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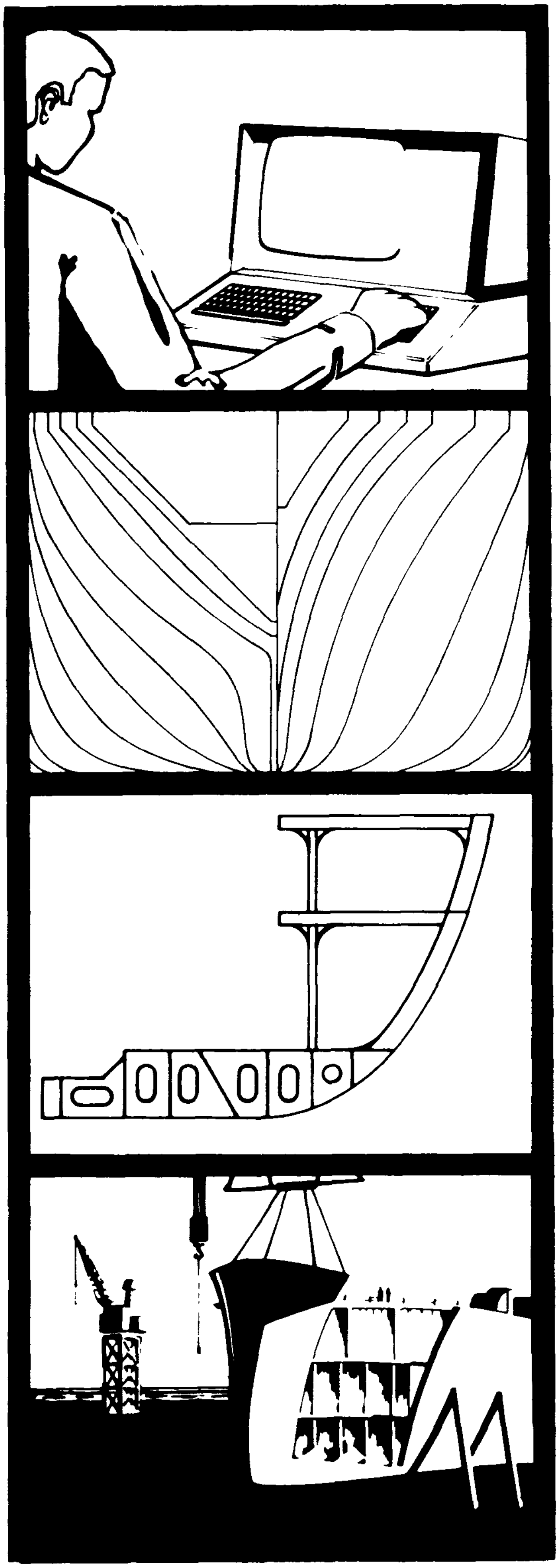

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AND
P RODUCTIVITY
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S HIPBUILDING

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Philadelphia, Pennsylvania

JAPANESE TECHNOLOGY THAT COULD IMPROVE U.S. SHIPBUILDING PRODUCTIVITY

James R. Vander Schaaf
Senior Naval Architect
IIT Research Institute
Chicago, Illinois

Mr. Vander Schaaf is responsible for the specification, development, training, and implementation of certain REAPS CAD/CAM products. He has IO years of experience in the development and application of various computer aided ship design and construction applications in use in government and industry.

Mr. Vander Schaaf holds degrees in aerospace engineering, naval architecture and marine engineering from the University of Michigan, and a degree in computer science from Johns Hopkins University.

ABSTRACT

This presentation highlights various aspects of Japanese Shipbuilding practices with emphasis on those of Ishikawajima-Harima Heavy Industries (IHI). Topics discussed include zone planning and outfitting, design and material definition and shipbuilding standards and modules.

FOREWORD

This presentation on Japanese shipbuilding methods and practices is based on a report[1] (the text of which follows) resulting from a visit to six Japanese shipyards by a team of six individuals with broad shipbuilding experience. The intent of this visit was to identify and examine low-investment high-return Japanese shipbuilding technology. The objective of the report was to encourage U.S. shipbuilders to adopt the observed advanced techniques for the purpose of improving productivity.

Information used in this presentation was also extracted from other sources, notably "Outfit Planning" [2] and "Improved Shipyard Production with Standard Components and Modules" [2].

[1] "Japanese Technology that could Improve U.S. Shipbuilding Productivity", J. R. Vander Schaaf, IIT Research Institute; P. E. Jaquith, Bath Iron Works; L. D. Chirillo, Todd Pacific Shipyards Corp; C. S. Jonson, Science Applications; J. J. McQuaid, National Steel & Shipbuilding; E. L Peterson, Peterson Builders Inc; National Shipbuilding Rerearch Program Publication, Maritime Administration, U.S. Department of Commerce, June 1980.

[2] References for these publications are contained at the end of this report.

1.0 INTRODUCTION

In January 1979 a study entitled, *Technology Survey of Major U.S. Shipyards* [l] [2] was completed and documented for the Maritime Administration (MarAd) by Marine Equipment Leasing (MEL), Inc. In the course of this survey the level of technology used by a cross section of U.S. shipyards was compared to the level of technology used by selected foreign shipyards. Japanese shipyards were included as a measure because of their preeminence in world shipbuilding. In conducting the study a major objective was to assist individual U.S. shipyards in the process of identifying those areas where the difference between U.S. technology and foreign technology is the greatest. A conclusion was that U.S. shipbuilding technology compared well in areas relating to modernized facilities and equipment, but was low in areas which are primarily management and methods oriented. In particular, nine of these critical areas[3] would require minor capital investment to raise the technology level significantly.

2.0 PROJECT OBJECTIVES

There are examples of successful transfer of Japanese technology to the U.S. shipbuilding industry such as for welding, automated pipe fabrication and other areas also requiring large capital investments. While this type of technology transfer is unquestionably valuable it was not the focus of this project.

Rather, the objective of this project was to identify and examine *low investment, high* return shipbuilding technology (e.g., methods, procedures, management and organizational techniques), placing emphasis on the critical areas cited in the MEL report. This examination was made by a team of individuals having broad shipbuilding experience in order to:

1. Identify specific techniques or methods,
2. Prioritize their values, and
3. Outline a plan for making them available to U.S. shipbuilders in the most efficacious manner.

3.0 PROJECT TEAM

The U.S. team formulated for this project consisted of the following six individuals:

Louis D. Chirillo
Todd Pacific Shipyards Corp.

Peter E. Jaquith
Bath Iron Works Corp.

Charles S. Jonson
Science.Applications, Inc.

John J. McQuaid
National Steel & Shipbuilding Co. (Retired)

Ellsworth L. Peterson
Peterson Builders, Inc.

James R. Vander Schaaf
IIT Research Institute (Project Director)

Summary resumes of these individuals are included in Appendix B.

4.0 JAPANESE YARDS VISITED

The shipyards were selected based upon IITRI contacts with the leading shipbuilding companies in Japan and their expressed interest to participate in this project. The following were visited during the period from October 29 through November 16, 1979 :

1. Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI)
   - Kure Shipyard
   - Aioi Shipyard
   - Tokyo Shipyard
2. Mitsui Engineering&Shipbuilding Co., Ltd.
   - Tokyo Head Office
   - Chiba Shipyard
   - Tamano Shipyard
3. Nippon Kokan Kabushiki Kaisha (NKK)
   - Shimizu Shipyard

With the exception of the Mitsui Chiba shipyard, all were old yards that had been modernized. All had under construction one to four ships of nonstandard design. Thus a good comparison could be made with U.S. practice.

It is also pertinent to note that in 1978, the Japanese Government requested that all shipbuilders reduce their facilities by 35 percent as a consequence of the worldwide oversupply of oil tankers. As a result, all of the companies visited have reduced their employment and/or have closed some of their new large shipyards. IHI closed its new Chita shipyard and NKK closed its most modern yard at Tsu.

[2] Numbers in brackets designate references at the end of this report.

[3] Extracted from the MEL report and presented as Appendix A of this report.

5.0 KEY OBSERVATIONS

Notwithstanding the reduction in shipbuilding capacity, shipbuilding production was high by U.S. standards. As an example, the Mitsui Tamano shipyard produced 9 ships (190,960 gross tons) and repaired 79 ships in 1978 with a total shipyard workforce of 3370 plus 2500 individuals from subcontractor organizations. In all yards, direct labor man-hour costs and construction schedules were approximately one-half when compared to U.S. practice.

5.1 Scheduling

- A typical milestone schedule for the construction of a new design nonstandard cargo, bulk, container or RO/RO Ship is as follows:

Contract award to start fab	- 6 Months
Start fab to keel	- 2 Months
Keel to launch	- 3 Months
Launch to delivery	- 3 Months
	14 Months

Further detail for this schedule is provided in Figure 5-1. A more detailed milestone schedule for a Mitsui bulk carrier is shown in reference 3, page 2-4.

- A typical IHI schedule for a 5200 ton destroyer is shown in Figure 5-2.
- In order to achieve the very short shipbuilding periods illustrated in these figures, Japanese shipbuilders have found it necessary to overlap[4] design, material procure-

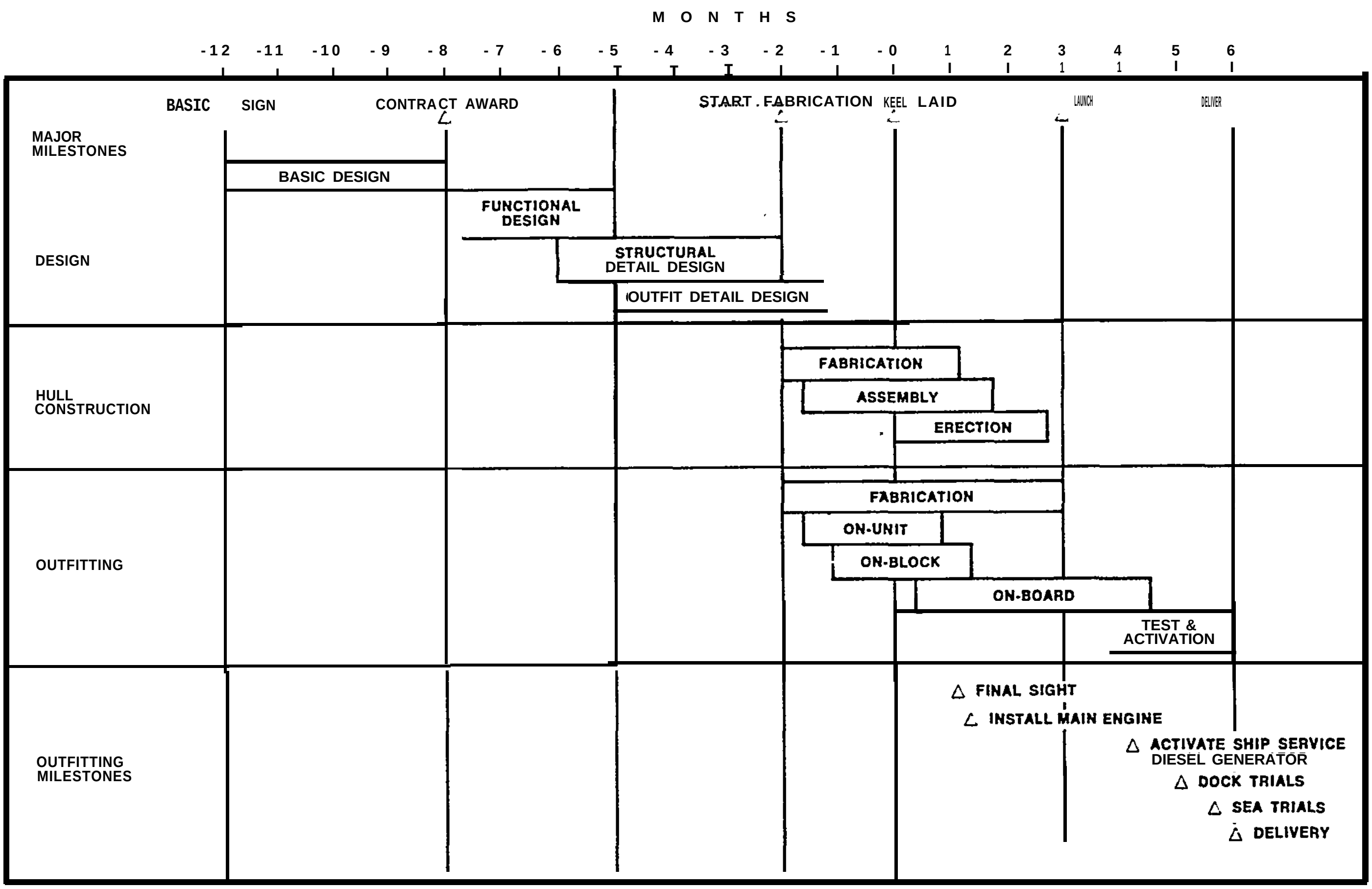


FIGURE 5-1: Major milestone schedule for commercial construction. It is typical with only minor adjustments for a new non-standard cargo, bulk, container or RO/RO ship.

[4]Overlap of design, material procurement and production is facilitated with a product-oriented detail design, i.e., delineating zones on drawings and listing materials that are to be assembled for each zone at a specific stage of construction.

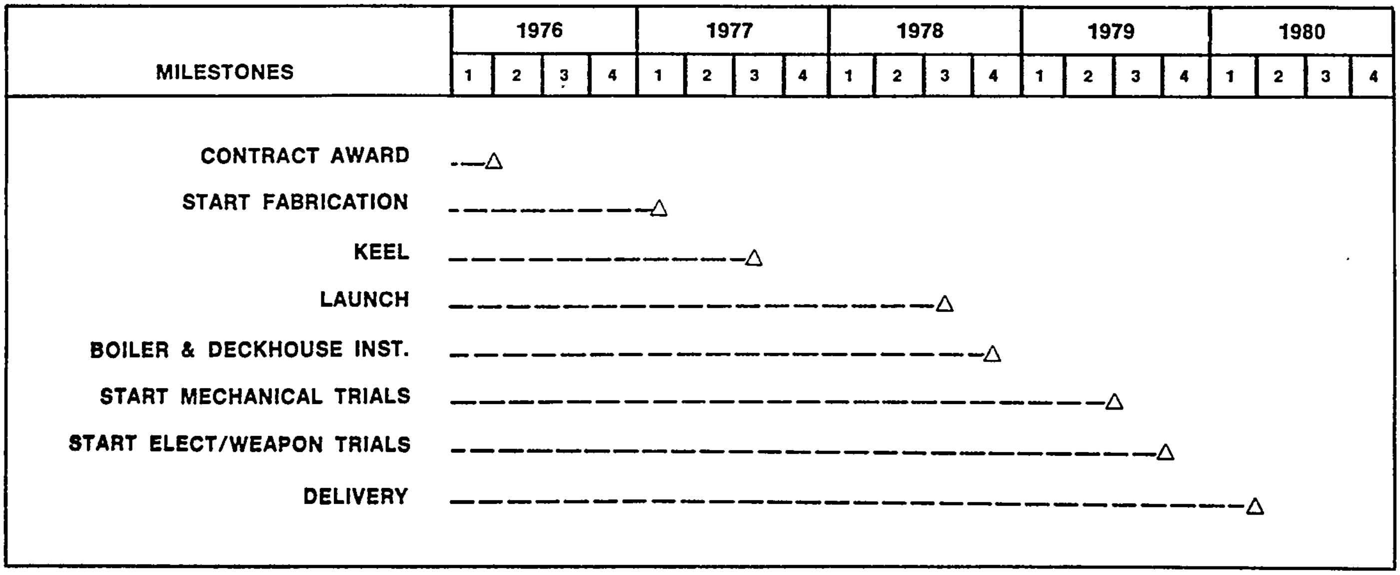


*FIGURE 5.*2: Schedule for a IHI 5200 ton destroyer (DDH). It is typical for the first of a class having similar machinery to a previous class. Limited on-unit and extensive on-block outfitting were used on the first hull.

ment and production as illustrated in Figure 5-3 [2,4].

- Scheduling is simplified by early creation of a zone[5] sequence to coordinate design, material procurement and production.

- Shipbuilding schedules are normally Gantt charts or simple lists. IHI, Kure personnel, indicated that they had tried PERT/CPM networks and found them too inflexible for the shipbuilding environment. They did, however, indicate that they had used a computer network analyses system (PMS)[6] for the design and production of a floating power and pulp plant for the Amazon River. The reason given for using network analyses on the latter project is that their previous shipbuilding experience did not directly relate and they needed a more detailed analysis to identify critical paths and establish schedules.

- The schedule control mechanisms are simpler and in less detail than U.S. practice because work packages are smaller and reference material lists which are structured to reflect the required sequence for assembling the ship.

- Additional explanations and examples of shipbuilding schedules can be found in reference 3, pages 5-4 to 5-11, and in reference 4, pages 30 to 33.

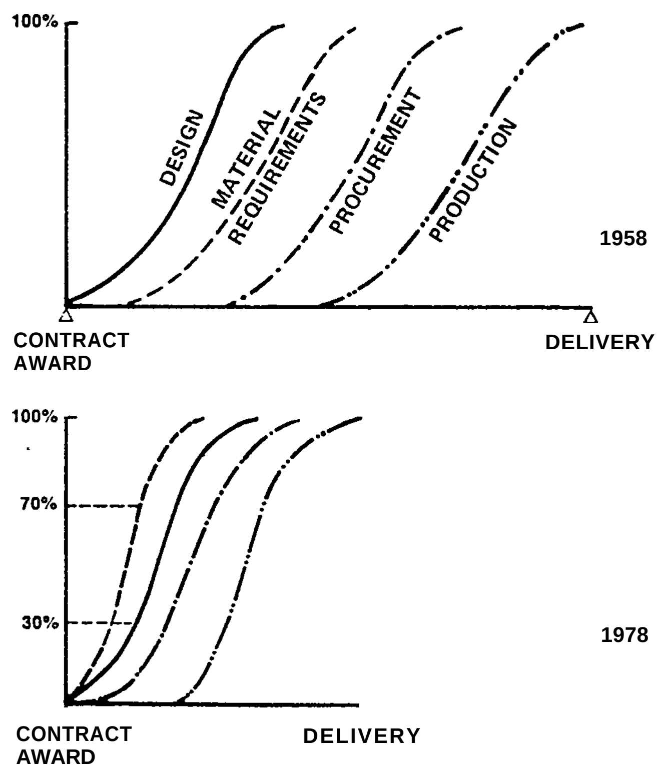


FIGURE 5-3: Overlap of design, material definition, procurement and production which has been achieved by the most competitive shipbuilders. When only 30% of a design is completed, 70% of its required material is defined.

[5]A zone is any three-dimensional subdivision of the planned ship which best serves for organizing information needed to support outfitting or steel construction at various stages (times).

[6]The Project Management System (PMS) developed by IBM, Inc.

5.2 Organization of Work

- The organization of work has been simplified by the product or zone orientation of both the design, and production organizations. A typical product or zone breakdown used with minor modifications in both design and production is as follows:
  - Hull Construction (Hull Fabrication, Assembly and Erection)
  - Deck Outfitting (Outfitting of Cargo and Deck Areas)
  - Accommodation Outfitting (Construction and Outfitting of Accommodation Spaces)
  - Machinery Outfitting (Outfitting of Machinery Spaces)
  - Electrical Outfitting (All Electrical Outfitting)

  This is shown for commercial shipbuilding in Figures 5-4 and 5-5 and for naval construction in Figure 5-6.

- Outfit Planning is a term used to describe the allocation of resources for the installation of components other than hull structure in a ship. Methods applied in Japanese shipyards have produced such benefits as [2] :
  1. Improved safety
  2. Reduced cost
  3. Better quality
  4. Shorter periods between contract award and delivery
  5. Adherence to schedules

- Three key features of the methodology are that the outfit design and planning functions are intimately linked, that they are linked because their principal product is the definition of modular, sometimes multi-system units called interim products, and that the design and planning of these units is controlled largely on the basis of geographical regions in the ship called zones.

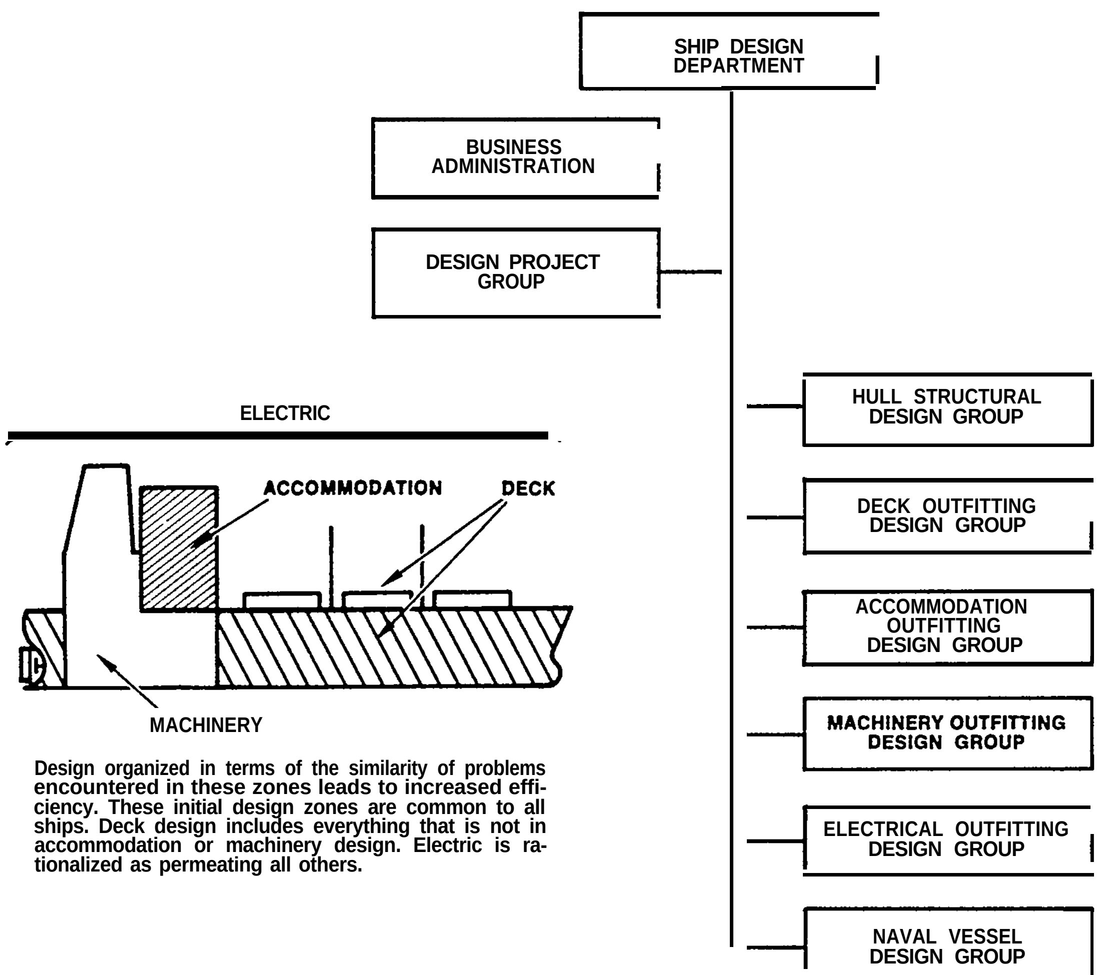


***FIGURE* 54: Organization** of the design department. IHI, KURE

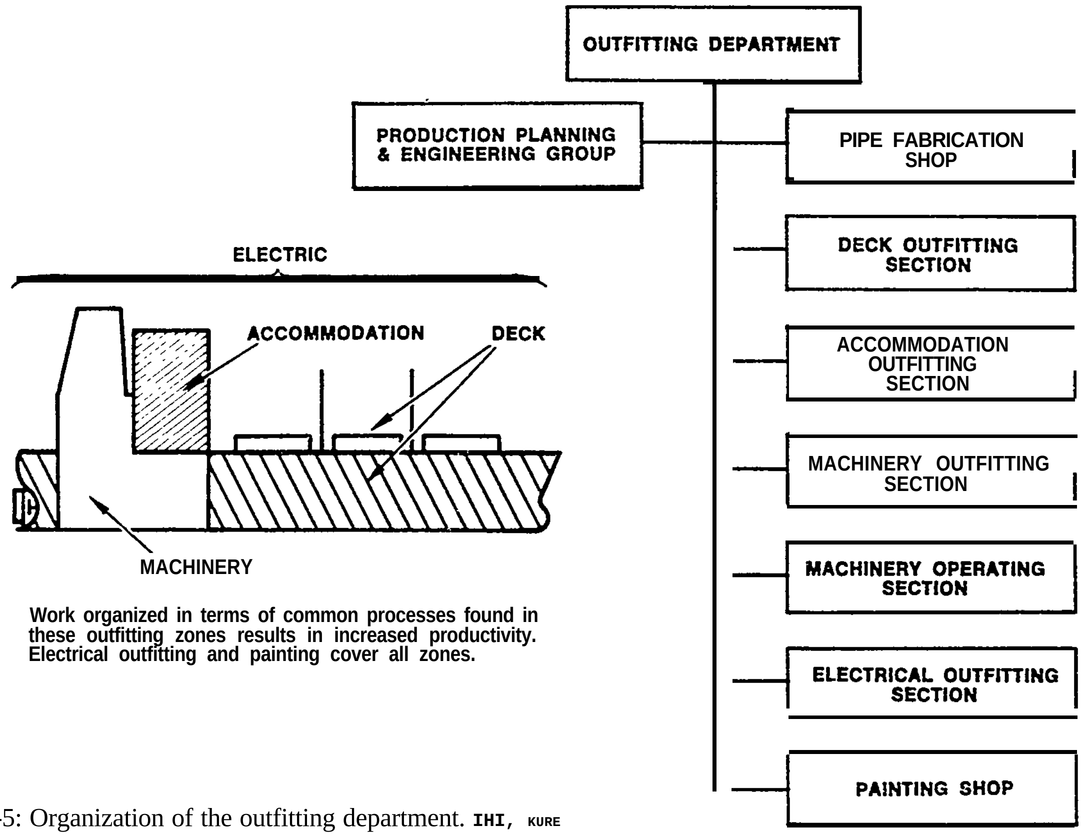


FIGURE 5-5: Organization of the outfitting department. IHI, KURE

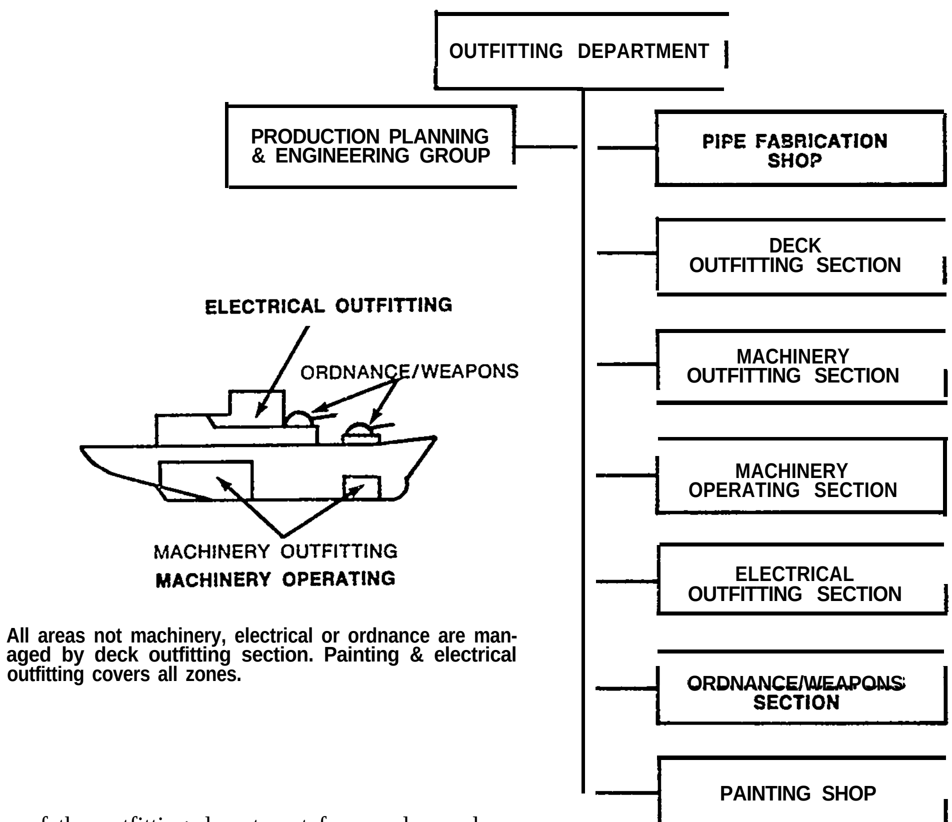


FIGURE 5-6: Organization of the outfitting department for naval vessels. IHI, TOKYO

- Zone outfitting, as contrasted with conventional outfitting by functional system, recognizes that certain multisystem interim products i.e., significant subassemblies of outfit materials, can be produced more efficiently away from hull erection sites. This approach allows most of the outfitting work to be accomplished earlier and in shops where it is safer and more productive. Outfitting, thus organized, is not a successor function to hull construction, but is accomplished simultaneously with it, and hence is free as much as possible from dependence on hull construction progress.
- Zone outfitting is divided into three basic stages listed by order of priority:

  1. On-unit
     The assembly of an interim product consisting of manufactured and purchased components not including any hull structure. On-unit outfitting is illustrated in Figures 5-7 and 5-8.
  2. On-block
     The installation of outfit components, which could include a unit, onto a hull structural assembly or block prior to its erection. On-block outfitting is illustrated in Figures 5-9 and 5-10.
  3. On-board
     Installation of any remaining outfit material and the connection of units and/or outfitted blocks. On-board outfitting is illustrated in Figure 5-11.

- The pallet concept is the method used to organize information to support zone outfitting. Literally a pallet is a portable platform upon which materials are stacked for storage and for transportation to a work site as shown in Figure 5-12. In production a pallet also represents a definite increment of work with allocated


MITSUI, CHIBA

FIGURE 5-S: Example of on-unit outfitting. These units consist of significant subassemblies of various components.

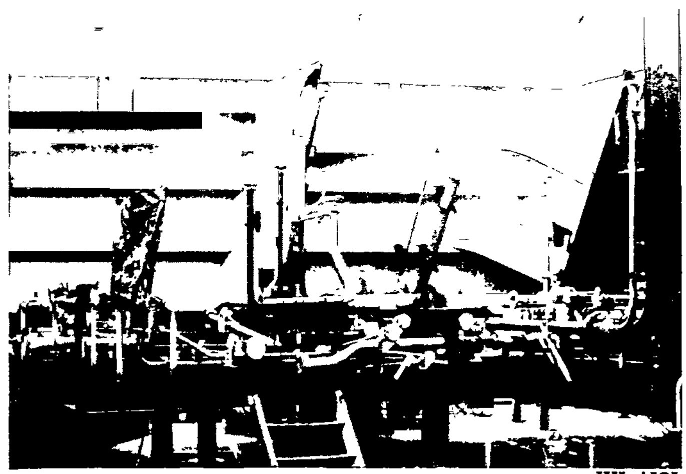

IHI, AIOI

FIGURE 5-9: Curved panel structural block outfitted upside down. Down-hand outfitting can significantly reduce manhours.

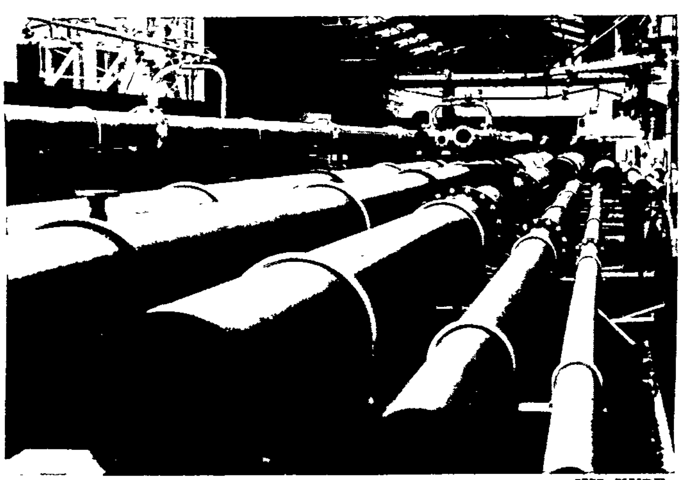

IHI, KURE

FIGURE 5-7: Example of on-unit outfitting. Such units are temporarily assembled together to insure that they will fit when landed on-board.


IHI, AIOI

FIGURE 5-10: Palletized material at site of on-block outfitting. For control purposes, pallets are typically limited to the assembly work one to three people can accomplish in one week.

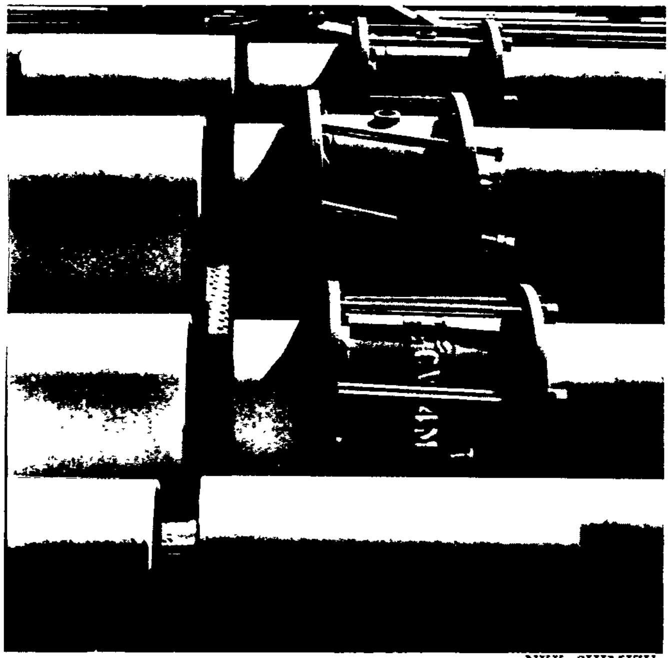


FIGURE *5-11:* Connection of units on-board by the use of removable-stop type flexible couplings which can accommodate some misalignment.

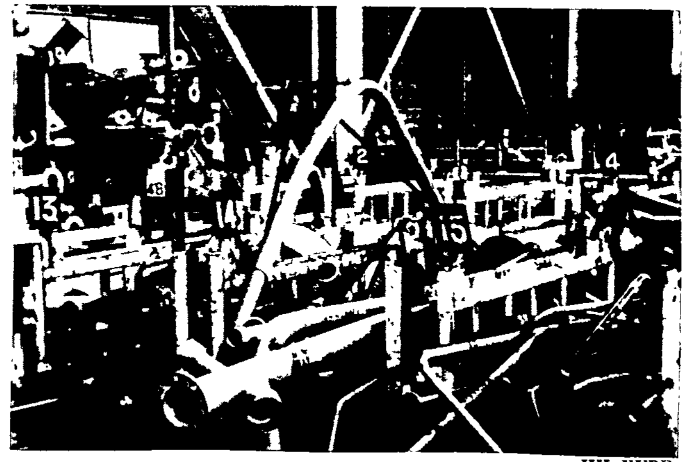
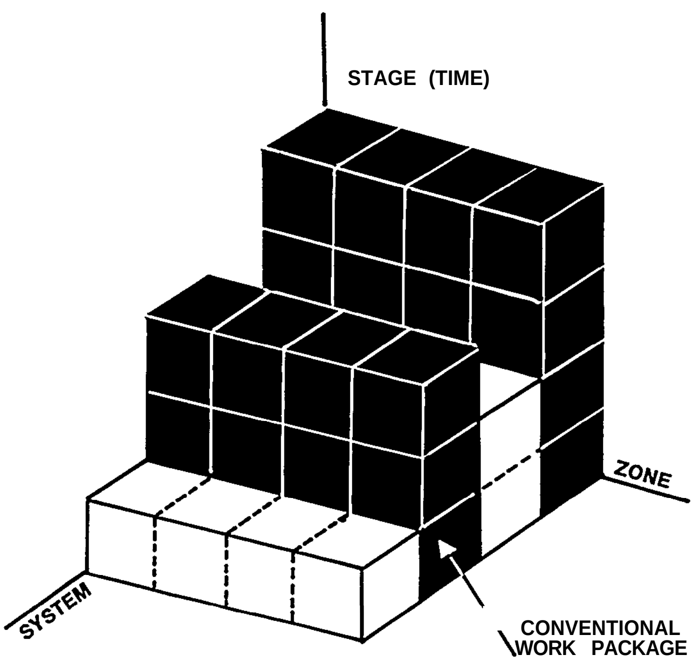


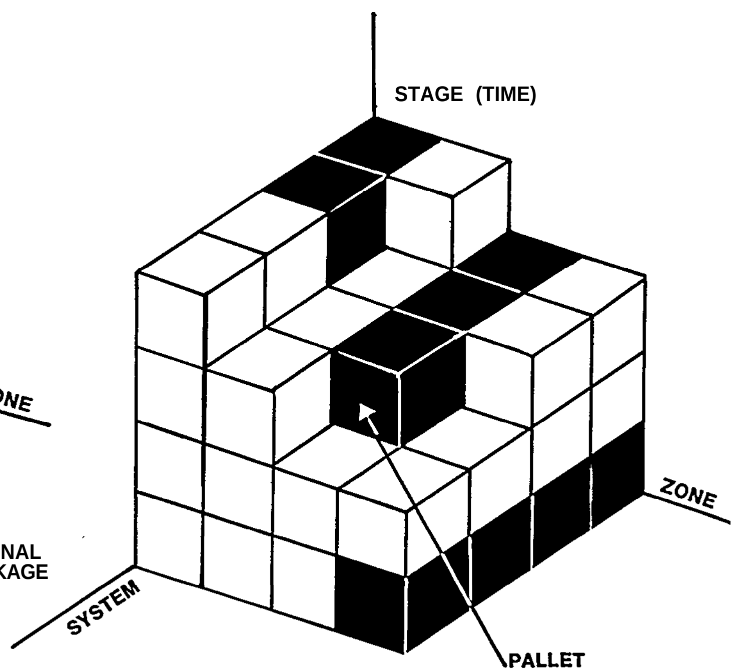
FIGURE 5-12: Outfit palletizing utilizes standard containers which may easily be handled by crane or forklift. In shipyards where zone outfitting is practiced, significant yard areas are devoted to sorting and storing (often on multi-tiered levels) palletized material.

resources needed to produce a defined interim product; hence it is a work package. In design a pallet is also a definition of components of the various functional systems in a particular zone at a specific stage (time) of construction. These aspects are contrasted with conventional work packages in Figure 5-13.



CONVENTIONAL OUTFITTING

Conventional system oriented work packages cross multiple zones and stages; therefore they do not reflect a product orientation.



ZONE OUTFITTING

Zone **oriented pallets cross multiple systems but align directly to production work being accomplished by zone and stage (time) thus giving good control; production activities are exactly matched to the assembly sequence.**

FIGURE 5-13: Conventional outfitting work packages contrasted with zone outfitting pallets.

5.3 Design and Material Definition

- Requirements for shortened periods between contract award and delivery have dictated an overlap of design, material definition and procurement, and production.[7] In order to achieve this overlap, design information is developed in less time, and, is structured in a manner which anticipates the requirements of material procurement and production.

- The design effort is divided into four successive stages **[2]:**

  1. Basic Design-e.g., specifications which establish performance requirements. It is more complete than U.S. practice.

  2. Functional Design-e.g., systems' diagrammatics developed from basic design. It includes simultaneous preparation of a material list, divided into unique material ordering zones, for each system diagrammatic. Functional design also includes preparation of other key drawings such as general, machinery and block arrangements.

  3. Detail Design-e.g., conversions from functional design to working drawings. This process yields composite drawings upon which work zones are delineated.[8] Certain material lists are initiated; these associate specific materials with specific work zones. The composites are sufficiently comprehensive so that details needed for manufacturing certain items, e.g., pipe pieces, may be derived. As they indicate the mounting positions of all components relative to each other, the composites are the basis for assembly instructions. The detail design stage also includes preparation of material detail design drawings, including their material lists, for items that must be custom fabricated such as pipe pieces, ladders and small tanks.

  4. Work Instruction Design-e.g., light-line contact prints, made from the composite drawings, on which only the components to be installed during a specific stage of construction are delineated by darkened lines. Thus, there can be more than one work instruction drawing per work zone. They are annotated with assembly instructions and each is accompanied by a specific material list per work zone per work stage. It is correct for designers to refer to each work instruction drawing and its material list as a pallet or work package. The work instruction design phase significantly overlaps the detail design phase and both are performed by the same people.

- During functional design, material lists are developed for all needed components and bulk raw materials by dividing the initial design zones (Figure 5-4) into three to seven "purchasing zones" that are used to facilitate accelerated procurement. These lists are called :

  MLS-Material List by (ship's functional) System (by purchasing zone).

- During material detail design, material lists for items which will be custom manufactured from raw materials are developed. Such lists are called:

  MLP-Material List for (manufacture of) Pipe (pieces)

  MLC-Material list for (manufacture of) Components (other than pipe) This is a list of subcontractor fabricated material such as ventilation ducting, walkways, ladders, etc.

- An additional material list is initiated during detail design and finalized during work instruction design. This is a list of material per pallet (work package) i.e., per work zone per work stage, for assembly of a specific interim product. There are three sources:

  1. Materials already incorporated in an MLS excluding the raw materials needed to custom manufacture other outfit materials.

  2. Custom manufactured components which are made from the raw materials identified in an MLP or MLC.

  3. Materials for which quantities are more exactly identified in working drawing preparation.

  Such lists are called:

  MLF-Material List for Fittings (per pallet, i.e., per work zone per work stage).

- The relationships of these material lists to design and to material procurement are illustrated in Figure 5-14. Material is ordered in progressive stages throughout the functional design, detail design, and work instruction design phases in order to suit material lead times. Long lead time material is ordered during basic design and sometimes prior to contract award.

- The use of these concepts to organize material requirements so that purchase and manufacturing orders can be placed as early as possible is a key element of high Japanese productivity.

[7]Mitsui personnel also indicated that on new ship design work, nearly all material would be defined when 30% of the total design man-hours had been expended.

[8]As an economic measure many work zones appear on one drawing. If a specific zone is very complicated, two or three drawings for one zone should be considered. The number of work zones per drawing is immaterial as long as the drawing issue schedule is derived from the pallet list.

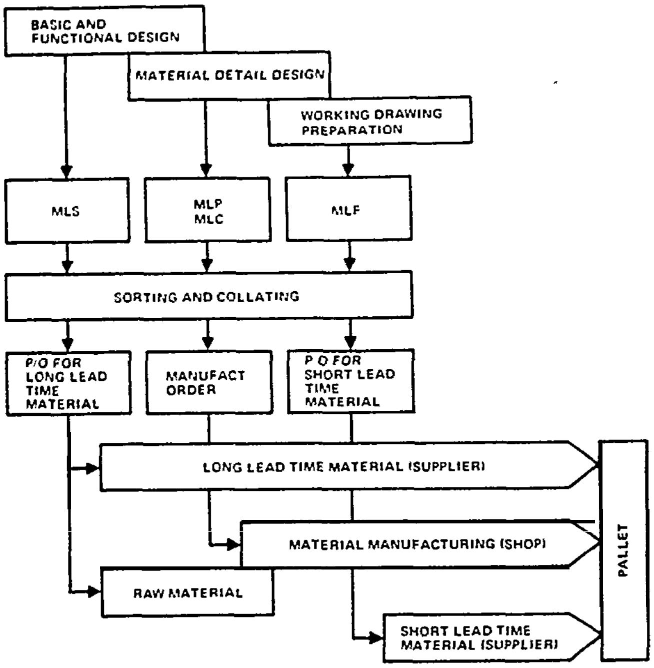
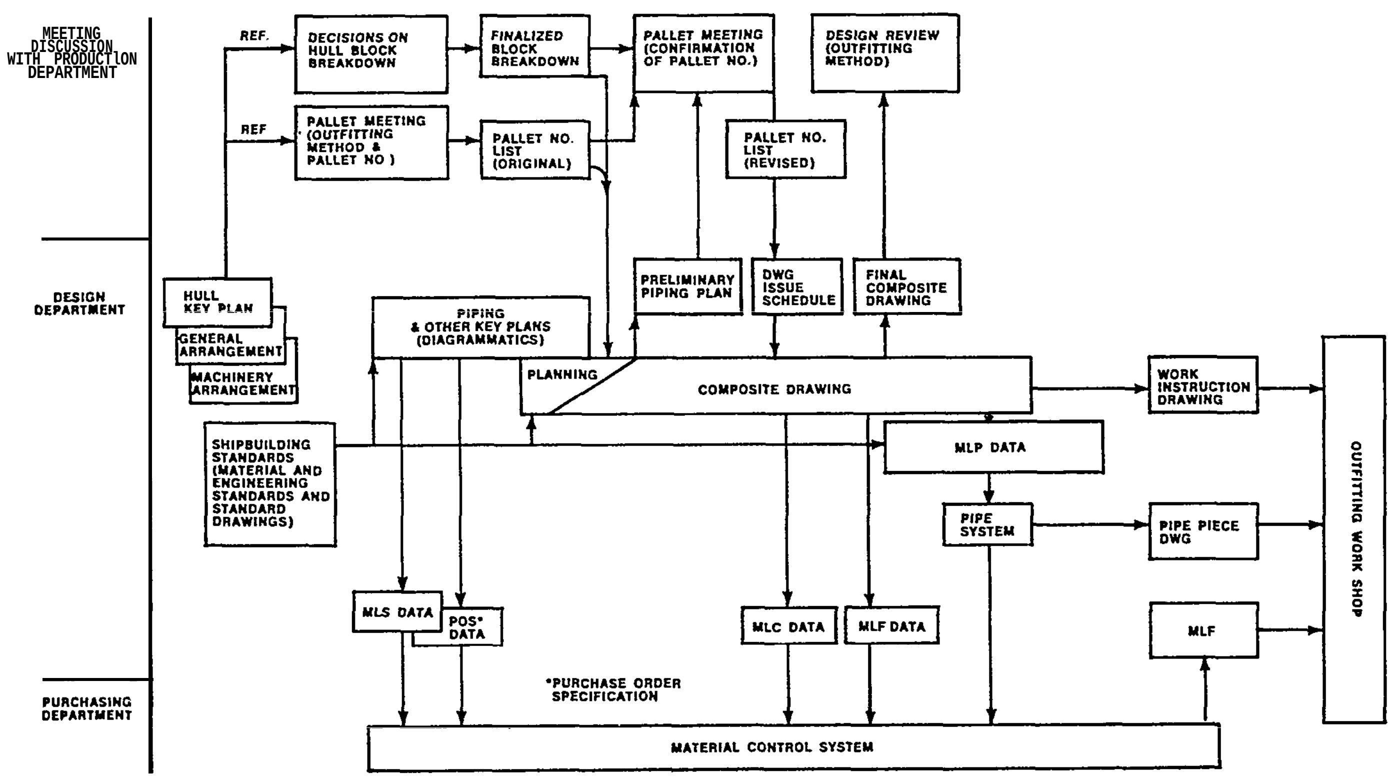


FIGURE 5-14: Relationships of material lists to design and to material procurement. Accuracy and timing of the sorting and collating functions are critical. In addition to sorting for long and short lead time and manufacturing-order materials, items identified in MLP, MLC and MLF must be compared to those in MLS. Also, the end product of each MLP and MLC must be accounted for in an MLF.

- Reference 4 pages 21 through 24 contains more detail concerning specifying and procuring materials through the use of standard classifications. These concepts are explained in detail in reference 2.
- The overall process of pallet design is illustrated in Figure 5-15. It is based upon intensive planning and production input early in the design process.
- Each of the basic outfitting stages, namely on-unit, on-block and on-board, are divided into the following substages to assist in the breakdown of work into pallets :
  1. On-block outfitting after a structural block is turned over for material pre-assembled into a unit.
  2. On-block outfitting for material pre-assembled into a unit.
  3. On-board outfitting for material pre-assembled into a unit.
  4. On-block outfitting for material to be installed piece by piece.
  5. On-block outfitting after a structural block is turned over for material to be installed piece by piece.
  6. On-board outfitting prior to an area being closed in by an overhead block.



Outline of the process of pallet design. Note that the drawing issue schedule is derived from the pallet list.

FIGURE 5-15: Outline of the process of pallet design. Note that the drawing issue schedule is derived from the pallet list.

7. On-board outfitting by zone or area prior to system tests (or other key events such as launch, trials, etc.).
8. On-board outfitting prior to launch.
9. On-board outfitting after launch.
10. On-board outfitting general category for items such as spare parts and touch up.

- The number of pallets which result for typical IHI standard vessels are shown in Figure 5-16. For control purposes, pallets are typically limited to the assembly work one to three people can accomplish in a week.
- The organization of pallets for an engine room lower level of a typical diesel machinery space consists of:

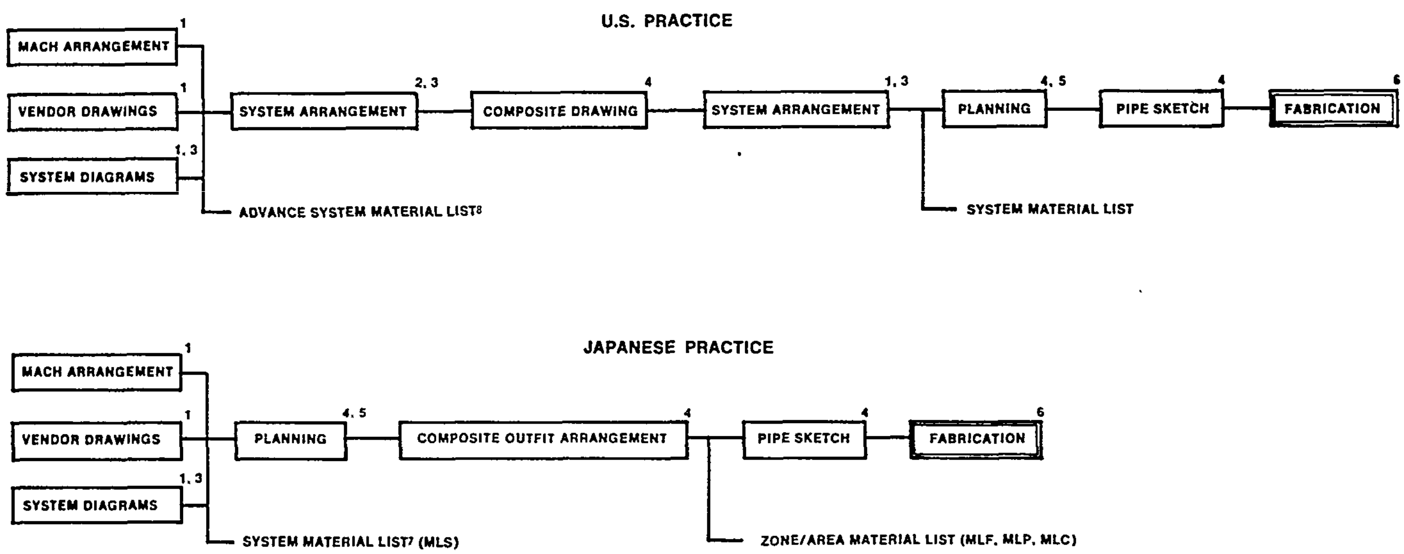
  -5 Structural Blocks
  -3 to 4 Pipe Units
  - 1 0 to 12 Machinery Units

- A sequence of zones by stages (a pallet list) provides the common documentation for design, material procurement, production, and control.

KIND OF VESSEL	ZONE \ STAGE	ON - UNIT		ON BLOCK	ON-BOARD	TOTAL
		FOR LANDING ON-BLOCK	FOR LANDING ON-BOARD			
FREEDOM MK-II 15,000 TON MULTIPURPOSE CARRIER	DECK	56	8	132	109	305
	ACCOMMODATION			34	408	442
	MACHINERY	30	49	66	107	252
	ELECTRICAL		44	90	82	216
	TOTAL	86	101	322	706	1215
FREEDOM 17,000 TON MULTIPURPOSE CARRIER	DECK		1	185	187	373
	ACCOMMODATION			24	285	309
	MACHINERY	17	45	32	227	321
	ELECTRICAL		19	11	52	82
	TOTAL	17	65	252	751	1085
FORTUNE 20,000 TON MULTIPURPOSE CARRIER	DECK		2	138	63	203
	ACCOMMODATION			69	159	228
	MACHINERY		81	35	110	226
	ELECTRICAL			33	88	121
	TOTAL		83	275	420	778
BULK CARRIER 60,000 TON	DECK	116	33	431	106	686
	ACCOMMODATION		2	87	239	328
	MACHINERY	18	78	32	144	272
	ELECTRICAL			46	173	219
	TOTAL	134	113	596	662	1505
BULK CARRIER 168,000 TON	DECK	94	44	515	112	765
	ACCOMMODATION		5	83	262	350
	MACHINERY	23	93	55	171	342
	ELECTRICAL			49	201	250
	TOTAL	117	142	702	746	1707
VLCC 250,000 TON	DECK	136	101	532	151	920
	ACCOMMODATION	18	5	58	234	315
	MACHINERY	5	106	84	208	403
	ELECTRICAL			40	196	236
	TOTAL	159	212	714	789	1874
VLCC 250,000 TON	DECK	124	83	487	139	833
	ACCOMMODATION	19	17	96	275	407
	MACHINERY	32	115	88	190	425
	ELECTRICAL			85	223	308
	TOTAL	175	215	756	827	1973

FIGURE 5-16: Number of outfit pallets (work packages) for IHI standard vessels.

- The use of the composite outfit arrangement drawing is a key element in the reduced working plan development time achieved by the Japanese yards versus U.S. practice. This is illustrated in Figure 5-17.
- Typical composite outfit arrangement drawings could be organized as follows:
  - -*Engine Room Lower* Level-Drawings include foundations; piping; grating framework, plating, and handrails; piping supports; and ladders.
  - -*Deck* Piping-Drawings include piping; grating framework, plating, and handrails; ladders; deck fittings: piping supports; and foundation installation.
  - --*Accommodations-Three* drawings could be used ; a) piping, ventilation, ladders, equipment and foundation installation; b) joiner installation and c) electrical installation.
- The outfitting composite drawings reviewed at all the shipyards were not sophisticated. The piping was shown as one line although the flanges appeared to be shown as double lines. The composite drawings did include elevations, sections and details and the drawings were coded with symbols or by shading to indicate the installation stage, i.e., on-unit, on-block, or on-board.
- Piping and other system diagrams are developed in schematic form by deck level similar to U.S. practice. Piping diagrams are complete in all respects and along with the machinery arrangements are the only piping drawings submitted for agency approval. The piping diagrams are used in conjunction with machinery arrangements to determine the pipe lengths for, the purpose of sizing and material calculations.
- Both functional and working plan development are greatly assisted through the use of comprehensive standards' and extensive experience on previous vessels.
- Typical structural working plans include deck, side shell, web frames, etc., for the complete block or for a group of similar blocks. Structural working plans do not include foundations which are issued on a separate book plan by zone.
- Additional explanations and illustrations of the Japanese design process can be found in reference 3, pages 3-1 to 3-8 and in reference 4 pages 7 through 11.



[1]Submitted for approval
[2]Omitted by some U.S. yards
[3]Prepared by system/hull
[4]Prepared by zone/area
[5]Planning of hull blocks and machinery outfit units
[6]Fabrication by zone/area/unit
[7]This list contains *all* material
[8]This list contains long lead time material only

FIGURE 5-17: Flow chart of the process of outfit working plan development (U.S. contrasted with Japanese practice).

[9]Documented standards or guidance data for use in the areas of functional and detail design, planning, production and quality control.

5.4 Shipbuilding Standards and Modules

- Both IHI and Mitsui have developed extensive standards for use in functional design, detail design, planning, production and quality control. Figure 5-18 pro: vides a classification of IHI standards.
- According to IHI, Kure personnel, standards have been developed to reflect high quality based on new requirements and reflecting past experiences. The use of standards is sold to the owner, during technical negotiations prior to contract award, based on the principals of proven service experience, reduced delivery time and reduced cost.
- The use of standards and modules in this manner is a key element in the significantly reduced design and production costs and schedules achieved by Japanese shipyards versus U.S. practice. [5][10]
- The IHI design approach appears heavily oriented to the use of design standards which have been developed based on standard ship designs. See Figure 5-16 for examples of standard IHI designs. Although these design standards are based on standard ship designs, they have been developed with the idea of solving a range of problems versus solving the specific design problems presented by the ship being designed. Mitsui, on the other hand, bases their designs on previous ships having similar engine types and power ranges. Neither IHI nor Mitsui appear to have a totally comprehensive documented set of standards covering all ship types. Standards for tanker and bulk ships appear to be very thoroughly developed, while standards for liner ships are less completely developed.
- An example of vendor catalog items adopted as shipyard standards is illustrated by Figure 5-19. These

Classification of Standards			Nos.
BASIC STANDARDS (IS)	MATERIAL STANDARDS (SO)	Common components	600
		Hull fittings	600
		Machinery fittings	200
		Electric fittings	200
	Sub-total		1,600
	ENGINEERING STANDARDS (SOT)	Design process standards	1,100
		Production eng. process standards	100
		Inspection process standards	200
	Sub-total		1,400
STANDARD DRAWINGS (SD)	Machinery drawings (SD1)*		1,200
	Component and fitting standard drawings		350
	Other guidance drawings		350
	Sub-total		1,900
GRAND TOTAL			4,900

*SD1 are standards where a change must be the result of a mutual agreement between IHI and a vendor or subcontractor.

FIGURE 5-18: Classification of standards-IHI.

DRAIN PUMP (Large Size)						MACH. NO.	M O 23	
						TYPE	V E C	
CARGO PUMP CAP		m3/h x m	3500 x 125	4000 x 125	500 x 150 4000 x 150	4000 x 150	4500 x 150	5000 x 150
CARGO PUMP SETS		KW x rpm	3		3	4	4	4
CAPACITY		m3/h x m	70 x 90	80 x 90	90 x 95	110 x 95	130 x 95	70 x 100
MAKER A	MODEL NO.		EVZ 100	EVZ 130			EVZ 130-2	EVZ-130
MAKER A	STAND. DRWG. NO.	SDx	440011360A	440011380			440011390	440011380
MAKER A	MOTOR CAPACITY	KW x rpm	37 x 1800	45 x 1800		55 x 1800	75 x 1800	45 x 1800
MAKER A	MOTOR MODEL NO.							
MAKER A	CAPACITY RANGE	m3/h x m	56~ 70 x 90	76~ 100 x 90	78~ 95 x 95	96~ 110 x 95	118~ 130 x 95	66~ 85 x 100
MAKER A	WEIGHT PUMP	t						
MAKER A	WEIGHT MOTOR	t						
MAKER B	MODEL NO.		200 x 100- 2YCSE-A	250 x 125 - 2VCDS - A			300 x 150- 2VCDS-A	250 x 125- 2VCDS-A
MAKER B	STAND. DRWG. NO.	S D I	440021730A	440021740A			440021390	440021740
MAKER B	MOTOR CAPACITY	KW x rpm	37 x 1800	45 x 1800		55 x 1800	75 x 1800	45 x 1800
MAKER B	MOTOR MODEL NO							
MAKER B	CAPACITY RANGE	m3/h x m	51~ 70 x 90	80~ 100 x 90	95 x 95	91~ 110 x 95	130~ 140 x 95	70~ 85 x 100
MAKER B	WEIGHT PUMP	t						
MAKER B	WEIGHT MOTOR	t						

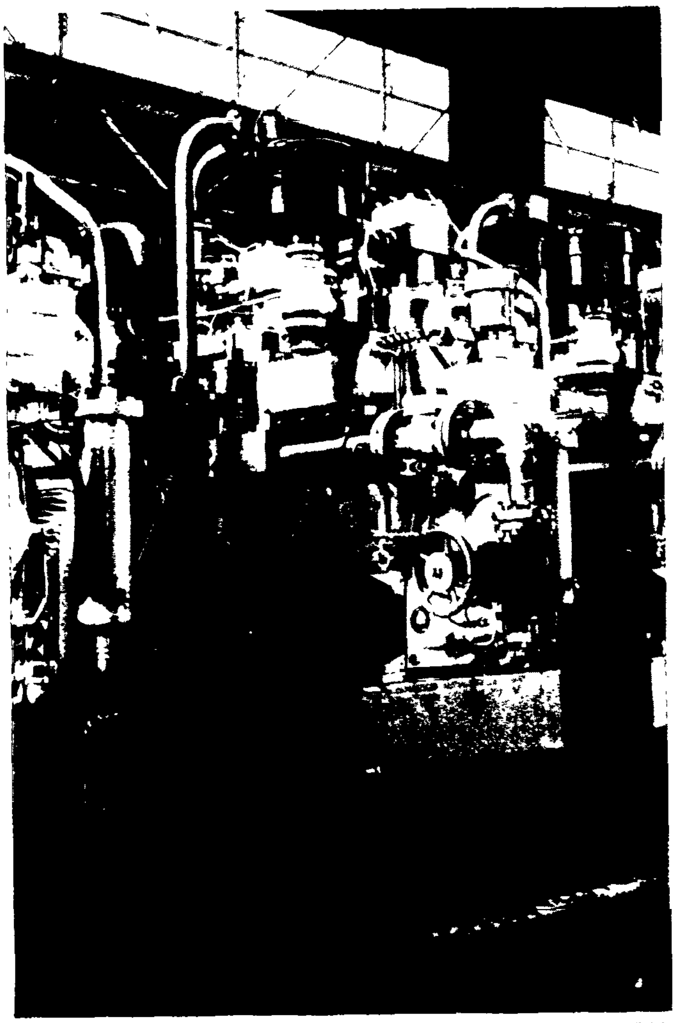
DRAIN PUMP (Mid Size)						MACH NO	M O 23	
						TYPE	V E C	
CARGO PUMP CAP		m3/h x m	3500 x 125	4000 x 125	3500 x 150 4000 x 150	4000 x 150	4500 x 150 5000 x 150	5000 x 150
CARGO PUMP SETS		KW x rpm	3		3	4	4	4
CAPACITY		m3/h x m	40 x 90	50 x 90	50 x 95	60 x 95	70 x 95	70 x 100
MAKER A	MODEL NO		EVZ 100					EVZ 130
MAKER A	STAND. DRWG. NO	SD1	440011360A					440011380
MAKER A	MOTOR CAPACITY	KW x rpm	30 x 1800			37 x 1800		45 x 1800
MAKER A	MOTOR MODEL NO.							225 M
MAKER A	CAPACITY RANGE	m3/h x m	40– 55 x 90		50 x 95	51– 70 x 95		66 85 x 100
MAKER A	WEIGHT PUMP	t						
MAKER A	WEIGHT MOTOR	t						
MAKER B	MODEL NO.		200 x 100 - 2VCSE-A					250 x 125 2VCDS-A
MAKER B	STAND. DRWG. NO.	S D 1	440021730					440021740
MAKER B	MOTOR CAPACITY	KW x rpm	30 x 1800			37 x 1800		45 x 1800
MAKER B	MOTOR MODEL NO							
MAKER B	CAPACITY RANGE	m3/h x m	40– 50 x 90		50 x 95	51~ 70 x 95		70~ 85 x 100
MAKER B	WEIGHT PUMP	t						
MAKER B	WEIGHT MOTOR	t						

***FIGURE* 5-19**: Examples of machinery component standards IHI. Machinery is selected from standard models of two or more proven manufacturers which have been pre-approved by the shipyard and registered as standard equipment.

[10]Reference 5 by Y. Ichinose, IHI contains a detailed description of IHI standards and modules.

standards have been developed to a range of requirements instead of being designed around a specific ship type. Designers using these standards do not have to wait for vendor furnished information to complete detail design tasks, such as foundation design illustrated by Figure 5-20.

- Both IHI and Mitsui have single main engine vendors for both low speed and medium speed diesel. IHI manufactures the low speed Sulzer and medium speed Pielstik engines while Mitsui manufactures the low speed B&W and medium speed Mitsui engines.
- Design and material standards start at the level of individual components and pieces of raw material and include progressive tiers to the level of standard machinery arrangement modules (see Figure 5-21) and system diagrams. They apply to various ships and various sizes of standard steam or diesel power plants.
- Functional design standards for a 60,000 ton bulk carrier engine room design[11] included the following:
  - -Engine Room arrangement based on a single engine type with alternative number of cylinders.
  - -Machinery arrangement including plan, elevation and section.
  - -A list of key equipment including alternate vendors except for the main engine.
  - -All system diagrams.
  - -An arrangement of outfitting units.



MITSUI, CHIBA

FIGURE 5-20: Standard diesel generators with subcontractor provided foundations and some piping attached,

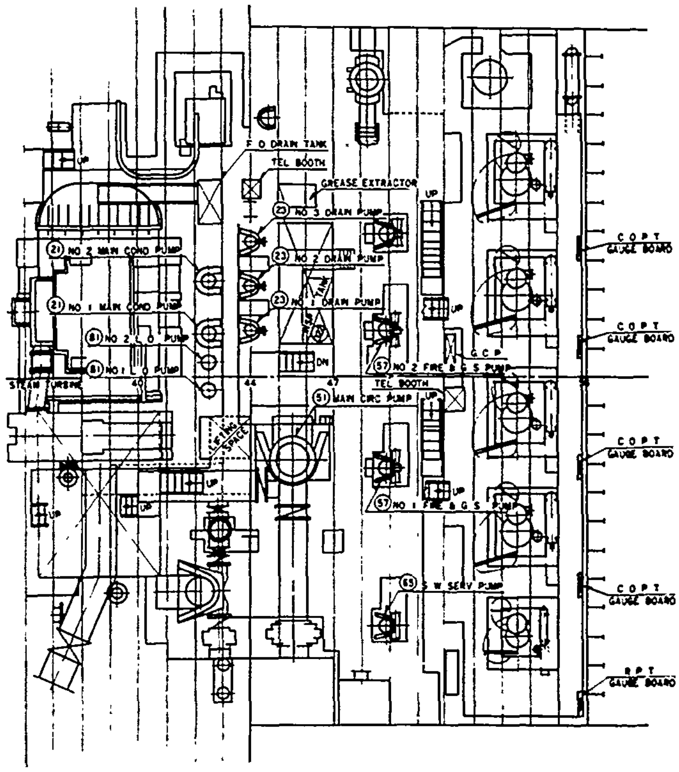


FIGURE 5-21: Each position in a reusable machinery arrangement has enough space around it to accommodate the several catalog items that are maintained in the standards file for that position. Pipe detail designers adjust for the different nozzle locations.

[11]The majority of machinery units or outfit packages shown for this design were based on standard machinery modules which are system oriented. Examples are lube oil purification, fuel oil treatment, jacket water heat exchangers, etc.

-Machinerv module designs (each consisting of a reusable diagrammatic and its machinery and piping arrangements and parts list)

- The design of system modules using functional design standards is illustrated in Figure 5-22. In this case, the design standards have allowed for alternative system capabilities and the designer selects from these alternatives to create the functional and working drawings for a new ship design. The basic elements used in these modules are the standard machinery components.
- IHI personnel indicated that they have previously forwarded to the MarAd Standards Program Manager, at Bath Iron Works, a proposal for technical assistance in the area of standards development. This proposal should be carefully reviewed, although, at this point, Mr. Hamada of IHI, indicates that the question of selling IHI standards or assistance in standards development is being reconsidered by IHI top management.
- Mitsui design standards, in the form of design manuals and design check lists, were reviewed. These design standards provide substantial guidance to designers in the form of partial system diagrams, tables or graphs simplifying engineering calculations, check lists of items required to properly complete functional or working drawings, check lists of items required to ensure reduced costs in the production area and check lists, based on experience, of items causing either production problems or problems in the guarantee area.
- This approach to standards has provided these shipyards a formalized way of documenting their experience. Further it permits developing new design or production procedures in a manner that facilitates their adaptation to new owner or service requirements.
- Additional explanation and examples of Japanese practice in the area of shipbuilding standards can be found in reference 3, pages 3-7 to 3-l 6, and reference 4 pages 14 through 19.
- Although IHI appears to have moved further in developing comprehensive shipbuilding standards, both Mitsui and IHI should be considered as potential subcontractors for the development of a comprehensive standards program.

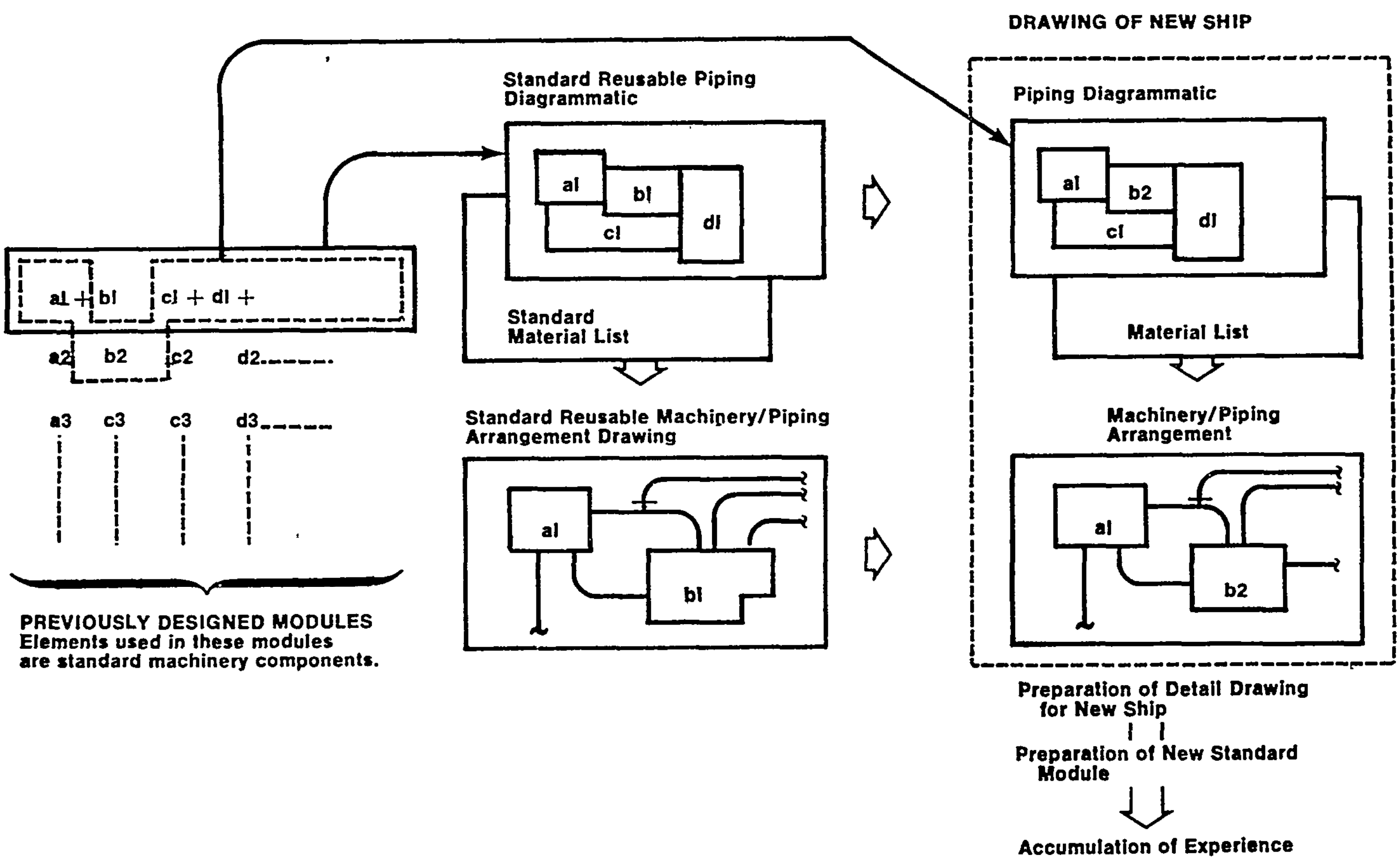
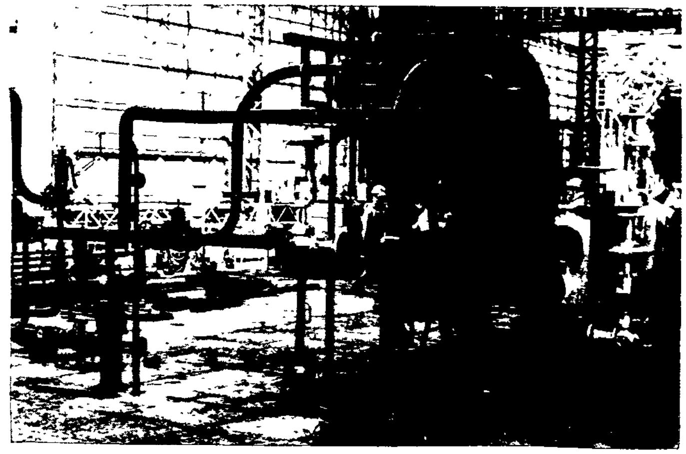


FIGURE 5-22: Flow chart of system module design (IHI) .

5.5 Outfitting Approach

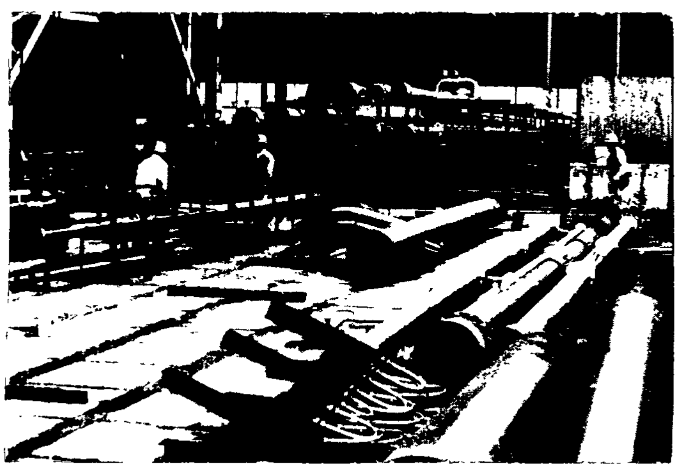
- On-unit outfitting offers the greatest potential for improving overall shipbuilding productivity as compared to the other two outfit methods i.e., on-block and on-board. Hence primary emphasis is placed on maximizing on-unit outfitting. The key advantages are:
  (1) Reduced construction time due to parallel construction of structure and outfit.
  (2) Minimal impact on hull construction schedules.
  (3) Increased outfit levels.
  (4) Reduced interface of outfitting and structural activities.
  (5) Improved sequencing and control of work. Earlier application of labor and material.
  (6) Work is performed in shops which provide ideal working conditions and promote higher productivity (see Figure 5-23).
- IHI and Mitsui stated the following man-hour savings for on-unit and on-block outfitting:

  on-unit versus on-board = 70% savings
  on-block versus on-board = 30% savings
- A high degree of on-unit outfitting was observed in all shipyards performing commercial construction.
- Pictures of the DDH construction viewed in IHI Tokyo indicated limited use of on-unit outfitting and extensive on-block outfitting.
- Many examples of methods employed to further reduce the work content of outfitting can be cited. Figure 5-24 provides an illustration of the use of modular support blocks used for temporary support during assembly of a unit. These blocks represent a system of standard heights. Detail designers specify the use of particular blocks.
- Figures 5-25 and 5-26 provide an illustration of the use of combined pipe supports which reduce man-hours and material.
- Outfitting on-block is the second best alternative to outfitting on-unit. As an example, significant reduction in man-hours may be obtained by on-block outfitting a containership hatch, as illustrated in Figure 5-27.



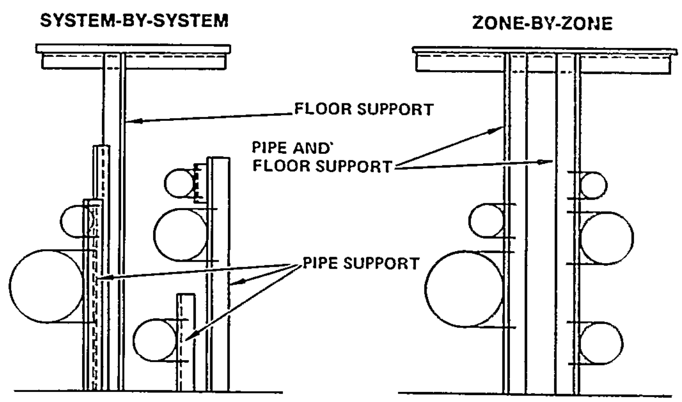
NKK, SHIMIZU

FIGURE 5-24: On-unit outfitting illustrating the use of various standardized modular support blocks.



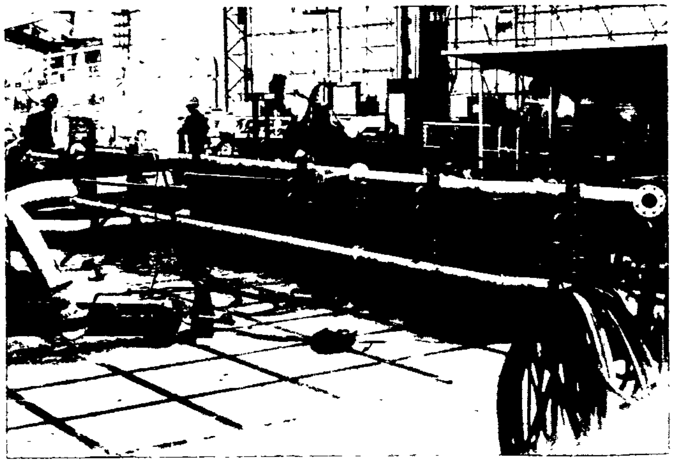
IHI, KURE

FIGURE 5-23: On-unit outfitting in progress. Work is performed in shops which provide ideal climate, lighting and access. Shop work increases the opportunity for improved safety and higher productivity. A platen area facilitates assembly of different type units.



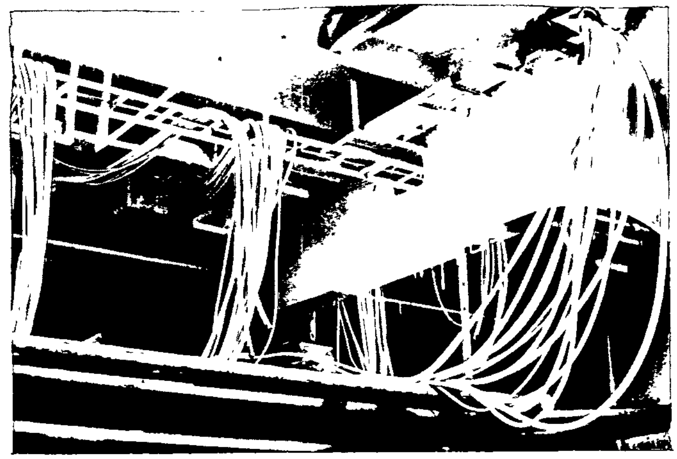
- PIPE SUPPORT AND FLOOR SUPPORT ARE COMMON WHICH REDUCES MATERIAL COST.
- WELDING LENGTH FOR SUPPORTS IS REDUCED.
- FITTING PROCEDURE FOR EACH PIPE IS CLEARLY DETERMINED. (FROM THE LOWEST PIPE)

FIGURE 5-25: Pipe support unit assembly approach.



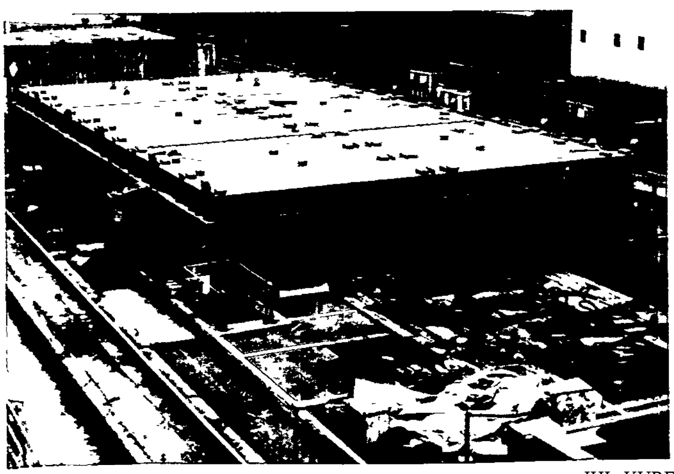
NKK, SHIMIZU

FIGURE 5-26: Combination of multiple pipes on single supports. Such pipe passages, especially when designed around main machinery, also serve to reduce the possibility of interferences.



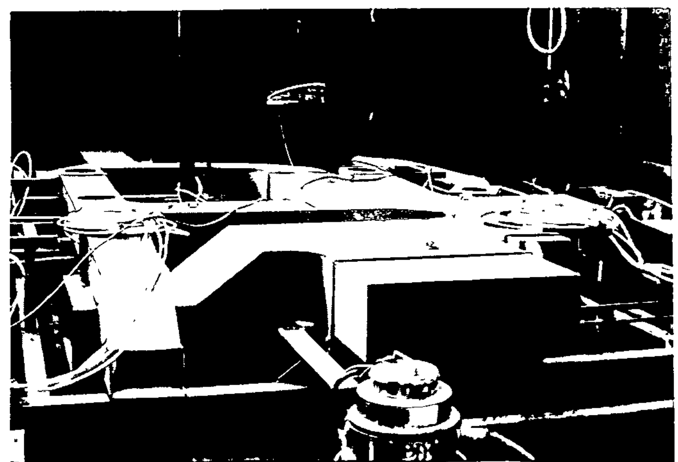
IHI, KURE

FIGURE 5-28: On-block final securing of pre-cut (palletized) cable. Cable pulling was performed down-hand before the structural block was righted.



IHI, KURE

FIGURE 5-27: Ground outfitting and assembly of containership hatch coamings with hatch covers, including the completion of all dogging, seating and gasketing.



IHI, KURE

FIGURE 5-29: On-block installation of pre-cut (palletized) cable while block is upside down.

- Labor intensive cable pulling may also be reduced by on-block outfitting, as illustrated by Figure 5-28. Additional productivity is gained if the block is upside down during electrical outfitting, see Figure 5-29.
- Multiple pipe penetrations through decks and bulkheads may be preassembled with a doubler for ease of installation (see Figure 5-30). The doubler is also designed to serve as a structural reinforcement.
- Piping make-up pieces are normally prefabricated with two flanges tacked and unwelded. In rare cases, such as for piping running at odd angles, make-up pieces are templated aboard ship.

IHI, AI01

FIGURE 5-30: Multiple pipe penetrations through decks and bulkheads preassembled with a doubler.

- In the pipe fabrication shop, work is organized by similar procedures or processes, such as bending pipe, which is the same process regardless of pipe function. This categorization of procedures is given the name Pipe Piece Family Manufacturing (PPFM) . Figure 5-31 illustrates the use of PPFM from design through palletizing.
- It is also more productive to paint these pipes and palletize them immediately following fabrication as shown in Figure 5-32, and also to perform required pressure tests in shops rather than on-board (see Figure 5-33).
- Outfit components, other than piping, are subcontracted for fabrication thus permitting shipbuilding managers to focus their attention on the assembly process. Figure 5-34 provides an illustration.
- Material control is enhanced if a single organizational unit has the responsibility to palletize both piping (fabricated within the shipyard) and other components

IHI, KURE

FIGURE 5-3.2 Use of pipe shop area for other than fabrication: 25% devoted to sorting by coating system, cleaning and painting, 25% devoted to palletizing.

MATERIAL AND TYPE		PPFM NO	NAME	REMARKS	ROUGH SKETCH FOR SHAPES
STEEL PIPES	GROUP 2 PIPES	01	STRAIGHT PIPES		
		11	AFTER-BENDING PIPES	PIPES TO BE BENT AFTER FABRICATION	
		41	PRE-BENDING PIPES	PIPES TO BE BENT BEFORE FABRICATION	
		51	FABRICATING PIPES		
		31	ASSEMBLING PIPES		
	GROUP 1 PIPES	21	PIPES TO BE SUBJECTED TO RADIOGRAPHIC TEST		
NON-FERROUS PIPES		87	NON-FERROUS PIPES	COPPER PIPES, ALUMINUM BRASS PIPES, COPPER-NICKEL PIPES, ETC.	
STEEL PIPES & NON-FERROUS PIPES	ADJUSTING PIPES	91	ADJUSTING PIPES		
CAST STEEL PIPES		71	STRAIGHT PIPES		
		73	BENDING PIPES		

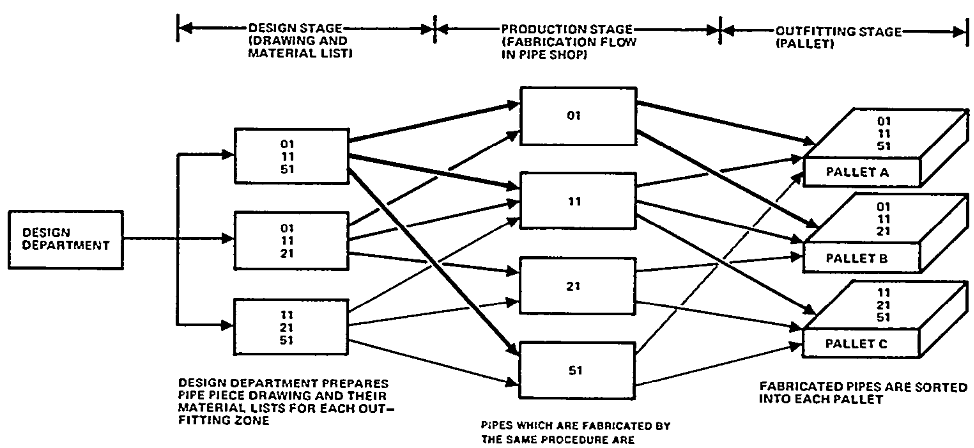


FIGURE 5-31: Pipe piece family manufacturing (PPFM).

NKK, SHIMIZU

FIGURE 5-33: Pipe pieces assembled together for pressure test in pipe fabrication shop.

MITSUI, TAMANO

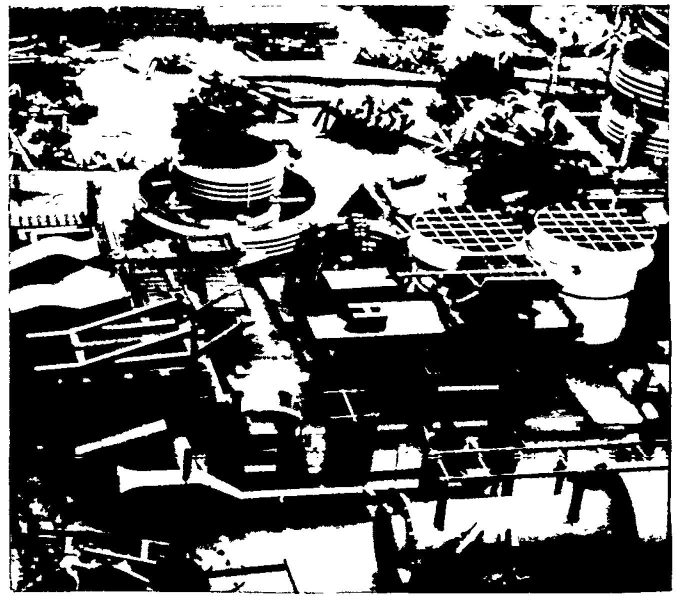
FIGURE 5-34: Subcontractor provided pipe supports which have galvanized U-bolts temporarily attached for ease of in-process material control.

(fabricated by subcontractors). This process is further simplified by control of the deliveries of subcontractor provided components (see Figure 5-35).

5.6 Dimensional Control

l Structural dimensional control was very advanced in the yards visited. Midship units were fabricated neat with no stock, and most bow and stern blocks were cut neat at assembly.

l The dimensional control approach was described as the monitoring and control of each fabrication, sub-assembly and assembly operation based upon worker and supervisory quality control inspection and documentation.



IHI, KURE

FIGURE 5-35: Views of subcontractor provided fabricated materials, delivered in lots that match specific pallets.

Dimensional control standards were stated to be based upon experience and statistical projections of cumulative errors.

This system is considered key in their low assembly and erection man hours as fitup was excellent and rework was minimal.

Stricter adherence to established schedules is achieved because the application of their dimensional control methods result in minimal rework. This is a factor of increased significance in the application of zone construction (parallel zone outfitting and hull block construction).

5.7 Steel Construction

l The block breakdown is defined very early in the contract period and is a key input for functional and detail design.

l The steel plate and shape storage yards are very small compared to U.S. practice. Steel is normally delivered only one or two days prior to fabrication.

l Steel fabrication and assembly shops are large and very well laid out. The area used for steel assembly, relative to the area devoted to ship erection, is greater than in U.S. practice.

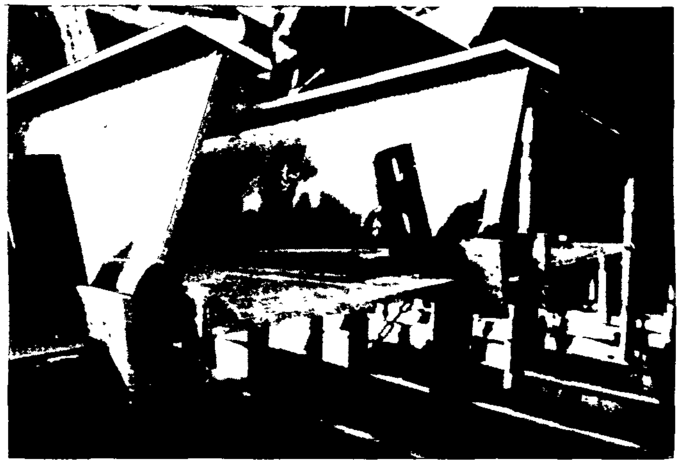
l Steel plates were typically laid out using optical projection in the electrophoto marking process (EPM). After layout, the plates were transferred to a cutting conveyor where they were cut to shape manually. Limited use of numerical control cutting machines was observed.

- Steel shapes were laid out and burned to shape manually while moving on conveyors. The burning conveyors for plates and shapes were similar to those used in the US. The use of conveyors in these applications eliminated crane and handling time.
- Limited use of plate rolls and presses was observed. Heat line bending of plates was observed in all shipyards visited except IHI Aioi [6].
- Subassembly areas were large and well laid out. The subassembly of small floors and web frames was typically accomplished on a moving conveyor or on raised pin jigs. The subassemblies for tanker web frames included staging clips, small lifting pads for use in assembly and handgrabs or ladders for use during assembly and erection.
- IHI has a preference for the "egg crate" assembly method (see Figure 5-36) because with a panel line:
    1. There are more trim and alignment problems with stiffeners.
    2. More facility is required.
    3. Their automatic fillet welders are a bottleneck.
- Directly after the flame planing or cutting of large plates to size, they were joined together and automatically welded with one side welding to form plate blankets.
- After welding of the grid assembly, it was joined to the flat plate blanket to form a complete flat panel block.
- Pin jigs were extensively used for the assembly of curved bilge and side shell units in all shipyards visited.
- All structural blocks were mechanically cleaned and painted prior to erection. Only limited capability for reblasting completed blocks was observed, for those blocks in storage waiting for erection.

NKK, SHIMIZU

FIGURE 5-36: Egg crate steel assembly mechanized jig.

- Midship blocks were fabricated neat with no stock, and most bow and stern blocks were cut neat at final assembly.
- Extensive use was made of jigs throughout the assembly and erection process. Figure 5-37 provides an illustration.



IHI, AIOI

FIGURE 5-37: Jigs used for curved panel structural assembly.

l Permanent access was designed into nontight structural members to facilitate access during assembly and erection.

l Heat line fairing [6], to correct for welding distortion, was observed at all sub-assembly and assembly stages. Figure 5-38 provides an illustration of this process on a large structural block prior to erection.

IHI, KURE

FIGURE 5-38: Heat line fairing to correct for welding distortion.

l Large capital intensive jigs or work fixtures have been developed for tanker and bulk carrier construction.

These include the following:

(1) At the Mitsui Chiba shipyard, the Rotas System was used for the construction of large 60 foot long by 1400 ton wing tanks. These large blocks were assembled on end, the vertical joints were welded using the electroslag process, and then the complete block was rotated mechanically for welding in various positions. After the completion of welding, the block was transferred mechanically to the edge of the dock, lowered into the dock, and transferred mechanically to the erection position.

(2) At IHI Kure shipyard, a mechanical device for rotating large panels on end and providing mechanical staging was observed. This system was used to allow complete downhand welding of the web frame to panel connections.

(3) At the IHI Kure and Aioi shipyards, mechanized work units have been developed to provide staging and services as well as mechanical assistance in the erection, fairing, and welding of shell, longitudinal bulkhead, and deck panels on large tanker and bulk carriers.

5.8 Welding

l The welding process is defined very early in the contract period and is a key input for functional and detail design.

l Subassembly welding was accomplished using gravity rods. The quality of gravity rod welding appeared excellent.

l Flat panel seams were welded using one side submerged arc welding. The one side welding process was used for thicknesses of 9 to 30mm (3/8 to 1¼ inch). The welding of the three-dimensional grids to the flat plate blanket was accomplished using gravity rods.

l Curved panel seams were welded using submerged arc welding against a temporary backing material. The welding of stiffeners and web frames to curved panels *was* accomplished using gravity rods.

l It appeared that all fitting was accomplished prior to releasing the blocks for welding. In some yards the assembly and welding of flat panel blocks was accomplished on a slowly moving floor conveyor.

l Erection welding was based on the maximum use of automatic and semiautomatic welding processes. Typical processes are as follows:

1. Deck plating was welded with submerged arc using temporary backing.
2. Vertical shell and bulkhead butts were welded using the electroslag process.
3. Sloping *or* overhead surfaces were welded using oscillating flux-core or solid wire MIG against temporary backing.
4. Vertical deck longitudinals were welded using the electroslag process. Deck longitudinals were flat bar to facilitate this process.
5. Bottom shell, side shell and longitudinal bulkhead stiffeners were welded using the electroslag process for vertical surfaces and the submerged arc process for horizontal surfaces.

l Mitsui has developed and is testing *two* versions of welding robots for fully automated fillet welding. A limited amount of information is contained in reference 3.

5.9 Computer Aids

- Extensive application of computer aids to all aspects of ship design and construction was evident in all yards, especially those of IHI and Mitsui. Figure 5-39 [7] illustrates the comprehensive coverage of shipbuilding applications at IHI. Refer also to Figure 5-40 which is a list of applications in use at IHI. Figure 5-41 illustrates a similar situation for Mitsui. This situation probably applies as well to NKK [15].

- A wealth of information on various computer aids was distributed to the U.S. team. This is contained in reference 3, pages 3-17 through 3-26, 4-l through 4-7, and references 7 through 15. The salient points pertaining to development and use of computer aids are highlighted in the following paragraphs.

- The IHI aim in computerization is rationalization: computerization does not directly imply the act of using computers, but rather is a means of rationalization, by which the quality of the work involved is improved by the process of job review undertaken in applying computers. Since IHI has a significant number of computer applications in place, it has obviously realized significant productivity increases through this process.

- Both IHI and Mitsui have developed computer applications in areas where the return on investment is the greatest. The following paragraphs cite specific examples.

- Both companies have developed and are using applications in the outfitting area that consist of material control (maintenance of material lists, procurement, palletizing) and outfit schedu1ing.[12] The computeri-

[12] IHI utilizes manual scheduling for ship construction, but used computer scheduling for complex projects such as the floating paper pulp factory (approximately 400 milestones and 30,000 activities).

zation of material lists for procurement and palletizing is considered by IHI to be one of their most important applications.

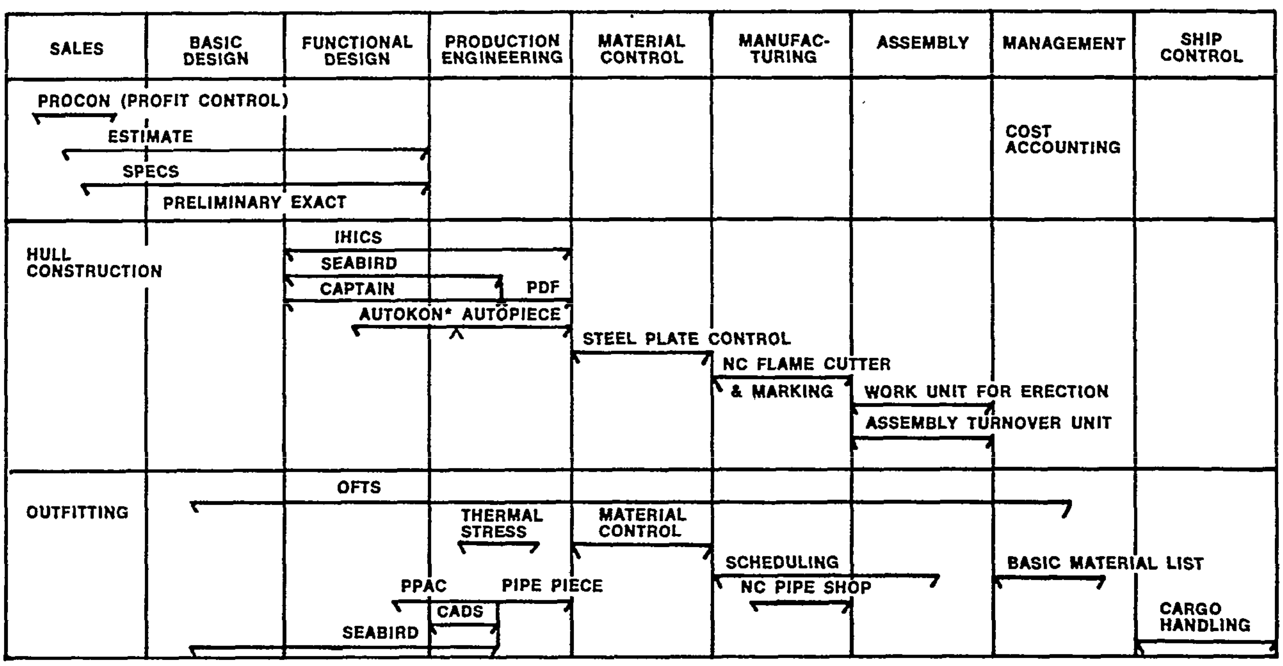
- Both IHI and Mitsui have developed and are using systems for automated pipe fabrication (Mitsui Chiba and IHI Aioi). They also use computer applications for piping design and engineering which either interface to their automated pipe shops or produce fabrication instructions (pipe piece drawing and material lists) for manual or semiautomated pipe fabrication. Their systems also produce pallet information for pipes. Mitsui 'claimed a 60% reduction in man-hours for 70% of the pipe fabrication jobs by utilization of their MAPS system [10] (a system for both design and automated fabrication). A 5O% reduction in man-hours was cited in using this system for preparation of pipe piece drawings and material lists. [3]

- Computer aided structural design and production systems were in use in all yards visited. In these systems in particular, the natural growth of computer development and usage has been from the production department back through the shipyard organization into design and engineering. These systems in general exceed current AUTOKON capabilities in that part coding, nesting and definition of part of the internal ship's structure have been implemented using interactive techniques, minicomputers, and early data base management methods. [13, 7, 8, 9, 11, 14, 15] In the past (1968 through 1976) IHI developed four separate computer systems for structural design and production. Significant reductions in man-hours (12.8 man-hours/NC tape to 3.5 man-hours/NC tape) were reported by Mitsui in utilizing an interactive minicomputer based system for part coding and nesting when compared to their conventional APT like system. [9]

- The use of standards and modules was described in section 5.4. It is apparent that the use of standards with an appropriate computer system has strategic importance in increasing productivity. The following is a quote from reference 5.

  "Standards and modules show their greatest advantage when integrated with a comprehensive computer system. As the design and production process is consistently modularized, the computer can automatically output necessary drawings, material lists, N.C. tapes, purchasing and production control parameters, etc., from very limited input data. Modifications to meet owner's options are easily available by replacing the input data of applicable modules."

- IHI has implemented an advanced interactive computer aided design system (for both structure and outfitting) called SEABIRD [7, 8, 11] which utilizes an early data base management system (IMS). This



*The insertion of AUTOKON on this figure is for comparison purposes only. IHI developed AUTOPIECE, an interface program for AUTOKON users to automate piece part production.

FIGURE 5-43: Shipbuilding computer applications-IHI.

Group	NAME OF SYSTEM	DESCRIPTION	PRESENT SITUATION (NOV. 1979) TOKYO	KURE	AIOI	DEVELOPMENT HISTORY (69 '70 '71 '72 '73 '74 '75 '76 '77 '78 '79)
	ZPLATE	STRUCTURAL ANALYSIS FOR PLANE STRESS (UNIVAC & IBM VERSION)	IN USE	IN USE	IN USE	ORIG-INAL; NEW VERS.
	ZUNIT	STRUCTURAL ANALYSIS FOR FRAME (UNIVAC VERSION)	IN USE	IN USE	IN USE	
	ZVIBRA	VIBRATION ANALYSIS (UNIVAC VERSION)	IN USE	IN USE	IN USE	
	SPECS	INTEGRATED SHIP CALCULATION •HYDROSTATIC PROPERTIES •STABILITY •TRIM •ETC (IBM VERSION)	IN USE	IN USE	IN USE	NEW VERSION
	TOTAL SYSTEM FOR SHIP PROPULSIVE PERFORMANCE	SHIP PROPULSIVE PERFORMANCE CALCULATION BASED ON TANK TEST, SEA TRIAL AND THEORETICAL CALCULATION FOR INITIAL DESIGN USE	IN USE (BASIC DESIGN) (UNIVAC)	/	/	
	APOLOS	APT TYPE PART PROGRAM SYSTEM FOR NC (IBM) BATCH TYPE	/	/	IN USE	
	IHICS	APPLICABLE FROM DESIGN STAGE FOR NC (HULL SYSTEM) IMS, PARTIALLY REAL TIME (IBM)	IN USE	IN USE	/	ORIGINAL; NEW VERSION
	CAPTAIN	APPLICABLE FROM DESIGN STAGE FOR NC (HULL SYSTEM) CADS USE (INTERACTIVE DESIGN) (UNIVAC)	STOP USAGE	/	/	
	SEABIRD	INTEGRATED DESIGN SYSTEM COVERING ALL FIELDS OF SHIP DESIGN FULL REAL TIME, INTERACTIVE DESIGN BY IBM 2250 (IBM)	/	/	STOP USAGE	
	SHELL	SHELL PLATE EXPANSION (IBM)	IN USE	IN USE	IN USE	
	LODACS	LONGITUDINAL FRAME DEVELOPMENT (IBM)	IN USE	IN USE	IN USE	
	STEEL PLATE ORDERING & CONTROL SYS	(IBM)	IN USE	IN USE	IN USE	
OUTFITTING TOTAL SYSTEM (OFTS)	PIPE PIECE DRAWING SYS	(IBM)	IN USE	IN USE	IN USE	
	WOODEN FITTING PIECE PROGRAM IN ACCOMMODATION	DEVELOPMENT OF WOODEN MATERIAL (IBM2250 USE) (IBM)	/	/	IN USE	
	ELECTRIC WIRE & CABLE WAY	DEVELOPMENT OF REQUIRED WIRE LENGTH & CABLE WAY (IBM)	IN USE	IN USE	IN USE	
	MATERIAL CONTROL SYSTEM	PALLET CONTROL (IBM)	STOP USAGE	IN USE	IN USE	
	PIPE FABRICATION SYSTEM	FOR PIPE SHOP (IBM)	/	IN USE	IN USE	
	OUTFITTING SCHEDULE SYSTEM	DETERMINATION OF REQUIRED DATE OF PALLET (IBM),	STOP USAGE	STOP USAGE	STOP USAGE	
	PPAC	AUTOMATIC PIPING LAYOUT (CADS USE) (IBM)	/	STOP USAGE		
	IR	INFORMATION RETRIEVAL OF ENGINEER-DOCUMENTS IN IHI. REAL TIME (UNIVAC)	IN USE	IN USE	IN USE	
	MICRO FILM	DOCUMENTS & DRAWINGS STORAGE & RETRIEVAL	IN USE	IN USE	IN USE	

FIGURE 5-40: Major shipbuilding software systems in use—IHI.

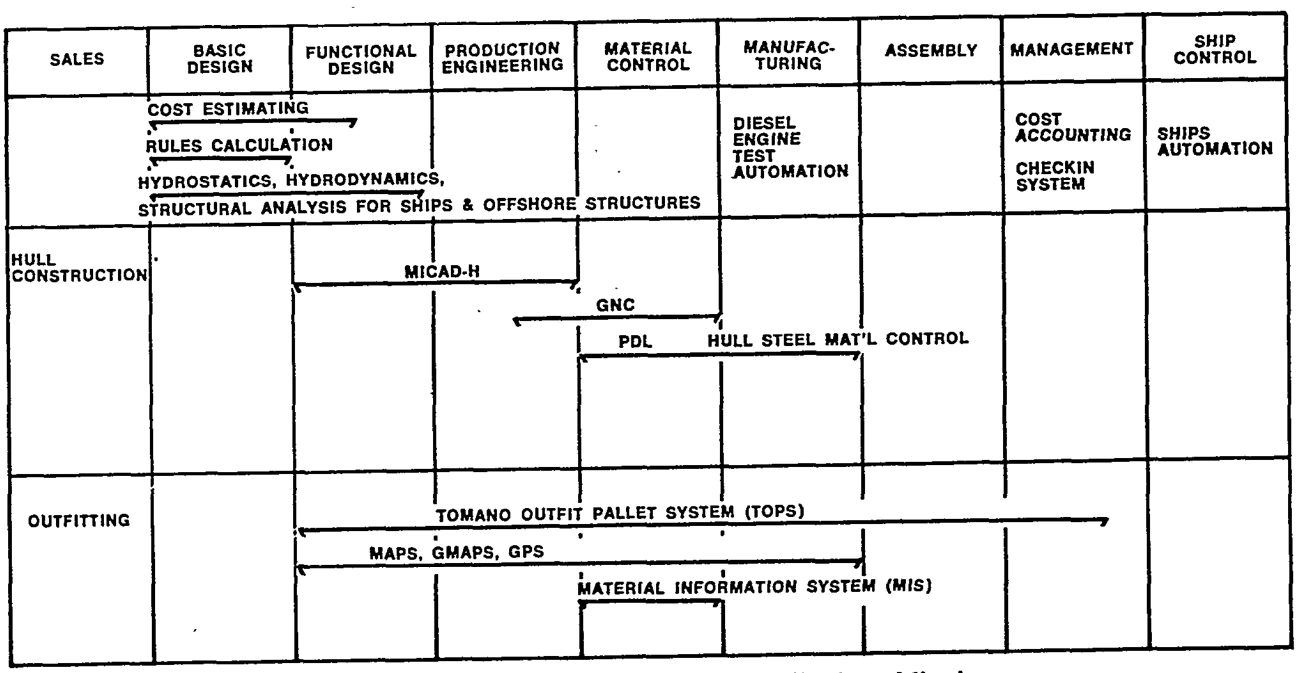


FIGURE 5-41: Shipbuilding computer applications—Mitsui.

system was used on 10 ships and resulted in a 30% savings in design cost and time. This system is no longer in use due to an excess of experienced designers[13] (in the current depressed market) and the costs required to update it to new computer technology (hardware primarily). IHI states they will use SEABIRD in the future when business improves. A significant aspect of this system is that it makes use of IHI standards and modules.

l IHI applied over 3900 man-days performing consulting services, and, developing very detailed computer system and program specifications for Italcantieri in the following areas:

1. Hull erection system and scheduling
2. Material control system
3. Budget and cost control
4. Unit outfitting methods and outfitting scheduling system.
5. Automated pipe manufacturing and system
6. Subassembly methods for hull construction

As a result, over a 6 year period Italcantieri, Monfalcone progressed from three 260,000 DWT tankers per year to five per year.

6. CONCLUSIONS AND RECOMMENDATIONS

Based on observations made in the six Japanese shipyards visited, the following items are cited as the primary reasons for their high productivity:

(1) The utilization and application of the logic and principles of zone planning and construction.

(2) The development and use of a very effective material classification scheme for definition, procurement, and control of material.

(3) The extensive use and continual development of high quality shipbuilding standards and modules.

(4) The rationalized development and use of effective cost/man-hour reducing computer aids.

While these techniques and methods are of unquestioned value in achieving productivity improvements, it is also important to note the human aspects of their application. Japanese shipbuilding middle managers are highly educated, and are rotated in various job assignments so that they acquire experience in all facets of the shipbuilding process.

6.1 Recommended Projects

A considerable amount of research and documentation of advanced methods and techniques has already been performed within the NSRP and is available with the publication of *Outfit Planning [2].*

Several U.S. shipyards (Avondale, Levingston, National Steel, Sun Shipbuilding, and Tacoma Boatbuilding) have already initiated implementation of IHI or other leading shipbuilders' methods.

Emphasis is being placed within the various panels of the Ship Production Committee to identify projects which will assist U.S. shipyards to adopt the techniques of zone planning and construction.

It is significant to note that panel SP-2 (Outfitting Aids) has already initiated the ongoing project Product-oriented Work Breakdown Structure (PWBS) in order to facilitate transition from system to zone orientation.

With these considerations in mind, and based upon the conclusions cited above, the project team has developed a series of recommended projects. Note that these recommended projects also address the nine areas cited in the MEL report [1], as those which would require minimum investment to implement. Furthermore, these recommendations are specifically oriented toward projects which will permit a more rapid adoption of the advanced technology. The following pages detail a series of proposed projects for the NSRP.

[13] Note that companies hire employees for the duration of their working life.

TITLE: Zone Planning

Background: The book, *Outfit* Planning, published in December 1979 by the NSRP introduced an advanced approach which was developed by IHI. It employs zones very productively, but impacts deleteriously to some degree on shipbuilders traditional goals to maximize steel throughput by facilitating both outfitting and painting precise zones at specified times. U.S. shipbuilders are adopting this logic and have a need to re-orient traditional hull construction and painting planners. Further, they have a need to teach outfit planners hull construction and painting options.

Objective: Expand the text of *Outfit Planning* to include hull and painting aspects of zone construction. Specifically, show that the logic for the hull block construction method and for zone outfitting and painting are identical.

Approach: In order to maintain consistency and the same level of comprehension, employ the same resource team, on a level-of-effort basis, that prepared *Outfit Planning.*

Benefits: Shipbuilders will be able to train all functionaries who impact on planning in a coordinated manner.

Cost: The overall estimated cost is $160,000.

TITLE: Zone Planning Example

Background: The book, *Outfit Planning,* published in December 1979 by the NSRP introduced an advanced outfitting approach which was developed by IHI. U.S. shipbuilders are rapidly acquiring an understanding and are formulating strategic goals. Some have already requested more detailed information to facilitate implementation.

Objective: Prepare a pamphlet for an IHI ship, which anticipates a type which would most characterize U.S. ship construction for the next decade. It is to contain examples of at least:

a. diagrammatics
b. material ordering zones
c. block breakdown
d. rough composite drawing
e. pallet list
f. composite drawing
g. work instruction drawing
h. MLS, MLP, MLC and MLF
i. etc.

Approach: Retain IHI Marine Technology, Inc., on a level-of-effort basis to prepare an English language pamphlet including explanatory material. Also, specify the level-of-effort for one subcontractor to prepare and make modifications needed for publication.

Benefits: Shipbuilders will be able to implement certain aspects of zone planning pending the end products of other more comprehensive pertinent research projects.

Cost: The estimated overall cost is $90,000 with one-half to be specified for the special graphics and modifications needed for publication.

Duration: 1 year.

TITLE: Zone Planning Educational Aids

Background: The book, *Outfit Planning,* published in December 1979 by the NSRP introduced an advanced approach which was developed by IHI. U.S. shipbuilders are already adopting the logic and have expressed a need for educational aids to assist implementation. Planning by zones necessarily means changes to traditional approaches such as those already proven by the world's most competitive shipyards.

Objective: The objective is to use the most effective techniques to describe various aspects of these new methods to lower and middle managers in U.S. shipyards.

Approach: Subdivide and prioritize the entire shipbuilding process into discrete functions. Establish the impact of the new methods on each functional category. Develop specific aids to permit understanding of the objectives and procedures already implemented by very competitive shipbuilders.

Benefits: Primarily due to the near perfect implementation of the zone approach, some shipbuilders abroad expend only one-half the time and cost per ship as compared to even the best U.S. shipyards. A general understanding will most certainly cause implementation throughout the U.S. shipbuilding industry. This would assuredly decrease these significant differentials.

Cost: The most critical training aid required would address functional and detail design. Its estimated cost is $150,000. Four additional subjects are estimated at a cost of $75,000 each.

TITLE: Handbook for Production Process Planning and Engineering

Background: The book, *Outfit Planning*, published in December 1979 by the NSRP advised U.S. shipbuilders of the relatively educated middle managers in the most competitive Japanese shipyards and their very effective development of planning and engineering of production processes. It is believed by the most successful Japanese shipbuilders, that U.S. shipbuilders are particularly deficient in not organizing and implementing in a similar manner.

Objective: Describe the pertinent logic, principles and methods of two of the most competitive Japanese shipbuilding firms. Apply special emphasis to organizations and the qualifications of incumbents.

Approach: Retain IHI Marine Technology, Inc. and Mitsui Engineering and Shipbuilding Co. on level-of-effort basis to prepare English language manuals that are well illustrated. Also, specify the level-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single manual.

Benefits: The benefits are optimized and continuously updated rationalized fabrication and assembly processes. These, when recorded as production process standards, are the bases for a shipyard's standard designs and/or provide beforehand necessary guidance for basic, functional and detail design. Further, they are an essential means for a shipyard to retain the accumulation of useful fabrication and assembly experiences.

Cost: The estimated overall cost is $280,000 with $100,000 applied to each shipbuilding firm's level-of-effort and the remainder for preparations needed for publication.

Duration: 2 years.

TITLE: Electric Cable Palletizing

Background: A few U.S. shipbuilders precut some cable to specified lengths before installation even in the first ship of a class. However, the technique is not fully exploited whereas it is a significant cost saving material control measure in general use in the Japanese shipbuilding industry. Paradoxically, because the USCG and ABS allow electric cable splices specifically to facilitate the shipbuilding process, U.S. shipbuilders have an opportunity to obtain greater such benefits than are available to shipbuilders abroad.

Objective: Describe the pertinent logic, principles and methods of two Japanese shipbuilding firms known to routinely precut cable for palletizing.

Approach: Retain Mitsui Engineering and Shipbuilding Co., and IHI Marine Technology, Inc. on level-of-effort basis to prepare English language pamphlets including explanatory materials. Also, specify the sublevel-of-effort for one subcontractor to integrate the materials, develop special graphics and make modifications as needed to produce a single pamphlet.

Benefits: The technique results in lower costs both for material procurement and handling and in vastly improved material controls and adherence to schedules.

Cost: The estimated overall cost is $140,000 with $50,000 applied to each shipbuilding firm's level-of-effort and the remainder for preparation needed for publication.

Duration: 1 year.

TITLE: U.S. Shipbuilding Standards Program-Long Term Objectives.

Background: Japanese shipbuilders have been able to achieve significant reductions in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their extensive design experience and the documentation of this experience in the form of standards. In that the U.S. industry has not developed this high level of design experience; and that at this time it is facing the requirement for achieving shorter design and construction periods; an expanded U.S. Shipbuilding Standards Program in the areas of functional design, detail design, and production processes is recommended. It is felt that standards developed in these areas on an industrywide basis would have greater value and acceptance than if developed only within the individual shipyards. Additionally, these standards will be a necessary input to the efficient use of advanced CAD systems that are projected to be available by the mid-1980's.

Objective: The development of a comprehensive set of U.S. shipbuilding standards in the area of functional design, detail design and production processes. These standards would be developed for the areas of hull structure, machinery, deck outfit, accommodations and electrical for the range of ship types and power plants projected for use in the 1980's and early 1990's. These standards would be used to update the MarAd shipbuilding specifications, and would be structured in a manner to facilitate their use in any advanced CAD system purchased or developed by the industry.

Approach: Purchase consulting assistance in the areas of standard development, organization, maintenance and possible purchase of existing standards from a leading Japanese shipbuilding firm (such as IHI or Mitsui) having extensive experience in these areas. Document and distribute the approach used for standards development and maintenance, and ensure the use of a standard coding system to the extent practicable. Additionally, assistance would be obtained from U.S. shipyards, design agents, owners, equipment vendors and regulatory bodies. Standards development would initially be based upon the MarAd standard designs; however, future standards development is envisioned to include the development and maintenance of standards covering the required range of ship types and power plants. The intent would be to maintain the maximum degree of similarity or standardization possible, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

Benefits: The proposed project would lead to increased U.S. design experience in many areas and the documentation of this experience in a form usable by shipyards, design agents, shipowners and MarAd. This would lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches. Additionally, documentation of design experience including feedback from all areas will assist in improving the quality of U.S. design work.

Duration: (a) Initiate the U.S. Standards Program-state objectives, develop a request for proposal, review the Japanese standards approach in the first half of 1980.

(b) Develop standards for key ship types during the 1980-1985 period (including MarAd standard designs).

(c) Expand and maintain program.

TITLE: U.S. Shipbuilding Standards Program-Functional Design Standards/Modules for Machinery Spaces.

Background: Japanese shipbuilders have been able to achieve significant reduction in design cost and schedule duration relative to U.S. practice. A significant part of this reduction is due to their experience and the documentation of this experience in the form of standards that include the area of functional design in addition to that of raw material and fittings as presently covered by the U.S. standards program. Note that the ability to speed up the design process is considered the key to the implementation of advanced outfitting techniques such as zone outfitting.

Objective: Develop with Japanese assistance in the technical and standards areas, functional design standards/modules for machinery spaces and related systems for the range of ship types and power ranges covered by the three MarAd standard designs. These would include reusable machinery space arrangements; system diagrams; definition of outfit units; pipe passage layouts; definition of system and equipment specifications; and to the extent practical, definition of alternate vendor's equipment for the main engines, generators, and key auxiliaries.

Approach: Functional design and standards development would be conducted with the assistance of consulting in the technical and standards areas from a Japanese shipbuilding firm (IHI or Mitsui) having extensive experience in these area. Additionally, assistance would be obtained from the vendors of main propulsion engines and auxiliary equipment. Functional design including arrangements, system diagrams, etc., would be developed for the three MarAd standard designs based upon two main engine vendors. The intent would be to maintain the maximum similiarity or standardization possible for this range of applications and power requirements, while retaining the flexibility of individual shipyards or designers being able to easily modify the standards to suit individual service requirements.

Benefits: The proposed project would lead to increased U.S. design experience in the area of machinery spaces and the documentation of this experience in a form usable by shipyards, design agents, shipowners and MarAd. This would in turn lead to a significant reduction in design cost and schedule duration, which is a key requirement to the implementation of advanced outfitting techniques such as zone outfitting and to achieving the significant savings in production cost imminent in these approaches.

Cost: To be developed.

Duration: 12 months-mid-1980 to mid-1981 depending upon funding.

TITLE: Construction Services

Background: For many years, U.S. shipyards have been plagued by a "helter-skelter" approach in supplying construction services to work areas for ship construction. Poor construction service practice results in poor housekeeping typified by cluttered decks and access passageways. These invite poor working conditions with resultant waste of man-hours and potential safety problems.

Objective: Develop a manual. for distribution to shipyards, which would describe and illustrate various methods by which construction services can be installed to conveniently supply all the needed services to shops and ships in a preplanned manner.

Approach: The developer of the manual should study various U.S. shipyards and selected foreign shipyards to determine present practices. Candidate areas for investigation are as follows:

1. Scaffolding is always a problem, particularly when needed in such high and hazardous places as the underside of the upper deck in large tankers and/or bulk cargo ships. Presently the scaffold builder is faced with a heel-handing operation to both build and remove such scaffolding. A possible solution is to have engineering, during development of structural drawings, design and detail special scaffolding brackets, etc., which could be installed during assembly of a hull block. Hopefully these would be approved by the owner of the vessel to permit welded clips, etc., to remain on the structure. This would make the scaffold builder's job safer in both installation and removal operations.

2. Temporary lighting, compressed air service, water for firefighting and other uses, gases used for cutting and welding, temporary phone service, etc., for on-board use. All of these services have posed big problems. Normally they are run from the ground and over the side of the vessel at the most convenient place for a worker to use at a given time. Many of these service lines remain in place and tend to accumulate into a mass of cables and hoses, mostly underfoot and down ladderways. A possible solution for on-board use, is to have a series of portable archways installed on the topmost deck of the vessel with all of the above services suspended from the top of the arch high enough above the deck to permit passage below. Standard length pipe sections (flanged) could be developed and manifolds for each system could be mounted on the archways at convenient spacing. Hoses could be used to connect systems to towers at the side of the ship which would carry service lines from distribution systems on the ground.

3. Improved material handling methods for all types of material and equipment such as various types and sizes of pallets, types of vehicles used to handle and transport and methods to lift aboard ship.

4. Welding power sources and welding power distribution systems.

5. Temporary ventilation systems for confined spaces.

6. Rigging methods and equipment to help workers handle and install all manner of equipment and material in both shops and on-board.

7. Access methods to aid in transporting workers from ground level to on-board areas, both interior and exterior. This item should also include a planned arrangement of temporary openings in ship structure for both horizontal and vertical access for workers and construction service lines.

The above list is not to be considered complete and the developer of the manual should work with shipbuilders to assure that all possible areas of construction service problems are included in this survey.

Benefits: If properly approached and accomplished, benefits would include:

1) Improved safety (dramatically)

2) Better working conditions that would produce:
   - more efficient work environment
   - reduced man-hours
   - shorter building schedules

Cost: The estimated cost is $120,000.

References: "Project Safe Yard" Long Beach Naval Shipyard.

Duration: Estimated duration is 1.5 years after award of contract.

TITLE: Jigs, Fixtures and Special Tools

Background: Observations of fabrication, assembly and installation operations at Japanese shipyards reveal many jigs and fixtures are employed to assist in joining various parts and assemblies. Many of these special tools could be readily adopted by U.S. shipyards to assist tradesmen in numerous production operations.

Objective: Develop a well illustrated manual which describes the use of jigs, fixtures and special tools.

Approach: The researcher should canvass shipyards, both foreign and domestic, for any jigs, fixtures or special tools now in use. Review equipment available from specialty-tool manufacturers who may have many tools already available (an example is the Ener-Pac Co. which markets a modified jack clamp using a small portable hydraulic jacking device for aligning structures for joining).

Benefits: The use of special jigs, fixtures and tools can yield:

- Safer and better working conditions
- Reduced manhours and cost
- More efficient use of material and services

Cost: The estimated cost is $100,000.

Duration: Estimated duration is 1.5 years after award of contract.

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