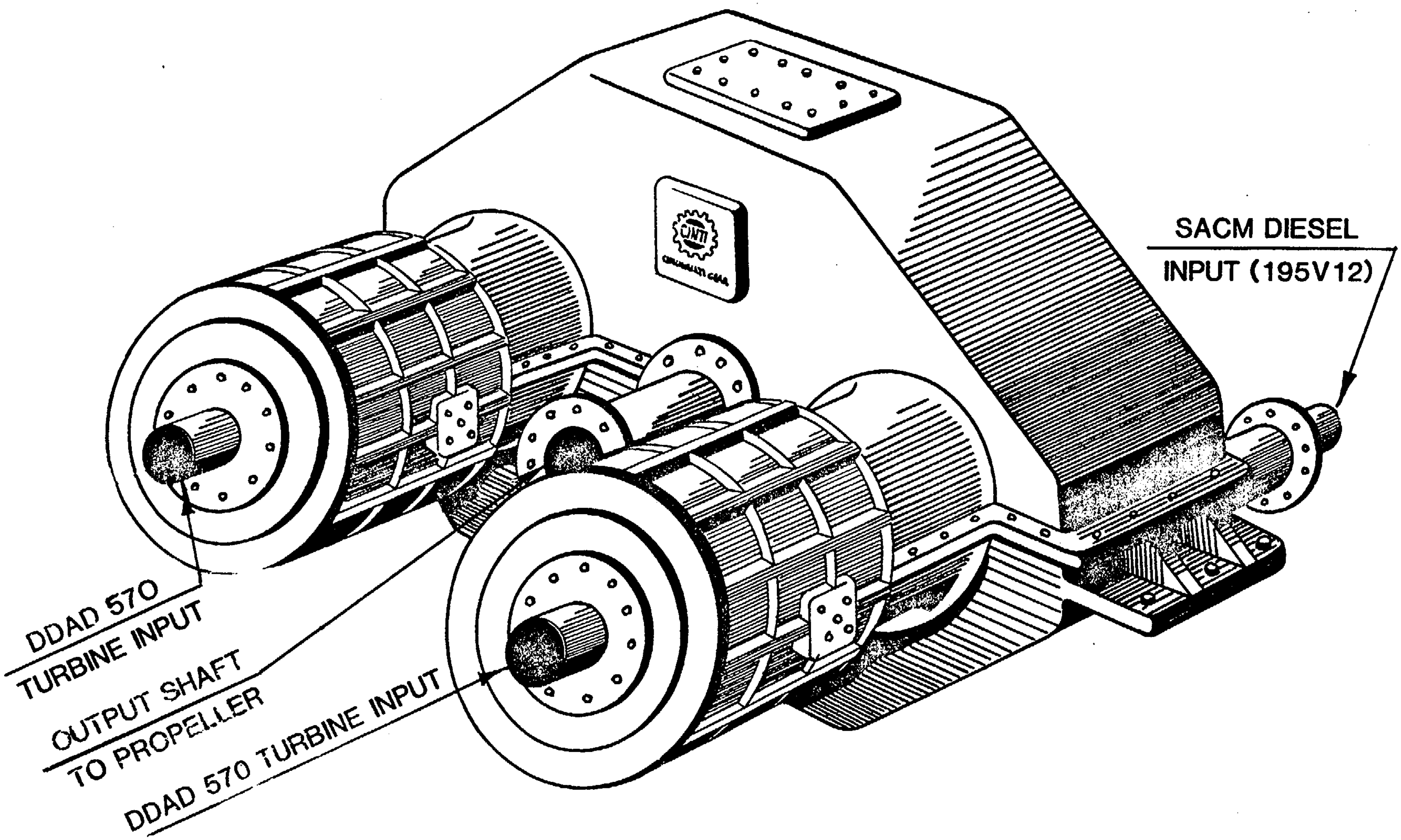

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FIGURE 5.3-5
TWIN TURBINE/CODOG TRANSMISSION

During diesel engine operation power is transmitted to the diesel input SSS clutch via an Eaton/Geislinger type torsional coupling to dampen 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, pinion and bullgear, and shafting to the controllable pitch propeller. Since the direction of rotation of one of the diesels has to be reversed, a reversing pinion is provided on the starboard gear. This is arranged in such a way that the distance between the diesel engine and gas turbine shafts is the same for both gear units. The port and the starboard diesels are also mounted at the same height. Appropriate shaft bearings, thrust block and stuffing box are fitted.

During gas turbine operation power from one or both engines is transmitted via an epicyclic reduction unit, SSS 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 arrangement 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 38.26/1 with an output speed of 300 rpm; the diesel reduction ratio is 7.80/1 with an output speed of 200 rpm. The gearbox efficiency is 97 percent and it's dry weight 17,000 pounds with steel gear case and 14,000 pounds with aluminum gear case.

5.3.3.4 Propulsor System

Propulsor selection was influenced by the requirements for high efficiency in both hullborne and cushionborne modes of operation, and for efficient low speed performance. Controllable pitch propellers were therefore selected.

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 two independent parametric studies indicate that for the installed CODOG system, a 12.5 foot diameter propeller with a maximum rotative speed of 300 RPM will achieve required performance over the craft operating range. This propeller has the following characteristics:

Number of Blades	4
Expanded Area Ratio (EAR)	0.60
Hub to Tip Diameter Ratio	0.4
Maximum Stress	18000 psi (fatigue limit)

Nickel Aluminum Bronze (NIBRAL) or stainless steel will be used for the propeller blades. 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). For partially submerged operation the propeller hub and the upper half of the propeller disk function in the "shadow" of the transom. This is achieved through proper design of sidehull geometry to obtain effective full propeller submergence or partial submergence when desired. This is accomplished by varying the streamlines of the local water flow through mechanical or hydrodynamic arrangements in front of the propellers. These details will be determined during the next design phase.

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 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 will 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 modulate engine noise. Demister modules remove moisture and other contaminants in the air. Bypass doors are included in the demister assembly to prevent blockage caused by 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 through a transitioning section and into the exhaust gas assembly. The exhaust assembly is installed horizontally exhausting through port and starboard outlets at the transom. The exhaust ducting is round in cross-section with concentric sound suppressors installed in the duct. The entire system is insulated. A seawater trap and closure doors are provided to protect the gas turbine from water entry.

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.

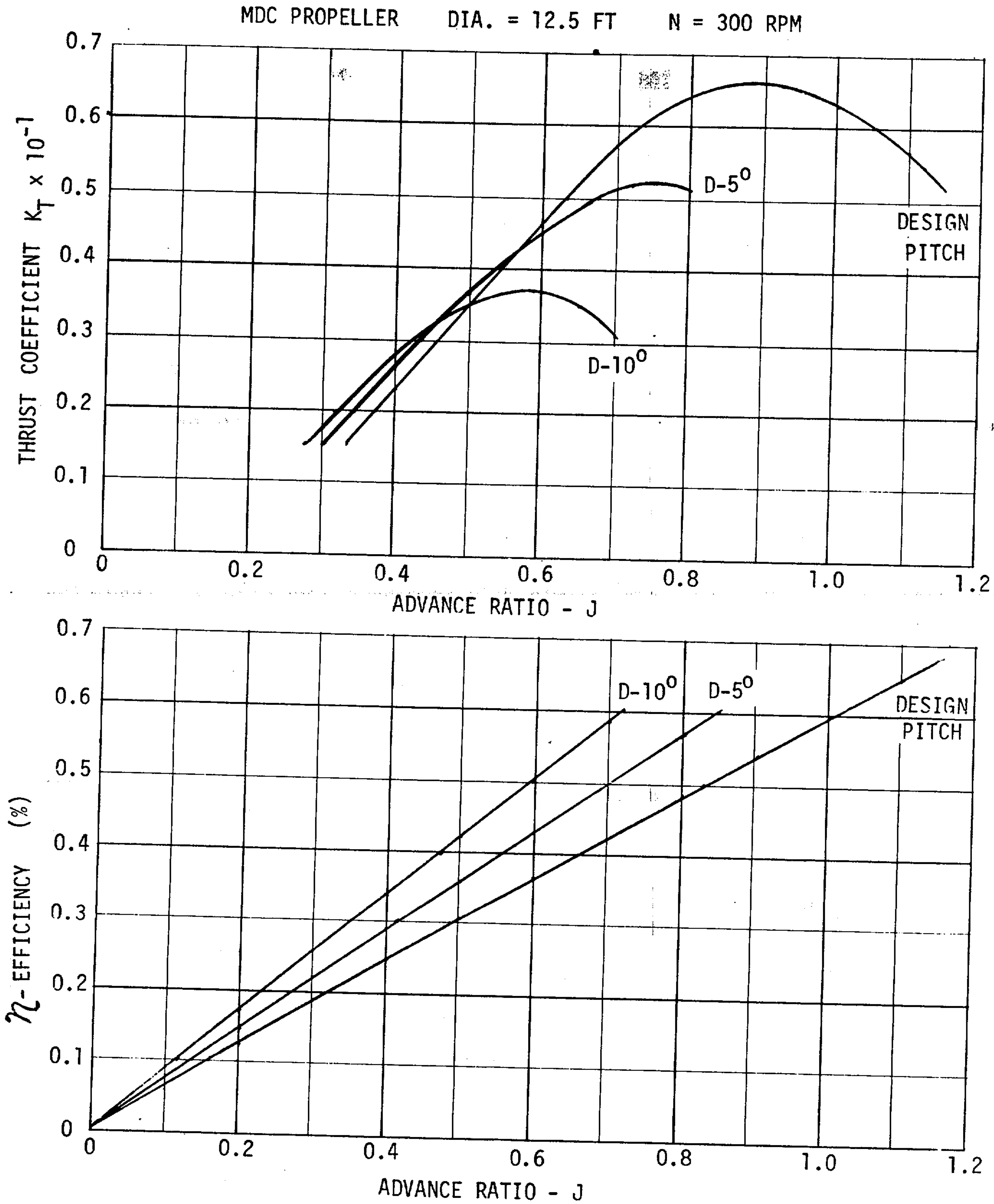

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FIGURE 5.3-7
PROPELLER PERFORMANCE

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 station or the bridge. Performance monitoring and evaluation of principal propulsion machinery elements can be undertaken from the central control position. Machinery compartments are normally unmanned during operation.

5.3.4.1 Hullborne Operation

The MDC propulsion plants provide an unusual degree of performance and flexibility of operation for the hullborne and partial cushion modes. Various combinations of gas turbines may be used to optimize performance and economy. The diesel engines of the CODOG system also are available for hullborne operation, providing speeds up to 18 knots with excellent fuel economy and ship range. Dockside and low speed maneuvering is accomplished by use of rudders, propeller reversal and/or RPM variations.

5.3.4.2 Hump Transition

The high cushion length to beam ratio of the MDC places the primary drag hump above the maximum speed of the MDC. 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 MDC 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

The gas turbine and reduction gearing weights, including the clutches are based on vendor information. The shaft, bearings and propeller weights are derived from parametric weight equations. The remainder of the SWBS Group 200 estimates are derived from the 3KSES weights which were the subject of extensive investigation. Weigth margins are included in the overall ship margin. 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 (LT)
234	Propulsion Turbines (4)	3.4
241	Reduction Gearing	16.0
243	Shafting	4.0
244	Bearings	3.5
245	Propellers	19.5
251	Combustion Air System	5.3
252	Propulsion Control	0.5
259	Exhaust System	3.6
261	Fuel Service	0.1
262	Lube Oil Service	1.5
298	Operating Fluids	1.2
299	Repair Parts	0.4
	Total Propulsion System	59.0

TABLE 5.3-i

5.3.6 Propulsion System Risk Assessment

A conservative design approach provides confidence that the propulsion system technical risk is sufficiently low so as not to place constraints on MDC construction.

The Allison 570 prime mover is marine (salt) qualified, with a rapidly increasing industrial experience base. The SACM marine diesel engine is in industrial and marine use world wide. The Cincinnati Gear reduction gear is of conservative, state-of-the-art design. The controllable pitch propeller installation is state-of-the-art and sized within the production capability of manufacturers.

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

5.4 LIFT SYSTEM

5.4.1 Lift System Description

The lift system consists of three 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 four aft fans supply the stern seal and the cushion with lift air.

Each set consists of two Aerophysics Incorporated, Rotating Diffuser (RD) Double Width Double Inlet (DWDI) fans with radially placed Inlet Guide Vanes (IGVs). Power is supplied to each pair of lift fans by one SACM 195 V12 CZSHR 2200 HP diesel engine with appropriate gearbox. No cross-connection exists between the three 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 fan intakes are vertical trunks up to the second deck and terminate with a personnel and debris safety screen/barrier contained in a plenum between the second deck and the main deck. The bow fan intakes are located forward on the second deck and open directly to the main deck with appropriate safety equipment fitted.

5.4.2 Lift System Arrangement

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

5.4.3 Lift System Components and Characteristics

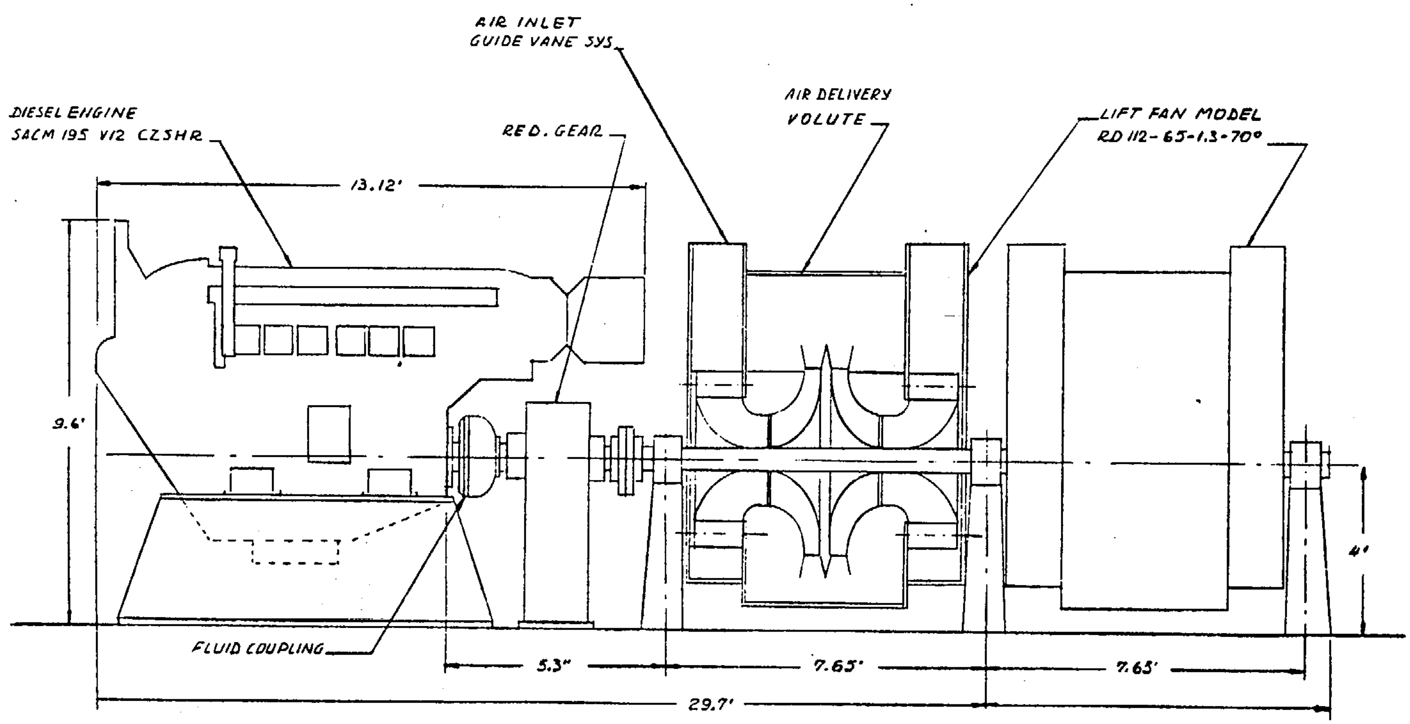
5.4.3.1 Prime Movers

The SACM 195 V12 CZSHR marine diesel engine described in Section 5.3.3.2 has been selected for powering the lift system. It most closely fits the CODOG propulsion requirements of the MDC, however other manufacturers have engines that could be substituted.

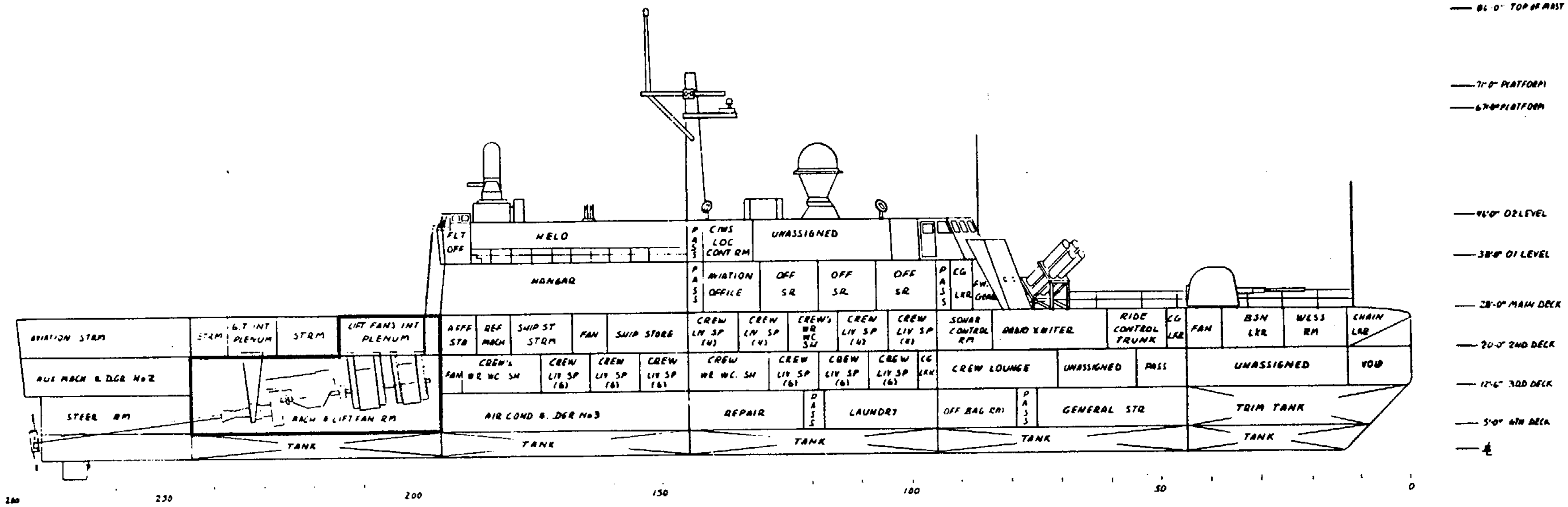
5.4.3.2 Gearbox

Lift gearboxes provide speed increase 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 to 1.586. The gearbox assembly includes the following components:

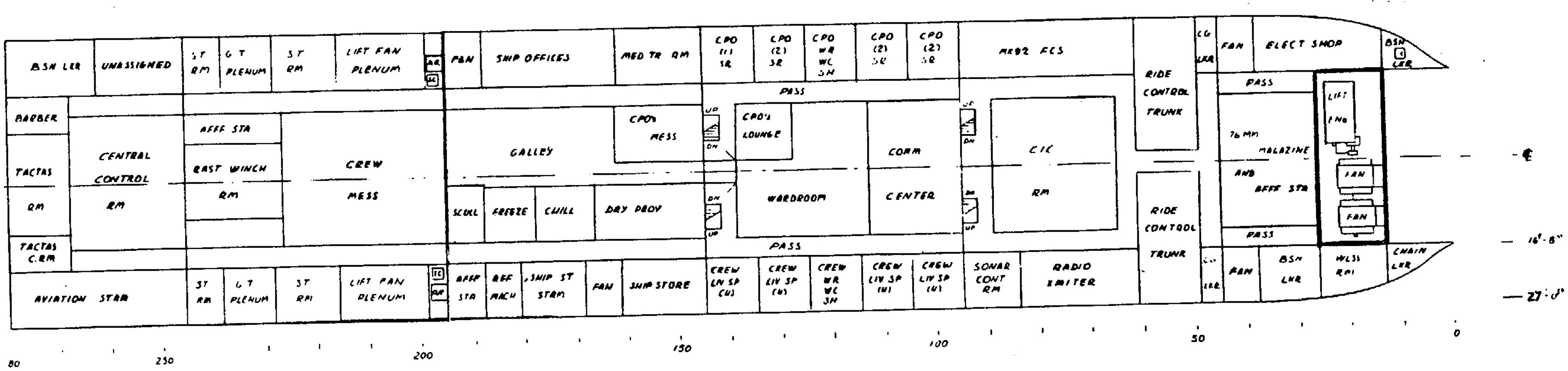
a. Gearing of helical design of modified involute form machined from non-welded CEVM 9310 forgings



MDC
FIGURE 5.4-2
LIFT MACHINERY SET



SIDE HULL INBOARD PROFILE STARBOARD SIDE 16' - 8" OFF L



SECOND DECK

MDC

FIGURE 5.4-1

LIFT SYSTEM KEY PLAN

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

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.

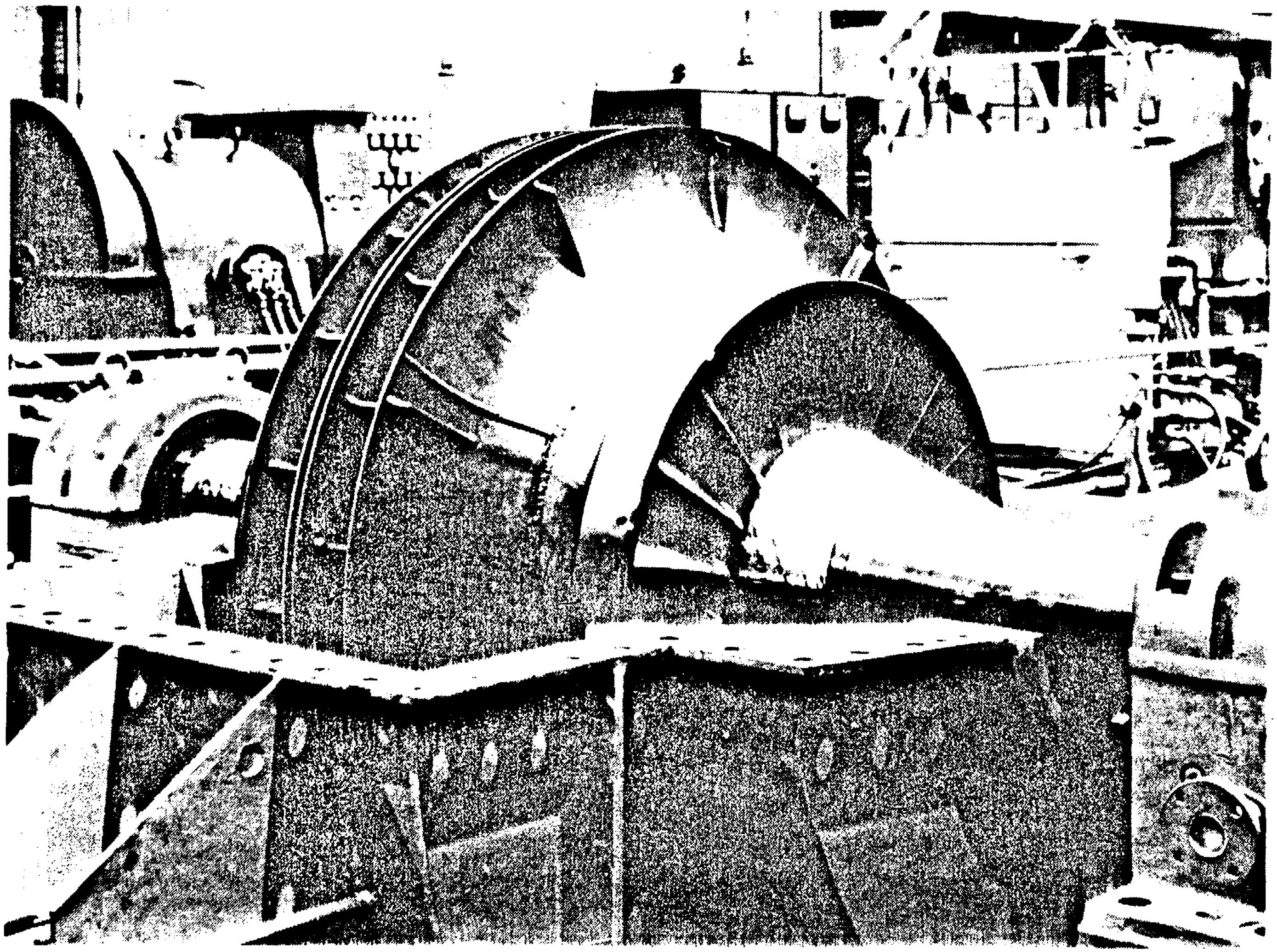
The accessory drive is designed as a self contained, detachable gearbox. It can be removed and replaced without disassembly of the pumps or gears. Bearings, removeable sumps, oil shields, brakes, and many other small components are interchangeable. Where possible, parts are unitized to eliminate joints 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 single discharge rotating diffuser type fan. All design performance requirements are met by six fans having a 3.7 foot diameter at the blade trailing edge.

The Aerophysics Incorporated rotating diffuser (RD) type fan shown in Figure 5.4-3 has been successfully used for many years in industrial and marine applications, and has been selected for the MDC. Figure 5.4-4 is a side view of an MDC size fan installed in a lightweight welded aluminum housing. Use of the RD fan on air cushion supported platforms was first investigated in studies sponsored by the United States 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 for SES was extended to very large sizes, Figure 5.4-5. At about the same time the RD fan was also installed on passenger ships and European Naval vessels where they were used as forced draft blowers for steam propulsion plants. As an example, 16 RD fans were installed on the liner "France". These 4.0 foot diameter fans (see Figure 5.4-6) often averaged 8000 hours per year and are



MDC
FIGURE 5.4-3
AEROPHYSICS INCORPORATED ROTATING DIFFUSER FAN

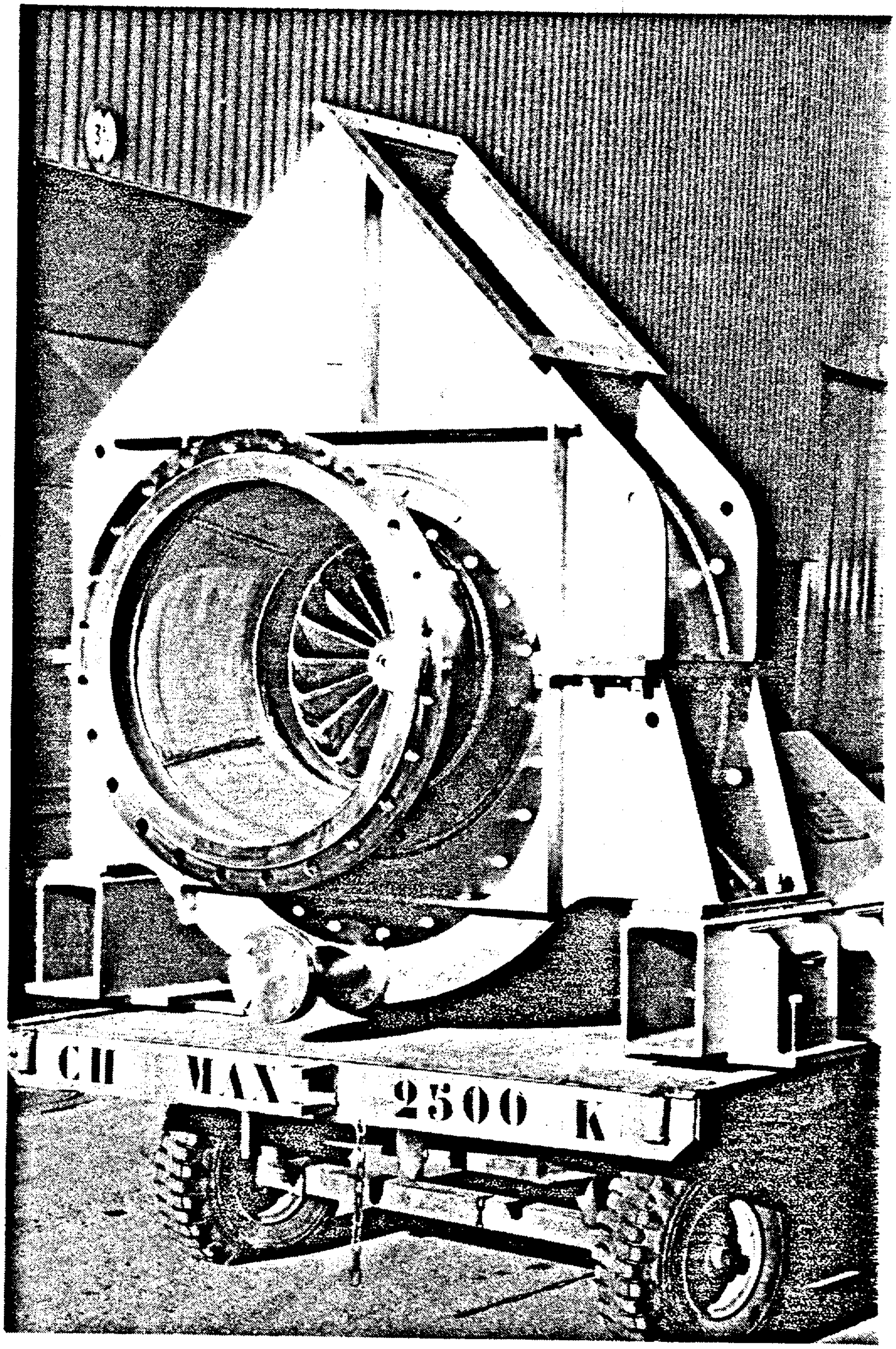


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FIGURE 5.4-4
AEROPHYSICS INCORPORATED ROTATING DIFFUSER FAN AND ALUMINUM HOUSING

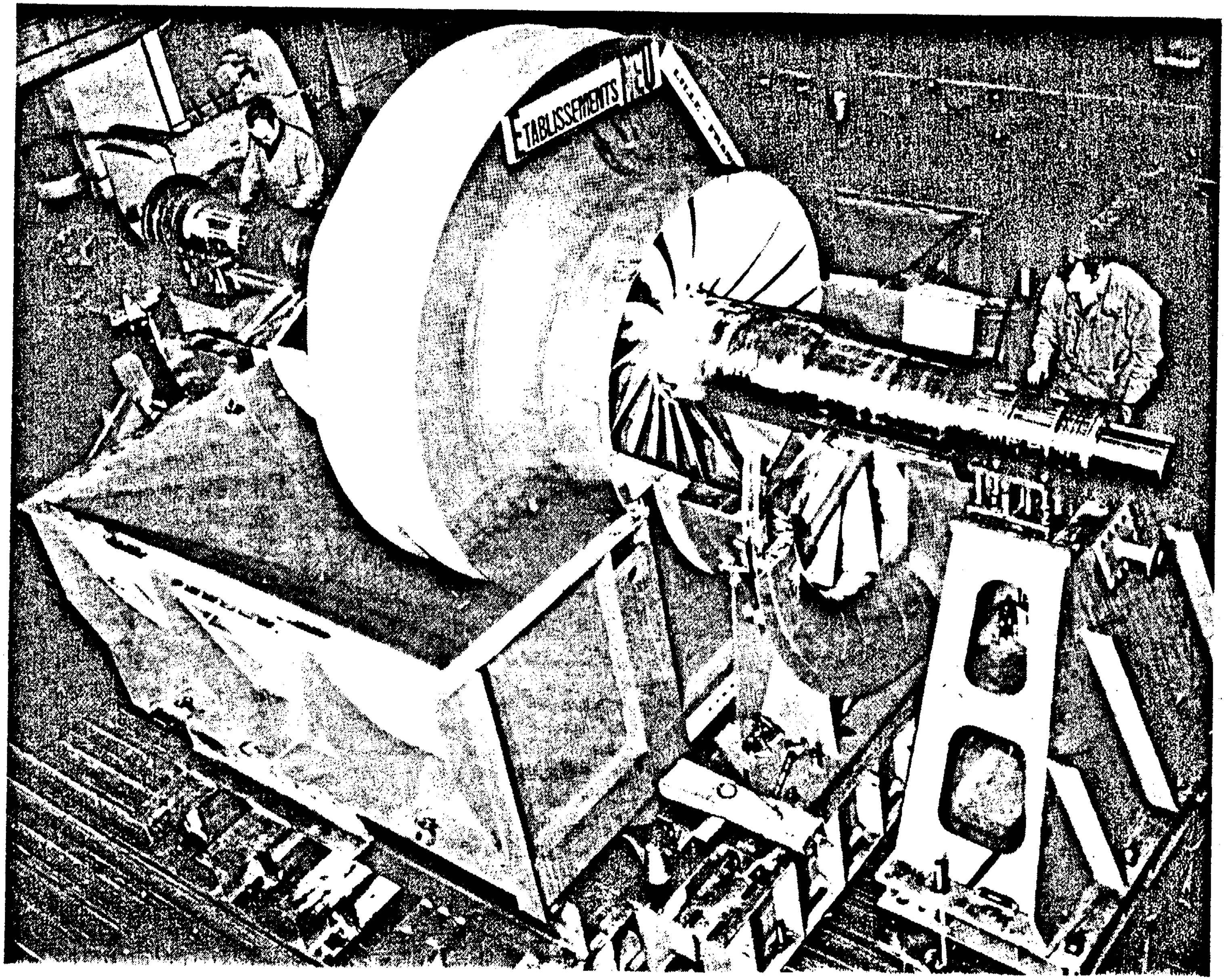

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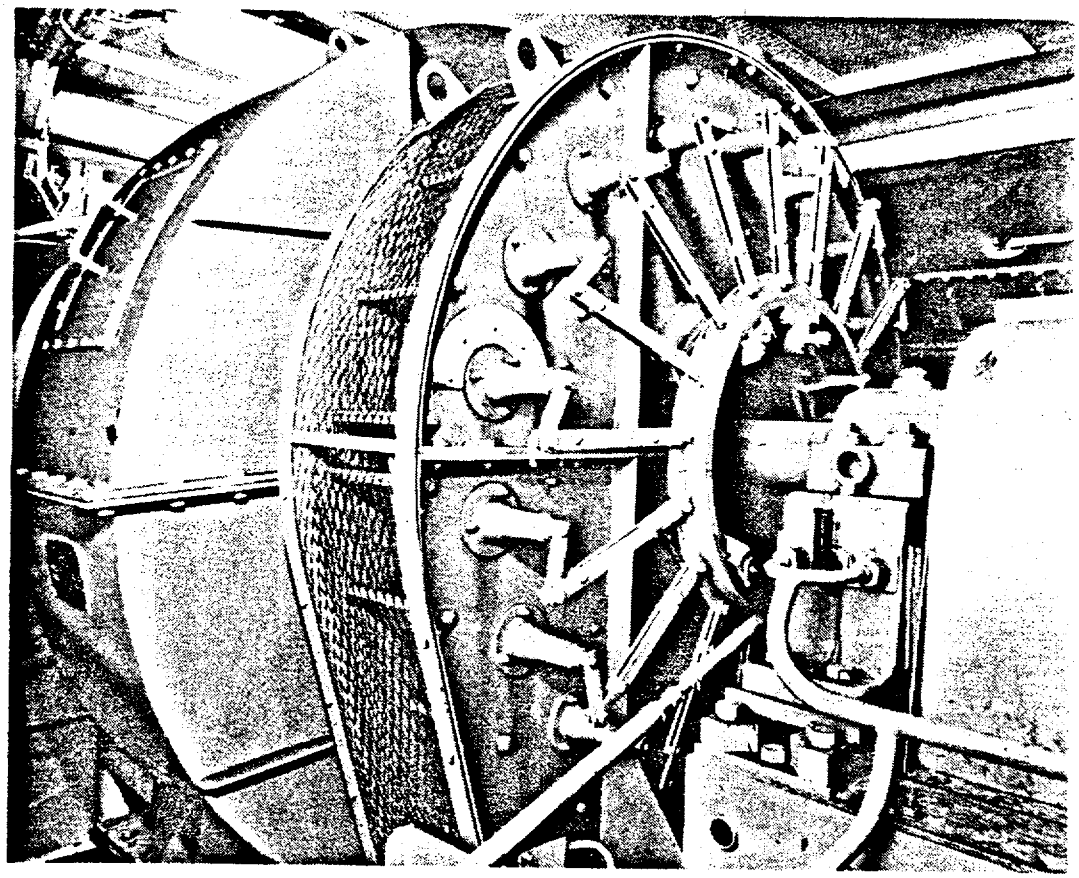
FIGURE 5.4-5
LARGE INDUSTRIAL ROTATING DIFFUSER FAN DURING ASSEMBLY



MDC
FIGURE 5.4-6
ROTATING DIFFUSER FAN ONBOARD THE PASSENGER LINER "FRANCE"

still operating today after 20 years. The "France" installation is a particularly good example since her fans fully match the MDC design requirements complete with radial inlet flow control guide vanes and could be installed directly in the MDC as is. The RD fan marine installation has high efficiency, surge free operation, low noise signature, high mechancial margins of safety and resistance to impact damage. Marine fan installations often have the fan intakes draw directly from the machinery compartment (see Figure 5.4-6) to serve a second function of machinery space ventilation through a negative pressure system that keeps machinery space fumes from propagating throughout the ship.

Recently, under the 3KSES contract, the detailed design of a modern RD lift fan was completed. The fan was under full-scale construction when the 3KSES program was terminated. In addition, aerodynamic and structural tests of a large scale model RD fan were recently completed at the David Taylor Naval Ship 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 dynamic environment.

The RD lift fan for the MDC is a small scale version of the 3KSES fan design. Performance data was obtained from direct half scale model measurements utilizing an approved American Air Movers and Conditioning Association (ASTM) code tester. Fan data is complete, including flow variations achieved with the radially installed inlet guide vanes. Table 5.4-i details the MDC fan's operating range of pressure and flow at an MDC displacement of 1030 LT. The fans are capable of lifting the MDC at operating static pressures of 310 PSF which corresponds to an overload displacement of 1600 LT. Figure 5.4-7 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 85 percent are achieved. Note the wide range of performance at above 80 percent efficiency.

Each 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 steel plates rather than airfoil blades and are installed axially in the inlet portion. The flat plate blades facilitate economical welded or cast construction and insure long life. The fan has a conventional rectangular aluminum volute. Each 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 as shown in Figure 5.4-6. 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 5.4-8 for a tip speed of 528 feet/second. The MDC fan noise levels at 476 feet/second are below the ISO 80 decibel level for non-ear protected spaces.

An available welded steel marine industrial type fan providing the required pressures and flows, can be utilized since the MDC is less weight critical than very high speed SES. This facet, together with the extensive trouble free operating history of this type of fan (over 3,000,000 hours) and extensive half scale testing in the dynamic SES environment provides the MDC with an essentially risk free lift fan.

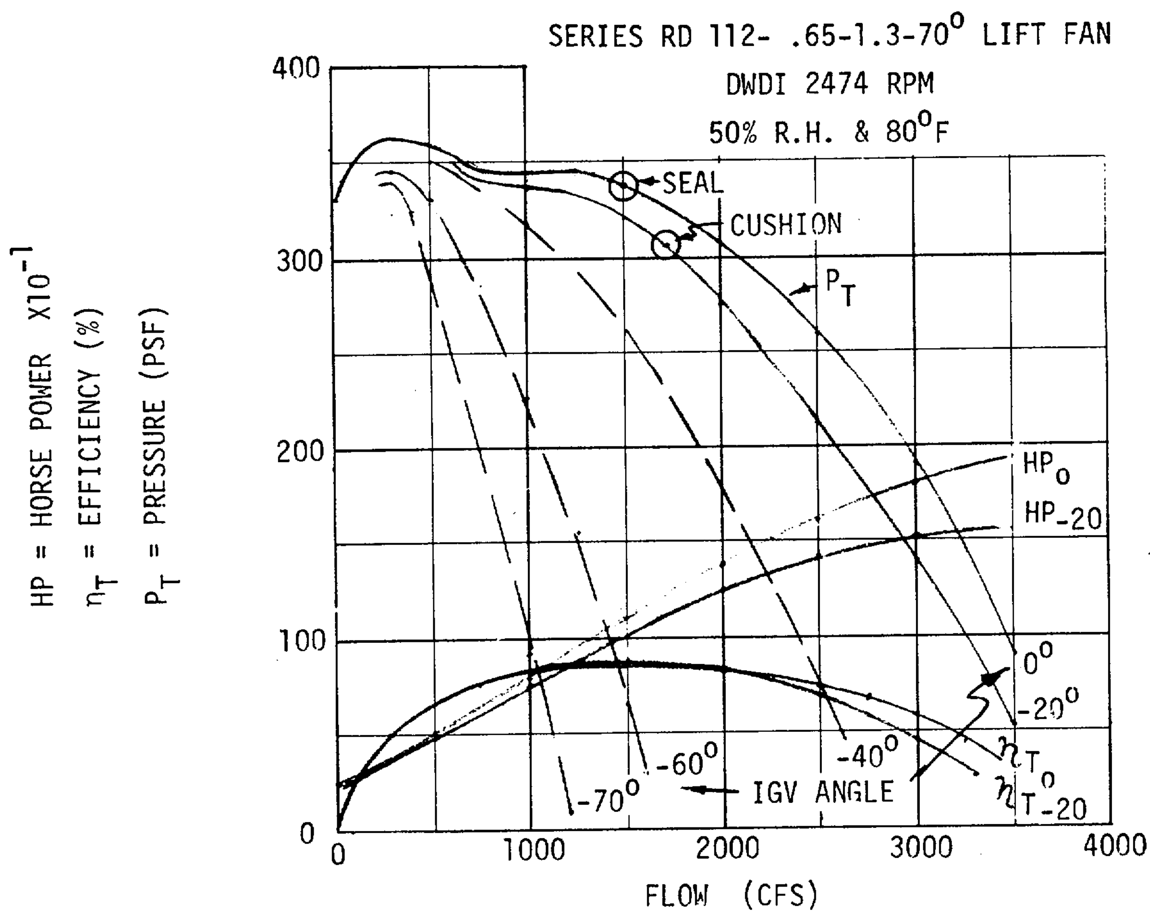


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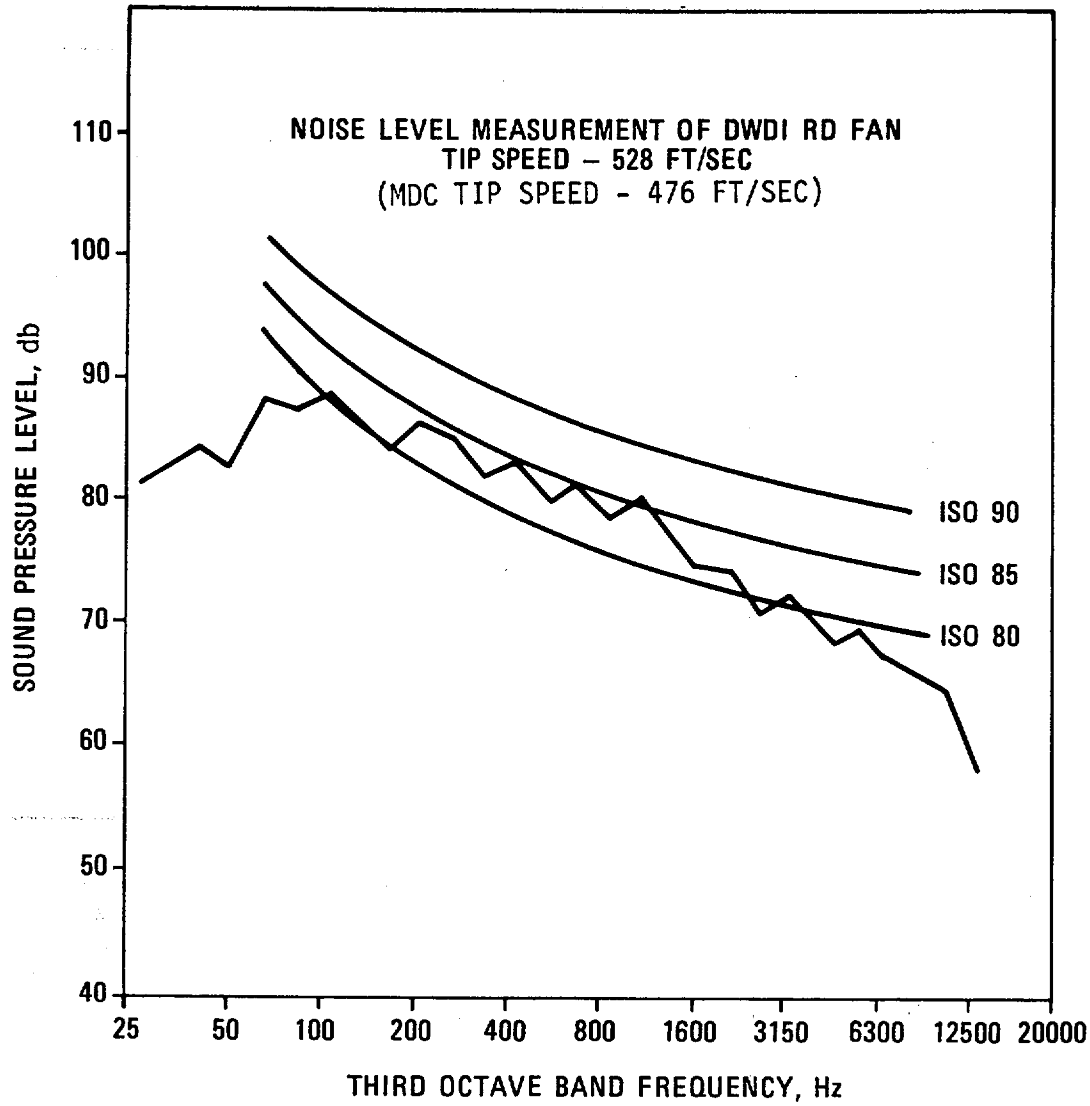
FIGURE 5.4-7
PERFORMANCE OF MC FULL SIZE ROTATING DIFFUSER FAN



MDC
FIGURE 5.4-8
FAN NOISE CHARACTERISTICS

LIFT SYSTEM PERFORMANCE REQUIREMENTS - (1030 LT)

SUB-SYSTEM	CUSHION	SEALS
NO. OF DWDI RD LIFT FANS	2	4
NO. OF INLETS	4	8
HORSE POWER AVAILABLE/INLET	550	550
P_S STATIC, PSF	272	310
P_T TOTAL, PSF	307	338
DELIVERED FLOW/INLET, CFS	845	750
TOTAL FLOW IN CUSHION, CFS	3380	-
TOTAL FLOW IN BOTH SEALS, CFS	-	6000
TOTAL FLOW/SHIP, CFS	9380	
C_{Pt}, TOTAL PRESSURE COEFFICIENT	.0714	.0786
C_d, FLOW COEFFICIENT	.397	.348
N_t, TOTAL EFFICIENCY	.85	.84
IGV BLADE SETTING, DEGREES	-20	0
SLOPE OF PERFORMANCE CURVE	STABLE	STABLE
TIP SPEED, FEET/SECOND	476	476
RPM, ENGINE - FAN	1560 - 2474	
GEAR RATIO REQUIRED	1.59 to 1	

TABLE 5.4-i

5.4.3.4 Lift Air Intake System

Intake air to the three lift fan sets (see Figure 5.3-1) is taken in through a large volume air plenum system that passes down from the flush deck grill and valve entrance on the ship main deck. The air trunk is provided with grilled openings, water traps and air balance valves. 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 also ventilated from above by the inlet air trunk. The volume and clearances about the fans allow free air flow into the inlet guide vane system. Any water that enters the topside intake would settle in the second deck rooms and be discharged overboard through the deck drainage system. The placement of engine, gearbox, and other drive train elements allows for a secondary cooling air flow over these elements before being exhausted by the lift fan. Like the uptake, this room is structured to resist lower than atmospheric pressure.

5.4.3.5 Lift Air Distribution System

The lift air distribution system accepts pressurized air from the fans and routes it 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 forward fan set feeds the bow seal and the cushion. Both fans can be valved to direct air flow to either the cushion or bow seal to provide system flexibility and redundancy. 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 5.3.4). 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 normally unmanned during operation.

The ship can operate on-cushion with any combination of the six fans. For economical travel, i.e., minimum total propulsive and lift power for a given speed, approximately half the lift power only is required and therefore only two or four fans, depending on speed, are normally required. This ensures that in the event of failure of one diesel-fan set adequate fan power will be available for most operations. All six fans are required for maximum dash speed and for high sea states. Secondary hump transition is possible with full-cushion, or partial-cushion and can be bypassed 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

The engine weights are based on vendor information and the fans on actual weights of comparable fans. The transmission and air distribution weights are calculated and cross checked with scaled data from the 3KSES design. Estimated weight of lift system components is presented in Table 5.4-ii. The total lift system weight is 46.6 LT.

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. The availability should be high since the ship can operate with any of the three independent fan sets.

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 MDC. 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.

WEIGHT OF LIFT SYSTEM - SWBS GROUP 119/248

LIFT SYSTEM	WEIGHT LT
SACM 195 V12 CZSHR DIESEL ENGINES (3) (Includes intake/exhaust system, fuel and lube systems, cooling water system, mounts and electronics)	28.40
LIFT FANS (6)	3.9
GEARS, SHAFTS, SUPPORTS, MOUNTS (3)	4.1
AIR DISTRIBUTION DUCTS AND VALVES	5.4
BOW SEAL	3.0
STERN SEAL	1.8
TOTAL LIFT SYSTEM	46.6

TABLE 5.4-ii

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 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.

The MDC electrical system is designed to provide electrical power as determined by an electrical load analysis of all the ship systems. From this it is estimated that the largest 60 Hz functional load will be 900 KW. For this electrical system loading a 60 Hz ship service generating plant consisting of three 500 KW generators has been selected. With either plant, the largest functional load can be supplied with one generator unit as standby. The 400 Hz power requirements are supplied by two 30 KW motor generator sets. Growth margins of 55 percent for 60 Hz and 20 percent for 400 Hz are provided.

5.5.2 Electrical System Description

The electrical system provides alternating and direct current power for normal ship's use, for engine cranking and for emergency. The location of the ship service generators is split, one generator set is located in the starboard fourth deck auxiliary space forward of the main machinery space. The two remaining units are located aft in the third deck port and starboard auxiliary spaces. Two watertight bulkheads separate all three generator units, thus eliminating requirements for an emergency generator.

Power generation is provided by three Caterpillar D-348 diesel engines driving three 500 KW, 450 volts, three phase, 1800 rpm 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 batteries to provide 28 volt direct current power for emergency radio, ship control system and emergency lights.

Power conversion to handle the 400 Hz loads is provided by two 400/60 Hz frequency motor generator sets, one unit for primary conversion and the second 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~~ 60 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

The weights for the major items: ship service generators, switchboards, motor generators and controls are based on vendor actuals. The remainder of the weight estimates have been calculated and cross checked against other known systems. 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 GROUP	ITEM	WEIGHT (LT)
311	Ship Service Power Generation	17.74
313	Batteries and Service Facility	1.21
314	Power Conversion System	1.55
315	Shore Power Receptacle	0.08
321	Ship Service Power Cable	6.91
322	Switch Gear and Panels	2.82
331	Light Distribution	0.32
332	Light Fixtures	3.49
333	Switches, Receptacles and Outlets	0.32
398	Electrical Plant Operating Fluids	0.32
399	Electrical Plant Repair Parts & Tools	0.10
	TOTAL ELECTRICAL SYSTEM	34.85

TABLE 5.5-i

5.5.4 Electrical System Risk Assessment

Electrical system design is based upon proven components in common usage. The Caterpiller D-348 diesel engine is used extensively in commercial applications and is marine qualified to Navy specifications. All MDC ship service electrical equipment is suitable for marine use and vibration levels and is compatible with all operating fluids. Technical risk is considered to be low and no special development is anticipated for this area.

5.6 COMBAT SYSTEM

The MDC as designed will augment the main surface forces, particularly in the Mediterranean and the Atlantic and Pacific. Capabilities of the MDC include surface, subsurface and air surveillance, detection, and attack of enemy forces. The MDC will have all weather capability, long range, good performance capability in high sea states and a significant speed advantage over conventional ships and submarines.

The combat systems described below have been chosen to meet these requirements though other systems could equally as well be engineered into the ship. With the proposed combat suite there remains sufficient space on the MDC to fit a surface to air missile system like Sea Sparrow. This would affect the ships full load displacement but only marginally affect ship performance. Heavier systems like the standard missile vertical launch could only be fitted at the expense of some other system.

5.6.1 Combat System Description

The sensor is the key to ASW as it relates to the MDC, whose role, is currently envisioned to be in the outer screen. The AN/SQR-19 is the passive sensor which in the time frame concerned will give good detection out to the second convergence zone (CZ) and in certain cases to the third CZ. The AN/SQR-19 will enable the Lamps III to have a high probability of sucessfully prosecuting a detection from this system. No ASW defense for self protection separate from the Lamps III is considered necessary because of the high speed of the MDC and the relative invulnerability when on cushion to the current torpedo threat.

Air targets can be detected by the Fire Control System (FCS) MK 92 MOD 1, the EW system 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 MDC, 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 MDC provides an engagement capability against patrol craft and small boats using the 76mm gun controlled by the MK 92 MOD 1 FCS. With HARPOON the MDC has 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 tne 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 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 MDC Combat System (SWBS Groups 4 and 7).

5.6.2.1 Radar Set AN/SPS-64(V)

The AN/SPS-64(V) which was selected as the surface search and navigation radar 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, and also used for transmitting emergency and altitude information for air control, and emergency signals for search and rescue purposes.

The AIMS MK XII IFF System consists of:

- o Two interrogators UPX-25(V)4
- o Transponder set AN/UPX-28(V)2
- o 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-6280Z/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 17 GHz. 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 MDC 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 to coordinate all ship's resources into an integrated combat system. The C^3 function 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.

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

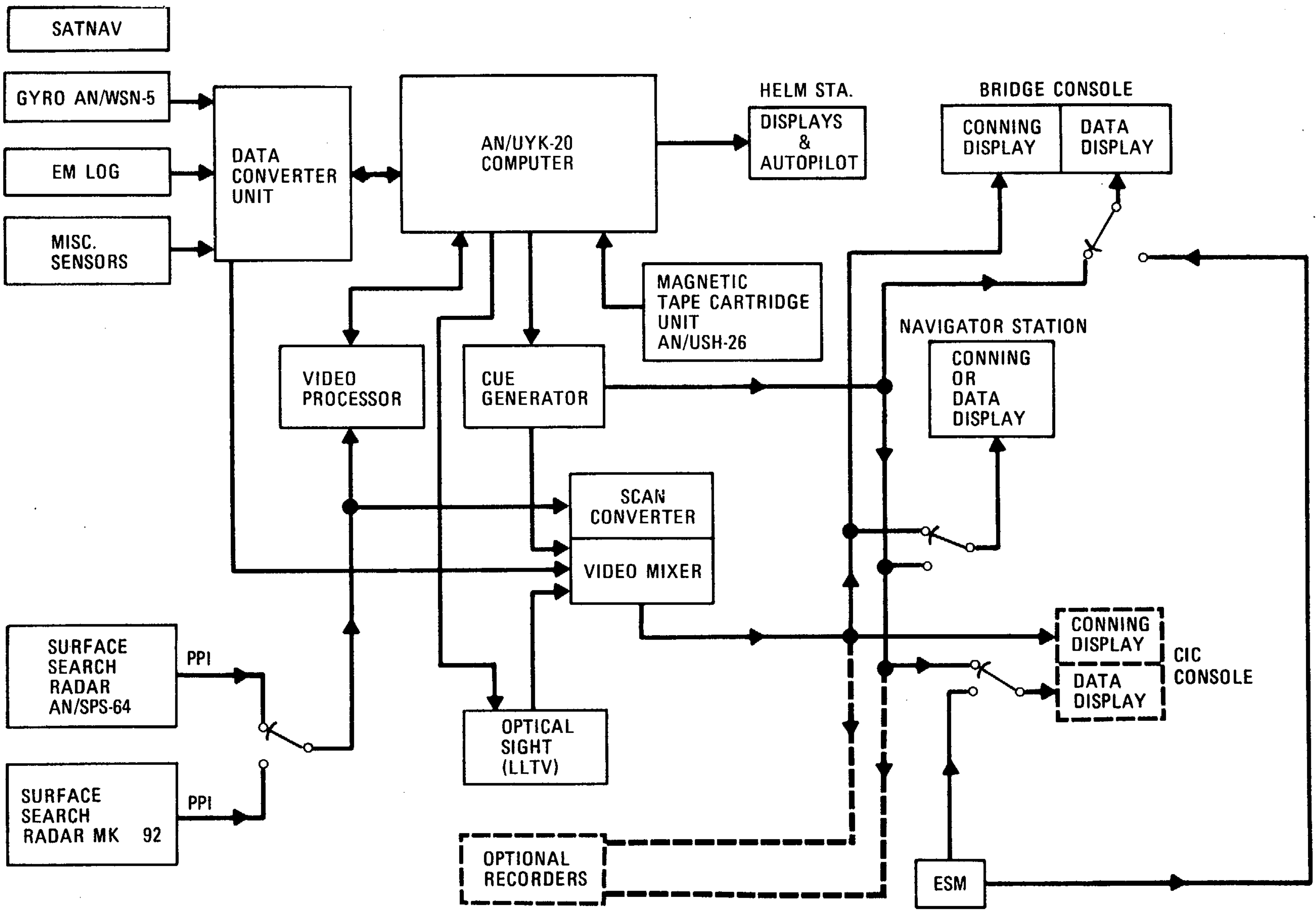
The Display Group consists of displays, support equipments and software programs which provide the interface between sensors, armament systems, data processing system and operators. The Display Group includes AN/UYQ-21 displays (Navy standard), Fire Control System displays (MK 92-WCC1), Radar Indicators,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

5.6.2.4.1.2 AN/UYQ-21 Standard Display Console

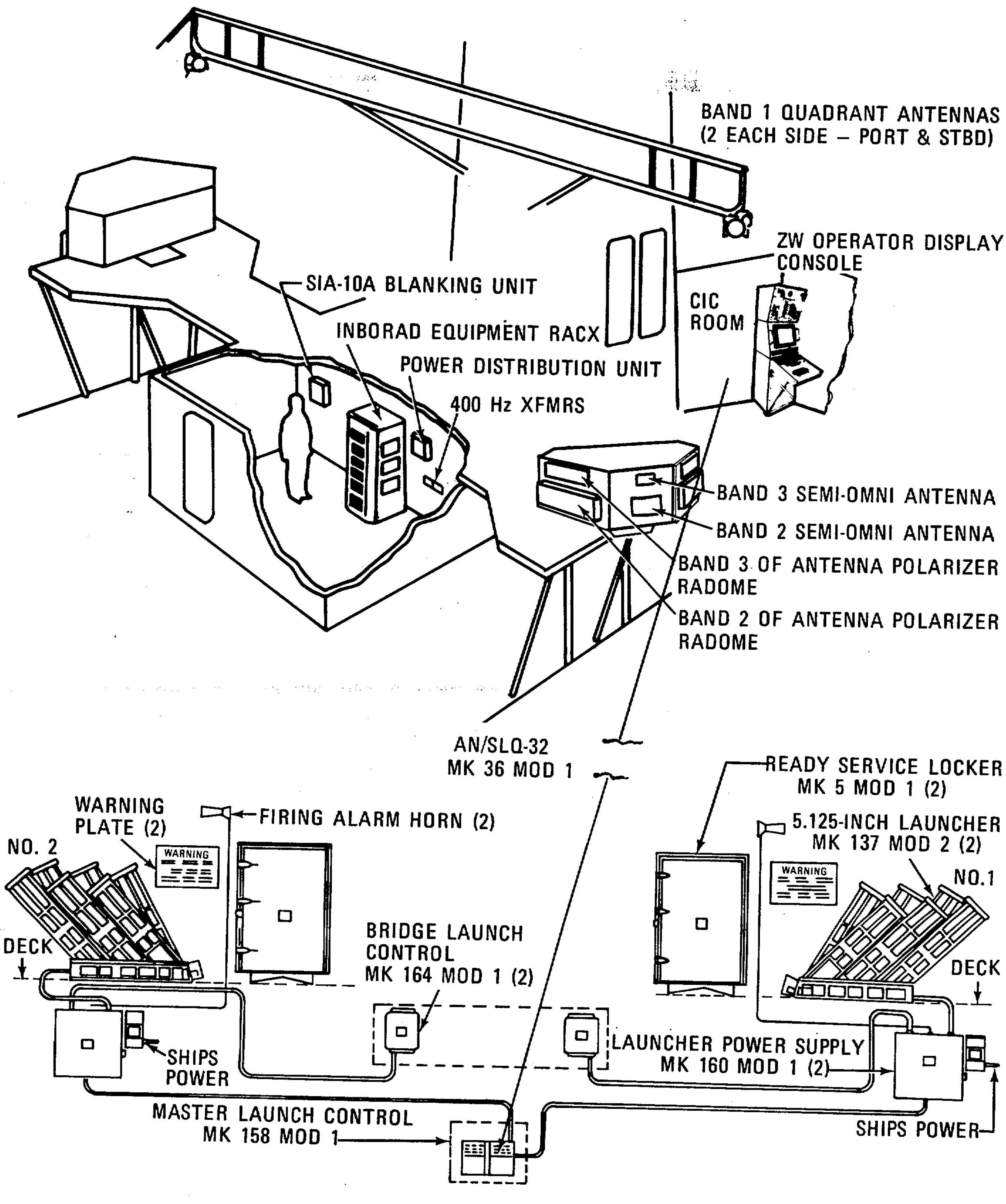
The Standard Display Console can accommodate a variety of entry and control panel types for tailoring to the requirements of a given application. The configurations are made up of a number of standard panels.

5.6.2.4.1.2 MK 92 - Weapon Control Console (WCC1)

Weapon Control Console (WCC1), 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 the 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.



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



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

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 this equipment 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 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 MDC 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 AN/UYK-7 computer. The computer has a software 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.

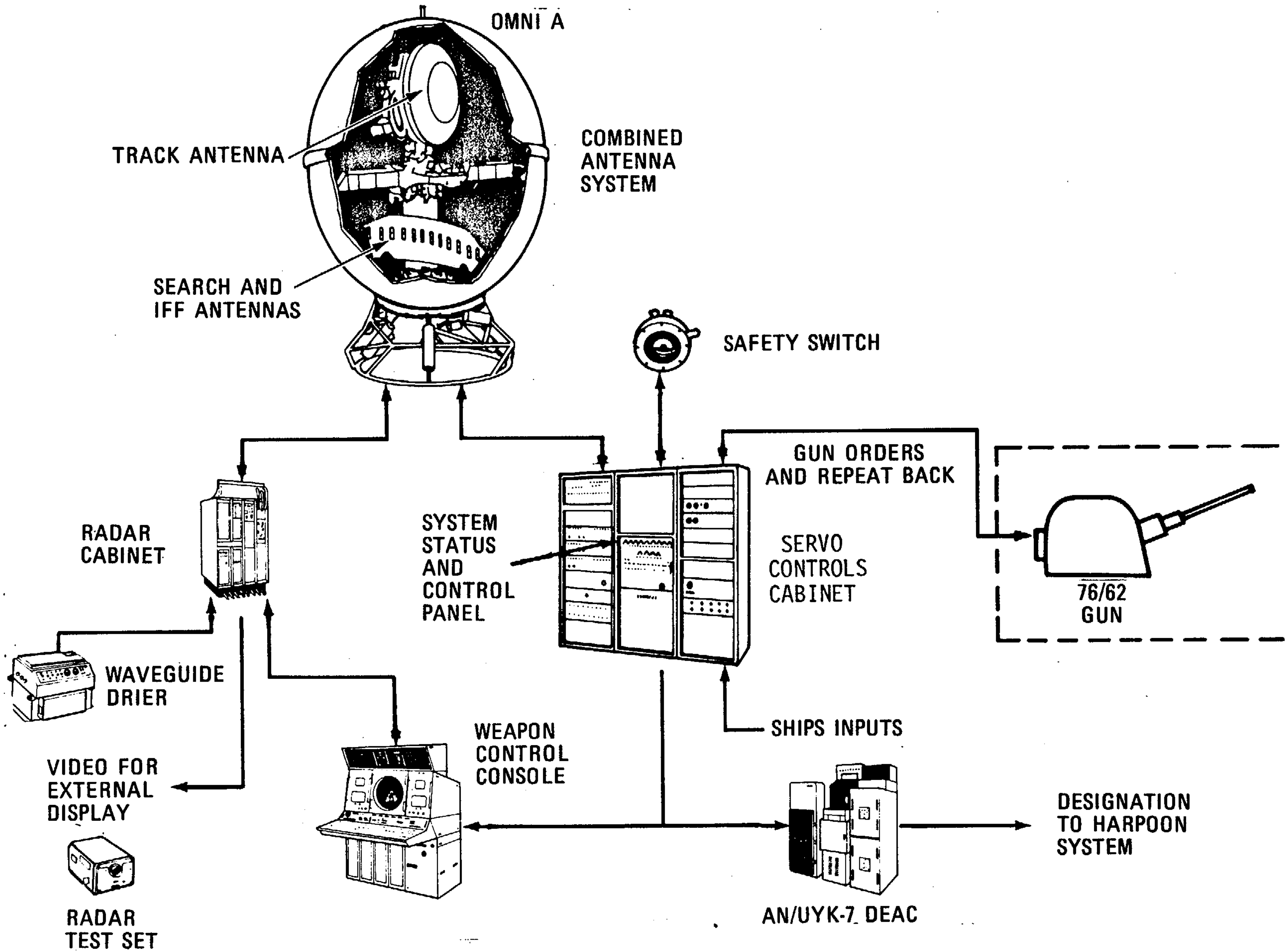
The following operational functions are provided by the Command and Control Software:

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 AN/UYK-7 Computer consists of the following modules:

- Central Processor Unit - Processes and executes instructions



MDC
FIGURE 5.6-3

FIRE CONTROL SYSTEM (MK 92 SYSTEM)

- 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 the 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 DEAC (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 the gyrocompass.

5.6.2.5.2 Satellite Navigation (SATNAV)

The Satellite Navigation system, which is a world-wide all-weather system, provides the MDC 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 from outside assistance at all times.

5.6.2.5.5 Ship's Data Equipment

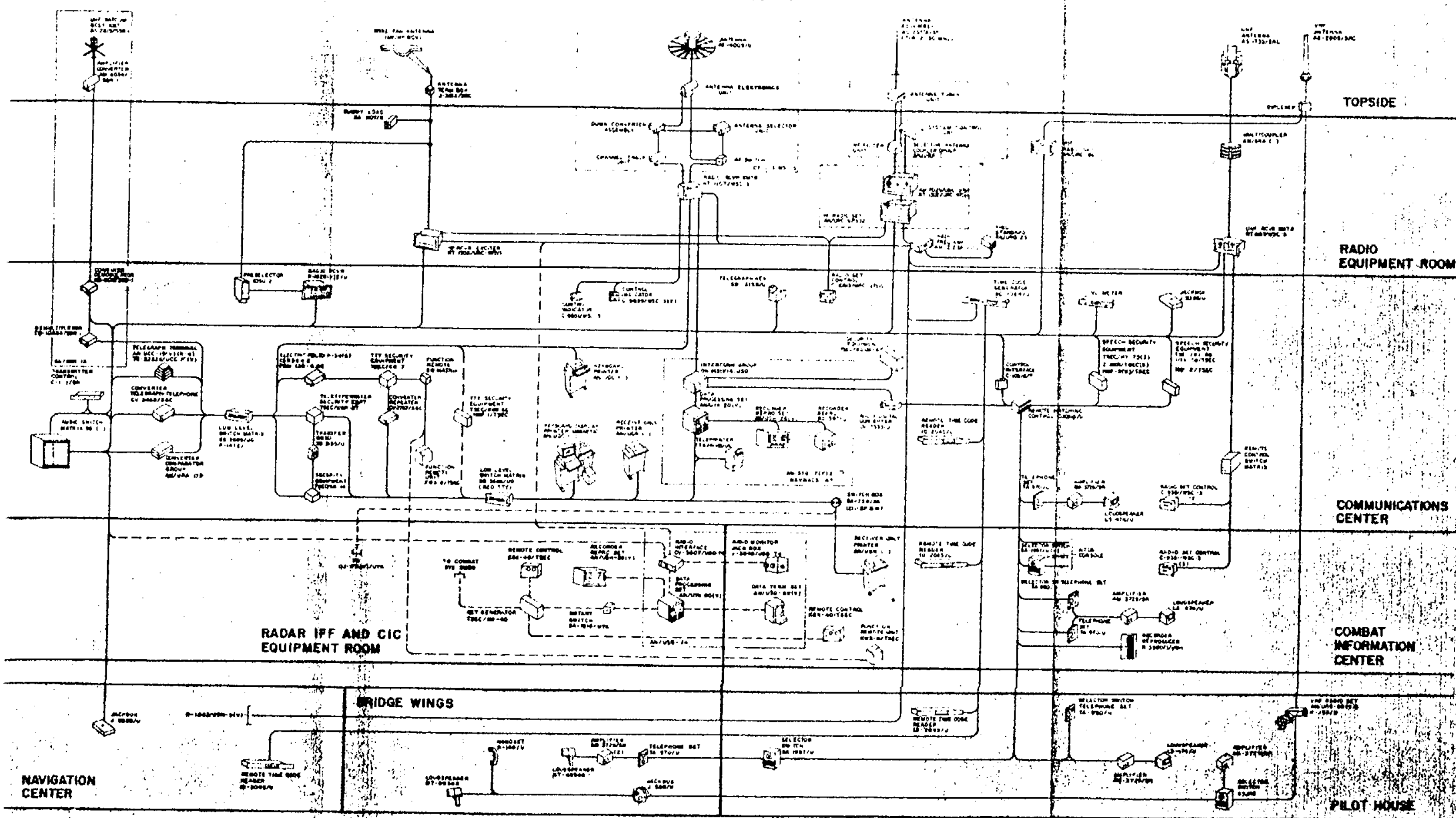
The Ship's Data Equipment consists of the Gyrocompass (previously identified), Wind Monitoring Equipment, and Depth Indicator. The Gyrocompass provides roll and pitch data for stabilization of Surveillance, Fire Control equipment and the ship control system. The Wind Monitoring Equipment provides wind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

5.6.2.6 Communications

The MDC 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.



NDC
FIGURE 5.6-4
EXTERIOR COMMUNICATION SYSTEM

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.

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

			QUANTITY
RADIO TRANSMITTING/TRANSCEIVER FACILITIES			
2.0 - 30		MHZ All Emissions (1KW)	4
115 - 156		MHZ A3	1
156 - 162		MHZ F3	1
225 - 400		MHZ A3/F3	6
225 - 400		MHZ Satellite Transceiver	1
RADIO RECEIVING FACILITIES			
0.5 - 30		MHZ A1, A2, A3, F1	1
2.0 - 30		MHZ All Emissions	6
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)	7
"S"	-	HF SC Secure Voice (Narrowband)	3
"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

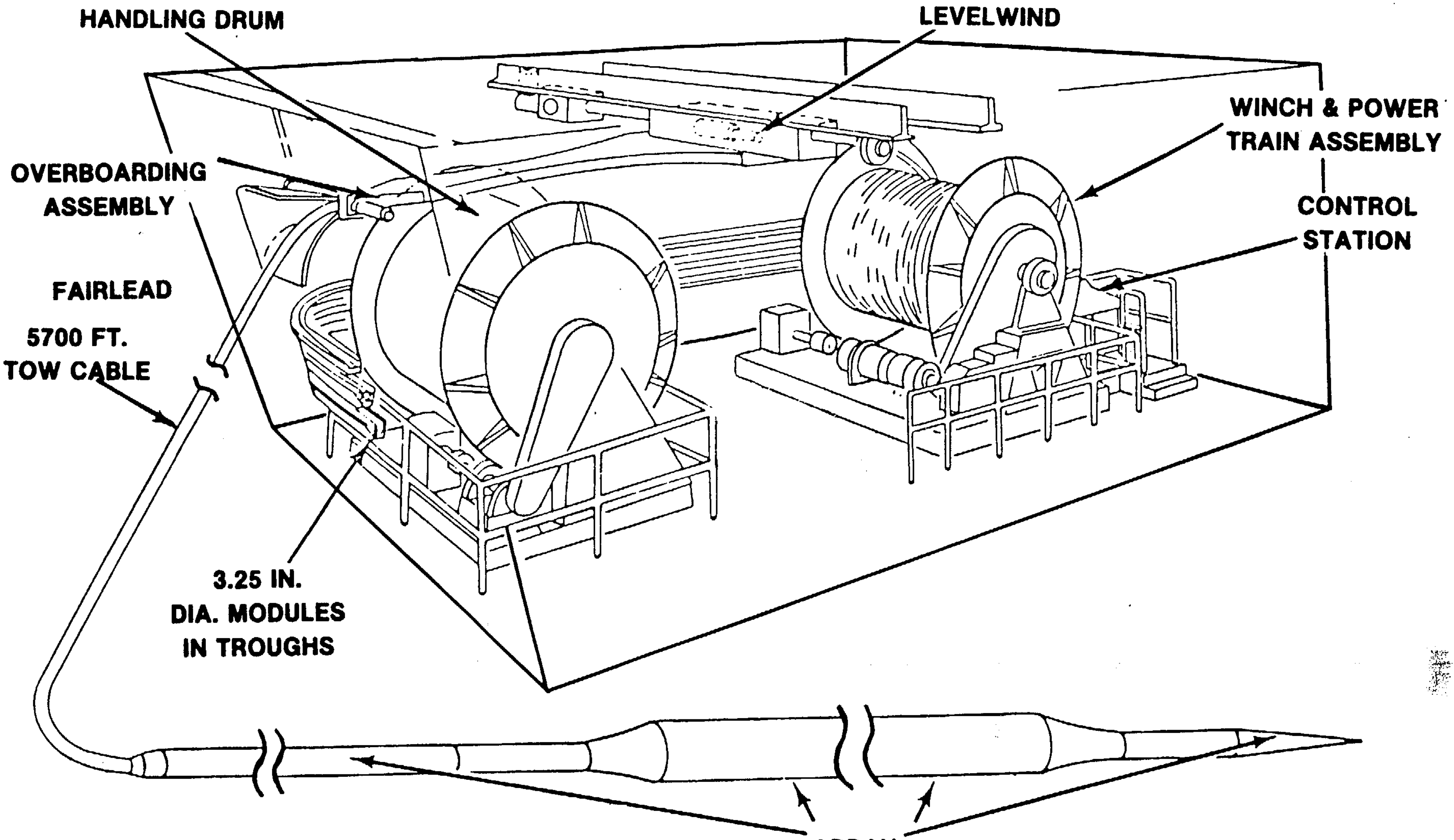
TABLE 5.6-i

5.6.2.7 Tactical Towed Array Sonar System AN/SQR-19 (TACTAS)

The AN/SQR-19 is a passive sonar system for surface vessels using a towed array acoustic sensor subsystem. The sonar is capable of detecting, classifying, and providing bearing estimation and bearing tracking of conventional and nuclear submarines, running torpedoes, and surface ships. When deployed, the system provides search and detection processing at all times for all azimuths.

The AN/SQR-19 is composed of three subsystems: Array, Handling and Storage Equipment (H&SE) and Ship-based Electronics.

(TACTAS)
HANDLING & STORAGE EQUIPMENT (H&SE)



MDC
FIGURE 5.6-5
AN/SQR-19 TACTICAL TOWED ARRAY SONAR (TACTAS) HANDLING AND STORAGE EQUIPMENT (HS&E)

The Array subsystem receives the acoustic signals and consists of:

a. A 316 foot line array of 96 hydrophone groups that form three nested acoustic aperatures; High (700 - 1200 Hz), Medium (350 - 700 Hz), and Low Frequency (140 - 350 Hz).

b. Non-acoustic instrumentation sensors to measure array depth (AD), array heading (magnetic) (AH), and water temperature; and a gain controlled signal amplifier, which accepts gain control commands from the ship based electronics subsystem (SESS).

c. A data handling electronic equipment for transmission of data and reception of commands from the tow ship via the coaxial tow cable.

The Handling and Storage Equipment (H&SE) subsystem provides for deployment, towing and retrieval of the cable and array. The H&SE consists of the following elements as shown in Figure 5.6-5.

a. Tow cable (5600 feet maximum)

b. Winch assembly and power train

c. Level wind assembly

d. Overboarding assembly and fairlead

e. Module storage troughs

f. Handling drum

g. Cable cutter

h. Control station

The Ship-based Electronics Subsystem (SESS) as shown in Figure 5.6-6 consists of equipments for signal processing, data processing, data storage, display/operator control, internal and external interfaces, performance monitoring/fault locating (PM/FL), and power distributions. This subsystem receives acoustic and non-acoustic signals from the array and provides power gain, and other control data to the array.

5.6.2.8 <u>Lamps Mk III Ship Electronics System (AN/SQQ-28)</u>

The Lamps MK III Ship Electronics System supports the Lamps Ship/Air Weapon System in performance of the primary missions of Anti-Submarine Warfare (ASW), and Anti-Ship Surveillance and Targeting (ASST). In addition secondary missions of Search and Rescue (SAR), communications relay, Medical Evacuation (MEDEVAC), and Vertical Replenishment at Sea are performed. It analyzes, processes, displays, and evaluates acoustic data received from the airborne sonobuoy receiver via the data link or from the ship board sonobuoy receiver, or both, or alternately the ASST sensor data received from the helicopter avionics via the same data link. The ship transmits tactical data to the helicopter for tactical direction and control. The Lamps Shipboard ASW System (SAS) interfaces with CIC for mission command primarily via the ASW Tactical Air Control Officer (ATACO). However, provision is also made for helicopter autonomous operation when beyond line-of-sight, under emission control (EMCON) conditions, or in the event of data-link failure. The remainder of this description deals with the Shipboard ASW part of the Lamps III system.

The Lamps SAS consists of Acoustic Signal Processing, Sound Recording and Reproducing, and Data Processor equipments. Source selection, signal distribution, signal conditioning, signal processing, and control and display functions are performed by these subsystems. The Data Processors also provides the message processing necessary to interface the Combat Direction System (CDS) with the airborne avionics system via the data link.

5.6.2.9 Sonar Signal Processing System (SSPS) AN/SQQ-28

This system accepts acoustic data and selects, records, reproduces, processes, detects, and displays the data as controlled by the Acoustic Sensor Operator (ASO). The SSPS is supplied with acoustic data from deployed sonobuoys in real-time, relayed from the helicopter through the shipboard data terminal, or as previously recorded acoustic sonobuoy data from magnetic tape. The SSPS accepts sonobuoy management data from the ATACO operating from the ship's Combat Direction System (CDS), analyzes the acoustic data supplied to it for discrete frequency, bearing, range, doppler, temperature, or sound pressure level data (as applicable); formats and displays the resulting information in a form the operator can analyze for target detection and classification, as determined by the system configuration, and transfers the resulting ASW tactical data to the CDS. The SSPS also manages Lamps Ship/Air data link communications. A display sharing capability with the shipboard Tactical Towed Array Sonar (AN/SQR-19) provides the ASO display. The ASO coordinates the helicopter sensor operation from one of the two AN/SQR-19 Acoustic Display Consoles (OJ-452(3)/UYQ-21) while AN/SQR-19 functions are continued, in a degraded mode, on the remaining console. This is possible through an operator controlled, software actuated, selection of either the AN/SQR-19 or the AN/SQQ-28 computer.

Acoustic processing capability aboard the ship will accommodate up to eight sonobuoys dependent upon sonobuoy type and processing mode selection. Combinations of the processing options are permissible within the replacement rules and receiver/processing channel restrictions specified. Three sources of acoustic data will be available as inputs for shipboard acoustic processing: data from the helicopter via the data link; data from the shipboard sonobuoy receiver; and data from a recorder/reproducer unit. The data will be selectable in one of the following three options:

a. Eight channels from the helicopter via the data link

b. Four channels from the helicopter via the data link plus four channels from the shipboard receiver.

c. Eight channels from a recorder/reproducer source.

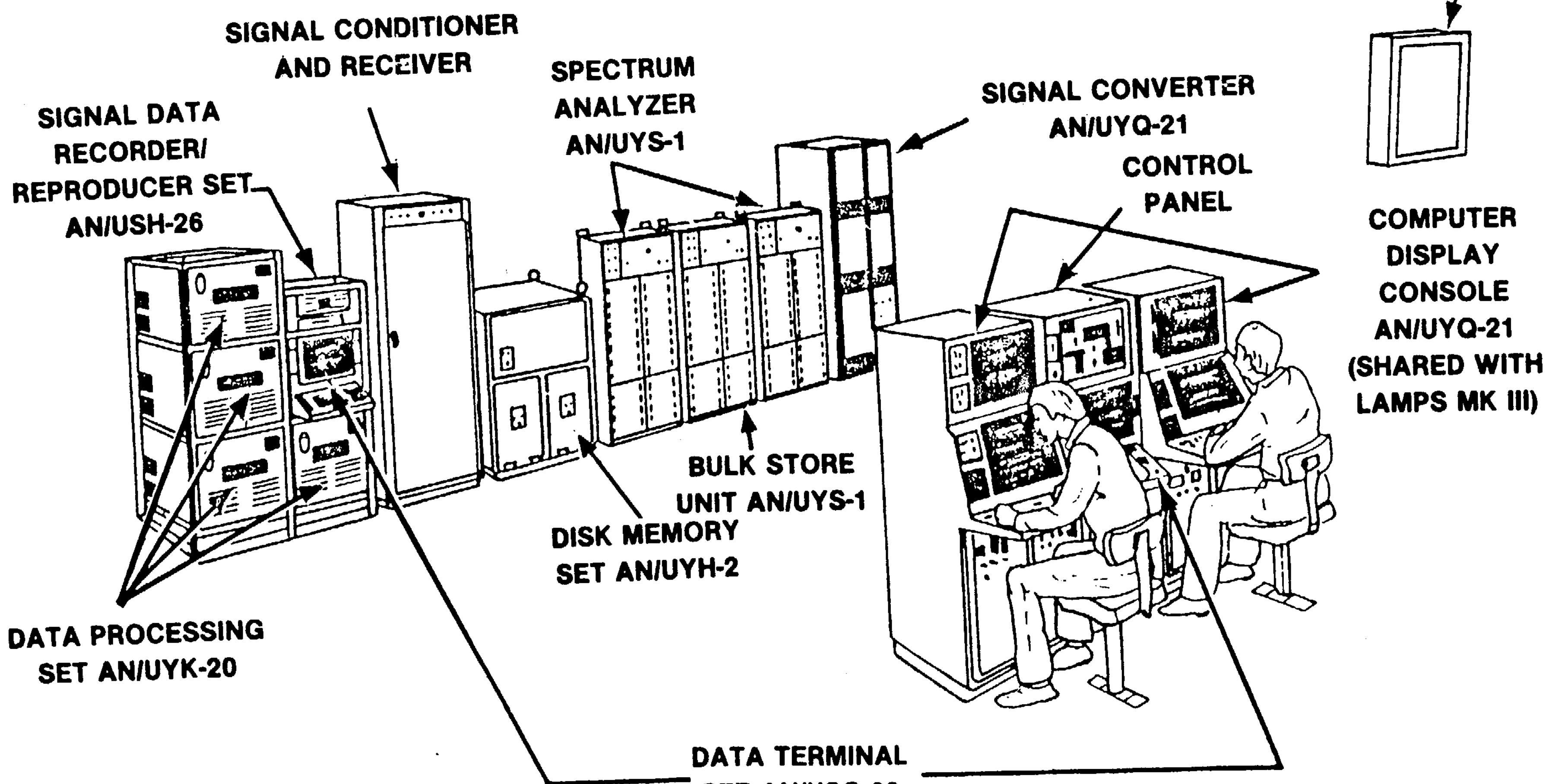
5.6.2.10 ASW Support Systems

5.6.2.10.1 Sonar Communication Set AN/WQC-2A

The Sonar Communication Set, AN/WQC-2A, is a single band, general purpose, voice/CW communications equipment, which provides communication between surface and subsurface vessels. The Sonar Communication Set consists of three major components and three transducers.

(TACTAS)

SHIP-BASED ELECTRONIC SUBSYSTEM (SES)



MDC
FIGURE 5.6-6
ANS/ AN/SQR-19 TACTICAL TOWED ARRAY SONAR (TACTAS) SHIP-BASED ELECTRONIC SUBSYSTEM (SES)

The Sonar Communication Set AN/WQC-2A is designed to provide voices and continuous wave (CW) communication in two (high and low) frequency bands which are used respectively for close and far range undersea communication. The Receiver-transmitter is normally operated from two Control Stations. The equipment is set to transmit from the transducers on either frequency band. Full or reduced transmission power may be selected depending on the distance from the receiving vessel.

5.6.2.10.2 Bathythermograph Set AN/SSQ-61

The Bathythermograph Set records ocean temperature versus depth. The set consists of expendable temperature-sensing Bathythermographs (Probe), a launcher and a Strip Chart Recorder. The Bathythermograph Set consists of three components:

a. Bathythermograph OC-14/SSQ-56 (XBT)

b. The Launcher MK-8577/SSQ-61

c. Recorder (Strip Chart) RO-326B/SSQ-56

The Bathythermograph probe contains a thermistor which is connected to a spool of wire. The wire is unreeled as the probe drops vertically through the water. The other end of the wire remains in the launcher. Changes in resistance of the thermistor due to temperature changes in the water are transmitted to the shipboard recorder through the wire and the launcher cable.

The chart-type recorder is programmed to convert time and thermistor resistance into depth in units of feet and temperature in degrees Fahrenheit. A continuous temperature/depth profile is traced on the chart as the probe descends. After 88 seconds, the temperature/depth profile has been recorded. One recorder chart roll is sufficient for 200 probe drops.

5.6.2.10.3 Sonar Sounding Set AN/UQN-4

The Sonar Sounding Set AN/UQN-4 is designed to measure the depth of water beneath the keel ranging from about 1 fathom to 6000 fathoms. The water depth is continually presented on a digital numeric display and may also be permanently recorded on a chart recorder which may be selectively disabled.

5.6.2.11 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.

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.

5.6.2.12 76mm/62 Gun Mount MK 75

The MK 75 gun mount shown in Figure 5.6-7 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.

5.6.2.13 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 5.6-8.

5.6.2.14 Decoy Launching System MK 36 MOD 1

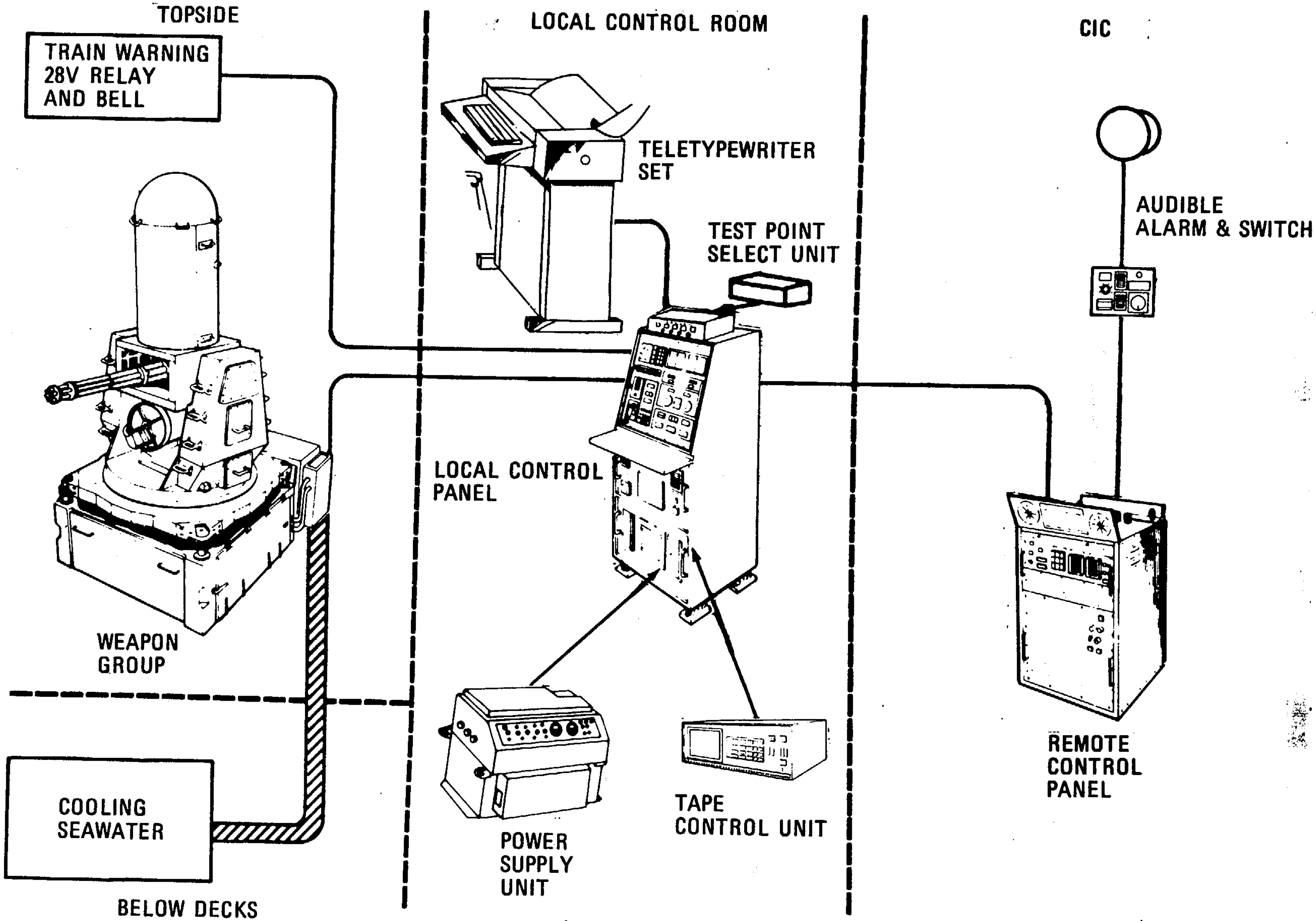
The Decoy Launching System MK 36 MOD 1 is a deck-mounted, mortar-launched, chaff countermeasure system used against a variety of threats. The purpose of the system is to project chaff aloft at specified distances from a ship for the purpose of confusing enemy guidance and fire control systems. Operationally, 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.

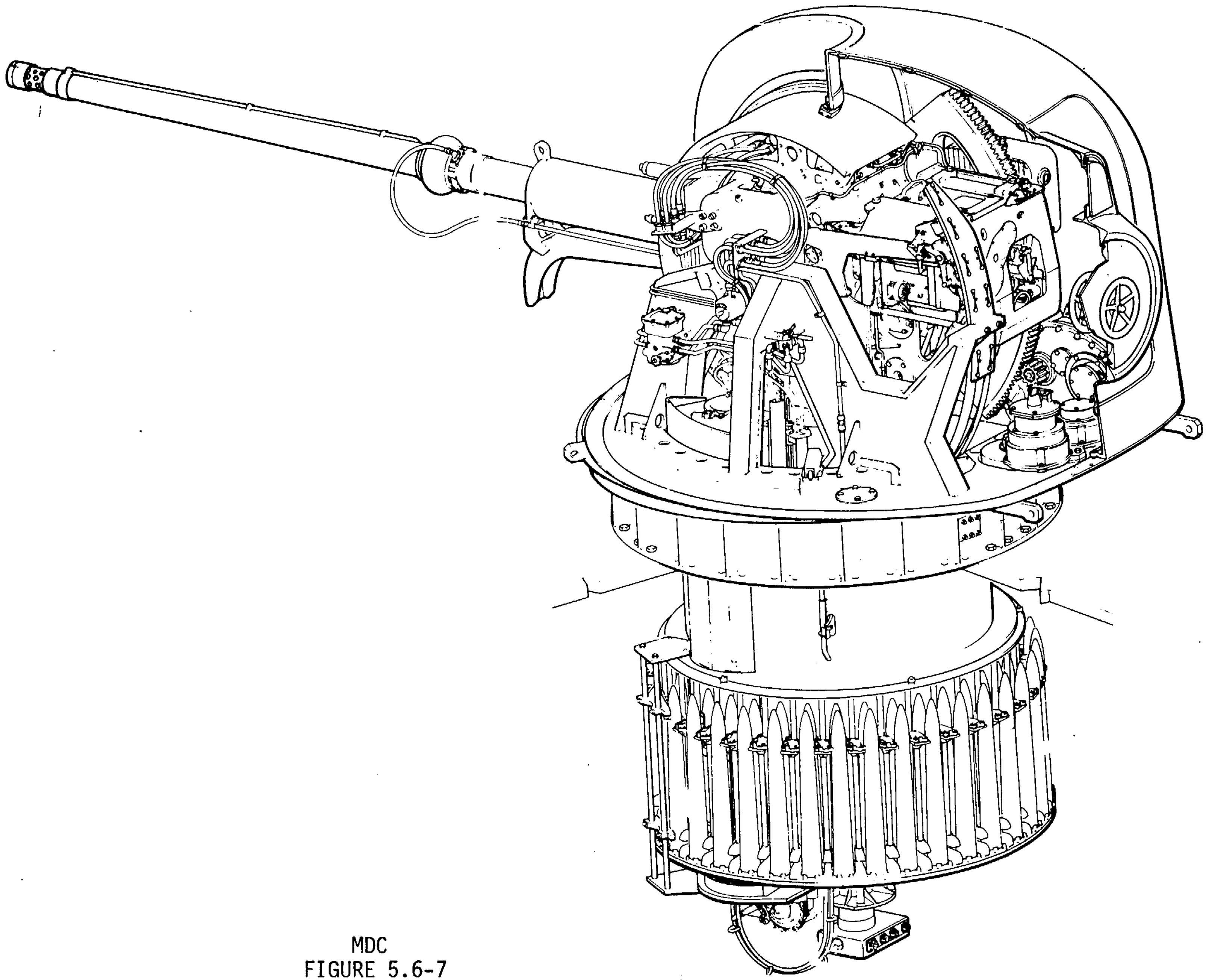
The ASMD/EW Decoy Launching System MK 36 MOD 1 is operated via the AN/SLQ-32(V) Display and Control Console (OJ-446/SLQ-32(V)). The authorization to dispatch chaff depends on the information provided by the ship's detection and threat analysis equipment. The Decoy Launching System also has bridge launching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

5.6.2.15 Harpoon Launchers

Two harpoon canister launchers are installed. Each launcher as shown in Figure 5.6-9 contains four harpoon missiles.



MDC
FIGURE 5.6-8
CLOSE-IN WEAPON SYSTEM INSTALLATION



MDC
FIGURE 5.6-7
76mm/62 GUN MOUNT, MARK 75 OVERALL VIEW WITH SHIELD SECTIONED

5.6.2.16 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

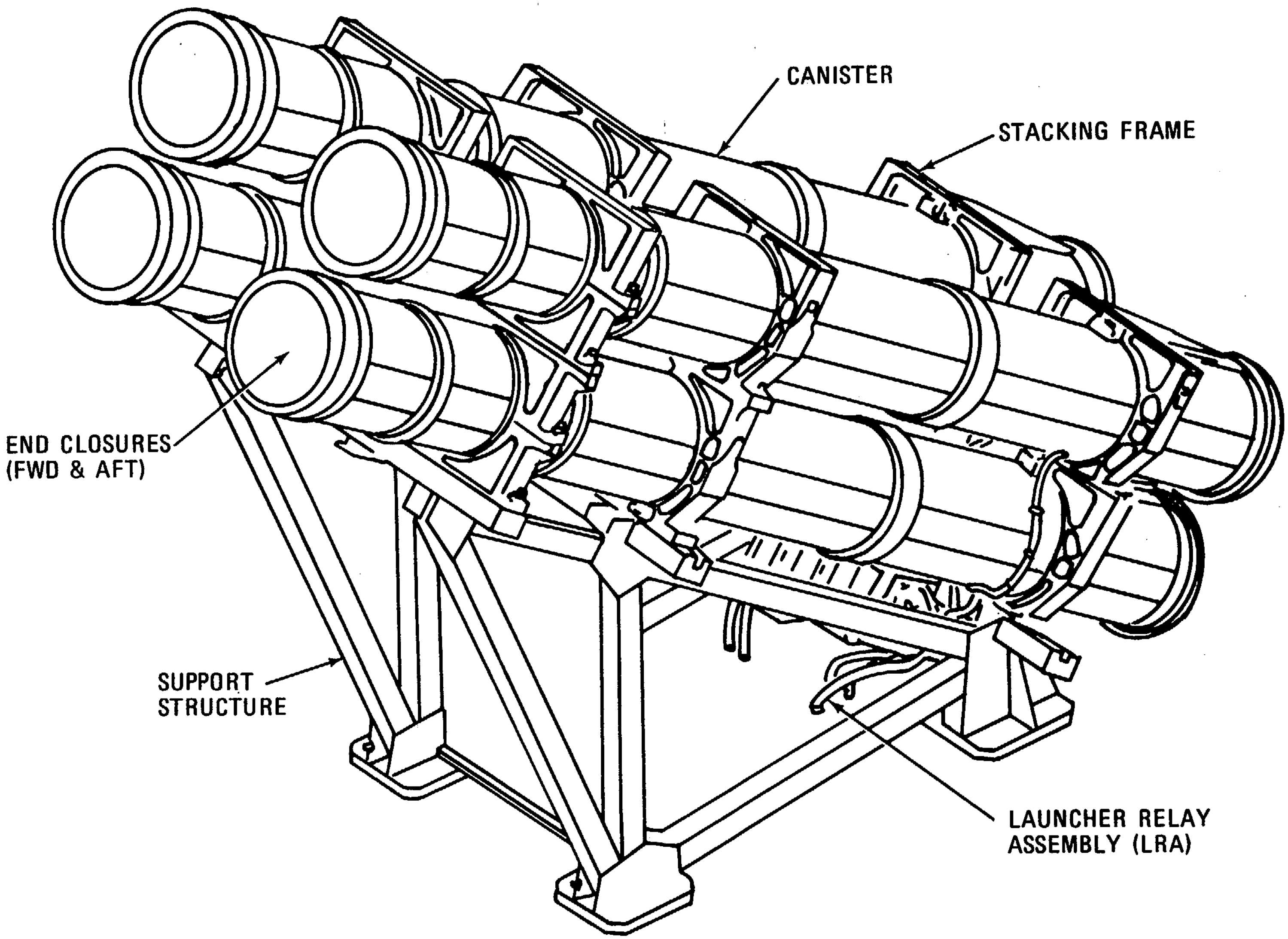
5.6.3 Combat System Weights Breakdown

The combat system weights are based on vendor supplied data, returned FFG-7 and PHM weighed weights, and detailed 3KSES combat system analysis. There are only minor changes necessary for the MDC installation. The 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. Table 5.6-v presents miscellaneous combat system weights associated with helicopter recovery and handling.

WEIGHT OF COMBAT SYSTEM - SWBS GROUP 400

SWBS GROUP	ITEM	WEIGHT (LT)
410	Command & Control	6.75
420	Navigation	5.51
430	Interior Communication	7.72
440	Exterior Communication	8.47
450	Surveillance (Surface)	1.15
460	Surveillance (Underwater)	17.51
470	Countermeasures	2.28
480	Fire Control System	7.16
490	Special Purpose	1.14
	TOTAL COMMAND & SURVEILLANCE	57.69

TABLE 5.6-ii



MDC
FIGURE 5.6-9
HARPOON CANISTER LAUNCHER

WEIGHT OF COMBAT SYSTEM - SWBS GROUP 700

SWBS	ITEM	WEIGHT (LT)
710	Gun Systems	14.01
720	Missiles Systems	2.63
750	Torpedo Stowage	3.64
760	Small Arms	1.27
780	Helo Weapon Handling	1.45
700	ARMAMENT	23.00

TABLE 5.6-iii

MDC WEIGHT OF COMBAT SYSTEM - VARIABLE LOADS

SWBS	ITEM	WEIGHT (LT)
F21	Ammunition	18.37
F22	Helicopter Torpedos	4.08
F23	SH-60B	11.61
F24	Ordnance Repair Parts	0.10
F26	Helicopter Support	9.94
F29	Sonobuoys	5.22
F42	Helo Fuel	22.5
F46	Other Fluids	0.46
		72.28

TABLE 5.6-iv

MDC WEIGHT OF COMBAT SYSTEM - MISCELLANEOUS

SWBS	ITEM	WEIGHT (LT)
586	Aircraft Recovery Support Systems with Aluminum Deck Track	12.5
598	Aircraft Handling, Servicing and Stowage	2.8
		15.3

TABLE 5.6-v

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 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 placed in the sidehulls in auxiliary machinery spaces located port and starboard on the third deck between frames 245 and 280, and port and starboard on the fourth deck between frames 145 and 195. These auxiliary machinery rooms contain major functional equipment such as the fuel distribution manifold and pumping systems, distilling plants, sea water pumps, sewage disposal system, air conditioning and central refrigeration machinery.

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.

Cabins, mess deck, lounges, CIC, electronic spaces, magazines, offices, commissary, sanitary, and control spaces are air conditioned by fan coil assemblies, duct cooling coils, input coolers for isolated locations, and gravity type cooling coils in areas where electric equipment is prohibited. The major air conditioner refrigeration machinery consisting of three R-12 35 ton units is located in the auxiliary machinery room on the fourth deck, starboard side. The ships vital air conditioning loads can be carried by one of these units.

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 Refrigerating Plants

Two refrigeration units are provided for ship's provisions each located adjacent to the reefers. Weights for this system are included in SWBS Group 638.

5.7.3.3 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. 1d.

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

5.7.3.4 Fresh Water Systems

Fresh water production and stowage is sized for a 110 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 3300 gallons per day each are provided. Hot water is provided by electric hot water heaters.

Fresh water stowage tanks of 4400 gallon capacity are provided for domestic use and additional 1000 gallon tankage is provided for gas turbine washing.

5.7.3.5 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 transfer system consists of electrically-driven main fuel pumps with filter coalescer systems valving and piping 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 service pump.

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

Aviation JP-5 for helicopter refueling is stored in dedicated tankage of 100 ton capacity. Separate service tank, pump and filter separators are also provided in accordance with Helicopter Facilities Bulletin Number 1d. A connection from the aviation JP-5 system is provided for emergency transfer of JP-5 to the ship fuel emergency 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.

5.7.3.6 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 two electrically driven 125 psi air compressors, each of 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. Starting air for diesel engines is provided from the high pressure air system through reducing valves with bypasses and starting air flasks at 3000 psi.

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.

5.7.3.7 Steering and Rudder 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.

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; orders 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.

5.7.3.8 Replenishment At-Sea Systems

The MDC 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 six inch hose rigs with saddles and trollies and span line supplied by the fueling ship. Two fuel probe receivers each are located port and starboard side on the 01 level amidship to receive fuel (diesel and JP-5) by probe and conventional methods. Maximum fueling rate is 120,000 gph for diesel fuel and 54000 gph for JP5.

Cargo and personnel transfer will be performed via highline rigging from port or starboard side on the 02 level amidship. 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. The forecastle is also suitable for Vertrep operations.

5.7.3.9 Mechanical Handling Systems

These systems comprise anchor handling and mooring and stowing.

An anchoring system capable of anchoring the MDC in a 70 knot wind and a 4 knot current in 240 feet of water will be provided. Bitts, chocks, mooring rings and bow and stern centerline chocks will be provided for mooring and towing operations. Weight estimates for these equipments are based on 3KSES design analyses.

5.7.3.10 Boat Handling and Stowage

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

5.7.3.11 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 garbage grinder is provided for the galley.

5.7.4 Auxiliary System Weight Breakdown

The weights are derived by scaling actual weights from other ships and by scaling the 3KSES estimated weights. The weight breakdown of the auxiliary subsystems is presented in Table 5.7-i.

AUXILIARY SYSTEMS WEIGHT - SWBS GROUP 500

SWBS	ITEM	WEIGHT (LT)
511	Compartment Heating	0.87
512	Ventilation	1.30
513	Machinery Spaces Ventilation	0.45
514	Air Conditioning	12.79
521	Firemain and Flushing	5.49
522	Sprinkler	0.18
523	Washdown	0.01
526	Scuppers and Drains	0.75
528	Plumbing Drainage	0.43
529	Drainage and Ballasting	2.06
531	Distilling Plant	3.12
533	Potable Water	3.81
541	Ship Fuel & Lube Stowage & Handling	1.95
542	Aviation Fuel System	0.22
551	Compressed Air	1.07
555	Fire Extinguishing	3.19
556	Hydraulic Fluid	0.53
561	Steering	1.60
562	Rudder	1.00
571	Replenishment At-Sea	0.39
581	Anchor & Stowage	4.13
582	Mooring & Towing	
583	Boat Handling & Stowage	1.89
584	Lamps and W. T. Doors	1.79
586	Aircraft Handling Equipment	12.51
589	Auxiliary Handling System	2.80
593	Environmental Pollution	3.74
599	Auxiliary System Parts & Tools	1.10
	TOTAL AUXILIARY SYSTEMS	69.17

TABLE 5.7-i

5.7.5 Auxiliary System Risk Assessment

All auxiliary systems selected are state-of-the-art and presently available, providing a reasonable basis for performance and weight estimates. No development effort or technical risk has been identified.

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 Ship Fittings

Deck stanchions for lifelines and awnings, liferails, frames for deck edge safety nets, jack and ensign staffs, scuppers and all other hull equipments covered by this section are of such construction and materials as to minimize weight and electromagnetic effects and be in accordance with Navy standard practice sizes.

5.8.3 Hull Compartmentation

Ladders, gratings, floor plates, windows, window wipers and washing system, metal joiner bulkheads, non-structural closures, and any other hull equipment covered by this section are based on past SES experience, extensive detail design and full scale testing of low maintenance light weight components conducted over the past ten years.

5.8.4 Preservatives and Coatings

Preservatives and coatings are in accordance with standard Navy practice for high performance ships.

5.8.5 Living Spaces

Living spaces, including recreation and lounge spaces, are outfitted and furnished with equipment in accordance with Navy specifications. Basic requirements are given herein for each category of personnel. Requirements for secondary equipment (e.g., soiled clothes lockers, drinking fountains and bulletin boards) are provided in accordance with the General Ship Specifications.

The commanding officer and executive officer are quartered in complexes consisting of a stateroom and bath. Ship department heads are provided single staterooms furnished with sanitary facilities. Ship junior officers are provided double staterooms and sanitary facilities.

Chief Petty Officers (CPOs) are quartered in double or single staterooms. A community-type sanitary facility is provided for the CPOs. A CPO lounge that is adjacent to the CPO living spaces is also provided.

Crew enlisted men berthing, sanitary and recreation spaces are arranged in coordinated complexes. The berthing spaces are outfitted with modular two and three high berths. Crew lockers are provided in adjacent spaces. Sanitary spaces are located adjacent to each group of eighteen berths. Crew lounges are provided for each group of living spaces.

5.8.6 Service Spaces

A central galley concept is provided with cafeteria type service aft for all enlisted personnel grades and sit down service forward for officers and NCOs. The crew mess line terminates within a separate messroom which is located, arranged, and equipped appropriately for the personnel served. Special care is taken that queue lines into the messroom and intra-compartment access are free of traffic conflicts. The total food service system is arranged and equipped as a fully coordinated complex around the galley to expedite stores handling, food preparation, food serving, operator traffic, and user traffic. It is properly interfaced with services, passageways, closures, and other ship systems. A large wardroom and CPO messroom each of which can accommodate all officers and NCOs during one serving period are located adjacent to the central galley.

The large crew mess also contains entertainment facilities, central stowage of library materials and a vending machine area. A ship store is provided with over-the-counter service. A medical treatment room is adjacent to the CPO living spaces. A centralized laundry facility is furnished with two 16 pound capacity washers, two 16 pound capacity dryers, three hand irons and ironing boards. A barber shop is furnished with suitable barber facilities.

5.8.7 Working Spaces

Furniture and equipment for office spaces, machinery and electronic control rooms, damage station, workshops and test areas comprise this group.

The Central Control Room contains both the ship's central machinery control and the damage control facilities. Damage Control (DC) Central contains the alarms and controls to permit centralized monitoring and control of the damaged status of the ship. Means of communication with the other DC spaces are provided. The Central Control Room is located in the aft section of the second deck.

5.8.8 Stowage Spaces

Furniture and furnishings for stowage space as required throughout the ships decks are in accordance with Navy practice or applicable specifications.

5.8.9 Outfit and Furnishings Weight Breakdown

Weights for the MDC were calculated from outfit and furnishings weights that were used in the 3KSES. Lightweight materials were used to minimize overall weight impact. Table 5.8-i provides estimated weights of outfit and furnishings for SWBS Group 600.

WEIGHT OF OUTFIT AND FURNISHINGS - SWBS GROUP 600

SWBS	ITEM	WEIGHT LT
611	Hull Fittings	1.2
612	Rails, Stanchions, Lifelines	2.3
613	Rigging & Canvas	0.5
621	Non-Structural Bulkheads	4.8
622	Floor Plates & Gratings	1.8
623	Ladders	0.9
624	Non-Structural Closures	1.2
625	Airports, Fixed Portlights, Windows	0.5
631	Painting	3.0
633	Cathodic Protection	0.1
634	Deck Covering	3.0
635	Hull Insulation	7.2
637	Sheathing	2.2
638	Refrigerated Spaces	1.5
641	Living Spaces - Officer	3.7
642	Living Spaces - CPO	1.0
643	Living Spaces - Enlisted	6.8
644	Sanitary Spaces & Fixtures	1.5
645	Leisure & Community	1.0
651	Commissary Spaces	4.1
652	Medical Spaces	0.5
655	Laundry Spaces	0.4
661	Offices	1.0
662	Machinery Control Centers Furnishings	0.3
663	Electronics Control Centers Furnishings	1.8
664	Damage Control Stations	2.0
665	Workshops	1.5
671	Lockers & Special Stowage	0.7
672	Storerooms & Issue Rooms	5.3
699	Repair Parts	0.1
	TOTAL OUTFIT & FURNISHINGS	61.9

TABLE 5.8-i

6 MANNING AND HABITABILITY

6.1 MANNING CONCEPT

The operational/maintenance manning objective of the MDC is directed toward efficient manning. The importance of this objective is reflected in the fact that man power costs account for approximately 55 percent of the Life Cycle Cost (LCC) of an average ship. Additionally, according to the Bureau of Labor Statistics, there will be a decline of approximately 2.2 million males in the prime service age group during the 1980's making it vitally important to efficiently utilize the available man power. The primary concepts considered to achieve this objective were:

a. Use of minimum essential military crew to safely operate and maintain the ship's systems and equipments

b. Utilization of available remote and automatic operation of machinery

c. Utilization of automated condition monitoring systems in mission essemtial electronics and machinery

d. Deferral of routine maintenance actions for in-port availabilities and shore facility maintenance support

e. Use of Reliability Centered Maintenance (RCM) analysis to identify preventive maintenance requirements that affect operating safety and military missions of the ship in order to support deferral of maintenance actions for in-port availabilities

f. Implementation of a component and module replacement strategy for operational and corrective maintenance of critical equipments

g. Utilization of shore facility assistance for accomplishment of corrective, preventive, and facility maintenance requirements

h. Expanded accessibility of components and systems for easier removal and installation during maintenance performance.

A three step methodology was utilized to develop a conceptual projection of manning requirements for the MDC:

(1) Conduct a parametric evaluation of similar ship types,

(2) Conduct a computer analysis utilizing NAVSEA's Manpower Determination Model (MDM), and

(3) Perform a watchstation/support requirements evaluation (without maintenance requirements) in a manner similar to the Preliminary Ship Manpower Document (PSMD) development process.

The first two stages of the analysis were conducted without application of the concepts above and reflect the impact of widely differing manning philosophies, ship configurations, maintenance requirements and operating profiles. The final stage of analysis after a synthesis of these results was the incorporation of the MDC objectives and concepts.

The parametric analysis evaluated ten ships from seven different countries (Israel, USSR, Italy, Saudi Arabia, France, Denmark, and USA) on the basis of full load displacement, weapons systems, speed, and range. A subjective ranking of the ten ships was developed based upon these characteristics and weighted mean crew size computed. The parametric crew size was 74 men with a standard deviation of 33 or a crew size ranging from 41 to 107.

The MDC was then evaluated using the Manpower Determination Model as a weaponized, conventionally manned, self-supporting ship. The MDM manpower requirement estimates were developed based upon a comparison of projected MDC equipments with similar equipments and systems currently in use in the Fleet and contained in the MDM data base. The projected crew size for a weaponized MDC was 133 men plus or minus five percent.

The final stage in the determination of manpower requirements was a synthesis of the parametrics, the MDM results and the previously described maintenance concepts with a determination of actual watchstation and support personnel requirements. This final phase of the analysis of manpower requirements resulted in a crew of 99 men. This crew size of 99 men is a very preliminary estimate that will be updated during follow-on ship design phases. Projected Condition I and Condition III watchstations with the associated support requirements are shown in Tables 6.1-i and 6.1-ii. Figure 6.1-1 through 6.1-6 detail a projected departmental organization by rank, rate and rating. Table 6.1-iii summarizes the projected departmental manning. Table 6.1-iv provides the variable loads weight estimate. To allow for growth, MDC habitability arrangements were sized for 109 accommodations. In addition, even with 109 accommodations many berthing spaces do not have the full complement of bunks. Adding these berths would allow 16 additional personnel to be accommodated with no rearrangements or additional sanitary spaces for a total complement of 125.

CONDITION I WATCHSTATIONS

SHIP CONTROL

1. Commanding Officer
2. Ship Control Officer (SCO)
3. Navigator
4. Quartermaster of the Watch (OMOW)
5. Ship Control Console Operator (SCCO)
6. Lookout (Port)
7. Lookout (Starboard)
8. Signalman
9. Plotter/Talker
10. Talker
11. Helmsman/Repairman

INFORMATION CONTROL

12. Tactical Action Officer (TAO)
13. Combat Information Center (CIC) Supervisor
14. Surface Plotter
15. Air Plotter
16. Assistant Plotter
17. Surface Detector/Tracker
18. Air Detector/Tracker
19. Electronics Support Measures (ESM) Operator
20. Combat System Officer
21. GFCS Air Detector Tracker/CIWS Operator
22. GFCS Surface Detector Tracker/ Harpoon Operator
23. Sonar Supervisor/Standby Operator
24. Sonar Operator
25. ASW Talker
26. Air Tactical ASW Control Officer
27. Anti-Submarine Air Control

COMMUNICATIONS CONTROL

28. Radio Supervisor
29. Radio Operator
30. Radio Operator
31. Messenger

ELECTRONIC CASUALTY CONTROL

32. Radar Equipment Repair
33. Communications Equipment Repair
34. Fire Control Equipment Repair
35. Sonar Equipment Repair

WEAPONS CONTROL

36. 76 mm Control Console Operator
37. 76 mm Handling Room Supervisor
38. 76 mm Ammo Handler
39. 76 mm Ammo Handler
40. SRBOC Loader

ENGINEERING CONTROL

41. Engineering Officer of the Watch (EOOW)
42. Propulsion/Lift Console Operator
43. Damage Control/Auxiliaries/ Electrical Console Operator
44. Auxiliaries/Electrical Console Operator
45. Rover/Equipment Monitor
46. Rover/Equipment Monitor
47. Phone Talker
48. Interior Communications (IC)/ Gyro Equipment Monitor/Repair

DAMAGE CONTROL

49. Damage Control Assistant (DCA)
50. DC Central Plotter
51. DC Central Phone Talker
52. Repair 2 (Forward) Party Leader
53. Repair 2 Messenger/Talker
54. Repair 2 Scene Leader/Plugman
55. Repair 2 Nozzleman/Investigator
56. Repair 2 Number 1 Hoseman
57. Repair 2 Number 2 Hoseman
58. Repair 2 Nozzleman/Investigator
59. Repair 2 Number 1 Hoseman/ Utilityman
60. Repair 2 Number 2 Hoseman/ Utilityman
61. Repair 2 Electrical Repair/Plugmen

TABLE 6.1-i

CONDITION I WATCHSTATIONS (cont'd)

DAMAGE CONTROL (cont'd)

62. Repair 3 (After) Party Leader
63. Repair 3 Messenger/Talker
64. Repair 3 Scene Leader/Plugman
65. Repair 3 Nozzleman/Investigator
66. Repair 3 Number 1 Hoseman
67. Repair 3 Number 2 Hoseman
68. Repair 3 Nozzleman/Investigator
69. Repair 3 Number 1 Hoseman/ Utilityman
70. Repair 3 Number 2 Hoseman/ Utilityman
71. Repair 3 Electrical Repair/Plug-man

HELICOPTER DETACHMENT

72. Officer in Charge/Airborne Tactical Officer (ATO)
73. Assistant Officer in Charge/ Maintenance Officer
74. Pilot/Operations Officer
75. Pilot/Administrative Officer
76. Pilot/Division Officer
77. Pilot/Quality Assurance Officer
78. Crew Chief
79. Crewman
80. Crewman
81. Crewman
82. Crewman
83. Crewman
84. Crewman
85. Crewman
86. Crewman
87. Crewman
88. Crewman
89. Crewman
90. Crewman
91. Crewman

HELICOPTER SUPPORT

92. Landing Signalman
93. Aviation Fuel Leader
94. Fuel Pump Operator
95. Ordnance Handling Team Leader

BATTLE DRESSING STATION

96. Medical Technician
97. Medical Assistant
98. Ship's Cook
99. Food Serviceman

TABLE 6.1-i (cont'd)

CONDITION III WATCHSTATIONS

SHIP CONTROL

1. Ship Control Officer (SCO)
2. Ship Control Console Operator (SCCO)
3. Quartermaster of the Watch (QMOW)
4. Lookout
5. Plotter/Talker

OPERATIONS CONTROL

6. Combat Information Center (CIC) Supervisor
7. Surface Detector/Tracker
8. Air Detector/Tracker
9. Electronic Support Measure (ESM) Operator
10. Gun Fire Control System (GFCS) Air/Surface Detector/Tracker
11. Sonar Operator

COMMUNICATIONS CONTROL

12. Radio Operator

ENGINEERING CONTROL

13. Electrical/Propulsion/Lift Console Operator
14. Rover/Equipment Monitor
15. Sounding/Security and Equipment Monitor

HELICOPTER DETACHMENT

16. Airborne Tactical Officer (ATO)/ Maintenance Officer/Pilot (6 Officers)
17. Crew Chief (1 CPO)
18. Crewmen (13 Enlisted)

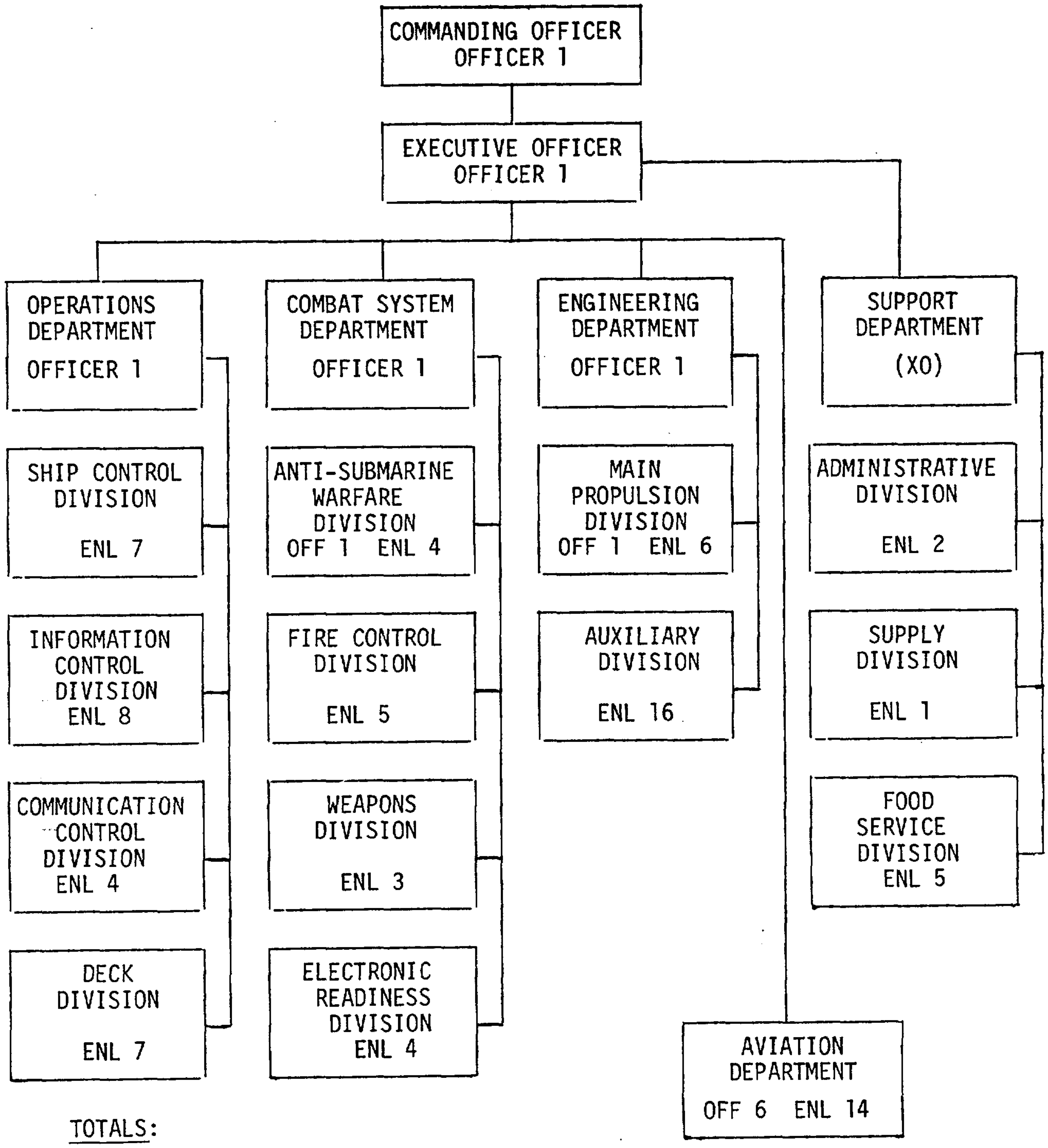
HELICOPTER SUPPORT

19. One (1) Officer
20. Five (5) Enlisted

TOTAL CONDITION III REQUIREMENTS:

Watchstations (15 x 3)	45
Helicopter Detachment/ Support	26
	71

TABLE 6.1-ii



TOTALS:

OFFICERS	13
CPO	5
ENLISTED (E1 - E6)	81
	99

FIGURE 6.1-1

MDC COMMAND ORGANIZATION

OPERATIONS OFFICER
LIEUTENANT JUNIOR GRADE

SHIP CONTROL DIVISION

QM1	1
QM3	1
QMSN	1
SM1	1
SM3	1
SMSN	1
SN	1

INFORMATION CONTROL DIVISION

OSC	1
OS1	1
OS2	2
OS3	3
OSSN	1

COMMUNICATION CONTROL DIVISION

RM1	1
RM2	1
RM3	1
RMSN	1

DECK DIVISION

BM1	1
BM2	1
BM3	1
BMSN	1
SN	3

TOTALS: OFFICERS 1 CPO 1 ENLISTED (E1 - E6) 25 = 27

FIGURE 6.1-2
OPERATIONS DEPARTMENT

COMBAT SYSTEM OFFICER
LIEUTENANT JUNIOR GRADE

ANTI-SUBMARINE WARFARE DIVISION

ENS (ASWO)	1
STC	1
ST1	1
ST2	1
ST3	1

FIRE CONTROL DIVISION

FTM1	1
FTM2	1
FTG2	1
FTGSN	1
SN	1

WEAPONS DIVISION

GMG1	1
GMG3	1
GMGSN	1

ELECTRONIC READINESS DIVISION

ET1	1
ET2	1
EW2	1
EWSN	1

TOTALS: OFFICERS 2 CPO 1 ENLISTED (E1 - E6) 15 = 18

FIGURE 6.1-3
COMBAT SYSTEMS DEPARTMENT

ENGINEERING OFFICER
LIEUTENANT JUNIOR GRADE

MAIN PROPULSION DIVISION

ENS (DCA)	1
ENC	1
EN1	1
EN3	1
ENFN	1
FN	2

AUXILIARY DIVISION

EMC	1
EM1	1
EM2	1
EM3	1
EMFN	1
EN2	1
EN3	1
ENFN	1
MM1	1
HT2	1
HT3	1
IC1	1
IC3	1
FN	3

TOTALS:

OFFICERS	2
CPO	2
ENLISTED (E1 - E6)	20
	24

FIGURE 6.1-4
ENGINEERING DEPARTMENT

AVIATION OFFICER
LIEUTENANT 1

ASSISTANT AVIATION OFFICER
LIEUTENANT JUNIOR GRADE

FLIGHT CREW	
LT	1
LTJG	3
AW2	2
AW3	1

MAINTENANCE CREW	
ADC	1
ADJ2	1
ADJ3	1
AE1	1
AE2	1
AE3	1
AMH2	1
AMS2	1
AT1/AX1	1
AT2/AX2	2

TOTALS:

OFFICERS	6
CPO	1
ENLISTED (E1 - E6)	13
	20

FIGURE 6.1-5
AVIATION DEPARTMENT

SUPPLY/ADMINISTRATIVE OFFICER
LIEUTENANT

ADMINISTRATIVE DIVISION	
PN1/YN1	1
HM1	1

SUPPLY DIVISION	
SK1	1

FOOD SERVICE DIVISION	
MS1	1
MS2	1
MS3	2
MSSN	1

TOTALS:

OFFICERS	0*
CPO	0
ENLISTED (E1 - E6)	8
	8

*Supply/Administrative Officer is a collateral function of the Executive Officer

FIGURE 6.1-6
SUPPORT DEPARTMENT

MDC ORGANIZATIONAL MANNING

ORGANIZATIONAL MANNING REQUIREMENTS DEVELOPED FOR THE MDC ARE:

OFFICERS	CPOs	OTHER ENLISTED	TOTAL
13	5	81	99

GENERAL APPORTIONMENT OF SKILLS IS AS FOLLOWS:

PETTY OFFICERS	-	74.4 percent
DESIGNATED STRIKERS	-	14.0 percent
NON-RATED TRAINEES	-	11.6 percent

PAY GRADE SUMMARY IS AS FOLLOWS:

E-7	-	5
E-6	-	19
E-5	-	21
E-4	-	19
DESIGNATED STRIKERS	-	12
NON-RATED TRAINEES	-	10

TABLE 6.1-iii

VARIABLE LOADS WEIGHT ESTIMATE

IN ACCORDANCE WITH NAVAL SHIP TECHNICAL MANUAL 1 NOVEMBER 1974
CHAPTER 096 PARAGRAPH 2.77

PERSONNEL	POUNDS PER MAN
Officers	400
CPOs	330
Enlisted	230

WEIGHT ALLOWANCES (CREW AND EFFECTS)

PERSONNEL	NUMBER	WEIGHT (POUNDS)
Officers	13	5,200
CPOs	5	1,650
Enlisted	81	18,630
	99	25,480

25,480 POUNDS = 11.4 LONG TONS (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 and Small Stores	0.07
Ship's Store	0.80
General Stores	1.06
	7.89

FOR 15 DAY MISSION

99 MEN x 15 DAYS x 7.89 LBS/MAN/DAY = 11,717 POUNDS
= 5.2 LONG TONS (LT)

TABLE 6.1-iv

6.2 HABITABILITY

Design of habitability arrangements for the MDC were performed during this analysis 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 standards were prepared utilizing requirements identified in OPNAVINST 9640 of 13 October 1979. The resulting design goals and considerations were as follows:

a. Provide comfortable and attractive 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 future 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.

Crew Accommodations. Crew living spaces are located amidships on the second and third decks with officer accommodations just above on the main deck. This location is best for ride quality and noise isolation. The ship's berthing, sanitary spaces, and lockers total 6076 square feet compared to 6115 square feet for the much larger FFG-7. This results in each man having 55 square feet of space compared to 33 square feet per man on the FFG-7. These attractively low crew densities are achieved without compromising overall ship displacement due to the inherent spaceousness of SES. It also means that if alternative MDC missions require increased manning there is plently of space available to substantially increase crew size. Messing and other crew support facilities are already large enough to accept these crew increases.

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 and convenience. Engineering spaces have been located fore and aft in each sidehull to provide for noise isolation and system separation for increased combat survivability. Shops and machinery central control are immediatly adjacent to the engineering spaces to reduce crew response time.

Ship Subsystems. The MDC allocates 7500 square feet of space to the ship's machinery subsystems. Some key features of this arrangement are:

(1) the location of engineering systems in the side hulls with the exception of small areas on the 2nd deck

(2) consolidation of ship's auxiliary machinery on the fourth deck to isolate noise sources

(3) gas turbines exhaust systems exit through the transom to minimize exhaust plume concerns

(4) full utilization of sidehull space for electronic equipment, provisions, spare parts, and general stowage

(5) aviation shops are located within the large helicopter hangers

(6) reserved spaces for addition of future systems.

Command and Control. The view from the pilot house and bridge wings 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. There is space on the main deck forward for the addition of an anti-air missile system such as the NATO Seasparrow. The main deck aft provides a very large uncluttered helicopter flight deck.

Flooding Prevention. The transverse and longitudinal watertight bulkheads are spaced to limit flooding caused by hull damage. The primary transverse watertight bulkheads are 0 (zero) 12, 45, 95, 145, 195, 245, 280 feet measured from the bow. The watertight longitudinal bulkheads are located 16 feet - 8 inches to port/starboard of the centerline. This major compartmentation arrangement offers very good damage survivability characteristics while providing a very functional general arrangement that offers design flexibility and efficient crew access to all areas of the ship.

7 LOGISTICS CONSIDERATIONS

7.1 MAINTENANCE AND MAINTAINABILITY CONCEPT

The ship system design will incorporate provisions which will maximize equipment utilization and minimize requirements for at-sea maintenance. The maintenance concept for meeting the objectives and availability goal of the MDC is:

a. Only perform operational and corrective maintenance on critical equipments aboard

b. Defer or schedule all non-essential equipments and components maintenance for in-port availabilities.

This concept of reduced maintenance will apply the principles of Reliability Centered Maintenance (RCM) analysis to identify preventive maintenance (PM) requirements that affect the ship's operating safety and military missions in order to reduce onboard PM requirements.

For design purposes, particular emphasis will be given to:

a. Maximum use of in service equipment items to permit use of standard maintenance procedures and supply support.

b. Use of performance and condition monitoring for detecting failures in critical equipments.

c. Provision for equipment accessiblity to support a component and module replacement strategy. The replacement strategy includes scheduled replacement, replacement on condition, and replacement at failure depending on the subsystem and equipment criticalities.

Ship systems will be designed to permit incremental overhaul of subsystems and subsystem accessories and related auxiliaries. Major maintenance actions will be accomplished by ashore maintenance activities during periodic upkeep and maintenance availabilities in accordance with ship utilization schedules. These maintenance activities will assist ship personnel in performing facilities maintenance (FM), preventive maintenance (PM), and corrective maintenance (CM).

Built-in test equipment will be used for electronics and control systems. 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 ship 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 requiring secondary structure rip-out or equipment removal.

The work load during regular overhauls will be minimized by intensive use of the upkeep periods as maintenance availabilities. The MDC will employ the concept of progressive equipment overhaul, replacement, and alteration during relatively frequent maintenance availability periods of short duration. Dry-docking will be planned for maintenance having a long periodicity as well as for underwater work. The ship system will be designed to be capable of incremental overhaul of its subsystems and subsystem accessories and related auxiliaries. Operational usage and scheduled replacement will be consistent with the major item replacement schedule. Equipment removal routes will be 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.

The operating and maintenance cycles which will determine MDC maintenance requirements are as follows:

<u>Operating Cycle</u>.	Sixty days of independent operation during which at least 7 days (5 of which will be consecutive) will be available in port for maintenance by ship personnel.
Maintenance and <u>Upkeep Cycle</u>.	Fifteen (15) days every 17 weeks will be available for restricted maintenance and upkeep at an intermediate maintenance facility.
<u>Overhaul Cycle</u>.	Ship Alteration and Repair periods of 30 days every two years will be planned at a depot level shipyard. Progressive overhaul concept will be used during maintenance and upkeep cycles to minimize regular overhaul requirements.

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.

7.2 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 MDC 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 60 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.

7.3 RELIABILITY AND AVAILABILITY

The reliability and availability requirements of the MDC will be high in order to minimize manning and at-sea maintenance requirements. Corrective maintenance will be performed on critical and mission essential equipments. Non-essential equipment maintenance will be scheduled for in-port availability periods. A full outfit of spares and repair parts will not normally be carried aboard the MDC, but replacement parts will be carried for mission essential equipments. Redundant equipments are fitted to assure continuous operation of the MDC by having parallel equipment in operation or by placing back-up equipment on line. Automatic monitoring systems will be used to indicate equipment malfunctions.

The following ship systems with established records in fleet marine usage have been selected to provide the high reliability and availability required by the MDC:

Propulsion System. Primary propulsive power is provided by four gas turbines which may be used either singly or in combination depending on the power requirement. They are available whether the MDC is cushionborne or hullborne. This gives considerable flexibility and redundancy at lower powers. Available also for propulsion when hullborne are either one or both of the after diesel engines. These are fitted primarily for driving lift fans but may be used for propulsion when off cushion to improve fuel economy and to give the MDC the flexibility of a CODOG system.

The gas turbines selected have been proven industrially and are marine qualified for salt-injestion to Navy specifications. The diesels are a successful widely used marine engine.

The port and starboard propulsion plants including prime movers, CODOG reduction units, shafting and controllable 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.

Electric Plant. Highly reliable diesels, proven components, and multiple switchboards are included. Two of the three 60 Hertz 500 KW generators adequately supply the full combat load enabling the third to be available on standby. Likewise, only one of the two 400 Hertz 30 KW motor generators will be required at any one time, the other remaining on standby.

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.

Lift System. In favorable sea conditions as few as two of the six fans can support the ship on cushion. This redundancy is reduced however if high speeds are required in adverse seas when all six fans may be desired. Off-cushion the ship will operate like any displacement ship. All equipment associated with the lift system has been selected for its reliability and availability. The fans are fitted in pairs, each pair being driven by one diesel.

The bow seals will be similar to the highly successful seals found on the SES-100B. Seal reliability will be further improved through ease of maintainability as the MDC seal will be two dimensional rather than three, as in the SES-100B. Additional reliability will be gained as the ship speeds are below those speeds considered critical to seal finger wear. Only about 10 percent of the time will the ship operate at speeds greater than 18 knots. Available test data on wear indicates that while finger wear never stops, there is a significant drop in wear rate at speeds below 60 knots. In tests, finger wear rate was measured at about 0.6 inches per hour at 70 knots, 0.06 inches per hour at 60 knots, and therefore only about .004 inches wear per hour is expected at 47 knots, the top speed of the MDC at its maximum continuous power. Ninety (90) percent of the ship's time at sea is expected to be at speeds in the 0 to 18 knot range where finger wear will be unmeasureable or the ship will be hull-borne, 10 percent of the time in the 18 to 47 knot range where erosion rate will be less than .004 inches per hour.

Auxiliary Systems. All systems are within the present state of the art and have been selected for their availability and previous marine record. Paralleling of equipments or redundancy is provided for in the design.

7.3.1 RMA Timeline

For analysis purposes, a 60 day deployment period (Wartime Cruising, Condition III) was chosen for an availability assessment. In addition, 24 hours of General Quarters Condition I) were used for the reliability assessment. Speed ranges of 0 to 14 knots, 14 to 18 knots, 18 to 31 knots and 31 to 47 knots were analyzed. Five "attack" modes, each identical to the Condition I profile, were inserted into the 60 day deployment period. Definitions of each mode timeline sequence, and respective time periods are found in Table 7.3-i for the Condition III mission profile. Table 7.3-ii provides the MDC mission profile for Condition I. Speed-time profile is shown in Figure 7.3-1.

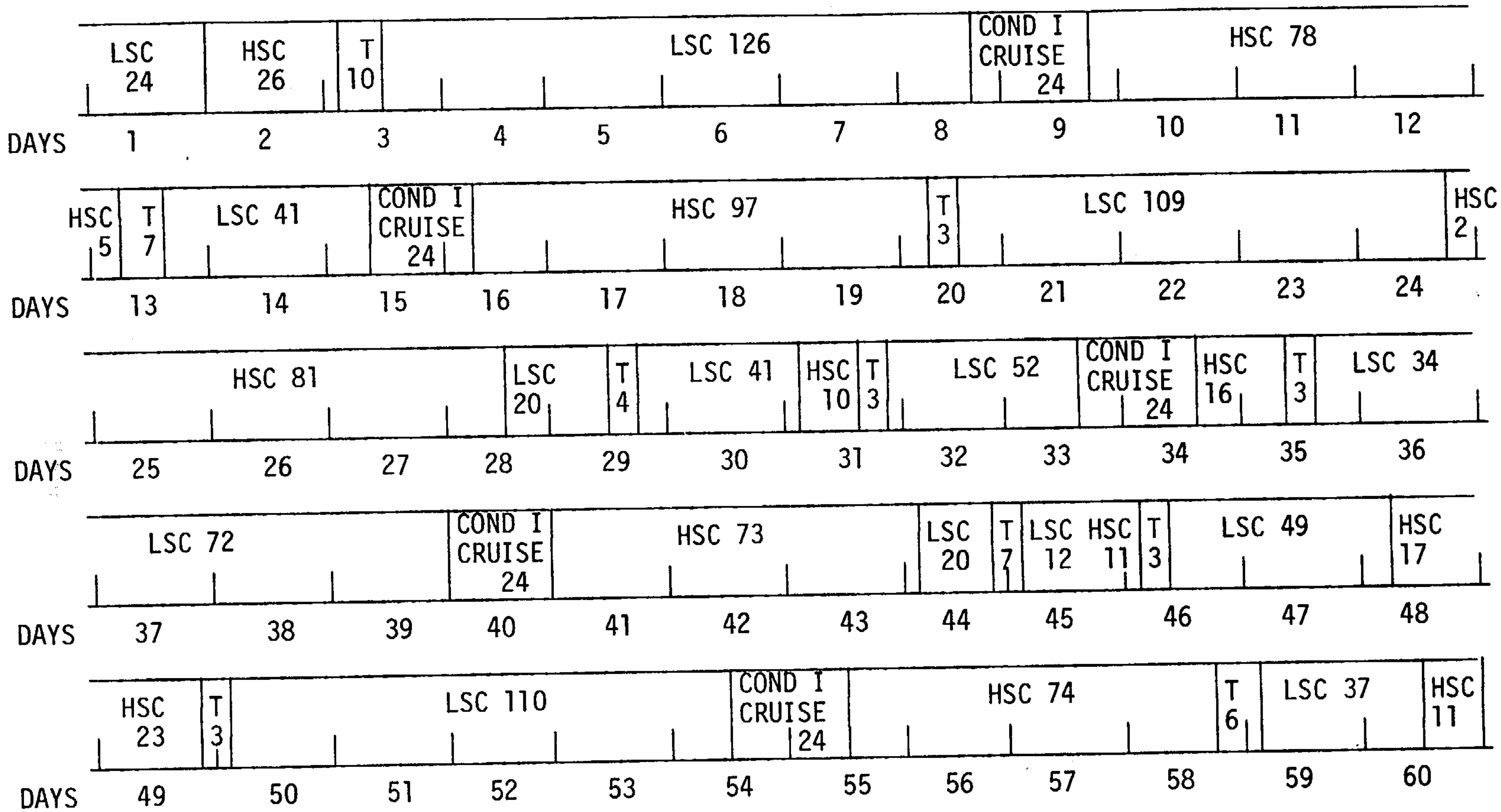
7.3.2 Analysis Approach

Given the equipment listing, reliability block diagrams (RBDs) were constructed for each equipment at the subsystem and system levels. While duty cycles were noted, they were not used in the calculation in order that the result be conservative. Additional equipment such as lubricating systems, intakes, etc., were added where they appeared to be necessary to system function. They were then serially "tied" together to reflect the demands of speed and sea state. Functional relationships for reliability and availability were then generated in order to determine platform values. The RBDs for the MDC platform with values of reliability and availability have been included as Figure 7.3-2. At the appropriate time NAVSEA's TIGER program will be used to generate a more complete assessment.

7.3.3 Results

Initial requirements for MDC deployment indicate that the minimum acceptable availability is .75, and the availability goal is .90. Figure 7.3-3 reflects the various combinations used for calculating the overall values of reliability and availability. In all instances the platform availability goal value of 0.90 has been exceeded.

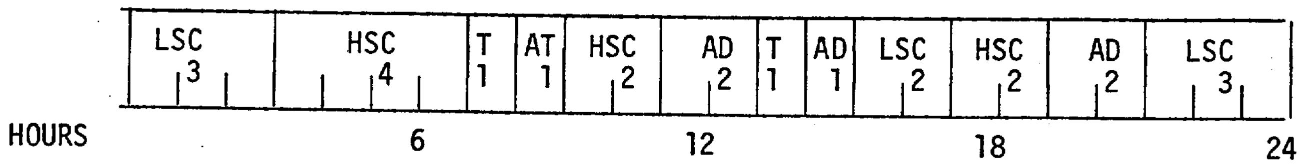
MDC MISSION PROFILE (CONDITION III - 60 DAYS)



MODE	DESCRIPTION	SPEED	SEA STATE	TIME (HOURS)	TIME (%)
LSC	Low Speed Cruise (Diesel)	0 - 18	≤ 4	747	51.9
HSC	High Speed Cruise (Diesels or 2 Turbines)	18 - 31	≤ 4	524	36.1
T	Transit (Turbines)	47	≤ 4	49	3.4
COND I CRUISE	Attack Mode	See Table 7.3-ii		120	8.3
				1440	100.0

TABLE 7.3-i

MDC MISSION PROFILE (CONDITION I - 24 HOURS)



MODE	DESCRIPTION	SPEED	SEA STATE	TIME (HOURS)	TIME (%)
LSC	Low Speed Cruise (Diesel)	0 - 18	≤ 4	8	33.3
HSC	High Speed Cruise (Diesels or 2 Turbines)	18 - 31	≤ 4	8	33.3
T	Transit (Turbines)	47	≤ 4	2	8.3
AT	Attack (Turbines)	47	≤ 4	1	4.3
AD	Attack (Diesels)	0 - 18	≤ 4	5	20.8
				24	100.0

TABLE 7.3-ii

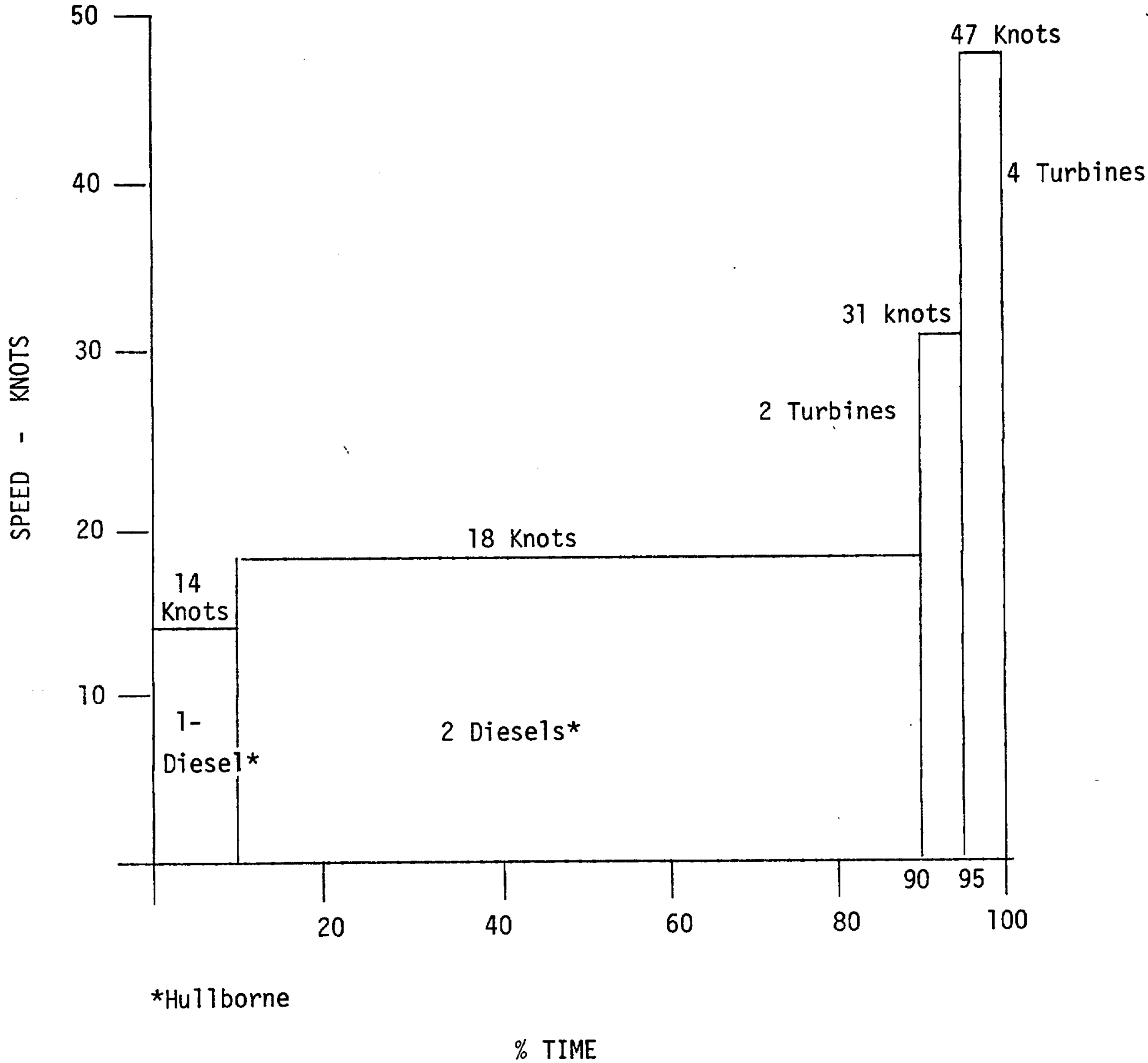
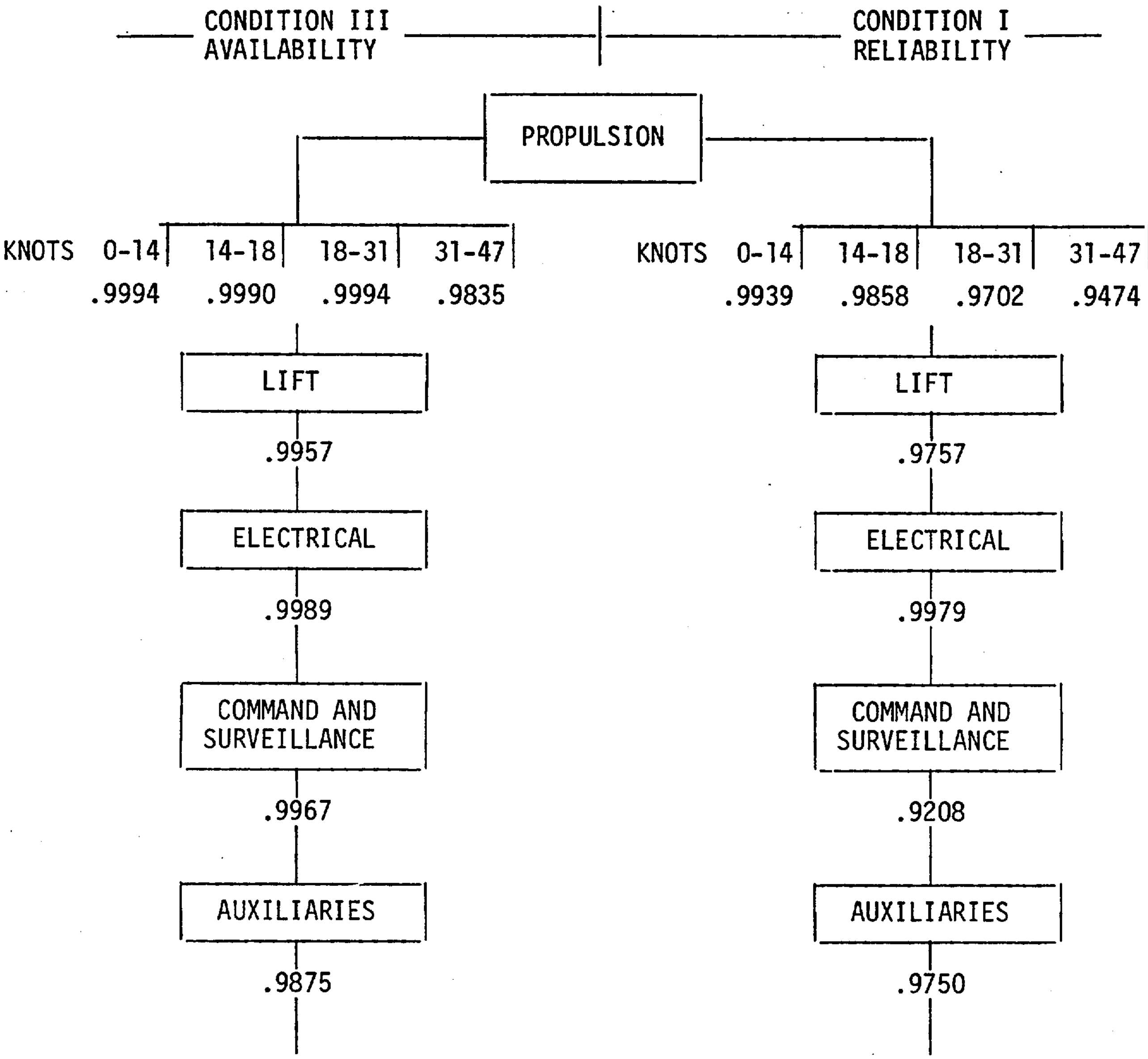


FIGURE 7.3-1
SPEED - TIME PROFILE



PLATFORM AVAILABILITIES		PLATFORM RELIABILITIES
.9783	0 - 14 KNOTS	.8688
.9780	14 - 18 KNOTS	.8617
.9783	18 - 31 KNOTS	.8481
.9628	31 - 47 KNOTS	.8281

FIGURE 7.3-3
PLATFORM AVAILABILITIES AND RELIABILITIES AS FUNCTIONS OF SHIP SPEED

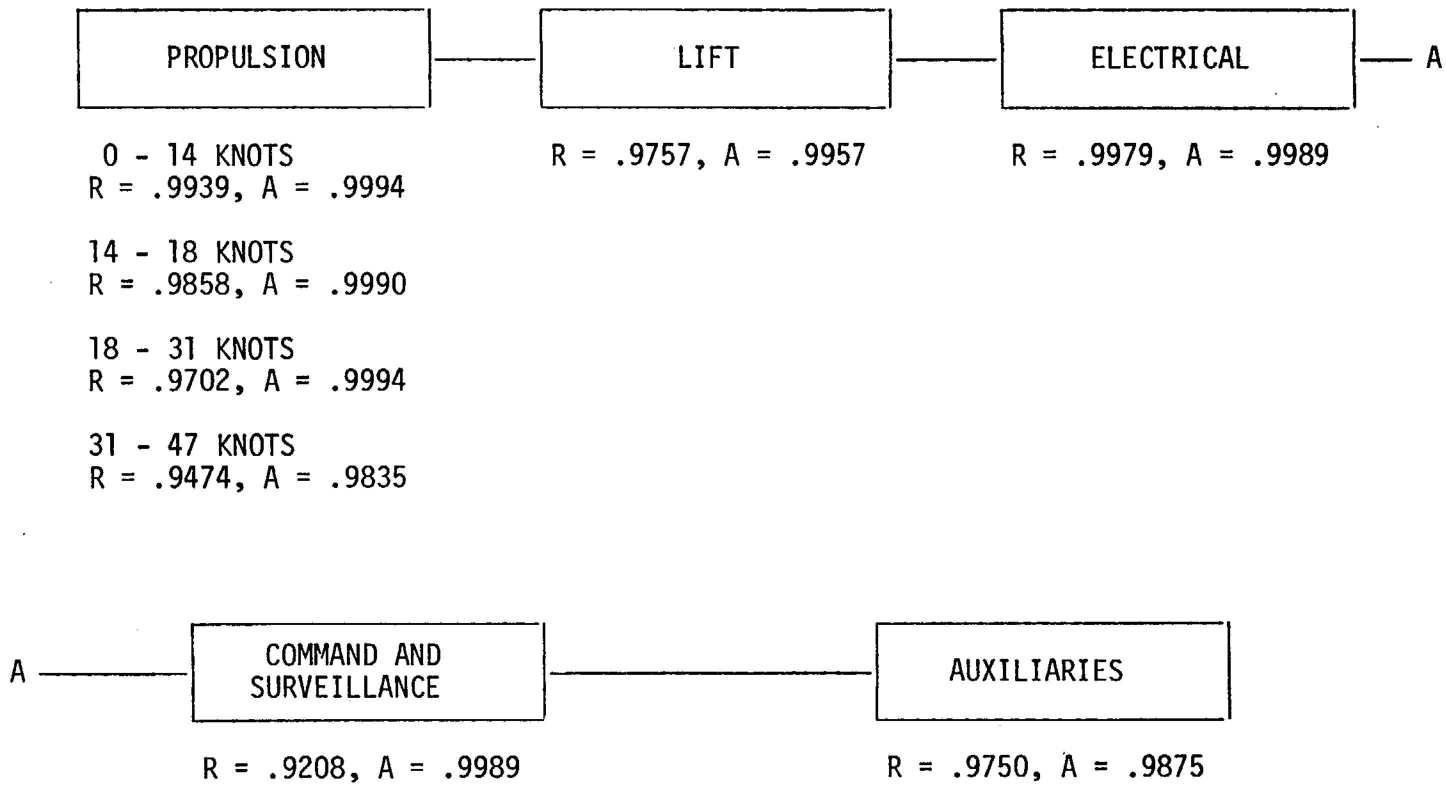


FIGURE 7.3-2

MDC PLATFORM RELIABILITY BLOCK DIAGRAMS