NSRP-SPC-SPE

NSRP 0200

A REPORT TO BATH IRON WORKS CORPORATION
ON
SHIP PRODUCIBILITY AS IT RELATES TO SERIES PRODUCTION

VOLUME II

SHIP DESIGN PROCESS

SUBMITTED TO:
BATH IRON WORKS CORP.
BATH, MAINE
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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

VOLUME II

PART 1

MIDSHIP CONFIGURATION

1.1 INTRODUCTION

Recognizing that the development of the midship section has a direct effect on the producibility of a given ship, the production characteris. tics of candidate sections were evaluated in order to determine the most advantageous configuration for producibility.

Using the basic principal dimensions of a model 150,000 DWT tanker, fourteen midship sections were initially reviewed and six were selected for detail development and analysis.

The IMCO rules for subdivision were considered in the design of the proposed sections, which were developed in accordance with the American Bureau of Shipping rules for tankers. The structural sections utilized for longitudinal stiffening are shown as tees, although inverted angles of comparable section properties can be satisfactorily substituted. This subject is addressed in greater detail in the "Structural Member Configuration" portion of the study, Volume II, Part 5.

1.2 IMCO REQUIREMENTS IMPACT

Those aspects of the IMCO requirements affecting structural arrangement are contained in Regulations 13 and 14, Segregated Ballast Oil Tankers, and Segregation of Oil and Water Ballast, respectively.

These regulations are stated as follows:

1.2.1 "Regulation 13 - Segregated Ballast Oil Tankers

a. Every new oil tanker of 70, 000 tons deadweight and above shall be provided with segregated ballast tanks and shall comply with the requirements of this Regulation.

b. The capacity of the segregated ballast tanks shall be so determined that the ship may operate safely on ballast voyages without recourse to the use of oil tanks for water ballast except as provided for in paragraph (3) of this Regulation. In all cases, however, the capacity of segregated ballast tanks shall be at least such that in any ballast condition at any part of the voyage, including the conditions consisting of lightweight plus segregated ballast only, the ship's draughts and trim can meet each of the following requirements:

1. The moulded draught amidships (dm) in meters (without taking into account any ship's deformation) shall not be less than:

$$dm=2.0+0.02L,$$

z. The draughts at the forward and after perpendicular shall correspond to those determined by the draught amidships (dm), as specified in sub-paragraph (a) of this paragraph, in association with the trim by the stern of not greater than O. 015 L, and ;

3. In any case the draught at the after perpendicular shall not be less than that which is necessary to obtain full immersion of the propeller(s).

c. In no case shall ballast water be carried in oil tanks except in weather conditions so severe that, in the opinion of the Master, it is necessary to carry additional ballast water in oil tanks for the safety of the ship. Such additional ballast water shall be processed and discharged in compliance with Regulation 9 and in accordance with the requirements of Regulation 15 of this Annex, and entry shall be made in the Oil Record Book referred to in Regulation 20 of this annex.

d. Any oil tanker which is not required to be provided with segregated ballast tanks in accordance with paragraph (1) of this Regulation may, however, be qualified as a segregated ballast tanker, provided that in the case of an oil tanker of 150 meters in length and above it fully complies with the requirements of paragraphs (2) and (3) of this Regulation and in the case of an oil tanker of less than 150 meters in length the segregated ballast conditions shall be to the satisfaction of the Administration. ''

1.2.2 "Regulation 14 - Segregation of Oil and Water Ballast

a. Except as provided in paragraph (2) of this Regulation, in new ships of 4, 000 tons gross tonnage and above other than oil tankers, and in new oil tankers of 150 tons gross tonnage and above, no ballast water shall be carried in any oil fuel tank.

b. Where abnormal conditions or the need to carry large quantities of oil fuel render it necessary to carry ballast water which is not a clean ballast in any oil fuel tank, such ballast water shall be discharged to reception facilities or into the sea in compliance with Regulation 9 using the equipment specified in Regulation 16(2) of this Annex, and an entry shall be made in the Oil Record Book to this effect.

c. All other cases shall comply with the requirements of paragraph (1) of this Reglation as far as reasonable and practicable."

1. 2.3 Derived Draft and Trim

Paragraph (c) of Regulation 13 governs the design, with a draft aft of 34 feet and a draft forward of 20.2 feet. The resulting draft admiship is 27. 1 feet. This is based upon the length between perpendiculars of 920 feet.

This ship has the largest possible propeller than can be swung, for reasons of efficiency. This consideration is the main reason why paragraph (c) is governing in the design.

1. 2.4 Dedicated Ballast Tank Arrangement

An approximate determination of the water ballast amount to achieve the drafts and trims of 1. 2.3 was made so that the double bottom depth necessary to hold this water could be determined. It must be recognized that for purposes of this study, a final ship design from which an exact tankage arrangement could be developed which satisfied both draft and trim requirements was beyond the scope of work. IMCO draft and trim requirements and the combination of tanks finaIly chosen in a ship design will be governed by a number of factors: (1) final propeller diameter (2) final shape of bow and stern as model tested for resistance and propulsion (3) simplicity of cargo and ballast system runs, to name a few, none of which are firm at the time of this study. The investigators feel that the midship sections studied will provide adequate flexibility for such an arrangement in a completed ship design, and that for the purpose of comparing their producibility, they are adequate.

1.3 DEVELOPMENT OF MID- SHIP SECTIONS

In the initial phase of the study, a critical survey was made of current trends in tanker construction, and six configurations were finally selected as being representative of the variations currently in use or expected to be adapted in the future.

On the basis of this selection, the six sections were developed in accordance with the ABS rules, including the shell, longitudinal, bulkhead and web frame scantlings.

The six sections are described as follows:

Section No. 1 - Configuration A-A

Typical centerline and wing tank configuration with web frames made of stiffened plate (figure 1-1).

Section No. 2- Configuration A-B

Configuration similar to Section No. 1 with web frames made of built up girders and brackets in lieu of stiffened plate (figure 1-2).

Section No. 3 - Configuration B-A

Centerline and wing tank configuration with innerbottom extending the full beam of the ship. Web frames built from stiffened plate (figure 1-3).

Section ‘No. 4. Configuration B-B

Configuration similar to Section N-o. 3 with web frames built of girders and brackets (figure 1-4).

Section No. 5 - Configuration C-A

Section with full depth wing tanks and a centerline tank which incorporates a centerline innerbottom (figure 1-5).

Section No. 6 - Configuration D-A

Complete double skin ship with double sides and bottom, created by a centerline longitudinal bulkhead (figure 1-6).

These sections are shown in the set of figures beginning on page 1-7. The detail calculations developed for each configuration are included at the end of the section for reference purposes.

At the time of the Mid - Term Review, it was suggested that the dep of the innerbottom depicted in the existing sections B-A and B-B were excessive for the volume of dedicated water ballast anticipated under the IMCO rules. At the request of the participants, this midship section was developed similar to B-B but with less depth of innerbottom.

The re-development of this section reduced the innerbottom from an original depth of 18′- 0" to a new depth of 16′-0″, and the resultant configuration is considered to be similar in nature to Section B-B as originally developed.

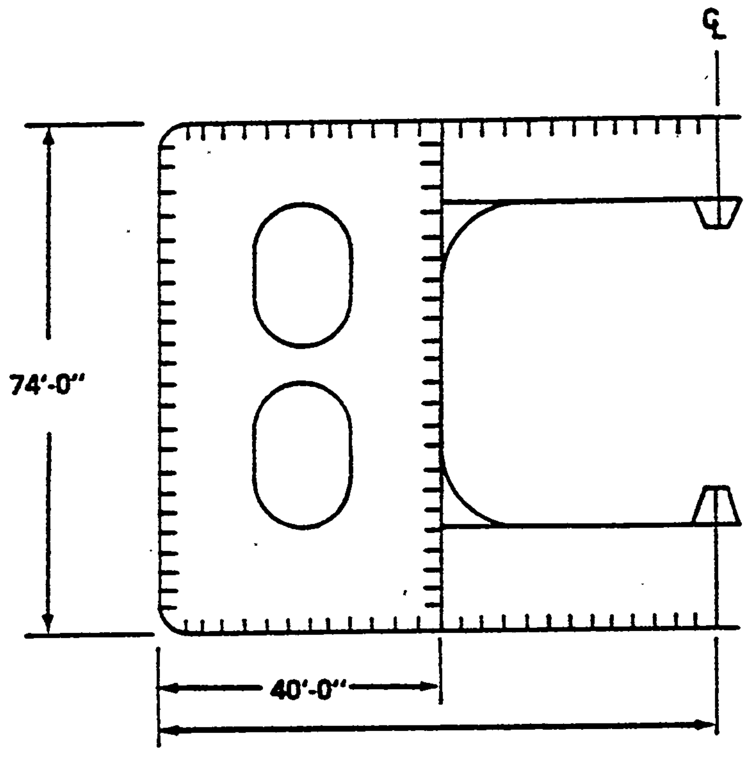


Figure 1-1. Section No. 1 - Configuration A-A

The above figure shows the Basic Ship Configuration with the possibility of all wing tanks as ballast or alternate wing tank ballast.

Advantages:

1. Light plates may be used in transverse wing bulkheads due to depth of web.

2. Very little oil outflow due to ramming, with either ballasting possibility.

3. Sub-assembly breakdown is fairly simple.

4. B/5 wing tank width complies with IMCO reg.

Disadvantages:

1. Large potential oil outflow in case of grounding casualty.
2. Requires lighter, but more plates in transverse webs.
3. More frequent cleaning of sludge from tanks.

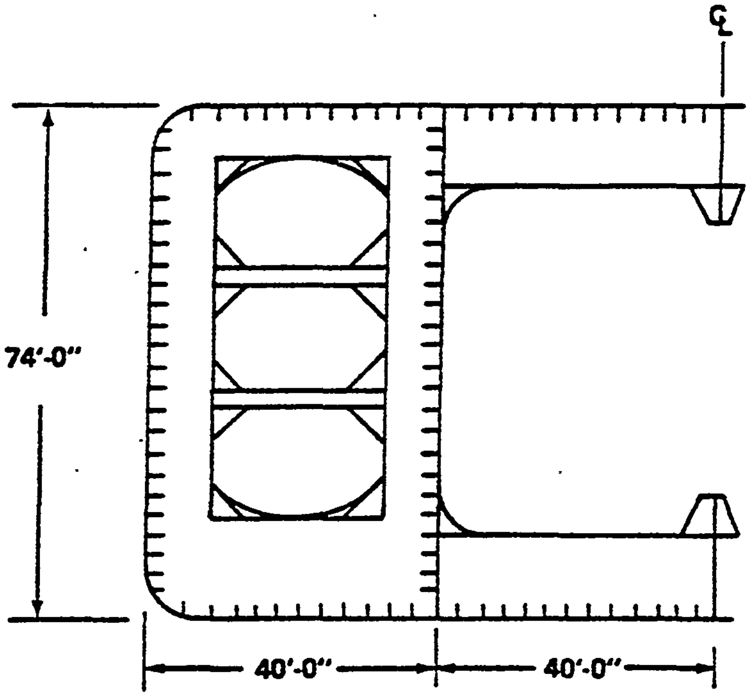


Figure 1-2. Section No. 2 - Configuration A-E

This figure shows the Basic Ship Configuration with the possibility of all wing tanks as ballast or alternate wing tank ballast.

Advantages:

1. Straight, flat panel construction suitable for automated fabrication processes.
2. Makes use of large standard shape sizes in transverse webs.
3. Very little oil outflow due to ramming, with either ballasting possibility.
4. Sub-assembly break - down is very simple.
5. B/5 wing tank width complies with IMCO reg.
6. Possibly one of the lighter midship section configurations.
7. Smooth wing bulkheads facilitate cleaning of center tank.

Disadvantages:

1. Large potential oil outflow in case of grounding casualty.
2. Requires heavier, but less plates in transverse webs.
3. Requires frequent cleaning of sludge from wing tanks.

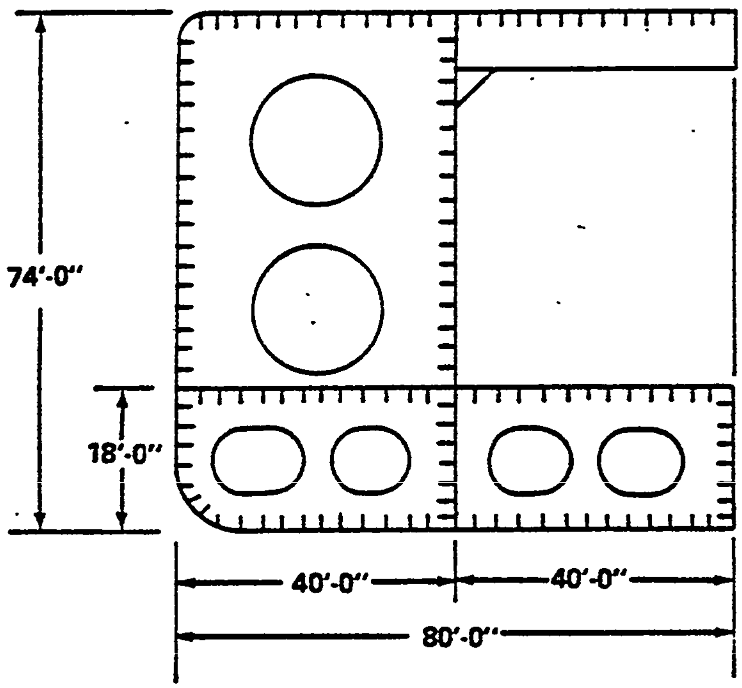


Figure 1-3. Section No. 3 - Configuration B-A

Ship Configuration with ballast in double bottom. Possibility of all tanks ballast or alternate tanks.

Advantages:

1. High degree of subdivision of ballast tanks
2. Simplified, but large assembly breakdown
3. Less frequent sludge cleaning due to smooth innerbottom
4. Very little oil outflow due to stranding
5. B/5 wing tank width complies with IMCO reg.
6. Large flat panels lend themselves to automated production.

Disadvantages:

1. Very large steel weight
2. High potential oil outflow in case of grounding casualty
3. High degree of welding is necessary

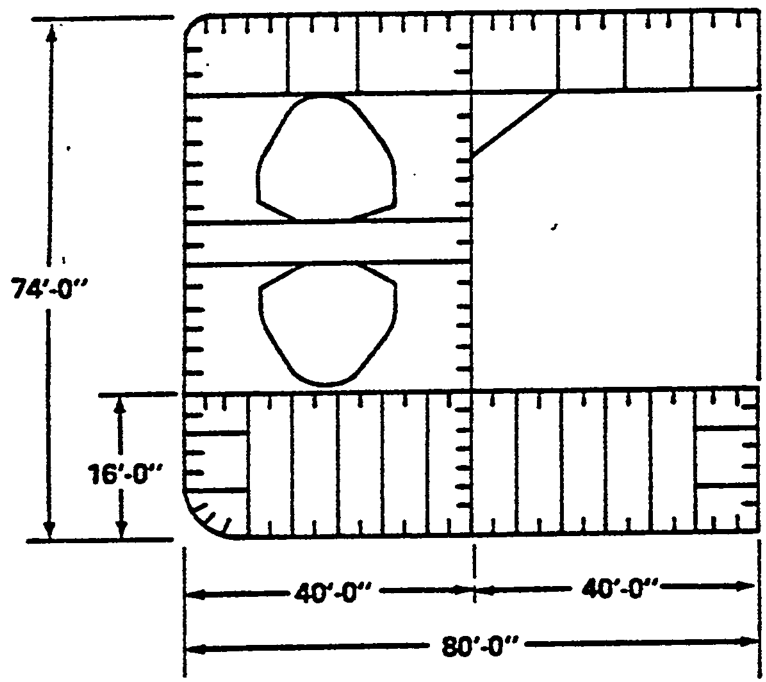


Figure 1-4. Section No. 4 - Cofiguration B-B

Advantages:

1. High degree of segregated ballast
2. Easy assembly and sub-assembly breakdown
3. Less frequent sludge cleaning due to smooth innerbottom
4. Very little oil outflow due to stranding
5. B/5 wing tank width complies with lMCO reg.
6. Large flat panels lend themselves to automated production.

Disadvantages:

1. High potential oil outflow in case of grounding casualty
2. Large steel weight
3. Large assembly and sub-assembly breakdown
4. Large amount of welding is necessary

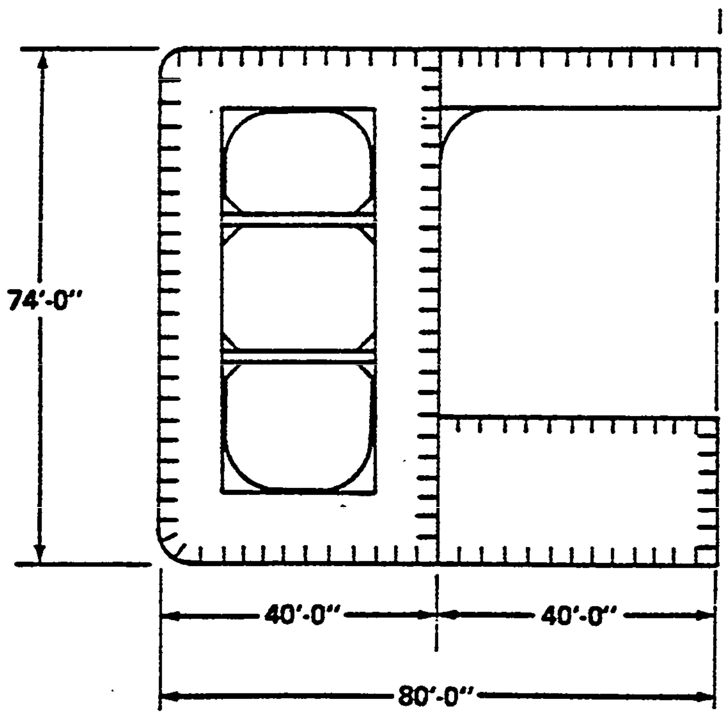


Figure 1-5. Section No. 5 - Configuration C-A

Ballast in double bottom only. Separate wing tanks.

Advantages:

1. Smooth center tank requires less cleaning due to sludge buildup
2. Possible use of standard shapes in wing tanks struts
3. Very little oil outflow due to stranding
4. Easy sub-assembly and assembly breakdown
5. Large flat panels easily fabricated by automated processes
6. Square bilge could produce cost saving.

Disadvantages:

1. Large potential oil outflow in case of grounding casualty
2. Great amount of welding is necessary.
3. Large wing tank assemblies and sub-assemblies
4. Small amount of segregated ballast

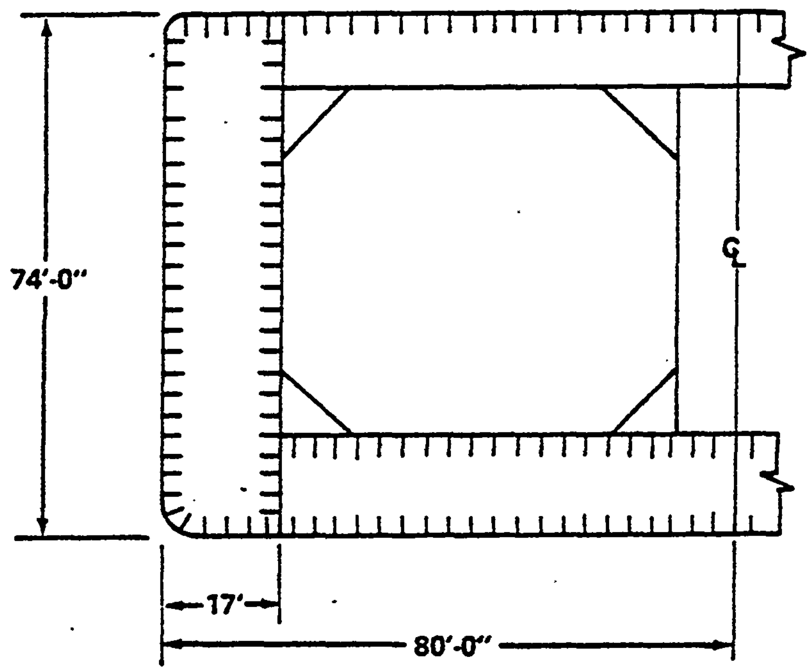


Figure 1-6. Section No. 6 - Configuration D-A

Double skin ballast system with wing bulkheads and centerline bulkheads.

Advantages:

1. Very good segregated ballast system
2. Very little oil outflow due to ramming or stranding
3. Possible lower insurance costs
4. Smooth tanks facilitate cleaning
5. Suitable for cargos other than oil
6. Lighter plates can be used in some cases
7. Flat plates can be fabricated by automated processes'
8. Lends itself to simple subassembly and assembly breakdown
9. Lighter stiffening may be used in some cases.

Disadvantages:

1. Excessive steel weight
2. Large amount of welding is necessary
3. Sludge buildup in double bottom and wing tanks
4. Cost more than twice as much per ton as double-bottom desigr

1.4 ASSEMBLY BREAKDOWN OF MIDSHIP SECTION

The following figures 1-7 through 1-II show the assembly breakdown for configurations A-A, A-B, B-A, C-A and D-A.

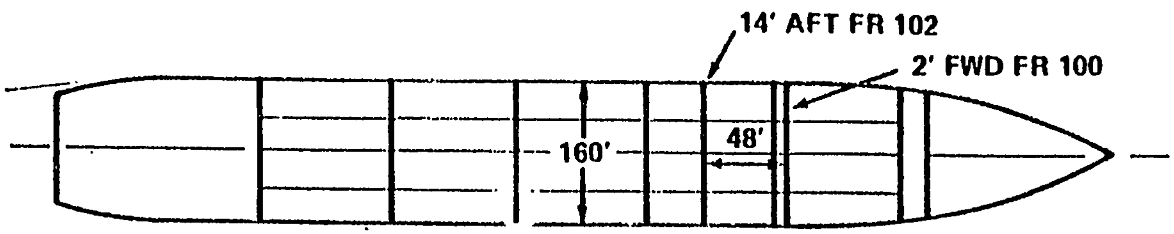
The establishment of the respective assemblies was accomplished primarily on the basis of fabrication and erection considerations, with no constraint being imposed on the required lifting capability.

For each of these configurations the assembly weights are shown in a table adjacent to the midship section, with assembly numbers correlating to those included in the respective section diagrams.

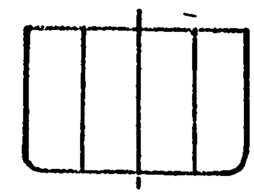
1.5 COMPARISON OF MIDSHIP SECTIONS

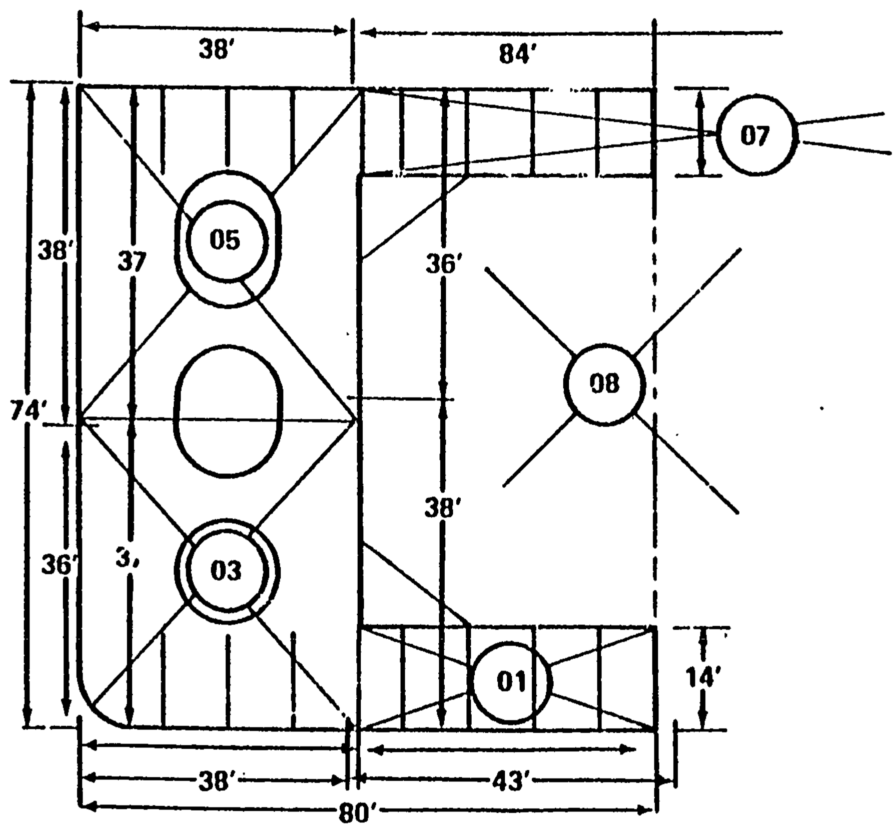
In order to compare the candidate sections, four characteristics were analyzed in detail:

1. Weight (Material Cost)
2. Ease of Fabrication
3. Ease of Erection
4. Coatings Requirements

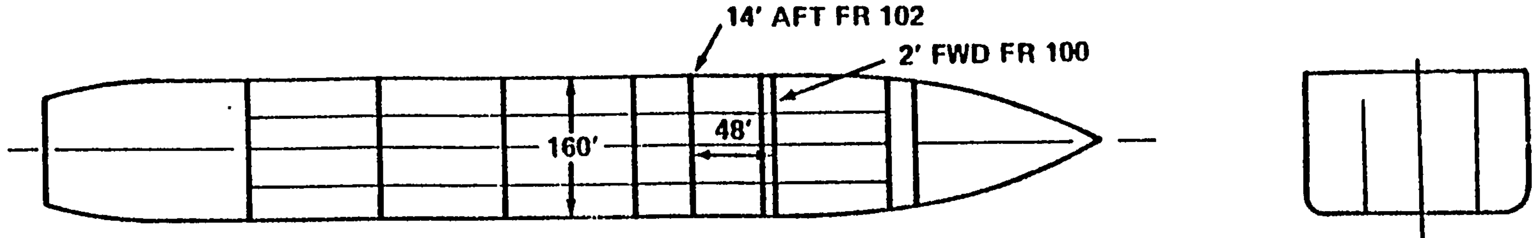


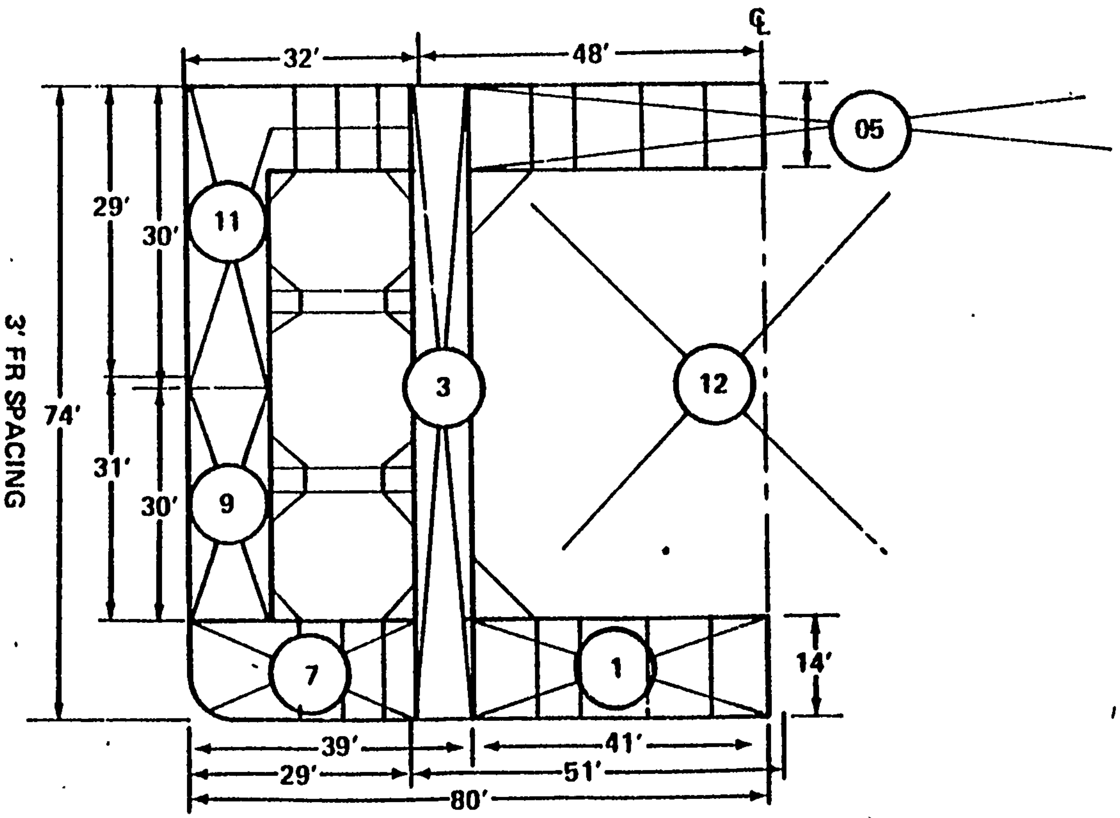
WT - 2' - 0" FWD FR 100 TO 14' - 0" AFT FR 102
1734.44 S. TONS 48' SECTION W/TRANS BHD
1540.48 S. TONS 48' SECTION WO/TRANS BHD





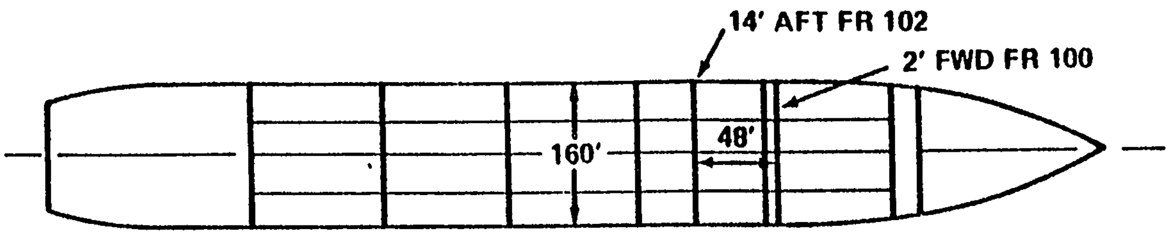
ASSY	WT (S. TONS)
01-0-P	175.32
02-S	175.32
03-P	265.99
04-S	265.99
05-P	250.25
06 S	250.25
07 P/S	157.36
08 P/S	193.96



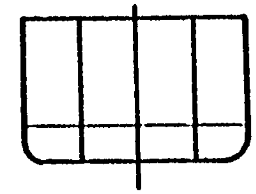


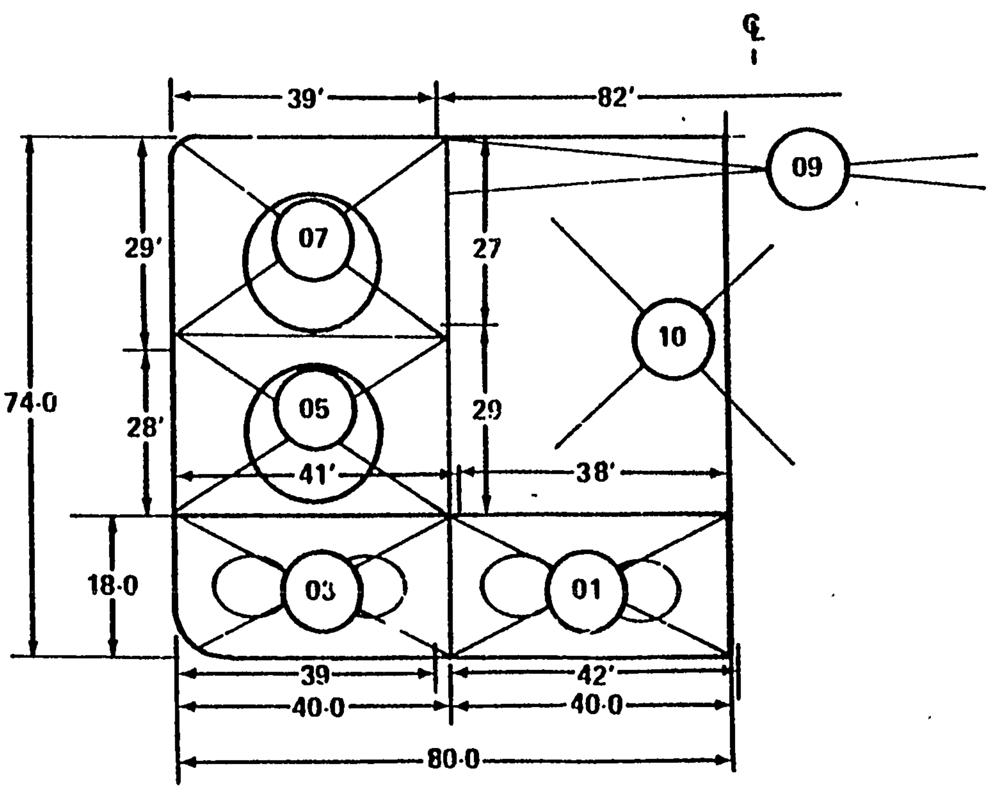
ASSY	WT (S. TONS)
01 P	175.32
02 S	175.32
03 P	107.57
04 S	107.57
05 P/S	2 5.07
06 S	165.94
07 P	165. 94
08 S	76.66
09 P'S	76.66
10 S S	150.55
11 P	150.55
12 S	193.86

Figure 1-8. Configuration A-B Assembly Breakdown

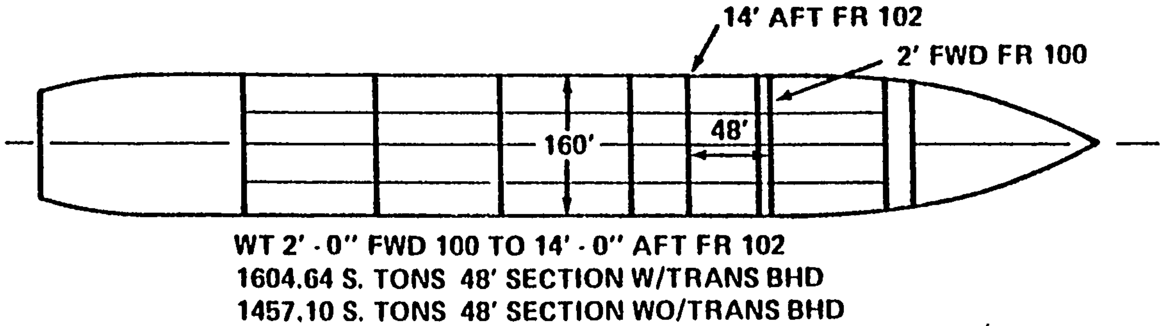


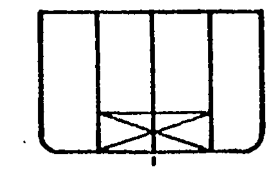
WT 2' FWD FR 100 TO 14' AFT FR 102
1744.40 S. TONS 48' SECTION W/TRANS BHD
1626.40 S. TONS 48' SECTION WO/TRANS BHD





ASSY	WT (S. TONS)
01 P	214.41
02 S	214.41
03 P	209.19
04 S	209.19
05 P	133.13
06 S	133.13
07 P	177.55
08 S	177.55
09 P/S	157.84
10 P/S	118.00





ASSY	WT (S. TONS)
01 P	238.23
02 S	238.23
03 P	239.50
04 S	239.50
05 P	192.87
06 S	192.87
07 P/S	115.90
08 P/S	147.54

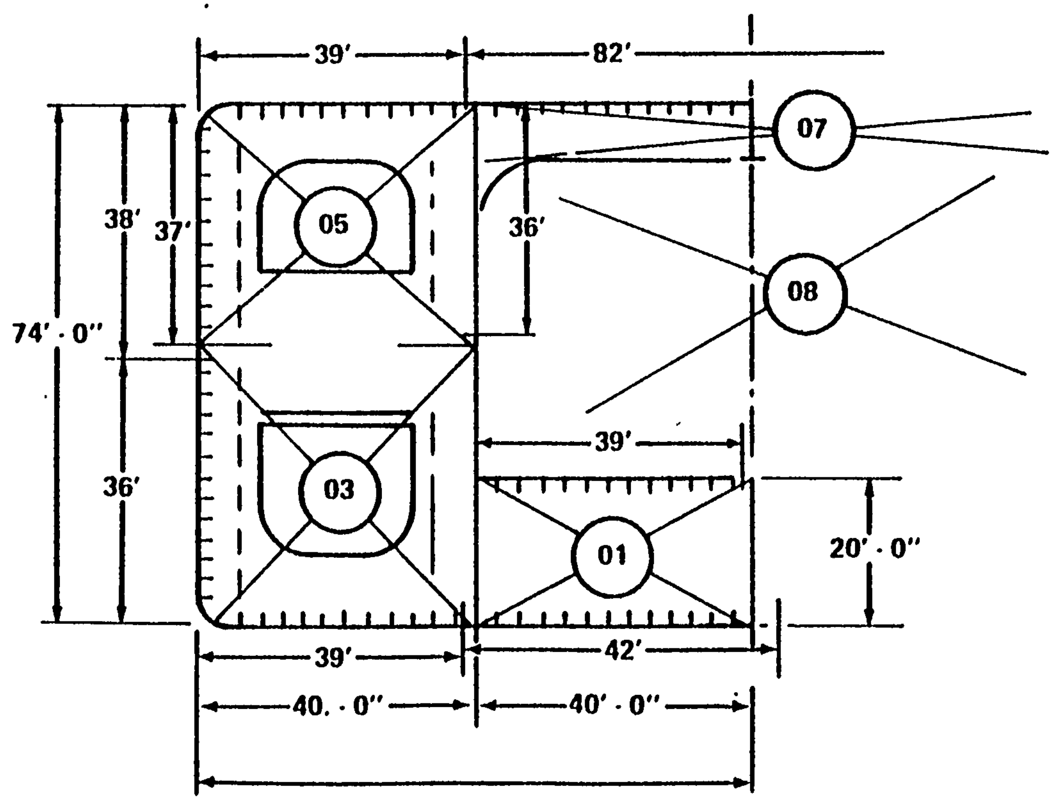
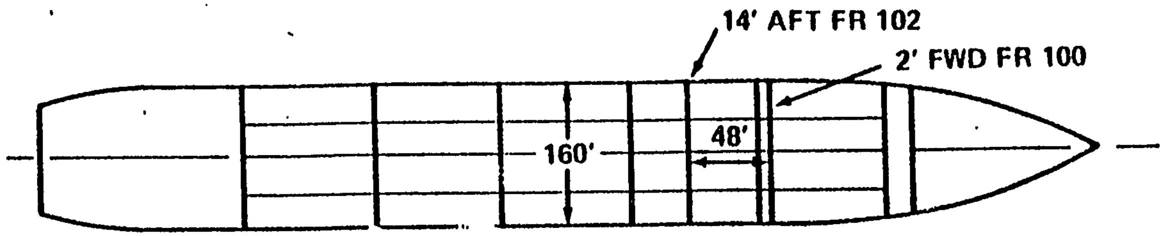
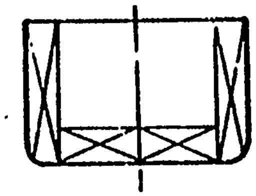


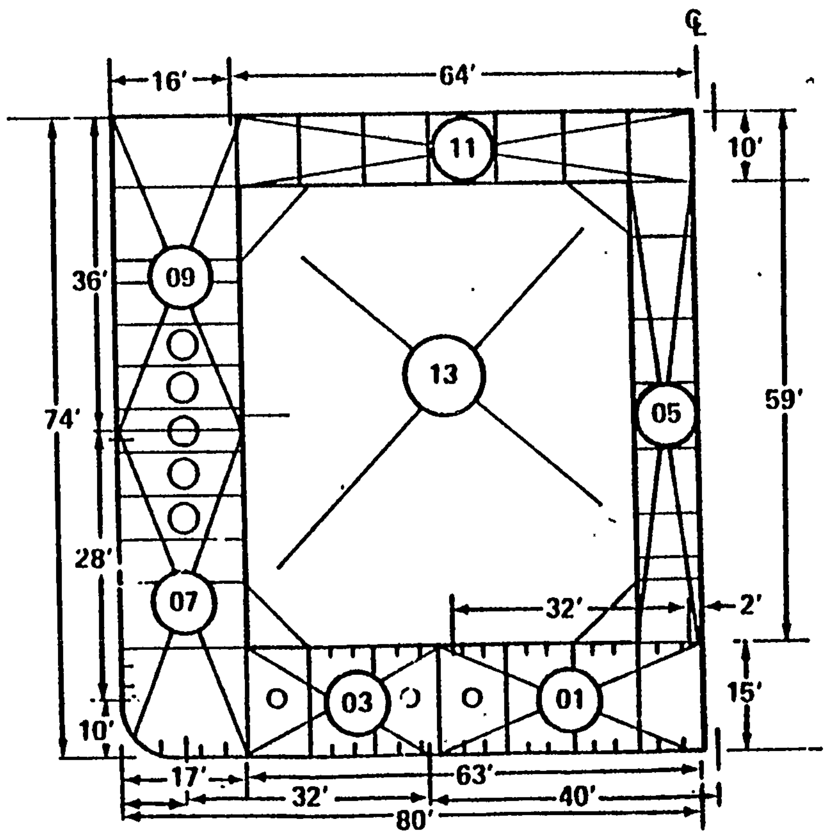
Figure 1-10. Configuration C-A Assembly Breakdown



WT 2' - 0" FWD FR 100 TO 14' - 0" AFT FR 102
1639.4 S. TONS 48' SECTION W/TRANS BHD
1478.7 S. TONS 48' SECTION WO/TRANS BHD



ASSY	WT (S. TONS)
01 P	144.61
02 S	144.61
03 P	117.18
04 S	117.18
05 ℄	91.74
06 S	177.00
07 P	177.00
08 S	112.71
09 P	112.71
10 S	102.00
11 P	102.00
12 S	120.33
13 P	120.33



1. 5.1 Weight Comparison

The variations in weight of the candidate midship sections are shown in the following tables:

	Weight of 16′ Section Lbs	Weight of 16′ Section In Short Tons	Weight of 576′ Midship Section In Short Tons
A-A Basic Configuration - Maximum Plate	605,015	302.50	10, 872
A-B Basic Configuration - Maximum Built-up Section	653,746	326.87	11,772
C-A DB CL Tank Only	778, 588	389.29	14, 004
D-A Double Skin	820,949	410.47	14,760
B-A DB Configuration - Maximum Plate	862,976	431.48	15,516
B-B DB Configuration - Maximum Built-up Section	864,536	432.26	15,552

The cost effects of the variance in weight are as shown, using a factor of $340. 00/ton for steel cost:

Configuration	Additional Weight of Midbody In Short Tons	Additional Material cost of Midbody	(2) Ships	(3) Ships	(4) Ships
A-A	0	0	0	0	0
A-B	900	306, 000	612,000	918,000	1,224,000
C-A	3, 132	1,064,880	2,129,760	3,194,640	4,259,520
D-A	3,888	1,321,920	2,643,840	3,965,760	5,287,680
B-A	4,644	1,578,960	3, 158,920	4,736,880	6,315,840
B-B	4,680	1,591,200	3,182,420	4,773,600	6,364,800

The additional weight imposed by the more complex sections is significant, particulary when viewed in terms of series production.

1. 5.2 Production Comparison of Midship Sections

In comparing the midship sections for production feasibility , an evaluation of the assembly breakdown was made which resulted in development of the following considerations:

a. Configuration A-A (Basic - Max Plate)

(1) Contains four assemblies which weight in excess of 200 tons, which could result in a requirement for excessive crane utilization or exceed lift capabilities of the shipyard.

(2) The maximum utilization of plate in the wing-tank ar is not considered to be advantageous since accessibility during assembly is limited by the swash bulkhead plating.

(3) Each of the four wing-tank assemblies will require an additional lay - down location, as required to set the partially completed (shell-plated) assemblies down on the longitudinal bulkhead plating and complete the bulkhead attachment welding.

(4) The 14′ high longitudinal floors and 12′ deep longitudinal girders represent a major deterent to accessibility while the assemblies are being built-up.

b. Configuration A-B (Basic - Built - Up Section)

(1) Contains one assembly which weighs in excess of 200 tons.

(2) The use of built-sections in the swash bulkhead areas is considered more desirable for both initial fabrication and final fit-up.

(3) Since the longitudinal bulkhead is a discrete assembly, fabrication of both the side-shell and bulkhead assemblies can be accomplished with the benefit of greater accessibility.

(4) Side-shell and bilge assemblies 07, 08, 09, 10, and 11 are more accessible during fabrication, than is true of the A-A configuration.

(5) Same as A-A, comment “d”.

c. Configuration B-A (Double Bottom - Max Plate)

(a) Contains four assemblies which weigh in excess of 200 tons.

(b) The four innerbottom and four wing-tank assemblies will each require (2) lay-down locations during assembly as required to attach the respective longitudinal bulkhead and tank- top platings.

(c) The 18′-0″ high tank top reduces accessibility ‘to the innerbottoms, and increases the height at which assembly connections must be made within the innerbottom.

(d) The maximum utilization of plate in the wing-tank area is not considenred to be advantageous since fitup of the transverse swash bulkhead and welding of the horizontal seam are undesirable requirement features.

(e) Lack of deep floors is considered desirable since it increases accessibility within the tank boundary.

d. Configuration B-B (Double Bottom - Built-Up Section)

(1) Same comments as applicable to B-A with exception of (d). Built-up transverse stiffening is considered to be more desirable.

e. Configuration C-A (Double Bottom - CL Tank Only)

(1) Contains four assemblies in excess of 200 tons.

(2) Minimum number of separate assemblies to be erected (8).

(3) The use of built-up sections as part of the swash bulkhead is considered more desirable than the alternate maximum use of plate.

(4) The. 20′ high centerline tank - top reduces accessibility to the centerline tank area.

(5) The absence of deep floors and girders is considered advantageous, for both producibility and accessibility.

(6) Fitting in the wing-tank area is minimal, and erection fitting in general is considered to be quite practical with this configuration.

(7) Four wing-tank and two innerbottom assemblies would require a minimum of two laydown positions as required to attach the longitudinal bulkhead and tank-top plating respectively.

f. Configuration D-A (Double- Skin - CL Bulkhead)

(1) Configuration requires the erection of the maximum number (13) of separate assemblies.

(2) Four wing - tank and four inner-bottom assemblies will require a minimum of two lay-down positions each, as required to attach respective second side plating.

(3) Wing - tanks and innerbottoms reduce accessibility during fabrication and after erection.

(4) Configurate ion incorporates one additional longitudinal bulkhead for length of cargo area.

(5) Deep floors and girders reduce accessibility during fabrication and after erection.

(6) This configuration is the only one reviewed which requires deck section to be erected in two separate assemblies.

In addition to the production considerations listed, the cost of fabricating the structural elements of the sections is reflected as follows:

Configuration	Additional Weight of 576′ Midbody In Short Tons	15 M/Hrs Ton Additional cost @ 12. 00/hr	2 Ships	3 Ships	4 Ships
A-A	0	0	0	0	0
A-B	900	162,000	324,000	486, 000	648, 000
C-A	3132	563,760	1, 127, 520	1,691,280	2,255, 040
D-A	3888	699,840	1,399,680	2,099,520	2,799, 360
B-A	4644	835,920	1,671,840	2, 507,760	3, 343, 680
B-B	4680	842,400	1,684,800	2,527,200	3,369,600

1. 5.3 Erection Comparison of Midship Sections

One of the major characteristics which contributes to the desirability of a mid-section design is the ease of erection which may occur as a result of the assembly configuration generated by the section.

By reducing the required erection span time for a given ship, the number of ships to be built per year can be increased (assuming adequate support) with an associated increase in revenue to the shipyard.

In evaluating the candidate sections in terms of erection span time, a detailed estimate was prepared for the erection process of each one with the following results:

Configuration	No. of Assemblies	Erection M/Hrs (48' Section)	Comparative Erection M/Hrs (576' mid-body)
C-A	8	2,801	33, 612
A-A	8	3,056	36,672
A - B	12	3,179	38, 148
B - A	10	3,452	41,424
D-A	13	3,672	44,304

Configuration C-A is believed to be the most efficient section for erection, due to the following inherent characteristics:

a. Minimum number of separate assemblies at erection
b. Contains four assemblies in excess of 200 tons.
c. Satisfactory access during and after erection.

However, it should be noted that this configurate ion ranks as the third heaviest section (behind A-A and A- BO per longitudinal foot, indicating a tendency for higher cost in the production areas, as required to fabricate and assemble the individual "building blocks" which are being put together here at the time of erection.

Using configuration C-A as a basis for comparison, the additional manhour costs expended at erection are projected as follows:

Configuration	Additional Erection M/Hrs	*Additional cost at Erection	2 Ships	3 Ships	4 Ships
C-A	0	0	0	0	0
A-A	3,060	36,720	73,440	110, 160	146, 880
A-B	4,536	54,432	108,864	163,296	217, 728
B-A	7,812	93,744	187,488	281,232	374,976
D-A	10,692	128, 304	256,608	384,912	513, 216

The basic conclusions resulting from this comparison which are considered to be of interest are as follows:

1. It cannot be assumed that the simplest or lightest midship section is necessarily the most attractive section when evaluating or comparing on the basis of erection span times.

2. Where a shipyard is constrained by the number of building positions which are available, manipulation of the midship section can affect the production capacity of the shipyard.

3. The variations in labor hours at the erection phase of construction which occur as a result of the midship configuration cause this area of consideration to merit significant attention during the development or adaptation of a section.

* (Based on $12.00 per hour)

1.5.4 Blast and Paint Comparison

The paint system utilized for comparison purposes is a “high build” two-pack epoxy paint system of 8.0 roils dry film thickness, similar to the “intergant” tank coating system as supplied by the International Paint Company or the Devron 24445 series as supplied by the Devoe and Reynolds Company.

With either of these applications, it is intended that cargo oil and fuel tanks retain the pre - construction primer, with no further paint application being required in these areas.

a. Square Footage

A detailed estimate of the surface area to be coated was completed for five of the candidate midship sections. The surface area total reflects the surface area to be coated for all plates, girders webs, force plates, toilers and brackets, with no correction for lost area in way of lighting or access holes. The following table lists the sections in order of increased total area for ballast tanks, since the cargo tanks require pre - construction primer only:

Configuration	Surface Area-Square Feet		
	Ballast Tanks	Oil Tanks	Total
C-A	640,632	1,677,317	2,317,949
A-A	668,831	1,505, 849	2,174,680
A-B	762,327	1,574,499	2,336,826
B - A	1,186,009	1,339,063	2,525,072
D - A	1,624,883	772,177	2, 397,062

NOTE: The wide variance in ballast tank area which has occur red as a result of varying the ballast and oil tank arrangement. This factor is reflected in terms of percentage as follows:

	% Ballast Area	% Cargo Oil Area
C-A	27.6	72.4
A-A	30.8	69.2
A-B	32.6	67.4
B-A	47.0	53.0
D-A	67.8	32.2

b. Material Costs - Ballast Tanks

Paint quantities were determined utilizing a theoretical coverage factor of 372 square feet per gallon, as required to achieve a thickness of 4.0 roils. For airless spray applications, this factor would be reduced approximately 17 percent to 307 square feet per gallon.

Paint quantities and estimated costs are summarized as follows :

	Gallons	Dollars
C-A	4,187	66, 364.
A-A	4,371	69,280.
A-B	4,983'	78,981.
B-A	7,752	122,869.
D - A	10,620	168,327.

c. Labor Costs - Ballast Tanks

In addition to the material cost variations for each configuration there is a corresponding labor-hour variation which, again, is a product of the wide variance in surface area as reflected in the square footage summary. using a $10.00 hour rate for burdened labor, the preparation and application costs are summarized as follows:

Configuration	Labor Hours	Labor Dollars
C-A	21,077	210,770.
A-A	22,005	220,050.
A-B	25,081	250,810.
B-A	39,019	390,190.
D-A	53,459	534,590.

d. Ballast Tank Summary

The combined material and labor costs for the ballast tank areas (only) are as shown:

Configuration	Total Dollars
C-A	277,134.
A-A	289,330.
A-B	329,791.
B-A	513,059.
D-A	700,917.

e. Cargo Oil Tanks

In the cargo oil and fuel tanks, there is no requirement for a protective coating. These areas do require a thorough cleaning which is normally achieved by either wire brushing with a power tool or by sandsweep in localized areas. The labor hours, using the sand - sweep method are estimated as follows:

Configuration	Cargo & Fuel Oil Tank Area	Labor Hours
C-A	1,677,317	36,733
A-A	1,505,849	32,978
A - B	1,574,499	34,482
B-A	1,339,063	29,325”
D-A	772,177	16,911

L Coatings Comparison

The combined costs for Ballast and Cargo Oil tanks for each configuration is summarized as follows:

Configuration	Ballast Tanks (Material + Labor)	Cargo (Labor Only)	Total
C-A	277,134.	367,330.	644,464.
A-A	289,330.	329,780.	619,110.
A-B	329,791.	344,820.	674,611.
B-A	513,059.	293,250.	806,309.
D-A	700,9170	169,111.	870,028.

Using Configuration A-A (no innerbottom) as a base ship, the following cost comparison can be made:

Configuration	Additional Coatings Cost 1 Ship	2 Ships	3 ships	4 Ships
A-A	0	0	0	0
C-A	25,354	50,708	76,062	101,416
A-B	55,501	111,002	166,503	222,004
B-A	187,199	374,398	561,597	748,796
D-A	250,918	501,836	752,754	1,003,672

g. Coating Summary

While the results of the paint comparison are fairly obvious from a ranking standpoint, the additional costs imposed by the double-bottom configuration in terms of dollars was quite surprising, and indicates that an analysis of this type should be made in support of future efforts to comply with the IMCO requirements.

In comparison to total - ship cost, configurations C-A and A-B do not represent a significant increase in paint costs, and are considered satisfactory substitutes for the basic configuration A-A.

1.5.5 Summary of Comparison

In summarizing the individual characteristics as previously outlined, the additional cost factors were combined for each configuration with the following results:

Configuration	Material Penalty	Fabrication Penalty	Erection Penalty	Coatings Penalty	Total Penalty
A-A	0	0	36,720	0	36,720
A-B	306,000	162,000	54,432	55,501	577,933
B-A	1,578,960	835,920	93,744	187,199	2,695,823
C-A	1,064,880	563,760	0	25,354	1,653,994
D-A	1,321,920	699,840	128,304	250,918	2,400,982

By re-arranging the ranking in terms of increased total cost, the configurations fall in the following order:

Configuration	Total Additional Cost Over Lowest	2 ships	3 Ships	4 Ships
A-A	0	0	0	0
A-B	541,213	1,082,426	1,623,639	2, 164,852
C-A	1,617,274	3,234, 548	4,851,822	6,469,096
D-A	2,364,262	4,728, 524	7,092,786	9,457,048
B-A	2,659,103	5,318,206	7,977,309	10,636,412

1.6 SUMMARY AND CONCLUSIONS

As would be expected, the basic section A-A has retained its position as the lowest cost configuration included in the comparison.

While it was anticipated that the bracketed sections would appear to be more attractive than the stiffened plate sections due to a man-hour savings in either production or erection, there was no evidence developed to substantiate this position, and as a result of the higher material and coatings costs associated with the bracket design, the stiffened plate approach must be considered more practical for producibility.

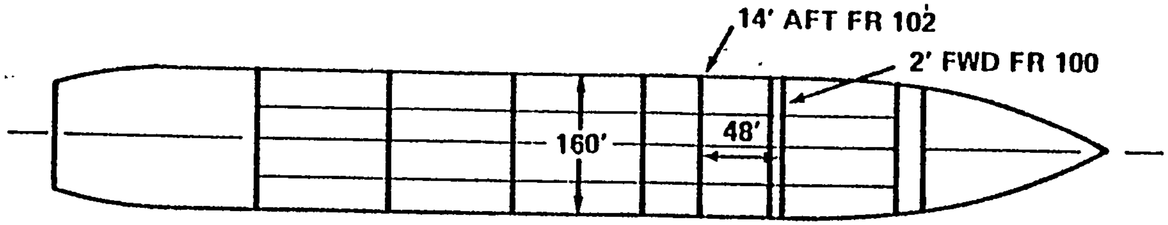
The relative costs of configuration C-A would indicate that the addition of a tank top as required to create a centerline double-bottom can be accomplished with minimum additional cost.

It does not appear that any of the double-bottom sections are competitive, and that this approach will only be adopted if required by regulatory bodies.

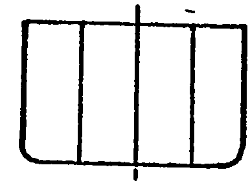
While the initial intent of the double bottom is to prevent oil spillage as a result of grounding, the advantage is offset by the problems of oil leakage into the dedicated ballast spaces in the double bottom and the associated explosion hazard which this condition creates.

With a double-bottom empty while the ship is loaded, stability is reduced and the ship would react adversely in the event of symmetrical damage.

As a result of the combined effects of these factors, it is expected that midship sections similar to the basic (A-A and A-B) configuration will receive first consideration in future applications, particularly in the absence of specific regulatory requirements or specific owner requirements for other configurations.



WT - 2' - 0" FWD FR 100 TO 14' - 0" AFT FR 102
1734.44 S. TONS 48' SECTION W/TRANS BHD
1540.48 S. TONS 48' SECTION WO/TRANS BHD



ASSY	WT (S. TONS)
01-0-P	175.32
02-S	175.32
03-P	265.99
04-S	265.99
05-P	250.25
06 S	250.25
07 P/S	157.36
08 P/S	193.96

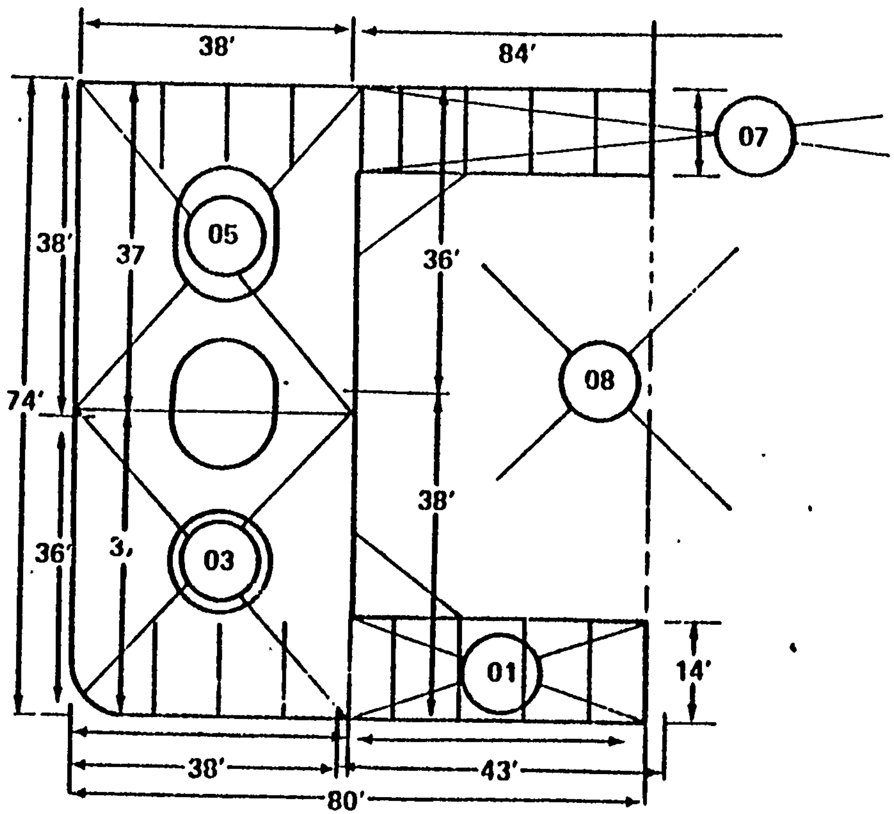


Figure 1-7. Configuration A-A Assembly Breakdown

PRELIMINARY SCANTLING REQUIREMENTS FOR SHIP CONFIGURATION A-A

SHIP PARAMETERS:

LBP - 925 FT.
B - 160 FT.
D - 74 FT.
d - 51 FT.

C_B - .84
L/B - 5.78
L/D - 12.50

BASIC ASSUMPTIONS:

TANK LENGTH - 96′
FR. SPACING - 16′
LONG′L. SPACING - 3′

BOTTON PLTG: (22.19.1)

(1) t = 0.0003937L (2.6 + 10/D)
t = 0.0003937 (925)(2.6 + 10/74)
t = .996 IN.

(2) $t = 0.00331(S)\sqrt{0.7d + 0.02(L-164) + 0.1}$ IN.
$t = 0.00331(36)\sqrt{0.7(51) + 0.02(925-164) + 0.1}$ IN.
t = .950 IN.

BOTT PLATING = .95 IN. (1″ PLT)

FLAT PLATE KEEL (22.19.1)

t = BOTT. PLTG 0.06 IN.
t = 1.01 IN.
F.P.K. = 1.01 IN. (1 1/8″ PLT)

SIDE SHELL PLATING (22.19.1)

(1) t = 0.0003937L (2.0 +21/D) IN.
t = 0.0003937(925)(2.0 + 21/74) IN.
t = .832 IN.

(2) $t = 0.00287(S)\sqrt{0.7d + 0.02L} + 0.1$ IN.

$t = 0.00287(36)\sqrt{0.7(51) + 0.02(925)} + 0.1$ IN.

$t = .86$ IN.

SIDE SHELL= .832 IN. (7/8″ PLT)

DECK PLATING 22.21.1

$t = 0.000883(S)\sqrt{L-174} + 0.0126\,(L/D) - 0.1$ IN.

$t = 0.000883(36)\sqrt{925-174} + 0.126\,(12.50) - 0.1$ IN.

$t = .930$ IN.

DECK PLATING = .930 IN. (15/16″ PLTj

DECK LOGITUDINAL: (22.29.2)

S.M. $= 0.0041\ chsl_b^2$ IN.^{3}

S.M. $= 0.0041(l.25)(8)\{3)(16)^2$

S.M. = 31.49

USE 8 X 7 X 20#T 0N 40.8# DECK PLATE

BOTTOM AND SIDE SHELL LONGITUDINALS

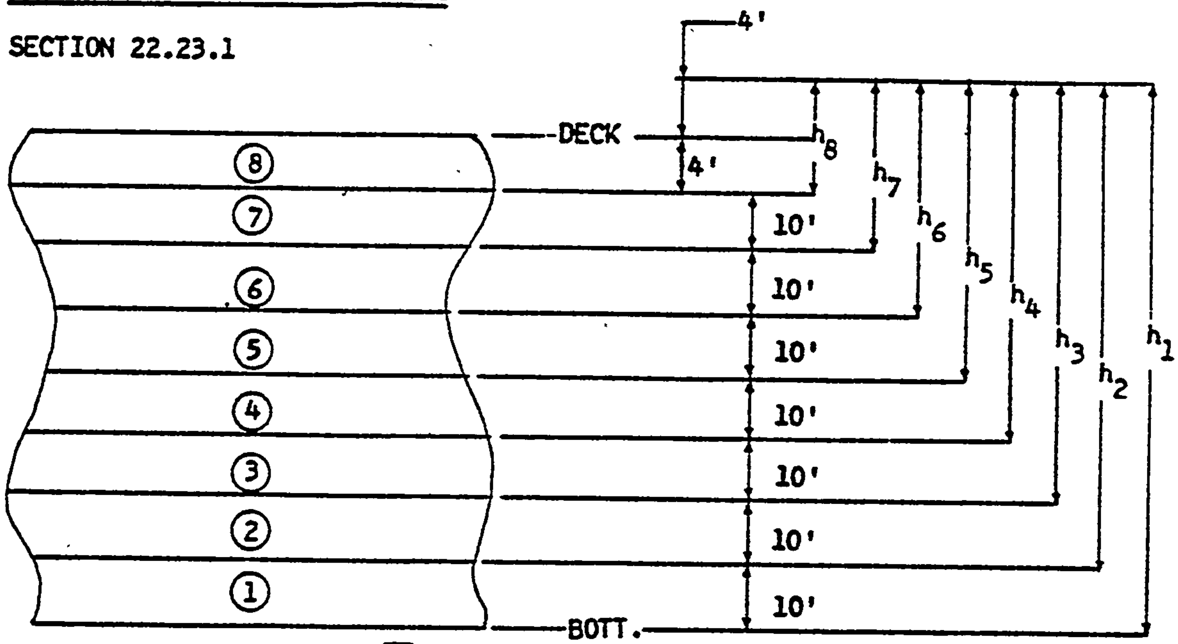
ABS 22.29.2 S.M. = .0041 chsl^2

SIDE = 7/8" PLT
BOTTOM = 1" PLT

LONG.NO.	LOCATION OF LONGL	HEAD TO 8'ABV.DK.	SPACING FT.	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	SIDE	11.0	3.0	.95	16	32.90	16x7x45#T	90.7	CUT WT. 32.62#
2	SIDE	14.0	3.0	.95	16	41.88	16x7x45#T		
3	SIDE	17.0	3.0	.95	16	50.85	16x7x45#T		
4	SIDE	20.0	3.0	.95	16	59.83	16x7x45#T		
5	SIDE	23.0	3.0	.95	16	68.80	16x7x45#T		
6	SIDE	26.0	3.0	.95	16	77.78	16x7x45#T		
7	SIDE	29.0	3.0	.95	16	86.75	16x7x45#T		
8	SIDE	32.0	3.0	.95	16	95.72	18x8 3/4x64#T	143	CUT WT. 45.19#
9	SIDE	35.0	3.0	.95	16	104.70	18x8 3/4x64#T		
10	SIDE	38.0	3.0	.95	16	113.67	18x8 3/4x64#T		
11	SIDE	41.0	3.0	.95	16	122.65	18x8 3/4x64#T		
12	SIDE	44.0	3.0	.95	16	131.62	18x8 3/4x64#T		
13	SIDE	47.0	3.0	.95	16	140.60	18x8 3/4x64#T		
14	SIDE	50.0	3.0	.95	16	149.57	24x9x76#T	217	CUT WT. 56.81#
15	SIDE	53.0	3.0	.95	16	158.54	24x9x76#T		
16	SIDE	56.0	3.0	.95	16	167.52	24x9x76#T		
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76#T		
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76#T		
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76#T		
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76#T		
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76#T		
22	BILGE	73.5	3.2	1.0	16	246.87	24x12x100#T	294	CUT WT. 70.48#
23	BILGE	77.0	3.2	1.1	16	284.48	24x12x100#T		
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108#T	369	CUT WT. 82.89#

LONGITUDINAL BULKHEAD PLATING

SECTION 22.23.1



$$t = \frac{s\sqrt{h}}{460} + .10 \text{ IN.}$$

① $t_1 = \frac{36\sqrt{78}}{460} + .10 = .791"$ ⟶ 7/8" PLT. (.875)

② $t_2 = \frac{36\sqrt{68}}{460} + .10 = .746"$ ⟶ 3/4" PLT. (.750)

③ $t_3 = \frac{36\sqrt{58}}{460} + .10 = .696"$ ⟶ 3/4" PLT. (.750)

④ $t_4 = \frac{36\sqrt{48}}{460} + .10 = .643"$ ⟶ 11/16" PLT. (.6875)

⑤ $t_5 = \frac{36\sqrt{38}}{460} + .10 = .583"$ ⟶ 5/8" PLT. (.625)

⑥ $t_6 = \frac{36\sqrt{28}}{460} + .10 = .514"$ ⟶ 9/16" PLT. (.5625)

⑦ $t_7 = \frac{36\sqrt{18}}{460} + .10 = .432"$ ⟶ (MIN. 1/2" PLT.)

⑧ $t_8 = \frac{36\sqrt{8}}{460} + .10 = .322"$ ⟶ (MIN. 5/8" PLT.)

LONGITUDINAL STIFFENERS FOR LONG'L BHDS

LONG.NO.	HEAD TO DK.+8FT.	BHD PLTG	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	11	25.5#	3'-0"	.90	16	31.13	14x6 3/4x34 I/T	59.0	(CUT WT. 24.30#)
2	14	20.4#	3'-0"	.90	16	39.62	14x6 3/4x34 I/T	57.6	
3	17	20.4#	3'-0"	.90	16	48.11	14x6 3/4x34 I/T	57.6	
4	20	20.4#	3'-0"	.90	16	56.60	14x10x61 I/T	103.7	(CUT WT. 40.54#)
5	23	20.4#	3'-0"	.90	16	65.09	14x10x61 I/T	103.7	
6	26	22.95#	3'-0"	.90	16	73.58	14x10x61 I/T	105.3	
7	29	22.95#	3'-0"	.90	16	82.07	14x10x61 I/T	105.3	
8	32	22.95#	3'-0"	.90	16	90.56	14x10x61 I/T	105.3	
9	35	25.5#	3'-0"	.90	16	99.05	14x10x61 I/T	106.6	
10	38	25.5#	3'-0"	.90	16	107.54	16x8 1/2x78 I/T	150.3	(CUT WT. 54.99#)
11	41	25.5#	3'-0"	.90	16	116.03	16x8 1/2x78 I/T	150.3	
12	44	28.05#	3'-0"	.90	16	124.52	16x8 1/2x78 I/T	152.0	
13	47	28.05#	3'-0"	.90	16	133.01	16x8 1/2x78 I/T	152.0	
14	50	28.05#	3'-0"	.90	16	141.50	16x8 1/2x78 I/T	152.0	
15	53	30.6#	3'-0"	.90	16	149.99	16x8 1/2x78 I/T	154.1	
16	56	30.6#	3'-0"	.90	16	158.48	24x9x76 I/T	213.4	(CUT WT. 56.81#)
17	59	30.6#	3'-0"	.90	16	166.97	24x9x76 I/T	213.4	
18	62	30.6#	3'-0"	.90	16	175.46	24x9x76 I/T	213.4	
19	65	30.6#	3'-0"	.90	16	183.95	24x9x76 I/T	213.4	
20	68	30.6#	3'-0"	.90	16	192.44	24x9x76 I/T	213.4	
21	71	30.6#	3'-0"	.90	16	200.93	24x9x76 I/T	213.4	
22	74	35.7#	3'-0"	.90	16	209.42	24x9x84 I/T	241.4	(CUT WT. 62.38#)
23	77	35.7#	3'-0"	.90	16	217.91	24x9x84 I/T	241.4	
24	80	35.7#	3'-0"	.90	16	226.40	24x9x84 I/T	241.4	

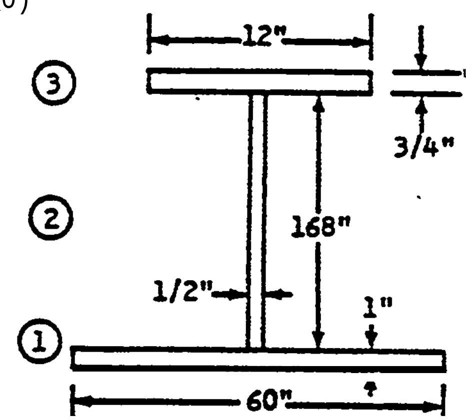
BOTTOM TRANSVERSES:

c = 1.75
h = 74
s = 16
l_b = 30

$S.M. = 0.0025\ chsl_b^2$

$S.M. = 0.0025\ (1.75)(74)(16)(30)^2$

$S.M. = 4662\ IN^3$



ITEM	AREA	Y	AY	AY^2	Io
1	60.00	.5	30.00	15.00	5.00
2	84.00	85.00	7140.00	606,900.00	197,568.00
3	9.00	169.38	1524.42	258,206.26	.42
	153.00		8694.42	865,121.26	197,573.42
				197,573.42	
		$\bar{Y}$ = 56.83		1,062,694.68	

$I_{NA} = 568,622.73\ IN.^4$

$S.M. = 5035.6\ IN.^3$

WING WEB PLATING:

STRAKES TO BE THE SANE AS LONG'L BHD.
STIFFENERS TO BE THE SAME AS LONGL BHD.

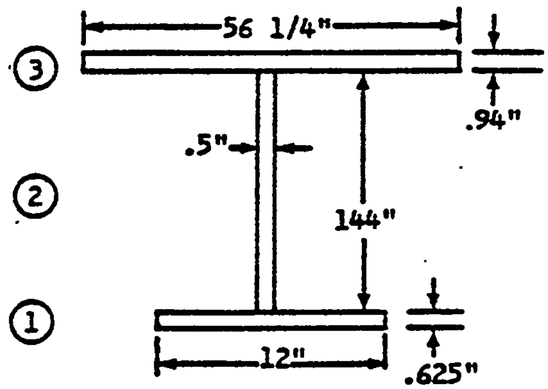
DECK TRANSVERSES:

c = 1.
h = 2
s = 1
l_b = 30

S.M. = $.0025\ chsl_b^2$

S.M. = $.0025\ (1.8)(20)(16)(30)^2$

S.M. = 1296 IN^3



ITEM	AREA	Y	AY	AY^2	Io
1	7.50	.31	2.33	.72	3.89
2	72.00	72.63	5229.00	379,756.13	124,420.00
3	52.88	145.10	7672.62	1,113,297.68	.24
	132.38		12,903.95	1,493,054.53	124,420.13
				124,420.13	
				1,617,474.66	

I_{NA} = 359,641.27 $IN.^4$

S.M. = 3689.5 $IN.^3$

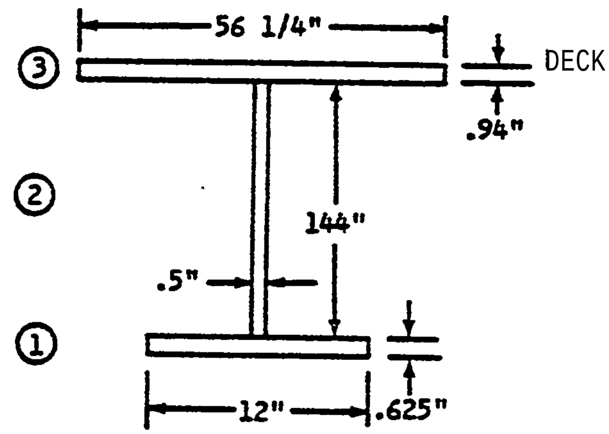
℄ DECK GIRDER

$c = 2.5$
$h = 20$
$s = 41$
$l_b = 24$

S.M. = $.0025\, chsl_b^2$

S.M. = $.0025(2.5)(20)(41)(24)^2$

S.M. = 2952 IN.^{3}



ITEM	AREA	Y	AY	AY²	Io
1	7.50	.31	2.33	.72	3.89
2	72.00	72.625	5,229.00	379,756.13	124,416.00
3	52.88	145.10	7,672.62	1,113,297.68	.24
	132.38		12,903.95	1,493,054.53	124,420.13
		$\bar{Y}$ = 97.48"		124,420.13	
				1.617.474.66	

I_{NA} = 359,641.27 IN.^{4}

S.M. = 3689.5 IN^3

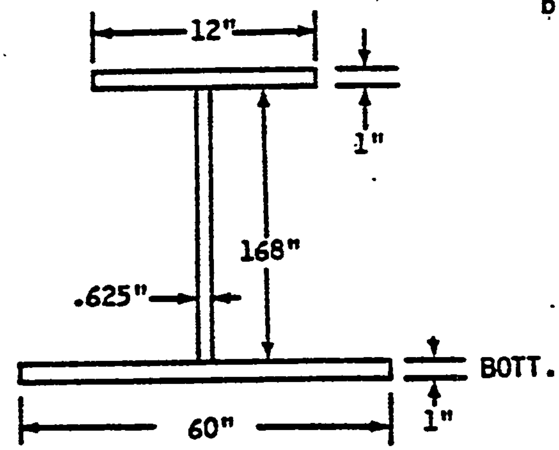
c = 2.00
h = 74
s = 41
l_b = 20

CENTER VERTICAL KEEL

$S.M. = .0025\, c h s l_b^2$

$S.M. = .0025(2.00)(74)(41)(20)^2$

$S.M. = 6068\ IN^3$



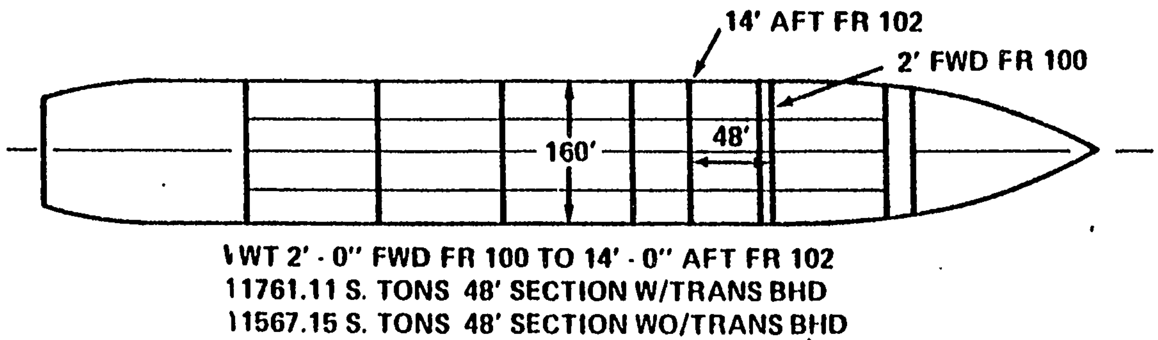
ITEM	AREA	Y	AY	AY^2	Io
1	60.00	.5	30.00	15.00	5.00
2	105.00	85	8,925.00	758,625.00	246,960.00
3	12.00	169.5	2,034.00	344,763.00	1.00
	177.00		10,989.00	1,103,403.00	246 966.00
				246,966.00	
		$\bar{Y}$ = 62.08		1,350,369.00	

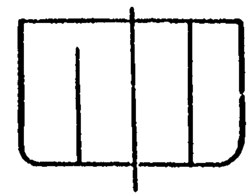
$I_{NA} = 668,120.73\ IN^4$

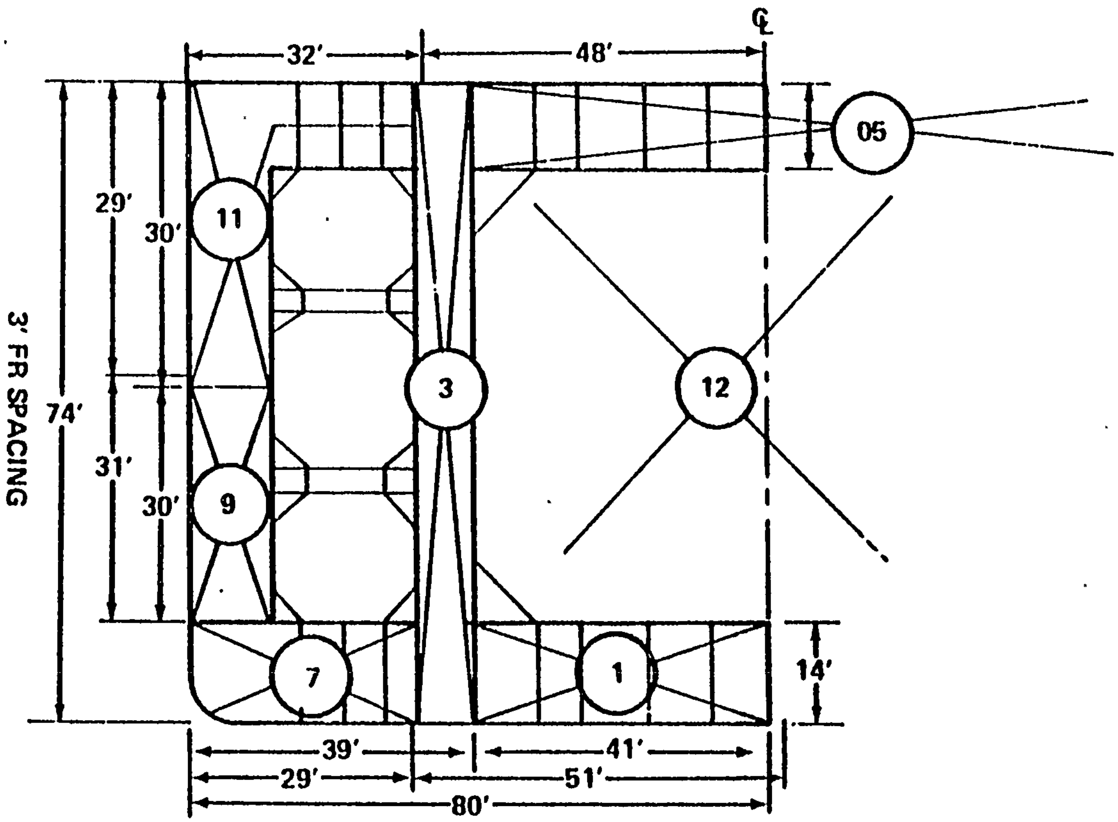
$S.M. = 6191\ IN^3$

WEIGHT OF ONE FRAME SPACE
(INCLUDING ONE TRANSVERSE WEB)

ITEM	WT./FT.	TOTAL WT.#
SIDE SHELL PLATING	35.7	73,113.6
BILGE PLATING	40.8	20,508.4
BOTTOM PLATING	40.8	87,475.2
FPK	45.9	4,406.4
DECK PLATING	38.25	97,920.0
WING BHD. PLATING	VAR.	65,280.0
WING BHD. LONG'L'S	VAR.	37,570.56
DECK LONG'L'S	20.0	15,360.0
SIDE SHELL LONG'L'S	VAR.	30,526.8
BILGE LONG'L'S	VAR.	7,163.2
BOTTOM LONG'L'S	52.89	61,007.0
TRANSV. WING WEB	VAR.	69,948.3
CVK	VAR.	6,365.0
BOTTOM TRANSV. GIRDER	VAR.	12,964.0
C DECK GIRDER	VAR.	4,324.80
DECK TRANSV. GIRDER	VAR.	11,082.30
		605,015.56 LBS.
LONG GDRS	9.63	
VENT GDRS		







ASSY	WT (S. TONS)
01 P	175.32
02 S	175.32
03 P	107.57
04 S	107.57
05 P/S	2 5.07
06 S	165.94
07 P	165. 94
08 S	76.66
09 P'S	76.66
10 S S	150.55
11 P	150.55
12 S	193.86

Figure 1-8. Configuration A-B Assembly Breakdown

PRELIMINARY SCANTLING REQUIREMENTS FOR SHIP CONFIGURATION A-B

SHIP PARAMETERS:

LBP - 925 FT.
B - 160 FT.
D - 74 FT.
d - 51 FT.
C_B - .84
L/B - 5.78
L/B - 12.50

BASIC ASSUMPTIONS:

TANK LENGTH - 96′
FR. SPACING - 16′
LONG′L. SPACING - 3′

BOTTOM PLTG: 22.19.1.

(1) t= 0.0003937L (2.6 + 10/D)
t = 0.0003937 (925)(2.6 + 10/74)
t = .996 IN.

(2) $t = 0.00331(s)\sqrt{0.7d + 0.02(L-164) + 0.1\text{IN.}}$
$t = 0.00331(36)\sqrt{0.7(51) + 0.02(925-164) + 0.1\text{ IN.}}$
t = .950 IN.

BOTT PLATING = .95 IN. (1″ PLT)

FLAT PLATE KEEL (22.19.1)

t = BOTT. PLTG 0.06 IN.
t = 1.01 IN.
F.P.K. = 1.01 IN. (1 1/8″ PLT)

SIDE SHELL PLATING (22.19.1)

(1) t= 0.0003937L (2.0 + 21/D) IN.
t = 0.0003937(925)(2.0 + 21/74) IN.
t = .832 IN.

(2) $t = 0.00287(s)\sqrt{0.7d + 0.02L + 0.1}$ IN.

$t = 0.00287(36)\sqrt{0.7(51) + 0.02(925) + 0.1}$ IN.

t = .86 IN.

SIDE SHELL = .832 IN. (7/8″ PLT)

DECK PLATING 22.21.1

$t = 0.000883(S)\sqrt{L-174} + 0.0126\ (L/D) - 0.1$ IN.

$t = 0.000883(36)\sqrt{925-174} + 0.126\ (12.50) - 0.1$ IN.

t = .930 IN.

DECK PLATING = .930 IN. (15/16″ PLT)

DECK LONGITUDINAL: (22.29.2]

S.M. = $0.0041\ chsl_b^2$

S.M. = $0.0041(1.25)(8)(3)(16)^2$

S.M. = 31.49

USE 8 X 7 X 20#T ON 40.8# DECK PLATE

BOTTOM AND SIDE SHELL LONGITUDINALS

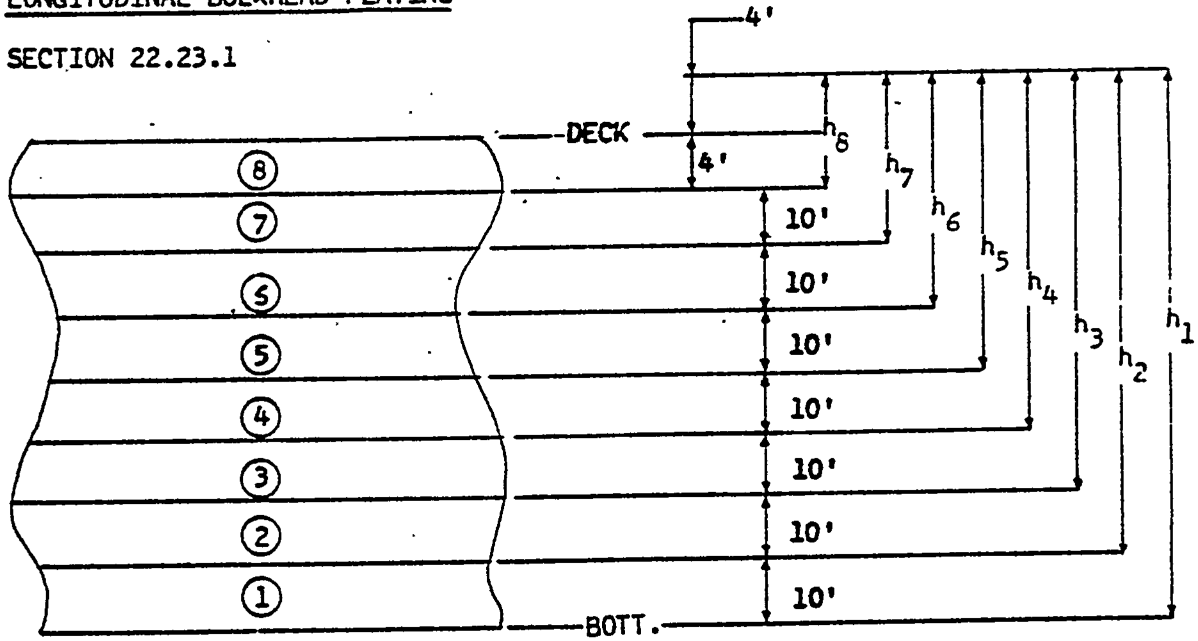
ABS 22.29.2 S.M. = .0041 $chsl^2_b$

SIDE = 7/8" PLT
BOTTOM = 1" PLT

LONG.NO.	LOCATION OF LONGL	HEAD TO 8'ABV.DK.	SPACING FT.	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	SIDE	11.0	3.0	.95	16	32.90	16x7x45#T	90.7	CUT WT. 32.62#
2	SIDE	14.0	3.0	.95	16	41.88	16x7x45#T		
3	SIDE	17.0	3.0	.95	16	50.85	16x7x45#T		
4	SIDE	20.0	3.0	.95	16	59.83	16x7x45#T		
5	SIDE	23.0	3.0	.95	16	68.80	16x7x45#T		
6	SIDE	26.0	3.0	.95	16	77.78	16x7x45#T		
7	SIDE	29.0	3.0	.95	16	86.75	16x7x45#T		
8	SIDE	32.0	3.0	.95	16	95.72	18x8 3/4x64#T	143	CUT WT. 45.19#
9	SIDE	35.0	3.0	.95	16	104.70	18x8 3/4x64#T		
10	SIDE	38.0	3.0	.95	16	113.67	18x8 3/4x64#T		
11	SIDE	41.0	3.0	.95	16	122.65	18x8 3/4x64#T		
12	SIDE	44.0	3.0	.95	16	131.62	18x8 3/4x64#T		
13	SIDE	47.0	3.0	.95	16	140.60	18x8 3/4x64#T		
14	SIDE	50.0	3.0	.95	16	149.57	24x9x76#T	217	CUT WT. 56.81#
15	SIDE	53.0	3.0	.95	16	158.54	24x9x76#T		
16	SIDE	56.0	3.0	.95	16	167.52	24x9x76#T		
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76#T		
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76#T		
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76#T		
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76#T		
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76#T		
22	BILGE	73.5	3.2	1.0	16	246.87	24x12x100#T	294	CUT WT. 70.48#
23	BILGE	77.0	3.2	1.1	16	284.48	24x12x100#T		
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108#T	369	CUT WT. 82.89#
25	BOTTOM	82.0	3.0	1.4	16	361.48	30x10 1/2x108#T		

LONGITUDINAL BULKHEAD PLATING

SECTION 22.23.1



$$t = \frac{s\sqrt{h}}{460} + .10 \text{ IN.}$$

① $t_1 = \frac{36\sqrt{78}}{460} + .10 = .791"$ ⟶ 7/8" PLT. (.875)

② $t_2 = \frac{36\sqrt{68}}{460} + .10 = .746"$ ⟶ 3/4" PLT. (.750)

③ $t_3 = \frac{36\sqrt{58}}{460} + .10 = .696"$ ⟶ 3/4" PLT. (.750)

④ $t_4 = \frac{36\sqrt{48}}{460} + .10 = .643"$ ⟶ 11/16" PLT. (.6875)

⑤ $t_5 = \frac{36\sqrt{38}}{460} + .10 = .583"$ ⟶ 5/8" PLT. (.625)

⑥ $t_6 = \frac{36\sqrt{28}}{460} + .10 = .514"$ ⟶ 9/16" PLT. (.5625)

⑦ $t_7 = \frac{36\sqrt{18}}{\ldots} + .10 = .432"$ ⟶ (MIN. 1/2" PLT.)

LONGITUDINAL STIFFENERS FOR LONG'L BHDS

LONG.NO.	HEAD TO DK.+8FT.	BHD PLTG	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	11	25.5#	3'-0"	.90	16	31.13	14x6 3/4x34 I/T	59.0	(CUT WT. 24.30#)
2	14	20.4#	3'-0"	.90	16	39.62	14x6 3/4x34 I/T	57.6	
3	17	20.4#	3'-0"	.90	16	48.11	14x6 3/4x34 I/T	57.6	
4	20	20.4#	3'-0"	.90	16	56.60	14x10x61 I/T	103.7	(CUT WT. 40.54#)
5	23	20.4#	3'-0"	.90	16	65.09	14x10x61 I/T	103.7	
6	26	22.95#	3'-0"	.90	16	73.58	14x10x61 I/T	105.3	
7	29	22.95#	3'-0"	.90	16	82.07	14x10x61 I/T	105.3	
8	32	22.95#	3'-0"	.90	16	90.56	14x10x61 I/T	105.3	
9	35	25.5#	3'-0"	.90	16	99.05	14x10x61 I/T	106.6	
10	38	25.5#	3'-0"	.90	16	107.54	16x8 1/2x78 I/T	150.3	(CUT WT. 54.99#)
11	41	25.5#	3'-0"	.90	16	116.03	16x8 1/2x78 I/T	150.3	
12	44	28.05#	3'-0"	.90	16	124.52	16x8 1/2x78 I/T	152.0	
13	47	28.05#	3'-0"	.90	16	133.01	16x8 1/2x78 I/T	152.0	
14	50	28.05#	3'-0"	.90	16	141.50	16x8 1/2x78 I/T	152.0	
15	53	30.6#	3'-0"	.90	16	149.99	16x8 1/2x78 I/T	154.1	
16	56	30.6#	3'-0"	.90	16	158.48	24x9x76 I/T	213.4	(CUT WT. 56.81#)
17	59	30.6#	3'-0"	.90	16	166.97	24x9x76 I/T	213.4	
18	62	30.6#	3'-0"	.90	16	175.46	24x9x76 I/T	213.4	
19	65	30.6#	3'-0'	.90	16	183.95	24x9x76 I/T	213.4	
20	68	30.6#	3'-0"	.90	16	192.44	24x9x76 I/T	213.4	
21	71	30.6#	3'-0"	.90	16	200.93	24x9x76 I/T	213.4	
22	74	35.7#	3'-0"	.90	16	209.42	24x9x84 I/T	241.4	(CUT WT. 62.38#)
23	77	35.7#	3'-0"	.90	16	217.91	24x9x84 I/T	241.4	
24	80	35.7#	3'-0"	.90	16	226.40	24x9x84 I/T	241.4	

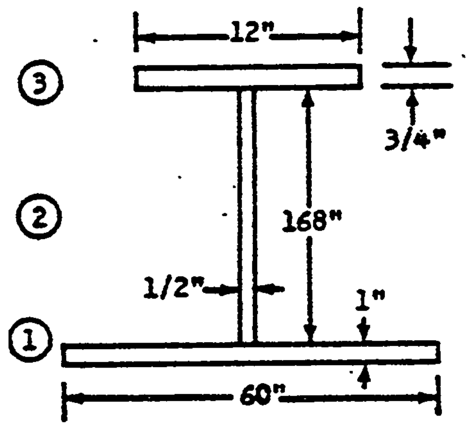
BOTTOM TRANSVERSES :

$c = 1.75$
$h = 74$
$s = 16$
$l_b = 30$

$S.M. = 0.0025\ chsl_b^2$

$S.M. = 0.0025\ (1.75)(74)(16)(30)^2$

$S.M. = 4662\ IN^3$



ITEM	AREA	Y	AY	AY^2	Io
1	60.00	.5	30.00	15.00	5.00
2	84.00	85.00	7140.00	606,900.00	197,568.00
3	9.00	169.38	1524.42	258,206.26	.42
	153.00		8694.42	865,121.26	197,573.42
				197,573.42	
				1,062,694.68	

Y = 56.83

$I_{NA} = 568,622.73\ IN.^4$

$S.M. = 5035.6\ IN.^3$

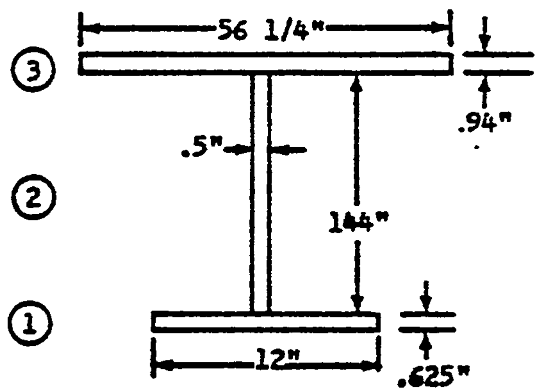
DECK TRANSVERSES:

c = 1.8
h = 20
s = 16
l_b = 30

S.M. = $.0025\ chsl_b^2$

S.M. = .0025 (1.8)(20)(16)(30)

S.M. = 1296 IN^3



ITEM	AREA	Y	AY	Ay^2	I_o
1	7.50	l 31	2.33	.72	3.89
2	72.00	72.63		379,756.13	124,420.00
3	52.88	145.10	7672.62	1,113,297.68	.24
	132.38		12,903.95	1,493,054.53	124,420.13
				124,420.13	
				1,617,474.66	

I_{NA} = 359,641 IN^4

S.M. = 3689 IN^3

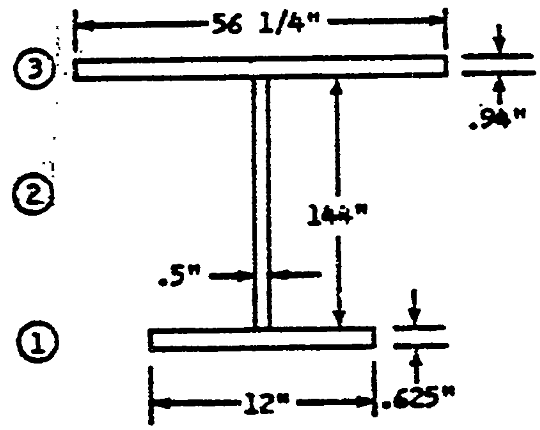
℄ DECK GIRDER

c = 2.5
h = 20
s = 41
l_b = 24

$S.M. = .0025\ chsl_b^2$

$S.M. = .0025(2.5)(20)(41)(24)^2$

$S.M. = 2952\ IN.^3$



ITEM	AREA	Y	AY	AY^2	Io
1	7.50	.31	2.33	.72	3.89
2	72.00	72.625	5,229.00	379,756.13	124,416.00
3	52.88	145.10	7,672.62	1,113,297.68	.24
	132.38		12,903.95	1,493,054.53	124,420.13
				124,420.13	
				1,617,474.66	

$I_{NA} = 359,561.27\ IN^4$

$S.M. = 3689.5\ IN^3$

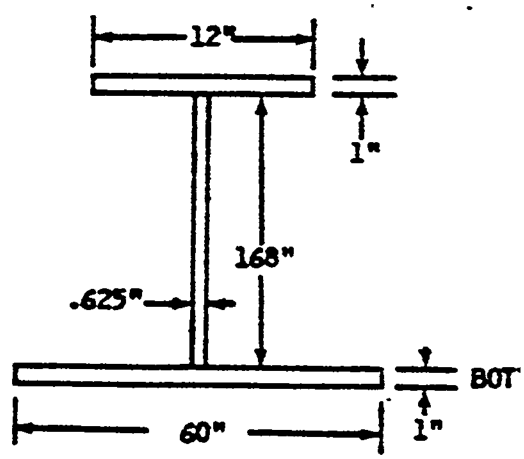
CENTER VERTICAL KEEL

$c = 2.00$
$h = 74$
s :
$l_b = 20$

$S.M. = .0025\ ChSL^2b$

$S.M. = .0025(2.00)(74)(41)(20)^2$

$S.M. = 6068\ IN^3$



ITEM		Y	AY	AY^2	Io
	60.00	.5	30.00	15.00	5.00
	105.00	85	8,925.00	758,625.00	246,960.00
	12.00	169.5	2,934.00	344,763.00	1.00
	177.00		10,989.00	1,103,403.00	246966.00
				246,966.00	
		$\bar{Y} = 62.08$		1,350,369.00	

$I_{NA} = 668{,}120.73\ IN^4$

$S.M. = 6191\ IN^3$

LOWER WING TANK STRUT

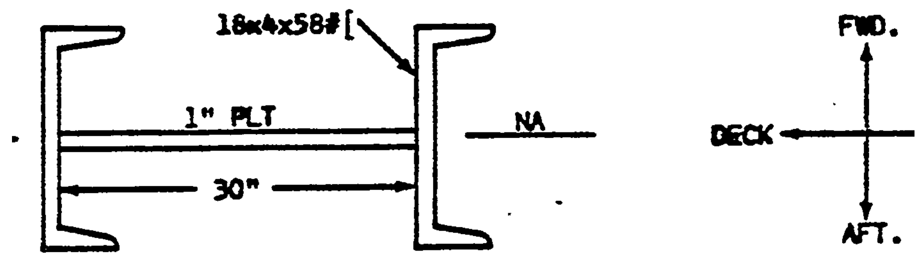
LOAD ON STRUT (22.27.9)

b = 13
h = 57
s = 16

w = 0.03 bhs LONG TONS

w = 0.03(13)(57)(16)

W = 355.7 LONG TONS



I_{NA} = 1344.4 IN^4

a = 63.96 IN^2

$r = \sqrt{\frac{1344.4}{63.96}} = 4.58$ IN.

PERMISSIBLE LOAD ON STRUT

W_a = [7.83 - .345(e/r)] ac

W_a = [7.83 - .345(13/4.58)] (63.96)(.90)

W_a = 394.3 L.T. >355.7 L.T.

1 = 13
r = 4.58
a = 63.96
c = .90

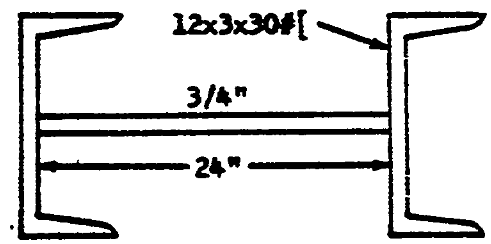
UPPER WING TANK STRUT

b = 13
h = 25
s = 16

W = 0.03 bhs LONG TONS

W = 0.03(13)(25)(16)

W = 156 LONG TONS



I_{NA} = 323.0 IN^4

a = 35.58 IN^3

r = 3.01 IN.

PERMISSIBLE LOAD ON STRUT

W^a = [7.83 - .345(e/r)] ac

1 = 13
r = 3.01
a = 35.58
c = .9

W_a = [7.83 - .345(13/3.01)] (35.58)(.90)

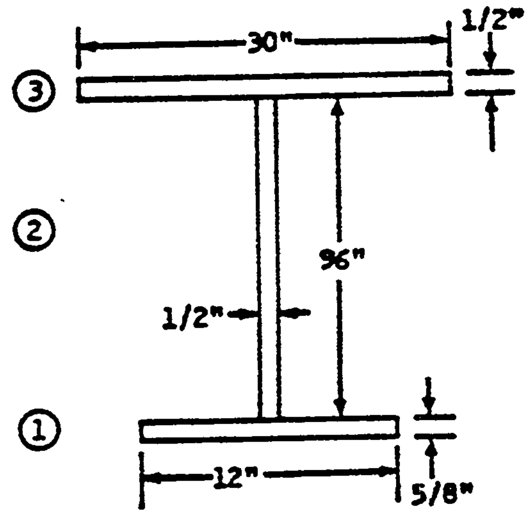
W_a = 2.03 L.T. >156 L.T.

VERTICAL TRANSVERSE WEBS

$S.M. = 0.0025\ chsl_b^2$

$S.M. = 0.0025(.65)(45)(16)(36)^2$

$S.M. = 1516\ IN^3$



c =
h =
s =
l_b =

ITEM	A	Y	AY	AY^2	
1	7.5	.38	2.85	1.08	
2	48.00	48.63	2334.24	113,514.10	36
3	15.00	96.88	1453.10	140,778.75	
	70.5		3790.19	254,293.93	36
				36,864.00	
				291,157.93	

Y = 53.76

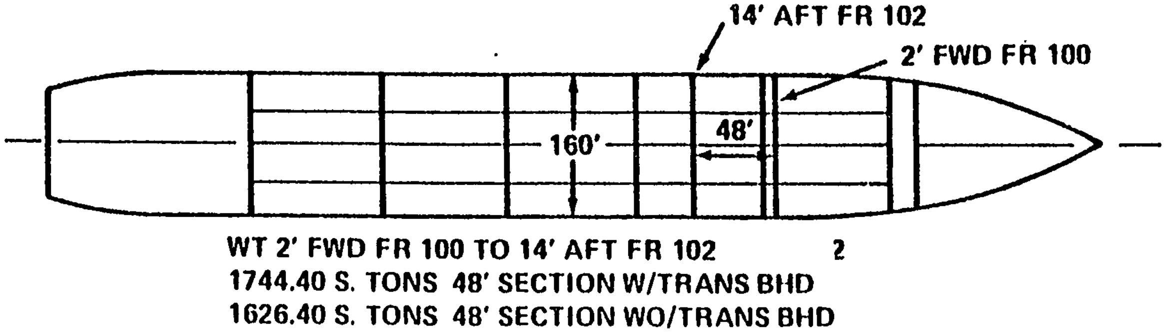
$I_{NA} = 87{,}391.1\ IN^4$

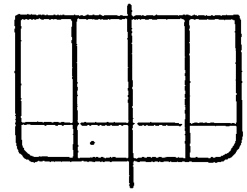
S.M. = 1626 IN^3

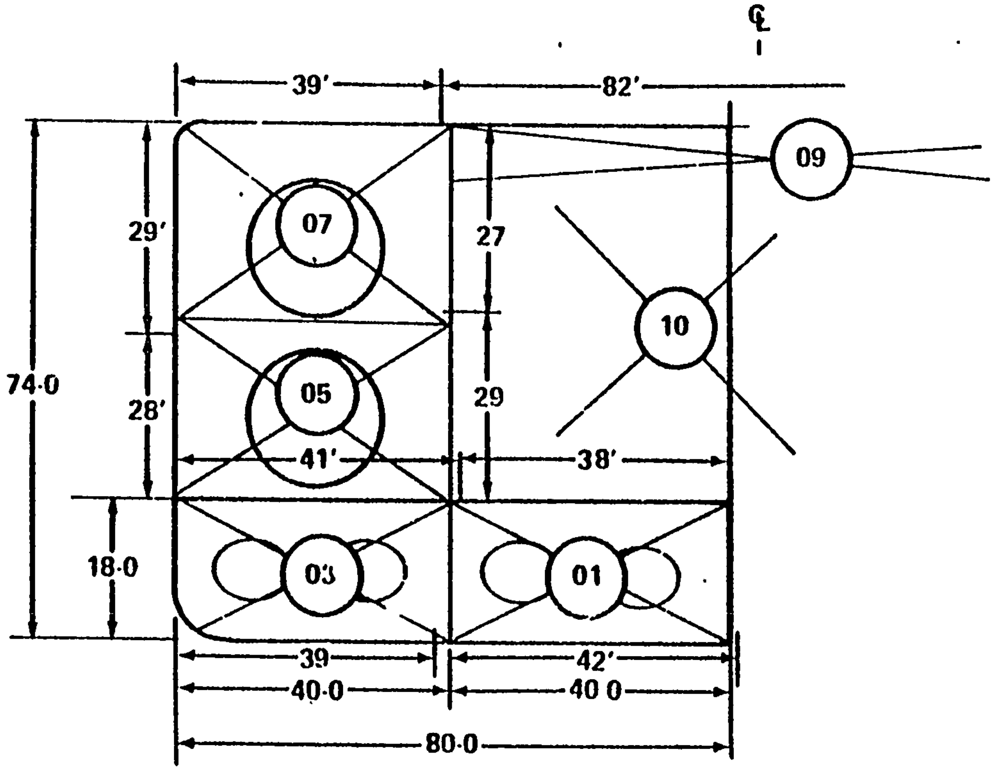
WEIGHT OF ONE FRAME SPACE

(INCLUDING ONE TRANSVERSE WEB)

ITEM	#/FT.	TOTAL WT.#
SIDE SHELL PLATING	35.7	73,113.6
BILGE PLATING	40.8	20,508.4
BOTTOM PLATING	40.8	87,475.2
FPK	45.9	4,406.4
DECK PLATING	38.25	97,920.0
WING BHD PLATING	VAR.	65,250.0
WING BHD LONG'L'S	VAR.	37,570.6
DECK LONG'L'S	20.0	15,360.0
SIDE SHELL LONG'L'S	VAR.	30,526.8
BILGE LONG'L'S	VAR.	7,163.2
BOTTOM LONG'L'S	82.89	61,007.0
WING WEBS & STRUTS	VAR.	48,882.0
BOTTOM TRANSVERSE GIRDER	VAR.	50,596.0
DECK TRANSVERSE GIRDER	VAR.	43,248.0
CENTER VERTICAL KEEL	VAR.	6,365.0
℄ DECK GIRDER	VAR	4,324.0
		653,746.2 lbs







ASSY	WT (S. TONS)
01 P	214.41
02 S	214.41
03 P	209.19
04 S	209.19
05 P	133.13
06 S	133.13
07 P	177.55
08 S	177.55
09 P/S	157.84
10 P/S	118.00

Figure 1-9. Configuration B-A Assembly Breakdown

C_R =

$\sqrt{0.7\ d + 0.02\ L + 0.1}$ IN.

$\sqrt{0.7(51) + 0.02\ (925) + 0.1}$ IN.

BOTTOM PLATING:

1.) $0.0003937\ L\ (2.6 = 10/D)$ IN.

$t = 0.0003937\ (925)(2.6 + 10/74)$ IN.

$t = .996$ IN.

2.) $t = 0.00331\ (s)\ \sqrt{0.7d + 0.02\ (L-164) + 0.1\ IN.}$

$t = 0.00331\ (36)\ \sqrt{0.7(51) + 0.02\ (925 - 164) + 0.1\ IN.}$

$t = .950$ IN.

BOTTOM PLATING = 1.0 IN.

FLAT PLATE KEEL:

BOITOM SHELL THICKNESS AMIDSHIPS INCREASED
BY 0.06 IN.

t = BOTTOM + 0.06 IN.

t = 1.01 IN. = 1 1/8″ ℄

DECK PLATING:

$t = 00000883\ (s)\ \sqrt{L-174 + 0.0126\ (L/D) - 0.1\ IN.}$

$t = 0.000883\ (36)\ \sqrt{925-174 + 0.0126\ (12.50) - 0.1\ IN.}$

$t = .930$ IN.

DECK PLATING = 15/16 IN.

DECK LONGITUDINAL

SM - 0.0041 chs L^2 IN^3

SM = 0.0041 (1.25)(8)(3)(16^2)

SM = 31.49 IN^3

SELECTED SHAPE FROM TABLE P-5d

8x7v20#on40.8# DECK PLATING

(S.M. = 35.1 IN^3) (60 t)

SIDE ℄ 7/8"

BOTTOM P = 1"

SM. = 0.0041 chs L^2 IN^3 DECK LONG'LS SHEET OF

LONG. NO.	LOCATION OF LONG	HEAD TO 8' ABV. DK.	SPACING OF.	C	L	CALCULATED SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	SIDE	11.0	3.0	.95	16	32.90	14x6 3/4x34# I-T	60.8	24.30
2	SIDE	14.0	3.0	.95	16	41.88	14x6 3/4x34# I-T	60.8	24.30
3	SIDE	17.0	3.0	.95	16	50.85	14x6 3/4x34# I-T	60.8	24.30
4	SIDE	20.0	3.0	.95	16	59.83	14x6 3/4x34# I-T	60.8	24.30
5	SIDE	23.0	3.0	.95	16	68.80	16x7x40# I-T	80.6	28.91
6	SIDE	26.0	3.0	.95	16	77.78	16x7x40# I-T	80.6	28.91
7	SIDE	29.0	3.0	.95	16	86.75	16x8 1/2x58# I-T	115.6	40.79
8	SIDE	32.0	3.0	.95	16	95.72	16x8 1/2x58# I-T	115.6	40.79
9	SIDE	35.0	3.0	.95	16	104.70	16x8 1/2x58# I-T	115.6	40.79
10	SIDE	38.0	3.0	.95	16	113.67	16x8 1/2x58# I-T	115.6	40.79
11	SIDE	41.0	3.0	.95	16	122.65	16x8 1/2x71# I-T	142.4	49.98
12	SIDE	44.0	3.0	.95	16	131.62	16x8 1/2x71# I-T	142.4	49.98
13	SIDE	47.0	3.0	.95	16	140.60	16x8 1/2x71# I-T	142.4	49.98
14	SIDE	50.0	3.0	.95	16	149.57	21x8 1/4x68# I-T	173.9	50.40
15	SIDE	53.0	3.0	.95	16	158.54	21x8 1/4x68# I-T	173.9	50.40
16	SIDE	56.0	3.0	.95	16	167.52	21x8 1/4x68# I-T	173.9	50.40
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76# I-T	217.2	56.81
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76# I-T	217.2	56.81
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76# I-T	217.2	56.81
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76# I-T	217.2	56.81
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76# I-T	217.2	56.81
22	BILGE	73.5	3.2	1.0	16	246.87	24x9x94# I-T	270.6	69.66
23	BILGE	77.0	3.2	1.1	16	284.48	27x10x94# I-T	297.8	70.53
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108# I-T	369.3	82.89
25	BOTTOM	82.0	3.0	1.4	16	3[illegible]1.48	30x10 1/2x108# I-T	369.3	82.89

B-A-30

DECK-SIDE AND BOTTOM LONGITUDINALS

LONGITUDINAL STIFFENERS FOR LONG'L BHD'S

SM. 0.0041 chs L^2 IN^3

LONG. NO.	HEAD TO DK + 8 FT.	BHD ℄	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	11	25.5#	3'-0"	.90	16.0	31.13	14x6 3/4x34 I-T	59.0	24.30
2	14	20.4#	3'-0"	.90	16.0	39.62	14x6 3/4x34 I-T	57.6	24.30
3	17	20.4#	3'-0"	.90	16.0	48.11	14x6 3/4x34 I-T	57.6	24.30
4	20	20.4#	3'-0"	.90	16.0	56.60	14x6 3/4x34 I-T	57.6	24.30
5	23	20.4#	3'-0"	.90	16.0	65.09	14x8x43 I-T	72.3	29.60
6	26	22.95#	3'-0"	.90	16.0	73.58	14x8x53 I-T	90.6	36.41
7	29	22.95#	3'-0"	.90	16.0	82.07	14x8x53 I-T	90.6	36.41
8	32	22.95#	3'-0"	.90	16.0	90.56	14x8x53 I-T	90.6	36.44
9	35	25.5#	3'-0"	.90	16.0	99.05	14x10x68 I-T	117.8	45.24
10	38	25.5#	3'-0"	.90	16.0	107.54	14x10x68 I-T	117.8	45.24
11	41	25.5#	3'-0"	.90	16.0	116.03	14x10x68 I-T	117.8	45.24
12	44	28.05#	3'-0"	.90	16.0	124.52	15x10 1/2x54 T	145.5	53.99
13	47	28.05#	3'-0"	.90	16.0	133.01	15x10 1/2x54 T	145.5	53.99
14	50	28.05#	3'-0"	.90	16.0	141.50	15x10 1/2x54 T	145.5	53.99
15	53	30:6#	3'-0"	.90	16.0	149.99	21x2 1/4x68 I-T	171.0	50.40
16	56	30.6#	3'-0"	.90	16.0	158.48	21x2 1/4x68 I-T	171.0	50.40
17	59	30.6#	3'-0"	.90	16.0	166.97	21x8 1/4x68 I-T	171.0	50.40
18	62	30.6#	3'-0"	.90	16.0	175.46	24x9x76 I-T	213.4	56.81
19	65	30.6#	3'-0"	.90	16.0	183.95	24x9x76 I-T	213.4	56.81
20	68	30.6#	3'-0"	.90	16.0	192.44	24x9z76 I-T	213.4	56.81
21	71	30.6#	3'-0"	.90	16.0	200.93	24x9x76 I-T	217.2	56.81
22	74	35.7#	3'-0"	.90	16.0	209.42	24x9x84 I-T	241.4	62.38
23	77	35.7#	3'-0"	.90	16.0	217.91	24x9x84 I-T	241.4	62.38
24	80	35.7#	3'-0"	.90	16.0	226.40	24x9x84 I-T	241.4	62.38

INNERBOTTOM PLATING

SECTION 7.5.1

t = 0.000445 L + 0.009s + 0.06

t = 0.000445 (925) + 0.009 (36) + 0.06

t = 796″ - 0.04= 756 = 3/4" ℄ (7.5.1)

lNNERBOTTOM LONGITUDINALS (7.3.1)

85% OF BOTTOM LONGITUDINAL

SMM = 361.48 x .85 = 307.26 IN^3

27 X 10 X 102 I-T (SM = 317.8)(WEIGHT PER FOOT = 76.19)

DEEP TANK TRANSVERSE BHD. PLATING (13.3.1)

$$t = \frac{s \sqrt{n}}{460} + 0.10$$

$$t = \frac{36 \sqrt{37.7 + 20}}{460} + 0.10$$

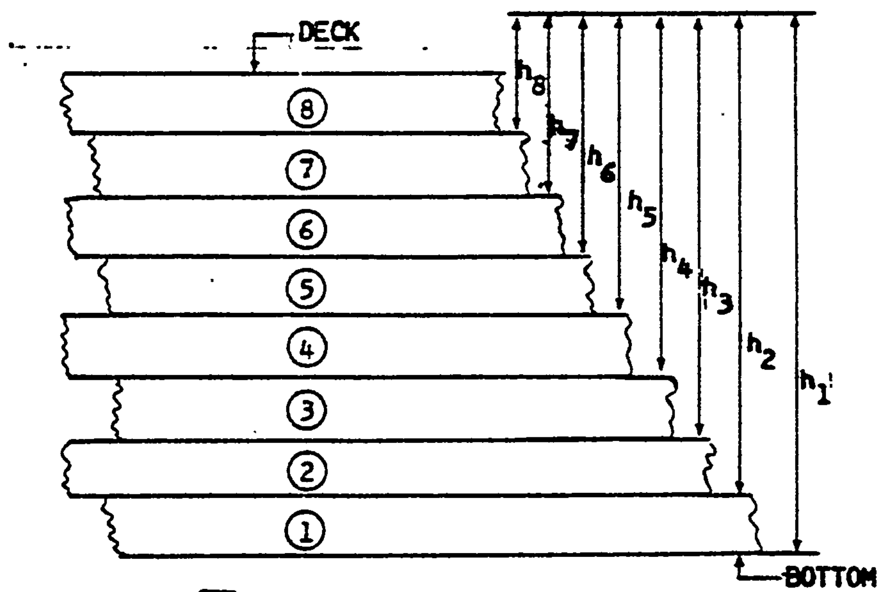
t = .595 + 0.10 = .695 IN.

t = 3/4″ PLATE

LONGITUDINAL BULKHEAD PLATING

ABS 22-23.1

$$t = \frac{s\sqrt{h}}{460} + .10 \text{ INCH.}$$



$t_1 = \frac{36\sqrt{78}}{460} + .1 = .791$ = 7/8" (.875)

$t_2 = \frac{36\sqrt{68}}{460} + .1 = .746$ = 3/4" (.750)

$t_3 = \frac{36\sqrt{58}}{460} + .1 = .696$ = 3/4" (.750)

$t_4 = \frac{36\sqrt{48}}{460} + .1 = .643$ = 11/16" (.6875)

$t_5 = \frac{36\sqrt{38}}{460} + .1 = .583$ = 5/8" (.625)

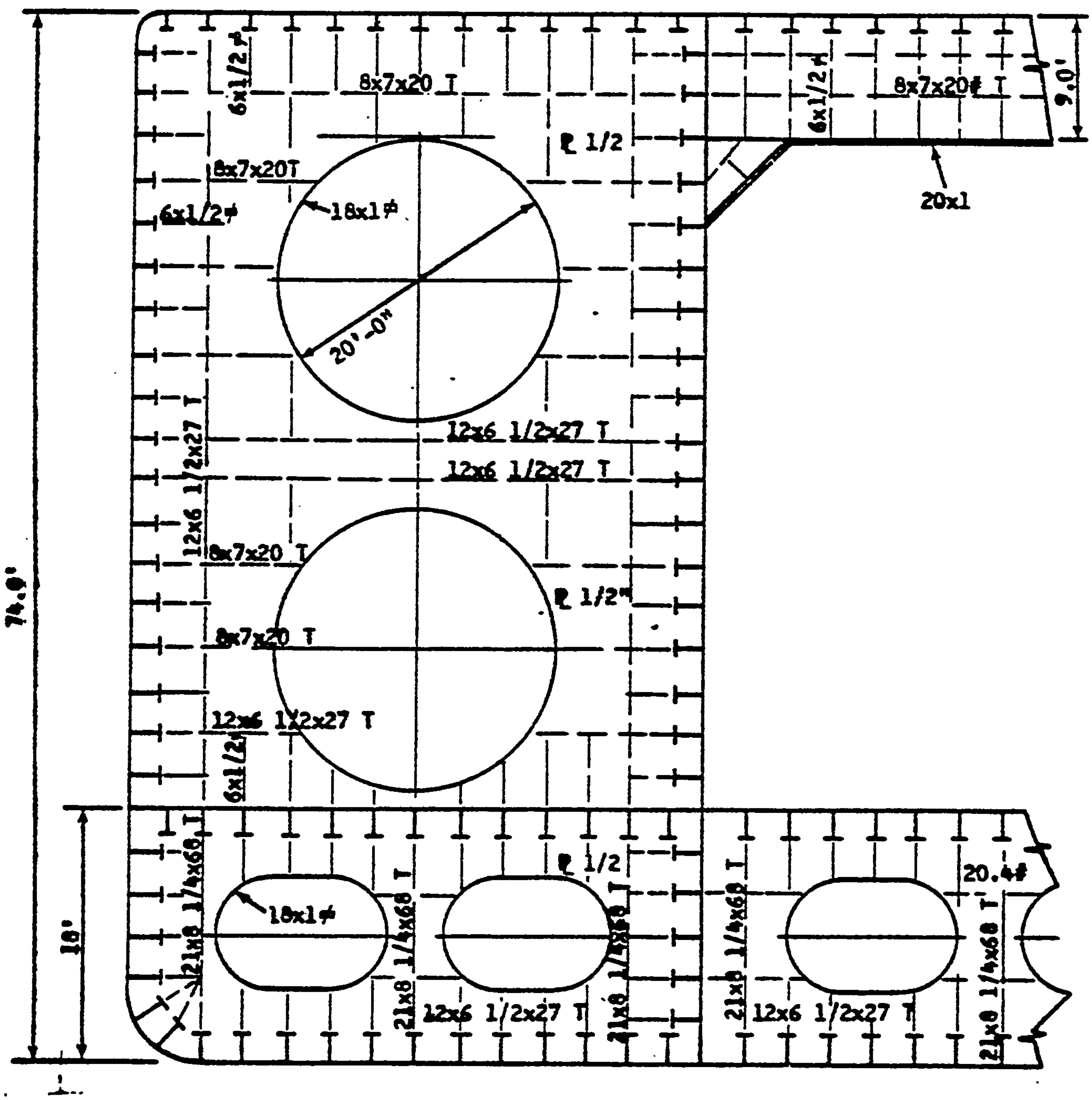
$t_6 = \frac{36\sqrt{28}}{460} + .1 = .514$ = 9/16" (.5625)

$t_7 = \frac{36\sqrt{18}}{460} + .1 = .432$ = (MIN. 1/2")

$t_8 = \frac{26\sqrt{8}}{460} + .1 = .322$ = (MIN. 5/8")

WEB GIRDER CALCULATION SHOWN ON

CONFIGURATION: (B-B)



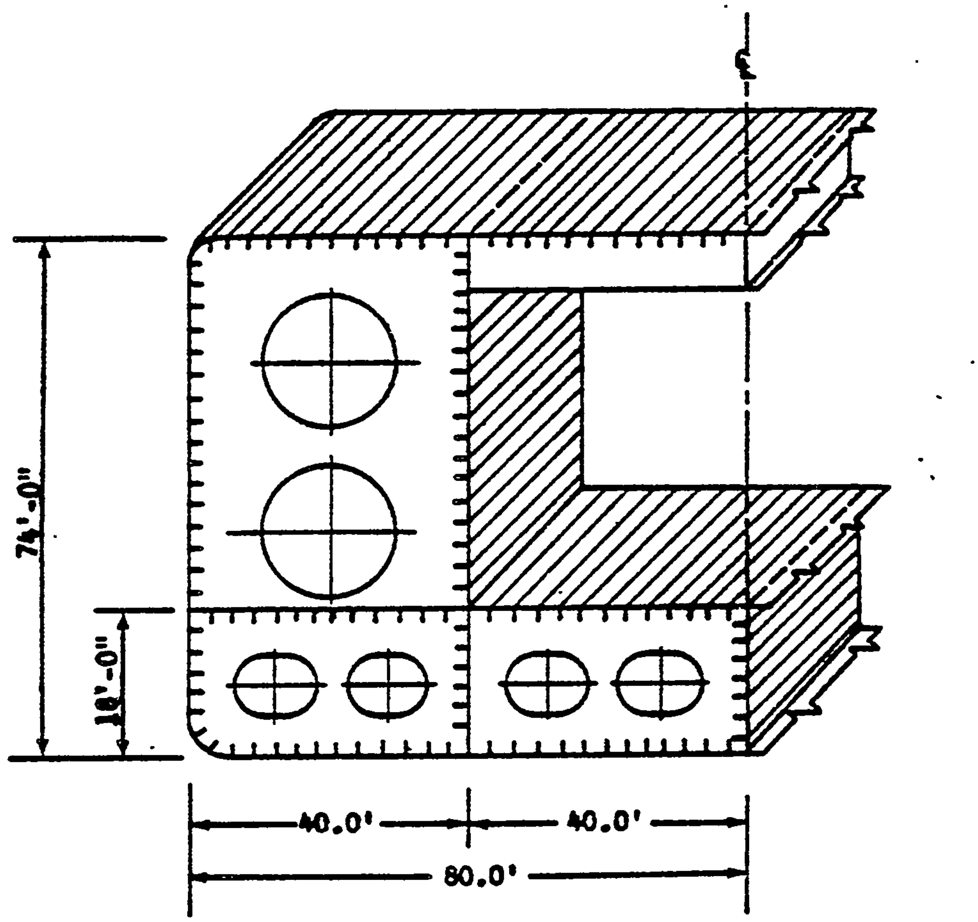
8x7x20 T
6x1/2#
P 1/2
8x7x20# T
9.0'
20x1
8x7x20T
6x1/2#
18x1#
20'-0"
12x6 1/2x27 T
12x6 1/2x27 T
12x6 1/2x27 T
8x7x20 T
P 1/2"
8x7x20 T
12x6 1/2x27 T
6x1/2#
P 1/2
18x1#
21x8 1/4x68 T
20.4#
12x6 1/2x27 T
12x6 1/2x27 T

SCALE 3/32" = 1'

MIDSHIP SECTION CONFIGURATION
CONFIGURATION (B-A)

WEIGHT ESTIMATE FOR A TYPICAL 16′-0″ LONG
TANKER SECTION MIDSHIPS

ESTIMATE INCLUDES: DECK, SIDEWELL, BOTTOM, LONG'L, BHD, INNER-BOTTOM-PLATING AND STIFFENERS. ALSO ONE COMPL. WEB GIRDER.



TOTAL WEIGHT = 862,976 LBS

1.)	DECK PLATING = 16 X 38.3 X 160	= 98,046
2.)	SIDE SHELL PLATING = 16 X 35.7 X 74 X 2	= 84,538
3.)	BOTTOM PLATING = 16. X 40.8 X 152	= 99,226
4.)	FLAT PLATE KEEL = 16 X 45.9 X 8	= 5,875
5.)	LONGITUD. BULKH. PLATING = 16 X 35.7 X 10 X 2	= 11,424
	16 X 30.6 X 20 X 2	= 19,584
	16 X 28.1 X 10 X 2	= 8,988
	16 X 25.5 X 10 X 2	= 8,160
	16 X 23.0 X 10 X 2	= 7,360
	16 X 20.4 X 10 X 2	= 6,528
	16 X 25.5 X 4 X 2	= 3,264
6.)	INNER BOTTOM PLATING = 16 X 30.6 X 160	= 78,336
7.)	INNER BOTTOM BHD. PLATING 16 X 30.6 X 10	= 4,896
	16 X 37.5 X 8	= 4,800
8.)	DECK LONGITUDINAL 16 X (8 X 7 X 20.T#) X 24 X 2	= 15,360
9.)	SIDE LONGITUDINALS 16 X (14 X 6 3/4 X 34#) X 24.3 X 4 X 2	= 3,110
	16 x(16 x 7 x 40#) x 28.91 x 2 x 2	= 1,850
	16 x (16 x 81/2 x 58#) x 40.79 x 4 x 2	= 5,222
	16 x (16 x 81/2 x 71#) x 49.98x 3 x 2	= 4,798
	16 x (21 x 81/4 x 68#) x 50.40 x 3 x 2	= 4,838
	16 x(24 x 9 x 76 #)x 56.81 x 5 x 2	= 9,090
	16 x (24 x 9 x 94#)x 69.66 x l x 2	= 2,230
	16 x (27 x 10 x 94#) x 70.53 x lX 2	= 2,256
	16 X (30 X 10 1/2 X 108#) X 82.89 X 1 X 2	= 2,652
lo.)	BOTTOM LONGITUDINAL 16 X (30 X 10 1/2 X 108#) X 82.89 X 24 X 2	= 63,660
	INNER BOTTOM LONG'LS 16 (27 X 10 X 102#) X 76.19 X 24 X 2	= 58,500
	SUBTOTAL	= 614,593 LBS

11.) TRANSV. GIRDER 16'-0" C. TO C.

a.) PLATING (74 x 40 x 20.4#) x 2	= 120,768
18 X 80 X 20.4#	= 29,376
6 X 6 x 20.4#	= 734
9.0 X 80 X 20.4#	= 14,688
b.) #18 x l x 544. FT (61.2)	= 33,293
#20 X l x 90 FT (80.9)	= 3,672
#6 x l/2 x 530 FT (20.4)	= 10,812
C-.) 8 X 7 X 20# T X 530 FT (19.99)	= 10,595
12 x 61/2 x 27 T x 300 FT (19.8)	= 5,640
21 X 8 1/4 x 68 T x 150 FT (50.40)	= 7,560

12.) **℄ TOP DECK GIRDER**

16 X 9.0 x 20.4#	= 2,938
16 X 2 X40.8#	= 1,306
24 x 9 X 0.5 X 20.4#	= 2,203
80 x 3 (8 x 7 X 20.4#T) (19.,99#)	= 4,798
SUBTOTAL	= 248,383
	614,593
TOTAL	962,976

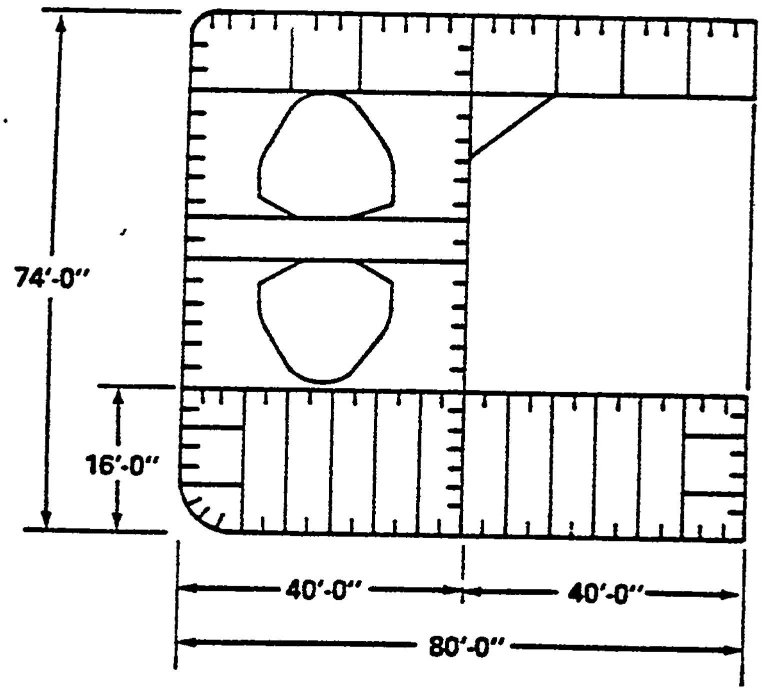


Figure 1-4. Section No. 4 - Configuration B-B

Advantages:

1. High degree of segregated ballast
2. Easy assembly and sub - assembly breakdown
3. Less frequent sludge cleaning due to smooth innerbottom
4. Very little oil outflow due to stranding
5. B/3 wing tank width complies with IMCO reg.
6. Large flat panels lend themselves to automated production.

Disadvantages:

1. High potential oil outflow in case of grounding casualty
2. Iarge steel weight
3. Large assembly and sub-assembly breakdown
4. Large amount of welding is necessary

SHIP PARAMETERS:

LBP = 925 FT.
B = 160 FT.
D = 74 FT.
d = 51 FT.
C_B = l 84
L/B = 5.78
L/D = 12.50

BASIC ASSUMPTIONS:

TANK LENGTH = 96' - 0"

TRANSV. GIRDER SPACING = 16' - 0"

LONG'L FRAME SPACING = 3' . o"

SIDE SHELL PLATING: (22.9.1)

1.) $t = 0.0003937\ L\ (2.0 + 21/D)$ IN.

$t = 0.0003937\ (925)(2.0 + 21/74)$ IN.

$t = .832$

2.) $t = 0.00287(s)\ \sqrt{0.7\ d + 0.02\ L + 0.1}$ IN.

$t = 0.00287(36)\ \sqrt{0.7(51) + 0.02\ (925) + 0.1}$ IN.

$t = .86$

SIDE SHELL= 7/8 IN.

BOTTOM PLATING:

1.) 0.0003937 L (2.6 = 10/D) IN.

t = 0.0003937 (925}(2.6 +.10/74) IN.

t = .996 IN.

2.) t = 0.00331 (s) $\sqrt{0.7d + 0.02\ (L-164) + 0.1}$ IN.

t = 0.00331 (36) $\sqrt{0.7(51) + 0.02\ (925 - 164) + 0.1}$ IN.

t = .950 IN.

BOTTOM PLATING = 1.0 IN. PLT

FLAT PLATE KEEL:

BOTTOM SHELL THICKNESS AMIDSHIPS INCREASED BY 0.06 IN.

t = BOTTOM + 0.06″ IN.

t = 1.01 IN. = 1 1/8" PLT

DECK PLATING:

t = 0.000883 (s) $\sqrt{L-174} + 0.0126\ (L/D) - 0.1$ IN.

t = 0.000883 (36) $\sqrt{925-174} + 0.0126\ (12.50) - 0.1$ IN.

t = .930 IN.

DECK PLATING = 15/16 IN.PLT

SIDE P 7/8"PLT

BOTTOM P = 1"PLT

SM. = 0.0041 chs L^2 IN^3 DECK LONG'LS SHEET OF

LONG. NO.	LOCATION OF LONG	HEAD TO 8' ABV. DK.	SPACING OF.	C	L	CALCULATED SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	SIDE	11.0	3.0	.95	16	32.90	14x6 3/4x34# I-T	60.8	24.30
2	SIDE	14.0	3.0	.95	16	41.88	14x6 3/4x34# I-T	60.8	24.30
3	SIDE	17.0	3.0	.95	16	50.85	14x6 3/4x34# I-T	60.8	24.30
4	SIDE	20.0	3.0	.95	16	59.83	14x6 3/4x34# I-T	60.8	24.30
5	SIDE	23.0	3.0	.95	16	68.80	16x7x40# I-T	80.6	28.91
6	SIDE	26.0	3.0	.95	16	77.78	16x7x40# I-T	80.6	28.91
7	SIDE	29.0	3.0	.95	16	86.75	16x8 1/2x58# I-T	115.6	40.79
8	SIDE	32.0	3.0	.95	16	95.72	16x8 1/2x58# I-T	115.6	40.79
9	SIDE	35.0	3.0	.95	16	104.70	16x8 1/2x58# I-T	115.6	40.79
10	SIDE	38.0	3.0	.95	16	113.67	16x8 1/2x58# I-T	115.6	40.79
11	SIDE	41.0	3.0	.95	16	122.65	16x8 1/2x71# I-T	142.4	49.98
12	SIDE	44.0	3.0	.95	16	131.62	16x8 1/2x71# I-T	142.4	49.98
13	SIDE	47.0	3.0	.95	16	140.60	16x8 1/2x71# I-T	142.4	49.98
14	SIDE	50.0	3.0	.95	16	149.57	21x8 1/4x68# I-T	173.9	50.40
15	SIDE	53.0	3.0	.95	16	158.54	21x8 1/4x68# I-T	173.9	50.40
16	SIDE	56.0	3.0	.95	16	167.52	21x8 1/4x68# I-T	173.9	50.40
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76# I-T	217.2	56.81
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76# I-T	217.2	56.81
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76# I-T	217.2	56.81
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76# I-T	217.2	56.81
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76# I-T	217.2	56.81
22	BILGE	73.5	3.2	1.0	16	246.87	24x9x94# I-T	270.6	69.66
23	BILGE	77.0	3.2	1.1	16	284.48	27x10x94# I-T	297.8	70.53
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108# I-T	369.3	82.89
25	BOTTOM	82.0	3.0	1.4	16	361.48	30x10 1/2x108# I-T	369.3	82.89

SHELL & BOTTOM LONGITUDINALS

DECK LONGITUDINALS

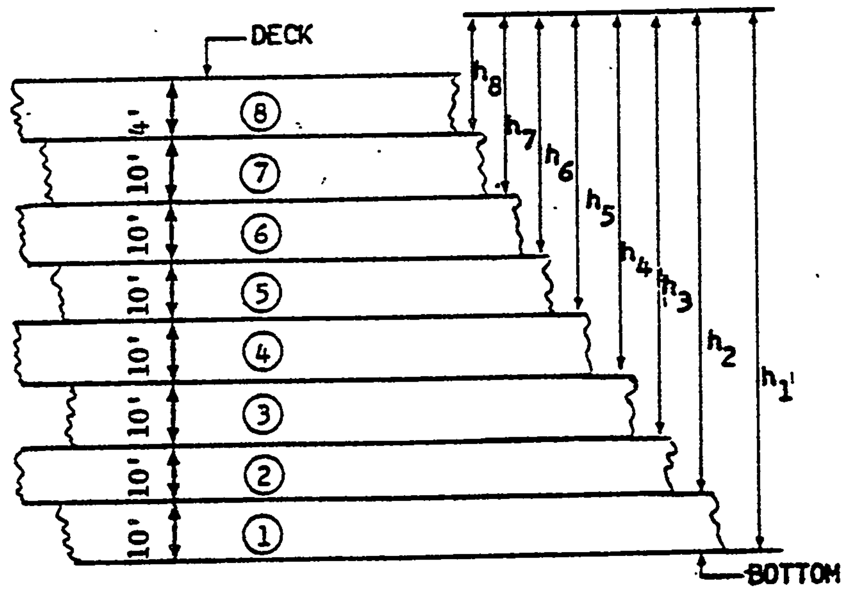
S.M. = 0.0041 chs1^2 I N^3

S.M. = 0.0041 (1.25)(8)(3)$06)^2$

S.M. = 31.49

8 x 7 X 20 # T ON 40.8# DK. PLTG. S.M. = 34.6 IN^3(36t)

$$t = \frac{s\sqrt{h}}{460} + .10 \text{ INCH.}$$



$t_1 = \frac{36\sqrt{78}}{460} + .1 = .791 = 7/8" \ (.875)$

$t_2 = \frac{36\sqrt{68}}{460} + .1 = .746 = 3/4" \ (.750)$

$t_3 = \frac{36\sqrt{58}}{460} + .1 = .696 = 3/4" \ (.750)$

$t_4 = \frac{36\sqrt{48}}{460} + .1 = .643 = 11/16" \ (.6875)$

$t_5 = \frac{36\sqrt{38}}{460} + .1 = .583 = 5/8" \ (.625)$

$t_6 = \frac{36\sqrt{28}}{460} + .1 = .514 = 9/16" \ (.5625)$

$t_7 = \frac{36\sqrt{18}}{460} + .1 = .432 = (\text{MIN. } 1/2")$

$t_8 = \frac{26\sqrt{8}}{460} + .1 = .322 = (\text{MIN. } 5/8")$

LONGITUDINAL STIFFENERS FOR LONG'L BHD'S

SM. 0.0041 $chsl^2$ IN^3

LONG. NO.	HEAD TO DK + 8 FT.	BHD PL	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	11	25.5#	3'-0"	.90	16.0	31.13	14x6 3/4x34 I-T	59.0	24.30
2	14	20.4#	3'-0"	.90	16.0	39.62	14x6 3/4x34 I-T	57.6	24.30
3	17	20.4#	3'-0"	.90	16.0	48.11	14x6 3/4x34 I-T	57.6	24.30
4	20	20.4#	3'-0"	.90	16.0	56.60	14x6 3/4x34 I-T	57.6	24.30
5	23	20.4#	3'-0"	.90	16.0	65.09	14x8x43 I-T	72.3	29.60
6	26	22.95#	3'-0"	.90	16.0	73.58	14x8x53 I-T	90.6	36.41
7	29	22.95#	3'-0"	.90	16.0	82.07	14x8x53 I-T	90.6	36.41
8	32	22.95#	3'-0"	.90	16.0	90.56	14x8x53 I-T	90.6	36.44
9	35	25.5#	3'-0"	.90	16.0	99.05	14x10x68 I-T	117.8	45.24
10	38	25.5#	3'-0"	.90	16.0	107.54	14x10x68 I-T	117.8	45.24
11	41	25.5#	3'-0"	.90	16.0	116.03	14x10x68 I-T	117.8	45.24
12	44	28.05#	3'-0"	.90	16.0	124.52	15x10 1/2x54 T	145.5	53.99
13	47	28.05#	3'-0"	.90	16.0	133.01	15x10 1/2x54 T	145.5	53.99
14	50	28.05#	3'-0"	.90	16.0	141.50	15x10 1/2x54 T	145.5	53.99
15	53	30.6#	3'-0"	.90	16.0	149.99	21x2 1/4x68 I-T	171.0	50.40
16	56	30.6#	3'-0"	.90	16.0	158.48	21x2 1/4x68 I-T	171.0	50.40
17	59	30.6#	3'-0"	.90	16.0	166.97	21x8 1/4x68 I-T	171.0	50.40
18	62	30.6#	3'-0"	.90	16.0	175.46	24x9x76 I-T	213.4	56.81
19	65	30.6#	3'-0"	.90	16.0	183.95	24x9x76 I-T	213.4	56.81
20	68	30.6#	3'-0"	.90	16.0	192.44	24x9z76 I-T	213.4	56.81
21	71	30.6#	3'-0"	.90	16.0	200.93	24x9x76 I-T	217.2	56.81
22	74	35.7#	3'-0"	.90	16.0	209.42	24x9x84 I-T	241.4	62.38
23	77	35.7#	3'-0"	.90	16.0	217.91	24x9x84 I-T	241.4	62.38
24	80	35.7#	3'-0"	.90	16.0	226.40	24x9x84 I-T	241.4	62.38

INNERBOTTOM PLATING

SECTION 7.5.1

t = 0.000445 L + 0.009s + 0.06

t = 0.000445 (925) + 0.009 (36) + 0.06

t = 796" - 0.04 = 756 = 3/4" R (7.5.1)

INNERBOTTOM LONGITUOINALS (7.31)

85% OF BOTTOM LONGITUOINALS

SM = 361.48 X .85 = 307.26 IN^3

27 X 10 X 102 I-T (SM = 317.8)(WIGHT PER FOOT = 76.19)

DEEP TANK TRANSVERSE BHD. PLTG. (13.31)

LIMITING FACTOR = 2/3 of TANKTOP TO OVERFLOW

2/3 x (58 + 2.5) = 40.33 = h

$$t = \frac{s\sqrt{h}}{460} + 0.10$$

$$t = \frac{36\sqrt{40.33 + 16}}{460}$$

t - .587 +0.10= .687

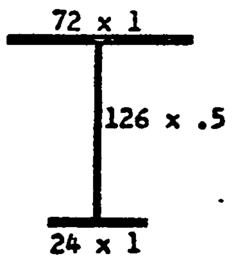
t = 3/4 R

DECK TRANSVERSE GIRDER

S.M.

$=0.0025\ (2.5)(14)(16)(34)^2$

$= 1618\ IN^3$



A	Y	AY	AY^2
24	.5	12	6.0
63	64	4,032	258,048
72	127.5	9,180	1,170,450
159		13,224	1,428,504
			83,349
			1,511,853

$\bar{Y} = 83.17$

*BEAM IS OVERLY STRONG DUE TO DEPTH OF BEAM ESTABLISHED IN EARLIER CRITERIA

$I = 1{,}511{,}953 - 16\ (93.17)^2$

$I = 412{,}015$

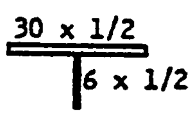
$S.M. = 4{,}953\ IN^3$

SIDE CDR. TOP: $S.M. = 0.0025(3.5)(34)(16)(15)^2$

$= 1071\ IN^3$

SIDE GDR. SIDE: $S.M. = 0.0025(1.10)934)(16)(30)^2$

$= 1346\ IN^3$



A	Y	AY	AY^2	Io
15	6.25	93.4	585.9	0.3
3	3	9.0	27.0	9.0
18		102.4	612.9	9.3
			9.3	
			622.2	

$I = 622.2 - 18\ (5.688^2)$

$I = 39.4\ IN^4$

WEB GIRDER STIFFENERS ATTACHED TO LONGITUDINALS

GIRDER STIFFENERS (22.27.7)

TO TRANSV., VERT, & HORZ GDRS.

$I = 0.38Lt^3 (L/S)^2 \ IN^4$

$= 0.38 \ (126)(0.5)^3 (3.5^2)$

$I = 73.31 \ IN^4$

BOTTOM SWASH
BHD. STIFFENERS

$I = 0.38 \ (240)(0.5)^3 (5.55)^2 \ IN^4$

$= 351.1 \ IN^4$

12 X 6 1/2 x27 I-T (18.8#/FT.) $I = 397.8 \ IN^4$

WT. ESTIMATE

1) DECK PLATING: 16 X 38.3 X 160		= 99,049
2) SIDE SHELL PLATING: 16 X 35.7 x 74 X 2		= 94,53!3
3) BOTTOM PLATING: 16 X 40.8 X 152		= 99,226
4) FLAT PLATE KEEL: 16 X 45.9 X 8		= 5,975
5) LONG'L. BULKHEAD PLT:	16 X 35.7 x 10 x 2	= 11,424
	16x30.6x20x2	= 19,584
	16x28.1x10X2	= 8,998
	16x25.5x10X2	= 8,160
	16 X 23.0X 10 X 2	= 7,360
	16x20.4X10X2	= 6,529
	16x25.5x4x2	= 3,264
6) 1.6. PLATING:	16 X 30.6 X 160	= 78,336
7) I.B. ¢BHD PLTG:	16 x 30.6 x 6	= 2,937
	16 X 35.7 x 10	= 6,000
8) DECK LONGITUDINAL	16x20#x24x2	= 15,360
9) SIDE LONGITUDINAL	16x24.3x4x2	= 3,110
	16x29.91x2x2	= 1,550
	16x40.79x4x2	= 5,222
	16x49.98x3x2	= 4,799
	16x50.40x3x2	= 4,939
	16x56.91x5x2	= 9,090
	16x69.66x1x2	= 2,230
	16x70.53x1x2	= 2,256
	16x92.89x1x2	= 2,652
10) BOTT. LONG'LS	16 X 82.89x 24x 2	= 63,660
I.B. CONG'LS	16 X 76.19x 24x 2	= 58,500
	SUBTOTAL	= 613,884

11) TRANSV. GDR. 16′-0″ =

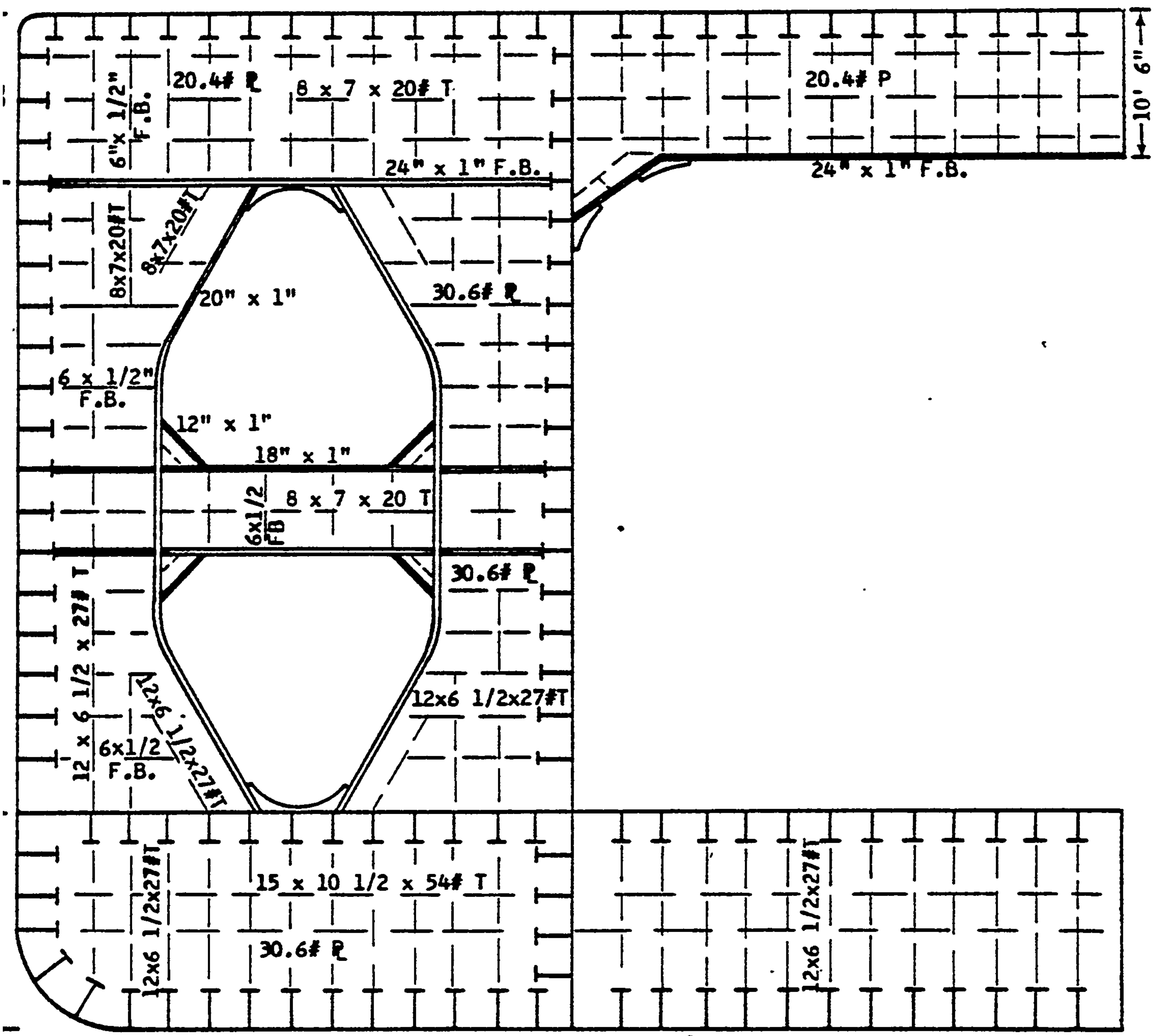
a) PLATING 12 x 160 x 20.4#	=	39,169
20 X 160 X 20.4#	=	65,290
4 x 10.5 X 42 X 20.4#	=	35,956
8 x $\frac{6 \times 6}{3}$ x 20.4#	=	2,939
2 x 6 X 20 X 20.4#		4,896
b) F.B. 2 X 160 X 40.8#	=	13,056
4 x 45 X 1.67 X 40.9#	=	12,264
4 x 4 X 1.5 x 40.8#	=	9,792
1 X 32 X 40.8#	=	1,306
0.5 x 20.4# X 1044	=	10,649
c) 8x7x20#T (19.9) x 640	=	12,736
12x61/2x 27 # T (19.9) X 650	=	12,220
15 x 101/2 X 54 # T (53.99) X 160	=	8,639
21 X 8 1/4 x 603#T (50.40) X 160	=	9,064

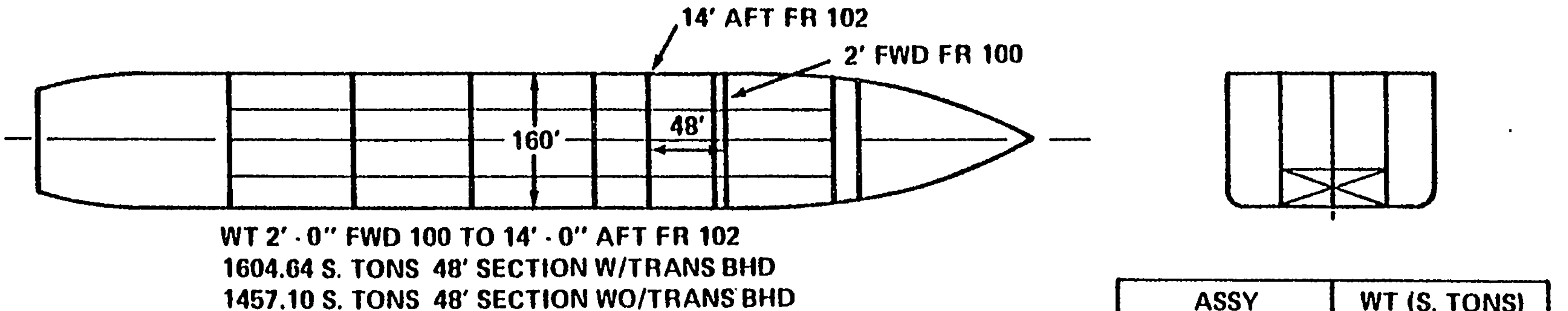
12) C TOP DECK GIRDER

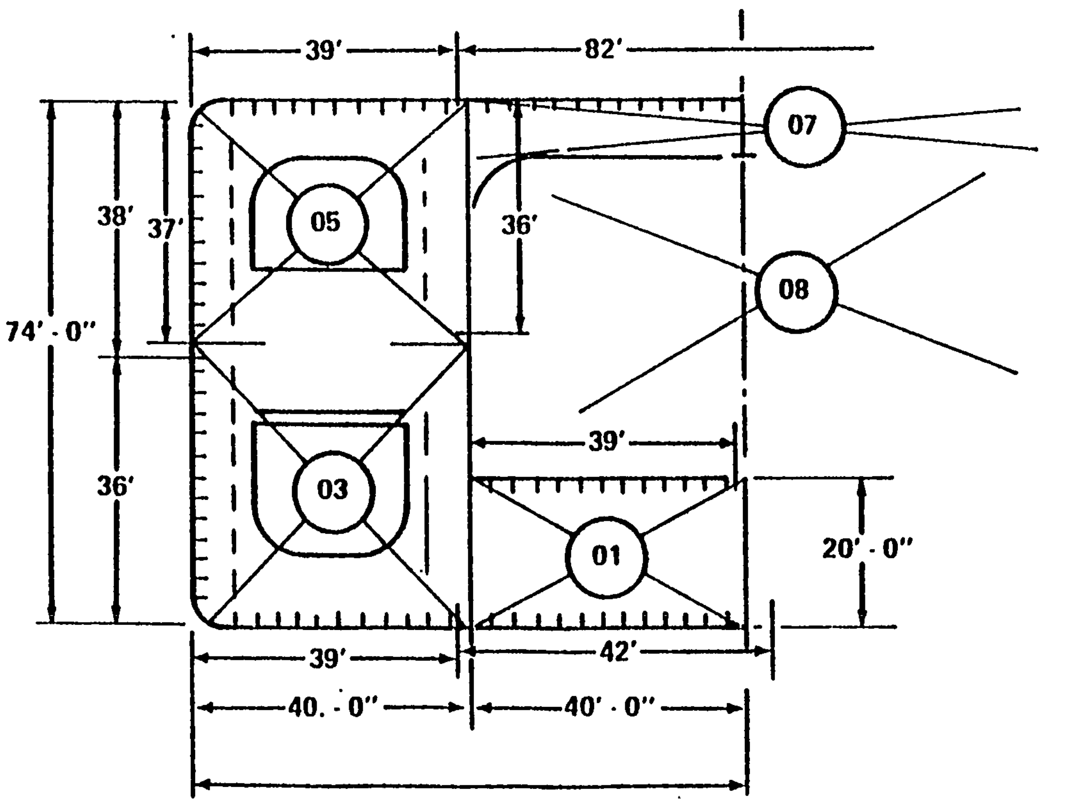
16x 10.5 X 20.4#	=	3,427
16 X 2 X 40.9#	=	1, 306
24x 10.5 X .5 X 20.4#	=	2,570
90x 3x 19.99 (9x7x20#T)	=	4,798
SUBTOTAL		
TOTAL		

WEIGHT ESTIMATE INCLUDES DECK, SIDE SHELL, BOTTOM, LONG′L BHD, INNER-BOTTOM PLATING AND LONGITUDINAL STIFFENERS. ALSO ONE COMPLETE WEB GIRDER.

STIFFENER & PLATE SIZES FOR TRANSV. WEB







ASSY	WT (S. TONS)
01 P	238.23
02 S	238.23
03 P	239.50
04 S	239.50
05 P	192.87
06 S	192.87
07 P/S	115.90
08 P/S	147.54

Figure 1-10. Configuration C-A Assembly Breakdown

PRELIMINARY SCANTLING REQUIREMENTS FOR SHIP

CONFIGURATION: C-A

SHIP PARAMETERS:

LBP = 925 FT
B = 160 FT
D = 74 FT
d = 51 FT

C_B = .84
L/B = 5.78
L/O = 12.50

BASIC ASSUMPTIONS :

TANK LENGTH = 96′ - 0″

TRANSV . GIRDER SPACING = 16′ - 0″

LONG 'L FRAME SPACING = 3′ - 0″

SIDE SHELL PLATING: (22.9.1)

1.) $t = 0.0003937\ L\ (2.0 + 21/0)$ IN.

$t = 0.0003937\ (925)(2.0 + 21/74)$ IN.

$t = .832$

2.) $t = 0.00287(s)\ \sqrt{0.7\ d + 0.02\ L + 0.1}$ IN.

$t = 0.00267(36)\ \sqrt{0.7(51) + 0.02\ (925) + 0.1}$ IN.

$t = .86$

SIDE SHELL= 7/8 IN.

BOTTOM PLATING:

1.) 0.0003937 L (2.6= 10/D) IN.

$t = 0.0003937\ (925)(\ 2,6 + 10/74)$ IN.

$t = .996$ IN.

2.) $t = 0.00331\ (s)\ \sqrt{0.7d + 0.02\ (L-164) + 0.1}$ IN.

$t = 0.00331\ (36)\ \sqrt{0.7(51) + 0.02\ (925 - 164) + 0.1}$ IN.

$t = .950$ IN.

BOTTOM PLATING = 1.0 IN.

FLAT PLATE KEEL:

BOTTOM SHELL THICKNESS AMIDSHIPS INCREASED BY 0.06 IN.

t = BOTTOM R + 0.06 IN.

t = 1.01 IN. = 1 1/8″ R

DECK PLATING:

$t = 0.000853\ (s)\ \sqrt{L-174 + 0.0126\ (L/D) - 0.1}$ IN.

$t = 0.000883\ (36)\ \sqrt{925-174 + 0.0126\ (12.50) - 0.1}$ IN.

$t = .930$ IN.

DECK PLATING = 15/16 IN.

SIDE P 7/8"

BOTTOM P = 1"

SM. = 0.0041 chs L^2 IN^3 DECK LONG'LS SHEET OF

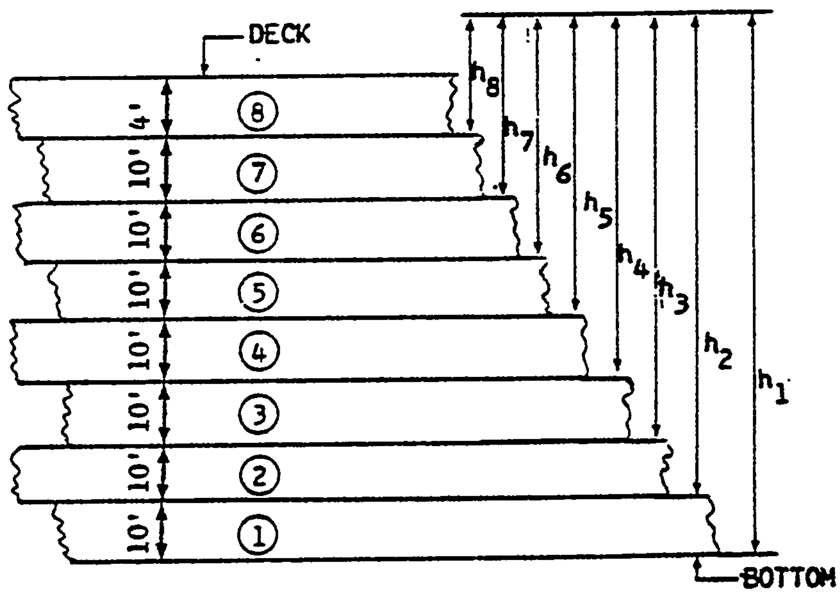
ABS 22.29.2

DECK-SIDE AND BOTTOM LONGITUDINALS

LONG. NO.	LOCATION OF LONG	HEAD TO 8' ABV. DK.	SPACING OF.	C	L	CALCULATED SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	SIDE	11.0	3.0	.95	16	32.90	14x6 3/4x34# I-T	60.8	24.30
2	SIDE	14.0	3.0	.95	16	41.88	14x6 3/4x34# I-T	60.8	24.30
3	SIDE	17.0	3.0	.95	16	50.85	14x6 3/4x34# I-T	60.8	24.30
4	SIDE	20.0	3.0	.95	16	59.83	14x6 3/4x34# I-T	60.8	24.30
5	SIDE	23.0	3.0	.95	16	68.80	16x7x40# I-T	80.6	28.91
6	SIDE	26.0	3.0	.95	16	77.78	16x7x40# I-T	80.6	28.91
7	SIDE	29.0	3.0	.95	16	86.75	16x8 1/2x58# I-T	115.6	40.79
8	SIDE	32.0	3.0	.95	16	95.72	16x8 1/2x58# I-T	115.6	40.79
9	SIDE	35.0	3.0	.95	16	104.70	16x8 1/2x58# I-T	115.6	40.79
10	SIDE	38.0	3.0	.95	16	113.67	16x8 1/2x58# I-T	115.6	40.79
11	SIDE	41.0	3.0	.95	16	122.65	16x8 1/2x71# I-T	142.4	49.98
12	SIDE	44.0	3.0	.95	16	131.62	16x8 1/2x71# I-T	142.4	49.98
13	SIDE	47.0	3.0	.95	16	140.60	16x8 1/2x71# I-T	142.4	49.98
14	SIDE	50.0	3.0	.95	16	149.57	21x8 1/4x68# I-T	173.9	50.40
15	SIDE	53.0	3.0	.95	16	158.54	21x8 1/4x68# I-T	173.9	50.40
16	SIDE	56.0	3.0	.95	16	167.52	21x8 1/4x68# I-T	173.9	50.40
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76# I-T	217.2	56.81
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76# I-T	217.2	56.81
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76# I-T	217.2	56.81
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76# I-T	217.2	56.81
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76# I-T	217.2	56.81
22	BILGE	73.5	3.2	1.0	16	246.87	24x9x94# I-T	270.6	69.66
23	BILGE	77.0	3.2	1.1	16	284.48	27x10x94# I-T	297.8	70.53
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108# I-T	369.3	82.89
25	BOTTOM	82.0	3.0	1.4	16	361.48	30x10 1/2x108# I-T	369.3	82.89

LONGITUDINAL BULKHEAD PLATING

$$t = \frac{s\sqrt{h}}{460} + .10 \text{ INCH.}$$



$t_1 = \frac{36\sqrt{78}}{460} + .10 = .791 = 7/8" (.875)$

$t_2 = \frac{36\sqrt{68}}{460} + .10 = .746 = 3/4" (.750)$

$t_3 = \frac{36\sqrt{58}}{460} + .10 = .696 = 3/4" (.750)$

$t_4 = \frac{36\sqrt{48}}{460} + .10 = .643 = 11/16" (.6875)$

$t_5 = \frac{36\sqrt{38}}{460} + .10 = .583 = 5/8" (.625)$

$t_6 = \frac{36\sqrt{28}}{460} + .10 = .514 = 9/16" (.5625)$

$t_7 = \frac{36\sqrt{18}}{460} + .10 = .432 = (MIN. 1/2")$

$t_8 = \frac{26\sqrt{8}}{460} + .10 = .322 = (MIN. 5/8")$

LONGITUDINAL STIFFENERS FOR LONG'L BHD'S

SM. 0.0041 chs L^2 IN^3

LONG. NO.	HEAD TO DK + 8 FT.	BHD ⅊	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	WEIGHT OF SECTION
1	11	25.5#	3'-0"	.90	16.0	31.13	14x6 3/4x34 I-T	59.0	24.30
2	14	20.4#	3'-0"	.90	16.0	39.62	14x6 3/4x34 I-T	57.6	24.30
3	17	20.4#	3'-0"	.90	16.0	48.11	14x6 3/4x34 I-T	57.6	24.30
4	20	20.4#	3'-0"	.90	16.0	56.60	14x6 3/4x34 I-T	57.6	24.30
5	23	20.4#	3'-0"	.90	16.0	65.09	14x8x43 I-T	72.3	29.60
6	26	22.95#	3'-0"	.90	16.0	73.58	14x8x53 I-T	90.6	36.41
7	29	22.95#	3'-0"	.90	16.0	82.07	14x8x53 I-T	90.6	36.41
8	32	22.95#	3'-0"	.90	16.0	90.56	14x8x53 I-T	90.6	36.44
9	35	25.5#	3'-0"	.90	16.0	99.05	14x10x68 I-T	117.8	45.24
10	38	25.5#	3'-0"	.90	16.0	107.54	14x10x68 I-T	117.8	45.24
11	41	25.5#	3'-0"	.90	16.0	116.03	14x10x68 I-T	117.8	45.24
12	44	28.05#	3'-0"	.90	16.0	124.52	15x10 1/2x54 T	145.5	53.99
13	47	28.05#	3'-0"	.90	16.0	133.01	15x10 1/2x54 T	145.5	53.99
14	50	28.05#	3'-0"	.90	16.0	141.50	15x10 1/2x54 T	145.5	53.99
15	53	30.6#	3'-0"	.90	16.0	149.99	21x2 1/4x68 I-T	171.0	50.40
16	56	30.6#	3'-0"	.90	16.0	158.48	21x2 1/4x68 I-T	171.0	50.40
17	59	30.6#	3'-0"	.90	16.0	166.97	21x8 1/4x68 I-T	171.0	50.40
18	62	30.6#	3'-0"	.90	16.0	175.46	24x9x76 I-T	213.4	56.81
19	65	30.6#	3'-0"	.90	16.0	183.95	24x9x76 I-T	213.4	56.81
20	68	30.6#	3'-0"	.90	16.0	192.44	24x9z76 I-T	213.4	56.81
21	71	30.6#	3'-0"	.90	16.0	200.93	24x9x76 I-T	217.2	56.81
22	74	35.7#	3'-0"	.90	16.0	209.42	24x9x84 I-T	241.4	62.38
23	77	35.7#	3'-0"	.90	16.0	217.91	24x9x84 I-T	241.4	62.38
24	80	35.7#	3'-0"	.90	16.0	226.40	24x9x84 I-T	241.4	62.38

DECK LONGITUDINAL

SM - 0.0041 Chs L^2 IN^3

SM= 0.0041 (1.25)(S)(3)(16^2)

SM = 31.49 IN^3

SELECTED SHAPE FROM TABLE P-5d

8 x 7 v 20# on 40.8# DECK PLATING

(S.M. = 35.1 IN^3) (60 t)

INNERBOTTOM PLATING

SECTION 7.5.1

t = 0.000445 L + 0.009s + 0.06

t = 0.000445 (925) +0.009 (36) +0.06

t =.796″ - 0.04 =.756 = 3/4″ R (7.5.1)

INNERBOTTOM LONGITUOINALS (7.3.1)

85% OF BOTTOM LONGITUDINALS

SM = 361.48x .85 = 307.26 IN^3

27 X 10 X 102 I-T (SM= 317.8)(WEIGNT PER FOOT= 76.19)

DEEP TANK TRANSVERSE BHD. PLATING (13.3.1)

$$t = \frac{s \sqrt{n}}{460} + 0.10$$

$$t = \frac{36 \sqrt{37.7} + 20}{460} + ($$

t = .595 + 0.10 =.695 IN.

t = 3/4″ PLATE

2/3 OF TANKTOP TO OVERFLOW
2/3 X (5d +2.5) = 37.7

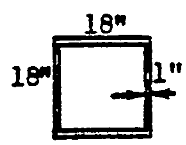
STRUTS: 22.27.9

TOP: W = 0.03 bhs LONG TONS
= 0.03 (20)(35)(16)
= 337 LONG TONS

BOTTOM W = 0.03 bhs LONG TONS
= 0.03 (20)(53)(16)
= 510 LONG TONS

PERMISSIBLE LOAD Wa

Wa = 7.83 - 0.345 (L/r) AC LT.



A	Y	AY	AY²	Io
18	17.5	315	5,500	1.5
36	9.0	324	2,920	4,100
18	0.5	9	5	1.5
72		648	8,425	4,103
			4,103	
			12,528	

Y = 9.0

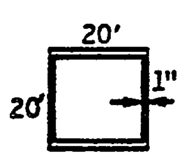
Ioo = 12,528 - 72(9^2) 12,528 - 5,840 = 6,688

Io - 6,688 IN^4

$r = \sqrt{\frac{6688}{72}}$ = 9.63 IN.

Wa = [7.83 - 0.345(L/r)] AC
= [7.83 - 0.345(20/9.63)] (72)(0.9)
= [7.83 - (0.345 x 2.08)] 64.8
= (7.83 - 0.72) 64.8

Wa = A61 LONG TONS



A	Y	AY	AY²	Io
20	19.5	390	7,600	1.67
40	10.0	400	4,000	5,830
20	0.5	10	5	1.67
80		800	11,605	5,833
			5,833	
			17,438	

Y = 10

Ioo = 17,438 - 80 (10^2) Io = 9,438

$r = \frac{\sqrt{9438}}{80}$

$r = \sqrt{118}$

r = 10.86

$$W_a = [7.53 - 0.345\ (L/r)]\ AC\ LT.$$

$$= [7.93 - 0.345\ (20/10.96)]\ (80)(0.9)$$

$$= [7.93 - (0.345 \times 1.945)]\ (7.2)$$

$$= (7.19)(7.2)$$

<u>Wa = 517 LONG TONS</u>

TRANSVERSE GIRDERS

SECTION MODULUS CALCULATIONS: (22.27.2)

DECK TRANSVERSE:

$SM = 0.0025\ chs\ L_b^2\ IN^3$

$= 0.0025\ (3.5)(45)(16)(20^2)$

$SM = 2520\ IN^3$

LONG'L BHD + SIDE GIRDERS:

$SM = 0.0025\ chs\ L_b^2\ IN^3$

$= 0.0025\ (0.65)(45)(16)(50^2)$

$SM = 2920\ IN^3$

BOTTOM TRANSVERSE:

$SM = 0.0025\ chs\ L_b^2$

$= 0.0025\ (2.40)(74)(16)(19^2)$

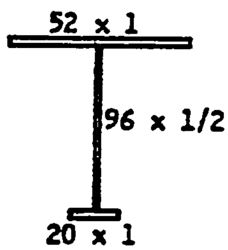
$SM = 2300\ IN^3$

TOP CENTERLINE GIRDER:

$SM = 0.0025\ chs\ L_b^2\ IN^3$

$= 0.0025\ (2.50)(45)(36)(16^2)$

$SM = 2600\ IN^3$



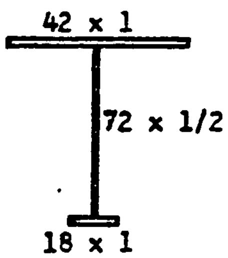
A	Y	AY	AY^2	Io
52	97.5	5,070	495,000	4
48	49	2,350	115,000	36,800
20	.5	10	2	
120		7,420	610,000	
			36,800	
			676,800	

Y = 61.9 IN

$$Ioo = 676{,}800 - 120\,(61.9^2)$$

$$= 218{,}800$$

$$SM = \frac{218{,}800}{61.9} = \underline{3520\ IN^3}$$



A	Y	AY	AY^2	Io
42	73.5	3,080	227,000	20,800
36	37.0	1,330	49,200	
18	0.5	9	4	
96		4,419	276,200	
			20,800	
			297,000	

$$Y - \frac{4419}{96} - 46\ IN.$$

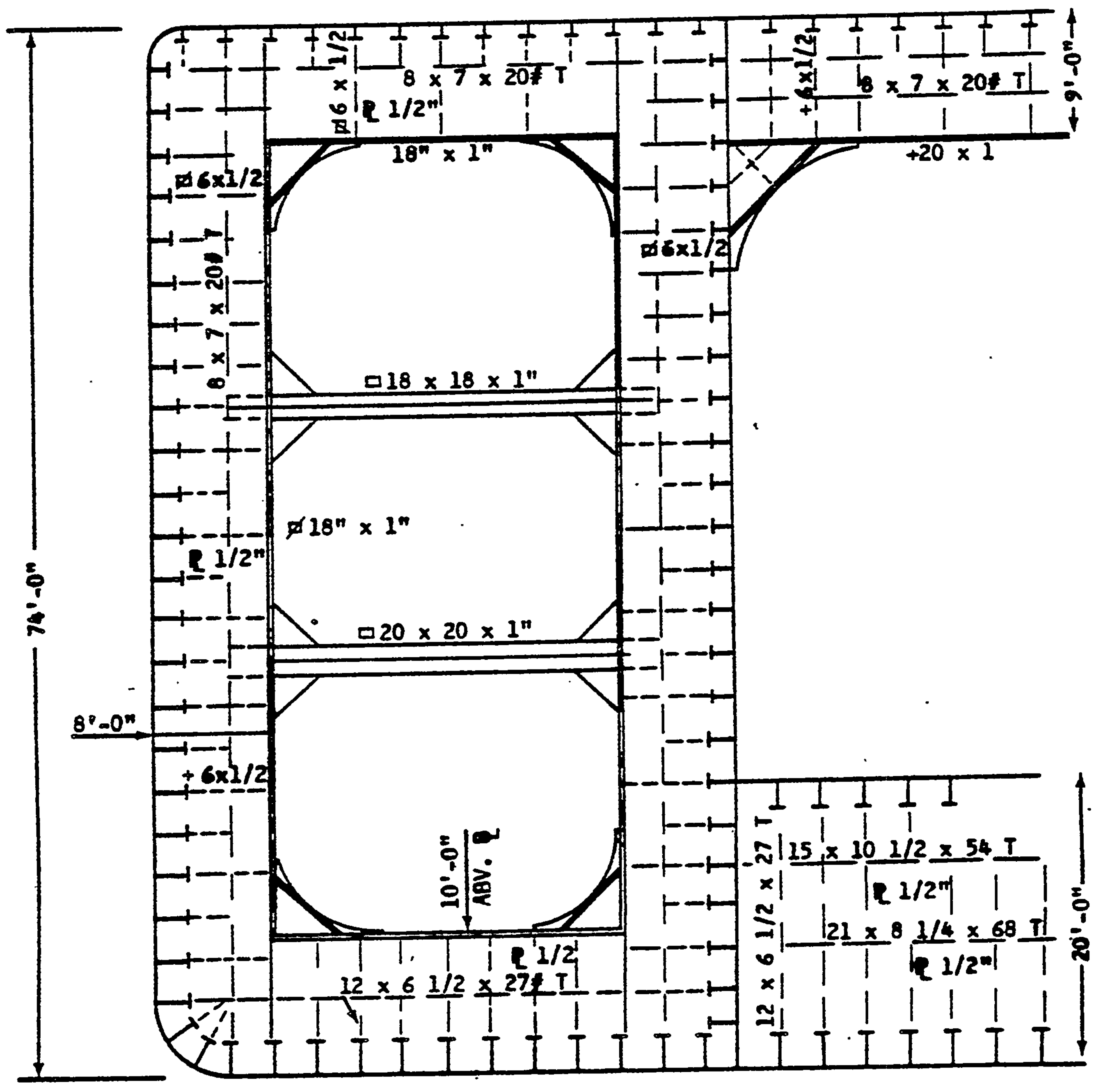
$$Ioo = 297{,}000 - 96\,(46^2)$$

$$= 297{,}000$$

$$- 203{,}000$$

$$Ioo = \overline{94{,}000}\ IN^4$$

$$SM = \frac{94{,}000}{46} = \underline{2020\ IN^3}$$



74'-0"
8 x 7 x 20# T
Ø6 x 1/2
℄ 1/2"
18" x 1"
+6x1/2
8 x 7 x 20# T
9'-0"
+20 x 1
Ø6x1/2
Ø6x1/2
8 x 7 x 20# T
□18 x 18 x 1"
Ø18" x 1"
℄ 1/2"
□20 x 20 x 1"
8'-0"
+6x1/2
10'-0" ABV. ℄
℄ 1/2
12 x 6 1/2 x 27# T
12 x 6 1/2 x 27 T
15 x 10 1/2 x 54 T
℄ 1/2"
21 x 8 1/4 x 68 T
℄ 1/2"
20'-0"

1.)	DECK PLATING = 16 x 38.3 X 160	= 98,046
2.)	SIDE SHELL PLATING= 16 X 35.7 X 74 X 2	= 84,538
3.)	BOTTOM PLATING = 16 x 40.8 x 152	= 99,226
4.)	FLAT PLATE KEEL= 16x 45.9x 8	= 5,875
5.)	LONGITUD. 3ULKH. PLATING= 16 X 35.7 X 10 X 2	= 11,424
	16 x 30.6 x 20 x 2	= i9,564
	16 x 28.1 x 10 X 2	= 9,998
	16 x 25.5 x 10 X 2	= 8,160
	16 x 23.0 X 10 X 2	= 7,360
	16 x 20.4 X 10 X 2	.= 6,528
	16 x 25.5 x 4 x 2	= 3,264
6.)	INNER BOTTOM PLATING = 16 X 30.6 X 80	= 39,168
7.)	INNER BOTTOM & BHD. PLATING 16 X 30.6 X 10	= 4,896
	16x 37.5 X 10	= 6,000
8.)	DECK LONGITUDINAL 16 X (8 X 7 X 20.T#) X 24 X 2	= 15,360
9.)	SIDE LONGITUDINAL 16 X (14 X 6 3/4x.34#) X 24.3 x 4x 2	= 3,110
	16 X (16x 7x40#) x29.91x2x2”	= .1,850
	16x (16x 8 1/2 x 58#) x 40.79 x 4 x 2	= 5,222
	16 X (16 X 9 1/2 x 71#) x 49.98X 3 x 2	= 4,798
	16 X (21 X 8 1/4x 68#) X 50.40x 3 X 2	= 4,838
	16 X (24 X 9 x 76#) x 56.91 x 5 x 2	= 9,090
	16 X (24x 9 x 94#) x 69.66 x l x 2	= 2,230
	16 X (27 X lox94#) x 70.53 x 1 x 2	= 2,256
	16 X (30x 10 1/2 X 108#) X 92.89x 1 x2	= 2,652
lo.)	BOTTOM LONGITUDINAL 16x (30 X 10 1/2 X 108#) X 82.99 X 24 X 2	= 63,660
	INNER BOTTOM LONG'LS 16 (27x 10 X 102#) X 76.19x 24x 2	= 59,500
	SUBTOTAL	= 576,625 LBS

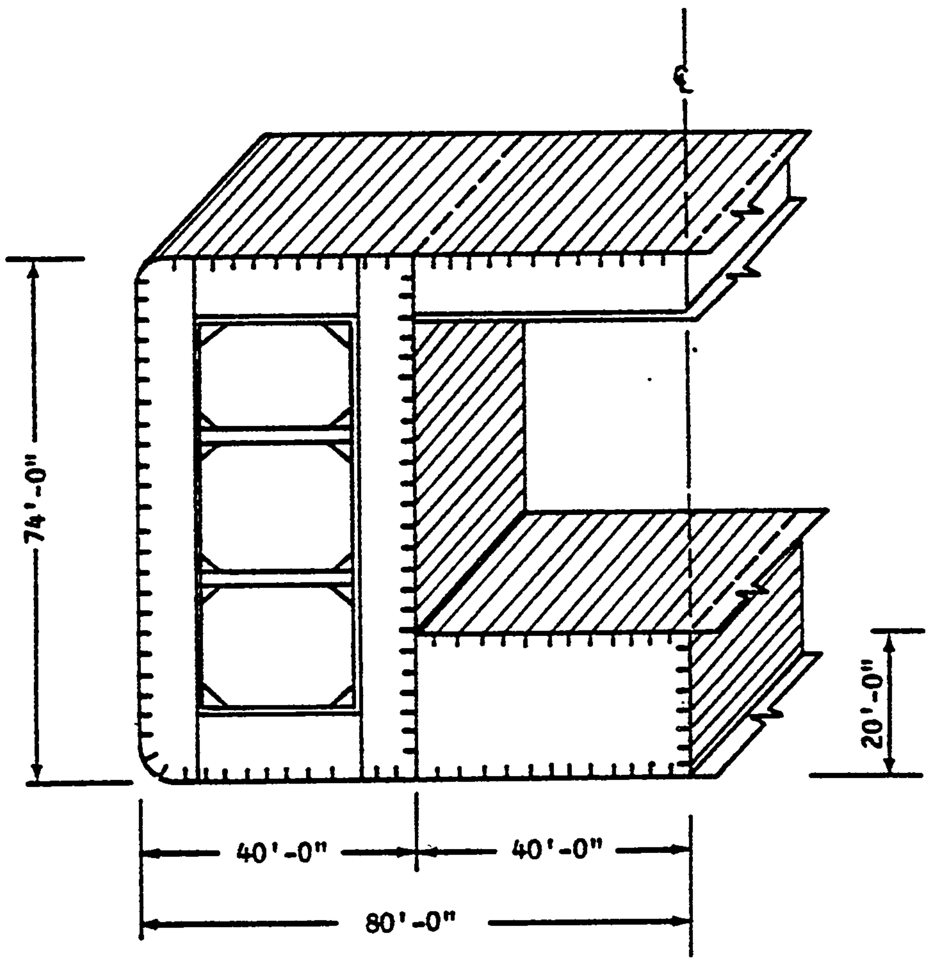
11.) TRANSVERSE GIRDER 16'-0" C. TO C.

a.) PLATING:	90 x 20 x 20.4#	= 32,640
	9.O X 80 X 2&Q#	= 14,689
	4.0 X 4.Ox 20.4#	= 326
	4x74x8x20.4#	= 48,307
	2x24x8x20.4#	= 7,834
	2 X 24x lox 20.4#	= 9,792
	12x4xdx20.4# .	= 3,917
b.)	1.67 X 40.9#x 80	= 5,451
	1.5 x40.8#x 56 x4	= 13,709
	1.5 x4f).8# X 24 X 4	= 59975
	1.67 x40.8# X 24 X 8	= 13,082
	1.5 X 40.8# X 24x 8	= 11,750
	0.5 X 20.4# X 400	= 4,080
	1 x40.8#x 50	= 2,040
c.)	8x7 X 20#T (19.9) X 540	= 10,746
	12 x6 1/2 x27#T (18.9) X 514	= 9,663
	15 X 101/2 X 54#T (53.99) X 90	= 4,319
	21 X 8 1/4 X 69# T (50.40) X 80	= 4.032
	SUBTOTAL:	= 202,251
	TOTAL:	= 778,588

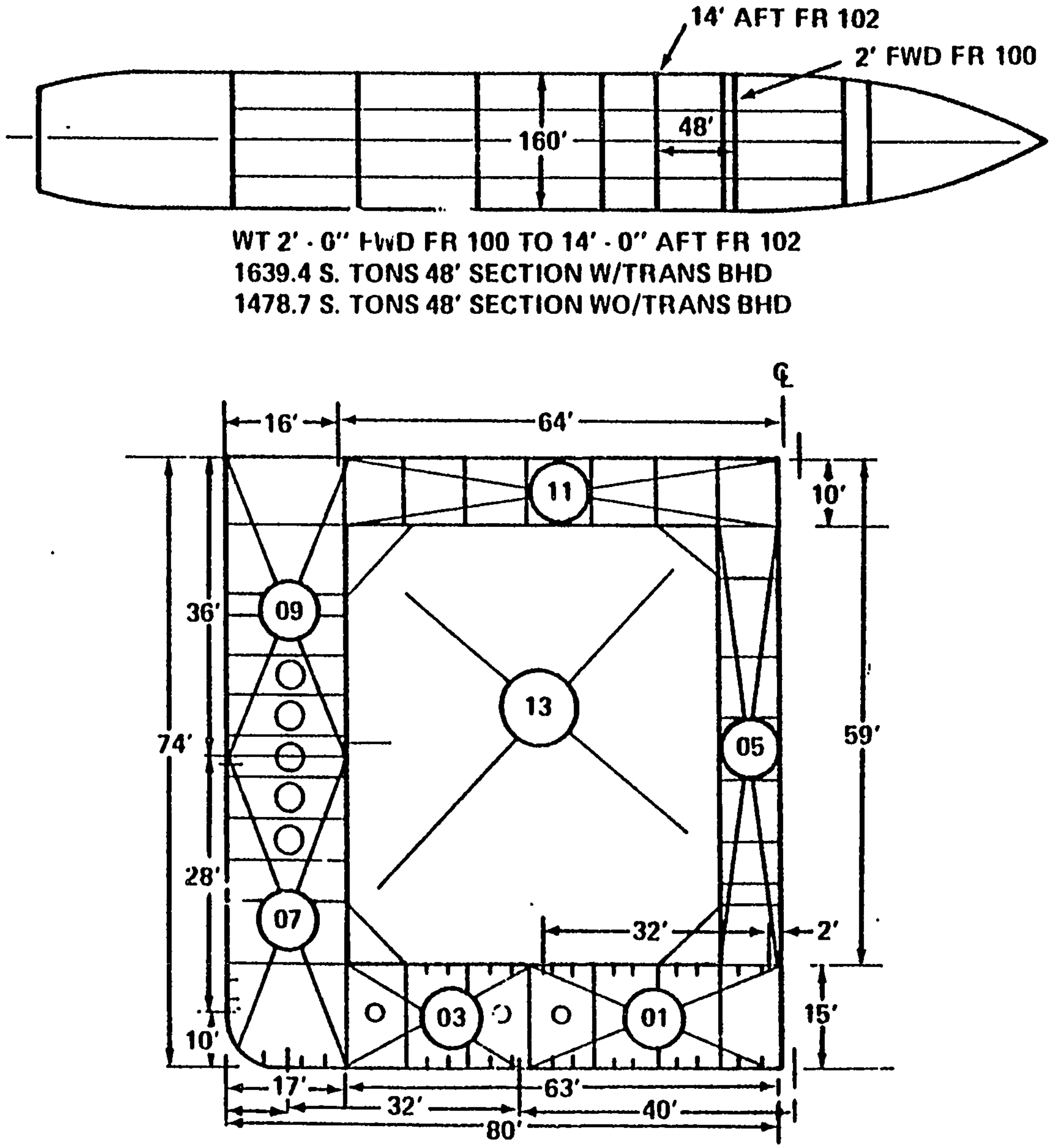
MIDSHIP SECTION CONFIGURATION
CONFIGURATION C-A

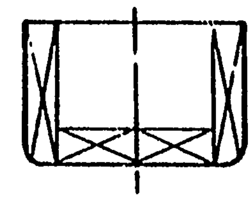
WEIGHT ESTIMATE FOR A TYPICAL 16'-0" LONG TANKER SECTION MIDSHIPS

(ESTIMATE INDLUDES: DECK, SIDESHELL, BOTTOM, LONG'L. BHD., INNER-BOTTOM-PLATING AND STIFFENERS. ALSO ONE COMPL. WEB GIRDER.)



TOTAL WEIGHT = 779,588 LBS





ASSY	WT (S. TONS)
01 P	144.61
02 S	144.61
03 P	117.18
04 S	117.18
05 ℄	91.74
06 S	177.00
07 P	177.00
08 S	112.71
09 P	112.71
10 S	102.00
11 P	102.00
12 S	120.33
13 P	120.33

Figure 1-11. Configuration D-A Assembly Breakdown

PRELIMINARY SCANTLING REQUIREMENTS
FOR SHIP CONFIGURATION D-4

SHIP PARAMETERS:

LBP = 925 FT.
B = 160 FT.
D = 74 FT.
d = 51 FT.

C_B = .84
L/B = 5.76
L/D = 12.50

BASIC ASSUMPTIONS:

TANK LENGTH - 96′
FR. SPACING - 16′
LONG′L. SPACING - 3'

BOTTOM PLTG: 22.19.1.

(1) t =0.0003937L (2.6 +10/D)
t =0.0003937 (925)(2.6 +10/74)
t = .996 IN.

(2) $t = 0.00331(S)\sqrt{0.7d + 0.02(L-164)} + 0.1 IN.$
$t = 0.00331(36)\sqrt{0.7(51) + 0.02(925-164)} + 0.1$ IN.
t = .950 IN.

BOTT PLATING = .95 IN. (1″ PLT)

FLAT PLATE KEEL (22.19.1)

t = BOTT. PLTG 0.06 IN.
t =1.01 IN.
F.P.K. = 1.01 IN. (1 1/8″ PLT)

SIDE SHELL PLATING (22.19.1)

(1) t = 0.0003937L (2.0 + 21/D) IN.
t = 0.0003937(925)(2.0 +21/74) IN.
t = .832 IN.

(2) $t = 0.00287(s) \sqrt{0.7d + 0.02L} + 0.1$ IN.

$t = 0.00287(36) \sqrt{0.7(51) + 0.02(925)} + 0.1$ IN.

$t = .86$ IN.

SIDE SHELL= .832 IN. (7/8″ PLT)

DECK PLATING 22.21.1

$t = 0.000883(S) \sqrt{L-174} + 0.0126\ (L/D) - 0.1$ IN.

$t = 0.000883(36)\sqrt{925-174} + 0.126\ (12.50) - 0.1$ IN.

$t = .930$ IN.

DECK PLATING = .930 IN. (15/16″ PLT.)

DECK LOGITUDINAL: (22.29.2)

S.M. = $0.0041\ chsl_b^2$ IN^3

S.M. = $0.0041(1.25)(8)(3)(16)^2$

S.M. = 31.49

USE 8 x 7 x 20#T ON 40.8# DECK PLATE (S.M. = 35.1 IN^3)

BOTTOM AND SIDE SHELL LONGITUDINALS

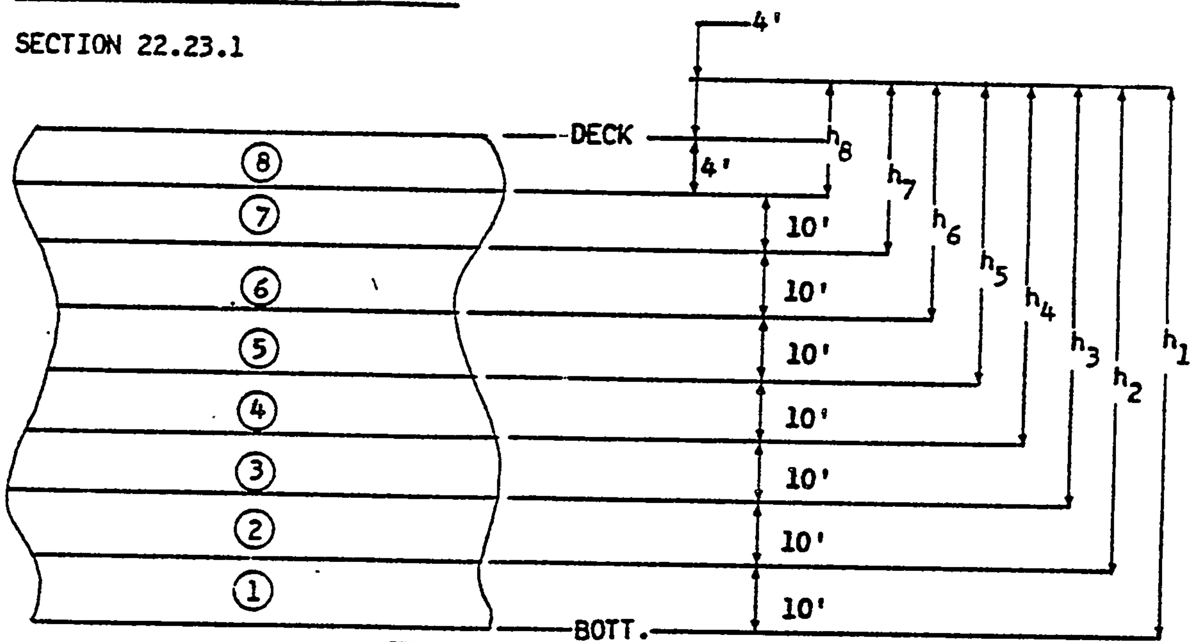
ABS 22.29.2 S.M. = $.0041\ chsl^2_b$

SIDE = 7/8" PLT
BOTTOM = 1" PLT

LONG.NO.	LOCATION OF LONGL	HEAD TO 8'ABV.DK.	SPACING FT.	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	SIDE	11.0	3.0	.95	16	32.90	16x7x45#T	90.7	CUT WT. 32.62#
2	SIDE	14.0	3.0	.95	16	41.88	16x7x45#T		
3	SIDE	17.0	3.0	.95	16	50.85	16x7x45#T		
4	SIDE	20.0	3.0	.95	16	59.83	16x7x45#T		
5	SIDE	23.0	3.0	.95	16	68.80	16x7x45#T		
6	SIDE	26.0	3.0	.95	16	77.78	16x7x45#T		
7	SIDE	29.0	3.0	.95	16	86.75	16x7x45#T		
8	SIDE	32.0	3.0	.95	16	95.72	18x8 3/4x64#T	143	CUT WT. 45.19#
9	SIDE	35.0	3.0	.95	16	104.70	18x8 3/4x64#T		
10	SIDE	38.0	3.0	.95	16	113.67	18x8 3/4x64#T		
11	SIDE	41.0	3.0	.95	16	122.65	18x8 3/4x64#T		
12	SIDE	44.0	3.0	.95	16	131.62	18x8 3/4x64#T		
13	SIDE	47.0	3.0	.95	16	140.60	18x8 3/4x64#T		
14	SIDE	50.0	3.0	.95	16	149.57	24x9x76#T	217	CUT WT. 56.81#
15	SIDE	53.0	3.0	.95	16	158.54	24x9x76#T		
16	SIDE	56.0	3.0	.95	16	167.52	24x9x76#T		
17	SIDE	59.0	3.0	.95	16	176.49	24x9x76#T		
18	SIDE	62.0	3.0	.95	16	185.46	24x9x76#T		
19	SIDE	65.0	3.0	.95	16	194.44	24x9x76#T		
20	SIDE	68.0	3.0	.95	16	203.42	24x9x76#T		
21	SIDE	71.0	3.0	.95	16	212.40	24x9x76#T		
22	BILGE	73.5	3.2	1.0	16	246.87	24x12x100#T	294	CUT WT. 70.48#
23	BILGE	77.0	3.2	1.1	16	284.48	24x12x100#T		
24	BILGE	79.5	3.2	1.3	16	347.12	30x10 1/2x108#T	369	CUT WT. 82.89#
25	BOTTOM	82.0	3.0	1.4	16	361.48	30x10 1/2x108#T		

LONGITUDINAL BULKHEAD PLATING

SECTION 22.23.1



$$t = \frac{s\sqrt{h}}{460} + .10 \text{ IN.}$$

① $t_1 = \frac{36\sqrt{78}}{460} + .10 = .791"$ ⟶ 7/8" PLT. (.875)

② $t_2 = \frac{36\sqrt{68}}{460} + .10 = .746"$ ⟶ 3/4" PLT. (.750)

③ $t_3 = \frac{36\sqrt{58}}{460} + .10 = .696"$ ⟶ 3/4" PLT. (.750)

④ $t_4 = \frac{36\sqrt{48}}{460} + .10 = .643"$ ⟶ 11/16" PLT. (.6875)

⑤ $t_5 = \frac{36\sqrt{38}}{460} + .10 = .583"$ ⟶ 5/8" PLT. (.625)

⑥ $t_6 = \frac{36\sqrt{28}}{460} + .10 = .514"$ ⟶ 9/16" PLT. (.5625)

⑦ $t_7 = \frac{36\sqrt{18}}{460} + .10 = .432"$ ⟶ (MIN. 1/2" PLT.)

⑧ $t_8 = \frac{36\sqrt{8}}{460} + .10 = .322"$ ⟶ (MIN. 5/8" PLT.)

LONGITUDINAL STIFFENERS FOR LONG'L BHDS

LONG.NO.	HEAD TO DK.+8FT.	BHD PLTG	SPACING	C	L	SECTION MODULUS	SECTION USED	S.M.	
1	11	25.5#	3'-0"	.90	16	31.13	14x6 3/4x34 I/T	59.0	(CUT WT. 24.30#)
2	14	20.4#	3'-0"	.90	16	39.62	14x6 3/4x34 I/T	57.6	
3	17	20.4#	3'-0"	.90	16	48.11	14x6 3/4x34 I/T	57.6	
4	20	20.4#	3'-0"	.90	16	56.60	14x10x61 I/T	103.7	(CUT WT. 40.54#)
5	23	20.4#	3'-0"	.90	16	65.09	14x10x61 I/T	103.7	
6	26	22.95#	3'-0"	.90	16	73.58	14x10x61 I/T	105.3	
7	29	22.95#	3'-0"	.90	16	82.07	14x10x61 I/T	105.3	
8	32	22.95#	3'-0"	.90	16	90.56	14x10x61 I/T	105.3	
9	35	25.5#	3'-0"	.90	16	99.05	14x10x61 I/T	106.6	
10	38	25.5#	3'-0"	.90	16	107.54	16x8 1/2x78 I/T	150.3	(CUT WT. 54.99#)
11	41	25.5#	3'-0"	.90	16	116.03	16x8 1/2x78 I/T	150.3	
12	44	28.05#	3'-0"	.90	16	124.52	16x8 1/2x78 I/T	152.0	
13	47	28.05#	3'-0"	.90	16	133.01	16x8 1/2x78 I/T	152.0	
14	50	28.05#	3'-0"	.90	16	141.50	16x8 1/2x78 I/T	152.0	
15	53	30.6#	3'-0"	.90	16	149.99	16x8 1/2x78 I/T	154.1	
16	56	30.6#	3'-0"	.90	16	158.48	24x9x76 I/T	213.4	(CUT WT. 56.81#)
17	59	30.6#	3'-0"	.90	16	166.97	24x9x76 I/T	213.4	
18	62	30.6#	3'-0"	.90	16	175.46	24x9x76 I/T	213.4	
19	65	30.6#	3'-0'	.90	16	183.95	24x9x76 I/T	213.4	
20	68	30.6#	3'-0"	.90	16	192.44	24x9x76 I/T	213.4	
21	71	30.6#	3'-0"	.90	16	200.93	24x9x76 I/T	213.4	
22	74	35.7#	3'-0"	.90	16	209.42	24x9x84 I/T	241.4	(CUT WT. 62.38#)
23	77	35.7#	3'-0"	.90	16	217.91	24x9x84 I/T	241.4	
24	80	35.7#	3'-0"	.90	16	226.40	24x9x84 I/T	241.4	

BOTTOM TRANSVERSE - CENTER TANK

SECTION 22.27.2

A.B.S. REQUIRED SECTION MODULUS

$c = 1.50$
$h = 74$
$s = 16$
$l_b = 63$

$S.M. = 0.0025\ chsl_b^2$

$S.M. = 0.0025\ (1.5)(74)(16)(63)^2$

$S.M. = 17{,}622\ IN^3$

SECTION 7.3.5 SOLID FLOORS

$t = 0.00043\ L + .18$

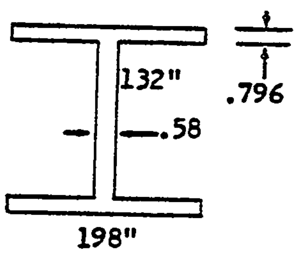
t = .578 IN. (5/8" PLT)

SECTION 7.5.1 INNERBOTTOM PLATING

$t = 0.000445\ L + 0.009s + 0.06$

$t = 0.000445\ (925) + 0.009\ (36) + 0.06$

t = .796" (7/8" PLT)



A	Ȳ	AȲ	AȲ²	Io
198	.5	99	49.5	16.5
76.56	67	5,129.5	343,677.84	102,613
157.41	133.4	20,998.5	2,801,199.1	8.29
431.97		26,277	3,144,926	102,637.8
			102,637	
			3,247,563	

Ȳ = 60.71

Ioo = 3,247, 564 - 431.97 (60.71)

Ioo = 1,655,196

S.M.= 27,263 IN^3 > 17,622

INNERBOTTOM LONGITUDINALS (SEC. 7.3.10)

S.M. = 361.48 x .85 = 307.26 IN^3

USE 27 x 10 x 102# T

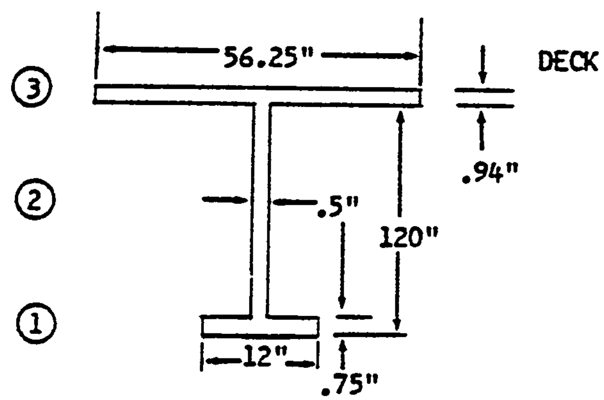
TRANSVERSE DECK GIRDER

$S.M. = 0.0025\ chsl_b^2$

$c = 1.80$
$h = 18$
$s = 16$
$l_b = 45$

$S.M. = 0.0025\ (1.8)(18)(16)(45)^2$

$S.M. = 2624.4\ IN^3$



ITEM	A	Y	AY	AY^2	Io
①	18	.38	6.84	2.60	.84
②	60	60.75	3.645.00	221.433.75	72,000
③	52.88	121.22	6,410.11	777,033.97	3.89
	130.88		10,061.95	998,470.32	72,004.73
				72,004.73	
		$\bar{Y}$ = 76.88			
				1,070,475.05	

$I_{NA} = 296,920$

$S.M. = 2,912.42\ IN^3$

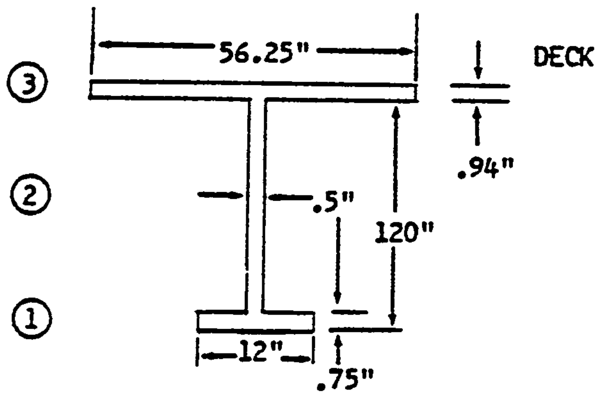
TRANSVERSE DECK GIRDER

$c = 1.80$
$h = 18$
$s = 16$
$l_b = 45$

$$S.M. = 0.0025\ chsl_b^2$$

$$S.M. = 0.0025\ (1.8)(18)(16)(45)^2$$

$$S.M. = 2624.4\ IN^3$$



ITEM	A	Y	AY	AY^2	Io
①	18	.38	6.84	2.60	.84
②	60	60.75	3.645.00	221.433.75	72,000
③	52.88	121.22	6,410.11	777,033.97	3.89
	130.88		10,061.95	998,470.32	72,004.73
				72,004.73	
				1,070,475.05	

$\bar{Y} = 76.88$

$I_{NA} = 296,920$

$S.M. = 2,912.42\ IN^3$

WEIGHT OF ONE FRAME SPACE

(INCLUDING ONE TRANSV. WEB)

ITEM	WT/FT	TOTAL WT#
SIDE SHELL PLTG.	35.7	73,113.6
BILGE PLTG.	40.8	20,508.4
BOTTOM PLTG.	40.8	87,475.2
FPK	45.9	4,406.4
DECK PLTG.	38.25	97,920.0
INNERBOTT. PLTG	35.7	71,971.2
WING BHD. PLTG.	VAR.	32,640.0
WING BHD PLTG	VAR.	32,640.0
℄ BHD PLTG.	VAR.	32,640.0
WING BHD LONGLS	VAR.	18,785.0
WING BHD LONGLS	VAR.	18,785.0
℄ BHD LONGLS	VAR.	18,785.0
DECK LONGLS	20.0	15,360.0
INNERBOTT. LONGLS	76.19	48,761.60
SIDE SHELL LONGLS	VAR.	30,526.8
BILGE LONGLS	VAR.	7,163.2
BOTT. LONGLS	82.89	61,007.0
VERT. WEB ON ℄ BHD	VAR.	15,096.0
BOTT. TRANSV.	VAR.	58,140.0
VERT. WEB IN WING TK.	VAR.	51,153.0
DECK TRANSV.	VAR.	24,072.0
	TOTAL	820,949.4 lbs

LONG 1 GDUS @ 9'-0" c

655,760

VOLUME II

PART 2

CONTAINERIZED CABINS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

VOLUME II

Part 2

CONTAINERIZED CABINS

2.1 INTRODUCTION

Superstructures have been built in most yards as build-in-place deckhouses. It has been the opinion of some investigators that superstructure costs can be reduced by modularization and that standard staterooms and compartment modules improve commonality and reduce unique design requirements, fabrication and outfitting cost. In the case of series production, an assembly area could be set up with work stations to assemble the superstructure compartments as they are released from receiving. Besides possible savings in fabrication cost, modular construction would permit a shipyard to subcontract up to 100% pre-finished modules or containers, outside their construction facility.

2.2 APPROACH

A realignment of the design process priorities to take advantage of the potential savings of contanerized cabins is indicated.

2.2.1 Design Superstructure Arrangement Compatible with Containerization.

The following arrangement factors must be applied to the design:

a. The first requirement is a strict one man cabin design as in figure 2-1.

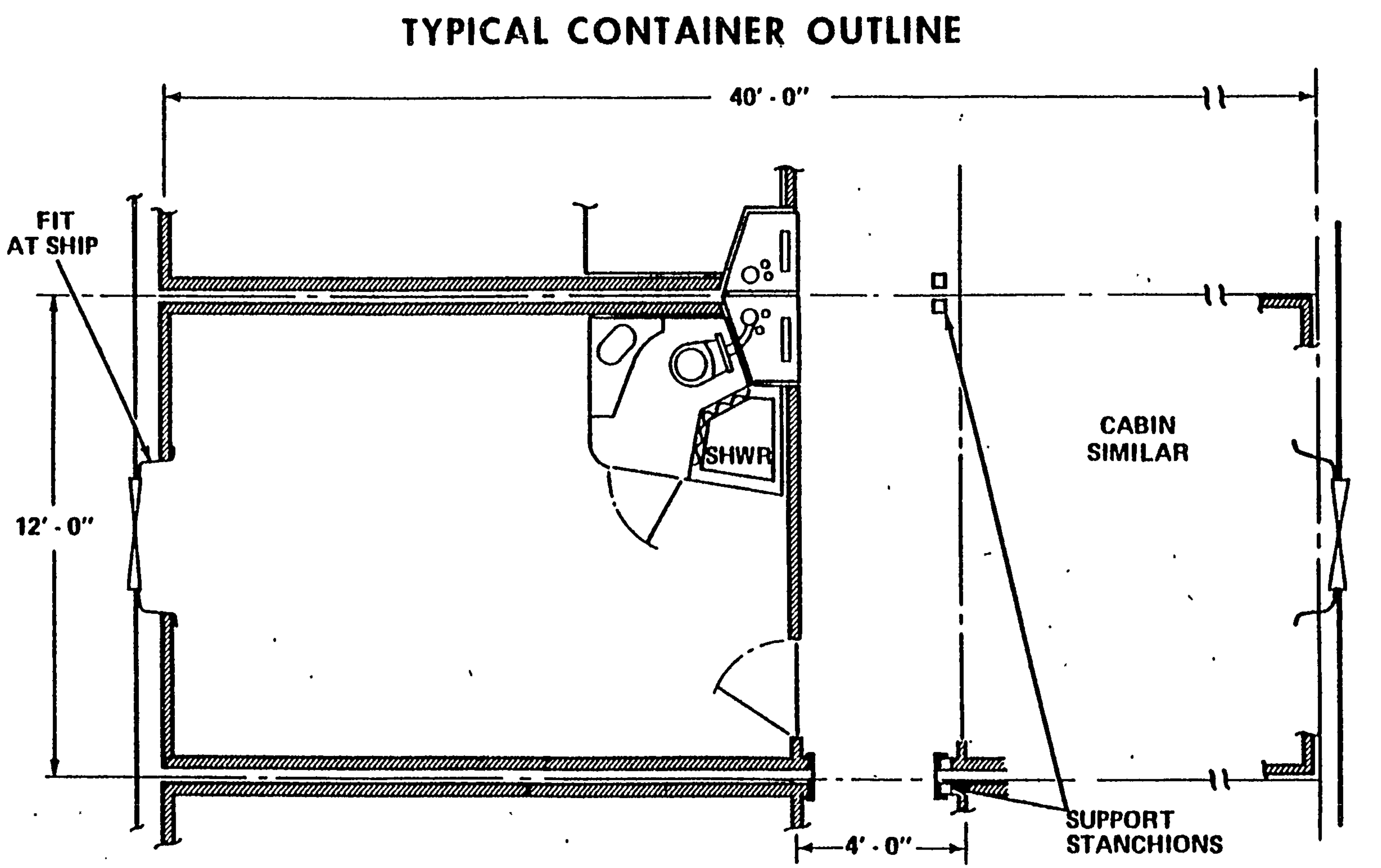


Figure 2-1 Typical Container Outline

b. The deckhouse should, as far as possible, be separated from engine noise and vibrations and designed as a "hotel" block.

c. The two lower decks of the deckhouse are raised above a three-foot crawl space for the purpose of access to services. These should have conventional steel decks for machinery, food storage, freezer, kitchen, bakery, restaurant, offices, etc.

d. Two rows of standardized, self-supporting containers, for crew and officers, make up the two higher deck levels.

2.2.2 Design Structural Configuration of Containers and Supports

a. Each container can be supported on each end by hand installed hangers, hooked into the fore and aft transverse end bulkheads, as in figure 2-2.

b. A compression column at half trailer length can be used to divide the unsupported length.

c. Poured foam around each container and between containers can be used to assure good insulation qualities and reduce vibration.

d. After fitting out and welding up the top deck, the air space between the deck and container top should be filled with foam poured through holes cut in the top deck. These holes will be welded closed after foam has set.

(1) Skeleton System

(a) The structure would consist of a system of load carrying beams and columns. End connections are

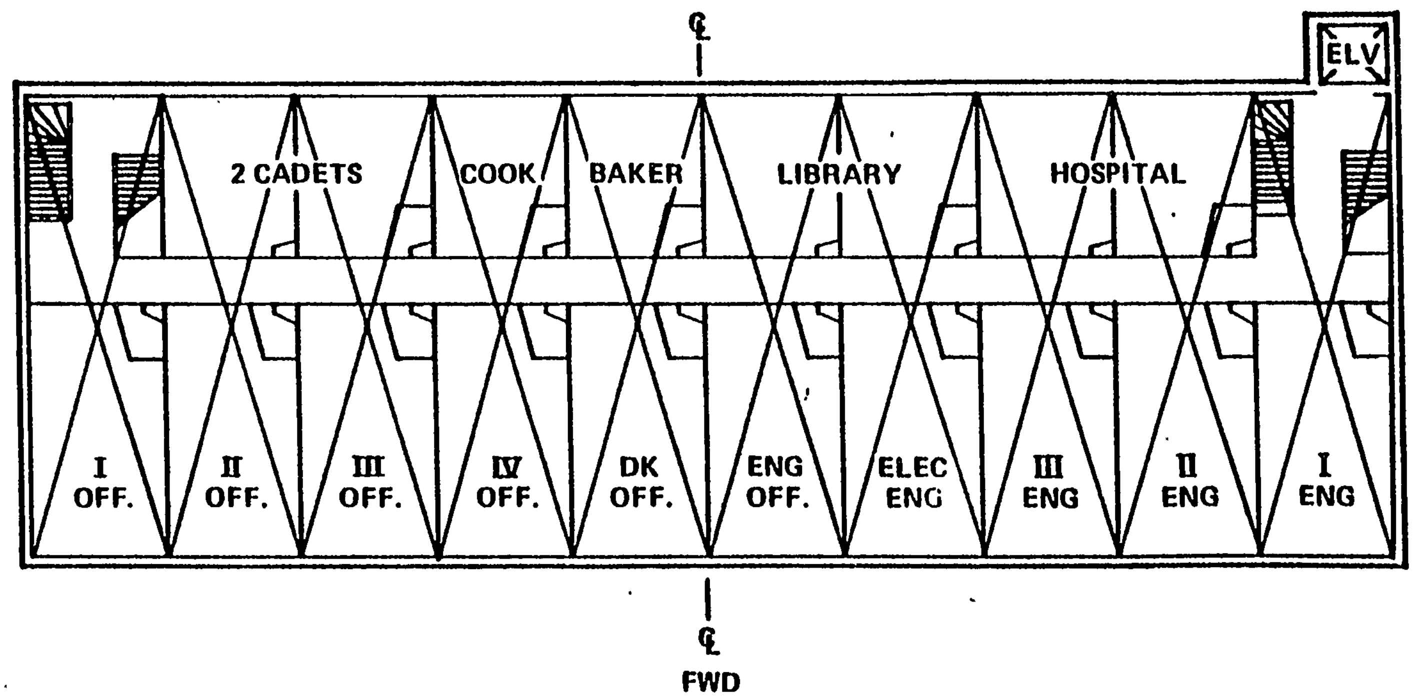


Figure 2-2. Typical Deck Arrangement

bolted with clips and brackets. Stiffening could be accomplished with large panels and tension bars.

(b) Standardization of these beams, columns, brackets and panels could simplify layout and fabrication.

2.2.3 Design Service Requirements to be Compatible with Containers

The following considerations can be developed for contanenrized cabins:

a. Each module container can have its own totally self- contained air conditioning unit, requiring only normal seawater cooling.

b. Each container should have a separate crawl space for all piping systems, including sait water, and flexible prefinished air ducts for central air conditioning, adjustable to individual owner!s choice.

c. Such 100% pre-outiitted box module containers for "plug-in" installation will enable the builder to lock up these spaces early, thereby reducing damages that could othewise result from the presence of shipyard workmen.

d. The superstructure will be engineered to the extent that it is build completely outfitted, including vibration reducing foundation and moved as one unit to the building ways.

e. A modular shower and toilet facility in each cabin 100% prebuilt, made from fiberglass (as in Fig 2-3) will increase savings in maintenance and up-keep, as compared to conventional installations requiring sequential work by several trades.

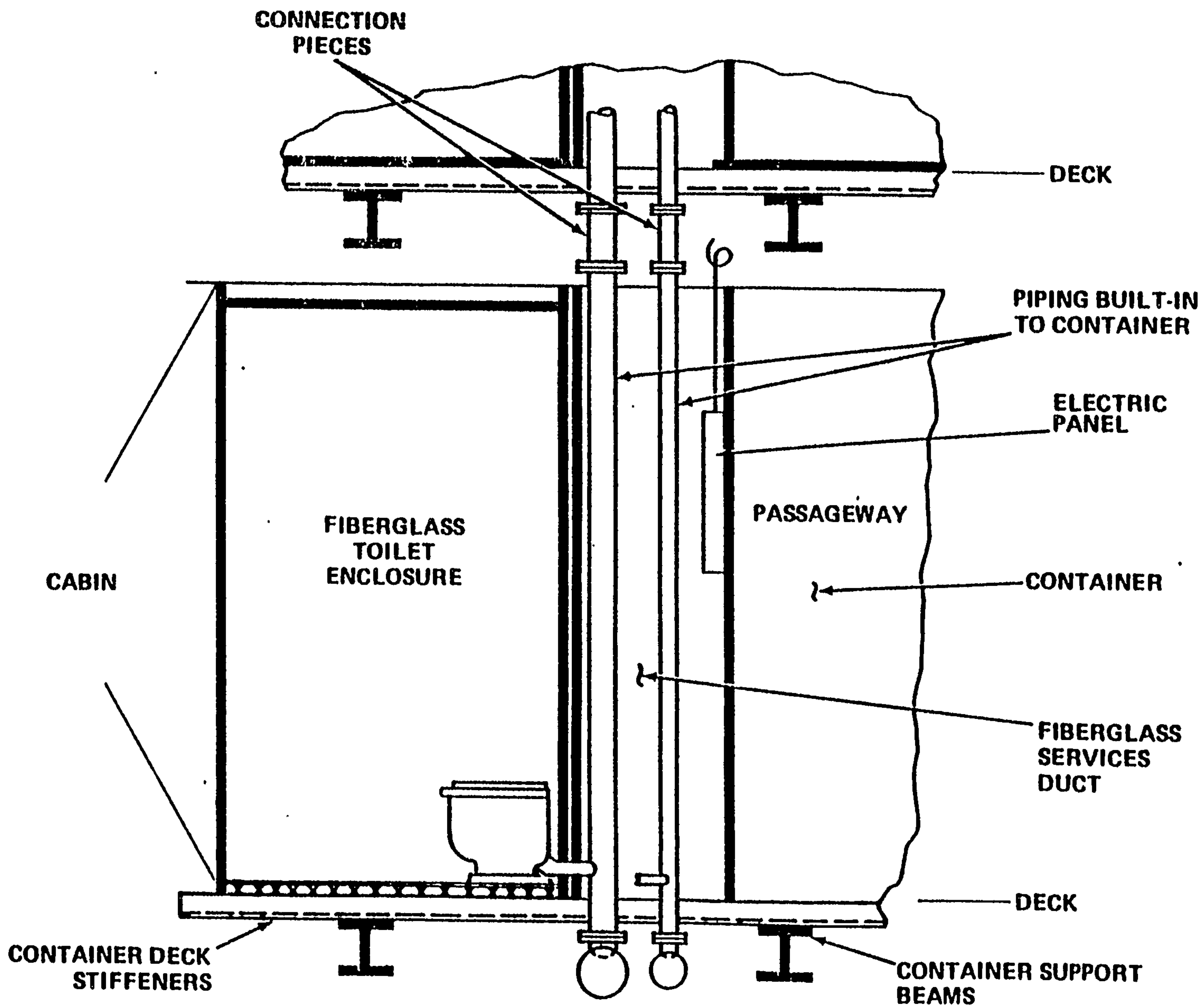


Figure 2-3. Centralized Distributive Systems

2.3 TRADEOFF COMPARISON OF CONTAINERIZATION VS. STANDARD METHOD

Work done in prior studies[1] has shown a decided shift in the manhour distribution for conventional superstructure installation as opposed to a similar containerization scheme, and a difference in total man hours required. This result, as shown in figures 2-4 and 2-5, suggests that similar shifts in distribution and reductions in total man hours might be characteristic of tanker superstructures. It was intended at the time of the mid-term review to investigate the tanker superstructure case, to generate comparative cost data, and to explore any other advantages and disadvantages which would be identified during the study. This was not done.

2. 3.1 Direction, Mid- Term Review

In January 1975, at the mid-term-review of the program, this subject and the progress to date was presented in the context of he total program.

It was the consensus of the review group that effort planned to be spent in completing this study should be rechanneled into other areas of the program adjudged to yield more data directly applicable to high priority series production problems of tankers.

[1] BUDOWNICTWO OKRETOWE 1970
BY - OLCHOWI & CHUDEICKI

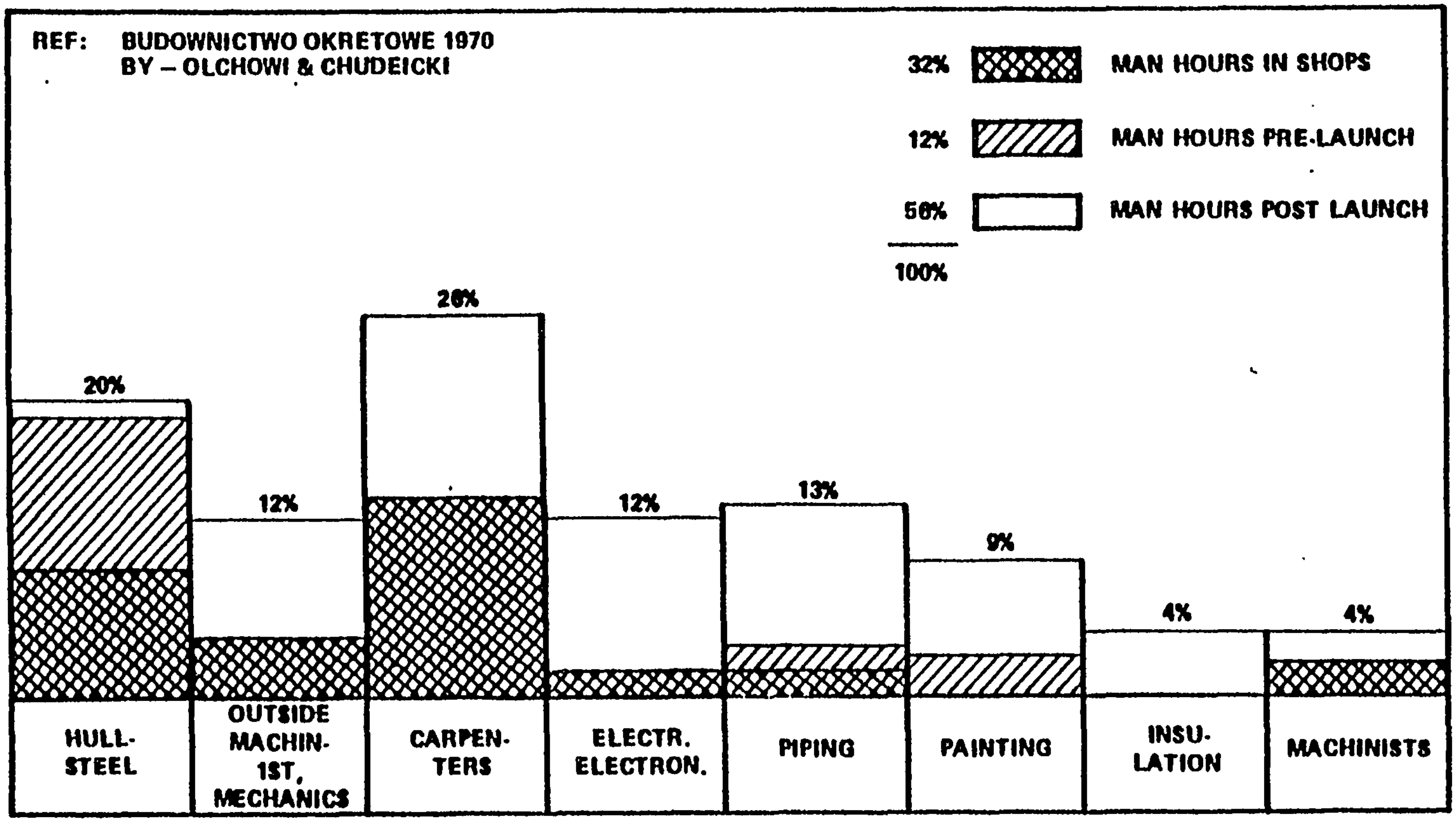


Figure 2-4. Conventional Manhour Distribution for Deckhouse Production

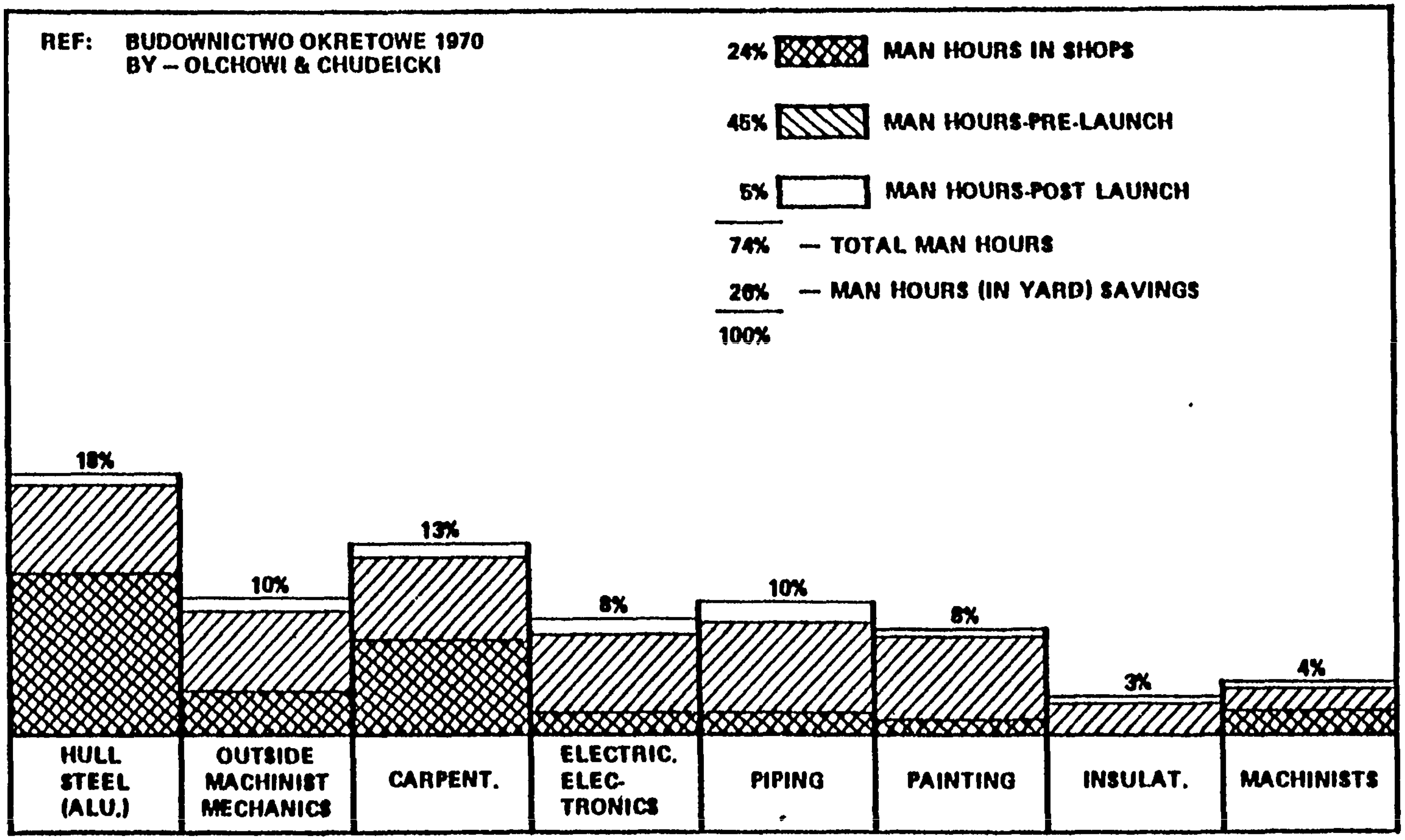


Figure 2-5. Manhour Distribution for Modularized Superstructure Construction

2.4 CONCLUSIONS AND RECOMMENDATIONS

There appears to be some merit to the containerized cabin concept, particularly the one man cabin concept with independent services.

Individual shipyards, depending upon their arrangements for outfitting labor skills, may want to pursue various aspects of this subject. Some shipyards prefer to place the highly variable outfitting manloading outside the yard, if possible" by make or buy decisions to subcontract, while others may absorb the fluctuations in outfitting trades by planned shifts within the yard work forces.

VOLUME 11

PART 3

CONSTANT PRINCIPAL DIMENSIONS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

VOLUME II
PART 3
CONSTANT PRINCIPAL DIMENSIONS

3.1 INTRODUCTION

The cur rent interest in standardized ships for series production in which a shipyard decides upon a design, goes into production, and sells identical ships to different owners, has brought about a corollary notion: the expandable ship. First it was determined necessary to examine independent variations of each of the three principal dimensions (length, beam and depth) as means to vary the deadweight capacity, while holding the other two constant. All these ships, would, to the maximum extent possible, have the same bow and stern modules. (See figure 3-1).

Ingalls subcontracted with Hydronautics, Inc. for the preliminary parametric variations phase of the investigation. The primary objective of the study was the identification of near- optimum ship characteristics for a range of given service requirements, directed toward the design and construction of a parallel body tanker series. Ship performance and operational requirements and restrictions were established by Ingalls Shipbuilding and a corresponding broad matrix of ship characteristics was selected for parametric study by personnel of Hydronautics, Inc. (See table 3- 1).

3. 1.1 Practical Consideration of Depth and Draft Variations

While this method of varying one of the principal dimensions appears superficially to have some merit it becomes obvious that the scantlings throughout the length of the ship may be adversely affected. For commonality of scantIings, the material contributing to longitudinal strength (mainly the bottom and deck plating and longitudinal) would be sized for the shallowest depth

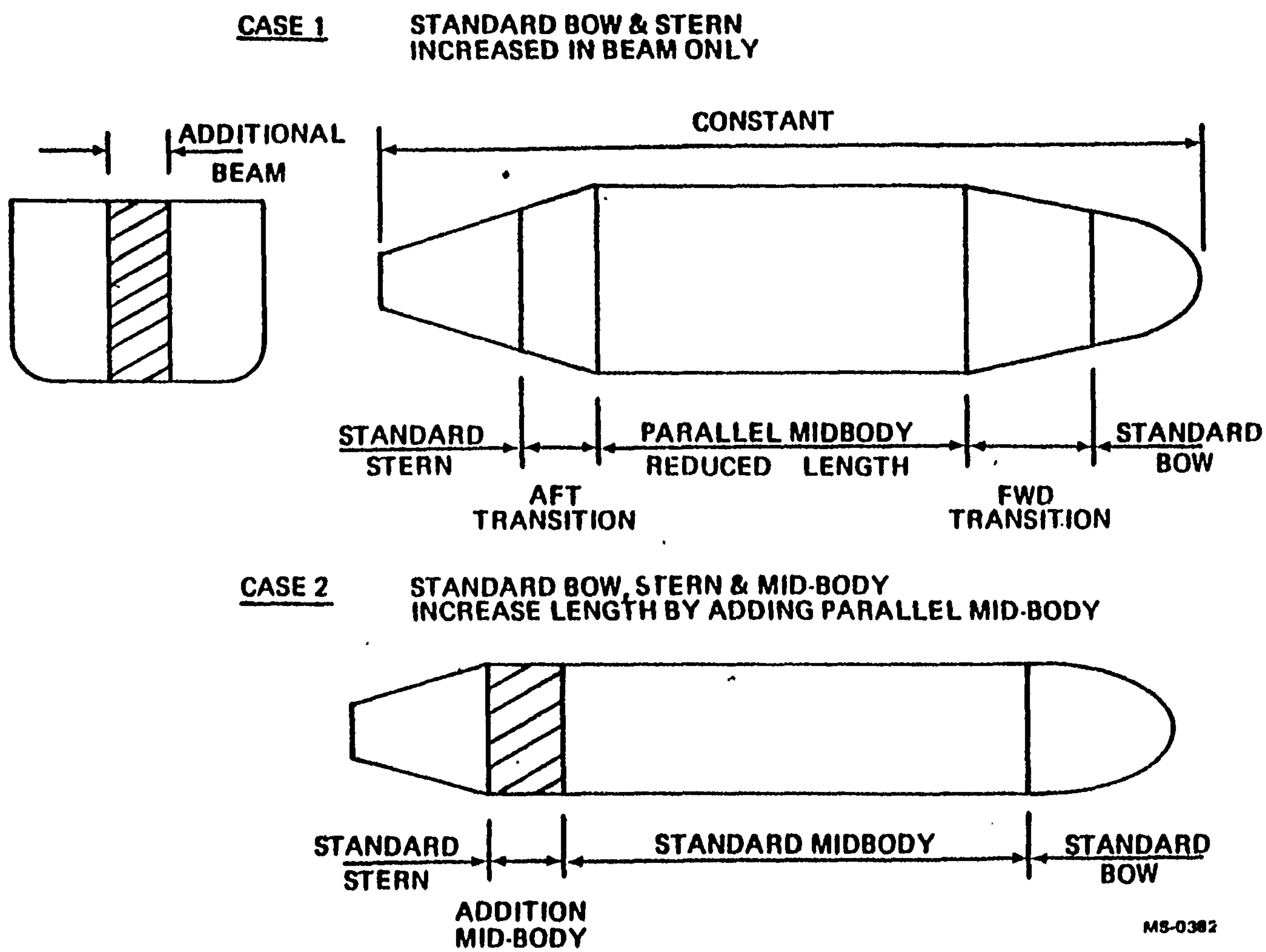


Figure 3-1. Principal Dimensions

Table 3-1 Principal Characteristics, Optimum Restricted Draft Tankers

Scantling, Draft, ft.	42	45	45	48	48	51	51
Length, B.P.	820' - 0"	850' - 0"	930' - 0"	925' - 0"	990' - 0"	1000' - 0"	1025' - 0"
Breadth, mld.	150' - 5"	161' - 4"	162' - 1"	177' - 5"	174' - 0"	185' - 3"	191' - 5"
Depth, mld.	60' - 2"	65' - 6"	64' - 0"	67' - 6"	67' - 10"	71' - 6"	72' - 7"
Draft, fbd., mld.	45' - 6"	49' - 8"	49' - 3"	52' - 0"	52' - 8"	55' - 8"	56' - 9"
Draft, scantling, mld.	42' - 0"	45' - 0"	45' - 0"	48' - 0"	48' - 0"	51' - 0"	51' - 0"
Displacement, total, tons	121,300	144,600	158,900	180,000	193,700	216,000	228,700
Deadweight, total, tons	100,000	120,000	130,000	150,000	160,000	180,000	190,000
SHP, max. continuous	24,300	27,000	32,800	29,300	31,300	32,550	33,900
Service speed (trial speed @ 90% max. SHP), knots	16	16	17	16	16	16	16
C_B	0.82	0.82	0.82	0.80	0.82	0.80	0.80
Tons/inch	263.2	292.7	321.7	340.1	367.6	387.6	410.4
L/B	5.45	5.27	5.74	5.21	5.69	5.39	5.36
L/D	13.61	12.97	14.52	13.71	14.60	13.96	14.12
B/T	3.58	3.58	3.60	3.69	3.62	3.63	3.75
RFR, 2500 mile voyage, mils/ton-mile	2.0119	1.8454	1.8136	1.6538	1.6495	1.5497	1.5411
Capital cost, three-ship basis, dollars	50,002,000	55,452,000	61,636,000	63,292,000	67,919,000	71,980,000	75,951,000
Dollars/DWT	500	462	474	422	424	400	400

ship, while that subject to hydrostatic loading would be sized for the deepest depth and draft (mainly the bottom plating and longi - tudinals and the lower bulkhead plating and longitudinal). The ‘ selected scantlings must simultaneously satisfy both conditions for all depths of hull. In addition, web frames would vary in their, scantlings in a similar manner. This did not appear to be worth further investigation, especially since there are almost no examples of “jumboizing” a ship in this manner to increase its cargo capacity.

3. 1.2 Practical Cons ideations of Beam Variation

A second method of varying cargo capacity without increasing length involves varying the beam of the parallel midbody of the ship, retaining the bow and stern unchanged. This method requires a transition section between the bow and the parallel body, and another transition between the stern and the parallel body. These transition sections would be different for each beam under consi- deration.

Significant variations of beam would require variations in the longitudinal bulkhead spacing, to retain proper relationships between centerline and wing tank bulkhead, engendering significant redesign of the transverse webs as the ship becomes wider. Much of the benefit of structural assembly standardization from one ship size to the next is lost.

Variations in beam of these magnitudes around an optimized ship beam will result in significant increase of the power required to make a fixed speed, or conversely, unacceptable loss of speed in the wide versions of the ship.

3.1.3 Practical Considerations of Length Variation

Variation of displacement and deadweight by variation of parallel body length is the least disruptive method when examined from the production impact viewpoint. If the length variation is plus or minus one cargo tank length, one assembly length, or one module length, then the production assembly line makes one more or one less unit for the longer or shorter ships. Shortening a cargo tank by the spacing between web frames (i. e. , one web frame deleted per tank) is another alternative for the reduced size ship which may not impact the tankage and trim flexibility inherent with more tanks.

Problems associated with achieving satisfactory trim in the full and down condition and ballast condition will be different for each length of ship and can be solved by the allocation of dedicated ballast tanks. This will have negligible effect on structure but will require modifications to the cargo and ballast piping systems.

The lengthened ship may require heavier scantlings in the mid length than the short ship or the baseline ship. Provision for this can be made in deck and bottom plating thickness changes, without longitudinal stiffener changes, if it is planned for in the baseline design. This again will have minimal impact on standardized assemblies for series production of the parallel body.

For the above reasons, this method of varying the displacement from a baseline design is preferred.

3.2 Development of Methods

The primary investigative tool used is a computer design program developed by Hydronautics, Inc. for concept design and cost stuides of dry and liquid bulk carriers, as described in Reference 1. The basic cost formulations in the program are essentially the expressions given by Dart in reference 2, suitably modified to reflect estimated current costs.

3.2.1 Study Requirements and Assumptions

a. Input Requirements

Initial ship and voyage requirements established by Ingalls Shipbuilding and Hydronautics, Inc. are summarized in the following tabulation:

Cargo density	40° API
Drafts, departure	42, 45, 48 and 51 ft.

Speed, service, defined as trial speed at 90 percent maximum SHP, to be determined from the study.

Bunker requirements, for definition of stowage factor = 5000 miles.

Pas sage length, one way, for determination of required freight rate values = 2500 miles, corresponding to the Alaska to California run.

Number of cargo tanks	Minimum, per IMCO requirements
Segregated ballast	As required by 1973 IMCO

Heating coils	None
Propulsion machinery	Geared steam turbine, 0.48 s.f. c., min. propeller RPM = 90
Complement	32
Ports /voyage	2
Utilization = 70 time carrying cargo	50%
Operating days / yr	345
Port time, hrs, each port	36

b. Assumptions

Assumptions inherent in the computer design program and other assumptions adopted for the study are summarized in the following notes.

c. Arrangement

The tank vessels are alI assumed to be of conventional arrangement with two longitudinal bulkheads, short forecastle with length = O. 07 LBP and all machinery, bunkers and accommodations aft. The cargo tank section was assumed divided into six or more compartments along the length, depending on ship size, which provided an arrangement compatible with IMCO outflow requirements and a two-compartment standard of subdivision. This arrangement was retained for designs incorporating 1973 IMCO segregated ballast requirements.

d. Complement

A crew of 32 was assumed, based on the following typical distribution of personnel:

Deck Dept.	Engine Dept.	Steward's Dept.
1 Master	1 Chief engr.	1 Steward/cook
3 Mates	3 Ass't. engrs.	1 cook/baker
1 Radio operator	3 Oilers	3 Mess lUtility men
6 A. B.	3 Fireman/ water tenders	
3 O. D.	1 Pumpman	
14 Total	11 Total	5 Total

Total Complement	30
Pilot	1
Spare	1
Total Accommodation	32

e. Propulsion

For the service contemplated, geared steam turbine machinery, with an all purpose fuel rate of 0. 48 lbs / SHP-Hr was considered appropriate. A minimum propeller speed of 90 RPM was established *as* a limiting condition. For the entire parametric study service speed was defined as trial speed obtained at 90 percent maximum continuous power at full load displacement, equivalent to a 25 percent service margin. No credit was taken for higher speeds in the ballast condition.

f. costs

The basic cost formulations given in reference 2 have been retained, escalated as appropriate to current cost levels. The nominal date of the original formulation is January 1970. Based on the advice of several private and government sources, a cost escalation factor of 2.5 was applied to the total ship cost computed for the 1970 base. This is assumed to bring the cost to a mid 1974 level. Other corresponding cost assumptions adopted for the study are summarized in the following listing. Items not listed were computed as shown in reference 2.

1. Capital charges = 0. 11017 x ship cost, corresponding to a 25 year life, no scrap value, sinking fund depreciation and 1070 return on investment.

2. Crew cost, average annual value per man = $36, 000.

3. Fuel cost, $65/ton

4. Miscellaneous voyage costs = 0. 025 x required freight rate

5. The following miscellaneous costs were escalated by the 2.5 factor above the formulations given in reference 2:

   Subsistence
   Stores and supplies

Maintenance and repair
P & I insurance

6. Overhead and certain miscellaneous cost items were neglected.

g. Boundary Conditions

The following boundary conditions were recommended by Hydronautics, Inc. in order to maintain ship characteristics within reasonable limits. These are primarily geometry related items and reflect recent experience with full form ship design and/or regulatory constraints,

LBD/B 25.0
LBP/D ≤ 15.0
B/T max. = 9.625- 7.5 C_B,

where T = draft
C_B = block coefficient

h. Cost Criteria

Cost information is provided in the computer output in the following forms:

1. Capital cost for procurement of one or more ships, according to the following learning curve assumptions:

No. of Ships	Cost Reduction Factor
Each *of 1*	*1.00*
3	0.88
5 -	0.84

2. Required Freight Rate (RFR), is computed from the relation:

$$RFR = \frac{CRF\ (\text{Capital cost}) + \text{Operating Costs}}{S\ (\mu)\ (dwt) N} \times 1{,}000$$

where

CRF = capital recovery factor,
= O. 11017 for the basic studies,
s = round trip voyage distance,
P = utilization,
dwt = cargo deadweight,
N = trips /year.

3.2.2 Parametric Studies of Basic Series Designs

a. Procedure

To provide a broad base for the selection of a family of restricted draft tank vessels, a parametric series of computer runs was prepared to define ship characteristics and costs for the following range of variables and conditions:

. Drafts, departure	42, 45, 48 and 51 ft.
Service speeds	15, 16, 17 and 18 knots
Block coefficients	0.78 to O. 86
Cargo	400 API

Effective stowage factor to account for IMCO segregated ballast requirements.

Requirements of the recent 1973 IMCO International Convention for the Prevention of Pollution from Ships were recognized with respect to requirements for segregated ballast for vessels of 70, 000 DWT and greater. The specific requirement pertinent to this study is the provision of sufficient segregated ballast capacity to obtain the following minimum operating drafts:

Draft, amidships = 2.0 + 0. 02L, in meters
Trim aft $\leq$ 0.015 L
Draft at A. P. sufficient to obtain full propeller immersion

A methodology was developed to properly simulate design characteristics *to* meet these requirements. (See reference 3).

3.2.3 Parametric Results

Results of the initial computer runs are summarized in figures 3-1 through 3-5 as values of RFR versus LBP, deadweight and service speed for the following conditions.

3.2.4 Parallel Body Series

a. Series I-VI

Data developed in the basic series study, described earlier in Section 3.0, served as the basis for developing a number of parallel body series designs developed from selected initial design characteristics. Initial cases I through VI,

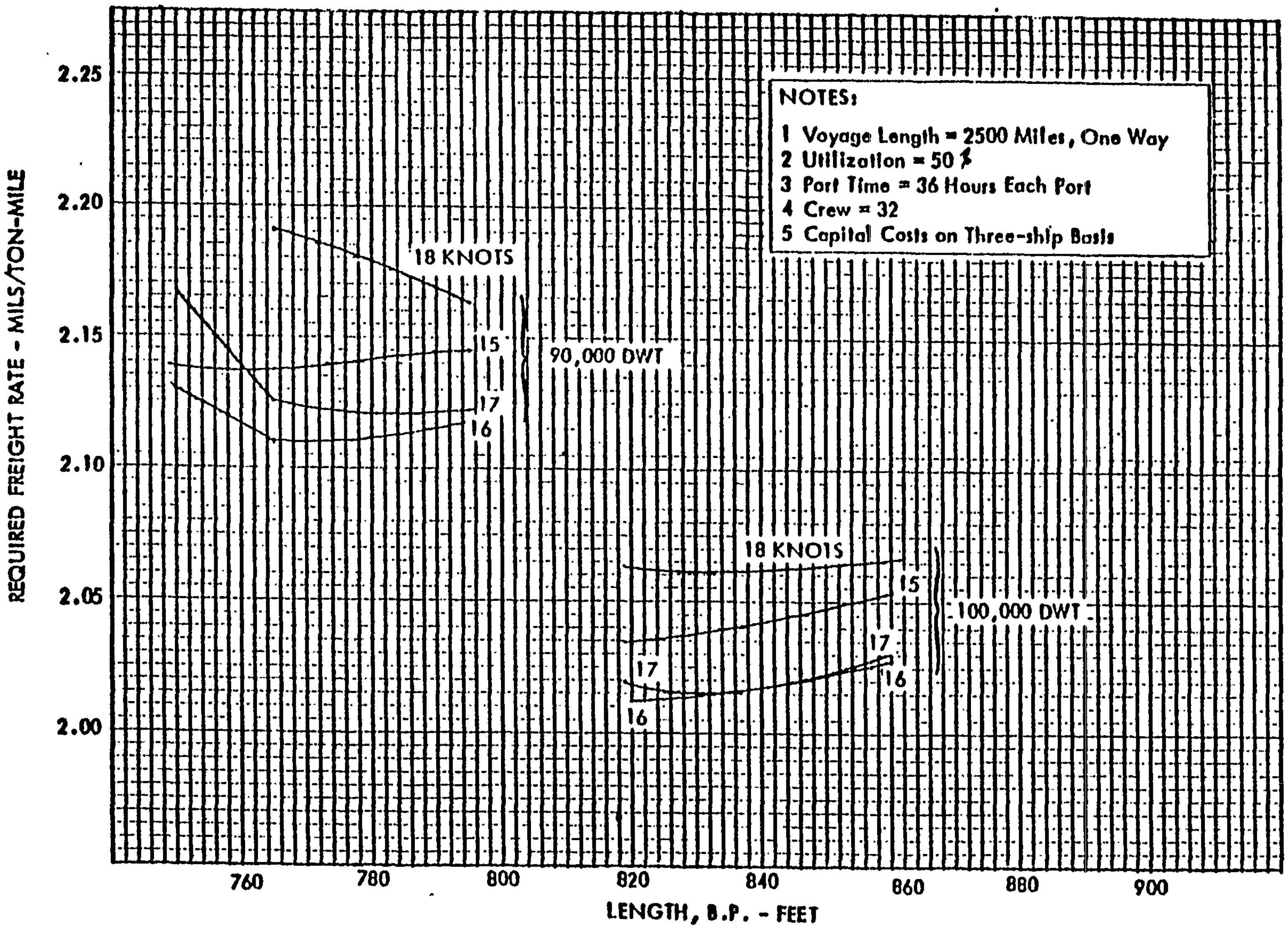


Figure 3-2. Required Freight Rate Versus Length for 42 Foot Departure Draft

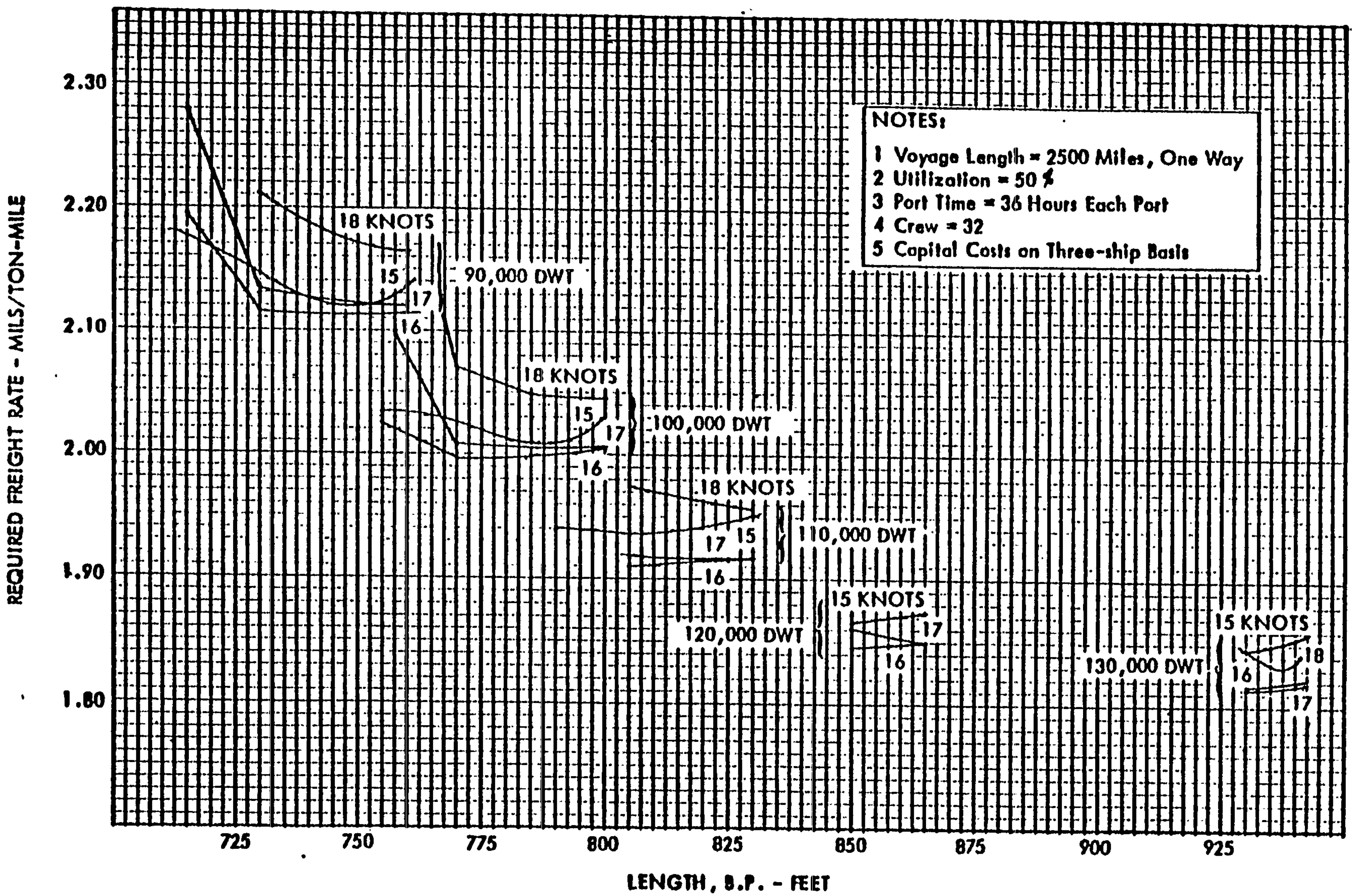


Figure 3-3. Required Freight Rate Versus Length for 45 Foot Departure Draft

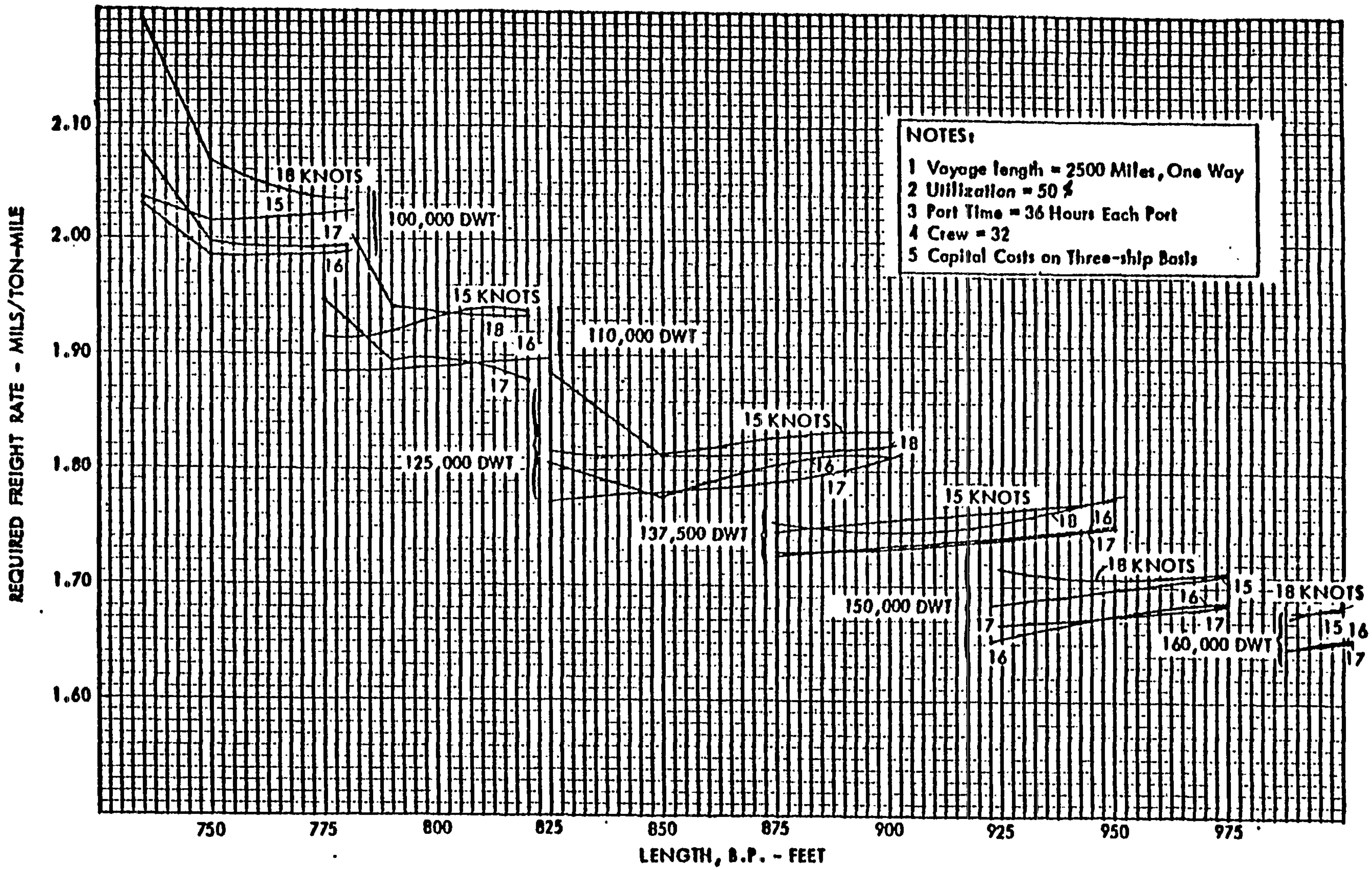


Figure 3-4. Required Freight Rate Versus Length for 48 Foot Departure Draft

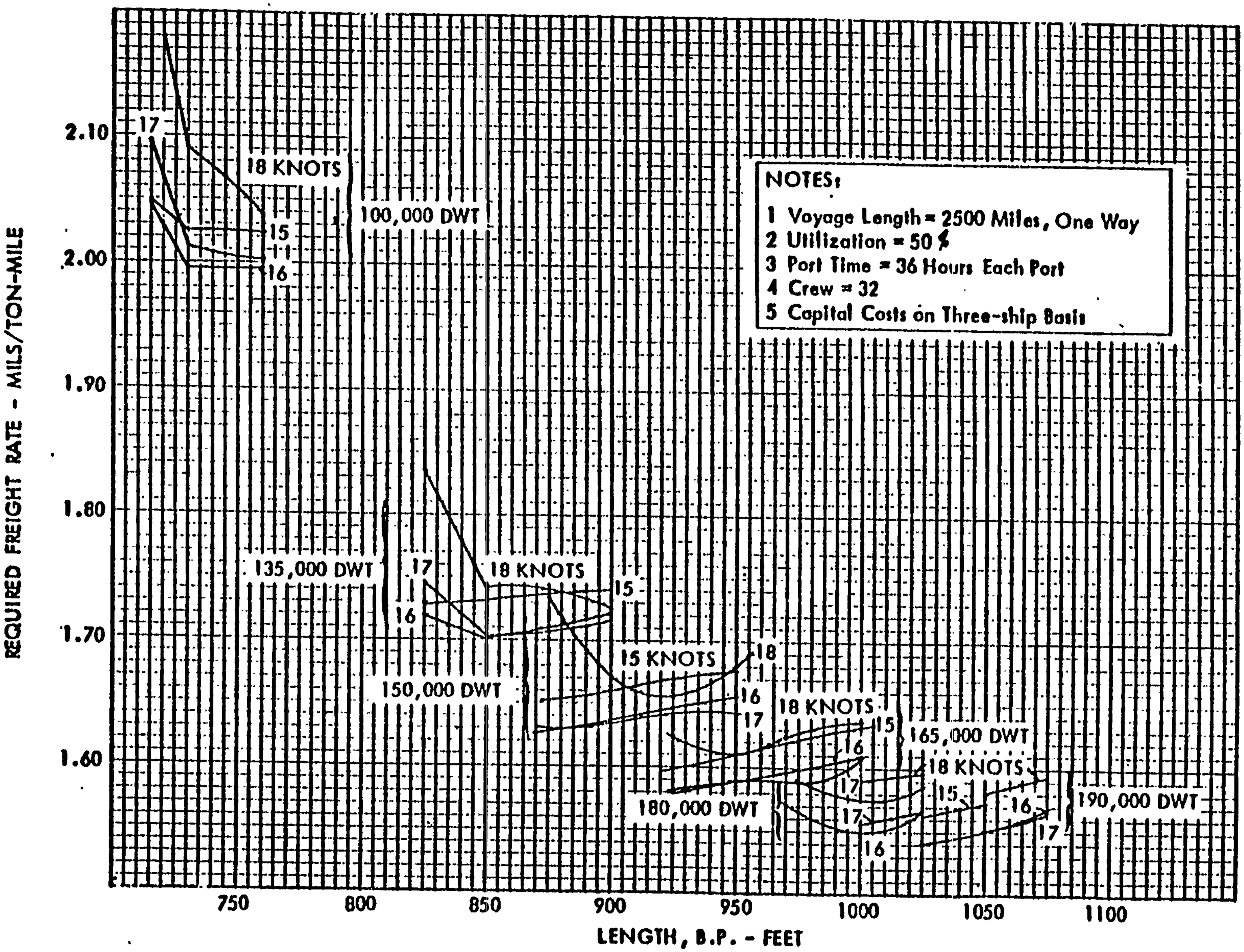


Figure 3-5. Required Freight Rate Versus Length for 51 Foot Departure Draft

identified in table 3-2, were selected by Ingalls personnel for further study and involved both shortened and lengthened variations of the basic hull. The following procedure was adopted:

1. For each baseline design, displacement and block coefficient, C_B, were computed for each change in length of parallel mid body.

2. Stowage factor was held constant.

3. Computer runs were prepared for speeds of 15 to 17 knots, for input values of computed displacements and Mock coefficients.

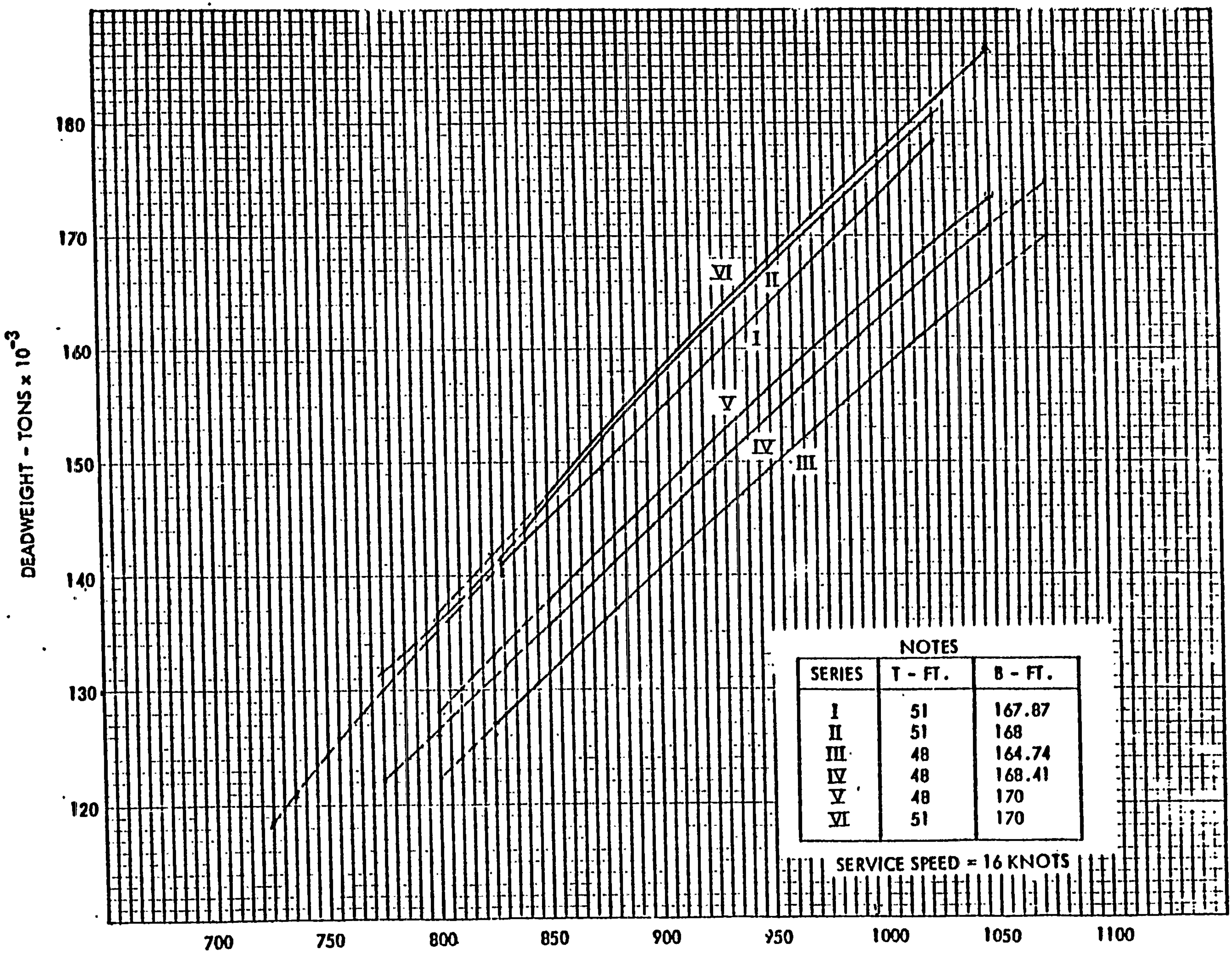
The results, given in figure 3-6 in terms of deadweight versus length, are plotted for the 1 b knot designs. The solid lines indicate the range of deadweights correspond-ing *to* acceptable design characteristics. Dotted lines are shown for regions where limiting values of L/B, L/D or B/T are exceeded. In general, a range of about 40, 000 tons between maximum and minimum lengths could be realized for given ends.

The following study limitations, related to the nature of the computer study, should be noted:

1. For a fixed stowage factor, the parallel body changes necessarily result in corresponding depth changes. For Series VI, 16 knot designs, for example, depth varies from 77 *ft. at* LBP = 850 ft to 73.6 ft at LBP = 1050 ft.

Table 3-2. Baseline Designs for Parallel Body Study

Series No.	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Length, B. P.	875.0	875.0	950.0	925.0	900.0	900.0	850.0	850.0	800.0	800.0	675.0	675.0
Breadth, mld.	165.87	168.0	164.74	168.41	170.0	170.0	170.0	170.0	160.0	160.0	135.0	135.0
Depth, mld.	76.96	74.0	69.31	70.17	74.0	72.0	-	-	-	-	-	-
Draft, scantling, mld.	51.0	51.0	48.0	48.0	48.0	51.0	49.0	49.0	48.0	48.0	51.0	135.0
Deadweight, total	150,000	-	150,000	150,000	-	-	-	-	-	-	-	-
C_B	0.84	0.84	0.84	0.84	0.84	0.84	0.80	0.82	0.80	0.82	0.78	0.80
Shaft HP, max.	31050	-	30735	30800	-	-	-	-	-	-	-	-
Service speed (trial speed at 90% max. SHP)	16	16	16	16	16	16	16	16	16	16	16	16



SERIES	T - FT.	B - FT.
I	51	167.87
II	51	168
III	48	164.74
IV	48	168.41
V	48	170
VI	51	170

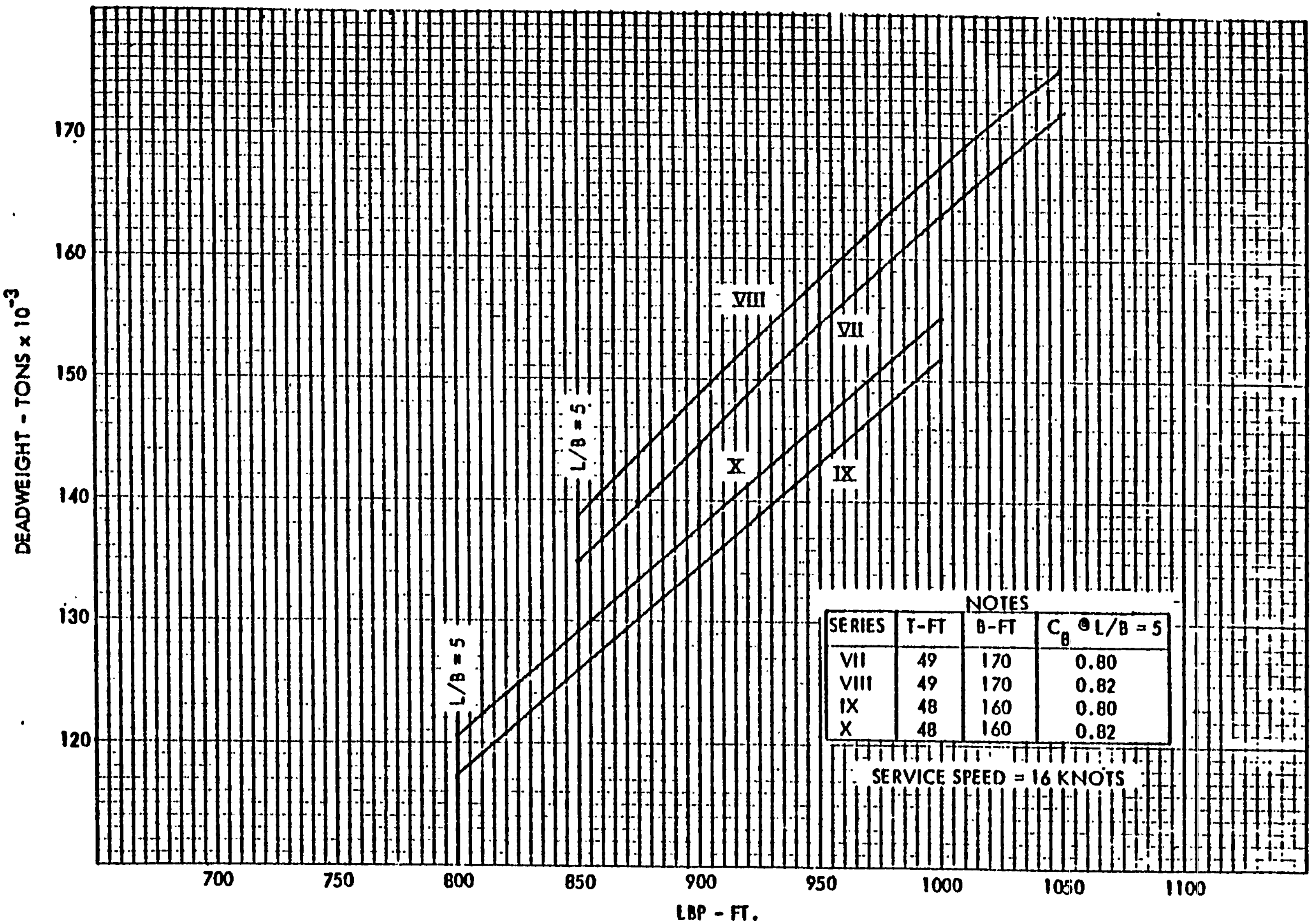
2. . Scantlings, frame and bulkhead spaces vary with each length change.

3. For a given service speed, power requirements *vary* with length and corresponding change in displacement. . For the Series VI, 16 knot designs, power required varies from about 30, 600 SHP at 850 ft LBP to about 35, 900 SHP at 1050 ft LBP. Accordingly, the computer printouts for the parallel body series were prepared for 15, 16 and 17 knot service speeds to permit preparation of cross-curves to relate speed, power and displacement.

b. Series VII - X

Figure 3-7 *centains* results for four additional series, designated Series VII through X. These series were established by defining baseline designs for L/B = 5.0 and C_B = 0. 80 and 0. 82. Basic dimensions of B = 170 ft for 49 ft draft and B = 160 ft ior 48 ft draft were assumed. The basic hulls were assumed lengthened until the limiting value of L/D = 15 was reached. Results for a 16 knot service speed are shown in figure 3-3. The approximate deadweight range attainable is given in the following tabulation:

B	T	C_B, Initial	Approx. DWT Range
170	49	0.80	135, 000- 172, 000
170	49	0.82	139,000- 176, 000
160	48	0.80	117,000- 152, 000
160	48	0.82	121, 000- 155, 000



SERIES	T-FT	B-FT	C_B @ L/B = 5
VII	49	170	0.80
VIII	49	170	0.82
IX	48	160	0.80
X	48	160	0.82

Figure 3-7. Deadweight Versus LBF for Parallel Body Series VII thru X

The variation in values of depth for a given stowage factor is approximately the following:

B/Initial C_B	D
170/0. 80	72.15 @ LBP = 850
	68.66 @ LBP = 1050
170/0. 82	72.87 @ LBP = 850
	70.00 @ LBP = 1050
160/0. 80	71.55 @ LBP = 800
	67.73 @ LBP = 1000
160/0. 82	?2. 37 @ LBP = 800
	68.46 @ LBP = 1000

The variation of power required for a 16 knot service speed is given in the following tabulation: .

*

B /InitiaI C_B	SHP
170/0. 80	27, 300- 33,500
170/0. 82	28,900- 34, 600
160/0. 80	25,400- 30, 900
160/0. 82	27,400- 31,800

C. Series XI and XII

A parallel body series, designated Series XI and XII, was studied for B = 135′ - O″, T = 51′ - O“ and service speed = 16 knots held constant. Results are summarized in figure 3-8 in terms of deadweight versus length for initial values of C_B = O. 80 and 0.78 at L/33 = 5.00. .The extreme range of feasibility permits obtaining the following range of deadweight values:

Initial C_B.	DWT
O. 78	85, 000- 145, 000
0.80	88,000- 148,000

Depth and power required varied with LBP and initial C_B in the following manner:

LBP	D	SHP
675	79.0@cB= 0.78	25,300 @ C_B= 0.78
	79.6@cB= 0.80	23, 800 @ C_B= 0.80
1050	71.1@cB= 0.78	30, 300 @ C_B= 0.78
	71.9@cB= 0.80	30,800 @ C_B= O. 80"

d. Discussion of Results

Results of the parallel body series study iridicate that the basic objective of obtaining a range of 120, 000 DWT to 150, 000 DWT within a single parallel body series is feasible. It should be noted, however, that the series cannot represent optimum ships throughout the length range. This is shown clearly later in this report.

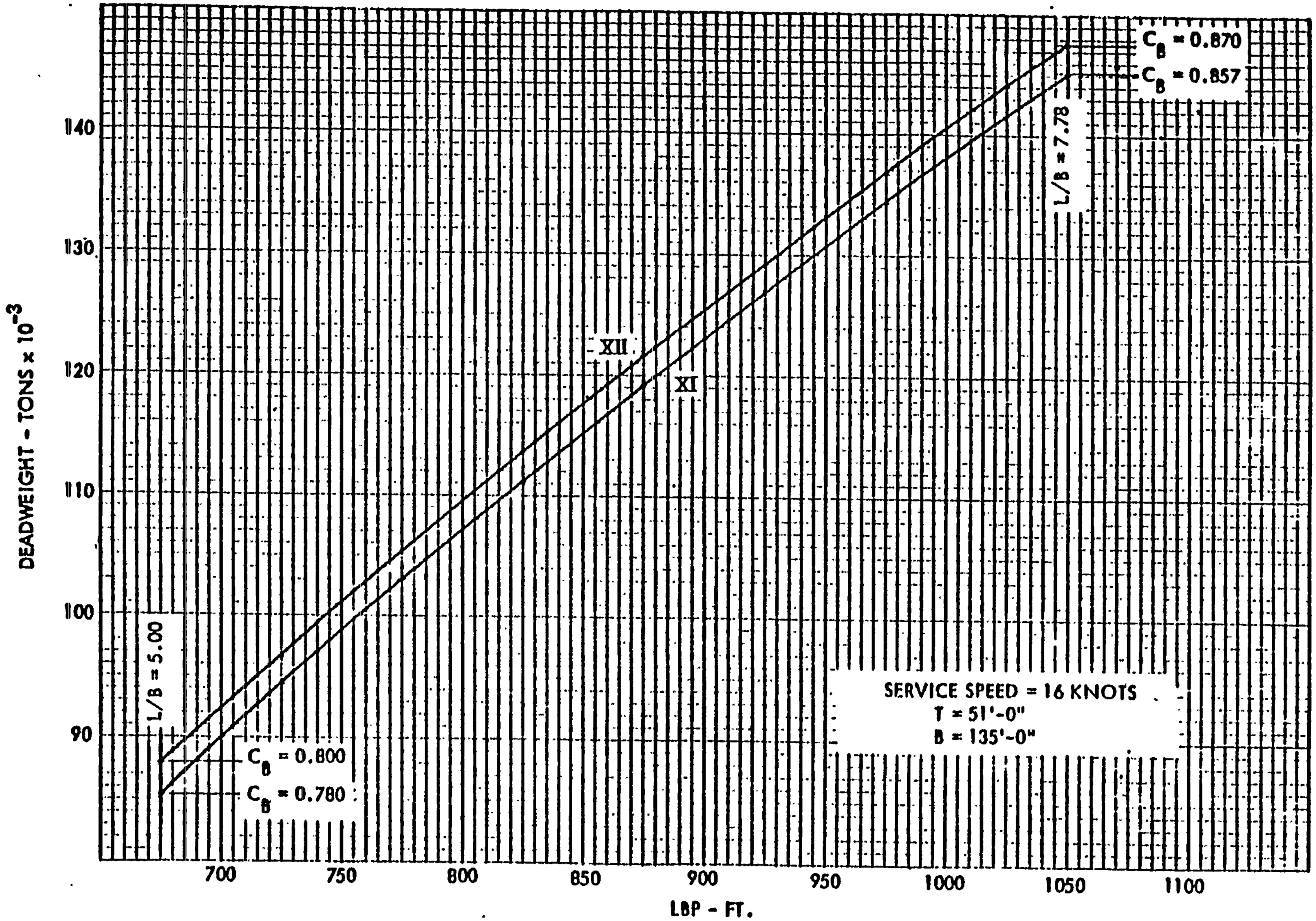


Figure 3-8. Deadweight Versus LBP for Parallel Body Series XI and XII

In general, the shortest designs, i. e., the short end of the series, will represent the least costly basic vessels for the corresponding value of deadweight. Further, the following modifications may be required at some point in the length variation:

1. Change in scantlings.

2. Change in arrangement to permit relocation of forepeak bulkhead.

3. Change in tank arrangement to assure that acceptable values of stowage factor, trim and bending moment are obtained at all conditions of loading, as a function -" of length variation.

3.3 Final Series Selection

Designs tentatively selected for further study are derivatives of Series X described in Section 3.2.4. The starting point for the proposed series has the characteristics:

LBP = 800' - 0"
B = 160' - 0"
D = 74' - 0"
T = 48' 0"
C_B = 0.82
SHP = 33,000

By a trial and error process, computer definitions of two lengthened versions were developed, assuming ends held constant, a simple addition of parallel body and draft of 51' - O" for the lengthened designs. Characteristics of the three-ship series are summarized in table 3. A summary of light ship weight is given in table 3-4.. "

Results given in tables 3-3 and 3-4 are taken directly from the computer printouts included in the appendix and reflect the following limitations of the study:

Costs of the selected 160 ft breadth series are compared in figures 3-9 and 3-10 with corresponding costs of the optimum basic series designs. The comparisons are not rigorous in that *service* speeds differ and cubic capacities of the longest vessels may be deficient. However, with respect to RFP., the 800 ft LBP and 925 f t LB P designs compare favorably with the optimum basic series designs.

3.4 Summary and Conclusions

The primary objective of identification of near optimum ship characteristics for a range of given service requirements was achieved. The definition of the principal dimensions of a baseline tanker and the practical limits to which its length could be varied was also achieved. These dimensions are shown in figure 3-11 and page 61 of the Mid Term Report.

In an environment where first cost dominates over final costs in the life cycle cost, a standard design, "stretched" or "shrunk" may be attractive. However, in the present world, fuel costs are rising as fast as construction *costs. In* this latter environment, there is some doubt that ships at either end of the range of this series (120, .000 and 180, 000 dwt) would be competitive with designs optimized for these deadweights. This opinion was also the concensus of the mid. term review group.

Table 3-3. Principal Characteristics 160 ft Breadth Parallel Body Series

Length, B.P. Breadth, mld. Depth, mld.	800'-0" 160'-0" 74'-0"	925'-0" 160'-0" 74'-0"	1050'-0" 160'-0" 74'-0"
Draft, fbd., mld.	55'-6"	56'-6"	57'-6"
Draft, scantling, mld.	48'-0"	51'-0"	51'-0"
Displacement, total, tons Deadweight, total, tons	143,900 120,200	182,800 153,800	211,800 175,500
SHP, max. continuous	33,000	33,000	33,000
Service speed (trial speed @ max. continuous SHP)	17.0	16.3	15.7
C_B	0.8200	0.8475	0.8651
Tons/inch	273.20	324.6	374.7
L/B L/D B/T	5.000 10.842 3.333	5.781 12.501 3.137	6.562 14.189 3.137
Capital cost, three-ship basis, dollars dollars/DWT	 56,441,000 496.56	 63,060,000 410.01	 71,573,000 407.82
RFR, 2500 mile voyage, mils/ton-mile	1.8618	1.6279	1.6078

Table 3-4. Light Ship Weight Summary
160 ft Breadth Parallel Body Series

Length, B. P.	800'-0"	925'-0"	1050'-0"
Steel	19,300	23,980	30,750
Outfit	2,530	2,910	3,250
Machinery	1,185	1,185	1,185
Margin	735	825	1,115
Light Ship Weight	23,750	28,900	36,300

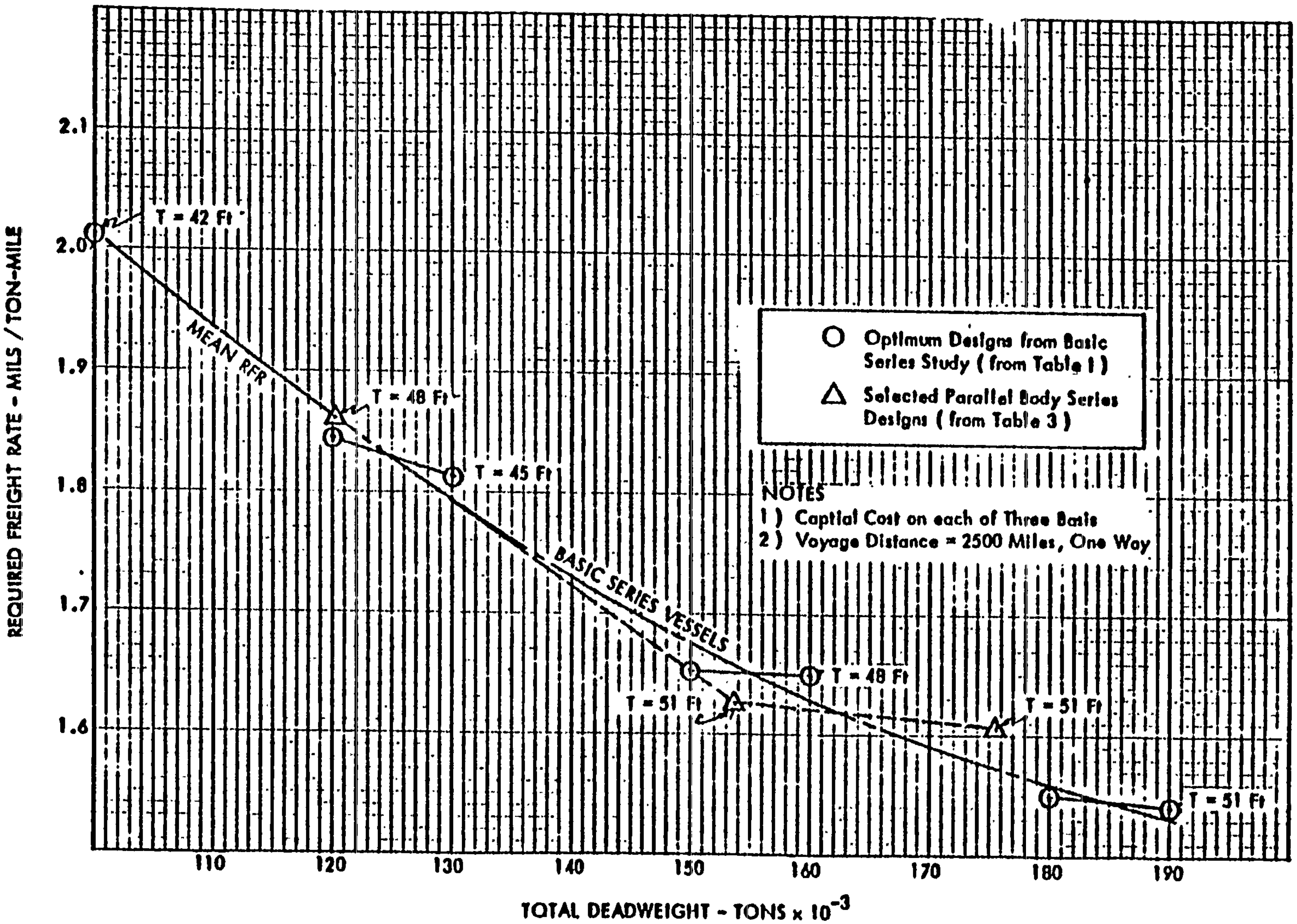


Figure 3-9. Required Freight Rate Versus Deadweight, Basic and Parallel Body Series

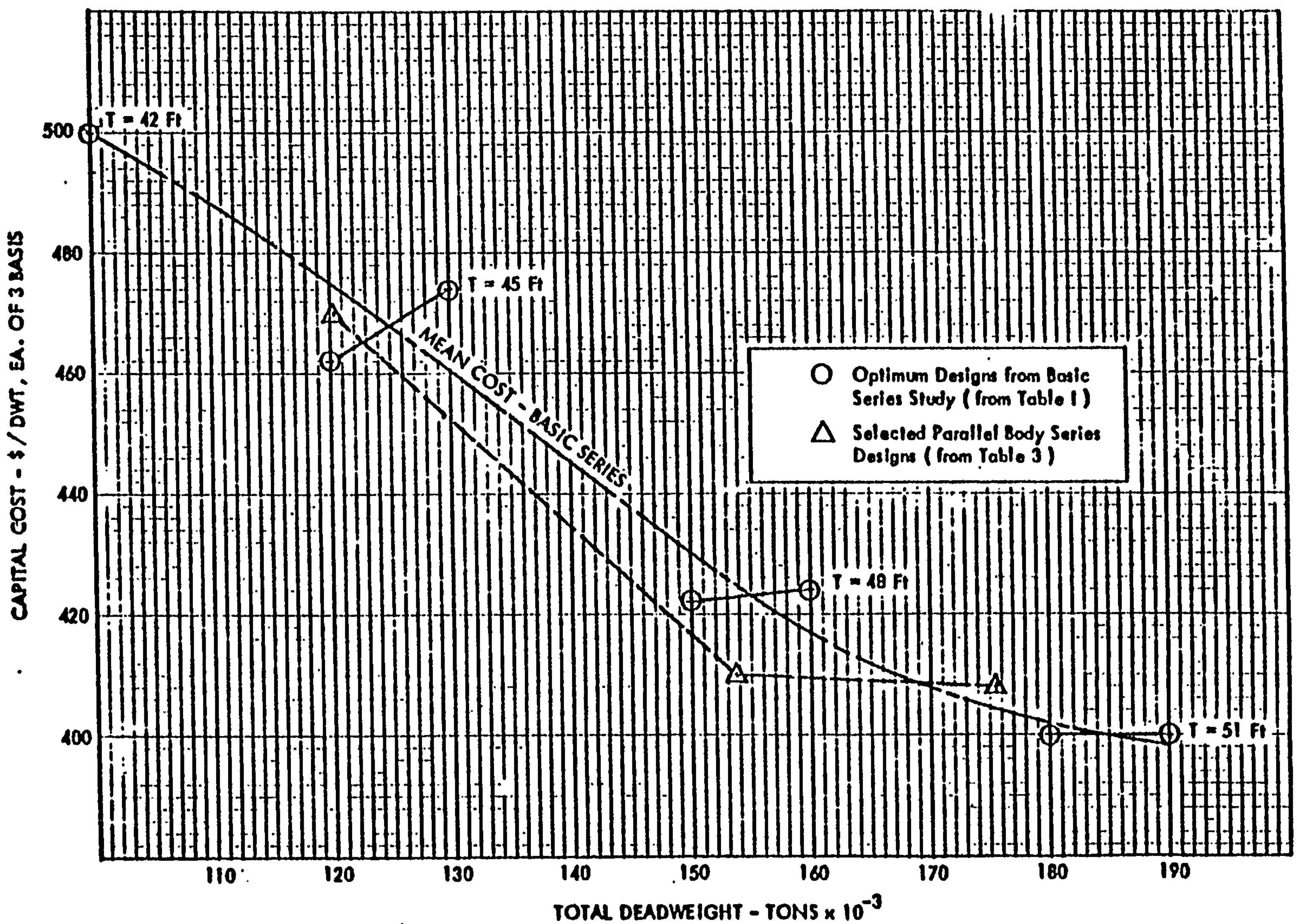


Figure 3-10. Capital Cost Versus Deadweight, Basic and Parallel Body Series

180,000 DWT
LBP 1088'
LOA 1109'
B 160'
D 74'

150,000 DWT
LBP 920'
LOA 941'
B 160'
D 74

120,000 DWT
LBP 776'
LOA 797'
B 160'
D 74'

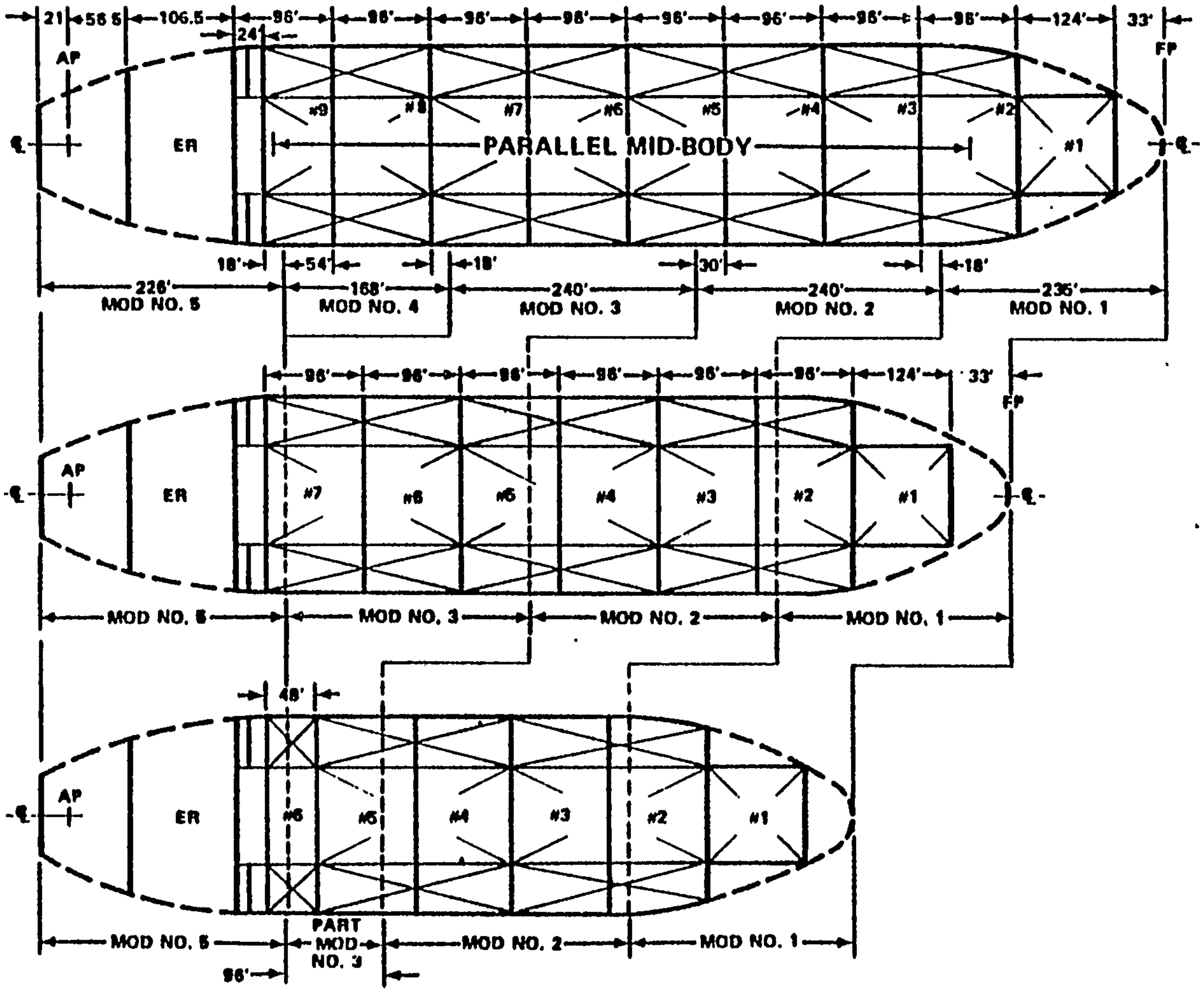


Figure 3-11. Principal Dimensions and Practical Length Variations

APPENDIX A

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VOLUME II

PART 4

MACHINERY SYSTEM MODULES/PACKAGING

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

VOLUME II

PAR T 4

MACHINERY SYSTEMS MODULES/ PACKAGING

4.1 INTRODUCTION

This part of the study was directed toward determining the feasibility of designing an arrangement for the main propulsion plant and sup. porting system equipment for a standard stern module of a 150,000 DWT crude carrier which would achieve the following objectives:

a. Arrangements and Locations within the module, selected for the main propulsion machinery and support systems equipment to be common for any one of the four main propulsion systems listed in paragraph 4.1. Additionally, the locations and arrangements for the machinery components are to be such that minimum, if any, hull structure altera. tions are required when any of the main propulsion plants in paragraph 4.1 are installed in the module.

b. For the purpose of promoting series production pre-outfitting of assemblies, the selected locations and arrangements of support system equipment (feed pumps, pre -heaters, piping arrangements) will be correlated to the assembly configuration established for hull design erection. That is, the location of the machinery components, including manifolding, etc. , will be such that these items are contained within a specific assembly or subassembly scheduled for integration . into the stern module. By achieving this objective, machinery components can be prepackaged and installed in assemblies prior to integration of the assembly into the stern module.

4.2 .STUDY APPROACH

Other MarAd studies and preliminary investigation conducted during the course of this study indicate that selection of a propulsion plant is a controversial subject with many owners, and the choice between steam, diesel and gas turbine may be -largely an arbitrary matter. Therefore, four different types of propulsion systems were selected to evaluate in terms of their degree of meeting the objectives set forth in paragraph 4.1 a and b. Vendor selection for the propulsion plants used in this study was based largely on the following criteria:

- Plant is existing and “representative of its type;
- Manufactured in U. S. A.;
- 25,000 Shaft Horsepower (SHP).

The propulsion plants selected were:

Steam Turbine -

Manufacturer - Westinghouse Corporation

Type - High Speed, Compound High Pressure and Low Pressure

Medium Speed Diesel -

Manufacturer - Colt Pielstick
Type - 18 Cylinders, “V”

Light Weight Gas Turbine

Manufacturer - Pratt-Whitney
Type - FT 9

Heavy Duty Gas Turbine

Manufacturer - General Electric
Type - Model MM 50002R-B, Frame 5 Regenerative

4.3 AUXILIARY MACHINERY INSTALLATION PACKAGE DEFINITIONS

For the purpose of clarity, an Auxiliary Machinery Installation Package is defined as a system or unit of functionally related machinery, including piping, valves, instrumentation, controllers, motors, foundations, etc., required for the primary unit to perform its engineered purpose. Additionally, for the purpose of this study, each similar auxiliary machinery package has been located in the same general area within the stern module for each type of main propulsion equipment.

4.3.1 Vendor Furnished Packages

These machinery packages are identified as primary machinery supporting components purchased from a vendor and include the designed installation,interface piping, controls, wiring, foundations, etc., to be provided by the vendor. Each component with application to another unit, is purchased by specifications that provide for package integration into the machinery module with minimum installation work being performed by the shipyard.

4.3.2 Shipyard Prefabricated Machinery Packages

These packages are defined as vendor procured machinery components, identified by engineering plans, that may be shipyard assembled, tested and subsequently installed as an integrated unit in the machinery module with minimum installation work required after Landing on Ship. These types of packages may include pre-fabricated manifolding and valving or any other components identified to a machinery system that may be pressembled prior to installation in the ship."

4.4 STERN DESIGN

During the several phases of this study, a number of alternatives were identified as possible cost saving items. Included in these alternatives was using a Modified Scow Stern (shown in figure 4-1) as a baseline for achieving the objectives of this part of the study. A preliminary analysis of this type stern indicated there would be less space available for-au0xiliary machinery components, which are required to support the main propulsion plant, (pumps, piping, cent rols, etc.') than in a conventional tanker stern design. This reduction of available machinery space in the scow stern was particularly in evidence in the lower level machinery space. A conventional stern design would provide more tank top surface area and less structural restriations than the scow stern (particularly at the lower level); therefore, there would be more arrangement flexi. bilit y. Based on the foregoing conditions it was concluded that if the objectives set forth in paragraph 4. 1 could be attained by using a modified scow stern, equal or better results could be achieved with minimum difficulty, when applying the same objectives to a conventional tanker stern.

4.4.1 STERN DESIGN CONSIDERATIONS IN RELATIONSHIP TO AUXILILIARY MACHINERY PACKAGES

Maximization of series production benefits from the machinery packaging technique and standardization of machinery arrangements requires that these factors be fully considered during the preliminary design phase of the stern module. During this phase of design, the machinery slated for package installation and the requirement for standardization of arrangement for the different main propulsion plants must be taken into account. In particular, the criteria that machinery packages be located insofar as practical clear of hull structural breaks is considered. Therefore, the stern structural assemblies should be clearly defined early in the design phase and the assembly breaks, insofar as practical, be established in conjunction with the requirements for machinery package installation and standardized machinery arrangements. l

In addition, consideration must be given during this phase to design of the foundations required for auxiliary machinery packages. Wherever possible the foundations should be designed as an integral part of the structural asse’mbly; the components can then be fitted and aligned directly on the structural assembly and no further alignment of the equipment should be necessary.

Machinery packages that are designed to .be installed and outfitted on weld-in-place foundations require final alignment to be accomplished after the foundation is welded to the ship’s structure in order to avoid warping the equipment out of alignment.

Well-planned auxiliary machinery packages should be located in the stern structural assemblies during the initial design phase of this part ,of the ship. This procedure can be followed as the space requirements for each package will be defined. Location of this type equipment, during the design phase of the machinery space layout, will assist in locating machinery packages adjacent to each other that have related functional application and commonality of piping systems. This location consideration will assist in simplifying the piping system layout between assemblies for related auxiliary machinery packages.

During the development phase of auxiliary machinery packages, consideration must also be given to protecting the more vulnerable items on the package such as instrumentation, electrical items, small valves, etc. , against damage during installation of the package in the stern module.

Special shipping devices may also be required for certain types of machinery packages to facilitate installation of the unit on structural assemblies, and should be clearly defined early in the design phase.

4.5 ARRANGEMENT DESIGN CONSIDERATIONS

In developing the main propulsion and supporting system arrangements in figures 4-2, 4-3, 4-4, and 4.5, special emphasis was placed on selecting standard marine equipment and on locating the equipment according to established marine design practices.

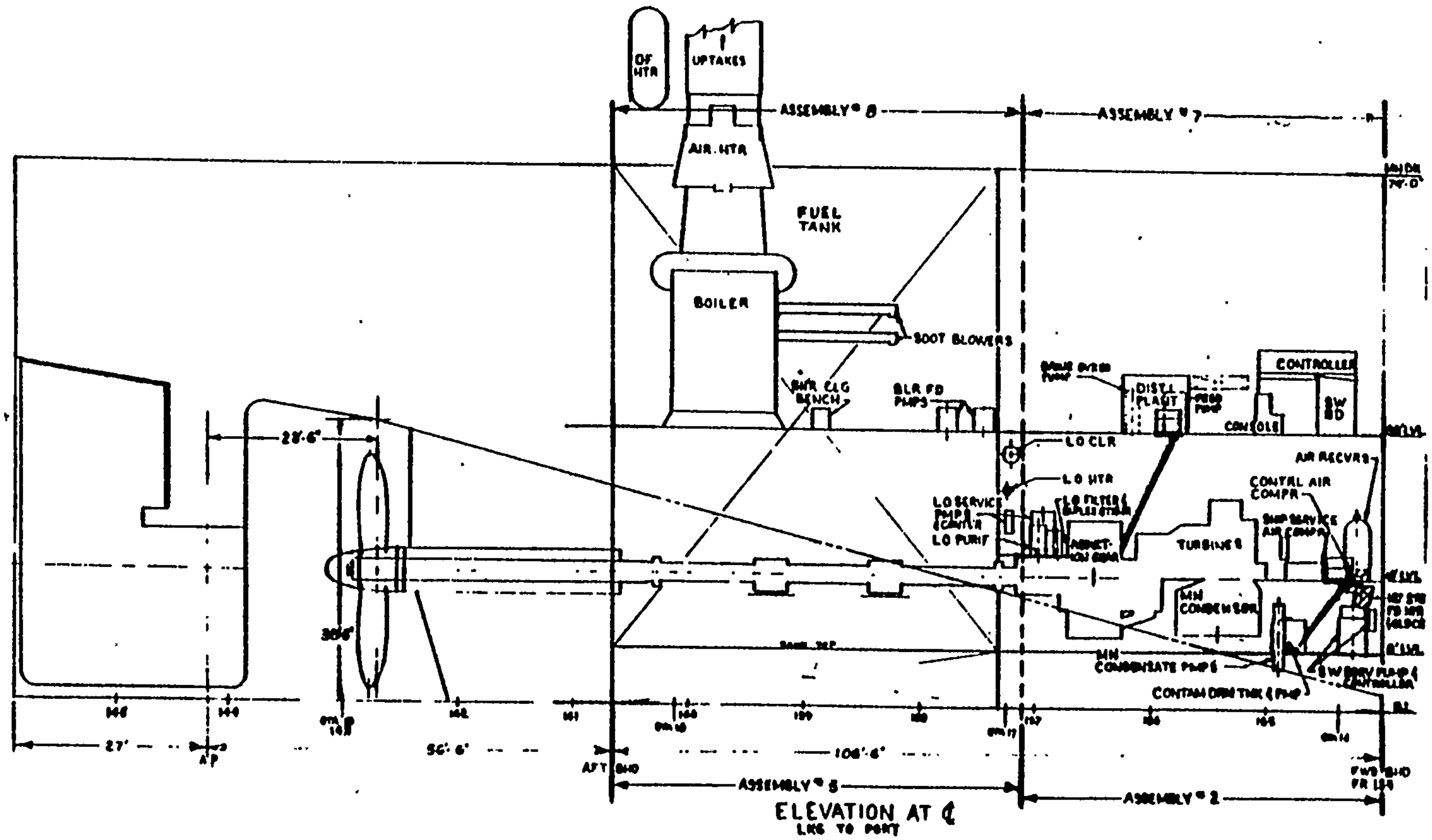
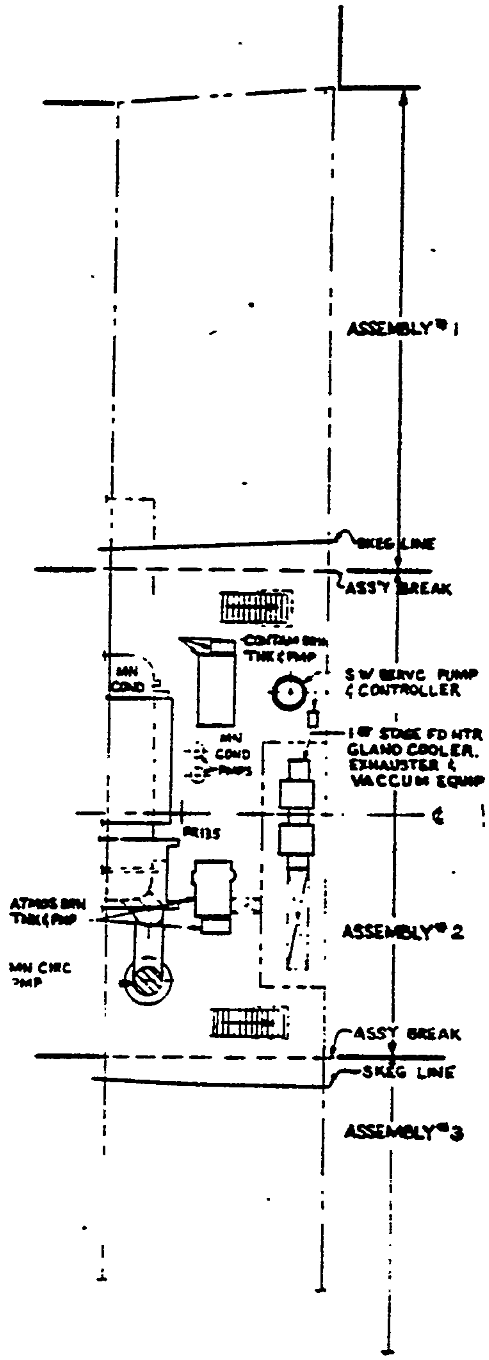


Figure 4-2. Steam Turbine Arrangement (Sheet 1 of 6)



PLAN VIEW
8 FT LVL

Figure 4-2. Steam Turbine Arrangement (Sheet 2 of 6)

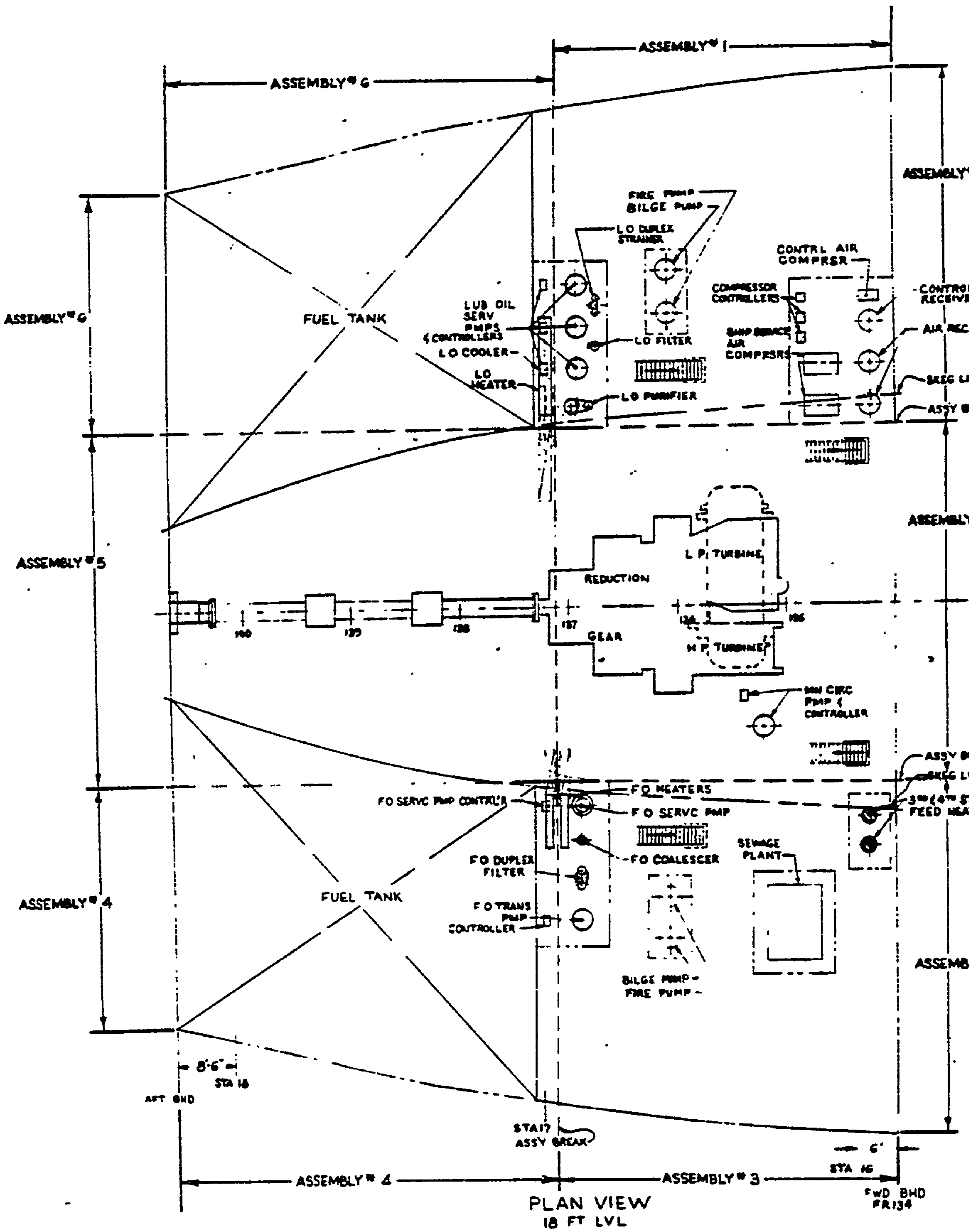


Figure 4-2. Steam Turbine Arrangement (Sheet 3 of 6)

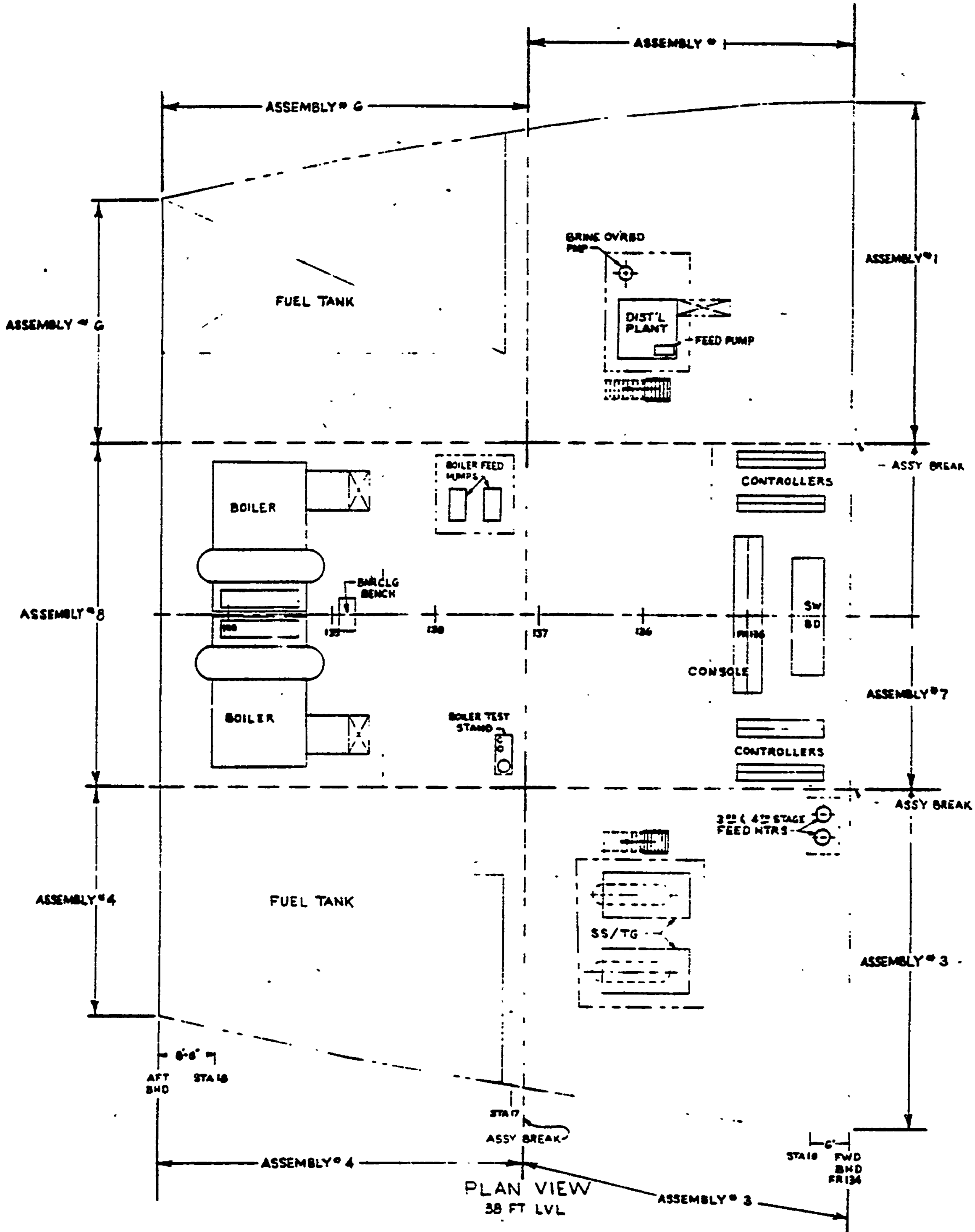


Figure 4-2. Steam Turbine Arrangement (Sheet 4 of 6)

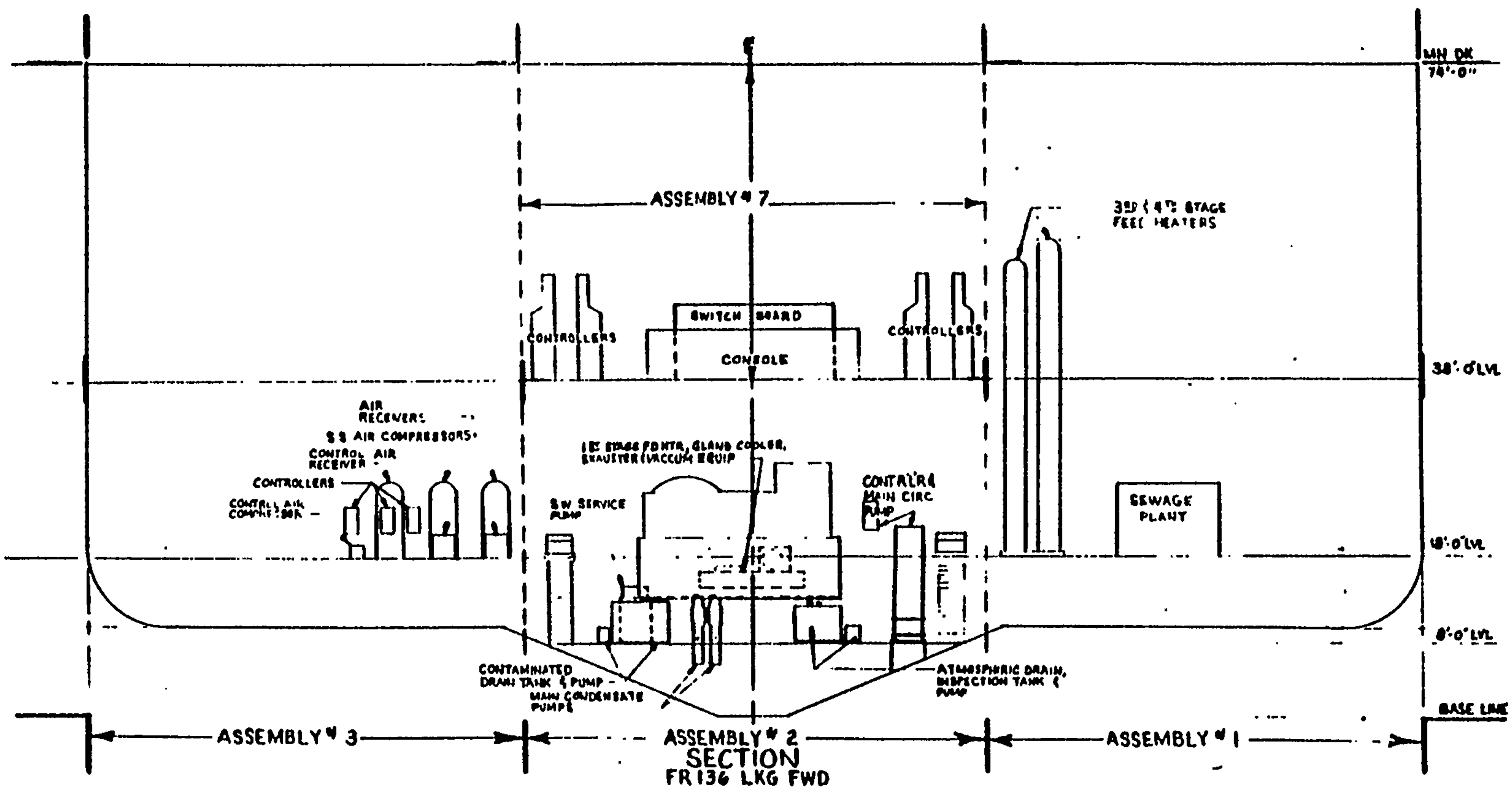


Figure 4-2. Steam Turbine Arrangement (Sheet 5 of 6)

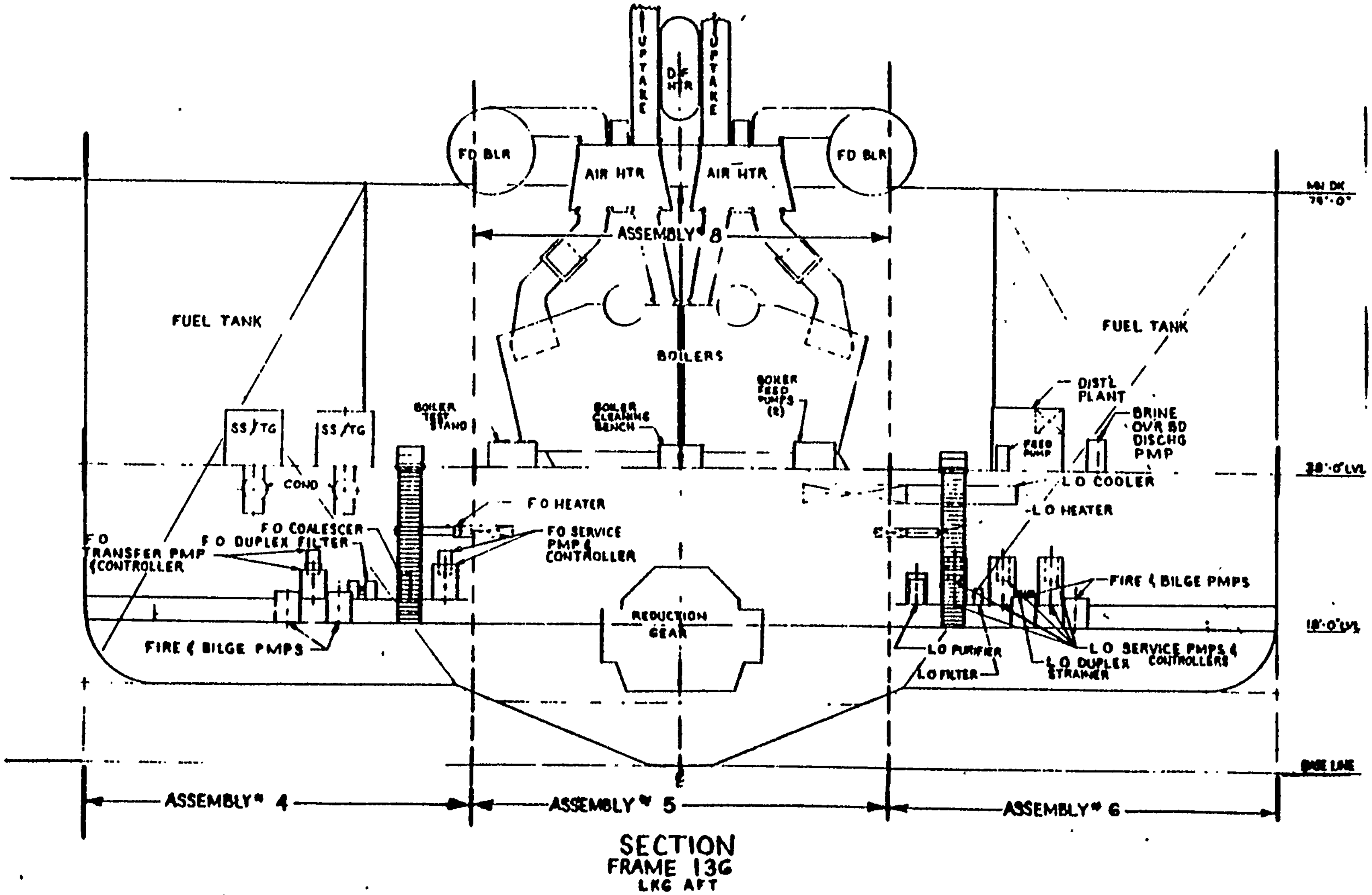


Figure 4-2. Steam Turbine Arrangement (Sheet 6 of 6)

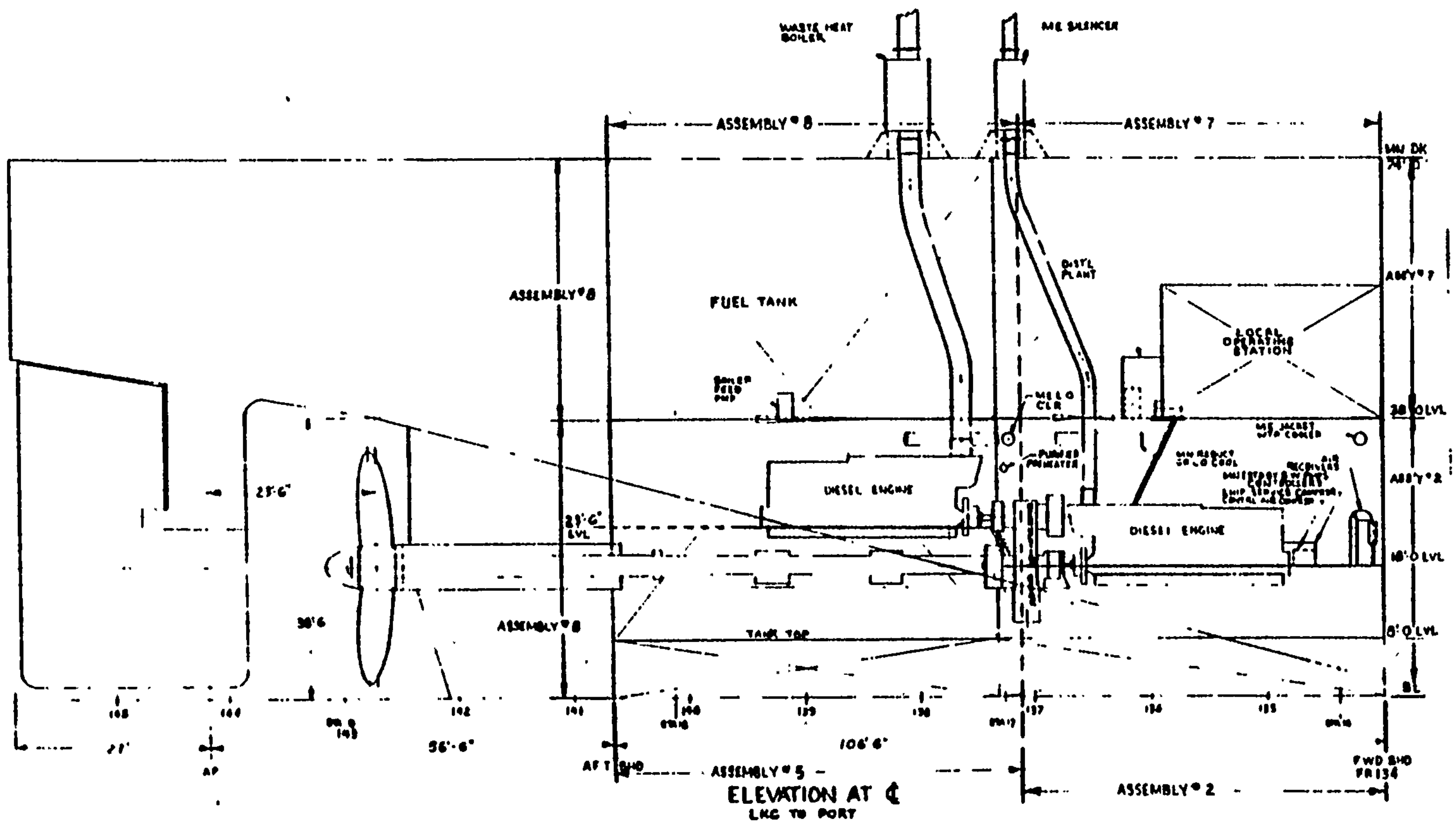


Figure 4-3. Medium Speed Diesel Arrangement (Sheet 1 of 5)

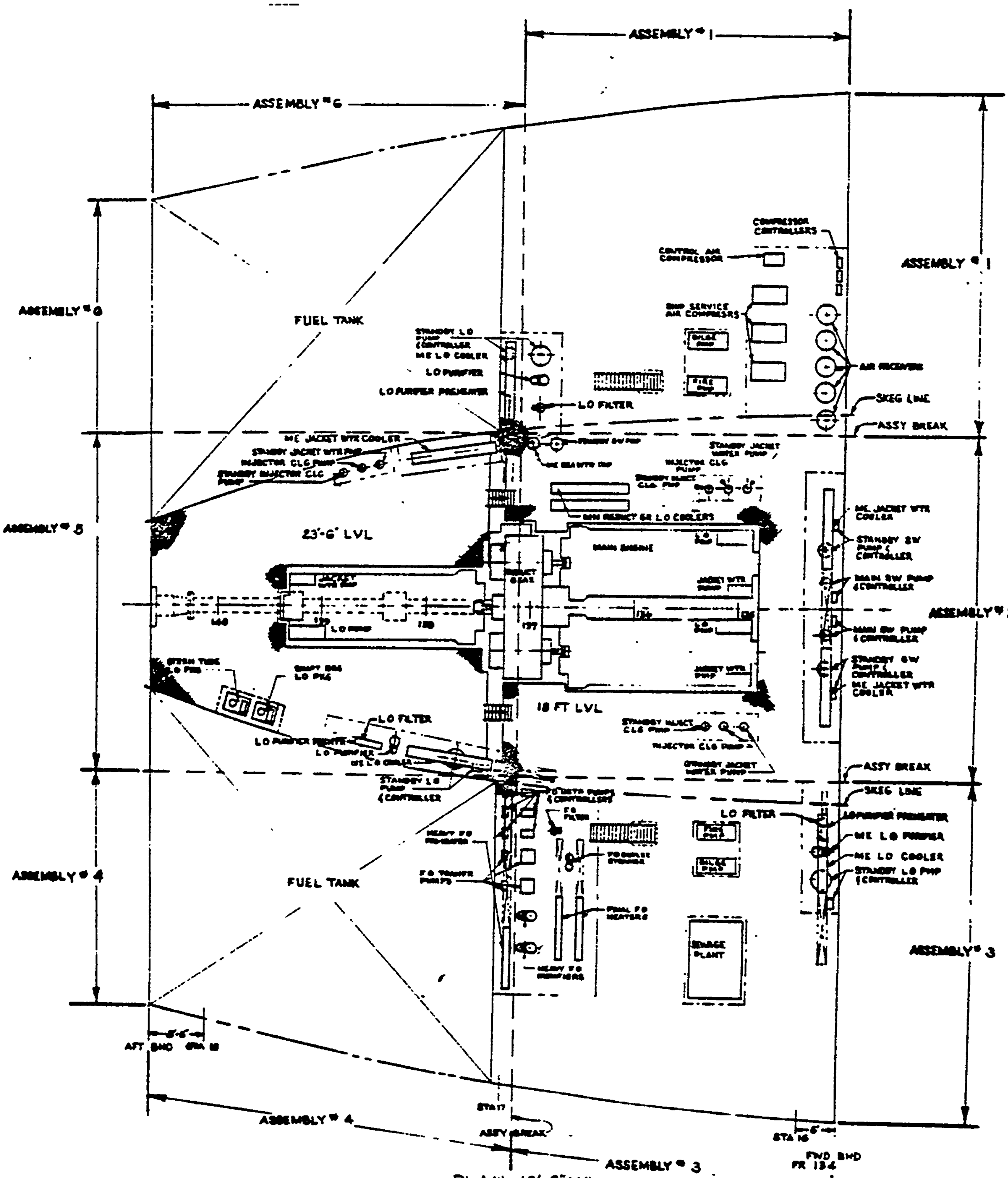


Figure 4-3. Medium Speed Diesel Arrangement (Sheet 2 of 5)

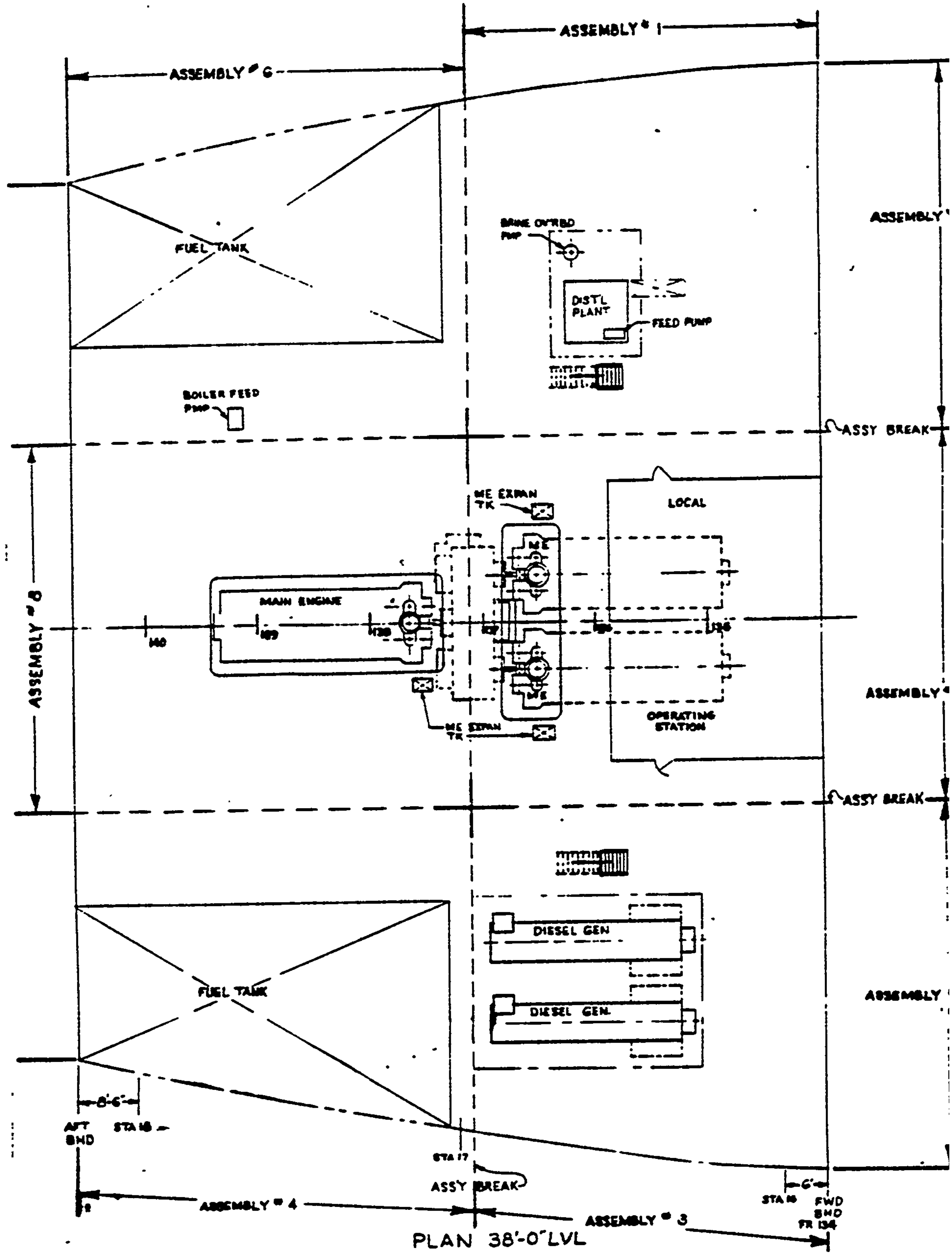


Figure 4-3. Medium Speed Diesel Arrangement (Sheet 3 of 5)

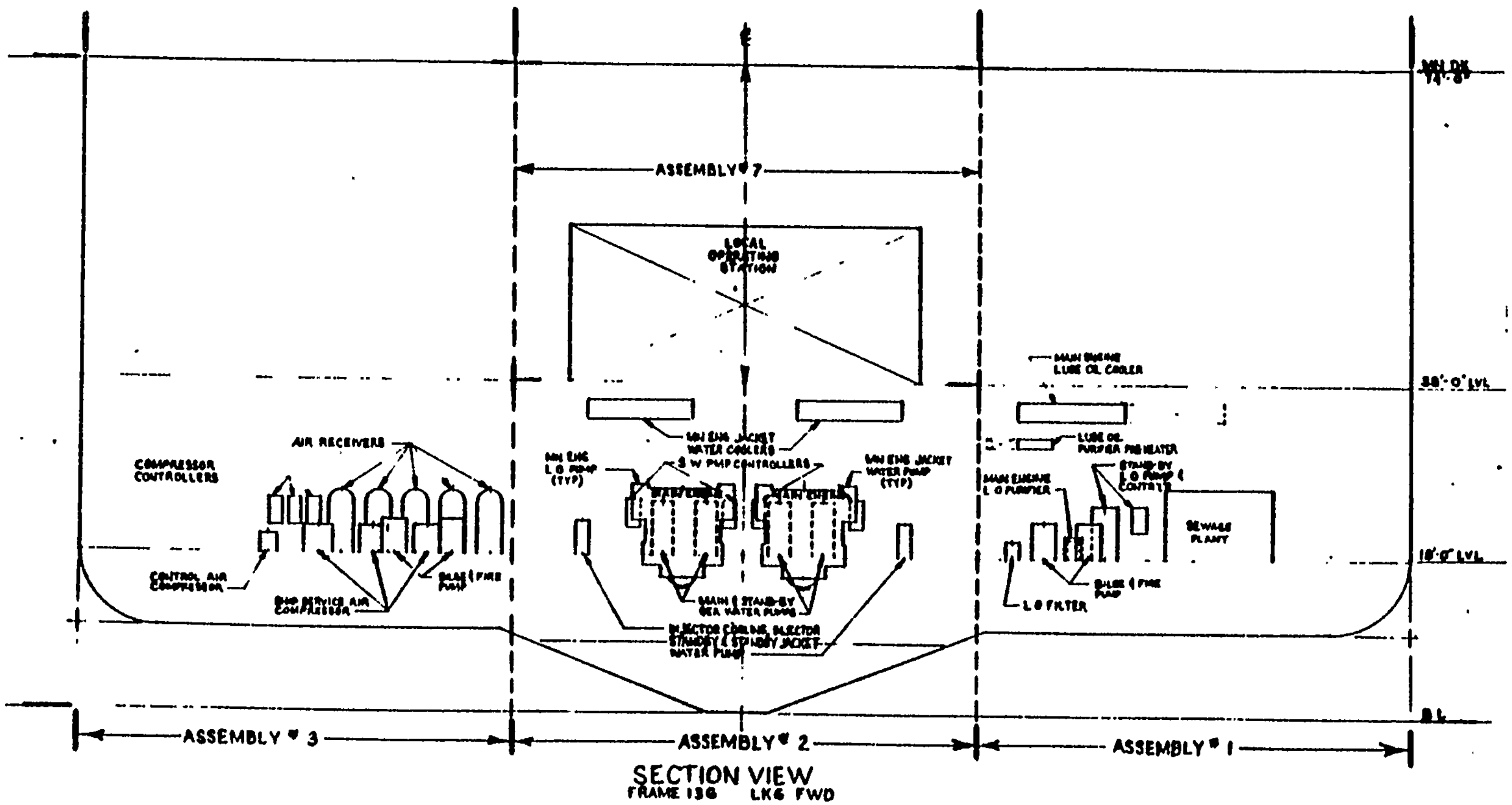


Figure 4-3. Medium Speed Diesel Arrangement (Sheet 4 of 5)

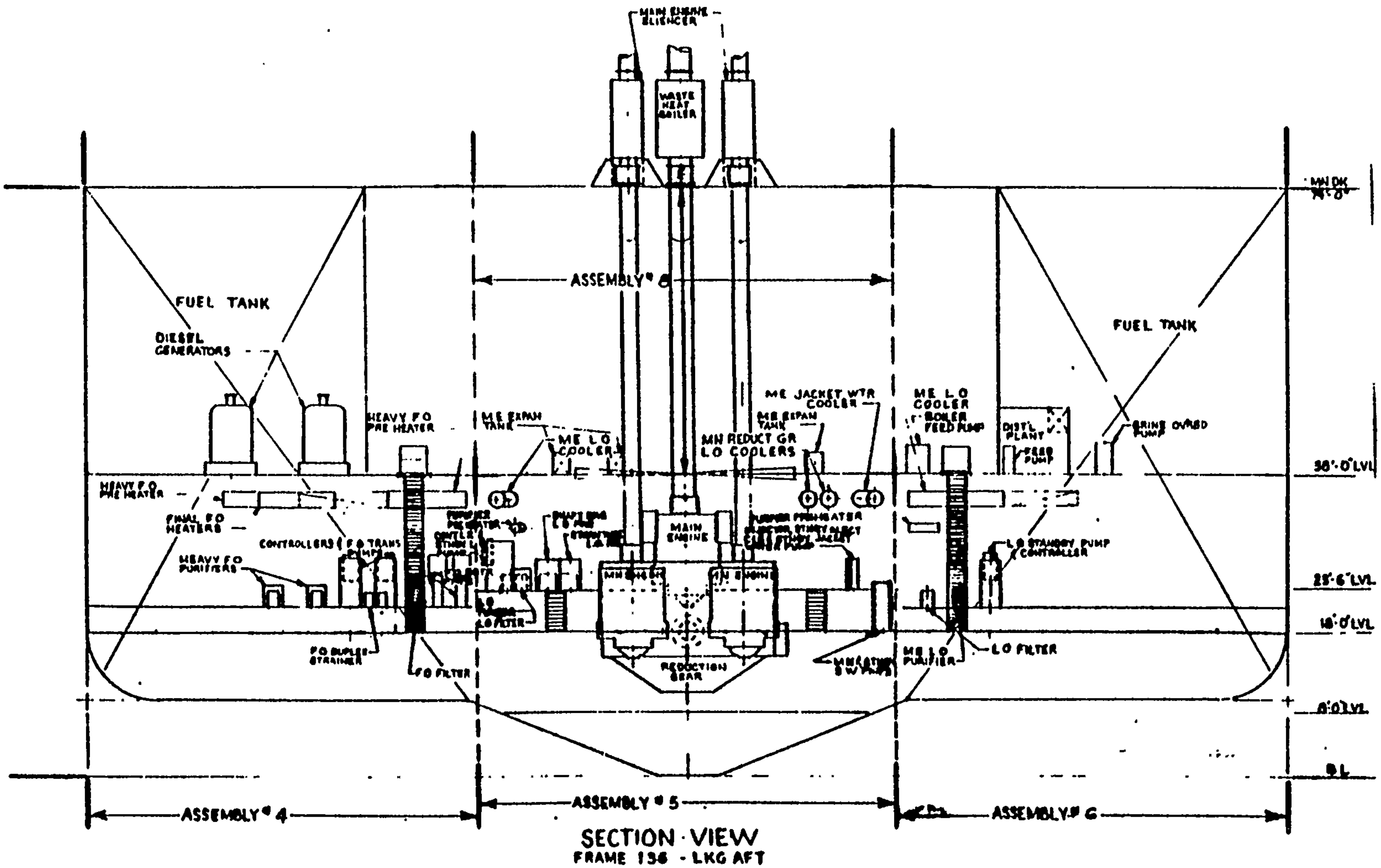


Figure 4-3. Medium Speed Diesel Arrangement (Sheet 5 of 5)

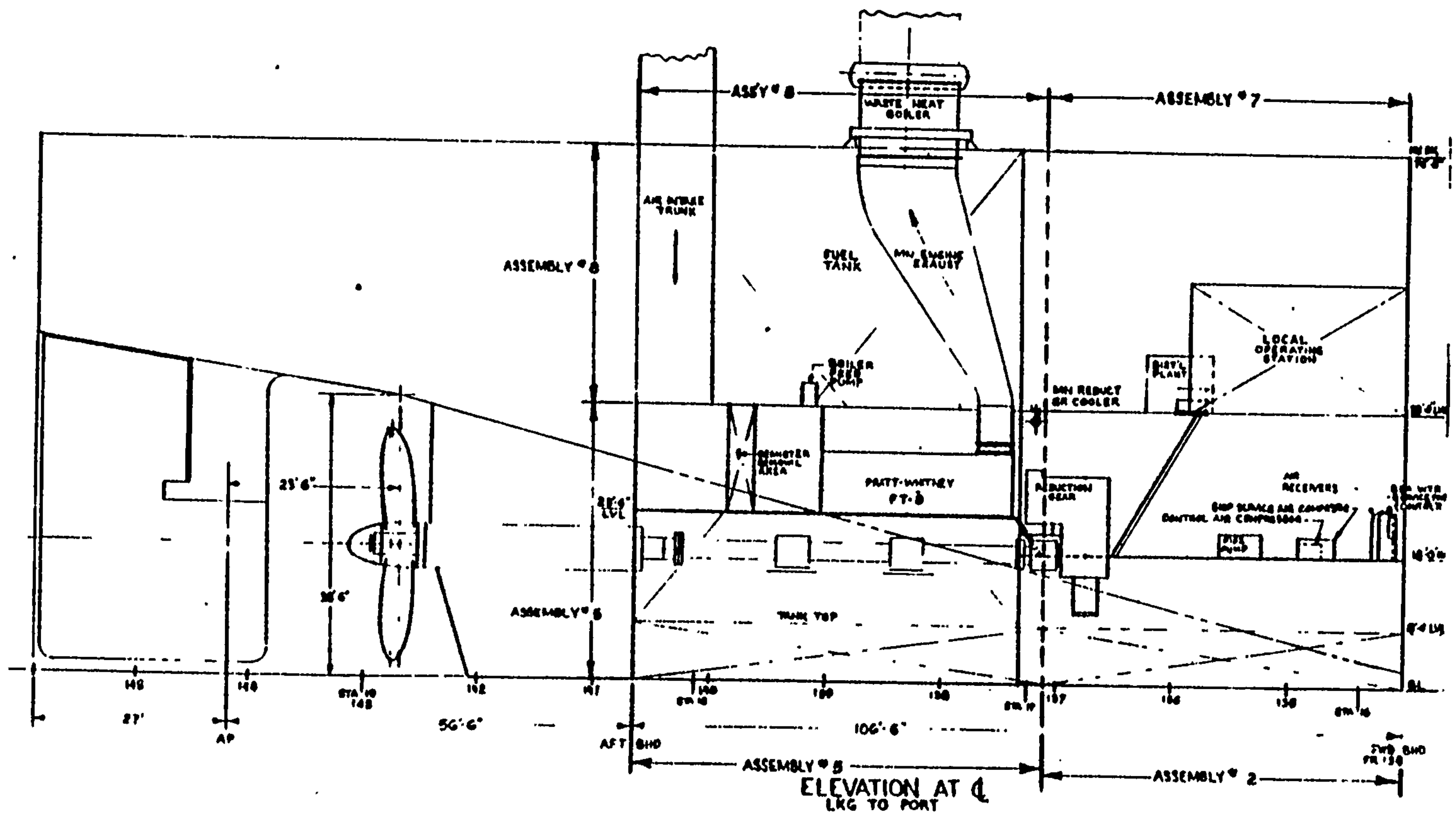


Figure 4-4. Light Weight Gas Turbine Arrangement (Sheet 1 of 5)

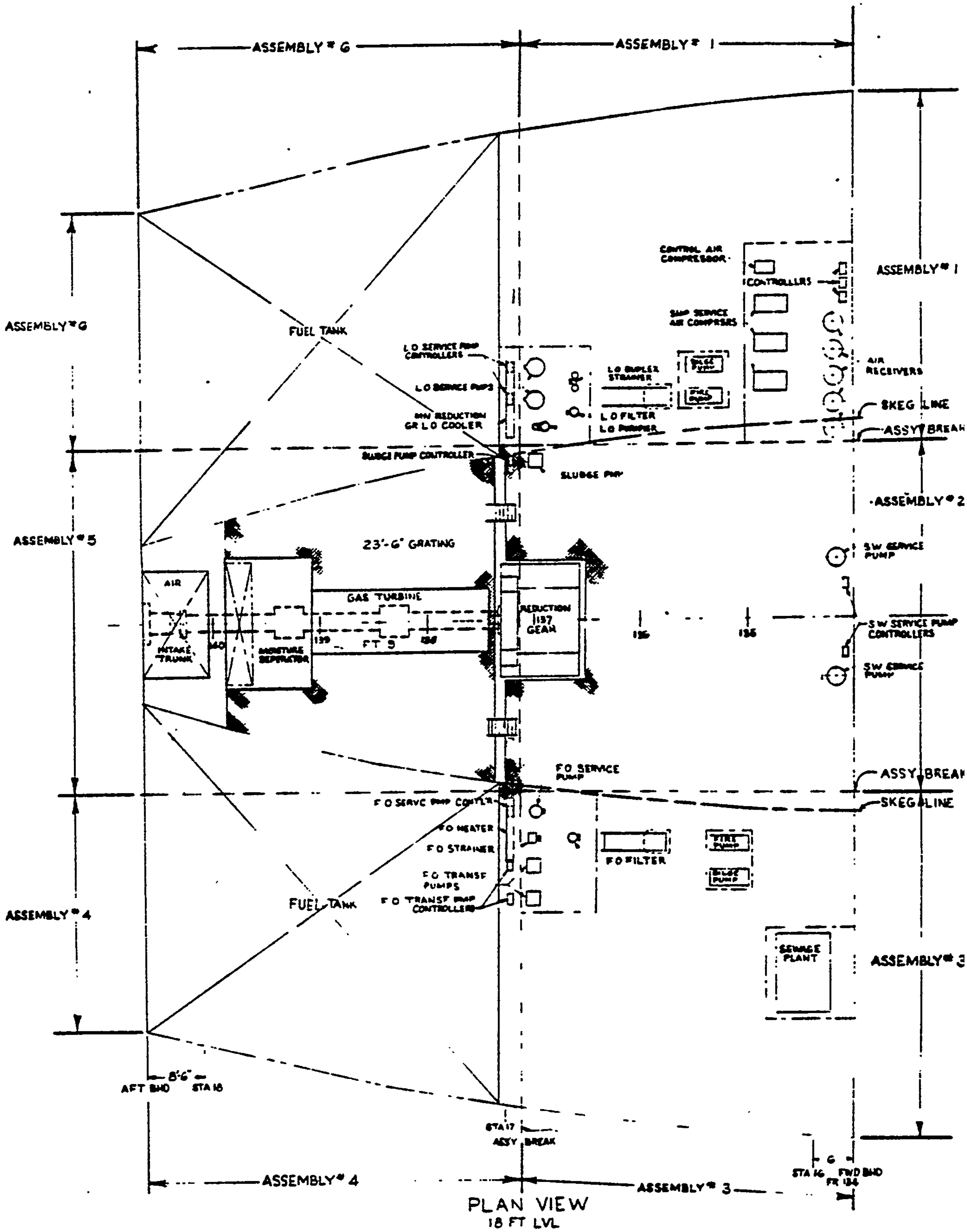


Figure 4-4. Light Weight Gas Turbine Arrangement (Sheet 2 of 5)

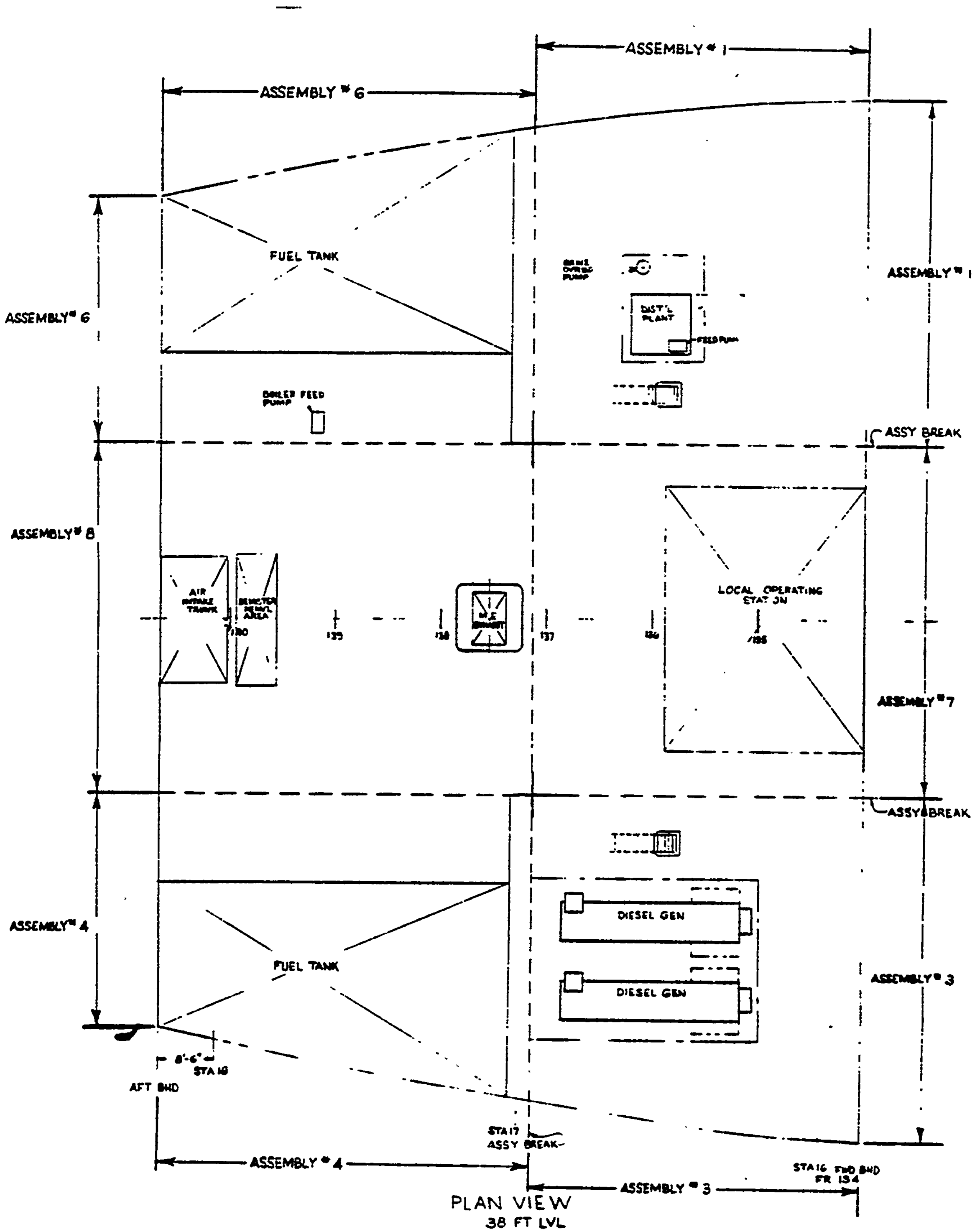
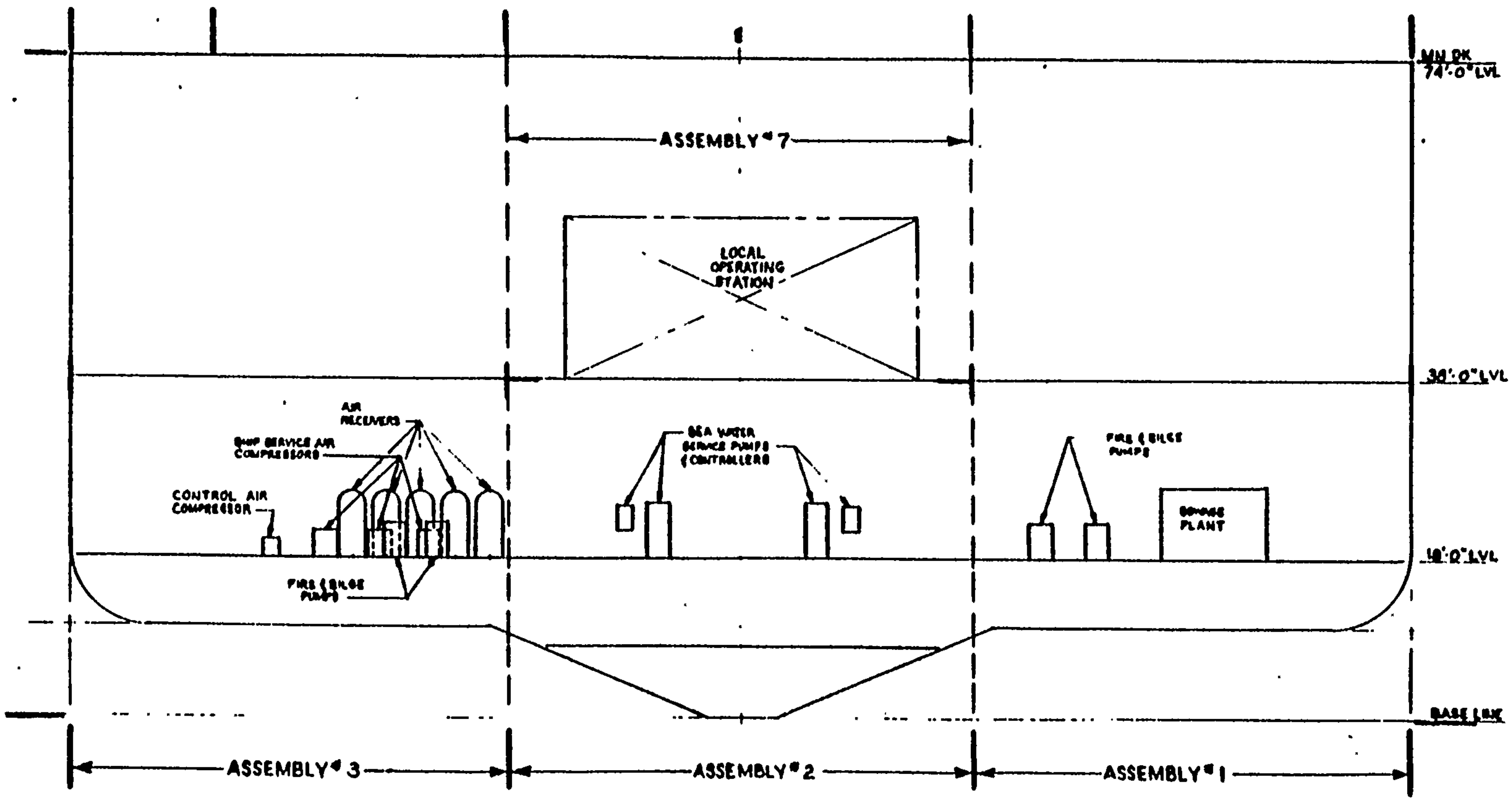


Figure 4-4. Light Weight Gas Turbine Arrangement (Sheet 3 of 5)



SECTION VIEW
FRAME 156 LKG FWD

Figure [illegible]. Light Weight Gas Turbine Arrangement (Sheet 4 of 5)

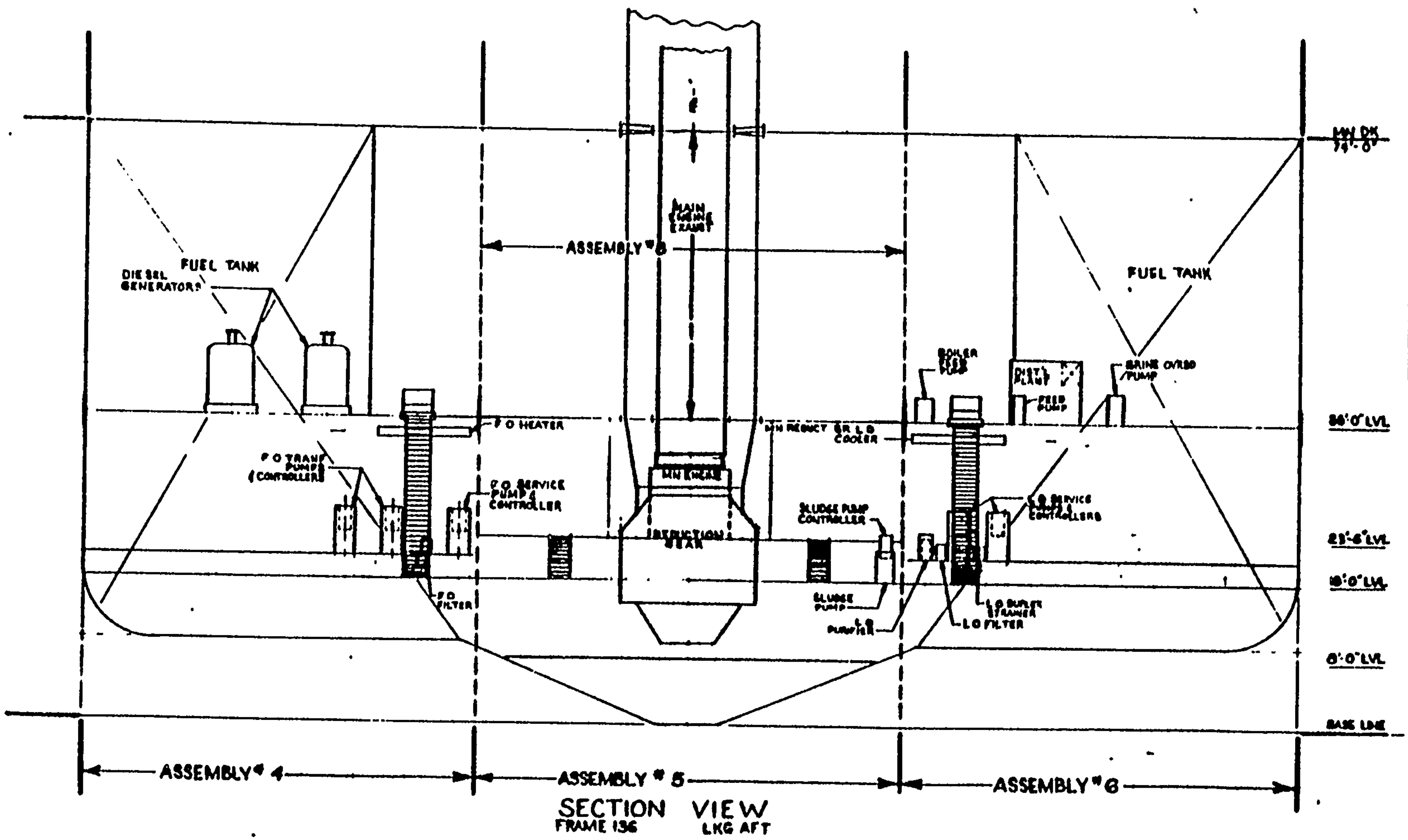
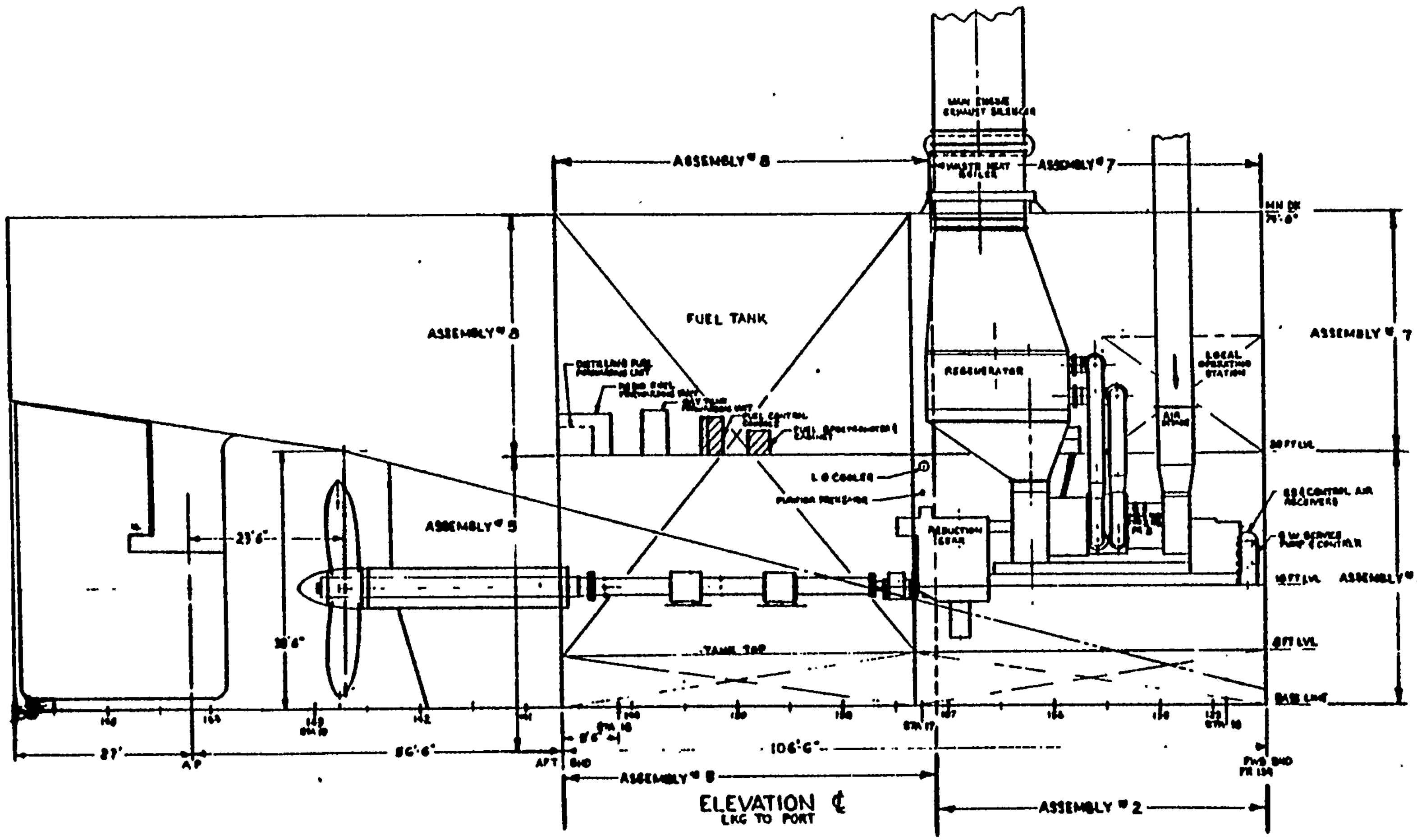


Figure 4-4. Light Weight Gas Turbine Arrangement (Sheet 5 of 5)



... Duty Gas Turbine Arrangement (Sheet 1 of 5)

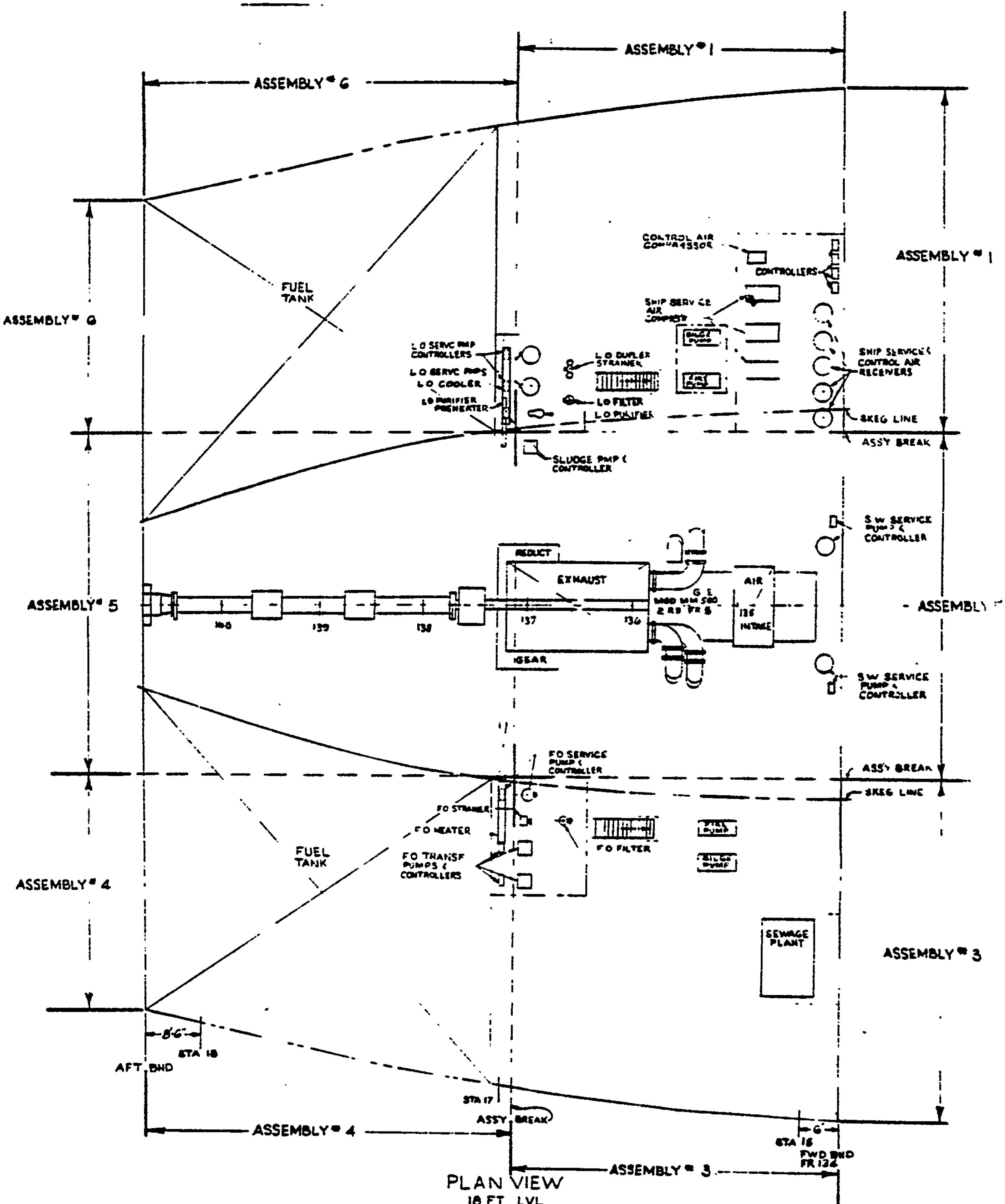


Figure 4-5. Heavy Duty Gas Turbine Arrangement (Sheet 2 of 5)

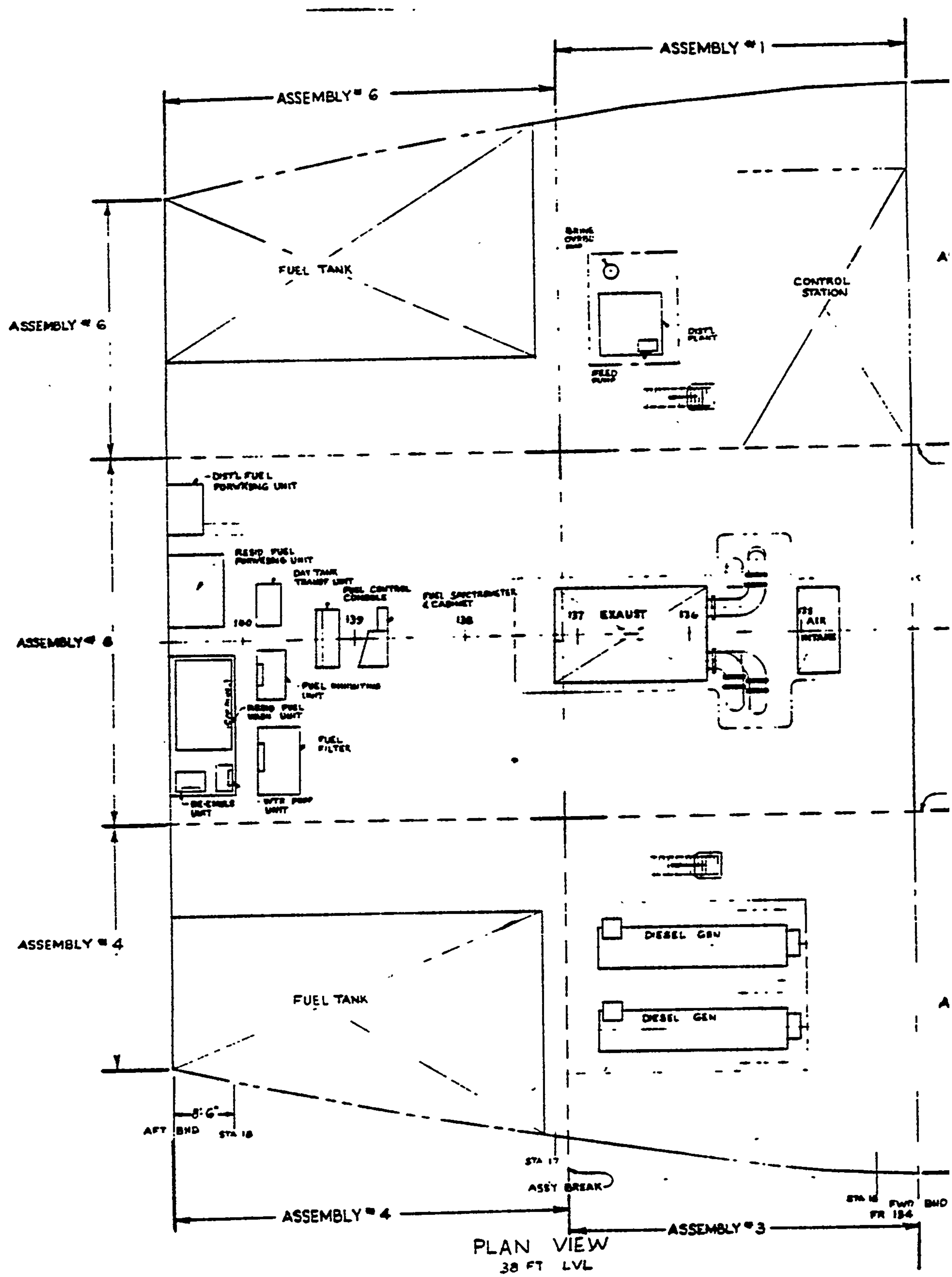


Figure 4-5. Heavy Duty Gas Turbine Arrangement (Sheet 3 of 5)

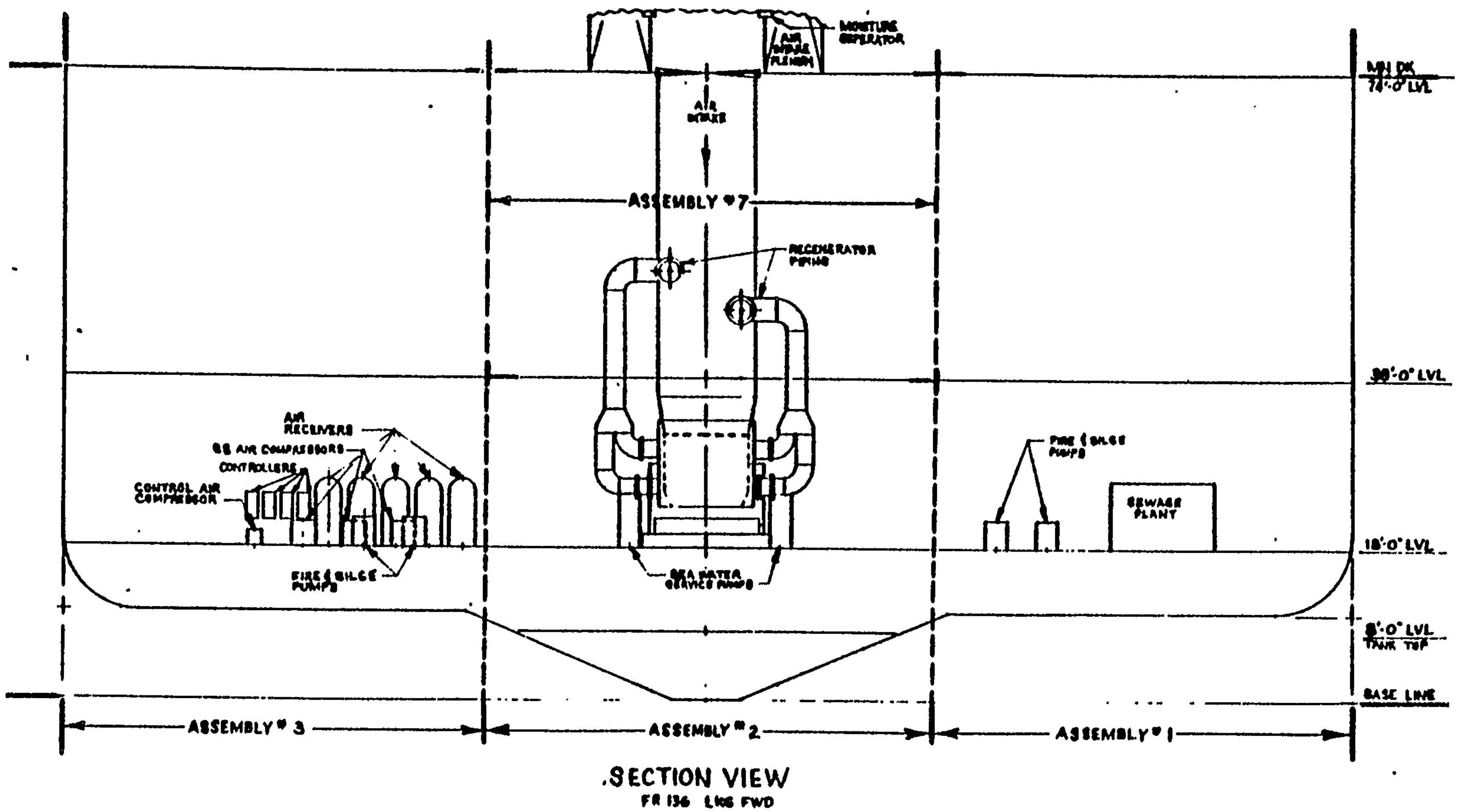
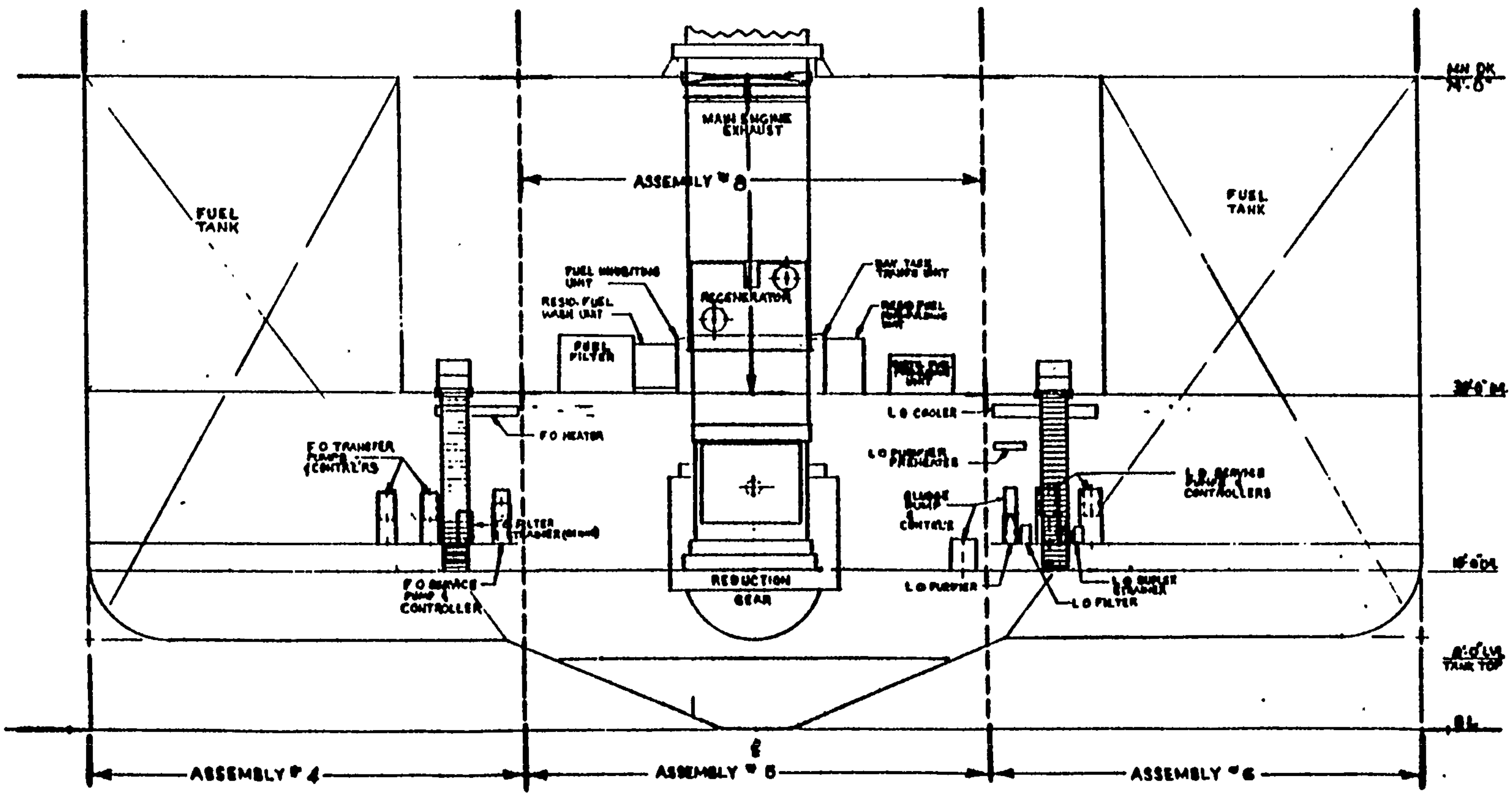


Figure 4-5. Heavy Duty Gas Turbine Arrangement (Sheet 4 of 5)



SECTION VIEW
FR 136 LKG AFT

Figure 4-5. Heavy Duty Gas Turbine Arrangement (Sheet 5 of 5)

4. 5.1 Packaging Relationship to Machinery Arrangement

In addition to developing a standardized machinery arrangement which would meet the objectives of paragraph 4. 1, consideration was also given to identifying and locating major system support equipment in such a manner that " shop" or "vendor" assembly of the major components of the system could be accomplished. This procedure promotes pre-outfitting by "landing on ship" of a complete machinery subsystem which has been assembled and shop tested prior to becoming a fixed ship installation. Typical examples of machinery support systems which are candidates for packaging checkout and testing prior to being integrated into the stern module are listed in paragraph 4.6.

4.5.2 Accessibility /Maintainability Relationship to Arrangement

The following special considerations were taken into account in designing the baseline machinery arrangements shown in figures 4-2, 4-3, 4-4, and 4-5:

a. Propeller shaft removal and accessibility;
b. Maintainability of equipment;
c. Lifting and removal of equipment components;
d. Location of engine room control center for accessibility;
e. Main engine and gear box foundations.

4.6 TYPICAL MACHINERY PACKAGE CANDIDATES

Below is a listing of identified typical machinery systems/subsystems which are evaluated as being suitable for pre - outfitting installation in series production of the 150, 000 DWT crude carriers. The machinery arrangements shown in figures 4.2, 4-3, 4.4 and 4-5 take into account package system installation for these systems.

a. Fuel Oil Service System

- 2-Fuel Service Pumps
- 4-Fuel Oil Heaters
- Automatic Self- cleaning Strainer
- Steam Strainer, Traps and Drains
- Suction Strainer
- Steam Supply Control Station
- Connections for Instrumentation
- Alarms
- Electrical Controllers
- System Piping, Valves and Fittings
- Pump Stop and Start Pushbuttons

b. Lube Oil Service System

- Standby Pumps
- Emergency Lube Oil Pump
- Electrical Controllers
- Strainers
- Connections for Instrumentation
- System Piping, Valves and Fittings
- Pump Stop and Start Pushbuttons

c. Lube Oil Purification System

- Lube Oil Purifier
- Lube Oil Heater
- Electrical Controllers
- Connections for Instrumentation
- System Piping Valves and Fittings
- Pump Stop and Start Pushbuttons

d. Water Distillation Plant System

Main Distillation Plant
Distillation Plant Feed Pump
Connections for Instrumentation
Electrical Controllers
Pump Stop and Start Pushbuttons
System Piping Valves and Fittings

e. Control Air System for Engineering Space

Air Compressor
Air Storage Flask
System Piping Valves and Fittings
Connections for Instrumentation

4-7 MAXIMIZATION OF PIPE DESIGN TO REDUCE PIPE FIELD JOINTS ABOARD SHIP

When machinery packaging techniques are applied to assembly methods of ship construction, special emphasis should be directed toward coordinating machinery component arrangements with piping design so that the pipe fitting work required to interface an auxiliary system between two different assemblies is kept to a minimum. Achievement of this objective will minimize the time consuming and costly pipe fitting work performed aboard ship after assembly of the ship's stern. This pipe design and arrangement criteria was applied to the four machinery arrangements shown in figures 4-2, 4-3, 4-4 and 4-5 to determine the approximate amount of pipe field joints that would be required to be made aboard ship. For a comparison of auxiliary machinery pipe field joints required to be accomplished aboard ship under the machinery packaging system, versus conventional methods of machinery space outfitting (pipe layout and fitting done after installation of machinery components), the same four propulsion plants and auxiliary components were used and conventional methods of outfitting applied. A comparison analysis between the two methods of machinery outfitting indicated that pipe field joints required to be performed aboard ship would be reduced by at least 3 to 1 ratio, when the machinery packing system is applied.

4- 8 MACHINERY PACKAGING APPLICATION

Figure 4-6 has been prepared for the purpose of illustrating the flow of major production oriented events that would normaliy occur when machinery packaging techniques are employed in series production of tankers. The chart depicts only those functional events performed, after engineering selects the components that make up the lube oil system and has designed the system integration manifolding, electrical wiring, etc. For illustration purposes, the shipyard prefabricated packaging system described in paragraph 4. 3.2 is used. When vendor furnished packages” are utilized, the flow of events would be simiiar except a lesser amount of work would be required by the Pipe, Fabrication and Machinery Assembly work station. Figure 4-7 shows the lube oil system package as it would appear on the structural subassembly prior to landing on ship for installation in the stern module.

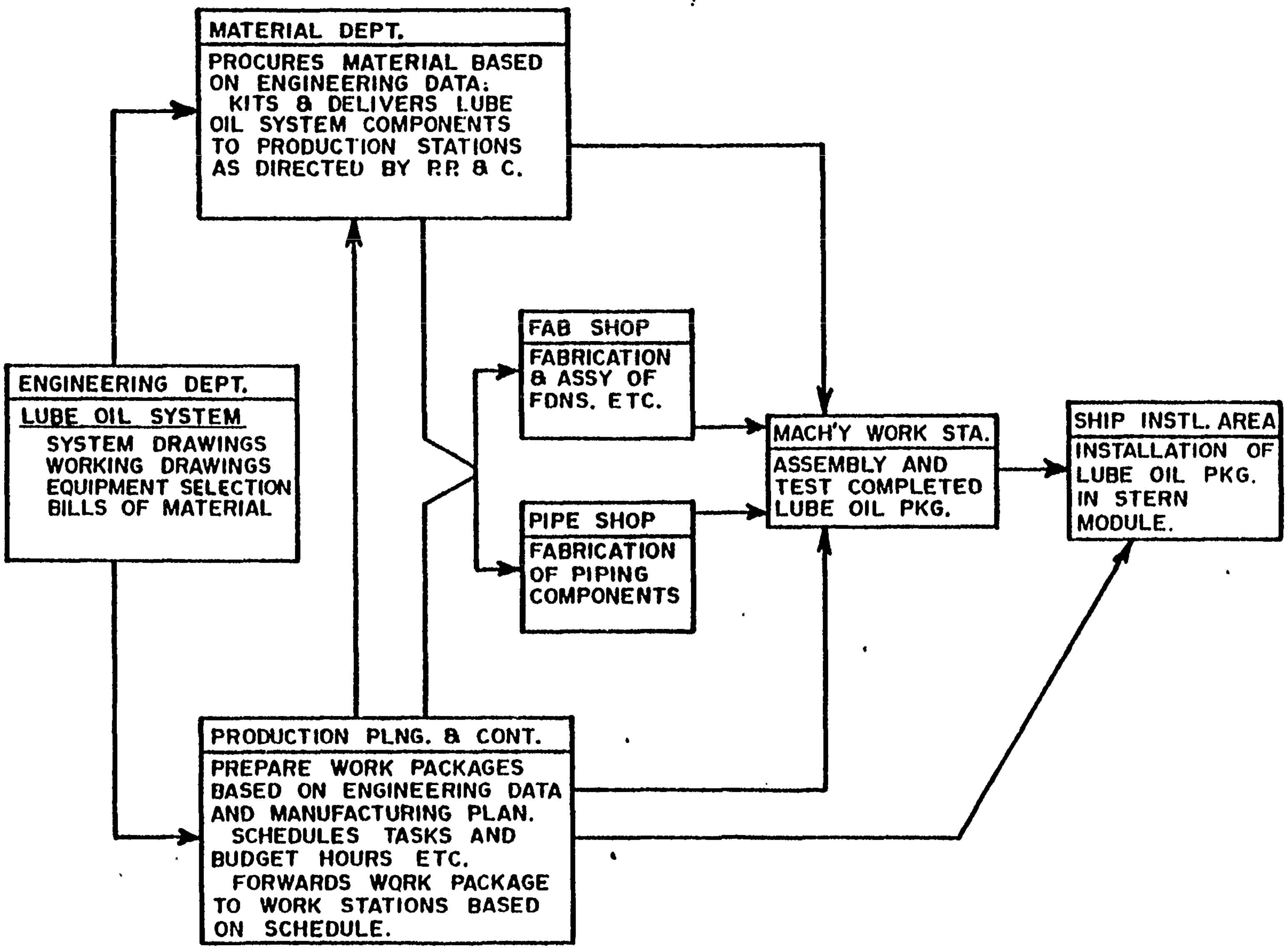


Figure 4-6. Machinery Package Production Events

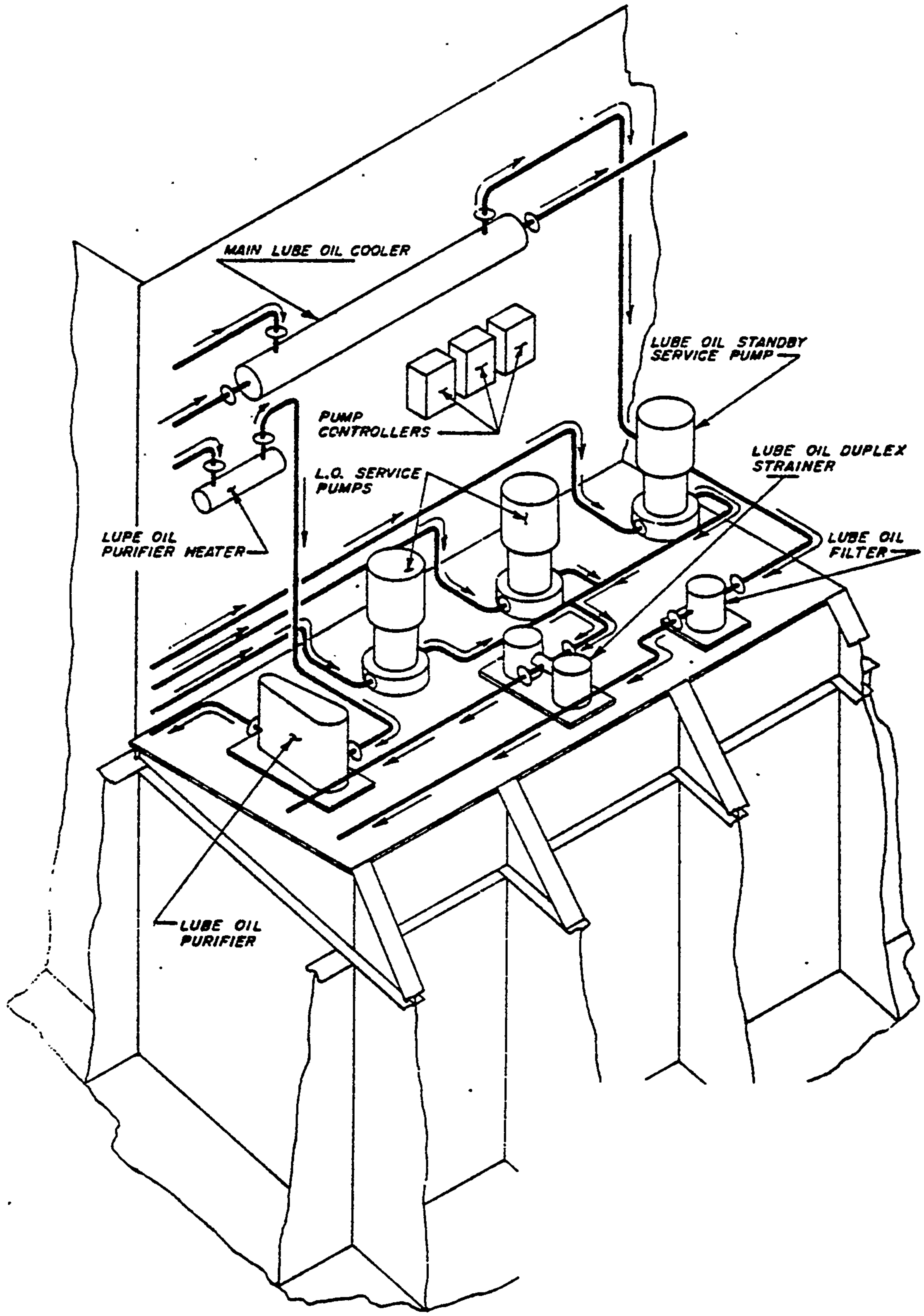


Figure 4-7. Typical Lube Oil Package

4.9 CONCLUSIONS

4.9.1 Machinery Arrangements (Standardization)

Four baseline machinery arrangements were developed using the modified scow stern as the standard stern module. Standardization of the layout of the four plants was achieved in the following areas:

1. A common overall length of machinery space was established suitable for the installation of any of the four selected power plants.

2. Main machinery flat height above baseline made common for all four arrangements.

3. Location of main fuel tanks made common for all four arrangements.

4. Location of main access hatches and ladders made common for all four arrangements.

5. Main propulsion shafting height above baseline made common for all four arrangements.

6. Propeller shaft length is standard for all four arrangements.

7. Stern tube length is standard for all four arrangements.

8. Line shaft bearings, located in the same relative position in all four arrangements.

9. Main propulsion reduction gears were located in the same relative position in all four arrangements.

10. In all four arrangements auxiliary machinery system packages were located in the same relative position within the standard stern module.

11. The foundations for the four selected main propulsion plant installed in the modified scow stern will be designed as an integral part of the basic hull structure and will be differen for each type plant.

4.9.2 Auxiliary Machinery System Packages

Well designed machinery packages would reduce the overall system cost due to the following:

1. Auxiliary machinery components are easier to assemble in the shop where equipment can be aligned more accurat than on board ship, and where the completed machinery packages can be pre-outfitted and thoroughly checked, and tested in the shop, and where any necessary corrections *or* modifications are made before the completed unit is installed on the ship.

2. Machinery packages can be shop assembled in advance of their scheduled date for installation on the ship allowing more flexibility y in scheduling the workload.

3. Machinery packaging will reduce the number of shipboard installed piping runs because most items associated with a particular system such as pumps, valves, filters, coolers, etc. , are already piped in the shop and shipboard piping would be simpler and easier to install between the completed , machinery package and its service.

4. This method of outfitting the machinery space will allow many of the outfitting crafts to pre--outfit the structural assemblies prior to stern module erection.

5. The more pre-outfitting of the machinery space that can be achieved in the shop and the ship erection area prior to launching, and the consequent reduction of time, labor and cost expenditures realized during ship construction will result in an overall cost saving. .

6. Standardization of machinery arrangements and machinery packaging techniques stresses the importance of advanced planning. The engineering departments involved in developing this method of ship construction would be required to spend more time in the concept design phase than has been done in the past. Far greater liaison between the departments would also be required to provide the best design methods of installation and construction within the building capabilitiess of a particular shipyard to gain the maximum benefits of standardization.

4.10 RECOMMENDATIONS

1. The Shipbuilder develop and establish standard machinery ‘arrangements covering a range of power plants and types of power plants suitable for installation in standard machinery space modules for all types of commercial ships capable of being built in U. S. shipyards.

2. Establish standard pre -outfitted machinery modular units capable of being installed on structural assemblies within the stern module, including design details and installation data.

3. Recommend that an in-depth study be carried out to establish hull structural configurations and designs, in conjunction with machinery installation requirements and machinery space outfitting with particular reference to the modified scow stern used in this study.

APPENDIX **A**

APPENDIX A

References:

1. Propulsion Standards Study Marad Contract 3-36233

2. Ship Producibility, J. S. McMullin; 1973
Prepared for Bath Iron Works Corporation

3. Design Improvements Report, Newport News Shipbuilding-
1971, Marad Contract MA-1 -35402

VOLUME II

PART 5

STRUCTURE MEMBER CONFIGURATION

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

VOLUME II

PART 5

STRUCTURE MEMBER CONFIGURATION

5.1 INTRODUCTION

In consideration for the large quantity of material which is represented by the longitudinal structural stiffening of a 150, 000 DWT tanker, the structural member configuration was selected as one of the design study areas which deserved particular attention for series production.

The objective of this section is to review the options which exist in developing or selecting the various structural members to be utilized, and to evaiuate the series production considerations which effect this area of the ship design process.

In accomplishing this task, the approach developed was as follows:

a. Using the 150, 000 DWT tanker as a basis, develop the structural member configurations as required to comply with the A. B. S. regulations regarding the required section modules.

b. Using the conventional members developed in step (a) as a base, , investigate alternate members with equivalent characteristics.

C. Compare alternate members with conventional, and evaluate differences, including production considerations.

d. Develop conclusions and recommendations

The candidate members which were selected for comparison are:

1. Structural "T'
2. Built -Up Shape
3. Built plate
4. Plate Web with Round Bar
5. Flanged plate

The material and production costs were developed for each of these sections, with the impact of a series production contract included in the fiscal analysis.

5.2 DEVELOPMENT OF STRUCTURAL MEMBER SIZES

In order to properly develop the required sizes for the respective structural members, a mid-ship section was designed in accordance with the A. B. S. regulations regarding minimum section modules. This mid- ship section, shown in figure 5-1, utilizes "conventional" structural members as would be procured from a U. S. steel mill.

Note that with the exception of the deck (8" x 7" x 20#T) stiffening, all structural members must be "re-fabricated" at the shipyard, as required to remove or "strip" the unused flange of the "I" Beam as received

a. 14" X 6-3/4" X 34# I/T
b. 16" X 8-1/2" X 58# I/T
c. 27" X 10" X 102# I/T
d. 30" X 10-1/2" X 108# I/T

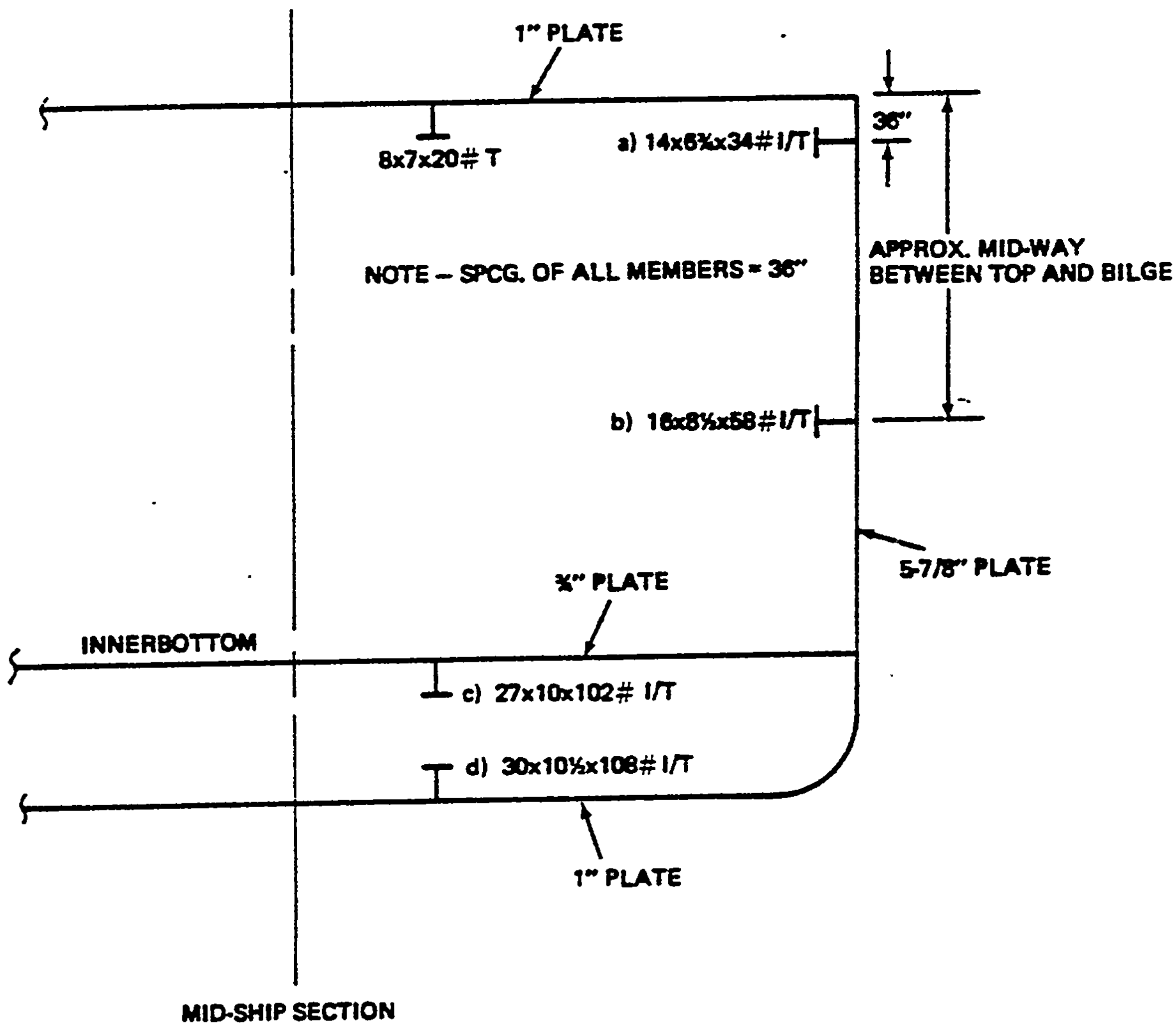


Figure 5-1. 150,000 DWT Tanker Typical Member Sizes

Using the size and section modules of these structural members as a basis, the following variations were chosen as suitable candidates for evaluation, and thus equivalent sizes were developed for comparison purposes:

a. Built-up shape = Weldment of two separate thicknesses of plate as required to form angle.

b. Bulbous Plate = Specially formed offset available from *foreign* mills only.

c. Built-up Offset = Weldment of a plate web and a round-bar offset.

d. Flanged Plate = Formed plate as required to form (flanged) angle.

(See Figure 5-2)

These candidate structural members were sized in accordance with their application and ranked by weight as shown

Top Deck Longitudinal

Sm req'd by ABS = 31.49 in.

	Member	Weight (lb/ft)	Section Modules w /pltg
1.	8"x7"20#T	20	34.6 $in.^3$ w/36" of 1" dk PL
2.	Bus - 8"x1/4" web, 7"x9/16" flg	20.19	33.3 $in.^3$ w/36" of 1" dk PL
3.	8"x5/16" web w/2-l /8" dia rnd bar	20.56	35 $in.^3$ w/36" of 1" dk PL

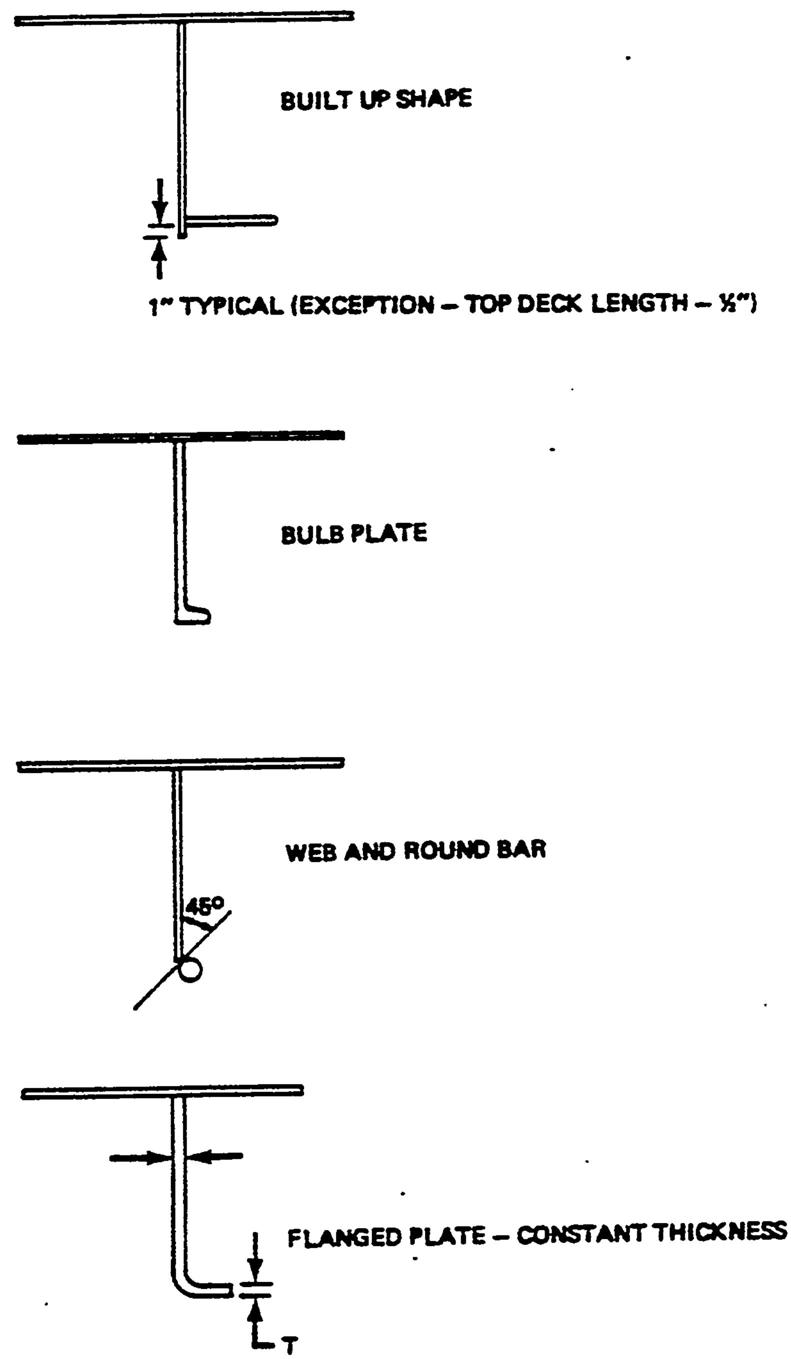


Figure 5-2. 150,000 DWT Tanker Details for Sections

	Member	Weight (lb/ft)	Section Modules w /pltg
4.	8"x6-1/2"'x20. 4# Flgd Plate	23.8	35.55 in.^{3} w/36" of l" dk PL
5.	*10"'x25. 19 lbs/ft bulb plate	25.19	34.34 in.^{3} w/36" of 1" dk PL

Side Shell Longitudinal (Top 3 long' ls)

Sm req'd by ABS = 32.9 in.^{3}, 41.88 in.^{3}, and 50.85 in.^{3} for long' ls. 3 ft, 6 ft, and 9 ft below top dk, respectively.

	Member	Weight (lb/ft)	Section "Modules w /pltg
1.	14"x6-3/4"'x34# I/T	24.3	60.8 in.^{3} w/36" of 7/8" shell PL
2.	14"x5 116" web w/2" dia rnd bar	25.56	61.71 in.^{3} w/36" of 7/8" shell PL
3.	Bus - 14"x3/8" web, 6-1/2" X 1/2" flg	28.9	62.44 in.^{3} w/36" of 7/8" shell PL
4.	*13-1 /2"'x33. 49 lb/ft bulb plate	33.49	63.56 in.^{3} w/36"of 7/8" hell PL

Longitudinal Mid-way between Top Deck and Bilge

Sm req'd by ABS = 113.67 in.^{3}

	Member	Weight (lb/ft)	Section Modules w/pltz
1.	16"3/8"web w/2-11/16" rnd bar	39.69	114.8 in.^{3} w/36" of 7/8" shell PL
2.	16''x8-l/2''x58# I/T	40.79	115. 6 in.^{3} w/36" of 7/8" shell PL
3.	16"x8-1 /2"'x20. 4# Flgd Plate	40.8	106.1 in.^{3} w/36" of 7/8" shell PL
4.	Bus - 16"x3/8" web, 8-1 /2"x3/4" Flg	42.1	115.4 in.^{3} w/36" of 7/8". shell PL

	Member	Weight (lb/ft)	Section Modules w /pltg
5.	16"x10x2O. 4# Flgd Plate	43.35	114.67 in. ^{3} w/36" of 7/8" shell PL

Innerbottom Longitudinal

Sm req'd by ABS = 307.26 in. ^{3}

	Member	Weight (lb/ft)	Section Modules w /pltg
1.	24"x20"x20. 4# Flgd Plate	73.95	307 in. ^{3} w/36 of 3/4" IB PL (Marginal)
2.	27"X1 /2" web w/3-1/4" dia rnd bar	74.11	302.2 in. ^{3} w/36" of 3/4" IB PL (less than ABS req' t)
3.	Bus - 27"X1 /2" web, 10''x7/8' Flg	75.65	307 in. ^{3} w/36" of 3/4" IB PL (Marginal)
4.	Bus - 27"x9/16" web, 10''x7/8" Flg	81.39	318 in. ^{3} w/36' of 3/4" IB PL
5.	27"x10"x102# I/T	76.19	312.7 in. ^{3} w/36" of 3/4" IB PL
6.	27"x1/2" web, w/3-3/8" dia rnd bar	76.32	317.08 in. ^{3} w/36" of 3/4" IB PL
7.	27"x12''x25. 5# Flgd Plate	81.55	310.87 in. ^{3} w136" of 3/4" IB PL
8.	30"x9''X25. 5# Flgd Plate	81.55	308.3 in. ^{3} w/36' of 3/4" IB PL

Bottom Shell Longitudinal

Sm req'd by ABS = 361.48 in. ^{3}

	Member	Weight (lb/ft)	Section Modules w /pltg
1.	30"xl/2" web, w/3-5 /16' rnd bar	80.3	365.7 in. ^{3} w/36" of l" Btm Shell PL
2.	30"x10-1 /2"xl08# I/T	82; 89	364.2 in. ^{3} w/36° of 1" Btm Shell PL

	Member	Weight (lb/ft)	Section Modules w/pltg
3.	Bus - 30"x9116" web, 9-1 /4"x7 /8" Flg	84.9	362.9 in.^{3} w/36' of 1" Btm Shell PL
4.	3011% 12"x5- 5# Flgd Plate	87.92	369.6 in.^{3} w/36" of 1" Btm Shell PL

* Manufactured by British Iron & Steel Corp.

5.3 COST COMPARISON OF 8" MEMBER

In order to evaluate the cost effects of the candidate sections, an estimate of both the material and labor costs associated with the fabrication of each 8" section was prepared as shown in the following tables 5-A, 5-B and 5-C.

Results of the comparison are summarized as follows:

a. The built-up shape is the lowest cost member included in the comparison.

b. The web and round bar built-up shape is impractical due to the high material cost associated with the use of the round bar.

c. The constant thickness flanged plate is the second lowest cost candidate and is considered a viable member in the smaller size range.

d. The bulb plate section is particularly attractive when available in the proper size, since it is received at the shipyard in a ready-to-use state and no "pre-fabricationtt at the shipyard is required. The high cost of special runs at domestic steel mills and the high transportation costs associated with importing these sections from foreign mills have limited the use of these sections in domestic shipbuilding programs to date.

Table 5-1

MATERIAL COSTS

Built-up Shapes

8" x 1/4" web, 7" x 9/16" flg

48' x 20.19 (lb/ft) = 969.12 lb

969.12 x 17¢ p/lb = $164.75 per 48' section.

Web and Round Bar

8" x 5/16" web w/2-1/8" dia round bar

48' x 12.75 (lb/ft) = 612.0 lb

612 lb x 17¢ p/lb = $104.04 per 48' section

2-1/2" dia R. B. @ $4.00 p/lin ft @ 48' = $192.00 per 48' section

Total mat'l price = $296.04 per 48' section

Flanged Plate - Constant Thickness

8" x 6-1/2" x 1/2" plate

48' x 23.8 (lb/ft) = 1142.4 lb

1142.4 lb x 17¢ p/lb = $194.21 per 48' section.

Bulb Plate

10" x 5/8" bulb plate

48' x 25.19 (lb/ft) = 1209.12 lb

1209.12 lb x 26¢ p/lb = $314.37 per 48' section.

NOTE: 1209.12 lb x 17¢ p/lb = $205.55 = Basic Cost
1209.12 lb x 09¢ p/lb = $108.82 = Shipping Cost
$314.37 = Total Cost

Table 5-2

FABRICATION COSTS
<u>Built-up Shapes</u>
8" x 1/4" web, 7"
<u>Weld in fixture (semi-auto)</u>
48' @ 36 IPM = 16 min p/48' section
16 min x 2 men = 0.53 manhours
0.53 manhours x $10/mhr = $5.33 p/48' section.
<u>Web and Round Bar</u>
8" x 5/16" web w/2-1/8" dia round bar
<u>Weld fixture (sub-arc)</u>
96' @ 36 IPM = 32 min p/48' section
32 min x 3 men = 1.6 manhours
1.6 manhours x $10/mhr = $16 p/48' section
<u>Additional Mat'l Hndlg in Jig</u>
15 min @ 3 men = 0.75 manhours
0.75 manhours x $10/mhr = $7.50 p/48' section.
<u>Flanged Plate - Constant Thickness</u>
8" x 6-1/2" x 1/2"
<u>Bend in Press</u>
30 min p/bend @ 2 men = 1.0 manhours
1.0 manhours x $10/mhr = $10 p/48' section
<u>Overhead Crane</u>
30 min p/bend @ 1 man = 0.30 manhours
0.30 manhours x $10/mhr = $5 p/48' section.

Table 5-3

SUMMARY OF COSTS	
Built-up Shapes	
Material cost	$164.75
Fabrication cost	5.33
Total Unit Cost	$170.08
Web and Round Bar	
Material cost	$296.04
Fabrication cost	23.50
Total Unit Cost	$319.54
Flanged Plate - Constant Thickness	
Material cost	$194.21
Fabrication cost	15.00
Total Unit Cost	$209.21
Bulb Plate	
Material, shipping cost	$314.37
Total Unit Cost	$314.37

5.4 COST COMPARISON OF LARGE STRUCTURAL MEMBERS

In the larger size structural member category, the two basic options most often utilized in shipbuilding are:

a. The procurement of "I" beams which are stripped of the unnecessary flange section as required to produce a "T" section operation, utilizing a tractor-type stripping machine with two cutting torches was prepared, as described below:

ESTIMATE - STRIPPING OPERATION

(Single Ship)

1. <u>Set-Up Time</u>

a.	Utilizing gravel crane, pick-up single beam and set in place on temporary cutting bed.	15 min
b.	Position and clamp (5 min each)	20 min
c.	Set -up track for tractor-type semi -automatic burning machine (Buz-o unit or equivalent)	15 min
d.	Set-up machine, check/adiust orieniation of cutting torches"	10 min

2. <u>Process Time</u>

Burn 48' - 0" (576" @ 15″ /min)	38 min

3. <u>Remove Machine and Track</u>

Turn off torches remove machine and adjust hoses	15 min
Remove track	15 min

4. <u>Remove “T" Section</u>

Utilizing chokes, pick up single beam and relocate to storage	10 min

5. <u>Summary</u>

Total Elapsed Time = 138 min

138 minx 3 man crew = 414 min or 6.9 m/hrs

Description	Material Cost @17¢/lb	stripping	Total Initial Cost
14" 34# I/T	277.44	69.00	346.44
16" 58# I/T	473.28	69.00	542.28
27" 102# I/T	832.32	69.00	901.32
30" 108# I/T	881.28	69.00	950.28

5.4.1 Cost Of Stripping (Series Production Method "A")

For the purposes of this study it was assumed that the stripping operation would be accomplished utilizing some form of semi-automatic device. Figure 5-3 shows one approach to this task. Here, eight sets of cutting torches are mounted *on* a welding gantry, *with* a following device or roller guiding each torch independently against the web of the "I" beam being stripped. The cost estimate for this operation is as follows:

ESTIMATE - STRIPPING OPERATION

1. <u>Set-up Time</u>

   a. Utilizing overhead crane, pick up (8) beams and set in place on cutting bed (10 min each) — 80 min

   b. Regulate final position of beams and clamp in place (5 min each) — 40 min

   c. Regulate starting position of gantry, check orientation of cutting torches — 15 min

2. <u>Process Time</u>

   Burn 48' - 0" (576" at 8" per min (average)) — 72 min

3. <u>Remove Scrap</u>

This operation is only accomplished once per shift and the time allowed is the pro-rated portion for one full shift of operation — 10 min

4. <u>Remove "T" Sections</u>

a. Utilizing chokers, pick up (3), (3) and (2) "T" sections (3 moves x 10 min) — 30 min

TOTAL 247 min

5. Summary

Total elapsed time = 247 min

247 min x 3 man crew = 741 min or 12.35 man hours

12.35 man hours x $10 m/h = $123. 50 Total or $15.44 per "T" section.

The cost of "T" sections, as fabricated from purchased "T" beams is summarized as follows:

Description	Weight per 48′ Section	Material cost @ 17¢/lb	Stripping cost	* Total Initial cost
14″ 34# I/T	1632#	$277.44	$15.44	$292.88
16″ 58# I/T	2784#	$473.28	$15.44	$488.72
27″ 102# I/T	4896#	$832.32	$15.44	$847.76
30″ 108# I/T	5 184#	$881.28	$15.44	$896.72

* This cost may be reduced by later sale of scrap material

5. 4.2 Use Of T-Beam Welding Machine (Series Production Method "B")

The T-beam welder is a commercially available machine which automatically welds tsvo pieces of flat stock together as required to form either an angle or a tee.

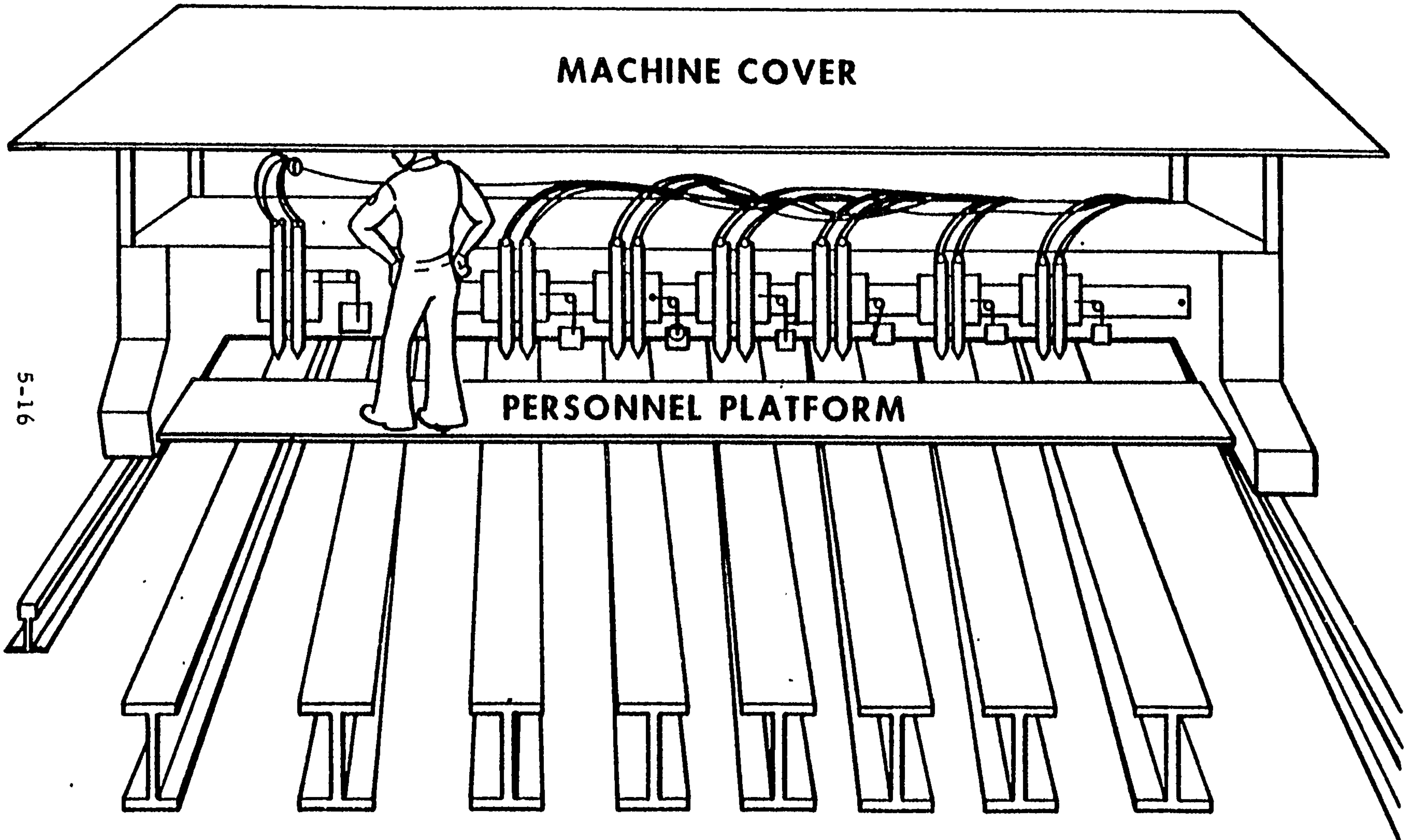


Figure 5-3. "I" Beam Stripping Machine (Series Production Method "A")

Since the operation of the machine is described in detail in the "Machines" section of the study (Volume III, Part 8) a description of the operation of the machine will be summarized here as follows:

Utilizing pre-set guides, the machine regulates the movement of the (raw-stock) web and flange materials and automatically makes the required welded joint at the intersection of the web and flange.

The machine is equipped with pre-heating torches, longitudinal straightening torches and a hydraulic device for straightening.

The following weld speeds can be consistently obtained with this equipment:

a.	For 3/16" (4.7 mm) fillets, single wire:	50-60" per min
b.	For 1/4" (6.4 mm) fillets, tandem arcs:	60" per min
c.	For 5/16" (7.9 mm) fillets, tandem arcs:	45" per min
d.	For 3/8" (9.5 mm) fillets, tandem arcs:	30" per min

Use of this machine requires that flat plate be cut to size, in accordance with the web height and flange width of the shape to be produced. The following estimate was prepared to show the costs associated with the use of this method in fabricating the structural members.

ESTIMATE - T BEAM WELDER

1. <u>Strip Plate into Proper Width</u>

a.	Utilizing overhead crane, pick up plate from stack and set in place on burning machine bed.	10 min

b. Regulate starting position of burning machine gantry, check cutting torches, plate position, etc. — 10 min

c. Burn 48' plate into proper width sections as follows:

Description	Plate Width	No. of Pieces	* Total Burning Time	Burning Time Per Piece
5/16" x 14" web	84"	6	32 min	5.3 min
3/8" x 16" web	96"	6	32 min	5.3 min
1/2" x 27" web	108"	4	32 min	8.0 min
9/16" x 30" web	90"	3	32 min	10.6 min
1/2" x 6-1/2" flange	78"	12	64 min (2 passes)	5.3 min
3/4" x 8-1/2" flange	68"	8	64 min (2 passes)	8.0 min
7/8" x 10" flange	90"	10	64 min (2 passes)	6.4 min
7/8" x 9-1/4" flange	74"	8	64 min (2 passes)	8.0 min

* (48' = 576" @ 18 IPM = 32 min)

d. Remove strips from burning machine utilizing overhead gantry crane — 10 min

TOTAL =

Strip Width	Fixed Time	Burning Time Per Piece	Total Min	Total Hrs	① Labor Cost x 3 x $10.00
14"	30 min	5.3	35.3	.58	$17.40
16"	30 min	5.3	35.3	.58	$17.40
27"	30 min	8.0	38.0	.63	$18.90
30"		10.6	40.6	.68	$20.40
6-1/2"	30 min	5.3	35.3	.58	$17.40
8-1/2"	30 min	8.0	38.0	.63	$18.90
10"	30 min	6.4	36.4	.60	$18.00
9-1/4"	30 min	8.0	38.0	.63	$18.90

Plate Weight	Material Cost per Plate	② Material Cost per Piece	①+② Total Cost of Strips
4,267#	725.42	120.90	138.30
5,875#	998.75	166.46	183.86
8,812#	1498.04	374.51	393.41
8,244#	1401.48	467.16	487.56
6,365#	1082.02	90.17	107.57
8,322#	1414.77	176.84	195.74
12,852#	2184.84	218.48	236.48
10,566#	1796.23	224.53	243.43

2. Weld Strips to Form Built-up Shape

Shape Size	Strip Cost	*T-Beam Welding Cost	48-ft Shape Total Cost
14" x 6-1/2"	245.87	3.80	249.67
16" x 8-1/2"	379.60	3.80	383.40
27" x 10"	629.89	3.80	633.69
30" x 9-1/4"	730.99	3.80	734.79

* (See Detailed Back-up in Volume III, Part 8)

5.4.3 Summary of Cost Comparison - Large Members

Web Size	Series Production Stripping Method (Unit Cost)	Unit Savings	Series Production Beam Welding (Unit Cost)	Unit Savings	Single Ship Semi-Automatic Stripping (Unit Cost)
14"	292.88	53.56	249.67	96.77	346.44
16"	488.72	53.56	383.40	158.88	542.28
27"	847.76	53.56	633.69	267.63	901.32
30"	896.72	53.56	734.79	215.49	950.28

The savings indicated for series ship production are projected as follows for the total 576′ mid- ship section:

a. Team Beam Welder

Size	Total Linear Feet	No. of units	Savings Per Unit	Total Savings
14"	9,216	192	96.77	18,579.84
16"	32,256	672	158.88	106,767.36
27"	27,648	576	267.63	154,154.88
30"	32,256	672	215.49	144,809.28
			Total Savings =	424,311.36

b. Series Production - Multiple Stripping

Total Linear Feet = 101,376

Savings per 48' Unit = 53.56

Savings per Linear Foot = 1.11

Savings per ship = 112,527.36

5.5 SUMMARY AND CONCLUSIONS

1. The structural member configuration represents a significant area of potential for cost ovoidance in series production.

2. In the smaller size range, there is no practical substitute for the sections currently available from U.S. steel mills.

3. In the larger size range, the use of an automated T-Beam welder is the preferred method for fabricating steel structural shapes. Custom-developed systems of a similar nature would produce similar benefits.

4. The net cost of any stripping operation will vary, depending on the revenues received from the sale of scrap material and the associated material handling costs.

5. At the present time there are no structural members readily available from domestic steel mills which are satisfactory for use in the construction of a 150,000 DWT tanker.

6. Development of a "seal" of domestically available structural shapes which could be utilized in commercial shipbuilding, would be a worthwhile subject for future study.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF EXHIBITS

VOLUME II

PART 6

SIMPLIFIED HULL FORMS

6.1 INTRODUCTION

The recent trend in low speed-length ratio bulk carrier hulls has been to initially begin with a rather simple hull form. Parallel mid-body *can* be considered a simplification, and a typical tanker hull features extensive parallel mid-body. Ship- shape bows and sterns have been fashionable for hydrodynamic terminations of the parallel body. Recent developments in current *use* include the cylindrical bow, which *is* without a clearly defined stem, thereby attaining an entrance which is satisfactory for a low ship speed (Froude No.). Transom sterns have been introduced as a simplification to reduce the overall length and *save on* construction costs; however, they are predominantly above the waterline, so are not hydrodynamically significant. Few *areas* remain to be *examined* other than the following categories:

a. No transverse curvature of the shell

b. No concave transverse curvature of the shell

c. No compound curvature of the shell

d. Limited compound curvature (such as can be achieved by packing the rolls) of the shell (no furnaced plates)

It is toward this range of candidate simplifications that this study Ingalls is directed.

6. 1.1 Other Uses of Simplified Hull Forms

During the past three decades there has been an increase in the use of straight-element, chine form hulls for ocean- going vessels up to about two hundred feet in length. The use of conventional, rounded form hulls has relatively decreased.

The design, manufacture and operation of vessels such as offshore supply boats, fishing trawlers, oceangoing and coastmise tugs and river towboats is on a surely competitive basis. No Government assistance or regulations affecting hull forms apply and the straight element forms presently being designed, or recently put into use, are the consequence of the natural laws of economics resulting in vessels of miximum serviceability, sea-worthiness, speed and maintainability of *the* lowest first cost. In other words, economic and practical interests of designers, builders and operators has tended to produce cost-effective hull forms in the above mentioned types of ships.

While it can be argued that many small shipyards do not presently have the know-how or facilities to *economically* produce hulls with much doubly curved shell plating, this *was* not true thirty years ago. At that time conventional rounded form hulls were far more common than straight- element, chine form halls. As a result of intelligent service evaluation by progressive owners and builders, more and more straight- element hulls were produced. Their relatively short building time, low construction cost and superior performance guaranteed their increased acceptance. At this *time (1975),* straight-element, chine form hulls are common and old fashioned hulls, with much doubly curved shell plating are a rarity.

A two hundred-foot long vessel can be regarded as a quarter fifth full size working model of a large tanker. Such a “model” does not precisely simulate the full sized vessel as the two hundred foot long model operates at an excessively high speed length ratio and can expect in normal service to encounter gross out of scale waves. In addition, the entrance and run of the “mo will probably be disproportionally long. These differences tend to support the theory that the ease of construction and outstandi performance associated with simplified hull forms in smaller ships will be repeated when similar hull forms are used for shi with linear dimensions one or two times larger.

6. 1.2 Genesis of the Square Bilge and Rounded End Hull

For many years British and European barges have had square bi and more or less ship-shaped, rounded, entrances and runs. Examples include the British Thames Sailing Barge and the Rege Canal Barge described and illustrated on pages 79 and 150 *respectively* of Small Seagoing Craft *and* Vessels for Inland Navi tion, Roorda and Neuerburg, The technical Publishing Company H. Stare, Haarlem, Holland, 1957.

Both of these designs have long parallel midbodies, short entra and runs, and bilges that are square or very nearly square. So what similar forms are in use as dumb barges and powered vess on American waterways.

Two out of the three simplified bows and all three of the simplifi sterns proposed herein have radius bilges. In all cases the radi or chamfered bilges transition into the square, parallel middle-body bilge.

6. 1.3 Examples of Applications of Simplified Hull Forms

Simplified hull forms of the straight-element types are used for the following types of vessels:

a. Planing hulls used as naval patrol boats, crew boats, yachts and launches. These vessels are operable in displacement, as well as planing, modes.

b. Displacement hulls used as offshore supply boats, trawlers, yachts, tugs, river towboats, naval landing and other craft.

c. Displacement- type cargo ships of the West. German "facet form”.

d. Self-propelled barges.

e. Dumb barges

Partially simplified hull forms and appendages embody chines and/ or straight elements for hydrodynamic reasons or to facilitate construction. Typical examples follow:

a. *Destroyer-type* hulls at junction of bottom aft and sides and transorn.

b. Junction of sides and flat or curved transom.

c. Topsides forward. To avoid excessive flare.

d. Counter sterns.

e. Skegs with warped surfaces and straight-elements or wi
developable surfaces and curved elements.

f. Double-plate streamlined rudders.

g. Bilge keels of the double-plate vee type.

6.2 APPROACH

A selection from the myriad of possible hull simplifications was made in order to limit the investigation to manageable size, with the scope of the program. Several types of simplifications were considered.

6.2.1 No transverse Curvature

A ship constructed without transverse curvature must necessaril feature chines and knuckles, between which the plating is either developable or somewhat misted. Such forms have been quite successful in high displacement length ratio ships where the spe length ratio is fairly high, such as trawlers, tugs, fishing boats, and river towboats. In these craft, the operating costs are not dominated by fuel *cost* considerations. This type of hull, in ord to be competitive with a fair-form hull featuring compound curva ture, should be model tested to align the chines with the flow in a manner so that the eddy-making portion of the residuary resista is not excessive. Much ingenuity has been applied to craft of thi type, and many new ideas are quite successful. Application of th type of construction to a 150,000 *ton tanker* brings about:

a. A judgment that sizeable resistance or propulsion may be incurred if tie lines *are* not model tested.

b. A judgment that the construction of the knuckles requires a significant amount of hand work in the form of fitting plate and welding the round bars or specially shaped chine sections of scantlings. The details of such connections are not a matter of standard practices at the present time, and they will require considerable dialogue with the classification societies before approval. Butt welds in these heavy sections do not lend themselves to machine welding techniques and will therefore require extensive manual operation and welding time.

6.2.2 NoConcave Transverse Curvature

From a hydrodynamic point of view, in the stern region, lack of concave transverse curvature increases resistance far less than the lack of convex transverse curvature. This is because the transverse flow component in the way of re - entrant corners involves a stagnation region and a flow separation bubble in a very low energy region, whereas convex corners which are not exactly aligned with the flow will shed separation vortices in a region of high energy flow, resulting in a significant increase in eddy resistance.

Construction involving no transverse concave curvature calls for the use of flat panel intersections in a region where massive reinforcement bars (as in the case of the chine) are not necessary. It appears that some savings can be made with this configuration in construction, without excessive hydrodynamic penalties. Such construction involves the “use of compound curvature wherever the bilge radius or skeg radius must conform with the longitudinal curvature of the hull.

6.2.3 No Compound Curvature

This type of a simplification is likely to give rise to knuckles in the longitudinal lines of the ship unless it is combined with the *use* of conic sections producing developable surfaces in conjunction with chines or knuckles. It is unlikely, for example, that one can easily merge the bilge radius into the radius of the stern without either knuckles or some compound curvature. No investigation has been made, under this program, of the feasibil of the use of developable surfaces with skewed conic axes to develop hull forms "easy on the flow", without compound curvatu It is the preliminary opinion of the investigators that the hydrodynamic penalties associated with no-compound-curvature woulc more than off set the small construction cost savings resulting from the avoidance of the use of packed rolls in the plate formin phase of construction. Further study is also required in this ar but is felt to be outside the scope of this investigation because a assessments of the hydrodynamic penalties must involve model testing.

6.2.4 Limited Compound *Curvature*

This approach to simplified hull forms is a very slight extensi of current good practices. It is dyiomatic that furnaced plates a expensive and wherever possible, the hull forms are designed sc that a minimum number, or no plates at all, require furnacing. The construction cost variations are related to the cost associat with attaining various degrees of compound curvatures, short of furnacing, by means of packing the rolls. In some cases, short plates with additional butts can achieve more compound curvatur that would a long plate, though the additional butts tend to run up the cost. The current trend in tanker design borders on this approach to simplified hull forms.

6.2.5 Desirable Features for Hull Envelopes

The following characteristics, which are not necessarily in their order of importance, merit special consideration in the question of simplified versus conventional hull forms.

a. Minimum resistance to propulsion at designed sea speed.

b. Satisfactory maneuvering characteristics in shallow as well as deep water.

c. Minimum flow of water across, instead of parallel to, chines.

d. Avoidance of separation.

e. Provision of satisfactory flow of water to propeller(s).

f. Minimum green water and spray on deck.

g Satisfactory performance in wind-driven waves.

h. Avoidance of excessive pounding and/or slamming.

i. Satisfactory hydrostatic qualities.

j Satisfactory directional stability.

k. Minimum length of entrance and run.

l Minimum surface area to be maintained.

m. Maximum contained volume for any given surf ace area.

n. Satisfactory compatibility of entrance and run and midbo

o. Avoidance of outlandish appearance.

p. Configurations based on existing *or* former designs that are giving, or have given satisfactory service.

q. Minimum manhours to build.

r. Minimum skill to build.

s. Minimum clapsed time to build.

t. Minimum shipyard facilities to build.

u. Maximum of repetitive, or semi-repetitive, work.

v. Minimum use of non-developable plates.

w. Minimum use of plates that cannot be cold-formed to shape or that cannot be pulled into the desired helicoidal or other configuration.

x. Maximum simplicity in designing, delineating and fairin lines.

y. Maximum simplicity in calculation of hydrostatic and tank properties.

z. Maximum cold-flanging of plates.

aa. Minimum doubly- curved plating.

ab. Elimination of furnaced plating.

ac. Minimum manhours to repair.

ad. Minimum skill to repair.

ae. Minimum elapsed time to repair.

af. Minimum facilities to repair.

ag. Satisfactory resistance to washboarding caused by welding shrinkage, pounding, slamming and wind- driven waves.

ah. Satisfactory resistance *to* damage from contacts with piers, piling, fenders, camels, the bottom, channeI banks, submerged wreckage, tugboats and other vessesl.

ai. Minimum weight of ordered steel.

aj. Minimum build weight.

6.3 METHODOLOGY

It was decided, after consideration of the factors enumerated in 6.2, that three bows and three sterns would be developed, as well as a square bilged midship section. These would, so far as practicable, be confined to developable surfaces, with a minimum of non-developable surface.

6.3.1 Envelopes for Simplified Hulls and Appendages

Shell plating and plating of shell appendages can form surfaces that are developable and non- developable. Some surfaces may in between in that strictly speaking they are non-developable bu are such that in practice plating can be pulled into a helicoidal other shape with little or no difficulty.

Developable surfaces include the following:

a. Flat surfaces as for bottom, side or transom.

b. Cylindrically curved surfaces as for radius bilge, side of bow, sides aft and cut up bottom with reverse curve The cylindrical curvature need not be circular.

c. Conically curved surfaces, not necessarily cylindrical as for any part of shell or skeg plating.

Non- developable surfaces include:

a. Straight- element, warped surfaces of helicoidal form, with fixed or variable pitch, as for skeg side plating.

b. Double curved surfaces

Double Curved Surfaces

a. Double curved surfaces can be further subdivided into convex surfaces (or concave) and saddle shaped surfac similar to a hyperbolic paraboloid.

6.3.2 Examples of Convex Surfaces

a. Examples of convex surfaces (formed by stretching the membrane in the middle, or shrinking at the edges)

(1) Convex surface at counter of a cruiser stern,

(2) Bilge surfaces at shoulder transition from parallel body to ends.

b. Examples of Saddle Shaped Surfaces are:

(1) Flare of the bow near stern
(2) Bilge plating in way of hollow, very fine entrance.

Any significant compound curvature which cannot be elastically produced during the attachment of the shell to the framing will require forming. Forming is expensive and should be avoided in the design to the maximum extend possible. Such forming may be done by “packing the rolls” when rolling transverse curvature, so as to achieve a limited amount of longitudinal curvature, or by furnacing, if the shape required is more severe than can be accomplished by packed rolls.

6.4 RESULTS

Based on the evaluation of hull forms presently in successful use, designs for the following three bows and three sterns were developed:

SHF- 1 Plumb bow with round bilge and square midbody bilge.

SHF- 2 Raked bow with round bilge and square midbody bilge.

SHF- 3 Raked bow with double chine bilge and square midbody bilge.

SHF-4 Straight cutup stern with round bilge and square midbody bilge.

SHF-3 Reverse curve stern with round bilge and square midbody bilge.

SHF- 6 Deadrise stern with round bilge and square midbody bilge

The following chine details are shown on the indicated drawings.

SHF-7 Type 1. Round bar chine with outboard sides of plates tangent to chine bar. Square plate edges. Normal weldin

Type 2. Round bar chine with outboard sides of plates tangent to chine bar. Square plate edges. Flush welding.

Type 3. Round bar chine with plates centered on chine ba Double beveled plate edges.

SHF-8 Type 4. Square bar chine with plates in line with sides of bar. Double beveled plate edges.

Type 5. Eighteen inch radius bilge plate.

SHF-9 Type 6. Round bar chine with plates centered on chine ba Square plate edges.

Type 7. 6" x 6" x 1" angle chine bar.

6.4.1 Simplified Bow Design

In all three cases the outline of the bows in the halfbreadth plans are radii. This will facilitate delineation of the bow lines and also result in standardized bilge plates, all of identical shape.

Each bow plan shows a pointed, or rather wedge-shaped stem, instead of a bow formed to a rather large radius. This will have less resistance than a blunt bow when propelled against wind-driven waves and will also ensure drier decks. In addition a blunt bow is more susceptible to damage from waves than is a sharp bow. A suitable stem is a solid round bar, say four inches in diameter, with the outboard surfaces of the shell plates tangent to the round bar.

Both the round-bilge bows are cylinders, the one with a plumb stem being a right cylinder. The other cylinder is identical to the first but is inclined. The chine bow somewhat resembles the bows of straight-element hull trawlers and offshore supply boats.

6.4.2 Simplified Sterns Design

Two of the proposed sterns have no deadrise. One of these has a straight cut up while the other has a reverse curve cut up. Both of these sterns are based on trawler and offshore supply boat sterns. The third stern has considerable deadrise. All three sterns have round bilges.

AU three skegs have helicoidal surfaces and have considerable breadth of their forward ends. These proportions result in the skeg being able to accommodate line shaft bearings, reduction gears, turbines or other propulsion machinery and foundations.

6.4.3 Square Bilge Design

Curyes of sectional areas of deposited weld metal versus chine bar sizes (cross sectional areas and diameters) are shown on SHF- 9. As would be expected, it is found that double beveling plate edges in contact with the chine bar reduces the quantity of deposited weld metal. The square bar chine requires the least weld metal. However, square edge plates with their outboard sides tangent to a round bar chine has been in use as a stem detail for many years and must be regarded as a viable bilge de

6.5 ANALYSIS OF RESULTS

6.5.1 Design

a. Feasibility and desirability is proven by several decad of successful operation of tugs, towboats, offshore sup boats, fishing vessels, yachts, naval vessels and barg in sea, coastwise and lake and river service.

b. A parallel middle body square bilge can transition into obtuse angle chines or conventional rounded forms for bow and stern.

c. Appearance of square bilge is superior to that of round bilge with bilge keel.

d. Square bilge has maximum displacement and maximum deadweight for any breadth and draft.

e. There is no need to determine the trace of the bilge ke during model testing.

6.5.2 Yard Facilities

A square bilge does not require that the building or repair yard have plate rolls.

6.5.3 Material

A square bilge requires less material than does a radius bilge with bilge keel.

6.5.4 Fabrication

The square bilge does not require the forming of bilge plates nor the fabrication and filling of bilge keels.

6.5.5 Seaworthiness

a. The square bilge has built- in anti- rolling properties.

b. A square bilge ship will make less leeway when exposed to a wind with an abeam component. Less fuel will be wasted in pointing up to resist leeway.

c. A square bilge ship will have greater directional stability and will be more maneuverable.

d. A square bilge ship offers greater resistance to heave, sway, roll, yaw and pitch, that is, to all motions except surge.

e. A square bilge ship can be expected to have less resistance than a ship with rounded bilges and bilge keels.

f. A "square" bilge need not be exactly square and can ha an angle of say 88 degrees if two or three outboard str are given a slight deadrise, say six inches) and two or three lower side strakes are given a flare of like amou A midship coefficient of less than one would result and resistance of bilge shell plating to damage from contac with the bottom or piling would be enhanced. In additio in the event of a list, draft on the low side would be les than if there was no deadrise.

6.5.6 Maintainability

a. A square bilge ship has no bilge keels which are subjec to damage and require repair or replacement.

b. A square bilge ship has less area to be cleaned, maintained and painted than does a round bilge ship with bilge keels.

c. A square bilge ship which has been damaged at the bilge can be more easily repaired because no formed plates, or means to form them, are required.

6.5.7 Plating and Framing

Shell plating of bows and stern can be arranged in a conventional mariner. Where radius bilge plating is curved longitudinally the plates can be in relatively short lengths so as to reduce, if not eliminate, double curvature.

Bow and stern framing is assumed to be transverse. In the case of the raked-stem bow, this will involve a very slight convexity of the transverse frames. This is because the axis of the cylinder forming the bow side plating is inclined relative to the base plane while the transverse frames are normal to the base plane.

The envelopes of the three skegs and the chine-form bow are helicoidal. Small yards with a minimum of manpower and facilities plate helicoidal surfaces as a matter of course when building offshore supply boats and trawlers. Considering that the liuear dimensions of a large tanker are four to eight times those of the straight-element hull regarded as a model axial that the plate thicknesses in the large tanker are only about double, those of the model, it would appear that skeg plating difficulties would diminish with size of vessel.

Experiments with a cardboard model of one side of a typical skeg suggest that skeg side plating should be run transversely, rather than longitudinally.

6.5.8 Cost Comparison - Square vs. Radiused Bilge

In comparing the simplified square bilge to the traditional radiused bilge, certain basic assumptions were made on the basis of observation:

a. The number and size of the longitudinal stiffeners will remain approximately the same in either case, and will therefore be disregarded in the analysis.

b. While the square bilge increases the area of the transverse floors as required to meet the corner of the hull form, this additional area is relatiyely insignificant, and the burning time for the floors will be comparable in either case.

c. The major differences in the two cases are the requir
for rolled plate with a seam weld for the radiused bilg
as opposed to no rolled plate with a requirement for th
welding of a chine bar at the joint of the keel and side-shell plating in the simplified square bilge.

d. Since there are a number of viable ways to design the square bilge, a representative amount of alternates would have to be considered in order to fairly apprais the square bilge.

With this basic study concept developed, five candidate joint designs were developed as shown in figure 6-1.

Types 1, 2, 3 and 4 are variations of a design which incorporat a solid round bar at the intersection joint. Type 5 incorporates a steel angle and type 6 incorporates a square bar in lieu of the round bar.

For the purposes of comparison, types 1 and 2, and 3 and 6, ha been considered together since they are variations of the same basic type joint.

In comparing these sections, it was considered essential that th study recognize the fluctuation in cost which would occur as a r of variations in welding process and the welding position at the of accomplishment. To do this, a matrix was developed which s the varying costs for a given welding process in a given welding position. This matrix was developed for each of the four welds making up the total joint, with corresponding welds numbered in the adjacent diagram for reference purposes. (See figure 6-2).

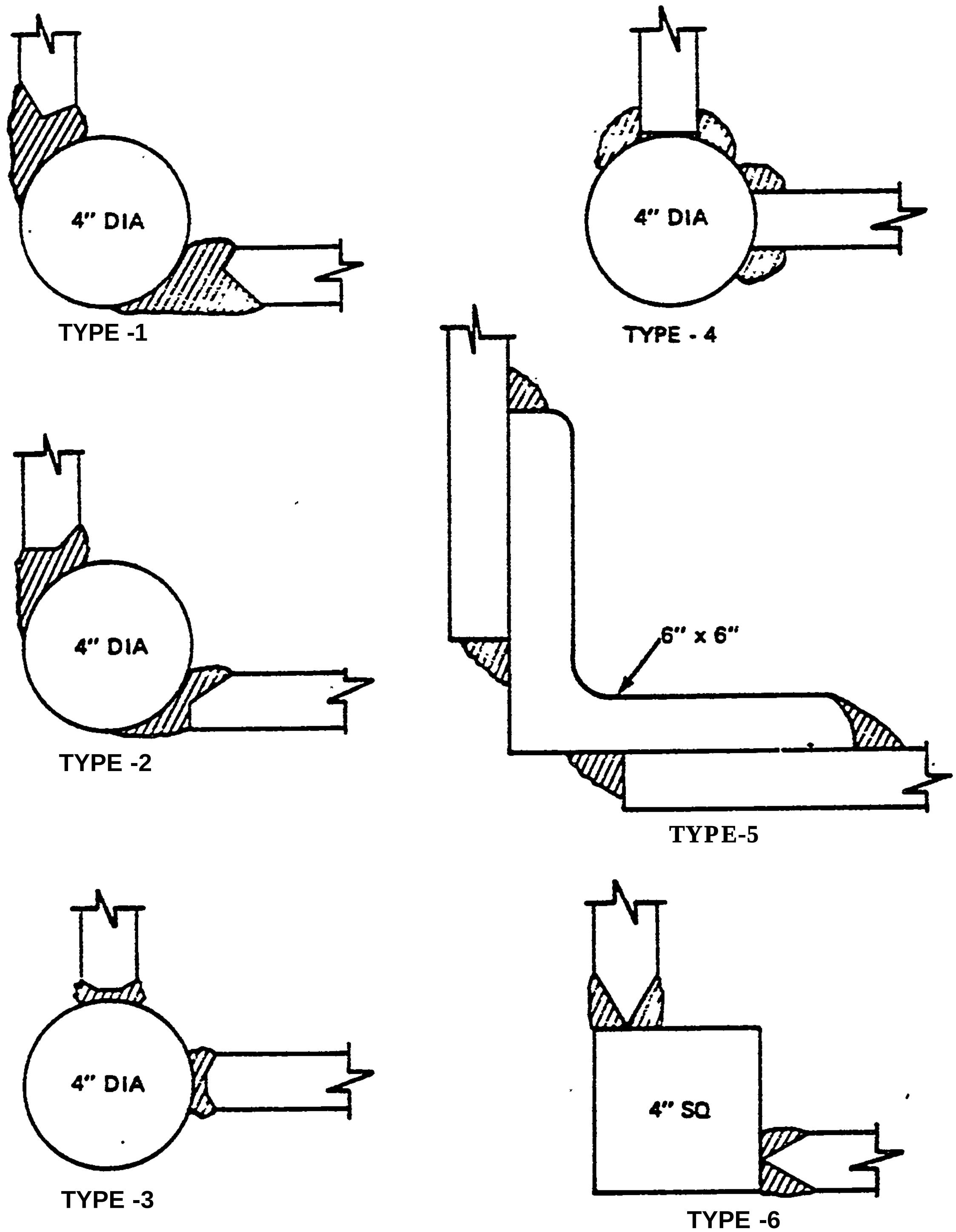
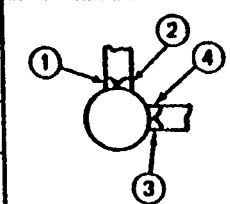
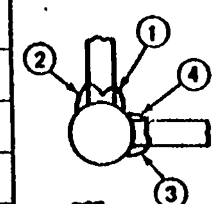
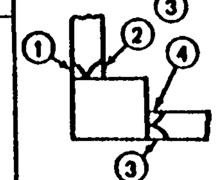
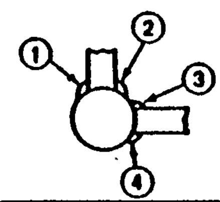
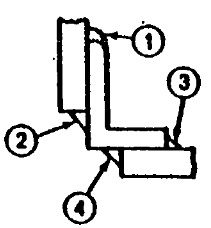


Figure 6-I. Square Bilge Candidate Joists Designs

JOINT WELD	EDGE PREP (CUT/BEVEL)	WELD, SIDE & POSITION	PROCESS FLUXCORE	SPRAY	STICK	SHORT	CARBON ARC GOUGE	FIT-UP	
1 & 2	.17 (SIDE)	① HORIZ.	$2.30	3.13	10.65		.17		
		② HORIZ	$1 15	1.57	5.32		.17		
	.17 (BOTT).	③ O.H.		3.13	10.65	3.13			
		④ FLAT	$1.15	1.57	5.32		.17		
3 & 6	.34	① HORIZ.	$0 68	$1.95	3.74				
		② HORIZ.	$0.68	$1.95	3.74		.17		
	.34	③ O.H.			3.74	0.98			
		④ FLAT	$0 68	$1.95	3.74		.17		
									
4 FILLET WELD 3/4" LEG		① HORIZ.	$2.09	$3.07	$10.47				
		② HORIZ.	$2.09	$3.07	$10.47				
		③ FLAT	$2.09	$3.07	$10.47				
		④ O.H.			$10.47	$3.07			
5 FILLET WELD 3/4" LEG		① HORIZ.	$2.09	$3.07	$10.47				
		② O.H.			$10.47	$3.07			
		③ FLAT	$2 09	$3.07	$10.47				
		④ O.H.			$10.47	$3 07			

After developing the matrix, the lowest combination of costs for a given joint were selected with the following results:

Types 1 and 2

SMAW (Stick)	31.95	
FCAW + GMAW (short arc)	7.73	= 7.73
GMAW (spray arc and short arc)	9.39	

Types 3 and 6

SMAW (stick)	14.96	
FCAW and GMAW (short are)	3.02	= 3.02
GMAW (spray arc and short arc)	6.83	

Type 4

SMAW (stick)	41.88	
FCAW and GMAW (short are)	9.34	= 9.34
GMAW (spray arc and short arc)	12.28	

Type 5

SMAW (stick	41.88	
FCAW and GMAW (short arc)	8.32	= 8.32
GMAW (spray arc and short arc)	12.28	

The resultant ranking of joints, in order of increased production costs, is as follows:

Type of Joint	Welding Cost Per Foot	Welding Cost per 48’
3 and 6	3.02	144.96
1 and 2	7.73	371.04
5	8.32	399.36
4	9.34	448.32

In order to compare these costs with the radiused bilge, the following estimate was made for the two rolled plates with the continuous seam weld as would be required:

Estimate

1. **Roll (2) plates 48’-0” x 7’-0”**

Set up time	15 min
Roll	45 min
Total Handling	30 min

Total 90 minutes per plate

(2) plates = 3.0 hrs

3.0 hrs x 2 men = 6.0 hrs total

2. **Weld 48’-0” Seam Welding**

1st side - V butt	.8999
2nd side - Back Gouge	.1155
2nd side - U type	.7968
Total	1.8122 man hours per ft

1.8122 x 48’ = 86.98

3. Total Cost

93 man hours @ 10. 00/hr = $930.00 per 48’ section

The final comparison of the two approaches is as follows:

Joint Design	Welding Cost 48 Ft Section	Welding Cost 576 Ft Midbody
Radiused Bilge	930	11, 160
Square Bilge *(type* 3 *or* 6)	145	1, 740
Savings per ship	$9,420	

The savings indicated are not considered to be of significant magnitude to warrant serious consideration, particularly since there may be additional costs associated with the square bilge in the following areas:

a. Making up the joints at the 48' intervals

b. Making the transition to the square bilge at the bow and stern.

c. Loss of manhours due to development of new methods as opposed to benefits of learning which would be realized using traditional methods.

6.6 SUMMARY AND CONCLUSIONS

6.6.1 Simplified hull forms up to about two hundred feet in length have demonstrated superior qualities of ease and economy of construction seaworthiness, operational characteristics *and* repairability over periods in excess of thirty years. In no case does it appear that- a well designed simplified hull form is inferior in any *way to* a well designed conventional hull embodying considerable areas of double curved plating. If existing simplified hull forms are increased in size by a factor of one or two, they will be operating at relatively lower speed length ratios and in calmer water and can be expected to operate even more efficiently than their smaller sized prototypes.

6.6.2 Investigations regarding production cost comparisons indicate that while the square bilge is particularly cost effective in small boat construction it will not appreciably reduce production costs in large ship construction when accomplished utilizing the welding techniques applied in the study.

The possibility does exist, however, that if a specialized production line approach was applied to the manufacture of the square bilge, the full advantages of the design could be beneficially utilized to reduce production costs.

6.7 RECOMMENDATIONS

6.7.1 A study is recommended to determine. the feasibility of Producin square bilge and square gunwale sections utilizing *an* automated *in-line* process. This study should include, but not be limited to, the following subjects:

a. Special tooling required
b. cost of tooling
c. Required departures from conventional methods
d. Cost effectiveness of total approach
e. Evaluation of subject in terms of increased productivity.

6.7.2 A study is recommended that the effects of simplified hull forms on the ship's performance characteristics be evaluated based on a comprehensive program as outlined:

a. Prepare lines plan for skeg of form similar to those proposed herein but with developable surfaces instead of the straight-element, helicoidal form used.

b. Evaluate developable and non-developable skegs and select the most suitable.

c. Have model tank construct and test three models with the bow and stern lines as shown by the accompanying drawings and with skegs as shown or with developable surfaces. Test results should include effective horsepower, shaft horsepower, maneuvering characteristics and directional stability in full load and IMCO ballast conditions.

d. If test results warrant, cut two or more models transversely and re-assemble using different combinations of bows and sterns and retest.

e. Select best hull form, make any final changes, and conduct final model tests.

f. Prepare faired lines plan and determine and tabulate offets.

g. Construct plating models of entrance and run, each model having a short length of parallel middle body. Draw shell framing, seams and butts on each plating model.

h. Draw shell expansion plan.

i. Calculate hydrostatic properties for entrance, run and complete hull, including wetted surface, and prepare plans showing curves of form and Bonjean curves.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

VOLUME II

PART 7

INSTRUCTIONS

7.1 INTRODUCTION

The development of working drawings which interpret the original ship design in terms of production information is considered to be one of the most critical support tasks affecting series production.

For the purposes of this study those events leading up to the development of the contract or system plans and specifications will be disregarded and the task of developing working drawings as required to support the production process will be addressed.

For series production, the objective of this effort is to match or tailor the drawing content to the production process so as to minimize the time required in production to interpret the drawing requirements.

In striving to achieve this objective, the preparation of the working drawings will often become more closely associated with the production planning effort than is normally the case for single ship production. This fact was emphasized in the “Facility Utilization” section of this report (Vol. III, Part 1).

Since the development of the working drawings is a task which need only be accomplished once in order to satisfactorily support production of a series of ships, any additional costs which may be incurred by expansion of this effort are considered to be justified by the additional benefits which will accrue throughout the duration of the series production contract.

7.2 OPTIONS FOR HULL WORKING PLAN DEVELOPMENT

In the development of the hull production drawings, a number of options exist regarding the level of breakdown or the boundary constraints which may be applied during development.

Recognizing that the production planning effort will require the hull structure to be divided into discrete assemblies and sub-assemblies which reflect the joining and installation of numerous piece parts, the production drawings can never-the-less be developed to reflect the major level of construction as outlined in the following descriptions for each type of plan.

Working plans are developed from contract/systems plans and contain sufficient information for ordering of material and for building of hull and house structures. Information on working plans can be grouped in at least four different ways as follows:

7.2.1 Whole Ship

in this system the ship is treated as one unit. One complete deck, for example, may be delineated in one drawing. In the case of a large ship, or in cases where the plans are drawn to a large scale, the single drawing may be divided into two or more sheets of approximately equal length. This, of course, is the conventional method of preparing ship plans.

7.2.2 Modules

This system is similar to the conventional whole ship system just described but plans are prepared and grouped to suit structural modules of a length best suited to the production facilities of the.

building yard. For example, if a nine hundred foot long ship is to be built in four modules of equal length, the hull will be made up of four modules each about 225 feet long. The deckhouse will consist of one or more additional modules. There will be four sets of structural plans for the four hull modules. Thus, instead of the main deck plating being on one plan, it will be on four . plans, each one showing a deck length of 225 feet.

7.2.3 Assemblies

Just as an entire hull can be made up of several structural module each extending the breadth and depth of the ship, so can one modu be made up of several structural assemblies. If we consider the case of a tanker with double bottom and wing tanks for ballast, the will be assemblies for the double bottom between the longitudinal bulkheads, and also two “D” shaped assemblies for wing tanks. Some of the structures, such as the main decks between longitudin bulkheads and the transverse cargo tank bulkheads between longi-tudinal bulkheads will be two-dimensional panels rather than three dimensional, box-like, assemblies.

The assembly method of plan delineation and grouping involves drawing all of the structure for each assembly on one drawing. Each structural plan will thus show the panels or subassemblies required to makeup one assembly plus views showing how the panels and subassemblies go together to make one assembly. A small scale key plan will show the location of the assembly in the hull.

Separate plane should be prepared for port and starboard assemblies, even if they are similar or opposite hand. This reduces the possibility of confusion and also provides vehicles for preoutfitting use in case there should be differences between the outfitting of port and starboard sides of the ship.

In way of the parallel middle body, if there is no change in structure, a structural plan for one assembly on one side of the ship could be used for other identical structural assemblies on the same side. Thus a starboard wing tank assembly drawn for tank No. 5, which might be amidships, could also be identified as being applicable to all other wing tanks on that side of the ship. Where differences in preoutfitting occur along the length of the ship additional views of some of the cargo tanks may be required. Photographic reproducibles can be easily prepared for this purpose with appropriate modifications to the affected plan data and title block.

7.2.4 Panels

In this system the working plans consist of delineations of structural panels, one panel to each sheet. Each structural plan shows all plates and stiffeners which make up the panel. A small scale key plan shows the location of the panel in the hull.

Separate plans are prepared for port and starboard panels, even if they are similar or opposite hand. The purpose is to reduce the possibility of confusion.

In way of the parallel middle body; if there is no change in structure, a plan for one panel on one side of the ship will be used for other identical panels on the same side. Thus a plan for a starboard shell panel in way of tank No. 5, which might be at arnidships, could also be identified as being applicable to several other ass emblies on that side of the ship.

7.2.5 Piece Part Plans

The working plans just described can be prepared on the basis of whole ship, modules, assemblies or panels. Any of these plan systems can be further refined by the preparation of piece part plans.

Piece part plans show one structural member, plate, stiffener, bar, or other part per plan. Such drawings are obviously particu- larly useful in fabrication as well as in operations preceding fabrication. Minimum skill on the part of the workman is require along with minimum opportunisty for error.

7.3 DISCUSSION OF MERITS OF PRODUCTION DRAWING METHODS

In addition to the basic definition of the various levels which can be used to define the working drawing system, there are a number of factors which need to be considered regarding the merits of eac

7.3.1 Whole Ship Working Plans

In this system, the whole ship, including the house, is treated as a single unit. The system is considered to be the oldest in existence and has the advantage of maximum' total visibility and of increased familiarity among the more experienced marine draftsmen and shipyard workers.

Whole ship plans are considered to be the easiest to develop, sinc the plan development is limited to a select number of draftsmen whose respective plans reflect a major portion of the ship. While coordination is easier and interface problems are minimized, the whole ship system requires the longest amount of time for develop ment, since the application of manpower to the drafting task is lin

7.3.2 Module Working Plans

This system is the next level of departure from the whole ship system, with the plans developed to reflect a major portion of the hull structure, as would be accomplished by the erection and . joining of several individual assemblies.

The working drawing package is composed of numerous sheets of drawings, reflecting the entire work content required to produce the total module.

All materials required to produce the module are included, and no materials relating to other modules are referenced or considered.

Assuming that the ship's hull is to be constructed in modules, there would be four or five for the hull of the 150, 000 DWT tanker addressed in this study. Each module would be reflected on a separate set of plans, with supplementary drawings developed to support the joining of the modules as would occur in a graving dock or other final assembly position.

The breaking down of the whole ship into modules is considered advantageous, since it becomes more manageable, and allows for bow and stern modules to be designed in such a way as to accommodate varying mid-ship modules.

Coordination of the plan development becomes more difficult than with the whole ship system due to the fact that continuous elements of the ship's structure are being developed as part of separate efforts. For example, the main deck and framing plan would be developed for four different modules, requiring more coordination to achieve a common objective.

Whole ship and module working plans are basically similar, the principal difference being that modular hull plans are drawn and grouped according to the modules in which the hull is divided and deckhouse plans are drawn and grouped to suit the deckhouse requirements.

7.3.3 Assembly Plans

In this system the total hull structure is divided into separate assemblies reflecting the production planning approach to the manufacturing process.

For each assembly consideration is given to the location of stack material in accordance with the erection sequence of the assembli Dimensional controls are also established to limit the effects of cumulative errors.

The development of assembly plans is generally accomplished as a second phase effort, working from information generated on a whole ship plan basis. All total ship requirements affecting development, arrangement and sizing of the hull structural elements are developed for 'the entire ship first, and then this information is made available to develop the individual assembly plans.

In accomplishing this task; whole ship drawings are normally furnished to the production planners for the purpose of establishing the assembly breaks, and this information is then furnished to engineering for final development of the assembly level drawings.

In an effort to reduce the drafting effort, assembly plans may be limited to one side of the ship with “mirror image” assemblies worked in production from the same plan.

In a similar manner, plans developed for assemblies on the parallel mid-body portion of the ship may be used repetitively for assemblies which are similar in nature throughout the length of the mid-bedy section.

The assembly plans approach is considered to be the most advantageous approach to the development of working drawings, since the plan content reflects the actual “building block” system utilized in production.

7.3.4 Panel Working Plans

As a further departure from the assembly plan which essentially addresses a three-dimensional structure, the panel working plan depicts the separate plate assemblies from which assemblies are built.

This approach is particularly attractive when applied to a production process which utilizes a separate panel shop for the construction of flat panels, as many shipyards do, since the plan content reflects the actual work accomplished in the shop.

Panel plans do not show how and where panels are to be used, and this system must be adapted to, or form a part of some more comprehensive working drawing system.

7.4 EVALUATION OF MERITS ASSOCIATED WITH WORKING PLAN SYSTEMS

In evaluating the four major approaches to the development of working plans as previously described, a value-merit system was developed which allows weighting factors to be applied to the characteristics which are common to all four systems.

The characteristics chosen for comparison purposes were selected in two categories: (1) those associated with software, and (2) those affecting hardware (the development of the product). (See tables 7-1 and 7-2.)

The results of the merit evaluation are summarized, in tables 7-3 and 7-4. The ratios of merit shown in these tables were developed on the basis of total score, for each system.

The results indicate a preference for assembly-level drawings, and while individual merit values may not be consistent with varying applications, the total result is considered to reflect to some degree, the advantage of the assembly working plan system.

7.5 MATERIAL INSTALLATION REQUIREMENTS

In reviewing the application of working plans to the production process, an effort was made. to identify that stage in the ship production process at which the majority of fabricated materials are installed.

Table 7-1. Merit Element Evaluation of Ships Working Plans Systems (Software Application)

ITEM NUMBER	MERIT ELEMENTS APPLICABLE TO SHIPS WORKING PLANS	WORKING PLAN SYSTEMS				
		WEIGHTING COEFFICIENT	WHOLE SHIP SYSTEM	SECTION/MODULE SYSTEM	ASSEMBLIES SYSTEM	PANELS SYSTEM
1	LEAST SKILLED DRAFTSMEN REQUIRED	20	180	160	40	20
2	MAXIMUM PLANNING SUITABILITY	15	30	30	40	45
3	SUITABILITY FOR USE BY OTHER ENGINEERING DEPTS.	10	40	30	20	10
4	MINIMUM PLAN COORDINATION	10	40	30	20	10
5	EASE OF PLAN CHECKING	10	40	30	20	10
6	EASE OF PLAN CHANGES	10	10	20	30	40
7	ADDED COST OF DRAWING TWO SIDES OF SHIP	6	24	24	10	10
8	ADDED COST OF DRAWING ISOMETRIC VIEWS	5	20	20	10	5
9	ADDED COST OF DRAWING KEY PLANS	5	20	20	5	5
10	DRAFTING SAVINGS DUE TO PHOTO REPRODUCTION	5	5	5	15	20
11	WEIGHT GROUP CALCULATION SUITABILITY	2	8	6	4	2
12	ASSEMBLY WEIGHT CALCULATION SUITABILITY	1	1	1	4	3
13	EASE OF REVIEW BY LOCAL REGULATORY BODY	1	4	3	2	1
	TOTAL	100	322	279	220	181

ITEM NUMBER	MERIT ELEMENTS APPLICABLE TO SHIPS WORKING PLANS	WEIGHTING COEFFICIENT	WHOLE SHIP SYSTEM	SECTION/MODULE SYSTEM	ASSEMBLIES SYSTEM	PANELS SYSTEM
1	AVAILABILITY OF ASSEMBLY PLAN INFORMATION	20	60	60	80	40
2	ABSENCE OF REDUNDANT PLAN INFORMATION	20	30	30	80	80
3	PREOUTFITTING SUITABILITY	10	10	10	40	40
4	MINIMUM PROBABILITY PLAN MISINTERPRETATION	10	20	20	40	30
5	MINIMUM N.C. TAPE ERROR PROBABILITY	10	20	20	30	30
6	MINIMUM FABRICATION ERROR PROBABILITY	10	20	20	30	40
7	MINIMUM ASSEMBLY ERROR PROBABILITY	5	10	10	20	5
8	MINIMUM ERECTION ERROR PROBABILITY	4	8	8	16	4
9	TRADITIONAL DELINEATION BEST UNDERSTOOD	4	16	10	8	4
0	CONSTRUCTION FLEXIBILITY	4	3	2	4	4
1	MINIMUM NUMBER ASSEMBLY PLANS	1	4	3	3	1
12	MINIMUM NUMBER PLANS	1	4	3	3	1
3	MINIMUM PLAN SIZE	1	1	2	3	4
	TOTAL	100	206	98	357	283

Table 7-3. Ships Working Plans Summary of Merit Value Analysis

STRUCTURAL WORKING PLAN SYSTEMS	HARDWARE APPLICATION	SOFTWARE APPLICATION	GRAND TOTAL ELEMENTS	MERIT RATIO OF PLAN SYSTEMS
	TOTAL VALUE ELEMENTS (TIMES 10)	TOTAL VALUE ELEMENTS		
WHOLE SHIP	2060	322	2382	0.63
SECTIONS/MODULES	1980	279	2259	0.60
ASSEMBLIES	3570	220	3790	Loo
PANELS	2830	181	3011	0.79

Table 7-4. Ships Working Plans Systems Arranged in Des tending Order of Merit Value

PLAN SYSTEM	MERIT RATIO
ASSEMBLIES	1.00
PANELS	0.79
WHOLE SHIP	0.63
SECTIONS/MODULES	0.60

To accomplish this, the ship structure was broken down into four major categories, each representing a stage of construction at which fabricated materials are installed:

a. Total Ship

b. Module or Major Assembly

c. Assembly or Unit

c. Sub-assembly

Against these four points of progress, or installation levels, five major categories of materials were matrixed, and each of these categories was assigned a weighing factor, reflecting the variances in direct labor associated with each craft or category for a single ship (see table 7-5).

Development of this matrix resulted in the following conclusions:

a. The major portion of the fabricated steel which makes up the hull structure is assembled into sub-assemblies or assemblies only. Further progress is only achieved by joining these type untis, with little or no additional material requirement.

b. Pipe is installed, or can be installed, at all levels of progress. While, historically the major portion of the total pipe installation is not completed until the hull structure is erected, continued progress is being made toward beg inning the pipe installation tasks earlier, with “pre-outfitting” now starting at the sub-assembly level.

Table 7-5. Material Requirements by Installation Level

DISCIPLINE	WEIGHTING FACTOR	MATERIAL	DESCRIPTION	INSTALLATION LEVEL: SUB-ASSY	ASSEMBLY	MODULE	SHIP
HULL	5.0	STEEL PLATE	THICKNESS, WGT/SQ.FT., SIZE	5	5		
		STEEL SHAPES	SIZE, WGT/FT.	5	5		
PIPE	2.0	PIPE-VARIOUS MATERIAL	DIAMETER, WALL THICKNESS, LENGTH	2	2	2	2
		FITTINGS & VALVES	TYPE, SIZE	2	2	2	2
SHEETMETAL	1.0	SHEET	GAGE, THICKNESS, SIZE		1	1	1
		ROLLS	GAGE, THICKNESS, WIDTH		1	1	1
MACHINERY	1.0	PURCHASED "PACKAGES"	PERFORMANCE,CAPACITY,CAPABILITY		1	1	1
		COMPONENTS	PERFORMANCE,CAPACITY,CAPABILITY		1	1	1
ELECTRICAL	1.0	CABLE	TYPE, CAPACITY, LENGTH		1	1	1
		COMPONENTS & EQUIP	TYPE, CAPACITY, SIZE		1	1	1
			TOTALS	14	20	10	10

c. Very little, if any, sheetmetal, machinery or electrical type equipment is installed at the sub-assembly level. This type of equipment is installed at the assembly level, and on. through to ship completion.

d. More material is fabricated to be installed at the assembly level than at any other level of progress in the ship construction cycle.

The indication here is that if the working plans were developed to reflect the total installation at the assembly level, they would better reflect the work content as accomplished in production, recognizing that lower-level or piece-part drawings would be required in order to support the assembly level plan, and that additional plans showing later installations which are accomplished after the joining of the assemblies would also be required.

7.6 RECOMMENDED WORKING PLAN SYSTEM FOR SERIES PRODUCTION

7.6.1 Assembly Plan Tree

Since assemblies become separate entities in the preferred system, there is considerable merit to consideration of an assembly plan tree. Such a tree would consist of (1) a Top Assembly Plan, (2) Hull Structural Assembly, (3) Pipe Installation, (4) Machinery Installation, (5) Electrical Installation, and (6) Sheetmetal Installation. Items (2) through (6) would completely define in detail the assembly, while (1) would define its scope (see figure 7-1).

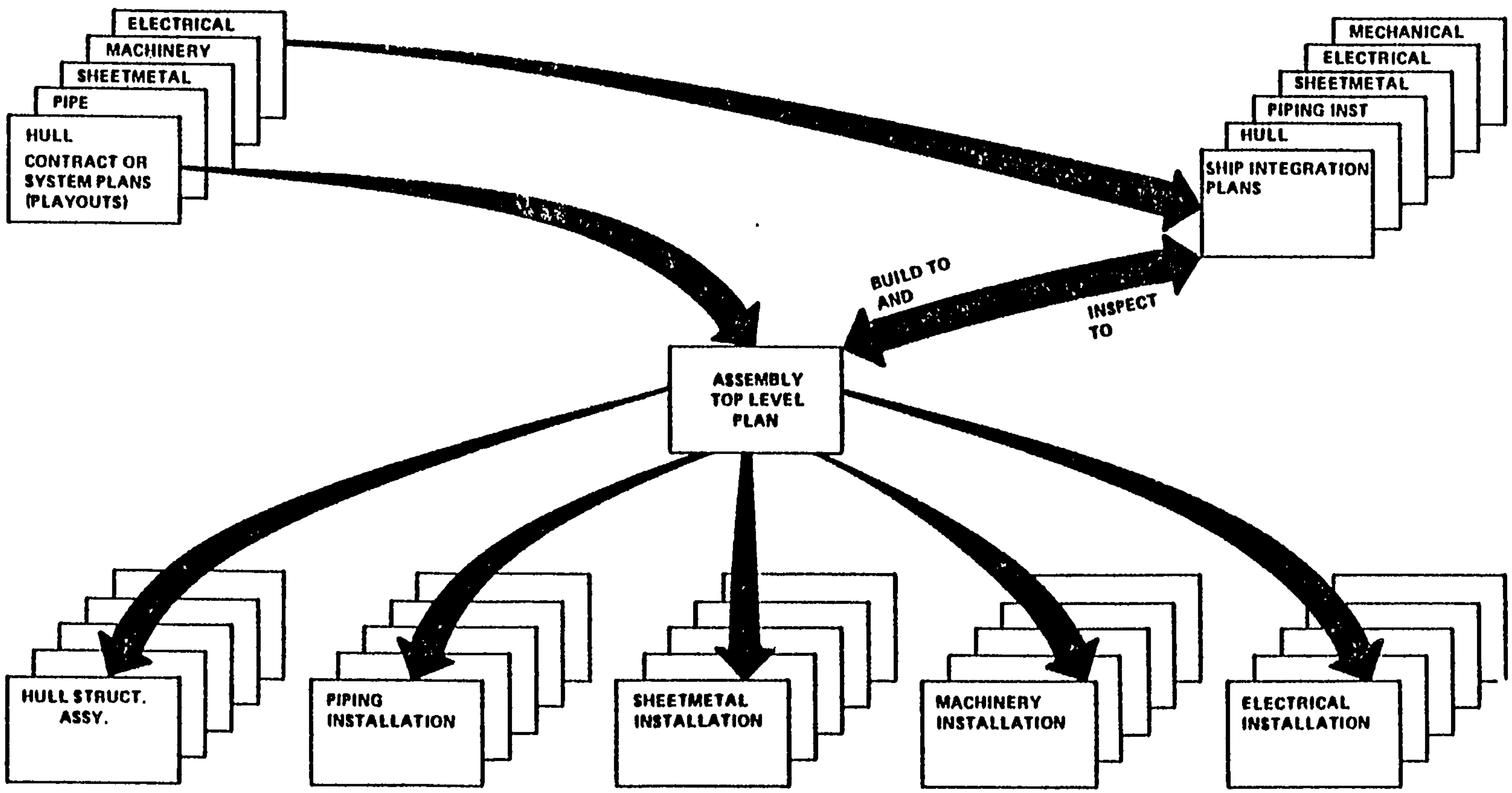


Figure 7-1. Assembly Level Plan Tree

Such a *plan* tree would *permit* inspection of all aspects of the pre-outfitted assembly, and such testing as can be completed at that level.

To supplement the assembly plans, integration plans covering the definition of makeup pieces, field butts, and other parts required during ship integration would be required. These plans could then be used for inspection *at* the time of integration.

7. 6.2 Recommended Structural Working Plan System for Series Production

The recommended structural working plan for series production is an assembly-level drawing augmented by:

a. Piece part drawings as required to manufacture standard parts and parts selected for batch release.

b. Sub-assembly drawings as required to reflect the work content at specific work stations.

c. Panel drawings as required to support fabrication of panels prior to installation in assembly. (See "Production Areas and Shops" Vol. III, Part 2).

d. Integration drawings and/or installation drawings as required to coordinate the joining of the structural assemblies and those installations which must be made after the ship is completely assembled.

7. 6.3 Method of Accomplishment

The total effort would be accomplished as follows:

a. Working from the whole ship plan or layout, individual working plans would be developed for the discrete structural assemblies.

b. Working from a whole ship plan or layout, the remaining disciplines would prepare working drawings to reflect the respective installations at the assembly level.

c. These drawings would be combined as required to prepare an assembly top Level drawing, reflecting and coordinating the total work content up to and including the completion of the assembly.

d. All subordinate drawings, such as peice part, panel or sub-assembly plans would be referenced and called for on the discipline assembly-level plan.

e. Final assembly or whole ship integration plans would be prepared, as required to support installations which must be accomplished after the completion of the assembly-joining process, in accordance with the particular method of manufacture.

Development of working plans to the assembly level is considered to be particularly suited to series production since this system achieves the highest degree of representation in plan content to work as actually accomplished in production, particularly when augmented as recommended.

7.7 ADVANTAGES OF RECOMMENDED SYSTEM

In addition to the advantages indicated by the merit value analysis in paragraph 7.4, and the review of various material installation levels in paragraph 7.5, there are certain practical considerations which, when applied to the assembly level drawing, enhance the application of the system to the benefit of the shipbuilding production process:

7.7.1 Use of Three-Dimensional Projections

A recognized departure from traditional shipbuilding plan preparation, is the extensive use of three-dimensional projections or 3/4 views. This practice is highly recommended for series production. Drafting time to accomplish this effort is considered to be minimal when compared to the time saved in production due to faster understanding of the drawing content, and to the benefits realized on each successive ship of the series production contract.

The application of this drafting technique is considered to be particulary complementaly to assembly level plans, since the assembly or any of its subordinate parts represents a realistic scope of work, not too large to be represented, not too small to justify the drafting time required to prepare the projection.

Three dimensional drawings can thus be used to augment:

a. Dimensional control of assemblies or parts (figures 7-2 and 7-3).

b. Installation of secondary items into the hull assembly (figures 7-4 through 7-7).

c. Protective coating applications and masking requirements (figure 7-8).

d. Relationship of subassemblies in making up total assembly (figures 7-9 through 7-11).

e. Unique or special features which are difficult to present utilizing traditional drafting practices.

The use of this technique can also have a considerable effect on the utilization of manpower, since the time required to train personnel in the reading of traditional drawings is greatly reduced by the use of three-dimensional projections.

7.7.2 Pre-Outfitting of Assemblies

In an effort to reduce the span time required for ship completion after launch, continued emphasis is being placed on the pre-outfitting of structural assemblies.

Since the major portion of this effort is accomplished at the assembly level, the development of separate installation drawings by discipline at the assembly level is considered to be most advantageous to the pursuit of these efforts.

The use of a photo-reproducible of the structural assembly drawing may prove to be acceptable as a basis for the development of the pre-outfitting plans, reducing the drafting time required for plan preparation in these areas.

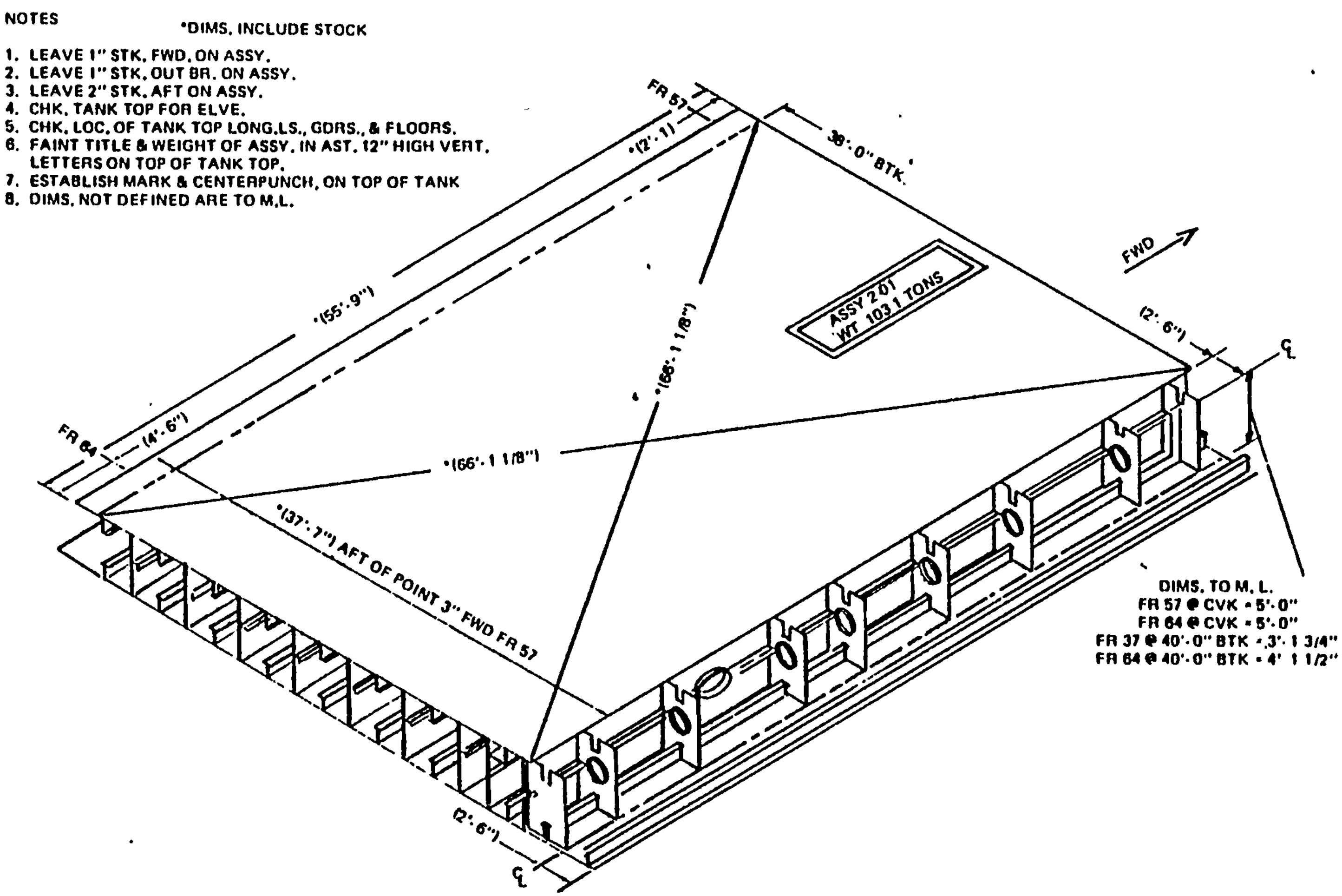


Figure 7-2. Three Dimensional Projection Used for Dimensional Control

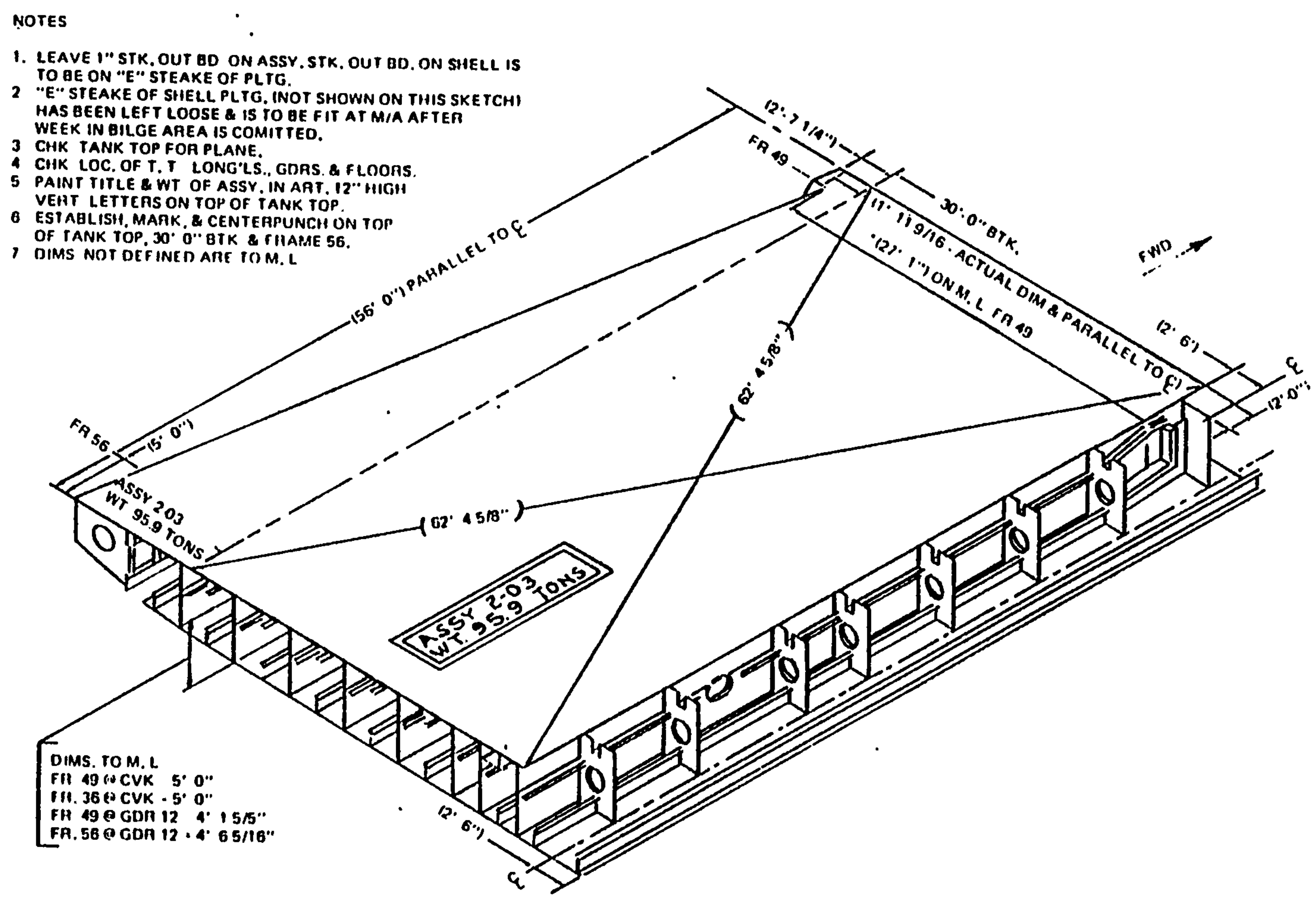


Figure 7-3. Three Dimensional Projection Used for Dimensional Control

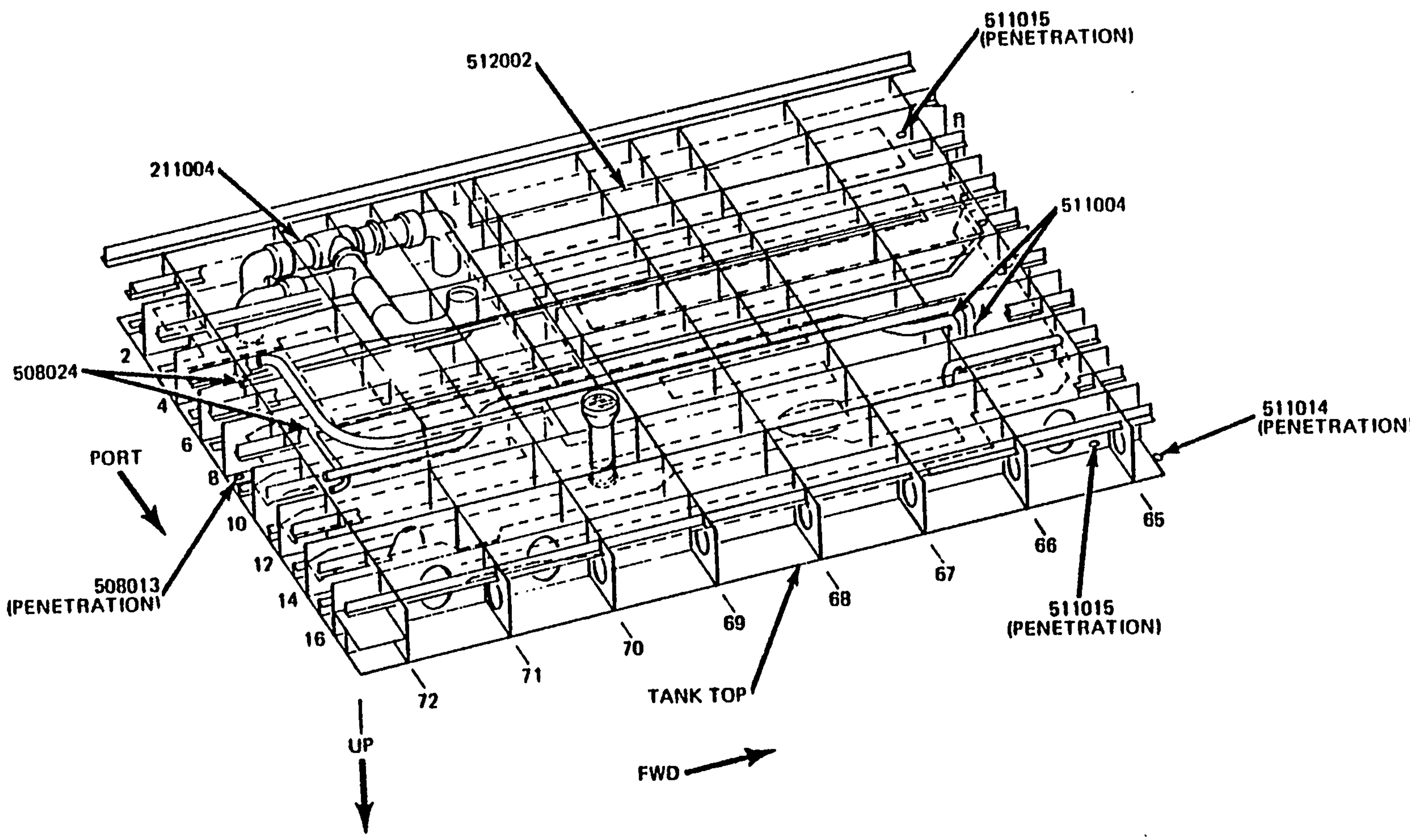


Figure 7-4 Three Dimensional Projection Showing Installation of Secondary Items

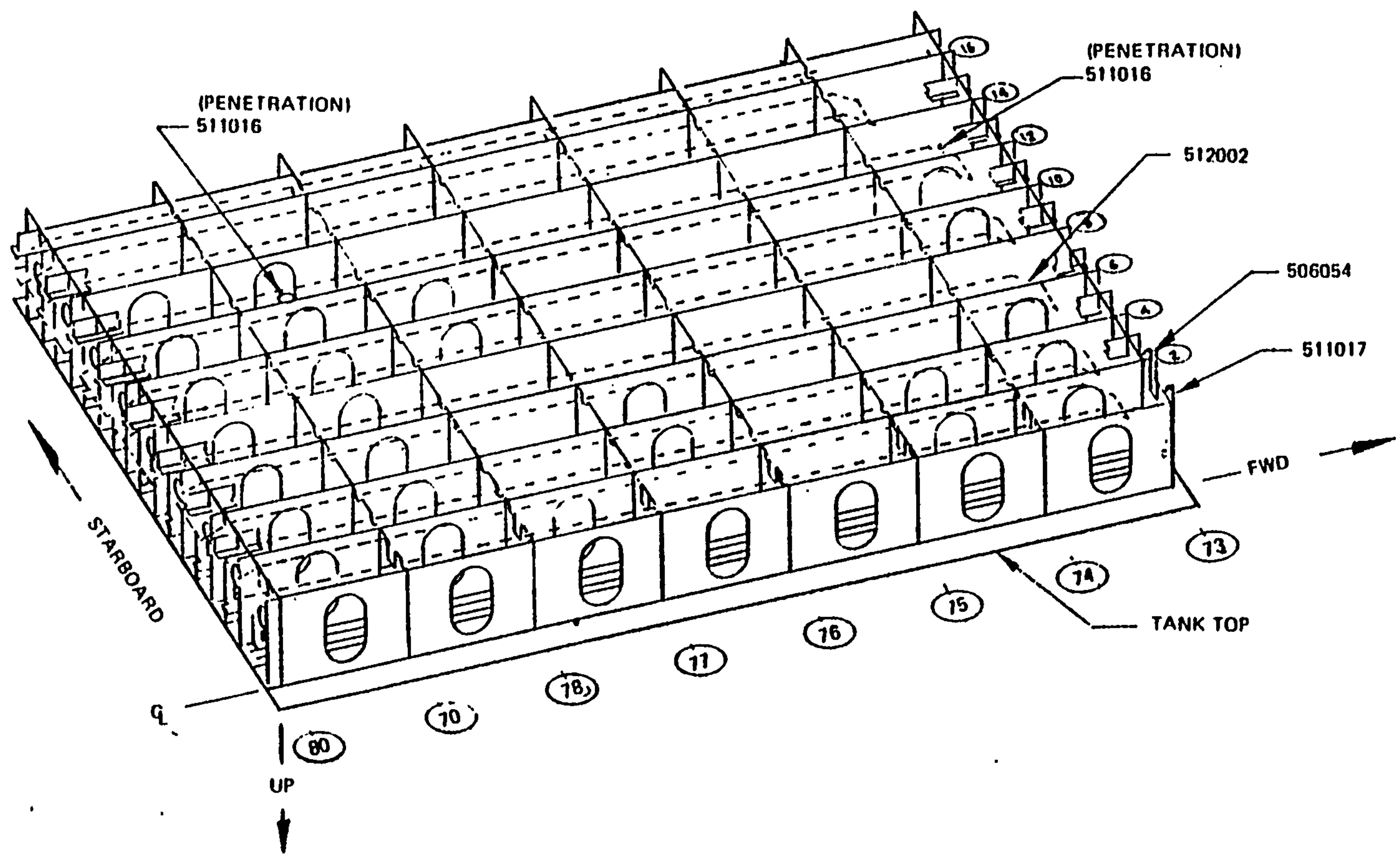


Figure 7-5. Three Dimensional Projection Showing Installation of Secondary Items

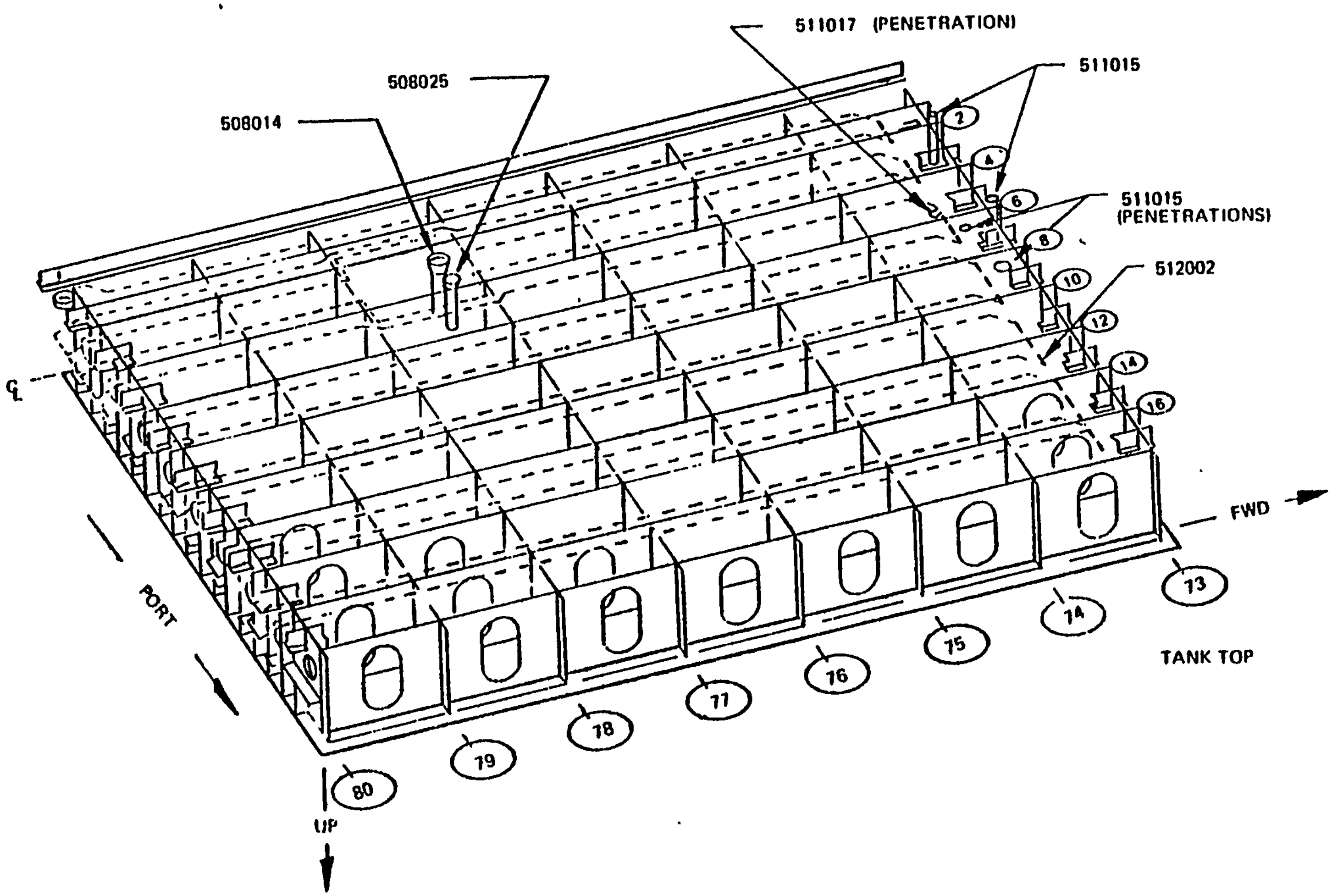


Figure 7-6. Three Dimensional Projection Showing Installation of Secondary Items

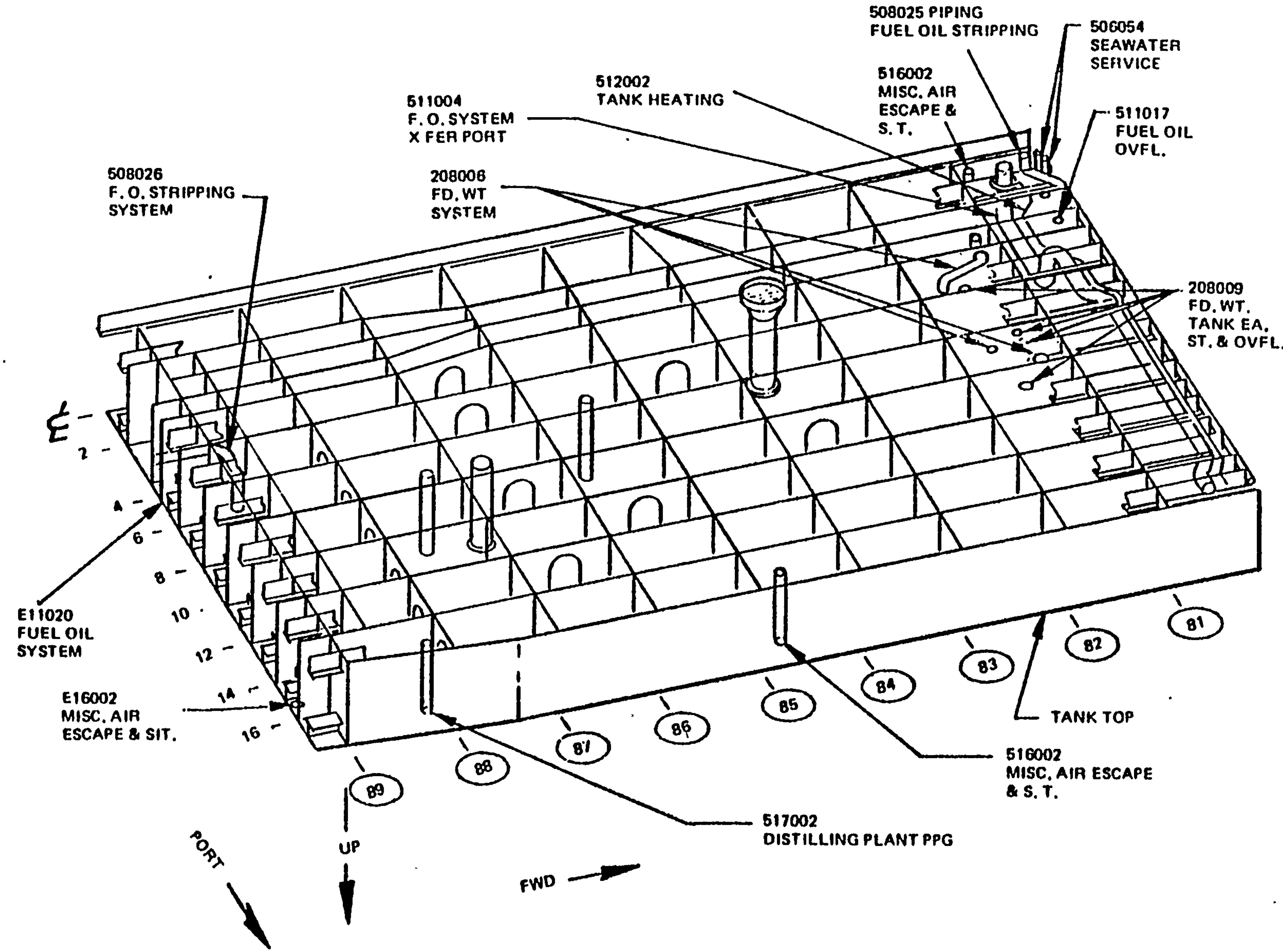


Figure 7-7. Three Dimensional Projection Showing Installation of Secondary Items

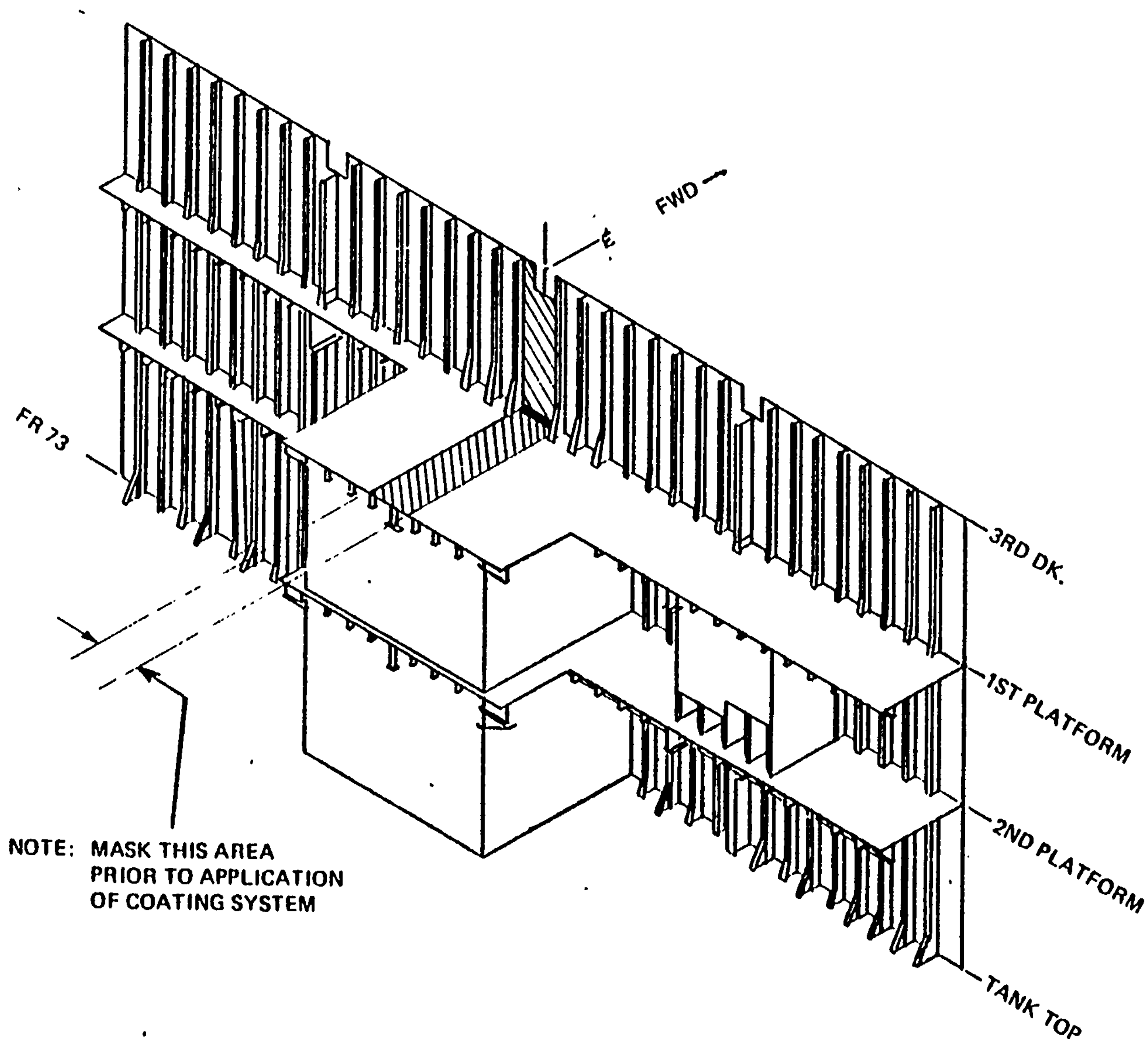


Figure 7-8. Three Dimensional Projection Showing Protective Coating Application

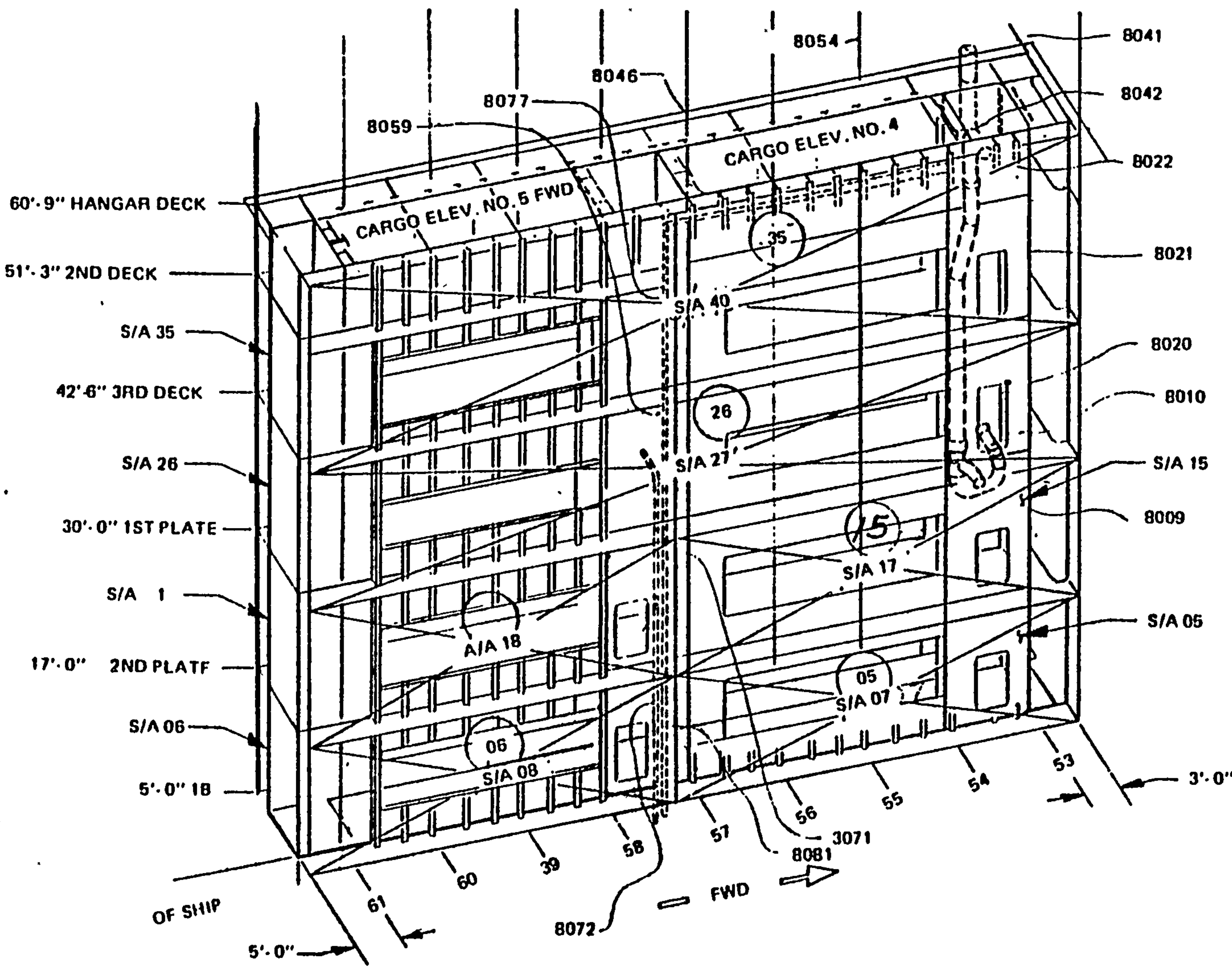


Figure 7-9. Three Dimensional Projection Showing Relationship of Subassemblies

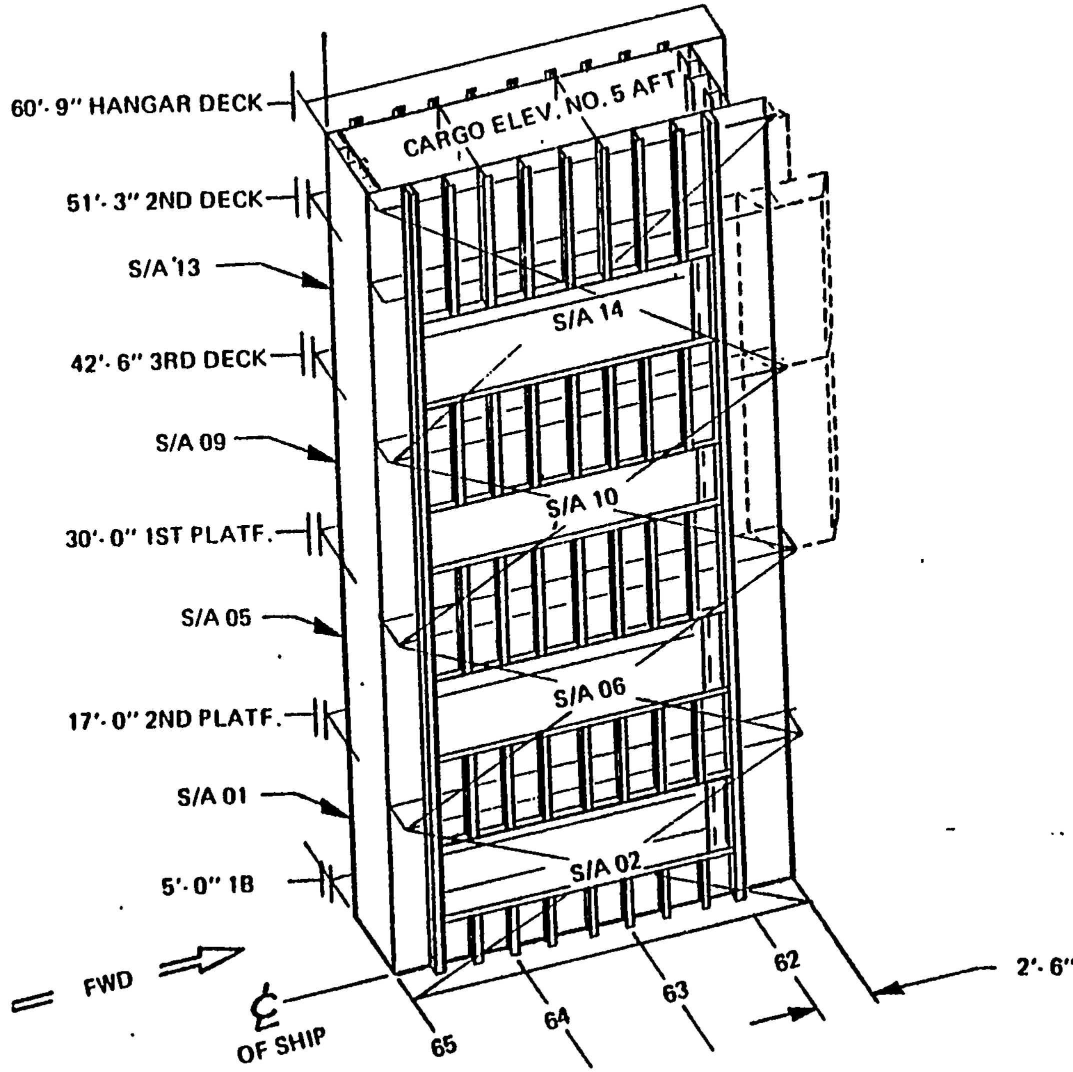


Figure 7-10. Three Dimensional Projection Showing Relationship of Subassemblies

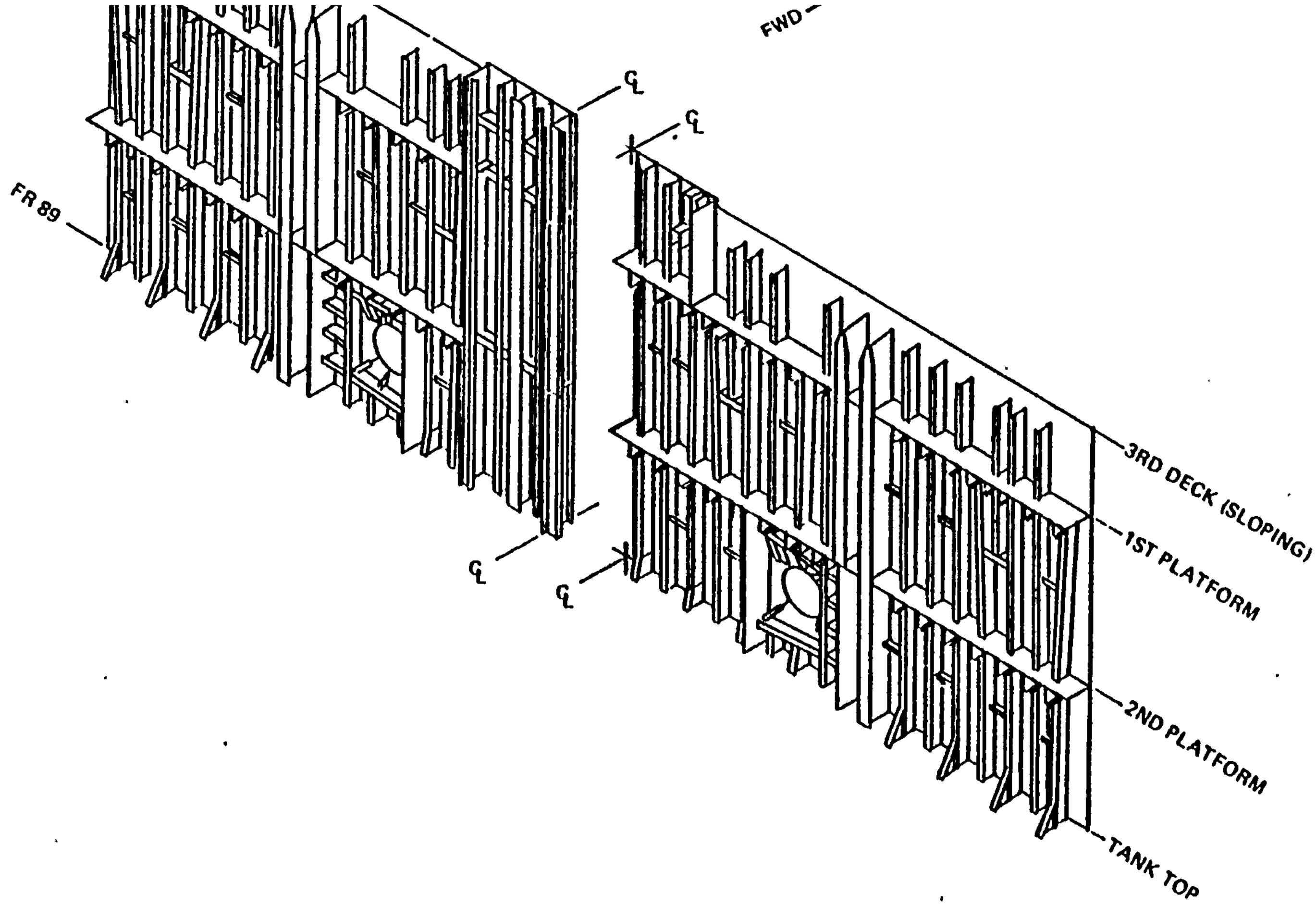


Figure 7-11. Three Dimensional Projection Showing Relationship of Subassemblies

7.7.3 Material Identification

With the production of a series of ships being accomplished concurrently in various areas of the shipyard, material identification and correlation of fabricated parts to the working plan becomes a significant requirement.

A part numbering system which allows for identification of a part in terms of intended use is a very desirable feature of the material control system. The assembly level plan is adaptable to this type of numbering system. See figure 7-12.

By coordinating the assignment of the assembly drawing number with the assignment of piece part numbers, a part can be identified in terms of its intended use and can be related to the drawing which generated the requirement for the part.

This coordinated numbering system may appear to be ambitious when consideration is given to the number of parts which make up a total ship, but when viewed in the proper perspective of series production, the effort required for implementation will certainly become more attractive.

7.8 SUMMARY

While the results of this study effort are concluded with a recommendation for adaptation of an assembly-level working plan system, it is fully recognized that departures from existing systems are not effected easily, nor are changes from existing methods always successful in achieving the desired improvement.

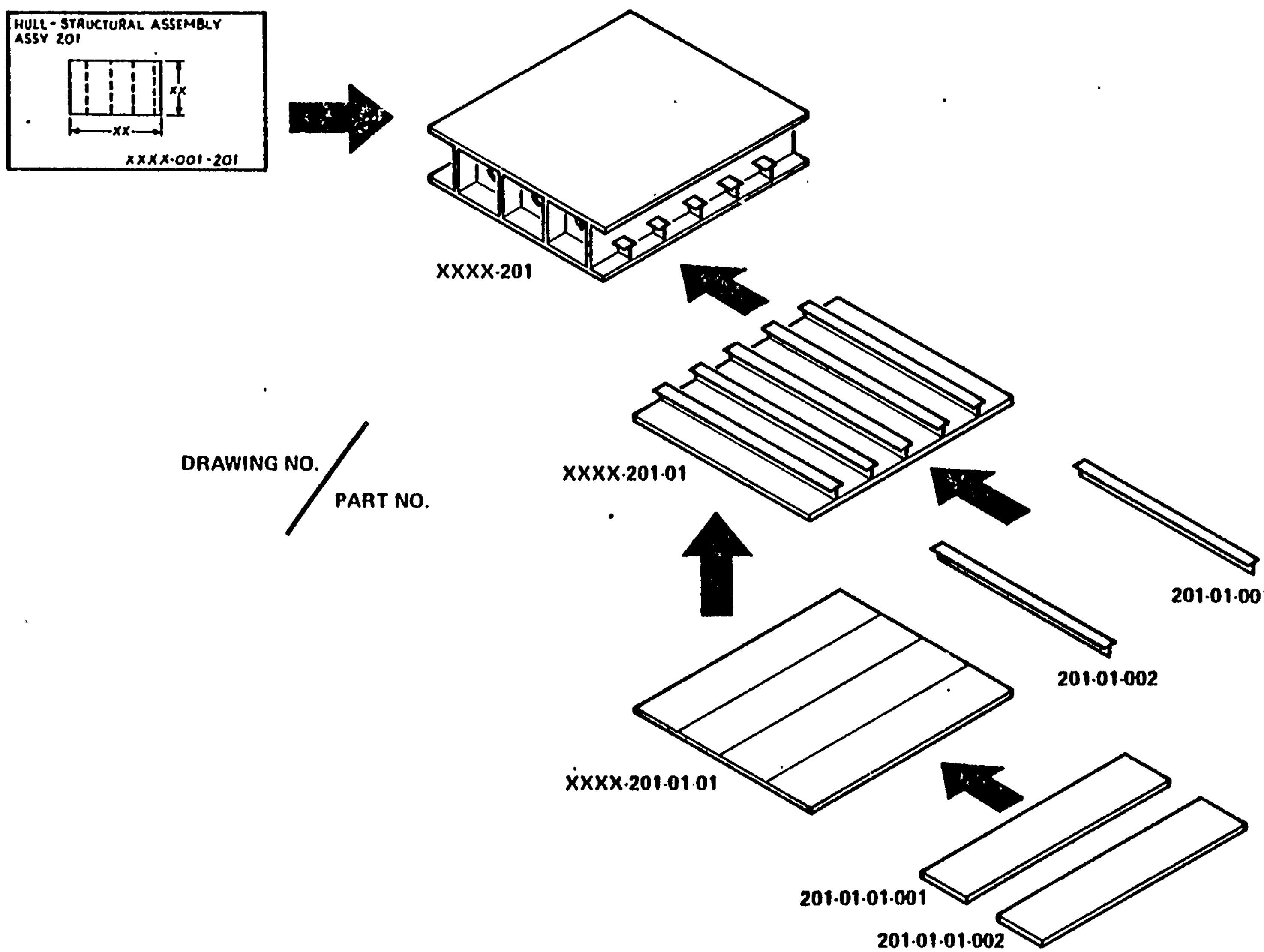


Figure 7-12. Indentured Part Numbering System