AUGUST 1975

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Final Report

Propulsion Plant Standards Feasibility Study

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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Final Report

Propulsion Plant Standards Feasibility Study

U.S. DEPARTMENT OF COMMERCE

MARITIME ADMINISTRATION

IN COOPERATION WITH

BATH IRON WORKS CORPORATION

EXECUTIVE SUMMARY

1. OBJECTIVE *OF STUDY*

The purpose of the study was to assess the technical feasibility and economic benefits and/or drawbacks of the development and implementation of propulsion plant standards. Emphasis was placed on reducing shipbuilding costs and delivery time in the United States by defining standards which could be useful to the marine industry.

2. DEFINITION OF STANDARDS AND AND APPROACH TO THE STUDY

An evaluation was made of the performance, operating, interface, packaging, installation and software requirements of the propulsion plants projected to be contracted to American shipyards during the next decade. Typical systems and equipment components were considered. Those system or equipment parameters suitable for inclusion in a standards development program were selected based on technical feasibility, economic potential, and industry acceptance.

Four groups of standards were defined. Essentially, these groups reflect the extent to which the propulsion system is covered by standards:

- Group I - Total Propulsion Plant Standards carried to the level of detail represented by sized system diagrams.
- Group II - Module Standards, which define performance sizes and interfaces for system modules.
- Group III - Envelope Standards, which define equipment performance, installation size, and interfaces independent of vendor source.
- Group IV - Individual Equipment/Component Standards which have three steps (or degrees of coverage).
  - Technical data standards
  - Procurement standards
  - Hardware standards

3. ESTIMATED COST SAVINGS

Evaluation of the economic benefits and industry acceptance of the four standard groups showed that the Total Propulsion Plant Standards (Group I) offer the greatest long-term potential. A combination of Technical Data, and Procurement Standards for Individual Equipment (Group IV, steps 1 and 2) offer the greatest near-term potential.

A detailed economic analysis was made to develop a conservative estimate of savings achievable by a shipyard using a combination of Group I with steps 1 and 2 of Group IV. This conservative estimate indicated that over 15% of the propulsion plant acquisition and installation cost could be saved by a shipyard on the first ship in each series.

4. <u>RECOMMENDED ACTION</u>

- Select a specific propulsion plant type and size likely to be utilized in U. S. built ships.

- Conduct a pilot program to develop one Total Propulsion Plant Standard and one or more combined Procurement Standard/Technical Data Standards for the selected plant.

- Apply these standards to a new shipbuilding program in *one or* more U. S. shipyards to measure the ability of standards to reduce propulsion plant engineering and installation costs.

FOREWORD

This study was accomplished as part of the Ship Producibility Program being managed by Bath Iron Works Corporation. The Ship Producibility Program is part of the National Shipbuilding Research Program originally defined by the Production Committee, one of the Society of Naval Architects and Marine Engineers' technical and research committees. The research was funded jointly by the Maritime Administration and the U. S. Shipbuilding industry under a cost shared contract. The Propulsion Plant Standards Feasibility Study was selected as a high priority task at a conference of shipbuilding management personnel held at Annapolis, Maryland in 1973. The study has been done by M. Rosenblatt and Son, Inc., under subcontract to Bath Iron Works Corporation.

A separate subcontract was awarded to Ingalls Shipbuilding Division to provide additional economic evaluation of utilizing propulsion plant standards for a specific design in an actual shipyard. Some of the results of this study have been incorporated into this report to substantiate the results (conclusions relative to the time savings that could be realized from selective application of standards). The complete Ingalls report is available through Bath Iron Works.

Special acknowledgement is due to the Advisory Council for their evaluation and important comments. This group composed of representatives of the marine industry provided valuable guidance and direction to the entire program. Their comments were in general incorporated into the final report.

CONTENTS

1. INTRODUCTION

I. INTRODUCTION

1.1 BACKGROUND

To help U. S. shipyards meet the challenge of reduced subsidy rates 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, 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, is a key element of the total National Shipbuilding Research Program.

This report presents the results of Task S-1, Feasibility Study of Propulsion Plant Standards, which is one of the priority tasks in the Ship Producibility Program.

The study was conducted by M. Rosenblatt and Son, Inc. under subcontract from the Bath Iron Works.

The duration of the study was about one year. The study was completed in April 1975.

1.2 A STUDY OF STANDARDS IS IMPORTANT AT THIS TIME

This study was undertaken to determine the potential benefits and problems associated with the application of propulsion plant standards to shipbuilding in the United States. The obvious questions which might be asked are, "what prompted the study and why is it significant at this time?"

At the Annapolis Ship Producibility Planning Conference held in 1973, senior personnel from twelve U. S. shipyards defined potential Ship Producibility tasks which offered significant economic benefits. The Propulsion Plant Standards Feasibility Study was among the top priority tasks.

It is also significant to note that many of the major Japanese and European shipbuilders have devoted considerable effort to the development of standards for ship systems and components. They are enthusiastic about the resultant benefits which include simplified procurement, lower costs (both purchase and installation), and shorter design and building schedules. As the more progressive foreign shipbuilders found significant benefits, it appeared likely that the U. S. shipbuilders could do so too. Clearly, the U. S. shipbuilders could benefit from simplified procurement methods, lower costs, and shorter building periods if these results could be achieved at reasonable cost.

The study is most significant at this time because U. S. shipbuilding is at a critical juncture. The Merchant Marine Act of 1970 expanded the total market for ships by making bulk carriers eligible for construction differential subsidy. At the same time, it put a challenge to U. S. shipbuilders to lower the cost of their product and increase their marketing efforts, emphasizing series production of ship designs that were engineered for low cost production. After several years of expanding order books, the world's shipyards are now booking few ships. The likely result will *be* more competitive pricing, which will affect the U. S. shipbuilders directly or indirectly. Delivery times are critical to both owners and shipbuilders. When a shipowner sees an opportunity to offer a special service to shippers, he wants to act quickly and obtain ships as soon as possible. He must act before the world economic picture changes or some other shipowner seizes the advantage. Therefore, reduced shipbuilding times can be very beneficial to shipowners, and it follows that shorter schedules can be very advantageous to a shipbuilder in obtaining orders and in achieving more production from a given facility. In summary, these pressing reasons led the shipbuilding community and the Maritime Administration to the conclusion that they should initiate a study of the potential benefits of applying standards to shipbuilding in the United States.

1.3 THE OBJECTIVES AND SCOPE OF THE STUDY

The purpose of the study was to assess the technical and economic feasibility of the development, industry-wide acceptance, and implementation of propulsion plant standards from the viewpoint of reducing the cost and time of shipbuilding in the United States. The study was to answer the question, "Can standards for propulsion plants benefit the shipbuilding industry?" A further objective of the study was to determine the type and level of standards appropriate for systems and subsystems of a propulsion plant and then to consolidate the standards into logical groups. Standards for both the software and hardware of propulsion plants were to be considered, and skeleton formats were to be prepared for the proposed standards. Once the technical feasibility was evaluated, the standards were to be submitted to a comprehensive economic analysis. The economic analysis was to give equal consideration to dollar savings and time savings in the design, procurement, and installation of machinery.

The overall objective of the study was to conclude whether the shipbuilding industry should pursue development of standards for propulsion plants. If an affirmative conclusion resulted then the study team was required to recommend a plan for the initiation of the standards development program.

The scope of work was set by limiting the study to the propulsion machinery for those commercial cargo carriers of 10,000 DWT and above likely to be built in the United States over the next decade.

1.4 THE STRUCTURE OF THIS REPORT

Chapter II of this report describes the approach taken to define and evaluate four groups of standards. The economic analysis undertaken as part of the evaluation is described in sufficient detail to demonstrate the validity of the approach taken. If the reader is not interested in the definitions or the details of the economic analysis, he may bypass chapter II and go to chapter III which presents the principal findings from the evaluation. Chapter IV summarizes the conclusions and recommendations stemming from the study.

II. DEFINITION AND EVALUATION OF STANDARDS

II. DEFINITION AND EVALUATION OF STANDARDS

The overall approach was designed to uncover industry-wide problems related to the acquisition and installation of propulsion plants, which might benefit from the application of standards. The investigators had extensive interviews with shipowners, shipbuilders, and machinery manufacturers. The project team also received valuable advice from the Project Advisory Council which was formed to make periodic review of the project. The council members were a rich reservoir of experience in standardization and ideas on the future application of standards.

The study consisted of three primary tasks:

- A forecast of shipbuilding and related propulsion system requirements for the next ten years.
- Selection and definition of candidate standards.
- Evaluation of the potential benefits of applying the several candidate standards to propulsion machinery.

2.1 SHIPBUILDING LEVELS FOR THE DECADE WERE FORECAST AS A BASIS FOR THE ECONOMIC ANALYSIS OF STANDARDS APPLICATION

2.1.1 Objective of the Forecasting Task

The commercial shipbuilding forecast was the initial task of the Propulsion Plant Standards Feasibility Study. It established the approximate number of the various propulsion plants required for the next ten years and therefore provided the basis for selecting candidate Propulsion Plant Standards offering the greatest potential for cost-effectiveness. It also provided a basis for broad estimates of the total potential savings from the selective application of Propulsion Plant Standards.

The forecast consists of estimates by type and size of the ships 10,000 DWT or larger, likely to be ordered from U. S. shipyards between 1975 and 1985, with an estimate of total U. S. shipbuilding extended to 1990.

2.1.2 FORECAST DERIVATION METHOD

The baseline data for the forecast was derived from the report of the Commission on American Shipbuilding and consists of projected foreign trade and domestic trade ships. Modifiers from the Commission's report were then applied to this baseline data for foreign trade ships to obtain the final forecast. These modifiers were the probable impact of a program to assist shipbuilders to reduce costs and legislation diverting a share of U. S. petroleum imports to U. S. ships. For the domestic trade ships, three other forecasts were used as modifiers to assess the effect of the Trans-Alaskan Pipeline (TAPS). In addition, the baseline data was adjusted to reflect the direction indicated by types and numbers of ships ordered in the last five years, and shipowners were canvassed to obtain their probable future requirements. LPG and LNG ship forecasts were based on the Maritime Transport Research report (March '73 & '74) entitled, "Merchant Ship Demand to 1980". The forecast for the LNG ships was further modified by several other published forecasts.*

2.1.3 Forecast Results

Approximately 350 U. S. built ships are projected for the period 1976 through 1985. There are a number of economic and political factors which could raise or lower this level, but it provided a sufficiently valid base for estimating the approximate number of power plants that will be required. The projected ships would require about 185 steam turbine propulsion plants of varying steam cycles, approximately 110 gas turbine propulsion plants of heavy-duty and/or aircraft derivative types, and some 75 diesel propulsion plants, composed of single or multiple medium-speed diesel engines. (For details of the forecast, see Appendix "A".)

The steam turbine, gas turbine, and the medium-speed diesel propulsion plants were each technically analyzed by developing a work breakdown structure showing equipment comprising the plant at the total package, major systems, major equipment/subsystems, and equipment/component levels.

* See Bibliography

2.2 FOUR GROUPS OF STANDARDS WERE DEFINED

The performance, operating, interface, packaging and software requirements for each system, subsystem, or equipment were considered individually, and the parameters suit. able for inclusion in a standards development program were established on the basis of technical feasibility, economic potential, and industry acceptance.

The systems and equipments which lent themselves to being included in the standards program were listed in matrices together with the standard parameters. A careful review of these matrices showed that the same parameters appeared at various levels of detail. Consequently, the common parameters were combined within the functions of the standards candidates to which they belonged, and four groups of standards resulted. The title of each group indicates how much of the propulsion system is covered by the standard.

The four groups are as follows:

- Group I - Total Propulsion Plant Standards
- Group II - System/Equipment Module Standards
- Group III - Equipment Envelope Standards
- Group IV - Individual Equipment/ Component Standards

It was concluded that three steps should be considered within the fourth group:

- Data Standards
- Procurement Standards
- Hardware Standards

The definitions and objectives of the four groups are contained in the following paragraphs.

Group I - Total Propulsion Plant Standards

The Group I Standards are documents that contain the technical information (in standard format) necessary to define and describe machinery which collectively forms a propulsion plant for a specific horsepower and a fraction above and below that power level. The definition covers the performance and type, description, and operating characteristics of the propulsion system including its principal subsystems.

For example, the system definition is carried to the level of equipment capacity and sized system piping diagrams for each power plant. The powers contemplated are shown in Appendix A, Tables 2, 4, and 5.

The objectives of Group I Standards are to achieve a systematic, consistent approach to power plant design, which would lead to reduced contract and detail design costs and shortened shipbuilding schedules.

Group II - Equipment/System Module Standards

Group II Standards are documents which contain the technical data and information required to define and describe complete subsystems or groups of equipment that are mounted on a common base, such as Fuel Oil Service System Module. The Group II Standard includes performance, type, description, and operating characteristics of the module. These standards also prescribe size and location of interfaces plus critical dimensions and weights for a given module.

The objectives of Group II Standards are to achieve reduced installation time and costs, as well as reduced test and checkout time. The modules permit a group interchange-. ability of equipment without imposing dimensional constraints on individual equipment.

Group III - Equipment Envelope Standards

Group III Standards are documents containing the technical data and information required to define and describe the performance and interface characteristics of equipment such as main boilers so that equipment of like characteristics from different vendors may be used interchangeably. These standards consist of imaginary envelopes which surround the equipment in question. This concept limits overall size and weight of the envelope and determines interface and installation requirement sizes and locations for that particular equipment independent of vendor source. These standards will be such that all eligible vendors will be able to meet the requirements of the standard by using a sub-base and adding interconnections between an item of equipment and its various interfaces.

The objective of this standard is to achieve the shipyard benefits of Hardware Standards without imposing the constraints on manufacturers that would be necessary for Hardware Standards (defined below).

Group IV - Individual Equipment/Component Standards

Group IV Standards are documents which contain the technical data and information required to define and describe individual equipment or components such as a main condensate pump. This group is subdivided into three distinct types of standards which may be considered as steps of a phased approach to the ultimate Hardware, or equipment, Standard.

The Data Standard is a document which contains technical reformation (in standard format) pertaining to vendor equipment required for propulsion machinery. The technical information included is that which is necessary for ship designers to perform propulsion plant designs at any level (preliminary design, contract design or detail design), without requiring additional information (such as contract drawings and specifications) from vendors.

The major objective of this standard is to provide the designer with certified equipment design data at the time the contract design is started. This eliminates the time-consuming process of obtaining owner and regulatory body comments and/or approvals of vendor plans and specifications before release for manufacture. The second objective is to eliminate the design changes usually incurred by the continuous updating of vendor data during a normal ship design cycle.

The Procurement Standard is a document containing the information required to purchase ship propulsion equipment from vendors. This document contains both the technical documentation and the legal documentation. The legal portion of this document contains the terms and conditions. The technical portion contains the data prescribed by a Data Standard.

The principal objective of this type of standard is to reduce the cost and schedule time of ship design tasks, procurement, and delays in installation of the equipment.

The Hardware Standard is a document containing the technical information necessary to define and describe hardware which would be interchangeable from any vendor. Interchangeable, in this standard, means like equipment of a given capacity will have identical--within specified limits--performance characteristics, interface dimensions, size limitations, weight, mounting dimensions, and compatibility of materials.

The several objectives of this standard include those of the Data Standard in that basic data would be available in a timely order. In addition, use of this standard would facilitate interchangeability with the added benefit of buying components from several vendors without design changes and reducing operational maintenance costs.

2.3 AN ECONOMIC ANALYSIS WAS MADE OF THE PROBABLE RESULTS OF APPLYING SEVERAL TYPES OF STANDARDS.

A methodology was developed and followed throughout the process of analyzing the economics of standards. Basically, it involved estimating the labor, material and schedule time reductions that should be realized from implementation of standards. The main objective in developing this methodology was to provide uniformity and simplicity in cost calculations and to insure a universal method of predicting available cost reductions when standards are utilized. The analyses were planned and performed in such a manner that they would not be dependent upon the procedures of any one shipyard, owner, manufacturer or designer. Furthermore, they were designed so that they could be readily *used* by any interested party through selective modification of certain variables to suit the operations of a specific shipyard.

2.3.1 Description of the Assumptions, Criteria and Approach

The following general assumptions were made for use throughout the analyses in order to insure conservative estimates of labor dollar savings:

- Constant July 1974 dollars were used for labor and material costs; costs were not escalated beyond July 1974.
- All direct yard labor man-hours were valued at $4.80 plus 25% for fringe benefits which totaled $6.00 per hour based on a review of major U. S. shipyard labor and fringe rates as of July 1974.

- All indirect yard labor man-hours were also valued at $6.00 per hour, including fringe benefits.

- All engineering and management services were valued at $9.00 per hour, again including fringe benefits.

In addition to these assumptions, and for use and guidance in performing the total cost calculations, the following criteria were established:

- Analyses were limited to items associated with a shipyard's designing, installing, checkout, and testing of the main propulsion plant and ancillary equipment.

- Numerical values for direct labor man-hours and schedule times used in the analyses were either estimated or based on engineering time data, work sampling, or historical data when available.

- Only real savings were considered; i.e., those which have a high probability of being achieved by appropriate management action.

- Overtime premium was not included in the cost analyses.

- Semi-variable and fixed cost portions of overhead as normally applied to labor hours were not included in the analysis of labor savings.

- Cost savings resulting from shorter building schedules were estimated based on an analysis of direct costs such as guards, insurance, supervision, utilities, and on-going fixed costs of depreciation and taxes associated with the shipyard facilities which are not tied up by the ship when it is completed earlier due to the use of standards.

Applying these guidelines, a sequence of operations was used in performing the individual cost analyses for each group of standards. These steps are outlined as follows:

- The first step was to describe the current approach used by most major U. S. shipyards to design procurement and installation of a propulsion system. Then a description was prepared for the approach which could be expected from application of a given type (group) of standard, i.e., standards approach. This was done for each of the candidate standards defined in Section 2.2.

- A cost breakdown *was* made for each approach, and cost items were subdivided to a level of detail required for significant cost resolution.

- Analyses were performed for each cost item to determine the direct labor and material costs and schedule times required to perform the work. described therein.

- Total direct labor man-hours and material costs required for each candidate standard were determined.

- The potential economic benetits of using a specific group standard was determined by comparing the estimated costs that would result from the use of that standard with the cost that would be experienced under the present method.

The results from the individual cost analyses thus performed were used in evaluating the comparative merits of various groups of standards. After reviewing these results and considering the advantages and disadvantages of each group of standards, they were presented to the Project Advisory Council. Their discussions, comments and criticism were carefully evaluated, and as a result modifications were made to the analyses.

It was then necessary to estimate the total labor savings available for specific propulsion plant applic-ations. This in turn necessitated the development of a method of generalization. The objective of the method was to predict the probable savings through utilization of standards on any component of the propulsion plant by comparing it with one of the components for which a detailed economic analysis had already been accomplished.

Briefly, the method of generalization can be described as follows:

- The potential contribution of each of the analyzed standards to the overall savings was estimated based on the size and complexity of the component.
- The component, for which a "generalized" estimate was to be prepared, was identified as nearly similar to one of the standards candidates which had been analyzed.
- A "size rating" and a "complexity rating" were assigned to the component to be estimated as compared to the similar previously "analyzed" standard.
- The size rating for the component was multiplied by the size contribution for the similar analyzed standard to obtain the probable percentage cost reduction based on the component's size.
- The same procedure was followed to obtain the probable percentage cost reduction based on the component's complexity.
- The two percentages *were* added to determine the overall percentage cost reduction for the component as compared to a similar standard which had been analyzed.
- In order to determine the estimated total savings for a component, the calculated percentage reduction was multiplied by the total savings for the similar analyzed standard.

2.3.2 The Cost Impact of Representative Standards

Cost analyses were performed on seventeen representative standard candidates. One analysis for each of Groups I, II, and III and one for each of three types of standards within Group IV, as being typical of the study, are summarized in the following paragraphs.

Analysis of Group I (Total Propulsion Plant) Standards Using a Steam Plant

The 24,000 to 26,000 SHP Steam Turbine Propulsion Plant was chosen as the example for evaluation of Group I Standards.

For the Total Propulsion Plant Standards (Group I), the "existing approach” was defined as follows:

- The design of the propulsion plant is not available.

- Starting with the owner’s requirements, a complete preliminary design and contract design are developed following normal procedures.

- Detail design is developed after contract award.

The definition of the “Standards Approach" was established as follows:

- A formal Total Propulsion Plant Standard for the power and type of propulsion plant in question is available to the shipyard and the designer.

- For the power range in question, the standard heat balances and sized system diagrams contained in the formal document will be usable with little or no modifications.

On the basis of these definitions, the costs for the development of complete contract and detail designs for the subject total plant were broken down to the level of detail necessary for comparison. Table II-1, page II-11, summarizes the cost elements used in the steam plant analyses for the contract design phase. Table II-2, page 11-12, lists the cost elements for the detail design phase.

GROUP I STANDARDS - ECONOMIC ANALYSIS
24,000 TO 26,000 SHP STEAM TURBINE PLANT
CONTRACT DESIGN

COST ITEMS		EXISTING APPROACH		STANDARDS APPROACH	
No.	DESCRIPTION	DIRECT LABOR MH	SCHEDULE MONTHS	DIRECT LABOR MH	SCHEDULE MONTHS
1	Prelim Heat Balance	1200	3.0	40	.2
2	Pump & Heat Exchange Sizing	1000	4.3	80	.5
3	Prelim Elect Load Analysis	800	5.0	40	.6
4	Schem E.R. Arrg't	200	5.0	80	1.0
5	Prelim. Piping Schem	600	5.3	60	1.2
6	Engine Room Arrangements	800	5.9	800	1.8
7	Piping Systems Diagrammatic Arrg'ts	1000	6.0	40	1.8
8	Lineshaft & Bearings Diag. Arrg't & Calcs.	400	6.0	80	1.8
9	Set of Secondary Contract Dwgs.	500	6.0	200	2.0
10	Contract Specs	1000	6.0	700	2.0
11	ABS & USCG Approvals	200	6.5	40	2 5
	TOTALS	7700	6.5	2160	2.5
	SAVINGS	5540	4.0		
	APPROX. SAVINGS	$50,000			

GROUP I STANDARDS - ECONOMIC ANALYSIS
24,000 TO 26,000 SHP STEAM TURBINE PLANT
DETAIL DESIGN

COST ITEMS		EXISTING APPROACH		STANDARDS APPROACH	
No.	DESCRIPTION	DIRECT LABOR MH	SCHEDULE MONTHS	DIRECT LABOR MH	SCHEDULE MONTHS
1	Specs for Equipment and Material	2000	5	1800	2
2	Bidding & Procurement	3000	7	2600	3
3	Final Heat Balance	300	8	40	3
4	Final Elec. Load Analysis	300	9	40	3
5	Shafting Calcs.	500	9	400	7
6	Piping Stress Analysis	1500	9	1000	8
7	Piping Diag. Arrg'ts.	500	9	150	8
8	Detail Working Dwgs.	18000	14	14000	11
9	Detail Specs	2000	8	1000	2
10	Test & Trial Memos	2000	15	1500	12
11	Approvals	1200	16	800	12
	TOTALS	31300	16	23330	12
	SAVINGS	7970	4		
	APPROX. SAVINGS	$72,000			

The combined overall savings obtainable through utilization of a total plant standard for the 26,000 SHP steam plant are approximately as follows:

Contract Design:	5500 Man-hour reduction = $50,000 and 4 months in schedule
Detail Design:	8000 Man-hour reduction = $72,000 and 4 months in schedule
Total Savings (direct costs)	$122,000

<u>Analysis of Group II (Equipment/System Module) Standards Using A Fuel Oil Service System Module as a Sample</u>

The existing approach for Group II equipment was defined as a non-standard module being assembled and installed on board ship by the shipyard. The standards approach called for the shipyard to use the module design depicted in the standard, assembling it in the shop and then installing the module on the ship.

The cost breakdown for the Fuel Oil Service System Module is as shown in the analysis form, Table II-3, page II-15. It can be seen that the estimated total costs for the existing approach is $26,600 as compared to $15,900 for the standards approach. Thus direct savings of about $10,700 are possible by utilizing a Group II standard for the Fuel oil Service System Module. This same form and approach was used in analyzing other Group II standards.

<u>Analysis of Group III (Equipment/Envelope) Standards Using a Main Boiler Envelope as a Sample</u>

It was assumed that in the existing approach, the equipment would be purchased by a shipyard through its normal procurement procedures. It would be stored within the shipyard. The shipyard would fabricate and install the foundation. All mechanical, electrical and other external connections would be made after the equipment was installed on board. With the standards approach, it was assumed that the equipment would already be in an “envelope” when delivered to the shipyard. The unit would come complete with its base and external connections to the interface points on the envelope surface.

The breakdown of cost items on this basis is shown on Table II-4, page II-16. As can be seen from the table, the total costs for the main boiler in the existing approach is $38,300 compared to $28,600 for the standards approach. Thus savings attainable in direct costs are approximately $9,700.

GROUP II - ECONOMIC ANALYSIS
FUEL OIL SERVICE SYSTEM MODULE

	COST ITEM	EXISTING APPROACH SHIPYARD ASSEMBLED NON-STANDARD MODULE	STANDARDS APPROACH SHIPYARD ASSEMBLED STANDARD MODULE
Procurement	Tech. Dept. Direct Labor	$ 5,976	$ 1,728
	Contracts Dept. Dir. Lab.	3,024	1,872
	P & E Dept. Dir. Labor	2,727	2,700
	Bid & Response	1,620	675
	Equipment Cost	1,310	1,310
	Sub-total	14,657	8,285
Installation	Direct Labor - Shop	2,832	2,700
	Direct Labor - Ship	1,230	900
	Crane Service	240	240
	Engineering Interface	1,350	1,000
	Set-Up	534	78
	Delays & Spool Piece	4,800	2,000
	Inventory	702	396
	Maint. & Repairs	246	174
	Sub-Total	11,934	7,468
	Test and Check-Out	E	E
	TOTAL	$26,591	$15,873
	SAVINGS		$10,718

E = Equal Cost

GROUP III - ECONOMIC ANALYSIS
MAIN BOILER ENVELOPE

	COST ITEM	EXISTING APPROACH	STANDARDS APPROACH
Procurement	Tech. Dept. Direct Labor	$ 4,356	$ 1,800
	Contracts Dept. Dir. Lab.	1,008	783
	P&E Dept. Dir. Labor	1,728	1,161
	Bid & Response	1,620	270
	Material Costs	750	1,500
	Sub-Total	9,462	5,514
Installation Phase	Direct Labor - Shop	10,200	9,408
	Direct Labor - Ship	9,180	7,020
	Crane Time	624	624
	Engineering Interface	2,280	1,200
	Set-Up Time	1,140	720
	Delays & Spool Piece	4,200	3,000
	Inventory	936	800
	Maintenance & Repairs	288	288
	Sub-Total	28,848	23,060
Test & Checkout Phase		E	E
	TOTAL	$38,310	$28,574
	SAVINGS		$ 9,736

E = Equal Cost

Analysis of Group IV (Individual Equipment/Component) Standards Using A Main Condensate PumP As An Example

An analysis was performed for each of the steps in the Group IV Standards. For the existing approach, it was assumed that the shipyards would go through the normal procedures for obtaining the equipment and installing it. For the standards approach, it was assumed that the information in the standards as described in Appendix "B" of this report is available at the start of the design. Tables II-5, II-6, and II-7 show the results of these analyses. The savings are summarized as follows:

Potential Savings Using Main Condensate Pump Group IV Standards

	Data	Procurement	Hardware
Man-Hours	290	570	1,260
cost	$2,600	$5,100	$10,900

2.3.3 Synthesis of Single Ship and Other Ship Savings

Components of the 24,000 to 26,000 SHP Steam Plant

The 24,000 to 26,000 SHP Steam Turbine Propulsion Plant was chosen for presentation of the synthesis of savings available in a single ship application. It was assumed that procurement type standards for all major equipment, except reduction gear and automation systems, were available and utilized.

Combined Savings for Group IV Procurement Standards

The total savings which could be obtained with such an application were investigated using the approach described in Section 2.3.1. As summarized in Table II-8, page II-21, if procurement type Group IV Standards were utilized for all major components of a 26,000 SHP steam plant, a labor cost savings of about $136,000 could be expected.

TABLE II-5

GROUP IV STANDARDS - ECONOMIC ANALYSIS

MAIN CONDENSATE PUMP

TYPE STANDARD: DATA

	COST ITEM	EXISTING APPROACH		STANDARDS APPROACH	
		DIRECT LABOR MH	SCHEDULE DAYS	DIRECT LABOR MH	SCHEDULE DAYS
PROCUREMENT	Establish Design Requirements	E	E	E	E
	Review Industry Availability	144	10	56	5
	Prepare Purchase Specifications	E	E	E	E
	Procure	240	6	180	5
	Incorporate into Ship Design	560	12	420	9
TOTALS		944	28	656	19
SAVINGS		288	9		
Approximate $ Savings		$2,600			

E = Equal

GROUP IV STANDARDS - ECONOMIC ANALYSIS

MAIN CONDENSATE PUMP

TYPE STANDARD: PROCUREMENT

COST ITEM		EXISTING APPROACH		STANDARDS APPROACH	
		DIRECT LABOR MH	SCHEDULE DAYS	DIRECT LABOR MH	SCHEDULE DAYS
PROCUREMENT	Establish Design Requirements	E	E	E	E
	Review Industry Availability	144	10	32	2
	Prepare Purchase Specifications	240	3	40	1
	Procure	240	6	120	3
	Incorporate Into Ship Design	560	12	420	9
TOTALS		1184	31	612	15
SAVINGS		572	16		
Approximate $ Savings		$5,100			

E = Equal

GROUP IV STANDARDS - ECONOMIC ANALYSIS
MAIN CONDENSATE PUMP
TYPE STANDARD: HARDWARE

COST ITEM		EXISTING APPROACH			STANDARDS APPROACH		
		Direct Labor MH	Direct Labor $	Sch Day	Direct Labor MH	Direct Labor $	Sch Day
Procurement	Establish Design Requirements	E		E	E		E
	Review Industry Availability	144	1,296	10	16	144	1
	Prepare Purchase Specifications	240	2,160	5	40	360	1
	Procure	240	2,160	6	40	360	1
	Incorporate Into Ship Design	560	5,040	12	--		-
Manufacture	Design	180	1,620	6	160	1,440	5
	Set Up	48	288	2	44	264	2
	Production	840	5,040	26	760	4,560	25
Installation		248	1,488	10	194	1,164	7
Test & Checkout		48	432	2	32	288	1
TOTALS		2,548	19,524	79	1286	8,580	43
SAVINGS					1262		36
Approximate $ Savings					$10,900		

E = Equal

TOTAL SAVINGS FROM GROUP IV PROCUREMENT/STANDARDS

EQUIPMENT-COMPONENT	UNIT SAVINGS FOR THE STANDARD $	NUMBER OF UNITS	TOTAL SAVINGS $
Main Boiler	15,000	2	27,300
Main Turbine	21,000	1	21,000
Main Condenser	7,200	1	7,200
Lube Oil Purifier	3,980	2	7,100
Forced Draft Fan	6,950	2	13,100
Main Feed Pump	5,400	2	9,800
Fuel Oil System	8,680	2	16,300
Main Circ. Pump	5,980	2	11,100
Main Condensate Pump	5,150	2	9,300
Lube Oil Cooler	1,500	2	2,500
Lube Oil Service Pump	3,860	2	7,100
First Stage Feed Htr.	1,500	1	1,500
Deaerating Feed Htr.	3,000	1	3,000
Total			$136,300

Integrated Labor Savings for a Single Ship

If Group I, Total Plant Standards, were implemented and utilized along with the Group IV, Procurement Standards, the resultant labor savings would be as follows:

From Group I Standards (page II-13)	$122,000
From Group IV Procurement Standards (page II-17)	$136,000
Total From Group I & IV Procurement	$258,000

These are conservative estimates of savings because as explained in section 2.3.1, the study purposely takes credit only for out-of-pocket direct labor costs of wages and fringe benefits. A well managed shipyard can make additional savings in indirect costs associated with reduction in direct man-hours.

Predicted Savings From Shorter Shipbuilding Schedules

Earlier in this report it was noted that when Group I Total Plant Standards are utilized they should result in schedule savings of at least 4 months in both the contract and detail design phases. The savings applicable to detail design would take place during construction of the ship and could potentially shorten the delivery period of the vessel. This possibility was investigated.

Most of the ships currently under construction or in planning have the engine rooms and accommodations at the stern. With this concentration of machinery and accommodations aft, the construction of the aft section is generally the controlling item in the construction of a ship. Most shipyards have focused special attention on approaches to reduce the construction time required for the stern section. Many yards pre-fabricate large sections, which may include machinery foundations and large piping. Those shipyards with large building basins will often start erection of the stern of a ship in the basin concurrently with the erection of another ship. In many ships the erection of the house sections cannot proceed until the major machinery items are installed. Thus installation of the main machinery components is generally a controlling item.

There are two pre-requisites to installation of the main machinery. The first is the availability of the components at the shipyard in a state ready for installation. This means that the components must be ordered in time to permit manufacture, delivery, and local assembly (when required as with boilers). In order for this to take place, it is necessary that sufficient information be available from the vendor for the shipyard to be able to release the component for manufacture. Study of current ship schedules for steam, gas turbine, and diesel power plants show that for the principal components, the time between contract signing and placement of purchase orders is about 5 months. The release for manufacture is an additional 6 months after the purchase order date.

The second pre-requisite to the installation of the main machinery is the installation of the principal foundations and piping in the stern section. This in turn requires availability of steel, piping, and the detail drawings for the installations. Development of piping and foundation drawings are constrained by information on the piping connections, weights, base shape and bolting locations, plus other features of the equipment.

To determine the potential schedule savings, an analysis was made of the current BIW ship schedules. From these schedules, it was estimated that at least 5 months could be saved in each of these pre-requisites by the use of Group IV Procurement (and Data) Standards and Group I Total Propulsion Plant Standards. This reduction of 5 months in each of the pre-requisites would offer a potential savings of 5 months in the construction of the first ship.

To fully realize these savings, other areas of the shipbuilding process associated with the machinery plant, such as auxiliary equipment and associated piping? cargo systems (on tankers), and electrical generating and distribution systems, will require that appropriate standards be implemented at the same time. It should be further realized that these potential savings may not be fully applicable to all U. S. shipyards as some yards are already using (their own) shipbuilding standards.

This analysis was verified by the results of a separate study prepared by Ingalls Shipbuilding Division. This study (prepared under a separate subcontract) evaluated the economic advantages of utilizing standards in an existing shipyard for a specific design project. The design project was a 150,000 ton deadweight tanker for U. S. flag operation. For one of the areas of the study, three senior shipbuilders with extensive marine experience, estimated the potential savings in ship schedule time (calendar days) by utilizing Group IV Procurement (and Data) Standards backed up by Group I Total Propulsion Plant Standards. The three independent estimates indicated an average saving of 161 days.

Assuming that a shipyard can produce about four ships of a class in one year (i.e., one every 3 months), the 5 month savings would permit 2 months of schedule savings in the second ship. Analysis of the current production in U. S. shipyards shows that on an average there are about four ships being built in a given series. Thus, there can be at least 7 months of construction savings per series.

The reasoning was carried one step further and the savings in tie-up costs, like insurance, security guards, and power combined with the on-going fixed costs of depreciation and taxes due to earlier delivery of a ship, was estimated at $5,000 to $10,000 per ship per calendar day.

These estimated savings were based on a comprehensive analysis done by the Bath Iron Works in the mid 1960’s. The analysis was done in great detail, and after thorough review was accepted by both owners and government audit teams. The study was made for the relatively small ships (C-5 size commercial ships and Navy destroyers) built at Bath during that period. The accepted value was $3,000 per ship per day. For the larger commercial ships built in new or modernized shipyard facilities (with their increased depreciation and taxes on these facilities) and a building period in the 1970's, $5,000 per ship per calendar day is a reasonable minimum tie-up cost.

Using $5,000 per day, the tie-up and on-going fixed cost savings were found to be as follows:

Applying the estimated savings of 5 months for the first ship in a series using the 26,000 SHP steam plant

5 months x 30 days x $5,000/day = $750,000

These, when added to the labor cost savings from utilization of standards, result in the following gross savings for the first ship:.

$750,000 + $260,000 = $1,010,000

or 15% of the total acquisition* cost of the propulsion plant for the first ship.

When the 2 months of savings for the second ship are added, it raises the savings to $1,310,OOO per series, which is about 4.8% of the total design, installation, and acquisition cost of the propulsion plants for 4 ships. This is summarized in the following table:

1st ship schedule savings	5 mos.	$750,000
1st ship labor savings		260,000
2nd ship schedule savings	2 mos.	300,000
3rd & 4th ship		-O-
Total Savings 4 ships		$ 1,310,000
Total Cost 4 ship Propulsion Plants		27,000,000
Savings (% of total cost)		4.8%

It should be remembered that the 4.8% is a minimum number based on company savings limited to directly related shipyard costs, as a percentage of an estimate of total costs including all labor costs burdened with full overhead plus the full purchase price of the plant equipment.

* Acquisition costs are based on a paper by Jose Femenia titled, "Economic Comparison of Various Marine Power Plants", presented at the SNAME annual meeting in New York on 11/15-17, 1973.

If in lieu of looking at the estimated savings in relation to the total design, installation, and acquisition cost for a steam plant, one examines the savings in relation to the shipyard's propulsion plant costs, exclusive of the purchase price of the components, the advantages of standards become more dramatic. Taking the shipyard design and installation costs for the 26,000 SHP steam plant at about $1,900,000* the labor savings would be about 14%. When the value of the schedule savings (which apply to the total ship) are added, the savings work out to about 55% of the yard propulsion plant installation costs for the first ship.

Integrated Savings for Additional Ships

Total savings on the class of 4 ships would be about 20% of the shipyard design and installation costs for the class.

Integrated Savings for Other Ships

The overall percentage savings for other steam plants were assumed to be the same as for the 26,000 SHP plant. For diesel plants, the estimated value of the labor savings developed in the study was approximately the same as for the steam plant. The estimated schedule savings from application of Group I and Group IV Procurement Standards for the first ship were about 4 months versus the 5 estimated for the steam plant.

2.3.4 Projected Industry-Wide Savings

The total savings for the decade *were* calculated using 4.8% (the average savings for a series of 4 ships) of the acquisition and installation costs of the power plants projected to be installed over the decade. With total acquisition costs estimated to be about $2 billion, these savings were calculated to be approximately $96,000,000 for the decade.

* Shipyard design and installation costs for a 26,000 SHP steam plant were taken from the results of the separate study performed by Ingalls Shipbuilding Division for this task.

III. PRINCIPAL FINDINGS

III. PRINCIPAL FINDINGS

This section summarizes the principal findings and conclusions of the study. Its contents are as follows:

- The overall results of the shipbuilding and propulsion plant forecast.
- A qualitative evaluation of the applicability of standards.
- The potential economic benefits of selective application of standards.

3.1 THE SHIPBUILDING FORECAST INDICATED THAT U.S. SHIPYARDS BUILD ABOUT 350 SHIPS REQUIRING ABOUT 370 PROPULSION PLANTS

The objective of the forecast was to indicate the numbers of the various types and sizes of power plants which would be required for the next decade. While any forecast is subject to a variety of unpredictable economic and political factors, the forecast as developed in this study provides a valid basis for selecting candidate propulsion plants standards and evaluating their technical feasibility and economic benefits.

The forecast indicated a U. S. shipbuilding level of about 35 ships (10,000 deadweight tons and over) per year would be maintained for the next ten years. These ships would require the following propulsion plants:

Type	Number Projected
Steam	185
Gas Turbine	110*
Diesel	75*
	370

Note: Some ships are forecast as twin screw, thus requiring twin propulsion plants.

*Forecast as of June 1974. Recent power plant analysis done by BIW and Ingalls Shipbuilding indicates diesel will predominate over gas turbine for commercial ships during the first half of the next ten-year period.

An estimate was made of the probable numbers of the various types of steam plants as follows:

Type	Number Projected
Steam Plants with 2 Boilers and 2 Heater Cycles	90
Steam Plants with 2 Boilers and 4 Heater Cycles	80
Other Steam Plants	15
	185

The present high cost of bunker fuel and the resultant demand for more efficient cycles may eventually prove that the number of single boiler plants, reheat cycles, and combined cycles may have been underestimated.

The gas turbine prime movers installed on ships in the future will probably be the heavy-duty industrial type rather than aircraft derivatives. This type permits the utilization of lower cost bunker fuel and lower maintenance costs.

Diesel plants are likely to be composed of multiple units of medium-speed engines until a U. S. company obtains a license to build a foreign slow-speed diesel design.

In view of the continuing U. S. shipowner preference for steam and the resulting large number of steam units forecast, it was concluded that the principal emphasis of this study should be placed on selecting and evaluating the standards for steam propulsion plants.

3.2 A QUALITATIVE EVALUATION OF THE APPLICABILITY OF STANDARDS

The results of the qualitative evaluation of the various types of standards are summarized as follows:

3.2.1 Total Propulsion Plant Standards (Group I)

- These are basic standards required for structuring the total propulsion-plant system.
- The principal benefits are in reduced design effort and shorter design and

construction schedules.

- The design hours saved are generally those of the experienced engineers. This, coupled with the increased utilization of less skilled technical personnel to prepare the design, would help alleviate the critical shortage of engineers.

- Use of this standard in the contract design should minimize the errors which now tend to be introduced by preliminary and incomplete vendor packages; thus, allowing the detail design to proceed more smoothly.

- This is a difficult standard to write as it must be flexible enough to cover a number of ship designs and yet specific enough to provide technical information required for designing the propulsion plant.

3.2.2 Equipment/System Module Standards (Group II)

- The use of locally designed modules for propulsion plant sub-systems has received wide applicability in U. S. shipyards today.

- The large variation in ship size, machinery arrangement, and type of requirements for individual modules would minimize the advantages of module standards.

- The resultant market for modules constructed to standards may be too small to attract module manufacturers.

3.2.3 Equipment Envelope Standards (Group III)

- Use of Equipment Envelope Standards would allow interchangeability of equipment from different manufacturers.

- Their application would permit a shipyard to proceed with the design prior to selection of a manufacturer as the equipment base and all interface points would be identical for the various manufacturers.

- Equipment Envelope Standards would permit preparation for the installation and connection of the equipment prior to its delivery.

- The required envelope might require extra space in the engine room. This could be especially critical for equipment having a requirement for tube removal.

- Some savings in design would be eliminated if pipe stress requirements change due to various locations of connecting pipes within the envelope.

- The response of the manufacturers of equipment was positive to the envelopes. They felt that they could cooperate with the shipyards without detriment to their own interests.

3.2.4 Individual Equipment/Component Standard (Group IV)

Data Standards

- The benefit of Data Standards is in having certified vendor information available when the vendor is selected.

- All shipyard representatives were in favor of applying Data Standards.

- Data Standards can eliminate communications gaps and delays caused by waiting for certified vendor plans.

- These standards can increase design efficiency appreciably as the iteration cycle resulting from updating of vendor information during design would be eliminated.

Procurement Standards

- The Procurement Standard includes the information from the Data Standard and the legal terms and conditions for procurement.

- The industry is generally in favor of the

Procurement Standards (as with the case of the Data Standards), with the exception of those shipyards which require adherence to their own specific terms and conditions.

- Procurement Standards can be effective in reducing the cost and time for procurement of equipment as the majority of the terms would be pre-established. Procurement Standards can reduce negotiations, but will not eliminate them.

Hardware Standards

- Hardware Standards would provide appreciable savings in engineering, procurement, and production.

- These standards would permit reduction in owner's inventory of spare parts.

- Hardward Standards may eventually evolve out of the general use of Data/Procurement Standards for certain equipment for which the shipbuilding market is large.

- Manufacturers are generally opposed to these standards, claiming that they would be incompatible with their existing industrial product line considering that the U. S. marine market is a small fraction of their total business.

General

- The Data Standard (developed with the Procurement Standard) could first present the desired standardized characteristics, operating conditions, materials, dimensions, and other special features of the class of component. This is the specification towards which it is desired the standardization would proceed as new designs are developed or old designs modified. Interchangeability would be the ultimate end product. Section 2 of this standard would then present the data bank of available components on the market including in the proper format all of the pertinent features of each described unit in a manner parallel to the desired standard. Such a Data Standard would form a solid base for developing Hardware Standards.

3.3 THE POTENTIAL ECONOMIC BENEFITS OF SELECTIVE APPLICATION OF STANDARDS

The potential economic benefits of the selective application of Propulsion plant Standards can be realized at various stages of design, procurement, and installation of equipment. The benefits result primarily from reduced man-hours and shorter construction schedule times. These savings were documented in Chapter II. Some adjustments to the economic advantages presented may be required to account for the cost of developing and implementing the standards when the plans are formulated for the standards development.

The conservative approach taken throughout the economic analysis provides increased confidence that the implementation of Group I, Total Propulsion Plant Standards in combination with Group IV, Data/Procurement Standards, can significantly reduce the installed costs of propulsion plants and improve ship producibility in the U.S. A further conservative aspect of the analysis was the approach to estimating dollar savings of the reduced construction period. Various shipyards and owners might estimate the benefits differently, but all would conclude that earlier delivery offers significant financial benefits under normal conditions. A shipyard could distribute their fixed overhead to a greater number of ships produced per year and increase their profit or reduce the price of ships proportionately. Again, if the contract period can be shortened, a shipyard would have less concern over rising costs due to inflation. A shipowner could put the new ship into service sooner and begin to earn revenue. earlier. There is yet another benefit to the owner due to a shorter delivery time. He doesn't have to be concerned as much about possible changes in the economic environment from those which provided the justification for his ordering the ship.

Another valuable benefit due to standards that must be stressed is in the reduced engineering man-hours, most of which would be saved by senior engineers and designers. Thus selective application of standards would certainly result in reduced design cost and would help to provide some relief in the critical shortage of engineers and designers, particularly in the area of machinery.

In assessing the economic benefits of standards, it should be appreciated that development and implementation will take time, and therefore, several ears *may* have elapsed before the potential benefits are realized.

Some of the U. S. shipyards have developed or intended to develop their own ship designs. Also, some of the yards have developed close working relationships with certain manufacturers of equipment. In effect, this has provided these yards with a form of data and procurement standards. Consequently, these yards may have less to gain from the proposed industry-wide standards.

The dollar and schedule savings estimated in this study stem primarily from those ships which are either one of a kind, or first of a class.

The labor savings that result from the combined Group I, Total Plant Standards and Group IV, Procurement Standards, to a 26,000 SHP steam plant were estimated to be worth about $250,000 on the lead ship. The labor savings by themselves are about 4% of the total acquisition costs or about 14% of the shipyard design and installation costs.

This combination of standards should permit a reduction of at least 5 months in the schedule for the first ship in a series (26,000 SHP steam plant) and about 2 months in the second ship of a class. An analysis of the time dependent costs associated with small to medium size ships built at Bath Iron Works over the last twelve years has identified $5,000 to $10,000 of fixed overhead and service costs per ship for each calendar day the ship is in the shipyard. Taking savings at $5,000 per ship per calendar day, the schedule savings are about $750,000. Thus, the total savings for the first ship in a series are about $1 million. This is 15% of the total acquisition cost of the propulsion plant.

Considering the potential savings of 2 months in the second ship of a series, raises the total savings for a class to about $1.3 million. This represents about 4.8% of the total acquisition and installation of the propulsion plants for a series of 4 ships.

If in lieu of looking at the estimated savings in relation to the total design, installation, and acquisition cost for a steam plant, one examines the savings in relation to the shipyard's propulsion plant costs, exclusive of the purchase price of the components, the advantages of standards become more dramatic. Taking the shipyard design and installation costs for the 26,000 SHP steam plant at about

$1,900,000, the labor savings would be about 14%. When the value of the schedule savings (which apply to the total ship) are added, the savings work out to about 55% of the yard propulsion plant design and installation costs for the first ship.

Potential maximum total savings for the decade were estimated by taking 4.8% of the total acquisition and installation costs of the plants projected for the decade (about $2 billion 1974 dollars). If propulsion plant standards were developed and used for the entire 10 year program, total savings from the combined application of Group I, Total Plant Standards and Group IV, Procurement Plant Standards would be about $96,000,000. The 96 million 1974 dollars of potential savings for the U. S. shipbuilding industry during a decade could not be totally realized as it assumes that the savings would be applicable to all commercial ships built in all U.S. shipyards. As some U. S. shipyards already have their own company standard designs, processes and procedures, these savings would not be fully applicable to all of the yards. It also takes time to develop and implement standards. However, given an active national standards program with four to six shipyards participating, total savings of over $30 million should be realized.

IV. CONCLUSIONS AND RECOMMENDATIONS

IV. CUNCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

Development and implementation of propulsion plant standards is both feasible and desirable. Early emphasis should be on Total Plant Standards and Procurement Standards.

The savings that can be realized from the application of these standards to a 26,000 SHP steam plant include:

- Labor savings of about $250,000 on the first ship in a series.
- Schedule savings of 5 months in the lead ship which would contribute additional savings on the first ship of $750,000.
- Schedule savings of 2 months on the second ship in a class, saving about $300,000, raising savings on a class to $1,300,000.
- Total savings on a class of 4 ships would be 4.8% of the propulsion plant acquisition and installation costs.
- Total savings on the class of 4 ships would be about 20% of the shipyard design and installation costs for the class.

For any one individual shipyard, these savings could be modified depending upon to what degree they have already standardized their designs and technical and procurement procedures.

Application of Total Plant Standards and Procurement Standards to the propulsion plants projected for the decade would save nearly $100 million on plants which will have an installed value approaching $2 billion.

4.2 RECOMMENDED NEAR-TERM ACTIONS

Adoption of standards and realization of their potential savings can only be achieved when the shipyard managers are convinced that the potential results indicated in this report are achievable in their yards. Only then will they be likely to apply the amount of top management attention that will be needed to overcome the early resistance of some owners, suppliers, or shipyard executives.

It is recommended that a pilot program be initiated for developing one Total Propulsion Plant Standard and one or more Procurement Standard with associated Data Standards for each equipment supplier's component. These standards should be applied to a new shipbuilding program in one *or* more U. S. shipyards to measure the ability of standards to reduce propulsion plant engineering and installation costs. The specific plant and components for each standard would be selected by the Propulsion Plant Standards Advisory Council or some other industry committee such as the SNAME Ship's Machinery Committee. The shipyard managers and other key maritime executives should be fully briefed on the results of this pilot program and the potential benefits of selective use of standards. If the pilot program confirms the projected benefits and feasibility, the program for implementation of standards should be continued to cover all Group I, Total Propulsion Plant Standards and all Group IV, Component Procurement Standards.

Both the shipyard managers and the Maritime Administration should give their continued support to the program because of its high potential pay-off to shipbuilders, ship-owners, and the supplier industry.

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APPENDIX A

Propulsion Plant Forecast

SHIP TYPE	DWTX1000	1973 ACTUAL	74	75	76	77	78	79	80	81	82	83	84	85	76-85 10 YEAR TOTAL
Container Carrier	14.6-20	-	4	2	2	1	-	-	1	2	2	4	4	4	20
RO/RO Ship	14.1-20	-	2	2	1	1	-	1	2	2	2	3	3	3	18
Barge Carrier	22-28	-	4	3	3	2	3	3	3	3	3	5	4	4	33
Bulk Carrier	19,29,80	5	4	3	3	2	3	3	3	3	4	5	5	5	36
OBO Carrier	80	-	-	1	1	1	-	1	-	1	1	-	1	-	6
LNG Ship	64-100	9	4	5	5	5	5	4	4	4	4	4	4	4	43
LPG Ship	27-45	-	-	-	1	1	2	2	2	2	2	2	2	2	18
Oil Tankers	25-37	9	10	9	9	6	5	5	6	6	7	7	6	7	64
Oil Tankers	50-90	10	6	7	6	7	6	6	6	6	6	6	7	6	62
Oil Tankers	120-180	-	3	3	2	2	2	3	3	3	1	1	1	1	19
Oil Tankers	225-265	3	2	4	4	3	2	2	2	2	2	1	1	1	20
Oil Tankers	400	-	-	1	1	2	2	2	2	2	1	1	1	1	15
TOTAL		36	39	40	38	33	30	31	33	35	35	39	39	38	354

SHIPS TO BE CONTRACTED FOR IN U.S. SHIPYARDS
AS FORECAST IN EARLY 1974
TABLE 1

(hatched) Unlikely due to depressed tanke

SHPX1000	15-17.5	24-26	28.5-32	36-40	43-45	50	TOTAL
YEAR							
1976	1	8	3	10	4	2	28
1977	2	7	3	9	2	-	23
1978	1	8	2	8	2	1	22
1979	-	9	2	6	1	1	19
1980	1	7	2	5	2	-	17
1981	-	7	2	7	1	1	18
1982	1	4	2	7	1	-	15
1983	1	4	2	6	-	1	14
1984	-	5	2	5	1	1	14
1985	1	4	2	5	1	1	14
TOTAL	8	63	22	68	15	8	184

FORECAST OF STEAM TURBINE PROPULSION PLANTS

BY SHP 1976 THROUGH 1985

AM PLANT CYCLE	RANGE SHP x 1000	76	77	78	79	80	81	82	83	84	85	TEN-YEAR TOTALS
Boilers Stage-Heating	16	1	2	1	-	1	-	1	1	-	1	8
	25	8	7	8	9	6	6	3	3	5	4	59
	30	3	3	2	2	1	1	1	2	2	2	19
Boiler r Stage-Heating	37	10	9	8	6	4	6	6	5	5	5	64
	44	4	2	2	1	1	-	1	-	-	1	12
	50	2	-	1	1	-	1	-	-	-	1	6
Boiler - Two Heaters	25	-	-	-	-	1	1	1	1	-	-	4
	30	-	-	-	-	1	1	1	-	-	-	3
Boiler - Four Heaters	37	-	-	-	-	1	1	1	1	-	-	4
eat Cycle*	44	-	-	-	-	1	1	-	-	1	-	3
	50	-	-	-	-	-	-	1	1	-	-	2
AL NO. OF PLANTS		28	23	22	19	17	18	16	14	13	14	184

-YEAR TOTALS BY TYPE OF CYCLE

Boilers-Two Heaters:	86
Boilers-Four Heaters:	82
Boiler-Two Heaters:	7
Boiler-Four Heaters:	4
eat Cycle:	5 *
TOTAL	184

* Present high cost of bunker fuel may increase number of reheat plants.

STEAM PLANT FORECAST BY CYCLE TYPE

TABLE 3

SHPX1000	12.5	20 to 30	35	40	60	TOTAL
YEAR						
1976	3	1	-	-	-	4
1977	2	3	-	-	-	5
1978	2	3	-	-	-	5
1979	2	4	1	1	0	8
1980	2	4	1	1	1	9
1981	3	6	2	1	1	13
1982	3	7	2	2	1	15
1983	3	6	4	1	4	18
1984	3	7	3	1	3	17
1985	3	7	3	1	3	17
TOTALS	26	48	16	8	13	111

FORECAST OF GAS TURBINE PROPULSION PLANTS

BY SHP TO 1985

SHPX1000	7	14-18	28	TOTAL
YEAR				
1976	2	5	-	7
1977	2	3	1	6
1978	2	3	-	5
1979	2	4	-	6
1980	2	4	2	8
1981	2	4	2	8
1982	2	4	2	8
1983	2	4	2	8
1984	2	4	2	8
1985	2	4	2	8
TOTAL	20	39	13	72

FORECAST OF DIESEL PROPULSION PLANTS

BY SHP TO 1985

APPENDIX B

Format for Standards

FORMAT FOR

GROUP-1 TOTAL PLANT STANDARD

STEAM TURBINE PROPULSION PLANT

TABLE OF CONTENTS

1. Title

Use: American Marine Standard Specifications for a Marine Steam Turbine Propulsion Plant.

2. Abstract

This standard is a top-level reference document which contains the technical information necessary to define and describe a ____ SHP to ____ SHP marine steam turbine propulsion plant with ____ stages of feedwater heating. It is intended for use in developing the design of shipboard steam propulsion plants; and the basic minimum requirements set forth in the standard are to be complied with.

3. Foreword

(This foreword is not a part of the American Marine Standard Specifications for a Marine Steam Turbine Plant.)

This American Marine Standard specifies the basic minimum requirements for marine steam turbine propulsion plants. The standard itself is a culmination of the National Shipbuilding Research Program and specifically of the Ship Producibility Program efforts. The objective of the standard is to reduce shipbuilding design costs by providing standard requirements which can be effectively used by the designer and the shipbuilder, or both. it contains all the information at the systems level from which specific detail designs can be developed to suit various types and sizes of ships. A complete heat balance diagram is included which can be used with little or no modification, depending on the size and type of ship. Equipment and components comprising the plant are listed and specified as to their basic performance and operational parameters. Lower level standards such as individual equipment or systems standards which are to be utilized in the total plant are referenced in the text.

The standard was developed under the Jurisdiction of

Suggestions for improvement of this standard will be welcome. They should be *sent* to the ______________________________

____________________ had the following members at the time it processed and approved this standard:

____

____

____

4. <u>Text</u>

American Marine Standard Specifications for a Marine Steam Turbine Propulsion Plant.

1. Scope

This standard lists the basic requirements and provides systems diagrams and major equipment listings for marine steam turbine propulsion plants of ____ SHP to ____ SHP range. Its use is recommended for the development of a detail design for the plant; and it is foreseen that by using the information contained herein considerable savings will be obtained in the overall engineering costs for building the ship.

2. Definitions and Terminology

{Following terms (and possibly others which may be considered necessary by the Committee to develop the standard) should be defined.

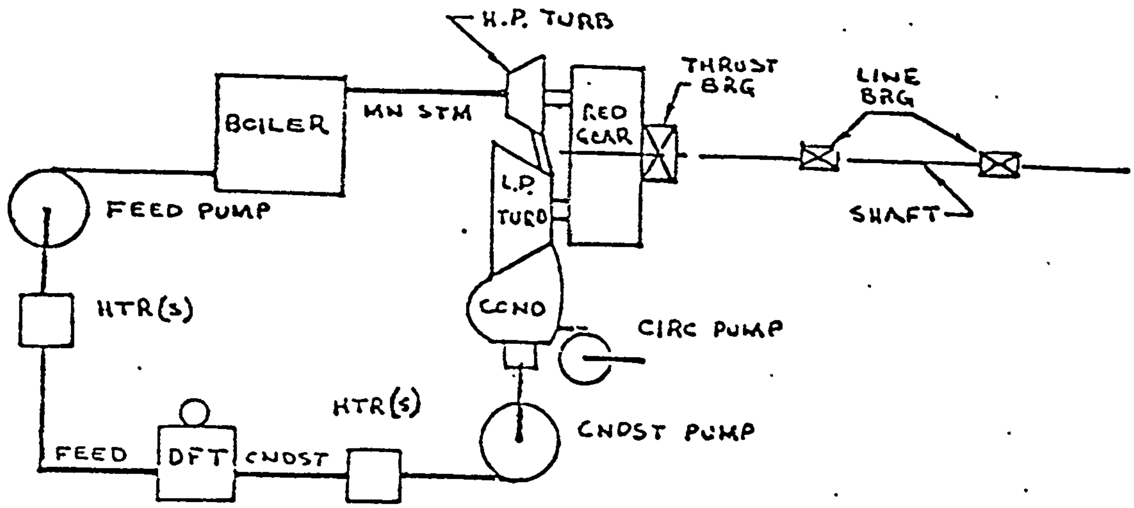
1. Automation
2. Auxiliary Exhaust
3. Auxilary Load
4. Auxiliary Steam
5. Ballast Pumping
6. Bilge Pumping
7. Boiler Fuel Rate
8. Cargo Heating
9. Cargo Pumping
10. Condensate
11. Desuperheated Steam
12. Distilling Plant
13. Euthalpy
14. Equipment/Component Standards
15. Feed Water
16. Flow
17. Galley
18. Hotel Load
19. Hull Pumping
20. Line Bearing
21. Low Pressure Bleed Steam
22. Machinery Space
23. Machinery Support Load
24. Main Steam
25. Maximum Continuous Service
26. Module Standards
27. Non-extraction Steam Rate
28. Operational Mission
29. Port Condition
30. Superheated Steam
31. Thrust Bearing
32. Turbine Steam Rate

3. Description of Propulsion Plant

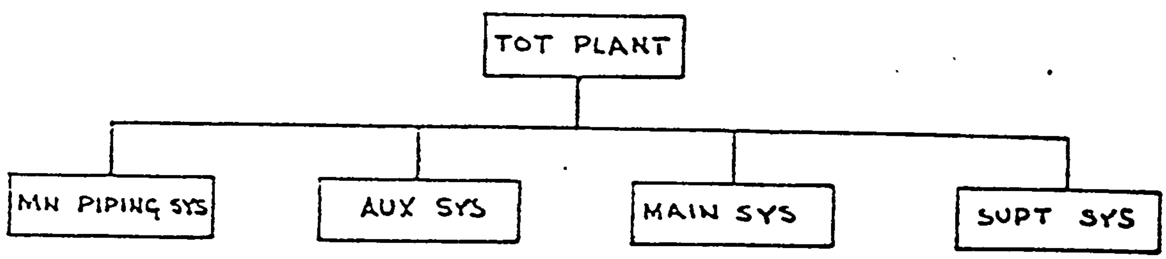
This standard covers a geared steam turbine propulsion pIant installation to be used in driving ship’s propeller(s) through the water.

3.1 Block Diagrams for Plant-and Systems

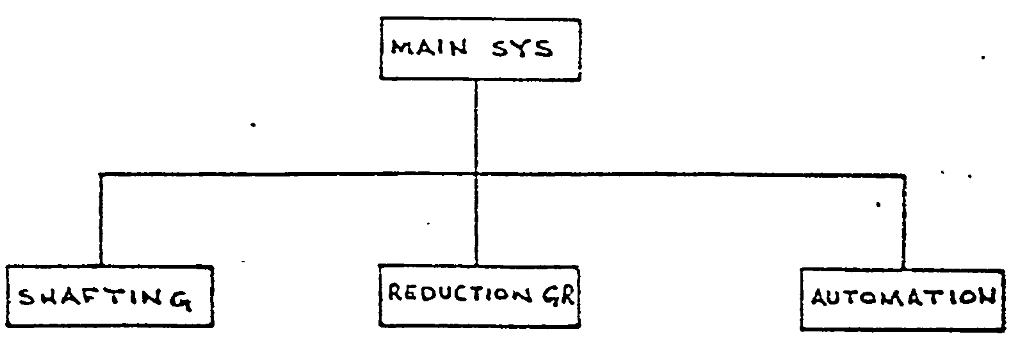
The total plant shall conform in general to the cycle loop and block diagrams shown below:



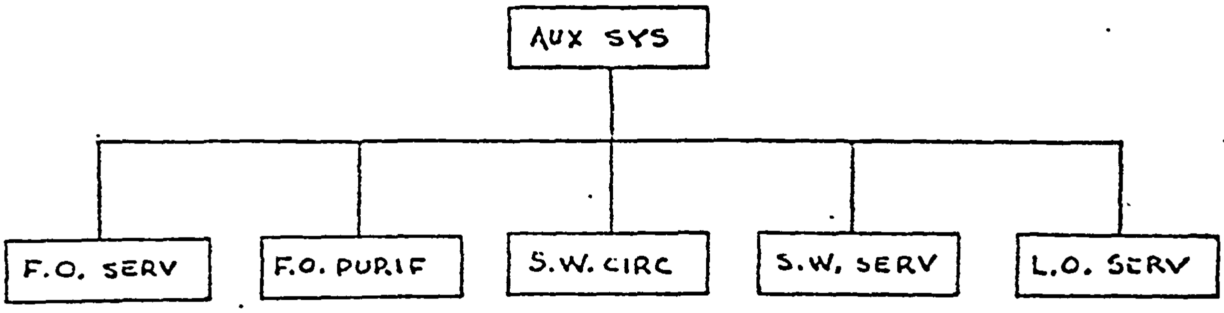
3.1.1 The main systems that comprise the total plant are as shown in the following block diagram:



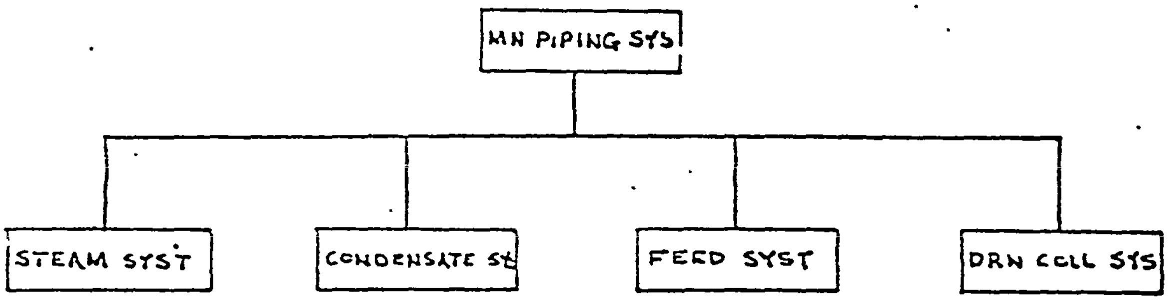
3.1.2 The propulsion systems consist of the following elements:



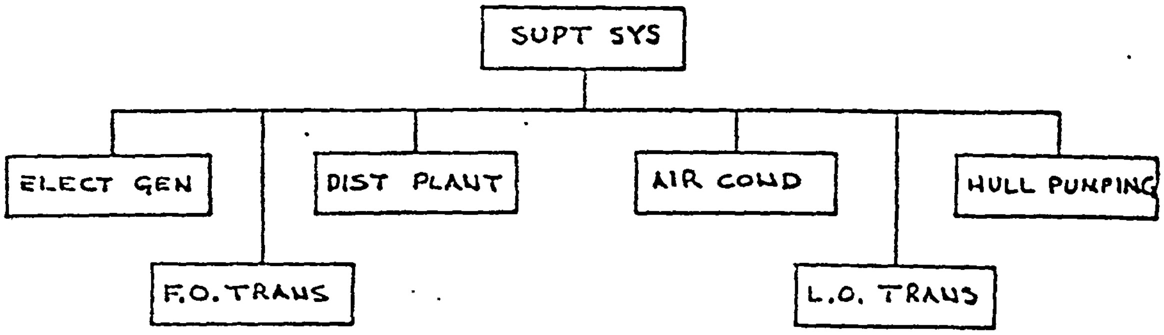
3.1.3 The auxiliary systems contain the following subsystems which are required for operation of the propulsion system:



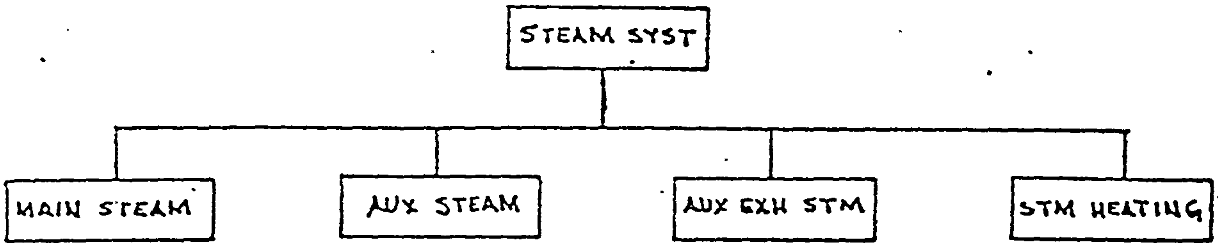
3.1.4 The sub-systems shown below are contained in the main piping systems:



3.1.5 The supporting systems are those which are required for accomplishment of the ship's mission and which interface with and affect the propulsion system. For the purposes of this standard, the supporting systems should be assumed to be of a general nature and not specific to any type or size of ship.



3.1.6 The steam piping systems segment of the main piping systems shall be further subdivided into the following main and auxiliary steam systems:



3.2 Standardized Parameters

The following total plant parameters shall be standardized:

3.2.1 Steam Conditions at Boiler Superheater Outlet:

Pressure: ____ lbs/in^2 gauge (____ Kg/cm^2 g)

Temperature: ____ °F (____ °C)

3.2.2 Main Condenser Vacuum: ____ in. Hg (___ cm.Hg)

3.2.3 Sea Water Temperature: ____ °F (___ °C)

3.2.4 Ambient Air:

Temperature: ___ °F (___ °C)

Relative Humidity: ___%

3.2.5 Machinery Space Air:

Temperature: ___ °F (___ °C)

Relative Humidity: ___%

3.3 Basic Minimum Requirements

In addition to the standardized parameters and systems subdivisions described in 3.2 and 3.1, respectively, the total plant shall meet the requirements of the heat balance diagrams as set forth in 4.1 and 4.2.

Should any of the required data for heat balance diagrams as delineated in 4.1 differ, for the specific ship application, from the values shown in the standard, the heat balance diagrams should be modified to account for the changes.

4. Heat Balance for the Plant Cycle

Heat balance calculations were performed using the standardized parameters and basic minimum requirements specified in 3.2 and 3.3, for the following three service conditions:

Maximum Continuous Service Condition

Port Condition

Operational Mission Condition

Note - Figure 1 is a sample heat balance diagram. The standard when completed shall have one separate diagram for each of above conditions.

4.1 Required Data for Heat Balance Diagrams

in performing the hat balance calculations, the data shown below *were* utilized as basic requirements in accordance with reference [1][1]

4.1.1 Steam conditions at Superheater Outlet

Pressure ____ lbs/in^2 g (Kg/cm^{2}g)

Temperature ____ °F (°C)

Enthalpy ____ BTU/lb (Kcal/Kg)

Flow Quantity ____ lbs/hr (Kg/hr)

(See heat balance diagrams for steam conditions at other locations.)

4.1.2 Feed Water Conditions at Inlet to Boiler:

Pressure: ____ lbs/in^{2}g (Kg/cm^{2}g)

Temperature: _°F (_°C)

Enthalpy: ____ BTU/lb (._K cal/Kg)

Flow Quantity: ____ lbs/hr (_Kg/hr)

(See heat balance diagrams for feed water conditions at other points in the cycle.)

Numbers *in* brackets refer to listing of references in Section 7.

4.1.3 Condenser Conditions:

Condenser Vacuum: ____ in Hg (___ cm. Hg)

Sea Water Injection at: ____^{o}F (___^{o}C)

Condensate Temperature: ____^{o}F (___^{o}C)

4.1.4 Fuel Oil and Air Conditions:

No. ___ Fuel Oil

Higher Heating Value: ____ BTU/lb (___ K cal/Kg)

Air to Forced Draft Fans: ___^{o}F (___^{o}C)

4.1.5 Consumptions and Losses:

Boiler Efficiency: . %

Boiler Fuel Rate: ___ lbs/SHP hr (___ Kg/SHP hr)

Main Turbine Non-extraction Steam Rate:

___ lbs/SHP hr (___ Kg/SHP hr)

4.1.6 Auxiliary Loads

Distilling Plant Load: ___ GPD (___ Tons/day)

Turbo-Generator Load: ____ KW

Heating and Hot Water Loads: ___ GPD (___ Tons/day)

Air Conditioning Load: ____ KW

Miscellaneous Steam Load: ___ lbs/hr (___ Kg/hr)

4.1.7 Equipment Operating Conditions

For the standard, operating conditions such as working pressures, relief pressures, system losses, efficiencies, etc., for all major equipment that make up the cycle loop for the plant should be listed and ranges specified.

4.2 Heat Balance Diagrams

4.2.1 Maximum Continuous Service Condition

For the standard, a definition of the maximum service condition should be included here along with major specific limitations - Figure number for diagram should be referenced.

4.2.2 In-port Condition

Definition, Specific Limitations, Diagram

4.2.3 Operational Mission Condition

Definition, Specific Conditions, Diagram

5. Systems Diagrams

For the standard, systems diagrams shall be developed for all of the systems listed below. Typically, each diagram shall consist of a one-line piping schematic showing the subject piping system with symbolic representations of all relevant equipment, materials such as valves, fittings, flanges, and instrumentation. Valve, pipe and fitting sizes shall be indicated on the diagram. Tables shall be included which list materials and their specifications, maximum allowable fluid velocities, pump and other equipment types, sizes and capacities.

Sample systems diagrams are included in this draft proposal to be used for guidance in preparing the finished standard (Figures 2 through 10).

Sample tabulations for material specifications, velocities, and equipment are included in this draft proposal for use as a guide in preparing the standard. (See Tables 1, 2 and 3.)

5.1 Steam Systems

5.1.1 Main Steam System

For the standard, a brief description of the main steam system shall be presented here.
Figure 2 is provided in this draft proposal for guidance in preparing the standard.

5.1.2 Auxiliary Steam System

Brief description of the auxiliary steam system -
Sample diagram included here in Figure 3.

5.1.3 Auxiliary Exhaust System

Brief description
Sample diagram - Figure 4

5.1.4 Steam Heating System

Brief description of the steam heating system and a schematic diagram shall be included here in the standard.

5.2 Condensate System

Description of the condensate system shall be included. Sample diagram, Figure 5, included in this draft proposal for guidance in preparing the standard. However, Figure 5 includes not only the condensate system but also the feed water, boiler blow and boiler water sampling piping. For the standard, it may be proper to separate these systems from one another by showing all but the system in question in phantom lines.

5.3 Feed Systems

Brief description of the feed system.

Separate diagram for the feed water piping shall be developed and included here in the standard. For guidance, see Figure 5.

5.4 Drain Collecting Systems

Brief description of system shall be included.

Separate diagram shall be included. For guidance, see Figure 5.

5.5 Auxiliary Systems

These systems cover all auxiliary equipment and installations which are required for operation of the propulsion plant.

5.5.1 Fuel Oil Service System

Brief description shall be included.

(F.O. Purifier should be treated with the service system.)

Sample diagram, Figure 6, included for guidance.

5.5.2 Salt Water Circulating Systems

Description of the system shall be included.

Sample diagram, Figure 7, included for guidance.

5.5.3 Salt Water Service Systems

Description of the auxiliary condenser S.W. piping and other S.W. systems in the machinery space shall be included here in the standard. Sample diagram, Figure 7, can be used for guidance.

5.5.4 Lubricating Oil Service System

Brief description of system shall be included.

Sample diagram, Figure 8, is included for guidance.

5.6 Propulsion Systems

These systems include the major equipment allied with the main propulsion plant which are required for operation of the ship.

For the standard the information shown under each of the systems listed below shall be developed, and the resulting data shall be included in the standard in the form of figures, tables, etc., as appropriate.

5.6.1 Shafting System

- o Dimensional diagram
- o Material requirements
- o Bearing types and locations
- o Thrust bearing (may be integral with the reduction gear)
- o Weight and force diagram

5.6.2 Reduction Gear System

- o Type
- o Load factors
- o K-factors
- o Gear diagram

5.6.3 Automation System

- o Type of system
  - Degree of automation
  - Duration
  - Location of controls
- o System block diagram
- o One-line diagram
- o Service requirements

5.7 Supporting Systems

For the standard, the information shown under each of the supporting systems listed below shall be developed, and the resulting data shall be included in the standard in the form of figures, tables, etc., as appropriate.

5.7.1 Electric Generating System

- o Hotel load
- o Auxiliary load
- o Machinery support load

5.7.2 Distilling Plant

- o Required Capacity
- o Efficiency

5.7.3 Air Conditioning, Ventilation

- o Required load

5.7.4 Hull Pumping Systems

- o Bilge Pumping System

  (Sample diagram, figure 9, included for guidance)
- o Ballast System

  Sample diagram, figure 9, which provides the interface of both bilge and ballast systems, can be used for guidance.
- o Fire fighting system

5.7.5 Fuel Oil Transfer System

(Sample diagram, figure 10, is included for guidance.)

5.7.6 Lubricating Oil Transfer System

(Sample diagram, figure 8, can be used for guidance.)

6. Available Standards for Equipment and Components

The total plant standard, at the time of its writing, can utilize, if found necessary and appropriate by the preparing activity, any lower-level equipment, component or systems standards which may have been prepared, approved and published. Table 4 is Included in this draft proposal for use as a guide in preparing the standard.

7. Reference and Source Material

For the standard, the activity preparing it should review the references and source materials which are listed below for guidance, add or delete appropriate references and prepare a final reference list for publication:

7.1 General References

- Society of Naval Architects and Marine Engineers, "Technical and Research Bulletin No. 3-11, Heat Balance Practices" 1973?
- M. Rosenblatt & Son, Inc., "Propulsion Plant Standards Feasibility Study," April, 1975.

7.2 American National Standards and American Marine Standards

The activity should establish if any American National Standards or American Marine Standards exist which have direct jurisdiction over the subject matter; and if there are, should include them in the reference listing.

8. Index

Since the subject standard will be rather lengthy, and in order to facilitate its use, the published standard should include a comprehensive index based on the final write-up for easy cross-referencing. The index should be arranged in alphabetical order to agree with AMS Style Manual requirements.

5. General Notes

The present "Draft Proposal for "American Marine Standard Specifications for a Marine Steam Turbine Propulsion Plant" is intended to serve as a guide to the Activity which will be assigned the function of developing the actual standard. As such, it is preliminary and tentative. Subject matter of the text and the format of the proposal is arranged in general conformity with the "AMS Style Manual" requirements.

However, when writing the final draft, complete conformity with the requirements of the AMS and ANSI Style Manuals should be provided in the following areas:

(Numbers referenced are applicable "ANSI Style Manual" section and article numbers)

Spelling	5.2
Hyphenation	5.3
Capitalization	5.4
Abbreviations	5.6.1 and 5.7
Tables	6.2
Figures	6.3
Notes and footnotes	6.5
References	6.6
Revision Section	6.7
Units of Measure	7.2
Word Usage	7.5
Numbering System	5.1
Trademarks and Proprietary Info.	7.4
Permission for Copyrighted Info.	7.6

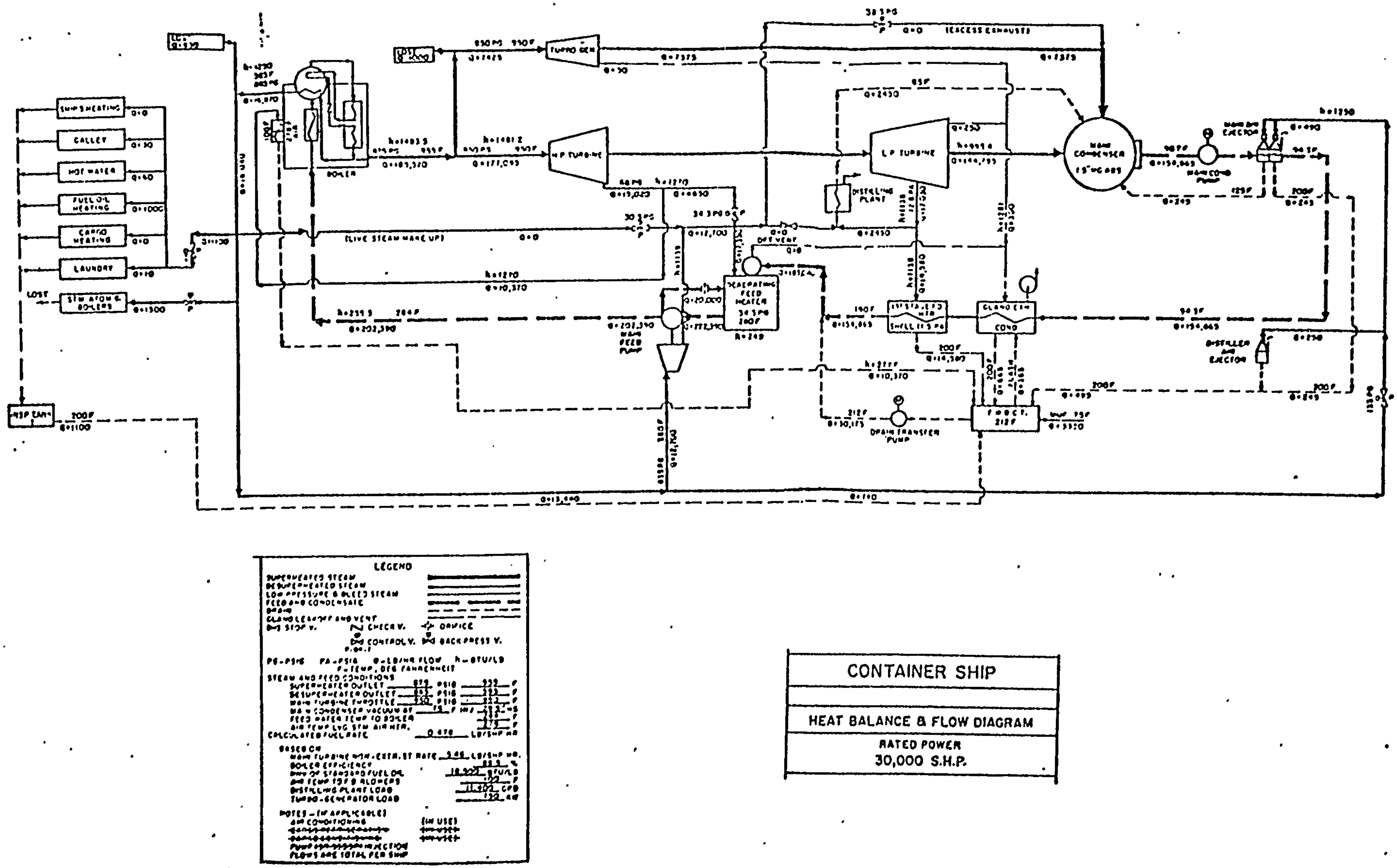


FIGURE 1 - HEAT BALANCE DIAGRAM

TABLE 1

MATERIAL SPECIFICATIONS

SYSTEM	IPS	PIPES	JOINTS	VALVES	FITTINGS	GASKETS
BUTTERWORTH SEAWATER SYSTEM	2" & ABOVE	WELDED STEEL GALV ASTM A-53 TYPE E GR B, SCHED 40	FORGED GALV. FLANGES ASTM A-181, GR1, SLIP ON WELDING -150 PSI, ANSI B16.5	CAST STEEL ASTM A-216 GR WCB. FLANGED ANSI B16.10 150 PSI, ST. STEEL TRIM	WROUGHT STL GALV. ASTM A-234, GRADE WPB BUTT WELD SCHED 40 ANSI B16.9 OR USE WELDED BRANCHES	COMPOSITION ASBESTOS SHEET-GARLOCK STYLE 7021
	1½" & BELOW		GALV STEEL UNIONS ASTM A-181 SCRD END. ST. STEEL SEATS 3000#	BRONZE-ASTM B-61 OR B-62 200# SCRD END OR BRAZED	FORGED STEEL GALV ASTM A-181, GR 2. SOCKET WELD ANSI B16.11 3000#	
BUTTERWORTH HOSE VALVES	2½"	—	—	BRONZE-300 PSI FLANGE X HOSE END 7½ THDS PER INCH. MONEL TRIM	—	
BOILER PRESS. DESUPERHEATED STEAM 100 PSI DESUPERHEATED STEAM-SEE NOTE BELOW:	2" & ABOVE	SEAMLESS STEEL PIPE ASTM A-106, GR B SCHED 80	FORGED STEEL FLANGES ASTM A-105, WELDING NECK 600 PSI, ANSI B16.5	CAST STEEL ASTM A-216 GR.WPB FLANGED ANSI B16.10 600 PSI, CHROME ALLOY (AISI.410 CB) TRIM	WROUGHT STL ASTM A-234 GR. WPB BUTT WELD SCHED 80. ANSI B16.9	SPIRAL WOUND METALLIC ASBESTOS GARLOCK STYLE 555 TYPE CR
	1½" & BELOW		FORGED STEEL FLANGES ASTM A-105. SOCKET WELD SCHED 80. ANSI B16.5	FORGED STEEL ASTM A-105 SOCKET WELD 600 PSI, SS OR STELLITE TRIM	FORGED STEEL ASTM A-105 SOCKET WELD 600 PSI, ANSI B16.11	

MAXIMUM VELOCITIES

WATER:					STEAM:				
SYMBOL	FLOW GPM	TEMP. °F	IPS	VELOCITY FT/MIN	SYMBOL	FLOW LB/HR	TEMP °F	IPS	VELOCITY FT/MIN
A	852	77	6"	568	J	50,000	540	5"	4,081
B	850	60	6"	566	K	50,000	440	8"	11,054
C	451	77	6"	301					
D	451	77	5"	434					
E	852	77	6"	568					
F	881	200	6"	587					
G	101	140	2"	577					
H	101	140	2½"	405					

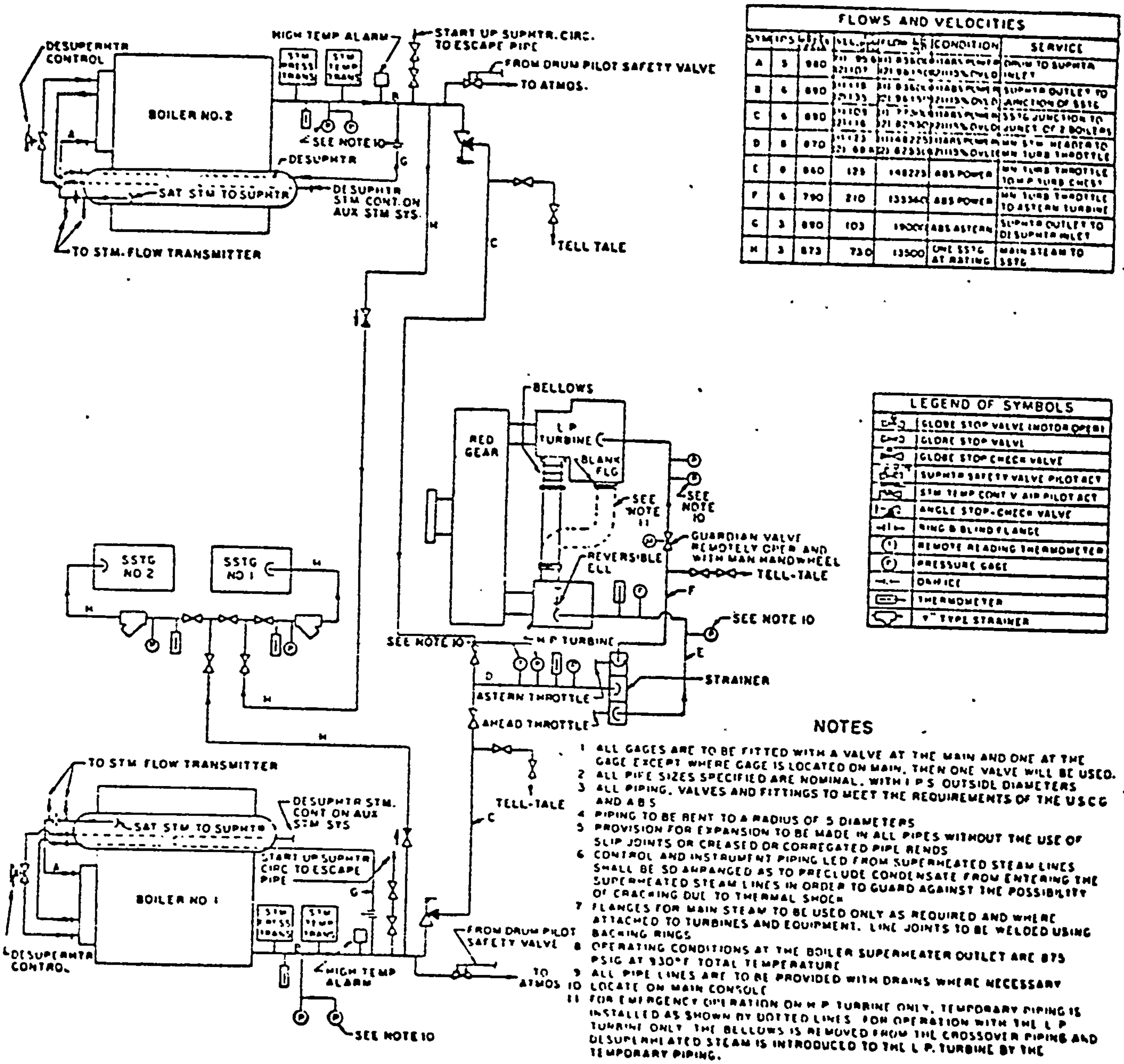
TABLE 2

PUMP TABLE

Nº OF UNITS	DESCRIPTION	TYPE	DRIVE	CAPACITY GPM	SUCTION LIFT	TOTAL HEAD FT
1	FIRE & BUTTERWORTH PUMP (EXISTING).	HORIZ CENTRIF	STEAM TURB.	450	FLOODED	456
1	BUTTERWORTH PUMP (NEW).	HORIZ CENTRIF	MOTOR	450 *	FLOODED	450 *
1	GENERAL SERVICE & FIRE PUMP (EXIST.) LOCATED IN SHAFT ALLEY.	HORIZ CENTRIF	MOTOR	350	FLOODED	255

* 400 GPM AT 470 FT HEAD

TABLE 3



FLOWS AND VELOCITIES						
SYM	IPS	[illegible]	VEL	FLOW LB/HR	CONDITION	SERVICE
A	3	880	[illegible]	[illegible]	[illegible]	DRUM TO SUPHTR INLET
B	6	890	[illegible]	[illegible]	[illegible]	SUPHTR OUTLET TO JUNCTION OF SSTG
C	6	890	[illegible]	[illegible]	[illegible]	SSTG JUNCTION TO JUNCT OF 2 BOILERS
D	8	870	[illegible]	[illegible]	[illegible]	MN STM HEADER TO MN TURB THROTTLE
E	8	860	175	148275	ABS POWER	MN TURB THROTTLE TO H P TURB CHEST
F	6	790	210	133340	ABS POWER	MN TURB THROTTLE TO ASTERN TURBINE
G	3	890	103	19000	ABS ASTERN	SUPHTR OUTLET TO DESUPHTR INLET
H	3	873	730	13500	ONE SSTG AT RATING	MAIN STEAM TO SSTG

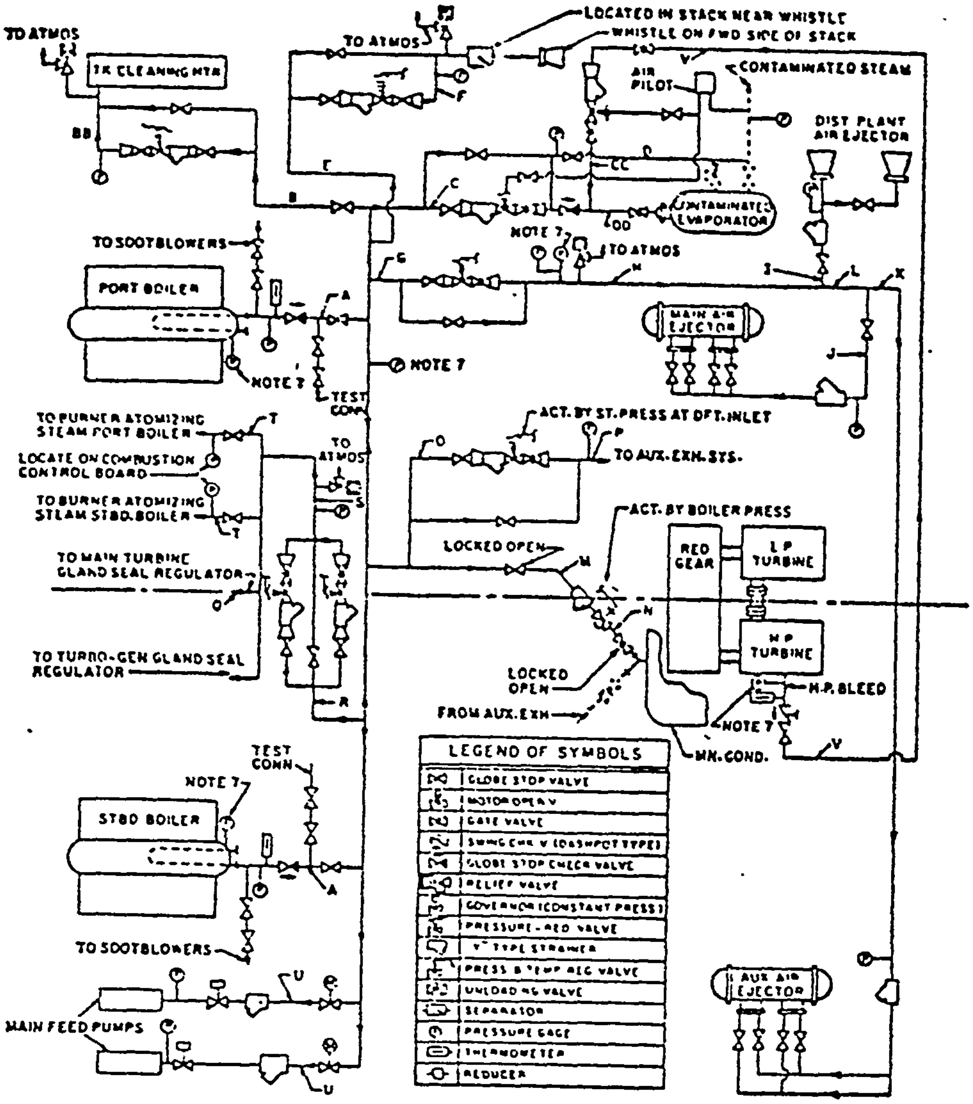
LEGEND OF SYMBOLS	
[symbol]	GLOBE STOP VALVE (MOTOR OPER)
[symbol]	GLOBE STOP VALVE
[symbol]	GLOBE STOP CHECK VALVE
[symbol]	SUPHTR SAFETY VALVE PILOT ACT
[symbol]	STM TEMP CONT V AIR PILOT ACT
[symbol]	ANGLE STOP-CHECK VALVE
[symbol]	RING & BLIND FLANGE
(T)	REMOTE READING THERMOMETER
(P)	PRESSURE GAGE
[symbol]	ORIFICE
[symbol]	THERMOMETER
[symbol]	"Y" TYPE STRAINER

NOTES

1 ALL GAGES ARE TO BE FITTED WITH A VALVE AT THE MAIN AND ONE AT THE GAGE EXCEPT WHERE GAGE IS LOCATED ON MAIN, THEN ONE VALVE WILL BE USED.
2 ALL PIPE SIZES SPECIFIED ARE NOMINAL, WITH I P S OUTSIDE DIAMETERS
3 ALL PIPING, VALVES AND FITTINGS TO MEET THE REQUIREMENTS OF THE USCG AND A B S
4 PIPING TO BE BENT TO A RADIUS OF 5 DIAMETERS
5 PROVISION FOR EXPANSION TO BE MADE IN ALL PIPES WITHOUT THE USE OF SLIP JOINTS OR CREASED OR CORREGATED PIPE BENDS
6 CONTROL AND INSTRUMENT PIPING LED FROM SUPERHEATED STEAM LINES SHALL BE SO ARRANGED AS TO PRECLUDE CONDENSATE FROM ENTERING THE SUPERHEATED STEAM LINES IN ORDER TO GUARD AGAINST THE POSSIBILITY OF CRACKING DUE TO THERMAL SHOCK
7 FLANGES FOR MAIN STEAM TO BE USED ONLY AS REQUIRED AND WHERE ATTACHED TO TURBINES AND EQUIPMENT. LINE JOINTS TO BE WELDED USING BACKING RINGS
8 OPERATING CONDITIONS AT THE BOILER SUPERHEATER OUTLET ARE 875 PSIG AT 930°F TOTAL TEMPERATURE
9 ALL PIPE LINES ARE TO BE PROVIDED WITH DRAINS WHERE NECESSARY
10 LOCATE ON MAIN CONSOLE
11 FOR EMERGENCY OPERATION ON H P TURBINE ONLY, TEMPORARY PIPING IS INSTALLED AS SHOWN BY DOTTED LINES. FOR OPERATION WITH THE L P TURBINE ONLY THE BELLOWS IS REMOVED FROM THE CROSSOVER PIPING AND DESUPERHEATED STEAM IS INTRODUCED TO THE L P. TURBINE BY THE TEMPORARY PIPING.

Diagram of main steam for a 24,000-shp ship

FIGURE 2



FLOWS AND VELOCITIES

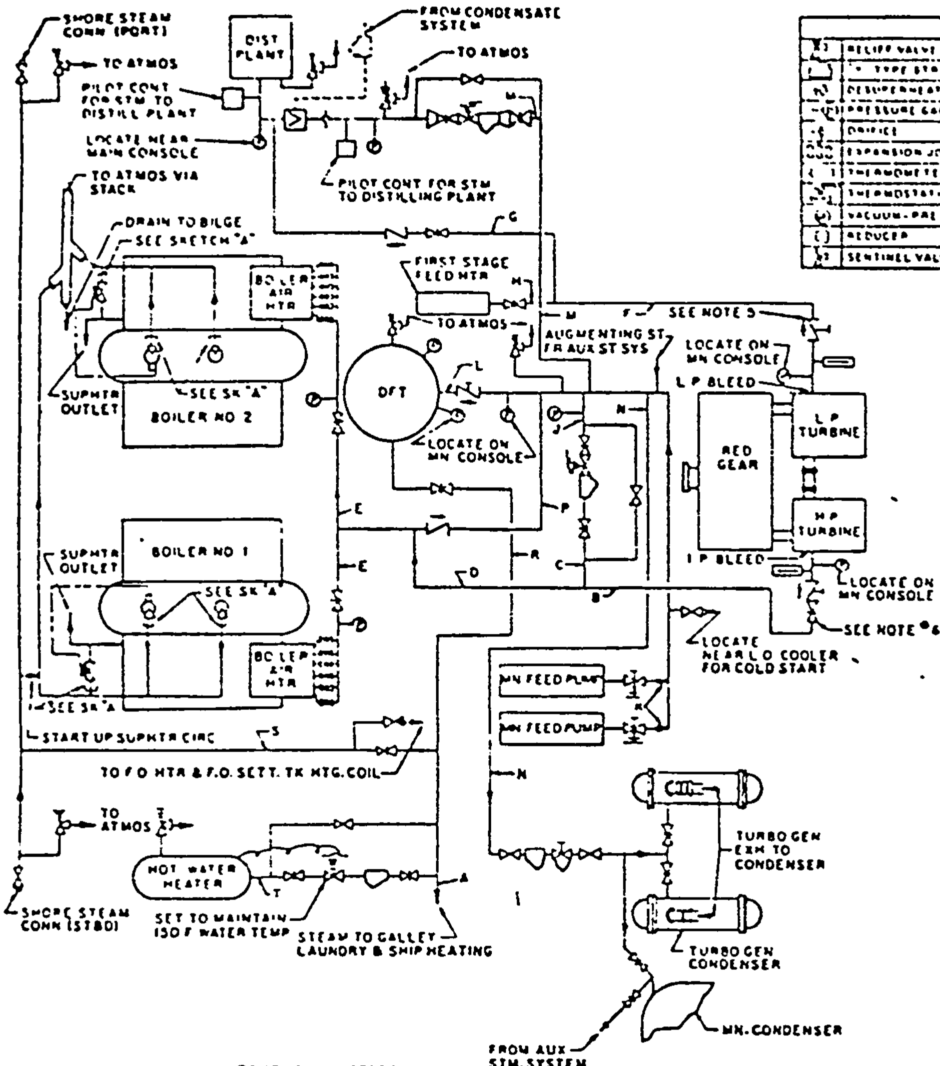
SYM	IPS	[illegible]	VEL FT/SEC	FLOW LB/HR	CONDITION	SERVICE
A	4	775	45.7	20000	MAXIMUM	DESUPERHEATER STM LOOP
B	2½	850	64.1	12000	RATED	850/150 RED STA
BB	5	150	81.8	12000	RATED	[illegible]
C	2½	850	55.4	10000	RATED	[illegible]
CC	4	185	42.0	4150	FULL POWER	[illegible]
D	4	150	91.3	6500	RATED	CONTAM EVAP BY PASS
DD	4	350	42.5	10000	RATED	FLOW TO CONTAM EVAP
E	1	850	47.2	1500	RATED	850/150 RED STA
F	2	140	57.0	1500	RATED	[illegible]
G	1½	850	16.2	1250	RATED	850/185 RED STA
H	2	185	47.0	1250	RATED	[illegible]
I	1¼	185	47.6	570	RATED	[illegible]
J	1¼	185	41.0	490	RATED	[illegible]
K	1	185	70.5	200	RATED	[illegible]
L	1½	185	42.4	690	RATED	[illegible]
M	2	850	202	20000	RATED	[illegible]
N	8	10	1302	21000	RATED	[illegible]
O	3	850	72.0	21000	ASTERN	850/35 RED STA
P	8	35	176	21000	ASTERN	[illegible]
Q	1¼	185	70.2	935	RATED	[illegible]
R	1½	850	17.6	1335	FULL POWER	[illegible]
S	2	185	50.5	1335	FULL POWER	[illegible]
T	1½	185	55.1	420	FULL POWER	[illegible]
U	2½	850	50.8	11010	RATED	[illegible]
V	2½	205	101	4150	RATED	HP TURBINE BLEED

NOTES

1. ALL PIPING, VALVES AND FITTINGS TO MEET REQUIREMENTS OF THE USCG AND ABS
2. PIPING ARRANGEMENTS SHALL BE DESIGNED WITH DUE REGARD FOR THERMAL EXPANSION AND ALLOWABLE LOADS ON PUMPS AND OTHER EQUIPMENT
3. FLANGES FOR AUXILIARY STEAM ARE TO BE USED ONLY WERE ATTACHED TO VALVES, FITTINGS OR EQUIPMENT. LINE JOINTS ARE TO BE WELDED USING BACKING RINGS
4. PIPING TO BE BENT TO A RADIUS OF 5 DIAMETERS.
5. ALL PIPE LINES ARE TO BE PROVIDED WITH DRAINS WERE NECESSARY
6. ALL STEAM PIPING TO THE CONTAMINATED EVAPORATOR AND H P BLEED STEAM PIPING DOWNSTREAM OF, AND INCLUDING, THE CHECK VALVE AT THE H P TURBINE ARE DESIGNED FOR FULL DESUPERHEATED STEAM PRESSURE OF 865 PSIG.
7. LOCATE ON MAIN CONSOLE.

Diagram of auxiliary and high-pressure bleed steam

FIGURE 3



	LEGEND OF SYMBOLS		
	RELIEF VALVE (SPRING LOADED)		GLOBE STOP VALVE
	"Y" TYPE STRAINER		GATE VALVE
	DESUPERHEATER		SWING CHECK VALVE
	PRESSURE GAGE		SWING CHECK VALVE (DASHPOT TYPE)
	ORIFICE		UNLOADING V AIR PILOT OPER
	EXPANSION JOINT		PRESSURE RED V AIR PILOT OPER
	THERMOMETER		SUPHTR SAFETY V PILOT ACT
	THERMOSTATIC CONTROL VALVE		GLOBE HOSE VALVE
	VACUUM-PRESSURE GAGE		COMB EXH RELIEF & BACK PRESS REG V
	REDUCER		BOILER SAFETY VALVE
	SENTINEL VALVE		

FLOWS AND VELOCITIES

SYM	[illegible]	[illegible]	VEL [illegible]	FLOW [illegible]	CONDITION	SERVICE
A	3	35	78.2	1700	[illegible]	[illegible]
B	6	67	203	22610	MAXIMUM	I P TURBINE BLEED
C	4	67	207	13070	MAXIMUM	I P BLEED TO EXH MN
D	3	67	124	9540	[illegible] POWER	2 BOILER AIR HEATERS
E	3½	67	123	4770	[illegible] POWER	1 BOILER AIR HEATER
F	12	[illegible]	180	18420	RATED	L P TURBINE BLEED
G	8	[illegible]	180	7220	RATED	[illegible]
H	10	[illegible]	[illegible]	12200	RATED	[illegible]
J	4	35	418	13070	MAXIMUM	I P BLEED TO EXH MN
K	6	35	130	11000	RATED	EXH - MN FD PUMP
L	8	35	136	14230	[illegible] POWER	EXH TO DFT
M	8	35	178	7220	RATED	EXH TO DISTL PLANT
N	4	35	105	4500	STAND BY	[illegible]
P	5	35	130	7297	ASTERN	[illegible]
R	3	35	92.2	2000	[illegible]	[illegible]
S	3	35	92.2	2000	[illegible]	[illegible]
T	1½	35	67.2	300	RATED	STM TO H W HEATER

● PSIG EXCEPT AS NOTED

NOTES

1. ALL PIPING VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF THE U S C G AND ABS
2. ALL PIPE SIZES SPECIFIED ARE NOMINAL WITH IPS OUTSIDE DIAMETER
3. PIPING ARRANGEMENTS SHALL BE DESIGNED WITH DUE REGARD FOR THERMAL EXPANSION AND ALLOWABLE LOADS ON PUMPS AND OTHER EQUIPMENT
4. PIPING IS TO BE BENT TO A RADIUS OF 5 DIAMETERS.
5. THE L P TURBINE BLEED STEAM SWING CHECK VALVE IS TO BE OPERABLE FROM THE FLAT AND SHALL BE FITTED WITH AN INDICATOR
6. THE GATE VALVE AT THE H P TURBINE I P BLEED SHALL BE ARRANGED TO PERMIT OPERATION FROM THE TURBINE OPERATING PLATFORM.

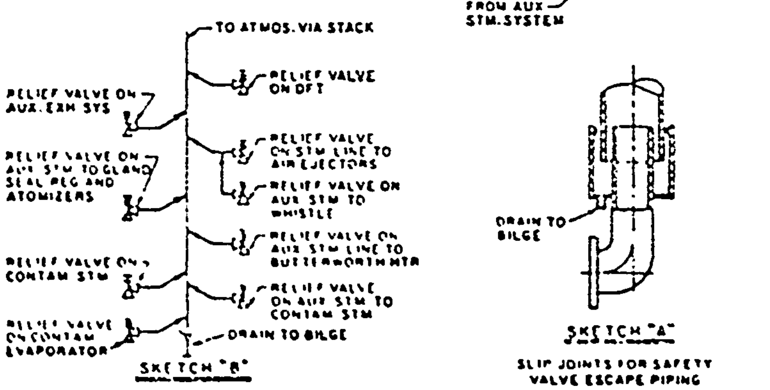
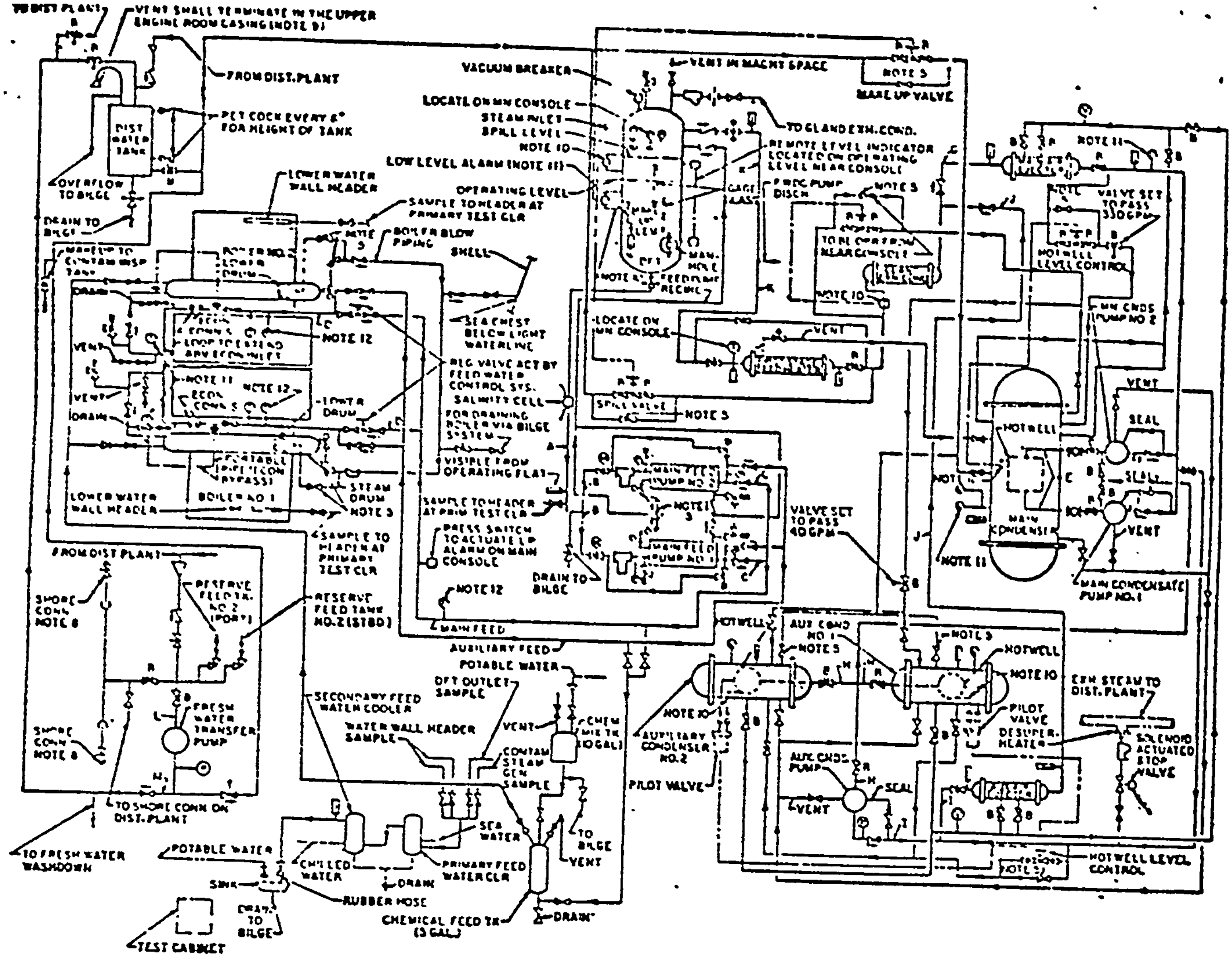


Diagram for auxiliary exhaust, intermediate- and low-pressure bleed steam, and escape piping

FIGURE 4



FLOWS AND VELOCITIES					
SYM	[illegible]	[illegible]	[illegible]	[illegible]	SERVICE
A	8		[illegible]	2.00	[illegible] SUCTION
B	6		450	4.99	MAIN FEED PUMP SUCTION
C	5		[illegible]	8.0	MAIN FEED PUMP DISCHARGE
D	4		225	4.50	FEED TO EACH BOILER
E	8		325	2.05	MAIN CONDENSATE PUMP SUCTION
F	4		3[illegible]	8.0	MAIN CONDENSATE PUMP DISCHARGE
G	5		355	5.0	MAIN CONDENSATE
H	2½		45	3.0	SSTG CONDENSATE PUMP SUCTION
I	2		45	4.29	SSTG CONDENSATE PUMP DISCHARGE
J	2		45	4.29	SSTG CONDENSATE
K	5		425	6.8	CONDENSATE TO DFT
L	5		25[illegible]	[illegible]	F W TRANSFER PUMP SUCTION
M	3		230	10.00	F W TRANSFER PUMP DISCHARGE

NOTES

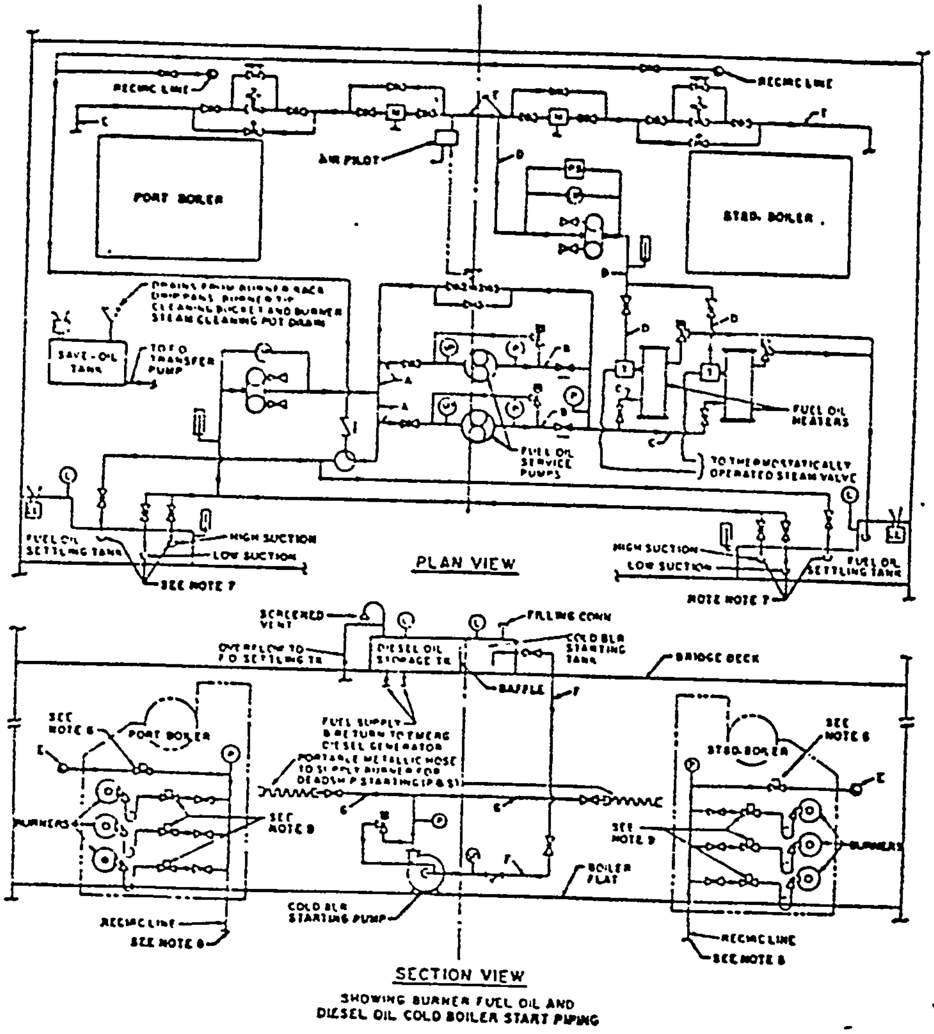
1. ALL PIPING VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF THE USCG AND ABS.
2. ALL PIPE SIZES SPECIFIED ARE NOMINAL WITH IPS OUTSIDE DIAMETER.
3. PIPING IS TO BE BENT TO A RADIUS OF 5 DIAMETERS.
4. ALL JOINTS SUBJECT TO CONDENSER VACUUM ARE TO BE GENERALLY FLANGED OR BRAZED. WHERE SCREWED JOINTS ARE USED, THESE JOINTS ARE TO BE TINNED OR HEAVILY DOPED.
5. VALVES REFERRING TO THIS NOTE SHALL BE LOCATED ON OR OPERATED FROM THE MACHINERY FLAT.
6. THE MOTOR OPERATED VALVE AT THE MAIN FEED PUMP SUCTION IS CONTROLLED FROM THE MAIN CONSOLE.
7. STOP VALVES SUBJECT TO VACUUM SHALL BE INSTALLED WITH THE VACUUM UNDER THE VALVE SEAT.
8. EACH DECK FILLING CONNECTION SHALL BE FITTED WITH HOSE CONNECTIONS AND PROVIDED WITH LOCK CAP AND CHAIN. EACH CONNECTION SHALL BE MARKED WITH AN ENGRAVED LABEL PLATE INDICATING THE SERVICE.
9. VENT PIPE TERMINALS SHALL BE FITTED WITH DOUBLE SCREENS WHICH SHALL BE REMOVABLE FOR CLEANING. THE INNER SCREEN SHALL HAVE 1/32" SQUARE OPENINGS. THE OUTER SCREEN SHALL BE FITTED 1/2" FROM THE INNER SCREEN AND SHALL BE OF STAINLESS STEEL WIRE WITH 1/4" SQUARE OPENINGS.
10. CONTROL VALVE SENSING LINES SHALL BE AS SHORT AS POSSIBLE.
11. LOCATE ON MAIN CONSOLE.
12. LOCATE GAGE TO BE READ AT COMBUSTION CONTROL CONSOLE.

LEGEND OF SYMBOLS
GATE VALVE
STOP VALVE
BUTTERFLY VALVE
DIAPHRAGM CONTROL VALVE
STOP CHECK VALVE
STOP VALVE (LOCKED CLOSED)
GATE VALVE (MOTOR OPER.)
HOSE VALVE
RELIEF VALVE
[illegible]
SALINITY CELL
THERMOSTAT
MULTIPLE ORIFICE
THERMOMETER
PRESSURE GAGE
VACUUM GAGE
VACUUM/PRESSURE GAGE
DIAL THERMOMETER-REMOTE
NEEDLE VALVE
LIFT CHECK VALVE
GATE VALVE (LOCKED CLOSED)
GATE VALVE (LOCKED OPEN)
ANGLE STOP VALVE
Y STRAINER
STOP VALVE (LOCKED OPEN)
STRAINER
BUTTERFLY VALVE (LO OPEN)
STOP CK VALVE (LOCKED SHUT)
ANGLE STOP VALVE (LO OPEN)
BUTTERFLY VALVE (LO SHUT)
SWING CHECK VALVE
ORIFICE
FUNNEL

PUMP TABLE				
QTY	SERVICE	TYPE	CAPACITY GPM	TOTAL HD PSI
2	MAIN CONDENSATE	VERT. CENT MOTOR DRIVEN	330	112.5
2	SSTG CONDENSATE	VERT. CENT MOTOR DRIVEN	45	112.5
2	MAIN FEED	HORIZ. CENT TURBINE DRIVEN	450	1100
1	F W TRANSFER	HORIZ. CENT MOTOR DRIVEN	230	100

Diagram—feed, condensate, boiler blow, and boiler water sampling

FIGURE 5



LEGEND OF SYMBOLS	
[illegible]	GATE VALVE
[illegible]	GLOBE STOP VALVE
[illegible]	ANGLE STOP VALVE
[illegible]	GLOBE STOP CHECK VALVE
[illegible]	SWING CHECK VALVE
[illegible]	HOSE GLOBE VALVE
[illegible]	[illegible] VALVE
[illegible]	SOLENOID VALVE
[illegible]	[illegible] PRESSURE VALVE
[illegible]	CONTROL VALVE
[illegible]	PRESSURE REGULATING VALVE
[illegible]	ANGLE RELIEF VALVE
[illegible]	PLUG COCK VALVE [illegible]
[illegible]	STRAINER "Y" TYPE
[illegible]	DUPLEX STRAINER
[illegible]	SCREENED FUNNELS
[illegible]	THERMOMETER
[illegible]	PRESSURE GAGE
[illegible]	VACUUM PRESSURE GAGE
[illegible]	DUPLEX PRESSURE GAGE
[illegible]	TANK LEVEL GAGE
[illegible]	HIGH LEVEL ALARM
[illegible]	LOW LEVEL ALARM
[illegible]	PRESSURE SWITCH
[illegible]	THERMOSTAT
[illegible]	[illegible]

FLOW DATA					
CODE	SIZE	CONDITION	FLOW G.P.M.	SERVICE	VELOCITY F.P.S.
A	4"	PUMP RATING	32	FUEL OIL SERVICE PUMP SUCTION	[illegible]
B	3"	PUMP RATING	32	FUEL OIL SERVICE PUMP DISCHARGE	[illegible]
C	3"	[illegible]	[illegible]	FUEL OIL HEATER INLET	[illegible]
D	2"	[illegible]	[illegible]	FUEL OIL HEATER OUTLET	[illegible]
E	1½"	[illegible]	[illegible]	FUEL OIL HEADER	[illegible]
F	¾"	PUMP RATING	8.0?	COLD BOILER START PUMP SUCTION	1.60?
G	¾"	PUMP RATING	8.0?	COLD BOILER START PUMP DISCHARGE	[illegible]

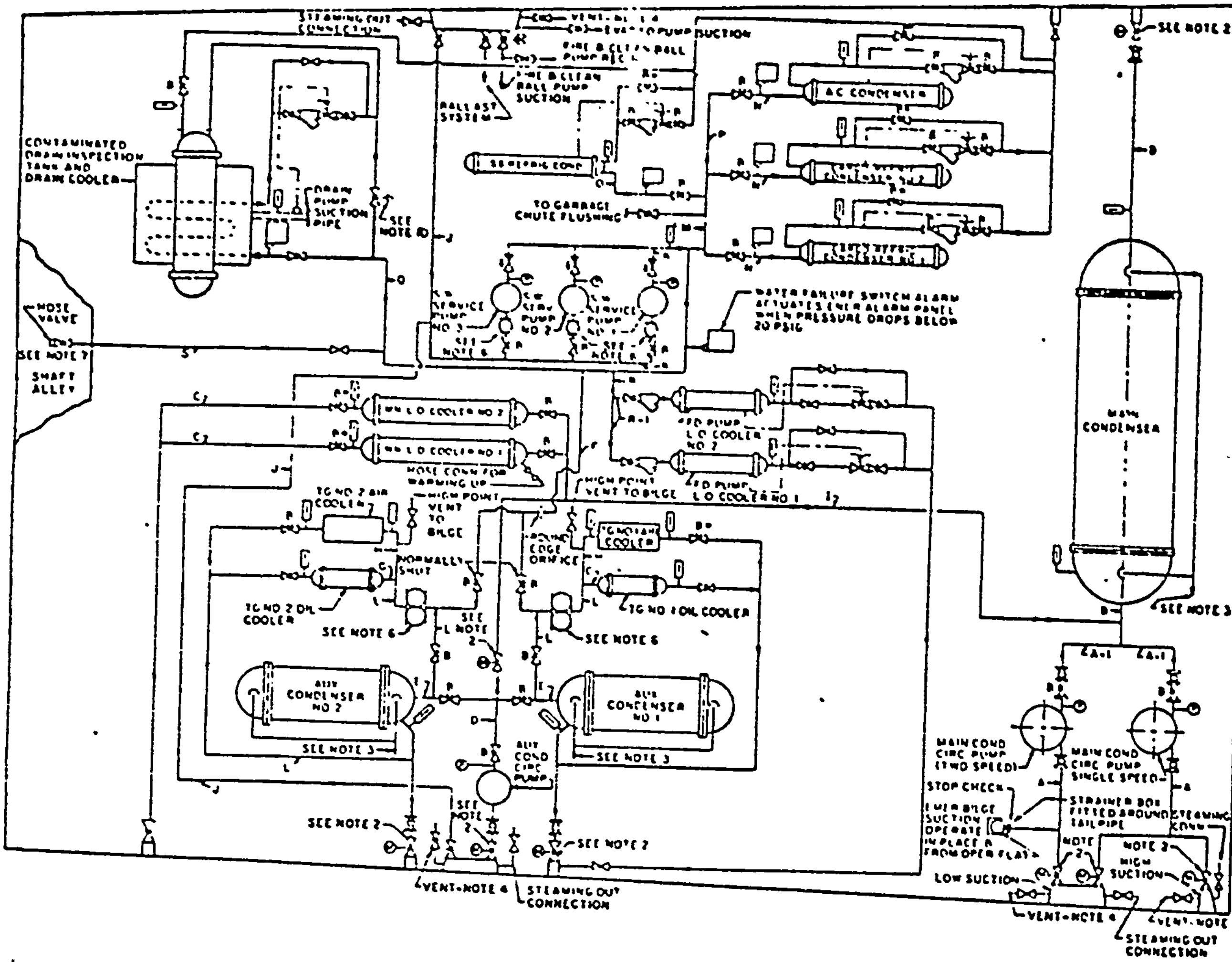
PUMP TABLE				
QTY	NAME	TYPE	CAP. G.P.M.	[illegible]
2	FUEL OIL SERVICE [illegible]	[illegible] MOTOR DRIVEN	[illegible]	[illegible]
1	COLD BOILER START	[illegible] MOTOR DRIVEN	[illegible]	[illegible]

NOTES

1. ALL PIPING, VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF THE U.S. COAST GUARD AND A.B.S.
2. ALL PIPE SIZES SPECIFIED ARE NOMINAL [illegible] OUTSIDE DIAMETERS.
3. [illegible], DRIP PANS, ETC. SHALL BE FITTED UNDER FUEL OIL SERVICE PUMPS, HEATERS, ETC. WHERE NECESSARY TO PREVENT OIL DRAINAGE TO BILGE.
4. ALL FUEL OIL PIPING TO BE INSTALLED AS REMOTELY AS POSSIBLE FROM HIGH TEMPERATURE STEAM LINES.
5. FUEL OIL SERVICE PUMPS SHALL BE CONTROLLED FROM THE AUXILIARY BOARD, ALSO THE PUMPS SHALL HAVE PROVISIONS OUTSIDE THE MACHINERY SPACE FOR EMERGENCY SHUT DOWN.
6. THE MAIN SOLENOID VALVE IS TO CLOSE IN EVENT OF LOSS OF POWER TO THE FORCED DRAFT BLOWER, LOW WATER OR TOTAL FLAME FAILURE WITHIN THE BOILER. A MANUAL TRIP SHALL BE PROVIDED ON THE VALVE.
7. HIGH SUCTION PIPE SHALL TERMINATE [illegible] ABOVE TANK BOTTOM. LOW SUCTION PIPES SHALL TERMINATE BELOW THE LEVEL OF THE BOTTOM OF THE TANK IN A DRAIN WELL.
8. FUEL OIL RECIRCULATING LINE IS TO ENTER NEAR TOP OF FUEL OIL SETTLING TANK AND TERMINATE NEAR THE BOTTOM OF TANK IN A 'U' BEND.
9. THE BURNER SOLENOID VALVE IS TO CLOSE IN EVENT OF BURNER FLAME FAILURE. A MANUAL TRIP SHALL BE PROVIDED ON THE VALVE.

Diagram of fuel-oil service system

FIGURE 6



FLOWS AND VELOCITIES					
SYM	SIZE IN	FLOW GAL/MIN	VELOCITY FT/SEC	OPERATING CONDITION	SERVICE
A	28	17720	9.22	MAXIMUM ? SPEED	MAIN S.W. CIRC PUMP SUCTION
A-1	26	17720	10.7	MAXIMUM PUMPED	MAIN S.W. CIRC PUMP [illegible]
B	36	33100	10.4	MAIN COND RATING	MAIN CONDENSER CIRC WATER OVERBOARD
C	6	885	6.87	[illegible] COOLER RATING	MAIN L.O. COOLERS S.W.
D	8	1650	9.75	PUMP RATING	AUX COND CIRC PUMP
E	10	1375	5.56	AUX COND	AUX CONDENSERS S.W.
F	3	62	2.98	[illegible]	T.G. L.O. & AIR COOLERS S.W.
G	2	33	2.51	[illegible] COOLER RATING	T.G. L.O. COOLERS S.W.
H	2½	30	2.02	[illegible] COOLER RATING	T.G. AIR COOLERS S.W.
I	12	2125	5.96	—	[illegible]
J	10	1370	5.6[illegible]	[illegible] SERVICE PUMP RATING	[illegible] S.W. SERVICE PUMP [illegible]
K	5	500	7.25	[illegible] RATING	S.W. SERVICE PUMP SUCTION AND DISCHARGE
L	3[illegible]	62	2.26	L.O. & AIR [illegible] RATING	T.G. L.O. & AIR COOLERS S.W.
M	6	1035	10.49	—	SUPPLY TO REFRIG EQUIP
N	[illegible]	300	[illegible]	[illegible] RATING	[illegible] REFRIG COND S.W.
O	2½	85	[illegible]	[illegible] RATING	[illegible] REFRIG CONDENSERS S.W.
P	3½	340	[illegible]	[illegible] RATING	AC CONDENSERS S.W.
Q	4	150	4.22	RATING	[illegible] INSPECTION TANK [illegible] DRAIN COOLER
R	1	10	[illegible]	[illegible]	FD PUMP L.O. COOLER
R-1	¾	5	[illegible]	[illegible] COOLER	FD PUMP L.O. COOLER
S	1	25	[illegible]	RATING	LINE SHAFT BEARING COOLING VIA HOSE

PUMP TABLE				
[illegible]	SERVICE	TYPE	[illegible]	TOTAL HEAD
2	MAIN CIRC	VERT CENT SINGLE STG	17000	46
1	MAIN CIRC	VERT CENT SINGLE STG	1650	32
3	S.W. SERVICE	VERT CENT SINGLE STG	300	86

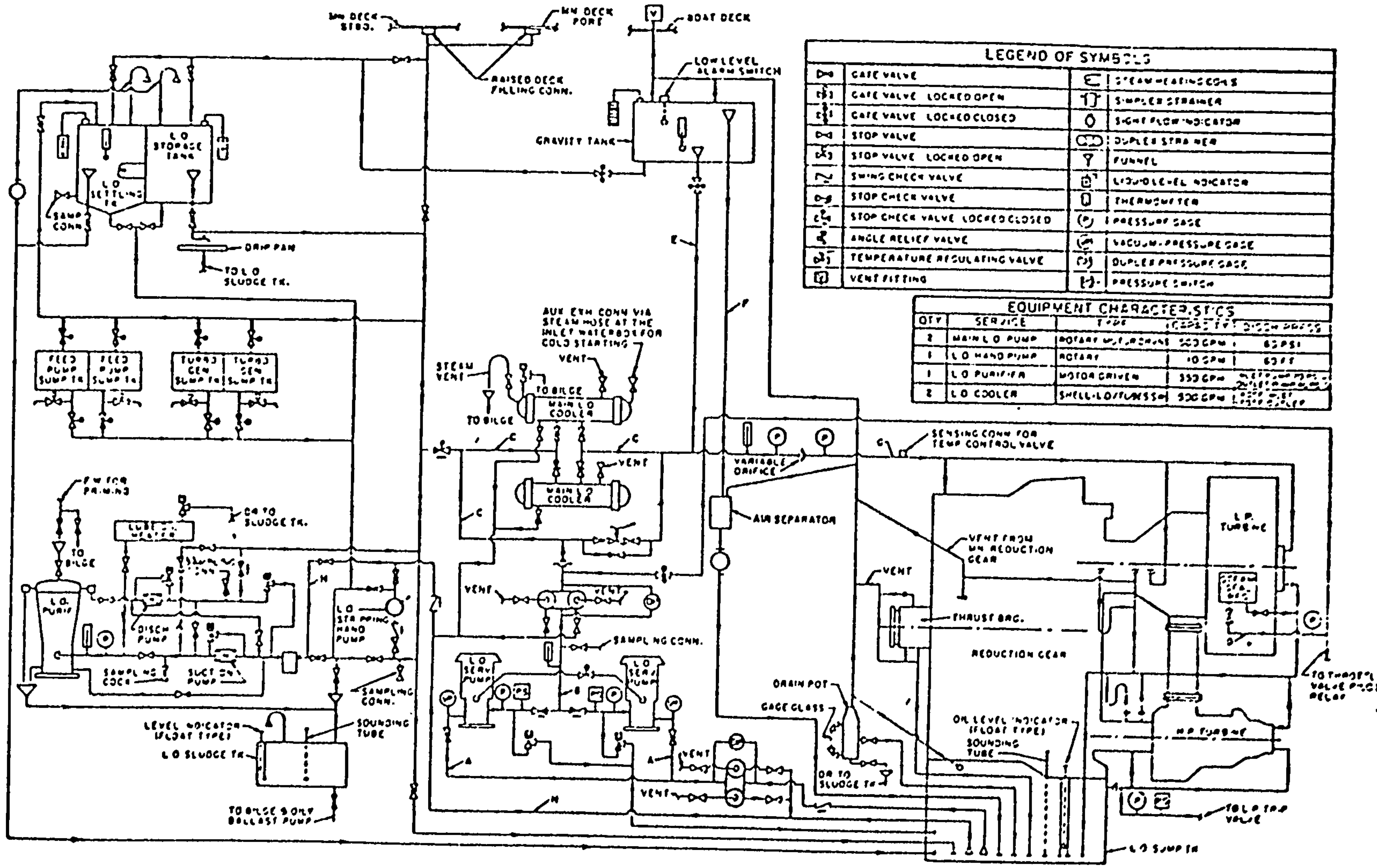
LEGEND OF SYMBOLS	
[illegible]	GATE VALVE
[illegible]	STOP VALVE
[illegible]	SWING CHECK VALVE
[illegible]	BUTTERFLY VALVE
[illegible]	TEMP REGULATING VALVE
[illegible]	STOP CHECK VALVE
[illegible]	RUBBER EXPANSION JOINT
[illegible]	PRESSURE GAGE
[illegible]	THERMOMETER
[illegible]	[illegible]
[illegible]	STRAINER [illegible]
[illegible]	STRAINER DUPLEX
[illegible]	SEA CHEST SUCTION
[illegible]	SEA CHEST DISCHARGE
[illegible]	GATE VALVE MOTOR OPERATED [illegible]
[illegible]	STRAINER SIMPLEX
[illegible]	NEEDLE VALVE
[illegible]	ANGLE RELIEF VALVE

NOTES

1. ALL PIPING, VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF THE USCG AND ABS
2. ALL MOTOR OPERATED VALVES ARE TO HAVE CONTROLS ADJACENT TO UNIT AND ALSO AT THE ENGINE ROOM OPERATING CONSOLE
3. CONDENSER HEAD VENTS SHALL SLOPE UP TO THE SEA CHEST VENT
4. THE SEA CHEST VENT SHALL TERMINATE ON THE WEATHER DECK
5. SWING CHECK VALVES SHALL BE INSTALLED IN THE FORE AND AFT DIRECTION
6. STRAINERS ARE TO HAVE PERFORATIONS SMALLER THAN SEA WATER PASSAGES IN EQUIPMENT BEING SERVED UNLESS THAT EQUIPMENT IS SERVED BY ADDITIONAL STRAINERS
7. ONE HOSE VALVE LOCATED MIDWAY IN SHAFT ALLEY, FOR EMERGENCY COOLING OF LINE SHAFT BEARINGS, SHALL BE PROVIDED WITH A HOSE OF SUFFICIENT LENGTH TO REACH THE MOST REMOTE BEARING.
8. PIPING IS TO BE BENT TO A RADIUS OF 3 DIAMETERS
9. ALL SEA CHEST CONNECTIONS SHALL BE INSTALLED ON THE SIDE OF THE SEA CHEST EXCEPT VENTS WHICH ARE MOUNTED ON THE TOP OF THE CHEST
10. NEEDLE VALVE MUST BE OPENED WHEN THE GENERAL SERVICE PUMP IS IN OPERATION AND REGULATED SUCH THAT THE TEMPERATURE OF THE CONTAMINATED DRAIN PUMP SUCTION DOES NOT EXCEED 180°F.

Diagram of seawater systems in machinery space

FIGURE -7



LEGEND OF SYMBOLS			
	GATE VALVE		STEAM HEATING COILS
	GATE VALVE LOCKED OPEN		SIMPLEX STRAINER
	GATE VALVE LOCKED CLOSED		SIGHT FLOW INDICATOR
	STOP VALVE		DUPLEX STRAINER
	STOP VALVE LOCKED OPEN		FUNNEL
	SWING CHECK VALVE		LIQUID LEVEL INDICATOR
	STOP CHECK VALVE		THERMOMETER
	STOP CHECK VALVE LOCKED CLOSED		PRESSURE GAGE
	ANGLE RELIEF VALVE		VACUUM-PRESSURE GAGE
	TEMPERATURE REGULATING VALVE		DUPLEX PRESSURE GAGE
	VENT FITTING		PRESSURE SWITCH

EQUIPMENT CHARACTERISTICS

QTY	SERVICE	TYPE	CAPACITY	DISCH PRESS
2	MAIN L O PUMP	ROTARY MOTOR DRIVEN	500 GPM	65 PSI
1	L O HAND PUMP	ROTARY	10 GPM	65 PSI
1	L O PURIFIER	MOTOR DRIVEN	550 GPH	[illegible]
2	L O COOLER	SHELL-L O/TUBES SW	500 GPM	[illegible]

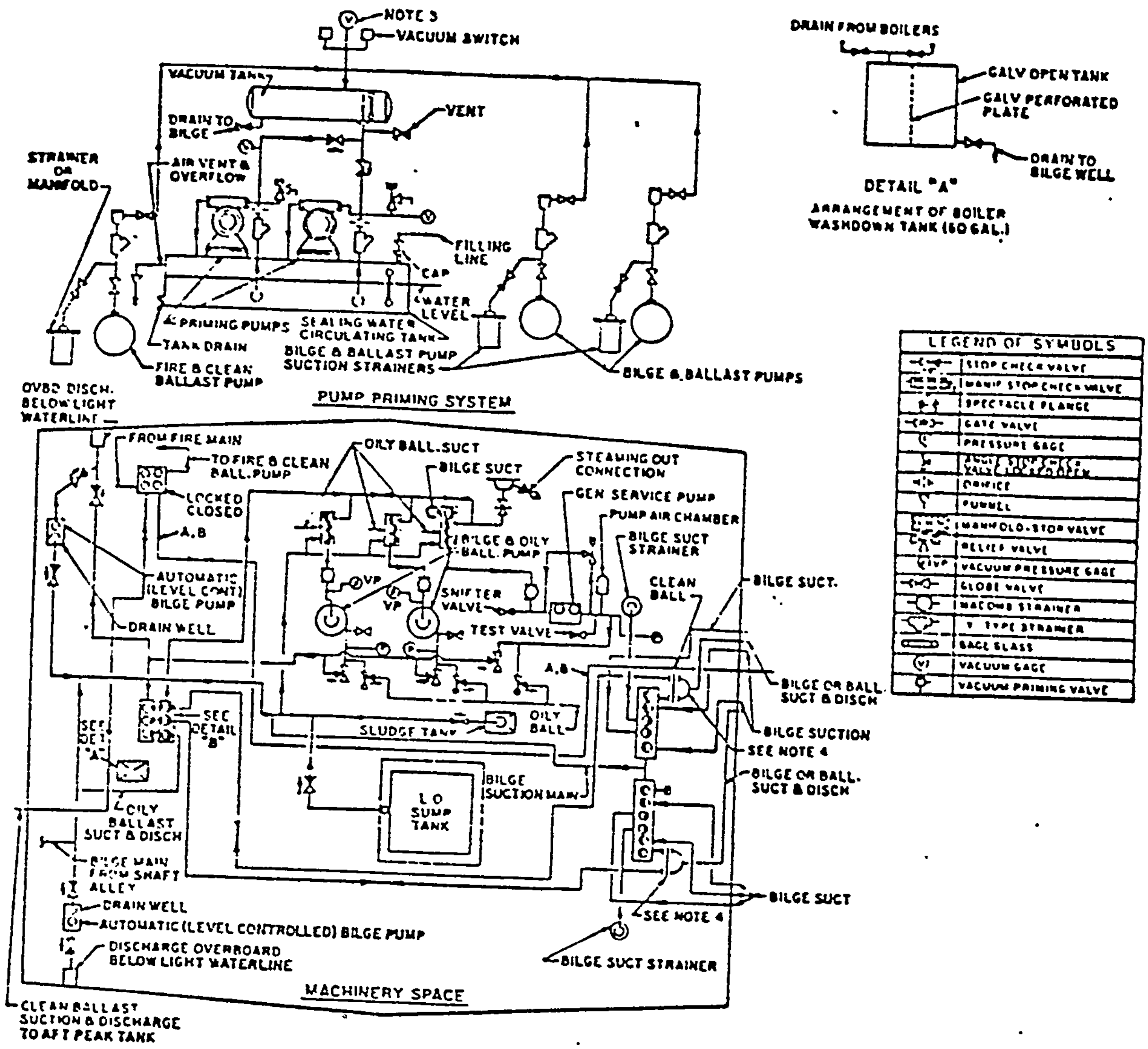
FLOW DATA				
CODE	SIZE	FLOW GPM	SERVICE	VELOCITY FPS
A	8"	500	L O SERVICE PUMP SUCTION	3 20
B	6"	500	L O SERVICE PUMP DISCHARGE	5 54
C	6"	500	L O HDR TO & FROM COOLER	5 54
D	3/4"	2 5	CONT OIL TO STEAM SEAL REG	1 90
E	6"	340 1	L O FROM GRAVITY TK TO BRGS	3 86
F	6"	151 9	GRAVITY TK OVERFLOW TO SUMP	1 68
G	6"	340 1	MN HDR TO BEARINGS	3 86
H	2"	13 40	[illegible] WITH TRANSFER PUMP	1 27

NOTES

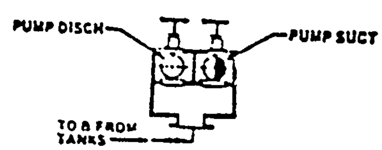
1. ALL PIPING, VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF THE U S COAST GUARD AND ABS
2. ALL PIPE SIZES SPECIFIED ARE NOMINAL WITH IPS OUTSIDE DIAMETERS
3. ALL DRAINS TO SUMP SHALL TERMINATE BELOW WORKING LEVEL AND AS REMOTE FROM PUMP SUCTIONS AS PRACTICABLE
4. KEEP ALL OIL PIPING AT SAFE DISTANCE FROM HOT SURFACES AND IN NO CASE CLOSER THAN 18" WHERE THE TEMPERATURE EXCEEDS 650°F IN ORDER TO MINIMIZE FIRE HAZARDS
5. THE MAIN TURBINE SUPPLY PIPING SHALL BE FITTED WITH A VARIABLE ORIFICE TO OBTAIN 10-15 PSIG PRESSURE AT THE REDUCTION GEAR HEADER INLET
6. SPECIAL CARE MUST BE TAKEN IN DESIGN AND INSTALLATION SO THAT THE ENTIRE LUBE OIL SYSTEM WILL BE ACCESSIBLE FOR THOROUGH CLEANING
7. ALL BEARING DRAINS MUST HAVE AN EASY FLOW PATH WITHOUT POCKETS, HORIZONTAL RUNS, OR SHARP BENDS.

Diagram of lubricating-oil system

FIGURE 8



FLOWS AND VELOCITIES						
SYM	OPERATING CONDITION	SIZE IPS	FLOW GPM	VEL. FT/SEC	PRESS DROP PSI	REMARKS
A	BALLASTING FORE PEAK TANK	6	700	7.76	10.	FIRE BILGE AND CLEAN BALLAST PUMP AT RATED CAPACITY
B	DEBALLASTING FORE PEAK TANK	6	700	7.76	10.	FIRE BILGE AND CLEAN BALLAST AT MAX PUMP SUCTION AVAILABLE



DETAIL "B"

TYPICAL SECTION THROUGH BALLAST MANIFOLD

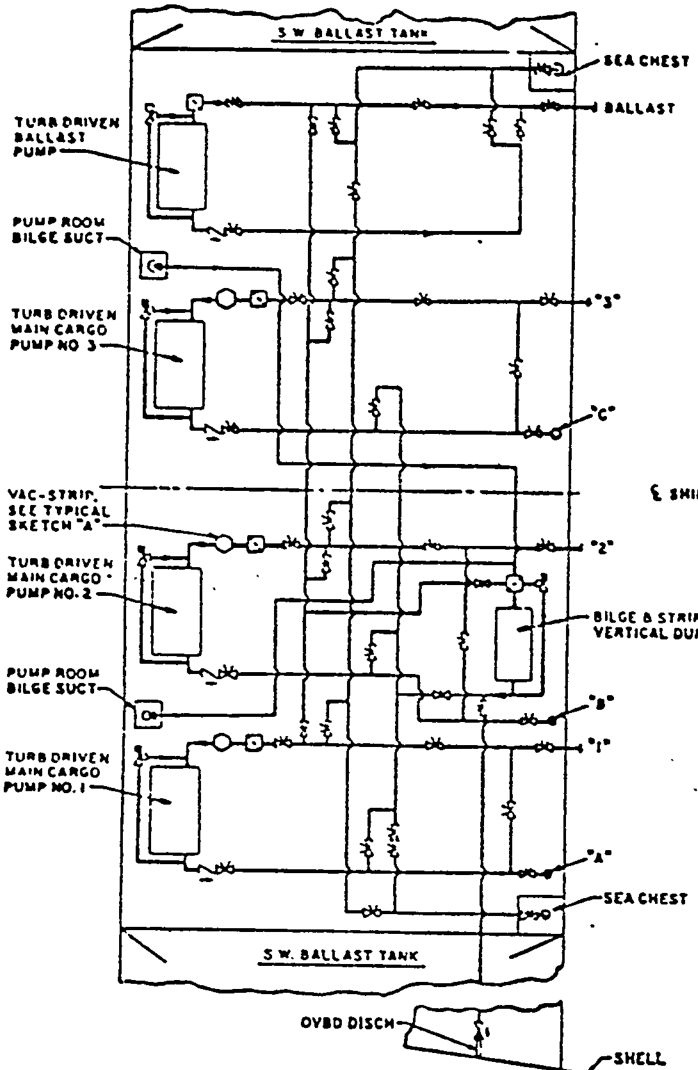
PUMP TABLE				
NAME	NO.	TYPE	CAPACITY	TOTAL HEAD
BILGE & BALL	2	VERTICAL CENTRIF	700 GPM	60 PSIG
GEN SERV CE	1	[illegible]	700 GPM	125 PSIG
BILGE PUMP	2	VERTICAL CENTRIF	30 GPM	30 PSIG
PRIMING PUMP	2	HORIZ ROTARY	30 CFM	15 HG VAC

NOTES

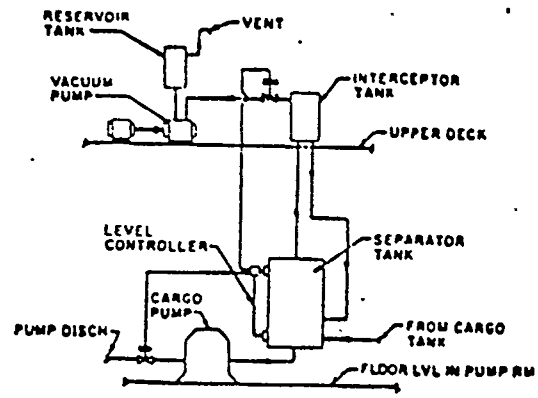
1. ALL PIPING, VALVES AND FITTINGS ARE TO MEET THE REQUIREMENTS OF USCG AND ABS
2. ALL PIPE SIZES SPECIFIED ARE NOMINAL, WITH IPS OUTSIDE DIAMETERS.
3. VACUUM SWITCH STARTS ONE PUMP WHEN THE VACUUM DROPS TO 15" HG, STARTS A SECOND PUMP WHEN IT REACHES 12" HG, AND STOPS THE PUMPS WHEN THE VACUUM REACHES 20" HG. THE SWITCH CONTAINS A MANUAL OPERATING FEATURE
4. SPECTACLE FLANGE TO BE POSITIONED TO ALLOW ONLY THE BILGE SUCTION TO BE USED WHEN CARRYING DRY CARGO IN THE DEEP TANKS FORWARD.

Diagram of bilge, clean ballast, and priming system in machinery space

FIGURE 9



PLAN VIEW - PUMP ROOM



SKETCH "A"

TYPICAL DIAGRAMMATIC ARR OF STRIPPING SYSTEM FOR CARGO OIL PUMPS

PUMP TABLE				
QTY	SERVICE	TYPE	RATED CAP GPM	TOTAL HEAD PSI
3	CARGO	[illegible]	40000	220
1	BALLAST	[illegible]	40000	60
1	BILGE	[illegible] DUPLEX	1940	200

LIST OF SYMBOLS	
	GATE VALVE
	STOP CHECK VALVE
	BUTTERFLY VALVE (HYD OPERATED)
	SWING CHECK VALVE
	ANGLE RELIEF VALVE
	REGULATING VALVE
	BELLMOUTH
	STRAINER
O	VACUUM STRIPPER

Diagram of cargo-oil piping in pump room

FIGURE 10

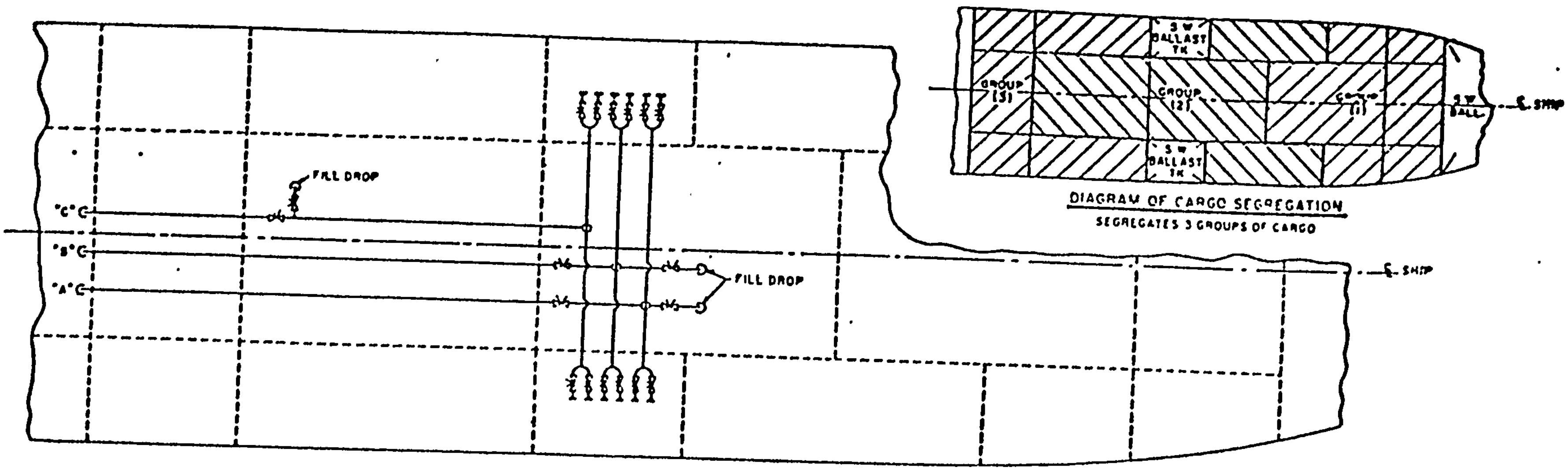


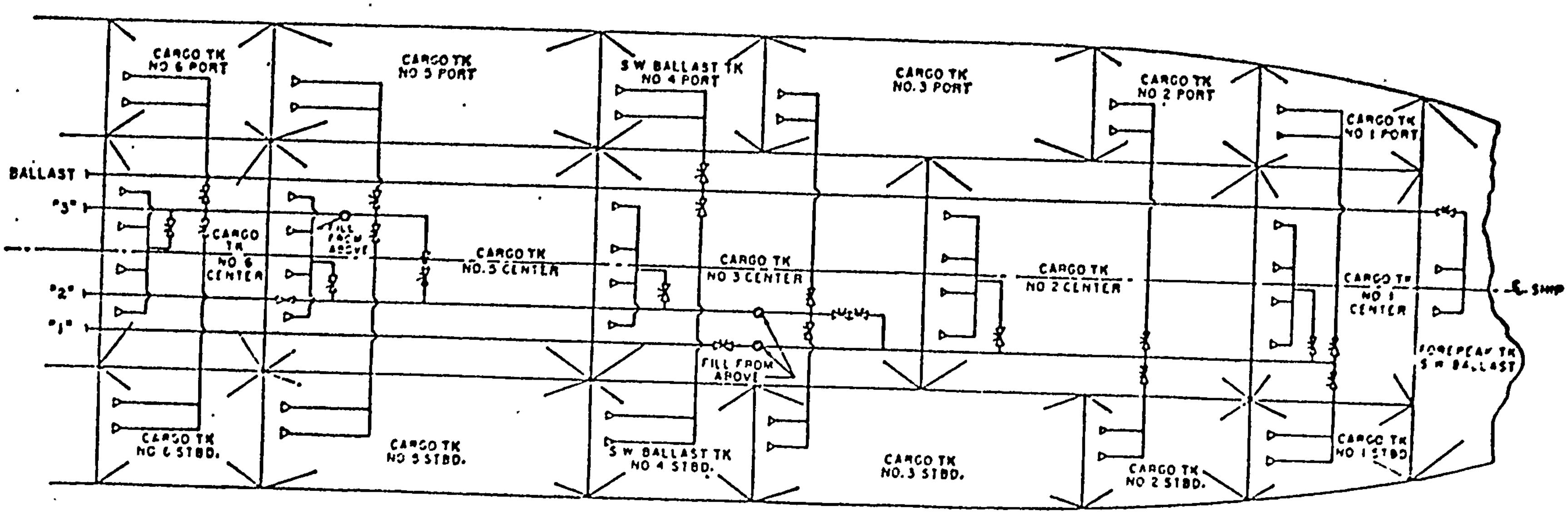
DIAGRAM OF CARGO SEGREGATION

SEGREGATES 3 GROUPS OF CARGO

PLAN VIEW - UPPER DECK

FWD

Fig. 19 Diagram of cargo-oil piping on deck

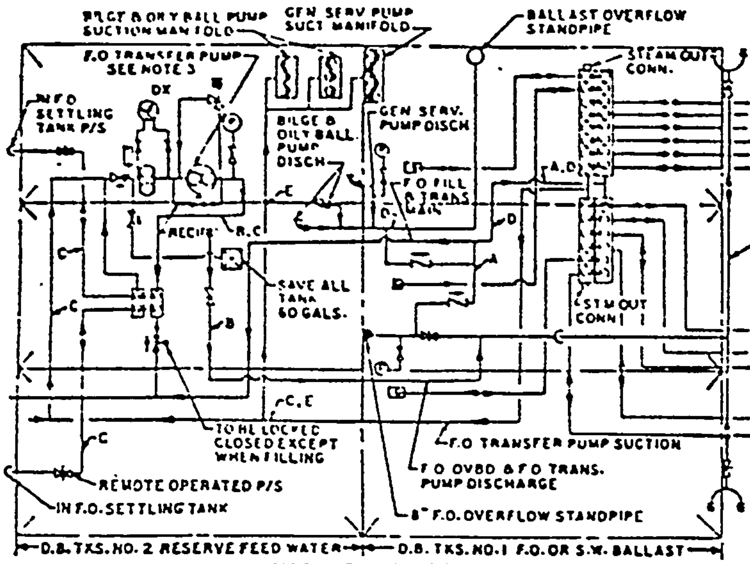


PLAN VIEW TANKS

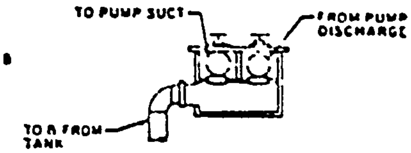
FWD

Diagram of cargo-oil piping in tanks

FIGURE 11

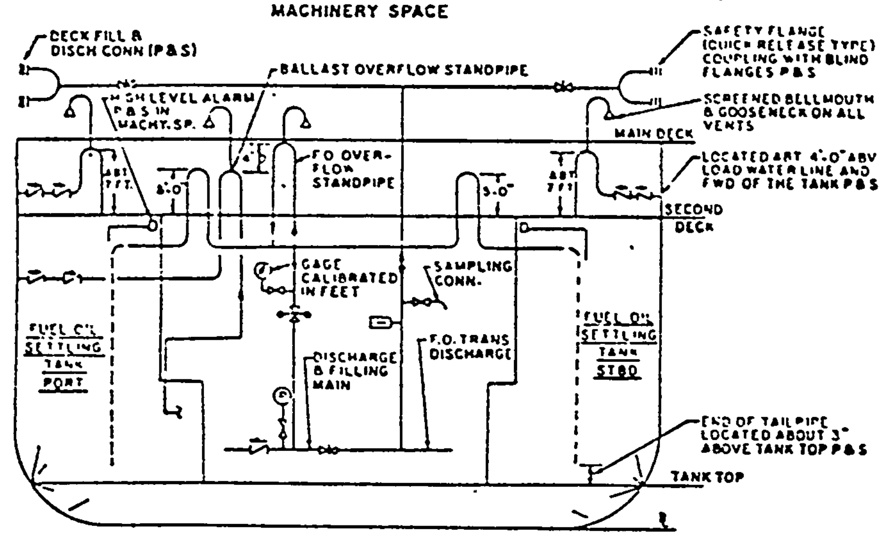


MACHINERY SPACE



SKETCH "A"

TYPICAL SECTION THROUGH FUEL OIL TRANSFER AND BALLAST MANIFOLD.



SECTION - OVERFLOW PIPING IN MACHINERY SPACE

LEGEND OF SYMBOLS
SWING CHECK VALVE
GATE VALVE
MANIFOLD STOP VALVE
MANIFOLD STOP CHK VALVE
ANGLE STOP CHECK VALVE
PRESSURE GAGE
RELIEF VALVE
ANGLE VALVE
THERMOMETER
DUPLEX STRAINER
GATE VALVE LOCKED OPEN
GATE VALVE REMOTE OPER
DUPLEX GAGE
BELLMOUTH
GLOBE STOP VALVE
GA STOP VALVE REMOTE OPER
STOP CHECK VALVE
STOP CHECK VALVE LOCKED CLOSED
INTERLOCKED VALVE MANIFOLD

FLOW DATA (1)						
SYMBOL	SERVICE	SIZE	VELOCITY FT/SEC	FLOW	PRESS DROP	REMARKS
A	F.O. FILL	[illegible]	[illegible]	2200 BBLS/HR (2)	30 PSI	TO NO 1 D B Tk
B	F.O. DISCH	[illegible]	[illegible]	300 GPM	30 PSI	TO F.L. CONN [illegible]
C	F.O. TRANS	[illegible]	[illegible]	300 GPM	30 PSI	FROM NO 1 D B Tk
D	BALLASTING	[illegible]	[illegible]	[illegible] GPM	25 PSI	TO NO 1 DEEP Tk
E	DEBALLASTING	[illegible]	[illegible]	700 GPM	30 PSI	FROM NO 1 D B Tk.

NOTES

1. FLOW DATA BASED ON FUEL OIL VISCOSITY 3000 SSU.
2. TOTAL FLOW OF 2200 BBLS/HR TO ALL TANKS INCLUDES FLOW OF 360 BBLS/HR TO NO 1 DOUBLE BOTTOM TANK
3. THE FUEL OIL TRANSFER PUMP IS A VERTICAL TWO-SPEED PUMP WHICH DEVELOPS A TOTAL HEAD OF 100 PSI AT 300 GPM

Diagram of fuel-oil filling, transfer, oily ballast, and overflows in machinery space

FIGURE 12

TABLE 4

Equipment/Component	Standard No.	Standard Group	Remarks
Main Steam Boiler			
Main Turbine (Set)			
Main Condenser			
Reduction Gear (Set)			
Main Lube Oil Pump			
Forced Draft Fan			
Main Feed Pump			
Fuel Oil Service Pump			
Main Circulating Pump			
Main Condensate Pump			
Fuel Oil Heater			
Lube Oil Cooler			
First-Stage Feed Heater			
Gland Exhauster			
Drain Cooler			
De-aerating Feed Heater			
3rd Stage Heater			
4th Stage Heater			
Automation System			

FORMAT FOR

GROUP IV DATA STANDARD

CENTRIFUGAL PUMP
FOR SALT WATER SERVICE

SAMPLE

CONTENTS

1. SCOPE

This standard contains the technical information necessary to define and describe a centrifugal pump suitable for salt water circulating service. The information has been certified as correct by the vendor on ________(date).

2. DESCRIPTION

The vertical centrifugal pumps described in this standard are type LRV, single stage, double suction, axially split, volute. The ratings range in capacities from 150-5,000 GPM and heads from 13-300 feet. The LRV can provide service for main condenser circulating, auxiliary condenser circulating, bilge, fire, ballast and general service, refrigeration condenser and brine circulating.

2.1 TYPE A typical LRV pump is shown in Figure 1.

2.2 MANUFACTURER The manufacturer is Worthington Sales Company, 270 Sheffield Street, Mountain Side, New Jersey 07092, Telephone (201) 654-3300.

2.3 TECHNICAL CONTACT The technical contact is Mr. Kenneth C. Hill, Engineer, Marine & Government Department.

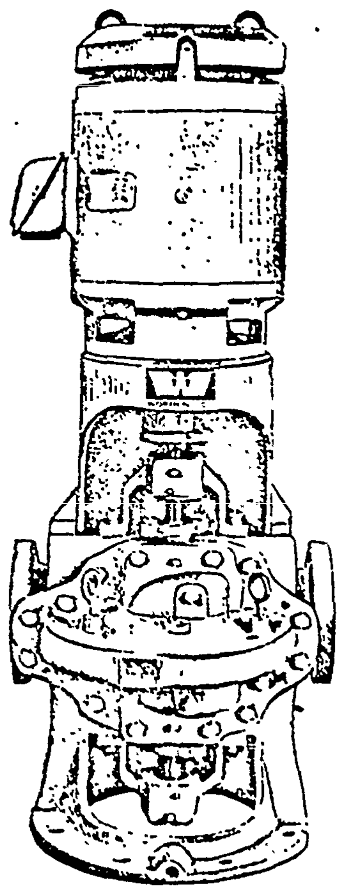
2.4 SPECIFICATIONS The specifications are listed below.

2.4.1 Casing The casing is of the volute type and is designed to produce a smooth flow with gradual velocity changes. It is designed for vertical mounting with heavy-duty flanges for base and motor mounting brackets. It is split on the shaft centerline for ease of inspection or removal of interior parts. This may be done without disturbing piping connection or pump alignment. The casing halves are sealed by a pre-cut gasket. Casing halves are accurately located by the use of straight dowel pins. This eliminates the possibility of a mismatch between halves which would impair both hydraulic and mechanical performance.

2.4.2 Impeller The impeller is a double-suction enclosed type. It is hydraulically balanced by its inherent design. The impeller is firmly secured to the shaft by a key and by external shaft nuts.

2.4.3 Renewable Case Rings The renewable case rings are locked in place and protected against rotation by two (2) monel pins. Securely held impeller rings can be supplied as an option.

FIGURE 1
LRV VERTICAL CENTRIFUGAL PUMP



2.4.4 Stuffing Box BushinG A renewable stuffing box bushing is provided which ensures freedom from packing trouble.

2.4.5 Shaft Sleeve Renewable shaft sleeves are provided which extend through the stuffing box. They are securely keyed and held in place with shaft nuts Incorporating nylon inserts for locking purposes.

2.4.6 Shaft The-shaft is of heat-treated steel, ground to accurate dimensions and polished to a smooth surface. The shaft sleeves protect the shaft at the stuffing boxes. The sleeves are secured in lateral position by external shaft nuts. The impeller keys are extended into the hub of the shaft sleeve to prevent slippage between the shaft and the sleeves. Sealing to protect against leakage under the shaft sleeve is accomplished by the use of "O" ring type seals, located between the sleeve and the shaft. It is adequately sized and designed to minimize deflection. The maximum runout of the shaft, at the stuffing box face, will not exceed .002".

2.4.7 Bearings The bearings are single row, deep-groove type ball bearings. They are designed and sized for at least 100,000 hours minimum rated bearing life. Each bearing is capable of carrying both line and thrust type loads. They are securely held to the shaft by an easily installed snap ring. Special flinger, shaft sealing O-ring and labyrinth all protect lower bearing from water seepage.

2.4.8 Bearing Brackets The bearing brackets are separate from the pump casing and are accurately machined and doweled to the casing. Perfect alignment between the housing and casing results in accurato alignment between rotor and casing. Removal of dowels permits rumoval of complete rotor *assembly* without disturbing piping, base, or motor.

2.4.9 Packing-Mechanical Seals As a standard, stuffing boxes will be packed with the best quality graphited asbestos packing. Die-moulded packing is supplied, as a standard, ensuring both a perfect seal and an easy installation. Mechanical seals are available, if desired, and are easily interchangeable with packing.

2.4.10 Cotplings A standard type flexible coupling *to* meet the specifications will be furnished by the pump manufacturer.

2.5 DIMENSIONS The dimensions shown in Figure 2 and Tables 1 and 2 pertain to the LRV pump.

2.6 MATERIALS OF CONSTRUCTION Materials for an LRV pump are shown in Table 3.

2.7 OPERATING DATA Typical operating data for the LRV.pump series is shown in Tables 4 and 5 with operating limitations as shown below.

2.7.1 Suction Ratings Flooded suction is required for proper operation of the LRV pump series. The required NPSH can be obtained from the rating *curve* shown in Table 5. The maximum suction pressure for the LRV pump series is 150 psi.

2.7.2 Temperature Ratings Temperature ratings for standard mechanical seals is 212°F. Temperature ratings for standard packed stuffing box is 250°F. Note: Seals and packing are available for higher temperatures.

3. APPLICABLE STANDARDS

All applicable standards will be suitably referenced.

4. APPROVALS

Approvals as required by the standards will be obtained from the proper regulatory bodies (ABS. USCG, U.S. Public Health, etc.).

FIGURE 2
LRV PUMP DIMENSIONS

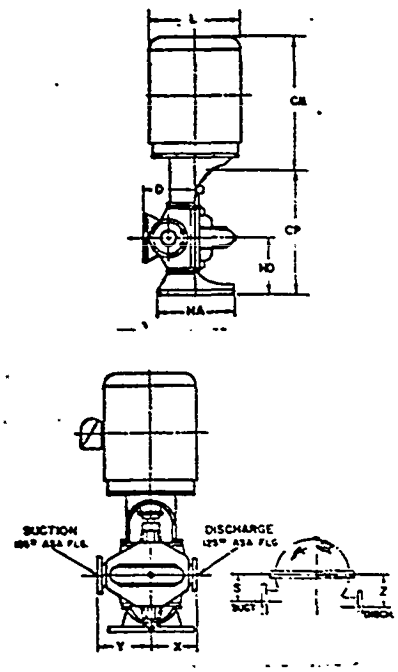


TABLE 1
MOTOR DATA

MOTOR FRAME	CH	L	WT
213 TP	20-3/4	10-7/8	165
215 TP	20-3/4	10-7/8	180
254 TP	24-1/2	13	205
256 TP	24-3/4	13	270
284 TP	25-5/8	13	330
286 TP	25-5/8	13	355
324 TP	27-1/8	14-1/4	400
326 TP	27-1/8	14-1/4	450
364 TP	29-1/8	16-1/4	520
365 TP	29-1/8	16-1/4	530
404 TP	38-7/8	18-1/2	890
405 TP	38-7/8	18-1/2	990
444 TP	44-1/4	20-1/2	1180
445 TP	44-3/4	20-1/2	1330

NOTES
1. All dimensions are in inches.

TABLE 2
LRV PUMP DIMENSIONS

PUMP	SUCT.	DISCH.	D	X	Y	CP	HA	HD	S	Z	WT
3 LRV-9	4	3	10-1/2	7-1/2	9	27-5/8	18	13	5-1/4	5-3/4	395
3 LRV-12	5	3	11-1/2	8-3/8	10-1/2	27-5/8	18	13	5-3/4	7-1/4	455
4 LRV-10	5	4	11-1/2	9	11	27-5/8	18	13	5-3/4	6-1/4	455
4 LRV-11	6	4	13	10	12-1/2	30-7/8	18	13-7/8	6-3/8	6-1/2	495
4 LRV-12	6	4	13	9	11	27-7/8	18	13-1/8	6-3/8	7-3/4	585
4 LRV-14	6	4	13	12	12-1/2	30-7/8	18	13-7/8	6-3/8	7-5/8	570
5 LRV-10	6	5	13	9-1/2	13	27-7/8	18	13-1/8	6-1/2	7	545
5 LRV-13	6	5	13	10-1/2	13	30-7/8	18	13-7/8	6-1/2	7-1/4	610
5 LRV-15	6	5	13	13	13-1/2	34-1/2	20	15-1/4	6-1/2	7-1/4	780
6 LRV-10	8	6	15-1/2	10	14	29	18	13-3/4	7-3/4	7-1/2	600
6 LRV-13	8	6	15-1/2	11	14	34-1/2	20	15-1/4	7-1/2	9	790
6 LRV-16	8	6	15-1/2	14	15	34-1/2	20	15-1/4	7-5/8	8-1/2	900
8 LRV-13	10	8	18	11-1/2	17	35-1/4	20	16	8-7/8	10	1065
10 LRV-15	12	10	21	141	18	39	25	18-1/4	10-1/2	10-1/2	1510

NOTES
1. All dimensions are in inches.

TABLE 3
MATERIALS OF CONSTRUCTION
LRV 3" - 10"

PART	Standard Fitted Pump	All Iron Pump	All Bronze Pump
	MATERIALS	MATERIALS	MATERIALS
Casing	Cast Iron	Cast Iron	Bronze
Bearing Bracket	Cast Iron	Cast Iron	Cast Iron
Bearing Cover	Cast Iron	Cast Iron	Cast Iron
Impeller	Bronze	Cast Iron	Bronze
Casing Ring	Bronze	Cast Iron	Bronze
Shaft Sleeve	Bronze	Steel	Bronze
Shaft	Steel	Steel	Steel
Shaft Nut	Bronze	Steel	Bronze
Stuffing Box Bushing	Bronze	Steel	Bronze
Gland	Cast Iron	Cast Iron	Bronze
Seal Cage	Teflon	Teflon	Teflon
Pump Base	Cast Iron	Cast Iron	Cast Iron
Motor Base	Fab. Steel	Fab. Steel	Fab. Steel

NOTES
1. Single stage, double suction, vertically mounted sizes 3" to 10".

5. ADDITIONAL DESIGN INFORMATION

5.1 PUMP SELECTION TABLE is illustrated in Table 4.

5.2 RATING CURVE A typical rating curve is shown in Table 5 of a pump with 3500 RPM.

5.3 VENDOR PLANS Are available from the manufacturer (see section 2.2).

TABLE 4
SELECTION TABLES
LRV PUMPS 3500 RPM
HEAD (IN FEET)

GPM	75	100	125	150	175	200	250	300	350	400
50	—	—	—	—	—	—	—	—	—	—
100	—	—	—	—	—	—	—	—	—	—
150	—	—	—	—	—	—	—	—	—	2½ LR 10 40 HP
200	—	—	—	3 LR 9 20 HP	3 LR 9 20 HP	2½ LR 10 20 HP	2½ LR 10 20 HP	—	2½ LR 10 30 HP	2½ LR 10 40 HP
250	—	4 LR 10 20 HP	4 LR 10 25 HP	3 LR 9 20 HP	2½ LR 10 20 HP	2½ LR 10 20 HP	2½ LR 10 25 HP	2½ LR 10 30 HP	2½ LR 10 40 HP	2½ LR 10 40 HP
300	—	4 LR 10 20 HP	4 LR 10 25 HP	4 LR 10 25 HP	2½ LR 10 20 HP	2½ LR 10 20 HP	2½ LR 10 30 HP	2½ LR 10 30 HP	2½ LR 10 40 HP	2½ LR 10 50 HP
350	—	4 LR 10 20 HP	4 LR 10 20 HP	2½ LR 10 20 HP	2½ LR 10 20 HP	2½ LR 10 25 HP	2½ LR 10 30 HP	2½ LR 10 40 HP	2½ LR 10 40 HP	2½ LR 10 50 HP
400	—	4 LR 10 20 HP	4 LR 10 25 HP	3 LR 9 25 HP	3 LR 9 25 HP	3 LR 9 30 HP	3 LR 9 40 HP	2½ LR 10 40 HP	2½ LR 10 50 HP	4 LR 11 75 HP
500	—	4 LR 10 20 HP	4 LR 10 30 HP	3 LR 9 30 HP	3 LR 9 30 HP	3 LR 9 40 HP	3 LR 9 40 HP	3 LR 9 50 HP	4 LR 11 75 HP	4 LR 11 75 HP
600	4 LR 10 20 HP	4 LR 10 25 HP	4 LR 10 25 HP	4 LR 10 40 HP	3 LR 9 40 HP	3 LR 9 40 HP	3 LR 9 50 HP	3 LR 9 60 HP	4 LR 11 75 HP	4 LR 11 100 HP
700	4 LR 10 25 HP	4 LR 10 25 HP	4 LR 10 30 HP	4 LR 10 40 HP	4 LR 10 50 HP	4 LR 11 50 HP	3 LR 9 60 HP	4 LR 11 75 HP	4 LR 11 100 Hp	4 LR 11 100 HP
800	4 LR 10 25 HP	4 LR 10 30 HP	4 LR 10 30 HP	4 LR 10 40 HP	4 LR 10 50 HP	4 LR 11 50 HP	3 LR 9 60 HP	4 LR 11 75 HP	4 LR 11 100 HP	4 LR 11 100 HP
900	4 LR 10 25 HP	4 LR 10 30 HP	4 LR 10 40 HP	4 LR 10 50 HP	4 LR 10 50 HP	4 LR 11 60 HP	4 LR 11 75 HP	4 LR 11 100 HP	4 LR 11 100 HP	4 LR 11 125 HP
1000	4 LR 10 25 HP	4 LR 10 40 HP	4 LR 10 40 HP	4 LR 10 50 HP	4 LR 10 50 HP	4 LR 11 75 HP	4 LR 11 100 HP	4 LR 11 100 HP	4 LR 11 125 HP	4 LR 11 125 HP
1200	—	4 LR 10 40 HP	4 LR 10 50 HP	4 LR 10 50 HP	4 LR 10 75 HP	4 LR 11 100 HP	4 LR 11 100 HP	4 LR 11 125 HP	4 LR 11 150 HP	—
1400	—	—	4 LR 10 60 HP	4 LR 10 100 HP	4 LR 11 100 HP	4 LR 11 100 HP	4 LR 11 125 HP	4 LR 11 150 HP	—	—

TABLE 5
RATING CURVE 3500 RPM