

STERN FRAME AND HAWSEPIPE CONSTRUCTION
TECHNOLOGY.

Prepared by Todd Pacific Shipyards
Corporation, Seattle Division

Sponsored by
Maritime Administration

1978

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 1978		2. REPORT TYPE N/A		3. DATES COVERED -	
4. TITLE AND SUBTITLE Stern Frame and Hawsepipe Construction Technology				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128-9500 MacArthur Blvd Bethesda, MD 20817-5700				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 203	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

NSRP-SPCSP-2

UNCLASSIFIED

48809

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Transportation
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ABSTRACT

A cross-section of the United States shipbuilding industry, including shipyards, ship design agents, classification societies, and foundries, is interviewed with the objective of establishing the state-of-the-art in stern frame and hawsepipe design and construction techniques.

The findings from the interviews are evaluated to determine different, more productive stern frame and hawsepipe configurations for single screw vessels in three recommended sizes most representative of the ships being constructed now in U.S. shipyards or contemplated for construction in the future.

For each of the three vessel sizes, alternative designs and producibility analyses, including cost estimates, are prepared incorporating the most feasible stern frame and hawsepipe configurations.

A comparative analysis is performed to establish the most productive designs for each component.

ACKNOWLEDGEMENT

The present study was performed for Todd Pacific Shipyards Corporation, Seattle Division, under Subcontract No. SE-93244 to U.S. Department of Commerce, Maritime Administration, Letter Contract No. 2-36233 as part of the National Shipbuilding Research Program's Project SP-V-K.

The Program Managers at Todd Seattle were Messrs. Louis D. Chirillo and John F. Curtis. The research work was conducted at M. Rosenblatt & Son, Inc., Naval Architects and Marine Engineers, New York, N.Y., under the direction of Mr. Nedret S. Basar, Project Manager, by a team consisting of the following individuals:

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Mr. James Bister, Naval Architect

Invaluable cooperation and assistance was obtained from the following institutions and agencies during surveys and interviews:

American Bureau of Shipping
Avondale Shipyards, Inc.
Bethlehem Steel Corp., Bethlehem Foundry Div.
Bethlehem Steel Corp., Sparrows Point Shipyard
FMC Corp. Marine and Rail Equipment Div.
George G. Sharp, Inc.
John J. McMullen Associates, Inc.
Litton Industries, Ingalls Shipbuilding Div.
National Steel and Shipbuilding Co.
Newport News Shipbuilding and Drydock Co.
Todd Pacific Shipyards Corp., Los Angeles Div.
Seatrains Shipbuilding Corp.

The project team would like to thank the many individuals in the above institutions for their contributions.

Acknowledgement and thanks are also extended to the organizations or individuals listed below for their contributions in the form of information, review comments, direct quotations, etc.:

Babcock & Wilcox
Birdsboro Corp.
Chicago Bridge & Iron
General Dynamics Corp., Quincy Shipbuilding
AB Gotaverken
Puget Sound Naval Shipyard
Ryerson Steel Co.
Members of the SNAME SP-2 Panel
Sun Shipbuilding and Drydock Co.
U.S. Coast Guard, 12th District (mmt)
Bath Iron Works Corp,
KPM, San Francisco, CA,

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SECTION 1.0

INTRODUCTION AND SUMMARY

1.1 Background and Objectives

The subjects of the present study, stern frames and hawsepipes, are both important contributors to the trouble-free and efficient operation of seagoing ships.

The stern frame, as the name implies, is the heavy stern-most structure of a ship supporting the rudder only or both the rudder and the propeller shaft, depending on the number of propellers.

review
The hawsepipe is a tube through which the anchor chain is led overboard; it is usually reinforced by bolsters at the deck and the shell to increase endurance and guide the chain and anchor.

The National Shipbuilding Research Program, under the sponsorship of the Maritime Administration, includes a study of the stern frame and hawsepipe fabrication techniques within the framework of "Outfit and Production Aids Projects." Expressed in most general terms, as in [1]*, the objective of the project is to "evaluate different alternatives to the presently purchased stern frames and hawsepipes, and determine the benefits, if any, to be derived."

More specifically, the objective was described in the specification for the subject study, by Todd Shipyards Corporation Seattle Division, [2], in the following manner:

"Large castings have become extremely expensive both in money and required lead times. The advances in welding technology, and the advent of inboard accessible stern tube bearings, permit virtually all weldments with the prospect of savings through better control of material quality, less weight, and more effective production control."

"...the objective of this project is to provide U.S. shipbuilders with meaningful comparisons which would assist them in identifying the most productive stern frame and hawsepipe designs."

These objectives were to be realized through visits to "at least six shipbuilding firms," contacts with regulatory bodies, and investigations of foreign trends by literature search and inspection

* Numbers in brackets denote references listed in Section 6.0.

of foreign-built ships. The alternative stern frame and hawsepipe designs and their technical and economic comparisons were to be developed on the basis of results obtained from the surveys and comments received from the shipbuilding industry.

The study was limited to stern frames for single screw vessels.

1.1.1 Stern Frame Configurations

For single screw vessels, the stern frames must support the rudder as well as the tail-shaft and the propeller.

Stern frames for single screw vessels can be categorized in four basic groups depending on rudder configuration:

The first group is for unbalanced rudders as shown in Figure 1-1, which is characterized by a shoe piece and a rudder post extending vertically downward from the hull to the shoe.

The second group is for balanced, top and bottom supported rudders, Figure 1-2, where the rudder post is no longer needed.

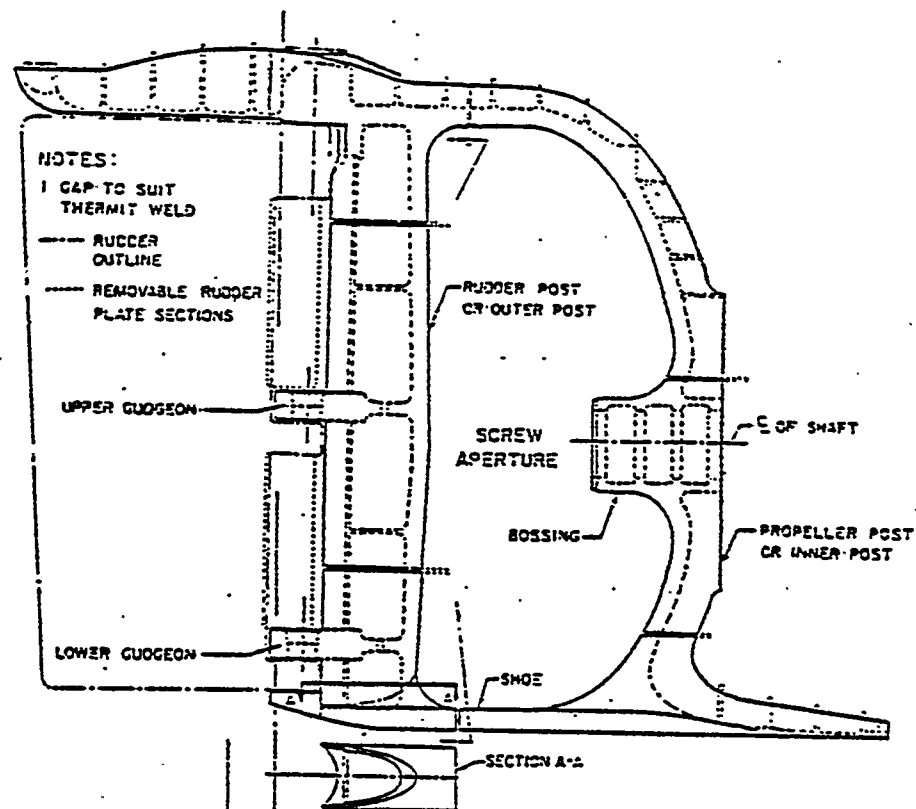
The third group is for balanced horn rudders, Figure 1-3, where the shoe is absent and the rudder post is replaced by a rigid horn that extends only part of the rudder span vertically downward from the hull, Figure 1-4.

Another stern frame configuration is the one for spade type balanced rudders, shown in Figure 1-5, which have no shoe, rudder post, or horn.

Details of arrangement and descriptions of the functions of each component in these stern frame configurations can be found in [3].

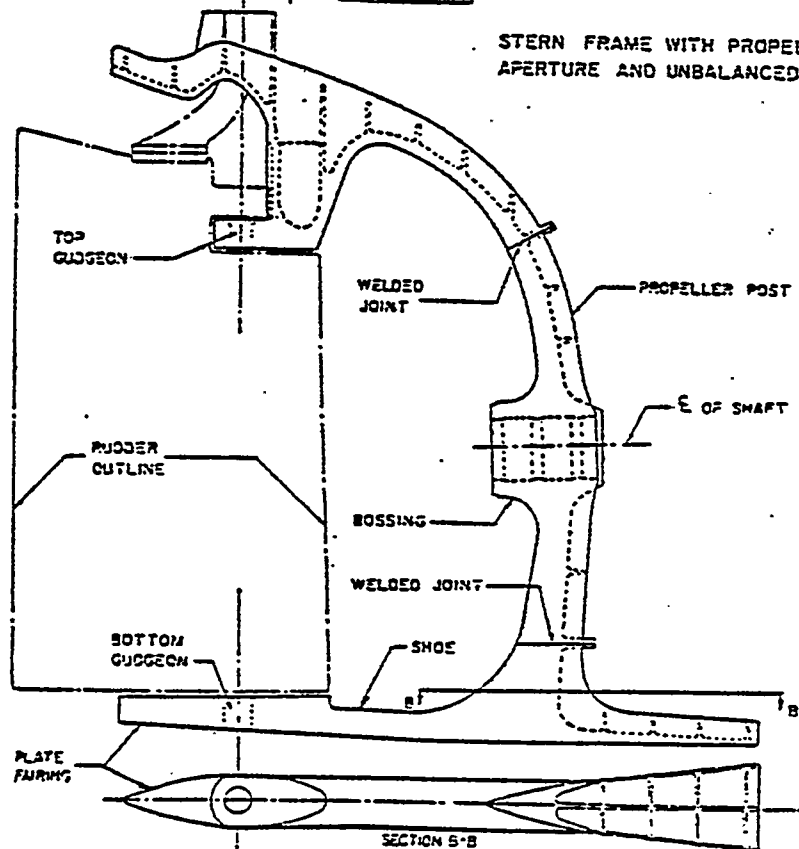
1.1.2 Hawsepipe Configurations

Hawsepipes can be manufactured from rolled plates, drawn pipes, or they can be cast pipes leading from the deck level through the bow structure to the side shell. They serve the purpose of guiding the anchor chain in its passage to and from the anchor windlass and of securing the anchor.



STERN FRAME WITH PROPELLER
 APERTURE AND UNBALANCED RUDDER

Figure 1-1



STERN FRAME FOR BALANCED STREAMLINED
 TWO-BEARING RUDDER

Figure 1-2

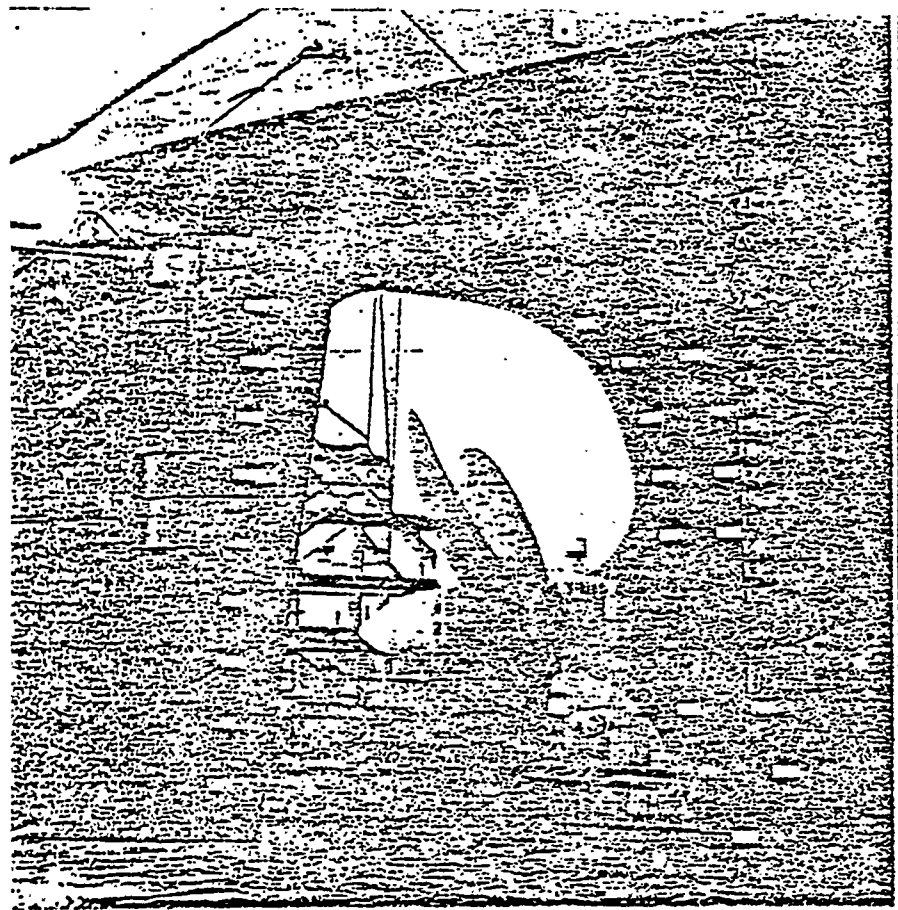


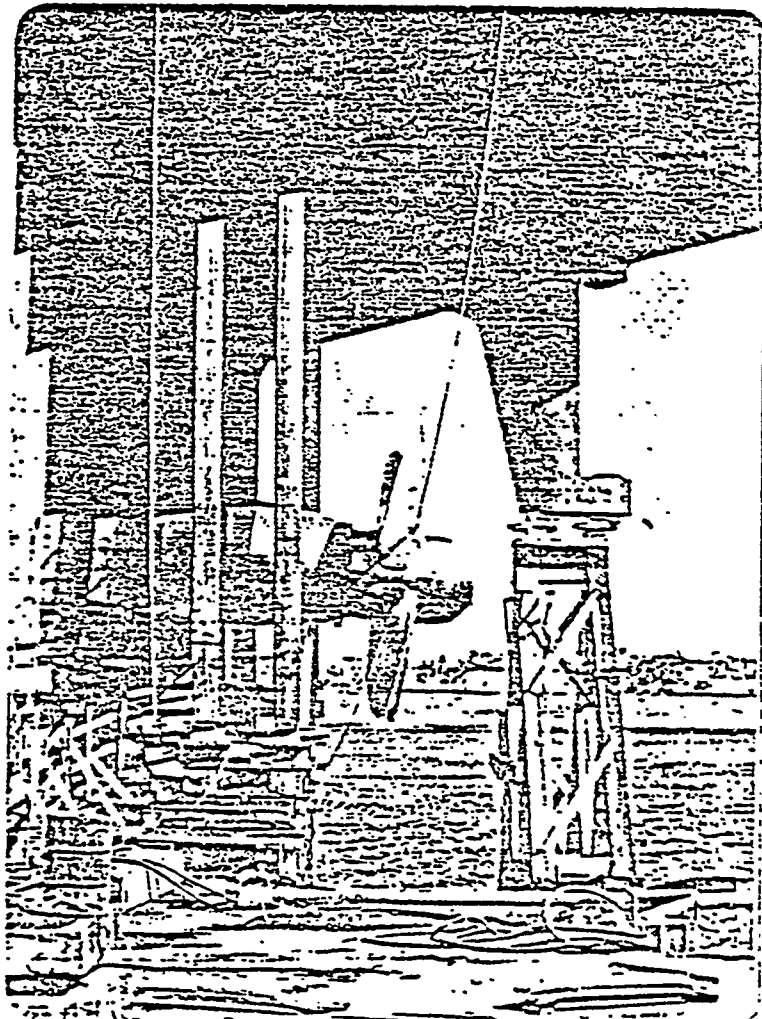
Figure 1-3:

Single Screw
Fabricated Rudder Horn
Stern Frame
(Reproduced from
Ref. #3, 1969 Edition)

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Figure 1-4:

Single Screw
Rudder Horn
Stern Frame



Hawsepipe configurations consist of the pipe through which the anchor chain runs and the anchor shank stows, Figure 1-6, and means of protecting the deck and shell adjacent to the ends of the hawsepipe, such as bolsters, doubler plates and/or chain rollers, Figures 1-6 through 1-8.

Other existing hawsepipe configurations include the anchor pocket to more safely stow the anchor, Figure 1-6, and the billboard type stowage which actually has no hawsepipe at all, Figure 1-9.

Additional information for hawsepipe configuration details can also be found in [3].

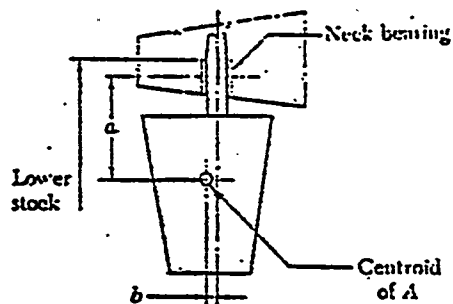
1.2 Study Approach

The statement of work as delineated in [2] was transformed into two major phases, and each phase was further divided into tasks as shown below:

- o Phase I: Surveys and Analysis
 - Literature Search
 - Preliminary Surveys
 - Final Surveys
 - Data Analysis and Evaluation
- o Phase II: Alternative Designs and Investigations
 - Determination of Baseline Ships
 - Development of Alternative Stern Frame and Hawsepipe Designs
 - Producibility and Comparative Cost Estimates

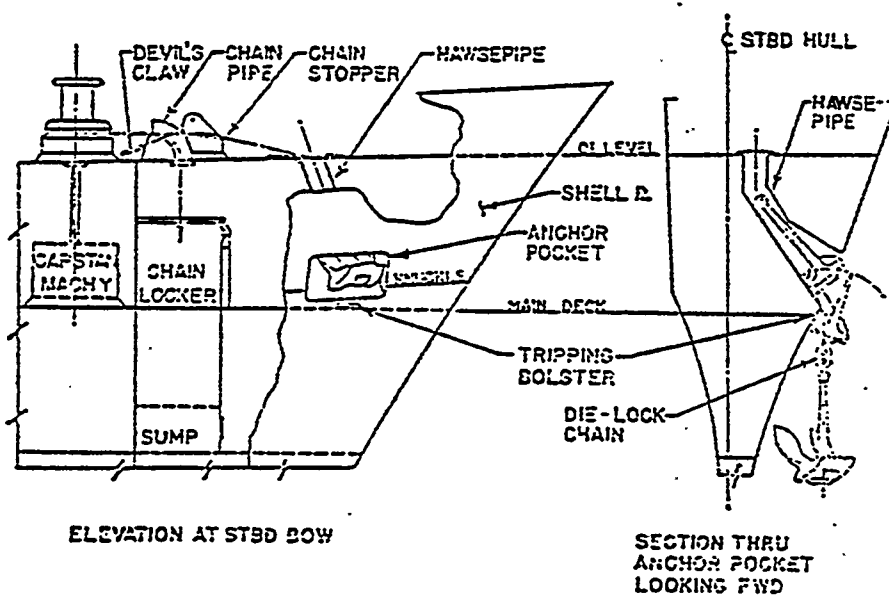
On the basis of alternative designs developed in Phase II, recommendations to be made to the classification societies regarding possible changes in the rules governing stern frame and hawsepipe designs were also considered.

In the first phase of the study the scope of surveys were expanded to cover eight major U.S. shipbuilding yards and two foundries, two design agents, the American Bureau of Shipping and the U.S. Coast Guard. The information sought, and recorded to the extent that it was made available, were the following:



b Spade rudder

Figure 1-5



Anchor handling arrangement with anchor pocket, for catamaran (AGOR)

Figure 1-6



Figure 1-8



Figure 1-9: Gotaverken
Billboard and Kockums
Chain Stopper

- o current and/or proposed detail designs
- o estimates of required resources to construct stern frames and hawsepipes in terms of manpower, material, facilities, and time
- o capability to produce and special skills required
- o problems encountered in planning, scheduling, manufacturing and testing
- o U.S. Government restrictions
- o Classification Society requirements

The second phase consisted of developing alternative stern frame and hawsepipes designs for three sizes of single screw vessels which were most representative of the ships being constructed or contemplated for construction in U.S. shipyards, and comparing them from the standpoint of producibility.

Alternative designs were to be proposed for three single screw ship sizes, of approximately 30, 80 and 200,000 DWT capacity, for which detail design drawings for the stern frame and hawsepipes arrangements were available.

By adaption of existing detail drawings, or by original effort where necessary, the following alternative feasibility designs were to be developed for each of the baseline ships as approved by the MARAD Research and Development Manager at Todd Seattle:

- o a stern frame incorporating conventional stern tube bearing and castings to the degree that they are still being used in U.S. shipyards
- o a stern frame featuring virtually all weldments and a conventional stern tube bearing
- o a stern frame consisting of virtually all weldments and an inboard accessible stern tube bearing
- o a hawsepipes of the conventional type without deck bolster
- o a hawsepipes of the billboard type

The scope of these designs and their level of detail was to be limited to only that necessary to perform the required comparisons of producibility.

The producibility of each design was to be considered in terms of the following major considerations:

- o Manpower: Labor required to layout, fabricate, assemble, and test.
- o Material: Direct material needed to construct and assemble the components.
- o Facilities: Special facilities such as welding or testing equipment needed in the manufacturing process.
- o Time: Length of time needed to manufacture complete units on a comparative basis.

1.3 Summary of Results

The data obtained from all preliminary and final surveys were tabulated in the form of an all-inclusive matrix. The survey results are presented in Section 3.0 in brief; excerpts from some surveys and the all-inclusive matrix are included in Appendix A.

The three baseline ships selected, and approved, for use as reference vessels for alternative stern frame and hawsepape feasibility designs and comparative producibility estimates were the following:

- o 38,300 DWT Oil Carrier
- o 89,700 DWT Oil Carrier
- o 188,500 DWT Oil Carrier

The criteria and rationale for the selection of these vessels as baseline ships can be found in Section 4.0 along with nine alternative stern frame and six alternative hawsepape feasibility designs developed for them. Back-up data is in Appendix B.

The comparative producibility estimates for each alternative design are summarized in Section 5.0 and the details and back-up information are provided in Appendix C.

Comments received from the shipbuilding community as a result of their reviews of the interim project report, the alternative designs/productibility estimates, and the draft final report are presented in Appendix D.

As much as practicable of these comments were incorporated into the final feasibility designs and cost estimates.

Only one proposed rule change, relative to the use of chain rollers in lieu of deck bolsters, was made to the American Bureau of Shipping; and the Bureau has indicated its intention to consider this change.

The authors' conclusions and recommendations along with suggested areas for further study are presented in Section 2.0.

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SECTION 2.0

CONCLUSIONS AND RECOMMENDATIONS

In the present study, primary emphasis was placed on determining the producibility of alternative stern frame and hawsepipe designs. However, in surveying the shipbuilding industry for this purpose and also in designing and analyzing various probable arrangements for these components, valuable insight has also been obtained regarding their configurations and designs.

Based on this insight, and also on comments received from a representative cross-section of the U.S. shipbuilding community, a number of conclusions were reached which may prove useful as a guide to the industry in the selection, design, and construction of stern frames and hawsepipes for new vessels.

The findings of the study and the resulting conclusions are presented below, in brief, separately for the two components, along with recommendations for future work as found appropriate by the project investigators.

2.1 Stern Frames

2.1.1 Findings

- o The U.S. shipyards, consistently, prefer a stern frame configuration incorporating a rudder horn (semi-spade rudder).
- o With the exception of two shipyards, where two recently built classes of vessels were equipped with inboard accessible stern tube bearings, little experience exists in the U.S. shipyards on IAST applications.
- o Vessels with both all-cast and all-welded stern frames are being presently constructed in the yards.

- o In designing the stern frames, most yards follow the classification society regulations and detail the designs on the basis of their own accumulated experience.
- o The yards anticipate serious difficulties in obtaining very large castings of good quality within acceptable lead times in the future. This problem, however, has not so far significantly affected their decisions to use castings or weldments.
- o Foundries are confident that they can meet the future needs of shipyards but emphasize that the two should work together to finalize the design of castings for favorable production delivery periods.
- o The prevalent delivery periods seem to range from 6 to 12 months depending on the size and the complexity of the stern frame designs.

2.1.2 Conclusions

- o Normal shipyard facilities are adequate for assembling both the all-cast and the all-welded stern frames.
- o Required shipyard manpower will be greater for all-welded stern frames since they are more labor intensive than castings.
- o Planning-scheduling considerations, manpower requirements, and available time frames vary from shipyard to shipyard and ship to ship. Consequently, when the results presented in this study are to be interpreted for a specific application these considerations must be taken into account on a case basis.
- o The stresses allowed in the stern frames are low. However, the mass and the rigidity of the stern frame structure are considered to be important criteria in minimizing shaft deflections and absorbing local loads without significant movement. These criteria must therefore be taken into account in the design stages.

- o The cost of fabricated stern frames is significantly smaller than that of cast stern frames for single as well as multiple ships.
- o An all welded stern frame with inboard Accessible Stern Tube (IAST) is significantly less expensive than a conventional cast stern frame.

2.1.3 Recommendations

- o The overall construction costs and life cycle costs of the inboard accessible stern tubes should be investigated. The adoption of IAST's in a stern frame design will affect the installation of propeller shafts and shaft bearings and the lifelong maintenance and repair costs for the vessels. In this sense, the shipbuilders may recommend to the ship owners that they favor the use of IAST in their new ships for the benefits of decreased maintenance costs as well as lower initial costs as compared to all cast designs.
- o As a long term objective, it may be suggested that the real necessity of having bulky and low-stressed stern frames be critically investigated. Such an investigation may result in modified stern configurations which may reduce the effort presently spent on this section of the ships and enable the yards to incorporate the stern structure into modular construction techniques in a more favorable manner.
- o Although purchasing stern frame castings is currently not very critical and may not be so in the near future, the significantly smaller costs of all-welded stern frames warrant their consideration for all new constructions.

2.2 Hawsepipes

2.2.1 Findings

- o Hawsepipes, or in more general terms, "anchor stowing configurations," show significant variation from ship to ship even within the same shipyard.
- o Aesthetics may play a large role in the selection of one or the other type of anchor stowing configurations.
- o Cast deck and shell bolsters are still in use on some ships; they have, however, been completely replaced by doubler plates and fairleads on some other ships.

- o The scantlings of hawsepipes are mainly governed by wear and tear considerations.

2.2.2 Conclusions

- o An all-welded hawsepipes is almost consistently considered to be more producible than a hawsepipes with castings.
- o The producibility analyses indicate that, on a comparative basis, the different hawsepipes or other anchor stowing configurations, do not show significant variations in cost. They are, in effect, relatively inexpensive parts of ships.

2.2.3 Recommendations

- o The selection of an anchor stowing arrangement for a specific vessel should be based on its compatibility with available deck spaces, with bulbous bows and bow thrusters, if any, and on maintenance and aesthetics considerations. Producibility of the arrangement is not considered to be a significant factor.
- o The billboard type anchor stowage arrangement deserves favorable consideration, wherever applicable, as a practical configuration.
- o No major classification society rule changes were found to be necessary; however, one minor suggestion to include the option of incorporating chain rollers in lieu of deck bolsters was made by the project investigators. Copies of Todd Seattle's letter forwarding this suggestion to the American Bureau of Shipping and the proposed rule change can be found in Appendix F.

SECTION 3.0

SURVEY OF U.S. SHIPBUILDING INDUSTRY

REGARDING STERN FRAME AND HAWSEPIPE PRACTICES

3.1 General

In order to realize the objectives of this study, and as called for in the specifications, the United States shipbuilding industry practices for the design, fabrication, and testing of stern frames and hawsepipes were subjected to a comprehensive survey.

Preceding the surveys was a thorough literature search to determine the state-of-the-art of fabrication techniques and to establish a methodology for conducting these surveys. Extracts from major references reviewed are included in Appendix E. In essence, the literature survey resulted in a compilation of the industry's past experience and future trends in the production of stern frames and hawsepipes.

It was considered necessary to include into the scope of surveys the questions covering the following areas as applicable to stern frame and hawsepipe practices:

- o Design loadings
- o Configuration
- o Construction techniques
- o Economics
- o Classification problems
- o Welding considerations
- o Problems with castings

These areas were explored during preliminary surveys, and the approach was formulated as a "survey questionnaire," which was then used as the basic methodology in conducting subsequent final surveys at shipyards, design agents, foundries, and regulatory bodies.

3.2 Survey Format and Questionnaire

The questionnaire, in its entirety, is included in Appendix A. Basically it consists of questions and information requests in the seven categories mentioned above. This type of a subdivision permitted discussions in depth within the limited subject matter and facilitated compilation and comparison of results from surveys at different shipyards.

The questions within the seven categories were intended to yield responses that would indicate what types of stern frame and hawsepipe configurations are likely to be built in the future; what specific construction procedures could be used; planning, scheduling and tooling considerations; available design loadings for development of alternatives; economics of producibility; welding capability and vendor interface and its impact on scheduling and planning.

3.3 Survey Results

Both the preliminary and the final surveys at shipyards consisted of interviews with key personnel using the questionnaire developed for this purpose. Plans of ships presently under construction and of ships built in the past were reviewed. A tour of the shipyard to inspect vessels being built and the manufacturing methods used in the production of stern frames and hawsepipes was included.

The data from these surveys were subjected to a comparison and evaluation in order to define those areas where more information was needed. The results of this continuing evaluation were used to modify and/or update the survey format.

Brief summaries of the results from surveys conducted at shipyards, regulatory bodies, design agents, and foundries and from industry comments received during various phases of the study are presented below separately for each category. More detailed information on survey results and a comprehensive comparison matrix can be found in Appendix A. Industry comments, in greater detail, are presented in Appendix D.

3.3.1 Configuration of Stern Frames and Hawsepipes

3.3.1.1 Shipyards

Two shipyards were visited for the purpose of preliminary surveys, and final surveys were conducted in six additional shipyards.

The stern frame and/or hawsepipe configurations for the following range of ship types and sizes were inspected during visits to shipyards:

Oil Tankers:	35,000 DWT to 390,000 DWT Capacity
LNG Carriers:	125,000 m ³ Capacity with Free Standing Rectangular or Membrane Tanks
Container Ship:	33,800 DWT Capacity
Ammonia Carrier:	32,000 m ³ Capacity (conversion)

Stern frame and hawsepipe configuration and arrangement drawings for most of above vessels were obtained from the shipyards building them.

(a) Stern Frames

Among all the stern frame configurations examined, the most frequent design was that for a single screw vessel using a semi-balanced rudder mounted on a horn, Figure 3-1. The reasons for this preference are that the flow to the propeller is unobstructed, that the horn can easily be incorporated into the stern module and provide good support for the rudder, and that the rudder stock diameter is acceptable.

A shoe piece, especially on a large ship, might cause vibration problems due to its size and proximity to the propeller. Large stocks required for spade rudders are considered to be significant sources of problems for this type of configuration. For these reasons, the configurations of stern frames with shoe pieces (see Figure 1-1 of Section 1.0) and with spade rudders (see Figure 1-5 of Section 1.0) are very seldom used.

The semi-balanced rudder with horn also appears to be the most favored configuration for future consideration. Shipyards indicated that they would build any type of stern frame required, but would try to influence Owners' opinions toward the adoption of the horn type configuration.

Stern frame configurations with inboard accessible stern tubes were also observed at two shipyards. Figure 3-2 is a photograph of the inboard accessible stern tube on a large tanker. Figure 3-3 shows the stern view of a small tanker where an inboard accessible stern tube is also installed.

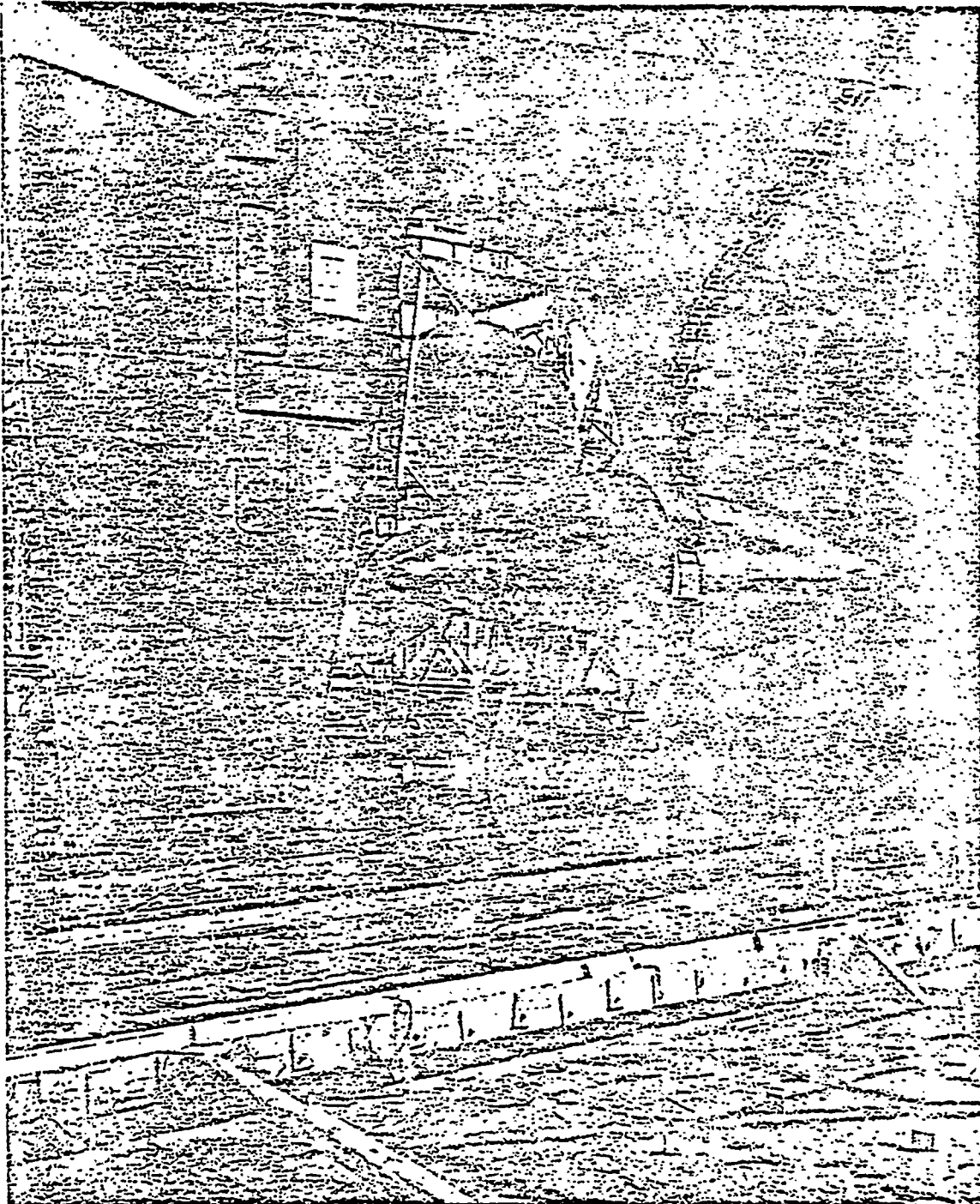


Figure 3-1: Semi-balanced Rudder on Horn
(Reproduced from Ref. #3, 1955 Edition)



Figure 3-2: Inboard Accessible Stern Tube on a Large Tanker

Figure 3-3: Inboard
Accessible Stern Tube on
38,000 DWT Tanker



Figure 3-4: Fabricated
Hawse Pipe of Two Half
Cylinders of Different
Thickness

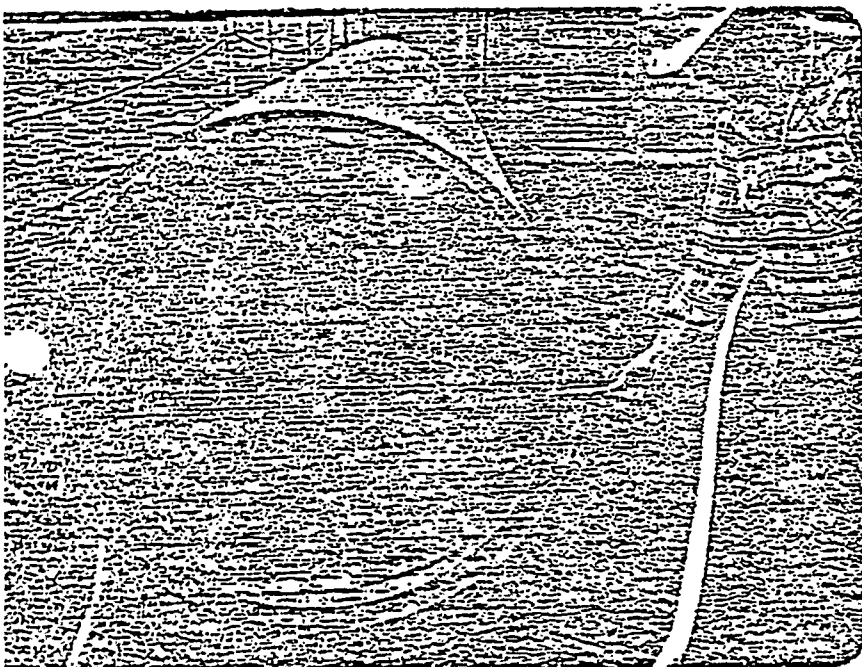
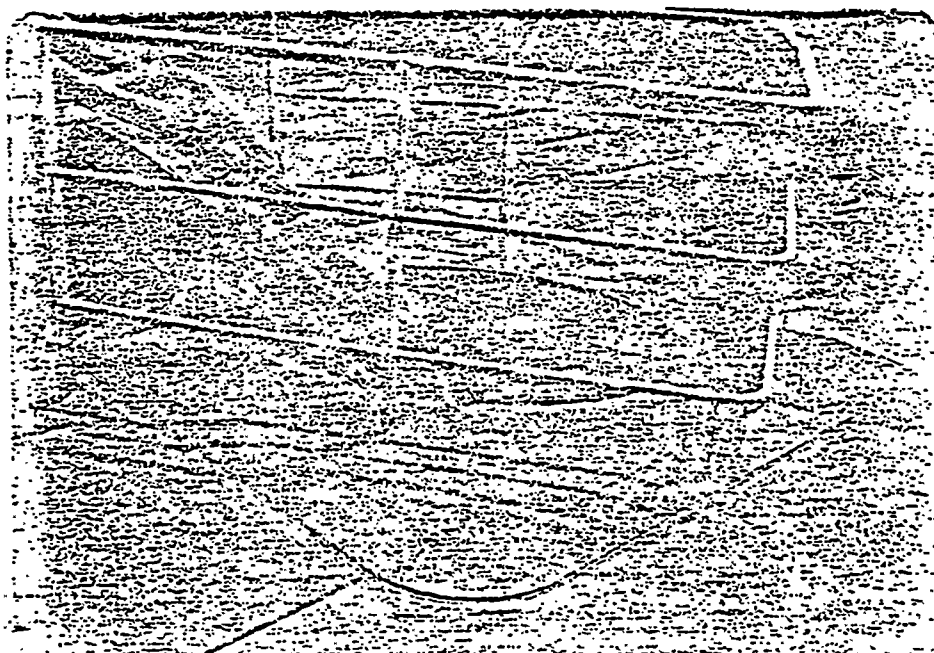


Figure 3-5: Deck
Doubler and Chain
Guide



The main reason for the selection of inboard accessible stern tubes for these two vessels was the ease of maintenance; the preference did not indicate thoughts given to favorable producibility of this configuration.

(b) Hawsepipes

In general the configuration of the hawsepipes varies with the type of bow and the size of the ship. On larger ships with a bulbous bow, the hawsepipes must be far enough aft to allow the anchor to drop clear. If the hawsepipes is too far aft, however, the anchor might accidentally drop on a working tug, or foul the bow thruster. Consequently, on every ship there is only a very narrow area where the hawsepipes can be located. A further consideration affecting the hawsepipes is the necessity of having the anchor high enough on the ship's side to be above the bow wave, which sometimes results in too shallow a slope, causing the anchor to jam in the hawsepipes. The most common solution to this latter problem is to get a fairlead roller near the inboard end of the hawsepipes to reduce friction or to cut away the shell plating creating a pocket at the lower end of the hawsepipes.

The hawsepipes configurations used in the more recent past all appear to incorporate fabricated pipes, as shown in Figure 3-4, but with different deck and sideshell protections such as deck doubler and chain guide (Figure 3-5), sideshell doubler plate (Figure 306). No specific configuration appears to be especially preferable to the shipyards. The choice appears to belong to the Owners.

One shipyard stated that they have had "excellent experience with a Kocks roller chock with built-in riding pawl" on one recent ship they constructed. Reportedly, this arrangement "eliminated the deck bolster and separate riding pawl, and eliminated the pinch on the chain at the deck with consequent reduction in friction load on the winch".

3.3.1.2 Regulatory Bodies

(a) Stern Frames

Regulatory bodies, either government agencies or classification societies, have no preference over one or the other stern frame configurations. They will approve the design and/or class the vessel as long as it meets the requirements of their rules and regulations. A synopsis of classification society rules regarding stern frame design and construction is included in Appendix E.

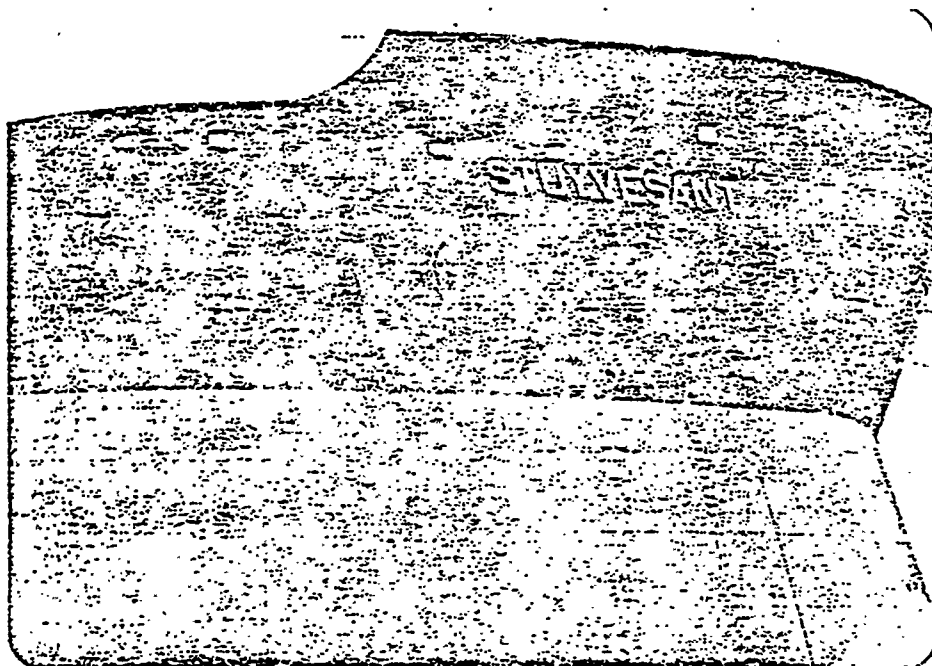


Figure 3-6: Shell Doubler Plate in Way of Anchor

The American Bureau of Shipping pointed out that the vibration of characteristics of cast sterns are different from those of plate fabricated stern structural components. The greater mass and stiffness of the cast sterns will significantly affect the overall vibration characteristics of the vessel.

(b) Hawsepipes

Similarly for the hawsepipes, the regulatory body approval is dependent upon meeting the rule requirements. Regulatory bodies expressed a preference for hawsepipes with bolsters, or at least with a large radius at the deck and sideshell to avoid damage to chain links and bending of the anchor shank. Approval has been given to some hawsepipe configurations without bolsters, but their performance is, reportedly, still being monitored as to how successful they are.

The classification society opinion on the recessed anchor pocket configuration is that this is primarily used in Navy vessels and is not common in commercial ships. However, approval will be given, if specifically requested, both for the recessed anchor pocket and for the hawsepipe configuration without a deck bolster.

3.3.1.3 Design Agents

(a) Stern Frames

The design agents interviewed stated that they would prefer a stern frame configuration consisting of a rudder horn with semi-balanced rudder without a shoe piece. Shoe pieces have been blamed for vibration problems on some ships. Any of their preferences would, however, be superseded by a client's ultimate desires.

(b) Hawsepipes

The approximate location of the hawsepipes and anchors would usually be shown on the preliminary or contract structural drawings by the design agents. It is up to the shipyards to decide on the final location and design details. Design agents emphasized that the anchor handling arrangement should be model tested in order to ensure a smoothly operating configuration.

3.3.1.4 Foundries

The casting vendors expressed the opinion that they are concerned with the production of castings rather than the configuration and strength considerations. They felt that a compromise must be reached between these two factors to produce a better casting at a lower price.

3.3.2 Construction of Stern Frames and Hawsepipes

3.3.2.1 Shipyards

(a) Stern Frames

During surveys at shipyards, stern frame constructions ranging from completely cast to completely welded types were observed.

A design incorporating a cast stern tube/propeller boss and a cast gudgeon with the remainder of the stern frame made up of weldments forming a stern module, as illustrated in Figure 3-7, was most representative of the present practice.

The present practice for construction of the stern frame is to incorporate it into the after hull structural modules which may be assembled anywhere in the yard and then transported to the building ways, as shown in Figures 3-8 and 3-9. This modular building technique allows a great deal of flexibility; none of the shipyards, accordingly, reported a need for any special facilities for the construction of modules.

As far as stern frame castings are concerned, shipyards without their own foundries obtain all castings from vendors, while those with their own foundries purchase castings larger than their capability as direct material from outside vendors.

One shipyard has used forgings instead of castings for stern frame components in two recent hulls of the same class even though they were follow-on to designs that originally called for castings. The reasons given were that forgings are inherently freer of defects and that their lead time is generally shorter than for castings.

Shipyards indicated that special skills were not required for the construction of stern frames. Welding of castings and thick plating is commonplace.

Practical restraints at the shipyards are generally related to crane capacity and furnace size for annealing of welded components, if needed.

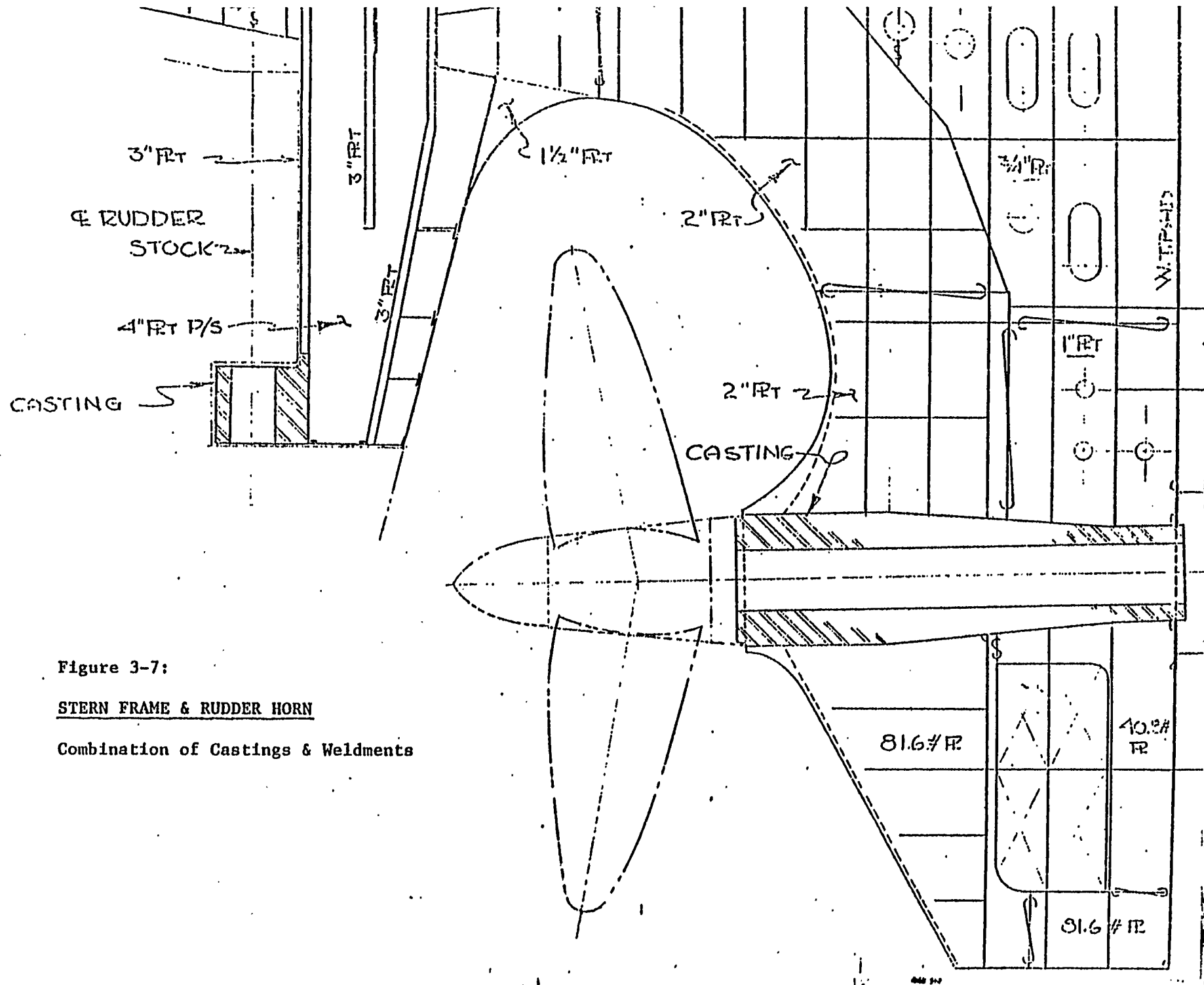


Figure 3-7:

STERN FRAME & RUDDER HORN

Combination of Castings & Weldments



Figure 3-8: Lower Stern Module

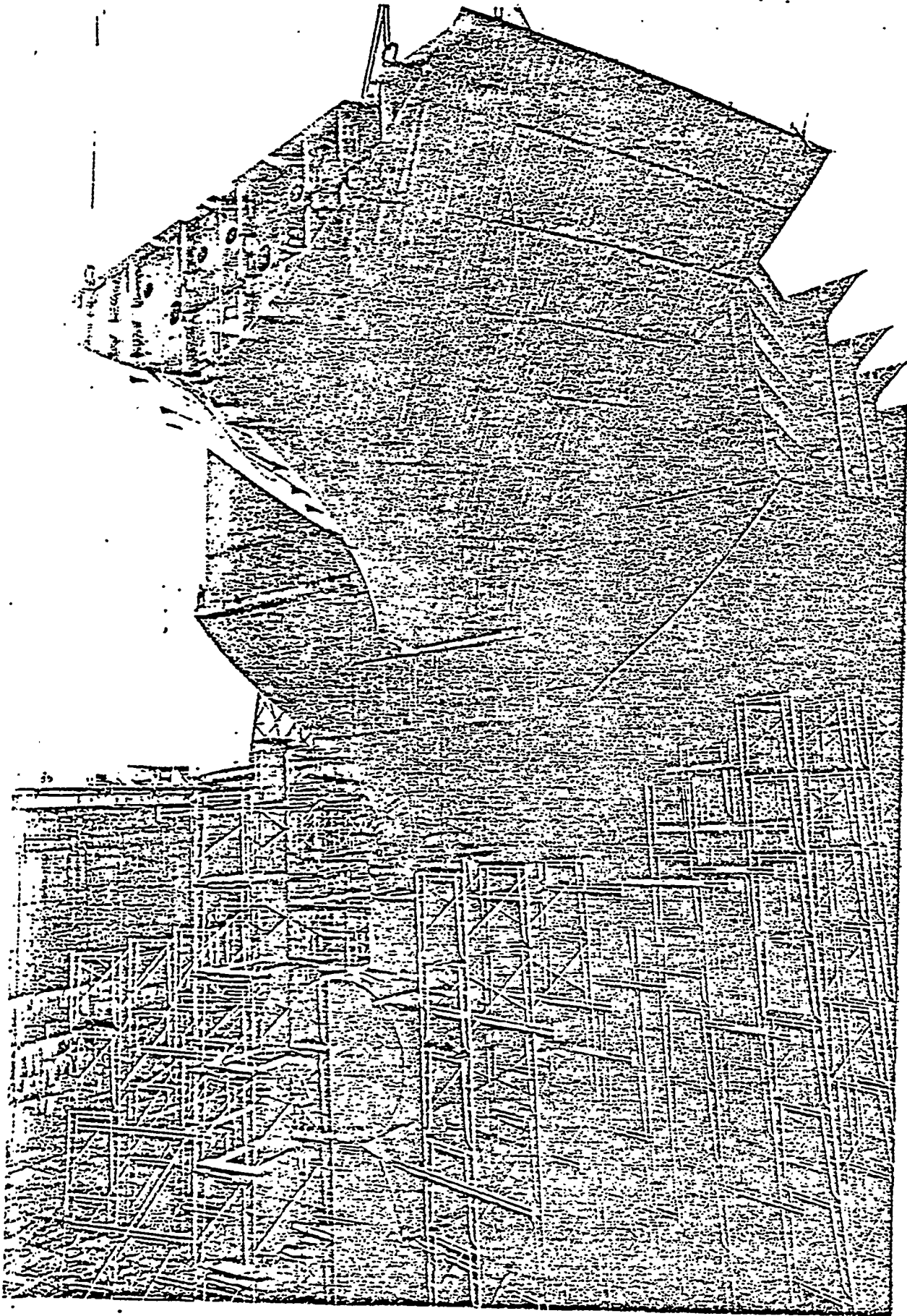


Figure 3-9: Upper Stern Module

(b) Hawsepipes

Hawsepipes observed during surveys were either fabricated from rolled plate or cast pipes. In either case they had cast bolsters at one or both ends of the pipe. One shipyard was building hawsepipes without any castings.

With welded hawsepipes, most shipyards would depend on outside vendors since they would probably not have the presses or the rolls necessary to form the pipe.

If the hawsepipe design without deck and/or shell bolsters should prove successful, improved producibility can be expected due to elimination of the castings entirely or reducing the sizes and complexities of castings.

The present practice at a majority of shipyards is to incorporate the hawsepipes into the forward hull construction modules before erection. Again, as in the case of stern frames, this modular construction technique allows a considerable degree of flexibility in the construction of hawsepipes since the size and complexity of each structural component can be kept within the yard's capabilities.

3.3.2.2 Regulatory Bodies

(a) Stern Frames

Appendix E contains a summary of various classification societies' rules and regulations governing stern frame construction. These rules cover construction requirements for both built-up and cast shoe pieces, rudder horns, stern tubes, etc. A combination of castings and fabricated components making up a complete stern frame structure is also acceptable. The general opinion is that certain components may work out better when cast (such as the rudder bearers and gudgeons) and certain others may tend to be easier to fabricate (such as the shoe pieces). Some components, such as the shaft bossing, do not lend themselves easily to fabrication, and consequently these must be castings.

The opinion was expressed by regulatory bodies during the interviews that getting a sound casting for very large pieces is a real problem. A thorough inspection cannot be made on castings; they can only be surface-inspected since no x-ray can penetrate deeply enough into large pieces.

Conversely, from a construction viewpoint, the aft section of the vessel is usually confined and therefore it may be difficult to fabricate completely welded stern frames.

About 50% of the ships classed by the American Bureau of Shipping have shoe pieces, and the other 50% are without shoe pieces. Of the ships with shoe pieces, 90% have stern frames made up of castings. Very few new ships are being fitted with shoe pieces.

Rudder horn construction is usually a combination of castings and weldments.

In response to general shipyard comments that classification requirements are not specific enough, the American Bureau of Shipping has commented that "the Rules are not intended to be a design manual, but rather a tool to establish the vessel's seaworthiness". The ABS further stated that they "have collected and developed data to publish additional requirements, and are closely monitoring the service feedback".

(b) Hawsepipes

No specific construction requirements were set forth by the regulatory bodies outside of the few guidance rules specified in [4] and excerpted in Appendix E.

3.3.2.3 Design Agents

(a) Stern Frames

The design agents interviewed appeared to prefer a combination of castings and weldments for stern frame construction. They always give the shipyards the option to modify the design to suit their modes of construction. In general, the design agents recognize that there are problems with castings, however they are not normally involved with the manufacturing details.

(b) Hawsepipes

The design agencies offered no comments on the construction of hawsepipes. Details of construction are normally accomplished by the shipyards.

3.3.2.4 Foundries

The only major comment made by the foundries during interviews with regard to stern frame and hawsepipe construction was in relation to quality control procedures. The foundries conduct extensive tests using x-rays which can penetrate 5" to 5½", magnetic particle inspection, and ultrasonic inspection.

Any defects found are repaired to the satisfaction of regulatory body surveyors before leaving the plant. The rejection rate of the castings was reported to be very nearly zero.

3.3.3 Design Loadings

3.3.3.1 Shipyards

With the exception of one, shipyards did not have any design loadings for use as a guide in determining the actual loadings that the stern frames and hawsepipes are subjected to. The yards generally are provided the detail designs for these components; the agency conducting the design analysis follows the class society rules as a guide only. One shipyard, reportedly, has its own design loading values based on experience and it conducts a full load analysis for each new stern frame design if it is specified to be their responsibility.

In general, specific design procedures are not available, and regulatory body rules are not considered to give adequate guidance on details of stern frame and hawsepipe design. The approach used in design is a combination of empirical methods developed from experience, and finite element analyses based on hydrodynamic loads determined by means of model tests in addition to the classification society rules.

3.3.3.2 Regulatory Bodies

The United States Coast Guard, as the certification agency, indicated that, as far as the structural integrity of merchant ships is concerned, they rely completely on the classification society (American Bureau of Shipping) to uphold the safety standards. The classification society maintains the standard by conducting surveys/inspections. The term "structural integrity" in this case includes the design and construction of stern frames and hawsepipes as well.

As evidenced from a review of excerpts from various classification society rules on hawsepipes, included in Appendix E, there are no design load criteria for these components. The American Bureau of Shipping does have an "in-house" approximate formula for determining hawsepipe and bolster thickness. A copy is included in Appendix E.* They feel, however, that their rules are complete enough to provide guidance for design, yet sufficiently flexible to allow individual designers to introduce innovations.

The allowable stresses in the rudder horns, and the shoe pieces if applicable, as determined from prescribed empirical formulas in the rules regulating design and construction of stern frames [4], are rather low, in the order of 6,700 psi for cast steel and 8,500 psi for steel plating.

The ABS stated that shoe pieces, if fitted, could be made up of weldments with satisfactory results; a reduction of required section modulus may be allowed for welded shoe pieces as in the case of welded rudder horns.

In the case of castings, the changes in section areas present serious problems and may cause discontinuities.

A case history on the cast steel stern frame troubles was made available to the project investigators during the interview by the ABS. Applicable specifically to stern frame configurations with skegs (shoe pieces), this document (a copy of which is presented in Appendix E) classifies the stern frame defects in the following manner:

- o Defects in stern frame skegs
- o Fractures in way of landing of shell plates to stern frames
- o Cracks in way of core holes
- o Other miscellaneous defects

This case history also includes statistical information on the frequency of occurrence of these defects for T-2 tankers and Victory Ships as well as a number of large tankers of 1949-50 vintage.

* This approximate formula has now been included in the ABS Rules (Section 4.9).

A simple guide for use in analyzing stern frame skegs, developed by ABS in 1959, was also made available to project investigators, and is presented in Appendix E.

3.3.3.3 Design Agents

In determining the scantlings of the stern frames and hawsepipes, the design agents comply with the rules of the classification society by which the ship is to be classed. They also perform a comparative check with the rules and requirements of other classification societies to ensure that the scantlings are reasonable.

The design agents had no statistical information or records of failures either for stern frames or for hawse pipes.

3.3.3.4 Foundries

Since, as stated earlier, they are concerned basically with the production of castings, the foundries did not express any comments on the design of either component.

3.3.4 Economics

3.3.4.1 Shipyards

The questionnaire used in the final surveys contained questions and information requests regarding significant economic considerations in manufacturing stern frames and hawsepipes as well as factual cost data on recently manufactured components. Qualitative discussions were held with the shipyards' personnel but no cost data were made available to the project investigators.

This was understood to be due mainly to the fact that no such cost data were available in most shipyards, as broken down to these components only.

It was stated that reporting a single unit cost to reflect the stern frame and/or hawsepipe costs on all ships is simply impossible. The size and configuration of these components on each ship are different and the costs, accordingly, are subject to great variations.

One shipyard suggested that if a figure had to be given, the cost of a stern frame casting could be approximately 70 cents (1977) per lb. of casting, plus the cost of manufacturing its pattern.

Despite the lack of factual cost data, qualifying statements on major economic factors affecting component construction costs were made. These comments can be summarized as follows:

- o Stern frames and hawsepipes, especially welded fabricated ones, are labor intensive items. Labor cost for these components is the largest single cost factor. Accordingly, in the interest of economy, their designs must be kept as simple and as easy to construct as possible.
- o Welded stern frames and hawsepipes are usually cheaper to construct. However, it requires much more shipyard labor to manufacture welded components than cast components.
- o Specifically for the case of one ship of a class being built, welding may certainly cost less since pattern costs, necessary for casting, would be eliminated.
- o For multiple ships of a class, with the cost of a pattern shared by several ships, casting costs may be comparable. However, the yards' opinions on this subject appeared to change from one extreme to the other.
- o One yard maintained that there would be no drastic differences between the costs of welded versus cast components. Cost of welding has been steadily going up, and it may eventually offset any differences from casting costs.
- o For welded type construction, keeping away from the use of high tensile steel (HTS) may keep costs down.

Rigidity of the component is more important and it can just as well be achieved with mild steel.

- o The castings for stern frames and hawsepipes are farmed out to outside vendors by most shipyards. The selection of cast components is usually based on availability of vendors. The casting is simply purchased and installed, eliminating extensively the need for excessive welding. This, naturally, improves scheduling performance especially when the castings are delivered without delay.
- o If a delivered casting has any defects in it, the casting vendor is backcharged until such time as the defective casting is repaired or corrected.
- o Very large castings may be manufactured by using several pieces cast separately and joined together by welds. In the casting process, slippage of core may present serious problems.
- o Shipyards with their own foundry facilities may prefer to use castings due to scheduling needs. The yard's foundry may need the work and may be able to meet the delivery dates favorably.
- o All charges and quotes for castings are made on the basis of weight, in terms of dollars per pound of casting. Cost of machining is generally treated as a separate and additional item.
- o One shipyard maintained that they have been constructing all welded stern frames for well over fifteen years, not only because they are cheaper but also that they have had very serious procurement problems with castings. Another shipyard had a similar comment and stated that "this policy is an executive decision made entirely upon the basis of uncertainty of obtaining a sound casting in consideration with the great exposure of the shipyard in the event of a failure".
- o In a study performed in 1977, this shipyard found that a complex stem assembly casting was 20% more expensive than a weldment.

3.3.4.2 Regulatory Bodies

No factual cost data were available to the regulatory bodies. Following comments were offered, however, as factors influencing the choice of weldments versus castings and also the cost of manufacturing:

- o The shape of the stern frame has a considerable amount of curvature, and will therefore necessitate the use of furnaced plates which may influence costs of fabricated components adversely.
- o Long lead times are necessary and delays are often experienced in this country in the delivery of castings from the foundry to the shipyard.
- o Corrosion of the joint welds of cast stern frames in a seawater environment presents a real problem; it may be necessary to preheat the casting in order to make repair welds, and this adds extra costs. In this context, the repairs of all welded stern frames will cost less.

3.3.4.3 Design Agents

The design agents could supply no cost information other than their own opinion that castings cost more to procure but are less labor intensive. Conversely, the weldments cost less in material but are more labor intensive.

3.3.4.4 Foundries

One foundry was visited and an interview was held with a representative of another foundry. One of the foundries was extremely reluctant to give out any cost figures. It was stated that the cost is dependent on the size of the casting, the intricacy of the mold, etc. On this basis, for a casting of 25,000 to 50,000 lb. weight, the unit costs were said to range from 50 cents to 2 dollars per pound.

Both foundries stated that labor is the principal cost and that the casting prices can be reduced if the design is kept simple.

Following additional comments by the foundries are noteworthy:

- o Marine castings constitute only a maximum of 20% of their total output.

- o The costs of patterns are charged separately.
- o Casting vendors normally do rough machining only. They can do final machining if they are asked.
- o They produce mild steel castings only and do all of their annealing themselves.
- o They perform first visual checks and tests (by magnetic particle methods and x-ray or ultrasonic equipment), if necessary, on the castings, and repair minor and major defects in accordance with classification society rules.
- o They leave the weld-joining of several pieces of castings to the yard.
- o They feel that in order to make the castings more economical and better products, the designers of stern frames and hawsepipes should consult with the foundry before making any final engineering decisions.
- o In general, the foundries feel that they can meet shipyards' delivery dates if given sufficient lead time.

3.3.5 Classification Problems

3.3.5.1 Shipyards

In answer to specific requests contained in the survey questionnaire, the shipyards provided the following summary comments:

- o According to a majority of shipyards, the classification society rules are not adequate for design and construction of stern frames and hawsepipes. Some yards said the rules were improving.
- o None of the yards reported any problems with the classification societies regarding stern frame and hawsepipe construction.
- o Most shipyards feel that the rules of all classification societies are about the same. However, some yards said they would prefer to use the Norwegian (det Norske Veritas) and/or the British (Lloyd's Register) rules because they provide more design information.

- o Only one yard out of the eight that were visited had "in-house" criteria for the development of stern frames and hawsepipes.

3.3.5.2 Other Institutions

Design agents and casting vendors did not have any additional comments to make regarding classification problems of stern frames and hawsepipes.

The design agents agreed with the shipyards that classification rules are not adequate to design these components. They normally use one or all of the classification society rules as guidance and complete the design on the basis of their experience.

In response to these comments by shipyards and design agents, the American Bureau of Shipping has indicated that they will consider developing further their rules for stern frames and hawsepipes.

In the performance of any vessel's design, shipyards have encountered no problems with the class societies in the design or inspection stages.

3.3.6 Welding Considerations

3.3.6.1 Shipyards

The responses of shipyards to specific welding questions can be summarized as follows:

- o On thin plates, conventional metal-arc type welding with stick electrodes is used.
- o For welding of thicker plates or for joining two cast sections by welding, submerged arc welding processes are employed. The process can be semi- or fully automatic.
- o With full-automatic electro-slag welding, the seam is welded in one pass vertically from the bottom up.
- o With hand held manual or semi-automatic processes, the multiple passes are made.
- o The electro-slag welding processes used for thick plate require good preheating before welding. The most common method is local preheating using electric heaters and asbestos blankets.

- o Some shipyards have their own heat treatment furnaces of sufficient capacity to allow them to preheat the thick plates in the furnace.
- o Shipyards with limited capacity furnaces or no heat treatment facilities prefer to do local preheating.
- o Post welding heat treatment and stress relieving operations are carried out in the same manner as in preheating.
- o Some shipyards stated that they have had bad experiences with thermit welding and therefore avoid it in favor of electro-slag welding.
- o Some shipyards reported that maximum thickness of plating they can weld is 2" while others expressed welding capability of up to 4" or 5" plates. A few shipyards said that they could weld any thickness of plating. It appeared to be a mutual opinion, however, that plates of more than 3½" or 4" thickness would give welding problems. Some twisting of these plates, after welding, has been experienced, and reportedly it has been difficult to correct.

3.3.6.2 Regulatory Bodies

Regulatory bodies request compliance with the minimum welding requirements as set forth in the rules [4]. The plans and specifications must indicate clearly the extent to which welding is to be used. Welding processes, filler metals, and joint designs must be shown in detail drawings, or on a separate document, prior to approval action by the classification society.

The American Bureau of Shipping, as indicated in paragraph 3.3.4.2 above, has pointed out the corrosion problems encountered at weld joint seams of cast pieces in a seawater environment. The repair of such welds would require the use of thermit welding which is a costly process due to the heating that is necessary.

3.3.6.3 Design Agents

The design agents gave no specific comments regarding welding problems with stern frame and hawsepipe construction. They normally leave the determination of welding processes and detail to the shipyards. One agent stated that they had no problems with welding of any thicknesses of platings they had specified, the maximum being 5".

3.3.6.4 Foundries

Foundries do not join two pieces of castings together by welding. Their customers, in this case the shipyards, normally do the joining.

In repairing or correcting defective parts of a casting, as determined by inspection, the foundries remove the defective portions to sound metal before welding. They use submerged-arc and electro-slag welding processes, and avoid thermit welding. Stress relieving is done locally by heating.

For major repairs, they have to document their repair procedure and submit it to the classification society for approval before doing the repairs.

3.3.7 Problems with Castings

3.3.7.1 Shipyards

The problems that shipyards experience with stern frames and hawsepipe castings have been discussed in connection with the yard's responses to the "economics" category (subsection 3.3.4.1) of the survey questionnaire. To repeat, the major problems as reported by shipyards were briefly:

- o Shipyards always farm out castings unless they or their parent organization have their own foundries. Two out of the eight shipyards visited had their own foundries, and they appeared to be satisfied with the castings delivered.

- o If the size of casting should exceed the capacity of a shipyard's own foundry, they would cast smaller pieces themselves and go to outside vendors for very large pieces.
- o In general, the lead times for castings range from a minimum of 6 months to a maximum of 18 months, depending on the size and complexity of the piece, as obtained from U.S. vendors. More favorable lead times and less frequent delays are reported by shipyards with foreign casting vendors than with U.S. vendors. One shipyard stated that the delivery period for the same casting could be up to a year by a U.S. vendor but only 6 months by a Japanese vendor. It was also stated that the U.S. casting vendors would most frequently meet their delivery schedules.
- o In general, the shipyards reportedly have good relations with outside casting vendors. Most stated that they experienced no major rejections on commercial ships' castings and that they had no significant delays in deliveries. A few shipyards stated that they have had serious problems with obtaining good castings and this has led them to favor fabricated stern frames and hawsepipes.
- o For a majority of shipyards, however, the problems with castings are not big enough to discourage the use of castings.
- o Increased non-destructive testing on castings reveals more defects; however, the defects are repaired by vendors and/or shipyards, depending on the extent of the defect and the degree of repair needed, to the satisfaction of the yards and the classification society surveyors.
- o From an economics standpoint, the cost of castings delivered by foreign sources, despite the additional cost of shipping, are reported to be less than U.S. costs.

3.3.7.2 Regulatory Bodies

As reported in subsection 3.3.2.2, the regulatory bodies expressed the opinion that getting a sound casting

for very large pieces is a real problem; long lead times and delays in deliveries are frequently experienced with the casting vendors in this country.

From a technical viewpoint, the non-destructive testing performance on castings are deemed to be unreliable to the extent that only surface defects can be detected. Additionally, the welds joining two separate castings are subject to severe corrosion in a seawater environment.

A review of the past experience with cast steel stern frame failures, as provided by ABS, is briefly discussed in subsection 3.3.3.2 and the case history is presented in Appendix E.

3.3.7.3 Design Agents

The design agents normally have no contact with the casting vendors; and as such, they did not comment on this item of the questionnaire.

3.3.7.4 Foundries

The foundries that were interviewed by the project investigators expressed a general willingness to manufacture castings of stern frame and hawsepipe components with delivery schedules acceptable to shipyards. They do not have any insurmountable problems with the production of castings; however, they offered the following thoughts relative to this question:

- o There is no limit on the weights of cast pieces. They have pouring capacities of up to 250 tons.
- o The size of the casting they can produce, however, is naturally limited by the dimensions of the foundry pits and their transportation facilities.
- o They allow, normally, for a shrinkage of $\frac{1}{2}$ ". Other clearances and tolerances they follow are in accordance with the specifications of "American Foundrymen's Society." [10]

- o They only do rough-machining on their castings; but they can do finish-machining as well when and if requested.
- o Delivery schedules start from the time the pattern for a casting is delivered to the foundry, or otherwise readied. The delivery periods for most stern frame castings, after receipt of pattern, range from 4 to 6 months.
- o Rejection rates for castings are very low. Minor repairs on completed castings may sometimes be necessary; but reportedly there is never a complete rejection. Repairs are made to the satisfaction of the classification society surveyors.
- o The defects experienced most frequently are sand inclusion and shrinkage.
- o The foundries maintained that for the inspection of castings, ultrasonic testing techniques are faster and cheaper than the x-ray technique. They would prefer to check the piece by UTS and then x-ray the suspect areas as established by the UTS check.

3.4 Review of Foreign Stern Frame and Hawsepipe Trends

The original intention was to survey three foreign built ships at the nearest U.S. ports. However in conducting the shipyard surveys, it was possible to see some foreign ships that were already in the yards at the time. Unfortunately, due to the fact that the vessels were waterborne, it was not possible to see much of the stern frame configuration. To make up for this lack of observability, the project team chose to obtain detail working plans of the following foreign built vessels from owners and operators, and to study these plans:

- o 263,000 DWT tanker built in Japan in 1972
- o 253,000 DWT tanker built in the United Kingdom in 1974
- o 31,000 DWT products carrier built in Sweden in 1973

In general, the configuration and the method of construction of stern frames and hawsepipes in foreign built vessels are not much different from those in vessels built in the United States. Following are a few items that are different and considered worthy of noting.

3.4.1 Recessed Anchor Pocket

In this configuration, the anchor is stowed in a recessed pocket instead of being exposed on the side shell. A typical arrangement is shown in Figure 3-10. It appears that this arrangement is very popular in European shipyards. The apparent advantages of this configuration are:

- o Attractive appearance
- o Less spray in heavy seas
- o Improvement in the slope of the hawsepipe for some vessels

3.4.2 Billboard Anchor Stowage

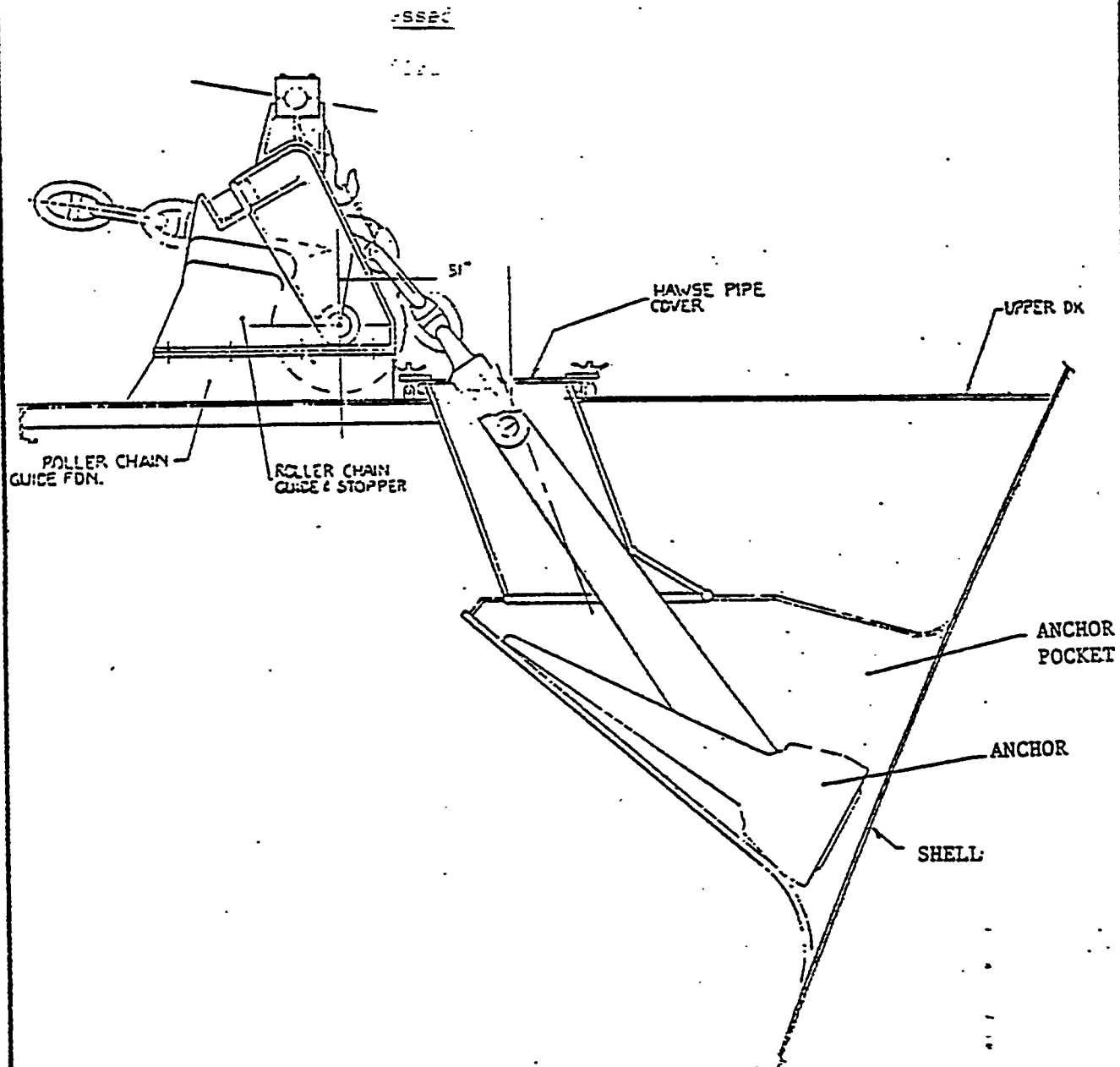
A billboard type of anchor handling system has been developed and patented by AB Gotaverken of Sweden. A copy of the U.S. patent is included in Appendix E. This system has been used on a few European built vessels. If this type of anchor handling system is used, the hawsepipe and the shell and deck bolsters can be eliminated. As can be seen from Figure 3-11, this type of anchor handling system affords the following advantages:

- o Readily accessible for securing, cleaning, maintenance and inspection
- o No penetration of the hull
- o Anchor is dropped further outboard than with the conventional system
- o No possibility of the anchor getting hung up due to lack of slope in the hawsepipe

More detailed information on the Gotaverken Anchor Stowage arrangement can be found in Appendix E.

3.4.3 Shoe Piece

A review of the plans for the above mentioned three foreign built vessels revealed that all are fitted with shoe pieces. It appears that foreign shipyards in Japan and Europe favor the shoe piece as opposed to other configurations.



Hawsepiped with Recessed Anchor Pocket

FIGURE 3-10

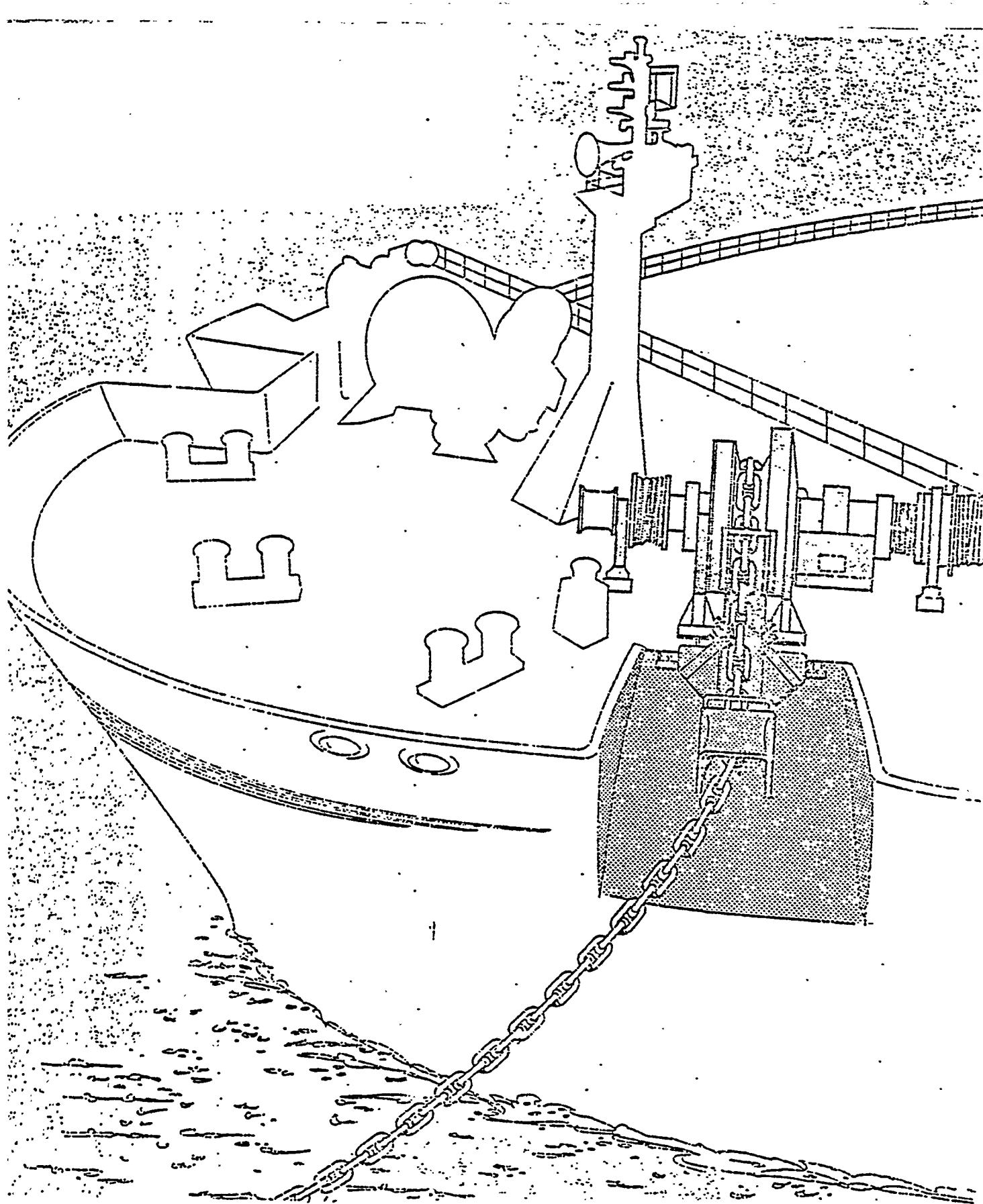


Figure 3-11: Billboard Type Anchor Handling System

3.4.4 Inboard Accessible Stern Tube

At least two vessels currently built in this country are fitted with inboard accessible stern tubes (IAST). All of the stern tubes fitted into these vessels have been manufactured in the United Kingdom. It is understood that more and more ships being built in Europe are being fitted with IAST's. Appendix E contains excerpts from literature on IAST.

3.5 Summary of Surveys and Industry Comments

It can be concluded that the most popular stern frame design in U.S., as reported by the shipyards surveyed, is that of a vessel with a semi-balanced rudder on a horn, although Japanese and European shipyards appear to favor the shoe supported rudder. The configuration of the hawsepipe varies with the type of ship being constructed.

The U.S. shipyards are using modular type construction to improve the flexibility in size and the erection sequence of the stern frames. All yards using thick plates in fabricated construction have no trouble with welding using commercially available equipment and techniques.

The regulatory body restraints are delegated to the classification societies where rules allow a great diversity of designs and are generally used as guides only.

There are some shipyards who are presently constructing all welded stern frames, and some others are installing all cast stern frames. The trend for the future appears to be towards using more weldments and smaller castings. It appears, however, that the yards would prefer to use castings if they could get them at a reasonable price, within an acceptable lead time and also within quality requirements.

For the conventional anchor handling system with hawsepipes and bolsters at the shell and the deck, the deck bolster can be eliminated on most of the new ships. A roller, if fitted immediately adjacent to and above the aft side of the hawsepipe on the deck, would be able to keep the anchor chain from rubbing the deck-edge and therefore, no deck bolster would be needed. The shell bolster may still be needed to guide and turn the anchor properly so it can go into the hawsepipe easily and support the anchor snugly when the chain is drawn tight. The shape

of the shell bolster is complex and it is difficult to fabricate and interface with the ship's structure. One shipyard has completely dispensed with the shell bolster, and encountered difficulties when the anchor was being pulled up. Another shipyard has replaced the shell bolster with a doubler plate and this shipyard also had some trouble. An investigation into the ways of replacing the shell bolster in future hawsepipe designs could bring about reductions in the cost of bolster castings and simplify the interface between the bolster and the shell.

SECTION 4.0

ALTERNATIVE DESIGNS

4.1 Baseline Ships

4.1.1 General

The requirements were that three single screw merchant ships in the range of sizes corresponding to 30, 80 and 200,000 DWT be used for the alternative designs, and that the hydrodynamic performance of the hulls not be significantly impaired by changes in the stern frames and hawsepipes. The hull forms were to be representative of the ships being constructed or contemplated for construction in U.S. shipyards.

4.1.2 Criteria for Selection of Ships

The first criterion for the selection of baseline ships for alternative designs was the deadweight capacity and the second was that the stern frames and hawsepipes should be representative of many single screw vessels to make the results generally applicable.

At first this might seem like an awkward requirement to fulfill, considering that single screw merchant vessels may vary from a full-lined slow tanker to a fine-lined high speed cargo ship. However, the stern frames as considered here are confined within a small area around the propeller aperture; this area varies significantly less on different ships than the general run of the rest of the hull.

Likewise, except for arrangement problems caused by varying deck widths forward and variations in, and/or the absence of bulbous bows with different ship types, the hawsepipes are also similar.

Furthermore, it is considered unlikely that the high speed ships of former years will be built in the future due to fuel economy considerations. Keeping these considerations in mind, it was decided that the criterion of general applicability could be satisfied by the alternative designs regardless of the type of baseline vessels selected.

The third and last criterion was that drawings of the existing selected vessels be available for use in developing the alternative designs.

4.1.3 Selected Ships

The baseline ships, selected as those which best satisfied the criteria and for which drawings were available, were the three classes of tankers built by National Steel and Shipbuilding Company:

- o 38,300 DWT Oil Tanker (Coronado Class)
- o 89,700 DWT Oil Tanker (San Clemente Class)
- o 188,500 DWT Oil Carrier (San Diego Class)

Although it is felt that stern frame designs for full form ships will be applicable to finer forms, as pointed out in the criteria, the following additional points should be considered:

- o No vessels other than Tankers and Oil Bulk Ore Carriers (OBO's) approach 200,000 DWT.
- o Fine vessels of greater capacity than 50,000 DWT usually have twin or more screws.

Detail drawings for both the stern frames and the hawsepipes are available for all three of the baseline ships selected [References 11 through 17]. Their forms are representative of the ships being built presently, and their hydrodynamic performance will not be affected by the alternative stern frame and hawsepipe designs.

Schematic arrangements of the stern frame configurations for all three selected baseline ship designs are shown in Appendix B. The configurations are all for a horn supported rudder and consist solely of castings. The horn type configuration was considered most representative since most shipbuilders indicated this to be their preference during the surveys.

The selected baseline ships all have conventional straight weldment hawsepipes with deck and shell bolster castings at the ends. Schematic arrangements are shown in Appendix B.

Tables 4.1 through 4.3 list the particulars of the three baseline ships.

TABLE 4.1:

National Steel and Shipbuilding CompanyCORONADO Class Tanker

LOA	-	688 Ft.
LBP	-	660 Ft.
Beam	-	90 Ft.
Depth	-	47 Ft.
Draft, Full Load	-	35 Ft.
Deadweight	-	38,300 L. Tons
Displacement	-	46,955 L. Tons
C _B	-	.792
Shaft Horsepower	-	15,000 SHP
Propeller Diameter	-	22'-0", 5 Blades
Anchors	-	2 Stockless; 17,200 Lbs.
Chain	-	2-11/16", Extra High Strength, GR.3
Year Built	-	1976

TABLE 4-2:

National Steel and Shipbuilding Company

SAN CLEMENTE Class Tanker

LOA	-	894 Ft.
LBP	-	855 Ft.
Beam	-	105 Ft.
Depth	-	64'-6" at side
Draft, Full Load	-	48'-11"
Deadweight	-	89,700 L. Tons
Displacement	-	106,000 L. Tons
C _B	-	.839
Shaft Horsepower	-	24,500 SHP
Propeller Diameter	-	26'-0", 5 Blades
Anchor	-	2 Stockless; 25,800 Lbs.
Chain	-	3-5/16", Extra High Strength, GR.3.
Year Built	-	1976

TABLE 4.3:

National Steel and Shipbuilding Company

SAN DIEGO Class Tanker

LOA	-	951 Ft.
LBP	-	915'-0"
Beam	-	166 Ft.
Depth	-	78 Ft.
Draft, Full Load	-	55 Ft.
Deadweight	-	188,500 L. Tons
Displacement	-	216,762 L. Tons
C _B	-	.843
Shaft Horsepower	-	28,000 SHP
Propeller Diameter	-	27'-4-3/4"
Anchor	-	2 Stockless; 39,200 Lbs.
Chain	-	4", Extra High Strength, GR.3
Year Built	-	1977

4.2 Alternative Designs

4.2.1 General

The alternative designs were to be developed for each baseline ship for three stern frames and two hawsepipes in accordance with the following, as applicable:

- o the first was to incorporate castings to the degree they are still being used in U.S. shipyards
- o the second was to feature virtually all weldments and a conventional stern tube bearing
- o the third was to consist of virtually all weldments and an inboard accessible stern tube bearing

For the stern frames these three alternatives give a general mix of different configurations with castings or weldments.

For the hawsepipe configurations which were not specifically defined at the outset, a billboard type anchor stowage system and a conventional arrangement without deck bolster were selected as the alternatives.

The billboard type of stowage is getting renewed interest in Europe. In this arrangement, the hawsepipe itself and the shell and deck bolsters are eliminated. A description of a typical billboard configuration and a patented chain stopper is given in Appendix B.

The advantages of the billboard system are discussed in Section 3.4.2.

For the conventional anchor handling system with hawsepipe and bolsters at the shell and deck, the deck bolster can be dispensed with by incorporating a roller on the deck immediately adjacent to and aft of the hawsepipe. This is generally accepted as being more facile and cost effective. The shell bolster is still needed to guide the anchor so that it will secure properly.

The all-welded alternatives do not contain any high strength steel for a number of reasons. For stern frames the mass of the material is considered an important factor in reducing movements due to local loads. This is reflected by the classification society rules which set limitations on the geometry and/or the

section moduli instead of limiting stress levels. For rudder horns the use of high strength materials will be considered by the classification societies but was deemed less desirable in this study because of the difficulty in working with it. For hawsepipes, the material must be thick enough to allow for wear, more importantly than withstanding stresses, making mild steel more attractive.

Although classification society rules may not explicitly discuss the requirements for the very thick plates considered in some of the alternative designs, they routinely allow their use under certain material provisions.

The scope and the degree of detail for all the alternative designs are limited to the level necessary to perform the required comparisons. In many cases structural analyses were not performed, but instead, designs were developed by adaption of designs from other ships for which drawings were available.

4.2.2 Stern Frames

The stern frame has been taken as the structure immediately adjacent to the propeller aperture from the keel to the aft side of the rudder horn. The internal floors and shell plates adjacent to the stern frame are assumed identical for either the weldment or cast type stern frames and therefore are not considered in any of the comparisons. Furthermore, the large center vertical keel in the welded designs is assumed to offset the floor extensions which are formed into the cast designs.

4.2.2.1 All Cast Stern Frames

Figures 4.1, 4.2 and 4.3 give the alternative designs for all cast stern frames for the 38,300 DWT, 89,700 DWT and 188,500 DWT vessels respectively.

In keeping with general U.S. shipyard practice, the stern frames are divided into sections according to the foundry and/or crane capacities. In this case the designs were taken directly from the NASSCO drawings for the respective baseline ships [11, 12, 13].

The sizes of the baseline ships' castings were compared to the minimum scantlings required by Det Norske Veritas [8] and by the ABS [4] and found to be reasonable and on the conservative side, in the order of 20% overall. They were therefore adopted in their entirety.

It should be noted that for the baseline ships considered in this study, the complete configuration consists of a lower stern section, an upper section, two rudder horn sections, and a propeller boss. For smaller ships, the number of individual castings is usually smaller too.

4.2.2.2 All Welded Stern Frames

Figures 4.4, 4.5 and 4.6 present the alternative designs for stern frames composed wholly of weldments except for the rudder gudgeons which are significantly more amenable to casting. These three designs are for the 38,300, 89,700, and the 188,500 DWT vessels respectively.

The stern frame arrangement for the 38,300 DWT vessel is derived primarily from the configuration of Todd Shipyards' 35,000 DWT tanker [18]. The only modification to the profile of the baseline ship is a slight shape change at the trailing edge below the propeller boss to simplify plate preparation.

Scantlings for the 38,300 DWT design were obtained partially by adaption from the Todd 35,000 DWT design [18] and from the Det Norske Veritas and the American Bureau of Shipping Rules.

The 89,700 DWT and 188,500 DWT designs were obtained by extending the basic configuration of the 38,300 DWT vessel with appropriate increases in the scantlings.

Additional details of the determination of all stern frame scantlings are given in Appendix B.

4.2.2.3 All Welded Stern Frames with Inboard Accessible Stern Tubes

Figures 4.7, 4.8 and 4.9 are the alternative designs for all welded type stern frames incorporating inboard accessible stern tubes (IAST) for the 38,300 DWT, 89,700 DWT, and 188,500 DWT vessels respectively.

The most extensive use of the IAST's has been in Europe. The two most popular IAST bearings are in the Ross-Turnbull [29] and Glacier-Herbert [28] designs. For purposes of ease in modifying the existing weldment designs (Figures 4.4 through 4.6) to incorporate the IAST's, one or the other of these bearings were utilized, based on the information available.

For the 38,300 DWT vessel, the existing all welded stern frame design was modified to incorporate the Ross-Turnbull IAST bearing, in accordance with the scheme for this bearing found on the FMC 35,000 DWT tanker [19 through 23]. The stern tube is approximately 3 ft. larger in diameter than the conventional stern tube. Even though the Ross-Turnbull bearing was selected for this vessel, it is also possible to use a Glacier-Herbert design. The manufacturer of the latter bearing type maintains that it will permit smaller boss diameters.

For the 89,700 DWT tanker, a scaled version of the Seatrain Shipbuilding 225,000 DWT tanker design with Ross-Turnbull stern bearing was used [24 through 27]. No profile changes were made to the baseline ship. The stern tube is approximately 4 feet larger in diameter than the conventional tube. For this vessel too, a Glacier-Herbert bearing could be used. The manufacturer's representative has expressed willingness to develop specific data for this purpose. A follow-on study on IAST applications could look into this possibility.

The 188,500 DWT vessel IAST alternative design incorporates a Glacier-Herbert bearing. Glacier-Herbert designs for a 250,000 DWT tanker [28] indicate that their configuration could be adapted without considerable stern changes to the all welded alternative design.

4.2.3 Hawsepipes

4.2.3.1 Conventional Type

Figures 4.10, 4.11 and 4.12 give the alternative hawsepipes designs consisting of a hawsepipes and shell bolster with a roller fairlead at the deck, for the 38,300 DWT 89,700 DWT and 188,500 DWT vessels respectively.

For the 38,300 DWT and 89,700 DWT vessels, the fore and aft locations of the alternative designs, and the lengths and inside diameters are identical to the actual designs. However, the deck bolsters of the original designs were replaced by heavy insert plates and roller fairleads.

In the case of the 188,500 DWT vessel, the alternative design replaced the existing anchor pocket system and is similar to those for the two smaller vessels, with the hawsepipes length, inside diameter, and plating thicknesses increased appropriately.

Additional details are presented in Appendix B.

4.2.3.2 Billboard Configuration

Figures 4.13, 4.14 and 4.15 give the billboard configuration anchor handling system alternative designs for the 38,300 DWT, 89,700 DWT and 188,500 DWT vessels, respectively.

The billboards have all been located forward of the anchor windlasses so that the existing deck machinery configuration is considered adequate.

The dimensions of the billboards were determined to adequately stow the actual anchors of the baseline vessels. The plating thicknesses were taken as identical to the conventional hawsepipes thicknesses without further analysis since adequate margin for wear and tear would be provided.

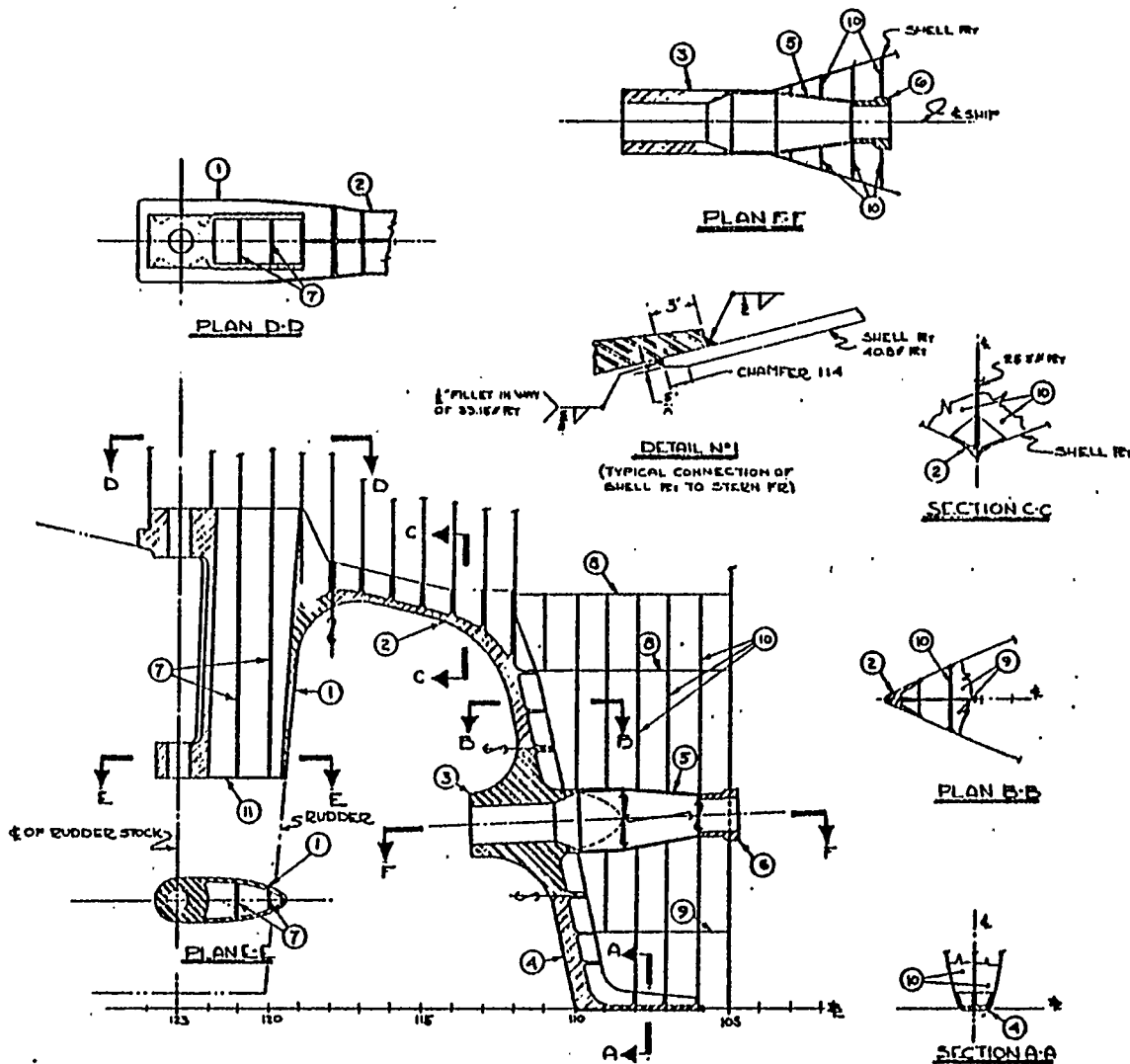


Figure 4.1

LIST OF MATERIAL		
ITEM NO.	QTY	DESCRIPTION
1	1	BUDDER HOZN
2	1	UPPER STERN FRAME
3	1	PROPELLER BOSS
4	1	LOWER STERN FRAME
5	1	STERN TUBE
6	1	FRD BEARING HOUSING
7	2	BUDDER HORN WIDS
8	2	UPPER PLATS
9	1	LOWER PLAT
10	10	PLATES
11	1	BUDDER HORN BOTTOM PL
12		
13		
14		
15		
16		

SECTION INDEX

- STEEL PLATES AND BMS ARE TO BE FURNISHED STRUCTURAL STEEL PER SECTION 4.3 OF THE AIS RULES, EXCEPT AS NOTED.
- CASTING SHALL COMPLY WITH THE REQUIREMENTS FOR CAST IRON, IN A MANNER TO BE AS WITH A 27-10, GRADE CO-31, AND SHALL BE PROPERLY TREATED. TREATED TESTS, DEFECTS, ETC., TO BE PROVIDED TO THE RULES AND TO THE SATISFACTION OF THE AIS SURVEYOR.
- WELDINGS ARE TO BE IN ACCORDANCE WITH SECTION 4.4 OF THE RULES, EXCEPT AS NOTED.
- CASTING SHALL BE SUPPLEMENTED BY THE FOLLOWING REQUIREMENTS: RESIDUE COILS, SKEWED, DEFECTS SHALL BE IN TOTAL WITHIN THE TIME BEEN THOROUGHLY EXAMINED.
- CASTING AND JOINTS SHALL BE SUBJECT TO PROVISIONAL ACCEPTANCE BY THE AIS SURVEYOR FOR TESTING FOR DEFECTS.
- PROVISIONAL ACCEPTANCE SHALL BE IN ACCORDANCE WITH THE RULES FOR CLASS 5 CASTINGS.
- PROVISIONAL ACCEPTANCE SHALL BE IN ACCORDANCE WITH THE RULES FOR DIRECT CURRENT FOR AS SUPPLIED.
- NO SUBJECT TO AIS APPROVAL, ULTIMATE PROVISIONAL ACCEPTANCE SHALL BE USED.
- A TYPICAL OF 300-300 PPM. DEFECTIVE IS TO BE PROVIDED TO THE AIS SURVEYOR FOR TESTING THE YIELDING PROCESS OF ALL YIELDING MATERIALS OF CASTING TO BE USED AND PROVISIONAL STEEL STRUCTURE TO CASTING. YIELDING IS TO BE PROVIDED TO THE AIS SURVEYOR FOR TESTING.
- CASTING IS TO BE 300-300 PPM. DEFECTIVE IS TO BE PROVIDED TO THE AIS SURVEYOR FOR TESTING.
- CASTING TO HAVE GOOD FINISH WITH ALL PROVISIONAL ACCEPTANCE. DEFECTS FOR CASTING TO BE 2" LONG UNLESS OTHERWISE NOTED.

NATIONAL SHIP BUILDING ASSOCIATION

FRASIE WITH DESIGN ALL
CAST STEEL FRAME
38300 TON TANKER

NO. DRAWN	DATE	BY	CHKD

REV 1/1/11

4-12

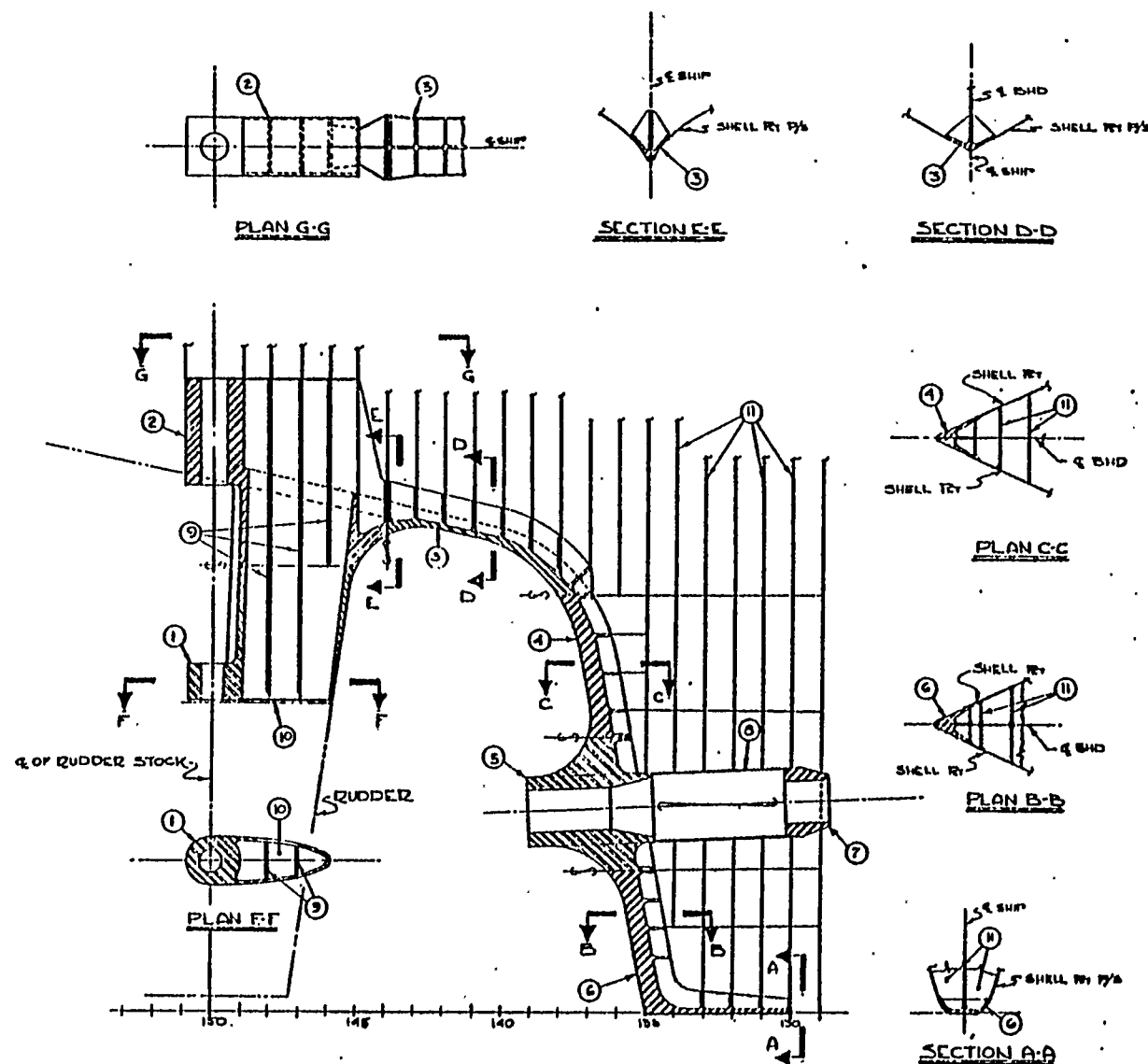


Figure 4.2

LIST OF MATERIALS		
ITEM NO.	QTY	DESCRIPTION
1	1	RUDDER HORN-LOWER
2	1	UPPER
3	1	STEEL FRAME-UPPER
4	1	UPPER
5	1	WELDED EDGE
6	1	STEEL FRAME-LOWER
7	1	UPPER BEARING HOUSING
8	1	STERN TUBE
9	3	RUDDER LOCK WEBS
10	1	UPPER
11	22	FLOORS
12		
13		
14		
15		
16		

MATERIAL	
COST	STEEL
612.715	
616.671	
40.251	
23.371	

DESIGN NOTES

- STEEL PLATES AND BARS ARE TO BE PROVIDED STRENGTH STRUCTURAL HULL STEEL PER SECTION 43 OF THE ABS RULES, EXCEPT AS NOTED.
- CASTING SHALL COMPLY WITH ABS REQUIREMENTS FOR HULL CASTINGS, HULL REQUIREMENTS TO BE AS PER A 27-30, CHIMES CO-31, AND SHALL BE DIFFUSIALLY ALIGNED. WELDED JOINTS, BOLTED JOINTS, ETC., TO BE PERMITTED TO ABS RULES AND TO THE SATISFACTION OF THE ABS SURVEYOR.
- WELDED JOINTS ARE TO BE IN ACCORDANCE WITH SECTION 30 OF THE ABS RULES, EXCEPT AS NOTED.
- CASTING SHALL BE SATISFACTORILY BUILT AND FINISHED AT THE FOLLOWING POINTS: POSSIBLE CRACKS, SAND INLES, DEFECTS SHALL BE REPAIRED UNTIL THEY HAVE BEEN DIFFUSIALLY ELIMINATED.
- CASTING AND BARS SHALL BE SUBJECTED TO NONDESTRUCTIVE AND/OR MECHANICAL TESTING FOR DEFECTS.
 - NONDESTRUCTIVE PARTICLE DETECTION SHALL BE AS PERMITTED BY ABS PER CLASS 5 CASTINGS.
 - MECHANICAL PARTICLE DETECTION SHALL BE IN ACCORDANCE WITH ABS PER CLASS 5 CASTINGS.
 - MECHANICAL PARTICLE DETECTION SHALL BE AS SPECIFIED BY ABS SURVEYOR.
 - SUBJECT TO ABS APPROVAL, ULTRASONIC OR OTHER METHODS OF DETECTION MAY BE USED.
- A METHOD OF 20% STIFFNESS TEST, TO DETERMINE IF IT BE PERMITTED AND INFLUENCED THROUGHOUT THE WELDING PROCESS OF ALL WELDED JOINTS, IS TO BE USED TO CASTING AND OTHER HULL STEEL STRUCTURE. WELDING OF JOINTS IS TO BE ACCORDANCE WITH THE CORRELATION OF ABS RULES WITH ABS RULES 6-10.
- WELDED JOINTS, IF USED, TO BE 20% WELDED JOINTS ON THE SIDE ONLY.
- CASTING TO HAVE CRACK FINISH BATH OF ALL FINISH SURFACES. FILLERS FOR CASTING TO BE 2" MINIMUM UNLESS OTHERWISE NOTED.

INTERNATIONAL SHIPBUILDING RESEARCH PROGRAM

FEASIBILITY DESIGN-ALL
CAST STERN FRAME
69,700 DWT TANKER

DATE	BY	TO

[illegible]

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- | | | |
|---|--------|----------------|
| NATIONAL S-POLICE RESEARCH PROGRAM | | |
| FLASHLIGHT DESIGN - ALL
WELDED STEEL FRAME | | |
| 3500 LB. TANKER | | |
| SA | VOLUME | "D" 1500 X 60" |
| | | |
| DATE | | 1978-10-15 |

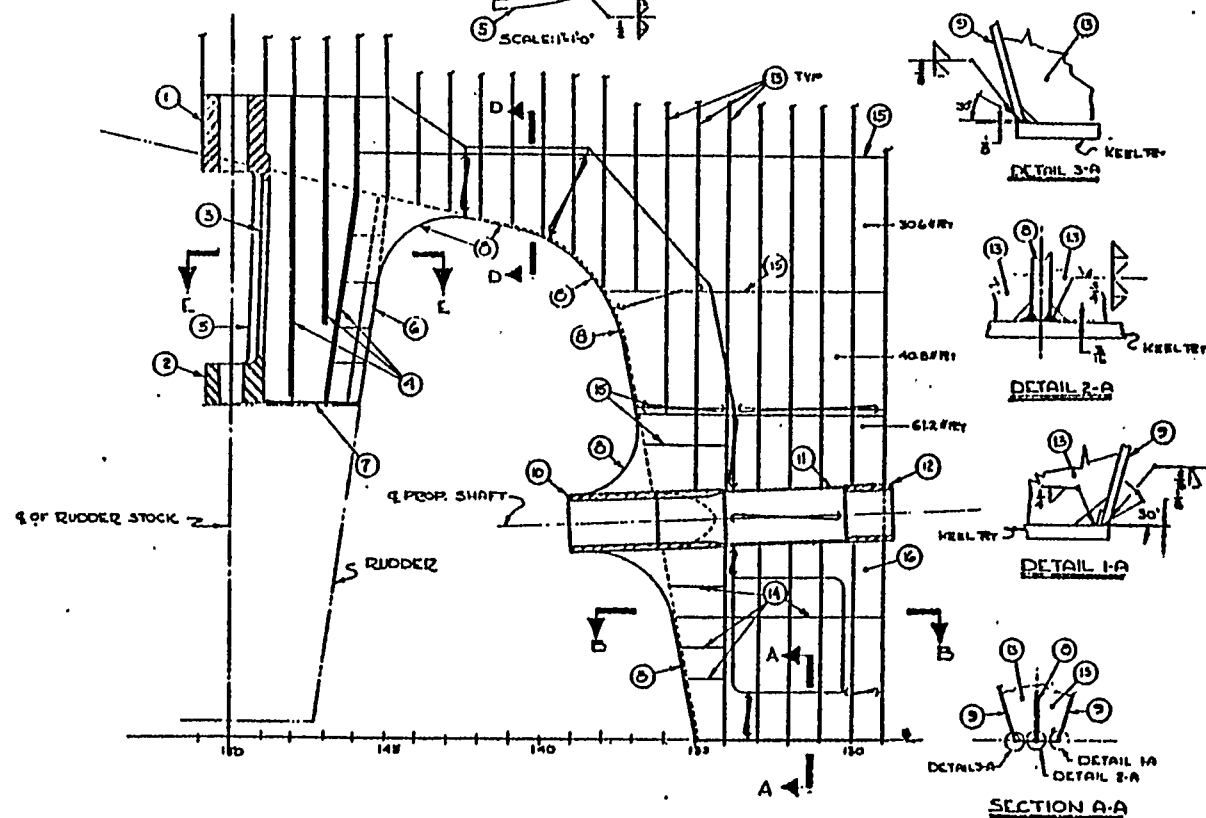


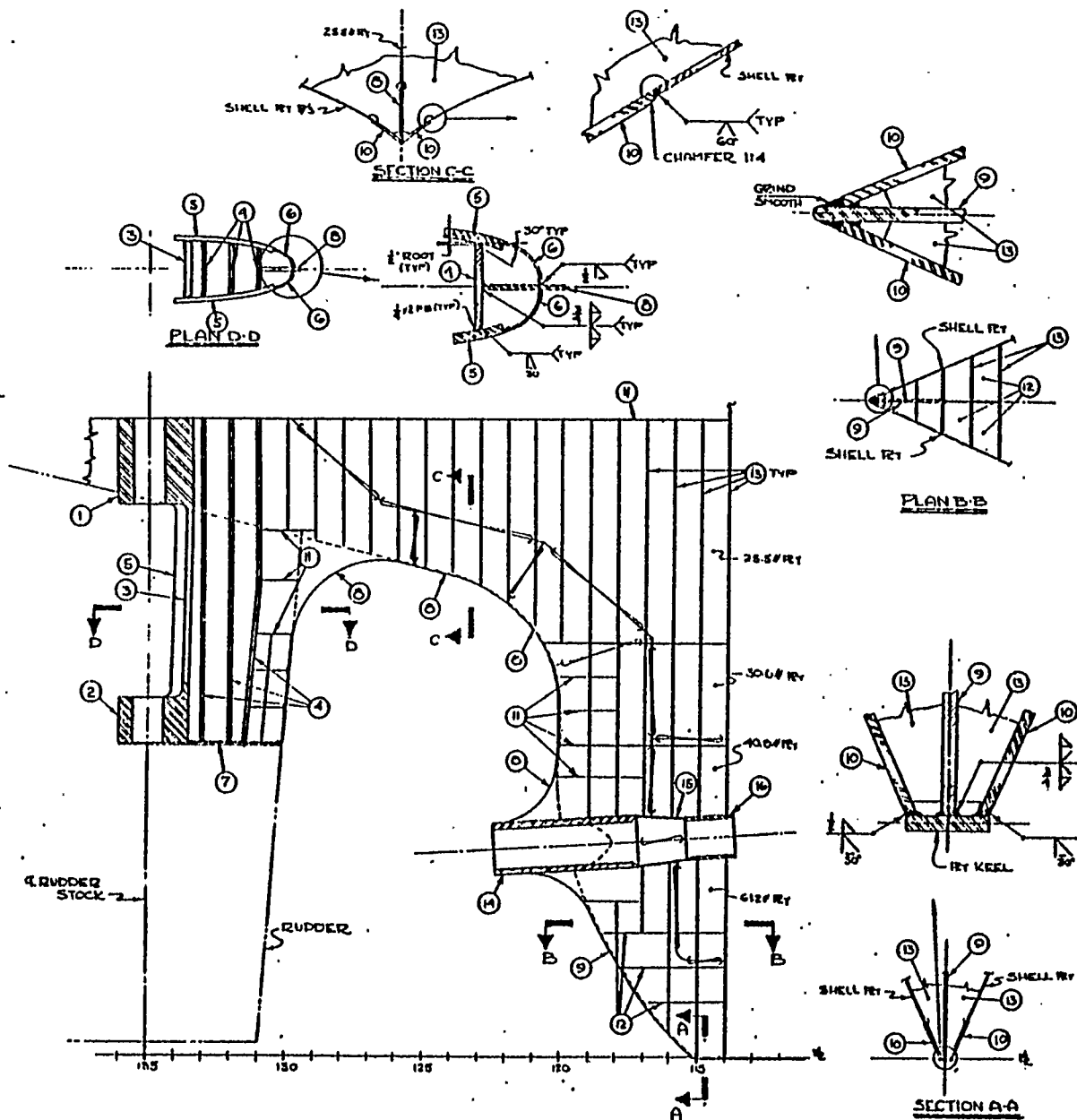
Figure 4.5

NO.	QTY	DESCRIPTION	MATERIAL
1	1	RUDDER GUDGEON PLATE	AST STEEL
2	1	RUDDER GUDGEON PLATE	AST STEEL
3	1	RUDDER GUDGEON PLATE	AST STEEL
4	3	RUDDER GUDGEON PLATE	AST STEEL
5	2	RUDDER GUDGEON PLATE	AST STEEL
6	1	RUDDER GUDGEON PLATE	AST STEEL
7	1	RUDDER GUDGEON PLATE	AST STEEL
8	1	RUDDER GUDGEON PLATE	AST STEEL
9	1	RUDDER GUDGEON PLATE	AST STEEL
10	1	RUDDER GUDGEON PLATE	AST STEEL
11	1	RUDDER GUDGEON PLATE	AST STEEL
12	1	RUDDER GUDGEON PLATE	AST STEEL
13	1	RUDDER GUDGEON PLATE	AST STEEL
14	1	RUDDER GUDGEON PLATE	AST STEEL
15	1	RUDDER GUDGEON PLATE	AST STEEL
16	1	RUDDER GUDGEON PLATE	AST STEEL

NOTES

- STEEL PLATES AND BARS ARE TO BE OPEN HEAT TREATED STRUCTURAL STEEL PER SECTION 43 OF THE AISC SPECIFICATIONS, EXCEPT AS NOTED.
- CASTING SHALL COMPLY WITH THE REQUIREMENTS FOR ALL CASTINGS. THE REQUIREMENTS TO BE AS PER A 27-70, CYCLES 01-31, AND SHALL BE NOTATIONALLY REPRODUCED. THERE ARE NO TESTS, UNLESS OTHERWISE NOTED, TO BE PERFORMED BY THE FABRICATOR AND TO THE SATISFACTION OF THE AISC INSPECTOR.
- WELDED JOINTS ARE TO BE IN ACCORDANCE WITH SECTION 30 OF THE AISC SPECIFICATIONS, EXCEPT AS NOTED.
- CASTINGS SHALL BE SACRIFICED INSIDE AND OUTSIDE OF THE FOLLOWING FOR CORROSION PROTECTION: COILING CYCLES, 500 HOURS. DEFECTS SHALL NOT BE RETAINED UNLESS THEY HAVE BEEN PREVIOUSLY DETECTED.
- CASTINGS AND JOINTS SHALL BE SUBJECT TO INDICATING AUSTINITE PARTICLE TESTING FOR DEFECTS.
 - INDICATING PARTICLE INSPECTION SHALL BE AS REQUIRED BY AISC E-71 FOR CLASS 5 CASTINGS.
 - INDICATING PARTICLE INSPECTION SHALL BE AS REQUIRED BY AISC E-71 FOR CLASS 5 CASTINGS.
 - INDICATING PARTICLE INSPECTION SHALL BE AS REQUIRED BY AISC E-71 FOR CLASS 5 CASTINGS.
- PLATES WITH 1/8" TO 3/4" THICK, YIELDS TO EACH OTHER IN 150° BENDING TESTS AND FURNISHED AT THIS REQUIREMENT SHALL BE 150° BENDING TO BE NOTIFICATION WITH INDICATING ELECTRODES TO E-71 FOR CLASS 5.
- A MINIMUM TENSILE AND ELONGATION REQUIREMENT OF 200 TO 310 IS TO BE FURNISHED FOR THE YIELDS OF 3" AND 4" THICK PLATES TO EACH OTHER AND TO THE OBJECT AND WELDED JOINTS. THE YIELD TEST REQUIREMENTS ARE TO BE MADE ON THE YIELDS BY COILING SURFACES FROM THE TENSILE REQUIREMENT AT THE RATE OF ABOUT 90° PER MIN TO PREVENT THE POSSIBILITY OF HEAT TREATING.
- A TENSILE OF 200 TO 310 F MINIMUM REQUIREMENT IS TO BE FURNISHED AND FURNISHED WELDED JOINTS TO BE MADE OF ALL THE STEEL STRUCTURES IN CASTINGS. YIELDS OF JOINTS TO BE NOTIFICATION WITH INDICATING ELECTRODES TO E-71 FOR CLASS 5.
- ALL BUCKLING BARS TO BE 5/16" YIELDS THROUGHOUT THE SIDE ONLY.
- CASTING TO HAVE 5/16" BARS IN ALL OF ALL FACING SURFACES, FLEETS FOR CASTINGS TO BE 2" THICK YIELDS THROUGHOUT.

NATIONAL SHIPBUILDING RESEARCH PROGRAM	
FEASIBILITY DESIGN: ALL WELDED STERN FRAME 89,700 DWT TANKER	
DATE: 12/10/70	DESIGNED BY: J. H. BROWN
REV: 1	DATE: 12/10/70
PAGE 3 OF 16	



PC	QTY	DESCRIPTION	MATERIAL
1	1	CORNER GULCH PROTECT	ST STEEL
2	1	2" SCHED. 40 CH. LUMBER	1" ST STEEL
3	1	2" DOG LEGS W/PL	162.72 MT
4	3	1/2" PL.	122.48 MT
5	2	1/2" PL	162.24 MT
6	1	1/2" PL	20.28 MT
7	1	1" BOTTOM CH.	40.58 MT
8	4	W/PL STEEL FLEX-LOCK	61.60 MT
9	1	LONGER STEEL FLEX-LOCK	61.60 MT
10	15	STEEL FRAMING 1/2"	61.60 MT
11	4	W/PL PLATE W/PL	35.00 MT
12	3	LONGER PLATE PKTS	30.00 MT
13	15	FLOORS	25.20 MT
14	1	PRO-CELLS BOXES	2.01 MT
15	1	STEEL TRAP	40.58 MT
16	1	END BEARING HOUSING	122.48 MT

CONCLUSIONS

1. STEEL PLATES AND BARS ARE TO BE ORDERED SPECIFIC STRUCTURAL STEEL PER SECTION 5 OF THE ASB RULES, EXCEPT AS LISTED.
2. CASTING SHALL COMPLY WITH ALL REQUIREMENTS FOR CAST CASTINGS, AND REQUIREMENTS TO BE AS PER A 27-10, 28-10, 29-10, AND SHALL BE THOROUGHLY INSPECTED. TENSILE TESTS, INSPECTION ETC., ARE TO BE FORWARDED TO ASB RULES AND TO THE SATISFACTION OF THE ASB INSPECTOR.
3. VOLUMETRIC ARE TO BE IN ACCORDANCE WITH SECTION 5 OF THE ASB RULES, EXCEPT AS NOTED.
4. CASTING SHALL BE SATISFACTORILY WELDED OUTSIDE OF THE FOLLOWING FOR FURNISHING POSSIBLE COLLING CRACKS, SINK MARKS, CRACKS SHALL NOT BE REPAIRED WHEN THEY HAVE BEEN NATURALLY DEVELOPED.
5. CASTINGS AND JOINTS SHALL BE SUBJECTED TO RADIOGRAPHIC AND METALLURGIC ANALYSIS TESTING FOR DEFECTS.
 - (A) RADIOGRAPHIC PARTICLE INSPECTION SHALL BE AS SPECIFIED BY ASTM E-70 FOR CLASS 5 CASTINGS.
 - (B) METALLURGIC PARTICLE INSPECTION SHALL BE IN ACCORDANCE WITH ASTM E-309 USING BRITISH SPECIFICATION AS SPECIFIED BY ASB SUMMARY.
 - (C) SUBJECT TO ASB APPROVAL, ULTIMATE TENSILE AND YIELD STRENGTH OF DEFECT-FREE AREAS TO BE TESTED.
6. PLATES WITH A 3/8" TO 2" THICK, VOLUMETRIC TO EACH OTHER TO BE INSPECTED BY X-RAY BEFORE WELDING AND INSPECTED AT THIS REQUIREMENT SHALL BE THE YIELD STRENGTH, FOLLOWING TO BE ACCOMPLISHED WITH LOW IMPACTED ELECTRODES (E-70 OR EQUIV.).
7. A MINIMUM TENSILE AND YIELD STRENGTH OF 27-10 TO 30-10 IS TO BE MAINTAINED FOR THE YIELDS OF 3" AND 4" THICK PLATES TO EACH OTHER AND TO THE CRACKS AND AFTER CASTINGS. FIRST YIELD LINE TREATMENTS ARE TO BE DONE ON THE YELDS BY COLLING SURVEY FROM THE MINIMUM REQUIREMENT AT THE RATE OF ABOUT 30 PSI PER HOUR TO PREVENT THE POSSIBILITY OF "HEAVY SINK".
8. A PRELIM OF 200-300 PSI MINIMUM TENSILE STRENGTH IS TO BE PROVIDED AND MAINTAINED THROUGHOUT THE WELDING PROCESS OF ALL FILL STEEL, SURFACES TO CASTINGS, WELDING OF JOINTS TO BE ACCOMPLISHED BY THE CONTINUOUS OPERATION USING LOW-IMPACTED ELECTRODES E-70 OR EQUIV.
9. ALL WELDING BARS TO BE 3/8" YELDED CYRANUMS OF THE SIZE GAY.
10. CASTING TO BE YIELD CABLES MUST BE WELDED OF ALL FILLING SURFACES, FILLERS FOR CASTINGS TO BE 2" IMPURE FILLING BEING USED.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

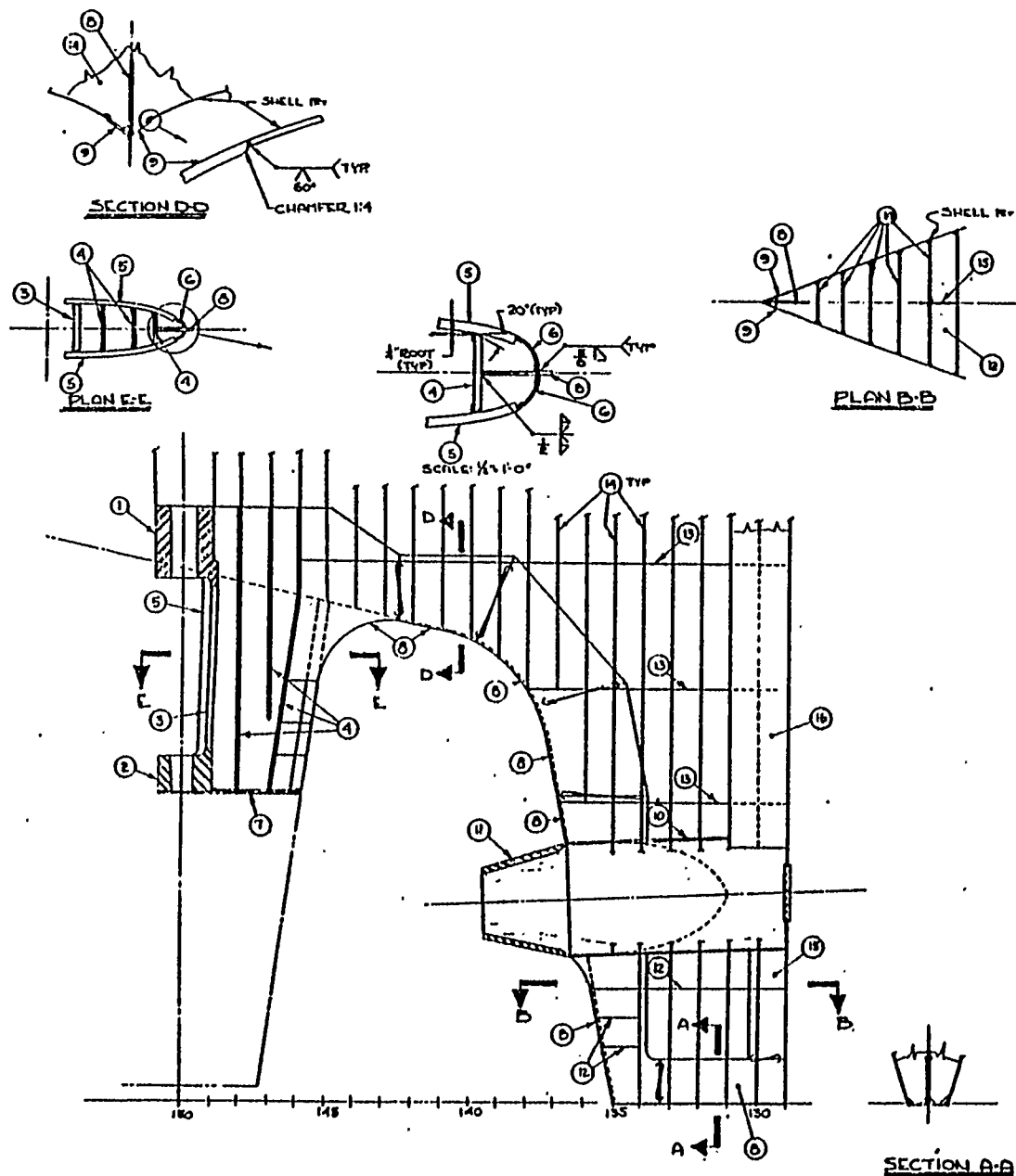
FEASIBILITY DESIGN ALL WELDED
STERN FRAME

100,500 DWT TANKER.

SIZE	HEAD CODE	TDCO DRAWING NO
DATE 4-1-77 AS NOTED		FILE NO

Figure 4.6

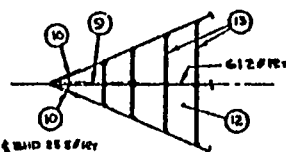
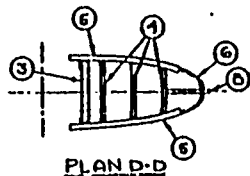
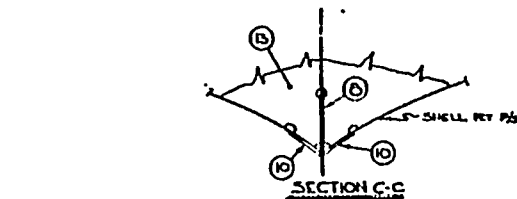
Figure 4.7



LIST OF MATERIAL			
#	QTY	DESCRIPTION	MATERIAL
1	1	PLATE STEEL JOIST	EAST STEEL
2	1	LOWER	
3	1	JOISTED ROOF	141.60 MT
4	3	WEB	122.40 MT
5	2	250 MT	163.60 MT
6	1	ROOFING	30.60 MT
7	1	BOTTOM	40.60 MT
8	7	STEEL FRAMEWORK	61.60 MT
9	2	SIDE IRIS	63.60 MT
10	1	STEEL TUBE	61.60 MT
11	1	PROPELLER DOGS	20.60 MT
12	3	LOWER FIRST BAKTS	30.60 MT
13	3	UPPER PLATE	40.60 MT
14	2	FLOORS	28.60 MT
15	1	1 MT BAT	61.60 MT
16	2	TRUNK AT	23.60 MT
17			
18			
19			
20			

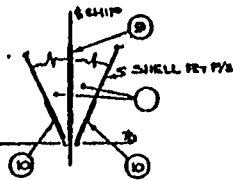
- [illegible]

NATIONAL SHIPBUILDING RESEARCH PROGRAM	
FEASIBILITY DESIGN ALL WELDED STERN FRAME WITH INBOARD ACCESSIBLE STERN TUBE 15000 DWT TANKER.	
SIZE	WELDED CANT.
	TOTAL DESIGNING NO
DATE	DESIGNED BY



PLAN B-B

NOTE:
FOR WELDING DETAILS NOT
SHOWN SEE SHEET NO. 100



SECTION A-A

LIST OF MATERIAL			
NO.	QTY	DESCRIPTION	MATERIAL
1	1	RUDDER GUDGEON, UPPER	CAST STEEL
2	1	RUDDER GUDGEON, LOWER	CAST STEEL
3	1	RUDDER GUDGEON, W/LP	100 2# RT
4	2	W/LP	100 2# RT
5	2	SIDE IRN	100 2# RT
6	1	NOSE RT	100 2# RT
7	1	BOTTOM RT	100 2# RT
8	4	UPPER STERN FRAME, CVK	01 6# RT
9	1	LOWER STERN FRAME, CVK	01 6# RT
10	10	STERN FRAME, P/S	01 6# RT
11	7	UPPER FLATS, 1/2 X 1/2	30 6# RT
12	5	LOWER FLATS, 1/2 X 1/2	30 6# RT
13	10	FLOOR	28 6# RT
14	1	INSULATOR, BOSS	20 10# RT
15	1	STERN TUBE	01 6# RT

REMARKS

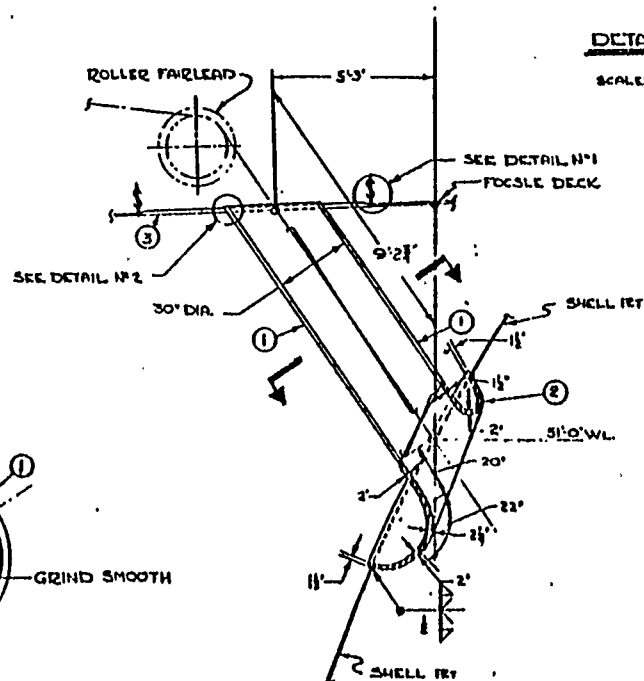
1. STEEL PLATES AND BARS ARE TO BE FORMED TO THE STERN FRAME, ALL STEEL FOR SECTION A-A OF THE AIS RAILS, CAST AS FOLLOWS.
2. CASTING SHALL COMPLY WITH THE REQUIREMENTS FOR ALL CASTINGS, AND, IN ADDITION, TO BE ASHTA 27-AI, GRADES 20-30, AND SHALL BE PROOF-TESTED. PROOF-TESTING, INSPECTION, ETC., TO BE PERMITTED TO AIS RAILS AND TO THE SATISFACTION OF THE AIS RESEARCH.
3. WELDINGS ARE TO BE IN ACCORDANCE WITH SECTION 10 OF AIS RAILS, EXCEPT AS JOINED.
4. CASTING SHALL BE SATISFACTORILY INSULATED AND OUTSIDE AT THE JOINTS FOR ENDURING POSITIVE CHILLING EFFECTS, AND INSIDE. WELDINGS SHALL BE IN ACCORDANCE WITH THE AIS RESEARCH.
5. CASTINGS AND BARS SHALL BE SUBJECTED TO PROOF-TESTING, AND THE PROOF-TESTING SHALL BE IN ACCORDANCE WITH THE AIS RESEARCH, AND THE PROOF-TESTING SHALL BE IN ACCORDANCE WITH THE AIS RESEARCH, AND THE PROOF-TESTING SHALL BE IN ACCORDANCE WITH THE AIS RESEARCH.
6. PLATES FROM 1/2" TO 2" THICK, WELDINGS IN EACH OTHER TO BE PROOF-TESTED BY 150% BEFORE WELDING, AND INSPECTION AT THIS REQUIREMENT, AND THE WELDING, WELDING TO BE ACCOMPLISHED WITH LOW FREQUENCY ELECTRICITY (E-70) OR EQUIV.
7. A MINIMUM OF 100% INSPECTION OF 20% TO 30% IS TO BE PROVIDED FOR THE WELDING OF 3" AND 4" THICK PLATES TO EACH OTHER AND TO THE STEEL AND AFTER CASTING. FIRST WELDING OPERATIONS ARE TO BE DONE IN THE FIELD BY COILING SURVEY FROM THE PROBABLY REQUIREMENT AT THE END OF ABOUT 5% FAILURE TO PREVENT THE POSSIBILITY OF BEING STOPPED.
8. A MINIMUM OF 300 - 300% INSPECTION OF 15% IS TO BE PROVIDED AND INSPECTION THROUGHOUT THE WELDING PROCESS OF ALL STEEL, STEELWELDS TO CASTINGS, WELDING OF JOINTS TO BE ACCOMPLISHED IN THE COIL WELDS WITH WELDING LOW FREQUENCY ELECTRICITY (E-70) OR EQUIV.
9. ALL WELDING BARS TO BE 3/16" WELDED THROUGHOUT IN THE STEEL RAIL.
10. CASTING TO THE 100% INSPECTION OF ALL PARTS, SPACES, FLEETS FOR CASTINGS TO BE 2" THICK WELDS INTERSECTED.

NATIONAL SHIPBUILDING RESEARCH PROGRAM	
FEASIBILITY DESIGN ALL WELDED STERNFRAME WITH INBOARD ACCESSIBLE STERN TUBE 100,500 DWT TANKER	
SEE REMARKS	TOTAL ESTIMATING NO.

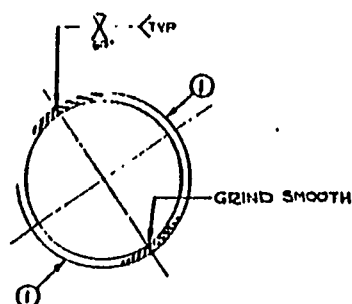
Figure 4.9

Diagram illustrating a chamfer on a fuselage deck. The chamfer is labeled "CHAMFER 1:1" and "TYP". The fuselage deck is labeled "FUSLAGE DECK MOLDED LINE". A dimension line indicates a distance of "3" from the left edge to the start of the chamfer.

SCALE: 3"=1'-0"



SECTION ON ϕ OF HAWSE PIPE



SECTION AA

GENERAL NOTES

1. THE SURFACES OF THE CASTINGS OVER WHICH THE CHAIN WILL BE SHALL BE SURFACE INSPECTED BY MAGNETIC PARTICLE INSPECTION.
2. CURVED AREAS OVER WHICH THE CHAIN WILL BE SHALL BE "W" SURFACES WITH WELD REPOSITED BY AN ELECTRODE SHALL BE 1/16" AFFORD 32". THE BEADS SHALL BE IN THE DIRECTION OF THE TURN OF THE CHAIN AND SHALL BE GROUNDED TO REMOVE SHARP EDGES WHICH WOULD SCORE THE CHAIN.
3. CASTINGS SHALL BE ASTM A 27-30 GRADE 40-EN-30 FULLY STRENGTH. MECHANICAL TESTS ARE TO BE PERFORMED TO MEET THE REQUIREMENTS OF ASTM AND AISI.
4. ALL BOUND SURFACES TO BE GROUND SMOOTH.
5. ALL INTERSECTIONS OF CASTINGS IMPLICATED BY UNIFORM STRESS TAKEN NORMAL TO THE OUTSIDE SURFACES AT THE POINTS GIVEN.
6. MINIMUM THICKNESS OF CASTINGS SHALL BE 1-1/2".
7. STEEL PLATES ARE TO BE ORDINARY STRUCTURAL STEEL IN FULL PLATE PER SECTION 405 OF THE AISI RULES. ACCEPT AS 4010.
8. WELDING SHALL BE IN ACCORDANCE WITH SECTION 305 OF THE AISI RULES.
9. WELDING SHALL BE OF 1-3/8" AND OVER ARE TO BE PREHEATED TO 150°F BEFORE THE WELDING AND POSTHEAT AT THIS TEMPERATURE DURING THE WELDING, IN ORDER TO BE ACCOMPANIED WITH LOW HYDROGEN ELECTRODES.

NATIONAL SHIPBUILDING RESEARCH PROGRAM

FEASIBILITY DESIGN
HAWSE PIPE ARRANGEMENT
30,300 DWT TANKER

SWT	TEST CAMP	THAT DOWNING IN

Figure 4.10

ITEM NO.	QTY	DESCRIPTION	MATERIAL
1	2	HAWSE PIPE	6160 HY. ROLLER
2	1	SHELL BOLSTER	CASEY STEEL
3	1	JACK WHEEL RT	6160 HY

GENERAL NOTES

1. THE SURFACES OF THE CASTINGS OVER WHICH THE CHAIN WILL RUN SHALL BE SURFACE INSPECTED BY MAGNETIC PARTICLE INSPECTION.
2. CURVED AREAS OVER WHICH THE CHAIN WILL RUN SHALL BE HARD SURFACED WITH WELD DEPOSITED BY AN ELECTRODE SUCH AS "VARD ALLOY 32." THE BEADS SHALL BE IN THE DIRECTION OF THE RUN OF THE CHAIN AND SHALL BE GRIND TO REMOVE SHARP EDGES WHICH WOULD SCREW THE CHAIN.
3. CASTINGS SHALL BE ASTM A 27-73 GRADE B-EN-73 FINELY ANNEALED. MECHANICAL TESTS ARE TO BE PERFORMED TO MEET THE REQUIREMENTS OF ASTM AND ABS.
4. ALL ROUND SURFACES TO BE GRIND SMOOTH.
5. ALL THICKNESSES OF CASTINGS INDICATED ARE THICKNESSES TAKEN NORMAL TO THE OUTSIDE SURFACES AT THE POINT SHOWN.
6. MINIMUM THICKNESS OF CASTINGS SHALL BE 2".
7. STEEL PLATES ARE TO BE ORDINARY STRUCTURAL STEEL WITH FULL PLATE PER SECTION 43 OF THE ABS RULES, EXCEPT AS NOTED.
8. WELDING SHALL BE IN ACCORDANCE WITH SECTION 50 OF THE ABS RULES.
9. WELDMENTS OF PLATE OF 1/2" AND OVER ARE TO BE PREHEATED TO 150°F BEFORE THE WELDING AND MAINTAINED AT THIS TEMPERATURE DURING THE WELDING. WELDING TO BE ACCOMPLISHED WITH LOW HYDROGEN ELECTRODES.

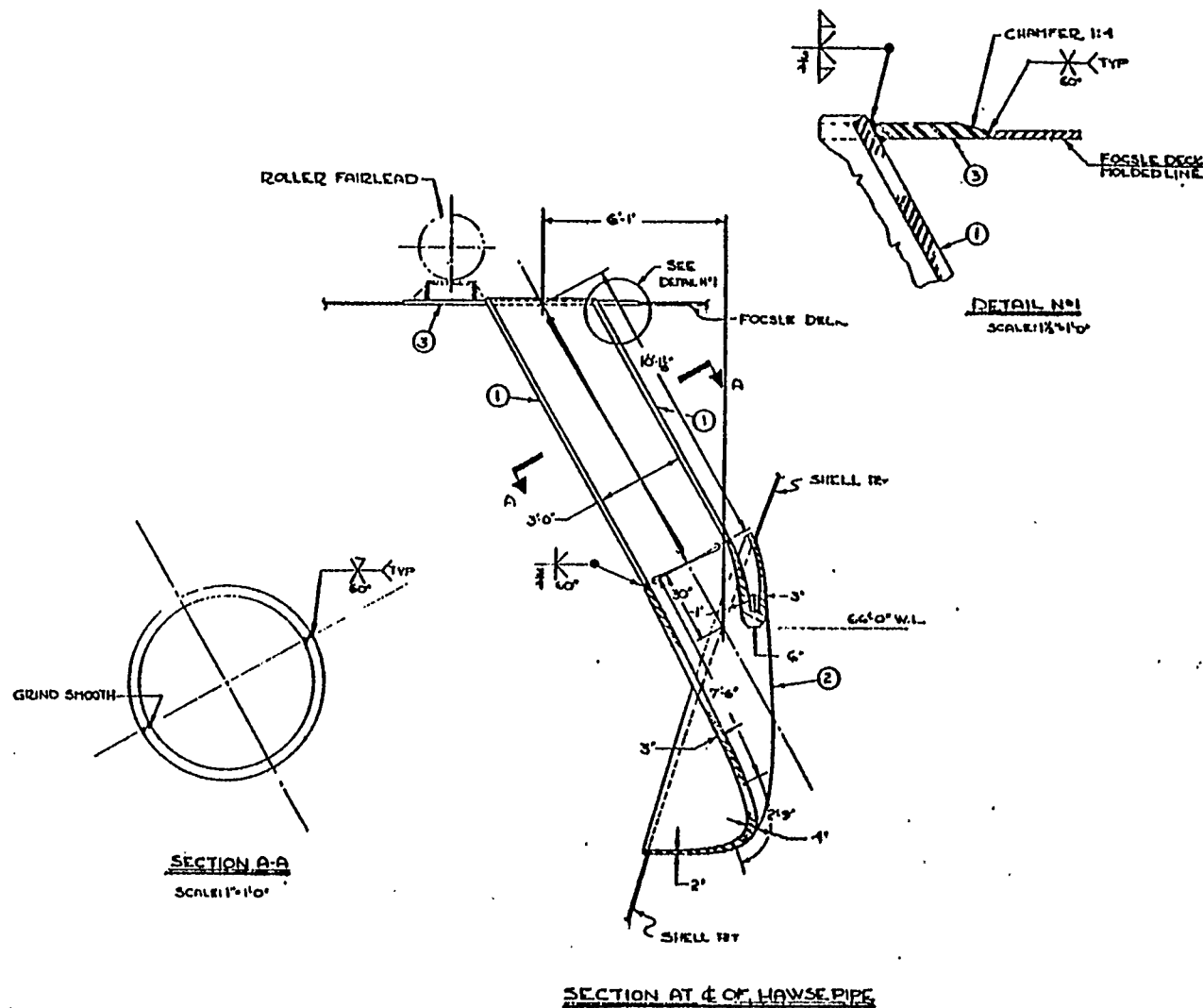
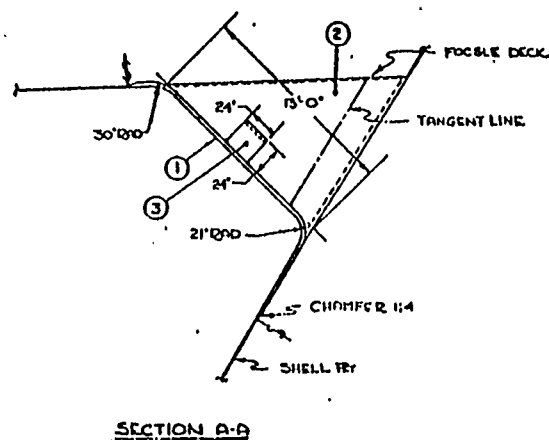


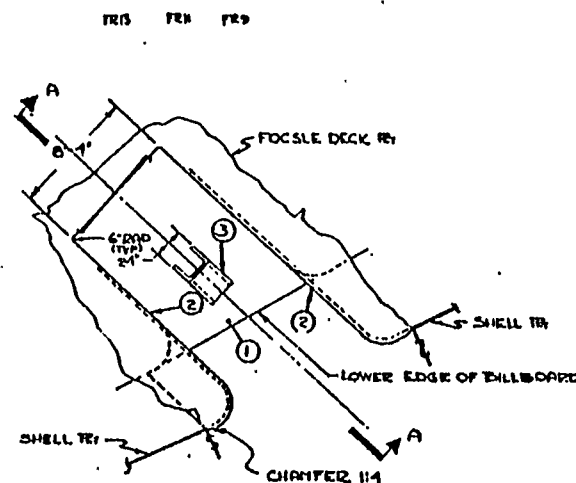
Figure 4.11

NATIONAL SIMULATING RESEARCH PROGRAM			
FEASIBILITY DESIGN HAWSE PIPE ARRANGEMENT 89,700 DWT TANKER			
SHEET NO.	DATE	BY	TOO
1	10/10/73	W. J. H. H.	W. J. H. H.
2			
3			
4			
5			
6			
7			
8			
9			
10			

NO.	QTY	DESCRIPTION	MATERIAL
1	1	PULL BOARD	12000
2	2	WHEELBOARD LUGS	61000
3	1	LOADING CHUCK	61000
4			
5			
6			
7			
8			
9			
10			



SECTION A-A



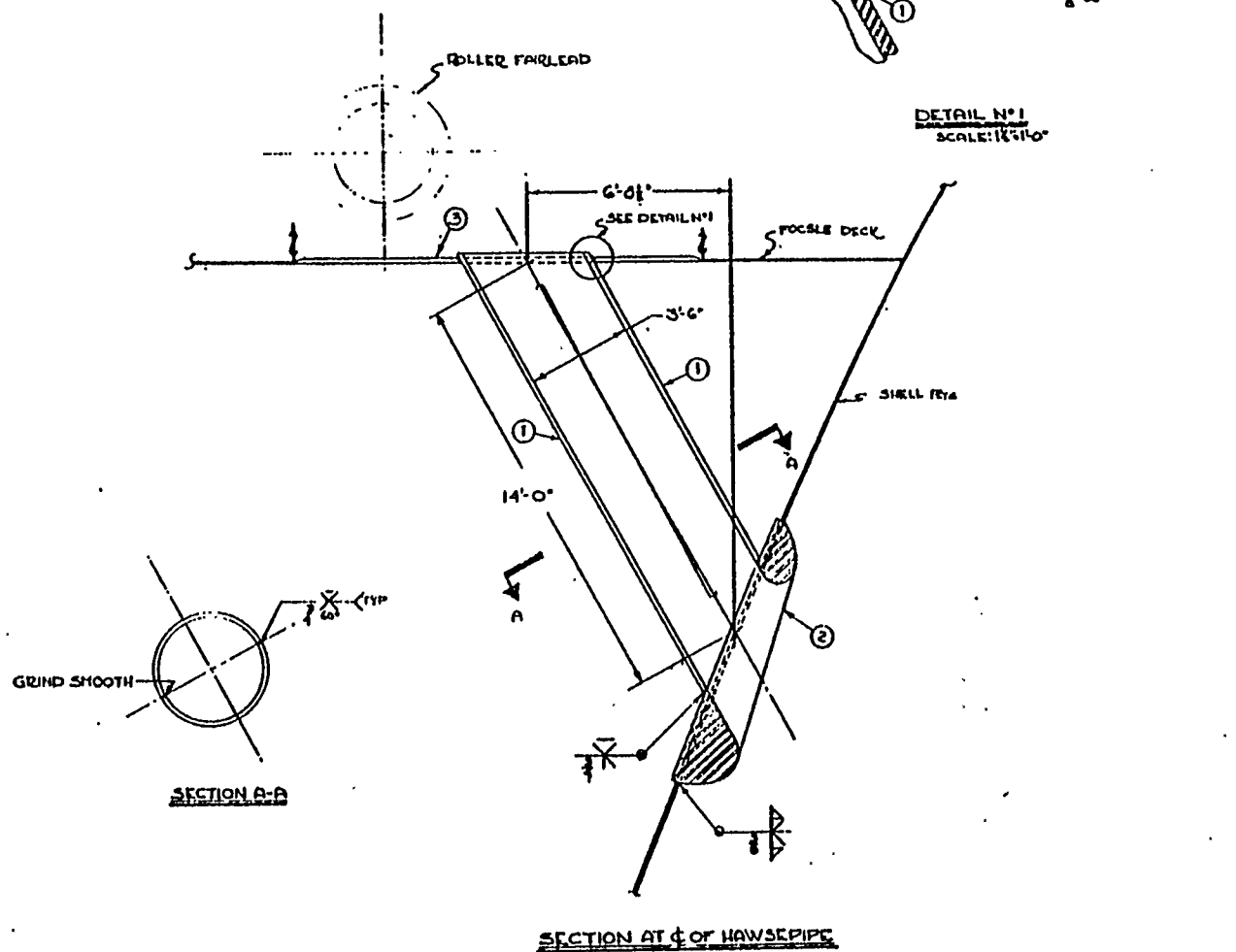
PLAN

GENERAL NOTES

1. STEEL PLATES ARE TO BE ORDINARY STIFFENING STRUCTURAL MILD STEEL PER SECTION 45 OF ABS RULES, EXCEPT AS NOTED.
2. WELDMENTS ARE TO BE IN ACCORDANCE WITH SECTION 50 OF ABS RULES.
3. WELDING OF PLATE OF 1-3/8" AND THICK ARE TO BE HEATED TO 150°F BEFORE AND DURING WELDING. WELDING TO BE ACCOMPLISHED WITH LOW HYDROGEN ELECTRODE.
4. CURVED AREAS OVER WHICH THE ANCHOR CHAIN WILL RUN SHALL BE HAND SURFACED WITH WELD DEPOSITED BY AN ELECTRODE SUCH AS "HARD ALLOY 32." THE WELD BEADS SHALL BE IN THE DIRECTION OF THE RUN OF THE CHAIN AND SHALL BE CYCLED TO "HUMP" SHARP EDGES WHICH WOULD SCORE THE CHAIN.
5. BILLBOARDS ARE TO BE RIGIDLY SUPPORTED TO MINIMIZE VIBRATION DUE TO RUN OF THE ANCHOR.
6. IT SHOULD BE NOTED THAT THERE IS A PATENTED BILLBOARD ANCHOR HANDLING SYSTEM ON THE MARKET. COMPONENTS OF THE BILLBOARD ANCHOR HANDLING CAN BE PURCHASED FROM THE PATENT HOLDER.

Figure 4.13

NATIONAL SHIPBUILDING RESEARCH PROGRAM	
FEASIBILITY DESIGN	
BILLBOARD ARRANGEMENT	
30,300 DWT TANKER	
DATE	TOTAL DOWNSHIP NO.
DATE	DATE
REV.	DATE
DATE	DATE



NO.	QTY	DESCRIPTION	MATERIAL
1	2	HAUSE PIPE	STEEL ROLLED
2	1	WELL BOLTER	AST STEEL
3	1	WELL INSERT KIT	AST R1
4			
5			
6			
7			
8			
9			
10			

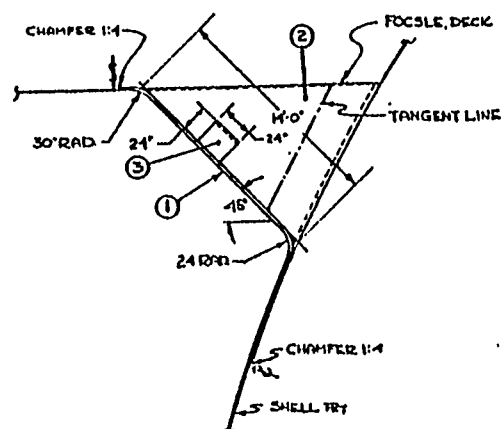
GENERAL NOTES

1. THE SURFACES OF THE CASTINGS OVER WHICH THE CHAIN WILL RUN SHALL BE SURFACE INSPECTED BY MAGNETIC PARTICLE INSPECTION.
2. CURVED AREAS OVER WHICH THE CHAIN WILL RUN SHALL BE HAND SURFACED WITH WELD DEPOSITED BY AN ELECTRODE SUCH AS "HAND ALLOY 32." THE BEADS SHALL BE IN THE DIRECTION OF THE PIN OF THE CHAIN AND SHALL BE GROUNDED TO REMOVE SHARP EDGES WHICH WOULD SCOUR THE CHAIN.
3. CASTINGS SHALL BE ASTM A 27-70 GRADE B-60-30 FULLY ANNEALED. MECHANICAL TESTS ARE TO BE PERFORMED TO MEET THE REQUIREMENTS OF ASTM AND ABS.
4. ALL ROUGH SURFACES TO BE GROUNDED SMOOTH.
5. ALL THICKNESSES OF CASTINGS INDICATED ARE TRUE THICKNESSES TAKEN NORMAL TO THE OUTSIDE SURFACES AT THE POINT SHOWN.
6. STEEL PLATES ARE TO BE ORDINARY STRUCTURAL STEEL PLATE PER SECTION 43 OF THE ABS RULES, EXCEPT AS NOTED.
7. WELDING SHALL BE IN ACCORDANCE WITH SECTION 50 OF THE ABS RULES.
8. WELDMENTS OF PLATE 1/2" AND OVER ARE TO BE PREHEATED TO 150°F BEFORE THE WELDING AND MAINTAINED AT THIS TEMPERATURE DURING THE WELDING. WELDING TO BE IN ACCORDANCE WITH LOW HYDROGEN ELECTRODES.

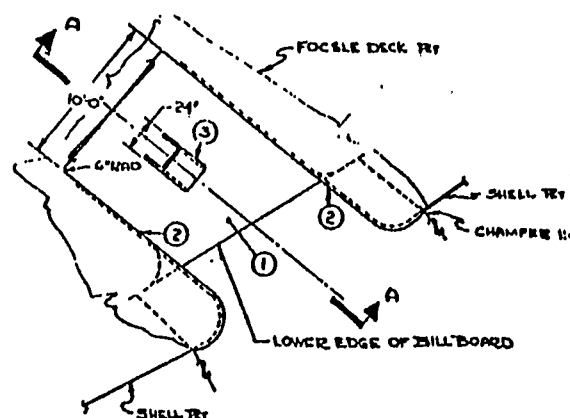
Figure 4.12

NATIONAL SHIPBUILDING RESEARCH PROGRAM			
FEASIBILITY DESIGN			
HAUSE PIPE ARRANGEMENT			
100,300 DWT TANKER			
DATE	BY	CHKD	APP'D

LIST OF MATERIALS		
NO.	QTY	DESCRIPTION
1	1	WELDED
2	1	FEASIBILITY DESIGN
3	1	CLOSED CHUCK
4		
5		
6		
7		
8		
9		
10		



SECTION A-A



PLAN

GENERAL NOTES

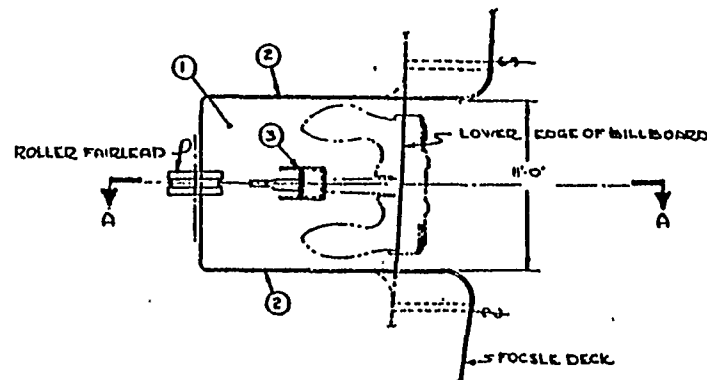
1. STEEL PLATES ARE TO BE ORDINARY STRENGTH STRUCTURAL MILD STEEL PER SECTION 43 OF ABS RULES, EXCEPT AS NOTED.
2. WELDMENTS ARE TO BE IN ACCORDANCE WITH SECTION 50 OF ABS RULES.
3. WELDING OF PLATE OF 1/2\"/>

Figure 4.14

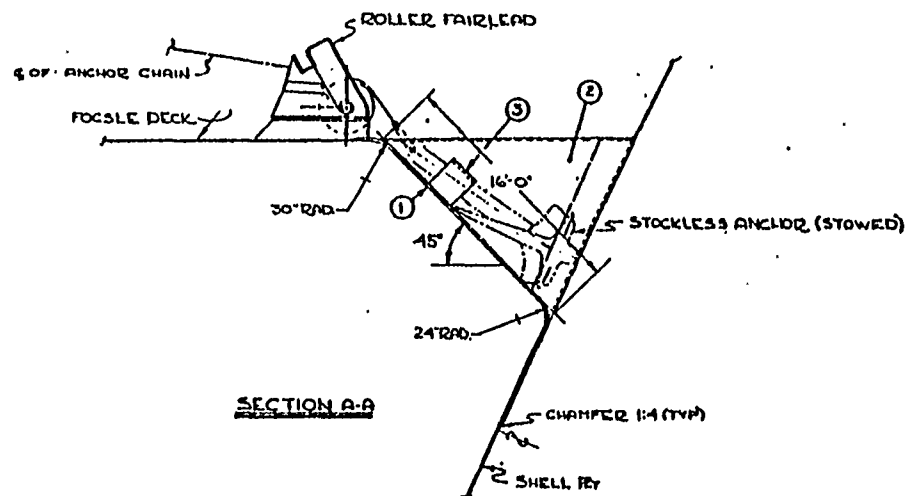
NATIONAL SHIPBUILDING RESEARCH PROJECT	
FEASIBILITY DESIGN	
BILLBOARD ARRANGEMENT	
69,700 DWT TANKER	
SHEET NO.	11 OF 11

REV. 11-1-01 SHEET 11 OF 11

NO	QTY	DESCRIPTION	MATERIAL
1	1	BILLBOARD	Q160 RT
2	2	FOR BILLBOARD FWD	Q160 RT
3	1	CLOSED CHUCK	Q160 RT
4			
5			
6			
7			
8			
9			
10			



PLAN



SECTION A-A

GENERAL NOTES

1. STEEL PLATES ARE TO BE ORDINARY STRENGTH STRUCTURAL MILD STEEL PER SECTION 43 OF ABS RULES, EXCEPT AS NOTED.
2. WELDMENTS ARE TO BE IN ACCORDANCE WITH SECTION 59 OF ABS RULES.
3. WELDING OF PLATE OF 1/2" AND OVER ARE TO BE HEATED TO 350°F BEFORE AND DURING WELDING. WELDING TO BE ACCOMPLISHED WITH LOW HYDROGEN ELECTRODE.
4. CURVED AREAS OVER WHICH THE ANCHOR CHAIN WILL RUN SHALL BE HAND SURFACED WITH YIELD STRENGTH BY AN ELECTRODE SUCH AS "MIG" ALLOY 52." THE WELD SHALL BE IN THE DIRECTION OF THE RUN OF THE CHAIN AND SHALL BE SPACED TO FORM SHARP EDGES WHICH WOULD SLOPE THE CHAIN.
5. BILLBOARDS ARE TO BE RIGIDLY SUPPORTED TO MINIMIZE VIBRATION DUE TO RUN OF THE ANCHOR.
6. IT SHOULD BE NOTED THAT THERE IS A PATENTED BILLBOARD ANCHOR HANDLING SYSTEM ON THE MARKET. COMMENTS OF THE BILLBOARD ANCHOR HANDLING CAN BE PURCHASED FROM THE PATENT HOLDER.

Figure 4.15

NAVY SHIPBUILDING RESEARCH PROGRAM	
FEASIBILITY DESIGN	
BILLBOARD ARRANGEMENT	
155,500 DWT TANKER	
NO. 1	TOTAL DRAWING NO.
REV	DATE
1	10/1/60

SECTION 5.0

PRODUCIBILITY OF ALTERNATIVE DESIGNS

5.1 General

Producibility in the broad sense of the word has been defined in this study in terms of the following parameters:

- o material
- o shipyard facilities
- o planning and scheduling
- o testing
- o construction
- o cost

It can be surmised that some of these parameters can be considered quantitatively while others can only be treated qualitatively. Furthermore, several parameters are dependent on the capabilities, the geographic locations and the related experience of the shipyards.

Each of the producibility parameters is discussed in limited scope in this section. The final subsection presents the results of the producibility analysis for the alternative designs described in Section 4.0.

5.2 Parameters for Producibility Analyses

5.2.1 Material

The materials associated with the construction of stern frames and hawsepipes include the following:

- o castings
- o steel plate
- o welding rods
- o weldments

The castings and weldments are those that are purchased from manufacturers outside the shipyard.

It has been found during the surveys that the situation with regard to the source of castings can be quite different from one shipyard to another. Where the shipyard itself or its parent company has a foundry, a casting poured therein is not a direct material item and not usually subject to the long delivery times required by independent casting manufacturers. In this study, however, it is assumed that all castings are purchased from independent manufacturers outside the shipyard, and the results should be interpreted accordingly. This approach seems practical particularly in light of the fact that even shipyards with foundries may not have adequate pouring capacity for very large castings.

Similarly, with respect to weldments, the plate bending capabilities of the yards may vary considerably. Where plates of 5 inches or greater thickness were used it was assumed that independent outside fabricators would be given the work. This occurred in the cases of the fabricated stern tube assemblies.

Welding rods and steel plates of any thickness do not appear to present any problems from a supply standpoint, as indicated by suppliers of these materials.

5.2.2 Shipyard Facilities

The yard facilities that may be used in the various stages of stern frame and hawsepipe construction are plate bending machines, welding and cutting equipment, heat treatment and stress relieving equipment in addition to the general open and covered yard areas, cranes, foundries, etc.

5.2.2.1 Yard Area

The yard area required for this construction is small and presents no problem. As a consequence, however, the stern frame construction may be performed anywhere in the yard and requires lifting and transportation to the erection site. A restriction on the area may occur if large castings requiring large deep welds are involved. In such cases it may be desirable to perform the welding under cover to keep the welding, once it begins, out of the rain and to "break the wind" in pre- and post-heating operations in cold climates. These factors are, however, fairly negligible from the standpoint of producibility since the space required is extremely small.

5.2.2.2 Cranes

Crane capacity places one of the greatest restrictions on stern frame component and overall size in particular. In this study the casting component sizes were kept at 40,000 pounds maximum. The overall allowable stern module weight was assumed to be 140 tons on the basis of maximum crane capacity. Both of these values are considered to be practical limits for a number of U.S. shipyards.

5.2.2.3 Plate Bending

Generally shipyards are equipped to bend relatively thin plates into shallow shell shapes. The fabrication of stern tubes and hawsepipes is most easily performed by rolling the complete cylindrical shape and making one weld seam. This type of bending in conjunction with the thick plates involved is not possible with all types of shipyard equipment. Consequently, in this study it has been assumed that stern frame castings are purchased from independent outside fabricators. In addition, it should be noted that welding the required thicknesses for stern tubes may not be possible at many shipyards. If cost benefits can be obtained from in-yard construction, the aforementioned factors should be taken into account on an individual basis.

5.2.2.4 Foundries

As discussed in connection with "material" in Section 5.2.1 above, it is assumed that no foundry is available at the shipyard. This should be remembered in interpreting the results of this study for a shipyard where in fact a foundry of adequate capacity is available.

5.2.2.5 Welding

The following welding processes are in more common use in the shipbuilding industry:

- o Manual welding using stick electrodes (Shielded Metal-Arc Process)

- o Submerged-arc welding
- o Gas metal-arc welding
- o Electro-slag or electro-gas welding

The various welding techniques differ in the amount of automation that can be incorporated, the type of equipment needed and the types of steels and welds for which they are most suited.

For the purposes of this study, the manual welding using stick electrodes was selected for the following reasons:

- o Suitable for thin and thick plate welding
- o Can be used on any welding joints including butt, tee and lap
- o Any shipyard will have the manpower and equipment available for this type of welding
- o Can be performed in any position: horizontal, vertical, or overhead
- o The irregularity of the stern frame contours does not lend itself very suitably to the use of semi- or fully-automatic welding processes

It is assumed that all equipment for welding is already available. Where cold and rainy weather is expected during the welding, a facility with overhead cover may be required.

5.2.2.6 Heat Treatment and Stress Relieving Equipment

Heat treating of castings and weldments prior to, during and after welding is not specifically required by regulatory bodies or classification societies. However, it is good practice to do so for ordinary strength steel in plates of over 1½" thickness. Some typical guidelines for heat treating and stress relieving operations are given in Appendix C.

The final requirements for pre-, interpass and post-heat treatment of weldments and castings used in this study were taken from typical shipyard drawings listed in Section 7.0. These requirements are:

- o Plates from 1-3/8" to 2" thick: Preheat to 150°F before welding and maintain during welding. Low-hydrogen electrodes to be used.
- o Plates from 3" to 4" thick: Preheat to 250°-300°F minimum before welding and maintain during welding. Post-heat treat by cooling slowly from the preheat temperature at the rate of about 50°F/hour. Low-hydrogen electrodes to be used.
- o Castings: Preheat to 200°-300°F minimum before welding and maintain during welding. This is to pertain to all welded attachments of casting to casting and other mild steel structure to casting. Low-hydrogen electrodes to be used.

The type of heat treatment and stress relief procedures just described can be adequately performed on stern frames and hawsepipes using electric heaters and insulating blankets. It was assumed that this equipment would be readily available in all shipyards.

5.2.3 Planning and Scheduling

It is difficult to quantify and analyze the planning and scheduling requirements for stern frames and hawsepipes since they consist of structural parts that can be assembled well after the construction of the vessel has begun, but must necessarily be installed before the construction is significantly near completion.

It is understood from the surveys that some shipyards do not have planning and scheduling problems with respect to stern frames and hawsepipes, yet others anticipate scheduling difficulties. The apprehension is due to the continual decrease in the number of large casting manufacturers in the U.S., the increasing lead times for delivery, and the decreasing quality.

No advantages or disadvantages are assigned to alternative stern frame and hawsepipe designs on the basis of planning and scheduling, since no significant problems have so far really been experienced despite the fact that they were anticipated.

For use in interpreting the results presented in this study, however, the following considerations are noted:

- o The expected lead time for a domestic cast stern frame (measured from the time the foundry receives the pattern to when the yard receives the casting) is 6 to 12 months. Foreign foundries, reportedly, can deliver a casting in 6 months.
- o Foundries and ship designers should endeavor to finalize the plans for castings collectively before production starts. This will help cut down the lead time due to elimination of the need for plan revisions suggested by the foundry in order to improve the casting and its production.
- o At the shipyard, the construction of welded stern frames is more labor intensive than the welding required for construction of most other parts of a ship.
- o Reference [30] discusses photogrammetry, which has been used by a shipyard to verify casting dimensions at the foundry before the casting was delivered to the shipyard, thus insuring an adequate fit. This will result in reduced delays for those castings which may be faulty.

5.2.4 Testing

The testing requirements of the castings and weldments can be derived from the American Bureau of Shipping and/or other classification societies rules and expanded by the opinions of the designers.

Shipyard contracts with casting manufacturers are generally worded such that the testing requirements must be met by the latter. Therefore, these costs appear as part of the direct costs to the shipyard for the castings and thus require no further consideration in this study.

Welding of castings to castings, plate to castings or plate to plate in stern frame and hawsepipe construction will entail satisfying several requirements of the American Bureau of Shipping and/or other classification societies. These can be summarized as follows:

- o Fillet welds of normal strength castings and thick plates do not generally require nondestructive testing

- o Butt welds or thick plates (up to around 2") or castings forming part of the shell will require ultrasonic testing
- o For butt welds of thick plates or castings much over 2" in thickness, regardless of location, radiographic testing will be required

Where nondestructive testing is not specifically required by the classification society, the designer may still decide to call for testing of thick plate welds. This would entail either magnetic particle tests or ultrasonic inspections.

As a synopsis of the various testing criteria discussed above, it is assumed for the purposes of this study that only the American Bureau of Shipping requirements must be satisfied; this would represent the general procedure.

5.2.5 Construction

The construction of all the alternative stern frame and hawsepipe designs developed in this study is considered to be feasible with existing shipyard manpower and equipment subject to the restrictions implied above.

Consequently, no additional assumptions or stipulations are deemed necessary regarding construction requirements.

5.2.6 Cost Estimates

5.2.6.1 General

The cost estimates for various stern frame and hawsepipe alternative designs were divided into the following separate categories:

- o Material
- o Welding
- o Cutting

- o Patterns and Layout
- o Rolling, Jigging, Field Cutting and Alignment, Heat Treating, Testing, Transportation

The cost estimates are based on 1977 dollars and are for constructing all parts in the United States. Furthermore, the cost estimates are based on producing a single ship. Non-recurring costs, such as patterns and layout templates, will be spread over several ships of a multiple order contract. It is felt that the cost for the shipyard production of a good casting pattern will be approximately equal to five times the cost of producing a good set of layout templates for weldment designs.

In the following subsections, each of the cost categories will be discussed in more detail and then collectively summarized.

Additional details of the cost estimates appear in Appendix C.

The costs are for the complete fabrication of the stern frame or hawsepipe alternatives but do not include the cost of welding them into the ship structure.

5.2.6.2 Cost Categories

(a) Material

The material costs include those for steel plates, welding rods, castings and weldments.

For plates a cost of \$.25/lb was obtained from several suppliers and verified by shipyards.

The costs of welding rods has been taken into account in the preparation of welding estimates.

The casting costs were obtained from the shipyards except for the bolster alternative design for the 188,500 DWT vessel and all gudgeon castings, which were estimated using available data on other similar castings. The costs of manufacturing, heat treating, shipping to

the yard, and testing are included in the overall casting costs. Other costs associated with castings are included elsewhere.

A number of fabricated components were assumed to be obtained from outside the shipyard. These are:

- o The stern tube assemblies for all conventional welded stern tube alternative designs
- o The stern tubes and bossings of the inboard accessible stern tube design alternatives

The costs of these components were estimated on the basis of a direct quote obtained from a weldment manufacturer for the 38,300 DWT vessel stern tube assembly.

The conventional stern tubes of the larger vessels were assumed identical to those of the smaller vessels since the actual sizes were very nearly identical.

The cost of the inboard accessible stern tubes was determined by adding a "net extra cost" of constructing an IAST instead of the conventional stern tube reported in [28]. The weldment costs include those for material, heat treatment, welding, testing and shipping. Internal structures such as bearing supports have been accounted for in both the conventional stern tubes and the IAST's through the use of a 10% margin.

The final costs of materials for all the alternative designs are given in columns 1 and 2 of the cost summary, Tables 5-1, parts A and B.

(b) Welding

For the determination of welding costs for all cases, the following procedure was used:

- o Measure length of various welds for the alternative designs from the drawings

- o Obtain weld metal weight per foot from Reference [31]. Tables give the required data as a function of weld type and thickness.
- o Obtain cost of welding per lb. of weld metal from Reference [32] by assuming a 30% operating factor defined as actual arc welding time to elapsed time. A labor plus overhead rate of \$20 per hour was assumed. The operating factor of 30% is rather low, but is considered reasonable for field welding of stern frames. In fact, one shipyard commented that welding may require even a lower operating factor.

The welding costs are summarized in column 3 of Tables 5-1, parts A and B.

(c) Cutting

Reference [33] indicated that cutting costs generally range from 15 to 40% of the material costs; some shipyards commented that even 40% may be somewhat low, but this figure was adopted in the study.

The results are listed in columns 3 and 4 of Tables 5-1, parts A and B.

(d) Patterns and Layout

Costs of patterns for castings were obtained from shipyards. These were taken to be 25% of one cast assembly for stern frames and 100% of one cast assembly for bolsters.

In the case of fabricated stern frames, the costs to the shipyard for the development of offsets and scribing of plates were assumed to be one fifth of the pattern cost for castings. For the hawsepipe alternatives, these costs are considered negligible.

Cost figures for patterns and layouts are listed in columns 4 and 5 of Tables 5-1, parts A and B.

(e) Rolling, Jigging, Field Cutting and Alignment,
Heat Treating, Testing, Transportation (In Yard)

The numerous cost items listed here were lumped into one category since data was not available for each. Shipyard comments have implied these costs can amount to 150% of the material costs and this value has been adopted for the analyses performed in this study.

Similar costs applicable to castings were assumed to be one fifth of those for weldments.

The cost figures for this category are shown in columns 5 and 6 of Tables 5-1, parts A and B, for stern frames and hawsepipes respectively.

5.2.6.3 Summary of Costs for Various Categories

The total costs for the construction of a single unit of the stern frame and hawsepipes alternative designs are given in columns 6 and 7 of Tables 5-1, parts B and A for hawsepipes and stern frames respectively.

For a multiple production order of five units, the costs are shown in Tables 5-2. The difference is due to the sharing of the pattern and layout template costs over the five units. Note that the layout template costs for weldment designs were taken as 1/5 of the pattern costs for cast designs. No advantages were given for learning in any of the configurations.

The costs for both single and multiple ships indicate that fabricated stern frames, whether with conventional tubes or IAST's, are significantly less expensive than cast stern frames.

The hawsepipes cost estimates reveal that for single ships the billboard type arrangement costs approximately the same as a fabricated conventional hawsepipes with a cast shell bolster. For multiple ships, the costs of the conventional system decrease somewhat while those of the billboard system do not.

5.3 Discussion of Results

In section 5.2, it was stated that for the purposes of this study, all factors except costs influencing the producibility of stern frames and hawsepipes were assumed to remain equal for various alternative designs. The reasons for this assumption were cited in applicable places. Consequently, the producibility of these components is being measured on the basis of costs alone. For individual cases, however, where some of the other producibility factors might be important and different from what was assumed here, the differences must be taken into account as previously indicated.

It is evident from a review of the cost summaries of Tables 5-1 and 5-2 that fabricated (all-welded) stern frames cost less than all cast stern frames.

The all cast stern frame costs for the production of a single unit range between \$418,000 and \$524,000; while the range for all-welded stern frames is \$155,000 to \$270,000. The accuracy of the absolute numbers and their applicability to any and all shipyards is naturally debatable; however, the trend becomes clear that all-welded stern frames are more producible. The fact that they are not selected by most shipbuilders today may possibly be a result of individual economic situations and possibly traditional preferences.

TABLE 5-1: Part A - Cost Summary for Alternative Stern Frame Designs

	1	2	3	4	5	6	7
Alternative Design	Stern Frame Material Costs (\$)	Stern Tube Constructed Costs (\$)	Welding Costs (\$)	Flame Cutting Costs (\$)	Pattern or Layout Costs (\$)	Rolling, Jigging, Etc. Costs (\$)	Total Costs (\$)
1. All Cast 38,300 DWT	329,700	NA	NA	NA	82,400	5,850	417,950
2. All Cast 89,700 DWT	335,000	NA	NA	NA	83,800	8,320	427,120
3. All Cast 188,500 DWT	411,000	NA	NA	NA	102,800	10,100	523,900
4. All Welded 38,300 DWT	19,400	41,580	40,700	7,800	16,500	29,100	155,080
5. All Welded 89,700 DWT	23,400	41,580	53,700	11,350	16,800	42,600	194,430
6. All Welded 188,500 DWT	33,600	41,580	63,700	13,400	20,600	50,400	223,280
7. All Welded 38,300 DWT IAST	19,400	77,000	40,700	7,800	16,500	29,200	190,600
8. All Welded 89,700 DWT IAST	27,000	104,900	53,700	11,100	16,800	41,500	255,700
9. All Welded 188,500 DWT IAST	33,600	104,900	63,700	13,400	20,600	50,500	286,700

TABLE 5-1: Part B - Cost Summary for Alternative Hawsepipeline Designs

	1	2	3	4	5	6
Alternative Design	Plating Costs(\$)	Shell Bolster Casting Costs (\$)	Welding & Cutting Costs (\$)	Pattern or Layout Costs(\$)	Rolling, Jigging, Etc. Costs(\$)	Total Costs(\$)
10. Billboard 38,300 DWT	6,200	NA	6,000	NA	9,300	21,500
11. Billboard 89,700 DWT	9,700	NA	9,500	NA	14,550	33,750
12. Billboard 188,500 DWT	11,300	NA	10,500	NA	16,950	38,750
13. Hawsepipeline 38,300 DWT	1,400	8,900	4,000	9,000	2,100	25,400
14. Hawsepipeline 89,700 DWT	1,900	23,800	7,780	24,000	2,850	60,330
15. Hawsepipeline 188,500 DWT	3,100	11,800	8,400	11,000	4,650	38,950

TABLE 5-2: Stern Frame and Hawsepipe
PART A Costs of Alternative Designs
 for
 Production of Five Units

Alternative Design	Pattern or Layout Template Cost (\$)	Single Unit Cost (\$)	Cost per Unit for Five Units (\$)
1. S.F.: All Cast 38,300 DWT	82,400	417,950	352,050
2. S.F.: All Cast 89,700 DWT	83,800	427,120	360,070
3. S.F.: All Cast 188,500 DWT	102,800	523,900	441,700
4. S.F.: Weldment 38,300 DWT	16,500	155,080	155,080
5. S.F.: Weldment 89,700 DWT	16,800	194,430	194,430
6. S.F.: Weldment 188,500 DWT	20,600	223,280	223,280
7. S.F.: Weldment IAST, 38,300 DWT	16,500	181,690	190,600
8. S.F.: Weldment IAST, 89,700 DWT	16,800	238,930	255,700
9. S.F.: Weldment IAST, 188,500 DWT	20,600	269,930	286,700

TABLE 5-2: Stern Frame and Hawsepipe
PART B Costs of Alternative Designs
 for
 Production of Five Units

2
3

Alternative Design	Pattern or Layout Template Cost (\$)	Single Unit Cost (\$)	Cost per Unit for Five Units (\$)
10. H.P.: Billboard 38,300 DWT	—	21,500	21,500
11. H.P.: Billboard 89,700 DWT	—	33,750	33,750
12. H.P.: Billboard 188,500 DWT	—	38,750	38,750
13. H.P.: 38,300 DWT	9,000	25,400	18,200
14. H.P.: 89,700 DWT	24,000	60,330	41,130
15. H.P.: 188,500 DWT	11,000	38,950	30,150

SECTION 6.0

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12. National Steel and Shipbuilding Company, Dwg. No. 398-119-001,
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2 Sheets
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Sheets 2-6
21. FMC Marine & Rail Equipt. Div. N&SA Dwg. No. 7248-5-2
Sheets 3-6 35,000
DWT
Tanker
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APPENDIX A

BACKGROUND DOCUMENTS

FROM INDUSTRY SURVEYS AND INTERVIEWS

<u>Appendix No.</u>		<u>Page</u>
A.1 :	List of Surveys & Interviews.....	A- 1
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APPENDIX A.1

LIST OF SURVEYS AND INTERVIEWS

A. Preliminary Surveys at Shipyards

1. TODD Pacific Shipyards Corporation
Los Angeles Division
San Pedro, California
2. SEATRAN Shipbuilding Corporation
Brooklyn, New York

B. Final Surveys at Shipyards

3. AVONDALE Shipyards, Inc.
New Orleans, Louisiana
4. BETHLEHEM Steel Corporation
Shipbuilding Division
Sparrows Point, Maryland
5. FMC Corporation
Marine and Rail Equipment Division
Portland, Oregon
6. LITTON Industries, Corp.
INGALLS Shipbuilding Division
Pascagoula, Mississippi
7. NATIONAL STEEL and SHIPBUILDING CO.
San Diego, California
8. NEWPORT NEWS Shipbuilding and Drydock Co.
Newport News, Virginia

C. Interviews with Regulatory Bodies

1. American Bureau of Shipping
New York, New York
2. U.S. Coast Guard
Merchant Marine Inspection Office
New York, New York

D. Interviews with Design Agents

1. George G. Sharp, Inc.
New York, New York
2. John J. McMullen, Inc.
New York, New York

E. Interviews with Casting Vendors

1. BETHLEHEM Steel Corporation
Foundry Division
Bethlehem, Pennsylvania
2. BIRDSBORO Corporation
Birdsboro, Pennsylvania

F. Correspondence With

1. General Dynamics Corp.
Quincy Shipbuilding Division
Quincy, Massachusetts
2. AB Gotaverken
Goteborg, Sweden
3. Chicago Bridge & Iron
Birmingham, Alabama
4. Sun Shipbuilding and Drydock Co.
Chester, Pennsylvania

APPENDIX A.2

SURVEY QUESTIONNAIRE

Configuration

1. What type of stern configurations are you now constructing or anticipate constructing (such as horn type rudder with transom stern, balanced rudder with shoe, etc.)?
2. What type of hawsepipe configurations are you now constructing (hawsepipe - no bolsters; hawsepipe with bolsters - anchor exposed; hawsepipe with anchor pocket; other)?
3. From fabrication point of view, which type of stern frame and hawsepipe does your yard prefer?
4. What is the shipyard's position in deciding the configuration of the stern frame and hawsepipe? Entirely decided by the owner's design agent?
5. Do you have any experience with inboard accessible stern tubes?

Construction

1. Are your stern frames and hawsepipes currently of the forged, cast, welded or mixed type?
2. What is the method of constructing the stern frame and hawsepipe in your yard?
3. Does your present method of constructing stern frames and attaching them to the rest of the ship require a specific stern frame design?
4. Have any specific designs given you significant construction problems?
5. What is your past experience with stern frames and hawsepipes, especially with substituting fabricated components in place of castings and forgings?
6. Did you ever encounter any failure in these components? How did you repair it?
7. Any special skills or extra engineering required by the yard?
8. Any problems with planning, scheduling, tooling, etc.?
9. What is the percentage of wastage from rough casting to finished, machined product?

Survey Questionnaire Continued

Design Loadings for Stern Frames and Hawsepipes

1. Any information on the loading that stern frames and hawsepipes are subjected to? Any loading values for basic rationed design?
2. How do you determine the slope of the shell bolster and its scantlings? What percent do you attribute to wear?

Economics

1. What do you think are the significant economic considerations for various stern frame and hawsepipes alternative manufacturing processes?
2. Do you have any cost data for recently manufactured stern frames and hawsepipes?
3. For larger ships, at least some weldments have replaced casting and forging. However, most ships still have the shoe piece, prop. bossing and rudder bearing support casts. Is this for economic reasons?
4. Do you have estimates for manpower, materials and special facilities required for production of stern frames and hawsepipes?
5. Are stern frames and hawsepipes labor intensive products?
6. Would you be willing to review our comparative cost estimate for alternative stern frame and hawse pipe designs?

Classification Societies

1. Do you think the present classification society rules are adequate from the standpoints of stern frames and hawsepipes?
2. Any problems with classification society rules for building and inspecting?
3. Which classification society do you prefer? Which one is more rational, easier?
4. Do you have in-house criteria to develop stern frame and hawsepipes scantlings?

Survey Questionnaire Continued

Welding

1. What type of welding do you use to weld two heavy castings?
2. Is your yard capable, from the standpoint of qualified welder, equipment and facilities, to weld thick plate? Up to what thickness?
3. What is your capacity to stress relieve any welded structure?

Vendor Supplied Castings and Forgings

1. Names of vendors used for specific castings and forgings (for stern frame or hawsepipe).
2. What lead time do they normally require? Delay in delivery? How about rejections?
3. How do they normally charge for castings? For forging? By weight?
4. How is the actual size of any casting decided?
 - a) Sole piece?
 - b) Stem tube?
 - c) Rudder carrier?
5. In general, history of relations with vendors?

APPENDIX. A.3

EXCERPTS FROM SURVEYS & INTERVIEWS

Table A. 1 lists the vessels by class and size which were examined and/or detail drawings for *stern* frame and hawsepipe arrangements obtained from their building yards.

Excerpts from surveys and interviews conducted with shipyards, regulatory bodies, design agents, and foundries are presented below.

AVONDALE SHIPYARDS

1. Could not procure castings as large as a 200,000 # in U.S. Foundry could pour but could not get in any time frame. In 1974, went to combined welding-casting system. Gudgeons are castings. Most of bossings are castings. Rest are weldment.
2. Use castings for bolsters. Cast in Avondale Foundry. On later ships cast rollers. Hawsepipe is rolled, same thickness all around. No hardening; no ships reported ~~any failures~~
3. Avondale has not built any ship with inboard accessible stern bearings. A possible design for an oil tanker was studied but never installed.
4. Plates used are 2"-3" mild steel. Electro-slag welding has been used for shell plates. Leave 1/2" material for machining.
5. No formulas for loadings. ABS has an allowable stress for casting of 6 KSI. Have performed a full analysis for rudder horn. Forces and moments from self-propelled model tests done by NSMB and fine element model analysis. Find stress distribution, 1 KSI max.
6. Cannot quote representative costs. Selected castings because of availability. Would like to buy the piece and plug it in because they want to eliminate welding.

(Avondale)

7. Furnace can handle a rudder horn turned sideways diagonally across the doorway. For a 100,000 DWT Tanker the casting can reach 240,000 # - can be a problem.

8. Had good relations with casting vendors in general. Never held up vessel with castings.

BETH. SPARROWS POINT

1. Most of the ships built in this yard are:
Rudder with horn, semi-balanced rudder and transom stern.
No ships with shoe pieces. Normal configuration for hawsepipes used in this yard, i.e. straight hawsepipe with upper and lower halves of different thickness anti all fitted with shell and deck bolsters. Recent ships have been fitted with a roller at the deck instead of deck bolster (have not built a recessed anchor pocket yet). They prefer a combination of casting and weldments. Stern tube bossing, rudder gudgeons (including lower portion of the rudder horn) are usually cast, the balance of the stern frames are fabricated.

2. Stern frame is constructed as portion of the stern module. Hawsepipes are individually fitted into the bow structure.

3. The shipyard can construct any type of stern frame. However, the stern frame itself should be one that can be constructed. Recently, they bought a design from one shipyard and they found out that it was not possible to construct the stern frame as shown on the drawings. Some modifications had to be made.

4. They never encountered any failures in the *stern frames*.

5. No loading criteria for design; ABS rules are used. They use a Hawsepipe Slope of 45°; and they always make an anchor handling model.

6. For best economy, keep design simple and easy to construct. Labor costs are the largest *single* factor. Keep away from HTS. Some designers use HTS but the scantlings are in accordance with ABS rules for M.S. It is just a *waste* of money.

(Beth. Sparrows Point)

7. No cost data available. It is impossible to give a single cost to reflect the costs on all ships.
8. Use manual electro-slag welding; never-use thermit welding. The shipyard is equipped to weld any thickness of plate. The size of the stress relief room is 34' long x 15' wide x 12'-6" height. Any component can be stress relieved if it can be fitted into this room. For local stress relief, there is no size limit.
9. **Bethlehem Steel's Foundry Division is the only one they deal with. Lead times can be 1 year for castings, 8 months for forging. There are normal delays, but not bad; no outright rejection yet.**
10. The normal charge for casting, with extra for pattern, if the foundry has to supply it. No figure for cost is worth giving; it is too complex, however, if a figure has to be given, would say \$.70/# plus cost of pattern.

FMC CORPORATION

1. Inboard accessible stern tube is installed on the CHEVRON Tanker. The tube was fabricated in this yard. 84" O.D.; 1" & 3^{1/2}" plates. The 1" plate extended to the aft collision Bhd. Rudder horn was cast by Washington Iron Works of Seattle, Wash. It was cast in 3 pieces and shipped to San Francisco, Bethlehem Steel Shipyard for machining. The 3 pieces were welded in FMC. The total weight of the rudder horn is 35 tons.
2. FMC can weld thick plates and has experienced no problems so far.
3. **Horn rudder and transom stern are fitted on the CHEVRON Tanker. Horn and shoe are cast; others are fabricated. (See Figure A.1 for a sketch of stern frame arrangement.)**
4. For hawsepipe, they would use heavy duty pipe (commercially hard drawn pipe) and cast bolster. Prefer exposed anchor, because of its cheaper installation. They build model and check anchor housing.
5. On the CHEVRON Tanker, Nickum & Spaulding, owners' design agent, did some analysis. Owner had requirements in addition to ABS requirements.

(FNC Corp.)

6. The stern frame and hawsepipe for the CHEVRON Tankers require no special skill and training.
7. Casting and weldment costs are 50/50. Costs more on cast if done outside but no labor involved. If fabricated in yard, it probably costs less but needs a lot of manpower. FMC has no foundry facility.
8. They use submerged-arc welding whenever they can. Use electro-slag and thermit welding for heavy work. They do not, however, have the equipment to do electro-slag welds. Would have to either procure the equipment or rent one.
9. 2" thick plate is the thickest they ever weld. They don't see any problem with thicker plate even though they have never done any.
10. Have no furnace for subassembly or *component* stress relief. For local stress relief, asbestos blankets and electric heaters are used. *This gives good results.*
11. 12 to 15 months lead time is required for castings. This is the latest delivery period they got from the bid they sent out for a recent new construction.

INGALLS SHIPBUILDING

1. Stern frames have been completely fabricated for 15 years. Needed to do this because not only cheaper for the yard but had scheduling problems with castings. Just the LHA & Destroyers under construction at this time.
2. LHA & DD hawsepipes are rolled plate; shell and deck bolsters are castings. The plate used on Destroyer is 1½" HTS, on LHA mild steel (2") rolled at Litton. Single roll with just one weld. Casting comes into hull at either end about 12".
3. No problems with weldments after construction; they are annealed after all welding; done at yard, but with difficulty because of the size of their furnace. Constructed bigger weldment pieces than castings to reduce labor and make better fairing.

(Ingalls Shipbuilding)

4. During the last five years deliveries of castings had become too long. For a reasonably larger size, need 32 weeks to 1 year. Vendors have been asking for smaller pieces which they then weld to make the bigger pieces. Yard then has to make sure that all welding is all right. Litton does some of its own fixing to needed quality.

5. They have welded in the past up to at least 5" thick plate.

6. In the years past, no real problems with vendors. In recent years had more problems but never insurmountable. Problems were not big enough to discourage completely the use of casting.

NASSCO

1. All ships presently designed are horn type, semi-balanced rudder, cast stern frame. The stern frame is divided into 5 pieces:

Lower shoe piece

Boss

Banana (curved portion above the boss)

Horn (2 pieces)

2. Spade rudder is very uneconomical due to its short span for support and the resulting large rudder stock diameter.

3. Study made on SAN DIEGO Class Tanker for "Shell Oil", 189,000 DWT. The casting for a single section weighs over 100 tons. No one in this country wanted to cast because of weight. One mixed design for rudder horn, etc., was sent out for cost estimate. Japanese yards suggested casting the whole thing and their cost was so low that NASSCO went for casting. Figure A-2 is a sketch of the stern frame arrangement for the SAN DIEGO tankers.

4. COLORADO Class Ship, 38,000 Tanker. Six built, castings were made by National Forge. The same cast pattern can be used for a 45,000 T. ship.

(NASSCO)

5. NASSCO designed a particular configuration of stern frame which can be used on different sizes of ships. Design is made for the bigger one so that it is slightly "over-designed" for the smaller ones. Figure A-3 shows the configuration for the 89,700 DWT SAN CLEMENTE class tankers.
6. They fabricate their own hawsepipes, with end removable roller, up to 24" hawsepipe; they use one thickness of pipe.
7. All latest NASSCO designs have high holding anchors with pockets. No chain pipe is needed, since chain locker is right below the deck.
8. NASSCO is very conservative about inboard accessible stern tube. The attitude is wait and see. They have not installed one as yet.
9. NASSCO does its own final machining; no serious problem; about 10% extra is allowed for final machining.
10. They use manual electro-slag welding on stern frames, one pass at a time with good pre-heat. They can weld any thickness of plate or castings. They can do stress relieving by using their furnace.
11. They remember hardly any rejections on stern frame or hawsepipe castings for commercial ships. The vendors would do any repairs needed such as sand inclusion. In commercial ships, NASSCO requires more inspections than ABS calls for in high stress areas; some x-rays, ultrasonics and die penetrant tests.

NEWPORT NEWS

1. They like the horn rudder configuration. Upper horn section and stern tube are castings. All castings except rudder horn were done at the yard's foundry. They have welded webs in horn casting.
2. They use snug storing anchor. The 390,000 DWT VLCC has a cylindrical bow, and a weldment to make anchor clear the side of ship in the forward end. They do not recommend the use of doubler plates in way of anchor stowage. They use rolled plate for hawsepipe construction;

(Newport News)

two different thicknesses for hawsepipe: generally thicknesses for top and bottom are chosen from previous designs.

3. They have looked at inboard accessible stern tubes, but did not use.

4. Stern module of subassemblies contains stern frames.

5. Very few rejections on castings. No substantial wastage.

6. Work scheduling requirements may call for the use of castings because the yard can always do that work and needs to keep *the* foundry busy.

7. Shipbuilding in general is labor intensive. Stern frames and hawsepipes are more labor *intensive* than other parts of ships.

8. Bethlehem has supplied the large castings for the ULCC. The yard does all castings up to 75,000 # however.

9. Newport News developed their own design loads. Complete analysis of the stern end for tanker was performed including a full structural analysis.

10. They don't anticipate using *shell* bolsters anymore. They made tests for tanker anchor handling arrangements.

11. They use electro-slag welding. No thermit welding. Unlimited thickness of plate can be welded.

12. They stress relieve the whole rudder. A very large furnace to stress relieve large structures is available.

SEATRAN

1. The large tankers are designed with a large spade type rudder.

2. They have no foundry and accordingly would not want to do a ship with large castings.

3. The TURNBULL type inboard accessible stern tube's split bearing on the tanker required a casting. Bearing tube was rolled from 2" plate. Had aft end of bearing housing cast in Norway for one or two ships, and others by Mester.

(SEATRAN)

4. Seatrain uses modular construction; builds from bottom up. Bearing casting is welded accurately in place. Boring is done before the installation. Laser beams are used for centering purposes.
5. They used "Norske Veritas" rules on the tanker. ABS rules are not adequate for designing stern frames and bearings.
6. It is difficult to separate cost of welded stern frame **because it is part of the** stern module.
7. **Welding of 4" plate** would require pre-heating and stress relieving. **It would have** to be mild steel (175° for pre-heat). **High strength steel would** require higher temperatures for **pre-heating**.
8. Lead time for castings range from 6 to 18 months, a real problem. Now they don't know where to go for castings. Foundries are *reluctant* because ship's castings are getting to be too big and complicated with too many chances for problems. Seatrain installed spade rudders on the tankers because rudder horn castings would be too *costly*.
9. No shell bolsters on the oil tanker; had a support ring near the end of hawsepipe originally but it was eliminated because no wear was reported.

TODD LOS ANGELES

1. Presently under construction is the forebody of an Ammonia carrier. This is to be joined with the stern of a T-2 tanker in Portland, Oregon, by Northwest Marine and Iron Works. Todd Los Angeles therefore has only the hawsepipes for this vessel. No *stern frame* construction.
2. Previously, they have built and delivered 25,000 DWT tankers for Marine Transport Lines and 35,000 DWT tankers for Zapata Corporation. These two vessels had identical stern frames and hawsepipes.

(Todd LA)

3. Hawsepipes for the Ammonia carrier are manufactured from rolled steel plates and they have a cast shell bolster. The rolled pipe is farmed out - bought as rolled per specifications prepared by yard. Shell bolster casting is also farmed out, but installed in place by the yard. The design of the shell bolster is such that the topmost periphery of the bolster butts onto the deck plating.
4. The weight of the shell bolster casting was 7,300 lbs. each and the hawsepipes weighed 7,500 lbs. each. The original lead time was 10-12 weeks (for shell. bolster only); it was actually delivered in 6 months. No machining was done on this casting in the shipyard. It was just sandblasted and installed. Therefore no wastage information exists.
5. ABS rules were followed in the design of hawsepipe. Todd's opinion is that the ABS rules are explicit and simple.
6. The design agent had used a model of the hawsepipe and shell bolster, but no load information is available at the yard. The loads, reportedly, are accounted for by the use of ABS equipment numerals.
7. No operational failures were experienced on any hawsepipes or stern frames in recent Todd Los Angeles memory. Production problems experienced with the hawsepipes of Ammonia carriers are fitting the bolster in place (requires very good ship fitters) and welding (problems associated with welding castings to mild steel).
8. On the 35,000 DWT tankers, the rudder horn and stern tube are castings. Stern frame is of welded construction. The yard, reportedly, received the rudder horn casting in "rough machined" form and did the finish-machining themselves.

AMERICAN BUREAU OF SHIPPING

A. Hawsepipe

1. There is no design load criteria for hawsepipes and bolsters. Whatever is already in the ABS rules has been working well and they are satisfied with it.

(ABS)

2. ABS does have an "in-house" approximate formula for designing hawsepipe and bolster.

3. Some large tankers have been built without any bolster (such as Seatrain's STUYVESANT). If this works out successfully, the bolster can be dispensed with. ABS' opinion is that some owner may try something different. But ABS still prefers a bolster or at least a large radius at the shell and the deck to avoid damage to chain links and bend of anchor shank.

- o There is no on-going study or research program regarding hawsepipes and bolsters at ABS.
- o Regarding recessed anchor pocket on some of the ships, ABS thinks that it is primarily a Navy configuration. It is still not widely used in commercial ships in this country. ABS will approve both the recessed type and the one with shell bolster.

B. Stern Frame

1. ABS thinks that fewer and fewer ships, especially the large ones, are using shoe pieces. Most new construction has a configuration of rudder horn and semi-balanced rudder. Some even have spade rudders.

2. ABS will approve both built-up and cast shoe pieces, rudder horn, stern tubes, etc. ABS will also approve combination of casting and built-up components.

3. Disadvantages of castings:

- o Getting a sound casting, especially a large piece, is a real problem.
- o Long lead times and often delays in the delivery of casting from foundry to shipyard are experienced in this country.
- o Change of sections is a problem, causes discontinuity.
- o Cannot be inspected thoroughly. Can only be surface inspected. No x-ray can penetrate deep enough.
- o Corrosion in welds in sea water is a problem (have to use expensive thermo-weld to repair).

4. Disadvantages of fabricated components:

- o Too narrow at the aft section to put some meat into it and hard to fabricate.
- o Shape changes a lot, may need furnace plate.
- o Certain components are just not made for fabrication, such as shaft bossing and gudgeon.

5. Repairs to fabricated components are comparatively easier than for cast ones. Cast components have to be heated sometime for welding work. This takes time and loss of revenue.

6. Allowable stresses for shoe pieces are low, in the order of 5,000 or 6,000 psi. The allowable stresses for rudder horns are published in the Rules and they are, too, rather low (approximately 6700 psi for castings and 8500 psi for plating) because stiffness is the governing criterion. ABS feels that these stresses should more appropriately be called stress numerals as they are directly related to one particular formula used to compute the loading.

7. No record is available on the percentage of welded stern frames vs. cast ones in all the ABS approved work. However, from what they can remember:

- o Ships with shoe and without shoe are about 50-50. For the ships with shoe pieces 90% are cast ones.
- o Ships with rudder horns, in general, use a combination of castings and fabrication. Probably a little more fabrication than casting.
- o For smaller size vessels, more are equipped with rudder horn than with shoe pieces.

8. ABS maintains that the classification requirements, i.e., the Rules, are intended for use as a tool to establish a vessel's seaworthiness. The Rules "tend to contain quite specific minimum requirements for the structural components, which, based on our experience, are considered either important or have been found troublesome, such as rudder horns and shoe pieces, while at the same time we try not to hinder the creative ingenuity of the Naval Architect".

J. J. McMULLEN

1. J. J. McMullen does not normally do any detail structural work. Their main work is feasibility studies and contract designs. In the contract design, the outboard or inboard profile configuration includes the stem frame but the shipyards can change it if they want to.

2. They have never specified any inboard accessible stern tube.

(J.J. McMullen)

3. They usually use combined castings and weldments for stern frames; stern bossing and rudder bearing supports are **always cast, or forged if they are small; others are fabricated.**
4. They have not encountered any design problems nor encountered any failures of stern frames.
5. They do not have any loading information on these items. They use BS or Norske Veritas rules.
6. They feel that the class society rules are not adequate. They use one or all of them for the design.

GEORGE SHARP

1. They do the design and configuration of the stern frames and hawsepipes, however, they give the shipyard the option to choose the best construction suited for the yard, i.e. completely cast, completely fabricated, or anywhere in between. Most ships are built with a combination of castings and weldments.
2. They have had no experience with the inboard accessible stern tube. The British manufacturer of the inboard accessible stern tube made a model demonstration. They observed but never used it.
3. They never encountered any stern frame failures. Once, they had some vibration problems; the shipyard had to change to a propeller with a different number of blades.
4. They do not see any problems with welding any thickness of plate specified. They always use ABS, 50 K. steel.* The maximum plate thickness they ever specified is 5".
5. They never designed any ship with a shoe piece. They use classification society rules for scantlings. The rules are very sketchy and they use them only as a guide. They have had no problems with any classification societies, either in the design or inspection stages.

* ABS Grade H-36 steel with ultimate strength of 50,000 Kg/mm².

(Bethlehem Foundry)

For minor repairs, the defective portion is completely removed to sound metal, then welded and locally stress relieved. For major defects, a procedure of repair has to be submitted to ABS for approval.

11. The most frequent defects are sand inclusion and shrinkage cavities, but they never get to the point where the casting has to be completely rejected.

12. They prefer to use the ultrasonic tests even if the results are subject to interpretation. If some area looks suspicious with ultrasonic test, they use other tests to check the area. Ultrasonic test is faster, less expensive and more flexible than other testing procedures.

13. They do not join two castings together. The customer usually does it. They use submerged-arc and electro-slag welding, but never do any thermit welding.

(Bethlehem Foundry)

For minor repairs, the defective portion is completely removed to sound metal, then welded and locally stress relieved. For major defects, a procedure of repair has to be submitted to ABS for approval.

11. The most frequent defects are sand inclusion and shrinkage cavities, but they never get to the point where the casting has to be completely rejected.

12. They prefer to use the ultrasonic tests even if the results are subject to interpretation. If some area looks suspicious with ultrasonic test, they use other tests to check the area. Ultrasonic test is faster, less expensive and more flexible than other testing procedures.

13. They do not join two castings together. The customer usually does it. They use submerged-arc and electro-slag welding, but never do any thermit welding.

APPENDIX A.4

MATRIX OF SHIPYARD'S RESPONSES

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
	<u>CONFIGURATION</u>				
1.	What type of stern configurations are you now constructing or anticipating?	• Rudder horn, semi bal. rudder, transom stern	• Rudder horn • semi bal. rudder • transom stern	• Only DE & DD's under constr. (twin screw)	Rudder horn
2.	What type of hawsepipe configurations are you now constructing?	• HI-holding anchor in pocket • cast bolsters • fab. pipe	• Exposed anchor cast bolsters • fab. pipe	• Exposed anchor • cast bolsters • fab. pipe	• Snag storing bolster, cast
3.	From the fabrication point of view, which type of stern frame and hawsepipe does your yard prefer?	<u>HAWSEPIPES:</u> • Cast bolsters • rolled plt, 2 pcs. <u>STERN FRAMES:</u> Castings & weldments would use casts if could buy	• Cast bolsters • pipe, hvy duty Castings & built-up	• Cast bolsters • rolled plt, 2 pcs. Completely welded	• Cast bolsters • rolled plt, 1 pc. Casting preferred
4.	What is the shipyard's position in deciding the configuration of the stern frame and hawsepipe?	Try to get owner to use their config.		Owner decides, yard has leeway	

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
5.	Do you have any experience with inboard accessible stern tubes?	None built, looked into	One built		Looked at, didn't use
1.	<u>CONSTRUCTION</u> Are your stern frames and hawsepipes currently of the forged, cast, welded or mixed type?	<u>HAWSEPIPES:</u> Rolled plt, cast bolsters <u>STERN FRAMES:</u> Castings & weldments; sub assembly	 Rolled plt, cast bolsters Castings & weldments; sub assembly	 Rolled plt , cast bolsters All welded; sub assembly	 Rolled plt , cast bolsters Castings, part of sub- assembly
2.	What is the method of constructing the stern frame and hawsepipe in your yard?	<u>STERN FRAME</u> Part of lower aft peak module <u>HAWSEPIPE</u> Rolled plt, welded	 Part of stern sub-assembly Welded into sub-assembly	 Prefab & weld into stern module Rolled plt sub assembly	 Part of stern module Part of module, rolled pl, 1 seam
3.	Does your present method of constructing stern frames and attaching them to the rest of the ship require a specific stern frame design?	No	No	No	No

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FHC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
4.	Have any specific designs given you significant construction problems?	No	No	No	Large castings have caused problems
5.	What is your past experience with stern frames and hawsepipes, especially with substituting fabricated components in place of castings or forgings?	S.F. all cast in 5 pieces and welded together	Some castings, some weldments	All welded for 20 yrs.	Built up S.F. in '50's., had a cast shoe break
6.	Did you ever encounter any failure in these components? How did you repair it?	Once	No	No	Cast shoe broke, used a forging, less brittle
7.	Any special skills or extra engineering required by the yard?	No	No	No	No
8.	Any problems with planning, scheduling, tooling, etc.?	Sound castings require long lead time	Long lead time; late delivery	Long lead time; small cast piece welded together.	
9.	What is the percentage of wastage from rough casting to finished, machined product?	+10% no problem			No substantial wastage

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
	<u>LOADINGS FOR THE DESIGN</u>				
1.	Any information on the loading that stern frames and hawsepipes are subjected to? Any loading values for basic rational design?	H.P. common design based on exper.	Design agt. did all details	No data available	Has own design loads - do full load analysis
2.	How do you determine the slope of the shell bolster and its scantlings? What percent of scantling do you attribute to wear?	Based on exper. very little wear	No wear noticed	No data use ABS rule formula	Has own data
	<u>ECONOMICS</u>				
1.	What do you think are the significant economic considerations for various stern frame and hawsepipe alternative manufacturing processes?	For a few ships welding; for more than 3-4 ships, castings	Depends on shape; simple-weld; complicated-cast.	Engineering on weldments; repair of bad castings	Castings in own foundry; cost of welding going up
2.	Do you have any cost data for recently manufactured S. F. and H. P.?	No	No	No	Cast/weld 50/50
3.	For larger ships, at least some weldments have replaced casting and forging. However, most ships still have the shoe piece, prop. bossing and rudder bearing support cast. Is this for economic reasons?	-	-	No shoe in last 20 yrs.	Schedule reqs. castings
4.	Do you have estimates for manpower, materials, and special facilities required for production of stern frames and hawsepipes?	No	No	No data available	

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
5.	Are stern frames and hawsepipes labor intensive products?	Yes	50/50		Yes
6.	Would you be willing to review our comparative cost estimates for alternative stern frame and hawsepipes designs?	Yes	Yes		
	<u>CLASSIFICATION SOCIETIES</u>				
1.	Do you think the present classification society rules are adequate from the standpoint of stern frames hawsepipes?	No	No	No	Improving
2.	Any problems with classification society rules for building and inspecting?	No	No		Use N.V. when ABS too vague
3.	Which classification society do you prefer? Which one is more rational, easier?	Lloyds			
4.	Do you have any in-house criteria to develop stern frame and hawsepipes scantlings?	No	No	Not now.	No

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
1.	<u>WELDING</u> What type of welding do you use to weld two heavy castings?	Electro slag weld on S.F., hand weld	Submerged arc Electro slag- no equipment	Electro-Slag	Electro slag no thermite
2.	Is your yard capable, from the standpoint of qualified welder, equipment and facilities, to weld thick plate? Up to what thickness?	Any thickness	2" max	Up to 5" plt	Unlimited
3.	What is your capacity to stress relieve any welded structure?	Specify stress-relief, even if not reqd.	No furnace ; local stress relief		Can stress relieve whole rudder (have very large furnace)
1.	<u>VENDORS FOR CASTING AND FORGINGS</u> Names of vendors used for specific castings and forgings (for stern frame or hawsepipe).	Kawasaki Natl Supply Natl Forge Beth. Steel U.S. Steel Stl. Caster of L.A. Wash. Iron Works	Wash. Iron Works Natl Forge Minn. Stl. Fdry. Falk Machry. Wiss.	Rockwell, Kan. NNS & DD Natl Forge Birdsboro	Own foundry Beth. Steel
2.	What lead time do they normally require Delay in delivery? How about rejections?	6 mo Jap. 1 yr. Amer.	12-15 months	-	
3.	How do they normally charge for castings? For forging? By weight?	By Wt (lb)	\$/lb.	-	

Appendix A.4 - continued

NO.	QUESTION	National Stl. & Shipbuilding	FMC Corp. Marine & Rail Equip. Div.	Ingalls Shipbuilding	Newport News Shipbuilding & Dry Dock
4.	<u>VENDORS FOR CASTINGS AND FORGINGS</u> <u>(Continued)</u> How is the actual size of any casting decided? a) Sole piece? b) Stern tube? c) Rudder carrier?	Use ABS & past experience for all	Stress analysis based on allow. stress	Owners give option on no of pcs.	Do full load analysis- can cast up to 75,000 lbs in yard
5	History of Relations with Vendors	Hardly any rejects on comml ships.	East coast foundry: higher cost.	No real problem in past years; recently more problems but not big	Does own castings

Appendix A.4 - continued

NO.	QUESTION	Seatrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Div. Sparrows Pt.	Todd Shipys Inc Los Angeles Div.
1.	<u>CONSTRUCTION</u> Are your stern frames and hawsepipes currently of the forged, cast, welded or mixed type?	<u>HAWSEPIPES:</u> Rolled plt, no bolster <u>STERN FRAMES:</u> Minimum cast'g; weldment, sub assembly	Rolled plt, cast bolster Castings & weldments, sub assembly	Rolled Plt, cast bolsters Mixed type; weldments & castings	Rolled Plt., Cast Bolsters Mixed type; castings & weldments
2.	What is the method of constructing the stern frame and hawsepipe in your yard?	<u>STERN FRAME</u> Part of stern module <u>HAWSEPIPE</u>	Sub-assembly in aft peak module	Sub-assembly; part of stern module	
3	Does your present method of constructing stern frames and attaching them to the rest of the ship require a specific stern frame design?	No	No	No	N o
4.	Have any specific designs given you significant construction problems?		No	No	No

Appendix A.4 - continued

NO.	QUESTION	Seatrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Division Sparrows Pt.	Todd Shipbldg Inc. Los Angeles Div
5.	What is your past experience with stern frames and hawsepipes, especially with substituting fabricated component in place of castings or forgings?	Can't get good castings; use weldments for stern frames	Use castings in sections; weld together	Use extensive weldments; some cast components	
6.	Did you ever encounter any failure in these components? How did you repair it?	-	No	No	No
7.	Any special skills or extra engineering required by the yard?		No	No	No
8.	Any problems with planning, scheduling, tooling, etc.?	-	Allow long lead time	Castings require Long Leadtime	
9.	What is the percentage of wastage from rough casting to finished, machined product?	-	Allow 1/2" for mach'ing.	Negligible	
1.	<u>LOADINGS FOR THE DESIGN</u> Any information on the loading that stern frames and hawsepipes are subjected to? Any loading values for basic rational design?	Used N.V. rules	No formulas; ABS allows stress 6 KSI, Model and finite element analysis; 1 KSI max found	No ABS rules used	

Appendix A.4 - continued

110.	QUESTION	Sealrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Div. Sparrows Pt.	odd Shipbldg Corp. Los Angeles Div
2.	How do you determine the slope of the shell bolster and its scantlings? What percent of scantling do you attribute to wear?	N.V. rules	Model test; finite element analysis	Hawse sloped 45°; always use a model	
1.	<u>ECONOMICS</u> What do you think are the significant economic considerations for various stern frame and hawsepipe alternative manufacturing processes?	No castings; hard to separate cast part of module	In the past, castings were selected because they were available	Keep design simple Avoid HTS.	
2.	Do you have any cost data for recently manufactured S. F. and H. P.?			No	
3.	For larger ships, at least some weldments have replaced casting and forging. However, most ships still have the shoe piece, prop. bossing and rudder bearing support casts. Is this for economic reasons?			Some parts cast for economy & ease of production	
4.	Do you have estimates for manpower, materials, and special facilities required for production of stern frames and hawsepipes?		Yes	No	No

Appendix A.4 - continued

NO.	QUESTION	Seatrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Div	Todd Shipbuilding Co. Los Angeles Div
5.	Are stern frames and hawsepipes labor intensive products?	If complicated castings cheap	Yes	Yes	Yes
6.	Would you be willing to review our comparative cost estimates for alternative stern frame and hawsepipes designs?	Yes	Yes	Yes, but not sure of value	
	<u>CLASSIFICATION SOCIETIES</u>				
1.	Do you think the present classification society rules are adequate from the standpoint of stern frames and hawsepipes?	No, N.V. good	No	No, use as a guide	Use ABS
2.	Any problems with classification society rules for building and inspecting?	-	No	No	-
3.	Which classification society do you prefer? Which one is more rational, easier?	N.V. on stern frames		All about same	ABS
4.	Do you have any in-house criteria to develop stern frame and hawsepipes scantlings?		Yes, for stern frame	No	

Appendix A.4 - continued

No.	QUESTION	Seatrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Div Sparrows Pt.	Todd Shipbldg Corp Los Angeles Div
	<u>WELDING</u>				
1.	What type of welding do you use to weld two heavy castings?	-	Electro slag ; bad experience themit weld	Submerged arc on MIG; electro slag	
2.	Is your yard capable, from the standpoint of qualified welder, equipment and facilities, to weld thick plate? Up to what thickness?	4" plt max	3-1/2"-4" start problems	any thickness	
3.	What is your capacity to stress relieve any welded structure?		Furnace can handle horn ; 18 x 18 door	Stress Relieve Rm 34'x15'x12'-6" High No limit for local stress relief	-
	<u>VENDORS FOR CASTING AND FORGINGS</u>				
1.	Names of vendors used for specific castings and forgings (for stern frame or hawsepipe).	Am. Brdg., Tex. Mester Natl Forge Norway	Birdsboro Natl Forge Beth. Steel NNS & DD	Bethlehem Steel only	
2.	What lead time do they normally require? Delay in delivery? How about rejections?	6-18 months	15 months	1 Year	
3.	How do they normally charge for castings? For forging? By weight?		\$/lb. plus repair	\$/lb.	

Appendix A.4 - continued

NO.	QUESTION	Seatrain Shipbuilding	Avondale Shipbuilding	Bethlehem Steel Shipbuilding Div Sparrows Pt.	Todd Shipbldg Cor; Los Angeles Div
4.	<u>VENDORS FOR CASTINGS AND FORGINGS</u> <u>(Continued)</u> How is the actual size of any casting decided? a) Sole piece? b) Stern tube? c) Rudder carrier?			Capacity of foundry , size of annealing rm. Best joint location Weight not a problem	
5.	History of relations with vendors?	Has problems getting good castings. Saves money with Norwegian casts, even with shipping costs	Good relations; one vendor didn't want to risk own foundry for smaller castings	Good relations No real problems	

APPENDIX B

BASELINE SHIPS

AND

ALTERNATIVE DESIGNS

BACK-UP DATA

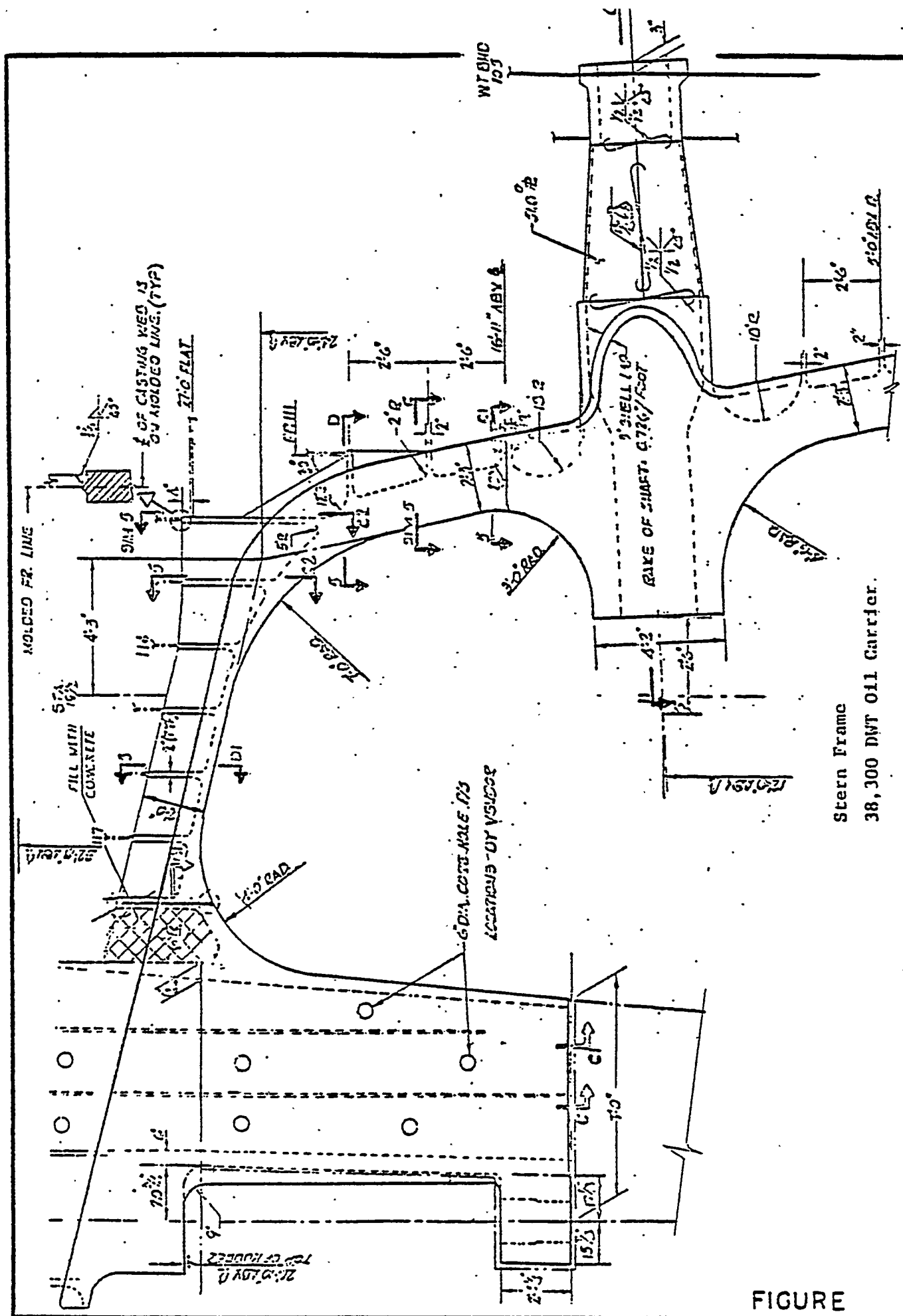
<u>Appendix No.</u>		<u>Page</u>
B.1	Baseline Ships' Designs.....	B- 1
B.2	Back-up Data for Alternative Designs	B-11

APPENDIX B.1

BASELINE SHIPS' DESIGNS

Figures B.1 through B.6 give schematic arrangements of the stern frame and hawsepipes configurations existing on the baseline ships discussed in Section 4.1.

On pages B-8 through B-10, an example of a billboard type stowage system and the patented Kockums chain stopper is presented.



Stern Frame
38,300 DWT Oil Carrier.

FIGURE

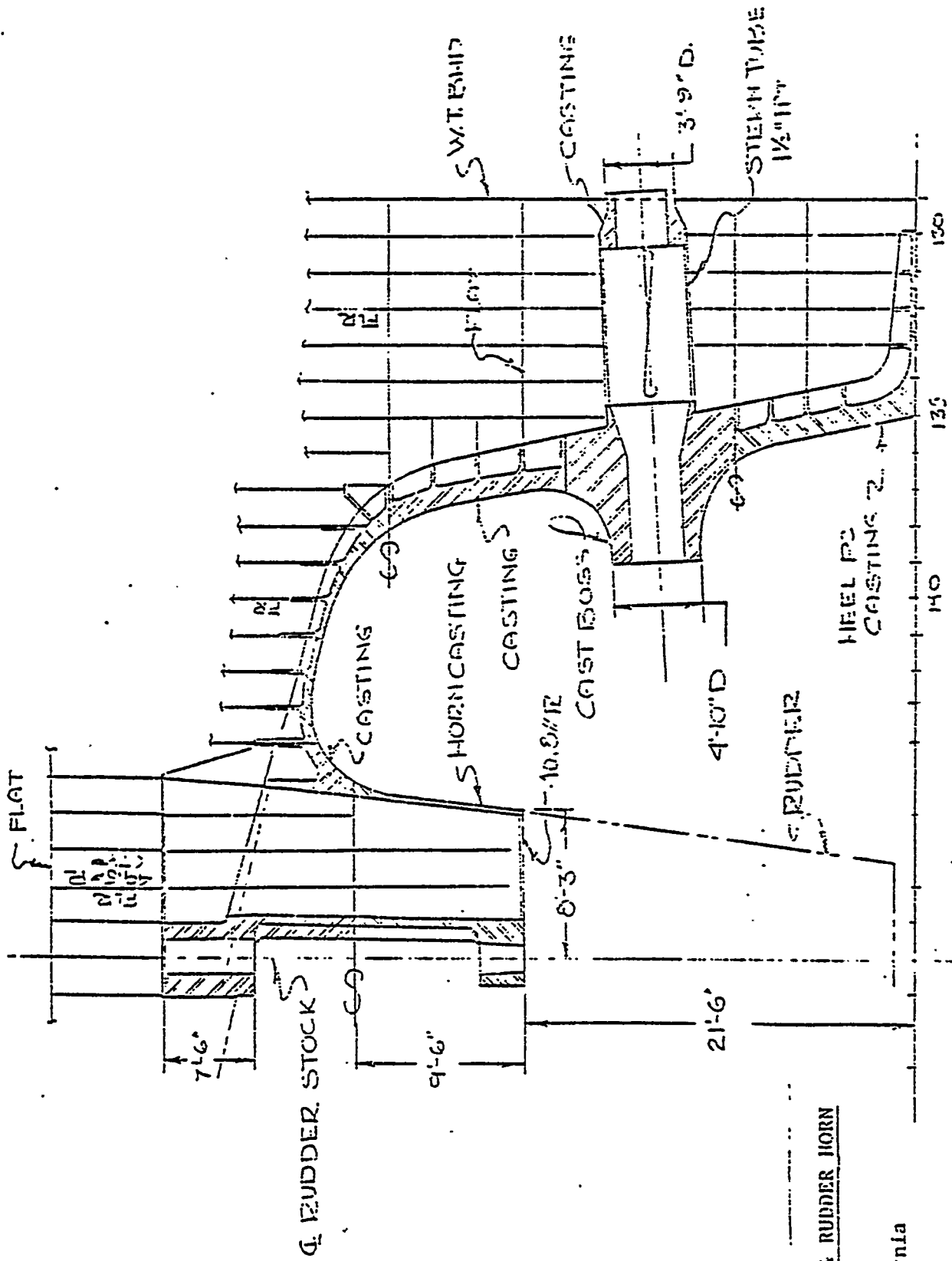


Fig. B-2:

CAST STERN FRAME & RUDDER HORN

HASCO

San Diego, California

89,700 DWT TANKER

SCALE: 1:96

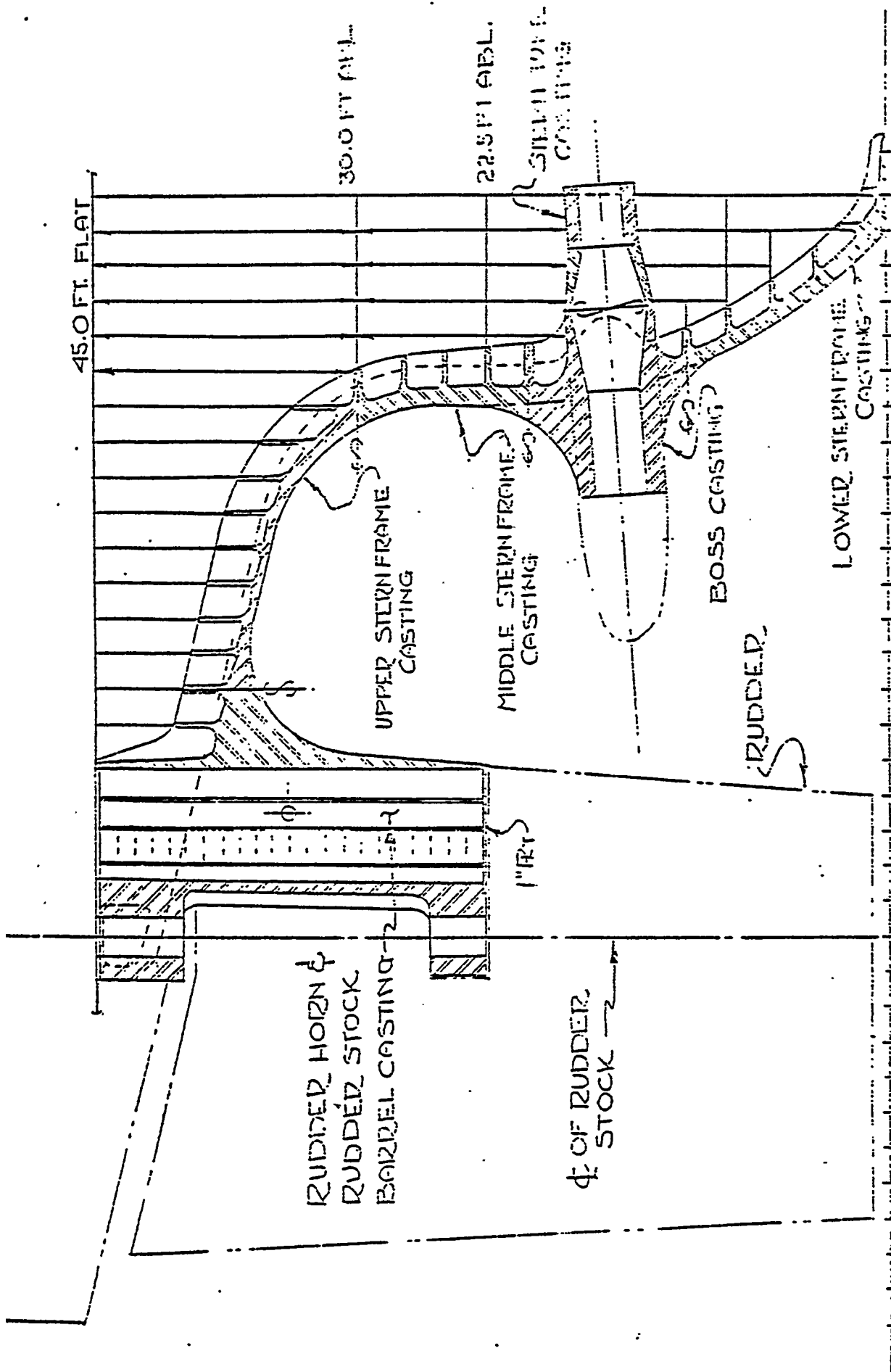


Fig. B-3:

CAST STERN FRAME & RUDDER HORN

NASSCO
San Diego, California
188,500 DWT TANKER

SCALE: 1:96

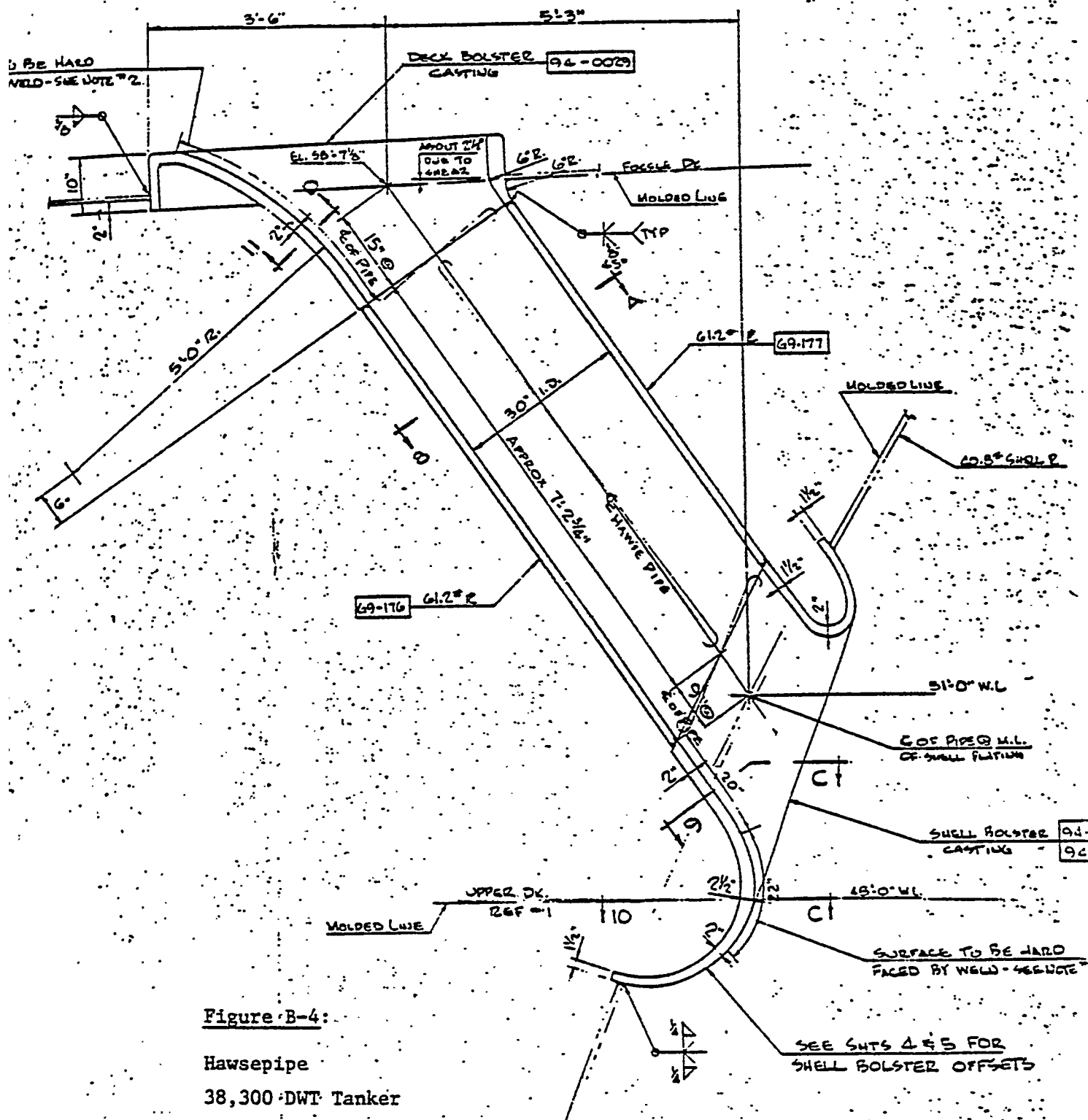
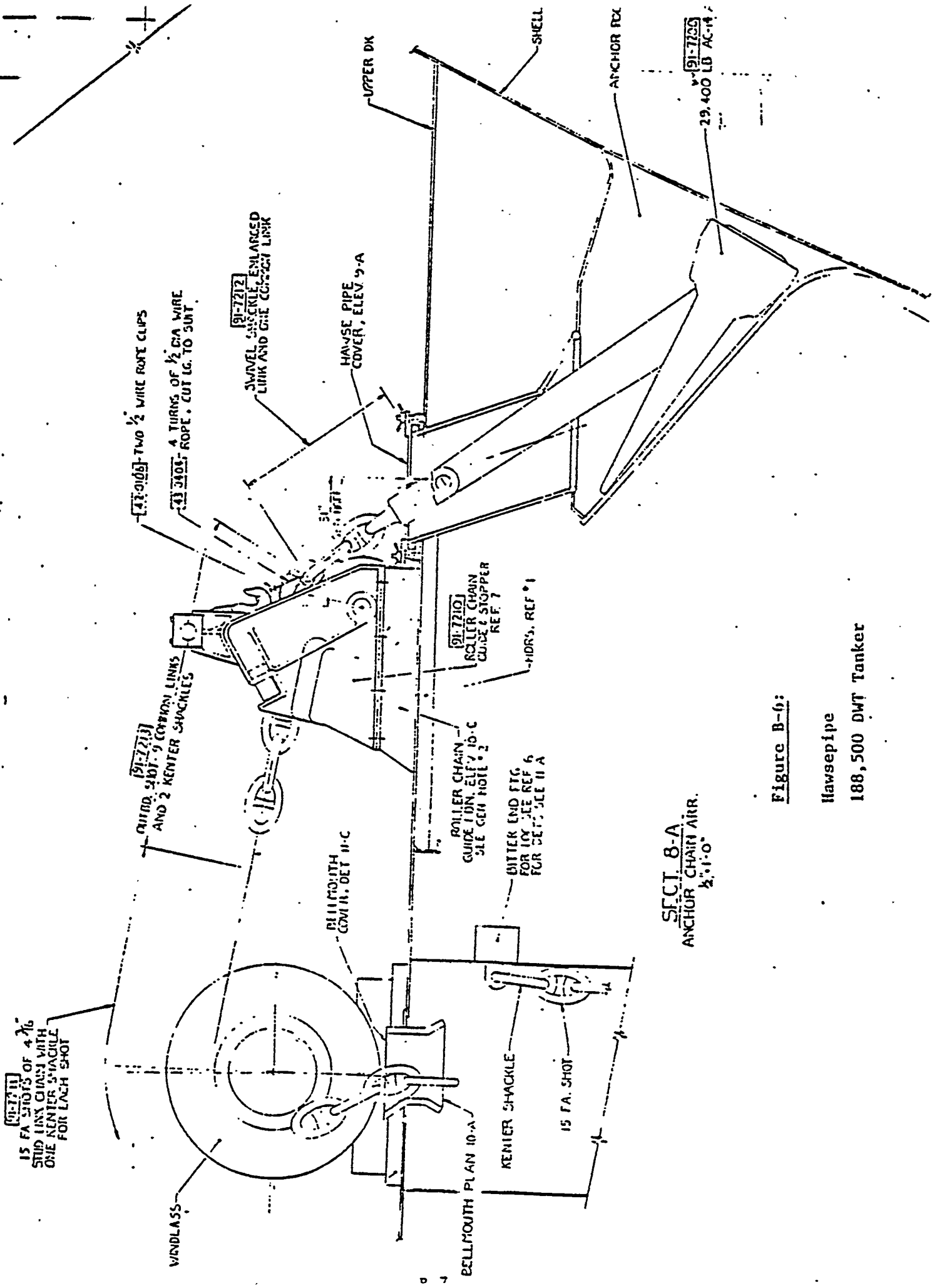


Figure B-4:

Hawsepiped

38,300 DWT Tanker



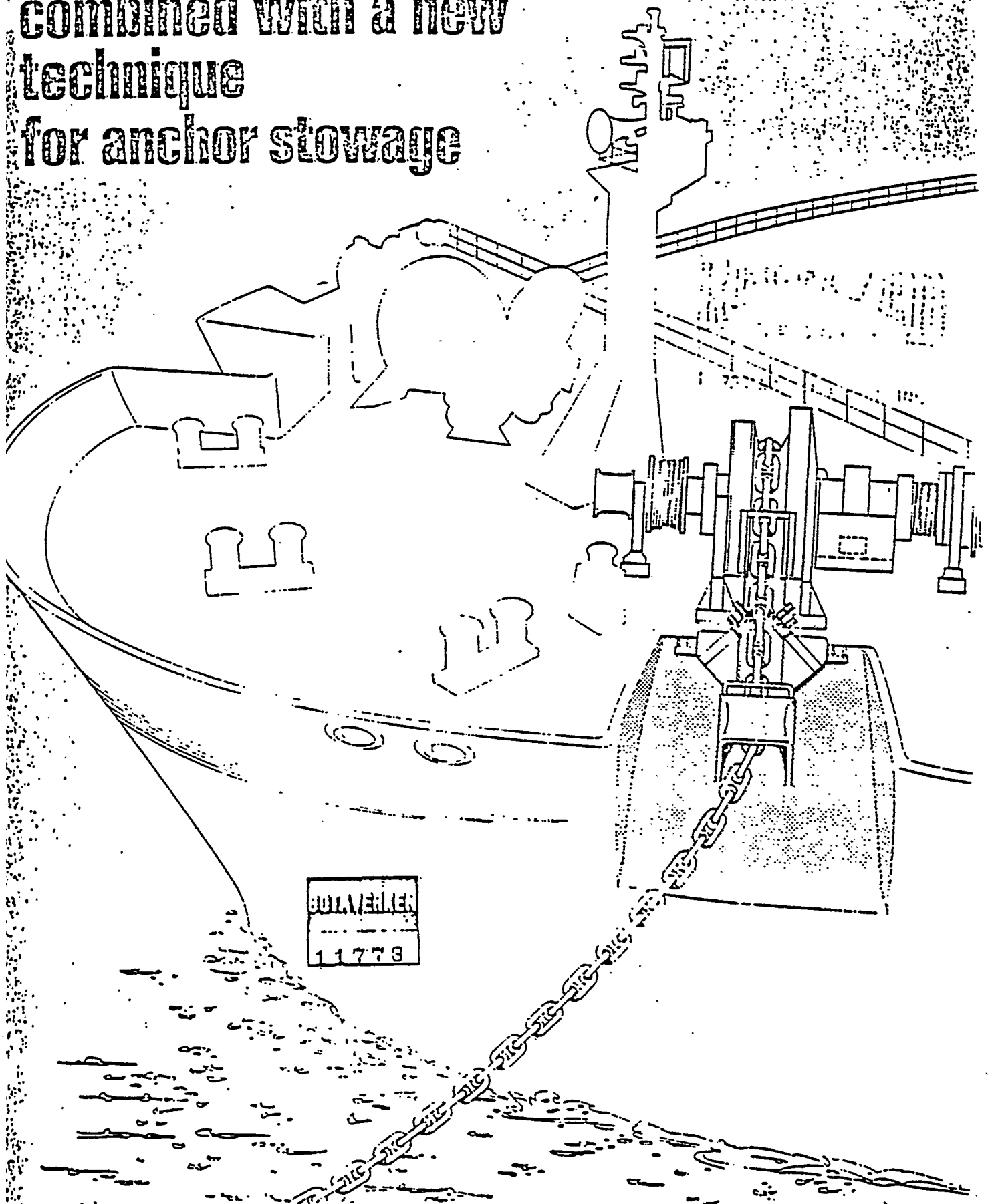


SECT. 8-A
ANCHOR CHAIN ARR.
1/2" 1'-0"

Figure B-6:

Hawsepole
188,500 DWT Tanker

The new Kockums chain stopper combined with a new technique for anchor stowage



New, efficient double-shearing chain stopper

The new Kockums chain stopper is distinguished by reliability and ease of handling. The KVA stopper is easy to operate even with very large chains. Pins are used to secure the stopper in both the open and closed position.

The new chain stopper can be used in conventional arrangements with chain pipes and hawse pipes or for stowage of the anchor on deck.

The KVA stopper locks the anchor chain with two shears, which means that the entire breaking load of the chain can be utilized. In contrast, only about half of the chain's breaking load can be utilized with conventional chain stoppers. The KVA stopper takes up forces which cannot be reduced to component forces and which are directed toward opening the chain stopper.

The KVA chain stopper has been patented by Kockums Shipyard. It can be supplied for chain sizes of 50 mm and upward. Chain stoppers for smaller chain sizes can be supplied on special order.

New technique for anchor stowage

On most ships, the anchor chain travels through a hawse pipe which runs obliquely downward from the deck to an opening in the shell plating. When the anchor has been hoisted, the flukes and the crown are outside the shell plating, where they are difficult to reach and are often exposed to the impact of the sea, which can result in damage to the shell plating. The new stowage method entails stowing and securing the anchor on an open bed. The bed is large enough to allow the anchor to be stowed with the crown entirely inside the contour line of the shell plating.

Since the anchor is stowed high over the water line, it is not exposed to the sea. Access to the anchor for inspection and cleaning is much more convenient, and it is stowed more secure. The new technique also facilitates production of ships by reducing the amount of outfitting work required. The chain stopper can be fitted simultaneously with and in some cases prior to the windlass. There is no need for boring holes or fitting fastenings for a hawse pipe. The cost of ship maintenance is reduced, since there is no risk of damage to the shell plating.

The new anchor stowage technique has been patented by AB Gotaverken Arendal and has been thoroughly tested for use with the KVA chain stopper.

The combination of a KVA chain stopper and the new stowage arrangement has already been installed aboard a number of ships.

A permit to use the new arrangement, together with appropriate drawings and recommendations can be supplied by Kockums Varv (Shipyard) AB.

<u>Pos</u>	<u>Description</u>
1, 2, 4	Slide- and guide way for chain links
3	Chain link, vertical position
5	Chain link, horizontal position
6	Lock pin
7	Bracket
8	Bracket fitting
9a	Chain lock body, bb fore - sb aft
9b	Chain lock body, fb aft - sb fore
10	Bracket
11	Bracket fitting-
12	Support
13	Shaft pin
14	Shaft pin

APPENDIX B.2

BACK-UP DATA

FOR ALTERNATIVE DESIGNS

Tables B-1 through B-3 summarize some details of the all welded stern frame alternative designs regarding structural scantlings and their determination. Tables B-4 through B-6 present similar data for the inboard accessible *stern* tube type configurations and Tables B-7 through B-9 are similar data for the hawsepiped alternative designs.

TABLE B-1 :

All Welded Stern Frames38,300 DWT Tanker Alternative Design

<u>Part</u>	<u>Method of Design</u>
1. 81.6 # CVK Stern Frame (S.F.) & Rudder Horn (R.H.)	Similar to Todd Dwg. No. 82872-s11-08-02 35,000 DWT Tanker
2. 61.2 # S.F. Side Plates (P1.)	Meets Norske Veritas, dimensions and section Modulus requirements, 20% over
3. 61.2 # Keel PI.	Todd 56.1 # 10% over
4. *163.2 # R.H. Side P1.	Similar. to Todd
5. *102 # R.H. 2 fwd web Pls.	^{1/2"} less than Todd
6. *122.2 R.H. aft web P1.	Similar to Todd
*Note: Rudder Horn stresses are 27% lower- than ABS required minimum for Todd's scantlings with MR&S dimensions. #5 was adopted with no further calculation.	
7. 30.6 # Nose P1. R.H.	Similar to Todd
8. 40.8 # B0t. P1. R.H.	Similar to Todd
9. Rudder Gudgeon Upper, Lower Cast	Used size that would fit NASSCO 38,300 DWT in profile and section of R.H. T.E.
10. *Upper and Lower Flats Brackets, 30.6 # P1.	Similar to Todd with minor variations
11. *25.5 # pl. Floors	Meets Norske Veritas required thickness, 11% over

*Note: Floors, Flats and Shell Plate considered
similar structure and equal cost for both welded
and cast designs.

Table B-1, cont'd.

<u>Part</u>	<u>Method of Design</u>
12. Aft Stern Tube (Boss) $t = 5''$ $L = 10''$ ID = 40''	9% over N.V. required t assuming shaft diameter = 24 1/2" Length required in order for shell. plate to intersect with thick section
13. FWD Stern Tube $t = 3''$ $L = 30''$ ID = 27''	Similar to NASSCO 38,300 DWT design Similar to NASSCO 38,300 DWT design Similar to NASSCO 38,300 DWT design
14. Middle Stern Tube Section $t = 1''$ L = 7'6''	t is 1/2" less than used in NASSCO 38,300 DWT design

TABLE B-2:

All Welded Stern Frame89,700 DWT Tanker Alternative Designs

<u>Part</u>	<u>Method of Design</u>
1. 81.6 # CVK Stern Frame (S. F.) & Rudder Horn (R. H.)	Similar to Todd Dwg. No. 82872-S11-08-02 35,000 DWT tanker
2. 61.2 # Stern Frame Side Plate (P1.)	Meets Norske Veritas dimensions and section modulus requirements.
3. 61.2.# Keel P1.	From 38,300 DWT vessel
4. 163.2 # Side P1. R.H.	Similar to Todd 35,000 DWT tanker
5. 122.4 # R.H. 3 fwd web Pls.	Similar scantlings as Todd 35,000 DWT tanker except with one extra web due to a longer section (parallel to water plane)
6. 142.8 # aft R.H. P1.	1" thicker than for Todd 35,000 DWT,tanker
7. 30.6 # Nose P1. R.H. -	Similar to Todd. Not considered in section modulus calculation. Just a fairing plate. *
8. R.H. Bet. Pi., 40.8 #	Similar to Todd*
9* Rudder Gudgeon Upper, Lower Cast	Used size that would fit NASSCO 89,700 DWT tanker in section and profile
10. *upper and lower flats brackets, 30.6 # P1.	Similar to Todd* with minor variations
11. *25.5 # P1. Floors	Meets Norske Veritas minimum required thickness
12. 61.2 # plate which butts to and is fwd of CVK P1. below. the boss	Similar to Todd* 50% over

Table B-2, cont'd.

*Flrs, flats, shell plate and Plate - above boss considered similar structure and of equal cost for both the welded and cast designs.

<u>Part</u>	<u>Method of Design</u>
13. Stern Tube 3 parts	Boss thickness from N.V. rules ODs or IDs, lengths from NASSCO dwgs .
Ø Fwd bearing housing 3'10" OD x 36" L x 3" t	
Ø Middle Stern Tube 10'9" L x 1½" t	
Ø Aft bossing 10' L X 3'10" OD X 5" t	

TABLE B-3:

All Welded Stern Frame188,300 DWT Tanker Alternative Design

<u>Part</u>	<u>Method of Design</u>
1. 81.6 # CVK	From previous practice
2. 61.2 # Side Plate (PI.) of Stern Frame (S.F.)	According to Norske Veritas rules
3. Rudder Horn (R.H.)	Similar to 89,700 DWT scantlings except for heavier aft web
o 4 webs 3 fwd 122.4 # 1 aft 163.2 #	
o 30.6 # Nose PI.	
o 163.2 # Side P1.	
O Bot. P1. 40.8 #	
4. Upper and lower gudgeon	Similar to NASSCO design
5. Stern Tube 3 parts	Boss thickness from N.V. rules IDs, Lengths from NASSCO dwgs .
o Fwd bearing housing 42" L x 37" OD x 3" t	
o Middle Stern Tube 7' L x 1" t	
o Aft bossing 10'6" L x 3'10" OD x 5" t	

Note: All structure and cost involved with floors,
flats, plating considered equal with same size ship
cast design.

TABLE B-4 :

38,300 DWT Tanker IAST Alternative Design

<u>Part</u>	<u>Method of Design</u>
1. Stern tube fwd 40.8 # Plate (Il.)	The whole stern tube is similar to FMC Chevron tanker
2. Stern tube middle and boss 20.4 # P1.	Fabricated boss replaces the cast bossing on FMC design

TABLE B-5:

89,700 DWT Tanker IAST Alternative Design

<u>Part</u>	<u>Method of Design</u>
1. Stern Tube 61.2 # Plate (P1.)	The whole stern tube is similar to Seatrain 225,000 DWT tanker
2. Propeller Boss 204 # P1.	Replaces the cast bossing shown on the Seatrain design

TABLE B-6:

188,500 DWT Tanker IAST Alternative Design

<u>Part</u>	<u>Method of Design</u>
1. Propeller boss 204 # Plate (P1.)	From Glacier-Herbert design

TABLE B-7 : 38,300 DWT Tanker Conventional. Hawsepipeline Alternative

<u>Part</u>	<u>Method of Design</u>
1. Hawsepipeline 81.6 # Roller Plate (P1.)	Meets ABS approximation formula acquired from interview (not in rules). Thinner plate may be used but presents a risk with respect to wear over the life of the vessel
2. Shell bolster cast	From NASSCO dwg.
3. 61.2 # Dk insert P1.	Standard practice
4. Roller Fairlead	Standard practice

TABLE B-8: 89,700 DWT Tanker Conventional Hawsepipeline Alternative

<u>Part</u>	<u>Method of Design</u>
1 .Hawsepipeline 81.6 # Rolled Plate (Pi.)	ABS' in-house formula
2. Shell Bolster cast	From NASSCO plan
3. 81.6 # Dk insert P1 .	Standard

TABLE B-9: 188,300 DWT Tanker Conventional Hawsepipeline Alternative

<u>Part</u>	<u>Method of Design</u>
1. Hawsepipeline 81.6 # Roller Plate (Pi.)	20% less than ABS in-house recommendation formula
2. Shell Bolster cast	Shape from FMC dwg.
3. 8-16 # insert P1.	Standard practice

APPENDIX C
BACK-UP FOR
PRODUCIBILITY ESTIMATES

C1: HEAT TREATING REQUIREMENTS

Table C-1 gives some minimum preheat and interpass temperature requirements for common weldable steels, which were developed by the American Welding Society and the American Institute of Steel Construction.

C.2: BREAKDOWN FOR COST ESTIMATES

A listing of the various cost elements considered in the estimates for alternative designs is presented in Table C-2.

The references and source materials used in estimating costs for individual elements also are shown in the table. The numbers for source materials on the right-hand side of Table C-2 correspond to similarly numbered documents which are on file in the MR&S offices.

Table C-1

MINIMUM PREHEAT AND INTERPASS TEMPERATURE
AWS D1.0-69 Table 3, AWS D2.0-69 Table 4, and AISC 1.23.6 (1969)

Thickness of Thickest Part at Point of Welding — Inches	Welding Process				
	Shielded Metal-Arc Welding with Other Than Low-Hydrogen Electrodes	Shielded Metal-Arc Welding with Low-Hydrogen Electrodes; Submerged-Arc Welding; Gas Metal-Arc Welding; or Flux-Cored Arc Welding		Shielded Metal-Arc Welding with Low-Hydrogen Electrodes; Submerged-Arc Welding with Carbon or Alloy Steel Wire, Neutral Flux; Gas Metal-Arc Welding; or Flux-Cored Arc Welding	Submerged-Arc Welding with Carbon Steel Wire, Alloy Flux
	ASTM A36; A53 Grade B; A375; A500; A501; A529; A570 Grades D and E	ASTM A36; A242 Weldable Grade; A375; A441; A529; A570 Grades D & E; A572 Grades 42, 45, and 50; A588	ASTM A572 Grades 55, 60 and 65	ASTM A514	ASTM A514
To 3/4, incl.	None (2)(3)	None (2)(3)	70°F	50°F	50°F
Over 3/4 to 1-1/2, incl.	150°F	70°F (4)	150°F	125°F	200°F
Over 1-1/2 to 2-1/2, incl.	225°F	150°F	225°F	175°F	300°F
Over 2-1/2	300°F	225°F	300°F	225°F	400°F

1. Welding shall not be done when the ambient temperature is lower than 0°F. When the base metal is below the temperature listed for the welding process being used and the thickness of material being welded, it shall be preheated (except as otherwise provided) in such manner that the surface of the parts on which weld metal is being deposited are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded, but not less than 3 inches, both laterally and in advance of the welding. Preheat and interpass temperatures must be sufficient to prevent crack formation. Temperature above the minimum shown may be required for highly restrained weld. For A514 steel the maximum preheat and interpass temperature shall not exceed 400°F for thicknesses up to 1-1/2-in. inclusive, and 450°F for greater thicknesses. Heat input when welding A514 steel shall not exceed the steel producer's recommendation.

2. When the base metal temperature is below 32°F, preheat the base metal to at least 70°F and maintain this minimum temperature during welding.

Members do not have to be preheated for single-pass tack welds that will later be remelted and incorporated into continuous submerged-arc welds.

For single-pass welds over 3/8-in. made with multiple-electrode submerged-arc, the preheat and interpass temperature may be such that result in a hardness in the heat-affected zone of less than 225 VHN for steels not exceeding specified T.S. of 60,000 psi and 280 VHN for steels not exceeding T.S. of 70,000 psi.

AISC A36 STEEL			
Non-Low-Hydrogen Electrodes		Low-Hydrogen	
To 1" incl.	None ²	To 1" incl.	None ²
Over 1" to 1-1/2" incl.	150°F	Over 1" to 2" incl.	50°F
Over 1-1/2" to 2-1/2" incl.	225°F	Over 2" to 2-1/2" incl.	150°F
Over 2-1/2"	300°F	Over 2-1/2"	225°F

3. This provision applies to A36 steel in thicknesses to 1-in. inclusive.

4. Minimum preheat for A36 steel in thicknesses up to 2-in. inclusive shall be 50°F.

Reproduced from "The Procedure Handbook of Arc Welding," Lincoln Electric Co.

TABLE C-2: COST ELEMENTS AND REFERENCES

COST ELEMENTS	REFERENCES/SOURCES	NO.
o Price-of Stern Frame and Bolsters for NASSCO 38,200 DWT, 89,700 DWT and 182,500 DWT Tankers, plus weights o Approx. Price of Patterns	o Fonecon: NASSCO 1/26/78	1
Plating Weights for Feasibility Designs (Excluding stern tubes)	MR&S Calc. 2/4/78 Material Weights	2
Cost of Plating	Fonecon: Ryerson Steel 2/10/78	3
o Location of Weld o Linear ft. of welding	o MR&S Calc. 1/31/78	4
o Weld Type o Joint Type, Position	o MR&S Calc. 2/6/78	5
o Weld metal weight 1 ft. o Cost, weld metal \$ per lb.	o Chapter 12, Determining Welding Costs, Lincoln Electric, "Procedure Handbook of Arc Welding", Tables 12- 2,3,4,5	6
	o Table III, p. 10 How to Determine Welding Costs	7
	o MR&S Calc. 2/8/78	8
Cost of Flame Cutting Steel	MR&S Compilation	9
Cost of Fabricating Stern Tubes Cost of Shipping	o Fonecon: 2/8/78 Chicago Bridge and Iron	10
	o Fonecon: 1/12/78 Babcock & Wilcox	11
	o. MR&S Calc. 2/10/78	12

TABLE C-2 (Cont'd)

COST ELEMENTS	REFERENCES	NO.
Weight of Avg. Stern Tube, plating	MR&S Calc. 1/12/78	13
Lead Time for Stern Tubes	Fonecon: Chicago Bridge and iron 2/10/78	14
Table II giving net extra cost of vessel with an Inbrd accessible stern tube. This cost was used as an addition to the price of conventional stern tube	"Stern Gear Design for Maximum Reliability - The Glacier Herbert System" Trans. 1. Mar. E. 1972 Vol. 84	15
Calculations for the weight of shell bolster used for MR&S feas. design Of the Hawse pipe arrangement for 188,500 DWT tanker	MR&S Calc. 1/11/78	16
Layout - Template Costs	MR&S Compilation	17
Rolling, Jigging, Field Cutting and Alignment, Heat Treating, Testing, Transportation Costs.	MR&S Compilation	18
Misc. Material Quotes	MR&S Compilation From Chicago Bridge & Iron and Babcock & Wilcox	19

APPENDIX D

COMMENTS FROM THE U.S. SHIPBUILDING INDUSTRY

BASED ON REVIEWS OF PROJECT OUTPUT

<u>Appendix No.</u>		page
D.1	Summary of General Comments	D-1
D.2	Excerpts from Industry Comments	D- 6

APPENDIX D. 1

SUMMARY OF GENERAL COMMENTS

The U.S. shipbuilding industry was kept involved with the project throughout its progress through surveys, informal discussions, and reviews of interim and draft final reports.

The background data from surveys and interviews are presented in Appendix A.

The comments received from the industry during the second phase of the study are summarized here.

1. Interim Report

The interim report submitted by MR&S was distributed by TODD Seattle to members of the SNAME Panel SP-2.

This report presented the findings from the interviews, surveys and the literature search. Specifically, the following were discussed:

- o " various types of stern frames and hawsepipes observed
- o degrees to which castings, forgings and weldments are incorporated into designs
- o joint types and welding processes employed in construction
- o special facility requirements for construction and testing of components
- o practical restraints
- o regulatory restraints
- o pertinent recommendations of the interviewees
- o proposed changes to the contract specification which could make the effort to fulfill its objective more efficient

Comments were received from General Dynamics, the U.S. Coast Guard, Puget Sound Naval Shipyard, and Avondale Shipyards. They did not recommend any deviations from the intended course of action as established by the project investigators.

Excerpts from some of the comments are included in Appendix D.2.

2. Alternative Designs and Producibility Studies

Towards the end of the second phase of the project, the interim report and thereafter the draft final report were submitted to the organizations listed in Table D-1. Presented for review were:

- o alternative designs
- o a qualitative discussion on productivity
- o assumptions for weights and costs
- o cost comparison for stern frame designs
- o cost comparison for hawsepipes and billboard type anchor handling systems

The reviewers were asked to discuss at least the following:

- o the validity of the discussions and assumptions for producibility studies
- o the feasibility of the design alternatives
- o the validity of the cost comparisons and suggestions for any improvements
- o submittal of as detailed a cost estimate as possible using standard practices

Valuable comments were received from several reviewers. Excerpts from some of the comments on the alternative designs and producibility studies are included in Appendix D.3.

A majority of the *comments on* details of alternative designs have already been incorporated into the drawings for these designs as presented in Section 4.0.

The reviewers' comments and criticism of the cost estimates for the alternative stern frame and hawsepipe designs were carefully noted, changes were made and incorporated into the final estimates presented in this report wherever possible.

Following is a summary of these comments which were taken into account in updating the initial estimates.

Bethlehem Steel

- 0 In addition to welding, the forming, handling and fitting of heavy plates in a stern frame unit contribute greatly to the cost. The accuracy of heavy formed plates must be assured in the shop since reshaping on the job is close to impossible with typical shipfitting equipment and techniques.
- 0 Relative costs, in terms of \$/lb seem to be correct.

NASSCO

- 0 price of steel, for fabrication, of 25c per lb. from the warehouse is O.K.
- 0 Casting prices 8-10% high.
- 0 Welding costs for fabricated stern frames 45% low.
- 0 Flame cutting costs for the fabricated stern frames is approximately 40% low.
- 0 Under the heading heat treating, rolling forming, shipping and inspection for fabricated stern frames, the cost should be approximately two (2) times what is shown.
- 0 Castings are less expensive than fabricated components for stern frames when three or more ships are being built since pattern costs spread out. A one or two ship program gets into an area where both costs are close to the point that a detailed estimate would have to be developed to make an accurate determination as to which is cheaper.

Todd L.A.

- 0 Differences between weldment and casting costs appear too large.

Avondale

- 0 Serious reservations in regard to estimated total cost of fabricated stern frames.
- 0 Agree with estimated cast prices.
- 0 Nothing seems to be allotted for:
 - Jigging Time
 - Lofting - Templates
 - Field Fitting and Alignment

[If included in column #6 this estimate is inadequate to cover the total scope.]
- 0 Welding and flame cutting seem to be adequate.
- 0 Expect prices for weldments to increase by 50% due to above items.

Following qualitative comments, however, could not be incorporated into final estimates:

- 0 The security-of the anchor against movement in severe sea conditions should be significantly more with the traditional hawsepipe than with the billboard type arrangements.
- 0 Aesthetics may play the greatest role in the selection of billboard types vs conventional hawsepipe arrangements regardless of the economics.

TABLE D-1 :
Organizations Contacted
for Review of Alternative Designs, and Producibility Estimates
and the Draft Final Report

- o National Steel and Shipbuilding Company*
- o Bethlehem Sparrows Point Shipyard*
- o Avondale Shipyards*
- o FMC Portland
- o Ingalls Shipbuilding
- o Newport News
- o Seatrain
- o Todd Los Angeles*
- o General Dynamics, Quincy*
- o Puget- Sound Naval Shipyard*
- o Sun Shipbuilding & Dry Dock Co.*
- o Bath Iron Works Corp.*
- o Kings Point Machinery*

* Comments were received from these organizations.

APPENDIX D. 2

EXCERPTS FROM INDUSTRY COMMENTS

In response to Todd Seattle's request, several reviewers provided the following comments on the progressive outputs of the study.

GENERAL DYNAMICS, QUINCY

Both castings and weldments have been used successfully for stern frames and for hawsepipes for a great many years. The economic viability has vacillated over this time period with preference for castings when they were obtainable for reasonable cost and when they were of high quality. On other occasions there were those shipbuilders who found that weldments could be produced at reasonable cost and with a good degree of weld reliability. There are other factors that play vital roles in selection of the type of component to be supplied. Of primary concern is delivery and scheduling as well as handling and transportation availability. Another consideration is weight since this is directly related to cost. As a rule, a weldment is lighter than a casting, but for stern frames and for hawsepipes, because of the nature of their working functions as major components of the complete vessel, it is desirable to have some degree of mass to absorb forces and vibrations inherent in those areas. Consequently, judgement must be applied to meet the needs on a case basis. Another consideration is the aesthetic effect, especially upon visible hull form as in way of hawsepipes. A second element present in conventional hawsepipes design is the stowage performance of the anchor and its impact upon the ultimate configuration chosen. In many instances, the only workable configuration obtainable requires the use of a casting made from a rather complicated shaped pattern. A 1/8th scale hawsepipes model should be employed to assure a working solution to the vessel's anchor stowage. It is noted that several vessels have been built with overly simple welded hawsepipes that were low in initial cost but would not house or handle an anchor successfully. These installations presented problems throughout the life of the ship and were costly to rectify.

The use of billboards for anchor stowage is prevalent among many mobile offshore drill rigs as well as with VLCC'S and ULCC'S. In these cases simplicity is obtained and aesthetics plays little or no part in the appearance created. The selection of billboards or conventional hawsepipes for a vessel will be dictated by the owners' preference as well as by the economics involved. This facility has no first-hand experience with billboard stowage and reserves judgement on its performance. Most hawsepipes have been one piece castings regardless of size to assure retention of all the necessary features obtained through the model and pattern resulting in a workable stowage. Other hawsepipes have consisted of shell bolsters and deck bolsters connected internally with a fabricated pipe. Hard welds on the wearing surfaces were provided. This type hawsepipes proved reliable and within reasonable cost.

When the cast stern frame design is supplanted by a built-up welded fabrication, it is still necessary to retain castings in certain areas (viz., gudgeons). Forgings may replace these castings in some instances but a degree of bulk is a desirable feature for these items. The welding of the several pieces comprising a built-up stern frame is usually manual because of the irregular configurations involved. Pre-heating is required for both castings and plates. Allowance for distortion, shrinkage and alignment movement must be made when setting up the component parts. The welded attachments of the stern frame to the hull structure (viz., floors and shell) is the same type of operation regardless of whether the stern frame is a casting or a weldment.

The castings and/or weldments depicted on plans 5037.1 to 5037.15 are representative of the designs existing or proposed but are not exclusive. Many variations could be derived and employed in their stead. All designs embody some features that are desirable.

The cost studies made for the subject designs appear to be reasonably relative without stressing the specific dollar values presented. If dollar cost is the sole consideration, the weldments are always the lowest price; however, other factors must be considered when a selection is made. The above statements are made without the detailed cost analysis that a cost estimator would perform when submitting a firm bid on any specific proposal.

Specific comments are as follows:

- o The researcher demonstrates an adequate knowledge of the objectives of the project.
- o The tables in Section 3.1.2 of the interim report are not in-depth enough (it was explained that they were merely a synopsis of many detailed trip reports - GD was satisfied with that answer).
- o The cost of welding and heat-treating in northern yards is a definite cost consideration when considering alternatives to castings.
- o Shipyards and foundries should have a "deal" to get better quality and delivery time.
- o A section in the final report on details the foundry would like from the naval architect would be helpful - a sort of "Foundry Guidelines for the Naval Architect."

U.S. COAST GUARD

- o No comments to offer; have no objections to any aspect of the interim report.

AVONDALE SHIPYARDS

In general concurrence with the discussions and assumptions, and the feasibility of the design and alternatives.

Has serious reservations regarding the estimated total cost of the fabricated stern frames, specifically for the jiggling time, lofting - templates, and field fitting and alignment. These comments have been noted. and incorporated into cost estimates presented in Section 5.0.

Specific comments on study results are:

- o Satisfied that the researcher has a good understanding of the project and is proceeding in the right direction.
- o The research does anticipate the yard's needs.
- o Particularly interested in the proposed feasibility designs concerning the "Billboard" type anchor handling system.

PUGET SOUND NAVAL SHIPYARD

To the best of our knowledge, chain rollers have not been used on Naval vessel anchor chains. They have, however, been used extensively on new construction oil and bulk carriers, especially the 200,000 plus DWT VLCC .

A review of the attached feasibility design indicates a considerable weight saving could be realized through the reduction in size of casting used for hawsepipe and shell bolster. This savings would be offset somewhat by the cost and weight of the chain roller. No information is available on the type of chain roller generally used or their cost.

Current new construction Naval vessels have utilized conventional design for hawsepipes, i.e., large castings. Since PSNS is no longer a new construction yard, it is anticipated a considerable time period will elapse before local work with chain rollers could materialize.

The use of chain rollers and welded hawsepipes would be an acceptable replacement for cast deck edge bolsters.

Specific comments are:

- o Researcher's understanding of objectives adequate.
- o Realizing that this is an interim report, it is hoped the data in the final report will be more complete and factual.

- o The coverage of the inboard accessible stern tube is too limited. This is a relatively obscure type and information should be provided on relative merits compared with the conventional type.
- o It should be helpful to investigate rudder, anchor stowage, and stern tubes from the operators' point of view as an additional aid in selection of systems.

BETH. SPARROWS POINT (CTD)

Lead time for castings: Our experience has been that lead times can vary from 6 to 10 weeks for a 1500 pound casting; up to 24 to 28 weeks for a 180,000 pound casting.

Casting design: Casting design should be discussed with each foundry being considered as a vendor. Techniques vary considerably from foundry to foundry as does quality. Simplification of casting design is highly desirable since it has a direct bearing on quality. Many foundries have lost their ability to produce castings of acceptable quality such as those shown in designs 5037.1 to 5037.3.

Casting size and availability: Extremely large castings should be avoided if possible. Generally a more satisfactory structure can be obtained by a composite design of castings and weldments. Castings thus can be used only where accessibility for welding is a problem or where pure mass is required such as the stern tube boss.

Casting defects: The real problem arises when the foundry and the shipyard disagree on whether or not a casting is repairable. Foundries will often spend weeks excavating and welding a large defect in order to save a casting. The result may still be unsatisfactory to the shipyard.

Inspection of castings: Few foundries have facilities for x-raying sections over several inches thick. Ultrasonic tests not only provide an acceptable substitute but in many cases are far superior to x-ray. Interpretation of UT reading is the key to such testing and it should be the responsibility of the shipyard to have their UT expert on hand for foundry UT of castings.

Rolling and forming of heavy plates: Farming out the shaping of heavy plates is not as easy as it might appear. There are few facilities in this country with equipment heavy enough to handle high strength plates say 5 inches thick. Our Bethlehem, Pa. plant has rolled 3" stem tubes and has formed 5", 80,000 psi yield strength rudder horn side plates. A recent stem tube was designed as a composite of castings in way of the tail shaft bearing and the inner bearing with the 3" rolled plate between for a total length of over 30 feet.

Welding costs: In addition to high welding costs for stern frame weldments, the forming, handling and fitting of heavy plates on a stern frame unit contribute greatly to the cost. The accuracy of heavy formed plates must be assured in the shop since reshaping on the job is close to impossible with typical shipfitting equipment. and techniques.

Billboard anchor handling: A billboard is an acceptable alternative arrangement especially useful on large tankers and bulk carriers and for ships with large bulbs since the chain generally leads further outboard. Otherwise it offers few advantages and some disadvantages over a well designed conventional hawsepipe arrangement.

Hawsepipes: I agree that billboards will generally be less costly to build than traditional hawsepipes, however the security of the anchor against movement in sea conditions for the designs shown does not approach that of conventional hawsepipes. The self-stowing capability of the anchor when hauling in, especially if the anchor comes up with flukes against the hull, must be verified by model tests.

NASSCO

"The general feeling is that castings are less expensive than fabrications for stern frames when say three or more ships of the same size and class are being constructed at the same time assuming the pattern costs to be spread across the contract. A one or two ship program gets into an area where both costs are close to the point that a detailed estimate would have to be developed to make an accurate determination as to which is cheaper."

"From the naval architect's point of view, the only comment we have is that the report does not say much about high-hold anchors, and their influence on the type of bolster method to use."

TODD LOS ANGELES

Reviewed the alternative stern frame and ahwsepipe designs and are in general agreement with the conclusions noted.

Additional comments are as follows:

- o It is our assumption that the foundry is responsible for making the pattern, with the final ownership of it a matter of negotiations.
- o Casting designs should be largely worked out in the early stages of production planning rather than prior to the start of production.
- o Thermit welding used in conjunction with castings does not require placing the unit in an oven for stress relieving. Localized stress relieving is sufficient.

- o Casting designs, and therefore costs, seem somewhat heavy in comparison to the equivalent weldment. This comment necessarily is based on gut feel rather than any in-depth engineering analysis of the comparative designs.

SUN SHIPBUILDING

"... We had occasion last year to make a detailed comparison of a weldment and a casting for a complex stern assembly. The result of this study confirms your conclusions. The cast stem piece was about 20% more costly than a weldment. In this case, the estimator tried to price out the actual cost of the weldment, up to the point at which it was in the same condition as a casting ready for installation."

APPENDIX E

LITERATURE SEARCH & BIBLIOGRAPHY

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APPENDIX E. 1

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APPENDIX E. 2

RELEVANT EXCERPTS FROM REFERENCES

General

Most of the text and reference books listed in the bibliography section contain chapters discussing stern frames; some also contain discussions of hawsepipes and anchor handling/stowage arrangements.

The most complete treatment of both components can be found in entries numbered A.2 and A.3. The latter is the revised final edition of the former. Some of the material contained in A.3 has actually been used in the study as referenced in appropriate sections. Two excerpts from entry B.6 discussing the stern frame and hawsepipes/anchor pocket design and construction for a class of 28,000 ton tankers is presented on pages E- 4 through E- 8.

Publications and journals of the professional technical societies contain few articles directly related to stern frame and hawsepipes design and construction. The treatment of these components is generally covered in the complete ship design and structural arrangement discussions,

THE DESIGN OF A CLASS OF 28,000-TON TANKERS

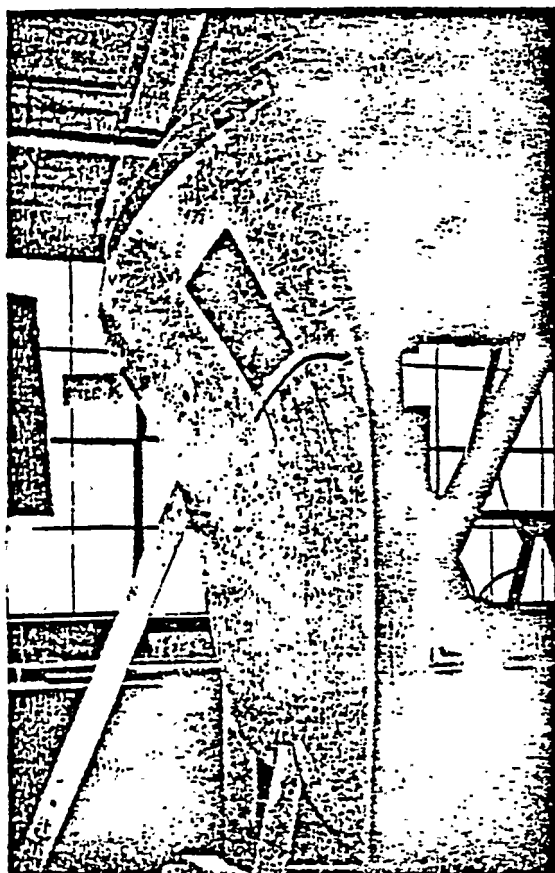


FIG. 4.—ANCHOR POCKET MODEL—Bow View

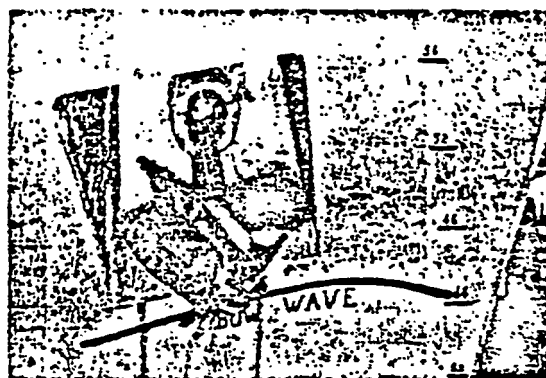


FIG. 5.—ANCHOR POCKET MODEL—Side View



FIG. 6.—ANCHOR POCKET MODEL—Deck View

Reproduced
from:
Transactions,
SNAME,
1950

TABLE 2.—HULL FORM DATA

Length between perpendiculars...	595 feet
Breadth, molded.....	84 feet
Draft, molded (designed LWL)...	33 feet
Length-breadth ratio.....	7.08
Breadth-draft ratio.....	2.55
Length of entrance.....	200 feet = 0.336 LBP
Length of parallel body.....	155 feet = 0.260 LBP
Length of run.....	240 feet = 0.404 LBP
Displacement, molded, bare hull..	36,044 tons
Block coefficient.....	0.7649
Prismatic coefficient.....	0.7699
Midship section coefficient.....	0.9935
Waterplane coefficient.....	0.8468
Vertical prismatic coefficient.....	0.9033
Displacement-length ratio.....	171
Longitudinal center of buoyancy, molded	9.40 feet for'd amidships BP = 1.58 per cent LBP
1/2 waterline entrance angle.....	27 1/4 degrees
Wetted surface, bare hull.....	73,219 sq ft
Wetted surface/ $\sqrt{\Delta L}$	15.8
Designed sea speed*	16 knots
Corresponding speed-length ratio.	0.656

* Defined as speed on trial, at designed load draft, with propelling machinery developing 80 per cent of rated maximum shaft horsepower. See Fig. 9 for actual trial performance which exceeded designed speed by about 0.6 knot.

THE DESIGN OF A CLASS OF 28,000-TON TANKERS

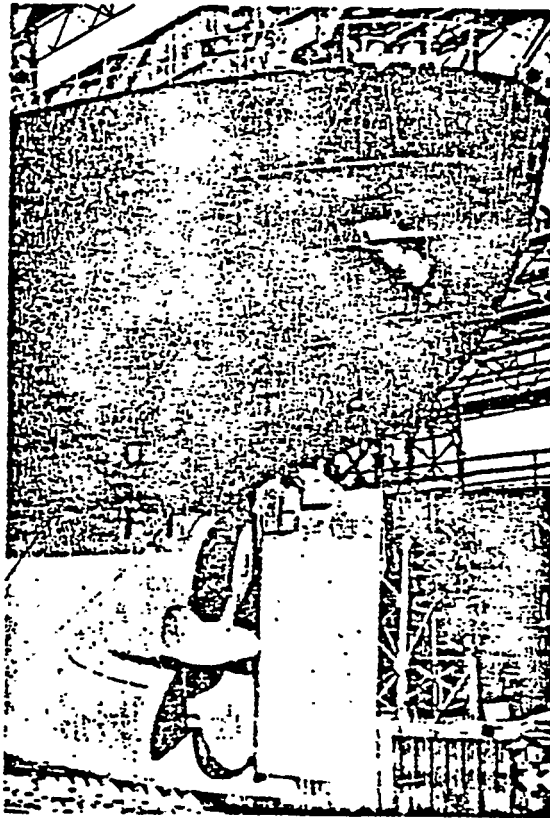


FIG. 8.—DETAILS AT STERN

The rudder is balanced, streamlined. In the preliminary stages of the design a stern frame with a fixed rudder post had been indicated, but the balanced-type rudder was adopted later to reduce the rudder torque. The rudder area is **1.33 per cent of the lateral plane area.** The vessels completed have demonstrated excellent maneuverability. The turning circle (diameter at full speed is about 3,000 feet (5 ships lengths).

Reproduced from: Transactions, SNAME, 1950 -

SOME OBSERVATIONS ON SHIP WELDING

MR. J. H. DEPPELER, *Associate Member*: Mr.

Arnett has discussed in detail the fabrication by welding of Liberty and other ships, but he has inadvertently left out any question of the welding of the heavy stern frames or the stems of these ships. Therefore, this discussion should not be considered in any way as a criticism of what Mr. Arnett has written but rather as a supplement to this.

As the paper does not mention the construction of the stern frames or stems, it may be assumed

Reproduced from: Transactions, SNAME, 1942

SOME OBSERVATIONS ON SHIP WELDING

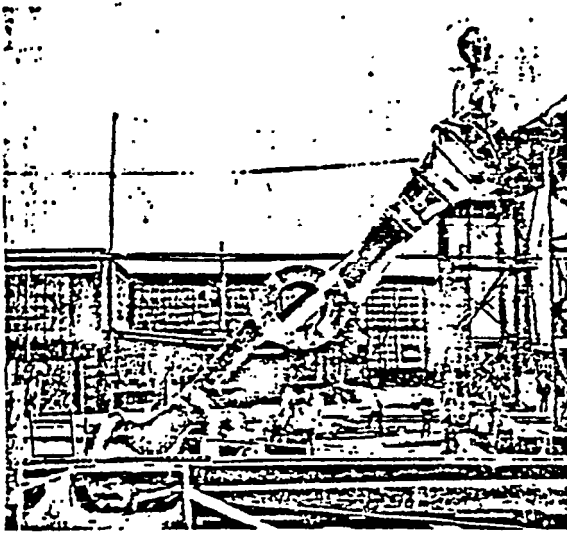


FIG. 24.—THERMIT-WELDED FRAME OF LIBERTY SHIP BEING RAISED, FULCRUMED ABOUT CENTERLINE OF KEEL, THUS SAVING CRANE CAPACITY

that these were joined by mechanical means, whereas most of the shipyards have called on the Metal & Thermit Corporation and this corporation has provided equipment and materials and furnished expert instructors, which enables the yards to proceed quickly with the making of their own stern frames by Thermit welding.

During the previous war these stern frames were furnished either as forged steel sections or, in many cases, wrought iron sections scarf-welded together by the well-known blacksmith method, or they were made of one-piece castings. But in subsequent years, many defects were found either in the scarf welds or in the junction points of the

heavy cast material, and these defects have greatly increased the amount of Thermit repairs made by the Metal & Thermit Corporation. It is, of course, well known that most ships are at present equipped with one Thermit weld and many with two or three of these welds, which, of course, all had to be made at the point of failure on the ship in dry dock and in whatever position the break was found. Many of these welds occurred at the inner end of the shoe and the melding of them required the removal of some of the plating. Others occurred close to a rudder-frame gudgeon or close to the propeller boss and such positions, of course, were more difficult to weld. Much could be said of the member of stem frames welded by Thermit and of the rigid approval called for by the American Bureau of Shipping and by Lloyd's Register of Shipping, but we are very glad to report that in all of these stern-frame repairs, many of them made at night with temperatures well below freezing, we have never yet had a single failure.

It was logical therefore when the Maritime Commission was called upon to authorize the building of ships rapidly, that it should call on Thermit to weld the heavy stern-frame sections. Most of the modern ships are equipped with either streamlined rudders or contra-molders and their stern frames arc, therefore, streamlined in sections either in a triangular shape or in a frustum of an ellipse, these sections measuring from 30 to 35 inches in length and from 18 to 30 inches in width.

The Metal & Thermit Corporation has worked with the Maritime Commission and with the naval architects designing ships, and located the Thermit welds in a way that would enable the stern frames to be built of four heavy castings (in certain cases five) with the welds conveniently located sufficiently far away from the gudgeons and

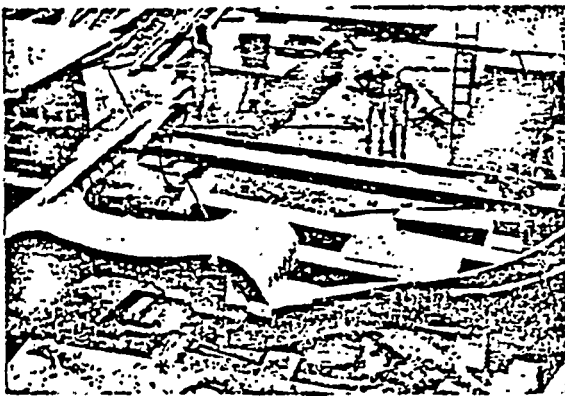


FIG. 25.—TWO THERMIT WELDS IN LIBERTY SHIP STERN FRAME



FIG. 26.—CLOSE-UP OF GAP USED IN THERMIT WELDING. THIS IS ON A TYPE OF FRAME USED IN TANKERS

SOME OBSERVATIONS ON SHIP WELDING

propeller bosses to enable this work to be done expeditiously. Such a weld takes from 500 to 900 pounds of Thermit.

The welding is done on parallel-sided gaps provided by oxy-cutting the ends of the pieces after they are lined up in position. The frame is usually welded in a horizontal position, in some cases at the end of the ship and in other cases at a remote point. Figs. 24 to 26 show various frames in various stages of completion.

Obviously, it would be difficult, if not impossible, to instruct a shipyard how to repair the broken stem frames because these failures occur at all sorts of angles and in all sorts of positions, therefore the Metal & Thermit Corporation maintains a staff of expert welders to handle these repairs. In the construction of the C-2'S, Liberty ships and the various troop ships, the Metal & Thermit Corporation has found it entirely feasible to instruct a yard in the Thermit welding method and, after the completion of one or two stem frames, to let this yard proceed on its own, with occasional supervision by the Thermit Corporation.

Liberty ship frames, which are of the single-bar type, are much simpler to make in one casting. This was done until recently, when orders for Liberty ships became so widespread that some of the smaller foundries were called upon to make the cast-steel frames. In this case, the Maritime **Commission has decided on a policy of making this** cast-steel frame in two or three pieces Thermit welded with either one or two welds.

In all of this construction, there is a very distinct advantage. In the first place, the smaller castings involved in making the four pieces for the Maritime Commission C-2 ships or the two or three pieces for the Liberty ships are almost bound to be very much sounder. These castings can be designed with the heavy propeller boss as the center or with the heavy gudgeons as a center. With this design, the castings are very much simpler to make and the Thermit welding of these parts no more difficult. The whole operation should result in a better construction.

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APPENDIX E.3

SYNOPSIS OF CLASSIFICATION SOCIETY RULES FOR STERN FRAMES AND HAWSEPIPES

The rules and regulations imposed on the construction and classification of stern frames and hawsepipes by the three major classification societies are excerpted below in summary form.

AMERICAN BUREAU OF SHIPPING

Stern Frames and Rudder Horns

- o Stern frame scantlings are determined by prescribed formulas where the scantling dimensions are directly proportional to the square root of the ship length for vessels over 590 ft. long. Casting designs are to fulfill the same requirements as above.
- o Rudder horn scantlings are determined by a prescribed formula for calculating stress in the horn and is a function of rudder area, design speed of the vessel, bearing locations, and the physical characteristics of the rudder horn. The calculated stress is to meet prescribed limits-set for fabricated and cast designs.

"Hawsepipes

"Hawsepipes are to be of ample size and strength; they are to have full rounded flanges and the least possible lead, in order to minimize the nip on the cables; they are to be securely attached to thick doubling or insert plates by continuous welds the size of which are to be in accordance with Section 30 for the plating thickness and type of joint selected."

LLOYD'S REGISTER OF SHIPPING

Stern Frames and Rudder Horns

- Stern frame scantling sizes are determined by prescribed formulas where the scantling dimensions are directly proportional to the product of a constant and the square root of the ship's summer draft. The constants are different for designing fabricated stern frames as compared to cast.
- o The rudder horn section modulus against transverse bending is not to be less than that determined by a prescribed formula which is a function of the ship speed and certain physical characteristics of the horn.

Hawsepipes

"Hawsepipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawsepipes are to be reinforced as necessary. Reinforcing is also to be arranged in way of those parts of bulbous bows liable to be damaged by anchors or cables.

Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large radiused faces to minimize the probability of cable links being subjected to high bending stresses.

Alternatively, roller fairleads of suitable design

may be fitted. Where unpocketed rollers are used it is recommended that the roller diameter be not less than 11 times the chain diameter."

DET NORSKE VERITAS

Stern Frames and Rudder Horn

- o Stern-frame scantlings are determined by prescribed formulas where the scantling dimensions are directly proportional to the product of a constant and the square root of the ship length. The constants are different for designing fabricated stern frames as compared to cast.
- o The design of the rudder horn is determined by prescribed calculations for shear forces, bending moments and torque, where these results are used in the minimum required section modulus, wall thickness, and areas of horizontal section equations which contain prescribed constants.

Hawsepipes

"Hawsepipes are to be of ample thickness and of suitable form to house the anchors. At the upper and lower ends of hawsepipes, there are to be substantial chafing lips to prevent excessive wear in way of the chains. The radius of curvature at the upper end should be such that at least 3 links of chain bear simultaneously on the rounded part.

Hawsepipes are to be arranged with an easy lead of the cables from the windlass to the anchors. Upon release of the brake, the anchor is immediately to start falling by its own weight.

The shell plating in way of the hawsepipes is to be doubled or increased in thickness and the framing "reinforced as necessary to ensure a rigid fastening of the hawsepipes to the hull."

APPENDIX E . 4

AMERICAN BUREAU OF SHIPPING INPUT

E.4.1	Case History on Cast Steel Stern Frame Troubles . . .	E-13
E.4.2	Stern Frame (Skeg) Analysis	E-21
E.4.3	Hawsepipe Bolster Design Guidelines	E-22

APPENDIX E.4.1: CASE HISTORY

December 11, 1955

CAST STEEL STERN FRAME TROUBLES

As you all know the service record of cast steel stern frames has not been entirely satisfactory, and stern frame repairs have been and still are a source of great expense to the shipowners. One of the main sources of trouble is lack of soundness which escapes detection by present methods of inspection used in foundries; and is of many years standing, and is not confined to vessels built during war years. Naturally, if it was economically **possible to X-ray cast steel sections up to thicknesses of 20 inches, most** of these deep sub-surface defects would be detected and properly repaired and for all practical purposes this whole problem would not exist. Until such methods of detecting deep sub-surface defects are used it seems advisable to suggest to the representatives from the leading casting producers that further refinements of foundry practice are necessary. In view of the experience with cast steel, some owners have already intimated their intention to use fabricated welded stern frames made of a combination of castings, plate material and forgings. (See Fig. 6). There are indications that this trend is underway and it is gaining momentum. It is quite obvious that the number and size of cast steel components to be used in these new designs will depend on the subsequent service records of these new stern frames.

Three typical cast steel stern frame sketches (Fig. 1, 2, 3) are attached which represent an aggregate service record of 20,000 ship years (service of one ship for one year). With some minor modifications in design for some, the above mentioned sketches portray the bulk of cast steel frames used in merchant marine. Every time a ship is drydocked, routine inspection of the stern frame is made by our Surveyors. Their survey reports describe a certain number of defects that are segregated for convenience as follows:

1. Defects in Stern Frame Skegs: The general location of the defects are shown in the attached sketches, and their nature can be better understood from the above photographs. At this point, it is pertinent to point out the sad record of the skegs of some 10 Super-Tankers (601 feet length) built in 1949 and 1950, that accumulated a service record of some 32 ship years. During that period 9 tankers out of 10 developed serious stern frame defects that had to be repaired and some frames more than once. In two cases, it was necessary to renew the section. Skeg in question is shown in Fig. 4, with the location where the majority of the defects have occurred.

A reflectoscope survey of the skeg of seven of the above tankers was conducted by an independent testing laboratory, starting in December, 1951, for the first one and completing the seventh one in May, 1952. The findings, although inconclusive, disclosed the presence of sub-surface defects in the nature of centerline porosity, inclusions or nests of hot tears. It was further stated that the castings under investigation were either coarse grained or spongy and good back reflections were not obtained which would cast some shadow on the general suitability of the reflectoscope inspection method for this particular application.

2. Fractures in way of Landing of Shell Plates to Stern Frames: Cracks through the flange of the stern frame, at the toe of the fillet weld on one side, and the relatively sharp radius of the frame on the other, as illustrated in Fig. 5a, have been the origin of serious troubles with stern frames. A number of photographs describes the magnitude and location of these fractures, and discloses unsound cast material in way of them. Later improvements in design, as shown in Fig. 5b and 5c would be effective only if the soundness of the castings was insured.

3. Cracks in way of Core Holes: These fractures are illustrated in the two attached photographs and sketches. It was found that in the original castings, square holes had apparently been left in the sides of these horn pieces by the casting makers for core support. These holes had been closed by welding square insert plates from the outside only, with welds that barely penetrated half the thickness of the casting. Cracks followed the horizontal edges of the welded insert plates. The detail drawings of these stern frames that we approved for the design agents did not indicate such openings.

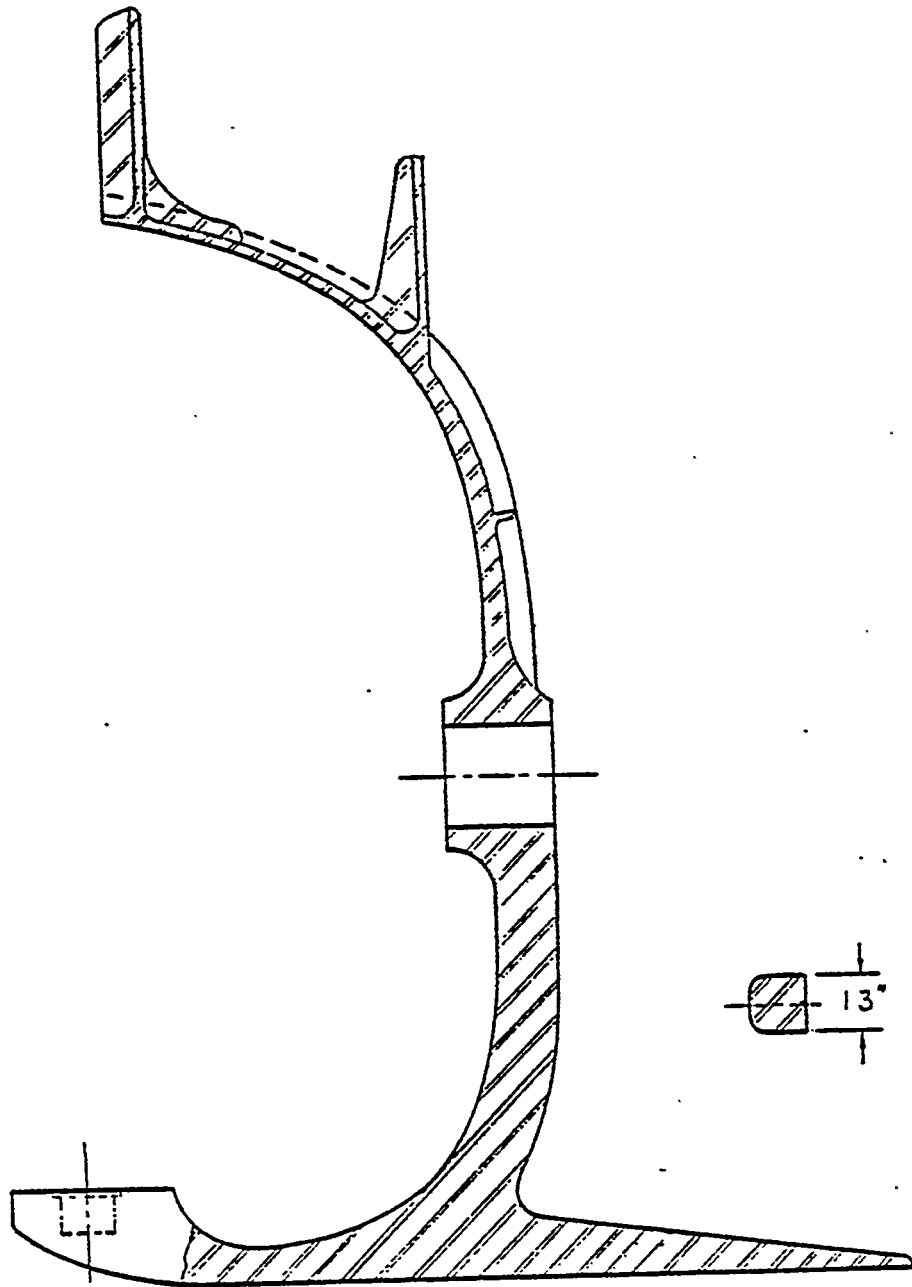
4. Other Miscellaneous Defects in Stern Frames: A full scale drawing shows the depth and extent of cavities resulting from the complete removal of unsound cast material in the upper section of stern frame, which was found a few days after the frame was attached to the main hull on the ways. These cavities had to be welded out of position and delayed the launching date of the vessel. Two more cases are shown in a photograph and a sketch, where defective cast material caused serious cracks in stern frames.

Serious pitting that develops on the surface of stern frames after a relatively short service is generally associated with porous cast material that was covered by a thin layer of sound material which escaped visual inspection. (See attached photo.)

The Frequency of occurrence of the above defects is as follows:

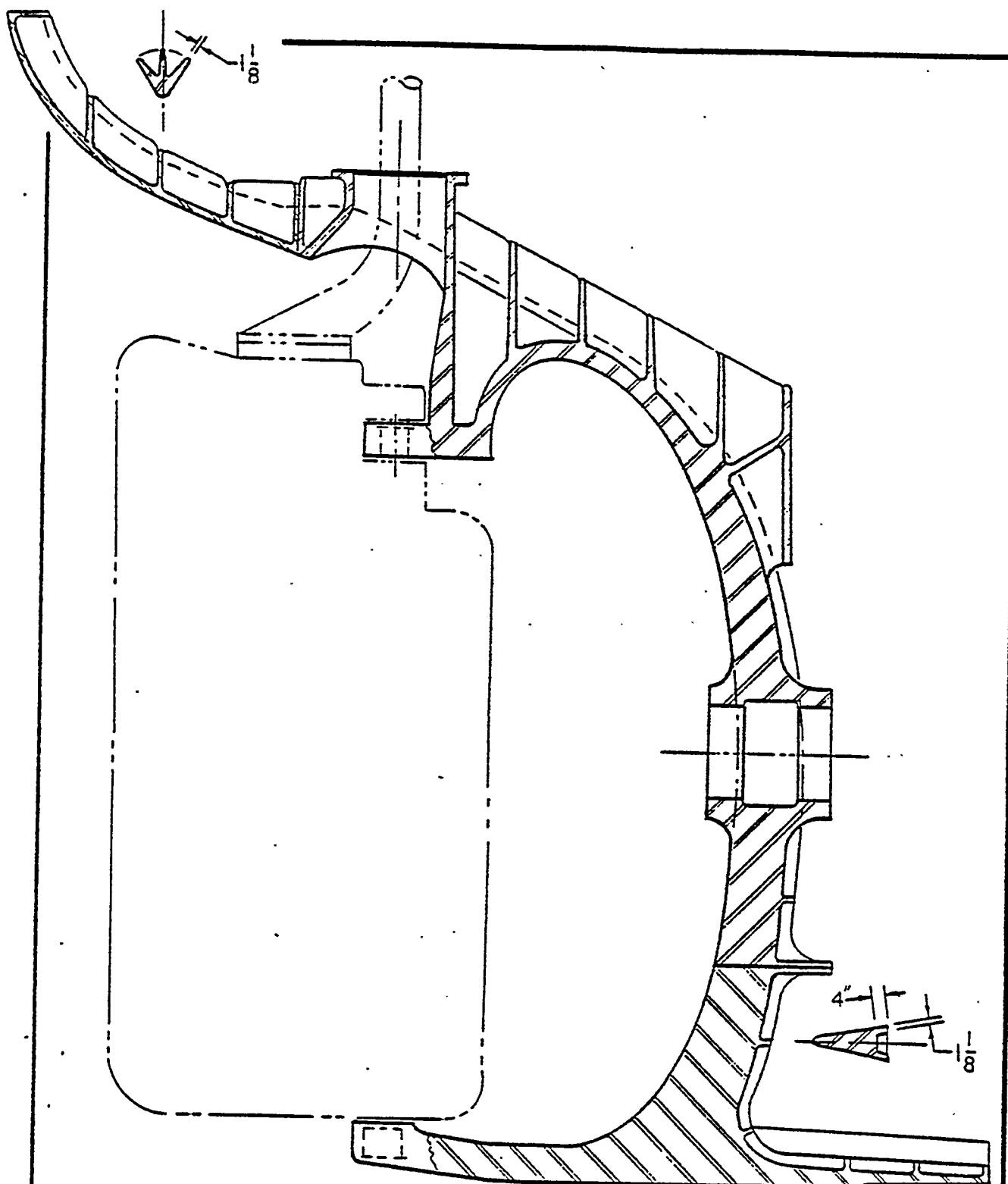
T2 Tankers: 525 tankers were built during the period 1943-1945, over 450 of them are still operating and they accumulated a service record of 3800 ship years. During that time 170 stern frames developed defects in the skegs that required repairs and some frames more than once. These repairs consisted of removing the defective areas and arc welding the cavities. Except in 10 cases it was possible to fill them by thermit welding and in 17 other cases the castings were so poor that it was necessary to renew the entire section. 88 stern frames developed cracks in the way of the landing of shell plates to stern frames. 25 stern frames were repaired in other miscellaneous locations. This amounts to 0.72 stern frame trouble for every ship operating one year.

Victory Ships: 534 ships were built during the years 1944 and 1945. Over 220 of them are still operating with a service record of 2700 ship years. During this period 19 developed defects in the skegs, 4 of which had to be renewed. 80 stern frames had cracks in the core holes, 2 in the landing of shell plates to frame, and 10 in miscellaneous other locations. The record is 0.40 stern frame trouble for each ship year.



LIBERTY SHIP

FIGURE 1



T2 TANKER

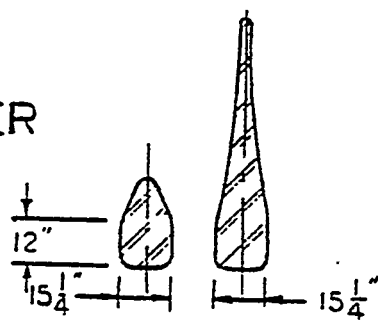
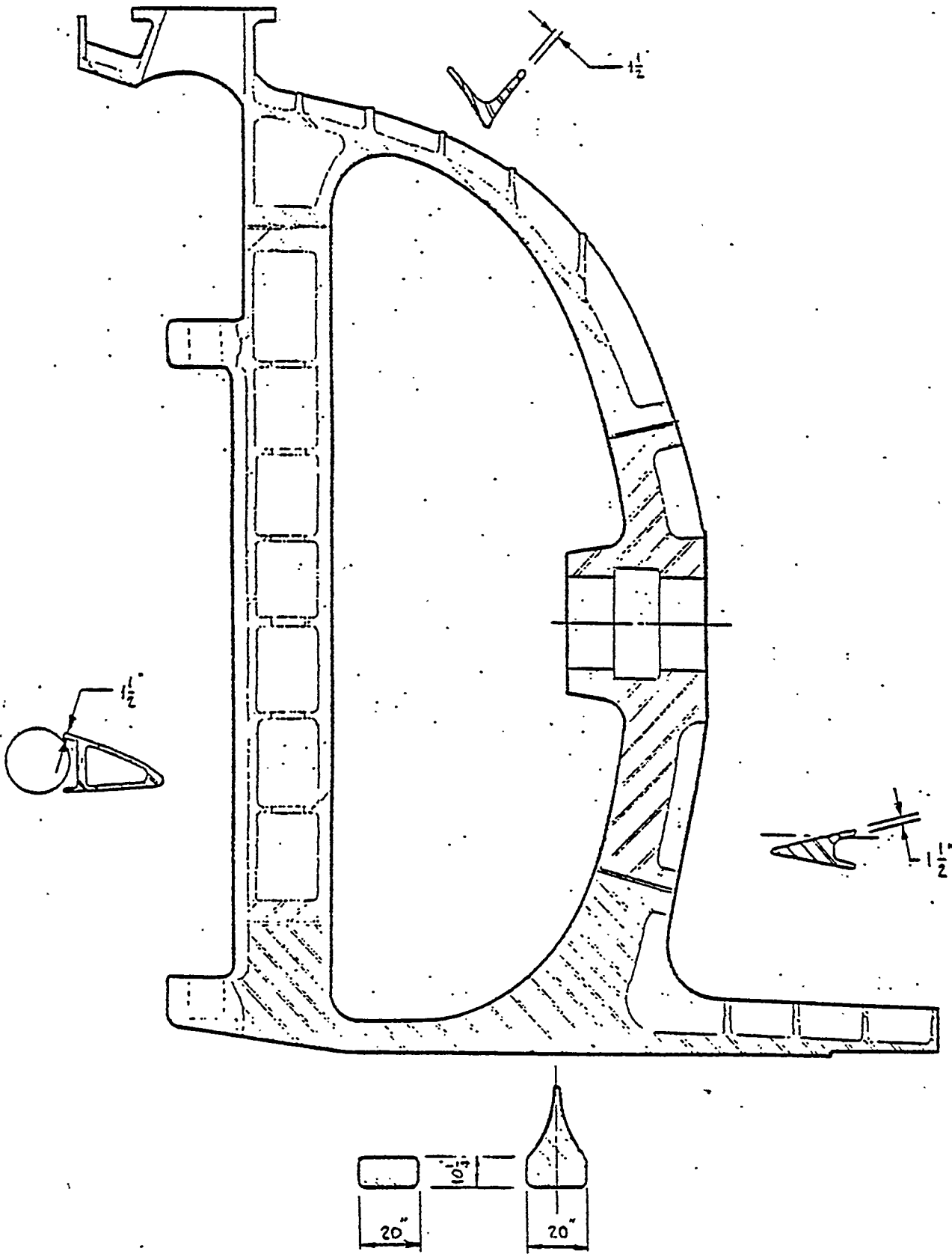
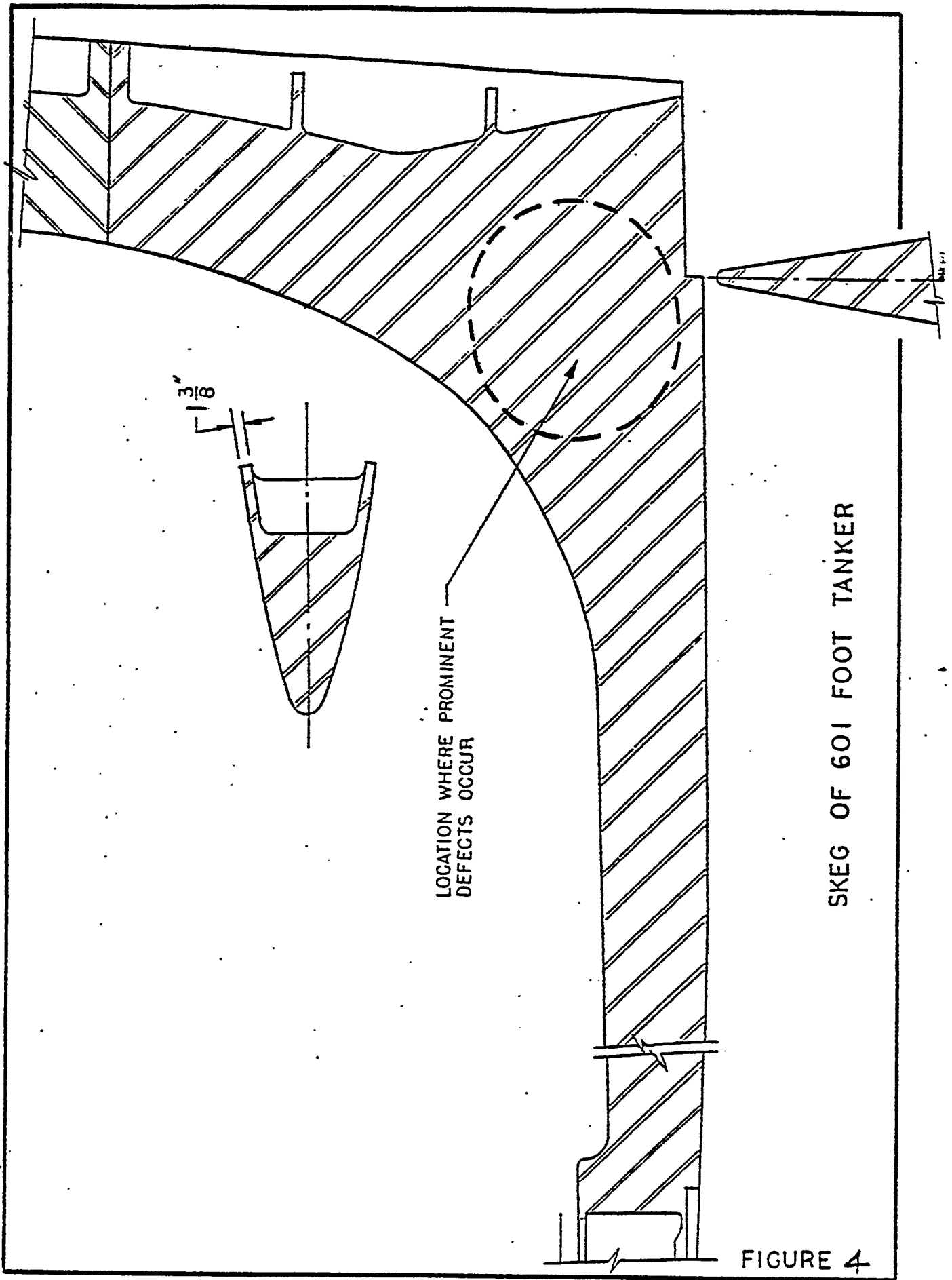


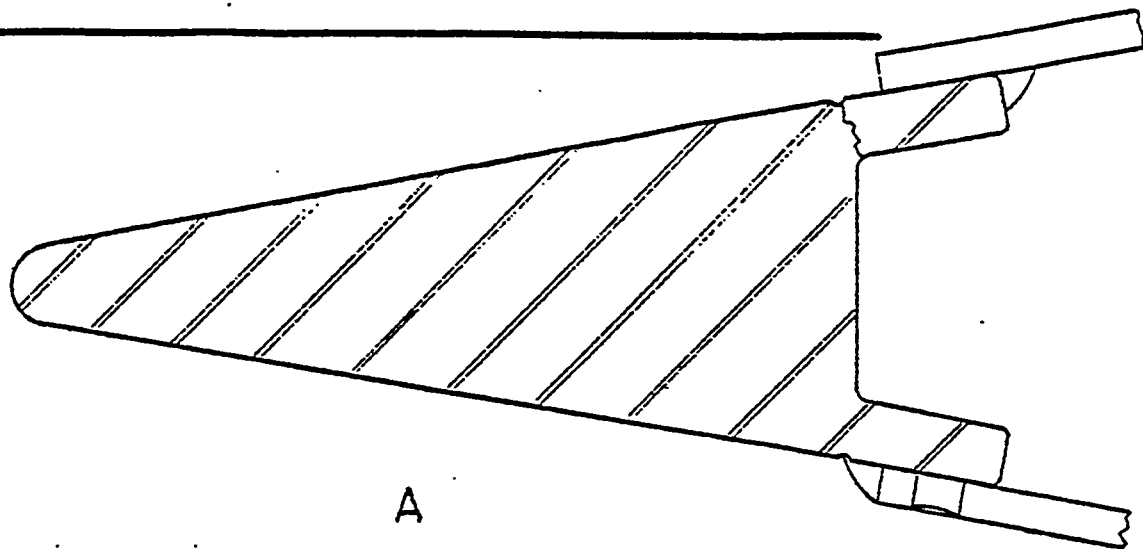
FIGURE 2



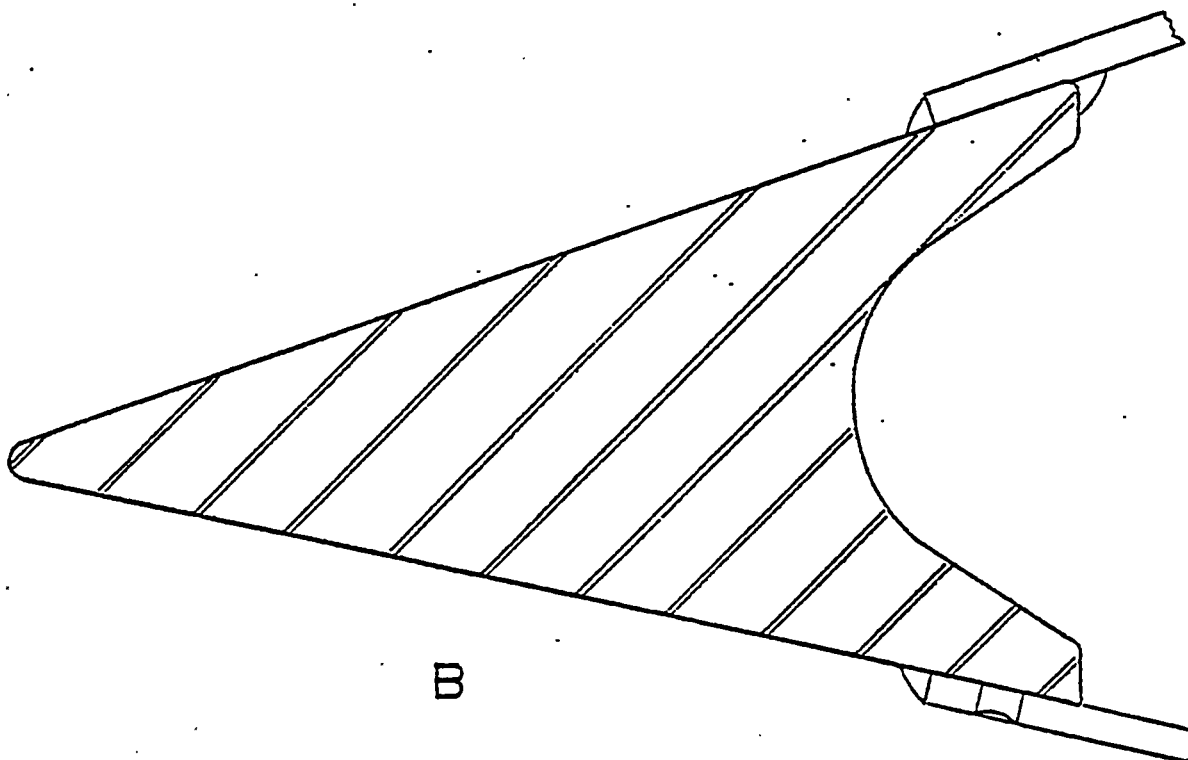
VICTORY SHIP

FIGURE 3

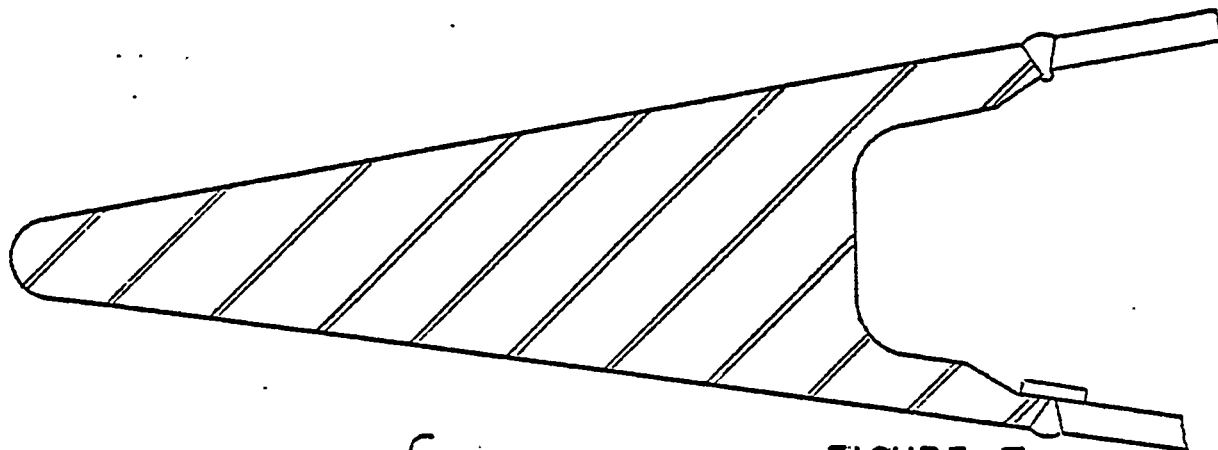




A



B



C

FIGURE 5

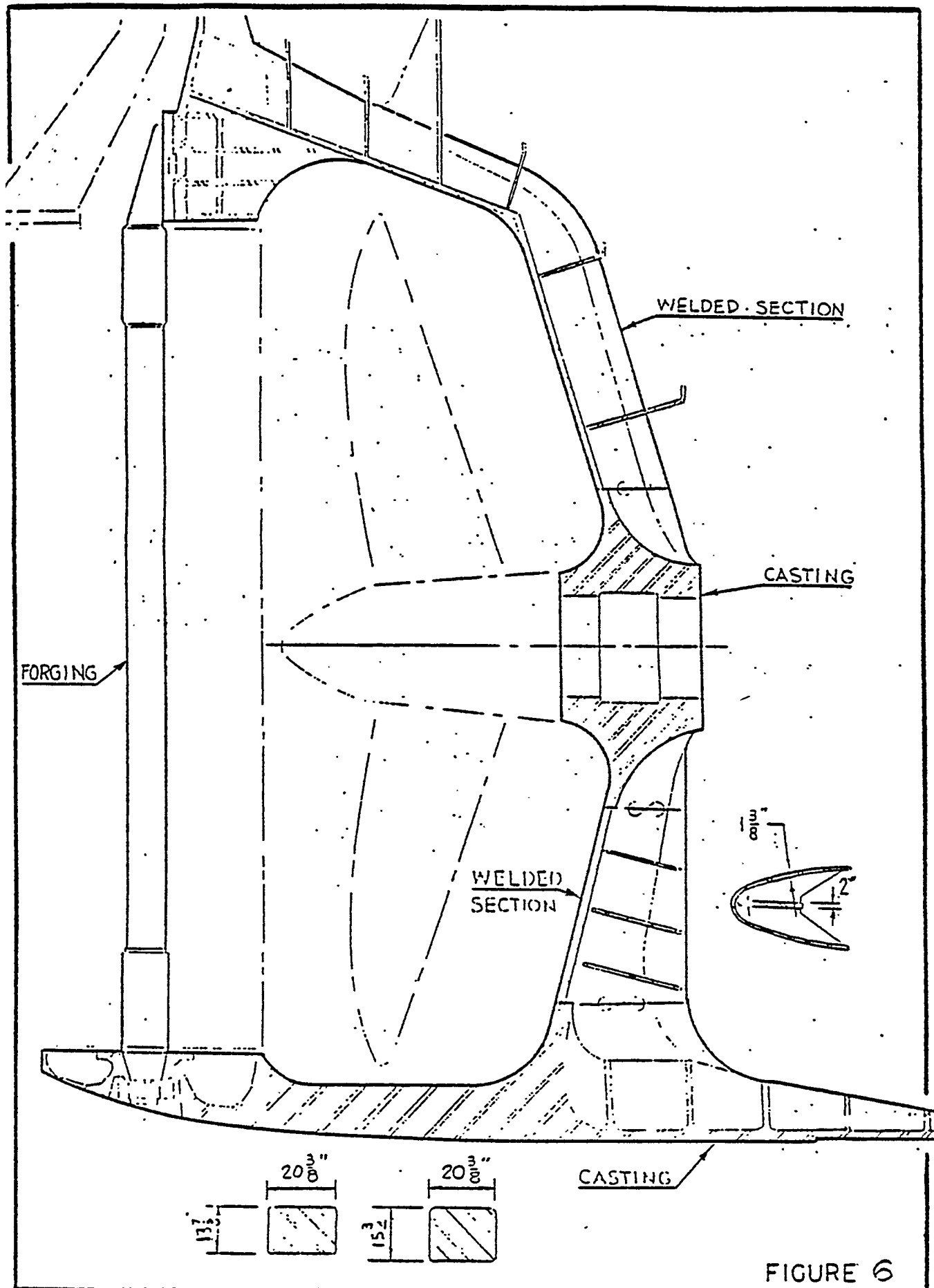
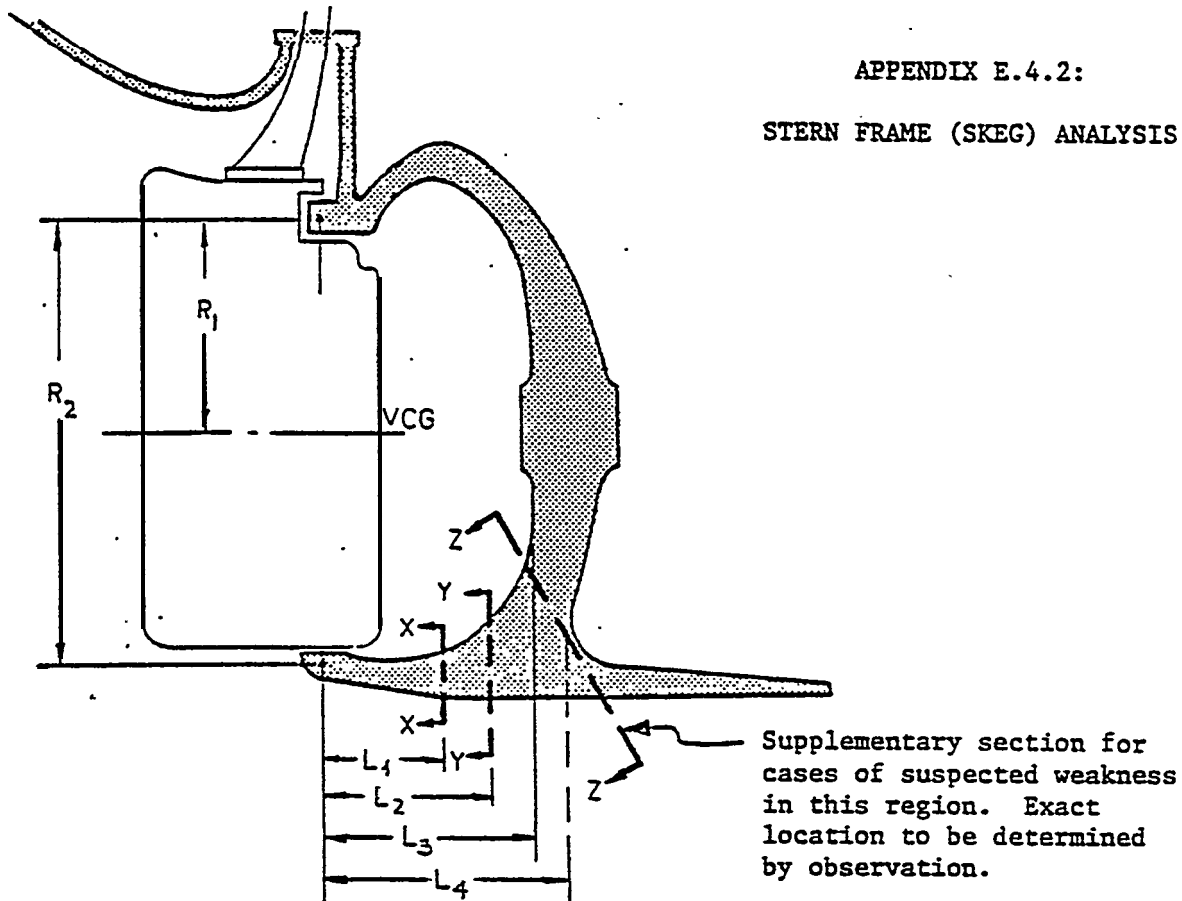


FIGURE 6

APPENDIX E.4.2:
STERN FRAME (SKEG) ANALYSIS



STERN FRAME SKEG ANALYSIS

PRESENT METHOD USED BY HULL TECHNICAL STAFF (APRIL-1950)

$$P_R = 3.71 \times 0.8 = A = V^2$$

$$P_S = P_R = \frac{A1}{A2}$$

$$\text{Stress @ Section (XX)} \quad L_1 = \frac{P_S \times L_1}{I_y (xx)}$$

$$\text{Stress @ Section (YY)} \quad L_2 = \frac{P_S \times L_2}{I_y (yy)}$$

$$\text{Stress @ Section (ZZ)} \quad L_4 = \frac{P_S \times L_3}{I_y (zz)}$$

Where

P_R = Force on rudder in lbs.

A = Area of rudder in sq. ft.

V = Speed of vessel in knots

P_S = Force on skeg in lbs.

X/Y = Section modulus about line of intersection of ϕ plane of vessel and athwartship plane at section

L_1 and L_4 - See sketch, in inches

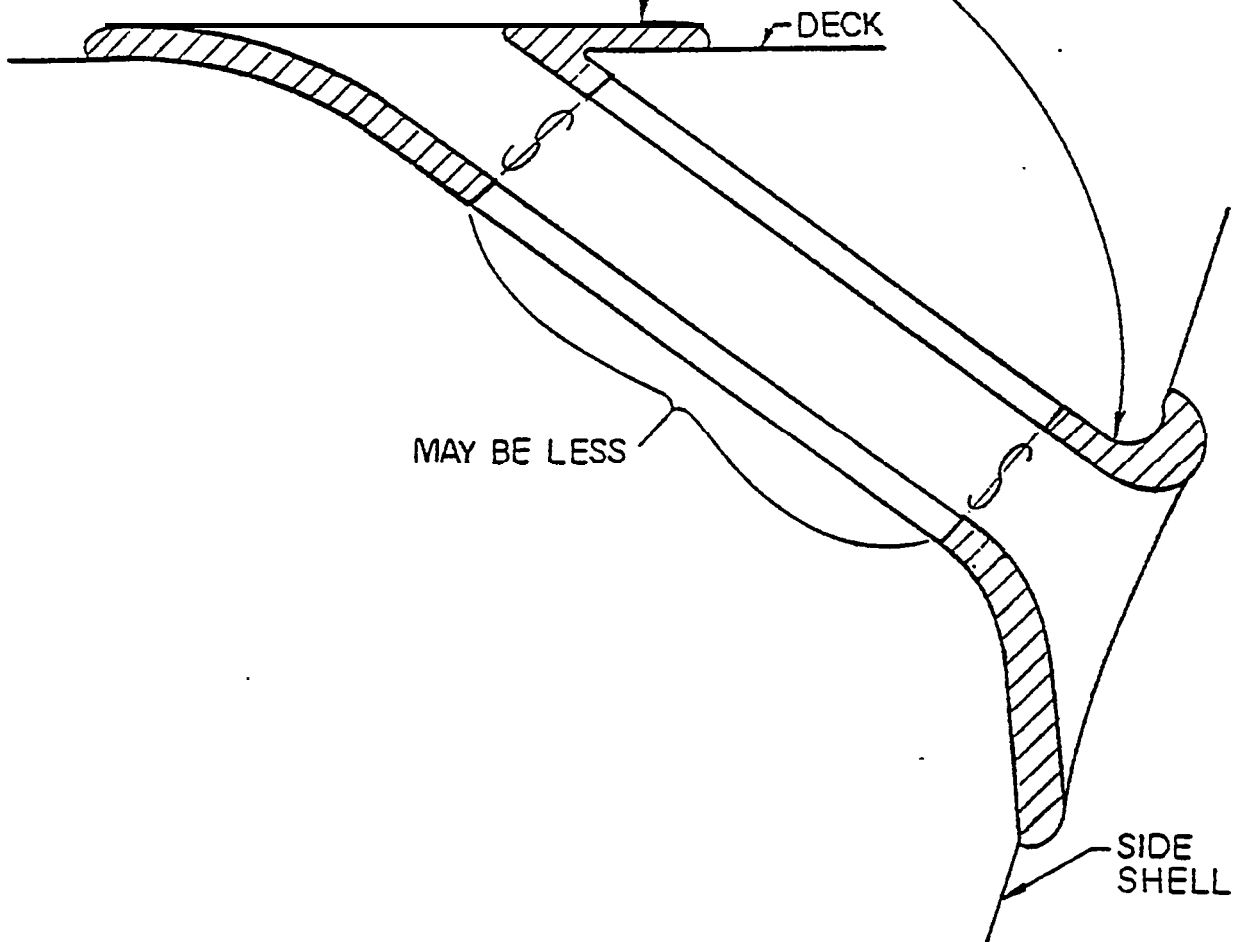
R_1 and R_2 - See sketch, in ft,

FIGURE 7

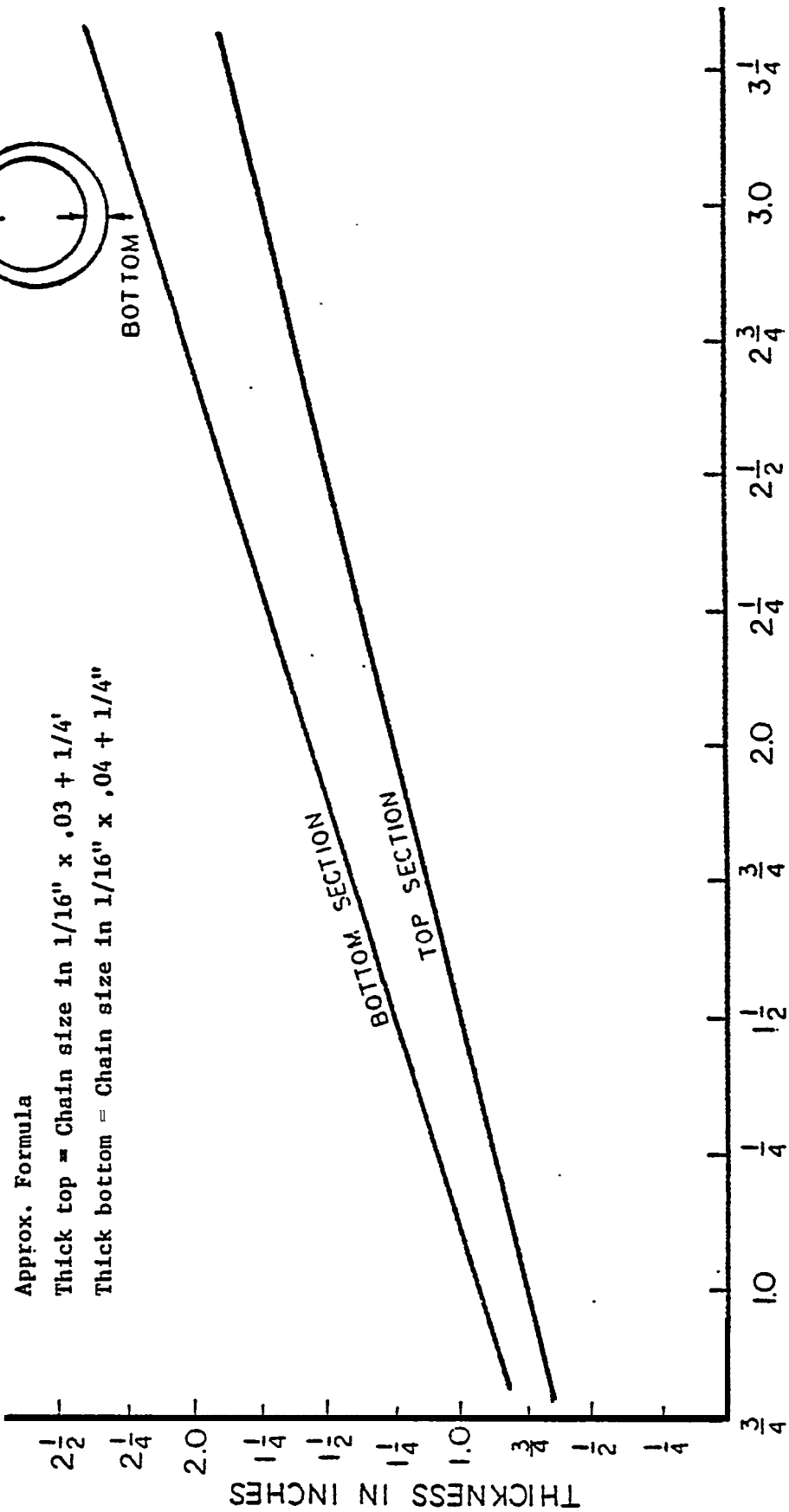
HAWSEPIPE BOLSTER DESIGN GUIDELINES

THICKNESS OF WALLS FOR CAST STEEL HAWSEPIPES

BOTTOM $t =$ Size of chain in $1/16^{\text{ths}}$ $\times .040625 + .25 =$
TOP $t =$ Size of chain in $1/16^{\text{ths}}$ $\times .03125 + .25 =$



FIGURE



SIZE OF CHAIN IN INCHES

FIGURE

APPENDIX E.5

A. B. GOTAVERKEN PATENT

FOR "BILLBOARD" ANCHOR HANDLING SYSTEM

M Rosenblatt & Son, Inc.
350 Broadway
NEW YORK, N.Y. 10013
U S A

RECEIVED
SEP 29 1977

M. ROSENBLATT & SON, INC.

Er ref.
Your ref.
NSB/MT

Ert brev
Your letter

Vår ref.
Our ref.
H-A Genberg/ee

Datum
Date
1977-09-23

Dear Sirs,

Re: Anchor Handling on Deck

With reference to your letter to Mr R Leandersson at our Technical Service Department dated 1977-09-14, File 5037-15, we hereby give you the following information about our new Anchor Arrangement.

The idea. to do something about the normal Hawsepipe Arrangement arose after discussions with shipowners and captains. They all pointed out the problems they had with slamming anchors, damaged shell plates, bad worki-environment in hard weather, specially when the vessels grew in size and the anchor weights increased.

In 1975, after having consulted the classification societies as Lloyd's Register of Shipping and Det norske Veritas and maritime authorities in England and Sweden, we introduced our new arrangement on a tank vessel built to the owner Rethymnis & Kulukundis.

In 1976 we built another three vessels with this new arrangement and the same year the Kockuns Shipyard contacted us and showed their interest in a co-operation which resulted in the fact that further two vessels obtained this arrangement built by Kockuns during 1976 and 1977.

We enclose one copy of our U.S. patent in which you will find background and advantages of this new Anchor Arrangement together with a pamphlet from Kockuns describing their chain stopper combined with the Arendal technique for another stowage.

We hope this will be to your satisfaction are we are glad to give you further information if necessary.

Yours faithfully,

AB GOTÄVERKEII
Arendal
Outfitting Design



Gunnar Widbom
Gunnar Widbom

Encl.

AB GOTÄVERKEN

E-24

Mailing address	Telephone No.	Telegram address	Telex	Postal account	Banking account	Bank
3-122 70 GÖTEBORG, SWEDEN	031/22 83 00 031/22 80 02	GÖTÄVERKEN	2283 GOTAV S	4 04 70-7	513-6197	SKANDINAVISKA ENSKILDA BANKEN

APPARATUS FOR STOWING AN ANCHOR

BACKGROUND OF THE INVENTION

In ships of conventional design the anchor chain passes through a hawser pipe, extending obliquely downwards from the ship's deck, through a space within the hull to an opening in the side plating. When the anchor is hauled-in its leg will extend into the hawser pipe, while the crown with its arms are located outside the side plating, where they are difficult to reach, and also will cause damage, especially during hauling-in.

SUMMARY OF THE INVENTION

The invention refers to novel means for receiving and stowing a so-called patent anchor, having a leg and a crown with arms pivotably connected thereto, upon an open bed arranged on a ship's deck, and is characterized in that the bed inside the side plating of the ship includes an inclined portion raising above the deck and adapted to receive the leg of the anchor, this raised portion being located inside of an outwardly open pocket, recessed below the deck and being downwardly defined by a surface of sufficient size to receive the crown of the anchor, substantially inside of the contour line of the side plating.

This novel arrangement has a number of advantages. The stowed anchor will not be subjected to the same action by the waves as in previous designs as it will be located higher above sea level and will be received inside of the contour of the side plating.

The anchor is furthermore easily accessible for locking, inspection and cleaning.

The arrangement also makes the installation more easy, which means that less fitting will have to be done during the busy days before delivery. A "stopper bed" may be mounted simultaneously with, or even before the windlass. There is no need to cut holes in the side plating for the hawser pipe and the doublings around the latter may be dispensed with. The maintenance and upkeep of the ship will be reduced as no damages to the hull around the mouths of the hawser pipes will occur, and as the anchor will be dropped from a higher point, and more outside of the side plating proper, damage to the paint coating will be reduced.

The location of the anchor is also more favourable from a safety point of view as it will be easier to arrange for secure locking, and it will also be possible to inspect and locate damage to the anchor.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a cross-section of a portion of a ship's deck at the position of an anchor bed, and

FIG. 2 shows the anchor bed and the windlass, as viewed from above.

DESCRIPTION OF A PREFERRED ARRANGEMENT

In FIGS. 1 and 2 the deck of a ship is denoted by 10 and the side plating by 11. The anchors are conventionally located in the fore part of the ship and here the upper areas of the side plating are markedly flared outwards. The higher up the anchor can be located, the further away from the side plating proper the anchor and the chain will pass when the anchor is dropped.

The anchor 12 is, in the drawing, shown in its stowed position and is attached to a chain 13, which, in the usual manner, is handled by a windlass 14.

The anchor 12 is of so called patent type and includes a leg 15 and a crown 17 having arms 16, the crown being pivotably connected to the leg.

The anchor is stowed upon a bed 18, which is open upwards and is adapted to receive the leg of the anchor. This bed is located above the deck 10 of the ship, having such an inclination that the anchor will slide downwards automatically, when a retaining force is released.

This retaining force is in the first place provided by the windlass 14, but in addition to that there is a locking arrangement, generally denoted by 19 and including levers or similar means adapted to engage and to lock against a link of the chain or the shackle connecting the chain to the leg.

Side supports 20 extend upwards along both sides of the bed 18 enclosing leg 15. At the bottom of the bed 18 a pocket 21 is recessed into the deck, being open outwards and generally adapted to receive the crown 17 of the anchor and the base portions of arms 16, so these parts, when the anchor is fully hauled-in, will be located inside of the contour line of the side plating 11 of the ship. The pocket 21 will form a hawser guiding the anchor so the chain will obtain the proper direction with respect to the locking arrangement 19 and the windlass.

The bills or end portions of the arms 16 will rest upon inclined supports 22 at the deck inside the pocket 21, the bottom surface of which is inclined downwards away from the bed.

At the transition between pocket 21 and the deck 10, a stopper 24 formed as a reversed U-shaped staple. This is adapted to straddle the bed and an anchor's leg 15 resting thereon. The side members of the staple are formed in such a manner that the arms of the anchor may be hauled-up, outside the staple and also the bed 18. Each side member is provided with a shoulder 25 located at such height above the knuckle 23 between the deck and the pocket, that the associated portion of the arm will be wedged between the shoulder and the knuckle.

What we claim is:

1. Means for receiving and stowing an anchor, having a leg and a crown with arms pivotably connected thereto, on a ship defined by side plating and a deck, comprising:

- a. an outwardly open pocket, recessed below said deck and being downwardly defined by a surface of sufficient size to receive the crown of said anchor, substantially inside of the contour line of said side plating,
- b. an open bed arranged on said deck, inside said pocket and including an inclined portion raising above said deck and adapted to receive the leg of said anchor, and
- c. stopper means, including a pair of spaced-apart, upwardly extending stopper legs, fitted between the raised portion of said bed and said pocket for straddling the bed and the leg of an anchor resting thereon while permitting the arms of the anchor to be moved inwards outside of the stopper means.

2. The means according to claim 1, in which each of said stopper legs is provided with a shoulder on its outward side located at a distance above said bed, corresponding to the thickness of that portion of an arm of said anchor being located opposite to the stopper means, when said anchor is in stowed position.

[54] APPARATUS FOR STOWING AN ANCHOR

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[73] Assignee: AB Gotaverken Company, Goteborg,
Sweden

[22] Filed: Feb. 17, 1976

[31] Appl. No.: 653,268

[52] U.S. Cl. 114/210; 114/179

[51] Int. Cl.² B63B 21/22

[53] Field of Search 114/210, 206 R, 182,
114/179

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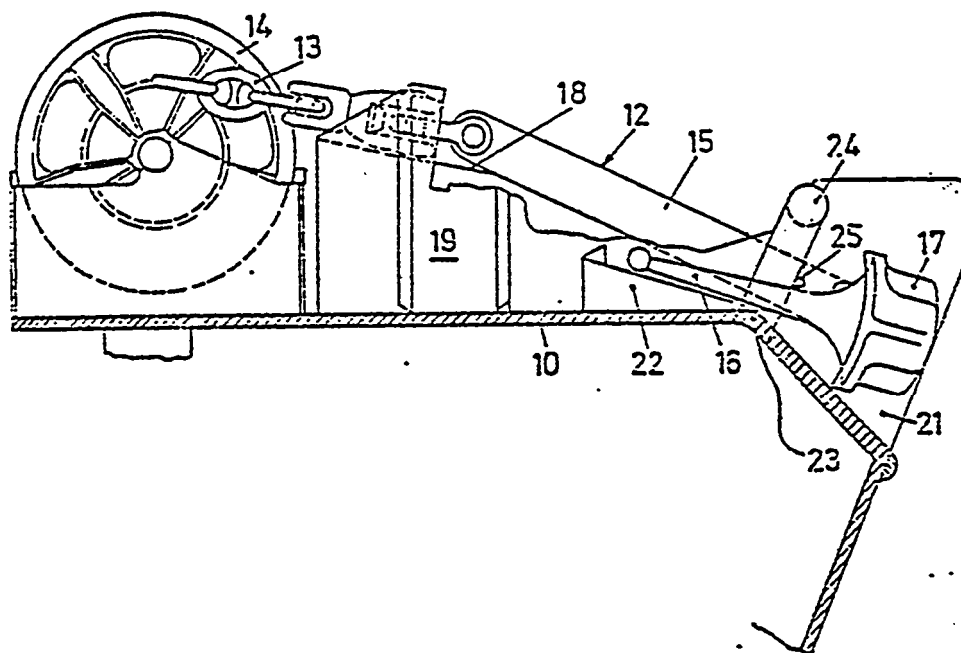
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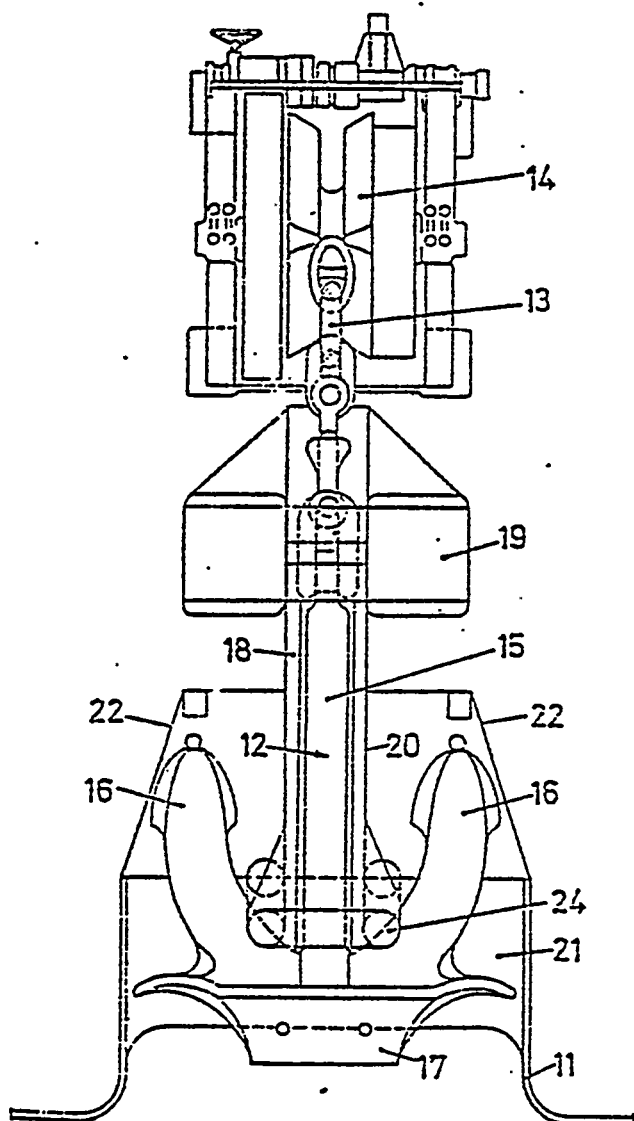
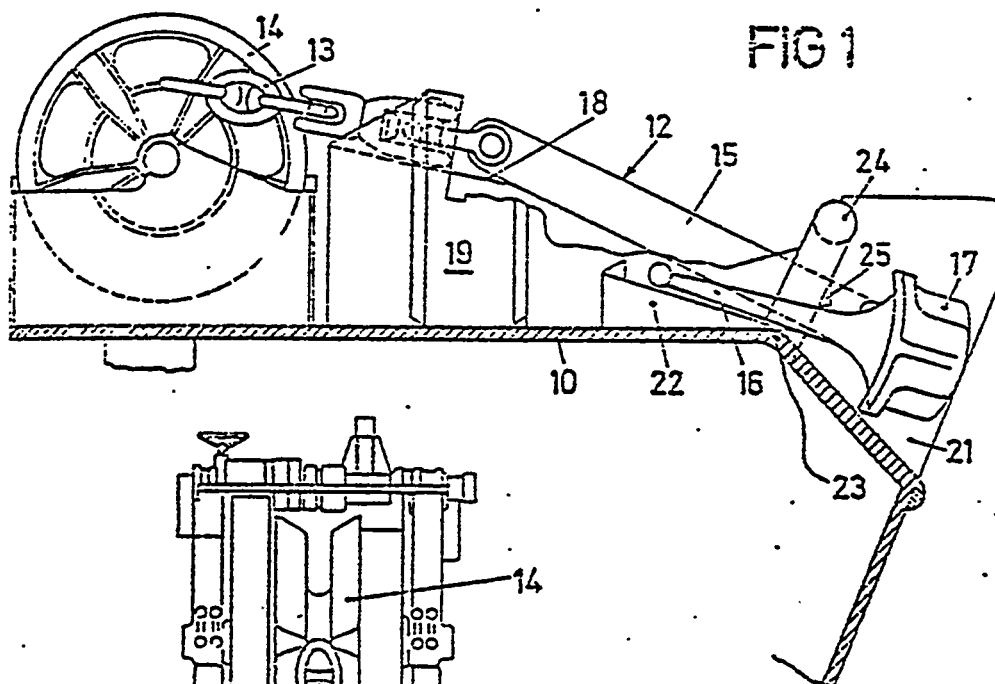
Primary Examiner—Trygve M. Blix
Assistant Examiner—Gregory W. O'Connor
Attorney, Agent, or Firm—Schovee & Boston

[57] ABSTRACT

The conventional anchor stowing arrangement on a ship includes a hawser pipe through which the anchor chain passes, and in which the leg of the anchor is normally located during a voyage. According to the present arrangement the anchor is stowed upon an open bed, easy to reach for inspection from the deck, and not likely to cause any damages during hauling-in.

3 Claims, 2 Drawing Figures





GÖTAVERKEN

APPENDIX E. 6

INBOARD ACCESSIBLE
STERN TUBE BEARINGS

"GLACIER-HERBERT STERN GEAR SYSTEM"

(GLACIER)

THE 'GLACIER-HERBERT'

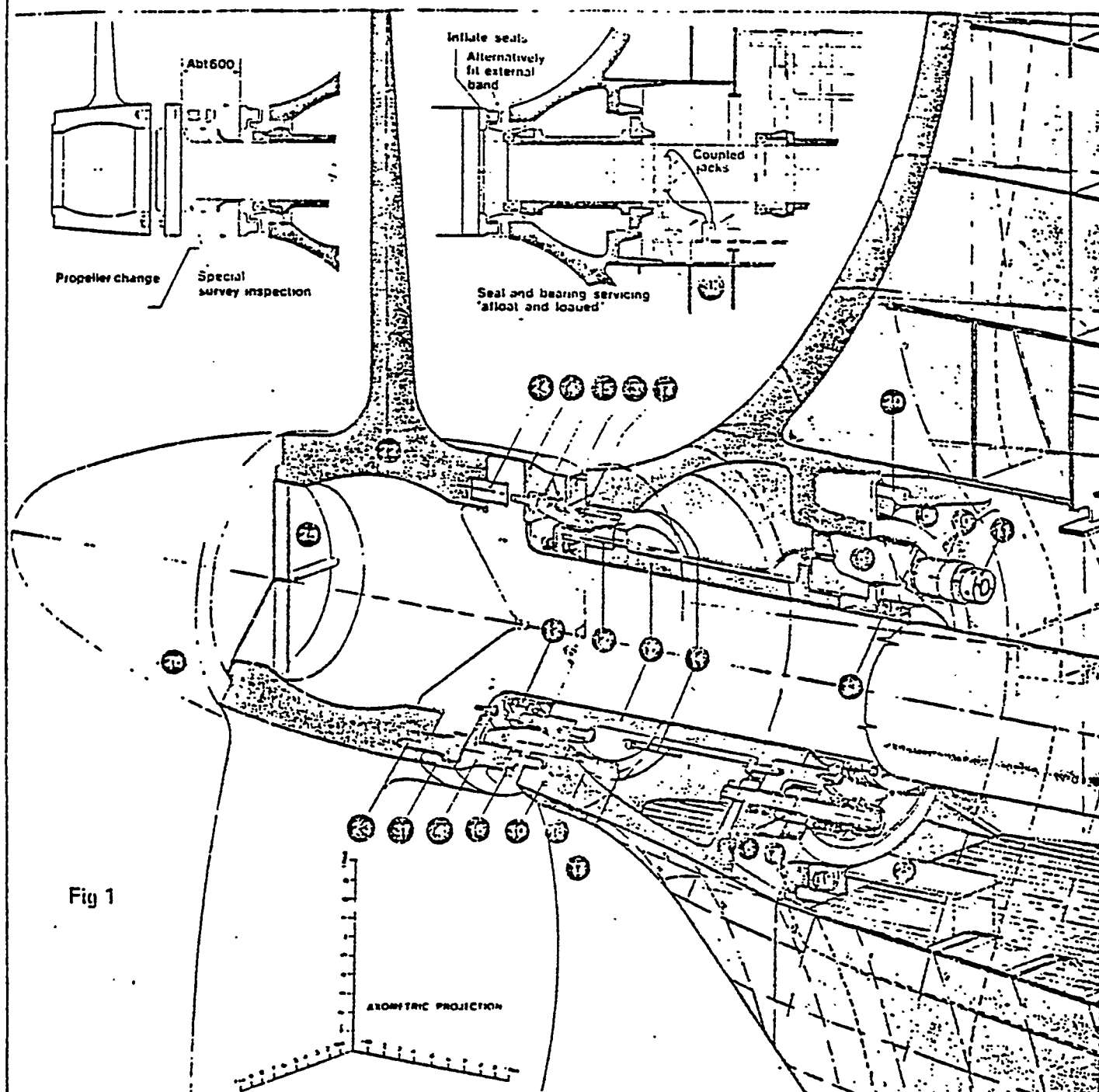


Fig 1

GLACIER-HERBERT DESIGN FOR MAXIMUM 'ON HIRE'

- 1 Outboard seal and stern tube bearing servicing with ship afloat and 'loaded'
- 2 Propeller changes and special survey inspection without tailshaft removal
- 3 Maximum shaft strength
- 4 Bearing reversible and invertable
- 5 Precision adjustable bearing alignment
- 6 Positive induced oil circulation and cooling

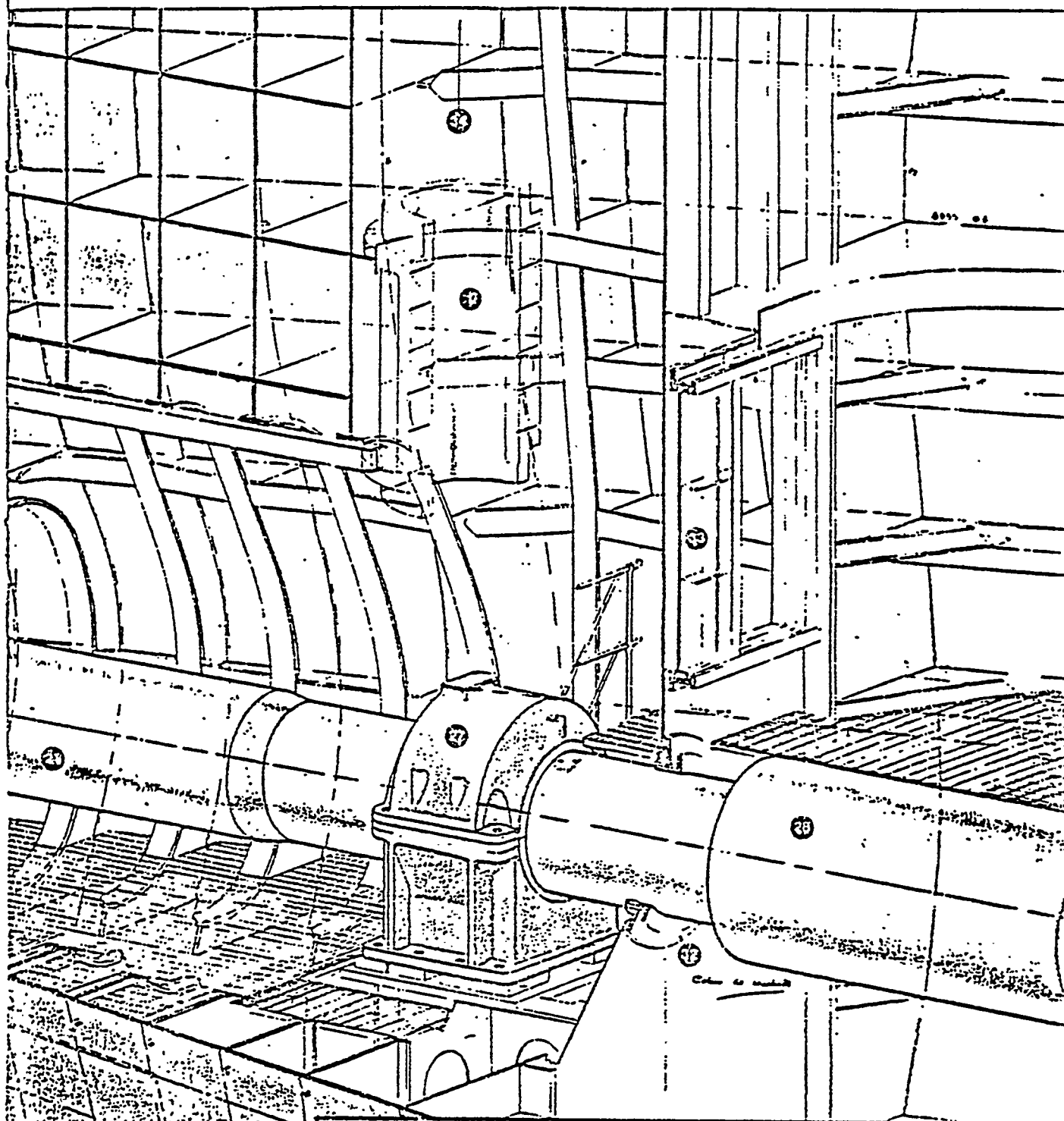
KEY TO COMPONENTS

1 BEARING HALL	8 BEARING SECURING CHUCK	15 INFLATABLE SEALS	22 PROPELLER	29 JACKING PAD
2 SPHERICAL CAMBER RING	9 AXIAL RETAINING POST	16 EXTERNAL COLLAR	23 PROPELLER FLANGE BOLTS	30 STERNWIRE CASTING
3 SPHERICAL SEATING RING	10 PRE-LOADED SPRING PIER	17 SEAL TEST CONNECTION	24 PROPELLER LOCATING PINS	31 FLANGE PROTECTION RING
4 FIRST CAMBER RING	11 PRECIP HYDRAULIC NUT	18 AIR SUPPLY TO SEALS	25 PROPELLER DIAPHRAGM PLATE	32 BULKHEAD GLAND
5 DIAPHRAGM	12 OUTBOARD SEAL ASSEMBLY	19 OIL PUMP & HEADS CON	26 PROPELLER CONE (Bushing)	33 VIT UNION (Local control)
6 LIFTING SUPPORT CHUCK	13 INBOARD SEAL ASSEMBLY	20 VIT TO HEADIN TANK	27 AFT INTERMEDIATE BEARING	34 SCRAM ESCAPE TRUNK
7 BEARING ALIGNMENT SHIM	14 OIL SUPPLY (50ml capacity)	21 PROPELLER SHAFT	28 S.W.T. SLEEVE COUPLING	35 JACKING OUTLET

Glacier-Herbert Patents: G.R. 1 209 786, 1 182 612, 1 186 858, 1 182 611; Denmark 118 995, France 1 599 912

STERNGEAR SYSTEM

GLACIER



GLACIER

STERN ARRANGEMENT FOR SUPERTANKER

265,000 TONS DW. CAPACITY . . . 32,444 SHP at 66 RPM

PROPELLER SHAFT DIA.	798
PROPELLER SHAFT LENGTH	9800
PROPELLER DIAMETER	8650
BOSS DIAMETER	1750
PROPELLER BOSS/DIA. RATIO	20 2/3
STERN BEARING LENGTH/DIA. RATIO	2

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