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May 1983

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Integrated Hull Construction, Outfitting and Painting (IHOP)

U.S. DEPARTMENT OF TRANSPORTATION
Maritime Administration
in cooperation with
Todd Pacific Shipyards Corporation

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FOREWORD

"Just give us the plans and material on time and we can build ships as productively as anyone." So say traditional production bosses. Nothing could be further from the truth because a critical element is missing. Managers of the most productive shipyards have succeeded in getting their ***production people highly involved in design mattens starting with development of contract plans. Thus,*** each of their design efforts begins and continues in the context of a premeditated building strategy for integrated hull construction, outfitting and painting. ***Design is truly an aspect planning.***

As compared to traditional shipyards, the organizations of people, information and work processes are different, interdependent and comprise constantly self-improving shipbuilding systems.

Very much is dependent on continuous hiring of recent-graduate engineers who start in shops as process engineers and are systematically transferred to achieve both production and design experiences in hull construction, outfitting and painting. Members of this intelligent cadre are assigned successively as shop managers, senior production engineers and department managers while shifting between organizations responsible for different types of work.

The integrated methods described herein were developed by Ishikawajima-Harima Heavy Industries (IHI) of Japan. An aspect that is particularly noteworthy is frequent reference to statistical control of manufacturing, i.e., accuracy control. As early as 1967, the Japanese Society of Naval Architects reported that accuracy control "epoch makingly" laid the foundation of modem ship construction methods.

This publication should be particularly useful to:

- senior managers who have decided to revolutionize their shipbuilding methods and who have sufficient authority to counter traditionalists,
- design organizations including independent design firms because of the disciplines described for communications between production people and designers, basic designers and detail designers, and between people having hull construction, outfitting and painting responsibilities in both design and production organizations,
- officials of the U.S. Navy who, early in 1983, announced plans to do their own design work for a new class of ships, and
- students or others concerned with management of any ***large*** industrial project.

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The material on which the contents are based was compiled by a project team led by Y. Okayama, International Division, Ishikawajima-Harima Heavy Industries Co., Ltd. (IHI) of Japan. Team members included K. Ando, M. Tomisawa and K. Honda. Their work was significantly rewritten, supplemented and reorganized by L.D. Chirillo assisted by R.D. Chirillo.

Appreciation is expressed to T. Yamarnoto of IHI who, on his own time, provided valuable explanations and examples. Appreciation is also expressed to Y. Ichinose of IHI Marine Technology, Inc. and to T. Lamoureux, L. Willets, D. Arnold and B. Coralles of Todd's Los Angeles Division, who furnished essential support.

This book is an end product of one of the many projects managed and cost shared by Todd for the National Shipbuilding Research Program. The Program is a cooperative effort by the Maritime Administration's Office of Advanced Ship Development and the U.S. shipbuilding industry. The objective, described by the Ship Production Committee of the Society of NavaI Architects and Marine Engineers, is to improve productivity.

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1.0 INTRODUCTION

1.1 Background

Even now, many years after welding replaced riveting, improved shipbuilding methods that welding made possible are still developing. Before welding, each ship's hull was built in essentially the same sequence. A keel was laid, frames were positioned and plates were fitted "plank by plank" reflecting the time honored sequence for building wood ships. The process was system oriented, i.e., first the keel was assembled as a system, then the frame system was erected, next the shell system and so on. System-oriented planning, including the preparation of system-oriented hull-construction drawings, was appropriate.

The advent of welding meant that parts of frames could readily be joined to portions of a shell. Such weldments could incorporate parts of decks, bulkheads and a keel. Therefore much assembly work was shifted from the building ways to platens in or near shops where work is performed with greater safety, efficiency and accuracy.

When sufficient block-like weldments were accumulated, a ship's hull was erected block-by-block. Thus, hull construction had become zone oriented. A few shipbuilders evolved zone-oriented hull-construction drawings to suit. The sequence specified for their preparation was the same as that planned for hull erection. Both detail design and production people concerned with hull construction were responding to the same building strategy.

With rare exception, even when block construction became routine, outfitting and painting continued as successor functions. That is, each hull was essentially complete before most outfit work was performed. Many outfit components were measured, fabricated and fitted on board with all attendant inefficiencies.

Some shipbuilders prescribed preoutfitting of blocks which is the division of outfit work into two basic stages, i.e., on-block and on-board. However, many continue to employ system-by-system outfit drawings and their work orders specify performance of outfit work by systems or portions of systems. Work order contents are relatively large so as to complicate attempts to achieve uniform and coordinated work flows. In response to such orders each work team usually competes with other teams for access to work. Within blocks being outfitted, to a lesser but still significant degree, the same problems are encountered as in conventional outfitting. There are redundant temporary services, e.g., staging, welding cables, compressed-air hoses and flexible ventilation ducts. Most overhead fitting work is still performed by workers reaching over their heads.

No less illogical, people who perform detail design, material definition and material procurement system-by-system are unnecessarily preoccupied with portions of systems that will not be required for some time. Detail design and material definition, both vital aspects of planning, and material procurement are system oriented whereas preoutfitting is zone oriented. Under such circumstances, the efficiency of even comprehensive preoutfitting is inherently limited because of the contacting building strategies. Focus on a single zone-oriented strategy led to the development of scientific shipbuilding methods.

The traditional approach was replaced by the world's most productive shipbuilders with integrated hull consttruction, outfitting and painting characterized by a number of remarkable features, e.g.:

- the Hull Block Construction Method (HBCM) wherein hull parts, sub-blocks and blocks are manufactured in accordance with the principles of group technology (family manufacturing) in organized production lines (also process or work flows),
- the Zone Outfitting Method (ZOFM) which disregards the archaic notion that outfitting is a successor function by providing precise zone-by-stage control for which there are three basic stages: on-unit, on-block and on-board outfitting and a sub-stage for ***down-hand*** outfitting on overheads when blocks are upside down,'
- family manufacturing, such as in Pipe Piece Family Manufacturing (PPFM), which replaces job-shop thinking with group technology logic in order to obtain production-line benefits for the manufacture of many different items in varying quantities, and most significantly
- adoption of a Product Work Breakdown Structure (PWBS) which facilitates the integration of the foregoing inherently different types of work by emphasizing expertise in contriving and classifying ideal interim products, e.g., parts and subassemblies which permit coordinated work flows.[2]

The history described in the foregoing, leading to integrated hull construction, outfitting and painting, is illustrated in Figure 1-1. Because shipbuilders who have mastered such integration routinely achieve over 90-percent completion of outfitting at time of launching, they had to substitute more meaningful progress indicators:

c percent of outfitting completed at keel laying, and

- percent of outfit planning completed at keel laying.

For them, achieving 35 and 85 percent respectively is not unusual.

1.2 Impact on Hull Construction

Integrated hull construction, outfitting and paintir (IHOP) impacts on every aspect of hull construction. Trac tional organizations of people, information and work a not suitable. As the most productive shipbuilders ha proven and are continuing to perfect IHOP, shipbuilde who must compete have no alternatives. They too m master IHOP. For them, changes in functional structure employment of information, and work processes are ii evitable.

Because of the usual predominance of hull construction the expense of the other types of work, effecting the nece sary changes for hull construction is likely to be the mo difficult. Some traditional managers would not find it ea: to accept, let alone direct, what appears to be subordinatic of "steel" throughput in order to achieve IHOP. But if the did, they would be surprised because the disciplines fi achieving coordinated process flows for different types work, also improve hull-construction productivity.

As shown in Figure 1-2, IHOP requires unprecedente collaboration between all shipyard departments. As theirs a lead role, production engineers for hull construction mu understand outfitting and painting needs. Integrated pla ning is achieved by discussion, trade-offs and ultimate mutual consent. The overriding goal is an increase in pr ductivity for an entire ***shipbuilding system.***

[1]The word unit is used to designate an assembly of just outfit materials. Thus, on-unit outfifting does not involve any hull structure.

[2]Other publications by the National Shipbuilding Research Program refer. See "Product Work Breakdown Structure - Revised December 1982" whi describes the hull block construction and zone painting methods, "Pipe Piece FamiIy Manufacturing - March 1982" and "Outfit Planning -Deceml 1979". Limited supplies of these publications and others referenced herein are available to U.S. shipbuilders at L.D. Chirillo Associates, P.O. Box 9 Bellevue, WA 98009.

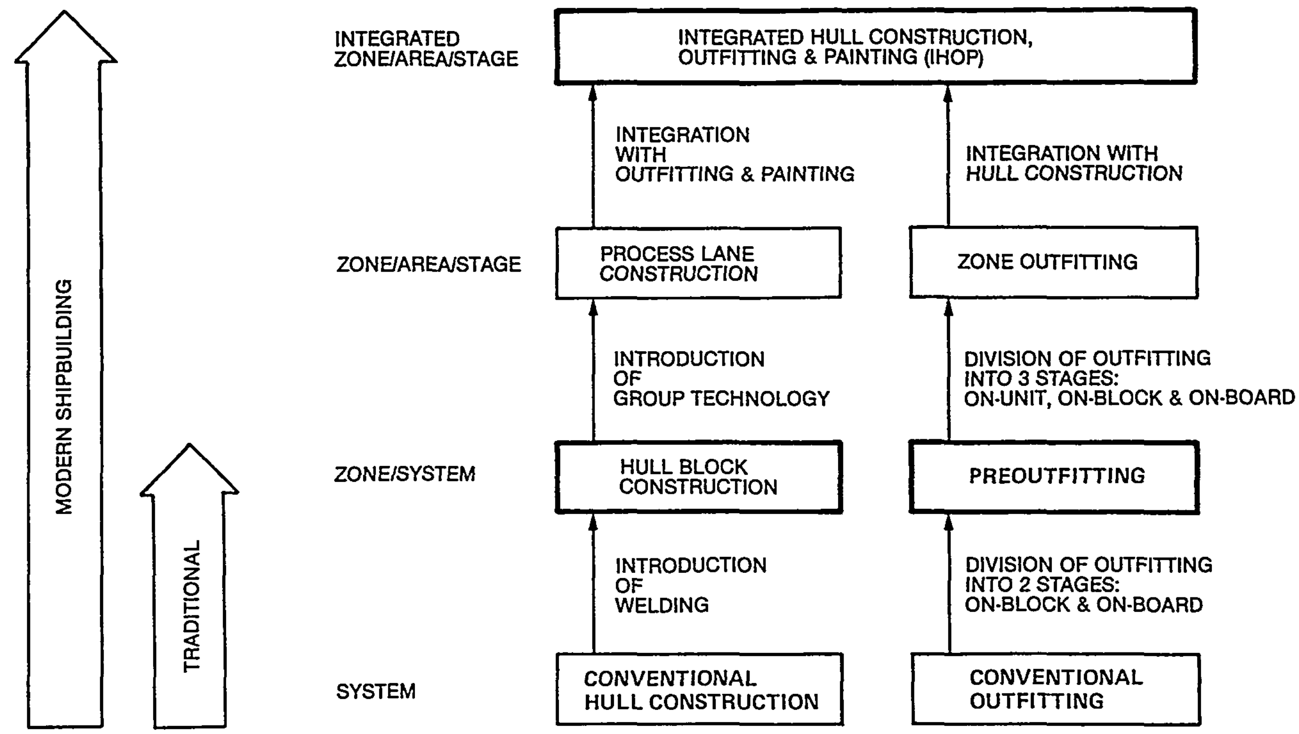


FIGURE 1-1: History of Basic Improvements in Shipbuilding Methods.

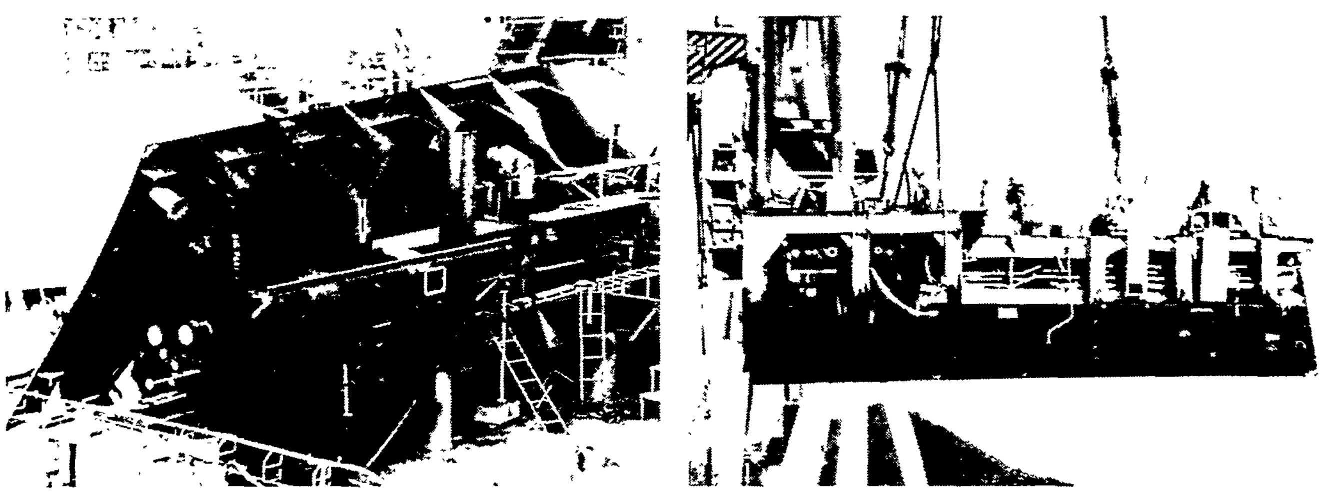


FIGURE 1-2: An extensively outfitted and painted block, shown before and after turnover, manifests integrated hull construction, outfitting and painting (IHOP). Opportunity for down-hand work on ceilings and access for extensive amounts of outfitting and painting work in accordance with the principles of group technology, enhance productivity.

2.0 BASIC RESPONSIBILITIES

2.1 Organization of People, Information and Work

Organizations similar to that shown in Figure 2-1 are optimum and will probably evolve wherever IHOP is pursued. Differences from traditional organizations are:

- the shipbuilding firm is very much involved in basic design,
- unified control of man-hour budgets, schedules and material, ***including purchasing, are*** assigned to the production control department,
- assignment of the production effort to two departments each concerned with an inherently different type of work, i.e., hull construction and outfitting,
- subdivision of the production departments into shops specialized by problem areas, an aspect of group technology,
- subdivision of the design department into groups by problem areas, and significantly
- assignment of production engineers (also called field or process control engineers) to the production departments and throughout shops.

The necessary grouping of information is reflected in the design and work-instruction processes for hull construction depicted in Figure 2-2. What is represented may be called ***dual grouping*** which first addresses a hull by functional systems such as shell, decks, longitudinal and transverse bulkheads, frames, webs, etc. A transition is shown wherein the design information is reorganized by blocks (zones) regardless of the hull systems represented. The requirements for the reorganization are specified by a hull planning (HP) group which is made up of production engineers assigned to the hull construction department including the various hull construction shops.

Because of their input, dual grouping addresses both how to design and how to produce. The system-by-system formats for key plans facilitate functional design and owner and regulatory approvals. The zone-by-zone format for yard plans, specified by production engineers, facilitates their management of stage-plan preparation for erection, assembly, subassembly and parts fabrication.' Dual grouping addresses both how to design and how to produce.

Figure ***2-3*** shows the paths of process flows for hull construction and outfitting which progress independently at first and later merge. The merged flows, through erection, constitute IHOP. Each process lane is divided into stages and is specially equipped to produce interim products of a particular manufacturing family, i.e., of a particular problem area. Information grouped by zone, problem area and stage, i.e., a work instruction or stage plan, provides information necessary for processing a particular interim product through a specific stage of a specific flow lane.

The HP group also requires that information produced during transition design be grouped to match work ***yards (also*** work cells); i.e., regions of significance for administrative purposes. A work yard usually consists of a number of contiguous stages within a process flow. Typically yard plans are organized to correspond with process flows for flat blocks, curved blocks, fore and aft body blocks and engine-room blocks.

2.2 *Considerations for Early Hull Construction Planning and Scheduling*

A singular problem that shipbuilding managers are confronted with is how to get their production people involved in basic design. The most competitive shipbuilders have met this challenge by their employment of one or two production engineers in each shop and by formalizing a ***basic planning*** effort which is implemented simultaneously with basic

' Throughout this publication the word assemblv is used interchangeably with block assembly and subassembly is used interchangeably with sub-Ablock assembly.

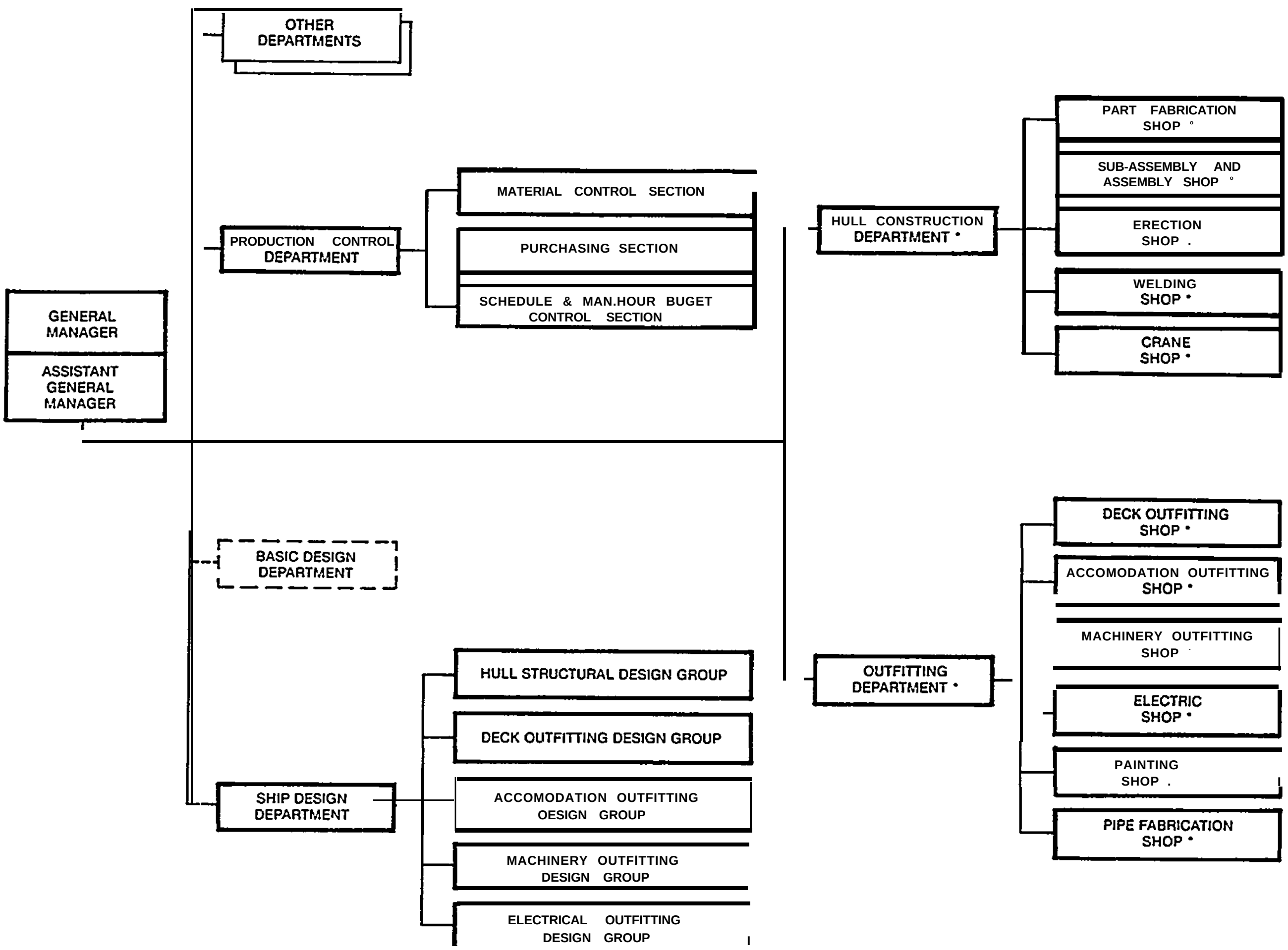


FIGURE 2-1: The organization shown facilitates integrated hull construction, outfitting and painting (IHOP). Control of basic design by the shipbuilding firm, regardless of where the basic design group is located, is vital. Another significant prerequisite is assignment of production engineers to the hull construction and outfitting departments and throughout shops. An ideL managerial career would feature the following assignments: field engineer, mold loft; field engineer, erection show engineer, any outfit design group, field engineer, machinery outfitting shop; field engineer, painting shop; shop manager or senior production engineer in the hull construction or outfitting department; manager of hull construction or outfitting department; manager of production control department; assistant general manager and general manager. The organization shown is that for the I HI Kure Shipyard which in 1982 delivered seven *different* ships varying in size from 29,900 to 294,700 and totaling 710,000-deadweight tons. When the workload was significantly greater, a separate department was in charge of painting and there were separate shops for subassembly and assembly. The basic design group is located in IHI's headquarters about 600 miles from Kure. Thus, the basic design group is somewhat like an independent design firm assisting the shipyard to develop contract plans. The same communication problems have to be overcome.

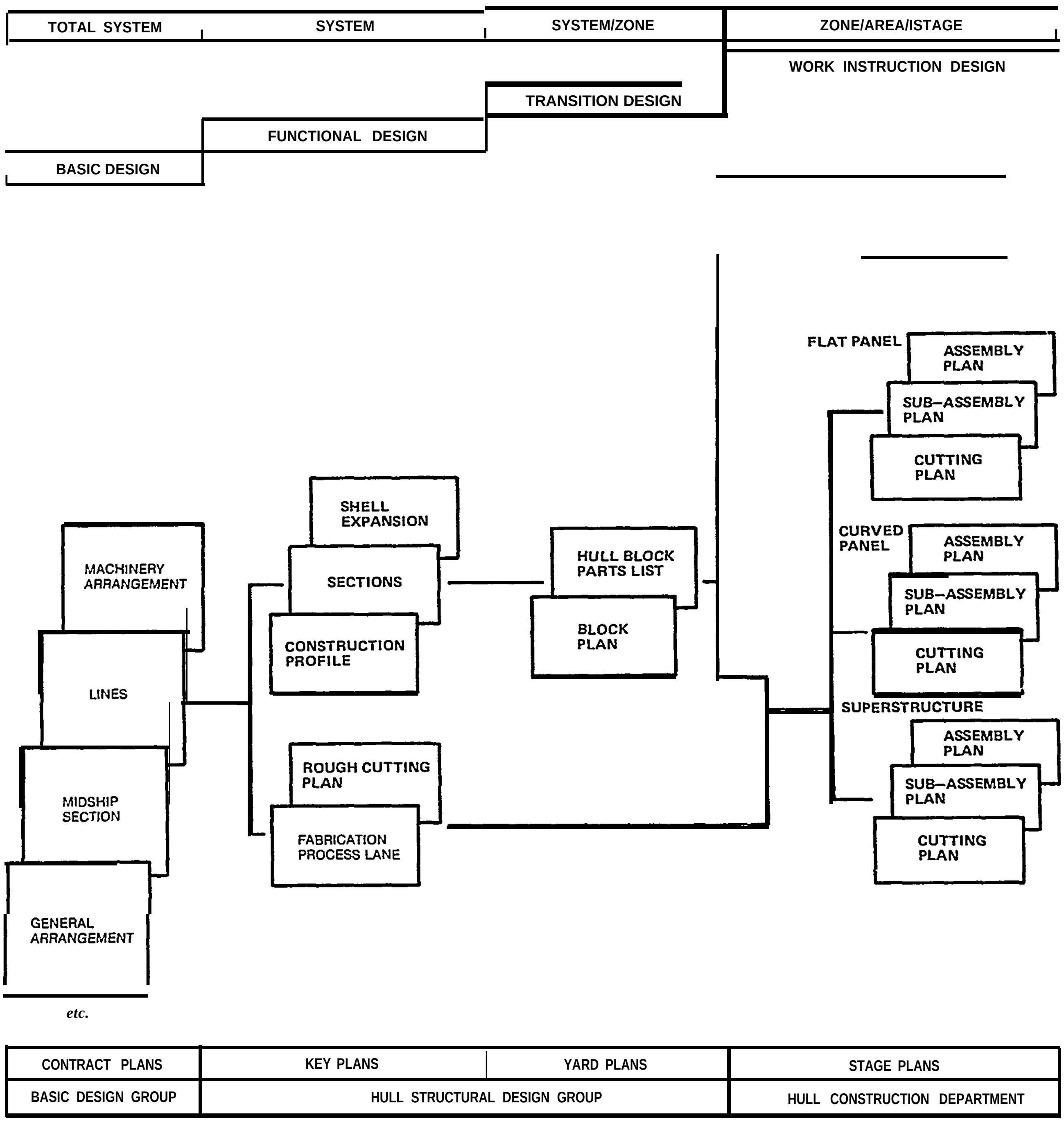


FIGURE 2-2: Production Oriented Design and Work Instruction Processes for Hull Construction. These processes should be regarded as the creation and organization of information. At first the information is organized by system to facilitate creation of a design and solicitation of owner and regulatory approvals. Then the information is reorganized by zone to reflect how the ship will be constructed.

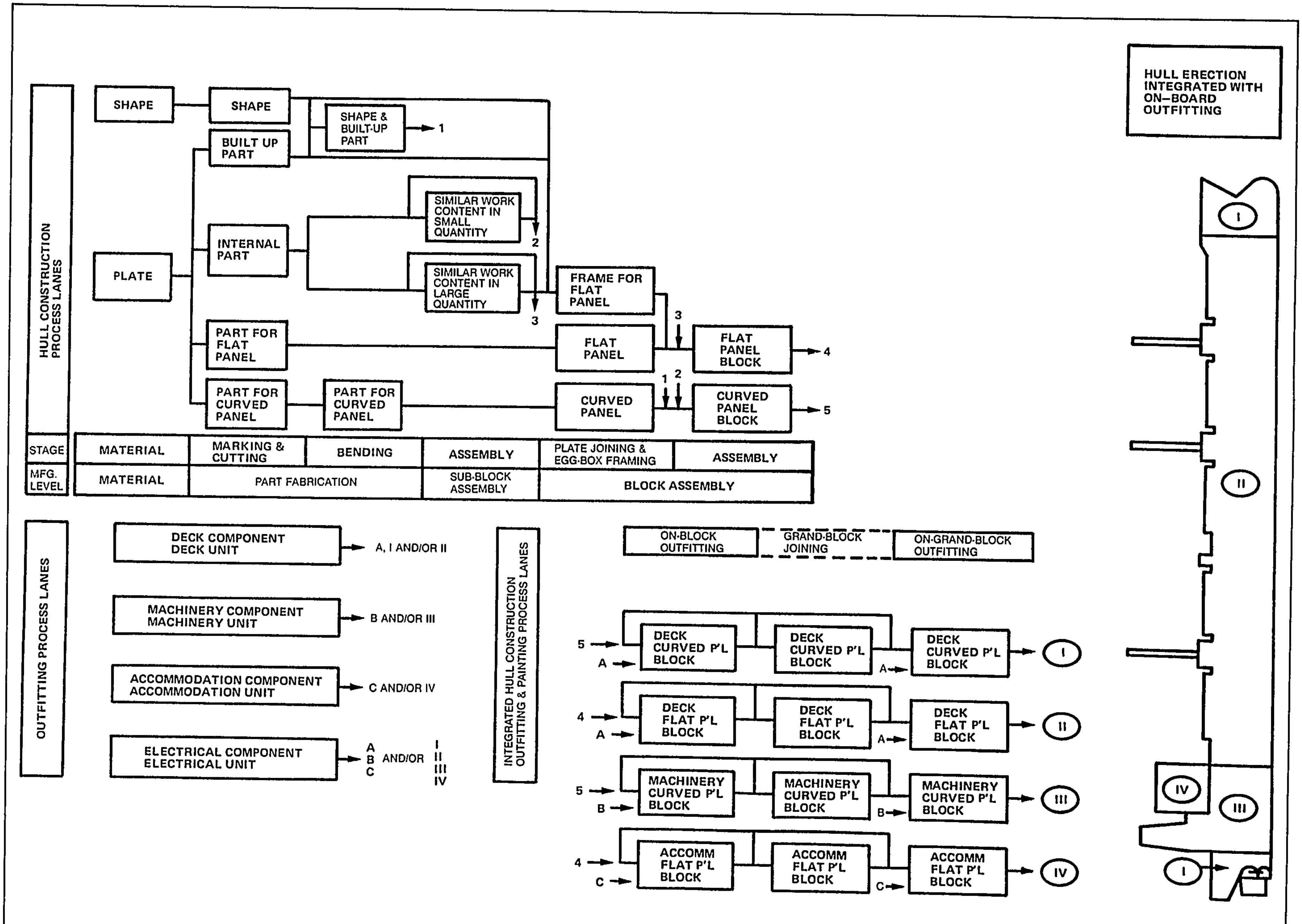


FIGURE 2-3: Simplified Integrated Process Flows. Painting would appear in additional sub-stages in various flow lanes (e.g., between block assembly and on-block outfitting). Sub-stages for outfitting the on-block before and after turnover are also omitted for simplicity.

design. The extent of each effort that is performed before contract award depends on

- uniqueness and complexity of a proposed ship, and
- a shipbuilder's prior experiences with an owner.

During basic planning production engineers pre-define blocks. Guidance employed includes a proposed general arrangement, midship section, machinery arrangement, etc. for a contemplated ship as well as limitations or other conditions which relate to the effectiveness of a particular shipyard. Such considerations include need to:

- define blocks of maximum size and weight permitted by the shipyard's assembly and erection facilities,
- minimize the number of blocks, if necessary by joining blocks which are sized to facilitate assembly into grand blocks in order to exploit a large capacity crane at an erection site,
- identify assembly and erection processes consistent with safety and the need for block accuracy and rigidity,
- minimize scaffolding, lifting, turnovers, etc.
- identify blocks which can be used as patterns for other blocks in-parallel midbody, and significantly need to
- identify preliminary zone, problem area and stage classifications for organizing work flows and, insofar as possible, equalizing the contents of work packages for block assembly, sub-block assembly and parts preparation.

Besides the foregoing, ***block pre-definition*** should consider how to:

- fit outfit components in cargo compartments,
- install machinery and fit other components in the engine room,
- arrange deck machinery, moorage fittings, etc., and
- perform more painting before hull erection.

Also, assessment of the efficiency of ***block-assembly processes*** in terms of durations, numbers of required resources, accuracy needed and quality of work circumstances, requires the following to be evaluated collectively:

- determinations of outfitting on-block or on-grand block,
- ease of outfitting and painting processes, and
- avoidance of damage to painted surfaces and to fittings when turning over or otherwise handling blocks.

As much as an erection master schedule must ultimately control sequenced durations for mold loft, fabrication, sub-assembly, assembly, and erection work, an integrated schedule must control all of the foregoing plus durations, appropriately interspaced, for outfitting and painting stages. The first manifestation of such integrated control is an ***IHOP pre-schedule.***

2.3 Interaction Between Designers and Production Engineers

Early and continued interaction between design and production people assigned responsibilities for hull construction, outfitting and painting is critical for successful integration of their different concerns. Meetings should be frequent for the purpose, as simply shown in Figure 2-4, of making known the requirements for efficient outfitting and painting in time for them to be incorporated in hull structural drawings.

Hull concerns which will be affected as a consequence of the increased consideration for in-process outfitting and painting include straking, block boundaries, holes to be cut in structure such as for passage of pipes, reinforcements for heavy outfit components, and the block erection sequence to insure that it is consistent with plans to land large machinery items.

The first integrated planning effort, see Figure 2-5, addresses block predefintion and for a first-of-a-kind or complex ship, could require consideration of the:

- general arrangement of main piping and valves in holds,
- main engine and auxiliary machinery arrangement,
- compartment and access arrangement,
- accommodation arrangement,
- general arrangement of deck piping and mooring machinery and fittings,
- basic plans for landing the main engine,
- painting schedule which outlines special requirements for certain areas and which addresses paint types and processes, and
- estimated weight for blocks and outfit components in order to insure that they could be lifted by cranes at the building site.

Much depends on all participants in block pre-definition having a good understanding of the entire shipbuilding system. Their pre-definition is the basis for quickly establishing the ***erection master schedule*** and the IHOP pre-schedule. The HP group necessarily assimilates outfitting and painting requirements and coordinates with the hull design schedule before producing the IHOP pre-schedule.

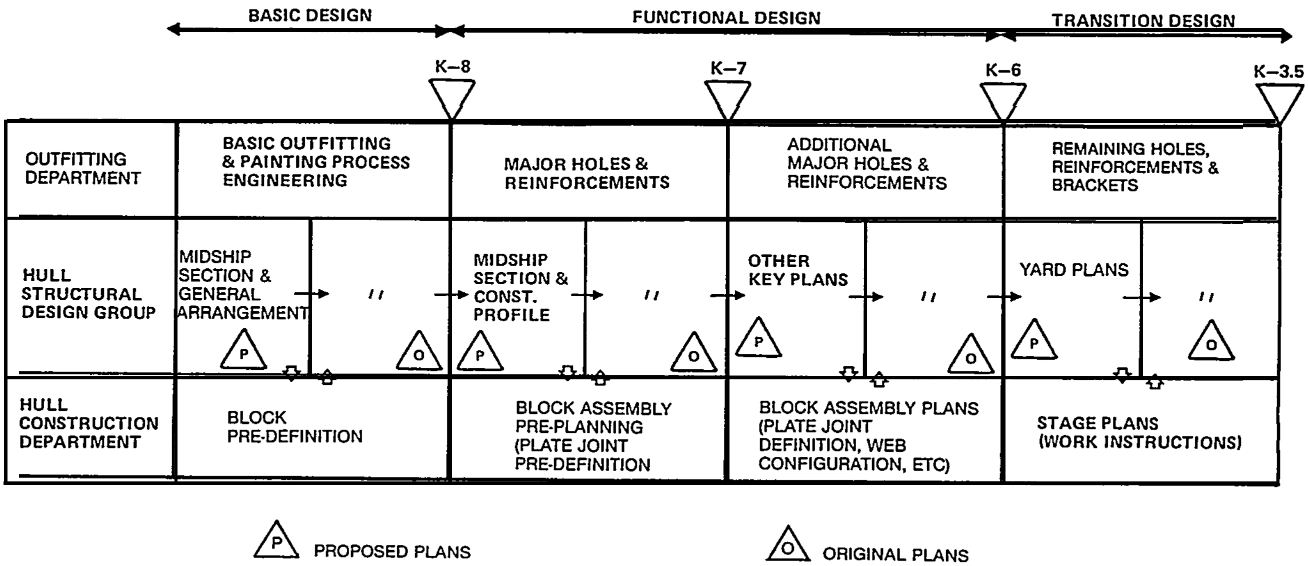


FIGURE 2-4: Integration of Design Data With IHOP Planning. During distinct phases, starting with basic design, the hull structural design group sub. mits proposed plans (including those for painting) to field engineers in the outfitting and hull construction departments. These reviewers then make known their requirements which must be included before issue of original hull structural plans. For the first-of-a-kind 100-to 150-thousand dead. weight-ton ship, other dates of interest are typically start fabrication K-2, Iaunching K +4 and delivery K+ 7.

The IHOP pre-schedule indicates dates for erection, assembly, fabrication, drawings, material requisitions, etc. It controls the derivation of all subsequent schedules. Thus, approval of the IHOP pre-schedule by department managers and the top manager is a matter of extreme importance.

After basic planning further joint discussions address ***block definition*** and ***block assembly pre-guidance.*** Items needed to support pertinent decisions are:

- job specifications for outfitting and painting for each side (frame and non-frame) of each category of hold blocks, i.e., bottom, side shell, longitudinal and transverse bulkheads, deck, etc.,
- job specifications for outfitting and painting for each side of fore, aft and engine-room blocks, and
- capacity limits of outfitting and painting facilities and equipment.

The end product is an ***assembly master schedule*** from which a ***shop pre-schedule is*** prepared which proposes control of the various shops in the hull construction department. The preparation of these schedules requires the HP group to consider productivity and accuracy during block-by-block studies. The block assembly pre-guidance process addresses every stage starting with joining plates (to form the pa upon which the block will be assembled) until the block ready for erection. The pre-guidance is sufficient for revi by field engineers for outfitting and painting. Af assimilation, adjustments and mutual agreement, t assembly processes per block are finalized in ***block assem guidance*** and in IHOP and ***shop schedules.*** They are t fundamental means for controlling on-block outfitting a painting.

Because of the integrated planning, hull constructi scheduling is inescapably dependent on:

- outfitting and minting schedules for each distincti region of the ship, e.g., deck, machinery and accom dation,'
- on-block outfitting and painting schedules for ea category of hold blocks, and
- on-block outfitting and painting schedules for ea fore, aft and engine-room block.

These schedules are incorporated in the ***IHOP schedu*** which indicates the sequence of stages and stage duratio for each block starting from the issue date for requir block-by-block yard plans until block erection dates.

[2] Deck refers to any region that is not machinery or accommodation. Thus, deck includes cargo holds and tanks.

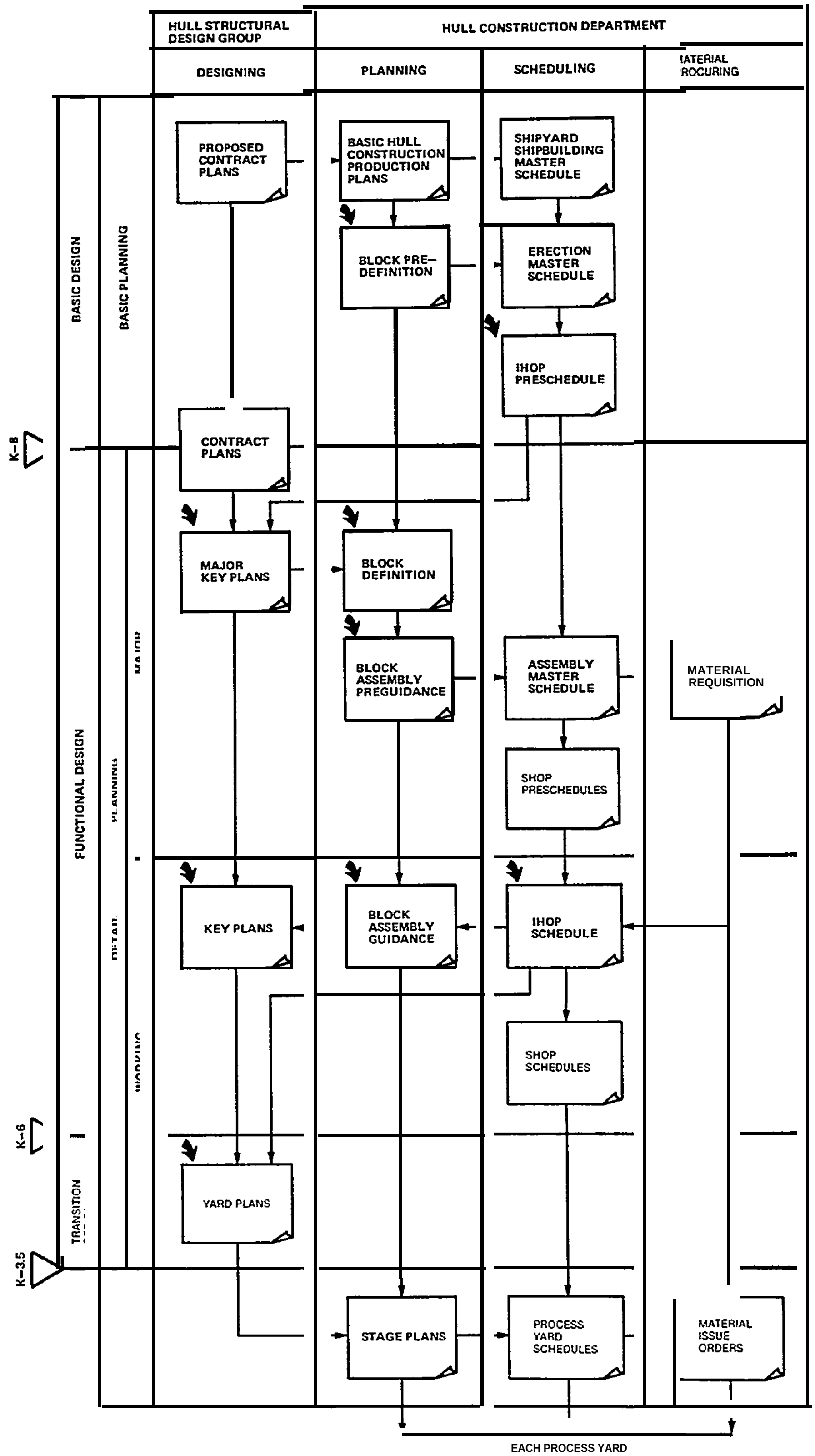


FIGURE 2-5: Coordinated Progress of Design with Planning and Scheduling by the Hull Construction Department. Design progresses in three distinct phases: basic, functional and transition. Planning and scheduling by the Hull Constrction Department proceed through four phases ***basic,*** detail (major), detail (working) and work instruction. The arrows indicate inputs by designers and field engineers concerned with outfitting and painting. Necessarily, certain schedules address all ships being built simultaneously, e.g., the shipyard shipbuilding master schedule, the assembly master schedule and the shop and process-yard schedules. The completion of basic design and planning before formalization of contract plans as shown, is ideal for first-of-a-kind or complex ships.

Clearly, Figure 2-5 shows that the HP group has to assume lead responsibilities. Outfitting and painting considerations are in a sense superimpositions on basic planning and scheduling for hull construction. However, creating the combination and controlling its continuous refinement until IHOP plans and schedules are sufficiently detailed for absolute control of flow lanes, requires members of the HP group to understand the overall shipbuilding system. Further, it requires a degree of production engineering sophistication not normally encountered in traditional hull construction departments. In the most effective shipyards, ***production engineers for hull construction are*** basically concerned with how to:

- divide a ship into blocks,
- assemble blocks, and how to
- ***devise an IHOP schedule.***

2.4 *Responsibilities of the Hull Structural Design Group*

The hull structural design group is sub-divided into a key-***plan subgroup*** and a ***yard-p[an subgroup.*** Each is sub-divided into two sections in order to better administer the:

. preparation of drawings, as distinguished from

“ performance of analytical tasks, e.g., strength calculations, vibration analyses, and data input for computer processing.

2.4.1 ***Key-plan subgroup*** responsibilities relate to functional design, e.g.:

- input of key plan data for computer processing such as for lines fairing (station offsets), structural lines (frame offsets) and shell expansion,
- hull structural development for existing and new type ships,
- strength and vibration analyses, and
- producing key plans, e.g., for:

  - structural scantling plans (stem, bow, cargo compartments, and engine-room construction),
  - stem frame,
  - rudder, rudder stock and carrier,
  - main engine and other foundations such as for boilers and generators, and
  - welding schemes.

2.4.2 ***Yard-plan subgroup*** responsibilities pertain to transition design and include:

- input of yard-plan data for computer processing such as for preparing a body plan (frame offsets), parts generation, etc.
- producing drawings such as for templates for castings and pin-jig settings,
- block plans (yard plans) including development of structural details,
- hull parts lists, and
- fabrication plans for foundations.

The block plan is a unique presentation of hull structural design. Some traditional shipbuilding firm still provide their hull construction departments with system-oriented structural drawings. In order to plan the assembly of a block, references have to be made to a number of different drawings. Ideally, a block plan is a compact booklet which applies to a group of adjacent blocks, of the same problem area, and which combines information contained on the various system drawings into one zone-oriented format.

Minimal work instructions are included in block plans as work instructions are more appropriately prepared under the direction of the HP group. A block plan is a working master plan or yard plan on which the transformation from system to zone has been made. A block plan is indispensable for creating effective IHOP stage plans.

2.5 *Production Planning, Mold Loft and Shops*

The functions assigned to a hull construction department include production planning as well as mold loft and shop work. The fabrication and assembly efforts are divided among shops as shown in Figure 2-1 so that responsibilities match the division of stage plans shown in Figure 2-2 and the division of process flows shown in Figure 2-3. In other words, the way the hull construction department is organized reflects a product-oriented work breakdown structure

In the above described manner, expertise in preparing cutting plans is matched to expertise in marking and cutting for parts fabrication, expertise in preparing subassembly plans is matched to the organization concerned with sub-block assembly and so on. Stage plans classified by zone/area/stage by virtue of such classifications describe what is to be processed and the information needed to perform work during a stage of a particular work flow. When man-hours required are related by some characteristic, such as weight or welding length, workload forecasts by flow lane, stage or any combination of stages can be readily determined. Shops are Supported by other divisions of the hull construction department, specifically, the HP group, mold loft, stage-plan group, welding shop and crane shop.

2.5.1 ***Hull Planning Group*** responsibilities are:

- all of the planning and scheduling, including incorporation of outfitting and painting concerns, as designated for the hull construction department in Figure 2-5;
- preliminary control data

  weight by structural system, i.e., by flat shell plate, curved shell plate, internal structure separately for that cut by manual, numerical control (N/C) or other methods and built-up longitudinals and rolled shapes,
  block weight and welding length,
  sub-block weight and welding length,
  erection welding by parametric length, i.e., taking into account weld size, type and position, and
  scaffolding planks per hull region, i.e., by hold, engine room, fore, aft and outside shell;

- fabrication data
  - process lanes,
  - rough cutting plan, and
  - scrap ratio;
- preparation of other required plans
  - sub-block and block assembly process plans,
  - erection welding plan for both manual welding and automatic welding,
  - scaffolding master plan, and
  - lifting master plan;
- feedback to design department
  - shrinkage allowance per block,
  - designation of margins per block,
  - plate edge preparation, and
  - block erection sequence;
- hull accuracy control (A/C) plan; and
- operation of the welding laboratory.

2.5.2 ***Mold loft*** responsibilities include:

- cutting-plan data, e.g., N/C tape, film for electro-photographic marking, parts-size drawings, such as a size list for flat bar,
- bending data, e.g., templates for bending, twisting, etc.,
- pin-jig settings, and
- feedback to hull structural design group concerning excess allowances, edge preparations, etc.

2.5.3 ***Stage-plan section*** responsibilities address the preparation of work instructions (stage plans) which include:

- marking data for assembly, e.g., steel measuring tapes for layout of block assembly marks, finish-cut dimensions per block, etc.;
- sub-block assembly process data
  - sub-block assembly plan, and
  - sub-block assembly fitting plan for lifting pads, guide pieces, scaffolding supports, etc.;
- block assembly process data
  - block assembly plan,
  - block lifting instruction plan,
  - fitting plan for lifting pads, guide pieces, scaffolding supports, etc., and
  - pin-jig settings for curved-block assembly:
- erection process data
  - shipwright dimensions plan, i.e., block alignment instructions,
  - scaffolding arrangement plan,
  - hull block arrangement handbook, and
  - block-support arrangement plan;
- work control-data
  - sub-block assembly weight,
  - block assembly weight,
  - sub-block assembly welding length,
  - block assembly welding length, and
  - erection welding parametric Iength, and
- material procurement
  - definition and listing,
  - requisitioning,
  - remnant control, and,
  - scrap control.

2.5.4 ***Welding shop*** responsibilities address:

- welding for erection processes only.

3.0 HULL CONSTRUCTION PLANNING

Other than the need to accommodate outfitting and painting there are a number of factors which influence planning of hull construction methods. Obviously they include timely completion of key and yard plans, i.e., timely transition from system to zone (interim product) orientation. The speed with which these processes are executed depends, among other things, on:

- the degree that the HP group is organized to communicate "how to build" to the design people responsible for describing "what to build" in key and yard plans;
- how far the key-plan subgroup extends preparation of key plans beyond owner and classification society approval requirements such as with more detailed sections and profiles;
- how well designers are organized and disciplined to minimize the effect of design changes through standardization of design methods and schedule adherence;
- the effectiveness of the file of standard material items (including vendor catalog items declared as shipyard standards for which design data is already available);
- the degree of standardization of hull construction planning items
  - procedures,
  - scheduling,
  - feedback, and
  - basic data;
- the degree of standardization of work processes
  - process lanes,
  - jigs, and
  - data collection and classification;
- adequateness of stage plans, e.g., if all work instructions were described in yard plans assembling a small sub-block would require a complex drawing beyond the comprehension of all but a few skilled people;
- the effectiveness of accuracy control measures;
- organization of hull construction schedules; and
- organization of process lanes.

The latter three justify further discussion.

3.1 *Accuracy Control'*

The term ***accuracy control (A/C) is*** misleading. What is meant is statistical control of manufacturing which could, theoretically, employ any parameter that varies when the ***way work & performed varies.*** The foremost objective of A/C is ***constant productivity improvement. Analyses*** of A/C feedback guides adjustments in design details, tolerances and work methods to harmonize the various process flows. When a flow is ***in statistical control,*** interim products are being produced just accurate enough for subsequent assembly without disruptive rework. Thus, WC is a production control mechanism for sustaining uniform work flows at minimal man-hour costs.

The degrees of accuracy normally required to harmonize work flows in shipbuilding are almost always well within tolerances specified by owners and ship classification societies. Therefore, enhanced accuracy beyond an owner's expectations is a ***by-product*** of statistical methods for control of production.

In order to implement an A/C program, the following systems are required:

- ***dimensional control***
  - means to minimize dimensional variations in interim products,
  - classification of variation limits by each type of hull block, and
  - determination of work processes required by such classifications;
- ***intercommunications***
  - providing feedback, pertaining to problems encountered in fabrication and assembly work and as they occur, to the field engineers having A/C responsibilities for resolution and analysis, and
  - providing immediate solutions to shops of problems encountered and feedback to the yard-plan subgroup pertaining to problem avoidance in the future.

' In its 1967 issue of "Technical Progress in Shipbuilding and Marine Engineering", the Japanese Society of Naval Architects reported that statistical accuracy control "epoch makingly" improved quality, laid the foundation of modem ship construction methods and made it possible to extensively deveIop automated and specialized welding. Accuracy control applied for hull construction is further described in the National Shipbuilding Research Program publication "Process Analysis Via Accuracy Control - February 1982".

3.2 Hull Construction Schedules

As described in Part 2.3 the IHOP preschedule is an erection master schedule upon which outfitting and painting controls are interposed. It is the master which strictly governs its own subsequent refinement and development of detail schedules for outfitting and painting as well as hull construction. Because of this interlinking, changes in the master schedule can have a considerably adverse effect on detail schedules. Thus, creation of schedules requires best efforts and particular attention to the following:

- ***organizing integrated work processes, e.g.***
  - each proposed ***hull construction*** work package classified by ship/zone/area/stage should be carefully checked for duration and its status in a sequence of such work by people responsible for design, outfitting and painting, and
  - the ***structure*** of work packages should be consistent for hull construction, outfitting and painting;
- ***forecasting workloads by stages, e.g.***
  - the volumes of block assembly work classified by area/stage should be determined and leveled, and
  - for each work package classified by area/stage, checks should be made to confirm sufficiently available facilities and space and to determine the effect of previously scheduled work.

In addition, a schedule tracking system is necessary ***to*** create feedback needed to keep work flows harmonized and to guide future production engineering developments.

3.3 Process Lanes

Effective process lanes cannot be organized independently of how a contemplated hull is going to be subdivided for designation of blocks, sub-blocks and parts. ***Sysyem*** and ***zone are*** characterizations of a ship design. ***Area*** and ***stage are*** categories of the work process. As much as possible, zones are contrived so that they require the right kinds and amounts of work to match preferred problem-area classifications.

The basic organization of work in accordance with a necessary product work breakdown is shown in Figure 3-1. Therein, typical manufacturing levels and their relationships to each other are shown. Each manufacturing level is further subdivided by manufacturing family (problem area), e.g., block assembly into ***flat-panel block assembly*** and ***curved-panel block assembly as*** shown in Figure 2-3. This approach, in essence, is the hull block construction method (HBCM) which is fundamental for productive shipbuilding.

The following characterizes effective IHOP process flows:

- the complete portion of a process flow within a manufacturing level is dedicated to manufacturing one family of interim products and is subdivided into stages each of which is specialized for the performance of one or more tasks (e.g., stages in a process flow for assembling a large quantity of same-size sub-blocks are: laying out, fitting, welding and distortion removal),
- the stages, including outfitting and painting stages, are arranged in accordance with a sequence per process flow and to feed interim products where they are needed next in another process flow (e.g., egg-box framing for a flat-panel block is completed near the site where flat-panel blocks are assembled),
- work yards (also work cells or regions of significance) for administrative purposes consist of a number of contiguous stages that may be aligned within one process flow or across process flows (an example of the former is a conveyor equipped production line for assembly of same-size sub-blocks; an example of the latter is a cell which includes marking and cutting for parts for more than one family, typically, parts for curved and flat panels and internal and built-up parts),
- yard perimeters sometimes change dependent upon rates of work flows and supervisors' control spans,
- shop supervisors are organized so as to match the organization of work yards, see Figure 3-2,
- yard plans are organized per work yard, and
- a systemized ***hull parts*** code employing symbolic logic is used to identify interim products by family and their required flow paths through various manufacturing levels.

An ideal sequence for flat-panel block assembly featuring ***real*** work flow is illustrated in Figure 3.3. That for curved-panel block assembly featuring ***virtual*** work flow is shown in Figure 3-4.

3.4 ***Communications***

Good communications are necessary between the hull structural design group and the hull construction department. Just as much, good communications are required between each of them and their counterparts for outfitting. Communication and feedback channels are shown in Figure 3-5 and typically concern the following matters:

- ***Coordination of Design Schedules***

  The hull structural design system features specific meetings and other communication exchanges to facilitate input from the various outfit design groups. The determination and scheduling of these events are based upon mutual agreement as they become milestones upon which all parties depend. ***Standard*** milestones which may be used for ship after ship are preferred.

- ***Coordination of Block Definition with Outfitting and Painting Requirements***

  For outfitting and painting that cannot be done on-unit, discussion centers on modifications to block boundaries that facilitate outfitting and painting on-block and on-board. These considerations favor on-block work in order to minimize on-board work and are further described in Parts 2.2 and 2.3.

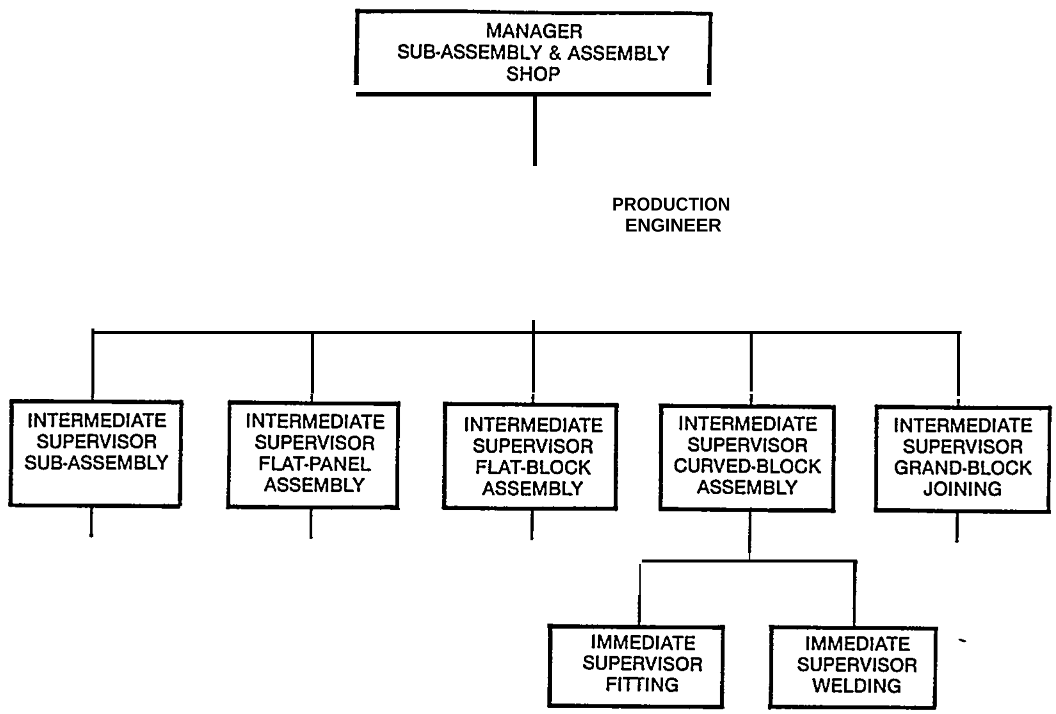


FIGURE 3-2: Typical Zone/Area/Stage Shop Organization.

- System for Organization of Integrated Information

The comprehensive planning and scheduling needed for effective hull construction, as shown in Figure 2-5, creates an excellent framework on which to impose similar needs for effective on-block and on-board outfitting. Thus, it is natural for the HP group to have the lead responsibility for integrating information. Such efforts are also most effective when performed systematically in accordance with ***standard*** events. In addition such efforts are facilitated by:

- coordination of timing for all phases of design development between the hull structural and various outfitting design groups, and
- standardization of outfitting impositions on structure, such as, holes, reinforcements, etc.

- Planning and Engineering the Block Assembly Process

The block assembly processes are explained to outfitting production engineers to facilitate their advance planning for effective on-block and on-board outfitting and their engineering of required outfitting processes. Their results are fed back to the HP group. This need to understand each other's responsibilities makes it important that the following be the subjects of written descriptions:

- block assembly process, and
- process lanes for block assembly.

- Planning and Engineering for Block Assembly in Process Lanes

Separate process lanes are needed for each block categorv. The most obvious such classification is ***flat-*** panel block for which real work flow is effective. Another is curved-panel block for which all required stages for each such block are scheduled for one pin-jig site. Other process flows separately address ***fore, aft,*** and engine-room inner-bottom blocks because their assembly imposes different problems. As mentioned in Part 3.3, contiguous stages of the process lanes are grouped into cells for administrative purposes. Figures 3-3 and 34 show that space for on-block outfitting and painting stages is best provided adjacent to the site for the last stage of block assembly. However, flat-panel blocks for an inner bottom often justify an on-block outfitting stage interposed between block assembly stages (e.g., following completion of a tank-top panel the stages are: fitting egg-box framing to tank top, welding, ***on-block outfitting of inner bottom pipe, fit***ting bottom panel, turnover and welding egg-box framing to bottom panel). Regardless of their locations, on-block outfitting and painting stages are controlled respectively by outfitting and painting supervisors.

- *Integrating Block-assembly and Erection Scheduls with Outfitting and Painting Scheduler*

  Outfitting and painting procedures must be written before preparation of block-assembly and erection schedules in order to facilitate their integration. Further, an IHOP-schedule tracking system is needed so that hull-construction, outfitting and painting field engineers can monitor progress of work packages.

- *Required Dimensional Accuracy of Blocks to Facilitate* ***Outfitting***

  Inaccurate blocks require more work and greater access to butts and seams during the erection stage. Special access is needed for scribing and trimming margins and installation of numerous fitting devices. Further, a block panel that is not flat enough requires margins in auxihuy-machinery foundations and in supports for outfit units to be landed. The required marking and trimming during outfitting on-block is rework. Blocks whic are inaccurate also causes the installation of some pipe pieces which could have been fitted on block to be deferred for less efficient fitting on-board.

  Thus, the number of fittings and the efficiency for outfitting on-block are both affected by the dimensional accuracy achieved by the hull construction processes. An accuracy control (WC) system is necessary to provide:

  - fabrication and assembly methods which yield accurate enough blocks,
  - assignment of A/C responsibilities to supplement normal design, mold loft, fabrication and assembly responsibilities,
  · control methods for operation of the A/C system,
  - accuracy performance planning and engineering, e.g., determination of required tolerance limits for each stage by statistical analysis of variations occuring during normal work, locations of vital points to facilitate accuracy in assembly work, etc., and
  - communication of accuracy achievements to guide subsequent work in a process flow and design and field engineers having A/C responsibilities for planning future shipbuilding projects.

3.5 Production Planning Standards and Modules

The goals of standardized and modularized planning for hull construction are to:

- increase the speed, accuracy and consistency of production data communications,
- improve productivity of production planning,
- achieve greater uniformity and reliability of interim products, and
- contrive interim products which better match production facilities and work processes.

In order to achieve these goals, good cooperation between design and field engineers is required.

Standards and modules of production planning may be grouped into two categories:

- long-term or controlled are those which effect a firm's shipbuilding system and which are common for building all ships regardless of design differences, and
- ***short term, i.e., those*** not controlled which may be adopted and changed at the discretion of the hull construction department to suit particular ships to be built.

Safety at work sites is addressed in both categories.

The following are examples of production planning standards that are effective for shipbuilding:

- ***designer's guidelines for production processes***
  - block divisions,
  - capacities of production processes, and
  - fabrication and assembly processes;
- ***design standards***
  - structural design by zone by ship type,
  - structural calculations,
  - structural reinforcement,
  - vibration-prevention design,
  - design details such as for part ends, scarfs, slots, etc., and
  - configurations of bilge keel, round gunnel, etc.;
- ***code for manual and computer-aided preparation of design details and work instructions***
  - slots, and
  - scallops, drain holes, air holes, manholes, lightening holes, etc.;
- ***symbolic parts code for workers to readily determine required fabrication and assembly work stage routing***
  - parts identification, and
  - designation of required interim-product manufacturing levels;
- ***work instruction symbol standard for designers prepared by process engineers in the hull construction department***
  - block names,
  - edge preparations,
  - amounts of excess, and
  - welding processes, etc.;
- ***work instruction symbol standard for shops prepared by process engineens in the hull construction department***
  - stage plans,
  - welding control parameters, and
  - mold-loft data;
- ***fabrication and assembly process standards***
  - edge preparation for each welding process,
  - conduct of each welding process,
  - conduct of each fabrication and assembly process, and
  - correction of fabrication and assembly errors.

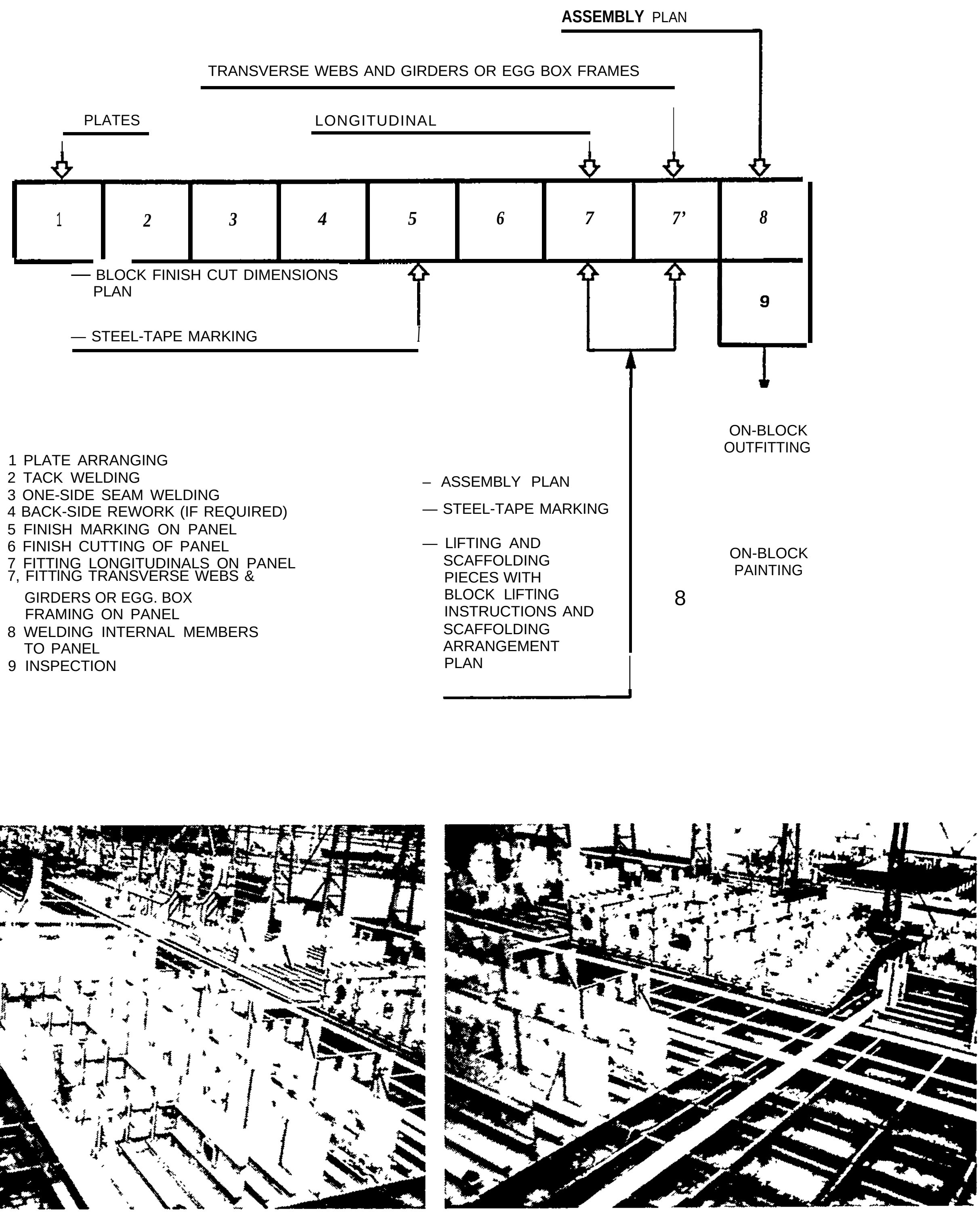


FIGURE 3-3: Typical Process Flow for Flat-block Assembly. The arrows indicate inputs for parts, sub-blocks, and stage plans. For inner-bottom blocks, stages would be added after position 8 for: outfitting, fitting bottom shell, turnover and welding bottom shell. As shown in the photographs, flat-block assembly is productively implemented with real work flow, i.e., with blocks being shifted from stage to stage.

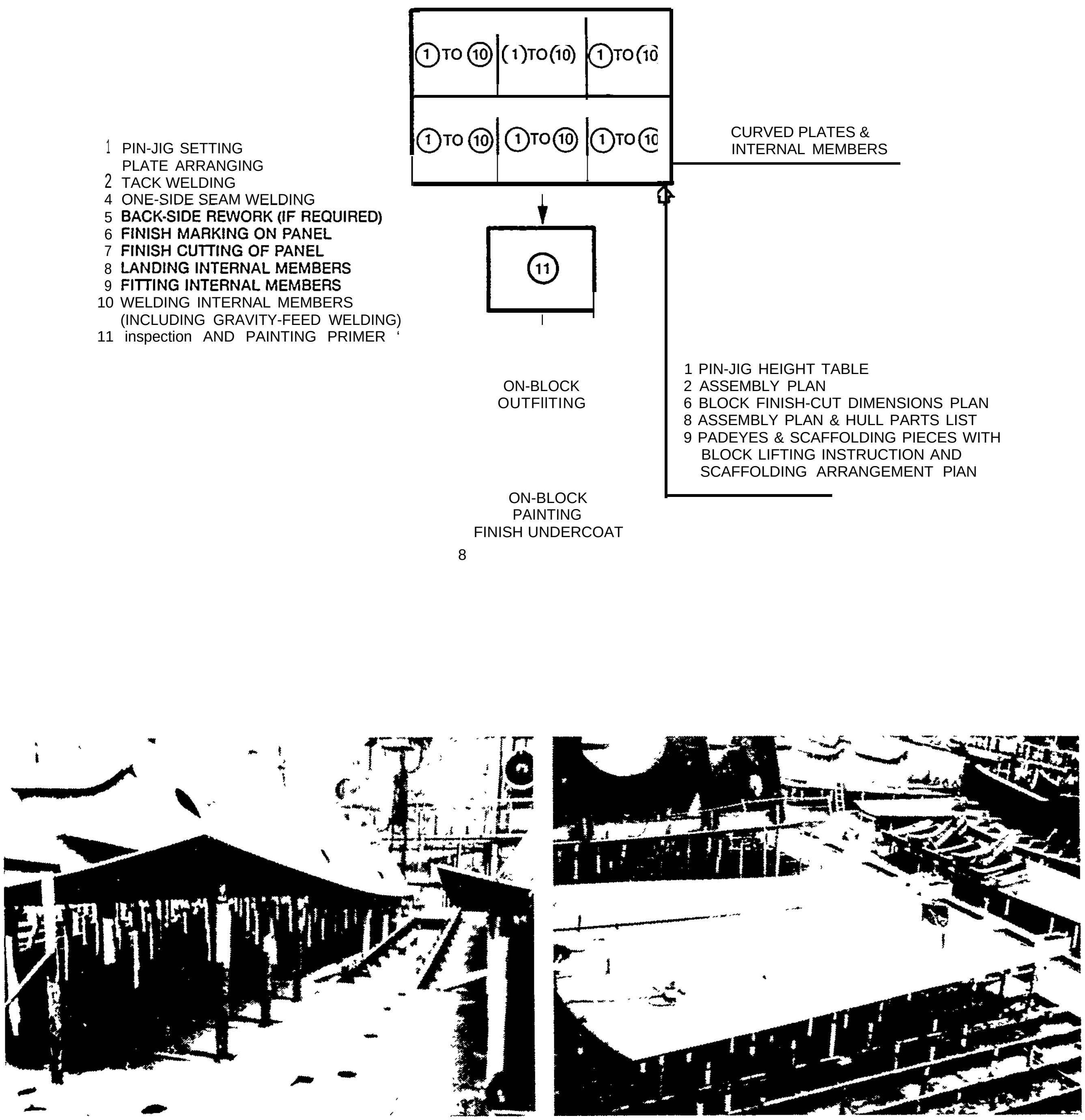


FIGURE 3-4: Typical Process Flow for Curved-block Assembly. The arrows indicate inputs of parts, sub-blocks and stage plans. All work stages for assembling each bIock are implemented in succession on the same pin-jig site. The specialized work teams shift from site to site. This technique is called virlual work flow because the impact on the workers is the same as if developing blocks were on a conveyor and moving past fixed work stations.

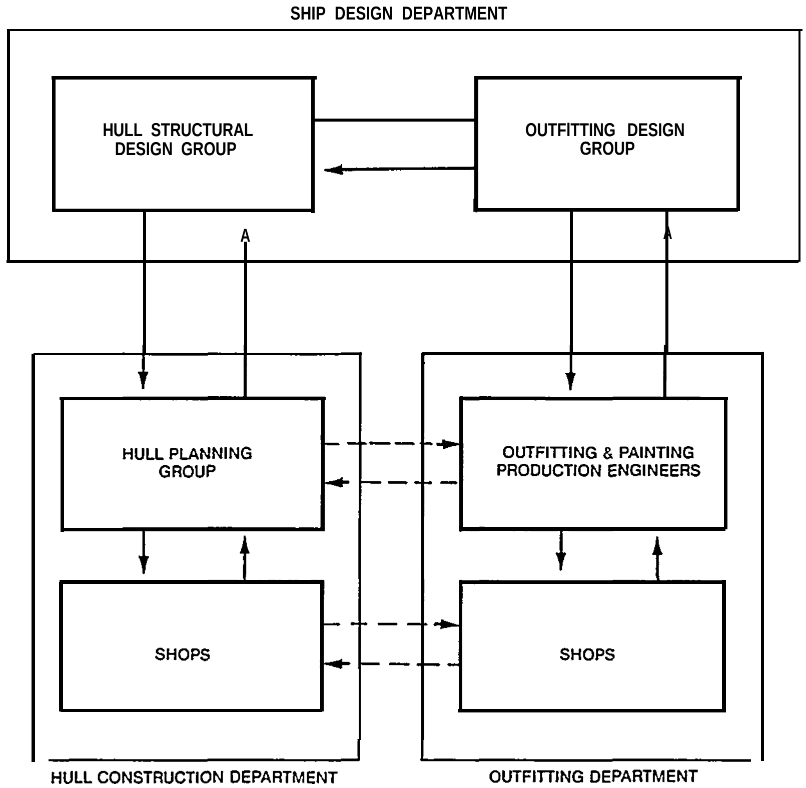


FIGURE 3-5: Communication Paths Between Design and Production Engineers for Hull Construction and Painting. The solid and broken lines respectively indicate primary communication paths before and after production starts.

The following are examples of ***controlled*** standards for planning and engineering hull construction:

. ***production planning standarDS***

- shell plate widths and thicknesses to minimize the number of seams,
- type of shape for longitudinals e.g., built-up tees or unequal-leg angles, and
- open- or tight-fit type cutouts for passage of longitudina.ls;

• ***accuracy performance standards***

- welding and distortion-removal shrinkage factors for fabrication and assembly processes,
- locations of finish cuts and margins for erection seams and butts,
- criteria for cutting and assembly workmanship, and
- standard ranges and tolerance limits;

• ***process standards***

- work procedures for each work station, and
- check lists for each work statiom,

• ***safety standards***

- safety regulations for each work station, and safety check list for each work station.

3.6 Code System for Hull Construction

Codes for identifying interim products should be hier archically organized so as to correspond with the ascendin manufacturing levels shown in Figure 3-1. The codes, neede to identify any part, sub-block or block for any ship bein built at the same time, should be in accordance with th same system and convey useful common guidance to peopl in various departments. For example, the alphanumeri identifier SU9-5-B8 is made up of three codes:

• ***SU9 is*** the block code,
. 5 is the sub-block code, and
. B8 is the part code.

Part B8 is needed to manufacture sub-block 5 and sub block 5 is needed to assemble the block SU9.

The letter ***Bin*** the part code designates a bracket. Othe letters are assigned to identify flat bar, web, face plate, etc The number in the part code, B8, simply identifies a specifi bracket type.

The sub-block code consists only of a serial number. Th two letters of the block code identify a particular type block In the example given, ***SU*** designates ***side shell upper.*** Th number which follows, sometimes two digits, identifies th position of the block relative to other ***SU*** blocks on a shi profile.

An interim-product code as described in the foregoing i essential for effective communications between productio engineers and designers.

4.0 BASIC PLANNING AND SCHEDULING

In that period when negotiations are being conducted with a prospective customer, review of the developing basic design by production engineers of the hull construction department is extremely effective. Feedback from production engineers that is incorporated in contract plans before contract award, avoids disruptive changes and associated negotiation and schedule adjustment problems after contract award.

During the period when the basic design for a ship is being investigated, the developing midship section and general arrangement should be critiqued by the HP group. Such review, always with regard for the need to facilitate outfitting and painting, addresses:

- ***hull structure producible with minimum man-hour cost***
  - longitudinal frame spacing and shell plate thickness,
  - transverse-frame spacing and shell plate thickness,
  - range of high-tensile steel plates, and
  - type of longitudinals (built-up tee, angle, etc.);
- ***minimal scrap ratio***

  summary of variety of plate thicknesses;
- ***block definition;***
- ***plate straking;*** and
- ***block assembly processes.***

This timely interchange of ideas is mutually beneficial as the alternative is to risk more changes which are disruptive in drawing offices as well as in shops. As a consequence of such input to the basic design group, a building strategy featuring productive ideas that permit IHOP becomes part of the initial contract.

4.1 Basic Planning

For a first-of-a-kind or complex 80,000 to 150,000 deadweight-ton merchant ship, typically, basic design terminates on contract award which occurs eight months before keel laying (K-8). Before contract award, the HP group has been performing ***basic planning*** by providing feedback to basic designers and by preparing a building strategy which is to be reflected in block pre-definition and the IHOP pre-schedule. These efforts enable rapid start-up on contract award.

At the same time, K-8, a ***B-meeting*** (go-ahead meeting) is held which marks the end of ***basic design*** by formalizing the release of contract drawings to the HP group. Specifics that are finalized at the meeting include:

- steel material procurement plans, and
- the issue schedule for key and yard plans.

Thereafter, the basic planning guides production tactics, the flow of information from design, the schedule for design development for IHOP and the preparation of work instructions. During these activities, the HP group assumes dynamic leadership.

4.2 Basic Hull Construction Production Plans and Schedules

A preparatory ***B'-meeting*** at least one month earlier (K-9 or more) provides basic-design inputs and time for the HP group to prepare basic hull construction plans and schedules, e.g.:

4.2.1 Hull Erection Layout Plan

This bar-chart is prepared in accordance with the shipbuilding master schedule which provides dates for start fabrication, keel laying, shifting, launching and delivery for each ship under construction. The chart enables the HP group to:

- check for adequate shipyard space, such as, for storage of completed blocks, for the joining stage to create grand blocks, etc.,
- fix the positions of temporary cranes for on-unit, on-block and on-board outfitting, and
- anticipate such other problems caused by building ships simultaneously.

4.2.2 *Block Pre-definition Plan*

Block pre-definition is performed by production engineers using a midship section, general arrangement and sometimes a machkery arrangement. The objective is to achieve high productivity for IHOP. Among things to be considered are:

- special hull structure and other features,
- special owner requirements, and
- master plans for outfitting and painting processes, e.g., for holds, engine rooms, etc.

The two parts of the block pre-definition plan are:

. midship section block pre-definition plan, and

. general arrangement block pre-definition plan.

4.2.3 *Hull Construction Processes Plan*

The production engineer having responsibility employs the block pre-definition plan to develop a ***hull construction processes plan.*** It includes the following which must be developed to the satisfaction of hull construction department officials, i.e., the department, shop and section managers and the senior production engineer:

- block definition on a midship section,
- size, weight and quantity of blocks per each category (bottom, side, longitudinal bulkhead, upper deck, etc.),
- joining blocks to create grand blocks,
- erection sequence including sequences by block categories,
- specific application of nesting, marking and cutting methods and a scrap ratio target,
- block assembly processes and different aspects of the processes for each category of blocks represented in a midship section which shows main and internal structure,
- specific application of scaffolding methods and special work units for erection, and
- specific application of automatic welding processes for erection.

4.2.4 *Hull Erection Master Schedule*

This network is the responsibility of a production engineer assigned to the erection shop who must coordinate with counterparts in the outfitting shops who prepare on-board outfitting schedules. The block pre-definition plan is the principal guidance employed. Particular attention is given to large machinery items such as diesel generators which are separately landed before additional blocks enclose the machinery space. This process, called ***blue sky*** outfitting, requires each such outfit item to be scheduled for erection just as if it was a block.

4.2.5 *Budget Control Work Volume*

Using the midship section and the block pre-definition plan, a hull construction production engineer allocates man-hours by using parameters based on normal past performances that relate man-hours to factors such as:

- hull weight by mild and high-tensile steel, block wei and sub-block weight,
- welding length for sub-block assembly and separat for block assembly,
- parametric welding length for erection, i.e., by ea weld size and position,
- quantities of blocks per hull region, i.e., hold and f engine room combined with aft, and
- quantities of scaffold planks per hull region, i.e., hc and the combination for aft, fore and engine room.

4.2.6 *Shipbuilding Activity Timing Schedule*

Employing the block pre-definition plan, the erecti master schedule and the basic outfitting and painting pla and outfitting master schedule prepared by counterparts the outfitting department, a hull department producti engineer produces an IHOP pre-schedule in bar-chart for It shows the timing required for each process including o fitting and painting processes from yard-plan issue to tion for each block. Further, the shipbuilding activity timi schedule is sectionalized so as to separately address each h region. Dates are incorporated for:

- erection,
- start and completion for block assembly,
- issue of hull construction and outfitting drawin
- requisitioning of steel material,
- issue of drawings required for material requisitio and
- erection of major outfit components. i.e., landing lan items on board during ***blue sky*** outfitt

The IHOP pre-schedule is a master from which all subse quent schedule-s are derived. It is a control mechanism f rapid start-up and continuing coordination of the IHC building strategy for which there is general agreement. Th schedule is approved by the general manager only aft assuring that department and shop managers are in agre ment.

4.3 *Conduct of Block Pre-definition*

As indicated by the following, block pre-definition r quires many things to be considered which may be groupe by ***midship section*** and ***general arrangement.***

4.3.1 *Midship Section*

- proposed block divisions are marked considering
  - locations of high-tensile steel parts,
  - ease and safety of required erection work,
  - minimizing alignment problems for shipwrights whe erecting blocks,

- limitations for employing work units during the erection process (see Figure 4-l),
- ease and safety of block-assembly work,
- accuracy required during block assembly, and
- size and weight limitations of assembly facilities;

- straking with standard-width plates;
- block lengths are determined as a function of frame spacing (f) and whole number of frames (n) in accordance with
  - maximum length (f x n) < limiting length imposed by block assembly facilities, or considering a cargo compartment
  - maximum length (length of cargo compartment/n)< limiting length imposed by block assembly facilities (whichever method yields the most similarity in blocks is the one employed);
- block weights are calculated including fittings which are to be fitted on-block, scaffolding and lifting gear;
- required parts to be fabricated are checked to insure that
  - plate weights and dimensions are not excessive, and
  - curvatures specified are within the capabilities of bending facilities;
- the adequacies of sub-block assembly facilities are checked regarding
  - sub-block weights and heights,
  - need to attach ***sub-block parts, i.e.,*** minor assemblies such as brackets, and
  - deck, bulkhead and shell plate thicknesses do not change within sub-blocks and blocks;
- limits of block assembly facilities are checked regarding overhead clearances, weights of egg-box framing, etc.; and
- after the foregoing checks are made. feedback is ~rovialed to the hull structural design group usually concerning
  - facility limitations,
  - types of longitudinals and types of cutouts required for passage of Iongitudinals,
  - need for an improved scrap ratio by addressing thicknesses for transverse webs, face and web plates of built-up longitudinal, etc.,
  - sub-block joints that are difficult to align, and
  - details regarding flat bar, brackets, etc.

4.3.2 General Arrangement

Block definition is separate for the parallel midbody and for the bodies fore and aft. Blocks are defined to be as large as facilities permit, always to facilitate outfitting and painting, and with specific attention given to:

- ***parallel midbody***

  sheer start points,
  - limits of parallel midbody per tangency points to curved shell,

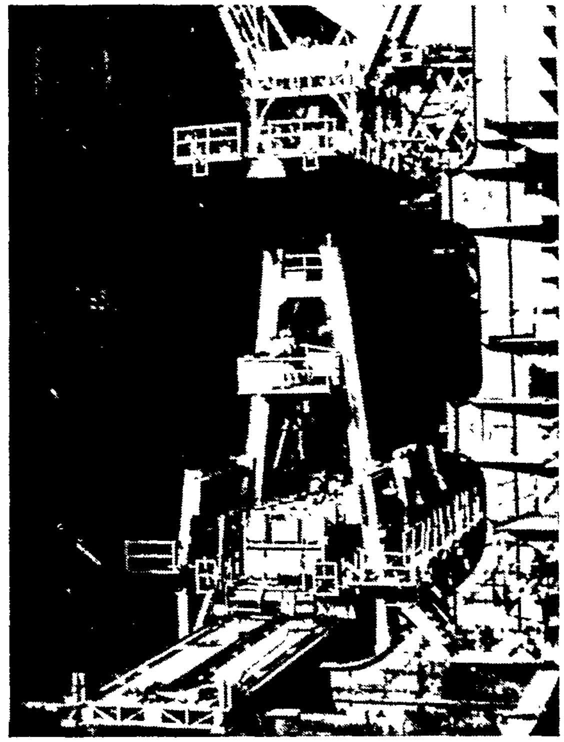


FIGURE 4-1: Typical Work Unit. The tower-type work unit shown is designed for erecting panels for longitudinal bulkheads and side shelt. Safe walkways and all necessary fitting and welding machinery are built into the unit.

  - requesting that the yard plan subgroup maintain the same scantlings for at least four tenths of hull length (0.4L),
  - positions of bulkheads per the cargo-compartment arrangement,
  - positions of fore and aft engine-room bulkheads and forepeak bulkhead,
  - deck piping arrangement,
  - block rigidity and stability,
  - fittings arranged in tanks,
  - setting, shifting and removing work units, installing and removing scaffolding,
  - determining the weight of each block including outfit and lifting gear, and
  - joining blocks to create grand blocks both to shorten the erection stage and to do more of the outfitting on-block than would otherwise be done on board.

- ***fore and aft bodies and engine room***

In order to increase the amount of on-block outfitting for the purpose of minimizing on-board outfitting, L-type grand blocks, shown in Figure 4-2 are defined. Each consists of a flat (deck) block joined to a curved (shell) block encompassing a greater volume of the region to be outfitted and painted. The yard-plan subgroup is requested to insure that shell seams do not cross decks or platforms. Consideration is given to the

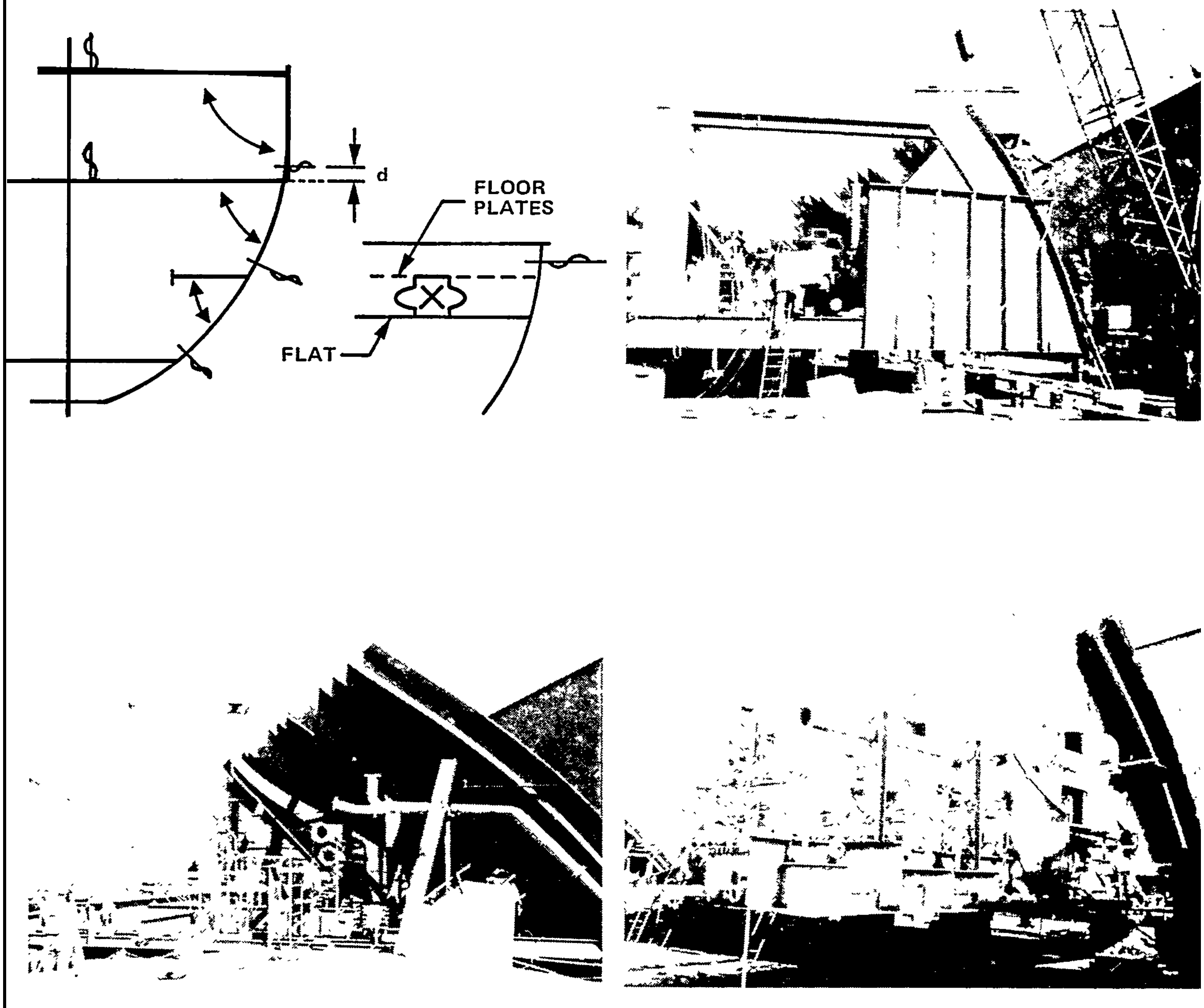


FIGURE 4-2: L-type Grand Blocks Consisting of a Flat (deck) Block and a Curved (shell) Block. As shown, ceilings are outfitted down hand before turnover. In order to improve productivity, outfitters are working smarter not harder.

relationships between block butts and seams and the following:

- machinery arrangement,
- tank arrangement,
- control room, elevator trunk, lifting beam, workshop, etc.,
- mooring arrangement,
- standard ranges and tolerance limits which reflect normally achieved accuracy when bending plates for curved shell,
- limit of curvature that can be accommodated on pin-jigs for assembling curved blocks,
- method for landing main engine (assembled or dk-assembled),
- block stability both before and after turnover,
- rigidness required for block turnover and block erection with little or no reinforcement, and
- determing the weight of each block together without-fit and lifting gear.

4.4 *Basic Block Definition Meeting*

As production engineers in the hull construction department are working to define ideal blocks, they are providing feedback to the basic design department and to the hull structural design group. The latter, also investigating the proposed basic design, addresses such items as:

- sides for stiffeners on bulkheads,
- arrangement of stiffeners considering block joints,
- stiffener spacing, setting angles (as to a cambered deck) and end details,
- types of cutouts for passage of longitudinal and orientations of non-symmetrical cutouts,
- provision for temporary access holes,
- form of camber,
- designation of shelf plates,
- edge preparations, and
- types of slots, scallops and stiffener ends to facilitate sandblasting.

Thus, much planning of a tactical nature is being discussed as a means for optimizing the strategy for the whole shipbuilding process. The ***basic block definition meeting*** is a working meeting, generally characterized by intense, even ***heated,*** discussion by engineers for hull construction, outfitting and painting from all departments. The meeting objectives are to coordinate the diverse recommendations, end the discussions and to produce a block pre-definition plan which optimizes the entire shipbuilding project. The plan so produced, reflects requirements for fast startup and enhanced productivity for which there is general agreement within the shipyard.

Figure 4-3 shows a scheme for defining blocks that is consistent with IHOP, compared to traditional block definition. Benefits are realized for hull construction in addition to outfitting and painting and include:

- more opportunities for on-block outfitting and painting, particularly outfitting and painting down hand,
- fewer blocks are defined,
- reduced welding during erection and in difficult positions,
- more stable and rigid blocks,
- fewer stays and shores are needed,
- significantly less scaffolding is required, and
- less damage to fittings and paint during erection.

All of the foregoing significantly enhance safety.

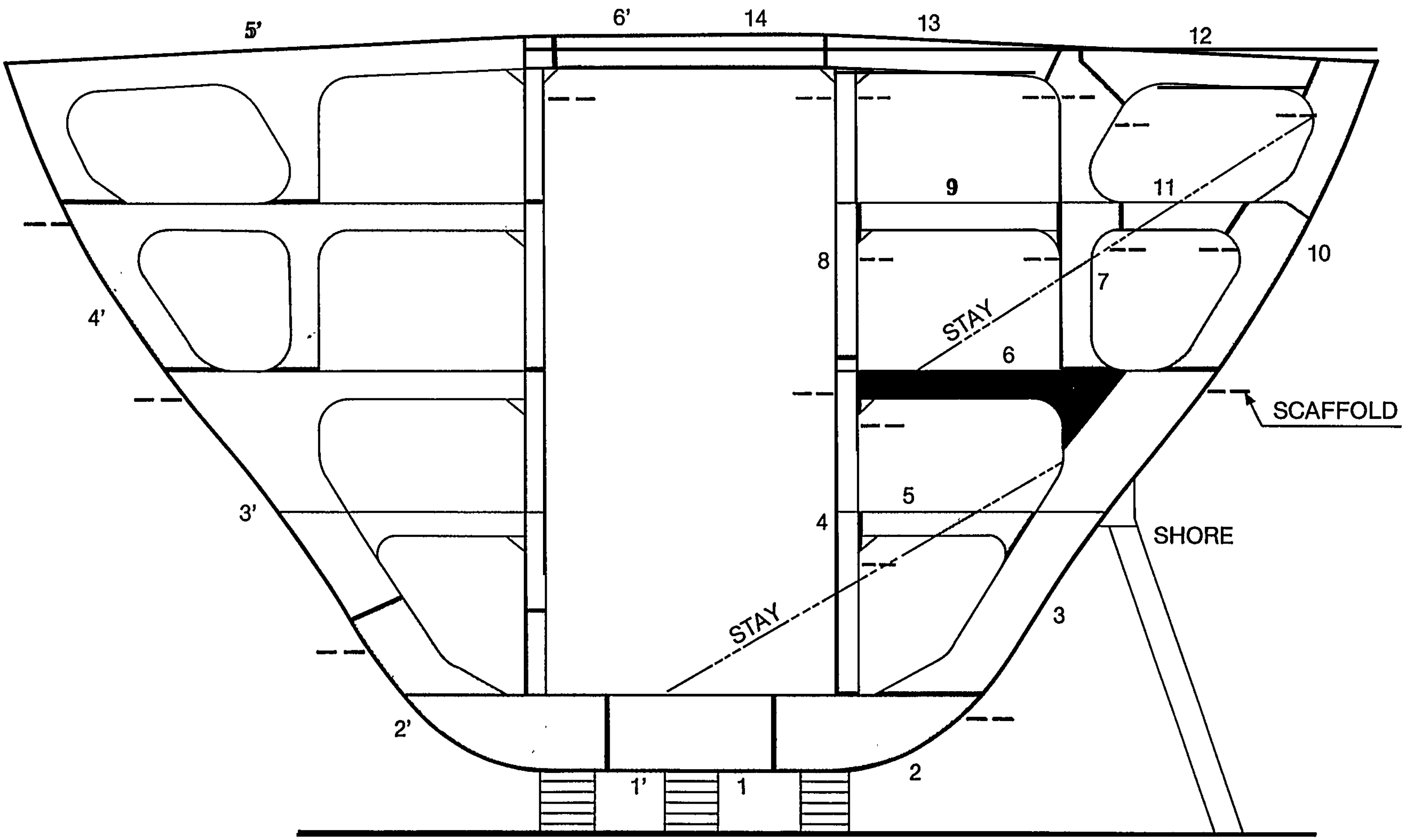


FIGURE 4-3: Comparison of Modern and Traditional Block Definition. The traditional approach, shown **on the *right*, schedules 14** blocks for erection and requires stays and shores. Block definition consistent with IHOP is shown on the ***left.*** Only 6 blocks are sequenced for erection, all are stable when upside down for outfitting and painting ceilings and require no temporary supports following turnover and remaining outfitting and painting on-block. Further, less scaffolding is required and the need for stays and shores during erection are virtually eliminated. As further shown on the ***left,*** the seam between blocks 2 and 3 is located well above the tank-top level so as to be clear of machinery previously outfitted on block.

5.0 DESIGN

In order to avoid having to change key plans because of an owner's approval comments, shipbuilders are detailing proposed contract drawings as much as possible. That is, more technical matters are negotiated before contract award than is the case in traditional shipbuilding. Such contract drawings, usually 1:100 scale, include indication of:

- steel material grades and thicknesses for panels and structure,
- joints in panel and structure only when there is to be a change in thickness,
- arrangements of structural members including flange orientations on longitudinals and stiffeners on webs and floors,
- end connections of stiffeners and longitudinals,
- penetration details for longitudinals,
- arrangement of access holes, and
- joint arrangement for internal structure.

A general note advises that as the design is developed there is possibility of altering or rearranging scantlings, the sides of transverse webs on which stiffeners are to be located, types of structural members, positions of seams and butts, various holes, etc., subject to the further approval of the owner and classification society.

After the B or go-ahead meeting, per a typical design master schedule and as shown in Figure 5-1, the key-plan subgroup develops the system-oriented functional design from K-8 to K-6 and the yard-plan subgroup effects the system to zone transition during their preparation of yard plans from K-6 to K-3.5. During both such developments the steel netweight of hull structure is constantly updated and incorporated in revisions of the budget control list presented at the B-meeting.

5.1 Design Process After Contract Award

Key plans are prepared for approval by the owner and the regulatory bodies and address:

- fore and aft shell expansions,
- sections,
- construction (or structural) profile,
- stern, engine room, hold and bow construction,
- stern frame and rudder, and
- major machinery foundations.

Key plans also include a:

- rough cutting plan for steel material, and
- fabrication and assembly lane plan.

Yard plans are formatted as compact booklets each of which applies to a group of adjacent blocks which can be assembled in the same process yard. They represent the first interrelationships between systems and zones. Only sufficient work instructions, generally those common to all stages, are included. Yard plans incorporate:

- structural configurations not generated on key plans,
- detail configurations not generated on key plans,
- holes and reinforcements for outfitting including foundations,
- symbolic coding of all interim products in accordance with ***block assembly guidance,*** and
- block-part lists generated by zone/area/stage.

5. 1. I *Functional Deign*

- ***fairing and landing***

As shown in Figure 5-2, immediately upon receipt of contract drawings, formally presented during a B-meeting, the key-plan subgroup employs a computer to fair the lines on frame positions in 1:50 scale. Afterwards, the locations of longitudinals and shell seams and butts are manually ***landed*** (defined) on the shell taking into account decisions reflected in the block predeftition plan.

- ***structural lines and shell expansions***

The computer next generates structural lines (frame offsets) and shell expansions which incorporate the previously processed fairing and landing data. After calculation of the shell plate thicknesses and longitudinal scantlings, positions of carlings and headers are landed manually. At this stage, data is sufficiently organized for developing all remaining key plans and the yard plans. Only parts drawings are excepted.

- ***panels***

Panels for the main deck, longitudinal bulkheads, flats, etc. are roughly defined during block pre-definition. They are refined automatically when the computer is provided with additional input, e.g., definition of panel positions, landings of Longitudinals and exact locations of seams and butts. These key plans are completed manually by adding such necessary information as scantlings.

- ***transverse sections***

Drafts of engine-room sections are computer generated and are used for checking the machinery arrangement and for calculating the scantlings of transverse rings. Internal members, scantlings, access holes, block joints, reinforcements (such as for large machinery), etc. are added to produce the final sections. The ring configurations for all sections are retained in computer files for use during yard-plan development for generating hull parts.

5.1.2 *Transition Design*

- ***fine fairing and landing***

As shown in Figure 5-3, fairing and landing are again performed in order to replace existing 1:50-scale data with 1:10 data; i.e., data accurate enough for computer-aided generation of parts.

- ***casting templates***

Templates are prepared for large castings such as for the stern frame, hawsepipe, etc.

- ***yard plans***

Yard plans represent reorganization and further refinement of data from various key plans as needed to facilitate block assembly by zone. Each defines a number of adjacent blocks which may comprise all or a large division of a hull-body part, e.g., stern, engine room, cargo compartment, bow, or large-machinery foundation. Yard plans:

contain details not shown on key plans which will be common for all stage plans to be subsequently prepared such as for: floors, longitudinal-end and tripping brackets, locations of liquid stops beneath fillet welds, stiffeners, air and drain holes, scallops, bilge wells, edge preparations, etc.,
include instructions for block assembly and erection pertaining to: positions and sizes of work-access holes, locations of liquid stops, temporary reinforcement and devices for automatic welding,
provide instructions for features that facilitate outfitting such as: holes, reinforcements, etc.,
incorporate some rearrangement of hull structure as may be justified during the transition to zone orientation,
identify all interim products, including parts for ou fit reinforcement and temporary stiffening, by a sym bolic code which indicates interim-product types ar required routings, i.e., classifications by zone/area stage,
incorporate the yard plan data and parts code assign ments thus far developed for preparing part drawings,
include preparation of sub-block drawings, needed t further define parts, which are later adopted as stag plans for sub-block assembly,
include lists of parts needed for fabrication, sub block assembly and block assembly, and
include such other instructions as parts drawings marking and cutting plans, shell-part expansions plans for bending and tables for pin-jig heights.

5.2 *Design Scheduling and Control*

5.2.1 *Scheduling Hull Structural Design*

Designers convene at the time of the B'-meeting to creat a ***design master schedule as*** typically shown in Figure Inputs for this schedule include constraints imposed by th IHOP pre-schedule, the design workload for other ships man-hours available and the lead times for major outf components. The relationships to each other of the va items listed are standardized, i.e., standard schedules for different cases such as when a B-meeting (co award) is K-10, -9, or -8.

A ***key plans schedule is*** depicted in Figure 5-5. For the ac tivities being controlled by the schedule, requisitioning shapes and plate are very significant milestones. Other signi ficant milestones are owner and regulatory body approval and development of key plans in time for preparation c yard plans. Yard plans should be essentially complete abou one month before steel shapes and plate requisitioning.

A ***yard plans master schedule is*** shown in Figure 5-6. It necessarily developed within limits imposed by the IHO schedule because it controls data needed for parts genera tion and for preparing stage plans. Each yard plan issue da is determined block-by-block.

The key-plan subgroup must coordinate with the outfi ting design groups in order to determine receipt dates fc vendor-furnished design information for such component as the main engine, reduction gear, boilers, cargo pumps etc. The yard-plan subgroup provides the latest dates, block by-block, consistent with providing outfit required hole and reinforcements in hull structure without disrupting nor mal work flows.

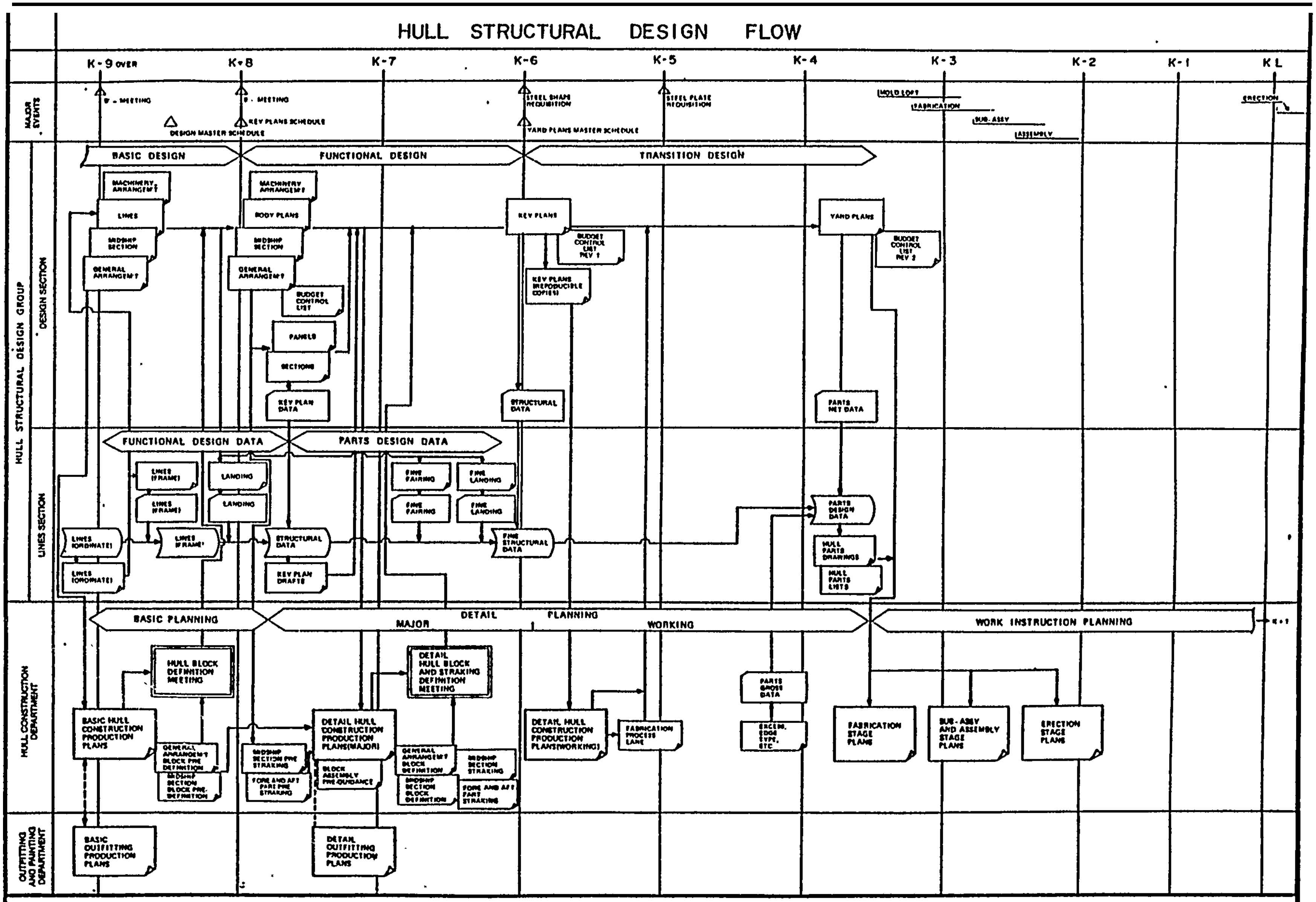


FIGURE 6-1: Hull Structural Design Flow

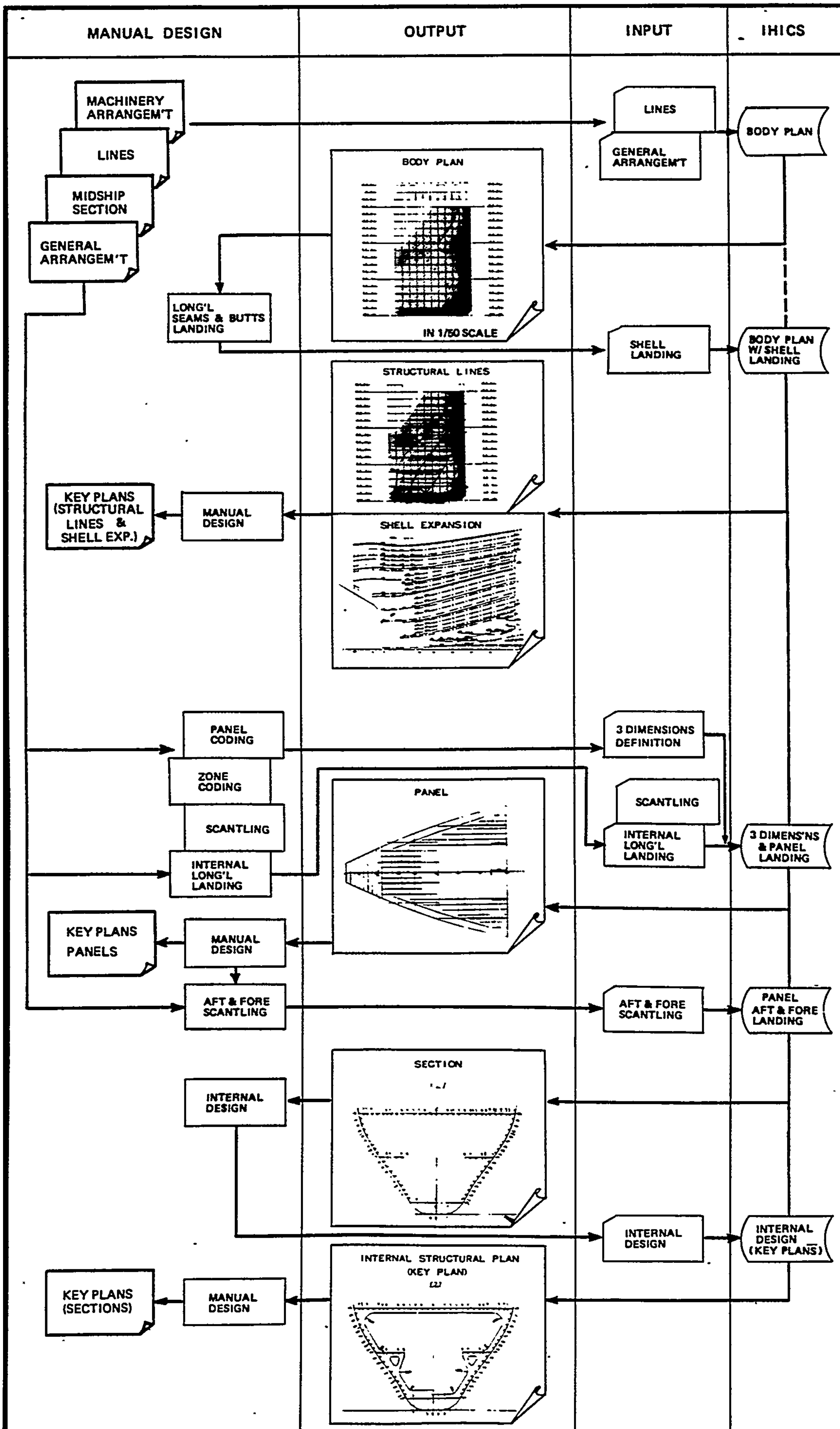


FIGURE 5-2: Design Process for *Key Plans* based on IHI's Integrated Hull Information Control System (IHICS).

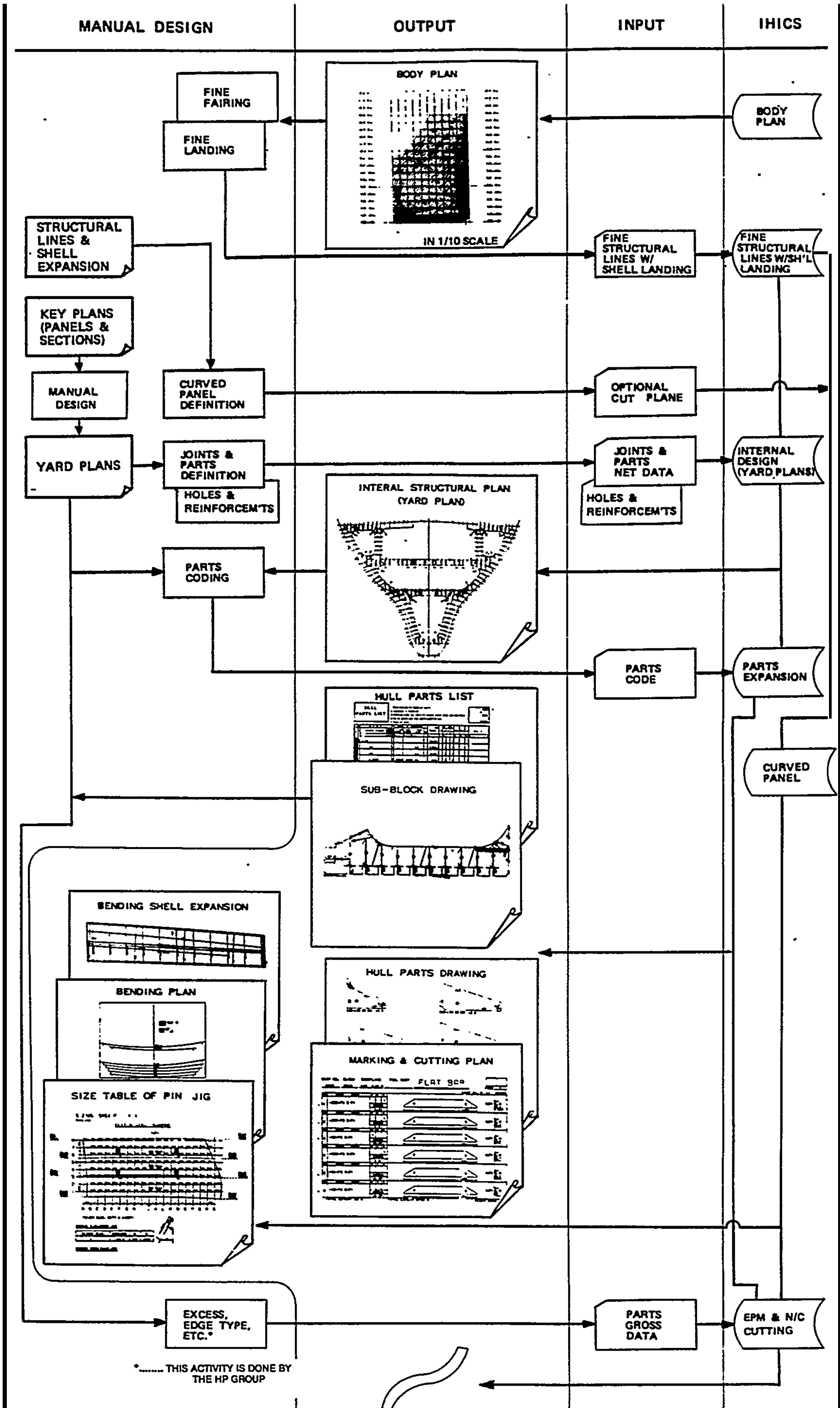


FIGURE 5-3: Design Process for *Yard Plans* Based on IHI's Integrated Hull Information Control System (IHICS). As mold lofts are now generally equipped with computer terminals, the *bending shell expansion, bending plan and size table of pin jig,* as they are true work instructions, are more appropriately classified as *stage plans* and prepared in production vice design.

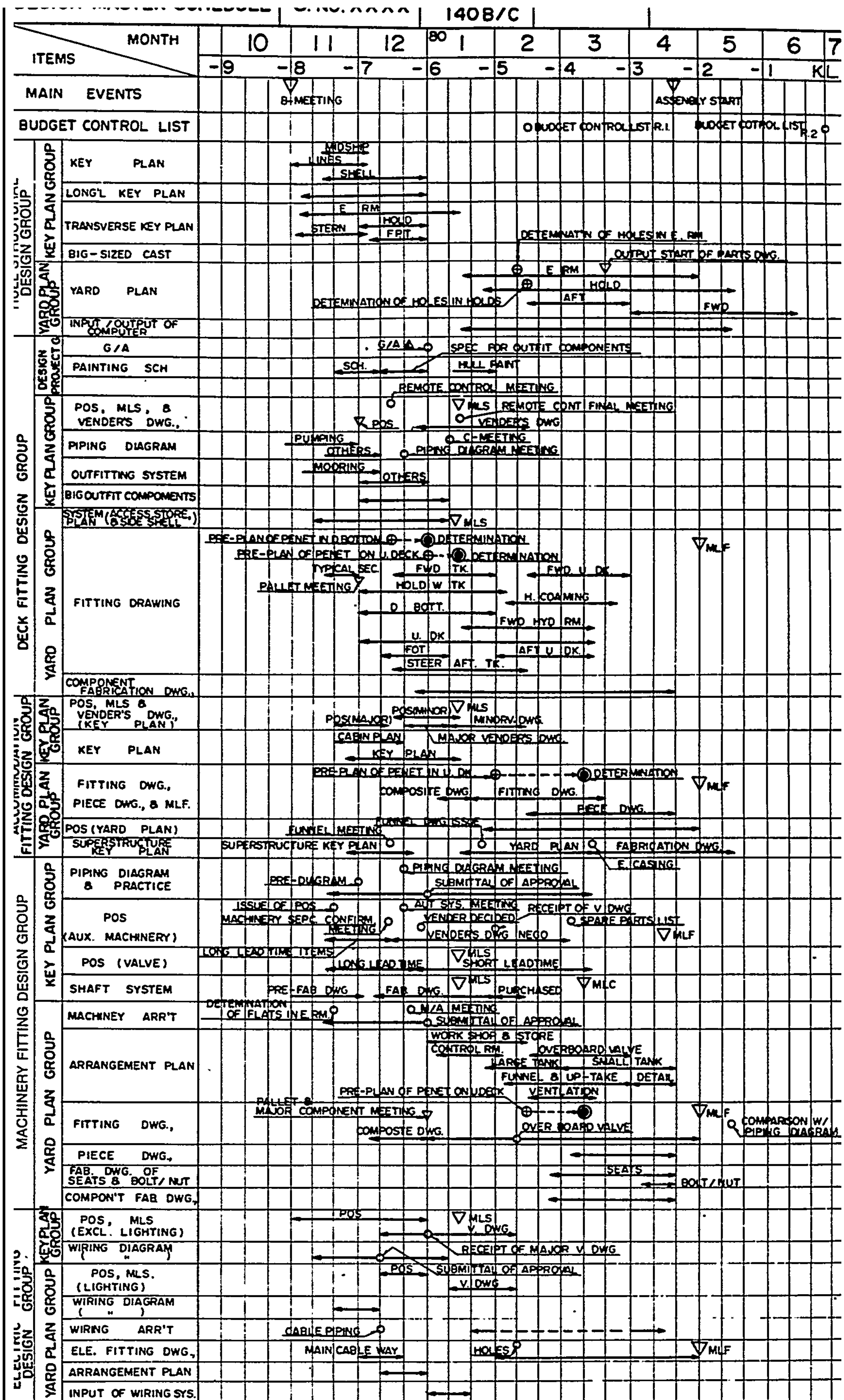


FIGURE 5-4: Design Master Schedule.

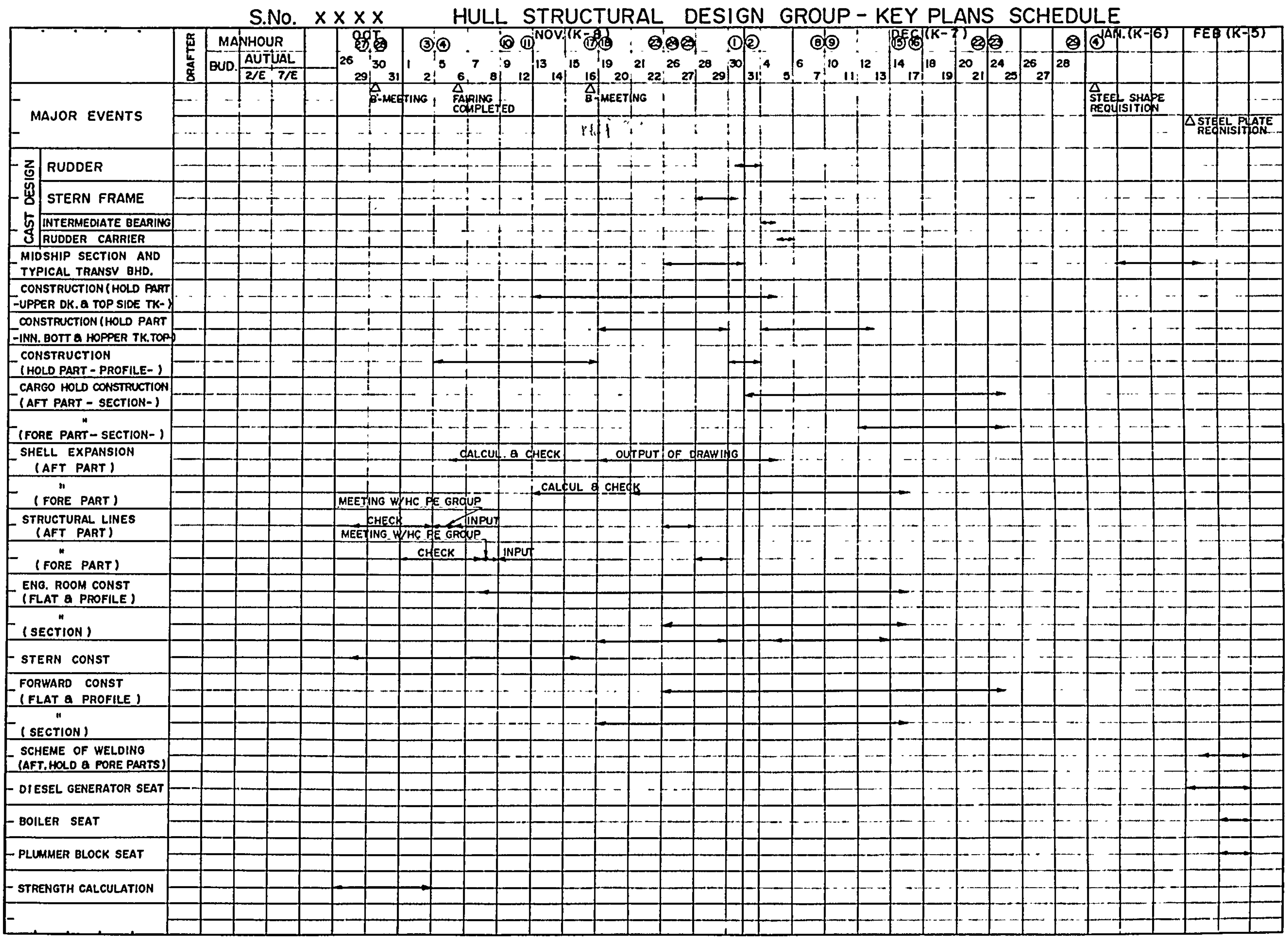


FIGURE 5-5: Hull Structural Design Group - Key Plans Schedule.

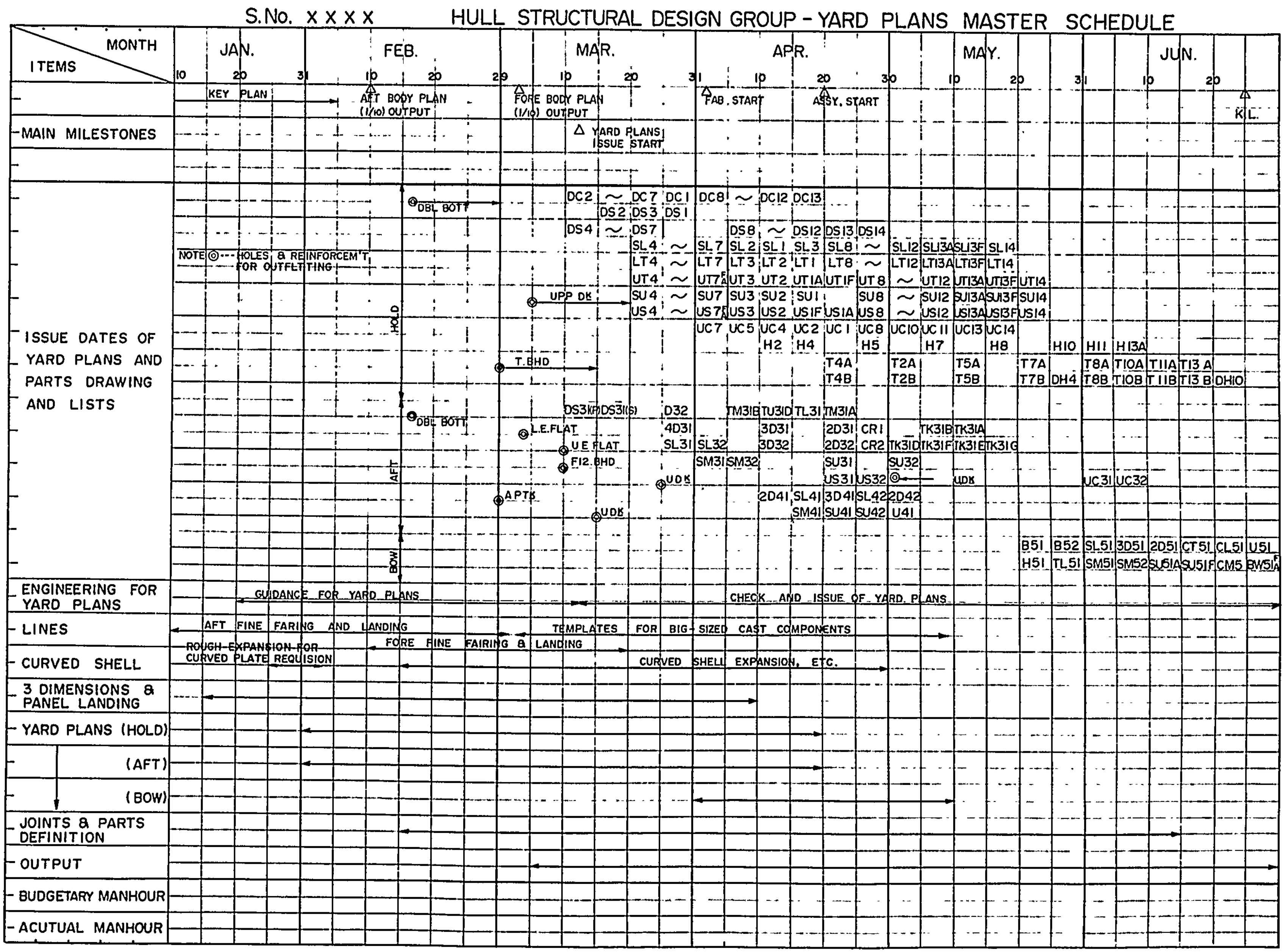


FIGURE 5-6: Hull Structural Design Group - Yard Plans Master Schedule.

5.2.2 Man-hour Control

The design man-hour budget is made in accordance with historical data recorded by type of ship, deadweight tonnage and by hull body part. Subgroup leaders continuously compare man-hours expended to budgeted man-hours on charts specifically devised for that purpose.

5.2.3 Steel-weight Control

Steel weight of hull structure is reassessed during succeeding design phases. The original weight estimate is performed during basic design and is replaced by calculations made from more definitive data as it becomes available during functional design. The latter is replaced by an accurate summation obtained during the precise definition of parts during transition design.

During the B-meeting, one of the documents given to the hull structural design group is a ***budget control list*** which contains the original (basic design) weight calculated from elements of the general arrangement and midship section.

During functional design, weight is updated by groups of hull body parts simultaneously with development of key plans. The calculations are performed manually and are also based upon historical data. The revised estimate serves basic designers as feedback to consider for improving their weight estimating methods. Also, weight deviations caused by owner and regulatory revisions and weight additions caused by reinforcements for outfitting components, are fed back to basic designers. This information identifies the causes of the weight changes and enables them to further perfect their methods for future weight estimates.

After completion of yard plans, hull structural weight is accurately determined by a computer-aided system which utilizes design data for parts. This final summarization of hull structural weight, also fed back to basic designers, is organized by

- hull body regions (cargo compartments, engine room, aft, fore and accommodation),
- steel type (mild, high tensile, casting and forging, and
- steel configuration (plate and shape).

6.0 DETAIL AND WORK INSTRUCTION PLANNING AND SCHEDULING

After the B-meeting.the HP group initiates ***detail planning*** in two phases: ***major which may be*** regarded as department-level planning, and working, a refinement of the former which addressess shop-level planning. The objective is to produce intemediate-level plans and schedules which facilitate the later preparation of productivity. enhancing product-oriented stage plans. This phased detail planing effort includes preparation of:

- detail hull-Construction production plans (major and working),
- an IHOP schedule for coordinating the efforts of the hull structural design group (particularly for yard-plan issue dates), and all shops of the hull construction and outfitting departments, and
- man-hour budgets based on parameters that are peculiar to each shops interim-product specialty.

The most essential aspect of the HP group's efforts to facilitate integration of outfitting and painiting, is introduction of a product-oriented strategy as early as possible. Thereafter, plans and schedules are refined until there is definition of a number of sequenced short-range objectives (blocks) which are classified by problem area. Otherwise, even the most sophisticated managers having unlimited resources could not achieve effective operation of integrated process lanes.

Immediately after the contract drawings are presented at the B-meeting, the HP group starts detail planning of work processes commensurate with the contract plans and the block pre-definition plan. The effort is divided into two phases, ***major*** and ***working,*** and is characterized by constant interchange of information with the hull structural design group to ensure that:

- the contemplated building strategy is incorporated in key and yard plans as they are being developed, and
- the building strategy is adjusted, if necessary, as a consequence of owner and regulatory body approval comments on key plans.

Figure 6-1 displays the production planning flow for hull construction. The documents prepared by the hull structural design group and the outfitting department are identified. This figure is organized in the same pattern as that for design flow (Figure 5-l).

Figure 6-2 displays a ***production scheduling*** flow for hull construction which is organized to facilitate comparison to the ***production planning flow*** shown in Figure 6-1. Both reflect flows through four distinct phases: ***basic, detail (major and working) and work instruction.*** Both provide for outfitting department concerns which include painting.

6.1 *Detail Planning (major) and Scheduling*

6.1.1 Planning (major)

Among the following items addressed in the first detail planning phase are some which influence key plans which are developing simultaneously:

- ***detail block definition***

  Block pre-definition is reexamined and finalized on key plans. The hull-body parts, especially fore and aft, which were not defined on contract plans are finalized in detail. The midship section straking is rechecked and extended into the fore and aft bodies. Seams are carefully located relative to decks and platforms so as to facilitate on-block outfitting and painting. The refined block definition and straking is provided as feedback to the hull structural design group.

- ***auto-welding application plan***

  The auto-welding application plan addresses welding of erection butts and seams and is prepared in the context of the hull construction processes plan prepared before the go-ahead (B) meeting. Specific welding methods are designated per butt and seam and are confirmed by process engineers assigned to the erection shop. This plan is also part of the feedback furnished to the hull structural design group.

- ***work-unit application plan***

  As work units are only employed to facilitate erecting the hull, planning for their use follows the same pattern as for the auto-welding application plan.

- ***block-assembly pre-guidance***

  Block-assembly pre-guidance is for curved portions of the hull, e.g., blocks that incorporate turn-of-the-bilge and blocks of the fore and aft bodies. This pre-guidance is prepared simultaneously with key plans such as for panels and sections.

- ***midhip lifting master plan***

This plan contains guidance concerning the handling of midship blocks, large-size grand blocks and blocks containing large quantities of outfit components. Necessarily, production engineers for outfitting and painting participate. All handling requirements are addressed, i.e., transfer, turnover and erection alignment. Plans are prepared for:

- shipwright and erection methods,
- turnovers,
- locations of lifting pads, and
- permanent and temporary reinforcements.

Specific requirements for enhancing block strength, particularly for lifting and turnover, are fed back to the hull structural design group. Also, man-hour budgets and material costs for lifting pads, receiving guides, stays, etc. are determined from the midship lifting master plan.

- ***midship scaffolding master plan***

This plan addresses all scaffolding requirements except those for the engine room as the engine-room design is not sufficiently developed during the major phase of production planning. The plan incorporates decisions regarding:

- types of scaffolding,
- avoidance of interferences with outfitted components, and
- locating scaffolding to commonly serve hull construction, outfitting and painting.

- ***btock weight and weld-length rough calculations***

Welding lengths for the subassembly and assembly processes are recalculated block-by-block from the more descriptive design being disclosed by the developing key plans. Similarly, block weights and parametric welding lengths for the erection process are recalculated. These more accurate lengths and weights are substituted for those estimated in basic planning in order to:

- update the ***budget control work volume*** prepared during basic planning,
- prepare the assembly master and other shop schedules,
- update the hull-steel weight in the ***budget control list*** prepared during functional design by the hull structural design group, and
- determine the sums of all lengths and all parametric lengths which are needed to calculate welding-rod requirements.

6.1.2 *Scheduling (major)*

As shown in Figure 6-2, the basic input is an ***erection schedule*** per ship which was prepared before contract award from an erection master schedule. The erection schedule features:

- the shortest practical erection period,
- an erection sequence which is easiest for shipwrights,
- durations required for aligning and fitting blocks, shift. ing work units and removing snffolding,
- the date for erecting each blocks and
- daily man-hour requirements for fitters and welders.

At the start of the detail planting phase, an ***assembly master schedule is derived*** from the erection schedule, the IHOP pre-schedule, the shipbuilding activities timing schedule and the ***design*** master ***schedule.*** On the assembly master schedule, forecasted work is leveled together with that for other ships using ***welding lengths*** for assembly that were calculated during basic planning. This schedule:

- displays the duration required for assembly of each block for all ships by each process flow (e.g., separately for flat- and curved-block assembly), and
- is a master schedule for scheduling shop activities for sub-block assembly, fabrication of parts, material requisitioning and mold-loft activities.

Next, with additional inputs from the outfitting department, specifically ***outfitting shop master schedules*** and ***block need periods for*** on-block outfitting, an ***IHOP schedule is*** produced while making small adjustments in the various shop schedules as necessary to insure their coordination.

The shop schedules, so refined, “look forward” for six months and are updated every two months together with the assembly master schedule by substituting more accurately determined welding lengths for those estimated during basic planning.

6.2 Detail Planning (working) and Scheduling

6.2.1 Planning (working)

Plans which are made after key-plan approvals are:

- ***block assembly guidance***

This plan is a finalization of block assembly preguidance described in Part 6.1.1 taking into account impact of the approval comments.

- ***fillet-weld on-block air-test plan***

This plan is superimposed on a copy of a key plan prepared for approval by the owner and regulatory bodies. The specific test details are included for pressurizing beneath fillet welds, e.g., positions of air fittings and air-stop welds. These tests are implemented on-block so as to eliminate the need to test the same fillet welds during hydrostatic or pneumatic tests onboard.

- ***work-access holes***

This plan shows holes allowed for temporary access on a copy of the same key plan used to develop the fiiet-weld on-block air-test plan. Its preparation involves coordination with engineers assigned to the outfitting and painting shops as well as the assembly and erection shops.

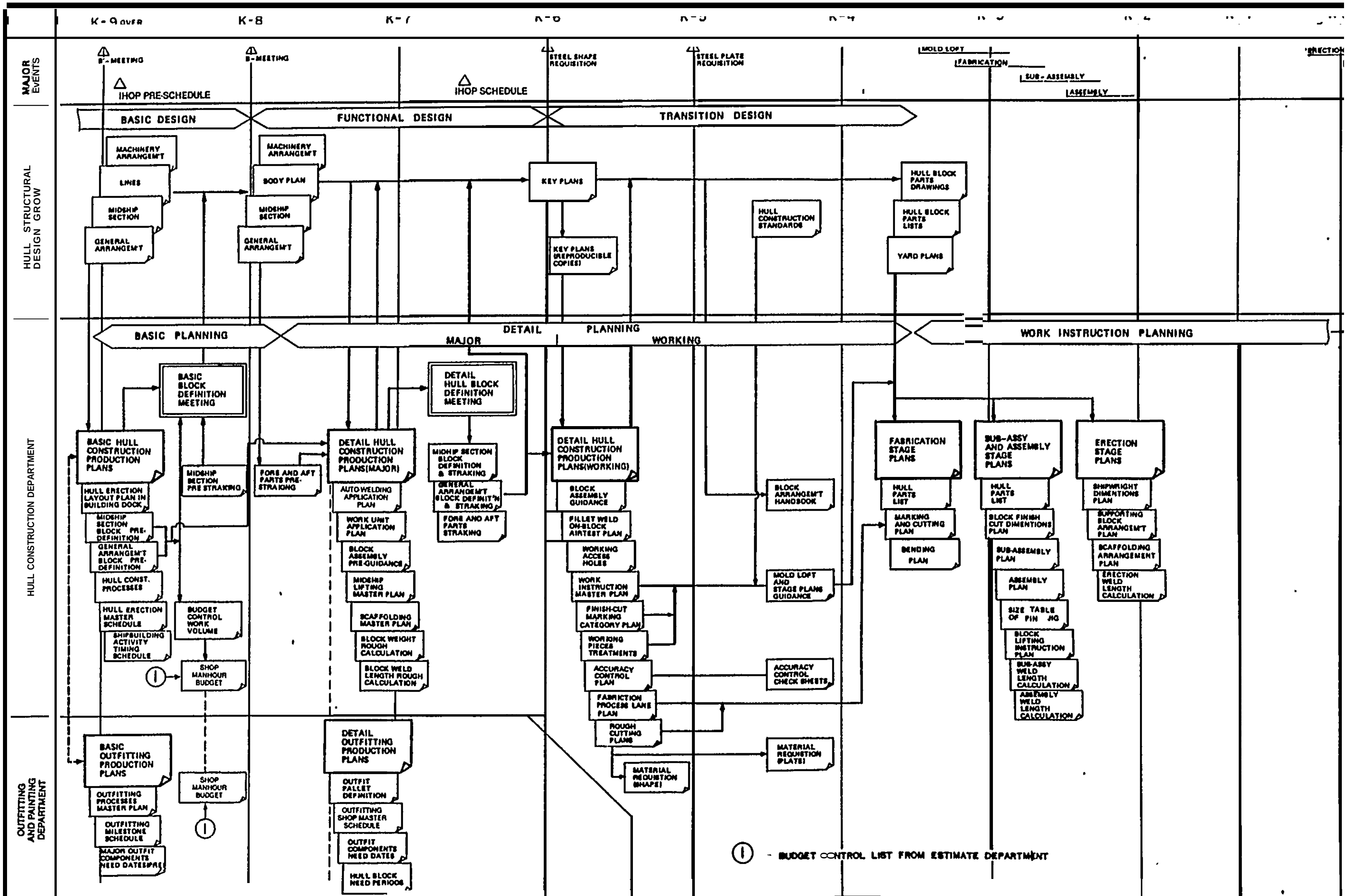
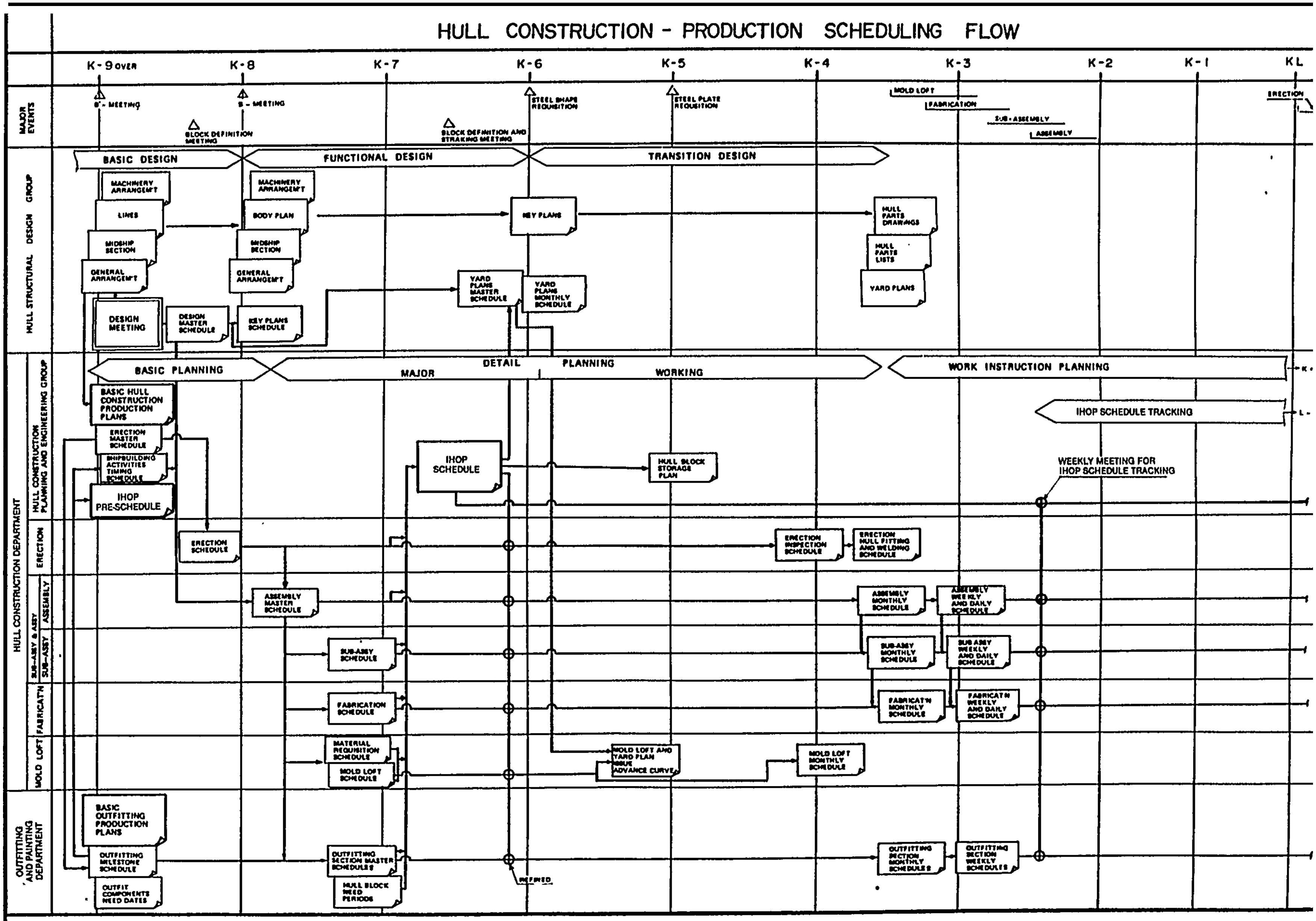


FIGURE 6-1: Hull Construction - Production Planning Flow. Outfitting department inputs are included



Prod Sched depart uded

- ***work instruction master plan***

This plan is the means by which work instructions which are to be common for the various work stages are provided to the hull structural design group for their inclusion in yard plans. A work instruction master plan addresses such things as:

- block code,
- semi-block code,
- erection sequence marks for the direction of blocks, the keel-laying block and insert blocks,
- hull parts assembly sequence for the subassembly and assembly stages,
- excess allowances and edge preparations,
- parts marking techniques such as electrophoto (EPM) or size lists, and
- vital dimensions needed for assembling blocks.

- ***finish cut and marking process plan***

This plan contains instructions for achieving the overall and layout dimensions for the panels on which blocks are assembled. It specifically addresses:

- dimensions for cutting each panel to finish size, and
- layout dimensions for longitudinals and transverse members.

- ***working pieces treatments***

This plan provides instructions regarding disposition of working pieces, i.e., padeyes, staging lugs, receiving guides, etc. It normally is processed for approval as it designates which working pieces may remain as permanent fittings, which have to be removed, and required surface treatments after removal.

- ***accuracy control plan***

This plan is developed as a master for A/C considerations that will be common to all work stages. It provides general guidance to be included on yard plans such as identifying the hull blocks which will be the most difficult to assemble and the types which were inaccurately assembled in the past. Specific instructions address:

- match lines needed on parts to facilitate subassembly and assembly,
- reference lines needed for assembly,
- specific length of butts and seams in complicated hull form which justify margins and the extents of such margins, and
- check points and pertinent dimensions to verify alignment of large assemblies.

- ***fabrication process lanes plan***

This plan indicates the types of marking to be employed for internal-structure parts, e.g., N/C, EPM or a simple size list. It serves as input for computer-aided processing by the hull structural design group. This planning effort is performed simultaneously with preparation of ***rough cutting plans.***

- ***rough cutting and material (plate and shapes) requisition plans***

Rough-cutting planning is needed for organizing the material requisitioning effort at an early stage commensurate with pertinent material lead-times. References include:

- key plans for types, grades, sizes and quantities of materials, and
- the assembly master schedule for required dates.

The following considerations apply:

utilization of standard size materials

Planning proceeds based on some estimated quantities because detailed plans are not yet available. Because of this need to employ estimates, the designation of standard sizes normally favors oversizing some hull construction materials. Size standards are established beforehand and designers are urged to refrain from designating alternatives in order to minimize the percentage of scrap, maximize interchangeability of materials and minimize storage requirements.

grouping of requisitions by lot by delivery date

The requisitions required per month pertain to various materials needed for a number of blocks for which there are different required dates. The requisitions are grouped into lots per month with prime consideration given to parts-fabrication sequence. This insures sustained work flows without the disruptive need to rearrange jigs, change machinery settings, etc. Consideration is also given to subassembly and assembly schedules and storage areas.

Requisitions for steel materials are made with reference to rough-cutting plans and stocks on hand. Their issue authorizes the purchasing section to combine requirements and place orders with steel mills.

Further, the planning performed is used as guidance for all marking and cutting plans which are the basis for steel material ***allocation sheets.*** These sheets are commonly used for steel material ***issue orders*** as well.

- ***block arrangement handbook***

The material in this pocket-size book is extracted from a number of key plans. It conveys the whole ship structure and block definition. Copies are distributed mainly to managers and production engineers in the erection shop.

- ***mold loft and stage plan guidance***

This guidance is compiled by extracting information from many documented plans, instructions, etc. that were prepared by hull structural designers and production engineers. The information is selected and edited specifically to serve the mold loft and the stage plan section for their work instruction planning.

• ***accuracy control check sheets***

Formal check and report sheets are prepared for each interim product per block by the production engineers who have been assigned A/C responsibilities. Their objective is to record variations in dimensions achieved which when analyzed statistically advise how the work processes are performing. Such analysis creates the feedback needed to exactly compensate for shrinkages such as caused by gas-cutting, welding and distortion removal. Further, production engineers employ such data to control the amount of rework (gas cutting of margins and back-strip welding) that will be encountered during hull erection.

6.2.2 Scheduling (working)

• ***assembly, subassembly and fabrication monthly schedules***

Each monthly schedule for block assembly, subblock assembly and fabrication, orders work for the next 1.5 months and is updated every two weeks in order to substitute the more accurate parameters being produced during transition design. The ***assembly monthly schedule is*** made in accordance with the ***assembly master schedule.*** The ***subassembly monthly schedule is*** derived from the ***subassembly schedule*** and the ***assembly monthly schedule.*** The ***fabrication monthly schedule is*** derived the same way. The impact of such updating requires adjustments in interim-product completion dates for workload leveling, specifying the use of overtime and/or engaging subcontractors. Shop schedules which are affected by the revised parameters are updated every two months.

• ***yard plan and mold loft issue curves***

Curves for planned issues of yard plans and mold-loft data are prepared to be used as the basis for checking actual progress including how progress by the mold loft relates to actual yard-plan issues. These visual presentations facilitate assessments of progress and, if needed, expediting measures. Updating the ***mold loft monthly schedule*** depends on yard-plan issues and progress of work in the mold loft.

• ***block storage plan***

In accordance with the IHOP schedule, a production engineer prepares a block storage plan which allocates space for storing completed blocks prior to their erection. The plan is revised every ten workdays and on each launching day. When all available space is allocated according to the block storage plan, the assembly master schedule has to be changed accordingly. Because erection work proceeds faster than assembly work, enough space is required near the erection site to insure an uninterrupted supply of blocks for the erection shop. This means, depending on ship types, 40 to 60% of required blocks must be on hand before keel laying.

• ***erection inspection schedule and erection hull fittin and welding schedule***

As controlled by the erection schedule, an ***erection inspection schedule*** is made to insure meeting star dates scheduled for on-board painting. This schedule i updated in the same way as other monthly schedule and it indicates dates for tank testing, cleaning removal of scaffolding, etc. Next, the ***erection hull ting and welding schedule is*** prepared to fix a duration for fitting and welding between the date each block i scheduled for erection and its scheduled test date. The manning plan for erection fitters and welders is m simultaneously with this schedule in order to be sure that they are compatible.

6.3 Work Instruction Planning and Scheduling

As described before, yard plans are product oriented as they conform with requirements for process yards in accordance with detail hull construction production plans (working) prepared by the HP group. Yard plans are organized by zone and manifest the end of the transition design. Further development of needed documents is by stage and is man aged by the HP group during the ***work instruction planning*** phase.

6.3.1 Work Instruction Planning

Work instructions (stage plans) address the workers for each stage within a process yard. They are prepared both in the mold loft and by the stage-plan section in accordance with requirements established by the HP group.

• ***mold loft***

Now that computer terminals are located in mold lofts, some planning responsibilities that are legitimate work instructions, have been shifted from the hull structural design group to the mold loft, e.g.:

- hull parts lists per stage,
- marking and cutting plan for parts fabrication,
- bending plan, and
- height tables for setting pin jigs.

Erection work instructions prepared in the mold loft in clude a:

- shipwright dimension plan, and
- supporting-block arrangement plan.

• ***stage plan section***

The stage plan section is a companion organization to the mold loft responsible for such instructions as the

- subassembly plan for sub-block assembly,
- assembly plan for block assembly,
- block finish-cut dimension plan for block assembly
- block lifting instruction plan and scaffolding arrangement plan for subassembly, assembly and erection (padeyes and guides are also fitted during subassembly),
- work-access holes plan, and
- block arrangement handbook.

Figures 6-3 through 6-7 illustrate typical process lanes for hull construction, their subdivision by stages, and the grouping of stages to create process yards. Each process yard is associated with a particular zone/area classification. Stage plans requirements are clearly indicated.

6.3.2 Work Instruction Scheduling

- ***weekly and daily scheduler***

  Weekly and daily schedules are made for assembly, subassembly and fabrication using the same pattern as for preparing their monthly schedules. A weekly schedule orders work to be performed over a two-week period and is updated every week. Sometimes a weekly schedule can be eliminated if the impact of changes are nominal and their effects can be controlled by annotations on a monthly schedule. Daily schedules are prepared for ordering work to be accomplished the next day and, of course, are updated daily. They are prepared by immediate or intermediate supervisors and serve to inform workers of their work assignments for the coming day.

- ***weekly meeting for IHOP schedule tracking***

  An IHOP schedule tracking meeting is held each Friday afternoon to check progresses of erection, assembly, subassembly, fabrication, outfitting and painting by each work yard (work cell) and the progress of the mold loft. A representative from each work yard and the loft are required to attend in order to exchange information and to annotate progress achieved on the IHOP schedule. As it is very important for continuing integration of the various different types of work, feedback from these meetings is employed to make adjustments in monthly, weekly and daily schedules.

6.4 Man-hour Budgeting and Control

6.4.1 Man-hour Budgeting

During basic planning, an original budget for the manhours needed by the hull construction department is estimated. This budget is "broken down" to establish shop budgets using parameters based on normal past performances as described in Part 4.2.5. The essential elements of this man-hour determination system are shown in Figure 6-8.

6.4.2 Man-hour Control

Budgeted and spent man-hours per unit time are both plotted on the same 10-workday report to facilitate their comparison. Evaluations of the differences are the bases for workload leveling decisions. Necessarily a field engineer oversees worker allocations made by supervisors on their daily schedules. The man-hour budget control imposed by a field engineer is based on normally performed rates of work, e.g., normal man-hours/subassembly welding-length. As the design develops, more accurate information is constantly substituted for previously assessed characteristics (e.g., assembly welding-length) on which the control parameters are employed.

6.5 Statistical Control of Accuracy

An accuracy control (A/C) system should be operated jointly by the hull structural design group and by production engineers and other field personnel of the hull construction department. A/C is necessary in order to achieve a ship of specified quality with maximum safety and minimum resources. Generally practiced quality control or quality assurance is not the same because:

- A/C is a production control technique for contantly improving design details, optimizing tolerance limits and perfecting work processes, and
- A/C responsibilities are assigned to people in the design and production departments to implement in addition to other regularly assigned work.

Applied to hull construction, the objective of A/C is to achieve blocks of sufficient accuracy to minimize rework during the erection process. There, rework such as marking and gas-cutting margins on butts and seams and extraordinary shipfitting measures is costly and relatively unsafe. A/C measures avoid much erection rework by exploiting statistical analysis of accuracy variations occurring in fabrication, subassembly and assembly processes preceding hull erection.

Much on-block outfitting is dependent on achieving a certain degree of accuracy in assembled blocks in order to assure alignment of such fittings after blocks are erected. The alternatives is much rework such as having to:

- provide margins on some pipe supports and foundations which are committed for marking and trimming after blocks are erected, and
- using more custom-fabricated interconnecting pipe pieces in place of straight "make-up" pieces having a loose flange.

In order to produce blocks which are accurate enough for outfitting, consideration must be given to:

- insuring that block assembly guidance reflects the specific degree of accuracy required,
- including accuracy related work-instructions in stage plans for assembly, subassembly and fabrication, and
- providing feedback to field engineers which describes the dimensional accuracy achieved in completed blocks, sub-blocks and Parts.

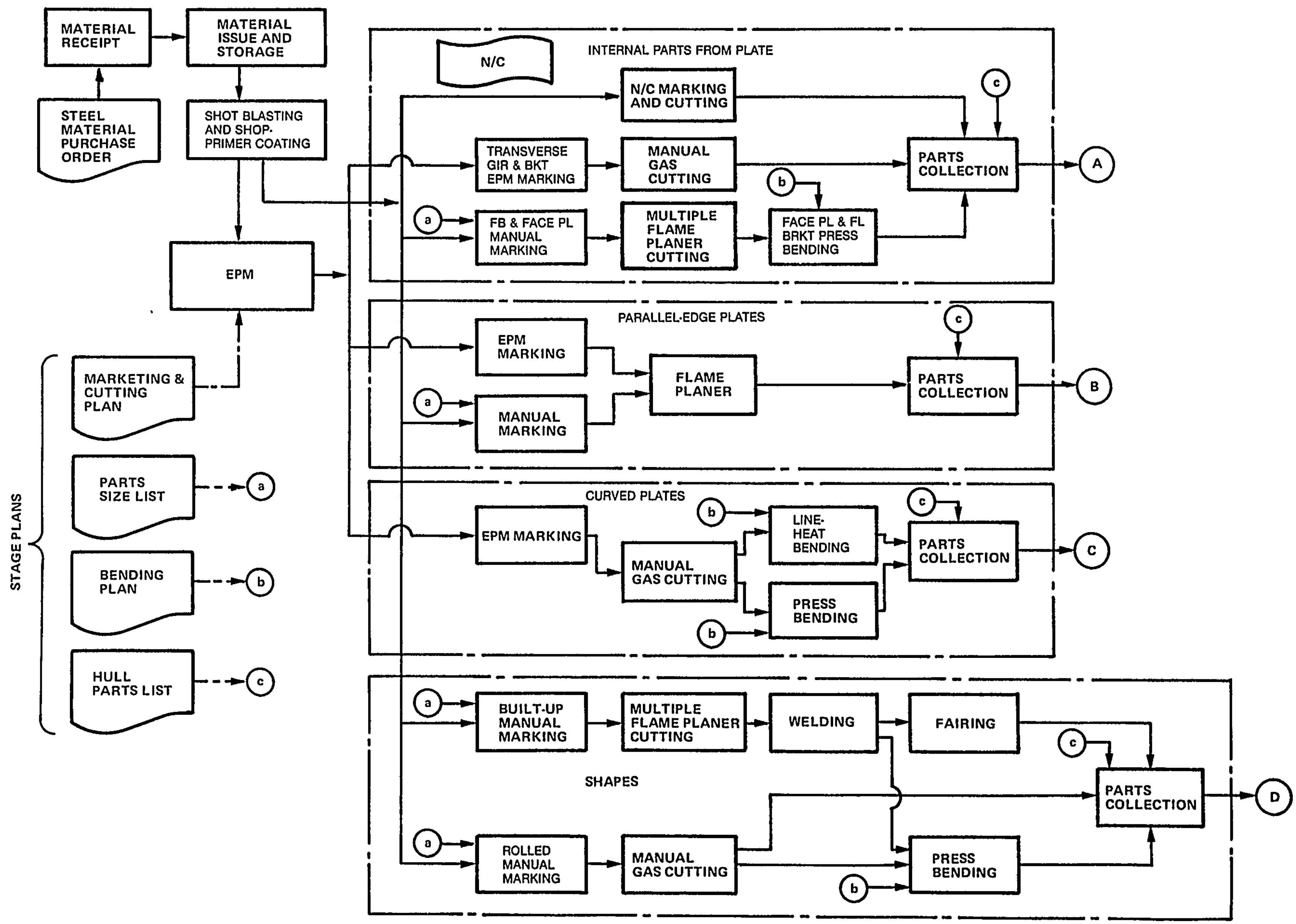


FIGURE 6-3: Typical Fabrication Process Lanes.

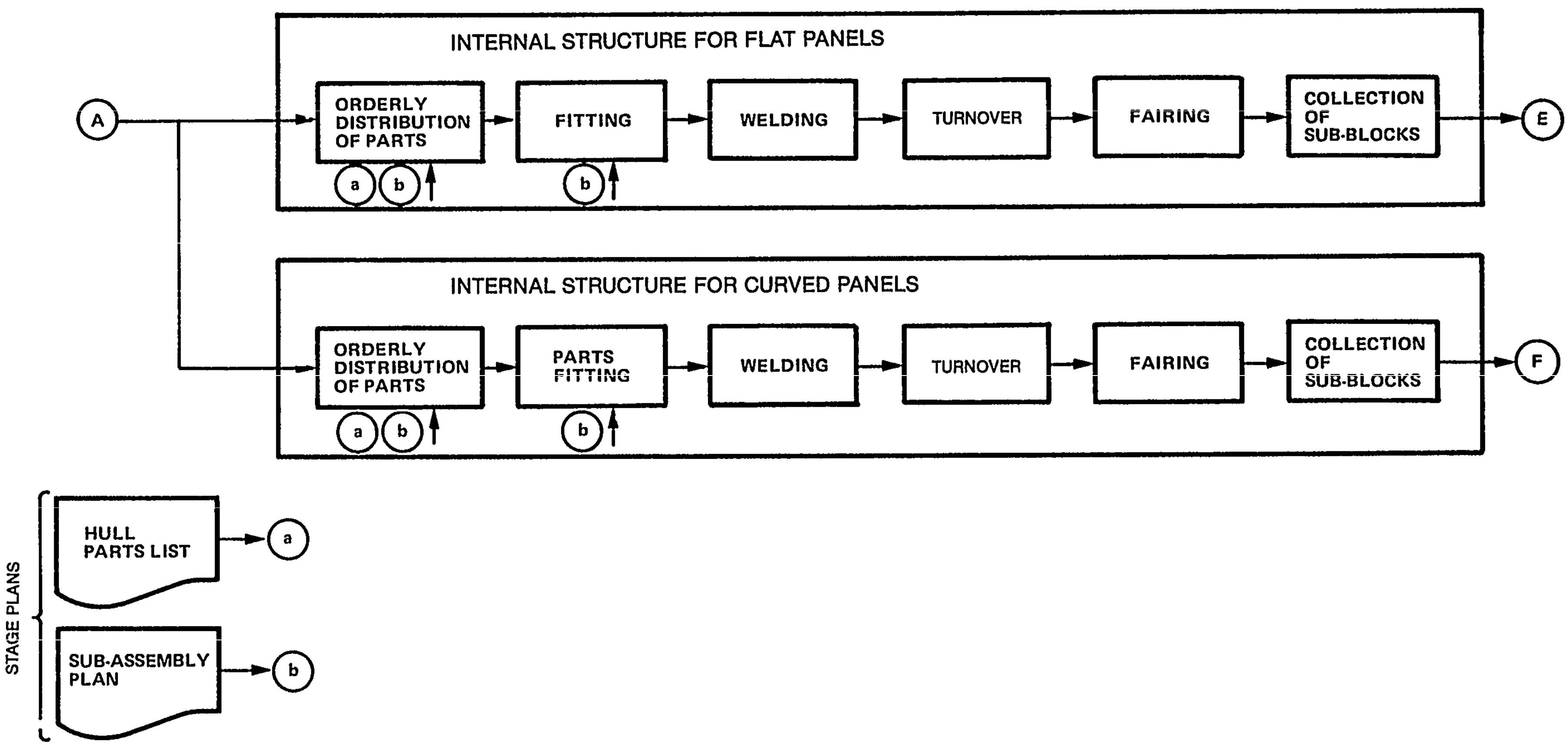


FIGURE 6-4: Typical Subassembly Process Lanes.

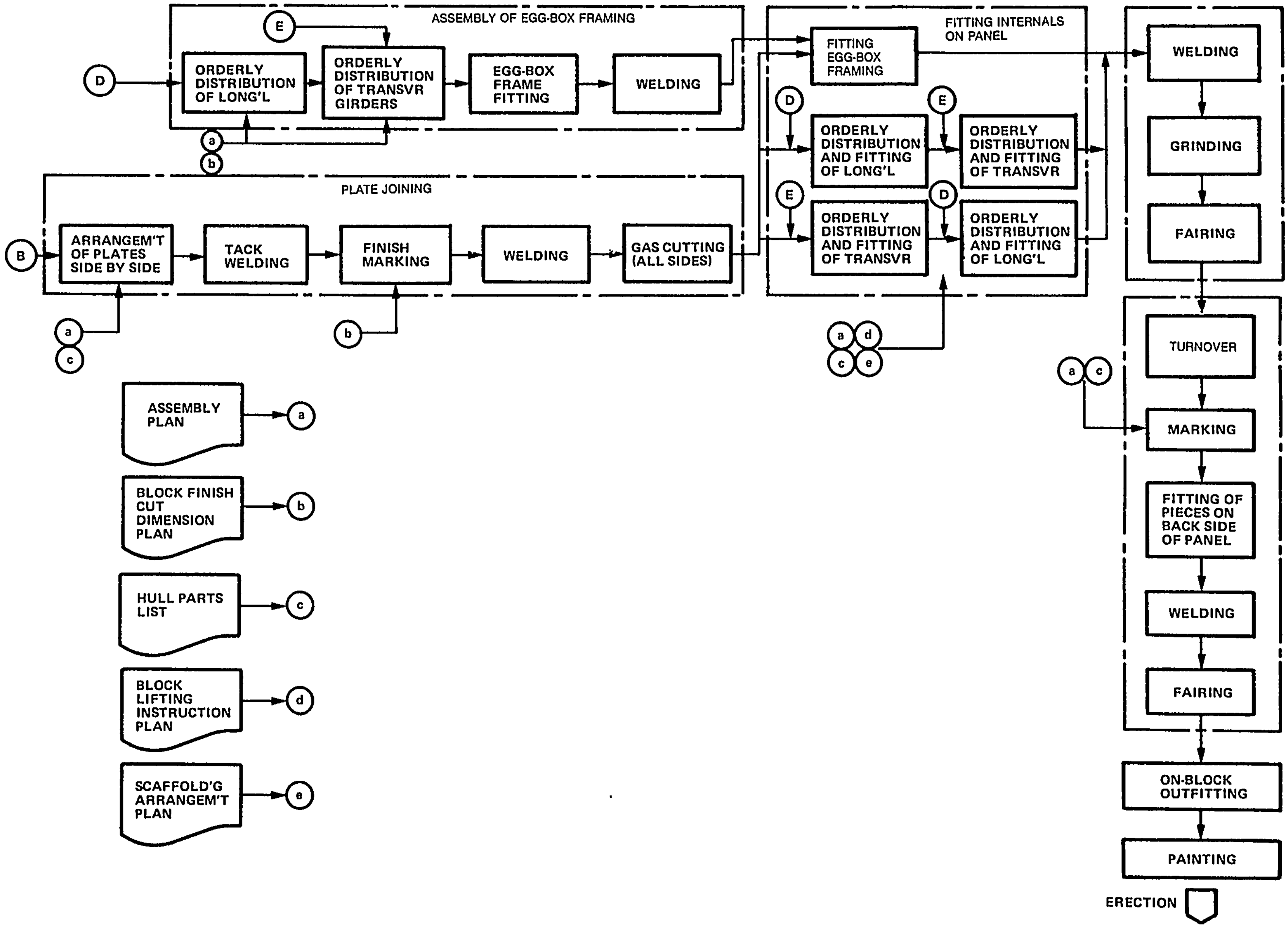


FIGURE 6-5: Typical Flat-block Assembly Process Lanes. For *plate joining*, locating *finish marking* before *welding* means that an efficient A/C system exists for accurately predicting the shrinkages that occur during welding. Three alternative flows are shown for *fitting internals on panels*. The variation equations employed during A/C analysis determine which such flows are employed. The entire *flat-block assembly process* is usually characterized by the developing blocks moving from stage to stage, i.e., *real work flow*.

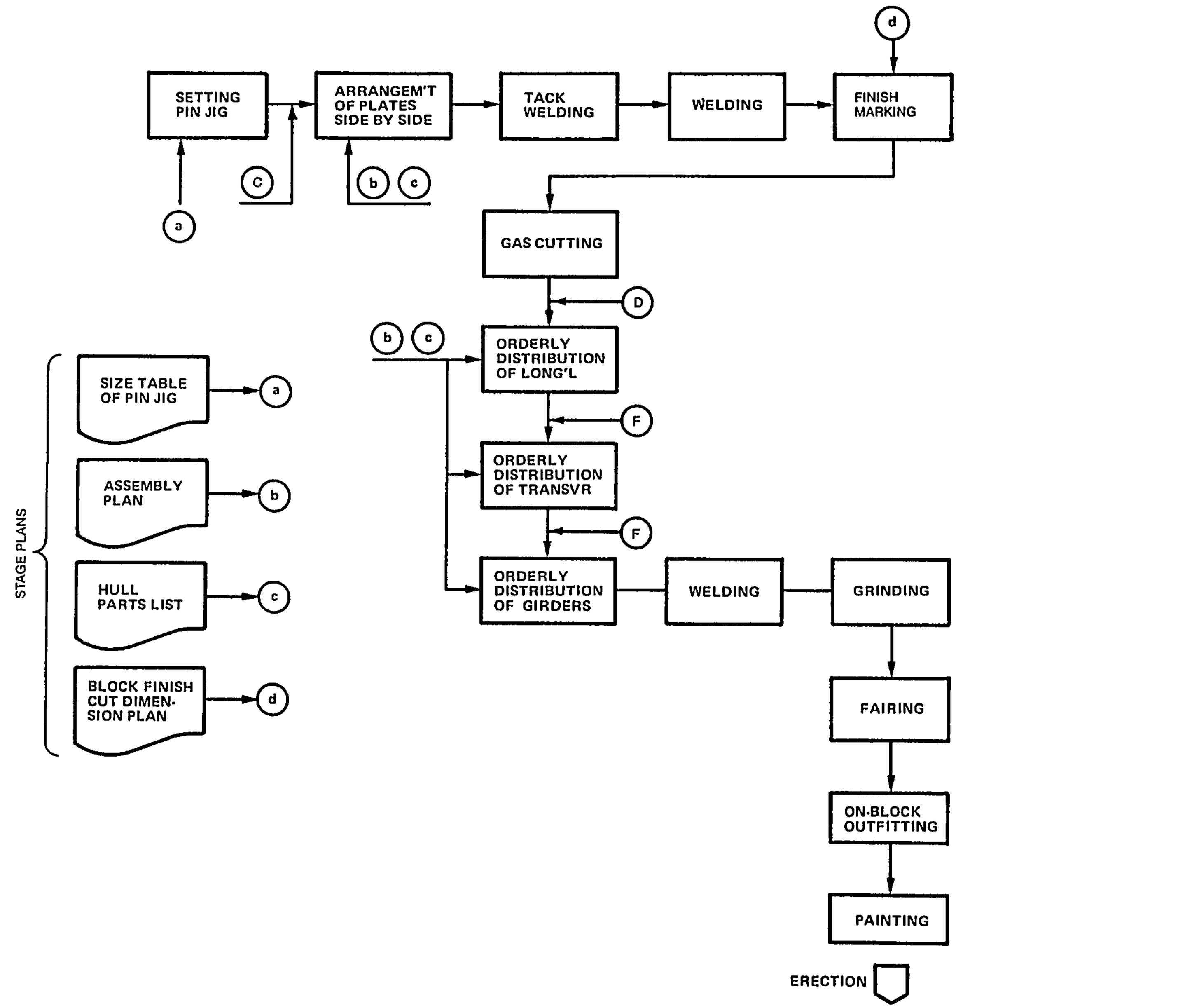


FIGURE 6-6: Typical Curved-block Assembly Process Lanes. For each block, the various stages are usually implemented on one pin-jig site. Specialized work teams shift from site to site. As the effect on the workers is the same as if they were stationed on a conveyor-equipped production line, the process is described as *virtual work flow.*

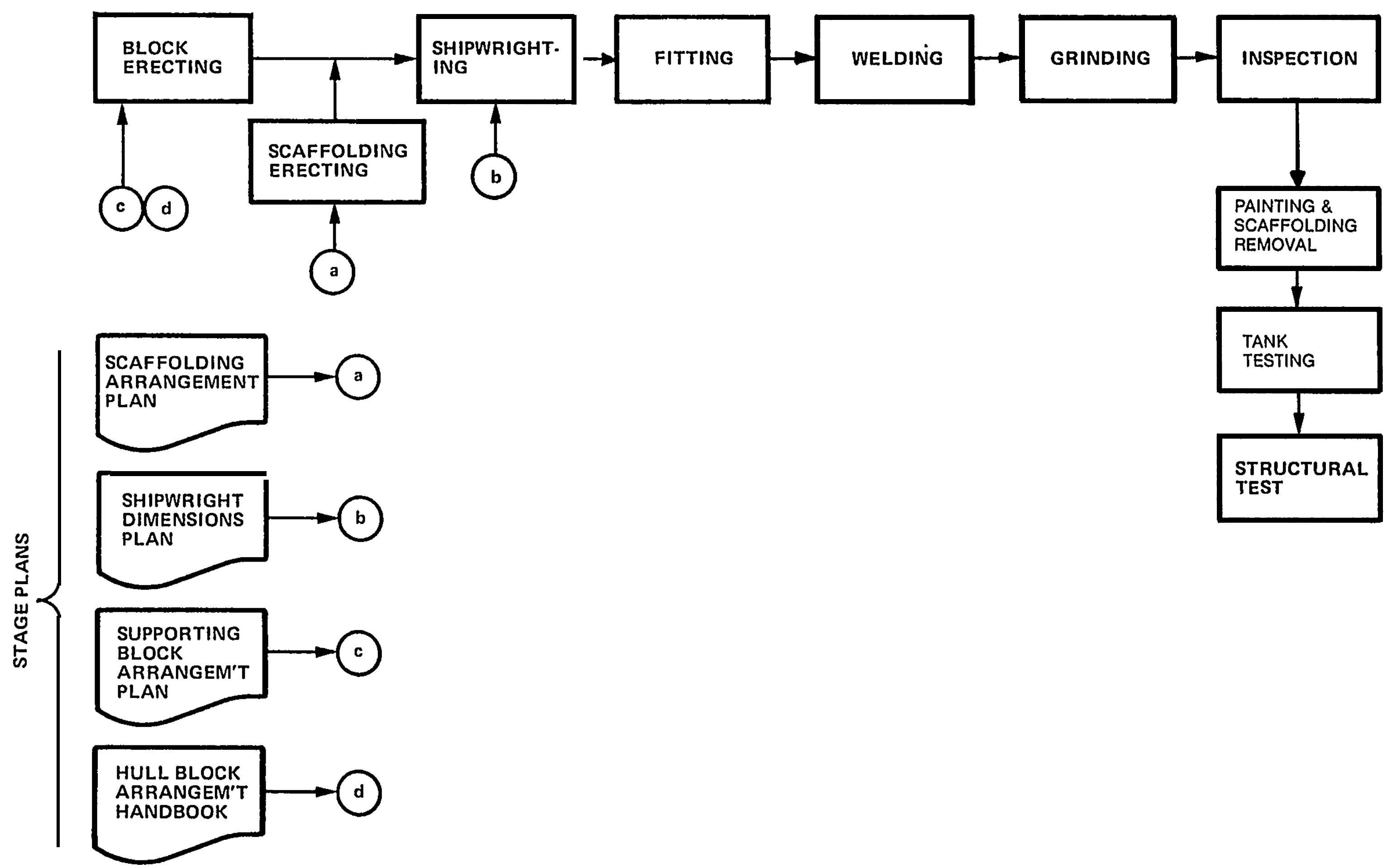


FIGURE 6-7: Typical Erection Process Lanes. This process is also described as *virtual work flow.*

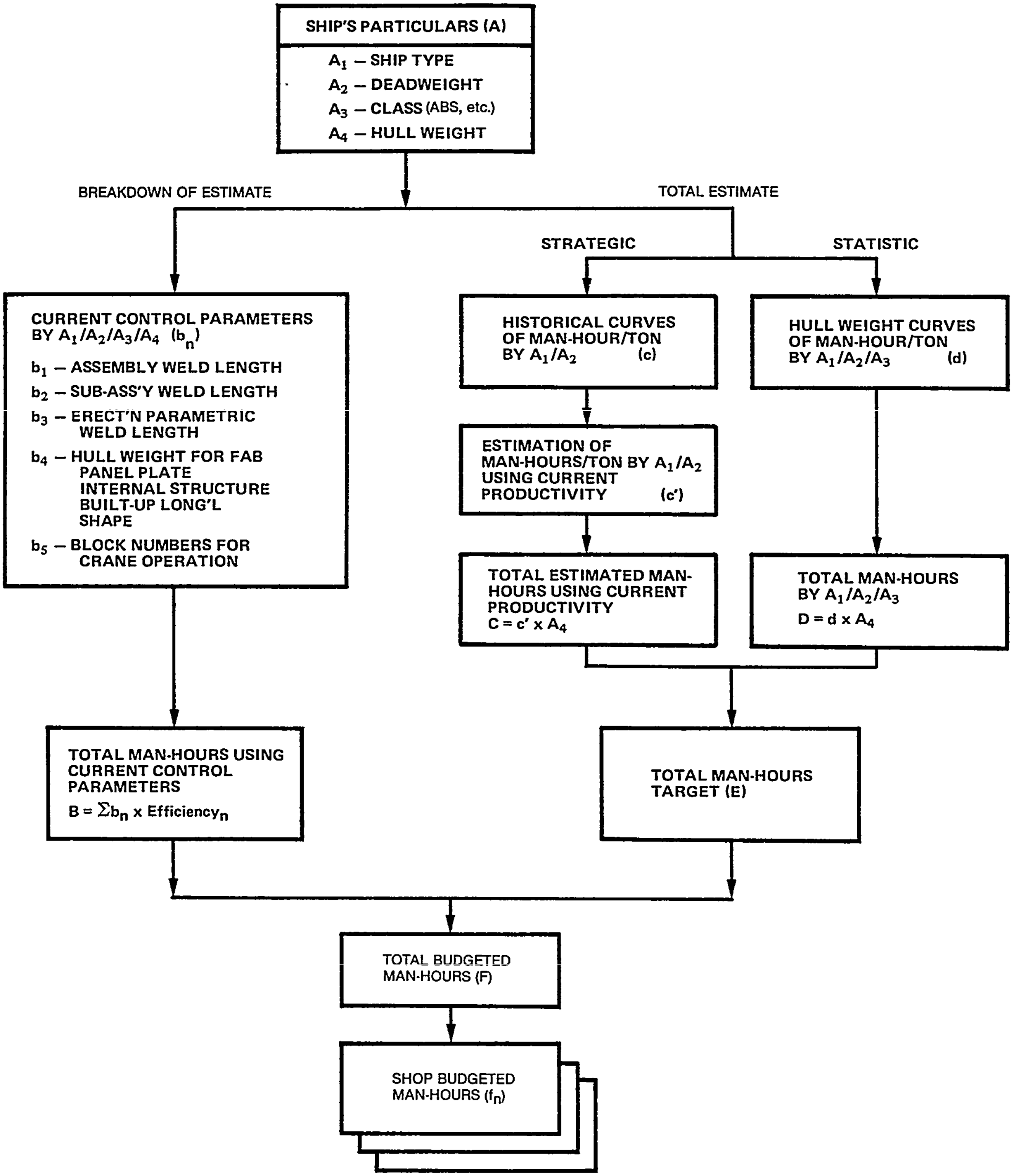


FIGURE 6-8: System for Determining Man-hour Budgets.

7.0 SHOP LEVEL PLANNING AND SCHEDULING

Each shop of the hull construction department is responsible for planning and engineering its own processes and for associated scheduling, material control, accuracy control, etc. Production engineers assigned to each shop insure that all pertinent shop documents are consistent with the logic and principles of IHOP.

For steel receiving, storing and issuing control, steel is requisitioned in relatively small lots which support block-by-block parts fabrication. Overstocking is inefficient because it commits capital and storage space that could be more productively employed. Also, overstocking generally increases man-hours spent for handling and causes misappropriations with attendant risks of disrupting the fabrication and following processes.

Upon material receipt, the following control techniques are implemented:

- storage of standard sizes at designated places size-by-size, otherwise by fabrication sequence/block/process lane, and
- issuing and transferring material by lot/day in accordance with issue orders which reference cutting plans (the need to facilitate material handling at the fabrication stages has priority over all other considerations).

7.1 Mold Loft

7.1.1 *Scheduling*

The schedule which controls the mold loft is organized by ship/block/day. Manning curves/block are determined from this schedule which is based on normal performances. But, the mold loft guidance prepared by a production engineer during detail planning (working) explains details and other essentials which are for the purpose of avoiding past inefficiencies and errors in order to further improve productivity.

Actual progress and man-hours spent are readily visualized when each day a colored pencil is used to indicate completed work on the shop schedule and spent man-hours on the manning curve. When one is divided by the other, the quotient is an indicator of productivity, e.g., man-hours/block.

As&e time allowed for design development and lofting is not extraordinary, expediting effort by the production engineer assigned responsibtities for inputs to and outputs from the loft are always worthwhile. For this purpose, the ***mold*** loft and yard plan issue advance curves are employed. These S-curves, plotted by number of sheets of yard plans vs. time, ***are*** schedules which when annotated with colored pencil clearly show the progress of yard plan receipts and processing by the loft. Expediting requires awareness that:

- overexpediting may cause loft errors which could snowball in succeeding work processes, and
- insufficient expediting could seriously disrupt compliance with coordinated schedules for IHOP.

7.1.2 *Accuracy Control*

Most of the loft errors and accuracy variations which cause problems remain undetected until assembly and erection. There, rework activities because of such problems are greatly magnified. In a well managed mold loft, process variations are usually too small to justify the application of classical A/C theory. However, loft errors (mistakes, omissions, etc.) are of great concern because they can be sleepers for untimely disruption. Error prevention measures such as the following are of utmost importance:

- a countercheck system by senior loftsmen following self-checks by loftsmen performing the work,
- routine education and training,
- clear mold-loft instructions and stage-plans guidance prepared by production engineers,
- written procedures for checking, recording, classifying and statistically analyzing errors, and
- maintenance of loft defect lists and posting graphic representations of frequency of occurrence.

7.2 Fabrication Shop

7.2.1 Scheduling

The shop fabrication schedule is made by process yard with reference to the erection and assembly master schedules. Start dates for each process yard are staggered as their rates of production are different and the parts needed for assembly must all be ready at the same time. For example, marking and cutting of parts which require bending are scheduled to start earlier than parts which are not to be bent. Particular care is given to fix the lead times for fore and aft body parts which are to have complex shapes.

Further, the shop production engineer who prepares the scheduIe considers the need to maintain uniform work flows, e.g.:

- relatively small parts or those which require a disproportionate amount of time for intricate cutting (also parts requiring special beveling) are separated from the main work flow, and
- identical parallel parts required for several different blocks will be flame planed in succession rather than per block in order to minimize tooling changes (productivity of a flame planer depends largely on the number of times gas-cutting tips are rearranged).

7.2.2 ***Material Control***

The objective of in-process material control is to deliver all required finished parts just in time for subassembly or assembly. Follow up is facilitated by providing a column on each hull-parts list for checkoff with colored pencil. This indicator of parts completion and sufficient material handling resources are especially necessary for collecting parts for one block that have been distributed in cutting plans for several in order to reduce scrap. In such cases additional time must be allocated for collecting all parts needed per block.

7.2.3 ***Progrers and Productivity***

In addition to checking off completions on the hull parts list, annotations in colored pencil are entered on schedules. The weights of parts completed are accumulated daily and spent man-hours are accumulated biweekly. This information is plotted on graphs per ship as:

- ***weight of completed parts vs. time*** for progressing, and
- ***spent man-hours vs. weight of completed parts*** for assessing productivity.

7.2.4 Accuracy Control

As the fabrication process precedes all other hull construction processes, the accuracy of parts is directly related to productivity and qualiy achieved during subassembly, assembly and erection. Thus, systematic A/C measures are required such as:

- the production engineer assigned to the fabricat shop, maintaining accuracy standard ranges and tolerance limits, for marking, cutting and bending, which are statistically derived from normally formed work,
- the shop manager assigning A/C tasks as collateral duties, e.g., self-checks by workers and sampling and recording variations by immediate and interme supervisors,
- posting statistical charts which advise how the processes are performing, disclose problems caused b ratically performing workers or machines (generally only 15%), and which indicate the problems cause the parts-fabrication system,
- educating shop personnel about how to read statistical charts and the significance of the A/C prograr
- giving meticulous attention to obtaining very sm gas-cut surfaces (this involves balance of nozzle-tip size, cutting-torch speed and height, and fuel- and oxygen-gas pressures for a given steel type and thickness and ***constant*** inspection of nozzle tips, cleaning clogged tips and replacing damaged tips).

A singular A/C function is to identify the amounts of excess material needed to ***exactly*** compensate for shrinkage caused by heat-applied processes, i.e., gas-cutting, welding and line heating. In some shipyards, the results of A/C analysis of shrinkage variations encountered are fed to computer-aided hull parts generation systems. The compensating excess is automatically included in the overall dimensions for each part and in layout dimensions for panels. Regardless of the data-processing method, net dimensions are provided by the hull structural design group while gross dimensions are the responsibility of the HP group.

Because ***the need to improve the manufacturing system never ceases,*** field engineers and shop supervisors who have A/C responsibilities are constantly improving work methods. One of the best examples is the development of line heating, i.e., systematic heating and cooling to very accurately and productively form curved parts to facilitate curved-block assembly. Statistical analysis of variations

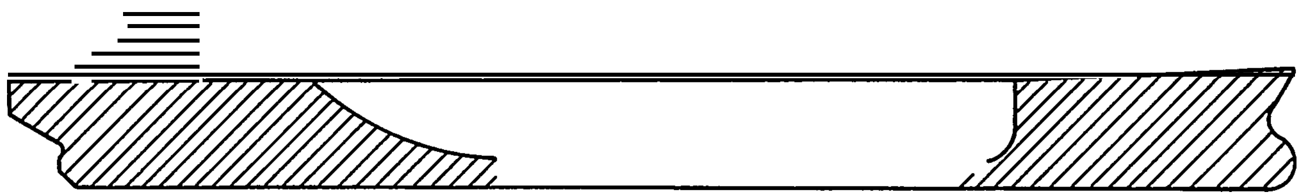


FIGURE 7-1: The Application Range for Bending Shell Plates by Line Heating. Typically for a 140,000-deadweight ton bulk carrier, line heating is employed to form 180 curved plates aft and 164 foreward. There are 302 flat plate and press bending is applied to 18 plates for the round gunwale and to 12 plates for turn-of-the-bilge.

normally achieved in curved-part dimensions provoked accelerated development of line-heating techniques so that they are as easy as welding for workers to learn.

Line heating, judiciously used in conjunction with a press as compared to just pressing facilitates:

- forming larger size plates into more complex or "tight" curvature as required for any shape bulbous bow, stem, stem, etc.,
- forming longitudinals having complex bend and twist,
- the use of semi-automation, e.g., a multi-torch line heating machine, and
- reductions in reauired man-hours by 1/2 to 1/3 while freeing the press-for other employment.

Figure 7-1 shows the application range for applying line heating to shell plates.'

7.3 Subassembly Section

Separation of subassembly work from assembly work makes sense because sub-blocks and blocks have significantly different work contents that make process flows impractical. Addressing subassemblies separately, enables work to be considered in small increments that are very effective for work load leveling, i.e., providing constant rates of work. Other benefits include:

- improved productivity because laying out, fitting, welding, and distortion-removal work is more accessible,
- better welding quality because more welding is performed down hand,
- less material handling and administrative chores during assembly as fewer material items and le.s scaffolding are then required,
- large facilities, e.g., heavy-capacity cranes and buildings with high ceilings and large doors needed for assembling blocks, are not occupied with work that can be performed elsewhere, and
- more opportunity to apply labor-saving devices, e.g., conveyors, automatic welders and eventually robots.

As many different sub-blocks are required in varying quantities, the application of group technology is employed in order to obtain the benefit of production line operations which are especially engineered for sub-blocks. For example, after ***flat*** sub-blocks are separated from ***curved*** sub-blocks their primary grouping is not by similarities in design. Instead it is by work content. When a group is large, it is scheduled for manufacture in a process flow. Groups which are small are jobbed using resources that do not diminish support of the process flows, e.g., overtime, second shift, workers borrowed from the assembly section or erection shop, or subcontractors. If subcontractors are employed, the shipyard's A/C requirements are invoked.

For more information on line heating see the National Shipbuilding Research Program publication "Line Heating - November 1982".

A technique which further facilitates work load leveling is production of relatively small weldments (assembled parts) as preparation for sub-block assembly. Assembled parts (typically one or two brackets welded to a short L-shaped section) are manufactured in a process yard which is dedicated to just such work.

7.3.1 Scheduling

A schedule is prepared for each process yard in accordance with the assembly master schedule. Important considerations are:

- separately addressing sub-blocks of the same family (same problem area and work content) for continuous running process flows,
- the time to be allocated between sub-block completion and block assembly and the limits of the sub-block storage areas,
- work load leveling based on man-hours per welding lengths.

7.3.2 Material Control

Material control at first addresses receipt and organization of parts required for manufacturing sub-blocks. Sufficient storage space is provided between the fabrication and subassembly yards for collecting and sequencing parts as required by subassembly schedules. As their efforts directly impact on productivity, material handlers and the information prepared for them have to be well organized. Special provision on the hull parts lists facilitates color annotations of the status of needed parts. The lists are also color annotated to maintain the status of sub-block completions. The accuracy of such data is vital as material handlers are required to collect, sort and stow sub-blocks for minimal periods in relatively little space.

7.3.3 Progress and Productivity

The progress of each process yard is checked daily by coloring the space provided for:

- receipt on the parts list for each sub-block, and
- completions on the subassembly schedule.

As welding comprises the major work effort, a most ful productivity indicator for subassembly work is ***arc tim per welder.*** Thus, production engineers who maintai awareness that the obligation to improve the manufacturin system never ceases, constantly strive to:

- increase ***welding length/hour/worker*** by enhancin worker skills and welding equipment,
- extend the use of automatic and semi-automatic (gravity-feed welding devices) methods,
- apply mechanical aids such as for turning over or trans ferring subassemblies, and
- increase interchangeabilitv of workers among all sub assembly types of work, i.e., material handling, fitting welding and fairing.

In order to monitor the rate at which productivity is im proving, the following performance indicators are plotte and ***posted*** at each subassembly flow lane

. ***man-hours/sub-block weight,*** and

. ***man-hours/welding length.***

7.3.4 *Accuracy Control*

During subassembly there are two A/C considerations:

- ***control for assembly***

  Inaccurate sub-blocks adversely effect assembl schedules and productivity. Therefore, accuracy relate problems described in feedback provided by the assem bly section must be immediately resolved.

- ***control for fabrication***

  Similarly, inaccurate parts adversely effec subassembly schedules and productivity. Therefore, ac curacy related problems must be promptly describe and fed back to the fabrication shop for resolution The consequences of such problems justify monitorin the impact of remedial efforts.

7.4 *Assembly Section*

Block assembly is the last process before hull erection an is initiated by material handlers who coordinate their c tion of subassemblies with the arrival of parts for a panel o which a block is to be assembled.

For organization of process flows, flat-panel blocks which require flat platens for their assembly are separated from curved-panel blocks which require pin jigs. Separate process yards are also organized for each of the other type blocks which impose different manufacturing problems and have widely varying work contents. Typically these include fore- and aft-body and engine-room blocks.

7.4.1 *Scheduling*

Separate schedules are made for each process but are kept within restraints ordered by the assembly master schedule. The block assembly guidance and assembly plan provide, beforehand, required stage sequences, welding lengths, need periods for outfitting and the time that a crane is required at each stage. Thus, the field engineers are able to prepare for each assembly yard a:

- manning schedule for welding, and
- crane schedule.

7.4.2 Block Storing

Productivity of the hull construction department is greatly dependent on planning for storing blocks. Theoretically, the assembly of each block should be completed just in time to meet hs scheduled erection date. This would:

- preclude need for relative large land areas and would minimize work associated with transferring and supporting bulky and heavy blocks, and would
- create more pressure to improve assembly processes until blocks were produced at the same rate that they are needed by the erection shop.

However, production engineers also have to consider:

- different quantities of required work (typically for hull construction: fabrication 10%, subassembly and assembly 50%, erection 40%),
- need to level load all shops,
- authority to transfer workers between shops, assign overtime and employ subcontractors, and
- costs for facilities (those for an erection dock and cranes are usually the most expensive).

Where shipbuilding is most efficient, the resulting trade-offs are manifested by

- a single building dock in which ships are rapidly erected,
- enough land to accumulate before keel laying, 40 to 60%'o of the blocks required per ship dependent on ship type and size, and
- enough resources to complete the remaining blocks in time to sustain a smooth work flow during remarkably short erection periods (2.5 to 4 months dependent on ship type and size).

Thus, planning for the storage of blocks is very dynamic and requires the utmost discipline in scheduling. Necessarily, some land avocations made before keel laying for a specific ship are reallocated as blocks are erected and additional blocks are produced after keel laying:

- for the same ship, and
- for accumulating blocks before keel laying of a second ship, and so on.

Other factors that production engineers must consider are the bulk of each block and actual block assembly progress as related to assembly schedules.

7.4.3 *Material Control*

Most sub-blocks are of sufficient size to be readily located. However because of their bulk, it is important that material handlers be controlled to insure delivery of sub-blocks to the particular stages of the assembly process yards in planned assembly sequences. This transfer effort requires meticulous crane schedules and skilled material handlers to insure that the schedules are faithfully implemented. Sufficient, not excessive, storage areas next to the stages where sub-blocks are needed enhance efficiency.

7.4.4 *Progress and Productivity*

Welding dominates assembly just as it dominates sub-assembly. Assessment of the lengths to be welded is needed beforehand to allocate the required number of welders per day commensurate with schedule adherence. Just enough material handlers, fitters and crane operators are allocated to avoid disrupting uniform welding-work flow. Thus, continuing to improve block-assembly productivity is dependent on:

- continuous improvement of welding productivity, and
- continuing necessary support service while minimizing the number of support workers.

Particularly regarding process flows organized for flat- and curved-block assembly, every effort is needed to avoid disrupting influences. If the assembly of one block stalls, work for all succeeding blocks and possibly for erection is adversely affected. Disruptive influences include:

- change orders,
- failure to exploit statistical control of manufacturing (A/c),
- manufacturing errors,
- errors in relocating durations required particularly for outfitting and painting.

Changes in block assembly productivity are assessed by monitoring:

- block weight/unit time (biweekly),
- welding length/unit time (biweekly),
- ***total*** man-hours/welding length,
- ***welder*** man-hours/welding length, and
- ***fitter*** man-hours/welding length.

7.4.5 *Accuracy Control*

As for subassembly processes there are two A/C considerations:

- ***control for erection***

  Inaccurate blocks adversely effect erection safety, schedules and productivity. Therefore, accuracy related problems fed back from the erection shop must be immediately resolved.

- ***control for sub-assembly***

  Similarly, inaccurate sub-blocks adversely effect block assembly schedules and productivity. Therefore, accuracy related problems must be promptly described and fed back to the subassembly section for resolution. The consequences of such problems justify monitoring the impact of remedial efforts.

More especially during assembly work, as compared to fabrication and subassembly, responses to the identification of problems by statistical techniques (A/C) is paramount. Emphatically, the productivity of the entire shipbuilding system is largely dependent on how effectively the assembly section has mastered A/C methods. When traditionalists release blocks for erection, there is insufficient knowledge about their accuracies. Required rework in a building dock involves relatively dangerous circumstances and hard-to-predict man-hour costs and durations which should be scheduled. Rework diminishes managerial control of production.

Statistical analysis of dimensional variations identified in sufficient accuracy of curved blocks as a particular problem. Production engineers responded by developing ***pin jig*** which are the most economic means for accurately creatin a curved surface in space strong enough to support a curve panel on which a block is to be assembled.

The pins are permanently freed equidistant from eac other in a base plane (x,Y) and are adjustable in the vertica direction (z). As two of the coordinates are fued, computer-terminal equipped mold loft can provide a tabl of pin-jig settings for each block that is readily understoo by workers.

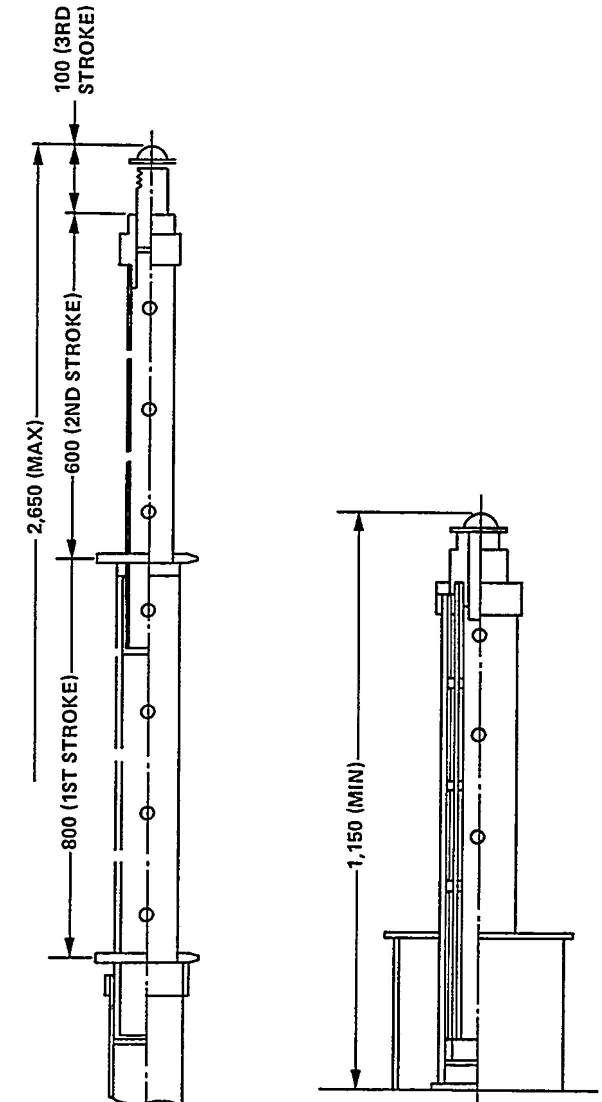
In spite of high initiaI costs, pin jigs are productiv because they are reusable for different curvatures an because they can be reset by relatively unskilled workers For a typical curved block, only one to two mandays are re quired for setting pin-jig heights provided the jigs are tele scoping and vernier equipped as shown in Figure 7-2.

7.5 *Erection Shop*

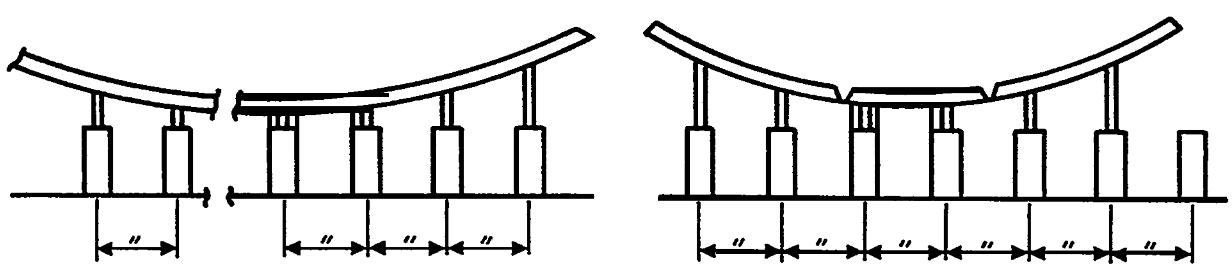
The erection process finalizes hull construction work an the erection schedule is the determinant for the hierarchy schedules for preceding work, i.e., assembly, subassembl and fabrication.

Hulls are erected in much the same way pyramids we erected in Egypt, block by block. Work is planned per hol or zone for stage-by-stage implementation. The stage include:

- block erecting,
- shipwrighting,
- scaffold erecting,
- main-structure fitting,
- main-structure welding,
- substructure fitting,
- substructure welding,
- on-board outfitting,
- cleaning and painting,
- internal visual inspection,
- scaffold removing, and
- tank testing.



PIN-JIG **DETAILS (RANGE 1,150** mm **TO 2,650** mm)



FRONT VIEW

SIDE VIEW

Pin Jig Arrangement (Dittos indicate equal distances. PinJig positions are fixed regardless of seam locations.)

FIGURE 7-2.' Pin Jigs. In spite of high initial costs, pin jigs are productive because they are reusable for different curvatures and because they can be reset by relatively unsktied workers. For a typical curved block, only one to two man-days are required for setting pin-jig heights provided the jigs are telescoping and vernier equipped as shown. Setting pin-jig heights could easily be done by a robot.

7.5.1 *Scheduling*

Scheduling for hull erection is performed as described in Part 6.1.2. Additionally, effective erection scheduling requires that:

- keel laying be ordered as soon as possible after launching a previous ship, and
- carefull coordination of scaffolding installations and removals with schedules for block erection, inspection and painting.

7.5.2 *Progress and Productivity*

Erection work must be thoroughly implemented zone by zone without any unfinished work remaining. Control of bits of outstanding erection work is difficult. Also, return to a previously worked site often requires reinstallation of temporary services and conflicts with outfitting on-board and finish painting. Unfinished erection work in congested spaces, such as engine and pump rooms, can have a deleterious impact far out of proportion to the amount of erection work which remains.

Welding-control sheets, which identify the types and parametric lengths of welds by zone, are color annotated each day by first level supervisors to check off completions of work. The welding-control sheets are particularly essential for welding internal structure because much is hidden and missing welds could easily remain undetected until after the ship is at sea.

The progress data annotated on welding-control sheets is used to adjust the manning plan for each zome/day. Completed work volumes by man-hour, weight, welding length, etc. are noted and compared to the data provided in detail hull construction production plans.

Erection progress is plotted as ***Ianded-weight/day*** and separately as ***welding parametric-length/day.*** Productivity is plotted as ***man-hours/landed-weight*** and separately as ***man-hours/welding parametric-length. As*** shown in Figure 7-3, when a straight-line plot for estimated man-hours for landing blocks and welding is superimposed on the man-hours/landed weight graph, the man-hour difference for each accumulation of weight provides a good indication of outstanding erection welding.

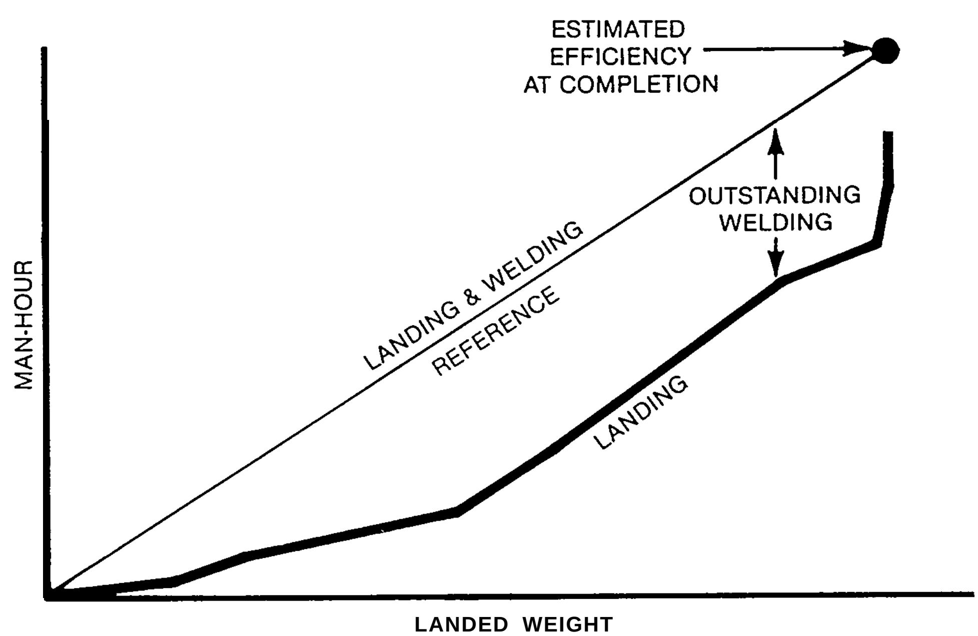


FIGURE 7-3: Productivity - Hull Erection. Because landed weight accumulates much faster than the progress of welding, field engineers employ a ***landing and welding*** straight-line reference based on estimated efficiency upon completion. Then, that portion of the ordimte between the two curves is an indication of outstanding welding man-hours relative to landed weight.

7.5.3 *Accuracy Control*

As for the previous hull construction processes, A/C during hull erection generates the feedback needed to advise the assembly section of problems encountered with blocks. The feedback also includes comments about vital points and dimensions that would further facilitate erection. However, the most significant element of the feedback is complete detailed data from which an A/C analysis report for hull erection is prepared. Typically, relative to the total lengths of main-structure butts and seams, the report identifies exact lengths, pertinent widths and locations where rework was necessary, i.e., gas-cutting and back-strip welding.

The purpose of the feedback is to provide production engineers with clues as to what design details, tolerances, work methods and allowances for shrinkages should be adjusted to further improve productivity of the hull-construction system. Shipbuilders who have mastered exploitation of such A/C feedback, cut virtually all parts neat. They regularly achieve perfect alignment of over seventy percent of all major structure when erecting a unique ship or first ship of a class (at least eighty percent for a second ship of a class).

A second aspect of A/C during hull erection addresses fairing or removal of any deformation caused by erection fitting and welding. The objectives include need to maintain the validity of vital points and reference lines in blocks already erected. The objectives also include need to achieve the degree of fairing specified in the shipbuilding contract.

7.6 *Time-frame Scheduling System*

One definition of the word ***frame is to enclose in a border.*** In this context, the ***time-frame scheduling system*** means ***ordering*** (scheduling) work for accomplishment within specific time frames (borders) which at first are relatively large because work required is not detailed.

As planning (design and resources definition) progresses through each phase as shown in Figure 6-1, the work required within each time frame becomes more detailed. In order to enhance control, the more “visible” work is ordered for accomplishment in subdivisions of the time frames first employed. This process is repeated for each planning phase so that scheduling is refined, as shown in Figure 6-2, commensurate with planning refinement.

The smaller time frames conceived at each level are not permitted to change the time boundaries established by a higher level schedule. This rule is necessary because the hierarchy of schedules must always be in the context of the highest level (erection master) schedule which orders implementation of a specific shipbuilding strategy relative to those for other projects.

Figure 7-4 is a tabulation of pertinent factors for an effective schedule hierarchy for control of shops. A graphic presentation of how they relate to each other is provided in Figure 7-5.

SCHEDULES	TIME		WORK VOLUME INDICATION			RESPONSIBILITY
	PERIOD	REVISED	SUMMARY UNIT	SUMMARY PERIOD	PARAMETER	
SHOP SCHEDULE	6 MONTHS	EVERY 2 MONTHS	INTERIM PRODUCT/ SHIPI PROCESS YARD	10 WORKING DAYS (2 WEEKS)	– WELDING LENGTH (ROUGH)	SHOP MANAGER
MONTHLY SCHEDULE	1.5 MONTHS	EVERY 2 WEEKS	STAGE/INTERIM PRODUCT/SHIP/ PROCESS YARD	5 WORKING DAYS (1 WEEK)	– WELDING LENGTH (ACCURATE) – NUMBERS PER CRAFT	INTERMEDIATE SUPERVISOR
WEEKLY SCHEDULE	2 WEEKS	EVERY WEEK	INTERIM PRODUCT/ SHIP/STAGE/ PROCESS YARD	1 DAY	– NUMBERS PER CRAFT – WORKER NAME	IMMEDIATE SUPERVISOR
DAILY SCHEDULE	1 DAY	EVERY DAY	INTERIM PRODUCT/ SHIP/STAGE/ PROCESS YARD	HOURS	– WORKER NAME	IMMEDIATE SUPERVISOR

FIGURE 7-4: Typical Elements of a Practical Time-frame Scheduling System. For the purpose of communicating work assignments, the term **work *station is*** substituted for the word ***stage.***

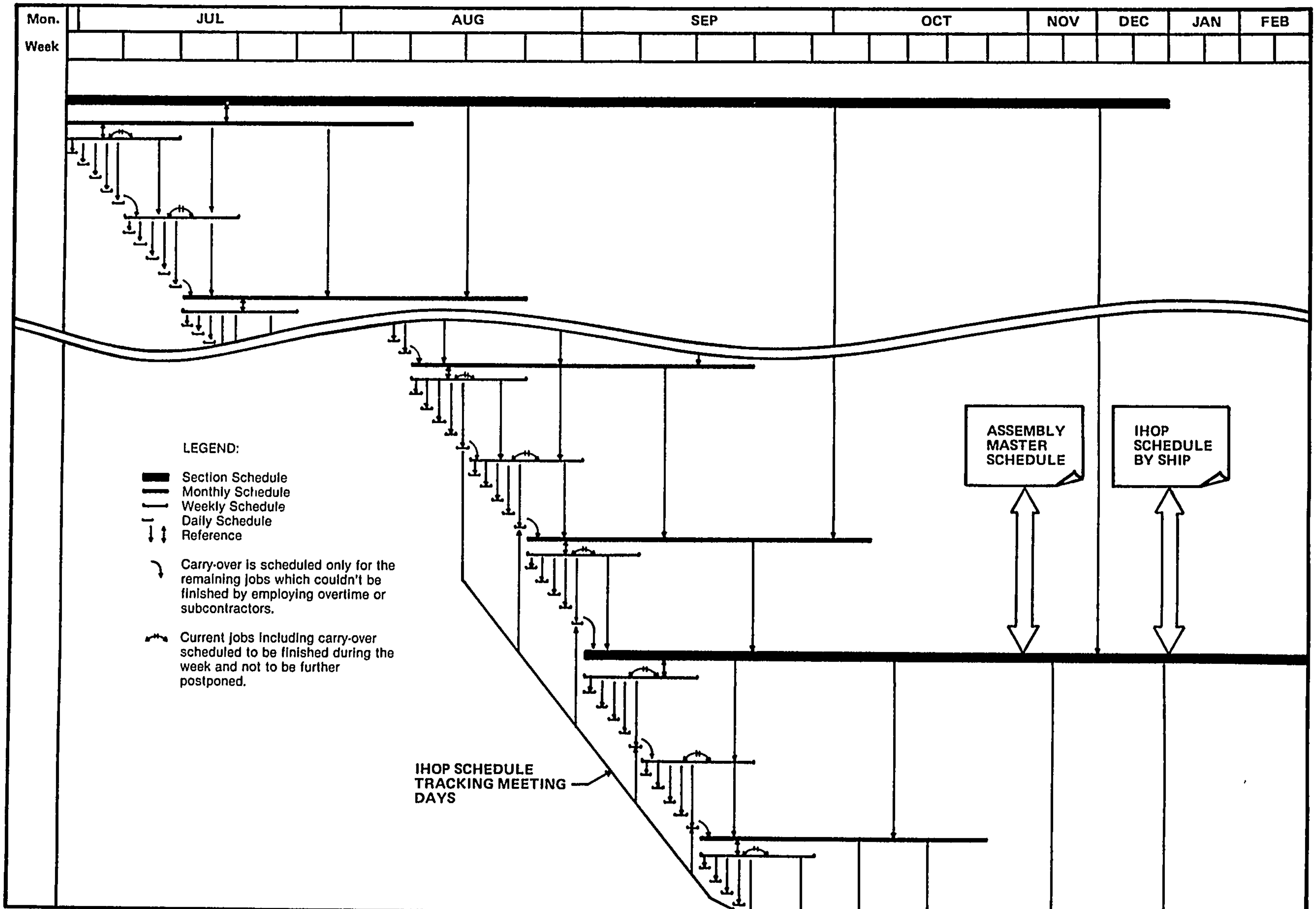


FIGURE 7-5: Logic of the Time-frame Scheduling System.