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TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

PLANNING AND PRODUCTION CONTROL SYSTEM

0029

PLANNING & PRODUCTION CONTROL VOLUME 1 REPORT

Prepared by:

Livingston Shipbuilding Company
in conjunction with:
IHI Marine Technology Inc.

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PREFACE

This report is one of several emanating from the Shipbuilding Technology Transfer program performed by Livingston Shipbuilding Company under a cost-sharing contract with the U.S. Maritime Administration.

The material contained herein was developed from the study of the Planning & Production Control systems presently in operation in the shipyards of Ishikawajima-Harima Heavy Industries (IHI) of Japan. Information for this study was derived from source documentation supplied by IHI, information obtained directly from IHI consulting personnel assigned on-site at Livingston, and from personal observations by two teams of Livingston personnel of actual operations at various IHI shipyards in Japan.

In order to place this study in context within the overall Technology Transfer Program, a brief overview of the program and its organization is provided in the following paragraphs.

THE TECHNOLOGY TRANSFER PROGRAM (TTP)

The U.S. shipbuilding industry is well aware of the significant shipbuilding cost differences between the Japanese and ourselves. Many reasons have been offered to explain this differential and whether the reasons are valid or not, the fact remains that Japanese yards are consistently able to offer ships at a price of one-half to two-thirds below the U.S. prices.

Seeing this tremendous difference first hand in their own estimate of a bulk carrier slightly modified from the IHI "Future-32" class design, Livingston management determined not only to find out why this was

true but also to attempt to determine precise differences between IHI and Livingston engineering and design practices; production planning and control methods; facilities, production processes, methods and techniques; quality assurance methods; and personnel organization, operations and training. The obvious objective of such studies was to identify, examine and implement the Japanese systems, methods and processes which promised a significant improvement in the Livingston design/production process.

With this objective in mind, and recognizing the potential application of the TTP results to the American shipbuilding industry, Livingston initiated a cost-sharing contract with MarAd to provide documentation and industry seminars to reveal program findings and production improvement results measured during production of the bulkers. At the same time, Livingston subcontracted with IHI Marine Technology Inc. (an American corporation and a subsidiary of IHI, Japan) specifying the areas to be explored and the number and type of IHI consulting personnel required during the period of re-design and initial construction of the first bulker.

Basically, the program is organized into six major tasks:

- 1 - Cost Accounting
- 2 - Engineering and Design
- 3 - Planning and Production Control
- 4 - Facilities and Industrial Engineering
- 5 - Quality Assurance
- 6 - Industrial Relations

Beneath each of these major tasks is a series of sub-tasks which

further delineate discrete areas of investigation and study. Each sub-task area has been planned and scheduled to: 1) study IHI systems, methods and techniques; 2) compare the Livingston and IHI practices; 3) identify improvements to the Livingston systems; 4) implement approved changes; 5) document program findings, changes to the Livingston systems, and the results of those changes; and 6) disseminate program findings and results to industry via MarAd.

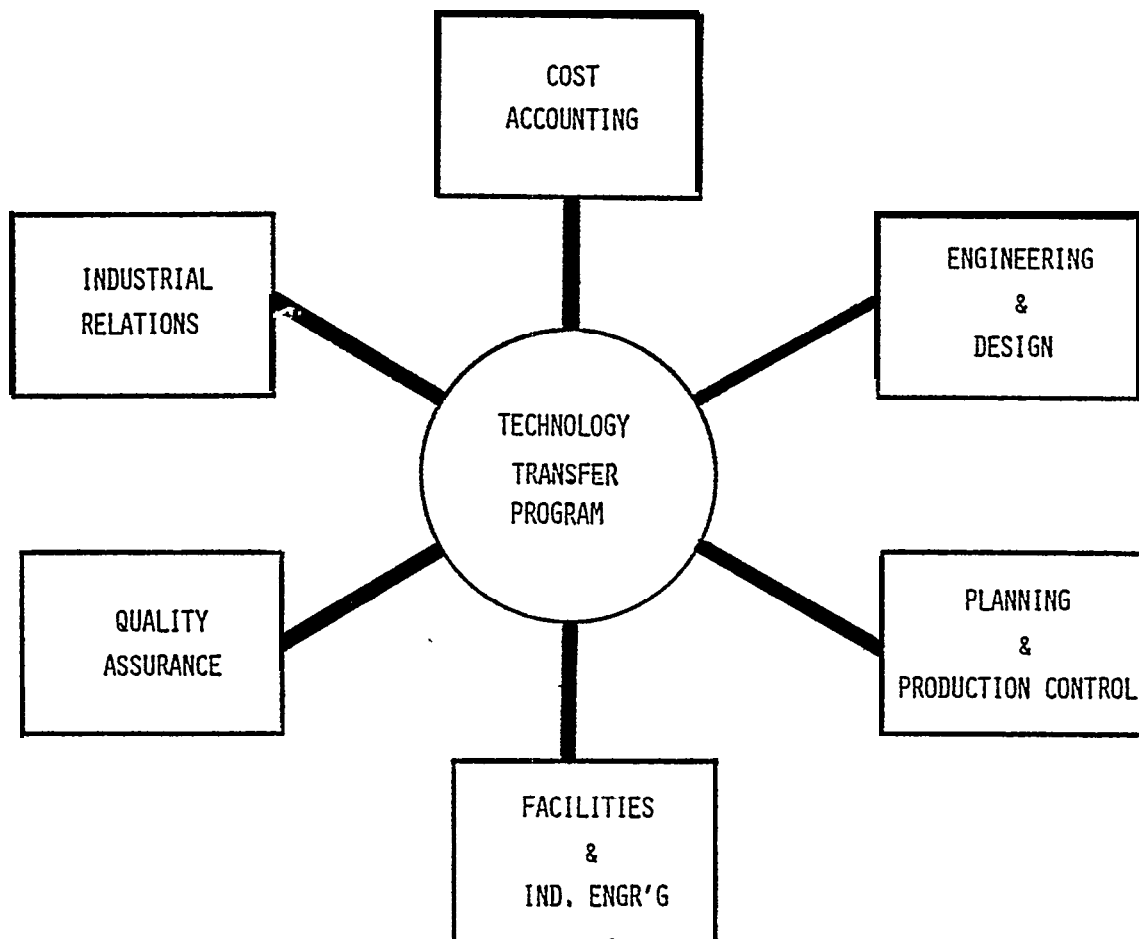


TABLE OF CONTENTS
VOLUME I - PLANNING AND PRODUCTION CONTROL

<u>SECTION</u>	<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE NO.</u>
1		INTRODUCTION	
	1.1	Purpose and Scope	1-1
	1.2	Organization of Report	1-1
	1.3	References	1-2
	1.4	Definitions	1-3
2		THE IHI PRODUCTION SYSTEM	
	2.1	General	2-1
	2.2	The Material Element	2-3
	2.2.1	Design	2-3
	2.2.2	Procurement	2-9
	2.2.3	Manufacturing	2-11
	2.3	Facilities	2-16
	2.4	Personnel	2-20
	2.5	Conclusion	2-22
3		THE IHI PLANNING SYSTEM	
	3.1	General	3-1
	3.2	Hull Construction Planning	3-2
	3.2.1	Preliminary Planning	3-4
	3.2.1.1	Block Assembly Planning	3-7
	3.2.1.2	Schedules & Plans	3-10
	3.2.2	Detailed Planning	3-11
	3.2.2.1	Assembly Specification Plans	3-12
	3.2.2.2	Other Plans	3-14

TABLE OF CONTENTS (CONT.)

<u>SECTION</u>	<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE NO.</u>
	3.2.3	Working Instruction Plans	3-14
	3.2.3.1	Working Instruction Plans for Fabrication	3-17
	3.2.3.1.1	Cutting Plans	3-17
	3.2.3.1.2	Bending Plans	3-19
	3.2.3.2	Working Instruction Plan for Sub-assembly and Assembly	3-24
	3.2.3.2.1	Block Parts List	3-24
	3.2.3.2.2	Block Lifting Instructions Plan	3-24
	3.2.3.2.3	Working Instruction Plan for Sub-assembly	3-26
	3.2.3.2.4	Working Instruction Plan for Assembly	3-26
	3.2.3.2.5	Finishing Dimensions Plan	3-26
	3.2.3.2.6	Assembly Jig Arrangement Plan	3-35
	3.2.3.3	Working Instruction Plans for Erection	3-35
	3.2.3.3.1	Hull Blocking Plans	3-35
	3.2.3.3.2	Shipwright Dimensions Plans	3-37
	3.2.3.3.3	Supporting Block Arrangement Plans	3-37
	3.2.3.3.4	Welding Process Instruction Plans	3-37
	3.2.3.3.5	Scaffolding Arrangement Plan	3-41
	3.3	Outfit Planning	3-41
	3.3.1	Design	3-45
	3.3.2	Procurement	3-60

TABLE OF CONTENTS (CONT.)

<u>SECTION</u>	<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE NO.</u>
	3.3.3	Material Control	3-60
	3.3.4	Production	3-68
	3.3.4.1	Pipe Shop	3-71
	3.4	Additional Planning	3-75
4		THE IHI SCHEDULING SYSTEM	
	4.1	General	4-1
	4.2	Ship Construction Master Schedule	4-6
	4.3	Major Milestone Schedule	4-7
	4.4	Erection Master Schedule	4-7
	4.5	Assembly Master Schedule	4-11
	4.6	Subordinate Schedules	4-15
	4.6.1	Fabrication Sub-schedules	4-19
	4.6.1.1	Mold Loft Schedules	4-19
	4.6.1.2	Marking, Cutting and Bending	4-20
	4.6.1.3	Sub-assembly	4-22
	4.6.1.4	Assembly	4-22
	4.6.1.5	Erection	4-27
	4.7	Outfitting Schedule	4-28
	4.7.1	Outfitting Milestone Schedule	4-30
	4.7.2	Outfitting Master Schedule	4-30
	4.7.3	On-unit, On-block and On-board Master Schedules	4-33
	4.7.4	Working Schedules	4-33
	4.7.5	Pipe Fabrication Scheduling	4-36

TABLE OF CONTENTS (CONT.)

<u>SECTION</u>	<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE NO.</u>
5		MANPOWER PLANNING	
	5.1	General	5-1
	5.2	Budget Planning	5-2
	5.3	Specific Manpower Planning Methods	5-3
	5.3.1	Production Planning Estimate	5-5
	5.3.2	Manhour Planning	5-7
	5.3.3	Work Load Schedule	5-7
	5.3.4	Manhour Efficiency Control	5-9
	5.3.5	Manhour Control	5-9
6		PRODUCTION CONTROL	
	6.1	General	6-1
	6.2	Production Control Department	6-2
	6.3	Production Planning and Engineering Groups	6-2
	6.3.1	Hull Construction	6-5
	6.3.2	Outfitting	6-13
7		LEIVINGSTON APPLICATION OF IHI TECHNOLOGY	
	7.1	General	7-1
	7.2	Chronology of the LSCo. Study and Application	7-3
	7.2.1	Block Assembly Planning	7-5
	7.2.2	Process Lanes System	7-6
	7.2.3	Gate System Planning and Scheduling	7-8
	7.2.3.1	Key Erection Plan	7-8

TABLE OF CONTENTS (CONT.)

<u>SECTION</u>	<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE NO.</u>
	7.2.3.2	Basic Production Flow List	7-13
	7.2.3.3	Unit Information List	7-13
	7.3	Outfit Planning	7-16
	7.4	Schedules	7-20
	7.5	Manpower Planning and Performance Measurement	7-20
	7.6	Current Livingston Application	7-24
		APPLICATION TO U.S. SHIPBUILDING	
	8.1	General	8-1
	8.2	Hull Construction	8-3
	8.3	Outfitting	8-4
	8.4	Conclusion	8-6

VOLUME II - APPENDICES

Glossary of Terms	A-1
Product-Oriented Work Breakdown Structure	B-1
Hull Blocking Plan	c-1
Block Assembly Plan	D-1
Field Plans	E-1
Gate System Implementation	F-1

LIST OF ILLUSTRATIONS

<u>FIGURE N O .</u>	<u>TITLE</u>	<u>PAGE NO.</u>
2-1	Design Development	2-5
2-2	Concept of Accuracy Control in IHI	2-7
2-3	Typical Purchasing Process	2-8
2-4	Design/Production Interface	2-10
2-5	Organization for Production	2-12
2-6	Flow of Outfitting Activities	2-15
2-7	Facilities Arrangement of Aioi Shipyard	2-17
2-8	Layout of Shipyard and Steel Flow Arrangement	2-19
2-9	Typical Organization for IHI Yards	2-21
2-10	Organizational Structure of New Construction	2-23
2-11	Organizational Structure of Design Division	2-24
3-1	Hull Construction Planning Flow with Milestone	3-5
3-2	F-32 Block Arrangement	3-8
3-3	Block Assembly Plan "Example"	3-9
3-4	Preliminary Assembly Specification Plan	3-13

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
3-15	Detailed Assembly Specification Plan	3-15
3-6	Development of Working Instruction Plans for Fabrication	3-18
3-7	Cutting Plan	3-18
3-8	Steel Material Allocating List	3-20
3-9	Size List for Flat Bar	3-20
3-10	Size List for Face Plate	3-21
3-11	Size List for Longitudinal	3-21
3-12	Bending Plans for Steel Plate	3-22
3-13	Size List for Bending Plans for Steel Plates	3-23
3-14	Bending Plans for Shape	3-23
3-15	Block Parts List	3-25
3-16	Block Parts List	3-25
3-17	Process Flow of Block Lifting Instruction Planning	3-27
3-18	Block Lifting Instructions Plan	3-28
3-19	Process Flow of Sub-assembly Planning	3-29

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
3-20	Working Instructions Plan for Sub-assembly	3-29
3-21	Working Instructions Plan for Sub-assembly	3-30
3-22	Process Flow. of Assembly Planning	3-30
3-23	Working Instructions Plan for Assembly	3-31
3-24	Working Instructions Plan for Assembly	3-32
3-25	Process Flow of Block Finishing Dimensions Planning	3-33
3-26	Finishing Dimensions Plan	3-34
3-27	Process Flow of Arrangement for Assembly Jig	3-36
3-28	Assembly Jig Size List	3-36
3-29	Hull Blocking Plan	3-38
3-30	Shipwright Dimensions Plan	3-39
3-31	Block Arrangement Plan	3-40
3-32	Welding Process Instruction Plans	3-42
3-33	Welding Process Instruction Plans	3-42
3-34	Scaffolding Arrangement Plan	3-43

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
3-35	Outline of Scaffolding Facilities	3-44
3-36	Flow of Outfitting	3-46
3-37	Material List by System	3-48
3-38	Different Ship Zones	3-49
3-39	Outfitting Zones	3-51
3-40	Material List for Pipe (MLP)	3-53
3-40 (Cont.)	Material List for Component (MLc)	3-54
3-41	Composite Drawing	3-55
3-42	Outfitting Design Development	3-57
3-43	Work Instruction Drawing	3-58
3-44	Material List for Fitting (MLF)	3-59
3-45	Procurement Information Flow	3-61
3-46	Functional Flow of Material and Requisition	3-62
3-47	Purchasing Process	3-63
3-48	Functional Flow of the Subcontracting Process	3-64

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
3-49	Functional Flow of the Warehouse & Palletizing Process	3-66
3-50	The Material Control System	3-67
3-51	Fitting Department	3-69
3-52	Process Flow of Fitting Work	3-70
3-53	Flow of Drawing and Material	3-72
3-54	Typical Pattern of Work Process and Drawings	3-73
3-55	Essential Elements of Pipe Fabrication Control System	3-74
3-56	Pipe Fabrication Control Process	3-76
4-1	Hierarchy of Schedules	4-2
4-2	Ship Construction Master Schedule	4-8
4-3	Ship Construction Master Schedule (Example)	4-9
4-4	Major Milestone Schedule	4-10
4-5	Erection Master Schedule	4-12
4-6	Advance Days Required for Additional Work After Assembly	4-14
4-7	Required Assembly Days Standard per Hull Structural Type	4-16

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
4-8	Comparison for Assembly Scheduling	4-17
4-9	Assembly Master Schedule	4-18
4-10	Mold Loft Schedule	4-21
4-11	Marking & Cutting Schedule (Skin)	4-23
4-12	EPM or Manual Marking and Cutting Schedule (Parts and Pieces)	4-24
4-13	Bending Schedule	4-25
4-14	Outfitting Scheduling System (IHI)	4-29
4-15	Outfitting Milestone Schedule	4-31
4-16	Outfitting Milestone Schedule	4-32
4-17	Outfitting Master Schedule	4-34
4-18	Outfitting Master Work Schedule	4-35
4-19	Monthly Schedule	4-37
4-20	Weekly Schedule	4-37
4-21	Long Term Schedule	4-38
4-22	Short Term Schedule - Pipe Shop	4-39

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
5-1	Budget Process	5-4
5-2	Production Planning by Weight, Cutting Length and Welding Length	5-6
5-3	Manhour Planning	5-8
5-4	Manhour Estimation Table	5-8
5-5	Work Load Scheduling	5-10
5-6	Manhour Efficiency Control	5-10
5-7	Manhour Planning and Control	5-12
5-8	Time Keeping Card by Job Order	5-13
6-1	Shipyards Production Control	6-3
6-2	Erection Block Weight List	6-8
6-3	Welding Process Check Plan	6-9
6-4	Welding Control Parameter Output List	6-10
6-5	Block DM List	6-12
6-6	Steel Weight Advance Curves of each Stage	6-14
6-7	Erection Advance Curve	6-15

LIST OF ILLUSTRATIONS

<u>F U E N O .</u>	<u>T I T L E</u>	<u>P A G E N O .</u>
6-8	Outfitting Scheduling System [IHI)	6-17
6-9	On-Board Piping Schedule in Engine Room	6-19
6-10	Performance Control Chart	6-19
7-1	Gate System	7-7
7-2	Livingston Yard Layout	7-9
7-2 (Cont.)	Material Flow	7-10
7-3	Basic Method of Planning and Scheduling	7-11
7-4	Key Erection Plan	7-12
7-5	Key Erection Times List	7-14
7-6	Basic Production Flow List	7-15
7-7	Unit Information List	7-17
7-8	Material Information List	7-18
7-9	Final Assembly Master Schedule	7-21
7-10	Unit to Unit Master Schedule	7-21
7-11	Component Assembly Master Schedule	7-22

LIST OF ILLUSTRATIONS

<u>FIGURE NO.</u>	<u>TITLE</u>	<u>PAGE NO.</u>
7-12	Panel Line Master Schedule	7-22
7-13	Long Term Gate Schedule	7-23
7-14	Short Term Gate Schedule	7-23
7-15	LSCO. Planning and Scheduling Flow	7-27

LIST OF TABLES

T3-1	Plans for Production	3-3
T4- 1	Typical Milestone List	4-31
T6-1	Hull Construction Control Graphs	6-6
T7- 1	Planning and Control Techniques Adopted by Livingston	7-25

SECTION 1
INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concepts of Planning and Production Control and their application in the actual working environment in the IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP), the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Livingston and in other medium-size shipyards in the United States.

In this examination of the IHI Planning and Production Control System all aspects of the IHI production system itself, the production planning process, the scheduling system, manpower planning, and production control are discussed together with a detailed account of Livingston's application of these techniques and methods. The various sections of this report detail these aspects of the IHI system and Livingston's findings, applications, and conclusions.

1.2 ORGANIZATION OF REPORT

This report comprises two volumes: I - Findings and Conclusions and 11 - Appendices. This volume consists of eight sections as follows:

- Section 1 - Introduction
- Section 2 - The IHI Production System
- Section 3 - The IHI Planning System
- Section 4 - The IHI Scheduling System
- Section 5 - Manpower Planning and Performance Measurement

Section 6 - Production Control

Section 7 - Livingston Application of IHI Technology

Section 8 - Application to U.S. Shipbuilding

Sections 2 through 6 detail the IHI production and production planning and control methods, whereas Sections 7 and 8 serve to synthesize these data for application to U.S. shipyards.

A series of appendices are also included in Volume II of this report as an adjunct to the findings and conclusions presented herein. These appendices comprise data provided by IHI in the course of this program. The appendices are listed below.

Appendix A - Glossary of Terms

Appendix B - Product-Oriented Work Breakdown Structure

Appendix C - Hull Blocking Plan

Appendix D - Block Assembly Plan

Appendix E - Field Plans

Appendix F - Gate System Implementation

1.3 REFERENCES

Throughout this report reference is made to other reports some of which were produced by Livingston, resulting from the Technology Transfer Program. A list of these reports is presented below.

<u>REPORT</u>	<u>REPORT NO.</u>	<u>DATE IS</u>
Final Report - Quality Assurance (LSCO.)	2123-5.1-4-1	3/3/80
Final Report - Industrial Relations (LSCO.)	2123-6.1-4-1	3/28/80
Special Report - Accuracy Control P1 arming (LSCO.)	2123-5.1-4-2	3/15/80
Report - Outfit Planning (Todd)		12/79

1.4 DEFINITIONS

Throughout this report several terms are used to denote fabricated sections of the ship which are ultimately erected in a building basin to form the complete ship structure. These terms have specific meanings within the context of the Japanese ship construction methodology. Although a more thorough Glossary of Terms is provided in Appendix A to this report, it is necessary to define certain of these terms in advance of the text to provide some clarification of the material for the reader.

ASSEMBLY - (Noun) A composite of fabricated parts and pieces assembled and affixed to form a whole element which will be installed as an entity in a larger assembly or in the ship under construction.

UNIT - A defined segment of the ship's structure capable of being individually constructed, handled, transported, lifted and landed as an entity aboard the ship under construction.

BLOCK - Japanese term for unit.

NOTE: In the following discussion the terms Unit and Block are used interchangeably, however, the term Block is used only to refer to formal IHI planning documents and techniques.

(e.g. Hull Block Planning)

SECTION 2

THE IHI PRODUCTION SYSTEM

2.1 GENERAL

The IHI Production System is a well designed and highly integrated composite of material, facilities and personnel. It comprises a series of sub-systems which, although they can be described as independent elements, are interwoven to form a functional whole capable of efficient operation at each stage of design and production and at every level of the organization.

The basic and total orientation of the IHI shipyards is toward the production of high-quality products at the least possible cost and every aspect of the production process has been refined and perfected over a number of years to serve this production objective. As a result of this system refinement and integration it is impossible to separate clearly each of the elements of the production system without at least a cursory understanding of the whole process. For example, to understand the Planning and Production Control function it is necessary to relate it to the basic shipyard organization, to the production system itself, to the activities of the Design Department and to the functions of Accuracy Control and Quality Control. To take any one element out of the context of the whole system is to deny any real understanding of the IHI production methodology. Therefore, to enable a better understanding of the subject of this report, a general overview of the IHI Production System is presented in the following pages.

It is possible to describe the IHI Production System in several ways: chronologically, by discrete functions, by organization, by process stages, etc. There are, however, inevitable distortions of the real situation inherent in any written description of such a complex subject. Also, one of the intrinsic characteristics of the IHI system is flexibility, which further limits the ability of any documentation to portray accurately the absolute functioning and methods of the IHI yards. Each yard superintendent is given some latitude in the implementation of the production system methodology but the essential elements of the system are preserved in each yard, regardless of minor deviations.

The essential elements of the system concern the three basic ingredients of any manufacturing enterprise: material, facilities and personnel. Each of these basic elements is subdivided into the functions, processes or arrangements necessary to provide the information, hardware and people requisite to the chronological sequence of the operation.

The following paragraphs describe these major system elements and the various subdivisions of each to familiarize the reader with the total system. This breakdown into material, facilities and personnel is not intended to define specific organizations, interrelationships nor the time-sequencing of the activities of the various subdivisions. Rather, it is intended simply as an overview of how the three major elements are structured in the total IHI production system. The description of the integrated functioning of these

elements is covered in later sections of this report and in the other Final Reports from this Technology Transfer Program covering Design & Engineering, Facilities & Industrial Engineering, Quality Assurance and Industrial Relations.

2.2 THE MATERIAL ELEMENT

2.2.1 Design

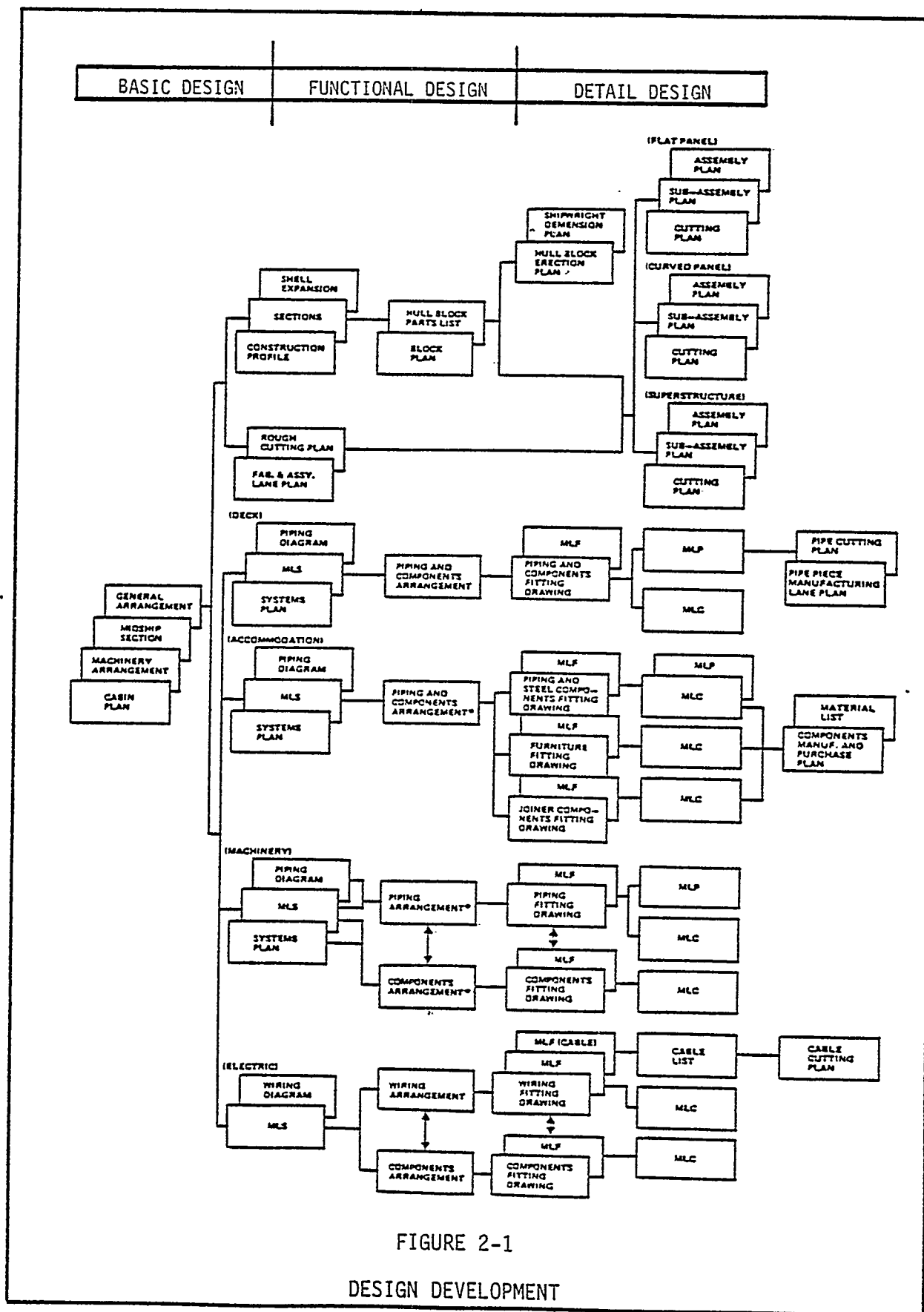
As is typical to all production firms, the material element is subdivided into Design, Procurement and Manufacturing. The function of design is performed in IHI by the Corporate Head Office, which accomplishes the top-level design necessary for the sale and the establishment of the general performance and design specifications of the ship, and in the shipyard design division.

Shipyard design activities typically accomplish a great deal of the production planning commensurate with the development of the detailed working drawings. However, a principal activity of the design function of the yard is to identify and define the material which is to be procured versus that which is to be manufactured internally. From system diagrams, shell expansion drawings, section drawings, shipyard standards and a series of material lists, design personnel determine the material to be procured including steel, components and consumables. Although there are many innovations in the IHI procurement system, the engineering/procurement interface and the purchasing procedures are relatively comparable to those of U.S. yards. Schedules for procured materials are part of the overall planning process of the yard and are covered in later sections of this report.

The design for manufacture is the primary function of the yard design division. From the top-level drawings and specifications, the details of the ship are progressively developed to the lowest level necessary for the fabrication of parts and pieces, sub-assembly of individual components (both hull parts and outfitting parts), assembly of hull units and final erection of these units on the ways. Figure 2-1 portrays the design plan for the development of these details.

Throughout the design development, detail planning and scheduling is performed by a consolidated group of design engineers, planners and production engineers. This planning is part of the design process in that an iterative cycle of design - planning - design occurs at each level of drawing development. On the basis of the top-level design, the hull is subdivided into major assembly units or blocks suitable for handling, outfitting and erecting. Subsequently, each assembly unit is further divided into its detailed parts which are identified on material lists for either procurement or manufacture. Design engineers progressively detail each level of the ship breakdown in drawings of unit assemblies, sub-assemblies of hull and outfitting components and detail parts and pieces.

As part of the planning/detail design development process, a series of planning documents are developed. Detailed assembly procedures are documented for each unit in Assembly Specification Plans and a series of Working Instruction Plans provide data relevant to: Marking, Cutting and Bending of plates during fabrication; Unit Assembly (or block) Parts Lists; Finish Dimension Plans for each unit; Sub-assembly Plans; Assembly Plans; Assembly Jig Size Lists; and Lifting Instructions for each unit. Working Instruction Plans are



also prepared for specific items of the erection process, such as: the Block Arrangements Plan; Shipwright Dimensions Plan; Support Block Arrangements Plan; Welding Instructions; and a Scaffolding Arrangements Plan.

Simultaneously with the design development and production planning, Accuracy Control Engineers designate the critical dimensions of the procured and manufactured components and units to assure the highest accuracy of the product at each stage of production. This Accuracy Control activity greatly influences the design and the selection of the production processes to be utilized. It also forms the basis for the quality control of each "interim product" (i.e. each sub-assembly or unit) as it is built up through the fabrication, sub-assembly and assembly cycle. Figure 2-2 depicts the concept of Accuracy Control in IHI. Several Livingston reports referenced herein discuss the application of Accuracy Control.

Throughout this design process Production Planning and Engineering personnel attached to each of the Panel, Hull and Outfitting Workshops, provide appropriate production information and requirements to the designers. The working drawings and plans are carefully prepared to match facility and production organization capabilities. The shipyard design division is considered a support organization to production in this activity and is thoroughly oriented toward providing all design and planning information required by the production workshops to enable the best possible flow of precise and accurate material throughout the construction process. Figure 2-3 depicts the interface between the design and production organization.

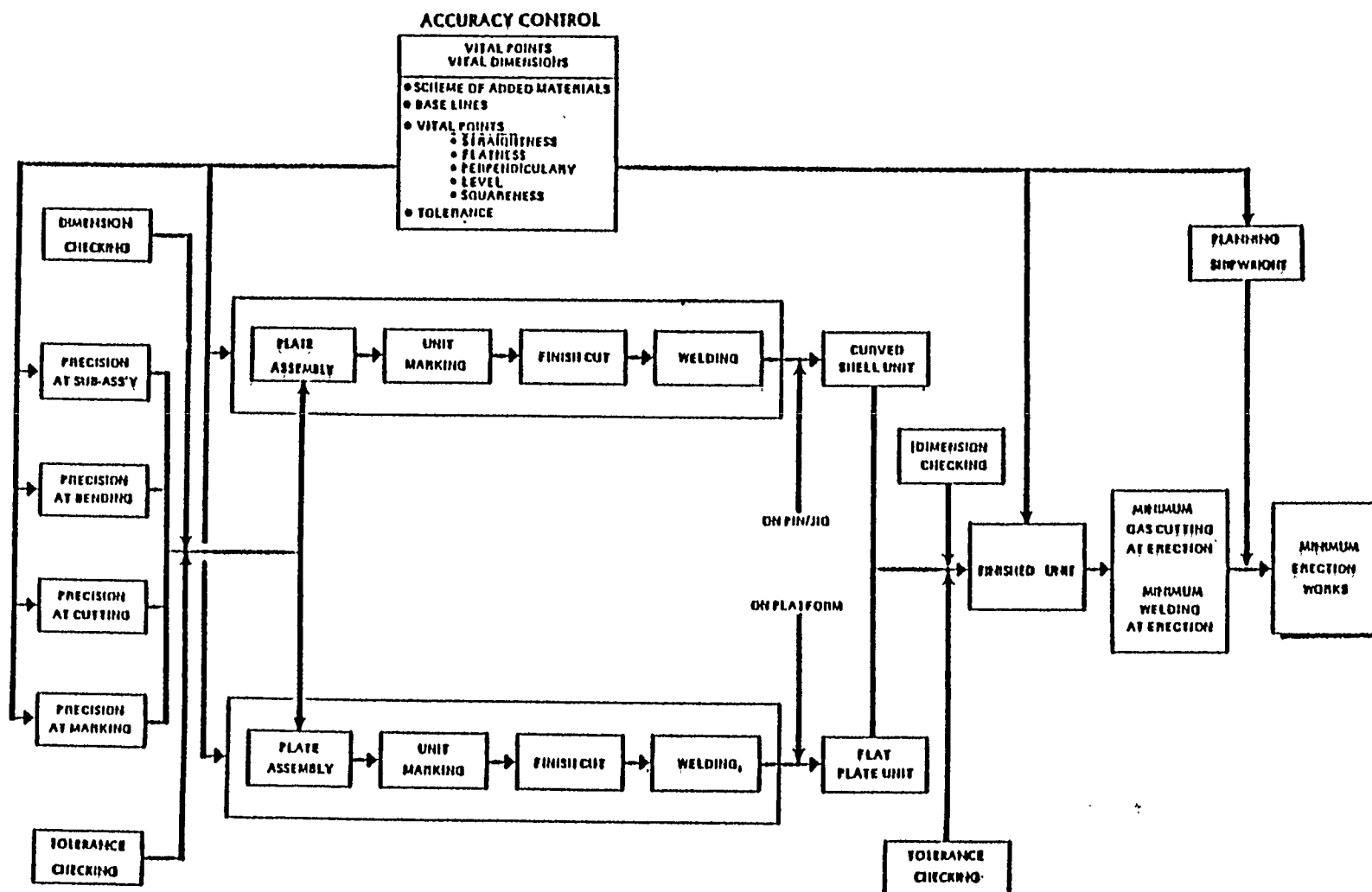


FIGURE 2-2

CONCEPT OF ACCURACY CONTROL IN IHI

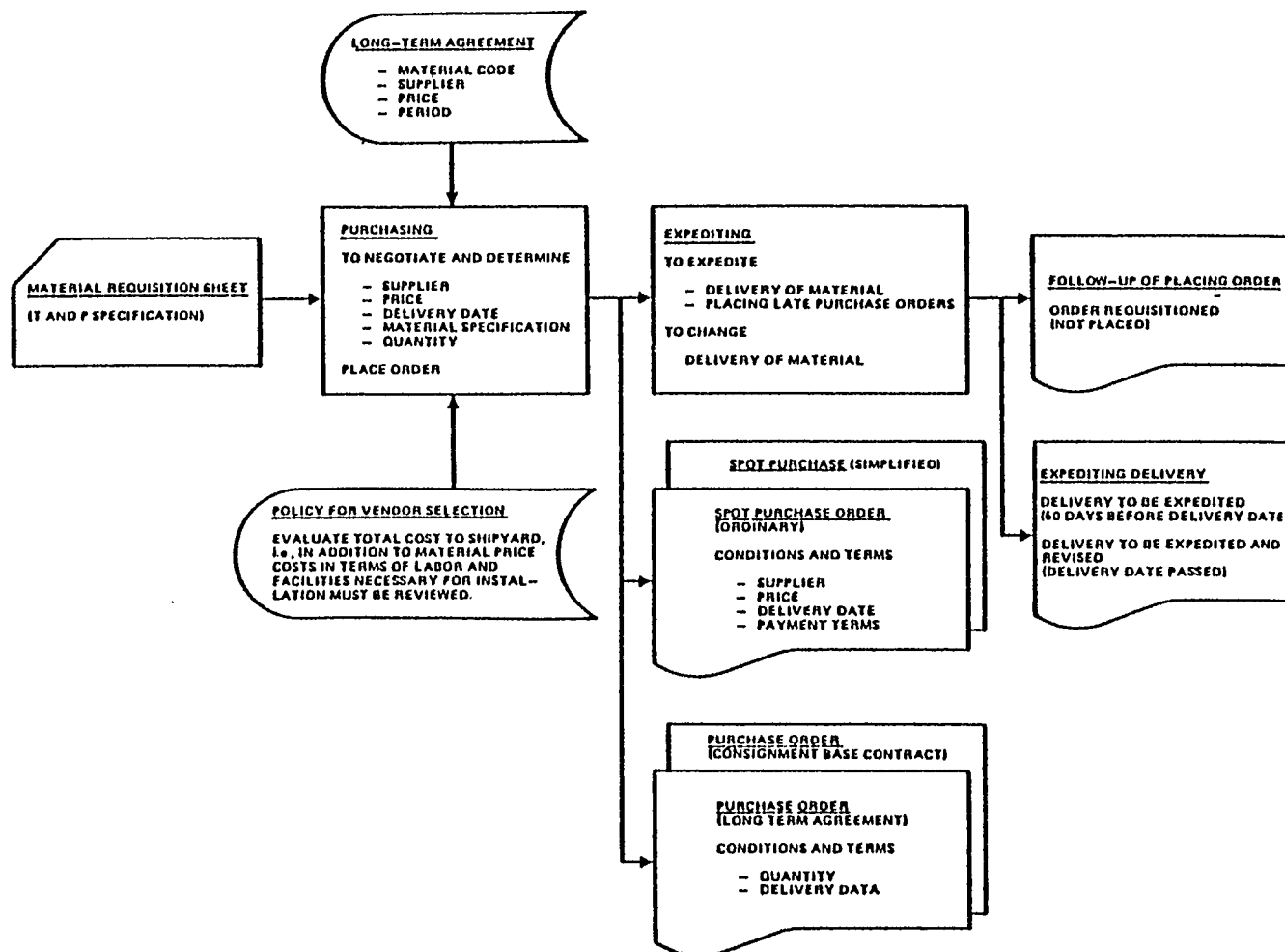


FIGURE 2-3

TYPICAL PURCHASING PROCESS

2.2.2 Procurement

The procurement system in the IHI yards is a highly perfected and standardized process which relies heavily on computer-based supplier data and the "family" of subcontractors that routinely supply the yard with the various raw materials and fabricated components required on most ships. The typical operations of the procurement function in the IHI yards is shown in Figure 2-4.

During the development of the "functional" design by the shipyard design department, procurement information is documented in system-oriented material lists. These lists form the basis for procurement activity in determining suppliers, lead-times and costs. Because of the established shipyard/supplier relationships and the vast amount of historical data available to planners in the procurement computer data base, it is possible to accomplish quickly the required procurement planning and to execute the placement of purchase orders.

Firm schedules are applied to all procured material to ensure the delivery of raw material in small quantities (e.g. as little as three days' supply of steel) at precise intervals so that the yard is not over-stocked with material at any time. Outfitting components are also rigidly scheduled for delivery as close to the need date as possible. This scheduling of material reduces the need for large storage areas and warehouses and also helps to maintain the movement of material in a smooth and orderly flow through the yard throughout ship construction.

Purchasing for the shipyards is coordinated through the Head Office of IHI and much of the procured material is bought by the Head

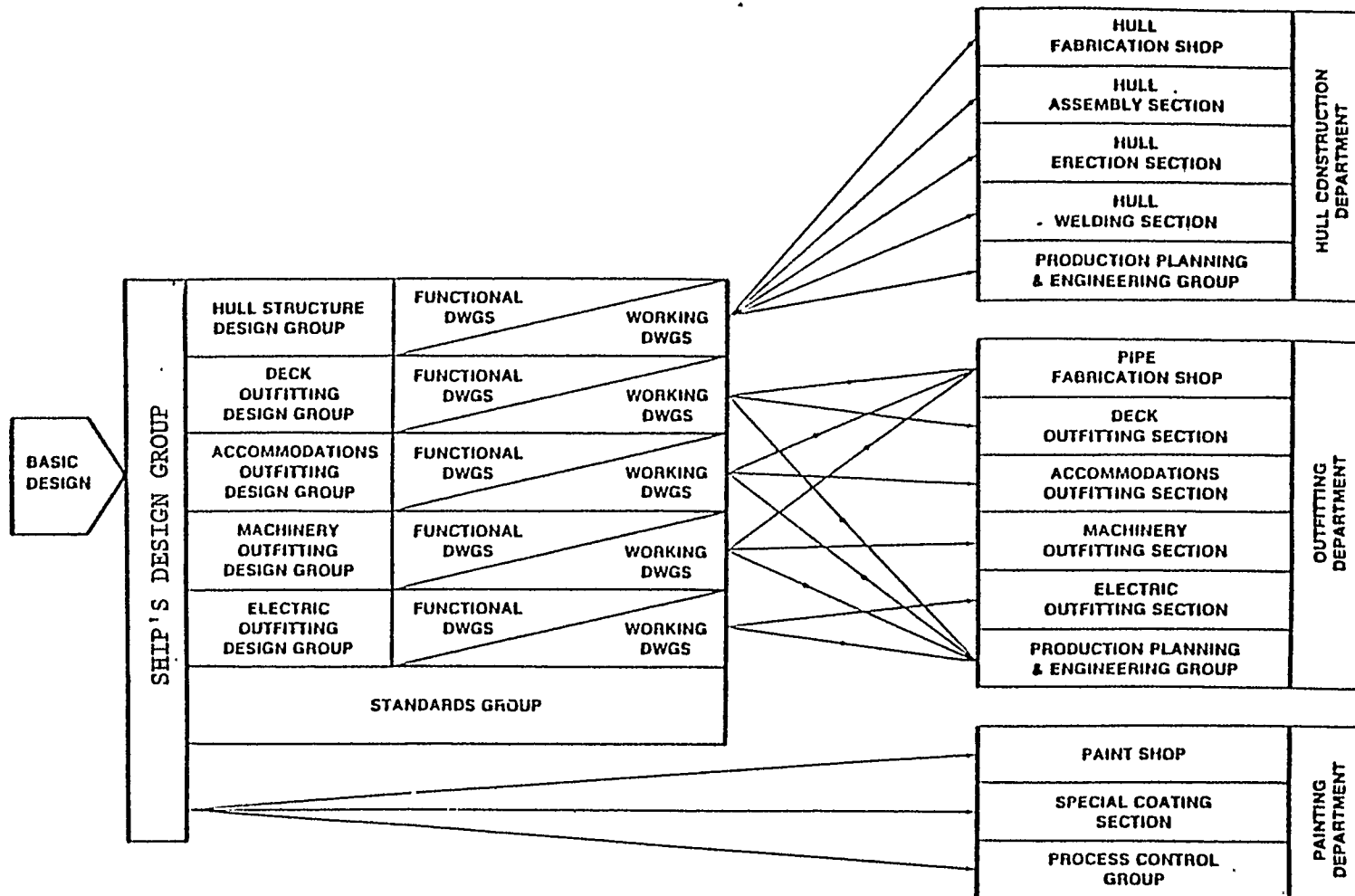


FIGURE 2-4
DESIGN/PRODUCTION INTERFACE

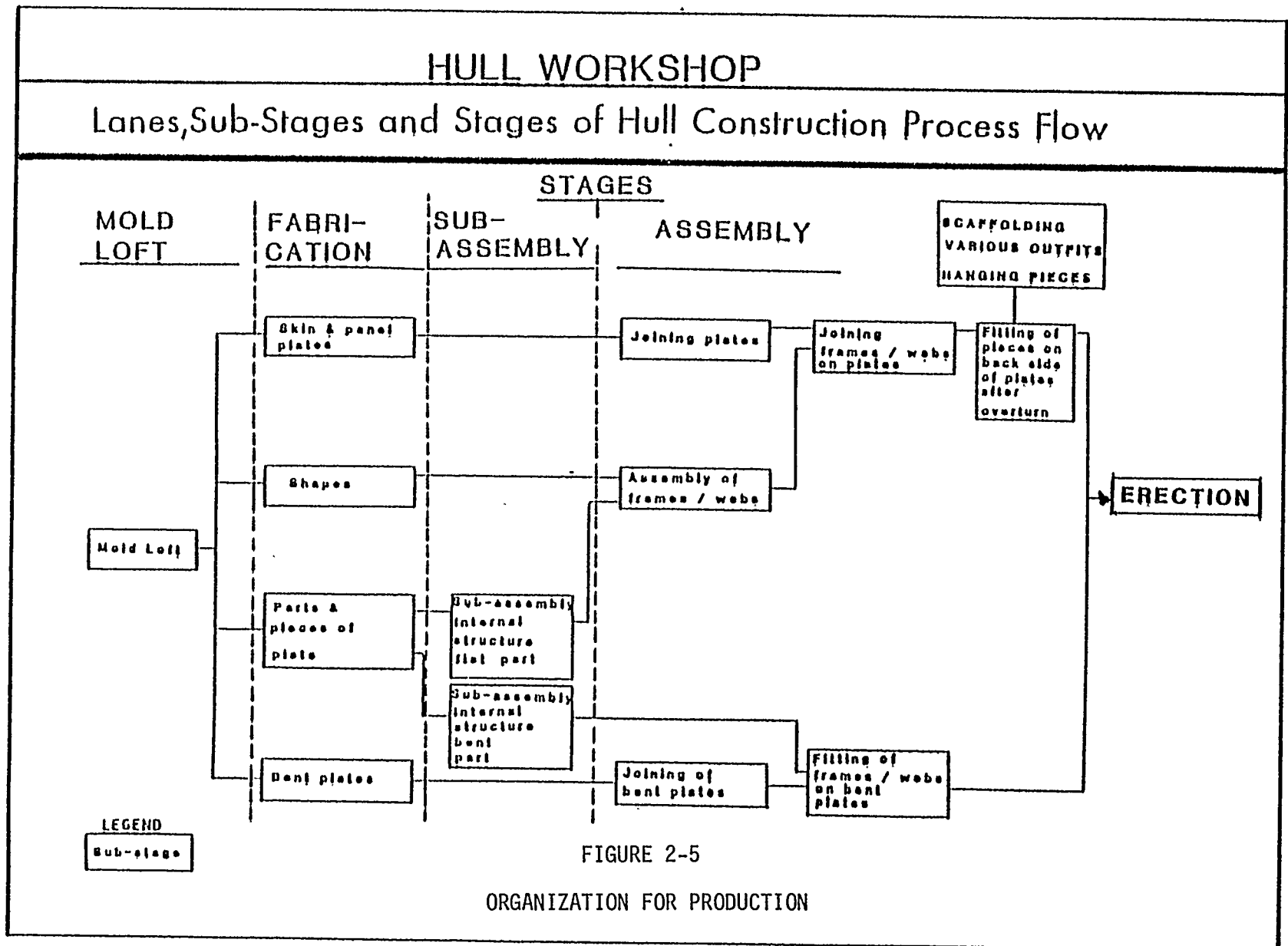
Office Procurement Group. This allows economic lot-quantity buying wherever possible.

2.2.3 Manufacturing

As in most shipyards the major production activities are divided into hull construction and outfitting. Each of these activities are organized and executed by a separate "Workshop". Hull construction encompasses all steel fabrication, sub-assembly, assembly and erection of the final hull units. Outfitting is planned and organized to correspond with the hull construction work so that appropriate outfitting of components and sub-assemblies is accomplished at the best time during manufacture of the steel unit assemblies.

The manufacture of steel parts and pieces, the assembly of these components into progressively larger and more complex units, and ultimately the construction of these units into the ship itself, is the function of the Hull Construction Workshop. In IHI the process of hull construction is a well defined system which utilizes designated material flow routes called "process lanes" for the processing of all material. "process Lanes" extend through several different physical areas either within shops or assembly areas in a series of operations referred to as "Sub-stages". These "Sub-stages" are part of a larger process step called a "stage". Figure 2-5 illustrates this organization of production into the various process lanes, sub-stages and stages.

This type of production system aligns the physical areas of the overall facility into several material flow paths which begin with the fabrication of detail parts and pieces, the subsequent sub-assembly



of these pieces into one or several minor assemblies which will then be integrated into a unit. For example, in the fabrication shops steel plates are sized, marked, cut and bent in different process lanes according to their eventual usage in flat-panel or curved units. These piece parts are routed to appropriate sub-assembly or assembly areas for use in the construction of the two different types of units. The typical flow is thus from the fabrication of panels or cut pieces to sub-assembly to assembly of either flat-panel or curved units. The completed units will subsequently be moved to a unit buffer storage area or to the platen area adjacent to the building basin. Approximately 30 to 60 percent of all ship units will be completed prior to the start of ship erection.

The second major activity of the production system is outfitting. IHI has developed its planning and production system so that as much outfitting as possible can be achieved during the build-up of the steel unit assemblies. This "pre-outfitting" has provided the IHI yards with substantial improvements in productivity over the past decade. Essentially, outfitting is considered in three distinct stages: on-unit, on-block and on-board. On-unit outfitting is the sub-assembly of outfitting components (such as piping) into a composite for eventual installation as a sub-assembly onto a steel structure. On-block outfitting is that performed while the assembly of the steel components is being accomplished in an assembly area. At the appropriate time in the build-up of a steel assembly, outfitting will be accomplished to the maximum extent possible. This may be before the

attachment of the top or bottom panels to a flat-panel unit or, in the case of a curved unit, while the unit is mounted and is being assembled on a curved unit assembly jig. On-board outfitting is that required after erection of the individual units in the building basin. Figure 2-6 illustrates the flow of outfitting activities during these production stages.

This progressive outfitting of units greatly enhances the productivity of the outfitting workforce through better accessibility, easier down-hand installation and welding of outfitting components, safer working conditions (i.e. on slabs versus on-board the erected ship) and less crowded working areas. Proper division of the ship into units and realistic schedules allow sufficient time for this type of outfitting at the proper point in the production cycle.

Throughout the ship construction process "mass production" techniques are utilized to obtain maximum production rates. These techniques are common to many U.S. industries but are seldom applied successfully to shipbuilding. IHI has, to a large degree, succeeded in implementing these practices. All work is divided into discrete stages and precise processes within each stage; particular facilities are allocated to the performance of a particular operation; personnel are allocated to a single location and type of operation; and work is moved to the workers in each location. The objective throughout the production of one or several ships is to maintain the maximum flow of material through the production process in the minimum period of time. This provides a full and constant workload at each work station throughout ship construction.

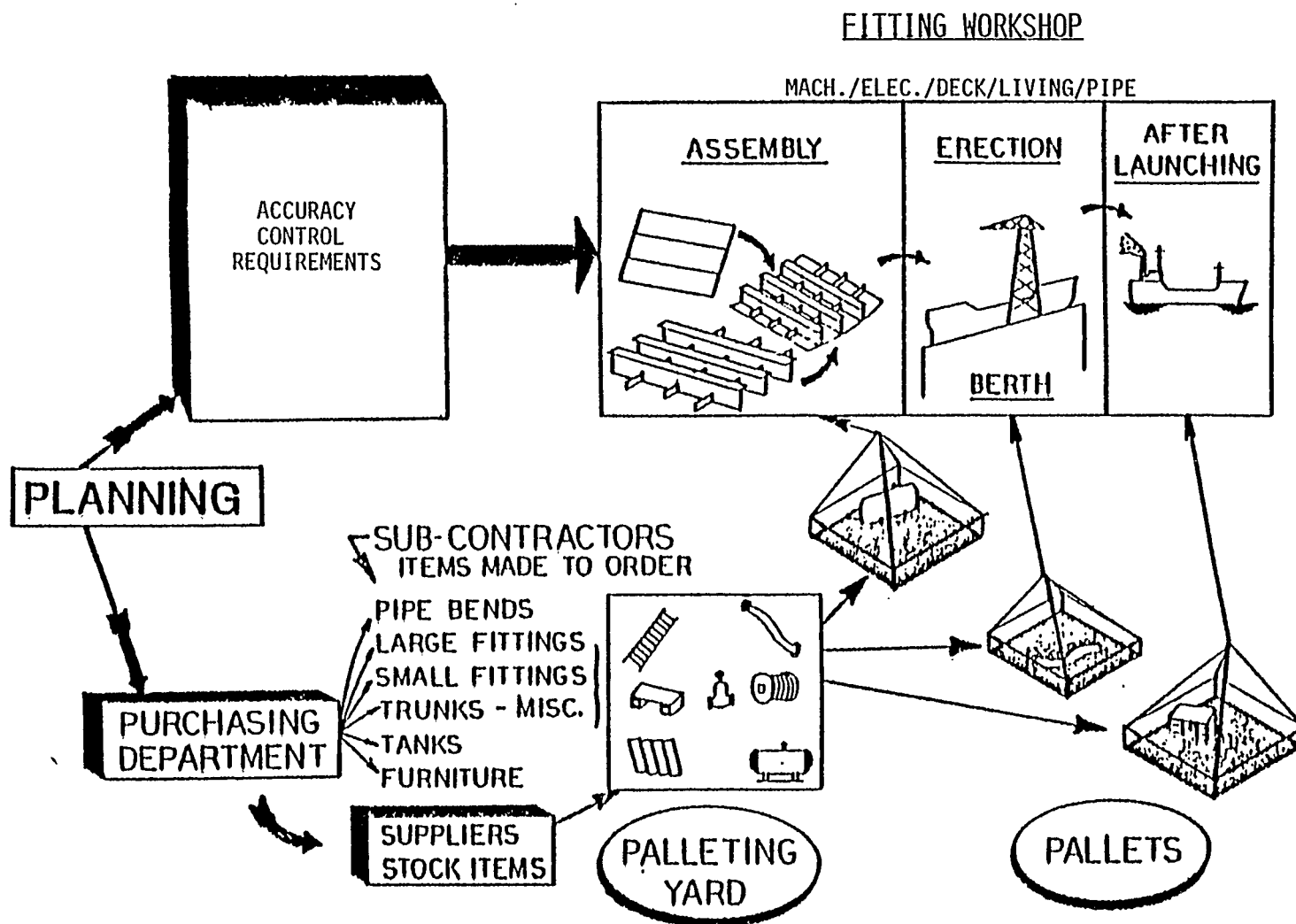


FIGURE 2-6
FLOW OF OUTFITTING ACTIVITIES

Another basic objective of the system is to minimize the time-consuming, expensive and relatively dangerous work during the erection stage. Therefore, accuracy of each component, sub-assembly and unit is stressed at each stage of production, and as much outfitting as possible is accomplished on the units prior to the start of erection to minimize on-board outfitting in the erected ship.

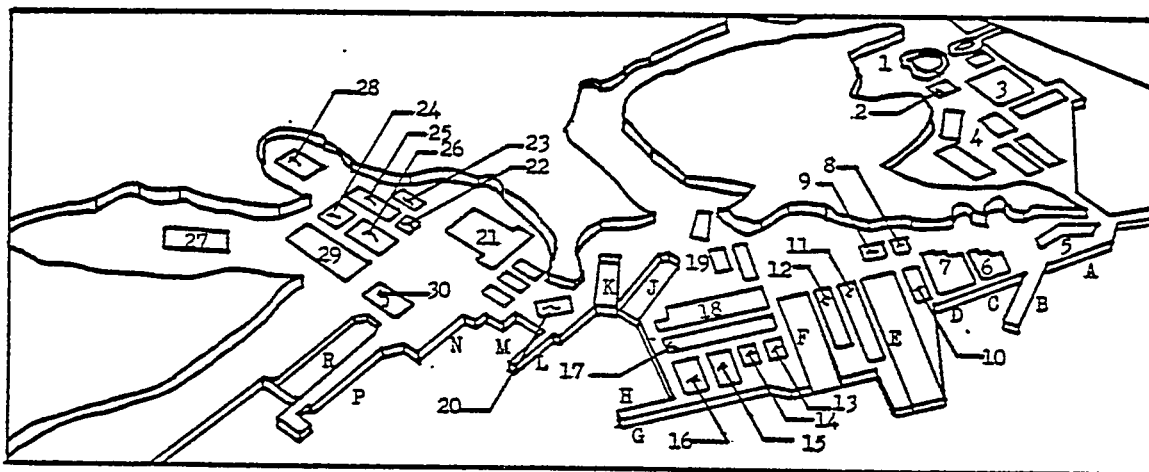
This highly effective system relies heavily on the thorough planning accomplished prior to the start of fabrication. This planning enables the total utilization of the facilities and personnel in a comprehensive and controlled manner throughout the ship construction process.

2.3 FACILITIES

The facilities of the IHI shipyards are some of the finest in the world shipbuilding community. Although these facilities differ significantly between yards, the basic components of the fixed facility in each yard varies only because of yard size or because of the product mix accommodated by each yard. For example, the IHI Chita shipyard was designed to build ultra-large tankers and the size of its shops and building basins and the lift capacity of the building basin cranes are considerably larger than those at Kure or Aioi.

For the purpose of this discussion, the IHI shipyard at Aioi is used as the model because of its close comparability in several respects to a typical medium-sized U.S. shipyard.

The Aioi Works Complex, located in the City of Aioi in Southwestern Japan, comprises four factories - the Aioi Shipyard, the Diesel Engine Works, the Boiler Works and the Casting and Forging Works. Figure 2-7 illustrates the arrangement of the facilities of the complex.



- | | | |
|---|--|------------------------|
| 1 Baseball Field | 16 Steel Stockyard | A No. 1 Quay |
| 2 Swimming Pool | 17 Fabrication Shop | B No. 2 Quay |
| 3 Land Boiler Works | 18 No. 6 Assembly Shop | C No. 3 Quay |
| 4 Accommodation for Supervisors and crew. | 19 Office for Hull Construction Workshop and Painting Workshop | D No. 4 Quay |
| 5 Main Office | 20 Repair Center, Ship Repair Superintendent's Office | E No. 1 Building Dock |
| 6 Fitting Workshop, Office | 21 Diesel Engine Workshop | F No. 3 Building Berth |
| 7 Workers' House | 22 Diesel Engine & Marine Boiler Works Office | G No. 7 Quay |
| 8 Superintendent's and Surveyor's Office | 23 Diesel Engine & Marine Boiler Works Supervisor's Office | H No. 8 Quay |
| 9 Shipyard Office | 24 Office for Marine Boiler Works and Casting & Forging Works | J No. 1 Repair Dock |
| 10 Unit Shop | 25 Forging Workshop | K No. 2 Repair Dock |
| 11 No. 2 Assembly Shop | 26 No. 1 Casting Workshop | L No. 9 Quay |
| 12 No. 3 Assembly Shop | 27 No. 2 Casting Workshop | M No. 10 Quay |
| 13 No. 4 Assembly Shop | 28 Hinoura Power Station | N No. 11 Quay |
| 14 Special Painting Shop | 29 Marine Boiler Workshop | P No. 12 Quay |
| 15 No. 5 Assembly Shop | 30 Ship Machinery Repair Shop | R No. 3 Repair Dock |

FIGURE 2-7

FACILITIES ARRANGEMENT OF AIOI SHIPYARD

The Aioi Shipyard is a compact area occupying the middle portion of the complex and consisting of a steel stockyard, a fabrication shop, several assembly and outfitting shops and areas, a pipe shop, a unit painting shop and two large building basins. Additionally, several shops, quays and dry docks are dedicated to ship overhaul and repair.

The Aioi yard comprises a total of 6,832,965 square feet of space of which 1,715,750 sq. ft. are utilized for shops, assembly areas and other working areas. Some 49 percent of the total utilized area (i. e. that stated above) is covered by permanent or temporary (i.e. moveable) enclosures.

The two building basins used for new construction have a capacity for up to 180,000 DWT vessels in the larger basin and up to 164,000 DWT vessels in the smaller basin. The larger basin is serviced by two 200-ton cranes and two 70-ton cranes. The smaller basin is serviced by two 120-ton cranes and two 80-ton cranes.

The flow of material within the yard is shown in Figure 2-8. As shown in the figure, steel moves from the steel stockyard through shot blasting and painting to either N/C cutting machines or the Electro-Photo Marking machine and then to the N/C cutting machines. These operations occur in one of the fabrication and sub-assembly bays of the main fabrication shop. Material processed in the fabrication shop is routed to one of several "Process Lanes" according to its eventual use in flat-panel or curved units. Sub-assembly of the fabricated parts and pieces occurs at the exit end of the four fabrication bays. Sub-assemblies are then routed to one of several assembly yards to be joined with other sub-assemblies or incorporated

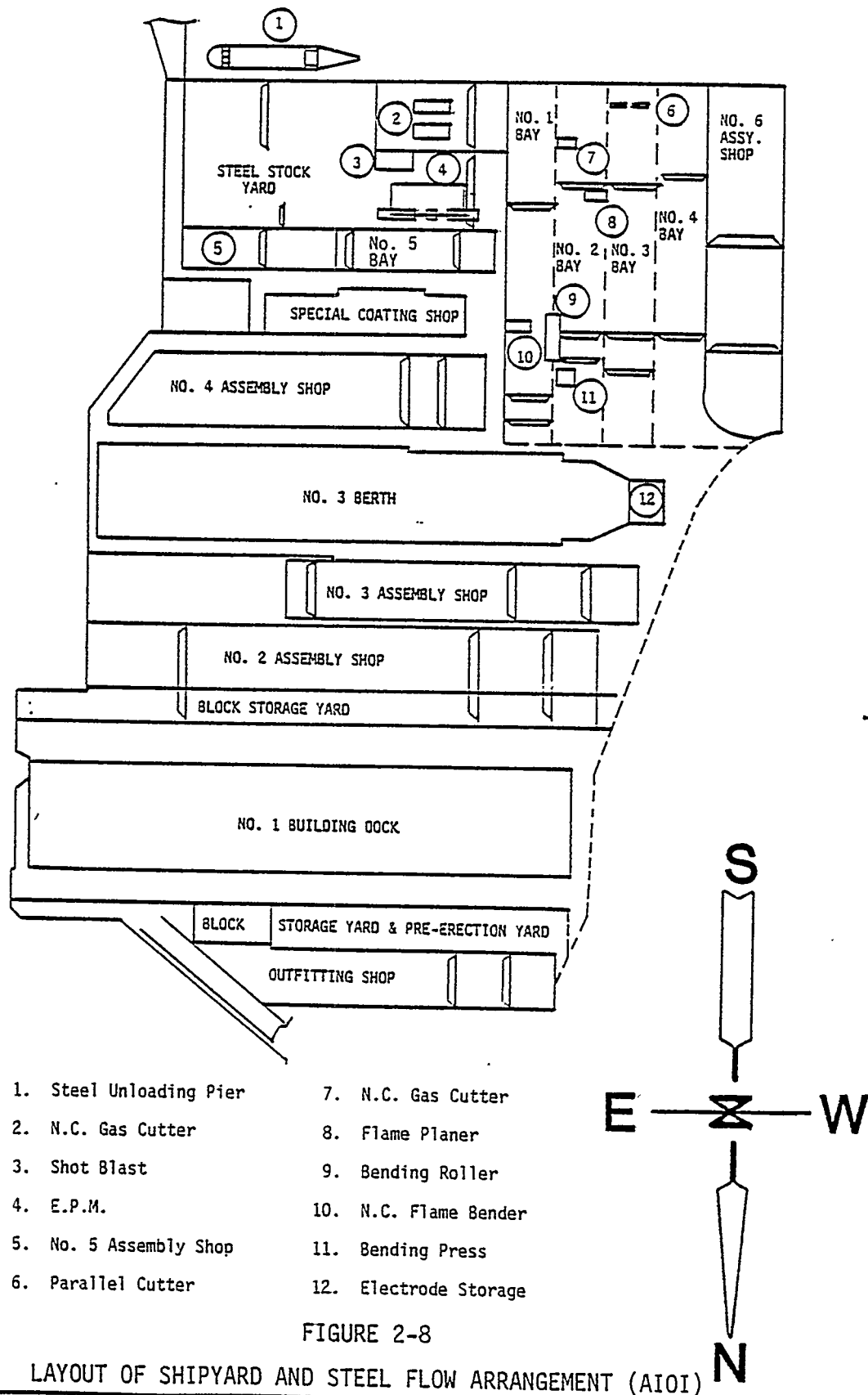


FIGURE 2-8

LAYOUT OF SHIPYARD AND STEEL FLOW ARRANGEMENT (AIOI)

into the unit being built-up in that yard. Pre-outfitting of the unit occurs at appropriate points in the build-up with the installation of pre-assembled outfitting component sub-assemblies or of individual outfitting components. When the unit is complete, it is moved either to the platen area of the building basin or to a unit storage area. Deck house units are built in an area separate from the other units. This "superstructure" assembly area is self-contained to provide all necessary finishing and outfitting of the house unit. The pipe shop, which is not shown on the figure, is located further to the North of the Outfitting Shop. Pipe components and sub-assemblies are moved to the appropriate outfitting location when required by the outfitting schedule.

2.4 PERSONNEL

The IHI shipyards are often part of a "District" or larger complex which produces several products other than new ships, such as diesel engines (as explained in paragraph 2.3). However, the shipyard portion of the complex is organized as a separate entity within this District, reporting to a General Superintendent. The organization within each of the shipyards is generally the same throughout the IHI yards. Figure 2-9 shows the typical organization for these yards.

The shipyard General Superintendent maintains five primary (or line) functions for the accomplishment of new ship construction and ship repair. These are the Design Division (or Department), the Hull Construction Workshop, the Outfitting Workshop, the Panel Workshop and the Ship Repair Workshop. The Panel Workshop provides panels for both new construction and for ship repair and is, therefore,

SHIPBUILDING / REPAIR ORGANIZATION

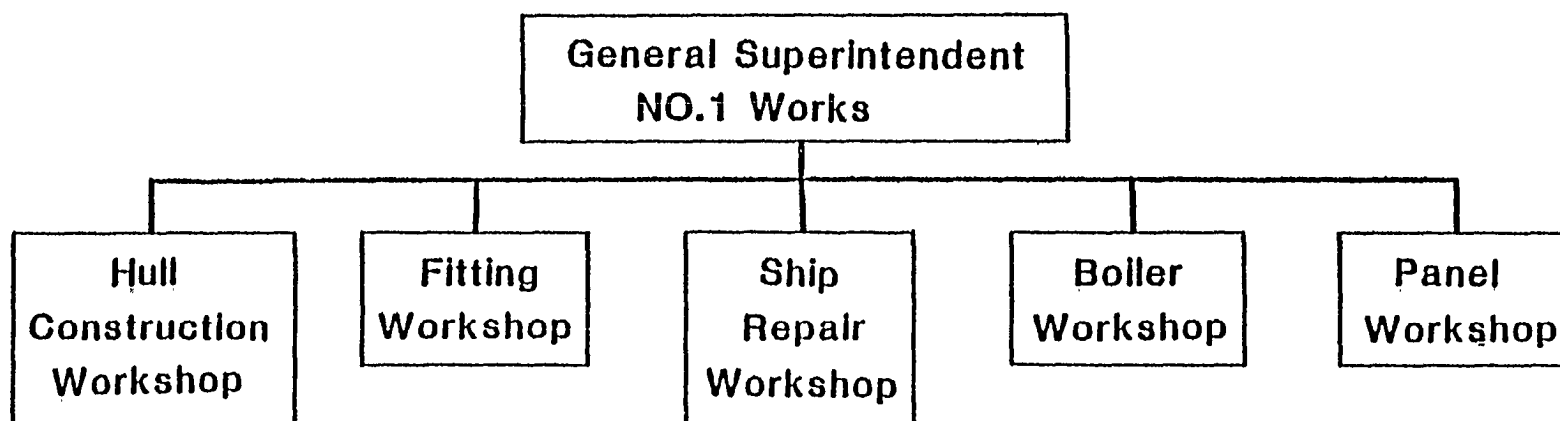


FIGURE 2-9

TYPICAL ORGANIZATION FOR IHI YARDS

separate from Hull Construction. The primary activities of the shipyard, oriented exclusively to new ship construction, are the Hull Construction Workshop and the Outfitting Workshop.

Figures 2-10 and 2-11 show the organizational structure of the new construction workshops and the Design Division.

Throughout the IHI shipyard organization an obvious attempt has been made to separate clearly the activities which do not directly contribute to production from the production functions. Also, the production functions have been established to operate autonomously but with a high degree of lateral interface between engineering personnel assigned within the workshops. These aspects of organization are thoroughly discussed in Livingston's Final Report on Industrial Relations (report number LSCo. 2123-6.1-4-1, dtd. March 28, 1980).

2.5 CONCLUSION

The IHI shipyard production system is a composite of facilities, personnel and the production system which achieves, through the careful integration of these elements, an extremely high level of productivity. The composite system relies heavily on the thorough planning and scheduling accomplished prior to the start of steel fabrication and which is continually refined throughout a production run of ships.

The IHI production system has been perfected over a number of years to a point where an established routine of design-planning-production-control is now in effect for the manufacture of any type of ship. This routine varies only slightly from yard to yard and the basic principles of this methodology are almost never modified.

PRODUCTION STRUCTURE

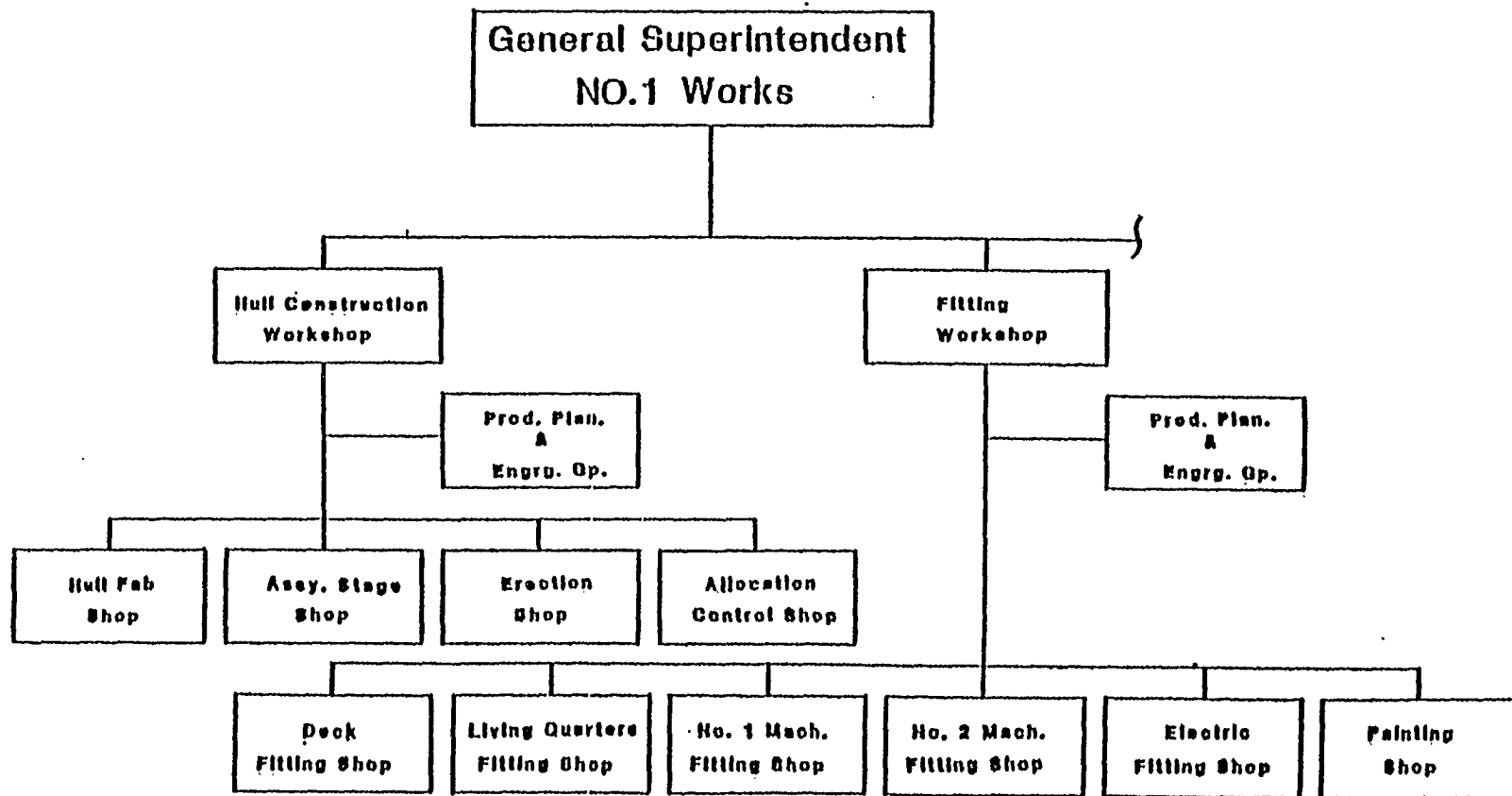


FIGURE 2-10

ORGANIZATIONAL STRUCTURE OF NEW CONSTRUCTION

SHIPYARD DESIGN

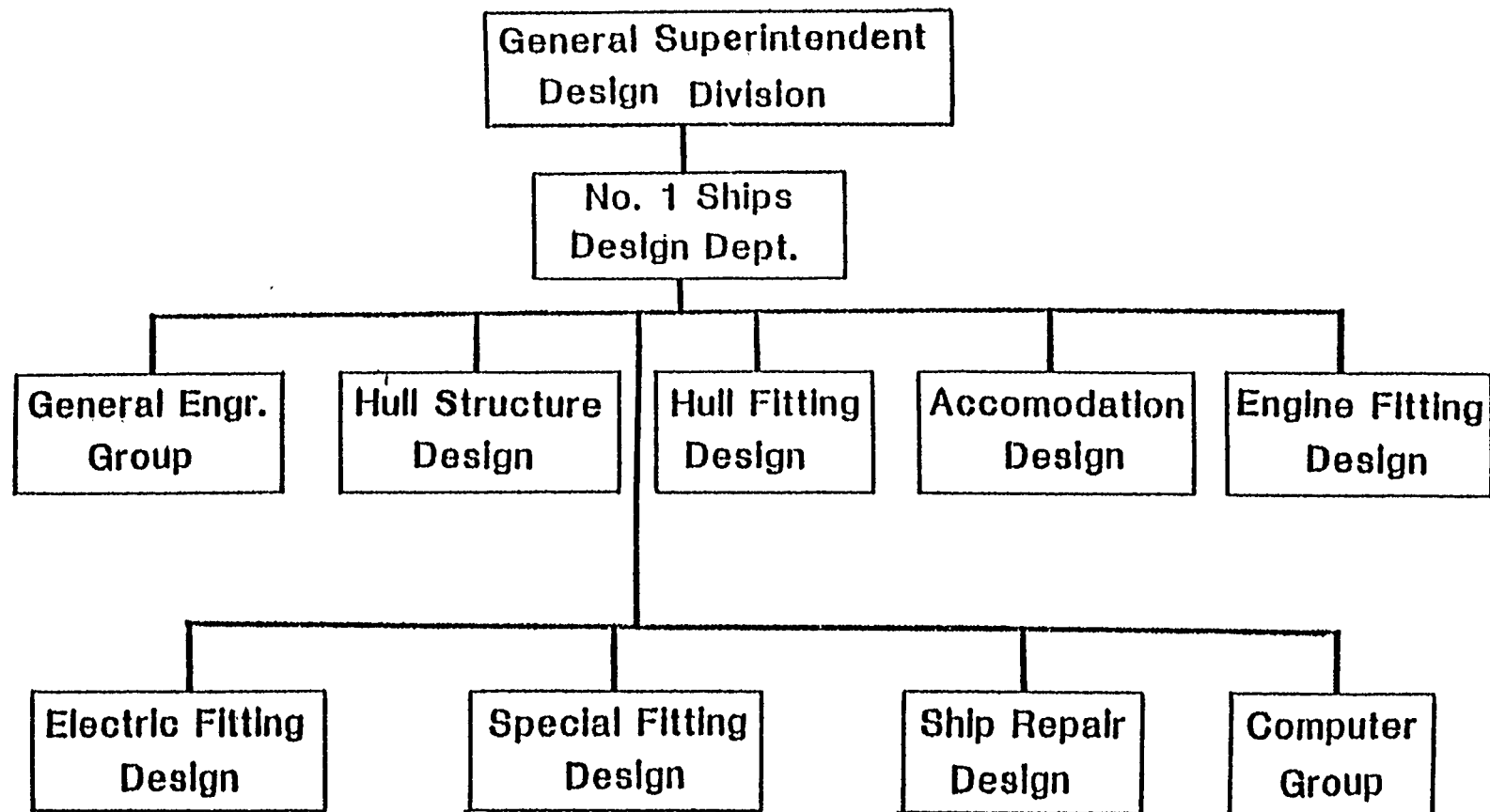


FIGURE 2-11

ORGANIZATIONAL STRUCTURE OF DESIGN DIVISION

separate from Hull Construction. The primary activities of the shipyard, oriented exclusively to new ship construction, are the Hull Construction Workshop and the Outfitting Workshop.

Figures 2-10 and 2-11 show the organizational structure of the new construction workshops and the Design Division.

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SECTION 3
THE IHI PLANNING SYSTEM

3.1 GENERAL

The IHI Planning system consists basically of two major activities - the planning for hull construction and outfit planning - extending through three stages of development: Preliminary Planning, Detailed Planning and Working Instruction Planning. Of these two activities, hull construction planning is the primary activity while outfit planning is accomplished essentially on the basis of the production flow of the hull units. Therefore, in this discussion the two types of planning will be discussed separately beginning with hull construction.

It is difficult to discuss planning, as it is accomplished in the IHI shipyards, as separate from scheduling since much of the planning is concerned with the development of schedules which coincide with the processes and movement of material through the production activities. The absence of this scheduling activity in any such discussion would seriously degrade the proper understanding of the planning activities and the flow of events in the planning cycle. Therefore, scheduling activities are included in this discussion where applicable, although a more definitive and comprehensive study of the scheduling hierarchy, methods and techniques is provided in Section 4.

This section of this report expressly deals with the planning system utilized by IHI. In preparing this report it became apparent

that the various yards of IHI use somewhat different terminology for the various elements developed during the planning phase. Also, in a later section the Livingston adaptation of this IHI planning system is described. This Livingston system uses still other terminology from that presented in this section. Every effort has been made to avoid confusion from this disparity in terminology, however, to help in clarifying the various terms and the description of the two systems a glossary of terms is provided as Appendix A to this report. Also, to assist the reader in assimilation of the information concerning the many planning documents utilized in the IHI planning system, Table T3-1 provides a listing of the plans and their application in the ship construction process.

3.2 HULL CONSTRUCTION PLANNING

Hull construction planning follows a prescribed methodology which progressively breaks down and details successively lower levels of the hull until the parts and pieces at the lowest level of fabrication are completely defined. This methodology is based on a "Product-Oriented Work Breakdown Structure" (see Appendix B) although the actual activity of defining the ship into its detail parts follows a somewhat different and more pragmatic approach. Essentially, the steps followed by shipyard engineers performing this breakdown are:

1. Unit division (i.e. dividing the ship into major units capable of being assembled, transported and erected);
2. Assembly breakdown (i.e. defining the component sub-assemblies and detail parts which constitute each of the units);
3. Specifying the fabrication, sub-assembly and assembly methods to be used in the fabrication of the detail parts and the build-up of these parts into progressively larger and more complex assemblies.

	FUNCTION				PRODUCTION STAGE			
	HULL CONSTRUCTION	OUTFITTING	FABRICATION	SUB-ASSEMBLY	ASSEMBLY	ERECTION	ON-BOARD	POST LAUNCH
1. Hull Block Plan	X	X			X	X		
2. Block Assy. Plan	X	X			X			
3. Assy. Spec. Plan	X		X	X	X			
4. Assy. Jig Plan	X				X			
5. Block Finish Dimen.	X				X	X		
6. Marking Plan	X		X					
7. Cutting Plan	X		X					
8. Bending Plan	X		X					
9. Block Parts List	X							
10. Sub-Assy. Plans	X			X	X			
11. Assy. Plans	X				X			
12. Assy. Jig Size List	X				X			
13. Lifting Instr. Plan	X				X	X		
14. Block Arrgmts. Plan	X					X		
15. Shipwright Dimens. Plan	X					X		
16. System Block Arrgmt. Plan	X					X		
17. Welding Instr. Plan	X					X		
18. Scaffold Arrgmts. Plan	X					X		
19. Zone Plan		X		X	X	X	X	X
20. Mat'l List by System		X		X	X	X	X	X
21. Mat'l List for Pipe		X		X	X	X	X	X
22. Mat'l List for O/F Comp.		X		X	X	X	X	X
23. Mat'l List for Fitting		X		X	X	X	X	X
24. Accuracy Control Check Sheets	X	X	X	X	X	X		
25. Added Material	X		X	X	X	X		
26. Field Plans	X	X				X	X	X

TABLE T3-1
PLANS FOR PRODUCTION

This methodology is well known to U.S. industries. It is the system developed long ago for engineering drawing development and for assembly line production. This system was developed and established as the traditional production methodology for the U.S. aircraft industry during World War II. Its application to shipbuilding is also well known and understood although few shipyards employ it to the degree that the IHI yards do.

While this breakdown of the overall product and of the successive lower-level "interim" products is being accomplished, a host of other planning activities are taking place. Facilities arrangements are confirmed; fabrication, sub-assembly, assembly and erection processes are determined; material requisitions are determined and issued; and manpower and performance measurement requirements are established. Figure 3-1 depicts the flow of planning activities prior to the start of hull construction.

To describe the individual planning efforts taking place during the planning phase of a new ship construction program, planning activities are described as they occur in each of the three time periods specified above, i.e., Preliminary Planning, Detailed Planning, and Working Instruction Planning.

3.2.1 Preliminary Planning

Hull construction planning begins immediately upon completion of the Basic Design (accomplished by the Design Department in the Head Office in IHI in Tokyo). The Basic Design consists of: Unfaired Ship's Lines, Midship Section, Construction Profile, General Arrangement and Machinery Arrangement drawings. On the basis of these plans,

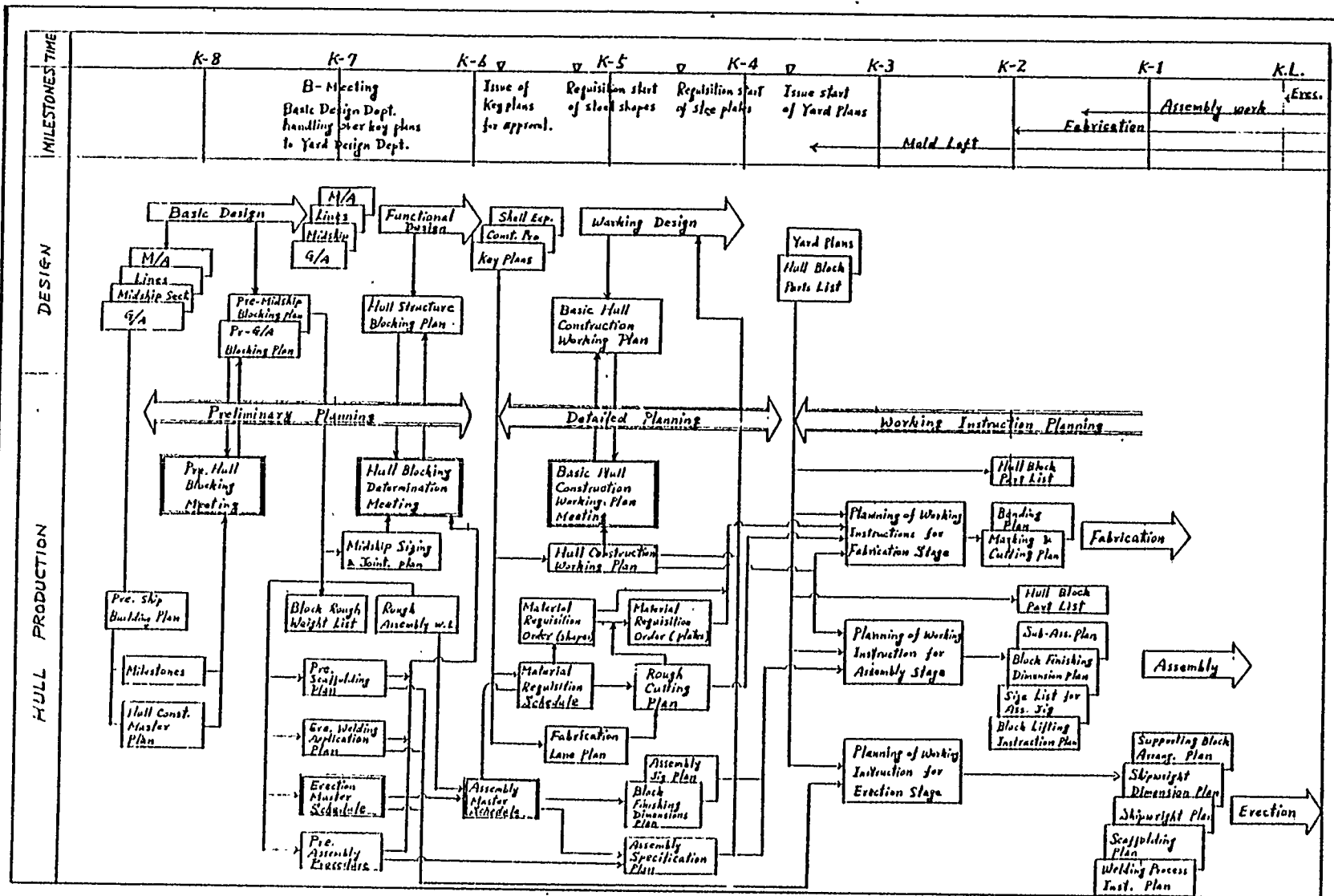


FIGURE 3-1

HULL CONSTRUCTION PLANNING FLOW WITH MILESTONE

the shipyard Design Department undertakes the breakdown of the ship into "Blocks" or units. This activity is called "Hull Block Planning" and consists of dividing the ship into manageable units suitable for assembly and erection.

This planning generally centers initially around the midship sections (i.e. cargo holds) since these sections represent the majority of ship units and because of the repetitive nature of the midship section units. The bottom units of these cargo hold sections are also the starting point for the development of the requirements for curved (bottom) units. Forward and aft sections of the ship are necessarily treated individually and require a more in-depth analysis to determine proper division into units.

Beginning with the bottom midship section of the ship, units are defined using the following criteria:

- 1) First unit to be laid in the building basin (this is generally the midship section unit just forward of the engine room).

- 2) Crane Capacity - The size of the units must be restricted to the lifting capacity of the available cranes both in the assembly **areas and** in the erection area.

- 3) Assembly Areas - Unit size is further limited by the size **of the assembly areas and facilities such** as over-turning equipment, transporters, cranes, etc. During over-turning and transportation the unit size must not be so great that deformation will occur during lifting or movement.

- 4) Work Flow - Unit size should be kept at an optimum to provide maximum work flow through the production work stations. Too big a

unit would require a prolonged assembly time thus creating a "bottle-neck" for following work.

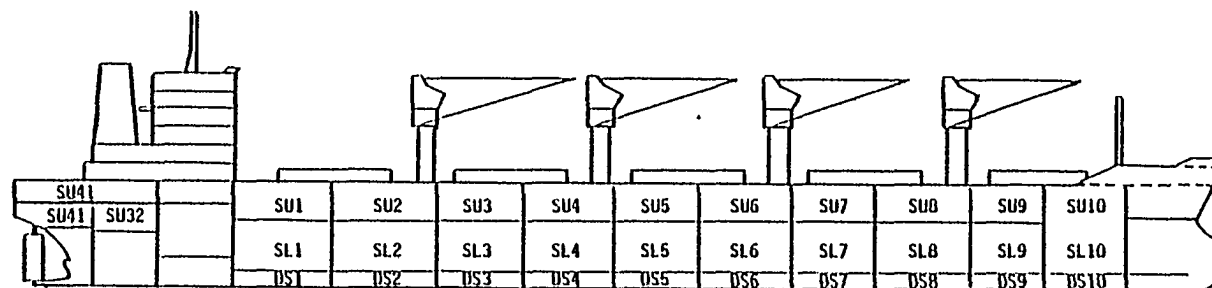
5) Reduction of Erection Work - Unit size and shape must be capable of being easily erected and must be stable during joining. Welding lengths must be minimal, especially for difficult (overhead) welding requirements.

6) Unit Outfitting - Assembly and outfitting schedules must be taken into consideration in sizing units. Units of too large a size or requiring an inordinate amount of outfitting will cause schedule delays, consume assembly area space, and delay following work (which may also result in idle time in following work stations).

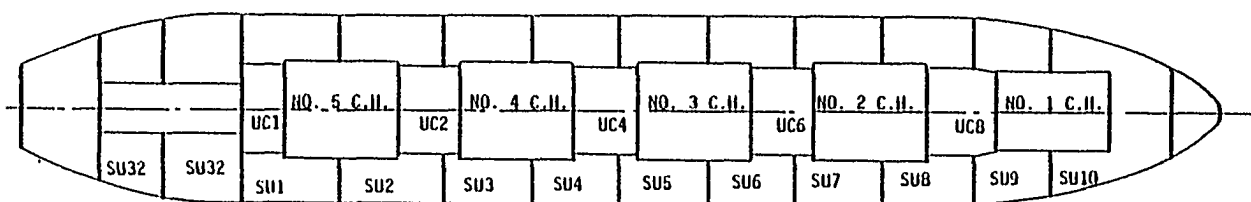
Using the above criteria, the ship is divided into manageable units which fit the facilities, equipment, manpower, and schedules established for ship construction. The overriding concern during this planning step is to derive the highest productivity at the stages of assembly and erection, and to maintain the highest accuracy of the manufactured units. Figure 3-2 presents an example of a ship's hull divided into units by the above process. Appendix C provides additional information concerning this process.

3.2.1.1 Unit Assembly Planning

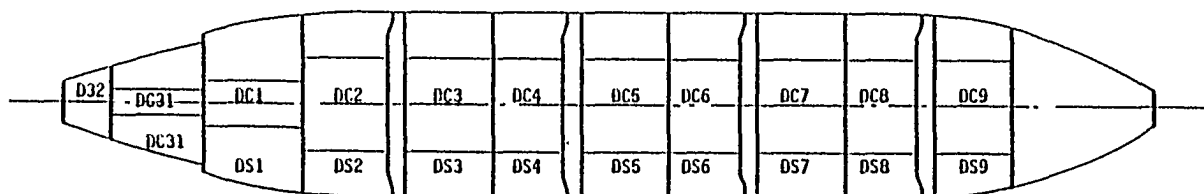
After division of the ship into manageable units, typical common-shaped units are analytically disassembled in a progressive breakdown from the entire unit to the component sub-assemblies and then to the parts and pieces which constitute the sub-assemblies. All unique units are broken down in this manner. Figure 3-3 shows a typical example of such a breakdown.



PROFILE



UPPER DECK PLAN



TANK TOP PLAN

FIGURE 3-2

F-32 UNIT ARRANGEMENT

UNIT ASSEMBLY PLAN "example"

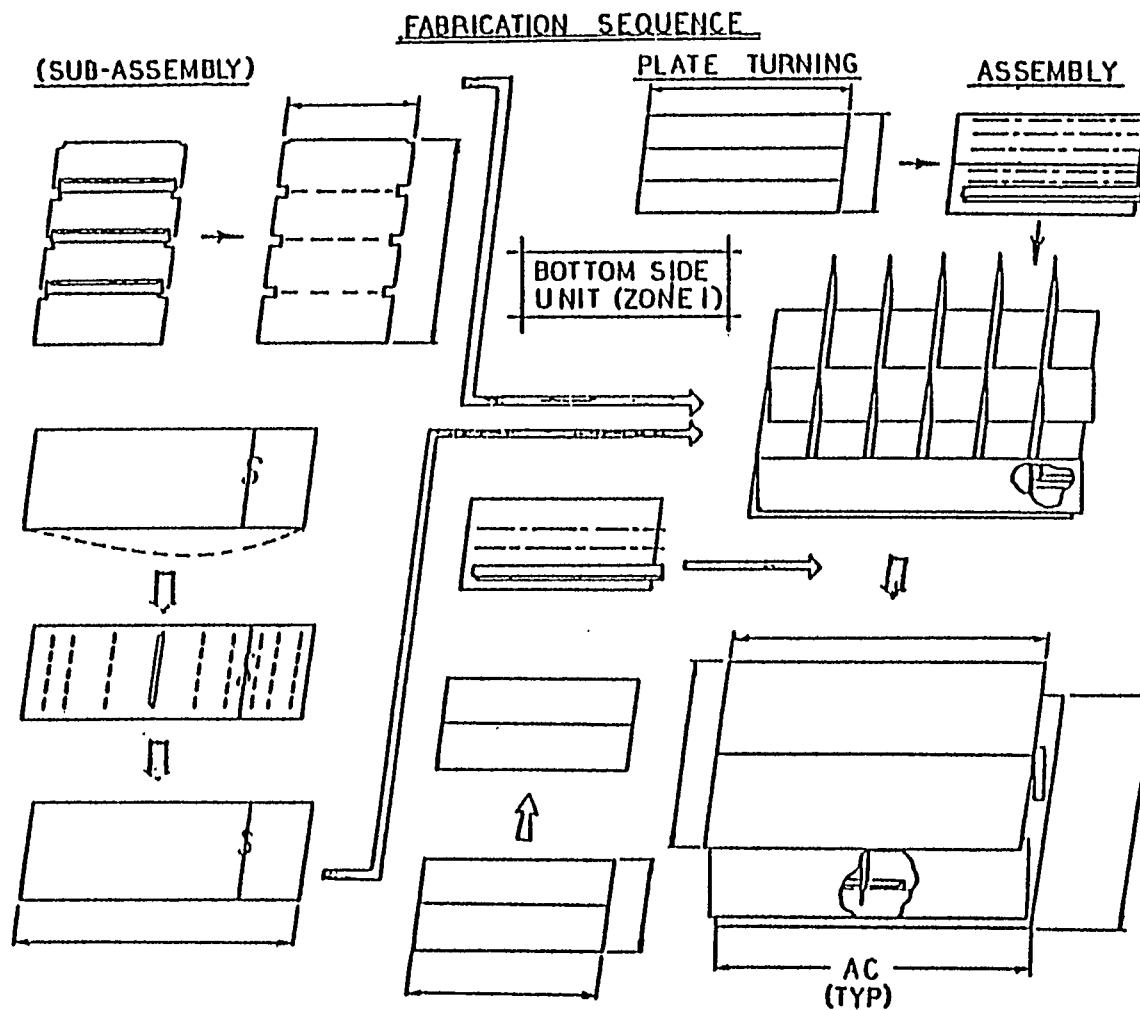


FIGURE 3-3

These breakdowns serve several purposes in addition to showing the basic assembly sequence of each unit. A preliminary evaluation of the assembly sequence yields details concerned with the necessary facilities and processes required for the assembly, e.g., required fitting jigs, probable welding processes, required assembly area size and capacity. Further details are developed including: the classification of sub-assemblies and assemblies; reference level and line; length and types of welding joints; welding edge-preparation requirements; and requirements for added material for adjusting seam and butt lines. Appendix D provides examples of this planning.

All of this planning is considered "preliminary" information for the development of "detailed process planning" which is documented and disseminated as "Assembly Specification Plans" and "Working Instruction plans".

3.2.1.2 Schedules & Plans

A Master Key Event Schedule showing milestones such as Program Start, Fab Start, Keel Laying, Launch and Delivery is determined when the ship is placed under contract. This schedule is established by the Head Office with input from the shipyard which will accomplish the ship construction. On the basis of this schedule, preliminary milestone schedules and general hull construction plans are generated. This rough information is considered in the formulation of the hull block planning.

A rough Unit Weight List, a unit assembly plan, a scaffolding plan, an auto-welding application plan, a midship sizing and joining plan and an erection master schedule are established for consideration

at a general meeting held to review and determine the validity of the initial Hull Blocking Plan. Upon approval of the plan, detailed planning is begun.

3.2.2 Detailed Planning

During the preliminary planning stage, the Basic Design generated by the Head Office Design Department is refined and elaborated to the extent necessary to fix the Hull Blocking Plan. This design is referred to as the Functional Design and upon approval of the Hull Blocking Plan the Working Design is started.

At the start of the detailed planning stage, the Assembly Master Schedule is prepared from the Erection Master Schedule. On the basis of this schedule, the Material Requisition Schedule and Material Requisition Orders are prepared. Detailed Hull Construction Working Plans (drawings) are also prepared by the Design Department defining the assembly units identified in the Hull Blocking Plan. A meeting, such as was held for the review of the Hull Blocking Plan, is held for a similar review and approval of the Hull Construction Working Plans.

Based on these working plans and on the material requisition schedule and a Fabrication Lane Plan (which details the processing of plate steel through the fabrication shops), a Rough Cutting Plan is generated. This plan is made to assist in the preparation of Material Requisition Orders for steel plates to minimize the number of sizes, thickness and the total quantity of plates required. The purpose of the plan is to improve the usage and control of remnants and scraps; to determine the quantity of steel required each month;

and to provide guidance for the preparation of the Cutting Plan to the workshop. The Material Requisition Orders are prepared on the basis of the information in this plan.

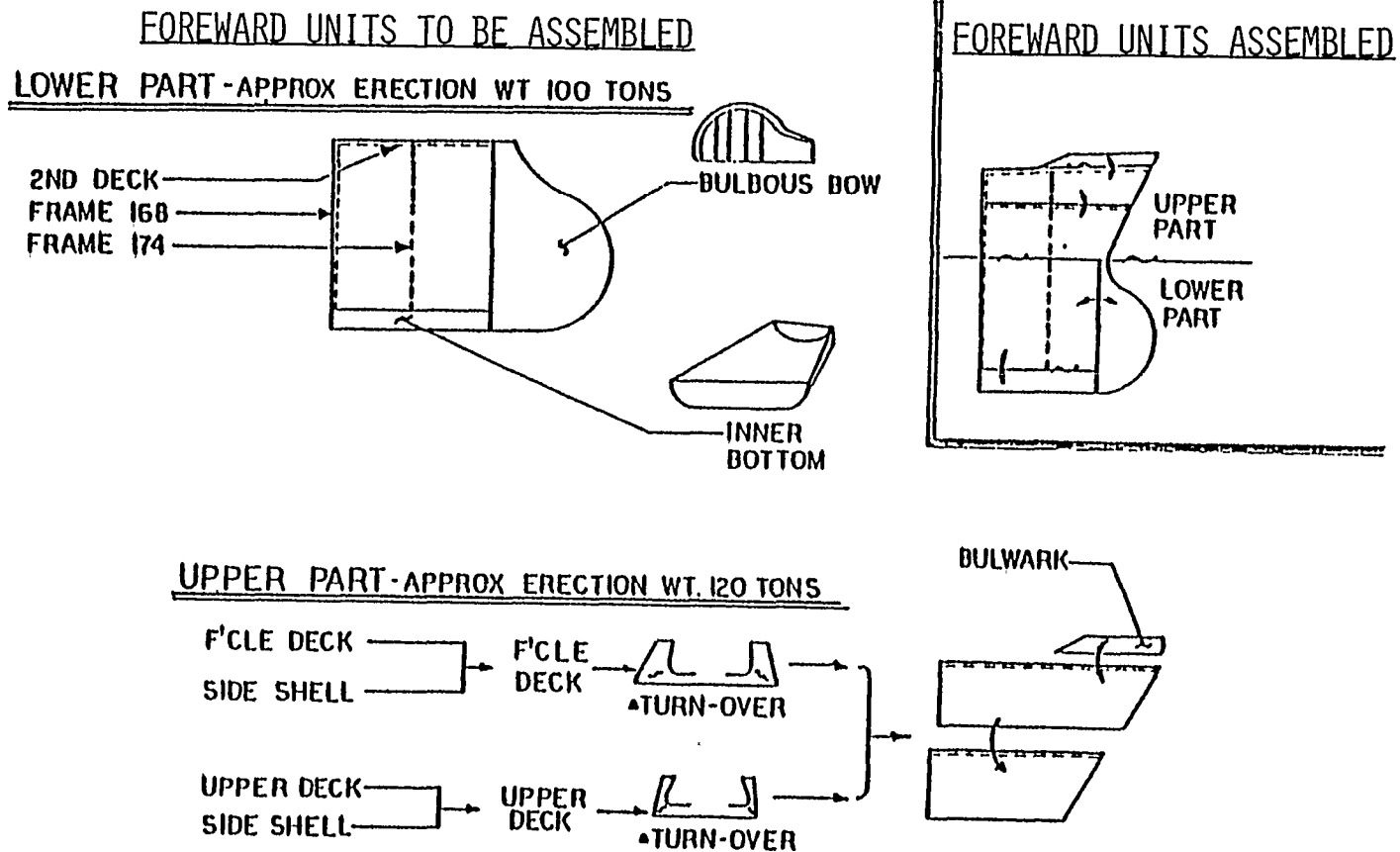
3.2.2.1 Assembly Specification Plans

Based on the information developed during the "preliminary process planning", formal Assembly Specification Plans are developed. These plans detail the methods to be followed during fabrication, assembly and erection. This planning is accomplished by engineering personnel in the Design Department and by accuracy control engineers in the various workshops.

Assembly Specification Plans are prepared for units of the fore and aft sections of the ship and for typical midship (cargo holds) sections. Evaluation of the assembly sequence is made to determine the assembly process lanes which must be used for curved versus flat units. This evaluation concerns an in-depth analysis of the processes through which each of the piece parts and the sub-assemblies must flow in order to be collected and assembled in the least possible time while simultaneously achieving full utilization of manpower, facilities and equipment. Figure 3-4 is an example of the Assembly Specification Plan prepared at this stage.

The planning accomplished during the preparation of the Assembly Specification Plans provides progressively more detailed information for lower-level planning in the workshops. From this relatively broad planning for assembly of units, Detailed Assembly Specification Plans are developed for each unit. These plans provide more precise assembly procedures to be utilized by the workshop personnel.

Preliminary Assembly Specification Plan



NOTE: THESE UNITS TO BE ASSEMBLED AS CONDITIONS PERMIT AT THE PRE-ERECTION STAGE.

FIGURE 3-4

The detailed plans specifically identify the assembly area to be utilized and the methods and processes to be used, such as: setting of jigs; joining of plates; marking of plates; the sequence of assembly; accuracy check points to be measured at each step in the assembly process; on-block outfitting; painting requirements; and performance control parameters (e.g. weld deposit per hour) and manhour forecasts for each unit.

These detailed plans provide the information for development of still lower-level detail contained in Working Instruction Plans. Figure 3-5 shows an example of these Detailed Assembly Specification Plans.

3.2.2.2 Other Plans

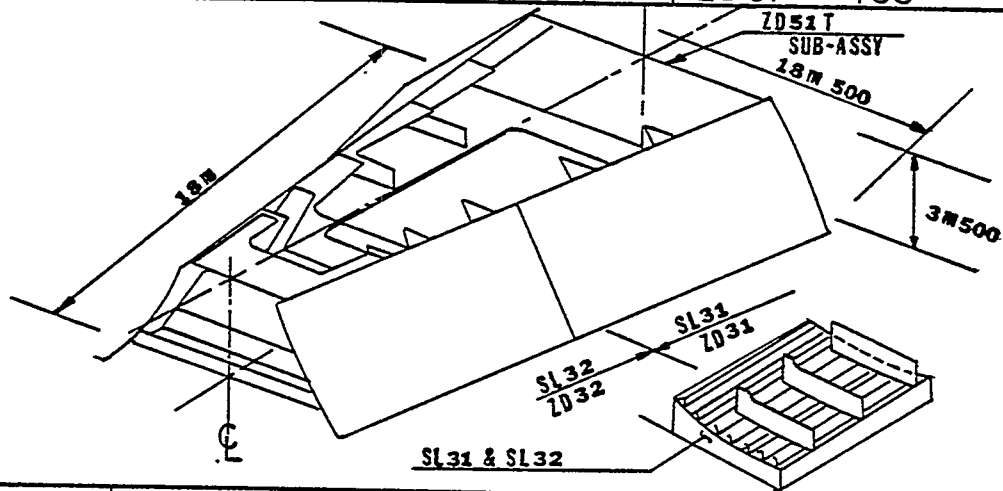
In addition to the Assembly Specification Plans an Assembly Jig Plan and a Block Finishing Dimensions Plan are prepared during this detailed planning stage. These plans provide additional detail to Design Engineers for inclusion in working drawings being developed for the unit assemblies. These plans will also be used by mold loft personnel in the development of Pin Jig Setting Lists for use on the curved units and by accuracy control and quality control personnel for assessing the finish dimension requirements on the various units.

3.2.3 Working Instruction Planning

During this final planning stage, the design department completes and issues detailed working drawings to the workshops. Also, detailed Working Instruction Plans are prepared to fully define all aspects of production and ship erection. With the issue of these plans and drawings, hull steel fabrication begins. In all, this planning cycle

Detailed Assy. Specification Plan

Block	GSL31	ZD31-SL31	WT	TOTAL 58 TONS
	GSL32	ZD32-SL32	DM	2D31 --- 403



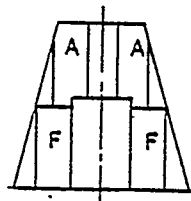
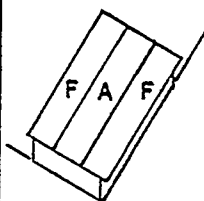
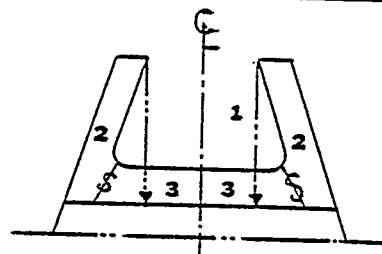
Steps	Assembly Process		ACCURACY CHECK Points
JIG SETTING	ZD 31&ZD32 HORIZONTAL JIG	SL31 & SL32 FIXED POINT JIG	HORIZONTALLY
PLATE JOINING (ALL FAB. WELDING)			ASSY. REFERENCE LINE BEAM--C TRANS-FLAT LONG GIR ZD32 BUTT ZD32 LENGTH BETWEEN BUTT LINE. & WEB
MARKING	ZD31 P/S ZD32 FINISH DIMEN. PLAN	SD31 & 32 BATTEN	
ASSEMBLY	ZD31-32 P/S EACH SL31-32 ASSY EACH SIDE PRE-ERECTION PRE-ERECTION FLAT BASE ZD 31 FITTING PARTS ON FLAT BASE		
CONTROL INDEX	WL-AUTO	90IM 288M	NONE
MAN-HOUR	ZD31-32 250 HRS.	SL31-32 420 HRS.	GS31-32 250 HRS.
			NONE

FIGURE 3-5

consumes from six to eight months of the total ship construction schedule. This thorough planning however, serves to considerably reduce both the time required for ship construction and also the cost of production.

Working Instruction Plans represent the final planning step, and are derived from the functional and detailed design, Detailed Assembly Specification Plans, and the other data which have been progressively developed from the Basic Design for each unit. Working Instruction Plans provide detail working-level data for the fabrication, assembly and erection of each unit. These plans complete the development of data from the design level information to the working level details necessary for workshop execution.

Three Working Instruction Plans are prepared for each unit in the area of fabrication: Marking Plan, Cutting Plan and Bending Plan (often the Marking and Cutting Plans will be combined into a single plan).

In the area of assembly, six plans are prepared on each unit as follows:

- Part Lists

- Finishing Dimensions Plan

- Sub-assembly Plans

- Assembly Plans

- Lifting Instructions Plan

Working Instruction Plans originated for erection include:

- Arrangements Plan

- Shipwright Dimensions Plan

Support Block Arrangements Plan

Welding Instruction Plan

Scaffolding Arrangements Plan

These plans provide all necessary information at each production stage for the proper manufacture and handling of each unit. The basic objectives intended for these plans are: 1) to effect control of the total workload and the products as the work progresses through the various process lanes, sub-stages and stages of the production system; 2) to effect control of the great number of parts and pieces of material as they flow through the production processes; and 3) to provide explicit instructions to all levels of personnel concerned with the fabrication, assembly and erection of ship components.

3.2.3.1 Working Instruction Plans for Fabrication

Three plans are prepared for the fabrication processes: a Marking Plan; a Cutting Plan and a Bending Plan. Figure 3-6 presents a flow chart representing the development of these plans.

3.2.3.1.1 Cutting Plans

These plans are constructed from Rough Cutting Plans by inserting small computer-prepared drawing pieces on a sheet of layout paper for each process lane and for each unit. This composite is used by workers to mark parts and pieces on steel plates. Figure 3-7 shows an example of this method.

These plans can also be constructed by affixing 1/10 scale drawings (transparent film) of the parts and pieces, (drawn in the automated drafter) on to a transparent base film.

Marking on the plate is accomplished by projecting the transparency

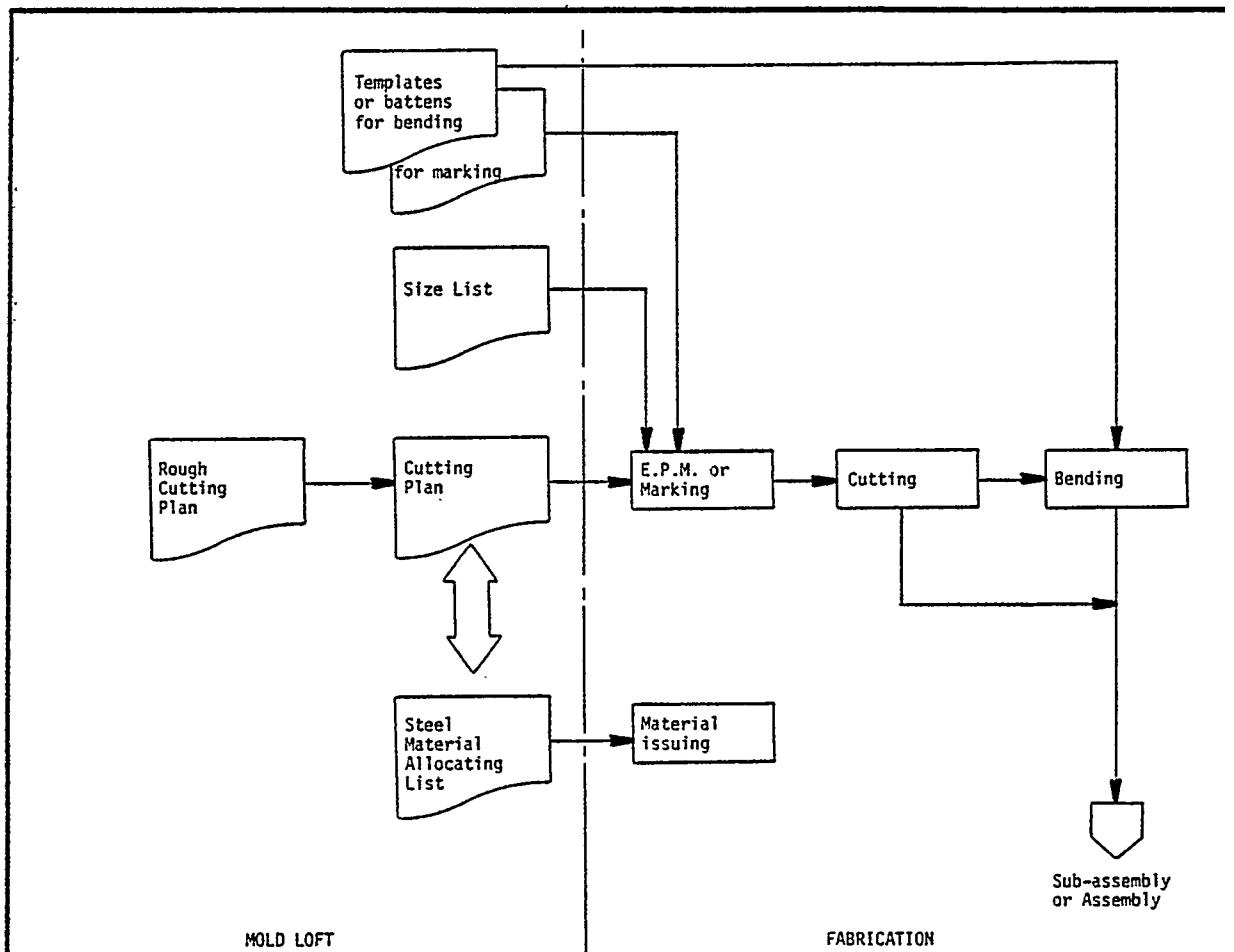


FIGURE 3-6
DEVELOPMENT OF WORKING INSTRUCTION PLANS FOR FABRICATION

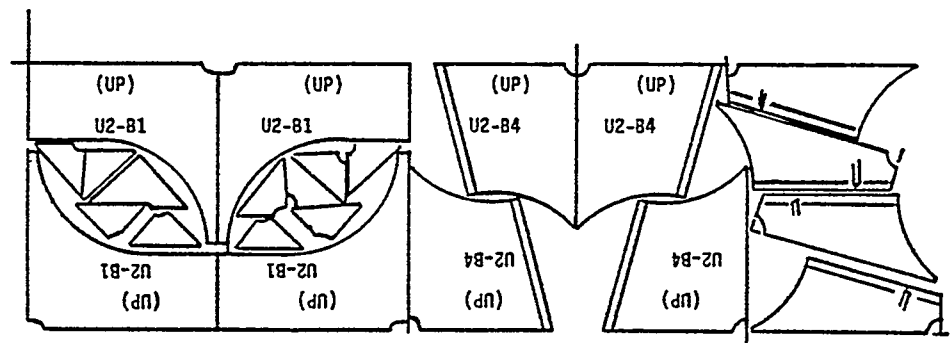


FIGURE 3-7
CUTTING PLAN (D.D.A.)

on to the plate in full scale which exposes a photo-sensitive powder on the plate causing the powder to adhere to the projected lines on the plate's surface. This is called Electro Photo Marking (EPM).

Steel Material Allocating Lists

These lists are prepared from Material Requisition Orders which are developed from the completed Cutting Plans. These lists are issued, together with the Cutting Plans, as Steel Material Issue Orders for the shops for the marking and cutting of material. Figure 3-8 provides an example of these lists.

Size Lists

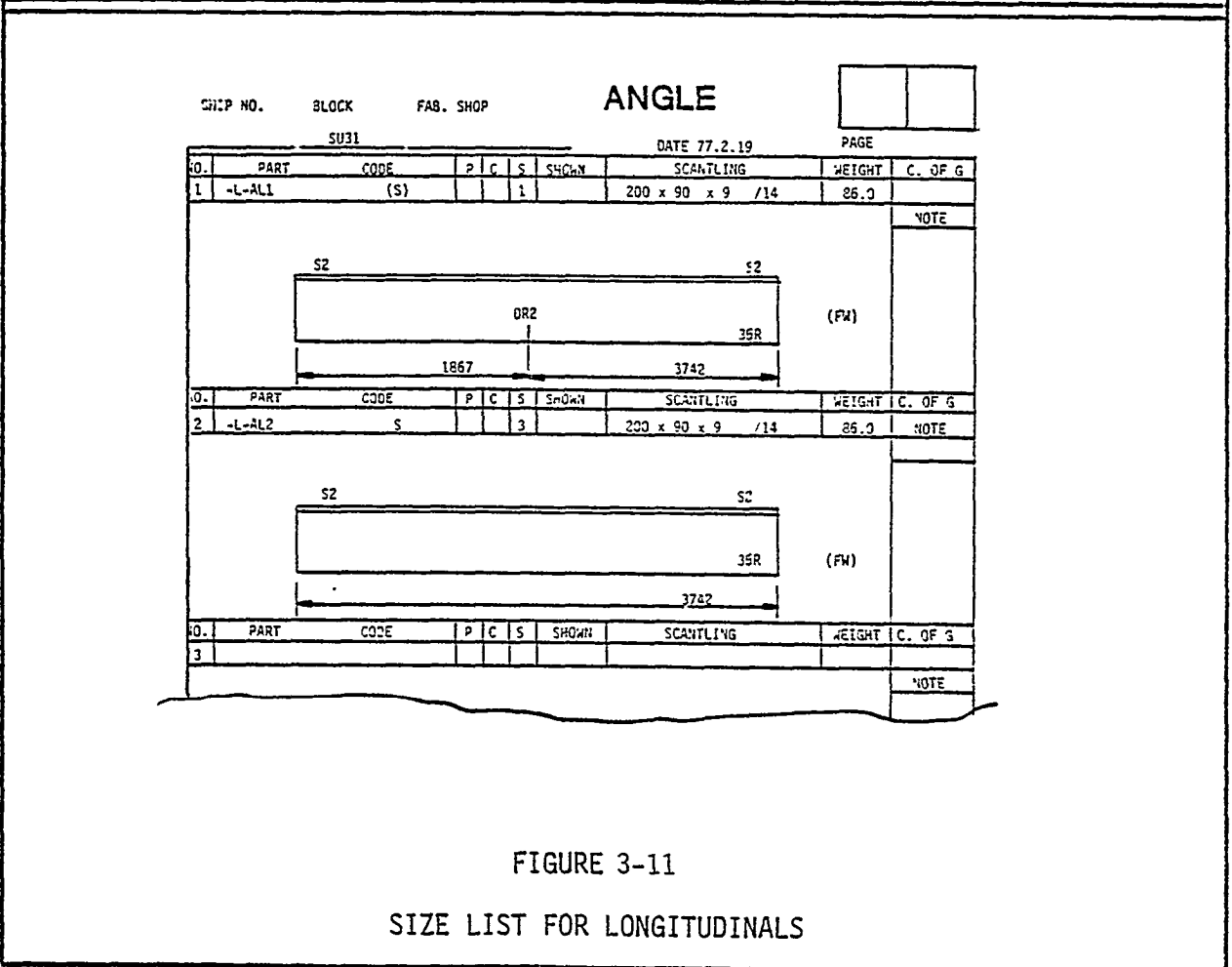
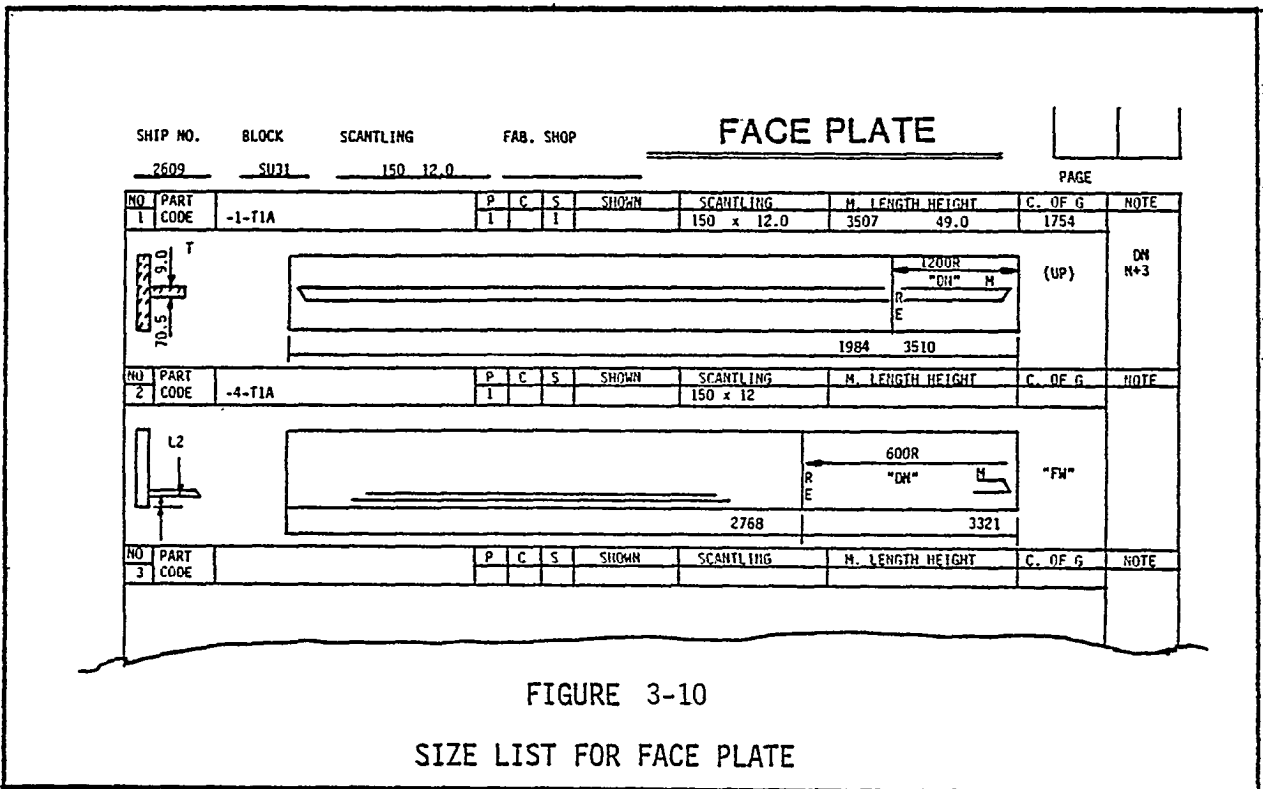
Size lists also accompany the Cutting Plans. These lists specify the size of flat bars, face plates, longitudinal for each material/unit/process lane. These lists provide information for the cutting of these items on plate remnants or on one entire plate regardless of the number of units involved. Figures 3-9 through 3-11 show examples of these lists.

3.2.3.1.2 Bending Plans

Bending plans are prepared for both steel plate and shapes.

1/10 scale plans are prepared by the computerized drafting system, (SHELL - Shell Expansion and Logical Layout System) for plate bending. Bending jigs are then used for the actual bending.

Figure 3-12 shows a 1/10 scale plan produced by the Automatic Drafter. Full size plans are used by Mold Loft personnel by projecting the scale drawing to full size and indicating the sizes necessary for making templates on the full sized plans. Figure 3-13 illustrates a Size List for Bending Plans for steel plates.



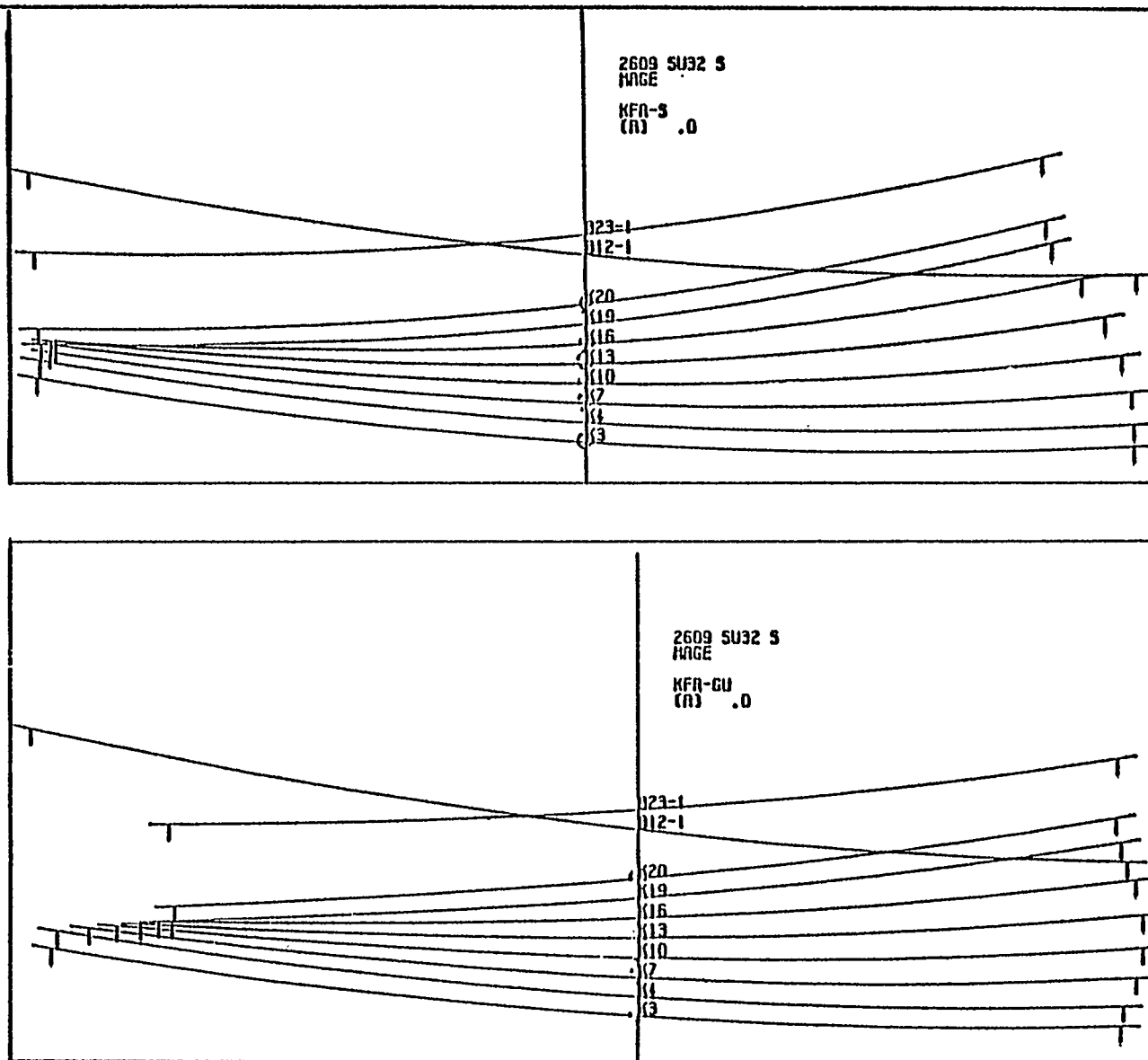


FIGURE 3-12 BENDING PLANS FOR STEEL PLATE

Bending Plans for Shapes show a curved line marked on webs as a guideline for bending. The bending of the shape is performed by straightening the curved line which has been marked on the material. Figure 3-14 illustrates this method.

3.2.3.2 Working Instruction Plans for Sub-assembly and Assembly

The Working Instruction Plans for sub-assembly and assembly are:

- Parts Lists
- Lifting Instruction Plans
- Sub-assembly Plans
- Assembly Plans
- Finishing Dimensions Plans
- Size Lists for Assembly Jig

Each of these plans are described below.

3.2.3.2.1 Parts Lists

These lists are issued for each unit for each production stage (i. e., Sub-assembly, Assembly and Erection). These lists are used by workers at each stage to assure the collection of components and that all components have been properly installed. Figures 3-15 and 3-16 show examples of the Parts List.

3.2.3.2.2 Lifting Instructions Plan

A Lifting Instructions Plan is prepared for each unit. This plan provides information for the attachment of pad eyes, the attachment of any reinforcing material required during lifts, attachment of pieces on the unit that will be required for joining during erection, the loading weight for lifting devices, the total block weight and the safety margin for all lifting conditions.

This plan is carefully constructed taking into consideration all movement of the unit during transport, over-turning and final erection of the unit on the ways. Figure 3-17 depicts the development of the plan for each unit. Figure 3-18 shows an example of the plan for one type of unit.

3.2.3.2.3 Working Instructions Plan for Sub-assembly

Sub-assembly plans for each unit are prepared to show the details of constructing the one or more sub-assemblies which will be included in the final units. These plans show necessary alignment, welding and finishing requirements together with the outfitting requirements for each sub-assembly. Figure 3-19 shows the development flow for the preparation of these plans. Figures 3-20 and 3-21 present examples of the type of instructions conveyed by these plans.

3.2.3.2.4 Working Instructions Plan for Assembly

Details of unit assembly are presented in these plans. Figure 3-22 shows the development flow of these plans. These plans extract information from Assembly Specification Plans and yard working drawings and simplify the data through presentation in the form shown in Figures 3-23 and 3-24.

3.2.3.2.5 Finishing Dimensions Plan

This plan is prepared for each unit to show applicable reference lines for assembly and erection, diagonal dimensions, fitting lines for outfitting parts and pieces and several other critical dimensions related to outfitting and installation of the unit during erection. Figure 3-25 illustrates the development of these plans and the pertinent information presented for each unit. Figure 3-26 shows an example of one such plan.

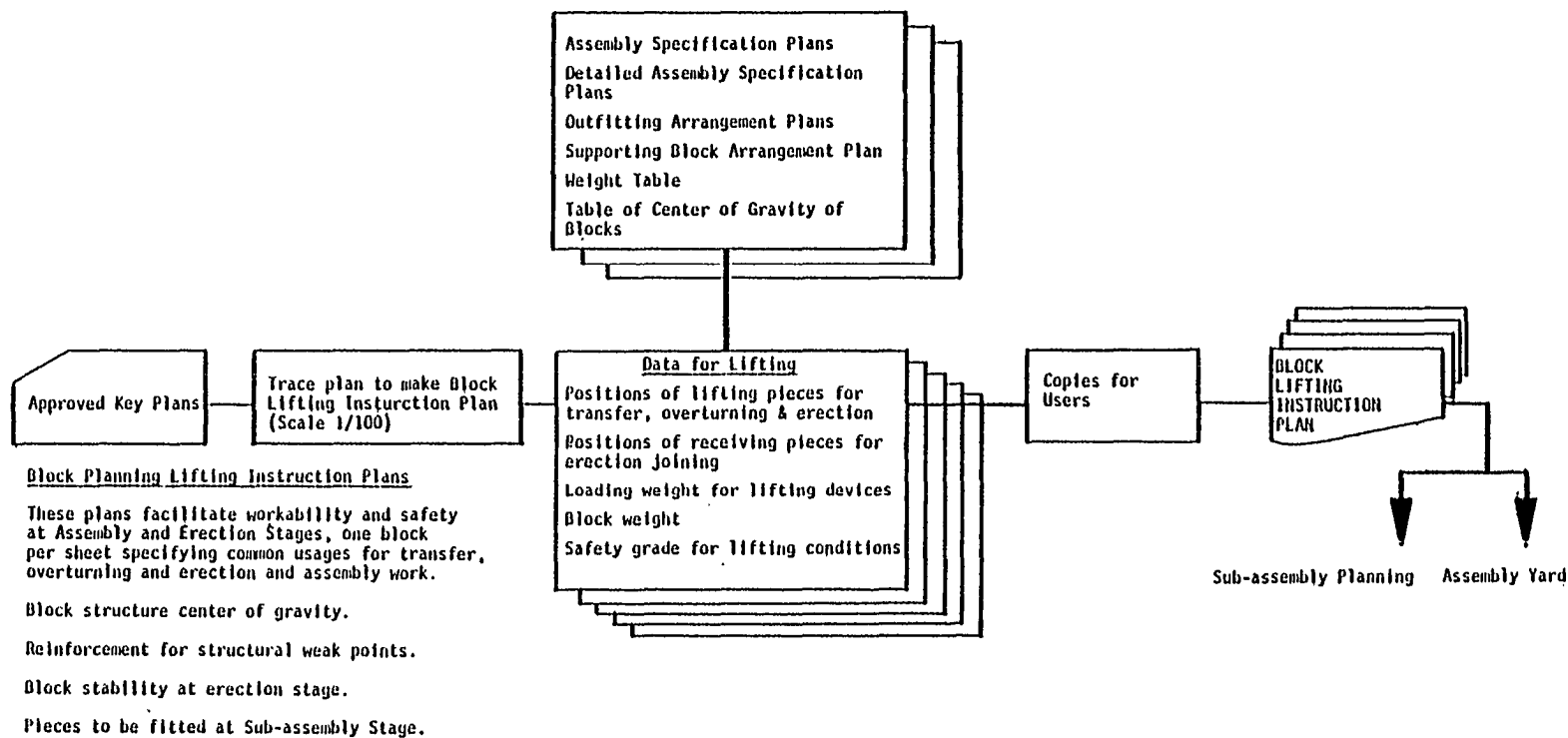


FIGURE 3-17

PROCESS FLOW OF BLOCK LIFTING INSTRUCTION PLANNING

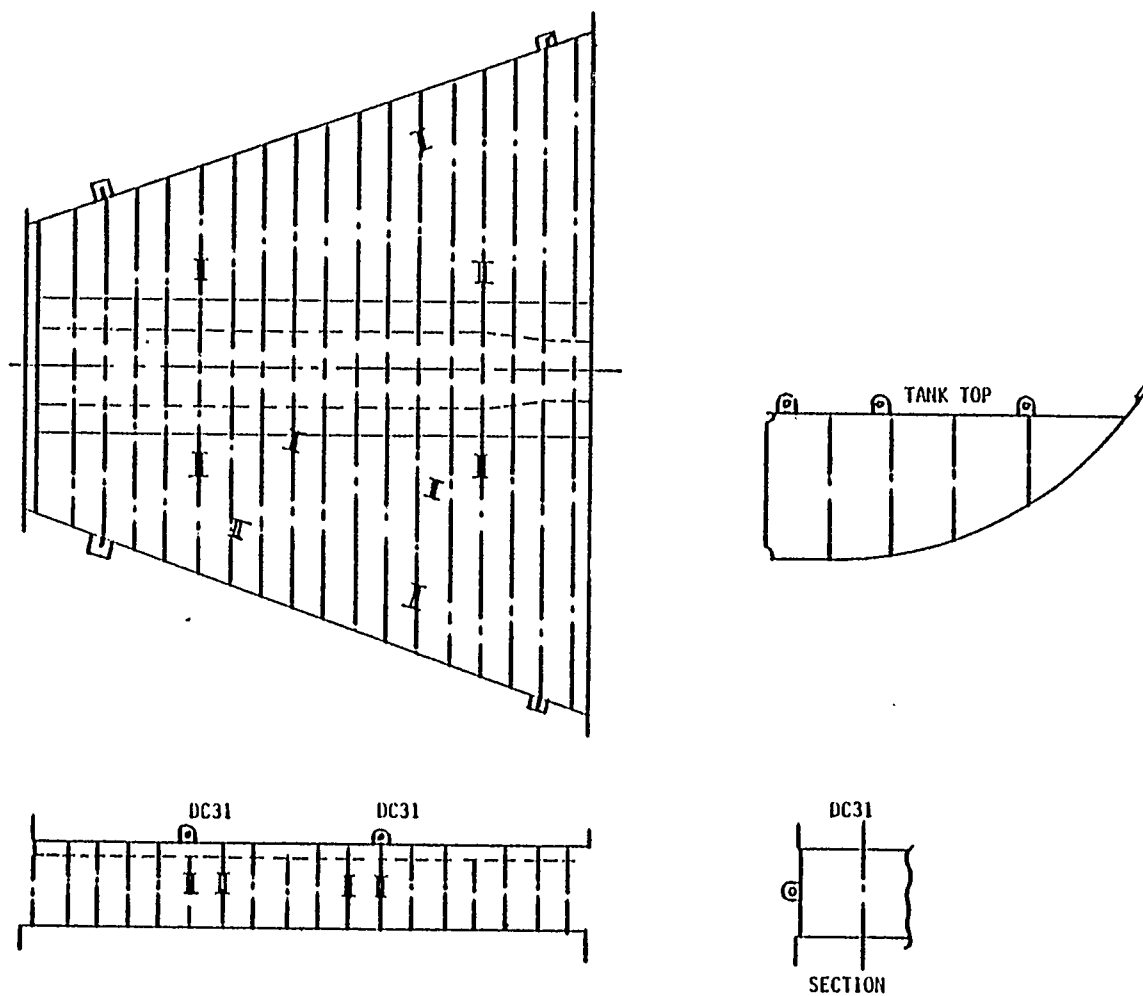


FIGURE 3-18

BLOCK LIFTING INSTRUCTIONS PLAN

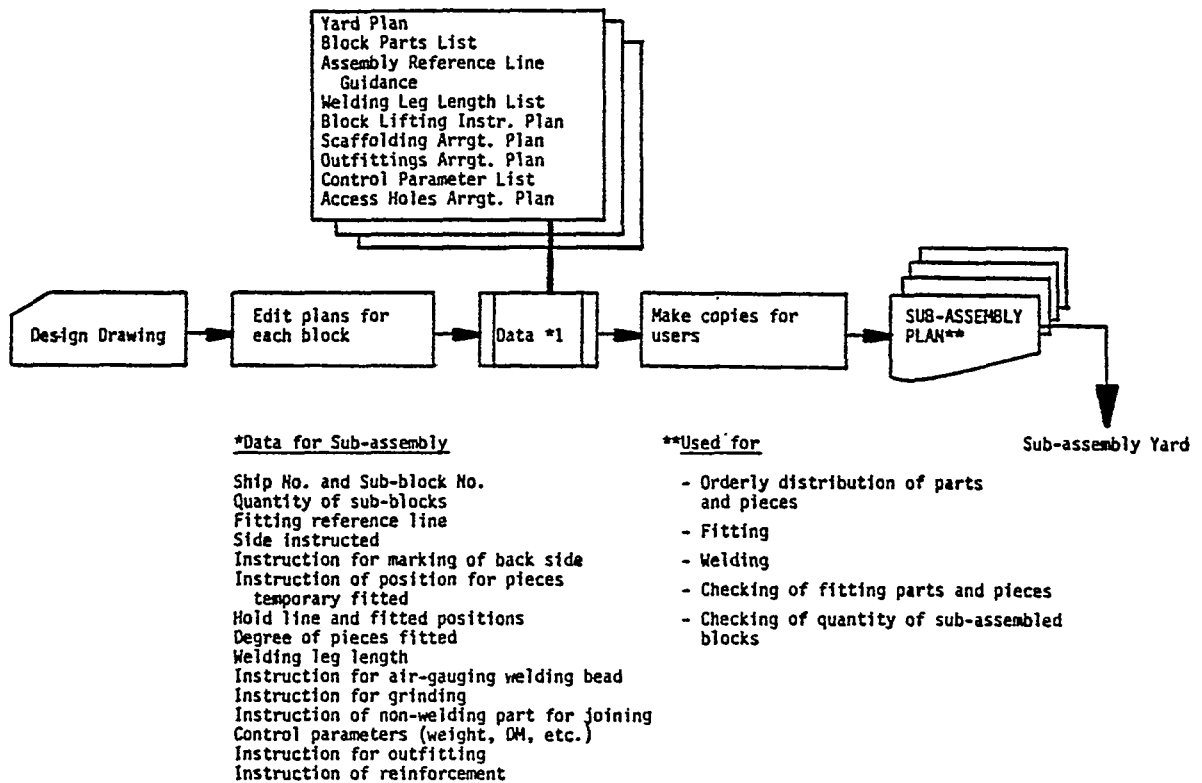


FIGURE 3-19 PROCESS FLOW OF SUB-ASSEMBLY PLANNING

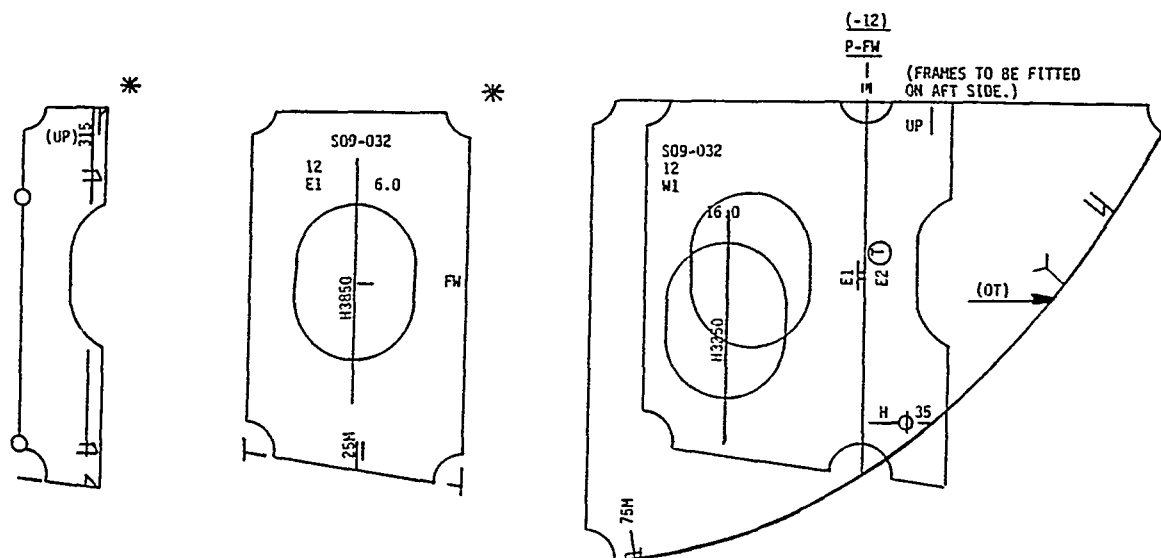


FIGURE 3-20

WORKING INSTRUCTIONS PLAN FOR SUB-ASSEMBLY

(BOTTOM KEEL INCLUDED) $\frac{4L}{8L}$ FRAMING (BOTTOM LONG'L EXCLUDED)	
TANK TOP (BILGE PLATE BILGE KEEL) (ZW)	
<u>BOTTOM</u> (LONG'L TO BE FITTED BEFORE ASSEMBLY) (ZW)	
(TANK TOP TO BE COVERED BY BOTTOM PLATE) (1A)	

FIGURE 3-24

WORKING INSTRUCTIONS PLAN FOR ASSEMBLY

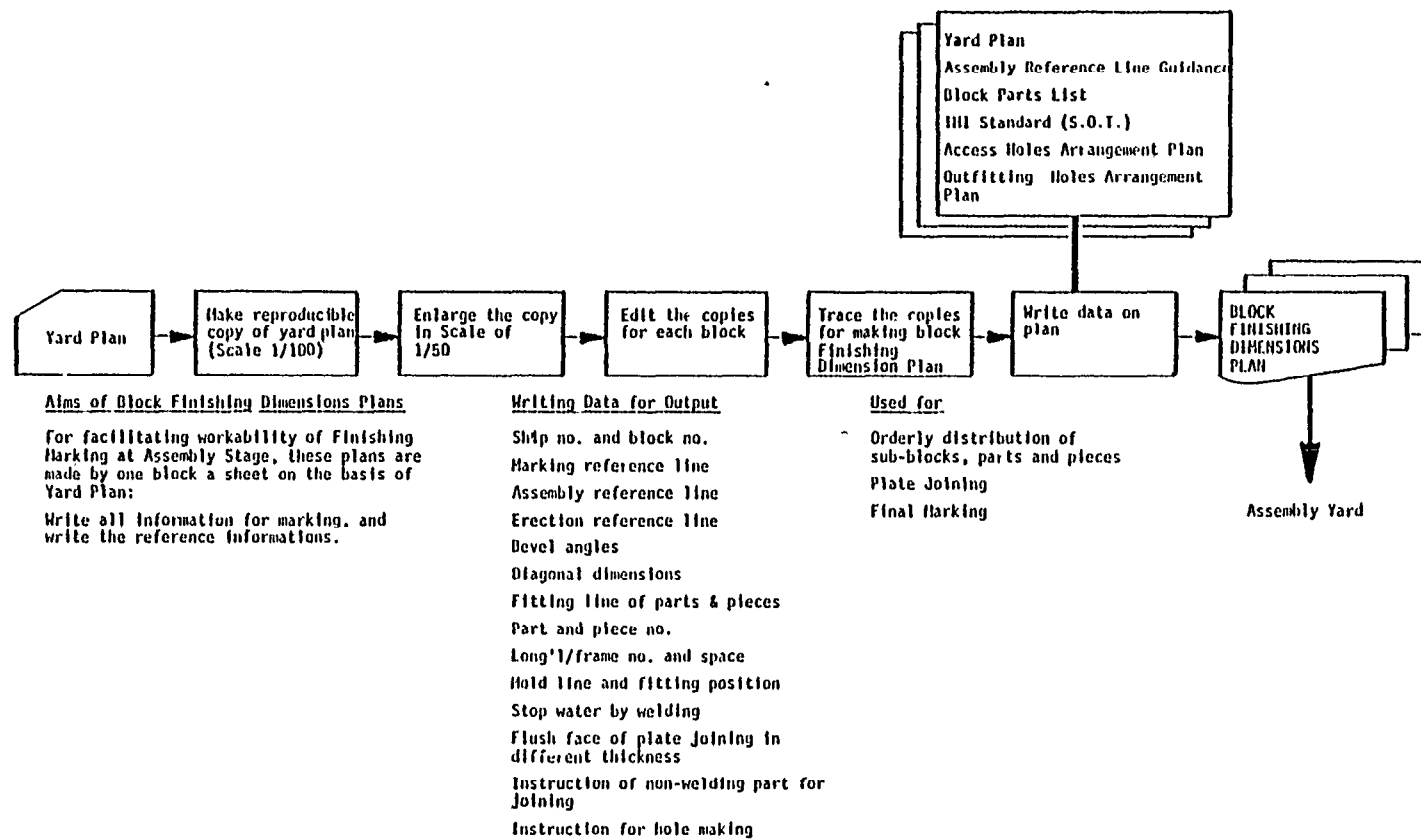


FIGURE 3-25

PROCESS FLOW OF BLOCK FINISHING DIMENSIONS PLANNING

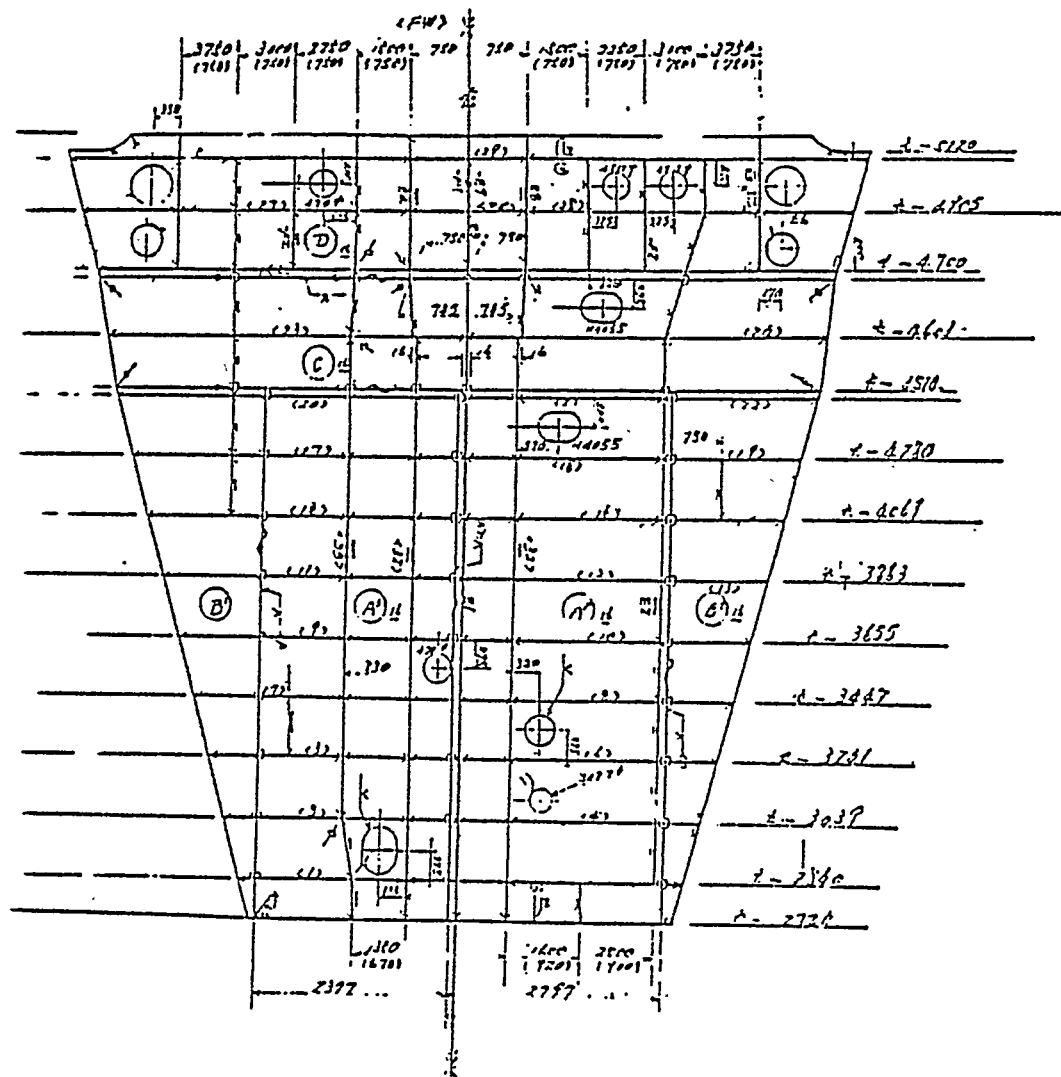


FIGURE 3-26
FINISHING DIMENSIONS PLAN

3.2.3.2.6 Assembly Jig Arrangement Plan

These plans, prepared for each curved unit, designate necessary information on the approximate size of plates, the gap length between the welding seam and the fixed point jigs, the position of the first setting plate, the weight of the jigs, and the slant of the frames. These plans are required for the adjusting or building of a proper curved unit assembly jig and for assembly area planning. Figure 3-27 shows the process of developing these plans and Figure 3-28 presents an example of an Assembly Jig Size List which provides the information for the construction of the jig for one unit.

3.2.3.3 Working Instruction Plans for Erection

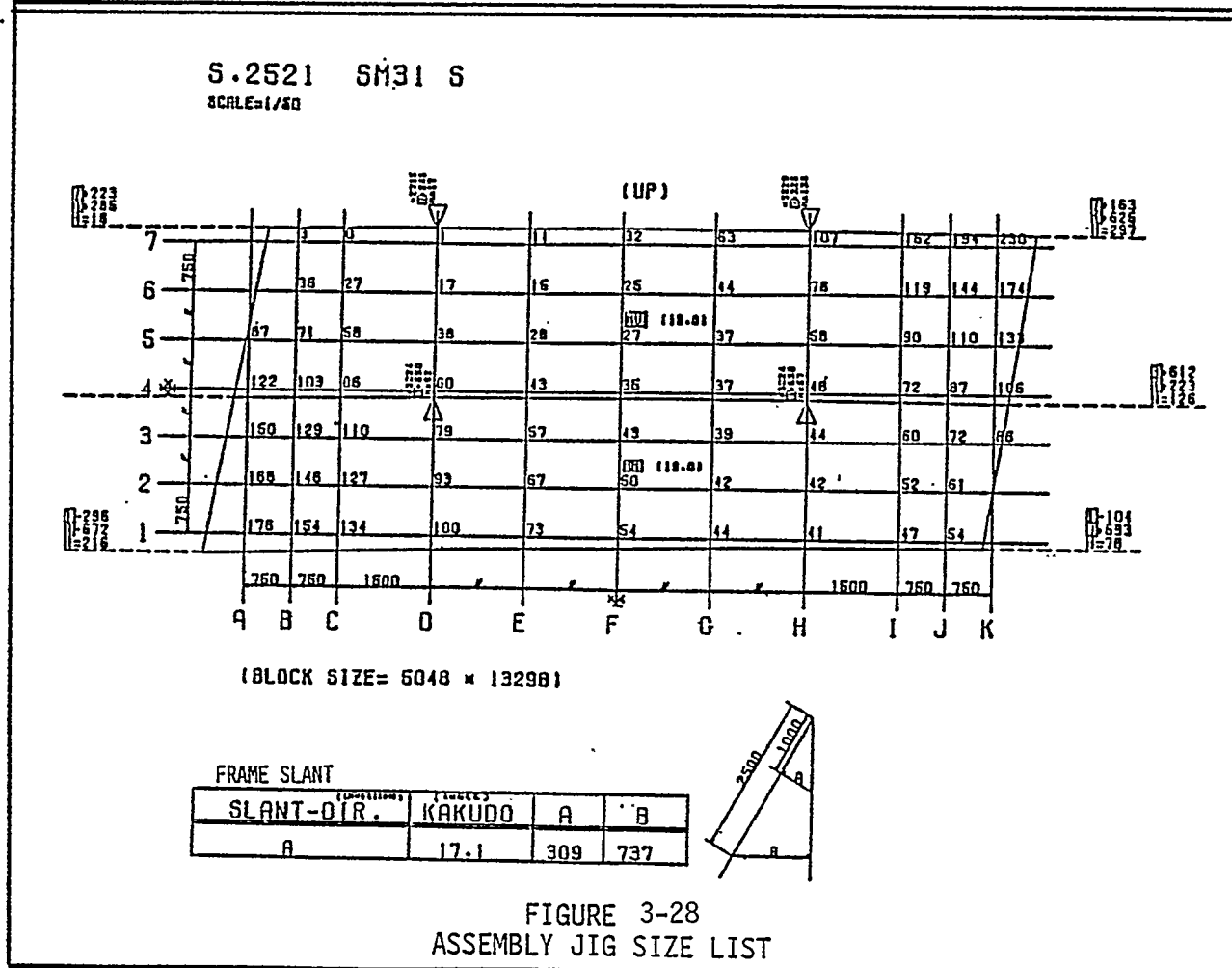
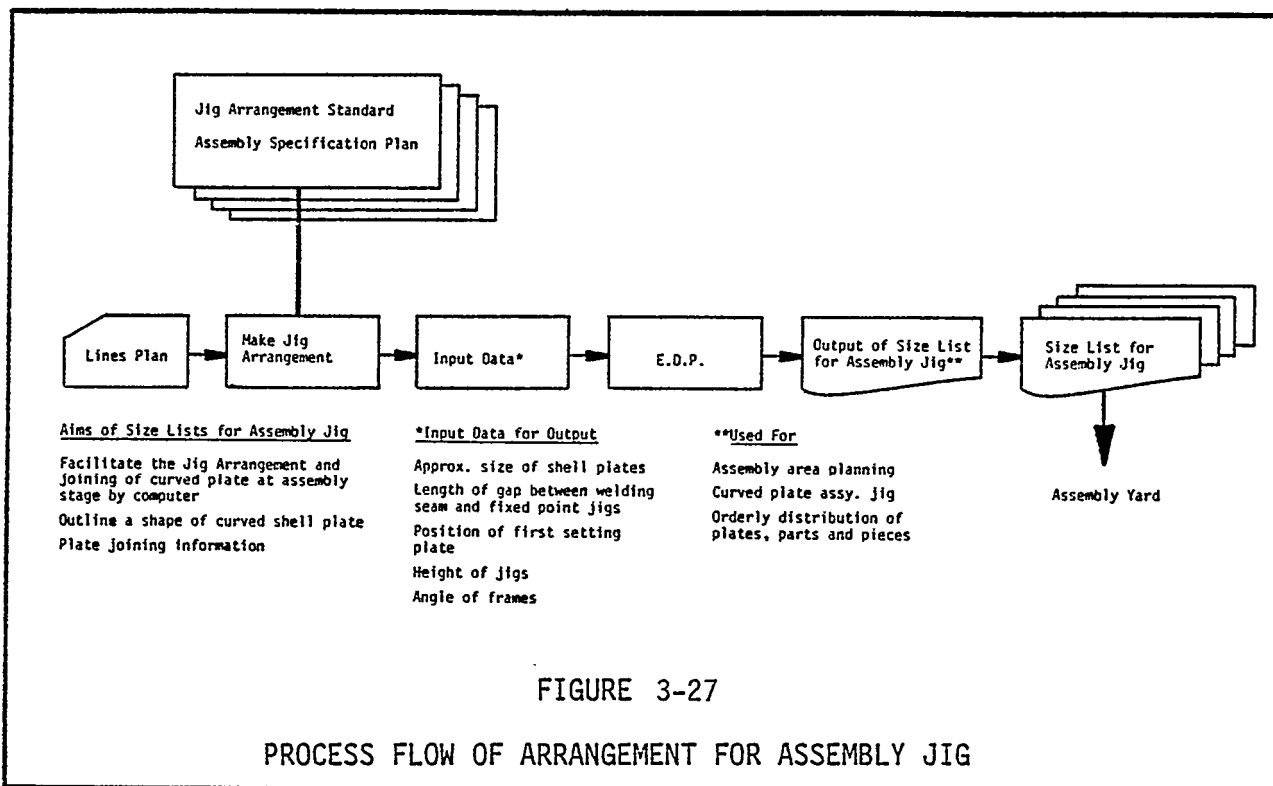
Working Instruction Plans for the Erection Stage are:

- Hull Blocking Plans
- Shipwright Dimensions Plans
- Supporting Block Arrangement Plans
- Welding Process Instruction Plans
- Scaffolding Arrangement Plans

3.2.3.3.1 Hull Blocking Plans

These plans provide detailed information for the erection of the individual hull units. In addition to the drawing showing the division of the ship into hull units other data includes information on:

- Hull joints
- Positions of joints in the distance from some frame
- Unit Code and Number
- Erection sequence and direction
- Insert blocks



- Loose plate and temporarily affixed pieces
- Sections in charge of work
- Access holes for working
- Bevel angle for welding at Erection Stage
- Frame spaces
- Longitudinal spaces
- Overlapping length of frames on skin plates
- Welding leg Length
- Scantling

Figure 3-29 provides an example of a hull blocking drawing.

3.2.3.3.2 Shipwright Dimensions Plans

These plans, which are prepared by computer (through a sub-system of the IHI Computer System or IHICS) describe the position of each unit in the erection sequence. This position is described by reference to adjacent frames. Figure 3-30 provides an example of this plan.

3.2.3.3.3 Supporting Block Arrangement Plans

These plans show the arrangement of under-keel and under-frame support blocks. Considerations for making these plans are:

Loading weight for each block 30 - 40 tons/unit

(Special attention is given to the blocks under Engine Room.)

Arrangement suitable for shipwrighting

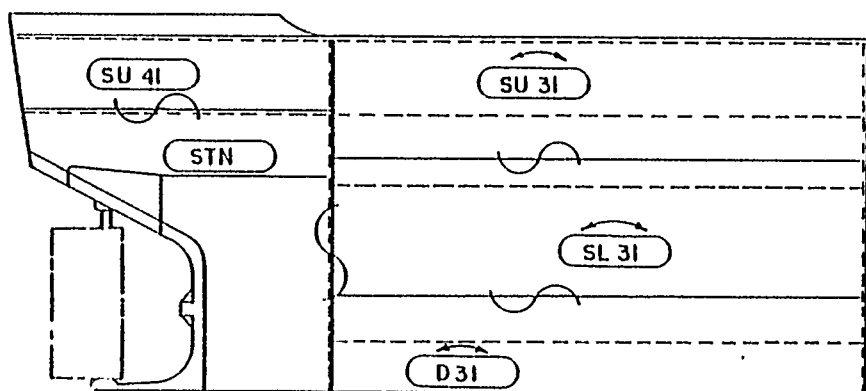
Prevention of shell plate damage at launch

Figure 3-31 presents an example of this type of plan.

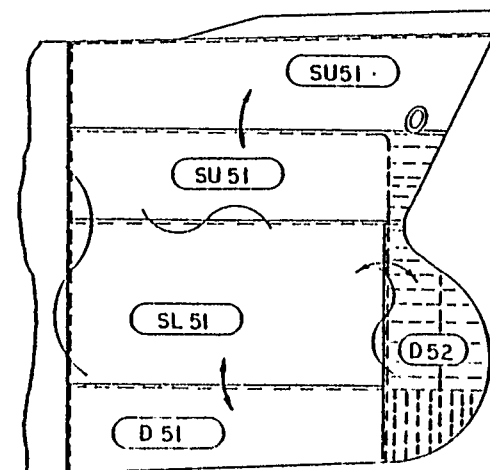
3.2.3.3.4 Welding Process Instruction Plans

Welding instructions are determined by the Hull Construction Workshop for inclusion in yard working drawings. These plans provide

HULL BLOCK PLANNING



BLOCKING PLAN OF AFT SECTION



BLOCKING PLAN OF FORE SECTION

FIGURE 3-29

** SH0.2609 **											
	D		**SL**			**SU**			**S**		
	(FRAME NO.) FR. NO.	D. HABA	H. TAKASA	FR. NO.	HABA	TAKASA	FR. NO.	HABA	TAKASA	FR. NO.	HABA
41				FC	(3.045*10.241)	FC		(5.344*13.193)			
				F12	(6.410*10.242)	F12		(8.413*13.194)			

32				F13	(4.983* 8.590)	F13		(8.606*13.195)			
				F23	(7.453* 8.592)	F23		(9.964*13.197)			

D12				F13	(0.977* 1.747)	F13		(1.347* 3.897)			
				F23	(2.786* 1.743)	F23		(3.836* 3.893)			

31				F27	(8.256* 8.593)	F27		(10.256*13.197)			
				F36	(9.591*8.595)	F36		(10.206*13.200)			

NOTE: HABA - BREADTH
TAKASA - HEIGHT

FIGURE 3-30
SHIPWRIGHT DIMENSIONS PLAN

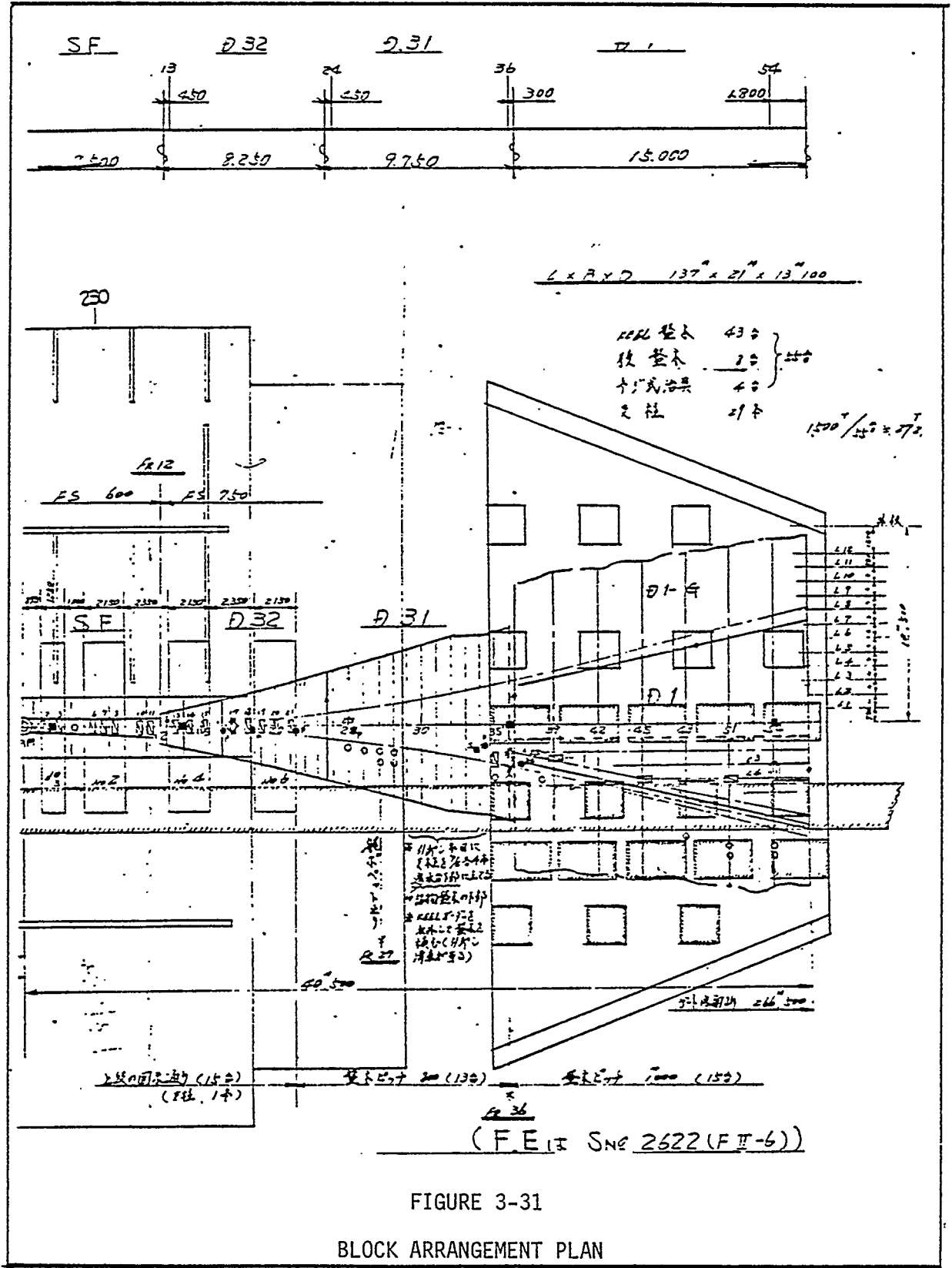


FIGURE 3-31
BLOCK ARRANGEMENT PLAN

information concerning automatic and semi-automatic welding processes for each hull unit. Bevel information is also included. These plans also provide detail instruction to welders during the erection process. Figures 3-32 and 3-33 provide examples of these instructions.

3.2.3.3.5 Scaffolding Arrangement Plan

The scaffolding plan prescribes the use of both interior and exterior scaffolding during ship erection. The use of moveable scaffolding stages greatly facilitates the use of the scaffolding but necessitates a definitive plan for its erection and take-down. Information regarding scaffolding hangers and materials described in this plan is also included in sub-assembly and assembly plans. Figures 3-34 and 3-35 present examples of the information contained in these plans.

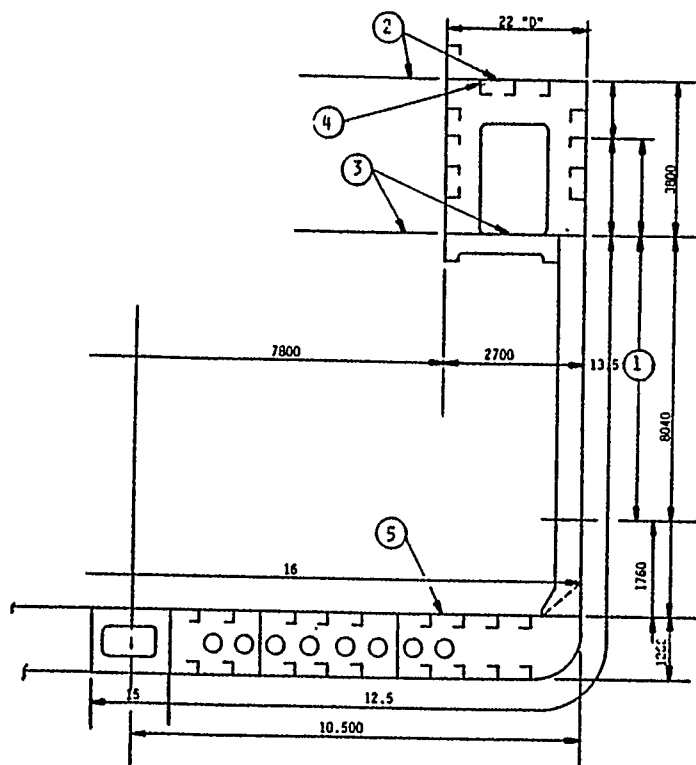
3.3 OUTFIT PLANNING

In IHI outfit planning begins immediately upon receipt of the Basic Design and parallels hull construction planning in the development of the Hull Blocking Plan, Unit Assembly Plans and the development of the functional and detailed design.

The IHI shipyards accomplish as much "pre-outfitting" of hull units as possible during the construction of these ship elements. This, of course, greatly reduces the amount of outfitting work that must be done during erection and after launch. The manhour and cost savings attributable to this approach are considerable and this approach is another factor in the high productivity achieved by these yards.

Pre-outfitting is a logical and highly effective method for reducing ship construction costs especially in light of the "modular"

SNO 2609 MID SHIP SECTION



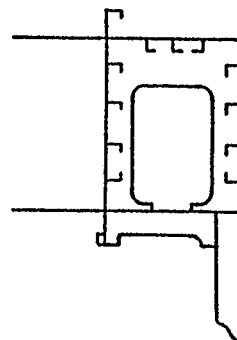
NO.	WELDING JOINTS	WELDING PROCESS
1	Side Shell Butt	E-Gas
2	Upper Deck Butt & Seam	CO2 One-Side
3	Tween Deck Butt & Seam	"
4	Deck Long	CES
5	Inner Bottom Butt	CO2 One-Side + UM

FIGURE 3-32
WELDING PROCESS INSTRUCTION PLANS

WELDING PROCESS FOR DECK

A) CES PROCESS

1) PREPARATION AND FITTING FOR DK LONG'L



NO	PROCESS	PREPARATION FOR FITTING
A	CES	1. Joint leveling to be done with jigs for dk long'l and wedges and dogs for ces. 2. Groove opening --- 24mm Groove shape --- I 3. No fittings to be fitted by 70mm in width from groove for copper plate setting.

CES TO BE APPLIED

FR36 - FR136

(U31xL1) - (L5 x L6)

2) COPPER PLATES AND WELDING MATERIALS

JOINT	SIZE OF MATERIAL	SIZE OF COPPER PLATE	SIZE OF NOZZLE	FLUX	WIRE
DK LONG'L	300 x 29 FB	Front Side 400 x 1 Back Side 400 x 1	KNZ-1 10 ⁴ x 500	MF-38 12 x 65	ES-50 2.4 ⁴ x S200

FIGURE 3-33
WELDING PROCESS INSTRUCTION PLANS

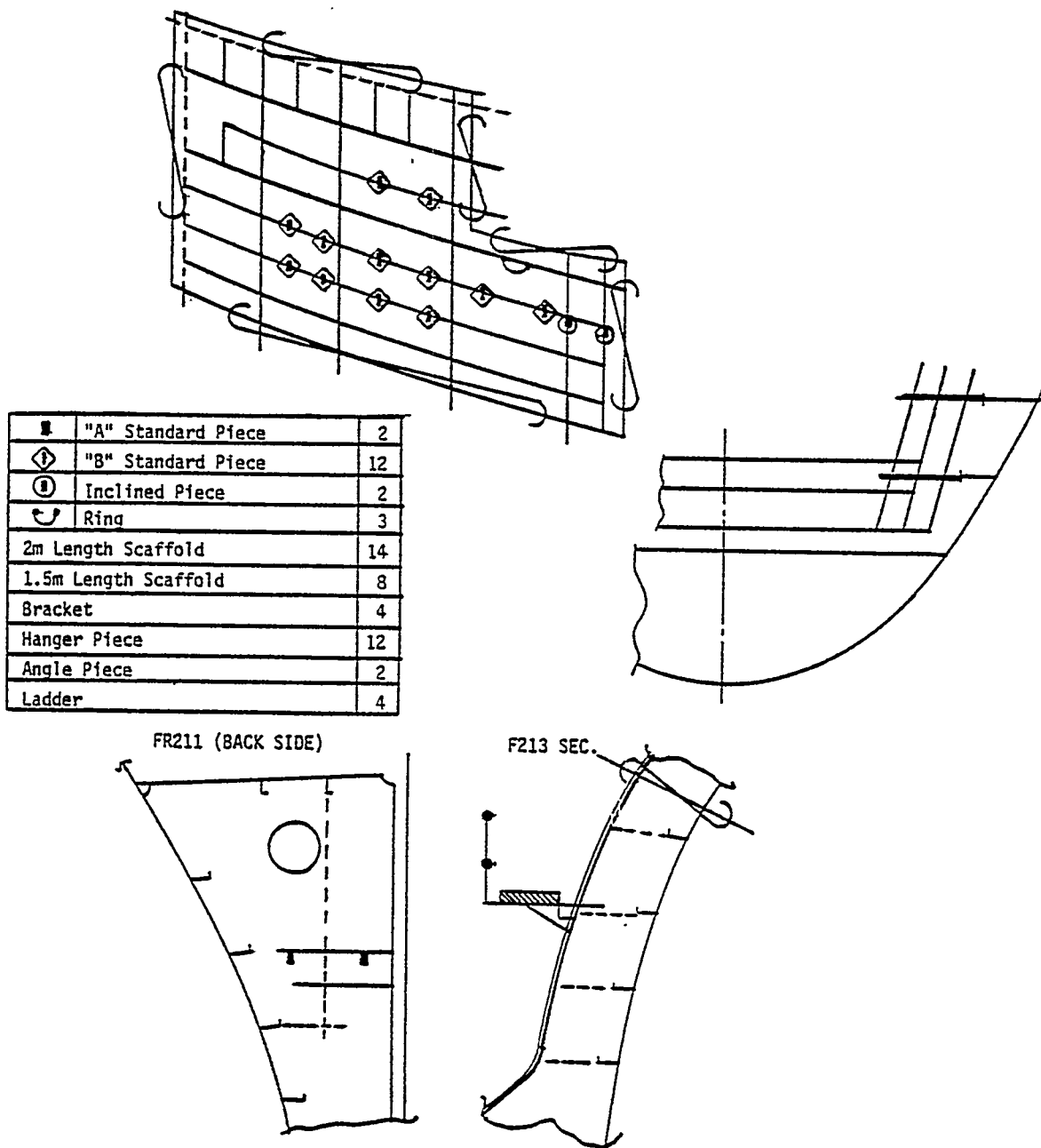


FIGURE 3-34
SCAFFOLDING ARRANGEMENT PLAN

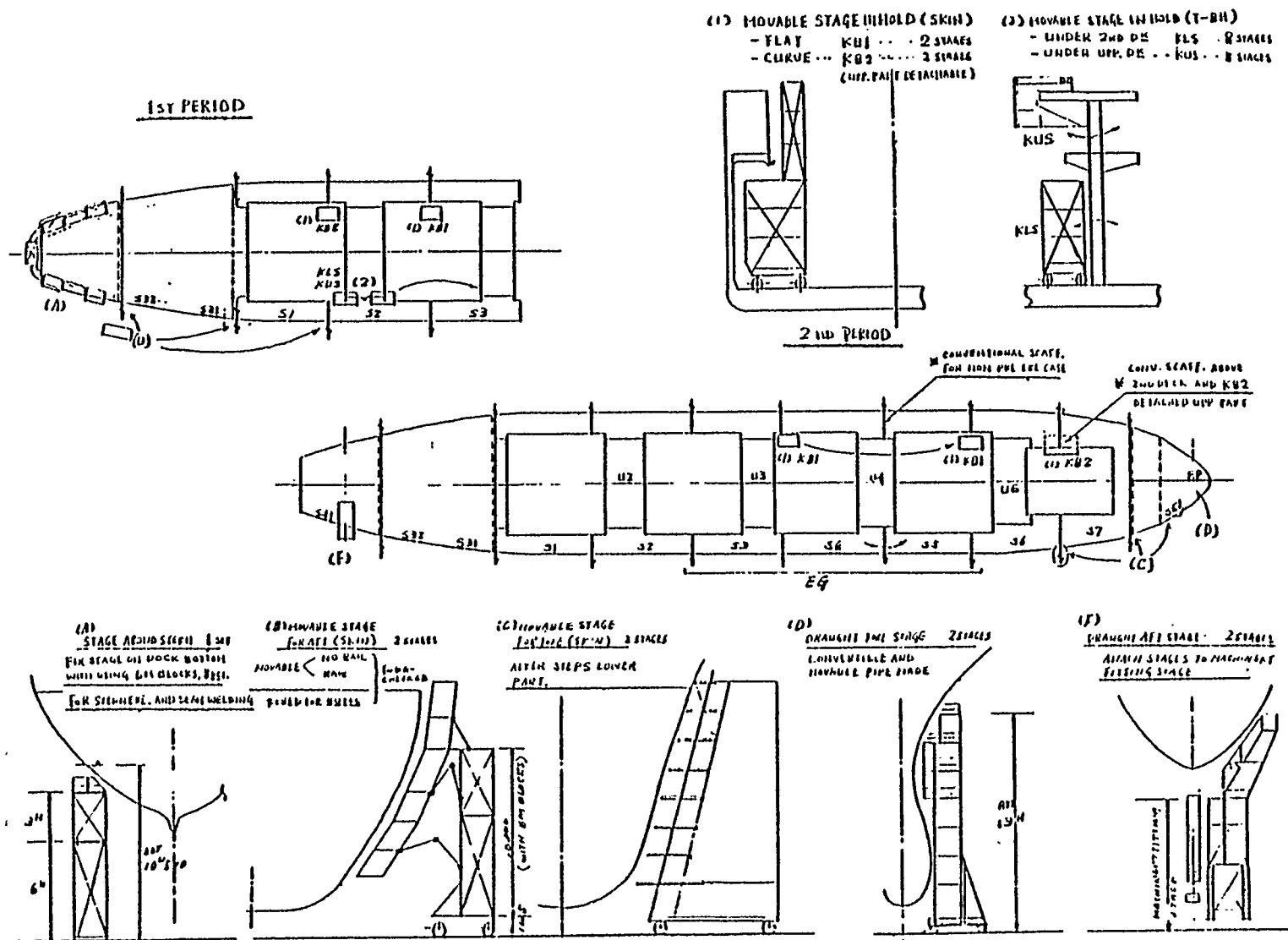


FIGURE 3-35
OUTLINE OF SCAFFOLDING FACILITIES

hull construction method used by IHI. The building of assembly units and the joining of units to form "grand units" provides an ideal condition for the installation of outfitting components and sub-assemblies at the various production stages of hull steel construction. Naturally, the outfitting work performed during the build-up of hull units in the assembly areas is far less costly, less dangerous and is more accessible and amenable to down-hand welding processes. This type of outfitting also corresponds to the IHI objective of shortening the work time in the building basin.

The outfitting practices of IHI have been the subject of much study and documentation in the recent past. Several excellent reports on the theory and practice of pre-outfitting in the Japanese yards are available through the Shipbuilding Research Program of MarAd (one of which is referenced herein as a source of additional information). Because of this existing information, this report has been structured to present the outfitting activities in the IHI shipyards as they actually occur and without any elaboration as to the theory or rationale behind such activities. These activities basically concern the functions of design, procurement, production, and material handling and control. Figure 3-36 illustrates the overall flow of outfitting activities through these several functions. Subsequent paragraphs describe these activities under their respective functions.

3.3.1 Design

The basic planning for outfitting occurs during the evolution of the basic design into the overall working drawings. Subsequent to receipt of the Basic Design the shipyard design department, in

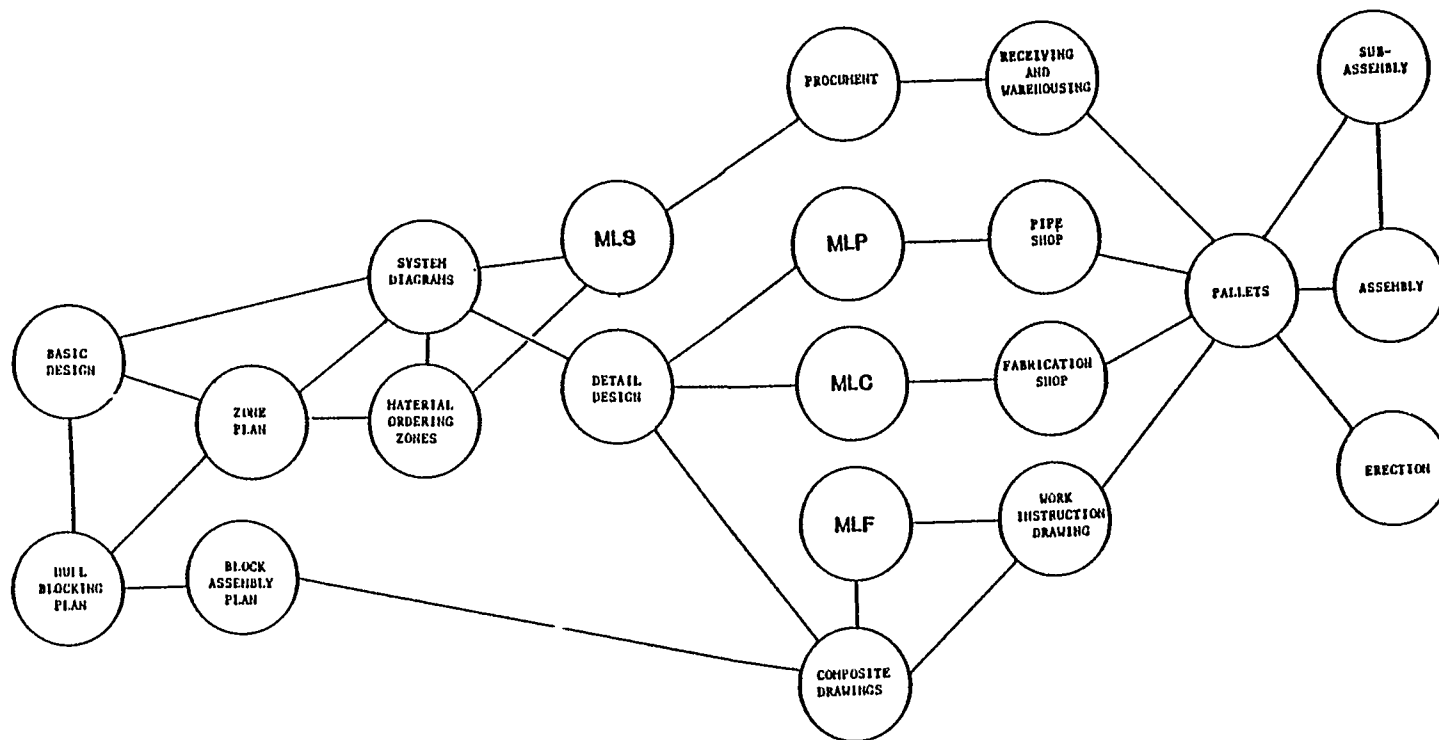


FIGURE 3-36

FLOW OF OUTFITTING

collaboration with the Fitting Workshop Production Planning and Engineering staff, develops system diagrams for each functional system of the ship. The diagrams define all components required in each functional system but do not reflect any sub-division of the ship into units or zones. On the basis of these diagrams, a Material List by System (MLS) is compiled. These lists provide an itemization of the bulk and raw materials and system components required for a particular Material Ordering Zone. Figure 3-37 provides an example of an MLS.

IHI establishes a series of "Zones" for each ship: major zones, which are primarily used for sub-dividing the ship for the purpose of hull construction; Material Ordering Zones, which are used to categorize material for procurement; Outfitting Zones, which designate major areas of outfitting; and Outfitting Work Zones, which are further sub-divisions of Outfitting Zones into discrete small packages of outfitting work. Figure 3-38 illustrates these different types of zones.

Material Ordering Zones range from four to seven depending on the type of ship. The first four zones are: the cargo hold, the engine room, the main deck, and the house. Electrical outfitting is nearly always considered as a separate zone which makes five basic zones of a ship such as a tanker or bulk carrier. Container ships or combination container/bulk carriers would require additional material zones.

The system-oriented material lists (MLS) for each Material Ordering Zone are sent to the Material Procurement Department for scheduling and ordering. Because of the wealth of historical data accumulated by the IHI yards over the past decades and because of the unique relationships between these yards and subcontractor/suppliers (which generally

● 番号別： ①＝①番用記、②＝②番用記、③＝③番用記
● 番号別分： ①＝①番用記、②＝②番用記
● 内容区分： ①＝作品、②＝引論、③＝引用、④＝付録、⑤＝加付
● 出版区分： ①、②、③＝本誌、④＝別冊、⑤＝無題、⑥＝先行
● 区分分： プラン＝①番用記、②＝③番用記、③＝④番用記
● ④＝⑤番用記、⑥＝⑦番用記、⑦＝⑧番用記、⑧＝⑨番用記、⑨＝⑩番用記、⑩＝⑪番用記、⑪＝⑫番用記、⑫＝⑬番用記、⑬＝⑭番用記、⑭＝⑮番用記、⑮＝⑯番用記、⑯＝⑰番用記、⑰＝⑱番用記、⑱＝⑲番用記、⑲＝⑳番用記、㉑＝㉒番用記、㉓＝㉔番用記、㉕＝㉖番用記、㉗＝㉘番用記、㉙＝㉚番用記、㉛＝㉜番用記、㉝＝㉞番用記、㉟＝㊱番用記、㊲＝㊳番用記、㊴＝㊵番用記、㊶＝㊷番用記、㊸＝㊹番用記、㊺＝㊻番用記、㊼＝㊽番用記、㊾＝㊿番用記

品名	DISCRIPTION / 材質、型式、規格、寸法 引当箇所示項目	PART 取付符号 PIECE NO.	単位	No. 数量(NET) 数量(GROSS)	S/T 重量(NET) 重量(NET)	引当図番	手配区域 SUB ZONE	備考
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X171----		98 18391
		FR-042V		1	1040	B4X171----		0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X171----		98 18391
		FR-043V		1	1040	B4X171----		0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X186----		98 19177
		O-025V		1	1040	B4X186----		0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X186----		98 19177
		O-026V		1	1040	B4X186----		0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X186----		98 19177
		O-027V		1	1040	B4X186----		0800
403002015	FC ANGLE VALVE FC/BC FL 5200B	33,10,00	A32	1	1040	B4X186----		98 19177
		O-028V		1	1040	B4X186----		0800
* 403002015	** SUB-TOTAL **	**		100		B4		
	** SUB-TOTAL **	**		100	10400			
403003008	FC S.D.C.GLOBE VALVE FC/BC FN 5065GB	31,30,00	A32	1	148	B4XM1AP--O		98 18392 2
		BS-222V		1	148	B4XM1AP--O		0800
* 403003008	** SUB-TOTAL **	**		10		B4		
	** SUB-TOTAL **	**		10	148			
403003009	FC S.D.C.GLOBE VALVE FC/BC FN 5065GB	32,60,00	A32	1	213	B4x118----O		
	922348 362902	FO-019V		1	213	B4x118----O		0800
* 403003009	** SUB-TOTAL **	**		10		B4		
	** SUB-TOTAL **	**		10	213			
403003010	FC S.D.C.GLOBE VALVE FC/BC FN 5080GB	33,10,00	A32	1	276	B4XM3AP--O		
	922367 364901	FR-201V		1	276	B4XM3AP--O		0800

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FIGURE 3-37

MATERIAL LIST BY SYSTEM

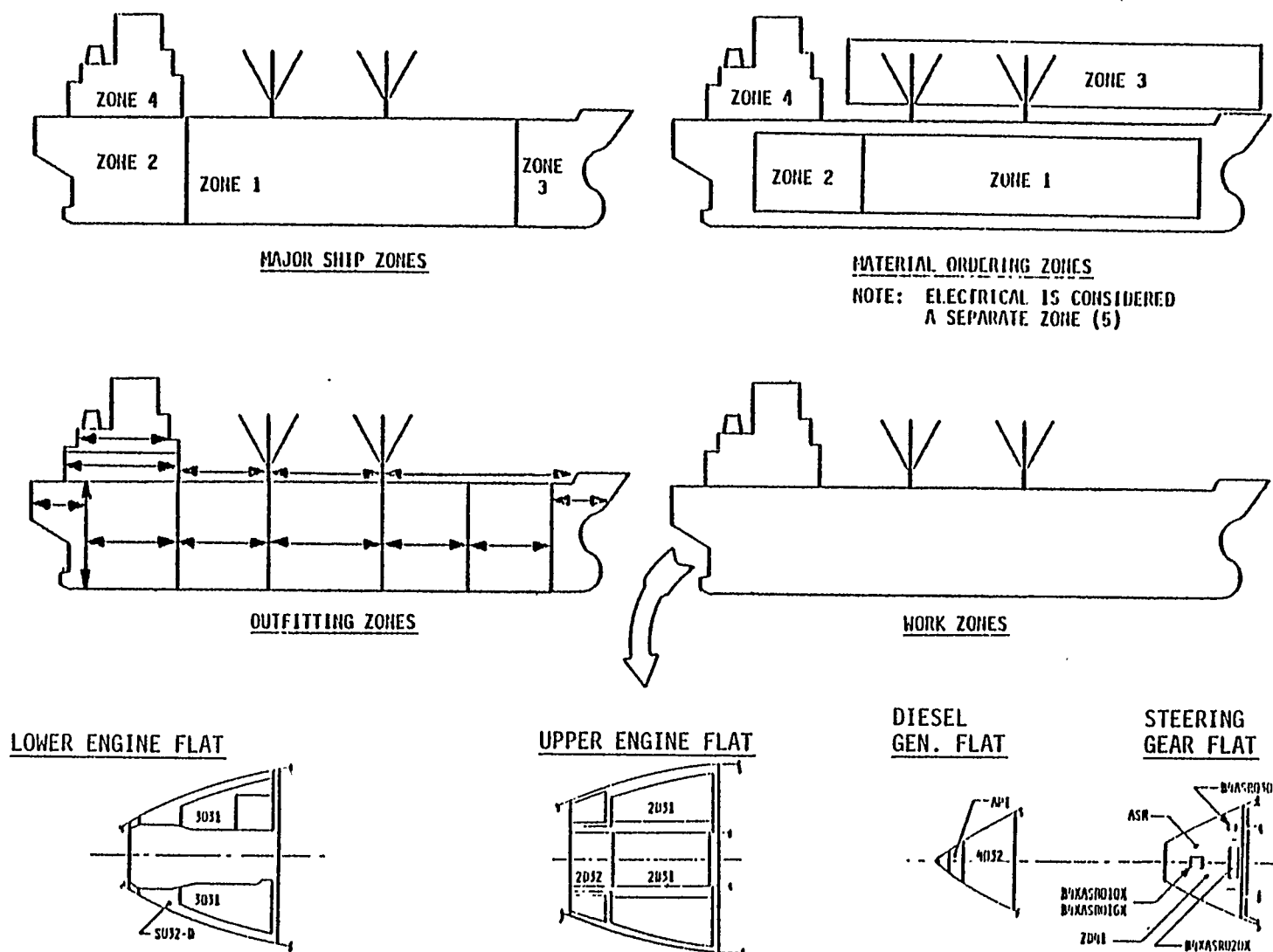


FIGURE 3-38

DIFFERENT SHIP ZONES

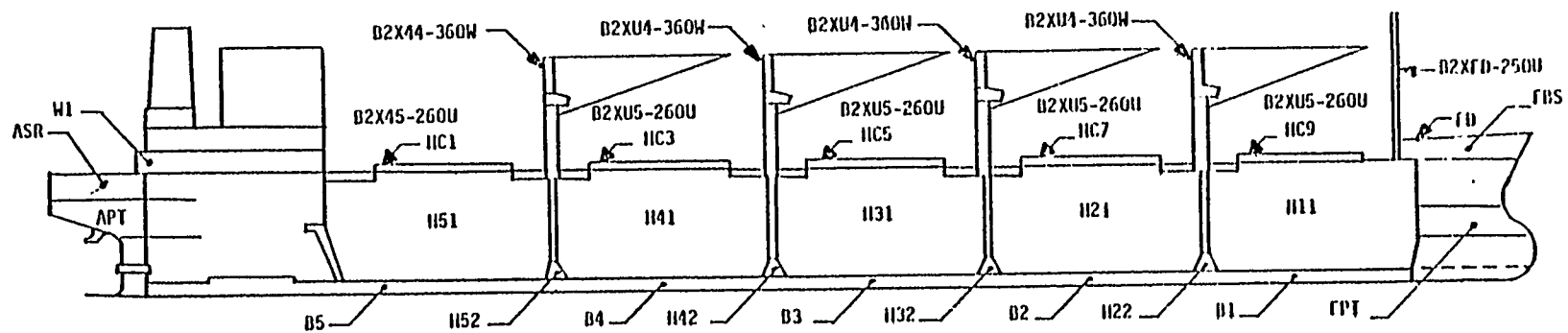
reside in proximity to the yards), the yard procurement function is able to construct immediately valid lead-time and cost information.

The majority of such information resides in a procurement computer data bank and is constantly updated by procurement personnel. A more complete explanation of the procurement function is presented in subsequent paragraphs.

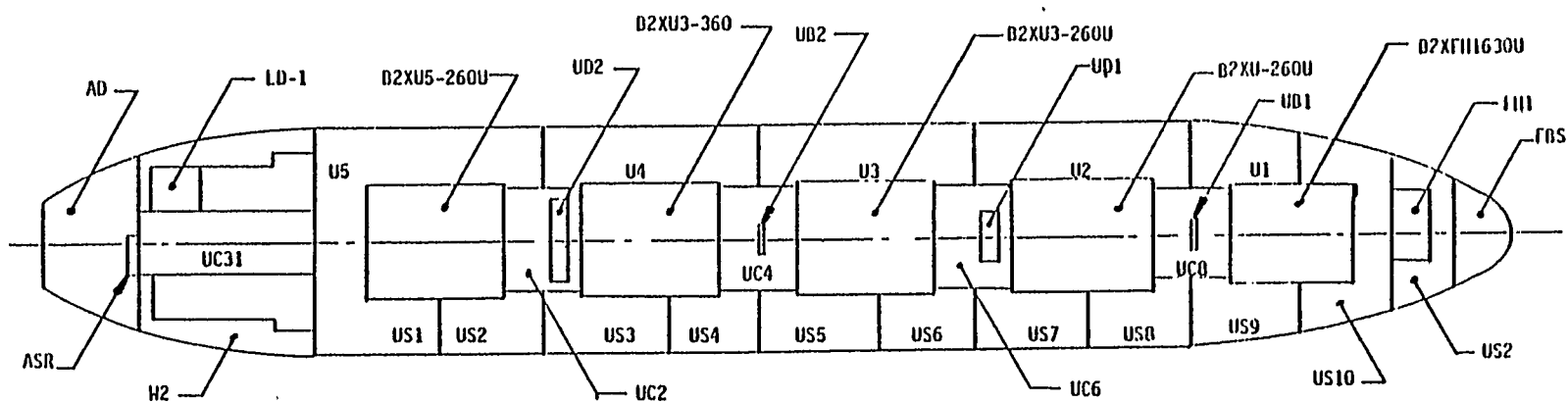
The system diagrams developed by the Engineering Department are part of the second stage of design development which is called "Functional Design". This stage translates the Basic Design to the next logical level of development, i.e. Detail Design.

During the Detail Design stage, the data from the functional design is converted into working drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also, at the detail design stage an Outfitting Zone Plan is developed for the ship. This outfitting zone planning essentially sub-divides the major ship zones into smaller areas concerned with outfitting activities in the major ship sections, i.e., cargo hold, engine room, deck house, main deck, etc. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to a particular system. Instead all systems within a given area are encompassed by the zone boundaries. An Outfitting Zone can represent a portion of a deck, a portion of several decks, one or more compartments, parts of adjacent compartments, etc. Figure 3-39 illustrates the Outfitting Zones identified for one type of ship.

The criteria for sub-dividing the ship into outfitting zones are based on the hull breakdown (in the Hull Blocking Plan), and the



FORE SECTION



UPPER DECK

FIGURE 3-39
OUTFITTING ZONES

identification of logical packages of outfitting work at each of the production stages of sub-assembly, assembly and erection. This identification of work packages parallels the construction of the steel sub-assemblies and assemblies since outfitting must be accomplished at precise periods in the hull construction schedule. As a consequence, Outfitting Zones are identified which correspond to the hull units specified in the Hull Blocking Plan.

With the identification and designation of Outfitting Zones detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops. Figure 3-40 presents examples of these material lists.

In addition to the above, the Detail Design effort also produces composite drawings showing the layout of all outfitting material in specific "Work Zones" (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining. Figure 3-41 provides an example of a composite drawing.

Upon completion of the composite drawings the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be installed

MATERIAL LIST FOR PIPE

MLP

DESCRIPTION	S NO	OUTFITTING CODE	C NO	MATERIAL CODE						WEIGHT
15A			94	161001	1			13	0	93.7
25A			94	161003	1			31	0	414.3
40A			94	161005	1			26	0	556.3
50A			94	161006	1			14	0	408.9
65A			94	161007	1			9	0	369.8
15B			94	162001	1			1	0	7.2
25B			94	162003	1			9	0	127.2
40B			94	152005	1			14	0	315.7
65B			94	162007	1			5	0	260.8
25C			94	162103	1			1	0	18.0
40C			94	162105	1			6	0	180.5
50C			94	162106	1			4	0	164.1
65C			94	162107	1			3	0	193.0
25CC			94	162118	1			1	0	18.0
40BB			94	162156	1			2	0	45.1
50BB			94	162157	1			2	0	59.8
65BB			94	162158	1			1	0	50.2
25CC NK			94	172022	1			2	0	35.0
40CC NK			94	172024	1			3	0	90.3
40CC AB			94	178024	1			1	0	30.1
40SC LR			94	184077	1			1	0	30.1
15B AB			94	188004	1			1	0	7.2
25B NK			94	188006	1			2	0	28.3
			94							
			94							
			94							
		TOTAL	94							3,499.6

FIGURE 3-40

MATERIAL LIST (MLP)

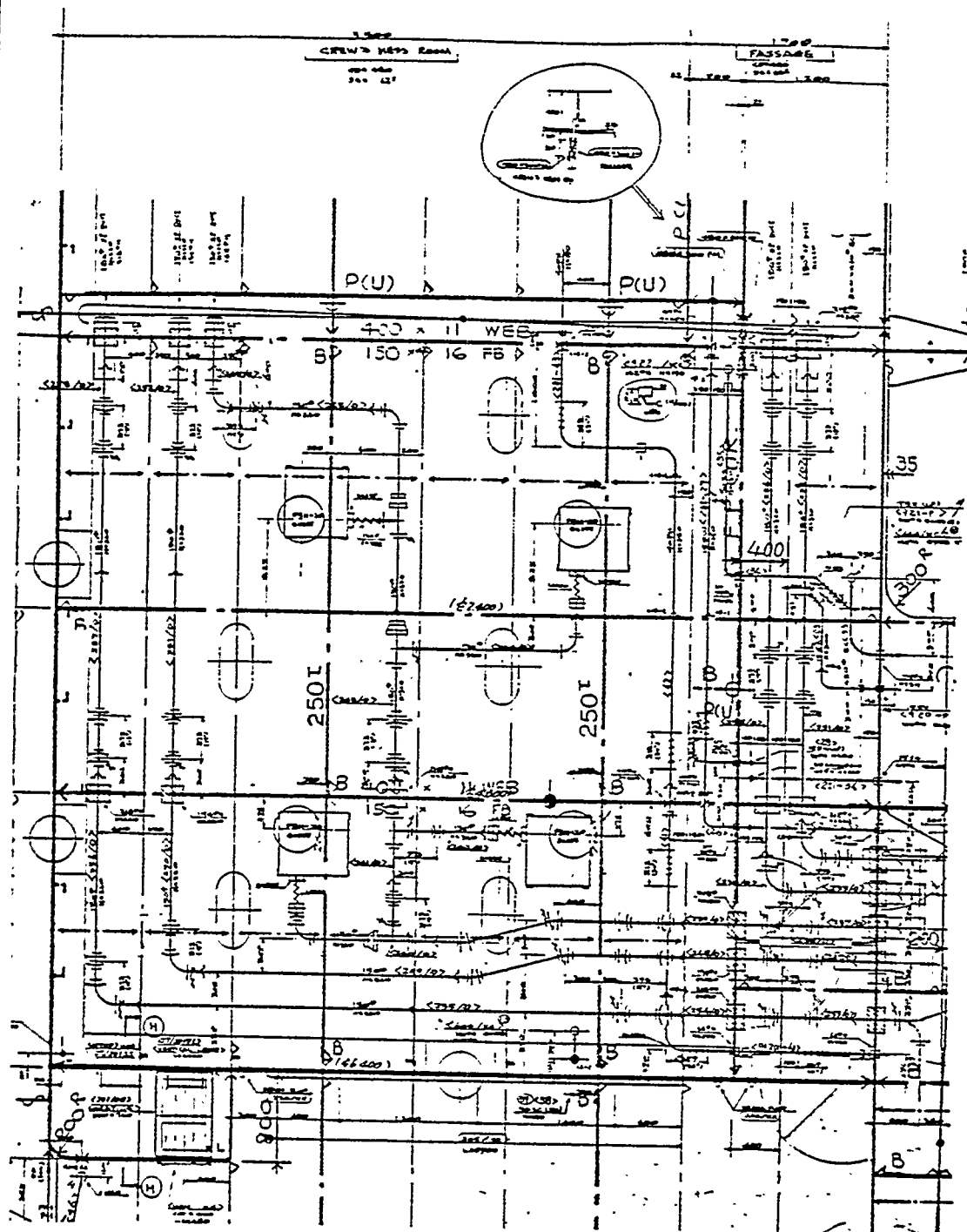


FIGURE 3-41
COMPOSITE DRAWING

at different production stages, e.g., sub-assembly, assembly, erection after launch. Figure 3-42 illustrates this development from top-level design data to individual Work Instruction Drawings. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production stage shown on the Work Instruction Drawing. This package of information describes the work to be done, the production stage at which it is to be done, and the list of materials which must be accumulated and present at the work site. Figures 3-43 and 3-44 provide examples of a Work Instruction Drawing and a Material List for Fitting, respectively.

The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a specific work package or "pallet" as it is defined by IHI. All information and all related material is collected at the proper work site, at the proper production work stage, and at the proper time interval to enable the outfitting of specific units or on-board the erected ship.

The "pallets" of information and material correspond to the "work zones" established for a given outfitting zone. These outfitting activities are rigorously scheduled to continuously parallel the hull construction sub-assembly, assembly and erection schedules.

Physical material is indeed "palletized" in the above system. Pallets of pipe and other outfitting components are organized by pipe shop and warehousing personnel and are transported to the outfitting area as required by the outfitting schedules. This "kitting" of material greatly facilitates the outfitting activities occurring at

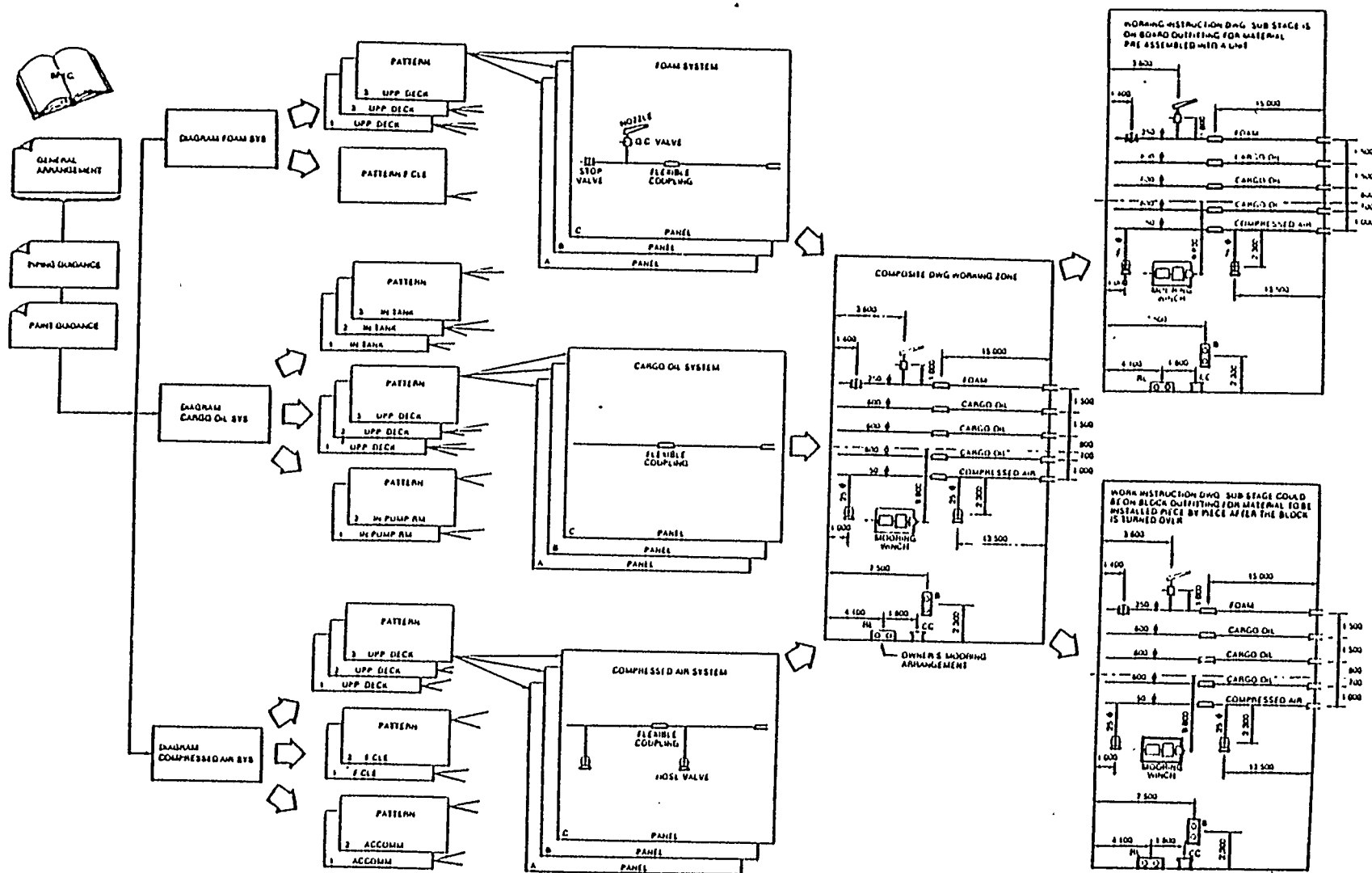


FIGURE 3-42
OUTFITTING DESIGN DEVELOPMENT

T4EM25P-0E T4EM23P-0E

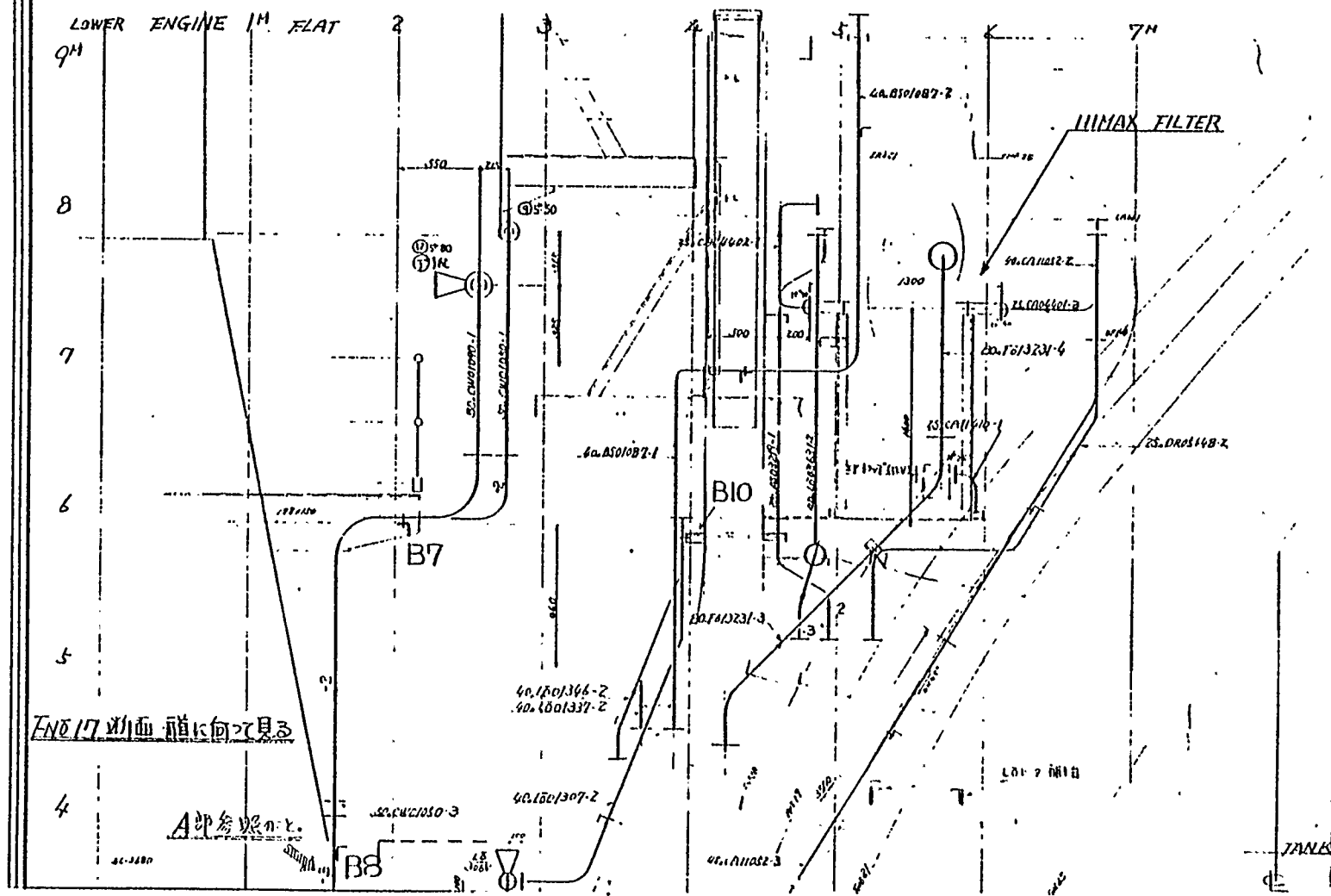


FIGURE 3-43 WORK INSTRUCTION DRAWING ON-UNIT FITTING

MLF

A : Information for unit assembly
 F : Fabrication sign.
 L : Temporary location sign for next stage.
 U : unit of quantity
 W : Indication of weight

Date
 19.05.11

DESCRIPTION	Piece No.	FL	Specifications	Qty	Unit	Weight	Paint	Ref.Dwg No MLF No for TLM	Mtl code	Remarks																						
BUTTERFLY VALVE(MANUAL)	SM-425V		FC25 SC51J 5K * 200	10	1	240	D42	N4044000	1404490000	+																						
BUTTERFLY VALVE(MANUAL)	SM-426V		FC25 SC51J 5K * 200	10	1	240	D42	N4044000	1404490000	+																						
BUTTERFLY VALVE(MANUAL)	SM-472V		FC25 SC51J 5K * 125	10	1	140	D42	N4044000A	1404490000	+																						
BLIND FLANGE SS41 GALV.FB 5K 80SS0				10	1	29	R44		44060101301A	+																						
WATER FILTER	SM-403S		5K-200C (200X250) FIRE GS	10	1	141	D42	N4082400C	1408250900	+																						
WATER FILTER	SM-404S		5K-200C (200X250) FIRE GS	10	1	141	D42	N4082400C	1408250900	+																						
FIRE & G S PUMP	MA-057AA		VEG 180/300M3/H * 80/35M	10	1	10000		N4451160A	1445116000	+																						
FIRE & G S PUMP	MA-057AB		VEG 180/300M3/H * 80/35M	10	1	10000		N4451160A	1445116000	+																						
MOTOR (FIRE & G S P)	P/FGR-M		75KW 1800RPM TE V B	20	1	13200		N4451170	1445117000	+																						
PIPE BAND SUPPORT			N=24	10	1	1872		F4634803	2463400000	+																						
ORIFICE	SM-401M		10K * 125	10	1	97	D42	N4699300E	1469930000	+																						
ORIFICE	SM-402M		10K * 125 (D*39)	10	1	91	N0P	N4699300D	1469930000	+																						
VERTICAL LADDER	NG-108V		VFS-5 L/800	10	1	110	D33	F4830212	2483020000	+																						
VERTICAL LADDER	NG-101V		VFS-5 L/950	10	1	130	D33	F4830212	2483020000	+																						
FLOOR & GRATING	NG-070C			10	1	90		F4831010	2483100000	+																						
<table border="1"> <tr> <td>S. No.</td><td>MLF - No.</td><td>Req. date</td><td>next stage</td><td>Work Dwg. No.</td><td>Shop</td><td>BC length</td><td>Total wt.</td><td>Control wt.</td><td>Exec wt.</td><td>Proc</td></tr> <tr> <td>2684</td><td>04Y057---</td><td>079 06 01</td><td>144P5315-0</td><td>2U01 .3</td><td>7</td><td>42</td><td>PM0.226</td><td>5171</td><td>5171</td><td>2171</td></tr> </table>											S. No.	MLF - No.	Req. date	next stage	Work Dwg. No.	Shop	BC length	Total wt.	Control wt.	Exec wt.	Proc	2684	04Y057---	079 06 01	144P5315-0	2U01 .3	7	42	PM0.226	5171	5171	2171
S. No.	MLF - No.	Req. date	next stage	Work Dwg. No.	Shop	BC length	Total wt.	Control wt.	Exec wt.	Proc																						
2684	04Y057---	079 06 01	144P5315-0	2U01 .3	7	42	PM0.226	5171	5171	2171																						

(222)

FIGURE 3-44
 MATERIAL LIST FOR FITTING (MLF)

many different locations throughout the shipyard at any one time.

3.3.2 Procurement

The procurement cycle is begun through the issue of the MLS, procurement specifications and drawings to the Procurement Department. The MLS, broken into discrete Material Ordering Zones, conveys the necessary information required to schedule and price raw materials and outfitting materials obtained from the various suppliers.

Figure 3-45 shows the flow of information into and out of the Procurement Department. As shown in this figure, the data supplied by engineering is processed through the computer system to determine suppliers, lead-times and current prices for each item. The computer generates a series of documents from this information: a Purchase Requisition or Order, a Delivery Time Control List, and a Leveling and Balancing List. These documents flow through the Purchasing or Material Control Section to the IHI Head Office for either domestic or overseas procurement. Material is received at the shipyard and stored in warehouses or in controlled areas for eventual "palletizing" and delivery to an outfitting area.

The processes utilized by IHI in its procurement function are well defined, but with the exception of the U.S. practice of competitive bidding on each job, are not unlike those used by procurement organizations throughout the United States. Figures 3-46 through 3-48 depict the flow of material control and purchasing activities typical of the IHI yards.

3.3.3 Material Control

The Material Control function within the IHI yards encompasses the activities of purchasing, receiving, warehousing, palletizing

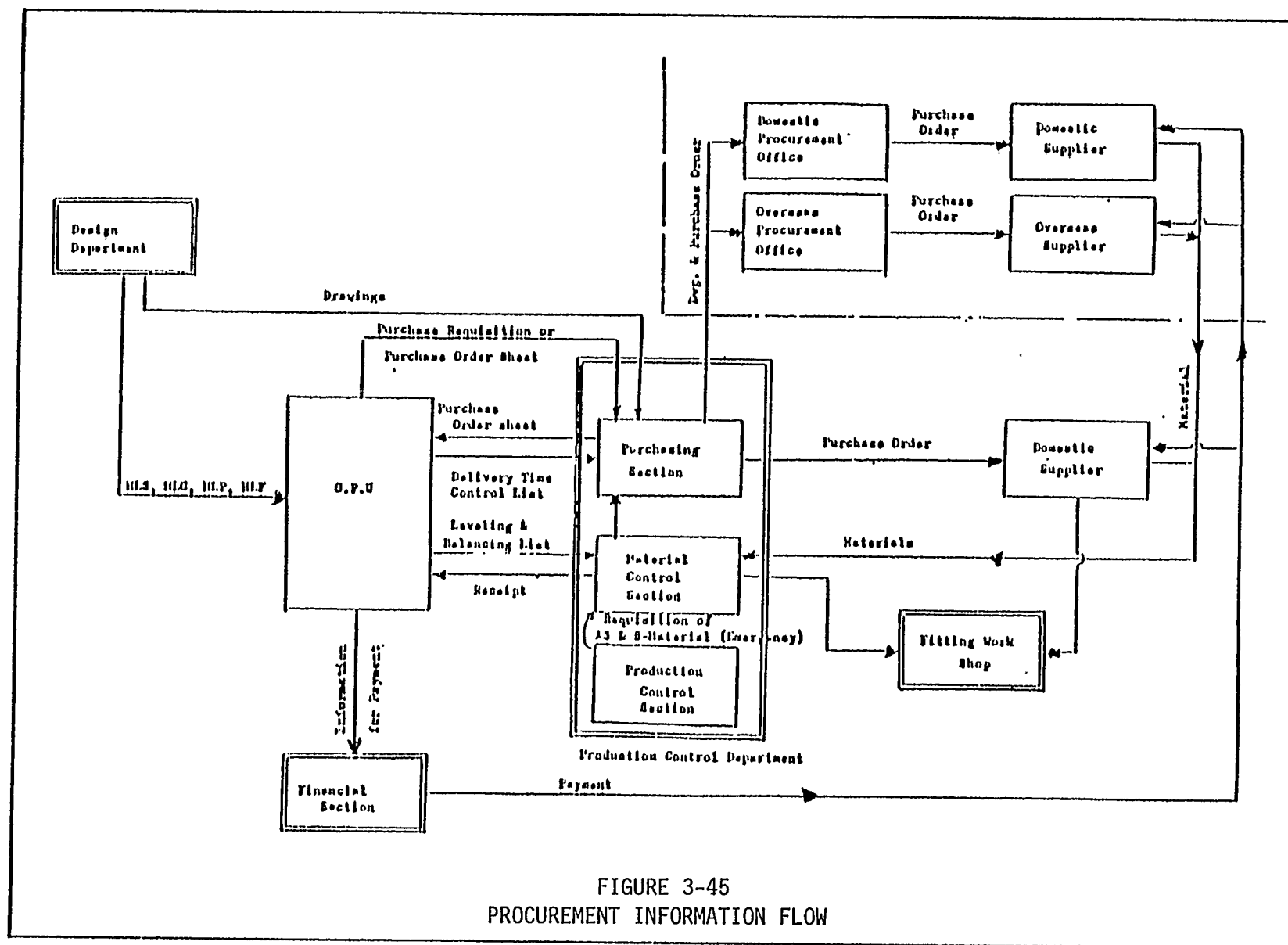


FIGURE 3-45
PROCUREMENT INFORMATION FLOW

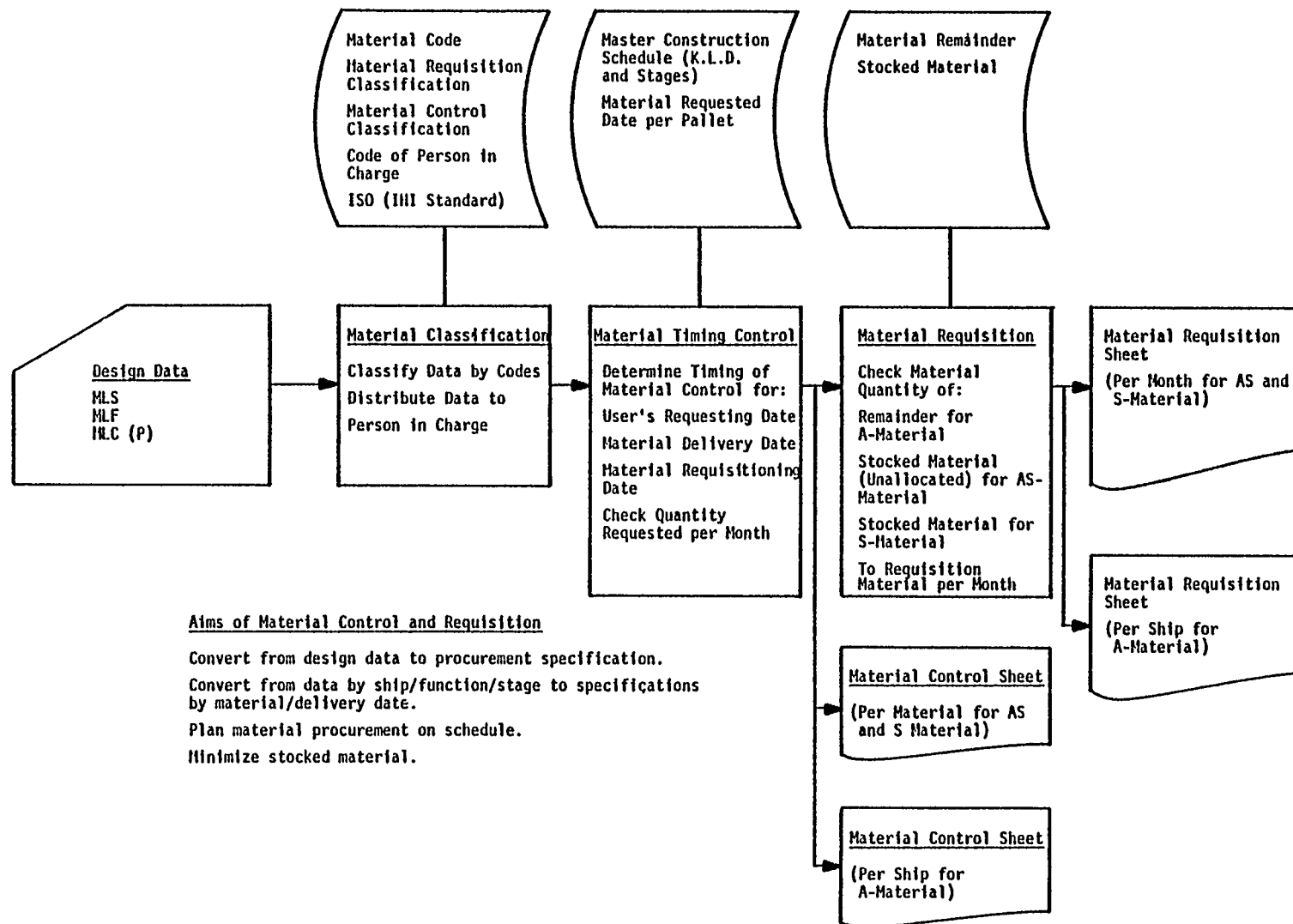


FIGURE 3-46

FUNCTIONAL FLOW OF MATERIAL AND REQUISITION

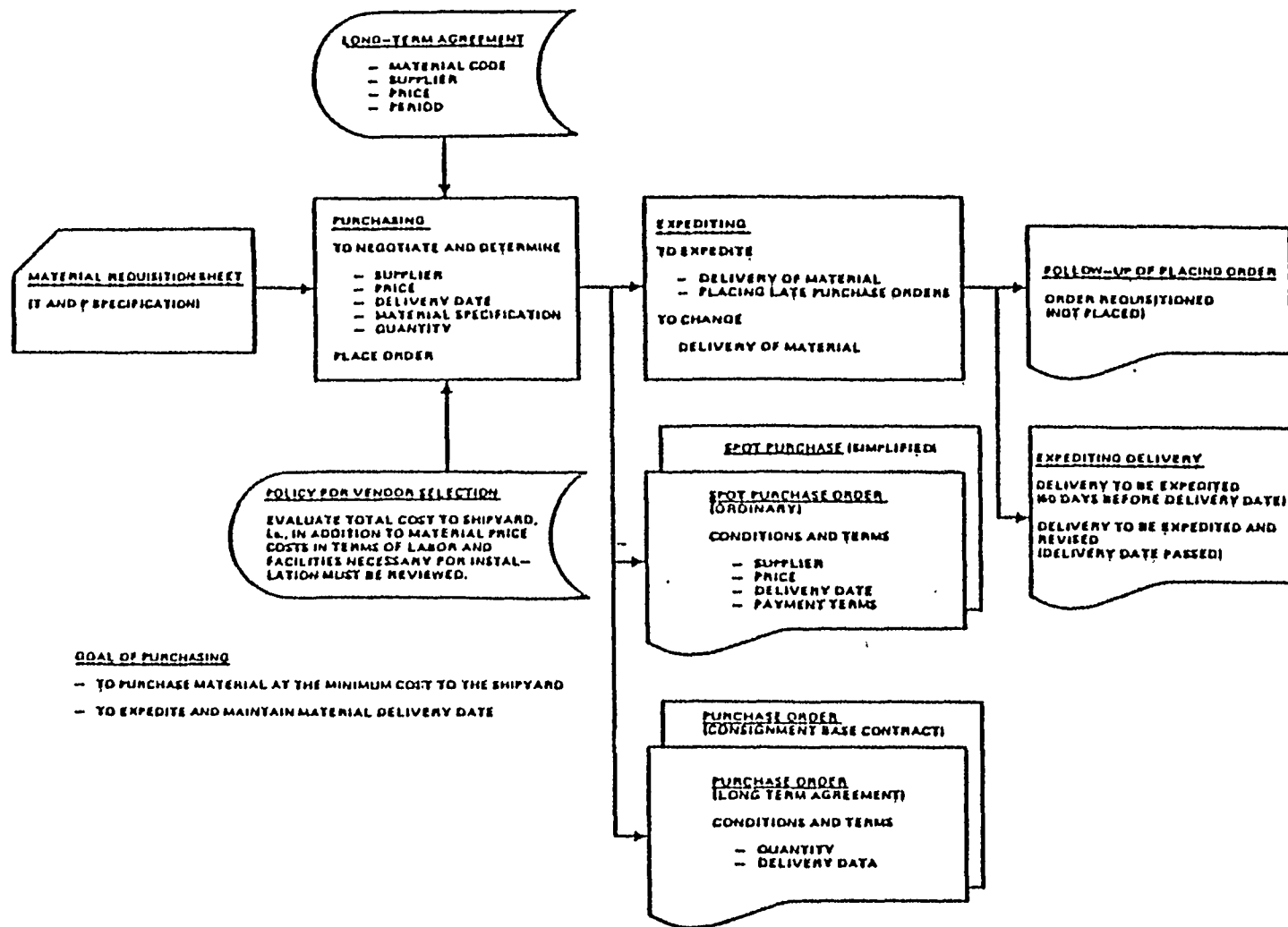


FIGURE 3-47
PURCHASING PROCESS

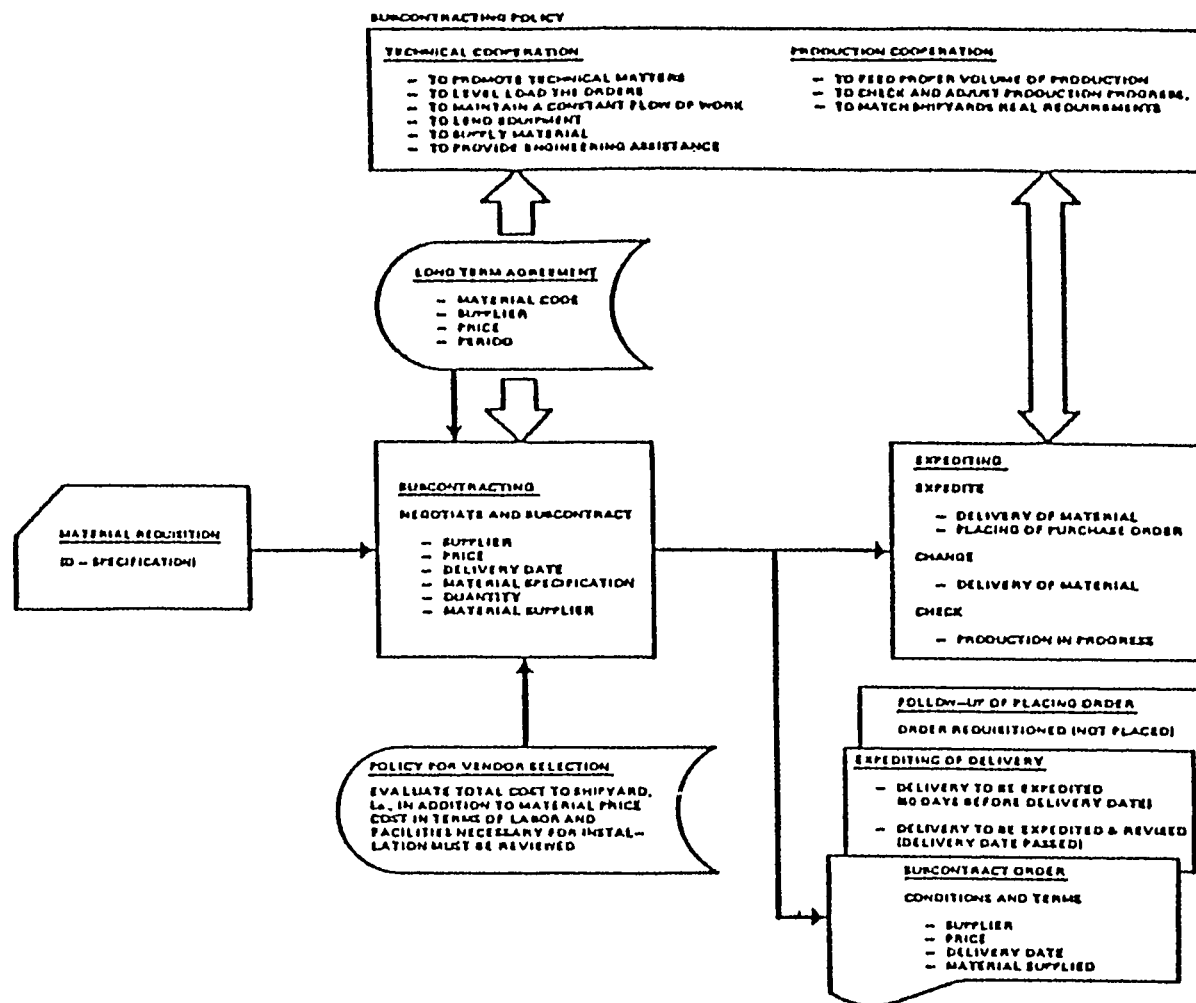


FIGURE 3-48

FUNCTIONAL FLOW OF THE SUBCONTRACTING PROCESS

and disbursement. The purchasing activity naturally precedes the other material control functions working parallel with the design development and production planning to identify and procure vendor-supplied material early in the program.

Material deliveries occur throughout the ship construction process at appropriate times to support hull construction and outfitting. One of the objectives of the material procurement activity is to maintain deliveries at an even level so that the yard is never over-stocked with steel or outfitting components.

Upon delivery of material, the warehousing and palletizing process begins. Figure 3-49 illustrates this process. Overall the process is similar to the material receipt, storage and disbursement activities common to most shipyards. In typical fashion the material is received, inspected, recorded and stored in an appropriate warehouse or storage area. The material is classified by a specific code number that identifies its use for a particular hull and the material is recorded in a Material Ledger. Upon receipt of a Material Issue Order the appropriate MLF is referenced and all material for a particular Work Zone is released to a palletizing area for collection into one or several pallets. Materials lists are checked as material is loaded into the pallets and any shortages are noted and forwarded to an Expediting activity (in the Purchasing Department) for immediate action. After all material (except that noted on shortage lists) has been collected, the pallets are transported to the appropriate outfitting area. Figure 3-50 depicts this entire design, procurement and outfitting process.

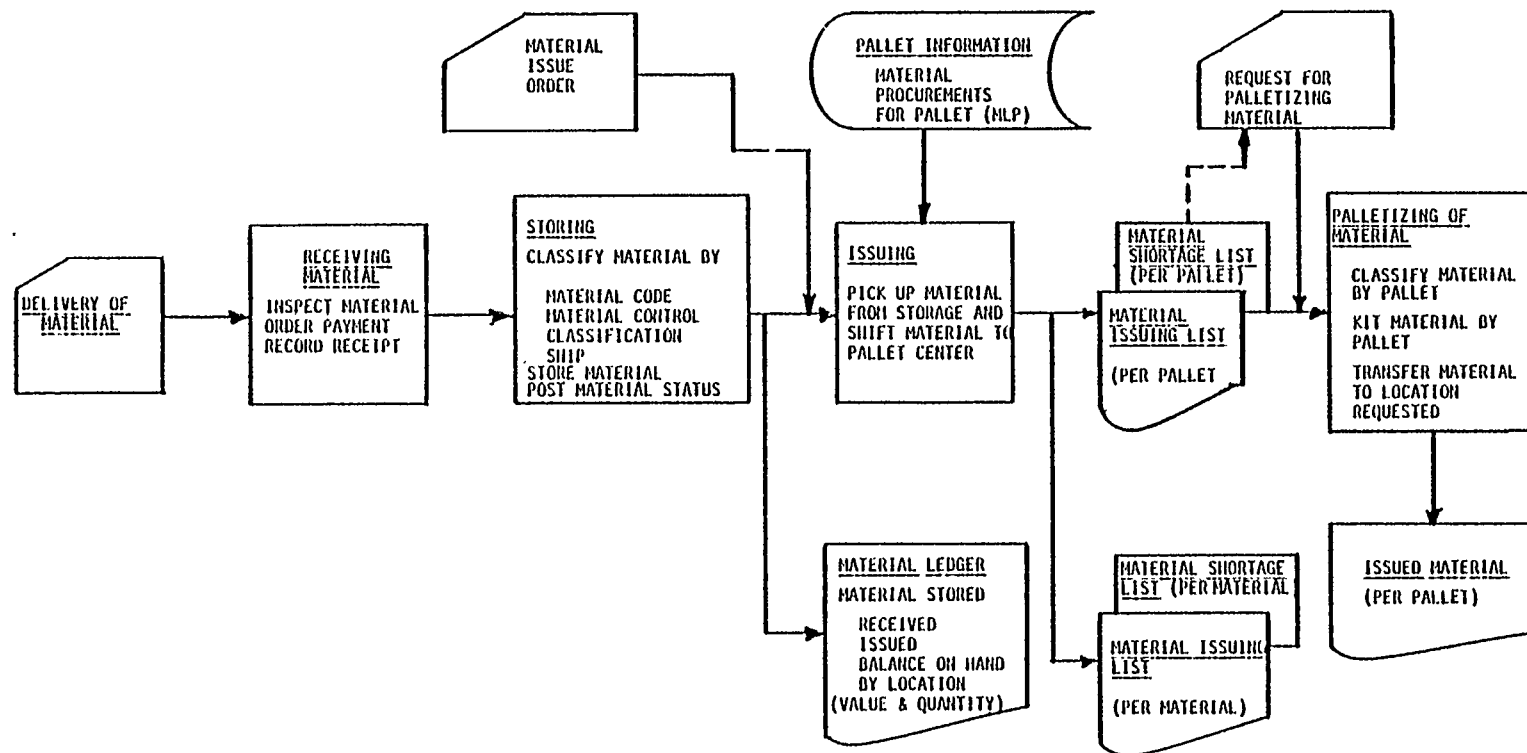


FIGURE 3-49

FUNCTIONAL FLOW OF THE WAREHOUSE AND PALLETIZING PROCESS

IHI MATERIAL CONTROL - SYSTEM

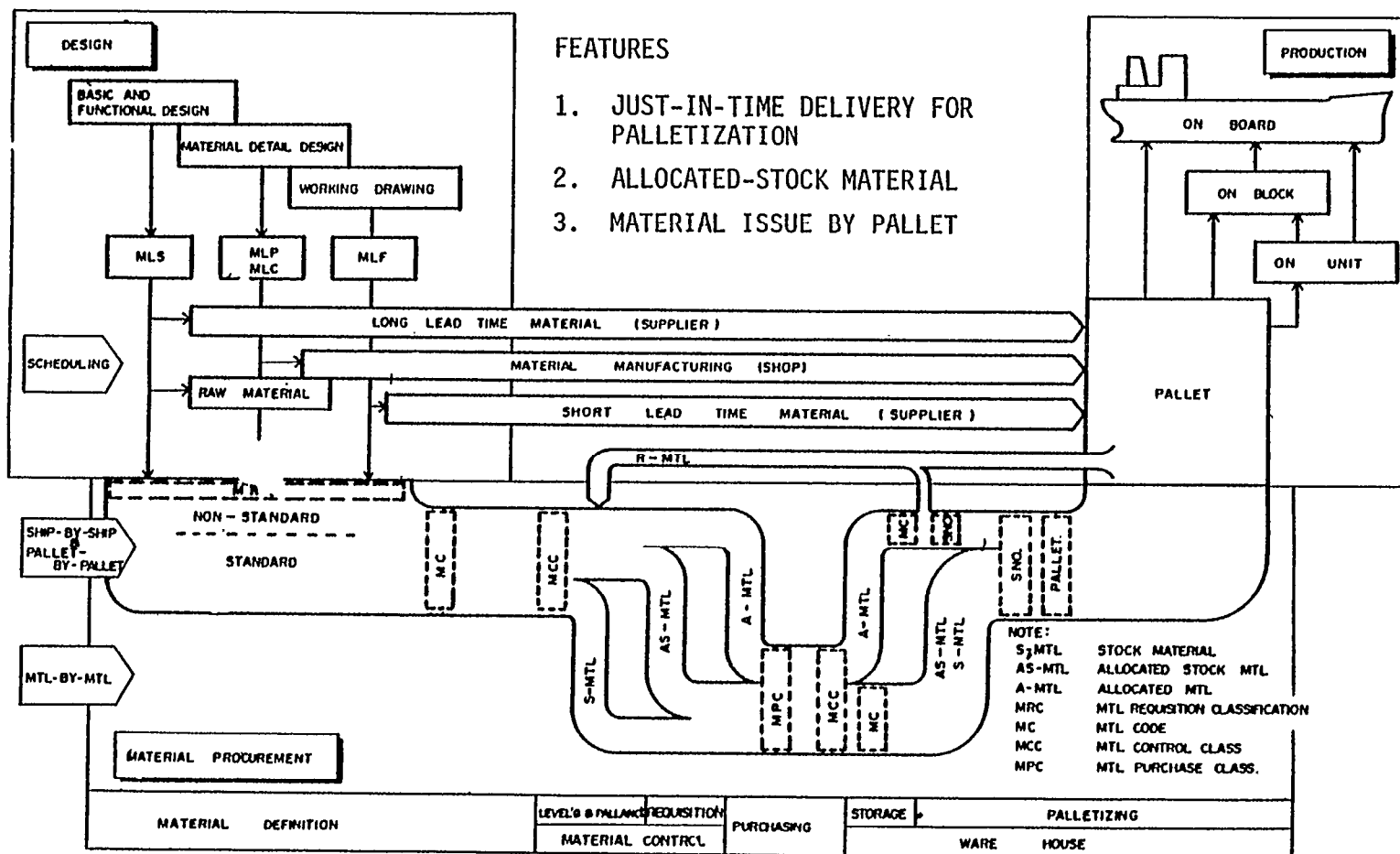


FIGURE 3-50

THE MATERIAL CONTROL SYSTEM

3.3.4 Production

The Fitting Workshop performs the actual fabrication of the manufactured outfitting materials and components except for those procured from outside sources, and physically installs these components in sub-assemblies, units and on-board the erected ship. This workshop is organized to parallel the major outfitting zones of each ship except for pipe and electrical which work across the outfitting zones. This organization is shown in Figure 3-51.

The production flow of outfitting work is a combination of design, procurement, manufacture of outfitting components and sub-assemblies in the yard, and the installation of components (both yard-manufactured and purchased) into units and on-board ship during erection and after launch. These numerous activities are carefully scheduled in a descending hierarchy of schedules from an overall master outfitting schedule to weekly schedules prepared by the Fitting Workshop Planning and Engineering Staff. Figure 3-52 depicts this production flow of outfitting activities as they proceed in parallel with the building of the hull construction units.

During the fitting process it is critical that the material and the appropriate information in the form of material lists, drawings and schedules flow together to the particular building stage and sub-stage. Since some of the fitting material is manufactured internally, not only the fitting schedules must be developed, but also the manufacturing schedules which provide the requisite material must be precisely developed to support the outfitting requirements. These manufacturing schedules are developed from the fitting schedules and "set back" to provide sufficient manufacturing and palleting time

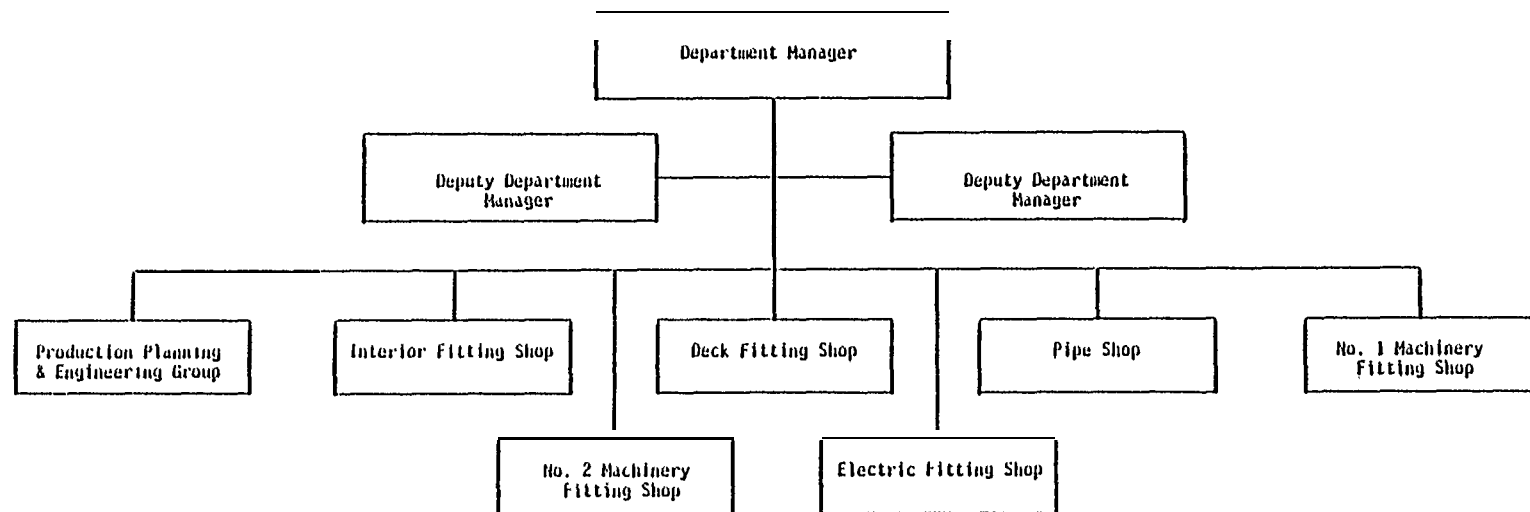


FIGURE 3-51
FITTING DEPARTMENT

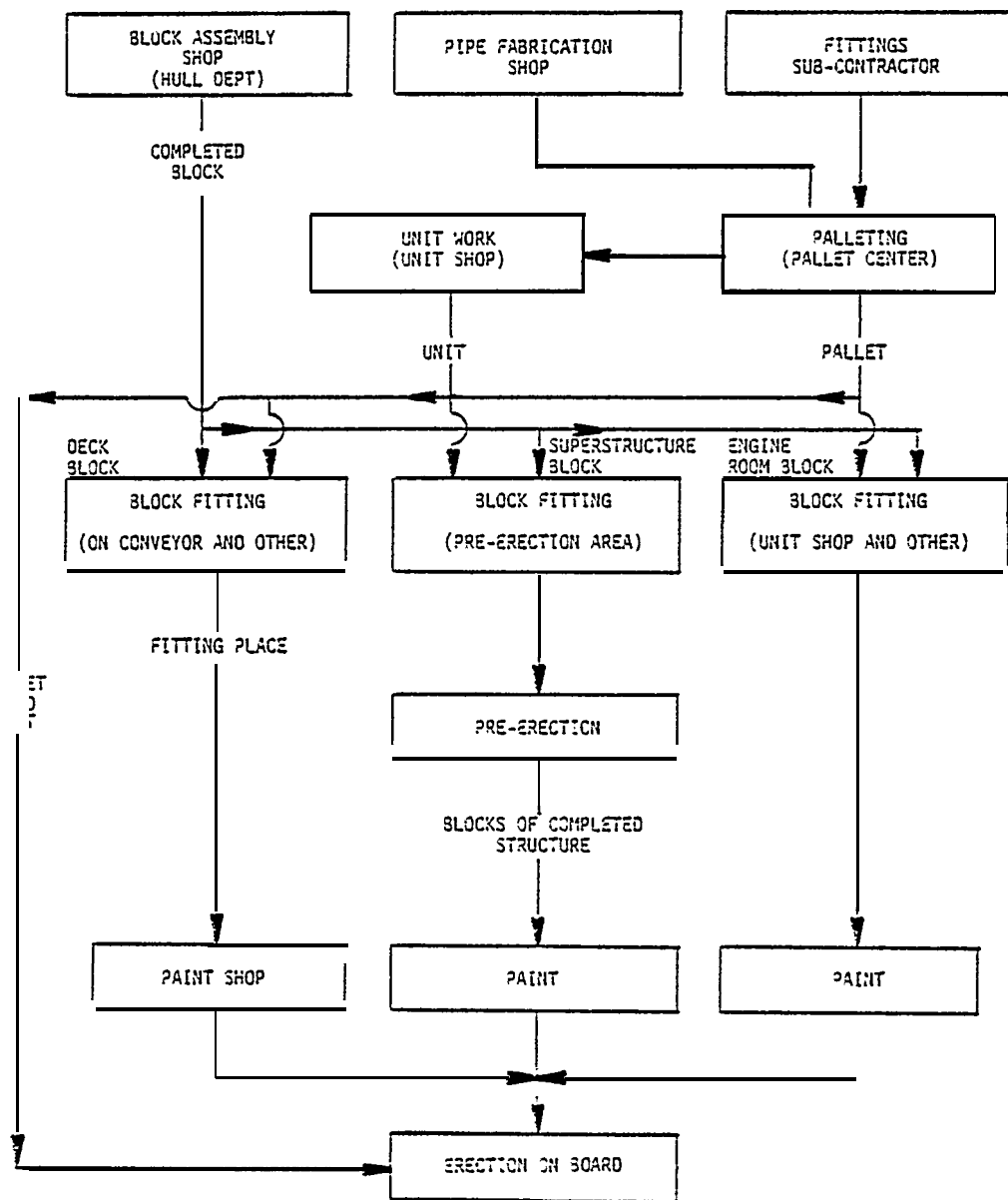


FIGURE 3-52
PROCESS FLOW OF OUTFITTING WORK

for all pipe pieces and other manufactured components. Figure 3-53 illustrates the flow of materials and associated data through the outfitting system.

Engineering data development continues well into the ship construction program with the documentation of MLF, drawings and test methods for the production stages of erection and post-launch. At each stage of production specific data are required for the outfitting activities for each unit or ship system (in the completed ship). Figure 3-54 provides examples of the data required at each production stage.

3.3.4.1 Pipe Shop

By far the most involved activity in the area of the manufacture of outfitting components is related to the fabrication of pipe and piping sub-assemblies. As explained above, the scheduling of this activity is critical to the supply of outfitting components to the fitting areas at the proper production stage of the hull units. Also, because of the many diverse parts and pieces of the piping arrangements, this activity must be carefully planned to avoid delinquencies and schedule slippages.

To assure that the pipe fabrication process is adequately planned and executed, a Pipe Fabrication Control System has evolved within IHI to direct this important production element. Figure 3-55 shows the essential elements of this system. As shown in the figure, the scheduling of raw material together with the appropriate engineering data flows to the pipe shop in a precise and controlled manner. The pipe is fabricated, bent, flanged and made ready for allocation to a specific pallet. The material is then held in pallets until required

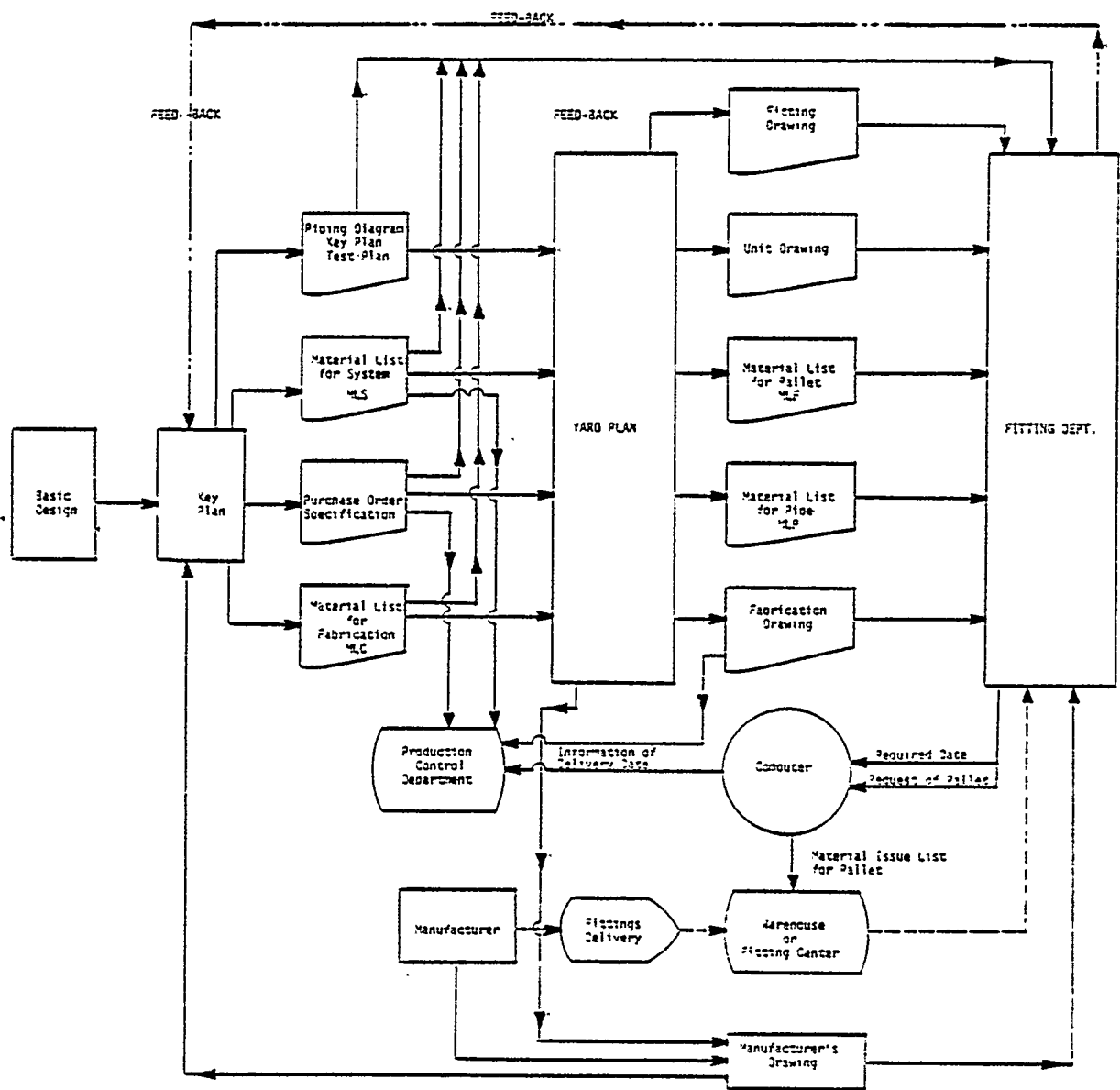


FIGURE 3-53
FLOW OF DRAWING AND MATERIAL

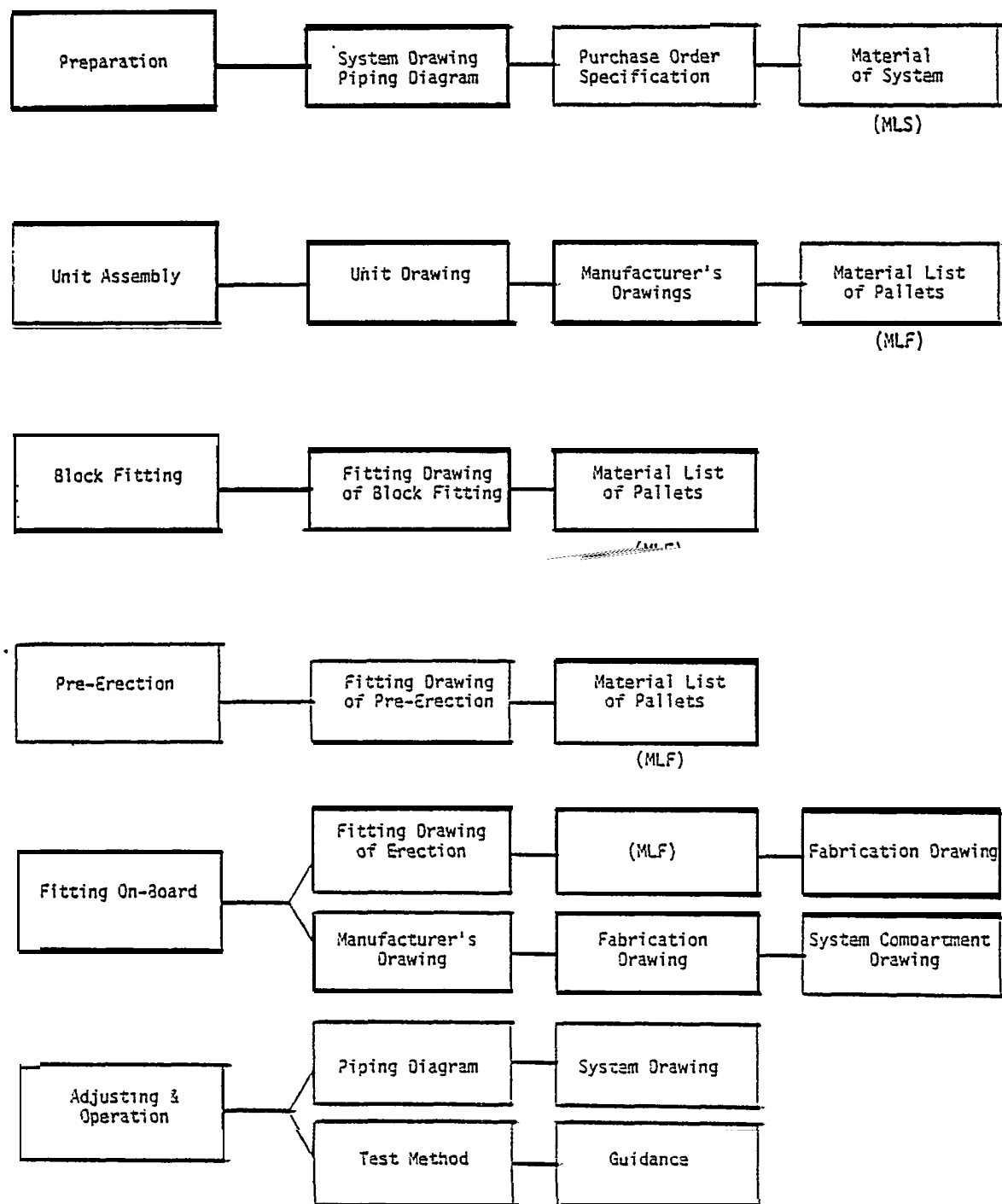


FIGURE 3-54
TYPICAL PATTERN OF WORK PROCESS AND DRAWINGS

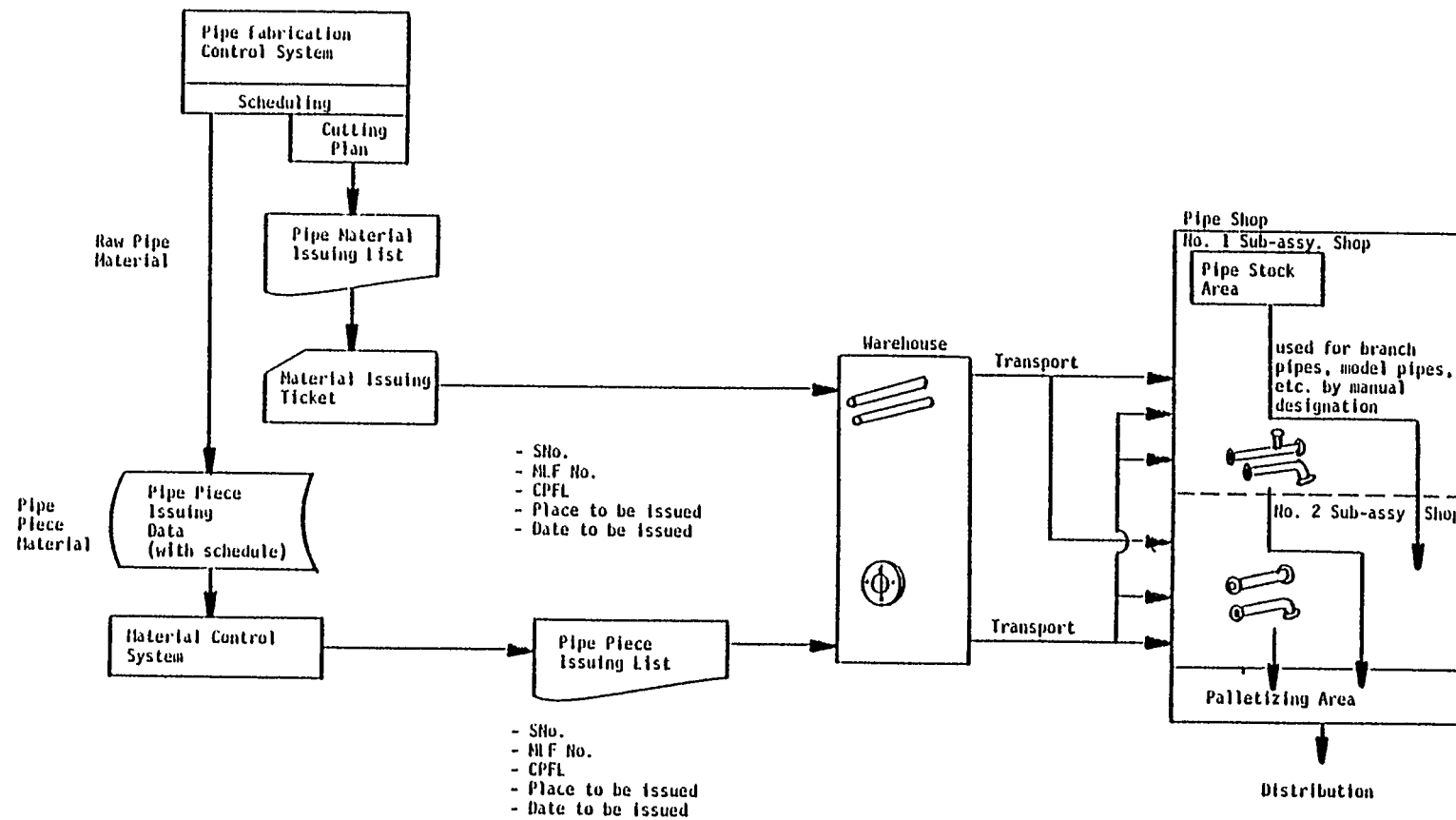


FIGURE 3-55

ESSENTIAL ELEMENTS OF PIPE FABRICATION CONTROL SYSTEM

at a specific time at a particular outfitting area. Figure 3-56 defines the schedules, lists and drawings required to support this process.

3.4 ADDITIONAL PLANNING

The Hull Construction and Outfit planning discussed in the foregoing pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the manufacture of the hull units, the outfitting of those units and the erection and outfitting of the entire ship. This discussion has purposely omitted some types of planning (that occur simultaneously) in order to simplify the production planning process. However, it is important to cover these other planning aspects to complete the overview of this involved process.

Throughout the planning occurring in the breakdown of the hull into its constituent bits and pieces and the outfit planning, a staff of Accuracy Control Engineers assists the planners and designers and formulates discrete accuracy control requirements for each unit, sub-assembly and piece part. These engineers develop detailed data concerning the vital dimensions and points of measurement to ensure that all manufactured components of the ship meet the highest accuracy standards possible. Additionally, these engineers develop a plan or scheme for providing added material at each stage of production to ensure that errors can be corrected without rework of the part and to provide for neat cutting at the various sub-assembly, assembly or erection stages. Accuracy Control Engineers also define the base lines which must be used for unit alignment to keep

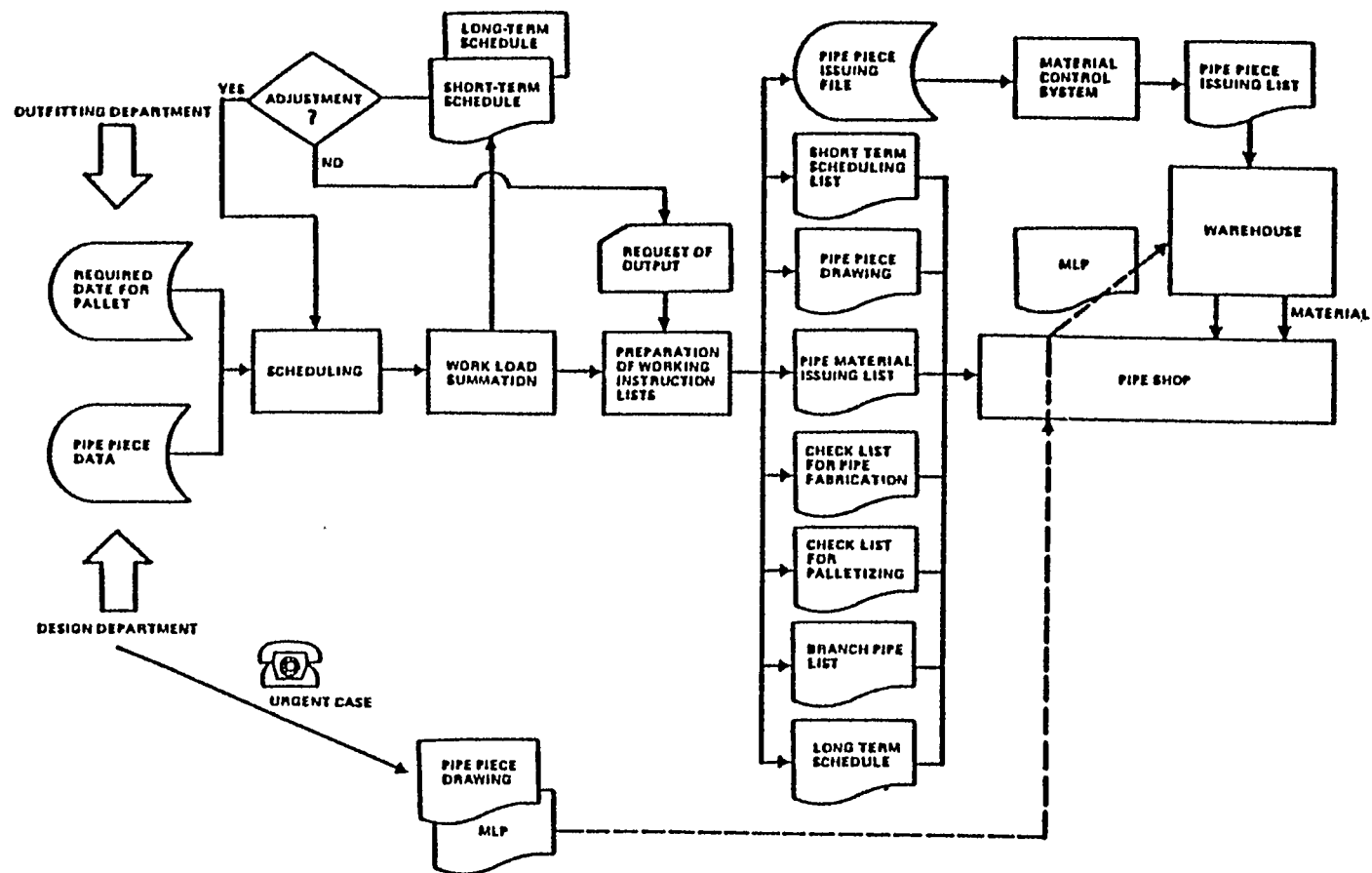


FIGURE 3-56

PIPE FABRICATION CONTROL PROCESS

maximum accuracy throughout the production, assembly and erection processes. The selection and application of process standards to the fabrication processes is also the responsibility of these engineers.

The objective of this accuracy planning is to effect the highest production efficiency by ensuring that each of the fabricated and assembled components meets prescribed standards and thereby requires no re-work as the material flows through the production process. This achievement of high accuracy reduces the amount of work required at the erection stage and ensures that the completed ship will meet or exceed all quality standards and will be in true alignment as required by design specifications.

The details of this accuracy control planning are contained in two Technology Transfer Program Reports: Livingston's Final Report on Quality Assurance, No. L2123-5.1-4-1, and the Special Report on Accuracy Control Planning for Hull Construction, No. L2123-5.1-4-2.

Other plans are prepared by workshop staff personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called "Field Planning" and consists of the following types of plans.

- Plan for temporary holes (in the hull during erection)

- Plan for ventilation and cooling of the hull on the ways

- Plan for supply of electrical power and gas lines

- Plan for stools arrangement on the ways

- Plan for equipment access on-board and on working staging

- Plan for standard shipwrighting techniques

- Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

Examples of these types of plans are presented in Appendix E.

SECTION 4

THE IHI SCHEDULING SYSTEM

4.1 GENERAL

The IHI scheduling system is a delineated hierarchy of schedules descending from the customer delivery requirement to the lowest working levels. The methods used by IHI in this scheduling system are not unique; however, some of the techniques are somewhat different in comparison to U.S. practice.

Basically, the system begins with the delivery schedule established by the Head Office. This schedule is reviewed in some detail by the Production Control staff of the shipyard selected to build the ship and can be adjusted if found to be impracticable. If the yard can accommodate the ship in the time established by the Head Office, the Production Control group (in the shipyard's General Superintendent's office) formulates a Ship Construction Master Schedule which places the total building period into context with all other construction work in the yard. Placement of a new ship program into the Ship Construction Master Schedule is based on availability of facilities and personnel to accomplish the work in the desired time frame.

The Ship Construction Master Schedule becomes the guiding master schedule for the development of all lower tier schedules and is regarded as the one absolute and inflexible schedule throughout the building process.

Figure 4-1 presents the hierarchy of schedules which are developed from this primary master schedule. The next schedule prepared is the Major Milestone Schedule which defines the time period designated in

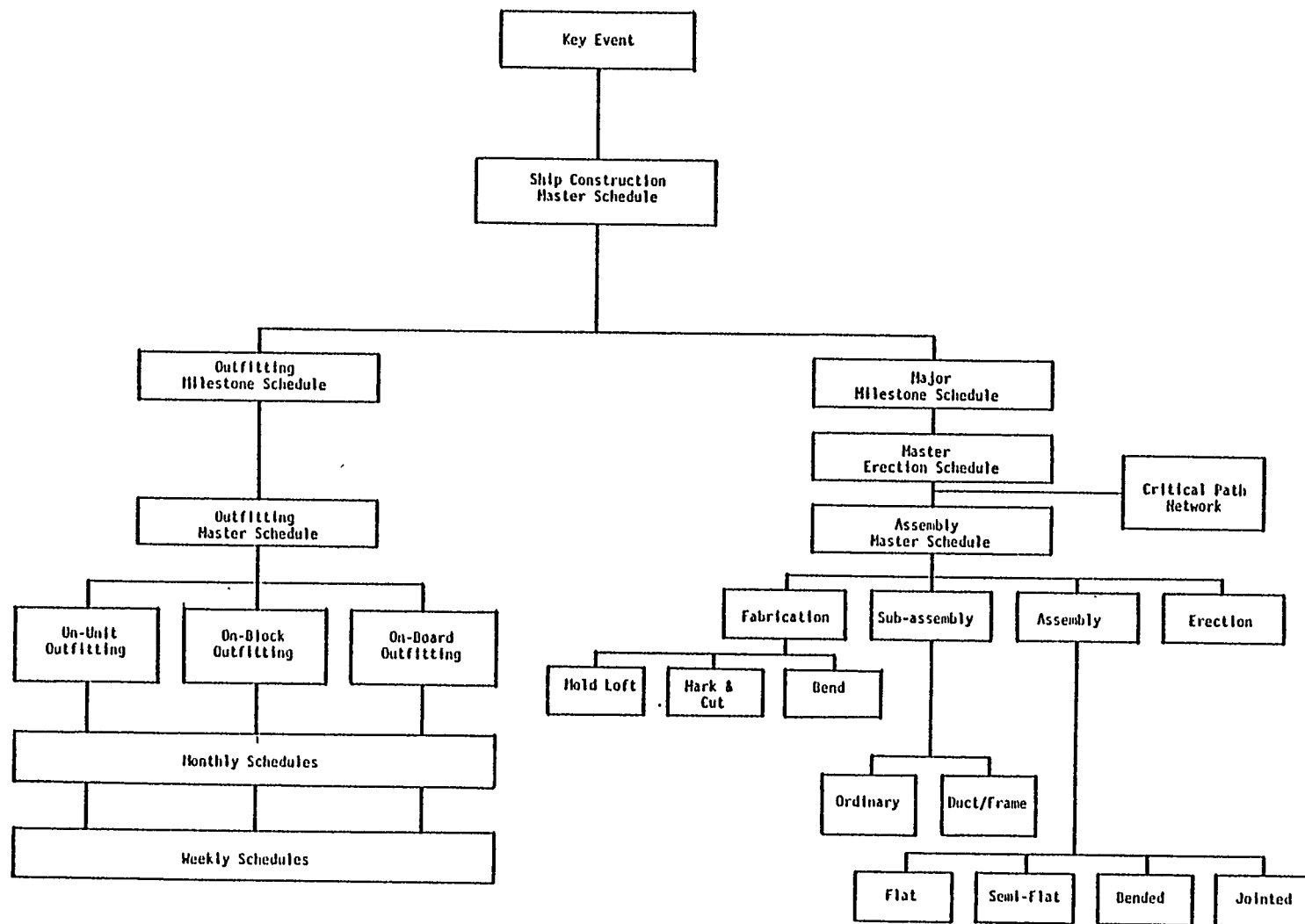


FIGURE 4-1
HIERARCHY OF SCHEDULES

the Ship Construction Master Schedule for construction of a particular ship or ships in terms of key events such as planning, fabrication start, keel laying, launch and delivery. Other key events that normally constrain the ship construction process, such as delivery of main engines or other long lead-time items that are procured from outside sources, may also be included. This schedule provides information for the construction of the Erection Master Schedule.

The Erection Master Schedule prescribes the sequence to be followed in the build-up of the ship in the building basin. The several major zones of the ship (i.e., mid-body, bow, stern and house) are separately scheduled and each of the units comprising these zones are scheduled individually for the precise time of landing in the basin. This erection schedule allows for the completion of all on-board outfitting work subsequent to the landing of the final unit on the erected ship. A precise set of standards is used to calculate the landing and joining of each unit to adjacent units already in the basin. These time standards dictate the amount of time required between each unit, and the schedule is developed as a series of "set backs" from the final unit in each zone.

Based on the mandatory erection time requirements for each unit, the Assembly Master Schedule is prepared. This Master schedule establishes the periods for assembly of each unit sufficiently ahead of the erection schedule to permit unit outfitting and transportation to buffer storage or to the building basin platen areas.

From the Assembly Master Schedule detailed subordinate schedules for hull fabrication, sub-assembly, assembly and erection are prepared.

These schedules are developed by the Production Planning and Engineering groups of the Hull Construction Workshop in conjunction with the applicable Section Managers and Foremen in the respective production stages and areas.

In the fabrication area specific sub-schedules are developed for the activities of the mold loft and for marking, cutting and bending of all materials for each of the hull units. In the sub-assembly area, schedules are prepared for the common or ordinary sub-assemblies (such as webs) which are typical to many units and for more complex sub-assemblies containing ducting or major frame components.

Detailed assembly schedules are prepared for each hull unit. Due to the different process lanes through which the flat versus curved units emerge, these schedules are prepared for each type of unit with somewhat different information presented thereon. Schedules are prepared for typical flat units (e.g. flat double bottom units), semi-flat units (e.g. curved shell and curved internal structure mounted on a flat panel such as the side double bottom units), bent or curved units (e.g. bow or stern units), and joined units (e.g. two units joined to allow the landing of a larger unit during erection).

The Erection sub-schedules detail the preparation, transport, buffer storage, and final erection of each unit in the building basin.

All of the above schedules are primarily concerned with the hull construction effort. In parallel with this effort, a series of outfitting schedules are prepared based on the Ship Construction Master Schedule and the hull construction schedules as they are developed for each stage of production.

After development of the Major Milestone Schedule, the Outfitting Milestone Schedule is prepared by the Production Planning and Engineering Group in the Fitting Workshop. This schedule expands the key milestones shown in the Major Milestone Schedule to include the periods where the fitting of the outfitting zones of the ship must begin and end. Other key events, which coincide with the receipt of major purchased equipment, are defined to indicate the completion of outfitting on critical sub-assemblies or units of the ship which will constrain the start of erection or the erection of specific units during the erection process.

The Outfitting Milestone Schedule provides the basis for development of the Outfitting Master Schedule. This schedule must of course coincide with the Assembly Master Schedule to allow proper time intervals for the installation of outfitting sub-assemblies and components during the build-up of each hull unit. Unit assembly instruction plans are carefully studied to determine the time requirements for outfitting, the outfitting area, and whether it would be more efficient to install individual components or outfitting sub-assemblies (e.g. a piping sub-assembly) into the unit.

Once the Outfitting Master Schedule has been developed, the detailed subordinate schedules are prepared. Individual schedules for the build-up of sub-assemblies of outfitting components (called on-unit outfitting), for the fitting of both these sub-assemblies and individual outfitting components in the hull units and for installation of other sub-assemblies or components on-board the erected ship are then constructed for each group of fitting personnel based on the fitting tasks to be accomplished in order to execute the individual

sub-schedules. These work schedules cover each month of the Outfitting Master Schedule and each week of each monthly schedule. These weekly schedules prescribe the task, the personnel and the time allowed for each outfitting activity each day.

In this descending hierarchy of schedules both the hull construction and the outfitting tasks are developed and sequenced to coincide with one another and with each higher level schedule. The Ship Construction Master Schedule usually contains only two weeks slack time which can be used to accommodate any unanticipated delays. This obviously requires careful and comprehensive schedule planning at each level of schedule development and a total commitment by all personnel to meet schedule dates once they are developed. The use of overtime is permitted in order to maintain schedule position, but unless overtime is purposely included in the schedules (by top-management decision) the use of overtime is restricted to the most dire circumstances.

This description of the IHI schedule system provides only a brief overview of this complex and highly refined scheduling process. The following paragraphs provide a more detailed description of each of the schedules in this system.

4.2 SHIP CONSTRUCTION MASTER SCHEDULE

The Ship Construction Master Schedule is the top-level construction schedule for all work in a given yard. When a new ship or ship program is introduced into a yard a suitable time frame must be allocated to its construction within the overall building schedule of the yard and with due regard to the delivery schedule established by the Head Office. This schedule is prepared by the Production Control Group of the shipyard through an estimation of the required man-hours per month based

on the through-put rates established for the yard facilities and workforce. This estimate is compared to the manpower available at specific times in the overall building schedule of the yard and times are adjusted to provide sufficient manpower for the construction task. Naturally many considerations are necessary to the fixing of the appropriate time period, especially if the yard is heavily loaded with work. However, the primary basis for the establishment of this schedule is the availability of manpower. Figure 4-2 depicts the requisites and flow of development of the Ship Construction Master Schedule. Figure 4-3 provides an example of this type of schedule.

4.3 MAJOR MILESTONE SCHEDULE

Figure 4-2 also shows the development of the Major Milestone Schedule as a continuance of the Ship Construction Master Schedule. This combined development is necessary to properly refine both schedules in an iterative process that takes into consideration the major constraining events to the ship construction cycle. These events typically portray keel laying, launch, sea trials and delivery, but may also be expanded to show other major events such as the landing of the main engines or receipt or installation of critical purchased items. Depending on the amount of work in the yard these schedules can be simple or elaborate as deemed necessary to delineate clearly mandatory scheduled events. Figure 4-4 shows an example of this Major Milestone Schedule.

4.4 ERECTION MASTER SCHEDULE

The Erection Master Schedule is the first working schedule prepared. This schedule establishes the erection times for each unit in each zone of the ship. The ship is typically built up from the mid-ship

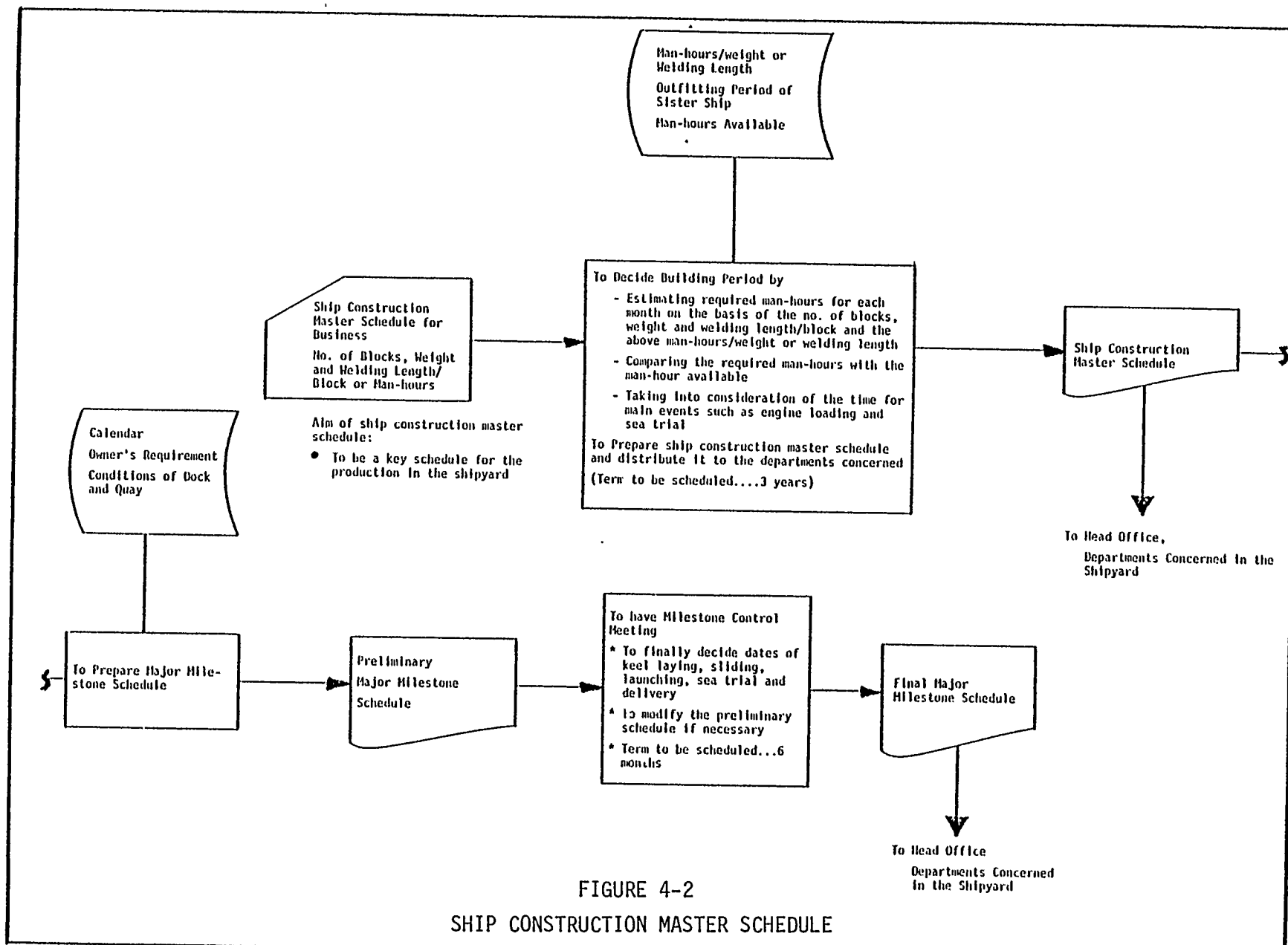


FIGURE 4-2

SHIP CONSTRUCTION MASTER SCHEDULE

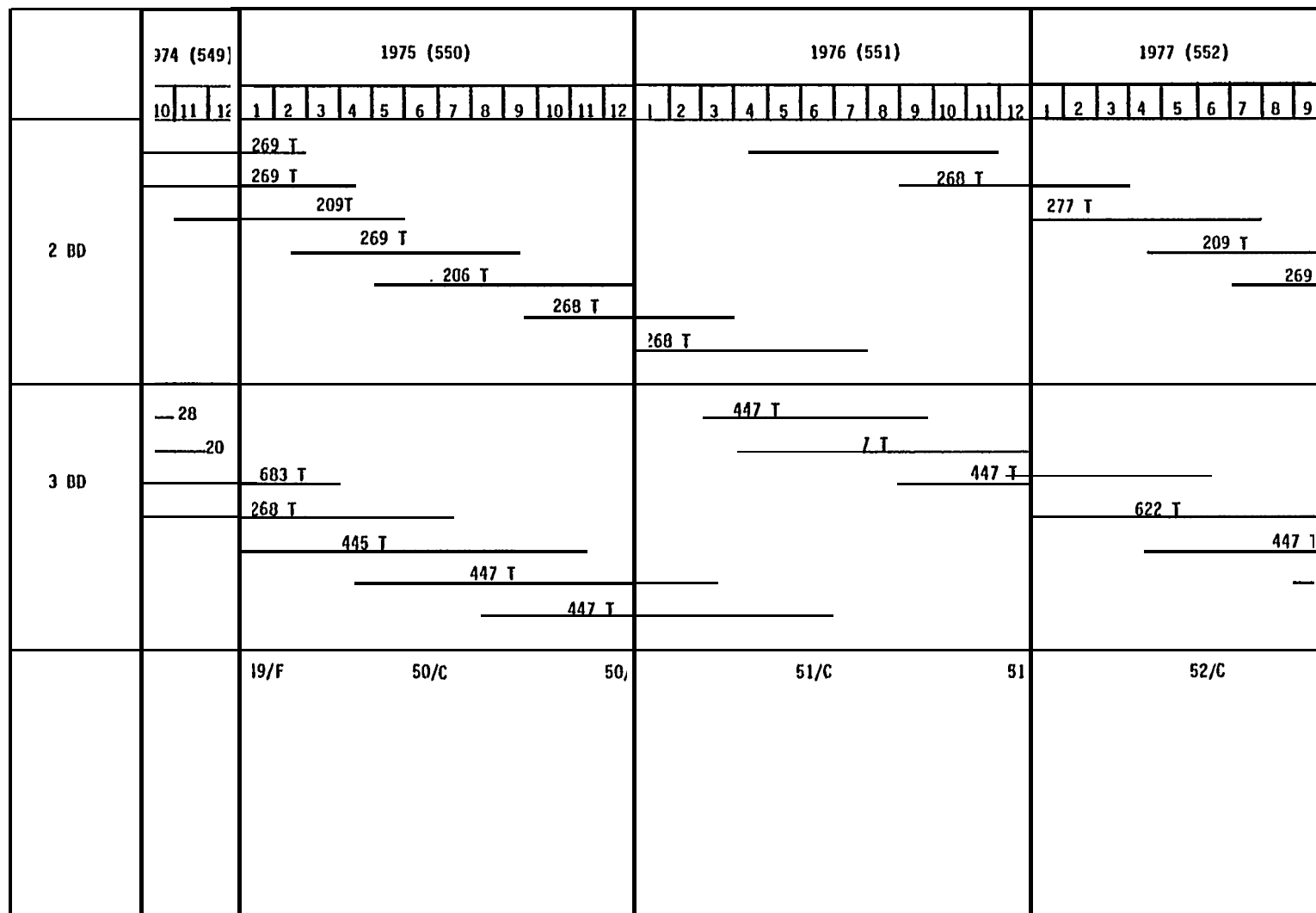


FIGURE 4-3

SHIP CONSTRUCTION MASTER SCHEDULE (EXAMPLE)

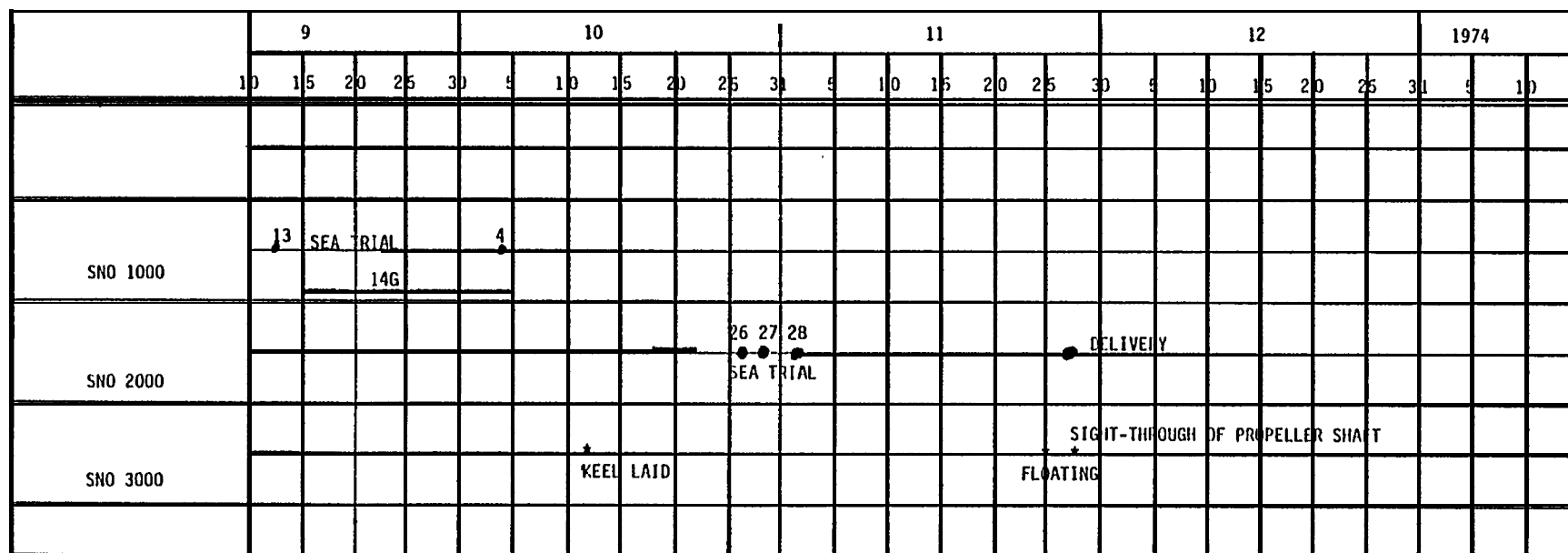


FIGURE 4-4
MAJOR MILESTONE SCHEDULE

sections starting with the first center bottom units just forward of the engine room. Bow and stern sections will be started subsequent to the joining of the bottom midship sections and the build-up will proceed in all three zones according to the erection sequence established in the Erection Master Schedule.

This schedule establishes the requirements for completed units which must be either in buffer storage, in storage in the building basin platen area, or being completed in time for direct movement to the building basin and immediate erection. This schedule is therefore structured taking account of the following:

1. Proper erection sequence
2. Erection process
3. Capacities of assembly yard
4. Capacities of storage yard
5. Crane Capacities
6. Capacities of outfitting and painting shops
7. Capacities of erection work groups

The objective of this scheduling activity is to maintain the best possible balance among all of these elements while preserving a good erection sequence and schedule within the total ship construction time frame. Figure 4-5 provides an example of the Erection Master Schedule.

4.5 ASSEMBLY MASTER SCHEDULE

The Assembly Master Schedule is prepared to show the time requirements for each unit during the assembly process. Each type of unit is sorted by the type of fabrication process required for its production

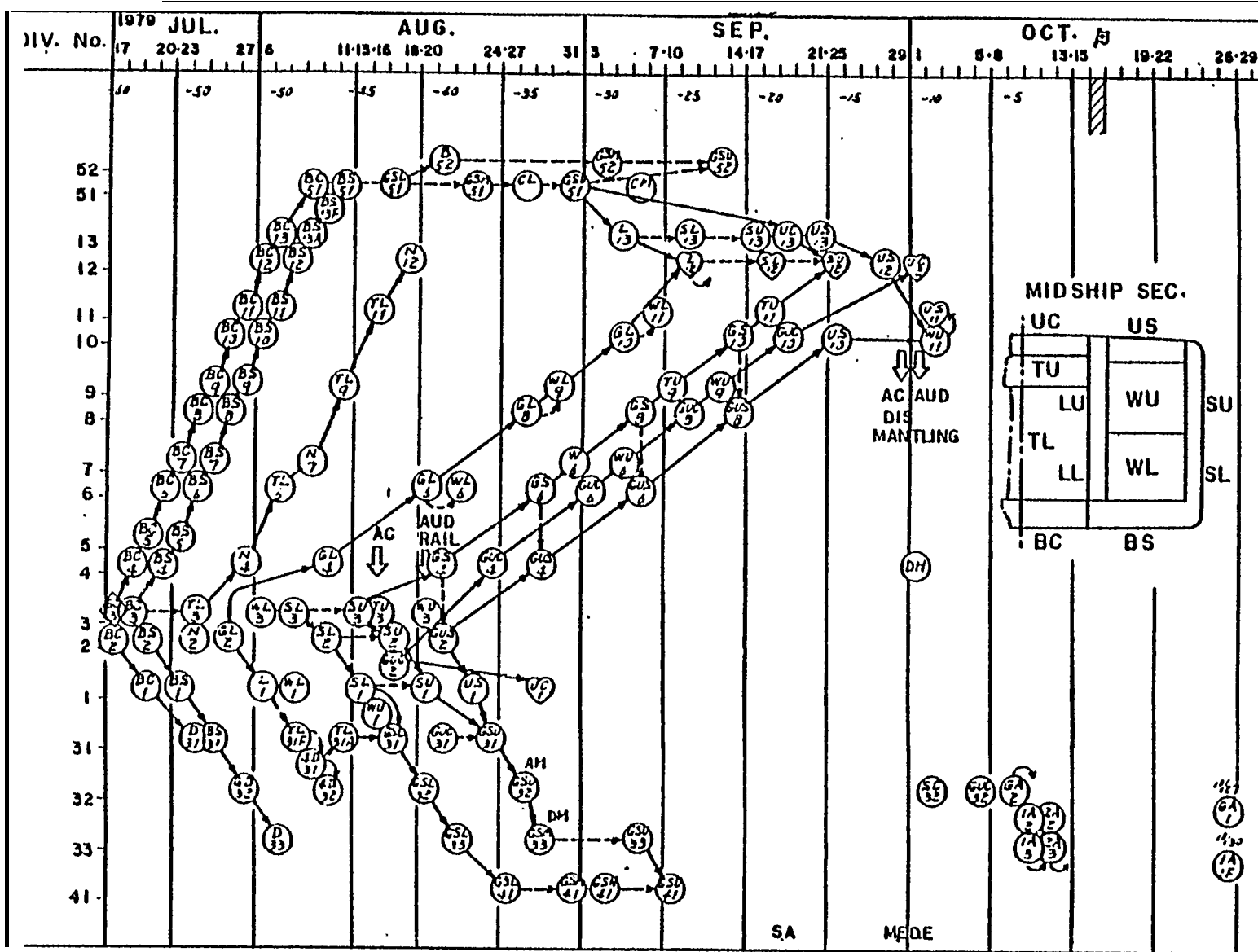


FIGURE 4-5 ERECTION MASTER SCHEDULE

into the following:

Flat Units (e.g. center double bottom units of the midship section)

Semi-flat Units (e.g. side double bottom units)

Curved Units (e.g. bow and stern sections)

Joined Units (e.g. two or more units joined to form a "Grand Unit")

After sorting of the units into the above categories a "latest completion schedule" is determined for each unit using the formula $C = E - A$, where:

C = Assembly completion date

E = Erection date

A = Advance days required for painting, outfitting, overturning, and joining with other units.

Using this formula, the latest completion date for each unit is computed.

The Advance Days required for additional work once the unit build-up is complete is standardized as shown in Figure 4-6.

Once the latest completion date has been established for each unit several other criteria are applied to arrange the units in a proper sequence and flow to maintain a full load and smooth flow through the assembly areas. These criteria are listed below.

1. Determination of the number of assembly days per unit
2. Assembly area requirements for each type of unit
3. Capacities of each process lane
4. Optimum manloading of each process lane
5. Outfitting requirements on units having major outfitting
6. Painting requirements
7. Storage requirements
8. Flow of structurally similar units in series

TYPE OF BLOCK	NO ADDITIONAL WORK	PAINT	OUTFITTING	OVERTURN	JOIN
Flat Unit	2	4	4	6	8
Semi-Flat Unit	3	5	5 - 10	8	0 - 20
Curved Unit		5	5 - 10		5 - 20
Joined Unit		6	5 - 10	10	

FIGURE 4-6
ADVANCE DAYS REQUIRED FOR ADDITIONAL WORK AFTER ASSEMBLY

These considerations enter into the scheduling of each individual unit and of each unit category. Every attempt is made to maintain a smooth and even flow of materials through the production and assembly process and to minimize the requirement to store a great many units in buffer storage areas.

The number of required assembly days for the different types of units is a standard in the yards. This standard is shown in Figure 4-7. Also the calculation of manloading is standardized through the computation of weld deposit required on the various units. Weld deposit (DM or Deposit Meters) per month per assembly area is plotted on a graph and compared to the established capacity of that area. If the plot shows that the scheduled work exceeds that of the established capacity, work may be shifted to other assembly areas, subcontracted or, in extreme cases, the erection date may be rescheduled. Figure 4-8 depicts a plot of a proposed assembly schedule versus the established capacity of a specific assembly area. Figure 4-9 provides an example of an Assembly Master Schedule.

4.6 SUBORDINATE SCHEDULES

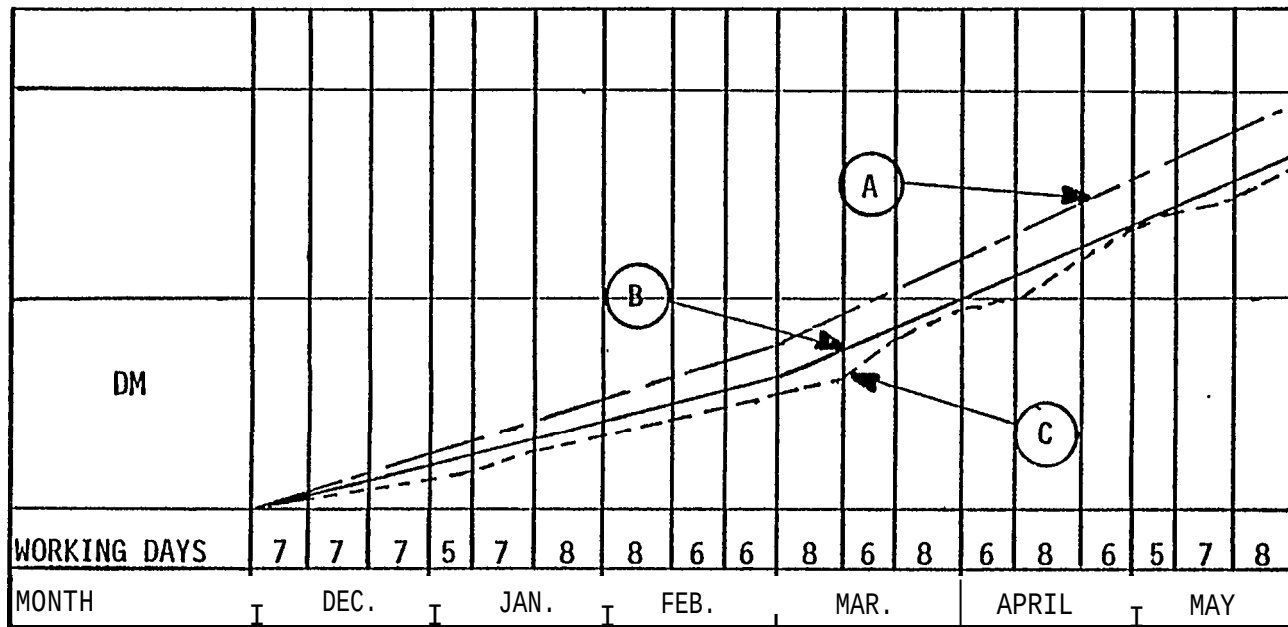
Using the information contained in the Assembly Master Schedule, Hull Construction Workshop engineers prepare detailed schedules for each sub-stage of the fabrication, assembly and erection stages. No overall schedule is prepared for each of the production stages; rather, the schedules detail the required dates for lofting, marking, cutting, bending, sub-assembly, etc., to meet the assembly dates established in the Assembly Master Schedule.

All of this sub-scheduling is an iterative process which generally

PART	UNIT	ASSEMBLY	JOIN
FORE	Curved Skin	8	15 - 20
	Semi-Flat	7	
	Pre-Ere.		
MID	Bottom	7	7 - 10
	Skin	7	7 - 10
	Bilge	7	10 - 15
	T. Bhd.	6	10
	L. Bhd.	6	
	Deck	6	
E/R	Engine Bed	8	10 - 20
	Curved Skin	8	
	Semi-Flat	7	
AFT.	Curved Skin	8	15 - 20
	Semi-Flat	7	
	Pre-Ere.		

FIGURE 4-7

REQUIRED ASSEMBLY DAYS STANDARD PER HULL STRUCTURAL TYPE



- (A) ASSEMBLY CAPACITY
- (B) PROPOSED ASSEMBLY SCHEDULE
- (C) LATEST ACTUAL COMPLETION ASSEMBLY SCHEDULE

FIGURE 4-8
COMPARISON FOR ASSEMBLY SCHEDULING

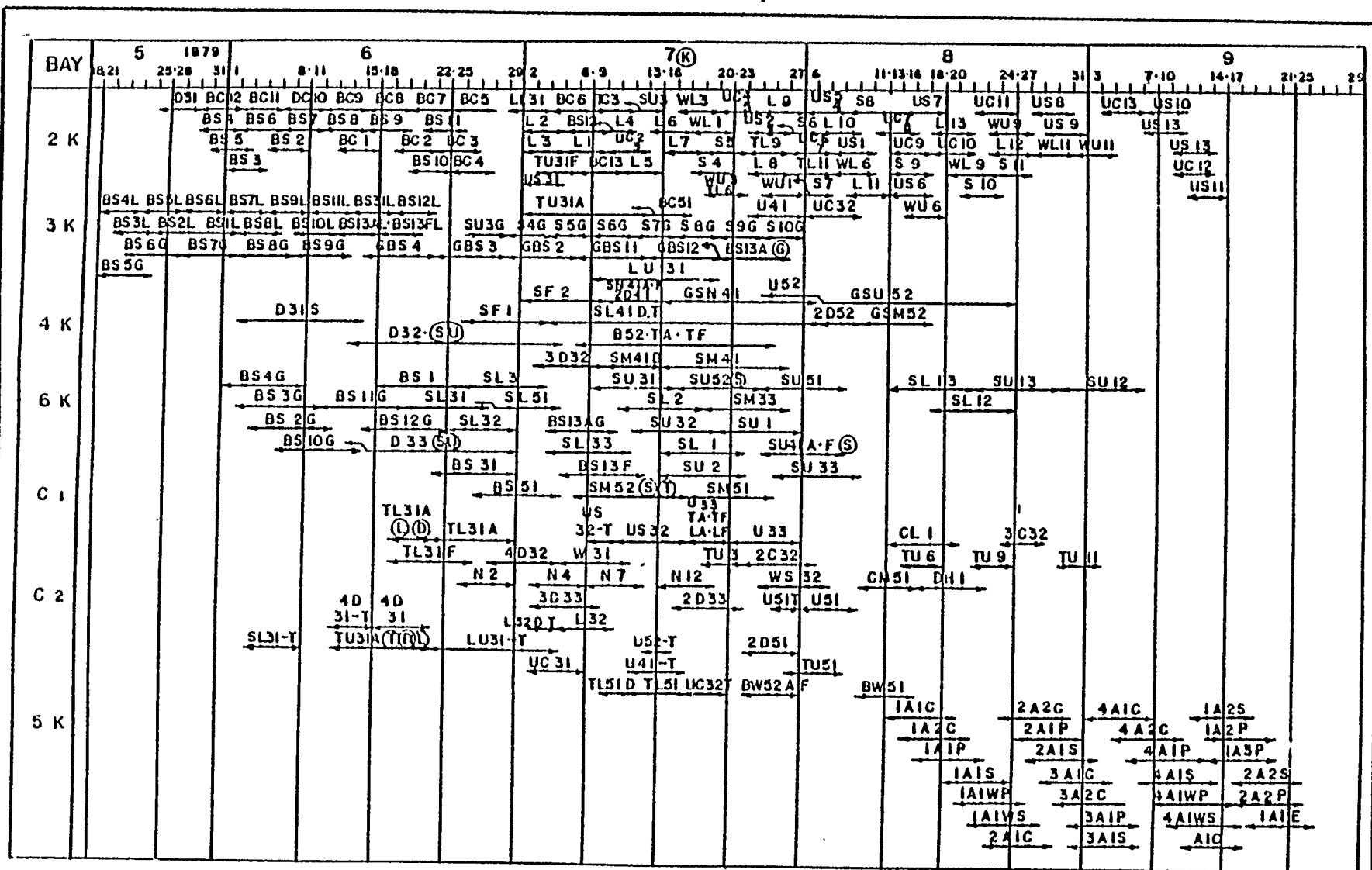


FIGURE 4-9

ASSEMBLY MASTER SCHEDULE

develops from the erection sub-schedule to the assembly sub-schedule to the sub-assembly sub-schedule. However, because of the many considerations of process times, manloading, maintenance of a continuous production flow, storage of sub-assemblies and units, etc., it is necessary to constantly adjust these schedules during their development. All of the sub-schedules really work as a "set" of schedules which detail the entire manufacturing process from start to finish.

4.6.1 Fabrication Sub-schedules

Detailed sub-schedules are prepared for each operation in the fabrication process (i.e., lofting, marking, cutting, bending, and sub-assembly). These schedules cover all of the work required for each ship set of parts, pieces, and sub-assemblies. For example, all of the work required by the mold loft is covered by one sub-schedule, marking by another, and so on. Each of these schedules is formulated taking into account the longer processing times of certain components versus other more simple components. Parts requiring mechanical and flame bending naturally require longer scheduling than simply cut pieces. Therefore, these parts will be started into the production process before the simpler pieces to assure that all required components are available in time to support sub-assembly or assembly of a unit.

4.6.1.1 Mold Loft Schedules

Mold Loft schedules are prepared for each unit of a given ship. The schedules define each day's activity for the mold loft for each unit. Lofting requirements are specified in the working drawings and these requirements and the daily schedule are coordinated by the Production Planning and Engineering group.

Precise lofting is considered vital to the "downstream" activities of fabrication and assembly for a mistake in lofting is often not recognized until parts have been fabricated and are being assembled. Also, lofting is the pacing activity for the fabrication operations and the careful and accurate scheduling of lofting activities is considered one of the major prerequisites to the smooth flow of material through the fabrication shops. Figure 4-10 shows an example of a lofting schedule.

4.6.1.2 Marking, Cutting and Bending

These sub-schedules are developed for each of the different process lanes of the fabrication shops. Basically there are four process lanes used to process the different types of steel components: 1) a lane for cutting of small pieces (e.g. internal structure members) using N/C or manual methods; 2) a lane for cutting skin or panel plates using a flame planer; 3) a lane for cutting and bending raw shapes such as angles; and 4) a lane for bending skin and panel plates for curved units. Each of these process lanes requires individual schedules for marking and cutting. Bending schedules are prepared for those lanes engaged in this activity.

These sub-schedules are prepared on the ultimate need date for the components for sub-assembly or assembly, and the length of time required to process bent or curved pieces versus simpler parts and pieces. Consideration is also given to any pieces requiring special cutting such as beveling which necessitates a longer process time and which should be removed from the continuous process flow, and to arranging a flow of similar or identical pieces through a given work station to maximize the production rate (e.g. plates moving through

COMPLETION OF PARTS DATA	12/26	2/	28	12/29	5	6	7	9	10	11	12	13	17	18	19	20	21	23	24	25	26	27	30	31	2/1
COMPLETION OF MASTER DWG	1/6	7	9	10	11	12	13	17	18	19	20	21	23	24	25	26	27	30	31	2/1	2	3	6	7	8
COMPLETION OF D.D.A.	12	13	17	18	19	20	21	23	24	25	26	27	30	31	2/1	2	3	6	7	8	9	10	13	14	15
ASSEMBLY START	2/1	2	3	6	7	8	9	10	13	14	15	16	17	20	21	22	23	24	27	28	3/1	2	3	6	7
	G54		G55						(C)		(D)														
2H	U2		U3		U4		U6		G57		G56		1H												
1/9	1A			GSU3	132(C.T.)																				
	2A			U7-5			GD7																		
S2638	3A			U51	GD4	GD6		GD5									GG54			157					
				T4			T6					T4-D	T4		T6-D	T6			207	U7					
P/L									GS151		GGSU57														
2H					G52		G53		G54		G55														
1/8								U2		U3				(C)		U4	U6								
	1H	G51	(D)											G57		G56	(D)								
S2663	1A	GD5				GD6			U51					GSU31	132									GG54	

FIGURE 4-10
MOLD LOFT SCHEDULE

a flame planing station). Examples of the marking and cutting, and bending schedules are presented in Figures 4-11 through 4-13.

4.6.1.3 Sub-Assembly

The breakdown of the units, performed during Block Assembly Planning, identifies the sub-assembly requirements for each unit. Using this information and the Assembly Master Schedule, workshop engineers develop the sub-assembly schedule for each block.

Sub-assembly of components allows a more gradual build-up of the units in diverse areas and in a less complex and more controllable manner.

Sub-assembly of steel components is performed at the end of the fabrication process lanes. The scheduling performed for components undergoing fabrication is primarily oriented toward completing all necessary components to support a smooth flow through the sub-assembly process. Sub-assembly schedules are constructed so as to support the assembly of units, just as the fabrication schedules support the build-up of the sub-assemblies.

An important consideration in the formulation of the sub-assembly schedule is the arranging of material flow so that identical sub-assemblies can be processed one after another until that type of sub-assembly is completed. This is not always possible due to the scheduling requirements for other types of sub-assemblies to support the assembly requirements of the units.

4.6.1.4 Assembly

Assembly sub-schedules are prepared for each type of unit i.e. flat or curved, and for each assembly area and each sub-stage. The Block Assembly Plans, Assembly Specification Plans and the Assembly

E.P.H. CUT COMPLETE ASSY START ASSY	11/10	21	23	24	25	26	29	30	12/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23
	11/22	24	25	28	29	30	12/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27
	12/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27	28	29	1/2	6	7	9
2H								13																	
		D4	D5		L2	L6	D4	3	L4	L6	D6	L5			L7						S2	D7	S3	U2	S4
(F0-6) 2612		5	5		3 3	4	4	D5 8	3 3	4	9	1 4			4 4						4	2	8	2	8
								4																	
							17							S2											
	D3		L6	L5	4		4 4		D5	4				4 4		S3	U2	S4	S5	U3	S26		U41	L1	5
(F0-7) 2642	5	3	4 4	4 4	D4	4	D6		5	D7	9					8	2	8	2 6	2			7	3 3	5
					5					2				4											
														D2		L1	D3	D2	D1	D4	L2		D5	L3	D6
(F0-8) 2637														3		3 3	3	4	3	5	3 3	4	5	3 3	4
		S10		S10																L5					
		S4		S5			L1				D1		D2	L2	D3	L3	L41		L7	4 4					

FIGURE 4-11
MARKING AND CUTTING SCHEDULE (SKIN)

EPH PROJECTION	11/17	18	21	22	24	25	28	29	30	12/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22
CUT. COMPLETED	11/22	24	25	28	29	30	11/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27
SUB-ASSEMBLY START	12/1	2	5	6	7	8	9	12	13	14	15	16	19	20	21	22	23	26	27	28	29	1/5	6	7	9
2610		G54	G57	G55																F57					
																				1					
2611		G56				D7-5											G57						F57		
					3																		1		
	D4-G	L6			L2	L7	L3		L4		L5														
	S/C				8	5 ⁵⁹	7 ⁵²				2														
2612	D4	D6			D6						D6							D7G		D7	G52			G53	
	7				9	1			S/C									S/C							
	D51	D5				D4-5	D6-G																	D2	
	3	4	1	1	S/C		S/C	S/C																	
	L4		L5	D25		D3-				L6		L7		G52		G53		G54		G55					
			3				S/C			8				S/C		S/C		S/C		S/C					

FIGURE 4-12

EPM OR MANUAL MARKING AND CUTTING SCHEDULE (PARTS AND PIECES)

F.P.M. & CUT BENDING COMP. ASSY	10/26	27	28	31	1/1	2	4	5	7	8	9	10	11	14	15	16	17	18	21	22	24	25	28	29	30
	10/31	11/1	2	4	5	7	8	9	10	11	14	15	16	17	18	21	22	24	25	28	29	30	12/1	2	5
2W																									
1W													S11				S42			S37					
(11-6)		S1	Block Code										S7				S1			S1			S6		
		(8)	Parts Quantity										(8)				(8)			(8)			(8)		
2612		NC	Numerical Cutting										2 2				NC			NC			NC		
										S51						S51	S51				S51	S51			
(FT-10)	SL31	SL32	SU31	SU32						SL31	SL32	SU31	SU32												
	(1)	(6)	(4)	(4)	(5)	(3)				(4)	(6)	(4)	(4)	(2)	(2)	(5)	(3)				(2)	(2)			
2643	NC	NC	NC	NC	5	3				NC	NC	NC	NC	8	2	5	3				2	2			

FIGURE 4-13
BENDING SCHEDULE

Master Schedule are the basis for these schedules.

The Assembly stage is divided into a series of sub-stages as follows:

Assembly and welding of stiffened panels

Assembly and welding of frames, webs and other internal structures

Assembly and welding of frames and webs to panels

Turning over of assembled blocks

Completion of welding

Fitting of frames, hanging pieces, scaffolding, outfittings, pipes, etc.

Painting

Each of these sub-stages is detailed for each assembly in the sub-schedules. Production Planning and Engineering group personnel develop the sub-schedules on the basis of the total welding requirements for each unit which also dictate the manloading for that assembly area. The use of cranes is also carefully scheduled especially for the heavy lifts after the units begin to be assembled.

Assembly scheduling is also concerned with the necessity to store units prior to ship erection. Since space is nearly always at a premium in the IHI yards, the storage of the large units can cause serious problems and result in excessive transportation requirements or in the slow-down of assembly work because completed units cannot be moved promptly. Ideally, units would be transported directly to the building basin and immediately erected. However, this is not possible due to the longer schedule time required for assembly versus erection. Therefore, a considerable number of units are completed and stored either on the basin platen area or in buffer storage areas

awaiting the start of erection. This provides sufficient time once erection begins for following units to be completed and moved to the building site by the time they are to be erected. This method allows a smooth flow of assembly units to the erection site throughout the erection stage.

4.6.1.5 Erection

As in the Assembly Stage, the Erection Stage is divided into a series of sub-stages detailing each step of the erection process.

These sub-stages are:

- Unit Erection
- Shipwrighting
- Scaffold Erection
- Main Structure Fitting
- Main Structure Welding
- Sub-structure Fitting
- Sub-structure Welding
- Cleaning
- Internal Visual Inspection
- Scaffold Removal
- Water Tank Test
- Completion

Erection is performed by zone or in the case of the cargo holds by individual tank or hold.

The erection sub-schedules are developed in concert with the Erection Master Schedule by detailing the steps involved in preparation, landing and joining the individual units either one at a time or

after being joined into a combination of units which are landed as a composite into the basin.

Fitting and welding manhours are calculated for each step in the erection sequence and the steps are "set back" from the preceding step the appropriate number of days to allow for the accomplishment of the requisite tasks. When completed the schedules are adjusted to coincide with the launch of the ship and with the start of the erection of the next ship scheduled for that building basin.

Schedules for the disassembly of erection scaffolding are closely tied to both the schedule of inspection and the schedule for final ship painting.

Examples of sub-assembly, assembly and erection schedules are provided in Appendix F.

4.7 OUTFITTING SCHEDULING

In parallel with the scheduling of the steel work through the Hull Construction Workshop, outfitting scheduling is developed to reflect the procurement, fabrication, sub-assembly and installation of outfitting components. The schedules coincide with the various production stages of hull work as it proceeds through the sub-assembly, assembly and erection process. Outfit scheduling is critical to the completion of hull units and must be carefully organized to avoid the interruption of the flow of work to the building basin.

The schedules prepared for outfitting are: the Outfitting Milestone Schedule; the Outfitting Master Schedule; Master Schedules for On-unit, On-block and On-board Outfitting; and Monthly and Weekly Shop Schedules. Figure 4-14 depicts this hierarchy of outfitting schedules.

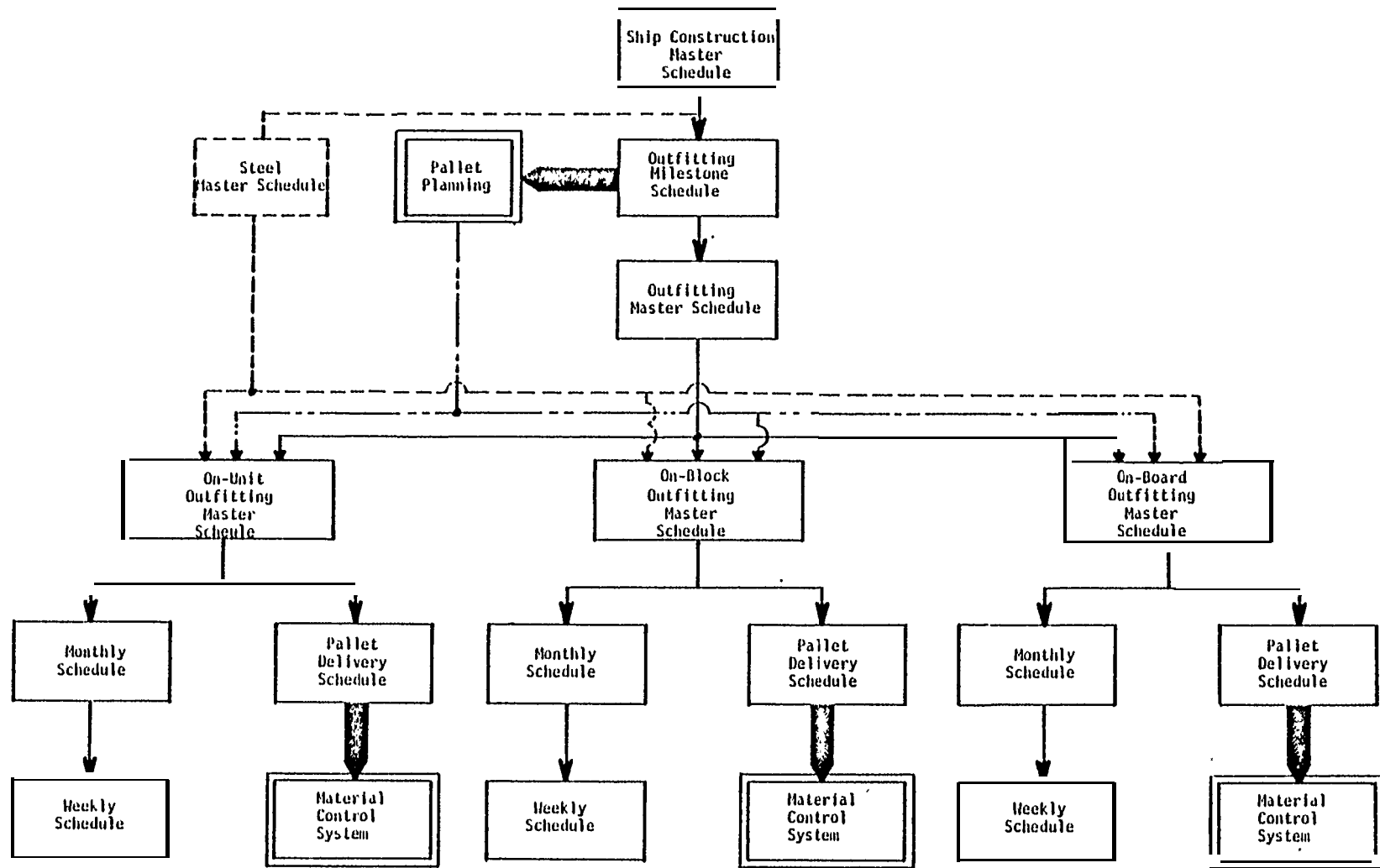


FIGURE 4-14

OUTFITTING SCHEDULING SYSTEM (IHI)

4.7.1 Outfitting Milestone Schedule

The objective of this schedule is to coordinate the principal outfitting requirements with those of hull construction and painting. Table T4-1 provides an indication of the types of milestones plotted in this schedule.

This schedule is prepared by the Production Planning and Engineering group in the Fitting Workshop and coordinated with the staff group of the Hull Construction Workshop. Each of the Fitting Shop Managers approves the scheduling of the milestones in his respective area and subsequently the schedule is reviewed and approved by the Managers of Hull Construction and Painting.

Figure 4-15 depicts the development of the Outfitting Milestone Schedule including the information required for its development and its distribution. Figure 4-16 provides an example of this schedule.

4.7.2 Outfitting Master Schedule

Based on the milestones established in the Outfitting Milestone Schedule, the Erection Schedule and the Master Assembly Schedule, the outfitting Master Schedule is prepared. The objective of this schedule is to establish firm dates for the build-up of outfitting sub-assemblies, the installation of these sub-assemblies and other outfitting components on the unit assemblies, and/or on-board the erected ship. The schedule contains the milestone events previously scheduled in the Outfitting Milestone Schedule and "set back" dates for the step-by-step activities required to achieve the scheduled event. Manpower availability is thoroughly investigated to ensure that sufficient manpower is available to accomplish the required outfitting as developed on the schedule. Dates may be adjusted in

TABLE T4- 1
TYPICAL MILESTONE LIST

Kee Laying	Working Unit Landing
Main Engine Landing	Sight-thru for Rudder
Main Boiler Landing	Working Unit Removal
Accommodation House	Engine Casing Landing
Forecastle Deck	Shore Power to Mach. Space
Propeller Install ation	Inert Gas Fan Start
Launch	Ship Off Shore
Main Boiler Firing	Lightweight Measurement
Turbo Generator Start	Builder's Sea Trial
Deck Final Paint Start	

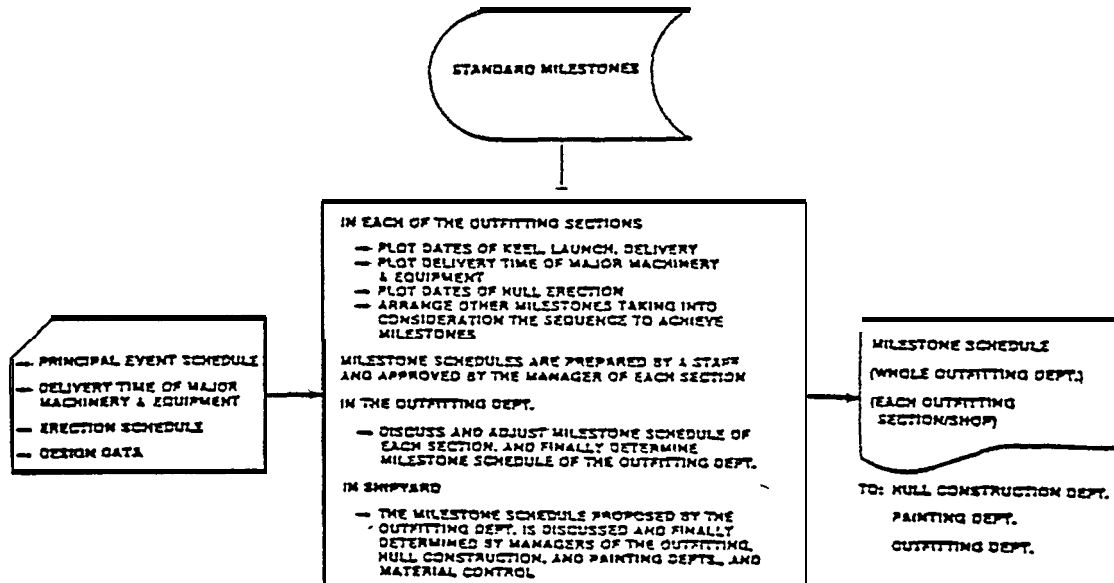


FIGURE 4-15
OUTFITTING MILESTONE SCHEDULE

[illegible]

FIGURE 4-16

OUTFITTING MILESTONE SCHEDULE

the case where manpower is not sufficient to accommodate the scheduled work.

Since all Fitting groups will be performing some type of work in many different areas during the execution of this schedule, the managers of each group review and approve the schedule of the work for their group. Figure 4-17 shows the development of this schedule and Figure 4-18 provides an example of the completed schedule.

4.7.3 On-Unit, On-Block and On-Board Master Schedules

A further breakdown of the Outfitting Master Schedule is made to isolate the distinct activities of outfitting concerned with the build-up of outfitting sub-assemblies (on-unit), the outfitting to be accomplished on the hull units (on-block), and the outfitting to be performed on-board the erected ship. Each of these production stages is covered by a separate schedule which is used by the outfitting section managers in creating the detail working schedules for their respective sections.

4.7.4 Working Schedules

Section Managers prepare two types of schedules to control and allocate resources to the individual jobs which must be performed by their sections. Each manager prepares a "Monthly" schedule which really encompasses the work to be accomplished over the next two month period. These schedules identify the outfitting activities which must be performed, the times at which pallets must be ordered to support those activities and to schedule fitting personnel for the different tasks. This schedule is prepared by a staff engineer, but is ultimately used by individual foremen within each fitting section and acts as a performance control chart in that each month's progress is measured

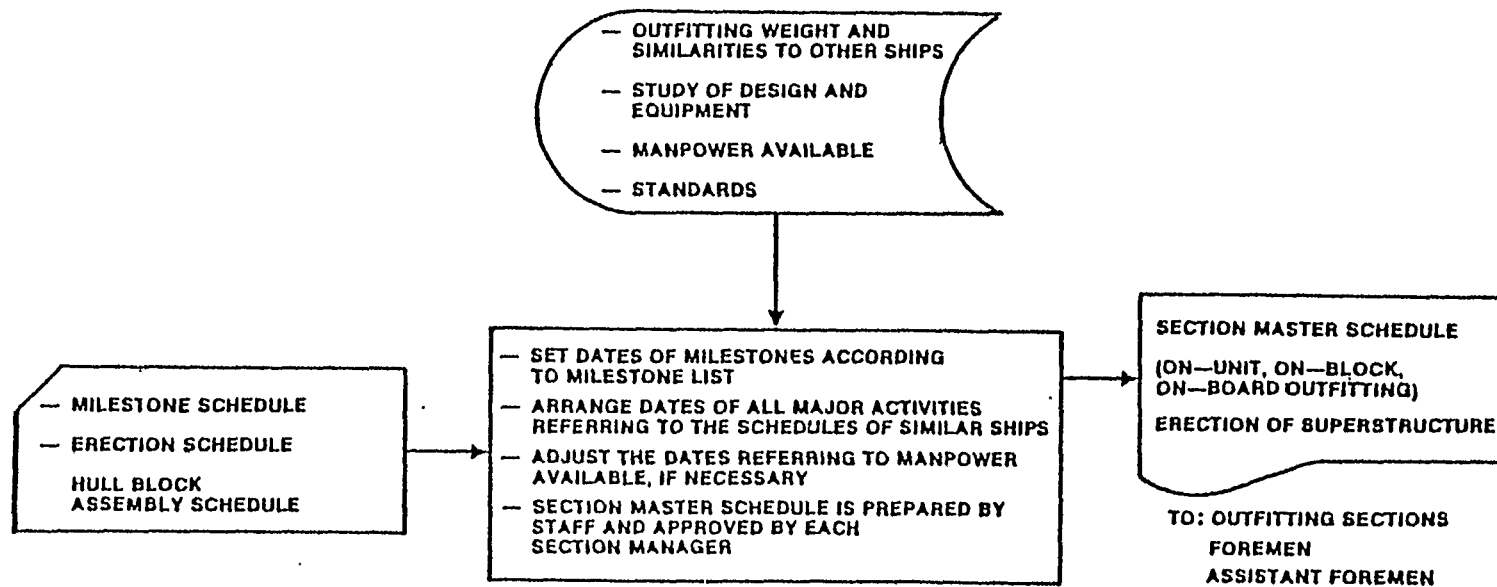


FIGURE 4-17
OUTFITTING MASTER SCHEDULE

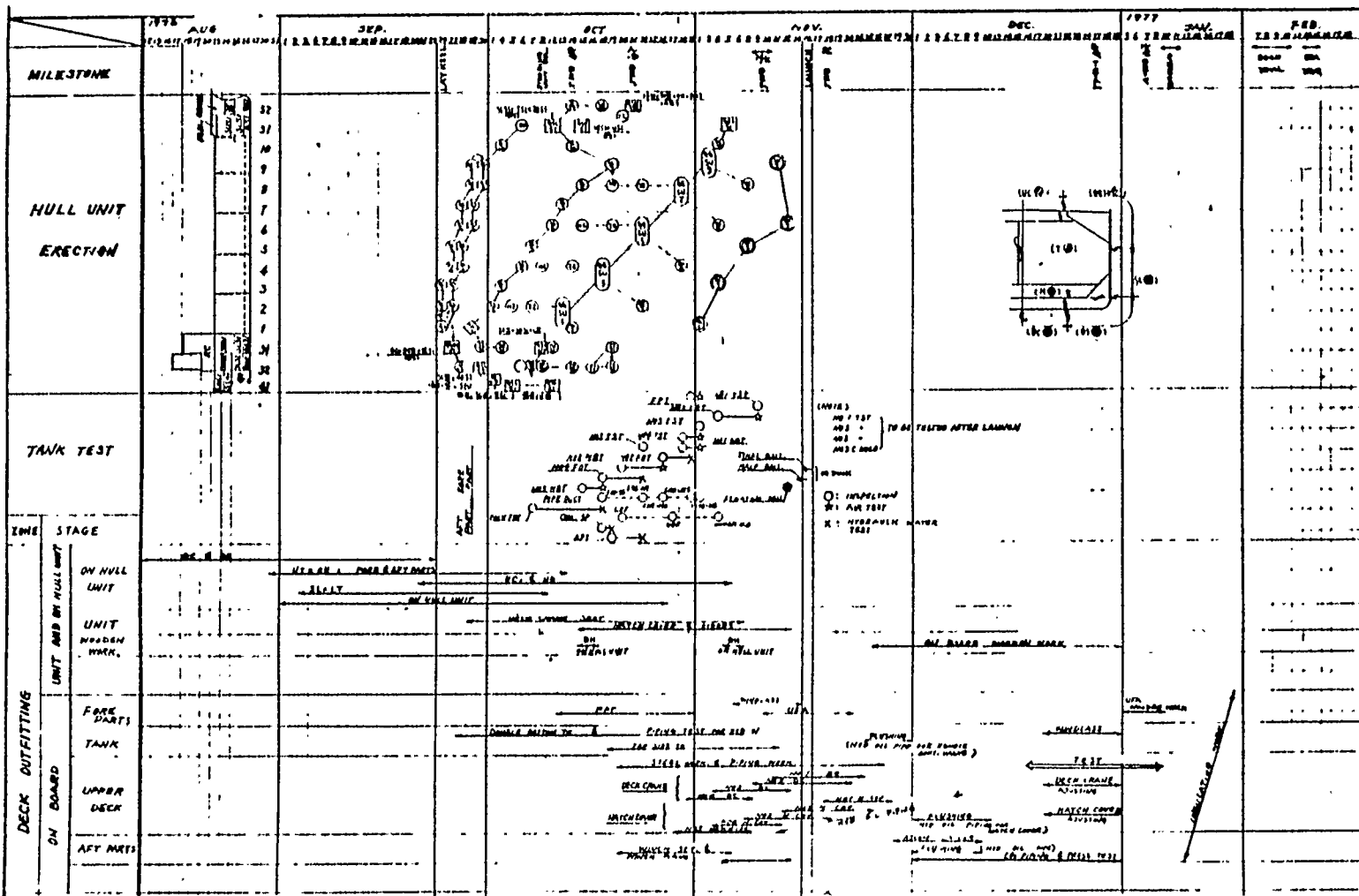


FIGURE 4-18

OUTFITTING MASTER WORK SCHEDULE

during the preparation of each subsequent month's schedule. Figure 4-19 depicts the development flow of these monthly schedules.

The second working schedule is prepared weekly on the basis of the monthly schedule for each section. This schedule is prepared by an Assistant Foreman and approved by the Foreman. The weekly schedule covers a two week period but is up-dated every week. The schedule is simply a more definitive breakdown of the activities shown on the monthly schedule and designates the day-by-day personnel assignments and tasks to be performed. Figure 4-20 illustrates the development of these schedules.

4.7.5 Pipe Fabrication Scheduling

The Pipe Shop is responsible only for the fabrication of pipe. Fitting work involving pipe is the responsibility of the other fitting groups. Because the fabrication of pipe to support the various fitting schedules is so critical specific pipe shop schedules are prepared. These schedules identify the pipe requirements for specific pallets as required by the MLF and the Outfitting Master Schedules. Pipe is then categorized by type or "family" and scheduled in "long-term" and "short-term" schedules. The development of the two different schedules is shown in Figures' 4-21 and 4-22.

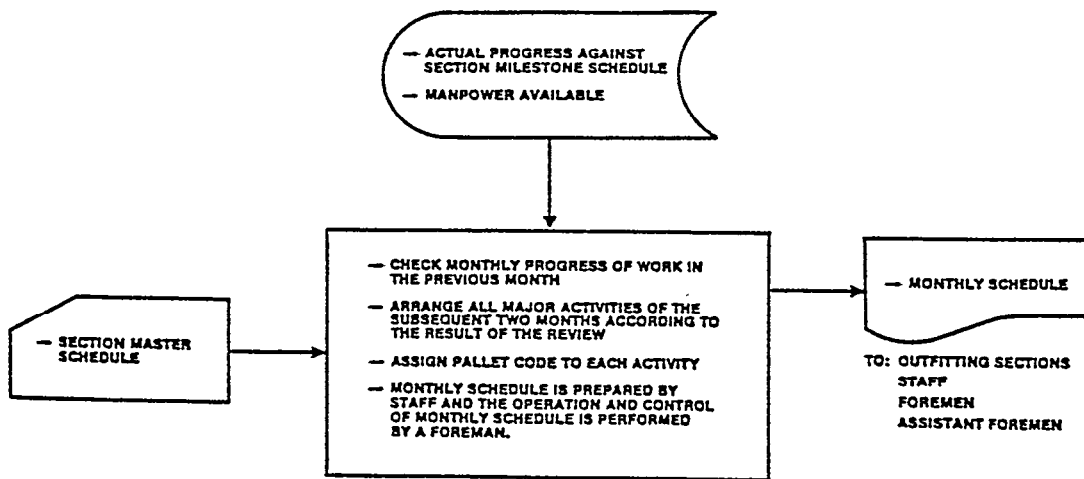


FIGURE 4-19

MONTHLY SCHEDULE

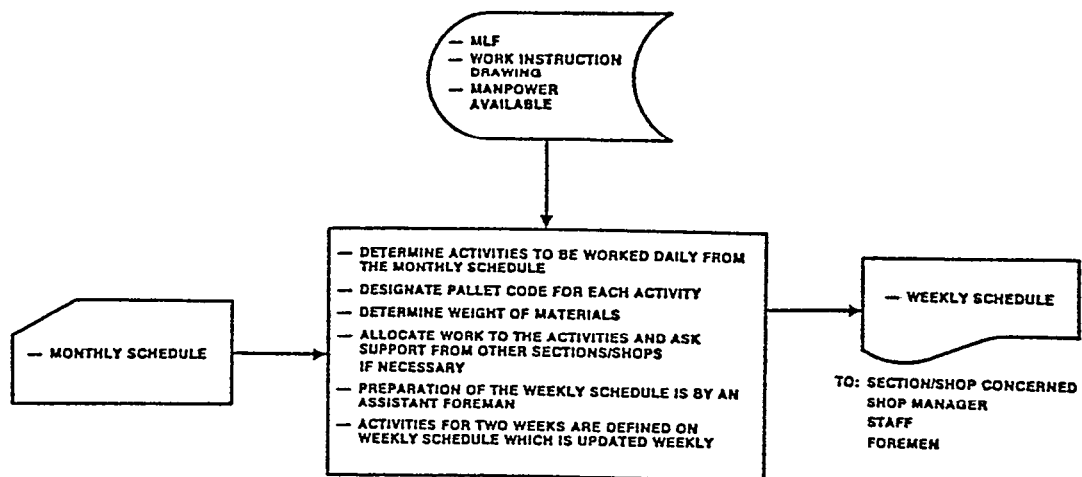


FIGURE 4-20

WEEKLY SCHEDULE

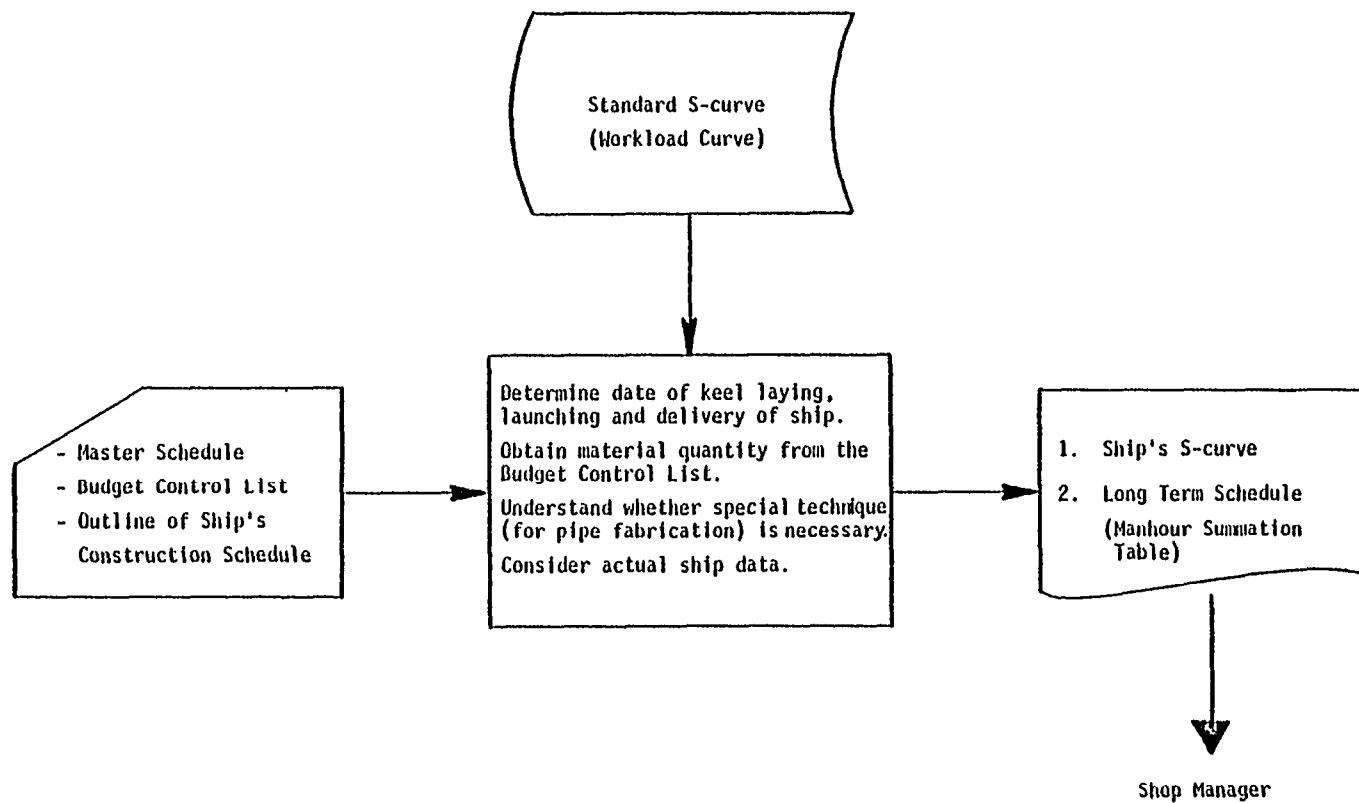


FIGURE 4-21
LONG TERM SCHEDULE
(FOR MANLOADING AND SCHEDULE OF PIPE SHOP, 4-6 MONTHS)

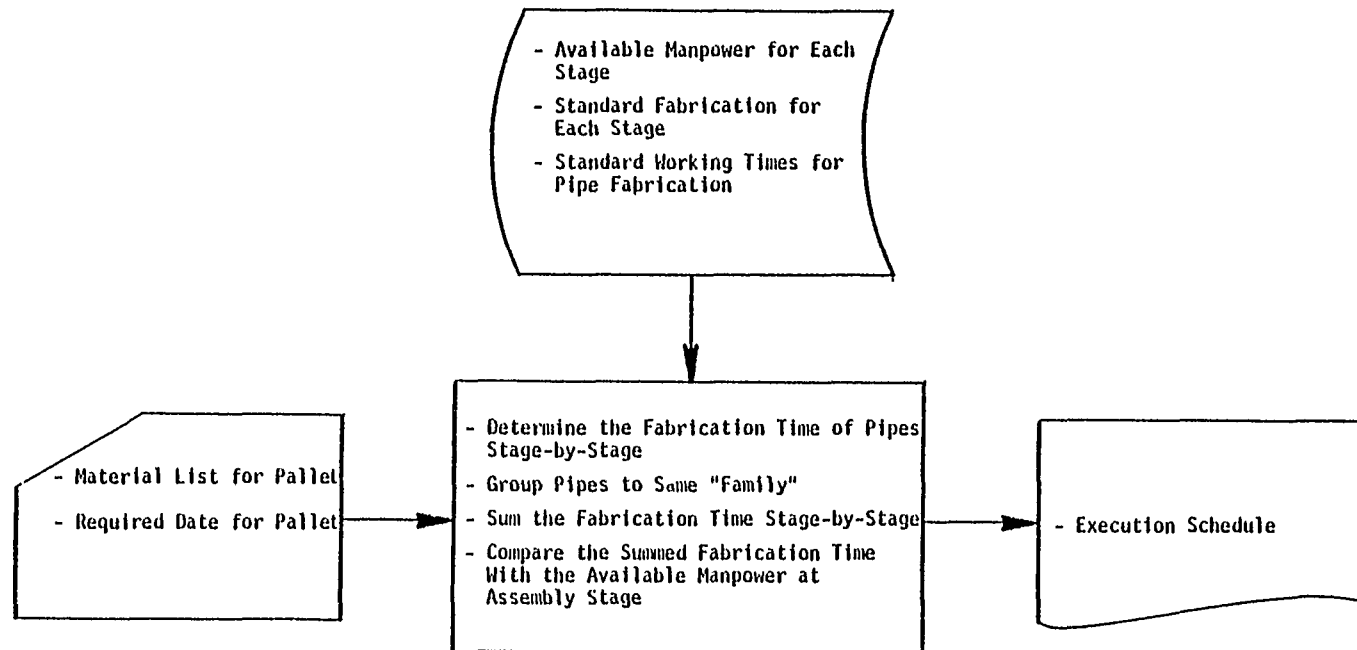


FIGURE 4-22
SHORT TERM SCHEDULE - PIPE SHOP

SECTION 5

MANPOWER PLANNING

5.1 GENERAL

Manpower planning in IHI is a precise method of applying personnel resources to each task of the well defined production process. The planning accomplished for hull construction and outfitting and the exact scheduling of these activities provides the framework for the application of manpower in discrete stages, sub-stages and time periods.

The entire production process is organized around the "process lanes" system. As previously discussed in Section 2, this system allocates specific types of work to particular work stations established in a fixed location within one of several process lanes. In Hull Construction these work stations are related to lofting, marking, cutting, bending, sub-assembly, assembly and erection. The activities of each of these work stations is defined in great detail in the plans prepared prior to the start of fabrication, and further delineated in the detailed schedules discussed in the previous section. The organization of the basic production system and this highly refined planning and scheduling allows the application of personnel to small increments of work at fixed times throughout the hull production process.

In outfitting the same basic methodology is applied although the locations and mix of personnel vary according to the type of outfitting being accomplished. Also, the fabrication of pipe is a discrete planning and scheduling effort of its own and the application of manpower is determined separately from that of hull construction and outfitting.

The computation of manpower in each of these major areas of hull construction, outfitting and pipe fabrication is based to a large extent on the historical data accumulated by the various yards from the prior construction of similar ships. This historical data has cataloged production rates per manhour in terms of weight of steel, weld metal deposited, cutting length, outfitting component weight and manhours required for sub-assembly or installation, painting and pipe fabrication. The application of these data to the same type of operations ship after ship is a routine and accurate process.

The concept of accuracy control plays an important part in the estimation and allocation of manpower to the specific tasks and areas of the production system. Because of the emphasis placed on accuracy control by the IHI yards and because of the continual improvement of accuracy in the production activities, the estimation of manhours for each production process is very precise. Under the concept of accuracy control it is assumed that few errors or discrepancies will exist in the processed material as it moves from work station to work station. Errors or discrepancies in workmanship are nearly always discovered in the area where they occur and are repaired prior to leaving that work station. This means that only the work programmed for a given work station need be performed at that work station. No rework or correction of defects passed on by a prior work station is necessary. This allows very accurate man-loading of each work station area.

5.2 BUDGET PLANNING

The budget planning process in IHI is not unlike that utilized in U.S. yards, although the participation of the workshops planning

staffs is a unique aspect and indicates that workshop managers participate more fully in the establishment of their budgets than their U.S. counterparts.

Essentially, the overall budget is established by the IHI Head Office and refined by the shipyard General Manager into working budgets for each department in each workshop. This refinement of the overall budget is accomplished both by the Production Control Department which is staff to the General Manager, and by the Production workshops. The estimate generated by Production Control is in more general terms and is based primarily on historical data collected from previous ship construction programs. Production department estimates are in precise terms of numbers of welding and fitting manhours required per day/week/month.

Subsequent to the initial estimation of manhours by Production Control and the production shops, a Budget Meeting is held and a decision as to the operating budget is made by the General Manager. This operating budget is then issued by Production Control to the various cost centers in the yard. No adjustment of the budget is made until one or two months before ship delivery. This adjustment is made on the basis of accumulated manhour expenditures at another meeting of Production Control, the affected shop(s), and the General Manager. Figure 5-1 shows this budgeting process.

5.3 SPECIFIC MANPOWER PLANNING METHODS

The manpower planning process involves several distinct steps to ascertain the precise numbers of the different types of personnel required for hull construction and outfitting. Essentially, this

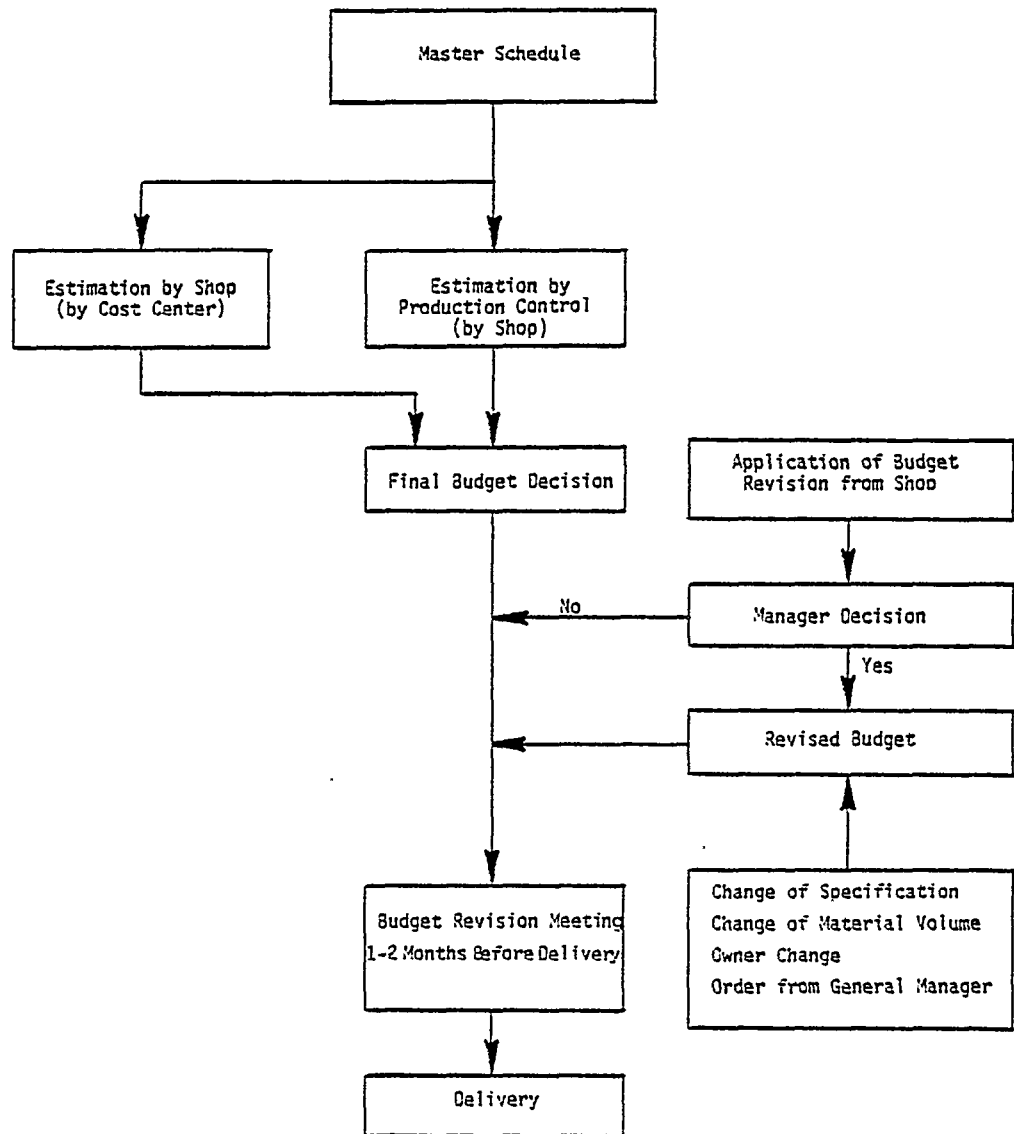


FIGURE 5-1
BUDGET PROCESS

planning evolves from an overall estimate of the manhours required for each production stage (i.e., lofting, fabrication, assembly, erection, outfitting) to a scheduling of these manhours on a month-by-month basis and, by means of these man-loading schedules, to an identification and allocation of appropriate personnel to the work groups at each work station. Monitoring of these manhours is then accomplished by means of production control charts maintained by the workshop staff groups.

5.3.1 Production Planning Estimate

The overall estimate of manpower is performed by the Production Control Department by first breaking down the estimate into the three main areas of hull construction, fitting and painting.

Using the ship specifications and a Budget Control List (prepared from historical data) and additional historical data from similar ships, the Production Control planners estimate the number of manhours required for hull construction based on the weight of the hull, probable welding lengths, and probable cutting lengths. Outfitting manhours are estimated using the weight of fittings and the electrical cable length. Main machinery weight is not included in this calculation. Painting is estimated by weight and by the area requiring painting.

These manhours estimates are plotted in a series of curves which are then aggregated in a "Production Curve" to show the total manhours requirement for the ship over the time allocated in the Shipyard Master Schedule for ship construction. Figure 5-2 shows the development of this overall Production Curve.

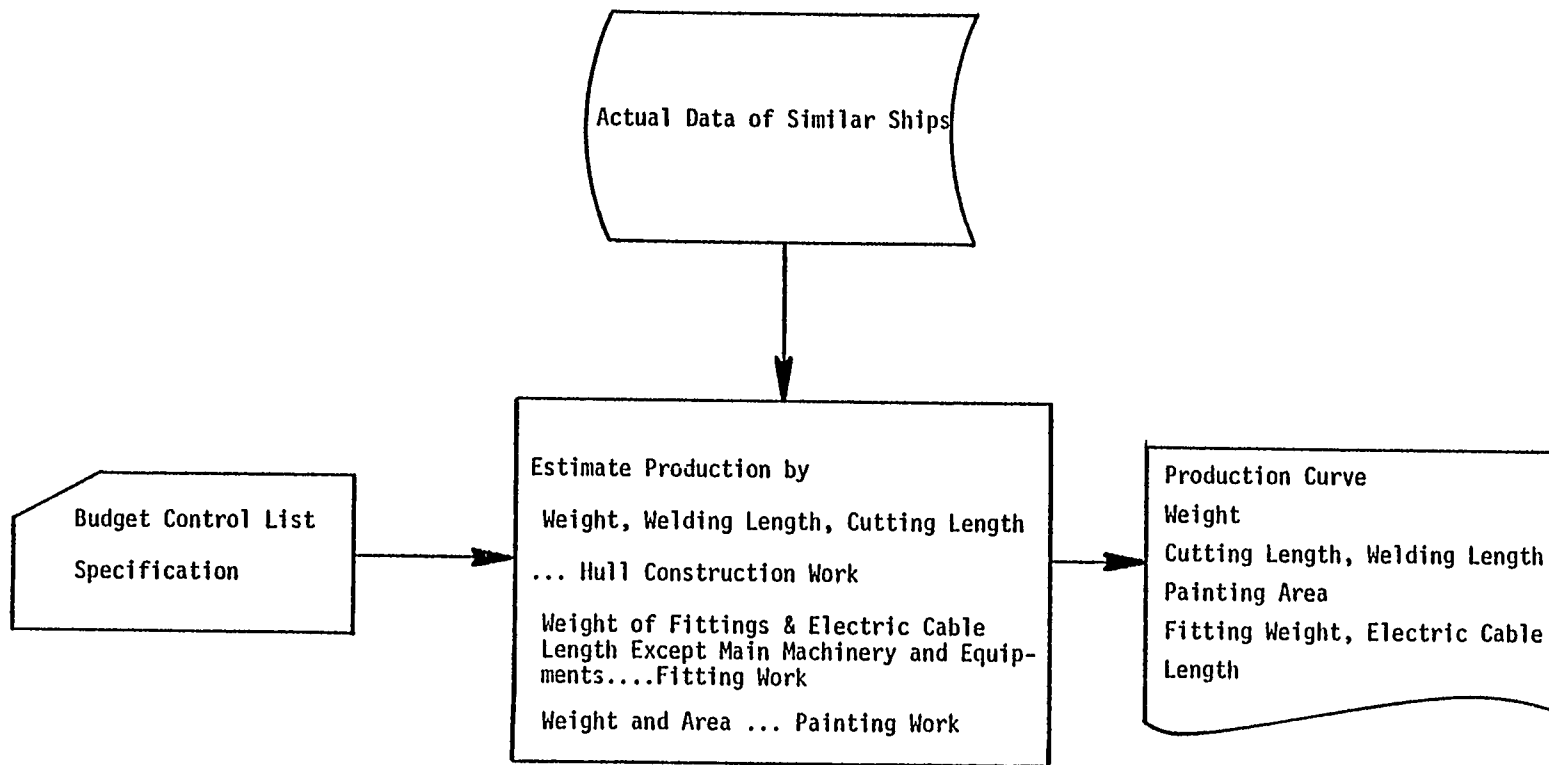


FIGURE 5-2
PRODUCTION PLANNING BY WEIGHT, CUTTING LENGTH AND WELDING LENGTH

5.3.2 Manhour Planning

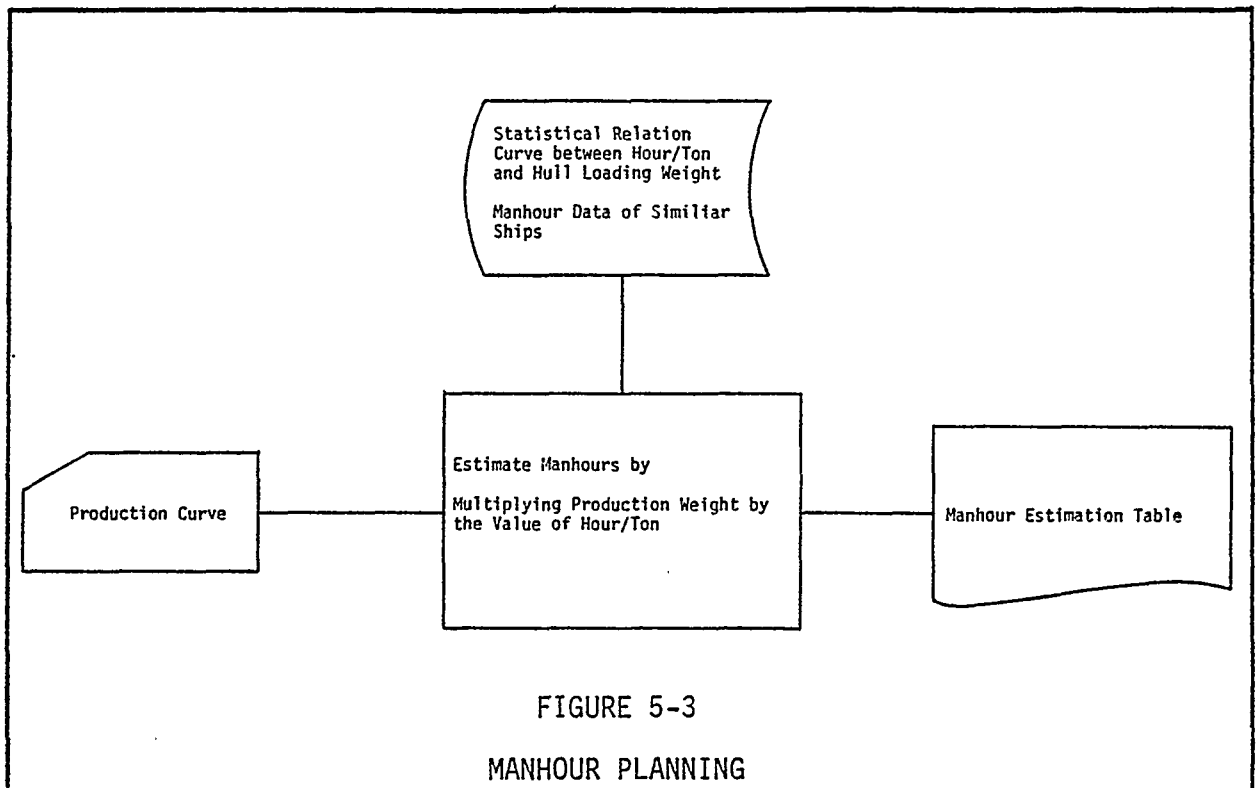
Using the Production Curve, manhours are computed in terms of manhours per ton for each stage of production. The output of this planning is a Manhour Estimation Table which details the hours per ton for the various operations of fabrication, assembly, erection and outfitting.

In hull construction the number of welder hours are determined together with the number of support personnel. In this workshop, welding is considered the primary activity and all effort is oriented toward providing a smooth flow of work through the welding processes at all times. Support personnel are considered to be all others who perform tasks concerned with the transport, preparation and removal of material to and from the welding stations.

In outfitting the number of manhours is determined for the various fitters in each of the fitting sections (i.e., pipe, interior, deck, machinery, electric) per ton of fitting material at each production stage. Figure 5-3 depicts the development of the Manhour Estimation Table and Figure 5-4 provides an example of this table. Examples of the manpower planning curves are shown in Appendix F.

5.3.3 Work Load Scheduling

The application of the hull construction and fitting manhours across the ship construction time frame consists of the identification and plotting of the number of manhours required for each activity in each sub-stage and stage of production. The summation of these manhours forms the manhours curve for the ship being planned. Comparison of this curve with a "standard" curve from a previous and similar ship indicates its validity and provides an assessment of questionable areas.



	SNO 1000					
Deadweight						
Kind of Ship						
L x B x D x d						
Owner						
Ship Name						
Classification						
Keel Laid						
Launching						
Delivery						
	MH	WT	H/T	m	H/m	%
Pipe Work						
Interior Work						
Deck Work						
Machinery Work						
Electric Work						
Control Work						

FIGURE 5-4
MANHOUR ESTIMATION TABLE

The purpose of this assessment is to determine the number of manhours required over the period of ship construction and to compare the requirements with the available manpower month-by-month. If several ships are in production it may be necessary to make arrangements for supplementing the yard workforce with subcontractor personnel, or for overtime or assignment of work to departments showing manpower availability.

The output of this overall work load scheduling is used to level load the production workshops and to ensure the availability of sufficient manpower for all ships in process. Figure 5-5 illustrates the development of this Work Load Schedule.

5.3.4 Manhour Efficiency Control

Estimated manhours for each shop and for each production stage are closely monitored each month to assure that the forecast hours are sufficient to accomplish the scheduled work. Work efficiency is also monitored by means of a comparison of actual hours expended to those expended on a prior similar ship. This control is exercised within the individual workshops through monthly and weekly shop schedules, manpower charts, and performance control charts developed by the Production Planning and Engineering staffs. This information is aggregated into the overall manhour efficiency curve by the Production Control group. Figure 5-6 shows the development of this curve. Examples of these curves are provided in Appendix F.

5.3.5 Manhour Control

Manpower planning is adjusted as necessary on the basis of returned or actual manhour expenditures in each shop. Manhours from each shop are collected each day by means of time cards submitted by

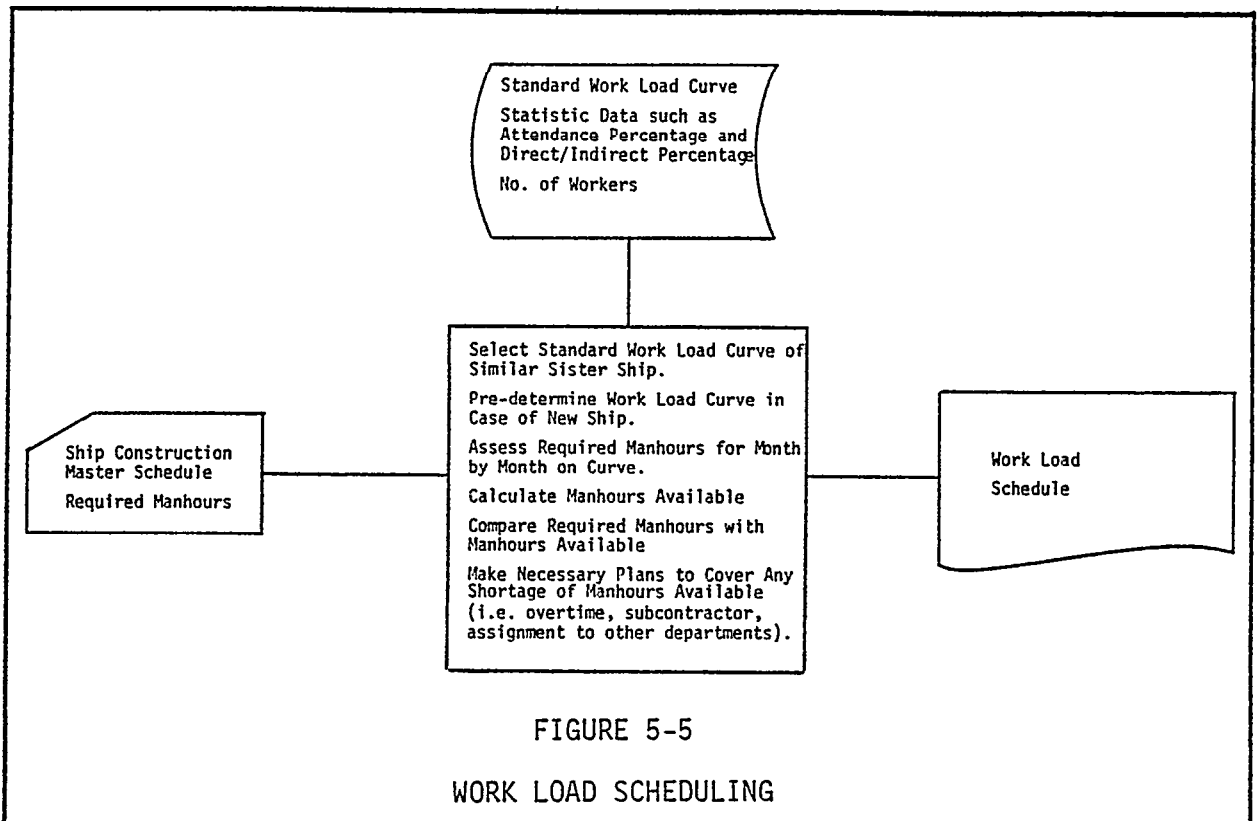


FIGURE 5-5
WORK LOAD SCHEDULING

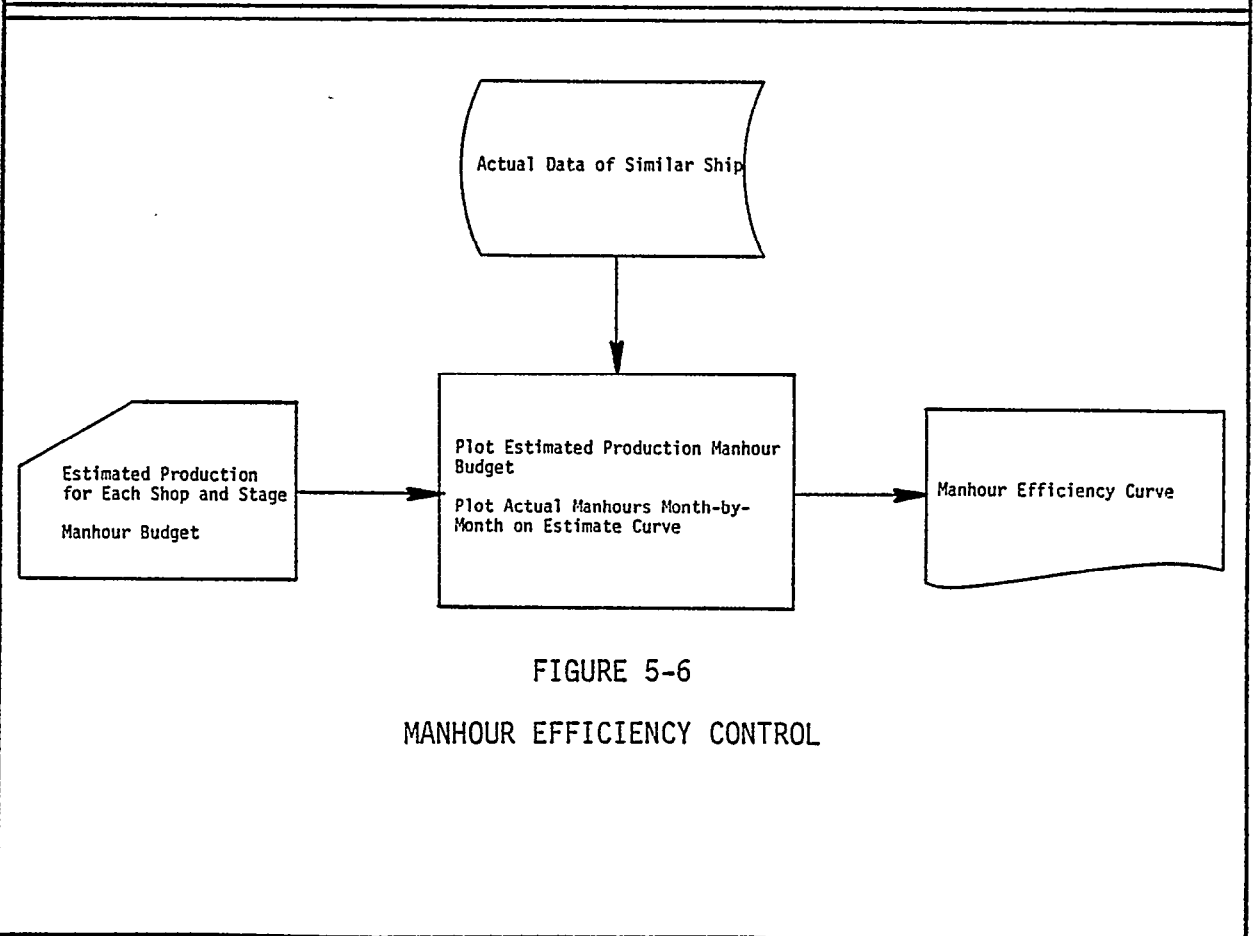
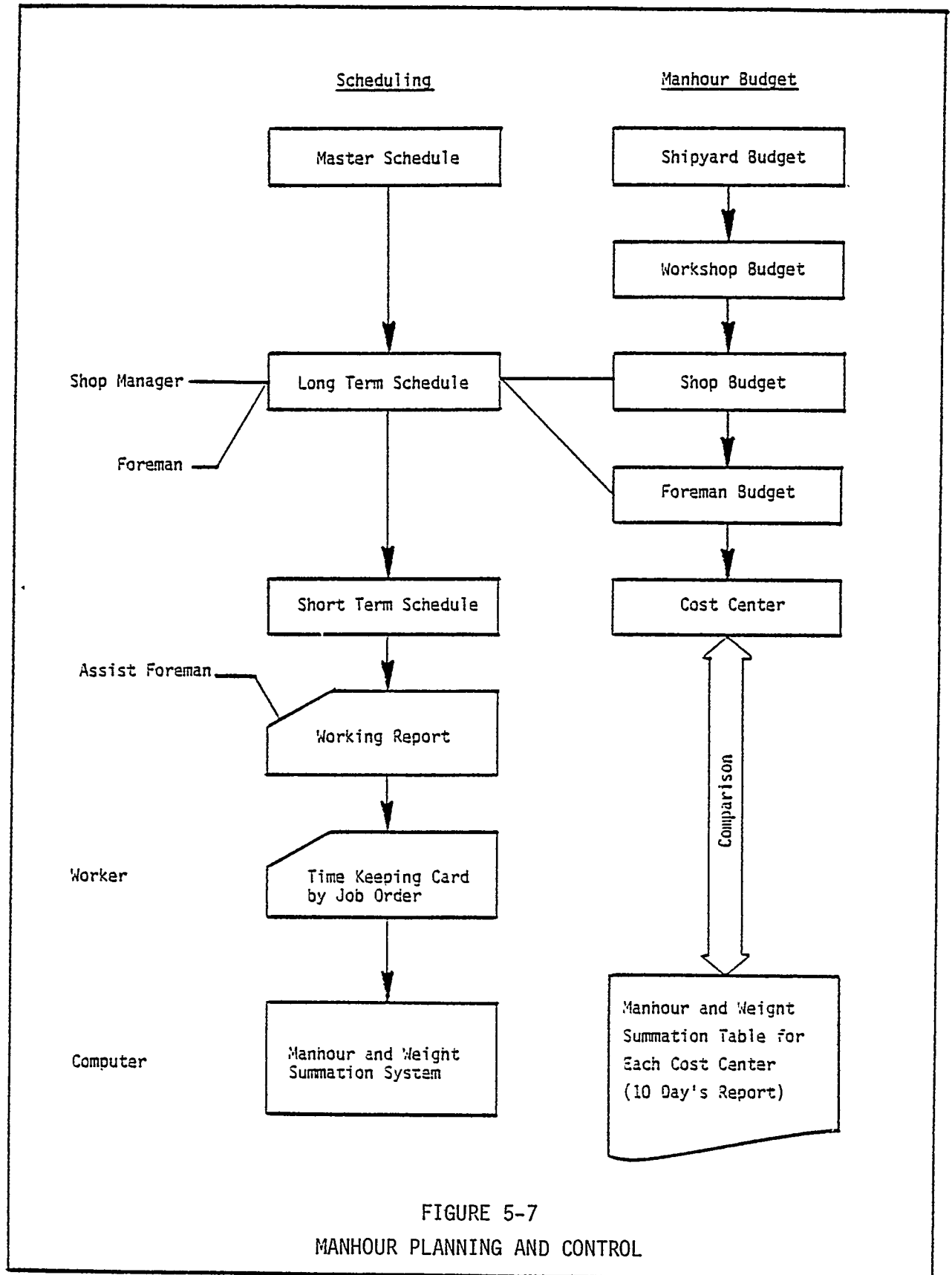


FIGURE 5-6
MANHOUR EFFICIENCY CONTROL

the shop foreman. These manhours are entered into the computer system and compilations are produced every ten days by cost center and by shop. This output is used to prepare the Manhour Efficiency Curve and the detail performance control curves for each shop and department. Figure 5-7 depicts the cycle of time charge collection and usage and Figure 5-8 provides an example of the time collection sheet used by shop foremen. Examples of these curves are provided in Appendix F.

The entire manpower planning cycle extends from the overall planning accomplished to establish the shipyard and department budgets to the manhour-plans of the individual foremen of each production area. Manpower planning at the working levels consists of the identification and scheduling of the work groups allocated either to the hull construction work stations or to the fitting tasks in the outfitting schedule. Manhours are continually weighed against the actual manhours used on previous ships and by the various factors of manhours/ton, manhours per length of weld deposited, cut lengths, outfittings weight, cable lengths, etc. This manpower planning, when combined with the production planning and scheduling (discussed in Sections 2 and 3), forms a complete framework of data for the performance of all work in each area of production.



①													② ⑬		⑤		⑫		⑭								
③													④		⑥		⑦		⑩		⑪						
0.1	8	8	8	8	8	8	8	8	8	8	8	8	2507-11	1.1	1.5	8	3	9	2	5.0	7	5.0	0	0	4.0		
	8	8	8	8	8	8	8	8	8	8	8	8	2607-11	1.1	2	1	1	2	5	0	7	5.0	0	0	2.1		
													38/0		1	5	8	3	9	2	0	0	3	8	1	0	1.6

① Laborer name
② Overtime hour
③ Total working hour
④ Note (Job number, costcenter etc.)
⑤ Department code
⑥ Cost Center Code
⑦ Job number
⑧ Sub job number
⑨ Component code
⑩ Subdivision code for subcontractor
⑪ Working hour
⑫ Subcontractor code
⑬ Assistant foreman name
⑭ Date

FIGURE 5-8

TIME KEEPING CARD BY JOB ORDER

SECTION 6
PRODUCTION CONTROL

6.1 GENERAL

Production Control in the IHI yards happens as a natural consequence of the production planning and scheduling system. The organization of the hull construction and outfitting shops and activities, the detailed planning accomplished for each of these activities and the use of working level schedules for small groups of personnel allows close monitoring and control of each step of the production process.

Basically, three organizations are concerned with production control: the Production Control Department and the Production Planning and Engineering groups for the Hull Construction Workshop and the Fitting Workshop respectively. This de-centralized control parallels the de-centralization which characterizes the planning and scheduling activities. The Production Control Department is primarily concerned with the overall yard aspects while the Production Planning and Engineering groups are concerned with the detail control of the workshop activities.

The activities of these three groups start from the overall yard planning and scheduling and descend to the levels of the individual work stations. However, once production has begun, the daily inputs from the working levels are coalesced into the control information required to judge the status of the total program. In the planning phase the production control system works from the top down, in the production phase the system works from the bottom up.

6.2 PRODUCTION CONTROL DEPARTMENT

The Production Control Department is responsible to the shipyard General Manager for the planning and scheduling of yard facilities and manpower for all ships and other types of construction in process and backlogged. This department prepares the Ship Construction Master Schedule; accomplishes the planning of production functions in terms of weight, cutting length, welding length, outfitting weight, cable length, etc.; prepares the overall yard manpower plans; prepares the overall yard work load schedule; and prepares the manhour efficiency control curves used to monitor shipyard performance. Figure 6-1 illustrates this production control function.

This top-level planning and control is translated to successively lower levels of the organization until each organization (i.e., workshop, section, group) and each production stage (i.e., fabrication, assembly, erection and outfitting) is fully detailed by planning, schedules and performance control data.

Because of the thoroughness of the planning and scheduling, usually only minor changes to the top-level plans and schedules are required. If changes are required, they are generally accomplished at the working levels such that the top-level plans are not affected. Although the overall status of each program is closely monitored by the Production Control Department, the majority of the actual production control activity is performed by the workshop staff groups (i.e. the Production Planning and Engineering groups).

6.3 PRODUCTION PLANNING AND ENGINEERING GROUPS

These groups, called the workshop staff groups, attend to a

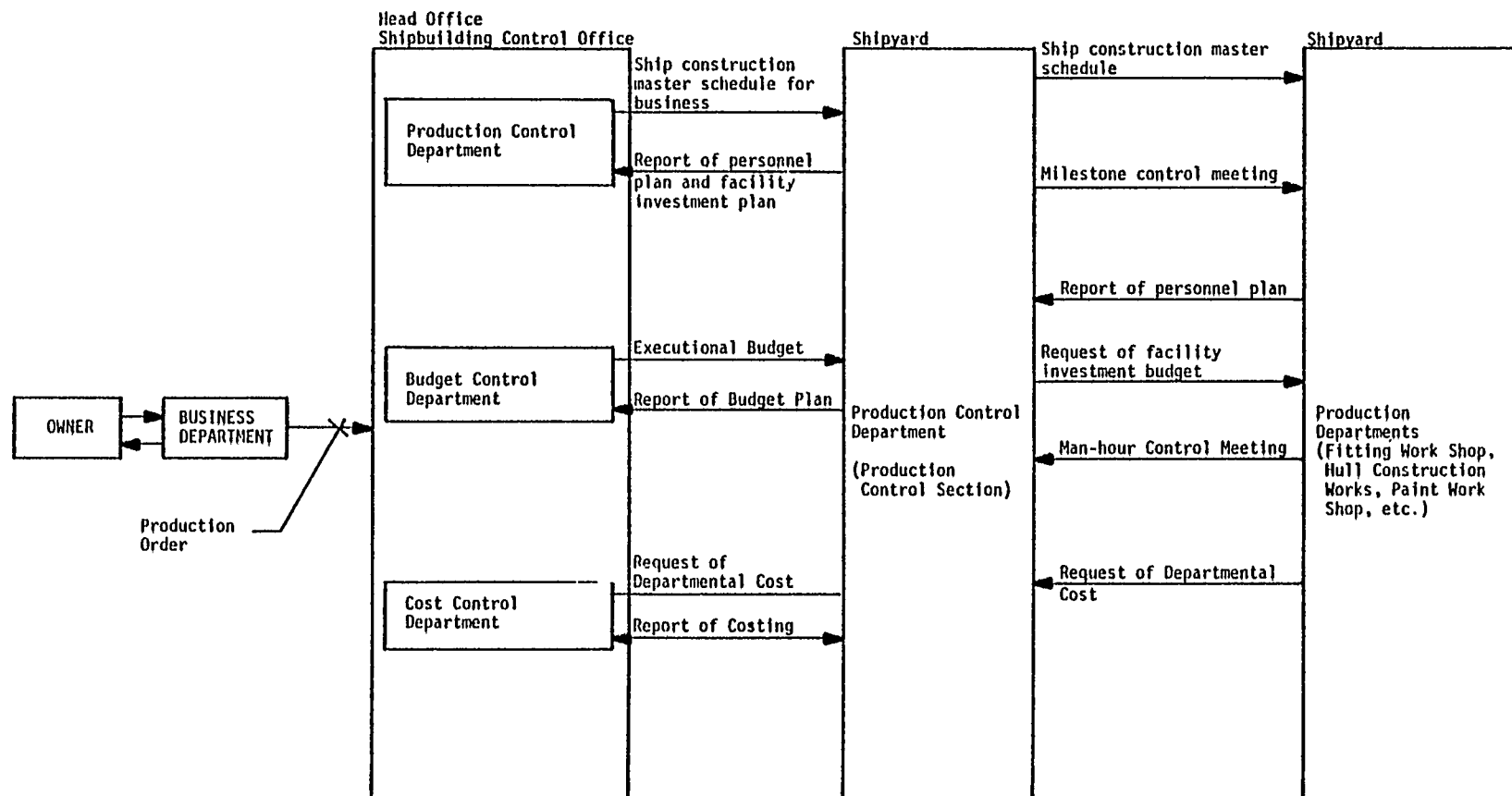


FIGURE 6-1
SHIPYARD PRODUCTION CONTROL

multitude of planning, scheduling, coordination and control functions. As previously mentioned, these groups are responsible for working with design engineers in formulating the various plans and schedules to be used throughout the production process. They also interface closely with the foremen, Section Managers and the Production Control Department in the preparation and updating of man-loading and performance control charts and graphs.

Once the top-level shipyard planning is accomplished by the Production Control Department, the workshop staff groups begin the development of the detailed plans and schedules for the actual operations of the various hull and outfitting groups. The wealth of planning data developed during the detail design process together with the master schedules form the basis for the preparation of these detailed shop and group plans and schedules.

Usually one member of the hull construction workshop staff group is assigned responsibility for a particular sub-stage within the fabrication, assembly or erection stages. This responsibility includes working with the cognizant foreman in developing the detailed plans and schedules for that area and preparation of performance control graphs that will show the daily/weekly through-put rates, the weight of steel processed, the length of weld metal deposited, and progress achieved against schedule.

In the outfitting area, workshop staff personnel are assigned to particular work groups concerned with the build-up of outfitting component sub-assemblies, or on-block or on-board outfitting. The tasks performed by these staff members are essentially the same as

those performed by staff members in the hull workshop. However, the organization of the work, due to the many different jobs related to outfitting versus the repetitive nature of hull construction, makes the outfitting staff work far more variable. These differences are discussed in the following paragraphs.

6.3.1 Hull Construction

Production Control of the various activities occurring in the Hull Construction Workshop involves the planning and scheduling and subsequent monitoring and control of the manpower, processes and methods utilized in these activities. The hull construction process, for purposes of production control, is divided into the following areas: Total hull, lofting, fabrication, sub-assembly, assembly and erection. Within each of these areas several different means are established to monitor production performance. Table T6-1 shows the various control graphs prepared for each area. Examples of these graphs are provided in Appendix F.

Prior to the preparation of the control graphs shown in the table, the workshop staff engineers prepare sketches and a series of lists detailing the weight of each hull block and the welding lengths in specific assemblies or erection areas. These are:

Block Weight List

Welding Control Parameter Output List

Block DM List

Welding Progress Check Plan

The Block Weight List provides the total outfitted weight of each block in the condition that it is to be erected. The list indicates the blocks of the bow, stern, cargo hold section and the engine

TABLE T6-1		
<u>HULL CONSTRUCTION CONTROL GRAPHS</u>		
AREA	TYPE OF GRAPH	BASE
TOTAL HULL	Advance Curve - Wgt.	Day
	M/H	Erected Wgt.
	M/H	DM
LOFTING	Engr. Dwgs. Vs. Loft Dwgs.	Day
	M/H Vs. Plan	Day
FABRICATION	Steel Wgt. Vs. Plan	Day
	M/H per Steel Wgt.	Day
SUB-ASSEMBLY	M/H	Wgt.
	M/H	DM
ASSEMBLY (Ea. Area)	M/H Vs. Wgt.	Day
	M/H Vs. DM	Day
ASSEMBLY (Total)	M/H	Wgt.
	M/H	DM
ASSEMBLY WELDER	M/H	DM
ASSEMBLY FITTER	M/H	DM
ERECTION	Advance Curve - M/H	Day
	Erected Wgt.	Day
	M/H	Wgt.
	M/H	Bn·L
	Hull Fitter M/H	Bn·L
	Welder M/H	Bn·L
Legend: DM - Deposit Meter M/H - Manhour Wgt. - Weight (ton of steel) Bn·L - Weld length x difficulty coefficient		

room, and the combined weight of any blocks that are to be joined during pre-erection for landing as a single block on-board the ship. Figure 6-2 provides an example of this list.

Using working drawings as a guide to the configuration of the various areas within the erected ship, workshop staff engineers prepare sketches of these areas defining the welding requirements of the various assemblies comprising the area and the joints requiring welding during erection. These sketches are annotated to indicate where welding will be accomplished.

Using Assembly Specification Plans and working drawings, the workshop staff engineers prepare sketches of the various assemblies and of the ship compartments or areas after erection showing the welding requirements at each stage. These sketches identify each joint requiring welding in a 3-dimensional view such as that shown in Figure 6-3.

When complete, the sketches are used to prepare the Welding Control Parameter Output List. This list which is produced by computer, itemizes each joint within an assembly, block or erection area and provides its welding length, the Deposit Meter, and an equivalency welding length which translates actual welding length into a calculated length based on the difficulty of the weld (Bn.L). Figure 6-4 provides an example of this list.

Deposit Meter is the standard established for the measurement of the amount of welding metal deposited in a given time. This calculation takes into account the cross-sectional areas as well as the length of the weld and is formulated as follows:

$$DM = p.S.L$$

ACTIVITY																									
UNIT NO.		P					S		SL		SU		B	FS	BN	L			T		2D		U		FD
													(C)												
	52													(C)											
	BOX																								
	51	(C)									(C)								(C)				(C)		(C)
		17					190.5		24.05		18.75												21.23		32.28
		(C)					19.38							1.03		30.69					(C)		(C)		
	7						19.38									30.69					(C)		(C)		
		(C)					20.88									38.28			(C)				(C)		
	6						20.88									38.25			3.95				18.01		
		(C)					20.88									28.88									NO. 1
	CARGO PART															28.29									
	5	13.15																							
		(C)					34.10									31.64			(C)				(C)		NO. 2
	4						34.10									31.70			29.29				20.70		

FIGURE 6-2
ERECTION BLOCK WEIGHT LIST

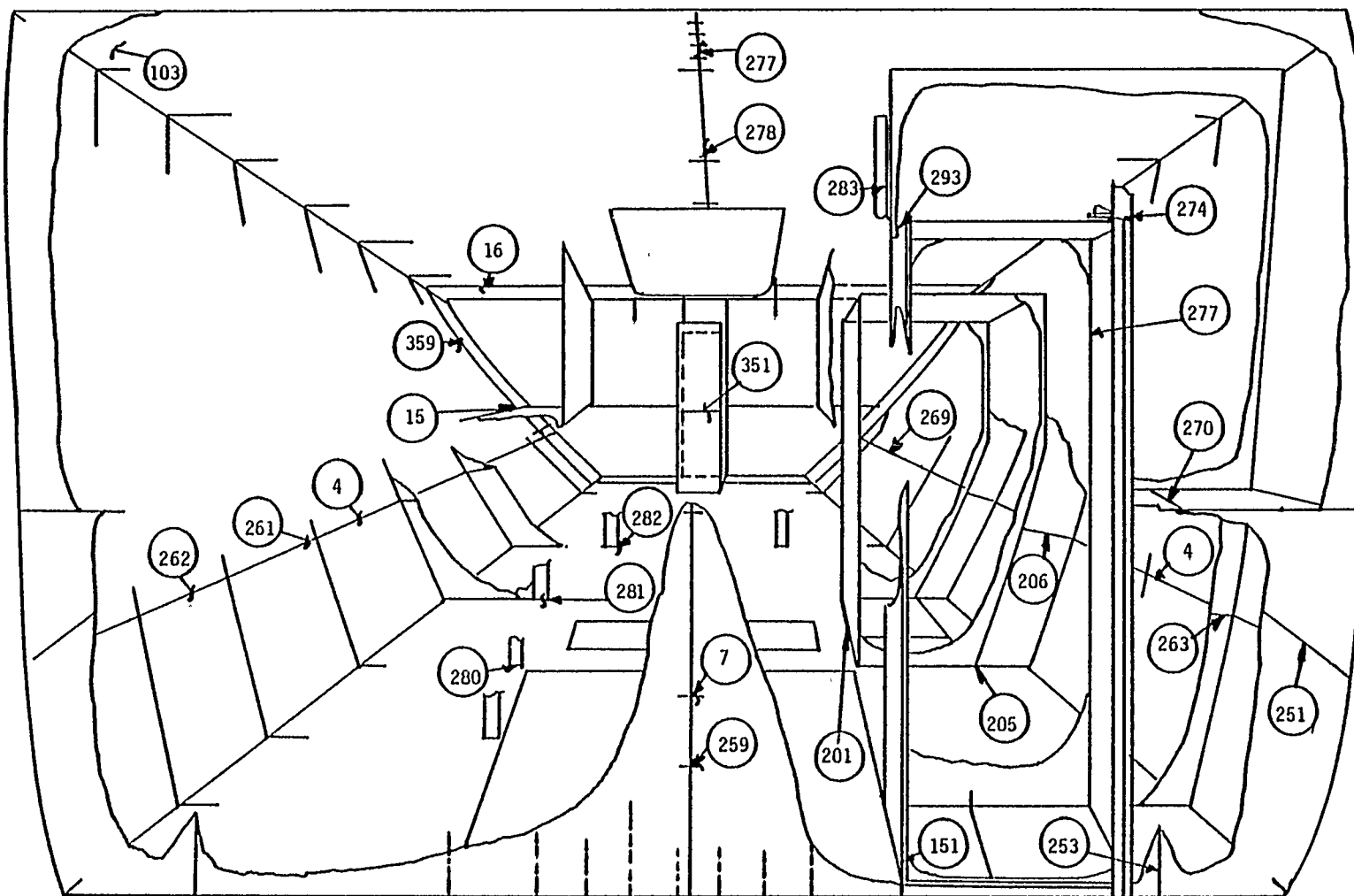


FIGURE 6-3

WELDING PROGRESS CHECK PLAN

WELDING CONTROL PARAMETER OUTPUT-2

(05/24/77) PNO 0

	SNO 2609	STAGE EREC	BLOCK D	1	C	LOT-NAME	
NOTE	JOINT-NAME	F/B	W.L	D.M	B.N.L	NO	
	*NAIKO * (INTERNAL)						
EI	F36H.P	F	2.0	1.62	19	581	
	* 2.00		4.0	3.24	38		
EI	F36H.P-COV	F	1.4	1.13	13	582	
	* 2.00		2.8	2.27	27		
EI	F36H.P-COV	B	1.4	3.58	63	583	
	* 2.00		2.8	7.17	125		
EI	F36H.P-COV	F	0.6	1.54	28	584	
	* 2.00		1.2	3.07	55		
EI	F36H.P-COV	F	0.6	1.54	11	585	
	* 2.00		1.2	3.07	22		
EI	F36H.P-COV	F	1.4	3.58	39	586	
	* 2.00		2.8	7.17	77		
EI	F36H.P-COV	F	0.6	0.49	4	587	
	* 2.00		1.2	0.97	8		
EI	CAR.FB	B	0.1	0.10	2	591	
	* 2.00		0.2	0.20	5		
EI	CAR.FB	F	0.7	0.17	4	592	
	* 2.00		1.4	0.35	8		
EI	CAR.FB	F	0.2	0.05	0	593	
	* 2.00		0.4	0.10	1		

FIGURE 6-4

WELDING CONTROL PARAMETER OUTPUT LIST

where: $p = \text{Constant}$

$S = \text{Sectional area of welding deposit}$

$L = \text{Welding Length}$

$Bn.L$ is the modified or corrected welding length necessitated to incorporate the varying degrees of complexity or difficulty inherent in the welding processes during the erection stage. $Bn.L$ is simply calculated as follows:

$$Bn.L = L \times D C$$

where: $L = \text{Welding Length}$

$DC = \text{Difficulty Coefficient}$

The Difficulty Coefficient is either an established standard derived from work on prior similar ships or is assigned by the staff engineer.

After the completion of the Welding Control Parameter Output List the Block DM List is developed. This list provides an aggregate DM for each block of the bow, stern, cargo hold section and the engine room and will be used for progress measurement during the assembly process. Figure 6-5 is an example of this list.

Using the Block Weight List, the Block DM List and the Welding Control Parameter Output List, the workshops' staff engineers prepare the control charts applicable to their area of responsibility. The majority of these control graphs reflect manhour expenditures versus steel weight or DM per day per area. This actual data is contrasted against the projections estimated for that area which will achieve the required production rate and maintain the forecasted manpower and schedule position. Since most of these control graphs are plotted

ACTIVITY		D						S		SL		SU		B	FS	BY	L			1T		2D		U	FD	IIC
UNIT NO.																										
BOX	52											224 ¹³														
	51	182.9		40 ¹⁵						146. ⁴		55.62								95.06				150. ⁶¹	255. ⁰⁷	
		40 ¹⁵								146. ⁴		55.62														
												12.12														
												18.14														
CARGO PART	7	146 ¹²		134 ²⁷	254 ³⁸			150 ⁸⁹							7.04		72.21					22.97		7.85		
					254 ¹⁹			150 ⁸⁹						7.04		72.21										
	6	7.91		140 ⁴⁶	166. ⁹¹			174 ⁷⁶	33.88								107. ⁵⁶			120.11				1.72	22.15	
					104. ⁶¹			174 ⁷⁶	33.88								107.41									
	6			78. ⁷⁷				175 ⁰¹										87.17								
				78. ⁷⁹					175 ⁰¹									87.17								
																	87.17									

FIGURE 6-5
BLOCK DM LIST

daily, deviations from projections are quickly recognized and corrective action initiated.

In the areas of total hull progress and erection progress an "Advance" curve is prepared to show the time intervals between the stages of production (for the total hull) and between the fitters and the welders during erection. In the case of the total hull advance curve, the total weight processed during fabrication is plotted over the time required for this processing. Then the total weight of the steel processed during assembly and the total erected steel weight is plotted over the time scheduled for each of these stages. Figure 6-6 shows an example of this type of curve.

The scheduled time between fitters and welders during the erection process is also a critical schedule interval and is plotted on the Erection Advance Curve. This application of personnel is especially important when a series run of ships is in production. Figure 6-7 shows an example of this type of curve.

6.3.2 Outfitting,

As mentioned previously, outfitting activities parallel the hull construction activities of sub-assembly, assembly and erection. With the exception of pipe fabrication and painting, these activities involve several or all of the fitting groups in the outfitting organization.

Although the outfitting organization is structured essentially around the outfitting zones of the ship (i.e. Interior or Accommodations Fitting group, Deck Fitting, No. 1 and No. 2 Machinery Fitting, and Electric Fitting group) the man-loading and scheduling of the outfitting

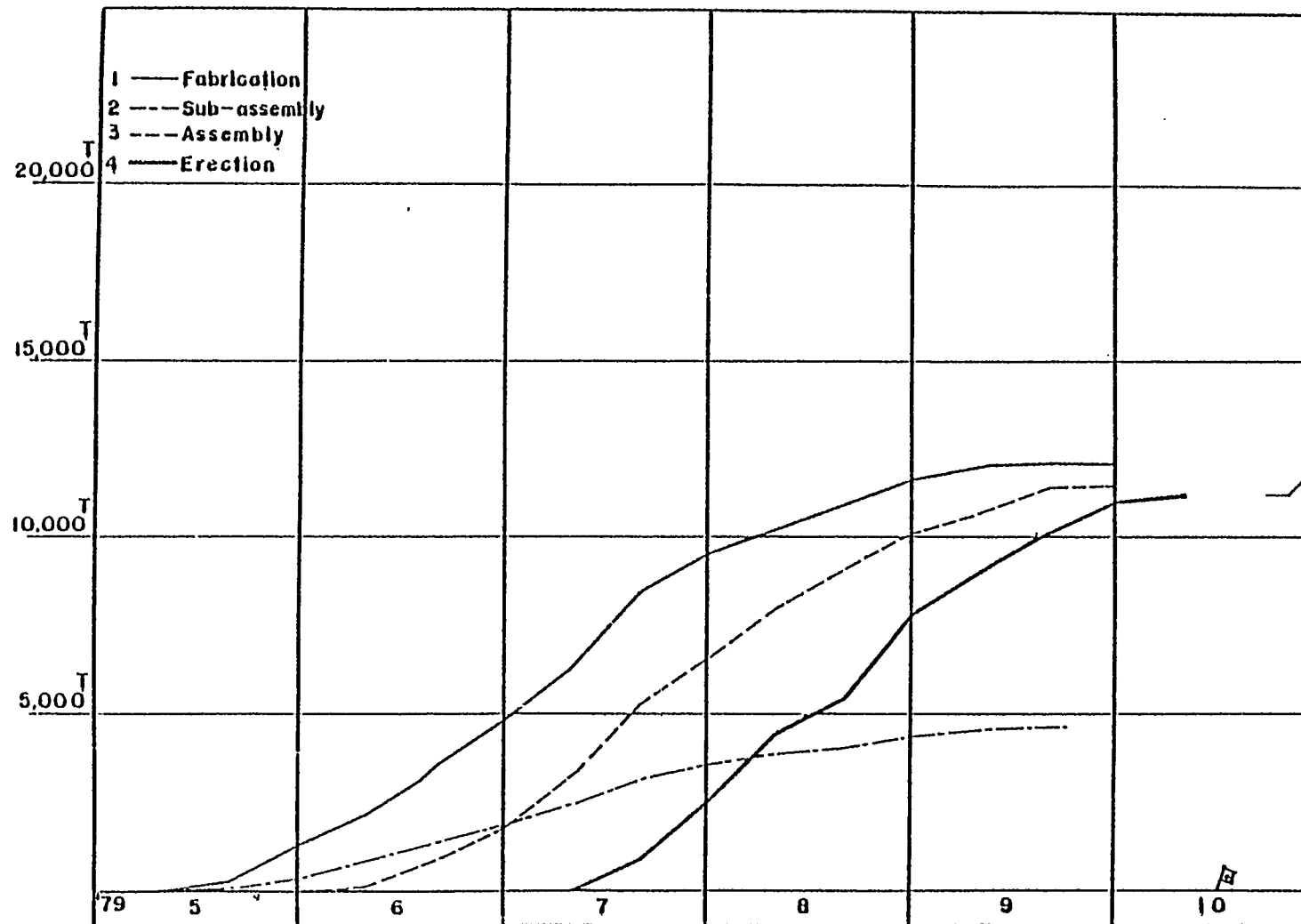


FIGURE 6-6
STEEL WEIGHT ADVANCE CURVES OF EACH STAGE

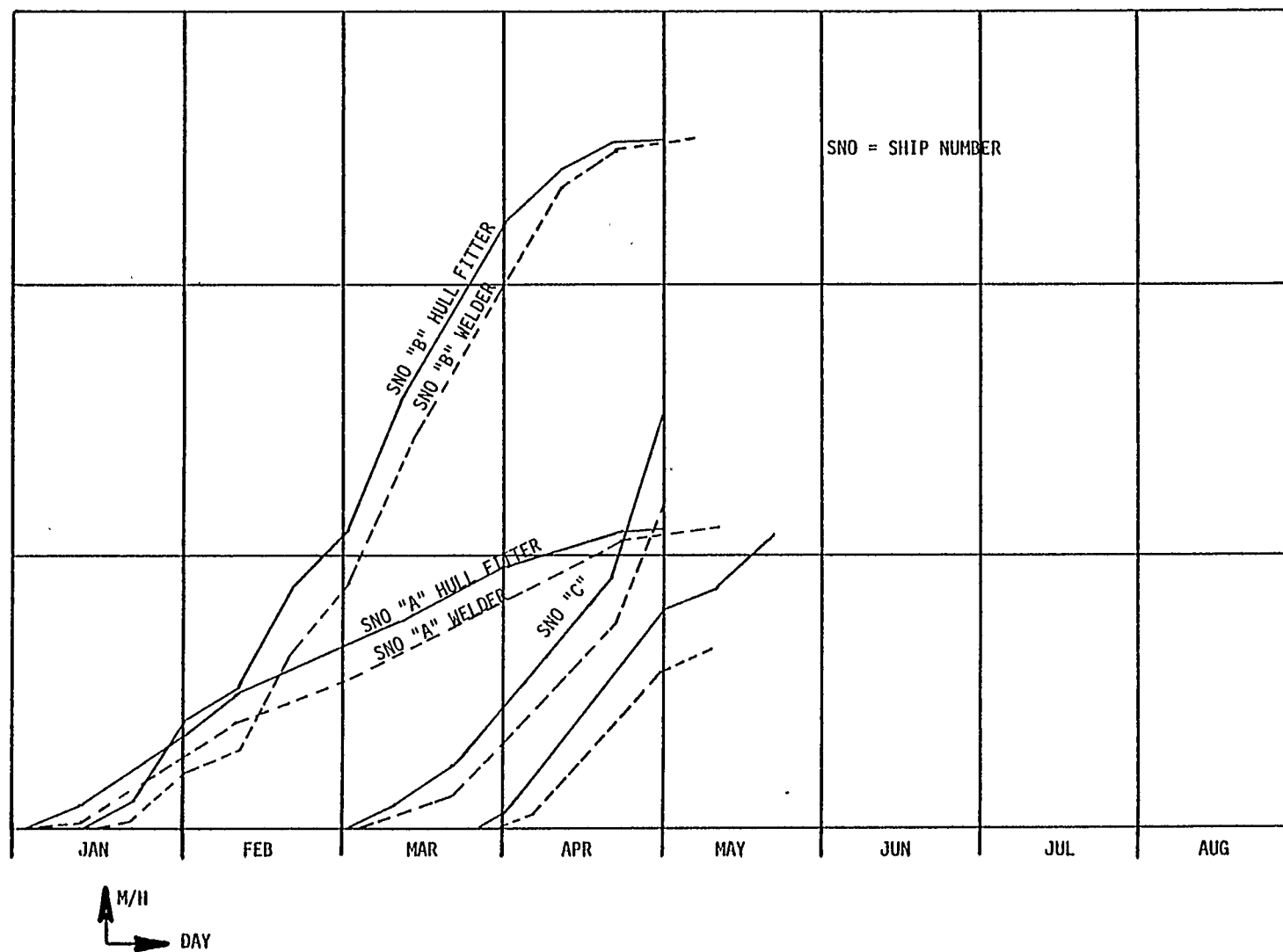


FIGURE 6-7 ERECTION ADVANCE CURVE

tasks is oriented toward On-unit (i.e. sub-assembly of outfitting components), On-block and On-board activities. Hence, the outfitting tasks require a blending of the skills of each of the organizational groups into the type of work groups required for a given task. Also, since the outfitting tasks are not of a repetitive nature (such as those in hull construction) and since these tasks are performed in a number of different locations, a distinctly different type of manhour and schedule control is required.

In outfitting there is far more reliance on the use of the monthly and weekly schedules than on performance control charts or graphs although such control graphs are used to measure the progress of each group.

As discussed in the Hull Construction paragraphs, Production Control evolves from the top-level planning, scheduling and control graphs to the successively lower levels of production. In outfitting this top-level planning and control is manifested by the Shipbuilding Master Schedule, the Outfitting Milestone Schedule, the Outfitting Master Schedule and the corresponding shipyard and Outfitting Section control charts. Beneath this level production control charts are prepared to reflect progress of each work group during On-Unit, On-block and On-board outfitting. Figure 6-8 illustrates this descending hierarchy of controls and the correlation between these control charts and the related schedules.

The primary measure of all of the top-level charts is the weight of the outfitting components installed plotted against a constant time base (i.e. day/week/month). Actuals are plotted against projections

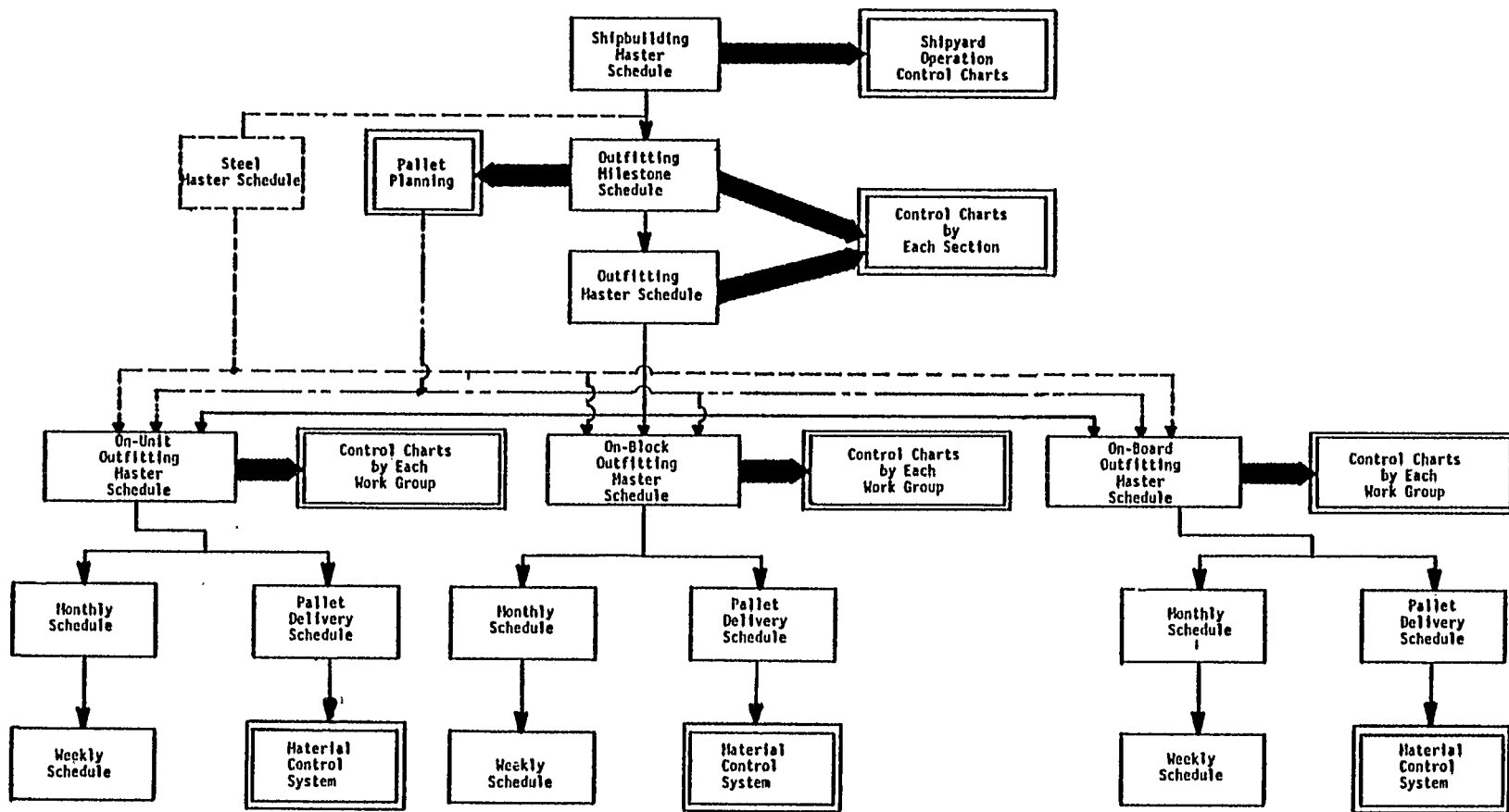


FIGURE 6-8
OUTFITTING SCHEDULING SYSTEM (IHI)

to ascertain any discrepancies between manpower and schedule and to take remedial action as necessary.

At the work group level control charts are precisely oriented toward individual fitting jobs such as the installation of piping in the engine room. In these cases performance control charts reflect actual work accomplishment in contrast to the projected schedule. Figures 6-9 and 6-10 show the schedule for the installation of pipe in the engine room (on-board) and the performance control chart showing the actual work accomplished, respectively.

The Production Planning and Engineering Group in the Fitting Workshop prepares and maintains these schedules and control graphs, and works with the respective foremen and section managers to adjust any apparent deficiencies in schedules or man-loading.

SECTION 7

LEIVINGSTON APPLICATION OF IHI TECHNOLOGY

7.1 GENERAL

During the course of the Technology Transfer Program, Livingston has adopted many of the IHI techniques of production planning and control. This has entailed a detailed study of the IHI system and a careful evaluation of the parts of the system applicable to LSCo.

The principal difficulty in the institution of the IHI methodology in another shipyard is the fact that the IHI planning and scheduling techniques are built around the process lanes, sub-stages and stages of the IHI production system. Also, the organization of personnel into work groups and staff groups who are permanently assigned to a given work station or area, which greatly facilitates the implementation of planning, scheduling, manloading and performance measurement data, is generally absent in U.S. shipbuilding practice. Any attempt to employ the IHI planning and production control techniques in a different type of production system is extremely difficult and only marginally effective.

As a result of the LSCo. studies, the decision was made to convert the Livingston production system to an approximation of the IHI system over a period of time and to initiate changes to the Livingston planning and scheduling system which would lead eventually to an IHI-type system. All of the planning data originated for the first of the modified Future 32 bulk carriers being built by Livingston was converted piece-by-piece to the IHI methods. Outfit planning, which had not progressed far when this decision was made, was started using the IHI

techniques. Schedules were developed which paralleled those used by IHI and were adapted for use in conjunction with the LSCo. Work Order System. Also, the planning for the changes required to the physical plant were accomplished and work orders were issued to conform with the modified flow of work through the facility.

In early 1980 Livingston began to modify its production system to one using the concept of the "Process Lanes" system of IHI. To avoid confusion during this period of re-organization the term "Gate System" was adopted to describe the production system of LSCo. Essentially, the system comprises a series of "gates" which are equivalent to the IHI sub-stages and stages (i.e., plate cleaning, marking, cutting, bending, sub-assembly, assembly, erection and the several outfitting stages of sub-assembly of outfitting components, installation on assembly units, and installation on-board the erected ship). Each of these gates has an assistant foreman or foreman permanently assigned and a number of worker personnel. The gates process steel according to detail gate schedules to support the assembly, outfitting and erection master schedules.

The implementation of the "Gate System" is far from complete at this writing. The conversion of the production system in the midst of producing the bulk carriers has been a formidable undertaking requiring a gradual step-by-step transition from the old methods to the new. The adaptation of the planning and scheduling data and the re-work of the work order system to match the new planning was accomplished throughout 1979. However, the modification of the physical plant to conform to the requirements of the "gates" is still in work.

Several of the problems encountered by LSCo. during this transition are worthy of note. The physical facilities required a detailed study to identify "gates" which would optimize material flow through the yard. Once this study was completed, considerable reorganization and relocation of some facilities was necessary. Also, the new techniques adopted for use in the system, such as flame bending, required new facilities and areas within the new material flow lanes. This reorganization of material flow necessitated the movement and restraining of personnel and a re-routing of material from previously used processing and storage sites. Movement and storage of components, sub-assemblies and unit assemblies became a significant problem and buffer areas between gates had to be developed to cushion the effects of the varying rates of production through each of the gates.

At present the system is only partially installed and operable. Several gates are functioning as true "gates", but many of the desirable characteristics of a totally operating and highly perfected "process lanes" system are still far in the future.

7.2 CHRONOLOGY OF THE LSCO. STUDY AND APPLICATION

The Technology Transfer Program was initiated simultaneously with the start of construction of the modified Future 32 bulk carriers. This, of course, did not allow for extensive prior study of the IHI methods of planning which so strongly influence the development of the detail and working level drawings. However, IHI consultants did join the LSCo. design team shortly after the effort had begun.

Senior designers and planners in LSCo. had already determined that the ship would have to be divided into manageable units which could be fabricated individually on the slab areas of the existing

LSCo. facility. This had led to a breakdown of the ship which very closely paralleled the Hull Block Planning of IHI. When the IHI engineers joined the design team, some minor revisions of the unit division were made. IHI documents describing the IHI Hull Block Planning had been available to the LSCo. planners and the unit division of Zone 1 (mid-ship section) of the ship essentially followed this planning.

The LSCo. engineers had used specific criteria in determining the ship breakdown for Zone 1. These criteria were:

1. Weight. It was decided to keep the units in the 40 to 50 ton range to allow ease of handling by the gantry cranes which operated parallel to the slab areas. From the General Arrangement drawing and scantlings, the weight per foot of steel had been determined to assist in deciding dividing points of the hull units.

2. Available Material. The decision was made to keep the units less than 40'0" long since this length is the optimum mill length for U.S. steel mills.

3. Natural Dividing Points. After studying the cross section of Zone 1, it was noted that the watertight bulkheads between the holds were evenly spaced at 73'6" centers. This was divided in half and the units were set at 36'9". The first unit was located in the center under the first watertight bulkhead. Alternately, the units were centered at the bulkhead and the units between the bulkheads were centered on the hold. This arrangement did not exactly match the IHI system where the first unit would have been started at the bulkhead between the engine room and the first hold forward of the engine room; however, some advantage was gained since only the four bilge units,

port and starboard at each end of the zone, had any curve and it was very mild.

The lengths of the rings were set and had to be divided to provide the highest productivity in assembly and to reduce on-board fitting and welding to a minimum. It became evident that the optimum dividing points meant that the weight parameter would have to be increased. After considerable study, the weight maximum for the assembly units was increased to 60 tons to take advantage of the best dividing points.

The division of Zone 1 (cargo holds) had been accomplished solely by the LSCo. engineers and planners after study of the Hull Block Planning methods of IHI. The division of Zones 2 (Stern) and 3 (Bow) was accomplished as a joint effort by the LSCo. Planners and the IHI Engineers.

7.2.1 Unit Assembly Planning

Concurrent with the subdividing of Zones 2 and 3 into units, IHI engineers developed a series of sketches showing the build-up of the assemblies in Zone 1. This activity paralleled the IHI "Block (Unit) Assembly Planning" discussed in the sections of IHI planning. These sketches show a step-by-step process of how to construct each unit and help in determining the processes required and the process lanes that should be used for fabrication, sub-assembly, and assembly. Initially, these diagrams simply portrayed the build-up process without any reference to the types of processing required. This additional information was dependent on the adoption of a "process lanes" system by LSCo.

7.2.2 Process Lanes System

In May of 1979, the IHI consulting engineers presented a plan that divided the construction area of the shipyard into "process lanes". The basis for the division was the type of work to be done, the quantity of the required work and the available facilities (especially the lifting capacity of the cranes). The plan was accepted for implementation by LSCo. and a more intense study began to fit the system to the LSCo. facilities. To avoid confusion between the IHI system and that adopted by LSCo., the name "Gate System" was selected to describe the new system.

The LSCo. shipyard was already divided into "work stations" which had been used to identify various process locations under the old ship construction process used by the yard. These work stations were re-organized to indicate work group locations within a specific "Gate".

The basic concept of the "Gate System" is the assignment of an area(s) for specific types of work, or processes; the assignment of a group of workers together with a foreman to a permanent area that processes the same type of work regularly, so that planning and scheduling becomes standardized and routine. Figure 7-1 depicts the concepts of the Gate System throughout the shipbuilding cycle.

The division of the facilities began at the start of the fabrication process, layout and cutting. After material passes through the painting process, it enters the "Gate System" and from that point through other appropriate gates depending on whether it is a flat or curved unit. After layout and cutting, the material passes into shaping gates (if shaping is required) or into a gate specifically concerned with sub-assembly. It next flows into component assembly gates and eventually into one of several gates designated for final assembly.

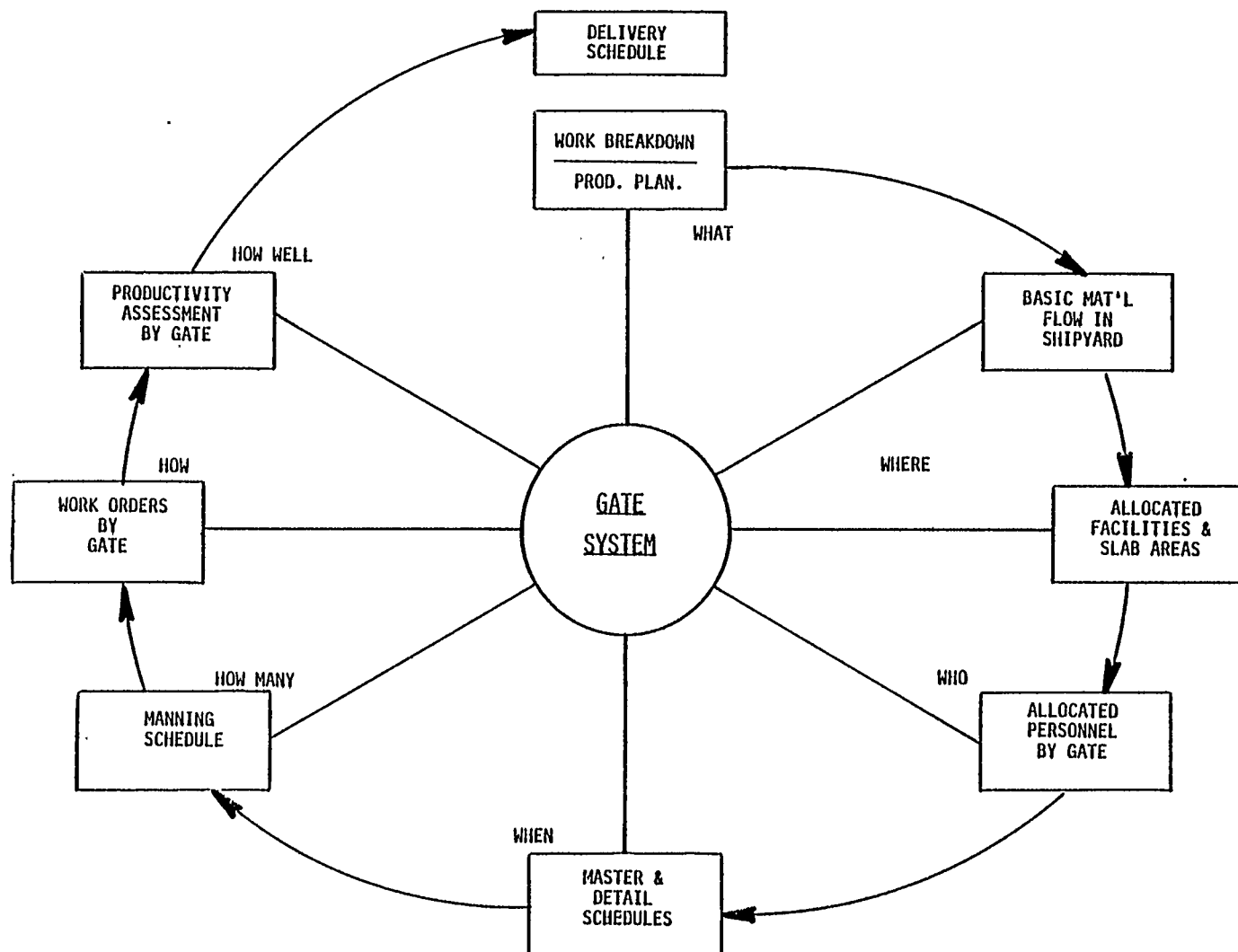


FIGURE 7-1

GATE SYSTEM

One further gate is concerned with unit-to-unit assembly and the final gate is the erection gate. Figure 7-2 shows the current layout and material flow in the Livingston yard. Appendix F provides additional detail concerning the implementation of this system at Livingston.

7.2.3 Gate System Planning and Scheduling

With the acceptance of the Gate System and the realignment of facilities to perform in a "process flow" manner, the IHI methods of planning and scheduling had to be more fully implemented. In August of 1979, the original schedule for the first bulk carrier required modification and this provided an opportunity to implement the IHI-type schedules for the first time.

Essentially, this re-planning and scheduling comprises eight different plans and schedules as shown in Figure 7-3.

7.2.3.1 Key Erection Plan

The Key Erection Plan, which is almost an exact duplication of the IHI technique, is prepared in network form, each node designating the point of erection of a unit. The connecting lines between nodes represent the length of time required between units and establishes the sequence of unit erection. Of course, in this case of first use, where many units had already been erected, the Key Erection Plan took account of the units already erected and simply scheduled those which were yet to be erected. Figure 7-4 provides an example of this Key Erection Plan.

Before the Key Erection Plan could be prepared, a chart of Standard Erection Times had to be developed. This chart provides a standard erection time period for each type of unit including the time required

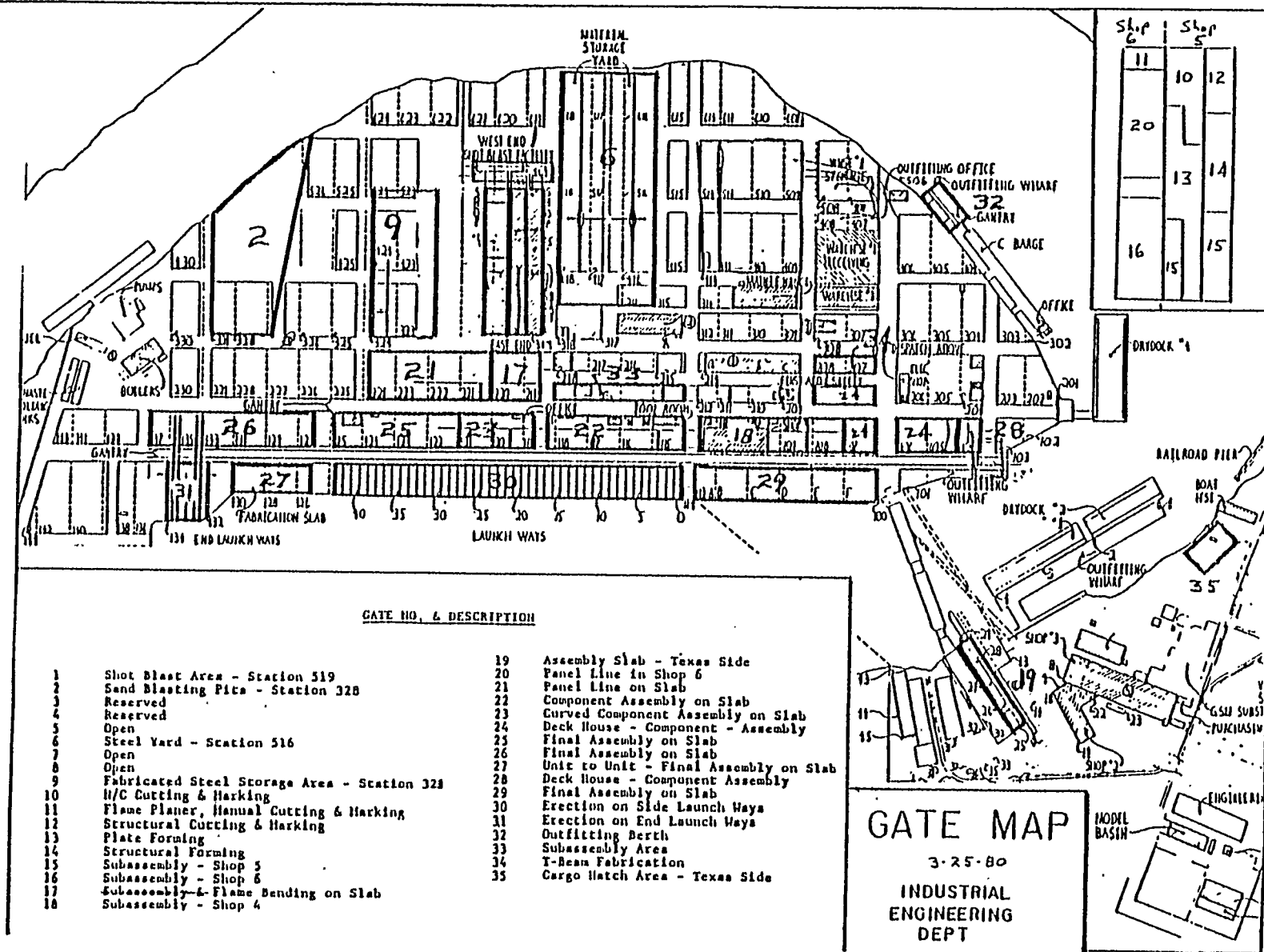


FIGURE 7-2
LEVINGSTON YARD LAYOUT

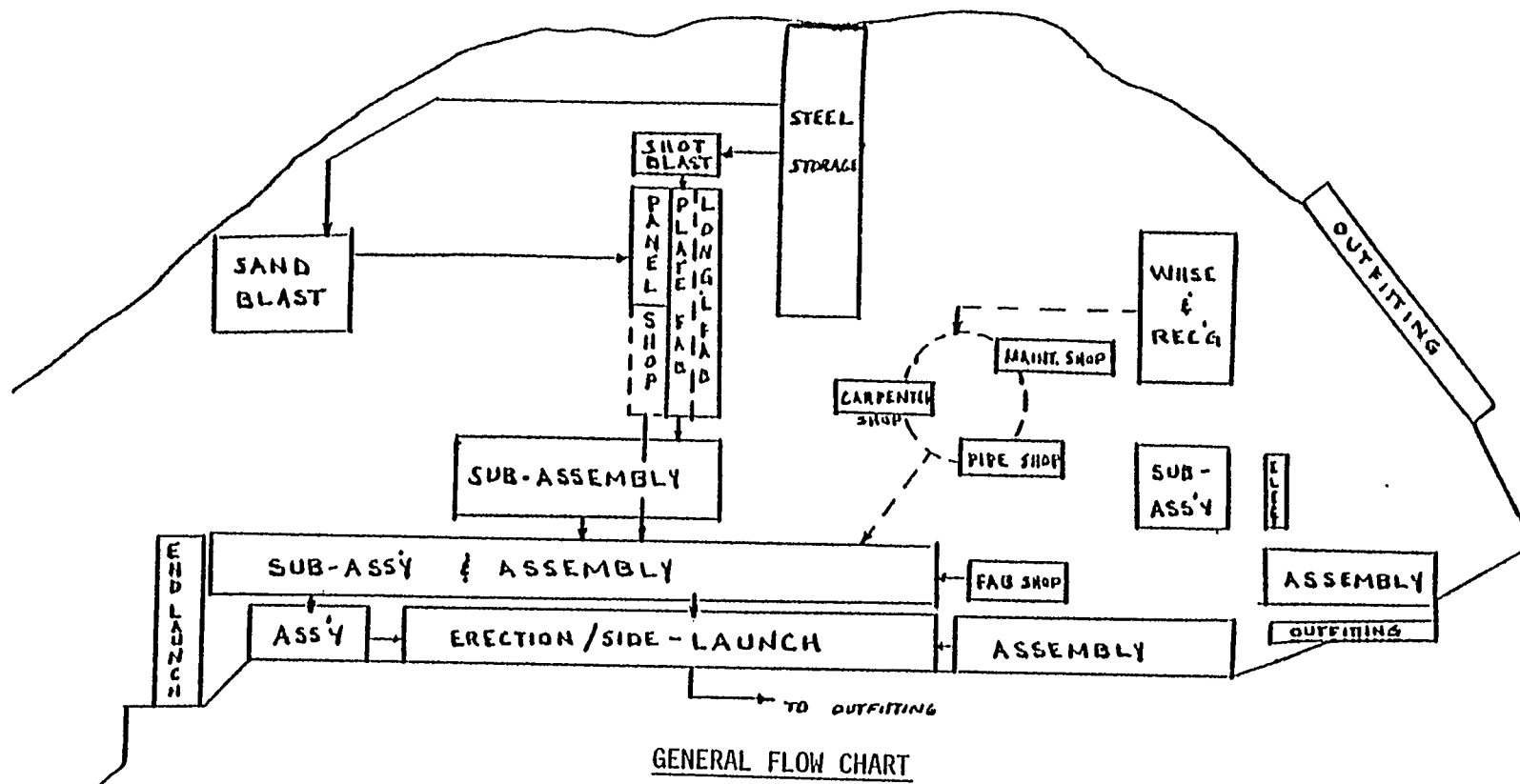


FIGURE 7-2 (CONT.)

MATERIAL FLOW

UNIT DIVISION AND ARRANGEMENT	The Breakdown of the Ship into Zones and Units.
GUIDE TO CONSTRUCTION OF UNITS	Handmade Sketches of the Step-by-Step Construction of Each Unit, Particularly Establishing the Base for Construction.
KEY ERECTION PLAN	The Preliminary Erection Plan that Establishes the Sequence of Erection and the Critical Path.
BASIC PRODUCTION FLOW LIST	The Basic Plan of How to Use the Available Facilities.
HULL PRODUCTION MASTER SCHEDULE	A Preliminary Control Chart to Establish the Tonnage Thru-Put.
ERECTION MASTER SCHEDULE	The Final Erection Schedule Based on the Key Erection Plan and the Hull Production Master Schedule.
UNIT INFORMATION LIST	Used to Establish the Time Periods and Man-hours Required for Each Gate.
FINAL ASSEMBLY MASTER SCHEDULE	This Schedule Establishes the Quantity and Flow of <u>All</u> Units.
MASTER SCHEDULE BY GATES	Similar to the Final Assembly Master Schedule, these Schedules Set the Quotas for the Other Gates.
DETAILED SCHEDULE BY GATES	Day-to-Day Schedules for Each Gate.

FIGURE 7-3

BASIC METHOD OF PLANNING AND SCHEDULING

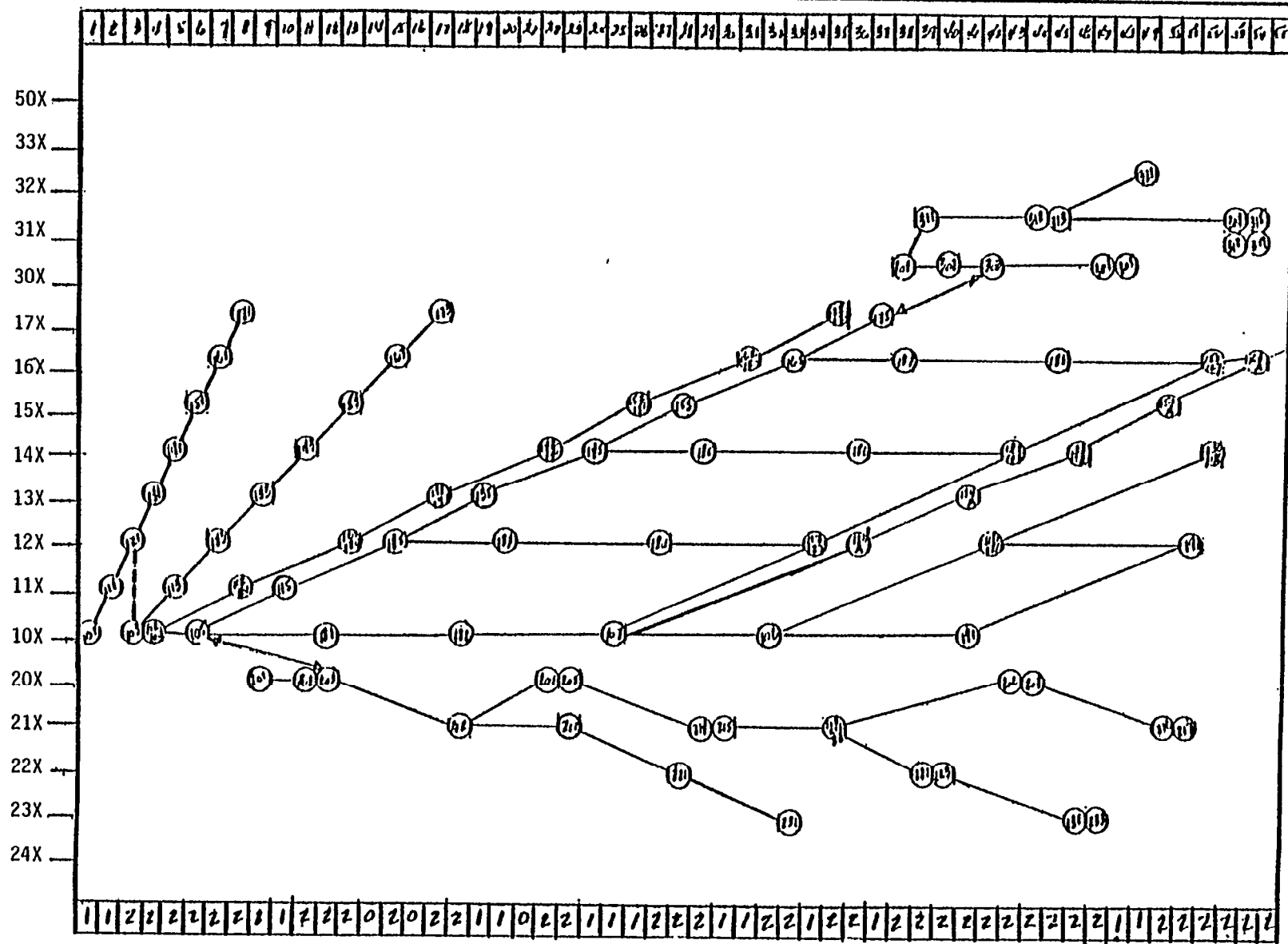


FIGURE 7-4 KEY ERECTION PLAN

to complete the fitting and welding necessary before the next adjoining unit can be landed. Figure 7-5 shows an example of a Standard Erection Times list.

7.2.3.2 Basic Production Flow List

As previously mentioned, the IHI engineers prepared a "Guide to the Construction of Units", which were a series of sketches showing the assembly sequence of each unit. In the process of breaking each unit down to components and sub-assemblies, the engineer can make basic decisions as to what process lane can be used to fabricate the component. Later, the engineer can also confirm the method and determine the gates through which the component will flow. This process was used to plan the flow of material through the new "Gate System". Considerations for determining the proper process gates were numerous including factors such as: crane capacities, the amount of area required, the amount of work that would have to be processed through each gate, buffer storage requirements, etc. When completed, this list became known as the Basic Production Flow List. Figure 7-6 shows an example of this list.

7.2.3.3 Unit Information List

Based on the Basic Production Flow List, a Unit Information List was compiled. This list established a time frame for the fabrication, assembly and erection of each unit and estimated the number of workers (in manhours) and the types of personnel required for each operation. The preparation of this list required intensive study of the facilities and capabilities of the LSCo. yard as revised to the new "Gate System". Naturally, no historical data was available for the estimation of time and manpower requirements and because of the urgent requirement for

PROCESS	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
TYPE OF UNIT	LIFT	SET	FIT MN. JTS.	FIT INT. JTS	WELD 1ST SIDE	BACK- GOUGE	WELD OP. SIDE	WELD INTS.	INSP.	OUT- FITTING	
Double-Bottom Center Units Days Required		.5	.5	.5	1	.5	1	1			
Double-Bottom Center Side Units Days Required		.5	1	1	1	.5	1	1			
Bilge Units Days Required	.5	1	1	1	1	1	1	2			
Stools Days Required	.5	2	1	1	1	.5	1	2			
Bulkheads Days Required	.5	2	1	1	1	0	1	3			
Top Side Tank Units Days Required	1	2	2	2	2	1	2	3			
Upper Deck Center Units Days Required	.5	1	1	2	1	1	1	2			
Curved Units Days Required	1	1.5	1.5	1	2	1	2	2			
Curved Unit-to-Unit Days Required	1	2	2	2	3	2	3	4			

FIGURE 7-5
KEY ERECTION TIMES LIST

ZONE 1	UNIT	COMPT.	PANEL LINE	COMPT. ASSY.	FINAL ASSY.	UNIT-TO-UNIT	ERECTION
	111	TANK TOP	(20/21) — (22)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)
		BOTTOM	(20/21) — (25)	(WT.) (X X)	(WT. 58.91) (X X)	(WT.) (X X)	(WT.) (X X)
	114	SLANT-PLATE	(20/20) — (22)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)
		SHELL PLATE	(25)	(WT.) (X X)	(WT. 42.10) (X X)	(WT.) (X X)	(WT.) (X X)
	112	TANK TOP	(20/21) — (22)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)
		BOTTOM	(20/21) — (25) — (27)	(WT.) (X X)	(WT. 37.49) (X X)	(WT.) (X X)	(WT.) (X X)
	181	STOOL	(25)	(WT. 19.69) (X X)	(WT. 19.69) (X X)	(WT.) (X X)	(WT.) (X X)
			(29)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)
	182	CORRUGATED BULKHEAD	(29)	(WT. 42.68) (X X)	(WT.) (X X)	(WT.) (X X)	(WT.) (X X)

FIGURE 7-6

BASIC PRODUCTION FLOW LIST

NOTE: Unit dimensions are specified
in brackets i.e. (L x W x H)

working level schedules this list was prepared with the foreknowledge that it would require many revisions before the information listed thereon became accurate. Figure 7-7 provides an example of this list.

7.3 OUTFIT PLANNING

Outfit planning on the first of the bulk carriers began using the IHI techniques. As in the IHI process, the ship was divided into a series of outfitting zones and the necessary outfitting was then planned for each zone. No attempt was made to closely tie this planning with the engineering or purchasing effort as that was considered an advancement of the planning activity that would require extensive future study and application.

The outfitting zones selected by LSCo. planners were essentially work zones in the IHI terminology and dealt primarily with the unit sub-assemblies and assemblies that had been identified during the hull breakdown.

The planning for each work zone included the identification of each part and piece of outfitting material (with the exception of electrical: that would be required for each assembly unit. These components were listed on a Material Information List which is the equivalent of the IHI Material List for Fitting (MLF). The list identified not only each component, but also the point in the building cycle of the assembly unit at which the component was to be installed, by whom (i.e. craft), and the estimated manhours required. Figure 7-8 presents an example of a Material Information List.

Pipe fabrication was handled in a manner similar to that of IHI. Pipe components were listed on a separate Pipe Material List

ZONE #	PART	UNIT	WT.	SIZE	DESCRIPT.	GATE	PROCESS FLOW	DAYS HOURS	START DAY	ERECTION DATE
1	BOTTOM RING TANK UNITS	Side Shell & Bilge Unit 114- 164	50.98 x 6	12'-5'2 36'-9	Bilge Curved Unit		115-165 (Inland)	2 days		
		Side Double Bottom 112-162			Bilge Part Unit	22	115-165 (Inland)	7 days		
		River Side		17'- 36'-9	Hopper Slope Panel	20 or 21	115-165 (Inland)	3 days		
					Unit	22	115-165 (Inland)	24 days		
				25'-9 36'-9	Final Assy	25	115-165 (Inland)	6 days		
							Shell Base (Hopper Slope)	68 days		
			91.62 x 10	33'-6 36'-9	Unit to Unit	29	Side Double Bottom x Bilge Base	9 days		
		Side Shell & Bilge Unit (104 & 174)	53.04 Tank x 2 Units	12'-5-1/2 36'-9	Bilge Part Unit	22	Inland Side (115-165)	160 days		
		x Side Double Bottom (102 & 172)			Hopper Slope Panel	20 or 21	Inland Side (115-165)	7 days		
				17'-8 36'-9	Hopper Slope Unit	22	Inland Side (115-165)	3 days		
					Final Assy.	25	Inland Side (115-165)	24 days		
							(Shell) Base x (Bilge Part) x (Hopper Slope)	8 days		

CODE:

S.A.W. - Submerged Arc Welding

L - Layout

B - Burning

AR - Arranging

F - Fitting

W - Welding

Ins - Unit Inspection

OF - Outfitting

P - Painting

T/O - Turnover

FIGURE 7-7
UNIT INFORMATION LIST

HULL NO. 758UNIT NO. 54 PAGE 1 OF 5 ALT. UNIT DESCRIPTION VERT. LADDERS BELOW NO. ☐ ORANGE ☐ GULFPORT ☐ WOODVILLE ☐ TYLERLEVINGSTON SHIPBUILDING CO.
MATERIAL LIST FOR STEEL

	BY	CHKD	DATE
ENGINEERING	<u>APC</u>	<u>L.P.</u>	<u>11-4-80</u>
MOLD LOFT	_____	_____	_____
PROD CONTROL	_____	_____	_____

DWG NO.	COMP NO. OR SUB-ASSY	PIECE NUMBER	DESCRIPTION	QUANTITY			ITEM - TITLE	PROCESS	LINE	TOTAL LN-SQ FEET	HEIGHTS		HC TAPE/TEMPLATE	MATERIAL REMARKS/CUT FROM	PAINT	MAT'L SPEC.	REQ'D	
				P	S	T					UNIT	TOTAL					NO.	LN
S-758-54-10			VERT. LADDERS				35-01		1									
			V.L. # 1	-	-	10			2									
			F.B. 3/8" x 2" x 3'-10"	-	-	20			3	77	2.55	196	TAB	(52) F.B. x 20'-0"		A-36	16111	1
			Sq.B. 3/4" x 1'-4 5/8"	-	-	10			4	55	1.91	105	TAB	(35) Sq.B. x 20'-0"				3
			F.B. 3/8" x 3" x 0'-3"	-	-	40			5	10	3.83	38	TAB	(1) F.B. x 20'-0"				2
S-758-54-11									6									
			V.L. # 2	-	-	4			7									
			F.B. 3/8" x 2" x 8'-11 1/4"	-	-	8			8	72	2.55	184	TAB	RMT. L-3				
			Sq.B. 3/4" x 1'-4 5/8"	-	-	36			9	50	1.91	96	TAB	RMT. L-4				
			F.B. 3/8" x 2" x 0'-9 3/4"	-	-	8			10	7	2.55	18	TAB	RMT. L-3				
S-758-54-12									11									
			V.L. # 3			2			12									
			F.B. 3/8" x 2" x 11'-10"	-	-	4			13	47	2.55	120	TAB	RMT. L-3				
			Sq.B. 3/4" x 1'-4 5/8"	-	-	24			14	33	1.91	63	TAB	RMT. L-4				
			"A" L 2" x 2" x 1/4" x 2'-2 1/2"	-	-	8			15	18	3.19	57	TAB	(15) L x 20'-0"			16111	5
			"B" L 2" x 2" x 1/4" x 2'-2 1/2"	-	-	4			16	9		29	TAB	RMT. L-15				
									17									
S-758-54-13			V.L. # 4	-	-	2			18									
			F.B. 3/8" x 2" x 22'-1 1/2"	-	-	4			19	89	2.55	227	TAB	RMT. L-3				
			Sq. BAR 3/4" x 1'-4 5/8"	-	-	48			20	58	1.91	111	TAB	RMT. L-4				
			"B" L 2" x 2" x 1/4" x 4'-7 3/4"	-	-	8			21	37	3.19	118	TAB	RMT. L-15				
			"C" L 2" x 1 1/2" x 1/4" x 0'-4"	-	-	4			22	1	2.77	3	TAB	(1) L x 20'-0"			16111	4
			"H" F.B. 3/8" x 3" x 0'-3"	-	-	4			23	1	3.83	4	TAB	RMT. L-5				
									24									
									25									

FIGURE 7-8

MATERIAL INFORMATION LIST

together with all relevant information as to zone number, schedule requirements, and whether the pipe was to be fabricated or purchased. Information from this list was then transferred to pipe fabrication schedules for use by the Pipe Shop and Material Control personnel.

The two material lists of fitting components and pipe were oriented by assembly unit and thus could be scheduled in accordance with the fabrication and assembly of steel during the unit build-up.

The objective of this planning was, as at IHI, to accomplish as much pre-outfitting as possible on the slabs during the build-up of the steel assembly units and thereby reduce the extensive on-board outfitting required by traditional methods.

The many changes occurring in both the planning and scheduling system and in the production system itself with the conversion to the Gate System minimized the effectiveness of this outfit planning on the first vessel. Too often pre-outfitting was prevented by the exigencies of material flow and excessive manhour requirements in the steel assembly process. However, the major assembly units, such as engine room flats, were outfitted on slab areas and were able to be landed in completed module form aboard the erected ship. This pre-outfitting planning is being more fully implemented on each succeeding ship.

During the initial implementation of the outfit planning it became apparent that the IHI concept of palletization was essential to the successful adaptation of the outfitting activity. Several studies were conducted by both IHI consultants and LSCo. Industrial Engineers to ascertain the minimal requirements for getting a palletization

system started to support the collection of pipe and other outfitting components. Once completed, recommendations from these studies were implemented and several different configurations of outfitting pallets were put into use. The concept of palletization includes not only the accumulation of material onto pallets which will be routed to outfitting locations on a specific schedule, but also the requisite information concerned with schedule, personnel and installation sketches or drawings. This system of palletization is being followed by LSCo. in its outfitting activity; however, not in the precise form utilized by IHI. As the system becomes more perfected, it is expected that the LSCo. system will more closely approximate that of IHI.

7.4 SCHEDULES

A descending hierarchy of schedules similar to those used by IHI was developed to support the Gate System. These schedules derive from the Key Erection Plan and basically evolve from the top-level shipyard schedule, to a Ship Erection Master Schedule, to a Final Assembly Master Schedule, to several subordinate master schedules by gate to detailed schedules for each gate. Figures 7-9 through 7-14 provide examples of each type of schedule presently used to support the Gate System.

7.5 MANPOWER PLANNING AND PERFORMANCE MEASUREMENT

The planning and implementation of the Gate System provided an excellent opportunity to establish manpower levels and manhour requirements for each operation within the yard. These levels and manhours were estimated initially by Production Control personnel and actual manhours are presently being monitored for comparison with these estimates. Once the gates are fully functioning, these estimates,

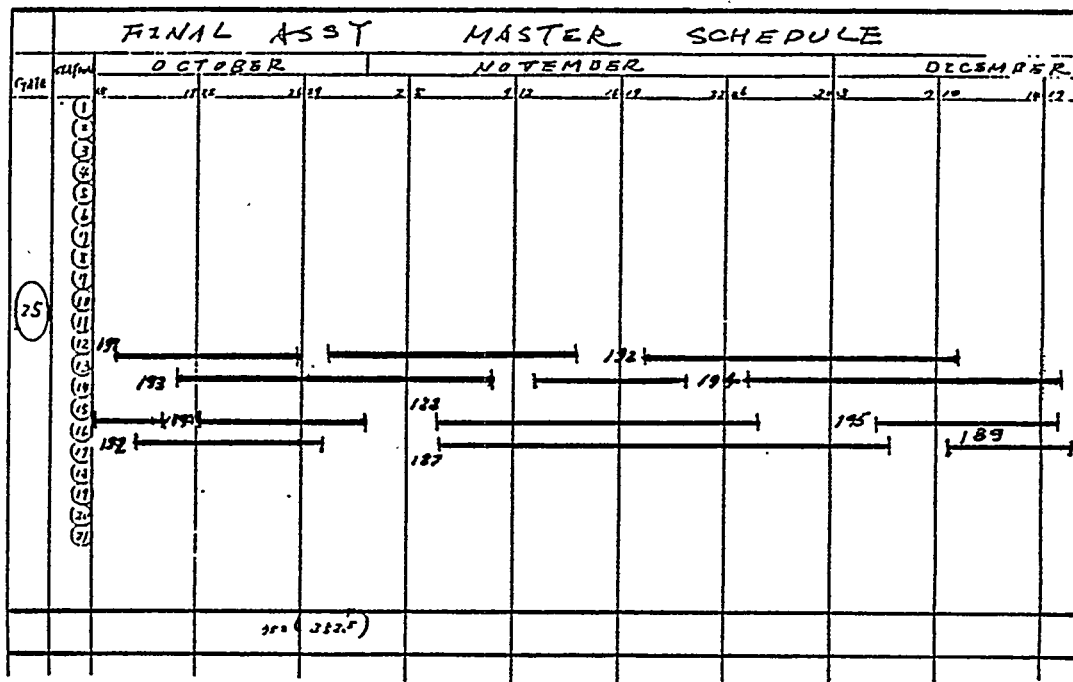


FIGURE 7-9

FINAL ASSEMBLY MASTER SCHEDULE

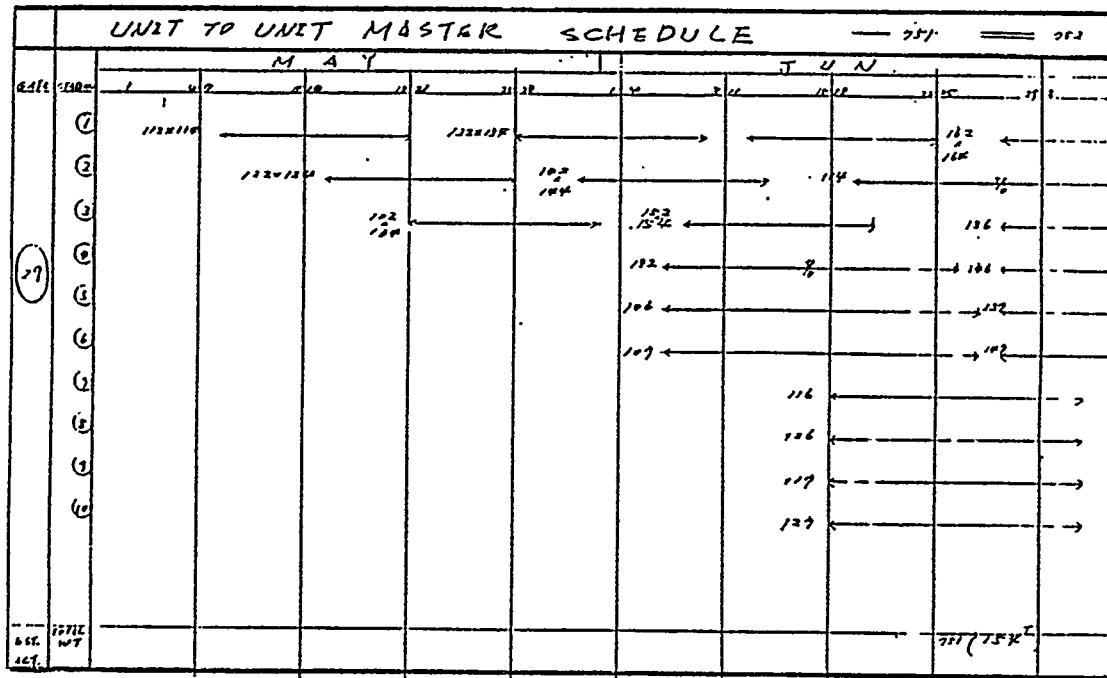


FIGURE 7-10

UNIT TO UNIT MASTER SCHEDULE

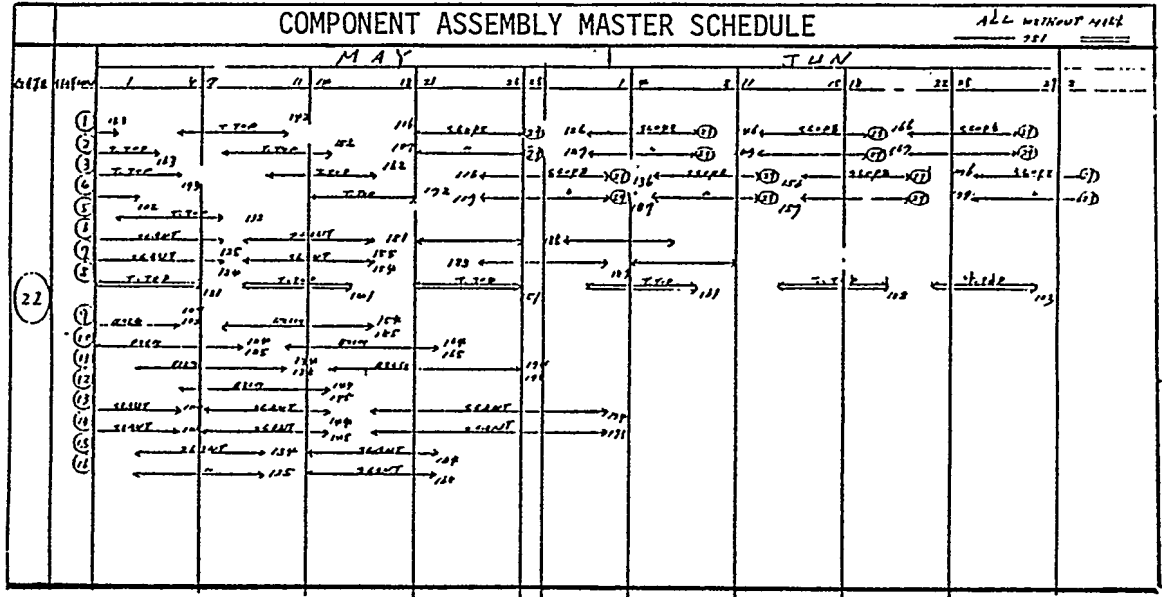
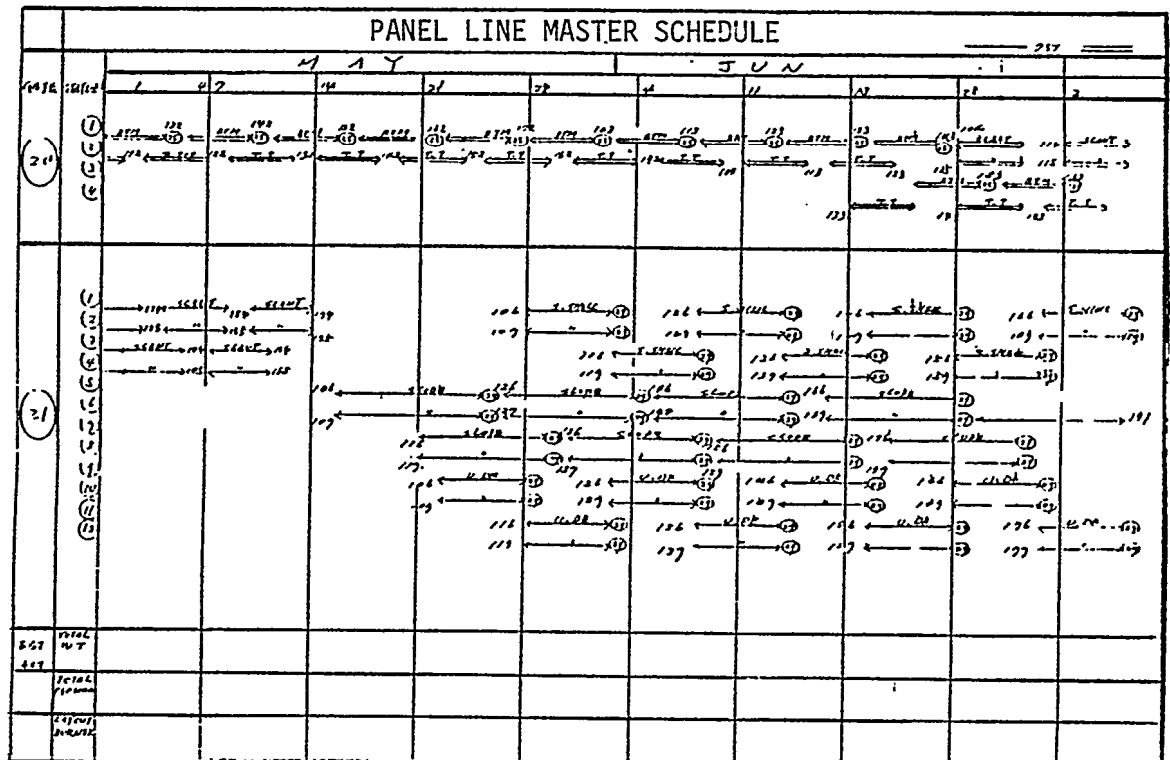


FIGURE 7-11

COMPONENT ASSEMBLY MASTER SCHEDULE



as adjusted to conform with actual experience, will become the standards for each process gate.

Performance measurement for gates already functioning is also being developed, initially on the basis of weight throughput. Studies of weld metal deposit per hour are also being performed and will be incorporated into the performance measurement activity in the future.

7.6 CURRENT LIVINGSTON APPLICATION

With the adaptation of the "Gate System" Livingston is fully committed to the application of the IHI production planning and control techniques. These techniques have necessarily been modified to fit the facilities, capabilities and personnel organization of Livingston. Many of the peripheral aspects of the system, such as Accuracy Control, decentralized planning and production control, the decentralized organization of work groups and staff groups, and total communication of planning and scheduling information to the work positions, have not yet been addressed in their fullest degree for application.

The re-orientation of an entire and traditional ship production system is a lengthy undertaking. A great deal of personnel training, as well as reorganization of facilities and material flow is involved and must be carefully structured in a step-by-step manner over a prolonged period.

Currently, Livingston has adopted only a portion of the planning methodology used by IHI. Table T7-1 shows the planning techniques presently utilized by LSCo. versus those of IHI. The planning shown in the table that has not been adopted by LSCo. is of course, accomplished in one form or another, but is generally less formal and

TABLE T7-1
PLANNING AND CONTROL TECHNIQUES ADOPTED BY LEVINGSTON

<u>IHI Planning & Control Technique</u>	<u>Adopted by LSCo.</u>
Hull Block Planning	Yes
Block Assembly Planning	Yes
Assembly Specification Plans	Not Completely
Work Instruction Plans	No
Marking Plan	
Cutting Plan	
Bending Plan	
Block Parts Lists	
Finishing Dimensions Plan	
Sub-assembly Plans	
Assembly Plans	
Assembly Jig Size Lists	
Lifting Instructions Plan	
Block Arrangements Plan	
Shipwright Dimensions Plan	
Support Block Arrangements Plan	
Welding Instruction Plan	
Scaffolding Arrangements Plan	
Outfit Planning	
Zone Planning	Yes
Material Ordering Zones	No
Work Zones	Yes
MLS - MLP - MLC - MLF	Mat'l Information List

less discretely identified than that of IHI. For example, many of the Working Instruction Plans shown as not adopted by LSCo. are prepared as part of the engineering or Industrial Engineering activities of LSCo. It is the planning concerned primarily with the fabrication, sub-assembly, assembly and erection of steel and the pre-outfitting and outfitting of the assembly units and the erected hull that has been emphasized by LSCo. in the Technology Transfer Program and until this planning and control methodology has been mastered and fully implemented, the remaining types of planning will be deferred.

The basic production system, the material handling and control system, scheduling, manpower planning and performance measurement systems have all been adapted to the LSCo. yard and although the implementation of these systems is far from complete, the basic decisions have been made and the eventual goals established for the complete reorganization of the LSCo. shipbuilding process. Figure 7-15 presents a diagram of the current Livingston planning, scheduling and manning control system as described in the preceding paragraphs.

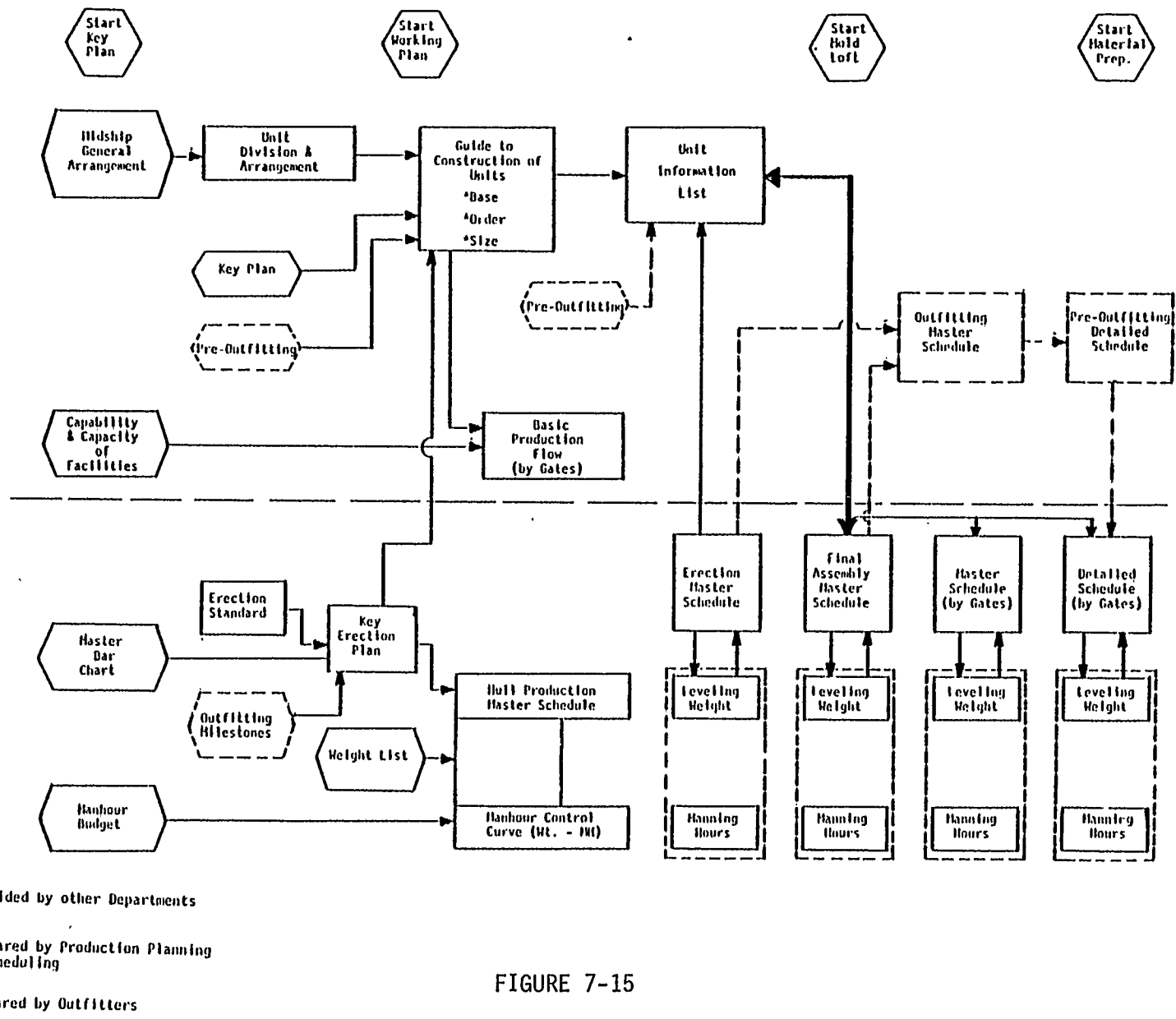


FIGURE 7-15

LSCo. PLANNING & SCHEDULING FLOW

SECTION 8
APPLICATION TO U.S. SHIPBUILDING

8.1 GENERAL

The application of the IHI Planning and Production Control system to typical U.S. shipyards is entirely practicable and desirable. The institution of this system, however, requires major modification not only to the planning and scheduling practices of the typical U.S. yard but also to the production system itself.

As explained previously, the heart of the Japanese system is the organization of the production flow through "Process Lanes". These lanes are the essential ingredient to the establishment of the planning and production control methods utilized by IHI. This may entail some radical changes in yards which have not been structured around an "interim product" or "module" type of ship construction.

Although module construction methods have been practiced by many U.S. yards, the full potential of these methods, as demonstrated by the Japanese, have seldom been realized in this country. Much of the reason for this is attributable to the traditional practices and reticence to change established production systems. Any re-organization of the physical facilities of many yards is an expensive and time-consuming undertaking. In the midst of ship construction this undertaking may severely penalize the work in process. It is therefore understandable why most yards are reticent to experiment with different production systems even though these systems are quite obviously more efficient and contribute to increased productivity.

The institution of the IHI system requires a thoroughly developed plan which must be executed at the beginning of each new contract. Since the majority of planning for production needs to be accomplished prior to the start of fabrication, this planning should be incorporated into the design effort and, in fact, be a part of the design development. Naturally, in order for this planning to be meaningful, the production system, both hull construction and outfitting, must be thoroughly developed and in place to support a rapid and optimized production schedule once fabrication has begun.

Several major obstacles present themselves in the institution of this type of planning and control system. The most formidable, of course, is the realignment of the production system into a "Process Lanes" type of organization. The second is the development of the planning and production control system organized around the new production structure. Additionally, restraining of personnel, material flow/handling/control, pre-outfitting, and the application of accuracy control and quality control methods to the new system must all be investigated to ensure that all aspects are integrated to form a precise composite that does indeed benefit and not degrade production rates.

Each shipyard has its peculiarities of location; geographical arrangement; facilities layout; physical plant complement of machinery, equipment, and transportation; and those related to the mix, skill levels and other characteristics of its workforce. For these reasons each yard will necessarily adopt the Japanese concepts of production in a somewhat different manner. Not all of the methods utilized by IHI will have direct application in each yard; however, the general methodology is applicable without exception.

8.2 HULL CONSTRUCTION

The practices of IHI regarding the division of the hull into unit assemblies (or interim products) is basic to the planning system and, of course, to the production system. This single aspect of the IHI methodology carries throughout all of the planning, scheduling, manpower planning, and performance measurement practices of the IHI yards. The production system is organized to produce the components necessary to build the sub-assemblies and the assemblies which ultimately will be erected in the building basin. The flows developed for this fabrication and build-up are extremely logical and practical with determined effort applied toward perfecting each process step to improve both efficiency and accuracy of each product.

After the breakdown of the ship into the assembly (or erection) units, the process becomes one of further defining the parts, pieces and processes for each assembly unit. A separate (but integral) part of this planning process involves the identification and scheduling of outfitting components to be integrated into the evolving hull units.

Once accomplished, this planning becomes the baseline for the planning of manpower at each process stage and sub-stage and, in an iterative process involving the application of manpower to schedules, the hierarchy of schedules is developed to provide the optimum loading of personnel into the shortest possible schedule.

This type of hull planning and construction is contingent on a thoroughly designed and established production system which to a large extent is predictable in its performance. IHI developed its production system over a period of 15 to 20 years and continually made modifications

to improve the system's performance. Even though a thoroughly designed model of the system exists (in the Japanese yards), U.S. yards seeking to institute such a system will have a difficult period of development before achieving anything close to the productivity rates of the Japanese. The realignment of any production system requires a total commitment and consistent dedication to effect the change and, even then, in an industry as complex as ship construction, the change will not be effected quickly.

Unlike many of the other systems of IHI, the Planning and Production Control System cannot be fragmented either for selective institution of a few parts of the system or for gradual implementation over a prolonged period of time. Because the planning system is intimately tied to the production system, each must reflect the other and no appreciable effect will be felt until both are developed to such an extent that the majority of the total system is effectively operating. Certain planning and scheduling techniques may be instituted and may have some beneficial effects on production; however, the great increases in productivity reflected in the Japanese system are not possible without the adoption of the total planning and production system.

8.3 OUTFITTING

Pre-outfitting is another area that has been widely discussed as a means to greatly reduce ship construction costs. Many U.S. yards currently employ some pre-outfitting to reduce the on-board outfitting of difficult functional systems. However, the IHI pre-outfitting practices are tied directly to the production of the hull assembly units and to the production system which produces them. The study

and application of the principles of pre-outfitting utilized by IHI must necessarily correspond to the principles of hull construction used by those yards. Otherwise, the advantages gained by the use of the IHI pre-outfitting methods will be marginal and may even have deleterious effects on production schedules.

Pre-outfitting, of course, can be instituted in U.S. yards a number of ways. Certainly, the IHI methods are not the only alternative in this important area. Any method of pre-outfitting which serves to diminish the time spent in erection or on-board outfitting will contribute to reduced costs; however, pre-outfitting itself is not a panacea for poor production efficiency. Rather, it is simply one of the many aspects of production which must be integrated in a total planning and production system. The attempt to institute the IHI pre-outfitting methods in a traditional ship construction system (i.e. a ship assembled and erected on the ways) simply would not work, and, even in a production system only slightly modified from the traditional approach, these methods would be extremely difficult and generally ineffective.

Livingston's study of the IHI system has derived one over-riding axiom for the application of IHI practices, that is: the IHI ship construction system is a well developed and highly integrated whole, pieces of which can be adopted for use in U.S. yards and can be effective, but only through the adoption of the total system can any great increase in productivity be effected. This applies especially to the planning and production control system. Only through the adoption of the IHI production system does the direct application of

the IHI planning and control system have meaning and, similarly, only through the adoption of the production system does the IHI pre-outfitting methodology have significant benefit. Each piece of the planning and production system is dependent upon every other piece. One piece cannot stand alone.

8.4 CONCLUSION

The IHI Planning and Production Control System is a comprehensive and effective system in the IHI shipyards, but because of its total orientation toward the production system, methods, processes and techniques of the IHI yards, its application to U.S. yards is dependent on the willingness of U.S. yards to change their production methodology. There is little doubt that should a U.S. yard successfully replicate the IHI planning and production system that such a system would have a significant effect on productivity although, because of the cultural differences between the two countries, U.S. yards may never achieve the productivity levels experienced by Japan. Many more aspects of productivity, besides those of planning and the production system, will influence the ultimate productivity equation and, although this area of production is by far the most significant in terms of technology that can be adopted by the U.S., it is entirely possible that the areas of non-technological application (such as personnel relations) can produce an influence of equal proportion. In any case, U.S. yards cannot help but derive benefit from the study of this technological area.