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THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

Outfit Planning

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

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FOREWORD

The outfitting methods described herein are based mostly on the sophisticated practices of Ishikawajima-Harima Heavy Industries (IHI) Co., Ltd. of Japan. They are per the authors' understandings and are supplemented with ideas from other sources.

Some of the techniques are or were practiced in the United States. Composite arrangement drawings marked to show how a ship is to be assembled and accompanied by structured material lists have their origin in B-29 drawings produced by the Boeing Airplane Co. Budget, schedule and material control organized in one department, was introduced by National Bulk Carriers, Inc. The latter also encouraged, among other things, the hull block construction method. Skyscraper construction in New York, also in the early fifties, stimulated application of the same logic to perfect zone outfitting and palletizing. The concepts, improved and combined by IHI with a very effective material classification scheme and other innovations, achieved unprecedented shipbuilding productivity. But, there are human prerequisites for their successful application.

IHI managers credit their excellent productivity record also to the high education levels possessed by middle managers. Virtually all have college educations or their equivalents. Further, this cadre is dedicated to managing the *process for assembling* ships. They are rotated in assignments which include actual conduct of functions such as production process planning and engineering, functional and detail design, and budget, schedule and material control. They also include incumbencies as assistant managers and managers of fabrication shops, assembly sections and various departments.

Preliminary copies of this book were used by a few U.S. shipbuilding firms for setting goals. Further, the Maritime Administration is continuing support, through the National Shipbuilding Research Program, to provide implementation assistance. A companion project which addresses a product oriented work breakdown structure, is nearing completion.

The authors of this book are C.S. Jonson and L.D. Chirillo respectively of Science Applications Inc. and Todd Pacific Shipyards Corporation, Seattle Division. Most of the substance was obtained by unprecedented arrangement between the latter and IHI Marine Technology, Inc.

Special appreciation is expressed to Y. Mikami, Y. Ichinose, K. Ogawa and Y. Okayama, IHI consultants and truly professional shipbuilders, for their continued concern and assistance even after contractural requirements were fulfilled.

Appreciation is expressed for the photographs that are incorporated and for the written critiques submitted in behalf of:

- General Dynamics, Quincy Shipbuilding Division
- Sun Shipbuilding & Dry Dock Co.
- Newport News Shipbuilding & Dry Dock Co.
- Peterson Builders, Inc.
- Avondale Shipyards Inc.
- National Steel & Shipbuilding Co.
- Todd Pacific Shipyards Corp., Los Angeles Div., and
- the Universities of Georgia, Michigan and Massachusetts.

Appreciation is also expressed to the people, particularly D.S. Hunter, of Todd-Seattle who furnished essential support.

This book results from one of the many projects managed and cost shared by Todd as part of the National Shipbuilding Research Program. The Program is a cooperative effort between 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 Naval Architects and Marine Engineers, emphasizes productivity.

This book is dedicated to the memory of
a shipbuilder
from Newport News, Virginia

Robert E. Thomas

February 5, 1926 – March 4, 1978

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1.0 INTRODUCTION

Outfit Planning is a term used to describe the allocation of resources for the installation of components other than hull structure in a ship. Methods applied in shipyards in other countries are recognized to have produced such benefits as:

- improved safety,
- reduced cost,
- better quality,
- shorter periods between contract award and delivery, and
- adherence to schedules.

Thus the purpose of this text, which is based upon a study of such methods and knowledge of domestic practices, is to identify the logic and principles which could lead to improving outfit procedures in the U.S. shipbuilding industry.

Shipbuilding, which is heavy construction, differs from the manufacturing sector in that to achieve optimum productivity much material procurement anticipates design and production must start before the design and material procurement efforts are completed. This intentional overlapping, illustrated in figure 1-1, is necessary to minimize interest costs for the substantial accumulating investment represented by construction progress and for achieving maximum utilization of expensive facilities such as a building dock. The overlap of these activities necessarily requires that information developed in one be formatted to the needs of the others. Shipyards which have recognized the need for overlap are currently striving, as a consequence of the depressed world market for new ships, to become more competitive by achieving greater overlap even for a mix of unique ships constructed simultaneously. Their goal is perfect integration of design, material procurement and production. The singular principle they applied is that design and material definition are aspects of planning. In the context of such logic, this text outlines an approach for support of the outfitting process from contract award to delivery.

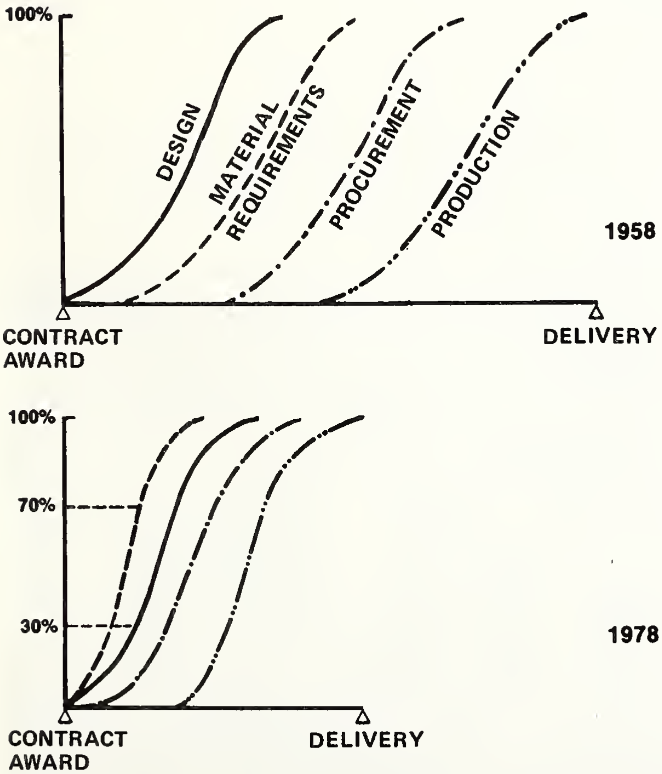


FIGURE 1-1: Overlap of outfit design, material definition, procurement and production which has been achieved by the most competitive shipbuilders. When only 30% of a design is completed, 70% of its required material is defined.

Conventional outfitting, still practiced to some extent, is planned and implemented by functional systems. It is typified by the allocation of resources to activities associated with ships' systems, e.g., cargo oil, bilge and ballast, main propulsion, etc., and does not recognize that certain interim products, i.e., subassemblies of outfit materials, can be produced more efficiently away from hull erection sites. Conventional outfitting is basically accomplished by landing large components, such as a main engine, during hull erection and subsequently installing various small components which make up supporting systems. Small components are usually installed as areas of the ship become structurally complete thereby concentrating outfit craftsmen in confined spaces over relatively short periods, especially between launch and delivery.

The assumption which a conventional planner usually makes is that outfitting should commence in a given area as soon as that portion of the ship is erected. With the pyramidal or block-by-block approach to hull construction, already significantly developed in the U.S., the areas available for outfitting are often occupied simultaneously by many workers who are installing components system-by-system and are competing for access with each other. It is generally recognized that such distribution of work complicates management and increases the probability of interferences and rework.

Because the work is usually planned as a follow-on to hull construction, the sequencing of the outfitting effort is acomplished system-by-system with designated starts not earlier than completion of the surrounding hull. However, planned completions must anticipate testing requirements. Thus constricted, the planned sequences and allocations for outfitting are not, with rare exception, optimum for minimizing resources. Further, extraordinary efforts are required at the hull erection site to preclude dangerous, dirty and poorly lighted work areas. Craftsmen are in environments where, in most cases, it is difficult or time consuming to get tools and materials. The natural result is more lost-time accidents, increased costs, poorer quality and longer shipbuilding periods.

Some shipbuilders are partially circumventing these problems by preoutfitting. This method applies resources earlier by outfitting large structural sections prior to erection of a hull. This necessitates construction of steel assemblies in a sequence which is probably not optimum for maximizing steel throughput with minimum expenditure of resources. Preoutfitting also requires dedication of appreciable time and facilities, e.g., large indoor or outside areas. Access is improved but components are still installed piece-by-piece using unchanged methods. There is great dependence upon hull structural planning which in turn complicates management of the production process (if a hull section is not available outfitting is disrupted).

Preoutfitting is usually planned by allocating resources to activities associated with ships' systems. Although access is somewhat improved, depending on the sizes of hull blocks, craftsmen still compete for time and space. Also, getting tools and materials to the work site is still not idealized. There is some improved ability to level load the outfitting trades which should improve productivity by permitting more uniform work flow. But savings in total manhours and the overall building period are inherently limited because the only real distinction between preoutfitting and conventional outfitting is where the work takes place. Sometimes preoutfitting a very large structural assembly is the equivalent of outfitting a small ship of equal tonnage by conventional methods.

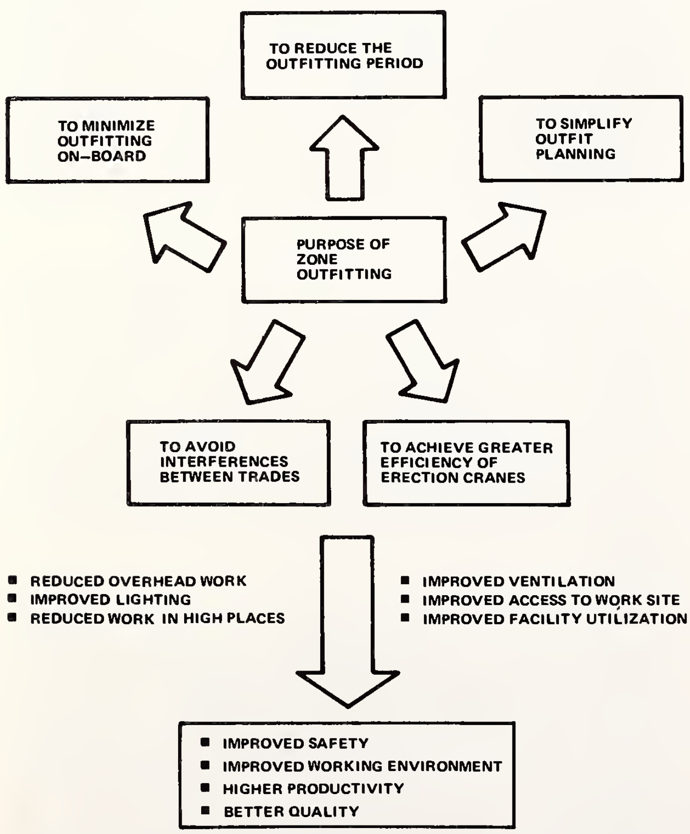


FIGURE 1-2: Goals and benefits of zone outfitting.

FUNCTIONAL UNIT

- POTABLE WATER AND FRESH WATER UNIT
- WATER DISTILLING UNIT
- F.O. PURIFIER UNIT
- REFRIGERATING PLANT UNIT
- ETC.

GEOGRAPHICAL UNIT

- PIPE PASSAGE ON DECK UNIT
- PIPE PASSAGE IN ACCOMMODATION SPACE UNIT
- PIPE PASSAGE IN ENGINE ROOM UNIT
- ETC.

COMBINATION UNIT

- ENGINE FLAT UNIT
- PUMP ROOM FLAT UNIT
- ETC.

FIGURE 1-3: Types of units.

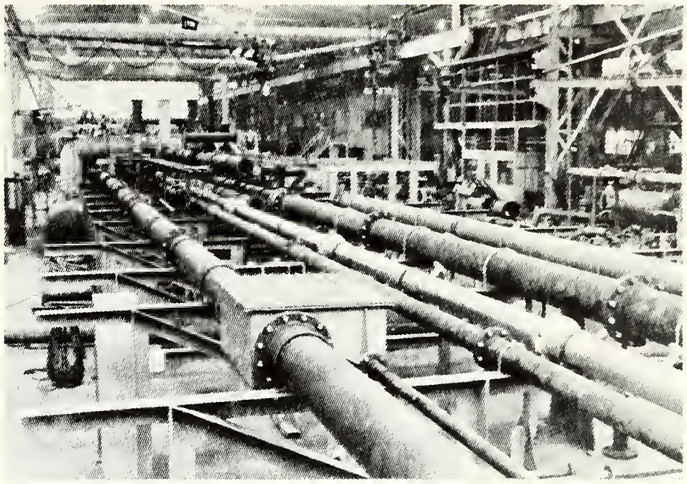
Zone outfitting which addresses everything within a limited 3-dimensional space, goes one step further. It frees outfitting as much as possible from dependence on hull construction progress and from arbitrary control as ships' systems. It achieves these ends by addressing certain interim products, i.e., significant subassemblies of just outfit materials that have been joined together away from a hull erection site or an outfit pier.

This added degree of freedom permits segmentation of a production process by classes of problems so that common solutions can be applied regardless of both product configurations and where outfit components belong in ships' systems. This is a principle of Group Technology which is a still developing industrial science, invoked to some degree everywhere for hull construction and yet to be applied by most shipyards for outfitting.

Zone outfitting is analogous to the Hull Block Construction Method (HBCM) which has been highly developed by shipbuilders throughout the world during the last three decades. In fact, the HBCM is a prerequisite for zone outfitting. The HBCM employs zone-by-zone construction as compared to the archaic system-by-system method. The singular advantage of zone-by-zone construction is that it permits more freedom in applying a logical work breakdown structure to achieve more uniform production flow. But while the HBCM has been almost universally adopted, the same logic for outfitting is not yet in general use. When the same logic is recognized there will be acceptance of the premise that outfitting is not a successor function and that it is necessary to plan and build a ship in a manner which will allow outfitting and hull construction to be accomplished simultaneously.

The zone approach permits and encourages most of the outfitting work to be accomplished earlier and in shops where it is safer, cleaner, and tools and materials can be delivered to work sites quickly and economically. It is product oriented in that it ignores systems during the construction phase and instead, focuses on interim products needed. These, which are assemblies incorporating various pieces of systems, are then installed in the shortest time frames possible in order to minimize total time at the erection site. The result is less lost-time accidents, reduced costs, better quality, shorter building periods, and adherence to schedules. Figure 1-2 summarizes the goals and benefits of zone outfitting.

Zone outfitting permits more opportunity for optimizing work flow to a uniform level by job type thereby providing more opportunity for semi-mass production techniques. This can reduce throughput time as well as reduce work-in-process. These techniques have been employed success-



IHI, KURE

FIGURE 1–5: A geographical unit provides passage for systems. Such units are assembled together to insure that they will fit on board. Each is relatively long. They can be vertical. Also, they may incorporate roller paths for self-unloaders in bulk carriers.

fully by shipbuilders having a simultaneous mixture of ship designs and contract peculiarities.

A zone might correspond to a compartment or even an integral part of a compartment such as a cargo hold or machinery space and their subdivisions. An entire superstructure, or just one of its levels, could be a zone even though a number of compartments are included. Also, a zone could encompass partial regions from two adjacent compartments even though separated by a bulkhead. Thus, a zone is any subdivision of the planned ship which best serves for organizing information needed to support outfitting at a particular stage of construction. Zone outfitting features three basic stages: on-unit, on-block and on-board.

Outfitting on-unit is the assembly of an interim product consisting of manufactured and purchased components. It includes all but a final paint coat. A unit is composed exclusively of outfitting materials and does not incorporate any hull structure. Techniques have been developed for extra stiffening to provide sufficient strength for lifting and transporting. Units can be categorized as functional, geographical or combination as listed in figure 1-3. An example of each type of unit is illustrated in figures 1-4, 1-5, and 1-6. On-unit outfitting should be given the highest priority even though there is some impact on hull construction progress because assembly is performed in shops which provide ideal climate, lighting and access. Shop work increases the opportunity for improved safety and higher productivity. Outfitting on-unit has less impact on the progress of hull structure as opposed to on-block outfitting.

Outfitting on-block is the installation of outfit components, or even a unit, onto a hull structural assembly or block prior to its erection. It is the next best alternative to outfitting on-unit. It includes all painting except a final coat and that paint omitted to anticipate welding of butts and

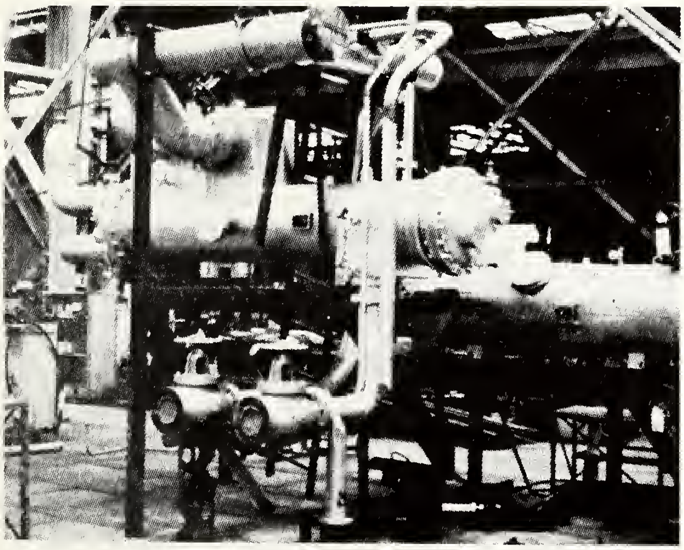


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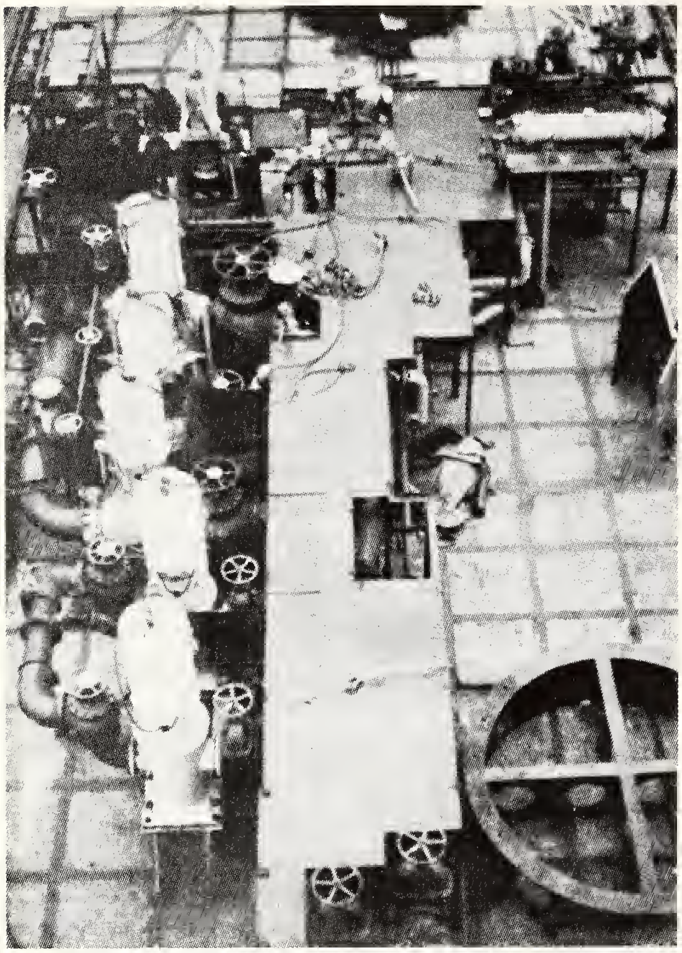
FIGURE 1–4: A functional unit consists mainly of components necessary for the operation of something, e.g., a heat-exchanger assembly. It is generally associated with one system.



MITSUI, CHIBA

FIGURE 1–6: A combination unit includes more than one system.

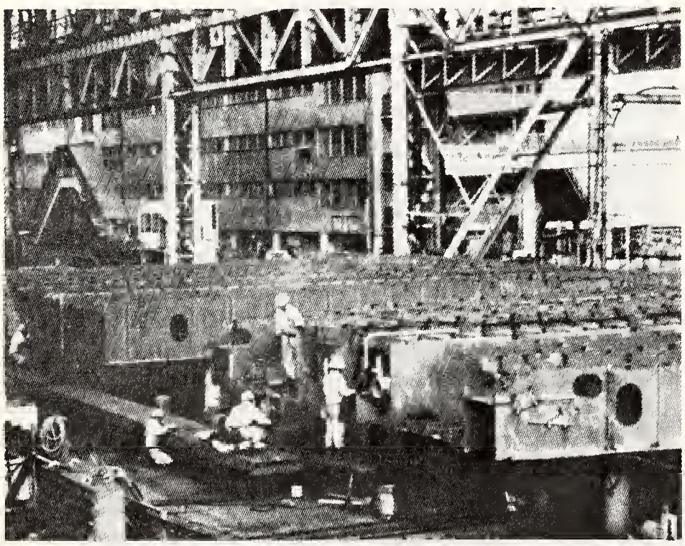


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FIGURE 1–7: Outfitting on-block in a hull assembly area.

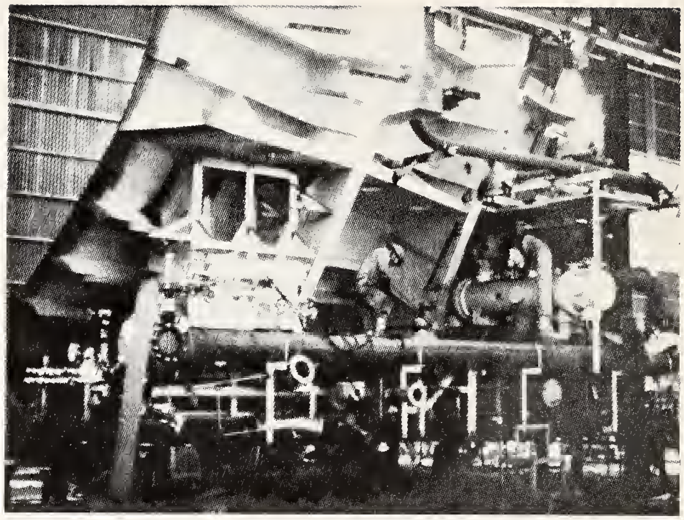

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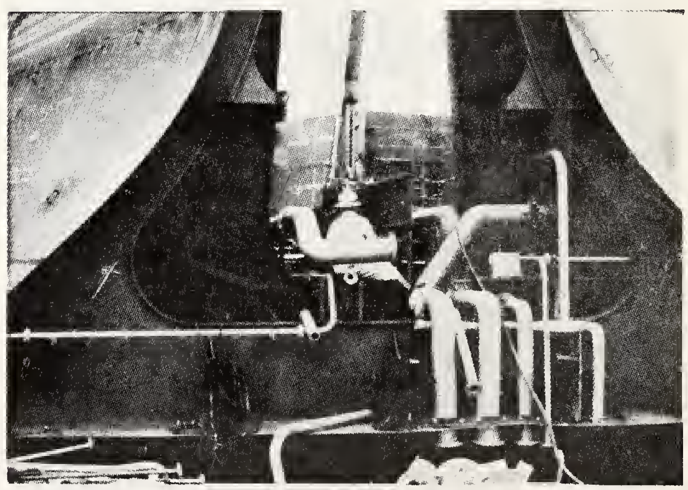
FIGURE 1–8: Outfitting on-block in an indoor outfit assembly area.

seams. Outfitting on-block requires good coordination between hull structure, outfit and painting planners and management surveillance to insure that none proceed without justification at the expense of others. Allocation of resources must address the structural, outfit and painting efforts simultaneously in order to minimize the total cost of an outfitted block. Setting a unit on-block enhances productivity because the time a block is required for outfitting is reduced. On-block outfitting may be done on a hull assembly platen, as shown in figure 1-7, or a block may be moved to an inside or outside area designated for outfitting; see figures 1-8 and 1-9.

Outfitting on-board includes, and ideally should be limited to, the connection of units and/or outfitted blocks, final painting, and tests and trials. It necessarily includes some



IHI, KURE

FIGURE 1–9: Outfitting on-block in an outdoor outfit assembly area.

installation of outfit components, in a hull at a building position or outfitting pier, which cannot be productively incorporated on-unit or on-block. Techniques, such as illustrated in figures 1-10 and 1-11, facilitate joining of units and/or outfitted blocks. The flexible couplings shown increase material costs but more than compensate by decreasing manpower, facilities and the overall time required for joining. Figure 1-12 shows placement of a unit at an erection site which was matched during assembly to its adjoining unit thus greatly simplifying alignment on-board.

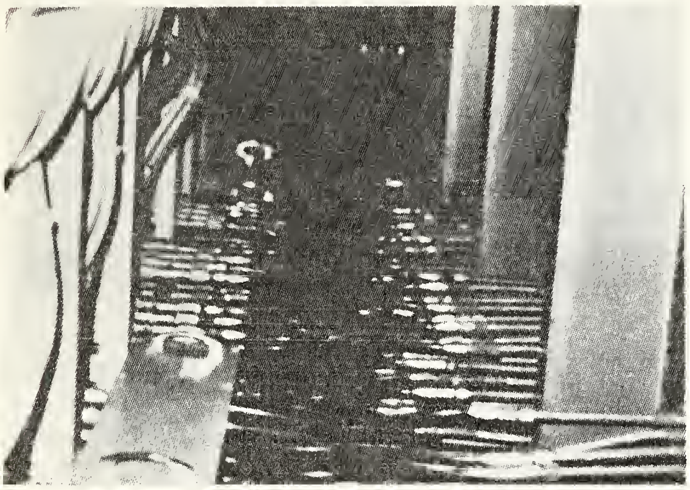


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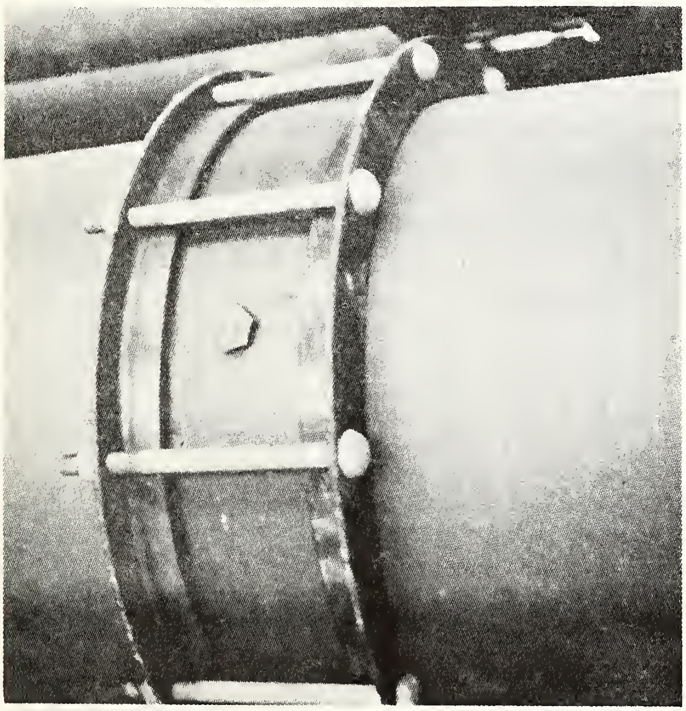
FIGURE 1–10: Flexible-hose assemblies increase material costs but reduce overall costs for joining tubing between blocks. No welding is required. Virtually all misalignment can be accommodated.

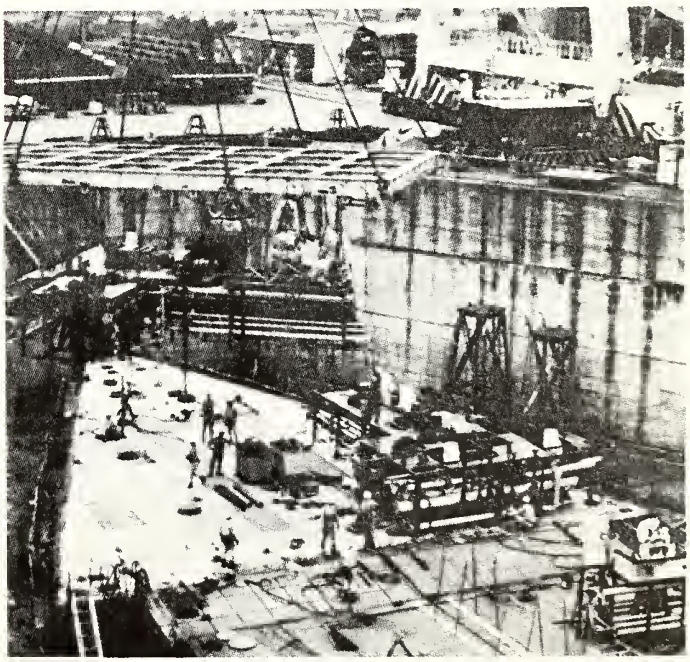


ASTANO, EL FERROL

FIGURE 1–11: Removable-stud type flexible couplings simplify planning. No welded clips and straps or elongated bolts are required. Some misalignment can be accommodated.

One method used to organize information to support zone outfitting is a pallet concept. Literally a pallet is a portable platform upon which materials are stacked for storage or transportation. It is useful to employ the word "pallet" to associate materials with information needed to support a job of assembling a unit, outfitting on-block or a discrete amount of outfitting on-board. It is a conceptual approach that allows information from design, material and production to integrate so that the various functionaries can have a common understanding of just how a ship will be constructed. As illustrated in figure 1-13, a pallet is the common link needed for zone outfitting; i.e., it is the basis for integration of design, material and production information. A pallet represents a definite increment of work with allocated resources needed to produce a defined interim product. It is correct to envision a pallet as a work package. A pallet is also a definition of components of the various functional systems in a particular zone at a specific stage (time) of construction. Figure 1-14 illustrates how these three aspects may be conceptualized.

Pallets address zones at particular stages of construction. These vary only slightly for different ship sizes and types while the ultimate contents of the pallets may differ significantly. Thus zones and stages can be sufficiently general so



MITSUI, CHIBA

FIGURE 1–12: Units which have been assembled together to insure that they fit, are landed on board. The sequence is specified in an erection schedule which incorporates both outfit units and hull blocks.

that an existing pallet scheme can be reapplied with slight modifications to many ship construction projects. Creation of a pallet list *before* the start of detail design is the means by which competitive shipbuilders more perfectly coordinate their detail design, material procurement and production efforts.

The pallet concept is extremely beneficial for staging or kitting material for delivery to a work site. The use of a kit ensures that a worker has all of the components necessary to do a job. A kit may consist of more than one container of material where it is inconvenient to deliver a large lot. Figure 1-15 illustrates the resources that are applied by

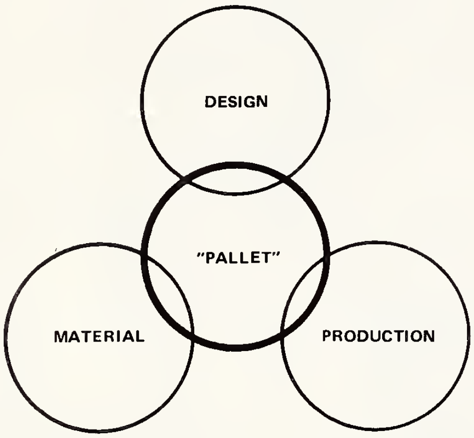


FIGURE 1-13: Pallet—The information link. The word "pallet" is used to define a zone at a stage of construction in design, to indicate a work package in production and, in a more literal sense, to designate a group of materials.

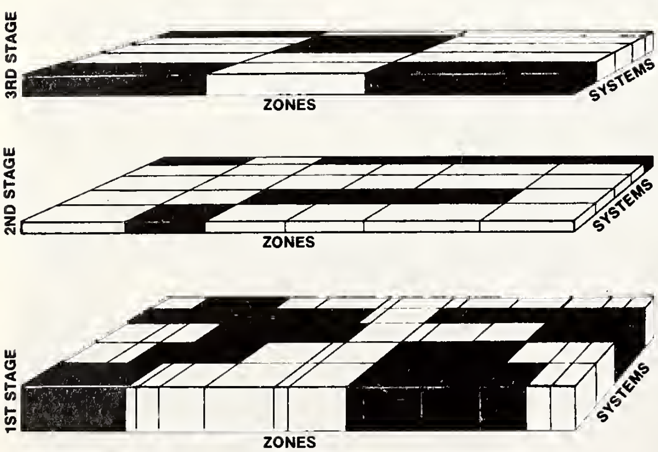
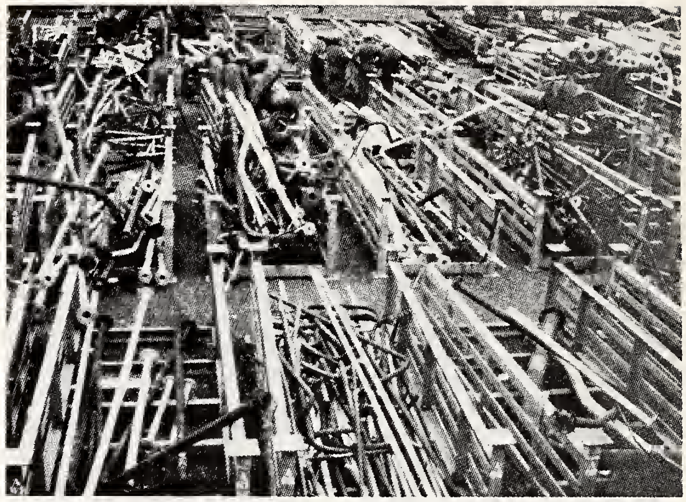


FIGURE 1-14: The three aspects of a pallet needed to group work are zone, stage and system. There are no arbitrary restrictions. Zone schemes can change from stage to stage and the durations of the stages can vary. Zones and stages from previous ships, with nominal modifications, can be reapplied to most ships of different sizes and types. As a detail design develops the contents of pallets, i.e., the amounts and types of systems incorporated, may differ significantly.



ASTANO, EL FERROL

FIGURE 1-15: Improved outfitting is dependent upon the availability of containers and yard areas needed for sorting and storing materials. The containers are designed to be handled by crane or forklift and to be stowed on top of each other.

some shipyards in Europe and Japan to organize material in kits ready for delivery to an outfit activity. Each kit is identified as a particular pallet or work package for on-unit, on-block, or on-board outfitting.

Zone outfitting has significantly contributed to the productivity gains achieved by the world's most competitive shipbuilders. Figure 1-16 illustratively summarizes the objectives and benefits, i.e., minimize low-efficiency on-board work and maximize high-efficiency shop work in order to reduce the overall time required to build a ship.

1) TO MINIMIZE WORK ON–BOARD (LOW EFFICIENCY WORK) AND TO INCREASE WORK IN SHOPS (HIGH EFFICIENCY WORK).
2) TO COMPLETE WORK ZONE–BY–ZONE IN ORDER TO SIMPLIFY MANAGEMENT CONTROL.
3) TO AVOID INTERFACE PROBLEMS WITH HULL CONSTRUCTION AND PAINTING AND THEIR ASSOCIATED WORK PROCESSES.
4) TO IMPROVE EFFICIENCY OF FACILITIES, SHOP, WAYS/DOCK, AND OUTFITTING PIERS BY EARLIER OUTFITTING AND MORE UNIFORM APPLICATION OF OUTFIT MANPOWER.

FIGURE 1–16: Summary of zone outfitting goals.

2.0 OVERLAP OF DESIGN, MATERIAL PROCUREMENT AND PRODUCTION

Significant overlap of design, material procurement and production is essential for reducing the overall construction period, but, overlap reduces the time needed to organize information developed by designers. Thus, from the onset design information must be formatted to more fully anticipate needs relating to material and production.

2.1 The Role of Design

Where zone outfitting is most advanced the design effort is divided into the following successive stages:

- Basic Design - e.g., specifications which establish performance requirements.
- Functional Design - e.g., systems' diagrammatics developed from basic design. It includes simultaneous preparation of a material list, divided into unique material ordering zones, for each system diagrammatic. Functional design also includes preparation of other key drawings such as general, machinery and block arrangements.
- Detail Design - e.g., conversions from functional design to working drawings. This process yields composite drawings upon which work zones are delineated.[1] It also includes the start of lists that associate specific materials with specific work zones. The composites are sufficiently comprehensive so that details needed for manufacturing certain items, e.g., pipe pieces, may be derived. As they indicate the mounting positions of all components relative to each other, the composites are the bases for assembly instructions. The detail design stage also includes preparation of material detail design drawings, including their material lists, for items that must be custom fabricated such as pipe pieces, ladders and small tanks.
- Work Instruction Design - e.g., light-line contact prints, made from the composite drawings, on which only the components to be installed during a specific stage of construction are delineated by darkened lines. Thus, there can be more than one work instruction drawing per work zone. They are annotated with assembly instructions and each is accompanied by a specific material list per work zone per work stage. It is correct for designers to refer to each work instruction drawing and its material list as a pallet or work package. The work instruction design phase significantly overlaps the detail design phase and both are performed by the same people.

Each design stage more clearly defines material requirements. Each successor stage honors commitments made and constraints imposed previously, while producing more detailed information. But most important, each successor stage transforms how the developing design is presented in order to fulfill the subsequent users' essential needs.

The information developed by designers provides the framework upon which other shipyard people build necessary data to procure material for and produce a ship. The development of this framework inescapably involves planning decisions such as definition of materials, construction details for fabrication and assembly, indentification of zone boundaries and designation of work stages. The concept that design and material definition are aspects of planning is most important because certain design groups are in the best position to contribute significantly. They are primarily the groups concerned with functional, detail and work instruction design.

For them the greatest departures from conventional practice, where material lists are prepared by systems as the last act in detail design, are:

- simultaneous preparation of diagrammatics and their material lists by material ordering zones in order to quickly determine *all* material requirements, and
- preparation of structured material lists during detail and work instruction design reflecting how a ship is to be assembled.

These lists enhance productivity because they are very useful tools for other aspects of planning.

Design people especially organized to support continuing development of information for material procurement and construction as described in the foregoing, are virtually prerequisite. Zone outfitting is facilitated if the various design outfit disciplines are grouped in a manner which compliments planned zoning, e.g.:

- Deck Outfitting[2]
- Accommodations Outfitting
- Machinery Outfitting
- Electrical Outfitting[3]

[1]As an economic measure many work zones appear on one drawing. If a specific zone is very complicated, 2 or 3 drawings for one zone should be considered. The number of work zones per drawing is immaterial as long as the drawing issue schedule is derived from the pallet list.

[2]Deck outfitting includes everything that is not in accommodations or machinery spaces.

[3]Accommodations, machinery and deck designate contiguous 3-dimensional zones. Electrical is rationalized as permeating all of the others.

Each of these groups prepares key drawings, working drawings, and material lists in a manner to suit initial zone designations such as those shown in figure 2-1. Thus design, as well as production, is segmented by classes of problems in accordance with the principles of Group Technology.

Within such groups there are improved "horizontal" communications such as that between piping and vent duct designers assigned to machinery outfitting. In addition, all become more expert about the unique nature of machinery spaces where assembly problems to be solved are different from those in accommodation spaces. As a consequence, they are led away from insignificant and non-productive fine tuning of systems and, instead, focus more on ideal interim products and their required materials. Where Group Technology has been so applied, some believe that the resulting improved communications and developed assembly expertise by zone are primarily responsible for their relatively interference-free composite drawings. These are essential for successful zone outfitting.

In order to achieve a greater overlap of design, material and production, it is necessary to organize material requirements so that purchase and manufacturing orders can be placed as early as possible. Emphatically, designers have the best opportunity to:

- Create lists as early as possible of all needed components and bulk raw materials. A few, such as a main engine, are often identified in basic design.[4] All of the remainder are listed by counting or estimating as system diagrammatics are developed in functional design. Material locations are fixed by an initial zone, i.e., machinery, accommodations, deck or electrical, which has been sub-divided into 3 to 7 "purchasing" zones that are needed to schedule accelerated procurement. Such lists are called:

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

- List the raw materials needed for outfit items which will be custom manufactured, e.g., pipe pieces, ladders, small tank assemblies, etc. These may require material detail design effort, such as details to produce a pipe piece. But, to a remarkable degree, the detail designs for such things as ladders and ventilation duct fittings can be obtained from standard drawings or from previous ship designs. Such lists are called:

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

  MLC - Material List for (manufacture of) Components (other than pipe)[5]

- List materials per pallet, i.e., per work zone per work stage, for assembly of a specific interim product. There are three sources:

  1. Materials already incorporated in an MLS excluding the raw materials needed to custom manufacture other outfit materials.
  2. Custom manufactured components which are made from the raw materials identified in an MLP or MLC.
  3. Materials for which quantities are more exactly identified in working drawing preparation.

  Such lists are called:

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

The various MLS are produced quickly not only to accelerate procurement, but also to check for major mistakes in the material estimate used to establish the contract price.[6]

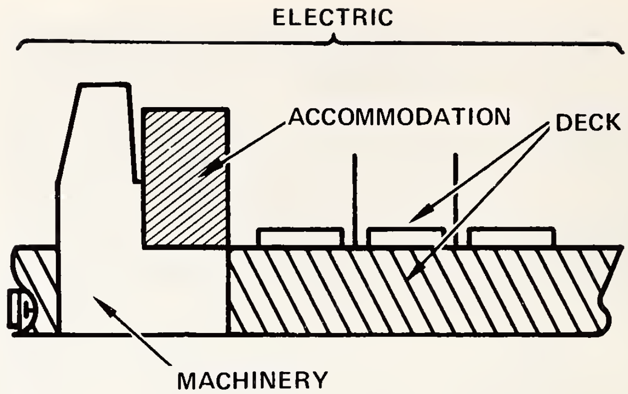


FIGURE 2–1: Initial design zones are common to all ships. They represent the first classification of problems in accordance with the principles of Group Technology.

[4]Usually purchase orders are issued as soon as such items are identified. Sometimes they are issued even before contract award when an item is identified during negotiations with a customer and the shipbuilder elects to speculate. Other such items are boilers, large auxiliary machinery, special cargo piping, special or large valves, castings, elevators, switchboards, etc.

[5]The lists for pipe (MLP) and the grouping of all other components to be fabricated in separate lists (MLC) apply in a shipyard which fabricates pipe pieces and assigns all other fabrication to subcontractors. If other items are fabricated in-house, such as products from a sheet metal shop, other lists analogous to those for pipe are recommended.

[6]Summations from MLS are sufficiently accurate and because they are by functional system are ideal for early feedback to estimators. The improved accuracy that would be obtained by summing from MLF doesn't justify the additional time that would be needed. Even an accurate count after the ship is completed is normally not worth the added effort.

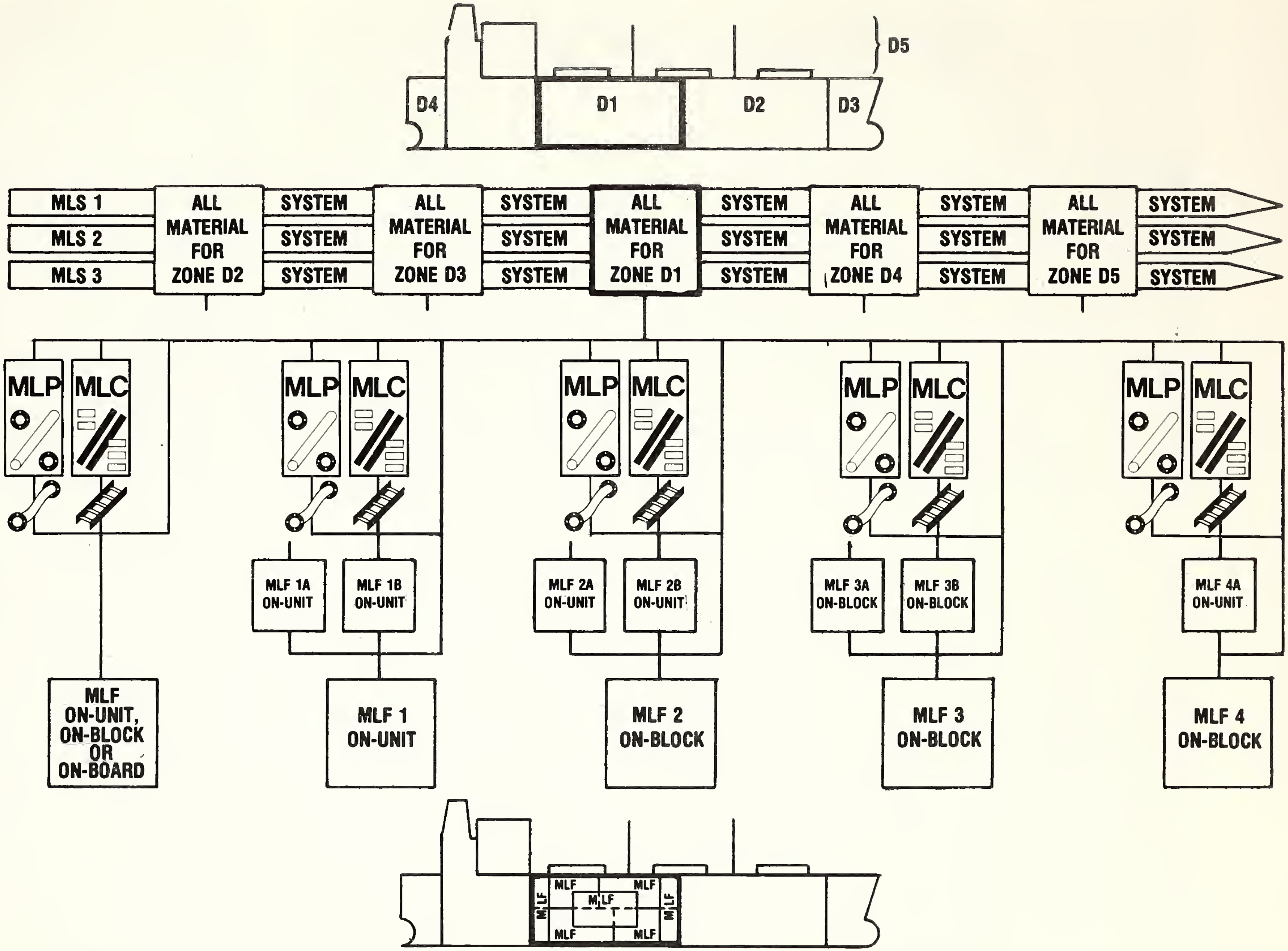


FIGURE 2–2: Relationships of material lists. MLS identify material by system and by material ordering zone. Five such zones for Deck, as illustrated, are typical. They may vary from three to seven, depending on ship type and size, for Accommodations, Machinery or Electrical. MLP, MLC, intermediate MLF (e.g., 2A and 2B) and final MLF relate to each other as structured bills-of-material. There can be more intermediate MLF levels. When their relationships are coded in a numbering system, or are otherwise clearly defined as in a computerized system, no additional terminology is required.

This permits managers to remedially adjust policies, if necessary, before major procurement begins. For example, if the MLS summations indicate significantly greater material requirements than had been estimated, a manager, within the latitude of the specifications and with regard for impact on installation costs, could direct usage of less costly materials or simpler systems. Accommodation areas, in particular, are usually susceptible to significant such savings.

MLS are systems oriented, which benefits estimators, and are simultaneously zone oriented in a way that facilitates early material procurement. In contrast, MLP, MLC and MLF are product oriented, i.e., they are structured bills of material for use as planning documents for specific interim products. They anticipate how a ship is to be assembled and provide the bases for the remaining planning and costing of interim products.

The MLS, MLP, MLC and MLF are readily identifiable material requirements formats for support of material control and production. Figure 2-2 shows their relationships to each other. Materials on an MLS are ultimately incorporated on an MLF, either directly or as a component of something custom manufactured. Similarly, materials on MLP and MLC are listed in their new identities as custom manufactured items on an MLF. Thus, an MLF includes all outfit materials needed for a planned interim product. It is the pallet needed to outfit a unit, outfit a block or outfit a discrete amount on-board. A pallet is a group of outfit materials necessary to perform a defined increment of work which is identified by an MLF. The pallet name is the MLF number.

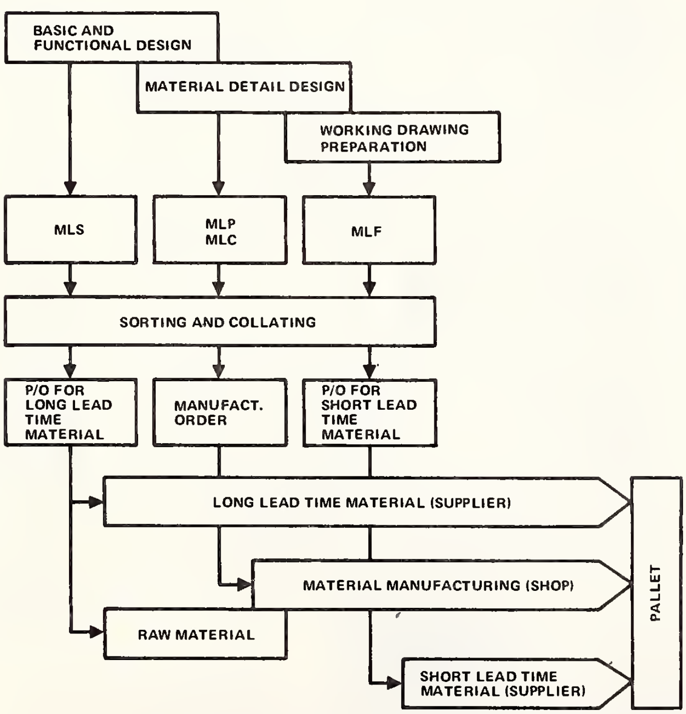


FIGURE 2–3: Relationships of material lists to design and to material procurement. Accuracy and timing of the sorting and collating functions are critical. In addition to sorting for long and short lead time and manufacturing-order materials, items identified in MLP, MLC and MLF must be compared to those in MLS. Also, the end product of each MLP and MLC must be accounted for in an MLF.

Such organization permits sorting and collating in a manner that enhances material, schedule and cost control. During the early design phases, identification of all pallets will not be known. Thus, the procurement process begins early using MLS and, as the design develops material is associated with specific pallets; i.e., MLF evolve and procurement information is refined. Figure 2-3 illustrates the relationships of the material lists to design and to material procurement aspects. Since it is disruptive for designers to have to reorient themselves to what they did before, managers should assign high priorities to computer applications for continously updating material lists. Today, in very competitive shipbuilding firms many regard maintenance of material lists as the most important computer applications.

Functional design proceeds in the context of initial zones (aspects of Group Technology) which are subdivided into purchasing zones. Each of the latter is scheduled to create a basic outfit sequence for preparation of diagrammatics and their material lists (MLS). As planning continues, detail design drawings and the breakdown of work to pallets proceed simultaneously. A specific work stage and a specific work zone is depicted on each work instruction drawing (see figure 2-4). Subsequently pallets are scheduled. This process is refinement of the overall schedule because the planning addresses smaller increments. Since the material requirements are contained first in MLS, and then in material lists by pallet (MLF), the procurement data is refined as well. If the shipyard is building a vessel which is very similar in configuration to previously built vessels, pallets will be defined almost simultaneously with the new zone definitions. This enhances both the speed and accuracy of informational support needed for overlapping design, material and production.

Another method for improving the timeliness and accuracy of design information is through the use of standards. To appreciate the full impact of standards, it is necessary to appreciate the entire management cycle because every management function benefits from the use of standards. Decisions made in forecasting, planning, scheduling and production are controlled by information both from previous steps and from feedback obtained from subsequent steps. Standards provide an opportunity for common understanding and improved communications among shipyard functionaries. Standards benefit the estimating, scheduling, and accounting functions by providing simplified quality information that facilitates prediction, implementation and evaluation. But, there is much greater potential benefit in planning, particularly for design and material definition, and in production.

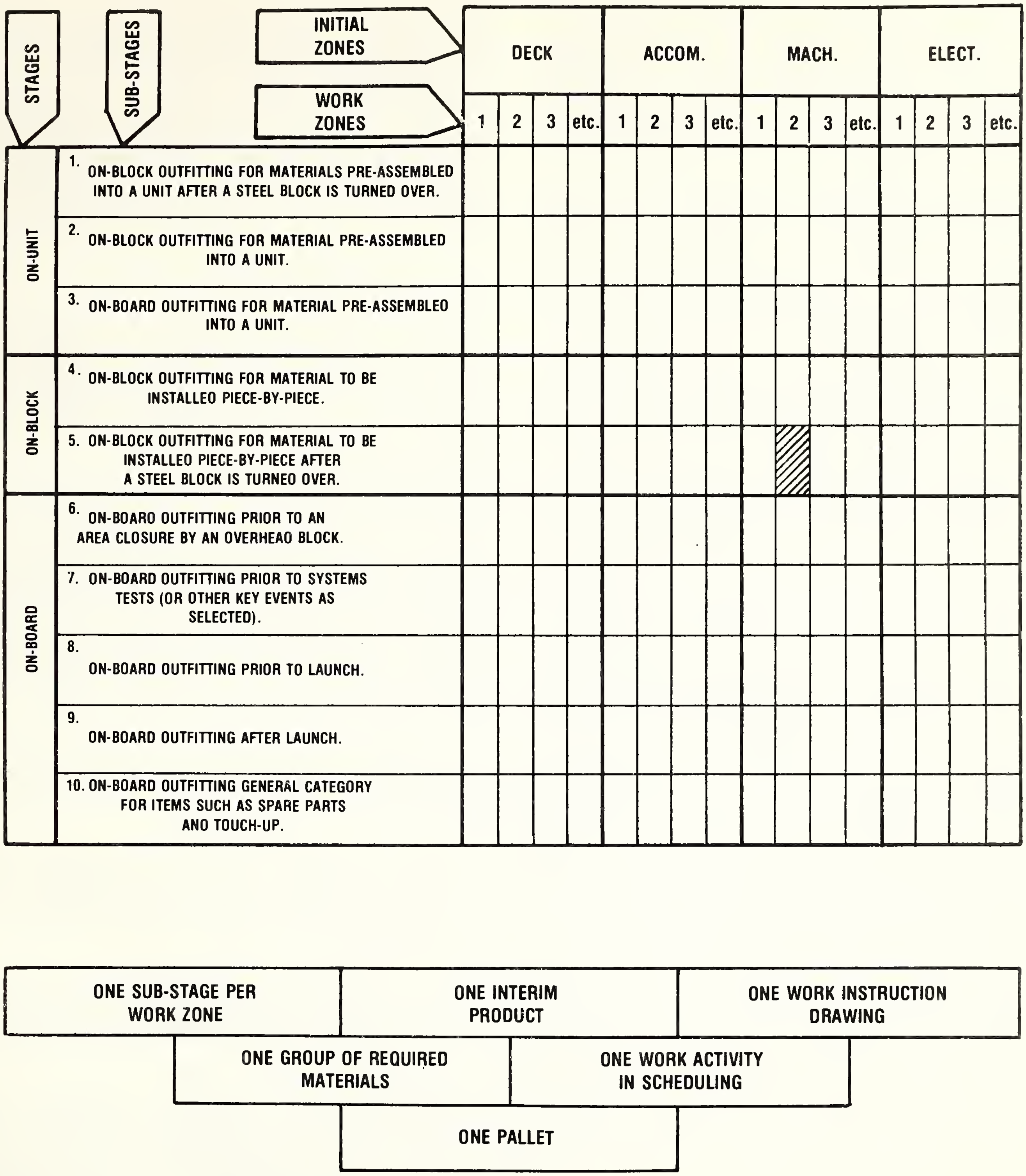


FIGURE 2–4: Typical breakdown of work to pallets. Each work instruction drawing addresses a specific work stage in a specific work zone such as that designated by the shaded box. Sub-stages are limited to ten so that only a single character is needed to identify a sub-stage.

Figure 2-5 shows a methodology for classifying standards. This organization facilities the cataloging and coordination of various types. Basic Standards (IS) are those that must be closely followed by design and production. Standard Drawings (SD) serve as guidance allowing some flexibility to meet individual requirements. Standards also provide opportunities for saving manhours, maintaining high quality and simplifying computerization.

Shipbuilders who have successfully standardized elementary components have extended their use to modules of arrangements of various components.[7] These "design modules" are intentionally general in nature so they may be reapplied in different ship sizes and types. They also anticipate different customer needs and therefore allow some flexibility in application.

Further development produced interim products for which the bulk of the planning data in file is immediately available for reuse. This includes diagrammatics, composites, MLP, MLC, MLF, material detail design and work instruction drawings.

Another important aspect is the incorporation of machinery selected from manufacturers' catalogs. Because each such machinery item is "approved" when it is designated as a shipyard standard, needed vendor furnished information is already on-hand and the time consuming vendor-drawing approval cycle is eliminated from the procurement process.

Classification of Standards				Nos.
IS	SO	Material Standards	Common components	600
			Hull fittings	600
			Machinery fittings	200
			Electric fittings	200
		Sub-total		1,600
	SOT	Design process standard		1,100
		Prod. eng'r'g. process standards		100
		Inspection process standard		200
		Sub-total		1,400
SD		Machinery drawings		1,200
		Component and fitting, standard drawings		350
		Other guidance drawings		350
		Sub-total		1,900
Grand total				4,900

FIGURE 2-5: Typical classification of standards. The quantities shown are from a corporation which operates five yards for building ships of various types and sizes from 15,000 DWT to 500,000 DWT.

The flow of design information, presented graphically in figure 2-6, starts with the basic contract data and results in early information developed in forms which anticipate all material control requirements. It is extremely important that designers know how critical their material related work is to the success of an entire shipbuilding project.

2.2 *Overview of Material Control*

Material Control includes authority for material requisitioning and direction over purchasing, expediting, warehousing, palletizing and delivery to the work site. Material control converts design data, which is by ship/system/stage, into terms of material-by-material and delivery to ensure meeting schedule requirements while minimizing inventories and *total* cost.

In order to facilitate the procurement process and provide information in a form readily useable in production, a series of standard classifications of material are applied. The material lists from design (MLS, MLP, MLC, and MLF) are coded with material identification numbers needed to facilitate computerization and the flow of information between shipyard functionaires. An approach for a coding system is provided in Appendix A. Whatever the coding system used, material can be classified into three basic categories:

A - Allocated Materials. These are purchased specifically against a contract requirement. Materials in this category include items such as a main engine, propeller, shafting, etc.

S - Stock Materials. These are common to most vessels. They are requisitioned and purchased by the most economical quantity based on historical usage data and design forecasts.

AS - Allocated Stock Materials. These are purchased against a specific shipbuilding contract based on the quantity identified in design plus some margin added in material control.

Figure 2-7 further describes these classifications which enhance effective material control by facilitating requisitioning directly from material lists produced by designers. Further, the requisitions themselves are categorized to speed the procurement process. This is done by specifying on the material lists from design the type of documents needed to initiate specific procurements. The three types are:

[7] See "Improving Shipyard Production with Standard Components and Modules" by Y. Ichinose, IHI Co., Ltd., Tokyo; Proceedings of the SNAME Spring Meeting, April 26, 1978, pp 10-1 to 10-11.

T - This designation indicates an item which appears on the shipyard's Table of Standard Materials. As the buyers and customary suppliers maintain standard drawing files, no additional descriptive information is required.

P - This designator identifies an item for which a Purchase Order Specification must be prepared. Approvals of vendors' drawings are required. The P designator should be used in place of T if there is an owner or regulator requirement for a specification even though the item is a shipyard standard. Because designers include the shipyard standard number in their material lists, buyers are informed that T-item purchasing procedures apply.

D - This designator identifies materials to be manufactured in accordance with Material Detail Design Drawings prepared by the shipyard.

The latter complete the classifications necessary to accelerate the requisitioning process by facilitating sorting and collating information from design and scheduling into formats for purchasing. The major steps in the development of requisitions are shown in figure 2-8.

The effectiveness of purchasing can be enhanced by the use of long term agreements with subcontractors. The rationalization considers the total cost of a particular component in terms of quality, timely delivery, design standardization, material storage, material handling, installation standardization and testing. It often happens that a particular component is higher in price from one manufacturer than another, but the *total* cost is reduced because of savings in manhours, facilities and elapsed time required for manufacture or assembly. Shipbuilders are generally alert to this and adequately evaluate total costs associated with high priced items, e.g., a main engine, during the basic and functional design (pre MLS and MLS) stages.

It is also very important during the detail design (MLF) stage to watch for low priced items that could precipitate high installation costs if they are not available for a planned work zone and work stage. Generally, they are short-lead time materials for which purchasing is initiated after they appear on an MLF. The unit price alone is not indicative of the importance of an item to the assembly process.

The use of standard components enhances the potential for overall shipyard savings. However, it is essential for the successful application of standards that they apply to high quality materials. This is particularly true for machinery items from manufacturers' catalogs that are listed as shipyard standards. Owners need guarantees about performance, parts availability, service, etc. Standards apply not only to raw materials and items such as valves, fittings, etc., but also to fabricated components such as hatch covers, ladders, gratings, miscellaneous tanks, and other small assemblies. Subcontracting for these items permits a shipyard to take advantage of skilled specialists who are qualified in their manufacture. This is another application of Group Technology.

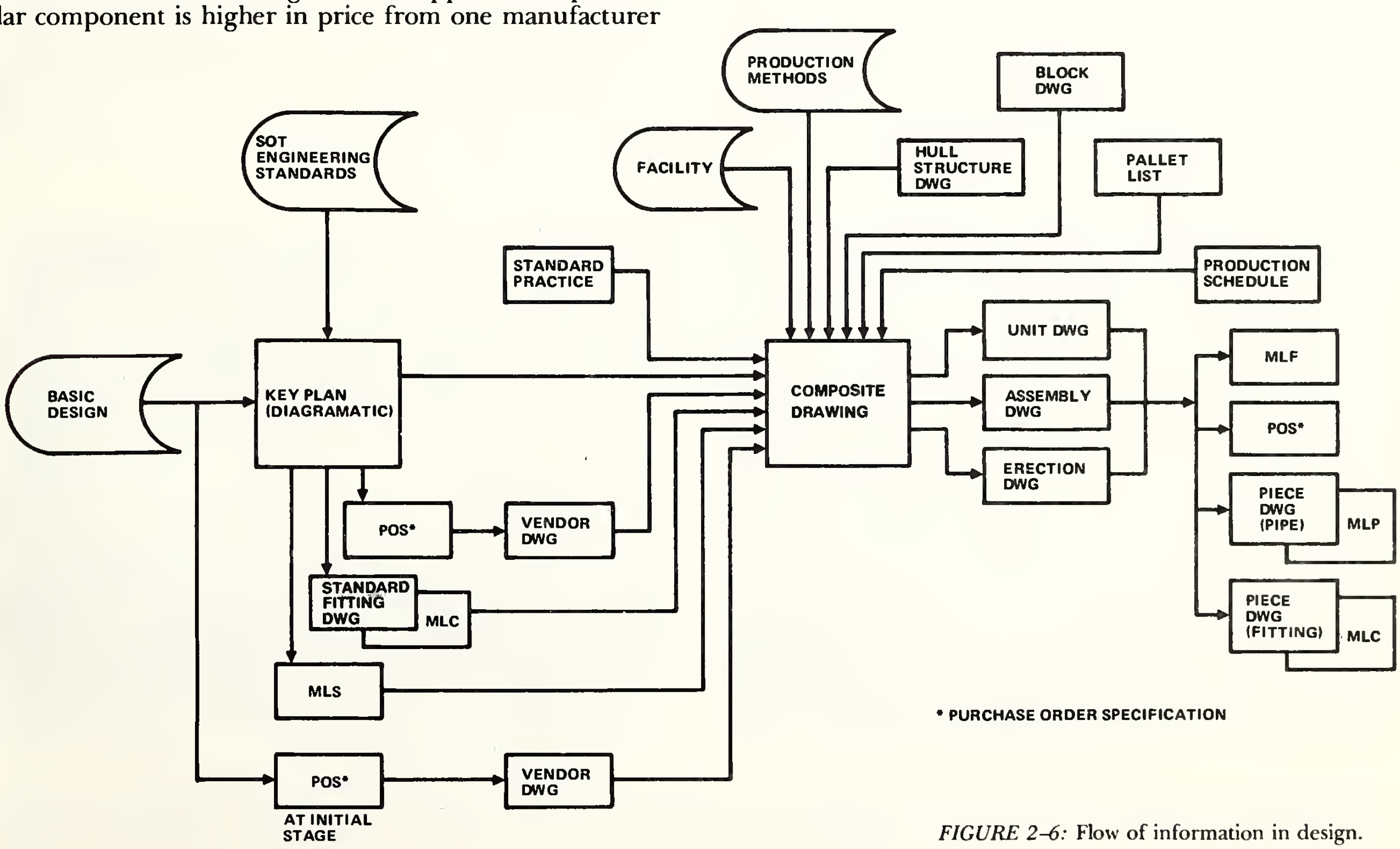


FIGURE 2-6: Flow of information in design.

	CLASSIFICATION	MATERIAL EXAMPLES	STANDARDIZATION	USAGE RATE	QUANTITY TO BE ORDERED
A	ALLOCATED MATERIAL	MACHINERY, SPECIAL EQUIPMENT & FITTINGS	GENERALLY NO	VARIABLE	BASED ON QUANTITY REQUIRED BY DESIGN DEPARTMENT.
AS	ALLOCATED STOCK MATERIAL	VALVE, EXPANSION JOINT	YES	VARIABLE	BASED ON QUANTITY REQUIRED BY DESIGN DEPARTMENT WITH SOME MARGIN.
S	STOCK MATERIAL	FLANGE, ELBOW, NUTS, & BOLTS	YES	CONSTANT	BASED ON STANDARD STOCK QUANTITY OR QUANTITY REQUIRED BY DESIGN DEPART– MENT WITH SOME MARGINS.

FIGURE 2–7: Classifications for controlling materials.

Subcontracting reduces a shipyard's administrative burden in terms of purchasing, warehousing, inventory control, material handling, special tooling and, more importantly, need to maintain and administer factories for manufacturing such components. Prudent subcontracting also takes advantage of a vendor's lower overhead costs for manufacture of small assemblies and permits concentration of a shipyard's resources on assembly of ships.

By identifying components on the material lists from design as either T, P, or D (standard, specification or drawing respectively), purchasing people can readily determine the type of procurement required. Those components identified as D are eligible for subcontracting. In order to acquire additional benefit, a shipyard can utilize its usually greater buying power and furnish certain materials to subcontractors (see figure 2-9). The capability to wisely subcontract is enhanced by design's preparation of MLP and MLC. Each lists the raw materials required for a component identified as D. The relationships of such raw materials to a ship's functional system are in an MLS. Thus, purchasing people have ready identification, not only of the components which can be subcontracted, but of the raw materials required for their manufacture.

The use of standards also enhances opportunities for long term agreements with vendors for the purchase of other materials identified as T or P. There is much potential benefit. Some vendors will maintain inventories which minimize a shipyard's investment and contribute to improved cash flow. Long-term agreements could introduce not otherwise obtainable price breaks based upon volume. Further, it is generally accepted that purchasing administration costs can be reduced by as much as 60 percent by amending existing purchase orders rather than issuing new ones. Typically, in the U.S., long-term agreements are

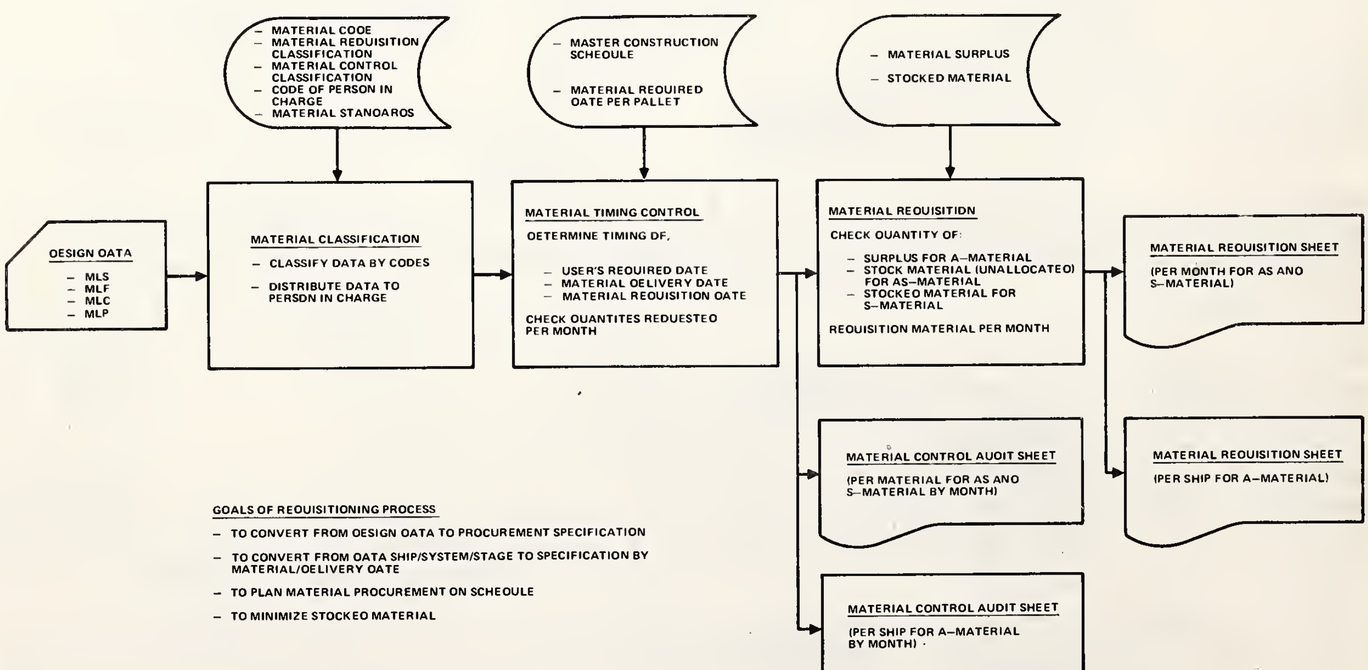


FIGURE 2–8: Functional flow of the requisition process.

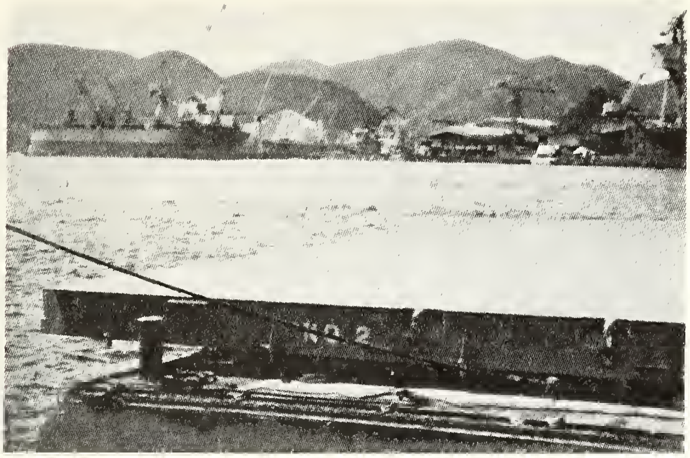


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FIGURE 2–9: The hatchcover is at the subcontractor's plant and is ready for delivery to the shipyard across the bay. The manufacturing drawing, material list and the materials, i.e., plate, fittings and paint were furnished by the shipyard. Other assistance, e.g., special tools or even Q.A. inspectors, would be furnished if needed for new products. These close relationships encourage sub-contractors to locate near shipyards and encourage shipbuilders to continue their growing tendency to use open-end purchase orders to fewer subcontractors as a means for improving productivity.

made when a shipyard has orders for several ships of the same design. The use of a greater number of standard components increases the potential for long-term agreements for materials needed to construct different ships. Regardless of the level of standardization, design's identification of materials as T, P or D can significantly improve a purchasing department's ability to support zone outfitting.

The warehousing function, as directed by material control, receives and stores material until an order is issued for its delivery to a work site. The goals of warehousing are to maintain accurate count and physical control of materials, while minimizing handling and storage costs. The inventory process is aided by the identification codes utilized for materials definition in the design stage. Coding and standardization of materials permits the same commodities for different contracts and hulls to be stored in common locations. This is a recognized cost saving measure in warehousing provided there is adequate record keeping. There has to be clear assignment of responsibilities for all warehouse transactions. Accurate inventory records are essential for support of zone outfitting.

Warehousing also includes the combining of materials, stored by material code number, into pallets for delivery to the work site. When a pallet issue order is received, material must be taken from storage to a kitting center where it is placed in one or more containers for delivery as a pallet. The kitting center, and pallets themselves, may be conceptual in that a large item may be delivered directly from a subcontractor's shop while several other components assigned to the same pallet may be separately transported to the work site in one or more containers. Figure 2-10 is an example of a palletizing center for fabricated pipe.

2.3 Production

Production people are the ultimate users of information and materials produced by design and material groups. In order to best use their services and achieve efficient zone outfitting, certain production functions may be regrouped to optimize resource utilization. By organizing the work in terms of common processes, improvement in outfit throughput can be achieved. Work so organized conforms

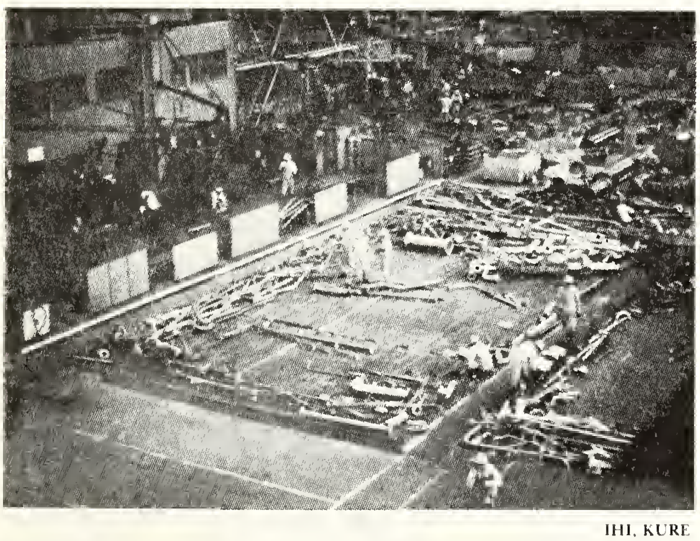

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FIGURE 2-10: It makes sense to sort pipe pieces as soon as they are fabricated. In at least one shipyard where the pipe fabrication shop has a palletizing capability, it is assigned the collateral job to integrate all other materials received from subcontractors and suppliers. Thus, split responsibility for palletizing is avoided.

to a Group Technology approach. In this context, zone outfitting can be greatly facilitated by dividing a traditional single production department into three departments, i.e., a Hull Construction Department, an Outfitting Department and a Painting Department.

This approach groups interim products regardless of their appearances or where they are to be located in a ship's functional system. Instead, interim products are grouped by similarities in production problems in order to match each group to a single set of solutions. For example, different structural panels, regardless of their location in a ship, would have the same classification and resources allocated in accordance with common parameters. Similarly, componets for diverse piping systems that can be manufactured by the same processes would have the same classification and be treated the same way in the management cycle.

Separation of the production functions by common processes permits their planning to proceed separately until they reach a level where they must interlock. This simplifies scheduling and performance of work.

Using this same approach, the Outfitting Department can be subdivided, based again on similarity of problems, as follows:

- Deck Outfitting Section,
- Accommodations Outfitting Section,
- Machinery Outfitting Section,
- Electrical Outfitting Section, and
- Fabrication Shops

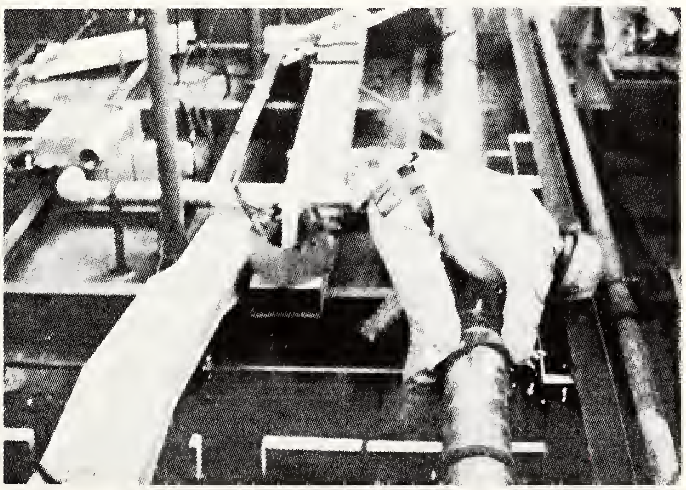

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FIGURE 2–11: The Accommodations Outfitting Section both constructs and outfits deck houses. Each deck house level is a separate block which is outfitted upside-down.

The first four are responsible for outfitting on-unit, on-block and on-board in the zones indicated.

As deckhouses are constructed of aluminum or lightweight steel, they do not impose the same problems inherent in hull construction. Thus, in accordance with the rationale of grouping by problems and seeking a single solution for each group, and because deck houses contain a great amount of outfit, it is prudent to assign assembly of deck houses to the Accommodations Outfitting Section.[8] This combined responsibility for construction and outfitting encourages more productive methods such as outfitting upside-down (see figure 2-11).

Typical types of work performed are:

a. Deck Outfitting Section

(1) On-unit assembly of pipe such as main deck sections of a tanker cargo system.

(2) On-block installation of pipe, valves, ladders, hand rails, mooring fittings, etc.

(3) On-board installation of cargo pumps, hatch covers, anchor handling equipment, anchor, steering engine, operation and testing of deck machinery, etc.

b. Accommodations Outfitting Section

(1) Construction of superstructures.

(2) On-unit assembly of pipe such as for control lines, sanitary systems, etc.

(3) On-block installation of units, vent duct, insulation, etc.

(4) On-board installation of vent duct, piping, false ceilings, refrigeration equipment, furniture, life boats, navigation instruments, etc.

c. Machinery Outfitting Section

(1) On-unit assembly of boiler piping, heat exchangers, main feed pumps, etc.

(2) On-block installation of pipe, vent duct, grating, foundations, etc.

(3) On-board installation of pipe, vent duct, ladders, main engines, shafting, boilers, generators, etc., testing, operation for trials, etc.[9]

d. The Electrical Outfitting Section installs cableways, small electrical foundations, etc., on-unit, on-block and on-board. It installs, hooks-up and tests all electrical cabling and small electrical equipments.

[8]In principle, a U.S. shipbuilder has already implemented this logic. Entire deckhouses for LNG ships were assigned to a single subcontractor for coordinated construction and outfitting.

[9]The Machinery Outfitting Section can be further divided to separate specialists required for installing, testing and operating main propulsion machinery from those who install piping, ladders, gratings, etc.

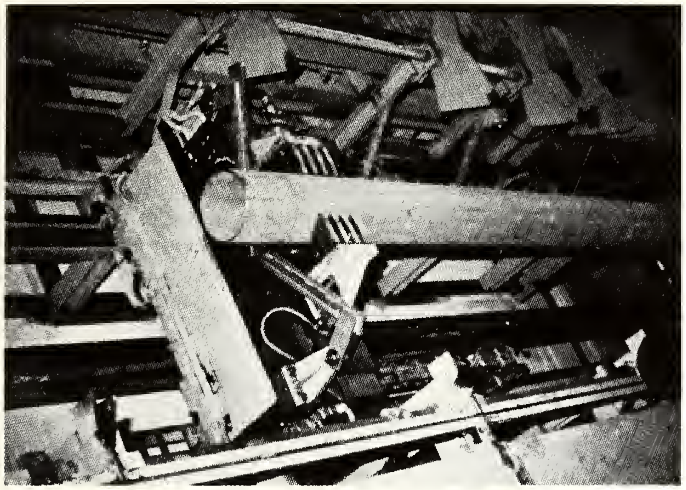

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FIGURE 2–12: The Pipe Piece Family Manufacturing (PPFM) number assigned by detail designers, is the basis for loading a pipe fabrication facility. Such concepts are essential for ideal productivity in pipe shops particularly if they are automated.

In addition it installs control tubing since associated problems are similar in nature to problems associated with installation of cable.

e. The fabrication shops supply in-house manufactured components to the outfitting shops to support the on-unit, on-block, and on-board outfitting. Shipbuilders abroad often limit in-house fabrication to just pipe. The other components such as vent duct, ladders, hand rails, grating, foundations, etc., standardized as much as possible, are funished by subcontractors.

The role of a pipe shop is to supply fabricated pipe pieces to the outfitting sections when and where they are needed. In order to manage this process, it is necessary to develop controls for schedule, manhours, material, and quality (the latter includes dimensional accuracy). This can be achieved by arranging the information in terms of flow lines organized by similar types of fabrication procedures. This is another application of Group Technology. For example, bent pipes, regardless of the number of bends, are fabricated by use of similar procedures such as for marking and cutting, bending, assembling, welding, and finishing. These procedures are obviously the same for bent pipe regardless of the functional systems in a ship they will eventually support. Thus, the procedure categorization is given the acronym PPFM for Pipe Piece Family Manufacturing. Pipe pieces are grouped by type of job from the shop control viewpoint. This grouping is for sequencing pipe through a shop. Grouped jobs are called the job stages. When grouped in this manner, the manhour requirements by job stage can be summed to form a work lot. In turn, this permits the control of work to be done by lot which improves the opportunity for management control by reducing the volume of information that must be dealt with.

PPFM is a methodology for identification of pipe to be fabricated by classifying the processing in terms of diameter, material, geometrical shape, treatment, and so on. Utilizing a standardized processing time for each PPFM category simplifies the scheduling for pipe fabrication. Since each pallet has a required date, the latest starting date can be quickly computed for each pipe piece identified with a PPFM number. Further benefits can be achieved in a computerized system because the volume of data is reduced. PPFM further simplifies capacity planning for a pipe shop by the introduction of standard processing times and production flow paths. These introduce semi-mass production techniques which are inherently beneficial. There is improvement in throughput time by reduction in set-up time, reduced scrap, improved machine utilization, and reduced work-in-process. PPFM is essential both for planning manufacture of pipe pieces in an automated shop (see figure 2-12), and for identifying the unique pieces which still require manufacture by hand.

PPFM numbers are established by designers and are incorporated on each MLP. This provides a means of simplifying communications between designers and shop personnel by identifying the processing route immediately in the design stage. Shop personnel and designers acquire common understanding of the processing required by use of PPFM numbers. The grouping of fabrication processes by PPFM numbers assigned in design, simplifies outfit planning and is a typical example of design as an aspect of planning.

Figure 2-13 shows a PPFM scheme and its application from design to palletizing. This same technique, already applied successfully in pipe fabrication, could also be applied for the fabrication of other components. The PPFM coding also provides additional information in terms of size and coating to be applied.[10] Figure 2-14 shows how PPFM can be applied to organize and identify the flow of material through the fabrication process.

2.4 Production Planning

Some degree of outfit planning is inherently incorporated in each shipyard function such as design, material control, industrial relations, facilities, quality assurance, etc. By organizing some of these functions and sub-functions in terms of common processes, the formal planning, which provides the framework for communication, can be simplified. As illustrated in figure 2-15 the planning function itself is concerned with different levels of detail to support the production process. At the top, plans concern themselves with long range business considerations, i.e., market analyses, facilities, financing, etc., and contain a great deal of uncertainty. Long range plans do, however, create a

[10]Appendix A provides an example of PPFM coding.

framework for the development of near term plans. These concern themselves more with contracts in-hand and probable business. Short and long range plans are the bases for assigning the resources required to accomplish current and anticipated work and provide management with basic guidelines needed for business decisions.

When a contract is awarded, more detailed planning is required. Decisions must be made as to how, where and when the ship is to be built. The "how" at this point involves decisions as to block size and sequence, zones, major units, etc. The "where" involves facility commitment. The "when" commits shipyard resources to specific calendar dates. As the design is developed and further information becomes available, more detailed plans evolve. By separating the production process into the three major groups (Hull Construction, Outfitting, and Painting), detail planning for each can proceed independently until such time as they must come together. This planning is facilitated by the use of on-unit, on-block and on-board outfitting techniques because the erection planner needs only to deal with components which are large assemblies. There are no overwhelming details. Instead, there is only need to sequence large interim products. This simplification of the planning process is achieved by quickly organizing information to describe interim products thus reducing the volume of data required (see figure 2-16).

Pre-erection planning is concerned with detail sequencing and short range allocation of resources to construct interim products. This planning is further simplified by the use of concepts, such as the pallet, which organize material and other resources into packages for construction of the interim products needed for erection.

Planning and scheduling the various shipbuilding activities involves every shipyard function to some extent. The planning function itself is a process which must be coordinated and scheduled to insure that needed information is available in a timely manner. One method to ensure timely development of planning information is to establish milestones for this purpose on a Principal Events Schedule. These milestones include the schedule dates for meetings at which time specific shipyard functionaires agree on key

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

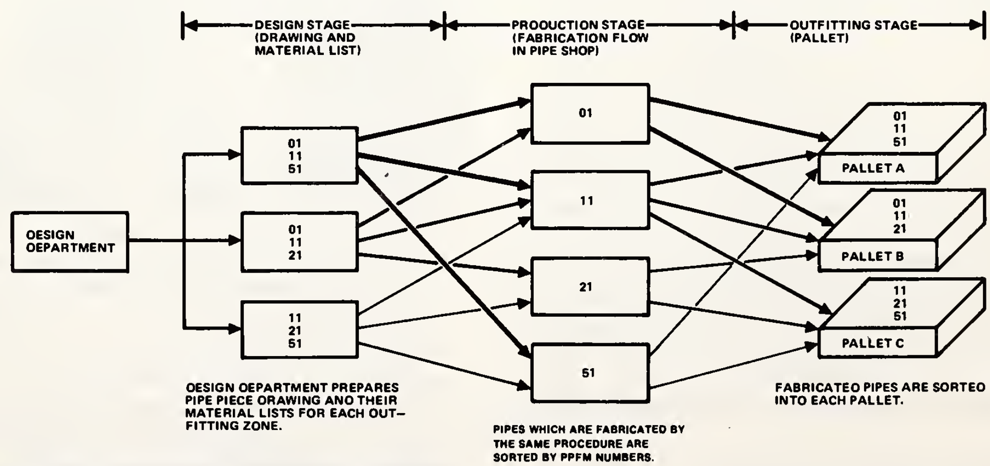

FIGURE 2-13: Pipe piece family manufacturing (PPFM).

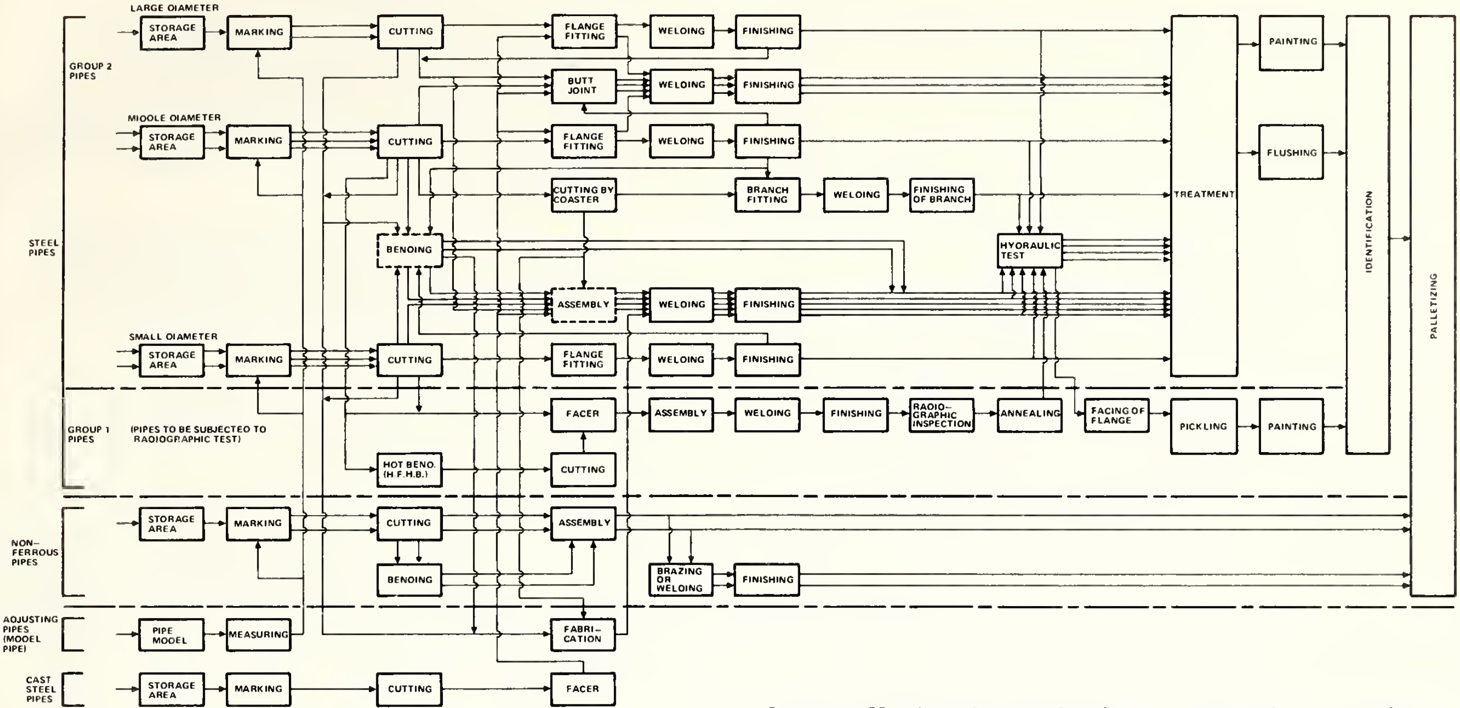

FIGURE 2–14: Pipe fabrication flow in pipe shop (PPFM).

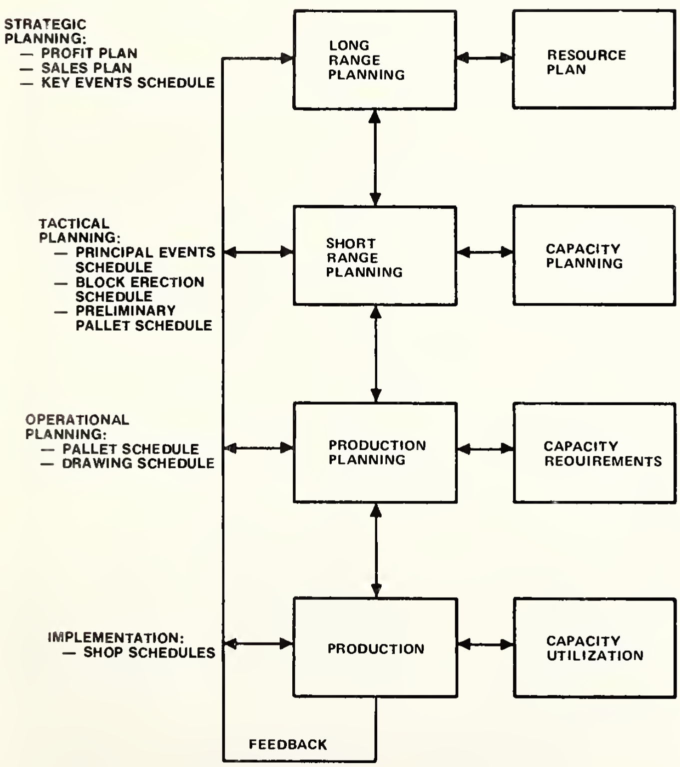

FIGURE 2-15: Planning different levels of detail.

factors affecting the production process. These meetings, called A-B-C-D meetings, provide pre-determined points in time by when the various people involved must reach agreement and make decisions concerning other specific planned milestones. Figure 2-17 illustrates the functions involved in each of the A-B-C-D meetings. Each meeting has a pre-determined agenda which concentrates on the items of primary interest to succeeding functions as illustrated in figure 2-18.

The organization of work by common processes results in simplification of outfit planning. The information which is developed in design is organized for use by material procurement and production people. The organization of information is simplified by use of the pallet, on-unit, on-block, and on-board concepts. The flow of information from design to outfitting illustrates the use of such concepts as introduced in this chapter; see figure 2-19.

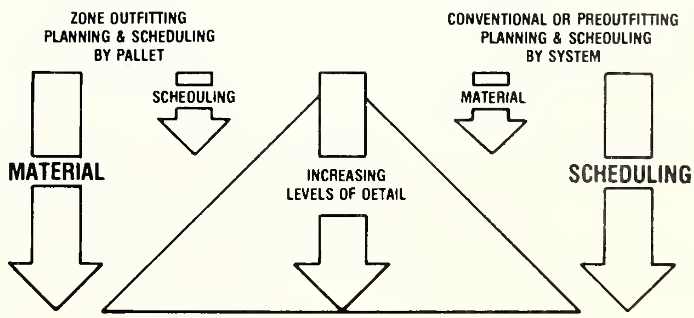

FIGURE 2–16: When material requirements are identified early and are quickly structured to match interim products (pallets), scheduling is simplified.

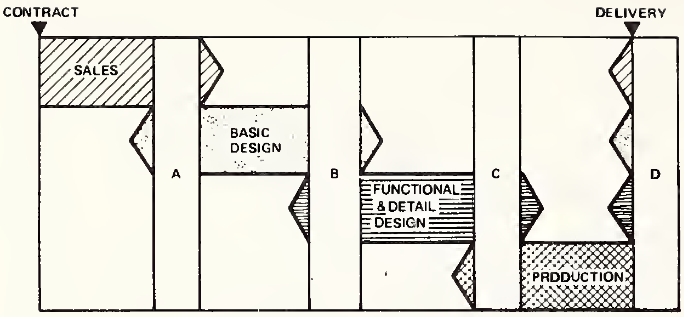

FIGURE 2–17: A—B—C—D meetings. Formal meetings are treated as essential milestones to ensure continuous communications and coordinated planning.

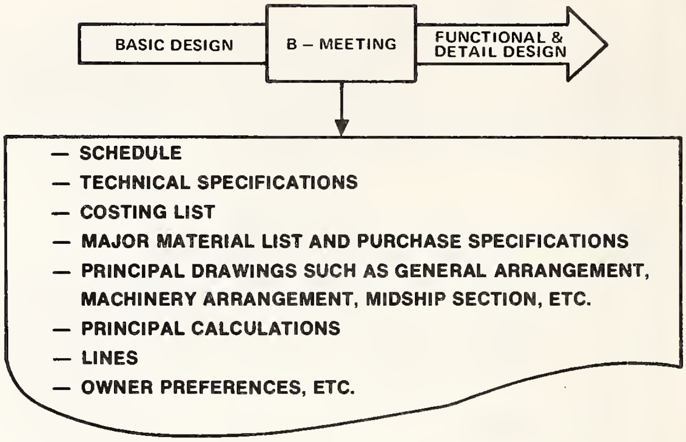

FIGURE 2–18: B meeting agenda. Other typical agendas are: "A" Meeting—contract background, specifications, cost, budget, key events schedule, information about owner; "C" Meeting—special design and material requirements, palletization grouping and coding, methods, detail schedule; "D" Meeting—technical, material, schedule and budget evaluations, guarantee items.

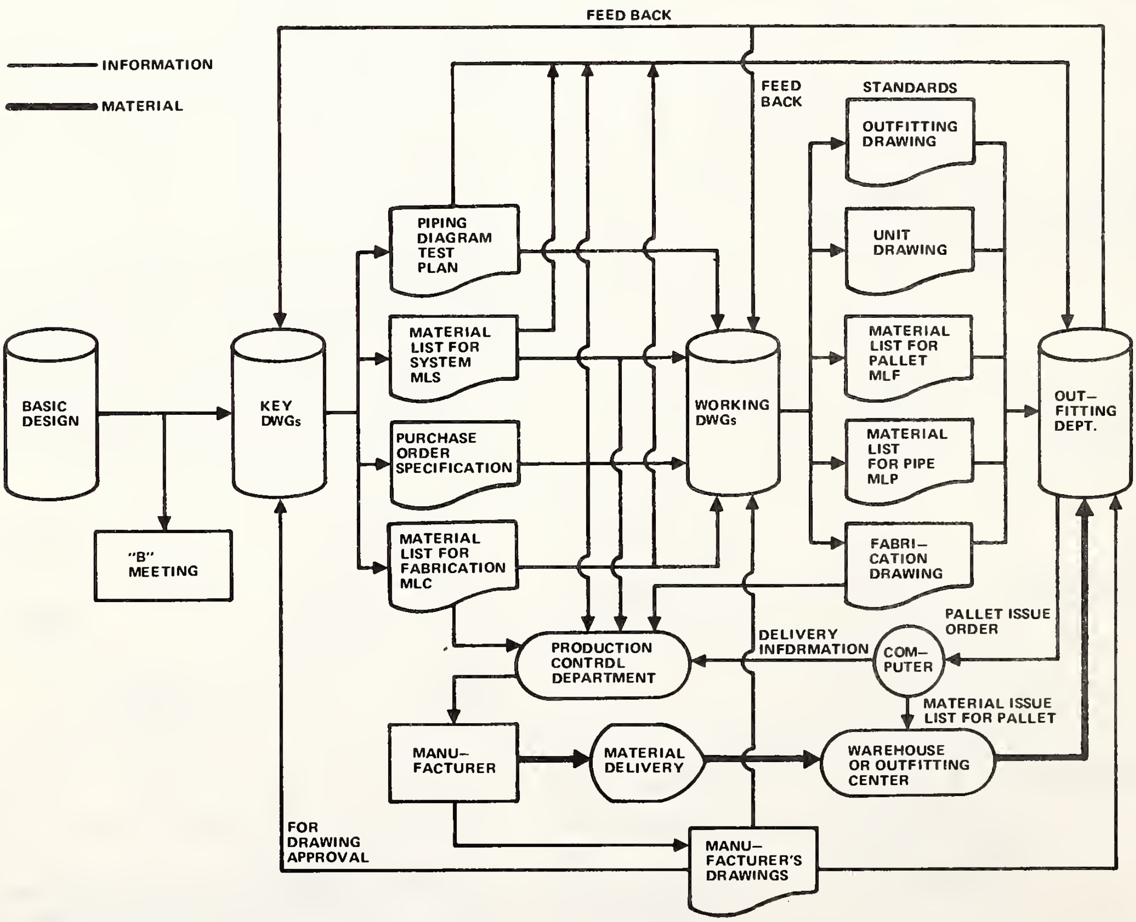

FIGURE 2–19: Flow of information and material.

3.0 DESIGN

The fundamental objective of zone outfitting is to simplify the ship production process. It is imperative where skilled labor shortages exist. Some shipbuilders who recognized the problem maintained a competitive position by both:

- simplifying assembly methods, and
- transfering more of the need to understand assembly techniques from production to design.

Such measures significantly increase the burden on designers. Thus, shipbuilding managers who address zone outfitting will encounter need to provide their design organizations with:

- special guidance, and
- additional resources.

And because minimizing elapsed time between contract award and delivery is a very strong competitive aspect, the attendant need to accelerate the entire design process requires consideration of different organizations and methods. Thus, it is necessary to supplement the basic concepts described in Chapter 2 with ideas for a more suitable framework in design for the organization and control of material procurement information and work instructions needed to support outfitting.

3.1 Organization and Responsibilities

A design organization which is segmented in the same manner as initial zone designations that apply to all ships (deck, accommodations, machinery and electrical) specifically addresses classes of problems in accordance with the principles of Group Technology. People so organized, develop expertise in assembly methods that are peculiar to their respective zones. Designers focus less on such things as absolutely minimizing pressure drops in pipe systems which sometimes impose design constraints that exceed the accuracy of their empirical flow factors. Instead, they concentrate more on routing, mounting and connecting distributive systems to facilitate ideal outfitting on-unit. Also, they focus more on hull construction options so that they may contribute to the coordinated planning which is necessary for efficient outfitting on-block (see figure 3-1).

Successful zone outfitting depends on reorienting detail designers to not think principally of functional matters although such knowledge is prerequisite. Their mission is to produce structured material lists and the drawings needed to make parts and assemblies. The latter, i.e., work instruction drawings, require detail designers to address separate work stages per work zone and incorporate work practices (e.g., specific designation of a make-up pipe piece with a loose flange) to an unprecedented degree.

Design departments, organized in terms of classes of production problems, can be subdivided into key drawing sections and working drawing sections. Each of these groups and their sections could have responsibilities assigned as follows:

3.1.1 Hull Structure Design Group

a. Key Drawing Section

(1) Hull structure key drawings

(a) Midship section and typical transverse bulkhead
(b) Steel scantling
(c) Stern frame
(d) Rudder, rudder stock, rudder carrier
(e) Main engine seat and major auxiliary eng. seat (boiler, generator, plumber block)
(f) Welding scheme
(g) etc.

(2) Research of local strength and vibration for hull structure

(3) Hull structure production control data

(a) Hull block weight
(b) Center of gravity of hull block
(c) Welding length

b. Working Drawing Section

(1) Hull block arrangement

(2) Hull structure working drawings (including detail structure design except for the deck house and casing)

(3) Piece list for hull structure

(4) Auxiliary foundation drawings for deck machinery, main engine, generator, steering gear, cargo pump in pump room, etc.

(5) Data input for management information system for hull structure

3.1.2 Deck Outfitting Design Group

a. Key Drawing Section

(1) Purchase order specifications and approval of vendors' drawings

(2) Key drawings

(a) General arrangement
(b) Hull piping diagram and guidance
(c) Fire-control
(d) Mooring
(e) Cargo gear
(f) Access
(g) etc.

(3) Material lists from key drawings (MLS)

(4) Detail drawings and material lists (MLC) for components other than pipe which are to be standard

(5) Calculations
   (a) Hydrostatic properties
   (b) Tank tables
   (c) Operational information

(6) Test guidance and records

b. Working Drawing Section

(1) Outfitting layout
(2) Pallet designations
(3) Arrangement drawings (composites)
(4) Work instruction drawings and their material lists (MLF)
(5) Material detail design drawings and their material lists for pipe pieces (MLP) and items other than pipe (MLC)
(6) Outfit weights and center of gravity calculations

3.1.3 *Accommodations Outfitting Design Group*

a. Combined Key and Working Drawing Section

(1) Purchase order specifications and approval of vendors' drawings

(2) Accommodation quarters key drawings
   (a) Cabin, including lighting and access arrangements
   (b) Deck house and machinery casing construction including funnel
   (c) Deck covering
   (d) Insulation
   (e) Lining
   (f) Piping diagram
   (g) Ventilation diagram
   (h) Refrigerated stores
   (i) Life saving

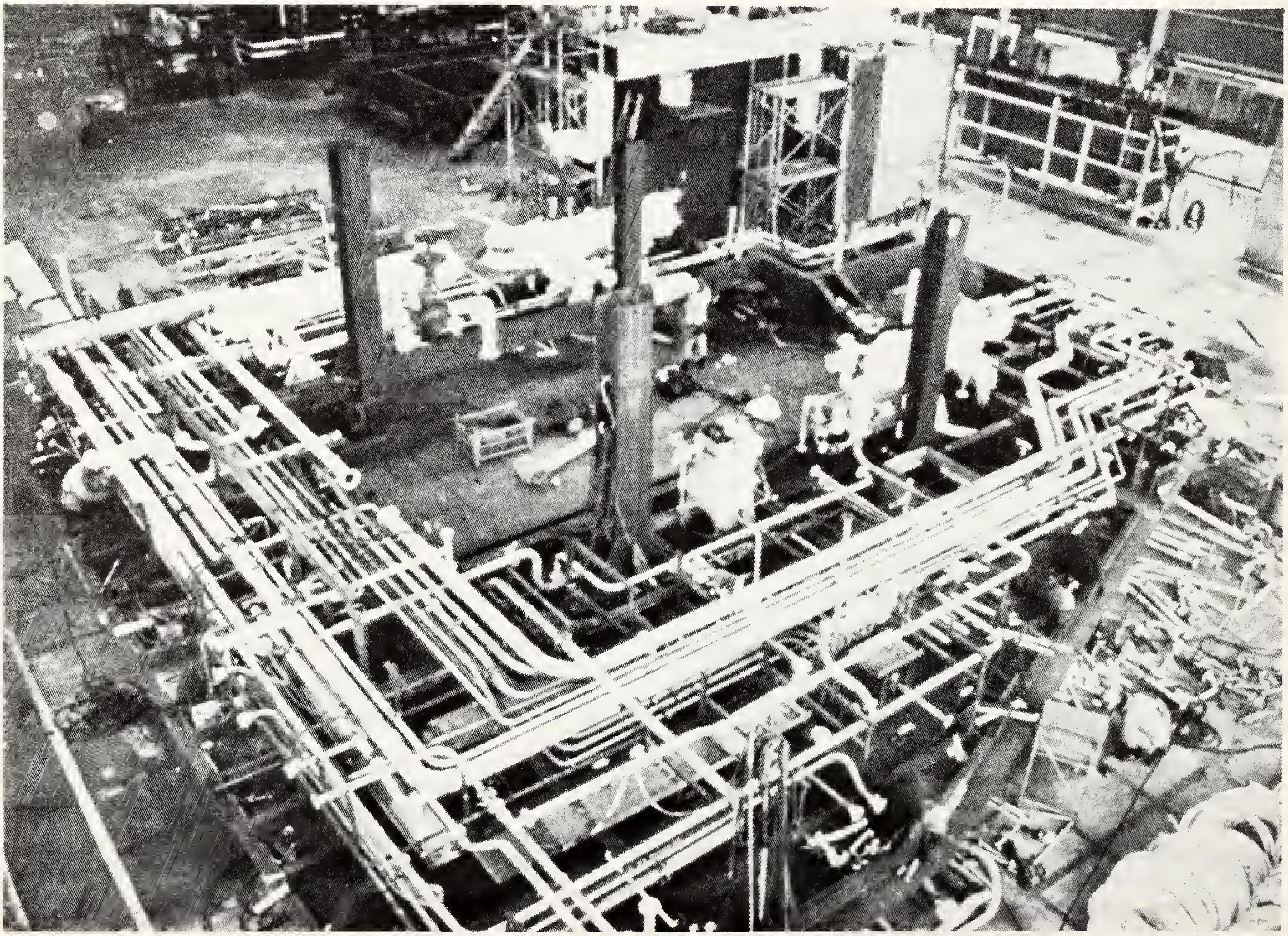

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FIGURE 3–1: Two blocks, upside down, are outfitted together to insure that everything will fit when joined in the building dock.

(3) Material lists from key drawings (MLS)

(4) Outfitting arrangement drawing

(5) Arrangement drawings (composites)

(6) Working drawing for deck house and machinery casing structure

(7) Work instruction drawings and their material lists (MLF)

(8) Material detail design drawings and their material lists for pipe pieces (MLP) and for items other than pipe (MLC)

(9) Test guidance and records for stores refrigeration, life boat handling, air-conditioning and ventilation system, elevator, trolley hoist, etc.

3.1.4 Machinery Outfitting Design Group

a. Key Drawing Section

(1) Purchase order specifications and approval of vendors' drawings

(2) Key drawings
   (a) Engine piping diagram and guidance
   (b) Shafting and propellor
   (c) etc.

(3) Material lists from key drawings (MLS)

(4) Detail drawings and material lists (MLC) for components other than pipe which are to be standard

(5) Test guidance and records

b. Working Drawing Section

(1) Machinery arrangements

(2) Pallet designations

(3) Arrangement drawings (composites)

(4) Work instruction drawings and their material lists (MLF)

(5) Material detail design and their material lists for pipe pieces (MLP) and items other than pipe (MLC)

3.1.5 Electrical Outfitting Design Group

a. Combined Key and Working Drawing Section

(1) Purchase order specifications and approval of vendors' drawings

(2) Electrical drawings

   (a) Arrangement of switchboards, group starter panels, control consoles, etc.
   (b) Electric load analysis
   (c) Schematic wiring diagram
   (d) Arrangement of navigation equipment
   (e) Etc.

(3) Material lists from key plans (MLS)

(4) Pallet designations

(5) Arrangement drawings (composites)

(6) Work instruction drawings and their material lists (MLF)

(7) Material detail design drawings and their material lists for pipe pieces (MLP) and items other than pipe (MLC)

(8) Test guidance and records

3.1.6 Standardization Group

(1) Research, development and maintenance of design standards.

The relationships of these design functions to production groups are illustrated in figure 3-2. Note that material control information is developed during both functional and working drawing preparation.

3.2 Pallet Identification

In order to minimize the elapsed time between contract award and delivery, outfit designers must contribute significantly to defining work packages. Their material lists generated from key drawings and work instruction drawings should be organized primarily to support material procurement and production. Figure 3-3 illustrates the relationships of material lists to product oriented work packages. Key drawings are used to generate MLS.[1] The various MLF are generated from work instruction drawings. Each MLF serves to identify the exact materials in a work package needed to build a specific interim product. The coding system for a pallet (MLF), and even for custom fabrication jobs identified by MLP and MLC, should be organized to provide information similar to the following:

a. Type

(1) Unit
   (a) Pipe
   (b) Other than pipe

(2) Other than unit
   (a) Pipe
   (b) Other than Pipe

[1]MLS - Material List by (ship's functional) System (by purchasing zone)
MLP - Material List for (manufacture of) Pipe (pieces)
MLC - Material List for (manufacture of) Components (other than pipe)
MLF - Material List for Fittings (per pallet)

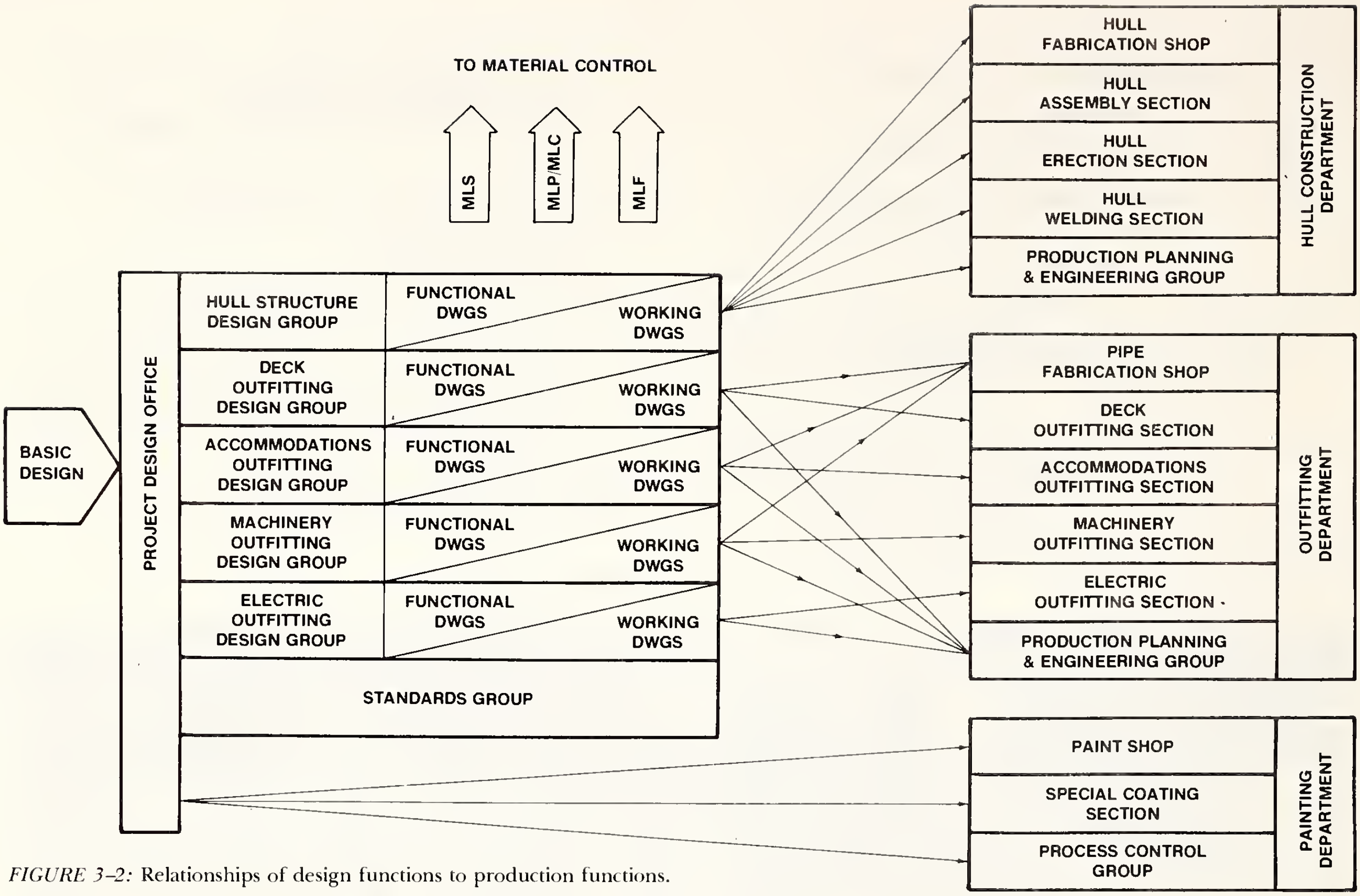


FIGURE 3–2: Relationships of design functions to production functions.

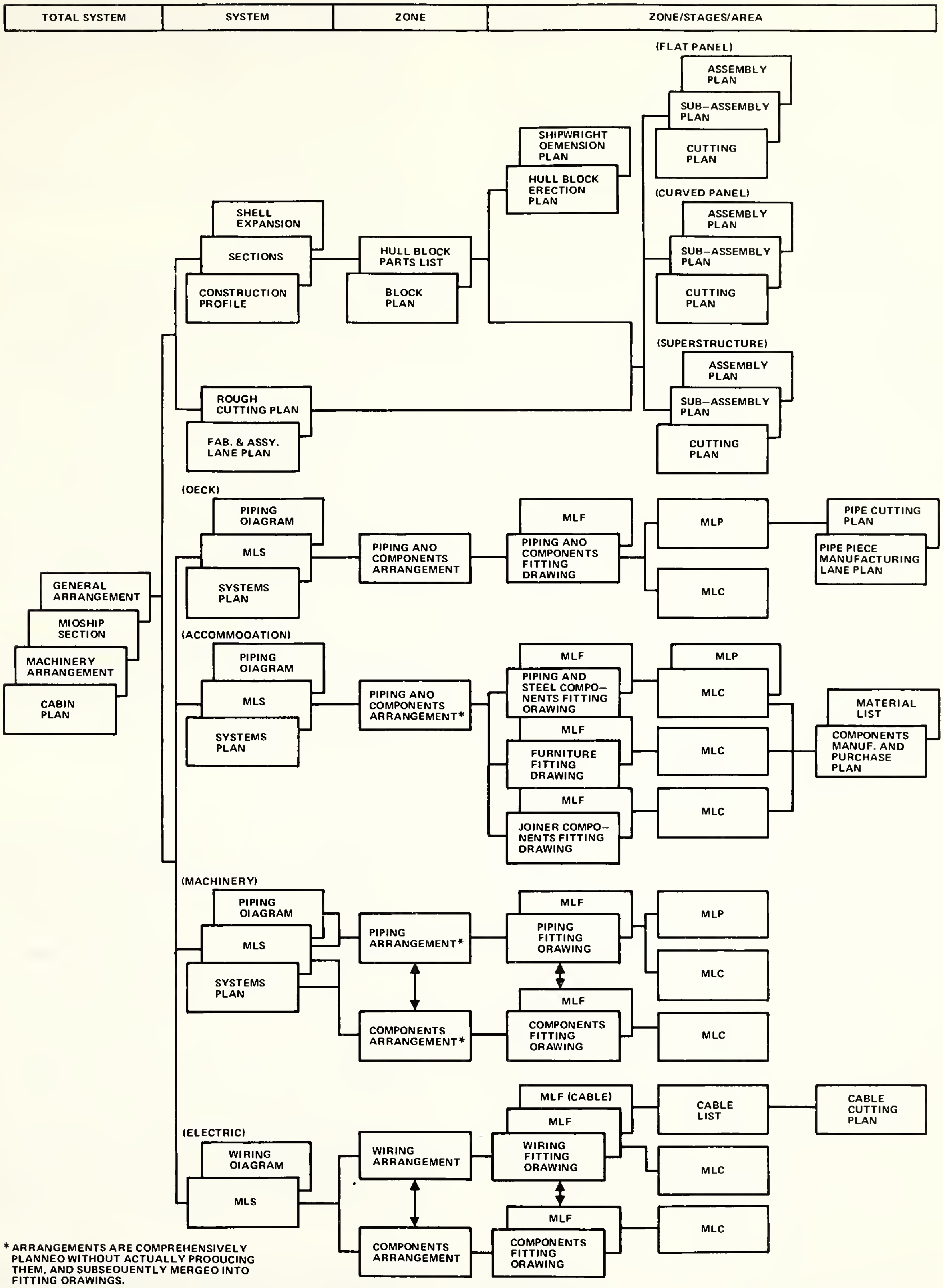
b. Production Group Responsibility
   (1) Hull Structure
   (2) Deck Outfitting
   (3) Accomodations Outfitting
   (4) Machinery Space Outfitting
   (5) Electrical Outfitting
   (6) Fabrication Shop(s)

c. Working Zone or Block Identifier

d. Work Sub-stage
   (1) On-block outfitting for materials pre-assembled into a unit after a block is turned over.
   (2) On-block outfitting for material to be installed piece-by-piece.
   (3) On-block outfitting for material to be installed piece-by-piece after a block is turned over.
   (4) On-block outfitting for material pre-assembled into a unit.
   (5) On-board outfitting for material pre-assembled into a unit.
   (6) On-board outfitting prior to an area closure by an overhead block.
   (7) On-board outfitting prior to systems tests (or other key events as selected).
   (8) On-board outfitting prior to launch.
   (9) On-board outfitting after launch.
   (10) On-board outfitting general category for items such as spare parts and touch-up.

e. Hull or Ship Number

Designers must consider factors which limit the size of a pallet. These should be documented so that there is mutual understanding of precise limits. If a unit is to be assembled in a shipyard, then criteria such as maximum size (length, width, height), maximum weight, mode of transportation, etc., must be defined. If the unit is to be assembled by a subcontractor, then the analogous constraints must be known to the designer. As a practical control measure, pallets for outfitting on-block or on-board should be limited by working time required. One rule-of-thumb for determining such pallet sizes is to limit them to the assembly work one to three people can accomplish in one week. Figure 3-4 is an example of the number of pallets that might result.



* ARRANGEMENTS ARE COMPREHENSIVELY PLANNEO WITHOUT ACTUALLY PROOUCING THEM, AND SUBSEOUENTLY MERGEO INTO FITTING ORAWINGS.

FIGURE 3–3: Design process for product orientation.

	30,000 DWT BULK CARRIER	250,000 DWT TANKSHIP
ACCOMMODATIONS	350	400
DECK AREA	300	800
MACHINERY	250	400
ELECTRICAL	200	300
TOTAL PALLETS	1100	1900

FIGURE 3-4: Typical numbers of pallets for ship types based on a maximum lift of 275 tons and size of 20 x 30 x 10 meters.

These basic concepts do not limit the number of levels of subassembly which can take place. The MLF relates to MLP and particularly to MLC as very useful multi-level bills-of-material. Information relating to a product in this fashion is also called a structure definition.[2] In building this information the top level, the MLF, is considered the parent and attached to it are its children, i.e., MLP, MLC and other materials needed for an assembly. There can be intermediate interim products such as two small units which will be joined to form a large unit. Other examples are illustrated in figure 2-2. The numbering scheme chosen for pallet identification should anticipate the desired levels of assembly in the production process.

Detail designers not only define stages of construction pallet-by-pallet, they also provide assembly instructions. That is, the same people who prepare a pallet's detail design prepare work instructions which may include the sequence for assembling pallet components. For these purposes they utilize a file of practice standards that has been prepared by the Outfitting Department's production engineers. In new situations they work with the production engineers to develop assembly methods. Incentive programs have been applied to encourage designers to suggest improved assembly techniques.

3.3 Standards

Inescapably, the responsibility for much of a ship's construction costs rests with designers. Sometimes a situation occurs where an extra hour or two over the budget allocated for designing certain features can save a week's work in production. But, the immediate design supervision is rarely in a position to authorize extra time. Thus, frequently the opportunity for cost reduction is rationalized away. Standards enhance design simplification but are even more valuable because they eliminate repetitive chores and allow designers more time to address productivity.[3]

For example, coding schemes for standards facilitate tabulations of material identities and quantities. Where they are used, designers do not have to repeat preparation of puchase specifications, manufacturing drawings and/or material lists. And when a code number is used to order a manufacturer's catalog item which has been adopted as a shipyard standard, detail designers do not have to wait for "vendor furnished information" nor do they have to approve vendor drawings.

Also, standards contribute to assurances for correct dimensions and quality. Therefore they permit a wider range of make-or-buy alternatives and require less involvement by detail designers.

However, standards infer conservatism. They also imply preference for one manufacturer's catalog item to the exclusion of others which could detract from productivity if acceptable alternatives exist. Therefore it is very important that sufficient design resources be assigned to:

- delete T-items (standards) that are not sufficiently used,
- add to the list of T-items whenever general usage of something new is expected,
- "upgrade" P-items (per shipyard specifications) and D-items (per shipyard drawings) to T-items if general usage is predicted, and
- create a reasonable number of alternate standards for each manufacturer's catalog item adopted as a shipyard standard.

Ideally, everything needed to outfit a ship would be incorporated in the shipyard's table of standards. Detail designers would then concentrate on identifying ideal interim products, assembly methods and updating the shipyard's file of design modules.

3.4 Design Modules[4]

One shipbuilder has exploited standardization with "modules" applied in accordance with a wide definition in design, procurement and production. The basic building blocks, or modules, are standard machinery components.

Examples of particulars for some families of standard machinery items for a steamship are presented in figure 3-5. Although only one manufacturer's main turbines are indicated, another's are included in the shipyard's file of standards. The provided information for the associated standard pump shows that at least two manufacturers can respond for each of the capacities specified.

The specific turbines and pumps were selected after evaluations of performance reliability, quality, installation requirements, delivery prospects and prices. Approvals were made at the time the pertinent specifications and

[2]Also called Structuring the Bill of Material

[3]Reduction in the number of different material items can save an estimated 15 to 20 percent in costs associated with material definition, purchasing, storage, retrieval and in-process material control. Additional savings may come from the increase in size of bulk orders.

[4]The figures and substance in this subchapter unless otherwise noted are from Ichinose, op. cit., Chapter 2.0, footnote 7; and from the July 5, 1979 letter by Y. Ichinose which commented on the intial draft of this manual.

MAIN STEAM TURBINE							MACH NO.	M001	
MAIN ENG. RATING			PS	24,000	27,000	30,000	33,000	36,000	40,000
M. TURBINE	TYPE			IMPULSE, 2-CYL, CROSS COMPOUND WITH 2-ST. RED. GEAR					
	MODEL	H.P. TURBINE		CNH-21		CNH-22	CNH-31	CNH-32	
		L.P. TURBINE		CNL-21		CNL-41		CNL-51	
	WEIGHT		t	46 61		49.83	52.03	55.25	
RED. GEAR	TYPE			TANDEM	DUAL TANDEM				
	PROP. SHAFT RPM			80					
	TYPE			C 45 A	D 49 A			D 51 A	
	WEIGHT		t	145.0	148.0			166.0	
STAND, DWG, NO.			SD 1	411121110	411121120	411121130	411121140	411121150	

MAIN CONDENSATE PUMP							MACH. NO.	MO 21	
							TYPE	VEC	
MAIN ENG. RATING			PS	24,000	27,000	30,000	33,000	38,000	40,000
CAPACITY			m3/h x m	70 x 95	75 x 95	85 x 100	90 x 100	100 x 100	110 x 105
MAKER A	MODEL			EVZ 130					EVZ 130-2
	STAND. DWG. NO		SD 1	440011380A					440011390
	MOTOR CAPACITY		KW x rpm	37 x 1800	45 x 1800		55 x 1800		75 x 1800
	MOTOR MODEL			225S	225M		250M		280S
	CAPACITY RANGE		m3/h x m	70 x 95	71 x 95 90 x 95	66 x 100 85 x 100	86 x 100	100 x 100	103 x 105 130 x 105
	WEIGHT	PUMP	t	0.59					0.64
		MOTOR	t	0.25	0.28		0.345		0.46
MAKER B	MODEL			250 x 125 - 2VCDS-A					
	STAND.DWG		SD1	440021740A					
	MOTOR CAPACITY			37 x 1800	45 x 1800		55 x 1800		
	MOTOR MODEL			225S	225M		250M		
	CAPACITY RANGE		m3/h x m	70 x 95	71 x 95	85 x 1800	86 x 100	100 x 100	110 x 105
	WEIGHT	PUMP	t	0.61					
		MOTOR	t	0.25	0.28		0.345		0.46

FIGURE 3–5: Examples of particulars for standard machinery components. For each family of machines in the standards file, alternates, i.e., different manufacturers' catalog items, are also certified as standards and maintained in file.

drawings were registered as shipyard standards. The latter are the basic modules for reusable layouts of machinery, figure 3-6, for which system diagrammatics are also maintained in file.

Similar "sets" of modules apply to diesel engines. Therefore, by selecting a main engine a designer automatically decides the particulars and specifications of ancillary machinery in one action.

Also, because the number of cylinders in particular model diesel engines vary for different power requirements, engine lengths vary while their heights and widths remain unchanged. Each applicable machinery arrangement anticipates the longest engine so that less powered engines can be substituted without interfering with the layouts of other machinery. Similarly, because one, two or even three pumps could be required for a specific function, their layout is based on the maximum number.

Design modules offer shipbuilders opportunity to continously improve designs and to achieve greater overlap of design, procurement and production. Their reuse in all aspects of planning facilitates some of the savings that are otherwise only associated with building standard series ships. Some specific benefits are:

- in design
  — accumulation of experiences
  — assurances for quality and functions
  — savings in manhours
  — less human error
  — easier application of computers
  — quicker response to changes
  — simpler purchase specifications

- in procurement
  — accumulation of experiences
  — lower material costs
  — simpler purchase orders
  — easier material control

- in production
  — accumulation of experiences
  — better adherence to schedules
  — savings in manhours

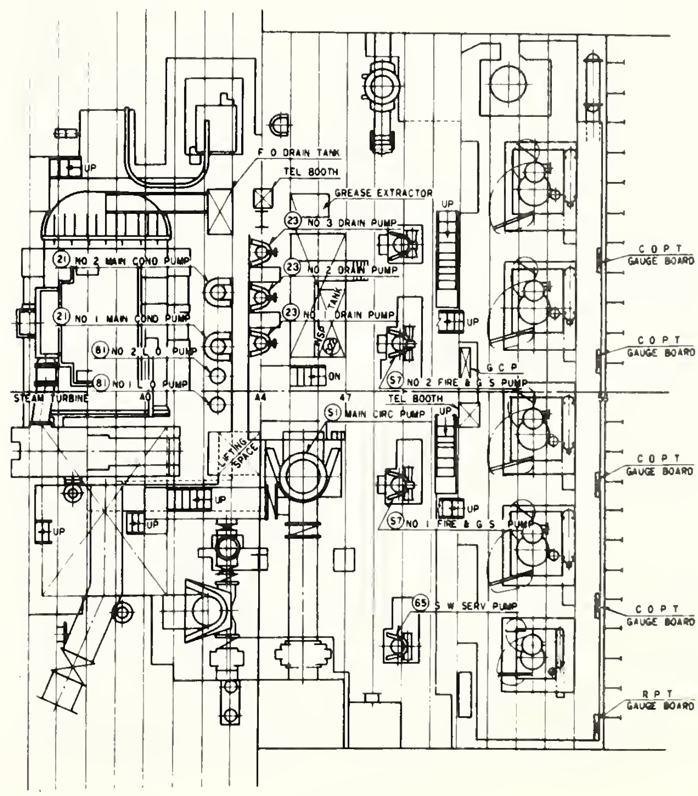


FIGURE 3–6: Each position in a reuseable machinery arrangement has enough space around it to accommodate the several catalog items that are maintained in the standards file for that position. Pipe detail designers adjust for the different nozzle locations.

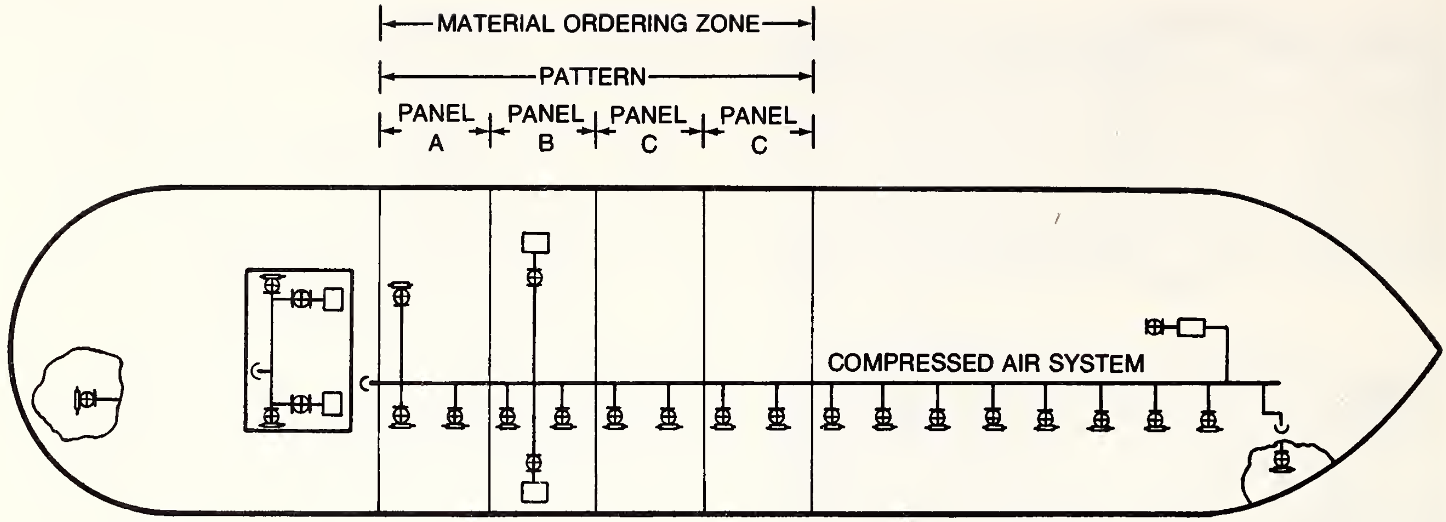


FIGURE 3-7: Diagrammatics within the same material ordering zones for different ships, often reflect similar patterns.

Not all owners inhibit such practices and some who have ships built abroad encourage them. They know that design modules and attendant equipment lists, test memos, equipment manuals, etc., regardless of ship size and type results "... in tremendous cost reduction. A state of affairs good for the shipyard and owner alike."[5] Realizing this, they now offer performance specifications.

But, even among such owners there are peculiar needs that require flexibility. Therefore, design modules that shipbuilders offer should be general enough to provide for:

- different performance ratings,
- different owner, regulatory and classification society requirements, and
- choices from among several manufacturers.

3.5 Patterns and Panels

"Patterns" and "Panels" are used to further systematize and accelerate design. The concept is practical because many system diagrammatics reflect patterns that are similar for different size and type ships particulary if compared by material ordering zones. See figure 3-7 which also illustrates that a pattern subdivided into panels corresponding to envisioned work zones, permits rapid grouping of information by system and by work zone.

One of each kind of panel is matched to panels from the shipyard's file. Each panel includes an arrangement and much of what is required to complete a material list for a specific application. A panel, because it is for general use, addresses ranges of material sizes, and includes:

- for standard fittings — exact quantities required and complete descriptions less only specific sizes,
- for other standard materials (e.g., pipe) — complete descriptions less both required quantities and sizes, and
- standard guidance for pipe detailing and painting.

The panels are formatted to facilitate adjusting them for a specific design project by functional designers who:

a. first modify the standard guidance for pipe detailing and painting as may be required by the shipbuilding specifications,
b. add standard fittings sizes,
c. add sizes and estimated quantities for standard materials other than fittings (e.g., pipe),
d. add descriptions and quantities of non-standard materials as appropriate, and
e. incorporate the foregoing in MLS.

As shown in figure 3-8, each modified panel is overlayed in detail design with such panels for other systems in the same work zone. Spacing is adjusted until an interference-free and functional layout is achieved. Next, as also illustrated in figure 3-8, the exact dimensions are entered and material requirements are precisely defined. Pallets are created when these materials are combined with those from other panels for the same zone and are separated by work stages.

[5]"Shipbuilding Standards An Owner-Operator's Viewpoint", interview with Robert J. Taylor, Technical Manager, Tanker Department, Exxon International Co.; ASTM Standardization News, June 1979, pp 8-10, 51.

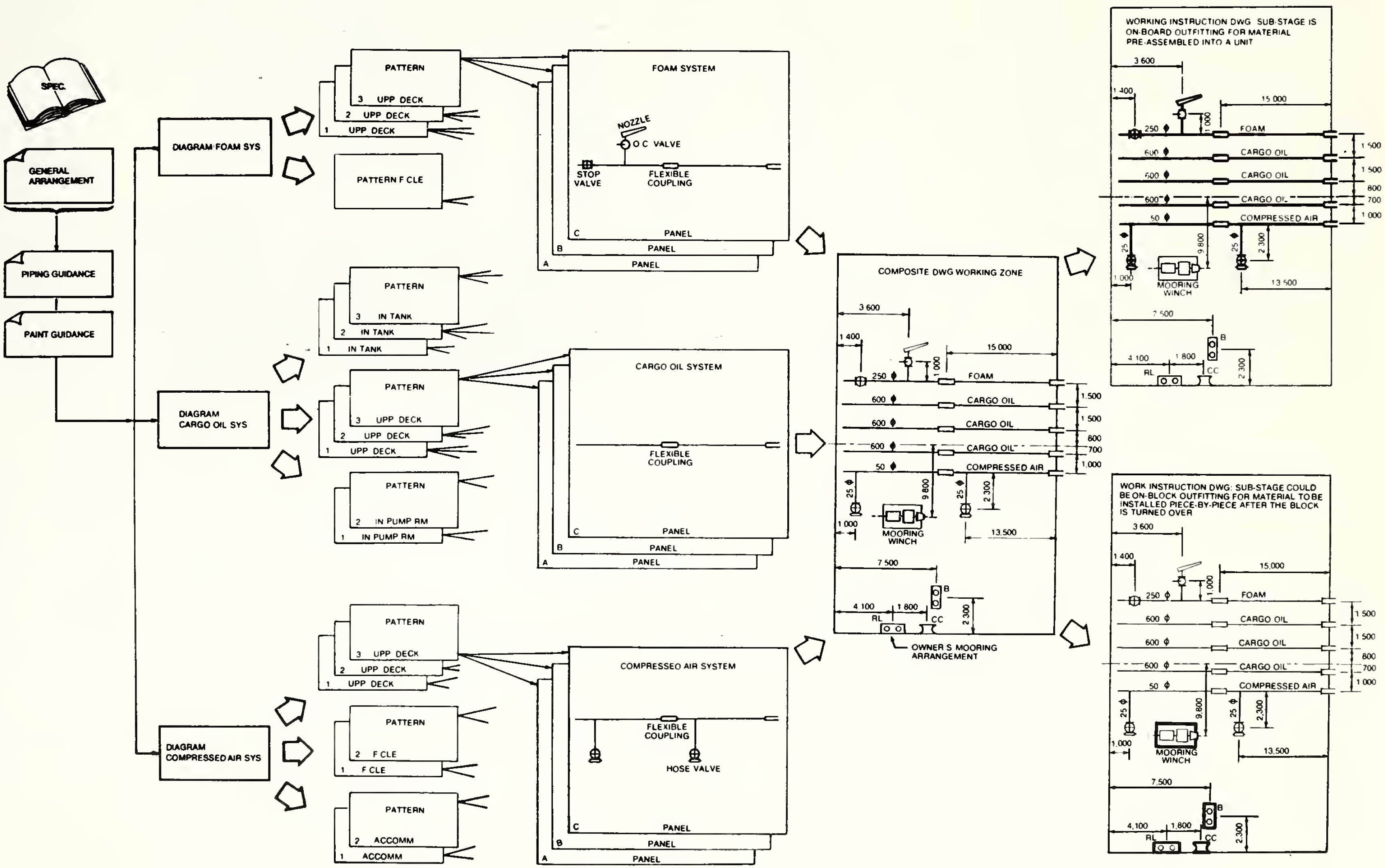


FIGURE 3–8: Application of patterns and panels.

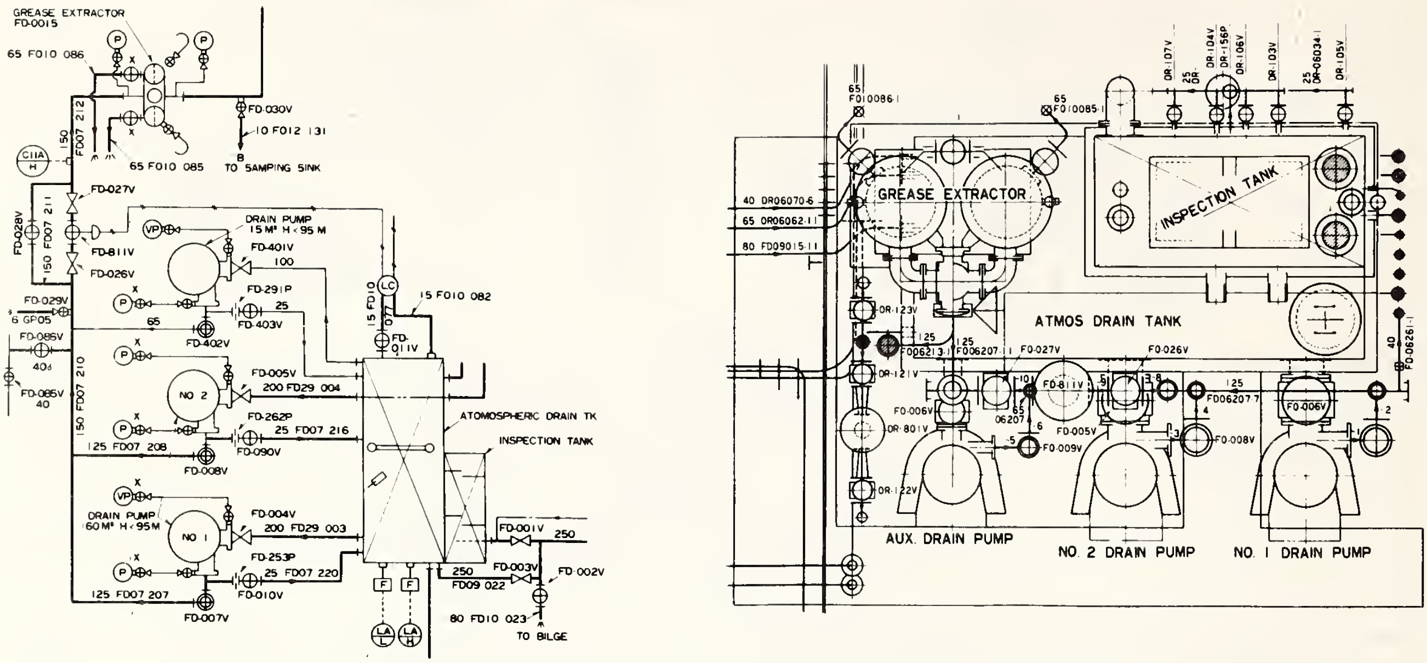


FIGURE 3–9: A reuseable diagrammatic and its machinery arrangement. They are not dimensioned because they apply to a range of capacities. A detailed pipe arrangement, unless it is very complicated is not retained in file in order to minimize the file size and because some pipe pieces vary with the alternate manufacturers' catalog items that are also certified as shipyard standards.

The concept, widely defined, has many applications. Any piece of machinery, or even a drain collecting tank, with its immediate piping arrangement can be a panel. When arranged with other panels it could be part of a pattern for a work zone; see figure 3-9. A pattern could apply to a complete up-to-date unit, such as that illustrated in figure 3-10, which represents the latest accumulation of pertinent experiences.

Interfaces of certain panels should permit their being repeated as adjoining panels as shown in figure 3-11. Considering this need and the requirement for flexibility, the preparation of panels for general application is relatively expensive. However, panels are capital. Their costs are justified by reuse in ship after ship just as costs for a building dock.

Where successfully applied, patterns and panels files have been gradually assembled using the contract requirements of new shipbuilding orders to continously:

- confirm traditional arrangements, and
- identify new arrangement trends that could be reused.

As all influences on past detail arrangements are not recorded, emphatically, start-up and maintenance of a patterns and panels file should be based only on the present and future.

Panels and even complete patterns that have been used before, with their accompanying work instructions, serve as preplanned work packages. They are adapted (nominal changes are generally required) in new ship designs primarily to accelerate functional design, detail design, and re-

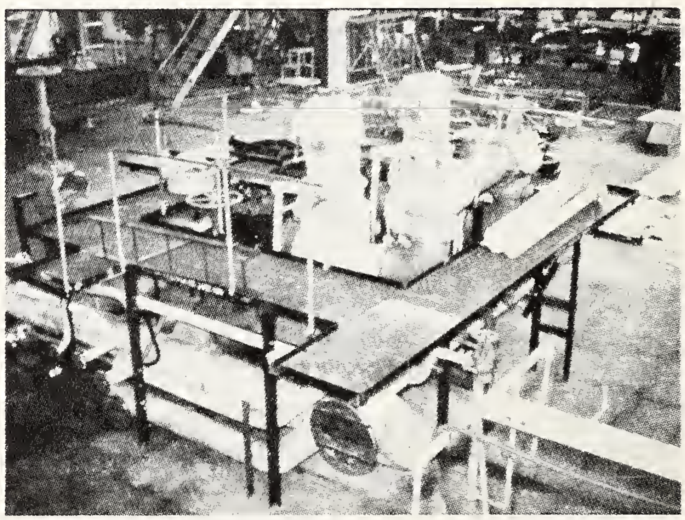


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FIGURE 3–10: The culmination of standard components and machinery, design modules, patterns and panels is a pallet such as for the illustrated unit. It is a module of accumulated experiences that can be applied again and again for different size and type ships. If the patterns and panels file is truly viable, such units will always reflect interim products suitable for modern ships. Where personnel turnover is a problem, an up-to-date patterns and panels file is essential if the shipyard is to retain the accumulation of useful experiences.

maining planning. Where applied, the manhours needed for such functions have been reduced.

Ideally, panels should feature standard components in addition to machinery which necessitate special long-term relationships with certain suppliers. This would ensure the availability of such materials in the reasonable future. However, such arrangements are not an absolute necessity as the use of non-standard components diminishes, but does not eliminate potential savings.

Obviously, successful application of patterns and panels depends upon design and material purchasing people understanding their significant support roles. It is also critically dependent upon managers addressing different purchasing policies and identifying some savings for owners.

3.6 Arrangement Zones

Different ship designs incorporating the same type of propulsion, e.g., diesel, can feature the same machinery arrangements to a remarkable degree even when different main engines are specified. Some shipbuilders already require detail designers to adhere to zones which are reserved for pipe systems. As illustrated in figure 3-12, these elongated zones are reserved around the main engine, between the tanktop and platforms, and both longitudinally and athwartships on platforms. With few exceptions, pipe systems are then detailed in parallel to each other and within the zones just as electric cable is committed to wireways. Pipe bends are minimized. More importantly, arrangement zones permit acceleration of detail design and facilitate all other planning aspects including the erection sequence.

In order to achieve maximum benefits from the concept of arrangement zones, units similar to those illustrated in figure 3-12, usually associated only with tanktop arrangements, are installed on platforms. They facilitate detail de-

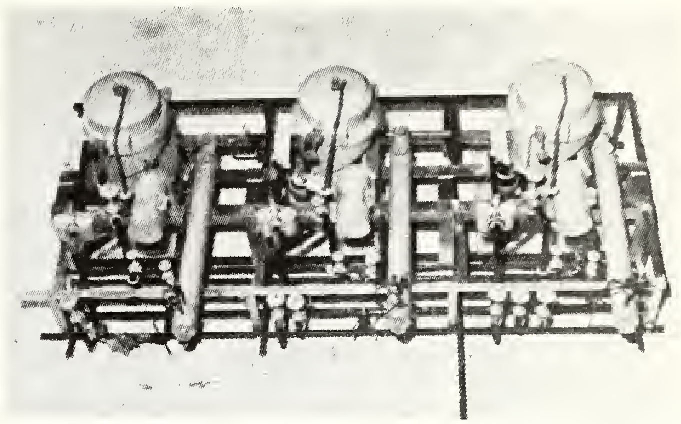

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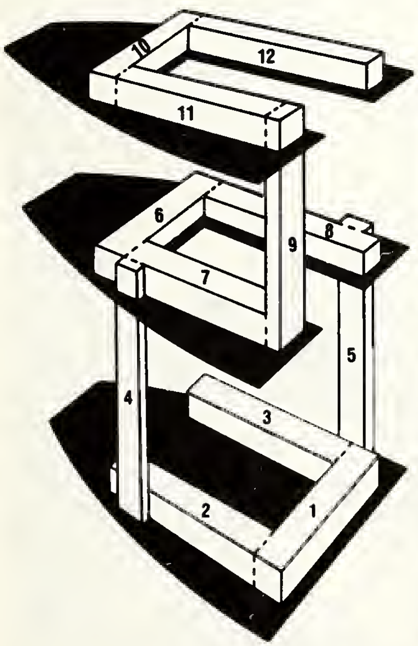
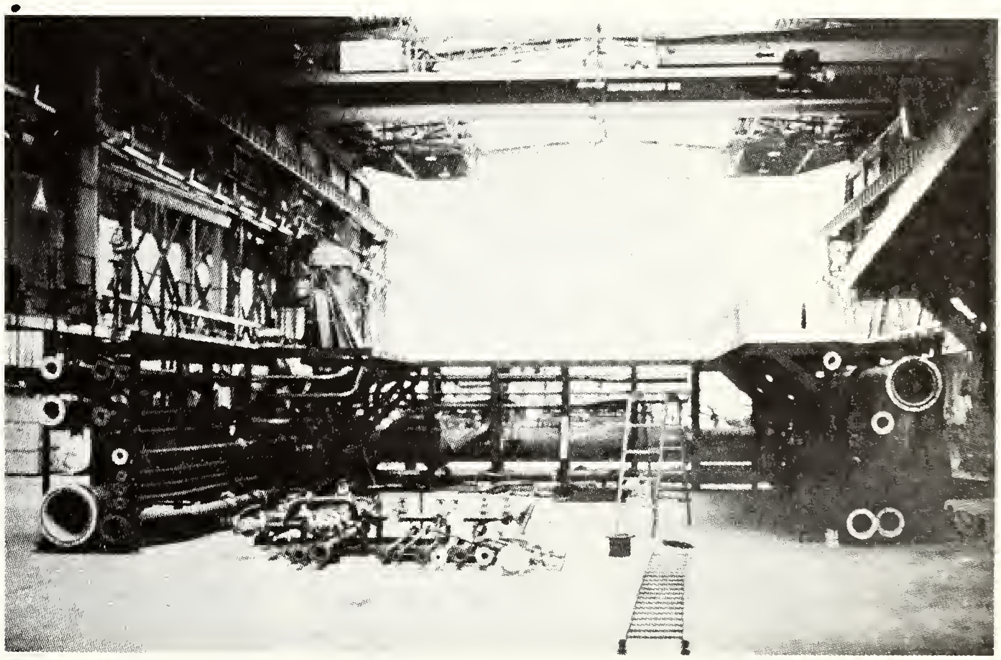
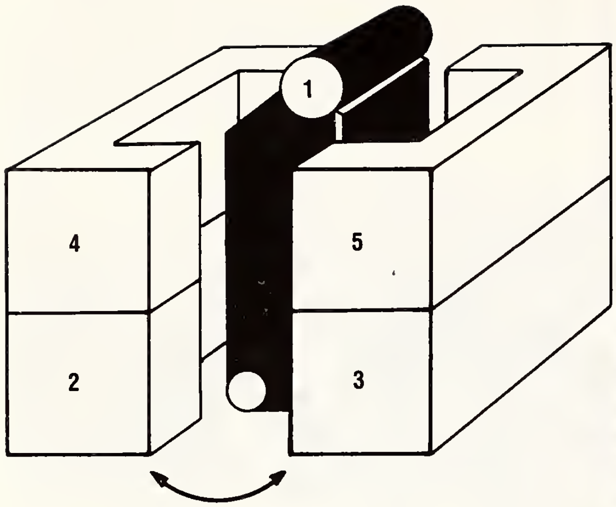
FIGURE 3–11: Repeated application of a panel. The pattern material list is simply three times that for a panel. Adjustment for sizes and nominal changes in material quantities are per the detail design sheet which is part of the panel.

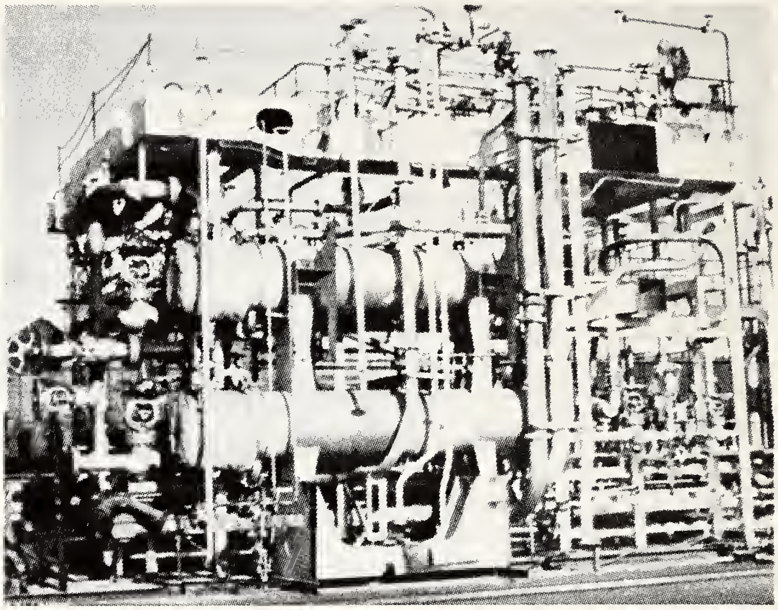




ITALCANTIERI, MONFALCONE

FIGURE 3–12: Arrangement zones around a main diesel engine. Three typical units matched during assembly are shown on the right. They feature pipe systems grouped beneath walkways (attached to the walkway supports), pumps, gratings and handrails. The latter two items permit access both during assembly and after the unit is landed on-block or on-board. Thus, there is no need for local temporary staging. When standard auxiliaries are incorporated, standard branches are detailed. However space is sufficient to employ custom designed adapters for non-standard machinery. A possible erection sequence, shown on the left, could remain unchanged regardless of ship type or size.





MITSUI, CHIBA

FIGURE 3–13: Arrangement zone around a boiler. One of the four required units is shown on the right. Its basic arrangement remains the same even for steamships of different types and sizes. The rectangular vent duct contributes to structural integrity and also serves as a walkway.

sign by minimizing special procedures for arranging pipe systems and avoiding many potential interferences with structural members, lighting fixtures, etc., that characterize the undersides of platforms.

In order to obtain acceptance, managers must address benefits to owners which in addition to shipbuilding cost savings at least include:

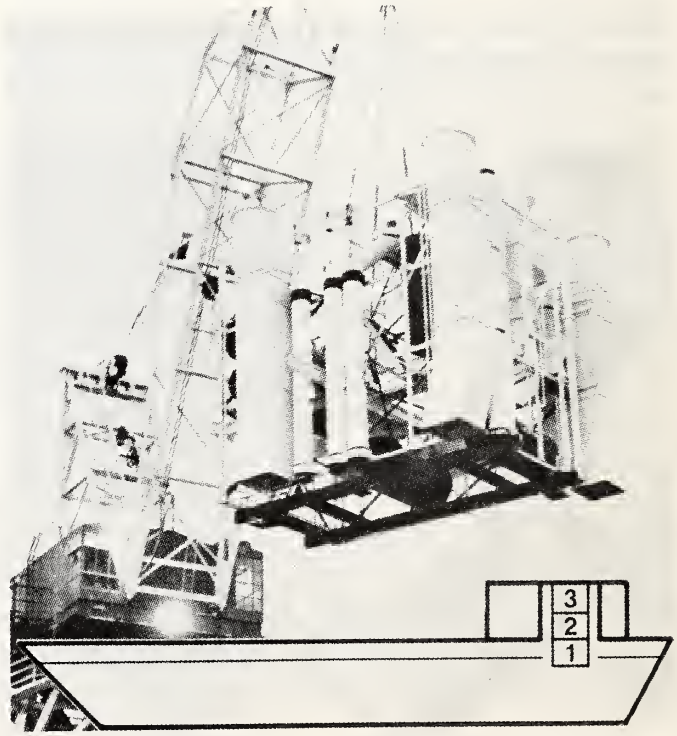
- the ease with which operating crews can trace systems, and
- improved access for reducing costs of repair work.

An example of an arrangement zone which encompasses the boiler of a steam powered ship is illustrated in figure 3-13. Another which pertains to uptakes is shown in figure 3-14. One for installation aft in a boiler space is illustrated in figure 3-15. Arrangement zones also apply to outfitting on block, see figure 3-16. Just as patterns and panels, arrangement zones are means for accumulating planning experiences for easy adaptation to new ship designs.

3.7 *Pallet Definition*

Delineating pallets is a result of one of the A—B—C—D meetings. The "C" meeting is called the pallet meeting and considered a project milestone. Actually, it is the last of a series of meetings during which all pallet definitions are finalized. Attendees are those involved in planning. This includes people representing the design, material and production functions.

The process of pallet definition is assisted by the use of standards such as for material and engineering. It is also



DAVIE, QUEBEC

FIGURE 3–14: Arrangement zone for uptakes in a diesel powered ship. Units 1,2 and 3 are mated to each other during assembly.

assisted by design modules, patterns and panels, and arrangements zones. All allow substitutions for auxiliary machinery (spacing is sufficient for custom fit adapters even

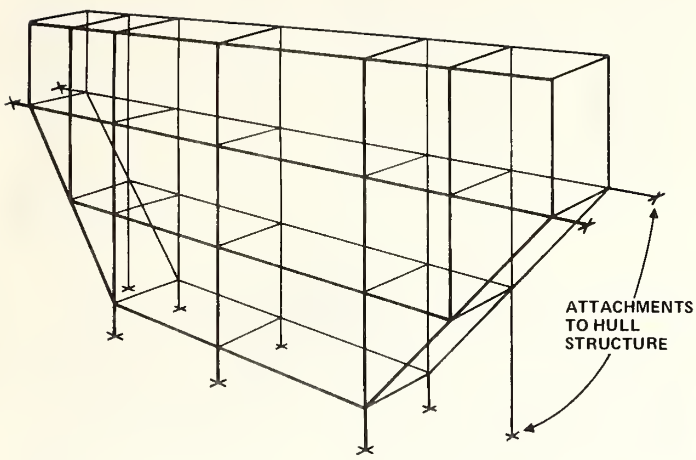
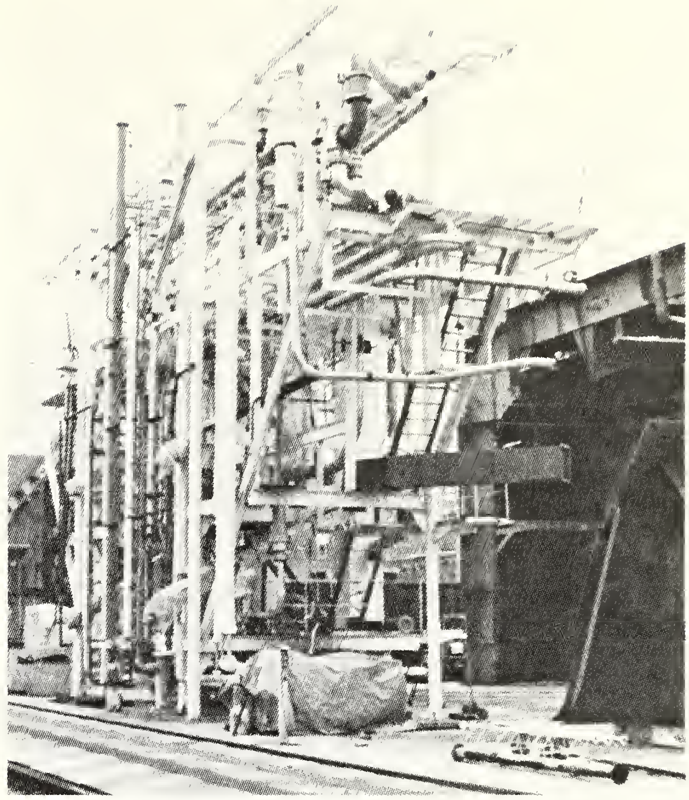
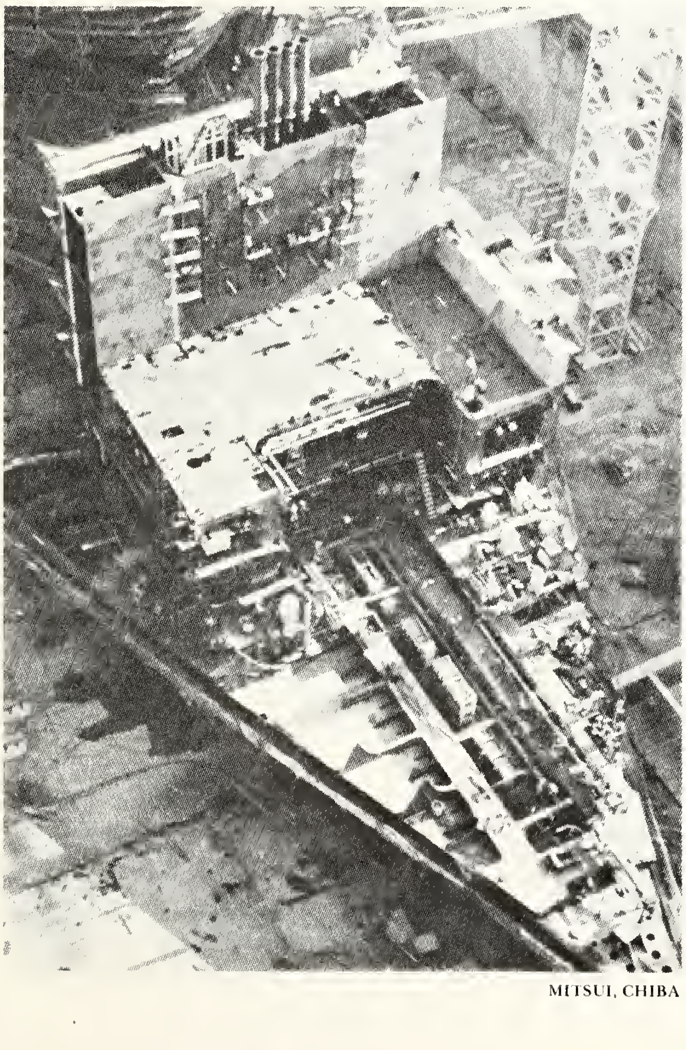


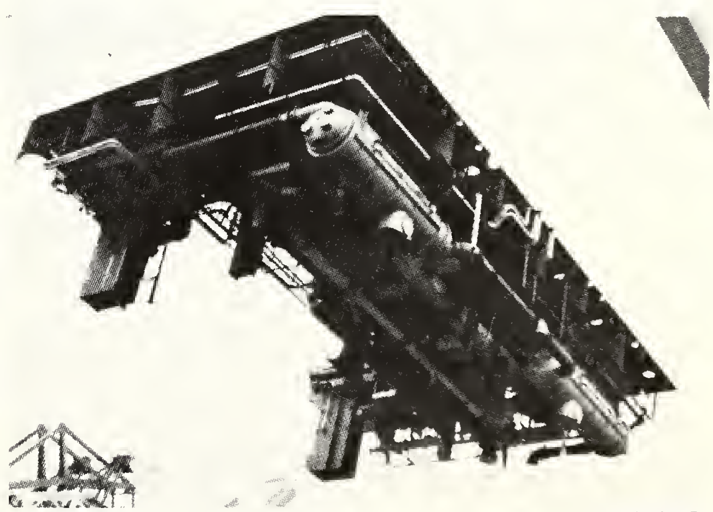
FIGURE 3–15: Arrangement zone aft in a boiler space. Fitting to curve hull structure is minimized. In addition to ladders, handrails, gratings, soot blowers, large pipe, pipe less than 2-inches in diameter and even tubing are outfitted on-unit.



IHI, KURE

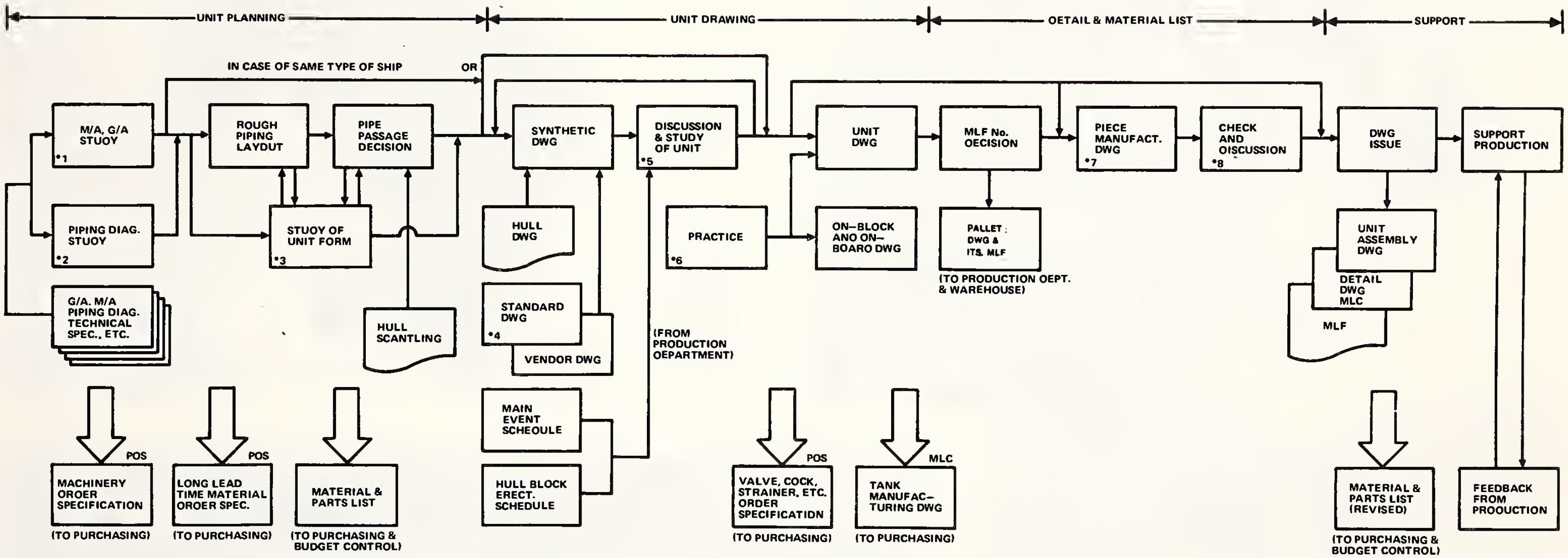


MITSUI, CHIBA



MITSUI, CHIBA

FIGURE 3–16: Each platform, forward in the machinery space, incorporates three block divisions, i.e., port, center and starboard blocks. These divisions and the basic arrangement of outfit can be virtually the same even for different types of diesel-propelled ships.



*NDTES –

*1 – MACHINERY ARRANGEMENT & GENERAL ARRANGEMENT	*2 – PIPING DIAGRAMMATICS	*3 – UNIT FORM	*4 – OESIGN STANDARDS
1. POSITION OF MACHINERY 2. ARRANGEMENT OF MACHINERY 3. REVIEW OF OPERABILITY ANO MAINTAINABILITY	1. REVIEW OF ABILITY 2. REVIEW OF CAPACITY 3. REVIEW OF COMPONENTS CONSIOERING OPERABILITY & REOUCTION IN SIZE OF PLANT	1. WHERE CAN THE ZDNE & PARTS BE PACKAGEO ? 2. WHERE IS THE ZONE FITTING JUST FOR THE UNIT ?	1. STANDARD UNIT DWG 2. STANDARO PIECE DWG 3. CHECK LISTS 4. ETC.
*5 – REVIEW OF UNIT	*6 – STANDARD PRACTICE	*7 – FABRICATION DWGs	*8 – FINAL REVIEW
1. ASSEMBLY PROCEOURE 2. LOAOING PROCEDURE 3. ON–UNIT → ON–BOARD ? OR ON–UNIT → ON–BLOCK ? 4. RELATION TO HULL BLOCK ERECTION SCHEOULE 5. RELATION TO HULL BLOCK ERECTIDN METHOD 6. WHERE CAN ZONE & COMPONENTS BE FITTED JUST FOR ON–BLOCK OUTFITTING ?	1. PIPING PRACTICE 2. FLOORING PRACTICE 3. INSULATION PRACTICE 4. VENTILATION PRACTICE 5. ETC.	1. PIPE FAB. DWG 2. VENT OUCT DWG 3. FLOOR & GRATING DWG 4. LADDER DWG 5. MACHINERY SEAT DWG 6. SPINDLE DWG 7. PENETRATIDN PIECE DWG 8. MAIN ENG. EXH. GAS PIPE DWG 9. UP–TAKE DWG 10. PIPE SUPPORT DWG 11. COAMING. GUTTER DWG 12. ETC.	1. UNIT DIVISION 2. UNIT ASSEMBLY PROCEDURE 3. UNIT LOAOING PRDCEDURE 4. PRACTICES 5. ETC.

FIGURE 3–17: Unit outfitting procedure in design.

for some non-standard machinery). When prudently applied, the definition of pallets for ships of different types and sizes should vary only slightly. Thus, much of the pallet divisions from previous ships can be reapplied with nominal adjustments. That is, a great amount of the planning scheme for zone outfitting is transferrable even though the contents of the pallets differ.

The process for developing unit drawings and material lists is illustrated in figure 3-17. Some pertinent considerations are:

a. All outfitting components located in the physical area a unit occupies should be incorporated into that unit.

b. After placing the unit on-block or on-board, only the installation work of the unit itself should be performed.

c. A unit should be independent of hull structural components for its construction. Each unit should be a "stand alone" component to be installed.

d. The duration of on-block or on-board outfitting should be kept to as short a period as possible thereby minimizing dependence on a hull structural assembly. The reduction in the time to install materials on-block or on-board reduces the necessary interfaces between oufitting and hull construction, and thereby shortens the overall time to construct a vessel. The unit should be designed to minimize installation time.

e. The connection of one unit to another unit or the connection of a unit to items outfitted on-block or on-board, should be simple with the number of connections kept to a minimum in order to simplify installation. Each unit should be designed and constructed so as to provide convenient access to attachments. Further, the type of connections used should not require a unit to be shifted horizontally after it is landed.

f. A unit should be designed so as to minimize deformation from lifting and transporting thus maintaining proper alignment at the time of installation. One method of ensuring initial alignment is to pre-mate units in assembly areas prior to installation.

3.8 Material Definition

As the duration between contract award and delivery is shortened, the time available for procurement is also shortened. Thus, materials information must be organized to facilitate earlier procurement. The organization of material requirements into four material lists, i.e., MLS, MLP, MLC and MLF, permits the same information to be sorted quickly into formats which are tailored to the specific needs of design, material, and production people. Design is interested in material ship-by-ship and pallet-by-pallet. Material control is interested in material ship-by-ship and material-by-material, whereas production, concerned with interim products, needs information pallet-by-pallet. For each material item the information is the same. The lists are just differently organized to better support the different functions. Figure 3-18 illustrates organization of information for effective material control.

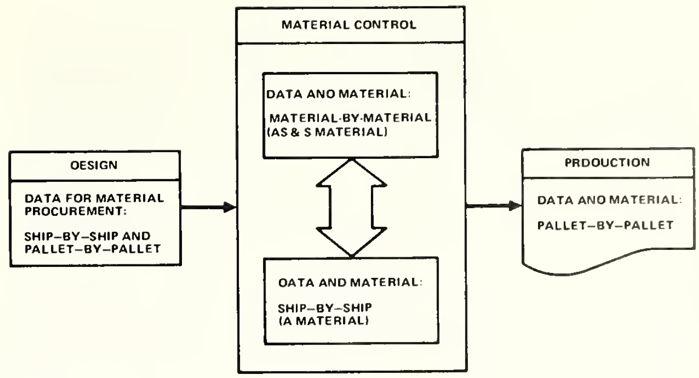


FIGURE 3-18: Control organization for material. The same information is sorted into different formats to satisfy various user requirements.

As the procurement process must take place earlier than in less competitive shipbuilding times, more dependence must be placed on counting or estimating material requirements in functional design. Then, as work instruction drawings are produced, definite quantities replace the estimates. Required dates for materials identified in functional design are based on the fabrication start date for the earliest pallet needed for each material ordering zone. The completion date for each work instruction drawing is based on the earliest assembly start date for the pallets incorporated. As the design develops, the material required dates from functional design are replaced by refined dates based upon completion of work instruction drawings. A flow chart for the materials definition process which should be performed by designers, is presented in figure 3-19.

There should be primary reliance on functional design for definition of high cost materials. The reason is that as there must be a function for everything shown on a diagrammatic, only necessary materials will be ordered. If there is dependence on detail designers, both the manhours for producing detail design drawings and material costs can be expected to increase. When directed to develop details by zone, detail designers are denied opportunities for costly critique of an entire system diagrammatic based upon personal experiences. Such diversions counter a shipyard's determination to use standard materials and to adapt existing design modules, patterns and panels, and arrangement zones.

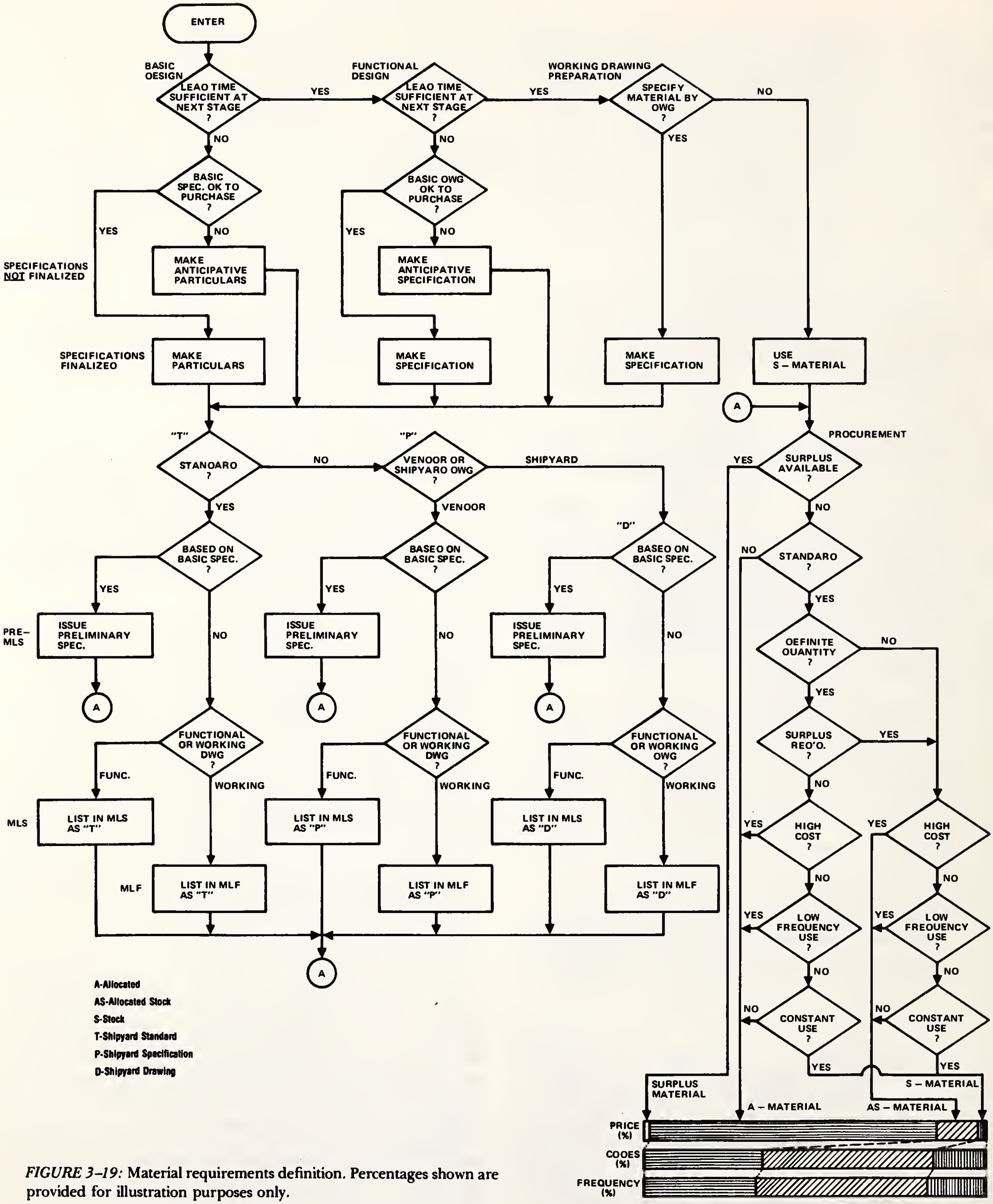
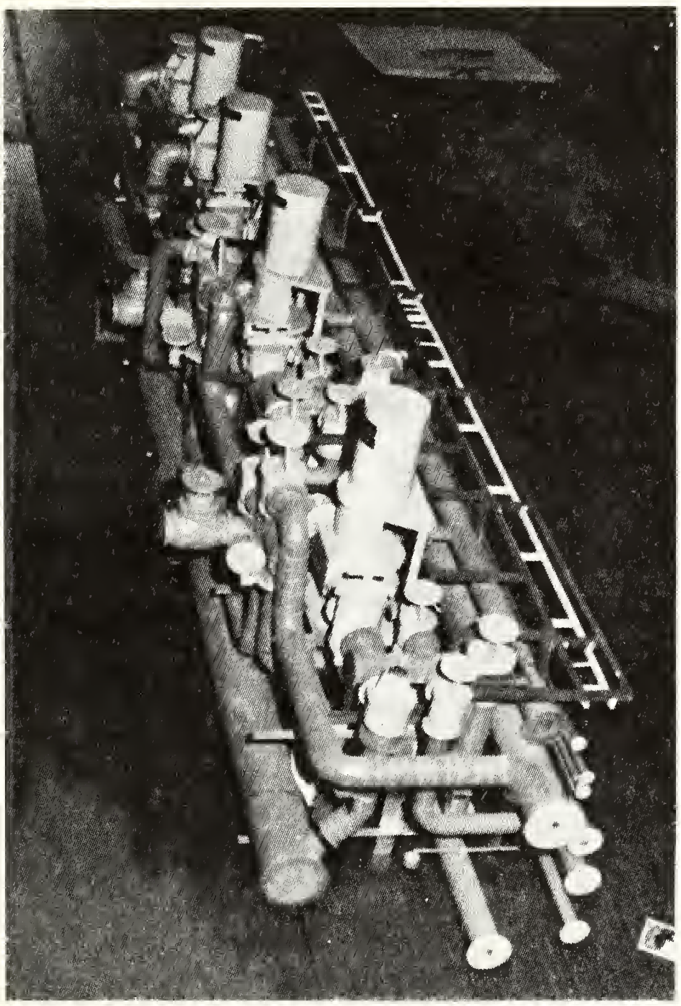


FIGURE 3–19: Material requirements definition. Percentages shown are provided for illustration purposes only.

3.9 Model Engineering

Shortages of prerequisite skills are being encountered in design as well as in production. As modern ships become more complicated people who can prepare sufficiently interference-free composite drawings are less available. Simultaneously, competitive needs require the design process to speed up and address more planning aspects.

Where there is relative inexperience the difficult to prepare and interpret traditional composite drawings cause rework due to both real and alleged interferences. This condition compounds designers' problems as they must immediately address solutions and/or as-built considerations, particulary if more than one of the same ship is being constructed. In order to minimize interferences and at the same time qualify more people to prepare composite arrangements, some shipbuilders have developed "model engineering", probably to a greater degree than anywhere else in heavy construction.



HITACHI, HIROSHIMA

FIGURE 3-20: Instead of drawing composites, the designer assembles models which are inherently interference free.

Because they are three dimensional, models facilitate understanding and thus improve communications. They are extremely useful in a C meeting. One shipbuilder is already constructing separate scale models of outfit on-unit, on-block and on-board so that assembly of the model anticipates ship erection. Furthermore, the same shipbuilder has productively replaced much of the tedious drafting effort with extremely legible, relatively interference-free, "drawings" produced from special photographs of the models.[6] A ship design agent has also developed a device to photographically produce "drawings" by laser scanning a design model.[7]

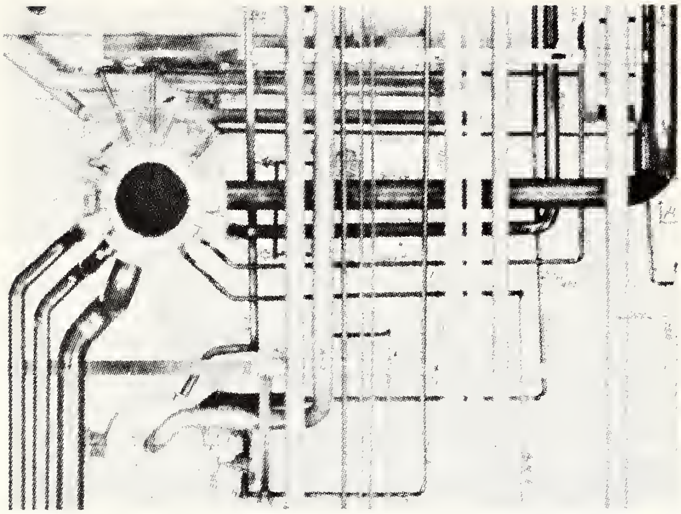
Model engineering, or design modeling, is the process of creating distributive systems arrangements by cutting, forming and joining pieces of plastic instead of using paper and pencil to prepare a composite drawing or using an interactive cathode-ray tube with a computer. The process is most advanced by shipbuilders abroad, and moderately developed by other industries in the U.S. As composite drawings are very complex, review is impractical so U.S. shipbuilders frequently employ a model maker to construct a "proof" model after the drawings are completed. This is significantly different from model engineering where a model is the first representation of the design. The model shown in figure 3-20, a product of model engineering, required eight manhours for assembly following certain preparations. These included acquiring model components representing standard pumps, valves, fittings and walkways, reference to arrangements and nominal freehand sketching of the proposed arrangement.

Models, so produced, are photographed with a special scanning camera which uses only parallel light rays. Negatives of the orthographic images obtained are used to photographically prepare sepia reproducibles upon which additions and/or deletions are made. A sample of a very legible final print is shown in figure 3-21.

Further, a photogrammetric method has already been demonstrated with a conventional mapmaker's three dimensional digitizer and stereo pairs of photographs of scale models. The researcher reported that if combined with model engineering, ". . .photogrammetry could serve as an

[6]Hitachi Shipbuilding and Engineering Co., Ltd. reported an application of model engineering, including photographically produced drawings, in design of a 30,000 SHP steam-turbine ship's machinery space reduced manhours and other costs to 60% and 75% of what they would have been for a conventional design method. See "Development of the Draft Camera - A New Camera for Orthographic Photo Drawings" by Y. Tomita, The American Engineering Model Society, May 1979 Seminar. A Hitachi subsidiary has cognizance, Nichizo Model Engineering Co., Ltd; Osaka, Japan.

[7]See "Making an Accurate Orthographic Projection from a Model "by Ari Elo of Eleomatic Oy, Turku, Finland; American Model Engineering Society, May 1979 Seminar.



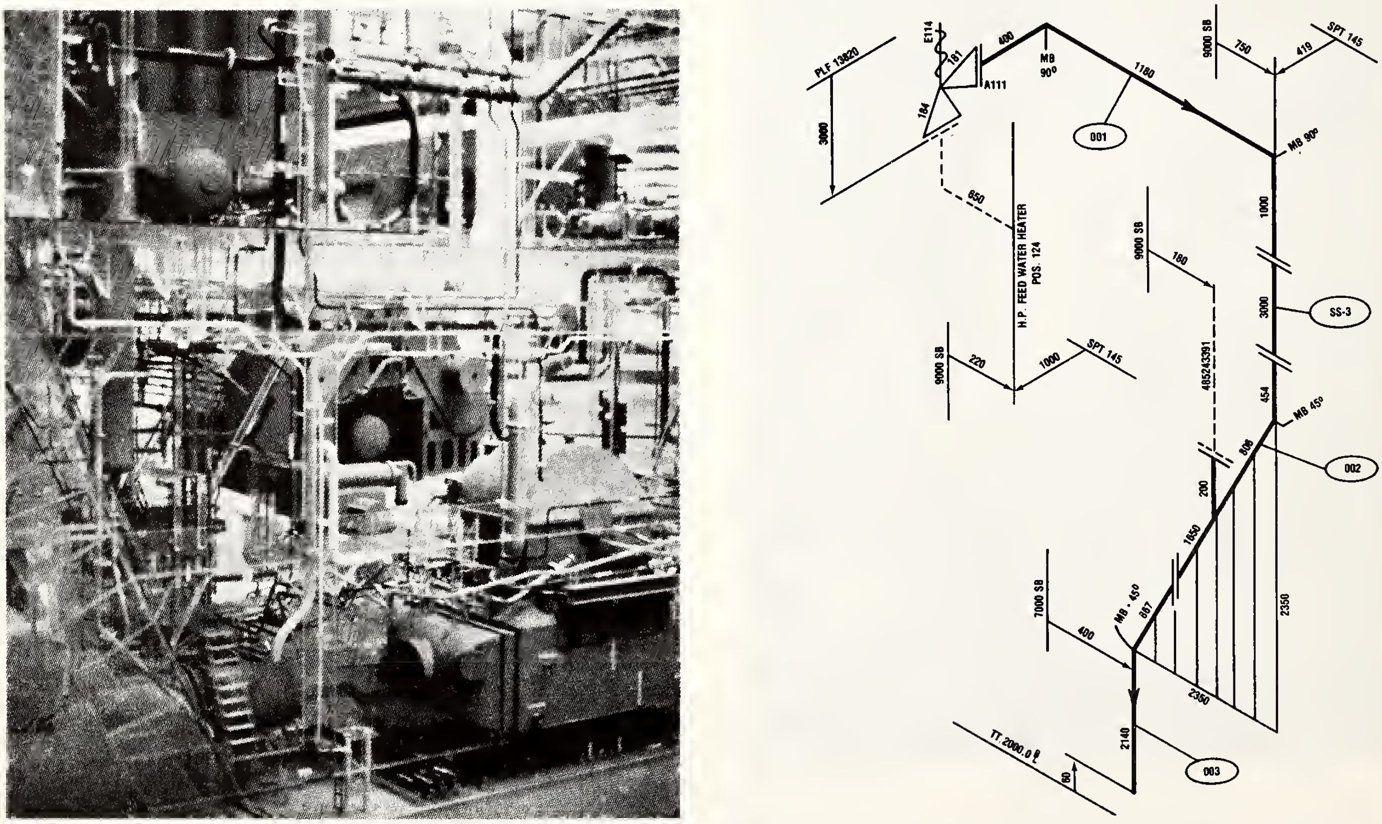
HITACHI, HIROSHIMA

FIGURE 3–21: The photographically prepared orthographic "drawings" are sufficiently accurate to scale off dimensions.

excellent input device which would permit a combined designer/model maker to put his inherently interference-free piping arrangements into a computer."[8] Another application of model engineering and an alternate method for input into a computer is described in figure 3-22.

Managers who consider model engineering have to assess the capabilities of their current work forces. Very experienced people now employed by the most competitive shipbuilding fims easily cope with conventionally prepared composite drawings of complex arrangements. But as a consequence of the decline in shipbuilding since 1973, new hirings diminished. An experience gap could be encountered in the future which would justify model engineering.

Further, model engineering is a tool which compliments "paper and pencil" and computer applied inter-active graphics. Certainly, conventionally drawn composites will always be most productive for relatively simple arrangements. Elsewhere, the availability of experienced people and costs should be the bases for selecting a method.



ODENSE, LINDO

FIGURE 3–22: Given the hull model containing main machinery components, the designer/model maker forms and joins plastic components to create the machinery space detail arrangement. Subsequently, isometrics are prepared for an envisioned subassembly by manually taking off dimensions. The isometric shown contains all needed information for ordering material, fabricating the various pipe pieces, joining components, and locating the subassembly in the ship. An interactive cathode-ray tube is used for putting the subassembly design into a computer. The owner is given a book of isometrics instead of conventional arrangement drawings for all but a few critical systems.

[8]"Investigation of Extracting Accurate Dimensions from Design Models by Photogrammetry" for the National Shipbuilding Research Program by John F Kenefick Photogrammetric Consultant, Inc.; Indialantic, Florida; The American Engineering Model Society, May 1979 Seminar.

4.0 MATERIAL CONTROL

Material control includes responsibilities for the acquisition and delivery of material to production. The organization of information in design anticipates material control need to add, delete or otherwise modify data to support the procurement process. Material control people use the lists described as MLS, MLP, MLC and MLF for preparation of the requisitions which authorize purchasing.[1] Thus, the list formats should be designed to facilitate requisitioning. For the purpose of procurement of the various kinds and quantities of materials, there are four general factors to consider:

- availability,
- price,
- reliability of estimated quantity needed, and
- frequency/constancy of use.

All of these influence procurement but only the last two are within a shipyard's control. Additionally, the need to minimize stock-on-hand while ensuring that sufficient materials are available also impacts on requisitioning and purchasing methods. One very competitive shipyard, in order to best deal with these factors, organized as follows:

- Materials are divided into two general classifications - stock material and allocated material.
- Stock materials are subdivided into two categories - allocated stock material and stock material.
- Stock materials are then separated by procurement method, i.e., regular purchased material, long term agreement material, and consignment based material.

These classifications are illustrated in figure 4-1.

4.1 Stock Material

Stock material is basically standard material, shipyard standard or industrial standard, contained in the shipyard's material catalog. Stock material differs from allocated stock and allocated material in that it is:

- generally used in every ship,
- more frequently used than allocated stock materials, and
- its lead time is relatively short (generally 60 days or less)

Further classification for control of stock materials by procurement method is in accordance with the following:

a. Regular Stock Material

(1) Neither a long-term agreement or another special type purchase agreement is obtainable.

(2) By the method for determining quantities required, i.e.:

(a) determined from a MLF, or

(b) based on order point.[2]

b. Long-Term Agreement Material

(1) Long-term agreement with vendor is feasible.

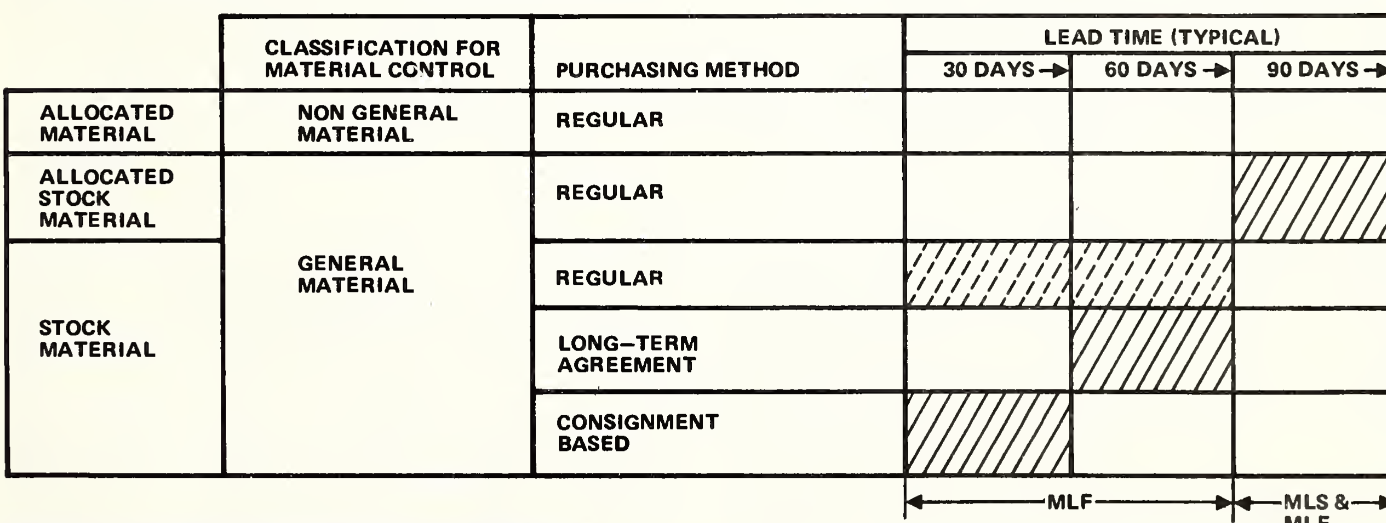


FIGURE 4–1: Comparison of material control classifications.

[1]One extremely important aspect applies to items which must be quickly processed. These are expensive, long-lead time items which are generally identified in basic design and sometimes even during negotiations with a prospective owner, e.g., main engines. Because they require special handling they cannot be included in the normal flow of planning activities. They require extraordinary management attention to insure that purchase orders are placed as early as possible. In exceptional cases commitment for purchase even before contract award is necessary.

[2]The on-hand quantity which is used to trigger an order for replenishment of stock. The order point is determined by an evaluation of the time required for replenishment and the anticipated usage between the time of order and receipt. Thus, a safety margin is usually included to ensure material availability during the requisition-order-receive cycle.

	IS IT POSSIBLE TO MAKE A – MLF IN DESIGN SECTION ?	IS SUPPLIER SPECIFIED ?	HOW TO PREPARE PURCHASE ORDER ?	PAYMENT ?
REGULAR STOCK MATERIAL	YES	NO	FROM MLF	ON DELIVERY
	NO	NO	BY ORDER POINT	
LONG–TERM AGREEMENT MATERIAL	YES	YES	BY CONSUMPTION SCHEDULE	ON DELIVERY
	NO	YES	BY ORDER POINT	
CONSIGNMENT BASE PURCHASE MATERIAL	YES	YES	BY CONSUMPTION SCHEDULE	BY ISSUING
	NO	YES	BY ORDER POINT	

FIGURE 4–2: Comparison of stock materials.

(2) Suppliers can meet requirements based on consumption estimates specified for a given period.

(3) Lead time is generally greater than 30 days and less than 60 days.

(4) The quantity to be purchased for the next specified period, generally 30 days, is based on a firm estimate.

c. Consignment Based Material

(1) Agreement for a consignment base contract is feasible.

(2) Suppliers can meet requirements at any time based on consumption estimates.

(3) Lead time is generally less than 30 days.

(4) Quantity purchased is specified in a purchase order amendment.

The above is illustrated in figure 4-2.

4.2 Allocated Stock Material

Allocated Stock (AS) is the term used to designate standard materials for which there is a history of problems, such as unexpected shortages when needed, or large surpluses remaining after a ship is delivered. Shortages generally result from miscounts when determining material requirements and also from damage and loss.

Surpluses occur because an individual designer, based only on his own prior experiences, adds a margin for "safety" for a particular troublesome material. Another designer producing a different material list for the same ship may also incorporate a margin for the same reason and for identical material. Others who are simultaneously listing materials for other ships may also contribute.

The AS concept avoids the multiplicity of margins by employing one authority, logically in material control, to apply a single margin for anticipated usage of a material item in the many different systems in different ships that are constructed simultaneously. Figure 4-3 illustrates how margins which are established independent of each other can cause the accumulation of material at an inordinate rate.

Further, the AS concept includes systematic allocating and reordering by the same material control authority to allocate even the reduced margin so as to maintain minimum inventory and achieve a zero balance when all ships are delivered.

4.3 Allocated Material

Allocated materials are purchased in direct response to a fixed requirement. They differ from stock and allocated stock materials because there is little opportunity for diversion to a different end use. Allocated material can be separated into two categories:

a. Regular Purchase Material

(1) Quantities are contained on an MLS and/or MLF.

(2) Price is generally high.

CONTRACT NUMBER	SYSTEM DESIGNER	QUANTITY REQUIRED	MARGIN APPLIED @ 10% *	QUANTITY REQUISI–TIONED
1	A	15	2	17
	B	24	3	27
2	C	4	1	5
	D	8	1	9
3	E	12	2	14
	F	24	3	27
	TOTAL REQUIRED:	87	TOTAL REQUISI–TIONED:	99

* AND ROUNDED TO NEXT INTEGER

FIGURE 4–3: The unnecessary growth of material requirements. The separately applied margins result in requisitioning 12 additional items. If a single 10% margin were applied to the total quantity required, only 9 would be added reducing the total requisitioned quantity to 96 vice 99.

	QTY. ON–HAND AT PERIOD START	PLANNED ISSUES	PLANNED RECEIPTS	QTY. ON–HAND AT PERIOD END	PLANNED ORDERS
PERIOD 1	△ △ △ △	△ △ △		△	△ △
PERIOD 2	△	△ △ △	△ △		△ △
PERIOD 3		△ △	△ △		

BY FORECASTING MATERIAL REQUIRED TO BE ISSUED BY PERIOD, ORDERS CAN BE PLACED SO AS TO MINIMIZE INVENTORY. THE USE OF COMMON OR STANDARD MATERIAL, REGARDLESS OF SHIP TYPE, ALLOWS A GREATER ABILITY TO REDUCE INVENTORY. IT ALSO ENSURES THAT PRODUCTION HAS THE NECCESSARY MATERIAL AT THE RIGHT TIME AS WELL AS REDUCING PROCUREMENT COSTS.

FIGURE 4–4: Leveling and balancing for entire shipyard material requirements.

(3) Quantity required is low.

(4) Usage is not constant.

b. Simplified Purchase Material

(1) Estimated quantities are not contained in an MLS or MLF.

(2) Because the material is generally available, requisition is made as required.

(3) Required quantity is generally small and therefore the materials are not maintained in the shipyard's inventory.

(4) Ceiling quantity is generally based on price.

(5) Purchase cannot be made by any other methods.

4.4 Leveling and Balancing

If MLS and MLF indicate large quantity requirements for a specific commodity in a single ship, there is a high probability that purchasing ship-by-ship would lead to over purchase and surplus material. If such materials are purchased by leveling the quantities needed for all ships under construction, sufficient stock could be maintained while reducing the value of stock that would otherwise be on hand.[3] Moreover, leveling enhances opportunities to purchase in more economic lots and is a means for greatly reducing or even eliminating surplus. Leveling is achieved by summing the estimated quantities by month by ship as illustrated in Figure 4-4.[4] Although leveling and balancing principally apply to AS materials, it is useful to also apply them to certain S materials identified in MLF.

4.5 Refining

Because design, material procurement and production must overlap significantly for improvement in productivity, procurement action cannot wait for completion of working drawings and an accurate count of certain AS material needs; e.g., valves that are not stocked by the shipyard. Purchasing of such items should therefore be based upon anticipated requirements derived during functional design, with continuous refinement of needs as work instruction drawings are produced.

Because each work instruction drawing describes everything by work zone and stage and its accompanying MLF defines detailed material requirements, completion of the last work instruction drawing in a material ordering zone establishes a checkpoint. It is used to compare summations from MLF within a material ordering zone to sums of material for the same material ordering zone as identified in the various MLS. Refinement occurs as the more accurate quantities identified during working drawing preparation are substituted for the material identified in functional design. The checkpoints and the impact of refinement on quantities are illustrated in figure 4-5. Although refining applies principally to AS materials it is also a useful control technique for certain A materials.

Required dates for materials are also refined as the design progresses. During functional design the date for the earliest required material in each material ordering zone is used for all material in that zone. As work zones and stages, i.e., pallets, are designated on working drawings, the date for the earliest required material in each pallet is substituted

[3]Analogous to leveling manpower requirements.

[4]Where inventory taxes apply material systems utilizing this process should provide for costing of materials received directly to an end use or special holding account.

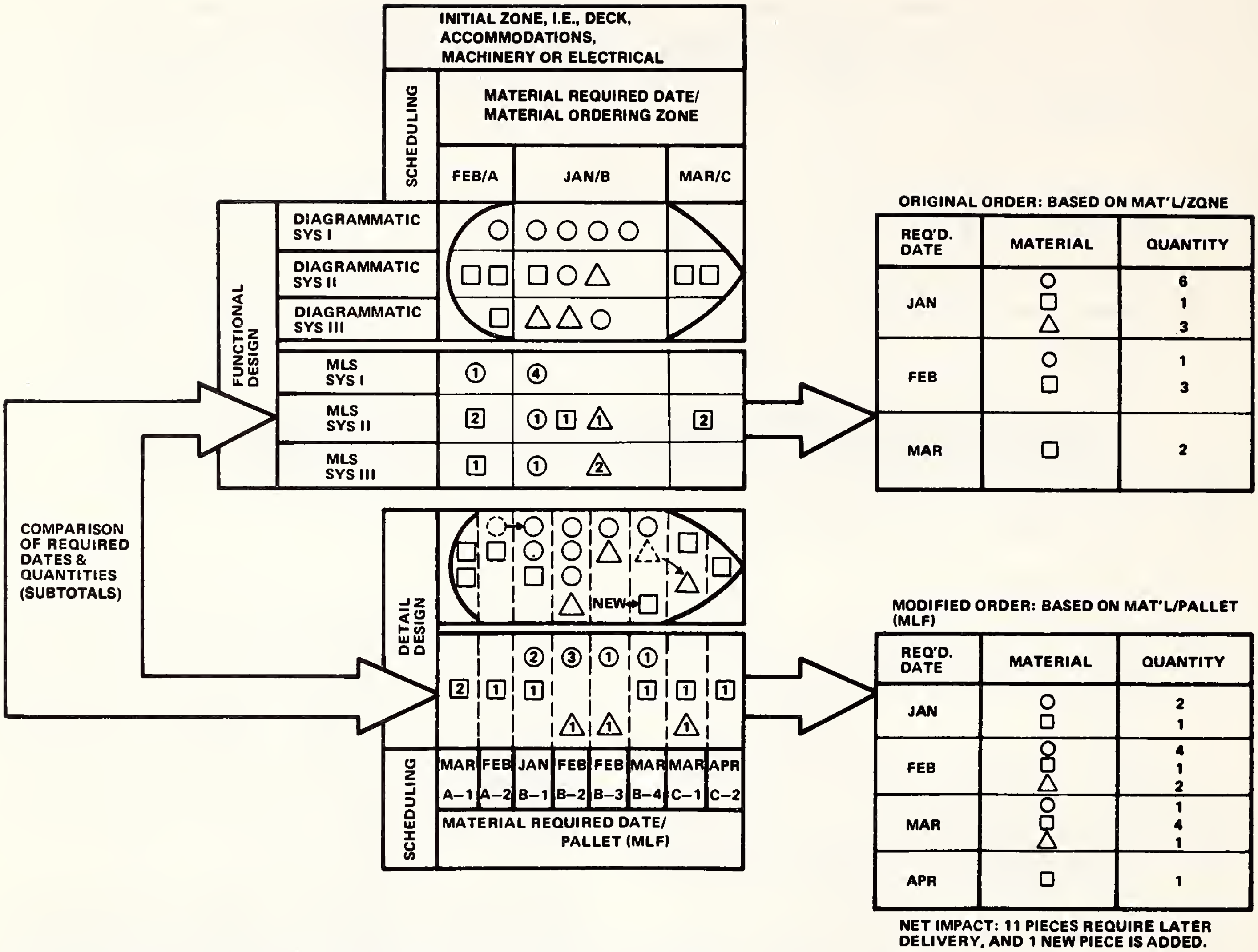


FIGURE 4–5: Refinement of procurement data for "AS" material as design develops.

for all material in the pallet. Thus, the dates which applied to large lots of material identified in functional design are replaced by dates which apply to the smaller lots identified during preparation of work instruction drawings. Figure 4-5 also shows how required dates are modified after work instruction drawings are produced and how changes to the original purchase orders are issued accordingly.

The quantities finally ordered are the result of leveling and ordering to the earliest requirement. Each MLS which accompanies a diagrammatic produced in functional design contains material requirements per system by material ordering zone, and is issued relatively early in the overall design process. A number of MLF are substituted later with actual quantities per work zones and stages, i.e., pallets, as determined from work instruction drawings. These drawings are of course sequenced, and the procurement schedule is determined based on material issue, lead time, handling time, etc. The flow of information for the various purchasing functions is illustrated in figures 4-6 and 4-7.

4.6 *Warehousing and Palletizing*

The flow of information for warehousing and palletizing is illustrated in figure 4-8. Material availability to production when and where it is needed is essential for higher productivity. Outfitting, for the most part, is the placement of various components, each in a prescribed location, in order to assemble distributive systems. Thus, marshalling materials to match pallets, i.e., materials required for a specific work zone and stage marked on a work instruction drawing, is critical. In fact, when palletizing is done accurately and on time, the overall outfitting effort will be more than 50% complete.[5] The remaining effort pertains to activities such as assembling, insulating, final painting and testing.

[5]This applies to all outfitting activities starting in basic design.

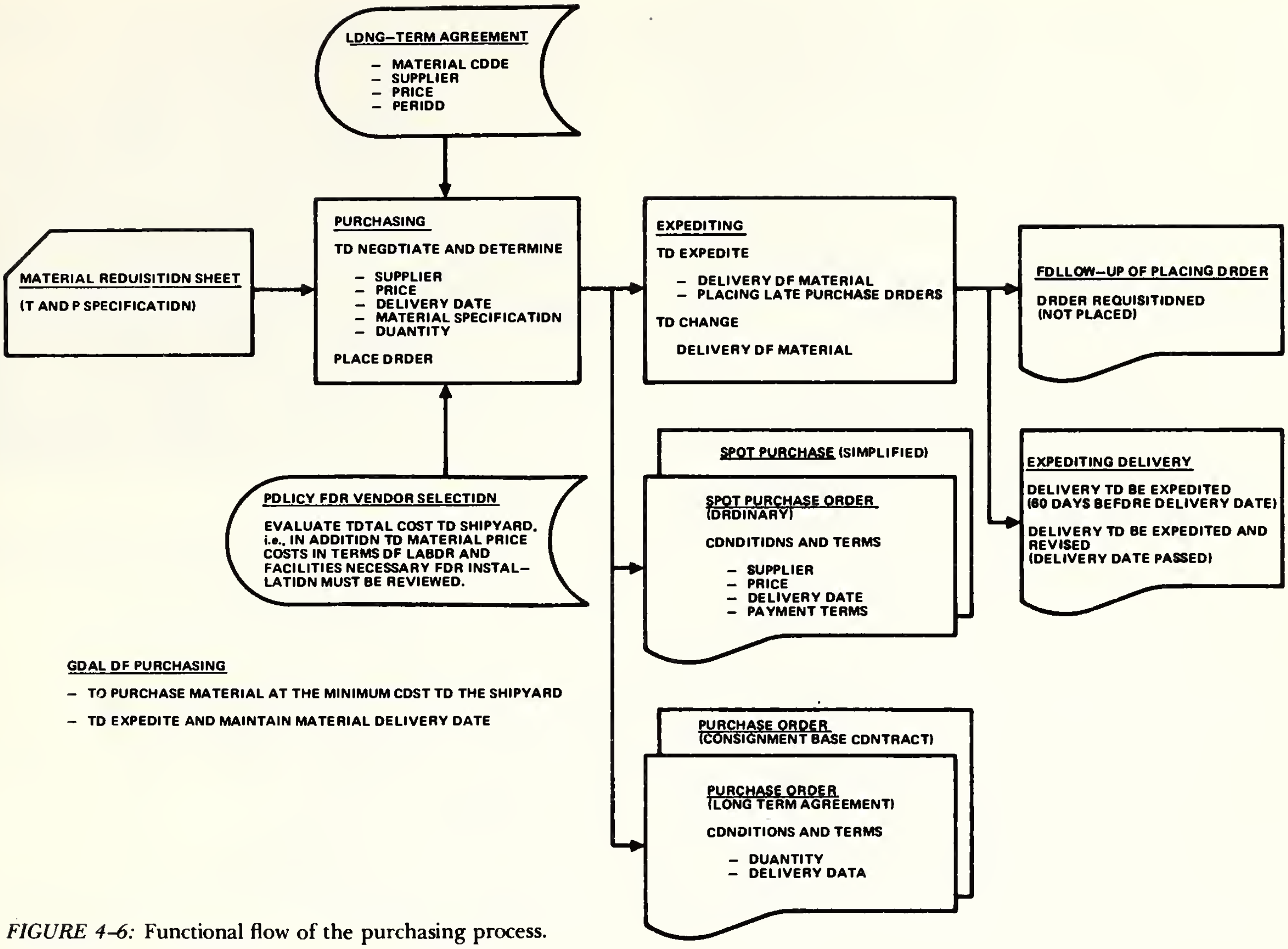


FIGURE 4-6: Functional flow of the purchasing process.

Palletizing is the act of collecting a group of materials together to match an MLF. In practice a pallet may represent all materials in one container, materials in more than one container or even a collection of large, bulky items that must be handled separately. In order to release the materials at the proper time and deliver them to the appropriate place, a pallet issue order must be made sufficiently in advance to allow enough time for palletizing. Should quantities be insufficient to marshall all materials for a specific MLF, the individual in charge must inform procurement people that expediting action is required and notify control people as they may wish to adjust the applicable planning and/or schedule to compensate. The proper maintenance of inventory records is essential for minimizing shortages. Improved outfit productivity is very dependent on the efficiency of warehouse people.

Materials may of necessity be stored in various warehouses. When a pallet issue order is received the materials may be transferred to a central location and kitted for delivery to a work site (see figure 4-9).[6] Large and subcontractor fabricated items may be consigned for direct delivery (see figure 4-10). Solutions of the problems associated with the transfer of materials can be simplified by simultaneouly issuing a material transfer order with the pallet issue order. Where computers are available, this process can be automated. Otherwise, the individual in charge must prepare daily transfer schedules.

The palletizing flow is illustrated in figure 4-11. Whatever numbering schemes or inventory methods are employed, resources, particularly people, for warehousing and palletizing must be enough to support the production effort. Nominal over capacity of such resources is prudent.

[6]It is efficient for a shipyard's pipe shop to palletize pipe pieces as soon as they are manufactured. In one shipyard where the pipe shop palletizes pipe pieces, the responsibility to palletize all other materials is assigned to the same shop as a collateral duty. Thus, split responsibility for palletizing is avoided.

FIGURE 4–7: Functional flow of the subcontracting process.

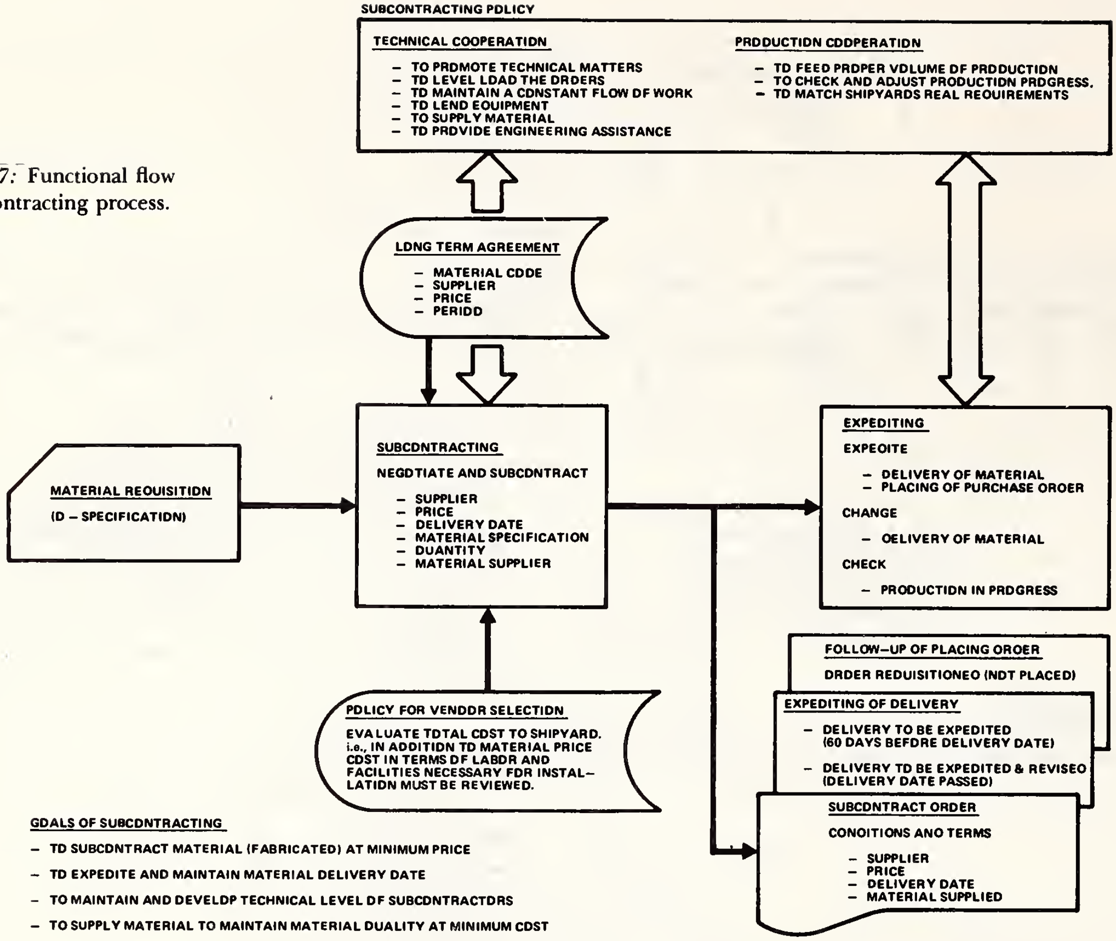
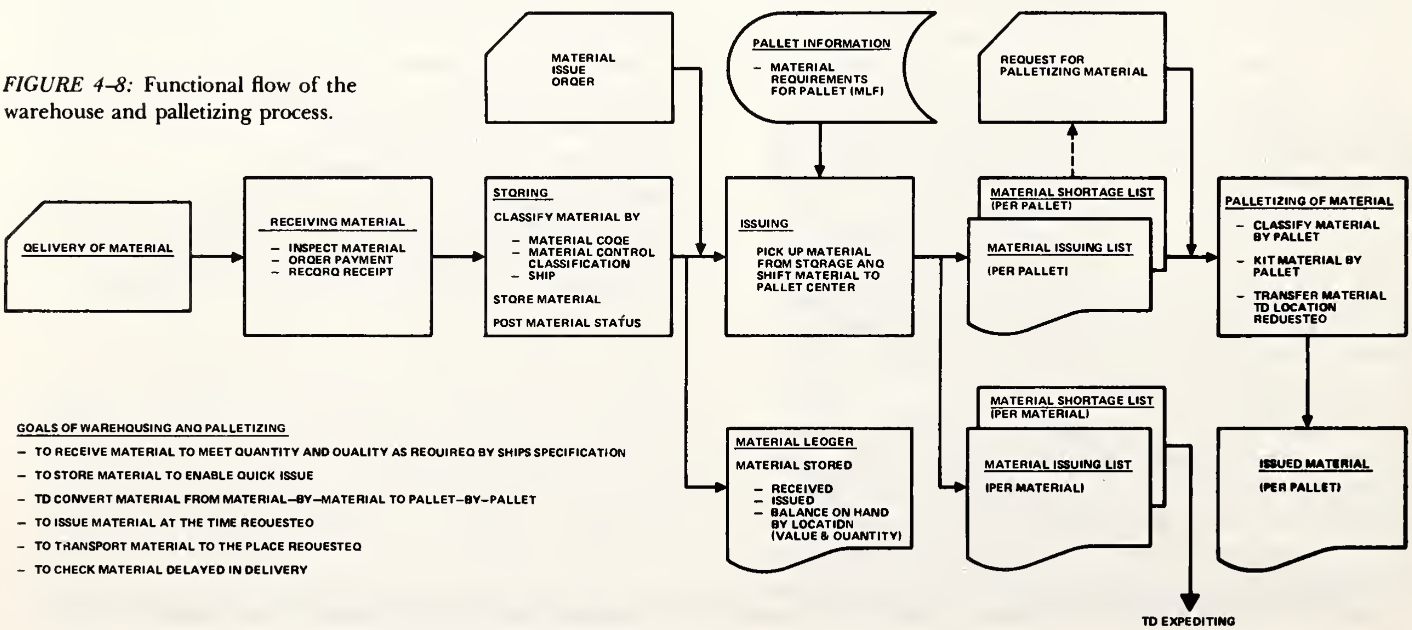
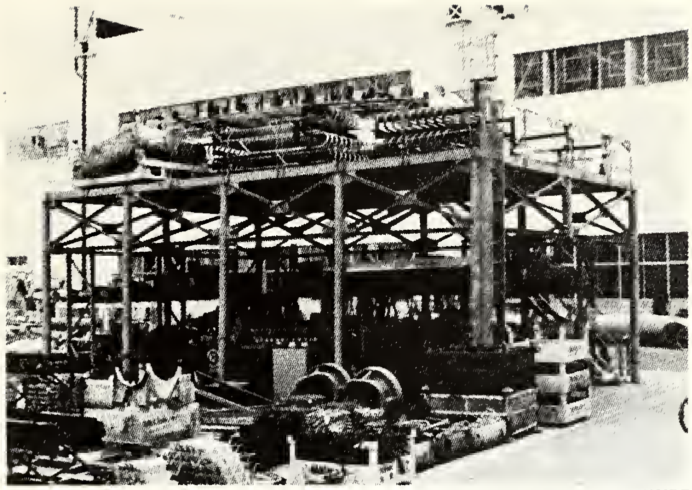


FIGURE 4–8: Functional flow of the warehouse and palletizing process.





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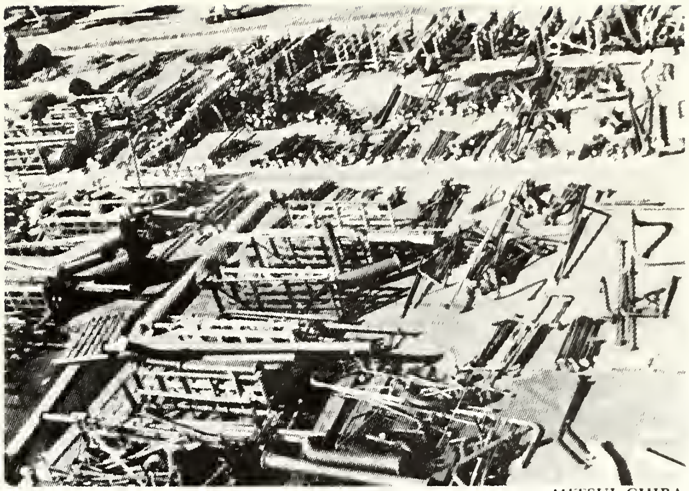

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FIGURE 4–9: Materials that are not apt to be diverted can be palletized and stored in unattended outside areas. The double deck structure permits greater use of stowage areas.

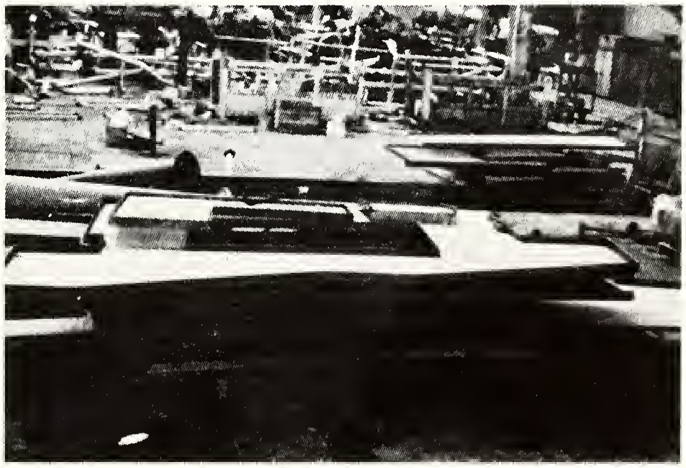

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FIGURE 4–10: Walkways, completely finished less a final paint coat, are delivered by subcontractors in lots that match specific pallets.

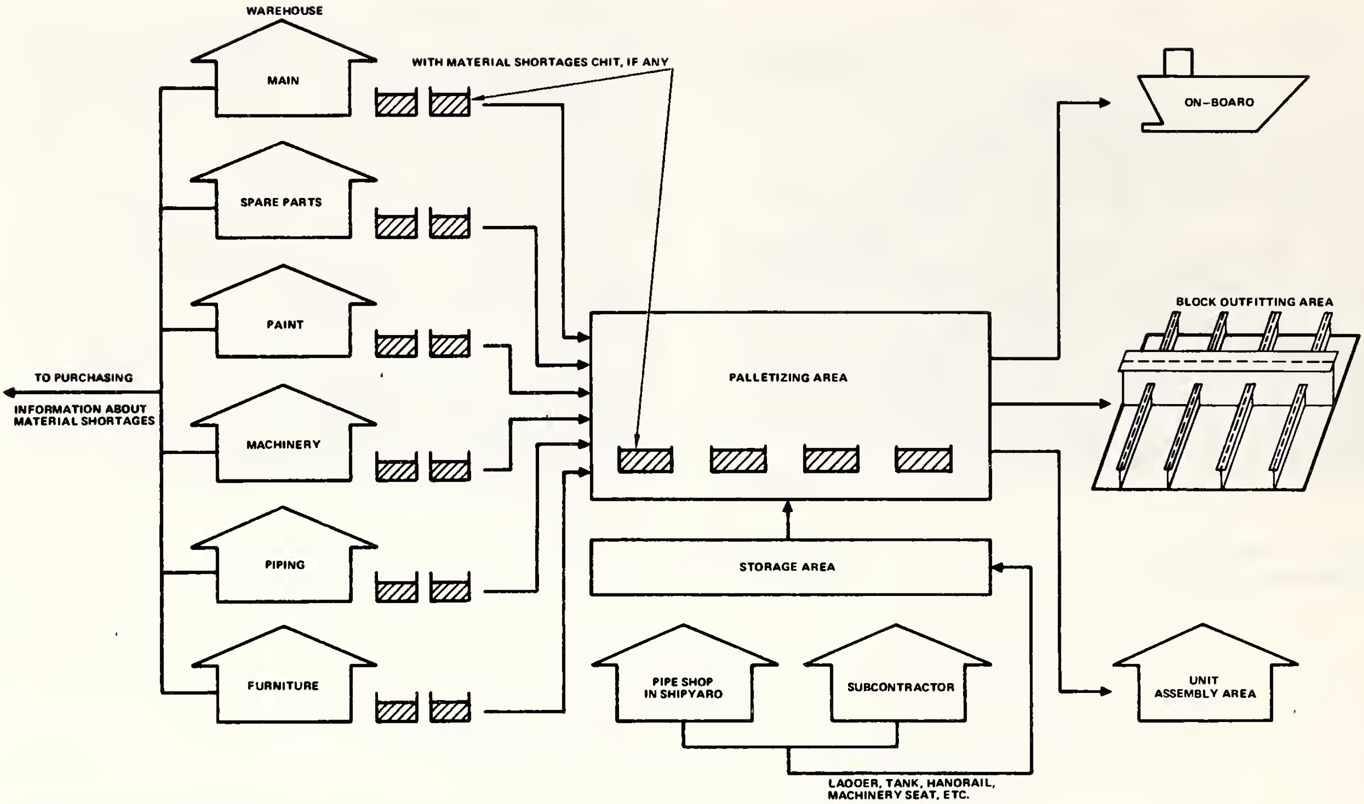


FIGURE 4–11: Palletizing for material issue.

5.0 OPERATIONAL PLANNING, SCHEDULING AND COSTING

The organization of work by similar problems enhances efficiency through the application of common solutions. This is a principle of Group Technology. If production is organized in a matching fashion, zone outfit planning is greatly simplified provided there is acceptance that design is an aspect of planning, and that people such as those who prepare functional and detail designs, material requisitions and work orders are likewise organized.

In one shipyard where zone outfitting is probably the most efficient in the world, both problems and production are divided to address three classifications, i.e., hull construction, outfitting and painting. Because outfitting problems vary significantly among themselves, both they and the outfitting department are subdivided to address the unique zones common in every ship, i.e.:

- Deck Outfitting Section (Outfits all spaces other than machinery and accommodation spaces; it includes tanks.)
- Accommodations Outfitting Section (Usually outfits the deck house only.)
- Machinery Outfitting Section (Outfits the machinery space only in a conventional ship. In other ship types, spaces for cable laying machinery, dredge machinery, etc., could be included.)
- Electrical Outfitting Section (Outfits in a rationalized zone that permeates the others.)

Recognizing that the manufacture of pipe pieces involves other kinds of problems, a fifth category is assigned for:

- Pipe Fabrication Shop[1]

Also in accordance with the logic of Group Technology the Machinery Outfitting Section is further subdivided into two groups:

- specialists for installing, testing and operating main propulsion components, and
- people who assemble pipe and ventilation systems, install ladders and walkways, etc.

Other than design and materials definition, planning includes methodizing and defining required resources. Although these are clearly planning functions as distinguished from scheduling which commits allocated re-

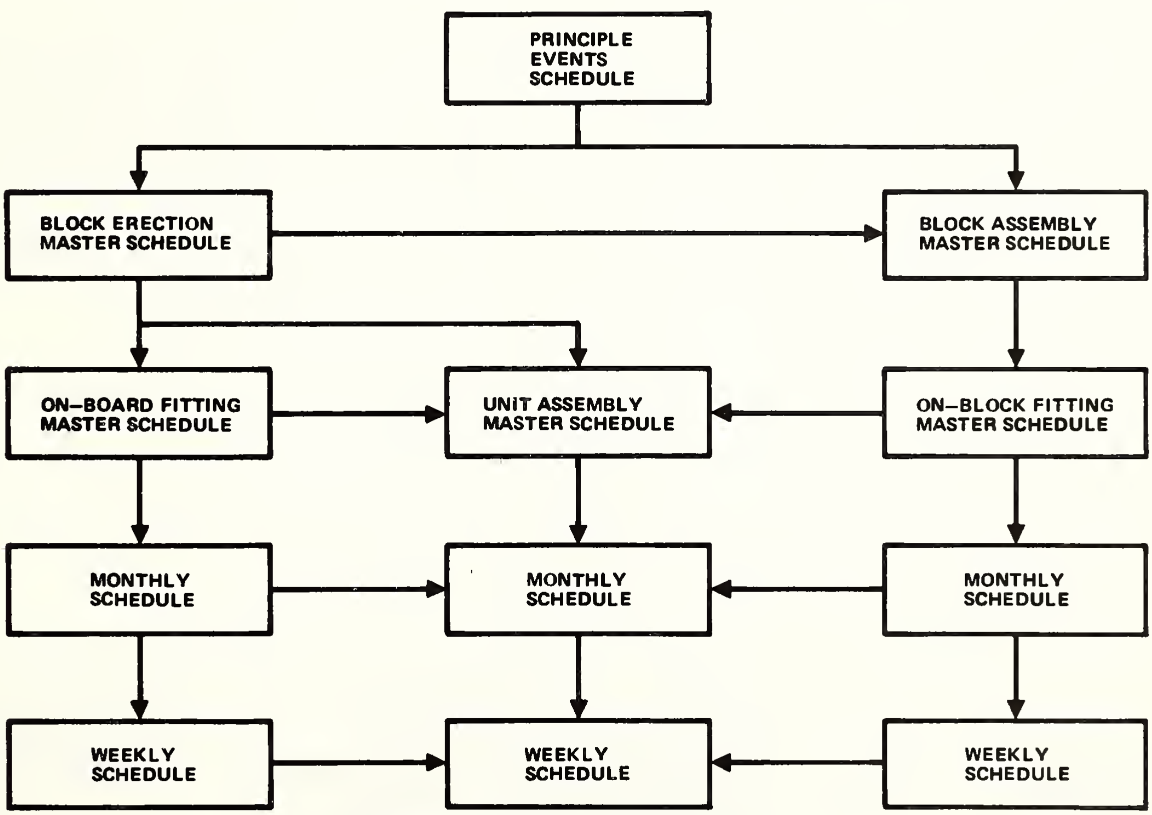
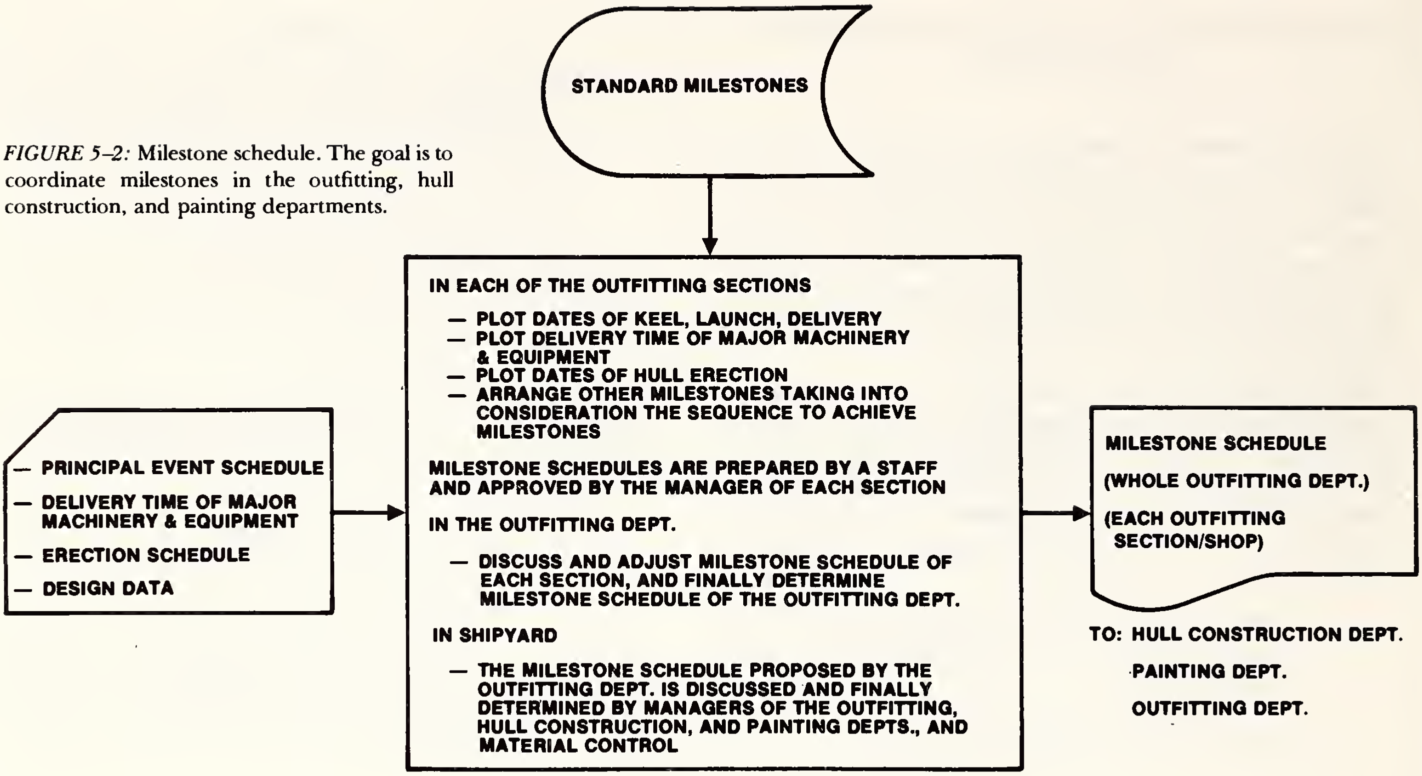


FIGURE 5-1: Organization of schedules from the top down for control.

[1]If the shipyard manufactured other components, such as ventilation duct, other categories and shops would be assigned accordingly.

FIGURE 5–2: Milestone schedule. The goal is to coordinate milestones in the outfitting, hull construction, and painting departments.

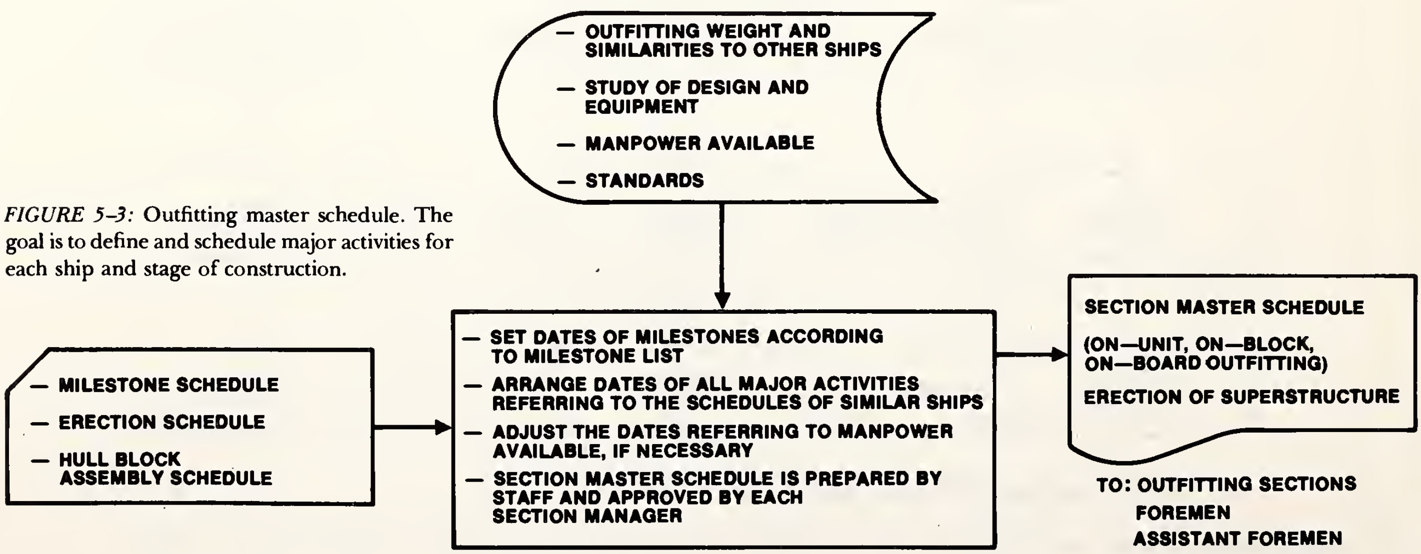


sources to specific calendar dates, they are inseparable from scheduling for overall shipyard planning, i.e., strategic planning. Planning, insofar as it includes the allocation of resources and sequencing work packages, would be meaningless if not in the context of a specific time period for which top management, in consideration of the shipyard's entire workload, authorized sufficient resources.

Planning is, for example, concerned with tentative allocations whereas scheduling is firm commitment. Thus, it is seemingly a paradox that planning and scheduling are separate functions, yet they are inseparable at the highest level where they are normally performed by the same people. Thus strategic planners are inescapably involved in scheduling. Their mixed output, which is the framework for more detailed planning and scheduling for an outfitting department, consists of:

a. ship construction principal events schedule
b. allocations by weight, cutting length, welding

FIGURE 5–3: Outfitting master schedule. The goal is to define and schedule major activities for each ship and stage of construction.



length, painting area, electric cable length, etc.

c. man-hour allocations
d. work load scheduling
e. productivity measurement

At the next level, outfit planners who are concerned with methodizing, allocating resources and sequencing are organized in groups which match an outfitting department's organization of outfit specialty sections and shops, i.e., for deck, accommodations, machinery and electrical. They too, and for the same reasons as for strategic planners, are inescapably involved in scheduling. Their mixed output applies only to outfitting and is a refinement of the applicable framework prepared by strategic planners. It consists of:

a. decisions regarding budgets
b. milestone scheduling
c. outfit group master schedules
d. monthly schedules
e. weekly schedules
f. pallet requirement schedules for material
g. working drawings (MLF) issue schedule

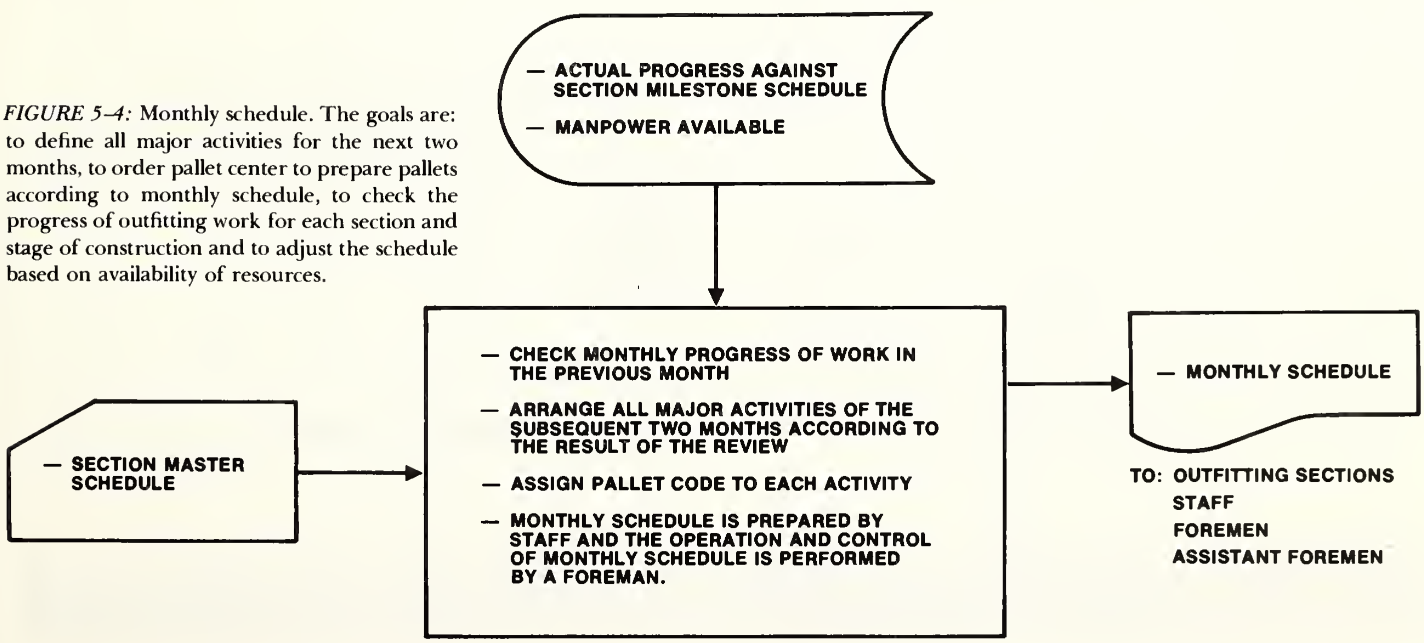
Production schedules form the framework which assists in the flow of information between the various shipyard functions. This information flow is necessary to ensure completion of a ship in an efficient and timely manner. Schedules are *control* mechanisms and are the means by which planned work packages are conveyed to the work force. Schedules vary in detail according to the function they are intended to perform and are usually organized in a hierarchical fashion. If not so organized with specific checkpoints needed for coordination, the many schedules necessary will not relate to each other and significant problems can arise. In some shipyards, each department, section, shop and/or work group develops its own schedule which relates only to its own area of responsibility. To prevent confusion and to facilitate control, a system which ensures consistency of schedules from the top down is essential.

Scheduling is simplified by the organization of information to support zone outfitting. Figure 5-1 illustrates how scheduling can be organized as a hierarchy. A principal events schedule can serve as the basic schedule for operations by fixing about 30 events such as dates for main engine landing, stern tube boring, boiler light off, generator tests, etc. This schedule is supported by the block assembly schedule and the erection schedule. The block assembly schedule specifies when and where blocks will be assembled and serves as the basis for determining when on-block outfitting will be performed. The erection schedule specifies when blocks and units will be joined together at the erection site and is the basis for outfitting milestone schedules. These schedules serve as the bases for more detailed schedules.

Each outfitting milestone schedule is further subdivided to provide implementation orders to a particular group. However, since they are all derived from the same outfitting milestone schedule, there is coordinated implementation for the deck, accommodations, machinery and electrical outfit sections and fabrication shops. This process is illustrated in figure 5-2 and 5-3. In turn these schedules are used to support even more detailed schedules such as monthly and weekly outfitting schedules, as illustrated in figure 5-4 and 5-5.

Production planning is simplified by the organization of both information and major shipyard functions into the

FIGURE 5-4: Monthly schedule. The goals are: to define all major activities for the next two months, to order pallet center to prepare pallets according to monthly schedule, to check the progress of outfitting work for each section and stage of construction and to adjust the schedule based on availability of resources.



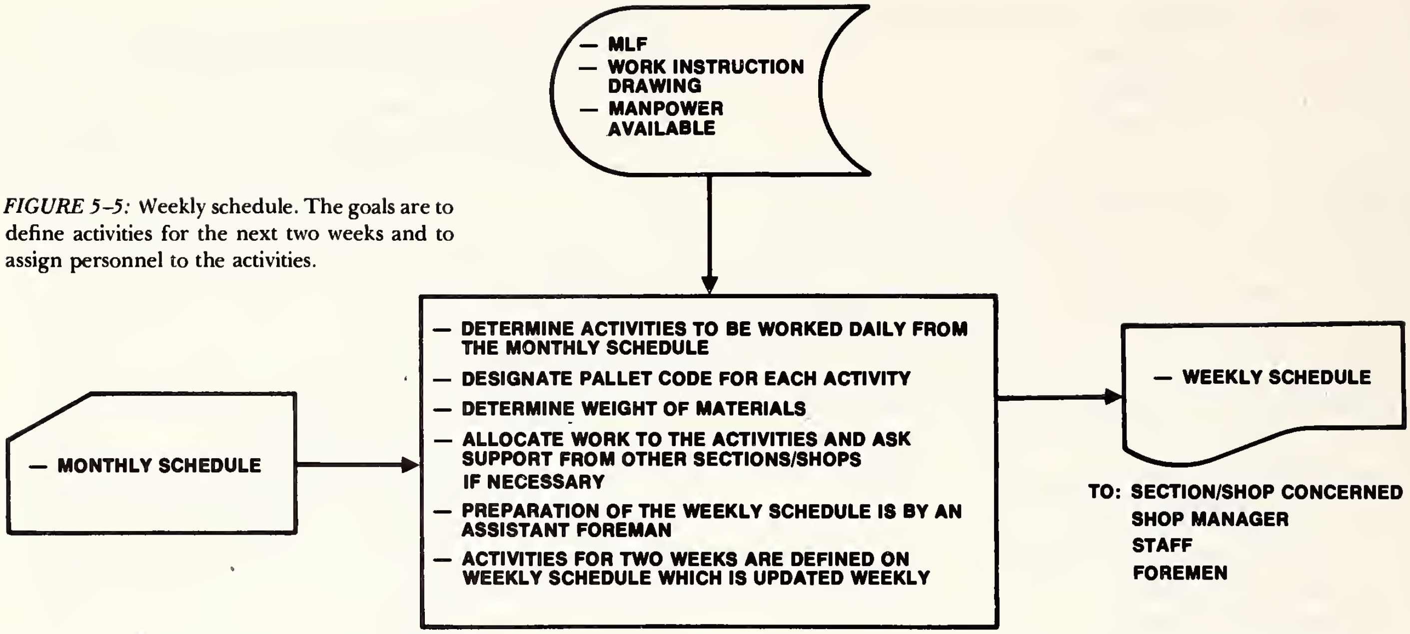


FIGURE 5-5: Weekly schedule. The goals are to define activities for the next two weeks and to assign personnel to the activities.

same grouping by similar problems. This permits the work packages that are represented in each of the formal schedules to be conveniently organized by zone by stage and by the kind of work to be done. Each work order or pallet or MLF - the terms can be used interchangeably - designates outfit work that is to be performed on-unit, on-block or on-board. Each is supported by smaller increments of work which must be accomplished earlier, i.e., the manufacture of pipe pieces or items to be manufactured other than pipe pieces (MLP and MLC respectively). The effort can therefore be organized in various ways to support each level of planning and also to provide a common link for identification of work between levels. For example, figure 5-6 illustrates how the pallet definition can be used to develop a sequence table which identifies off-ship and on-ship pallets. Similar sequence tables can readily be developed by each outfitting section and then by each fabrication shop.

Scheduling is further aided by the organization of information from design. Material lists produced in functional and detail design permit rapid development of manhour requirement plans. By developing a ratio of weight of fittings to estimated hours by system, a manhour per fitting value can be derived[2]. Since each MLS is developed in functional design by material ordering zone which is time phased, an initial estimate of the distribution of manhour requirements over time can be quickly derived. Just as for material requirements, this assessment permits early verification of the estimated manpower requirement used to establish a contract price. If a catastrophic error exists, managers have an opportunity to react before significant manpower expenditures occur. Further, since MLF represent defined increments of work by stage of construction and work zone and therefore reflect the sequence of production activities, a refined manpower requirements prediction ensues which is still in advance of expenditures. MLP and MLC also contribute because they represent defined increments of work which also predict impact on designated work areas.[3]

WORK ZONE / KIND OF WORK	OFF-SHIP		ON-SHIP		
	UNIT	BLOCK	DECK	ACCOM.	MACH.
PIPING					
STEEL					
VENTILATION					
INSULATION					
PAINTING					

FIGURE 5-6: Example for a sequence table.

[2]Weight excludes main machinery and equipment. Each ratio is specific for a particular system. For electrical, cable length can be used.

[3]"Area" is defined as a division into similar types of work. It is dependent upon trade skills by shop or section. An area could be designated for collecting costs for assembling anything by bolting. For example bolting together walkway sections, flanged pipe pieces and vent duct sections, etc. Within a pipe fabrication shop areas could be assigned to separately monitor costs for welding, bending, pickling, etc. On board, an area could be defined just for collecting costs of electric cable pulling.

Pallets define specific increments of work and represent interim products to be assembled. Costs returned against each pallet can be distributed to systems by weighted values. Cost accuracies are greatly improved because production people report against meaningful products. Further benefits are inherent because data by system is returned faster and with greater accuracy which facilitates improved estimating for other shipbuilding prospects in the near term.

Shipbuilders who practice zone outfitting at first continued to report costs in accordance with traditional systems oriented work breakdown structures. It subsequently became apparent to them that, while not disregarding system, it was essential to focus on classifications by similarities in production problems (Group Technology) so that they could more efficiently divide work by zone, area and stage. Therefore each substituted a product oriented work breakdown structure (POWBS).

Managers who wish to fully exploit zone outfitting by incorporating a POWBS will have to assure traditional estimators that they will continue to receive good cost information by system (see figure 5-7). A few can be expected to continue to object regardless of the fact that some U.S. shipyards already report hull construction costs by hull block, i.e., in a product oriented manner. The same logic identifies need for product oriented work breakdowns for both hull construction and zone outfitting.

Estimates are developed using statistical data from previous ships and by considering present circumstances. Thus, material lists developed by designers facilitate material procurement, detail planning and rapid updating of parameters used for estimating.

The on-board outfitting schedule is constrained only by the erection schedule. The on-block schedule is constrained both by the erection and block assembly schedule. The on-unit schedule permits the most freedom and is constrained only by the schedule for landing a unit on-block or on-board. All of the outfitting effort, of course, is constrained by the availability of materials and drawings.

The fabrication shops must prepare short term detailed schedules that anticipate their needs. Preparation of such schedules is assisted by the PPFM[4] identification from design. As fabrication is dependent on finite equipment and manpower, these schedules must assure timely fabrication while attempting to maintain a constant work load. This needed leveling is best accomplished by utilizing long and short-term schedules. A long-term schedule, typically four to six months, enables a shop to establish the work load estimate needed to rearrange a detail schedule for optimum throughput. This process is illustrated in figure 5-8 for pipe fabrication. The short-term schedule development is simplified by standardizing the execution times by category of fabrication lines such as the PPFM. This is illustrated in figure 5-9.

The development of on-unit schedules is flowcharted and presented in figure 5-10.

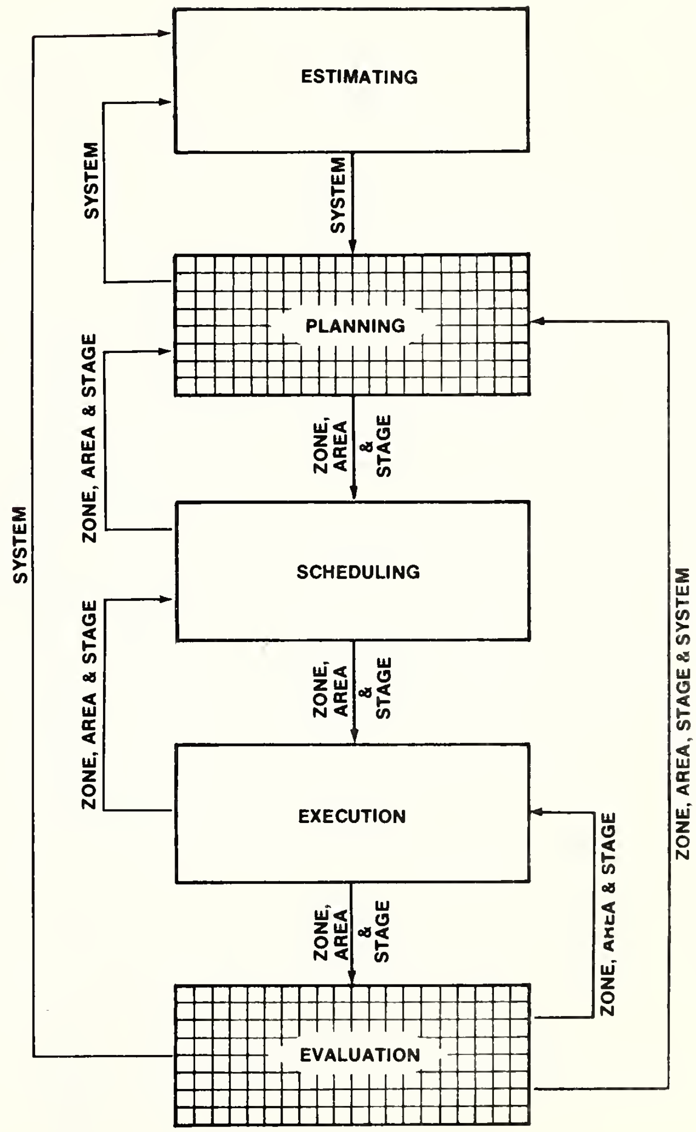


FIGURE 5-7: The management cycle. Zone, area, stage and system information flow is in accordance with a product oriented work breakdown structure. The crosshatching represents the matrices which maintain the relationships between system and zone.

[4]Pipe Piece Family Manufacturing; see chapter 2.

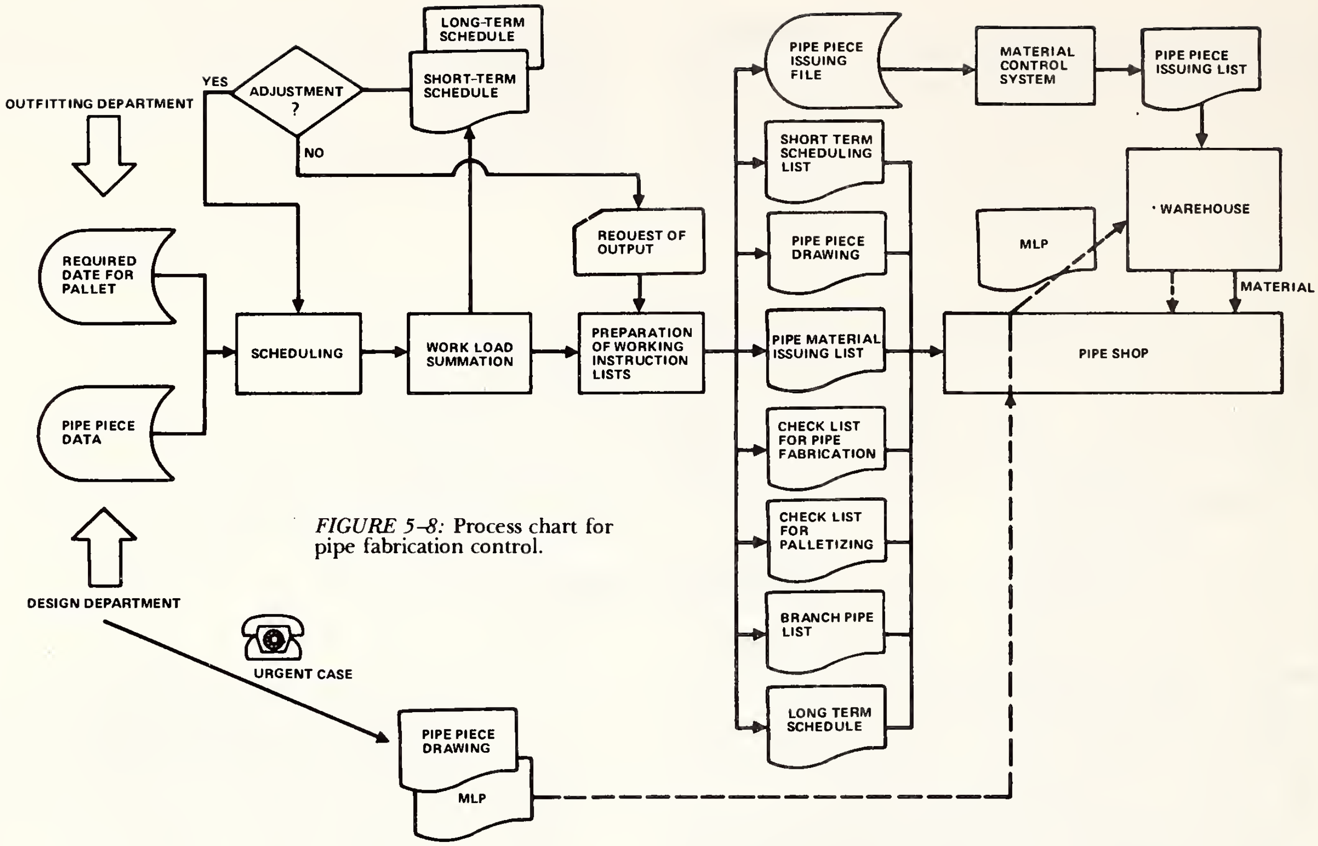


FIGURE 5–8: Process chart for pipe fabrication control.

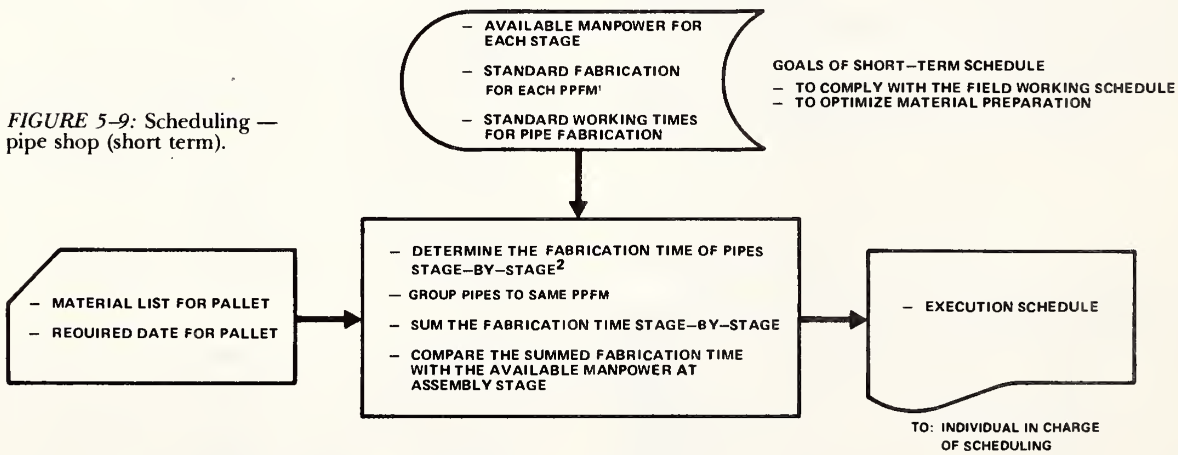
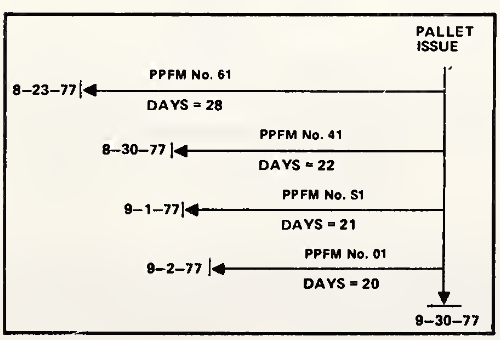


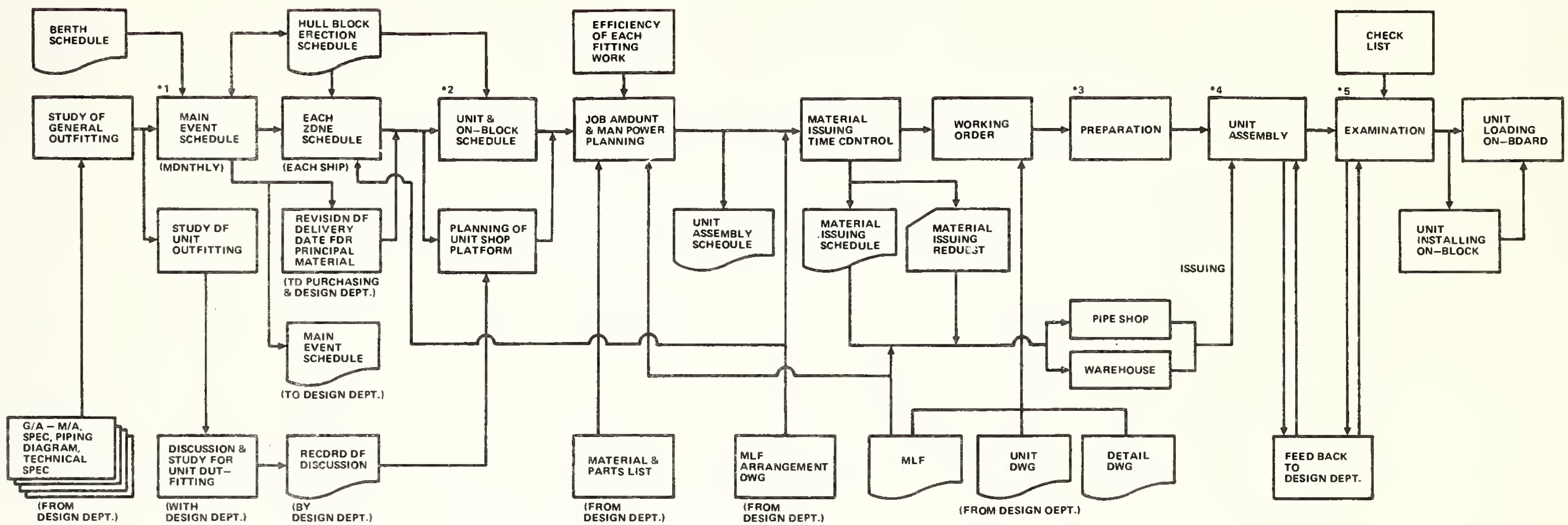
FIGURE 5–9: Scheduling — pipe shop (short term).



[1]STANDARD FAB PERIOD FOR EACH PPFM USED TO COMPUTE START DATE

[2]FABRICATION TIME ESTIMATE

FABRICATION TIME (MINUTES)					
PPFM No.	MARKING CUTTING	BENDING	ASSEMBLY	WELDING	FINISHING
01	195	–	151	101	18
51	15	–	100	95	40
41	105	82	95	80	20
61	40	–	45	50	25



*NOTES –

*1 – EXAMPLES OF EVENTS:	*2 – SCHEDULES:	*3 – PREPARATION:	*4 – PROCEDURE:	*5 – REVIEW (Q.A.):
1. START CONSTRUCTION 2. KEEL LAYING 3. CARGO OIL PUMP UNIT ERECTION 4. DIESEL GENERATOR ERECTION 6. BOILER ERECTION 6. SHAFT SIGHTING 7. MAIN SWITCH BOARD ERECTION 8. HATCH COVER ERECTION START 9. MAIN ENGINE ERECTION 10. PROPELLER FITTING 11. LAUNCHING 12. BOILER FIRE–UP 13. DIESEL GEN. RUNNING TEST 14. MAIN ENG. STARTING TEST 15. ETC. ABOUT 30 – 36 EVENTS FOR ONE SHIP	1. MONTHLY SCHEDULE 2. WEEKLY SCHEDULE 3. LEVELING FOR OTHER SHIP UNIT ASSEMBLY (CAPACITY PLANNING)	1. REVIEW OF UNIT ASSEMBLY PROCEDURE 2. PREPARATION OF MACHINE & TOOLS 3. CHECK OF ISSUED MATERIAL (NUMBER, FORM, ETC.)	1. MARKING 2. SETTING OF MACH. SEAT 3. SETTING OF PIPE SUPPORT 4. INSTALLATION OF MACHINERY 5. FITTING OF VALVE, COCK, PIPE, STRAINER, SPINDLE, HOPPER, ETC. 6. FITTING OF FLOOR SUPPORT & FLOOR 7. HANDRAIL & STANCHION 8. FITTING CABLE WAY & ELECTRIC EQUIPMENT 9. EXAMINATION (SEE *6) 10. PAINTING 11. TRACER PIPE FITTING 12. INSULATION 13. PROTECTION	1. DIMENSION CHECK 2. CHECK OF COMPLETE WELDING 3. CHECK OF COMPLETE BOLTING 4. CHECK OF COMPLETE PROTECTION 5. CHECK OF COMPLETE PAINTING 6. REINFORCEMENT FOR LIFT–UP 7. CHECK SAFETY FOR TRANSPORTATION 8. ETC.

FIGURE 5–10: Unit outfitting procedure in production.

6.0 ORGANIZATION

Shipbuilders abroad who applied zone outfitting did not predict that there would be need to change their organizations.[1] Early experiences led to conclusions that the full potential of zone outfitting methods and the pallet concept was dependent upon their being applied in accordance with the principles of Group Technology. The latter in matching sets of solutions to groups of problems, inescapably addresses people.

Prudent division of responsibilities and application of unique skills require understanding of the entire situation in a shipbuilding endeavor. Figure 6-1 shows the relationships between the basic management functions inherent in any industrial process as they apply to each other and to the material, schedule and cost areas that must be controlled.[2]

Building ships is heavy construction which differs profoundly from industries comprising the manufacturing sector. The essence of the difference is that heavy constructors, particularly modern shipbuilders, must employ operational planning which is concerned with performance tactics. It is analogous to military planning with manpower, material and facilities allocated to sequenced time intervals related to a "D-day". In similar manner, shipbuilding planning must be organized to serve an implementing authority, i.e., a controller who must be prepared to react to any disruptive influence by rescheduling and/or issuing orders for replanning.[3] The objectives, always, are to implement realistic options. Just as much as in a military operation, material, schedule and budget control must be coordinated in shipbuilding.

Another consideration not generally understood is clearly illustrated in figure 6-1. That is, those who execute the coordinated orders include in addition to production people:

- buyers,
- suppliers,
- subcontractors,
- warehousemen, and
- people charged with reporting costs.

Each has a specialty to perform without which there can be no successes.

An organization which has evolved as a natural consequence of product orientation, i.e., the hull block construction method and zone outfitting, is illustrated in figure 6-2. Unique aspects worthy of notice are:

- The Control Department is the implementing authority having combined responsibilities for coordinated material, schedule and budget control.
- The Purchasing Section is in the Control Department. This greatly facilitates buying decisions based upon the lowest total costs to the shipyard instead of lowest material prices. This feature is largely responsible for a select family of subcontractors who are really an extension of the shipyard's work force.
- The production effort is apportioned among three departments, i.e., the Hull Construction, Outfitting and Painting Departments. This division, in accordance with the principles of Group Technology, facilitates planning and is the basis for unprecedented control over sequencing hull structure, outfitting and painting work.
- Each of the departments is subdivided into sections and shops, also in accordance with the principles of Group Technology. For example, each subdivision in the Outfitting Department, except the Pipe Fabrication Shop, matches a specific outfit zone, i.e., accommodations, machinery, deck or electrical. Thus, craftsmen assigned to a particular section acquire expertise in applying their various trades to the unique requirements of the respective zone.
- Similarly, the Design Department is organized in the same manner and for the same reason.

The three methods of zone outfitting (on-unit, on-block and on-board) the pallet concept and Group Technology are already proven tools of the world's most competitive shipbuilders. However, they cannot be applied by themselves. There must be assurance that material will be present. Sufficient material will not be available until designers more expeditiously develop information to support procurement and until different procurement practices are adopted. Sufficient resources for palletizing is another prerequisite.

Further, outfit planning must be approached with the whole shipbuilding situation in mind. It must address hull construction and painting as problems requiring solutions at the same levels of management. This means that many people, heretofore only concerned with managing just one aspect of shipbuilding, must more fully develop as managers of the entire shipbulding process. Otherwise, they

[1]The principles of Zone Outfitting emerged in the early fifties. They were assigned higher priority in the aftermath of the 1973 oil embargo. The market changed from large tankers to small relatively outfit intensive ships. A compatible shipyard organization was recognized as a critical competitive need.

[2]The basic management functions are estimating, planning, implementation and execution.

[3]Planning includes design, material definition, methodizing and resource allocation.

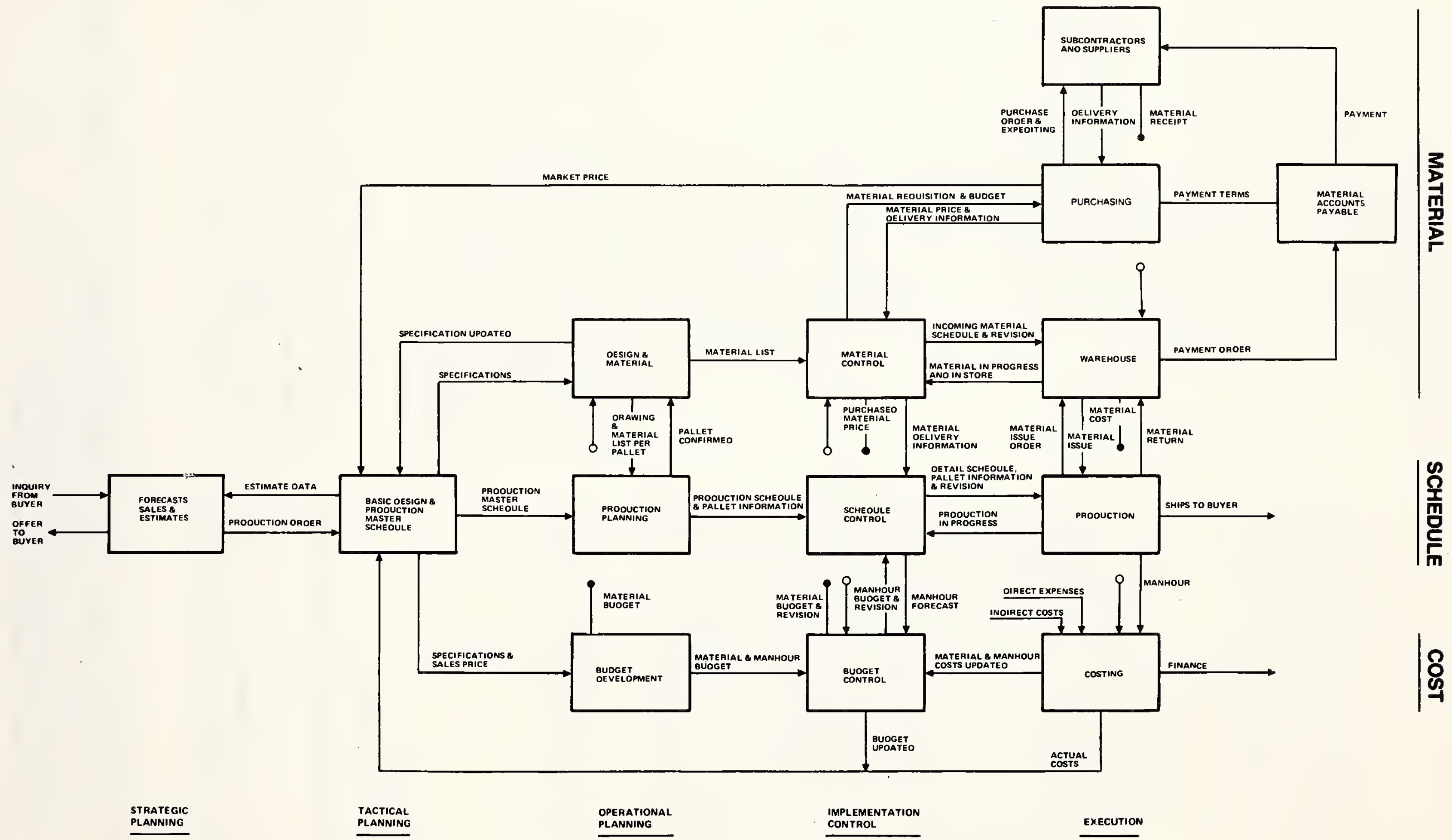


FIGURE 6–1: Information flow among shipbuilding functions.

could not easily concede their traditional practices to facilitate even great productivity gains elsewhere.

For example, zone outfitting impacts deleteriously on shipbuilders' traditional goals to maximize steel throughput by facilitating both outfitting and painting precise zones at specified times. Thus, some managers who consider zone outfitting will be faced with reorienting themselves as well as traditional hull construction planners. If they adopt zone outfitting, they will ultimately have to teach outfit planners hull construction options and will have to develop coordinated planning for hull construction, outfitting and painting.

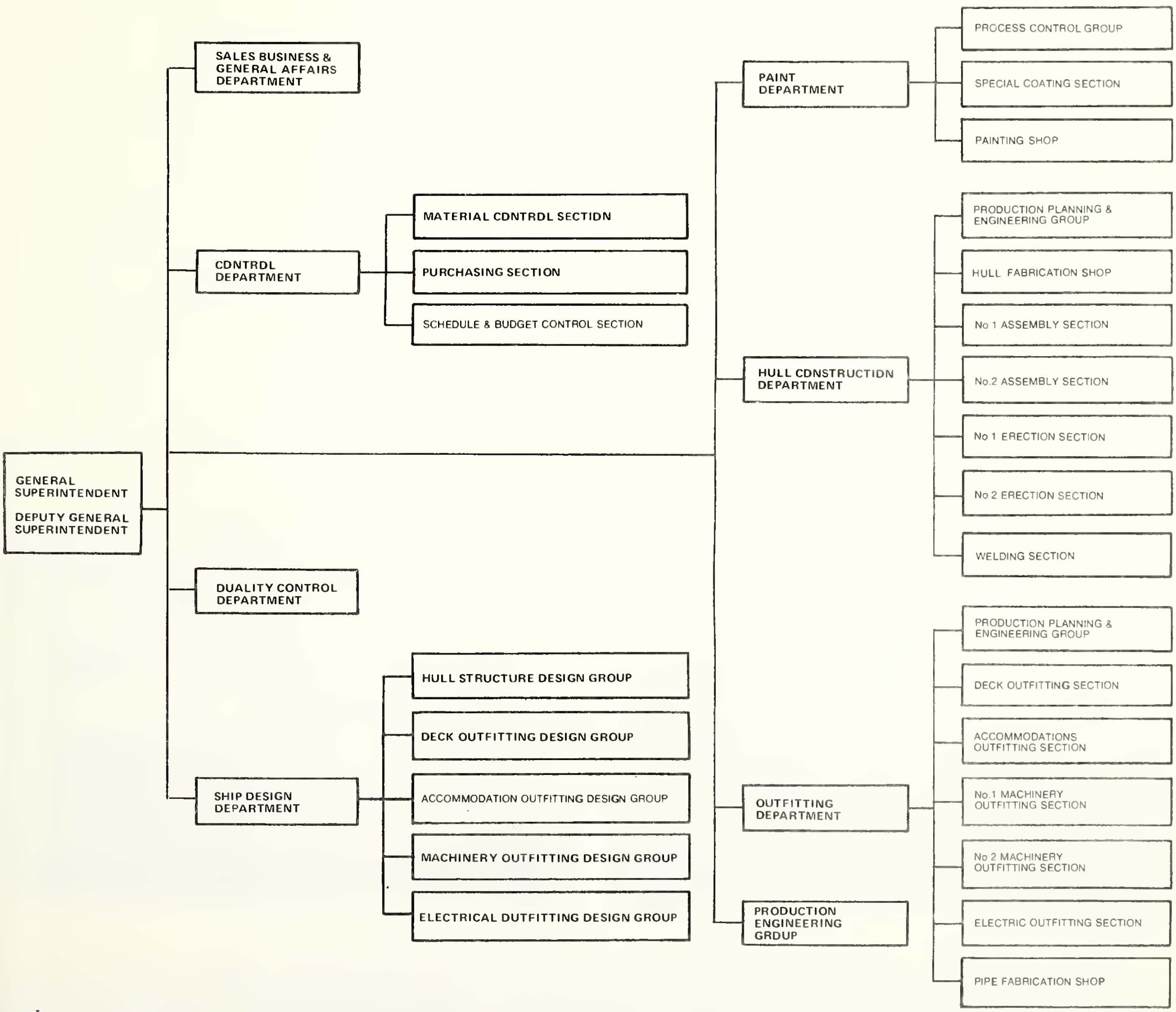


FIGURE 6–2: Shipyard organization chart.

7.0 PRACTICAL SUGGESTIONS

Zone outfitting assuredly increases productivity. However, many practical ideas already proven by shipbuilders throughout the world contribute significantly.

7.1 Outfitting On-unit

On-unit outfitting offers the greatest potential for improving overall productivity during construction of a ship as compared to the other two outfit methods, i.e., on-block and on-board. In shipyards where on-unit procedures are highly developed, certain guidelines have emerged which impact on all planning functionaries, especially those who produce diagrammatics and detail design drawings:

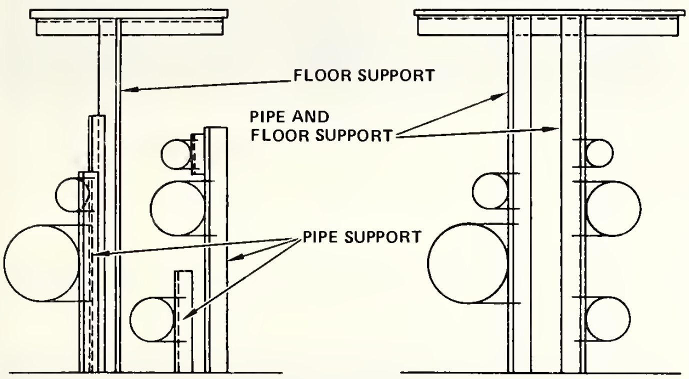
7.1.1 Joining any two outfit items in a shop, even the smallest, is preferable to separately fitting them on-block or on-board, A good example is attachment of heat-shrink type electric cable entry seals to junction and distribution boxes.

7.1.2 Two or more pipes which follow the same path should be incorporated as a unit.

7.1.3 Wherever possible supports should be combined with other supports, see figure 7-1.

7.1.4 Walkways, gratings, handrails and ladders should always be included as they enhance structural soundness and they reduce, if not eliminate, the requirement for staging during assembly of units and afterwards when units are landed on-block or on-board.

7.1.5 Common foundations made from angles should be used as much as possible. They minimize connections to hull structure, simplify lofting procedures, and permit better access for assembling components. When heavier foundations are needed they should be designed to distribute stresses from above decks only. This permits their incorporation in units and eliminates troublesome reinforcement beneath decks which is often dependent upon receipt of vendor drawings. See figure 7-2.



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

FIGURE 7-1: Pipe support unit assembly approach.

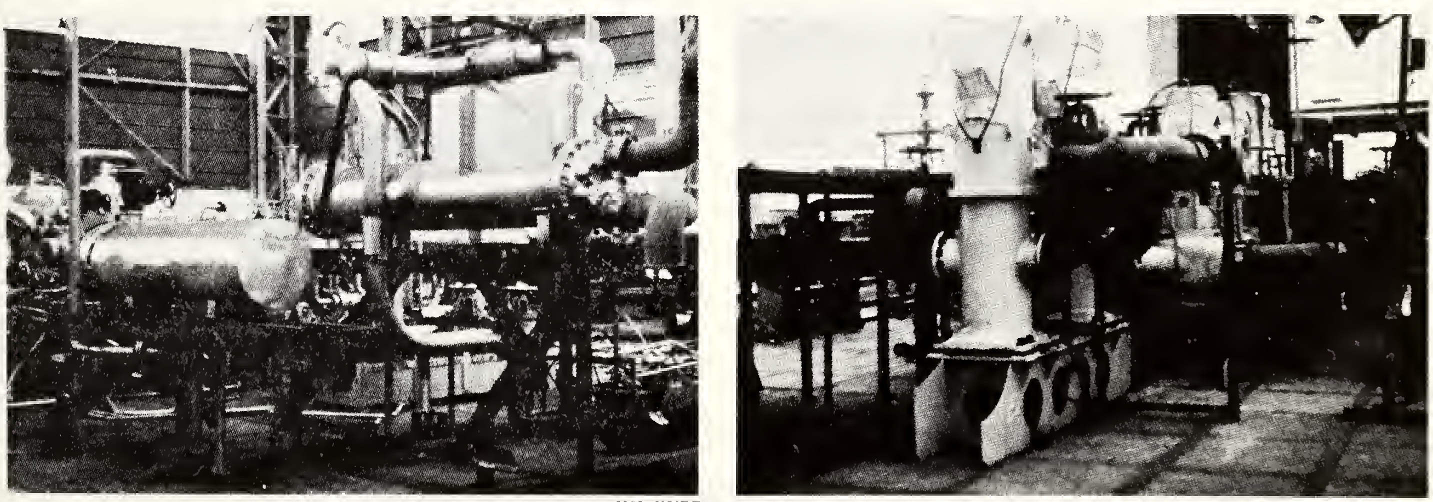


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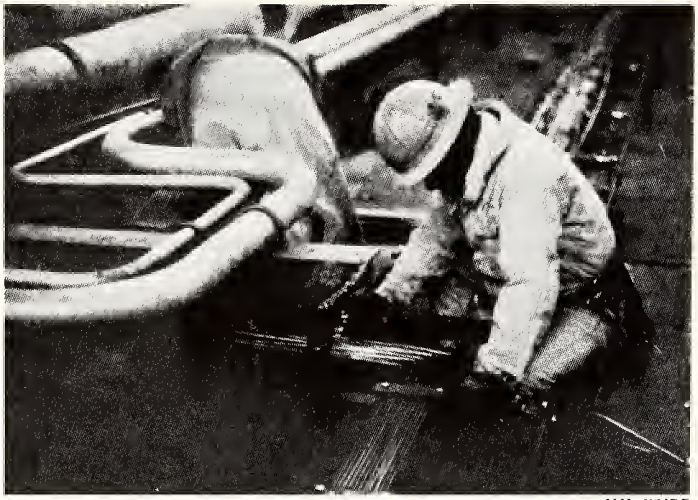
FIGURE 7-2: Angle iron is used for most foundations to simplify their fabrication. Also, foundations are combined as much as possible to minimize the number of pallets. This simplifies scheduling. Lightweight angle iron is used for temporary stiffening or support. The need to add support after a unit is landed on-block or on-board is avoided. Foundations for heavier loads are designed to distribute stresses from above decks so that they may be entirely incorporated in units. All electrical components, in addition to the motors illustrated, are protected from weather.



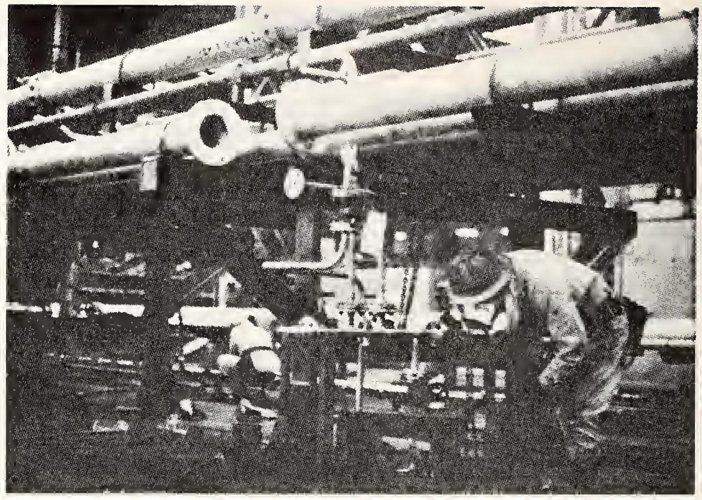


FIGURE 7–3: The attachment of small components is greatly facilitated if performed on-unit indoors where climate and lighting can be reasonably controlled. Access is ideal. Bins for small bolts, gaskets, etc. are never more than 50 feet away.

7.1.6 Even small components, such as drain piping and tubing as illustrated in figure 7-3 should be outfitted on-unit. Such work is greatly facilitated by access to nearby bins for small bolts, gaskets, etc., in addition to the better work environments in outfit assembly areas.

7.1.7 A work instruction drawing for a unit should incorporate references that can be laid down on an assembly area floor. These, marked on grounds which establish the platen, see figure 7-4, facilitate layout of the unit before its assembly.

7.1.8 Detail designers should employ standard elevations which correspond to a system of modular support blocks. The latter should be used for temporary support during assembly of a unit, see figure 7-5.

7.1.9 Wherever non-standard pipe heights are necessary, an adjustable jig similar to that shown in figure 7-6 should be used.

7.1.10 Alignment problems between units should be avoided by assembling adjoining units together or by using a jig, see figure 7-7. Also, couplings for joining units should be in the same plane and should be of a type that permits a unit to be lowered into its final position from overhead, e.g., even between two adjoining units.

7.1.11 Care must be exercised to ensure that the distances between pipes are sufficient to provide access for coupling. Flanges are preferred and welded pipe butts should be avoided. Provided there are sufficient pipe anchor points, other suitable couplings are simple removable-stop type flexible couplings, figure 7-8, and flexible hose assemblies, figure 1-10, which already feature fitting configurations for virtually all pipe systems in ships. [1,2]

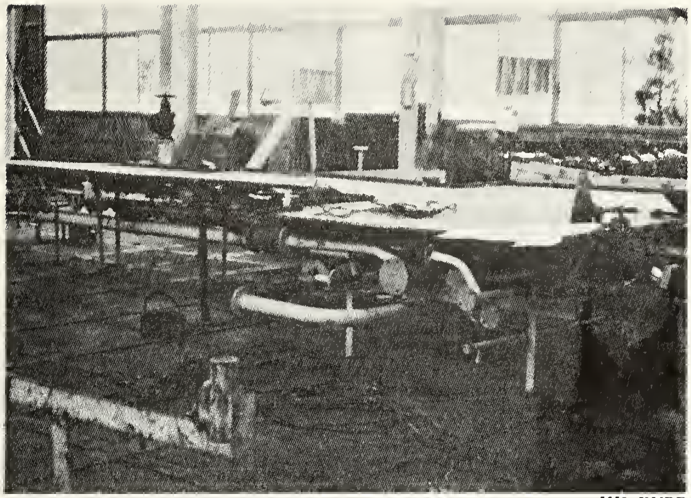
7.1.12 Outfit components should have at least one coat of paint before assembly into a unit. Each unit, less only insulation which could deteriorate in weather, should have all but its final coat of paint before landing on-block or on-board.

7.1.13 As shown in figure 7-9, units are structurally strong enough to be lifted without special rigging. Temporary stiffeners are sometimes needed to maintain the positions of unit supports.

7.1.14 One pallet applies to installation of a main engine when it is assembled on-board because work instructions are provided by the engine manufacturer.

[1]U.S. Coast Guard letter (G-MMT-2/82) 16703/46-56; 1000 Dresser, dated 8 February 1978, advised that the simple removable-stop type flexible coupling is acceptable.

[2]SS ALLISON LYKES was delivered in February 1964 with an extensive amount of Aeroquip hose in place of CuNi pipe in various SW systems. This special case was USCG approved to develop data which could justify regulation changes to generally permit such installations. By letter dated 10 October 1975 the USCG reported "the installation was generally acceptable" after 11 ½ years service but mainly because of a lack of standards it would be difficult to change the regulations. The ASTM Committee F-25 on Shipbuilding is addressing the prerequisite standards. Regardless of the latter, the 11 ½ years service in ALLISON LYKES and the many installations in naval ships (for noise and vibration isolation) are sufficient justification for the USCG to include in 46 CFR 56.30-40 permission to employ flexible hose assemblies to facilitate on-board attachment of sections of pipe previously outfitted on-unit and on-block. Precedent exists in 46 CFR 111.60-40 which specifically allows splices to facilitate the attachment of electric cable in one subassembly to cable installed in another subassembly.

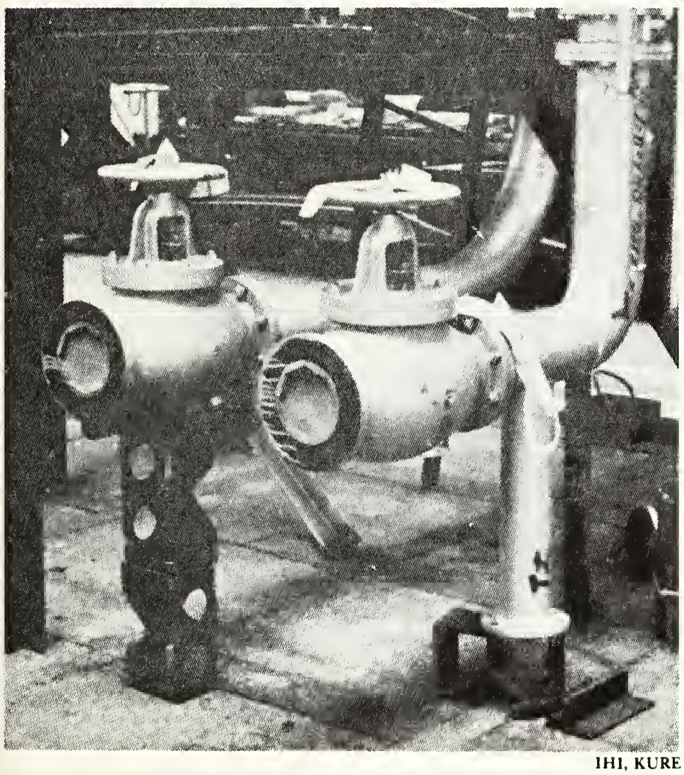


IHI, KURE

FIGURE 7-4: A platen area facilitates assembly ot different type units. The references which are laid down are very discernable and apply only to the unit to be assembled.

Where crane capacity is sufficient, complete main engines should be placed on-board as a single lift. Regardless of the number of lifts all platforms and ladders should be attached, see figure 7-10.

7.1.15 Detail design of a unit and division of the adjoining hull structure into blocks are interdependent. In fact, units, blocks and combinations of units already fixed to blocks must all be sequenced for joining at a building site by the same erection schedule. Figure 7-11 illustrates some concerns that detail designers and methodizers for both hull construction and outfitting must share in order to plan installation of a unit. Certainly there is impact on block boundaries which traditionally were established only for maximum "steel throughput." Therefore, implementation of outfitting on-unit introduces the need for managers to re-orient traditional hull construction planners and to teach outfit planners more about hull construction options.



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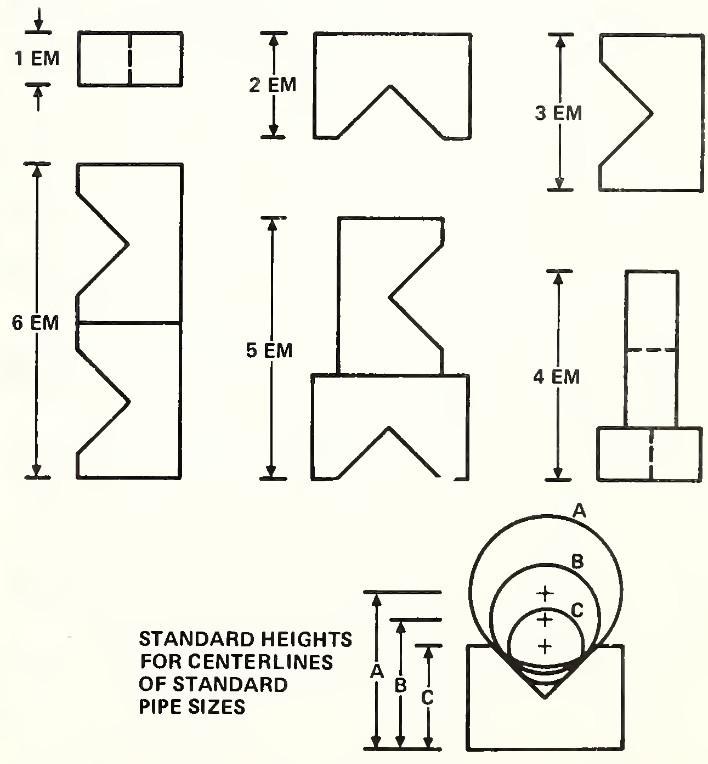


FIGURE 7-5: Modular support blocks. As in the printing industry an EM is defined as a square using any dimension elected as a standard size. Six inches or 20 centimeters would be useful for on-unit or even on-block outfitting. Detail designers should then use, insofar as possible, standard heights as follows: 1 EM 6" or 20 cm, 2 EM 12" or 40 cm, etc. Standard heights for centerlines of pipes are as shown, dependent upon the outside diameters of pipe sizes selected as standards. The modular support blocks could be cast from metal or plastic or cut from wood.

7.2 Outfitting On-block

On-block is the second best alternative for significantly improving overall productivity during construction of a ship. It is generally employed to some degree in all shipyards, but, because it impacts adversely on traditional goals for maximum steel throughput, it has not yet been fully exploited. Outfitting on-block is highly developed by the world's most competitive shipyards thus useful guidance is available:

7.2.1 Planning block configurations must incorporate compromises that facilitate both the hull block construction method (HBCM) and outfitting on-block with a single goal of reducing their combined costs. Therefore, blocks should be three dimensional and when placed for outfitting, often upside down, should always permit crane access from above. In addition, block configuration should facilitate near the ground access for people and small portable cranes from at least two sides. Seemingly, these are conflicting requirements but figures 7-12, 1-7, 1-8 and 1-9 show different type blocks all of which conform. Figure 7-12 is especially noteworthy because it shows that only a small portable crane and a reserved area are needed for outfitting most blocks. Outfitting requirements are usually simplified when the stack structure is separate from the deck house.

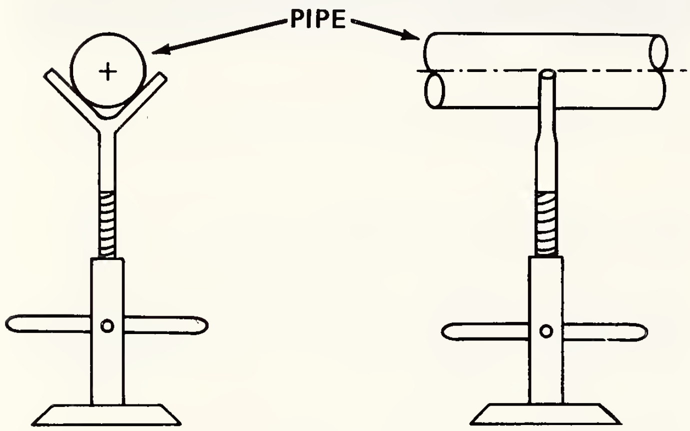


FIGURE 7-6: A simple adjustable jig can be used for accuracy control of non-standard heights for pipe.

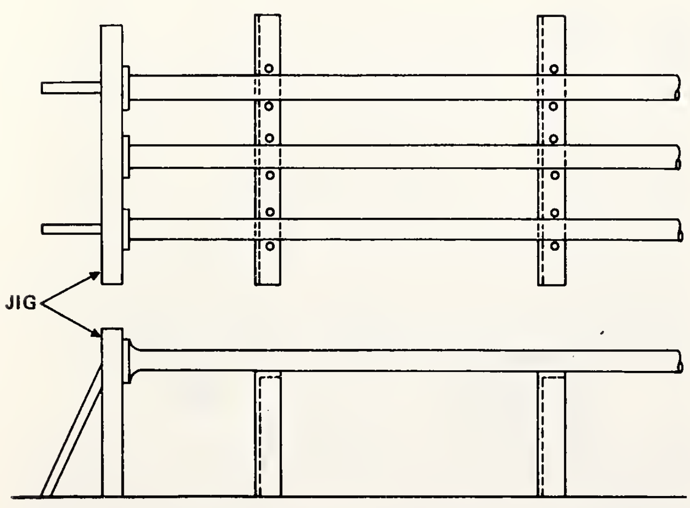
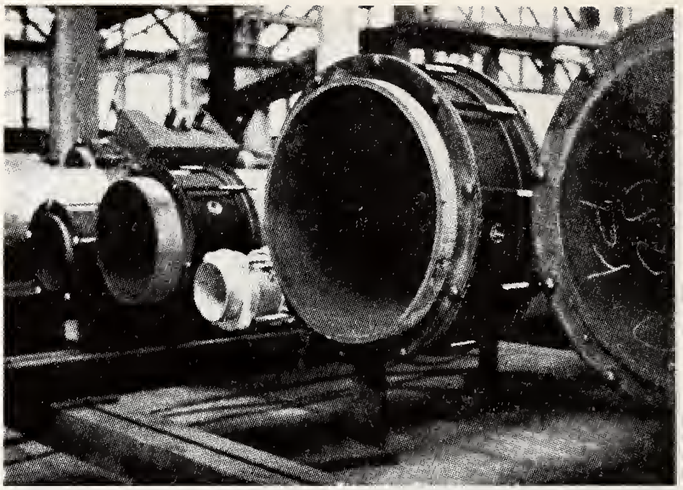


FIGURE 7-7: A jig should be employed to ensure correct flange alignment for certain geographical units. This eliminates adjustments on-board.



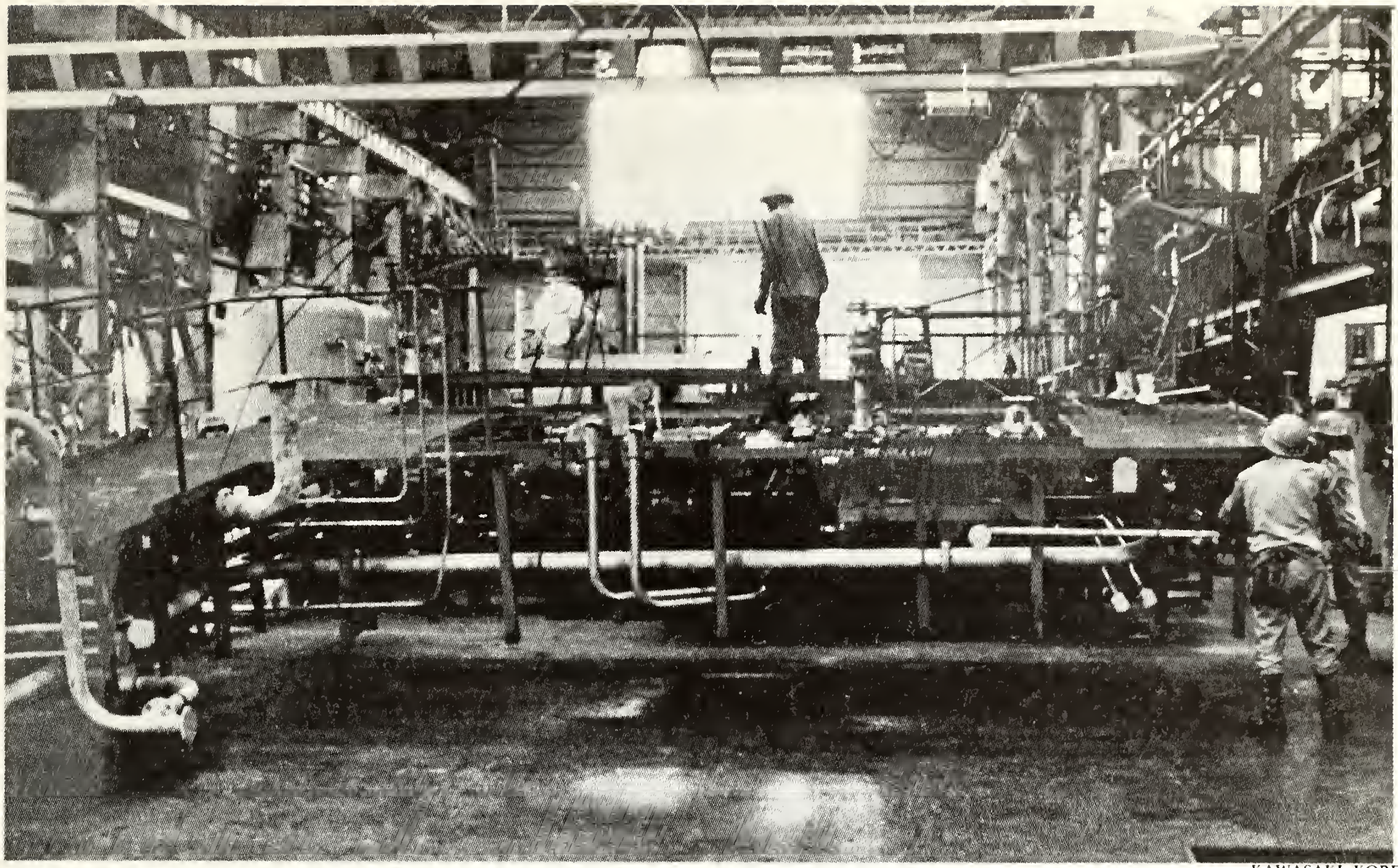
ITALCANTIERI, MONFALCONE

FIGURE 7-8: Simple removable-stop type flexible couplings are temporarily fixed on unit. Thus, in-process material control is simplified. The similar but more expensive couplings which feature undesired clips welded to the pipe, sometimes preclude this cost saving measure. The particular unit on which the couplings are temporarily fixed is specified in Work Instruction Design by the same people who performed Detail Design.

7.2.2 Oil and watertight boundaries in blocks should be inspected for pinhole leaks before attachment of fittings, see figure 7-13.

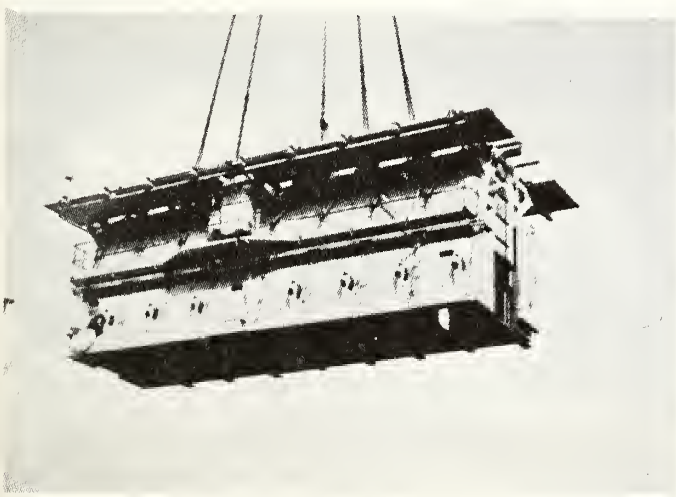
7.2.3 Everything needed within a block, less only insulation and electronics that could be damaged by weather, should be part of the outfit pallet. Even items such as chain falls and temporary staging should be included; see figures 7-14 and 7-15 respectively. In at least one shipyard where outfit planning was perfected, temporary service pipe systems, e.g., for oxygen, gas and compressed air needed within a machinery space during erection, were outfitted on-block; see figure 7-16.

7.2.4 Assuming conventional paint systems, blocks should have at least one paint coat over a primer before outfitting commences and all but the final paint coat after outfitting is completed. As shown is figure 7-17, painting is greatly facilitated because most is downhand with no staging required.



KAWASAKI, KOBE

FIGURE 7–9: Generally, just the walkway structure and pipe provide enough stiffening so that units can be made strong enough to be lifted by a single-hook crane without the use of padeyes or a spreader. The unit shown is being moved over a platen area that was recently painted as preparation for layout of the next unit to be assembled.



MITSUI, CHIBA

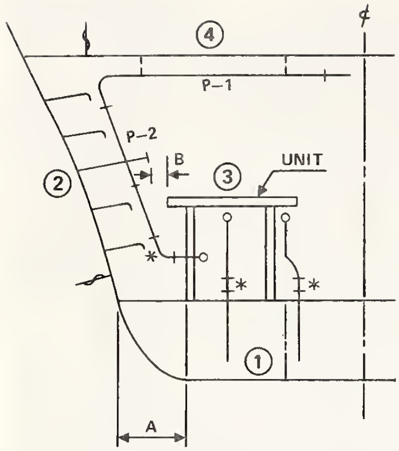
FIGURE 7–10: Ladders and walkways should already be attached to main diesel engine subassemblies when landing them on-board. They enhance safety and are productive because they eliminate the need for temporary staging in congested machinery spaces.

7.2.5 For certain blocks, as in figure 1-7 for example, schedules must address when structural work should stop to permit painting, outfitting, painting again, and then the resumption of structural work.

7.2.6 Similarly, outfitting on both sides of a block, as in figure 7-18, requires work packages and schedules to address the sequence for painting, outfitting, painting, turnover, painting, outfitting and painting. Separate pallets for each type of work per stage (before turnover and after turnover) facilitate precise control.

7.2.7 Planners should consider combining penetrations such as in the assembly shown in figure 7-19 which was manufactured by a subcontractor. It appeared as a single MLF item and thus simplifies material control and installation on-block.

7.2.8 Make-up pipe pieces and loose flanges should be provided for coupling pipe outfitted on-block to pipe in other blocks, or to pipe outfitted on-unit. Figure 1-10 illustrates the use of flexible hose assemblies as a productive means to couple tubing that was installed in



ERECTION SEQUENCE

BLOCK ① AN INNER BOTTOM; IT CONTAINS SOME PIPE OUTFITTED ON–BLOCK.

BLOCK ② CONTAINS PIPE P–2 WHICH WAS OUTFITTED ON–BLOCK. (P–2 COULD HAVE BEEN TEMPORARILY ATTACHED IF ITS REMOVAL WAS REQUIRED FOR LANDING UNIT.)

UNIT ③ UNIT DETAIL DESIGNERS CONSIDERED THE MINIMUM DISTANCE "A" NEEDED FOR ACCESS FOR WELDING THE SEAM BETWEEN BLOCKS ① AND ② SO THAT UNIT ③ COULD BE LOWERED IN PLACE. ALSO DETAIL DESIGNERS CONSIDERED NEED FOR CLEARANCE "B".

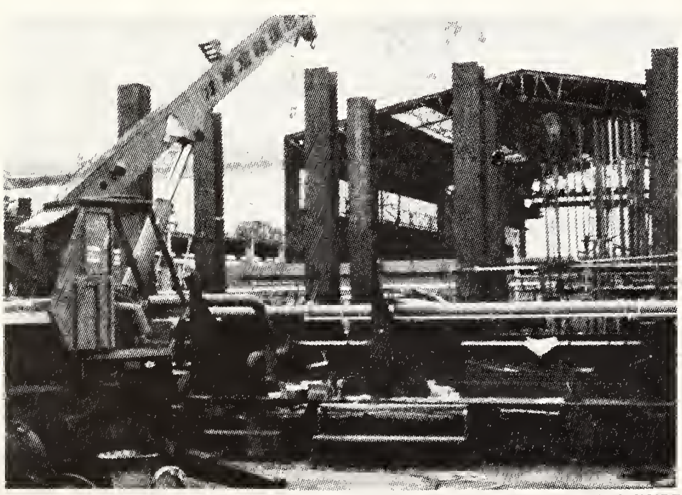
BLOCK ④ CONTAINS PIPE P–1 WHICH IS TEMPORARILY ATTACHED. IT WILL BE PERMANENTLY SUPPORTED AND ATTACHED TO PIPE P–2 AFTER THE DECK SEAM IS WELDED.

* PIPE PIECES OUTFITTED ON–BOARD AFTER WELDING OF UNIT TO TANK TOP AND SHELL SEAM ARE COMPLETED.

FIGURE 7–11: The erection sequence addresses both units and blocks.

adjoining blocks. The guidance for couplings contained in paragraphs 7.1.10 and 7.1.11 should also be considered.

7.2.9 Electric cable should be at least partially installed in blocks of modest size, see figure 7-20. Whether electric cable should be spliced between blocks, as permitted by the U.S. Coast Guard,[3] should be based solely on cost trade offs. In shipyards which produce very large blocks as interim products, e.g., thirds and halves



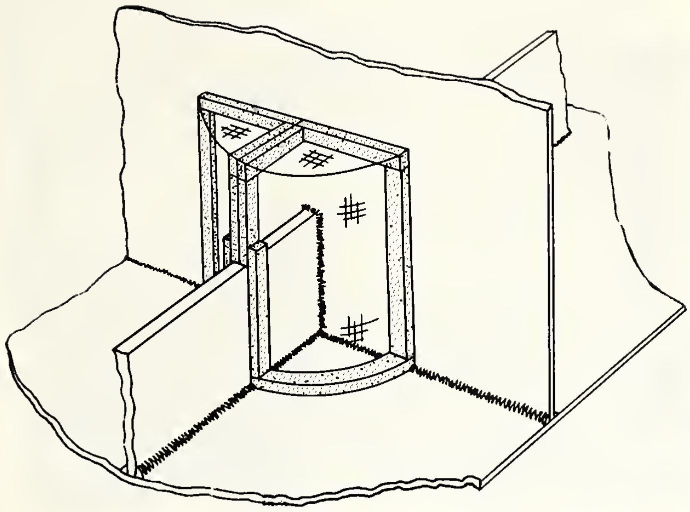
IHI, KURE

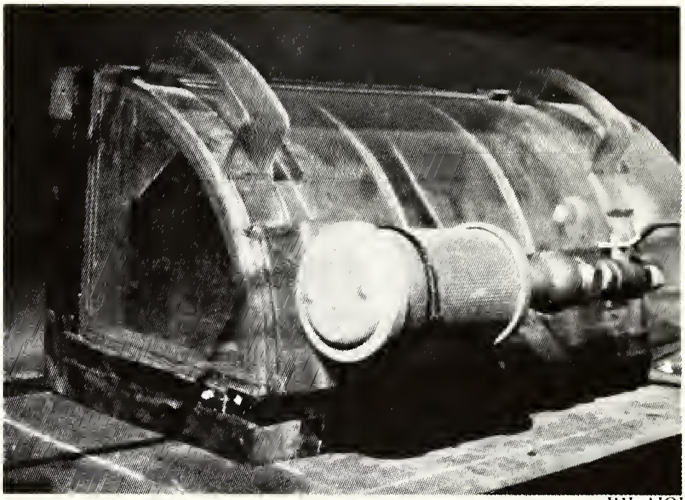
FIGURE 7–12: A machinery-space overhead is being outfitted upside-down. Material is landed by a small portable crane. There is no requirement for labor-intensive horizontal shifting of heavy weight. This combined with near to the ground access enhances safety.

of hulls and separate deck houses, the use of electric cable splices will permit better level loading of electricians and simultaneously reduce the number of man-hours required for the very labor intensive cable pulling. In order to acquire these benefits, managers will have to advise traditionalists among electrical systems planners, including designers, that electric cable splices are simply joints analogous to pipe couplings, ventilation duct flanges and hull master butts that must be designated to facilitate construction of a ship. Further, managers will have to address some owners as a few remain who still do not permit electric cable splices even though all original cable characteristics are restored. Paradoxically, they permit couplings in frequently more dangerous fuel oil, hydraulic oil and compressed air systems. Figure 7-21 shows electric cable splices installed to facilitate attachment of a completely outfitted deck house to the hull of an LNG ship. Similar installations have been made in ULCC.

7.2.10 Managers should address hull construction accuracy control not only to minimize structural rework but also to facilitate outfitting on-block. For example, shipbuilders who have such control already finish bore sterntube bearings on-block; i.e., boring at the erection site is completely eliminated. Each block containing a finished sterntube bearing is erected within tolerances that insure on-board alignment of propulsion machinery with chocks of conventional thickness.

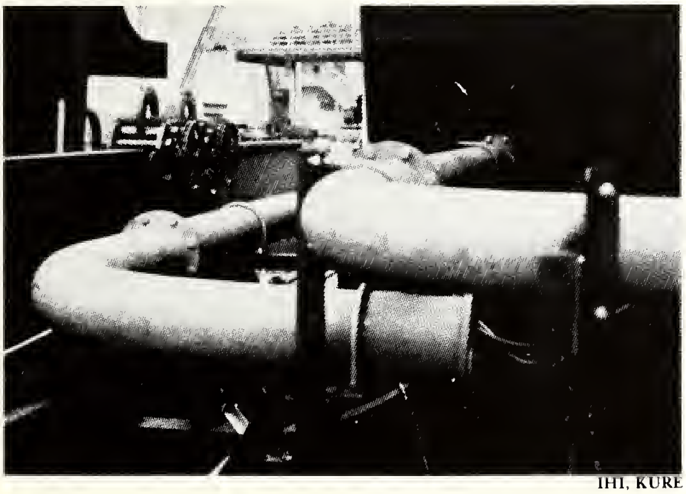
[3]See Code of Federal Regulations, 46 CFR 111.60-40(a)(1): "A cable installed in a subassembly may be spliced to a cable installed in another subassembly." Also see 35.139.5 of the American Bureau of Shipping Rules for Building and Classing Steel Vessels: ". . . approved splices will be permitted at interfaces of new construction modules . . ."





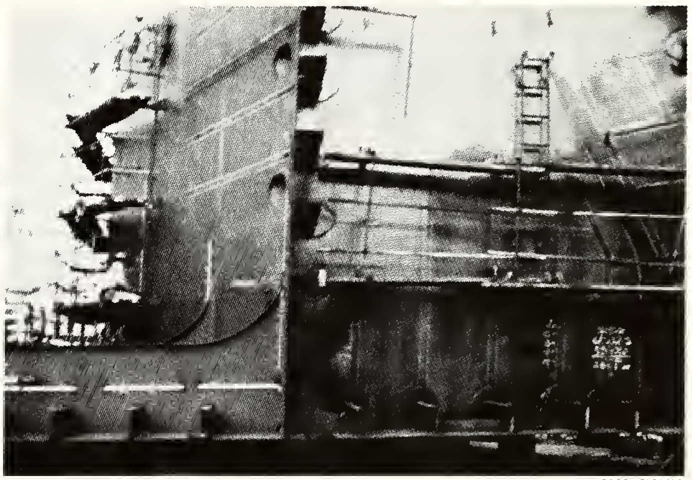
IHI, AIOI

FIGURE 7–13: Transparent vacuum boxes each feature soft thick gaskets, a valve-eductor-silencer assembly and a fitting for connection to the shipyard's compressed-air system. Some are made in two parts for testing flat-bar, tee or angle penetrations of tank boundaries on-block. Others are hemispheres sized to inspect installation of deck fittings, e.g. sounding tubes.



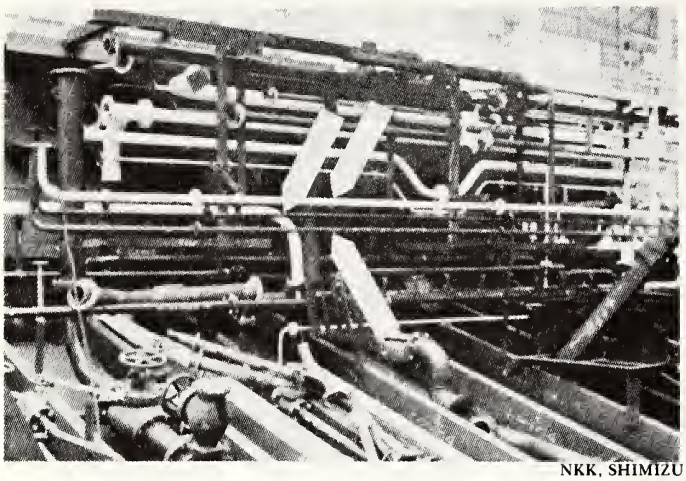
IHI, KURE

FIGURE 7–14: The chain fall is tied with soft iron wire to prevent movement during block turnover. When the block is fitted at the erection site, the ship's chain fall is immediately available for outfitting on-board.



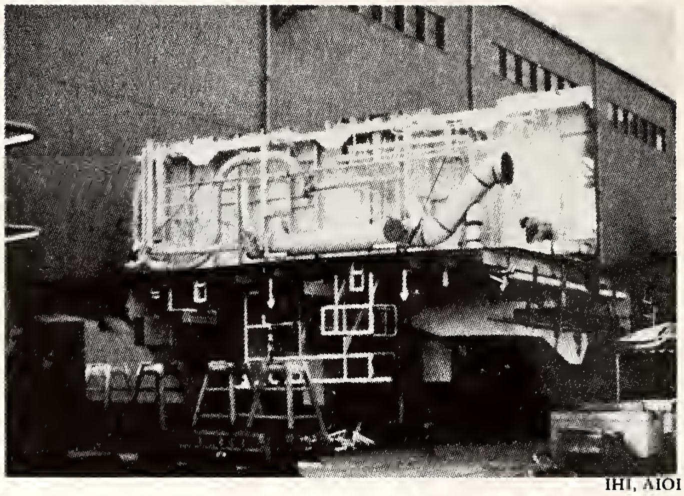
IHI, KURE

FIGURE 7–15: Anticipating turnover, some staging is installed on-block upside-down. Soft iron wire secures staging planks.



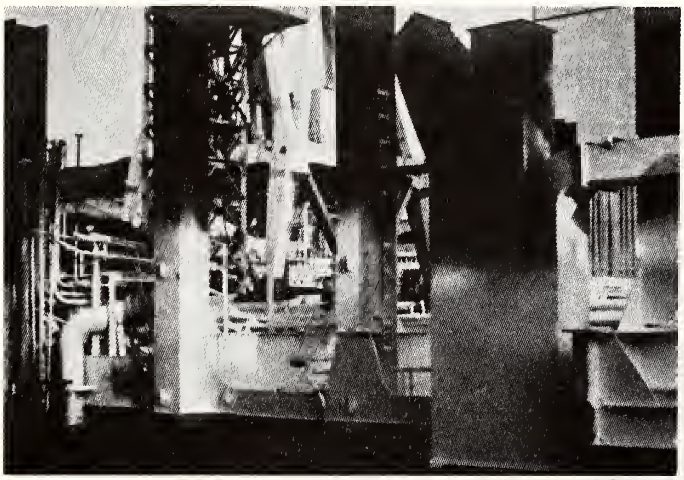
NKK, SHIMIZU

FIGURE 7–16: Arrows designate temporary services pipe which will lead to manifolds. When on-board outfitting is completed, these systems will by scrapped or will remain if the owner wishes them to facilitate repair work.



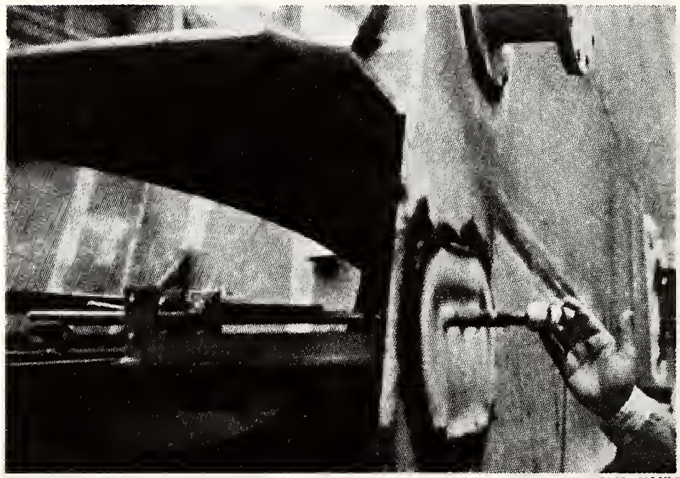
IHI, AIOI

FIGURE 7–18: Outfitting and painting on-block down hand can reduce manhours to one tenth of that required for overhead work. Therefore, the effort for turnover is frequently a good investment if both sides of a block require outfit.



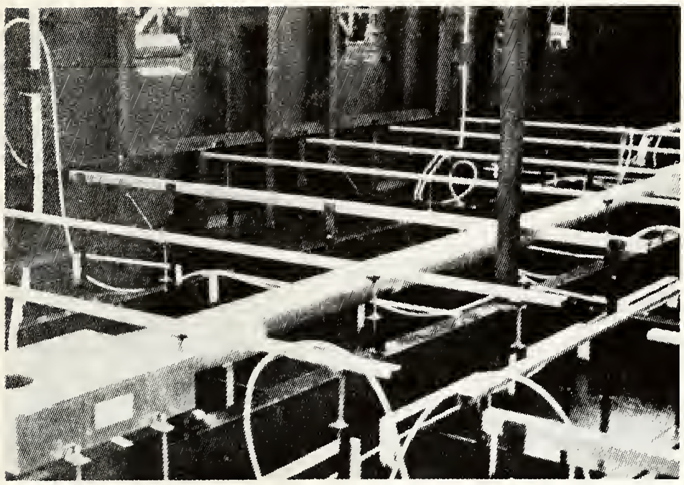
IHI, KURE

FIGURE 7–17: The grouping of production effort into hull construction, outfitting and painting permits precise planning for virtually all painting at the best opportunities and minimizes paint rework. Painting down hand with no requirement for staging is highly productive.



IHI, KURE

FIGURE 7–19: Three tubing penetrations and their angle-iron supports are combined in a small subassembly produced by a subcontractor. Management techniques for the assembly of a ship, particularly computer applied management information systems, are necessarily designed for large complex assemblies. The application of such expensive, large capacity resources to small subassemblies is simply not worthwhile.



IHI, KURE

FIGURE 7–20: Much electric cable can be completely or partially installed on-block. Moreover, productivity is greatly enhanced if the block is upside down.

7.2.11 Inboard accessible sterntube bearings simplify outfit planning because they are furnished by their manufacturers completely finished. Even the need to bore on-block is eliminated. Because such bearings have adjustable internals they can be successfully fitted on-block even where hull construction accuracy control is not perfected. Further, a sternframe weldment featuring an inboard accessible sterntube bearing is generally less costly than a conventional sternframe assembly which contains large castings. This is another example where a higher priced material item can lead to reduced overall costs.

7.2.12 If inboard accessible sterntube bearings are used and provided hull construction accuaracy control is sufficient, consideration should be given to aligning and chocking the main engine even before the sternframe block is erected. This permits earlier start for flushing the main engine lube oil system and its sump.

7.2.13 Successful outfitting on-block is critically dependent upon hull construction, outfitting and painting planners learning more about each other's functions and finding ways to compromise in order to reduce the overall cost of ship construction. As illustrated in figures 7-22 through 7-27, there are many opportunities for more productivity which are only limited by planners' imaginations and the degree of acceptance that design, in particular, and material definition are aspects of planning. Figure 7-27 is significant because it shows the beneficial impact of unified planning of outfitting on-block applied to ship repair.

7.2.14 In order to construct deck house levels separately for outfitting each upside down, the exterior surface panels should be intercostal relative to decks. Each of the latter, being continuous, will project a small distance beyond exterior panels to create seating surfaces for the next deck house level to be erected.

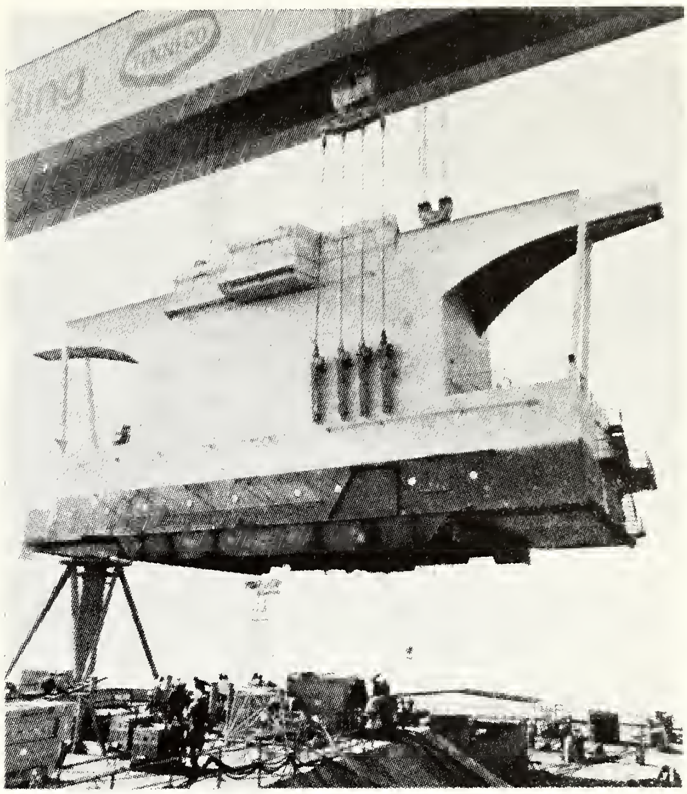


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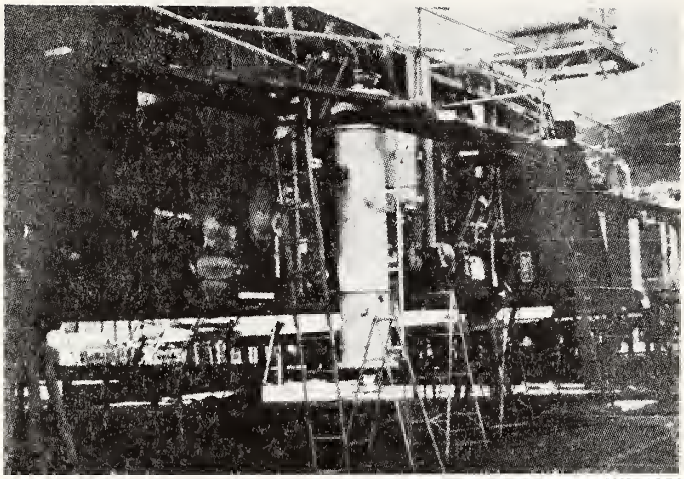
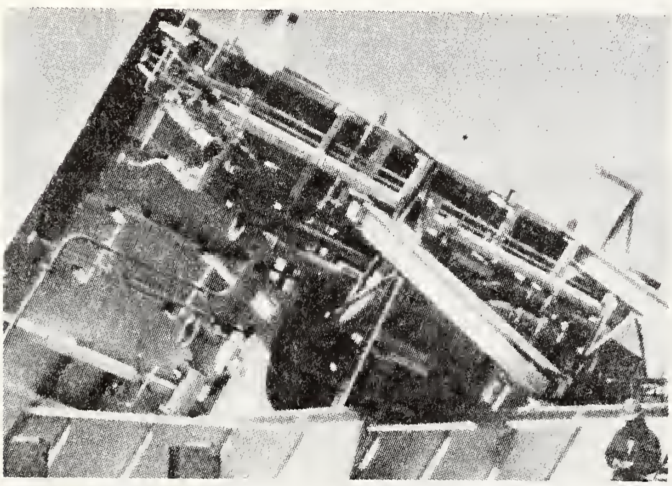
FIGURE 7–21: In this application 114 electric cables in the deck house were spliced to cables already installed in the hull. The conductor sizes ranged from 1,119 to 250,000 circular mils as in cable types TTRSA and TAVIB. The numbers of conductors per cable varied from 2 to 62 and there were 28 different types and sizes. Shielded cables were also spliced but required specific USCG approvals. Designating electric-cable splices to facilitate the shipbuilding process is as much a planning responsibility as designating pipe couplings, vent duct flanges and hull master butts.



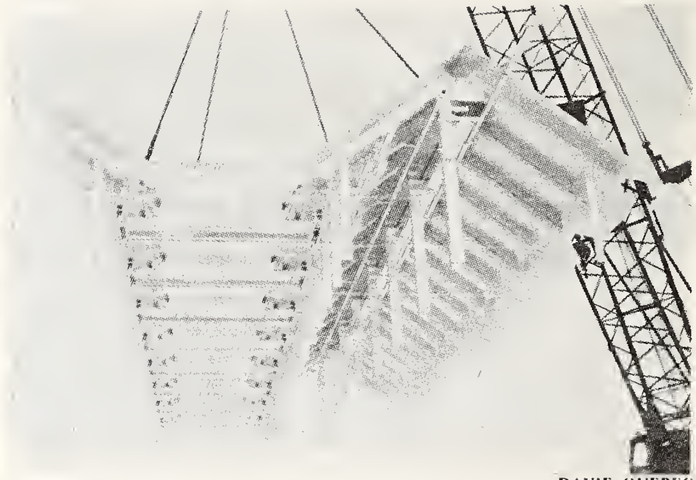
IHI, AIOI

FIGURE 7–22: Outfitting on sides of blocks is particularly easy because of ready access by small portable cranes.



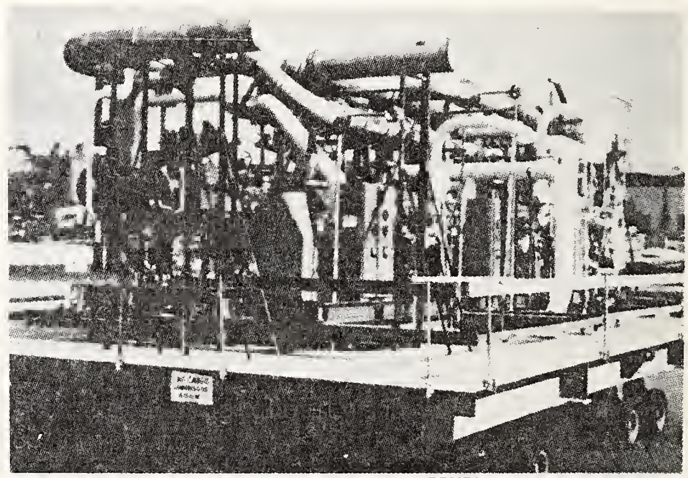
WHYALLA, MELBOURNE

FIGURE 7–23: A block, completely outfitted, is temporarily stowed awaiting erection.



DAVIE, QUEBEC

FIGURE 7–24: Actuators and hopper doors are already outfitted on-block.



GENERAL DYNAMICS, QUINCY

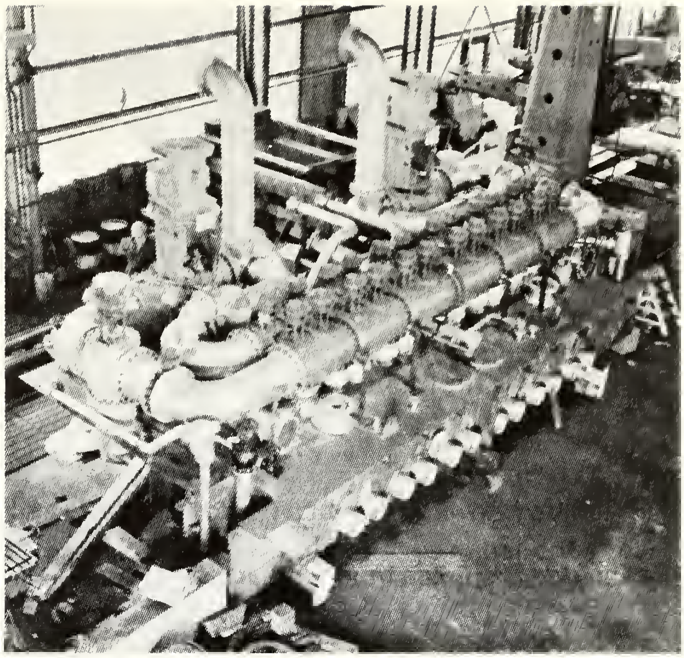
FIGURE 7–25: An LNG ship compressor room is outfitted on-block.

7.3 Outfitting On-board

If outfitting on-unit and on-block is fully exploited, outfitting on-board would be limited to:

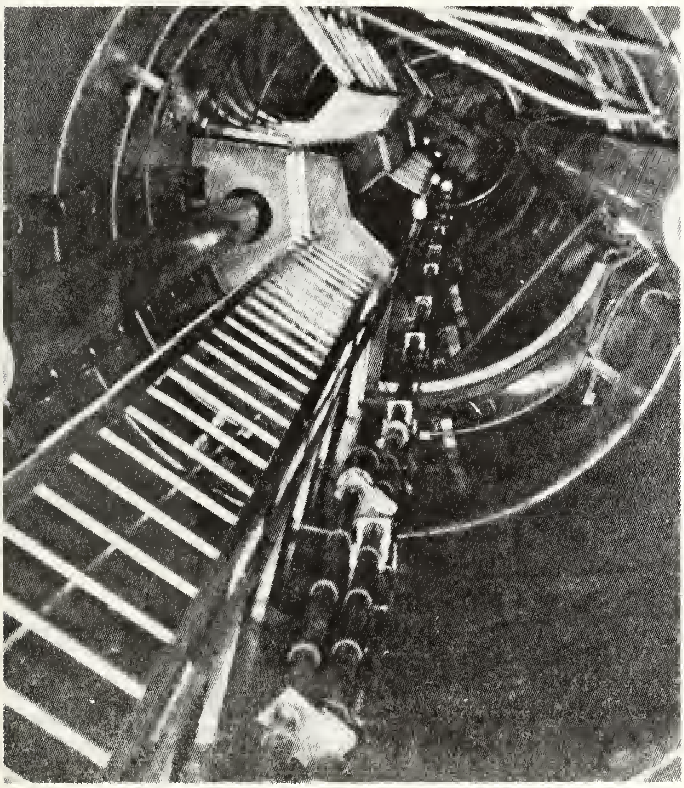
- some electric cable pulling,[4]
- installation of electronics equipment and insulation that would otherwise be damaged by weather,
- connecting system interfaces between units and blocks,
- rigging and loading ground tackle,
- applying the final paint coat,
- tests and trials.

7.3.1 Units placed on-board in the vicinity of propulsion machinery should remain unattached until the machinery is aligned as the units may have to be temporarily shifted to provide access for installation of chocks and foundation bolts; see figure 7-28.



DAVIE, QUEBEC

FIGURE 7–27: The work order, during an overhaul, specified replacement of a pump, manifold and contiguous double-bottom pipe. By electing to renew some hull structure, the complex assembly was productively outfitted on-block.



GENERAL DYNAMICS, QUINCY

FIGURE 7–26: Ladders, platforms, wiring and level indicating sensors are outfitted in an LNG ship pipe tower prior to its installation in a spherical cargo tank.

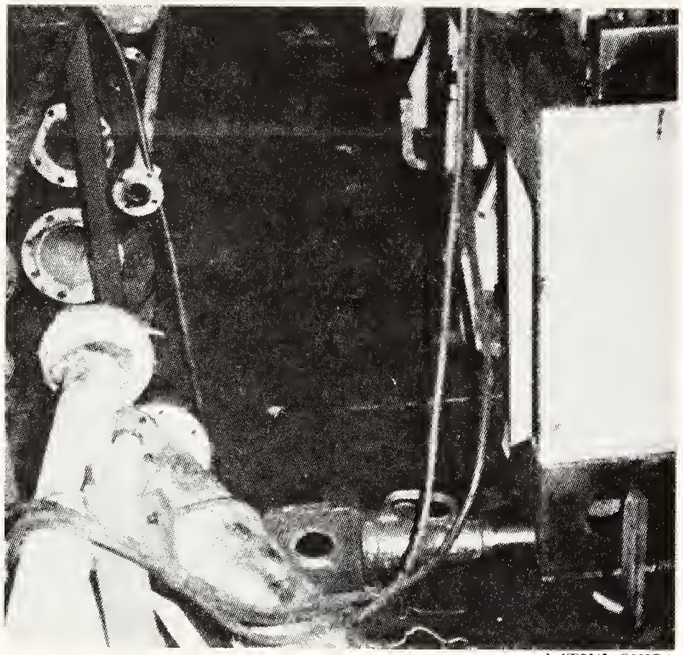
7.3.2 Epoxy chocking compounds have been successfully used to fix the alignment of main engines since 1966. Their use significantly reduces time required by eliminating the need to machine foundations and for highly skilled craftsmen to reiteratively measure, grind and fit metal chocks; see figure 7-29.

7.3.3 Electric cable should be palletized in cut lengths as needed for specific cable runs. Some shipbuilders successfully apply computers to calculate required lengths and provide precut cable even for unique ships or the first ship in a series.

7.3.4 In order to ease labor intensive pulling and to reduce the time required, planners should consider installing an electric cable of large size or exceptional length in two or more pieces, see figure 7-30. Splices for this purpose are specifically permitted by the U.S. Coast Guard.[5] When two or more such cable pieces are installed simultaneously, the zones which they transit become available earlier for starts of other outfit work.

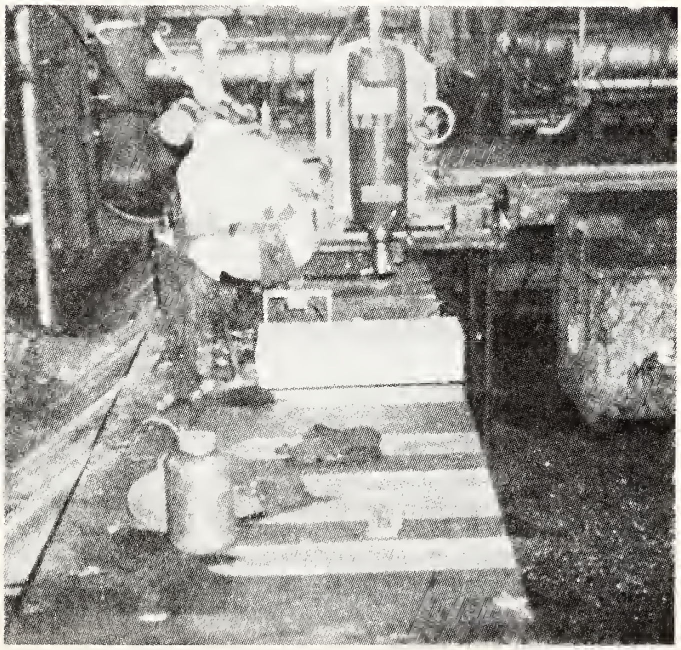
[4]For example, lengths which were partially installed on-block with the remainder temporarily coiled. Also, where blocks were not large enough to justify installation and subsequent connecting with splices.

[5]See Code of Federal Regulations, 46 CFR 111.60-40(a)(3): "A cable having a large size or exceptional length may be spliced to facilitate its installation." Also see 35.135.9 of the ABS Rules for Building and Classing Steel Vessels: ". . .splices will be permitted to provide for cable of exceptional length."



MITSUI, CHIBA

FIGURE 7–28: Adjacent units remain free until the main engine is aligned and chocks are installed. The padeye used for handling the double-bottom block also serves as an anchor needed to shift the engine during alignment.



MITSUI, CHIBA

FIGURE 7–29: Some owners still specify metal liner chocks which require machining foundations by positioning and repositioning a cumbersome milling machine and much skilled-labor-intensive hand fitting. Shipbuilders prefer poured epoxy chocks which have a satisfactory history, even for main engines, and which save time during the critical on-board outfit period just before launching a ship.

7.3.5 An electric cable which transits a machinery space (50°C) and other spaces (40°C) is sized larger than it would be otherwise because of an ampacity limit based upon the "high temperature" machinery space. Therefore, when relatively long cable lengths are required outside of machinery spaces and voltage drops are not limiting, splicing to smaller cable sizes should be considered. The required copper can be reduced by as much as 15%. For example, TXIA 250 cable (230 amps @ 50°C) within a machinery space could be spliced to TXIA 212 (233 amps @ 40°C) outside the machinery space.

7.3.6 At least one shipbuilder installs cargo lights and their cables on masts in an outfit assembly area. When placed on-board, temporary power cables are spliced for immediate use of the ship's cargo lights for nighttime operations at the erection site. Later, the temporary services are severed and the completed ship's circuits are permanently attached with splices.

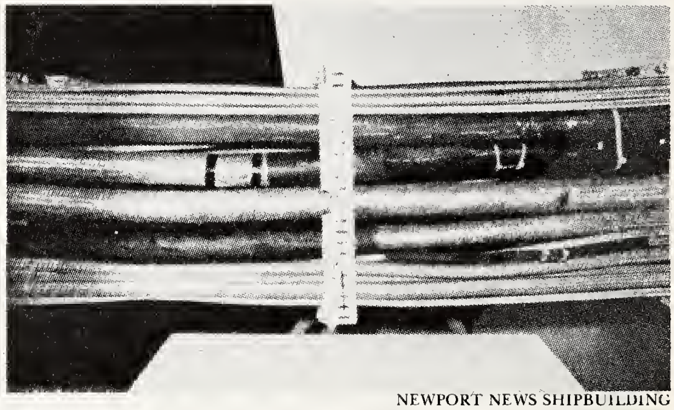


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FIGURE 7–30: Electric cable pulling in ships is difficult for cable weighing as much as 3 pounds per foot. Electricians generally regard it as undesirable work. The process can be made easier by the judicious use of splices.

7.3.7 One very unique electric-cable splice application occurred in 1959 during construction of the first nuclear-powered aircraft carrier. The main machinery spaces were ready for start of electrical tests before a significant amount of the forward structure was completed. So that tests could start and continue without interruption, connections to the switchboard were completed with certain power distribution cables simply terminated at the forwardmost completed bulkhead. Subsequently when the forward structure and cable installations were completed, twenty T-400 size cables were joined with in-line splices.

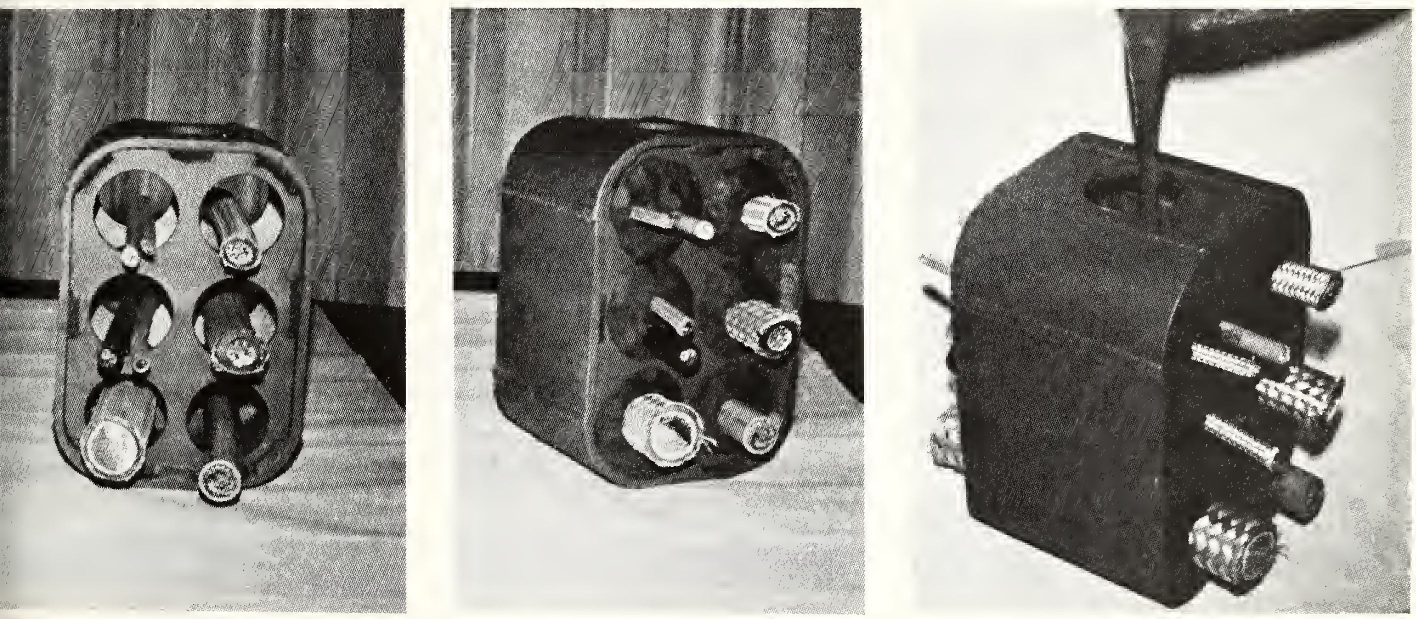
7.3.8 Another shipbuilder used splices to shift from conventional power cable to short lengths of finely stranded cable of the same capacity. This allowed small radius bends just before cable terminations.

7.3.9 Planners should consider greater use of the poured-type electric-cable deck and bulkhead penetration seals (see figure 7-31). As compared to traditional methods such as the multiplicity of split resilient blocks and stuffing tubes, both of which are sized to specific cable diameters, the poured-type accommodates all cable diameters. This greatly simplifies planning because material definition addresses significantly fewer material items. As a consequence, savings follow in purchasing, warehousing and in material control. But even greater savings are achieved in the manhours required for installation. This has been demonstrated where poured seals replaced the split block type in LNG ships' deck penetrations. The tedious process of assembling the many blocks from above with an extra man below to support them until all were in place and tightened was eliminated.[6]

7.3.10 As it is very productive to outfit tubing and small diameter pipe on-unit and on-block, relatively new heat recoverable couplings should be considered for joining such systems on-board. Although more expensive than conventional couplings they are especially productive in hydraulic and pneumatic systems as they do not introduce contaminants, nor do they require certified skills as do welded and soldered joints. They are the easiest couplings to install, particularly where access is limited.[7]

7.3.11 Each hatchcover should be secured to its coaming before fitting the latter on-board. This requires only one lift vice two and insures that the hatchcover will fit after the coaming is welded in place.

7.3.12 Pallets for on-board outfitting may apply to overlapping zones. Conflicting activities are avoided by time phasing, i.e., designating different stages.



NATIONAL SHIPBUILDING RESEARCH PROGRAM

FIGURE 7–31: Poured-type bulkhead seals using certain water-mix refractory cements are both firetight and watertight.

[6]Poured-type seals using certain water-mix refractory cements are both fire tight and water tight. Acceptance is recorded in USCG letter (G-MMT-2/82) 9620/2-1 dated 3 September 1975 re: Todd Seattle Drawing 4966-SK-005 for the National Shipbuilding Research Program.

[7]Expanded couplings are delivered immersed in a cryogenic bath, usually liquid nitrogen. They stay expanded at low temperature. Removed from the bath and installed, they quickly shrink to their original diameters as they recover heat from the ambient. As of July 1979, Raychem Corporation reported that more than 24,000 of their heat recoverable couplings have been installed in U.K. submarines and surface ships. Additionally, over 6,000 of their couplings were used by Ingalls Shipbuilding in 4,500 psi air and 3,000 psi hydraulic systems to facilitate construction of naval ships (DD963 and LHA Classes). Since the usual non-destructive tests are not applicable, reportedly, QA joint record cards are not required.

APPENDIX A

1.0 SOME THINGS TO CONSIDER PRIOR TO COMPUTERIZATION

1.1 Material Control

1) Classification of material
   - Material Code
   - Material Control Classification
   - Material Supply Form Classification
2) Effectiveness of material control
   - To study and settle material Control Classification for avoiding material shortages with minimum stock.

1.2 Design

1) Standardization of design
   - Dismiss sectionalism traditions
   - Reduce the varieties of standards by considering total cost and handling
   - Discourage owner's special requests
2) Standardization of vendors
   - Make more long-term agreements with vendors for material based on cost and quality
3) Exceptional cases

1.3 Purchasing

1) Standardization of purchasing procedures
   - contract for long-term agreements
   - contract delivery and payment terms
2) Establish purchasing policies for:
   - Purchasing procedures material-by-material.
   - Spot orders
   - Long-term agreements
   - Consignment base contracts

1.4 Warehousing

1) Receiving, issuing and storing material in accordance with Material Control Classification
2) Standardization for palletizing material

1.5 Goals of computerization

1) Instructions to facilitate production progress such as:
   - Sequence drawing issues
   - Quantity and delivery dates of material
   - Issuing materials
2) Job control planned by control data
3) Purchased quantity readily understood
4) Purchased quantity based on both user's required date and material lead time.
5) Reduction of manual calculations and postings such as:
   - Payment orders
   - Cost accounting
   - Bookkeeping
6) Comparison of budget and cost
7) Early discovery of exceptions or emergency matters such as:
   - Late issue of drawings
   - Late issue of purchase orders
   - Late delivery of material
   - Material not issued
8) Prevention of errors due to manual calculations and transposition.
9) Standardization of job procedures

2.0 RATIONALE FOR IHI CODE SYSTEM

2.1 Function of the "Code"

The function of the "Code" in a computerized system can be summarized as follows:

- "Indication" of the nature or meaning of the information and/or date represented by the "Code".
- "Key" for sorting and grouping of data handled by the computerized system.
- "Designation" of the sequential flow of automatic processing by the computerized system.

Each code in the system will be either mono-functional or multi-functional according to its application in the computerized system. By integrating the function of each code, highly organized operations of the computerized system can be achieved.

2.2 Special Features of IHI's Code System

2.2.1 Number of "Codes" is minimized by a "Compound Code"

"Compound Code" means a code number having two duties. For example, a material code is composed of an indication of the material specification and cost category. This reduces the volume necessary for data storage without affecting function.

2.2.2 Logical configuration

IHI's coding system was developed by careful analysis of the job itself, flow of information, mode of operation, etc. Then, the elements after analysis were re-composed to satisfy the function, duty and usage of that code. Data after coding is simple to maintain and understand by the user.

2.2.3 Multi-service

Each code in the code system is designed to be used in multi-service. The connection between each subsystem is made by the codes. These form the keys to the total outfitting system. Some examples of these multi-purpose functions are illustrated in figure A-1.

2.2.4 Flexibility for future expansion

Flexibility for future expansion was also taken into consideration at the time of code design. This feature is important since it provides the capability of adding to or revising the code itself. It also ensures the flexibility of the system operation over time thus preventing the premature obsolesence of the computer aided system by change of environment.

2.2.5 Sorting and grouping

"Code" is, in short, a symbolized indication of an orderly and systematically arranged data set belonging to one group or category of information. One particular data in a group or category of information must be recognized by only one code and, at the same time, the same data can be sorted into a sub-group by utilizing the code. This function is aided by IHI's code system. By using this function the user is able to select necessary and useful information from among thousands of elements of data.

2.2.6 Designation of sequence

Some types of codes define the method and sequence of processing within the computerized system. Therefore, the code is the matching point between the hardware and the user who requires information. If the code is well designed, the user will be able to readily obtain the needed information. The code system is specially designed to serve the users.

2.2.7 Easy memory

"Code" is a kind of language written by a combination of numerical figures and/or alphabetical letters. Such a combination of characters is a necessary feature for the language handled by the computer. However, it is also handled by the user; therefore, the meaning of the code should be easily recognized by both the computerized system and the user. The computer and user requirements are sometimes in conflict. Therefore, configuration of the code should be logically constructed with each component representing its own meaning. In this way people who handle the code are able to easily recognize significance.

	CODE								
EDP SYSTEM OR OPERATION FIELD	WORK NUMBER (e.g. HULL)	MATERIAL CODE	CLASSIFICATION FOR MATERIAL CONTROL	CLASSIFICATION FOR MATERIAL REQUISITION	CLASSIFICATION OF COMPLETED ASSEMBLY OR COMPONENT	DRAWING NUMBER	PALLET CODE	PIECE NUMBER	DEPARTMENT CODE
MATERIAL CONTROL SUB–SYSTEMS	●	●	●	●	●	●	●	●	●
BUDGET AND COST ACCOUNTING SUB–SYSTEM IN MATERIAL CONTROL SYS.	●	●	●						●
MASTER SCHEDULING SUB–SYSTEM	●								
DETAIL SCHEDULING SUB–SYSTEM	●					●	●		●
DATA PREPARATION SYSTEMS	●	●	●	●	●	●	●	●	●
DESIGN FIELD	●	●		●		●		●	
MATERIAL CONTROL FIELD	●	●	●	●	●	●	●	●	
PRODUCTION FIELD	●	●				●	●	●	
COST ACCOUNTING FIELD	●	●							●

FIGURE A–1: Application of codes.

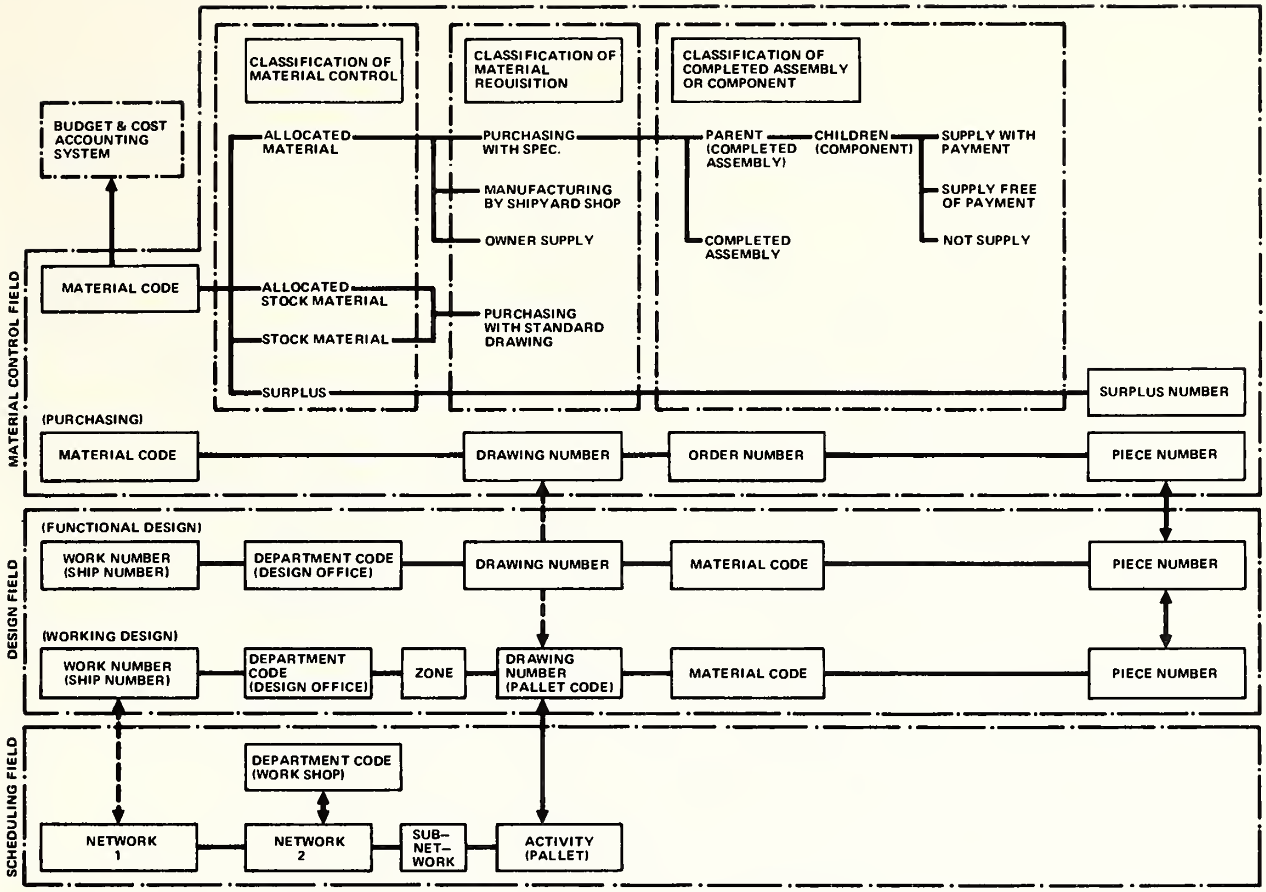


FIGURE A-2: Diagram of code system.

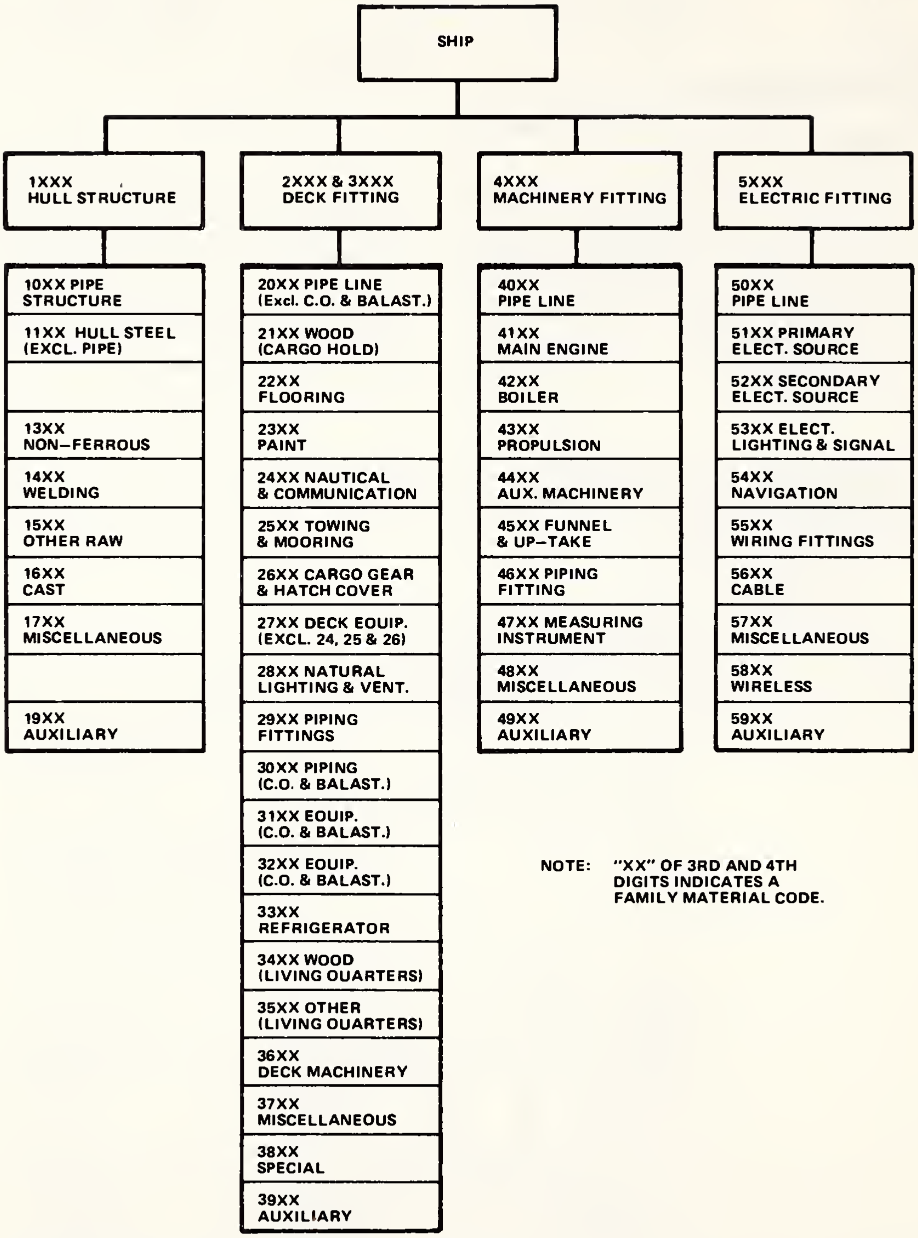


FIGURE A–3: Structure of material cost classification.

<table>
<tr><th rowspan="2"></th><th rowspan="2">W/S</th><th colspan="4">MATERIAL IDENTIFICATION</th><th>IDENTIFICATION ON SHIP</th></tr>
<tr><th>COMMONNESS</th><th>REQUISITION CLASSIFICATION</th><th>STANDARDIZATION</th><th>MATERIAL CODE</th><th>PIECE NUMBER</th></tr>
<tr><td rowspan="14">MATERIAL</td><td rowspan="4">HULL CONSTRUC–TION</td><td rowspan="3">STEEL MATERIAL SHIPBUILDING GRADE</td><td rowspan="3">AS</td><td>SKETCH SIZE</td><td rowspan="3">MATERIAL/GRADE/SIZE</td><td rowspan="4">SHIP/BLOCK/SUB–BLOCK/ SERIAL NUMBER</td></tr>
<tr><td>STANDARD WITHIN A SHIP</td></tr>
<tr><td>STANDARD</td></tr>
<tr><td>OTHER MATERIAL</td><td colspan="3">SAME AS FITTING</td></tr>
<tr><td rowspan="8">FITTING</td><td rowspan="4">COMMON</td><td rowspan="2">AS & S</td><td>INDIVIDUAL</td><td>BLANK/FULL DESCRIPTION</td><td rowspan="8">SHIP/SYSTEM/SERIAL NO.</td></tr>
<tr><td>FAMILY</td><td>NIL</td></tr>
<tr><td rowspan="2">A</td><td>INDIVIDUAL</td><td>BLANK/FULL DESCRIPTION</td></tr>
<tr><td>FAMILY</td><td>BLANK/FAMILY DESCRIP.</td></tr>
<tr><td rowspan="4">NON–COMMON</td><td rowspan="2">AS & S</td><td>INDIVIDUAL</td><td>SYSTEM/FULL DESCRIP.</td></tr>
<tr><td>FAMILY</td><td>NIL</td></tr>
<tr><td rowspan="2">A</td><td>INDIVIDUAL</td><td>SYSTEM/FULL DESCRIP.</td></tr>
<tr><td>FAMILY</td><td>SYSTEM/FAMILY DESCRIP.</td></tr>
</table>

A – ALLOCATED MATERIAL
AS – ALLOCATED STOCK MATERIAL
S – STOCK MATERIAL

FIGURE A-4: Identification codes for material.

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SHIP PRODUC
FACILITIES I
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INDUSTRIAL ENGINEERING
SHIPBUILDING S
DESIGN/PRODUCT
COMPUTER AIDS
SURFACE PREPARATI
ENVIRONME
TECHNOL
W
R