3.0 HULL CONSTRUCTION PLANNING

Other than the need to accomodate 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[1]

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 is 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, A/C 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.

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[1] 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 modern ship construction methods and made it possible to extensively develop 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".

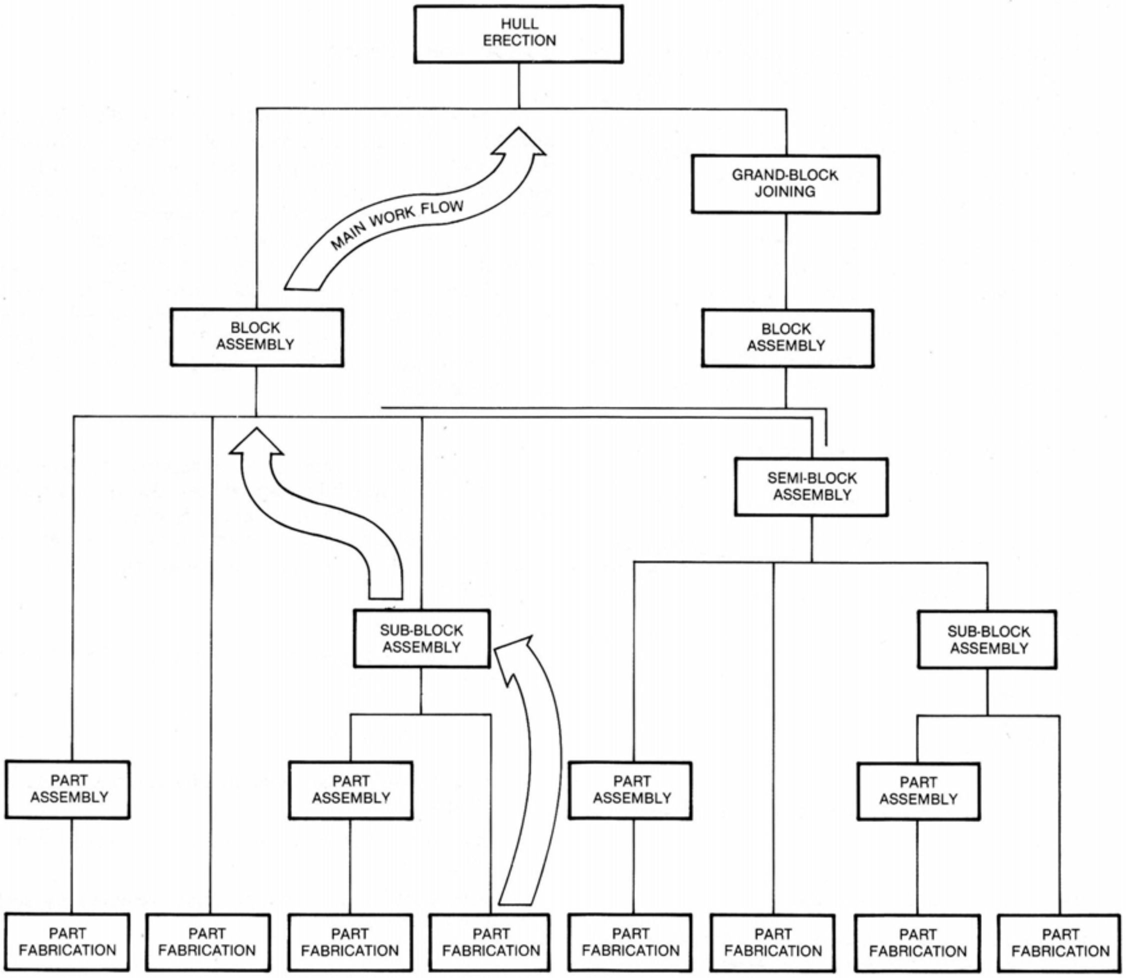


FIGURE 3-1: Typical Manufacturing Levels for the Hull Block Construction Method. A manufacturing level is achieved when a combination of work stages transforms various inputs into distinct interim products, e.g., raw materials into parts, parts into sub-blocks, sub-blocks into blocks and blocks into an erected hull. The levels which are not shown in the main work flow are for special circumstances.

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. *System* 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.

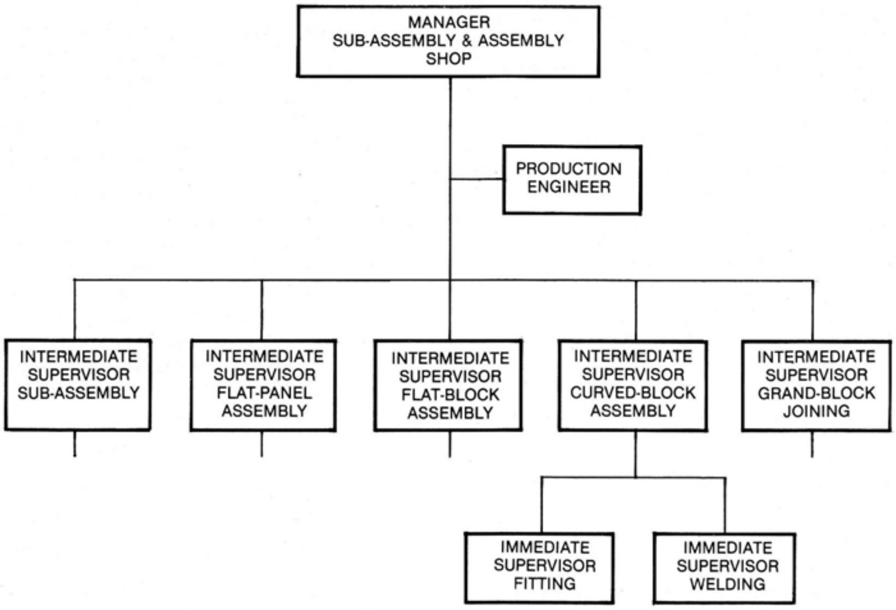


FIGURE 3-2: Typical Zone/Area/Stage Shop Organization.

- *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 category. 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 3-4 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,* fitting 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 Schedules with Outfitting and Painting Schedules*

  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 auxilary-machinery foundations and in supports for outfit units to be landed. The required marking and trimming during outfitting on-block is rework. Blocks which 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 (A/C) 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.

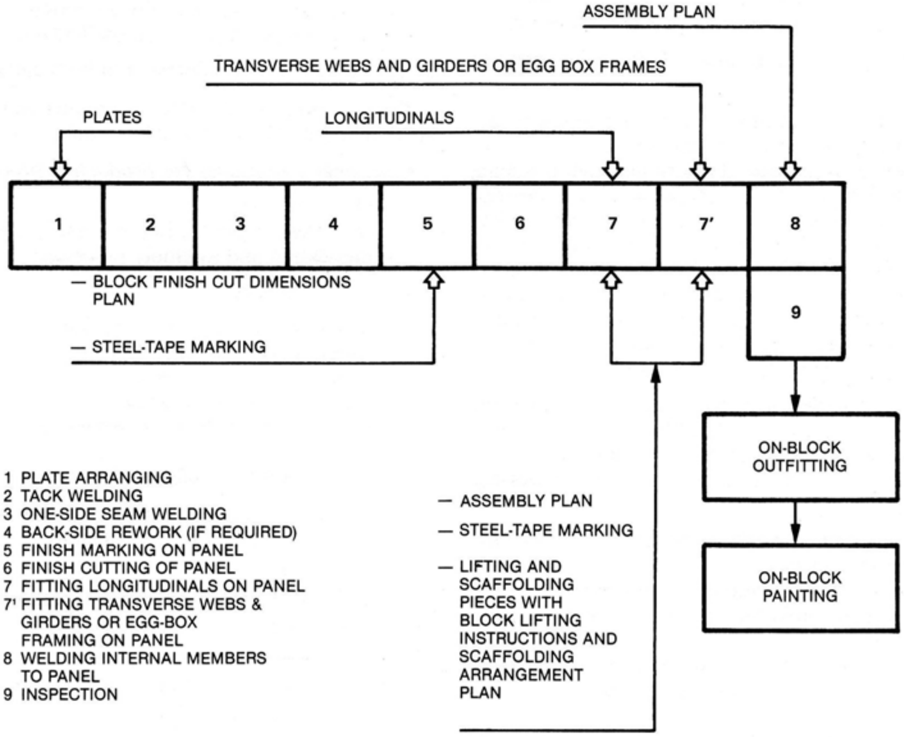
Standards and modules of production planning may be grouped into two categories:

- *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 engineers 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.



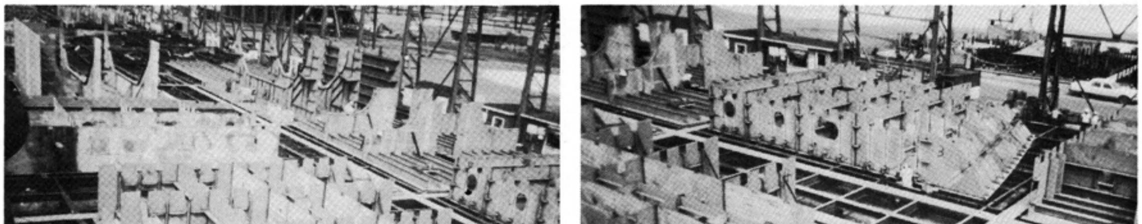


FIGURE 3-3: Typical Process Flow for Flat-block Assembly. The arrows indicate inputs for parts, sub-blocks, and stage plans. For inner-bottom blocks, stages would be added after position 8 for: outfitting, fitting bottom shell, turnover and welding bottom shell. As shown in the photographs, flat-block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

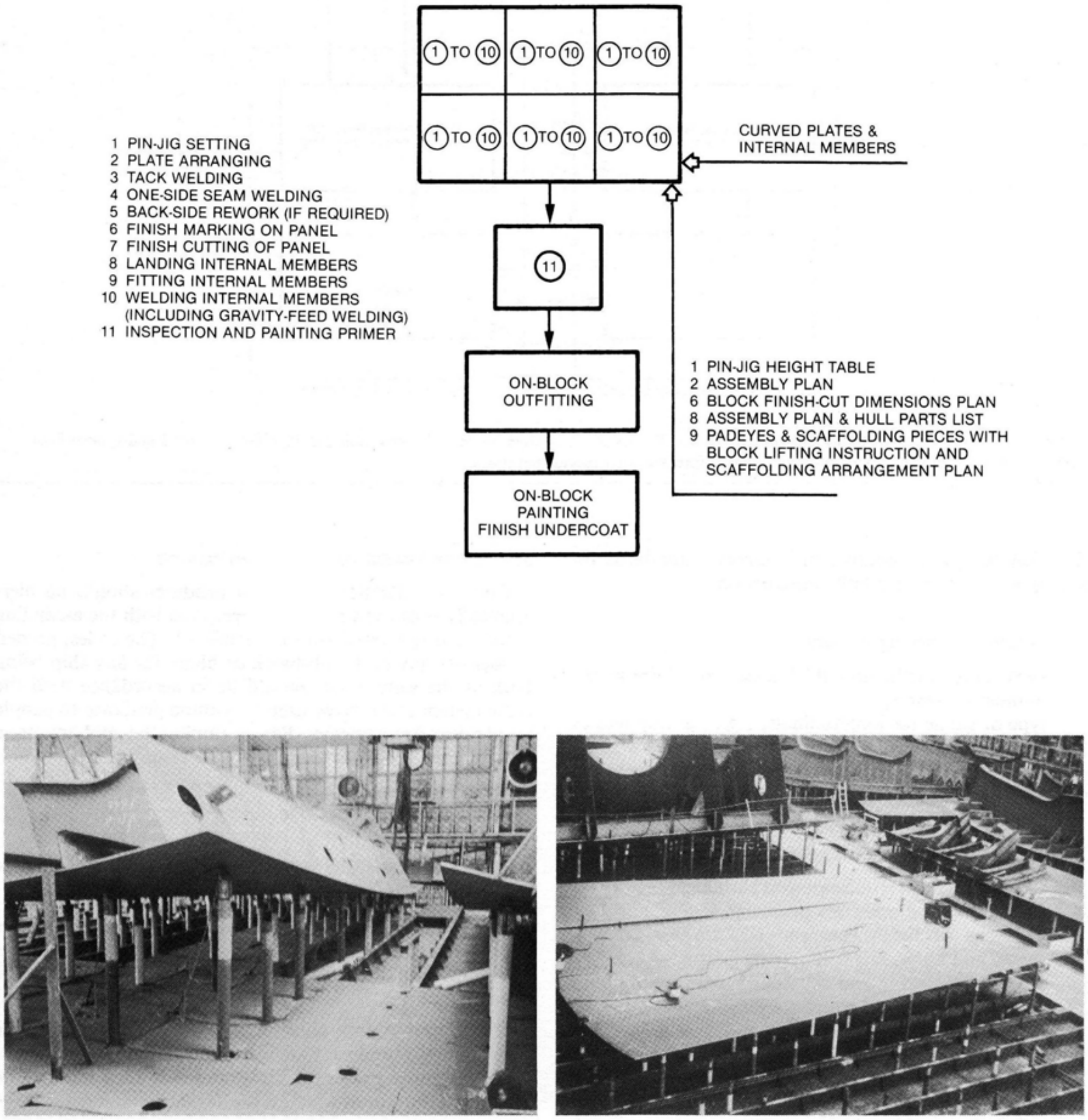


FIGURE 3-4: Typical Process Flow for Curved-block Assembly. The arrows indicate inputs of parts, sub-blocks and stage plans. All work stages for assembling each block are implemented in succession on the same pin-jig site. The specialized work teams shift from site to site. This technique is called *virtual* 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.

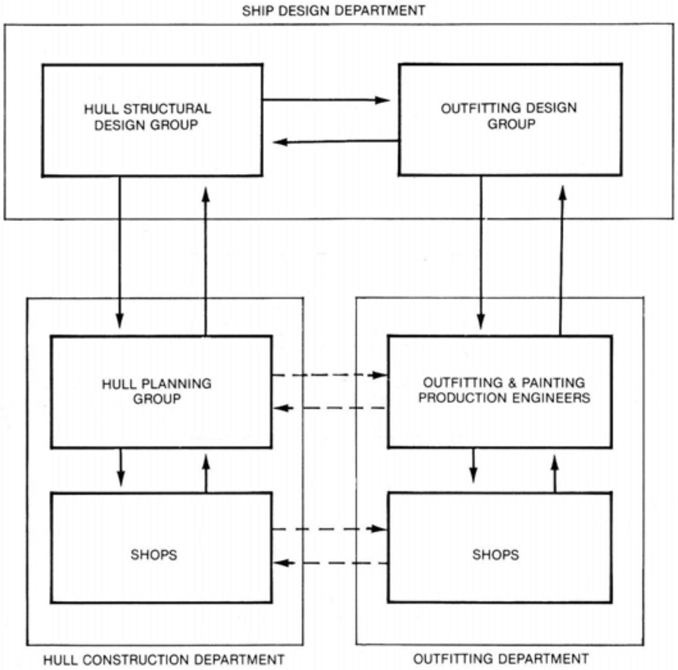


FIGURE 3-5: Communication Paths Between Design and Production Engineers for Hull Construction and Painting. The solid and broken lines respectively indicate primary communication paths before and after production starts.

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 longitudinals;
- *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 station;
- *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 hierarchically organized so as to correspond with the ascending maufacturing levels shown in Figure 3-1. The codes, needed to identify any part, sub-block or block for any ship being built at the same time, should be in accordance with the same system and convey useful common guidance to people in various departments. For example, the alphanumeric 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 *B* in the part code designates a bracket. Other letters are assigned to identify flat bar, web, face plate, etc. The number in the part code, *B8*, simply identifies a specific bracket type.

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

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