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FINAL REPORT

IMPROVED DESIGN PROCESS

part of the

SHIP PRODUCIBILITY PROGRAM

of

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

IMPROVED DESIGN PROCESS

FINAL REPORT

U. S. DEPARTMENT OF COMMERCE  
MARITIME ADMINISTRATION

IN COOPERATION WITH  
BATH IRON WORKS CORPORATION

## Report Documentation Page

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## FOREWORD

To help U. S. Shipyards meet the challenge of reduced subsidy rates as set forth in the Merchant Marine Act of 1970, the Maritime Administration initiated a U.S. Shipbuilding Research Program as a joint industry/Maritime Administration venture. The Ship Producibility Program is a key element of the total National Shipbuilding Research Program with its overall objective being to develop technical information which can be used effectively by U.S. shipyards to reduce the time and cost of building ships.

This report presents the results of Task D-2, Improved Design Process, which is one of the priority tasks in the Ship Producibility Program.

The study was conducted by General Dynamics' Quincy Shipbuilding Division under sub-contract from the Bath Iron Works.

The duration of the study was about eighteen months. The study was completed in April 1977.

This study could not have been completed without the interest and cooperation of the organizations interviewed, and the constructive criticism of the advisory committee selected by Bath Iron Works.

Avondale Shipyards, Inc.  
Bath Iron Works Corporation  
Bethlehem Steel Corporation, Sparrows Point  
Ingalls Shipbuilding Division-Litton Industries  
National Steel and Shipbuilding Company  
Newport News Shipbuilding and Dry Dock Co.  
Todd Shipyards  
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## SECTION 1

### OBJECTIVE

The primary objective of this task as part of the National Shipbuilding Research Program was to reduce the cost of shipbuilding in US shipyards. Specifically, it was intended to develop an improved ship design process with increased emphasis on producibility. Early results led to the consensus of all concerned that no improved process, per se, would result from this study, but that a number of significant improvements in the design process were possible. The design process as used herein includes the engineering and design work necessary to develop the preliminary and contract design plans and specifications and the construction drawings and data to build the ship.

Prior to the Merchant Marine Act of 1970 (MM'70), the preliminary and contract designs for most foreign trade commercial ships were developed by the ship owner, generally through the services of a naval architect. The design gave prime consideration to the owner's requirements, and because of MarAd competitive bidding and technical information requirements, the ship design could not be developed to specifically suit the different production facilities and methods of construction which were available at the various shipyards. Under the MM'70, the shipbuilder is encouraged to prepare his own design and market it to prospective owners. Thus, it is possible for the shipyard to tailor the design to its own facilities and methods resulting in a more producible design for his plant. It is also possible for an owner and his naval architect to use a design and contract negotiation process that will be equally cost effective.

Therefore, the purpose of this task was to study the preliminary and contract design processes and to define systematic approaches to contract level design, including definition of responsibilities and sequence of design and contracting tasks.

It was also the purpose to study the design processes used in various yards to produce the detailed construction drawings and methods of improvement to make them more cost effective and producible.

## SECTION 2

### SURVEY OF CURRENT PRACTICES

#### A. INTRODUCTION

The design practices used in various ship design offices were screened based on published papers and reports of past research supplemented by interviews, to identify the design processes in use and methods of designing for producibility that have been and are being used.

Work done or being done under other studies was not repeated. In general, repetitious descriptions have been omitted when references to previous papers fulfill the purpose, but brief summaries have been included when considered especially pertinent to this study.

Initially the Maritime Research Information Service and the Society of Naval Architects and Marine Engineers indices of publications were reviewed, and about 200 titles listed as possibly being pertinent. Elimination of duplications and those of doubtful value which were unavailable, reduced the number to about 80. Review of the papers or abstracts reduced the number to those now listed in the Bibliography, Appendix C. These documents were reviewed and brief annotations are given therein.

The SNAME book "Ship Design and Construction", Chapter I, by E. Scott Dillon, thoroughly considers the basic design, including development of the ship performance requirements, the determination of ship dimensions and proportions, and steps in the ship design process. Appendix C, item B11 describes the various steps in the precontract design process as applied to naval ships, and item A10 covers the post contract design process for a naval ship in great detail.

Appendix C, item B1 describes Japanese practices in preliminary design, scope and problems. discussion of engineering practices, schedules for design, design staff organization, etc.

Segments and facets of the ship design process are covered in items B6, B7, B8, B9 and B10, as indicated by the annotations. Item B5 illustrates a good structural design for producibility.

Various developments and possible improvements in the ship design process are considered in Appendix C items as follows:

Structural Design and Producibility	A1, A5, C20
Structural Member Configuration	A5, B5
Standards	A1, A6,B6, B7, B8
Use of Models	A1,A2, D5, D6
Computer Aided Design	A1, B6, C1, C6, C7, C9, C16, C17, C20
Machinery and Piping Modules	A3, A5, A6, D3, D4, D5
Working Plan Development	A3, A5, B7, B8, C17
Piping	A7, A9, C5, D5
Specifications	A6, A8

## A. INTRODUCTION (Cont'd)

In addition to screening the items listed in the bibliography, examples of bidding plans and specifications, owners' requests for proposals, and a few structural designs for producibility were examined. These covered 21 different designs: 7 by 4 different US design agents, 2 by 2 foreign design agents, 5 by 5 different owner's staffs, 2 by 2 foreign shipyards, and 5 by 4 US shipyards. Of these, four were prepared in 1968 and 1969, and the remainder (17) in 1971 to 1974. The designs developed for competitive bidding show little evidence of designing for simplicity and producibility of the steel structure; and it appears that the structural designs were based on rule requirements and minimum weight. In a number of cases, the designs have as many as four different stiffener spacings, curved (haunched) web frames and other high cost connections, many different shapes, non-symmetrical location of stiffeners on plates, etc. In contrast, examples of producible designs utilize only one stiffener spacing, symmetrical stiffener locations on plates, about one-half as many different shapes, simpler structure with fewer brackets, etc.

Based on the foregoing reviews, it was decided that the most benefit would result from interviews of US shipyard personnel concerned with design for producibility.

It was found that the interviews could not follow a pre-established outline, due to differences in the form of the interviews (individual vs group) and availability of personnel. Accordingly, various topics of interest were suggested, giving comments based on the literature review, to get the discussion started, and then a free ranging discussion followed. Before concluding each interview, suggestions for improvements in the design process were requested. Appendices 4 and B summarize the notes made during the interviews.

The following two pages titled "Ship Design", were taken from a document prepared by the Maritime Administration and furnished during the interview for this project, define concisely the various stages of ship design. It was the only written ship design definition available, although others have been developed for preliminary ship definition by computer, and others are described in the Bibliography items referred to above. In this report, precontract design includes MarAd's conceptual, preliminary, and contract design, and post contract design covers MarAd's working plans. It has been noted that the Design Spiral diagram has appeared in different form in other publications and could be different for different type ships. Considering the thrust of this study, producibility considerations would be incorporated in the spiral at arrangements, structure, light ship weight, and cost estimates.

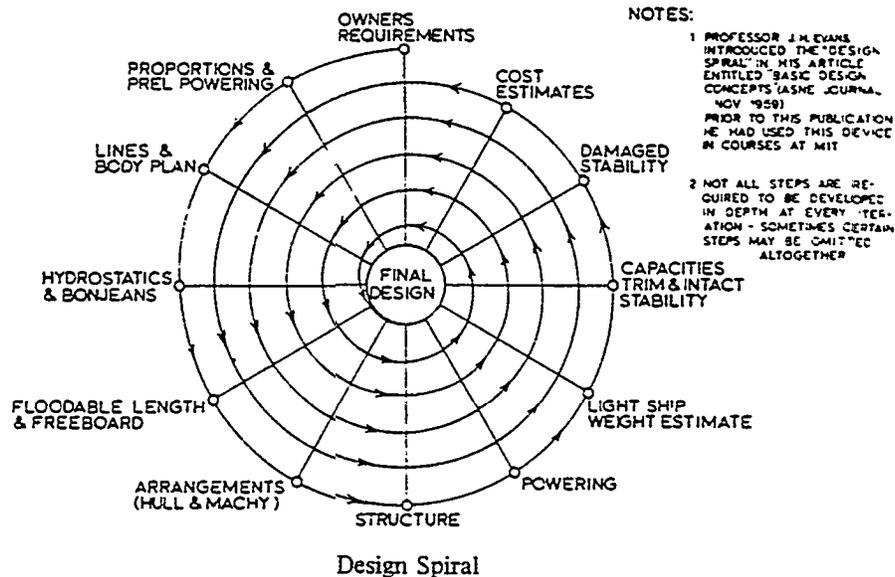
The following sub-sections on precontract and post contract design identify the design practices used and the scope of these phases, based on the literature review and the interviews.

## SHIP DESIGN

The term "ship design" takes on many meanings depending upon who is defining the term and in what context the term is used. The design of a ship generally progresses through four stages of development from overall to detail considerations with some overlapping between stages. These stages are:

1. Concept Design
2. Preliminary Design
3. Contract Design
4. Working Plans

After proportions have been tentatively selected, "ship design" becomes an iterative process as represented by the design spiral illustrated below. The "Final Design" state is the "ship design" ready for bids.



### 1. Concept Design

The first stage called concept design is an attempt to put the Owner's requests down on paper. This is basically a technical feasibility study to determine the basic characteristic of the proposed ship such as length, beam, depth, draft, speed, power, cargo cubic and deadweight. It will also include a preliminary weight estimate of light ship usually derived from curves, formulas and experience. The concept design is used as a talking paper for obtaining ball park construction costs for presenting Owner's requirements to a shipyard or design agent. This study is used as an input for the next stage of design development, the Preliminary Design.

### Preliminary Design

A ship's preliminary design is concerned with determination of major ship characteristics affecting cost and performance. It encompasses selection of ship dimensions, hull shape, powering, arrangement of hull and machinery, and major structure to assume attainment of desired speed, endurance, cubic capacity and deadweight. It also includes checks and adjustments for achieving the required cargo handling capacity, quarters, hotel services, subdivision and stability standards, free board, and tonnage measurements. The preliminary design terminates

## 2. Preliminary Design (Cont'd)

when there is reasonable assurance that the major features have been determined with sufficient dependability to allow the development of contract plans and specifications.

## 3. Contract Design

The final design, or contract design stage of a ship design is concerned with developing a set of plans and specifications which identify the ship contractually. If the Owner is to go out for competitive bids, these plans and specifications are part of the bidding documents. If the Owner is negotiating a contract, they describe the vessel to be built as mutually agreed between the Owner and the Contractor and also become part of the contract documents. They represent several more loops around the design spiral where each loop is a refinement of the previous one. Having established tentative proportions in the preliminary design stage, this stage delineates more precisely such features as hull form based on a faired set of lines, powering based on model testing, seakeeping and maneuvering characteristics more closely determined, the effect of propellers on hull form, determination of the structural design concept based on a midship section such as framing, (transverse, longitudinal) arrangement of stanchions, use of different types of steel, location and type of frame spacing, etc. Paramount, among the contract design features is a weight and center of gravity estimate giving the location of each major item in the ship as contracted with the lump sum values of steel, outfit and machinery developed during the preliminary design on concept and feasibility study. The final general arrangement of the ship is developed during this stage. This fixes the overall volumes, areas, and interrelationships between each feature on the ship such as room relationships, cargo handling features and machinery components.

## 4. Working Plans

The final stage in ship design is the detailed working plan stage. These plans are the installation and construction instructions to the ship fitters, welders, outfitters, air conditioning installers, machinery vendors, pipefitters, etc. They include such details as welding symbols, dimensions and size of holes, location of furniture, port lights, window cutouts, ladders, rails and stanchions, etc. There are literally thousands of working drawings needed for each ship. These working plans are also an indication of how a particular shipyard will put the ship together and cannot necessarily be used by another shipyard since each yard has its own sequence of erection and method of construction. Many yards have standard detail working plans which can be used from ship to ship. Such items as fastenings, some welding joints and procedures, and other procedures are examples.

These working plans are supplied to MarAd, usually on microfilm at the end of each ship construction contract for the Government's use in building future identical ships in national emergencies.

## B. PRECONTRACT DESIGN

### 1. General

This includes conceptual and preliminary design and contract plans and specifications.

There have been two fundamentally different approaches used in the recent past:

Preparation of the precontract design by the ship owner and his design agent. This is the method used prior to the Merchant Marine Act of 1970 for subsidized ships and for ships to be bid competitively.

Preparation of the precontract design by the shipbuilder. This method has been used by shipyards responding to inquiries from ship owners, and since the MM'70 it has also been used in conjunction with negotiated contracts for ships receiving government aid. This method generally results in more producible and lower cost ships, since the design is tailored to the facilities and production processes of the specific shipyard.

However, with the ship price levels existing in 1976, it was necessary under the MM'70 to have competitive bids in order to obtain a realistic subsidy rate. Thus, another design and bidding approach would be necessary to obtain the benefits of producible design and competitive bidding, unless the 35 percent CDS ceiling applicable to negotiated contracts as provided by MM'70 was modified. Bill HR-11504 to this effect was introduced in early 1976, passed the Congress, and was signed by the President in midsummer 1976.

It is apparent that with appropriate modifications to the bid form and pro forma contract, the precontract design process can be modified if it should become necessary so as to permit competitive bids on producible designs based on plans and specifications developed by an owner and his agent, as suggested later.

It should be noted in connection with the second method, that until recently, the inquiries received from ship owners defined the performance requirements, and little else, for the proposed ship, generally a tanker. In some recent cases, the inquiry requested an expression of interest and budget price and were accompanied by a preliminary design and brief specification. Then, after selection of the shipyard, the contract plans and specifications have been developed as a joint responsibility. In other cases, the ship owner inquiries were in considerable detail but did not include a preliminary ship design. The most significant example of this was for the El Paso LNG tankers and resulted in each bidder preparing a complete contract design and specification at considerable cost.

The following describes the scope of these precontract design approaches, the differences found, and suggestions for improvements.

## B. PRECONTRACT DESIGN

### 2. Owner Prepared Design for Competitive Bidding (Generally for Subsidized Ships)

The scope of the Specifications and Contract Plans and other data required by the Federal Maritime Board, now the Maritime Subsidy Board, under Title V for construction-differential subsidy is given by Form FMB-8 (dated 9-59, revised by internal MarAd memorandum dated November 5, 1970).

In the past, the FMB-8 scope was apparently considered to be inadequate by the owners and shipyards because the permissible minimum provided insufficient definition to the shipyard for pricing and to the owner to know what he is buying. The specifications were amplified and more guidance plans included. The November 1970 revision of FMB-8 and the MarAd Standard Specifications for Merchant Ship Construction dated December 1972 are more complete and list more plans than FMB-8, but both require less data than provided by owners in the past.

The differences between the MarAd Standard Specifications and Plans listed therein, and practice used by owners and design agents are evident from the tabulations on pages 2-9 and 2-10 and primarily are:

(1) Owner's specification is substantially more detailed and definitive (750 vs 450 pages). Specifications by foreign design agents are also more detailed in many areas.

(2) More plans by owners to define:

Cargo handling and stowage, especially for ships with sophisticated cargo systems.

Structural scantlings, especially for special ship types, and to support the detailed weight estimate.

Deck arrangement plans (1/4-inch scale) for each deck in the accommodations and service areas to incorporate all requirements embodied in crew union-management agreements.

Piping systems, utilizing the designers' standard diagrams and more detail to avoid misunderstandings.

### 3. Shipyard Prepared Design for a Negotiated Contract

The scope used by various shipyards on different projects range from a specification about 1/2 the size of MarAd's accompanied by four plans, to a specification more detailed than MarAd's accompanied by 32 plans. The larger scope was influenced by Government aid being involved in the project, so that it was necessary to define the ship more carefully, as the give and take of negotiation between owner and shipyard would be restricted.

## B. PRECONTRACT DESIGN

### 3. Shipyard Prepared Design for a Negotiated Contract (Cont'd)

The smaller scope is partly due to the fact that the contracts were almost always for tankers or bulk carriers, as compared with the more complex cargo and container ships of the subsidized projects. Also, in most cases, the basic design was developed by the shipyard and then modified to suit each owner's cargo systems, crew accommodations, etc., but retained the shipyard's standard practices in such areas as steel construction, outfit, propulsion plant, and quality of equipment. Thus, the shipyard developed specification did not have to be as detailed, as their standard practices were well defined by current or recent construction. The smaller scope of contract plans and specifications has proven adequate during execution of the contracts. Unanticipated developments generally were not due to the scope of the contract documents but to new interpretations of ABS or USCG rules or owners' requests for construction in excess of the ABS and USCG requirements invoked by the specifications.

Foreign shipyard's specifications and plans for negotiated contracts are brief and depend on standard practices or reference to a previous ship for detail definition.

### 4. Other Approaches

A recently used approach which was described at an Advisory Council meeting, and which was found to have been used on other occasions, consisted of:

- (1) Preliminary design was prepared by the owner's design agent and consisted of an outline specification, general arrangement plan, midship section plan, comprehensive equipment list and a weight estimate.
- (2) The preliminary design was submitted to various shipyards with request for budgetary estimate of price and delivery.
- (3) Conferences were held with interested shipyards to discuss budget price and define a level of confidence for the ship definition.
- (4) One shipyard was selected, and the owner and shipyard shared the responsibility (technical and financial) for developing the contract design to suit the shipyard facilities and practices and to obtain a completely mutual understanding of the contract plans and specifications.
- (5) Contract, with price and delivery finalized.

In the case of the LNG tankers, El Paso (J.I. Henry) prepared a soliciting specification which was in considerable detail (almost 300 pages - single spaced) supplemented by 13 guidance plans and contained the performance and quality requirements. It was not possible for the owner to prepare a definitive design because of the very significant differences in the LNG containment systems. Thus, each bidding shipyard developed a ship design and prepared their contract plans and specifications.

## B. PRECONTRACT DESIGN

### 4. Other Approaches (Cont'd)

The effort in each case (and that of the unsuccessful proposers) was in excess of \$500,000.

### 5. Bidding Plans and Specifications

During the interviews the shipyards cited deficiencies in current practices and suggested improvements in bidding plans and specifications with the object of reducing uncertainties, reducing bid time and costs to all bidders and cost to the owner.

These suggestions include:

- (1) In some areas, specifications should be more definitive such as standards for quality and acceptability.
- (2) In other areas, specifications should be more flexible to permit improvements.
- (3) Plans should be more definitive, and where pertinent should be approved by the regulatory bodies before issue for bids.
- (4) Piping diagrams should be sized and approved by USCG. (However, it is currently USCG policy not to act on plans for ships not under contract.)
- (5) Ratings of all engineered equipment should be given in the specifications.
- (6) Some additional plans are necessary to clearly define regulatory body interpretation of rules before bidding.
- (7) In cases where hull vibration and propeller cavitation may be a problem, investigation prior to contract should be made or special provisions incorporated in the contract.
- (8) Backup calculations and data prepared by the designer should be furnished to the bidders, such as model tests, detail weight estimate, strength calculations, volume calculations for cubic sensitive ships, vibration and cavitation studies, owner's design requirements and abbreviated design history, etc.
- (9) Scantling plans in addition to the scantlings, should show the required selection modulus for the stiffeners, frames, etc. to aid the shipyard in selecting their equivalent standard shapes.

Specific examples and more details, which are given in the appendices A and B, are considered in Section 3.

B. PRECONTRACT DESIGN

6. Scope of Bidding Plans and Specifications for Subsidized Ships

	FMB-8 1958	FMB-8 1970	MARAD STD SPECIFICATION 1972	TYPICAL SUBSIDIZED SHIP
Specification	Requires detail spec.	Requires detail spec. similar to MarAd	Standard Specification	Detail Specification
Specification Pages				
Sec 1 General			10	1 8
Sec 2-27 Hull			151	244 + 70 sketches
Sec 50 Machy General			2 + list	8 + 23 page list
Sec 51-86 Machy and Piping			166	253 + 14 page list
Sec 87-98 Electrical			67	127 + 7 sketches
Sec 99 Central Control			15	16 + 19 page list
Sec 100 Plans			13	17
Sec 101 Trials			1	
Sec 102 Portable Equip. and Tools			40	88
			445	777
Contract and Guidance Plans				
General Arrangements:				
Deck and Holds	X	x	x	x
Inboard Profile	X	x	x	x*
Outboard Profile	X	x	x	
Lines	X	x	x	x
Midship Section	& X	& x	x	x &
Machinery Arrangements:				*
Plans, Elev. Sec	X	x*	x*	On Machy Arr'gt
Arrangement Shafting	X	*	*	*
Power and Lighting-One Line	X			
Arrangement of Accommodations		*	*	X
Arrangement of Crew Quarters @	*	*		*
Arrangement of Service Spaces	*			
Accommodation Deck Plans @				*
Fire Control Diagram	*			
Steel Scantling Plan	*			
Scantling Plans. Sec and Elev		*	*	*
Cargo Handling (Dry)		*	*	*
Capacity Plan	*	*	*	*

LEGEND: X- Contract Plan  
\* - Guidance Plan

& - Approved by Regulatory-Bodies  
@ - 1/4-inch scale

B. PRECONTRACT DESIGN

6. Scope of Bidding Plans and Specifications for Subsidized Ships (Cont'd)

	FMB-8 1959	FMB-8 1970	MARAD STD SPECIFICATION 1972	TYPICAL SUBSIDIZED SHIP
Contract and Guidance Plans (Cont'd)	*	*		*
Curves of Form	*	*		
Floodable Length Curves	*	*		
Bonjean Curves	*	*		
Damaged Stability	*	*	*	
Intact Trim and Stability	*	*	*	
Vent and AC Diagram	*			*
Heat Balance Diagram	*			*
Piping System Diagrams		X	X	
FO Filling	*	*	*	*
FO Transfer	*	*	*	*
Ballast	*	*	*	*
Bilge		*	*	*
Firemain			*	*
Main and Auxiliary Steam			*	*
Boiler Feed and Condensate			*	*
FO Service		*	*	*
Main and Aux Circ			*	*
SW Service			*	*
Lube Oil Service			*	*
Lube Oil Purifying and Transfer			*	*
Aux Exh and Escape				*
Fresh Water				*
Feed Treatment				*
Cargo oil			*	*
Tank Cleaning				*
Diesel Generator Piping				*
Piping Material Schedule			*	In Spec
List of Motors and Controls				*
Electric Load Analysis	*	*	*	*
Typical Lighting Fixtures	@			In Spec
Lighting Fixture Schedule	@			In Spec
Electronics Antenna System				In Spec
Design Studies and Calculations (to MarAd Only)				
Lightship Weight and Center	@	*		*
Long Strength Study	@	*		*
Model Basin Test	@	*		*
Bonjeans				*
Curves of Form				*
Tables of Capacities				*
Loading Conditions				*
Damaged Stability				*

LEGEND: X - Contract Plan & - Approved by Regulatory Bodies  
 \* - Guidance Plan @ - 1/4-inch scale

B. PRECONTRACT DESIGN

7. Scope of Precontract Design for Negotiated Contracts

The scope of the precontract design plans and specifications for a negotiated contract has been whatever the parties to the contract agreed to, basically sufficient for the shipyard to price. and for the owner to understand the performance capabilities and quality of the ship he is purchasing

a Minimum Scope

The minimum scope, which applied to a tanker, consisted of:

Specification - About one half the size of the MarAd standard specification but very definitive on equipment and outfit being furnished, coatings, materials for piping systems, and some quality type constraints. Vendor names are used to define quality of machinery and outfit items.

General Arrangement. 1/16-inch scale

Accommodations Arrangement (but not showing furniture arrangement)  
(Specifications list all equipment in each room)

Structural Drawings (2)

Cargo System Diagram

With this minimum scope, the total definition of the ship depends on the shipbuilder's standard practices as exemplified by current construction and working plans.

b. More Definitive Scopes

For a tanker of a new design for a new client, shipyard prepared for a negotiated contract, the precontract design consisted of

Specifications - about the same size as MarAd standard

General Arrangement

Midship Section and Transverse Bulkheads

Arrangement of Machinery

Heat Balance and Flow Diagram

Diagram of Cargo Oil System

Diagram of Firemain System

Diagram of Foam Fire Extinguishing System

## B. PRECONTRACT DESIGN

### 7. Scope of Precontract Design for Negotiated Contracts (Cont'd)

Diagram of Inert Gas System

Diagram of Nine Propulsion Piping Systems

Elementary Wiring Diagram - Electrical Distribution System

For a container ship, owner prepared for a negotiated contract, the precontract design consisted of

Specification, about 450 pages

General Arrangement, profile and decks, 1/16-inch scale

Quarters Arrangement, including furniture arrangement, 1/8-inch scale

L i n e s

Midship Section

Machinery Arrangement

Heat Balance

Piping Diagrams (for systems in way of container holds)

Electric System Load Analysis

Container System Plans (9)

## C. POST CONTRACT DESIGN

Although varying in scope, methods, and details, all approaches to post contract design are fundamentally the same. The most fruitful sources for improvements to the post contract design process are the different criteria used by different shipyards in designing for producibility. These are described in items 1-9 which follow.

### 1. Producibility and Standardization of Steel Structure

#### a. General

Facilities and producibility requirements at each yard will generally result in a different midship section and basic structural design, as well as differences in the type of plans. These result from difference of opinion as well as differences in:

- Annual steel thruput capacity
- Unit sizes
- Plate sizes
- Frame and stiffener spacing
- Use of mill shapes or fabricated shapes
- Use of different standard structural details
- Fixity of unit production sequence
- Degree of nesting used
- Batch manufacturing of standard parts

Minimum prices and maximum profitability will usually result from series production of one ship type in a shipyard specifically designed for the purpose. Some yards are designed for such a purpose, whereas others are more flexible to handle a mix of ship types, with limited numbers of each.

#### b. Yard Constraints and Producibility

The yard constraints identified covered a wide range.

One yard has a fixed annual steel thruput, to optimize the manufacturing process, with facilities and other factors designed to match this requirement. Thus, for example, two large tankers or four smaller tankers may be produced per year, with significant difference in the thruput for outfit, machinery, etc.

Maximum plate sizes are limited by facilities, from 3 size of 90 inches x 40 feet to 120 inches by 60 feet. For a given design, standard plate sizes are selected considering hold or tank length, frame and stiffener spacing, etc. One yard buys only mill edge plates, and one yard buys only cold flange quality plates.

## C. POST CONTRACT DESIGN

### 1. Producibility and Standardization of Steel Structure (Cont'd)

Maximum unit or assembly sizes are determined by facilities. Weight Limits for most fabricated units are in the range of 80 to 200 tons except for one yard where it is 60 to 80 tons. Capacity in limited areas range from 400 to 1000 tons.

Frame and stiffener spacing is usually selected to suit the design but may be compromised to suit facilities where a process line is used to produce stiffened panels or to suit availability of mill shapes vs fabricated sections.

Some yards prefer to buy mill shapes to the maximum extent to minimize welding by eliminating manufactured equivalents. Channels up to the maximum depth obtainable ( 1.8 inches) are purchased and one flange stripped to produce an angle, whereas two yards manufacture all shapes above 9 inches depth. The Ingalls study (Appendix C, item A5 recommends fabricated shapes as less costly. At some yards, flanging or stripping is not allowed, and necessary shapes are manufactured.

Most yards determine the erection sequence schedule at the start of the contract and do not depart from the sequence. Schedule may be expanded or contracted to suit progress, but sequence is practically never changed. This permits cross nesting which most yards prefer not to do, but do to some extent. Two yards cross nest, one covering 10 units or a 2-week production schedule.

#### c. Standardization and Producibility

Most yards use standard structural details which are available on standard plans or in booklet form. These are updated and expanded as necessary for different contracts. Only one yard batch manufactures standard parts which are stock piled.

Most yards standardize plate sizes for most of the required quantity. One yard is using 124 different standard plates representing 77 percent of the steel plate weight plus about 260 different plan marked plates, both including variations in grade due to temperature requirements. The 124 different standard plates result from 36 lengths, 8 widths (44 sizes), 20 thicknesses and 6 grades. The total number of standard plates is about 6300, and the total number of plan marked plates is about 1100. Examples of plate standardization are evaluated in Section 3. Another yard uses about 400 different plates on a current tanker contract. Another yard building ships with considerable shape found that the scrap rate was too high when using standard plates and returned to plan marked plates throughout. Yards would like to use more standard plates than at present but feel the scrap rate would be too high.

## C. POST CONTRACT DESIGN

### 1. Producibility and Standardization of Steel Structure (Cont'd)

The scrap rate (where known) ranged from a low of 6 to 7 percent where all plates are plan marked and where parts are NC cut from lightening holes, etc., to 12 to 14 percent and increased to 14 percent with increased standardization.

Most shipyards attempt to standardize shapes, both mill and fabricated, which can be done with minor penalty in steel weight. Examples are discussed in Section 3.

### 2. Working Plans for the Steel Structure

Three types of plans were identified, as follows:

- Basic scantling plans, about 14 to 20 to cover the entire ship,
- Working plans or conventional system plans for decks, bulkheads, shell, etc.,
- Unit, assembly, shop or module plans.

Some yards use all three types of drawings, but one of these yards is considering omission of the second type. Three yards use only the first two types of plans with the units identified on the system plans, but one of these yards is considering unit plans for a new contract. Generally more than one unit is shown on each drawing. Three yards have used one unit per drawing, but only one is still doing so.

One yard shows all outfit items such as foundations, access ladders, pipe, vent ducts, etc., on the unit plans; one did so on a previous contract but is not doing so now; and one yard indicates only ladders and steel for foundations by part number of the standard detail. However, yards install piping and other outfit in the units before erection using the applicable system plans.

All agree that structural design is more costly than heretofore but saves cost in the yard, especially where a high labor turnover rate exists (agrees with Appendix C, Item AS, Final Report, pages 3-15, 16, 17).

### 3. Plans and Plan Approvals

The number of plans developed for a design is now substantially more than heretofore. Comparing plan schedules for tankers, the number of plans listed ranged from 347 for the smallest tanker to about 1100 for the largest. However, the latter also included many unit plans which increased the number significantly. Considering the intermediate sizes, the number of plans is approximately 325 plus 1.2 (dwt/1000)(4 of 6 yards, other two 350 higher).

## C. POST CONTRACT DESIGN

### 3. Plans and Plan Approvals (Cont'd)

The substantial increase in number of plans has been counteracted by steps taken by some yards to reduce the number submitted for approval. This includes:

Submittal and approval procedure proposed by ABS and USCG to minimize duplication is being used.

Basic structural plans are developed in such format and detail that these suffice for approval purposes. Unit plans are not submitted except when specifically requested, such as for the LNG ships.

The piping diagrams are prepared in such format and detail that approval of the diagrams is sufficient, and piping arrangement plans are not submitted except when specifically requested after submittal of the diagram.

Submittal of the plan schedule to regulatory agencies for them to indicate plans to be submitted is counterproductive. Shipyards should prepare the list of plans for submittal based on the ABS and USCG rules requirements and list of key plans required by MarAd.

However, problems still exist. Shipyards have suffered financially from reversals of regulatory agency approvals and new interpretations of the regulations. At least one yard has protected itself by including changes in interpretations of rules with changes in the rules as a change under the contract. Also, yards pointed to owners who appear unwilling to accept ABS requirements as being adequate, requiring considerable engineering effort to justify the rules.

### 4. Lofting and Numerical Control

Lofting and hull planning is within the production department, where fabrication and erection work packages and NC tapes are prepared, at all shipyards, except that nesting and NC tape development is a design function at one shipyard. This NC group monitors tape performance at initial use and makes corrections, if necessary, immediately. QC monitors dimensional control of units and fit up and notifies the NC group immediately of any necessary corrections.

NC is used for burning all shipyards except one, which uses an optical method.

## C. POST CONTRACT DESIGN

### 5. Holes Control

Holes list is submitted by the various departments to the hull structural section (generally) for approval, and compensation noted if required. At one yard all holes are shown on the structural plans of tankers, but only holes requiring compensation are shown on structural plans of other ship types. One yard tracks only holes 1-1/2-inch diameter and greater. Generally holes are field cut, but at least two shipyards incorporate holes on the NC tape as soon as practicable, generally after the first few hulls.

### 6. Machinery and Piping Modules or Packages

Purchased or shop assembled machinery and piping modules have been used by a number of yards, up to 15 modules per ship, to simplify design, expedite installation, and reduce costs. It was noted that equipment must be ordered sooner so that the large modules can be assembled in the shop and installed in the engine room at an earlier stage than if the components are installed individually. This reduces time in the critical path which usually includes the engine room.

The modules or packages may be small, such as a reducing station piping assembly, or quite large, such as a fuel oil service system which includes pumps, heaters, strainers, motors and controllers, control, regulating and relief valves, instruments and gage boards, all interconnecting piping and valves, and ail mounted on a common foundation, or a pump room assembled on a tank top unit.

Use of packages simplifies piping design thru use of the local composite.

Also, see Appendix C, item A6 and Vol II of Item A5.

### 7. Piping

Piping design uses four types of plans - diagrams, arrangements, composites, and details.

Piping diagrams may be of the conventional type or a more complete type as used by two shipyards to permit obtaining regulatory approval of the diagram as the only piping system plan that will be submitted. For the latter, the diagrams are more carefully drawn for arrangement significance and include on the diagram or on additional sheets the symbol list, general notes, material schedule, valve list, instrument list, pump data table, flow data table, and system design characteristics. These yards also make a practice of purchasing only USCG certified valves, etc. which minimizes approval problems.

## C. POST CONTRACT DESIGN

### 7. Piping (Cont'd)

Arrangement plans are prepared either before or after the composites, or not at all, and may be single or double line. All yards use composites for interference control, and usually the engine room and other congested space piping systems are developed on the composites. Piping systems outside these spaces are usually developed on the arrangement plans and checked locally for interferences on composites.

Composites may be only a tool for interference control, or may be a base for the arrangement plan, or may be the only arrangement plan. One shipyard develops the arrangement plan and uses the composite only as a tool to check interferences. One yard develops the systems on the composite, makes a number of reproducibles from the composites, and then heavies up one system on each reproducible to become the system arrangement plan after addition of the title block, notes, material identification etc. This method of producing arrangement plans is also used in European shipyards. One yard prepares a composite arrangement plan of all systems in various three dimensional zones of the engine room. These composites are the arrangement plans and are used along with the diagram, which is the only system definition, for installation purposes. Other yards prepare the arrangement plans by lifting the piping arrangement from the composites.

The pipe details are generally prepared in the pipe shop, except for stressed systems. At one shipyard, the pipe details are prepared by design and are now being developed and drawn by computer.

A number of shipyards have tried piping interference control by a commercial computer service firm that had developed programs for this purpose. The results were unsatisfactory, too late, and costly, Yards have tried models for interference control, with similar results.

European shipyards, Kvaerner Moss as an example, develop their engine room piping arrangements by use of a large scale model of the engine room. Piping designers and model makers work together, developing the piping runs in the model using the piping diagram. When the model piping is complete, freehand isometric pipe details are prepared based on dimensions taken from the model, and the material data added. The piping design then consists of the diagram, the pipe details, and the model, and the installation is made from these. Moss considers this method to be satisfactory and cost effective. only one US yard appeared interested. MarAd pointed out that their rules require a complete set of drawings upon ship completion, so that duplicate ships could be built during an emergency by other shipyards which would be difficult if not impossible without piping arrangement or composite plans. Also, see Appendix C items A2, A9, A13, D5, D6 and additional discussion of models in Section 3.

## C. POST CONTRACT DESIGN

### 8. Material Control

This is generally computerized, although a few Yards still use manual means. These will be computerized, as the material control technicians are a vanishing race.

### 9. Equipment Specifications

Generally these are not standardized, the most recent similar specifications serving as a base. One yard with a Materials Division in the Engineering organization has standardized purchase specifications and terms and conditions. Also, see Appendix C, item A6.

#### D. ENGINEERING AND DESIGN ORGANIZATION

The Engineering and Design organization in the shipyards reviewed have many differences. Appendix D shows 4 examples.

It will be noted that there are two fundamental variations, (1) where Engineering and Design responsibilities are separate and report to the Director of Engineering, and (2) where the Naval Architecture, Marine Engineering and Electrical Engineering managers report to the Director of Engineering and Design. In the later, for example, the Chief Marine Engineer has responsibility for engineering and drafting of the machinery plant. There are other variations as shown on the charts.

Undoubtedly these variations affect the design process, and all may have merit. The type of organization & most often responsive to the work load and production requirements and to the personalities and experience of the individuals in the top levels.

Study of the examples may suggest an improvement where a problem may exist.

## E. USE OF COMPUTERS

### 1. General

Today, the application of data processing to the ship design process is common throughout the world. Design agents, shipbuilders, educational institutions, regulatory bodies and governmental agencies all utilize computers in varying degrees throughout ship design from concept development to the preparation of instructions to automated devices. This spectrum of computer related activity in shipbuilding, as it has in industry in general, has come to be known as Computer Aided Design and Manufacturing (CADAM). Effective improvements to the total ship design process can be realized through increased CADAM.

### 2. Questionnaire

To recommend specific improvements, it is first necessary to research the current use of computers as well as identify existing and potential applications which are consistent with today's technology. To this end contemporary literature, both foreign and domestic, was reviewed and compared, and publications relating to CADAM identified and listed in a separate category in Appendix C. In addition, each of the design activities visited were asked the extent of their current CADAM activity and were requested to complete a prepared questionnaire. Two forms were submitted, one concerning precontract design and the other applicable to post contract design. Seven replies were received concerning precontract and eight related to post contract design applications. A summary of the responses is contained in Table E-1 of this Section. The completed questionnaires provide information on data processing hardware and programming resources as well as programs used and their source for each major design task including lofting and NC data preparation.

The individual tasks identified in the questionnaire are not meant to be all-inclusive of those required for a ship design effort but represent principal activities in order to provide a valid sampling of CADAM activity. The applications added by the respondents give additional indications of the extent to which the computer is being used as a tool in performing diverse design tasks.

The analysis of the responses provides a good overview of the application of computers to commercial ship design in the United States today. In addition it identifies tasks not presently performed with computer assistance and thus provides candidates for program and system development.

All activities responding have their own in-house, large scale computers, with all but one using IBM equipment. Each has a staff of technical programmers ranging in size from 2 to 16 people. Three activities reported that they also use external service bureaus for specific applications which require sophisticated analysis methods and programs. Access to commercial systems for finite element analysis of structure is a prime example.

## E. USE OF COMPUTERS

### 2. Questionnaire (Cont'd)

As indicated in the table, the bulk of the program development, between 65 percent and 70 percent, is performed by in-house programmers, while approximately 17 percent to 22 percent of the programs are acquired from Government sources. The majority of these programs is provided by the Navy with the balance by MarAd. The programs are available at no cost to yards performing Government contracted work. The balance of the programs is purchased from commercial sources.

Questionnaire results indicate that both the pre and post contract design phases rank high in efficient use of computers. Naval Architecture tasks receive the greatest coverage while computerized drafting receives the least. The spread in number of applications reported is not great, indicating that computer utilization is probably about the same level throughout the industry.

### 3. Precontract

Much of the precontract design studies, calculations, etc. are accomplished through use of computers. The replies to the questionnaire indicate high usage and small opportunity for any major improvement.

### 4. Post Contract

For post contract design, the basic computational tasks appear to be well covered by most activities. Other tasks appear to be adequately covered by some yards but not others. Some broad areas are generally deficient in programs such as heating, ventilation and air conditioning. There is relatively little application of computers to plan production or drafting as well as drafting room tasks such as interference checks or holes control.

The responses show that few activities utilize weight programs for precontract design, illustrating the emphasis on empirical data during this stage of the design cycle. All those responding use one or more programs during post contract design to assist in weight control and the preparation of a detailed weight estimate. Experience has shown that final weight and center of gravity estimation is still primarily a manual lift of lengths, areas, and lever arms from plans and unit weights from tabulated data, with computer use limited to calculations and summation of weights and moments.

## E. USE OF COMPUTERS

### 4. Post Contract (Cont'd)

Some applications listed are performed as part of numerical control systems such as AUTOKON and SPADES. Lines fairing with the aid of a computer has been developed to a high degree of accuracy as part of these systems. The data thus developed forms the basis for many design and related manufacturing tasks such as the Lines Plan, Shell Expansion Plan, engineering and working drawings and sketches, the 1:10 Body Plan for lofting, shell plate development, NC tapes for flame cutting ships parts, production control data and development of various jigs and fixtures. Six of the seven shipyards responding currently have systems of this type.

Information from the Visits, questionnaires and other surveys such as those conducted by Avondale and CADCOM, Inc. (Appendix C, items C9, C10, C11), define the current status of CADAM in US shipbuilding and constitute the basis for suggested improvement. Areas identified from the questionnaire of current practices as possessing cost savings potential through expanded application of computers include:

- Holes Control and early incorporation in NC burning
- Heating, Ventilation, and Air Conditioning design calculations
- Computer Aided Drafting
- Computerized Pipe Details

These applications were reviewed, and the extent of computerization desirable, general approach, economic analysis and implementation suggestions are discussed in Section 3.

TABLE E1

SURVEY RESULTS ON THE  
USE OF COMPUTERS IN THE SHIP DESIGN PROCESS

Based on returns of questionnaires submitted to Ship Design activities. One respondent does no Precontract Design and some respondents have several programs applicable to the same task. Those tasks marked with an asterisk (\*) were added to the list by respondents.

Task	No. Using Computer	Program Source				Use Outside Service	Remarks
		In House	Navy	Marad	Other		
1. Prelim. Ship Definition		2	-	-	1	-	
2. Economic Analysis	5	5	-	1	-	-	
3. Hull Form Generation	5	4	1	1	1	-	
4. Preliminary Hydrostatics	7	6	2	-	1	-	
*Irregular Shapes - Marad	-	1	-	NA	-	-	
5. Loading, Trim, Stability	6	5	2	-	1	-	
*Floodable Length - Marad	-	1	1	NA	-	-	
6. Damaged Stability	7	4	2	-	1	-	
7. Resistance & Powering	5	4	-	1	1	-	
*SHP Calculations - Beth Stl	-	1	-	-	-	-	Converts EHP to SHP
8. Longitudinal Strength	7	6	2	-	1	-	
*Section Mod of Long's - Beth Stl	-	1	7	-	-	-	
*Tanker Stresses - Beth Stl	-	1	-	-	-	-	Stresses for Various Tanker Designs
9. Transverse Strength	3	1	-	1	1	1 <sup>(1)</sup>	(1) ABS "DAISY"
*Optimum Webs on O1 Bhds - Beth Stl	-	1	-	-	-	-	
10. Weight Analysis	2	2	-	-	-	-	
*Wt. Curve drawing - Avondale	-	1	-	-	-	-	
*Ship wt. Report - Avondale	-	1	-	-	-	-	
11. Capacities and Tonnage	5	3	1	-	1	-	
12. Sea keeping	4	1	-	1	3	-	
13. Prelim. Heat Balance	6	4	1	1	-	-	
14. Load Line Cales. (Freeboard)	3	2	-	2	-	-	
15. Prelim. Vibration Analysis	4	4	-	-	-	-	



Postcontract

2-26

Task	No. Using Computer	Program Source				Use Outside Service	Remarks
		In House	Navy	Marad	Other		
1. Final Hydrostatics	8	4	3	-	1	-	
2. Intact Stability	8	3	3	-	2	-	
3. Damaged Stability	8	3	3	-	2	-	
4. Tank Capacities	8	5	1	-	2	-	
5. Sounding Table Calcs	8	8	-	-	1	-	
6. Launching Calcs	5	5	-	-	-	-	
7. Inclining Calcs	2	2	-	-	-	-	
8. Weight Control	8	7	1	-	-	-	
9. Structural Section Properties	7	7	-	-	-	-	
10. Frame Analysis	7	3	-	-	1	3	
11. Stiffened Plate Analysis	6	4	-	-	1	1	
* Structural Analysis Plots - Avondale	-	1	-	-	-	-	
12. Hull Girder Vibration Analysis	3	2	-	-	-	-	
13. Cargo Boom Analysis	2	2	1	-	-	-	
14. Mast & Rigging Design Calcs	3	3	-	-	-	-	
15. Rudder Design	2	2	-	-	-	-	
16. Heat Balance	6	4	1	1	-	-	
17. Propoller Design Calcs	3	2	1	-	-	-	
*Straight Cut Prop. Sections - Avondale	-	1	-	-	-	-	
*Blade pattern Sections - Avondale	-	1	-	-	-	-	
*Propeller Blade Gauges - Avondale	-	1	-	-	-	-	
*Cavitation - Avondale	-	1	-	-	-	-	
18. Pipe Stress	7	2	4	-	-	1	
*Pipe Vibration - Avondale	-	-	-	-	-	1	
19. Pipe Sizing	5	2	3	-	-	-	
* Ovbd discharge lines - Avondale	-	1	-	-	-	-	Half-breadth and Angle
* Pipe Friction Tables - Avondale	-	1	-	-	-	-	
20. Vent Duct Sizing	4	3	-	1	-	-	
21. Pressure Drop Calcs	4	4	-	-	-	-	
22. Heating & Cooling Loads	4	2	1	1	1	-	
23. Airborne Noise Calcs	1	1	-	-	-	-	

Task	No. Using Computer	Program Source			Use Outside Service	Remarks
		In House	Navy	Marad Other		
24. Shafting Calcs	6	4	1		1	-
* Shaft Vibratton - Nat. Stl.	-	-	1		-	-
* Torsional Vibration - Avondale	-	1	-		-	-
25. Bearing Sizing	4	3	1		-	-
26. Voltage Drop Calcs	3	2	1		-	-
* Fault current - Avondale	-	1	-		-	-
* Fault Current - GD	-	1	-		-	-
* Fault Current - Newport News	-	-	1		-	-
* Fault Current - Natl. Stl	-	-	1		-	-
* Illumination Survey - Avondale	-	1	-		-	-
27. Electrical Load Calcs	6	6	-		-	-
* lighting System Loads - Avondale	-	1	-		-	-
28. Cabling & Wiring	4	1	2		-	1
29. Computer Aided Drafting						
System Diagrams	1	1	-		-	-
Structural Plans	4	1	-		3	-
Arrgt. Plans	2	1	-		1	-
Mechanical Plans	1	-	-		1	-
Piping Plans	3	2	-		1	-
Ventilation Plans	0	-	-		-	-
Electrical Plans	1	1	-		-	-
* Lines Plan - Avondale	-	-	-		1	-
* Lines Plan - GD	-	1	-		-	-
* Shell Expansion Plan - GD	-	-	-		1	-
30. Interference Cheek	0	-	-		-	-
31. Holes List	1	1	-		-	-
32. Material Control	3	3	-		-	-
* Spare parts & Repair Cent - Ingalls	-	1	-		-	-
33. Material Ordering	3	3	-		-	-
34. Plan Scheduling & Progress	4	4	-		-	-
35. Lofting	6	1	-		5	-
36. Piping Fabrication	2	2	-		-	-
37. Numerical Control	6	1	-		5	-
38. Testing & Trials	1	1	-		-	-
* Torque - Beth Stl.	-	1	-		-	-

Calc. Propulsive  
Properties from Trials

<u>Task</u>	No. Using <u>Program Source</u>				Use Outside Service	Remarks	
	Computer	In House	Navy	Marad Other			
<b>39. Other</b>							
* Valves - Beth Stl.		1				Evaluates Fire Main Sys.	
* Foam System - Beth Stl		1					
* Harmonics - Beth Stl		1				Calculates Cycling Distribution (Wake)	
* Derrick Barge Design - Beth Stl		1				Draft, Trim, Heel	
* Turbine Nozzle Stm. Flow - Beth Stl.		1					
		Totals	138	30	3	29	7
		% of Total	67%	15%	2%	14%	3%

## F. DESIGN COSTS

The proposal for this project suggested cost evaluation of the differences in the design processes. Insufficient data is available for meaning analysis.

The shipyard engineering and design departments recognize that manhours used for ship design currently are much higher than heretofore. This results from the determined efforts to design for producibility and to provide clear and accurate detail fabrication plans to the production departments. Evaluations have been made by the shipyards of the higher design costs, and they have been justified by reduced production costs. It was commented that high production labor turnover forces the higher plan requirements, and that an extensive parts numbering system for inventory and production control increases design hours significantly but reduces cost elsewhere.

Currently precontract design for a negotiated contract for tankers similar to a previous design but modified for the new owner's requirements required about 3000 to 5000 hours. For a new and more complete tanker design, the effort expended was about 13,000 hours. For new technology designs, the precontract effort expended was 25,000 hours and upwards. Pre 1972 precontract design for competitive bidding (excluding model tests) cost about 2 to 2-1/2 percent of the cost of one ship. Insufficient data is available for the post 1972 period to provide a similar yardstick.

Post contract engineering and design costs during the pre 1972 period for cargo ships and container ships ranged from 7 to 14 percent of the cost of one ship. Again, post 1972 data is scarce, but it appears that the percentage is in the same range. Some examples of manhours being used for engineering and design are given on pages 3-21, 3-27, 3-29.

## SECTION 3

### DISCUSSION AND EVALUATION OF SELECTED IMPROVEMENTS

#### A. INTRODUCTION

##### 1. Precontract Design

The foregoing SECTION 2 defined the precontract design processes used by shipowners and shipyards, the scopes thereof, and identified problem areas and suggested improvements. The principal problem areas were (1) the conflict between the specific detailed precontract design developed by the shipowner and/or his design agent, and the shipyard production optimized design, especially when competitive bidding was necessary in order to obtain a realistic construction differential subsidy, and (2) what design approach should be used to obtain the price benefits of producibility.

Partial solution of the first problem has resulted from enactment of public law (PL 94372) Negotiated Shipbuilding Contracts Act of 1976 which will minimize the occasions when competitive bidding is necessary. For negotiated contracts, the shipyard's producibility features can be introduced into the contract plans and specifications during the negotiation phase and prior to final price determination and contract signing. Then the acceptability of the producibility features should result from precontract technical negotiations between the shipyard and the shipowner and/or his design agent.

Also, from the survey, it was clear that one shipyard's optimum design for producibility would not be optimum for others. and that bidding on a design suitable for only one shipyard would not result in competitive bidding. It was also noted that some suggested precontract design improvements were indicative of contacting desires for increased flexibility so as to introduce design for producibility and for increased design definition and detail to reduce cost estimating uncertainties.

It is doubtful if all these conflicts can be resolved, and it is not possible to examine them in depth within the scope and budget for this study. The basic problem was discussed in depth in the SNAME 1975 paper "Toward Responsible Shipbuilding" by Boylston and Leback (Appendix C, item B9). As stated therein, the plans and specifications should be complete, definitive, and not ambiguous, and the contract should be clear, concise, and clearly define the responsibilities of the parties.

## A. INTRODUCTION

### 1. Precontract Design (Cont'd)

These conflicts are most significant for advanced ship designs and for these, the definition of responsibilities may indicate little incentive to introduce cost saving producibility in the design considering the risks. For more conventional designs it should be possible to furnish the increased definition and detail to expedite pricing and minimize uncertainties in the areas suggested and to define in the bid or contract documents the areas of the design which may be modified for shipyard producibility. This resolves itself into defining the plans and technical information furnished for bidding as firm contractual requirements, guidance plans, or bidding information, and the assignment of responsibility for each.

While the major item of producibility is the structural design, this and other areas identified as having a significant impact on producibility and price include:

- Structural design
- Coating system
- Machinery plant
- Central control system
- Type of accommodations and joiner construction
- Cargo systems
- Specifications for components
- Standard details and practices
- Quality and workmanship standards

Modified precontract design procedures and scopes are presented below in subsection B, and other specific improvements are discussed in subsections E, G, and H.

### 2. Post Contract Design

In the post contract design phase, it was the general concensus that no improved design process. per se, would result from this study, but that a significant number of improvements were possible. Most of the improvements identified are not new. It was found that at least one shipyard is practicing or developing each of the improvements, but on the other hand. there is no shipyard employing or developing all of the improvements. The list of possible improvements was reviewed, and a number selected for economic evaluation and others for discussion and qualitative evaluation. It will be noted that the primary study areas are structural and piping design which consume about one half of the engineering and design budget and about 65 percent of shipyard labor. These are covered in subsections C and D. and other specific improvements are discussed in subsections E, F, G and H.

## B. PRECONTRACT DESIGN

### 1. Design Procedure for a Negotiated Contract

As the first step it is assumed that the owner solicits shipyards for proposals for budget price and delivery for the shipbuilding project. He should furnish the yards with project requirements and information as follows:

- (1) Performance requirements
  - Number of ships, route, fueling ports
  - Cargo types, deadweight, and capacities
  - Service and trial speeds with design deadweight
  - Endurance range
  - Route and port restrictions
- (2) Outline specification, or owner's standard specification including Class, Flag, and Regulatory Agencies
- (3) Type of power plant, preferred or required
- (4) Cargo handling and stowage requirements
- (5) Crew requirements, including all requirements embodied in crew union-management agreements. and preferably including sketches of the accommodation and service areas
- (6) Central control systems, preferences or requirements
- (7) Coating systems, preferences or requirements
- (8) If MarAd participation will be involved a copy of the preliminary Design Study, Schedule I. as required by FMB-8.

After consideration by the shipyards, the owner would contact and hold conferences with the interested shipyards to discuss budget price and to define a level of confidence for the ship definition, price, and the ability of the yards to produce.

Then a shipyard would be selected and the owner and shipyard would combine technical skills and financial involvement to develop the contract design. The objective is to produce a design which suits the owner's needs and the shipyard facilities and practices and to promote a completely mutual understanding of the contract plans and specifications.

## B. PRECONTRACT DESIGN

### 1. Design Procedure for a Negotiated Contract (Cont'd)

If MarAd participation is involved, the first step in the development of the contract documents should be the preparation of the Preliminary Design Schedule I-A and II. as required by FMB-8.

The scope of the precontract design which would result from this procedure would vary depending on circumstances, as suggested in the following articles.

### 2. Scopes of Recontract Design

#### a. Minimum Scope (for non-subsidized projects)

The minimum scope, which could apply to a tanker which is basically similar to previous or current construction, would consist of the following:

**SPECIFICATION** — This need not be as detailed as the MarAd standard specification in areas where similar previously constructed ships can be cited as examples but would be very definitive on machinery, equipment and outfit being furnished. central control systems, coatings. materials for piping systems. and some quality type consultants. Sender names would be used to define quality of machinery and outfit items, and the term "or equal" would be carefully defined.

**GENERAL ARRANGEMENTS, HULL AND ACCOMODATIONS** – Incorporating the owner's requirements and desires as agreed to, and compatible with the structural design. Scale 1/16 inch to 1 foot. Room arrangements not shown.

**STRUCTURAL DRAWINGS** - Two or three drawings to show the basic structure and the producibility features and practices, preferably approved by ABS or other classification society.

**CARGO SYSTEM DIAGRAM** – Complete and detailed to show owner's requirements and reflect shipyard's practices. Approved by ABS and USCG, if possible.

This minimum scope defines the basic contract parameters. The total definition of the ship quality standards. etc.. depends on the shipbuilder's standard practices which are exemplified by and readily referred to current construction in the yard. existing working plans for similar ships and shipyard standard plans; all of which maybe examined by the owner during negotiations.

## B. PRECONTRACT DESIGN

### 2. Scopes of Precontract Design (Cont'd)

#### b. More Definitive Scope (for non-subsidized projects)

For a new design and a new client, the precontract design scope should be more extensive and more definitive. Typically, it may consist of the following:

**SPECIFICATION** - About the same as the MarAd standard, but more definitive in the areas suggested above, and including quality, workmanship, and fit standards, etc. Areas where shipyard optimum producibility standards can be applied should be defined and allow the yard to improve producibility during precontract design. Areas of risk which cannot be resolved prior to contract should be defined, and a method for resolution agreed to. Shipyard standards to be used should be invoked by reference in the specification.

**GENERAL ARRANGEMENTS, HULL AND ACCOMMODATIONS** – Arrangements of all Decks and Inboard Profile (Hull 1/16" scale, Accommodation 1/4" scale) showing owner's required standards incorporating yard standard practices, and reflecting crew union/management agreements.

**STRUCTURAL DRAWINGS** – Midship section (ABS approved), transverse bulkhead, scantling plans including sections and elevations. These should incorporate yard standard practices, provisions for optimum producibility, and acceptable alternatives.

**ARRANGEMENT OF MACHINERY** – Including arrangement of key areas such as pump rooms, auxiliary machinery spaces, steering gear room, etc.

**HEAT BALANCE AND FLOW DIAGRAM** - For design ship, and other pertinent operating conditions.

**DIAGRAM OF CARGO OIL SYSTEM** - Or for different types of ships, the container system plans, loading and stowage plans, etc.

**FIRE CONTROL DIAGRAMS** - Firemain system, foam fire extinguishing system, inert gas system, hazardous area diagram, etc. Diagrams should be prepared along USCG "Guidelines for Minimization of Piping Arrangement Plans", CCGD3 (mmt) 11 March 1975 and approved, if possible. (See subsection D3.)

**DIAGRAMS OF KEY PROPULSION SYSTEMS** - About ten key systems such as main and auxiliary steam, boiler feed and condensate, etc. These should be prepared along USCG guidelines for immediate approval, interpretation of rules and minimization of further arrangement plans.

## B. PRECONTRACT DESIGN

### 2. Scopes of Precontract Design (Cont'd)

#### DIAGRAM - ELECTRICAL DISTRIBUTION SYSTEM LINES

TECHNICAL DATA, ETC. (Developed to support the design.)  
(\*Usually furnished as a contract document)

\*Curves of form and bonjeans

\*Table of capacities

\*Loading conditions

Stability analysis

Estimate of lightship weight and center

Longitudinal strength study to extent required by ABS, and when pertinent,  
analysis of shear forces and deflection

\*Electric load analysis

### C. Scope for Subsidized Ships

If the ship construction is to be subsidized by MarAd, the scope of the precontract design must be in accordance with the requirements of MarAd Form FMB-8. Generally accepted practice indicates that more extensive and more definitive specifications and plans should be developed for contract purposes, as well as for estimating domestic and foreign cost for subsidy purposes, and for contract administration when the Government is involved. This scope is listed in Article B-6 of Section 2 of this report and should not be less than described in b. above. Also, Article B-5 of Section 2 lists improvements suggested by the shipyards. and subsections G and H of this section discuss some of these in more detail. Although the suggested improvements relate to bidding documents for modernized ships, they are also pertinent to non-subsidized vessels.

It is suggested that the plan and data requirements given in MarAd FMB-8 be reviewed and modified to be more consistent with current practices. For example, the Floodable Length Curves should be deleted since more comprehensive damaged stability calculations are necessary to comply with other requirements.

### 3. Owner Prepared Design for Subsidy and Producibility

In order to comply with the requirements of FMB-8, it is necessary for the owner to develop the design of a ship that fulfills the needs of the service and to project its economic feasibility in the service. This may be done in several steps, first making an initial application for Government aid on the basis of a preliminary study and a preliminary design which minimizes financial risk by obtaining an approval in principle for the project, and then proceeding with the development of the contract plans and specifications in the detail necessary for bidding and contract.

## B. PRECONTRACT DESIGN

### 3. Owner Prepared Desire for Subsidy and Producibility (Cont'd)

The comments made and factors discussed during the shipyard interviews clearly showed that one yard's optimum design for producibility is not optimum for anyone else and that bidding on a design tailored to one yard does not result in competitive bidding.

For example, the Ingalls ship producibility study (Appendix C, item A5) showed their concept of the optimum midship section for a 150,000 dwt tanker. All shipyards interviewed indicated that it would not be optimum for them. Also, in Appendix C item B1, which discusses Japanese design practices, the same producibility problem arose when one corporation's preliminary design office prepared the basic design for ships which would be constructed simultaneously in two of their own yards.

To fulfill the FMB-8 requirements, a detailed estimate of Lightship weight, a longitudinal strength study, and an approved Midship Section plan, as well as steel scantling plans must be prepared and submitted. Thus a structural design in considerable detail is necessary. In the past, this has generally been developed on the basis of the minimum weight to comply with the classification society rules unless other considerations such as concentrated loads and special cargo handling or stowage requirements dictated otherwise. In recent years, a few examples of simplification, producibility, and standardization features have been incorporated in the basic design, but obviously these cannot satisfy all bidders. Also, the bidding and contract documents did not permit changing the structural design in the post contract period without a change order and did not permit bidding on a different structural design since the bid would be considered non-responsive. Thus the owner did not obtain the bid price advantage of producibility. and the shipyard had little or no incentive to offer it.

A solution to this structural design problem, as well as other producibility items, could result from the following:

- (1) The structural design developed by the owner for justification of the design and its economics should have classification society approval and be accepted by all concerned as being feasible but not mandatory. In order that a shipyard may bid on and use a design which is more economical to manufacture, the owner's structural design should recognize this objective and include some degree of standardization and producibility which generally means that the design will not be of minimum weight. This might be accomplished by using a slightly larger than normal margin on steel weight\* and by making the designer's detail weight

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\*See subsection C, article 10

## B. PRECONTRACT DESIGN

### 3. Owner Prepared Design for Subsidy and Producibility (Cont'd)

estimate (which is required by FMB-8) available to the bidding shipyards. Thus the bidder's producible design should result in a steel weight comparable to that used by the owner in determination of the principal characteristics and dimensions of the ship and avoid any change in these. Alternatively, the owner's design could be based on scantling and freeboard drafts slightly in excess of the design draft resulting from his light ship weight estimate and specified deadweight, so that margin exists for a slightly heavier but more producible and less costly design.

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The bidder's structural design should be submitted with the proposal for owner and (MarAd) evaluation and should be approved by the classification society. If approval is not feasible within the bidding period, it would be the bidder's responsibility to obtain such approval without change in the bid price.

(2) The owner's specification should permit optional coating systems to suit shipyard facilities and practices. It might also permit option for extra heavy or double extra heavy pipe in some applications in lieu of coated pipe. It might also permit cathodic protection in lieu of coatings in some applications. These options should be bid as separate items for evaluation and negotiation of acceptability.

(3) The owner's specification should permit alternative types of joiner construction for shipyard selection or optional proposal.

(4) The owner's specification should permit optional machinery plants to permit shipyards to bid on plants which have already been developed and used. This might have to be an option price item for evacuation considering bid price and fuel, crew, and maintenance costs, etc.

(5) The owner's specification should permit optional central control systems to permit a shipyard to bid on a system which it has already developed and used. This might have to be an option price item if manning differences are involved.

(6) The contract should provide for essential and unessential changes, where the former are Limited to regulatory body changes and the latter do not have to be made by the shipyard (such as changes which delay construction and adversely affect all other work).

## B. PRECONTRACT DESIGN

### 3. Owner Prepared Desire for Subsidy and Producibility (Cont'd)

(7) The contract should permit the shipyard to improve systems to reduce cost without requiring a price reduction.

## C. POST CONTRACT STRUCTURAL DESIGN

### 1. Design Reiteration

It is usually found necessary to prepare and release purchase orders for steel prior to completion of the structural design due to the lead time required for delivery of steel. Thus the purchase orders are necessarily based on incomplete or preliminary information. It has been found that the preliminary plate sizes and material orders should be thoroughly re-examined and evaluated as soon as the design is essentially complete and requirements established before ordering steel for follow-on ships.

Improvements resulting from such reiteration would be reductions in the number of different types of standard plates, plate sizes, plan marked plates, mill shapes, fabricated shapes, etc. and in the amount of steel ordered through improved nesting, batch manufacture of parts and utilization of cuttings. Examples of each of these have been examined to determine the possible savings in material and labor, although in some cases only a qualitative result can be indicated.

### 2. Standard Stock or Coded Plates

These are plates whose size is selected to suit yard facilities, the manufacturing plan, the requirements of the specific design, and are normally used in large quantities. In one case there were 124 different standard plates representing about 77 percent of the purchased steel plate weight. The 124 standard plates result from 36 lengths and 8 widths (44 different sizes), 20 thicknesses and 6 grades, and total about 6300 plates.

At design completion, it was found that there were 26 codes having 10 or less plates per code totaling 105 plates and 410 tons. These were examined for standardization possibilities with the following results:

Two codes could be combined into one, totaling 10 plates.

Thirteen codes could be combined with other codes by upgrading material or slightly increasing size (47 plates).

Two codes could be combined with plan marked plates ( 10 plates).

Nine codes were unique, without cost effective possibilities of standardization (38 plates).

Other standardization possibilities were found in codes having more than ten plates/code.

B. POST CONTRACT STRUCTURAL DESIGN

2. Standard Stock or Coded Plates(Cont'd)

The cost of various degrees of standardization was estimated with the following results :

	<u>Increases</u>	
	<u>Weight</u>	<u>Dollars</u>
26 codes (1 to 9 plates/code)		
Reduce by 12 codes	5.15	3340
Reduce by 4 more codes	14.35	4235
18 codes (10 to 19 plates/code)		
Reduce by 2 codes	1.10	311
Reduce by 6 more codes	6.21	2147
Others (20 or more plates/code )		
Reduce by 1 code	0.7	198
Reduce by 5 more codes	18.6	5408

The first line of each of the above groups reduces the number of codes by 15 (115 plates) at an increase in purchased steel of 6.95 short tons and \$3849, or \$257 per code eliminated. The additional reduction of 6 codes (89 plates) increases total weight purchased to 13.16 tons and cost to \$5996, or \$285 per code eliminated. The reduction of the remaining 9 codes rapidly increased the cost to about \$1070 per code eliminated.

A reduction in codes provides more stack positions in the plate yard for plan marked plates and will reduce shuffling when extracting a desired plate. Based on a plate yard of about 150 stacks with coded plates stacked one code per stack, a reduction of 21 codes, or stacks, was estimated to save about \$350 per stack in reduced shuffling costs. The \$5996 increase in the purchase cost of steel associated with the 21 code reductions is more than offset by the estimated \$7350 savings in handling rests. Intangible but significant savings will accrue from the reduced purchasing and inventory control bookkeeping costs and potential improvement in the availability of plates to satisfy scheduling at various work stations.

3. Plan Marked Plates

These are plates whose grade, size, and thickness are dictated by specific or unique design requirements and usually only a few plates per type are required. In one case there were about 1100 plates representing about 23 percent of the purchased weight of steel plates.

Study showed that if these plates had been sized for minimum weight, there would have been 364 types. By standardization and upgrading, this could be reduced to 293 types with an increase in weight of purchased steel of 18.4 short tons and a material cost increase of \$5300. A further reduction of 46 types (to 247) would

### C. POSTCONTRACT STRUCTURAL DESIGN

#### 3. Plan Marked Plates (Cont'd)

increase the weight by 12.9 tons and cost by \$3400, and a further reduction of 23 types (to 224) would increase the weight by 15.6 tons and cost by \$4200. The material cost includes freight and a credit for the additional scrap generated.

The benefits are:

- Reduced handling (shuffling) in the plate yard
- Improved traceability of types
- Reduction in material cost extras due to low tonnage
- Reduced bookkeeping in Purchasing, Design, Inventory Control
- Increased flexibility if revisions of parts are required.

The significant parts of the first reduction from 364 to 293 types were incorporated in the design without a formal study based on an assessment of the benefits. This reduction of 71 types was attained by a weight increase of 0.26 tons per type eliminated and a cost increase of \$75 per type eliminated. The estimated costs and weight differences for each step studied are:

<u>Step</u>	<u>Total Types</u>	<u>Types Eliminated</u>	<u>Purchased Increment Tons</u>	<u>Weight Increase Per Type Eliminated</u>	<u>Cost Increase Dollar Increment</u>	<u>\$/Type Eliminated</u>
Base	364	-	-	-	-	-
1	293	71	18.4	0.26	5300	75
<b>2</b>	<b>247</b>	<b>46</b>	<b>12.9</b>	<b>0.28</b>	<b>3400</b>	<b>74</b>
3	224	23	15.6	0.68	4200	183

Thus, in this case, the apparent optimum number of plan marked types of steel plates is only 247 versus 364 required for minimum weight which is obtained at an increase of 31.3 tons in purchased weight and \$8700 in cost.

The number of different plates (coded plus plan marked) is reduced from 489 to 351 which is in reasonable agreement with the 400 different plates being used by another shipyard.

C. POST CONTRACT STRUCTURAL DESIGN

4. Shape Consolidation and Substitution

a. Example 1.

The cost improvement which will result from shape consolidation and substitution is illustrated by the design of a special tanker which was received for bidding in early 1976. The contract design used 96 different shapes which could be reduced to 46 to improve producibility, with the results shown in Table C-1. This was accomplished by standardization of shapes as well as the substitution of some manufactured shapes for mill shapes.

Table C-1 shows a decrease of 176 tons in purchased steel, but a net increase in steel weight of the ship of 70 tons, with a net cost reduction of \$43,000, including material, freight, scrap, and labor (direct labor plus fringe benefits).

An increase in ship operating costs results from the increase of 70 tons in light ship weight. This increases displacement by 70 tons, or 0.15 percent, which will increase fuel costs by 0.10 percent. The increase in fuel cost based on operating at design speed for 300 days per year and fuel at \$80 per ton is about \$3770 annually. The decrease of \$43,000 in acquisition cost is worth about \$6500 per year. (Actually, the small increase in steel weight could be absorbed in the design weight margin.)

Therefore, the proposed shape consolidation and substitution is advantageous to both the shipbuilder and ship operator.

b. Example 2.

Another example of shape consolidation, which was applied in the post contract design of a large ship, resulted in a reduced number of shapes and an increase in steel weight as follows:

<u>Shape</u>	<u>Number</u>	<u>Reduced to</u>	<u>Increase Tons/Ship</u>
<u>Proposed consolidation:</u>			
Mill angles	18	13	26
Built-up tees	36	16	36
Built-up angles	<u>38</u>	<u>25</u>	89
	92	54	151
<u>Adopted after evaluation:</u>			
Mill angles	18	18	0
Built-up tees	36	18	21
Built-up angles	<u>38</u>	<u>25</u>	<u>89</u>
	92	61	110

TABLE C-1

SHAPE CONSOLIDATION AND SUBSTITUTION - E.XAMPLE 1

<u>Specified</u>		<u>Number</u>	<u>Weight, Short Tons</u>		<u>Material \$</u>	<u>Labor</u>
<u>Item</u>	<u>Shape</u>		<u>Gross</u>	<u>Net</u>		
1	Mill Angles	23	233.2	233.2	60,872	-
2	Mill Tee	12	59.5	59.5	22,563 **	-
3	I-T	11	247.0	190.7	78,050	No Change
4	I-T	24	934.8	670.7	254,067 *	\$ 21,600
5	Fabricated T	<u>26</u>	<u>525.5</u>	<u>482.1</u>	<u>143,052</u> *	No Change
Total		96	2,000.0	1,636.2	558,624	

<u>Proposed Consolidations and Substitutions</u>		<u>Number</u>	<u>Weight, Short Tons</u>		<u>Material \$</u>	<u>Labor</u>
<u>Item</u>	<u>Shape</u>		<u>Gross</u>	<u>Net</u>		
1	Mill Angles	6	239.8	239.8	62,603	-
2	Mill Tees	5	62.5	62.5	23,689 **	-
3	I-T	7	255.3	197.5	80,675	No Change
4	Fabricated T	15	728.0	693.3	200,955 *	\$26,300
5	Fabricated T	13	<u>538.1</u>	<u>513.1</u>	<u>147,842</u> *	No Change
Total		46	1,823.7	1,706.2	515,764	

<u>Differences</u>		<u>Weight</u>		<u>Cost</u>		<u>Labor</u>
<u>Item</u>		<u>Gross</u>	<u>Net</u>	<u>Material</u>	<u>Frt</u>	
1	Mill Angles	6.6	6.6	1,731	132	
2	Mill Tees	3.0	3.0	1,106	60	--
3	I - T C o n s	8.3	6.8	2,625	166	--
4	I-T to Fab T	-206.8	22.6	-53,112	-5,228	4,700
5	Fab T	<u>12.6</u>	<u>31.0</u>	<u>4,790</u>	<u>233</u>	<u>--</u>
Total		-176.3	70.0	-42,860	-4,637	4,700
Gross Total \$					42,797	

\* Includes credit for scrap.

\*\* Includes splitting extra

\*\*\* Items 1, 2, 3, 5 involve consolidation by standardization of sizes, and Item 4 involves substitution of fabricated tees for I's cut to tees and consolidation.

## C. POST CONTRACT STRUCTURAL DESIGN

### 4. Shape Consolidation and Substitution (Cont'd)

The number of different shapes includes variations in cross sections and grades but excludes variations in length. The 110-ton increase in steel weight is about 0.45 percent of the steel weight and was absorbed in the weight margin without change in the guaranteed deadweight. The increased material cost was offset by improvements in labor and machine productivity as well as reduction in scrap and handling.

### 5. Batch Manufacturing

#### a. Background

Only one shipyard of those interviewed batch-manufactures and stockpiles structural parts. Small parts such as chocks, brackets, etc.. are usually cut individually on a Travograph, as required, from large cuttings or full plates. However, a review of plates marked for nested cutting of large parts revealed significant unused triangular or wedge shaped areas (e.g., plates containing transverse web parts at the turn of the bilge, floors, etc) that ideally lend themselves to placement of brackets and other small parts. Utilization of these portions of plates for such parts can reduce scrap, steel requirements, and handling. Thus design development should standardize the part dimensions and specify thicknesses which utilize potential scrap.

#### b. Method

Brackets, chocks and other small parts that are required in large quantities throughout the hull should be nested on the unused portions of plates between large parts, cut on the ABM at the same time the large parts are cut, and stored for later use. Thus the plate is essentially totally utilized in one handling on the ABM. The small parts are flat plates which can be stacked easily and will occupy minimal space. Part thicknesses or grades can be evaluated and revised to utilize the small parts cut from plate codes which would otherwise generate high scrap rates. as discussed under Article C-9 below.

#### c. Evaluation

The proposed method minimizes scrap and the handling of large cuttings or plates which normally are transported to storage, inventoried, retrieved and transported to a Travograph for cutting.

## C. POST CONTRACT STRUCTURAL DESIGN

### 5. Batch Manufacturing (Cont'd).

The method requires some additional burning time on the ABM's, but this will be minimal (2-3%) as compared to the other large parts being automatically burned not only because of the small part sizes but less torch stops are required due to fewer directional changes.

A study of some of the structural plans for a 900 foot container ship revealed ten bracket types which were used in quantities of 50 to 1300 each, having web parts consisting of 4 to 14 square feet of material. These brackets are presently being burned from large cuttings or full plates when needed for a unit assembly. Examination of the nesting sketches for 29 modules (units) for a two week fabrication schedule showed that 276 brackets utilizing 21.7 tons of material could be produced from material which would normally go to scrap. Extrapolating this sample to the complete ship indicates a saving of about 300 tons of material at a net material cost reduction (after credit for scrap) of \$70,000 per ship.

In addition, there will be a labor cost reduction due to reduced handling of large cuttings, as noted above or to handling of full sized plates.

### 6. Nesting

#### a. General

The process of nesting parts for fabrication from steel plates consists of two tasks: first, the arrangement of parts; and second, preparation of a template or numerical control (NC) data which directs the cutting flame along the correct path. The review of current methods conducted as part of this study indicates that the first, or "puzzle" part of nesting is performed in all yards in the traditional manner with little or no recent innovation. The second part of the process has undergone some change as yards become committed to computerized NC systems which generally have a nesting capability. This capability does not perform the placing of parts but allows the efficient preparation of NC data for prepared nests either as paper tapes or drawings for optical followers. These systems generally provide summary data for each nest, which is useful to production control, such as machine time required to cut the nested parts and a measure of plate utilization. Several technological developments have been made recently which are applicable to the nesting process.

## C. POST CONTRACT STRUCTURAL DESIGN

### 6. Nesting (Cont'd)

At least one computer program exists in this country which will access a data base of stored ships parts, arrange them on a series of specified plates and produce paper tapes acceptable to NC drafting and flame cutting machines. The program, COMPUNEST, is the proprietary property of Precision Patterns, Inc. The primary benefit of this program is its ability to rapidly prepare a series of nests and their related NC data. The efficiency of material utilization achieved by the program is, in most cases, less than that which can be achieved through the manual placement of parts. The nests prepared by the program can be reviewed and the parts repositioned for those nests having unacceptable scrap” - ‘ levels. This program can be a useful tool for determining optimal plate sizes when ordering material.

Several programs have been developed recently, usually in conjunction with one of the NC part fabrication systems, which allow manual nesting of parts using a Cathode Ray Tube (CRT) associated with a computer terminal. A series of parts to be nested are called from computer storage and displayed on the CRT screen. The parts can be manipulated on the screen by the user and placed within an outline of a plate to produce a satisfactory nest. While only one nest can be prepared at a time, this method does have the advantage of complete user control over the placement of parts. When the satisfactory nest is obtained, the picture displayed is converted by the computer to produce the NC data for flame cutting. The AUTOKON approach is described in Appendix C, item C1 8B. An Italian shipyard implemented such a system and claims significant labor savings using the CRT.

Certain advantages accrue from both of the above approaches. A possible solution is a combination of both methods by which an image of the automated nest is projected on a CRT, either accepted or manually modified by the user, and the production data produced.

#### b. Design or Loft Function

During shipyard visits, it was found that lofting and hull planning, including erection work packages and NC tape development, are within the Production Department at all but one shipyard where nesting and NC tape development are design functions. Examination of performance at another shipyard indicates the high probability of improved producibility if the nesting, NC tape development and structural planning personnel are assigned to work in close proximity with the engineers and designers from design development through NC tape preparation.

## C. POST CONTRACT STRUCTURAL DESIGN

### 6. Nesting (Cont'd)

The engineers and designers have an early and more comprehensive view of the total parts requirements of the ship's structure which can result in increased efficiency of lofting and NC parts coding. The Loftsmen knowledge of fabrication methods and details will have a positive impact on the evolutionary development of the design. Good coordination will stimulate those changes in method and material utilization which can produce significant reduction in construction costs.

As discussed under Structural Design Iteration various aspects of the structural design should be modified for cost advantage just prior to completion of the structured design and in time to revise and consolidate steel orders for follow-on ships. The knowledge that the designers possess relative to the design iteration, substitutions and parts standardization should be utilized to improve nesting, NC tape developments, and final steel orders.

#### c. Small Parts

In order to improve the utilization of steel plates, batch manufacturing of small parts should be used, as discussed previously, which permits the designer or loftsmen to nest small parts for current and later units on unused portions of plates being lofted for major or large parts. If batch manufacturing is not being used, and especially when nesting is confined to single units, utilization of steel plates can be improved by nesting parts which require a lower grade or thinner plate on the higher grade or slightly thicker plate being cut for the major parts, thereby reducing scrap and handling. Familiarity of the engineer with permissible substitutions of grade and thickness will result in cost effective substitutions.

#### d. Cross Nesting

Cross nesting of parts also improves material utilization and reduces scrap and is used by a few shipyards to some extent. Most yards use a fixed unit production sequence, so predetermined cross nesting over a number of units is feasible within limits. However, when units for following hulls are to be produced concurrently with units for the first hull, cross nesting would be somewhat more limited or more complicated. This could be accommodated by cutting a number of cross nesting units for another hull, or if the unit sequence for all hulls is fixed, then cross nesting across various hull units could be used. Alternatively, especially if the unit sequence is subject to change, dynamic nesting could be used which would mean preparing nests as required for the units scheduled for production in one week (or other period). In order to determine the economic possibilities of cross unit nesting, a study was made of material utilization obtained with single unit nests as compared with cross nesting of the same unit.

C. POST CONTRACT STRUCTURAL DESIGN

6. Nesting (Cont'd)

For the comparison, the units scheduled to be produced in each of four weeks (two consecutive in February and two in July) were selected to obtain a range of types of units. The units scheduled for each week (which included units for 2 or 3 hulls) were cross nested, and units for one two-week period were also cross nested, with the following results.

Week	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	Total 4 Weeks	1 & 2
No. of units	8	21	20	13	62	<b>29</b>
ABM Tonnage	717	1010	600	734	3061	<b>1727</b>
ABM Plates	181	270	173	202	826	<b>451</b>
No. of NC Tapes	92	158	99	89	438	250
No. Affected	14	23	9	16	62	41
Full Plates Elim.	4	11	1	3	19	18
Cuttings Elim.	4	3	1	2	10	7
No. Reduced Size Plates	7	6	10	20	43	18
Tonnage Saved	18.1	38.6	13.5	27.8	98	67.8
Tonnage Saved %	2.5	3.8	2.3	3.8	3.2	3.9

Thus, one week's cross nest will save about 3.2 percent of the steel going to the Automatic Burning Machines. Based on the one two-week cross nest sample, the saving is increased to only 3.9 percent.

Projecting the 3.2 percent saving to the total ABM plate tonnage for the whole ship, the material cost reduction after allowance for reduced scrap was estimated to be \$100,000/ship. To obtain this gain, about 14 percent of the NC tapes for the ABM's would require re-nesting, using the codes for each individual part previously stored in the computer. It was estimated that the cost for design, lofting, work package planning, and inventory control would be increased by about \$25,000 per ship for this dynamic nesting resulting in a net saving of about \$75,000/ship.

## C. POST CONTRACT STRUCTURAL DESIGN

### 7. Holes Control

#### a. General

The location and size of holes cut in ships structure to accommodate distributive systems such as piping, electrical cables, control linkages and ventilation ducts must be reviewed to insure that interferences are avoided and that the strength of the hull structure is not compromised. In most yards the locations of structural penetrations are selected by the system designer, and data on size and location of the holes for each system is submitted to a "holes control group", usually in the structural design department. The data is compared with ship structure and hole locations of other systems. Interferences are identified to the system designer and the routing of the system adjusted to maintain proper clearances. Penetrations which may detract from the structural integrity of the vessel are referred to the structural engineers for evaluation and necessary compensation. Data on acceptable penetrations comprises a "Holes List" which is forwarded to production for layout and cutting in preparation of system installation. The lists are usually issued on a piecemeal basis as the data becomes available for the individual systems, and holes are generally cut in the field after the structure has been assembled or erected often requiring multiple trips by a layout man and burner to specific areas aboard ship. Late data or changes may result in damaging completed coating systems causing significant rework. Reductions in the costly operations of manual layout and field cutting of the many penetrations required in a modern ship's structure can be achieved by:

Reducing field cut holes by increasing the number of penetrations included in the initial cutting process of the related structural part.

Consolidating systems data so that the layout and the cutting of holes in a specific area, unit, or module can be performed as a single task.

#### b. Reduction in Field Cut Holes

Reduction in the number of holes which must be cut in the field can be accomplished by early identification of size and location prior to issue of structural plans for fabrication, thereby obtaining maximum efficiency by incorporating penetrations as part of the initial layout process. For those parts cut by numerically controlled equipment, the penetrations can then be included in the coding of the part thus eliminating manual layout and burning. Holes cut by NC have the added advantage of smooth cuts to simplify fitting and no ragged edges which might be the source of stress concentrations.

## C. POST CONTRACT STRUCTURAL DESIGN

### 7. Holes Control (Cont'd)

The key to incorporation of holes on plans is early decisions on the routing and sizing of distributive systems. The information necessary to accomplish this will result from the procedures proposed in subsection F. The areas to be allocated to various systems can be reserved and checked against the vessel's detailed structure as it is developed. Incompatibilities can then be resolved between the system and structural designers and satisfactory penetrations determined before the issue of the structural plan for fabrication. The availability of holes information to support plan issue must be considered when plan issue schedules are established. The developmental work on systems related to specific structural units should be scheduled with ample time to support the issue of the structural plan. It is estimated that at least 80 percent of the penetrations outside of the machinery space can be identified and included on plans prior to issue for fabrication. For multiship programs, data on the balance of the holes should be included on the appropriate plans as soon as available so that they may be incorporated into follow ship structure at the earliest possible point in the production cycle.

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Success in early identification of penetrations has been demonstrated by several U. S. yards. By introducing changes in scheduling plan production and requiring early submittal of vendor's equipment data, one yard was able to locate 70 percent of all holes 2 inches and above in time to be included when cutting parts for the first ship of a series. They anticipate that a 90 percent level will be reached for the first ship of another tanker series. Another yard is now including holes data for all penetrations, with the exception of those in the deck house on their structural plans with 80 percent accuracy for the first and nearly 100 percent for the second ship of a series. At this yard holes changes are minimized by giving control of alterations to the structural design group. After the initial cooperative identification of penetration location and size all changes require approval by structural design.

In both of the above instances success was achieved by careful planning and cooperation between all parties involved as directed by upper levels of management. A third yard includes penetrations in parts cutting instructions when available but has no system for early identification of data. As a result only 10 percent of the penetrations are included in initial cutting with nearly 100 percent added by the third ship of a series. Other yards canvassed make no special effort to avoid field cutting of penetrations.

## C. POST CONTRACT STRUCTURAL DESIGN

### 7. Holes Control (Cont'd)

#### c. Cost Data

A study was made as part of this project to determine the approximate manhour costs of penetrations made under various circumstances. The results are summarized as follows:

#### (1) Cost of incorporating holes in numerical control data (tapes)

Added as part of initial coding:

<u>Additional coding</u>	.05 Hours/hole
<u>Additional burning time</u>	<u>.10</u> Hours/hole
Total	.15 Hours/hole

Revised hole:

Changes to coded part data	.25Hours/hole
Revise NC burning tape	<u>.10</u> Hours/hole
Total	.35 Hours/hole

#### (2) Cost of field cut holes

At assembly

Layout of holes	1.25 Hours/hole *
<u>Burn holes</u>	<u>.50</u> Hours/hole *
Total	1.75 Hours/hole

On board ship:

Layout of holes	1.35 Hours/hole *
<u>Burn holes</u>	<u>.55</u> Hours/hole *
Total	1.90 Hours/hole

- Includes allowance for locating proper area, climbing, pulling cables, rework, etc.

## C. POST CONTRACT STRUCTURAL DESIGN

### 7. Holes Control (Cont'd)

#### (3) Cost to patch revised hole

Layout, cut, fit blank	2.0 Hours/hole
Weld blank	2.5 Hours/hole
Prime patch	<u>.5 Hours/hole</u>
Total	5.0 Hours/hole

Add an additional 4.5 Hour/hole if finished coating must be repaired.

#### d. Cost Comparison

A sample of the penetrations found in an LNG tanker design was reviewed to identify the types of holes required and to provide a basis for estimating potential savings. For simplicity the sample was limited to penetrations within the hull envelope but outside the machinery space and did not consider systems installed in the deck house. The size of the sample probably is not representative of other types of vessels, since many of the fore and aft systems in the LNG vessel are run through a duct keel and an underdeck passage rather than penetrating transverse structure.

About 1200 holes were identified and included wireway and ventilation ducting penetrations as well as piping. By reviewing the hole locations on the structural plans it was determined that 625 holes or 52 percent of the holes occurred in parts cut on numerical control equipment and thus could be included on NC tapes.

Assuming an average of the demonstrated and anticipated experience, then 80 percent or 960 holes can be identified for the initial issue of the structural plans, and 500 holes (52 percent of 960) can be included in the NC coding. This would result in a saving of at least \$6700 per ship as compared with field cut holes, all other factors remaining unchanged.

However, an additional comparison was made of the cost of penetrations, for a conventional approach with holes field cut from a holes list, and for the newer approach with special effort made to provide early size and location data for penetrations to be included on the NC cutting tape. This comparison was based on 1200 holes per ship and the following factors for the newer approach:

C. POST CONTRACT STRUCTURAL DESIGN

7. Holes Control (Cont'd)

Holes in ABM cut plates	32 Percent	625
Holes identified for initial issue	80 Percent	
Holes identified for initial issue on ABM's		500
Field cut holes, as assembly		460
Field cut holes, after erection	20 percent	240
(Including 25 percent - 80 holes after painting)		
Revision rate, both NC and field cut (of these 1/2 after painting)	20 percent	

On following ships, all holes properly located and cut at assembly.

For the conventional approach, based on factors supplied by one shipyard:

For the first ship, all holes field cut, 40 percent at assembly, 60 percent aboard ship, with one half the latter requiring coating repair. 30 percent revision rate, with one half requiring coating repair.

For the second ship, all holes field cut at assembly, with a 5 percent revision rate.

For the third ship, all holes in ABM plates cut by NC burner (52 percent) and all other holes field cut at assembly, no revisions.

Based on these factors and the cost data tabulated, the estimated cost of 1200 holes on the first three ships of a series by the two methods is as follows:

Method:	<u>Conventional</u>	<u>Improved</u>	<u>Difference</u>
<u>Hull</u>			
First	\$54,000	\$28,800	\$25,000
Second	20,200	9,200	11,000
Third	<u>10,000</u>	<u>8,400</u>	<u>1,800</u>
Total	\$84,400	\$46,400	\$38,000

## C. POST CONTRACT STRUCTURAL DESIGN

### 7. Holes Control (Cont 'd)

Although the sample used is small, since it excluded holes in the engine room structure and the superstructure, the comparison demonstrates a worthwhile saving for early identification of structural holes, so that they may be cut by the NC burner where feasible and field cut at assembly for the other plates not being cut on ABM's.

Holes data is identified and issued by the system designer by distributive system since the consolidation of the data to specific locations within a vessel is a formidable task. This effort may be reduced to a practical and useful level by initially preparing the holes data to a format which can be readily keypunched and stored in a computer memory. As the data regarding each system is added, a file of holes data is created which can be manipulated for various purposes. For instance it becomes a relatively simple matter to sort the data file to produce a list of holes, with all related data, pertaining to the various systems located within a specific construction unit or location. This list locates all holes in a specific area which is helpful to a parts coder and minimizes the number of visits to an area for laying out or cutting field cut holes. Holes Lists may be included on structural plans by incorporating such a computer produced list as a portion of the plan or issued as an attachment as is sometimes done with Bills of Material. The data filed in this manner can be easily revised as changes take place and updated Holes Lists readily produced by the computer and reissued. Including holes data as a list is simpler and less costly than maintaining up-to-date drawings showing each penetration.

However, a check on interferences and structural integrity must be maintained by the "Holes Control Group", either on a record copy of the structural plans, or by use of the holes files, which can be accessed to prepare the input data directing a numerically controlled plotter to draw the holes within a given location. Such a drawing can be overlaid on a structural arrangement drawing to identify interferences or structural compromises.

## C. POST CONTRACT STRUCTURAL DESIGN

### 8. Mill Edge Versus Sheared Edge Plates

One of the shipyards interviewed stressed the point that it ordered only mill edge plates which resulted in lower cost. Investigation showed that mill edge plates are not available from all steel manufacturers and are not always available from manufacturers producing them. However, when mill edge plates are available, it is apparent that they are less costly than sheared edge plates.

Mill edge plates – plates are ordered to the required size, and the steel manufacturer insures that the specified size can be cut from the delivered size. A mill edge plate may have non-linear edges as well as excesses in length and width which vary from plate to plate. The shipyard is charged for the theoretical weight of a plate of the specified size, and shipping charges are based on the actual plate weight.

Sheared edge plates – plates whose edges and ends are sheared by the mill after rolling. The sheared edges are not true, and therefore width, length, and camber tolerances are set by the steel mills, and these must be considered when ordering. The following allowances are suggested by the steel manufacturers when resquaring to size by flame planing or machining:

Specified width should equal the desired final width plus the under tolerance for width plus the camber tolerance plus one-half the normal thickness of the plate.

Specified length should equal the desired final length plus the under tolerance for length plus one-half the over tolerance for length.

For example, if the desired plate size is 516 inches x 88-1/2 inches x 1/2 inch, the manufacturer's tolerances for a sheared edge plate are:

Tolerance under specified-width and length – 1/4 inch

Tolerance over specified-width – 3/4 inch, length - 1-1/2 inch

Tolerance on camber – 1/8 inch in width for every 5 feet of length

Thus the specified dimensions of the sheared plate would be:

**Width, 88-1/2 inches + 1/4 inch ÷ (1/8 inch x 43/5) + 1/4 inch = 90 inches**

**Length. 516 inches + 1/4 inch + 3/4 inch = 517 inches**

## C. POST CONTRACT STRUCTURAL DESIGN

### 8. Mill Edge versus Sheared Edge Plates (Cont'd)

Then a comparison of cost for the desired plate 1/2-inch thick would be as follows:

Type <u>Plate</u>	Specified <u>Size</u>	Theoretical Weight	Material cost *	Avg. Size <u>Shipped</u>	Freight <u>cost**</u>	Total <u>cost</u>
Mill	516 x 88-1/2	6469	1,044.74	517x92-1/2	67.74	1,112.48
Sheared	517X90	6591	1,064.44	517-3/4X 90-3/8	66.30	1,130.74

\* At \$323 per ton

\*\* At \$20 per ton

Thus, if mill edge plates are available, they should be purchased in lieu of sheared edge plates, since the cost is about 1.6 percent, or almost \$6 per ton less, and since there is no labor difference in the shipyard as flame planing or machining is necessary for both types of plates if a true rectangular plate is required.

### 9. Details - Alternative Scantlings

Details for collars, chocks, clips, and flat bar stiffeners usually have thicknesses specified at 1/8-inch increments whereas plates are usually specified at 1/16 inch or 1/32 inch thickness increments. Thus there may be a significant tonnage of cuttings available at a thickness of 1/16 inch to 3/16 inch in excess of that shown on the details. Study of this in one case showed about 310 tons of cuttings were available and not being used due to thickness differences.

Review of the details for 18 different collars, chocks, clips, etc. and 9 different flat bars showed that they could be revised to use up more than the available cuttings. More than twice the available cuttings and scrap could be used at an increase of 118 tons in net steel weight. Authorized substitutions if fully utilized would use about 400 tons of cuttings at a net increase in steel weight of 68 tons. (This example does not include the larger parts of the example used in Article 5 above.)

### 10. Steel Weight Growth and Margin

Designing for producibility, which involves standardization and consolidation, will nearly always result in an increase in steel weight, and some allowance for this should be included in the design weight estimate. The amount will depend on the degree of producibility incorporated in the design plans on which the estimate is based, as well as that used in the design development.

## C. POST CONTRACT STRUCTURAL DESIGN

### 10. Steel Weight Growth and Margin (Cont'd)

In one case, the producibility items incorporated after the contract weight estimate included the following:

- Consolidation of shapes
- Standardization of plate sizes (no increase in net weight)
- Insert plates for heavy lift purposes
- Increased deck plate thickness in local areas
- Shape substitutions due to change in availability
- Bulkhead simplification

The increase in net steel weight was 0.75 percent which was equal to 8.5 percent of the total design weight margin but only 19.5 percent of other steel weight developments. In addition, optional scantlings were permitted for small parts, such as collars, chocks, clips, and flat bar stiffeners, which if utilized 100 percent would result in the foregoing percentages being increased to 1.04 percent, 11.7 percent, and 27 percent respectively.

### 11. Structural Plans

The number of plans required for structure is now substantially more than heretofore due to the addition of unit or module plans to assist production. The manhours used for structural design in one case amounted to about 5 percent of the manhours used in fabrication and erection of the steel structure which appears reasonable.

However, the volume of paper work is high, and measures have been adopted in some cases to minimize submittals for approval. The submittal and approval procedure developed by ABS and USCG to minimize duplication has been favorably received. More effort should be used to develop the scope, format, and details of plans which will provide all the information required for approval by ABS, so that unit or module plans will not be required to be submitted. The ABS requirements for structure are defined in their "Rules for Building and Classing Steel vessels, 1976" in Sections 1.11, 6.3.2a & b, 6.9, 30.1.2, plus a few others for special ship types. While the information furnished is not conclusive, it appears that all the ABS requirements can be covered by about 15 drawings, including the Longitudinal Strength Study, Structural Details, Welding Details, Welding Recesses and Procedures, Nondestructive Test Requirements, Midship Sections, Scantling Plans - Decks, Profiles, and Sections, Shell Expansion, Rudder, Rudder Horn, Stem and Stem Frames, Stem and Bow Framing, and Superstructure Scantlings. These are the basic scantling plans.

## C. POST CONTRACT STRUCTURAL DESIGN

### 11. Structural Plans (Cont'd)

Concentrating the initial effort on these basic scantling plans will expedite submittals to and action by the approval agencies. It has been noted that foreign shipyards follow this procedure, having a list of "class drawings", which are developed in English, for ABS, Lloyd's, and Owner's approval, while other plans will be in the local language.

It was previously noted that there are three types of structural plans, the basic scantling plans, conventional system plans for decks, bulkheads, shell, etc., and unit or module plans. It was the consensus that only two types should be sufficient (although all three had been used by some yards) and that these should be the basic scantling plans and the unit or module plans.

Also see Article F., Classification Drawings.

## D. POST CONTRACT PIPING DESIGN

### 1 General

This subject is being covered in depth under MarAd/BIW Task S-4, Advanced Pipe Technology, by Newport News Shipbuilding and Dry Dock Company; and the scope of this study is limited to consideration of possible improvements in the design process.

Piping design encompasses the conversion of governing specifications into finished drawings to furnish shipyard trades with all information required to fabricate and install the shipboard piping systems and, as necessary, to obtain approval of the cognizant regulatory bodies.

Piping design is a large consumer of manhours in the engineering and design departments of the shipyards the hours being comparable to those used for structural design. The ratio of piping engineering, design and material identification hours to pipe fabrication and installation hours is 10 times higher than for structure which means that there is about one design hour for every two production hours.

### 2. Current Practices

The difference in piping design practices in the shipyards is described in Article C-7 of Section 2.

A more complete and detail description of current piping design processes is given in Appendix C, item A9.

### 3. Elimination of Conventional Piping Arrangement Drawings

As a result of proposals made by two shipyards to eliminate most of the piping arrangement plans required by regulatory agencies, the USCG CCGD3 (mm5) issued Guidelines dated 11 March 1975 (copied herein pages 3-39 and 3-40) and ABS followed with letter SK/pb File T-18-6 dated October 21, 1975 (copied herein, page 3-41 ). If these guidelines are followed, it will result in a significant reduction in the number of piping arrangement plans that must be prepared and submitted and in the manhours required for their preparation.

If the diagrammatic plans are developed in the format and detail required by the USCG criteria, then they should provide all the data necessary to verify that a system complies with the regulations so that submittals of arrangement plans on request will be unnecessary. It is noted that ABS will require the submittal of arrangement plans for one piping system on each of four types of ships (see page 3-41).

## D. POST CONTRACT PIPING DESIGN

### 3. Elimination of Conventional Piping Arrangement Drawings (Cont'd)

This approach requires an early development of the piping system routing so that the arrangement aspects of the system may be indicated on the diagrammatic plan. This earlier development of routing may be only a more accurate development of sketches made for material take-offs during the cost estimating phase and may also be used for early structural holes identification as discussed in Article C-7 of this Section.

### 4. Drawing Development

At the two shipyards using only the diagrammatic plans for regulatory approval, the piping plans are as follows:

#### Shipyard A

(1) Diagrams are developed per USCG criteria Drawings are booklet size and separate sheets are used for supporting information, i.e., symbol list, material list, general notes, etc.

(2) Composites are developed for all piping 2 inches and above for all congested areas of the ship, i.e., Machinery Space, Pump Rooms, Control Rooms, Ventilation Fan Rooms and others. The Machinery Space is subdivided into a number of areas (3 dimension spaces) with about four per level. Piping 1-1/2 inches and below is indicated on the composites diagrammatically. Scale of composites used included 1/2 inch, 3/4 inch and 1-1/2 inch = 12 inches. Each system on a composite is identified by a code which uses one or two alpha characters. Pipe, valves, flanges, gaskets, bolting, and fittings are numerically serialized by blocks of numbers. The combination of the system identification code plus serial number correspond to a line item on a master Bill of Material which is produced on a system basis. The composite is completely dimensioned, continuations referenced, hangers given approximate locations, type of hangers indicated by coded identification and in general all information normally found on a system drawing.

(3) Pipe details are prepared in the pipe shop, from issued composites, except for stressed systems which are prepared by Design. The individual pipe fabrication breakdown is given a numerical sequence identification which appears on the composite as a suffix to the system identification code and the Bill of Material line item number.

## D. POST CONTRACT PIPING DESIGN

### 4. Drawing Development (Cont'd)

#### Shipyard B

(1) Diagrams are developed similar to that previously described except the diagram provides unique numbers for each valve in the system and a valve list provides all the required information for each valve in the system. Each diagram is assigned a block of numbers to be utilized for valve numbering. Diagrams are booklet size, and a separate booklet provides general notes, material schedule, valve list, instrument list, pump table, flow data table, and design characteristics.

(2) Composites are utilized to develop piping systems by areas convenient to design without regard to erection sections. Conventional arrangement drawings are then prepared by tracing composite arrangements. System arrangement drawings are prepared as single line drawings with double lines utilized where *necessary* for clarity. The Bill of Material is abbreviated to the point whereby it gives only the piece mark, quantity, brief description and source. The system Bill of Material refers to the diagram for detail information on all material.

(3) Pipe details, which cover a complete shop assembled unit, are prepared in Design. They are free hand drawn with an abbreviated Bill of Material. Each detail assembly is fully dimensioned and is identified on the piping arrangement. On the *most* recent ship contract pipe details are being developed by computer. Design prepares input data forms for each detail on arrangement drawing. Data includes all controlling point dimensions and material information. Data is card-punched and input to the computer and a readout is obtained in the form of a sketch and printed information. Fabrication activities work from computer readout subsequent to a design check for accuracy.

### 5. Recommended Piping Systems Design Procedure

Based on study of the current practices and particularly the practice at the two shipyards using only diagrams for approval purposes, the recommended approach to piping system design lies between the two described in 4 above.

(1) Diagram development should adhere to the USCG policy. Each valve, special fitting and instrument should be uniquely identified. Diagrams should be booklet size to a length suitable to the system being developed. A separate booklet of standard size sheets should be developed providing general notes, material schedule, valve list, instrument list, pump table, **flow data base, design**

## D. POST CONTRACT PIPING DESIGN

### 5. Recommended Piping Systems Design Procedure (Cont'd)

characteristics, etc. The material schedule of the diagram should be the basis for all procurement data with the system Bill of Material giving only an abbreviated description along with system quantity requirements.

(2) Composite drawings should be utilized in the preparation of and will become the installation drawing for all piping systems. The composites should be developed by area or zone, broken down into a workable combination of erection units. In general, piping with a diameter of 2 inches over insulation or 1-1/2 inches IPS without insulation should be routed, dimensioned, and shown double lined on the composite. All smaller piping should be run diagrammatically and single line on the composite, with instructions to the installing activity to run to suit shipboard conditions and to install valves, special fittings, etc., in a position where they are readily accessible or in a position easily operable by an extension stem. Dimensioning should be from points shown on structure in lieu of molded lines and should be to the extent necessary to detail and install the piping. Each support should be located as necessary. Three views should be provided only where necessary. The scale of the composites should be to the largest scale feasible, with auxiliary views, as required by good drafting practice.

(3) All pipe details should be calculated by a computer programmed to provide all necessary information for fabrication including a Bill of Material for each detail assembly. Where capabilities allow, a tape for automatic bending machines should be produced. Input to the computer will be taken from the composite, and computer printout of assemblies will be issued to suit yard fabrication schedule.

(4) Piping modules should be utilized wherever possible to facilitate installation. In essence, the objective of modular piping installation is to group all valves, controls, gages, etc., associated with a particular station or component, in such a manner that it may be shop assembled as a unit or station and placed into the ship as a complete unit. This requires actively pursuing candidates for modular installation early in the layout stages of the composites. (Also see discussion of machinery and piping modules.)

(5) Each piping system on the ship should have one master Bill of Material. The system diagram should give all procurement and regulatory requirements, with the system Bill of Material providing system quantity requirements and a brief description. The numbering of system components should be as discussed

## D. POST CONTRACT PIPING DESIGN

### 5. Recommended Piping Systems Design Procedure (Cont'd)

in the following paragraph. Initial takeoff of material should be to the diagram requirements and estimated quantities where necessary. As composites are finalized, adjustments to Bill of Materials will be made. All material lists should be fed into a computer programmed to interface Engineering and Design, Inventory Control, and Purchasing. The computerized system would provide (1) material availability check by system and in-yard required dates, (2) material requirements projections by time period, (3) selective printing of material requisitions, (4) automatic plan and mark inventory and (5) detail material analysis for the ship.

(6) Identification of systems and parts should be simple and only as complete as required for material control.

(a) Each system should be identified by an alpha code of one and two characters (A = Air, compressed and control; B = Bilge and Ballast; C = Main and Auxiliary Circulating Water, etc.).

(b) Pipes, valves, flanges, gaskets, bolting and fittings should be numerically serialized by blocks of unique numbers within a system (Pipes 0-99, Valves 100-199, Flanges 200-299, etc.). These numbers also will represent the line item of a system Bill of Material. The unique number assigned to each item in a system is to aid identification and traceability. The items will also be defined by a shipyard standard catalog code number supplemented by pseudo code numbers for special items.

(c) Each pipe detail and module should be given a unique number which is added as a suffix to the combined system identifier and pipe identification number, i.e., AS-16-2.

(d) Spring hangers, anchors, rod hanger, sway braces and miscellaneous supports should be given code identifiers as to type and unique identification by numerical suffix, within a system, that represents a line item of the Bill of Material. A symbol for each general type of support will be also shown in the desired location of the appropriate pipe.

### 6. Piping System Models

The foregoing recommended composite drawings as the method to be used for development of the piping system arrangements because this represented the consensus of the shipyards visited. As noted in Section 2, a number of European shipyards use scale models to develop the piping arrangements in the main engine room, and other congested areas.

## D. POST CONTRACT PIPING DESIGN

### 6. Piping System Models (Cont'd)

The use of models was investigated under the National Shipbuilding Research program Project SP-2-13 by Todd in 1974. The report "use of Scale Models as a Management Tool" covered distributive systems models briefly, noting the divergent views as to usage, as a check of design for interference control and access, or as a tool to eliminate drawings. The construction of such models is described in detail, noting the availability of model scale pipe and fittings as a result of the petro-chemical industry's move to designing process plants by the use of models. A few models by or for US shipyards were illustrated and discussed. The use of an engine room piping model to eliminate drawings is briefly discussed, and reference made to two German papers on this subject.

The use of pipe system models for design at the Odense Steel Shipyard in Denmark is briefly described in the National Shipbuilding Research Program report "Photogrammetry in Shipbuilding" prepared by Todd Shipyards Corporation. as follows:

"It was observed in June 1976 that Odense Steel Shipyard Ltd, in Denmark, successfully combined pipe-systems design and modeling to create 1:15 scale models of ship machinery spaces without preparing piping systems or composite arrangement drawings. With input from production people, sufficient model detail is provided to identify multi-ton piping units, consisting of a number of different systems, which are planned for shop assembly. Dimensions are manually lifted from such models and recorded on a simple isometric sketch for each planned piping subassembly (on the average a subassembly consists of about eight pipe pieces and eight fittings). Each isometric, sketched on an 3-1/2 x 11 inch sheet, contains all material requirements, pipe piece details, and ship location references. Thus, each isometric combines all design data required for production, a significant amount of completed planning, and all information necessary for the remaining planning and scheduling functions. Further, each isometric sketch, being sufficient, is then coded for computer preparation of material lists, pipe bending instructions, work orders, schedules, etc. .More details of this Odense design/modeling process are to be incorporated in the report for the study "Advanced Pipe Technology", also part of the National Shipbuilding Research Program, which is expected to be published in early 1977."

A similar system at Rosenberg Verft in Stavanger, Norway was observed in 1972. The model shop is located within the engineering and design area, and piping designers and model makers work together to develop the piping runs in the model using the piping diagrams. The model is built in sections, using plexiglas for the structure.

## D. POST CONTRACT PIPING DESIGN

### 6. Piping System Models (Cont'd)

Scale pipe and fittings are obtained from suppliers in Germany, and equipment components are modeled from plexiglas shapes and foam to simple extreme perimeters. When the model piping is complete, isometric pipe detail sketches are prepared using dimensions taken from the model manually by scale and calipers, and the material list added or appended. Thus the piping design consists of the diagram, the pipe details, and the model, and the installation is made from these. Moss Rosenberg Verft considers this method of developing the piping arrangement to be satisfactory and cost effective. Development of this method is probably due to the scarcity of experienced pipe designers, especially for steam propulsion plants.

A copy of one isometric pipe detail is shown on page 3-42. Note the location dimensions and the part identifications.

Before the USCG action which permits elimination of the piping arrangement drawings, the US regulatory requirement undoubtedly was a hindrance to the use of the model method. Now, with approvals obtainable on the basis of the diagram only, with pipe details of the type illustrated, and with the pipe detail numbers indicated in the diagram to aid installation, this method should be given serious consideration.

The study of photogrammetry proposes that the pipe detail dimensions be obtained from the model by photogrammetry, and the detail produced by computer.

MarAd pointed out that their rules require a set of drawings upon ship completion, so that duplicate ships could be built by other shipyards during an emergency, and doubted that this would be possible without arrangement plans. It is believed that the system described will be sufficient to permit construction without arrangement plans, as the details are defined and dimensioned as to location.

Central design agencies for multiple ship programs during World War II made models of engine rooms including all equipment, access facilities, and piping, ventilation, and wireways, for interference control and design check. Piping was modeled by tie with slip disks thereon to check clearances. While the model was expensive, at a scale of 1-1/2 inch to 1 ft, the cost was fully justified due to the elimination of interferences which were prevalent in the drawings made by inexperienced non-marine piping designers and because piping for many ships was being fabricated far om advance of installation, so that interference elimination was essential to ship cost and production schedules.

## D. POST CONTRACT PIPING DESIGN

### 7. Machinery and Piping Modules

Purchased or shop assembled machinery and piping modules or packages have found increasing applications in ships during the past 40 years. One of the initial examples was the combination of several low pressure heat exchangers into a combined unit that replaced the twin 2-stage air ejectors with inter and after condensers, the gland leakoff condenser and exhauster, the Lp. feed heater and drain cooler, traps, valves, interconnecting piping, etc. This resulted in considerable saving in space, lower overall cost, less piping and valves, simpler foundations, and easier installation.

During World War II many modules were developed by vendors to supply the new high production shipyards. These packages included refrigeration units, distilling plants, fuel oil heating and pumping sets, lube oil purifier, heater, pump set, hydropneumatic pressure sets, and air compressor and receiver units.

Packaging was also applied to more significant equipment. Ship service turbo-generators were developed into completely packaged units with integral foundation suitable for three point support. In some cases, the auxiliary condenser was made integral with the SSTG set foundation, the circular condenser shell providing a very stiff unit suitable for three-point support, and with an elongated hotwell on which the condensate pump was mounted.

In 1962, various vendor and shipyard shop assembled machinery and piping packages were proposed (Appendix C, item D3) with the objective of simplifying the systems, eliminating unnecessary redundancy making a more functional design, standardizing subsystem arrangements and piping, and to reduce costs. The figures in the reference paper illustrate many of the proposed packages. A few years later one shipyard followed these proposals and shop assembled 13 different machinery and piping modules, including a feed pump package that consisted of the two main turbo-driven pumps, a common foundation that fitted into the auxiliary flat, all interconnecting piping and valves for low and high pressure feed and steam and exhaust, *controls*, instruments, etc.

More recently, machinery and piping modules have been recommended in the reports resulting from a research project, see Appendix C, item A5, as items which will improve producibility

The piping for each shop assembled module is designed on a composite with careful consideration for operation and accessibility of all equipment, valves, and controls. When a good arrangement is obtained, it can be standardized and used from job to job, enlarging as necessary to suit larger higher capacity components.

## D. POST CONTRACT PIPING DESIGN

### 1. Machinery and Piping Modules (Cont'd)

When modules are used, it is usually necessary to obtain delivery of components from vendors at an earlier date, in order for the preassembled module to be placed aboard ship at the proper time before structural erection is too advanced.

In other cases, shop assembled modules expedite delivery. For example, on the LNG "tankers at Quincy, the gas compressor and cargo control rooms are shop assembled and preoutfitted. The control room is a critical path item, since it cannot be installed until after the cargo tanks and covers are installed.

The use of modules by the shipyards visited ranged from nil to extensive. In one or two cases unusual space restrictions limited effective use of modules. Those yards not using modules to any significant extent were interested in the results at other yards and recognized the possibilities and advantages.

GUIDELINES FOR MINIMIZATION OF PIPING ARRANGEMENT PLANS  
CCGD3 (mm5) -11 Mar 1975

These guidelines are the result of:

- a. Proposals by two shipyards to eliminate most of the presently required piping arrangement plans.
- b. Previous favorable reactions by the OCMNs involved and by this office.
- c. Recent conceptual acceptance of the proposals by the Commandant (G-MMT).

Since the Commandant (G-MMT) ruled that "arrangement drawings may be eliminated as is deemed acceptable by the cognizant Technical and Inspection Offices provided enough data is available to verify that a system complies with the regulations", CCGD3 (mmt) has established the following policy guidelines:

- a. An arrangement plan of the main steam and other high temperature systems may be required for the purpose of thermal stress analysis. An isometric and diagrams may be sufficient in some cases.
- b. A detailed material list, including the information required by 46 CFR 56.01-1 0(d)( 1 ) and in the case of valves and fittings, calling out either an approved standard (56.60-1 as cited in 56.20-1 (a)), or the manufacturer and model number of a valve or fitting which is not to an approved standard, (to determine applicability of and compliance with 56.20-1 (b) or (c)), shall be required for each system or group and for each ship or class.
- c. Weld details and other pertinent typical details shall be submitted either on the diagrammatic plan or separately.
- d. The diagrammatic plans shall be of superior quality and shall include:
  - (1) indication of location, such as compartment name, level, frame and P/S
  - (2) all valves, fittings, branches, etc. properly located
  - (3) sizes of piping
  - (4) all attachments to other systems, with appropriate identification and references
  - (5) clear and well-defined symbols (definitions may be submitted separately)
  - (6) indication of remote and/or powered controls.
- e. Incomplete and poor quality plans and bills of material, previously accepted for diagrams when arrangements were anticipated, will not be accepted in lieu of arrangements.

## GUIDELINES FOR MINIMIZATION OF PIPING ARRANGEMENT PLANS (Cont'd)

f. The following arrangement plans may be required and shall be submitted on request of the Officer in Charge, Marine Inspection or Technical Office.

- (1) classes I, I-L, II-L, and nuclear piping systems
- (2) casualty-control systems such as firemain, foam, sprinkling, bilge, ballast, etc.
- (3) high-hazard systems such as piping to bum LNG boiloff in boilers
- (4) other systems for which 46 CFR 56.01-1 O(c) presently requires arrangements.

g. The yard shall make all existing plans, diagrams, prints, fabrication and outfitting sketches and/or models, etc. available to the inspector upon his request.

h. Where diagrammatic do not provide sufficient information, but in the judgement of the Technical Office arrangement plans of the entire system are not necessary, the Technical Office may utilize one or more of the following alternatives:

- (1) request a sketch of a detail (such as manifolding, interlocks, etc .)
- (2) require particular dimensions to be added to the diagrammatic (exact locations of foam monitors, etc.)
- (3) direct the Inspector's attention to the questionable detail and comment on what would or would not be acceptable.

# American Bureau of Shipping

Forty-five Broad Street

New York, N.Y. 10004

Refer to: SK/Pb

File Ref. T-18-6

21 October 1975

Guidelines for Minimization  
of Piping Arrangement Plans  
CGD3(mmt)

United States Coast Guard  
3rd. District Customhouse  
Governors Island  
New York, NY . 10004, :

Gentlemen: Attn: "Cmdr. J. W: Kime

We have a copy of the U. S. Coast Guard's letter of 11 March 1975 with the proposed "Guidelines for Minimization of Piping Arrangement Plans," and in general we would have no objection to the procedure outlined in subject document.

We would however, require arrangement drawings for the following:

- a) Cargo oil and venting systems on oil tankers
- b) Cargo systems on LPG and LNG Carriers
- c) Cargo and venting systems on Chemical Carriers
- d) Refrigeration piping on vessels receiving \* RMC

The above are in addition to the arrangement drawings required by CGD3(mmt) .

Yours Very truly,

AMERICAN BUREAU OF SHIPPING

K. D. MORLAND  
Vice President

by



E. Schoenfeld  
Chief Surveyor - Machinery

CGD3(mmt)

OCT22 1975

RECEIVED



## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 1. General

The bulk of routine design calculations, both precontract and post contract, are now accomplished by the use of computers which are also being applied to manufacturing tasks at an increasing rate. However, some improvements can result from standardization of programs for each task to facilitate acceptance by industry and regulatory bodies through simplified submittals and review of the required calculations. Some tasks which do not lend themselves directly to computerization, such as development of plans, may be aided by the computer. For example, if more complete steel scantling plans, including a shell expansion, are developed in the precontract design phase as suggested, then the computer could be used in the development of the shell expansion plan as well as the frame, bulkhead and deck outlines for the structural plans using computer faired lines as a base.

The lack of applications of the computer to other tasks may, in many cases, be the result of the good judgement of the yards sampled rather than any obstacles to development. Comments made during visits by project team members to the various activities indicate this to be the case in some instances. Several yards have tested computerized methods for interference control and have concluded that the required results are achieved too late to be of practical value. Similarly it is the consensus of those yards who have considered the automated placement of ship's parts on the steel plate from which they are to be cut (nesting) that human judgement is superior to algorithms used in computer programs for automatic placement. While past conclusions on a manual or automated approach to specific tasks may have been valid, such tasks should be constantly reviewed in light of current technology as well as the impact on these tasks by method and procedural changes on related tasks. Examples are the hardware and software advances in the field of computer graphics which in recent years have made automated design and plan production based on a central data base feasible. This concept has been successfully implemented in some industries. Also, it is possible that the savings in time required to prepare nests for producing parts using automated methods may outweigh the inefficiencies of part placement.

### Efficient Computer Utilization

A significant number of the yards interviewed reported difficulty in realizing maximum potential from their technical and manufacturing applications. High costs and slow response time were cited as factors which tend to reduce the efficiency of CADAM throughout the industry. Often these factors are the result of a mismatch between technical program requirements and the data processing facilities available.

In the shipbuilding industry, as in most other industries computers were initially introduced to perform accounting, payroll, inventory control and other "business" type functions. Such jobs involve a minimal amount of calculations, large amounts of output, and are run on a regularly scheduled basis. The computers selected were usually large machines suited to this type application and administered by the financial branch of the organization. Technical

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 2. Efficient Computer Utilization (Cont' d)

applications, on the other hand, usually require a relatively small amount of output but a large amount of calculation, often dependent upon the complexity of each job, and are run on an irregular basis. These factors inhibit scheduling of technical jobs along with the routine, high volume "business" jobs and result in claims of low priority, high cost, and unacceptable turnaround time.

While most yards have existing commitments in computer facilities and organizational structures, an evaluation of both can result in improved CADAM efficiency. The requirements of business and technical applications must be recognized and a proper balance of the hardware and efficient operational environment for each achieved. Such a balance cannot be specified for the industry as a whole but must be defined by each yard. Factors which must be considered are:

Diversity of requirements within the total organization served.

Size and sophistication of the organization.

Availability of computers.

Size of programs and systems to be processed.

Type and amount of output required.

Size and number of data bases to be maintained.

Requirements for communications with other computers.

Because of its diverse nature CADAM requires an efficient inter-relationship between a specific application and the hardware upon which it is processed. In some instances only a small amount of computer power is needed while for others the manipulation of large amounts of data is required. The rapid evolution in data processing equipment has resulted in processors and peripheral devices applicable to a broad range of program requirements. The spectrum of data processing equipment available for application in ship design today extends from the low cost programmable desk top computer through the versatile minis to the large computers with their high speed and ability to manage the vast amounts of information contained in central data bases.

Development of the small desk top computers with programs stored on magnetic cards or tape cassettes has led to more computerization of routine engineering tasks. Typical of this type of computer are the Texas Instrument SR60 and Wang 700 Series, both with hard copy output, and the Hewlett Packard 9820. The programs developed by individual engineers and used by them on equipment located in their immediate work area represent a significant but hard to measure portion of ship design computerization. Such applications are not reflected in the survey conducted as part of this study. Typical examples of such applications are properties of structural sections and calculation of weights and moments. Another application for desk top computers is the recent development by Lloyd's Register of programs to assist in reducing plan approval response time.

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 2. Efficient Computer Utilization (Cont'd)

These programs are part of the Lloyd's Register Plan Appraisal System for Ships (LR. PASS) and provide the means for a Lloyd's surveyor or ship designer to immediately assess design decisions in the areas of structure and cargo handling gear. A paper describing the system can be found in Appendix C, item C-19(d). Although these computers are extremely useful they are limited to relatively simple programs, and larger computers are necessary to perform the complex calculations which are sometimes necessary.

Mini computers, such as those marketed by Digital Equipment Corp, Data General Corp., Hewlett-Packard and several other manufactures will accept sophisticated programming languages and have expandable memory capabilities. They are compact, inexpensive and well suited to "hands-on" programming and operation by the technical user. They are capable of supporting a wide variety of peripherals such as printers, paper and magnetic tape devices and cathode ray tubes (CRT). With these devices and expanded memories they are capable of performing almost any operation possible on the large computers. However, they are slower than the large scale processors and are comparatively less efficient when expanded to large configurations. They are best applied to specific applications such as controlling devices or processes, self-contained graphics systems, processing repetitive programs, functioning as a terminal to a large scale computer or any combination thereof. When evaluating one's needs in terms of a mini, consideration should be given to the compatibility of existing programs and other software to a mini, requirements for accessing centrally stored data, and the relative costs of processing by a mini rather than the more efficient larger machine.

Large computers such as the IBM 360 and 370 series, UNIVAC 1100 series and CDC 6000 series have high acquisition costs, require a supporting organization and need a high volume workload to be effective. This workload is usually comprised of both business and technical application which give rise to the problems referred to earlier. Such processors are mandatory for some CADAM applications and provide significant advantages for others under some modes of operation. Programs involving large amounts of data and extensive calculations such as finite element analysis of complex structures and NC systems with elaborate data base structures can only be handled by these larger machines. Such machines are also required to allow the interfacing between large programs or data bases.

Recent trends in data processing have been to combine the advantages of the minis with those of the large scale computer. Such an approach can be well suited to ship design and manufacturing when a mini-computer dedicated to technical and manufacturing applications also functions as a terminal for accessing a large scale computer, either within or external to the organization. The large computer is then available to process those technical data handling tasks and programs for which it is best suited, while the mini or series of minis processes the simpler applications and provides the interface to the larger machine. Such an "intelligent terminal" provides engineers and production workers with a greater calculating capacity than the desk top computer and, in addition, establishes a remote batch job entry or time share access to large computers for complex applications.

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 3. Computerized Drafting

In recent years the evolutionary development of computer applications has included the ability to provide pictorial output from computers through devices such as cathode ray tubes and numerically controlled plotters. Today systems are in use which can develop, store and produce graphic output associated with engineering calculations and plans. These systems can access data bases such as those developed for numerical control systems making large amounts of information relative to a vessel's geometry and structure available. Such systems have a high potential for bringing about significant reductions in the cost of plan production which represents about 2/3 of the total cost of a post contract design effort.

AUTOKON, SPADES and other NC systems generate the data to prepare the drawings defining hull configuration, hull fairing, lines plans, shell expansion, body plans for lofting, ships parts verification, etc. on NC plotters. In addition, one yard has used the AUTOKON Parts Program to produce partial plans on their large NC flatbed plotter. The general approach is to use the AUTOKON parts coding language to describe the basic geometry contained in the views comprising the finished plan. These views are drawn by the plotter on the paper or cloth original of the plan and given to the designer or draftsman to complete by finishing the views provided, adding views and details not coded as well as dimensions and annotation. The views prepared in this manner are primarily of ship structure and use information from the AUTOKON Data Base.

The method has been used to provide the primary views on structural plans as well as structural backgrounds for piping and electrical system plans. The yard has used the method for one design to date and reports its application on 36% of the structural plans and 13% of the piping and mechanical plans with an average net savings of 10% of the man-hours associated with each plan. The method was conceived and developed concurrently with the plan production effort so that it could not be applied to those plans with early start dates. When applied to a total effort, the percentage of plans assisted by this method will increase to about 75% of the structural plans and 25% of the piping and mechanical plans. Other applications which will benefit substantially from this approach are arrangement drawings, composites, and sketches for foundation development. Details of this application of a computerized numerical control system to plan production are contained in item C-17 of Appendix C.

Numerous computer graphics systems capable of producing plans are commercially available. Most are stand-alone systems comprised of computers and peripheral devices as well as proprietary software and constitute a significant expense with prices broadly spread in the six figure range. Usually, complete plans are created and stored within the system. A primary feature is the ability to rapidly make changes to the stored plans and produce revisions on a peripheral device. To date the complexity and size of ship's plans as well as the system cost has been a deterrent to shipbuilding application.

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 3. Computerized Drafting (Cont'd)

A non-shipbuilding user of one of the leading commercial systems reports that it utilizes the system for mechanical, electrical, structural and composite drawings. It estimates a 30 percent saving on initial preparation and updating of electrical plans and a 50 percent saving on composites. Most of the plans produced in this reamer require no manual work after leaving the system's plotter. The 3000 drawings required for a nuclear plant can be stored on 3-4 reels of magnetic tape.

Some of the systems currently being marketed are:

United Computing Corporation, Carson, CA.

Computervision, Bedford, MA

ADAGE, Boston, MA

Applicon, Burlington, MA

Auto-trol Corporation, Denver, CO

Abroad, the British Ship Research Association is currently developing a method to optimize outfitting and arrangements at an early stage in ship design using an Applicon system. In addition to accommodation layout the method will also encompass electrical schematics and pipe and vent duct routing. An Applicon system has also been installed at the Finnish Wartsila shipyard.

### 4. Piping Details

Computerized preparation of piping system fabrication instructions is discussed in subsection D. A system to prepare these instructions by digitizing completed composites or arrangement drawings is currently under development at Newport News. This is a cost sharing project funded by Mar Ad as part of the REAPS program and will become available to the US Shipbuilding industry upon project completion estimated to be early 1978.

A demonstration of a photogrammetric method for digitizing from scale models is described in the manual "Photogrammetry in Shipbuilding" (Item AI 3, Appendix C). Specifically the manual predicts: "Such digital representations could be manipulated to automatically plot system arrangement drawings, composites or isometrics at any desired scale. Also pipe bending details could be automatically generated as has been demonstrated elsewhere. Ultimately the digital data could be merged with other automated design systems. For these potential applications it is clear that photogrammetry could serve as an excellent 'input' device which would permit a combined pipe-systems designer/model maker to put his inherently interference-free piping arrangements into a computer."

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 4. Piping Details (Cont'd)

Several piping design systems exist which produce fabrication instructions as part of their output. One such system is the HICASS-P system developed by Hitachi Shipbuilding & Engineering Co., Ltd., and marketed by C. Itoh & Co., Ltd., Tokyo, Japan. In addition to fabrication instructions the system can produce arrangement drawings, purchasing information for fittings, fitting lists, control cards for NC bending and production control data.

The automated preparation of piping fabrication instructions is also being developed as part of the Navy's Computer Aided Piping Design and Construction (CAPDAC) system. This large scale system is being developed at the David Taylor Naval Ship Research and Development Center and will include modules for the design, planning and fabrication of shipboard piping systems, both Navy and commercial.

### 5. Avondale Reject

A survey was conducted as part of the "Research on Computer Applications to Shipbuilding" project contracted by MarAd to Avondale Shipyards, Inc., in late 1972. Its purpose was to identify the shipbuilding oriented programs then available and to establish a priority listing for development of needed programs. The survey results and a catalog of available programs are included in the Final Report, items C-9 and C-10 in Appendix C. Upon completion of the project, all data was turned over to ITT Research Institute to become a part of the ongoing REAPS program.

Specifications were developed by individual yards under subcontract to Avondale for programs in twenty-four of the highest priority areas. These specifications were circulated through the shipbuilding community and the resulting comments and recommendations added. It was anticipated that in the future programs would be developed which would meet all regulatory body requirements and represent standard programs for the industry. A list of the program specifications prepared and available from MarAd is contained in Avondale's Final Report.

The priority items identified have been reviewed in light of the yard interviews, questionnaire results, and literature search of the current study. It is apparent that some of the programs have been developed by the individual yards to meet their own needs and that other program development has been sponsored by governmental agencies.

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 5. Avondale Project (Cont'd)

Examples are: the Propeller Forces program to aid in hull vibration analysis, item C-20 in Appendix C, developed at Stevens Institute of Technology under Navy funding; the Seakeeping program written at MIT under MarAd funding; and the Damaged Stability program currently being prepared at Bethlehem Steel Company as part of the MarAd sponsored REAPS program.

For other applications, such as Interference Control, yard experience has yet to establish the practicality of computerization.

In the case of some priority applications, the questionnaires show that most yards are still deficient in programs related to that task. In several instances, industry approved program specifications have been prepared for these programs. Typical of these applications is Heating, Ventilation and Air Conditioning System design where only one half of the respondents report using a computer to perform some portion of the required calculations. While HVAC engineering and calculation represent only a small percentage of design costs, it is comprised of tasks which are common to all designs and all yards and thus represent a continuing cost to the industry. One yard estimates a 25-30 percent saving by using a program similar to that identified by the Avondale specifications (Appendix C, item C-21).

Some selected Avondale priority applications with high potential for computerization which the current study indicates are still not performed with computer assistance at a majority of the yards sampled are:

- HVAC System Design
- Commercial Ship Weights and Centers
- Holes Control (described in subsection C7)
- Thermal Analysis of Structure

### 6. REAPS

The "Research and Engineering for Automation and Productivity in Shipbuilding" (REAPS) program, part of the National Shipbuilding Research Program, is a cooperative effort by the Maritime Administration and participating shipyards to improve productivity and reduce Government subsidy rates in the US shipbuilding "industry through technical and manufacturing applications of computers. A description of the program, including a list of almost 90 funded projects can be found in the paper "The National Shipbuilding Research Program 1971-1976", item A-12 in Appendix C.

## E. COMPUTER AIDED DESIGN AND MANUFACTURING (CADAM)

### 6. REAPS (Cont'd)

REAPS membership is limited to US shipyards, and current members are Avondale Shipyard, Bethlehem Steel, General Dynamics (two yards), National Steel and Newport News. The program provides a forum for interyard communications on common problems and functions as an advisory group to MarAd concerning development of computer applications. The program is managed by IIT Research Institute, Chicago, Illinois, under contract to MarAd for this purpose.

It is recommended that standard programs for design tasks following industry approved specifications, such as those prepared as part of the Avondale project, be funded by MarAd under the direction of the MarAd sponsored REAPS program.

## F. CLASSIFICATION DRAWINGS

In a few cases, improvements in the design process have been initiated to minimize the number of drawings which must be submitted for classification and regulatory body approval, as well as for MarAd and owner approval, and to streamline the submittal and approval procedure to minimize duplication. These have been noted in Section 2 and discussed in subsections C11, D3, and D5 of this section. These improvements in the structural and piping design areas, when integrated with the basic design work in other areas, could result in a significant improvement in the post contract design process.

In the normal design process, the step from the precontract level documentation to basic design plans prepared during the post contract design phase involves a substantial increase in the Level of detail as well as the scope of examination. In addition, due to the general lack of definition in the precontract design regarding producibility related matters and design interfaces, such matters are often fully resolved only well downstream in the post contract detail design effort, frequently in a less than optimum manner. In cases where they form part of the design process, "Classification win-", are developed in the immediate post contract period primarily as a basis for obtaining class approval of principle structure and to provide a definition of the basic structural arrangements and scantlings of the ship. Development of basic structural system plans at the detail plan level are carried out subsequently.

If, however, this procedure is modified so that piping system diagrams, hull and machinery arrangements required for classification and regulatory approvals, and other design documentation are developed to a basic design level in parallel with the preparation of the structural "Classification Drawings", and integrated with these drawings, a means is provided for early and effective input of ship producibility decisions related to shape and plate size consolidations, module boundary definition, holes requirements, etc.

By utilizing the development of these "Classification Drawings" as a means of evaluating and integrating the principal demands of arrangements, structure and distributive system a very beneficial dual purpose is served by such plans, that is, not only is the normal intent of the "Classification Drawings" realized but also a comprehensive and well integrated overall definition of the total design obtained relatively early in the overall design period.

Numerous benefits can be realized by such a procedure, including: coordinated input of producibility considerations on a broad and timely basis, reliable early material and equipment purchasing, coordinated development of structure and arrangements and arrangement of distributive system to establish penetrations and minimize later interferences. In general, producibility of the design is improved and engineering risk reduced. The drawings and design data forming the output of this process should be sufficiently definitive that all class and regulatory agency approvals can be obtained therefrom.

## F. CLASSIFICATION DRAWINGS (Cont'd)

In order to accomplish this goal, as well as to minimize the number of drawings required for this purpose, some revision in the scope, format, and details of the drawings, as compared with conventional practice, will be necessary. This has been done for piping system drawings, as discussed in subsection D, and should be developed for arrangements, structure, machinery, ventilation, electrical, and other systems.

## G. STANDARDS

### 1. General

A standard is an agreed upon published description of an item and/or procedure defining characteristics within specified tolerances. It normally represents a tried and approved method of doing something, and many applicable to ship design have been developed, approved, and used in the past. In the design process, their use reduces design time and cost, minimizes errors, reduces risks, and improves the product. Some standards can be effectively used for decades, whereas others require change periodically as technology advances.

MarAd, design agents, shipyards, and professional societies have all developed engineering and design standards, and a few have become industry standards, such as the SNAME Trial Codes. MarAd's standard ship specification could perform a more important role if it is expanded to define and describe the standards of acceptable quality in order to reduce the day-to-day arguments which occur between the owner and shipyard representatives.

### 2. Standard Structural Details

This subject is being covered in depth by MarAd/BIW Task S-11 Standard Structural Arrangements. Most, but not all, shipyards use standard structural details which are available on standard plans or in booklet form. Most shipyards state that these standards need updating, and pointed out that standards change frequently. Regulatory bodies (ABS, USCG and MarAd) endorse standards, preferably industry standards, and once approved they expect adherence to the standards without requests for relief or deviations. However, it is recognized that different manufacturing techniques will create a need for a specific set of standard details unique to that process, but these alternative details should be minimized.

Standard structural details and parts can improve the ship design and producibility if they are properly used and controlled. Obviously their use will reduce design and drafting time. The application of the standard to the design must be checked for adequacy, and the temptation to innovate when a standard part is more than adequate must be controlled.

Once the standard detail is developed and approved by the regulatory bodies it may be coded in a subroutine, stored in the data base, and recalled at will by a coder when preparing a NC burning tape. Standard parts may be recalled and nested with other parts on a plate.

### 3. Standard Welding Details

This subject is also being covered by MarAd/BIW Task S-11, and comments similar to the above apply. Manufacturing and welding methods are not the same at all yards.

## G. STANDARDS

### 3. Standard Welding Details (Cont'd)

Shipyards generally have a plan or booklet of standard welding details so that specific details may be referenced on structural drawings, avoiding repetitive detailing. Often, the AWS standards are used.

### 4. Standard Frame Spacings

This subject is also being covered in depth by MarAd/BIW Task S-11. --

Standard frame and stiffener spacings are an advantage to producibility, especially where the shipyard uses equipment of the type which automatically and simultaneously welds more than one stiffener to a plate. Because of equipment and plate limitations (90 inch width to 120 inch width) different stiffener spacings may be necessary at different shipyards, and therefore bidding and contract plans should not be restrictive.

When different ship designs are being built concurrently, it is beneficial to production to use the same frame and stiffener spacings and stiffener sizes for both designs. This was carefully examined and determined to be economically feasible for a 100,000 dwt tanker to be constructed concurrently with an LNG tanker, again indicating that bidding and contract plans should not be restrictive.

### 5. Standard Fittings

A number of shipyards have prepared standard plans for fittings of various types and sizes, including:

Mooring bitts	O.T. & W.T. hinged hatch covers
<b>Mooring</b> pipe with horns	Manholes, various types (11)
Panama Canal chocks	Boom steps
Roller chocks	Stowage boxes and lockers
Closed chocks	Racks
Roller fairlead	Notice boards, signs, etc.
Cleats	
Painter's stage and Bosn's Chair	
Ladders.	

Many of these are now outdated, and there is a tendency to buy more and make less. It is not a significant cost item in the design process, but approved industry standards would provide a definition of acceptable practice.

## G. STANDARDS

### 6. Standard Specifications for Component Procurement

This subject was included in the MarAd/BIW Ship Producibility Program in the Repulsion Plant Standards Feasibility Study performed by M. Rosenblatt and Son, Inc. (Appendix C, Item A6). The report recommends development of standard procurement specifications for components, including the technical specifications, the terms and conditions, and vendor data.

Of the shipyards visited one had developed standard specifications and terms and conditions. Others prepared the technical specification by updating a previous specification. When there had been many similar contracts, they provided a backlog of developed specifications which often could be used simply by changing numbers. Terms and conditions are generally standardized for each ship contract and used for each component.

It was suggested that industry-standardized technical specifications for strictly marine components would also be advantageous in defining the vendor-shipyard interface, particularly on details such as instrument connections, and electrical connections such as wires or lugs or terminal boards, etc.

### 7. Standard Repulsion Systems Diagrams

These standards were proposed in the previously referenced study (A6). In this study a number of the shipyards interviewed indicated that it would be advantageous to have sized and approved diagrams to minimize development time and enhance acceptability by the customer. The latter is a major problem in many cases, with too many opinion and preference items being added by owner's representatives. Also, if the standard diagrams are prepared in accordance with USCG guidelines (see Section D) and approved by USCG, then there should be few changes due to interpretations of the rules which have been a problem.

Some shipyards have prepared standard diagrams for a number of systems and for a specific project insert the capacity data and pipe sizes on a reproducible of the standard diagram. One yard uses a standard diagram with pipe sizes designated by letters with tabulations on the diagram for various shaft horsepower giving the capacity data and pipe sizes keyed by the letters.

It may be difficult to obtain industry acceptance of standard diagrams, particularly by owners, but the attempt should be made because of its importance in setting a standard of good practice. This may be implemented as proposed in the reference study (A6) or as a part of the recommendation in the following article, or preferably by a MarAd/Industry research project to be performed by one shipyard with others assisting significantly through a compensated Advisory Council.

## G. STANDARDS

### 8. Standard Specifications for Ship Construction

The Maritime Administration has developed standard specifications for the construction of cargo ships and tankers and with different types of propulsion machinery. These specifications are good and are used as standard references, but they should be improved to include adequate definition of acceptable quality in many areas. They have not been used as a contract document in any case, but many sections of owner's specifications have been verbatim copies of the MarAd specification.

The standard specifications were prepared by MarAd and submitted to many organizations for review. The time and cost required to make a thorough meaningful review was a significant deterrent to many. If complete comments had been made by all solicited, they would have been conflicting in many aspects. An example of comments submitted in one case is included herein, Pages 3-58 and 3-59, and indicates some of the inadequacies.

If standard technical specifications for component procurement are developed (Article 6 above), they could be invoked by reference in the standard ship specification, eliminating many pages and providing much better detail and definition of quality. Alternatively, a "Qualified Products List" could be developed which would include those components that have demonstrated successful performance, reliability and maintainability in U.S. commercial service.

It is recommended that MarAd sponsor financially and lead a study team, staffed by representatives of MarAd, shipowners, shipyards, and design agents, to produce a modified and amplified standard specification that will provide standards for quality and acceptable construction. It is also recommended that the cooperation of the Shipbuilder's Council and American Institute of Merchant Shipping be obtained to strengthen final acceptance of this project.

### 9. Standard Central Control Systems

At present ABS, USCG, and MarAd have requirements for central control systems and each owner has additional requirements. It is recognized that the emphasis is different for ABS, USCG, and the owners, but there should be agreement on the requirements for an adequate, safe, and reliable system. The USCG requirements are given in NVC 1-69 "Guide for Automation of Main and Auxiliary Machinery". This was issued in 1969 and is still a guide, with requirements which design and service experience have proven to be unnecessary or unsafe still being omitted by obtaining a waiver.

Embellishments by owners may add so many monitors, alarms, and trips that the system tends to become less reliable than the basic plant, with false alarms and shutdowns.

## G. STANDARDS

### 9. Standard Central Control Systems (Cont'd)

Experience has shown that unless the central control system is defined in complete detail in the specifications, inevitably there are disagreements with resultant cost increases during design development.

Therefore, it is recommended that the MarAd sponsor financially and lead a study team, staffed by representatives of the ABS, USCG, MarAd, shipyards, shipowners, vendors and design agents, to develop a standard specification for automatic and remote control systems by:

(1) Establish consistent basic design standards, acceptable to the USCG, ABS, MarAd and Owners.

(2) Provide detailed and specific standards for what is required to properly control the basic plant for various types of plants and proposed manning levels, based upon careful design analysis, past operating experience and economic factors, to minimize the continued inclusion by owners and others of special functions and features which result from a broad interpretation of the present non-specific and often inconsistent design standards.

It is suggested that these be prepared for two man and one man watch systems, unattended engine rooms, and for geared steam-turbines, gas turbines, and geared diesel propulsion systems. Initial efforts should be confined to two man and one man watch systems for steam propulsion plants which are of primary interest to U.S. owners of U.S. flag ships and which are most controversial. Later, these specifications may be extended to unattended engine rooms and other types of propulsive plants if satisfactory results and acceptance of initial efforts are obtained.

The proposed revisions should take greater cognizance of the operating and maintenance requirements of central control systems with emphasis on increased operating reliability and reduced maintenance time and expense. Detailed specifications and requirements which emphasize design simplification, consistent with the operating requirements, and also the importance of a failure mode analysis of critical systems, will support these objectives.

COMMENTS ON PROPOSED STANDARD  
SPECIFICATION FOR TANKER CONSTRUCTION

- Section 1 Table of characteristics needs clarification and proper definitions.  
  
Model test program is a minimum. It would not provide assurance in regard to cavitation and vibration.  
  
Vibration clause is weak and wouldn't satisfy many Owners nor protect the shipyards. --  
  
Noise clause should be improved.
- Section 2 Does not include adequate structural standards in regard to fairness, line up and fit, correction of defects, etc.
- Section 13-14 Probably inadequate for current tanker practice.
- Section 19 Invokes MarAd OB and MA furniture which is expensive and not of best quality and appearance.
- Section 27 Requires ship's stores (dry and reefer) to be carried in containers. This is inconsistent with Section 66.
- Section 50 This section is brief, except for list of machinery. It describes a conventional steam plant on which the rest of the machinery specification is based. It does not include improvements recommended in past MarAd research and design studies. There are inconsistencies between Section 50 and the other sections.
- Section 53 Repeller tolerances should be revised.
- Section 54 Does not include specification for the atmospheric condenser which is required by Section 50 and the system description.
- Section 57 Requires gravity type l.o. system, two l.o. coolers, etc. Could be simplified.
- Section 58 Uses salt water for all miscellaneous cooling requirements with no alternative mentioned for fresh water cooling as recommended in MarAd CMX study and used in tankers being built. Also, mixes bilge and clean ballast systems, voiding pollution abatement requirements. Selection of S.W. pumps for various service should be further considered.

COMMENTS ON PROPOSED STANDARD SPECIFICATION FOR TANKER  
CONSTRUCTION (Cont'd)

- Section 60            Condensate system requires hotwell level control, which means no cavitation in pump, yet pump specifications require materials good for a cavitating pump.
- Section 61            Appears to include inconsistencies and redundant requirements. Apparently doesn't require superheat control Burner, steam air heater, and regenerative air heater specifications are inadequate.
- Section 67            This applies to reefer cargo, which is questionable for tankers.
- Section 68            Cargo oil systems - Inadequate. Should be expanded
- Section 70            Too many general cargo ship requirements. Needs revision to specifically suit tankers and their variations and to be consistent with Section 61. Invokes shore side stack emission standards, but Section 61 specified fuel oil with up to 6 percent sulphur. No low sulphur oil system specified.
- Smoke indicator in Section 70 doesn't agree with Section 61.
- Section 72            Inconsistent with Section 50.
- Section 73            Needs review and revisions of pump materials, doesn't adequately cover cargo pumps. Redundant description of specific pumps
- Section 74            Specifications required further detail.
- Section 75            Should be simplified
- Section 76            Doesn't permit alternative recommended by MarAd CMX study.
- Section 100           Fifteen pages of detail requirements which are far in excess of usual tanker practice.
- Section 101           This section, Test and Trials, is only one page. It invokes SNAME and MarAd trial and tests codes and procedures which are not definitive as to what trials and tests are required. Also, requirements for trials to demonstrate guarantees, base conditions, corrections of trial data, etc., are not included.

## H. OTHER PROBLEMS AND SUGGESTED IMPROVEMENTS

Many problems and suggested improvements in both the precontract and post contract design processes have been described and studied in the foregoing sections of this report. This subsection will cover briefly other problems and suggested improvements.

Some problems identified affect the contract. Change was one of these. Some changes are an essential part of a shipbuilding project, such as those to comply with regulatory changes, and others are desirable to respond to new technology or new owner's service requirements; but the latter can be extensive and result in delays in construction which adversely affects all other work in the shipyard. One shipyard minimized the latter problem by having the contract provide for essential and unessential changes, where the former is limited to regulatory body changes, and the latter include all other changes and do not have to be made by the shipyard. Changes interpretations of regulations by regulatory bodies is another troublesome item. One shipyard had the foresight in 1972 to provide in a contract that new interpretations of regulations would be treated as a change in regulations and therefore eligible for a cost increase. This protects the shipyard, but doesn't cure the problem. The cure should be implemented by direct approach to the agency concerned with specific examples, recommending that interpretations made by district offices should be unified by headquarters which wrote the regulation, and that clarifications and interpretations of the rules and regulations be issued to all at frequent intervals to be followed by revised or cited rules not less frequently than annually. A unified approach by the shipbuilders (or the Shipbuilders Council) and MarAd to the US Coast Guard headquarters in Washington may be the proper method with the best chance of success.

There has been a tendency in recent years to make new regulations apply at a cascade of dates including at contract, keel laying or delivery. This is particularly true of regulations originating in IMCO. This generates complications in extended series of ships under contract. Except under extraordinary circumstances new regulations should not apply after contract. If conditions do warrant it, new regulations should apply to all vessels after some time period. Rule changes occurring at any time after contract are likely to cause significant disruptions due to the long lead times in planning, scheduling, ordering and subassembly work. The agencies should be encouraged to abandon these post contract, predelivery application dates.

New ship designs of an advanced type may have areas of technical risk which cannot be resolved in the pre-contract phase. These should be recognized by all concerned, defined, and agreement reached in the contract on how they will be handled during design development, technically, legally, and financially. These risk areas often include those of excessive propeller cavitation and hull induced vibration which generally cannot be thoroughly investigated in the pre-contract design phase, and even when studied in depth no guaranteed solution may be possible within the state-of-the-art. Risk areas may also include the applications of a developmental system required by the shipowner. Responsibility for the system and design should be defined in the contract.

## H. OTHER PROBLEMS AND SUGGESTED IMPROVEMENTS

Many of the identified problems and suggested improvements affect the Ship Specifications, and some are covered in the preceding sections. There has been much discussion of performance versus definitive specifications. One shipyard tried a brief performance type specification for a negotiated contract with unsatisfactory results. The consensus was that specifications for competitive bidding should be of better quality, more definitive, and more complete than heretofore. Generally the ship specification is a combination of performance and definitive specifications, and when the shipyard is responsible for the overall design, they are responsible for meeting performance requirements originally defined by the shipowner (except for defined risk areas). For subsystems, the specifications may set forth performance requirements and quality constraints and leave definition to shipyard design development, or the specification may set forth the performance objective but define the subsystem in detail including quality constraints. In the latter case, -- the definitive specification should govern, although shipyards noted cases where owners wanted it both ways.

It was the consensus of the shipyards that the contract specifications should define quality constraints and acceptable standards for construction so that acceptability does not depend on owner preferences. (See Article B2a of this section for one method of identifying standards of construction.)

It was the consensus that better definitions are required to clarify the intent and applicability of contract plans, guidance plans, and technical data furnished for information. It should be possible to make plus and minus changes to guidance plans without a change order. It should be possible for the shipyard to make improvements to the design (which may reduce costs) without a cost reduction change order, since the owner will be getting an improved product for the same price.

It was the consensus that if ABS is named as the Classification Society, that their Rules (which they define as a minimum for class) are adequate and become the acceptability standard for any item affecting class including inspection by surveyors. If this is not satisfactory to the owner, it should be so stated prior to contract and other criteria specified. It should not be the responsibility of the shipyard to prove by engineering analysis that the ABS Rules are adequate, nor should other Classification Society Rules which may be more restrictive be used as a standard of acceptability unless such requirements are invoked in the specifications.

It was the consensus of the shipyards that the contract specifications and plans should be as complete and definitive as possible for all cargo systems and for the central control systems including automation features and instrumentation. For the former, the owner's requirements should govern, and for the latter the development of standard acceptable systems is recommended in preceding sections of this report.

## H. OTHER PROBLEMS AND SUGGESTED IMPROVEMENTS (Cont'd)

Valve design, materials, and trim specifications have been the cause of high cost and long delivery, where valve specifications are neither commercial standard nor Coast Guard approved. Two shipyards make a practice of buying only USCG approved valves which are ordered promptly and delays eliminated or minimized. When developing the previously recommended improved standard ship specification, the valve design and material specifications therein should be modified to benefit from this experience.

As a producibility item, it was suggested that the standard ship specifications permit electric cable splicing where permitted by and in accordance with USCG regulations.

As noted in Section B, the type of joiner work is a producibility item of cost significance. It is recommended that owners permit the shipyards to propose alternative systems, covering modular units and different types of joiner bulkheading and erection systems.

It was the consensus that contract plans should be approved by USCG prior to contract, particularly piping diagrams and fire control systems, as indicated in Section B. Recently Coast Guard has refused to look at plans for a ship that is not under contract and won't give an opinion without a written proposal. Considering the importance of USCG approved systems to the contract design and price, and considering the prevalence of new interpretations of regulations, a unified approach to Coast Guard should be made by MarAd and the shipbuilders (or the Shipbuilders Council) to urge USCG approval action on precontract plans prepared by Design Agents under contract to Shipowners for the design of subsidized ships.

Improved plan approval procedures were urged by some shipyards. Lack of timely approval by owners was cited in a few cases. Some suggestions for reduction in the number of plans submitted for approval were made in preceding Sections of this report. MarAd has reduced their requirements significantly, and the action period of 20 days required on subsidized ship contracts should be considered timely. That is much more prompt than ABS or USCG action. The ship contract should require prompt action and specify a deadline.

SECTION 4  
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

A. GENERAL CONCLUSION FROM THE SURVEY OF CURRENT PRACTICES

1. Precontract Design

a. There have been two fundamentally different approaches used for precontract design: (1) for competitive bidding, and (2) for negotiated contracts.

b. There is a wide variation in the scope of precontract design depending on:

New design or adaption of an existing design

Subsidized or non-subsidized shipbuilding project

Complexity of the design

c. Many modifications in bidding plans and specifications are desired by the shipyards to permit development of, and bidding on, more producible designs and to facilitate competitive bidding.

d. It is clear that one shipyard's optimum design for producibility would not be optimum for others, and that bidding on a design suitable for only one shipyard would not result in competitive bidding.

2. Post Contract Design

a. Although varying in scope, method, and details, all approaches to postcontract design are fundamentally the same. The most fruitful sources for improving the postcontract design process are the different criteria used by the different shipyards in designing for producibility.

b. It was the consensus that no improved design process, per se, would result from the study, but that a significant number of improvements are possible. **Most** of the improvements identified are not new, and it was found that at least one shipyard is practicing or developing each of the improvements, but there is no shipyard employing or developing all of the improvements. Structural and piping design were found to be the primary areas for study since together they consume about one half of the engineering and design budget, and about 65 percent of shipyard labor hours.

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 1. General

- a. Conclusion. Increased emphasis should be directed to the producibility features of ship design (page 3-1).\*
- b. Conclusion. Enactment of public law (PL94-372) Negotiated Shipbuilding Contracts Act of 1976 will minimize the occasions where competitive bidding is necessary, as was the case after enactment of MM'70, thereby facilitating the inclusion of shipyard producibility features in the contract plans and specifications (page 3-1).
- c. Conclusion. The major item of producibility is the structural design, but nine other areas are identified as having a significant impact on producibility and price. (page 3-2).
- d. Conclusion. Designing for producibility generally increases weight. It is recommended that the contract weight estimate make allowance for this, approximately one percent of net steel weight (page 3-7, page 3-27).

### 2. Precontract Design

- a. A negotiated contract design procedure is recommended whereby the owner solicits shipyards for proposals for budget price and delivery for his shipbuilding project, and furnishes the following information:

Performance requirements

Outline specification

Power plant preferences or requirements

Cargo handling and stowage requirements

Crew requirements

Central control system preferences or requirements

Coating system preferences or requirements

-Preliminary Design Study required by the Maritime Subsidy Board's Form FMB-8 if MarAd participation is contemplated.

After selection of a shipyard the owner and shipyard would combine technical skills and financial involvement to develop the contract design (page 3-3).

\* Page numbers in parentheses refer to detail discussion and/or evaluation of the subject in Section 3.

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 2. Precontract Design (Cont'd)

b. Alternative scopes of precontract design suitable for different circumstances are recommended (page 3-4). The minimum scope for a design similar to previous or current construction would consist of the following:

Specification  
General Arrangements, Hull and Accommodations  
structural Drawings  
Cargo System Diagram

**This minimum scope defines the basic contract parameters but the total definition of the ship includes the shipbuilder's standard practices as exemplified by current construction.**

A more definitive scope is required for a new design and a new client, and in addition to the above would include:

**Arrangement of machinery  
Heat balance diagram  
Fire control diagrams  
Diagrams of key propulsion systems  
Diagram of electrical distribution systems  
Lines  
Technical data**

If the ship is to be subsidized by MarAd, the scope of the precontract design must meet the requirements of FMB-8, and generally is more extensive and in more detail than the foregoing for contract purposes, for estimating domestic and foreign cost as well as for contract administration with Government involvement (page 3-6).

c. A procedure is proposed for owner prepared designs for subsidy and bidding which provides for flexibility in the structural design to suit the producibility features of individual yards, specification options to suit shipyard facilities and practices, and contract recognition of essential and unessential changes (page 3-6).

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 3. Post Contract Structural Design

a. The number of structural plans presently required when designing for producibility is substantially more than heretofore. The manhours used for structural design in one case amounted to about five percent of the manhours used in fabrication and erection of the steel structure which appears reasonable.

It is recommended that the basic scantling plans (about 15 drawings) be developed in more detail, and in such format and scope that they provide all the information required for classification approval. (These plans are then similar to the "class drawings" submitted by foreign shipyards.) It is also recommended, that if the basic scantling plans are developed in accordance with the foregoing, that the conventional system type plans can be deleted, and the unit or module plans can be developed directly from the basic scantling plans (page 3-28). (See Article B-6 for other "Classification Drawings".)

**b. It is recommended that the structural design be thoroughly re-examined and evaluated as soon as the design is essentially complete, and before ordering steel (at least before ordering steel for any following hulls) to obtain improvements in producibility through standardization and consolidation of plates, shapes, and parts, and to obtain reduction in ordered steel through improved nesting, batch manufacture of parts and utilization of cuttings (page 3-10).**

While consolidation and standardization may result in a small increase in net steel weight, it results in reduced ship price through significant benefits realized in the areas of:

Reduced handling

Reduction in material cost extras due to low tonnage

Reduced scrap levels through improved nesting and batch manufacture of parts

Improved traceability

Reduced bookkeeping in purchasing, design and inventory control

Increased flexibility for revisions

Improvements in labor and machine productivity

Conclusions from the evaluations of various examples are given in the following paragraphs.

c. It is concluded from studies and specific evaluations that consolidation and standardization of stock or coded plates, plan marked plates, and shapes can be profitable to both the shipyard and ship owner (page 3-10).

## B: CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 3. Post Contract Structural Design (Cont'd)

d. It is concluded that batch manufacturing of and stockpiling of parts through the nesting of chocks, brackets, etc. on the unused portions of plates to be cut on the Automatic Burning Machine can result in reductions in scrap, steel purchased, and handling. One specific example showed a saving of 300 tons of material and \$70,000 in cost (page 3-15).

It is recommended that the development of the structural design should be responsive initially and by re-iteration to the needs of batch manufacturing of parts, by standardizing part dimensions and by specifying thicknesses which utilize potential scrap.

e. It is concluded that the present process of nesting parts for fabrication is the most efficient, based on available experience. In this process, the or, or “puzzle” part of nesting is performed manually in the traditional manner and the second part the preparation of a template or numerical control (NC) data is performed by computer in most instances (page 3-16).

It is recommended that current developments in the computerized placement of ship's parts for nesting and preparation of NC data of completed nests be closely monitored by the shipyards, since there is a potential for additional savings (page 3-17).

f. In order to properly integrate the loftsmen's and structural planner's knowledge of fabrication methods with the engineer's and designer's comprehensive view of a vessel's structural requirements, it is recommended that these groups work in close proximity from design development through NC tape preparation (page 3-17).

g. It is concluded that cross unit nesting, the placement of parts from several erection units on a single steel plate, can improve material utilization and reduce the scrap. The results of a cost evaluation at one yard and the experience of another shipyard indicate that cross unit nesting within units fabricated in a one-week period can yield material savings in the order of three percent of the steel fabricated on Automatic Burning Machines at a savings of about \$25,000 per ship. It is recommended that this concept be considered by other shipyards (page 3-18).

h. It is concluded from the study of holes control, that significant reductions in the costly operations of manual layout and field cutting of the many penetrations required in the ship structure can be achieved by increasing the number of penetrations included

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 3. Post Contract Structural Design (Cont'd)

in the initial cutting process, and by consolidating systems data so that layout and cutting in a specific area, unit, or module can be performed as a single task (page 3-20). A cost evaluation shows a conservative saving of \$38,000 for a three-ship program (page 3-23).

**It is recommended that the sizing and routing of distributive systems be developed early in the design cycle in parallel with the structural drawings, to permit identification of holes' list and location on the structural drawings prior to initial issue for fabrication (page 3-21).**

It is recommended that a file of distributive system holes data be stored in a computer memory. This data can be recalled, sorted by unit or system, and used to assist in identifying interferences, the incorporation of holes in NC parts tapes, preparing lists of field cut holes, and the preparation and updating of holes list (page 3-~5).

- i. It is recommended that mill edge plates should be used when available as their cost is about 1.6 percent less than sheared edge plates. Designers specifying plate sizes should be well acquainted with the steel manufacturer's specifications and tolerances for all types of plates being used (page 3-26).
- j. It is recommended that alternative acceptable thicknesses be specified by the designer for detail parts such as collars, chocks, clips, and flat bar stiffeners in order that the parts coder may utilize potential scrap and cuttings (page 3-27).
- k. Designing for producibility almost always increases the steel weight. It is recommended that the contract weight estimate make reasonable allowance, for this through an increased weight margin. An example indicates that an allowance of one percent of the steel weight should be sufficient (page 3-27).

### 4. Post Contract Piping Design

- a. It is concluded that there are significant differences in the piping design procedures in the various shipyards, but all use composites for interference control, since the use of computers and models has been unsatisfactory for this purpose to date in US experience. Also, it is concluded that piping design is a large consumer of manhours in the engineering and design departments of US shipyards, based on methods currently used; the hours being comparable to those used for structural design, and the ratio of piping design hours to pipe fabrication and installation hours is ten times higher than for structure (page 3-30).

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 4. Post Contract Piping Design (Cont'd)

b. It is concluded that almost all conventional piping system arrangement drawings can be eliminated by the use of improved piping diagrams and composites. The improved piping diagrams are defined by USCG and ABS action on proposals submitted by two shipyards to permit elimination of arrangement drawings (page 3-30).

c. A recommended piping design procedure is presented in the Report (page 3-32) and includes:

Preparation of diagrams following the USCG guidelines, which require diagrams of superior quality, pertinent system and component design characteristics, identification of each fitting and component, material schedule, and bill of material.

Composites developed by area or zone, to be used as the installation drawings for all piping systems.

Pipe details prepared by computer which contain all the information for fabrication including a Bill of Material for each piping assembly.

Early identification of candidates for modular installation in order to realize the advantages of shop assembly.

A computerized Bill of Material system which interfaces engineering, design, inventory control and purchasing.

A simplified method for identifying systems and parts.

d. Based on successful European experience, it is concluded that scale models can be used for the development of the engine room piping layouts in lieu of composites and arrangement drawings (page 3-34).

It is recommended that any shipyard desirous of improving their piping design method should evaluate the model procedure which has proven to be cost effective for commercial shipbuilding in European shipyards. With this procedure, the piping design would consist of the diagrams to USCG requirements, the model, the isometric pipe details and the Bills of Material.

e. Purchased or shop assembled machinery and piping modules or packages have found increasing applications in ships, and are recommended as items which will improve producibility (page 3-37).

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 5. Computer Aided Design and Manufacturing (CADAM)

a. Computers are utilized extensively for ship design and calculation throughout the industry, but there is room for improvement in the efficient integration of engineering and business use of computer facilities to reduce costs and response time for CADAM applications (page 3-43).

It is recommended that individual shipyards review their existing computer facilities and organizational structures and the advantages of a mini-computer dedicated to technical and manufacturing work, to improve response time, reduce cost and also to serve as a terminal for accessing the large scale computer (page 3-43).

b. Computers have been successfully applied to the preparation of structural plans for modules, structural backgrounds for machinery, piping and ventilation arrangements and composite drawings, resulting in cost saving of about ten percent. Lines fairing and lines plans, shell expansion, large scale (1/10) body plan for lofting, etc. are routinely produced as part of NC systems such as AUTOKON and SPADES. It is recommended that at least the foregoing extent of computerized drafting be considered by all major shipyards. It is also recommended that the rapid development of computerized graphics and drafting systems be monitored for shipbuilding applications (page 3-46).

c. It is recommended that computerized piping system fabrication instructions under development as part of the US Navy's Computer Aided Piping Design and Construction (CAPDAC) program and by Newport News Shipyard as part of MarAd's REAPS program as well as other piping design systems available here and abroad be evaluated for use by each shipyard (page 3-47).

d. It is recommended that further research be applied to the photogrammetric method for digitizing from a scale model so that a combined piping system designer/model maker can put his inherently interference free modeled arrangements into a computer (page 3-47).

e. It is recommended that standard computer programs be prepared in accordance with industry approved specifications, such as those prepared as part of the Avondale project, and be funded by MarAd as part of the MarAd sponsored REAPS program (page 3-48 and page 3-49).

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 6. Classification Drawings

a. It is recommended that the post contract design procedures be modified so that hull and machinery arrangements, piping system diagrams, and other design documentation required for classification society and regulatory agency approval are developed to a basic design level in parallel with the preparation of the basic scantling plans and integrated with these to form the "Classification Drawings". These plans would provide early and effective input of coordinated ship producibility decisions. In addition to meeting submittal requirements, these "Classification Drawings" provide a comprehensive and well integrated overall definition of the total design early in the post contract design period (page 3-51).

### 7. Standards

a. It is concluded that design standards, which are tried and approved methods, and their expanded use in the ship design process, can reduce design time and cost, minimize errors, reduce risk, and improve the product (page 3-53).

It is recommended that the use of standards be substantially increased, through development of new standards and improvements in others. It is noted that new standards for structural details, welding details and frame spacing are being developed under the MarAd/BIW Task S-11 (page 3-53), that standard specifications for component procure-merit were recommended in MarAd/BIW Propulsion plant standard feasibility Study, and that others have been recommended in other research projects (page 3-55).

It is recommended that standard propulsion system diagrams, proposed in the MarAd/BIW Propulsion Plant Standards Feasibility Study, be prepared by a MarAd/ Industry research project. These industry standards should provide sized and approved diagrams which will minimize development time and expedite Coast Guard approval and owner acceptance (page 3-55).

b. It is recommended that the MarAd standard specifications for ship construction be improved and amplified to include standards for quality and acceptable construction as well as the applicable results of the various studies conducted as part of the National Shipbuilding Research Program. It is suggested that the revised specification be prepared by a MarAd sponsored and lead study team representing MarAd, ship owners, shipyards and design agents (page 3-56).

c. It is recommended that MarAd sponsor financially and lead a study team staffed by representatives of USCG, ABS, MarAd, shipyards, ship owners, vendors and design agents to update the USCG, ABS and MarAd requirements for central control systems, and to develop in greater detail standard specifications for automatic and remote control systems, including basic design standards, specific detail standards and operating reliability and maintenance provisions, with the objective of providing specifications for adequate safe and reliable systems which are acceptable to all concerned (page 3-56).

## B. CONCLUSIONS AND RECOMMENDATIONS FROM THE STUDY

### 8. Other Problems and Suggested Improvements

- a. It is recommended that MarAd's standard pro forma ship construction contract be reviewed by an Industry study group and modified to incorporate provisions responsive to the problem areas identified, including essential and unessential changes, changes in interpretation of rules and regulations, definition of areas of technical risks and how they shall be handled, meaningful definition of contract plans, guidance plans, bidding information, definition of acceptability standards, etc. (page 3-60).
  
- b. Considering the importance of Coast Guard approved systems to the contract design and price, as well as the effect of new interpretations of regulations, it is recommended that a unified approach be made to the USCG by MarAd and the shipbuilders to discuss these problems, so that the contract design plans may be considered and approved by USCG prior to contract signing, and so changes in interpretation of rules by district offices will be minimized and unified (page 3-60).

APPENDIX A

NOTES MADE DURING INTERVIEWS ON PRECONTRACT DESIGN

## SHIPYARD A-PRECONTRACT DESIGN

Has prepared contract design (bidding plans and specifications) for own use in contract negotiations and for ship owners use in competitive bidding. All recent experience is for own use in contract negotiations.

Design prepared in response to tanker owners performance type specification which specified deadweight, cubic, limits on length, beam and draft, speed, type of machinery. Reposal design included:

1. Specification - about one third size of MarAd standard, but very definitive on equipment and outfit being furnished, coatings, material for piping systems, and quality type constraints. Names vendor or equal to define quality of machinery and outfit items.
2. Plans - General Arrangement, including accommodations

Two structural Drawings

Cargo System Diagram

Effort spent on design sufficient for preparing contract price ranged from about 2400 hours to 5000 hours. After tentative agreement, the specifications and plans may be developed in more detail to suit owner's comments, particularly in regard to outfit items, before the contract is finalized and signed. This effort is normally not large.

The specification is definitive to a point, but does not define many detail practices, fit, workmanship, etc. However, these are defined by the shipbuilder's plans and workmanship as exemplified by current construction.

The shipbuilder is not offering a standard design, but rather a base design, and accommodates the ship owner's requirements in essential areas. Cargo oil and related systems are designed specifically to suit the requirements of the owner's terminals and practices. Owner's manning, accommodations, painting, etc. requirements are met, unless they affect production rate. Machinery component selection by the shipbuilder normally prevails.

### Comments

Optimum for one yard is not optimum for all. Bidding on a design tailored to one yard is not competitive.

Bidding on performance specification requires shipyards to expend considerable time and money on a preliminary design for producibility.

Owners generally are not interested (to any extent) in production techniques, and little in structure other than in previous problems areas.

Performance type specification places greater burden on MarAd and Owner to determine responsiveness of bids to evaluate the different approaches used in the proposals.

## SHIPYARD B-PRECONTRACT DESIGN

In a recent case for a tanker, the owner provided minimum criteria (deadweight, speed, draft). The contract plans prepared by the shipyard were:

- General Arrangement
- Midship Section and Transverse Bulkheads
- Arrangement of Machinery (plans, elevations and sections on two drawings)
- Heat Balance and Flow Diagram
- Diagram of Cargo Oil System
- Diagram of Firemain System
- Diagram of Foam Fire Extinguishing System
- Diagram of Inert Gas System
- Diagram of Nine Propulsion Piping Systems
- Elementary Wiring Diagram - Elec Distribution System

The specifications were about as extensive as the MarAd Standard Specifications.

The owner would have liked more detail, but the time constraint imposed by a Government year end deadline on financing prevented this. Consequently there have been change orders, but not of a significant nature.

Effort expended on precontract design was about 13,000 manhours.

### Comments

Interpretations of rules cause problems when the results were changes. Needs tightening up.

**Boylston and Leback paper - no comment made - but don't agree that shipyards need stringent** product control through definitive specifications. Prefer specification to be more performance oriented so more flexibility in construction, but definitive specification is to the shipyard's advantage because everything is spelled out (if it is correct). Some owners want specification both ways, which is not equitable.

Boylston and Leback - doubt if can eliminate all ambiguities. If too specific - no incentive to offer improvements (example - bridge venturi).

Trouble with owner who considers ABS requirements inadequate, even though specification and contract invoke ABS rules and class. Owner keeps asking for more, i.e., increased scantlings quoting Lloyds, DNV, BV - whoever has requirement. Increased engineering costs to prove ABS is right, when owner won't approve on basis of ABS minimum. Had to do a great deal of vibration checks for stiffened plate panels to convince owner.

## SHIPYARD C-PRECONTRACT DESIGN

Basically - need a closely defined design for bidding and contract purposes. Less costly to have owner spend more than \$500,000 on bidding plans and specifications than to have four or five bidders spending \$250,000 each.

### Scope of Plans and Specification

Specification - about two inches thick

MaRad format

Equipment lists

Very definitive

Data and Calculations, etc.

Good detail weight take-off

Volume calculations for cubic sensitive ship

Short abbreviated report giving backup data, rationale, etc. (similar to US Navy design history)

Design Agent should put out the best data possible to back up the design, and there should be a real good design review (by MarAd technical).

If the shipyard intends to depart from the structural guidance plans, for the purpose of producibility, it is up to the shipyard to prepare the contract structural plans and weight estimate.

Standards for machinery plants, piping systems, procurement specifications and vendor plans, as proposed in Rosenblatt study, were favorably received.

## SHIPYARD D-PRECONTRACT DESIGN

Elements in past procedures that should be improved.

1. Typical arrangement of structure

Bid document should permit option to modify structure to suit yard facilities, etc., changes in structural arrangement - i.e. fore and aft peaks, shapes, grades, etc.

If bid document provides for optional structural arrangement, then up to yard to get ABS approval - maybe time constraint - or assume risk of ABS approval after contract.

If owner doesn't like proposed structural design of the low bidder, then negotiate (owner, MarAd, low bidder). Low bidder should not be disqualified by owner preference without evaluation.

2. Owner's specification must cover acceptable standards, not just owner's preferences.

3. One of greatest savings in bid process will result from providing sized diagrams approved by the USCG for the Firemain, Foam System, Insert Gas System, Fire Insulation and Hazardous Space Boundaries. (This will require USCG to act on plans of ship for which contract is not signed which will be a problem.)

4. Specification should permit producible systems of yard choice, in such areas as:

- Coating systems

- Coating systems vs XXH pipe

- Coating systems vs cathodic protection

- Joiner modular construction by subcontractor

- Cable splicing where approved by USCG

5. Time for bidding should be increased, if circumstances require, i.e., if too many bids being requested in the same period, to get time for ABS approval of alternative structural design, etc.

6. There should be more input at the time of bid, in regard to stem vibration, etc.

If definition is lacking, bidding time does not permit adequate consideration of possible vibration or cavitation problems.

7. Shipyard should be able to build the ship specified and bid on. (Essential changes and unessential changes should be included in contract terms. Essential changes (regulatory body changes) are the only ones that shipyard must incorporate.)

8. Bid package must include:

Specifications, at least MarAd standard  
Crew accommodations and quarters arrangements  
Lines, model tests, and horsepower  
Weight estimate

9. Need better definition of valves and valve materials in ship specifications, preferable commercial standard, to reduce cost and delivery time. Partly non-compatibility of USCG and commercial, and partly Owners vs Commercial and USCG, especially for trim.
10. Ship specifications should be explicit on owner's requirements for maintenance of piping systems (pipe sections as well as valves). More specific definition rather than general clauses, which are often conflicting.
11. Standardization - standard piping diagrams for propulsion piping systems, sized and approved by USCG, would be very helpful in advancing delivery, and avoiding owner comments.

## SHIPYARD E-PRECONTRACT DESIGN

Specification - Based on MarAd specification - but modified to suit. Tried a thin performance type, but found it to be unacceptable. Need details on quality, etc.

Not detailed in steel workmanship and fit, but based on experience any question in this area is always resolved satisfactorily.

### Contract Plans and Guidance plans for a tanker

- Unes
- General Arrangement - Plans and CL Profile
- \* Machinery Arrangement, Plans, Elevation, Sections
- \* Heat Balance (but guarantee Sfc in specification)
- Midship Section, transverse bulkhead, longitudinal elevation
- Approved by ABS prior to contract
- \* Scantlings, Plans, Elevations, Section  
(14 sheets on most recent design)
- \* Arrangement of Accommodations
- Piping Diagrams - Cargo Oil
  - Ballast
  - Bilge
  - FO Fill and Transfer
- \* Electric Load Analysis
- \* Electronics Antenna System
- \* Power and Lighting - one line diagram
- \* Shafting Arrangement
- \* Capacity Plan
- \* Curves of Form

### Comments

FO Fill and Transfer diagram for a tanker was included as a guidance plan because it was on MarAd's list, but is not very significant for a tanker.

Specifications should include ratings of all equipment, and piping diagrams should be sized, and approved by agencies. However, the definition of guidance drawings should permit changes (plus and minus) without a formal change order. Also, contract and specifications should permit shipyard to improve the design of systems which may reduce costs without cost reduction to the owner.

Cargo systems should be developed thoroughly in the precontract stage.

Automation and instrumentation should be completely defined in the specifications, so that additions requested by owners may be defined as a change.

Specifications should not be too definitive on material for trim of valves, because of impact on availability and schedule.

## MARAD - PRECONTRACT DESIGN

1. For subsidized ships, they expect return to the old method (owner developed design and specifications) due to the fact that the legislated subsidy rate when applied to present US ship prices does not give a reasonable foreign cost. To obtain the higher rate necessary to equillize US and foreign prices requires competitive bidding. (Later legislation modified subsidy limit.)
2. Scope of Preliminary and Contract designs is defined by FM3-8. Copy of Office of Ship Construction suggested changes was furnished.
3. MarAd Standard Specification is being improved. Also specifications for tanker, and other power plants are nearing completion.

No one has used the MarAd Specification as a contract document, but the complete detail specification prepared for contract purpose often includes sections which are verbatim copies of the MarAd Standard.

4. MarAd Standard Specification includes list of Contract and Guidance Plans which is basically up-to-date, with additional plans used where necessary to define special features of a given design.

MarAd pointed out that Guidance plans have to be reasonably correct, as lawyers consider them to be equivalent to Contract Plans.

5. To provide for competitive bids, and for producible detail design by the shipyard, better specification and contract language is necessary to give the shipyard the option of developing and using the producible design within the bid price without a cost reduction change.
6. Use computer in preliminary and contract design. Generally use the programs listed by them as given in SNAME bulletin. (Questionnaire later completed and returned.)
7. Cost yardstick - Did not have information readily available.
8. Were in favor of an improved plan approval procedure. Use of Key plan or Classification plan list acceptable, but MarAd wants a copy of all final plans for their use as data bank in design, cost estimating, etc.
9. Use of models to eliminate drawing, such as Moss for piping arrangements, might pose a problem, as MarAd requires set of microfilms or equivalent of all plans so that ships could be built by other yards if necessary during an emergency.

10. Favored use of modular production, including shop assembled machinery systems complete with foundations, equipment, piping, local controls and wiring, etc. Commented favorably on this in specific cases. Also noted the uneconomical multiplicity of paper work in a specific case.
11. Recent plan review experience results in MarAd seeing very little, so no comments on use of standard drawings and standard purchase specifications.
12. Better designs and design plans and specifications needed to keep changes to a minimum.

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#### Comments

Bidding plans and specifications - less drastic changes but many disputes.

Negotiated plans and specifications - more drastic changes but less disputes.

## LNG TANKERS - PRECONTRACT DESIGN

The precontract design for El Paso LNG tankers was discussed with the bidders.

El Paso (J. J. Henry) prepared a specification as a basis for the design plans and contract specification to be prepared by the shipyards. It was not possible for the owner to prepare a definitive design because of the very significant differences in the LNG containment systems. Thus, each bidding shipyard developed a ship design, and prepared their contract plans and specifications. The effort in each case (and that of the unsuccessful proposers) was in excess of \$500,000.

The soliciting specification was in considerable detail (almost 300 pages - single spaced) supplemented by 13 guidance plans. It contained performance and quality requirements.

## DESIGN AGENT - PRECONTRACT DESIGN

1. Scope of precontract design is available to General Dynamics, Quincy Shipbuilding Division from past projects.
2. Favors a two-tier specification
  - a. Performance (like an executive summary)
  - b. Shipyard to submit a detail specification such as used to price the ship.
3. Plan approval - believes that it is not easy to reduce scope. System plans for approval and unit plans not for approval would be satisfactory if properly defined. This was done by a shipyard on one class of ships.
4. Favored models as a design tool in special cases.
5. Raised question about the use of Casdos, and referred to test of the system being undertaken by the Navy at Newport, R.I. Shipyard.
6. Has no written procedure for preliminary or contract design.
7. Improvements
  - a. Feedback from ships in service to the designers should be improved.
  - b. There should be more communication between operators and designers and shipbuilders.
  - c. Designers need more cost data from shipyards and operators for optimization and evaluation of alternatives.
  - d. Designers need more reliability data.
  - e. Designers need more feedback from trials and guarantee period in regard to design corrections, improvements, etc.

APPENDIX B

NOTES MADE DURING INTERVIEWS ON POST CONTRACT DESIGN

## SHIPYARD A - POST CONTRACT DESIGN

### A. Producibility and Standardization

1. Yard Constraints
  - a. Basic thruput of 120,000 tons steel/year.
  - b. 60 ft x 60 ft unit (assembly).
  - c. 40-ton erection in limited areas, 200-ton limit out of panel shop to assembly area.
  - d. Plate size 60-ft long x 10-ft wide. Have not standardized plate sizes to anywhere near extent done at Quincy (penalty of weight and scrap).
  - e. Use mill edge plates.
2. Shapes
  - a. Use mill shapes to maximum practicable extent.  
Won't fabricate anything they can buy.  
Use cut channels for angles to 18 in. depth  
(example mentioned - 18in. 50 lb/ft channel with one flange trimmed off - no straightening required).  
Lengths are not standardized - buy as required.
  - b. Manufacture of angles, tees, etc. in the larger ( >18 in.) sizes is done by an incentive group with no labor constraints.
3. Standardization
  - a. Shapes - see above.
  - b. No options provided on plans for thickness of detail parts.
  - c. Don't usually allow upgrading (weld problems).
  - d. Use standard structural details, which have been updated recently. Standards are used rigorously, and are on tapes.

## SHIPYARD A - POST CONTRACT DESIGN

### A. Producibility and Standardization (Cont'd)

#### 4. Nesting

- a. Don't nest by computer, think loftsmen using doilies is more imaginative. Then goes on tape.
- b. Don't cross nest because of control problems.

#### 5. Scrap rate

- a. Didn't know - Use of mill edge plates will affect rate.

#### 6. Mold loft is under Production. Steel is listed by Design, allocation by Production.

### B. structural Drawings

1. Set of basic (system) drawings defines all structure. Getting more complex with each contract.
2. Set of unit plans (more than one unit per plan). These are shop drawings, and are not submitted to ABS for approval (cover a two or three dimensional unit).
3. Tried module plans - one to a unit.
4. Now proposing (for a new contract) to omit the system drawings, and proceed directly from the basic plans to the unit plans.
5. Structural design is more costly than heretofore, but saves cost in the yard where a high labor turnover rate exists.
6. Intend to exercise their NC system to go from scantling plans to parts program. Haven't run solely on this yet, but have made checks.

### C. Machinery

1. Don't have standard procurement specifications, per se, but have had many similar contracts which provide a backlog of developed specifications which often can be used simply by changing numbers.
2. Inquiry specification, after vendor is selected, is modified to name the vendor, and to delete or add as necessary to reflect the equipment purchased.

## SHIPYARD A - POST CONTRACT DESIGN

### C. Machinery (Cont'd)

3. Have stayed with the same steam cycle for many years. It is not the most economical, but is satisfactory.
4. Technology permits a one-man or unmanned control, but owners and unions may not want. Yard has developed a standard design for a two-man watch. On occasion, they have built a more elaborate system when the owner wanted it and was willing to pay the extra.
5. Machinery arrangement is essentially standard, except where it can be improved by experience and overall space availability. Machinery arrangement and design, from beginning to end is responsibility of the Chief Engineer. There is very early coordination between hull and machinery on the location of engine room bulkheads machinery casings, and basic structure in the engine room.
6. Test procedures prepared by the engineers. Test group is under Production.

### D. Machinery and Piping Drawings

1. Plan list furnished for a tanker.
2. Critical delivery item is now the boilers; it has been cargo pumps and valves in the past.
3. Composites are used for interference control (2-in. and up). (Use "holes list" for holes control - done by another group) Tried computer for interference control - but unsatisfactory.
4. The composites are the piping arrangement plans. The composites are prepared by area (3 dimensional space). The only system definition is the piping diagram, see below. Scales used - 3/4 inch and 1-1/2 inch.
5. Components and material are usually ordered prior to CG approvals. However, valves specified are USCG certified items so no question of disapproval. Release for construction is sometimes given before USCG approval. preliminary material list prepared by Design based on diagrams. Refined when plans are developed.

EM's made by system -no code numbers - use word description. Order Department consolidates - Valves are marked by Vendor when delivered. Valves and piping no problem - but fittings more difficult. (Admits this system requires degree of intelligence which may be disappearing. )

## SHIPYARD A - POST CONTRACT DESIGN

### D. Machinery and Piping Drawings (Cont'd)

6. Pipe details done in shop, except for stressed systems which are done by Design. Computer is not used for pipe details. No numerical control of pipe bending etc.

### E. Pipe Diagrams

1. Obtained USCG approval of diagrams on last contract, as complete piping approval without submittal of arrangement plans. The diagrams are more detailed as to material and "arrangement significance". (See USCG memo of 11 March 1975)
2. Definition of material might lead to problems unless valves are confined to USCG approved items, which is shipyard's policy.
3. Sample diagram furnished.

### F. Modules

1. Have used modules, and they worked fairly well for machinery. About 13 used on recent - large tankers. They went in late on the first ship, but on schedule on following ships.

### G. Models

the job as a design tool rather than a check.

3. Have been used on occasion for complex arrangements - such as for the main propulsion of an innovative system.

### H. Yard Liaison

1. Two men full time, supplemented when necessary.

### I. Numerical Control

1. Primarily burning.
2. Some in machine shop.
3. Not used for piping.

## SHIPYARD A - POST CONTRACT DESIGN

### J. Use of Computers

1. Questionnaire will be answered.

### K Improvements in Design Process

1. More computer in basic design, but rule changes inhibits (Tankers LNG, particularly). More investigation of shear forces in basic design. Almost impossible to develop optimized production by computer. Use computer for pieces, but manual integration.

Desk calculator (HP800) is a big improvement, with much less demand on the central computer.

2. Stop rule changes, and varying interpretations of rules (USCG).
3. Responsibility on approvals, make approvals stick.
4. USCG refuses to look at proposal plans. Can't get an opinion without a specific proposal for a specific contract.
5. Get USCG and ABS to agree in more areas, so don't have to contend with both on some items.

### L- Persons Interviewed

Technical Manager  
Chief, Basic Design  
Chief Engineer  
Chief, preliminary Design  
Chief, Computer Applications  
Assistant Manager Ship Sales

## SHIPYARD B - POST CONTRACT DESIGN

### A. Design for Producibility

1. A current design is not good due to requirements for the cargo system (3 different frame spaces per hold which a new design would not require). Standardized plates and shape sizes, collars, etc.
2. For a new tanker design, considered producibility from initial concept. Strake shell plating for producibility. Same depth longitudinal - varied spacing to minimize weight. Standardized plate grades and sizes.
3. Use fabricated shapes for 18-inch depth and up. Use some flanged plates.
4. Structural details - standardized (aware of BIW Task S11).
5. Many refinements to allow processing thru panel line. For webs - stiffeners parallel to flange to eliminate twist. Allow longitudinal to float off normal up to 10 degrees in order to reduce twist - but Owners object.
6. Unit size -90 to 250 tons. Sixty feet is optimum length- but riot able to do yet. Ship units are 45-ft long - put up to three together for lift into building dock. Units being outfitted with piping, backing for foundation, etc. Tried to eliminate as much of the foundation backup as possible.
7. Tanker midship section is not similar to any in the Litton study. It has a large horizontal girder at mid depth, and keel depth is same as transverses.

### B. structural Plans

1. Scantling plans - fairly large scale - detailed
2. Detail Plans - conventional working drawings of decks, bulkheads, etc. Material listed.
3. Shop Plans - one for each unit with everything shown - with piece marks
4. Items 1 and 2 are submitted for approval

Plan list sent to Regulatory Agencies for marking.

Normally 40 percent requested by USCG, ABS 60 percent, for special design - 100 percent.

## SHIPYARD B - POST CONTRACT DESIGN

### B. Structural Plans (Cont'd)

5. Owner gets detail plans at completion of the ship. Scantling plans are not kept up to date, which Owner doesn't like.

### c. Piping Design

1. Diagrams are the prime basic plans, and are complete for approval, without subsequent approval of arrangement plans.

Diagrams show arrangement of significance, pipe sizes, design conditions, material specifications, valve list, etc. Diagram has all information so that designer does not need to refer to ship specifications. The valve list is complete, with a unique number for each valve, which is used in the system instructions, label plate, etc.

Block of numbers assigned for each diagram.

2. **Composites are then prepared by the designer, using the pipe diagrams and the machinery arrangement. The initial routing is done in the composites considering structure, equipment, ventilation, wireways and piping in the space.**
3. The system drawing is prepared by lifting the arrangement from the composite. Single line is used wherever possible, two lines only where necessary for clarity. These arrangement drawings are used for installation in the ship. Arrangement drawings are sent to USCG if requested, but the CG practically never comments.
4. Pipe details, for piping 1-1/4 inch and up, are prepared by Design, generally free hand. For a new design, pipe details are being prepared by computer. Pipe detail or assembly, which may contain valves, strainers, etc. is made up in the shop, tagged and stored. An advance copy of the arrangement plan is marked by production to show grouping based on order needed for installation. Then a senior designer breaks down the system to the pipe detail assembly level. Information required to prepare the pipe details is taken off the arrangement drawing and is input to the Computer program (CAPDAMS). The output is a computer printed pipe detail including all information required for fabrication.
5. Piping Material. Valves are listed on the diagrams; fittings and pipe are estimated from the diagram. A large amount of open stock is maintained in the Yard. When ordering they don't anticipate using stock but order everything and use stock to supplement. The estimates for following contracts are adjusted for overage from previous. Don't galvanize, use coating or schedule 80. There is one booklet list of material for each system. Valves, etc.- buy only USCG Certified items. One man controls material and inventory.

## SHIPYARD B - POST CONTRACT DESIGN

### D. Material

Engineers prepare the technical specifications. After orders are placed design handles vendor drawing approval, but drawings are referred to engineers for comment. Buy only USCG certified items.

Material Control at present is manual, done by three men (excluding steel), one of whom handles everything in the engine room. They are preparing for computer control.

Technical purchase specifications - update of previous similar.

### E. Yard Standards

Old standards for bits, chocks, etc., are out-dated. Many new structural detail standards were prepared for a current design.

### F. Machinery and Piping Modules

Fabricated piping modules in pipe shop, such as reducing stations, etc. See pipe assemblies above. Fabricate other piping and fit up in shop, (for example, all piping around feed Pumps) but then install the piping in the ship. Have purchased modules, for example, compressed air unit including compressors, tanks, filters, controls, interconnecting piping, foundation.

### G. Special Module

Due to special circumstances, a very large *steel structure*, including all outfit therein, was subcontracted, and barge delivered to the shipyard.

### H. Yard Liaison

No permanent assigned liaison. Handle problems as required on an individual basis. May assign temporary liaison if a large change is required.

### I. Test Section

Is in Engineering. Write test forms, and supervise and witness tests.

### J. Comments

Have not found any contract which could take advantage of arrangement from a previous design. Current tankers of same basic design, but have different diagrams from same specifications for two owners. Change requested by one presented to both, but often only one owner buys change. "Owners will buy a standard tanker from a foreign yard but not from a US Yard."

## SHIPYARD B -POST CONTRACT DESIGN

### J. Comments (Cont'd)

In regard to standard plan and system diagrams, as proposed by Rosenblatt study, this would be good if it eliminated Owner's differences. (Appendix C, item A6).

### K. Persons Interviewed

Technical Manager  
Hull Technical Manager  
Engineering Project Manager  
Naval Architecture Section Manager  
Structural Design Section Manager  
Piping Design Section Manager

## SHIPYARD C - POST CONTRACT DESIGN

### A. General Introductory Comments

1. Detail design depends on shipyard facilities, manufacturing methods, etc. Present ship types use very large modules.
2. **Space control techniques are necessary to avoid interferences, etc. Tried computers, but the cost cannot be justified. Computers have been used successfully in chemical plant design, covering basic design, layout and ordering, but are too expensive for ships.**
3. Paperwork requirements are excessive, even for commercial work
4. Models or mockups have been used on present contracts, and successfully.
5. Present contracts had standardization as a defined goal This applied to structure, purchased equipment, etc.

### B. Interference and Penetration Control

1. Each designer responsible for his system. This forces coordination and discipline, but can never produce interference free design.
2. Appeared impressed by Kvaerner-Moss system for piping design.
3. Used composites on one current project to resolve interferences, but complete reliance on composites is not enough. This led to policy, (1) above.
4. Models used for one current project for studies of cargo handling.
5. Future - allocation of space
  - prepackaged units, which are not used to any extent currently (although yard used 13 prepackaged machinery and piping modules on ship contract in the 1965-1967 period).
6. Holes control by Hull Design. Individuals in all departments fill out form and submit. Request checked against master list, and compensation indicated where necessary. List printed by computer, giving location, size, compensation. Don't monitor holes below 1-1/2-inch. Holes up to 6-inches cut in field. Large holes by NC beginning on a later hull.

## SHIPYARD C - POST CONTRACT DESIGN

### C. Producibility and Standardization

1. On Navy ships, all plates are end use marked. Tried standard plates in first four hulls, and there was too much scrap. On tankers used 90-inch standard plate width.
2. Purchased fabricated tees up to 44 inches depth.
3. Standardized shapes at 8-inch depth of various thicknesses on one contract.
4. Have booklet of standard structural details, which are made as required -no inventory stocked.
5. Policy not to cross nest, but do to some extent.
6. Unit sequence is fixed, and schedule expands or contracts, but sequence not changed. Did make sequence changes on one class of ships, and then had to renest.
7. Hull Design prepares the NC tapes, and monitors use to control errors. NC group has man in Fabrication Shop to identify problems. QA people report on erection problems.
8. Will burn parts within lightening holes and manholes to reduce scrap. Rate about 6 to 7 percent.
9. Dimensional control of units in Fabrication Shop by QA inspectors, based on booklet of dimensional checks prepared by design.
10. Yard constraints - maximum beam about 150 feet, largest lift (superstructure) by four cranes is 300 to 400 tons.
11. Production Planning Control makes up work packages.

### D. Field Liaison Group

1. About 55, covering all disciplines.
2. Includes change incorporation group, to change the drawings based on the change notices. Large changes incorporated by Design.
3. Change notices are originated by the field group or design.

## SHIPYARD C - POST CONTRACT DESIGN

### E. Material

1. Initial estimates for steel made by naval architects.
2. Previously control of steel was done by naval architects, but now steel take-off done by procurement.
3. All material now in computer, TDIB (Technical Data Information Base). This has piece number, part number, compartment number, and ship number. Used by Material to buy. Quick response, one day from approval of change notice to TDIB.

Advanced BM's also sourced in TDIB.

### F. Persons Interviewed

Vice President, Engineering  
Director, preliminary Design  
Director, Design Engineering  
Director, Engineering Coordination  
Director Field Engineering  
Manager, Naval Architecture, and Hull Technical  
Manager, Hull Design  
Manager, N. C. and Manufacturing Aids

## SHIPYARD D - POST CONTRACT DESIGN

### A. Structure

1. Use system plans - may use unit/module plans in the future. Units identified on the system plans. Built as a unit - production Engineers unitize. Unit size 60 to 80 tons.
2. Standardization - Plates 40 ft long x 8 ft wide (10 ft on one contract)

Bulk of the plates are standard size.

Try to minimize material and scrap.

Try to nest within unit, seldom cross nest.

NC is Yard function.

Scrap -10 to 12 percent.

Planned sequence of units is adhered to, although still prefer to avoid cross nesting.

Design standardization is reviewed with production, and is not necessary the same on each ship series. Customized system for each ship series is generated. Must be flexible due to various ship types under contract.

3. Shapes - Try to reduce number of different items.

In past, availability was a problem.

Manufacture tees for tankers.

Used channels and angles for designs with double skin hull.

Minimize welding where practicable by buying shapes.

Stripping channels is a problem (tolerances).

Would like bulb angles.

No process line for manufacturing angles, etc. in the past, but now due to new contracts, will have this capability.

4. Standard details - not overstandardized, but are increasing use due to NC.

5. Material -

Steel takeoff done in design.

Generate requirements for advance orders in advance of testing (for midbody). Work with NC group for more complex material for bow and stern. NC process requires lead time, so must bypass if material availability is critical.

Computerized and stored on tapes for updating.

No computerized nesting, as not considered advantageous.

## SHIPYARD D - POST CONTRACT DESIGN

### B. Computer

1. Use Strudl - McDonnell Douglas version - for finite element analysis
2. All hull calculations are computerized.

### C. Approvals

1. On structure, use ABS-USCG agreement procedure, but no USCG approval of structure on tankers.
2. Owner's approvals are not always timely.

### D. Piping

1. Use composites for interference control.

Piping is developed on the composites for ER piping and other machinery spaces.  
Piping is developed on the arrangements for systems outside the ER, and then locally checked on composites.

2. Models are not used for interference control as they are too late and inaccurate. Models were used for one class of ships, but were not accurate, and interferences were not found. (Scale 1 inch= 1 foot).
3. When piping developed on composites, reproducibles are made, and then one system is heaved up on each to produce the system arrangement plans.
4. HoIes control -by a hole list, with all departments submitting for approval.

Holes are cut in the field. Too much delay to incorporate on NC tape, but may catch up on tape *on* third hull and beyond.

5. Haven't tried computer for interference control.
6. Diagrams should be explicit so that USCG approval will be complete, and not have questions arise much later on the arrangement, which impacts items such as sea chest locations. (Also applies to contract diagrams.)

## SHIPYARD D - POST CONTRACT DESIGN

### D. Piping (Cont'd)

#### 7. Pipe - Valves - Fittings

Uses a standard material catalog with a 6-digit number. Plan also carries an identification number, which is also listed in the BM. Vendor tags valve with the catalog number. Computer generates BM for PO. Purchasing believes manual is more economical.

#### 8. Diagrams and arrangements are submitted for USCG approval.

### E. Machinery

1. Machinery and piping shop assembled modules is an excellent idea, which they have not used to any extent. They did build a fuel oil system module for one class of ships. Machinery availability was too late in many cases to permit assembly and large lift into the ship engine room *at an early* date.

#### 2. **Standard purchase specifications.**

This would be helpful in fixing the vendor-shipyard interface, particularly on minor details, such as instrument connections, electrical *connections* such as wires or lugs or terminal board, etc.

Do not have in-house standard purchase specifications.

### F. Personnel Interviewed

Vice President - Engineering  
Chief Engineer  
Chief Naval Architect  
Assistant Chief Mechanical Engineer  
Project Manager

## SHIPYARD E - POST CONTRACT DESIGN

### A. Producibility and Standardization

1. Midship Section is developed with input from Production.
2. Yard has a standard list of sections that the designer is permitted to use. A selection is made from this list for each contract.

Standard mill shapes include:

- 19 angles
- 50 flat bars (1/8 inch to 1 inch thickness)
- 5 channels
- 12 wide flange I'S

For one tanker design the manufactured shapes included:

- 2 tees
- 18 angles, excluding variations in length
- 45 angles, including variations in length

All the manufactured angles (80 to 90 percent of all angles) are made with 1/2 inch web and 3/4 inch flange, with 1 inch offset to facilitate Yard welding.

3. There are about 1200 different acceptable plates, due to size, thickness, and grade variations. On current tanker contract about 400 different plates are used, all bought for end use. Delivered marked with stock number. Plates have maximum size of 40 ft x 10 ft.
4. Scrape rate (bought weight vs finished weight) was about 12 percent, but increased to 14 percent due to standardization.
5. Units are stiffened panels, except for double bottom assemblies. Unit weighs from 30 to 150 tons. On tankers, it doesn't pay to make three dimensional units (except D.B.).
6. Ship designed for sequence of erection. Deviations from sequence would require drawing changes.

Nesting is done per erection sequence, extending over about 10 assemblies, or 2 weeks.

7. Flat bars for stiffeners may be purchased or stripped from plates. Will buy a mill shape if it is efficient, but stripped shapes to produce angles or tees result in about 30 percent scrap. Prefer built-up sections.

## SHIPYARD E - POST CONTRACT DESIGN

### A. Producibility and Standardization (Cont'd)

8. Batch manufacturing of standard parts is used.

### B. Plans and Plan Approvals. Structure

1. Scantling Plans (about 14) are complete and show all details, and are used for approvals. Other working plans are not submitted. Engineering determines and locates butts to satisfy Yard requirements.
2. Standard size drawings are used, with more than one assembly per drawing. For example, 24 inner bottom assemblies are shown on one drawing, but normally about 10 to 12 units.
3. Ladders, access, etc. are installed on assemblies, and standard numbers for the parts are indicated on the drawings.
4. A very extensive part numbering (coding) system is used. It is considered worthwhile by the Yard, although it increases design costs significantly.
5. Assembly drawings for Kingpost include fittings, ladders, etc.
6. Midship Section being used on the tankers is not like any in the Ingalls series production study, Appendix C, item A5.

### C. Computer and Nc

1. Computerized NC system is used for fairing and producing NC tapes.
2. Loft does nesting manually - believes man can do better job than computer.
3. Holes for piping etc. are cut by NC after first few hulls.
4. The system is not yet developed to produce structural plans for use by other disciplines. Intend to do so.

### D. Piping

1. Inside the engine room, the piping is developed on composites which show structure, piping, vent ducts, wireways, ladders and grating etc. Then a system arrangement plan is made, showing piping down to 2-inch size in double line.

## SHIPYARD E - POST CONTRACT DESIGN

### D. Piping (Cont'd)

2. Outside the engine room, the piping is developed on the arrangement plan, and composites used where necessary to check interferences, prior to finalizing the arrangement.
3. On the tankers, all systems on the main deck are shown on one plan, and all piping in the pump room is shown in one composite.
4. Models are not used for interference control as they are too late.
5. Plans have piece number, and BM has standard catalog number. Advance orders are used, and then computer control.
6. Pipe details are prepared manually in the shop.
7. Trades are held to the quantities shown on the piping drawings.
8. Piping plans are often started in advance of final diagrams and vendor plans.
9. NC is not used for pipe bendins
10. Piping diagrams and arrangements are submitted for approval.
11. One complete automation diagram for the central control system including instrumentation is prepared. Vendor has system responsibility, but Yard buys equipment such as reducing stations, etc. (Automation and instrumentation must be defined in the contract specifications so Owner additions can be handled as changes.)

### E. Machinery and Piping Modules

1. Have used for cargo oil, fuel oil, lube oil, potable water, etc.

### F. Material

1. Organization has a Material Division (equal rank to Hull, Machinery, Electrical Divisions).
2. Purchase specifications and terms and conditions are standardized.
3. Specifications are computerized for typing, to ease handling of changes, and to save copy checking. Also using computer for damage control, label plate lists, etc.

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F. Material (Cont'd)

4. Specification inquiries are prepared for ship bidding, and rebid after contract.  
After purchase, detail specifications are prepared to reflect equipment purchased.

G. Testing

1. By a section in the Machinery Division.
2. Prepares procedures and requirements for tests, the test memos, takes the data, and checks that criteria are met and evaluates results.

H. Persons Interviewed

Director of Engineering  
Project Engineer  
Chief Naval Architect  
Chief Hull Draftsman  
Assistant Chief Marine Engineer  
Chief Material Engineer  
Chief, Computer Support  
Machinery and Piping Design Leader

## SHIPYARD F - POST CONTRACT DESIGN

### A. General

1. A Design Agent is used for preparation of the working plans, but the yard works closely with the D.A. to obtain a producible design. Special considerations were necessary for the structural design of a recent ship, which resulted in a grillage design, use of HS steel, finite element computer analysis, etc., culminating in a very complete and detail set of scantling plans. Reduction in steel weight as compared to the contract structural design was substantial.

### B. Reducibility and Standardization

1. Major producibility considerations were for structure, with little effort on outfit and machinery. Steel shapes were standardized.
2. Unit size and weight established by crane and transporter, 100 to 200 tons.
3. Detail structural plans covered a number of units, but on a unit basis, i.e., showed deck, shell, bulkhead. Standard size drawings were used, which resulted in about 8 unit plans in the length of the ship. Experience indicates that they would not go to one unit per plan on a future contract. Engineering costs increase with number of plans and interfaces, and ingresses out of proportion to yard improvement.
4. Pre-outfitting of the units is done in the large assembly building using regular plans (piping, foundations, access, etc.).

### C. Plans and Plan Approval

1. After development of the plan, and approval by the shipyard, it is submitted by the D. A. to the regulatory bodies, and the action and comments returned to the yard, who take over at this point. If there are comments of technical significance, they may be referred to the D.A. for resolution.
2. On current contract, about 20 revisions per plan, but many were minor revisions to suit the yard. On a previous tanker only about 8 revisions per plan.
3. On a current contract, owner's plan approval was done by the Owner's staff at the shipyard.
4. The complete set of scantling plans were submitted for approval, but the unit plans were not except for special units such as the rudder, stem frame, etc.

## SHIPYARD E - PRECONTRACT DESIGN

### D. Steel

1. There is a close tie between Design and Lofting. A steel control group under Design is located in the Loft. They lift and assign the steel and markup the plans, then the Loft does the actual detail.
2. **Primarily optical cutting.**
3. **Plate and shape standardization done for each contract. Good feedback from steel control group to designers to maintain standardization.**

### E. Steel Plant

1. The steel plant for receiving, storage, blasting, layout, burning, shaping, and *minor* fabrication is not within the shipyard boundaries.
2. Storage - prior to 1971, steel was edge stacked. Then the steel yard was changed to flat stow by size - length, width, and gauge. Later, the steel plate was stored by unit (all sizes and thicknesses) which applies to about 75 percent of the piles; and the remainder, the most common sizes and unallocated plates are stowed by size.
3. Shapes are stored by size and are removed from *storage* and cut about one week after the plates to which they will be attached.
4. Cuttings are stowed vertically.
5. Steel plant output consists of Stiffened Plates, Web Frames, Built-Up Sections, and Small Foundations. Output is transported over the road to the shipyard.

### F. Interference Control

1. Composites are used for piping These are done by the D.A. initially and then in the Machinery Section, but also cover structural, electrical, ventilation, etc.
2. Models were used on some contracts but were always behind design, and are considered less effective as a tool.
3. Composites cover pipes 2 inch and above.

Next time will go down to 1 inch.

## SHIPYARD F - POST CONTRACT DESIGN

### F. Interference Control (Cont'd)

4. Holes control is done by the composite group.
5. Tried computer interference control four or five years ago, but its findings were too late.

### G. Piping

1. No computer aided design to produce structural background drawings for machinery and piping plans.
2. Pipe detail sketches by shop.
3. Piping is installed in the structural units using the normal piping plans.

### H. Machinery and Piping Modules

1. These were considered for a recent design, but due to space limitations they could not make efficient use of modules.

### I. Machinery Standardization

1. Agrees with much of the Rosenblatt study, Appendix C, item A6.
2. Reduction in time to release for manufacture would be very beneficial as machinery is in the critical path.

### J. Liaison

1. Have a liaison group to resolve yard questions. Normally about six men per contract.

### K. Material Procurement

1. For machinery and equipment, the technical specifications are prepared by the design agent. The design agent has been different on different jobs, so no standardization. Some items could be ordered from a standard specification as recommended in Appendix C, item A6.
2. Terms and conditions and general requirements are standardized.

## SHIPYARD F-PRECONTRACT DESIGN

### K. Material Procurement (Cont'd)

3. Non-engineering items are cataloged and computerized. Plan BM lists piece mark and catalog number. Ordering and utilization is maintained on the computer.

### L. Technical Department

1. Use of computer-questionnaire will be answered.
2. Covers Hull, Machinery, Electrical, Technical Procurement, Laboratory

Totals 41 people plus 5 section heads.

About 6 of 41 are engineers. Others have draftsman rating, and change drawings, make calculations, do testing, data takers, etc.

3. Do weight control, launching, inclining, machinery arrangements, piping diagrams. Also monitor and check work of the design agent.
4. Laboratory - registered chemist - gas hazard work, tensile tests, monitoring OSHA items, weld qualifications, etc.

### M. Personnel Interviewed

Marketing Manager  
Technical Manager  
Design Manager  
Procurement Manager  
Project Manager  
Project Engineer

APPENDIX C

BIBLIOGRAPHY

GROUP A- RESEARCH REPORTS

GROUP B - TECHNICAL PAPERS

GROUP C - COMPUTER AIDED DESIGN

GROUP D - MODULES AND MODELS

## BIBLIOGRAPHY

### GROUP A - RESEARCH REPORTS

A1 The National Shipbuilding Research Program -1973 Booklet

Items described which impact the design process:

- (1) Use of models in the design process
- (2) Ship producibility -
  - (a) The design process must be responsive to production
  - (b) Use of standards
  - (c) Effect of less costly shipbuilding methods on design
- (3) Autokon '71
- (4) Computer Aids

A2 The National Shipbuilding Research Program  
Use of Scale Models as a Management Tool - May 1974  
by Todd Shipyards Corporation for MarAd

pertinent to the design process.

A3 MarAd Ship Design Improvement Project - Design Review  
by NNSB&DD Co. Jan 17-18, 1972

Items pertinent to improvements in the ship design process include:

- Modular design of machinery and piping
- Reduced working plan schedule
- Reduced requirements for plan approval.

GROUP A RESEARCH REPORTS (Cont'd)

- A 4      Report for the Ship Design Improvement Projects  
by Newport News Shipbuilding and Drydock Co. Contract MA-1-35402

Vol I - Summary of Research Report

Vol II - Research Report

Vol III - Design Improvements Report

Primarily covers design requirements, rather than design process improvements.

- A 5      Report - Ship Producibility as it Relates to Series Reduction  
by Ingalls Shipbuilding Division of Litton, September 1975

Study sponsored by MarAd, Administered by Bath Iron Works

3 Volume Report

Vol I summary

Vol II Ship Design Process

Vol III Ship Production Process

Portions of Vol II are pertinent to Task D-2

Improved Design Process, in particular:

Part 1 - Midship Configuration

Part 4 - Machinery System Modules/Packaging

Part 5 - Structure Member Configuration

Part 7 - Instructions

GROUP A RESEARCH REPORTS (Cont'd)

- A 6     Report - Repulsion Plant Standards Feasibility Study  
by M. Rosenblatt & Son, Inc., August 1975

Study sponsored by MarAd, administered by Bath

This report is pertinent to improvements in the design process. It recommends developments of standards for machinery system and components to simplify procurement, lower purchase and installation costs, and shorten design and building time.

covers four groups of standards:

1. Total propulsion plant
2. System/equipment modules
3. Equipment envelope
4. Individual equipment/component standards

- A 7     Engineering Analysis of the Piping Recess

Design Area - Work Session 10-13 June 1974

Planning and Production Areas - Work Session 24-27 June 1974

by NSRDC Code 185 August 1974

These are minutes of the work session with shipyard and consultants, and cover diagrams, preliminary arrangements (composites), arrangements, pipe details, ancillary drawings, design guidelines, design calculations, pipe routing, and design process analysis. Recommendations in regard to computer aided piping design and construction (CAPDAC).

- A 8     A Report for the CMX Project. Maritime Administration  
by Newport News shipbuilding and Dry Dock Company  
Contract MA-4882  
Volume II Research Report

## GROUP A RESEARCH REPORTS (Cont'd)

A portion of this report is pertinent to the ship design process, namely,

### Section 5, Ship Procurement and Contracting

- Analysis of Specification Use
- Detailed Design Specifications
- Performance Specifications
- Proposed Alternative for Ship Procurement
- Ship Pricing Process

#### A 9 Advanced Pipe Technology, Task S-4

Study sponsored by MarAd, Administered by BIW

Final Report, by Newport News Shipbuilding and Dry Dock Company  
December 1976

Includes pertinent and complete discussion of the piping design process.

#### A 10 Guided Missile Destroyer - Ship Design Recess

Level IV Detail Design/Construction -5 Volume Report prepared by Gibbs and Cox for Naval Ship Engineering Center Contract NOO024-70-C-5562 Serial S4633, Task 13447 (Restricted distribution list)

#### A 11 Functions in the Shipyard

REAPS program, Technical Memo 6039-5-002a, dated May 1975 by IIT Research Institute

#### A 12 The National Shipbuilding Research Program 1971-1976

By J. J. Garvey, of MarAd. Paper presented to SNAME, Philadelphia Section, April 1976

A description of the organization and operation of the Maritime Administration Research program including status report on each project.

GROUP A RESEARCH REPORTS (Cont'd)

A13 The National Shipbuilding Research Program

Photogrammetry in Shipbuilding by Todd Shipyards Corporation, July 1976

## GROUP B - TECHNICAL PAPERS

- B1 Japanese Shipbuilding Practices, by McQuaide & Christensen  
Marine Technology, October 1969 22p.  
  
Pertinent discussion of preliminary design, scope, problems, etc, and discussion of engineering practices, schedules for design, design staff organization, etc.
- B2 Technical Management Tools for Ship Design by Kauffman (USN)  
Chesapeake Section, SNAME, February 1965 15p.
- B2 Notes on Ship Design Procedures by K. W. Fisher  
Hawaii Section - SNAME - November 1971 26p.
- B4 A Ship Design Procedure, by T. Lamb (Maryland SB&DD Co.)  
Marine Technology, October 1969 43 p.
- B5 Design and Construction of the San Clemente Class Tanker by Evans and Uberti  
SNAME Spring Meeting, May 1975  
  
Illustrates design for producibility
- B6 Shipbuilding Changes by A. J. Marr  
RINA July 13, 1972  
  
Overview of developments in ship design and shipbuilding in the U.K, with particular based on BSRA work. Indicates use of computers in ship design. in resistance and propulsion, structures, engineering systems, etc. Good Bibliography
- B7 Shipbuilding Costs as seen by the Shipbuilder by P. Atkinson (Sun)  
N. Y. Metropolitan Section - SNAME - March 1961 17p.  
  
Good coverage of cost reduction, with specific suggestions pertaining to “paper work”, plans and specifications, American standards, design changes, standardization, elimination of working drawings, computers, etc.

GROUP B - TECHNICAL PAPERS

B8 Ship Procurement - Isn't There a Better Way by Charles Zeien

Marine Technology, July 1967 8 p.

Pertinent to the ship design process, discussing subjects such as proposal efforts, owner's RFP, standardization, development of ship plans, performance type specifications.

B9 Towards Responsible shipbuilding - by J. W. Boylston and W. G. Leback  
Trans - SNAME 1975

Pertinent to the ship design process, discussing definitive contracts, plans and specifications and responsibilities of the shipbuilding participants.

B10 The Role of the Classification Society in Relationship to Design Responsibility  
By R. T. Young

Trans - SNAME 1973

ABS role in preliminary design review, and finite element analysis, LNG structure analysis, and other examples.

B11 A Ship Design Process by Richards T. Miller

Marine Technology October 1965-20 pages, many illustrations (which simplifies text)

Naval Ship Design Process for:

Design feasibility studies

Preliminary design

Contract Design

## GROUP C - COMPUTER AIDED DESIGN

- C1 The International Conference on Computer Applications in the Automation of shipyard Operation and Ship Design Tokyo - August 28-30, 1973
- Preprint of Conference Papers (book including 54 papers)
- Report of Conference and Visits to Japanese Shipyards by the U.S. Survey Team.
- These present a comprehensive overview of the use of computers with programs covering the entire range from preliminary design thru automated manufacture to performance data analysis. It is apparent that the use in Japan far exceeds that in the U.S. in the various phases.
- C2 Computer Aided Design and Production Control for Shipbuilding
- Shipbuilding and Engineering - September 6, 1974 5p.
- C3 Computer Aided Ship Arrangement Design by Carlson & Cebulski
- Journal ASNE October 1974 8p.
- Discuss progress for naval ships.
- For commercial ships - "intuitive human judgement will arrive at acceptable or optimum arrangement very quickly".
- C4 Preliminary Ship Design with the Aid of a Computer -by J. W. Schmidt  
(Center for Naval Analysis)
- N. E. Section - SNAME - May 1964 16p.
- C5 Arrangement of Shipboard Piping by Digital Computer by John B. Woodward
- Marine Technology, April 1975 8p.
- C6 Computer Aided Structural Detailing of Ships (CASDOS) by Nachtsheim, Romberg, O'Brien
- SNAME Proceedings, Spring 1967 16 pages

## GROUP C - COMPUTER AIDED DESIGN

- C7 Proceedings of the REAPS Technical Symposium, June 24-25, 1975 Palm Beach Shores, Florida by IIT Research Institute

Includes a number of papers on the use of computers in the ship design process, including software, economic justification, experience, etc.

- C8 HIZAC -74. October 1975

Booklets describing the Hitachi Zosen developed systems for the design and production of hull structures ,in all phases from hull lines fairing to fabrication of hull parts with a high degree of accuracy.

- C9 Research on Computer Applications to Shipbuilding Vol I - Final Report of MarAd Contract No. 3-36228 by Avondale Shipyards, Inc. May 1975

Summarizes results of project which include(1) an industry survey to identify programs available within specified application categories and establish priorities for development, (2) development of standard program specifications for 24 high priority categories, (3) list of available programs, (4) recommendations for future projects.

- C10 Research on Computer Applications to Shipbuilding Vol II - Final Report of MarAd Contract No. 36228 by Avondale Shipyards, Inc., May 1975

Contains abstracts and procurement information on approximately 1013 computer programs in use at various shipyards.

- C11 Pilot Models for Determination of Civilian Utility of DOD Developed Products

Computer Aided Ship Design and Construction

CADCOM Report 73-24 January 1974

Indicates commercial shipyard and design agents use of Navy developed ship design programs.

- C12 Computer Definition of Ship Characteristics by Thano P. Boumis

Marine Technology July 1968 18 pages

## GROUP C - COMPUTER AIDED DESIGN

General data and philosophy of the use of computers for preliminary and detail design with emphasis on the system concept and optimization. Current and future trends are discussed.

C 13 NC-Shipbuilding Symposium in Madrid -1970 A/S Kongsberg Vapenfabrikk

A series of papers on the application of NC Flame Cutting and Drafting around the world including organizational and economic aspects of NC and descriptions of AUTOKON and STEERBEAR.

C 14 The STEERBEAR System at Sun Ship by Eugene Schorsch

Marine Technology April 1975 8 p.

Discussion of N/C Flame Cutting Development at Sun and description of the Swedish computer based design and steel processing system STEERBEAR as used at Sun. Not used in design process by Sun.

C 15 Tanker Preliminary Design - An Optimization Problem with Constraints by Nowacki, Brusis, Swift

Trans - SNAME 1970

Pertinent to the preliminary design process, with specific reference to tankers. Good discussion.

C 16 Computer Aided Ship Design at MarAd by A. H. Woodyard

IEEE Proceedings June 1974

C 17 The Application of Numerical Control Systems to Plan Production by A. Wickham and R. Kucharski, REAPS Technical Symposium, Atlanta, June 15-16, 1976

An example of how the AUTOKON Parts Program and an NC Drawing Machine were used to assist in the drawing of ship's plans:

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- (c) Computer Aided Nesting, by L. Magnusson and I. Hansson
- (d) LR. PASS and Its Application in Sweden, by A. C. Viner and S. T. A. Janzen, both of Lloyds Register of Shipping
- C 20     Proceedings of the National Computer Conference '76 Session "Computers in the Shipbuilding Industry" published by Sun Shipbuilding and Dry Dock Co., Chester, Pa 19013
- (a) "Computer Analysis and Evaluation of Marine Structures", by D. Liu and M.E. Wojnarowski, American Bureau of Shipping
- (b) "Some Computer Related Advancements for Enhancing U.S. Shipyard Productivity", by R. B. Wise and D. J. Martin, ITT Research Institute"
- (c) "Computer Use in Shipyard Production and Engineering", by W. T. Herrmann, Avondale Shipyards, Inc.

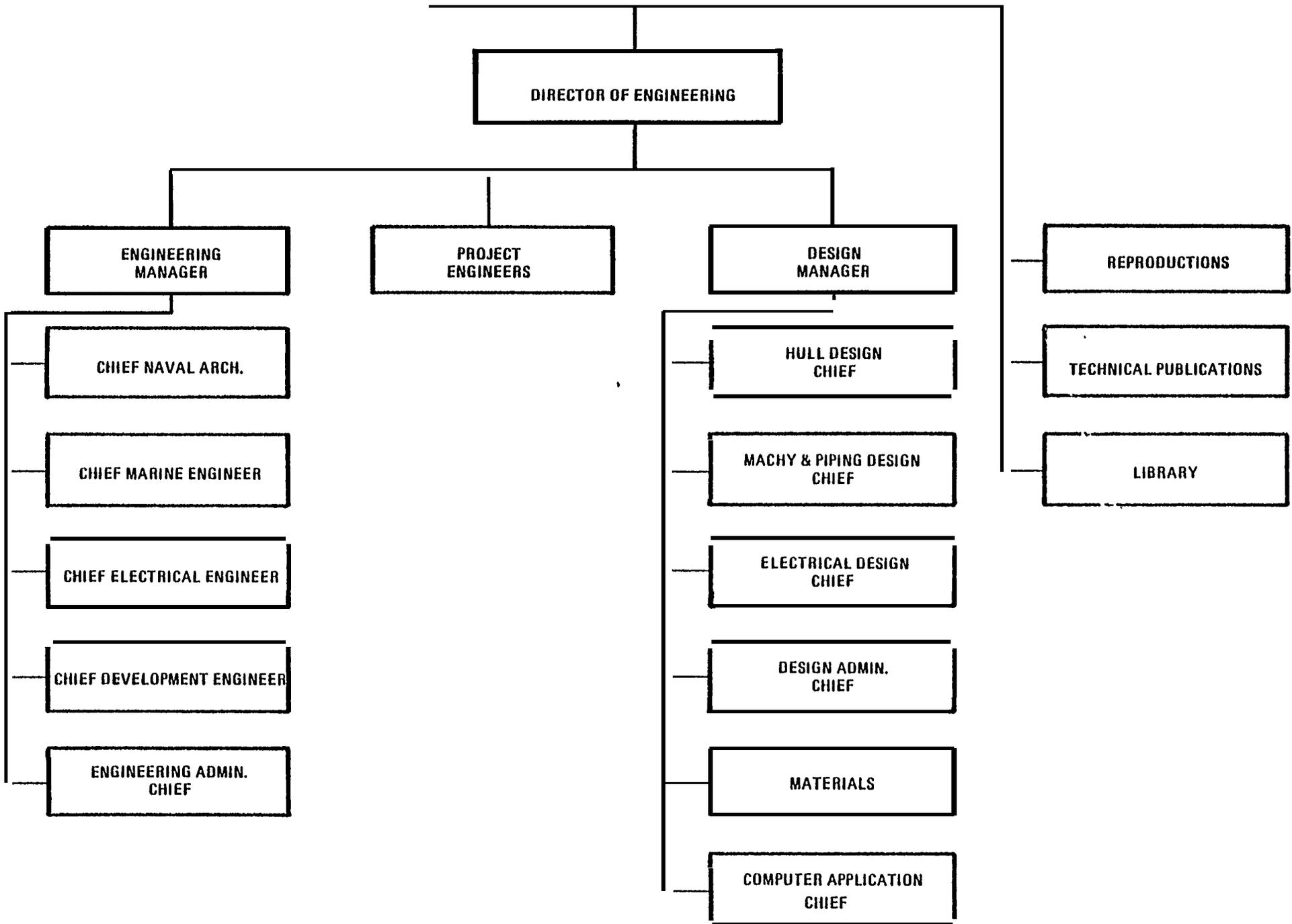
## GROUP D - MODULES AND MODELS

- D1 Models - See items A2, A13
- D2 Modules - See items A3, A5, A6
- D3 Improved Steam Propulsion Plant to Reduce Building and operating costs  
by MacMillan and Rohde, SNAME Transactions 1962 (Modules)
- D4 Packaged Fluid Systems for Marine and Industrial Applications  
Bulletin of Modular Systems, Inc. 1972
- D5 One Step Isometrics from Models  
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- D6 Model Making - A Priceless Tool  
Bechtel Briefs, February 1970

APPENDIX D

ENGINEERING AND DESIGN ORGANIZATION CHARTS

(4 examples)



**VICE PRESIDENT  
ENGINEERING**

