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SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
OUTFITTING AND PRODUCTION AIDS
INDUSTRIAL ENGINEERING FOR SHIPBUILDERS
SHIPBUILDING STANDARDS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATIONS
SURFACE PREPARATION AND COATINGS
FLEXIBLE AUTOMATION
EDUCATION AND TRAINING
WELDING

THE NATIONAL
SHIPBUILDING
RESEARCH
PROGRAM

Manufacturing Technology for Shipbuilding —

Project Condensation

U.S. DEPARTMENT OF TRANSPORTATION
Maritime Administration
in cooperation with
The University of Michigan

MANUFACTURING TECHNOLOGY FOR SHIPBUILDING

A Condensation of Four Reports
Prepared by
Avondale Shipyards
New Orleans, Louisiana

for

National Shipbuilding Research Program

The Society of Naval Architects and Marine Engineers
Ship Production Committee
Education and Training Panel (SP-9)

February 1986

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16. Abstract

As part of the government/industry-supported National Shipbuilding Research Program (NSRP), a technical evaluation of the operation of Avondale Shipyards, Incorporated (ASI), was performed by consultants from Ishikawajima-Harima Heavy Industries Company, Limited (IHI), in 1980.

ASI subsequently implemented four major IHI systems recommended in that evaluation: Accuracy Control, Production Planning, Design Engineering for Zone Outfitting, and Process Lanes. The implementation of these systems has decreased production time and increased productivity, thus materially reducing costs.

ASI's experience with these improvements is shared with the shipbuilding community via four seminars at the shipyard held from 1982 to 1984. The voluminous material which constituted the lecture notes of those seminars is condensed in this report. Essential material from all of the seminar lectures is included, but detailed discussions and examples of complex schedules and documents used at the shipyard have been left out. The complete work is included in the NSRP Microfiche Library (See Reference [3]).

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ACKNOWLEDGMENTS

This report has 27 authors, all of whom participated in the revolutionary changes at ASI which attended their implementation of the IHI technology. They are listed in the Appendix, along with the titles of the lectures they prepared for the Technology Transfer seminars. The editor acknowledges their contributions with appreciation and with the hope that he has been faithful to their original expression of their experience.

The editor of the seminar material is Professor Robert B. Zubaly. Professor Richard P. Neilson and Professor Norman A. Hamlin gave expert advice and participated in the editing and review of this report. Their advice is appreciated. The work was done under the direction of Professor Everett C. Hunt, Director of Research at Webb Institute of Naval Architecture.

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

I. JAPAN-U.S. SHIPBUILDING TECHNOLOGY TRANSFER

Under the authority of the Merchant Marine Act of 1970, which provided for government and the shipbuilding industry to jointly develop plans for improving shipbuilding productivity, the Maritime Administration and the Ship Production Committee (SPC) of the Society of Naval Architects and Marine Engineers (SNAME) initiated the cost-shared government/industry National Shipbuilding Research Program (NSRP). Many projects have been carried out under this program [1, 2, 3]*.

Among the early projects sponsored by the continuing NSRP consortium, several involved sending American shipyard managers and researchers on tours of highly productive shipyards in Europe and Japan to study their methods in order to identify promising management and production techniques that could be applied to domestic shipyards to improve their productivity [4, 5, 6, 7]. The system employed by the shipyards of Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) was selected as the most promising source for transfer to interested U.S. shipbuilders [4]. IHI consultants were retained to disclose the details of their methods by preparing a series of reports [8 through 37] on a broad range of topics, including quality assurance, planning, design, production control, zone outfitting, accuracy control, group technology, and standards, among others.

II. THE IHI-AVONDALE PROJECT

In fiscal year 1980, MarAd and Avondale Shipyards, Inc. (ASI) cooperated on a "technical evaluation of Avondale's production operations and organization, the development of a long-range facilities plan, and the integration of both" [38]. The technical evaluation of Avondale's production operations and organization was performed by IHI. Avondale concluded that it could significantly improve its productivity by using the IHI technology, but that so many areas could be affected--many of them outside the shipyard's control--that Avondale could not implement all of the recommended changes at one time.

To improve productivity the most with the least amount of disruption, Avondale decided to implement four of the IHI systems recommended in the technical evaluation:

- Accuracy Control
- Production Planning
- Design Engineering for Zone Outfitting
- Process Lanes

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* Numbers in brackets designate references listed at the end of the report.

The objectives were to decrease the time between the contract date and ship delivery and to increase productivity and reduce cost. Each of the four systems was broad and extensive. To implement the systems, the following action was taken:

(a) ASI selected the specific elements within each of the four systems that promised the most significant improvement in productivity with the least amount of disruption during the integration period.

(b) ASI determined to what extent the selected elements must be tailored for adoption for Avondale and for use as an Americanized version of Japanese technology.

(c) ASI determined what elements of the four systems are measurable, so that a comparison could be made between the method previously being used and the method finally adopted.

This effort was to be a demonstration intended not only for the benefit of Avondale but of all U.S. shipyards. Avondale was required to work closely with MarAd and the U.S. shipbuilding community to ensure adequate dissemination of information.

III. TECHNOLOGY-TRANSFER SEMINARS

To share what was learned with personnel from other shipyards, ASI conducted a series of four seminars at the shipyard. Each of the two-day seminars was organized to cover one of the four systems listed above with a series of in-depth presentations by key shipyard personnel. Also included in each were lectures describing the interactions of other departments in the yard with the activities of the primary subject of the seminar. Shipyard tours were conducted so that participants could observe the new techniques first hand.

The four seminars were conducted over a period extending from May, 1982, through June, 1984. Lecture materials in the form of text, figures, drawings, and illustrations were furnished to participants in the seminars. That material, consisting of four volumes of some 1,000 total pages [39, 40, 41, 42] has not been widely disseminated in printed form to those who did not attend the seminars, although the complete work is included in the NSRP Microfiche Library (See Appendix B of Reference [3]).

This report is intended to make generally available a condensation of the four original Avondale/IHI Technology-Transfer Reports: "Manufacturing Technology for Shipyards" in a single document. Although the present report is significantly reduced in length compared to the original work, essential material from all of the different lectures is included, much of the condensation having resulted from elimination of repetitive material necessitated by the four-session format spread over two years. The text of this report is as faithful to the original presentations as possible, and is in the words of the original authors, except where continuity of text or consistency of style necessitated editorial revision.

CHAPTER 2

PRODUCTION PLANNING AND SCHEDULING

I. INTRODUCTION

Before the new technology began to be applied at Avondale, the planning and scheduling of hull and outfitting functions was low-profile and conventional. The production crafts performed much of the planning and scheduling, particularly when changes were required. This was necessary, because the basic planning function did not provide sufficient detail during development of the initial plan. The "Product Work Breakdown Structure" was not utilized to the extent necessary to provide detail visibility and controls. Initial planning and scheduling was normally undertaken after award and continued up to launch. The conventional planning and scheduling was accepted because of the lack of a detailed plan that could assure the production of each unit of the ship with predictable accuracy on a reliable schedule.

An increased awareness of the need to improve the methods, controls, and predictability of construction prompted a serious study of how the logic and techniques of the Product Work Breakdown Structure could be initiated at Avondale. This study resulted in development of a basic approach to hull planning and scheduling that provides for integration of division responsibilities and functions and specifies relationships and dependencies among the hull, outfitting, and facility requirements. Probably just as important, it highlights all requirements, beginning early during the marketing stage through final delivery of the end product, and provides for top milestone meetings essential for visibility and control.

The new technology has significantly improved Engineering and Production communications and the subsequent deliverables (drawings, material, etc.). Up-front development of the plan is a must to assure that Engineering is fully apprised of the construction methods • before award for inclusion in the preliminary engineering development. Figure 2-1 compares the planning, engineering, and production efforts of the conventional versus the new approach, which is discussed below.

II. TOTAL CONTRACT PLANNING REQUIREMENTS

To support the new technology, the total contract requirements must be planned in advance of hull construction. Figure 2-2 provides a general outline for the basis of a total requirements planning effort.

This approach to planning, as with any other method of planning, requires a well organized planning group and the involvement of top management to assure visibility of the total contract requirements and their relationship to other contracts.

Before the advent of the new shipbuilding technology, many impromptu planning and scheduling changes were made in the field during the production process. Under these circumstances, top management had to rely on the scheduling

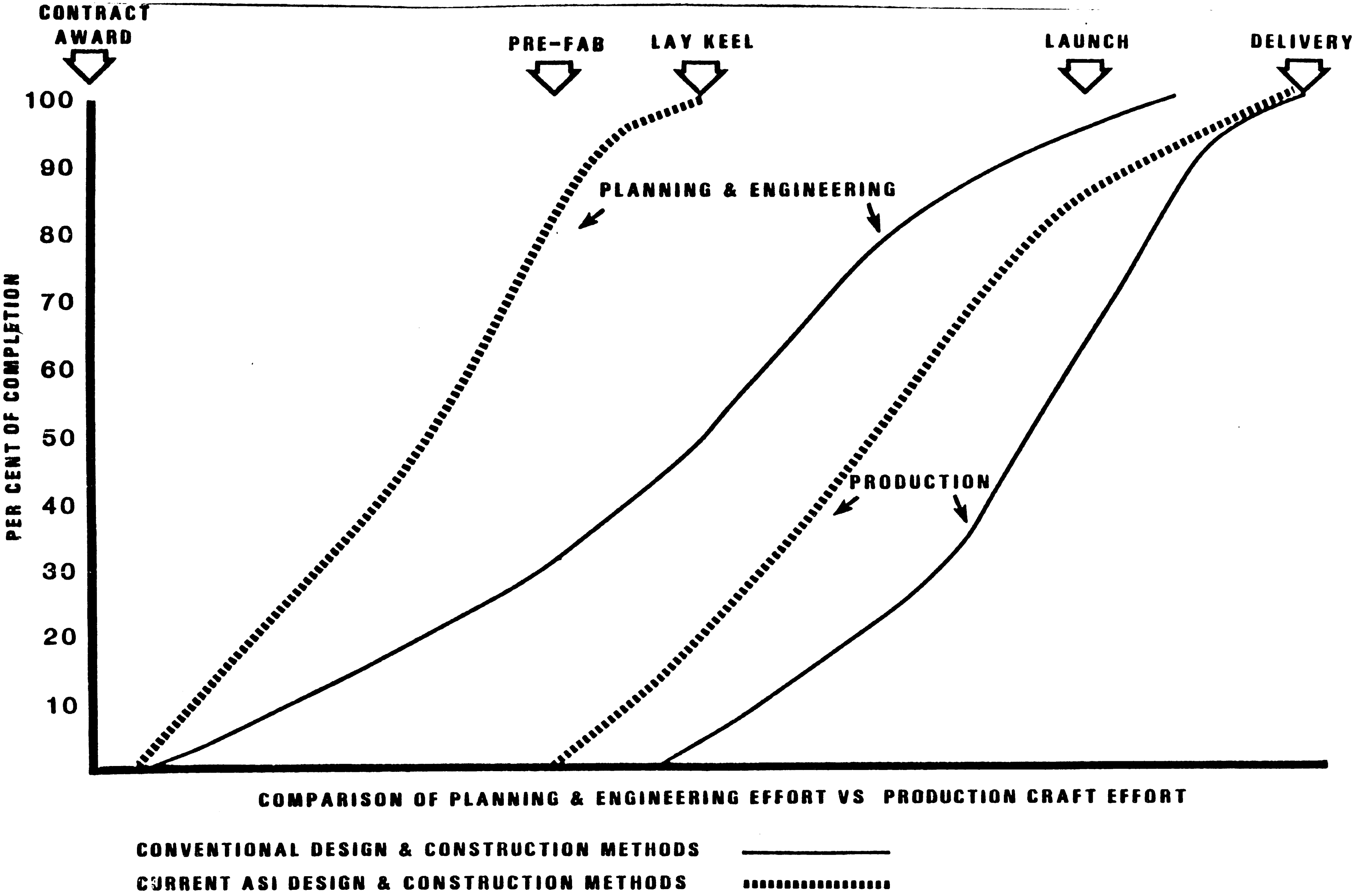


Figure 2-1 New Technology Versus Conventional

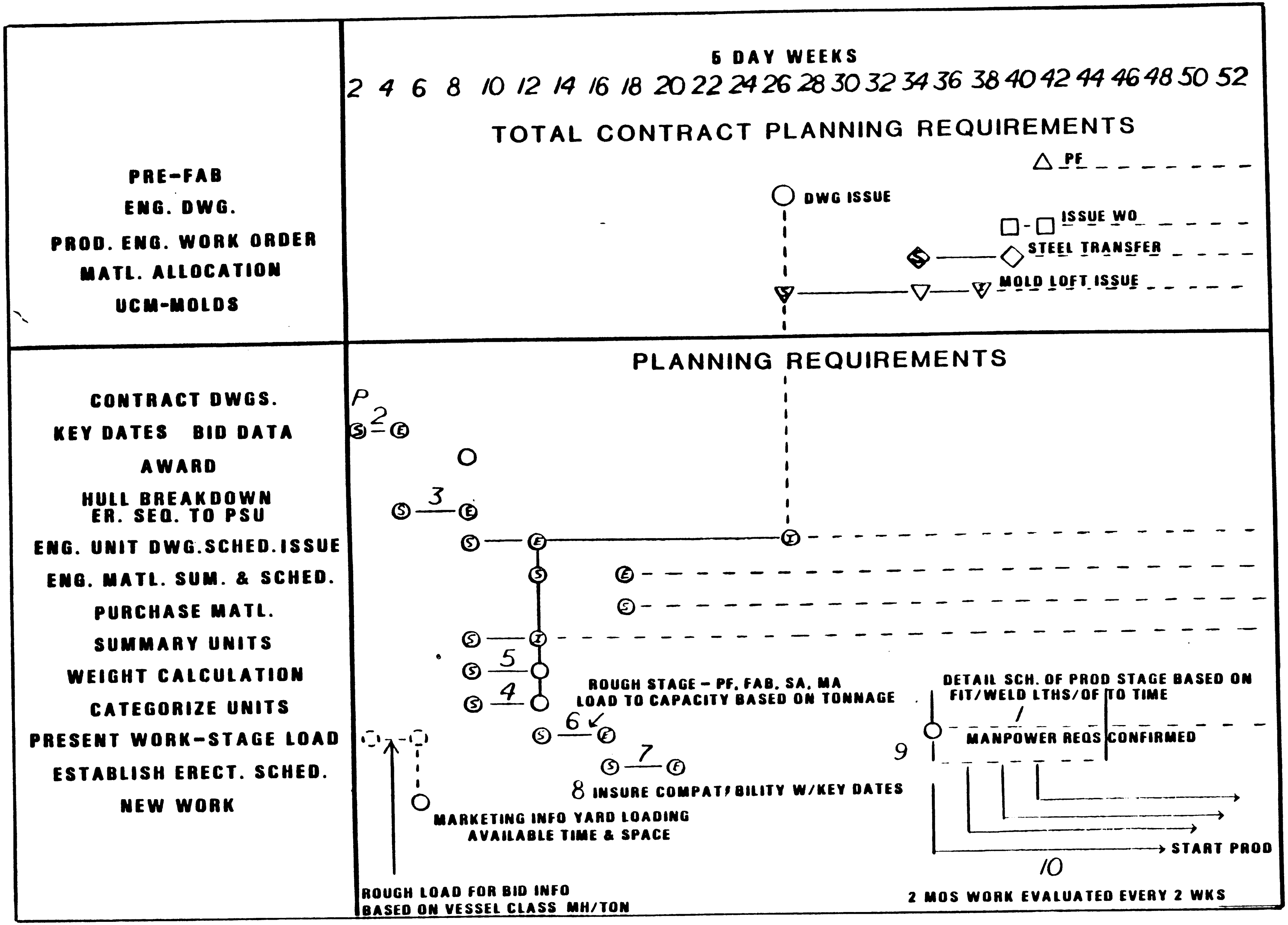


Figure 2-2 Total Contract Planning

and planning made by the work force during the many "fire drill" situations which arose, thus surrendering their authority out of a necessity to keep the production of steel moving, regardless of the inefficiencies along the way.

The changeover to total contract planning began by analyzing the percentage of the total hull construction manhours that were devoted to moldloft and cutting, assembly, and erection. The results of this breakdown are shown in Figure 2-3. The next IHI study at Avondale was a comparison of steel breakdown production, using a base of 7,000 short tons per month, which was comparable to one of the IHI shipyards. This is shown in Figure 2-4.

The first question to be answered was, "Is there enough steel production real estate at Avondale in which to build the various categories and subcategories of modular structures, using the IHI methods of product work breakdown?" A study was made to identify those categories of main assembly blocks or units used to construct an average product carrier or container vessel. This categorization is shown in Figure 2-5. Then the estimated category percentages by weight in tons per month were targeted for a reasonable total monthly production at ASI of approximately 8,000 tons. This breakdown is shown in Figure 2-6. Then assuming that American productivity of area would be one-half that being produced at Kure, Japan, production area requirements were determined. Figure 2-7 shows that the existing Avondale work areas, or platens, have sufficient area available to produce 8,000 tons of steel per month. On this basis, it was clear that whatever technological hull planning and scheduling principles were adopted, there would be no need for a great expenditure of capital funds for real estate.

III. ORGANIZATION CHANGES FOR THE NEW TECHNOLOGY

Many changes in the engineering planning and production planning organizations had to be made to implement much of the IHI technology. By the same token, some of the IHI technology had to be modified to fit those social and traditional parts of the ASI organization that could not or should not be changed at first.

(1) New groups had to be established by the Moldloft to implement line heating and unit control manuals.

(2) A new department was created and called "Operation Services" to handle all the various lifting devices and turning methods needed to implement process lanes.

(3) The Production Planning Department was reorganized into two divisions - Hull and Outfitting.

(4) A new group of skilled burners was formed to create a "line heating crew."

(5) An accuracy control team of four people under a qualified engineer was initiated to improve dimensional control.

(6) A production group called Shop Planners was formed to reinforce the process lane concept at the local level.

Figure 2-3 Hull Construction Manhour Breakdown

MOLD LOFT & CUTTING	10%
SUB ASSEMBLY & ASSEMBLY	50%
ERECTION	40%

Figure 2-4 Japanese Shipyard Area Productivity

CATEGORY	UNIT NAME	ASSY WT. TON MONTH	AREA M^2	PRODUCTIVITY OF AREA TON MONTH M^2
PANEL UNIT	MID PART: D. BOTTOM T. BHD. S. SHELL U. DECK	4,060	7,700	0.53
SEMI PANEL UNIT	A & F PART: DECK, FLAT, T. BHD.	1,314	3,200	0.41
3 DIM. UNIT	A & F PART: D. BOTTOM	450	1,000	0.45
CURVED UNIT	A & F PART: CURVED S. SHELL	1,176	2,700	0.44
ASSEMBLED MONTHLY TONN.	TOTAL:	7,000	14,600	0.48

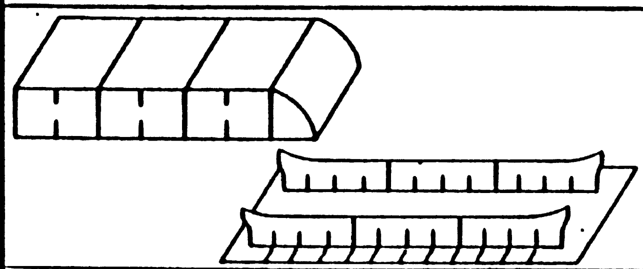
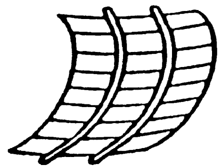
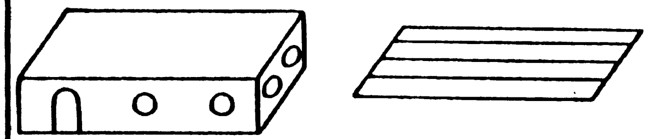
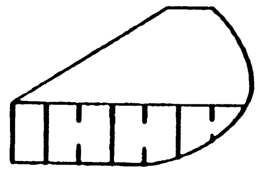
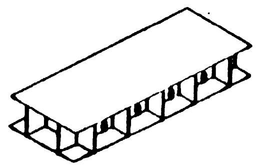
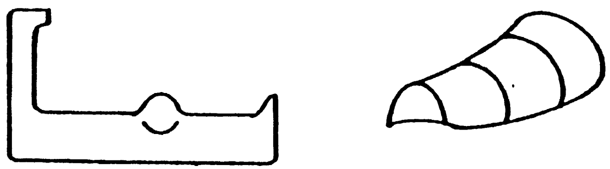
CATEGORY	UNIT NAME	PLATEN SUPPLYING FABRICATED PARTS	SHAPE	ASSEMBLY PLATEN
No. 1 FLAT PANEL UNIT	MID PART DOUBLE BOTTOM SIDE SHELL LONG BHDS.	23 24		20
No. 2 CURVED SHELL UNITS	AFT & FORE PART SIDE SHELLS	16		17
No. 3 SUPERSTRUCTURE UNITS	DECKS FLATS BULKHEADS HOUSES ETC.	16		8 9 11
No. 4 FORE PEAK AFT PEAK	LARGE AND VERY HEAVY 3 DIMENSION UNITS	16		10 13 307
No. 5 ENGINE ROOM INNER BOTTOMS	LARGE AND HEAVY INTRICATE UNITS	16		14 307
No. 6 SPECIAL UNITS SKEGS RUDDERS ETC.	BULBOUS SHAPES STERN CASTINGS	16		19

Figure 2-5 Categories of Hull Units

Figure 2-6 Estimated Avondale Production by Category

CATEGORY	%	WT. /MONTH (TONS)
FLAT PANEL UNIT	52.8%	4,224
SEMI-FLAT PANEL UNIT	8.2%	656
CURVED UNIT	14.8%	1,184
3 DIM. UNIT	8.5%	680
A & F END UNIT	9.6%	768
OTHERS	6.0%	480

TOTAL AVONDALE PROJECTED MONTHLY TONNAGE - 8,000 TONS MONTH

Figure 2-7 Avondale Shipyard Area Productivity

CATEGORY	ASSWT TON	PRODUCTIVITY OF AREA T. M.M2	REQD AREA M2	BAY	EXISTING AREA M2
FLAT PANEL UNIT	4,224	0.26(0.53)	16,246	20	16,800
SEMI-FLAT PANEL UNIT	656	0.20(0.41)	3,280	WAYS	4,000
3 DIM. UNIT	680	0.23(0.45)	2,960	14	4,750
A & F PART: DOUBLE BOTTOM					
CURVED UNIT	1,184	0.22(0.44)	5,380		4,350
A & F END UNIT	768			UP & LOW WAYS	
OTHERS MASTS - RUDDERS	480			19	3,100

IV. PLANNING FOR PROCESS LANES AND ZONE OUTFITTING

What was needed first was a method to control and handle materials quickly, efficiently, and economically. The best way to accomplish this task was through the process lanes method. Process lanes means the categorization and separation of like kinds of work, and the development of work centers specifically designed to produce that kind of work efficiently and economically. Process lanes establish the greatest amount of "learning curve" efficiency by having the same people at the same work centers doing the same type of work every day with a constant organized efficient flow of material.

Process lanes, as defined above, did not exist at ASI because different types of units were assembled at the same location. Assembling different types of units at one location requires:

- different assembly periods of time,
- different types of assembly platens,
- different types of construction methods.

When units having different characteristics are produced in the same locations, those obstacles must be overcome. This tends to decrease productivity and accuracy. Because of the use of different types of material, on-site storage becomes very difficult, resulting in increased material handling costs.

When process lanes were established at ASI, there were controls to create detailed process lane schedules based on the volume and quantity of work for each process lane work center, thereby enabling ASI management to determine work center cost and efficiency.

A. Unit Categorization

Process lanes require the units of a vessel to be divided into categories based on the size, shape, weight, and method of construction.

Categorization of hull components is required, primarily by the Planning Department and later by shop or work center planners. This will assist them in basic and detailed planning and scheduling, as well as establishing an orderly flow of materials. Categorization also allows planners to determine where a component will be constructed, as well as elapsed time in, and control through, the process lanes.

Hull units are divided into six basic categories.

(1) Category No. 1, Flat Panel Units

These units are comprised of panel line components assembled on a flat surface as the base of a unit. This flat surface could be a deck, innerbottom, bulkhead, or even the shell. They are relatively simple units that require short construction time. Category No. 1 units usually comprise approximately 50 percent of the total hull weight, the exact proportion depending on hull type.

Since this category contains the largest number of units to be constructed, the most productive and largest platen at ASI was designated for Category No. 1. This platen is also very suitable because of its relationship with the panel line and the material flow from the fabrication platens. There are four (4) designated construction stages on this platen:

- Subassembly
- Preoutfit (on unit)
- Main Assembly
- Final Assembly and Outfitting, Welding, and Inspection

Establishing the four construction stages on the platen allows for the same kind of work to be done by the same people every day in that specific location, where all of the work tools, welding machines, etc., needed for that work are readily available. Thus, the work moves to the workers rather than having the workers relocate to the work, requiring the movement of all their special tooling.

(2) Category No. 2, Curved Shell Units

These units are assembled on curved shell, knuckled longitudinal bulkheads or innerbottoms, in fixed or pin jigs. Examples would be wing tanks or outboard sections of wings with curved shell plating. These units are, in general, more complex in construction, requiring different construction methods and techniques and more elapsed time in assembly position than the Category No. 1 units. The platen for this category is convenient to the prefabrication shop for economical material flow and convenient to the preoutfitting area and blast and paint shop.

(3) Category No. 3, Superstructure Units

Category No. 3 units are the superstructure units, along with engine flats with bulkheads or side shell below. Because Category No. 3 units are generally large, a significantly large area is needed for their construction. These units are typically those being built with a deck or a flat as the base of the unit. An example is the pilot house built with the house top as the base of the unit. There may be partial subassembly for this type of unit. After the fitting and welding is completed, the unit would be released for the preoutfitting work and final inspection. Category No. 3 units will stay on the platen longer than most Category No. 1 and No. 2 units because of their outfitting and piecemeal construction. Therefore, a separate process lane is required.

(4) Category No. 4, Large and Heavy Modular Units

Category No. 4 units consist of large and heavy modular units which are difficult to build. Due to close fitting tolerances and some confined areas, they require (along with Category No. 5 units) the most qualified mechanics available. Category No. 4 units are fore and aft peaks, along with some engine room innerbottoms. These units are required to stay on the building platens for a longer period than the Category Nos. 1, 2, 3 types of units. Because of this, a separate process lane is required.

(5) Category No. 5, Machinery Space Double Bottom

These units are typically those with the engine room innerbottom as the base. The assembly period is long, with close fitting tolerance, extensive outfitting, and usually piecemeal rolled shell plate work.

(6) Category No. 6, Special Weldments

These units are specialty items, such as rudders, skegs, anchor pockets, etc. There was no change from current construction procedures for this category.

B. Hull Planning Controls

Functional and sequential planning control guidelines were established as basic steps essential in support of the process lanes concepts, as well as the overall planning development. The following guidelines were considered to be steps paramount to support a successful construction effort (See Figure 2-2):

- Determine present platen loading;
- Establish key dates;
- Divide hull into units and develop erection sequence;
- Categorize hull units;
- Weight calculations by unit (rough);
- Platen load (Platen #20) to capacity;
- Establish the erection schedule;
- Ensure compatibility with key dates;
- Prepare assembly schedules;
- As detailed drawings become available, refine weight estimates and all schedules.

Summaries of the planning controls required for each of the above guidelines are as follows:

(1) Determine Present Platen Loading

First, the present and long-term platen loading for contracts in progress is determined. The platen loadings are constantly monitored, and the loading for any given week should be immediately available for each platen and all contracts on hand for the duration of their long-term schedules.

(2) Establish Key Dates

The Planning Department must establish the possible key event dates (start of prefabrication, keel, launch, and delivery) as early as possible, based on the required delivery date set by the customer and within the overall master (long-term) yard schedule. This effort must be "rough cut" or preliminary for contract bid purposes and then refined upon signing of the contract (or letter of intent). During the key event review, lead times for engineering drawing development and lofting development must be given priority attention.

(3) Divide Hull into Units and Develop Erection Sequence

The unit arrangement drawing is prepared by Production Planning for purposes of identifying the finalized unit erection breaks and unit numbering. This evolution is essential for further development of the desired erection sequence. A list of units with the basic unit descriptions is prepared. Preliminary weights for planning purposes are added to the unit description sheets prior to issue.

(4) Categorize Hull Units

The hull units are then categorized within the process lanes concept, and a separate list of units is prepared for each of the six categories, along with basic unit descriptions. The planning engineers then begin a detailed study of the construction method for each individual unit.

(5) Weight Calculations

Weight estimates must be developed for each unit in Category 1 and Category 2 for the purpose of proper platen loading on Platen No. 20 (Process Lane No. 1) and Platen No. 17 (Process Lane No. 2).

(6) Load Platen No. 20 to Capacity

After thoroughly reviewing the current loading from existing contracts of Platen No. 20 (Guideline No. 1) for the duration of a new contract, based on its established preliminary key event dates, the platen should then be loaded (week by week) to capacity. This establishes the number of units per week (based on their weights) that will be available from Platen No. 20 for erection during any given week from start to launch. The number of units per week thus established is then reviewed against the preliminary unit erection schedule (Guideline No. 3), and the erection schedule can be finalized.

(7) Establish Erection Schedule

Using the sequence of erection developed in Guideline No. 3 and the number of units per week available from Platen No. 20 developed in Guideline No. 6, the erection schedule can be developed. For example, if the first five units to be erected are numbered in sequence and the unit weights are:

Unit No. 1 =	86.5	Tons
Unit No. 2 =	125.0	Tons
Unit No. 3 =	125.0	Tons
Unit No. 4 =	86.5	Tons
Unit No. 5 =	86.5	Tons
Total	509.5	Tons,

then Units No. 1 through No. 5 can be erected in one week, leaving 600 - 509.5 = 90.5 tons (based on 600 tons per week output Platen No. 20) available for units of another ship.

Note that the number of Category 1 units per week to be erected (all jobs) cannot exceed this maximum tonnage output per week available from Platen No. 20. This condition can be adjusted via either expansion of the platen grids or via the level-loading process while developing the long-term schedules, if additional tonnage is necessary at the erection site. Further refinements can be made to the erection schedule after completion of the level-loading process, if necessary.

(8) Ensure Compatibility with Key Dates

The prepared erection schedule is checked to be sure that all units can be erected in a timely fashion within the rough draft key event dates established in Guideline No. 2 and consistent with machinery and material requirements. Adjustments to platen loading (Guideline No. 6) are made if required. Attention must be given to engineering drawing issue dates and lofting leadtime requirements.

(9) Prepare Assembly Schedules

The assembly or platen loading schedules are then prepared. Short-term schedules are developed and issued for one- to two-month intervals for the platens. The platen schedules are dynamic, with routine review and update from feedback via shop planners, etc.

(10) Detailed Drawings - Refine Schedule

As detailed drawings are developed and become available, a review of all weight estimates is continued, and lengths of fittings and welds are determined to further refine and update production manhours and platen loading schedules.

The lead hull planners start development of the construction methods by unit early during the key plan stage (See Figure 2-8). The detail breakdown of units into partial subassemblies and main assembly is completed early and assigned to specific process lanes. The issue of detail drawings allows for detailed refinement of the working instructions and preparation of Unit Parts Lists (UPL) prior to final issue to the loft.

C. Outfit Planning

The goals of outfit planning for Zone Outfitting are:

- to maximize the prefitting of components of all systems in zones of the onboard divisions and into the sub zones of hull units;
- to maximize the assembling of components of systems in the zones of onboard divisions into the sub zones of machinery and pipe package units;
- to minimize the amount of outfitting after hull erection;

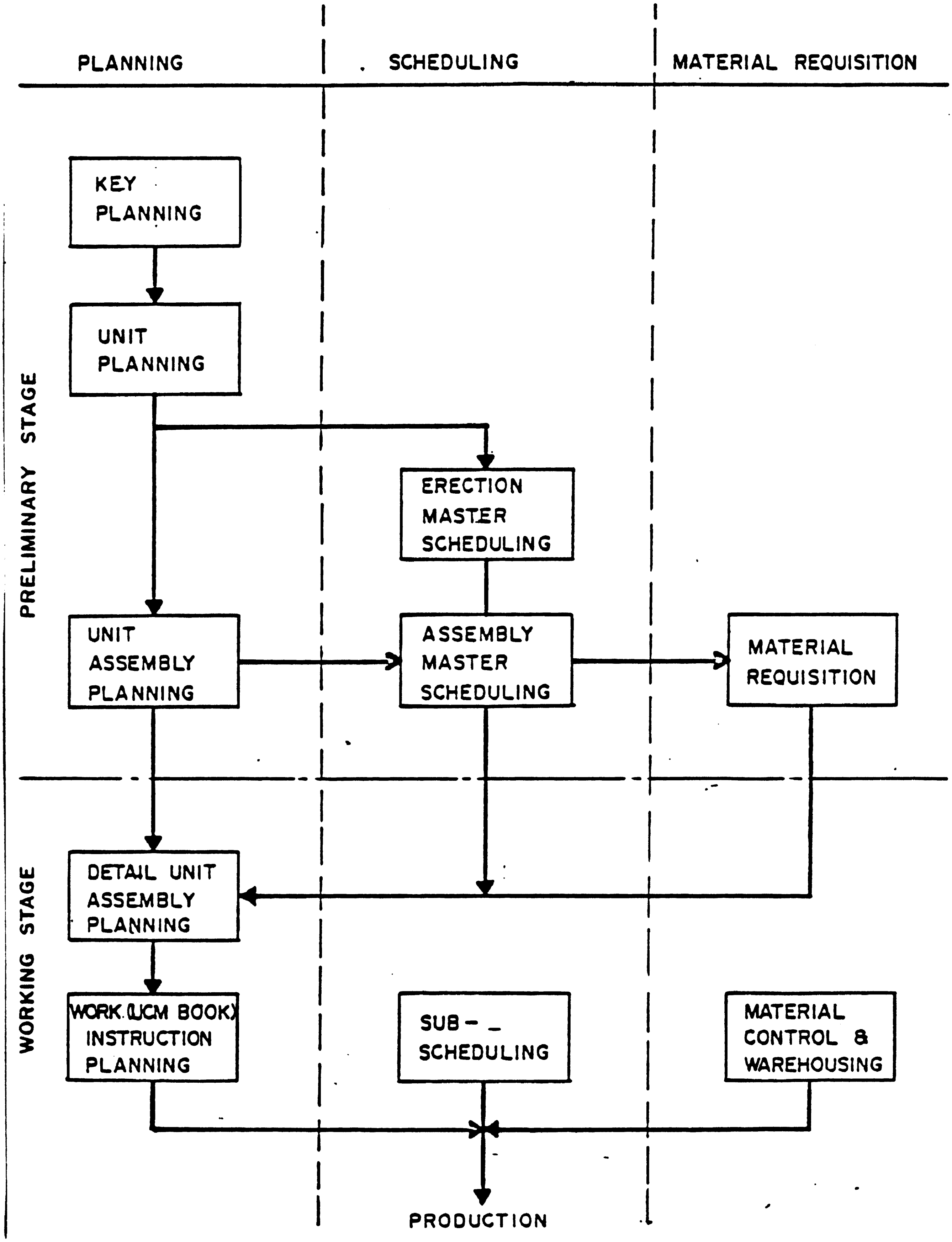


Figure 2-8 Flow Diagram for Unit Construction

- to orient assemblies requiring steel fitting and foundation work to an easy position assisted by gravity rather than opposing gravity, avoiding difficult overhead work;

- to transfer work environments from closed, narrow, high, or unsafe locations to open, spacious, low, and safe locations, and also to facilitate transportation of materials.

There are three types of zone outfitting practiced at Avondale as a result of implementing the new shipbuilding technology:

- Package Unit Preoutfitting
- On-Unit Outfitting
- On-Board Outfitting

Figure 2-9 illustrates a typical example of each.

(1) Package Unit Preoutfitting

Basically, components are assembled into package units as long as their independence can be preserved with rigidity and stability without the help of intensive temporary reinforcements or supports. Package units have been used in increasing numbers on succeeding contracts at ASI.

Types of package units are:

Machinery Package Units -- An assembly of machinery, combined with adjacent components such as the foundation, pipe pieces, valves, gratings, ladders, supports, etc.

Zone Package Units -- An assembly of pipe pieces and pipe racks, combined with valves, access ladders, gratings, etc. A good example of zone package units are the main deck pipe racks of a product carrier. Zone package units are also called pipe package units.

(2) On-Unit Outfitting

The primary objective of on-unit outfitting is, of course, to complete the outfitting on ceilings and in doublebottoms before hull unit erection. Outfitting a unit involves various types of outfitting tradesmen working in a small space; therefore, it by itself tends to create an unbalance in the work schedule. One recommended solution to this problem is to allocate multi-trade workers to each unit, that is, to train new trade workers called assemblers. The fitting and welding on ceilings are undertaken with the unit upside down, while the fitting and welding on floors are implemented after the unit is turned.

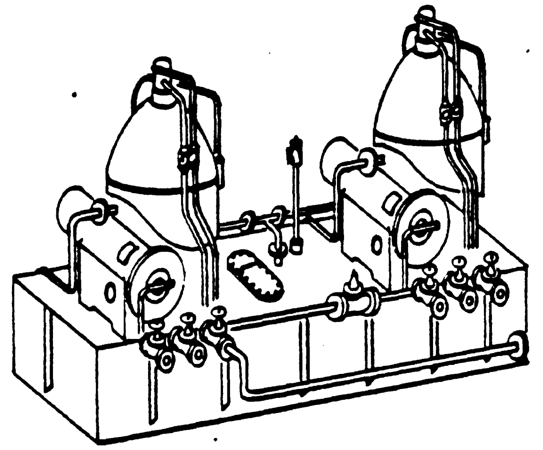
(3) On-Board Outfitting

On-board outfitting is designed to be as minimal as possible and is limited to the following:

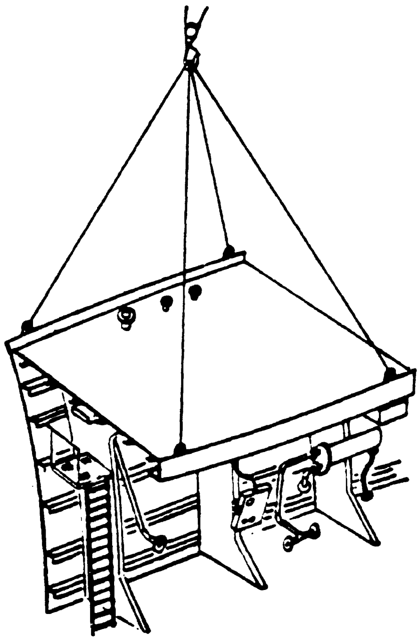
- outfitting items or package units too heavy or big to load onto the unit prior to erection;

ITEM

1. PACKAGE UNIT PRE-OUTFITTING



2. ON - UNIT OUTFITTING



3. ON - BOARD OUTFITTING

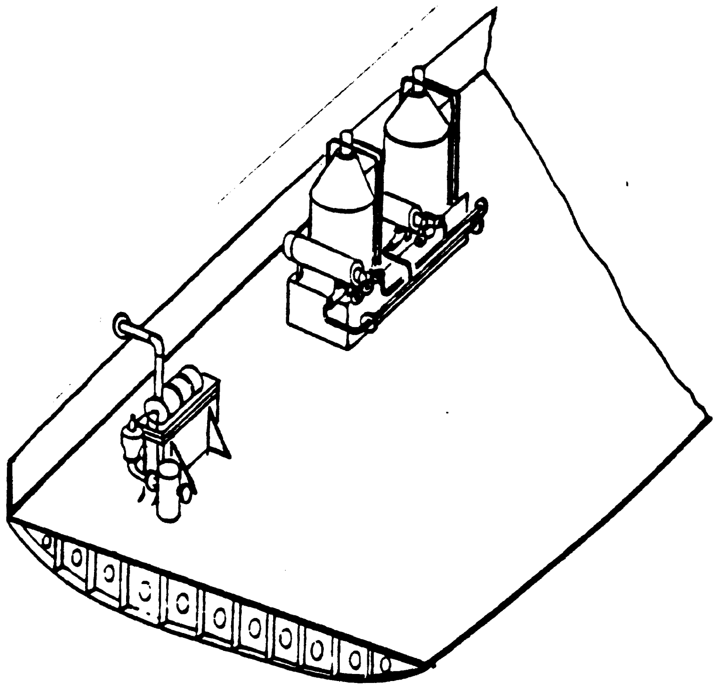


Figure 2-9 Three Types of Zone Outfitting

- fragile components and water-vulnerable components that are impractical to be fitted on-unit, such as joiner panels, insulation, etc.; items subject to damage from handling and weather;

- connection components between package units and hull units, such as pipe makeup pieces, cable, etc.

On-board outfitting is planned and scheduled zone by zone, subzone by subzone.

V. PLANNING INSTRUMENTS AND PROCEDURES

The basic approach to hull planning and scheduling begins before contract by the use of a document entitled Job Description At Each Stage In New Hull And Outfitting Engineering Procedure at A.S.I., referred to more simply as "Job Description At Each Stage Schedule." This document describes a meaningful and realistic approach to the planning and scheduling process.

A. Job Description At Each Stage Schedule

Figure 2-10 shows the overall effort in simplified format. It is important that the stages of the total contract requirements, as well as process lanes, be time phased to assure that adequate lead time is provided for all functions (Engineering, Production Planning, Purchasing, Moldloft, and Production Engineering) to perform their tasks in a timely manner.

Beginning very early during the marketing stage, predetermined meetings are conducted to review stage development, and these meetings continue throughout the duration of the contract.

As indicated on Figures 2-11 through 2-13, the "marketing" stage definitions are well detailed and provide key pieces of information necessary for all of the subsequent stages. The contract specifications, ships lines, and contract drawings are essential. The midship sections, scantling plans, and shell expansions provide much detailed planning information. Machinery arrangements and diagrammatics are needed for outfitting and hull planning development. The calculations and technical data developed at this time are essential to the following engineering stages. Preliminary procurement specifications must be started for resolution at contract.

One month after contract the second or "go" meeting is held with Engineering, Planning, and top management to assure that the preparation stage is progressing satisfactorily. See Figure 2-14.

As shown in Figure 2-15, four months after the "go" meeting, the third meeting referred to as the "K" meeting (or key plan stage) is held to assure that approvals from the regulatory bodies and the customer are available. At this time, key plans should be completed. A pallet schedule is issued at this time on all outfitting material for on-unit and on-board work.

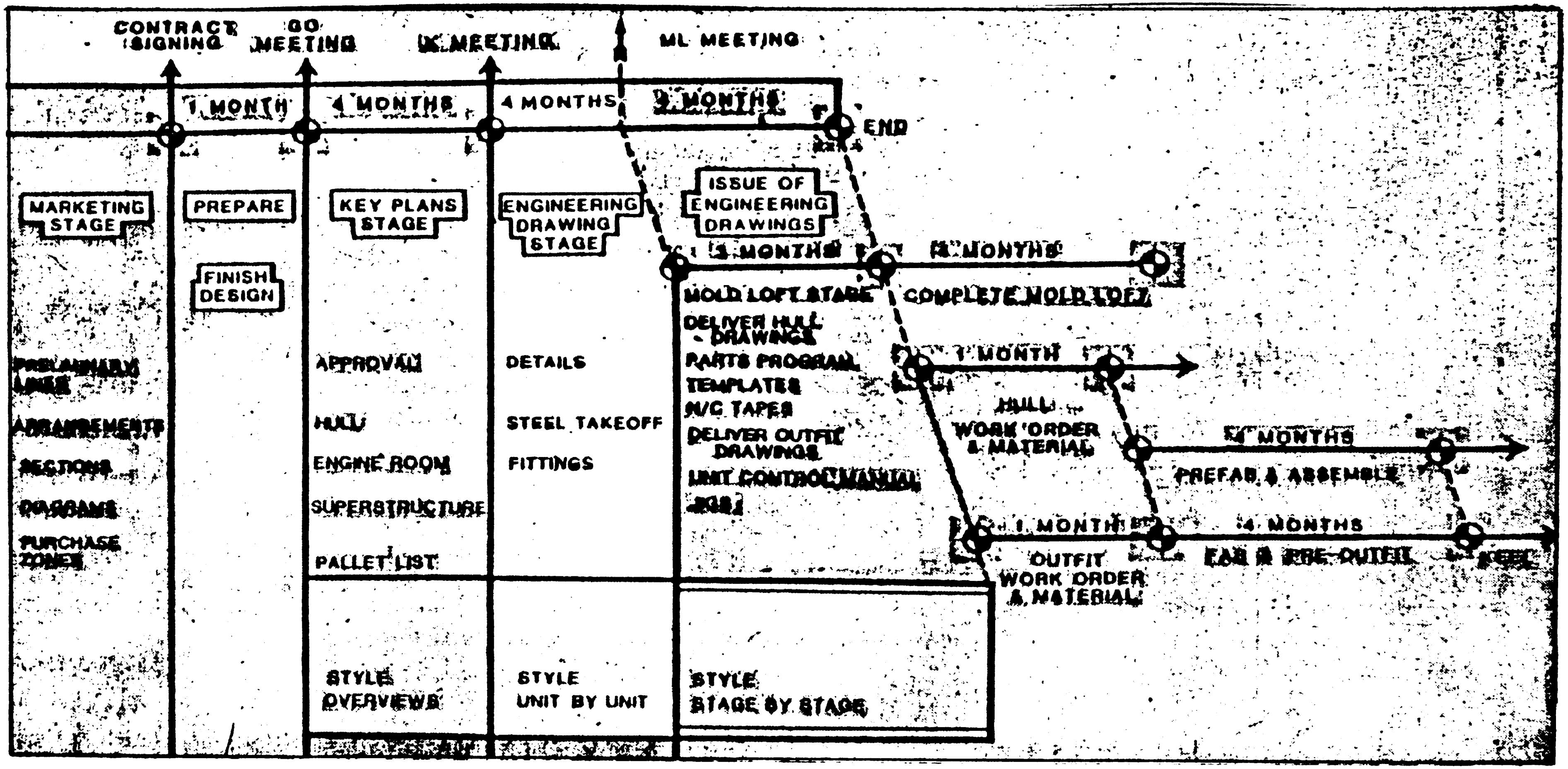


Figure 2-10 Hull and Outfitting Engineering Schedule

MARKETING

MARKETING STAGE DEFINITIONS

(A) – CONTRACT SPECIFICATION
- SHIP PROPORTIONS
- DRAWINGS
  - LINES
  - GENERAL ARRANGEMENT OF HULL AND MACHINERY
  - SUPERSTRUCTURE AND QUARTERS ARRANGEMENTS
  - MIDSHIP SECTION
  - SCANTLING SECTIONS
  - PRELIMINARY SHELL EXPANSION
  - CARGO OIL SYSTEM DIAGRAM (3)
  - INERT GAS, DEHUMIDIFICATION AND CARGO VENT DIAGRAMS (3) – 43 TANKS
  - ENGINE – RELATED AND OTHER PIPING DIAGRAMS
    - DIAG. MAIN ENGINE LUBE OIL SYSTEM
    - DIAG. MAIN ENGINE CYLINDER LUBE OIL SYSTEM
    - DIAG. LUBE OIL FILLINGS, TRANSFER AND PURIFIER SYSTEM
    - DIAG. STERN TUBE LUBE OIL SYSTEM
    - PIPING MATERIAL SCHEDULE
    - DIAG. ENGINE ROOM BILGE & BALLAST SYSTEM
    - DIAG. SEGREGATED BALLAST SYSTEM
    - DIAG. FEED AND CONDENSATE SYSTEM
    - DIAG. FIREMAIN – ENGINE ROOM
    - DIAG. FIREMAIN – ACCOMMODATIONS
    - DIAG. FIREMAIN AND FOAM SYSTEM – MAIN DECK
    - DIAG. CENTRAL FRESH WATER COOLING SYSTEM
    - DIAG. MAIN ENGINE JACKET WATER COOLING SYSTEM
    - DIAG. MAIN ENGINE PISTON COOLING WATER SYSTEM
    - DIAG. MAIN ENGINE FUEL VALVE COOLING WATER SYSTEM

Figure 2-11 Marketing Stage

– DIAG. MAIN SEA WATER COOLING SYSTEM
– DIAG. AUXILIARY SEA WATER COOLING SYSTEM
– DIAG. VENTS, SOUNDING TUBES AND OVERFLOWS
– DIAG. STEAM SYSTEM
– DIAG. SHIP'S SERVICE, STARTING AND CONTROL AIR SYSTEM
– DIAG. FUEL OIL SERVICE SYSTEM
– DIAG. FUEL OIL FILLING, TRANSFER, AND PURIFICATION SYSTEM
– DIAG. DIESEL OIL SYSTEM
– DIAG. FUEL, SLUDGE AND MAIN ENGINE CLEANING SYSTEMS
– DIAG. TANK HEATING COILS

– CALCULATION OR OTHER TECHNICAL DATA
- WEIGHT ESTIMATE
- LONGITUDINAL STRENGTH
- HYDROSTATICS
- TANK CAPACITIES
- BONJEANS CURVES
- INTACT TRIM AND STABILITY DATA
- LOADING CONDITIONS
- DAMAGED STABILITY EVALUATION
- WAKE SURVEY
- RESISTANCE AND SELF-PROPELLED TESTS
- ELECTRIC LOAD ANALYSIS
- ELECTRIC ONE LINE DIAGRAM
- VENT SYSTEM DEVELOPMENT AND DUCT OPENING

Figure 2-12 Marketing Stage (Continued)

CONTRACT

– PROCUREMENT SPECIFICATIONS

MAIN PROPULSION ENGINES
DIESEL GENERATORS
CARGO OIL PUMPS
BALLAST PUMPS
WASTE HEAT BOILER
ANCHOR WINDLASS
MOORING WINCHES
INERT GAS SYSTEM
DEHUMIDIFICATION UNITS
LUBE OIL, FUEL OIL, AND DIESEL OIL PURIFIERS
PLATE HEAT EXCHANGERS
ENGINE ROOM CONSOLE
CARGO SYSTEM CONSOLE
ELECTRIC MOTORS FOR CARGO PUMP
BOW THRUSTER
STEERING GEAR
BLENDING UNIT
AUXILIARY OIL FIRED BOILER
FUEL OIL PUMP / HEATER SETS

– OTHER REQUIRED DATA

✓ INITIAL REGULATORY BODY REVIEW
✓ PRELIMINARY UNIT DEFINITION
✓ IDENTIFICATION OF CONSTRUCTION METHOD
✓ ESTABLISH OUTFITTING ZONES FOR PURCHASING
✓ STUDY AND PRELIMINARY ASSIGN PACKAGE UNITS
ON-BOARD AND ON-UNIT MATERIAL

Figure 2-13 Marketing Stage (Continued)

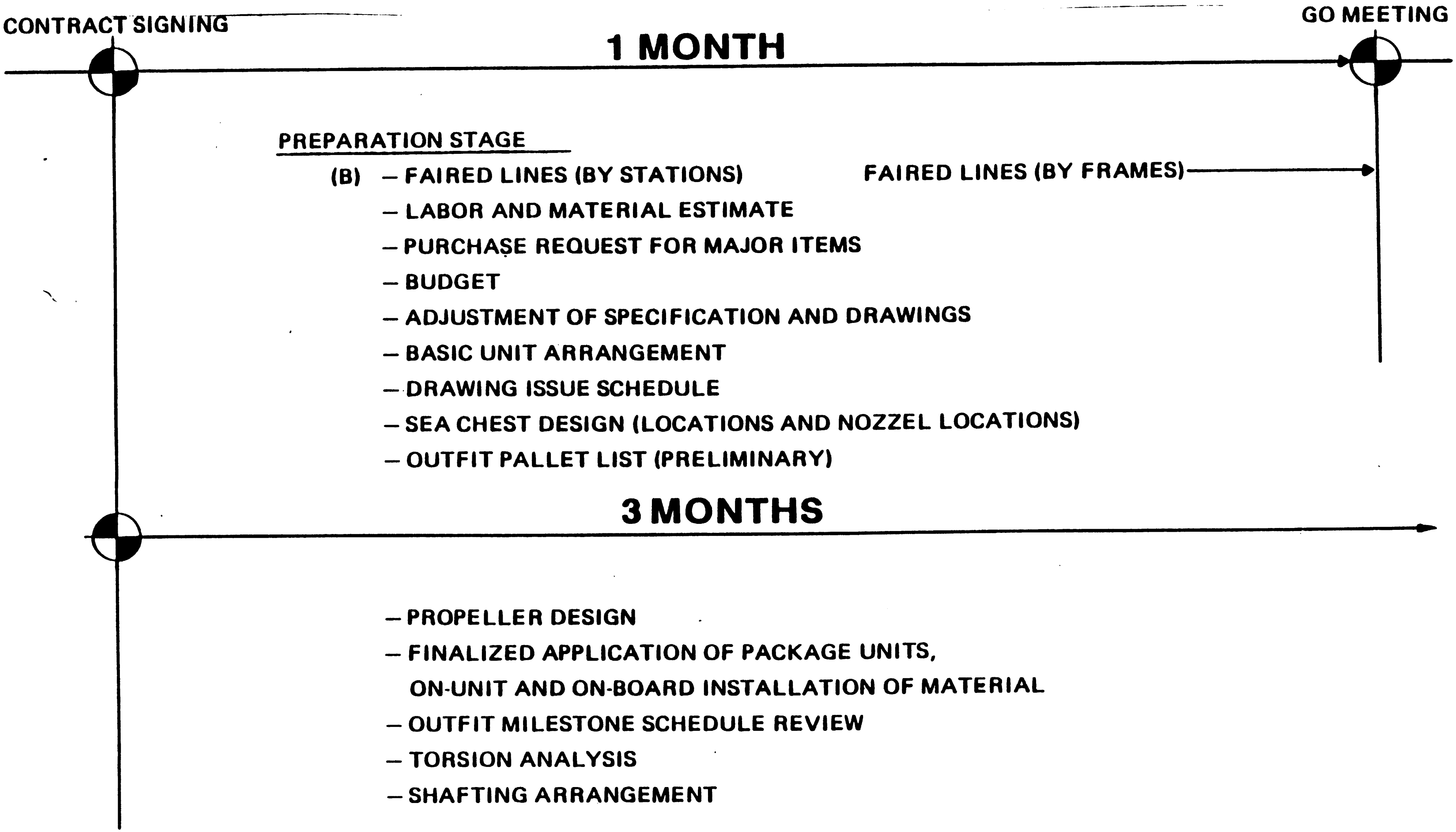


Figure 2-14 Contract to "GO" Meeting

GO MEETING — 4 MONTHS — K MEETING

2 MONTHS: KEY PLAN CARGO BLOCK

1 MONTH: AFT, PEAK AND E. R. SUPERSTRUCTURE

1 MONTH: FORE BODY FWD. OF CARGO BLOCK

KEY PLAN STAGE

- FRAME BODY PLAN (BASED ON FAIRED LINES)
- SHELL EXPANSION
- FORE CONSTRUCTION
    - DECK, FLAT AND STRINGER
    - ELEVATION (LONGITUDINAL BULKHEAD AND GIRDER)
    - EVERY FRAME SECTION AND TRANSVERSE BULKHEAD
- HOLD CONSTRUCTION
    - DECK AND FLAT
    - ELEVATION
    - EVERY FRAME SECTION AND TRANSVERSE BULKHEAD
- ENGINE ROOM AND AFT CONSTRUCTION
    - DECK AND FLAT
    - ELEVATION
    - EVERY FRAME SECTION AND TRANSVERSE BULKHEAD
- SUPERSTRUCTURE CONSTRUCTION
- SET UP OF SPADE DATA BASE
- APPROVAL OF REGULATORY BODY AND OWNER
- FINAL UNIT ARRANGEMENT AND LIST
- 70% – 75% STEEL BILLED – BUY STEEL AS NEEDED
  DETERMINE PLATES TO BE FURNACED BY "K" MEETING
- ISSUE FINAL OUTFIT MILESTONE SCHEDULE
- ISSUE FINAL PALLET LIST

STYLE OF DRAWING:
OVERVIEW OF STRUCTURE

Figure 2-15 "GO" Meeting to "K" Meeting

Four months after the "K" meeting, hull drawings are issued to the Moldloft to start its unit control manuals. A meeting is held at this time, called an "ML" (Moldloft) meeting, to ensure to top management that this schedule is being followed. See Figure 2-16.

Parts programming, templates, numerical control tapes, outfitting drawings, and jig instructions are delivered to Production, starting three months later.

The eight months between the ML meeting (end of month number 9) and keel laying (end of month number 17) are divided into the following activities, as shown in Figure 2-17:

- Moldloft production of work plan	3 months
- Issue of work orders and assembly of material	1 month
- Fabrication, subassembly and assembly of units	4 months

B. <u>Processes and Functions of Hull Planning and Scheduling</u>

To keep productivity high, primary planning and scheduling should be developed beforehand for the following stages:

- material procurement
- fabrication
- subassembly
- assembly
- erection

The work in these stages should be executed in accordance with planning and scheduling instructions. These instructions should be issued to each group that has the same nature of work and should be the bible of hull construction. In other words, the plan and the schedule should drive the work and not allow the work to drive the plan or the schedule.

The basic process for hull planning is:

- to divide a hull into units to meet the best requirements of the erection sequence;

- to assemble each unit with high productivity and quality, using a product work breakdown grouping.

The basic planning for unit sequence and unit erection is made by Avondale, using the IHI methods and considering the following:

- the choice of the first units to be put down (as a rule these are the engine room units to allow complicated outfitting to start early);

- the capacity of the cranes in assembly and erection areas;

- the area facilities in the assembly yard;

- maintaining the accuracy of the unit when turning for position welding;

K MEETING

ML MEETING

4 MONTHS

ENGINEERING DRAWINGS STAGES

- STRUCTURE DETAILINGS
- PENETRATION CUT-OUT
- PIECE NAME
- STEEL PLATE TAKE-OFF
- UNIT PARTS LIST
- DEFINITION OF EDGE PREPARATION AND EXCESS
- SET UP OF PARTS DATA BASE
- SUB-UNIT BREAKDOWN
- HULL CASTING
- RUDDER SUPPORT SYSTEM AND RUDDER
- CLOSURES (DOOR AND WINDOW LIST)
- ANCHOR HANDLING SYSTEM
- MOORING ARRANGEMENT
- CARGO HANDLING SYSTEM
- SEA CHEST
- CARGO CONTAINMENT
- UNIT OUTFIT DRAWINGS DEVELOPMENT AND PALLET L/M
- START WEEKLY OUTFIT MEETINGS – ENGINEERING AND PRODUCTION

STYLE OF DRAWING:

UNITS BY UNITS

Figure 2-16 "K" Meeting to "ML" Meeting

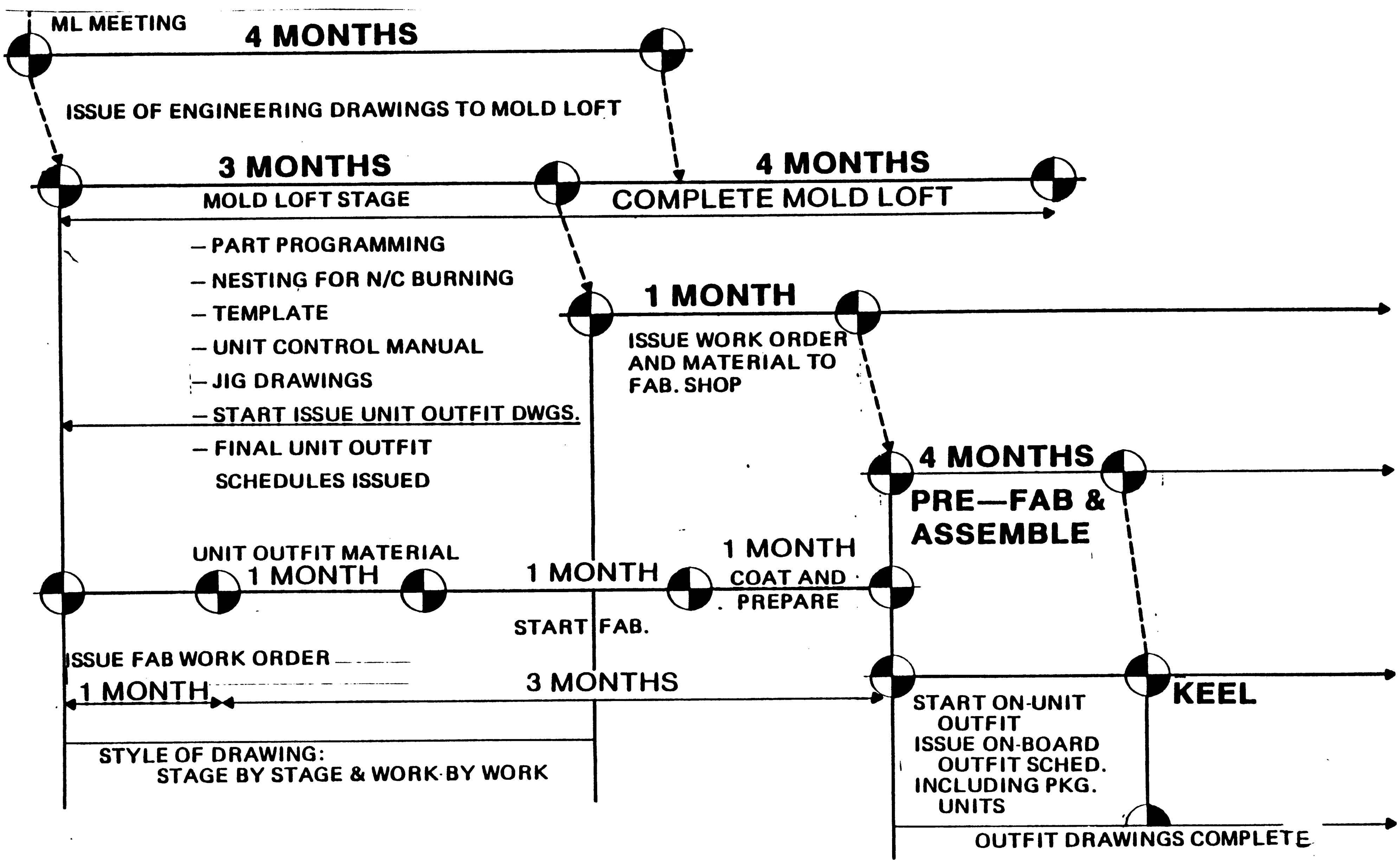


Figure 2-17 "ML" Meeting to Keel Laying

- the lengths (lineal feet) of fittings and welds required on each unit, which will determine their length of stay at each construction stage;

- the required on-unit outfitting;

- the size of the unit, which should be determined and adjusted with the outfitting schedule so that the merits of both hull construction and on-unit outfitting can be achieved.

The first hull document made is the "Preliminary Unit Definition," Figure 2-18, developed prior to the contract meeting. The unit arrangements are refined during the Preparation stage (Figure 2-14) and finalized in the Key Plan stage (Figure 2-15).

The key plans developed during the key plan stage are basically done in conjunction with the three main zones of the vessel shown in Figure 2-19:

- cargo block and fore body - Zone "D"
- engine spaces and aft construction - Zone "M"
- superstructure - Zone "A"

Also during this period, 70 to 75 percent of the required steel is requisitioned, and the number of steel plates that have to be furnaced is determined by the Moldloft. Every effort is made at this time to standardize as many units as possible in the area of the flat midbody.

An order of sequence in unit erection is then established and charted on an erection sequence master diagram, shown in Figure 2-20. The erection sequence is designed to provide an evenly distributed grouping of units that fall into a regular cadence of erection. This permits the use of the same people and the same equipment in predetermined and production line type of erection sequences. Note that a similar cadence occurs with longitudinal bulkheads, transverse bulkheads, deck sections, and side shells. This type of cadence also allows a maximum efficient movement of personnel, from ship to ship in multi-vessel construction, performing the same jobs.

C. Subunit Breakdown

Subunit breakdown planning is developed by the lead hull production planner in charge, giving every consideration to the following:

- hull unit categories
- fitting sequence
- fitting jigs (pin and fixed), facilities, etc.
- welding processes
- subassembly and assembly areas

The next step taken by the lead hull planner is the division of the ship's units into hull shape categories described in Figure 2-5. These categories become the keystone for establishing the process lane method of hull construction.

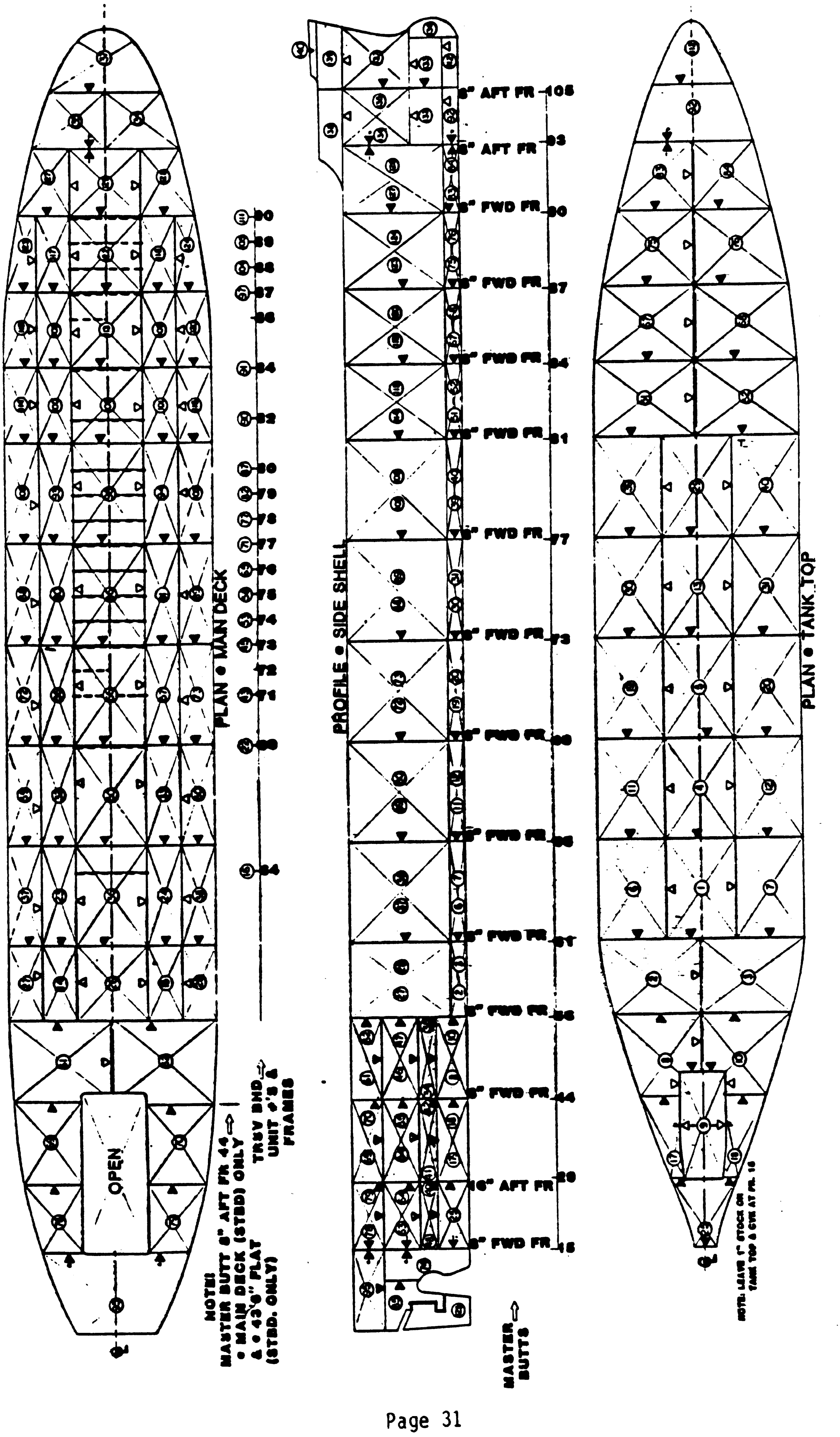


Figure 2-18 Preliminary Unit Definition

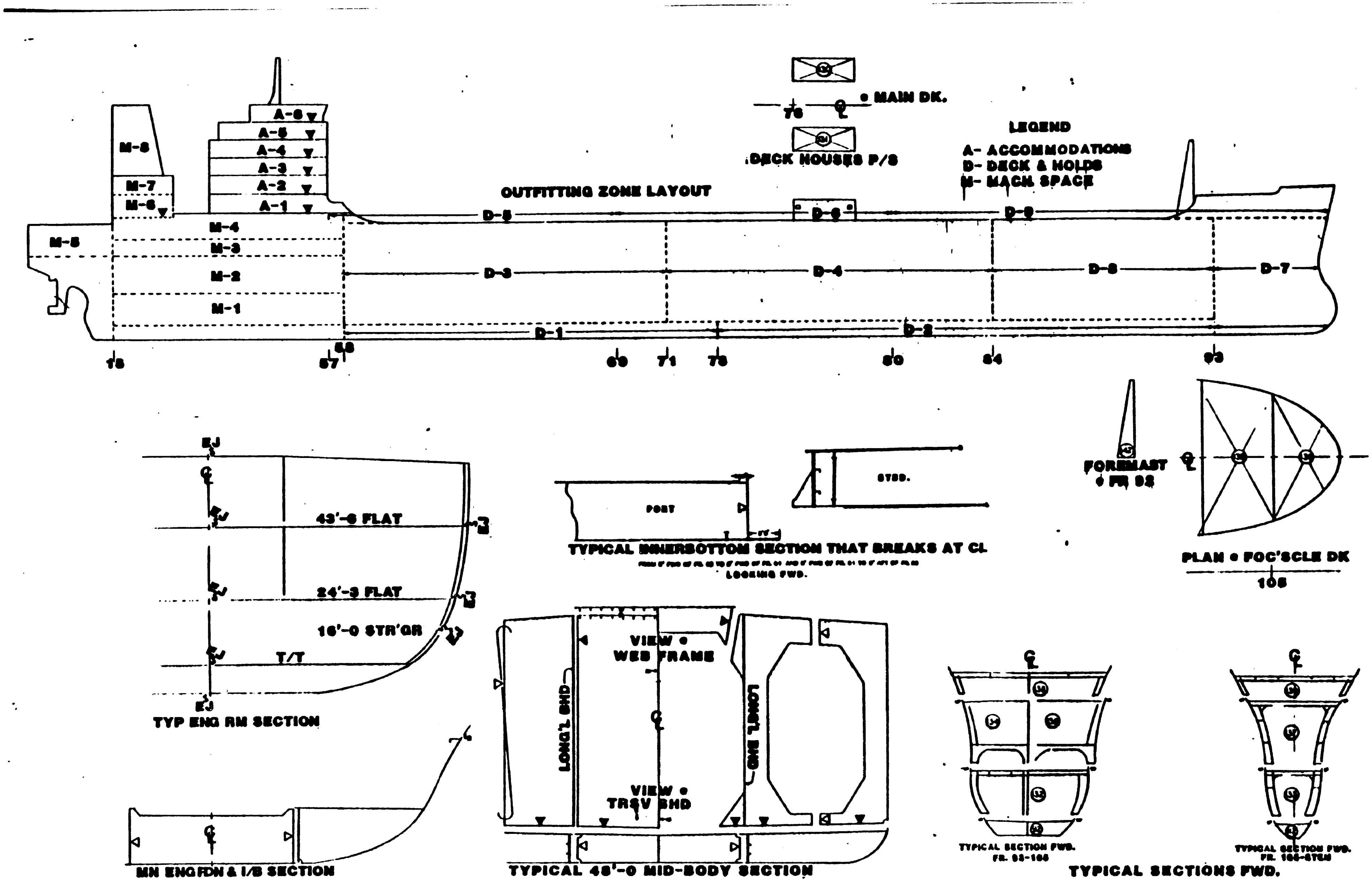


Figure 2-19 Preliminary Unit Zones

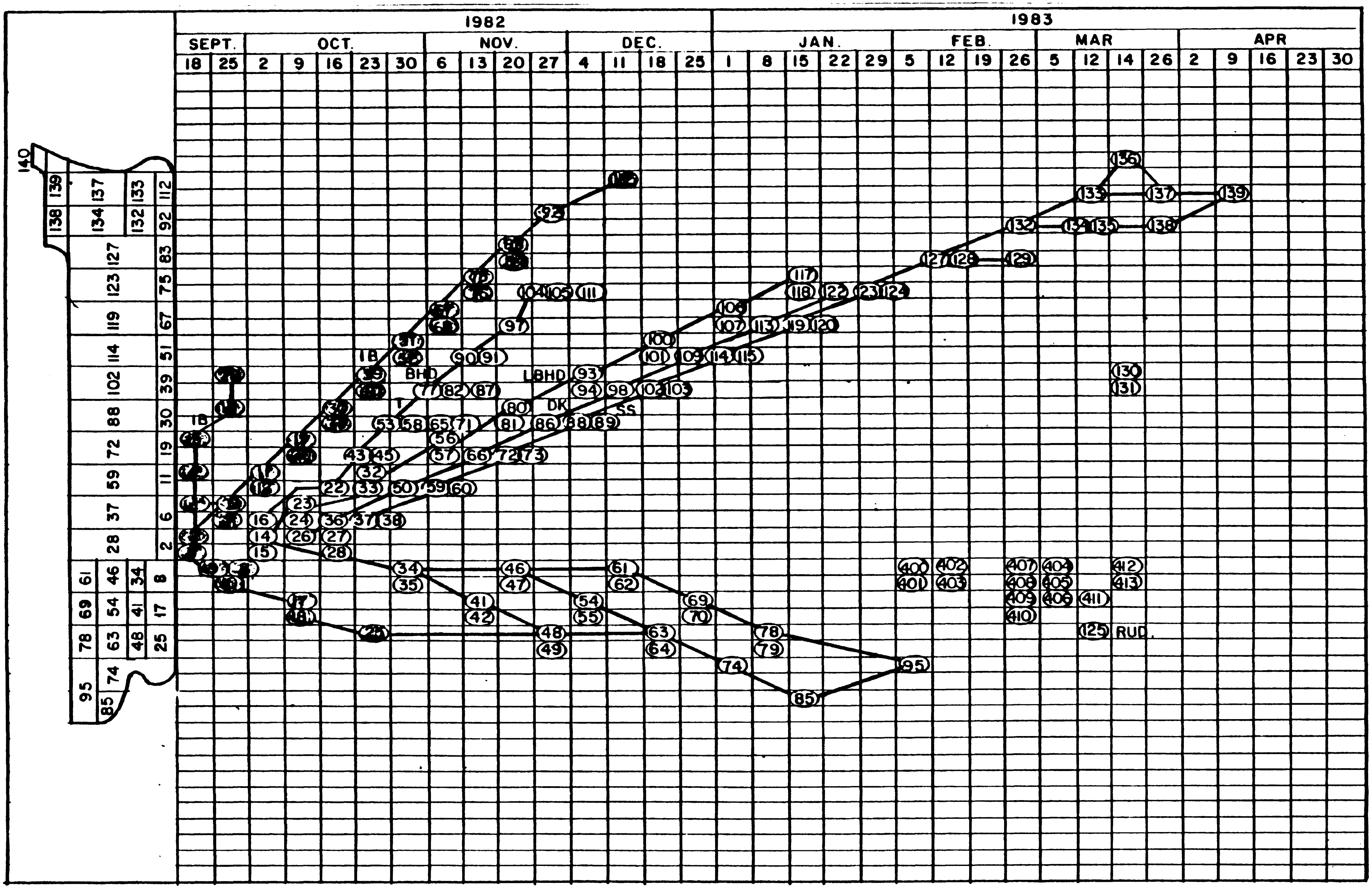


Figure 2-20 Tanker Erection Schedule

These units are further divided into subassemblies, partial subassemblies, and pieces. Using this as a basis, the lead hull planner then starts writing his construction method instructions in great detail, assigning partial subassemblies, subassemblies, and main assemblies to the specific manufacturing process lanes as generally depicted by Figures 2-21 through 2-24.

The above planning produces a document called "The Unit Breakdown Summary Sheet." Figure 2-25 is a partial writeup of Unit No. 36 (a deck section) and the routing and work instructions for processing the unit from start of construction to blast and paint.

This document takes into consideration the following:

- classification of parts (partial subassemblies, subassemblies, assemblies, pieces, etc.),

- lines and type of weld connections,

- beveling of welded edges,

- extra stock for adjustment,

- provisions for accuracy control,

- preoutfitting and blast and painting.

Rationalization and standardization of the work packages in this manner improves construction productivity and encourages new and better methods through repetitive operations. The unit breakdown summmary sheets for each unit become the work instructions to hull engineers and draftsmen to make the detailed unit-by-unit yard plans which are sent to the Moldloft with a unit parts list.

D. Unit Control Manual

With the yard plans and unit parts list, the Moldloft then creates a work instruction booklet for each unit called a "unit control manual."

The unit control manual is made in the form of a booklet of drawings and instructions so that it can be easily divided and distributed to each work group in each of the stages of process lane construction on a need-to-know basis. This unit control manual is discussed in more detail in Chapter 4.

At each lane and at each stage, controls are assigned to shop planners. The shop planners must control the daily schedule unit by unit, looking ahead approximately six to eight weeks. This monitoring of the short-term schedule is based on the long-term schedule developed by the Production Planning Department. These schedules are used by the platen foremen to determine the weekly work load. Thus, the unit subassembly and assembly process progresses on schedule up to and including erection, each stage of which becomes one section of the hull construction method.

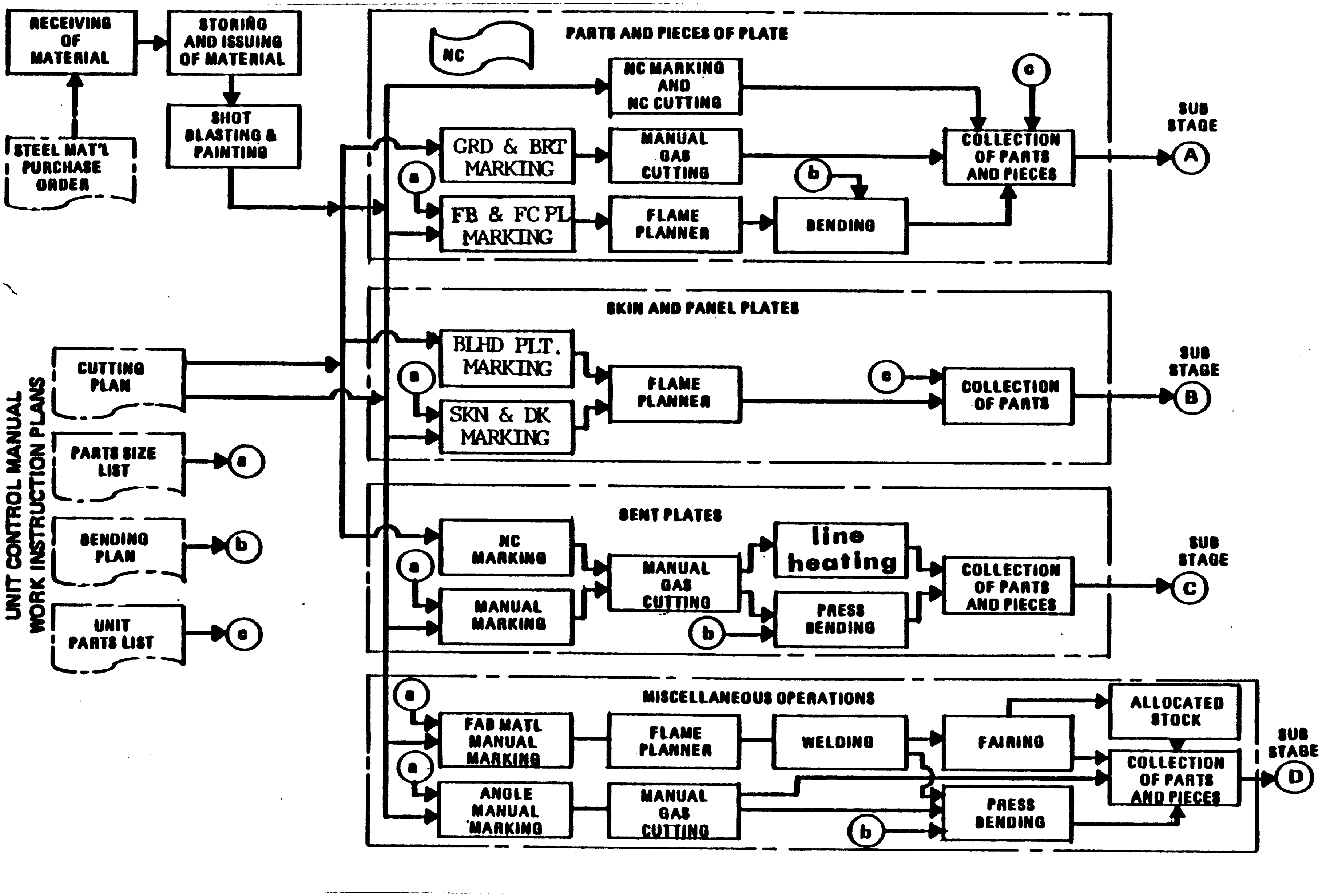


Figure 2-21 Process Lanes for Prefabrication Stage

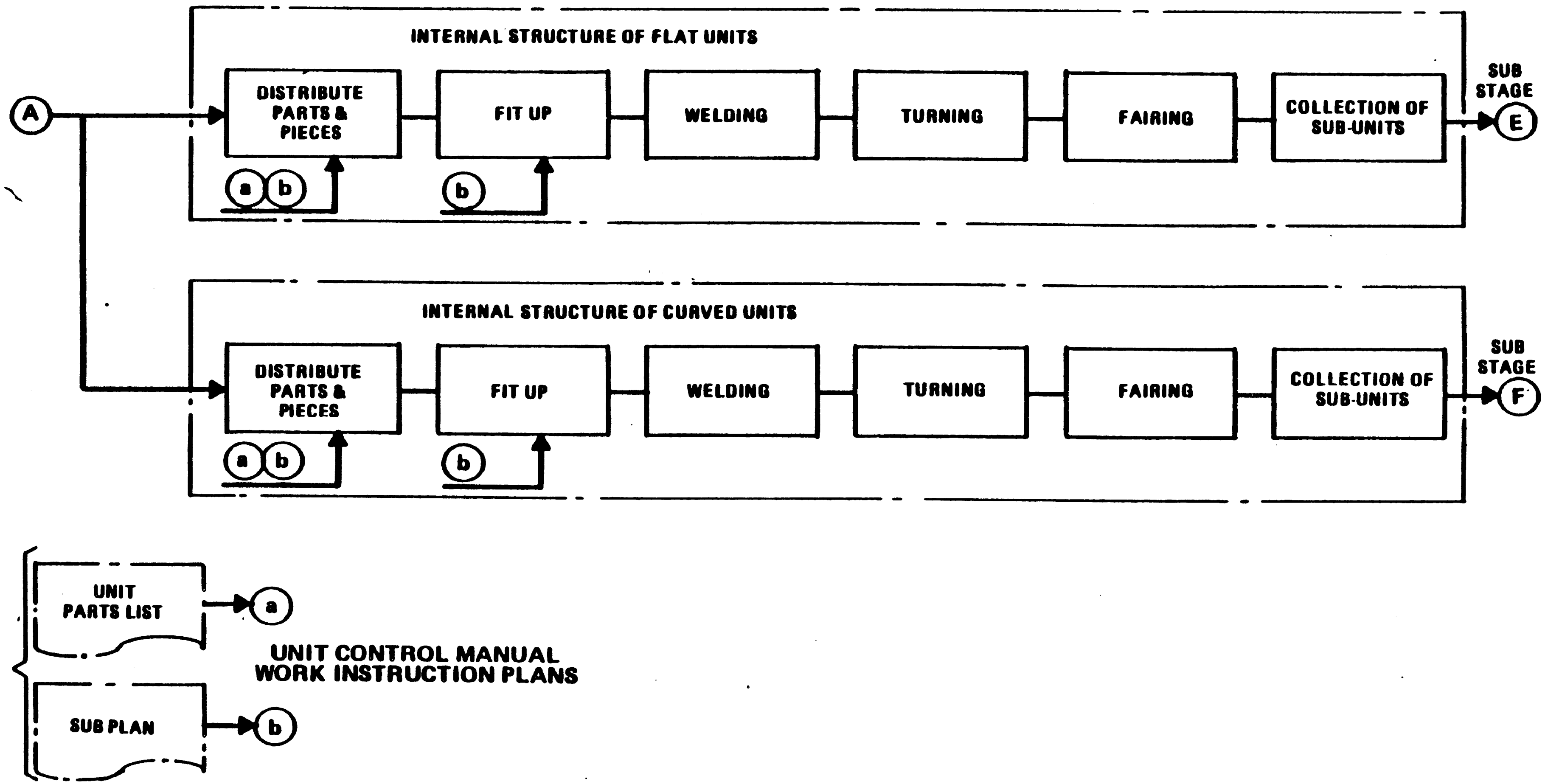


Figure 2-22 Process Lanes for Subassembly Stage

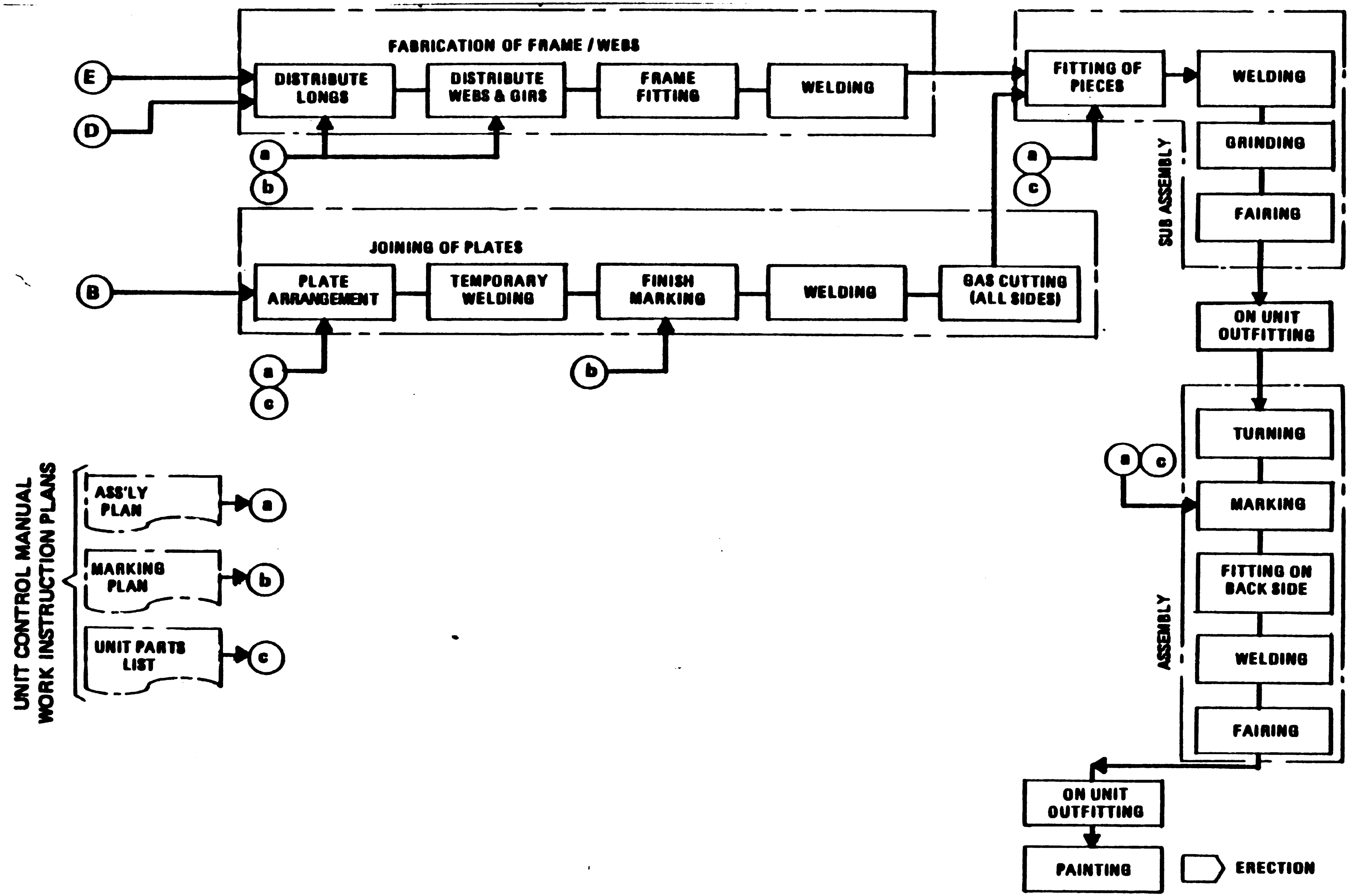


Figure 2-23 Process Lanes for Assembly Stage (Flat Units)

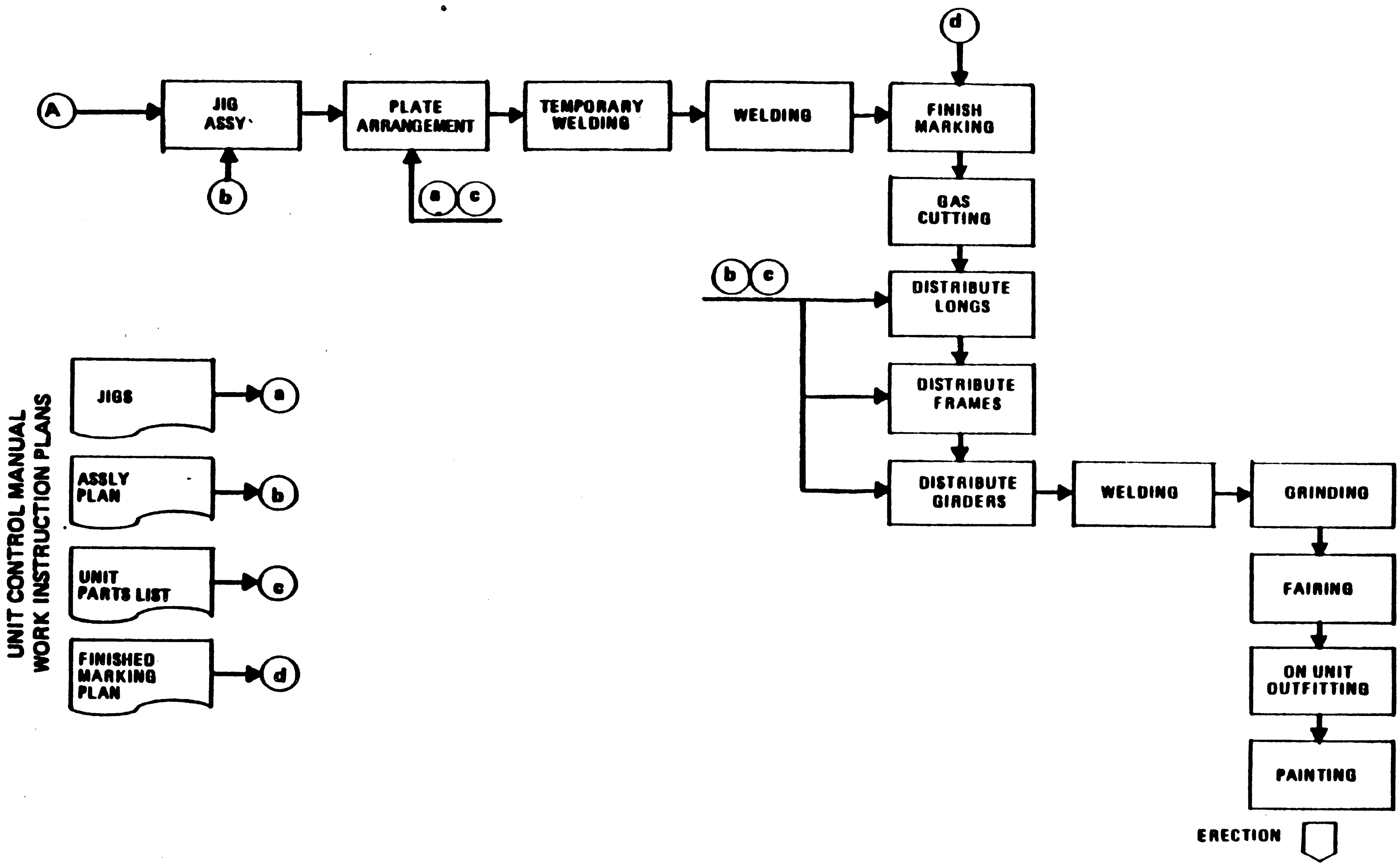


Figure 2-24 Process Lanes for Assembly Stage (Curved Units)

UNIT #36 (CATEGORY #1) WGT (TONS) 38.0
DATE: 03/03/82 REV. #2

CENTER SECTION OF MAIN DECK FROM 8" FWD. OF FR. 61 to 8" FWD. OF FR. 65
(48'0"x35'8½")

A. PARTIAL SUB UNIT #036-001-001
WORK CENTER — PLATEN #23
FABRICATE AND PARTIAL SUB ASSEMBLE THE CENTER SECTION OF TRANSV. DK. WEB AT FR. 62, WITH WEB FR. BKTS.

(1) 036-001-002 — WEB FR. 62
(2) 036-001-003 — BKT. ON CL.
(3) 036-001-004 — BKT. 7'11¼" OFF CL. PORT
(4) 036-001-005 BKT. 7'11¼" OFF CL. STBD.

B. PARTIAL SUB UNIT #036-001-006
WORK CENTER — PLATEN #23
FABRICATE AND PARTIAL SUB ASSEMBLE THE CENTER SECTION OF TRANSV. DK WEB AT FR, 63, WITH WEB FR. BKTS.

(1) 036-001-007 — WEB FR. 63
(2) 036-001-008 — BKT. ON CL.
(3) 036-001-009 — BKT. 7'11¼" OFF CL. PORT
(4) 036-001-010 — BKT. 7'11¼" OFF CL. STBD.

Figure 2-25 Portion of Unit Breakdown Summary Sheet

E. Assembly Stage Planning

This stage consists of the assembly of subunits from various process lanes and panel lines into larger and complete hull units. As previously mentioned, the grouping of these unit assemblies is by category and is dependent on the following:

- the supporting facilities of the area (flat jigs for flat units, fixed and pin jigs for curved units);

- the staying time in process as determined by outfitting lengths, welding lengths, preoutfitting, etc.

The assembly step sequences, days required for each step, crane hours, etc., are determined and graphed as shown in Figure 2-26. This is the basic scheduling network that is typically used for all parts from cutting to erection.

F. Blast and Paint Planning

Planning and scheduling the coating system is just as much of the total hull picture as scheduling the hull and outfitting stages. The goal is to accomplish as much surface preparation and undercoating as possible during hull construction and prior to the vessel's being erected.

Zone painting methods will vary, depending on many factors, such as:

- shipyard space for unit storage,
- capacity of cranes,
- construction methods.

About 70 to 80 percent of painting is done before launch in the zone painting method, compared to only 45 to 50 percent using previous panel construction methods. This achieves safer work and higher productivity once the vessel has been launched, and greatly reduces the use of blowers, scaffolds, etc., on board.

G. Erection Stage Planning

Defaults at this stage can affect the ship's launch date and delivery; therefore, special attention should be paid at this time to safety. Scheduling of the erection stage is the key to all of the preceding steps.

The work sequence of the erection stage is that of joining hull units together for each tank or zone according to the erection schedule. At this time, the units lose their individual identity and begin to become part of the zone.

The erection stage is divided into a series of substages as follows:

(1) Unit erecting
(2) Shipwrighting
(3) Scaffold erecting
(4) Main structure fitting
(5) Main structure welding

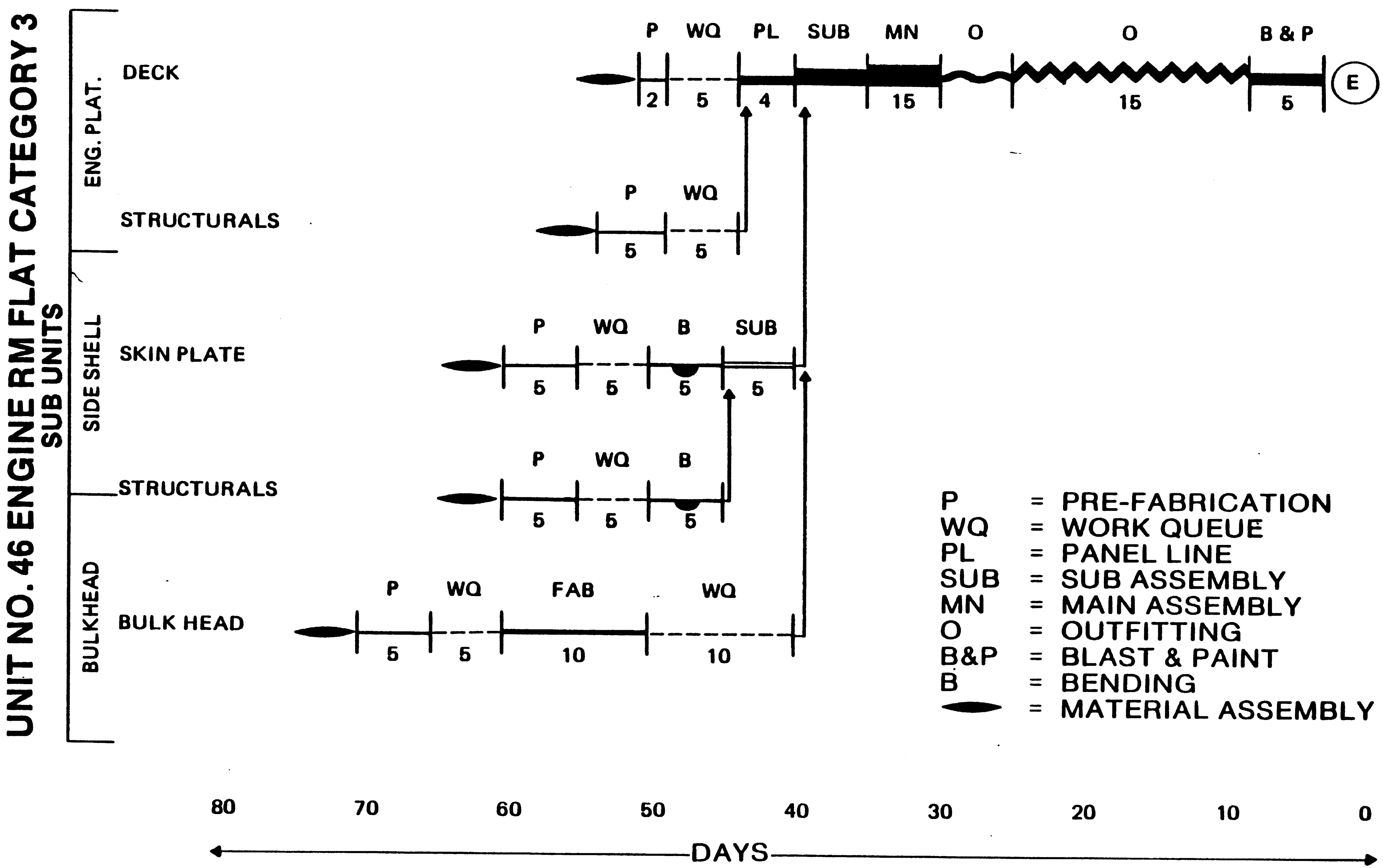


Figure 2-26 Assembly Stage Planning

(6) Sub structure fitting
(7) Sub structure welding
(8) Cleaning
(9) Internal visual inspecting
(10) Scaffold removal
(11) Air test
(12) Painting (coated tanks)
(13) Water test
(14) Completion

These substages are listed and scheduled for each tank, zone, and subzone and are generally performed by the same grouping of personnel per stage: a shipwright crew, a rough fitting crew, a finish fitting crew, a welding crew, an inspection crew, a testing crew, and a painting crew.

The erection substage work should be completed with no work remaining. Unfinished work negatively influences the total shipbuilding process; it is especially detrimental in engine room, boiler room and cargo oil pump rooms. To illustrate the cost of unfinished work, an example was taken from one particular ship of a contract and is shown in Figure 2-27.

For every ton left to be finished after launch, the cost is more than doubled. The costly delays to other crafts are not shown here, but they become perhaps the most serious.

The progress and productivity of each tank and each zone completion are checked at Avondale by the erection shop planners. This includes checking the progress of each trade by utilizing its particular parameter of gauging progress, such as feet of fitting, length of welding, weight of pipe, numbers of pipe pieces, square feet of paint, and so on.

VI. PRODUCTION OUTFITTING PLANNING PROCEDURE

The phrase "outfit planning" describes the planning and scheduling necessary to install and test and operate all the components of a ship, other than the hull structure.

Concurrent with the hull planning and scheduling activities described previously, the Production Outfit Planning Group develops the information, documents, and schedules needed to implement zone outfitting. Outfit planning begins early, before contract signing, and requires frequent interaction of outfit planners, with hull planners, engineering planners, and other departments. The steps and procedures for outfit planning during precontract and contract stages are described below.

A. Precontract

- As early as possible in the precontract negotiating period, the Production Planning Department establishes the major milestone dates of keel, launch, and delivery. After contract signing, these dates are shown in the Master Yard Schedule.

THE TOTAL COMPARATIVE COST OF HULL WORK PRIOR TO LAUNCH AS OPPOSED TO COST OF HULL WORK AFTER LAUNCH

	BEFORE LAUNCH	AFTER LAUNCH
FIT WELD HYDRO CHIP & GRIND	42.6 M/H PER TON	96.3 M/H PER TON

APPROXIMATELY 10% OF THE TOTAL TONNAGE OF THE VESSEL WAS LEFT TO BE FINISHED AFTER LAUNCH AND AMOUNTED TO FITTING - WELDING - CHIPPING - GRINDING - AIR TESTING - WATER TESTING AND INSPECTION.

Figure 2-27 The Cost of Unfinished Work After Launch

- Production Outfit Planning then develops the zone outfitting master planning schedule, which is a schedule of schedules, activities, and events.

- Production Planning receives, from other departments:

    - Contract specifications
    - Midship section
    - Scantling plans, sections, and details
    - General arrangement
    - Machinery arrangement
    - Key system diagrams

- The ship is then divided into large purchasing zones by Outfit Planning for the advance ordering of material and equipment. A date for the earliest required items is assigned to each zone. The document entitled "Advanced Purchasing Zones" is shown in Figure 2-28. It is one of the standard planning and scheduling tools used by ASI. This document is sent to the Engineering and Purchasing Departments prior to contract signing. Long-lead-time material is ordered at this time by component and by diagrammatic system. The ordering takes place long before working drawings are completed. For these advanced orders, material lists are produced for each zone and each subzone shown on the document.

- Production Hull Planning develops the preliminary unit arrangement, with master butts, and develops the preliminary prefabrication and subassembly schedule and the main assembly and erection schedule, as described previously.

- Production Outfit Planning and the Engineering Outfitting Sections decide on the preliminary application of:

    - machinery package units;

    - pipe package units;

    - the various types of on-unit outfitting (innerbottoms, flats, etc.);

    - zone outfitting on board.

B. <u>Contract Signing</u>

- Production Outfit Planning develops the detailed zone arrangement and the preliminary pallet list.

- Engineering develops the Preliminary Drawing Schedule, which is submitted to Production Planning for need dates.

- Production Outfit Planning develops the Master Milestone Construction/Zone Outfitting Schedule.

- The Hull Construction and Milestone Schedules are reviewed by Production Operations, Production Engineering, and Production Planning, and joint meetings are held to finalize them.

LEGEND

ZONE "M" - MACHINERY SPACE

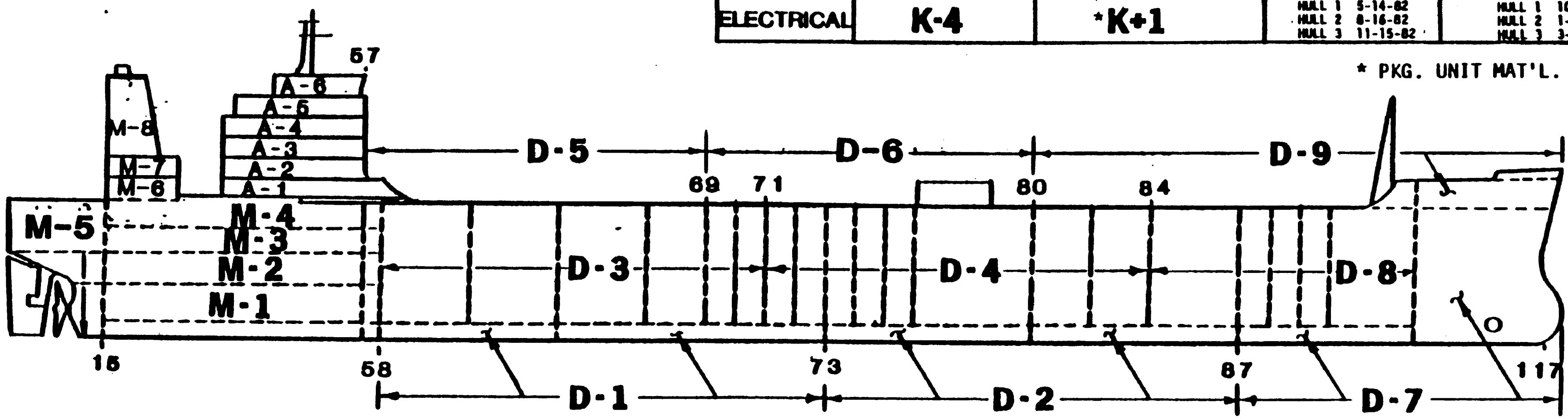
ZONE "A" - ACCOMMODATIONS

ZONE "D" - DECK & HOLDS

1

OUTFITTING MATERIAL - ADVANCE PURCHASING ZONES				
ZONE	STANDARD TIME		DATES	
	FAB MAT'L.REQ.	PURCHASED ITEMS REQ.	FAB MAT'L.REQ.	PURCHASED ITEMS REQ.
D-1,D-2,D-3 D-4,D-5,D-6	K-4 MONTHS	K-2 MONTHS	HULL 1 5-24-82 HULL 2 8-16-82 HULL 3 11-15-82	HULL 1 7-19-82 HULL 2 10-11-82 HULL 3 1-10-83
M	K-4	K-3	HULL 1 5-24-82 HULL 2 8-16-82 HULL 3 11-15-82	HULL 1 6-21-82 HULL 2 9-13-82 HULL 3 12-13-82
A	K	K+2	HULL 1 9-14-82 HULL 2 12-7-82 HULL 3 3-1-83	HULL 1 11-8-82 HULL 2 1-31-83 HULL 3 4-25-83
D-7,D-8,D-9	K+1	K+2	HULL 1 10-11-82 HULL 2 1-3-83 HULL 3 3-28-83	HULL 1 11-8-82 HULL 2 1-31-83 HULL 3 4-25-83
ELECTRICAL	K-4	*K+1	HULL 1 5-14-82 HULL 2 8-16-82 HULL 3 11-15-82	HULL 1 10-11-82 HULL 2 1-3-83 HULL 3 3-28-83

* PKG. UNIT MAT'L. K-3



C1-0015
EXXON PRODUCT CARRIER

LENGTH O.A.	635'-6"
BREADTH MLD.	105'-10"
DEPTH MLD.	60' 0"

	KEEL	LAUNCH	DELIVERY
NO. 1	9-14-82	5-14-83	10-15-83
NO. 2	12-7-82	8-6-83	1-7-84
NO. 3	3-1-83	10-29-83	3-31-84

PRODUCTION PLANNING JAN. 1981

Figure 2-28 Advance Purchasing Zones

- All the schedules previously discussed are submitted to upper management for approval and, upon approval, are distributed to the yard.

- Unit construction plan is finalized by Production Hull Planning at a series of meetings with Production Operations, Outfit Planning, Moldloft, Engineering, and all other interested parties.

- Outfit Planning begins publication of the Unit Outfitting Synopsis, a brief description of the outfitting procedure for each unit.

- The Pallet Schedule is finalized by Production Outfit Planning and issued to the yard.

- The Engineering Drawing Schedule is finalized and weekly meetings begin between the Engineering Outfitting Sections, Production Hull and Outfit Planning, and Production Operations to review and discuss as they develop:

  - advance design composite sketches,
  - the working drawings,
  - pallet codes and the pallet lists of material.

- Outfit Planning begins publication of the "Unit Outfitting Lists of Material" and the "Zone Outfitting Lists of Material."

- Work orders are issued by Production Engineering, and the fabrication, sorting, collection, and packaging of outfitting material begins.

- On-unit and package unit outfitting begins.

- On-board outfitting begins.

- Production Outfit Planning issues the Compartment Completion and the Machinery Testing Schedule, which is developed from information contained in the Master Milestone and Pallet Schedules and from the Test Memoranda developed by the Quality Assurance Section of Engineering.

VII. DEVELOPMENT OF SCHEDULES

There are basically three types of schedules:

- the master yard schedule
- long-term schedule
- short-term schedules

Figure 2-29 shows the overall tree structure of schedules at Avondale. It also shows who is involved in schedule creation, and more important, who becomes responsible for the checking of schedule progress. This, in turn, breaks down all work effort into detail schedules for execution. Participation effort in making these schedules originates all the way from front line foremen and mechanics to middle and upper management.

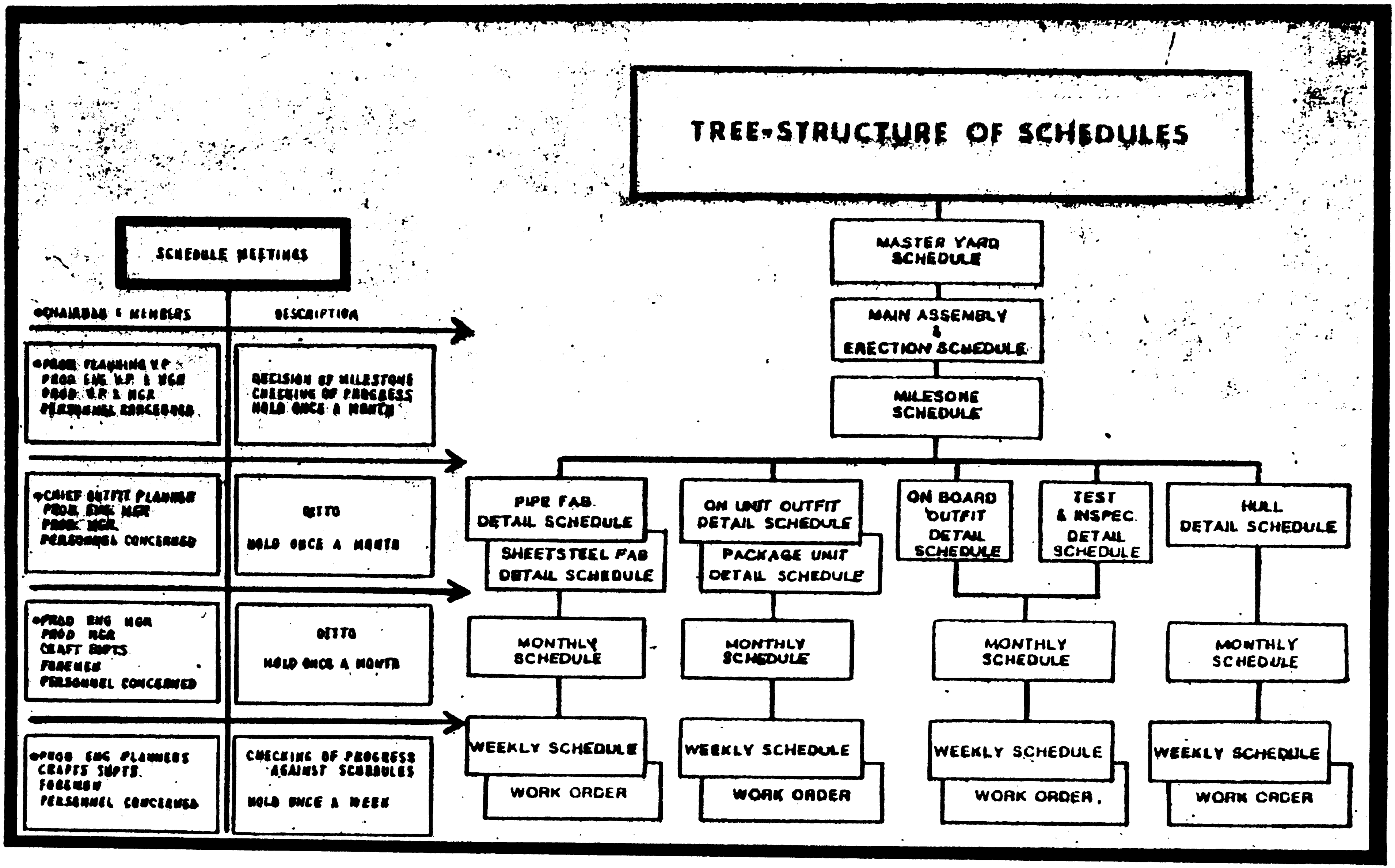


Figure 2-29 Tree Structure of Schedules

It is extremely important that schedules be:

- REALISTIC That is to say, safely within the maximum loading capability of the facility and personnel.

- RECOGNIZED This means they are official documents of top management and can be changed only by top authority.

- RESOLUTE This indicates they are regarded by all employees as steady and determined work guides.

Figure 2-30 is a list of some of the types of schedules made and their distribution in vessel construction at ASI.

A. The Master Yard Schedule

The master yard schedule defines the long-term scheme of the assembly, based on the ship construcion program of all contracts in progress. The master schedule sets forth not only the assembly stage operation but the shipyard operation policy. Therefore, this schedule is fundamental in establishing each production stage schedule in the shipyard. The following items are indicated on the master yard schedule.

1) Ship construction program for each contracted vessel:

a. Keel laying
b. Launching
c. Delivery

2) Erection and assembly weight per month, based on past experience.

3) Accumulative erection and assembly weight curves by vessel.

The function of the master yard schedule is to give management the following:

- an understanding of the necessary manhours and required assembly area,
- ability to make adjustments to the assembly platform capabilities,
- ability to adjust manpower to suit hull construction schedules.

B. Long-Term Assembly Schedule

The functions of the long-term assembly schedule are as follows:

- To support smooth relationships between production stages. It is very important, for example, that relationships between fabrication, prefabrication, and assembly be as smooth as possible.

- To level-load the work volume at each assembly stage. The work volume for units, subunits, partial subunits, and pieces should be established at this time. The necessary number of manhours can then be calculated. The work centers are level-loaded, based on standard manhour requirements for fitting, welding, and other tasks obtained from control charts called category recap sheets.

TYPE SCHEDULE	PURPOSE & USE	GENERATED BY	DISTRIBUTED TO	FREQUENCY OF
MASTER YARD SCHEDULE	TOTAL WORK LOAD INDICATOR PROJECT UP TO 3 YEARS	PRODUCTION PLANNING	TOP MANAGEMENT	MONTHLY
JOB STAGE DESCRIPTION FOR HULL & OUTFIT ENGINEERING	ESTABLISH NEED DATES FOR INFOR & DWGS. CONTRACT ORIENTED	ENGINEERING PRODUCTION PLANNING & ADVANCED PRGMS.	TOP MANAGEMENT	PRE-CONTRACT
HULL UNIT BREAKDOWN	IDENTIFY MODULAR SECTIONING OF SHIP	PRODUCTION PLANNING	TOP MANAGEMENT ENGINEERING PRODUCTION PURCHASING	PRE-CONTRACT
ADVANCED PURCHASING ZONES	PROJECT STANDARD ZONE DELIV. DATES	PRODUCTION PLANNING	DITTO	PRE-CONTRACT
MASTER MILE STONE	ESTABLISH ALL KEY EVENTS AND ALL MAJOR MILESTONES	PRODUCTION PLANNING	DITTO	AFTER CONTRACT AND MONTHLY UPDATE
PALLET SCHEDULE	ESTABLISH STAGE CODES AND DATES FOR MATERIAL PALLETS	PRODUCTION PLANNING	DITTO	AFTER CONTRACT
MAIN ASSEMBLY AND ERECTION	ESTABLISH ERECTION SEQUENCE AND UNIT IDENTIFICATION	PRODUCTION PLANNING	TOP MANAGEMENT ENGINEERING PRODUCTION	AFTER CONTRACT MONTHLY REVIEW
PRE-FAB & SUB ASSEMBLY	IDENTIFY LEAD TIME & STAGES OF FABRICATION	PRODUCTION PLANNING	DITTO	AFTER CONTRACT MONTHLY REVIEW
DRAWING SCHEDULE	IDENTIFY ALL DWGS AND ESTABLISH ALL NEED DATES	ENGINEERING	DITTO	AFTER CONTRACT
DRYDOCK & WHARF SCHEDULE	ESTABLISH DRYDOCK PERIODS AND WHARF TIME & LOCATION	PRODUCTION PLANNING	DITTO	MONTHLY
LONG-TERM PROCESS LANES	LONG TERM PRODUCT WORK BREAKDOWN FOR HULL WORK	PRODUCTION PLANNING	DITTO	AFTER CONTRACT REVIEW MONTHLY
SHORT-TERM PROCESS LANES	SHORT TERM PRODUCT WORK BREAKDOWN FOR HULL WORK	FABRICATION SHOP PLANNERS	DITTO	AFTER CONTRACT REVIEW WEEKLY
COMPARTMENT COMPLETION	ESTABLISH COORDIN-ATED COMPLETIONS OF COMPARTMENTS	PRODUCTION FIELD PRODUCTION PLANNING	DITTO	AFTER CONTRACT REVIEW WEEKLY
MECHANICAL TEST SCHEDULE	ESTABLISH COORDIN-ATED COMPLETIONS OF TEST PROCEDURES	PRODUCTION FIELD PRODUCTION PLANNING	DITTO	AFTER CONTRACT REVIEW WEEKLY

Figure 2-30 Major Schedules Issued at ASI

- Make adjustments to the manhour scheme calculated for the purchasing of steel material and arrival designations.l

The following documents are required:

- Master Yard Schedule
- Erection Schedule
- Key Plan
- Unit Recap Sheets
- Unit Arrangement
- Platform Arrangement

First, the date that each unit is in its last day of construction is determined by the erection schedule, considering outfitting time and blast and paint time. This date for each unit is then transferred to the appropriate assembly stage chart. Using Category 1 as an example, the grand assembly schedule, which is the last assembly stage for Category 1, is the first schedule for which these critical dates are determined. When all the dates for each unit that goes to grand assembly are transferred to that chart, the first schedule can be prepared. The units are then level-loaded, considering the information in the unit recap sheets and the platform arrangement appropriate to the grand assembly construction stage.

After the grand assembly schedule is completed, ensuing schedules--final assembly, main assembly, preoutfitting, and subassembly and panel line--are made, each one depending upon the critical dates established by the previous construction stage schedule.

Then, from the panel line schedule forward in time, loading and dates are refined to ensure that critical dates are not in conflict and that work areas are not overloaded, adjusting the panel line schedule so as to accommodate the refinement of the various schedules.

An important point in accomplishing level loading is keeping in mind the capacities of work areas at each stage and backing off in time, where necessary, to meet critical dates without overloading those work capacities. Also important to level loading is the grouping and loading of similar work groups together. When the work is arranged in this manner, because the work groups are similar, the construction time periods are similar.

As these scheduling principles are applied to each individual category, the resulting sum is a level-loaded construction schedule for the duration of the contract.

These schedules are not meant to be an absolute final product. They are long-term assembly schedules and will be continually updated and refined as efficiencies change and as new contracts are taken into account. They are perfectly adequate at this stage for preparation of unit control manuals and templates, and for the scheduling of material purchases.

C. Long-Term Fabrication Schedule

After choosing which platens would be best suited to support each stage of construction using the process lane theory, the fabrication schedule for each fabrication line is determined from the subsequent subassembly schedule so that the partial subassemblies can be completed before the critical dates needed on the subassembly platen. Fabrication platens are divided into two fabrication lines for Category 1 units:

- Line 1 - Longitudinal bulkhead webs, side shell webs, transverse bulkhead and horizontal girders.

- Line 2 - Floors, girders, and small pieces.

D. Long-Term Bending Schedule

To ensure proper material flow to develop detailed shop schedules from raw materials to a finished product, there are certain factors required at each work center.

For bending schedules, the factors are:

- Need Dates: Using subassembly schedules and main assembly schedules, determine the date material is needed.

- Total number of plates and structurals that require bending:

  Using shell expansion drawings and Moldloft bending criteria, plates are classified as to the bending process.

- Total number of plates and structurals that require line heating:

  Using shell expansion drawings, Moldloft bending criteria.

- Total number of plates and structurals that require forming:

  Using shell expansion drawings, Moldloft bending criteria, and need dates for forming jigs.

- Length and thickness of plates:

  To determine work center or alternate work centers.

- Capacity of rolls and frame bender:

  Largest-smallest T.

- Production output at each work center:

  Capacity of rolling, frame bender, line heating and press.

E. Prefabrication Schedule

The prefabrication schedule should be made for each type of cutting machine or work area, such as structurals and flat bar prefabrication area. Therefore, in preparing the prefabrication schedule, the following should be included:

- Exactograph - for straight skin plates
- N.C. (3 axis) - for curved shell plates and internal plates
- N.C. (2 axis) - for internal plates
- Servograph - for small pieces
- Shearing - for small pieces
- Structural cutting area
- Flat bar cutting area

The prefabrication schedules are made up from three schedules--the panel line schedules, fabrication schedule, and the bending schedule--by deducting the number of days it will take for cutting, marking, punching, and stacking of material for the next stage.

F. Scheduling Mechanism and Network

The scheduling mechanism and network shows how each stage schedule is retained. A longitudinal bulkhead Category 1 chart (Figure 2-31) is an example. (An example for a different type of unit was shown in Figure 2-26.)

First, all units are broken down into subunits. Longitudinal bulkhead units are broken down into three subunits:

LONGITUDINAL BULKHEAD, which is a subunit that consists of:

1) Skin for longitudinal bulkhead,
2) Longitudinal for longitudinal bulkhead,
3) Internal members, such as web frames.

TRANSVERSE BULKHEAD is a subunit that consists of:

1) Skin for transverse bulkhead,
2) Longitudinal for transverse bulkhead,
3) Internal members, such as horizontal girders.

UPPER DECK, which consists of:

1) Skin plate for upper deck,
2) Longitudinal and headers for upper deck.

Then each individual piece is scheduled to allow a constant flow of material through each stage so that each piece can meet at the proper stage at the proper time to be fabricated and become a subunit and, finally, a unit.

On the scheduling and mechanism and network chart, everything is keyed to the erection date, at which time the unit has to be complete. Working backward in time, there are five days for the final outfitting stage. Prior to outfitting is grand assembly, to install the brackets and the trunk to the longitudinal

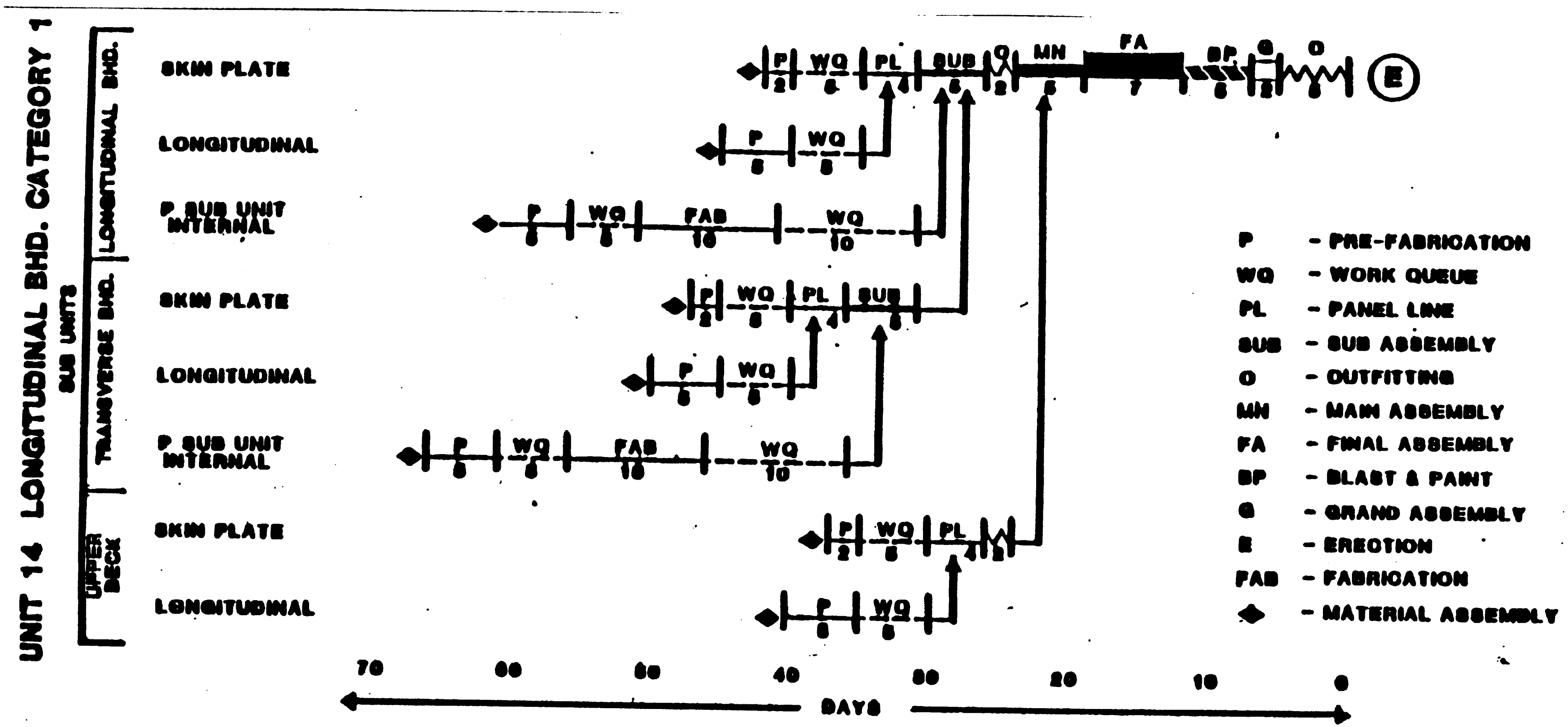


Figure 2-31 Scheduling Mechanism and Network

bulkhead (two days). Prior to grand assembly is blast and paint (five days), where the unit is sent through the shot blast and painted. Prior to blast and paint is the final assembly stage of seven days in which all welding, fitting, and outfitting of all the previous stages are to be completed so the unit can be inspected and accepted for blast and paint. Prior to final assembly is the main assembly stage, in which upper deck is joined to the longitudinal bulkhead and transverse bulkhead (five days). Prior to main assembly is the two-day preoutfitting stage for fitting subunits with piping, ladders, etc. Prior to the preoutfitting stage is a five-day subassembly stage in which the transverse bulkhead is joined to the longitudinal bulkhead.

The starting dates of each subunit are chosen so that each is completed in the same week at the main assembly stage.

In prefabrication, prior to subassembly, the longitudinal bulkhead, transverse bulkhead, and deck plating are on the panel line to install the stiffeners to the skin plates. Four days are allowed for each panel to be fabricated at the panel line.

Prior to the panel line and subassembly is a work queue period of five days for the skin plates and longitudinals and ten days for internals to make sure all material is available for the panel line. This also allows some time for unpredictable adjustments. For skin plates, prior to the work queue is the prefabrication period, when the skin plates are cut on the exactograph, allowing two days for cutting.

For longitudinals, five days are allocated for punching, marking, and cutting. Prior to the work queue on the internals is the fabrication period of ten days to fabricate the girders and web frames. Prior to fabrication of internals, another work queue is scheduled for five days to gather all material for fabrication. Prior to this work queue is prefabrication for the internals, during which the various pieces are cut to size.

G. Short-Term Schedule (Monthly-Weekly)

Production activities are based upon the long-term schedules. With the long-term schedules established, each shop planner can then prepare a short-term schedule based on the capacities of each machine and work area. The short-term schedules are issued on a regular basis, considering the following points:

- gives an understanding of the work progress status for prior and subsequent stages,

- indicates exceptions to normal routine working methods of items.

The objectives of the shop planner and short-term schedules are:

1) Material Control

a) Preparation of necessary material.
b) Identification of the previous stage, conditions, or status.

2) Process Control

a) Maintenance of the schedule by knowing

- status of material,
- status of units,
- scheme of manning flow,
- scheme of platform flow.

3) Accuracy, Safety, and Manufacturing Method Control

a) Achievement of an accurate unit.
b) Reduction of cost with safety.

4) Efficiency Control - Control Chart

a) Collection of data from work centers, for example:

- weight,
- welding/fitting lengths,
- consumed manhours.

Proper loading and use of these schedules should provide a steady flow of material and a constant work load throughout the shipyard.

H. Drawing Schedules

For zone outfitting to succeed, the engineering design effort must get off to a fast start, must peak early, and must remain intensive until completion. This can be accomplished only if the engineering effort is carefully planned and scheduled. At Avondale, the Engineering Planning and Scheduling Section consults with management and engineering section leaders and builds, maintains, and monitors engineering drawing schedules and material procurement schedules.

As early as possible, the "keys" to planning for vessel construction are developed by the Production Planning Department and the Advanced Programs and Hull Technical and Design Sections. These keys are:

Production Planning

- Production Major Milestone Dates
    - including the dates steel is required in the yard, start of prefabrication, start of main assembly (preoutfit), date of keel laying, date of launch, and date of delivery.
- Unit Arrangement.
- Zone and Subzone Arrangement.
- Prefab and Subassembly Schedule.
- Main Assembly and Erection Schedule.

Advanced Programs/Hull Technical and Design

- Specifications.
- Midship Section.
- Scantling Plan.
- Scantling Section and Details.
- General Arrangement.
- Machinery Arrangement.
- Systems Diagrams.

As the above planning keys are made available, the engineering sections review them and prepare a definition of the scope of work they must accomplish in order to provide Production with the necessary working drawings and other engineering data. This scope will include a drawing list which will indicate those drawings that Production will need and an estimate of the manhours required to prepare each diagram, drawing, and set of calculations. Also included in the scope is a list of the units for which composites will be made and the estimated hours needed for these composite drawings.

Key Plans are required for long-lead material procurement or to support other engineering disciplines. The Key Plan schedules are Gantt-type with symbols representing drafting activity, checking activity, and scheduled reviews with the Assistant Chief Engineer to monitor drawing progress.

Yard Plan schedules for the Outfitting Section are also prepared. Manpower requirements for the Outfitting Section for the scheduled job are counted for each week and the required weekly totals are shown for drafters and checkers. Manpower requirements are also determined for the accommodations composite activity and a Grand Total is shown. If the schedule is manned to the levels indicated, and if the estimated manhours for the drawing activity are reasonably accurate, then the schedule should be met.

Similar schedules and manpower estimates are made for drawings of the Hull (Key Plans and Yard Plans), Piping and Machinery Composites, and other engineering sections.

I. Drawing Schedule Monitoring

It is not enough to build schedules, issue them with management blessing, and then assume that the job will be done as scheduled. Schedules can slip due to alterations in work scope, change orders, inadequate manning, etc., or work can sometimes move along more rapidly than expected, thus accelerating the schedule. It is important for management that schedule activity be monitored closely and the results reported so that prompt corrective action can be taken if required.

In order to facilitate schedule monitoring and review, drawing schedules are displayed using magnetic labels on large porcelain boards in the Engineering Planning and Scheduling "Operations Room." In addition to displaying the schedule information, the large schedule boards also contain information on manhours actually spent on each drawing activity and other engineering activities.

Each week, Engineering Planning and Scheduling prepares a computer report for each schedule which shows the manhours expended against each drawing, as well as the total equivalent men who worked on that schedule. These actual manhours can then be compared with the scheduled ones to determine that sufficient manpower is being brought to bear where required. Total spending against each drawing is also monitored on the schedule boards so that the actual progress in terms of percent complete can be compared with percent of budget expended. If required, projections for manhours to be expended by drawing completion are revised at schedule reviews which are held in the Operations Room each week.

J. Material Procurement Schedule Preparation

The timely receipt of vendor information is critical to any design engineering process. It is even more critical to design which is supporting zone outfitting construction. For this reason, Engineering Planning and Scheduling builds "Material Procurement Schedules" for each engineering section. These schedules list each item that the engineering section is responsible for procuring and indicates when each item must be requested and when a purchase order must be placed. In order to build material procurement schedules, Engineering Planning and Scheduling requires the following information:

- "In Yard" production need dates (from Production Planning),

- Engineering vendor information need dates (from drawings schedules),

- List of material items and drawing on which material appears (from Material Requisitioning Section),

- Vendor lead time (from Purchasing Department).

When the above information has been received, Engineering Planning and Scheduling builds and issues initial material procurement schedules for each Engineering section.

The schedules show:

- Scheduled material requisition issue date,

- Actual material requisition issue date,

- Scheduled purchase order issue date,

- Actual purchase order issue date,

- Vendor "preliminary" information need date (this is vendor information typically available at P.O. issue),

- Vendor "detailed" information need date (this is vendor information typically not available until approximately 45 days after P.O. issue),

- Vendor manufacturing lead time,

- Production need date,

- Scheduled drawing submittal date.

Just as with the drawing schedules, careful monitoring is required for the material procurement schedules. Each week, Engineering Planning and Scheduling receives material update information from the Material Requisitioning Section and the technical engineering sections. This data is used to prepare a "Material Procurement Schedule Review Report" for each engineering section. An important feature of these reports is an indicator of "Trouble Area - Action Required" which is printed when actual dates of requisition, purchase order, or vendor information receipt fall behind the scheduled dates. Like the review reports used to monitor drawing schedules, the material schedule review report is designed to provide management with an instrument that can be used to easily spot problem areas.

VIII. SOURCE MATERIAL FOR CHAPTER 2

The following lectures in the Technology Transfer seminars were used as source material for Chapter 2. They are listed in the Appendix. Lectures 2, 3, 4, 5, 19, 20, 30, 33, 40, 41, 43, 44.

CHAPTER 3

DESIGN ENGINEERING FOR ZONE OUTFITTING

I. INTRODUCTION

The concept of a precontract effort in unit and zone outfitting methods of shipbuilding is perhaps the ultimate recognition of the many differences between Japanese and U.S. shipbuilding philosophies and working environments.

The majority of commercial ship contracts in Japan rely heavily upon previous ship designs, industry standardization, and gradual implementation of new technology, thereby resulting in a well defined ship design at time of contract. In contrast to this, the U.S. shipbuilding market offers only a limited number of new construction opportunities for widely varying types of vessels, each of which generally incorporates quantum jumps in technology over previous designs, making the effective use of previous design details limited at best. The method of ship contracting in the U.S., the issue of design responsibility between shipowner and shipbuilder, and the role of independent naval architecture firms all contribute to uncertainty in many key aspects of a ship design during the proposal and contract negotiation stage.

These uncertainties in a basic vessel design generally have two pronounced implications for the shipyard. The first issue is a scarcity of complete and workable details of the ship design, which makes the preparation of accurate cost estimates risky. The second major issue, although not totally independent of the first, is the lack of sufficient technical information at the time of contract to enable rapid engineering development to proceed as necessary to accomplish the goals of unit and zone outfitting.

It is extremely important to recognize the overall scheduling concept associated with unit and zone outfitting to understand the combined impact on the engineering scheduling effort. It is expected that the total construction period from keel laying to delivery for a unit outfitted ship will be significantly reduced as compared to a conventionally constructed vessel of similar configuration, enabling the shipyard to offer a quicker delivery with the vessel cost less subject to escalation. This savings in time is generally applied to the total contract time with theoretically no impact on the engineering lead time. However, the system of unit outfitting dictates that far more work must be completed by the time of keel laying, necessitating the start of prefabrication several months further in advance of the keel laying date than in conventional construction methods, resulting in a shortened engineering lead time. The unit outfitting methodology also requires that a far greater level of engineering be complete at the start of prefabrication so that all possible work is accomplished on-unit.

In unit and zone outfitting methodology, the scheduling of key plans becomes of critical importance, because these drawings are intended to depict all aspects of the vessel design which are necessary for detail drawing development during the yard plan stage. The concept of key plans is really not a new idea to U.S. shipbuilders, as the vessels' principal design drawings have been referred to as key plans by the U.S. Maritime Administration for many years.

For a typical commercial ship construction program with a twenty-eight month construction period, the engineering lead time period is twelve months prior to prefabrication. This twelve-month period would generally be divided into a five-month key plan stage and a seven-month yard plan stage. There are obviously overlaps in that time frame, with many of the key plans scheduled for completion within the first month or so after the contract, and the five-month period representing the completion of all designated key plans.

The determination of which drawings are to be identified as key plans is done during the initial preparation of a drawing list and is the basis for the first drawing scheduling effort for any engineering section. In general, any drawing which depicts design details of the vessel in way of arrangements or system configuration or is necessary for the procurement of long lead-time material will be designated as a key plan.

One pitfall which must be avoided in making key plans is placing too rigid an interpretation of drawing completion during the key plan period. If drawings are configured in a more or less conventional fashion, many key plans will require information which is not available as yet due to lack of vendor information or additional development work required. This must not be allowed to hold up the distribution of the design information aspects contained on the key plans, as this information has been integrated into detailed schedules and is needed by other sections to start their effort. This potential problem can be overcome by the use of separate design sketches which later form the basis of a yard plan, or by the creation of additional drawings whose scope is limited to the design details.

A good example of this is the area of compartment and arrangement drawings, where on commercial contracts ASI does not produce a final compartment and access drawing but rather a complete general arrangement drawing. To satisfy the needs of the key plan period, sketches called "compartment and access studies," with information limited to that needed by others at that time, were created. These same drawings would be ultimately expanded to become the general arrangement drawings to be prepared during the yard plan period. In other areas, such as piping diagrams where virtually all the data are needed early by other segments of the shipyard, the drawing is completed to the maximum extent feasible, with outstanding vendor data or other information, which is not truly needed by others at that time, held in reserve. The important concept is that there must be excellent communication during this design period, so that no one waits to issue a final perfect plan to the detriment of others who require valuable data.

In order to support unit outfitting requirements, the quantity of engineering information required has grown substantially, adding to the burden of time. The added levels of engineering for each discipline will be covered in this chapter.

II. IMPACT OF ZONE OUTFITTING ON OVERALL ENGINEERING EFFORT

A. Six Major Innovations in Engineering

Zone outfitting has an effect on all engineering sections and disciplines. Figure 3-1 shows this impact in six important areas.

Figure 3-1 Six Major Innovations in Engineering

- MODIFICATIONS TO ENGINEERING APPROACH (FABRICATION/INSTALLATION DRAWINGS ARE NO LONGER SYSTEM-ORIENTED)
- MORE DATA IS DISPLAYED ON EACH DRAWING
- NUMBER OF DRAWINGS PRODUCED IS SIGNIFICANTLY INCREASED
- PACKAGE UNIT GROUP ESTABLISHED
- SCHEDULE ADHERENCE BECOMES CRITICAL
- OVERALL WORK SCOPE INCREASED

(1) Modifications to Engineering Approach

There are a number of significant changes in the approach to development of drawings which are either necessary or desirable to most effectively adapt to the revised techniques involved in unit-oriented construction.

Analyzing the Engineering efforts during the detail design phase yields the conclusion that there are three basic processes:

(a) Final System-Level Design
(b) Selection of Equipment
(c) Fabrication and Installation Design

The time periods of Process (a) and Process (b) greatly overlap, while Process (c) must follow the other two. The first of these may be known as the Key Plan Stage. Key plans are those necessary to define the system design in sufficient detail to satisfy regulatory body and owner requirements, as well as to support the preparation of technical specifications for equipment and material procurement. In general Processes (a) and (b) are not conceptually different from conventional shipbuilding practice.

It is in the development of the fabrication and installation drawings that the approach to the design effort is significantly different. In the conventional approach, these drawings were system oriented. The entire fire main would be detailed in one drawing; another piping system would be shown in a separate drawing. Structural drawings were essentially presented to production personnel deck by deck, bulkhead by bulkhead, and frame by frame.

Zone-oriented engineering requires drawings that describe the units which will be built, not whole systems. The reason is obvious: the ship will be built unit by unit, so that's the way the production personnel need the information. That's the key to the whole philosophy of this design phase. The designers must be totally immersed in considering what information production people need at each stage of construction and in providing just that information in a format most useful to the production people. To do this, designers must have a complete understanding of precisely how each unit will be built, and then they must configure the systems in each unit so as to simplify that installation. This is accomplished by having Production provide a detailed, written, unit-by-unit description of how each unit will be constructed. Joint meetings of Engineering and Production personnel are held weekly to discuss the optimum timing of installation of each system - and the engineering drawings reflect those agreements.

Composite drawings of areas and spaces are extensively employed subsequent to the key plan effort and preceding the installation drawing effort to develop system routing and to assure that maintainability requirements are satisfied.

Fabrication drawings (pipe details, vent ducting, etc.) are developed unit by unit, rather than system by system, as a part of the installation drawing package. Component identification codes identify not only the unit on which the component will be installed, but the stage of subassembly or assembly of that unit which defines the building site at which the installation will take place. Thus, the drawing becomes a material control document in addition to all other functions.

In a further effort to orient the design product to the production worksite, most ASI drawings now are produced in "booklet" form, using many smaller sheets rather than fewer larger sheets to contain essentially the same information.

(2) <u>More Data is Displayed on Each Drawing</u>

In order for zone outfitting to be successful, the Engineering Department must be closely involved with the methods and sequences of production that are to be used. The "Unit Breakdown Summary Sheet" produced by Production describes in detail the intended methods to be used to manufacture each unit. This methodology must be carefully studied by each Engineering section and reflected on the drawings they produce. It is not enough to know that a run of pipe or a valve will be located in a particular spot on a certain unit, the installer must also be told at what stage in the unit's assembly that the components are to be located. The information required by Production relative to when equipment and components are to be installed must be shown on each drawing.

Information concerning material control must also be reflected on the drawings. In addition, certain work previously left for field accomplishment must now be reflected on the drawings, such as the detailing of small bore pipe (3/4" to 2") which was previously field run.

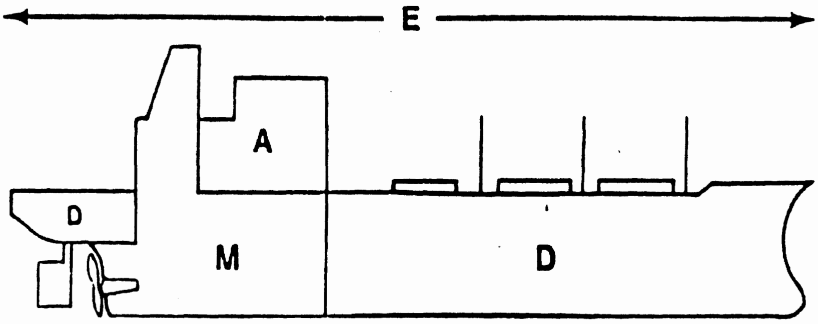
(3) <u>Number of Drawings Produced is Significantly Increased</u>

The preparation of drawings on a unit basis has greatly increased the number of drawings. As stated above, the total amount of information supplied is greater because of the added scope, but by no means is it in the same ratio as the increased number of drawings. Each drawing covers a smaller portion of the ship, as compared to the conventional method. There are only a few very large size drawings. Most of the drawings are of the booklet type.

The zone outfitting approach requires approximately twice as many drawings. The major reason for this is in the method of presenting the piping work. There are about three times as many piping plans for the zone-outfitted ship. This is because a piping arrangement drawing which may apply to two units is accompanied by two pipe detail drawings and two lists of materials, one each for each unit. Previously, the arrangement drawing would have included more units and would be accompanied by one pipe detail booklet and one list of material. The change is necessary because the pipe is fabricated by unit, then stored by pallet code to await installation. The list of material must be by unit to suit the pipe fabrication sequence.

(4) <u>Package Unit Group Established</u>

Some reassignment of work in the Engineering sections was necessary to better equip the Engineering Department to accomplish zone outfitting; however, there was no major reorganization. The most significant organizational change was to establish the Package Unit Group in the Mechanical Engineering Section. This group develops complete machinery package units for the machinery space. They detail the equipment foundations, gratings, and handrails, as well as the piping, instrumentation, etc. IHI consultants had recommended to Avondale management an engineering organization similar to theirs. Figure 3-2 shows the basic engineering organization utilized by IHI. It consists of four Engineering



IHI	AVONDALE
D - DECK	HULL
M - MACHINERY	MECHANICAL/PACKAGE UNIT
A - ACCOMMODATIONS	OUTFITTING
E - ELECTRICAL	ELECTRICAL

Figure 3-2 Organization of Engineering Departments

Groups: Deck, Machinery, Accommodation, and Electric. Such a change was not considered necessary at Avondale. Functionally, however, our current organization embodies some of these concepts. Examples are as follows:

- The newly established Package Unit Group handles all aspects of the Package Unit design.

- Our Outfitting Section essentially controls the arrangement and routing of all systems in the accommodation areas.

- The Mechanical Section controls the routing of all systems in the machinery space.

- The Hull Section still handles the steel superstructure and machinery space structure, except for the Package Unit foundations and support structure which is handled by the Package Unit group.

- The output of the Hull Section is the Yard Plans which are used by the Moldloft to produce the working drawings.

These procedures are very similar to the IHI concept. Regardless of the organization or how it is constructed, the most necessary ingredient is effective communication.

(5) Schedule Adherence Becomes Critical

Under the conventional system approach, a particular drawing had a required issue date based on when Production intended to start work on that system. Production work on the entire system may have spanned a considerable length of time. Under zone outfitting, the same amount of production work will be portrayed on many drawings. Each drawing, however, has a much more critical issue date, since work on that portion of the system is closely knit into the preoutfitting plan. This means that Engineering must very effectively plan the start, the progress, and the issue of all drawings and the support activities necessary to provide the information needed for developing these drawings. The Engineering Planning and Scheduling Section has been expanded to effectively handle this task.

(6) Overall Work Scope Increased

The use of zone outfitting at Avondale has increased the scope of the engineering job and, consequently, the engineering costs. However, it has been demonstrated that this increase has been more than offset by savings in manhours and time in production. The first use of zone outfitting in engineering involved a considerable learning period. Many operational procedures were established only through painstaking investigation and some trial and error. These costs will not be repetitive.

The next zone outfitting engineering job, the T-AO's for the U.S. Navy, has benefited greatly from experience. As methods are improved and all concerned become more familiar with the system, less information will be required from Engineering. It is also intended that many of the methods and details developed for this first job will become a standard on future jobs, thus reducing the engineering costs. It is anticipated that, as methods are standardized and improved over several jobs, the engineering costs may actually become equal to those under conventional methods. Of course, the savings in Production will also improve as their techniques are further refined.

B. Effects of Zone Outfitting Technology Common to All Engineering Sections

It is now possible to examine some of the specific effects of zone outfitting technology on the various Avondale Engineering sections. A number of these were common to a greater or lesser degree to all of the sections. Figure 3-3 lists six of these effects.

(1) Engineering Effort Must Begin and Be Completed Earlier Than in Conventional Design Methodology

The phrase "engineering essentially complete" can be used to illustrate the overall scheduling goal at time of prefabrication. Typically, the percentage of total engineering manhours spent at time of prefabrication increases from approximately 50 percent in a conventional construction system to approaching 75 percent in a fully unit outfitted concept.

The net effect of the overall vessel scheduling is a far greater level of engineering effort to be accomplished in a far shorter period of time. (See Figures 3-4 and 3-5.)

In order to provide the needed engineering response in light of a doubled level of intensity, it is imperative that a precontract level of effort be expended to properly position the engineering disciplines for this tremendous post-contract effort. The exact objectives of the precontract effort will obviously vary from program to program and will be decided by management in consideration of the business environment at that time.

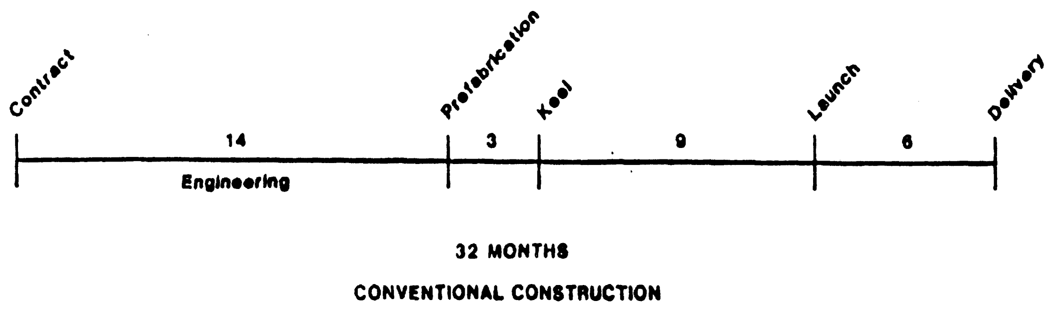
A prime consideration in the planning of the engineering effort must always take into account that with a level of effort twice that of a conventional contract, every post-contract uncertainty, design change, etc., has twice the impact, due to the rapid pace at which the engineering and installation details are being developed. It must be remembered that the precontract effort is virtually always funded at the shipbuilder's expense, and, therefore, the effort must be well managed and be as productive as possible.

Simply stated, the objectives of the precontract effort are to ensure that design parameters, contract requirements, construction methods, scheduling, and long-lead-time material needs are all well defined at time of contract such that the intense engineering effort can begin. The engineering effort immediately after contract is called the "key plan" stage, at which time all facets of the engineering design are to be finalized to enable unimpeded development during the yard plan stage. (See Figure 3-6.)

The overall effectiveness of the precontract period is largely controlled by the method of ship contracting and the commitment of the vessel's owner in participating in this endeavor with the shipyard. In competitive bidding situations, whether for private or government contracts, relatively little dialogue will be possible with the owner, and the shipyard's effort must be

Figure 3-3 Effects of Zone Outfitting on Engineering

- ENGINEERING EFFORT MUST BEGIN AND BE COMPLETED EARLIER THAN IN CONVENTIONAL DESIGN METHODOLOGY
- ROLE OF THE ENGINEERING AND PRODUCTION ORGANIZATIONS AS PARTNERS MUST BE STRESSED MEANINGFUL DIALOGUE IS ESSENTIAL
- ENGINEERING DRAWINGS ARE DEVELOPED AS UNITS, NOT AS SYSTEMS
- STRUCTURAL "KEY PLANS" ARE USED IN DRAWING DEVELOPMENT
- MATERIAL ON DRAWINGS MUST BE "PALLET CODED"
- ADVANCE ORDERING ON LONG-LEAD MATERIAL IS EMPHASIZED



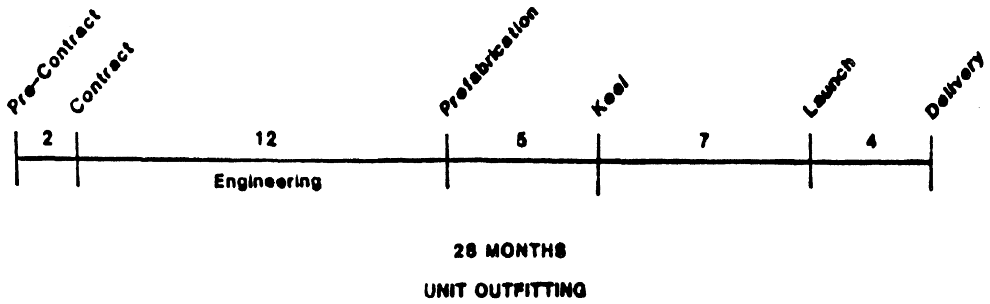


Figure 3-4 Impact of Unit Outfitting on Overall Scheduling

Figure 3-5 Intensity of Engineering Effort

CONVENTIONAL CONSTRUCTION

- **Total Engineering Manhours - - - - - - - - - - - - 350,000**
- **Percent Complete At Pre-Fabrication - - - - - - 60%**
- **Months From Contract To Pre-Fabrication - - - 14**
- **Manhours Per Month (avg) Prior To Pre-Fabrication- 15,000**

UNIT OUTFITTING

- **Total Engineering Manhours - - - - - - - - - - - - 500,000**
- **Percent Complete At Pre-Fabrication - - - - - - 80%**
- **Months From Contract To Pre-Fabrication - - - 12**
- **Manhours Per Month (avg) Prior To Pre-Fabrication - 33,333**

SUMMARY

- **Engineering Intensity More Than Twice As Great In Unit Outfitting**

Figure 3-6 Objectives of Precontract Effort

CONSTRUCTION & SCHEDULING

- Hull Unit Construction Arrangement
- Outfitting Zone Assignment
- Material Need Dates
- Package Unit Determination
- Drawing List & Scheduling
- Key Plan Determination & Scheduling
- Manpower Planning

MATERIAL REQUIREMENTS

- Purchasing Department Terms & Conditions
- Purchase Specifications For Major Equipment

CONTRACT PACKAGE

- Contract Specification
- Complete Contract Drawing Package
    - Piping Diagrams
    - General Arrangements
    - Structural Drawings
    - Electrical One-line
- Naval Architecture Calculations
    - Longitudinal Strength
    - Intact & Damaged Stability
    - Weight Estimate
    - Lines Plan

ADDED ENGINEERING EFFORT

- Model Testing
- Initial Regulatory Body Review
- Lines Fairing
- Ventilation System Development

adjusted accordingly. On the other hand, negotiated contracts with owners who have in-house technical staffs can result in precontract efforts that resolve numerous design details and pave the way for effective design development after contract.

(2) Role of the Engineering and Production Organizations as Partners Must be Stressed

In some respects, the listing of precontract objectives may seem routine, but the demands of the unit outfitting system require extremely close cooperation among all facets of shipyard operations and the early involvement of Production Planning in the design effort. As a few examples of the interrelationship which exists, consider that in the unit outfitting system a drawing list cannot even be compiled by Engineering until the hull unit construction arrangement is defined. Further, the material need date for the same piece of equipment can vary as follows, depending on construction method:

CONSTRUCTION METHOD	MATERIAL NEED (MONTHS)
On-Board	17
On-Unit	14
Package Unit	12

Unit outfitting methods are a powerful tool for ship construction, but they place a substantially increased burden on the engineering and planning activities. In order to meet the schedules imposed, it is imperative that there be a clear and concise understanding of the task at hand at time of contract and that a sizeable expenditure of company resources must be made in anticipation of a contract.

(3) Engineering Drawings are Developed as Units, Not as Systems

This concept is, of course, seminal to zone outfitting technology. Prior to zone outfitting at Avondale, almost all engineering drawings were developed to describe a single system or entity, such as the main deck, transverse bulkheads, bilge and ballast system, fire main system, etc. This systems approach was adequate for the production philosophy where the ship was built in sections and these sections assembled into a complete hull before most of the outfitting material was installed. Production work was steel-work oriented, and piping and other outfit material were added only after the hull was complete. However, with zone outfitting, Production is supplied with unit drawings that depict all the systems that are to be installed in each unit.

(4) Structural "Key Plans" are Used in Drawing Development

Structural key plans are very detailed scantling plans that show all aspects of the vessel's structure. The vessel is divided into three main divisions with each division having its own key plan. The first area is the foward structure from the stem to the collision bulkhead; the second is the cargo hold structure between the collision bulkhead and forward machinery bulkhead; and the third is the after body and peak structures. All frames, bulkheads, decks, flats, stringers, stiffeners, shell plates, and major penetrations, along with most major equipment foundations, are included on each respective key plan.

The primary purpose of the key plans is to provide a document depicting all details related to the vessel's major structural components for use by all departments, both Engineering and Production, in their own respective functions or tasks related to the shipbuilding effort. For example, the Hull Drafting Section uses the data shown to develop the yard plans or unit drawings. The Piping Section uses the plans to locate major interferences of their piping runs. Production Planning uses the plans to aid in the unit breakdown development. Since the key plan is a tool for other departments, the drawings must obviously be completed very early to allow the accelerated Engineering completion dates to be met. This obviously requires all support tasks necessary for the development of the key plans to likewise be completed earlier.

(5) Material on Drawings Must be "Pallet Coded"

Each unit drawing must contain only that information necessary to do the desired job at the planned time. The designer must also consider the physical progress of the surrounding area at the time of installation. It is very important that the drawings reflect the agreed-upon construction sequence, since they also control the flow of material. Portions of piping systems, manholes, ladders, reach rods, wireway hangers, etc., may require installation as a particular unit is being constructed, maybe before the unit is complete or before it is painted. The drawing reflects this by specifying when the material or component is installed. This specification is called a pallet code. Each piece of material is pallet coded. The Material Control Section of Production uses the pallet code information to assemble all material to be installed at a particular time and routes it to the exact location for installation. The importance of the pallet code cannot be overemphasized, since it controls the flow of material. In zone outfitting, the flow of material basically controls the cost of the job. Figure 3-7 is an example of the pallet code system used at Avondale.

The pallet code is basically an eight-character designation. The first two characters represent a craft labor cost code. The middle three characters specify the unit number for material to be installed on unit, or the zone for material to be installed on board. The sixth and seventh characters are the pallet serial number. The last character in the code indicates the stage of contruction at which time the material will be installed. To assist Production in the control of material, each drawing title page has a tabulation of the pallet codes contained on the drawing.

(6) Advance Ordering on Long-Lead Material is Emphasized

It is, of course, a prime concern of any shipbuilder to identify, specify, and purchase long-lead materials as soon as possible. The implementation of zone outfitting makes this task critical. The design effort depends on the receipt of vendor information at an early date, and zone outfitting production schedules require earlier-than-conventional receipt of material and equipment. This can only be achieved if each engineering discipline becomes involved with the ordering of long-lead material at contract start or sooner.

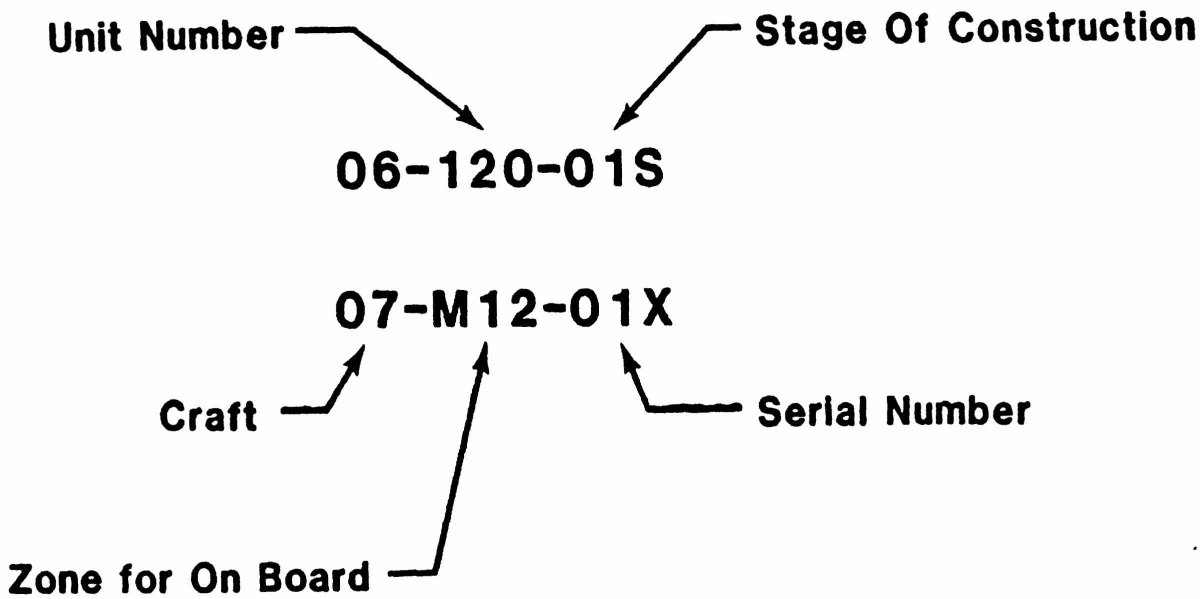


Figure 3-7 Examples of Pallet Codes

III. UNIQUE EFFECTS OF ZONE OUTFITTING TECHNOLOGY ON THE ENGINEERING SECTIONS

Some of the effects of zone outfitting technology were experienced uniquely by the Engineering sections. Following is a look at some of these effects on seven of the sections.

A. Hull Technical and Design Section

The Design Section is composed of naval architects, civil engineers, computer programmers, weight programmers, and drafting support personnel. The responsibility delegated to the Design Section under the conventional shipbuilding system is the design and preparation of midship sections and associated scantling plans, fairing of lines, naval architectural calculations and drawings, weight estimates, and support functions for other sections on an "as-needed" basis.

(1) Development of Structural Key Plans

Since the introduction of zone outfitting at Avondale, the Hull Technical and Design Section, which handles the naval architecture functions, has shifted most of its work effort to a much earlier time frame within the contract period, in order to produce structural drawings called "Key Plans."

Simply stated, key plans are very detailed scantling plans that show the entire overall structural envelope of the vessel and detailed information of all decks, frames, bulkheads, stringers, flats, and shell plates. The key plans must also incorporate major interfaces from all Engineering disciplines (e.g., foundations, vent trunks, large penetrations, etc.). By having these key plans, all Engineering and Production Departments can proceed with their planning and drawing preparation using a common drawing. Therefore, by design, the key plan must be available to all departments very early within the contract period, so that the accelerated IHI drawing issue schedules can be met.

In order to issue the key plans early, support tasks that are used to develop the key plans must be completed sooner than under conventional systems. Scantling plans, damage stability studies, hull girder strength calculations, fairing and finite element studies must all be completed prior to issue of the key plans. The early completion of these support tasks assures that major changes to the vessel will not occur after issue of the key plan, thereby avoiding cascading disruptions of all subsequent work.

(2) Creation and Maintenance of the Data Base

This function was the responsibility of Production's Moldloft under the conventional system. The data base is a storehouse of information that, through the use of designated computer programs, defines all structures within the vessel inclusive of the vessel's shell contours. The data base is developed or created in a systematic manner, starting with the definition of the vessel's final faired lines. Then, surfaces such as decks and bulkheads are added, along with shell longitudinal traces and shell seams. This data base is updated and maintained through the span of the contract to reflect any and all developments that occur as production proceeds.

The data base is used to develop computer-prepared drawings. Any frame, bulkhead or deck contour can be retrieved and drawn depicting the associated stiffeners. Once the drawings have been developed and the data base verified, the data are used to control the N/C burning machines in the Plate Shop, the generation of templates, bending of frames, etc.

(3) Review of Yard Plans

Once the key plans are issued, the Hull Section uses them to develop the yard structural plans or "yard plans" that are subdivided into each particular hull construction/erection unit. These unit drawings are complete with the smallest detail shown and defined to allow the preparation of the unit parts list, "UPL's," from which the Moldloft prepares the unit construction manuals, "UCM's." The UCM's are the documents from which the steel is nested, marked, punched, and burned within the construction sequence. Therefore, to assure the accuracy of the data released to Production, the Design Section reviews the unit drawings to verify that all details are in accordance with the intended design and latest developments.

(4) Increased Role in Production/Engineering Liaison

Since the Design Section is responsible for the development of the key plans, questions and problems that arise during development of yard plans and N/C burning are channeled through the Design Section for resolution. Although this is not a new function of the Design Section, the amount of day-to-day involvement has intensified due to the increased detail of the actual design work now undertaken. Also, since the data base maintenance requires daily involvement, the flow of input to and from the Design Section has increased drastically.

B. Hull Structures Section

Prior to introduction of zone outfitting at Avondale, the hull structural drawings were developed and presented to the Production Department utilizing a system-by-system approach. The drawings were developed presenting the decks as a system, the shell as a system, the web frames as a system, and so on.

The system-by-system approach presented the entire shell, deck, or longitudinal bulkheads to the Loft, from which the various structural units had to be extracted. The system-by-system drawings did indicate the unit breaks or erection joints, but the individual unit's extent was not so discernible graphically. Additionally, the system-by-system approach required the user to possess other system plans in order to obtain the knowledge of all of the components of a particular unit. Many reference plans were necessary.

(1) Yard Plans

The greatest influence that zone outfitting had on the functions of the Hull Section was in the development of the hull structural plans, or yard plans. Zone outfitting introduced four major changes in methodology for producing the structural drawings:

- The structure would be developed and presented unit by unit.

- The individual units would be developed from a key plan rather than from a rough scantling plan. The key plan conceptually is a more complete scantling plan delineating secondary structure to a more detailed level.

- The structural drawings would have their respective unit's various components identified by a designation system that was keyed to the intended construction sequence or stages for that particular unit.

- Each unit drawing would be accompanied by a complete accounting list of material for that unit, known as a Unit Parts List.

ASI still maintains the obviously required system drawings, such as the rudder support system, mooring system, and anchor handling system. The development methodology of these system drawings has remained essentially unchanged under the zone outfitting concept.

(2) Standards

The adoption of zone outfitting has led to creation of a large number of standardized structural details. The adoption of standardized structural details has led to uniformity in configuration and application. Repetitious detail requirements are simply referred to the standards.

Some standardized notations, where certain letters of the alphabet singularly, or in combination, are assigned certain meanings, are used in the yard plans. These standardized notations are directly tied to ASI's Standard Structural Details.

(3) Symbolic Logic

The next area where the adoption of zone outfitting has had an influence is in the use of symbolic logic. Prior to zone outfitting, ASI structural plans utilized symbolic logic to some degree. Now, the use of symbolic logic has increased significantly. Symbolic logic is now employed to denote mold line side, dimensioned side of member, stock allocations, etc. In the future, additional symbolism will be utilized in an effort to further standardize repetitious meaning or intent, and thus reduce wording or graphic presentations on the plans. The attending cost saving is an obvious initiating factor.

(4) Unit Parts List

The next area in which the adoption of zone outfitting has a significant influence is in the decision to create a document known as the Unit Parts List, or UPL. Essentially, the UPL is a document that accounts for all the pieces in a unit. In addition to accounting for every piece, the UPL lists the pieces in the order of ascending stages of construction, grouped into the various partial subunits and subunits required for both the assembly and erection stages of construction. The UPL is an accounting system that presents its information in the same order as a document produced by the Production Planning Department, the "Unit Breakdown Summary Sheet."

The UPL is constructed from the "Unit Breakdown Summary Sheet." There are additional items of information in the UPL. These include notations to the Loft as to what pieces require "lofted" dimensions, what pieces require stock, what pieces require special attention in the lofting and manufacturing stages, etc. The UPL will be used at the various work stations.

The UPL is a baseline document that can be used by other groups or departments in Production for such functions as material accounting, sorting, routing, storage, etc.

(5) Penetrations

Penetrations in structural components for piping, ventilation, mechanical and electrical routings are shown in the yard plans when those penetrations fall into either one of two categories: penetrations requiring structural reinforcement, and those that can be cut by numerical burning.

Until the advent of zone outfitting, only the penetrations that required structural reinforcement were shown. Zone outfitting has provided for earlier identification of system routings, with the attending benefit of being able to include those penetrations into the yard plans.

(6) Process Lanes Integration

The concept of process lanes has been incorporated into the yard plan. The notations for the various structural components, designating them as subunits, partial subunits, combined partial subunits, or just individual pieces to be left loose until assembly or erection, are a function of the area or location of their manufacture.

This designated manufacturing location is one of the basic concepts of the process lane principle. The yard plan notations are obtained from the Unit Breakdown Summary Sheet prepared by the Production Planning Department. By knowing the meaning of the process lane coding notations, one can determine the location of manufacture of a particular structural component.

C. Mechanical Design Section

The concept of producing zone outfitting drawings for the various mechanical systems requires a new design philosophy and requires that the Mechanical Section change its method of developing drawings. This change increases the engineering time required to produce the vessel's design, but should be offset by the manhour savings which can be realized by Production.

This section will discuss the major engineering/design effort required by the Mechanical Section and briefly show the differences between traditional mechanical design and design incorporating zone outfitting.

(1) Scope of the Job

The scope of the engineering required for any job is put into definition by formulation of the plan schedule required for that job. Traditionally, this has been easily obtainable by the Mechanical Section at the beginning of the contract, since engineering drawings were system oriented. The plan schedule provided an early and fairly accurate definition of the job.

However, with zone outfitting, most Mechanical Section drawings are not system-oriented but rather are unit- or zone-oriented. After a unit breakdown is made by Production Planning, the Mechanical Section must determine its drawing breakdown by units. Time must be spent for advanced planning in order to define what systems are contained in various units. This is accomplished with a comprehensive advance planning program for system routing.

At ASI, the Mechanical Section has implemented what is called "Advance Design Composite Study" (ADCS). ADCS's are produced by top designers taking the functional system diagrams and making a schematic one-line routing of the systems on scaled arrangement drawings. When the designers are routing the systems, they must ensure that the routing shown is obtainable. The ADCS is greatly improved if the designer has good scantling drawings and major equipment drawings. A well-thought-out ADCS by top designers will completely define the scope of the job. Then, from the ADCS, a realistic plan schedule for Mechanical Section drawings can be obtained.

(2) Composites

Development of detailed composites has changed from the traditional development methodology as follows:

- The breakup of the composited area follows the unit breakdown rather than the traditional level breakdown.

- Development of the composites is done basically unit-by-unit in lieu of system-by-system. The proposed routing which has previously been determined on the ADCS's is followed as closely as possible.

(3) Arrangement Drawings

Since Production personnel are outfitting small pieces of the ship which are basically unrelated to the ship as the whole, arrangement drawings are done unit-by-unit with accompanying lists of material done unit-by-unit in lieu of the traditional system-by-system. In addition, all material and pipe spools must be coded to the unit, so that Material Control can palletize the material and deliver it to the unit outfitting site.

Following is a list of problems which had to be overcome by the Mechanical Section in the implementation of zone outfitting as it relates to arrangement drawing preparation:

- The total quantity of drawings is increased, which increases the basic burden of interface control, drawing handling, and distribution.

- A system change that would have affected only one drawing in the traditional design may now cause revisions to many arrangement drawings and associated L/M's and pipe spools.

- Additional detailing is required in dimensioning the drawing, since traditional reference lines such as frame lines and ship's centerline may be non-existent on particular drawings.

- Since finished painting is part of the zone outfitting philosophy, all pipe spool drawings must contain the internal and external coating requirements which are dependent on system and location.

- Designers must be more aware of each system's requirements, since many systems are involved in each unit drawing. Materials can be easily confused, since many diagrams must be used for one drawing. There can be no system specialist designers.

- Designers must be aware of which materials can be installed at various stages of construction (e.g., fiberglass piping cannot be installed before blasting without damage).

- The system arrangement must be developed to be compatible with the method of fabrication for a particular unit (e.g., if a unit is fabricated with a bulkhead facing down, pipe should not be routed on the underside of that bulkhead if at all possible).

(4) Package Units

Engineering has organized, within the Mechanical Section, a Package Unit Design Group. This group is responsible for the complete design of all machinery package units, including piping, structure, outfitting, instrumentation, painting, label plates, etc. Having this design in one group ensures the integration of all design facets. This method also simplifies the development of the machinery space composites, since a package unit becomes a "mini-composite."

(5) Piping Racks

As much as possible, ASI tries to rack piping on structural frames, which then can be installed as one complete assembly. The Mechanical personnel responsible for the piping racks are also responsible for the detailing of the rack structure to ensure integration of structure and piping.

(6) Computer-Aided Drafting

ASI is presently developing a computer-aided drafting system with Lockheed and IBM known as CADAM. A pipe spooling program is presently being used to improve the accuracy of the pipe spools and increase productivity.

(7) Material Procurement

Material procurement must be done at a very early stage of the contract for all systems, because the first unit planned by Production for zone outfitting may contain small portions of many systems. Therefore, in order to have material in time for Production's needs, advanced ordering of material must take place. Advanced ordering of long-lead material is done from the complete ADCS's, rather than from functional schematic diagrams, since a more accurate material take-off can be obtained.

All material on systems is coded to coincide with actual fabrication and installation sequence. This requires close working contact with Production personnel.

(8) Vendor Information

To do worthwhile advanced planning, vendor information is required at a much earlier stage in the contract. This is required for feasibility of equipment hook-up and determination of any problems with the physical location of the equipment. Also, the arrangement of certain systems is dependent upon individual vendor-furnished equipment.

D. Piping and HVAC Section

The advent of zone outfitting technology has had many far-reaching effects on the operations of the Piping and HVAC Section. This is because perhaps no other Engineering Section was as "systems oriented" as was Piping and HVAC prior to zone outfitting.

Drawing preparation has been complicated, in that there are more drawings to be produced and they are more complex than were systems drawings. Gone are the days when designers could specialize in a handful of systems that they could work from job to job. Now a designer must be knowledgeable about many systems, because all piping systems within a given unit must be worked as the particular unit drawing is being prepared.

Gone also are the days when designers had only to know the basics about production techniques that were to be used. Now a designer must become intimately familiar with the particular method of fabrication to be used on each unit he is to work. The document used to instruct Engineering as to Production's fabrication methods is the "Unit Breakdown Summary Sheet and Construction Procedure." This document provides Engineering with step-by-step details about each unit's construction sequence. This, then, allows Engineering to properly code each piece of equipment - pipe, fittings, etc. - so that it arrives at the correct job site when required by Production.

The impact of revision activity has been greatly increased due to the increased number of drawings. A change in a pipe size on a particular diagram could have an effect on numerous unit drawings and their appended lists, whereas in the past, only the system drawing affected by the diagram would have been altered. Therefore, it is critical that design changes be kept to an absolute minimum.

This section will focus on the preparation of piping drawings to accommodate zone outfitting. Much of what is said of these drawings is applicable also to HVAC and Mechanical Machinery drawing preparation, as previously alluded to. Piping development effort is subdivided into the following areas for a typical tanker:

- machinery composite
- machinery space, tank heating coils, and innerbottom
- outside machinery space and main deck racks
- machinery package units
- quarters

The first four areas will be examined with the knowledge that the same techniques apply to quarters piping development. Also discussed will be the way in which the preparation of piping details (P/D's) and lists of material (L/M's) have been affected by zone outfitting technology.

(1) Machinery Composite

For over twenty years, Avondale's Machinery Composite Group has provided the primary design for machinery space and main deck arrangements. These composites are not merely interference checks but are used to provide the arrangement groups with completely routed systems for working drawing development.

Basically, the procedure for machinery composite development has remained the same with zone outfitting. The composites are done at scales of 1/2" to 1" to the foot, depending on area, and are divided into the required plan and section views to clearly represent the area depicted. The composites show all systems within the machinery space, including piping, HVAC, and wireways, as well as outfitting items such as ladders, gratings, and so on. The major difference between composites now and before zone outfitting is the manner of presentation to the arrangement group. Before, an entire system was routed on composite and then forwarded to the arrangement group for development into working drawings. Now, the composite group routes all the systems within a particular unit and then forwards that unit to the arrangement group.

Since machinery spaces are developed from the lower levels up, the obvious problem with zone outfitting is to be certain that all systems in a given unit have been routed prior to issue to the arrangement group. Avondale's answer to this problem is the Advanced Design Composite Study or ADCS. The ADCS is a 1/2" scale, single-line routing of all systems in the machinery space, main deck, or other congested area of the vessel. It should take approximately six weeks for the "preliminary" ADCS to be developed for a vessel like the multi-product carrier Avondale is currently (1982) building, and approximately three months for the final ADCS to be developed. This, of course, assumes that vendor information and contract drawings are ready at the start of ADCS development. It also assumes that first-rate designers are available to handle the assignment.

Another difference between the traditional and the new composites is that now the unit breaks or joints are clearly shown on the composites. This is to ensure that machinery is not located on the break lines and to ensure that allowance is made for flanging make-up pipe pieces to bridge unit breaks after erection.

(2) Machinery Space, Tank Heating Coils, and Innerbottom

It is a longstanding procedure at Avondale to prepare arrangement drawings from reduced photographic copies of machinery composites. This procedure is being continued for the drawings being prepared for zone outfitting. The task is, however, more difficult than in the past. With systems drawings, the systems not being developed could be subdued and the subject system highlighted. However, with zone outfitting, all the systems in a given unit must be highlighted. In especially congested areas, such as the machinery space lower level, this task is almost impossible to accomplish. What must be done in these situations is to present a number of views of the same area, with each view depicting a certain number of systems for clarity.

(3) Outside Machinery Space and Main Deck Racks

The outside machinery space drawings are prepared similarly to the machinery space drawings, with the major difference being that they are prepared without benefit of design composites. The arrangement group must examine piping diagrams and develop the ADCS from which the arrangement drawing is then taken.

The main deck rack drawings for the present Exxon contract are quite different. Composites similar to those prepared for the machinery space area were done for the main deck, which was then divided into three zones with six to eight racks in each zone. Each rack contains sections of pipe together with the necessary supporting structure, walkways, and gratings. It is quite an improvement to assemble the rack completely outfitted and lift it in one piece aboard ship, as opposed to the traditional procedure of assembling pipe structure on the ship and then adding the pipe, piece by piece. As with the tank heating coil drawings, the Piping Section is responsible for developing the rack structure, as well as the pipe routing and detailing. The Outfitting Section provides the ladder and grating drawings for the racks.

On the product carrier contract, model engineering has been used rather extensively to depict the main deck rack development. The model of the main deck pipe rack is composed of the assembled racks and can be broken down to duplicate the planned construction technique. Aside from assisting Avondale Engineering, the model has already proven to be a real benefit for Production, owners, and regulatory bodies.

(4) Machinery Package Units

Although Avondale has built package units in the past, this current effort is the most comprehensive to date and certainly the most successful. One of the major factors in the success of the package unit program has been the construction of the Machinery Package Unit Assembly Shop, a large shop with overhead cranes and a clean environment. The rapport that has been established between the shop foreman and Engineering personnel is excellent. A good many more engineering manhours beyond original projections have been expended on package unit development; however, initial reports from the shop indicated that a Production man-hour savings in the neighborhood of 15 percent may be hoped for.

There are two basic types of package units. First, there is the custom-built type, which is designed to suit certain conditions of the vessel being designed. These package units will differ from design to design and are usually found in congested areas, such as the lower level of the machinery space--for example, the bilge and ballast pump package unit. The other type of package unit is the standardized type, such as the fuel oil pump package unit. These package units are suitable for reuse on other jobs and are usually found in less congested areas, such as the upper levels of a machinery space. Of course, the ultimate goal should always be to design package units so that they are reusable.

Like the main deck racks, the package unit drawings are self-contained and are produced completely by the Piping Section. Even ladders and gratings are done by the Piping Section.

As with main deck racks, complicated package unit drawings have been prepared with the assistance of design models. These models have been extremely useful during the design phase in catching interferences and other problems that might otherwise have gone unnoticed. Their real value is realized as Production consults them during actual package unit construction. The models are in a location close to the Package Unit Assembly Shop and are used constantly.

(5) Piping Details

Each unit, machinery package unit, and main deck rack contains a piping detail drawing (P/D). The procedure for producing P/D's under zone outfitting has not changed a great deal from the traditional method. The major difference really is the addition of the pallet code number and the attention that is paid to pipe shop work station routing and coating procedures. Adding routing and coating information is the result of adapting to Avondale's new semiautomated Pipe Shop to accommodate zone outfitting technology, and the need for more accurate computer-aided scheduling required for zone outfitting.

The Pipe Shop routing is determined by a designer familiar with pipe fabrication who enters the information into a computer program called COPICS. Entered into this program is the shop routing, material listing, and pallet codes. COPICS then can automatically schedule the work in the Pipe Shop in order that fabrication schedules are met for installation of the piping in the units and to level-load the work in the Pipe Shop at the various work stations.

(6) Lists of Material

Separate lists of material are prepared for each unit and main deck rack. The procedure used now for generating the list of material (L/M) is almost identical to the procedure used prior to zone outfitting technology, with the exception that an L/M is prepared for each unit or rack and the L/M must contain the pallet code for each item.

(7) Conclusion

The Piping and HVAC Sections' entry into the realm of zone outfitting technolgy has been a true "trial by fire." Not only did they and all of the other Engineering sections have more to do than ever before, but they had less time to do it. It was extremely difficult to estimate the manhours that would be needed to accomplish the assigned tasks. There have been budget overruns; however, the savings to be realized on the Production side will more than compensate for the additional expenditures in engineering.

E. Outfitting Section

Avondale Engineering's response to zone outfitting has been geared toward Production needs, especially in the areas of Hull Structure, Piping, Machinery, and Material Control. In order to support this effort and to keep current with the changing work procedures, the Outfitting Engineering Section has attempted to respond to the needs that have been created by the implementation of zone outfitting technology.

The Outfitting Section responded in two main areas:

- To provide engineering information early enough to support the timely development of work in all other engineering sections.

- To respond to the Production Department needs created by zone outfitting.

(1) Outfitting Response to Engineering Section's Needs

Because a lack of outfitting information required by other engineering sections is a potential cause of schedule slippage, these items must be addressed early on, even in the precontract stage, if possible. In addition, new U.S. Coast Guard regulations require submittal of drawings such as hazardous area definitions, fire control information, and bulkhead and deck classifications "up front," right at the beginning of the contract. As a result, this information must be scheduled for development as early as possible.

To support zone outfitting, the Outfitting Section must have an early start to provide the following information:

- access information
- compartmentation definition
- equipment system definition
- paint information
- identification and location of joiner systems
- vendor identification
- classification of decks and bulkheads
- insulation requirements
- hazardous area definitions
- weight information

(2) Outfitting Response to Production Needs

The Production Department needs from the Outfitting Section to support zone outfitting are straightforward and in the four general areas of production work:

- material control
- material fabrication
- material routing
- material installation

The Outfitting Section must respond as follows in each of these areas.

a. Material Control

Production's need to control material is of prime importance to the implementation of zone outfitting technology. This control is facilitated through the use of computerized material control systems such as COPICS. However, in order for any computerized system to work, there must first be an identifier for the item to be controlled so that the computer will be able to distinguish each item. This is best accomplished by the use of a raw material "catalog" in which all raw material items are assigned a yard-wide standard number.

Originally, this "catalog" existed for only piping materials, but now ASI is proceeding with the development of such a catalog for all raw materials, and the Outfitting Section is handling the catalog development for all outfitting materials. The material catalog numbers are also being added to the drawings in anticipation of the implementation of this computer system.

b. Material Fabrication

Another development which has been incorporated into the drawings is the isolation of the fabrication information, so that only the information required to fabricate a given subassembly is shown. Once the raw material is fabricated into finished items, then the various raw material piece numbers can no longer be used to track the material; therefore, a new identifier must be assigned. This new identifier is called a "Subassembly Number." For example, VL = Vertical Ladder, IL = Inclined Ladder, etc.

After having gone almost completely through the product carrier contract and using the subassembly numbers throughout, the list of subassembly numbers is still smaller than 100. That is, the fabricated items which the Outfitting Section supplies can be described or identified by fewer than 100 components.

Using the subassembly numbers as a heading, the Production Department has the capability of loading into the computerized material control system all the raw material required to fabricate a given subassembly. Some of the more commonly used subassembly components are in the process of being converted into yard standards, which will eliminate the need to draw the same subassemblies over and over again.

Material lists have been broken down so that the material for each subassembly is separate from the next subassembly to facilitate easy entry into a computer data base. Painting information is shown for each subassembly in the same area as the details for the fabrication.

c. Material Routing

Because of the process lanes system, there are now many different locations in the yard where material is being installed on the various units. Where a given piece of outfitting is to be routed depends on many different factors, all of which must be considered by the outfitting engineer. Some of these factors are:

- What unit does it go on?

- At what time in the construction sequence is the unit in the best position for installation?

- What handling is required?

- Is painting a problem?

Once these questions have been answered and a decision made, then the material is "addressed." The address is the pallet code, a series of numbers which route the material to a specific time and location in the yard.

Outfitting's response to Production's request for material routing is the preliminary assignment of the pallet code and the arrangement of the pallet code information on the various drawings in such a manner that the information may be easily entered into a computer data base.

Another facet of material routing is the arrangement of the drawings in such a way as to keep all the information for a given unit together so that it is possible to read and work with the drawing unit by unit. In some cases, the outfitting drawings have been arranged so that it is possible to literally take the drawing booklet apart and each drawing will still be complete for each trade or work crew.

d. Material Installation

An important part of zone outfitting technology is the elimination of as much field fabrication as possible. The ultimate aim is to convert the field worker from a fabricator into a skilled "installer." This is accomplished by the prefabrication of as many outfitting items as possible, and by separating installation information from fabrication information.

If a given subassembly comes to the installation site in a finished or prefabricated state, then the person doing the installation has no need for any of the fabrication information. He only needs to know where it goes and how it is installed. Often the designer may build into the subassembly some feature such as a slip joint to make the job of installation easier. He may ask for locating "shop marks" as part of the fabrication process. These special features are then noted on the installation part of the drawing.

The two-digit subassembly numbering system is a help to the installers, in that over a period of time they develop a sort of jargon which will convey much more information than previously. For example: "Get me one VL-10 and a PT-6 right away," tells the man immediately that the subjects of the conversation are a 10'-0" vertical ladder and type 6 platform. The Outfitting Section is developing arrangement drawings which show the installation of the subassemblies using the subassembly numbers only. The location dimensions on these drawings are to the nearest structure or to a datum line so as to ensure that the installer has a "real" place to measure from, because often the unit is not assembled into the hull form, and the conventional datum lines may not be on the unit at all.

With much more material being added to the units before they are assembled one to another, the weight of the added outfitting material becomes an important factor in unit handling. The weight is also a good indication of the percent complete of the ship. For example, if 100 tons of outfitting material is assigned to a given unit or package and only 75 tons have been installed, then that job is 75 pecent complete.

A spin-off of the separation of fabrication and installation information on the drawings will be the ability to reuse the fabrication details on other contracts quite easily, because in most cases the outfitting subassembly is drawn without any reference to the ship's structure. This makes it easy to apply to another contract by simply photocopying the fabrication detail and drawing new installation details to suit. This can lead to a file of pre-engineered sheets which are inserted into the drawings as needed or which may be converted to yard standards.

(3) Effect on Drawing Development and Information Presentation

In order to support Production in the implementation of zone outfitting, outfitting drawings had to undergo a significant change from their traditional configuration and method of preparation. It is not that entirely new information or data had to be created, but rather that the old information has had to be expanded and placed in different order on the drawings and, in some cases, additional details and schedules had to be developed.

(4) Example of Detail Drawing Development

The best way to show how the Outfitting Section has handled the various Production needs is by an illustration using a typical Outfitting Section drawing that covers a large area of the ship (a multi-unit drawing). The drawing will be discussed in detail and the various changes made to the drawing to accommodate zone outfitting technology explained.

a. Title Block

A stick-on schedule has been added to the title sheet under the General Notes area of the drawing so that Production will know at a glance the time sequence for the installation of the outfitting items contained within the drawing. The affected areas of the ship have been added to the title block so that anyone reading the title will know what areas are covered by the drawing.

b. Index Sheet

The arrangement of the sheets within the drawing has been made so that all of the fabrication information for a given subassembly may be removed from the drawing and will stand alone. Likewise, all of the information required to install the subassembly can be removed and will stand alone.

The fabrication information for one subassembly is also separate from the fabrication information for the next subassembly.

The order of presentation is as follows: First comes the parts list (purchasing data), then key plans, fabrication information, and finally installation data. This order was chosen because it closely follows the actual sequence of operations at ASI.

c. General Notes

In addition to the usual General Notes, there has been added an explanation of the various subassembly numbers used in the drawing to ensure that they are understood. Also added to the General Notes is an explanation of how the subassembly information is shown in the key plans. This system of conveying information has been developed because it is a simple way to inform the reader exactly where to go to find out how to fabricate or how to install the given subassembly.

d. <u>Total Parts List (Material List)</u>

This sheet serves as a purchasing document for the total amount of raw material required to fabricate everything on the drawing. It includes, for each part, the "unit weight" and "ASI Standard Part Number." The unit weight column allows the weight group to calculate the weight of the added outfitting material for a given unit for purposes of unit lifting and handling. The ASI Standard Part Number allows the Material Control Group to enter the raw material designator into a computer data base where many different kinds of operations may be performed on it.

e. <u>Subassembly Parts List</u>

The subassembly parts list is a completely new type of schedule which has been added to facilitate computerized material lists per pallet, parts lists for each subassembly, requisitions for material, and many other functions.

Its most important function is to present the material on the drawing broken down to such a level of simplicity, that when the information is put into a computer data base, the computer will be able to "build" or connect the information in ways that will provide the operator with the required answers to such questions as, "How much material is in this pallet? How much does it weigh? Is all the material available?"

f. <u>Key Plans</u>

The key plans have been added as a visual indication of the area of the ship covered by the drawing and the approximate location of the various subassemblies. Each subassembly number is placed in a hexagon with a horizontal line extended from it. All information relating to the fabrication of the subassembly is above the line, and all of the information relating to the installation of the subassembly is below the line. Thus, the key plan becomes a sort of index for the fabricator or installer.

g. <u>Detail Tabulation Sheets</u>

Tabulation sheets have been developed to supply dimensions for subassemblies which are the same shape and construction but which have size differences. Vertical and inclined ladders are good examples of these types of subassemblies.

The detail tabulation sheets are fabrication documents and contain information which is for fabrication only. They give the dimensions for each subassembly one time only, no matter how many times the subassembly is used on the ship. The quantity of each subassembly is not given on this sheet but is included, instead, on the subassembly parts list.

h. <u>Subassembly Fabrication Detail Sheets</u>

The details for the actual fabrication of a subassembly are given in pre-engineered detail sheets which are photographed and inserted into the drawing. It is these pre-engineered fabrication detail sheets which are prime candidates for a program of standardization.

i. Location Tabulation Sheets

The location tabulation sheet provides the installer with the exact information he needs in order to install a given subassembly. It is here such items as datum lines for "real" location points and a column for special installation details which may be required are identified.

It is on this sheet, also, that the pallet code or "address" for each subassembly is found. Because the "address" may be different for each subassembly, though the subassembly may be exactly like others and have the same subassembly number, it must be listed on its own line in the location tabulation sheet.

j. Installation Detail Sheets

These sheets contain details which show special problems relating to the installation of the subassembly or else show the orientation aboard the ship. They serve as a visual aid to the installer and as an extension of the location tabulation sheet.

(5) Effect on Time Frame, Budget, and Personnel

The need for more information "up front" has caused the Outfitting Section more work at the beginning of the contract, sometimes even at the precontract stage of the job, than has been done previously. This means that more time and personnel have to be made available at a time when they may be needed to finish up on another contract. More time is needed to complete some drawings and, as a result, they must be started earlier in order to hold Production need dates.

The changes made to the Outfitting Section drawings as a response to Production needs have generally resulted in a drawing which is larger than previous drawings of the same type.

These drawings are more complex to put together for the Outfitting engineer because he has to put on several "hats" in the course of the drawing development (fabrication, installer, material control, etc.), while the drawings are much simpler for Production because the man in the field is not required to wade through the information of another phase in order to get to his own area of responsibility. He doesn't even need to have a complete drawing for his work, only those sheets which pertain to him. Therefore, more manhours are required for the drawing development and larger engineering budgets are called for, at least for the initial contracts on which zone outfitting is applied.

Since the Engineering budget on any contract is quite small in relation to the budget for Production, and since the ratio of hours saved by Production to hours used in Engineering is high, the increased expenditure is easily justified.

Education of the engineers and draftsmen in the Outfitting Section is another aspect of zone outfitting which should be mentioned. Once the initial "shock" of finding out that the conventional or "old way" is not going to be good enough, and once the instinctive resistance to change is overcome, then the basic comment of personnel to this system has been favorable. Such comments as "it's only common sense" and "it's simple, once you get into it" have been heard. There is no question that there has been a "learning curve" price to pay in adopting this system.

(6) Future Developments

Increased use of computer technology, development of yard standards, use of pre-engineered detail sheets and/or computer drafting, and valuable input from Production feedback, as well as improvements made by personnel in the section, should combine to reduce the extra in manhours considerably in the future.

F. Electrical Section

Of the design engineering disciplines, Electrical Engineering most certainly qualifies as one of the least affected by zone outfitting. The impact on the electrical engineering implementation of zone outfitting to a particular job is primarily centered in changes to the design of the wireways and drawing format changes in the list of materials for deck plans and isometric wiring diagrams.

(1) Installation Procedures

Due to the nature of electrical installation, most of the equipment and cabling are installed during the "on board" phase of zone outfitting. For most equipment, this is necessary to ensure that the electrical components are not subject to adverse environmental factors such as weather, sandblasting, dust and paint spray, during the early stages of zone outfitting. Additionally, the unwanted exposure of electrical equipment to these elements could weaken the shipyard's position in claims negotiations with vendors concerning liability for subsequent warranty deficiencies. Electrical equipment installed "on unit" tends to be concentrated on vendor-applied module packages and shipyard-built machinery package units.

Long runs of cable through the ship are installed in the traditional manner of pulling the cable from one endpoint to the other. Connection of the cables can then be handled by a hook-up crew at a later date. An alternate method of installing some of the multi-conductor runs would be to prewire each unit to its own central junction box and then connect these junction boxes via jumper cables once the units are joined together. At present, this method is not used at ASI, because the resultant large increase in connection time, checkout time, and increased electrical system complexity would not represent a real savings in the cost of the final product to the shipyard. The production electrical foreman has the option of installing cables in a unit and coiling the ends of the cables for future installation through adjacent units as they are joined together. This technique is used on a case basis where some specific production goal can be achieved. The disadvantage of coiling cables is the disruption and inconvenience caused when the coils obstruct equipment or walkways.

Local runs of cables in a unit are treated as field installlations and are left to the discretion of the Production Department. The production foreman can install these cables on unit or on board as dictated by his work order.

(2) Wireway Design

Wireway design is well suited to modular construction techniques. The wireway hangers, being made of steel, can be phased in with the orderly erection of a unit during main assembly prior to blast and paint. In designing the wireways for "on unit" installation, ASI has experienced an increase in design time of approximately 50 percent due to the increased level of detail required for modular construction as opposed to the manner in which wireways have historically been designed. The increased effort also represents a shift in material takeoff and hole location efforts from the production foreman to the wireway designer.

Using the zone outfitting concept, wireway arrangement drawings are segmented by unit number to allow the production foreman to identify exactly which hangers are in each unit. The list of material is broken down by units to show the number of hangers of each type. Each type of hanger is detailed. Each slight variation of one hanger from another generates a new hanger detail. The end result of the additional detailing is to generate a unique piece mark number for each hanger which can then be entered into a computer program for tracking purposes by Production Planning and Management. Ultimately, it would then be possible to know how many hangers of each type are available in the yard for all jobs. This would allow stockpiling of commonly used hanger types and reduce disruption of the work flow on a given job when requirements for new hangers are generated after the bulk of the hangers for the job have already been constructed. It would be possible to screen all jobs to locate presently unused hangers of the type needed for the new hanger requirements.

The fabrication and installation of wireway non-watertight collars is an area where zone outfitting has made a significant contribution. Using the traditional manner of collar fabrication, the production foreman obtained dimensions from hole lists and then had the collars constructed by a specialist in his electrical department. Before installation of the collars in the bulkheads, the holes would be burned out by his layout crew, utilizing dimensions provided by the hole list. In zone outfitting, however, the production field crew's work effort is reduced considerably. Collars are standardized to a limited number of commonly used sizes.

Early in the design of the vessel, dimensional information for numerical hole cutting by automatic burning machines is provided to the Moldloft. This allows the holes for the wireways to be accurately cut by the automatic burners during the erection of the unit in main assembly. Effectively, the electrical field production crew's responsibility for non-watertight collar fabrication and installation is reduced to simply obtaining the precut non-watertight collars and installing these collars in precut holes. A logical extension of this work reduction effort would be to remove the electrical work crew completely from the process by having the collars installed by the steel workers during erection of the unit. Collars for bulkhead transits are still made in the traditional manner due to the close tolerances required to fit the transit to the collar. However, the holes for these collars are also numerically cut by the automatic burning machines.

The net result of the increase in engineering effort in wireway design is to reduce the complexity of the wireway installation to the electrical production crew, thereby allowing the use of less skilled workers doing less manual labor than the traditional method of wireway installation.

(3) Drawing Format Changes

To facilitate zone outfitting, the formats of electrical deck plans and isometric wiring diagrams have been revised to include additional unit construction information. Previously, these drawings depicted the electrical system in the body of the plan with a list of materials which provided total quantities for the material distributed throughout the drawing. For zone outfitting, however, these same drawings now have leader lines in the body of the plan which segment the ship into the various zones. Also, the front of the drawing has a table above the title block which indicates for cursory drawing reviewers that the drawing contains material which must be installed in any of twelve different stages of construction, such as during subassembly on unit or before closing in on board. As a further aid, the title block itself identifies the ship zones affected by the electrical system shown on the drawing.

The list of material for deck plans and isometric drawings is subdivided by the pallet codes associated with each unit or zone. Under each pallet code is listed the electrical material contained on the drawing which will be installed in that particular unit or zone. An exception to this technique of material listing is the listing of cable quantities. Cables are summarized at the end of the list of material with no reference to any particular unit or zone. The reason for this apparent anomaly is related to the manner in which cable is handled and installed in the shipyard. Cables are purchased, stored, and transported to the worksite on reels. As the cable is being installed, the electrical crew cuts the length required for the installation from the reel. The production foreman coordinates the overall cable installation to minimize cable waste. Since cable is expensive and is a long lead item for procurement, cable footage must constantly be monitored. Therefore, to identify specific cable lengths in each pallet would not contribute to a more efficient, less costly installation.

On some isometric wiring diagrams, such as the general alarm system, there exists a sizeable number of identical pieces of electrical equipment distributed throughout many of the zones on the ship. If the list of materials was divided based on the different pallets, the resulting list would be excessively long. To alleviate this problem, a matrix arrangement for identical equipment in a list of material has been devised. Each equipment piece mark number is listed in horizontal rows and pallet codes are listed in the vertical columns. A number placed in the field of the matrix would indicate the quantity of a specific piece mark number for a specific pallet. Present piece mark numbers used for electrical equipment at ASI remain identical to the numbering system used in the past. However, when the computer program associated with zone outfitting develops to the point where a particular numbering system for electrical equipment can be utilized, then that numbering system will be used on future ship construction projects.

Keeping the body of the deck plan and isometric wiring diagrams substantially the same as on previous jobs allows an easy transition of production workers into the new technique of zone outfitting. Also, the drawings have not become so specialized and fragmented that they would be unsuitable for system review by representatives of the various cognizant regulatory bodies and owners, who may be unfamiliar with zone outfitting.

(4) Package Units

Machinery package units constructed by the shipyard require coordination during the design phase of a job to ensure that all devices belonging on the package unit are installed during assembly of the package unit. Typical electrical devices which are installed on the package unit are motors, motor controllers, pushbutton stations, solenoids, sensors, and heat tracing cabling. The locations of these devices are established by the package unit designers, with inputs supplied from the various engineering disciplines, including electrical.

Particular attention is paid to electrical equipment and cabling which will be installed on tanks, that are a part of the package unit, to ensure that the proper provisions have been made for foundations and cable studs. Since the tank will be fully constructed and tested before it leaves the package unit shop, any welding to the tank exterior in the field would result in damage to the tank interior coating, which would require retesting of the tank.

In some instances, the machinery package unit is designed before certified drawings are received from the electrical equipment vendors. To minimize the disruption to the package unit design, the size of devices such as motor controllers and pushbutton stations is estimated based on previous experience with the particular equipment. Also, by using motor control centers, many of the vagaries of motor controller sizes are eliminated as the controllers would then be part of a motor control center remote from the package unit.

In keeping with the zone outfitting concept, it is necessary that vendor-furnished package units be supplied as complete as possible. Typical vendor-furnished package units would be such machinery as purifiers, propulsion engines, engine-generator sets, and reduction gears. For example, propulsion engines have been supplied to the shipyard in the past with numerous sensors not installed on the engine, even though they were required by the ship's specification. Also, electrical devices on the engine were not wired to a common connection point. After installation of the engine on the ship, it then became the field production crew's responsibility to mount the missing sensors and to run cabling over the surface of the engine. To obtain a complete package unit, the vendor is now required by his purchase order to furnish and install all of the electrical devices on his equipment and to wire these devices out to a common point, such as a connection box, where shipyard cabling can terminate. During vendor plan approval, his design is checked to confirm that ASI's electrical production crew will have minimal work effort to connect to the engine electrical devices.

(5) Added Electrical Engineering Responsibilities

Other Electrical Engineering Section responsibilities are generated due to the implementation of zone outfitting. One of these added responsibilities is the Electrical Engineering Section's participation in the pre-engineering phase of the job on an "as needed" basis. A typical example would be the generation of the one-line diagram by the shipyard's Marketing Department. Electrical Engineering drafts the one-line diagram based on the conceptual ideas obtained from Marketing and provides comments to Marketing on the suitability of the design based on previous experience with various regulations and Production Department requirements. The finished one-line diagram then becomes a contract document.

Another responsibility of the Electrical Engineering Section is to provide meaningful and timely interface with other Engineering groups during the development of engineering designs. Traditionally, the bulk of electrical engineering design is started long after most of the other engineering groups have completed substantial portions of their designs. However, to develop accurate zone outfitting designs, it is necessary for the Electrical Engineering design to begin earlier to keep pace with other engineering disciplines.

A further responsibility of the Electrical Engineering Section is to participate in construction planning meetings with the production planning group of the Production Department. In these meetings, potential problems and cost savings ideas are discussed, and engineering designs for the job are reviewed. As has often happened, the Production Department can request modifications to the designs to facilitate ease of installation. Engineering is expected to honor these requests, if at all possible, even though it means, in many cases, that drawings must be remade. Also, Electrical Engineering is expected to review Production Planning erection summaries for possible comment.

IV. ENGINEERING DEPARTMENT INTERFACES

In reviewing engineering operating practices and procedures, the goal was always to change only what had to be changed, so that the impact of the move to zone outfitting could be cushioned as much as possible with things familiar. For example, only two Engineering sections underwent slight reorganization. The Mechanical Section addded a "Machinery Package Group" to handle the entire development of machinery package units, and the Engineering Administration Section added an "Operations Services Group" to handle the lifting arrangements required by Production, so that outfitted structural units could be lifted with safety. Avondale Engineering has demonstrated that zone outfitting can be absorbed into the design organization without the need for violent internal reorganization.

A. Planning/Scheduling Interface with Engineering

The earlier the start that Engineering has, the better the chance that all required engineering work will be completed at start of prefabrication. To this end, it is most desirable that engineering work start prior to contract signing, if at all possible. This can be done through a "letter of intent" arrangement or through some other means, but the owner, as well as the shipyard, will reap benefits for money spent during the "precontract" phase. If a "precontract" start is not possible, the engineering effort must commence immediately upon contract signing. In either case, potential problems will come to light at an early stage, the chance for timely material procurement of long-lead items will be enhanced, the shortened building period that zone outfitting offers will be protected, and initial regulatory reviews can be conducted early.

Precontract engineering effort should include work on mechanical system diagrams, weight estimate, longitudinal strength, hydrostatics, tank capacities, bonjeans curves, intact trim and stability data, loading conditions, damaged stability evaluation, wake survey, resistance and self-propelled tests, electric load analysis, electric one-line diagram, vent system development, and duct opening, as well as the development of procurement specifications on long-lead material items such as main propulsion engines, diesel generators, cargo oil pumps, anchor windlass, steering gear, etc.

During the precontract phase, a constant dialogue must be maintained between Engineering and Production concerning such areas as preliminary unit definition, identification of construction method, the establishment of outfitting zones for purchasing, and the preliminary assignment of machinery package units and pipe racks for main deck. This dialogue, which begins during precontract, is essential to the successful implementation of zone outfitting techniques and must continue throughout contract design development and construction. In fact, the major beneficial "fallout" of the implementation of zone outfitting at Avondale has been the renewed spirit of cooperation between the Engineering and Production organizations.

B. The Engineering/Production Planning Interface

The interface between the Hull Section and the Production Establishment can be broken down into two broad types. The first type of interface is necessary for the Hull Section to accomplish work for which it is responsible. This type of interface is termed primary interface. The second type of interface is one in which the Hull Section engages to assist other entities to accomplish their assigned tasks. This type of interface is termed support interface.

(1) Primary Interface

The primary interface between the Hull Section and the Production Establishment lies mainly in the information that the Production Establishment provides to the Hull Section prior to, and for use in, preparing the yard plans. This primary interface provides information for three distinct systems which appear on the yard plans:

- Ship Erection Breakdown
- Plate Edge Preparation
- Ship Unit Construction Method

The three above-mentioned systems are governed by production considerations and the need to accommodate production techniques and methods. The three systems and their interaction profile with the production establishment will be briefly reviewed.

a. Ship Erection Breakdown

Ship erection breakdown starts with the Production Planning Department breaking up the vessel's hull into main and subassemblies. Once the major planes of division are established by Production Planning, this information is passed to the Hull Section in the form of a document known as the "Hull Unit Arrangement," from which the yard plans are developed to incorporate the desired erection planes. If a Production Department break is not desirable from an Engineering consideration, then this structural division line is brought back to the Production Planning Department, where a compromise erection joint line is established. This interface, therefore, establishes a structural erection line that preserves both sound technical parameters and production fabrication methodology.

b. Plate Edge Preparation

Every yard plan addressing itself to main hull and superstructure construction displays plate edge preparation weld identification notations. The selection of the proper edge preparation is a result of interface between the Production Welding Department and the Production Planning Department and Hull Section, whereby the joint design is discussed and the Production Welding Department recommendations are incorporated.

c. Ship Unit Construction Method

The Production Planning Department issues a document to the Hull section known as a "Unit Breakdown Summary Sheet." This document describes in great detail the intended methods to be used to manufacture the unit in question. This document assigns partial subassemblies, subassemblies, and main assemblies of the unit to the specific manufacturing process lanes. This document is utilized to develop the yard plan and Unit Parts List. Interaction discussion is carried on between the Production Planning Department and the Hull Section, whereby refinements are made to the Unit Breakdown Summary Sheet incorporating Engineering considerations.

One more area of primary interface consists of establishing drawing production need dates. The Production Planning Department provides the Hull Section with production-required need dates for all structural drawings. After receipt of the production need dates, a review is conducted in the Hull Section and, if any changes are desired, the Production Planning Group is requested to review its initial requirements and provide revised dates, if possible. The production-required need dates provide the Hull Section with the necessary information for the development of the drawing schedule which, in turn, delineates the required order of drawing development.

(2) Secondary Interface

The secondary interface between the Hull Section and the Production Establishment exists primarily in providing the Production Establishment with information on material and with yard plans and shop drawings in the case of systems such as mooring, anchor handling, etc. For example, discussions with the

Machine Shop Superintendent are carried on during the development of the rudder support system in order to apprise the shop of specific engineering requirements as well as receive information on manufacturing limitations, procedures, requirements, etc.

With regard to the yard plans, the Hull Section is in constant communication with the Moldloft during the Loft's development of the unit control manuals. The Hull Section works closely with the Production's Accuracy Control Section in its research and investigations. An area of particular concern for the Hull Section and Accuracy Control is welding design to minimize distortion. Where possible, suggestions made by the Accuracy Control Section are implemented at once. Another area which demonstrates the close cooperation between these two groups is in the inclusion of at least one datum line within each structural unit to facilitate Production operations. This suggestion was made by Accuracy Control and implemented by the Hull Section.

V. SUMMARY

Thus far, Avondale Engineering's implementation of zone outfitting techniques has been most satisfactory. By and large, the problems encountered are many of the same ones which plague the engineering effort utilizing conventional design techniques--lack of vendor information, lack of industry standards, customer changes, etc. However, with zone outfitting, the consequences of these problems are more acute than with conventional design techniques. The philosophy that must be adopted by an engineering organization that is going to implement zone outfitting techniques could be condensed into the following key items:

- START ASAP, before contract signing, if at all possible.

- COMMUNICATE with Production from the start.

- MATERIAL SPECIFIED AND ORDERED ASAP: Have vendors ready to go upon contract signing. The sooner purchase orders are issued, the sooner vendor information required for drawing development will be received.

- PLAN AND SCHEDULE ENGINEERING WORK: With all the drawings needed, and the short amount of time to do them, a good plan and a good schedule are crucial.

- REMEMBER TO MAKE IT HAPPEN: With zone outfitting, there is no time to sit around and wait for the "other guy" to call. If something is needed, get it.

VI. SOURCE MATERIAL FOR CHAPTER 3

The following lectures in the Technology Transfer seminars were used as source material for Chapter 3. They are listed in the Appendix. Lectures 6, 11, 12, 13, 14, 15, 16, 17, 18, 31, 47.

CHAPTER 4

MOLDLOFT

I. INTRODUCTION

Moldloft management worked with IHI technicians for a period of two years, during which time there was an interface of Japanese and American shipbuilding concepts and methodology. Those two years of work resulted in many innovations in the Moldloft.

Many of these innovations were easily merged into, or substituted for existing systems in the Moldloft. Those procedures that were unusable because of the vast differences in our two computer systems were modified to suit ASI needs while trying to retain the original IHI concepts. Change was implemented to either improve the existing ASI system or to replace an existing system with a more efficient one. The system that ultimately evolved is a combination of ASI and IHI procedures, and the new procedures described in this chapter include:

- Moldloft planning,
- Scheduling by stages,
- Unit control manuals,
- Steel tape system,
- Line heating method,
- Pin jig utilization,
- Piece numbering system,
- Key lines,
- Shrinkage factor.

Additional manning was required for some procedures such as steel tape production; some areas were a trade-off in manpower. Manhours utilized for line heat templates were partially absorbed by the elimination of steel plate forming jigs, for example.

The greatest additional cost incurred by the Moldloft was the formation of the Unit Control Manual group. This group provides the yard with the fabrication drawings for all stages of ship construction, plus all of the data necessary to cut structurals and plates. The UCM concept, although not directly a result of IHI technology, was developed in conjunction with the various IHI systems. The UCM concept was also compatible with the Japanese idea of "stage plans," which are drawings relating to each stage of ship construction and following the "need to know" philosophy.

The impact on N/C programming work was minimal. Specialized programs were formulated by members of the N/C programming group to create the data required for production of steel tapes and key lines. The impact on the Nesting Department by implementation of IHI technology was also minimal. Some recommendations for earlier ordering of steel and for a different sequence of nesting were studied, with the results being beneficial to the process lanes concept. Accuracy control dimensions and accuracy check points for N/C burning tapes were incorporated into the system by the Accuracy Control Section.

IHI's greatest influence on the conventional Moldloft resulted in the additional responsibility of producing line heating templates and the steel tapes.

II. MOLDLOFT ORGANIZATION

Avondale's Moldloft is in the realm of Production and reports directly to the Vice-President in Charge of Production Engineering. The operation consists of four separate departments, each having its own area of responsibility.

The Part Generation Section employs N/C programmers to provide numerical control parts which are programmed and extracted from the "SPADES" data base. This group also provides the sketches for cutting structurals. Each structural is placed on its parent part and validated for accuracy by utilizing CADAM CRT units. The Nesting Group uses these N/C parts in preparing computerized burning data for the N/C cutting machines. The Unit Control Manual (UCM) Department provides the prefabrication and fabrication drawings for hull work within the shipyard. This task is automated and computerized to a great extent by the merger of the CADAM and SPADES programs. These UCM work packages are distributed and maintained by the Loft. The Conventional Loft provides the wooden templates such as roll sets, line heating templates, etc.

Much computerization is evident in the Moldloft. The extensive use of CRT units with SPADES and CADAM programs provides the Loft with the flexibility to accommodate any job.

III. MOLDLOFT PLANNING

The establishment of a Moldloft Planning Group was an IHI innovation that was necessitated by the huge amount of data flowing through the Moldloft from other departments.

Many of the inconsistencies that used to occur on a daily basis due to the large volume of lofting material have disappeared by the extensive use of comprehensive standard procedure manuals. As problem areas are discovered by the planners, meetings are held, the problems discussed, and the resolution incorporated into a standard. Thus, the Moldloft planners have aided the programmers and loftsman to become more efficient in their work and have contributed in standardization of information forwarded to the field.

IV. SCHEDULING BY STAGES

Development of process lanes, level loading at stages, and shop planning require the Loft to do detailed scheduling of each contract very early. Scantling drawings and other pertinent data are examined to make preliminary schedules for:

- N/C Parts Generation (by unit),
- N/C Nesting (number of burning tapes),
- Unit Control Manual Group (number of documents),
- Shell Plates.

As more detailed drawings are received, the preliminary planning effort is enhanced to include such items as number of shell plates that have to be line heated, rolled, or formed, stock requirements, and a list of raw material sizes to be provided.

Curved shell plates are classified according to the area of the vessel on which they appear:

- Afterbody,
- Engine Room,
- Cargo Area,
- Forebody.

It is then possible to determine and tabulate the amount and type of bending, rolling, or heating process required for each curved plate. Applying manhours required for each operation against these figures enables planners to produce a level-loaded schedule for the Blacksmith and Plate Shops.

Other detail schedules are produced for each stage of construction that utilizes information produced by the Moldloft. Schedules are provided for:

- Completion of N/C parts,
- Completion of burning tapes,
- Completion of templates,
- Completion of key line tapes,
- Jig scheduling.

The documents in the Unit Control Manual are separately scheduled, based on level-loaded shop and production schedules.

Moldloft planners then have the visibility, based on detailed scheduling, to foresee problem areas. As this occurs, they can inform the shop planners so that production schedules can be modified with as little disruption as possible.

V. UNIT CONTROL MANUAL

The Unit Control Manual (UCM) is a group of seven different documents designed to be used by the yard workers in every stage of hull construction from prefabrication to the erection of a unit on the ship. The objective of the UCM effort is to break down the Engineering Yard Plan into basic components so that the average worker in the shipyard will be able to understand and follow these simplified instructions and thus to work accurately and quickly.

The seven documents comprising the UCM and the stages of construction in which each is utilized are as follows:

Document	Construction Stage
Cutting List	Prefabrication
Panel Line Booklet	Prefabrication
Partial Subunit Booklet	Fabrication
Subassembly Booklet	Subassembly

Document	Construction Stage
Main Assembly Booklet	Main Assembly
Erection Booklet	Erection
Lifting Lug Arrangements	Erection

Each of these documents is released separately to the shipyard prior to the work effort addressed. The information in a document is confined to the specific type of work to be done in each stage of construction so that the worker has only that information needed to complete his specific task, thus reducing the possibility of misinterpretation of nonessential information that could result in errors.

UCM production is accomplished by the use of the SPADES Numerical Control System and the CADAM interactive graphics system. Special programs were written by ASI to develop interfaces that allow the merger of these two systems.

The data used for production of UCM booklets is stored in the CADAM data base. The Numerical Control parts generation group provides structural and plate components which are stored in the computer and used as a base for the UCM shop drawings. UCM production is interfaced with the SPADES data base, so that the UCM draftsman can utilize as much data as possible from the computer. Various components, as required for the drawing, can be retrieved from the SPADES data base and displayed simultaneously on the CRT screen. The merger of these components and the addition of necessary details creates the desired drawing. Each drawing is then filed by module and subgroup into the CADAM files. The CADAM standards file is constantly utilized and entered directly on the drawing without having to redraw the various details each time. As new standards are created, they are added to these files. Final output is a hard copy of the drawing by means of a Versatec electrostatic plotter. Turnaround can be within minutes when necessary. The books are then assembled, copied, and distributed by the Loft.

Information that can be found on UCM drawings varies, depending on the stage of construction the drawing addresses.

A. Cutting List and Panel Line Booklet

The cutting list is the first document to be released to the shipyard and is ultimately utilized by the Plate Shop. Cutting lists are prepared from the UPL (Unit Parts List) from Engineering, with the Moldloft adding additional data as necessary. A total cutting package includes UCM cutting lists, N/C burning tapes, structural sketches, frame bending data, templates, pin jig data, and Panel Line drawings, as indicated in Figure 4-1. Each unit is scheduled with its own "start prefabrication" date as established by the shop planners in accordance with the process lanes directive and level-loaded plate shop schedules. Once prefabrication commences and steel is being cut according to the schedule, the parts are palletized according to need date and sent to the various platens where they will be used. Storage of parts has been virtually eliminated by scheduling a smooth flow of material to the fabrication platens.

Figure 4-1 Prefabrication Information in U.C.M.

PREFABRICATION INFORMATION IN U.C.M.	TYPE OF INFORMATION PLATE SHOP WILL RECEIVE	LABELING MEDIUM
N/C Burning Tape Numbers	1. 1" scale drawing representing steel plate to be burned 2. Burning data stored on IBM System 7	1" scale burning tape drawing
Servo (Servograph)	Full size optical tracing template (film)	Full size servograph template
Temp. (Template)	Full size wooden or paper template	Full size wooden or paper template
N.T. (No Template)	Cut to size given in "Dimensions" column of U.C.M. Cutting List	U.C.M. Cutting List
Exacto No. (Exactograph)	Exactograph Sketch	Exactograph Sketch
FRBD (Frame Bending)	1. Frame bending computer printout of inverse curve 2. Paper end cut templates	Frame bending computer printout
MLCSK No. (Moldloft Cutting Sketch)	1. Sketch of structural showing dimensions and processing instructions 2. Standard end cut template (if applicable)	Moldloft Cutting Sketch
PLCSK (Panel Line Cutting Sketch)	Sketch of panel (butt station) indicating lengths, widths and bevels of plates to be cut on exacto machine	Butt Station Drawing (found in panel line booklet

The cutting list contains such information as piece numbers, quantities required, type of material, and cutting medium information for every part in a given unit to be burned, with the exception of foundations and outfitting items.

B. Partial Subunit Booklet (Figures 4-2 and 4-3)

This booklet is distributed to certain platen areas where initial fabrication of pieces is to be done. The information contained in this booklet includes parts list and pictorial references showing how to fit and weld all the pieces together that apply to this fabrication stage. Utilizing the yard plan and UPL, the CADAM draftsman extracts those details required from the yard plan to produce a shop drawing. Only information essential to the fabrication of one partial subunit (PSU), presented in its simplest form, is given to the worker in the yard who will be doing the fabrication. Many hours of drawing research are eliminated and a less skilled worker can be used, since blueprint reading requirements are minimized.

A PSU can be as simple as fabricating a flat bar to a bracket or as complex as fabricating shaped floors to a girder. Each PSU has its own UCM drawing and unique identity in the system. Note that the "pieces" in a more complex PSU may themselves be previously fabricated PSU's. Thus, the PSU of Figure 4-2 is a piece in Figure 4-3.

C. Subassembly Booklet (Figure 4-4)

This document is distributed to work areas where subassembly work is to be performed. This fabrication involves the combination of larger assemblies as opposed to individual pieces being welded together. The booklet contains a sequence of construction, part lists for each subassembly being built (if more than one), and an isometric drawing of the subassembly with all necessary details needed to complete the desired work. The parts list includes PSU's as well as individual pieces.

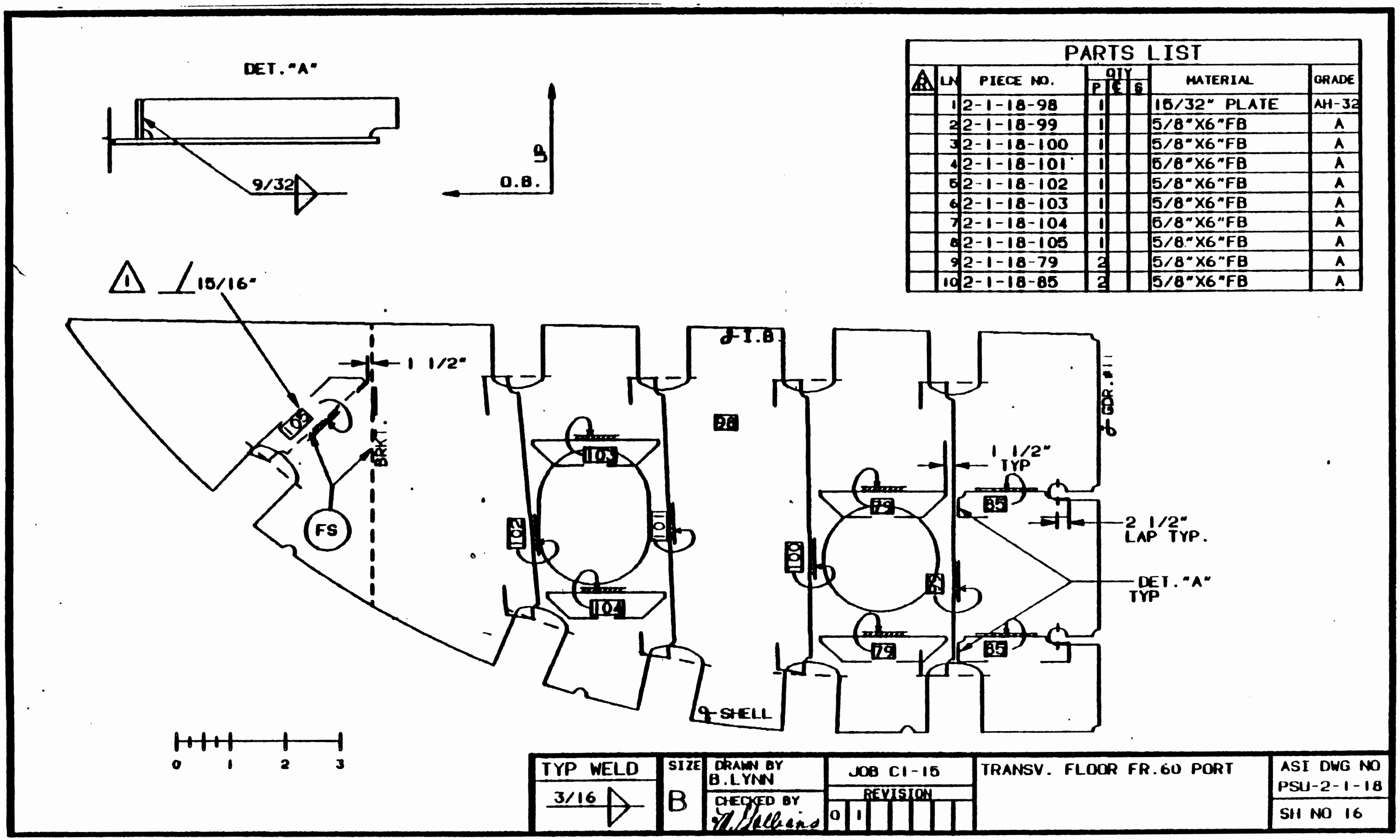
D. Main Assembly Booklet (Figures 4-5 and 4-6)

The work effort addressed by this document deals with the closure of a unit by combining a subassembly with a panel of plating along with miscellaneous items such as collar plates, clips, chocks, etc. The booklet contains a sequence of construction, a parts list and all necessary drawings (including details) to complete the final hull work on a given unit.

E. Erection Booklet (Figure 4-7)

This is the final booklet required for actual hull assembly. It provides information concerning leveling requirements and attachment of the unit to the erected portion of the hull, with relevant details for fabrication of miscellaneous items that could not be built with the unit at an earlier stage.

The unit control manual was used in the Exxon contract and proved to be an invaluable tool. Many of the IHI innovations are utilized as part of the data found in the UCM documents. Although the UCM was developed at Avondale prior to the IHI technology transfer, it readily serves the same purpose as the Japanese



PARTS LIST

LN	PIECE NO.	QTY P	QTY ℄	QTY S	MATERIAL	GRADE
1	2-1-18-98	1			15/32" PLATE	AH-32
2	2-1-18-99	1			5/8"X6"FB	A
3	2-1-18-100	1			5/8"X6"FB	A
4	2-1-18-101	1			5/8"X6"FB	A
5	2-1-18-102	1			5/8"X6"FB	A
6	2-1-18-103	1			5/8"X6"FB	A
7	2-1-18-104	1			5/8"X6"FB	A
8	2-1-18-105	1			5/8"X6"FB	A
9	2-1-18-79	2			5/8"X6"FB	A
10	2-1-18-85	2			5/8"X6"FB	A

Figure 4-2 Partial Subunit Drawing

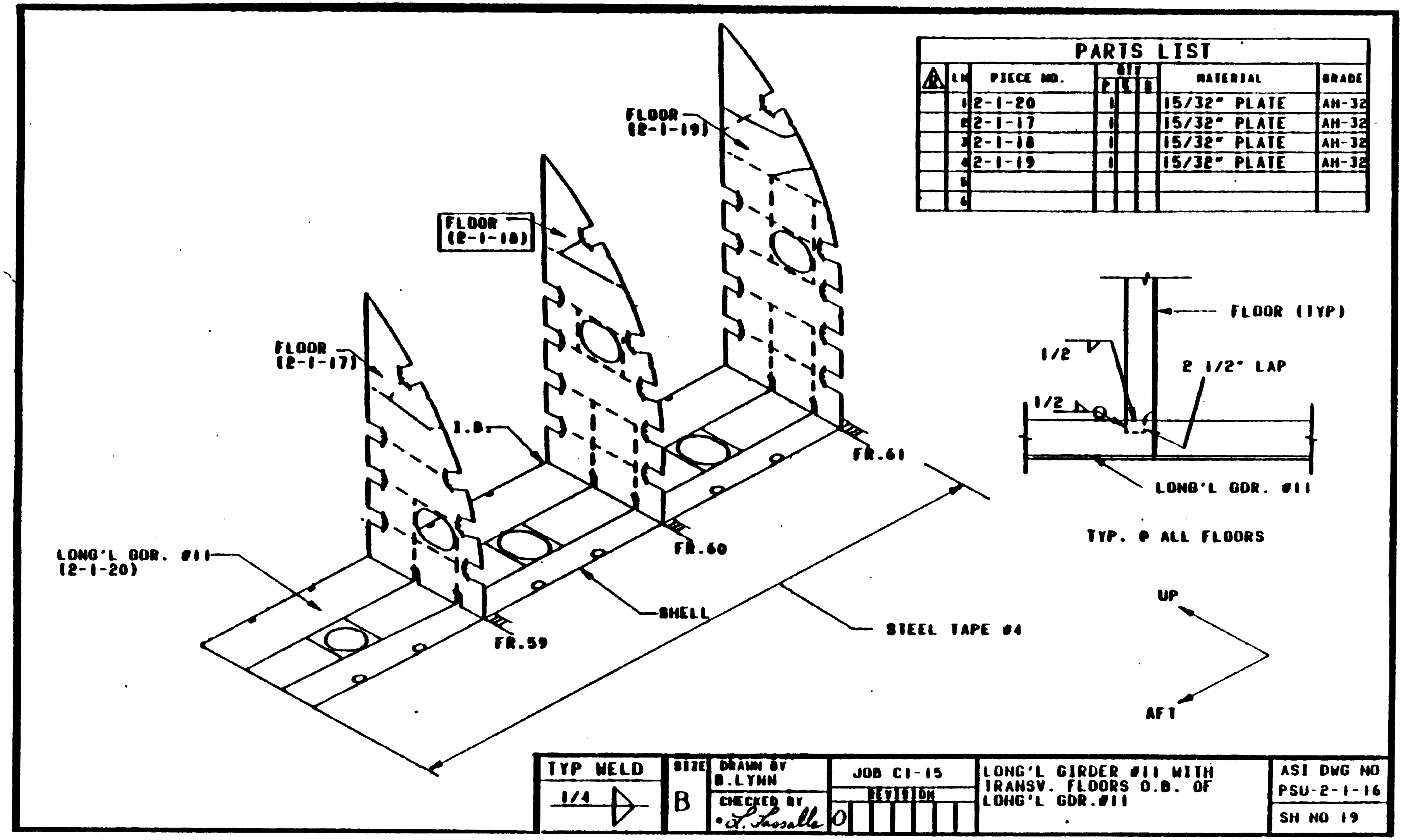


Figure 4-3 Larger Partial Subunit Drawing

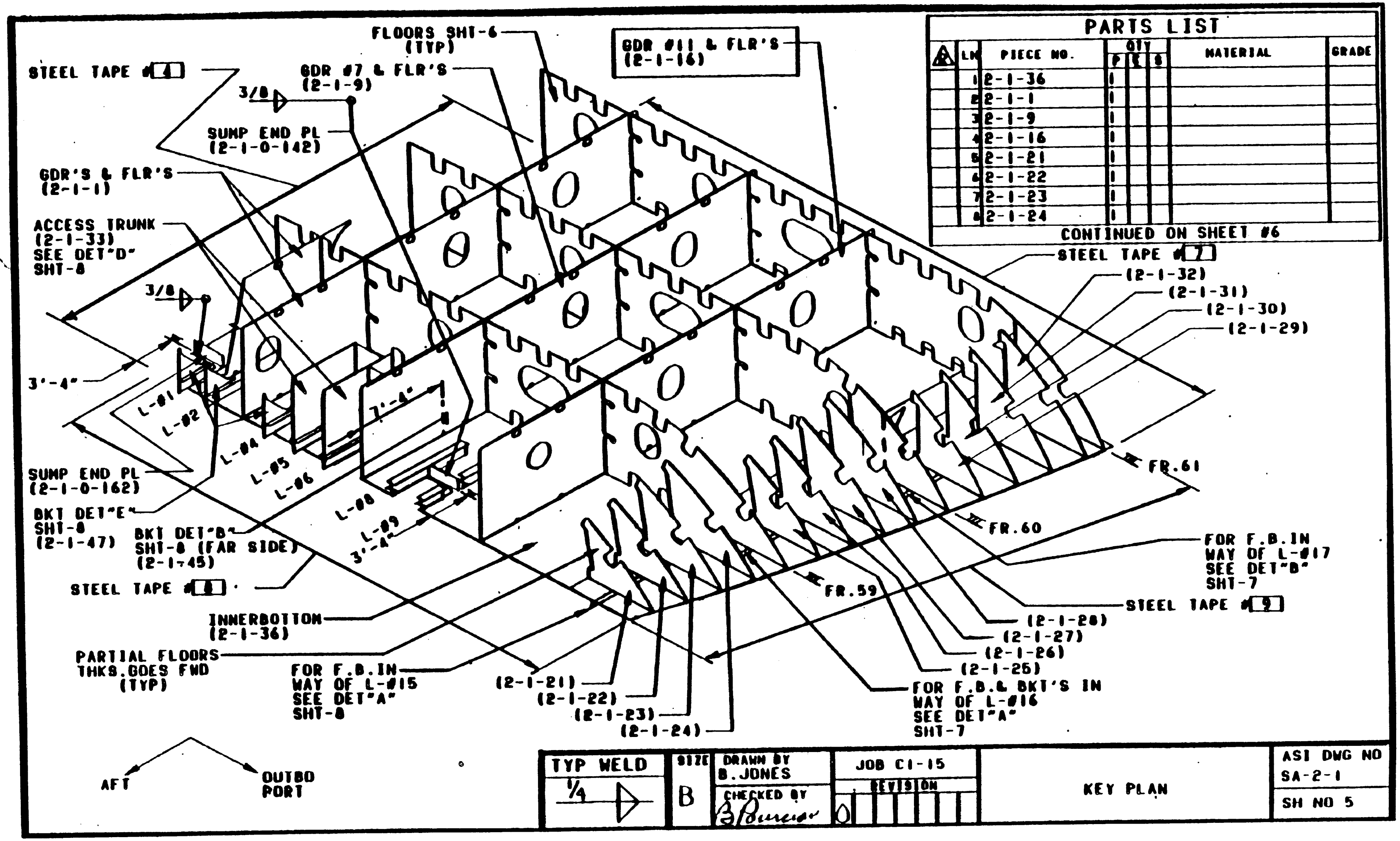


Figure 4-4 Subassembly Drawing

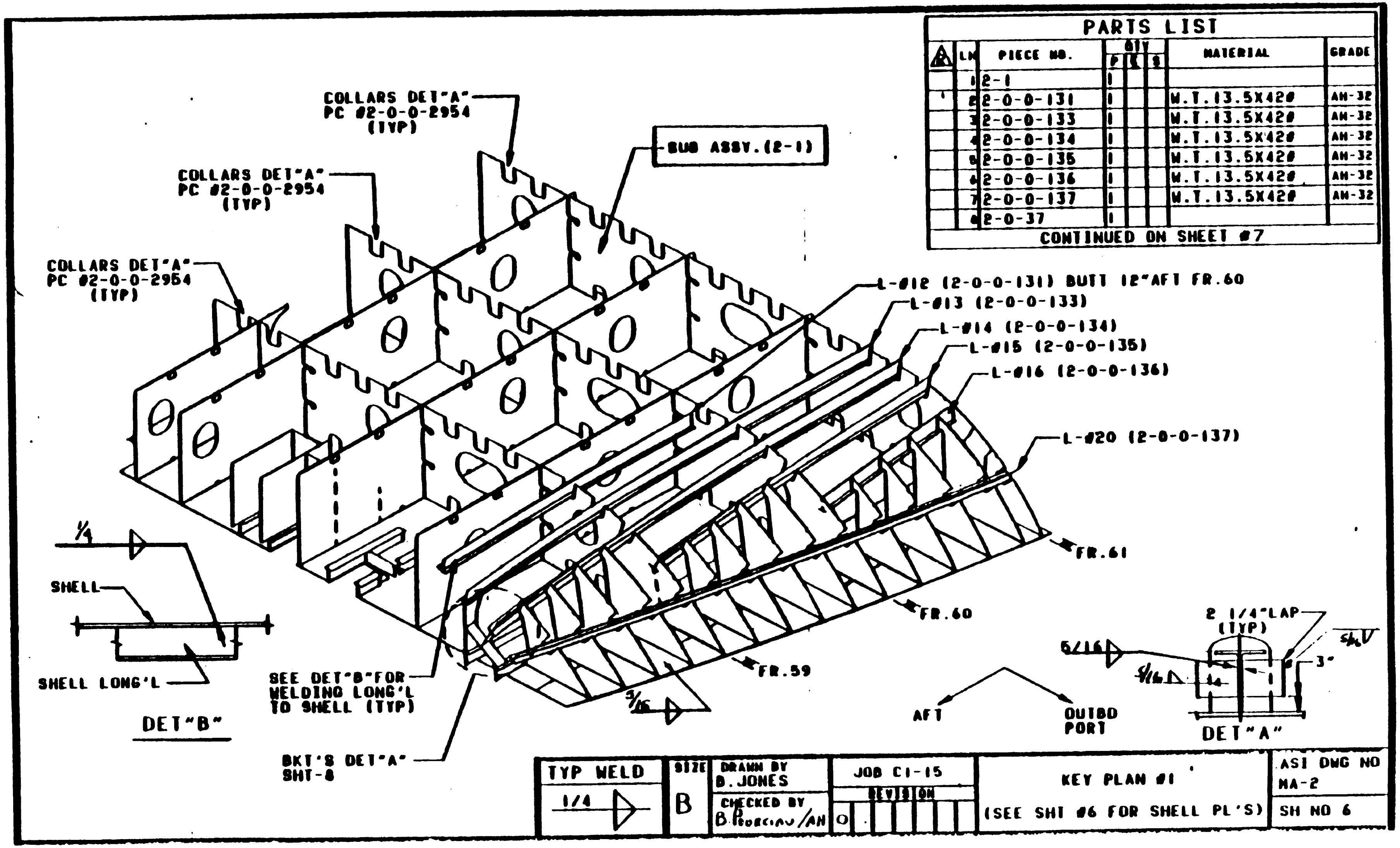


Figure 4-5 Main Assembly Drawing

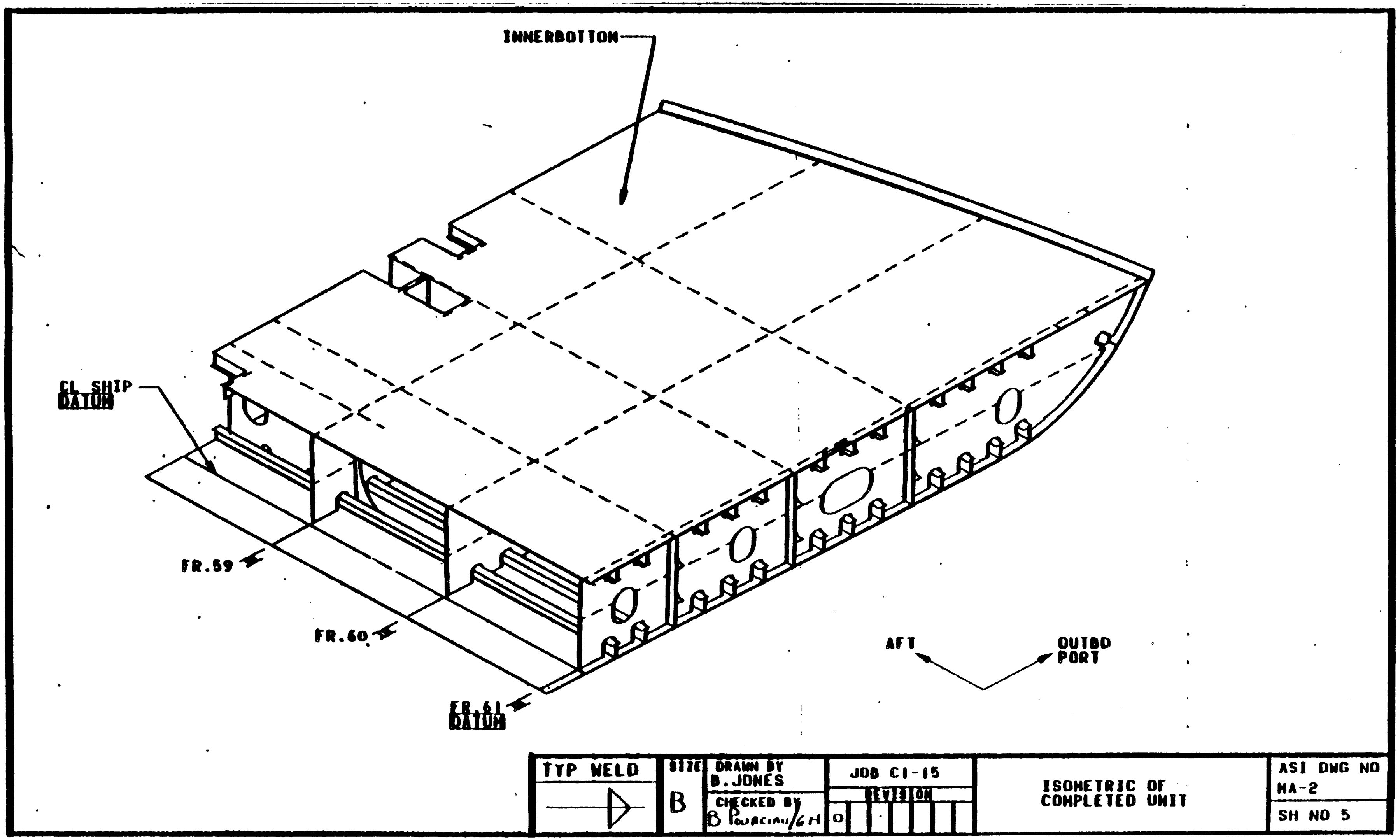
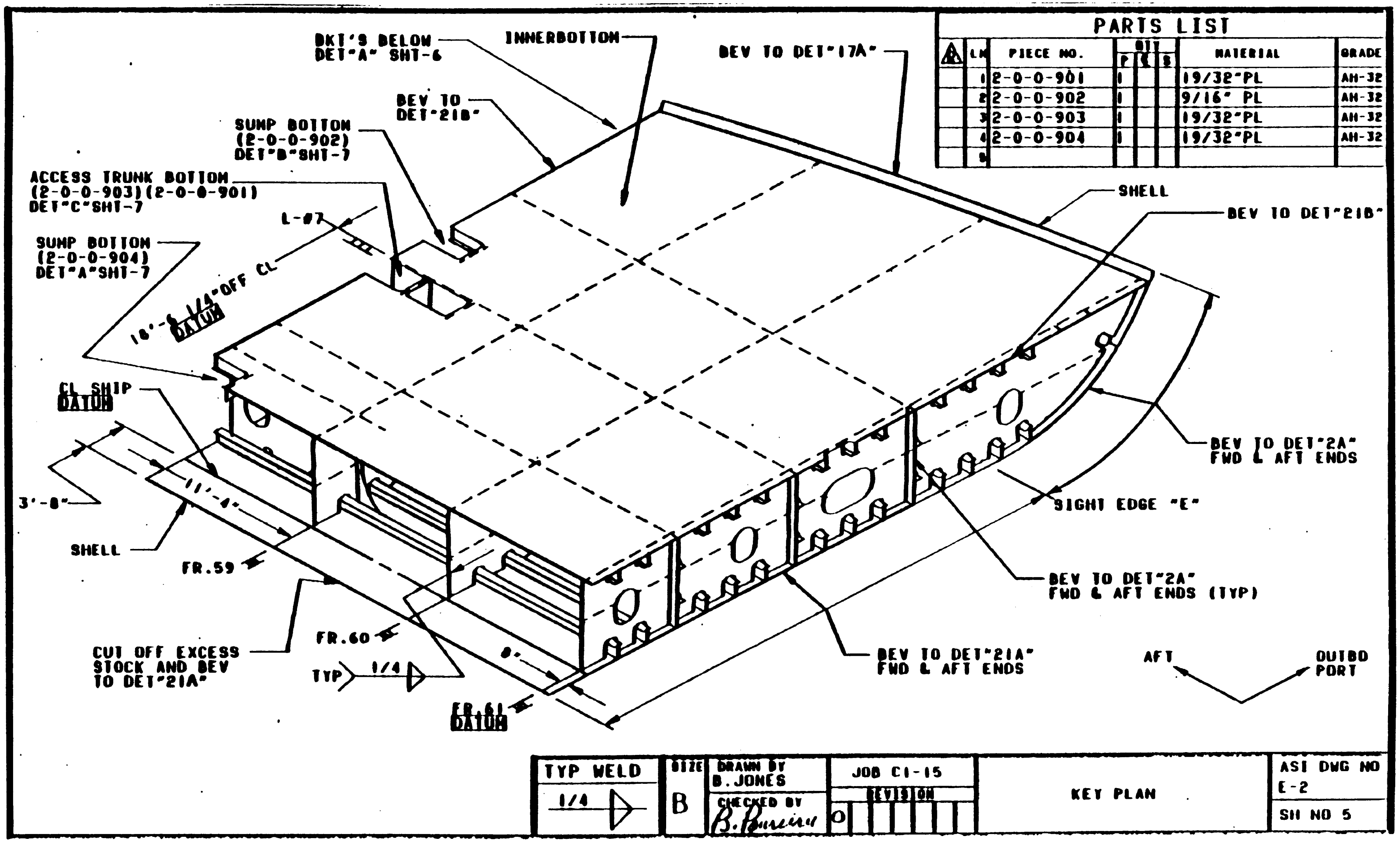


Figure 4-6 Main Assembly Drawing, Completed Unit



PARTS LIST

LN	PIECE NO.	QTY P	QTY S	QTY S	MATERIAL	GRADE
1	2-0-0-901	1			19/32"PL	AH-32
2	2-0-0-902	1			9/16" PL	AH-32
3	2-0-0-903	1			19/32"PL	AH-32
4	2-0-0-904	1			19/32"PL	AH-32
5						

Figure 4-7 Erection Drawing

concept of Stage Plans. A total of 635 UCM booklets were provided to the shipyard workers on the Exxon contract. Such IHI innovations as steel tape identification numbers and datum lines are contained in the UCM's.

A most important advantage of the UCM is that it is a simple document that the average yard worker can easily understand. The UCM improves worker efficiency and allows yard supervisors more time to directly manage the workers rather than to interpret documents for them.

VI. STEEL TAPE SYSTEM

To lessen the use of measuring devices and assure continuity across sections joined together, the IHI steel tape system was incorporated into the Moldloft's effort. The tapes are fabricated from steel bands and produced by the conventional Moldloft. A special measuring table was constructed which aids the loftsman in this work.

The N/C Loft provides computer programs which are utilized to extract the steel tape data. These programs provide a printout to the loftsman for marking the girths, etc., on the tapes. Steel tapes are used extensively by the yard in the fabricating and erection processes. The total number of steel tapes for active jobs within the yard in mid-1984 was 693 steel tapes. Each tape is catalogued and prepared in duplicate in case of loss or breakage.

Each steel tape is uniquely numbered with one side of the tape providing finished dimensions and the other side of the tape providing "expanded" dimensions before welding. UCM documents guide the workers by indicating where and what steel tapes are to be used. Steel tapes are marked with a scratch awl and show locations of structural elements such as frames, girders, longitudinals, decks, and stringers. Also shown are plate seams, key reference lines, and expanded girths.

Steel tapes are provided for all stages of ship construction. They eliminate the use of measuring rulers and the errors associated with using those devices. The same information is used over and over, which increases accuracy and consistency when fabricating the units. Steel tapes have contributed to reduced costs at the erection site and an overall reduction in fitting problems.

VII. LINE HEATING

Traditionally, shell plates in the shipyard were shaped by one of the following methods:

- Rolling
- Pulling in place on unit with jacks or weight blocks
- Furnaced plates from the blacksmith shop

With the implementation of line heating technology, these processes have virtually been eliminated (with the exception of rolling) in the shipyard. Shell plates with compound shape that customarily cause fitting, welding, and distortion problems to the units have been replaced with shell plates accurately preformed to the configuration of the unit. Experience on the Exxon ships has shown that practically every shell plate with some compound shape was eventually line heated.

As each unit is processed by the Moldloft, the conventional loft provides form templates (usually on frame lines) with sight edges and sight lines for line heating clearly marked. The sight lines are on an axis normal to the roll axis of the plate. The declivity angle for each frame is also indicated, so that the templates are held in the proper orientation. The roll set templates give the desired transverse shape. The plane established normal to the roll axis at each frame gives the amount of twist; the thread line or sight line, when straightened, determines the amount of longitudinal shape. A plate has the correct shape only when the roll sets fit the plate on the prescribed declivity, the vertical plane is sighted as flat, and the sight line is straight. (See Figure 4-8.)

Results of the line heating process as applied to the Exxon tankers were excellent. Each unit was carefully monitored as the shell plates were installed, checking tolerances for shape and overall fit to the units. Not every shell plate fit the jig or unit without some adjustment, but the number of misfits was minimal and adjustments were easily made.

A total of 600 shell plates were line heated over the course of the three-ship Exxon contract. A similar method is used to twist formed longitudinals.

The benefits already realized by utilizing the line heating method are:

- elimination of the furnaced plates;
- more accurately shaped plates;
- less fitting time on the platens;
- eliminating dogs, clips, and lugs and having to restore surfaces;
- reduction in misalignment across units;
- larger plates can be utilized without furnace size restrictions.

VIII. PIN JIGS

The implementation of pin jigs at ASI has reduced some of the cost of N/C coding and nesting. Prior to the Exxon contract, all fabrication jigs were cut from plate and assembled in an assigned area. This operation was costly to the yard because of manhours and material involved with the fabrication, storage, and cutting of steel for the jig. Moldloft costs were also involved because all jigs were N/C burned. The pin jig concept has reduced these costs by approximately 50 percent.

Forty construction jigs were used on the Exxon contract. Twenty-one of these jigs were pin jigs, nineteen were fixed or solid jigs. Those units that required a solid jig were units that had excessive curvature, excessive twist, or a width too narrow to be suitable for pin jig fabrication. Most of them were in the fore peak or aft peak.

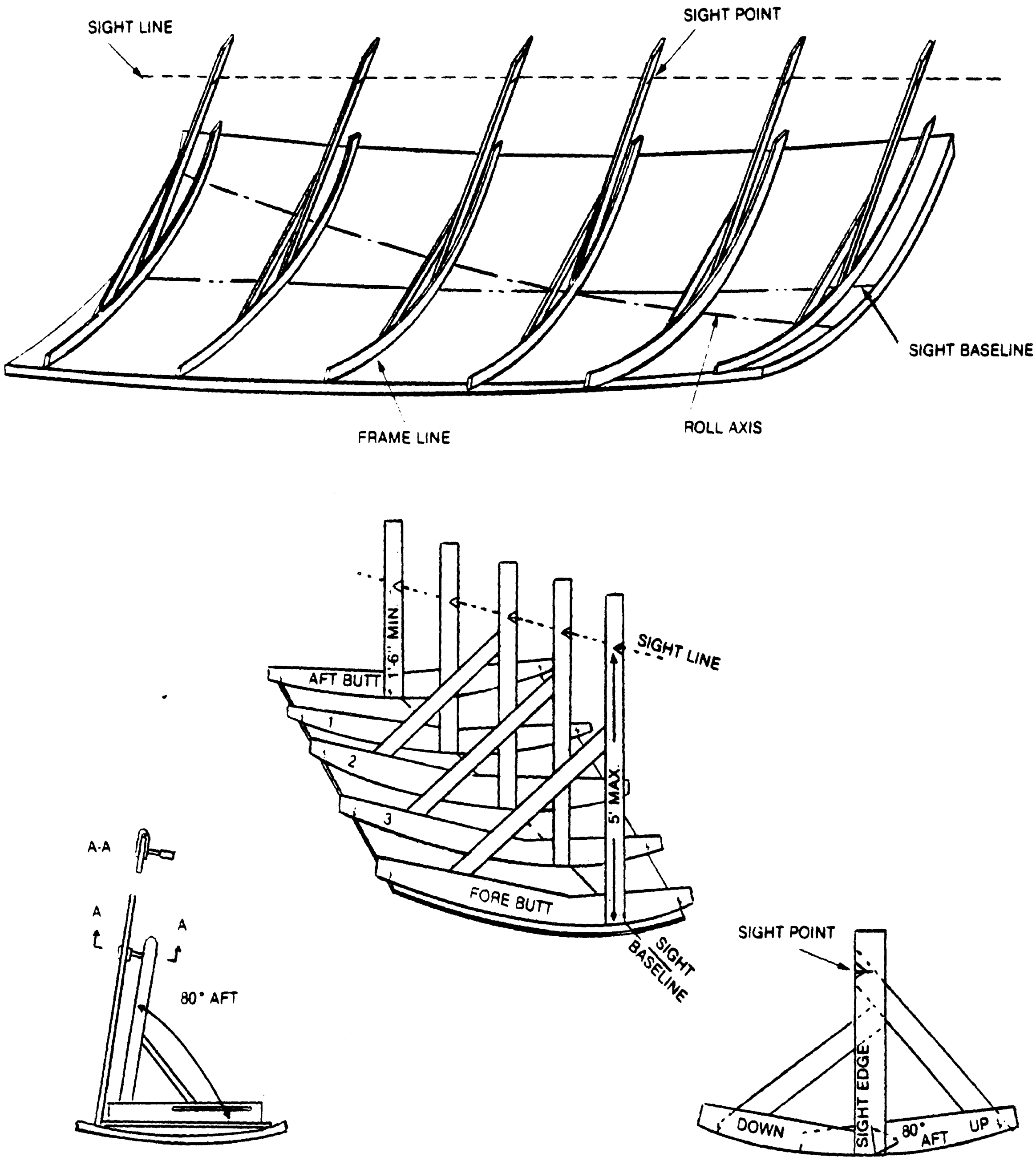


Figure 4-8 Line Heating (Source- Reference 13)

(a) Reference Lines for Template Positioning

(b) Template Marking and Sight Line Alignment

Data required by production to set the pin heights, check dimensions, etc., are derived from the SPADES pin jig computer programs. This information, along with a sketch of pins to be utilized, is used to set the jig for the unit.

Success of pin jig implementation is directly attributed to accurately line heated shell plates. The shell plates must fit in the jig correctly. Once plates are installed on the pins, they cannot be "pulled" down into position as on a fixed jig. False frames at the ends of the unit are a prerequisite when using the pin jig method. False frames are used to align shell plates and longitudinals in the pin jig to assure fairness at the erection stage.

Accurate layout of the frames and longitudinals is provided by the "Key Line" method and steel tapes.

Some of the advantages to be gained by utilizing pin jigs are:

(1) Moldloft cost/effort is reduced.

(2) Setup time in the field is shorter.

(3) The costly storage of fixed jigs is eliminated.

(4) The material costs of steel plates for fixed jigs is eliminated.

(5) Welding costs and fitting costs for fixed jigs is eliminated.

(6) The cost of N/C burning the fixed jigs is eliminated.

(7) Pin jigs are reusable for different units.

IX. PIECE NUMBER SYSTEM

A major factor in the successful use of process lanes was the new piece numbering system. This number consists of a twelve digit hull piece identification number. The staging or construction route of a part is indicated by this number. Individual hull components are numbered on the hull engineering drawing. These drawings are used by the hull production planner to assign the staging piece number in the form of a parts list. The drawings are also used to write a unit summary sheet of how the unit is to be built.

The four basic components used in the piece numbering (Figure 4-9) are:

- Unit Number
- Subunit Number
- Partial Subunit Number
- Piece Number

Individual pieces are fabricated together to form a partial subunit (PSU). The combination of PSU with other PSU's and/or individual pieces, depending on the fabrication site, creates a uniquely numbered, larger partial subunit. The fabrication of a subassembly to another subassembly will create another unique subunit. If the work is done at the main assembly site, the result is the main assembly of the unit.

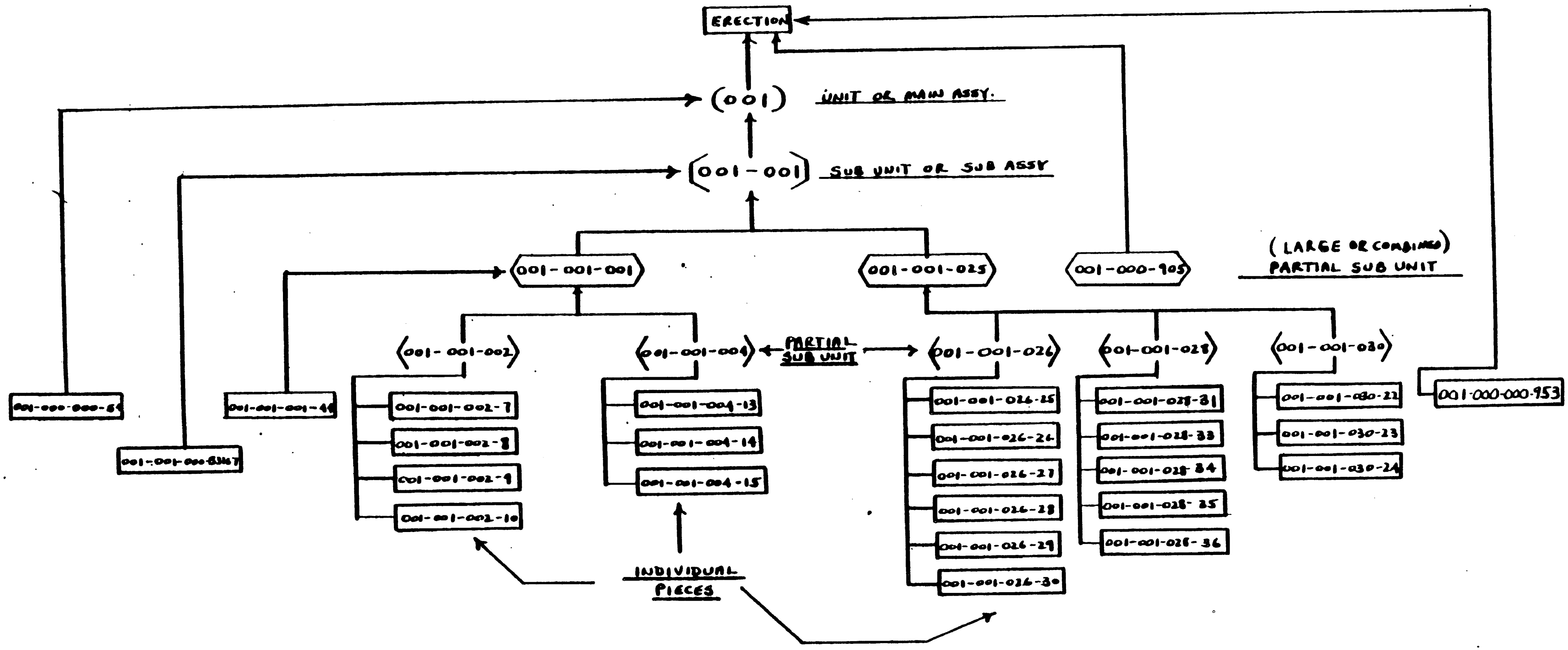


Figure 4-9 Piece Numbering System

In all cases, the location of the fabrication work done on pieces or assemblies determines the type of assembly produced. If the work is done on an initial fabrication platen, then the result is designated as a PSU. If fabrication is done on a subassembly or main assembly platen, then the result is a subassembly or main assembly, respectively. An individual piece (before fabrication) will always have the following numbering configuration:

Unit No. - Subunit No. - Partial Subunit No. - Piece No.
For example, 003 - 001 - 017 - 143

A partial subunit will always have this configuration:

Unit No. - Subunit No. - Partial Subunit No.
For example, 003 - 001 - 017

That is, the piece number is no longer needed after fabrication to create a PSU. Similarly, a subassembly (003-001) loses its PSU identities, and at the final or grand assembly, the assembly is identified with only the unit number. Special codes are used to designate items routed directly to the erection stage without subassembly. Thus, the information given by the piece number explicitly indicates not only the unique identity of a part or assembly but also its next destination in the process lane.

X. THE KEY LINE METHOD FOR MARKING SHELL LAYOUT

Integrated into the Molfloft's procedures is the IHI method for checking N/C or manual layouts on curved shell units. The key line method utilizes a series of steel marking tapes and wooden templates to verify the marking on a shell plate in a jig of the locations of structural entities such as bulkheads, shell longitudinals, and frames. The key line method is used to check an existing layout either from N/C burning or from a manual layout. The use of the girth table is not enough to obtain accurate curved shell units because the girth table indicates distances of structures from the centerline of the ship. Since many units do not contain the ship centerline, it is difficult to determine what seam position should be the starting point.

In order to obtain accurate curved units, it is necessary to establish two key lines which are perpendicular to each other on the curved shell. One is the frame line nearest the center of the unit (Key Frame) and the other (Key Line) is a line perpendicular to the key frame and near the center between seams. (See Figure 4-10.) From these key lines, the curvature of the plate in both directions and the locations of all structural attachments are measured using the prepared steel tapes, thread lines, and angle templates, as shown in Figure 4-11, for example.

Computer programs have been written to provide the complex data required for the key line layout. Variable names for sight edges, etc., are put into these programs and the output is retrieved from the ship's data base. These computer printouts are provided to the loftsman to generate the steel tapes and declivity data required for a key line layout. The key line method for marking shell plate layouts in fabrication jigs has been used extensively at ASI. All of the units requiring jigs on the Exxon contract (approximately 50 units) were

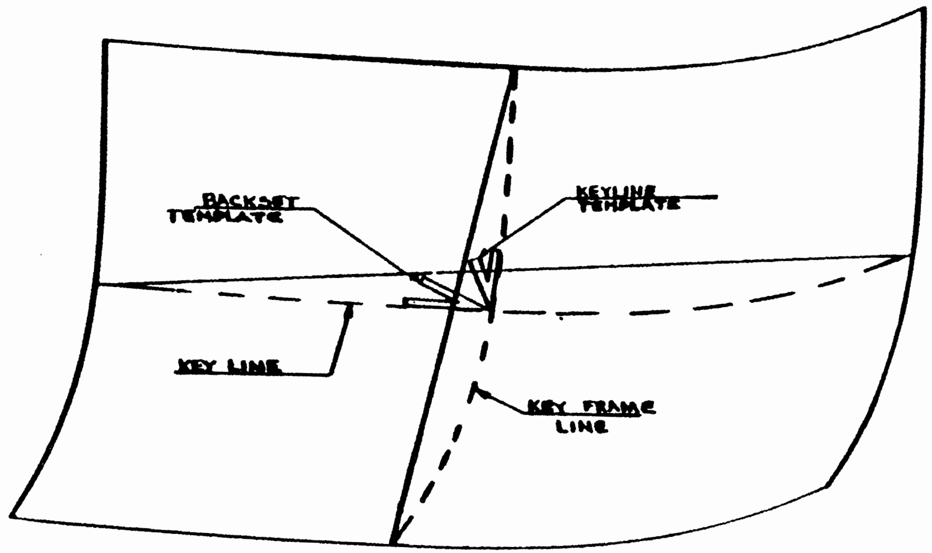


Figure 4-10 Key Line Marking of Curved Plate

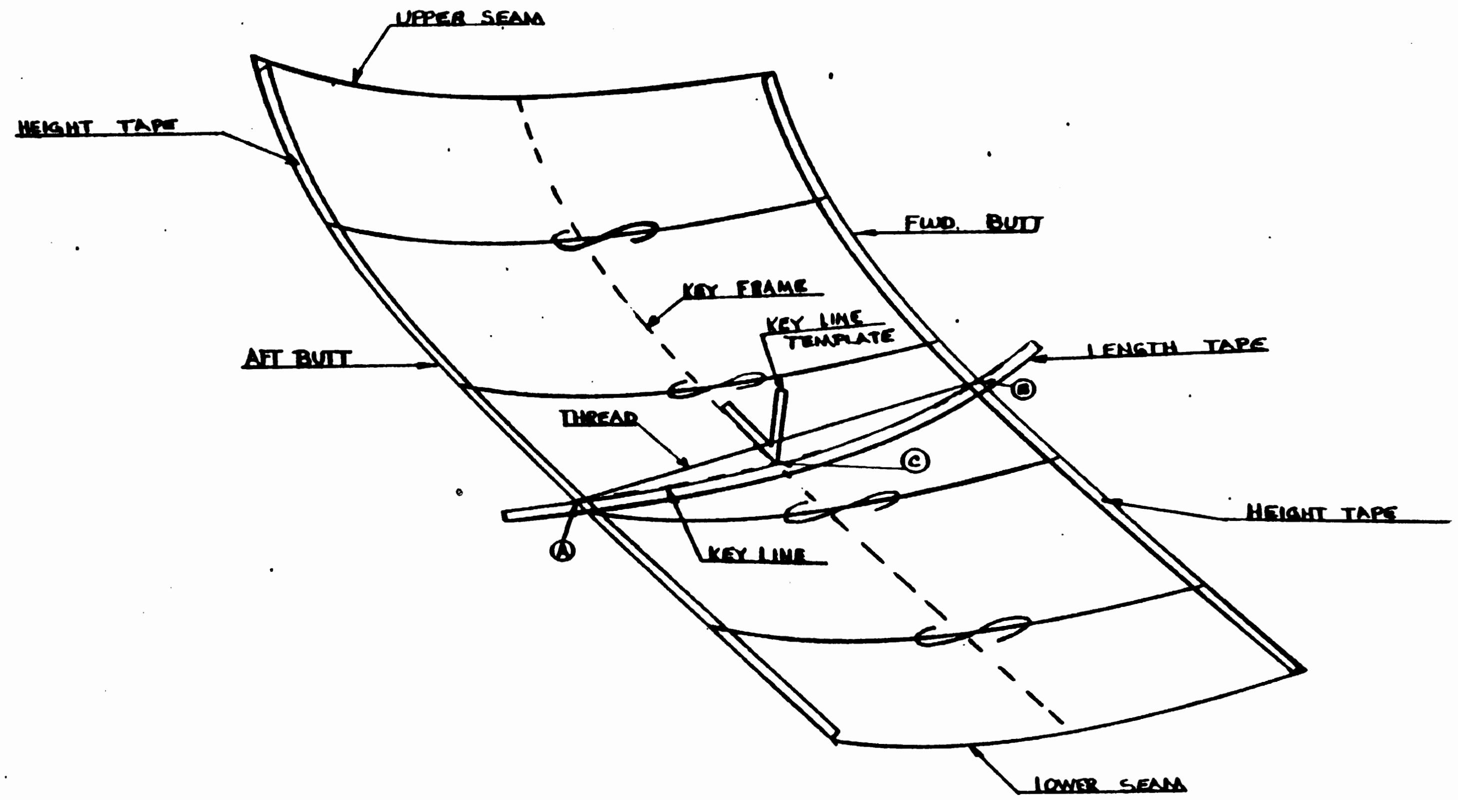


Figure 4-11 Use of Steel Tapes, Thread Lines and Angle Templates on Curved Plate

verified by using the key line method. The results were very favorable, with reduced costs and a reduction of rework for those units built in jigs. Other benefits were the elimination of stock in certain areas of the ship and higher accuracy obtained at the erection site.

XI. SHRINKAGE FACTOR FOR WELDING

One of the prime objectives in ASI's studies with IHI was to produce more accurate output pertaining to welding shrinkage factors. Over the past fifteen years, based on feedback from the field, these factors have been modified many times, sometimes adding extra material, sometimes reducing material as conditions warranted. This data was assembled and examined by a committee of Avondale supervisors and IHI experts. Many meetings were held to examine past performance at Avondale against present practices at IHI, from which it was concluded that the existing expansion factors could be refined. A close examination of what was being done in Japan identified these differences in the two methods:

- Japanese shipbuilders do not introduce any shrinkage factor into structural components (i.e., angles, tee beams, etc.).

- Expansion factors are accumulated according to stage (i.e., factor required at PSU stage is utilized but some excess remains for subassembly, if required).

- A factor is introduced for line heating.

- Different factors are used for manual and automatic welding.

As a result of these studies, ASI developed graphs and tables of shrinkage factors based on number of stiffeners, amount of welding, thickness of plate, and length of plate to be welded. This system is far superior to what has been done in the past. As experience increases and as accuracy control engineers (See Chapter 6) collect measurements in the yard, these tables will expand to encompass such items as type of welding and beveling.

XII. STANDARDS

The object of implementing engineering standards was to reduce the number of different conventions and configurations of details found on engineering drawings and to give the draftsmen and loftsmen guides to improve efficiency and consistency in their work output. Through constant use, standards ultimately become recognizable to the workers in the yard.

Many areas of the engineering drawing were standardized. A committee of Loft and Engineering representatives spent many manhours and countless discussions reviewing past practices regarding standards. For example, previous contracts were reviewed and all of those structural cutouts for side shell longitudinals, etc., that were used in the past were scrutinized. Data used in the SPADES program was also involved. One objective was to have a correspondence between the symbolism used in the SPADES data base and the notation used on the engineering drawings.

A comprehensive standard book has been assembled by Engineering and is extensively used by the Moldloft. These standards have reduced the matrix of items that the Loft and the yard must utilize on a daily basis.

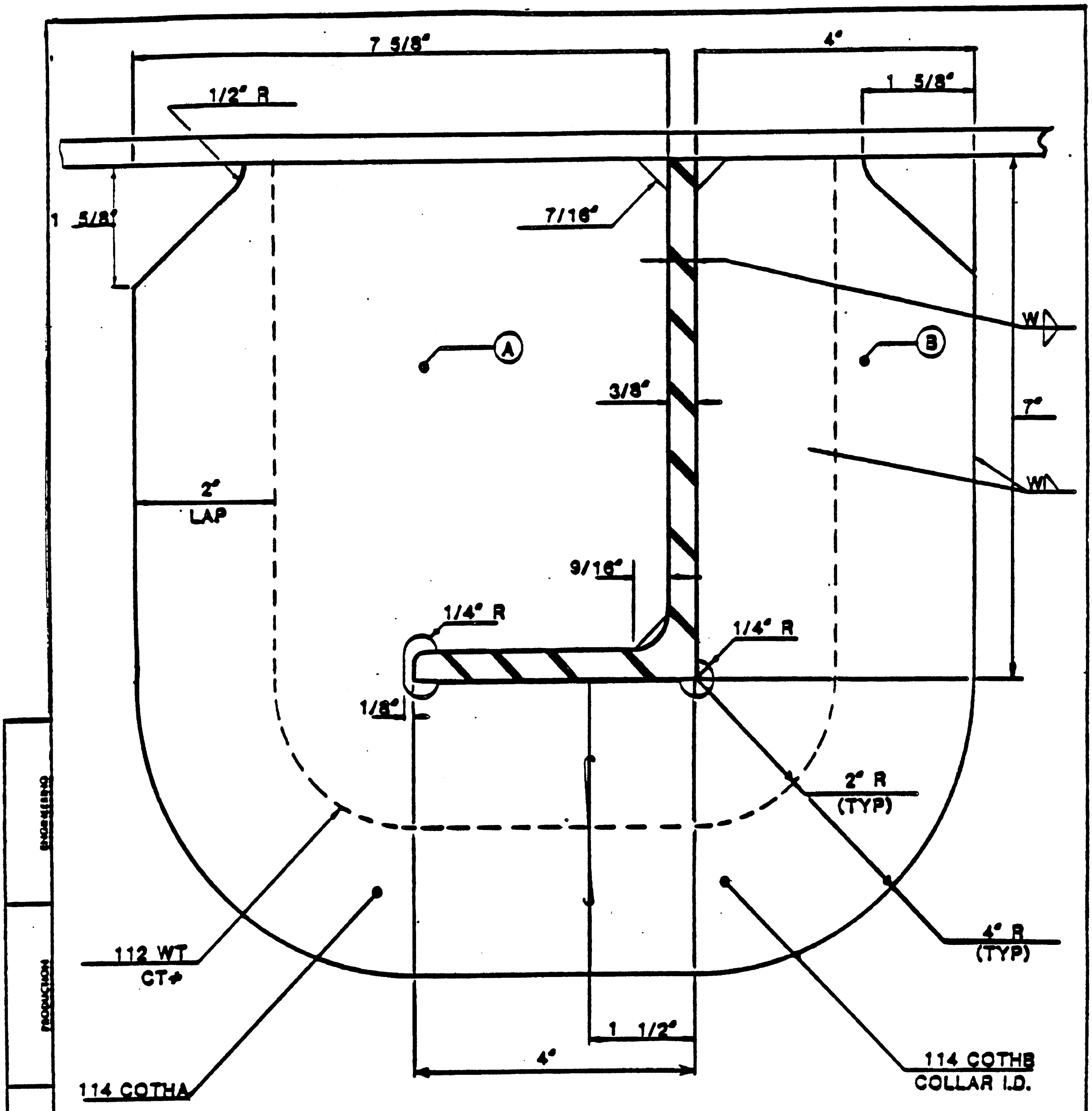
Standards have been adopted for:

- bracket configuration
- clips and collars (See Figure 4-12 for example)
- structural cutouts
- ratholes and waterstops
- chocks
- drain and air holes.

In addition to the engineering standards, a set of moldloft standards for working procedures was developed by the Loft. As these standards were developed, each one was carefully reviewed by those departments influenced by the standard. The standards system in the Moldloft serves as a "how-to" guide for all Loft personnel (Figure 4-13, for example). Periodically, new standards are added, reviewed, and implemented. Adoption of Moldloft standards has reduced the supervisors' time spent answering routine, procedural type questions. More consistent work is evident, with a good reduction in errors.

XIII. SOURCE MATERIAL FOR CHAPTER 4

The following lectures in the Technology Transfer seminars were used as source material for Chapter 4. They are listed in the Appendix. Lectures 7, 21, 27, 45.



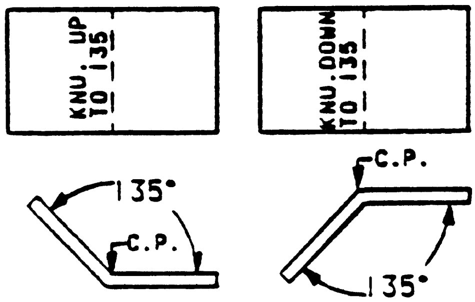
COLLAR TABLE				
TH		PC MK A	PC MK B	W
16ths	inch			
4	1/4	S0475	S0461	3/16
5	5/16	S0476	S0462	7/32
6	3/8	S0477	S0463	1/8
7	7/16	S0478	S0464	9/32
8	1/2	S0479	S0465	5/16
10	5/8	S0480	S0466	3/8
12	3/4	S0481	S0467	7/16

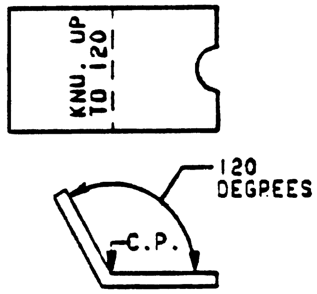
SPADES DBCT+ 101WT

AVONDALE SHIPYARDS INC P O BOX 50280 NEW ORLEANS, LA 70150	STANDARD AS SD	TITLE CT & CO FOR 7 x 4 x 3/8 ANGLE	DWG NO 114 WT	REV O
			SCALE DATE 11/17/80	SH NO 82 OF

Figure 4-12 Typical Engineering Standard - Collars

LABELING:	
WHEN LABELING A PART OR TEMPLATE, IF THE PLATE IS TO BE KNUCKLED IN THE DIRECTION OF THE SIDE OF THE PLATE THAT IS CENTERPUNCHED, THE CORRECT LABEL IS "KNU. UP TO-(DEGREES)". IF THE PLATE IS TO KNUCKLE AWAY FROM THE CENTERPUNCHED SIDE, THE CORRECT LABEL IS "KNU. DOWN TO-(DEGREES)". THE LABEL "TRANSFER CENTERPUNCH AND KNU. UP", IS INCORRECT. SEE EXAMPLES BELOW.	THE RESULTING ANGLE(IN NUMBER OF DEGREES) IS TO BE LABELED ON THE PART OR TEMPLATE. ONLY SPECIAL CONDITIONS WILL ALLOW THE USE OF THE LABEL,"KNU.TO SET". SEE SUPERVISOR IF IT IS NOT POSSIBLE TO LABEL THE KNUCKLE IN DEGREES. THE DEGREE SYMBOL (°) WILL NOT BE USED IN LABELING THE KNUCKLE ANGLE. ONLY THE NUMBER OF DEGREES, ROUNDED OFF TO THE NEAREST 1/2 DEGREE, WILL BE INDICATED. A TYPICAL LABEL WOULD BE "KNU. UP TO 120" MEANING THAT THE RESULTING ANGLE CREATED ON THE PLATE IS 120 DEGREES. SEE EXAMPLE BELOW.





SOURCE OF INFORMATION: PRODUCTION MEETING WITH GENERAL FOREMEN BUTCH LIVACCARI, BOOGIE GALATAS, K. HONDA ON 7-14-81.	APPLICABLE TO JOB: ALL	
REVISIONS:	DATE	REV.

TITLE: KNUCKLES-LABELING AND HOW TO INDICATE.	DRAWN BY L.LASSALLE	DATE 7-16-81	S.P.512
	ORIGINATOR G.HARMEYER	DATE 7-16-81	
	APPROVED	DATE	SHT 5.4

Figure 4-13 Typical Moldloft Standard

CHAPTER 5

PROCESS LANES

I. INTRODUCTION

In this chapter, the sequential development of the process lanes concept at Avondale is traced. The concept is described, as is the subsequent application of the process lanes principles within the Avondale environment. It is very important to note that the many significant features of process lanes can be developed and implemented independently or in varying combinations in the pursuit of achieving a total system. This point highlights the important flexibility feature of the process lanes application.

II. THE PROCESS LANES CONCEPT

The process lanes concept means very simply the categorization and separation of "like" kinds of work and subsequent development of work centers specifically designed to efficiently and economically produce that kind of work. Process lanes establishes the greatest amount of "learning curve" efficiency by having the same people at the same work centers doing repetitive types of work every day with the support of a well organized and efficient flow of material.

The process lanes concept of categorization and flow is not so new in this country, just new to the shipbuilding community. In fact, American yards have been using a few of the basic principles of process lanes in shipbuilding on specific isolated processes for some time.

III. THE REQUIREMENTS OF PROCESS LANES

Obviously, with the advent of the process lanes study and a sound comprehension of the concept, it was determined that the principles of process lanes, as well as many of the controls, did not exist at Avondale. In fact, those conditions contrary to process lanes and prevalent in the conventional construction method did indeed exist as follows:

- Different types of units were assembled at the same location.

- The same units required various assembly duration times.

- There were different types of assembly platen.

- Different types of material were required at each assembly platen.

- Material flow presented on-site storage problems, thus increasing material handling and storage costs.

These conditions of conventional construction methods tended to decrease efficiency, productivity, and accuracy of the product. Naturally, these observations present a variety of obstacles that must be overcome in the course of developing and implementing the requirements of an effective process lanes system.

The implementation of an effective process lanes system at ASI has placed detailed emphasis on several requirements which include the physical aspect of process lanes (facilities), unit breakdown, material flow, coding systems, cost system, planning systems, scheduling systems, and control systems. The principles of the Product Work Breakdown System (PWBS) provide the base for evolvement of the above-identified requirements.

Prime ingredients to the success of developing and executing the process lanes system are discipline and attention to detail in every phase of design and construction, and to every interim product.

Process lanes schedule development provides the controls and visibility essential to determining work center cost and efficiency. The detail emphasis on the entire process enhances both flexibility and control, and achieves a uniform work flow within each work center and coordinated outputs for all work centers.

The IHI concept requires that industrial engineers be assigned to work centers for each stage of construction, to study and establish work center schedules, to collect and monitor performance and adherence to schedule of each work center foreman daily, and to prepare management reports. Avondale has adopted a similar approach in which Production Planning monitors and reports schedule progress on each work center. Daily detail attention to each work center's progress is provided by the addition of a strong shop planning function. In addition, Production Engineering routinely monitors and reports each work center's cost and actual manhour cost per ton versus projected cost per ton efficiency. This system allows feedback from the work centers to be acted on and options exercised to assure that corrective action is taken, if required.

It is quite simple to envision change in technology; it is quite another matter to implement change. The transition from conventional methods to the process lanes concept has demanded hard work and retraining on the part of all departments, but this has been supported by executive management commitment. The development and implementation of the process lanes system has been achieved with a wide cross-section of ASI personnel which includes the management and workers of Production, Design, and the support departments. Advisory services from IHI have contributed immensely to its success. The system justifies the effort; it is feasible; it is workable; it has definable benefits; and, furthermore, Avondale is fully committed to accept the new technology as a basic functional way of doing business.

IV. PHYSICAL PROCESS LANES

It was obvious at the onset of the process lanes study that the physical yard platform layout would require considerable thought to support the new concept. Area requirements, crane capacities, and material flow were major considerations. In the selection of the assembly, subassembly, and fabrication sites, the volume of work for each category and the method of construction of each unit had to be considered. The six categories of units, described more fully in Chapter 2, are as follows:

CATEGORY NUMBER	DESCRIPTION	% HULL WEIGHT (TANKER)
1	Flat Panel Units	48
2	Curved Shell Units	5
3	Superstructure Units	28
4	Forepeak and Aft Peak	10
5	Engine Room Innerbottoms	5
6	Special Units (Skegs, Rudders, etc.)	4

Naturally, on vessels with a significant amount of shape, Category 2 units will comprise a much higher percentage of units. Based on the previously mentioned criteria, the assembly platforms were selected and laid out.

A. Platen No. 20

Platen No. 20 was selected as the site for the construction of Category 1 units because of the high work volume it can produce, its nearness to the panel line, and the ease of material flow from fabrication Platens 23 and 24. The production effort on this platen is divided into four specific stages.

(1) First Subassembly Stage (36,000 Sq. Ft.)

At this stage, most typically two or three web frames or the floors and girders are fitted and welded to the base panel of the unit which was produced at the panel line. The area has been divided into a gridwork of twelve unit platforms, each 48 ft. by 52 ft. Each grid is clearly delineated by flat bars colored with paint. Upon completion of the work at the subassembly stage, the units are moved to the adjacent preoutfitting stage.

(2) Preoutfitting Stage (16,032 Sq. Ft.)

Outfitting work is accomplished in this area while the unit is open, which reduces substantially high position work and thus increases efficiency. There is a gridwork of eight (8) platforms. Upon completion of outfitting, the subunits are sent to the main assembly stage. The exceptions would be centerline main decks and similar type units which are finished at this stage.

(3) Main Assembly Stage (18,240 Sq. Ft.)

Here, subunits are combined to make units. This is where scaffolding work, as necessary, is accomplished. A total of six (6) platforms have been dedicated for use by this stage. Upon completion, the unit is sent to the final assembly stage.

(4) Final Assembly Stage (15,840 Sq. Ft.)

Most typically, the connection work of outfitting, inspection, and weld completion is accomplished at this stage. Upon completion, the unit is sent to blast and paint.

The above stages establish specific locations on the work centers for each stage. The establishment of the four construction stages on Platen No. 20 allows for the same kind of work to be performed every day by the same personnel at a specific location, utilizing the same tools, welding machines, etc., for accomplishing the defined work. The work moves to the personnel instead of relocating workers. This is a fast-moving platen area for easily constructed units with short construction time. The preoutfitting work stage provides a work queue storage of on-unit pallets for one week's backlog of work. Outfitting can proceed without disruption from the subassembly process which preceded. After main assembly, the unit is turned, as required, to accommodate "final" preoutfitting, welding, and inspection. After completion of downhand welding and preoutfitting, the unit then moves to blast and paint prior to erection.

B. Platen No. 17

Platen No. 17 was selected as the site for Category 2 curved shell units. Category 2 units are all curved side shell units requiring the use of curved side shell jigs, either the fixed or pin type, depending on the degree of curvature. These units are, in general, more complex in construction, requiring different construction methods and techniques and more elapsed time in assembly position than the Category 1 units. Since these units require a separate process lane, apart from the faster-moving Category 1 units, Platen No. 17 was selected as being the most appropriate. Its location is convenient to the prefabrication shops for economical material flow and convenient to the blast and paint area. After units are removed from the jigs, they can proceed to the buffer/preoutfit area of No. 17 or straight to blast and paint.

C. Platen No. 14

Platen No. 14 was chosen to construct Category 5 units because of the location to the Plate Shop with its panel line and the material flow from fabrication Platen No. 16.

A work queue area (backlog for the next week's work) is at one end of the platen. Miscellaneous material coming from the prefabrication and fabrication stages is stored here for sub and main assembly. A subassembly stage area separates the miscellaneous work queue from the panel line work queue.

There are five areas set aside for main assembly of five engine room double-bottom-type units simultaneously, if required, along with an area set aside at one end of the platen as a buffer or unit outfitting area for two additional units. At the extreme end is a work queue/outfitting subassembly area.

A three-foot-high flat platen construction jig extending the entire length of the platen is required to support this construction. Category 5 units require long construction time because of the complexities of close-fitting tolerances, size, and outfitting work.

D. Platen No. 10

On Platen No. 10, superstructure units (Category 3) and heavy engine flat units are assembled. Fourteen platforms are available, seven for heavy units and seven for light units. No outfitting is done in this area. After all the hull work is completed, the units are moved to the lower yard building ways and the outfitting is completed there. Platen No. 16 supplies the fabricated material.

E. Platen No. 307

Grand assembly and main assembly of Category 4 units are completed in this area. There are fifteen platforms in this work area, and they are used for main assembly work only. There is no need for platforms for grand assembly because at that point, most units have to be blocked up. Platen No. 16 supplies the fabricated material.

F. Platen No. 16

Platen No. 16 fabricates for Category Types 2, 3, 4, 5 and 6 units. The fabrication consists of web frames, stringers, built-up members, miscellaneous bulkheads, horizontal girders, floor, girders, and brackets. At the extreme end of the platen is a work queue for incoming material from the prefabrication stages for the upcoming week's schedule of work.

G. Platens No. 23 and No. 24

Platens No. 23 and No. 24 fabricate for Category 1 units. Platen No. 23 fabricates floors, girders, and miscellaneous brackets. Platen No. 24 fabricates web frames and girders. A portion of these platens is dedicated to turn over for welding, chipping, and grinding. The area between the two platens is the work queue for both platens. Material from the prefabrication stages is stored here for the next week's scheduled work.

H. Prefabrication

Prefabrication is broken down into three primary categories. They are:

(1) Skin Plates

a) Straight (straight cut)
b) Curved (irregular cuts)

(2) Internal Members (Plates)

a) Main Plates (N/C cut)
b) Attached Plates (N/C, servo, shear or manual cut)

(3) Internal Members (Structural)

a) "T" Beams
b) Built-up Beams
c) Angles
d) Flat Bars
e) Miscellaneous Others

The objective of the prefabrication shops is to cut and shape the hull parts to the exact size with the greatest accuracy possible to allow quick assembly and construction through the assigned work centers and to minimize handling and movement of material. The work methods of the various prefabrication operations need not be modified from existing methods.

The Plate Shop receives about 700 tons of raw steel plate per week to feed N/C, exacto, and servo burning. This process cuts floor, girders, and miscellaneous brackets, longitudinal bulkheads, transverse bulkheads, side shell plates, and flats.

Some of these plates move to another area in the shop for rolling, bending, or cutting of tabs, while others go to the panel line for fabrication. All material (except panel line material) is separated and palletized in the shop and sent to the appropriate fabrication work queue.

Platen No. 18 is designated as the structural steel prefabrication process lane. It contains the punch press, frame and angle benders relocated from the Plate Shop. It can process approximately 300 tons of structural steel per week. On completion of all cutting, punching, and forming, structurals are palletized and sent to the appropriate fabrication stage work queues.

V. FACILITY CAPACITY LOADING

Based on the main yard assembly capacity of 4,200 short tons per month, Avondale plans current and prospective work loads in a manner which ensures full capacity utilization without creating overloaded facilities. This concept is of primary importance when the work currently in progress and known future work is plotted according to key events of those contracts, using erection tonnage as a base line. It is important to note that when scheduling multiple contracts or multi-hull contracts, consideration must be given to the projected erection sequence and category of units to be erected on the hulls concerned.

The objective is to prevent the overloading of assembly work centers which is the ASI control point of hull construction, while remaining as close as possible to the total yard assembly capacity of 4,200 tons per month. The task of level loading and placing fabricated components/units in storage or work queues is the means to that end. This detailed level of planning is a constantly changing process which creates the flexibility to accommodate variations between actual progress and the project plan and to absorb the impact of additional work created by new contract signing.

VI. SOURCE MATERIAL FOR CHAPTER 5

The following lectures in the Technology Transfer seminars were used as source material for Chapter 5. They are listed in the Appendix. Lectures 35, 36, 37.

CHAPTER 6

PRODUCTION CONTROL

I. INTRODUCTION

Process lanes has resulted in many changes to ASI's Production Engineering policies and techniques. Production Engineering's most important document, the Production Estimate, is used as a guide by the production engineers to issue budgets to the work centers. This document has undergone a major change in format. Categorizing hull structure into similar kinds of work and setting aside specific work centers allows the production engineer the flexibility to establish a cost code system for each work center. The new cost code makes each work center a cost center, thereby allowing management to observe work center efficiency as well as to monitor job cost.

Outfitting materials are now being marshalled by the Material Control Group and palletized from pallet code listings furnished by the Production Planning Department. Prior to process lanes methods, outfitting items suffered costly damage and deterioration from the elements.

The basic concept of good material control is effective material flow. The main objective has been to minimize the number and length of material movements, reduce bottlenecks, meet production schedules, and reduce the ratio of material handling time to production time.

With process lanes, steel cutting is scheduled and work stages level-loaded to the point that 92 percent of cut steel flows directly to the fabrication platens, thereby reducing the cost of steel transport by 85 percent.

The Accuracy Control Department is a newly formed group consisting of four qualified engineers. The efforts of this group are aimed at development of accuracy standards and assembly sequences to be used by each production stage for proper accuracy control.

The Accuracy Group interfaces with all departments of the shipyard. They have been instrumental in updating expansion factors used in the Moldloft for parts generation. They have caused design changes which have resulted in cost savings. They have determined certain items of work which should be routed through other process lanes for improved cost. The activities of this group have been very successful in improving dimensional and accuracy control of work being performed at Avondale Shipyards.

II. PRODUCTION ENGINEERING

The Avondale Production Engineering Department consists of three sections: Hull, Outfitting, and Mechanical. Each section works from standards which have been developed from past history, and the responsibilities of the production engineers vary among the sections. Each production engineer is experienced in solving the production problems of the crafts and disciplines working within his section.

A. Responsibilities of the Production Engineer

Although the standards and problems vary among the sections, there are responsibilities which are common to all three:

- to make working drawing take-offs and prepare direct labor cost estimates;

- to prepare work orders for the various manufacturing facilities in accordance with the Production Plan and the various hull, outfitting, machinery, and testing schedules;

- to assist the planning engineers in the preparation of schedules and information regarding the most economical and practical manufacturing areas in which to place construction;

- to monitor the production progress of the program and to ensure its completion in a timely and economical manner;

- to work closely with the Design Engineering Department to ensure that economical production techniques and practices are used;

- to study cost reports to stay abreast of the direct labor expenditures;

- to prepare cost projections as may be required by management;

- to monitor work as required to determine production efficiency and to verify work standards;

- to make and/or propose changes in the production effort, where cost overruns are projected.

Last, and perhaps most important, the Production Engineer must provide the leadership and assume the initiative to achieve maximum production efficiency by persuading all departments to give their best efforts toward that end.

B. Prerequisite Production Effort

The work order is management's primary instrument to initiate all production work and to monitor cost, work progress, and efficiency. Before the work order can be prepared and used as a cost collection tool, certain other production functions must, in order of priority, take place. They are listed below and described fully in Chapter 2.

(1) Master Plan - an outline of the specific major contractual requirements of the job, such as key event dates leading up to and including delivery and any special criteria for the development of schedules and proposed methods of construction.

(2) Hull Unit Arrangement - a breakdown of the hull configuration into units, prepared by the Production Planning Section.

(3) Hull Unit Summary - prepared by the Production Planning Section, describes in detail how, and at which work center, the hull unit construction will take place.

(4) Long-Term Schedule - prepared by the Production Planning Section to reflect the best overall construction schedule while providing for work center level-loading for steady flow of product and a constant level of manning.

(5) Short-Term Schedule - a hull work schedule prepared to ensure a steady day-by-day flow of material and manufactured product.

(6) Unit Weight and Centers Calculation - prepared by the Hull and Structural Section of the Design Engineering Department.

(7) Contract Specifications and Developed Engineering Drawings - prepared and furnished to the Production Department by Contract Administration and the various Design Engineering groups.

(8) Unit Control Manual (UCM) - a set of construction drawings and information in booklet form for each stage of hull unit construction for each hull unit, prepared by the Moldloft.

(9) Production Plan and Summary Estimate - a detailed breakdown of direct labor in manhours prepared by the Production Engineering Section. The Production Plan allocates the overall manhour budget for each vessel of a contract divided into trade or craft cost groups, subgroups, and items in accordance with work/cost center schedules, outfitting schedules, and the Cost Code Manual produced and maintained by the Comptroller. The Summary Estimate is prepared as the "top sheet" of the Production Plan and summarizes the craft budget totals. An example of a Summary Estimate is shown in Figure 6-1.

C. Work Order Estimating and Preparation

Work orders are prepared by the Production Engineering Department in two different forms:

(1) Shop Order - (Figure 6-2) - used primarily for packages of work to be accomplished at a specific machine within a work center, such as a lathe in the machine shop or a numerical control burning machine.

(2) Work Order - (Figure 6-3) - used primarily when the work effort has progressed beyond the prefabrication stage and usually describes fabrication, assembly, erection, or installation work.

The work order contains the following information:

- job number;
- cost group, subgroup, item number, and vessel number (obtained from production plan);
- weight (in tons) obtained from the Ship Production and Control Report (SPAC);

COST ESTIMATE SUMMARY
PRODUCTION

CUSTOMER: ______ DATE: ______

JOB: PRODUCT CARRIERS (3 VESSELS) ______ ESTIMATE: ______

		Ves. 2	Ves. 3	Hull 1	Hull 2	Hull 3	Ave. 1 of 3
1	ENGINEERING			203,127	203,127	203,127	203,127
2	HULL	96.4	94.4	634,608	611,762	599,070	615,147
3	SUPERSTRUCTURE	96.9	95.1	68,776	67,613	66,357	67,915
4	JOINER			-	-	-	-
5	PIPING	92.3	88.1	210,828	194,594	185,739	197,056
7	MACHINERY	98.2	97.2	65,627	64,446	63,789	64,621
8	ELECTRICAL	92.9	89.0	150,713	140,012	134,135	141,620
9	SHEETMETAL	97.0	95.3	102,200	99,134	97,397	99,577
10	CARPENTRY			428	428	428	428
11	INSULATION	96.9	95.1	32,226	31,227	30,647	31,367
12	CLEAN & PAINT	96.9	95.1	243,608	236,056	231,671	237,112
13	CONSTRUCTION SERVICES	97.0	95.3	67,266	65,248	64,104	65,539
16	FITTINGS	96.0	93.8	119,673	114,886	112,253	115,604
17	OUTFITTING	97.0	95.3	31,292	30,353	29,321	30,489
18	DECK COVERING	97.0	95.3	1,454	1,410	1,386	1,417
19	JIGS & DIES			45,036	45,036	45,036	45,036
20	FOUNDATIONS	89.1	83.3	57,903	51,592	48,233	52,576
21	CRANES			100,619	100,619	100,619	100,619
23	TESTS & TRIALS	96.9	92.4	61,041	59,149	56,402	58,864
25	MOLDLOFT			38,262	38,262	38,262	38,262
26	LAUNCHING	93.0	89.1	36,593	34,031	32,604	34,408
27	PRODUCTION DEPT.			41,433	41,433	41,433	41,433
28	QUALITY CONTROL			23,513	23,513	23,513	23,513
31	WAREHOUSING			53,535	53,535	53,535	53,535
32	CLEAN DURING CONST.	97.0	95.3	56,336	54,646	53,588	54,890
33	DRYDOCKING & SHIFTING			9,000	9,000	9,000	9,000
34	INSURANCE			-	-	-	-
43	WELD RODS, STEEL FREIGHT			-	-	-	-
45	PACKAGE UNITS	94.77	91.9	22,833	21,639	20,984	21,819
81	PROGRAM MANAGEMENT & EXPRESS ENGR.			14,007	14,007	14,007	14,007
82	ESTIMATING			1,224	1,224	1,224	1,224
95	REWORK	97.0	95.3	14,189	13,763	13,522	13,824
99	DELIVERY			-	-	-	

Figure 6-1 Production Plan Summary Estimate

Job No.	Group No.	Sub-Group	Item No.	Ves. No.	Title

SHOP ORDER

Drawing No.	Alt. No.	Sheet No.	Serial No. U 5101

TO

Superintendent

Foreman

Work Center

FROM

Originator

Date

Transfer No.

Machine or Equipment	Total Est. Hours	To Be Started	To Be Completed

YOU ARE INSTRUCTED TO PERFORM THE FOLLOWING WORK:

OPERATION	NO. AND KIND OF PIECES	SIZE, LENGTH, ETC.	UNIT HOURS ALLOWED	HOURS ALLOWED FOR OPER.

TOTAL HOURS ALLOWED, Including Supervision →

GENERAL INSTRUCTIONS:

NOTE: Foreman to report actual date started, inspected and completed. Return to Production Dept. office when completed.

DATE STARTED	DATE INSPECTED AND COMPLETED	Signed

ASI 45 (R 2/76)

ORIGINATOR'S COPY

Figure 6-2 Shop Order

Job No.	Group No.	Sub. Group	Item No.	Ves. No.	Unit	Zone	Weight (tons)	Serial No. F 9151

WORK ORDER

Title	

TO		FROM	
Superintendent		Originator	
Foreman		Date	
Work Center		Transfer No.	

Drawing No.	Alt. No.	Sheet No.	Total Est. Hours	To Be Started	To Be Completed

YOU ARE INSTRUCTED TO PERFORM THE FOLLOWING WORK

NOTE: Foreman to report actual date started, inspected and completed. Return to Production Dept. office when completed.

Date Started	Date Inspected And Completed	Signed

ASI - 44 (R4/82)

ORIGINATOR'S COPY

Figure 6-3 Work Order

- manhour estimate, prepared by the Production Engineer through detailed drawing take-off and "weighted" with the production plan manhour-per-ton estimates for the stage of construction and work/cost center. This individual work order estimate has the net effect of issuing the manhours (reflected in the cost "items" in the production plan) to the manufacturing superintendent in small, measured increments which can be closely monitored;

- indicates the work/cost center and authorizes the manufacturing superintendent to accomplish the work;

- describes the work to be accomplished based on instructions contained in the Hull Unit Summary and the UCM construction details;

- indicates the starting date and completion date obtained from the short- or long-term schedules;

- serial number to identify the work order for data processing tracking and control.

The work order also serves as a vehicle for accumulating daily direct labor costs expended at each work/cost center. The mechanism by which such data is collected and analyzed is described below.

D. Establishment of Work/Cost Centers

Unit categorization, the grouping of similar kinds of work, and the assigning of a specific work center to perform each type of work, has enabled Avondale to consider each work center a cost center. In the past at Avondale, a given work center could not be a specific cost center because the types of construction and the resulting cost per ton at each work center varied too widely to provide meaningful monitoring of work center efficiency. The flow of varied kinds of material, both prefabricated steel and purchased outfitting, was inefficient and costly.

Process lanes now has provided specific work/cost centers for fabrication, subassembly, preoutfitting, and main assembly for each of the six major categories of units. Each of these work centers has been assigned a unique cost code which is carried by the individual work order when issued to the work center for construction of a specific block of work.

When the Production Engineer releases a work order to a work center, a copy goes to the Data Processing Department where D/P cards are key punched with the cost codes, estimate, weight, serial number, etc., and returned to the Production Engineering Department affixed to the superintendent's copy. Data Processing also enters the work order into the computer data base. As the work prescribed in the text of the work order progresses, the actual direct labor manhours are entered directly into the computer data base by the work/cost center superintendent at a local terminal. The computer accumulates the manhour charges and daily D/P printouts are run and forwarded to the Production Engineer for continuous monitoring of progress (percent completion) and cost (actual spending versus estimate). D/P printouts can be sorted in various ways to facilitate overall job monitoring, such as the listing of all "active" work orders on one report and all "closed" work orders on another. The daily reports are used to monitor individual work order efficiency and progress, whereas the "closed" and "active" reports are used for determining overall percent completion and a projection of work remaining to be accomplished.

E. Work Center Cost Collection and Monitoring

Three EDP reports used for controls and which utilize the work order as a primary source of information are:

- The Combined Work Order Report
- The Closed Work Order Report
- The "Late Complete" Work Order Report

All three reports draw information from the work order file and are used in a number of applications within the system. The Combined Work Order Report, as it relates to process lanes technology, is a source document supplying information concerning total direct labor manhours issued on both active and closed work orders, along with the total accumulated tonnage issued to any given process lane work center. The Closed Work Order Report is a source document which supplies the same information but on closed and completed work orders only. The information supplied by these two reports is utilized as the basis for the Process Lanes Hull Work Efficiency Report.

The "Late Complete" Work Order Report flags those work orders which were not closed as being complete on the scheduled completion date. This control alerts both the Production Engineer and the Planning Engineer so that subsequent review can be done and appropriate action taken.

After each work center's loading and schedule are prepared, the Production Engineering Section analyzes the scope of work assigned to the center and applies appropriate labor rate standards to establish each work center budget. Charts are then prepared to reflect the targeted tonnage, targeted manhour budget, and targeted manhour/ton efficiency, as shown by the broken lines in Figure 6-4.

As work progresses through the center, the actual accumulated manhours and actual completed tonnage are plotted for continual monitoring of actual cost of work compared to the budget. The solid lines in Figure 6-4 show the actual manhours and tonnages for comparison to the targeted values.

F. Hullwork Efficiency Report

The Hullwork Efficiency Report (Figure 6-5) is an extremely useful control utilized by the Production Engineer. The report is generated for every process lane work center and is updated and reviewed weekly. From the Combined Work Order Report, the total manhours and tonnage issued to the work center are input and the subsequent manhour/ton efficiency that those work orders represent is calculated. This control provides a continuous evaluation of work order estimates to be sure that each work order estimate is consistent with overall targeted budget. Actual tonnage and manhour data from the Closed Work Order Reports are also input, and the manhour per ton efficiency being experienced is computed. Period actuals are then input to review the weekly production efficiency, as well as to serve as a source document for subsequent forecasting analyses.

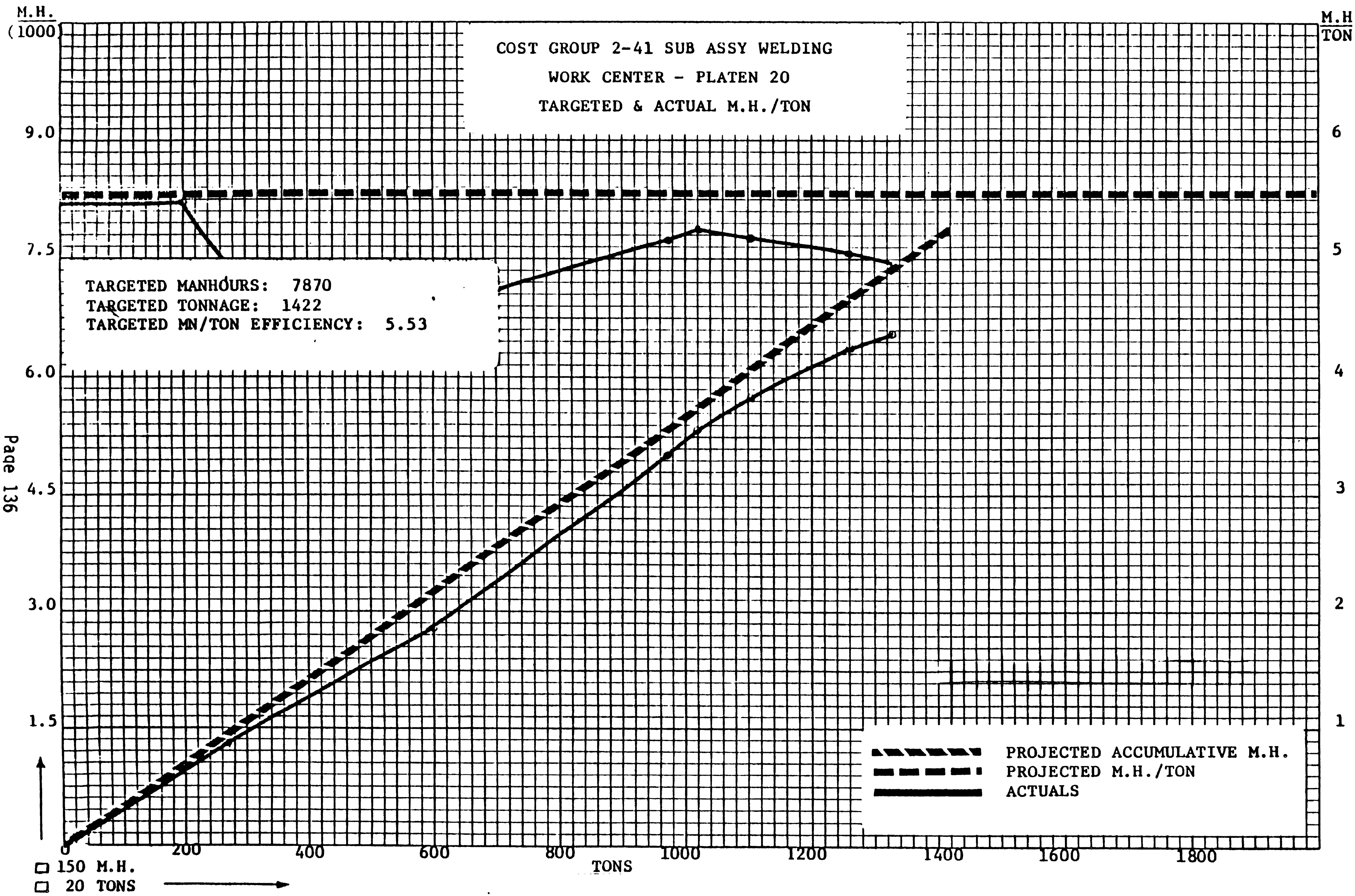


Figure 6-4 Work Center Efficiency Chart

JOB C3-170

1ST VESSEL ONLY
COST GROUP 2-41
PLATEN 20 - SUB ASSY WELD

TARGET TONNAGE: 1422
TARGET MANHOURS: 7870
PROJ. EFFICIENCY (MH/TON): 5.53

DATE	PERIOD ACTUALS			ESTIMATED - CLOSED WORK ORDERS			ACTUALS - CLOSED WORK ORDERS		
	COMPLETED TONNAGE	TOTAL SPENDING	EFFICIENCY MH/TON	COMPLETED TONNAGE	TOTAL ISSUANCE	EFFICIENCY MH/TON	COMPLETED TONNAGE	TOTAL SPENDING	EFFICIENCY MH/TON
12/19/83				1005	5001	4.976			
12/27/83				1005	5001	4.976			
1/3/84				1215	6044	4.974			
1/8/84				1215	6044	4.974	195	1068	5.477
1/15/84	77	241	3.130	1215	6044	4.974	272	1309	4.813
1/23/84	328	1506	4.591	1367	7013	5.130	600	2815	4.692
1/30/84	375	2219	5.917	1367	7013	5.130	975	5034	5.163
2/6/84				1412	7090	5.021	975	5034	5.163
2/13/84				1412	7090	5.021	975	5034	5.163
2/20/84	44	324	7.364	1412	7090	5.021	1019	5358	5.258
2/27/84				1412	7090	5.021	1019	5358	5.258
3/5/84	86	383	4.453	1412	7090	5.021	1105	5741	5.195
3/12/84				1412	7090	5.021	1105	5741	5.195
3/19/84	155	645	4.161	1412	7090	5.021	1260	6386	5.068
3/26/84	68	177	2.603	1412	7090	5.021	1328	6563	4.942
4/2/84				1412	7090	5.021	1328	6563	4.942

Figure 6-5 Hullwork Efficiency Report

The process lanes concept of hull construction has opened the door to apply linear regression forecasting methodology. Prior to process lanes technology, this type of analysis was neither feasible or possible at the work center level. The period actuals from the Hull Efficiency Report serve as the statistical basis for forecasting computations. The weekly tonnage "actuals" are input as the independent or predictor variable, and the weekly manhour "actuals" become the basis for computing the dependent or response variable. The results of the analysis produce mean manhours per week, mean tonnage per week, standard deviation of both tonnage and manhours, intercept, slope, correlation coefficient, and the projected completion manhours.

G. Benefits

The benefits of this cost center data collection effort are:

- fewer work orders to prepare, issue, and monitor;

- less paperwork for field supervision and Data Processing to manage;

- the manhour per ton efficiency ratio thus established for each category is usable for all construction of similar types of ships.

Management can thus observe the progress of the job and its projected cost and determine the overall efficiency of the work center and its supervision.

Thus the total engineering and production effort is a finely meshed system which centers around, contributes to, and coordinates with the process lanes concept. From initial planning, drawing preparation, scheduling, work center loading, budgeting, order release, cost control, to cost analysis and projections, the systems all complement and enhance the process lanes concept.

III. MATERIAL CONTROL

Material Control is one of the most essential activities for productive shipbuilding. In this heavy industry, material costs account for about 60 to 70 percent of all the shipbuilding costs. Therefore material control directly affects interest payable, handling cost, storage area, as well as the disruption of the production schedule and the cost of the material. The fundamental target for material control is to save these kinds of undesirable surplus costs.

The application of the IHI technology has effected significant cost savings through material control at ASI. These cost savings are not necessarily realized in the Material Control Branch itself but throughout the various crafts served by the Material Control Branch.

A. Material Flow and Facility Layout Analysis

One requirement of good plant layout is effective material flow. The objective is to minimize the number and length of routes and eliminate any unnecessary movements such as back-hauls, cross-hauls, transfers, etc. Material flow problems can arise because of changes in the design of a process or they may develop because of gradual changes over time that finally manifest themselves as bottlenecks in production, crowded conditions, poor housekeeping, failure to meet schedules, and a high ratio of material handling time to production time.

Prior to process lanes implementation, a material flow analysis was performed at Avondale, concentrating on some quantitative measures of material movement between departments, work centers, and activities. Since the shipyard layout had already been designed to facilitate the flow of the product, this analysis was concerned with the flow of materials. Some of the factors that affect material flow are:

- external transportation facilities;
- the number of items to be moved;
- the number of units to be produced;
- material storage locations;
- location of manufacturing service areas.

The analysis employed flow diagrams--yard maps on which material flow routes are indicated--to determine the distances involved. Comprehensive logs of material movements extracted from Material Control Department and mobile crane servicing area reports were used to construct "From-To" charts which tallied and summed the number of pieces moved between each of 39 origins and destinations within the yard. Two types of materials were tracked:

- plates and structurals, and
- fabricated pieces between platens and other sites.

The outcomes of the study, conducted in a ten-week period in 1981, are shown in the "Past Method" columns of Figures 6-6 and 6-7. To assess the impact of process lanes operation on material flow, the Process Lanes Committee rerouted the same materials to the work sites appropriate to the new methods of construction. The result is shown in the "Process Lanes" column on the figures.

In the past, many steel plates and structurals, after they were cut or fabricated, were sent to the steel fabrication storage area. This was the result of multi-hull cutting and fabricating. The process lanes concept eliminates multi-hull cutting and fabrication, thereby eliminating material flow (except Outfitting) to the fabrication storage area. Materials go directly to the work site storage queue in which there is one week's backlog of either precut raw material for a fabrication platen or a week's work backlog of fabricated pieces for an assembly platen. The end result is a very large reduction of material going to storage and an appropriate increase in material going to the work sites from the Plate Shop and Platen No. 18, where the structurals are cut.

A comparison of the two methods shows that under the past facility layout and storage method 9,174 pieces were moved per week, of which 60.7 percent was moved to or from the fabrication storage area. The process lanes method moves 6,571 pieces per week of which only 8 percent is involved with the fabrication storage area. The reduction of 2,603 pieces per week is due to the large reduction in double handling. A reduction of 28.4 percent in the number of pieces handled per week is realized by the process lanes concept, with the attendant saving in manhours.

HULL STEEL MATERIAL MOVEMENT COMPARISON BY PIECES

DESCRIPTION	PAST METHOD	PROCESS LANES	DIFFERENCE
Pieces/week	9,174	6,571	−2,603
Pieces To - From Fabrication Storage	5,564	532	−5,032
Percent To - From Fabrication Storage	60.7	8.0	
Trips/week	170.5	145.2	− 25.3
Pieces/trip	53.8	45.3	− 8.5
Trips/week To - From Fabrication Storage	81.5	9.3	− 72.2
Percent To - From Fabrication Storage	47.8	6.4	

Figure 6-6 In-Yard Material Movement

HULL STEEL MATERIAL MOVEMENT COMPARISON BY TRIPS AND DISTANCE

	PAST METHOD	PROCESS LANES	DIFFERENCE
Material Handling Distance/week (Miles)	66.6	43.4	23.2
Material Handling Distance To-From Fab. Storage	39.3	5.9	33.4
Percent M. H. Distance To-From Fab. Storage	60.0	13.6	
Trips / week from Plate Shop	42.3	62.3	(20.0)
Trips/week from Platen 18	5.3	11.4	(6.1)
Trips/week from A-Crane Storage	31.3	7.7	23.6
Distinct Moves	177	119	58

Figure 6-7 In-Yard Material Movement

The former method had a total steel material movement of 66.6 in-plant miles per week, of which 60 percent was to and from the fabrication storage area. Under the process lanes method, movement is 43.4 miles per week, of which 13.6 percent is to and from the fabrication storage area. A reduction of 23.2 miles per week (34.8 percent) is realized under the process lanes concept.

There were 177 distinct moves from area to area under the past material flow method. Under the process lanes method, this is reduced by 58 for a total of 119, resulting in a 32.8 percent decrease in the number of distinct moves.

In summary, a savings of approximately 30 percent in the handling of steel is realized as a result of the implementation of the process lanes concept. The appropriate cost savings can be obtained by evaluating the manpower, equipment, and energy reductions which result from a 30 percent reduction in the handling of steel material. It is evident from the analysis shown here that one of the major reasons for process lanes implementation is the evolution toward an ideal material handling system.

B. Effects of Unit Construction and Zone Outfitting

In the past, the basic rationale for the listing, requesting, procuring, receiving, and issuing of material was on a system basis, as compared to the new technique of unit, zone, and subzone method employed today. The basic physical control of material is enhanced by this new technique, in that it involves smaller increments of material to be handled, with much less storage time in the field.

Material is now requested and procured to the unit and zone level. Advance purchasing zones are set up early in the job. Procurement is timed to satisfy fabricated material requirements and purchased material requirement dates.

The basic instrument for zone outfitting in the IHI concept is the pallet, under whose number the packages of outfitting material are grouped. The term "pallet" in the context of zone outfitting technology does not refer to the familiar wooden platform used to move material about with a forklift truck.

The pallet for zone outfitting consists of:

(1) A work package, or kit of outfitting material, to be installed in the hull of a ship in a specific place and at a specific advantageous time during construction.

(2) The manhours allowed for its installation. Ideally, the pallet should require approximately 100 manhours to install, about one week's work for two men.

(3) A pallet number which identifies the material and which is both significant and unique.

An overall Material Marshalling Plan has been implemented to accomplish the recording, expediting, palleting, and delivering the various categories of material to the process lanes.

Two departments at Avondale have responsibility for material control. Raw steel (plates and structurals) is handled by the Steel Control Section. Material handled by the Material Control Section is categorized into the following types:

- prefabricated steel;

- fabricated preoutfitting items (such as manholes, W.T. doors, deck fittings, foundations, etc.);

- warehoused (purchased) materials;

- raw piping material input to Pipe Shop;

- fabricated pipe details from the Pipe Shop.

Procedures for the handling of each type of material are discussed below.

C. Raw Steel Plates and Structurals

The main objective of the Steel Control Section is to assure for all jobs that steel will be available in accordance with the Long-Term Schedule. Further, Steel Control maintains Steel Tonnage Reports, debits and credits by cost code and vessel, with the objective of making cost projections in the early stages of each job.

(1) Steel Procurement

Engineering (Hull Section) prepares a Steel Request or Steel Summary from the advance hull drawings. The Steel Summary is grouped by unit, and lists plates and structurals by grades.

Upon receipt of an advance copy of the Steel Summary, Steel Control enters all requested items into a computer program for weight computation, sorting, and sequencing. The program "screens" the list against stock; that is, it checks the summary against inventory of stock already in the yard but not assigned to a job. The final list is thus separated into a list of screened (in stock) items and a list of items to be purchased. Each Steel Summary item is assigned a specific date needed in yard (4 weeks prior to prefab), according to the Long-Term Schedule. This computer run then replaces the written steel request and it is used by Purchasing to issue Purchase Orders in the same basic order as prefab. Outfitting and fitting requests basically follow the same procedure as the Steel Summary.

A time schedule for each purchase lot, or "buy," is determined by the prefabrication dates on the Long-Term Schedule. The release of the Steel Summary from Engineering is to be 12 weeks before the commencement of delivery from the steel mill for a given "buy," or 22 weeks before prefabrication. The 12 weeks allow one week for Steel Control screening, one week for release of Purchase Orders by Purchasing, and 10 weeks for steel mills to schedule and roll. Plates are normally rolled in 8 weeks and structurals are rolled in accordance with the steel mill's rolling schedule.

(2) Storage of Steel

Grids for storage are set up by units in the same order as the prefabrication of units. Therefore, the storage area becomes available for future jobs as the subject job progresses through unit-by-unit construction. Figure 6-8 shows that on the three-ship Exxon contract, steel tonnage in storage would peak at 13,000 tons. As the shipments are received from the steel mills, all plates are sorted and stored in their proper grid. Structurals are stored by sections, sizes, and grades. Unlike plates, a specific structural member is not allocated for a specific unit until it is picked up for delivery by the transfer system.

(3) Steel Transfer System

A steel transfer is a document, bearing an individual control or identification number, used for controlling the movement and accountability of any steel.

Upon receipt of the released UCM from the Moldloft and in accordance with the Long-Term Schedule, the Steel Control Department prepares the necessary transfers for a given unit. These transfers list purchased sizes of plates or structurals for a given unit and specify which components of the unit are cut from them. Separate plate transfers are written for different burning operations or functions (for example, tapeograph, exactograph, servograph, shears). Structural transfers require less breakdown because all cutting of structurals is done in one area under one supervisor.

Transfers are issued at least three weeks before the scheduled start of prefabrication. This allows enough time for Production Engineering processing and time for the prefabrication supervisor to program the steel into the burning schedule. Copies of the transfers are forwarded to the Production Engineer, who writes work orders completing a work package. These work packages (work orders, transfers, and UCM) are sent to the Prefabrication Department.

(4) Blasting, Painting, and Delivery

In accordance with their work load and schedule, the prefabrication supervisors order out the transfers, designating the delivery location. This is normally done five work days before the burning date. Upon being ordered, transfers are put on an active or working board and a pick-up work sheet is made in accordance to the ordered sequence of the prefabrication supervisor. Plates and structurals are then picked up from their respective storage area and processed through the Plate and Structural Shot Blast Systems.

A Plate Shot Blast Sheet records all plates processed through shot blast. These sheets are used as a sign off or delivery acceptance by prefab supervisors and also for computation of tons issued for the Weekly Steel Disbursement Report. Yard Movement Documents serve the same purpose for the accountability of structurals as the Shot Blast Sheet does for plates.

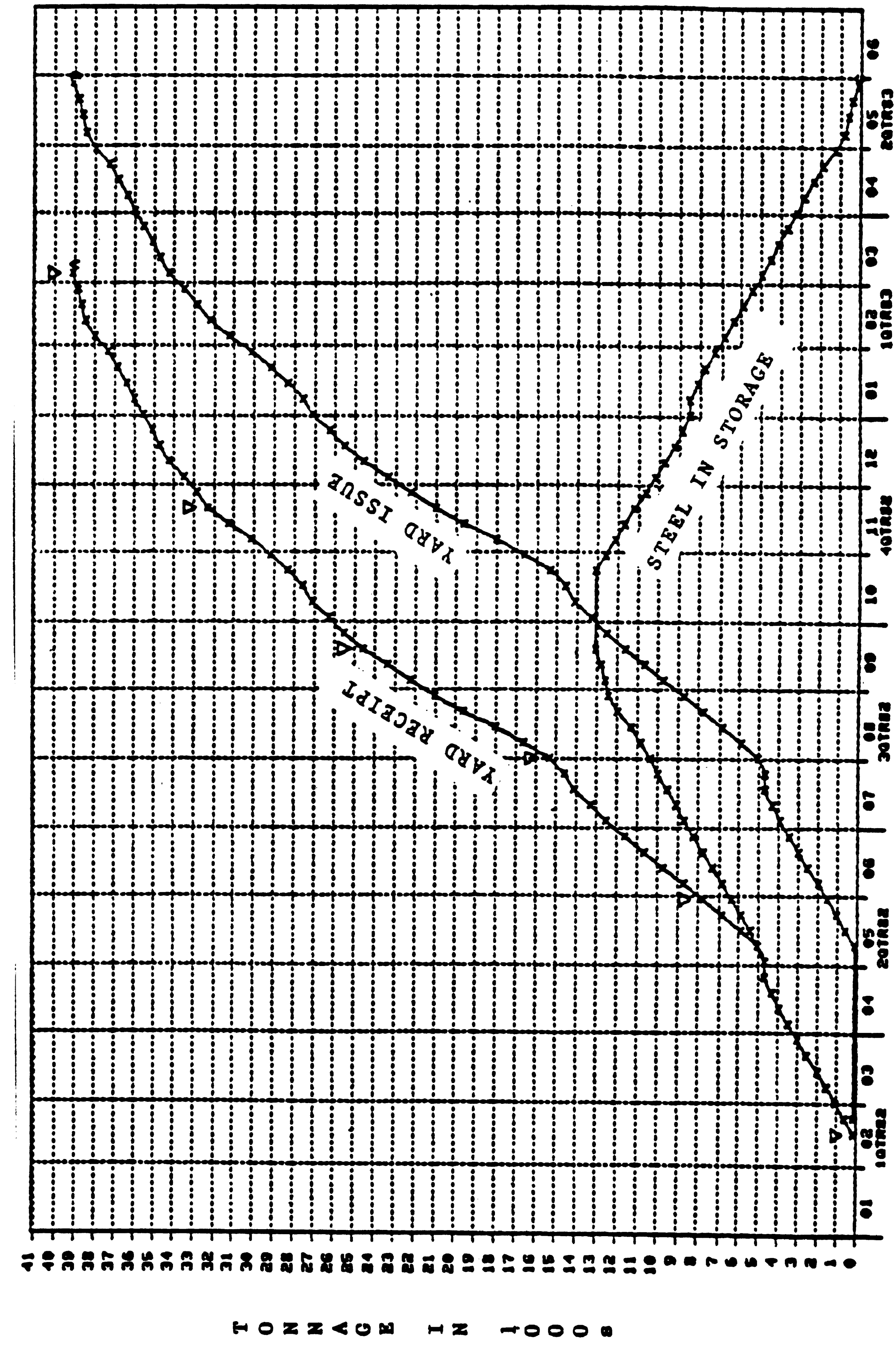


Figure 6-8 Steel Curves

(5) Inventory

The Kardex Card System is the main tool used in keeping steel inventory control. Information from the Purchase Orders is posted on the top card to show quantities on order, summary item numbers, and unit numbers. As steel is received, all receiving reports are posted on cards, and as steel deliveries are made, the steel transfer is also posted. The Kardex Cards always reflect an on-hand balance and storage location. Physical counts are done annually and corrective action is prompt.

(6) Efficiency of the System

The efficiency of steel handling depends greatly on the detailed information available at the time of purchasing. Much progress has been made since the days of the steel request ordering square feet of plate and lineal feet of structurals. Grouping the steel summary by units increases the efficiency of storage area.

As a result of implementing Process Lanes, the cost of receiving steel has increased by 8 percent. This is caused by the ordering sequence not being adhered to by the steel mills, so that sorting of plates is required on arrival. But the cost of delivering steel to the prefab work area has decreased by 16 percent because all the steel is stored by units. The combined activities of receiving and delivery are realizing an 8 percent reduction in the handling of raw steel.

Also in the past, about 18 percent of the entire steel handling time was devoted to handling bevel plates--deck, bulkhead, shell, innerbottom, and rectangular plates burned ahead of schedule. With the elimination of multi-ship burning and proper scheduling, bevel plate storage has been completely eliminated.

D. Prefabricated Steel

Prior to implementing the zone outfitting and process lanes technique, virtually all prefabricated steel moved from the plate shop to interim storage at the fabricated steel storage area. Now only a small portion of prefabricated steel moves to interim storage, while the overwhelming bulk moves directly to process lanes.

Incorporating storage queues at the process lanes work site has greatly aided the continual, smooth flow of material. The normal storage time in queue at the work site is one week, but occasionally two weeks storage is tolerated.

The prefabricated steel for partial subunits, subunits, and units is, in general, tracked through the plate shop and process lanes work platens by the supervisors of the shop and platens rather than by the Material Control Group. Constant monitoring by the shop planners has achieved significant cost savings.

Adherence to schedules by both the plate shop and the process lanes is of paramount importance in maintaining a smooth, orderly flow of prefabricated steel. Occasionally, a process lane may fall behind schedule because of, for example, inclement weather. In anticipation of such an event, a contingency has been built in to allow orderly marshalling. A three-week delay contingency can be handled by setting aside a marshalling area for prefabricated steel. An area containing storage grids (about 3 weeks output at 14 subunits per week) requires about 50,000 square feet. This is much smaller than former storage requirements and, most important, tracking the stored material is vastly simplified.

E. Fabricated Preoutfitting Material

Fabricated preoutfitting items, such as foundations, ladders, W.T. doors, manholes, etc., were formerly fabricated in entire multi-hull jobsets, thus creating many material handling problems, for example:

- the need for a very large storage facility,
- double and triple handling,
- deterioration due to long-term storage,
- loss of material,
- damaged material,
- obsolescence of stored material due to design revision.

The process lanes concept, with its thrust for level loading, dictates a new approach in this category of material. With a few exceptions, fabricated preoutfitting items will not be fabricated in entire shipsets, or even in entire jobsets. Instead, they will be controlled in smaller groupings compatible with short-term scheduling needs. This very effectively eliminates most of the handling and storage problems formerly encountered.

In the former method, some fabricated preoutfitting items moved directly from the fabrication shop to the jobsite, causing the entire shipset, or shipsets, of material to be at the jobsite much too early for installation. Now, all of this material moves to interim storage for palletization by units, or zone, thus necessitating more line items to be handled by Material Control. The cost of this small additional volume of pieces to be handled is more than offset by the reduction of remakes.

This material is controlled by the pallet system. Requirements for pallet loading are obtained from the unit and zone outfitting lists prepared by the Planning and Scheduling Department. Material Control can then expedite this material through the shops, using the pallet release date minus a lead time of two to four weeks. Formerly, this expediting effort was lacking and, thus, with a much more clearly defined management system, greater cost savings are being realized.

F. Warehoused (Purchased) Material

Warehoused or purchased material, other than piping, is still purchased in group lots, but allocated against units and zones. This material is received and stored by material family groupings, by job and purchase order number.

Working with the unit and zone preoutfitting lists, this material is palletized at the warehouse in accordance with craft type. Material Control is responsible to deliver it to the work site by the required pallet release date. If any item of material is short, Material Control notifies the expediting section of Purchasing that there is a deficiency, monitors this shortage and, upon receipt of the item, notifies Production and determines the proper point of issue (it may have moved from unit to zone). Rigid control of the flow of material to the work site establishes a discipline that demands a specified work effort. Overloading work areas with materials or failure to deliver the proper quantity of material at the proper time causes a profound loss in productivity and resultant loss in efficiency and competitiveness.

G. Raw Piping Material Input to Pipe Shop

Fabricated pipe details are presently being implemented for fabrication in a semiautomated pipe shop. The engineering and shop fabrication effort is driven by a CADAM/COPICS EDP program. While the details of this system for enhancing the engineering and fabrication effort is covered elsewhere, the material control aspect of this operation is examined here.

Under the old system of outfitting procedures, the Mechanical Section of the Engineering Department would produce a pipe detail (P/D) drawing for each piping system. This P/D drawing and its attendant list of materials (L/M) contained both shop fabrication and "on ship" installation information, which had to be separated by the Material Department to determine which materials were "shop load" and which were to be installed "on board." In the meantime, advance lists of materials based on preliminary system diagrammatics were used to establish material ledgers, to be screened against surplus stock, and to generate purchase orders, expediting, receipt, and issue information. Subsequent drawing changes in the final P/D's frequently caused duplication of bookkeeping and receipt of unnecessary surplus material.

With the new unit/zone outfitting procedures, the Mechanical Section of the Engineering Department produces a pipe detail drawing for each unit. These drawings include all shop fabricated piping within the confines of the unit, and each is assigned a pallet code, work station routing, and coating information. The P/D drawings contain all the pipe details that are to be fabricated for the unit, regardless of which system they belong to. The information on each P/D is then input to an EDP program called "Copics," which is used to schedule the pallets, P/D's, and the individual pieces that make up each P/D according to its pallet number. From all of this information, a weekly shop load list is produced containing all of the material required for P/D fabrication for each pallet that is scheduled to start fabrication that week.

This list of material is reviewed by the Material Control Department to determine if all materials are on hand. Since only parts of systems and, in fact, only parts of units are fabricated weekly, a manual material take-off would be very impractical. The computer listing makes this procedure unnecessary.

The procedures followed under the old system-oriented method for issuing materials to the Pipe Shop were triggered by the production work order. One work order was written to schedule a whole piping system of fabricated pieces through the shop at one time, with only a tentative start and complete date. Before releasing any material to the Pipe Shop, however, it was necessary to confer with the Pipe Shop superintendent to determine if the shop load was such that this material could be accommodated at that time, since shop loading was not considered in the overall schedule. If it was determined at that time that the Pipe Shop could handle the system in question, the Material engineer released the material requisitions to the Warehouse for issue and, at the same time, sent a copy of all shortages listed against that system to the Pipe Shop for information and to the Expediting Department of Purchasing for action. The Warehouse would then fill all the material requisitions and send all the material available to fabricate the whole system to the Pipe Shop. All materials not on hand were assigned to the "deliver on arrival" category and sent to the Pipe Shop whenever they arrived. If, after consultation with the pipe superintendent, it was decided not to fabricate the system due to shop loading or overloading, the material requisitions were held by the Material engineers until called for by the pipe superintendent. In effect, the Pipe Shop scheduled its own work, based more on shop loading than on schedule requirements.

The system for issuing materials to Pipe Shop under the new "shop management, unit outfitting" procedures is somewhat reversed from the old method. After reviewing the material listing from Data Processing's weekly load list, the Material engineer determines those P/D's for which all of the required materials are on hand. These P/D's are then released via a CRT in the Material Control Department and become available for fabrication on the scheduled date. This information is fed to Production engineers so that work orders can be written only for those P/D's released and to the Pipe Shop so that the materials and the P/D's to be built will coincide. As with the old system, material requisitions are then written to the Warehouse for issue to the Pipe Shop. The materials sent to the Pipe Shop will be separated by categories, such as flanges, elbows, reducers, etc., for ease of machine station loading in the Pipe Shop. P/D's that were scheduled during this time period, but not released due to a lack of material, are reviewed each week and released to the Pipe Shop when the material arrives.

Unlike the old system, the Pipe Shop superintendent is not contacted prior to deliveries, nor does he have the option to halt deliveries due to shop overloading. Rather, he must take other corrective steps such as increasing capacity by working extra shifts, rerouting, overtime, or subcontracting. The zone outfitting concept forces this discipline upon everyone because it is more important to the overall success of the shipbuilding process than is shop level-loading.

H. Fabricated Pipe Details from the Pipe Shop

The storage and issuing of finished pipe details under the old system method presented the Material Department with many handling and record-keeping problems. As pipe details were fabricated in the Pipe Shop with perhaps several systems being built at one time, they were sent directly to the fabricated pipe storage yard where they were off-loaded on to other trailers depending upon the coatings required; or, if no coatings were required, the pipe was palletized, stored, and located in a manual locator system. As coated pipe details were returned to the storage area, they too were palletized, stored at random, and recorded. This resulted in the components of one system being stored on many pallets in many locations. When the installation work order was written, it was to install the entire system over a rather long period of time. Since it was impractical to issue all the P/D's for an entire system at one time, the installing foreman would call for P/D's as he needed them. This resulted in taking the appropriate P/D's from a pallet containing other P/D's, in effect, double handling nearly all P/D's. The length of time the P/D's remained in storage often caused other problems such as deterioration, damage, or loss.

Today, pipe details are received from the Pipe Shop as they are built and off-loaded to the various coating areas much as under the old system. However, each P/D is now pallet coded and placed into a metal container with other P/D's designated for that particular pallet. Since the Pipe Shop is building to a much shorter schedule due to the fewer P/D's required in a unit as compared to a system, P/D's remain in storage a relatively short time. When all P/D's required for a pallet are received and ready for installation, the metal containers are banded and only await the scheduled installation date to be issued. This method results in a smoother flow of fabricated parts to the building areas, along with a reduced amount of handling by the Material Department.

I. Summary of Benefits

To date, ASI's experience with the IHI concept of unit and zone outfitting is proving that it is a valuable management tool. From a material management point of view, it provides the capability to review material needs in smaller, more controllable packages and in a much more timely manner. The savings from process lanes implementation is real and measurable. The returns from a reduction of lost material alone are significant. The savings obtained from standardization of pieces including lifting lugs and padeyes greatly reduces the overall cost. The elimination of multi-ship burning has greatly reduced rework cost via established procedures for material flow through process lanes.

The methods that have been developed over the past few years are a giant step forward toward a complete and fully operational zone outfitting material control system. Obstacles still remain to be overcome but continued advances, especially in computerization, should find ASI in a position to respond to future changes and advances with a minimum of disruption. The hardest part--the understanding of how the zone outfitting methods function--has been accomplished, and the greatest gains in productivity are yet to be realized.

IV. ACCURACY CONTROL

If absolute accuracy were required in ship construction, it would imply that the finished individual parts, and ultimately the ship itself, would exactly coincide with all design dimensions and details. Obviously, no such exactness could be expected to actually exist. Measurements show that there is no such thing as absolute accuracy, because variations from specified dimension of a workpiece are always measurable and normal. One of the functions, perhaps even the primary function, of an Accuracy Control Department is to establish realistic goals within normally achieved ranges of accuracy within which a shipyard Production Department can operate, with proper consideration being given to the demands of both quality workmanship and sound economics.

The word "Control" should be quite literally accepted; the required controls should be implemented in such manner as to ensure the degree of accuracy desired.

Thus, the two initial functions of an Accuracy Control Department are:

- the establishment of realistic goals in the area of accuracy;

- the development of proper procedures or controls to permit the achievement of those accuracy goals.

Successful implementation of accuracy control in shipbuilding presupposes a basic philosophy in management that is committed not to just doing a job the best way possible, utilizing all the facilities that are available, but is rather committed to doing that job the best way possible the very first time it is attempted. Any other philosophy is a positive commitment to the necessity of rework. The elimination of rework should be inherent in all of the activities of an Accuracy Control Department.

A. Activities of an Accuracy Control Department

The activities of an Accuracy Control Department should span all phases of construction from the burning of the plate and structurals to the final erection of all material in the completed ship. These activites may be roughly divided into three categories:

- Checks
- Controls
- Statistics

Although these are distinct and separate activities, they are so thoroughly interrelated that any one cannot be effectual without the involvement of the other two.

These efforts should have a dual impact: the improvement of immediate work and the improvement of future work. Without an accuracy control program, a poor product is the predictable end result, both for immediate and future work. Checks alone will identify inaccuracies but cannot improve the end product. The development and implementation of controls, in addition to checks, results in an improved product for immediate work but develops little potential for the improvement of future work. With the implementation of a well coordinated Accuracy Control Department, utilizing checks, controls, and statistical record keeping, the results are a good product in immediate work, the potential for a good product in future work, and the potential for improved design concepts, improved engineering concepts, and improved production concepts.

(1) Checks

Checks are utilized for three primary purposes:

- To isolate specific problems of inaccuracy that require controls.

- To monitor construction to ensure that proper controls are being utilized and are, in fact, effective.

- To identify and assist in minimizing human errors.

Accuracy Control engineers spend a great part of their time measuring--slow, methodical, painstaking, tedious measuring. This can at times seem like the most plodding of work, but it is also the most necessary of work. From careful measurements, methodically recorded and statistically analyzed, proper controls may be developed. A component like a web frame (Figure 6-9) must be measured before the butts are welded, after the butts are welded, and after the stiffeners and face plate are welded. This is necessary to determine average shrinkage

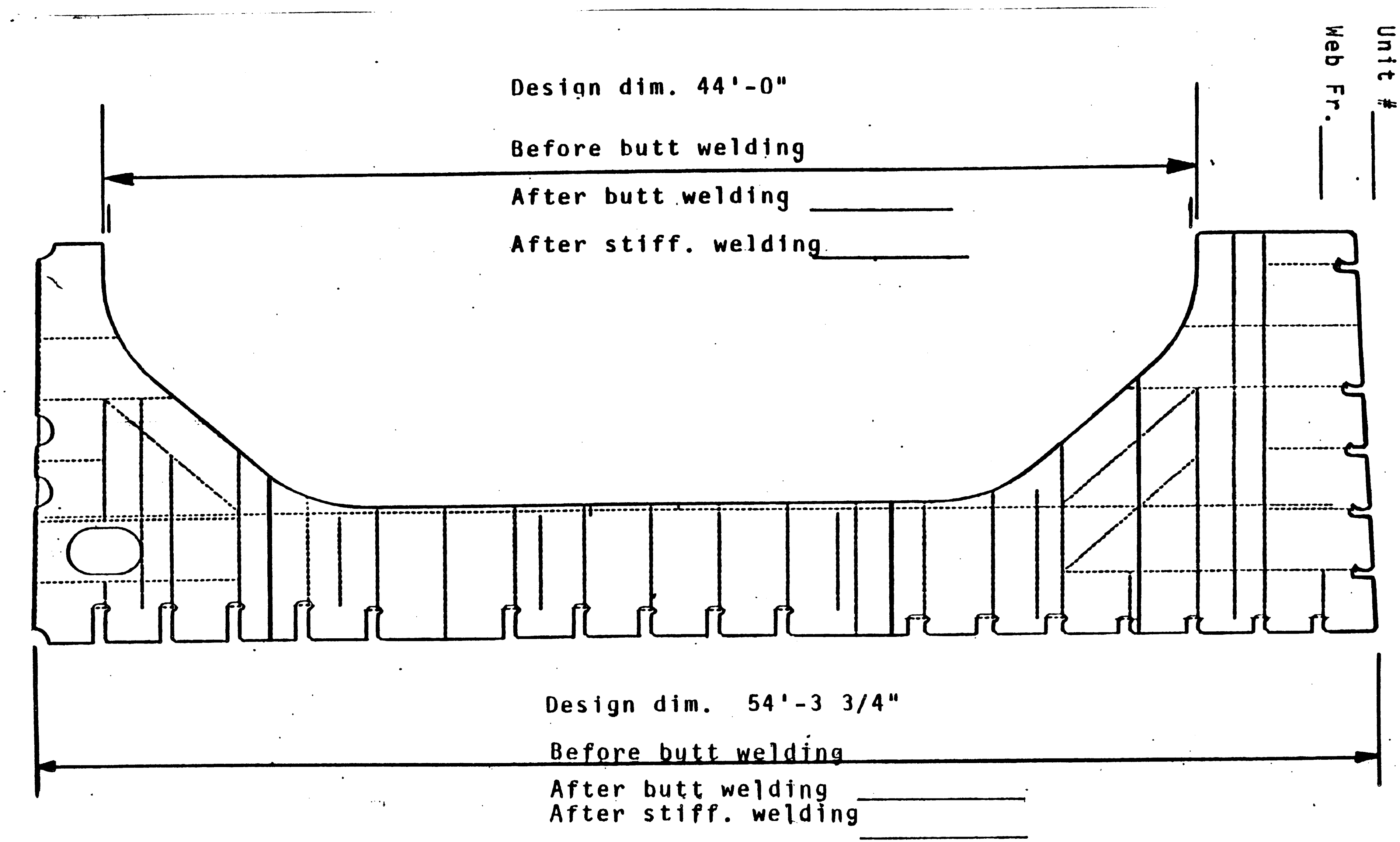


Figure 6-9 Accuracy Control Reporting Form

factors to be utilized in the cutting of component plating. This information is also used to develop assembly procedures that will minimize deformation of the component. The dimensions shown on each component's reporting form provide all the information necessary to make possible these evaluations.

Utilizing typical measurements of this kind and rather uncomplicated programs that can be fed into hand-held calculators, it is possible to predict the final shape and measurements of the most common types of units. Such procedures of measuring and checking have almost unlimited potential for improving the accuracy of future production.

(2) Controls

a. Control Lines

Control lines, otherwise called master lines or datum lines, are water lines, frame lines, or buttocks that are laid out on various components of units to facilitate the building and erection of the unit. These lines must be located with unvarying accuracy. They are incorporated into the engineering drawings in the UCM and are transferred to the structural elements by using the steel tapes produced by the Moldloft.

b. Burning Procedures

The accurate burning of all pieces of units, subunits, or partial subunits is of primary importance, because anything else is a commitment to rework. Figure 6-10 shows several areas where this accuracy is demanded. The fit of floor stiffeners to shell longitudinals requires not only that the stiffener be cut to proper length but that the shell longitudinal must also be trimmed to the proper height. A minimum gap of 1/4" requires that each of these members be cut within 1/8" tolerance. A fit that will always ensure no burning at assembly requires even closer burning tolerance.

The fit of floor to girder requires a burning tolerance of 1/32" if all of the floors are to be fitted on a unit without reburning. Unit No. 17, the first unit completed on the Exxon contract, with the exception of one shell plate that had stock on it when it should have been neat, was completely assembled without the use of a torch during assembly.

c. Uniform Shrinkage Factors

Few activities are of greater consequence than the development of uniform shrinkage factors. Accurate burning is of little consequence without the utilization of such factors. Floors, as shown in Figure 6-10 with an excessive shrinkage factor built in, would require occasional reburning to offset a cumulative build-up, even if individual floors were only 1/16" oversize. Web frames (See Figure 6-9) require a different shrinkage factor than the longitudinal bulkhead to which they must be fitted. Specific factors must be developed for all components of a unit. Data gathered and analyzed by Accuracy Control engineers are used to determine shrinkage factors for each type and stage of construction.

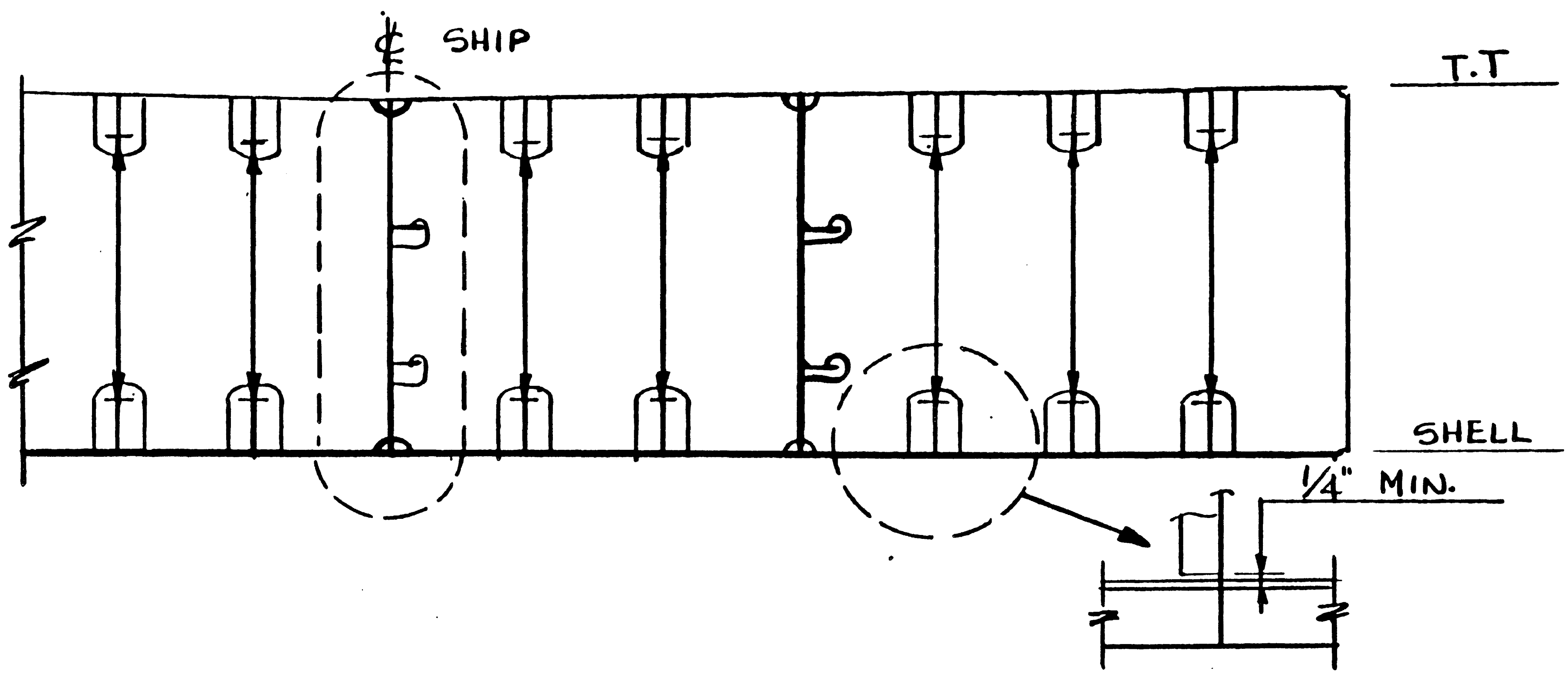


Figure 6-10 Accuracy Control Burning Tolerance Specification

d. Construction Procedures

Proper construction procedures such as fitting and welding sequences may well offer the most positive and immediate reward for the efforts of an Accuracy Control Department.

Many detailed fabrication and erection sequences have been developed at ASI. A typical analysis follows. Unit No. 7 is a fairly typical innerbottom unit, which might be found on most contemporary design ships (See Figure 6-11). Three major areas of heat introduction by welding can cause built-in stresses or deformations of this unit:

- butt welds;
- vertical welds, floors to girders;
- welding of loose shell longitudinals.

Since this unit was built upside down and the tank top was delivered to the platen fully welded with all longitudinal stiffeners fitted and welded, these parts did not contribute to any deformation of the unit. The longitudinal girders were delivered to the platen with the floors immediately outboard already fitted and welded. This, then, necessitated fitting of all girders and attached floors to the tank top, the fitting of all floors to girders immediately inboard of them, the fitting of all loose shell longitudinals and the fitting of all shell plating to girders, floors, longitudinals and to the tank top.

Each of these steps presented a very distinct potential for deforming the unit. No predetermined construction sequence was utilized in the building of Unit No. 7 on Hull No. 1. Figure 6-12 (Hull 1) is a profile that was developed from measurements taken on the innerbottom plating of the unit after assembly (vertical scale exaggerated). A crown in excess of 5/8" developed on the tank top of this unit. Other similar, but larger, units developed crowns up to 7/8".

Various attempts were made to minimize this deformation, including building in a reverse crown, but most of these efforts tended to be ineffective (Hull 2). Ultimately, a detailed construction sequence was developed and implemented (See Figure 6-13).

This procedure controlled the three basic problem areas. It did not reduce the heat introduction, but only permitted the components to deform in such a manner as to minimize the cumulative deformation of the final assembly. The resulting unit on Hull No. 3 (Figure 6-12) was virtually flat.

The deformation of units like this one resulted primarily from the introduction of heat, in the form of welding, at the shell plate side of the unit while the tank top of the unit was totally restrained by prior fitting and welding. This resulted in horizontal movement in excess of 5/16 of an inch on the shell plate side of the unit. Since the tank top side of the unit was restrained and not permitted to move, the crowning of the unit was the unavoidable result. This result is both predictable and calculable. The entire construction sequence was developed to permit a uniform movement of the components of the unit, thereby minimizing the cumulative deformation.

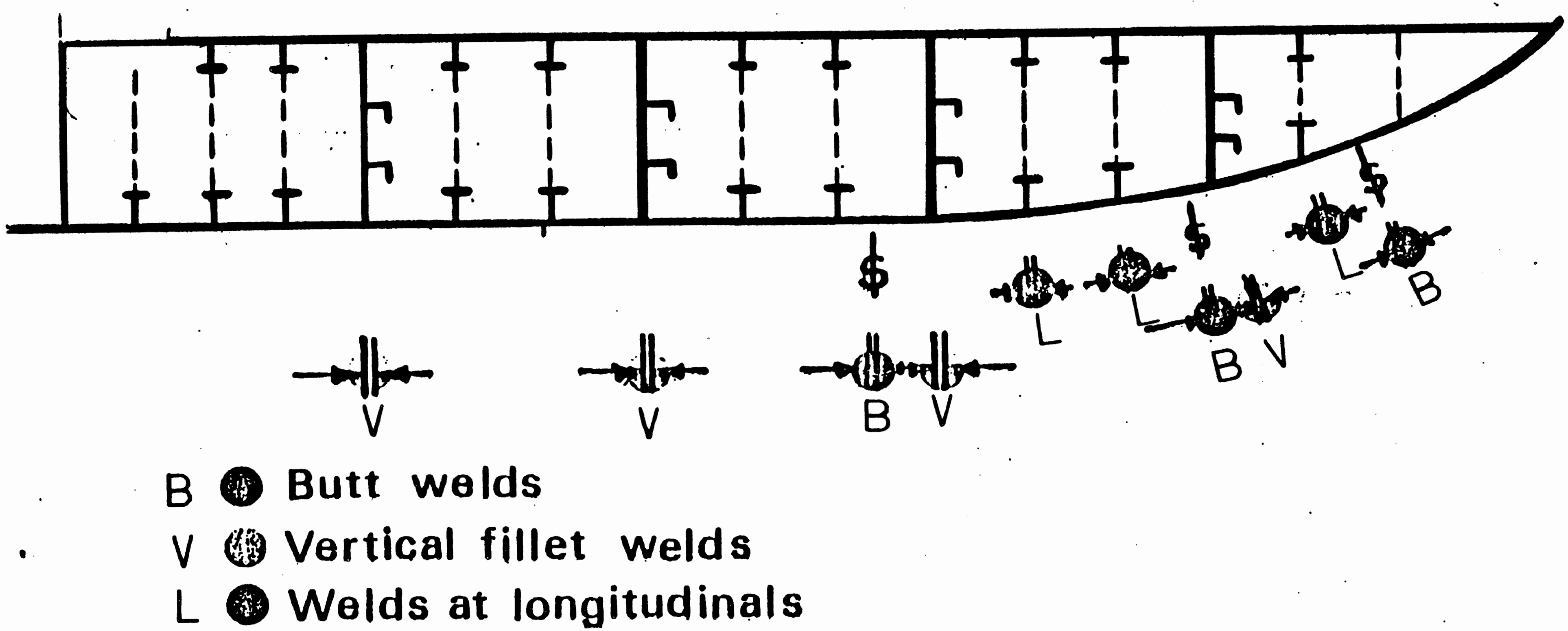


Figure 6-11 Heat Introduction to Typical Innerbottom Unit

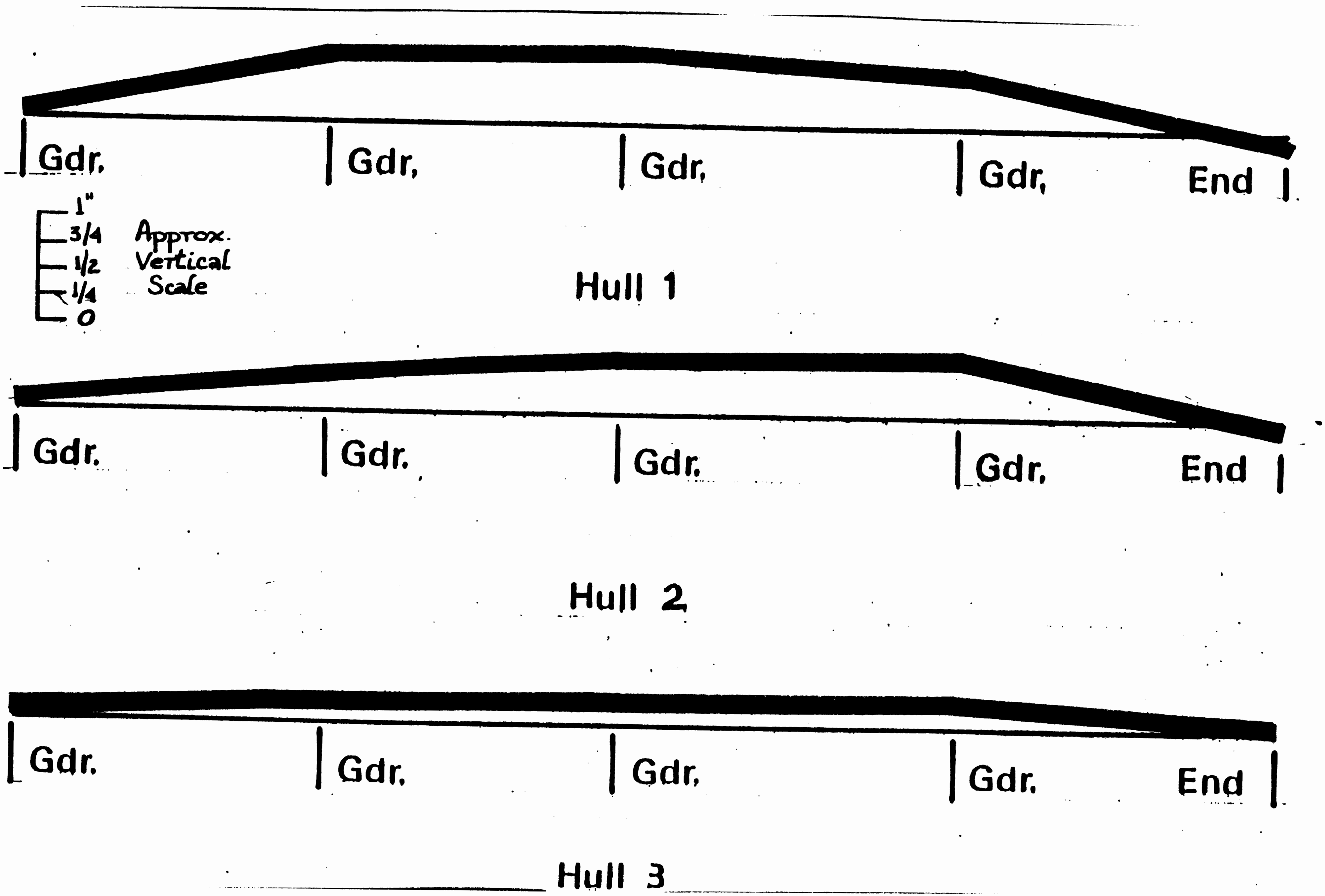


Figure 6-12 Effect of Construction Sequence on Deformation of Innerbottom Unit

Figure 6-13 Main Assembly Construction Sequence

1. Lay down tank top panels on platen.

2. Hang girders to which floors have been previously fitted and welded.

3. Fit girders to tank top. (2'-0" fwd. and aft. of each frame should left free of tacks)

4. Level unit. (Tack to platen with clips)

5. Fit floors to girders. (Do not fit floors to tank top)

6. Weld all floors to girders, backstepping four times.

7. Fit floors to tank top.

8. Flat weld all girders and floors to tank top.

9. Fit all stiffeners, collars, brackets, clips, etc., at tank top.

10. Weld stiffeners, collars, etc., at tank top.
    Note: No piping to be installed prior to this stage of construction.

11. Hang and fit all loose shell longitudinals.

12. Weld clips or collars at shell longitudinals.

13. Hang and fit shell plate nearest to centerline of ship. (If this is a blanket, fit entire blanket, tacking to floors, girders and longitudinals)

14. Hang adjacent shell plate.

15. Weld shell plate butt.

16. Repeat procedure prescribed in item #14 for each of remaining shell plates up to extreme outboard plate.

17. Hang extreme outboard shell plate. If shell longitudinals fall under this plate, fit as previously described. Otherwise fit shell plate to floors, utilizing welding clips. (Do not fit to floors) Do not fit to tank top at this time!

18. Weld last shell plate butt.

19. Fit shell plate to tank top.

20. Flat weld shell plate to tank top.

21. Turn unit right side up and finish fitting at shell.

22. Flat weld floors, girders and longitudinals and backgouge and weld butts.

23. Check ends of all girders and longitudinals for proper alignment with adjacent units. Fair if necessary.

e. Erection Procedures

The Accuracy Control Department at ASI is primarily involved in work during stages prior to erection. However, erection is a principal beneficiary of the use of control lines. These lines, when laid out with predictable accuracy, are an invaluable aid in setting units at erection. Also, the elimination of stock, or excess material, is virtually impossible without the use of these lines.

f. Construction Aids

Many tools may be developed to assist the Shipfitting Department in completing accurately built units, but the erection joint steel tapes, described previously, have perhaps the greatest practical value. They show the proper position of all structurals at each erection joint. Where they are utilized properly and in conjunction with other procedures, they make it possible to locate such structurals within a tolerance of one quarter inch or less. This procedure has proven itself so effective that it is routinely used at all erection joints.

Figure 6-14 shows a backside marker. This piece of equipment permits the accurate transferral of centerpunch marks from the layout side of plating to the opposite side. Accuracy is required in the location of control lines to be used in the construction and erection of the ship.

(3) Statistics

An Accuracy Control Engineer might be more aptly called a Statistical Engineer. The "statistician" determines the goals to be achieved and the "engineer" develops the controls necessary to achieve these goals. It then remains only for this information to be properly and precisely communicated to the various agencies of the shipyard so that the necessary controls can be implemented. Communicating his findings can be the most demanding part of an Accuracy Control Engineer's job, because it requires such detailed and documented and effectively presented information that he can make his case conclusively enough to overcome preconceived ideas that might run counter to it.

Statistics analyzed by accuracy control engineers may be divided into two categories:

- Those that are applicable to shipfitting work throughout the ship,

and

- Those that are applicable to a specific unit, that is, a unit history.

Basic statistical principles for calculating the mean values and standard deviations of measurements taken from single processes (marking, cutting, bending, welding) and merged processes are applied to all shipfitting work to develop standards for shrinkage factors, excess material allowances, etc.

Unit histories are merely the methodical recording of all problems encountered in the production of a specific unit. All stages in the evolution of a unit are included in establishing a unit history - from engineering, moldloft,

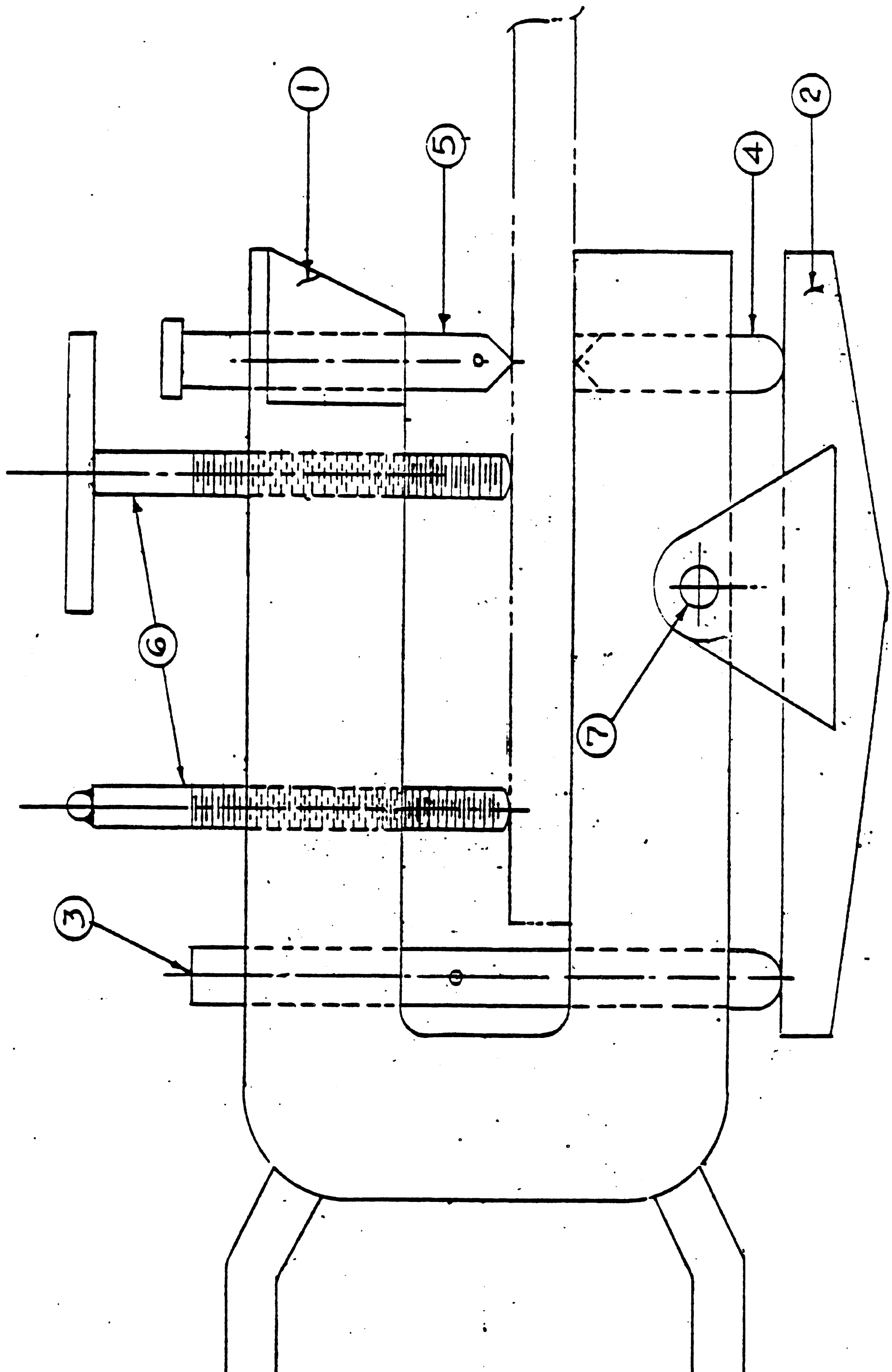


Figure 6-14 Backside Punch

and numerical control through burning, fitting of structurals, welding, and handling. This data is used in the development of procedures that will assist in minimizing the effect of any particular problem on subsequent units. This is particularly useful on multi-ship contracts.

V. SOURCE MATERIAL FOR CHAPTER 6

The following lectures in the Technology Transfer seminars were used as source material for Chapter 6. They are listed in the Appendix. Lectures 5, 8, 9, 22, 23, 25, 26, 28, 29, 32, 38, 39, 42, 46.

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8. "Outfit Planning" (for TPS), NSRP Report 0096, December 1979.

9. "Product Work Breakdown Structure" (for TPS), NSRP Report 0117, November 1980 [See also Reference (14)].

10. "Process Analysis via Accuracy Control" (for TPS), NSRP Report 0143, February 1982.

11. "Recommended U.S. Shipbuilding Standards Program Long-Range Plan - Final Report" (for BIW), NSRP Report 0144, February 1982.

12. "Pipe-Piece Family Manufacturing" (for TPS), NSRP Report 0147, March 1982.

13. "Line Heating" (for TPS), NSRP Report 0163, November 1982.

14. "Product Work Breakdown Structure - Revised" (for TPS), NSRP Report 0164, December 1982 [Revision of Reference (9)].

15. "Integrated Hull Construction, Outfitting, and Painting" (for TPS), NSRP Report 0169, May 1983.

16. "Zone Painting Method" (for ASI), NSRP Report 0177, August 1983.

17. "Design for Zone Outfitting" (for TPS), NSRP Report 0179, September 1983.

References (18) through (37) comprise a chronological listing of reports prepared by Levingston Shipbuilding Company in conjunction with IHI Marine Technology, Inc., under the auspices of the National Shipbuilding Research Program (NSRP). See Appendix B of Reference (3) for abstracts of these reports.

18. "Quality Assurance System," NSRP Report 0025, March 1980.

19. "Quality Assurance - Volume 1: Final Report," NSRP Report 0026, March 1980.

20. "Quality Assurance, Volume 2: Appendices," NSRP Report 0027, March 1980.

21. "Special Report: Accuracy Control Planning for IHI Construction," NSRP Report 0014, March 1980.

22. "Cost Accounting, Final Report," NSRP Report 0016, March 1980.

23. "Industrial Relations. Executive Summary," NSRP Report 0017, March 1980.

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42. Avondale Shipyards, Inc., "Manufacturing Technology for Shipbuilding; Process Lanes and Design Engineering for Zone Outfitting, Volume IV," NSRP Report 0140, 1984.

APPENDIX

LIST OF LECTURES PRESENTED AT THE SHIPBUILDING TECHNOLOGY TRANSFER SEMINARS

Seminar #1, Planning and Scheduling, May 1982 [Reference (39)]

1. Overview and Background, O.H. Gatlin
2. Hull Planning and Scheduling, C.J. Starkenburg
3. Details of Hull Planning: Process Lanes Procedures, D. Sours; Long-Term Schedules, D. Smith
4. Outfit Planning and Scheduling, C. Starkenburg
5. Details of Outfit Planning, G.B. Grimsley
6. Engineering Interface, J.J. O'Callahan
7. Moldloft and Production Engineering Interface, E.E. Blanchard, Jr.
8. Material Control Interface, F. Logue
9. Accuracy Control Interface, J. Taylor and W. Weidman

Seminar #2, Design Engineering for Zone Outfitting, July 1982 [Reference (40)]

10. Overview and Background, O.H. Gatlin
11. Engineering Introduction, T. Doussan
12. Precontract Effort and Key Plans, A Nierenberg
13. Design Section (Key Plans), D. Niolet
14. Hull Section (Yard Plans), W. Seibert
15. Mechanical Design Section, A. Nierenberg
16. Piping and HVAC Section, S. Caronna
17. Outfitting Section, W. Calvin
18. Electrical Section, D. Mouney
19. Engineering Planning and Scheduling Section, J. Busch

20. Production Planning Interface, C. Starkenburg

21. Moldloft Interface, B. Pourciau

22. Material Control Interface, D. Decedue

23. Accuracy Control Interface, J. Taylor

Seminar #3, Moldloft, Production Control, Accuracy Control, November 1982 [Reference (41)]

24. Overview and Background, O.H. Gatlin

25. Introduction, E.E. Blanchard, Jr.

26. Production Engineering, R. Oehmichen

27. Moldloft, B. Pourciau

28. Material Control, F. Logue and D. Decedue

29. Accuracy Control, J. Taylor and W. Weidman

30. Production Planning Interface, C. Starkenburg

31. Engineering Department Interface, T.H. Doussan

32. Steel Control Interface, F. Marks

33. Production Operations Interface, E. Taylor and J. Hartman

Seminar #4, Process Lanes and Design Engineering for Zone Outfitting, June 1984 [Reference (42)]

34. Background and Introduction, R.A. Price

35. Process Lanes Concept, E.L. James

36. Physical Process Lanes, D. Smith

37. Unit Breakdown and Scheduling, D. Smith

38. Coding System, A. Dufrene

39. Material Flow, G. Grimsley

40. Schedule Planning for Hull Construction, E.L. James

41. Planning Controls under Process Lanes, D. Bergeron

42. Production Cost Controls, R. Oehmichen

43. Production Planning and Control, D. Bergeron

44. Zone Outfitting Concepts, G. Grimsley

45. Moldloft, B. Pourciau

46. Accuracy Control Interface, J. Taylor and W. Weidman

47. Design Engineering for Zone Outfitting, J.R. Wilkins, Jr.