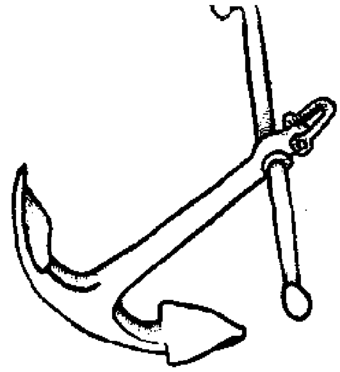
MASGC-T-73-010

Southern Marine Systems



MISSISSIPPI STATE UNIVERSITY
COLLEGE OF ENGINEERING

PRESENTED BY

RICHARD L. BUCKHEISTER
MICHAEL D. HODGES
S. E. RUSH
ROBERT D. WALKER

PRESENTED AS PARTIAL REQUIREMENT

FOR COMPLETION OF

MAT 3024, SHIPBUILDING TECHNOLOGY II

OF THE CURRICULUM IN

MARINE ENGINEERING TECHNOLOGY

OF THE

GULF COAST TECHNICAL INSTITUTE

THIS CURRICULUM

IS SUPPORTED IN PART BY

SEA GRANT GH-25

OF THE

NATIONAL SCIENCE FOUNDATION

SOUTHERN MARINE SYSTEMS

by

Richard L. Buckheister

Michael D. Hodges

Shirrell E. Rush

Robert D. Walker

TABLE OF CONTENTS

FORMAL PRESENTATION OF COMPREHENSIVE SHIPBUILDING PROGRAM

During the final semester of the senior year in Marine Engineering Technology a formal presentation is made by the graduating seniors of a comprehensive shipbuilding program. This "program" or "project" consists of the development of shipyard oriented activities necessary to the construction and delivery of an assigned series of ships, with an emphasis on the responsibilities of the Engineering Department. A list of these activities is attached.

In order to accomplish the program, the class is divided into teams, representing different shipyards. Each team will then enter into direct competition with the other teams. The preliminary plans given to each team are identical, and work done by each team is normally treated as confidential material until the time of presentation.

Each team decides for itself how the items on the list of activities will be distributed among its members. In this way, individual students may specialize in desired areas of competance. Of course, the efforts of every member must be compatable with the general efforts of the team.

INFORMATION ON SHIP USED FOR SPRING 1970 PRESENTATION

LOA	1149 ft
LBP	1089 ft
beam	156 ft
depth	78 ft
draft	35 ft
displacement	98,850 tons
C_B	.568
C_P	.598
C_M	.949
C_W	.746
C	.760
SHP	165,000 HP
deadrise	2.33 ft
bilge radius	10.00 ft
speed	28 knots
containers	1,812

The ship chosen was designed by students in the Department of Naval Architecture and Marine Engineering at the University of Michigan. The presentation of their preliminary design is the starting point for our development. It is admittedly a "state-of-the-art" vessel with liberal use of high strength steel, gas turbines as main propulsion, relatively complicated cargo handling gear, and very fine hull form. We must therefore apply modern techniques to accomplish the desired result.

WEIGHT ANALYSIS

Light Ship	36,750 LT
Steel Weight (MS),,................	29,333 LT
Machinery Weight	1,037 LT
Hull Engineering & Outfit	6,379 LT
Weight of Containers	54,360 LT
Crew and Stores	40 LT
Wash Water	788 LT
Potable Water	71 LT
Fuel Oil	6,841 LT

SOUTHERN MARINE SYSTEMS INC.

The Southern Marine Systems Shipyard employs the modern production line technique of producing ships. Designed by Richard Buckheister, Dick Hodges, Ned Rush, and Robert Walker, this yard utilizes two building and launch areas in a mass production process. These two building and launch areas give great versatility to the yard as each launch area is capable of producing a 1500 foot ship. Up to four smaller ships may be produced simultaneously. The only requirement is that any two ships being produced simultaneously on the same launch area do not total more than 1500 feet. With this in mind the yard is versatile enough to produce up to four different classes of ships and launch up to four ships per month. With the two launch ways the yard accommodates a minimum number of workers with the tremendous increase in output. This yard employs approximately 15,000 people, the bulk of which are located in the building and launch areas. As the ship moves from station to station instead of the people, each man becomes more specialized in his work. This has produced an excellent learning curve.

Because the yard is capable of producing a lot of ships fast, it is even more beneficial to produce the same class of ship. This saves paperwork in the engineering and material ordering departments. This fits our yard perfectly as the trend is toward larger ships as well as larger contracts. The mass production of ever different classes of ships eventually becomes repititious for all of the yard workers.

The shipyard layout is almost unique in design. The yard employs approximately 600 acres of land surrounded on three sides by deep water. The idea is to produce ships fast and economically. We felt this was best accomplished by centrally locating the storage and building areas. All support areas feed into these two areas from surrounding positions. This saves a tremendous amount of time in material handling. Almost all of the shops are located in the combined shop area which includes; the machine shop, the electrical shop, the pipe shop, the Sheetmetal shop, the carpentry shop, the paint shop, and the maintenance shop. Also located in the combined shop area for safety reasons is the infirmary. Most injuries in a shipyard occur either in the shops or the building areas. Both of these areas have good access to the infirmary. Adjoining each shop is a storage area for that shop. This saves in warehouse area and mainly in material handling. By delivering parts and material directly to their respective shops, valuable manhours are saved. The warehouse will store material which is fed directly to the working areas and keep records on all previous ships. This yard also has a cafeteria which will serve on shifts. There is also ample parking for all employees. To save time and reduce confusion the Engineering building and Administration building are separate. The material flow is good in that it makes the least number of turns and has the minimum break in flow.

The material flow is concise, fast, and very efficient. The yard is programmed to function smoothly as every man has a job to pefform and he must do it or the operation is halted.

Material such as plates and some shapes are received mainly by barge. Steel plates are unloaded off the barges by a magnetic 20-ton gantry crane in the Plate Storage Area. All steel plates and shapes will be stored here. Steel will be shipped regularly to the yard in the sequence of assembly in order to support the construction schedule. Large inventories of steel would only pile up and begin to rust. The Storage Area is a level space where the plates are piled in flat stacks. This method of stacking plates is found to be more efficient than one where the plates are arranged vertically on edge in storage racks. The 20-ton gantry crane which traverses the entire expanse of the Plate Storage Area is fitted with an electromagnet. It also has an adaptable vacuum for aluminum plates. The gantry crane is run by one man. As the plates are received they are stacked in designated piles. The designation mark is often placed on the plate at the steel mill. To facilitate this crane there is a small flat car on rails which serves as a carrier for the plates. The crane takes the plates off the barge and places them on this flat car until it has a load. It then travels to the plate storage location where the crane then lifts the plates off the car and places them in their respective stacks. One man operates this flat car which is self-propelled. As each plate is requested the gantry crane collects the plate from its stack and delivers it to the conveyor-rollers located at the end of the Fabrication Shop.

Once inside the Fab shop the plates are first metal blasted to rid the plate of any dust, mud, or rust which may have deposited on the plate. The metal is very fine and is collected, almost completely, and reused. The amount lost is almost negligable. The plate then continues on the conveyor to the plate straightener where the plate is flattened for easier handling and marking. The next phase the plate goes into the marking gantry. Here the plate is marked for cutting by an automatic marking gantry. The marking gantry is fed computer programming tapes which mark the plate and all penetrations involved. The plate is then marked with its part number manually. This may be easily done by one man right after the marking gantry. Next, the plate is cut by an automatic cutting gantry which not only cuts out each plate and its penetrations but also cuts it into the desired edge preparations. Each cutting location is fitted with three cutting torches as each plate is cut with the correct edge preparation in a single pass.

Now we have particular plates and pieces with all penetrations, edge preparations, and numerical identification already completed and ready to assemble. The flat plates are moved directly to the Panel Shop. The curved plates are transported to another location in the Fab shop where a large press cold bends them to the specified shapes. This press is a capacity that it is capable of bending 6" plates of steel to a 4' radius and have almost no deformation in the thickness. It is also capable of making double bends. There are, however, some plates which cannot be curved correctly by the large press and require heat to be used. These are generally very irregular shapes which cannot be fitted into the press. There is a small furnace at the last station in the Fab shop to accommodate these irregular shapes. The curved plates are then transported to the Shell Shop via large flat bed trucks. These trucks also transport the flat plates and shapes to the Panel Shop.

In the Panel Shop the plates and shapes are welded by an automatic gantry welder which is run by computer tapes also. This type of welding is very inexpensive, efficient, and produces a good quality weld. Since all the welds are straight line welds, it can be very fast. The plates are first welded on the back side or side opposite the stiffeners and girders. The sub-assembly is then flipped over by a large crane which can handle plates in widths up to 56' by 56'. The back side is then welded and the stiffeners are welded to the plates. The sub-assembly then continues out on the Panel Shop conveyors.

In the Shell Shop the curved plates are fitted together and welded by hand. The welding gantry would be far too complex to weld curved plates and is omitted. Because there are not nearly as many curved plates as flat plates, the fact that they are welded manually is of little consequence. After the curved plates are welded, the stiffeners are welded to them.

Now we have sub-assemblies coming from both the Panel and Shell Shops. These subassemblies are moved on very large flat bed trucks to the Sand Blasting Shop. Here each subassembly is sand blasted from every angle to a white metal. It remains in this shop until it is completely sand blasted which gets the subassembly very hot.

This takes anywhere from half an hour to two hours depending upon the size and/or complexity of the subassembly. Once the subassembly cools it is moved by the large flat bed trucks to the Paint Shop. The subassembly is raised up into the air for bottom access and completely sprayed with primer. This primer is a quick drying paint and the subassembly is gone in a matter of hours. Just before leaving the Paint Primer Shop, the subassembly is numbered by the Numerical Identification Department. From here the subassembly is moved to the Storage Area by the large flat bed trucks.

When the subassembly is needed it is moved by large 200-ton gantry cranes to the assembly erection site. Each subassembly is fitted together to produce assemblies. These assemblies are then moved to the Module Erection location where they are put together. These modules are the last step before the ship takes shape. The modules are completed and moved to the Module Assembly area. This is the final phase where the ship is assembled as the modules come together to form the ship which is ready for launching. There are many small pieces and equipment which are installed before launching and are handled by small 15-ton portable cranes. These cranes are on large wheels and are extremely versatile. All support areas such as shops feed the building area via small trucks. The large 200-ton cranes are capable of making 90° turns proving their versatility.

CONTRACT PROPOSAL

A contract is a formal agreement between two or more parties, especially one that is legally binding. To be legally binding a contract must contain an offer, acceptance, obligations of each party defined, and adequate consideration. A contract can be oral, hand written, or typed. Normally it is typed and signed for record or proof.

Quite often a need arises for a change. There must be an article on changes with ship's contracts. The types of changes which may be made under change articles within the scope of the contract are drawings, designs, and specifications. Only a contracting officer has the authority to order or authorize a change. The shipyard should furnish its legal department with full, complete, accurate, and timely information with respect to changes. Requests for changes are generally made for betterment, correction, and Waivers or Deviations. Where a change is requested a preliminary estimate of cost should be submitted. The shipyard must keep the best possible records of changes, especially these which are being requested because of verbal or other instructions other than formal change orders.

When a change order occurs an equitable adjustment must be made. An equitable adjustment is the difference in cost of performance of the work as changed by the change order and the work had the change order not been issued plus an allowance for profit.

There are many types of delays involved in building ships. The "Force Majeure" type are acts of God such as weather, strikes, etc. The acts of government include plan approval delays, change orders, government furnished property, priorities, stop work or suspension orders, etc. Vender delays must be excusable for the vender also. Difficulties in meeting specifications requiring advancement in State of Art delays are also excusable delays. Notification is the major key to having delays recognized as excusable. Any suspected delaying matter should be brought to the attention of the legal department so they may immediately give timely notice to the customer and cooperate in seeking solutions and providing documentation of the amount of delay incurred. It is also essential that the actual amount of delay caused to the ultimate delivery schedule be documented.

The importance of delay determination, notification, and documentation is a direct result of money. A company may be subject to penalties including liquidated damages, termination for default, damages for breach of contract, and refusal to award other contracts.

There are two major types of contracts which are fixed price contracts and cost reimbursement contracts. To further define types of contracts each of these types are broken down into detailed types. There are three types of fixed price contracts designed to facilitate proper pricing under varying circumstances. These three types are:

1. firm fixed price contract - this is the type most preferred by the government because the maximum risk is placed on the contractor.

2. fixed price contract with escalation - this type provides for an upward or downward adjustment of contract price.

3. fixed price incentive contracts - this type provides for upward or downward adjustment of the contract price by a formula based on the relationship of the negotiated final cost to an initial target cost.

At the outset the government or owner and contractor negotiate a target cost, a target profit, a price ceiling, and a formula for establishing final profit and price. After performance of the contract, the final cost is computed and audited. The final contract price is then established in accordance with the formula. Where the final cost is less than target cost, the formula provides a final profit greater than the target profit should be. Conversely, where final cost is more than target cost, application of the formula results in a final profit less than the target profit, or even a net loss.

There are also three cost reimbursement contracts which favor the company. They differ from fixed price contracts in that a contractor is reimbursed for the allowable costs that he incurs up to an amount originally estimated for contract performance. Risk to the contractor is minimized since he is generally under no obligation to continue with contract performance after the total estimated cost of the contract has been expended.

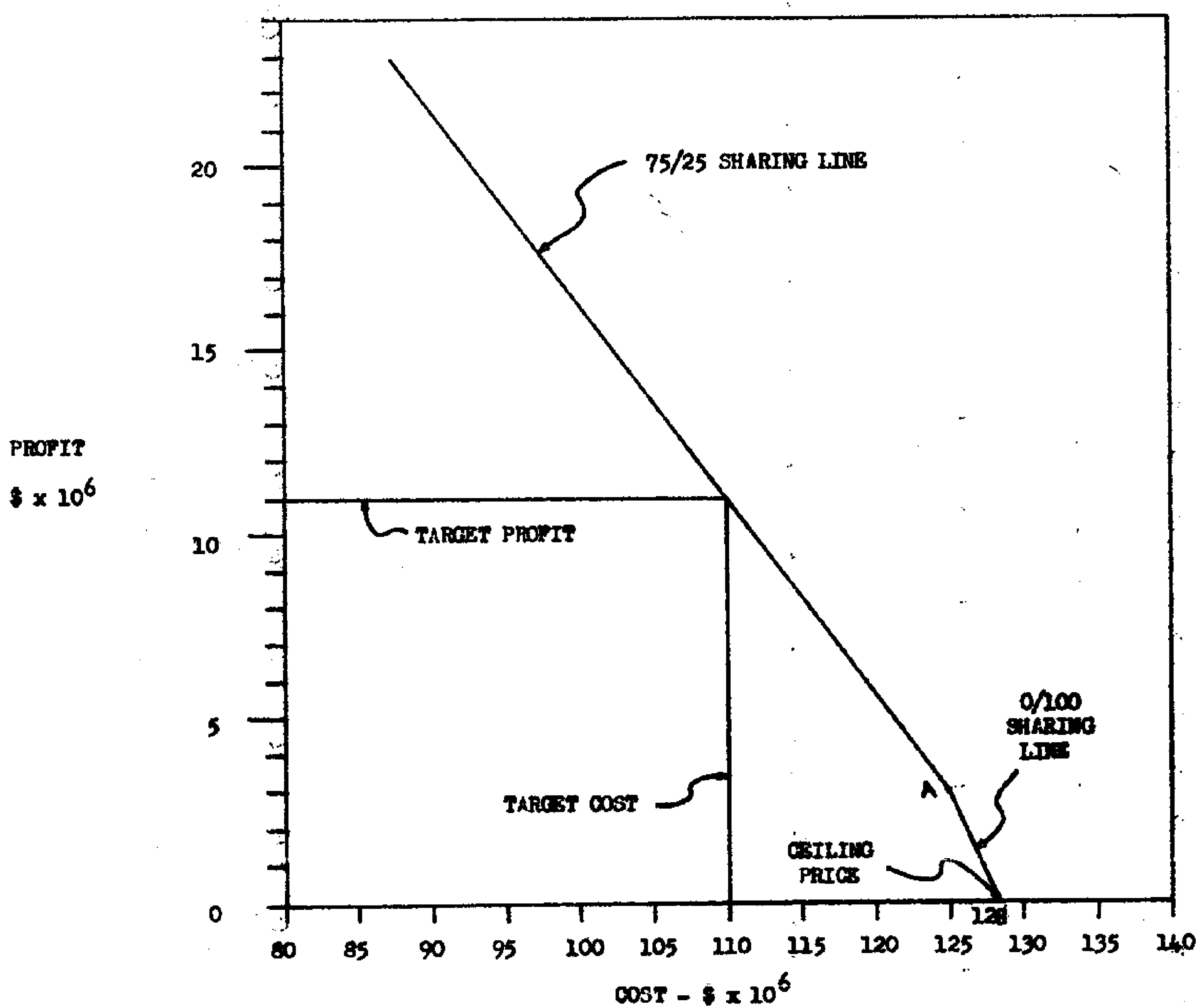
Cost reimbursement type contracts are not to be used except when it is likely that it will be less costly to the owner, or when it is impractical, jue to the nature of the supplies or services being procured, to use other contract types. These three types are:

1. cost contract - under this type, the contractor is reimbursed for his allowable cost of performance but receives no fee.

2. cost plus fixed fee contract - this type is the least desirable for the owner since it affords little or no incentive to the contractor for cost reduction. The contractor is reimbursed his allowable costs and is given a fixed fee established at the contract start not to be affected by actual costs.

3. cost plus incentive fee contract - this type provides for the initial negotiation of a target cost, target fee and a minimum and maximum fee together with a fee adjustment formula.

The Southern Marine Systems Shipyard proposes a fixed price incentive contract with a 75/25 sharing line. The target cost is set a 110 million dollars while the target profit is set at 11 million dollars or 10% of the target cost. The ceiling price is 128 million dollars. We propose a contract of this type because we feel we can meet the schedules and observe a maximum profit. We feel the contract will be ours for this contract is attractive from the owners point of view. It will result in two ships produced in a minimum of time resulting in maximum return.


PROFIT
$ x 10^6
20
15
10
5
0
75/25 SHARING LINE
TARGET PROFIT
TARGET COST
A
0/100
SHARING
LINE
CEILING
PRICE
128
80
85
90
95
100
105
110
115
120
125
130
135
140
COST - $ x 10^6

PRELIMINARY PLANNING

Preliminary Planning is an organizing procedure to construct a ship. It involves a series of steps to see just what the shipyard has or needs to complete a particular contract. There are three basic necessities to preliminary planning which are; make a shipway schedule chart, make launching calculations, and check for adequate crane capacity. To make a shipway schedule chart the shipyard must first establish dates for keel laying, launching, and delivering. There are several factors affecting these key dates. Facility requirements of the shipyard should be adequate to handle the contract or else steps should be taken to get proper facilities. This includes items such as heavy or light machinery, space in which to build subassemblies, and launching facilities. Manpower requirements must also be checked for the yard may be lacking in technical aspects such as welding, joining procedures, and new products in machine applications such as bending presses. The general labor situation should also be checked. If the shipyard is having labor problems, they should allow for this in their time estimates. If a shipyard is in good condition with the labor unions they will probably make a closer estimate on the key dates. The raw material market should also be observed for the shipyard would not set a date for delivery knowing the steel for the ship might not arrive in time to build it. This is a hard item as the shipyard may not know when a steel company will have a strike leading to postponement of their launching date. In conclusion, all of these aspects should be estimated as accurately as possible keeping in mind that they are only as good as the people you depend upon. These people, such as vendors, may have difficulties beyond their control which will affect the key dates in the shipyard. All of these factors must be considered in bidding on contracts. No shipyard wants to pay penalties when it could have been avoided by a little more research on one of the previously mentioned areas.

In making bids on contracts or working preliminary plans some method of procedure should be followed in order to complete a bid with accurate dates and figures. The following is a typical Preliminary Planning Procedure:

I. Establish Key Dates.

II. Make a chart for the Key Dates.

III. Make consideration for farm in and/or farm out work.

IV. Check plant facilities to see if the yard needs:

- A. any new machinery
- B. new type of workers
- C. more employees
- D. more warehouse space
- E. more storage space
- F. heavier lifting equipment

V. Make a detailed construction schedule.

- A. including all important tasks with start and completion dates
- B. should be capable of easy modification to reflect actual conditions
- C. most yards now use the critical path method

VI. Make orders for long lead time material such as boilers, reduction gears, etc.

VII. Engineering and/or design work must be scheduled to support both the procurement and production efforts.

- A. This includes a working plan schedule consisting of structural, machinery, piping, ventilation, electrical, and joiner plans.

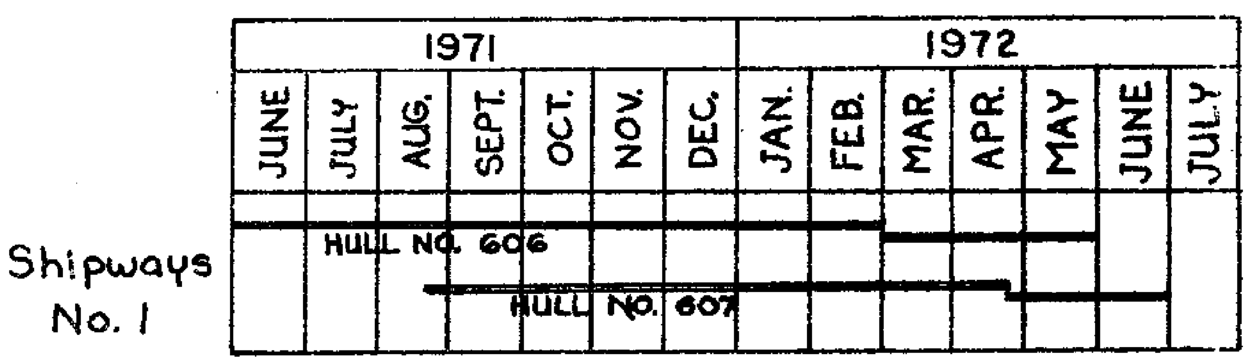
VIII. Change Order Procedure.

IX. Plan an erection sequence.

The Shipway Schedule Chart listed in the Preliminary Planning Schedule is a chart showing the key dates in a contract. There are actually two charts involved. One chart shows the actual dates of keel laying, launching, and delivering for each hull. The other chart is actually a bar graph plotting the hull completion sequence versus time.

In the Southern Marine Systems Shipyard the new system has a "plate cutting" date rather than a keel laying date. Since this yard does not actually lay a keel, we set the corresponding date to the time when the first plate of a ship is cut in the Fab Shop. The launching and delivering dates are the same. Our schedule is as follows.

ship	#1	#2
fabrication	1 Feb 71	22 April 71
keel laying	1 June 71	22 August 71
launching	1 March 72	1 May 72
delivering	1 June 72	1 July 72



COST ESTIMATE

The building costs for the ship as a whole are divided into different catergories. These are as follows:

(1) Hull structure cost

(2) Outfitting and Hull Engineering costs

(3) Propulsion machinery costs

(4) Miscellaneous costs

(5) Overhead costs

(6) Profit

Each category is further broken down to determine the total building costs of the vessel.

The hull structure cost is based on an average steel material cost of $264 per long ton net weight. Included in this is transportation and covers special shapes, welding rods, castings, forgings, and a nominal quantity of aluminum and special steels as well as ordinary shipbuilding steel.

Hull Structure Cost

steel material cost = W_s x cost per long ton net weight

= 29,333 x $264 =$7,740,000

Outfitting Costs

outfitting material cost = W_o x material cost per long ton

= 2,900 x$980 = $2,840,000

Hull Engineering Costs

hull engineering costs = W_{HE} x material cost per long ton

= 3,479 x $2700 = $9,400,000

Machinery Propulsion

In order to estimate the machinery propulsion costs, conventional empirical formulas for steam propulsion were used. Since our ship is gas turbine propelled an estimate was made from these of the material costs.

$$\text{material costs} = \$416{,}000\left(\frac{\text{shp}}{1000}\right)^{.6}$$

$$= \$416{,}000\left(\frac{165{,}000}{1000}\right)^{.6} \times 0.8$$

$$= \$7{,}110{,}000$$

Miscellaneous Costs

All of the foregoing gosts have been confined to specific parts of the ship. The miscellaneous, or nonweight costs, must also be considered. In order to estimate the cost, the subtotal of material costs for structure, outfitting, hull engineering, and machinery were increased 10 per cent.

miscellaneous costs = \$2,709,000

Similarly, labor costs are increased by about 33 per cent for miscellaneous labor.

labor costs = \$929,000

Overhead Costs

Estimating the overhead is approximated as a percentage of labor cost. The ratio of overhead to labor was approximated to be 70%. This value is particularly sensitive to the level of work and to the level of investments in labor-saving devices.

overhead costs = \$13,029,000 x 70% = \$9,125,000

Profit

Profit was calculated as a percentage mark-up of the summation of all the material, labor, and overhead costs. This was estimated to be 10%.

profit = $5,500,000 per vessel

Estimating

Estimating is an independent department reporting to top management because of the nature of its work and the company confidential information handled. The functions of the Estimating Department covers three broad areas: cost estimating, preliminary budgets, and contract administration.

Labor estimates are prepared from contract plans, specifications, and material pick-off quantities. Estimated material prices which are not covered by vendor quotations are assigned from current estimating pricing data. In general yard labor is summarized by system in accordance with type of work center or trade.

MAN-HOUR ESTIMATES

Man hour estimates are calculated in a manner similar to that of cost estimates, using empirical formulas. These estimates are broken up as follows:

Hull Structure

$$MH = c\left(\frac{W_S}{1000}\right)^{.85}$$

W_S - net weight of steel in long tons

c - coefficient based on an efficient yard

$$= 68,000\left(\frac{29,333}{1000}\right)^{.85}$$

$$= 1,198,000$$

Outfitting

$$MH = \left(c\frac{W_O}{100}\right)^{.9}$$

W_O = net weight of outfitting in long tons

c - coefficient of average value

$$= \left(20,000\ \frac{2900}{100}\right)^{.9}$$

$$= 358,500$$

This breakdown assumes no subcontracting of deck covering or joiner work.

Hull Engineering

$$MH = \left(c\ \frac{W_{HE}}{100}\right)^{.75}$$

W_{HE} = weight of hull engineering items in long tons

c - coefficient

$$= \left(51,000\ \frac{3479}{100}\right)^{.75}$$

$$= 1,779,000$$

Machinery

$$MH = \$24,000\left(\frac{165,000}{1000}\right)^{.6} \times 50\%$$

$$= \$514,000$$

The total cost of the vessel was based on an average hourly rate of $3.75.

total cost per vessel = $55,000,000

OFFSETS

This is a table of offsets set up for our shipyard. We give dimensions in feet, tenths of feet, and hundredths of feet. This differs from the conventional method of giving offsets in feet, inches, and eighths of an inch. (Example: 21-5-6 which reads as 21 feet, 5 inches, and 3/4 of an inch) The reason for this difference in dimensioning is because of our modular construction and numerically controlled equipment which operates using this numbering system.

STATION 0

Waterline	Distance Off Centerline	Distance Off Baseline
4'	3.00'	4'
8'	3.45'	8'
16'	1.95'	16'
24'	0.84'	24'
32'	0.00'	32'
40'	0.75'	40'
48'	1.85'	48'
56'	3.00'	56'
64'	4.64'	64'
72'	6.98'	72'
80'	9.98'	80'
88'	15.00'	88'
93'	19.25'	93'

STATION 1

4'	6.50'	4'
8'	6.98'	8'
16'	6.72'	16'
24'	6.50'	24'
32'	8.00'	32'
40'	9.75'	40'
48'	11.62'	48'
56'	14.20'	56'
64'	17.50'	64'
72'	22.00'	72'
80'	27.98'	80'
88'	34.25'	88'
90.25'	36.40'	90.25'

STATION 2

Waterline	Distance Off Centerline	Distance Off Baseline
4'	10.24'	4'
8'	11.80'	8'
16'	13.95'	16'
24'	15.50'	24'
32'	17.00'	32'
40'	19.54'	40'
48'	22.49'	48'
56'	26.00'	56'
64'	30.46'	64'
72'	36.34'	72'
80'	44.00'	80'
87'	51.82'	87'

STATION 3

Waterline	Distance Off Centerline	Distance Off Baseline
4'	15.00'	4'
8'	19.00'	8'
16'	22.45'	16'
24'	25.45'	24'
32'	28.00'	32'
40'	30.25'	40'
48'	34.98'	48'
56'	38.46'	56'
64'	43.25'	64'
72'	48.70'	72'
88.5'	54.00'	88.5'

STATION 4

Waterline	Distance Off Centerline	Distance Off Baseline
4'	21.62'	4'
8'	28.00'	8'
16'	33.99'	16'
24'	37.75'	24'
32'	41.00'	32'
40'	44.42'	40'
48'	48.00'	48'
56'	51.36'	56'
64'	55.98'	64'
72'	59.25'	72'
78.47'	62.50'	78.47'

STATION 5

Waterline	Distance Off Centerline	Distance Off Baseline
4'	30.00'	4'
8'	37.50'	8'
16'	45.20'	16'
24'	50.00'	24'
32'	53.25'	32'
40'	56.47'	40'
48'	59.50'	48'
56'	62.20'	56'
64'	65.00'	64'
72'	67.43'	72'
78.20'	69.50'	78.20'

STATION 6

Waterline	Distance Off Centerline	Distance Off Baseline
4'	38.00'	4'
8'	48.00'	8'
16'	56.44'	16'
24'	61.00'	24'
32'	64.00'	32'
40'	66.15'	40'
48'	68.00'	48'
56'	70.00'	56'
64'	71.82'	64'
72'	73.34'	72'
78'	74.75'	78'

STATION 7

Waterline	Distance Off Centerline	Distance Off Baseline
4'	50.00'	4'
8'	58.25'	8'
16'	65.15'	16'
24'	69.25'	24'
32'	70.97'	32'
40'	72.40'	40'
48'	73.75'	48'
56'	74.56'	56'
64'	75.25'	64'
72'	76.00'	72'
78'	76.58'	78'

STATION 8

Waterline	Distance Off Centerline	Distance Off Baseline
4'	62.00'	4'
8'	68.50'	8'
16'	74.00'	16'
24'	75.50'	24'
32'	75.99'	32'
40'	76.20'	40'
48'	76.50'	48'
56'	76.75'	56'
64'	77.00'	64'
72'	77.25'	72'
78'	77.50'	78'

STATION 9

4'	72.00'	4'
8'	76.00'	8'
16'	77.20'	16'
24'	77.65'	24'
32'	77.70'	32'
40'	77.75'	40'
48'	77.80'	48'
56'	77.85'	56'
64'	77.90'	64'
72'	77.95'	72'
78'	78.00'	78'

STATION 10

4'	74.25'	4'
8'	77.25'	8'
16'	78.00'	16'
24'	78.00'	24'
32'	78.00'	32'
40'	78.00'	40'
48'	78.00'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 11

Waterline	Distance Off Centerline	Distance Off Baseline
4'	74.00'	4'
8'	77.00'	8'
16'	78.00'	16'
24'	78.00'	24'
32'	78.00'	32'
40'	78.00'	40'
48'	78100'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 12

4'	68.20'	4'
8'	74.15'	8'
16'	77.50'	16'
24'	78.00'	24'
32'	78.00'	32'
40'	78.00'	40'
48'	78.00'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 13

4'	59.00'	4'
8'	68.00'	8'
16'	75.80'	16'
24'	77.50'	24'
32'	78.00'	32'
40'	78.00'	40'
48'	78.00'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 14

Waterline	Distance Off Centerline	Distance Off Baseline
4'	43.00'	4'
8'	56.50'	8'
16'	70.00'	16'
24'	75.45'	24'
32'	77.20'	32'
40'	78.00'	40'
48'	78.00'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 15

.40'	3.00'	.40'
4'	24.00'	4'
8'	40.75'	8'
16'	60.50'	16'
24'	71.50'	24'
32'	75.50'	32'
40'	77.20'	40'
48'	77.85'	48'
56'	78.00'	56'
64'	78.00'	64'
72'	78.00'	72'
78'	78.00'	78'

STATION 16

4.5'	3.00'	4.5'
8'	17.00'	8'
16'	45.00'	16'
24'	62.50'	24'
32'	71.00'	32'
40'	75.00'	40'
48'	76.85'	48'
56'	77.46'	56'
64'	77.75'	64'
72'	77.75'	72'
78'	77.75'	78'

STATION 17

Waterline	Distance Off Centerline	Distance Off Baseline
12'	3.00'	12'
16'	22.00'	16'
24'	49.00'	24'
32'	64.00'	32'
40'	71.00'	40'
48'	74.40'	48'
56'	75.95'	56'
64'	76.90'	64'
72'	77.00'	72'
78'	77.25'	78'

STATION 18

21.75'	3.00'	21.75'
24'	22.00'	24'
32'	54.98'	32'
40'	65.50'	40'
48'	70.00'	48'
56'	72.99'	56'
64'	74.40'	64'
72'	75.00'	72'
78.25'	75.50'	78.25'

STATION 19

28.50'	0.00'	28.50'
32'	41.00'	32'
40'	58.00'	40'
48'	64.00'	48'
56'	67.00'	56'
64'	69.00'	64'
72'	70.25'	72'
78.45'	71.10'	78.45'

STATION 20

33'	0.00'	33'
40'	50.00'	40'
48'	56.50'	48'
56'	60.30'	56'
64'	62.75'	64'
72'	64.50'	72'
78.50'	65.90'	78.50'

GENERAL ARRANGEMENTS

The general arrangements for this ship present some unique problems because of the cargo handling system. First, there could be no longitudinal deck beams because of the monorail cranes; thus the hatch covers have to span the entire cargo hold. The container cranes require a 30 foot minimum clearance above the main deck thus requiring the placement of the bridge completely aft. The forward structure is, therefore, limited to a maximum of 30 feet.

The hold arrangement was determined such that the best possible arrangement of containers could be obtained. Because of the possibility of damage to containers caused by shipping water over the bow, no containers were placed on deck for holds #1 and #2. In addition, the forward bulwark was extended past the forecastle deck to provide added protection for the containers. The ship carries 1,812 8' x 8.5' x 40' containers weighing 54,360 long tons.

The machinery space is located approximately three-quarters aft because of the hull form and the necessity of using triple screw propulsion. Above the machinery space (which is 100' long) we located the engine intakes and the quarters for the machinery officers and crew. Aft of the cargo holds, the deckhouse contains the messrooms, deck officers' and crews' quarters, and the navigation bridge. The bridge deck is located high enough to provide a view of the forecastle deck over the containers above main deck level. The quarters arrangements were determined from present practice using the ABS rules that were applicable.

The drawing shown is typical of the general arrangement of the ship, giving the inboard and outboard profiles and a plan view of the cabin deck. The cabin deck was also used for a typical airconditioning installation.

ERECTION SEQUENCE OF THE SHIP

The ship is broken down into six basic modules. The modules are the largest existing elements of the ship before the actual formation of the ship. Since each module cannot be exactly the same in construction, some modules should be started earlier as they are more complicated. These complicated modules consist of bow, stern, and machinery modules. The machinery space module will be designated as module #1 since it is the most complicated. Following the machinery space module, the order of construction will be: the stern module, #2; the bow module, #3; and then modules #4, #5, and #6 will be started simultaneously since they are mainly cargo hold modules.

The stern module, #2, is very complicated in that it contains the propeller, shafting, rudder, steering gear, aft deckhouse, and multitudes of curved plates. The bow module, #3, is started next since it contains anchor handling equipment, fore peak, and critical curved plating and bulkheads such as the collision bulkhead. The remaining modules are mostly cargo holds with some curved plating.

Once the modules are completed they are rolled into the erection area. Here the modules are moved together in their last stage of construction in the building area. They are moved together and connected in this sequence: The bow module, #3, is moved to module #4 and connected at the same time module #2, the stern module, is moved to module #1, the machinery space module and connected. The next step involves the combination of modules #3 and #4 moving to #5 and the combination of modules #2 and #1 moving to

#6. Here they are connected and the aft end of the ship will remain stationary. The final step moves the forward half of the ship to the aft portion where they are connected.

Onee the ship is assembled it is moved out onto the launching pontoon where it is launched.

STEEL ORDERING SCHEDULE

Structural steel is the most important construction material in a modern ocean-going vessel; therefore, it is given priority over other materials. Mill orders are prepared by the Engineering Department. Plate sizes are selected from plans and the plating model. A detailed schedule of erection sequence is prepared and from this schedule plates and shapes are ordered according to their time of fabrication. Steel is ordered 60 to 90 days in advance of its use. This permits Southern Marine Systems to have a minimum steel inventory but at the same time it allows for unavoidable delays in the receiving of the steel.

Physical tests of the steel are conducted at the place of manufacture. These tests must conform to the requirements of the ABS. If the tests are completed satisfactorily, the steel is punch-marked and shipped to Southern Marine Systems' steel receiving area. The steel is then stacked according to thickness, length and width, and grade. Great care is taken to segregate the higher strength steels from regular mild steel because of the serious consequences that would result if the two types were confused.

CRITICAL PATH EXAMPLE FOR

MODULE HOOKUP

There are often several methods of conducting a given task. In order to determine which method is the shortest and fastest, all methods or paths must be recognized, considered, and accepted or rejected. The critical path is the longest and most expensive method of obtaining an objective. Most processes are time limited. Time represents gains or losses in money. Since money is man's medium of values, he will naturally follow the shortest and most economical path in reaching a goal in order to make the most money. There are many tasks throughout the operation of a shipyard involving such complicated tasks as plan schedules to much simpler items as deciding different shifts in the cafeteria.

We have shown the critical path example for module hookup. This involves connecting the modules to complete the ship. There are four basic paths which we may follow in connecting the modules to form the ship. Other paths involve the same time elements except in a different order and may be omitted in this example. The four paths are:

modules are assumed to be spaced at 50'

	Path #1 C stationary	Path #2 #2 stationary	Path #3 #6 stationary	Path #4 #6 stationary
1.	5 - C = 25'	1 - 2 = 50'	1 - 6 = 50'	3 - 4 = 50'
2.	6 - C = 25'	6 - 1 =100'	5 - 6 = 50'	4+3-5 = 50'
3.	4 - 5 = 75'	5 - 6 =150'	2 - 1 =100'	5+4+3-6 = 50'
4.	1 - 6 = 75'	4 - 5 =200'	4 - 5 =100'	2 - 1 = 50'
5.	3 - 4 =125'	3 - 4 =250'	3 - 4 =150'	1+2-6 = 50'
6.	2 - 1 =125'			
TOTAL	500'	750'	450'	250'

Path #1 is omitted because it contains six(6) separate steps and covers 500' in the process. It is obviously too long and would result in a great deal of expense. Path #2 with module #2 stationary will not be used either. It is the critical path as it contains five separate steps and involves 750' of distance. Path #3 is better than the previous paths as it involves 450' in three steps. However, path #4 with module #6 as stationary involves only three steps and 250'. This is obviously the shortest and fastest path. We feel this method may be adequately used in saving both time and money.

SUBASSEMBLY BREAKDOWN

Each module is broken down into assemblies. An assembly consists of subassemblies which in turn are composed of pieces, fabrications, and plates. In this manner each particular piece may be traced back to its origin. In the subassembly breakdown we have taken a subassembly out of a typical cargo hold bulkhead assembly located at the forward end of Module #5. The subassembly is shown with only the pieces required in the construction of that subassembly. Often there are more pieces involved such as brackets which go into construction of assemblies. These brackets are not shown on the subassembly but on the assembly drawing showing all erection components.

The selected subassembly typifies bulkhead construction as it shows plates, stiffners, large webs and flanges, and flat bar stiffners. Each of these pieces is shown in a separate drawing showing its size, dimensions, and type of material. Some pieces are fabrications which consist of two or more pieces. Many angles and tees are fabrications. Each fabrication drawing consists of the pieces required to construct the fabrication. Many items such as angles are used throughout the hull and differ only in length. These pieces are designated as standard drawings and reflect one piece number. Other locations for this piece may refer to that drawing and call for a different dimension.

MATERIAL IDENTIFICATION

Most procedures in our shipyard center around the modern production line technique, as does the material identification system. Raw materials such as plates and shapes are color coded according to their chemical makeup and size. A computer keeps a running inventory of all plates, shapes, and material, the location of each, and quantities available. An identification number is placed on each piece as that piece is cut.

The material identification system employed consists of 13 digits. These 13 digits give the exact location of each piece in the ship.

first 3 digits	hull
next digit	module
next 2 digits	assembly
next 2 digits	subassembly
next 2 digits	fabrication
last 3 digits	piece

Example:

hull number   assembly number   fabrication number

606-1-33-24-10-121

module number   subassembly number   piece number

number designation	range
hull number is a 3 digit number	000 - 999
module number is a 1 digit number	0 - 9
assembly number is a 2 digit number	00 - 99
subassembly number is a 2 digit number	00 - 99
fabrication number is a 2 digit number	00 - 99
piece number is a 3 digit number	000 - 999

In a module drawing the hull number and the module number are the only numbers required. Therefore, the remaining numbers are designated with zeroes. There are also many drawings such as a lines plan drawing which will contain a hull number only leaving the remainder of the numbers as zeroes. For the few drawings occurring in this manner an alphabetical list is composed including all of these "no number" drawings. We feel that this system is adequate for the few drawings of this type pertaining to each ship. This system leads to less confusion for the laymen in the field as they will probably never see any other type of drawing.

PLAN SCHEDULE

When constructing a ship many plans are required. Obviously, some plans will be required at an earlier date than others. A plan schedule is a list of required plans in the correct construction sequence. This enables the various departments in the yard to call for certain plans at the proper time. This insures availability of the plans and reduces the possibility of misplaced or forgotten plans. There are many drawings which are considered standard drawings, such as details, doorways, electrical fixtures, plumbing fixtures, etc. The plan schedule must determine the times when these standard drawings will be available and needed. To prove the necessity of a plan schedule the outfitting crew would not want the portable furniture layouts before the final painting plans.

To further illustrate the necessity for a plan schedule a few drawings or plans are given below in the respective plan schedule:

Cabin Deck General Arrangement Plan

Cabin Dedk Structural Plan

Cabin Deck Penetrations Plan

Cabin Deck Electrical Plans

Cabin Deck Piping Plans

Cabin Deck Ventilation, Heating, and Airconditioning Plans

Cabin Deck Insulation Plans

Cabin Deck Paint Schedule Plan

CERTIFICATION AND GUARANTEES

In compliance with the following regulating bodies; 1) American Bureau of Ships, 2) United States Coast Guard, 3) Unites States Public Health Service, 4) Federal Communications Commission, and 5) the United States Customs Department, Southern Marine Systems will present the following certificates to the owner upon delivery.

1. Seaworthy Certificate
2. Load Line Certificate
3. Anchors, Chains and Towlines Certificate
4. Hull Classification Certificate
5. Loading Manual
6. Machinery Classification Certificate
7. Safety Construction Certificate
8. Inspection Certificate
9. Stability Letter
10. Safety Equipment Certificate
11. Deratization Exemption Certificate
12. Certificate of Sanitary Construction
13. Safety Radiotelegraph Certificate
14. Radio Station License
15. Certificate of Admeasurement
16. Official Number Certificate
17. Home Port Certificate

As a service to the owner, Southern Marine Systems will turn over the following plans and manuals.

1. Master Carpenter's Certificate
2. Certificate of Deadweight
3. Register of Cargo Gear

4. List of Instructions Books

5. List of Plans

6. Trim and Stability Book

In addition to the preceding certificates, Southern Marine Systems will present the owner with a six-month guarantee on performance and against failure of the ship or its equipment as a result of material defects or faulty workmanship.

MIDSHIP SECTION MODULUS

The midship section of the 1,149 foot containership is of standard design except for the box girder, where four vertical longitudinal bulkheads help add to the longitudinal strength. All plating in the box girder is two inch (2") thick 47,000 yield steel. The following table gives some of the properties of this high yield steel.

Mechanical Properties	Mils 16113B Gr HT
yield strength, psi - min.	47,000
tensile strength, psi - min.	88,000 max.
elongation in 8" - %	20
approx. NDT range °F	-60 to 0
available thickness range	no limit
relative cost,[a] Dec. '63, ref. ABS Class "B"	1.67
heat treatment	normalized
weldability	very good
Chemistry	
C	.18 max.
Mn	1.30 max.
P max.	.04
S max.	.05
Si	.15 - .35
Cr	.15 max.
Ni	.25 max.
Mo	.06 max.
V	.02 min.
Cu	.35 max.
Ti	.005 min.

The following are the requirements for both top and bottom of the ship according to the American Bureau of Shipping.

Mild Steel	444,000 in^2ft
HSS (47,000 yield)	329,000 in^2ft

$$SM_{HSS} = SM_{MS} \times Q$$

$$Q = \frac{100,000}{Y + U} \qquad \begin{array}{l} Y = 47,000 \\ U = 88,000 \end{array}$$

$$Q = \frac{100,000}{135,000}$$

$$Q = .74$$

$$SM_{HSS} = 444,000 \times .74$$

$$SM_{HSS} = 329,000 \text{ in}^2\text{ft.}$$

The actual SM calculated by Southern Marine Systems using 47,000 yield steel in the top to the bottom of the box girder, and in the bottom until the upper turn of the bilge for the entire midship .4L was:

$$SM_T = \frac{I}{C_T} = \frac{2(7,136,904)}{41} = 349,000 \text{ in}^2\text{ft}$$

$$SM_B = \frac{I}{C_B} = \frac{2(7,136,904)}{38.68} = 369,000 \text{ in}^2\text{ft}$$

As the figures show the ship is over designed for the midship section modulus is considerably larger than it need be according to ABS. Southern Marine Systems therefore recommends that with the owners permission the midship section be modified to bring it into closer agreement with the requirements of ABS.

WELD INSPECTION

The Southern Marine Systems yard is equipped with a radiographic laboratory which contains X-ray equipment, radioisotopes, ultrasonic testing equipment, a dark room, and equipment for inspecting pipe and small castings. Portable equipment is taken to various parts of the yard to inspect ships and large pieces of work as required. High pressure steam piping joints and pressure vessels of many kinds are required to be radiographed, and much of this inspection is done in the laboratory using large X-ray machines which may be moved about the shielded portion of the laboratory. This is an economic advantage in that it saves time and money. The laboratory is also equipped with surface inspection equipment such as magnetic particle and liquid dye penetrant.

Sub-surface inspection of hull welds is a random type of inspection aimed at maintaining welding quality at a high level. Nondestructive subsurface inspection is accomplished by radiography or by ultrasonic means. Inspection of the welding of the main hull structure is confined usually to the midship three-fifths length and concentrated on the upper strength deck and bottom shell where the plating is over ½-inch thick. According to recent merchant ship specifications, there are 150 to 350 specific inspections for hull welding. Practically all of the locations are in transverse butt welds and weld intersections in the vicinity of the gunwale, bilge, and hatch corners. Southern Marine Systems institutes a systematic inspection as a yard quality control function and, at the same time, as a means of meeting classification society requirements.

Where low alloy steels are used, an increase in the required amount of inspection can be expected.

With respect to locations to be inspected, it is important to note that where extensive deck or shell fractures have occured in butt-welded types of joints, essentially all fractures developed in transverse butt welds; that is, in the highly stressed areas of the deck and bottom, not in fore-and-aft seam welds.

Acceptability of welds is governed by the particular type of weld condition and the location of the weld in the ship. Since classification societies have rather general requirements for guidance of their inspection force as regards subsurface examination, the shipyard and inspection force must exercise careful judgment on many occasions.

Most subsurface inspection of welded plates is up to about 1½-inches thick is carried out with portable X-ray equipment. The results are recorded on photographic film, generally 17 x 4½ in. When the X-ray machine is in operation, the immediate area must be roped off for about a 20 foot radius to keep workers from walking through the radiation zone. As a health precaution, radiographers carry film badges which measure radiation exposure. The badges are checked at frequent intervals.

For inspection of the thicker plates or castings, a radioisotope such as cobalt 60 or Iridium 192 is used. The health precautions are somewhat more restrictive than requirements for X-ray inspection. The inspection results are recorded on photographic film, as in the case of X-ray.

This type of inspection is frequently used for large tubes and pressure vessels. When a butt weld of a large tube of any thickness is required to be radiographed, it may be advantageous to place the capsule in the center of the tube and record the results on photographic film previously placed all around the butt weld.

Ultrasonic testing is a relatively new method of inspection and is used in conjunction with radiography. Pulsed sound is sent through the steel and is reflected by any discontinuity in the steel along the sound beam. This method relies on a portion of the surface of a defect being essentially perpendicular to the sound beam. The reflected signals are observed on the oscilloscope. An ultrasonic beam introduced perpendicular to the plate surface is especially valuable in detecting laminations which are parallel to the surface, but it will not easily pick up cracks normal to the surface. Therefore, in checking for defects normal to the surface, the sound must be directed into the plate at an agle. Interpretations of the oscilloscope indications are made by well-qualified and experienced personnel.

Magnetic particle is used to detect the presence of discontinuities at or near the surface. It is used on magnetic metals. This method of inspection is most useful in repair of castings and heavy weldments, especially when cracks or large defects are present. It also can be used in conjunction with subsurface inspection.

Dye penetrant is used to inspect weldments in nonmagnetic piping. The following prerequisites are met before this type of inspection is used:

1. Penetrants must conform to rigid standards controlling toxicity, flammability, flash point, halogen point, and other contaminants.

2. Clean test surface: get rid of contaminants

3. Control temperature of test surface

4. Adequate lighting and ventilation

Getting a smooth enough surface finish before you inspect saves a lot of time and rework. Surface roughness may present stress riser conditions, but this condition isn't so severe as a crack or other obvious defect. A lot of the nuisance variables associated with dye penetrant inspection are eliminated by closely following specified time allotments for each step of the process. The result is efficiency, reliability, and repeatability.

WELDING SEQUENCE

The Southern Marine Systems integrates into the construction of a ship welding sequences. The main purposes for using specific sequences in making welded joints is to control shrinkage. By controlling shrinkage, distortion and dimensional changes may be minimized. Furthermore, the welded structure may contain residual and reaction stresses, locked-in stresses, which may encourage crack initiation. Also the greater distortions present in welded structures may induce additional stresses, as an example, when initially curved plating is subjected to edge compression. It is therefore essential that in welded ships the correct welding sequence must be followed.

The welding sequences that we propose are both simple and practical as possible. Being simple, it is easily understood and therefore is likely to be followed by everyone concerned. Also if it is practical, it will not interfere with production requirements or with the placement of a sufficient number of men on the job.

A welding sequence is the order of progression in the making of related welds. Most ship structures consist of plating and attached reinforcing members. The welded sequence of these attachments must be coordinated with that for the plating. To reduce fairing and shrinking operations, an increase in plating must be used if the weight margin permits.

The effect of welding sequence is more fully realized when the members of the joint have no external restraint.

When the joint members are not free to move, the effect of the welding sequence on shrinkage is dependent upon the nature of the external constraint. Southern Marine Systems adopts several types of sequences of which the following are the most common:

1. Continuous sequence. A longitudinal sequence consisting of passes which are made continuously from one end of the joint to another. This is used almost exclusively in automatic welding.
2. Back-step sequence. This is a longitudinal sequence consisting of weld bead increments which are deposited in the direction opposite to the progress of the weld.
3. Symmetrical back-step sequence. Welding proceeds longitudinally from the center towards both ends of the joint, using the back-step sequence.

Multi-pass welds are also used which include: built-up sequence, block sequence, and cascade sequence.

The main considerations in making a welding sequence are:

1. Welding of stiffeners to only completed weld attachment.
2. Do not run a weld into another weld perpendicular to it.
3. Always weld symmetrical as possible.
4. Always weld up and out as a general rule.

When making a weld sequence many other important considerations must be made. Good accessibility is most important. Overhead welds should be reduced to a minimum. The complexity of the structure should be reduced as much as possible. This prevents small welds of bits and pieces. The sequence of fabrication must be considered. This ensures that the structure can be built in such a way that locked-in stresses due to welding are as small as possible. Abrupt changes in shape or section must be avoided. The stresses at discontinuities in welded structures can reach very high values. Butt welds are generally preferable to fillet welds because they avoid the built in crack always present in a fillet weld and they can be radiographed more easily.

MAIN PROPULSION LAYOUT

The required main propulsion engines were gas turbines. With the calculation of the required horsepower of 165,000 hp, a gas turbine was chosen with capabilities of moving the vessel at the required speed. An FT 4 A-14 gas turbine, manufactured by Pratt and Whitney Aircraft, is used which produces 28,800 free turbine shp. These ratings are based at 80° F and sea level (29.92" Hg abs or 14.7 psia). This turbine is recommended for base power plants where extended time between overhauls is of prime importance. The maximum specific fuel consumption is 0.53 lb/shp/hr. based on fuel LHV of 18,500 Btu/lb.

The machinery layout includes six(6) FT 4 A-14 gas turbines producing a total of 172,800 installed horsepower. Each screw is propelled by two FT 4 A-14 gas turbines. The power transmission system makes use of a single reversing reduction gear for the centerline shaft and standard reduction gears for the outboard shafts. All three screws have fixed pitch propellers. The reduction gears are coupled to the marine gas turbines, clutches attached to the gears provide for disengaging from the ahead mode and transferring to the astern mode.

The main engines are mounted on a raft which is directly attached to the reinforced inner bottom. Care must be taken to keep the engines and gearboxes close to avoid the need for excessive coupling shaft length. Other factors in the design of the engine foundation that must be considered would be vibration analysis, thermal effects of expansion, shock movements, and the effect of roll and pitch of the ship. The foundation must be capable of transferring the load into the existing structure. An oil sump is provided in the inner bottom for lubrication of the reduction gears.

Diesel auxiliary generators are installed for in-port service.

To calculate the necessary effective horsepower of the ship, Taylor's standard series was used.

Necessary data was given as follows:

Ship velocity = 28 knots

LWL = 1,114 ft.

$C_M = .949$

$C_P = .598$

Beam = 156 ft.

H = 35 ft.

From this data, the following values were calculated:

C (factor for wetted surface) = 16.1

$$\frac{R_f}{\Delta} = 6.56$$

$$\frac{R_R}{\Delta} = 2.22$$

$$\frac{R_T}{\Delta} = 8.78$$

$$EHP = \frac{R_T}{\Delta} \times \Delta \times V \times 0.00307 = 74,600 \text{ Hp.}$$

Delivered horsepower was calculated as follows:

$$DHP = \frac{EHP(1-W_T)}{\eta_O \eta_R (1-t)} = 120{,}000 \text{ hp.}$$

$W_T = 0.05$

$t = 0.12$

$\eta_R = 1.0$

$\eta_O = 0.67$

The installed horsepower requirement was then calculated using 3% loss in efficiency due to friction from bearings and using a standard 25% allowance for losses during service life of the vessel.

$$IHP = \frac{DHP}{0.97(0.75)} = 165{,}000 \text{ hp}$$

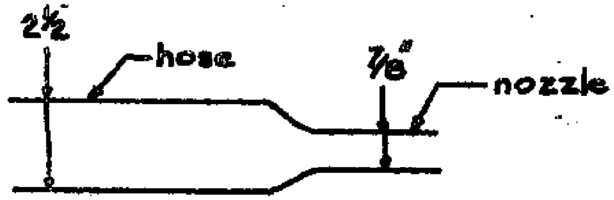
PIPING

The fuel oil supply consists of three separate systems to provide adequate fuel to the turbines. These are all provided with emergency crossover valves. A clean fuel oil supply must be provided to the turbines. The first stage of protection makes use of centrifugal separating purifiers in transferring fuel from the ship's settling tanks to the service tanks. Fuel boost pumps take fuel from the service tanks for a second stage of cleaning in duplex filter coalescers. For emergency operation during power failure situations, a header tank is used. The header tank operates on gravity feed which supplies a limited amount of clean fuel. The turbines must be supplied with clean fuel in order to operate at maximum efficiency.

An example of a fire main system was chosen to represent a piping plan. We also calculated the size of the fire pumps and other necessary data. The fire main is often used for services such as deck washing, tank cleaning and anchor chain washing, which do not interfere with its basic functions. Sea water is the basic fire fighting medium.

To calculate the required flow, three major resistance factors were considered. These are head loss, loss of head due to friction, and loss of head due to velocity.

The size of hose used was 2½" with two (2) orifices at 7/8" each. The pump shall be designed to deliver water simultaneously from the two highest outlets at a Pitot tube pressure of 50 psi.



flow through the nozzle:

$$Q = VA$$

$$Q = 8.6 \text{ ft/sec} \times .00415 \text{ ft}^2$$

$$Q = 0.357 \text{ ft}^3\text{sec} - \text{per nozzle}$$

Delivering water to two nozzles simultaneously:

$$Q = 2 \times 0.357 \text{ ft}^3/\text{sec}$$

$$Q = .714 \text{ ft}^3/\text{sec} - \text{per pump}$$

using 4" pipe from pump to nozzle:

$$A = 12.6 \text{ in}^2 = 0.0875 \text{ ft}^2$$

$$V = \frac{0.714 \text{ ft}^3/\text{sec}}{0.0875 \text{ ft}^2} = 8.15 \text{ ft/sec}$$

head loss due to friction:

$$\text{Reynolds number} = \frac{\rho V l}{\mu} = 2.2 \times 10^5$$

Using galvanized pipe and a relative roughness $\frac{e}{D}$ of .001. From this, a friction factor can be found to be; $f = 0.02$

Equivalent length due to loss in fittings:

gate valve (6) = 66'

elbow 90° (2) = 60'

equal tee (1) = 90'

216'

Length of piping: 436'

$$\text{Loss of head} = f\frac{l}{D} \times \frac{V^2}{2g}$$

$$H = .02 \times \frac{652}{.333} \times \frac{(8.15)^2}{2(32.2)}$$

$$H = 42.5 \text{ ft}$$

Equivalent $P = 42.5 \times 64 = 2{,}720$ psf = 18.9 psi

Head due to gravity = 94'

$p = 94 \times 64 = 6,010$ psf $= 41.9$ psi

Total required pressure = 41.9 + 18.9 + 50 = 110.8 psi

Using efficiency factor of 80%:

$$\text{Horsepower required} = \frac{(110.8 \times 144)(.714)}{550 \times 0.8} = 25.8 \text{ hp}$$

Electrical efficiency of motor - 85%

$$\frac{25.8}{.85} = 30.4 \text{ Horsepower} = 22.6 \text{ Kilowatts}$$

TAILSHAFT ARRANGEMENT

According to ABS the least diameter of the tailshaft was calculated to be 34.59 inches. The calculations are:

lineshaft - solid shaft

$$d = c \sqrt[3]{\frac{kH}{R}}$$

$$d = .875 \sqrt[3]{\frac{64 \times 55,000}{109}}$$

$$d = .875 \sqrt[3]{32,285}$$

$$d = .875(31.8)$$

$$d = 27.82 \text{ inches}$$

c = constant = .875

H = SHP = 55,000

k = constant = 64

R = rpm = 109

tailshaft

$$T = 1.14(d) + \frac{P}{c}$$

$$T = 1.14(27.82) + \frac{288}{100}$$

$$T = 31.71 + 2.88$$

$$T = 34.59 \text{ in. solid shaft}$$

c = constant = 100

P = prop. dia. in ins.= 288

d = diameter(lineshaft)=27.82

A 35 inch solid forged shaft was selected over a hollow shaft of equivalent strength because; 1. the hollow shaft would be more costly to build and install, 2. produced very little weight savings, 3. and would require more couplings due to its shorter lengths.

Once the type and design of the lineshaft and tailshaft were decided upon, an examination was made of the shafting details through the deadwood. It was readily discovered that the deadwood from the after bearing to where the shaft re-entered the main hull was 30 feet long! Also, it was only 8 feet wide at the top and 6 feet wide at the baseline. After the shaft is located in its proper position there is only a 30" clearing between the shaft and the side of the deadwood. This distance does not take into account the bearings and couplings that must be located in this short space. A single shaft 80 feet long cannot be considered as practical because of the difficulties of fabrication and installation, and if this shaft ever broke it would involve a tremendous expense to replace. Also there is no space for a walkway alongside the shaft for inspection and lubrication.

All the preceding factors have convinced Southern Marine Systems that the design of the deadwood and tailshafting arrangement must undergo a thorough redesign. Southern Marine Systems is in the process of formulating a solution to this problem. A detailed proposal will be submitted for approval that will give the economic, time, and structural factors considered in the proposed redesign of the tailshaft.

STRUCTURAL PLANS

Southern Marine Systems recognizes the large number of structural members that go into a completed ship. As a representation of Southern Marine Systems' ability to design ship structures, the collision bulkhead and rudder plans will be presented. Both plans were designed to the specifications of the ABS.

Collision Bulkhead

The collision bulkhead is the most important subdivision bulkhead on a ship. This bulkhead must remain intact after a collision (at the bow) in order that the damaged ship can make it to a port for repairs. The collision bulkhead is therefore heavier and/or stronger than any other subdivision bulkhead. Furthermore, this bulkhead is required to be not less than one-twentieth the length(L/20) of the ship and not more than one-twentieth plus ten feet(L/20 + 10) from the fore perpendicular.

The location of the collision bulkhead on the 1,149 foot containership is 55.70' aft of the fore perpendicular. This distance is exactly equal to L/20. Forward of the collision bulkhead is located the chain locker, 33.67' above the baseline and the stores flat located 68.16' above the baseline.

The bulkhead was designed to meet the requirements of Section 12, "Watertight Bulkheads", ABS. The plating thicknesses were calculated and standard sizes were used throughout in order to reduce the number of plates of different thicknesses. The stiffners were framed horizontally (toe down) because the horizontal direction had the least span of unsupported length. In order to reduce the size of the stiffners, a vertical girder extending from the CVK, Center Vertical Keel, to the stores flat deck and two girders eight feet (8') off centerline extend from the stores flat deck to the main deck.

Horizontal webs at the chain locker deck and the stores flat were added in order to support the vertical girders and to distribute the stresses into the main hull girder.

Rudder

The twin rudders for the 1,149 foot containerships are semi-balanced, streamlined, and attached to a rudder horn. The rudder area(425 ft^2 per rudder) is 2.1% of the product of the length between perpendiculars and the design draft, which conforms closely to merchant practice.

The rudders are designed to be turned 35° to port and starboard. External rudder stops shall be fitted to prevent the rudder from being turned to a greater angle than 35°.

Rudder construction is similar to that of the 20-knot Mariner Class vessels. The rudder is supported on the horn and conforms to the shape of N.A.C.A. .0010 symmetrical airfoil. Internal stiffning is provided by horizontal and vertical webs of 24 inch and 36 inch spacing respectively. The leading edge and trailing edge bars are castings and the vertical and horizontal webs and rudder shell are 20.4# plate. Since the rudder is of the closed plate type, special closing arrangements are necessary.

STRUCTURAL DETAILS

On a complicated modern ship there are thousands of structural details that the shipyard must design. Most of these structural details are fairly standard because they serve the same purpose on different types of ships. The two sample details of the bulwark and hold frame bracket are examples of this.

The bulwark shown is fitted as a protection to personnel walking on the main deck and cargo deck. The bulwark is of the floating or free type because it is not attached directly to the main structure of the ship. The advantage of this arrangement is that the bulwark is not welded to the sheer strake and therefore does not act as part of the ship girder. The six inch opening between the bulwark and sheer strake provides freeing space for water on the deck to escape overboard.

The hold frame bracket is necessary in order to prevent a "hard spot" from forming where the hold frame is welded to the tank top. The bracket is made large enough to provide adequate fixity but need not be any thicker than the web of the hold frame. A sloping chock is welded to the tank top and inner bottom floor where the flange of the hold frame bracket is welded to the tank top. This is again done to eliminate a possible "hard spot".

SEA CHEST

In the design of the sea chest the most important aspect considered was the stress raising effect of a penetration in the strength envelope. The penetration therefore must be reinforced by one of the following three ways; 1. doubler plate, 2. face bar, or 3. insert plate. The insert plate was chosen to reinforce the opening because of its easier fabrication, weight saving, and for less interruption of flow around the hull.

The sea chest shown is located in the "D" strake of bottom plating below the machinery space double bottom. After the method of reinforcement has been selected, the thickness of the added material must be determined. Using an optimum percentage of reinforcement of 50%(Guide to Sound Ship Structures, D'Archangelo) the insert plate thickness was calculated to be two inches or (86.1#Pl.CH). Next a strength check was run to make sure that the opening did not cause a stress over the yield stress of the material. Using a stress concentration factor of 2.1 and an acting nominal stress of 4.88 tons per square inch, the maximum stress at the penetration was calculated to be 10.25 tons per square inch or 23,000 psi. This is an acceptable stress because it has a 2.02 factor of safety against yielding.

The sea chest is covered with a metal grill or grating to keep out foreign matter.

<u>PENETRATION in STRENGTH ENVELOPE</u>

$$\sigma = \frac{M}{Z} \qquad M = 1{,}461{,}421 \text{ foot tons}$$

$$\sigma = \frac{1{,}461{,}421}{369{,}000} \qquad Z = 369{,}000 \text{ in}^2 \text{ ft}$$

$$\sigma = 3.96 \text{ tons/in}^2$$

Plate 8' wide x 1.31	Hole 18" x 18" x 1.31
$A_p = 8 \times 12 \times 1.31$	$A_h = 18 \times 1.31$
$A_p = 126$ sq.in.	$A_h = 23.6$ sq.in

Percentage of reinforcement = $\frac{2a}{A} \times 100$

$.50 = \frac{2a}{23.6} \times 100$

$2a = \frac{23.6 \times .50}{100}$

2a = 11.8 sq. in.

(23.6 + 11.8) = 18 x t

$t = \frac{35.4}{18}$

t = 1.97 in. Pl.   Use 2" Pl
86.1#CH.

Stress concentration factor

$k = \frac{\text{max } \sigma \text{ at discontinuity}}{\text{nominal } \sigma \text{ at discontinuity}}$

$k = \frac{r}{b} = .30 \qquad \frac{w}{b}$ use 3.24

k = 2.1

$n = \frac{s(96 \times 1.31)}{(78 \times 1.31)} = 3.96 \frac{\text{ton}}{\text{in}^2} \times \frac{96}{78} = 4.88$

$n = 4.88 \text{ tons/in}^2$

$\sigma \text{ max} = 2.1 \times 4.88$

$\sigma \text{ max} = 10.25 \text{ tons/in}^2$

$\sigma = 10.25 \times 2240 \frac{\#}{\text{ton}} \times \frac{\text{ton}}{\text{in}^2}$

$\sigma = 23{,}000$ psi

f.s. yield = 2.02

RATPROOFING

Rats have traditionally been a constant source of trouble for man. Rats carry diseases, destroy man's possessions, and interfere with his economic and physical well-being. To eliminate this source of trouble Southern Marine Systems designs and fabricates the ship in such a manner as to eliminate or render inaccessible those spaces which may afford a rat harborage or be a source of food or water for rats.

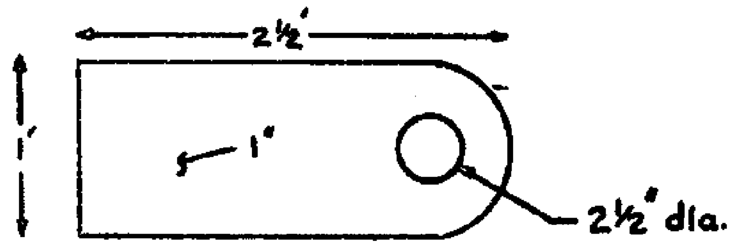
To accomplish this goal Southern Marine Systems follows the detail requirements of the "Handbood on Sanitations of Vessel Construction", United States Public Health Service. The first detail shows the arrangement of multiple and single cable penetrations of a steel bulkhead. The second detail shows a pipe penetration. In no case can an opening be greater than ½ inch at the least dimension.

SUBASSEMBLY LIFTING ARRANGEMENT

The lifting arrangement is shown on subassembly No. 7 of module No. 5. This subassembly is part of a typical transverse bulkhead. The weight of the subassembly is 44.58 long tons and the center of gravity is located vertically 20 feet from the top of the subassembly and horizontally 14.5 feet from the outboard end. The subassembly consists of plating, stiffners, and girders and webs which have a depth of 8'-0" and flanges of 60" and 24" respectively.

In order to understand the lifting arrangements for this subassembly, the method of construction must first be explained. In the panel shop all the individual pieces that make up this subassembly come together. The flat bulkhead plating is welded on one side and then flipped over and welded on the other side. Next the stiffners are attached and followed by the vertical girders and horizontal webs. The pad eyes are then attached to the vertical girders and the subassembly is then shot blasted and primed and taken to the storage area. At the proper time the subassembly is lifted by a large crane with a load spreader. The load spreader has the advantages of producing only tension in the pad eyes, and the rope between the crane and the spreader can move horizontally in order to place the point of load and point of support in the same vertical plane.

Two pad eyes are required to lift the subassembly. Pad eyes with the following dimensions are recommended.



Considering the hole in the pad eye as a rivet hole in a piece of plating, the four methods of riveted connection failure were investigated. The results are:

Shear of bolt	29.9 tons
Bearing or crushing of plate	58.2 tons
Shearing of plate	54.6 tons
Tensile failure of plate	31 tons

The shearing of the bolt was the critical method of failure. The actual load on each bolt is 44.58/2 or 22.29 tons. The factor of safety is therefore 1.34.

Also shown on the slide is the method of joining subassemblies. The plates and stiffners are joggled and the stiffners are left loose for 4 to 5 feet from the end to facilitate easy allignment.

ANCHOR SELECTION

Anchor size is based on anchor holding power in fine sand and the forces acting on the ship under design conditions of 70 knot winds and a 4 knot current. Calculations should be made for light load and full load drafts, and the condition giving the greater load used to determine the anchor size.

The required anchor holding power is:

$$H = ZR$$

where;

H = holding power of anchor

R = total wind and current reaction on a ship which is equal to the wind force(Fw) plus the skin friction force(Fs) plus the propeller drag force(Fp).

The wind force may be satisfactorily approximated by:

$$Fw = .004\ AV^2$$

where;

Fw = wind force

A = transverse projected area above the waterline in sq.ft.

V = wind velocity in knots

The skin friction force may be determined using Taylor's Method to get the wetted surface;

$$S = 15.5\sqrt{\Delta L}$$

Holding Power to Weight Relationship for various types of anchors:

mushroom anchors	H = 2.5W
commercial stockless anchors	H = 4.7W
Navy commercial stockless anchors	H = 7.1W to 9.1W
Stock anchors (Navy)	H = 7.3W
Danforth anchors	H = 16W to 21W
Navy lightweight (LWT)	$H = 83W^{.818}$

Our ship makes use of two commercial stockless anchors per ship.

Δ = displacement in long tons

L = length of ship in feet between perpendiculars

$$Fs = fsv^{1.825}$$

where;

Fs = skin friction force

f = constant

s = wetted surface area in square feet

v = velocity of current in knots

1.825 is a constant exponent

The propeller drag force is found by:

$$Fp = 3.17CV^2 \; Ap$$

where;

Fp = propeller drag force

V = velocity of current in knots

C = projected area of propeller blades minus the hub divided by the propeller disk area

Ap = propeller disk area in square feet

In order to get the required anchor weight in air, a constant Z is used which is the factor for transient loads caused by wave slap and motion of a ship while swinging at anchor.

Z = 1.00 for submarines

Z = 1.25 - 1.50 for destroyers

Z = 1.50 - 1.75 for large cruisers

Z = 1.75 - 2.00 for merchant ships, aircraft carriers, and naval auxiliaries

The required anchor weight (in air) is:

$$W = \frac{ZR}{H/W}$$

where H/W is the holding power to weight ration for the anchor selected.

Our anchor selection calculations are as follows:

$A = 11,689$ sq.ft.

$V = 70$ knots

$Fw = .004\ AV^2$

$Fw = (.004)(1.1689 \times 10^4)(7 \times 10^1)^2$

$Fw = (.004)(1.1689 \times 10^4)(4.9 \times 10^3)$

$Fw = (.004)(5.72 \times 10^7)$

$Fw = 2.29 \times 10^4$

$Fw = 22,900\#$

$S = 15.5\sqrt{\Delta L}$

$S = (15.5)\left[(9.885 \times 10^4)(1.114 \times 10^3)\right]^{\frac{1}{2}}$

$S = (15.5)(1.1 \times 10^8)^{\frac{1}{2}}$

$S = (15.5)(1.05 \times 10^4)$

$S = 1.627 \times 10^5$

$S = 162,700$ sq.ft.

$F_s = fsV^{1.825}$

$Fs = (9 \times 10^{-3})(1.627 \times 10^5)(4)^{1.825}$

$Fs = (9 \times 10^{-3})(1.627 \times 10^5)(1.26 \times 10^1)$

$Fs = (1.463 \times 10^3)(1.26 \times 10^1)$

$Fs = 1.845 \times 10^4$

$Fs = 18,450\#$

$Fp = 3.17cV^2Ap$

$Fp = (3.17)(2.145 \times 10^{-1})(4)^2(4.52 \times 10^2)$

$Fp = (6.81 \times 10^{-1})(1.6 \times 10^1)(4.52 \times 10^2)$

$Fp = (1.09 \times 10^1)(4.52 \times 10^2)$

$Fp = 4.93 \times 10^3$

$Fp = 4,930\#$

$C = \dfrac{\text{projected blade area}}{\text{disk area}}$

$C = 211/452 = .2145$

$Fp = (3)(4,930)$

$Fp = 14,790\#$

$R = Fw + Fs + Fp$

$R = 22,900 + 18,450 + 14,790$

$R = 56,140\#$

Required anchor weight in air is:

$$W = \frac{ZR}{H/w}$$

$$W = \frac{(1.75)(5.614 \times 10^4)}{4.7w/w}$$

$$W = \frac{9.81 \times 10^4}{4.7}$$

$W = 2.09 \times 10^4$

$W = 20,900\#$

Chain size and scope are determined to suit the anchor size and the depth in which the ship will anchor, using the following catenary equation:

$$Wc = \frac{H}{.87Ac} \quad \text{or} \quad Ac = \frac{H}{.87Wc} \qquad (1)$$

$$Ac = \frac{Sc^2}{2y} - \frac{y}{2} \qquad (2)$$

$$\frac{H}{.87Wc} = \frac{Sc^2}{2y} - \frac{y}{2} \qquad (3)$$

$$Sc = \left(\frac{2yH}{.87Wc} + y^2\right)^{\frac{1}{2}} \qquad (4)$$

where;

Ac = catenary parameter, determine from equation(2), using assumed scope of 180 fathoms

.87 = constant to current chain weight in air to weight in water

Sc = scope of chain in fathoms

y = water depth plus height of hawsepipe above water

Wc = chain weight in air, pounds per fathom

Determine chain weight using equation(1). If calculated weight falls between chain sizes, use the next larger chain size. Determine the required scope of this size chain by using equation(4). The static load factor of safety for the selected chain may be determined by:

$$FS = \frac{\text{ultimate strength}}{H + Sc(.87\ Wc)}$$

The required length of chain to reach from the hawsepipe through the windlass to the chain locker, must be added to the calculated scope. Since the chain is procurred in 15 foot/fathom or shots, the length of chain must be the next full multiple of 15 feet/fathom.

$$H = ZR$$

$$H = (1.75)(5.614 \times 10^4)$$

$$H = 9.81 \times 10^4$$

$$Wc = \frac{9.81 \times 10^4}{(8.7 \times 10^{-1})(1.316 \times 10^3)}$$

$$Wc = \frac{-9.81 \times 10^4}{11.43 \times 10^1}$$

$$Wc = 8.56 \times 10^2$$

$$Wc = 856\#/\text{fathom}$$

$$Ac = \frac{Sc^2}{2Y} - \frac{Y}{2}$$

$$Ac = \frac{(360)^2}{2(44)} - \frac{44}{2}$$

$$Ac = \frac{129,600}{88} - 22$$

$$Ac = 1,316$$

Standard anchor 20,900#, proof load 208,800#

Standard chain- 3 7/8" link - 360 fathoms

Chain proof load 540,000# ultimate 771,500#

The chain weighs 12,850#/shot = 15 fathoms   chain Wc = 856 #/fathom

$$FS = \frac{771,500}{(9.81 \times 10^4) + (360)(.87 \times 856)}$$

$$FS = \frac{7.715 \times 10^5}{(9.81 \times 10^4) + (3.6 \times 10^2)(7.46 \times 10^2)}$$

$$FS = \frac{7.715 \times 10^5}{(9.81 \times 10^4) + (26.9 \times 10^4)}$$

$$FS = \frac{7.715 \times 10^5}{(9.81 \times 10^4) + (26.9 \times 10^4)}$$

$$FS = \frac{7.715 \times 10^5}{3.671 \times 10^5}$$

$$FS = 2.1$$

Chain pipe size:

$Cp = 6\frac{1}{2}\ d$ where; d = inside diameter

$$Cp = 6.5 \times 3.875$$

$$Cp = 25.1 \text{ in.}$$

Chain locker size for a commercial stud link:

$$V = .75\ ld^2$$

$$V = (7.5 \times 10^{-1})(3.6 \times 10^2)(3.875)^2$$

$$V = (2.7 \times 10^2)(1.498 \times 10^1)$$

$$V = 4.04 \times 10^3$$

$$V = 4,040 \text{ cu.ft.}$$

Horsepower required for windlass:

$$HP = \frac{W + wd}{364.5}$$

$$HP = \frac{41,800 + (5.14 \times 10^4)(3 \times 10^1)}{3.645 \times 10^2}$$

$$HP = \frac{41,800 + 154,200}{3.645 \times 10^2}$$

where; W = weight of anchor

w = wt/fathom of chain

d = depth in fathoms

$$HP = \frac{196,000}{3.645 \times 10^2}$$

$$HP = 538$$

A commercial ship must be capable of lifting 2 anchors from a depth of 30 fathoms at the rate of 6 fathoms/min.

ELECTRICAL PLAN

It is well understood that electrical systems generally contain an infinite number of parts. Therefore, Southern Marine Systems prefers to handle components rather than parts wherever possible. The drawing shown reflects our navigational lights system. You may note that the lights plug into the cables rather than having an internal hook-up for each. This greatly speeds construction because the cable ends are assembled in the electrical shop. Thus the only electrical connection in the field is the connection between the locking plugs and the recepticles.

There are many similar forms of wiring installations throughout the ship accompanied by prewired terminal boxes. However, the locking plugs and terminal boxes are sometimes undesirable. In such a case the wiring is installed in a module or subassembly and enough cable is left in a coil to make the run to its termination point.

PAINT SCHEDULE

The painting system in our yard follows closely with our modern production line technique. After the panels are completed in the Shell and Panel shops, they move directly to the Blasting Shop where they are machine blasted and sent on to the Primer Shop. Here they are masked for additional fitup, primed, and marked for assembly. From there they move to the Storage area.

Using the machine blasting technique we are able to greatly lower the cost of a coating job. It cost approximately 3¢(three cents) per square foot to machine blast versus 20¢(twenty cents) per square foot for manual blasting, thus saving half the total cost of a coating job. This savings can be used to apply one of the new epoxy coating systems, which otherwise cost more than a regular painting system if manual blasting were used.

We highly recommend an epoxy coating system for this class of vessels because of their long life. This would allow the vessel to go longer between drydocking and repainting, saving money in the long run.

The coatings which we will use are put out by USS Chemicals. The general system which we intend to use is as follows:

Exterior	Coats	Coating	DFT mils
keel to light load line	1	zinc rich shop primer	1
	1	zinc rich 110	2
	1	Tarset C-200	8
	1	Tarset 305 AF	12
boot topping	1	zinc rich shop primer	1
	2	Tarset C-200	16
deep load line to rail	1	zinc rich shop primer	1
	1	high build Epoxy(color)	5
working weather decks Focsle deck & catwalks	1	zinc rich shop primer	1
	1	Tarset C-200 non-skid	8
	1	high build epoxy(color)	2

Exterior(cont.)	coats	coating	DFT mils
weather decks(other)	1	zinc rich shop primer	1
	1	high build epoxy(color)	5
superstructure(steel)	1	zinc rich shop primer	1
	1	high build epoxy(color)	5
superstructure(alum.)	1	shipyard primer	½
	1	high build epoxy(color)	5
masts, stocks, fittings	1	zinc rich shop primer	1
	1	high build epoxy(color)	5

Interior	Coats	Coating	DFT mils
dry cargo spaces	1	zinc rich shop primer	1
	1	high build epoxy	5
lining spaces	1	zinc rich shop primer	1
	1	high build epoxy	5
machinery & equipment	1	zinc rich shop primer	1
spaces above the bilge	1	high build epoxy	5
voids & cofferdams	1	zinc rich shop primer	1
	1	high build epoxy	5
potable water	1	zinc rich shop primer	1
	1	zinc rich 110 potable	2
clean petroleum	1	zinc rich shop primer	1
products & tanks	1	high build epoxy	5
wet bilges	1	zinc rich shop primer	1
	2	high build epoxy	8

Paint Data

U.S.S. Tarset 305 AF

Use: To provide up to 25 months or more of protection against fouling of vessels in sea-going service. Combines anti-fouling and anti-corrosive properties into one material. Can be applied directly over Tarset Standard, Tarset C-200, Epoxy System Primer or Shipyard Primer.

Typical Properties

theoretical coverage	-	1120 sq. ft./gal./mil
practical coverage	-	85 sq. ft. @ 12 mils (17 mils wet)
dry to touch	-	4 hours @ 77° F
dry to undocking	-	24 hours @ 77° F
color	-	black
pot life	-	2 - 6 hours
weight	-	10 lbs./gal. (mixed)
flash point	-	150° F (mixed)
solids by volume	-	70%
component ratio	-	A : B, 3.3 : 1 (vol.); 4.6 : 1 (wt.)
shelf life	-	one year

Application Data

surface preparation	-	near white blast (SSPC 10-63T) for base steel. Whip blast for aluminum and plastics.
equipment	-	brush, roller or spray
thimmer	-	USS Tarset AF thinner
equipment cleaning	-	USS Tarset or USS epoxy system thinner
minimum application temperature	-	50° F

USS Tarset C-200

Use: Heavy duty protection for immersion or atmospheric surfaces requiring abrasion and corrosion resistance. Suitable for use in potable water. Can be applied to abrasive blasted surfaces, or over USS Epoxy System Primer, USS Shipyard Primer, or USS Zinc Rich 110.

Typical Properties

theoretical coverage	-	1200 sq. ft./gal./mil
practical coverage, per coat	-	110 sq. ft./gal. @ 8 mils(10½ wet)
dry to touch	-	3 hours @ 77° F
dry to recoat	-	when dry to touch
color	-	black
pot life	-	2 to 4 hours @ 77° F
temperature resistance	-	30° to 300° F(dry); 160° F(wet)
flash point	-	over 175° F (mixed)
weight	-	10.7 lbs./gal. (mixed)
odor	-	none after 48 hours curing
sag resistance	-	good (12 mils wet)

Application Data

surface preparation	-	near white blast (SSPC 10-63T)
equipment	-	brush, roller or spray
thinner	-	USS C-200 thinner
equipment cleaning	-	USS C-200 thinner
minimum application temperature	-	50° F

USS Shipyard Primer

Use: Protects properly prepared steel surface by providing inhibitive protection for up to six months until a complete, compatable coating system can be applied. Provided excellent adhesion for subsequent coats of USS Tarsets and USS High Build Epoxy, Tanmastics and Insulmastics. Provides excellent protection for aluminum surfaces.

Typical Properties

theoretical coverage	-	400 sq. ft./gal./mil.
practical coverage	-	800 sq. ft./gal. @ .4 mils(1½ mils wet)
dry to touch	-	15 minutes @ 77° F
dry to recoat	-	8 hours minimum @ 77° F
color	-	yellow-green
weight	-	11.5 lbs./gal.
flash point	-	56° F (mixed)

Application Data

surface preparation	-	near white blast (SSPC 10-63T)
equipment	-	spray or brush
thinner	-	not required
equipment cleaning	-	USS Epoxy System Primer Thinner
minimum application Temperature	-	40° F

USS Zinc Rich Shop Primer

Use: To provide interim protection during fabrication or assembly of steel plates and shapes. Fast drying permits use of automated blasting and priming equipment. Is weld and burn through. Should be top coated with compatable coatings such as USS Zinc Rich 110, USS Tarset C-200, USS High Build Vinyl, or High Build Epoxy.

Typical Properties

theoretical coverage	-	350 sq. ft./gal./mil
practical coverage	-	280 sq. ft./gal. @ 1 mil(4½ wet)
dry to touch	-	2 minutes @ 77° F (maximum)
dry to handle	-	5 minutes@ 77° F
color	-	blue
metallic zinc in dry film	-	90% minimum
weight	-	14.9 lbs./gall
flash point	-	15° F

Application Data

surface preparation	-	near white blast (SSPC 10-63T)
equipment	-	spray
thinner	-	not required
equipment cleaning	-	USS Epoxy System Primer Thinner
minimum application temperature	-	40° F

USS Zinc Rich 110

Use: Single coat, galvanic protection of steel surface in atmospheric exposure. Has flexibility and adhesion typical of epoxy binders with ease of mixing and application of single pack. Should be top coated with USS High Build Epoxy, or USS High Build Vinyl Coating or Tarset C-200 for immersion surface as in acid or alkaline exposures. It is weld through.

Typical Properties

theoretical coverage	-	510 sq.ft./gal./mil.
practical coverage	-	200 sq.ft./gal. @ 2 mil(6 wet)
dry to touch	-	1 hour @ 77° F
dry to recoat	-	24 hours @ 77° F
metallic zinc in dry film	-	91%
temperature resistance	-	350° F
flash point	-	118° F
weight	-	19 lbs/gal.
color	-	blue

meets military specification MIL - ? - 21035

US PHS approved for potable water

Application Data

surface preparation	-	near white blast(SSPC 10-63T)
equipment	-	spray or brush
thinner	-	provided at spray viscosity
equipment cleaning	-	USS Epoxy System Primer Thinner
minimum application temperature	-	40° F

USS High Build Epoxy Coatings

Use: To provide one coat, color, and protection in severe atmospheric or immersion surfaces. Used as a highly resistant, durable coating over USS Epoxy System Primer, or USS Zinc Rich or USS Shipyard primer.

Typical Properties

theoretical coverage	-	700 sq. ft./gal./mil
practical coverage	-	135 sq. ft./gal. @ 5 mil(11 wet)
dry to touch	-	4 hours @ 77° F
dry to recoat	-	24 hours @ 77° F
temperature resistance	-	200° F (wet or dry)
colors	-	9 basic and safety colors will match to order
weight	-	11 lbs./gal. (mixed)
flash point	-	102° F (mixed)

Application Data

surface preparation	-	clean, dry, free of oil, grease and other contaminates
equipment	-	brush, roller, or spray
thinner	-	not required
equipment cleaning	-	USS Epoxy System Primer Thinner
minimum application temperature	-	50° F

To find out how many gallons of paint it would take to paint the hull from the light load line to the keel, you need the wetted surface area. The preliminary design was woefully lacking in all respects. Thus, in order to get the surface area we had to blow up the Xeroxed body plan so that planimeter could be used to read the area of each station (see slide). The engineering staff of Southern Marine Systems has at its disposal a computer. Mr. Buckheister prepared a program to find the displacement(see slide). The results were then plotted to produce a displacement curve. We knew the displacement at the 35 foot waterline which allowed us to calculate the per cent error. From this we were able to arrive at a draft for the light condition. We went back to the copy to scale the water line length.

There are two methods of finding wetted surface. The two methods are Denny's and Taylor's. We chose Denny's because of the vessels speed and cargo characteristics.

Denny Method for slow bulk cargo ship

$$S = 1.7\,LT + \nabla/T$$

where

S = wetted surface area of molded form in square feet

L = length in feet between perpendiculars

T = molded mean draft in feet

∇ = molded volume of displacement in cubic feet

Taylor Method for fast war and passenger ship

$$S = C\sqrt{\Delta L}$$

where

S = wetted surface area in square feet of molded form when floating in salt water at a molded displacement in long tons

L = mean length of immersed form, which is usually somewhat less than length of load waterline

C = a coefficient depending on the value of C_m, the midship section coefficient, in association with the ratio of the molded breadth, B, to molded mean draft, T.

Given Values

midship coefficient	-	.949
length between perpendiculars	-	1,089 ft
length on waterline	-	1,114 ft (loaded)
draft	-	35 ft
beam	-	156 ft
displacement	-	98,850 long tons
light ship	-	36,750 long tons = 12.83×10^5
station spacing	-	55.7 ft
length on light load line	-	986 ft
draft at light load line	-	19.5 ft

Planimeter Data

Station	8' WL Area sq.ft.	16' WL Area sq.ft.	24' WL Area sq.ft.	32' WL Area sq.ft.	40' WL Area sq.ft.
0	21.15	38.2	46	46	46
1	45.2	91.2	140.5	191	254
2	70	161	256	366	515
3	104	256	435	632	660
4	147.5	373	647	857	1272
5	218	526	890	1286	1695
6	272	646	1090	1563	2060
7	369	825	1325	1865	2400
8	414	852	1495	2070	2620
9	471	1035	1610	2205	2790
10	484	1062	1630	2220	2810
11	484	1062	1630	2220	2810
12	464	1023	1610	2200	2780
13	361	937	1514	2100	2690
14	270	775	1312	1900	2480
15	162	523	1023	1572	2155
16	3.41	274	675	1178	1748
17	0	42.6	319.5	724	1253
18	0	0	42.6	378.5	818
19	0	0	0	11.08	460
20	0	0	0	0	294

Denny Method

$$S = 1.7\,LT + \frac{\nabla}{T}$$

$$= 1.7(986)(19.5) + \frac{12.83 \times 10^5}{19.5}$$

$$= 1.7(9.86 \times 10^2)(1.95 \times 10^1) + \frac{1.283 \times 10^6}{1.95 \times 10^1}$$

$$= 98{,}350 \text{ sq.ft.}$$

Paint required for keel to light load line

coats	coating	DFT mils	practical coverage
1	zinc rich shop primer	1	280 sq.ft./gal.@ 1 mil(4½ wet)
1	zinc rich 110	2	200 sq.ft./gal.@ 2 mils(6 wet)
1	Tarset C-200	8	110 sq.ft./gal.@ 8 mils(10½ wet)
1	Tarset 305AF	12	85 sq.ft./gal.@12 mils(17 wet)
4 coats		23 mils	

Required gallons of paint for this ship using this system:

zinc rich shop primer $\frac{9.835 \times 10^4}{2.80 \times 10^2} = 3.51 \times 10^2 = 351$ gals.

zinc rich 110 $\frac{9.835 \times 10^4}{2.0 \times 10^2} = 4.81 \times 10^2 = 481$ gals.

Tarset C-200 $\frac{9.835 \times 10^4}{1.10 \times 10^2} = 8.93 \times 10^2 = 893$ gals.

Tarset 305AF $\frac{9.835 \times 10^4}{8.5 \times 10^1} = 1.155 \times 10^3 = 1{,}155$ gals.

The coating system involving USS Tarset 305AF cost 30¢ per sq.ft. applied. So to paint from the light load line to the keel it would cost 30¢ x 98,350 sq.ft. = $29,405.

C-FOCAL.. 1968

```
01.01 T "SOUTHERN MARINE SYSTEMS INCORPORATED PROGRAM 10001",!
01.02 T "DISPLACEMENT CALCULATIONS FOR VARING WATERLINES",!!!
01.07 FOR I=0,20; S N(I)=0
01.08 FOR I=0,20; ASK "HALF AREA  ",N(I),!
01.09 S A(0)=N(0)*1; S A(1)=N(1)*4; S A(2)=N(2)*2
01.10 S A(3)=N(3)*4; S A(4)=N(4)*2; S A(5)=N(5)*4
01.11 S A(6)=N(6)*2; S A(7)=N(7)*4; S A(8)=N(8)*2
01.12 S A(9)=N(9)*4; S A(10)=N(10)*2; S A(11)=N(11)*4
01.13 S A(12)=N(12)*2; S A(13)=N(13)*4; S A(14)=N(14)*2
01.14 S A(15)=N(15)*4; S A(16)=N(16)*2; S A(17)=N(17)*4
01.15 S A(18)=N(18)*2; S A(19)=N(19)*4; S A(20)=N(20)*1
01.20 S Y=A(0)+A(1)+A(2)+A(3)+A(4)+A(5)+A(6)+A(7)+A(8)+A(9)+A(10)
01.22 S Z=A(11)+A(12)+A(13)+A(14)+A(15)+A(16)+A(17)+A(18)+A(19)+A(20)
01.24 S W=Y+Z
01.26 T "SUMATION OF HALF AREAS",    W,!!
01.28 ASK "STATION SPACING",P,!!
01.30 S D=(W*2*P)/3
01.31 T !
01.32 T "THE DISPLACED VOLUME", D," CUBIC FEET",!!
01.34 S N=D/35
01.35 T !
01.36 T "THE DISPLACED WEIGHT ",N," TONS",!!
*
```

```
SOUTHERN MARINE SYSTEMS INCORPORATED PROGRAM 10001
DISPLACEMENT CALCULATIONS FOR VARING WATERLINES

HALF AREA  :46
HALF AREA  :254
HALF AREA  :515
HALF AREA  :860
HALF AREA  :1272
HALF AREA  :1695
HALF AREA  :2060
HALF AREA  :2400
HALF AREA  :2620
HALF AREA  :2790
HALF AREA  :2810
HALF AREA  :2810
HALF AREA  :2780
HALF AREA  :2690
HALF AREA  :2480
HALF AREA  :2155
HALF AREA  :1748
HALF AREA  :1253
HALF AREA  :818
HALF AREA  :460
HALF AREA  :294
SUMATION OF HALF AREAS=+104014.00

STATION SPACING:54.4

THE DISPLACED VOLUME=+3772240.0 CUBIC FEET

THE DISPLACED WEIGHT =+107778.00 TONS

*
```

TYPICAL FOUNDATION

In designing the foundation for H32SL-12W09 compresser and condensing unit we needed to calculate its effective weight with the ship rolled to 30°. This supplies the necessary shear forces acting on the anchor mounting bolts to calculate the proper size. These bolts were already sized by York. We made a check calculation to see if the bolts were the proper size. Next, the required section modulus for the stiffners to distribute the load to the deck beams and longitudinals had to be calculated. Upon knowing the effective plating, section modulus of the combined section, stiffners and plate, was calculated. The results revealed a 2" x ¼" piece of scrap deck plating would be well sufficient for the stiffners. To attach the stiffners to the deck plating we decided to stagger the welds which were 1/8" fillet welds.

combined weight of unit = 1,080# = .482 tons

roll angle of ship = 30°

period of roll = 14 sec.

roll radius = 54'

$$W_{eff} = W(\sin \quad + \frac{R4 \quad 2}{g T_r \; 2})$$

$$" \quad = .482(.5 + 4 \times \frac{30}{180} \times \frac{2}{32.2} \times \frac{54}{(14)}2)$$

$$" \quad = .336 \text{tons} = 731\#$$

There are eight bolts holding the compresser and condenser to the deck. Each bolt is loaded by 91.5#.

$$S = \frac{P}{A} = \frac{91.5}{.0767} = 1,190 \text{ psi}$$

The allowable shear is 8,800 psi giving a factor of safety

of:

$$FS = \frac{\text{allowable stress}}{\text{actual stress}} = \frac{8,800}{1,190} = 7.4$$

Deck design:

living spaces, offices and passageways on the main deck and above = 75 psi

Unit weight = 1,080#

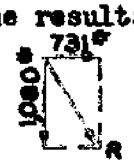
Design with a factor of safety of 1.5 to result in a unit weight of 1,620# if allowed to load 75 psi.

$$\frac{1,620}{x} = 75$$

$$x = 21.6 \text{ ft.sq.}$$

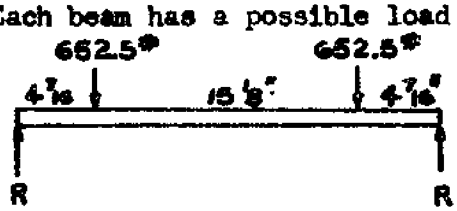
therefore, you need to distribute the load over at least 22 sq.ft.

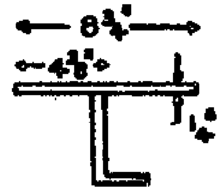
The resultant force with the ship at a 30° list is:



$$R = \left[(731)^2 + (1,080)^2\right]^{\frac{1}{2}} = 1.305 \times 10^3 \#$$

Each beam has a possible load of 652.5# at 4 7/16" away from each end.





section modulus, $Z = \frac{I}{c}$ $M = SZ$ $FS = 2$

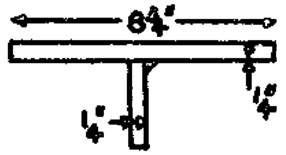
$$Z = \frac{M}{S} = \frac{(6.525 \times 10^2)(4.4375)}{1.65 \times 10^4} = .175 \text{ in}^3$$

2" x 1/4" flat bar section modulus calculation:

trial and error produced: $Z = \frac{I}{c} = \frac{.748}{1.986} = .376 \text{ in}^3$

$I = .748 \text{ in}^4$ $c = 1.986$ in

The thickness of weld required:



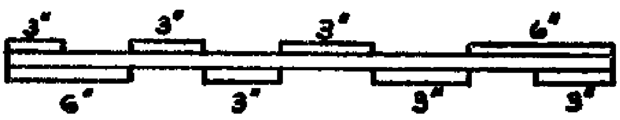
The allowable shear for a weld = 17,000 psi

FS = 4

$$\tau = \frac{17,000}{4} = 4,250 \text{ psi}$$

$$t = \frac{A(.125)(652.5)}{I} = \frac{(2.9)(1.25 \times 10^{-1})(6.525 \times 10^{2})}{(7.48 \times 10^{-1})(4.25 \times 10^{3})} = .074''$$

We will use 1/8" weld staggered every 3 inches starting with 6" on one side and 3" on the opposite side.



AIRCONDITIONING AND VENTILATION

The type of ventilation used depends upon the nature of the space and the service of the ship. It can be natural, mechanical, or a combination of the two, and may include equipment for heating, cleaning, humidifying, and dehumidifying.

Ships' ventilating systems are usually designed for an outside winter air temperature of 0° F and summer temperature of 95° F. Sea water temperatures of 88° F maximum and 28° F minimum are used when estimating heating and cooling loads for spaces below the waterline.

The quantity of air required for each space ventilated is determined by heat transfer or empirical calculations, based on transmission of heat through structure, outside air conditions, internal heat loads, and similar factors. These air quantities must satisfy the maximum allowable temperature rise, minimum allowable fresh air per person, or permissible rate of air change.

There are several systems that may be considered. The natural flow system contains no fans and air movement is created by the differnece in temperature and density of inside and outside air and the trimming of cowls or air intakes toward the wind. This system is generally limited to a few shops, lockers, and store-rooms, and some dry cargo holds. The mechanical system consists of a suitably weather protected inlet or outlet, an electrically driven fan, a duct to the area served, and distribution branch ducts with terminals designed to suit the supply or exhaust air function required. The supply and exhaust system is the method of ventilation we chose to use. The supply system conveys outside air which has been filterd and/or heated as necessary to the fan and from the fan to the spaces ventilated. An exhaust system, requiring similar ducts, conveys vitiated air out of the ventilated spaces through a fan which discharges it to the atmosphere. When mechanical exhaust is not provided, the air escapes to the atmosphere through natural exhaust openings, being forced out by the pressure of the supply fan.

In designing a ventilation system, our aim was to run the ducts in as nearly a straight line as possible, avoiding sharp bends, abrupt changes in duct sizes or shapes, and all other contruction which may cause excessive pressure losses. It is seldom possible to achieve an ideal duct system in ship installations, due to structural limitations, low ceiling heights, and interferences with piping and other systems. Cross-sectional areas of ducts should be large enough to permit the air to flow at moderate velocities to avoid power waste and reduce noise. In areas where quiet operation is essential, 2,000 fpm is maximum, and in areas where quite operation is not essential, 3,500 fpm is maximum. Obstructions are often found during insulation of the ductwork, and about 10% of the total fan pressure should be reserved in the system for these additional losses.

Good duct design can contribute much to the economy of system operation. Abrupt changes in duct sizes or direction of airflow are always to be avoided. Abrupt expansions are partucularly bad having as much as 5% of the total available fan pressure can be lost in a single expansion. Elbows should be designed for smooth airflow. It is desirable to make the throat radius of the elbow equal to the dimension of the duct in the plane of the bend. Where this is impossible and a shorter radius is required, splitters should be added in these elbows. Where conditions require square elbows, curved turning vanes should be provided.

When smaller ducts are taken off the main supply duct to serve individual spaces, a division of the main duct is the most desirable method and is based on proportional division of air; i.e., the air quantity is divided in proportion to the area of the duct. Where headroom and structural requirements do not allow this arrangement and for small air quantities, branch takeoffs may be used; i.e., small ducts connected in the main duct at a 30° angle from the direction of the airflow in the main. It should be recognized, however, that these branch takeoffs create a loss in the main duct. A series of such branches may generate sufficient loss in the system to require a step up in fan horsepower.

Frequently, fan rooms are too small for a properly engineered installation. This results in bad duct approaches to fans and finned heat exchangers, poor access for routine maintenance, and high installation costs. Adequate fan room volume should be provided during the initial design of a ship and checked for adequacy early in the detail design phase. Allowance should also be made for supplemental equipment, including power panels, motor controllers, piping, control valves, and spare filter storage.

All systems should be checked for proper air delivery after installation is complete. Usual requirements are: minimum of 90% of design air quantity to each space, and 80% of design air quantity at any terminal where more than one terminal serves a space. Some means of orificing each branch should be provided in the design of the system which is easily accessible, especially when ducts are placed above ceilings. This will save considerable money and time when balancing the system.

Ducts may be constructed of galvanized sheet steel in order to withstand corrosion and vibration. Ducts may also be constructed of aluminum in order to save topside weight. Because of headroom requirements, most ducts are rectangular, round ducts being used only in smaller sizes. Circular or oval ducts are used when passing through beams, girders, and other strength members. A heavy section of ductwork is usually welded into the penetrated structure where structural compensation is required. Handholes, access holes, and portable sections are provided to permit cleaning, painting, and inspection. Ducts passing over electrical equipment are made watertight. Flanged connections are provided for making all ducts portable, and flanged coamings are provided where they penetrate bulkheads, decks, and other structure. Ducts are made with either riveted, welded, or hook seams and are airtight. Ship joints may be used for joining duct sections, but good workmanship is essential to prevent leakage. Mechanical exhaust is provided to exhaust the air from hoods over heat-producing equipment. Supply air to the galley is usually preheated in the winter. To maintain habitable temperatures in machinery spaces for the operating personnel, spot cooling with large quantities of air at high terminal velocities is used at operating stations. Exhaust terminals should be located over heat-producing equipment. Often, natural exhaust is used, allowing some of the air to escape into the outer casing of the smokestack, the rest being utilized for forced-draft blowers returning it to the boilers for combustion air.

The total cooling load was calculated to be 19,150 BTU/hr. The main blower has to supply 1200 cfm at 1500 ft/min. with a pressure drop of 1.1625 inches of water. The fresh air supply blower has to supply 540 cfm at 1500 fpm with a pressure drop of 1.5493 inches of water.

COMPARTMENT TEST SCHEDULE

Compartments are to be tested according to the degree of tightness desired. IE, oil tight, water tight, air tight, fume tight. Each compartment to be tested will have a specific test procedure to be carried out by the Engineering Test Department. The Engineering Test Department will insure that the compartment test procedure is in compliance with the requirements of regulating bodies, where they apply.

The following notes are examples of specific test requirements for various compartments and equipment on board ship.

1. Testing throughout shall be in accordance with A.B.S., Maritime Administration and specification requirements.
2. All shall not tested by tank pressure shall be hose tested.
3. Pressure of all hose testing to be not less than 30 p.s.i. at nozzle distance to nozzle as dictated by A.B.S. Local.
4. All weather decks & boundaries of all deck houses are to be hose tested.
5. All water-tight & weather-tight doors, hatches & side ports shall be hose tested.
6. All windows & fixed light shall be tested by hose with nozzle pressure of 30 p.s.i. at a distance of 10 feet.
7. All toilet & wet spaces to be tested by filling with water to top of coaming.
8. Folding W.T. hatch covers shall be hose tested.
9. Machinery casing bhds. to be hose tested.
10. Miscellaneous tanks to be tested by filling with water to top of overflow.
11. All testing to be done after all penetrations are completed and kick pipes, spool pieces, etc. are installed.
12. Rudder, rudder trunk & horn, to be soap & air test to 5 p.s.i. prior to internal coating.

13. No paint other than prime coat, shall be applied to structure prior to testing.

14. Drain wells in cargo oil tanks to be tested to same head pressure as applied to tanks.

15. Pipe chase to receive soap & air test to 5 p.s.i.

16. Reefer drainwells to be tested by filling with water to deck drain.

The following is a sample hydrostatic test for double bottoms 4 and 12. This test must be carried out to suit the requirements of the A.B.S. In the sample test procedure the test procedure is outlined. If the test is completed satisfactorily, the test is certified by the inspectors; however, if not satisfactorily completed the defect must be repaired and the test rerun.

The Quality Assurance department shall be the body charged with running these shipboard tests and with certifying the satisfactory or unsatisfactory completion of the tests.

SOUTHERN MARINE SYSTEMS INC.

SHIP TESTING PROCEDURE FOR COMMERCIAL SHIPS

TEST PROC. NO. ____________________ TITLE: ____________________

____

PREPARED BY: ________________ DATE: _____ REVIEWED BY: ____________ DATE: _______

TECHNICAL APPROVAL: ______________________________ DATE: ___________

MANAGER, TEST SECTION

TEST PROCEDURE APPROVAL

____ DATE: ___________

MANAGER, QUALITY ASSURANCE DEPT.

OWNER: APPROVAL LETTER NUMBER ______________ DATE: ___________

A.B.S. REPRESENTATIVE ______________________ DATE: ___________

CERTIFICATION OF COMPLETION OF TEST

ALL TESTS COVERED BY THIS PROC. SATISFACTORILY COMPLETED

A.B.S. TEST NO. ____________ S.M.S. HULL NO. ____________ DATE: ___________

S.M.S. QUALITY ASSURANCE	OWNER	A.B.S.

REMARKS: ____

____

____

____

____

____

____

1.0 Purpose: The purpose of this test is to demonstrate the satisfactory construction of the double bottom tanks.

2.0 Requirements: A.B.S. requires that double bottoms are to be tested with a head of water up to the freeboard deck, the Bulkhead deck or the highest point to which the contents may rise under service conditions, whichever is the highest. The test is to be made before the vessel is launched, but after air pipes, sounding pipes and all other connections outside the double bottom have been fitted; if not finished before launching, the tanks should be tested again after all connections have been fitted.

3.0 General Notes:

3.1 A hole is to be cut in the tank top plating and a pipe running from the tank top to the bulkhead deck is to be welded in the hole.

3.2 The double bottom and the pipe are to be completely filled with water.

3.3 The double bottom is then to be visually inspected to check for leaks or buckled plating.

3.4 Double bottoms 4 & 12 are to be tested and if found satisfactory the test shall serve as a test for the remaining double bottoms.

3.5 All tests are to be carried out with regard to good practice for safety of personnel and equipment.

4.0 Test Reports:

4.1 Report any unsatisfactory condition to the proper authorities for remedial action and comment.

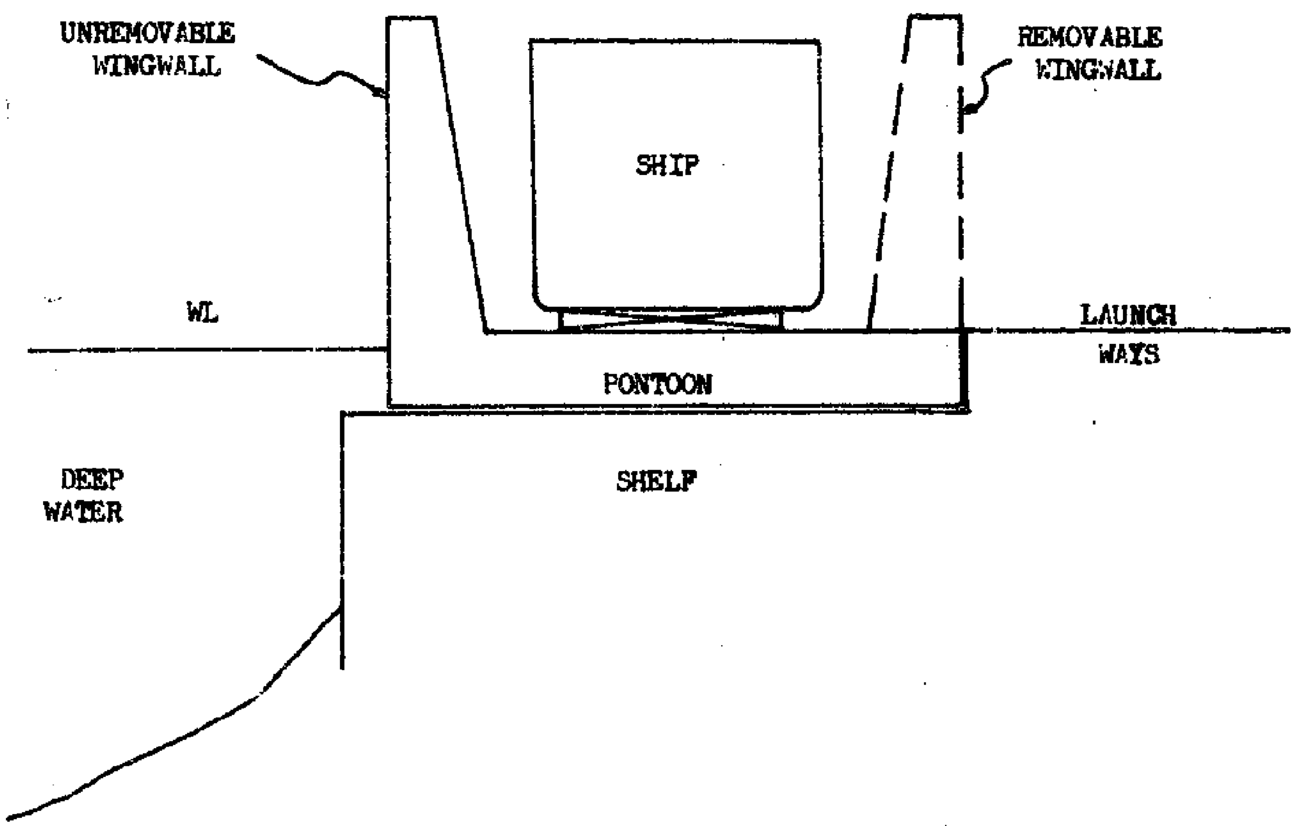
4.2 After correction, if any, rerun test and record applicable data.

4.3 Certify completion of satisfactory test on Page No. 1.

WEIGHT CALCULATION

Instead of the conventional end launching facilities used by most major shipyards today, Southern Marine Systems launches its vessels from a floating pontoon. After the modules have been joined together the nearly completed ship is moved onto the pontoon which rests on a shelf below the water. The shelf is designed to withstand only one half the estimated weight of the ship-pontoon combination. The remaining weight is supported by buoyant forces from the pontoon which is progressively deballasted during the ship transfer process. Using this process less costly underwater construction was required when the yard was constructed; therefore, great care must be taken to insure that the shelf does not become overloaded. To accomplish this the pontoon supervisor must have exact information regarding weight and center of gravity of the ship at the various stages of transfer. The information is supplied to the pontoon supervisor by the Weight Department of Hull Engineering.

The Weight Department receives all approved plans and breaks up the drawings into individual pieces. The weight of each piece and the distance from its center of gravity to; 1) the centerline of the ship, 2) the keel, 3) midships are tabulated and fed into a computer which keeps a constant record of centers of gravity from the above three planes. With the weight and center of gravity data the Engineering Department runs a stability calculation to make sure that when the water immerses the pontoon deck (the point of lowest GM because the only stabilizing waterplane is that of the wingwalls) the ship-pontoon combination does not tip over.



LAUNCH PROCEDURE ILLUSTRATION

STABILITY

In order to determine stability and buoyancy data under different loading conditions many curves of form were derived. These curves of form are plotted and can be used to describe the ship's characteristics in different stability situations. These hull characteristics represent functions of form. Because the basic variation in underwater hull form is the result of varying drafts, the ordinate scale is in feet of mean draft. The absicca is in tons of displacement. For functions of drafts other than displacements, suitable scale factors are provided to convert the reading in tons to the proper dimensions.

The following page is a computer program to find the longitudinal center of buoyancy.

C-FOCAL,1969

```
01.01 SOUTHERN MARINE SYSTEMS INCORPORATED
01.02 PROGRAM TO FIND LONGITUDINAL CENTER OF BUOYANCY
01.10 FOR I=0,9; S N(I)=0
01.12 FOR I=0,9; ASK "HALF AREA",N(I),!
01.14 S A(0)=N(0)*10; S A(1)=N(1)*9; S A(2)=N(2)*8
01.16 S A(3)=N(3)*7; S A(4)=N(4)*6; S A(5)=N(5)*5
01.18 S A(6)=N(6)*4; S A(7)=N(7)*3; S A(8)=N(8)*2
01.20 S A(9)=N(9)*1
01.22 S X=A(0)+A(1)+A(2)+A(3)+A(4)+A(5)+A(6)+A(7)+A(8)+A(9)
01.30 FOR J=0,9; S Y(J)=0
01.32 FOR J=0,9; ASK "HALF AREA",Y(J),!
01.34 S B(0)=Y(0)*1; S B(1)=Y(1)*2; S B(2)=Y(2)*3
01.36 S B(3)=Y(3)*4; S B(4)=Y(4)*5; S B(5)=Y(5)*6
01.38 S B(6)=Y(6)*7; S B(7)=Y(7)*8; S B(8)=Y(8)*9
01.40 S B(9)=Y(9)*10
01.50 S W=B(0)+B(1)+B(2)+B(3)+B(4)+B(5)+B(6)+B(7)+B(8)+B(9)
01.52 S D=X-W
01.54 ASK "STATION SPACING",H,!
01.56 ASK "SUMATION OF HALF AREAS",S,!
01.58 S G=(D*H)/S
01.60 IF (G) 1.62,1.68,1.70
01.62 T "LCB                      ",G,"FEET AFT OF STATION 10",!!
01.64 QUIT
01.68 T "LCB IS ON STATION 10",!!
01.69 QUIT
01.70 T "LCB                         " G, "FEET FORWARD OF STATION 10",!!
*
```

LAUNCHING

Anyone who has been to a ship launching well remembers the long speeches, the high school bands, the multitudes of people, and the loud horns from everywhere as the ship slides down the ways. As the world progresses, time becomes mans most prevalent factor. To continue to advance, time is becoming even more important. Man must then decide whether he wants to mix pleasure with work, or just work. Experience tells man to forego the pleasures and do what he must. This is evidently the case in the Southern Marine Systems Shipyard. This yard has no long speeches or any of the pleasures in launching a ship.

As the ship is built it reaches a stage where subassemblies are combined to make assemblies which become modules. At this time the ship, or module, is constructed on low platforms which move toward the launch area with respective completion stages. When the module is completed it is ready for connection into the final stage, the ship. The modules then roll together and are connected. The ship is then rolled out onto the launching pontoon on the same rolling platforms. The removable wing wall on the launching pontoon is retrieved from its storage area and returned to the pontoon. The pontoon is then lowered by flooding compartments. The pontoon is then pulled off the launch platform which is a massive bed of concrete piling driven into the sand next to the dock. The pontoon sinks evenly until it is completely free of the ship. The ship which has gained buoyancy from the water covering the pontoon is now afloat by itself. The ship is then towed to the wet docks for outfitting.

This appears to be a very simple operation but is quite complex and hazardess. As a floating dry dock is flooded down or pumped up with a ship, its stability is constantly changing. It is very important that the dockmaster, a single man with total responsibility, be aware when minimum stability exists, what the stability is at that time, and when to expect a large change in stability. In flooding the pontoon the G.M., the distance from the combined center of gravity of the ship and pontoon to the metacenter, is stable until the deck of the pontoon submerges. At this point there is a large decrease in G.M. Any initial listing of the pontoon will suddenly multiply the G.M. change. To avoid this multiplication effect the pontoon should be kept as level as possible until the ship is submerged. As the ship obtains buoyancy the G.M. will again increase until the ship is completely afloat and free of the pontoon.

At the time of launching, the ship is approximately 90% complete. The pontoon is then pumped out and returned to the launching platform ready for the next ship. The rolling platform must be removed and thoroughly cleaned after the removable wing wall is dismantled and stored.

As one may see, there are no bands, no speeches, and no champaigne when a ship is launched. The Southern Marine Systems Shipyard produces ships, not parties.

INCLINING EXPERIMENT

To illustrate the method of determining the vessel's center of gravity after construction, Southern Marine Systems employ a standard inclining experiment procedure.

The following conditions must exist while the experiment is being made:

(a) The least possible water and wind disturbances.

(b) Ship must float free.

(c) No free surface of liquids. If any exists, free surface corrections must be made.

(d) Nothing aboard may be moored during the experiment.

(e) The men must stay on the centerline of the ship if possible.

Procedures:

1. Place certain known weights, "w", on centerline.

2. Move weights off centerline a known distance, "d".

3. Measure change of angle of inclination, "ɸ".

4. Use plumb line of length "l".

5. Measure distance of plumb bob movement, "s".

6. Immerse plumb bob in bucket of oil to dampen its movement.

Calculations Required:

Inclining moment = $w \times d \cos \phi$

Righting moment = $\Delta \times GM \sin \phi$

$$w \times d \cos \phi = \Delta \times GM \sin \phi$$

$$GM = \frac{wd \cos \phi}{\Delta \times \sin \phi} \quad , \quad \frac{\cos \phi}{\sin \phi} = \cot \phi = \frac{l}{s}$$

$$\therefore \quad GM = \frac{w \times d \times l}{\Delta \times s}$$

Find displacement;

Read draft marks forward and aft

Find mean draft (and trim)

Find Δ for mean draft from curves of form.

Correct for trim.

Correct for density of water.

$$\Delta \text{ (actual)} = \frac{\Delta \text{ sw (from curves)} \times 35}{\delta}$$

δ = density of water in cubic feet per ton

Find KM $\quad KM = KB + BM$

Then $\quad KM - GM = KG$

KG = vertical position of center of gravity above base line.

OUTFITTING

Generally, planning and scheduling for outfitting is more detailed than for hull construction or for machinery installation. Our trend is to incorporate into the large subassemblies as much outfitting as possible. This scheduling includes that of tests for rigging, lifeboats, deck gear, and other equipment outside of the machinery space. Much of the outfitting work in a shipyard is done by venders or outside contractors as in the case of Southern Marine Systems. Many venders, as in our case, request that their own personnel install some equipment in order to assure correct installation. The normal sequence of hull erection is often modified to facilitate outfitting. Spaces which are generally ready at an early stage are the cargo holds for the fitting of ceiling, cargo battens, and ratproofing, and the refrigeration spaces for the installation of piping, insulation, and ventilation. Our yard subcontracts a great deal of joiner work. This procedure is advantageous as outfitting is only a small task in our shipbuilding program. By subcontracting we assure correct installation and employ fewer employees required for outfitting. Although the subcontractor may assume responsibility for protecting some of his installations, the yard must be alert to provide good working conditions with undue interference from other trades and to protect the completed installations from damage.

Steps involved in the progress of outfitting work in living quarters should follow some definite order, based on experience, to avoid confusion and possible renewal of outfitting work completed previously. A typical procedure for operations after completion of steel structure is as follows:

1. Make pipe and electrical penetrations.
2. Fair buckled plating.
3. Install air ports or windows.
4. Perform hose testing.
5. Fit insulation, wiring, ventilation ducts, piping, and joiner furring.
6. Fit joiner partitions and ceilings.
7. Install plumbing fixtures.
8. Lay floor covering.
9. Install built-in furniture.
10. Fit joiner trim and doors.
11. Install wiring drops and fixtures.
12. Complete painting.
13. Fit carpets and drapes.
14. Install portable furniture.

Where crane capacity permits, deckhouses are assembled either completely or in sections on the ground in advance of the time when the ship is ready to receive them. Southern Marine Systems generally includes deckhouses as assemblies and are assembled on the module in the correct erection procedure.

It is important to control the occupation of the spaces by the outfitting trades in larger and more complicated vessels. Our yard makes use of a printed form authorizing the use of a space by a certain trade. Authorization is given only after it is determined that the work to be performed will not interfere with subsequent work to be performed by other trades. It is desirable to prepare and issue work lists during the progress of outfitting. In addition to critical items to be completed, the work list should include items pertaining to safety, inspection and approval, and the scheduling of tests for the various systems. This is more commonly known as a Systems Test Agenda. As the work nears completion, unsatisfactory items should also be noted on the work lists. Inspectors and owners' representatives should be approached in connection with any additional or unsatisfactory work on which action is required in a particular space before final painting in the area is started. Early inclusion of such items will usually insure prompt correction, thus avoiding a long list of work to be performed just prior to acceptance of the ship.

As the outfitting work nears completion, the work effort is concentrated in selected areas to facilitate completion of the work in accordance with the compartment completion schedule. This involves finishing all items on the work list before final cleaning and painting. After painting, all fixed furniture and hardware should be in place and the doors securely locked. It is obvious that it would be highly desirable to have all testing completed within the area beforehand.

Many of the spaces must be used during ship trials, and a certain amount of cleaning up after trials is required. Our yard expends considerable effort in protecting painted areas and coverings, such as carpets, during the trials.

SEA TRIALS

The purpose of the sea trials is to determine the ship's characteristics under operating conditions. The ship should be loaded as nearly as possible to full load draft. On a tanker this is readily accomplished as the cargo tanks can be filled with water through the ship's cargo pumping system. On occasion, additional tanker trial runs are conducted at ballast draft. It is often necessary to complete the filling of tanks after the ship leaves restricted draft channels.

On a general cargo ship, all available tanks are filled. In some cases, such as ours, solid ballast is placed in the holds. Generally it is not practicable to bring a general cargo ship or a bulk carrier down to the designed draft for trial.

Our yard often conducts a short builder's trial on the first ship of a class, to shake down the ship before the official trial.

A list of principal events of a typical trial is given below:

1. depart shipyard
2. ballast to trial draft
3. adjust magnetic compasses
4. adjust radio direction finder
5. standardization runs
6. four-hour economy run at normal power ahead
7. two-hour endurance run at maximum power ahead
    1. perform turning circles
    2. perform Z-maneuver
    3. perform ahead steering test, rudder hard over to hard over
    4. crash stop to full power astern; measure reach

8. one-hour endurance run at full power astern

   1. perform astern steering test, rudder hard over to hard over

   2. crash stop to full power ahead; measure reach

9. two-hour run at a desired lower power ahead

10. anchor test

11. deballast

12. return to shipyard

The events need not be run in the order they are given. The schedule of events is often changed during the trial because of weather, delay, daylight, etc. The economy runs are made principally to determine fuel rates and to verify machinery design and heat balance. In some cases, the ship specifications require the trials to be in accordance with the latest SNAME Trial Codes.

Standardization is normally specified for the first ship of a class. The ship's bottom must be clean and smooth, which invariably means that the ship must be drydocked for bottom painting immediately before trials. Standardization consists of running the vessel over a fixed line course in both directions at several different powers to determine the ship's speed power curve. Usually three runs over the course are made at each power.

Although measured mile courses in deep water close to land are available at several places, including Rockland, Maine, Guantanamo Bay on the southeastern tip of Cuba, most standardization trials are now conducted using a radiolocation system, such as Raydist. If one transmitter is used, the ship must run away from and toward the transmitter, which may be on land or afloat in deep water many miles offshore. If the transmitter is afloat, a course can be run from the transmitter in a direction which will minimize the effect of current, wind, and waves.

A two dimensional system, employing two land based transmitters, can be used where a deep water course is available within about 100 miles of the transmitters. The optimum site and course can be selected to suit weather and sea conditions. The two-point fix determines the location of the ship relative to the transmitters at all times. A receiving antenna and a strip-chart recorded aboard the ship automatically record the entire path of the ship on a time base with remarkable accuracy. Since the path of the ship can be determined and plotted almost instantaneously, it is possible to make an number of runs over an exact predetermined straight course of any length in both directions. This method can give the path of the ship during turning circles, ahead and astern reaches, and steering tests. Of course, the usual current and wind corrections would be required. When standardization is included in the trial schedule, the length of trial will be at least two days, with one day devoted primarily to standardization.

Compass adjustment is done by turning the ship slowly in a place where accurate bearing fixes can be obtained. An outer harbor sometimes is found to be a desirable place to adjust the compass. Usually, a check with the gyrocompass is made.

Steering gear tests are conducted during or at the end of the maximum power endurance run and consist of:

1. turning circles
2. hard-over to hard-over steering
3. Z maneuver

The time for turning the rudder from hard-over to hard-over is about 25 seconds. The Z maneuver gives a relative measure of ship response and maneuverability. In this maneuver, with the vessel proceeding on a straight course, the rudder is turned 20 degrees right. After the ship has turned 20 degrees to starboard, the rudder is turned 20 degrees left and held until the vessel has turned 20 degrees to port of the original course. The rudder is again reversed and held until the ship is headed on the original course. The time to complete the maneuver is recorded. Turning circles are measured both to the right and to the left, each circle starting with the vessel proceeding on a straight course. The ship's heading is recorded continuously so that it can be determined for any position of the ship on the turning circle.

It is rather difficult to obtain an accurate determination of the path of the ship during the turning circle, which is about 1/3 to 1/2 mile in diameter. A plot of the ship's position from data provided by a two-dimensional radiolocation system gives an accurate turning circle path. Other methods of determining the turning circle path, such as by taking bearings about a buoy or by making plots of radar positions with respect to a buoy, are considered less accurate.

The anchor test is conducted in deep water. Each anchor is dropped separately under free fall to about 60 fathoms, with the anchor being snubbed to predetermined intervals to test the windlass brakes. Usually the windlass is required to be able to hoist both anchors simultaneously from a 30 fathom depth at an average speed of 30 fpm. The housing of the anchor is witnessed at the end of the hoist. Navy ships generally require the windlass to be capable of hoisting a single anchor from a 60 fathom depth at an average speed of 6 fathoms per minute or 36 fpm.

The Head and Astern reaches are measured when crash stops are made. With the vessel proceeding ahead at maximum power, the engines are reversed to full power astern. The distance required to bring the ship to a stop is termed the head reach. For a ship such as ours the head reach is about one mile and takes about 5 minutes to complete. The ship then proceeds astern for the astern run. At the conclusion of the astern run, the engines are reversed to maximum power ahead. The distance required to bring the vessel to a stop at this time is the astern reach. Since the vessel will not be able to maintain a straight course during these reaches, reach measurements are not particularly definitive unless a plot of the ship's course is obtained. Wind and current can have an appreciable effect on the ship's path during these maneuvers. Crash stop maneuvering is performed several times if the ship has automated machinery.

SPECIFICATIONS

Specifications are the heart of any shipbuilding contract since they describe the work to be performed. Poorly or carelessly written specification can cost a shipyard much of its anticipated profit.

There are generally three types of specifications used in the shipbuilding business:

Performance Specifications - The contractor accepts general responsibility for design, engineering, and the achievement of the stated requirements of performance.

Design Specifications - The buyer accepts general responsibility for design and for retailed omissions, errors or deficiencies in the specifications and drawings given to the contractor.

Purchase Description Specifications - A particular brand name is specified and an "or equal" phrase is sometimes added. If the specified brand name is furnished by the buyer, then the buyer accepts responsibility for proper performance. If an "or equal" product is furnished by the vendor, then the vendor accepts the responsibility.

The following set of specifications is a basic set of purchase description specifications for the ship's propellers.

The horsepower requirements of this vessel make it necessary to go to a triple screw configuration.
The power split into the three propellers is 1:1:1.
The two outboard screws are 40 feet off the centerline.
All three screws have a diameter not to exceed 24 feet.

The pitch relation of all three screws is 1:1.

Tentatively the three propellers are to be TROOST Series B 4.70, i.e. four blades with a developed area ration of .70, operating at 120 rpm.

A_p (projected disc area)	211 ft^2
A_o (overall area)	452 ft^2
A_D (developed area)	258 ft^2
η_o (open water efficiency)	67.3 %

The propellers can be either TROOST series B 4.70 as described above or equivalent. So long as the wheel does not exceed a diameter of 24 feet and the open water efficiency of the wheel does not fall below 67.3 % operating at 120 rpm.

CONCLUSION

According to ABS we feel the strength of the midship section modulus is much stronger than necessary. We also feel a reconsideration of the design of the centerline propeller shaft should be made. We feel it is not of adequate width for inspection, lubrication, or removal if necessary. It appears that the width could be extended slightly without drastic changes to the propellers.

A bow thruster located in a bulbous bow would improve handling on the seas by decreasing the bow wave and docking with greater assurance, safety, and ease.

Considering the limited amount of information we received and the time allotted we could not dwell on any given subject. Our objective was to demonstrate our understanding of many topics rather than specific details.

ACKNOWLEDGEMENTS

We gratefully acknowledge the never ending help of Professor J.F. Hallock whose guidance and advise made this project possible. Appreciation is expressed also to Professors Bartlett and Bryant for their thoughtful advise and suggestions concerning the project. Thanks are also expressed to Mr. S.Posner for furnishing us with additional information. We would also like to express our thanks for the cooperation of Mr. J.E. Thomas. Thanks also go to the following members of the Junior Class for their assistance: Jim Pittman, Joe White, and Joe Fisher.