DESIGN FOR PRODUCTION MANUAL

VOLUME 3 OF 3

THE APPLICATION OF PRODUCTION ENGINEERING

FINAL REPORT

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MOORESTOWN, NEW JERSEY

DECEMBER 1985

A PROJECT OF

NATIONAL SHIPBUILDING RESEARCH PROGRAM

BY

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
SHIP PRODUCTION COMMITTEE PANEL SP-4
DESIGN PRODUCTION INTEGRATION

CONTRACT DTMA91-82-C-20018

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
DEC 1985	**N/A**	**-**

4. TITLE AND SUBTITLE
Design for Production Manual Volume 3 of 3 The Application of Production Engineering

5a. CONTRACT NUMBER
5b. GRANT NUMBER
5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

5d. PROJECT NUMBER
5e. TASK NUMBER
5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**331**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DISCLAIMER

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production information.

ENCLOSURE (1)

FOREWORD

This manual is the final report of a project managed and cost shared by Newport News Shipbuilding for the National Shipbuilding Research Program under Maritime Administration contract DTMA91-82-C-20018. The program is a cooperative effort of the Maritime Administration's Office of Advanced Ship Development and Technology and the United States shipbuilding industry. Industry direction was provided by the Society of Naval Architects and Marine Engineers' Ship Production Committee Panel SP-4, Design Production Integration.

Principle research was conducted by Bethlehem Steel Corporation, Sparrows Point Yard who enlisted the services of A&P Appledore Limited, Newcastle-upon-Tyne, UK and J. J. Henry Company, Incorporated of Moorestown, New Jersey.

Project development demanded industry participation to insure that the manual respond to a need, that potential users were identified and that basic manual coverage was defined. Formal questionnaires were used in the early stages supplemented by telephone contacts and twelve face-to-face follow up meetings on the east, west and gulf coasts. As the need, potential user and basic content were confirmed, it became apparent that, for best results, industry should be involved in determining the manual structure and content. This was accomplished via development workshops on the east and west coasts and in the Great Lakes area. Forty eight individuals from 20 organizations participated. Shipyards from large to small were represented as were design agents and the Maritime Administration. Finally, to avoid duplication of effort and to benefit from as many responsible sources of input as reasonably possible, liaison was established with the Society of Naval Architects and Marine Engineers' Ship Design Committee.

Care has been taken to blend the needs, wants and advice of many into an orderly and authoritative work on efficient ship design and production. It is intended that users take advantage of the loose leaf format to make the manual even more useful by expanding it with their own implementing procedures.

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VOLUME 3 - THE APPLICATION OF PRODUCTION ENGINEERING

SYNOPSIS

PART 1 - PRODUCTION ENGINEERING CONCEPTS

This Part of the manual describes a number of aspects of production engineering and examines the relationship and implications of production engineering on design, planning and other shipyard functions. Production engineering is an interface function which helps to transform design information into production information. Its overall objective is to create a set of balanced work packages which are matched to a production system so that cost, time and quality requirements can be met.

The importance of standardizing the approach to ship construction and the interim products from which a ship is made is emphasized. This allows attention to be focussed on the unique, non-standard features of any vessel. If the associated production processes are also standardized, the achievement of production engineering objectives is facilitated.

The way in which the development of standards can extend the application of Group Technology is also discussed. This allows much of the benefit of volume production to be applied to the generally small batch environment of a shipyard.

Finally, techniques of process analysis and spatial analysis are outlined.

PART 2 - SHIP GEOMETRY AND LAYOUT ENGINEERING

This part of the manual sets out guidelines for the ship designer in developing the structural arrangement of a vessel and in developing the layout of spaces in a vessel. It does not seek to demonstrate conventional design principles, but rather to supplement them. Various techniques are discussed and these can be applied at one or more of the design stages.

The most significant change in the design techniques is the use of spatial analysis. This develops a vessel as a series of functional spaces at the preliminary and contract stage, and only develops the detail of these spaces when the information is essential to verifying the design or preparing production information.

PART 3 - SHIPBUILDING POLICY

This part develops the framework for the shipbuilding policy which was established in Part 3 of Volume 1 of the manual. It puts forward some basic rules for the breakdown of the vessel into hull and outfit planning units and interim products. The hierarchy of steelwork and outfit interim products is identified and the relationship between interim products and production facilities is highlighted.

Later chapters identify production stages and their relationship to interim products, Finally, some basic rules and examples of identification coding are set out.

PART 4 DETAILED PRODUCTION ENGINEERTNG APPLICATIONS

This part of the manual is intended to illustrate how the methods which have been described in other parts can be applied. Because of the size of the topic it is not possible to cover the whole range of design for production activities. Therefore only a few relatively simple examples are given to illustrate the ideas.

Users may well wish to supplement these examples by additional material taken from their own experience.

The first three chapters show how the production engineering function might operate. A particular production problem is identified, various alternative solutions are developed and one is selected.

The fourth and fifth chapters give examples of how design alternatives can be developed, which satisfy production needs without any loss of ability to satify the functional requirements of a vessel.

A point to emphasise is that it is not always possible to give concrete examples of "good" and "bad" design. In all cases the particular circumstances of the interaction between design and production will dictate the best course of action in that case.

“The Design for Production Manual”

An Executive Summary

Many, many years ago, some wise caveman invented the wheel. It is more than likely that the first wheel was delivered late and over budget! Some things in the past millions of years have not changed. Maybe it is now time for change.

The manual that follows this summary is not a re-invention of the wheel. Some of the ideas presented herein may strike a familiar note as you read through the manual. The developers of the manual attempted to collect and assemble a multitude of ideas and techniques involved with shipbuilding; all having the common directive of Design/Production Integration. Their intent, however, was not only to collect these ideas but to also present them in such a manner as to assist you and your organization in a re-thinking process concerning shipbuilding design and production.

To this end, the writers want to emphasize that this manual is not a common cure for all of the U.S. Shipbuilding Industry’s woes. It is merely presented to you as, hopefully, the catalyst to initiate the required re-thinking process and to give some information to you concerning the most effective starting points as to where this re-thinking effort should be directed.

The most logical way to summarize a piece of work having the magnitude of the manual is to try to clearly define its title “Design for Production”. A possible definition of the manual and its objective could be “Designing to reduce production costs to a minimum, compatible with the requirements of the vessel to fulfill its intended function with acceptable reliability and efficiency”. It is readily ascertainable that this definition protects the interests of the shipowner but also states the desired interests of the shipbuilder. Historically, the shipowner was primarily interested in those aspects of his vessel that most affected his dollar. Items such as vessel speed, fuel consumption, cargo carrying and handling capabilities and mission requirements were paramount in the owner’s thinking. A private design agent would be hired to protect the owner’s interests as listed above and the design developed around these interests led to an expensive, difficult to build, but functionally correct vessel. By the time the shipbuilder received the design, he would find himself tied to a design, more often than not, totally unsuitable for the production personnel, techniques and facilities available at the building yard.

It is apparent, or it should definitely be apparent, that high productivity shipbuilding is critically dependent on the effectiveness of the relationship between the shipbuilder and the ship designer. Their intertwined efforts should constantly strive to optimize the design processes, planning processes, production techniques and facilities available.

Ever so slowly, the situation is changing. There have been advances in construction techniques and shipbuilding facilities have been modernized. However, vessels are still being designed that do not utilize effectively these new techniques and facilities. This is the underlying problem. The design function is still ignorant of the needs of production and the production function is not knowledgeable of the design process. Shipyards are designing vessels around the use of pre-outfitted modules but ignoring the building basin crane capacity to lift the completed modules. Units are being designed utilizing plates of a given length ignoring the fact that the panel shop can operate more efficiently using plates of another length. Both of these examples must sound very academic; however, as shipbuilders and designers, we know that these types of design problems do, in fact, take place in our shipbuilding world.

Again recalling the definition of "Design for Production" given earlier and realizing that problems as described in the previous paragraph do take place, we, as members of the domestic shipbuilding industry should remember that the uppermost objective of the shipbuilder should be ".... to reduce production costs ....". This is where our profits come from and also where they are lost.

The expansion of the design process to include a "Design for Production" function should have as its foremost objectives:

- To produce a design which represents an acceptable compromise between the needs of a shipowner and a shipbuilder. (Functionability versus Producibility)

- To produce a design which has features compatible with known characteristics of the shipyard's facilities. (Availability versus Producibility)

- To produce a design which facilitates the integration of the outfitting effort with the structural steel fabrication and assembly effort. (Integrability versus Producibility)

For all of this to work, the designer has to be familiar with production and the producer has to be familiar with the design function. To state the obvious, it will not be possible to achieve short delivery times and high productivity levels unless design and production work "hand in hand". After review of the manual, you will see that this idea is the common thread throughout the manual.

All U.S. shipyards are, in some fashion, moving along the Design/Production Integration Highway. Some have gone far and done well while others have stalled. The objective of the manual is to clearly show the way forward. The road is long and does have hazards but the final destination is clearly defined. That final goal is a vigorous and competitive U.S. Shipbuilding Industry.

VOLUME 3

THE APPLICATION OF PRODUCTION ENGINEERING

PART 1

PRODUCTION ENGINEERING CONCEPTS

3.1 PRODUCTION ENGINEERING CONCEPTS

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3.1.1 IMPLICATIONS FOR THE MAIN SHIPYARD FUNCTIONS

The adoption of a policy of design for production has implications for all of the shipyard's functions. It is not the purpose of this manual to examine these implications in detail and this chapter has been included purely as an introduction to some of the issues.

The chapter is principally concerned with the wider implications of design for production for those functions that will be most involved in its implementation. The chapter also covers product development and marketing, and personnel and organizational development.

CROSS-REFERENCES

1.1.4 Design/Production Integration

1.1.5 Design and Production Engineering

1.2.2 Basis for Shipbuilding Policy Development

1.2.3 Implementation of Shipbuilding Policy

2.1.2 Producibility Objectives

2.2 Ship Design Stages

2.3 Ship Production

2.4 Planning

3.1.2 Production Engineering Decisions

3.3 Shipbuilding Policy

3.1.1.1 Product Development

The main objective of a product development strategy is to develop desiqns which are both highly marketable and which-allow the lowest production cost to be achieved. The product development process may result in a standard desiqn, but is more likely to result in a family of related ship types.

For example, a shipyard might develop a family of bulk carriers with the same hull form, machinery and accommodation arrangement but with variations in the number of cargo holds. A similar approach may be adopted for other ship types - ro-ro, container, general cargo, etc. The aim is to have as much commonality as possible between designs within the family. Commonalitles can be generated across families, as in machinery and accommodation arrangements. The objective must be to reduce to the minimum the amount of original design work that needs to be done for any particular inquiry or new contract.

In order to achieve this objective, designs must fully reflect the tradinq and operatinq requirements of the shipowner and they must also include the producibility features which reflect the construction requirements of the shipbuilder,

Producibility features would concentrate on defining standard plate lengths, block breakdown and outfit assemblies and maximizing flat panel construction while minimizing curved shell . Each vessel in the product range would be analyzed to define similar structures and features so that a first attempt at a standardized approach to product development can be made.

Each company’s product development policy will, of course, be unique. It will be shaped according to particular shipbuilding ambitions and objectives with regard to product range, rate of output, facility development, build method and orqanization. However, the product development must allow a construction method which has the followinq characteristics.

i) The work breakdown structure is product oriented. The final product, the ship, is subdivided into a hierarchy of interim products, zones,plannina units and assemblies which are progressively, joined toqether, stage by stage, to make the finished product,.

This means that. any design prepared by or for the shipyard should reflect the hierarchy of interim products defined in the company shipbuilding policy.

ii) Work organization, working drawings and material control are correspondingly based on the same interim product hierarchy. The desiqn will be based on the interim products defined in the shipbuilding policy. The interim products are matched to the facilities and work stations available for their manufacture. Work station drawings will be prepared for each interim product.. Material control procedures will center on the need to bring packaqes of parts for an interim product to the riqht work station at the right time.

iii) Estimatinq and cost control are product oriented for labor and system oriented for materials.

Labor budgets can be prepared by usinq parametric estimatinq. The work quantity to be carried out at each department or work station will be estimated. The appropriate performance parameter, say, man hours per foot of joint lenqth, man hours per pipe, man hours per ton of pipe, is applied to the work quantity to give hours. Man hour costs can be monitored in the same way, by recording manhours to the work station and then plotting the performance aqainst the parametric value. Thus estimates and cost control are product and work station oriented.

For materials, initial estimates of quantities and costs are made system by system from the ship specification, which is itself system oriented. Material cost control would also be on a system basis.

iv) Planninq is simple and structured. Control is by planning unit/department at the higher level and by work packaqe/work station at the detail level.

v) Accuracy requirements are high, with many changes of responsibility between stages. Control is exercised by workers and foremen at each stage.

3.1.1.2 Marketing and sales

As a result of a well defined product development policy, potential clients will be offered ships from the product range, or options based on the product range.

Product pricing can be carried out quickly and easily and with a high degree of confidence because costs can be related to interim products.

Should an owner's requirements be outside the company's product range, then it will be readily possible to identify problem areas and their impact on the shipyard's facilities.

If, for example, an owner wished to increase the crew complement it may be necessary to increase the number of decks in the accommodation. This could affect the yard policy to lift the superstructure as a, complete, fully outfitted block. Alternatively, an owner may wish to change the position of the control room from the yard standard position. This could affect main cable ratings, the ability to manufacture the control room as one unit or the ability to install it in a block before erection.

Thrnuqh the application of the company shipbuilding policy with its inherent production engineering, improved work organization and technical information, build cycles will be reduced and improved delivery terms can be offered.

The development of a defined product range which reflects the company shipbuilding policy will allow the company's representatives to go out to sell ships which:

- Are well desiqned for performance and producibility.
- Have specifications for steel, outfit and equipment already prepared.

Can be priced with up to the minute equipment, material and labor costs.

Are well constructed to a hiqh standard.

With a developed and implemented shipbuilding policy, the marketinq and sales team will know how owner variations will affect cost and they know to what extent owner variations are goinq to affect build programs. They can therefore respond to requests for chanqe more quickly and with greater confidence. This confidence allows them to offer more competitive prices and delivery. The unknowns that must be covered by contingencies built into both cost estimates and delivery promises are substantially reduced.

3.1.1.3 Engineering

All departments within the shipyard exist to support the production effort. Design and drawing offices are of significant importance because so many of the early decisions they make irrevocably affect production activities.

Traditionally, designers and draftsmen have been used to produce plans which are, in effect, technical pictures instead of producing sets of working instructions. The need to provide specific work station information to be shop floor will only be achieved by a chanqe of procedure within the engineering department.

i) Desiqn Lead Time

The desiqn lead time is defined as the time between contract signing and the start of fabrication.

Many leading shipyards originally increased their design lead time in order to put more effort into production engineering detailed design and planning. This led to the greater development of design for production techniques and procedures. A short ship production cycle time itself requires a longer design lead time to carry out the necessary technical work to allow cycle times to be reduced. The overall delivery period has not, until relatively recently, been significantly shorter as a result. The extensive investment in design for production procedures has, however, now facilitated shorter design lead times without improved productivity being sacrificed.

Design for production is primarily concerned with two specific objectives:

- Designing work content out of the ship,
- Reducinq the construction cycle time.

If these two objectives can he achieved, further benefits will he obtained from better use of the working day and improvements in working Environment and quality of work. Better use of the working day will come from improved work flow as interim products related directly to workstations are incorporated in the design in increasinq numbers. Other benefits will derive from work being done in workshops in controlled conditions rather than on the berth.

ii) Implementing Design for Production Procedures

Many design for production procedures, particularly relating to qeometry and block breakdown, do not of themselves affect lead time significantly. It is possible to implement these aspects of design for producton even if the design lead time is short. Other procedures,particularly developing large outfit assembly techniques, require an investment in both time and manpower to realize the potential benefits. In these cases it will be necessary for each individual shipyard to review its position and define the extent of implementation.

Whatever the lead time, the implementation will in fact consist of two parallel and inter-related processes:

- Generalized experience and practice gained by systematically attempting to implement procedures by the ship designer on desiqns which are produced at the inquiry stage and may or may not be built. Experience can also be gained by looking at the published designs of overseas shipyards in the light of their production facilities. Visits by ship designers to the more productive yards should incorporate a study of the extent to which the suggestions made in this document have been adopted.

Specific experience from ships actually built by the yard. This is qained by following throuqh to the production staqe and comparinq achievement with the objectives set.

By consciously decidinq to implement design for production in this way and by involving the appropriate members of the technical., and management team, experience gained on specific contracts can be added to the qeneral body of experience. In the future, design decisions may be taken in a routine manner to combine the requirements of design for performance and production.

iii) Reducinq Design Lead Time

Methods of reducinq design lead time fall into two overlapping areas:

Techniques which themselves reduce tbe necessity for lead time. These are mainly concerned with the application of computer methods to the design development and production information processes. Applications cover not only naval architectural considerations but also steelwork, accommodation layout, pipework and electrical design.

Techniques which allow more extensive application of design for production procedures in the time available - however short. These are concerned with digesting the qeneral experience in applyinq procedures in design decisions. This process can be regarded as an extension of the approach to standardization in the yard. In particular, it will be vital to incorporate decision rules to define the most suitable block breakdown for the yard facilities, especially as far as the relationship to maximum plate-lenqth is concerned.

The need for desiqn 1ead time is a product of the level of technoloqy employed in the design process and the balance chosen within total contract period between design lead time and Production time.

iv) <u>Early Material Specification</u>

Shipbuilding differs from other manufacturing industries because, in order to achieve maximum productivity, most of the material requirements must be established before the design of the vessel is finished.

Shipyards in Japan and Europe which have recognized the need for the overlap between design and procurement are currently striving to become even more competitive by achieving greater overlap, even for a mix of ships being constructed simultaneously.

Their goal is to achieve perfect integration between design, material procurement and production.

Objectives of early material specification are:

- to ensure early ordering of all materials,
- to provide a parts database that will enable material control procedures to operate effectively,
- to provide a survey of work quantity to be used for broad estimates of manhour requirements.

The benefits to be gined may be summarized as follows:

- Materials are available in the yard when required in production.
- Materials can be organized to be in the right place at the right time, thus ensuring continuity of work, improved utilization of labor and hence improved productivity.
- It is possible to define work packages with a balanced work content that will enable more efficient use to be made of production resources.

In order to reduce the amount of design lead time required or, alternatively, to make the best use of the limited lead time available, it is essential to identify, specify and order material at the earliest time possible.

This is achieved by a hulk material take off carried out at the contract design stage. Where quantities are known or can be measured or calculated there is a reasonable degree of confidence about quantities. In the more uncertain areas an estimate must be made. As the design progresses through contract, transition and detail design levels more detailed and accurate information on material quantities will become available. Checks can be made between the aggregate requirements for any particular item and the bulk quantity ordered at the preliminary design stage. If quantities need to be modified then this information will be given to the purchasing department. In order to control the process this is an area ideally suited to the use of a computer system.

Material specification is concerned with the listing of materials and their attributes in order to provide information to the procurement and production administration systems.

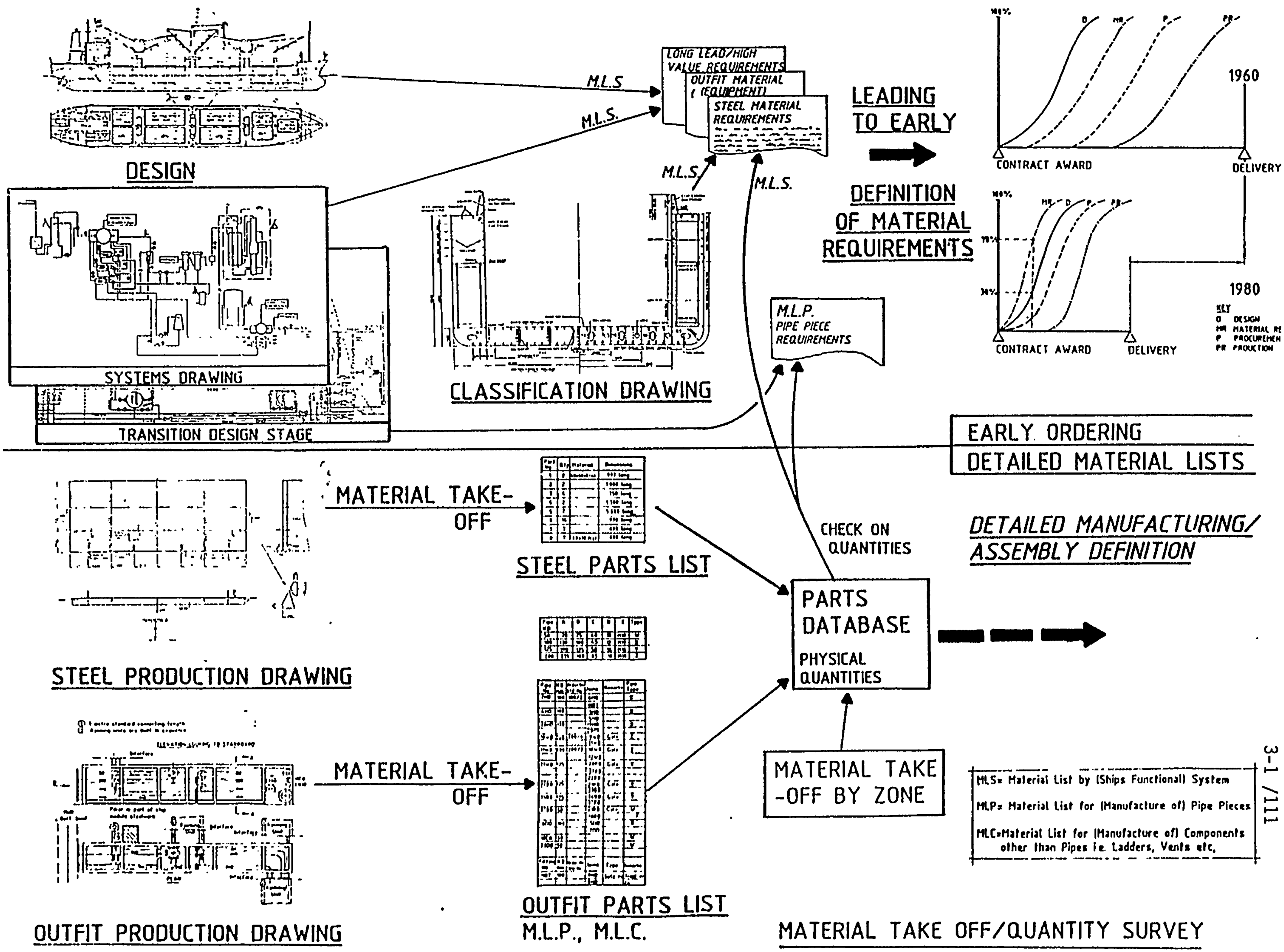
At the present time, material take-off procedures may operate at different levels of detail according to the status of the contract:

Long lead items are defined either pre-contract or early in the life of the contract.

Detailed material lists are prepared from production drawings.

It is important to bring forward the material take-off as early in the life of the contract as possible. To this end, purchase listings should be prepared direct from diagrammatics and classification drawings, making estimates of quantities to be refined later where necessary.y.

As precise data become available work packages of balanced work content can be defined. Work package material lists will then be used to coordinate and control the movement of materials on the shop floor.


DESIGN
M.L.S
M.L.S.
LONG LEAD/HIGH VALUE REQUIREMENTS
OUTFIT MATERIAL (EQUIPMENT)
STEEL MATERIAL REQUIREMENTS
M.L.S.
M.L.S.
LEADING TO EARLY
DEFINITION OF MATERIAL REQUIREMENTS
CONTRACT AWARD
DELIVERY
1960
CONTRACT AWARD
DELIVERY
1980
SYSTEMS DRAWING
TRANSITION DESIGN STAGE
CLASSIFICATION DRAWING
M.L.P.
PIPE PIECE REQUIREMENTS
EARLY ORDERING
DETAILED MATERIAL LISTS
MATERIAL TAKE-OFF
STEEL PARTS LIST
CHECK ON QUANTITIES
DETAILED MANUFACTURING/ ASSEMBLY DEFINITION
STEEL PRODUCTION DRAWING
PARTS DATABASE
PHYSICAL QUANTITIES
MATERIAL TAKE-OFF
MATERIAL TAKE -OFF BY ZONE
MLS= Material List by (Ships Functional) System
MLP= Material List for (Manufacture of) Pipe Pieces
MLC=Material List for (Manufacture of) Components other than Pipes i.e. Ladders, Vents etc.
OUTFIT PRODUCTION DRAWING
OUTFIT PARTS LIST
M.L.P., M.L.C.
MATERIAL TAKE OFF/QUANTITY SURVEY

It will be important that any material listing system have the ability to provide data sorted to suit user requirements:

by block
by zone
by work package

Since work content estimation is likely to be based on physical attributes of material, i.e., joint length, length or weight of pipe, paint area, etc., the potential for incorporating quantity surveying processes alongside material take-off needs to be realized.

v) Design Stages

There are five design stages. These stages give increasinqly detailed information and lead from a system orientation to a zone by area by stage orientation for production:

Conceptual design is the first stage of design where designers are working closely with sales and marketing function to identify marketable products for the company,or to respond to specific customer inquiries.

Contract design is system oriented and describes the ship as a total system which is ideal as far as estimating is concerned but, even at this stage, must consider design for production.

Functional design is a development of the systems to a point where bulk material purchase can be organized and purchase zones identified.

Transition design is the development of the design from a system to a zone orientation, During this transition the system diagrammatics are combined into single line composite arrangements which very effectively convey the layout and system/zone relationship to the detail designers.

Detail design is the development of the transition design. The detail designers refine the arrangements and incorporate stage definition as they produce work instructions, material lists and detail design drawings for fabrication and assembly.

To give further clarification of the transition design stage it is worth noting that the key is the production of single line composites. Normally, the composites will show all systems within each particular zone, with the systems being indicated as straight lines running im parallel and usually restricted to a plan view. Congested areas where necessary will be indicated in isometric fashion.

The production of the transition design is of immense value not only to the design department but also to the production, planning and purchasing functions.

vi) Ship Definition Policy

The Need for Change

In order to understand the need for change in the technical areas there are two fundamental ideas that must be established:

Modern shipbuilding practice is based on a consistent approach to the processes of assembly and requires that information corresponds with each stage in the assembly process.

Any vessel can be seen as an aggregation of a hierarchy of standards,of which the highest level possible is applied at each staqe.

Traditionally shipyard drawing offices developed the detail definition of a vessel by system - steel system, woodwork systems, pipe systems, electrical systems, etc. These drawings in terms of development, format and content were approval oriented and described what the finished vessel consisted of, not how it would be produced. The use of this type of drawing for production purposes in an industry which, in recent years, has changed its production methodology from being system oriented to being zone by stage oriented has dramatic effects. Firstly, it is impossible to achieve consistency in production because interpretation of the supplied information varies throughout the workforce. Secondly, establishing some function to ensure consistent interpretation, in terms of either another technical department or additional responsibilities being allocated to existing departments, is not a solution in that:

It increases the number of staff and consequently the overhead.

It increases the amount of duplication of information and consequently reduces the efficiency of the non-production departments,

Clearly what is required is a totally different ship definition policy.

Interfacing Organization and Systems

If a comprehensive ship definition policy is to be established a number of inter-related policies and procedures must also be in place. Without these, the effectiveness of the ship definition policy will be diluted or even completely negated:

A comprehensive shipbuilding policy.

Production work station definition together with the corresponding production engineering.

A comprehensive production control system in terms of planning, material control, work content estimation, manpower allocation and recording, etc.

The organizat on of the technical function into multi discipline groups dedicated to the definition of the vessel by zone and stage.

A coding system which will identify parts and assemblies either uniquely, or as a ship or yard standard.

A datum system with well defined application in detail design and production.

The inclusion of loft work as part of production information and its expansion to cover outfit.

General Criteria

In the development of a ship definition policy tbe following criteria must be applied:

Duplication of information and efforts to be avoided wherever possible.

production definition is to be developed as a hierarchy of spatial analysis and production engineering.

The format and content of drawings will be such as to promote the development and application of standards.

The production engineering function will be directed towards the identification of interim product families, their associated processes and production method development. This work is carried out for the total product range and the information is supplied to the technical function for application to future contracts.

The way in which these criteria can be met is discussed in Volume 2 of the manual where the operation of the technical function is described in detail.

3.1.1.4 Planning and Production Engineering

i) Shipbuilding Policy Development

The company shipbuilding policy sets out the ideal or optimum breakdown and build method for the ships in the company's product range. Its objective is to bring into balance the yard facilities and the ships to be built. Where imbalances occur this may lead to facility developments in order to ensure the optimum method can be used.

The objectives of developing a shipbuilding policy, which will be prepared and maintained by the production engineers at the strategic level are:

To define a work breakdown structure which is product oriented. The final product, the ship, is subdivided into a hierarchy of interim products which are progressively fabricated and assembled, stage by stage, to make the finished product..

To identify a work organization based on the same interim product hierarchy.

To define a planning system which is simple and structured. The basis for control is by planning unit and department at the higher level; by work package and work station at the detail level.

To prepare rationalized facilities data giving work station definition and capacity for the manufacture of interim products.

To systematically introduce Production engineering techniques which will significantly reduce cost.

To identify those areas of the production facilities that require development.

To develop construction and outfit philosophy for each type of vessel within the company product range.

ii) The Link between Technical and Production Functions

To achieve any production task effectively, it is necessary to make available to the production worker the relevant information needed to complete the assigned task. Traditionally, much of the cutfitting work in shipbuilding was accomplished on-board the vessel by installing the outfit materials into a series of compartments after the steel hull was built and launched. The installation team therefore solved many of the interface problems on site through direct communication and conflict. These workers were supplied with various forms of arrangement drawings which showed relationships between systems but not. always to a level of detail which fully defined the requirements. Often, drawings had to be interpreted and detail generated from the experience of the production worker.

lntegrated assembly requires similar tasks to be accomplished on structure which often has no identifiable physical relationship to a compartment. For example, Installing pipes and vent trunks on to a flat steel panel which may be any bulkhead, deck or deckhead within almost any space. The product of this effort is an advanced outfitted piece of structure. Without precise and adequate information about the "product", the production worker is in a dilemma whether to seek more information or guess without reference. The pressure under which he often works tends to make him take a chance. When advanced outfitted products are assembled or installed and misalignment or interference occurs, it can often be related to poor information. Many attempts at integrated assembly have failed or have had limited success due to engineering information being used which is system rather than zone oriented and therefore not well related to the way in which the work was to be done.

Developments in the shipbuilding industry over the years have arrived at a situation where craft workers commonly produce their own detailed information. Examples of this are the loft, pipe sketchers and sheet metal development. For manufactured components, these craft workers produce their own information as a development of engineering information.

The development of computing applications has been far reaching in steelwork, to the degree where almost any structural component is now defined mathematically, and manufacturing information is a product of the system in the form of tape, drawing, code sheet, etc, or may be by direct link between computer and machine.

The greater proportion of the production work associated with shipbuilding is in the assembly areas. Advanced outfitting techniques recognize this and are aimed at organizing this work through a Planned relationship of integrated products. The physical relationship between integrated products can only be controlled by adequate engineering information.

Given that control can be established over the design process, concentration must be directed to the identification of products and the establishment of the factors such as planning, material control and work station organization as required to support integrated assembly. The engineering contribution to this is clearly to produce information relevant to these products and processes in accordance with the planned phases of construction.

The build strategy outlines the erection sequence. The erection schedule is produced from resource analysis and smoothing of the basic sequence. The erection schedule is the core of the program and all other activities are related to it. Consequently, the erection schedule must be adhered to if the ship is to be delivered as planned.

It follows that each unit must be available, fully fabricated and pre-outfitted, in time for its scheduled erection. It equally follows that every sub-assembly, minor assembly, piece part and plate or shape must be available for the succeeding process. Thus planning becomes a back-scheduling exercise from the erection date. The back-scheduling process is based on planning units. A subnetwork is developed for each planning unit setting out the activities to be carried out to complete work on the planning unit. If the end date for the planning unit is known from the erection schedule then dates for all preceding activities can be calculated.

Obviously, the technique can be used to establish when technical information is required by production amd ultimately when the production of such information must start.

3.1.1.5 The Production Engineering Function

The decisions shout what. is the best way to build a ship are many and complex, and production engineerOng contributes to the decision making process.

The definition of what constitutes "the best" is in itself a complex set of trade-offs between often mutually exclusive criteria. For example, reductions in steelwork assembly cost can sometimes be achieved only at the expense of increased steel weight.

For every ship that is built, therefore, some production engineering must have been carried out. This is true even if the evaluation of the "best" may to build the ship is left to a craft foreman just before a production task takes place.

In recent years the range of ship types has increased significantly and the complexity of shipboard installations has increased dramatically. Concurrently there has been a move towards reducing the skill content of many tasks. In these circumstances it is no longer practical to rely solely on the experience based skills of craftsmen.

It has become necessary to develop more formalized processes for applying production engineering.

i) Objectives of Production Engineering

To assist. production departments to achieve or improve upon targets and goals set out in the shipbuilding policy.

To order and control decisions which will affect manufacturing and assembly processes.

To monitor production technology developments in the industry.

To identify opportunities and submit proposals for cost and time reductions in production processes.

By definition it can he seen that production engineering is the function which builds bridges between departmental structures although production engineering itself may not necessarily exist as an identifiable department.

For the objectives of production engineering to be achieved, the Scope of the function must range across many departments and disciplines and, to be fully effective, will require the application of a wide variety of skills. The rationale for applying these skills so widely is to keep production costs to a practical minimum.

ii) Production Engineering Applications

When production engineering techniques are applied during the design development stage, a different approach is required from that which faces the. production engineer with a preconceived design with no consideration having been given to producibility. The main difference is that in one situation there is no calculation of saving; the design is engineered by the application of techniques to be low cost. In the other situation, design changes have to be engineered which will produce a cost benefit; otherwise there is no reason for changing the design. In the second case therefore, the amount of savings to be accrued is a function of how bad the original design is from the producibility standpoint. The principal difference between these two approaches is the cost to engineering departments of work associated with redesign.

Production engineering may be an implicit or an explicit function. That is to say, it can be incorporated into the general engineering process, or, design work may be reviewed by a separately created function. As an implicit. function it is most cost. effective, but this requires that design engineers have the knowledge and ability to make decisions relating to production techniques, practices and conditions. Conversely, if production engineering is an explicit function, it has to be assumed that the production engineer will have design and production knowledge and experience, and has the ability to mediate between the functional requirements and the production requirements of the design. In either case, the implications of production engineering can impact on shipyard operational costs, direct and indirect contract costs, capital expenditure, labor practices and therefore profit.

By building up data related to production actvities, it is possible to lay out a set of standard references which can be used by designers and production engineers. Such documentation will include data on:

facility capability
work station operations
product range
production phases
working practices
subcontract policy
standards
build policy

All of this documentation must be input to the technical department.

iii) Input to Work Station Drawings

Work stations for manufacturing purposes have existed in shipbuilding for many years but, because they were not linked by conveyors, the question of balancing the workload at each work station was not so critical as with interlinked equipment.

The introduction of linked and highly specialized production equipment into steelwork manufacture has promoted investigation on how to ensure maximum production from the machines. One approach has been to reduce tbe level of responsibility of the equipment operators by reducing or limiting the choice of how to produce the finished steel unit..

This approach has the effect of removing from the shop floor the decision on how a unit. will be built. In conjunction with this, the information presented to each operator has been simplified and presented in a clearer fashion to minimize the amount of time required to interpret, traditional drawing information and to reduce the possibility of error.

iv) Steelwork Work Station Drawings

The drawing presentation delivered to the production department from the drawing office should meet the demands which the workshops require in order to carry out rational production.

When all the working procedures are known and are being planned at the same time as the work station drawings are being prepared, the opportunity is provided of adhering to a standard format of the work station drawing so that satisfactory drawings can be given to the planning department and to the workshops.

A process work station drawing system should include the following characteristics as appropriate for either assembly or preparation processes:

Drawing divided into process phases.

Working side shown, i.e., the drawing is prepared such that the man on the shop floor does not have to do a mental transposition of information. A marking drawing should be drawn so that as the marker stands on the plate(s), panel(s), deckhead(s) the drawing shows the item as he sees it. It is often the case that in order to mark off deckhead outfit, the marker is given a drawing drawn looking through the deck from above, with the items under (those he is trying to mark off) shown dotted. If he is to mark the deckhead while it is upside down in the ship, this is the way the drawing should appear.

Production measurements indicated from datum lines.

Edge preparation symbols shown.

Cutting processes indicated.

Piece part numbering and route coding indicated.

Joint length and cutting lengths indicated.

Isometric assembly and assembly/parts coding specific to the production stage.

Fairing descriptions and methods.

Welding sequences and welding particulars given.

Dimensional accuracy checks.

Material collection instructions.

Machine setting,parts identification, material utilization.

Planned load and NC tape information.

Cutting information: length, speed and time.

Raw plate information.

v) Outfit Work Station Drawings

Areas of outfitting work can be treated in the same way as steel unit construction in that a collection of work station drawings can be produced for an equipment module or outfit assembly.

At the design development stage, the contents or appendages of each unit or block can be identified and drawings produced showing the items and processes involved. This will apply to steel units or outfit modules independent of, as well as dependent upon, the structural units. For example, to construct a free-standing machinery space floor plate module incorporating pipes, valves and minor steelwork, a process work station drawing would be required to contain the following information:

Drawing giving an overall view of the unit with assembly stages illustrated where necessary, suitably dimensioned.

Assembly instructions.

Raw material lists with cutting lengths given for minor steelwork.

Pipe list and sketches.

Stock standard items list.

Vendor furnished items list.

Fabrication details and details of any special fixings to be manufactured in-house.

As can be seen, the process is similar to that for steelwork but will cover a wider range of material including vendor furnished items. This feature will create a need for very close liaison between the purchasing, planning and the engineering departments. Information from suppliers must be received at the earliest possible time to ensure that dimensions and weights are available to be incorporated in the work station drawing.

vi) Technical Information for Work Packages

In order to plan, control and monitor production work effectively, the work is best broken down into a number of discrete work packages, where each work package will define a specific amount of work to be done at a particular stage of production. Ideally, each work package should be defined so as to have a time span of one or two weeks. If the time span is longer, control and monitoring becomes less effective. A shorter time span will lead to a larger number of work packages and possibly too much data.

Work packages will initially be generated from the process analysis carried out by production engineers at the tactical level. The object is to produce a coordinated and integrated technical information package for each work package, containing only the information required at that particular stage in the production process. Work packages will be prepared for every stage in production right through to ship completion.

Technical information for each work package will be provided in the form of work station instruction drawings, prepared from drawings submitted for approval to the regulatory bodies. Drawings will depict appropriate assembly processes and be produced preferably on standard 8½ x 11 and 11 x 17 sheet sizes. One sheet for each trade, may be required. All information must be concise and unambiguous.

The following information should be included on or with each work station drawing:

- Flow Process of Material diagrammatically showing the assembly sequence of the various interim products and piece parts for the appropriate production stage.

- Dimensional Data, identification of the critical dimensions required for interfacing with the subsequent production stages. All dimensions measured from datum lines.
- Drawings of the Interim Product, in isometric projection and showing the level of completion at that stage in Production. Dimensions to locate steel and, where appropriate, outfit parts, will be measured from datum limes. Parts coding will refer specifically to the production stage.
- Work Station Arrangement, showing the orientation of the assembly in the work station for handling and movement to subsequent stages.
- Production Methods, describing the assembly sequence, fairing methods and welding processes to be used together with work content. Lifting lug arrangements and turninc arrangements will also be defined.
- Material Collection, Information will completely define a list of interim products and parts required at, the work station for the production stage.

vii) Standards

The aim in preparing standards is to:

reduce variety.
ensure suitability for purpose.

The benefits that are looked for will differ in emphasis according to the nature of what is being standardized.

The first aim, reduction of variety, is pursued primarily for economic reasons. to reduce the costs of design, manufacture and maintenance. For example, a range of standard designs, once available, reduces or eliminates the need for further design work during the life of the standard. Manufacturing costs can be reduced by concentration on a range of standard products. The benefits resulting from series production can become very substantial as the scale of production increases and the use of special-purpose jigs and tools, flow line production, etc. is implemented.

The second **aim,** fitness for purpose, includes factors such as functional suitability, safety, cost effectiveness, reliability maintainability and quality assurance.

If shipyards use vendor standards, or work with vendors to define a standard range, then there are benefits for the vendors, shipyard and the shipowner:

The vendor is able to streamline his production system, and simplify material ordering and material control on the shop floor. All of which mean shorter lead times and keener prices.

The shipyard has the benefit of more competitive prices and shorter delivery periods.

The shipowner is buying a standard proven item. His requirement to hold spares may also be reduced.

There are four ways in which standards may be implemented.

Performance Standards. These specify overall performance to be achieved, without defining the design in detail. They are particularly valuable for assemblies of equipment in that:

they give maximum freedom to the designer, and

they allow the user to make direct comparisons of fitness for purpose.

Envelope Standards. These specify sufficient overal1 dimensions (the “envelope”) to ensure interchangeability.

Fully Detailed or Product Standards. These contain all the information necessary to manufacture an item.

Application Standards. Provide guidance on the suitability of different equipment or materials for specific uses.

Table 1 shows the hierarchy of standards used within a typical sophisticated shipyard. Essentially, the basic standards must be strictly observed by all concerned. The standard drawinqs serve as basic guidance plans, allowing some flexibility for individual requirements.

Material standards prescribe the size and scantlings of elementary materials, such as steel plates, sections, pipes, etc, and also include scantlings and configuration of individual fitting pipe pieces, vents, moorings, doors, ladders, etc, which form the basis of design standards.

Design standards prescribe the design philosophy criteria, specifications and applications of various structures and systems, and include some basic modules.

Production engineering standards prescribe the methods and criteria of quality control and procedures of testing and inspection.

Standards drawings consist of standard equipment layouts of system modules, practices and manuals, etc., which can be utilized as quidance plans.

These standards are controlled and updated by special groups in the shipbuilding headquarters and local shipyard design departments. Updating is mainly based on feedback from actual ship operations and from production lines. The number of standards is kept to a minimum by identifying and cancelling those which are obsolete or not worth keeping. The approximate number of those adopted might be as shown in Table ?.

Table 1

CLASSIFICATION OF SHIPBUILDING STANDARDS

BS (Basic Standards)	SO (Material Standards)	Raw Material Basic Components Standard Fittings Standard Units
	sol (Engineering Standards)	Design Standards Methods Standards Inspection Standards
SD (Standard Drawings)	SD1 Machinery Standard Drawing SD2 Practice Drawing SD3 Components & Fitting Standard Drawing SD4 Standard Diagrams SD5 Design Manuals SD6 Production Manuals	

Table 2

NUMBER OF STANDARDS IN CURRENT PRACTICE

Classification of Standards			
	Material Standards	Common Components	600
		Hull Fittings	600
		Machinery Fittings	200
		Electric Fittings	200
	Sub-total		1,600
SOT	Design Standards		1,100
	Production Engineering Standards		100
	Inspection Standards		200
	Sub-total		1,400
SP	Machinery Drawings		1,200
	Component and Fitting, Standard Drawings		350
	Other Guidance Drawings		350
	Sub-total		1,900
GRAND TOTAL			4,900

3.1.1.6 Production Technology

To support the new shipbuilding policy, it is important to ensure that the equipment and procedures available within each work area are clearly defined and documented and are appropriate to the levels of technology required to be applied during the manufacturing and assembly process.

A considerable number of work areas in shipyards are operated on a jobbing basis, where each job is treated as a single item of work to be completed by one or more craftsmen. In such cases, the actual work processes are determined by craftsmen based on their idea of how the job should be done. The result is that methods applied in doing similar jobs may differ, technology employed will depend on technology locally available, and the necessity for versatile and multi-skilled craftsmen will be high.

As a result of the definition of interim products and work stations the current levels of technology **employed** for the assembly and manufacturing processes need to be reviewed to see whether or not they are appropriate for the volume and quantity of products associated with the work stations.

In order to define the technology to be used,it will be necessary to consider the product, craft skills, machinery and equipment, jigs and fairing aids, and work area allocated to producing the product.

It is probable that most work stations will have suitable technology available to perform their allocated tasks, while others will require improvements to be made. Changes in technology do not necessarily mean expensive, new equipment. Localized facility improvements such as tooling fairing aids, jigs and fixtures and improvements to methods and processes are relatively inexpensive and can be implemented very quickly.

3.1 .1. 7 Personnel Training and Organizational Development

This element. of the shipbuilding policy cannot exist by itself. It is totally dependent upon and interrelated with the other elements. Those elements are concerned with bringing about changes in techniques, methods, facilities and organization of work. Training and organizational development is concerned about developing skills. knowledge and attitudes in order to implement the changes required.

The major objectives are:

To identify the training needs of individuals and groups of individuals that relate to the new approach. That is to identify what needs to be known, what is known, and what is the gap to be filled.

To satisfy the training needs by the provision of the relevant training, education and experience.

To maximize the involvement, participation and decision making of managers in the belief that the best training is by doing.

To evaluate and monitor the progress and performance of the training and the participants.

The major benefits are:

A structured and rational approach to development of managers in the short term.

A management team that is provided with the skills and knowledge required to implement. the necessary changes.

ln the long term the formulation of a consistent approach to management. development.

In order to ensure that the new technology is successfully introduced, it is important that all those involved with the implementation should understand fully its concepts, techniques and skill requirements. Presentations in the yard must be linked with implementation and must provide individuals with opportunity to make their own contribution to development and improvement in performance. The priorities will vary from yard to yard. The introduction of new technology and changes will impact upon existing organization structures. Changes required will need to be identified and detailed.

i) Training Needs

In order to identify the priority training needs, it is necessary to decide the priority and timing of the implementation of the various elements of technology. Which of the elements should be chosen as the lead element for the yard? In what form does the training need manifest itself - lack of skills, knowledge, changes in attitude, organization?

How can the need be best fulfilled? Is there a course available and is this the most appropriate vehicle? Is involvement in a "project" more relevant? Is there a project? How can it be structured to suit the training requirements?

Which managers require the training? Why do they require it?

Are the skills and knowldge a prerequisite to implementation?

What is the best environment for the training? Does it affect one function, or is it multi-function - design, production, planninq, etc? Are the skills and knowledge transferable across the corporation?

Training plans would consist of:

- Brief statement of training need.
- Method of fulfilling need - course and project.
- Participants.
- When and duration - does it fit the logic of an action plan.
- Method of evaluation and monitoring.

iii) Evaluation

The training activity must be linked to action and change and to the monitoring process and procedures and must be built around answering the following:

- What changes in technique, procedure, method were envisioned?
- Have they been achieved?
- If not, what obstacles to achieving the goals were found?
- How can they be removed?
- What contribution has the individual manager made to the change?
- Is there any further formal training requirement to increase his level of performance?
- Are those involved in the current organization structure to carry out this work on a long term basis?

iii) Organization for Change

Changes in technology would be achieved by carrying out a number of related projects. It is envisioned that each project, would be the **responsibilityv** of a nominated manager. Such a manager would be responsible for all aspects of the project, including the training requirements. This is in accord with the view that training and management development is the manager's responsibility and not that of a training department. The latter is there to provide specialist assistance and administration.

The Project Manager would be responsible for:

Delegation to his managers for sub-elements of the project.
Setting targets for managers.
Review of the targets.
Helping with identification of training needs.

IV) The Pole of the Supervisor

Some yards have had area supervision for some time while others have not. However, suppervisors will be required to change in a number of ways.

They will have to supervise a group of trades on a work station/zone basis rather than one trade on a wider basis. Not only will the supervisors be expected to supervise the quality, methods and pace of work of a variety of trades, they will also be responsible for the totality of the production of products of the work stations under their control. This implies a greater responsibility and accontability than may have been the case in the past.

Surpervisors are crucial to the achievement of change. While all levels of management will require training in new technology supervisors are a particularly important group.

At the same time a greater responsibility for quality control will be put on to production personnel, through “self-checking” systems. Supervisors will have a prominent role in implementing these systems.

Work stations will be the basis for feedback of the information needed by management for control and improvement of the production process. Typical of the information will be that needed for labor cost control, which requires accurate allocation of time and for accuracy control , which requires (for the purposes of statistical analysis) feedback of actual dimensions achieved. Supervisors will have an important role in collecting and reporting such information.

The role and status of supervisors will be ”significantly enhanced by the above changes. However, supervisors will be required to acquire new skills in the following areas:

Expertise in trades other than their own.
Expertise in “supervision”.
Expertise in “planning and organization”.
Appreciation of the principles of accuracy control.
Application of quality control systems.
Application of health and safety requirements.

Assistance must be given to supervisors both in the form of training and in improved service to the work stations from the other shipyard departments, such as engineering and planning. The supervisor’s position. will also he made easier by a clearer definition of the role and responsibilities of production managers, who are faced with a similar degree of change in their traditional roles,

3.1.1.8 Time Registration and Cost Control

The accuracy of data collected on the shop floor and its processing to provide management. information is vital to the successful operation of the company. If the information is to be of value then great care must be taken to ensure the codes against which data are collected will enable relevant information to be prepared.

The objectives of the system are to ensure that management know the hours that have been worked and the progress that has been achieved for those hours. It must. also he possible to make confident. projections of the cost to completion.

The time registration system has two aspects:

First a set of codes that allow data to be recorded on the shop floor against work packages. This is necessary because the work package will become the basis for the control and coordination of work. Data collected by work package must then be transformed to provide data against system to tie in with estimating procedures.

Second, a means of physically collecting the data. Problems such as who should collect the data, what medium should be used (job cards, daily labor returns or electronic systems, etc.) and how the data is to be entered to a computer system for job costing and payroll procedures, need to be addressed.

It is vital that accurate data are collected if management are to obtain reliahle information on current status and forecast of cost to completion. The best way of achieving accurate forecasting is to estimate, record and analyze manhours against relatively small work packages (for example, 500-1,000 manhours).

Time recording is concerned with the collection of attendance hours for each employee. There are a variety of methods which can be considered:

- Clock cards.
- A manually written time card,
- A simple tally system.
- Magnetic badge readers - which may be connected directly to a computer system.

All of these systems are being used within the industry.

Manhour recording is the collection of hours against individual jobs. The options include:

- Job cards, where hours are recorded by the man and initialed by the foreman.
- Labor returns prepared by the foreman.
- Badge or card readers located on the shop floor linked directly to the computer.

Whatever method is used to collect hours against jobs, the system must be set up so that codes entered to the computer are checked on entry and invalid codes rejected.

The first step in the reconciliation of hours is to check that time recorded hours and hours worked per man as obtained from the manhour recording system are the same.

Currently, relatively few yards record hours against work packages and those who do often record against very large work packages. This results in poor cost return data and makes cost estimating for future projects difficult.

In the longer term, it is anticipated that hours will be recorded against a well structured work package code. The means to provide information for job costing must be established. Job costing will be carried out on the basis of ship systems which reflect the structure of the ship specification and the estimate. The split across ship systems where work packages include work on more than one system will be achieved by dividing the hours worked on the work package across the systems in the ratio of the calculated work content for each system.

A major decision to be made is how often hours should be recorded and submitted for entry to the computer system. There needs to be a balance between two conflicting requirements:

The need to be able to obtain information quickly. This would indicate a daily return and an increase in the number of codes to be entered.

The need to reduce the number of codes to be entered. This would indicate a weekly return, meaning that data may be outdated before it is available.

It is vital that the data recorded is as accurate as possible. One way to achieve this is to simplify the code structure against which hours are recorded. The second must be to impress on the supervisors the need for accurate data and his role in obtaining it. The data should always be checked and initialed by him before it is entered to a cost control system.

It will clearly be essential to define in detail the outputs required, before methods of recording data, the code systems used and the method of processing data are defined. Consideration must be given to the possibilities of providing on-line inquiry in order to reduce the volume of paper work generated.

The labor cost control system must be designed to provide each supervisor and manager with the information he requires in an appropriate format. The information should define the hours worked against budget or target and form the basis for a forecast of cost to completion.

3.1.2 PRODUCTION ENGINEERING DECISIONS

This chapter sets out the scope of production engineering activity. The relationships between the production enqineering, design and planning functions are described.

CROSS REFERENCES

1.2 Shipbuilding Policy Development

2.1.7 The Need to Document Facility Capability and Constraints

2.1.8 The Need to Document. Production Process and Method Information

2.1.9 Communication between Design and Production

2.2 Ship Design Stages

2.4 Planning

3.1.6 Process and Spatial Analysis

3.3 Shipbuilding Policy

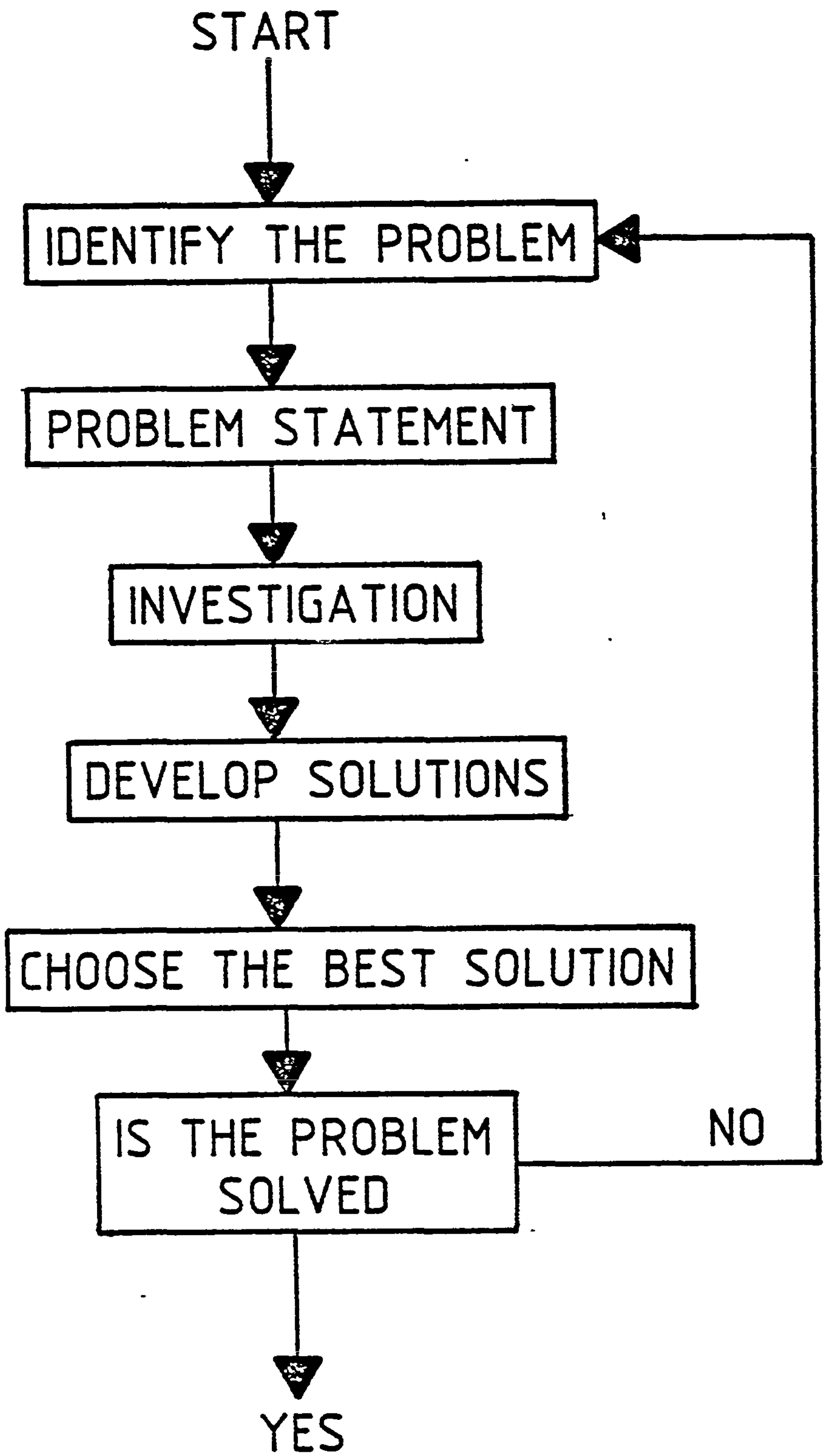
3.1.2.1 Definitions

Production engineering is a function which is concerned with the transformation of a saleable design into a physical product. It acts as a bridge between design, as specifiers of a product and production and as producers of that product. It also interfaces with the planning function.

Production engineering can be defined as engineering the shipyard's production system to make specified products to time, quality and cost requirements.

Production enqineers adopt a structured approach to the questions of problem definition and analysis as shown in the flow chart Fig 3-1/203. Consideration of the analysis will lead to the development and evaluation of potential solutions and finally the selection of the preferred solution.

before discussing the scope of production engineering and the activities to be carried out it is necessary to define the term planning unit. Planning units are the control entity around which production engineering and planning work is organized. Typically two similar blocks port and starboard; an outfit block which is an aggregation of outfit, assemblies; a zone on-board the ship.


START
IDENTIFY THE PROBLEM
PROBLEM STATEMENT
INVESTIGATION
DEVELOP SOLUTIONS
CHOOSE THE BEST SOLUTION
IS THE PROBLEM SOLVED
NO
YES

3.1.2.2 Objectives

A major objective of the production engineering function is to assist with the development and maintainance of the company shipbuilding policy. The figure page 3-1/205 shows the overall relationship between design, production, planning and production engineering. In achieving the objective of defining the company shipbuilding policy, production engineers must draw together and balance the requirements of the other three functions in a way that allows the overall corporate objectives to be met.

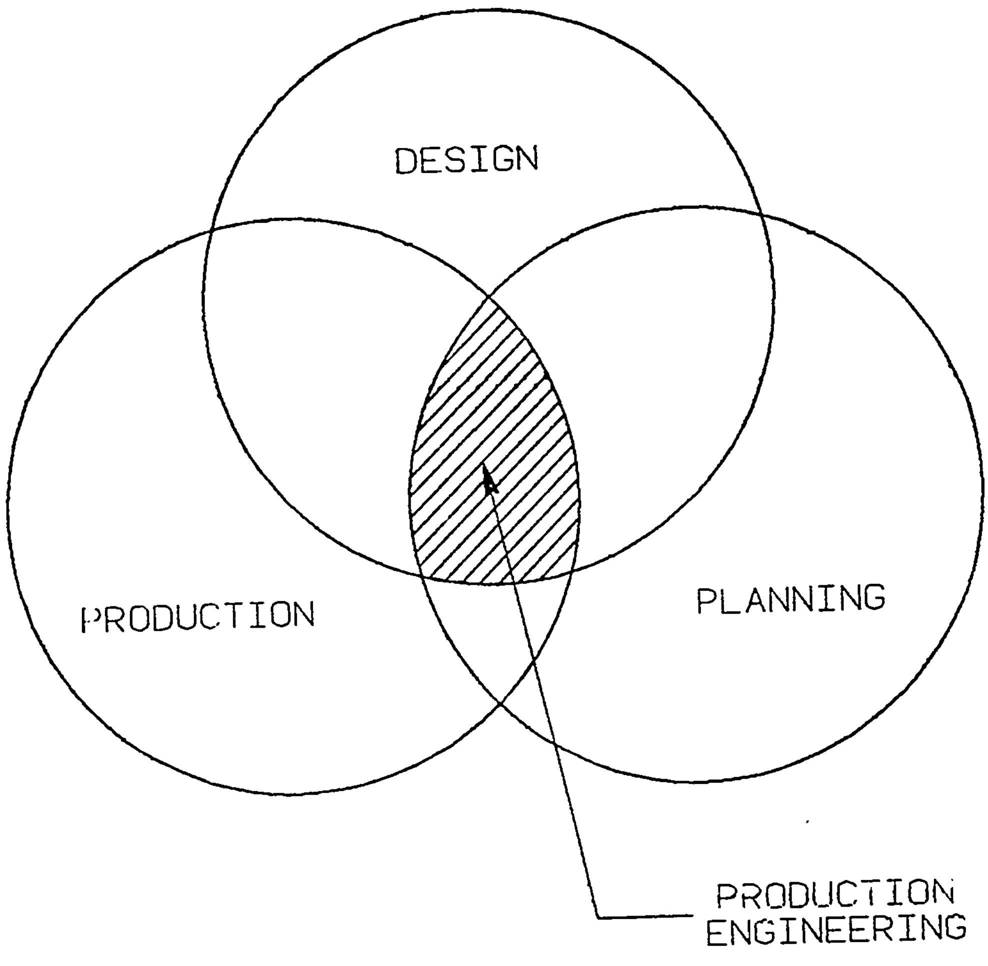
In the particular context of design for production, the objectives of the production engineering function must be to ensure that the structure and outfit of the ship are designed so as to be produced with the minimum possible manhours while achieving all mission requirements. As important as minimizing manhours is the achievement of target dates. Production engineers must consider how the design should be developed in order to achieve timely production. Production engineers must be involved in the decisions on block breakdown and the machinery arrangement, and all other design features that affect producibility. Following contract signing their responsibilities will be to define:

What work has to be done - the division of the ship into a hierarchy of interim products, ideally based on a clearly defined range of standard interim products, and a standard approach to the build strategy for any given ship type. The standard interim product definitions will be held in the company shipbuilding policy.

Where work has to be done - the identification of the work stations for manufacturing and of the work packages for installation.

How work has to be done - the definition of the processes and principal sequence of events to be carried out in the completion of a work package.

The objective of the production engineering function is to ensure that balanced work packages are defined. This will lead to better organization of work on the shop floor, a higher utilization of labor and facilities, in particular process lanes or on-flow areas, and hence improved productivity.


DESIGN
PRODUCTION
PLANNING
PRODUCTION
ENGINEERING

3. 1.2.3 Scope

The object of production engineering throughout the pre-production stages should be to apply the principles of:

Standardization
Simplification
Specialization

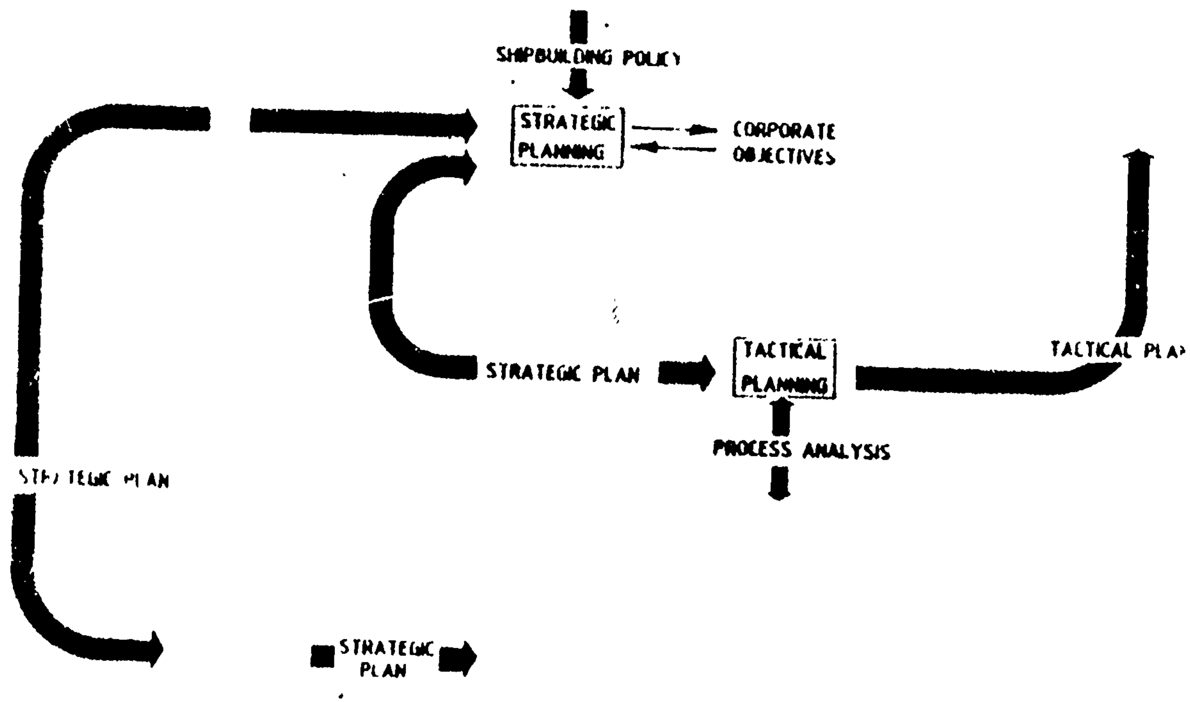
arg to develop the breakdown of the ship structure in order to maximize the production of similar structural components, assemblies and blocks in both steel and outfit. Production engineering covers the detailed examination of the ship from a production and facilities point of view, from the initial design stages through all staqes of the preparation of technical information.

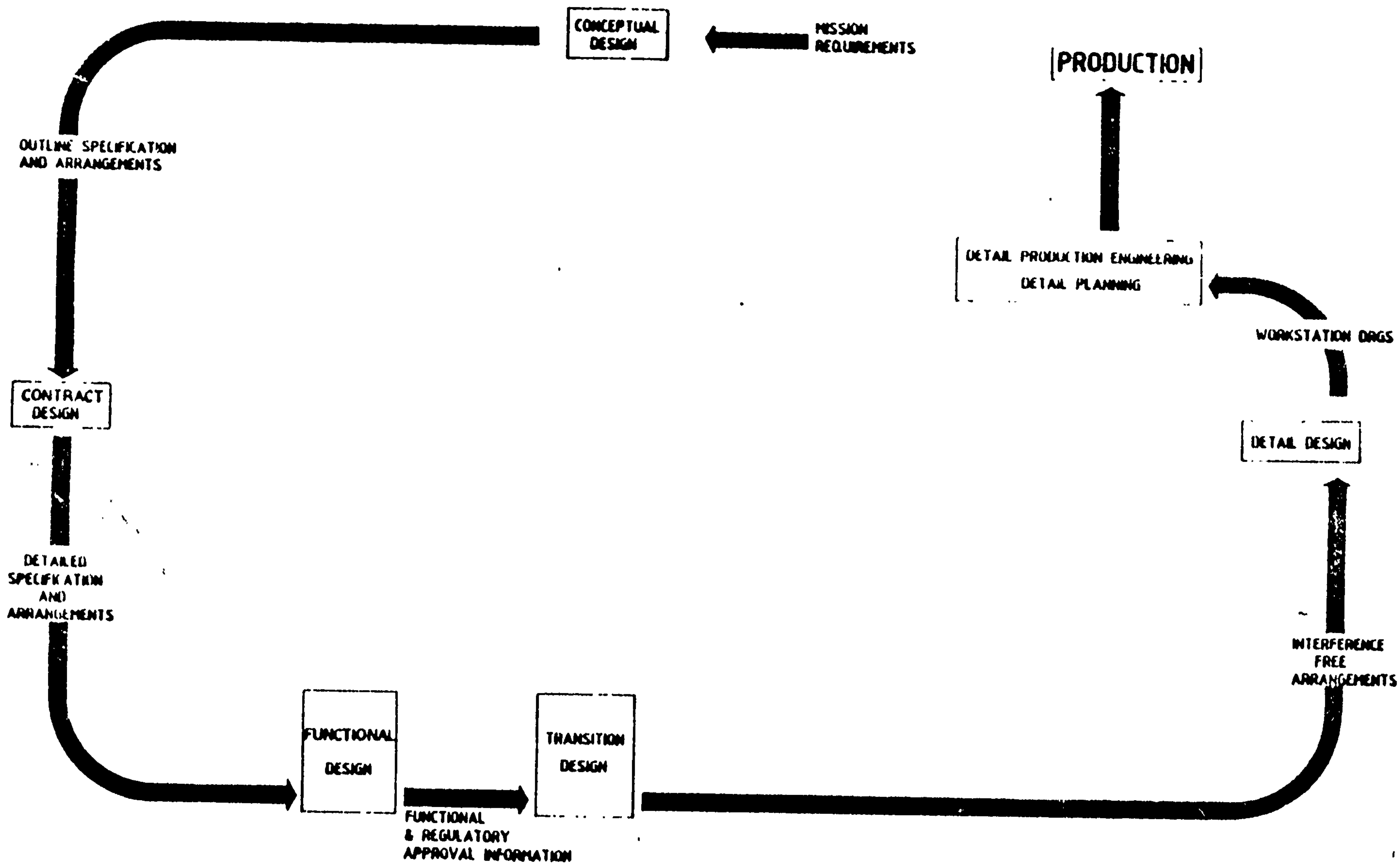
Production engineering operates on the same three levels as planning strategic or long term, tactical or medium term and detail or short term. These three levels correspond to the five design levels as shown in the figure page 3-1/207. The outputs of production engineering at the strategic level feed into conceptual and contract desiqn; outputs at the tactical level feed into functional,transition and detail design; outputs at the detail level feed into detail design and production and back into production engineering itself so that experience gained on the shop floor can and does bring about improvement in future designs.

The tasks to be carried out at the strategic production engineering level are concerned with the preparation and maintenance of the company shipbuilding policy. (Volume 1, Part 2)

The tasks to be performed at the tactical production engineering level are:

Work with the design function at the functional and transition design stages to determine the detailed breakdown of the ship into interim products based on the company shipbuilding policy and the preliminary design drawings and the build strategy document. The end product will be a list of interim products and a diagram showing the build up of the planning unit through each production stage.

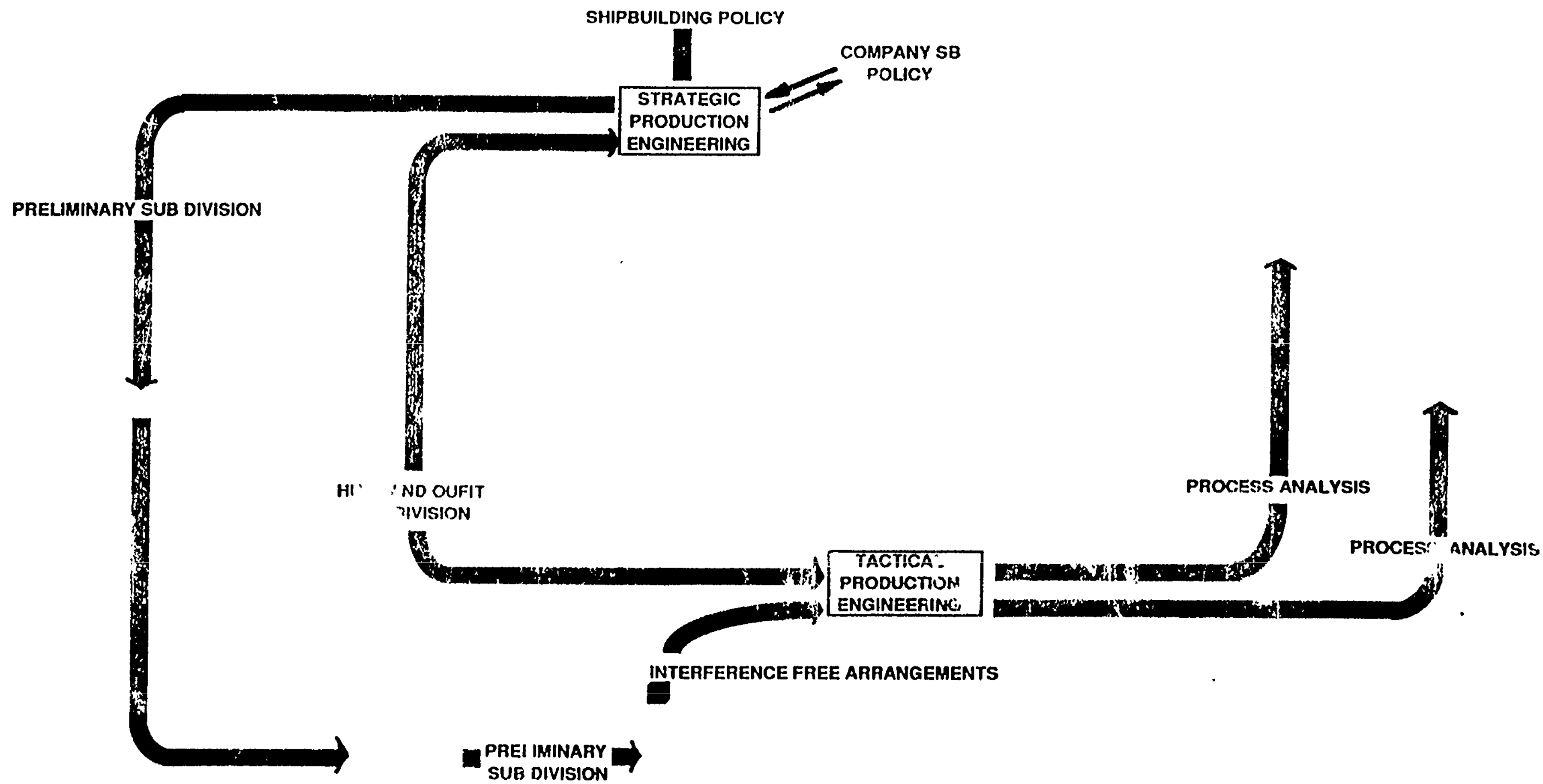

SHIPBUILDING POLICY
STRATEGIC PLANNING
CORPORATE OBJECTIVES
STRATEGIC PLAN
TACTICAL PLANNING
PROCESS ANALYSIS
STRATEGIC PLAN


CONCEPTUAL DESIGN
MISSION REQUIREMENTS
PRODUCTION
OUTLINE SPECIFICATION AND ARRANGEMENTS
DETAIL PRODUCTION ENGINEERING
DETAIL PLANNING
WORKSTATION DRGS
CONTRACT DESIGN
DETAIL DESIGN
DETAILED SPECIFICATION AND ARRANGEMENTS
INTERFERENCE FREE ARRANGEMENTS
FUNCTIONAL DESIGN
TRANSITION DESIGN
FUNCTIONAL & REGULATORY APPROVAL INFORMATION

ROUTE MAP

DETAILED BUILD STRATEGY

PRELIMINARY BUILD STRATEGY


SHIPBUILDING POLICY
COMPANY SB POLICY
STRATEGIC PRODUCTION ENGINEERING
PRELIMINARY SUB DIVISION
PROCESS ANALYSIS
PROCESS ANALYSIS
TACTICAL PRODUCTION ENGINEERING
INTERFERENCE FREE ARRANGEMENTS
SUB DIVISION

- Prepare relevant method descriptions for each interim product.

- Identify work Packages.

The tasks to be carried out at the detail level of production engineering are:

- Prepare works instruction sets (job cards, transport cards, material requisitions).

- Monitor production experience to identify areas for improvement considering both design features and production procedures, tools and equipment.

As mentioned above, the key activity at the strategic level is the preparation and maintenance of the company shipbuilding policy. On specific contracts, strategic level production engineers are involved in the preparation of the build strategy document. The build strategy document sets out the company policy with regard to a contract and identifies variances from the standards in the company shipbuilding policy.

Production engineering activities at tactical and detail levels are described in more detail in the following sections.

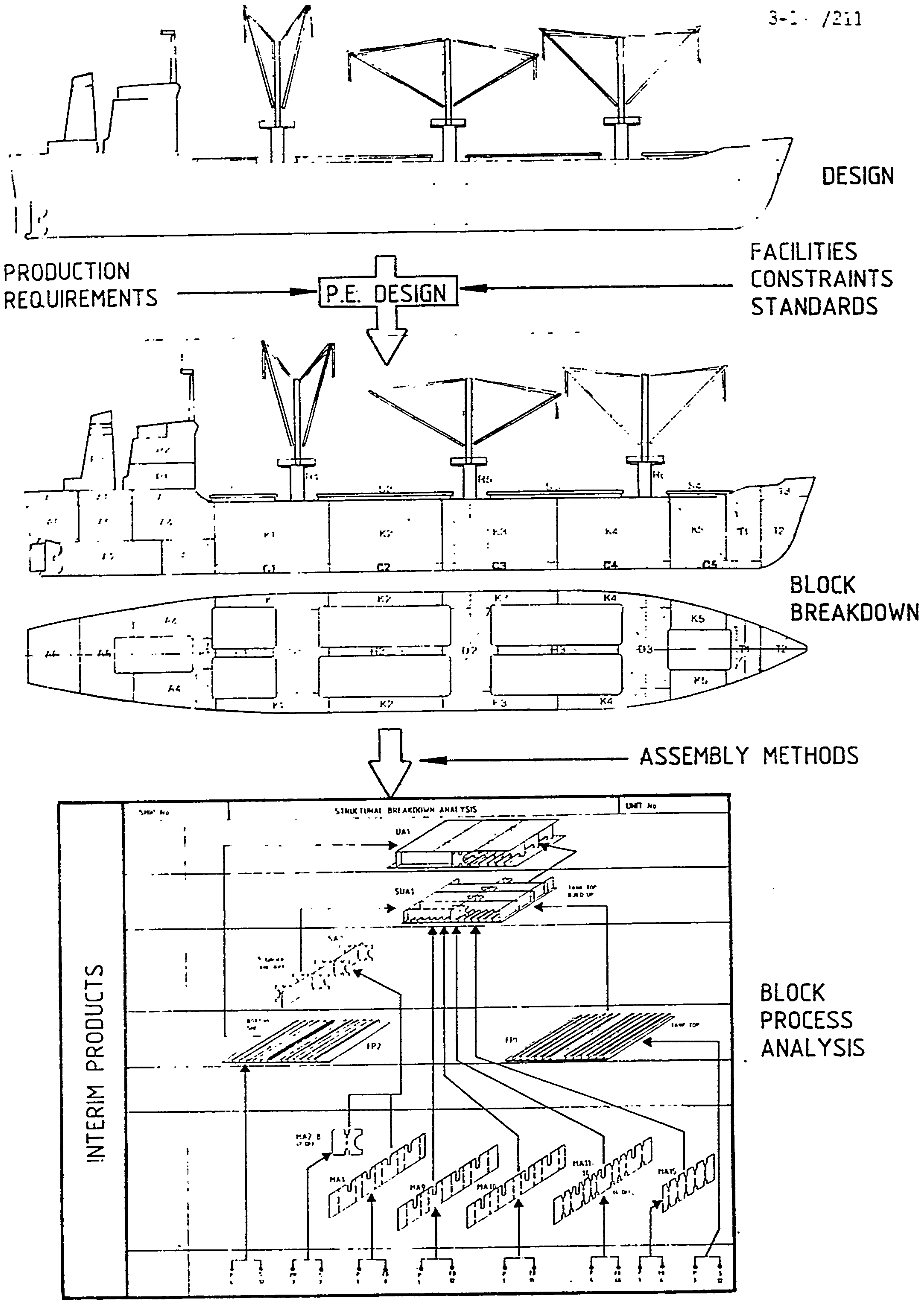
3.1.2.4 Production Engineering - Tactical Level- Steelwork

For ease of presentation the production engineering function has been divided between steelwork and outfit. This is an arbitrary division; clearly it is essential that., in all technical areas there is an effective integration of steel and outfitting work, particularly in the production engineering area where interim products and work packages are defined.

i) Block Process Analysis

The first and most important action is to review the block breakdown. The block breakdown is initially prepared as part of the build strateay. The build strategy document will be prepared at the strategic level. however. tactical Production engineers will review it in detail on the basis of more detailed structural drawings - profile and decks and structural sections - that are not necessarily available immediately after contract signing when the build strategy is prepared. The next stage is to define in detail the way in which each block is to he constructed. This will involve a study of each block taking into consideration the layout and facilities available. The objective will be to define the most efficient sequence of construction. This may or may not reflect current practice. The method defined should be based on an analysis of alternatives. A. further objective will be to highlight potential problem areas and indicate how details of the structure should be designed and drawn to simplify the construction process.

The output of this work will he a series of balanced work packages based on a preliminarv work content analysis, each identified with a work package number. The production engineers will have defined the what?, where? and how? for the block. This analysis may require fine tuning when detailed work content data becomes available from the work station drawings.


DESIGN
PRODUCTION REQUIREMENTS
P.E. DESIGN
FACILITIES
CONSTRAINTS
STANDARDS
BLOCK BREAKDOWN
ASSEMBLY METHODS
SHIP No
STRUCTURAL BREAKDOWN ANALYSIS
UNIT No
INTERIM PRODUCTS
BLOCK PROCESS ANALYSIS

The zones into which tbe vessel has been divided are also analyzed to determined at what stage the outfit will be installed. The fiqure page 3-1/213 shows an example of zone analysis.

There is clearly an interface with this outfit work in that the production engineers will define what?, where? and how? for outfit parts to be installed on block and painting work to be carried out. The steel planning unit. numbers are identified on the zone analysis,

ii) Preparation of Assembly Diagrams

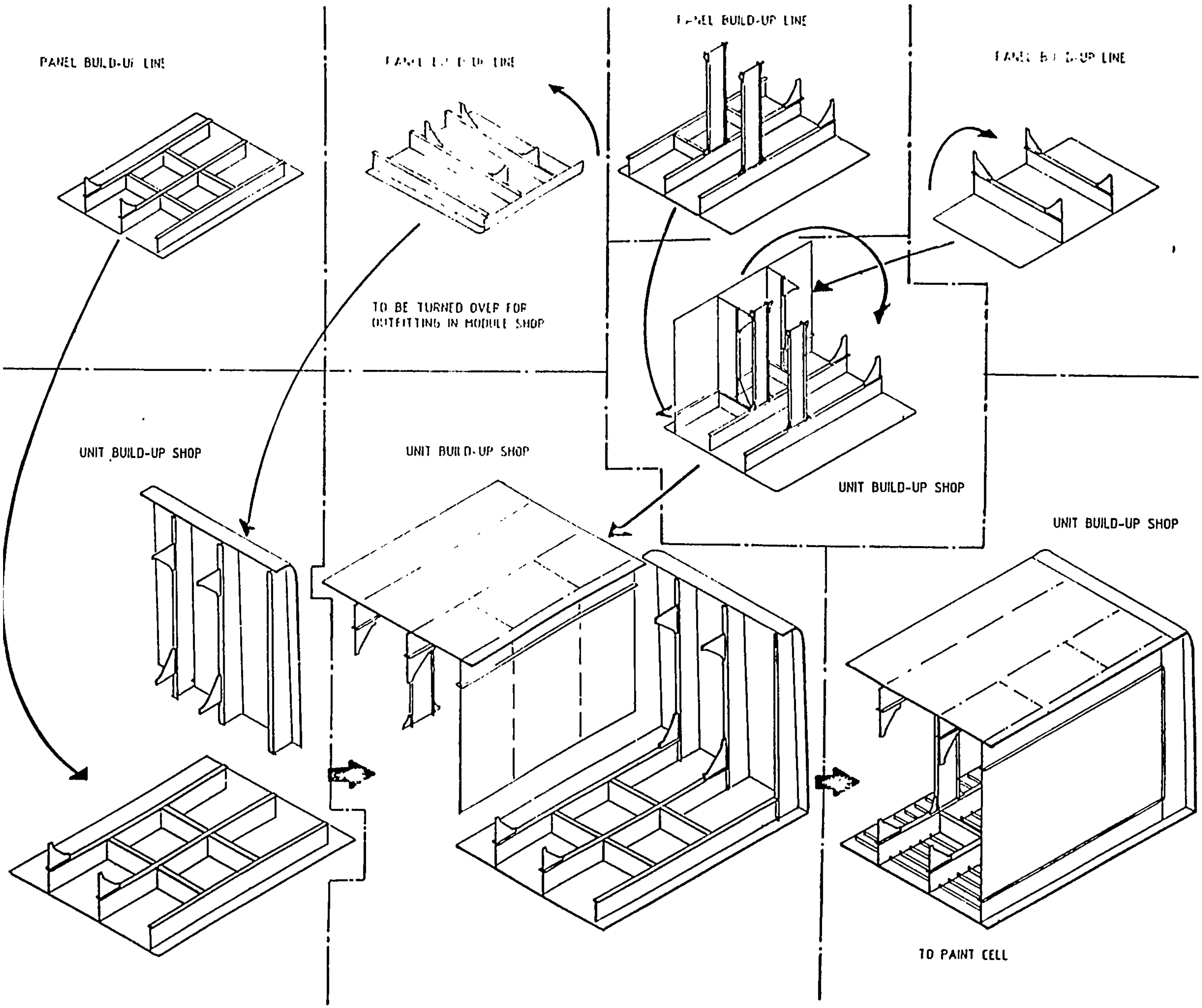
The assemlhlv diagram is a simple written form of the block process production stage at which work will be carried out. It is a written presentation of the block process analysis and may replace the diagrammatic presentation for simple blocks or blocks for which the process analysis has been standardized.

iii) Balance Work Content - Work Packages

A Preliminarv check should be made across blocks that the work contents of work packages goinq throuqh any one work station are balanced. This, is important if the on-flow work is to be maximized and scheduling work simplified. Again this aspect will require further checkinq on completing of work station drawinqs.

iv) Define Build or Process Locations

Work stations must be defined such that that are required to manufacture a limited variety of interim products. A check must be made to ensure that the work stations allocated to each process are handling products requirinq the same equipment, facilities, balance of skills and numbers of men. This is important if the balanced flow of work through each work station is to be achieved.



UNIT PROCESS ENGINEERING

DESCRIPTION

SIDE TANK WELDMENT K31
PRODUCTS TANKER

PROJECT	S G	BLOCK	ASSEMBLY
8 0 P T	K	3	K 3

DRAWN BY	SHEET 1 OF 1	REV ORGL

STAGE	WORKSTATION	WEIGHT	ROTATION

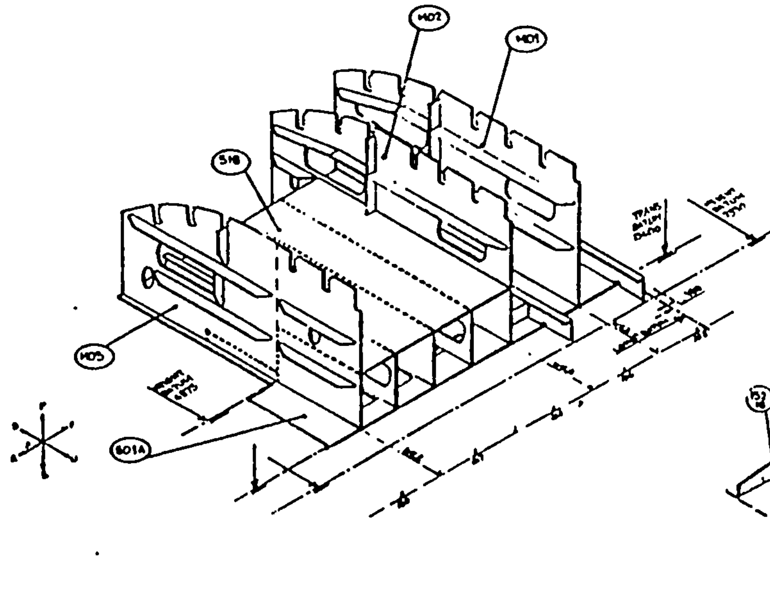
v) Preparation of Work Station Drawings

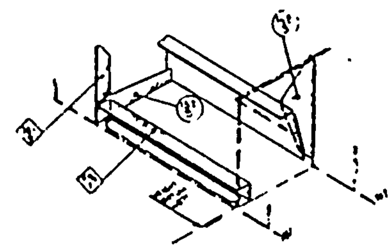
The preparation of working drawings is a technical function carried out, at the detail design stage. However, the production enqineers will pass the block process analysis sheets and assembly diagrams to the engineering office. These documents will then form the basis for the preparation of work station drawings. With the process sequence and work stations clearly defined, it will be straightforward for the detail design engineers to prepare the drawings required.

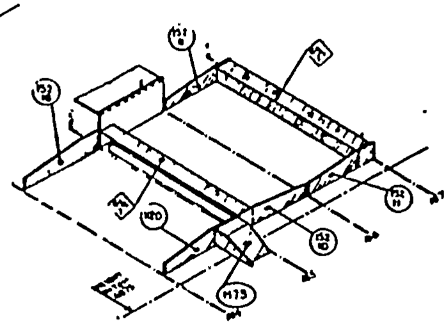
Part of the process of preparing the work stati ons drawings will be:

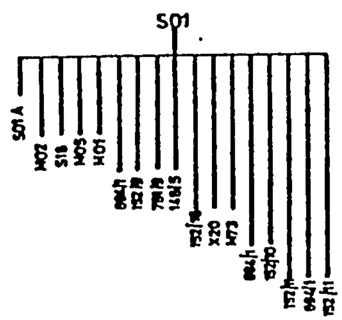
- the clear identification of all materials and sub-assemblies required,
- the preparation of the parts list,
- the calculation of work content.

The first two aspects are straightforward. Materials must be identified using a standard coding-system and the parts list should be included in the standard work station drawing format. Parameters to be used for the calculation of work content must. be defined for all work stations. Production engineers will be involved in this process. The parameters used must be relevant to the work stations and must be such that work content may be calculated early from the work station drawing.

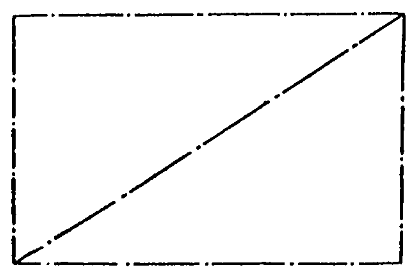




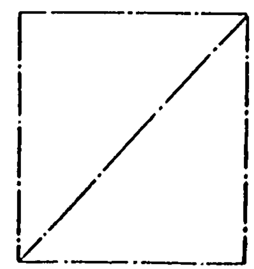




FLOW PROCESS



DIMENSIONAL ACCURACY



WORKSTATION ARRANGEMENT

WORKSTATION DRAWING

DESCRIPTION

LONG^L BHD 1DK - 2DK
FRAMES 141 - 148 PORT

PROJECT	DWG	ASSEMBLY
1 2 1	J 1 1	S 0 1

START DATE	COMPLETION DATE	WORKSTATION

QUANTITY	TOTAL WEIGHT

FAIRING

DESCRIPTION	PROC	FACT	ADJ

WELDING

DESCRIPTION	PROC	LEG	FACT

JOINT LENGTH

BUTT	HAND		M/C	
FILLET	HAND		M/C	

PARTS LIST

CODE No	QTY	CODE No	QTY	CODE No	QTY
S01A	1	152/18	1		
M02	1	781/9	1		
S18	1	149/5	1		
M05	1	X20	1		
M01	1				
M73	1				
084/1	3				
152/9	1				
152/10	1				
152/11	2				

3.1.2.5 Production Engineering - Detail Level - Steelwork

The task of forming the link between production and pre-production functions is carried out at the detailed production engineering level. Some of the work is concerned with formal procedures and documentation. However, much of the work is concerned with identifying problem areas, seeking solutions to problems, defining better ways of working and maintaining communication between production and pre-production functions.

i) List Tools and Equipment

Lists Will be prepared of any special tools and equipment required to carry out any given work package. The lists will concentrate on special tools not normally part of the tools available at any given work station.

ii) Prepare Work Instruction Documentation

The form of work instruction documentation may vary from yard to yard. However, it is essential that there is a formal document that is issued when work is authorized to start. The documentation must relate to individual work packages and contain all relevant information - parts lists, the equipment list, manhour budqets, process analysis, work station drawings.

iii) Documentation of Production Engineering Standards

It will be important to write up and issue Production engineering standards. These standards will cover all aspects from the method of approach to the construction of a double bottom unit, the way in which bracket connections are made or the approach to the block breakdown of any specific ship type. The aim must be to document current best practice in order to:

ensure that the proven best methods are used at all times,

ensure that the basis for further improvement is established.

The documentation of standards must not implv inflexibility or rigidity. As more thinkinq is done and new methods are developed the standard should change to reflect current best practice.

3.1.2.6 Production Engineering - Tactical Level - Outfit

The work carried out by production engineers on outfit planning units follows the same pattern as for steel planning units. The key inputs to the work at the tactical level are the outputs of transition design from the technical function in the form of single line composites for each zone on-board the ship. The tasks carried out by production engineers at the tactical level are:

- definition of outfit assemblies,
- process analysis for outfit assembly work, outfit installation work carried out before steel is erected and outfit installation work carried out on-board the ship,
- identification of outfit installation work packages.

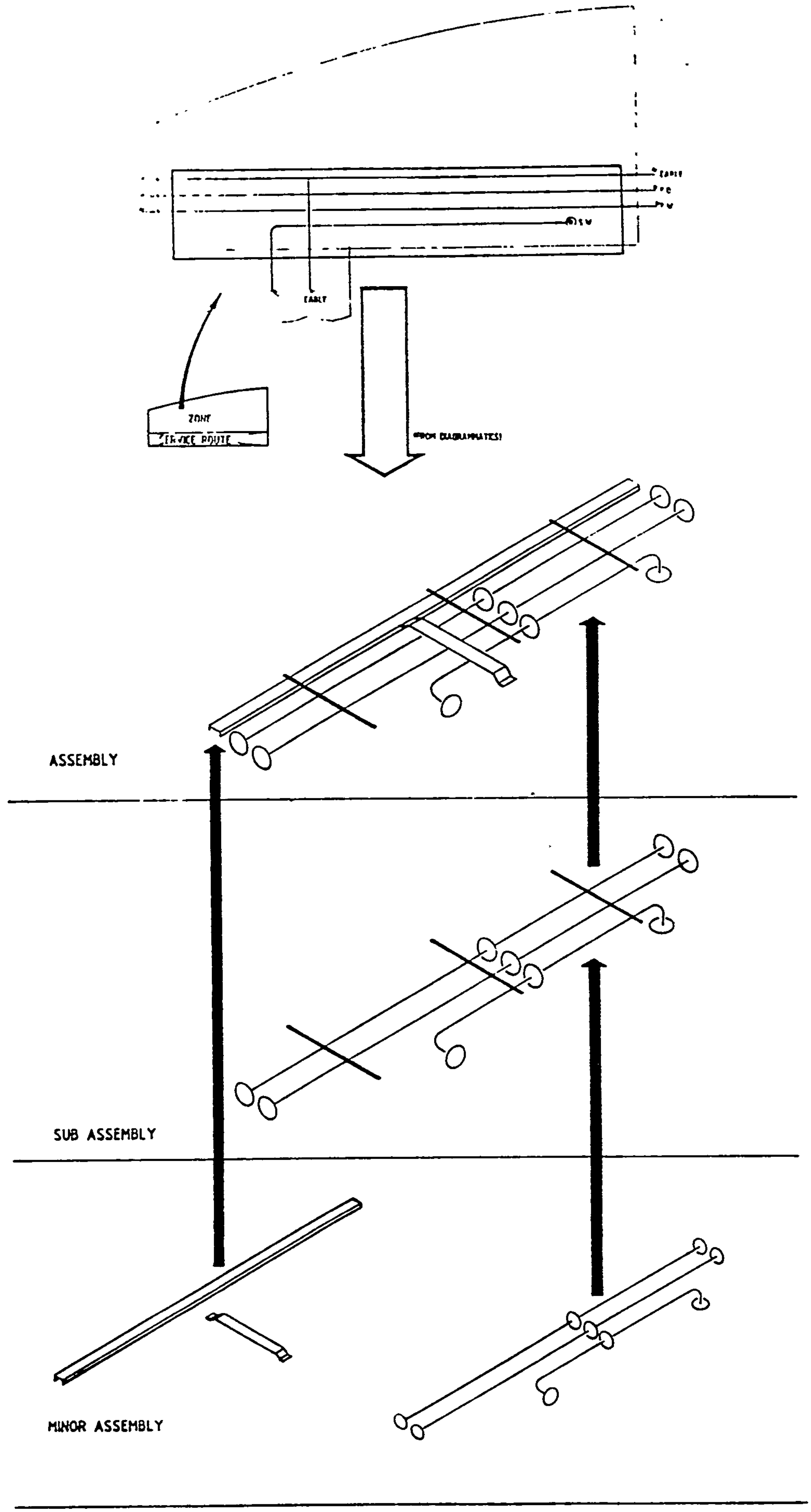
i) Definition of Outfit Assemblies

This task is the outfit equivalent of the steel block breakdown. The assemblies defined must recognize the block breaks so that installation of assemblies can take place before erection and be clear of block butts.

ii) AssemblY and Zone Process Analysis

As for steel, this will involve a study of the assembly taking into account the, facilities available. The objective will be to define the most, efficient sequence of construction. The output of this work should lead to the subsequent identification of balanced work packages so that a smooth production flow can be established.

For zones the analysis will highlight work sequences taking into account outfit assemblies and work carried out, before erection.


ASSEMBLY
SUB ASSEMBLY
MINOR ASSEMBLY

iii) Identification of Work Packages

Work package identification will follow logically from the process analysis, work. A check will be made on the degree of balance of the work content of work packages so as to generate as smooth a flow of work as possible.

The process analysis and work package details will be used by the detail design engineers to prepare installation drawings. Work package parts lists will be prepared by the detail design engineers.

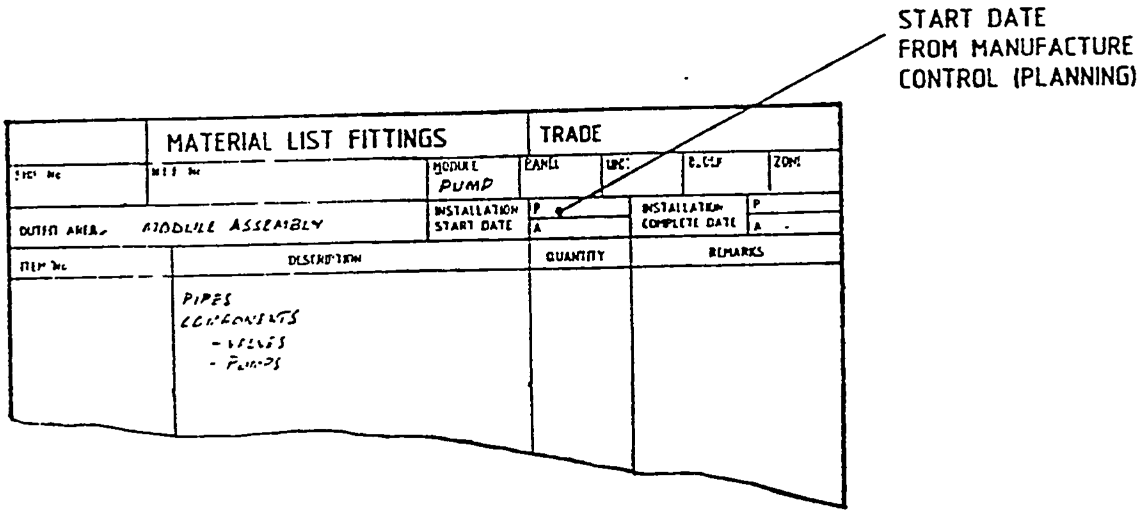
In all of the above three processes there is a clear need for integration of steel and outfit work. To achieve this, steel and outfit production engineers should be physically located in the same area.

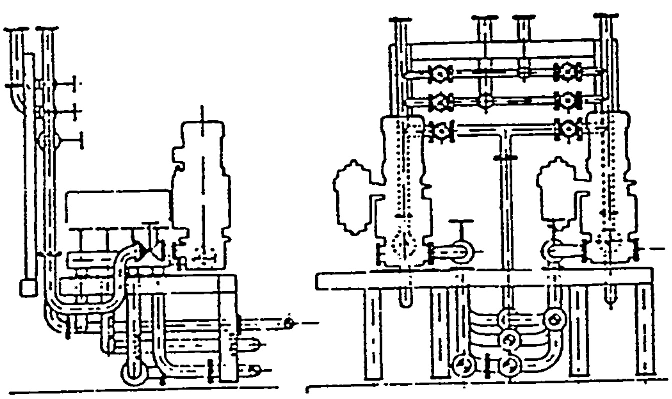
3.1.2.7 Production Engineering - Detail Level - Outfit

The tasks to be carried out parallel those for steelwork:

- list tools and equipment,
- prepare work station or work package documentation,
- document production enqineering standards.

WORK PACKAGES, PARTS LIST, WORK ORDER SETS (JOB CARDS, TRANSPORT CARDS, MATERIAL REGISTERS)





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3.1.3 STANDARD APPROACH TO SHIP CONSTRUCTION

This chapter defines what is meant by a standard approach to ship construction and the benefits and objectives of adopting this approach. The chapter concludes with a brief statement of the impact the approach has on the organization of work on the shop floor.

CROSS REFERENCES

1.2.2 Basis for Shipbuilding Policy Development

1.2.3 Implementation of Shipbuilding Policy

2.4.1 Structure and Organization of Planning

3.3 Shipbuilding Policy

3.2.6 Using Standards to Produce Layouts

3.1.3.1 General

The reduction of the overall project time, the time between contract signing and delivery, is an essential company objective. In shop production this is achieved largely through the application of assembly techniques coupled with the integration of steelwork, outfitting and painting activities.

If these activities are to he performed efficiently and in the minimum length of time it is essential that a standard approach to ship construction he developed. The designers at all the design levels must be fully aware of this approach and prepare the design accordingly. This can be achieved through the extensive use of design standards.

It has been found from research into the design process in a wide range of industries that not more than 10% of all design work is truly innovative. The remainder is achieved through the use, combination and modification of standards or established designs. Clearly, the wider the use of design standards the lower the design cost and the shorter the design cycle. Standardization of the design facilitates the development of a standard approach to ship construction.

Thus there is an information loop starting with the approach to ship construction being supported by production friendly design with the development of design standards; this leads to the ongoi ng development of standard working methods in production. Experience gained in production is fed back to production engineering and the information gathered will be used to refine construction standards. These standards will be incorporated into the company shipbuilding policy for use on future designs.

3.1.3.2 Benefit

The benefits to be derived from the development of a standard approach to ship construction may be described as follows:

a) It facilitates the use of scientific management methods and specifically the application of statistical methods in accuracy control, planning and performance measurement and evaluation.

b) lt facilitates the implementation of the 80/20 rule, 80% of the work to be done in planning and organizing production activities can be completed using only 20% of the planning resources thereby allowing the majority of the resources to be utilized in solving problems that are specific to the new contract.

c) It provides a basis on which to develop production facilities and methods since the process flow lanes will be consistent.

d] It enables the benefits of the “learning curve” to be realized in that problems encountered during one project can be eliminated before the next is started. Likewise workers are able to apply the experience gained during the completing of each work batch to the next and, by so doing, to reduce the time taken and to improve quality levels. This experience data naturally includes useful information for the development of the facilities and work methods.

The combination of these benefits leads to better quality products produced in less time at reduced costs. The design function also benefits in that it is able to provide a far higher service level in a highly cost effective manner.

3.1.3.3 Objectives

In addition to the development of design standards, what should be the procedure when establishing a standard approach to ship construction just as with the development of design standards where full consideration must be taken of the ship owner's requirements with regard to ship operation and maintenance, so the development of standard ship construction methods must reflect the requirements of production. The primary objectives therefore must be to:

a) reduce work done during and after erection- by fewer blocks and advanced outfitting,

b) simplify the construction method and improve the workinq environment - by improving access and safety,

c) facilitate the use of automated production methods through improved fit-up,

d) facilitate the high utilization of labor and facilities and

e) provide flexibility and scope for continuous improvement.

3.1 .3.4 About the Approach - Basic Principles

The standard approach can be viewed at two levels:

> First, the standard way of sub-dividing the ship into planning units. This should be the same for all ships of the same type. Furthermore, as far as it is possible, the subdivision rules should apply across the entire company product range.
>
> The second is the definition of the method of build for each type of unit. The build method must cover steel, outfit, electrical and painting work.

The approach to ship construction will vary in detail from yard to yard depending on the facilities available. However, there are some basic principles which should be applied of which the most obvious will be product subdivision.

The aim is to subdivide the vessel into assemblies which afford a simple erection method. The assemblies themselves should be built up from a narrow range of lower level interim products produced at fixed work stations using consistent methods and operation sequences. If the work content of each interim product is very similar to that of all others of the same family it will be possible to achieve high utilization of facilities and labor.

A detailed explanation of the principles of hull subdivision is given in chapter 3.3.1. However, at this point it is important to stress that the aim is to subdivide all products in basically the same way.

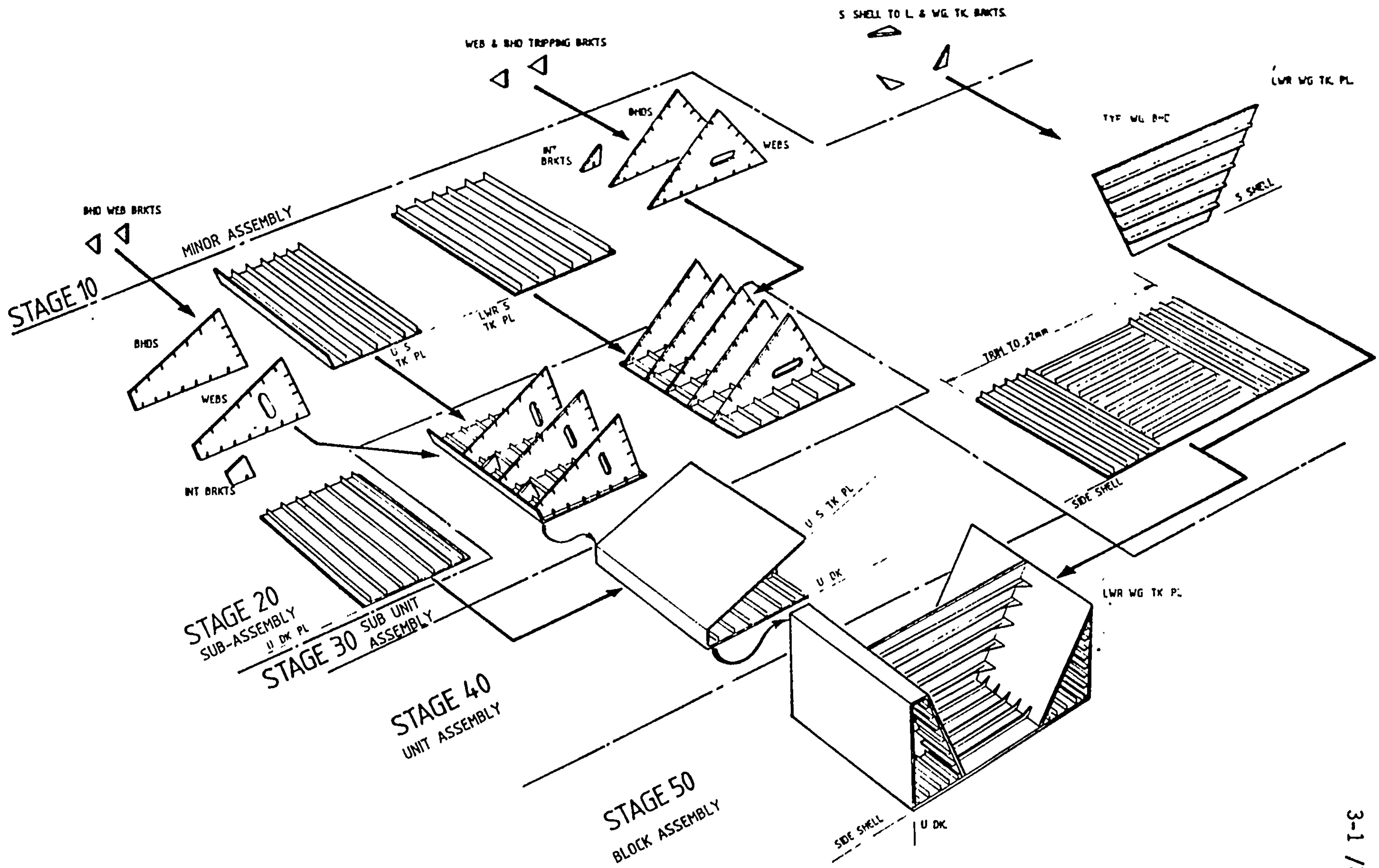
As well as subdividing the hull into assemblies it is equally important to assemble as much outfitting work as possible prior to installation. This may be achieved by grouping outfit items together into functional groups by routing pipes, vents and electrical cable runs, along predefined spaces. This enables the various groups to be supported together on common foundations or supports, thereby facilitating the building of outfit assemblies.

The hull subdivision must also be made in such a manner as to facilitate the installation of large and heavy outfit equipment assemblies by crane, in the open sky condition. To reduce post erection work as much outfit as possible will be installed before erection. To provide a high level of motivation to the worker it is necessary to adopt a "right first time, every time" approach to work. To apply these principles to outfit installation work carried out before steel is erected, such that the outfit items are installed in their correct position and firmly secured at that time, it is necessary to provide a means of absorbing dimensional errors in the steelwork and outfit. parts and assemblies. This may be done by introducing closing pieces or flexible couplings in way of block breaks and installing these after completing the joining of the blocks.

The sequence of block erection is also important especially when short build cycles are required. It is particularly important to Start. the erection of the hull in areas of high work content. This frequently means starting at, or immediately adjacent to, the machinery spaces. Some shipyards have taken this one stage further through the introduction of tandem construction methods. When applyinq these methods the machinery space of a given vessel is erected in parallel with the remaining part of the previous vessel. This method has the effect of doubling the length of time available for erecting and outfitting the machinery space.

Another way of speeding up the erection process for very large vessels is to use the multi-start method. In this case, the bottom Iayer of the vessel is initially erected very fast and then erection continues fore and aft of two points, for example, at the forward end of the machinerv space and at a point. around midships.

The adoption of a standard method of subdividing the hull, standard erection sequences, and a hull block numbering system coupled with a high level of design standardization leads to simple planning. Examples of the level of design standardization considered here include standard machinery space layouts for a given main engine and standard accommodation arrangements. The adoption of this level of design standard facilitates the achievement. of the objective of making continuous improvements since both the technical and production functions are able to build on real and recent experience.



SUB DIVISION OF A SIDE UNIT SHOWING INTERIM PRODUCTS BY STAGE

3-1 /307

3.1.3.5 Organization of Work

The planning of construction of the vessel utilizes the subdivision principles. The control entity is the planning unit. This can be one or a pair of blocks, or an outfit assembly at the pre-erection stage of production, alternatively a geographical area or zone at the post erection stage. Other planning units may be across the ship, for example, trials, testing and commissioning or installation of main power electrical cables.

The completion of work relating to a planning unit is done during a number of stages. Work is organized along with the relevant information and materials on the basis of planning unit by stage by work type or work station.

lf a standard approach to ship construction is adopted there is great potential for an increase in on-flow work as opposed to off-flow work.

3.1.4 THE NEED FOR DEVELOPMENT OF INTERIM PRODUCTS AND-PRODUCTION PROCESS STANDARDS

This chapter summarizes why standard interim products are necessary and the benefits that flow from the development of standard products. The two basic types of interim products - on-flow and off-flow are described. The last section of the chapter lists and explains the reasons for the need to develop production process standards.

REFERENCES

2.1.8 The Need to Document Production Process and Method Information

2.3.3 Guidelines for Production Process and Method Information Documentation

3.1.5 The Application of Group Technology

3.3.2 Hull Steel - Identification of Interim Products

3.3.5 Outfitting - Identification of Interim Products

3.1.4.1 General

This chapter is closely related to the previous one since the development of standard interim products and a standard construction method normally go “back to back.”

The development of standard interim products facilitates the application of the principles of mass production. These may be defined as “The same personnel, working in the same places, making repeated operations to produce large numbers of cheaper products .“

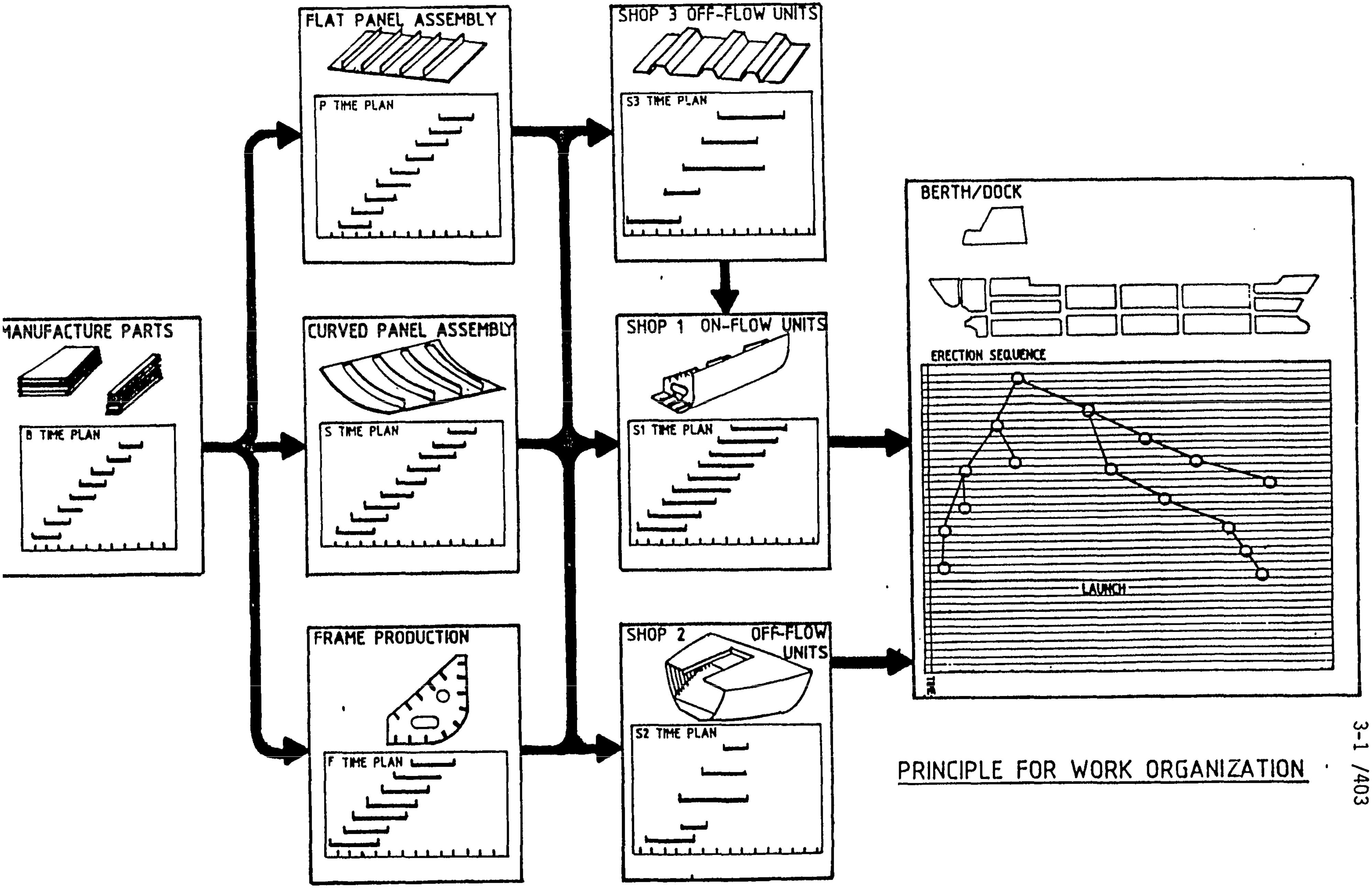
3.1.4.2 Objective

The objective of the design function is to design each vessel such that it may be subdivided into a narrow range of interim product family groups. The interim products in each family group should be designed such that they may be produced employing the same operation sequences, methods and skills. They should, ideally take the same time to complete and all be produced at the same work station.

Process flow lanes may be established for the manufacture of interim products based on the application of group technology. Using these principles, interim products relating to one or a number of production stages may be produced in cells or work stations employing standard work methods. Examples of the application of group technology may be seen in the manufacture of brackets, webs, flat and curved built up panels (employing- both the line and eggbox assembly methods) and in the manufacture of pipe spools.

The figure page 3-1/403 shows typical groups of steel interim products .

Monitoring the production of such interim products quickly enables methods and quality to be substantially improved and for simple planning and control work content parameters to be established.



PRINCIPLE FOR WORK ORGANIZATION

3.1.4.3 Types of Interim Products

Family groups which contain large numbers of interim products are referred to as on-flow types. The remainder are off-flow types. Clearly the objective is to attempt to maximize the former and to eliminate the latter.

There is a hierarchy of interim products, within which there are a number of levels. The lowest level is the raw material and at the higher levels there are assemblies and blocks. It is important to start the standardization of interim products at the lower levels of the hierarchy. It will then be possible to develop standards at the higher levels.

The development of on-flow type interim products is particularly important. It increases the numbers of similar products and makes worthwhile the analysis in depth of the method of manufacture. The analysis would be carried out with a view to establishing highly efficient work stations designed to produce large numbers of specific types of interim products in the most efficient manner.

Further details of types of interim product may be found in Chapter 3.3.2 with a number of illustrations which will help to readily identify interim product types and their classification.

The figure on the previous page shows the relationships between the subdivision of the vessel at the various assembly levels, the erection sequence and the process flow lanes developed around a range of standard on-flow and off-flow interim products. This relationship is the basis for the organization of production.

3.1.4.4 Production Process Standards

Having developed a series of standard interim products the next step is to develop a standard manufacturing process for each. The principal advantages of adopting standard manufacturing processes are listed below:

i) Better Organization of Resources

A work station can be established for each process. It can be desiqned specifically with that one process in mind and the most appropriate manpower, tools and machines which are available may be allocated to it.

ii) Improved Productivity/Efficiency

A standard process allows production personnel to familiarize themselves with their work and hence with practice to become better at it. A danger which must be avoided however is that work becomes so repetitive that it is no longer interesting.

iii) Improved Accuracy/Quality Control

Production by standard process allows the use of statistical control methods. The mean and standard deviation of a process can be calculated and any variation in either may be quickly identified allnwino timely corrective action.

iv) Easier and More Accurate Planning

It is a simple task to measure the output, and costs of a standard process. This information is then very easy to use in planninq future production of the same or very similar products.

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3.1.5 THE APPLICATION OF GROUP TECHNOLOGY

This chapter provides a definition of group technology and other terms associated with group technology such as product families and groups for both steel and outfit.

Group technology is an approach to production which identifies similarities in the manufacture of products and organizes production facilities as a series of groups, or cells, containing the necessary resources to make the products.

CROSS-REFERENCES

2.3 Ship Production

3.1.4 The Need for Development of Interim Product and Production Process Standards

3.3.2 Hull Steel - Identification of Interim Products

3.3.5 Outfitting - Identification of Interim Products

3.1.5.1 Background

Group technology is an approach to production which aims to gain economy in batch, and one of a kind, production.

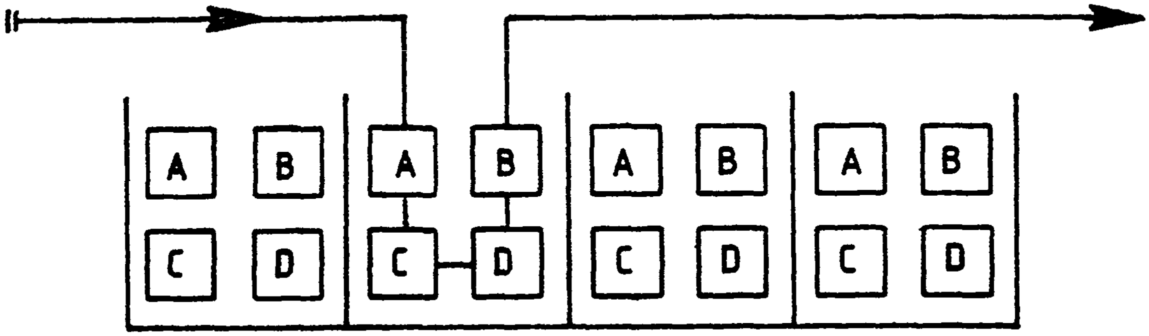
Conventionally, factories involved in small batch production or one of a kind production use a functional layout, where similar machines or processes are grouped in a department. The alternative, for mass production, has been a flow line where machines or processes are arranged sequentially. The line allows sequential operations to be balanced, and gives benefits in relatively short manufacturing times, low inventory and low production costs.

However, early lines were dedicated to single products and therefore impacted only a limited proportion of manufacturing.

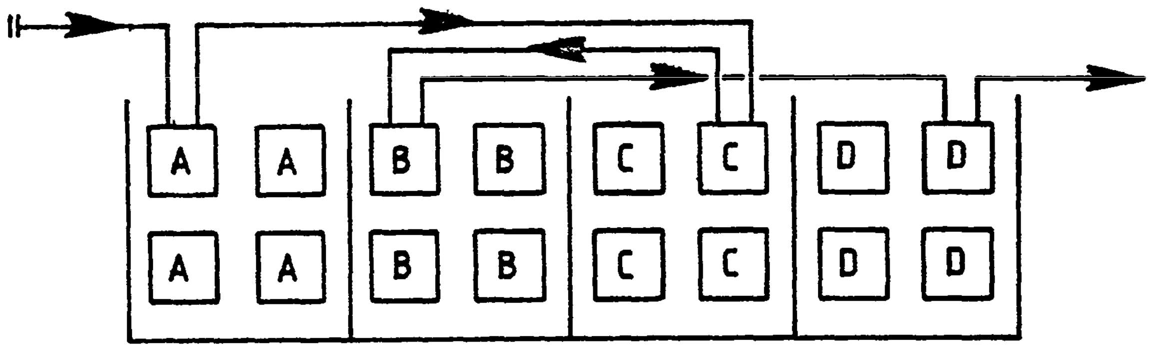
The more recent introduction of flexible machines, with short set up times, has allowed the large quantities associated with line production to be made up from a number of smaller batches. The line can now make families of similar parts, rather than a single part. The range of applications is small, and in industries such as shipbuilding, only a few examples can be found.

In shipyards the flat panel production and semi automatic pipe production lines are the most common examples. Historically, the ability to use more than basic technology for most shipbuilding problems has not been realized.

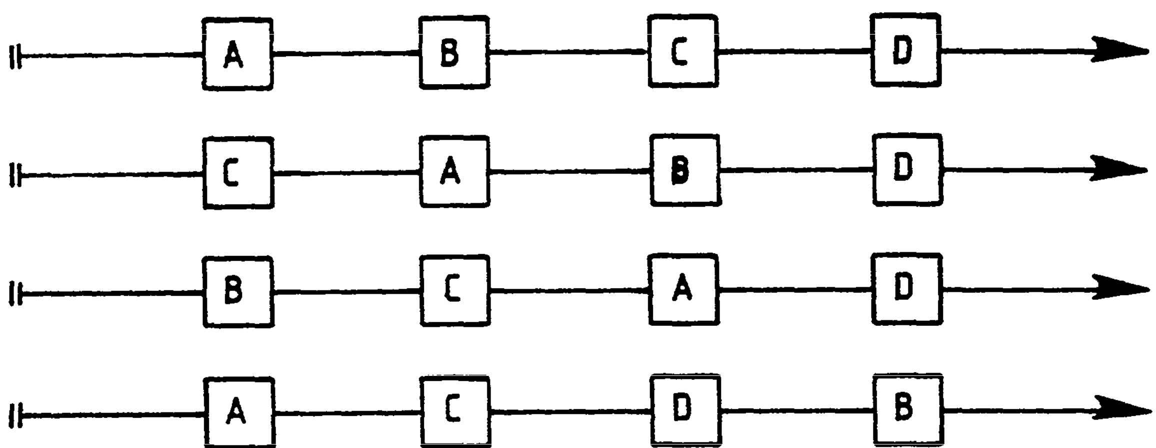
GROUP LAYOUT



FUNCTIONAL LAYOUT



LINE LAYOUT



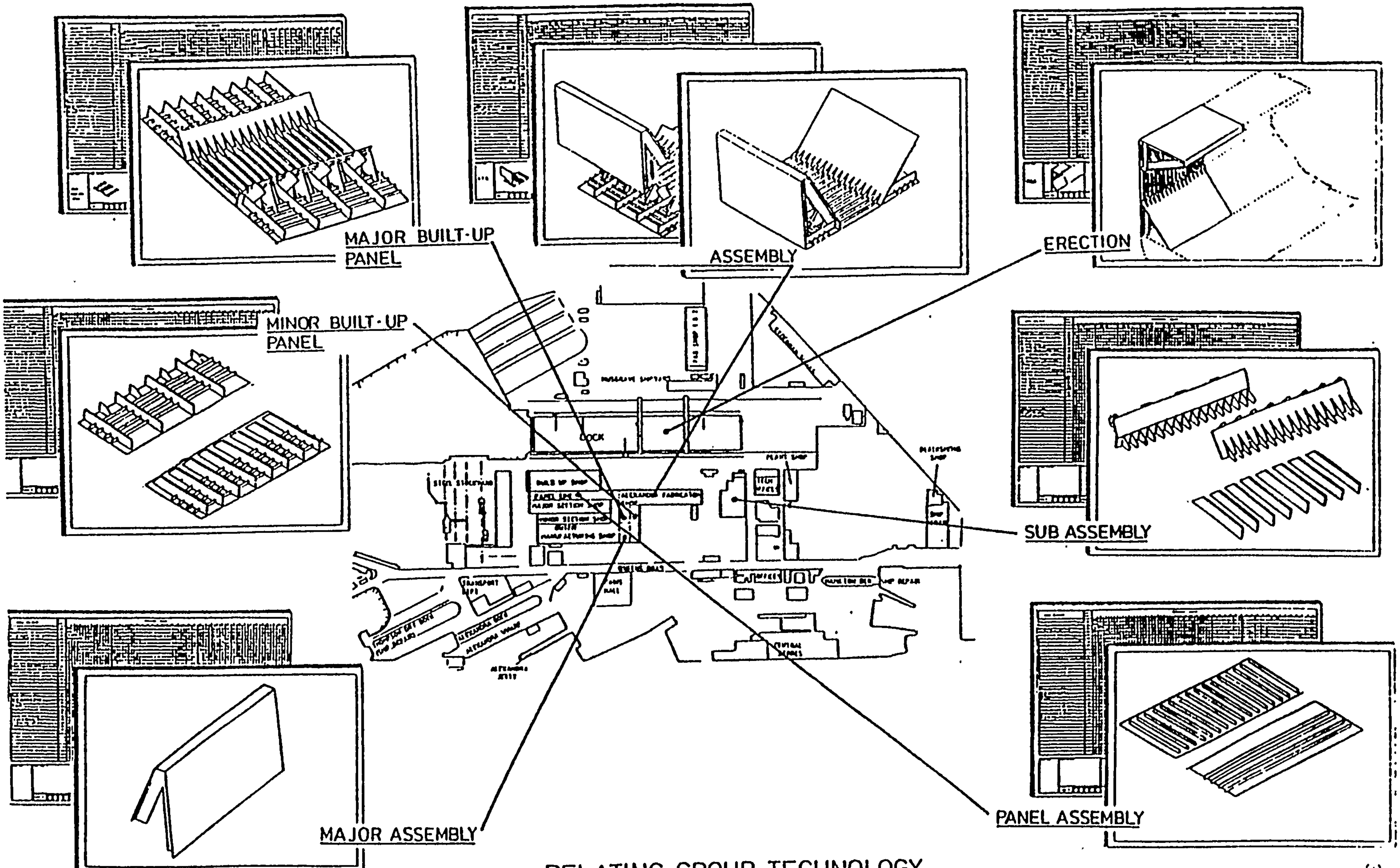
3.1.5.2 Group Technology

The relatively narrow use which can be made of the flow line does not. prevent the benefits being realized. Group technology is an approach which places the machines or processes associated with a product close together and organizes planning, information and materials to support them.

The key features of group technology are the families of products related by their production requirements and the groups of production equipment and personnel arranged to produce the products within a family. Families can be related to areas of the facility as shown in the-figure page 3-1/505.

This concentration on the production of completed products in predefined locations allows manufacturing times to be significantly shorter than where products are moved several times during their manufacture.

The flow of materials can be simplified since only completed products (as sub assemblies and assemblies) or batches of components for a product, move around the facility. The quantity of work in progress is reduced and with it inventory and material control problems.



RELATING GROUP TECHNOLOGY
TO THE FACILITY

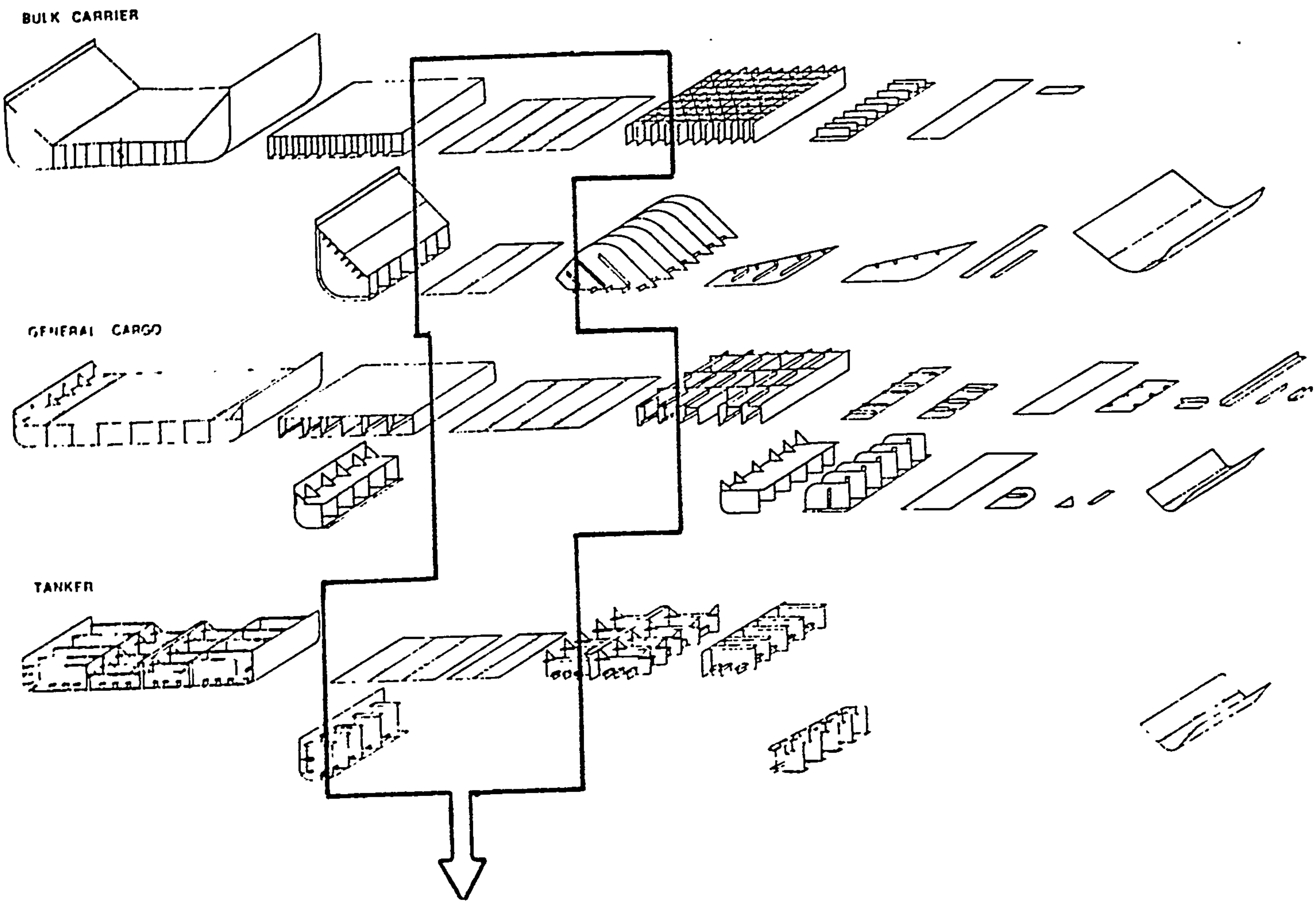
3.1.5.3 Families - Steelwork

The application of group technology in shipbuilding requires the identification of families of products. The families are interim products with similar production characteristics. Each family will flow through the same, or very nearly the same, work station sequence. The members of a family will be physically similar and have similar dimensions and weight. Most importantly, the members of a family will have a similar work content to each other, so that the balancing of the production system can be made easier.

All the families in a vessel, or across several vessels, can be viewed as a hierarchy.

The figure page 3-1/507 shows the principle applied to the midship portion of three different vessel types. Although the vessels and their structural arrangements differ, their breakdown into units and sub-assemblies reveals a number of related interim products. The most obvious example is the flat panel.

However, other similarities in products across the different vessel types can be seen and these form the basis of organization of facilities.



IDENTIFICATION OF FAMILIES OF PRODUCTS

3.1.5.4 Groups - Steelwork

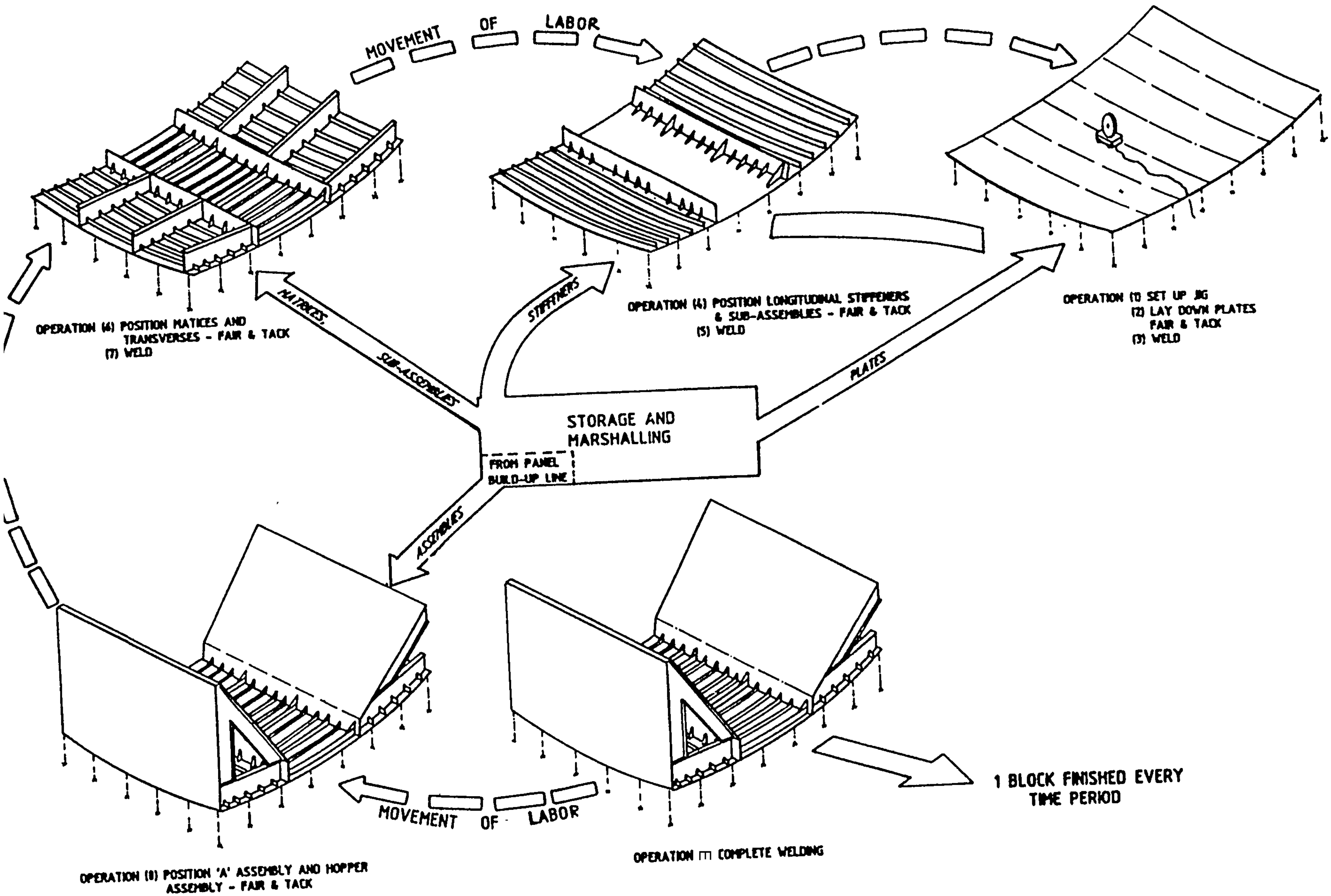
The families of products which can be identified are associated with groups. A group consists of a number of work stations, all or most. of which are required in the production of a family, or several families of products.

In some cases, there may be sufficient volume of production to justify a flow line. The shotblasting and priming of steel raw material often uses a flow line, where the various machines are linked by conveyors. The production of flat, stiffened panels is also frequently carried out using specialized machines linked by conveyors. with the introduction of more automation and robotics, more flow lines may be seen in future in sub-assemblv areas.

In the case of steel assembly, the products are often unsuited to movement by conveyor because of their size, weiqht or configurations. Nevertheless, the number of products needed and the time to produce each one may dictate several work stations.

The production of the units shown opposite requires five work stations. The production work is divided into five sets of operations, each of which is assigned to a group of workers, with appropriate specialized equipment. The times to complete each set of operations are made as equal as possible, as is the case with assembly line balancing. The groups of workers move from work station to work station, in sequence. This movement is,shown in the figure page 3-1/509.

This approach allows production to reach levels of efficiency close to those achieved in flow lines.



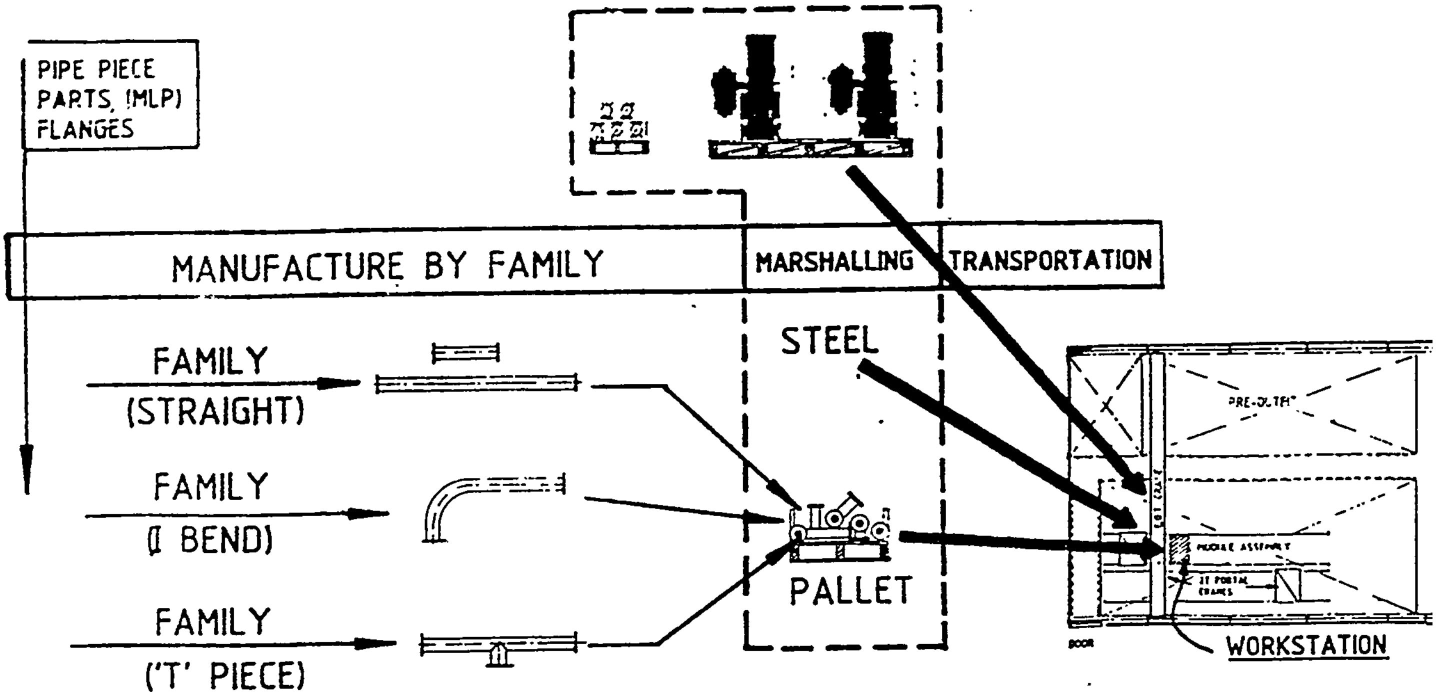
MOVEMENT OF LABOR
OPERATION (4) POSITION MATICES AND TRANSVERSES - FAIR & TACK
(7) WELD
OPERATION (4) POSITION LONGITUDINAL STIFFENERS & SUB-ASSEMBLIES - FAIR & TACK
(5) WELD
OPERATION (1) SET UP JIG
(2) LAY DOWN PLATES FAIR & TACK
(3) WELD
MATRICES,
SUB-ASSEMBLIES
STIFFNERS
PLATES
STORAGE AND MARSHALLING
FROM PANEL BUILD-UP LINE
ASSEMBLIES
1 BLOCK FINISHED EVERY TIME PERIOD
MOVEMENT OF LABOR
OPERATION (8) POSITION 'A' ASSEMBLY AND HOPPER ASSEMBLY - FAIR & TACK
OPERATION (7) COMPLETE WELDING

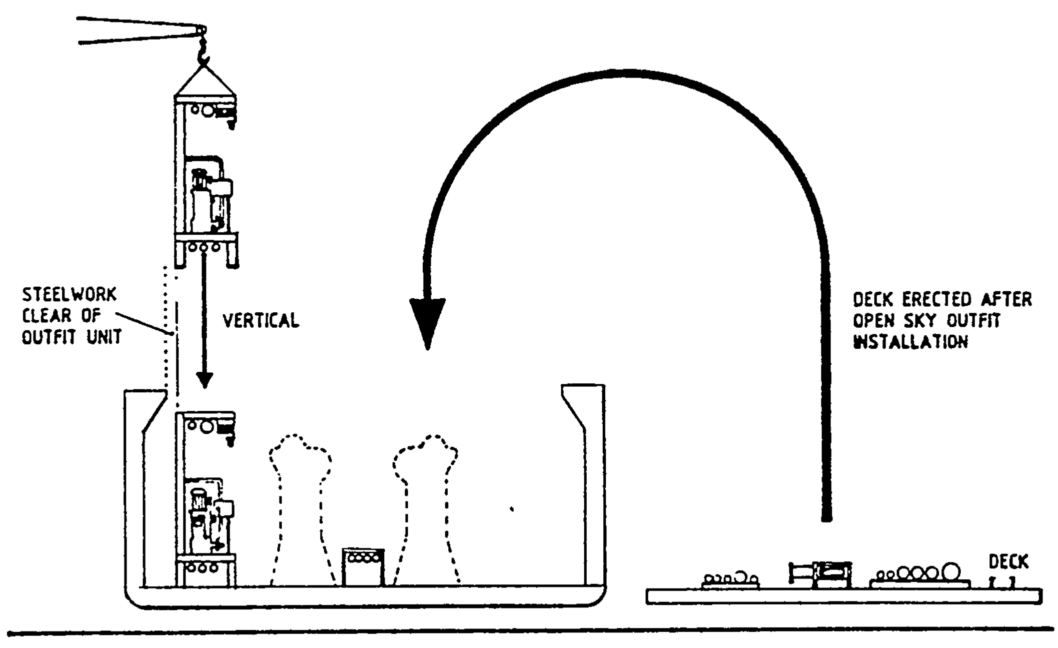
3.1.5.5 Families - Outfit

Outfitting involves the installation of equipment and fittings in the ship. This is an activity which can take place before erection, or on-board before or after launch. Some elements of outfitting can be identified as assemblies, whereby some of the equipment to be installed is aggregated first. These outfit assemblies can be allocated to families.

Were outfit is conventionally installed, the principles of group technology can still applv. The work of installation cap still be grouped in Packages, each ideally of similar content requiring the same mix of skills and equipment. In addition to the manufacture of outfit assemblies, outfit installation work will be done at various states of steel assembly. If the installation of outfit at a steel assembly stage becomes a standard practice, for example, the installation of pipes in double bottom units, then these items can become part of the steelwork product.

Manufacturing outfit parts can he treated in the same way as steelwork.


PIPE PIECE
PARTS, (MLP)
FLANGES
MANUFACTURE BY FAMILY
MARSHALLING
TRANSPORTATION
FAMILY
(STRAIGHT)
FAMILY
(I BEND)
FAMILY
('T' PIECE)
STEEL
PALLET
WORKSTATION


STEELWORK
CLEAR OF
OUTFIT UNIT
VERTICAL
DECK ERECTED AFTER
OPEN SKY OUTFIT
INSTALLATION
DECK

3.1.5.6 Groups - Outfit

For the manufacture of outfit parts and the production of assemblies, groups can be identified. In some cases a flow line may be appropriate where volume is sufficient.

The composition of groups will be varied, consisting of machines and operators for fabrication and personnel with small tools, lifting equipment and jigs for assembly.

For installation, the groups will be more varied. Installation at various stages of steelwork will involve small numbers of outfit parts which may be more conveniently attached to steelwork groups, with the steelwork products defined as including the outfitting content.

For installation on-board, group technology can also be applied. For example, the outfitting of accommodation spaces on all ships will require a similar mix of skills and equipment. The group is therefore defined as the personnel, with their tools, required to complete the work. Organization of the work - how the members of the group move from task to task - is determined within the group to meet overall planning targets.

Although the group moves around the ship, from product to product, the organization required is identical to that for production within a static group.

3.1.6 PROCESS AND SPATIAL ANALYSIS

This chapter provides definitions for process and spatial analysis. Process analysis develops the hierarchical breakdown of a vessel into planning units and smaller products. Spatial analysis relates this to the design process. These two techniques are vital to desiqn/production integration. They provide the means whereby communication between production engineering, planning, design and production functions can be achieved.

CPCSS PEFERENCES

2.2 Ship Design Stages

2.2I Planning

3.1.2 Production Engineering Decisions

3.2 Ship Geometry and Layout Engineering

3.3 Shipbuilding Policy

3.1.6.1 Application of Production Engineering

Earlier chapters have outlined how the Production Engineering function should develop a definition of how the shipyard should applv certain principles in planning the construction of-a vessel. It is now necessary to consider the application of these principles to the development of the design of the vessel.

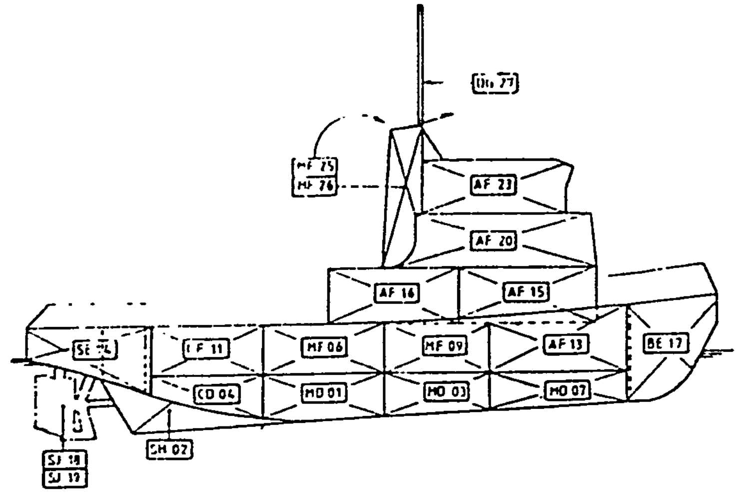
The application process is circular, and one which refines ideas over a number of vessels. That is, the definition of production will influence the design process, and the requirements of the design will be the basis for the production system, and so on.

3.1.6.2 Process Analysis

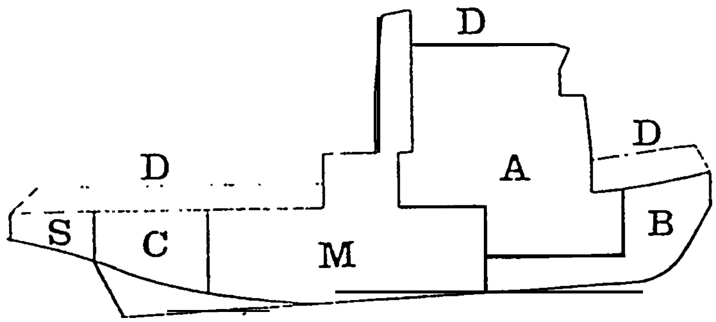
Process analysis is a task carried out by production engineers. Production engineering is carried out at three levels - strategic, tactical and detail - process analysis is part of both strategic and tactical production engineering.

The basis for process analysis is the planning unit. Planning units are the central entity around which production engineering and planning work is organized. Typically a planning unit is a block, or a pair of blocks, an outfit block or unit or a zone on-board the ship.

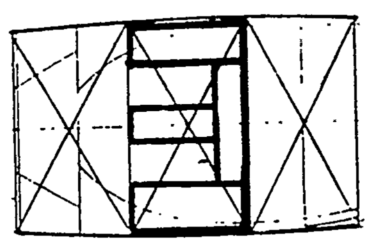
Having identified the planning units, production engineers will decide upon the sequence of work that will be carried out in order to complete the planning unit in the required time and to the required level of quality. Production engineers will define what work has to be done at each production stage, and at which work station work has to be done. To be effective, production, design and planning people should be involved in the process analysis work.



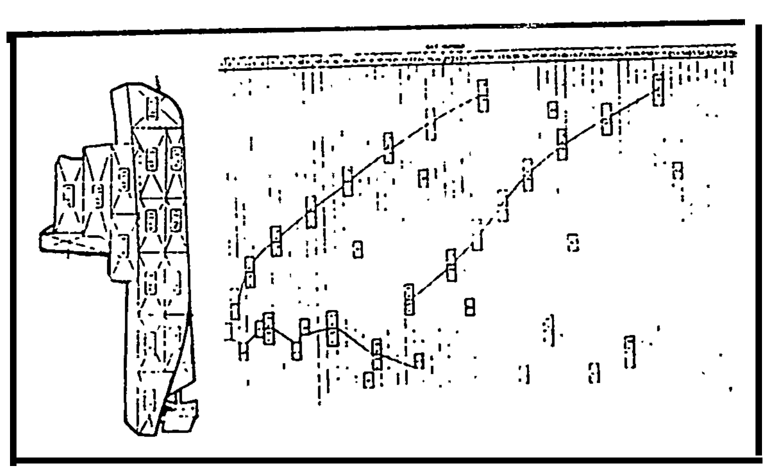
STEEL



INSTALLATION ZONES



OUTFIT UNITS



TYPE PLAN

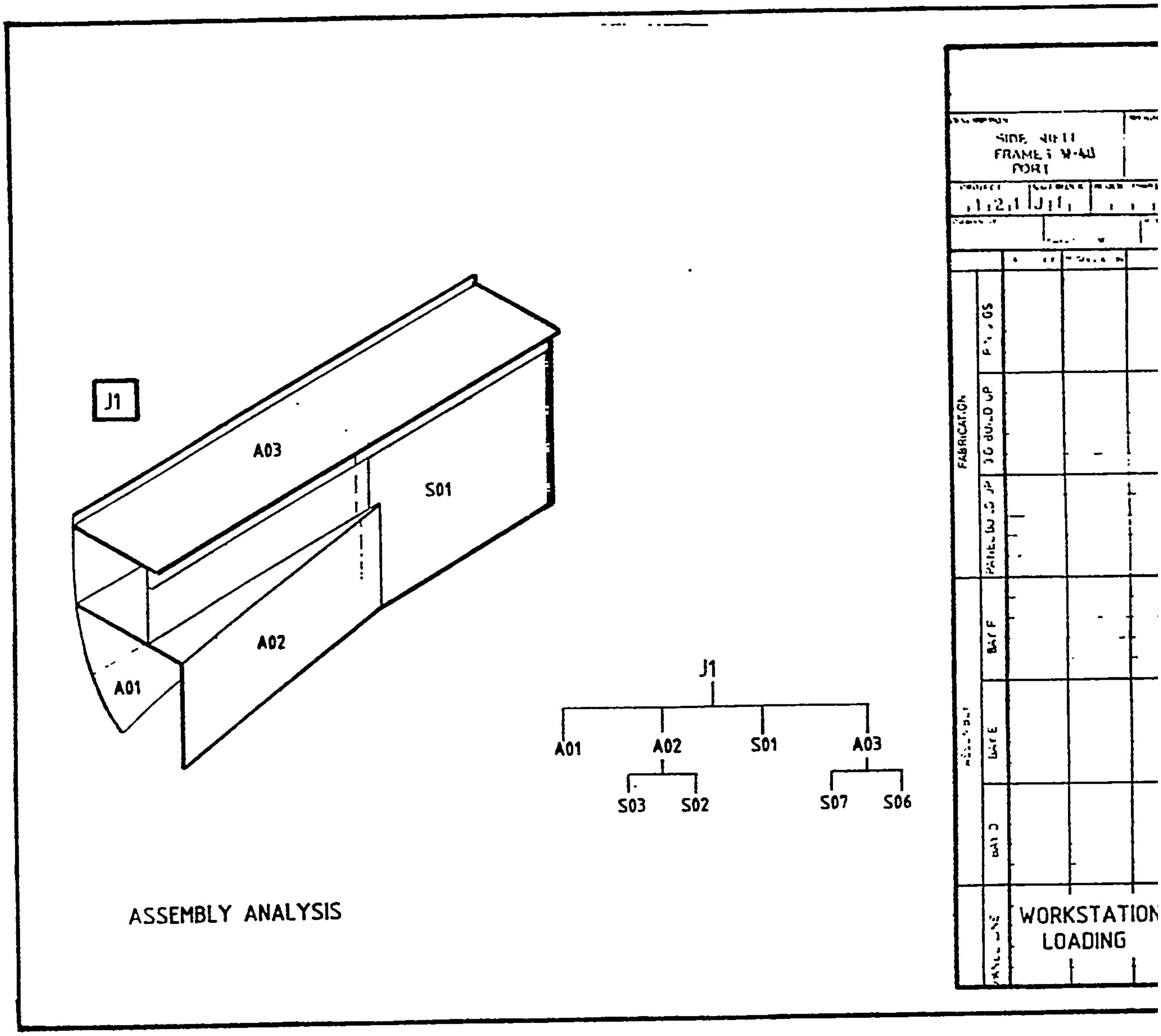
PLANNING UNITS

Planning units are identified at the strategic level and if any degree of design standardization has been achieved it will be possible, even at this level, to make use of historical information to carry out process analysis. It will only be necessary to carry out process analysis for typical planning units rather than all units. Analysis of typical planning units will provide enough information to enable overall capacity loading to be carried out.

At the strategic level some process analysis will be specific to contracts, for example, identifying where and how planning units for a particular ship differ from the standard. Other work will center around the development of the standards themselves.

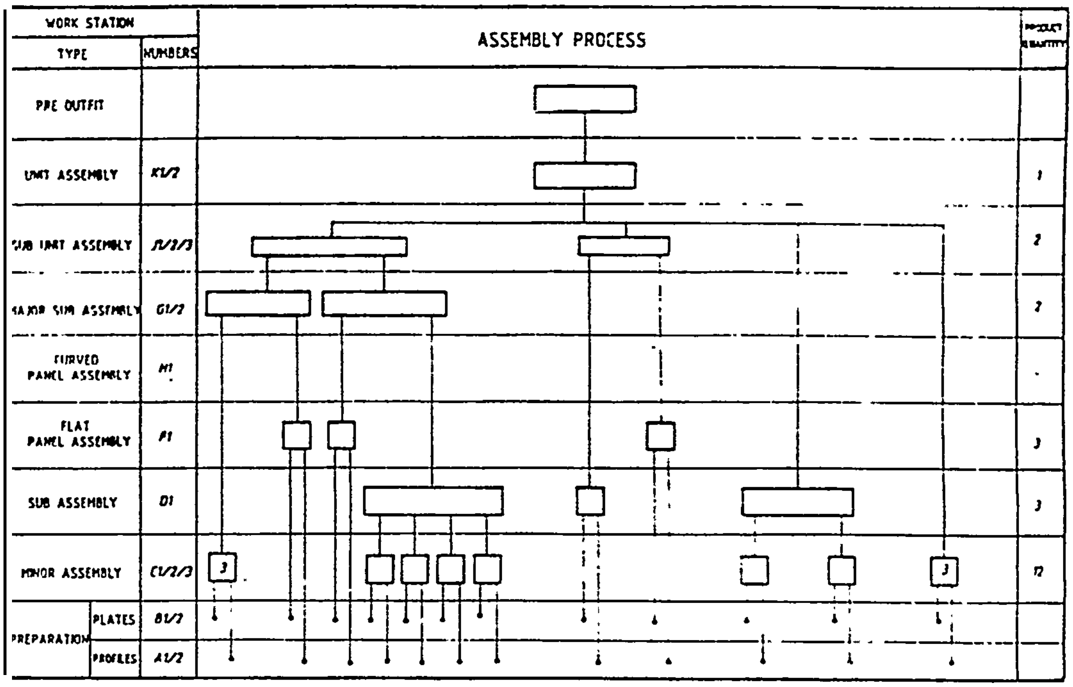
At the tactical level, process analysis will be carried out in detail for all planning units. Technical inputs will come from transition design and the outputs will be used as the basis for the preparation of work station drawings. The preparation of work station drawings in some yards is a design function, in others a production function.

Process analysis therefore provides detailed information that forms the basis for the preparation of work station drawings and for production. At the same time, the analysis may well lead to the identification of improved production methods. These improved methods would be incorporated in the shipbuilding policy and then in future designs.



PRODUCTION OUTPUTS

ASSEMBLY ANALYSIS



WORKS' ATION LOADING

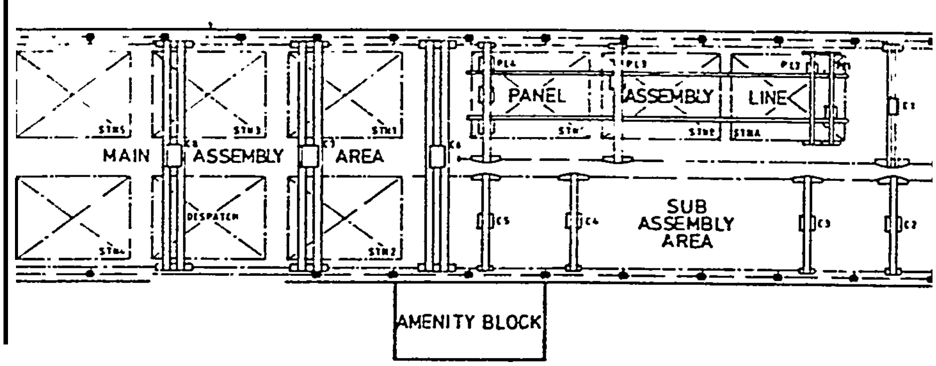
WORKSTATION PERFORMANCE RECORD		WORKSTATION ...... MINOR ASSEMBLY 2C										WEEK Nos.............. TO							
PARAMETER	AV/ TOTALS TODATE	WEEK No.		WEEK No.		WEEK No		WEEK No		AV FOR LAST 4 WEEKS	WEEK No		WEEK No		WEEK No		WEEK No		AV FOR LAST 4 WEEKS
PARAMETERS RECORDED MANHOURS PER METRE OF JOINT LENGTH		THIS WEEK	TO DATE	THIS WEEK	TO DATE	THIS WEEK	TO DATE	THIS WEEK	TO DATE		THIS WEEK	TO DATE	THIS WEEK	TO DATE	THIS WEEK	TO DATE	THIS WEEK	TO DATE	
PARTS COMPLETED		(a)																	
JL COMPLETED		(b)																	
PLATERS/STOWER ETC MHRS		(c)																	
MANHOURS PER M/JL																			

SHIPYARD NAME	CHAP	SECTION	SHEET No
FACILITY CAPABILITY DOCUMENTATION	REV	DATE	

WORKSTATION DEFINITION

NAME	SHEET 4 OF 5
OUTLINE DRAWINGS	

EQUIPMENT



3.1.6.3 Spatial Analysis

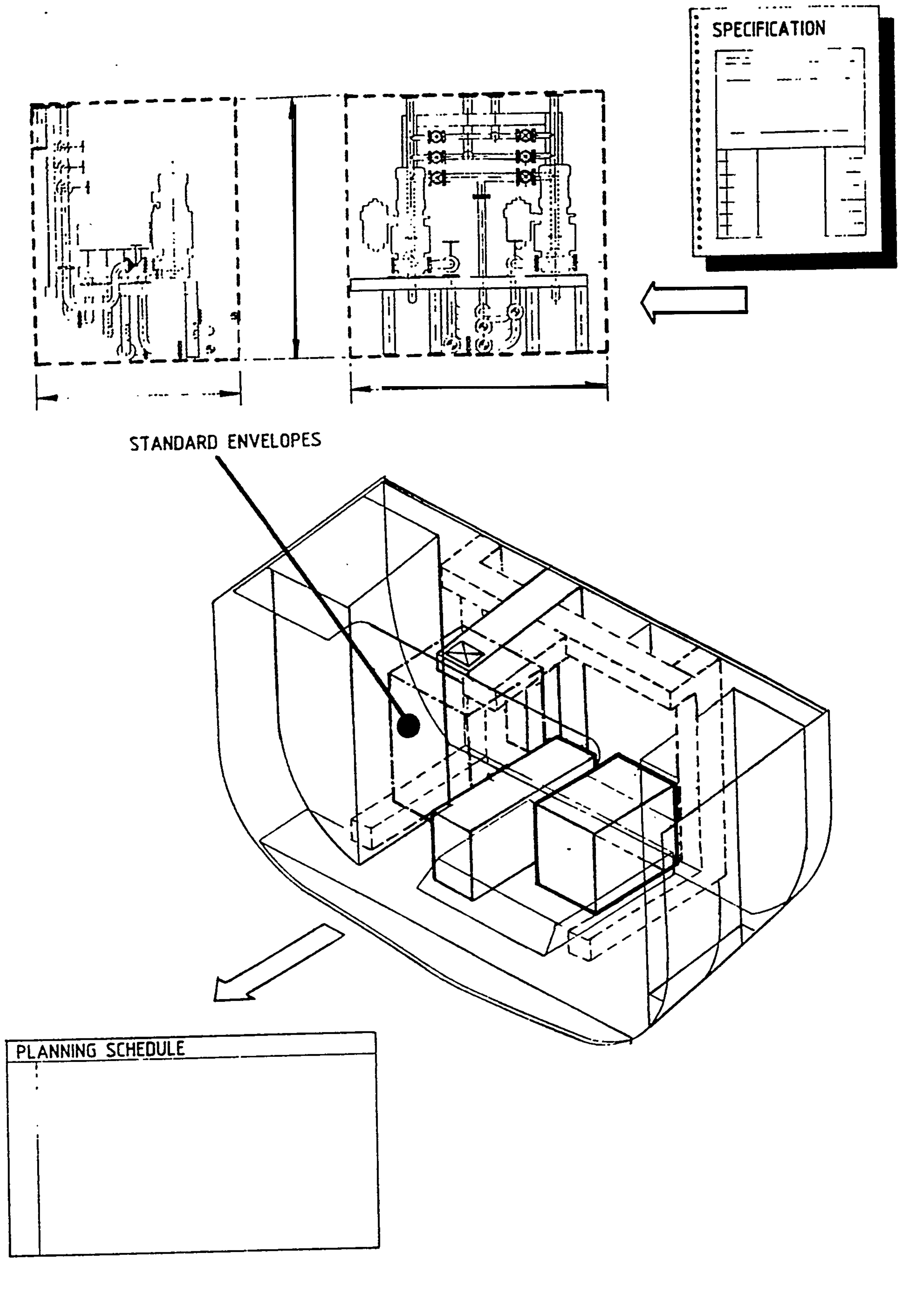
Process and spatial analysis are the basis for design/production integration.

Production engineers are involved in the definition of the block breakdown and the identification of planning units. Production engineers then carry out process analysis which further subdivides planning units to identify interim products and production and assembly processes. Process analysis leads to the development of standard interim products and standard production and assembly processes. Standard outfit assemblies make it possible to define standard envelopes for outfit assemblies.

Spatial analysis is a methodology for building up the complete ship design as a series of related functional spaces or spatial envelopes. At the contract and functional design levels the designer is able to develop the design by aqaregating standard envelopes to define, for example, the arranagement of a machinerv space,accmmodation block or cargo handling system on the upper deck. The desiqner need not necessarily know the details of the content of the envelope in order to define the arrangement. If the arranqem~nt is subject. to alteration this does not delay the lower levels of design as the details of what is contained within an envelope can be developed independentlv and in parallel. The size of each envelope is determined from standards or an analysis of outfit, assemblies. In the ideal situation the contents of the envelope will themselves be standard.

Spatial analysis first considers the function of different spaces on the vessel, and seperates them on this basis, as shown in the figure page 3-1/609. Each functional space can be defined within an envelope, which gives its overall dimensions, without internal detail.

Once the series of spaces have been defined, they are aggregated to build UP a picture of the whole vessel. Each spatial envelope includes not only the equipment, or structure within it, hut also operating space requirements, access ways, maintenance and withdrawal spaces.



DESIGN OUTPUTS

Spatial analysis is concerned with layout of a vessel. It must be integrated with hydrodynamic and other requirements defined by the naval architect, to ensure the ship will operate properly.

Benefits of the spatial analysis approach to the designer are:

ability to use standards,

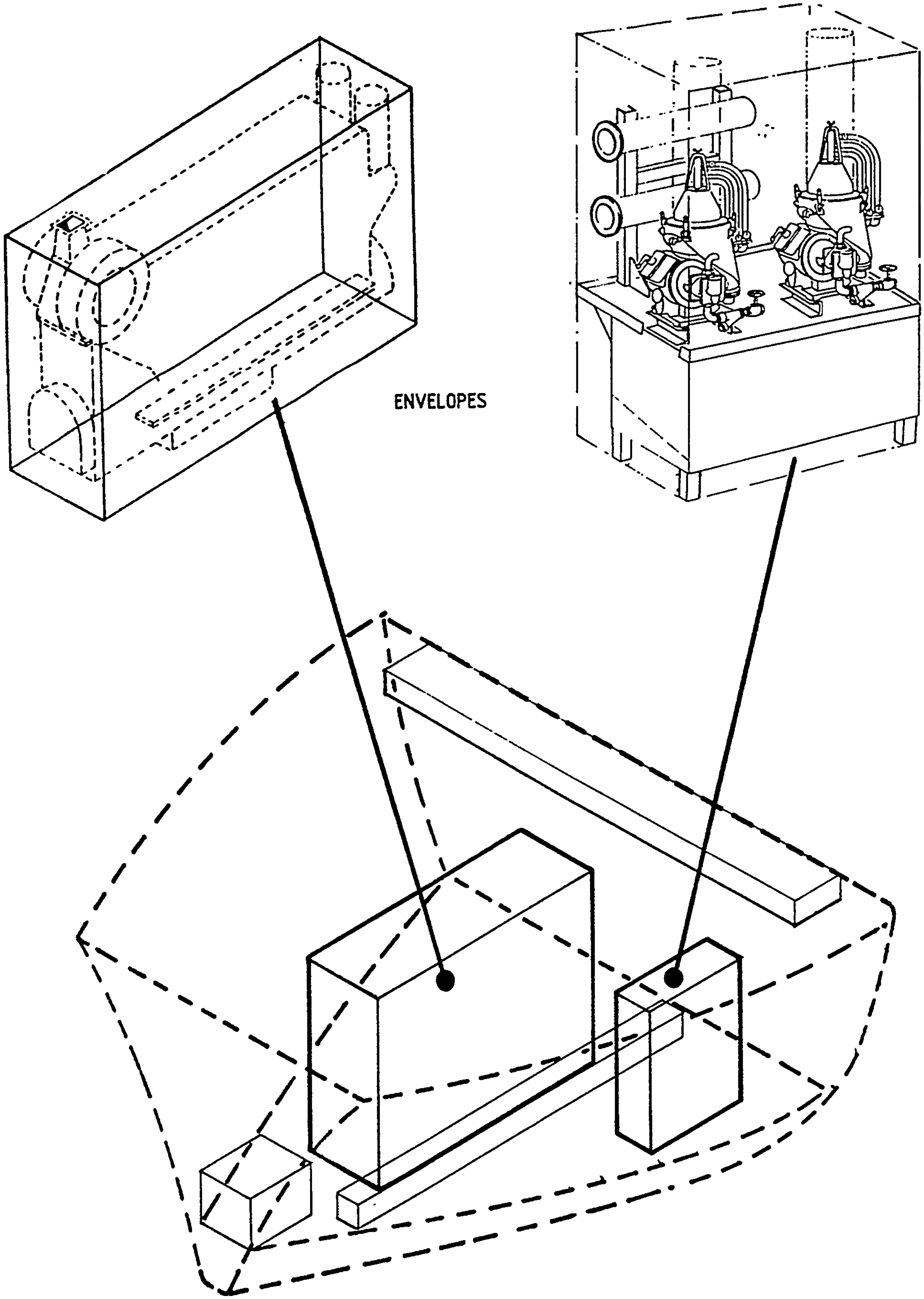
ability, after the analysis, to work independently on the detail design of the content of the envelopes.

For the producer:

incorporation of standards,

ability to relate design timetable to production requirements.

spatial analysis therefore is a technical function carried out principally at. the contract and functional design levels. The technique can of course he used at the conceptual design stage and could substantially reduce the time neded to produce the conceptual desiqn.


ENVELOPES

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VOLUME 3

THE APPLICATION OF PRODUCTION ENGINEERING

PART 2

SHIP GEOMETRY AND LAYOUT ENGINEERING

3.2 SHIP GEOMETRY AND LAYOUT ENGINEERING

Contents

3.2.1 HULL FORM

This chapter highlights the production advantages to be gained-from designing the hull form with as large a proportion of simple geometric shapes as possible. The shapes involved in defining a hull form are listed in order of the priority in which they should be incorporated into the hull envelope.

Certain areas of the under water and above water portion of the hull envelope are discussed and general points to be considered are noted.

CROSS-REFERENCES

3.1.3 Production Engineering Decisions

2.1.6 Impact of Facilities

2.2.1 Conceptual Design

2.2.2 Contract Design

2.2.3 Functional Design

2.3.1 Modern Ship Production Technology

3.2.1.1 Production Orientation

Consistent with technical and operational requirements, the aim of the designer should be to produce a hull form which is made up of as large a percentage as possible of simple shapes, so that the work reauired to produce the structure forming the envelope of the hull will be minimized.

The shapes to be used, in order of priority are:

Straight lines or flat surfaces.

Surfaces having a mathematically defined curvature in a single plane only.

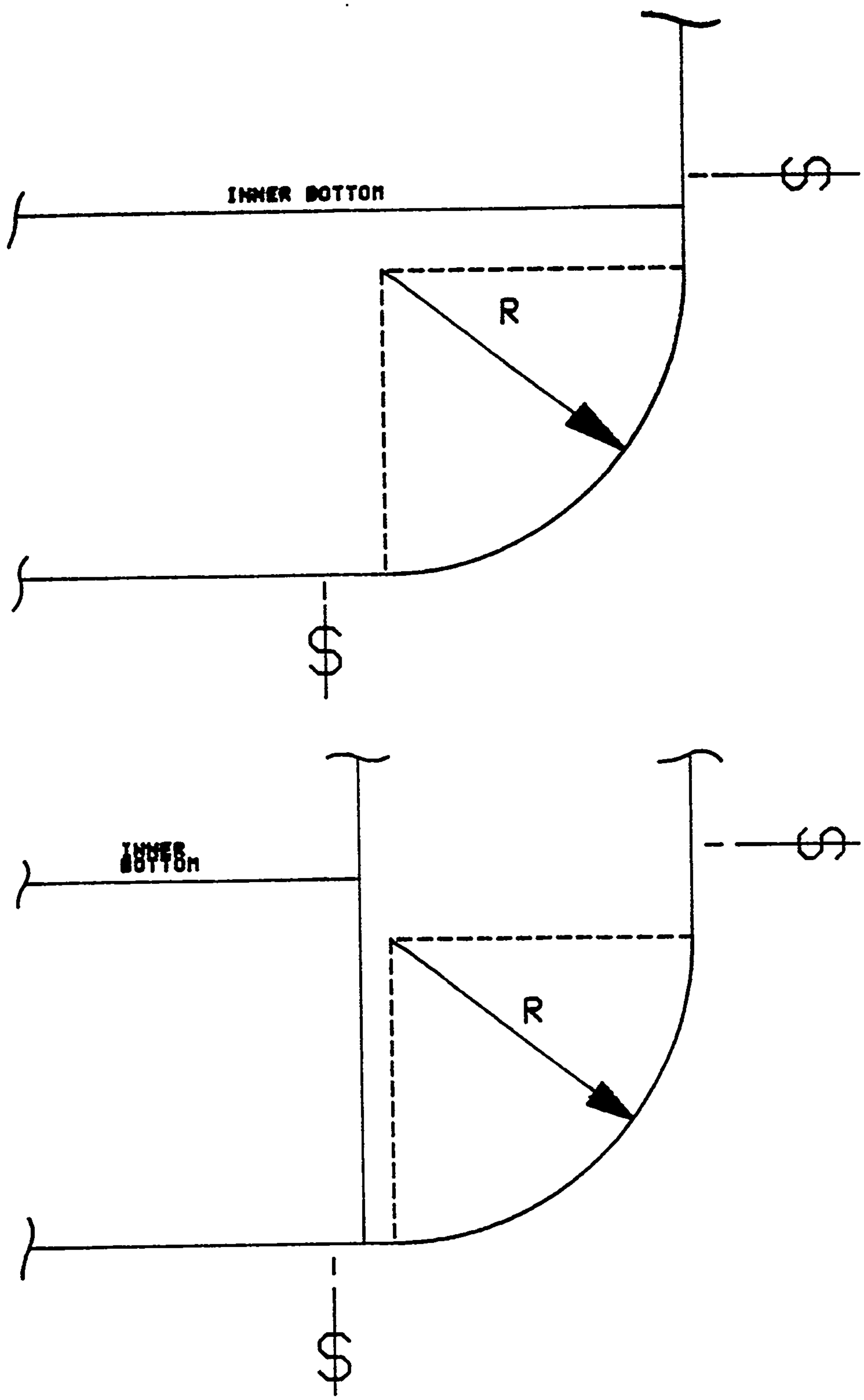
Surfaces having a non-mathematically defined curvature in a single plane only.

Surfaces having mathematically defined curvature in two planes.

Surfaces having non-mathematically defined curvature in two planes.

Not only is the work of physically producing the hull envelope reduced by applying the higher priority shapes but also is the effort required to produce the technical information necessarv to build the vessel. lt is self-evident that drawing a straight line and reasuring along it, or from it, is much quicker and simpler than performing the same operations on curved lines. Also, where curved surfaces are involved then curvature, frame curvature and sets and jig heights all have to be specified. Simple curvature clearly simplifies the process.

A simple hull envelope will alse lead to simpler interfaces between the internal structure and the outer envelope.



BILGE RADIUS

The scope for applying simple shapes to the underwater portion of a ship's hull is more restricted than the above water portion due to the possible detrimental effect upon the resistance and propulsion characteristics.

The hull form will be considered from the earliest design stages. At the conceptual design stage the lines will not be considered in any detail. The key characteristics of the hull in terms of form coefficients will be developed along with initial power and speed calculations. The lines will be developed fully at the contract design stage.

It is very difficult to quantify the effects of simplifying the underwater hull form. However, the following areas should be considered:

- bilge radius,
- parallel mid-body,
- knuckles,
- rise of floor,
- fore end,
- aft end,

These areas are considered in the following sections.

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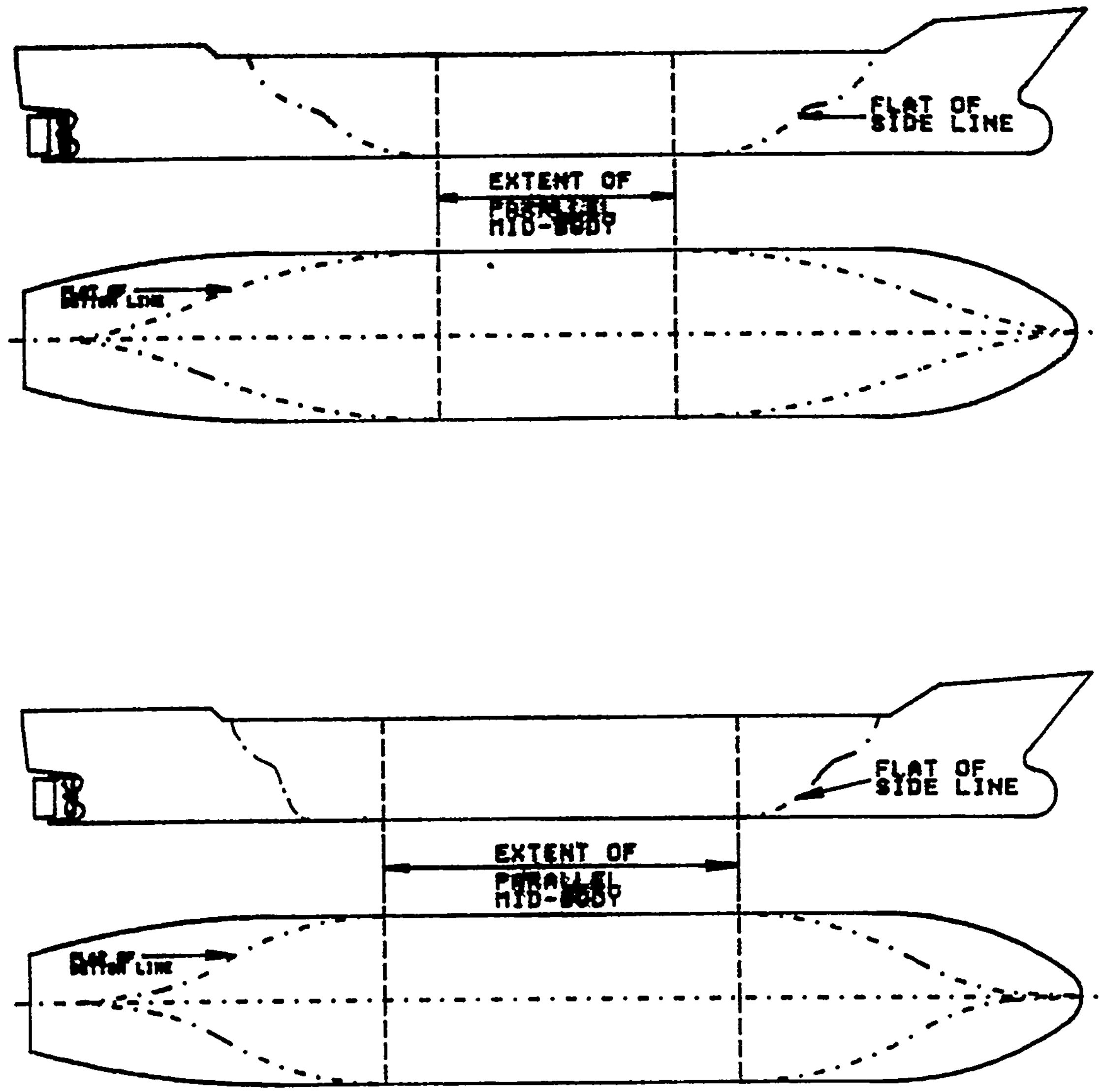
3.2.1.2 Bilge Radius

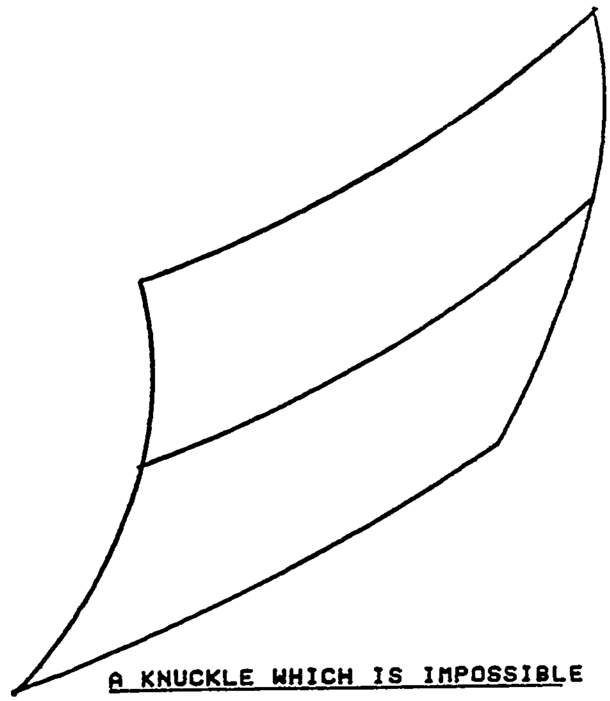
Increasing the bilge radius will extend the length of parallel mid-body. It will usually reduce the resistance of the hull but probably adversely effect the rolling characteristics.

From a production point of view, the center of the bilge radius should lie below the level of adjacent horizontal surfaces, such as the inner bottom and within any wing compartment. The seams of bilge plating should lie above the level of adjacent horizontal surfaces and, if possible, inboard of the boundary to a wing compartment and certainly clear of the curved portion. If possible, the bilge plating should be formed b.y a single plate in the athwartship direction.

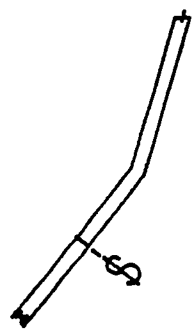
The figure page 3-2/105 illustrates the position of the bilge radius below internal structure.



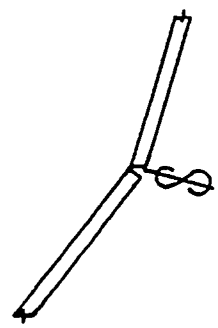
PARALLEL MID-BODY AND
FLAT OF BOTTOM & SIDES



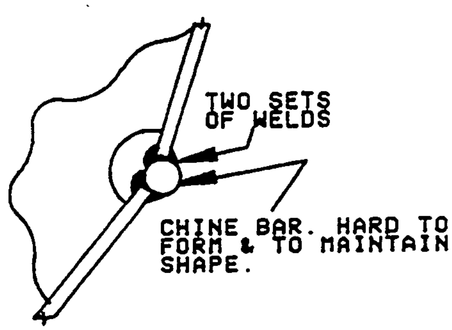
A KNUCKLE WHICH IS IMPOSSIBLE TO PRODUCE



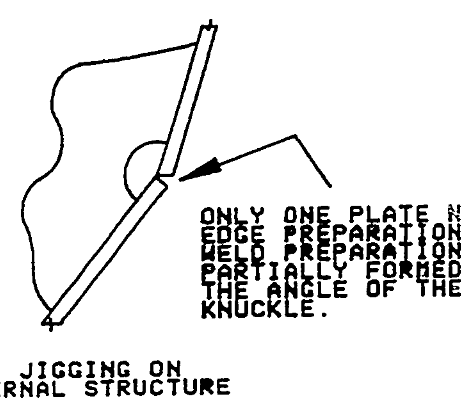
DIFFICULT TO PRODUCE



NATURAL KNUCKLE POSITION



CHINE BAR



NO CHINE BAR

KNUCKLES

3.2.1.3 Parallel Mid-Body

The figure page 3-2/107 shows how the parallel midbody length can be increased in order to increase the number of identical elements within the midship portion of the ship. Care must be taken that the shoulders formed at the ends of the parallel mid-body do not become too "hard" and cause hydrodynamic problems. If the angle of run into the propeller is too steep, then flow separation can occur which will drastically reduce propulsive efficiency.

INTEGRATED HIERARCHY OF DOCUMENTATION

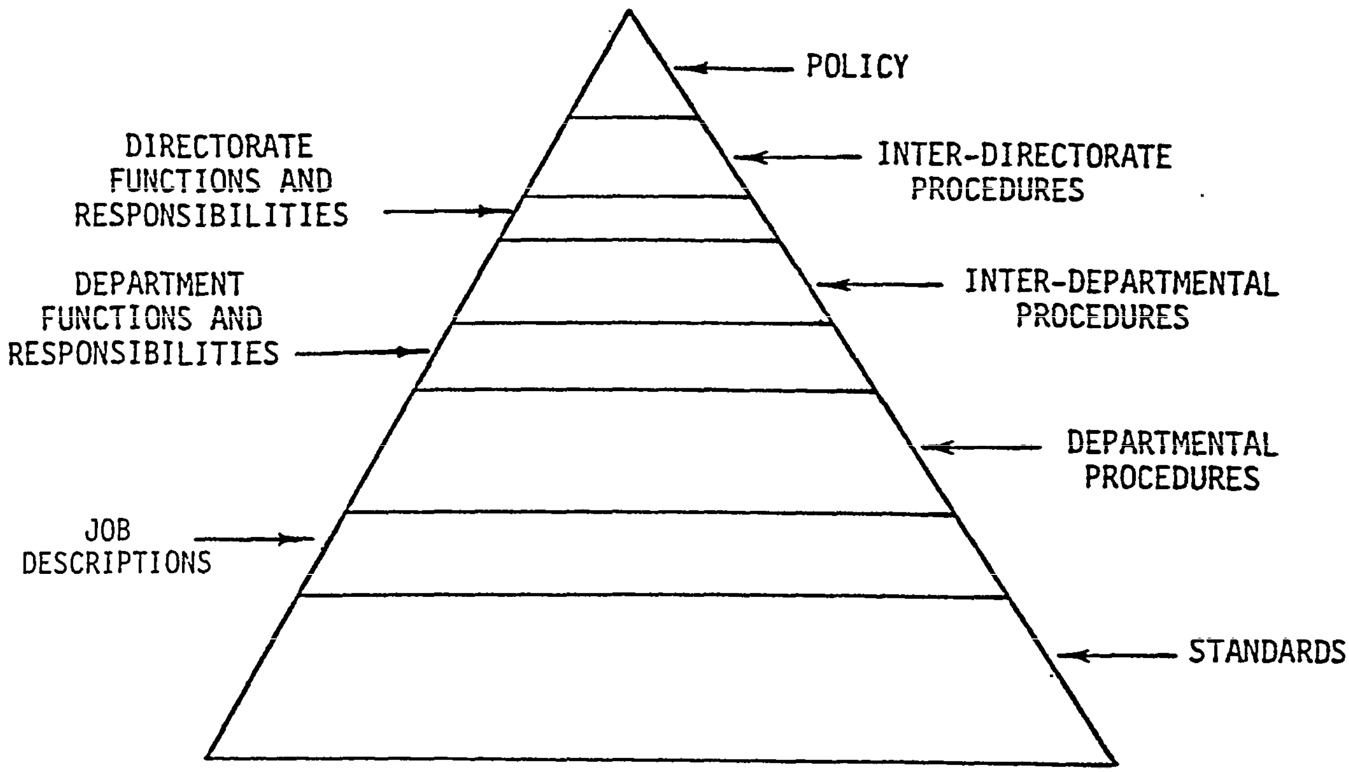


FIGURE 1-1

3.2.1.4 Knuckles

In order to reduce the number of curved plates, knuckles can be introduced.

The following points should be noted with regard to knuckles:

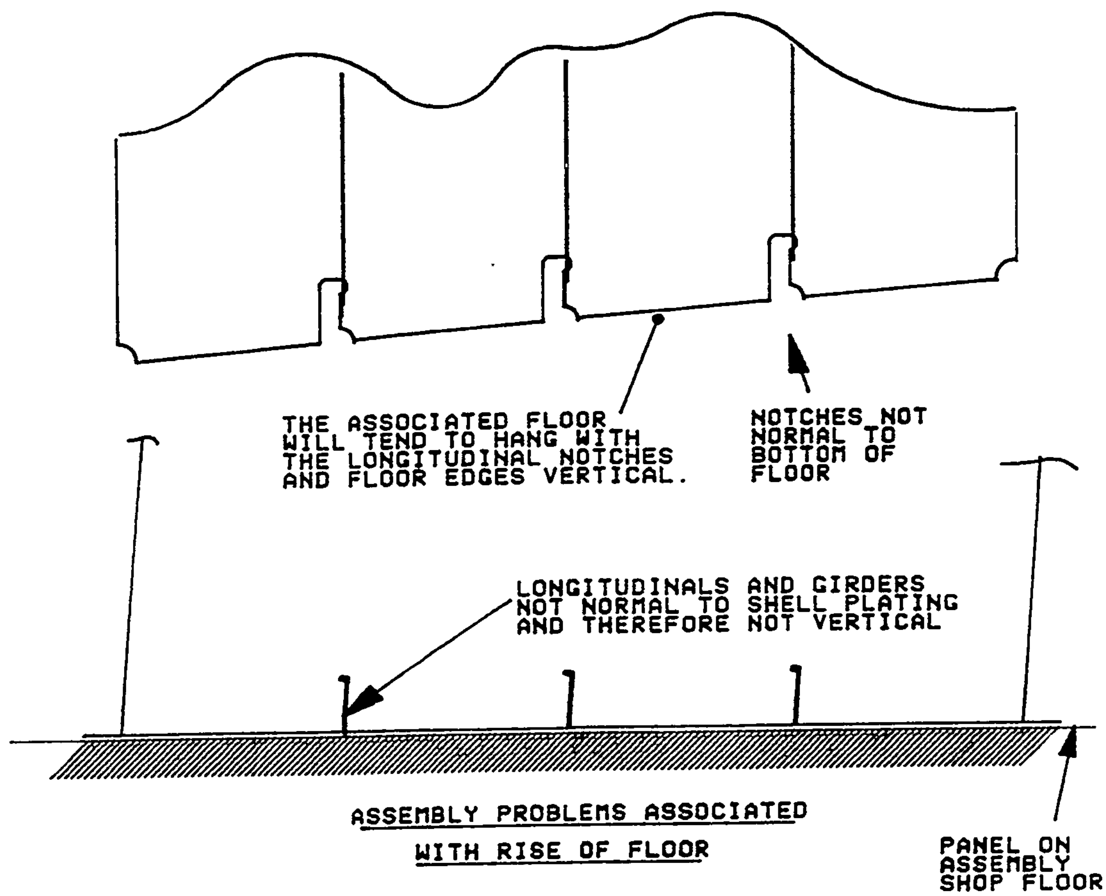
They should coincide with a seam in the plating.

Chine bars should not be fitted as they increase the complexity of assembly operations and the joint length.

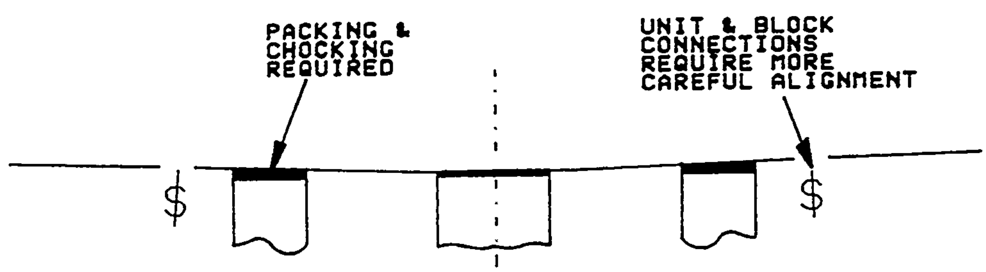
The upper illustration page 3-2/109 shows a knuckle with curvature in two dimensions which is extremely difficult to produce.

In the middle illustration, the left hand version, where the knuckle does not coincide with the seam can not be produced unless the knuckle is straight. Even in that case, the accuracy required from the forming process will be hard to achieve.

The lower illustration shows the problems associated with a chine bar. The increased volume of welding required is clearly shown. Physically forming the bar to a sufficient accuracy and supporting it in the correct location during assembly are also time-consuming. The bar does not confer any production advantage in terms of maintaining shape since without the bar the internal structure provides sufficient guidance.



ASSEMBLY PROBLEMS ASSOCIATED WITH RISE OF FLOOR



THE FAIRING BETWEEN ADJACENT SECTIONS OF THE BOTTOM STRUCTURE IS MADE MORE COMPLEX.

CONSTRUCTION PROBLEMS ASSOCIATED WITH RISE OF FLOOR

RISE OF FLOOR

3.2.1.5 Rise of Floor

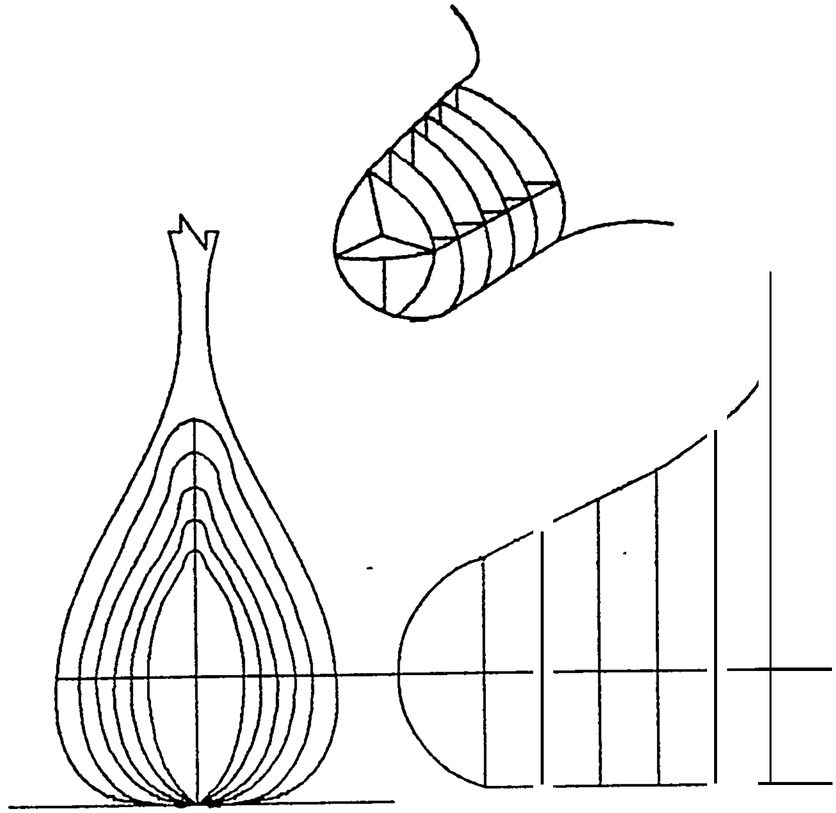
Rise of floor is useful for providing liquid flow to suctions located near the centerline of the ship but is not essential for this purpose.

Unless absolutely necessary to achieve a low midship section area coefficient for fine form ships, rise of floor should be eliminated.

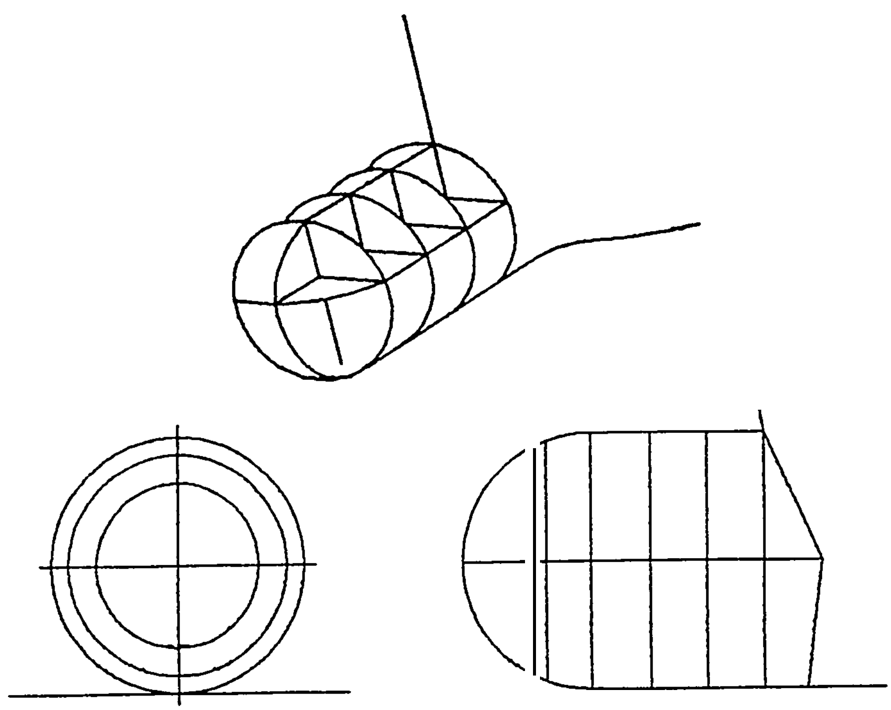
The upper illustration shows the problems at the assembly stage. where rise of floor is necessary from a design, consideration, it’is common to arrange the bottom stiffeners vertically. During assembly of the shell panel, the stiffeners therefore have to be supported at an angle to the vertical, which requires more time or equipment. The floor which is fitted cannot be dropped directly into position and problems can be created, especially where both longitudinal and transverse girders are fitted.

It is preferable to arrange the stiffeners normal to the plating.

The lower illustration shows the need for packing in settling up the bottom with rise of floor. It is inherently mere difficult to maintain accuracy.

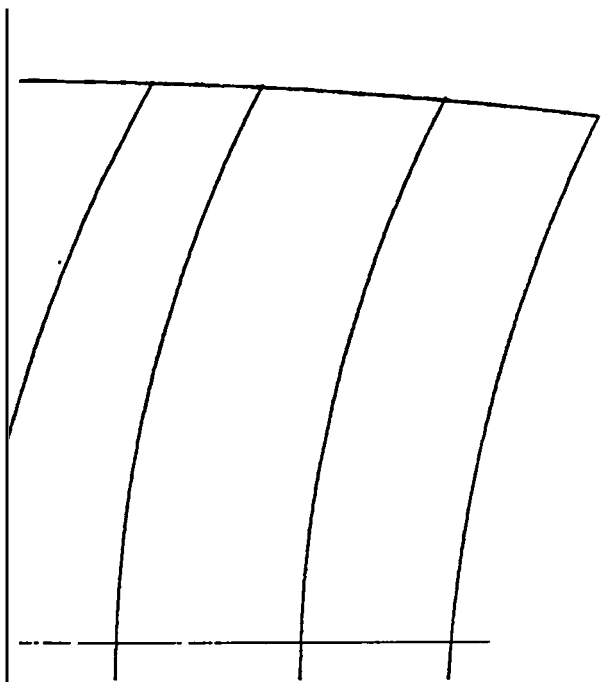


COMPLEX SHAPES

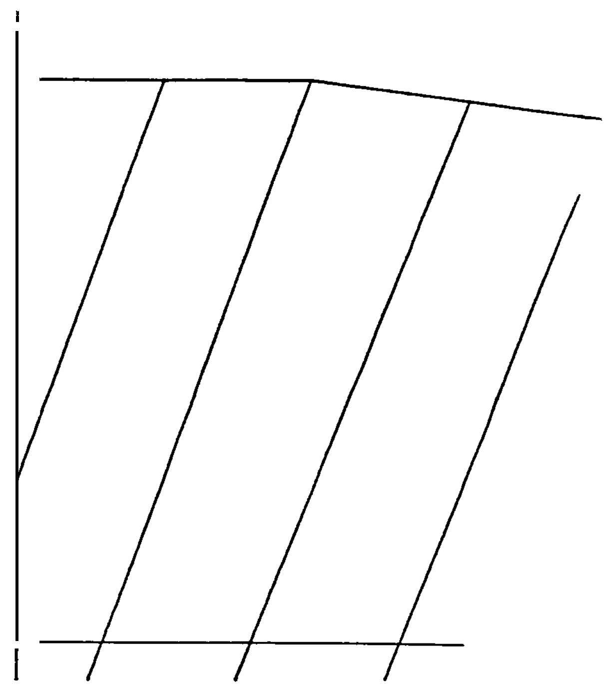


STANDARD SHAPES
SIMPLE FORM

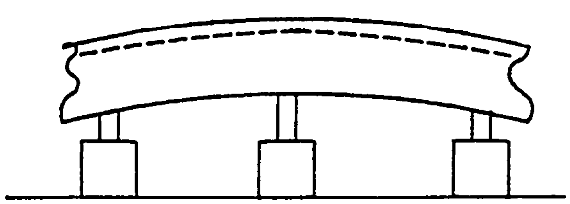
BOW SHAPES



FORWARD ABOVE-WATER
BODY SECTIONS

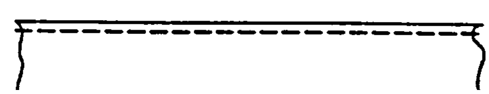


ALTERNATIVE ABOVE-WATER
BODY SECTIONS



PLATES REQUIRE FORMING.
FRAMES REQUIRE BENDING.
JIG REQUIRED TO ENSURE
CORRECT CURVATURE.
INCREASED LEVEL OF TECHNICAL
INFORMATION REQUIRED TO DEFINE:
PLATE CURVATURE,
FRAME CURVATURES & SETS,
JIG HEIGHTS.

THIS IS BETTER



FLAT PANELS POSSIBLE.
SINGLE CURVATURE PROBABLE.

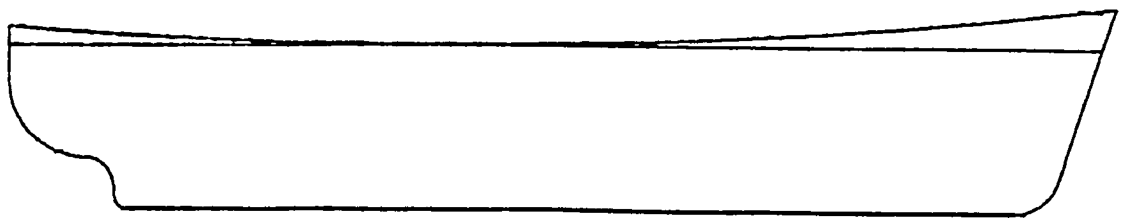
REDUCING CURVATURE ON ABOVE WATER HULL FORM

3.2.1.6 Bow and Stern

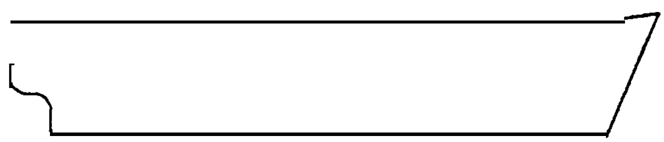
A forward end without a bulbous bow can be considerably easier to produce than one with a bulbous form but often hydrodymanic considerations will determine whether a bulb is to be fitted or not. If a bulbous bow is to be fitted, construction can be made easier by producing it from easily developed and formed geometric shapes such as part cones or cylinders.

In non-bulbous fore ends, care should be taken that the form does not become too narrow at the extreme end for the easy access of personnel during construction.

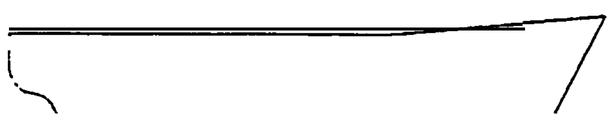
Time spent on designing the stern form can produce significant reductions in the curvature without incurring hydrodynamic penalties. Computer aided design and drafting aids are useful, as the process usually requires several iterations to achieve the desired results. Jf CAD/CAM systems are not available, the task Must. be carried out manually. Because of the time and resource requirments it is not always possible to carry out as many iterations as would be possible with a CA1l/CAM system.



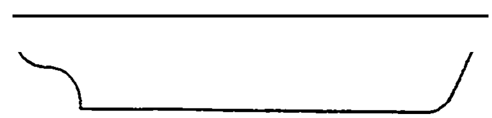
DECK



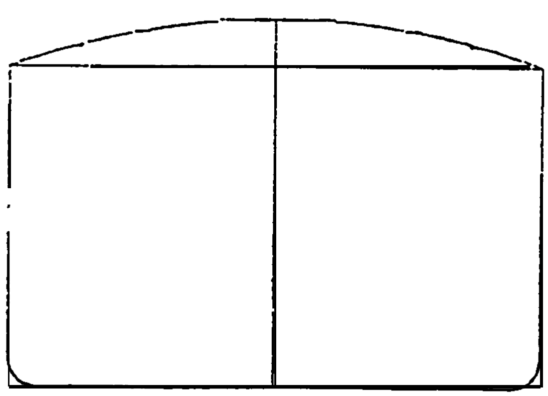
CURVED SHEER



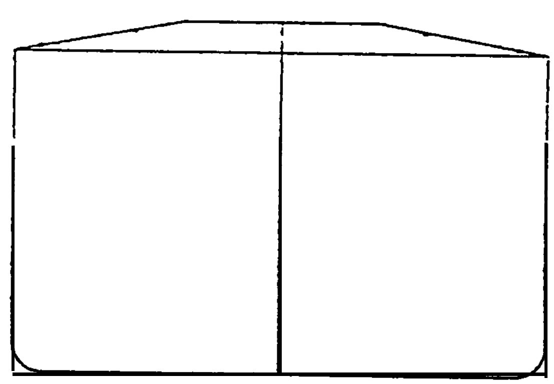
KNUCKLE SHEER



NO SHEER



PARABOLIC CAMBER



STRAIGHT CAMBER

3.2.1.7 Above Water Curvature

Design time spent on the above water form removing as much curvature as possible can be repaid many times over durina production of the hull structure.

Items which need to be considered when attempting to reduce the amount of curvature are:

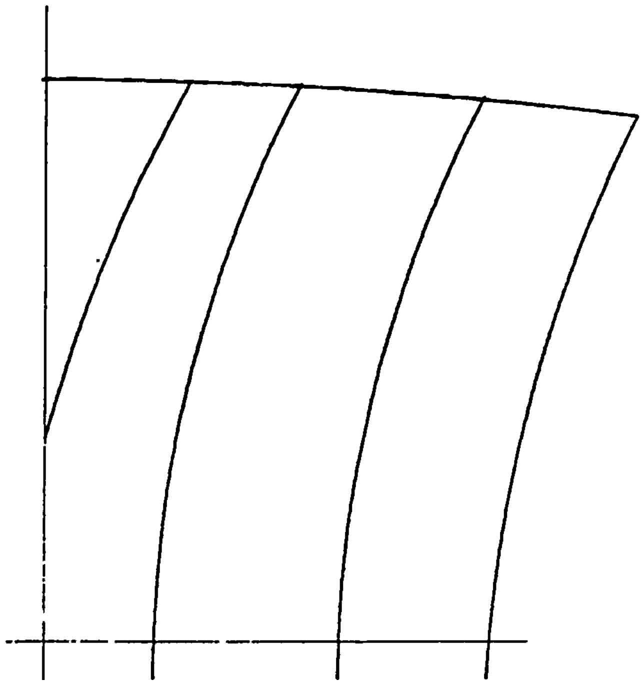
ii Flare

A certain amount of flare is required at the forward end in order to eliminate deck wetness. The amount of flare required will depend upon the vesssel 's service, its speed, how fine it is and whether it has a forecastle or not.

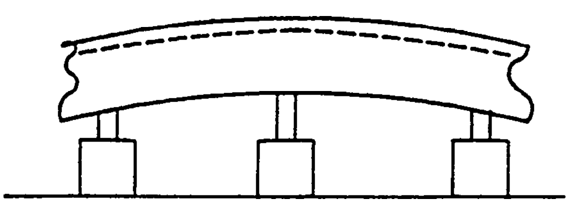
Flare also provides additional deck area for mooring purposes, etc.

ii) Cargo Stowage

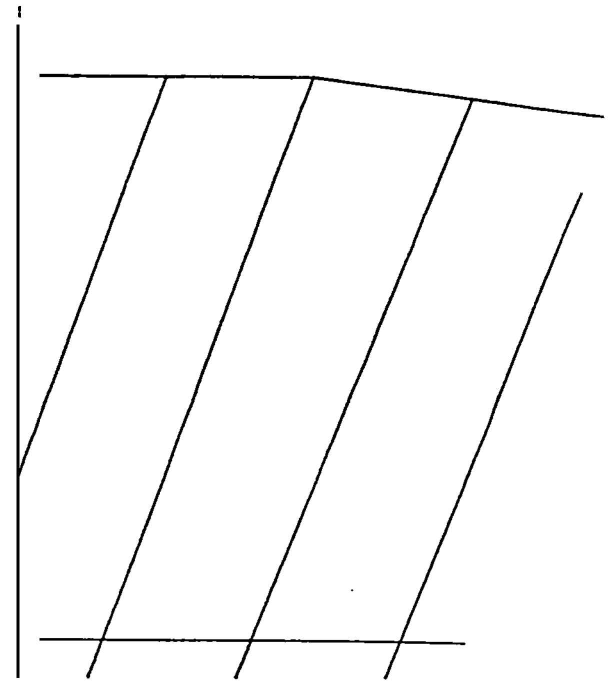
Flattening and straihtening the hull envelope will have a beneficial effect on the stowage of carqoes and other items within the hull.



FORWARD ABOVE-WATER
BODY SECTIONS

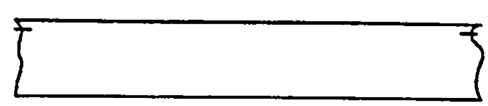


PLATES REQUIRE FORMING.
FRAMES REQUIRE BENDING.
JIG REQUIRED TO ENSURE
CORRECT CURVATURE.
INCREASED LEVEL OF TECHNICAL
INFORMATION REQUIRED TO DEFINE:
PLATE CURVATURE,
FRAME CURVATURES & SETS,
JIG HEIGHTS.



ALTERNATIVE ABOVE-WATER
BODY SECTIONS

THIS IS BETTER



FLAT PANELS POSSIBLE.
SINGLE CURVATURE PROBABLE.

REDUCING CURVATURE ON ABOVE WATER HULL FORM

iii) Sheer

In most instances, sheer can be completely eliminated from ships and all decks can be made parallel to the base line.

If sheer forward is considered necessary, it can be arranged on the forecastle deck only and be of the straight line form.

iv) Camber

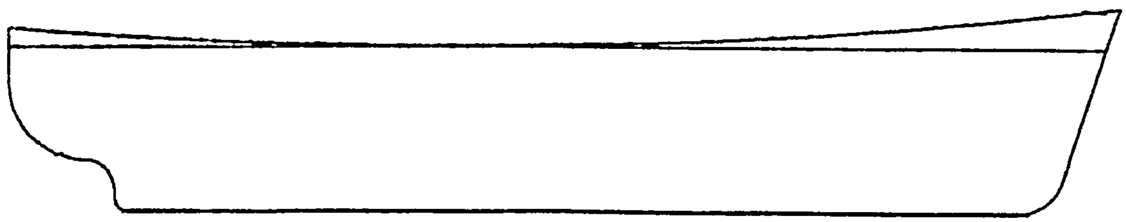
There are a number of different opinions relating to the usefulness of camber. From a production point of view it should be eliminated.

If it is to be fitted, then it should be in the form of three straight. lines with the center portion being horizontal.

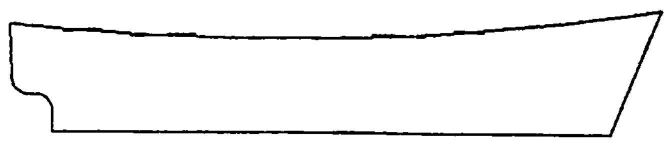
In the case of Ships with hatches, so that they sit on a flat horizontal surface, the camber knuckle should be arranged outboard of the hatchway. The side umit lengths are independent of hatchways and the deck between hatches can be erected with the transverse bulkhead. In ships with wide hatchways, the decks outboard of the coamings are not usually of sufficient breadth to make the accumulation of water a problem and camber is not necessary.

v) Stern

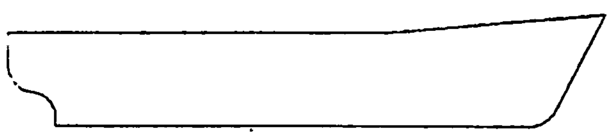
If possible, the stern should be arranged as a vertical flat transom type with areas of flat or nearly flat plating leading into the transom.



DECK

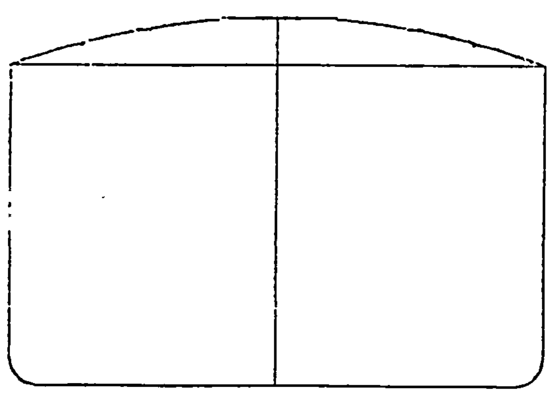


CURVED SHEER

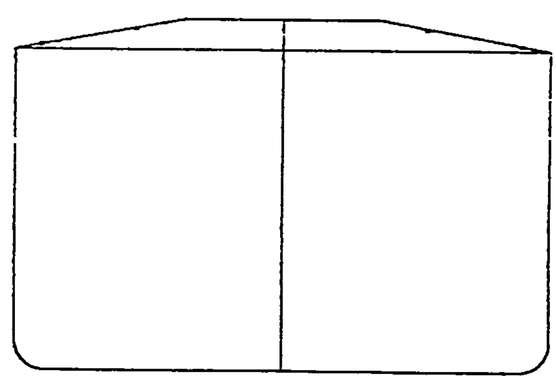


KNUCKLE SHEER

NO SHEER



PARABOLIC CAMBER



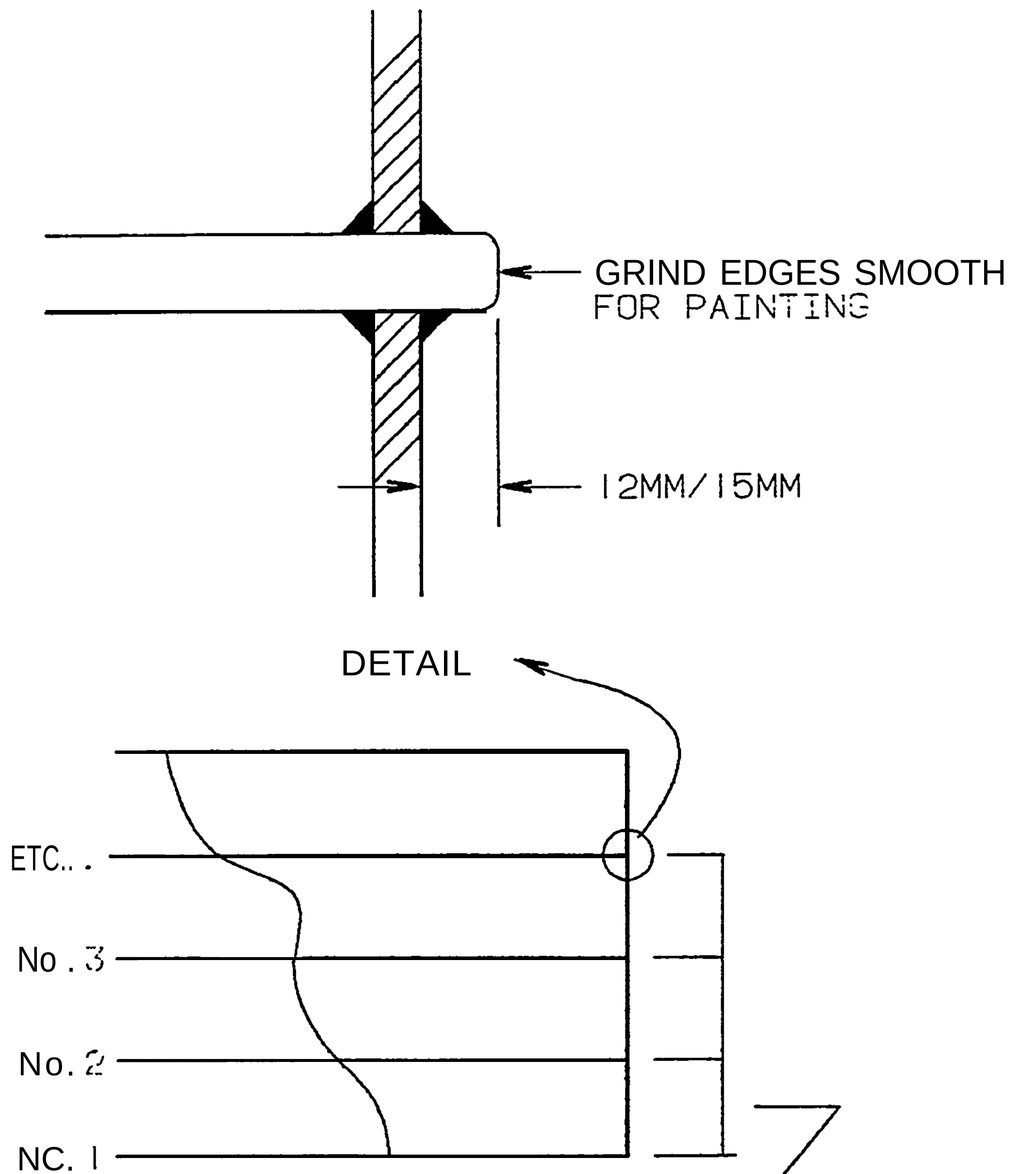
STRAIGHT CAMBER

vi) Deckhouses/Superstructure

Although not strictly hull envelope, the aim of using only single shapes should be applied also to the deckhouses. This is an area where all of the plating can be in the form of flat panels without any great penalties in performance.

in addition to the benefits gained in producing the steelwork panels, there will be substantial gains in the outfitting of the deckhouses.

DEKHOUSE ASSEMBLY DETAILS



STD DIMENSION 2700 MIN - 3000

NO CAMBER ON DECKS. ONLY ON NAV. BRIDGE WINGS

DECKS TO BE THROUGH GOING - INTERNAL BULKHEADS SUGGESTED

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3.2.2 INTERNAL SURFACES AND SPACES

The uses to which internal. surfaces and spaces within a hull form are put is discussed in this chapter and the need to keep the number of surfaces to a minimum consistent with the vessel's service is stressed.

The importance of the continuity of internal surfaces both from a structural point of view and for production are indicated. Methods of achieving continuity are discussed for various parts of a ship's structure.

CROSS-REFEIRENCES

3.1.4 Standard Approach to Ship Construction

3.1.5 The Need for Dwelopment of Interim Product and Production Process Standards

3.2.2.1 Principles

The minimum number of platforms and bulkheads compatible with the service of the ship should be arranged within the hull.

When determining the number and position of platforms and bulkheads, the following aspects need to be considered:

Separation of commodities/services/machinery/accommodation.

Provision of watertight subdivision.

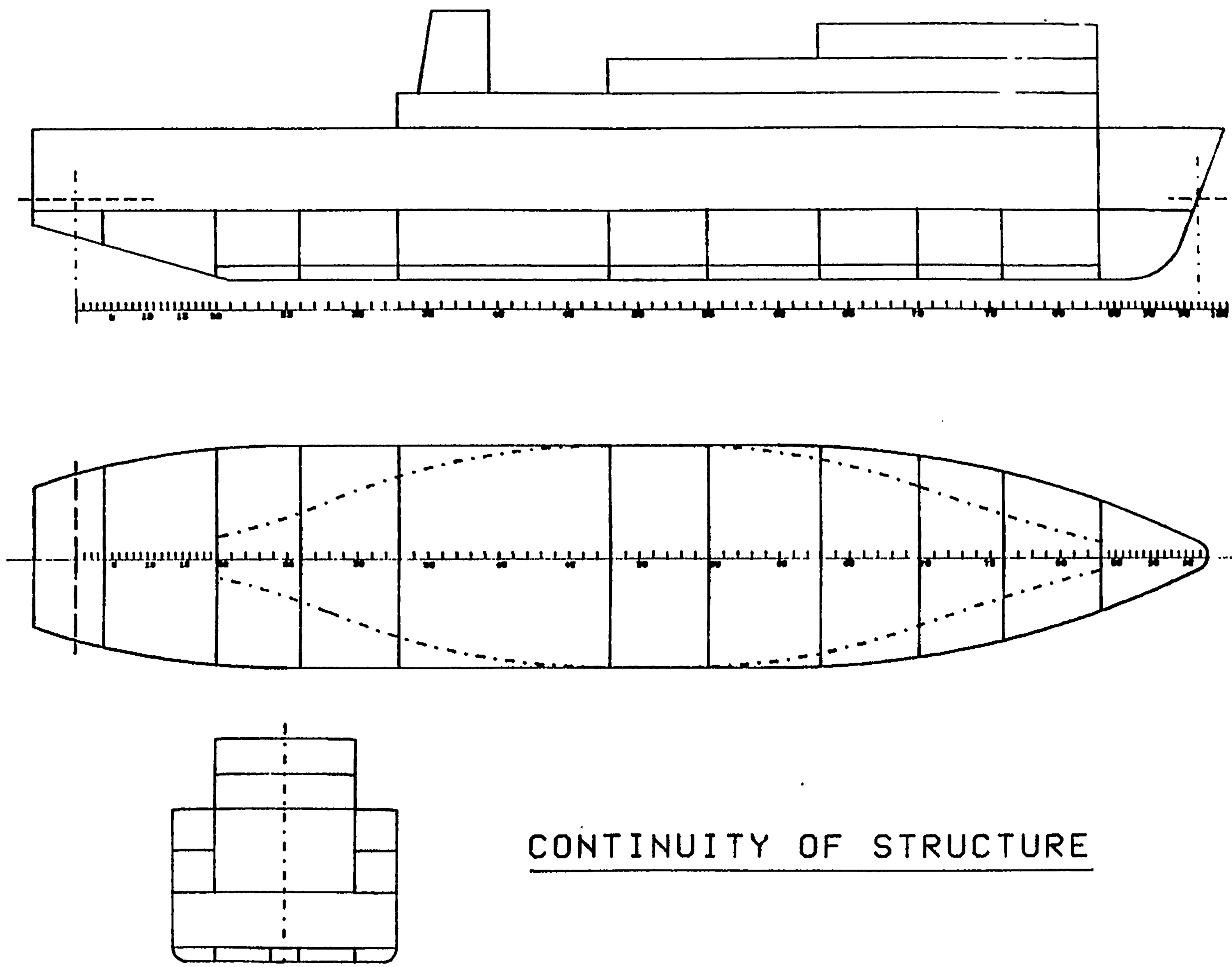
Provision of structural strength.

Provision of fire barriers.

Support for items of equipment.

It is desirable both from a structural and producibility point of view that internal surfaces within the hull should be continuous wherever possible and that thev should lie within the principal planes. Structural discontinuity leads to the need for local compensation and hence increased complexity which leads in turn to additional material having to be fitted in a piecemeal fashion. It is also structurally less efficient.

Areas where structural discontinuities often occur are discussed in following sections.



CONTINUITY OF STRUCTURE

3.2.2.2 Inner Bottom Height

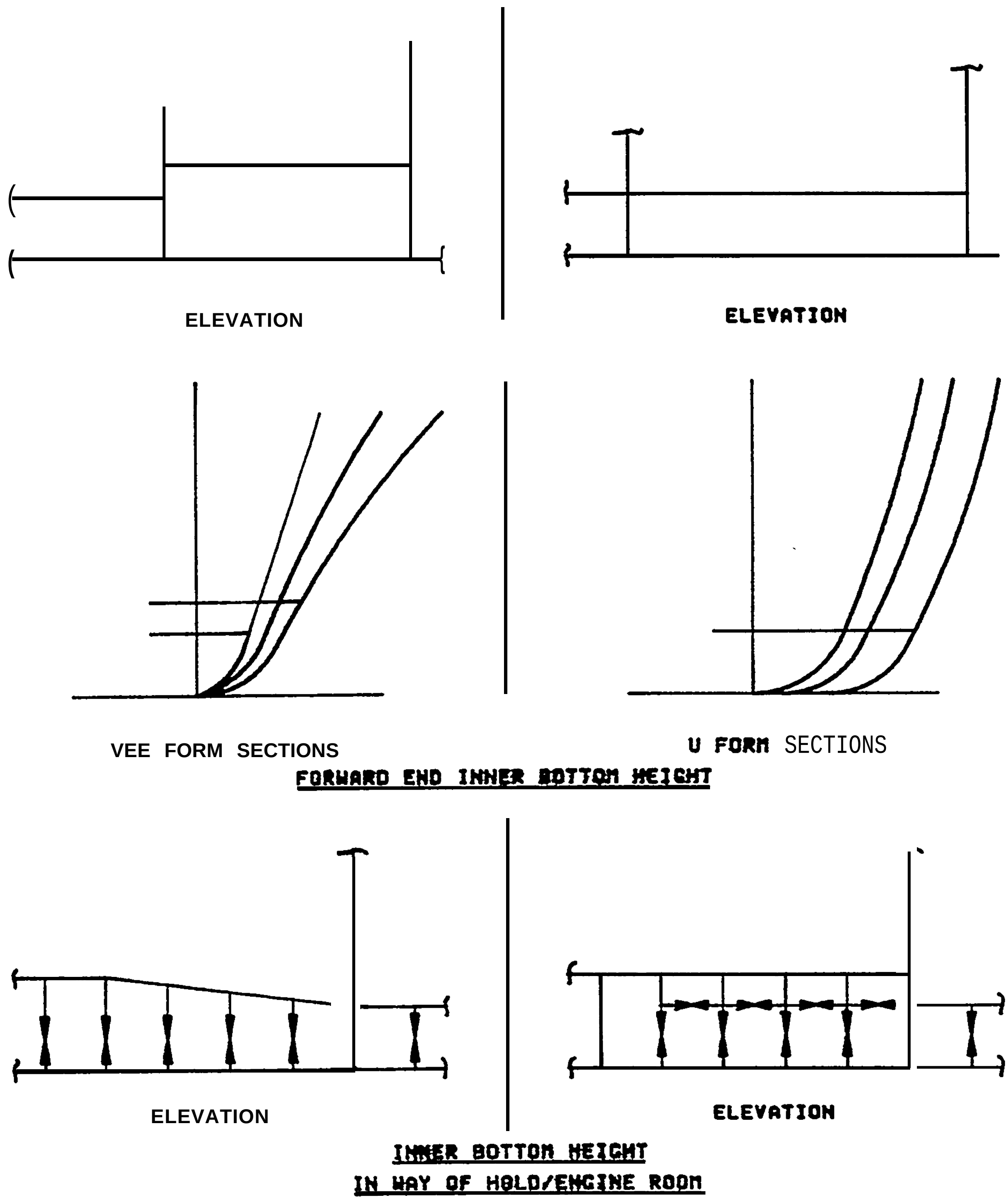
It is quite common in finer ships to find that the height of the inner bottom in the forward hold has been raised to provide a platform having reasonable width for cargo loading. This is shown in the upper part of the illustration page 3-2/205. The increased width of the carqo loading arm will provide increased utilization of the available hold volume.

The need to raise the height of the inner bottom can sometimes be avoided if ‘U’ shaped sections are incorporated forward, in preference to ‘V’ shaped sections.

The height of the inner bottom in the hold area of a ship is normally made as low as possible to reduce material quantities for double bottom structure and for stability reasons. The height of the inner bottom within the engine room is determined b.y the minimum heiqht required by the prime mover or by the required height of shaft centerline to accommodate the propeller.

It is unusual that the most desirable heights for both the engine room inner bottom and the hold inner bottom, would coincide. The usual manner in which the two different heights are accommodated is by allowing the heights to change over a number of frame spaces. In order to maintain horizontal surfaces, a method of scarfinq the structures by continuing the lower height some way under the higher mav be worth considering. This is shown in the lower part of the illustration opposite.

There are trade-offs to be considered by the designers and production engineers at the conceptual and contract design stages. An increased double bottom height provides better access during construction. A reduced double bottom heiqht has poorer access but is structurally more efficient. Consideration of this kind of trade-off would logically lead to the possible use of robots for internal double bottom welding. This would allow minimum height double bottoms to be adopted as standard.

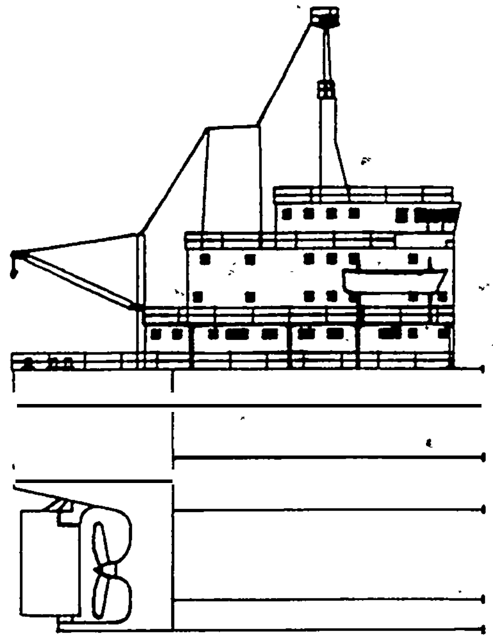


CHANGES IN INNER BOTTOM HEIGHT

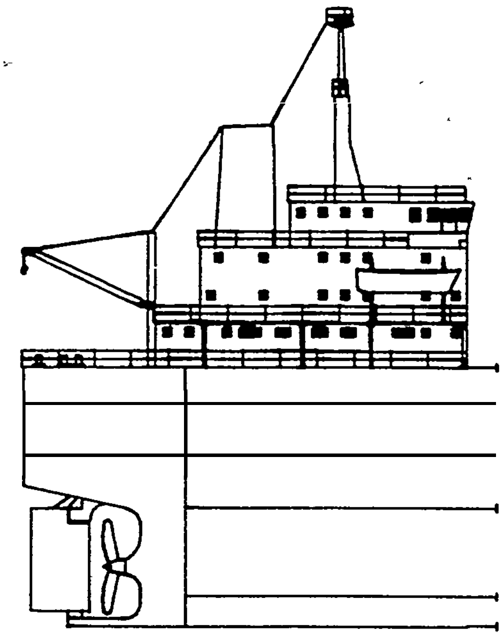
3.2.2.3 Deck and Flats

If possible the steering gear flat should be aligned with an engine room flat or with a deck if the engine room is not situated aft. As the steering gear flat can be repositioned *more easily* than a deck or engine room flat, in the event of a non-alignment, changing the height of this flat should be considered.

Ideally, the engine room flats should be aligned with any decks fitted outside of the engine room. In this instance, it may be easier to reposition engine room flats than decks which are sited to suit the operational requirements of the ship.

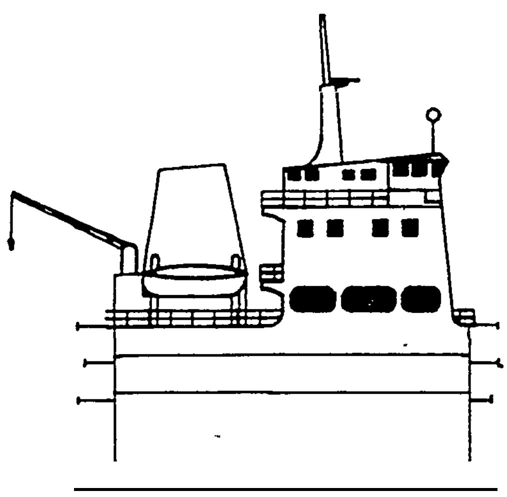


NON ALIGNED

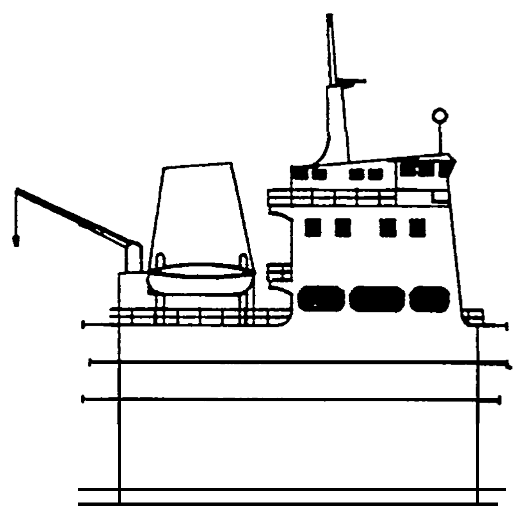


ALIGNED

ALIGNMENT OF STEERING GEAR
AND ENGINE ROOM FLAT



NON ALIGNED



ALIGNED

ALIGNMENT OF STEERING GEAR
AND ENGINE ROOM FLATS

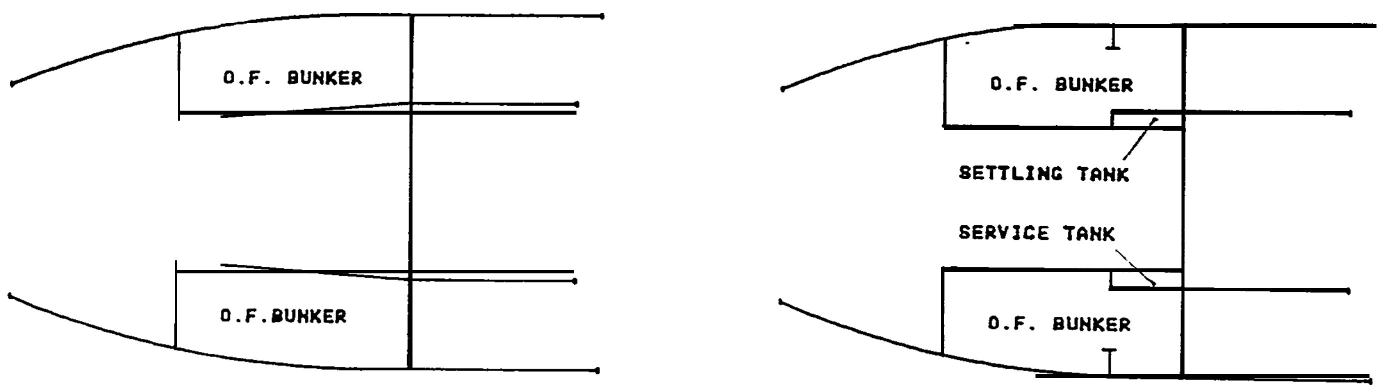
DECKS AND FLATS

3.2.2.4 Longitudinal Bulkheads

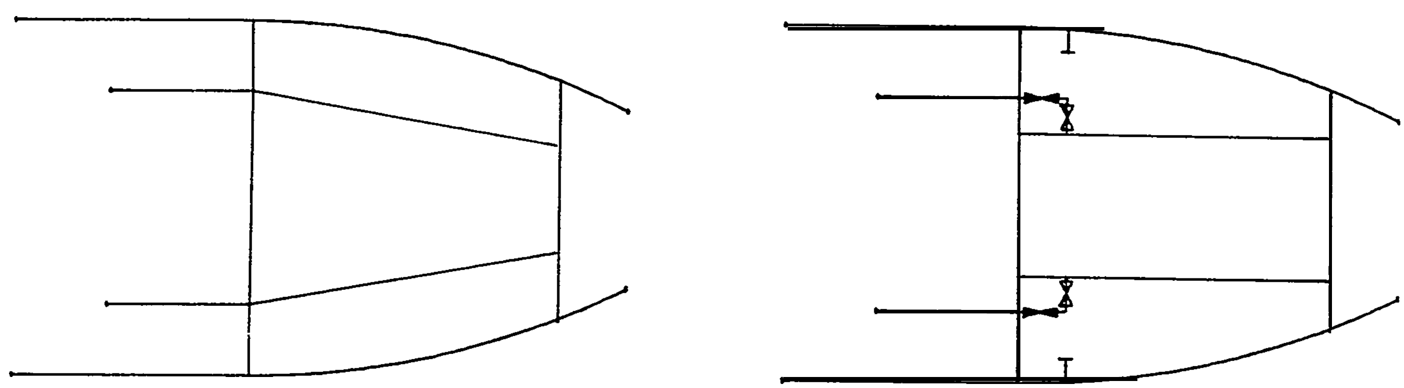
When lonqitudinal bulkheads are extended into aft end engine rooms or forward carqo spaces, they often have to be cranked to form sensible sized side compartments in those regions. A design for production objective is to eliminate the crank in the longitudinal bulkhead if at all nossible. The crank may be unavoidable if it is necessary to minimize the amount of, segregated ballast in a tanker.

TcI maintain the bulkheads in the plane parallel to the centerline, consideration should be given to allowing the bulkheads to run alongside other longitudinal bulkheads for a short distance. This allows all of the transverse structure on either side of the bulkhead to be normal to the bulkhead.

The alternatives discussed as shown in the illustration page 3-2/209.



IN WAY OF AFT ENGINE ROOM



IN WAY OF FORWARD TANKS

NOTE THAT EXTENDED LONGITUDINAL
BULKHEADS TERMINATE ON MAIN
TRANSVERSE RING STRUCTURES

LONGITUDINAL BULKHEADS

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3.2.3 FUNCTIONAL SEPARATION OF SPACES

The adoption of a spatial analysis approach to the allocation of spaces within a ship is discussed in this chapter as is the way in which this analysis leads to a division of spaces into functional entities.

Drawings are included which indicate how the approach is applied to a complete vessel, to the engine room of a ship and to deckhouses.

CROSS-REFERENCES

3.1.7 Process and Spatial Analysis

2.2.1 Conceptual Design

2.2.2 Contract Design

2.2.4 Transition Design

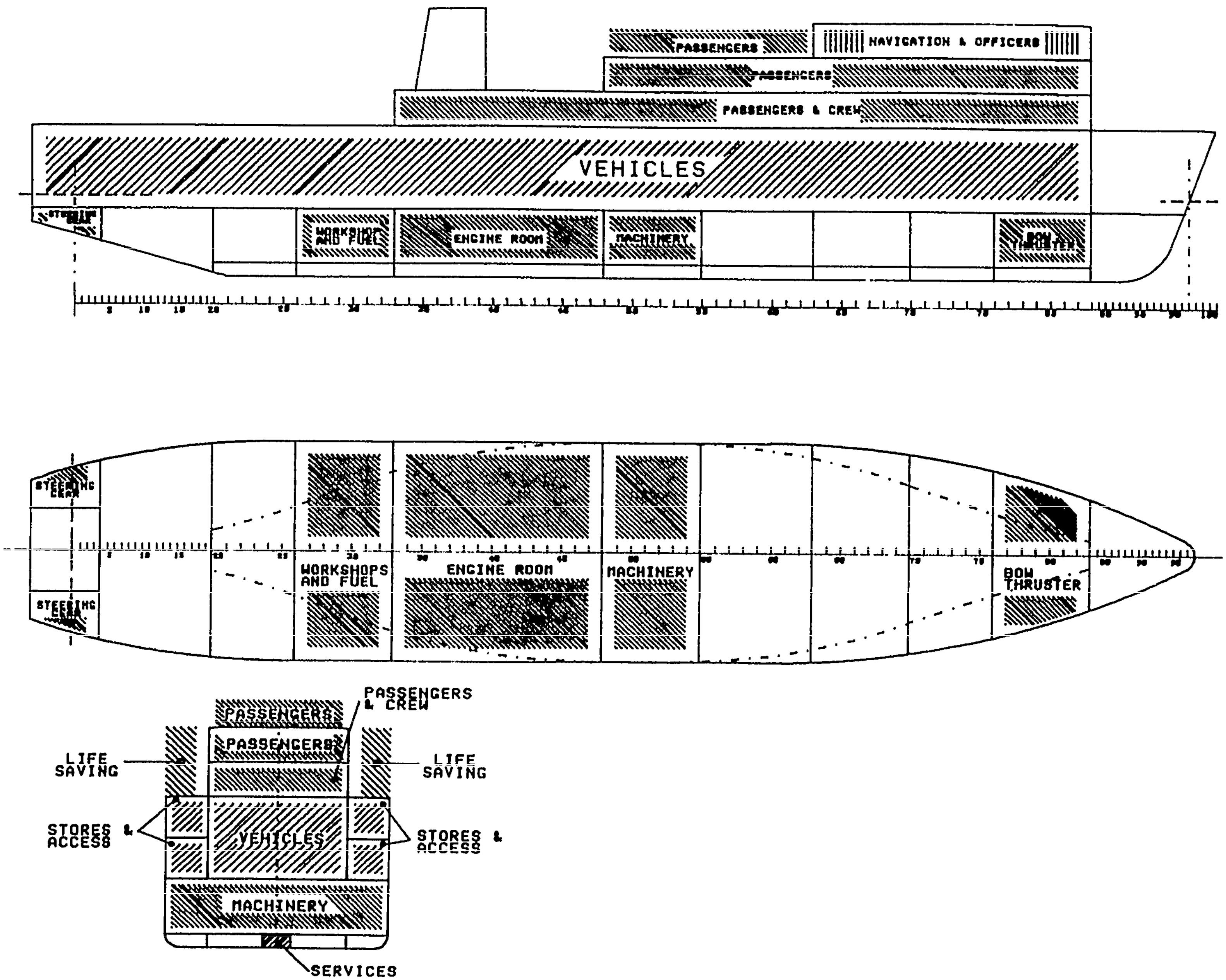
3.2.3.1 Introduction

Any vessel is a collection of spaces which are allocated to different operating functions. The equipment, fittings and associated structure in each space are related and interconnected. Those in different functional spaces have limited, or no, relationships.

The principle of functionally separate spaces leads to a design approach based on spatial analysis. This approach can be developed to generate standards, both in the layout of functional spaces and in their relative locations.

The functional spaces are linked by systems (pipes, cables, trunks, passages). An analytical approach to the grouping and routing of these systems is detailed in the next section.

The various figures in this chapter illustrate the use of spatial envelopes rather than equipment arrangements to define functional spaces early in the desiqn process.


PASSENGERS
NAVIGATION & OFFICERS
PASSENGERS
PASSENGERS & CREW
VEHICLES
STEERING GEAR
WORKSHOPS AND FUEL
ENGINE ROOM
MACHINERY
BOW THRUSTER
WORKSHOPS AND FUEL
ENGINE ROOM
MACHINERY
BOW THRUSTER
STEERING GEAR
PASSENGERS & CREW
PASSENGERS
PASSENGERS
LIFE SAVING
LIFE SAVING
STORES & ACCESS
VEHICLES
STORES & ACCESS
MACHINERY
SERVICES

3.2.3.2 Machinery Spaces

If the various types of machinery used to power ships are considered, then for each type of propulsion system, items of common auxiliary equipment can be identified. There are certain items common to all propulsion systems:

Machinery space bottom structure and associated service pipework.

Shafting and shaft bearings.

Propeller(s) and sternframe, or shaft brackets.

Auxiliary equipment which can be common among propulsion systems of a specific type include:

Oil fuel transfer and purification equipment with associated tanks.

Lubricating oil transfer and purification equipment with associated tanks.

Air compressors and air receivers.

Fresh and salt water cooling systems with heat exchangers.

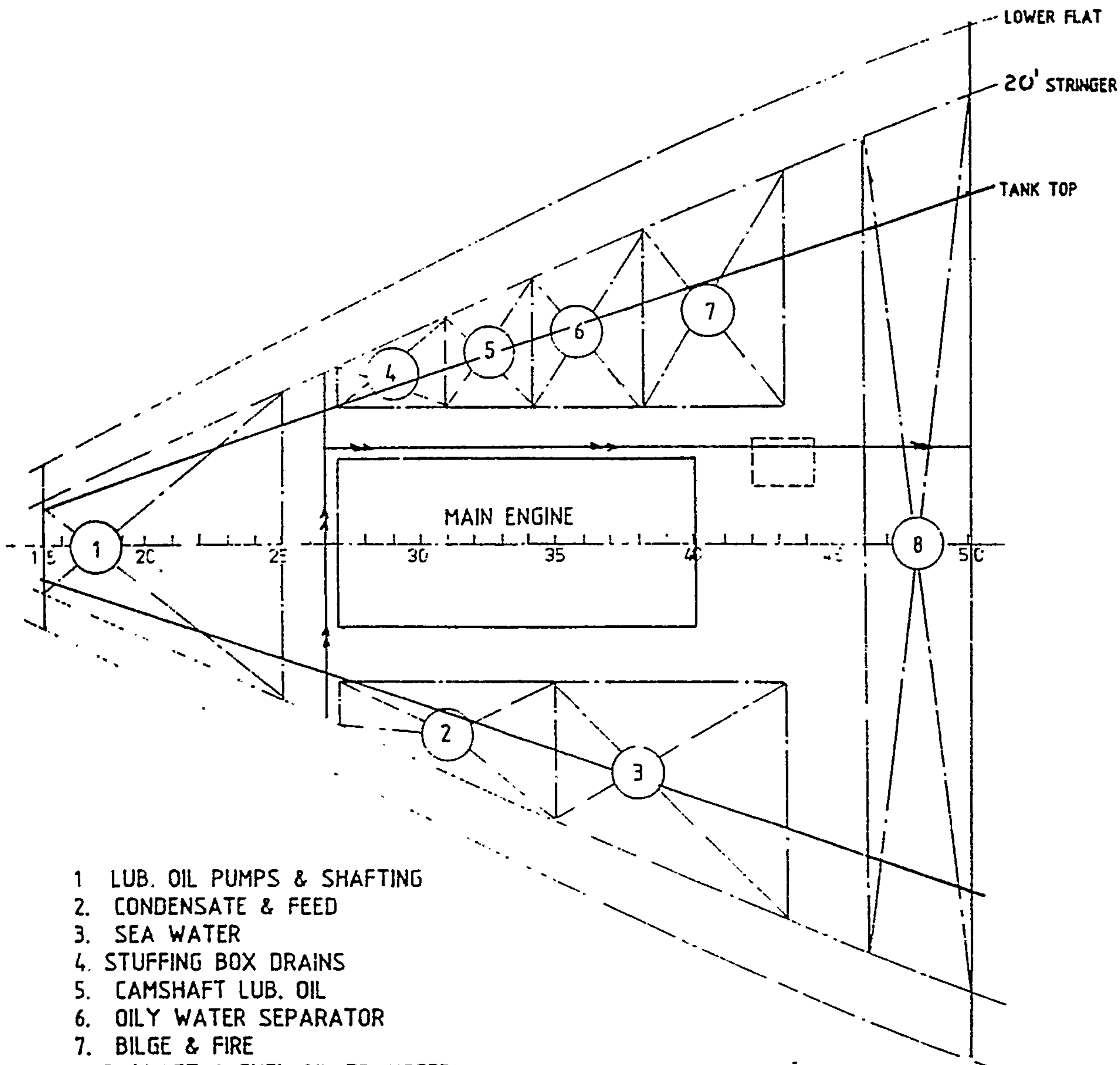
Generators for electrical power.

Other equipment and services found in a machinery space include:

Bilqe, ballast, fire and general service pumps.
Control room and switchboards.
Ventilation systems.
Sewaqe systems.
Header tanks.
Exhaust uptakes.
Waste heat recovery boiler.

All of the above are amenable to the application of a method of grouping together items which have a common function. A standard approach to.the layout of a machinery space can thus be developed for the various types of prime mover. When the layout has been established, then the equipment within each functional area can be grouped toqether to form modules.

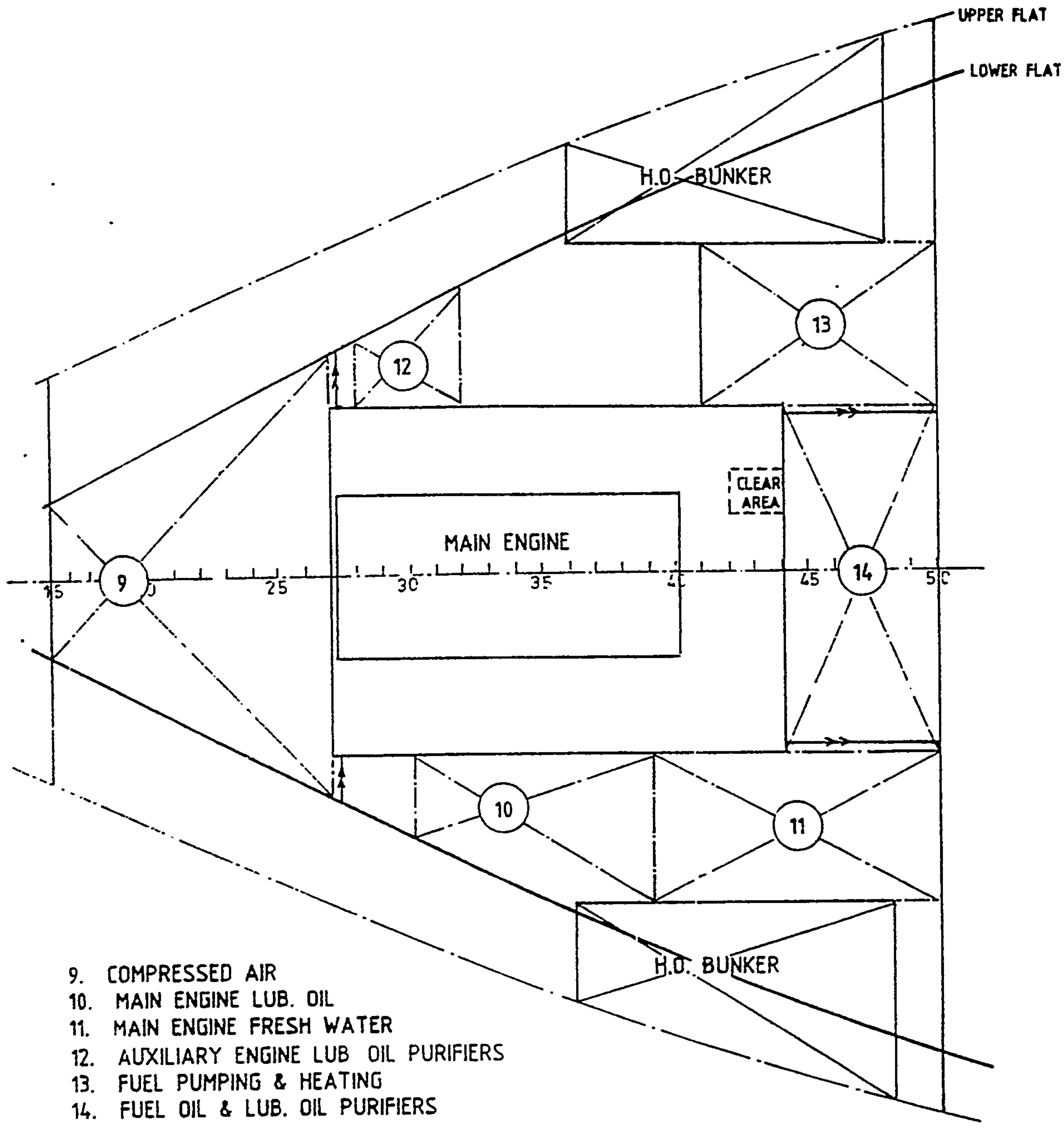
ENGINE ROOM FUNCTIONAL SPACE ALLOCATION



1 LUB. OIL PUMPS & SHAFTING
2. CONDENSATE & FEED
3. SEA WATER
4. STUFFING BOX DRAINS
5. CAMSHAFT LUB. OIL
6. OILY WATER SEPARATOR
7. BILGE & FIRE
8. BALLAST & FUEL OIL TRANSFER

FLOOR PLATE LEVEL

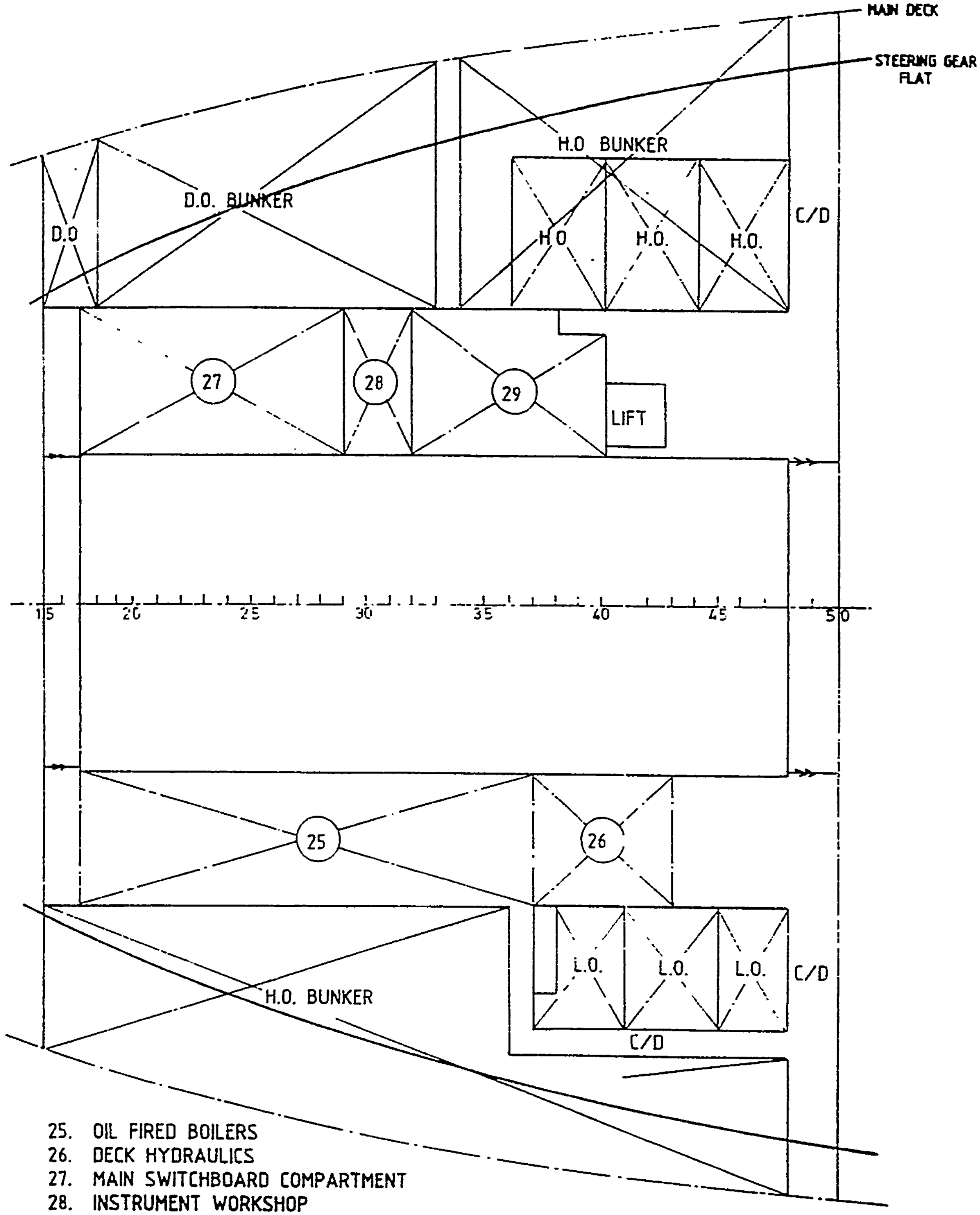
ENGINE ROOM FUNCTIONAL SPACE ALLOCATION



9. COMPRESSED AIR
10. MAIN ENGINE LUB. OIL
11. MAIN ENGINE FRESH WATER
12. AUXILIARY ENGINE LUB OIL PURIFIERS
13. FUEL PUMPING & HEATING
14. FUEL OIL & LUB. OIL PURIFIERS

LOWER FLAT

ENGINE ROOM FUNCTIONAL SPACE ALLOCATION



25. OIL FIRED BOILERS
26. DECK HYDRAULICS
27. MAIN SWITCHBOARD COMPARTMENT
28. INSTRUMENT WORKSHOP
29. CONTROL ROOM & OFFICE AREA

UPPER FLAT

3.2.3.3 Accommodation and Stores

Accommodation and control spaces can be approached in a similar manner to machinery spaces by qrouping together spaces which have a similar function such as:

Dry storerooms.

Cold storerooms.

Small machinery spaces - air conditioning, refrigerating machinery, incinerator room, emergency generator room.

Sleepinq quarters.

Public toilets and bathrooms.

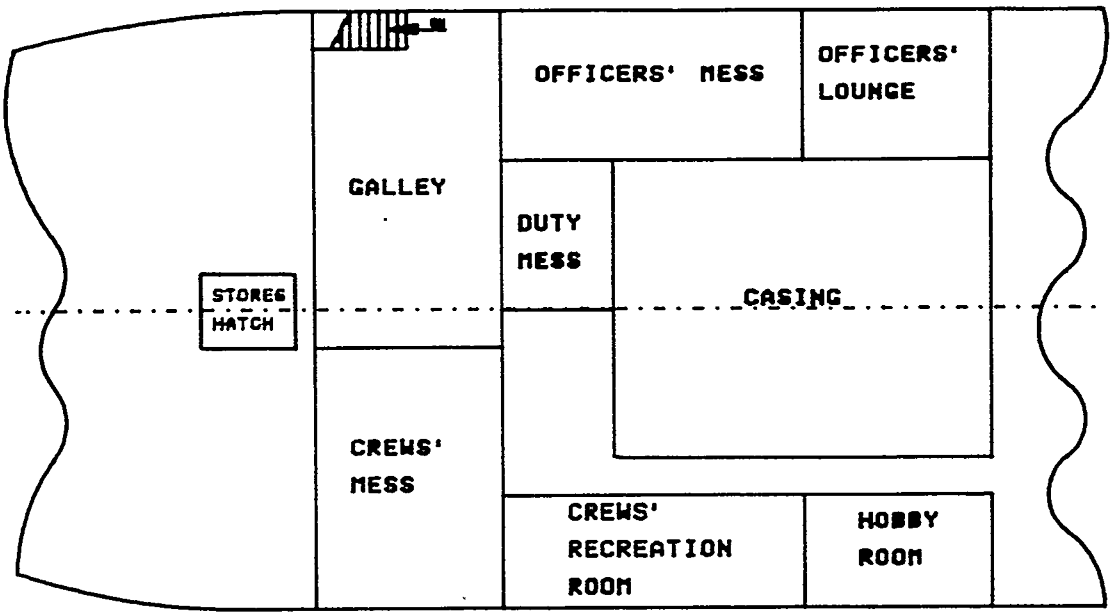
Service spaces - galley, messrooms, pantries, etc.

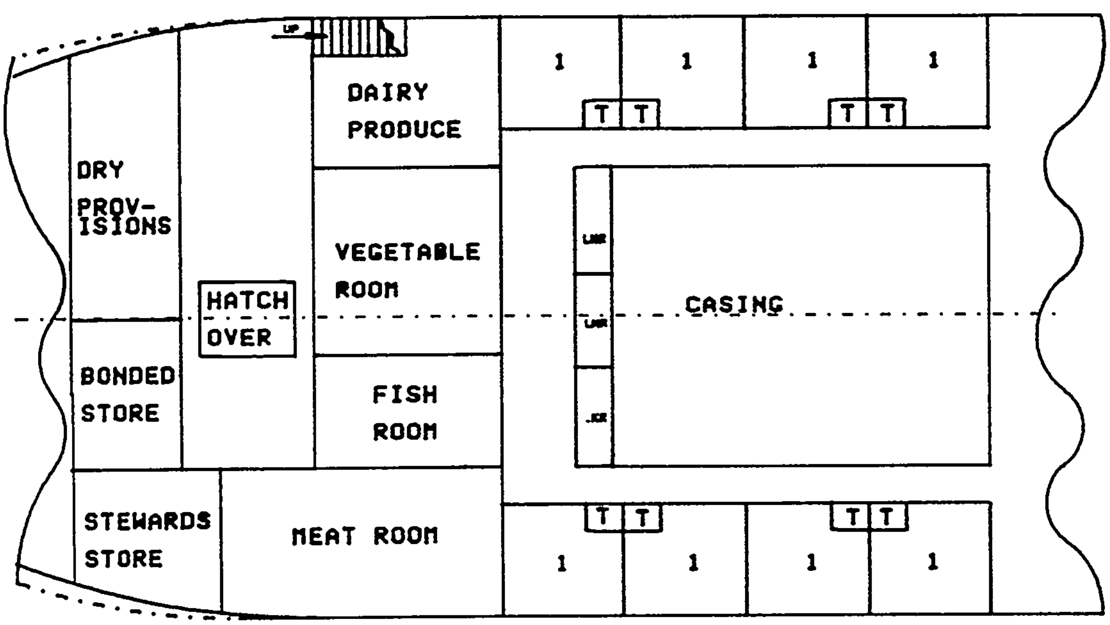
Recreation rooms - hobby room, gymnasium, etc.

Control rooms - navigating bridqe, chart room, radio room, etc.

Service routes.

Once established, the standard layouts can be used to quickly produce an overall layout of the acccommodation and machinery spaces for any given ship.





PART PLANS OF ACCOMMODATION DECKS
SHOWING FUNCTIONAL AREAS FOR STORES,
ACCOMMODATION, SERVICE & RECREATION

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3.2.4 SYSTEMS GROUPING AND ROUTING

This chapter discusses the production objectives of adopting a methodology for grouping together the various systems within a ship and of leading them through common routes.

The various stages of system design and the development of the routes and the interfaces between the routes and the functional spaces are identified.

Drawings are included which show how the approach is applied to a complete vessel and to the engine room of a ship.

CROSS-REFERENCES

2.2.1 Conceptual Design

2.2.2 Contract Design

2.2.3 Functional Design

2.2.4 Transition Design

2.2.5 Detail Design

3.1.7 Process and Spatial Analysis

3.?.4.1 Objectives

In parallel with the development of functional spaces, the systems which connect them are defined, and assigned to predetermined, orthogonal routes.

From a production perspective, the objectives are:

to maximize the opportunities to create and manufacture outfit assemblies,

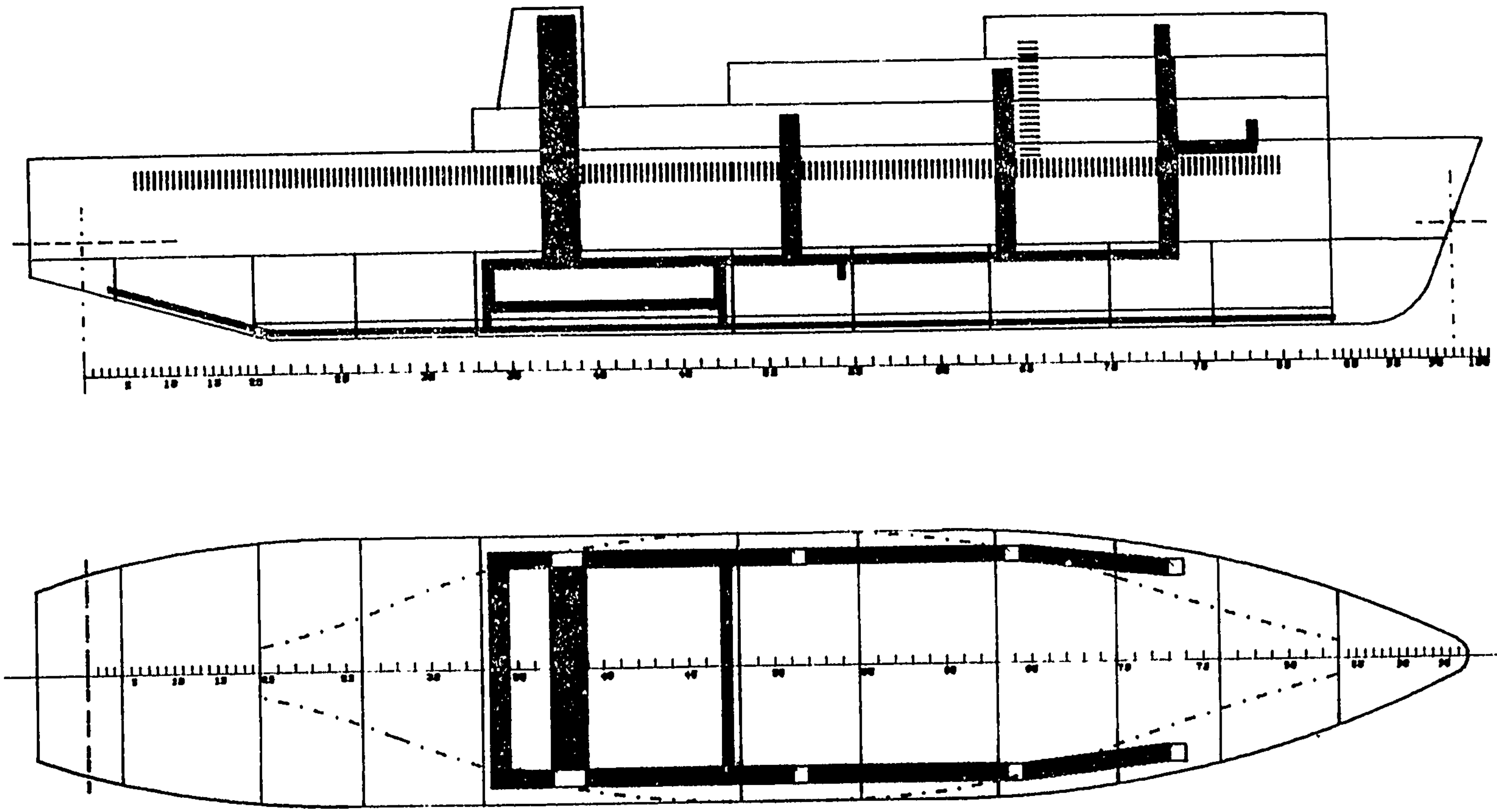
to simplify pipe and other system geometry,

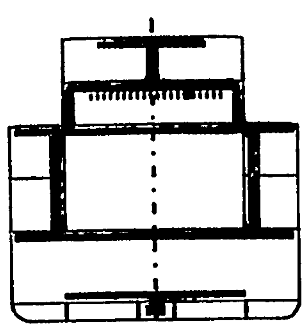
to increase standardization,

to reduce material costs.

The illustration paqe 3-2/403 shows the identification of main service routes at conceptual design.

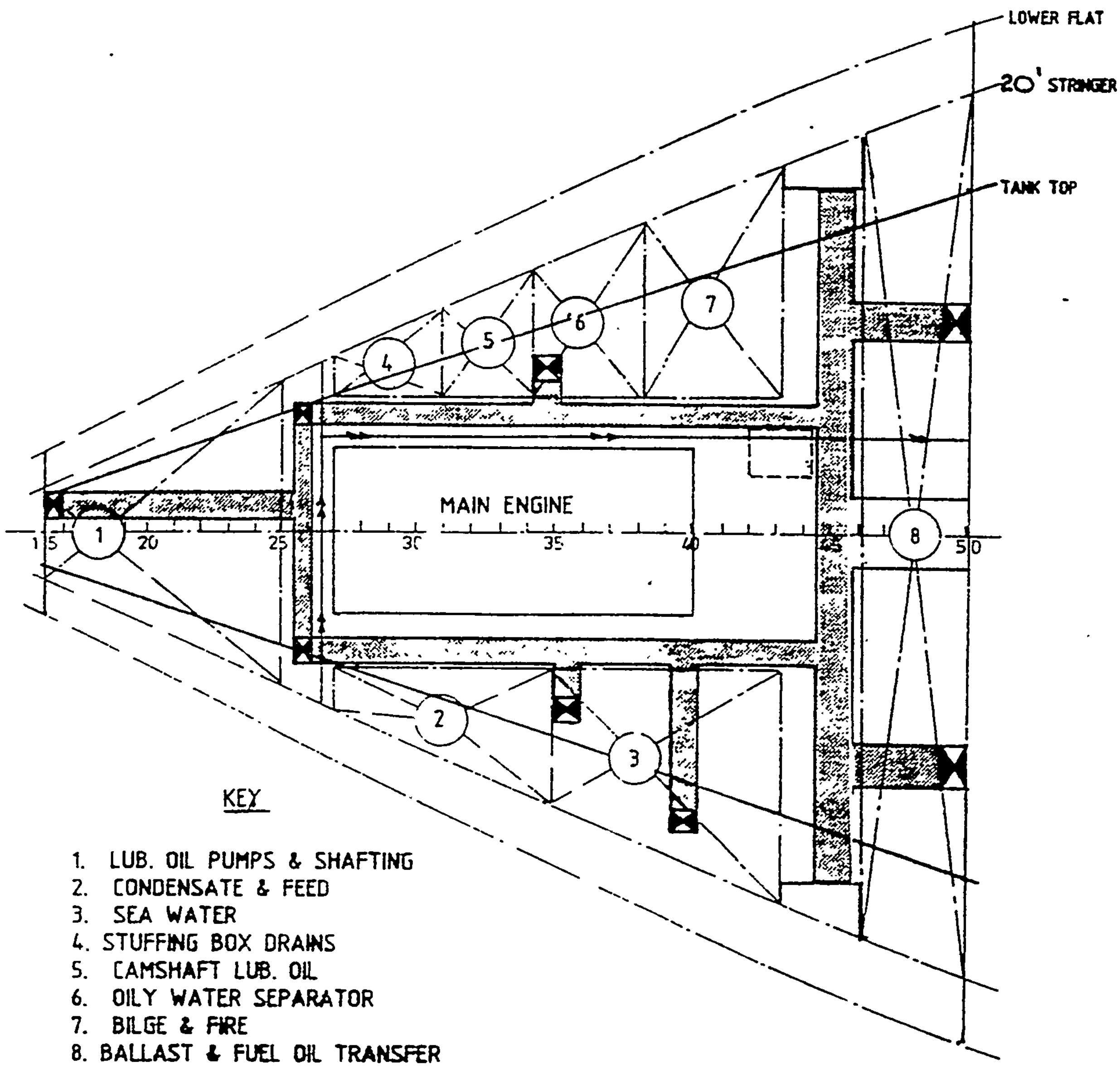
Subsequent illustrations show the identification of service routes for systems in a machinery space at contract design.





MAIN SERVICE ROUTES

ENGINE ROOM SERVICES TRANSIT ROUTES



KEY

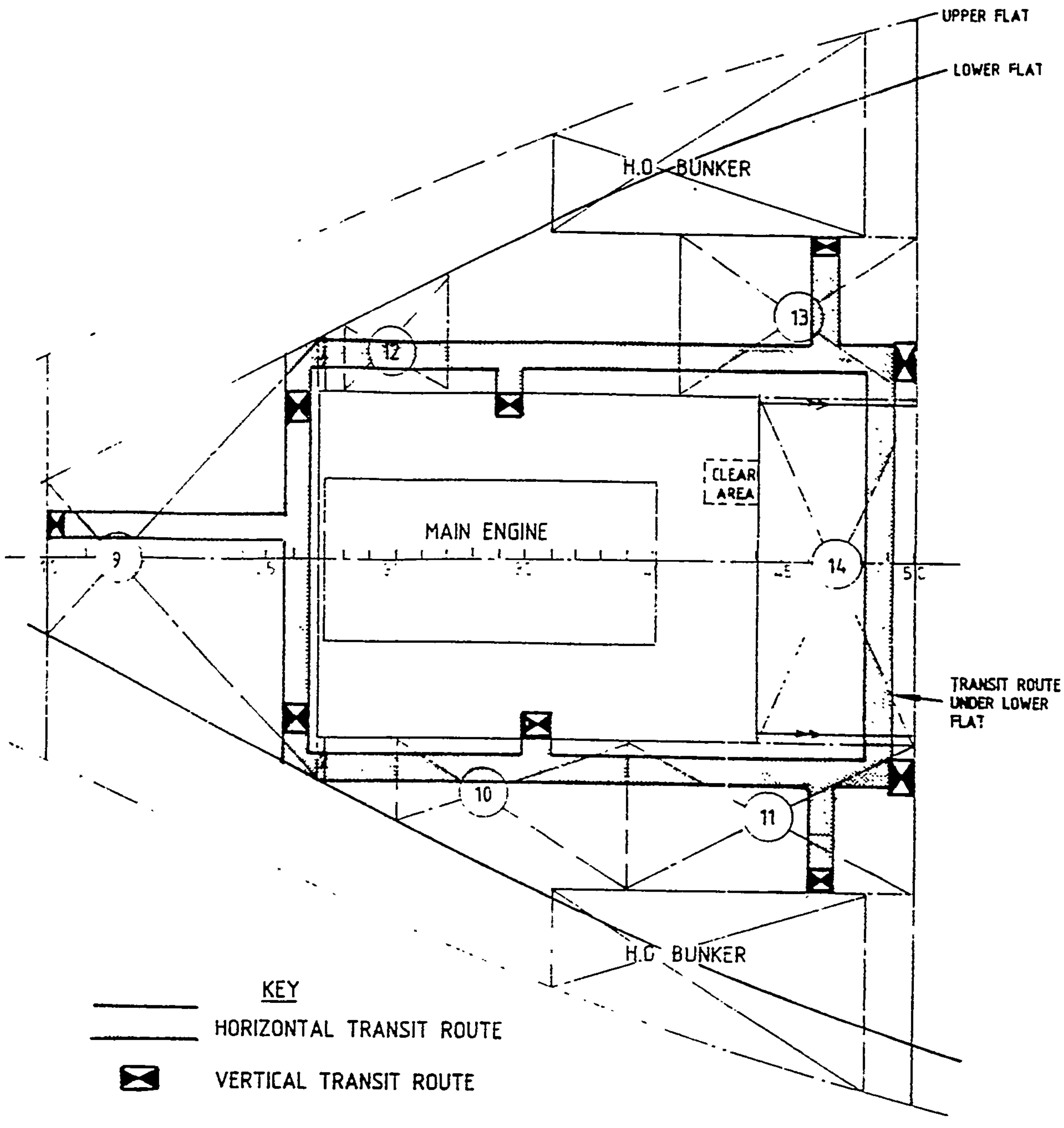
1. LUB. OIL PUMPS & SHAFTING
2. CONDENSATE & FEED
3. SEA WATER
4. STUFFING BOX DRAINS
5. CAMSHAFT LUB. OIL
6. OILY WATER SEPARATOR
7. BILGE & FIRE
8. BALLAST & FUEL OIL TRANSFER

HORIZONTAL TRANSIT ROUTE

VERTICAL TRANSIT ROUTE

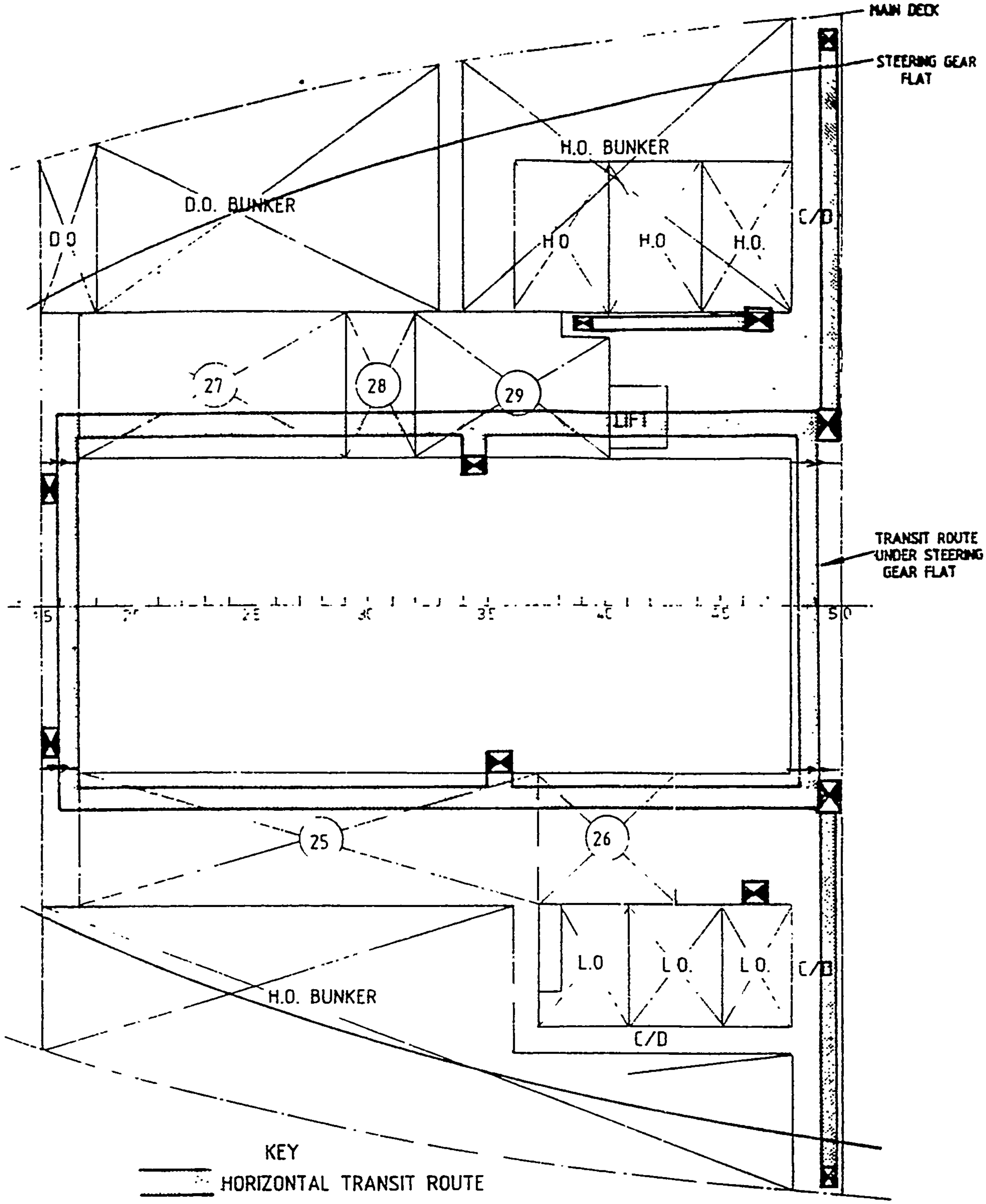
FLOOR PLATE LEVEL

ENGINE ROOM SERVICES TRANSIT ROUTES



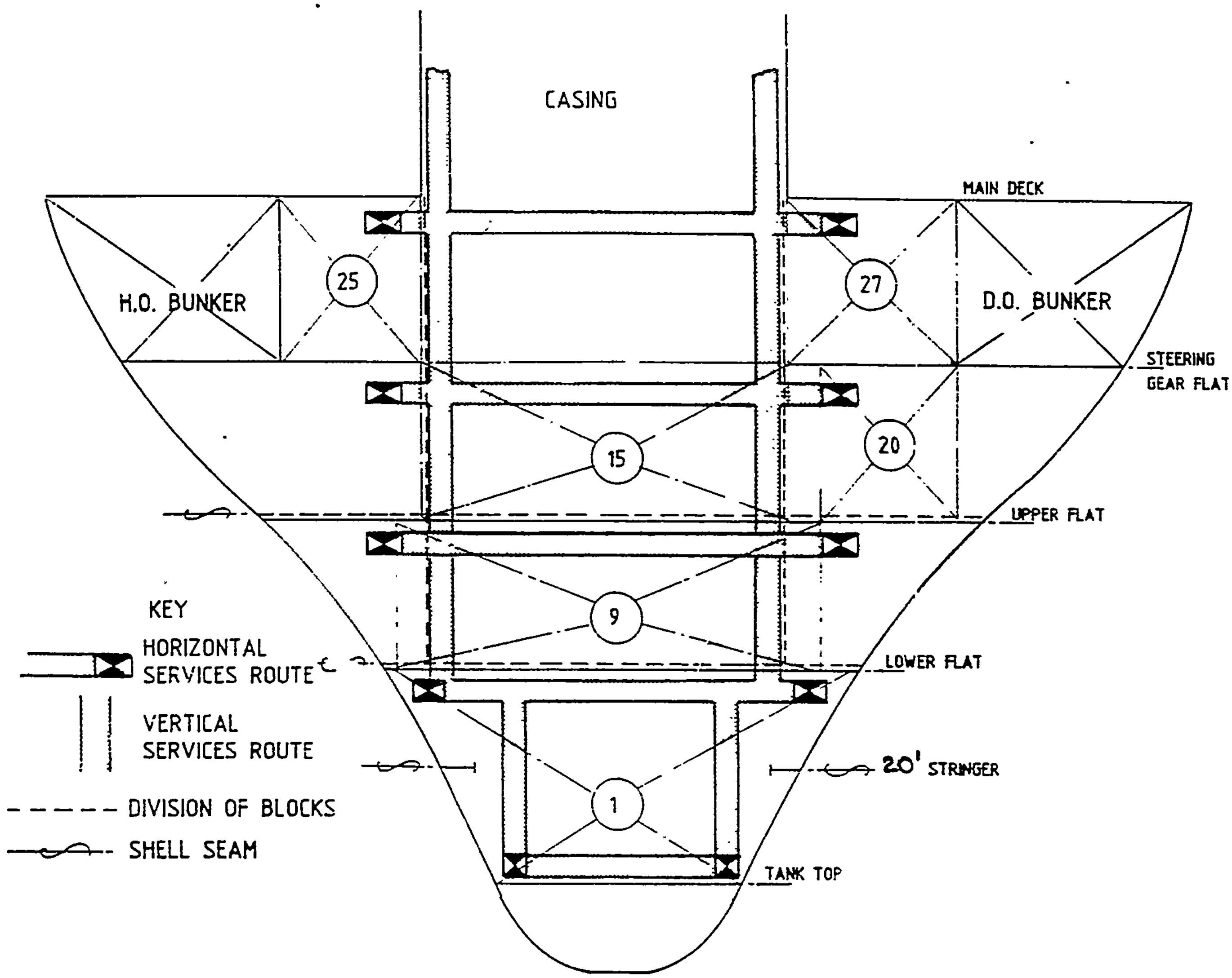
LOWER FLAT

ENGINE ROOM SERVICES TRANSIT ROUTES



UPPER FLAT

ENGINE ROOM SERVICES TRANSIT ROUTES



SECTION AT FR.27 LOOKING AFT

3.2.4.2 Design Stages

The development of the systems design follows .the stages of design described in Volume 2, Part 2.

Conceptual design is concerned with the overall definition of a vessel which includes functional spaces and main systems routes.

At. the contract design stage arrangements are produced for the engine room and accommodation, together with a General Arrangement. In conjunction with these, schematic drawings showing the ship's systems are produced.

Where possible, service ducts or passageways should be provided in order to maximize the number of straight lengths of pipework, cables and trunking, which can be built as large assemblies for installation within the ducts or passageways durinq construction.

After arranginq the main service routes, the paths which the individual pipes, trunks and cables will follow within the route, need to be established. This will indicate whether the sizes of the routes are adequate to accommodate the required services. Occasionally, the establishment of main service routes will identify an area in which a modification of the equipment layout will result in improved service runs.

This is radically different to the conventional approach where routing would be considered system by system after the layout of equipment had been determined. The new approach adopted at the contract design stage is to include service routes and ducts in the arrangement of functional spaces developed from the spatial analysis.

The system diagrammatic drawings, which relate the systems to the ship's structure, are developed, and the pipe sizes calculated, at the functional design stage. The engine room and other arrangements are further developed from those prepared at the contract design stage to include all services routes. These service routes are, In effect, functional spaces which accommodate all the services which pass through a given area. At this stage they are only spaces, the size of which is based on a preliminary estimate and experience.

It might appear that the adoption of the approach outlined here would lead to larger enqine rooms. The actual effect is to reduce space requirements-because the system runs within any given part. of the ship are collected together and are not randomly spread throughout the space as would often be the case.

The transition design stage is of the greatest importance in ensurinq that production requirements, implicit in the pre-defintion of routes, are made explicit. At this stage, the svs-tem diagrams are overlaid on to the overall arrangement. The routes have already been defined. A composite drawing is developed by layering the various systems. Interference and space checks are made. The output shows the relative position of the various systems and the interface between the various service routes and the functional spaces which they link.

At the detail design stage, the output is production information. The various functional spaces can be designed independently, subject to interface checks as described in the next section. Where required. spare routes can be left to allow additional systems to be incorporated later in the life of the vessel.

Because the detail design is based on orthogonal routes, maximum use can be made of standard details, such as:

standard pipe lengths,
standard bends,
standard supports.

The use of standards and straight lines leads to minimum scrap and wasted material. Larger batches, manufactured or bought, can thus be organized.

3.2.4.3 Interfaces

Interfaces are the points at which functional spaces and systems routes join. These joints must be carefully controlled. Interfaces between spaces can be treated in two ways.

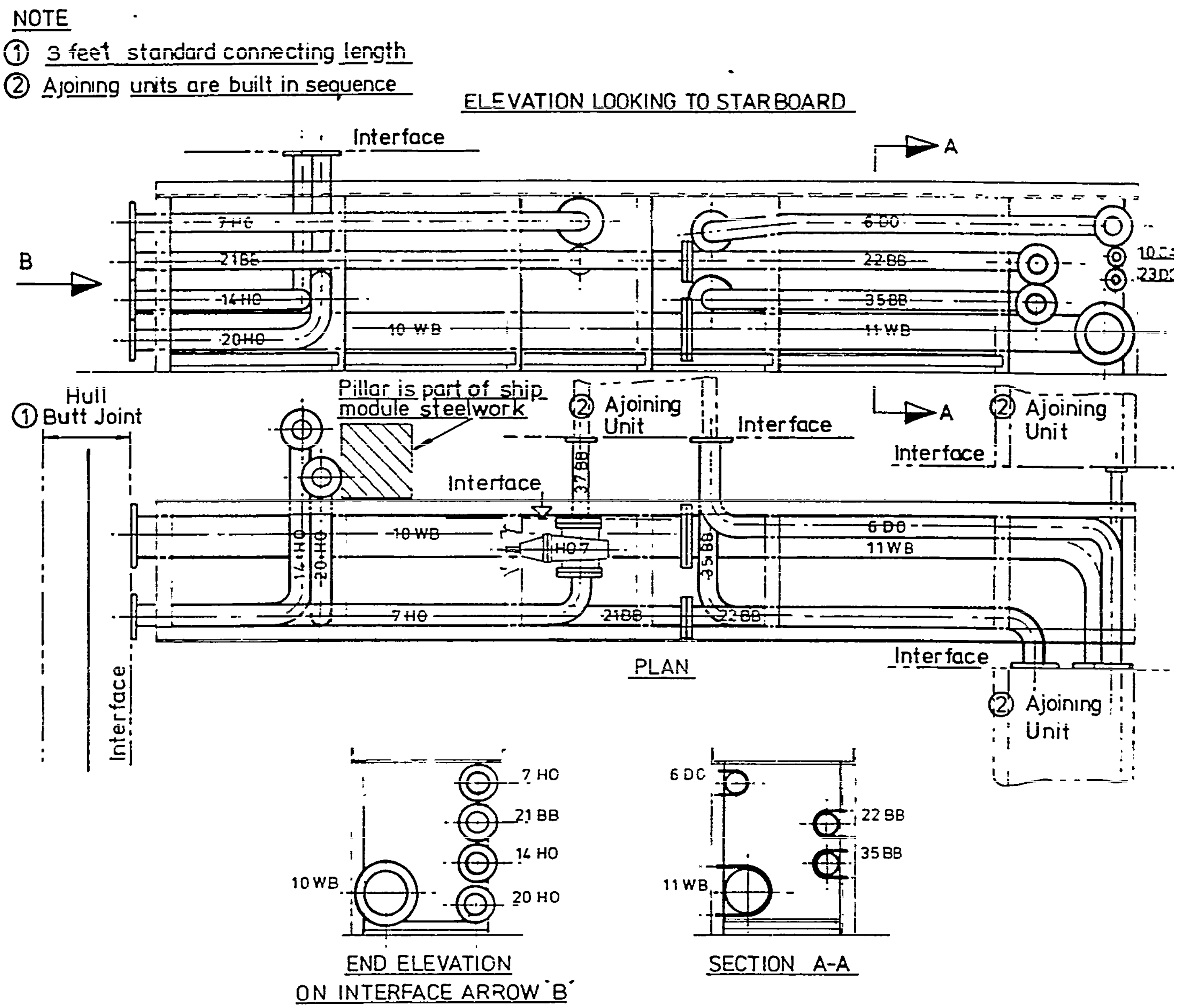
Where independent outfit assemblies are installed and joined on the ship after erection, they can be made to be independent of structure and therefore only require adequate dimensional accuracy in the interface. It should be arranged that each successive assembly is only critical in one plane. Connections between outfit assemblies should be arranged sequentially so that insert pieces are not required. Such connections should be in the plane of the joint but staggered connections are acceptable if the pipework or the access is simplified.

Where outfit assemblies or sub-assemblies are installed on main structure prior to erection, the emphasis should be on completion of all work. At the interface between the structural assemblies, there is a dependence on the associated structural accuracy and the use of closing pieces for systems is necessary.

Where interfaces are located across the boundaries of units and blocks, the service runs should terminate approximately 18 inches either side of the steelwork connection. All terminating flanges should be arranged in the same plane as the steelwork connection to allow all cross joint, insert pieces to be of standard length.

Access is required to weld the butts between blocks. This same space provides access to the outfit units, pipework and ventilation trunking on either side of the butt. It is therefore possible to use that space to measure or lift templates for the closing pieces required to connect systems across the block butt.

When arranging service runs and connections, due attention should be paid as to how maintenance can be undertaken once the assembly is erected in position.


NOTE
① 3 feet standard connecting length
② Ajoining units are built in sequence
ELEVATION LOOKING TO STARBOARD
Interface
A
B
7 HO
21 BB
14 HO
20 HO
10 WB
6 DO
22 BB
35 BB
11 WB
Hull
① Butt Joint
Pillar is part of ship module steelwork
② Ajoining Unit
Interface
37 BB
HO 7
35 BB
PLAN
Interface
END ELEVATION ON INTERFACE ARROW 'B'
SECTION A-A
6 DC
11 WB
10 WB

PIPE MODULE

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3.2.5 STRUCTURAL ARRANGEMENT ALTERNATIVES

This chapter discusses the structural configurations for a number of areas of the ship and indicates items which should be taken into account when determining the actual arrangement to be adopted.

The importance of taking due account of the purposes of the various structural areas is highlighted and many drawings are included to illustrate the points made in the text.

CROSS-REFERENCES

2.1.6 Impact of Facilities on Design

2.3.1 Modern Ship Production Technology

3.4.4 Steelwork Applications - Examples and Illustrations

3.2.5.1 Structural Functions

When determining the structural configuration within any region of a hul1 due account has to be taken of the purposes which any material has to serve, such as:

Watertight barrier
Support for cargo or equipment
Overal1 hul1 strength
Local strength only
Fire barrier

Also structural continuity with adjacent parts of the structure has to be considered.

Certain main parts of a ship's structure are considered in the following sections and some items which have to be considered when determining the structural configurating are discussed.

3.2.5.2 Double Bottom Within Cargo Holds

Classification societies have rules governing the minimum depths of center girder and any depth equal to or greater than this wi11 be acceptable to them. If the rule depth is less than the bilge radius, consideration may be given to increasing the depth. Paragraph 3.2.1.2 discussed the bilge radius. In order to simplify assembly and to reduce the need for jigs to support curved plates, it is desirable that the internal structure should be of greater depth than the bi1ge radius.

The spacing of longitudinals and girders will be a function of the breadth of the ship but there will not necessarily be an exact number of 1ongitudinal spaces to make up the breadth. Girder spacing wil1 be a multiple of longitudinal spacing and will be affected by the anticipated cargoes to be carried. For example, if containers are to be carried then a suitable girder spacing would be that which supports the sides of containers. If possible, girders should be spaced equidistant so that the floors between girders will be identical sub-assemblies.

The cargo hold length must be an exact multiple of frame spacing and floor spacing. Again, the anticipated cargoes should be taken into account. Attention should be paid to any transverse web frames which will be fitted within the holds and particularly those that wi11 be required at the end of the hatchways, so that such structure aligns with a double bottom f1oor to provide a strong transverse ring structure.

Where the structural spacings are not constrained by cargo considerations, it may be possible to relate them to maximum material size. For example, the longitudinal spacing can be arranged so that the plate width is an exact multiple of the spacing. The maximum plate can then be used. In the same way, frame spacing can be related to plate 1ength. Using the largest available plate can reduce the volume of welding, and the number of units.

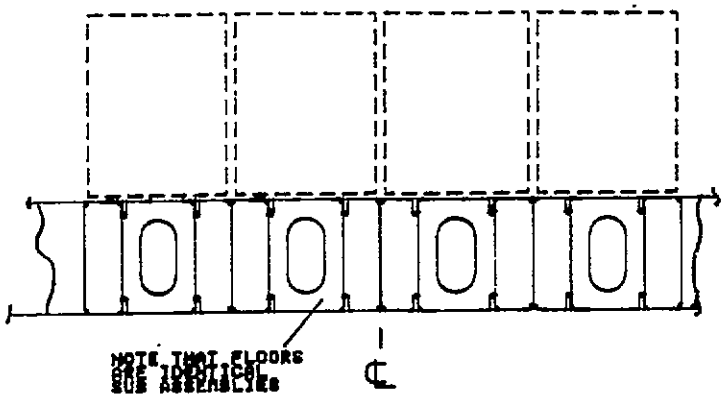
Adequate access manholes must be provided in non-watertight floors and girders. Where the double bottom is high then the access manholes should be located so that alternative manholes are positioned close to the bottom shell and the inner bottom plating. The access holes should be positioned so that easy access is possible whether the double bottom is inverted or correct side up. To achieve this the designer will have to know the orientation of the steelwork during assembly. This will only be possible if a standard approach to assembly has been developed.

Providing struts tying the bottom longitudinals to the inner bottom longitudinal between the floors in order to reduce their scantlings introduces a 1arge number of extra parts to be produced, handled and welded and therefore should be avoided whenever possible. If it is impossible to avoid fitting struts then they should be lapped on to the longitudinal.

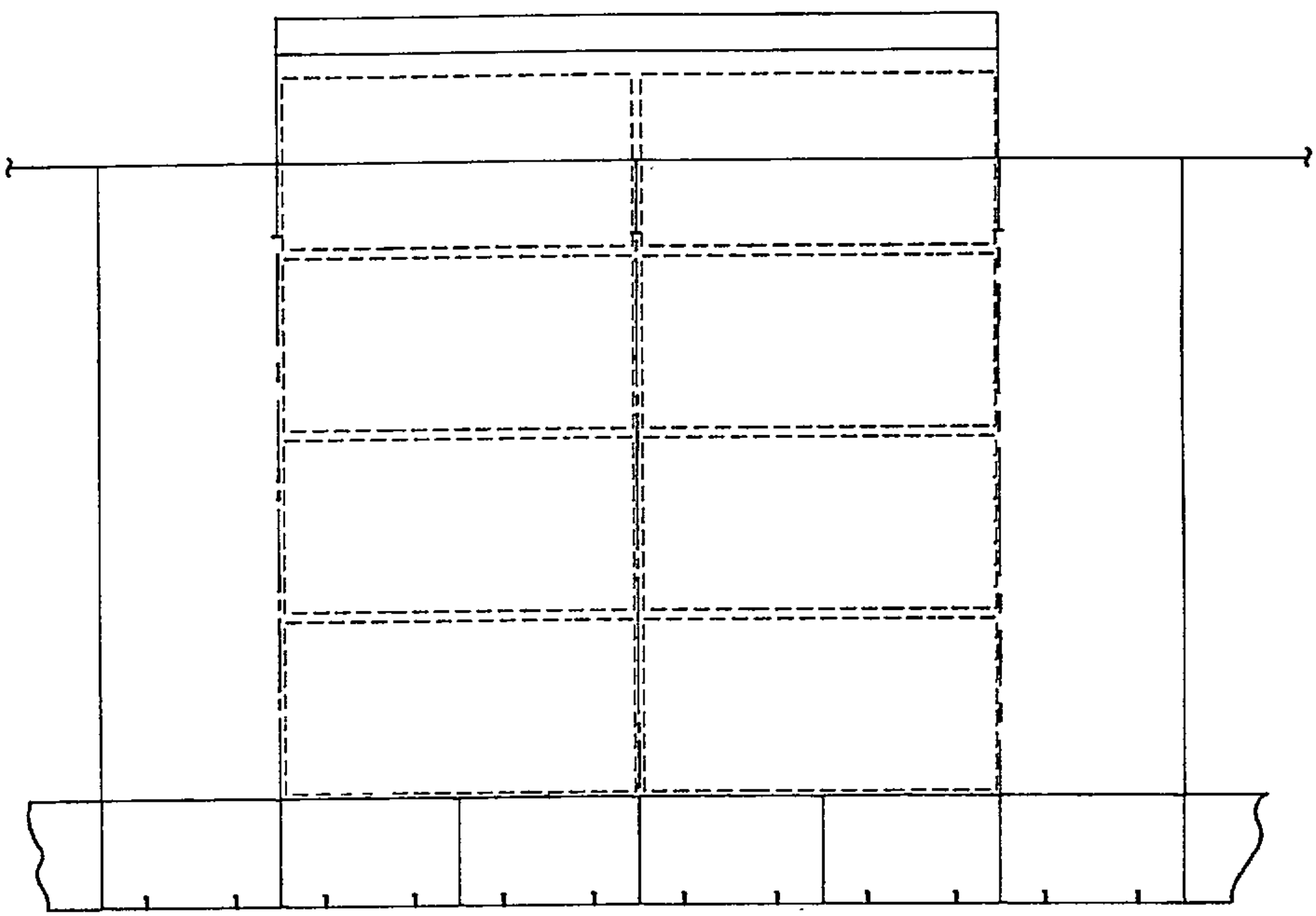
The illustration shows a vessel designed for containers. The points to note are:

Hold length is a function of floor spacing.

Relation between girder and longitudinal spacing.



DOUBLE BOTTOM WITHIN CARGO HOLDS



FRAME AND FLOOR SPACING WITHIN
CARGO HOLDS

CARGO HOLD SPACINGS

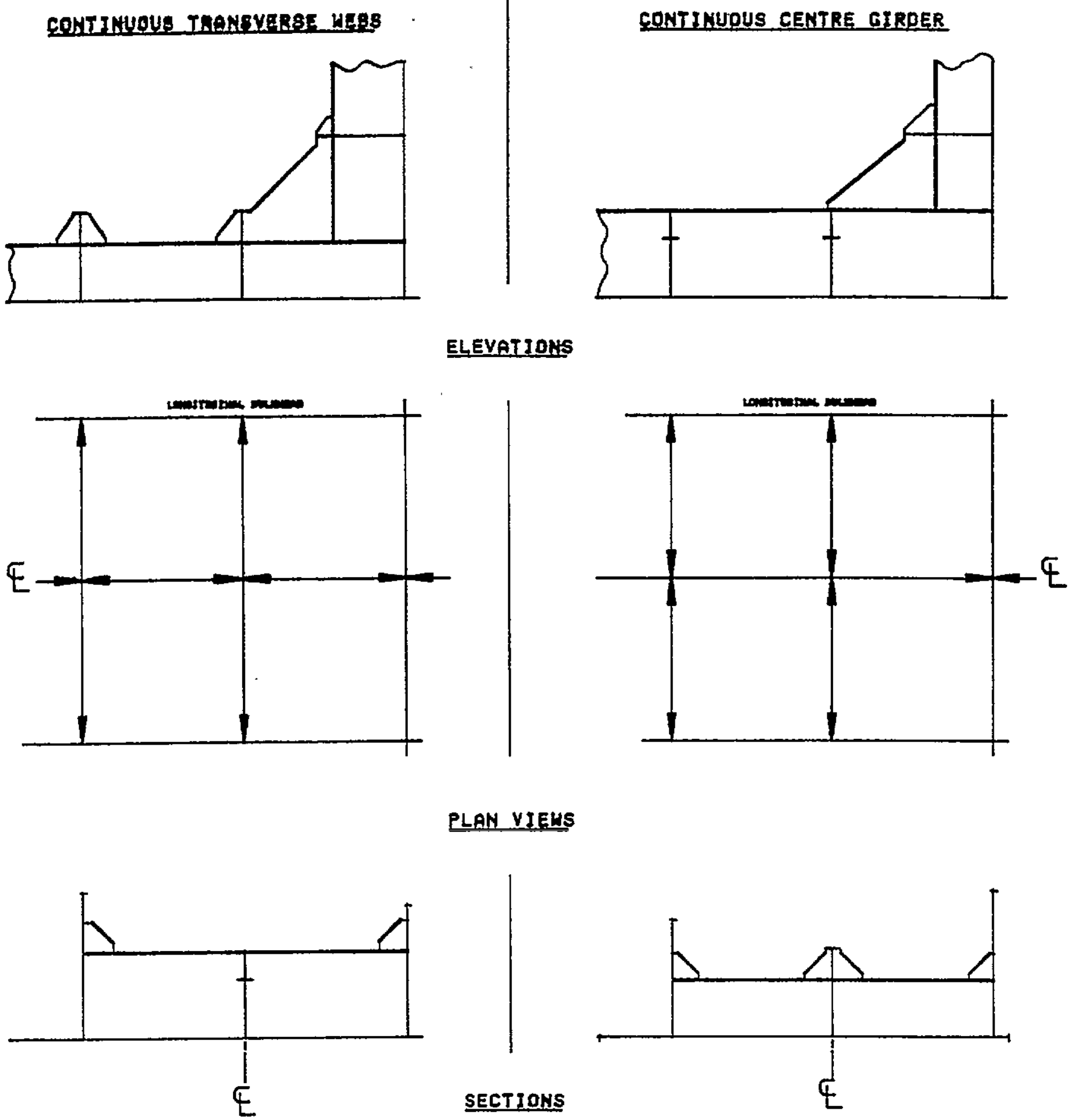
3.2.5.3 Bottom Structure within Cargo Oil Tanks

The Classification Societies have rules relating to whether the centerline girder can be continuous and support the transverse webs or vice versa. The 1ength and breadth of the cargo tanks are the main parameters in determining this. It should always be borne in mind that if the means are available for performing structural analyses, then novel arrangements can be produced and wi11 be considered by the societies. The novel arrangements may wel1 arise as a result of process analysis work or the introduction of new technoloqies.

The spacing of bottom Iongitudinals wil1 be a function of the distance between the longitudinal bulkheads. These bulkheads wi11 have been positioned to suit operational requirements such as minimizing the amount of segregated ballast carried (if applicable).

Transverse web spacinq wil1 be a function of the cargo tank lenqth. Both transverse web spacinq and cargo tank lengths have maximum values associated with them and care must be taken not to exceed these values.

If the carqo tank proportions allow it, the centerline girder should be made continuous. This arrangement allows the center tank bottom structure to be formed in two parts across the width if its size or weight requires it, but if it can be formed in one part then the structural arrangement. is the same. An operational benefit can accrue with this arrangement in that the transverses will be of a relatively shallow depth and this assists in tank cleaninq operations, especially if a horizontal girder is fitted low down on the transverse bulkhpad. The “shadow” areas of the tank are thus reduced.



BOTTOM STRUCTURE OF OIL TANKERS

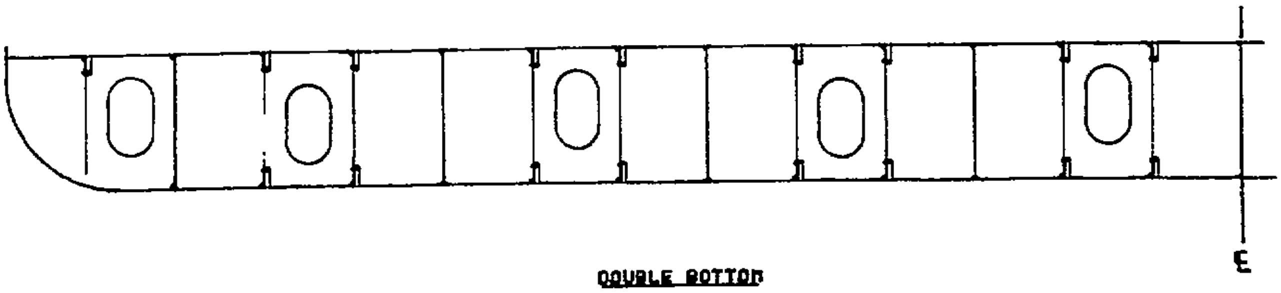
3.2.5.4 Side Tanks in way of Dry Cargo Holds

Where possible, the shel1 and longitudinal bulkhead should be longitudinally stiffened. This provides for the fullest possible use of a panel line if one is available, and for smoother operation as the semi-automatic or mechanized welding machines do not have to be stopped for notches in way of shell seams as they wou1d be for transverse stiffening.

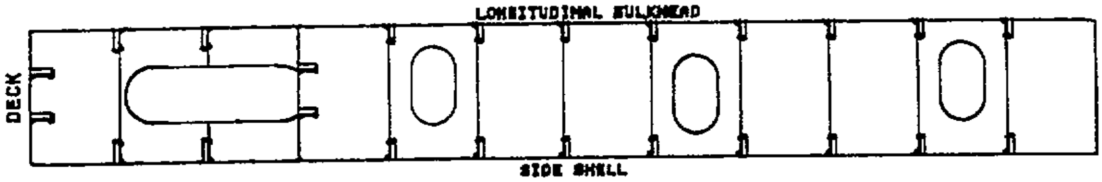
A longitudinally stiffened side tank provides interim products similar in type and size to a double bottom tank and a block approximately equal to half the width of the double bottom.

If the inner bottom plating is continued through into the side tanks, then it provides a useful platform for landing the side shell blocks upon.

The designer needs to appreciate the significance, in production terms, of changing from longitudinal to transverse framinq. The objective must be to maximize the use of a high cost-item of capital equipment like a panel line if it is available. This can be best achieved by making bottom, side, longitudinal bulkhead and deck blocks as nearly identical as possible.



DOUBLE BOTTOM



SIDE TANK

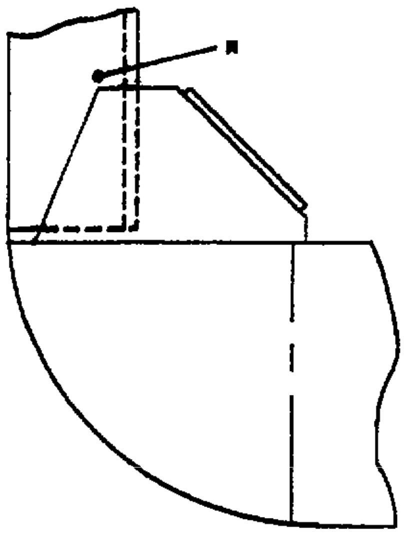
SIMILARITY BETWEEN DOUBLE BOTTOM & SIDE TANKS

3.2.5.5 Dry Cargo Holds Extending to Ship's Side

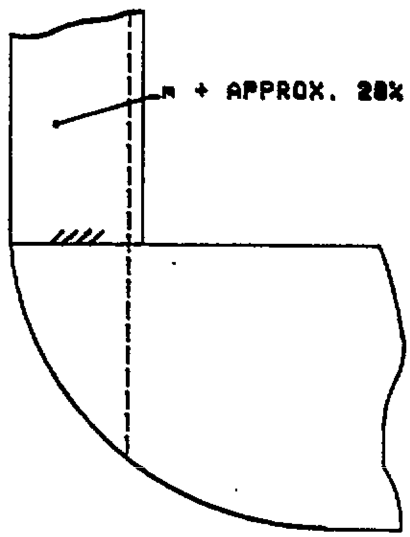
In general, if the Classification Society's rule required modulus for side frames is exceeded by approximately 20%, the brackets at the frame foot. can be eliminated.

Fabricated web frames may also be eliminated. The rule modulus is multip1ied by the number required if they were to be fitted and added to the total required modulus of the other frames within the hold. The fiqure thus obtained is divided by the total number of frames to obtain the modulus required by each frame. The use of this technique allows for the introduction of standard frames within the cargo hold area. This provides benefits in purchasing and material control because of the reduced variety of vendor furnished itemns.

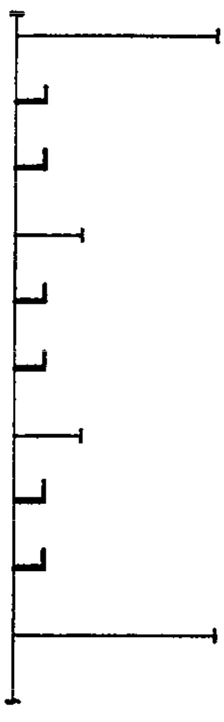
If excessive side loads are anticipated as in ships with large, open, hatchways then the above proposals may have to be supported by structural analysis.



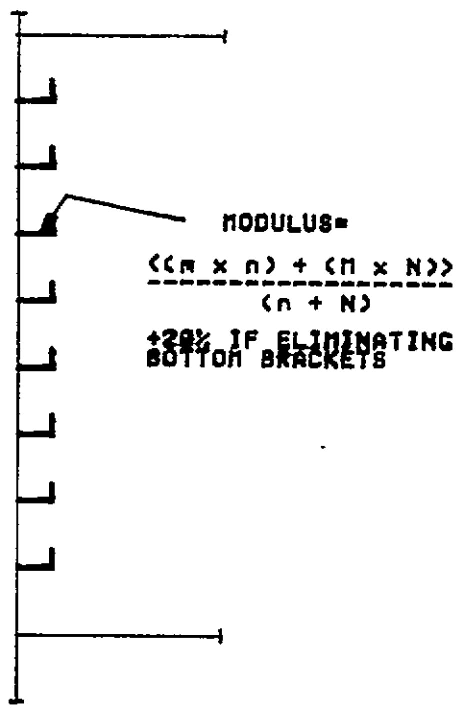
BRACKETED CONNECTION



BRACKETLESS CONNECTION



ROLLED & FABRICATED STIFFENERS



ALL ROLLED STIFFENERS

m = RULE REQUIRED MODULUS OF FRAMES

n = NUMBER OF FRAMES

M = RULE REQUIRED MODULUS OF WEB FRAMES

N = NUMBER OF WEB FRAMES

SIDE FRAMING IN DRY HOLDS

3.2.5.6 Hopper Tanks in Bulk carriers

The arrangement shown in the upper illustration Paqe 3-2/513 should be used whenever the hopper tank is of such dimensions that the transverse webs within the tank can be formed from a single plate. The hopper tank should then be produced separately. Depending upon the facilities, it could be erected with the double bottom or with the side shell and the upper wing tank.

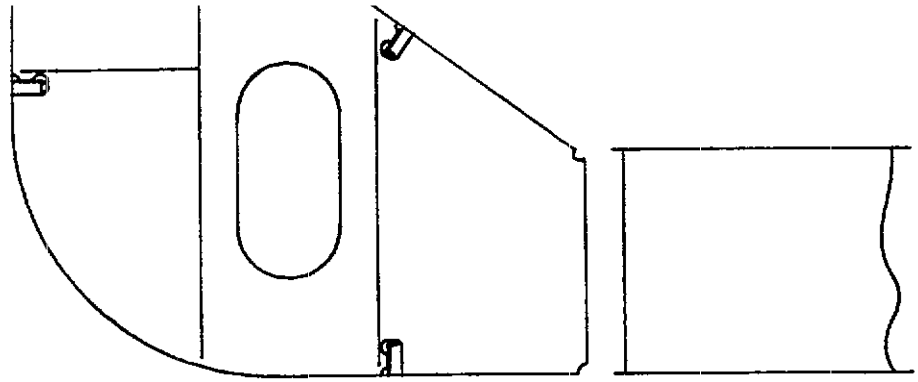
When the size of the hopper tank determines that the transverse webs within the tank cannot be formed from a single plate, as shown in the lower illustration opposite, then three separate webs should be fitted as follows:

The bottom shell web should have a depth equal to the depth of the double bottom f1oors, extend for the ful1 width of the tank and have a symmetrical face flat. fitted.

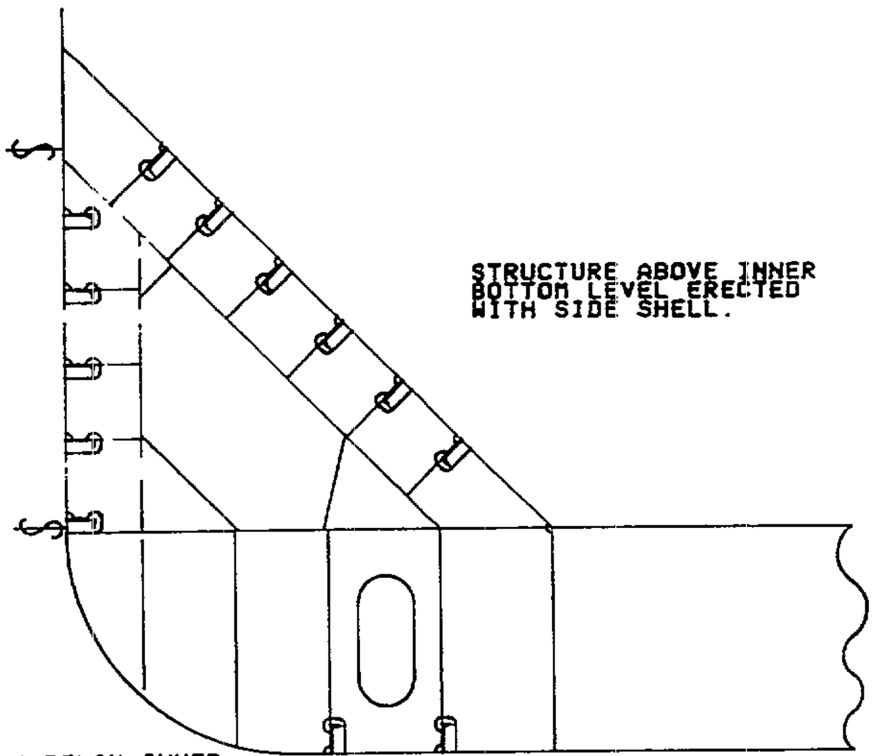
The web to the hoppered plate should have a depth at least satisfying strenqth requirements (but not less than twice the depth of the notches for the associated longitudinal). The face flat to this web should extend out to the side shell.

Side shell webs will have their depth determined to satisfy the criteria described above for hoppered plate webs. The face flat will be sufficient to extend between the face flats of the other webs.

With this form of internal construction and provided the facilities would allow it, the lower portion of the hopper tank should be attached to the double bottom. The upper portion consisting of the side shell and hoppered plate and associated lonqitudinals should be erected with the remainder of the side shell.



SINGLE PLATE WEB



THREE PLATE WEB

HOPPER TANK INTERNAL STRUCTURE

3.2.5.7 Upper Wing tanks

As with hopper tanks, the arrangement shown in upper illustration on page 3-?/515 should he used if the size of the upper wing tank is such that the transverse web structure can be formed from a single plate. To avoid difficulties in landing the upper winq tank unit on to a previously erected side shell unit, these two types of unit should be joined together before erection at the berth if the block created is within the capacity of the berth cranes.

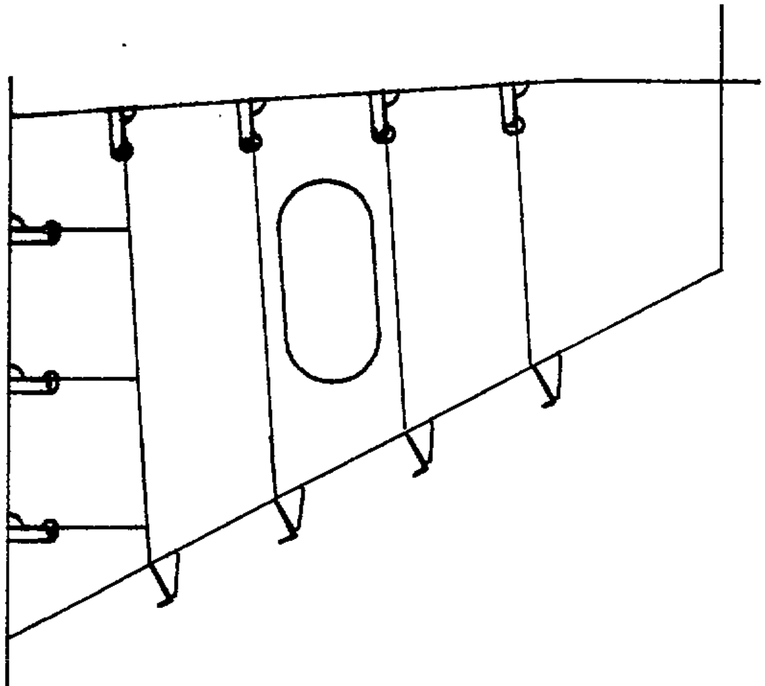
When the tank size is such that the transverse web structure can not be formed from a sinqle plate, as shown in the lower illustration opposite, then three separate webs should be formed as follows:

The deck web should have a depth at least satisfying strenqth requirements (but not less than twice the depth of the notches for the associated longitudinal). The face flat to this web should be symmetrical,extend over the full width of the tank and be normal to the side shell,

If the longitudinal to the sloping bulkhead are arranged on the hold side of the plating, then the depth of the webs to this platinq, which are situated within the tank, need only have a depth to suit strength requirements. With this arrangement, there are no notches required in the webs and the connection to the plating is in the form of two continuous fillet welds. The face flats to these webs are probably best fitted between those to the other two webs.

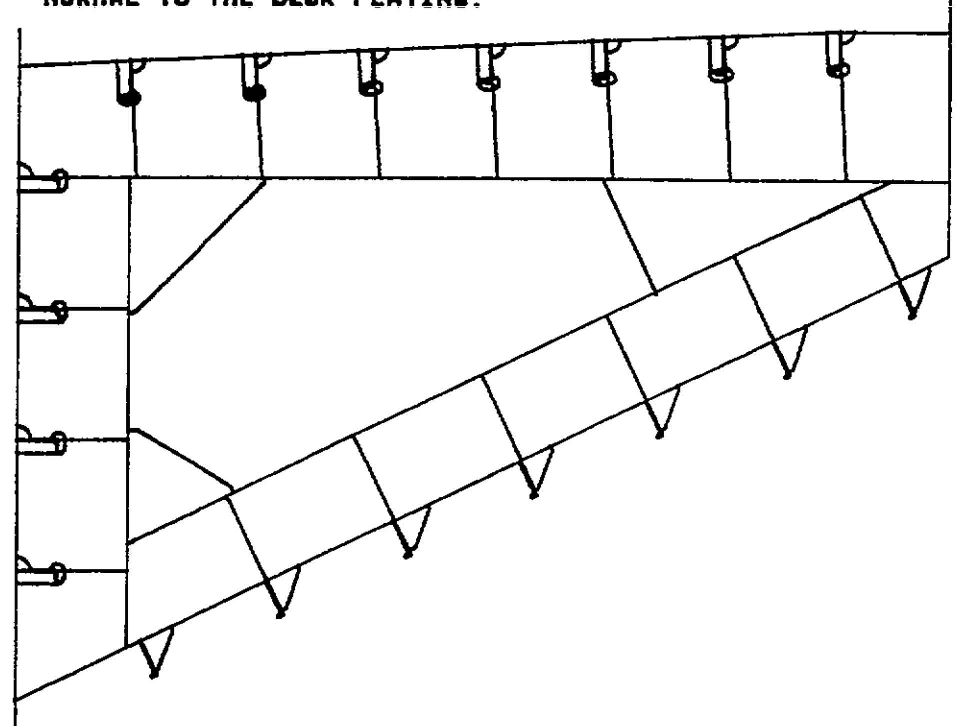
The web to the side shell must have a depth to suit strength requirements (but not less than twice the depth of the notches for the associated longitudinal). The face flats to these webs are probably best arranged to be continuous from the sloping bulkhead plating to the deck web face flat.

Web spacing within upper winq tanks can often be twice that of double bottom and hopper tank webs. This has the effect of increasing the required size of longitudinals. A web should be arranged in way of each end of a hatchway.



SINGLE PLATE WEB

NOTE THAT LONGITUDINALS ARE FITTED NORMAL TO THE DECK PLATING.



THREE PLATE WEB

UPPER WING TANK INTERNAL STRUCTURE

3.2.5.8 Transverse Watertight Bulkheads

i) General

Bulkheads can be formed in a number of different ways:

Plane plating with rolled stiffeners, either vertical strakes in association with vertical stiffeners or horizontal strakes with horizontal stiffeners.

vertically corrugated Plating with or Without bottom and/or top stools or horizontally corrugated Plating.

Cofferdam type.

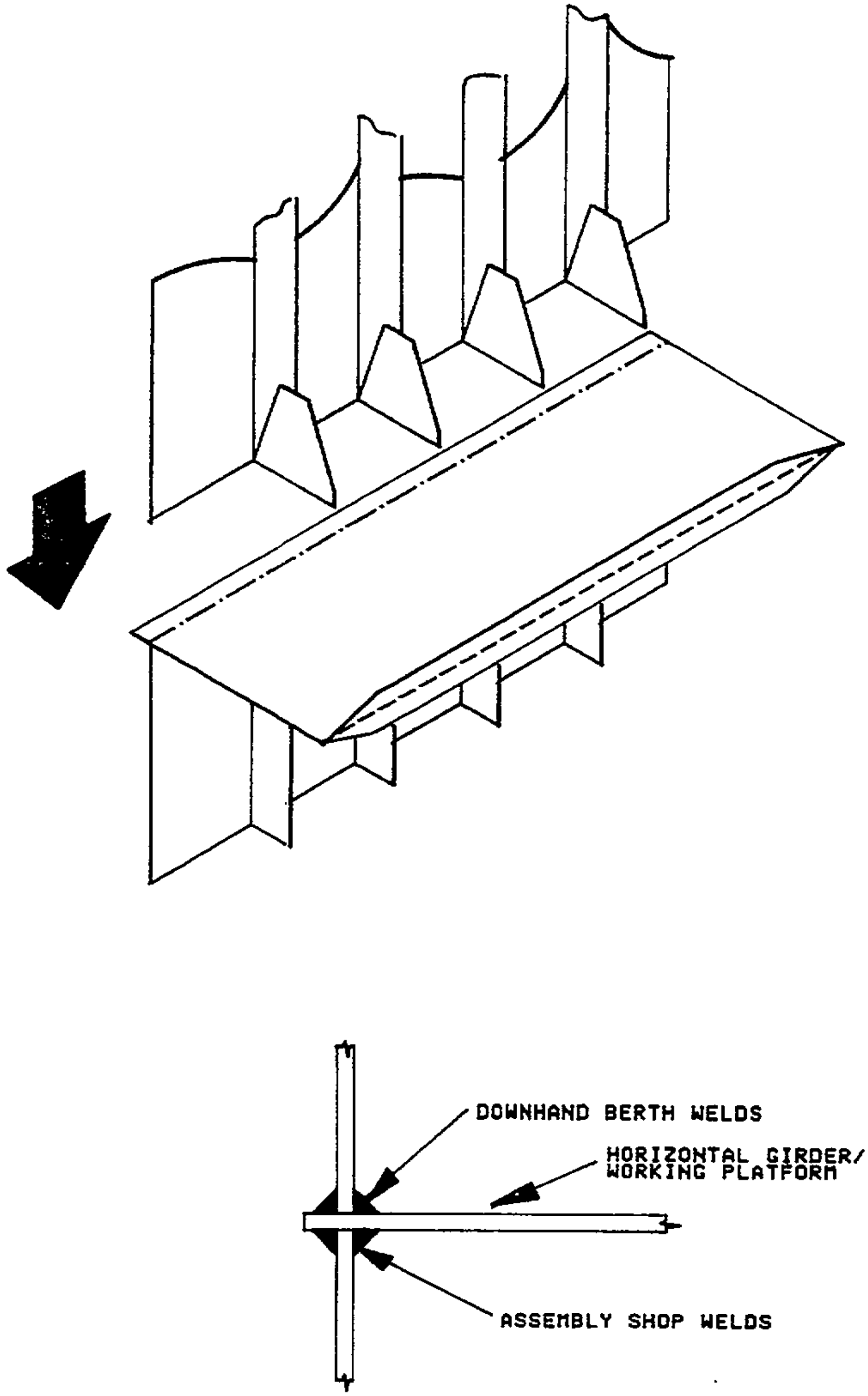
The manner of forming bulkheads depends mainly upon ship type and size, but some of the pros and cons of each method are discussed on the following pages.

ii) Plane Platinq with Rolled Stiffeners

Vertical Strakes with Vertical Stiffening

This method of forminq bulkheads is usually adopted for general cargo ships, container ships. multi-purpose ships, ro-ro ships and is also common on oil tankers.

Where the depth of the bulkhead is such that to use a sinqle stiffener for the full depth would result in an excessively large stiffener, it is usual to introduce a horizontal girder, or girders, to reduce the span(s) as shown opposite. The positioning of horizontal girders should be determined taking due account of continuity of adjacent structures and so that the rule scantlinqs for stiffeners fitted between the girders are as uniform as possible. The stiffeners fitted between girders can be either a single stiffener runninq thorouqh the girders or intercostal stiffeners fitted between the girders. The former method wi11 require notched horizontal girders but does not require brackets other than tripping brackets for the girders and is preferred.



HORIZONTAL GIRDER

AS A WORKING PLATFORM

Where it is proposed to erect a bulkhead having a horizontal girder or girders, in more than one piece, consideration should be qiven to using the natural breaks at one of the girders and making the depth of the girder of sufficient size to form a working Platform. The bulkhead stiffeners at this position would have to be intercostal and bracketed to the horizontal girder.

Horizontal Strakes with Horizontal Stiffeners

This method of forminq bulkheads is usually only adopted for ships which carry liquid cargoes adjacent to the bulkheads.

The thickness of the strakes of plating will gradually increase down the depth of the bulkhead as wi11 the scantlings of the stiffeners. The only way of avoiding this is to reduce the width of straking and spacing of stiffening towards the bottom of the bulkhead. Adopting this procedure would mean that there would be no uniformity of plate sizes for the bulkhead and that marking of stiffener positions would be more complex. Vertical webs are used to reduce the spans of the stiffeners.

Production enqineers workinq at the tactical and detail levels would have to carry out an analysis in the context of a specific shipyard and its facilities. This analysis would provide the data on which to base a decision on whether to have stiffeners of uniform scantling, preferable if automated equipment is available for panel manufacture; or to have uniform spacing of stiffeners, preferable if marking and positioning of stiffeners is done manually. An advantage of uniform stiffener sizes in either case is the ability to use a standard notch.

iii) Vertically Corrugated Plating

Bulkheads can be formed from vertically corrugated platinq for all ship types but are mainly used for dry and liquid bulk cargo carriers. In order to reduce the distance between the flanges of the corrugations, it is quite common to introduce stools at the bottom and/or top of these bulkheads.

Rough rules of thumb in determining when stools are required are given below:

> If the breadth of the ship exceeds 90ft, fit stools at the bottom and top of the bulkhead. Where the bulkhead bounds a hold which can carry water ballast, then the top stool should be of the same form as the bottom stool, otherwise a box beam type structure will suffice.
>
> If the distance between the flanges and/or the thickness of the plating becomes excessive,then consider fitting a stool at the bottom and possibly the top of the bulkhead.

iv) <u>Geometry of Corrugations</u>

The geometry of an individual trough of a corrugated bulkhead can take several forms, some of which are shown in the figure page 3-2/521 discussed below. The individual trough for (a) and (b) should be capable of being formed from a single width of plating.

Type (a) trough is usually used where the structural, demands on the bulkhead and the dimension "d" and the thickness "t" will have relatively small values. Given the rule requirements and the angle and the depth "d" which will result in the lightest bulkhead.

Where the structural demands on the bulkhead are high, then type (b) trough geometrv is usually adopted as for a given plate width "d" can be maximized, thus allowing "t" to be kept to acceptable thicknesses which can be handled by the shipyard's facilities.

Where structural demands on the bulkhead are high and the arrangement shown in (b) can not be formed from one plate of acceptable thickness, and it is desired to avoid fitting a stool, then the arrangement (c) may be adopted. If it is made thicker than "t" then the depth "d" can be kept within reasonable dimensions.

The decision on whether to adopt arrangement (c) with its large number of plates and welded joints can only be made after designing the bulkhead in a number of arrangements and examining the work contents of each.

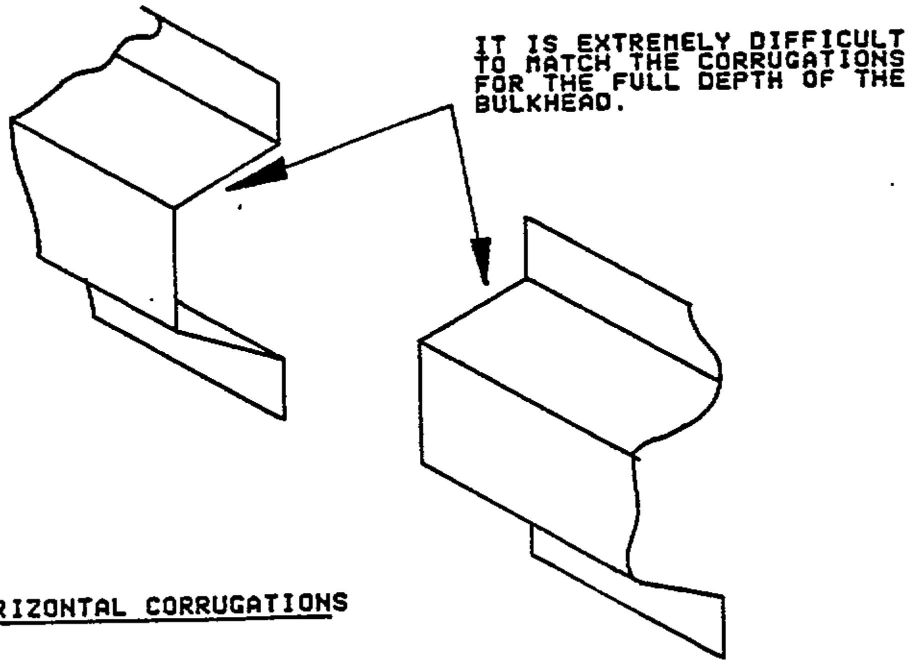
Bulkhead as (c)

Bulkhead with stool at the bottom

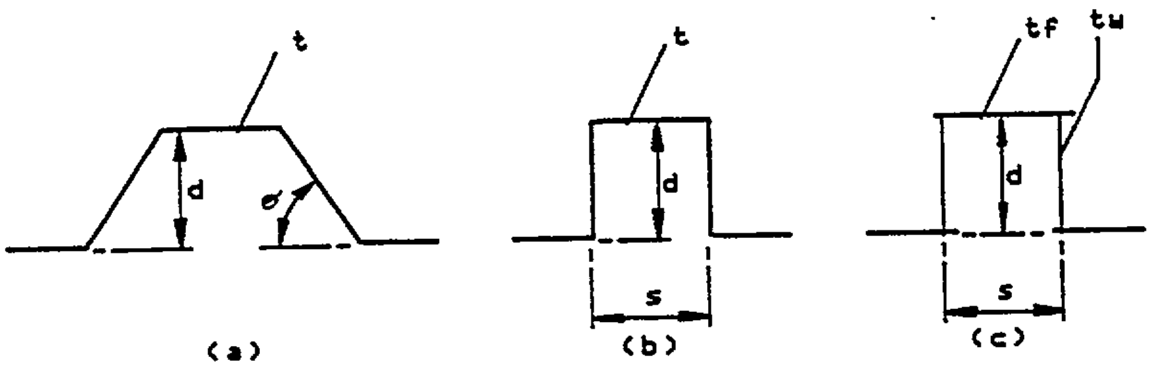
Bulkhead with stools at the bottom and top.

v) Horizontally Corrugated Plating

This type of bulkhead construction is usually fitted in liquid cargo carrying ships. To keep the depths of the corrugations and the plating thicknesses down to reasonable figures, vertical webs are fitted to form span points. The dimensions of the corrugations should be held constant for the full depth of the bulkhead.



HORIZONTAL CORRUGATIONS



CONFIGURATIONS OF CORRUGATIONS

ALTERNATIVE METHODS OF FORMING CORRUGATIONS

BULKHEAD CORRUGATIONS

vi) Bulkhead Stools

Stools arranged at the bottom of bulkheads should always be of the type shown in the figure page 3-2/523. The actual longitudinal elevation will largely depend upon the structural arrangement at the top of the bulkhead as the corrugations may have to pick up deckhead structure. The bottom of the stool should always be in alignment withh double bottom floors. The internal stiffening to the stool should be in alignment with double bottom longitudinals and girders. Stool depth for symmetrical stools should be approximately equal to the fore and aft length.

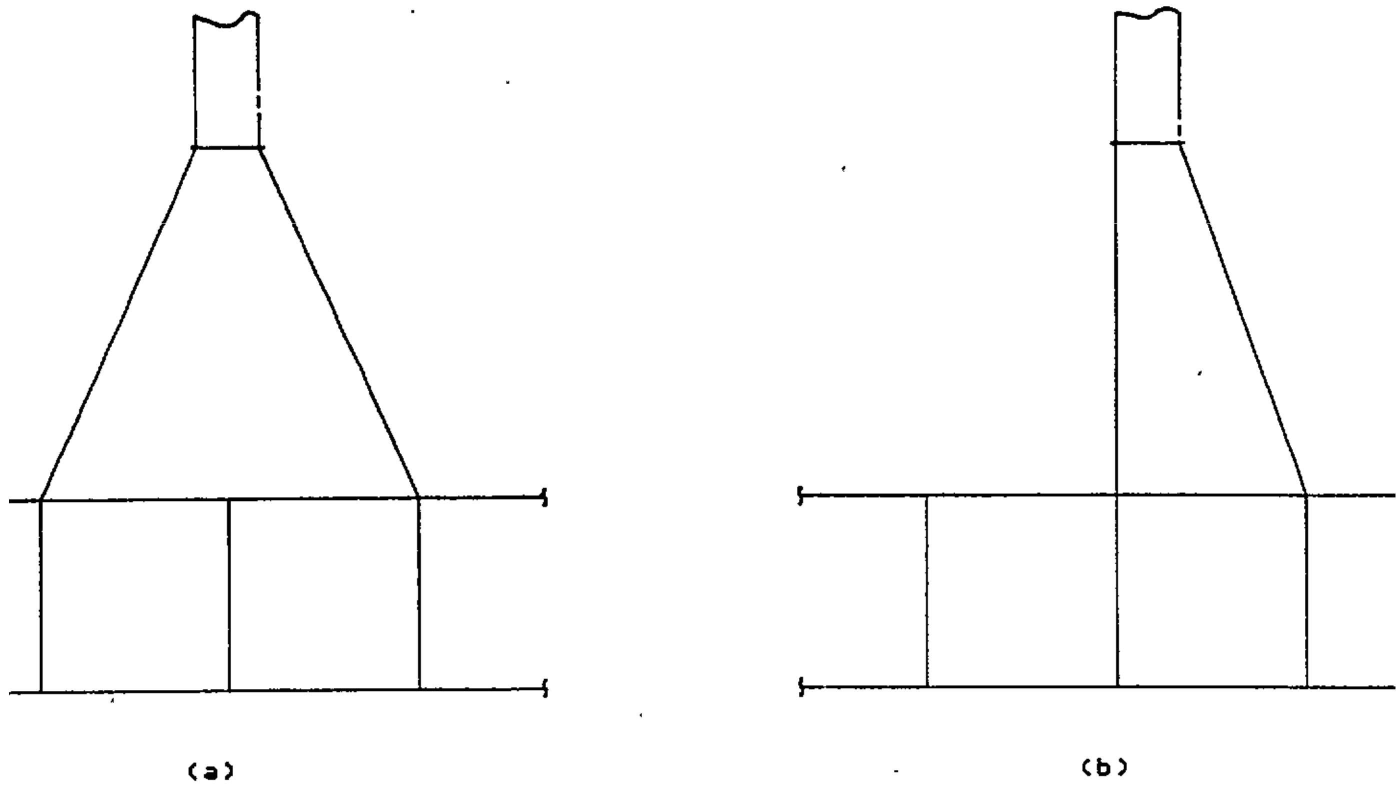
The question of alignment is clearly a design for production consideration. If alignment cannot be achieved then additional steelwork will be required to distribute the stress between non-aligned structure. The additional steelwork involves increased numbers-of pieces and weld length.

Stools arranged at the top of bulkheads can take several forms as shown opposite.

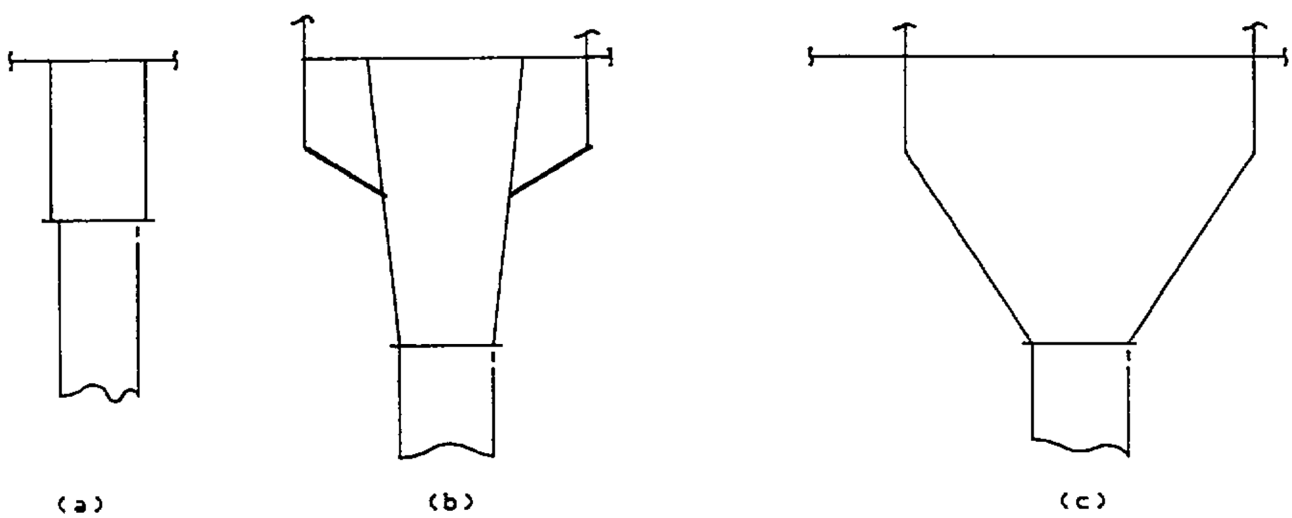
The box beam type of upper stool can only be fitted to bulkheads which do not bound holds which can carry water ballast. The depth will usually be approximately the same as the hatch side girder and the width that required to adequately land the corrugation upon.

When the bulkhead bounds a hold which can carry water ballast or in order to reduce the scantlings of the corrugations then upper stools of the type shown in (b) or (c) are fitted. The length of this type of stool is usually the full distance between the ends of adjacent hatch covers. Stool depth wil1 be approximately the same as that or the bottom stool.

Where the bulkhead corrugations are formed from square troughs the internal structure for the top stools (and the brackets in the case of arrangement (b)) should be in alignment with the trough webs.



BULKHEAD LOWER STOOL CONFIGURATIONS



BULKHEAD TOP STOOL CONFIGURATION

Arrangements (a) and (b) are shown with the butts between trouqhs in the center of a flat flange of the trough but consideration could be qiven to arranginq the butts at. a corner of the trouqhs as shown in the fiqures (d) and (e).

This arrangement. of butt results in only three bending operatons per trough as opposed to four with the original arrangements shown in (a) and (b).

For arrangements (b) and (c) the distance s should be the same as the stiffener spacing of the structure on which the bulkhead sits.

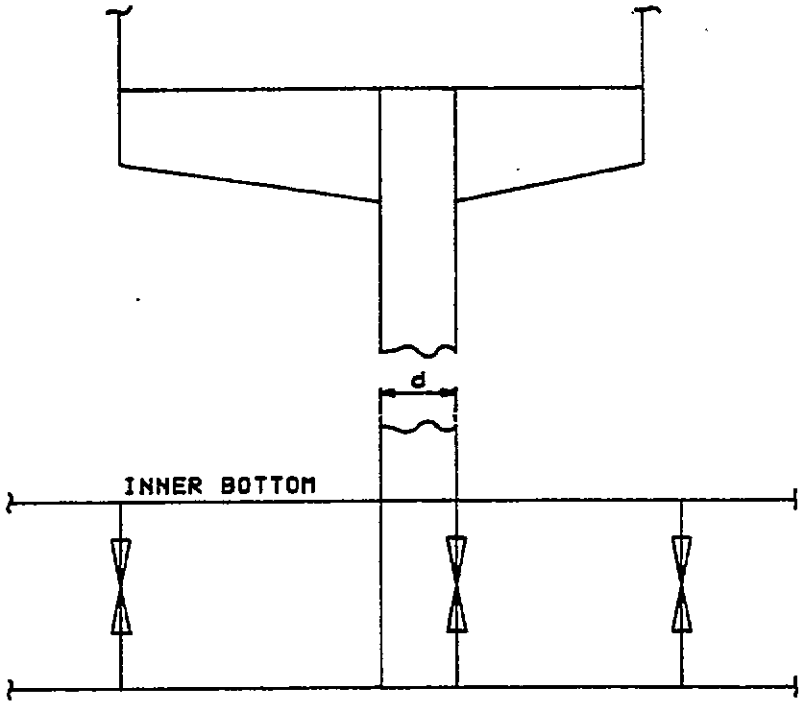
It is important to carefully consider the design of a corrugated bulkhead as several alternatives which satisfy structural requirements may be developed, but they will all have different work content. For example, a certain configuration which in association with light scant lings would be simple to produce could be relatively difficult to produce when associated with heavy scantlings.

vii) <u>Cofferdam Type</u>

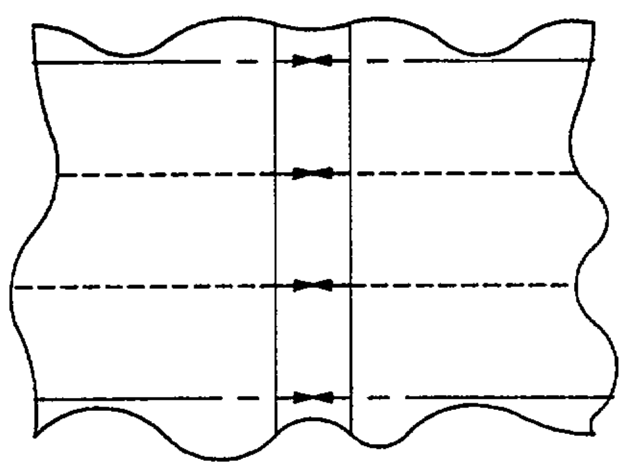
This type of bulkhead is formed by two plane panels of platinq arranqed close toqether and igined by internal stiffening within the cofferdam thus formed.

Cofferdam type bulkheads are usually fitted in the larger vessels which carry 1iquid cargoes, the larger vessels which carry dry bulk cargoes or the larqer combination carriers. One major advantage of cofferdam type bulkheads is that they form a smooth, easily cleaned, surface within the holds. They may be fitted in association with stools or extend from inner bottom to deck plating.

The distance between the plane panels of plating, “d”, as shown in the figure page 3-2/525, should be sufficient to allow Pasy access for sea-going personnel and for shipyard personnel durinq construction and maintenance.



ELEVATION



PLAN VIEW AT INNER BOTTOM

COFFERDAM TYPE BULKHEAD

Internal stiffening within the cofferdam should align with the structure upon which the bulkhead sits and is probably best arranged in the form of vertical diaphragm plates, provided that the distance "d" is such that the diaphragm plates themselves do not require to be stiffened.

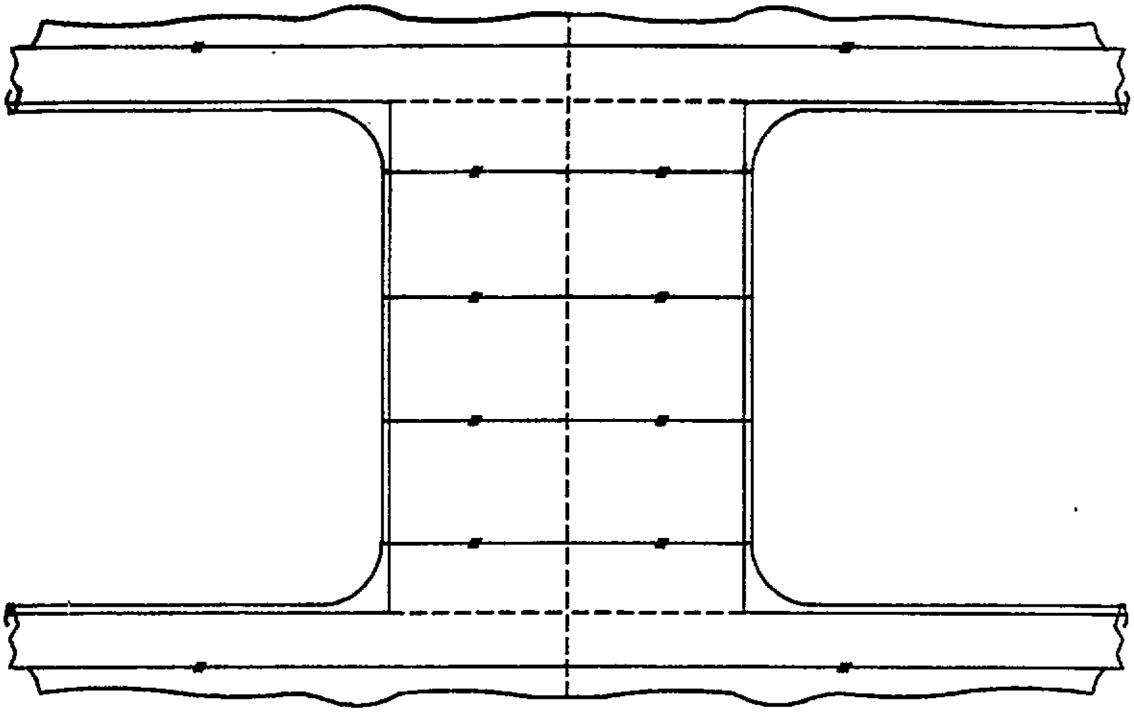
3.2.5.9 Deck Stiffening between Hatchways

The stiffening of the deck plating between hatchways can be in the form of beams in association with girders or longitudinal, using the top of the bulkhead as the span point.

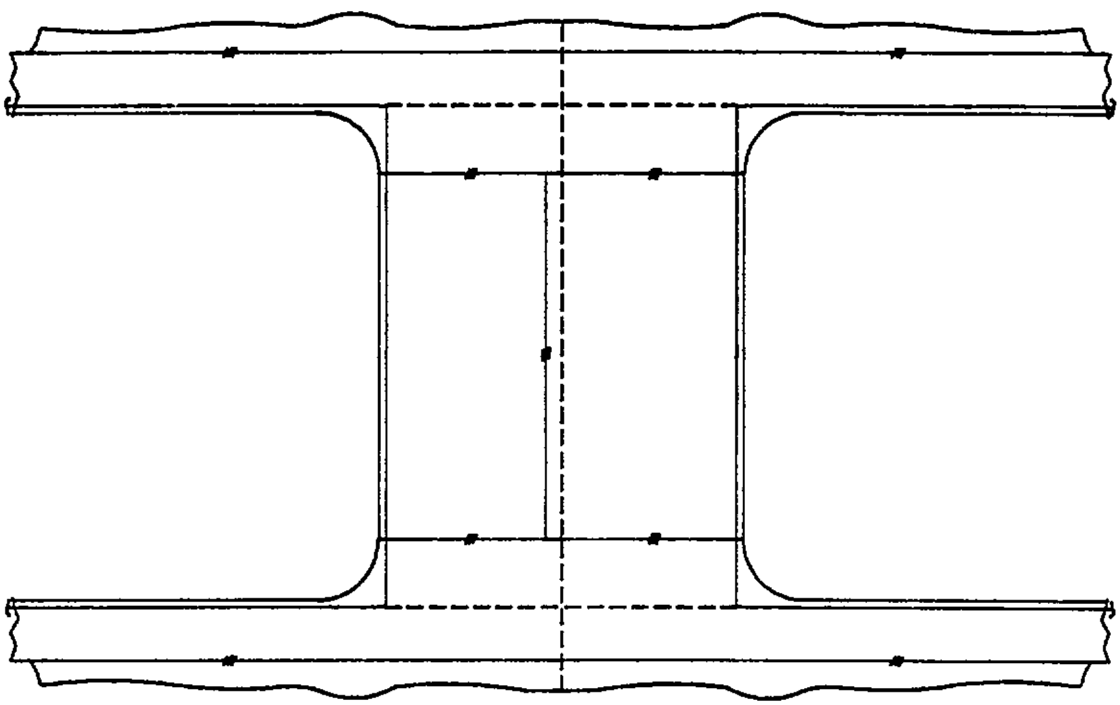
Longitudinals fitted between hatchways are not considered to contribute to the hull girder moduli and do mot greatly reduce the 1ikelihood of primary buckling occuring in this region, as the top of the bulkhead plays the major role in this respect.

Beams are considered to play an important part in the transverse strength of "the ship by tying together the deck structures outside the 1ine of hatchway openings. For ships with wide hatchway openings, deck beams between hatchways should be seriously considered.

If beams are fitted between hatchways, then consideration may be given to arranging transverse strakes of plating between the hatchways so that the welding of the beams can be as continuous as possible. The number of plates and the joint length will also be reduced.



LONGITUDINALS & LONGITUDIAL STRAKING



BEAMS WITH TRANSVERSE STRAKING

DECK BETWEEN HATCHES

3.2.5.10 Adding Material to Achieve a Required Modulus

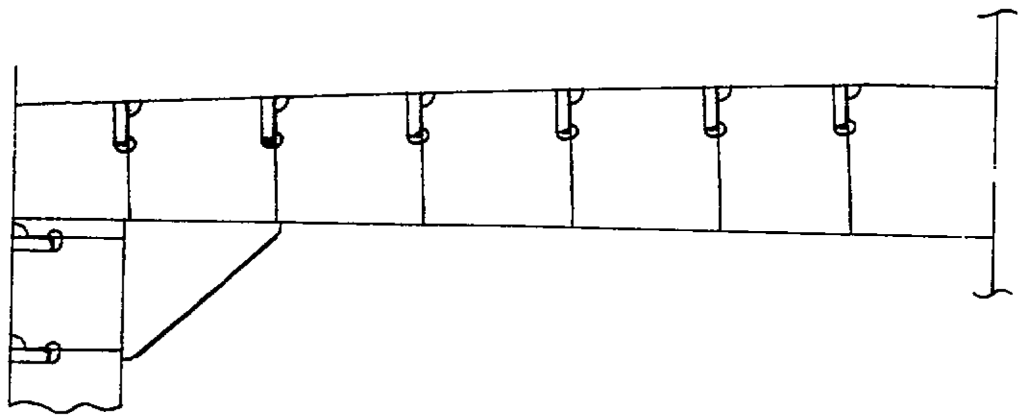
Often the midship section moduli calculated using the scantlings which satisfy local strength requirements are deficient at the keel and/or the deck. To increase a deficient modulus, material has to be added to the plating or longitudinals, or both, in the region of the deficiency.

If material is added to the plating alone, the following points should be noted:

- This will add the smallest amount of material as the lever from the neutral axis to the plating is the largest.
- The resulting thickness may become excessive requiring that a higher tensile steel be used or that material is also added to the longitudinals in order to avoid this.
- Even if higher tensile steel is not used then the grade may have to be higher due to the thickness required.
- Extra weld material will be required for the thicker plating.
- If the thickness of the plating outside the hatchways is greater than that between hatchways by approximately 0.5 inch then a strake of plating having a thickness mid-way between these two thickness will have to be inserted.

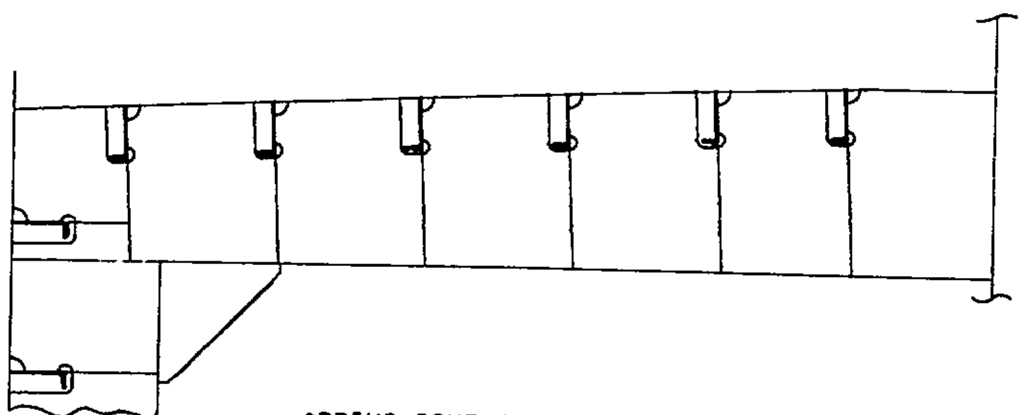
If some or all of the material is added to the longitudinals the following points should be noted:

- As a general rule the area of longitudinals should not exceed the area of the plating to which they are attached.
- The amount of material required will be greater than if material was added to the plating alone.



ADDING MATERIAL TO PLATING ONLY

LESS MATERIAL IS REQUIRED TO ACHIEVE MODULUS, MORE WELD METAL IS REQUIRED TO JOIN PLATING IN THE SHOPS. LONGITUDINAL AND WEB SCANTLINGS PLUS WELDS ARE UNALTERED.



ADDING SOME OR ALL MATERIAL TO THE LONGITUDINALS

MORE MATERIAL IS REQUIRED TO ACHIEVE MODULUS AND SECTIONS ARE USUALLY MORE EXPENSIVE THAN PLATING. WELDS TO JOIN LONGITUDINALS TO PLATING WOULD BE INCREASED IN THROAT THICKNESS. WEBS WOULD BE INCREASED IN DEPTH & PERHAPS THICKNESS. WELDS TO JOIN WEBS TO PLATING MAY BE INCREASED IN THROAT THICKNESS. NOTCHES FOR LONGITUDINALS WOULD BE INCREASED IN DEPTH, INCREASING FLAME CUTTING LENGTH. STIFFENERS TO WEBS WOULD BE INCREASED IN LENGTH, INCREASING JOINT LENGTH.

ADDING MATERIAL TO ACHIEVE A DEFICIENT MODULUS

The depth of the stiffener notches will be increased and this, in turn, wil1 increase the required burn length.

Webs associated with the longitudinals will have to be increased to maintain them at least twice the depth or the notches.

The area of fillet welds will be increased to suit the increased scant1ings of the longitudinal.

If the resulting plating thicknesses are acceptable then material should be added to the plating only in order to achieve the required modulus. This wil1 reduce the additional material required and also minimize the work content associated with the structure.

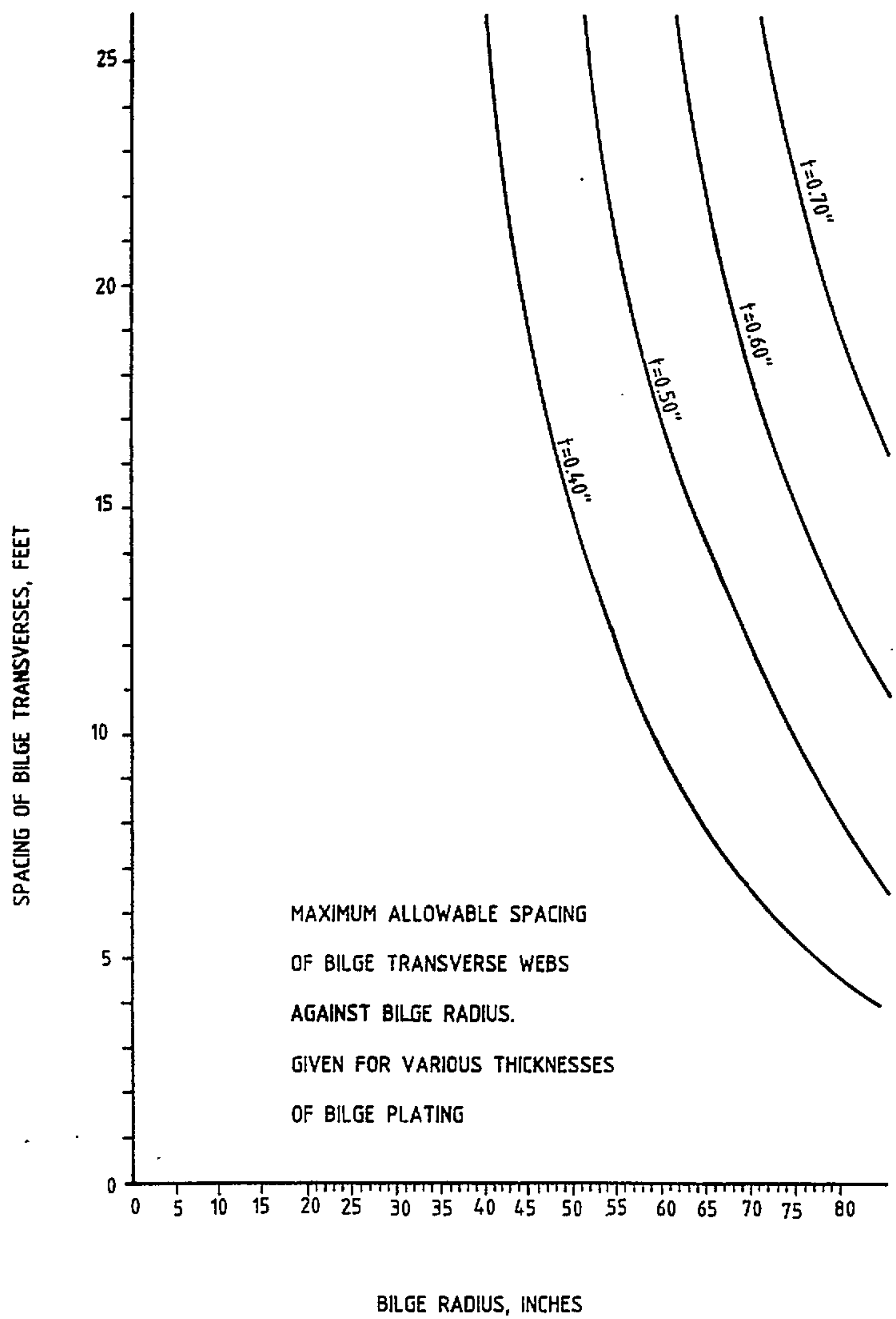
3.2.5.11 Bilge Stiffening

If the spacing of bilge transverse webs and the thickness or the bilge plating satisfy certain requirements laid down by the Classification Societies. then the need to stiffen the bilge region with Iongitudinals or brackets between floors can be eliminated.

The figure page 3-2/531 indicates the requirements of the Classification Societies and is included to indicate that, for most practical hilge radius/bilgy plating thickness relationships, bilge transverse webs spaced equal to the double bottom floor spacing will be sufficient to stiffen the bilge.

Each ship type will have to be specially considered when it is proposed to eliminate bilge stiffening and for every ship type regions of high stress along the bilqes must be investigated.

The benefits of removing bilge longitudinals are in greatly simplified assembly operations.



SPACING OF BILGE TRANSVERSES, FEET
25
20
15
10
5
0
t=0.70"
t=0.60"
t=0.50"
t=0.40"
MAXIMUM ALLOWABLE SPACING
OF BILGE TRANSVERSE WEBS
AGAINST BILGE RADIUS.
GIVEN FOR VARIOUS THICKNESSES
OF BILGE PLATING
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80
BILGE RADIUS, INCHES

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3.2.6 USING STANDARDS TO PRODUCE LAYOUTS

The concept of applying standards in a hierarchical- manner from complete ships to individual elements is outlined in this chapter. The concept of standards can be applied at all levels from a complete vessel down to single piece parts. To the extent that standards are adopted, design effort can be saved and applied to aspects of a vessel which are unique.

CROSS-REFERENCES

3.1.5 The Need for Development of Interim Product and Production Process Standards

3. 1.7 Process and Spatial Analysis

3.2.3 Functional Separation of spaces

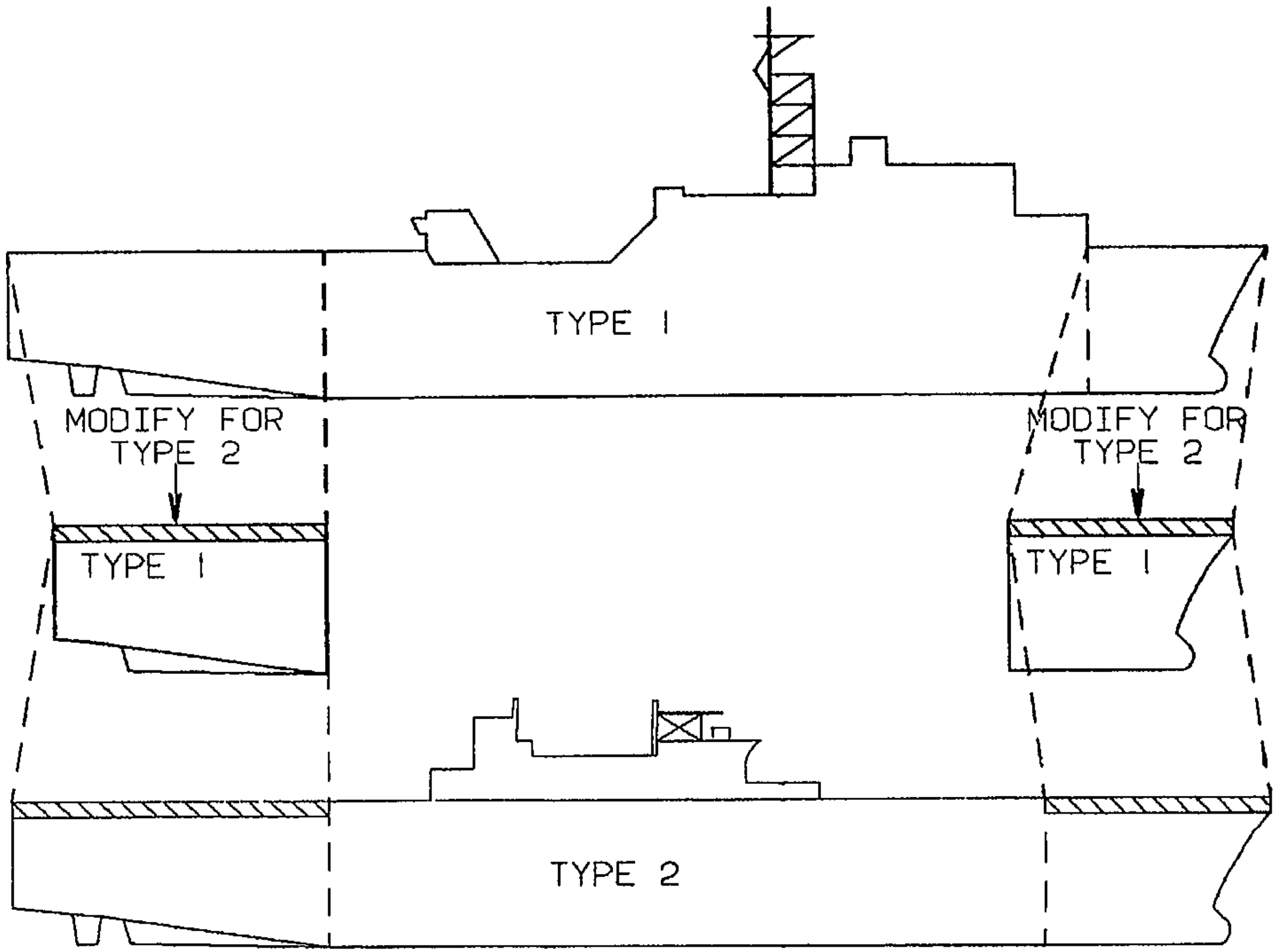
3.2.4 Systems Grouping and Routing

3.2.6.1 Introduction

The very earliest decisions in the design process have the greatest impact on production, the obvious ones being the vessel's dimensions, its hul1 form and the arrangement of the spaces within the ship.

The use of spatial analysis has been described earlier (Chapter 3.1.7 Application of spatial analyses will result in a layout within the vessel which consists of a series of functional spaces interconnected by the systems routes. Considering all ship types and sizes it is clear that there are certain spaces on board which have common functions. Although the size of these functional spaces can differ greatly, their similarity of purpose enables a degree of standardization to be adopted.

The concept of a ship as a hierarchy of functional spaces and the use of these as planning units, which are themselves broken down into assemblies, subassemblies and components, underlines the use of standards. It is to the advantage of both design and production if standard products can be used. The illustration shows, at a conceptual level, how two different vessels could adopt essentially the same fore and aft end,



STANDARD DESIGN

3.2.6.2 Standardization

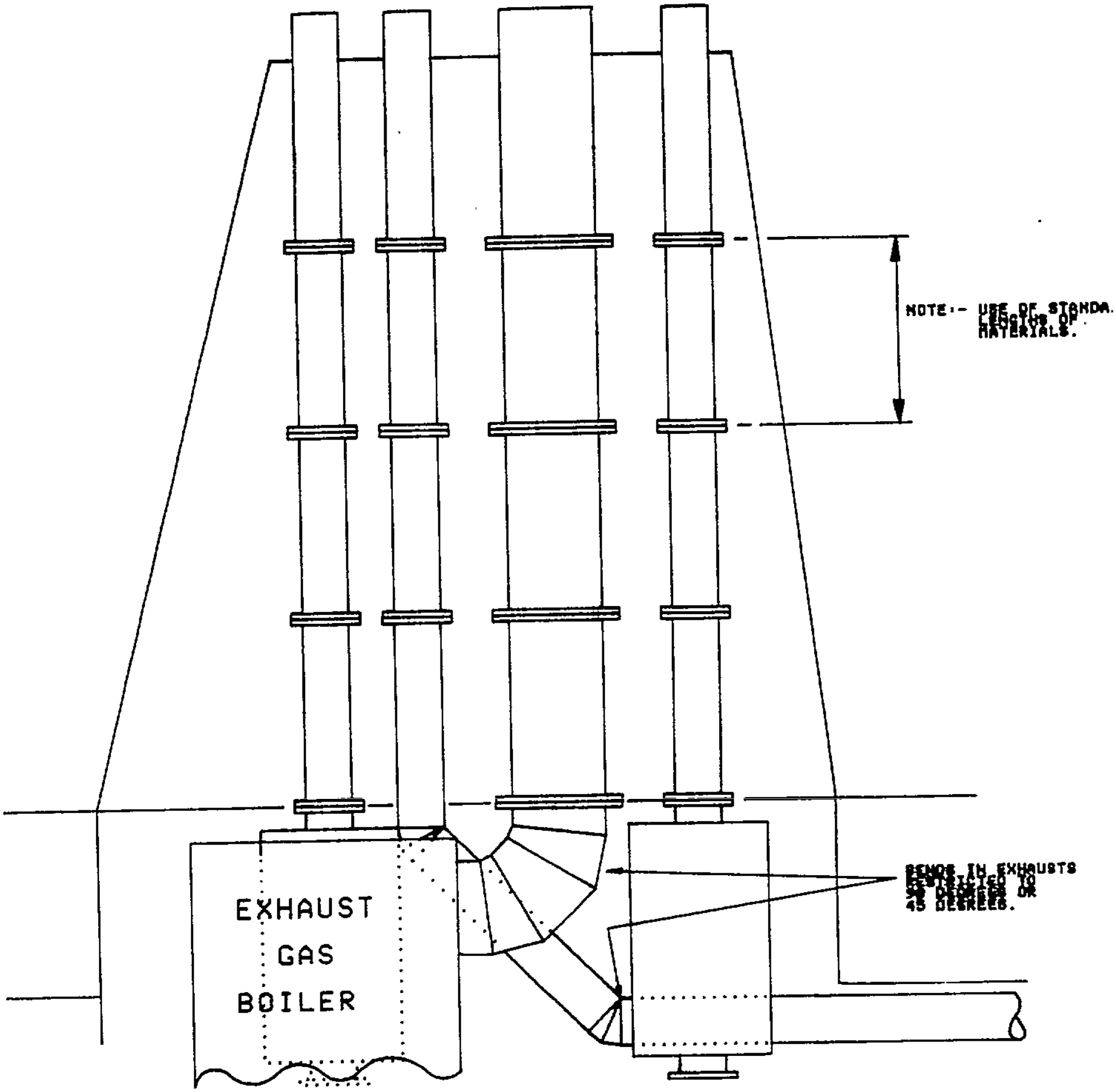
The adoption of a shipbuilding policy by a shipyard signals its intention to optimize and then standardize its shipbuilding Process. The policy wil1 be to adopt standard methods and products, but to do so in a way that allows a flexible response to change in technology and markets. Therefore, the shipyard wil1 have a hierarchy of products from raw material to units, which it is organized and equipped to produce.

ideally, the shipyard would use these products to build a standard vessel. There have been examples of standard ships which have sold in large numbers. The benefits of series production are well-known. However, it is rarely possible to achieve the standard ship, and technology eventual1y dictates a revision of the design.

In this case, or in the case of a new design, it is still possible to retain parts of the existing standard. If the complete ship is not standard, it may be possible to retain zones. The same deckhouse could be utilized or the same hul1 form.

However, if this cannot he achieved, then it will be possible to maintain the same overal1 arrangement.. The relationships of the primary zones, and the zones within them can be maintained from vessel to vessel. Using the functional space approach to layout, the internal configurations of the spaces (and therefore the outfit assemblies from which they are built) can be maintained. At the simplest, a standard sewage treatment assembly for a given crew size can be used in different vessels. Given design effort, the same principle can be applied to many other functional spaces, The layout then becomes a set of standard elements, linked by a set of service routes which depend on the vessel.

At a level below the outfit assemblies, sub-assemblies or parts can be standardized, so that even where the assemblies differ, they are built up from identical elements. The illustration shows pipe standards applied to a particular use. Uptakes are 1ikely to vary from vessel to vessel, but their overall configuration and their components can be standardized.



FUNNEL SHOWING GROUPING OF UPTAKES

The important point is that standards can be applied at all levels of the interim product hierarchy. Further than that, arrangements or machinery spaces, service ducts and trunkings, accommodation blocks, hatches and cargo handing equipment and deck machimery can also be developed and included in the shipbuilding policy.

VOLUME 3

THE APPLICATION OF PRODUCTION ENGINEERING

PART 3

SHIPBUILDING POLICY

3.3 SHIPBUILDING POLICY

Contents | Page No.

xvi) <u>Material Type</u> nnnn

The material type is four letters used to classify material for both steel and outfit. The material type codes, therefore, include codes for steel grades.

3.3.1 BASIC OBJECTIVE OF HULL BLOCK BREAKDOWN

The basic objectives of hul1 block breakdown may be summarized as fol1ows:

1) To make the erection process as simple and consistent as possible.

2) To minimize erection and construction work time on the berth.

3) To achieve high labor utilization.

The basic rules to be applied in order to achieve the stated objectives are described on the fol1owing pages.

REFERENCES

1.2.1 The Impact of Welding and Assembly Methods

1.2.2 Basis for Shipbuilding Policy Development

1.2.3 Implementation of Shipbui1ding Policy

1.2.4 Contract Bui1d Strategy

3.1.4 Standard Approach to Ship Construction

3.3.2 Hul1 Steel - Identification of Interim Products

3.3.6 Production Stages - Steel

3.3.1.1 General

HU11 block breakdown is a task carried out by production engineers with the involvement of technical, production and planning functions. At the strategic 1evel of production engineering the standard approach to hul1 block breakdown should be defined for each ship type in the company product range. The standards should then be incorporated into the company shipbuilding policy.

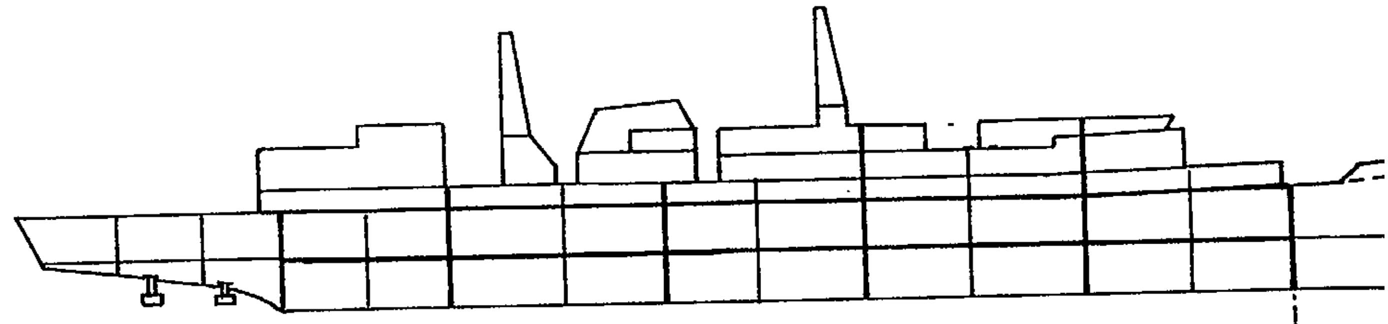
The principles of hull block breakdown incorporated in the company shipbuilding policy, must be known by the designer and be taken into account at the earliest design stage. The hul1 block breakdown should therefore be incorporated in the build strategy. Unless the ship is of a type totally new to the shipyard, it can be included even in a preliminary bui1d strategy prepared before contract signing. If the ship type is new to the yard then a preliminary block breakdown can be included in the preliminary build strategy and the final details can be worked nut as the build strategy is developed and the design progresses through contract and functional stages. The preparation of a bui1d strategy document is a task involving technical, production engineering, planning, purchasing and Production functions.

3.3.1.2 Objectives

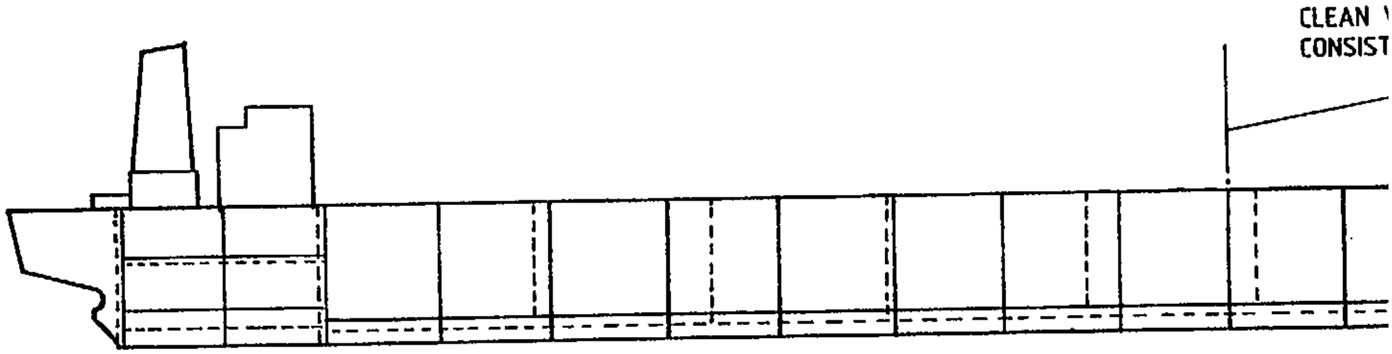
Objective 1 - to simplify the erection process

a) Fore and aft ends should include the fore and aft peak bulkheads, with the shel1 butts close to bulkheads, as shown in the figure page 3-3/103.

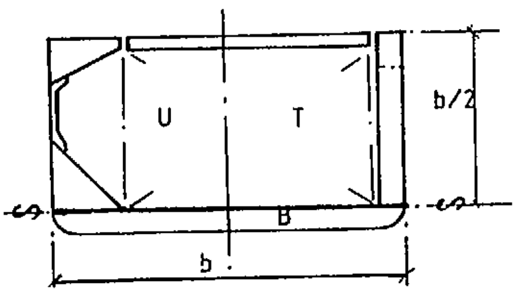
BASIC PRINCIPLES OF SUB DIVISION



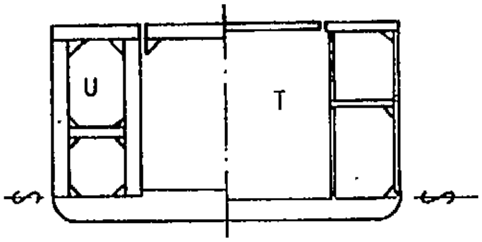
NAVAL VESSEL



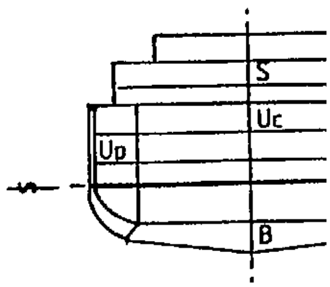
MERCHANT VESSEL



CROSS SECTIONS THROUGH A TRADITIONAL BULK CARRIER(LEFT)



CROSS SECTIONS THROUGH A TANKER (LEFT) AND A DRY CARGO VESSEL (RIGHT)



CROSS SECTION THRO NAVAL VESSEL

b) The remainder of the hull should be cleanly cut into a number of even length slices across the ship. The position of the shell butt should be a regular dimension from a frame 1ine, close enough to retain a "hard edge" but allowing sufficient space for easy welding access. The hard edge is created when the butt is located close to the bulkhead or other transverse structure. Since the butt is close to transverse structure, the edge wi11 remain firm when the edge on the adjoining block is brought to it and the butt is faired. Fairing is more difficult when the butt is positioned an equal distance from the transverse structure on both blocks. In that case both edges are "soft" and will probably distort under fairing.

c) The length of each slice should be a whole number of frame spaces and be as near as possible to the maximum plate length which can be processed at the shipyard. The figure pa.3-3/105 shows this concept. Blocks 1P/1S through 4P/4S are assembled in pairs with the block length lying across the shop. Blocks or panels are usually turned along their length and most cranes are designed to turn assemblies across rather than along the direction of the crane rails. Clearly if the various assemblies shown in this figure were of widely varying dimensions, not only would planning be difficult and space utilization be low, but labor utilization would also tend to be low since there would not be a balance, between the fitting and welding activities.

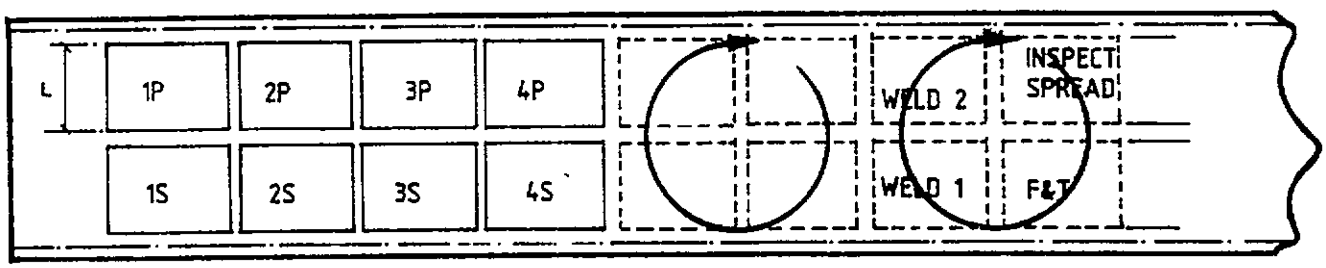
d) S1ices should be subdivided into a minimum number of self-supporting blocks. See cross sections on page 3-3 /103:

e) Erection breaks should be clean, in line, and should avoid cutting through structural members if at all possible.

f) When subdividing the hull every attempt should be made to design blocks which have the same work content.

g) The use of fillet, downhand and automatic welding should be maximized.

It may be seen that the basic block breakdown rules apply equally to a wide range of ship types. The same rules may also be applied successfully to offshore structures, semi-submersible dri1ling rigs and accommodation platforms.



FABRICATION AREA

SHOP WIDTH ≏ 2L + 5m TO INSIDE FACE OF COLUMNS WHERE L = PLATE LENGTH

Objective 2 - to minimize erection and construction time

a) Blocks should be as large as possible (according to shipyard facilities) and designed as 3-dimensional right angled structures.

b) Blocks should be designed to allow a maximum degree of pre-outfit. Al1 hot work except that in way of block breaks should be completed before erection, to facilitate painting.

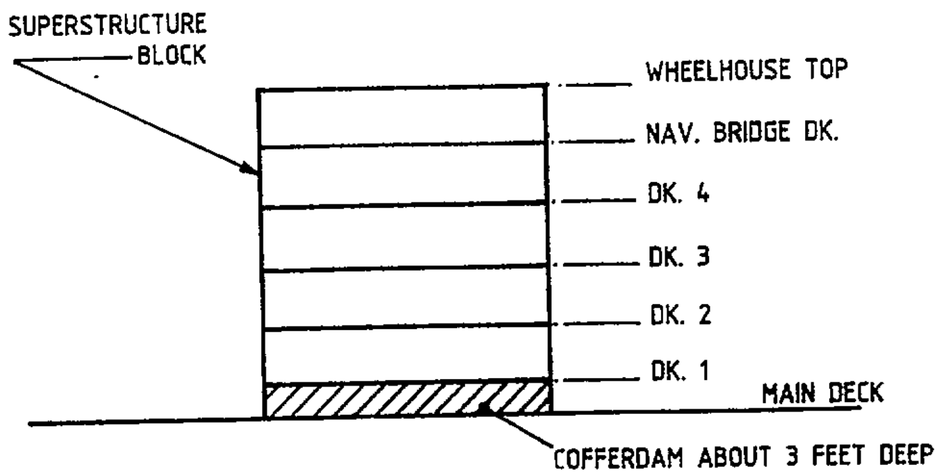
c) The superstructure and engine casings, preferably separated, should be subdivided such that they may be built as outfit assemblies and erected pre-outfitted, in as few pieces as possible.

Objective 3 - to achieve high labor utilization

a) Blocks should be designed so that the volume and work content of each is clearly defined and similar at each stage of assembly.

b) Avoid the need for staging by subdividing in such a way that the structure itself provides a work platform. breaks at tank top shown in cross sections on page 3-3/103. Stringers, horizontal girders, flats, or purpose designed structural arrangements may all be used to reduce staging requirements.

c) Restricted space working should be kept to a minimum. In some cases, however, a restricted space may offer a significant advantage. For example, a superstructure joint may be designed in a cofferdam to enable hot work to proceed without damage to outfitting and painting work in adjacent areas, as shown in the figure page 3-3-/107.


SUPERSTRUCTURE BLOCK
WHEELHOUSE TOP
NAV. BRIDGE DK.
DK. 4
DK. 3
DK. 2
DK. 1
MAIN DECK
COFFERDAM ABOUT 3 FEET DEEP

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3.3.2 HULL STEEL - IDENTIFICATION OF INTERIM PRODUCTS

The identification of interim products and the relationship between interim products and production facilities is crucial to the development of an efficient production system. This chapter identifies the hierarchy of steel work interim products.

CROSS-REFERENCES

1.2.2 The Impact of Welding and Assembly Methods

1.2.3 Implementation of Shipbuilding Policy

1.2.4 Contract Bui1d Strategy

3.1.4 Standard Approach to Ship Construction

3.1.5 The Need for Development of Interim Product and Production Process Standards

3.1.7 Process and Spatial Analysis

3.3.1 Basic Rules for Hull Block Breakdown

3.3.6 Production Stages - Steel

3.3.2.1 Introduction

In order to construct ships in short periods of time it is important to minimize the number of erection blocks, which natural1y leads to the building of larger blocks. In order to reduce the time to build a large block it is necessary to assemble it from a number of smaller sub-blocks. The making of parts, subassemblies, blocks, etc, is carried out progressively in what are called stages. As each block is being built up from smaller parts it is said to be at a different assembly level. These assembly levels form a hierarchy of interim products.

Interim product is the term used to describe any piece of steel structure or outfit designed to be joined with one or more other pieces to make a 1arger structure. Interim products range from parts such as a flame planed plate to major, three-dimensional hull blocks.

Having defined the major hul1 blocks, following the guidelines laid down in Chapter 3.3.1, the next task is to subdivide the blocks themselves into their lower level interim products. This further division is made by assembly level and proceeds through to parts manufacture.

This task is carried out by production engineers during process analysis. Process analysis is described in Chapter 3.1.7 and involves not only production engineers, but also inputs from technical and production functions. Outputs from process analysis work will be used at the conceptual and contract design stages. The greatest interface between process analysis occurs between tactical level production engineering and contract design.

The object of this division is to create as small a number as possible of interim product “families”. Each family wou1d be characterized by similarity in the size, structure, process sequence, skil1 requirement and work content of its constituents.

3.3.2.2 Family Groups

From experience it has been found that the primary family groups are as follows:

- 3D Block Cargo Part
- 3D Block Engine Room
- 3D Block Superstructure
- Flat Built-Up Panels
- Curved Built-Up Panels
- Light Plate Flat Built-Up Panels (superstructure)
- Complex 3D Blocks (aft peak)
- Double Bottoms (on-flow type)
- Composite 3D Blocks (flat plus curved built-up panels)

Examples of these interim product family groups are shown in the figures on the following pages.

The different assembly levels of interim products broadly fall into five categories, an example of each is shown on the next two pages:

1) Piece Parts - Pieces cut to shape and possibly formed directly from the raw material, for example, a flat bar stiffener, plate parts.

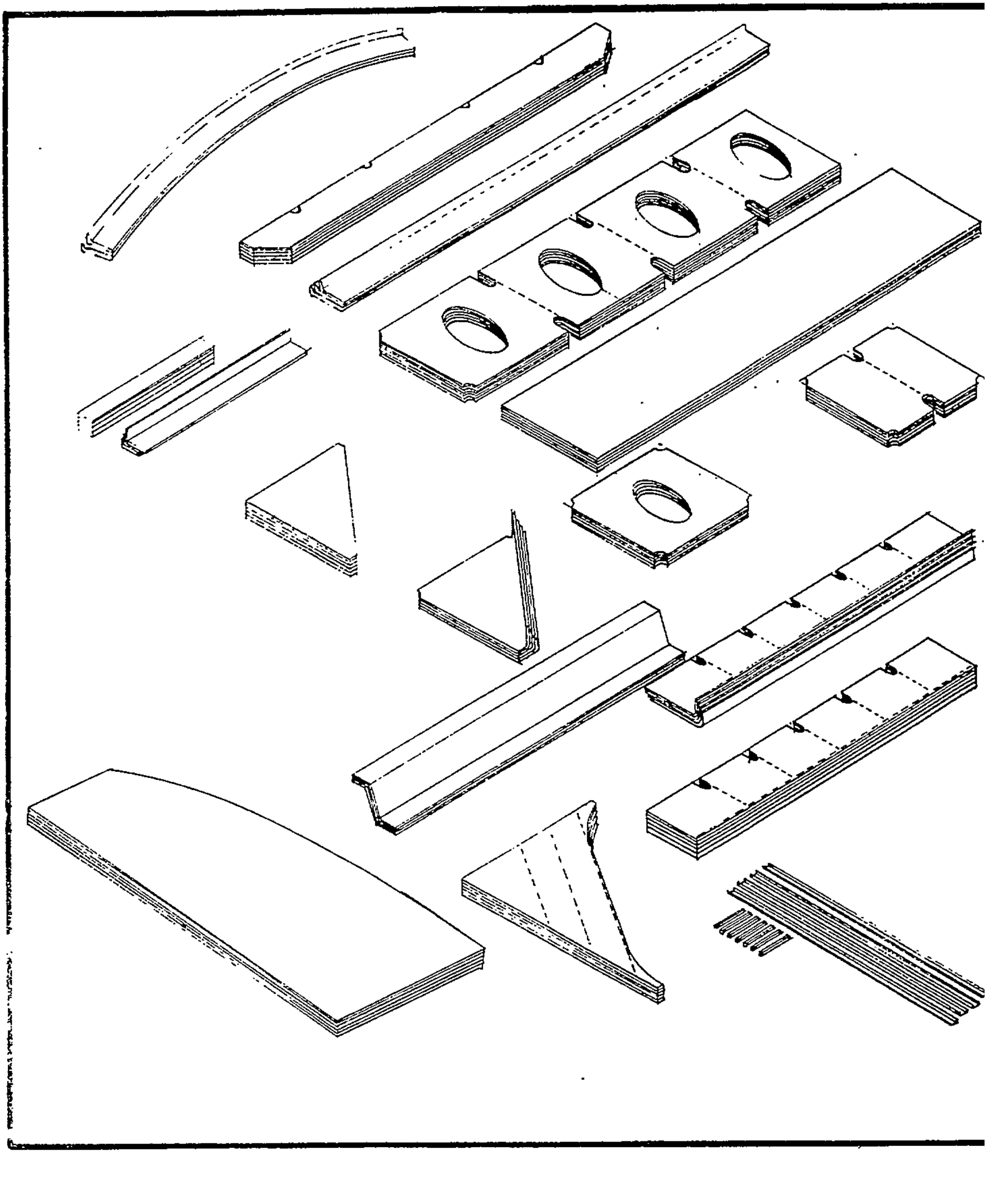
2) Minor Assembly - The lowest level of assembly usually consisting of a single plate part plus one or more stiffeners joined together, for example, web, girder, floor, stiffened bracket.

3) Subassembly - Slightly more complex than a minor assembly, may be built from two or more plate parts plus a number of stiffeners or a combination of parts and minor assemblies.

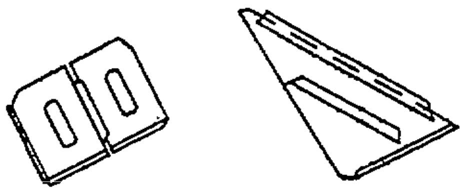
4) Unit Assembly - Built from sub and minor assemblies and possibly some additional component parts, for example, flat built-up panel.

5) Blocks - Large pieces of structure which are ultimately joined together on the berth to build the ship. Blocks are built from lower level interim products, may be pre-outfitted and can weigh up to several hundred tons, for example, superstructure, ends, hull bottom, side blocks.

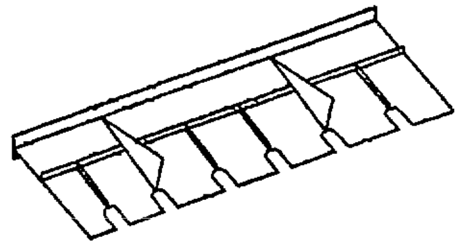
PARTS



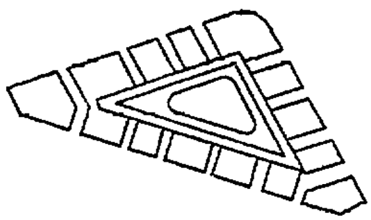
MINOR AND SUB-ASSEMBLIES



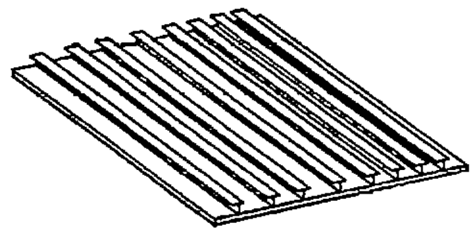
A: SINGLE PLATE ASSEMBLY
EG. FLOORS & STIFFENED BRACKETS



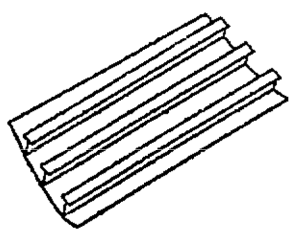
B: WEB LINE WEB
IE.WEBS, TRANSVERSES, ETC.
WITH 50/50 FB STR



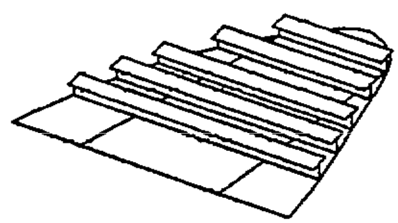
C: WEB NON-WEB LINE
EG. STIFFENED 1 SIDE ONLY OR
CURVED 50/50



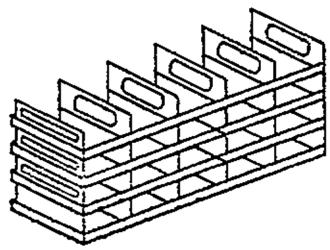
D: FLAT STIFFENED PANEL
ON FLOW TYPE



E: CURVED STIFFENED PANEL
EG. SHAPED SHELL



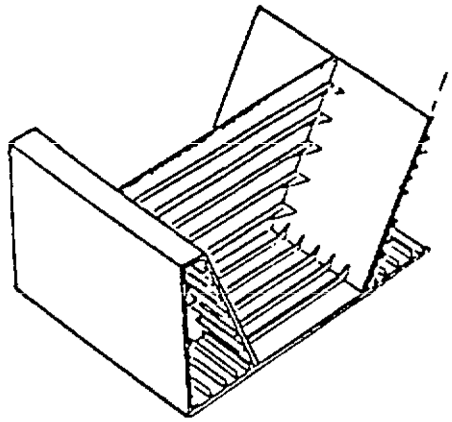
F: LIGHT PLATE FLAT STIFFENED PANEL
OFF FLOW



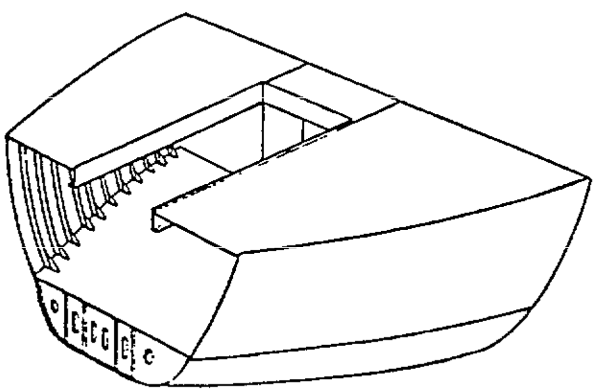
G: EGG BOX (SUB-ASEMBLY)
EG. DOUBLE BOTTOM FLOORS
AND GIRDER

INTERIM PRODUCTS GROUPS

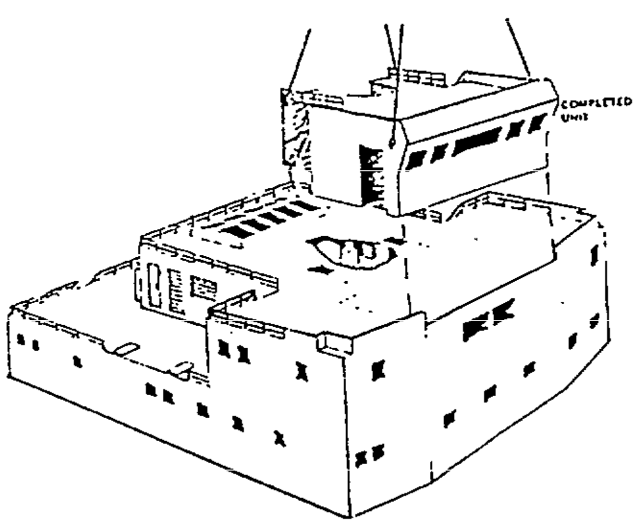
BLOCKS



1: 3D Block Cargo Part



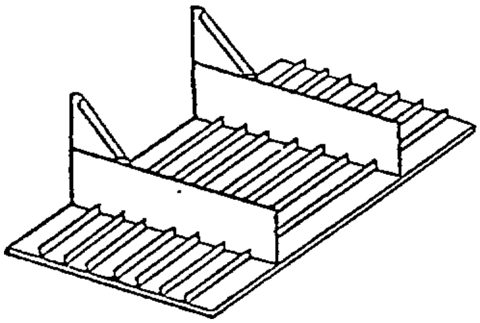
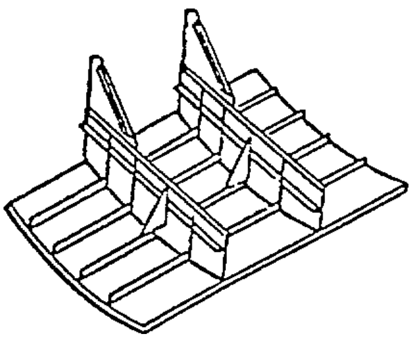
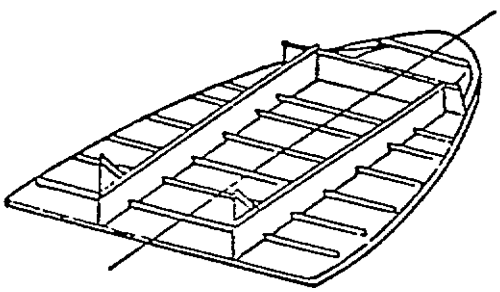
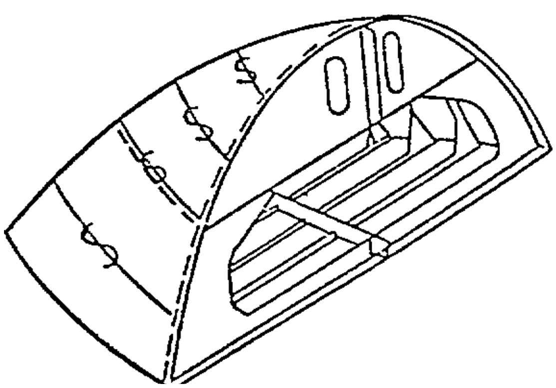
2: 3D Block Engine Room



3: 3D Block Superstructure

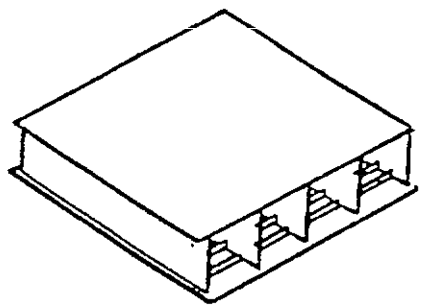
INTERIM PRODUCTS GROUPS

UNITS

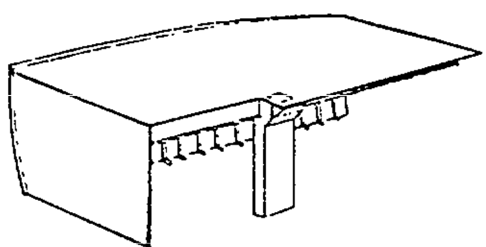
	4: Flat Built-Up Panel
	5: Curved Built-Up Panel
	6: Light Plate Flat Built-Up Panel
	7: Complex 3D (Skinned plate by plate)

INTERIM PRODUCTS GROUPS

BLOCKS



8: Double Bottom
(on flow type)



9: Composite 3D
(flat plus shell)

Interim products which are regular in work type and content and which form relatively large sets are said to be on flow, whereas those which vary greatly in size and/or complexity and are required in relatively small numbers, would be considered to be off flow.

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3.3.3 OUTFITTING - INITIAL BREAKDOWN

The definition of the initial outfit breakdown parallels that of the initial hull block breakdown. This chapter outlines an approach through an analysis of outfit processes. This approach is adopted on the basis that there is much greater Variety of Outfit Processes than there is steel.

REFERENCES

1.7..2 The Impact of Welding and Assembly Methods

1.2.3 Implementation of Shipbuilding Policy

1.2.4 Contract Bui1d Strategy

3.1.4 Standard Approach to Ship Construction

3.3.4 Outfit Zones

3.3.5 Outfitting - Identification of Interim Products

3.3.7 Production Stages - Outfit

3.3.3.1 General

The initial outfit breakdown is the equivalent task in the outfit area to the initial hull steel subdivision. It is important to recognize that, although these two topics are discussed separately in this manual, in the shipyard they must be very closely integrated. The initial outfit breakdown is a task carried out by production engineers working c1osely with technical Planning and production people.

Production engineers working at the strategic level should define the standard approach to the outfit breakdown for each ship type in the company product range. The approach wi11 identify standard machinery and accommodatiom arrangements. Within these arrangements standard outfit assemblies - machinery and equipment modules and pipe banks - will be identified. These standards should be incorporated in the company shipbui1ding policy.

The principles of the outfit breakdown must be known to the designer and be taken into account at the conceptual design stage and al1 subsequent design stages. As for initial hul1 block breakdown the outfit breakdown will appear in the build strategy document.

3.3.3.2 Processes

Outfit products must be identified in order that families and groups can be defined so that the principles of group technology can he applied. As a first step it is necessary to identify the outfit processes, since there is a much greater variety of outfit parts and assemblies than there is for steel.

For outfit parts, a primary division can be made between:

Manufacturing - producing outfit parts and assembling both in-house and vendor furnished parts.

Installation - fitting both assemblies and parts into their locations on the vessel. Installation can take Place prior to erection of the associated element of the ship structure.

An analysis of these two primary divisions is contained in the following two sections.

3.3.3.3 Manufacturing

Three types of manufactured products can be identified. These are:

Foundations: machinery and equipment seats, supports, clips, etc.

Connections: pipes, trunks, cables, etc.

Assemblies: made from vendor furnished items, mounted on foundations and connected as appropriate.

The shipyard products must be related to the manufacturing capabilities of the shipyard, and must acknowledge any restrictions imposed by those capabilities. The products should be standardized and grouped into families with similar characteristics.

During manufacture, products will pass through a number of stages. These are:

- marking
- cutting
- forming
- assembly
- fixing
- testing
- finishing

Restrictions, in terms of capacity, maximum length, weight or other parameters, will apply in some of these stages.

Presentation of manufacturing process and product information to the designer will necessarily be in a structured form. The Principal vehicle for the presentation of process and product information will be the company shipbuilding policy. A further input wil1 be contained in the bui1d strategy document in which any variations from the standard wil1 be identified. Variations from the standard should be accepted only if absolutely necessary for a Particular ship. Inputs to the design process at the detail design level will be obtained from process analysis carried out by production engineers working at the tactical level. Taking account of manufacturing requirements may restrict the freedom of the designer. However, this need not impose any restriction on the operating capability of the system which is designed.

3.3.3.4 Installation

The fact that significant reduction in installation hours can be achieved if work is done off the ship rather than on board should a1ways be in the mind of the designer and production engineer. To achieve the objective of maximizing shop work, the following two courses of action are available:

Install outfit items before the steel is erected.

Manufacture outfit assemblies. These assemblies can themselves be installed before steel is erected.

These principles should be taken into account during the work of identifying zones and outfit interim products. Zones are identified at the preliminary design level and are refined at the contract design level. Zone identification wil1 be included in build strategy documents. The task of zone identification wil1 be carried out by production engineers working at the strategic level, and further developed at the tactical level. It will be at the tactical level that outfit process analysis is carried out and interim products ar identified.

3.3.4 OUTFIT ZONES

This chapter defines the meaning of the term zone and discusses zone identification. The process of zone outfitting and its relationship to outfitting carried out at other stages is described.

CROSS-REFERENCES

1.2.2 The Impact of Welding and Assembly Methods

1.2.3 Implementation of Shipbuilding Policy

1.2.4 Contract Build Strategy

3.1.4 Standard Approach to Ship Construction

3.3.3 Outfitting - Initial Breakdown

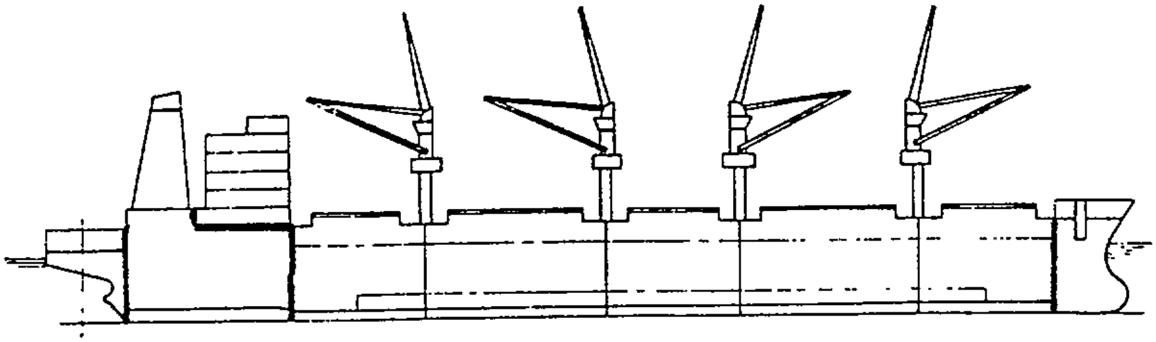
3.3.5 Outfitting - Identification of Interim Products

3.3.7 Production Stages - Outfit

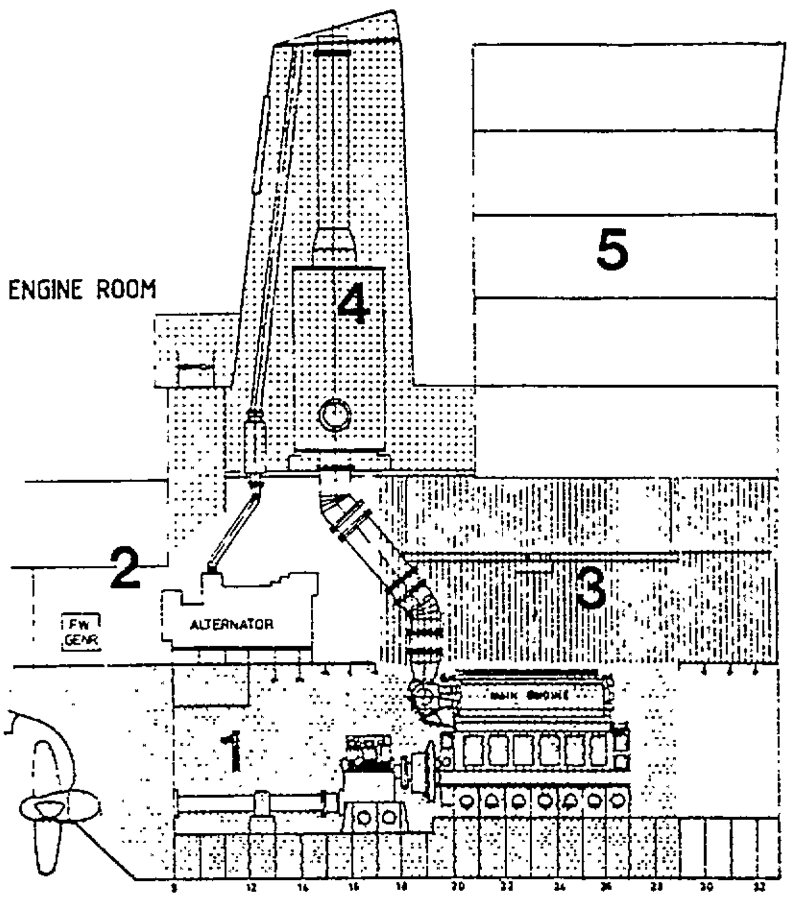
3.3.4.1 Definition

A zone is a volume within the ship which can be readily planned and monitored. It provides an address for outfit parts and assemblies. The total work content associated with a zone can be measured.

There are two 1evels of zone, “primary zones” and “zones”. Primary zones are the result of the initial subdivision of the ship into functionally related spaces - machinery space, cargo space, accommodate on space. The primary zones are divided into smaller zones, which are defined geographical subdivisions of the ship and which are the basis for planning. Zones are planning units, the entities around which planning and production engineering is organized.



MAJOR ZONES



3.3.4.2 Zone Identification

Each zone is uniquely identified by a code which indicates the approximate location of the zone within the primary zone area. The zone identification may indicate a layered approach, with the double bottom zone being numbered from forward to aft with odd and even numbers indicating port and starboard respectively. Tank top, engine room flats and funnel, etc. , would form separate 1ayers, each layer being indicated by a different first digit.

A zone reference can be given to a specific task such as main engine build or shafting alignment. In this context the reference enables time and materials to he recorded against a particular activity and also provides an address to which materials can be linked and forwarded.

A zone can be available for different activities or trades at different stages in production. It is not therefore a "once and for al1" boundary definition for al1 trades and all trade activities. It is an aid to planning and should be used to assist the progression of work in a coordinated manner. This concept is explored more fully later in this chapter.

A zone is a major planning unit, in that costs are recorded against it., drawings are provided for it and the activities or stages associated with its production and completion are clearly identified and planned. A zone becomes available as the result of steelwork progression. The zone will become available as the result of steel work being erected at the berth or completed elsewhere ready for outfit. The availability of the zone is a major planning milestone (as is its completion) and, as such, should be an event on the contract plan.

The function of a zone is to assist with control of the shipbuilding process. A typical zone will be a compartment containing diverse equipment, but where completion is readily identifiable. Completion includes all equipment installation, painting, insulating and testing. Trials and commissioning of systems are considered separately.

3.3.4.3 Zone Outfitting

The activities of an outfit installation worker are basically the same regardless of trade discipline. There are six basic activities:

- Marking
- Foundation/support installation
- Equipment installation (outfit units, assemblies, parts, etc.)
- Installation of "template" items and "make-up" pieces
- Testing and commissioning
- Finishing (painting, cleaning, inspection)

When outfitting a zone, most trades pass through each of the above activities and the technical support provided by the engineering department, purchasing and planning functions has to be coordinated accordingly.

A subnetwork identifying the tasks related to the outfitting of a zone will include all the above activities, as well as technical, material procurement and marshalling. A benefit of this approach is that it enables technical information to be presented simply for each activity, so that that marking information is presented on one drawing, foundations and supports on another drawing, etc. This approach aids material control and progress monitoring and also al1ows performance rates to be established for each of the tasks in terms of meaningful parameters.

These performance rates can then be used to balance the progress of activities through the various zones. Ideally, a group of workers will move from one zone to another carrying out the same type of task and be fol1owed through the zones by the next group of workers carrying out the next task in line. There are certain activities, however, which may wel1 cut across the general zone boundaries, as with pulling cable, painting, lagging, etc. The zones for these activities may therefore have different boundaries than those for other activites.

Outfit installation work must, as far as possible, be carried out at earlier stages of steelwork assembly and block assembly. The outfit work at these earlier stages would follow the same basic pattern of activity described above. By carrying out outfit instal1ation work early, advantage can be taken of the position and orientation of steel work. Furthermore, access to the work is significantly improved, as is the working environment and the availability of support services. Work left to be done on board is thus greatly simplified and reduced in content. Since work carried out off the ship requires less man-hours, there is significant labor time saving available.

3.3.5 OUTFITTING - IDENTIFICATION OF INTERIM PRODUCTS

This chapter defines the hierarchy of outfit interim products. A description of each product is provided and examples are given for each level in the hierarchy. The chapter also discusses assembly analysis and installation analysis.

CROSS-REFERENCES

1.2.2 The Impact of Welding and Assembly Methods

1.2.3 Implementation of Shipbuilding Policy

1.2.4 Contract Bui1d Strategy

3.1.4 Standard Approach to Ship Construction

3.1.5 The Need for Development of interim Product and Production Process Standards

3.1.7 Process and Spatial Analysis

3.3.3 Outfitting - Initial Breakdown

3.3.4 Outfit Zones

3.3.7 Production Stages - Outfit

3.3.5.1 Definitions

Process analysis of each zone of the vessel wil1 be carried out by production engineers. The analysis will yield a number of interim products. The process analysis is similar to that carried out for steel planning units.

For steelwork, each steel planning unit is broken down into a hierarchy of smaller assemblies. The lowest level is the raw material. The interim product classification varies from shipyard to shipyard but follows the following basic levels:

Block
Unit assemblies
Subassemblies
Minor assemblies
Piece Parts
Raw Material

Outfit is more complicated, as:

a greater number of trades is involved,
there is a larger variety Of parts,
there is a larger variety of raw material.

Outfit items fall into a number of categories, distinguished by the respective trade group:

pipework,
steel work,
sheetmetal work,
electrical work,
joiner work, etc.

In considering the identification of outfit interim products into parts, minor assemblies and assemblies, it is best to make a clear division between the subassembly and the assembly Stages, whereby interim products below the subassembly stage are based on single trades, and outfit "assemblies and outfit units are multi-trade products.

stage	Type of Product
outfit block outfit unit outfit assembly:	multi-trade products, such as pipe banks, equipment and machinery modules
sub-assembly minor assembly part raw material	single trade products, such as pipe, outfit steel, venti1ation, electrical, joiner work

The subassembly level is normally an assembly of outfit. items dominated by one trade, with a smaller input from another trade.

Traditional outfitting consisted of taking manufactured outfit Parts and installing them on-board. From that developed "pre-outfitting" techniques whereby parts were installed before erection.

Modern outfitting consists of the assembly of outfit parts into units, separate from the steel structure of the ship, followed by the installation of these units onto steelwork before erection or on-board after erection.

The figures on the next two Pages illustrate the classification of outfit interim products. The way in which the steel classification is mirrored can be clearly seen.

The next section lists and discusses each interim product classification and gives typical examples of the products.

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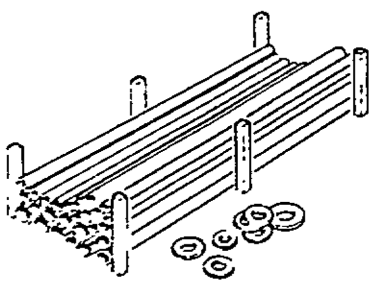
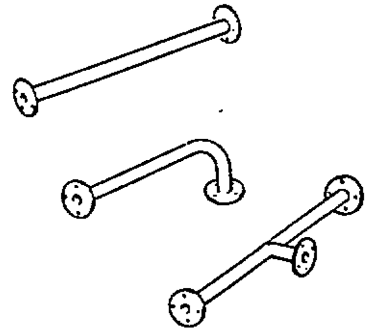
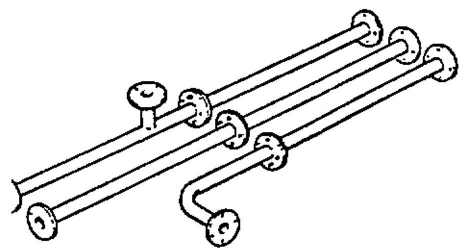
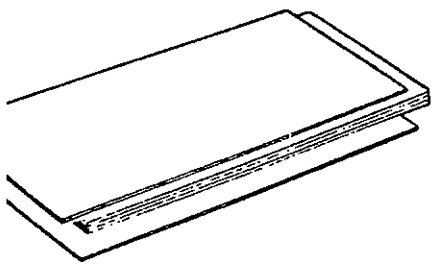
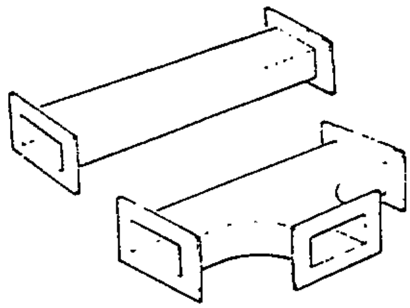
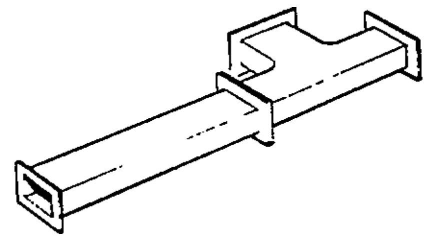
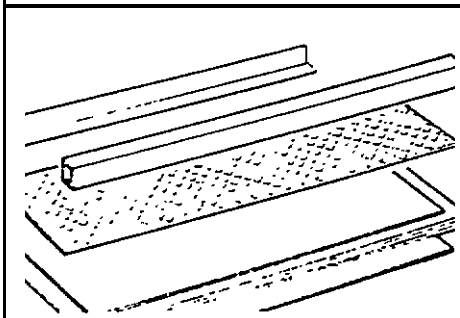
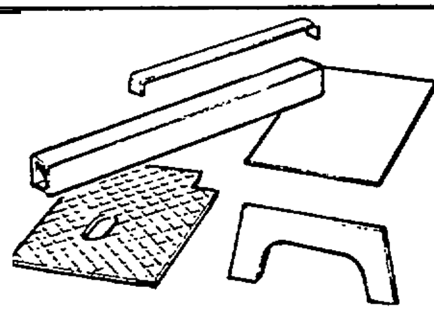
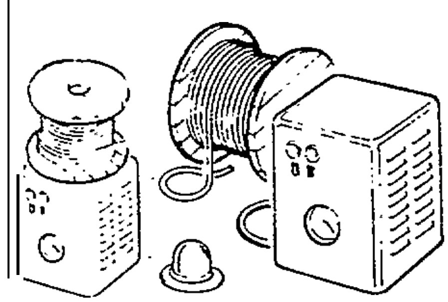
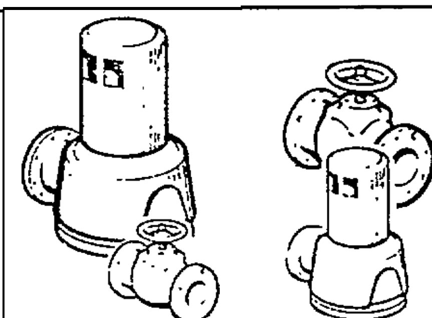
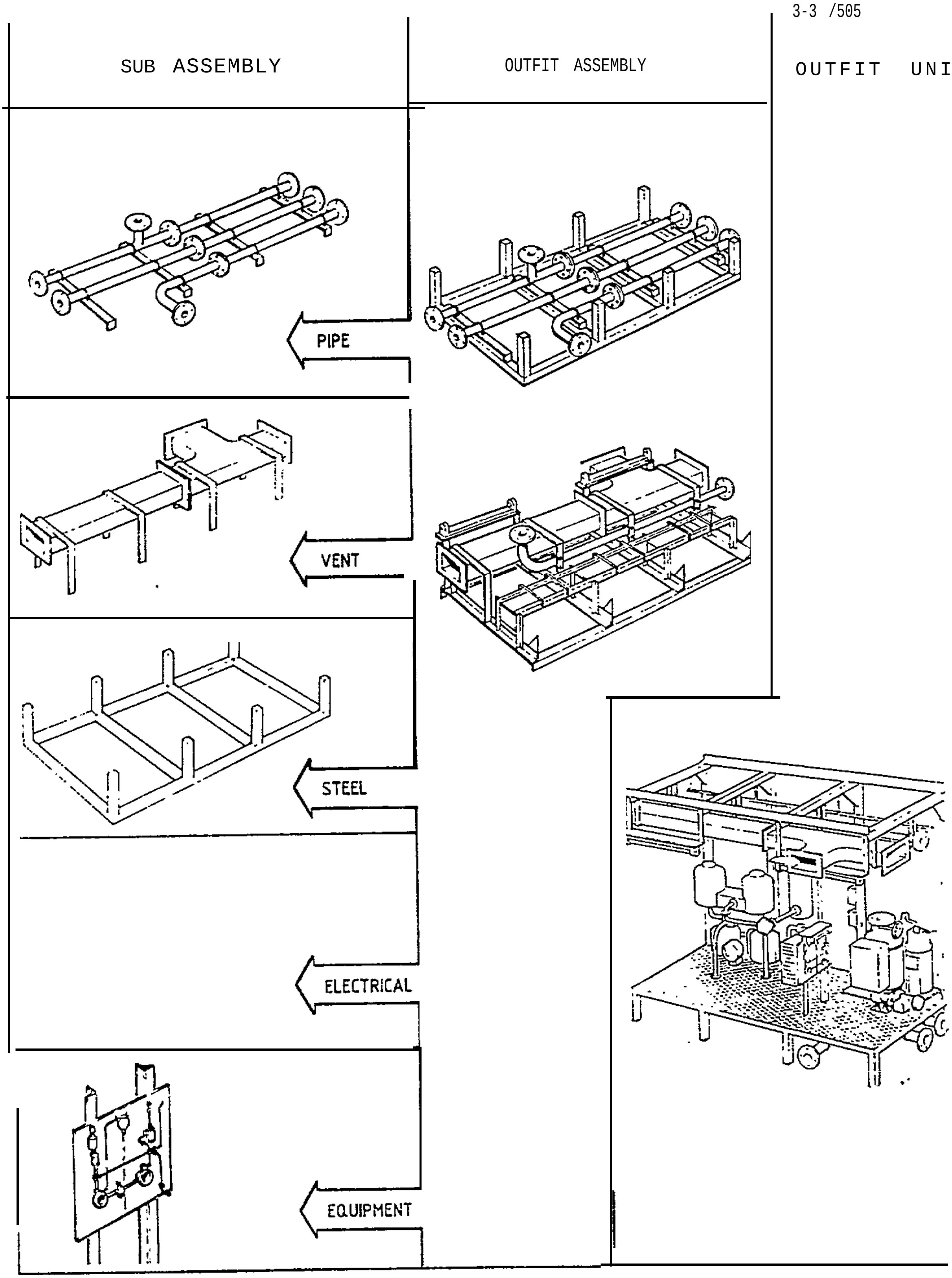
		
		
		
		
		


SUB ASSEMBLY
OUTFIT ASSEMBLY
OUTFIT UNI
PIPE
VENT
STEEL
ELECTRICAL
EQUIPMENT

3.3.5.2 Interim Product Classification

i) Outfit Material

The raw material is the lowest level of vendor furnished material which is used to manufacture outfit parts. It does not therefore include vendor furnished equipment items, such as valves, which are classified as outfit parts. Typical raw materials are i11ustrated on page 3-3/507.

ii) Outfit Parts

Outfit parts are the products from the manufacturing stage and are individual items which will be joined together during the outfit. assembly stages. The majority of vendor furnished outfit items are parts, such as pumps, valves, doors, hatches, etc. These have effectively gone through the manufacturing stage outside the shipyard.

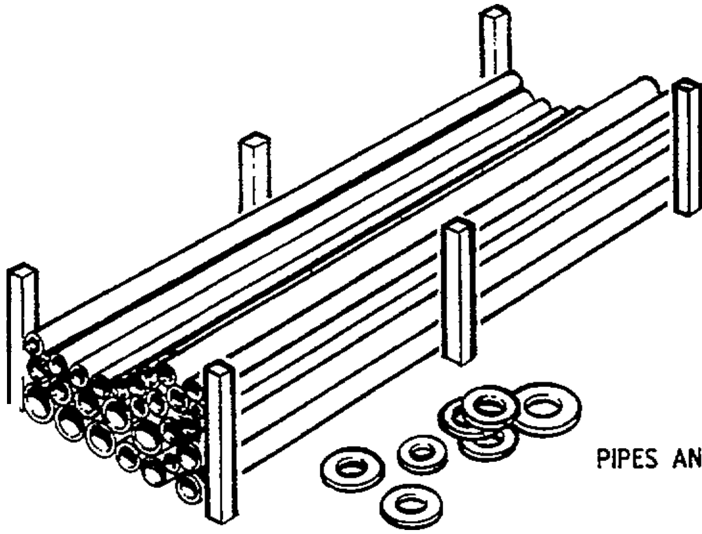
pipes

Pipe parts consist of individual pipes which have been cut, formed, fianged, cleaned, tested and painted. Not al1 pipes go through all these operations but a pipe part is distinguishable by the fact that it is ready for further joining operations.

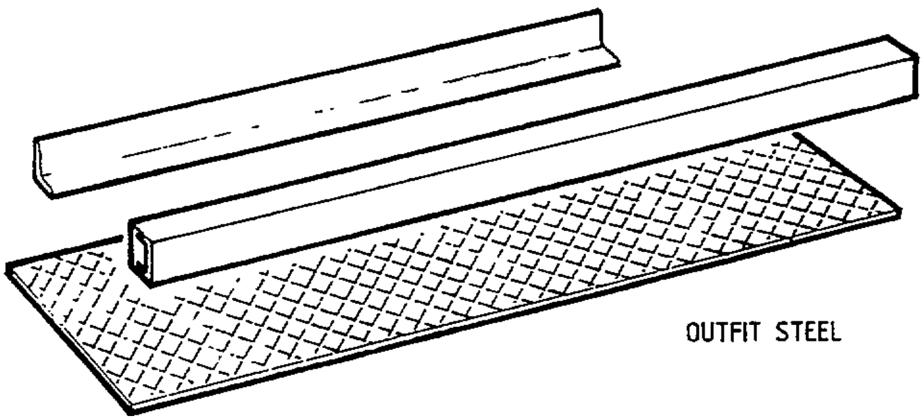
Outfit Steel

Outfit steel parts will have gone through one or more of the following stages:

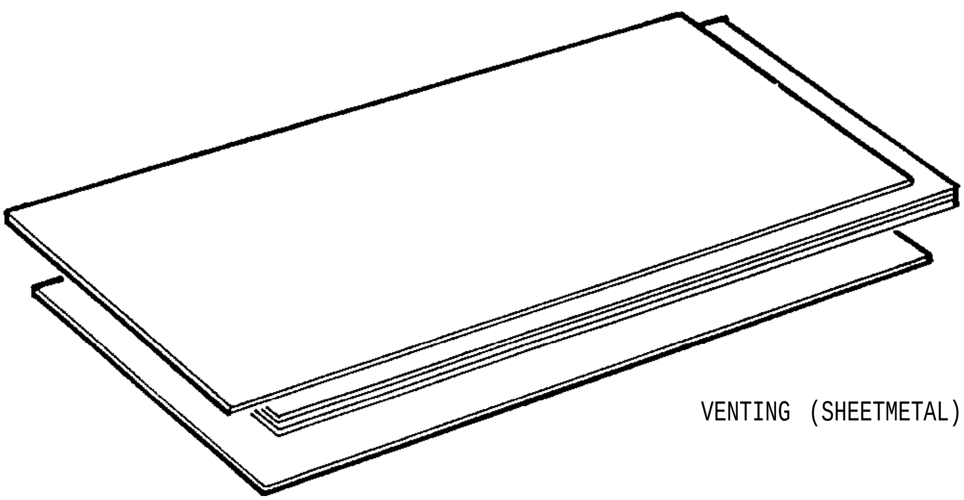
cutting to length,
cutting to shape,
forming.



PIPES AND FLANGES



OUTFIT STEEL



VENTING (SHEETMETAL)

OUTFIT RAW MATERIAL

Examples are:

- cut to length angle or box sections for framework,
- cut and formed flat bar (pipe, vent, cable supports),
- cut and edge prepared plate (for machinery foundations).

Ventilation

Individual vent parts are manufactured from sheet metal and might have flanged ends.

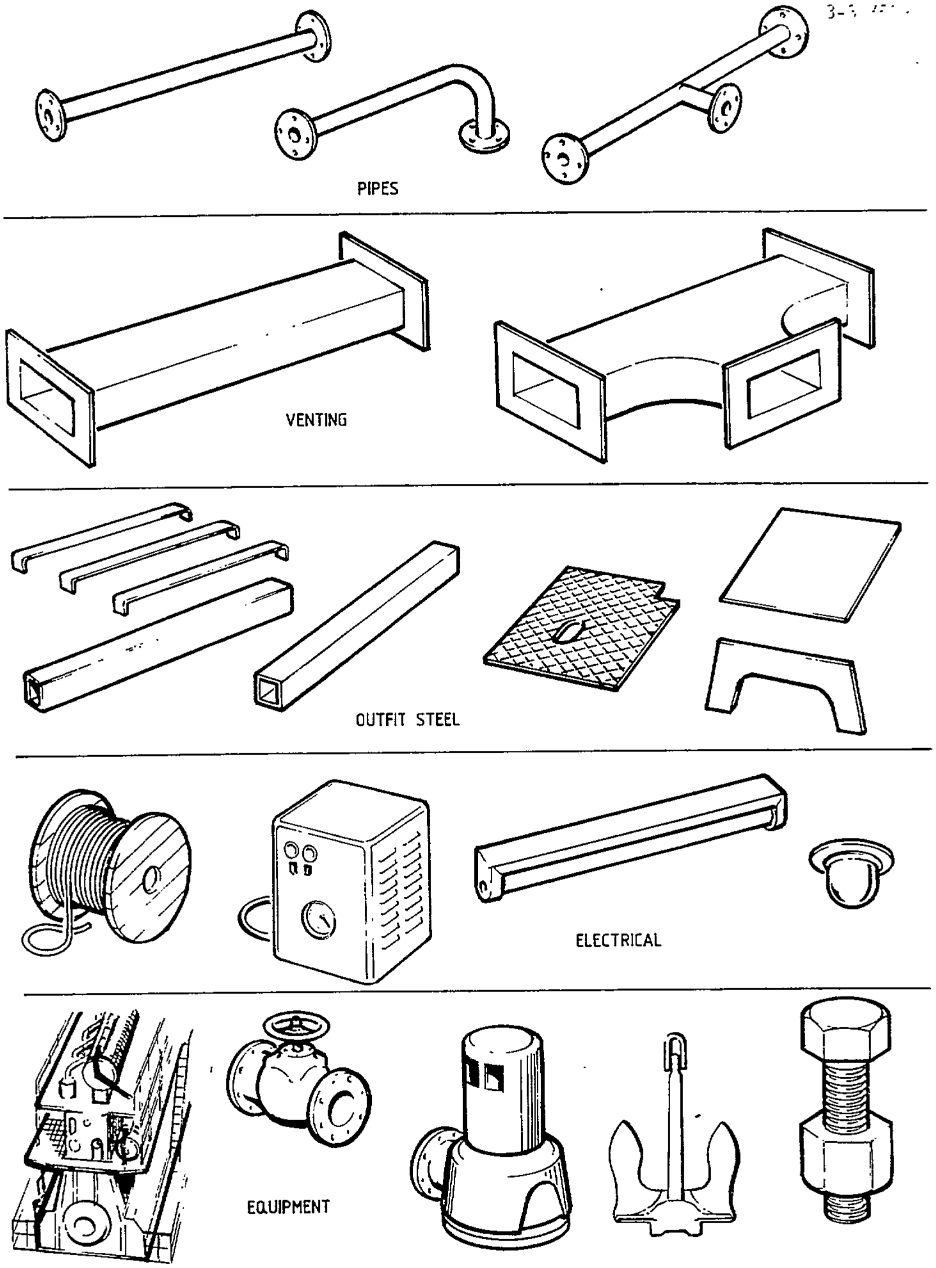
Electrical

Electrical parts cover the majority of vendor furnished electrical items, such as starter boxes, electrical cabinets, 1ights and cables. where the shipyards bui1ds its own cabinets and then installs the electrical parts, the complete cabinet wou1d be classified as a subassembly.

Equipment/machinery

Equipment and machinery parts include all vendor furnished items other than raw material , such as:

- pumps,
- valves,
- nuts and bolts,
- winches,
- main engine.



OUTFIT PARTS

iii) Outfit Minor Assemblies

Outfit minor assemblies, similar to steel minor assemblies, consist of two or more outfit parts joined together. They are strictly single trade and are normally small in size. The majority can be manhandled.

Pipes

Pipe minor assemblies consist of two or more pipes joined together, either bolted through their flanges or welded together.

Outfit Steel

Outfit steel minor assemblies consist of two or more steel parts welded together.

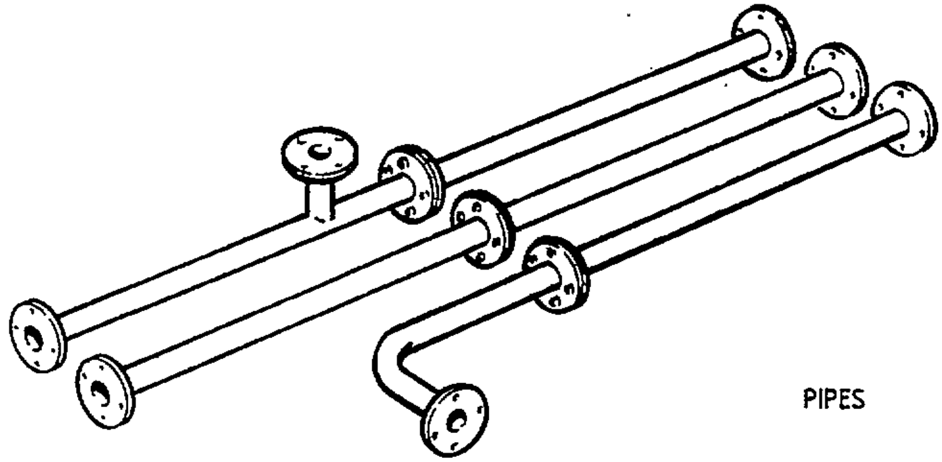
- part of an outfit unit framework
- a foundation for a piece of equipment.

Ventilation

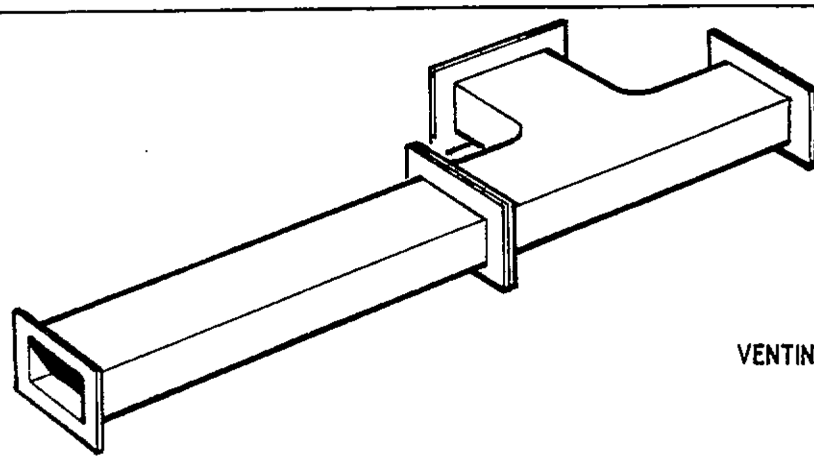
Vent minor assemblies consist of two or more vent parts joined together, normally by bolted flanges.

Equipment

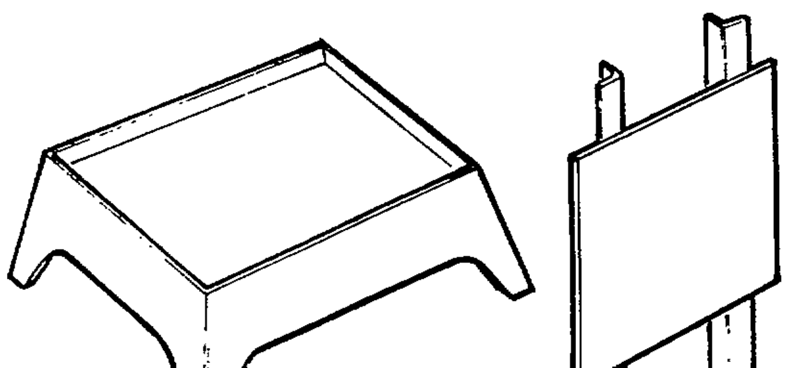
An equipment minor assembly is made up of a number of equipment or machinery parts joined together.



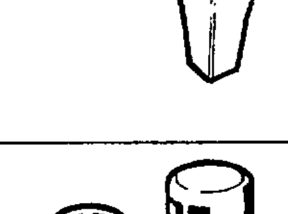
PIPES



VENTING



OUTFIT STEEL



EQUIPMENT

iv) Outfit Subassembl ies

Outfit subassemblies consist of a number of minor assemblies and parts joined together and, 1ike minor assemblies and parts, are categorized by a trade group. They may however involve more than one trade in thei’r production.

Pipes

Pipe subassemblies consist of a number of pipe parts or pipe minor assemblies bolted to common steel supports, which will then be installed either:

on an outfit assembly or unit,
on a steel unit or block.
on-hoard the vessel .

Joining the individual pipe parts into a pipe subassembly reduces the work content at the installation stage.

Vents

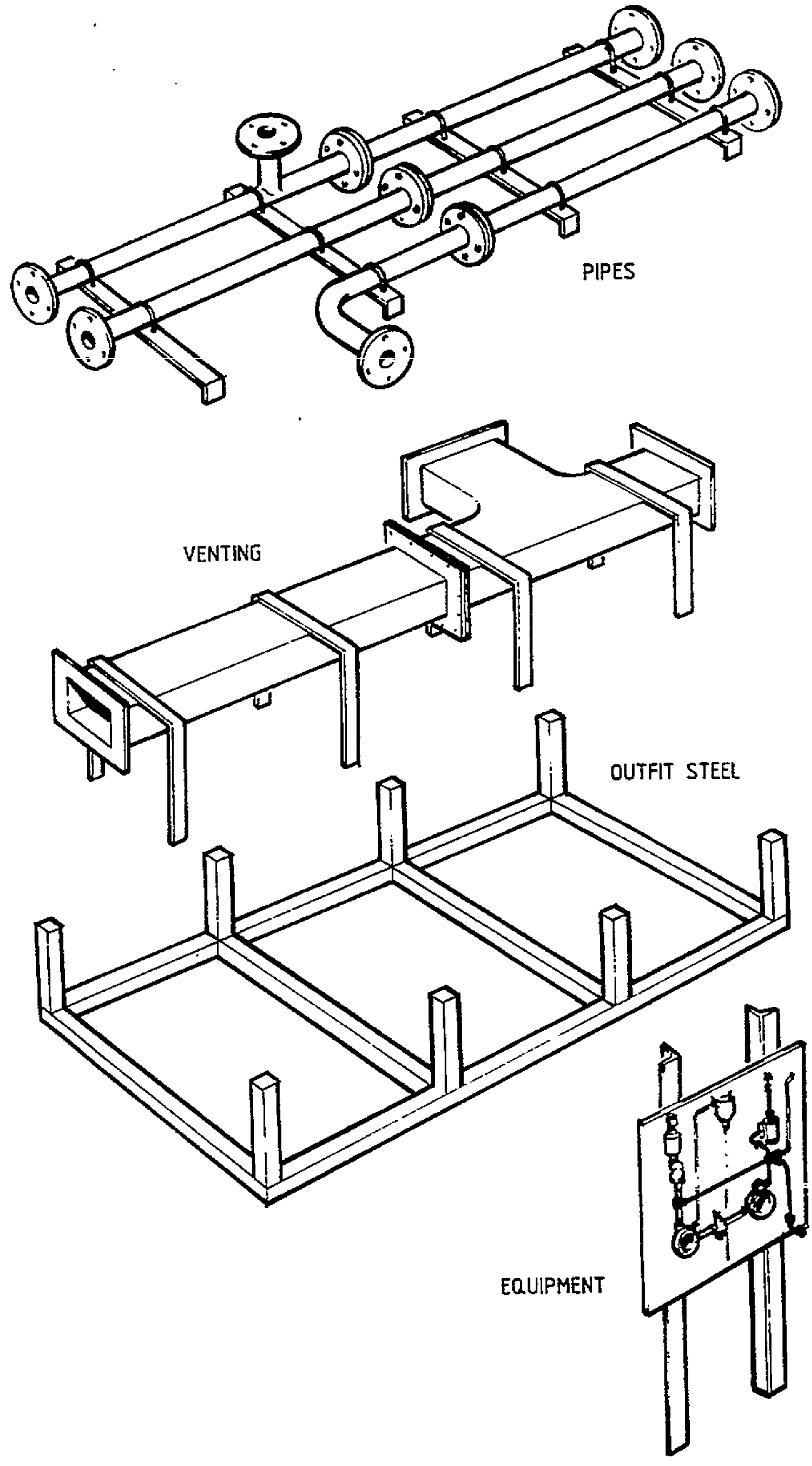
Similar to pipe subassemblies, they consist of a ventilation run attached to steel supports.

Outfit Steel

Outfit steel subassemblies consist typically of self-supporting frameworks, on which equipment subassemblies are supported.

Outfit Eouipment

Outfit steel subassemblies consist predominantly of smal1 equipment parts joined together on a steel frame or base, such as an hydraulic valve array connected by smal1 diameter piping.



OUTFIT SUB-ASSEMBLIES

v) Outfit Assemblies

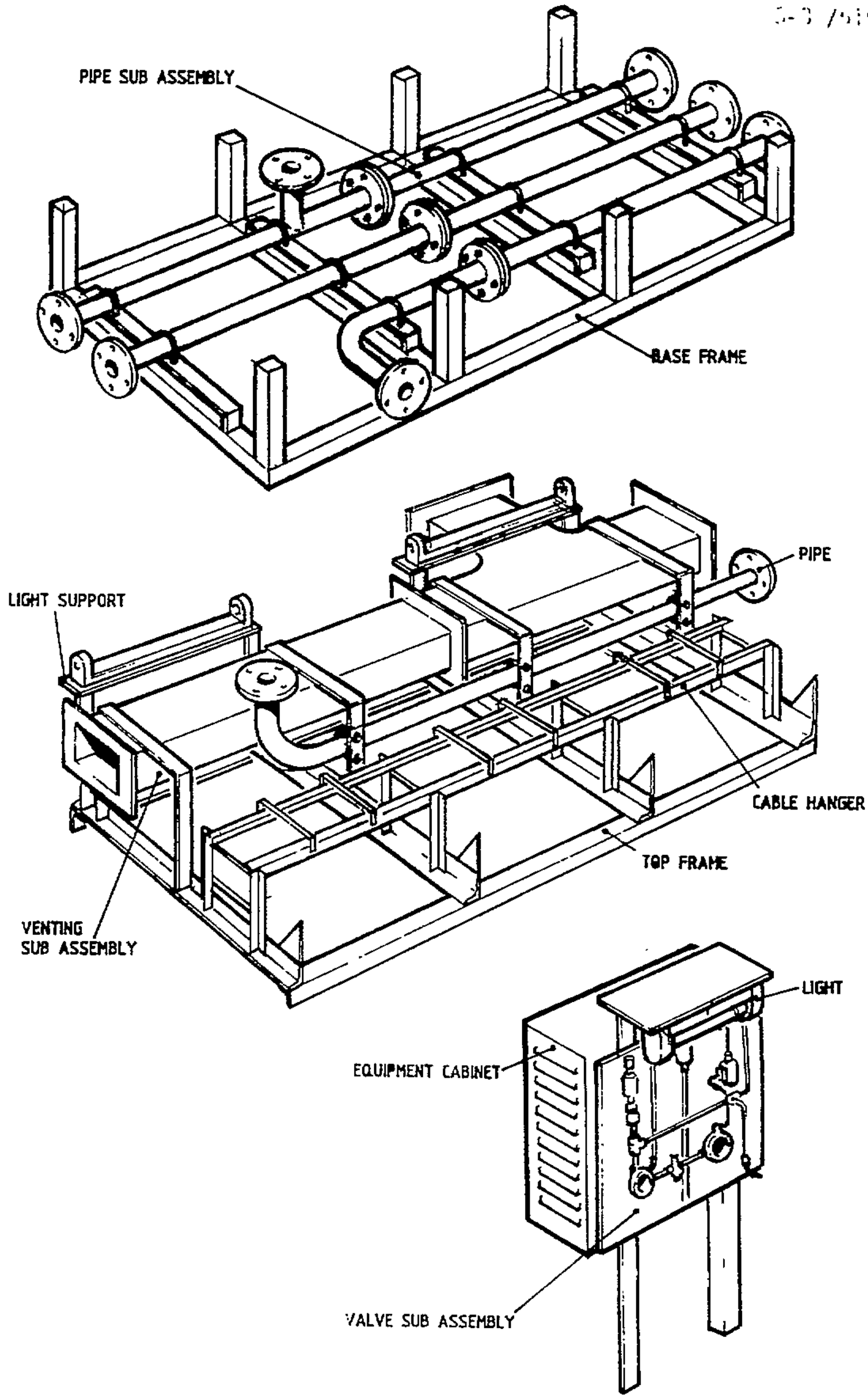
Outfit assemblies are made from a number of subassemblies, minor assemblies and parts. The size and weight of these assemblies are relatively large and require cranes for handling.

These assemblies may then be joined to form larger outfit units or else are inspected, tested and painted and installed on steel panels, blocks or on-board the vessel .

Typical outfit assemblies consist of a steel frame on to which pipes, venting, light supports or lights and cable trays are attached. The two assemblies identified in the figure opposite are:

The outfit unit base frame with a pipe subassembly. (Installation is with the framework upside down).

The outfit unit top frame, complete with venting, cable tray and lights.



OUTFIT ASSEMBLIES

vi) <u>Outfit Units</u>

Outfit units are large enough to be identified at the earliest design stages and defined. in the build strategy document for the vessel.

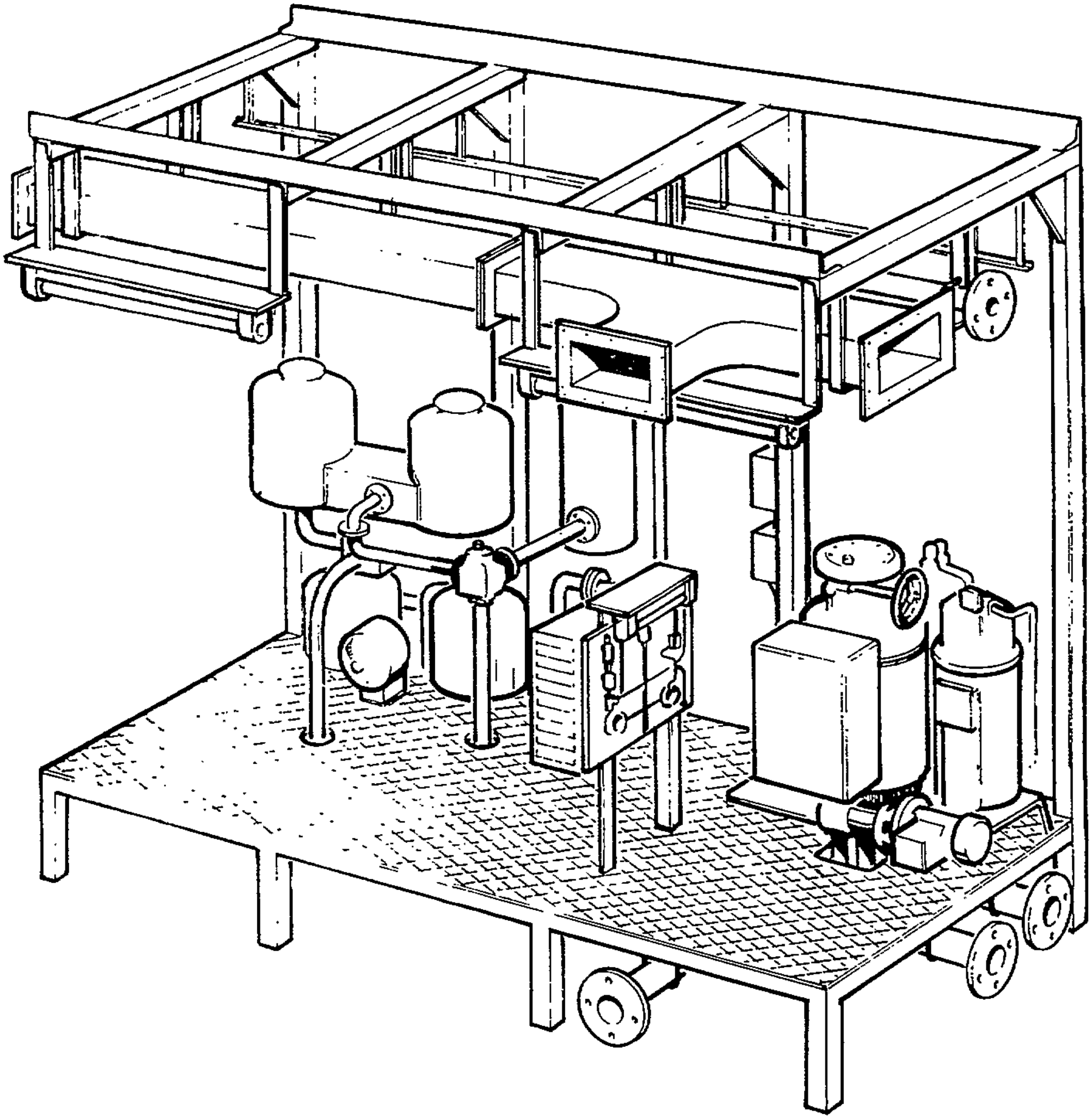
The work content in the production of an outfit unit warrants independent planning and monitoring and thus outfit units are also defined as planning units. For outfit units:.

Installation on-block or on-board is planned and monitored.
An assembly program is generated and monitored.
Separate drawings are produced.

Outfit units are assembled from outfit assemblies, minor assemblies and outfit parts, and are painted, inspected and tested to as great an extent as possible before being considered complete.

Cables are also installed on the unit. If a cable run remains within the boundaries of the outfit unit, it is completed. Where the cable run passes to a further destination remote, it is installed as far as possible and the remaining length of cable is coiled for final pul1ing and fitting on-board the vessel after the installation of the outfit unit.

Two types of outfit unit are readily identified, equipment modules and pipe banks.



OUTFIT UNIT

vii) Equipment Module

An equipment module is an outfit unit made up of functionally, operationally or geographically related equipment items and installation parts. Operational and maintenance accessibility have to be ensured and the relationship of its components and its relationship to other modules and equipment, has to be considered from the point of view of safety and habitabi1ity.

At the conceptual and contract design stages, the development of machinery and accommodation arrangements will be carried out using the technique of spatial analysis which uses envelopes for machinery, equipment modules and pipe banks. The envelopes will be defined on the basis of standards incorporated in the company shipbuilding policy. The content of the envelope wi11 also standard and wi11 reflect safety, habitability, operational and maintenance factors. If the content of the envelope is nonstandard, the detai1s wi11 be developed at the contract design 1evel and it will be at this time that these features will be considered.

The overall size of the module has to be defined together with its center of gravity and the size and position of connections. This 1atter information permits the off-ship assembly to proceed based on the datum system. Considerations made when arranging module groupings should reflect facility and machine restrictions such as door sizes, crane capacities, manufacturing processes and manpower skill levels.

The mounting arrangements for an equipment module should be kept as flexible as possible, permitting local adjustment on-board when aligning and installing.

Modules can be built in frameworks or cages made from angle or box sections and arranged to fit and interconnect one with the other. Weiqht is an obvious consideration in this type of construction.

viii) Pipe Banks

Pipe banks,like equipment modules, are significant outfit units, and tend to be straight with a bend or branch at a predetermined position. They are designed to f011ow preferred service routes within a machinery space or through a vessel and are built within a predetermined cross-section and route configuration.

Spatial analysis, initially considered at the conceptual design 1evel and developed during contract design, wi11 identify where pipe banks wi11 be routed. Details of which pipes are in which bank wil1 be developed at the transition design stage. The preferred service routes are defined early in the design process when the overall spatial analysis carried out.

The pipe banks should be built from pipes of standard 1ength and shape which are part of the company standard pipe configurations. Pipe banks should be made as large as possible off the ship and, if necessary, broken down (into smaller banks) for shipping on-board. The support arrangements should be engineered so that wherever possible the supports are part of another structure and can, by supporting the pipes, provide a dual function. Examples of the latter include floor plate supports, machinery foundations and cable support systems.

As with equipment modules, the shipping of a pipe bank is a major event requiring the use of cranes and this requirement should be identified and planned into the berth 1ifting requirements.

The interfacing of the pipe connections between the pipe bank and its adjoining outfit units, pipe banks or equipment parts or assemblies should be fully analyzed and detailed to ensure minimum difficulty during connecting. This analysis will be carried out by production engineers at the tactical level when outfit process analysis is carried out. Techniques such as the use of variable height fittings or shoes at the foot of pipe bank supports to provide flexibility during installation will be considered when process analysis is carried out. It may not always be possible to connect the pipe bank up to its adjoining equipment and it is necessary therefore to ensure that the datums to which the various modules and pipe banks are located are also used during the build and assembly stage and that access is carefully considered when detailing the connections.

As far as possible, the individual parts are grouped before installation. Installation may take place before steelwork erection, for example, on a deckhead, when in the "downside up" position.

ix) Outfit Block

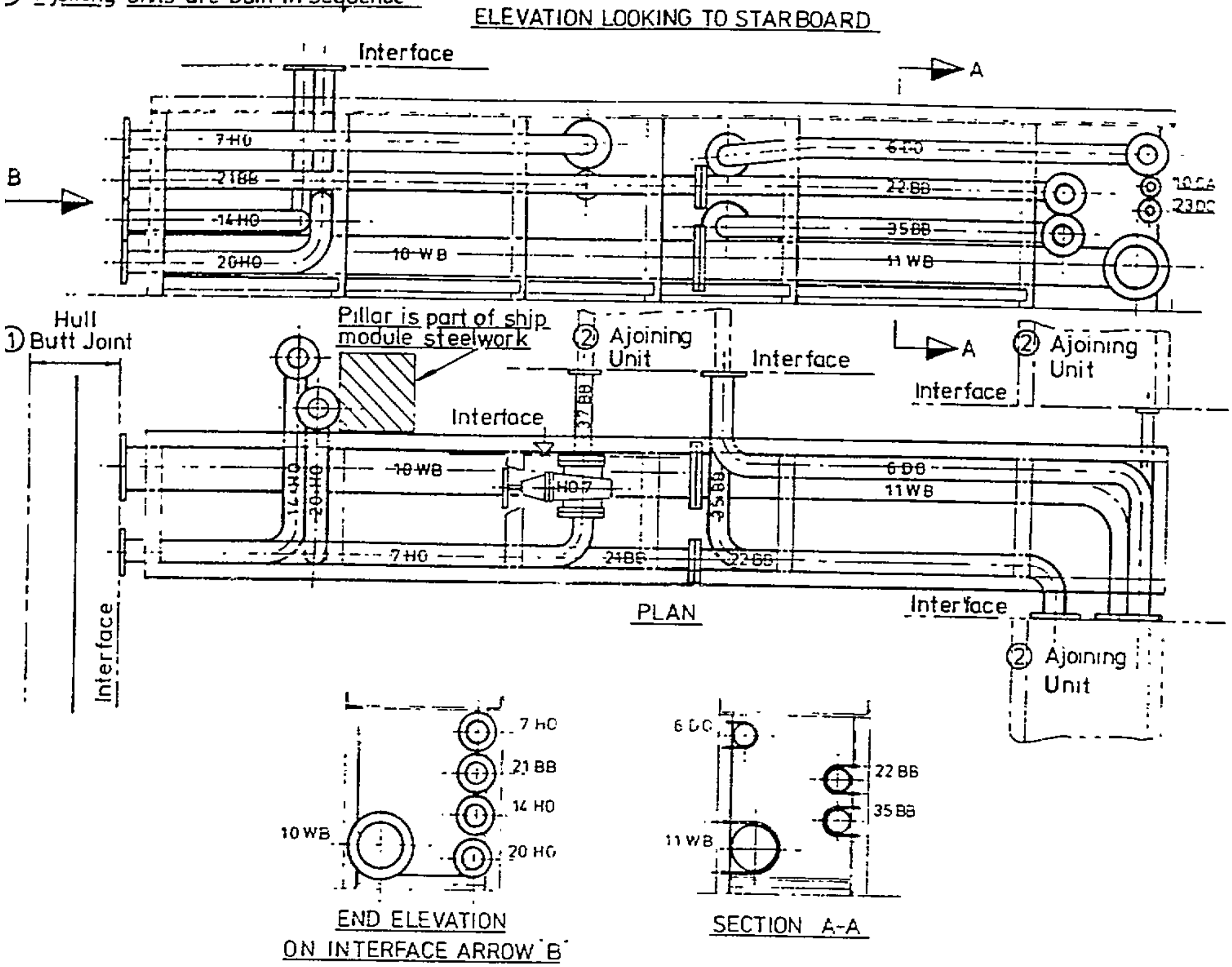
An outfit block consists of outfit units joined to form a large unit which may, in some instances, be two or three decks high. The unit is installed on to the ship in one lift. The advantage of constructing outfit blocks is that the work content at the ship is further reduced and there are better opportunity es for systems testing of the outfit block before installation on-board.

The size and weight of outfit blocks are 1imited by crane capacity and transport within the yard.

NOTE

1) 3 feet standard connecting length

2) Ajoining units are built in sequence



PIPE MODULE

3.3.5.3 Imstallation Analysis

Installation process analysis is carried out by production engineers working at the tactical level. For each planning unit the same basic analysis is performed, the purpose of which is to identifv the outfit content and where and when the outfit will be installed.

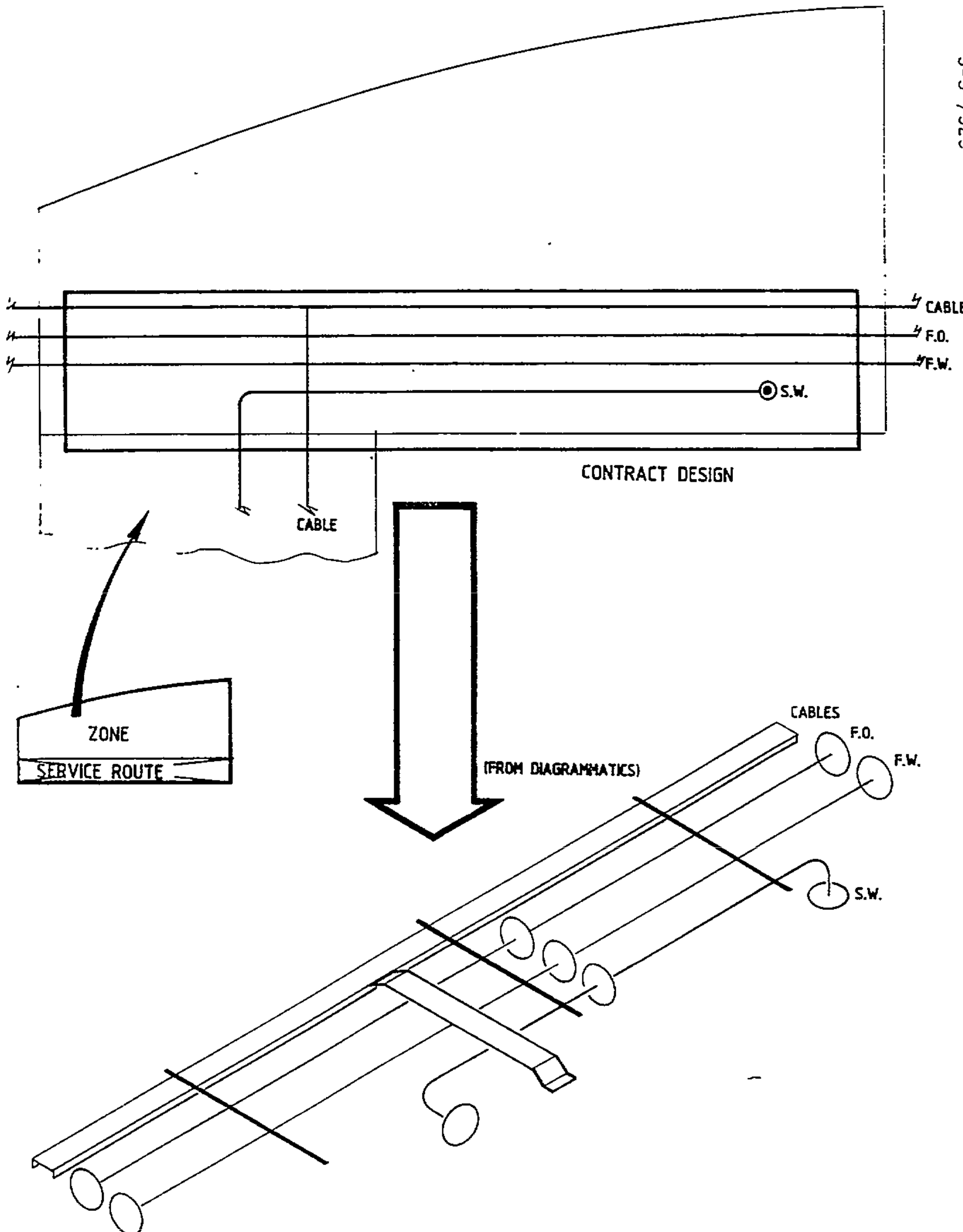
Outfit units wil1 have been identified at the contract design staqe as planning units. As the design and definition progresses to the functional design stage and more information becomes available, outfit interim products can be identified in greater detail and material 1ists can be developed more accurately.

The analysis, followinq the identification of outfit units with an on board zone, will identify all the outfit items within the zone. This is done from the preliminary layouts, ship specification and yard standards. The next step is to _identify the production stage at which the outfit. items are to be installed.

Outfit. assemblies are identified for pipework, ventinq, etc. , from the piping and venting schematics at. the transition design Stage. As an example, where a number of pipes run alonqside each other on a deckhead, they may be identified as a pipe subassembly. If a Vent trunk also runs alonq the same service route it, too, mav be included with the pipes to form an outfit assembly.

The lower 1evel outfit interim products are identified at the detailed of design staqe when minor assemhlies and individual parts mav be defined.

If the shipvard does not have a formal shipbuilding policy guidelines for the analysis can otherwise be established via a preliminary build strategv for the specific vessel . This build strategv will also have identified any areas which require special consideration.



IDENTIFICATION OF OUTFIT ASSEMBLIES

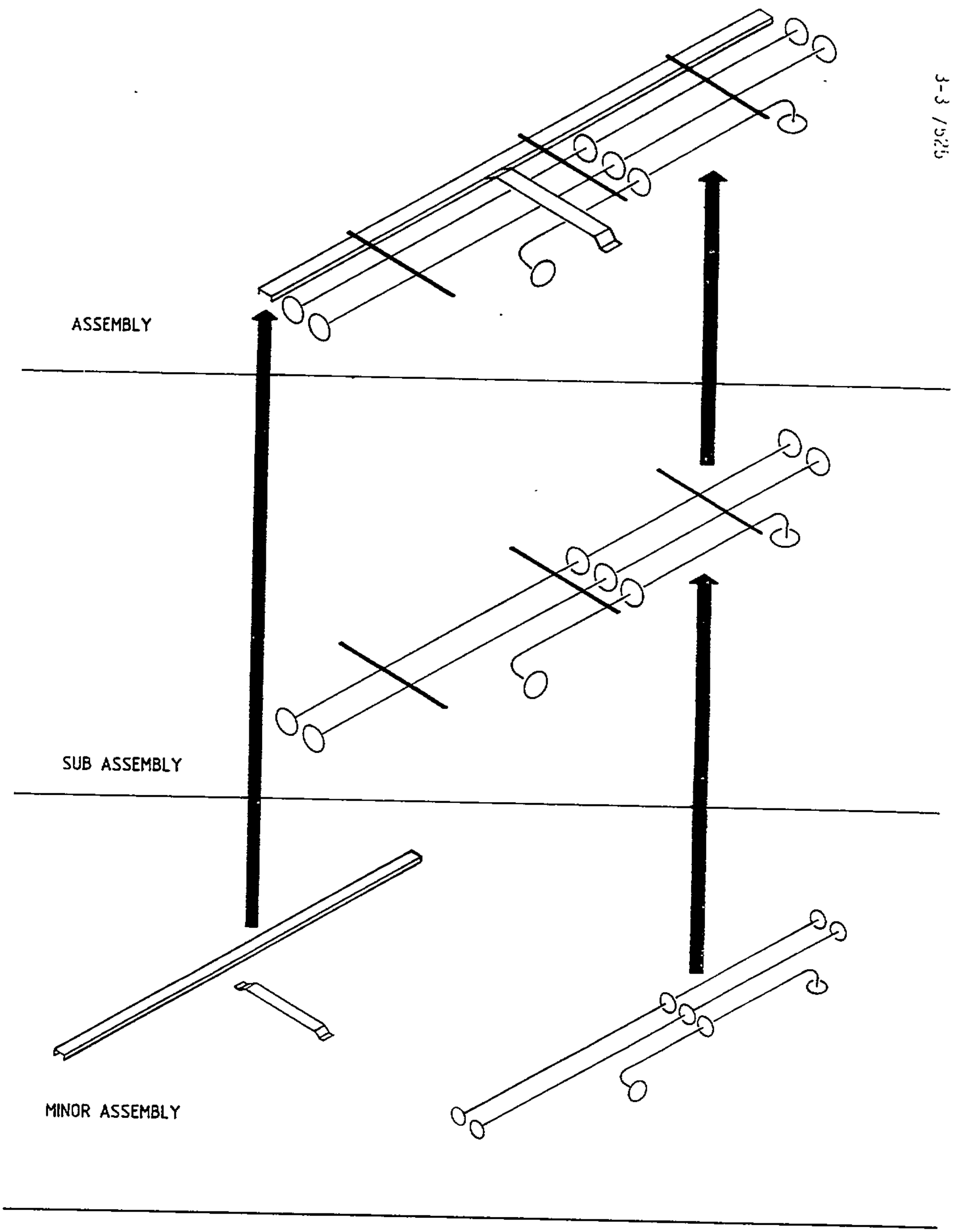
The designer who identifies the material must be aware of advanced outfitting possibilities and the interim product classifications so that he may, at the earliest of identification stages, allow outfit items to be grouped into assemblies.

The existence of a formal shipbuilding policy and build strategy will ensure that the outputs of the process analysis work reflect the most appropriate production practices.

From the process analysis, installation work packages will be identified which form the basis of the detail design process.

The first level analysis will identify the outfit installation work to be carried out at each stage. The second level analysis will consider each stage in detail in order to identify workpackages such that an even pattern and flow of work for outfit workers, or groups of workers, can be defined. The outfit installation work carried out at each stage wil1 follow the same basic pattern or sequence of events.

Each outfit activity requires production information. A single set of information may be sufficient for each activity. Where there are craft demarcations, or specific reasons to separate types of work for safety reasons, the activity may be split.



IDENTIFICATION OF SUB AND MINOR ASSEMBLIES

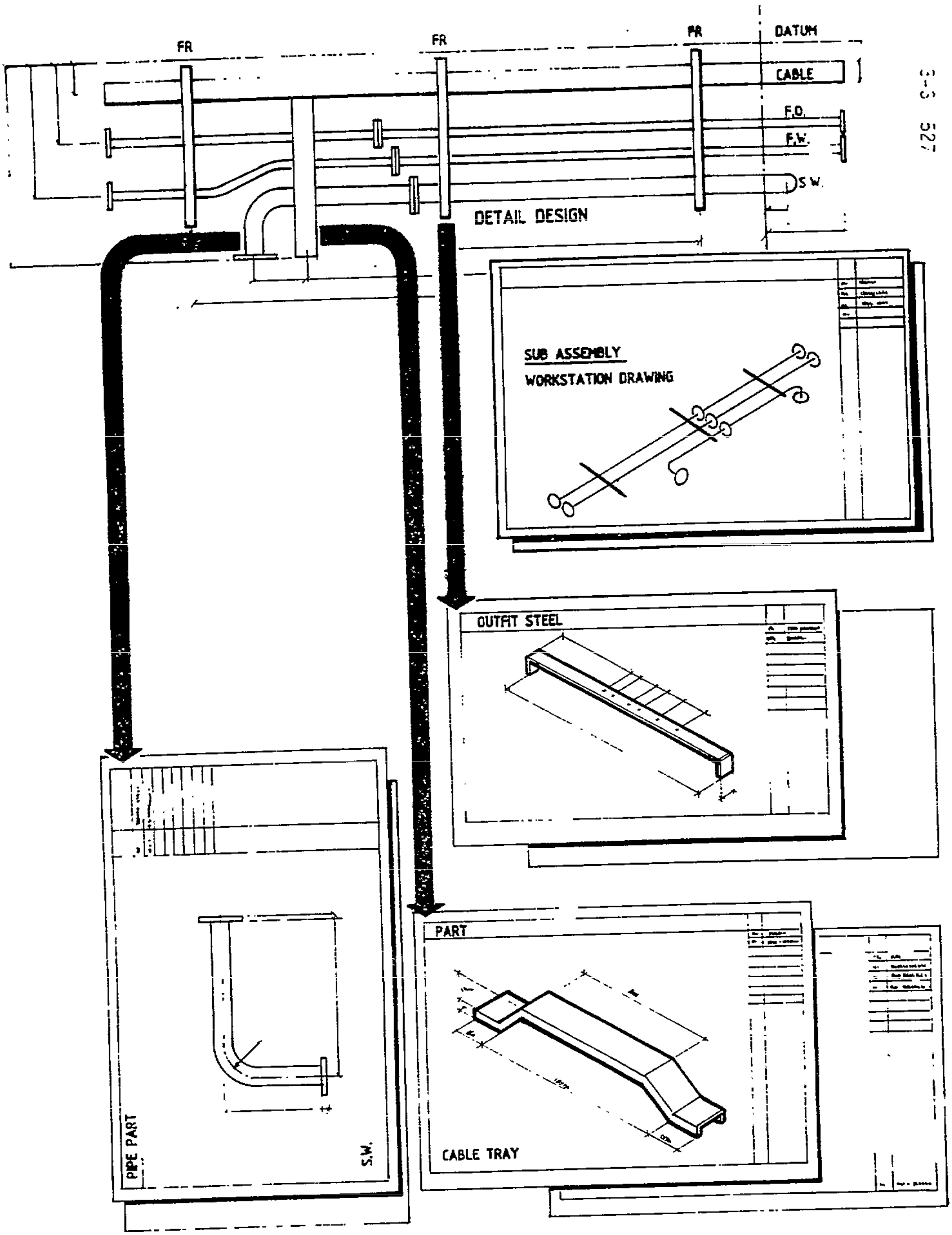
3.3.5.4 Assembly Analysis

For the outfit blocks and units. and for any additional assemblies identified by the installation analysis, further production information is required. This covers the work of building the various assemblies. The stages of work are:

- assembly,
- mounting,
- testing,
- finishing.

The assembly analysis wil1 break down the outfit units (equipment modules and pipe banks) into a hierarchy of interim products, and a statement will be prepared which covers assembly methods, painting, inspection and testing. For frames and foundations, standard material sizes and arrangements are adopted.

Some of the finishing operations (for example, painting of the steel framework) may be completed prior to fixing of equipment.



IDENTIFICATION OF PARTS

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3.3.6 PRODUCTION STAGES - STEEL

The Identification of steel interim products was discussed in Chapter 3.3.2. This chapter identifies the production stages and shows the relationship between the interim products and the stages.

CROSS-REFERENCES

1.2.2 Basis for Shipbuilding Policy Development

1.2.3 Implementation of Shipbuilding Policy

2.3.1 Modern Ship Production Technology

2.3.2 Guidelines for Faci1ity Capabi1ity Documentation

2.3.3 Guidelines for Production Process and Method Information Documentation

3.1.5 The Need for Development of Interim Product and Production Process Standards

3.3.2 Hull Steel - Identification of Interim Products

3.3.6.1 Introduction

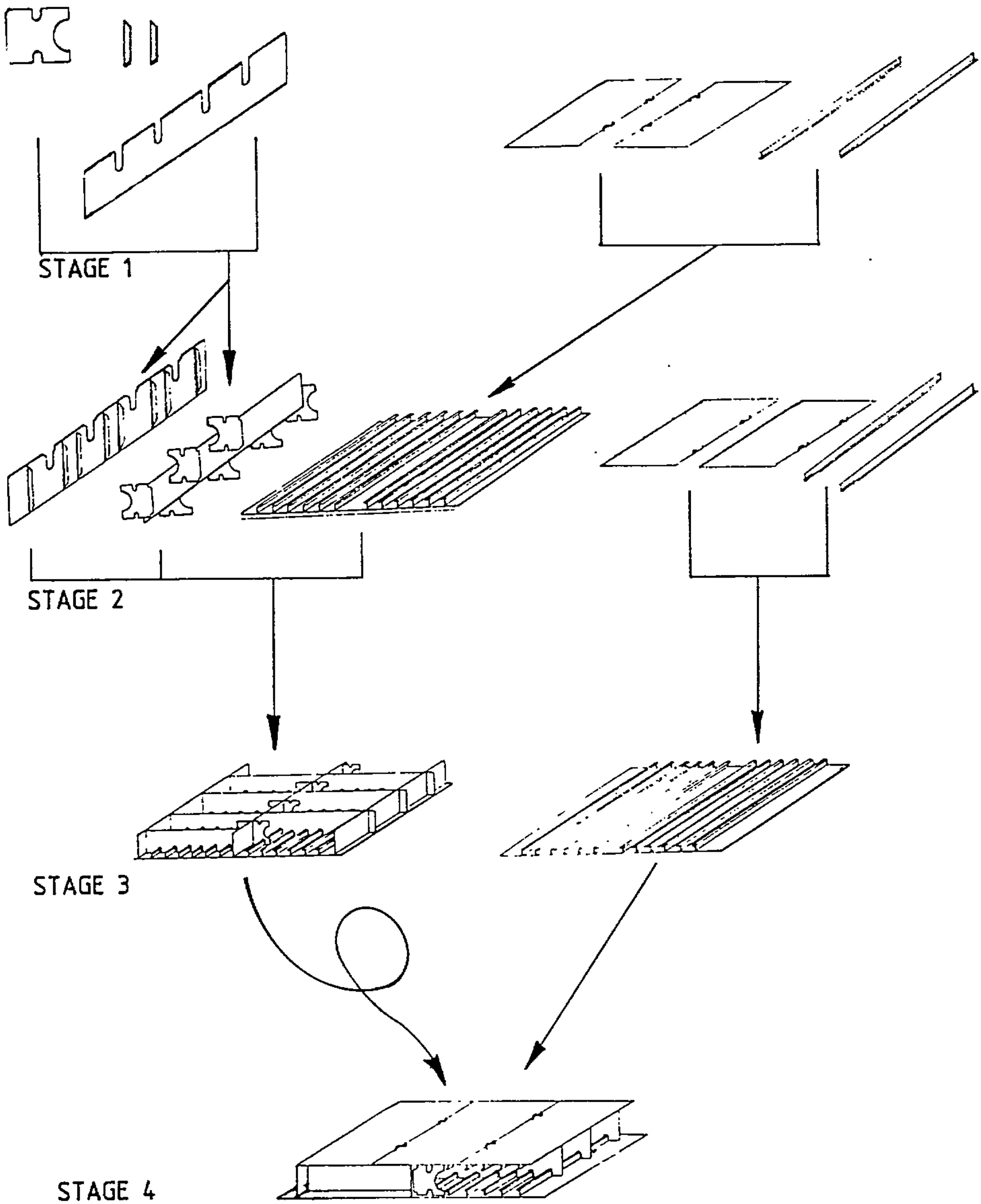
The steel hull of the ship can be subdivided into a hierarchy of interim products. It is necessary to relate the interim products to the production facilities available. This must be an iterative process. There is clearly 1ittle point in identifying a hierarchy of interim products that are not able to be manufactured efficiently in the facilities. The two must be brought into balance.

The identification of interim products is central to the development of the company shipbuilding policy, which aims to identify optimum production methods. Faci1ity bottlenecks or problem areas will be identified as the ideal interim products are mapped onto production facilities and areas of incompatibility are identified. The company then has to decide either to change the interim products so that existing facilities can be used, or to develop facilities so that the ideal product breakdown can be applied.

The first production engineering task to be undertaken for any contract is the definition of the block breakdown. The breakdown will be carried out by production engineers working at the strategic level with the involvement of production management and the conceptual and contract design team. An extension to the work on the block breakdown is the identification, by the same production engineering, technical and production group, of other planning units zones, outfit blocks and outfit units. The identification of interim products can then proceed within the context of the identified planning units.

Five stages of steel manufacture are considered here:

Parts Manufacture
Minor Assembly)
Subassembly) Shown merged on illustration opposite
Unit Assembly
B1ock Assembly


STAGE 1
STAGE 2
STAGE 3
STAGE 4

In some yards there may be fewer stages, for example. minor and subassembly may be merged in yards building small vessels.

Production stages are used to define a time envelope during which specific work is carried out. The start and completion of stages are used as datum points when planninq the manpower, tools. materials. and information which are required at a work station.

Althouqh each successive stage results in a higher level assembly and the main ingredients used at each stage are the products of the prceeding staqe, there is usually an input of parts and minor assemblies throughout the buildinq Process. For example, the figure on the previous page shows the building of a double bottom in four staqes; staqe two involves the manufacture of minor and subassemblies from parts cut during stage 1, but at the same time parts may be cut which are to be used during stage 3 to make a second flat stiffened panel .

3.3.6.2 Parts Manufacture Fabricatinn

Prts fabrication is the first manufacturing staqe and covers cuttinq and torminq of plates and shapes. It is not impossible for some minor assembly work to be carried out at this stage if, for example, parts have to be joined before forming. If this were to be a reqular occurence then a specific work station would be identified and set up.

The equipment used at this staqe will generally lead to the application of qroup technoloqv in that machines are designed to carry out a 1imited variety of tasks - two axis plate cutting, three axis plate cutting, flame planing, shape cutting, plate or shape forming. The skill of the desiqner, at all design stages, will be used to ensure that this 1imited variety working can be maintained in subsequent production stages.

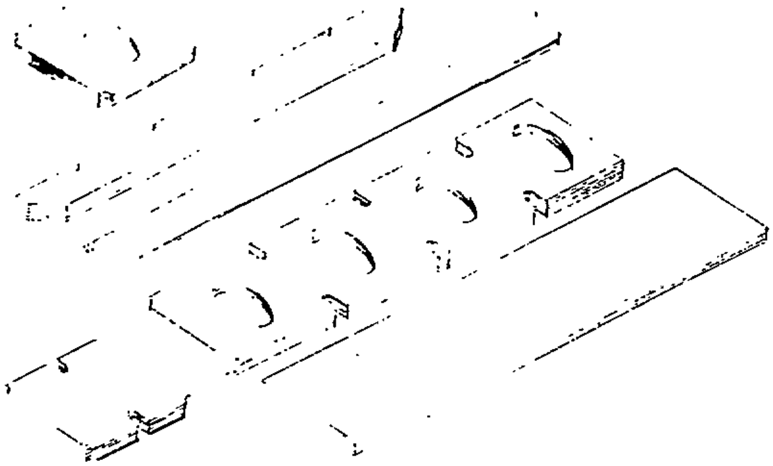
3.3.6.3 Minor Assembly and Subassembly

These are the stages at which assembly starts, with cut and formed parts brouqht together. Minor assemblies will generally be two dimensional, for example, web and bracket assemblies. Subassemblies could be either two or three dimensional as with built up girders and webs. The appli cation of group technology princip1 es wil1 1ead to the identification and setting up of work stations with limited product variety. In order to achieve a balanced flow of work the interim products associated with a particular work station should all have approximately the same work content. In order to ensure efficient utilization of the facilities they should all require the same tools, equipment and skills. If a series of processes is required to produce an interim product in large quantities, then a series of work stations should be established on the shop floor to provide a process lane.

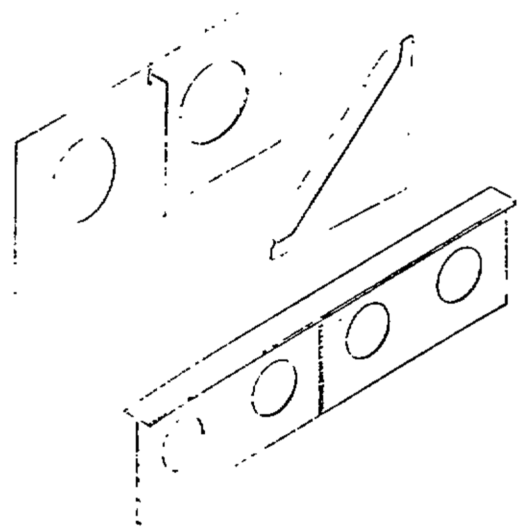
3.3.6.4 Unit and Block Assemblv

Units and blocks are created by the aqgreqation of 1ower 1evel interim products - manufactured parts; minor assemblies and subassemblies. It is possible that some outfit could be introduced at the subassembly stage, for example, pipe penetrations. At the unit assembly stage, more outfit is introduced and the fitting of foundations, pipe clips, cable trays, dockinq pluqs, striking plates and ladders are typical nf the type of outfit wnrk that could be carried out. It is possible that nutfit assemblies, units or blocks could he installed at the steel unit assembly stage and some painting work also done.

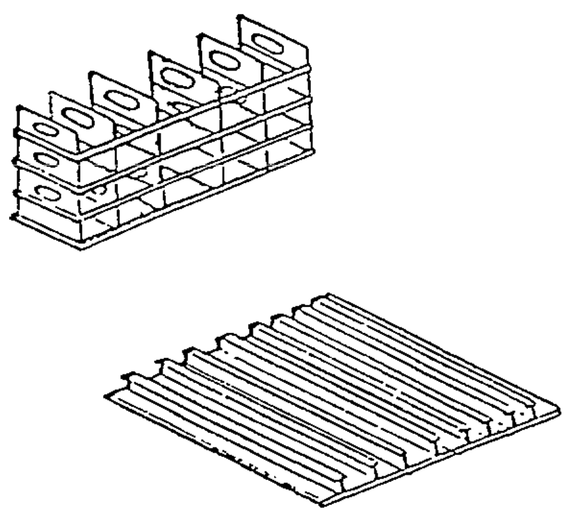
At the block assembly staqe the aim should be to complete as much outfit work as possible (except in way of the block butts}.



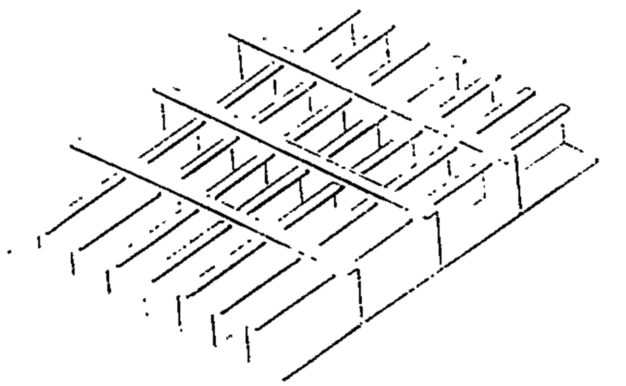
1. PARTS



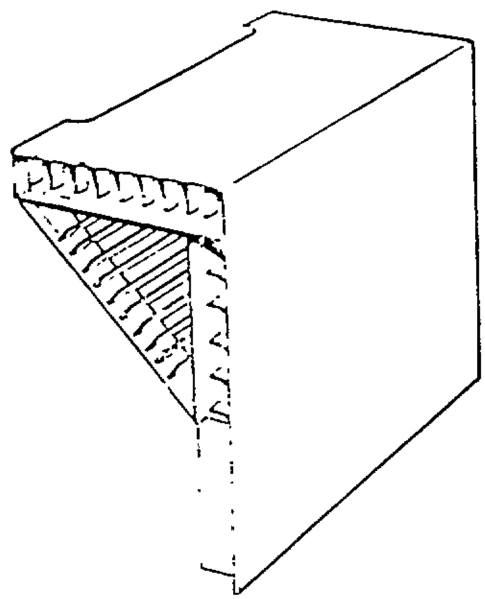
2. MINOR ASSEMBLIES



3. SUB ASSEMBLIES



4. UNIT ASSEMBLY



5. BLOCK

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3.3.7 PPODUCTION STAGES - OUTFIT

The identification of outfit interim products was discussed in Chapter 3.3.5. This chapter identifies and describes the five outfit production stages and establishes the relationship between interim products and stages.

CROSS-RFFERENCES

1.2.2 Basis for Shipbuilding Policy Developemnt

1.2.3 Implementation of Shipbuilding Policy

2.3.1 Modern Ship Production Technology

2.3.2 Guidelines for Faci1ity Capability Documentation

2.3.3 Guidelines for Production Process and Methad Information Documentation

3.1.5 The Need for Development of Interim Product and Production Process Standards

3.3.5 Outfitting" - Identification of Interim Products

3.3.7.1 Introduction

As described in Chapter 3.3.6, the first production engineering task to be carried out on any particular contract is to define the block breakdown. The production engineers wi11 work with the conceptual or contract desiqn team and production management to complete the task. The next step wil1 be to identify other planning units - zones, outfit blocks and outfit units. These planning units will then be subdivided into a series of interim products. The interim products must relate directlv to one of the production stages:

- parts manufacture
- collecting
- subassembly
- assembly
- installation

Each of these is described in more detail in the following sections.

The purpose of the shipbuilding policy is to define the optimum production method for the ship types in the company product range. The first step in this process wil1 be the identification of the hierarchy of interim products relating to the production stages. The final part of the process is the mapping of products onto work stations. This wil1 lead to the identification of bottlenecks and areas in which either the interim products must be chanqed or the facilities developed.

Work done earlv in the desiqn process, at the conceptual or contract design stage, must relate directly to production facilit ies and work stat inns if optimum production methods are to be used.

3.3.7.2 Manufacturing

The manufacturing stage of production is the work done on raw materials to create individual parts.

The majority of equipment, and machinery outfit, items are purchased by the shipyard, and **so in most,** shipyards, in-house manufacture is limited to:

pipes.
venting.
outfit steel .

Of these, the manufacture of pipe parts is the most significant activity with regard to the expenditure of manhours.

i) Pipe Part Manufacture

The raw material brought into the yard consists of Pipes of standard length and diameters in a range of materials, includinq steel, copper and plastic.

Pipes are manufactured usinq the principles of group technology, wherever pipe parts are produced in families combining the advantages of "just in time" manufacturing with the benefits of batch manufacturing. The families are defined by the operations carried nut on the pipe, such as bendinq and flanging, the pipe material and the diameter of the pipe.

The simplest family of pipes, and the one with the lowest manhour content, is the flanged straight pipe, which is easy to handle and avnids the time corsuming bending operation. Good accuracy is most easily achieved when forming is not involved, and thus the designer must attempt to maximize the number of straight runs. The lenqth of the run should be commensurate with the standard pipe length purchased.

After straight. pipes, the most. preferred family of pipes is sinqle bend pipes (with flanges). These pipes mav he cut to length and have their flanges welded on before bending, thus to a qreat extent followinq a similar process path to the straiqht pipes.

The desiqner's aim must be to arrange the pipe bend anqle to be a standard, such as 30 degrees, 45 degrees, 60 degrees or 90 degrees. Standard templates can then be used for checking purposes. Secondly, the desiqner must desiqn bend radii which comply with the capability of the bendinq machines in the yard. This information is available throuqh the facility capabilitv and process documentation discussed in Chapters 2.3.2 and 2.3.3.

The most cnmplex pipe to manufacture is the fabricated pipe. A fabricated pipe is an assembly of pipe pieces, preformed bends, “T” nieces or other vendor furnished items. It becomes necessarv to make fabricated pipes if the yard does not. have the equipment for pipe bendinq. In yards that do have bending equipment, equipment 1imitations will determine the pipes that must be fabricated rather than bent.. The fabricated pipe is inefficient to produce as it. involve: a hiqh manhour content in marking, cutting, setting up and tacking, welding and testinq. Pipe bendinq is a more efficient nrocess, than fabrication, but less efficient than straight pipe manufacture.

Large diameter pipes mav be outside the capability of the bending machines and therefore must be fabricated. The designer must be aware of the pipe shop capability and avoid the use of fabricated pipe$ throuqh the use of smaller bore piping and bending where possible.

P i p e are ready for further joining Operations, and are therefore cleaned, inspected, tested and painted as necessary, prior to the next stage.

ii) <u>Ventilation Trunking Manufacture</u>

Ventilation trunking is produced from sheet metal by a series of cutting, forming and securing operations.

As with pipe manufacture, the simplest vent to produce is straight and of a length compatible with the standard length of sheet metal. To maximize the use of straight venting, straight service routes are identified at an early stage of design and venting is routed along these routes, together with cables and pipes.

Where venting is vendor furnished (normally circular section), manufacture involves cutting to 1ength and riveting of end plates and purchased bends and "T" pieces.

iii) <u>Outfit Steel Manufacture</u>

Outfit steel parts consist of:

cut to length steel sections for example angle bar or box sections, for the assembly of frameworks and foundations,

cut to length and formed flat bar for pipe, vent, cable tray and light supports,

profile cut plate for foundations and floor plates, etc.

Where possible the frameworks are of similar configuration and use standard steel sections. Production engineers working at the detai1 level, i.e. staff or field engineers, will work with production supervision and management to develop standard frameworks, clips and supports. These standards wil1 be available to the designers at all levels. In those yards with CAD/CAM equipment the standards wi11 be held within the system and any attempt by designers to use details other than standards must be resisted. It is possible using a CAD/CAM system to calculate the number of times a standard is used. This would be the basis for the maintenance of the standards library. Standards with a high utilization would be designated as stock items and be controlled by a stock control system.

3.3.7.3 Collecting

Colletting is the gathering together of outfit parts, such as pipes, vents and outfit steel which comprises an identifiable “package” of outfit work, which may be carried out prior to erection or on-board the vessel.

The co11ecting process therefore 1inks the manufacturing stages with the assembly and installation stages. Outfit work is converted from being related to the physical attributes of the outfit part (family manufacturing), to being related to a physical assembly area or a zone on the vessel, and stage (when the work wil1 be carried out).

The 1ist of outfit parts for each particular work package is generated as early as possible to allow planning of outfit to be progressed. Using these 1ists, expediters insure that the right outfit material is in the right place at the right time.

Collecting involves the use of a code system, by which every outfit part, whether manufactured or vendor furnished, is 1inked to a vessel and to a unique work package. For example, as each pipe part is completed, it is coded and placed either in a buffer store or directly on to the pallet for the work package for which it is destined. When the work package is due to start, the complete pallet is delivered to the place of work, which may be an outfit assembly work station or a pre-erection outfitting area, or to an area adjacent to the vessel for on-board outfitting.

Simi1arly, items from the stores are collected and delivered to the relevant work area as required.

3.2.7.4 Subassembly

Outfit subassembly is the joining of outfit parts manufactured by one trade qroup (or predominantly one trade group). This precedes the assembly stage where outfit from more than one trade is combined before installation.

Subassembly work is carried out at predefine work stations which are equipped with the necessary tools and equipment for the work to be done. For example. a pipe subassembly work station. at which pipes are joined, and possibly mounted on to a steel ffrane, will be equipped:

- low capacity cranes (2t-5t) for handling the completed subassemblies,
- welding gear,
- storage bins for stock parts, such as:
  - pipe clips, divided by bore
  - nuts and bolts
  - flange gaskets

Stock parts need not he included on the work package outfit material list. They may be stored at the work station and used as required. This cuts down the work involved in outfit material control, both at the definition stage (in the technical office) and at the collecting/ material handlinq staqe (on the shop floor).

The designer can therefore reduce the work involved in the organization of outfit by maximizing the use of shipyard standard parts which are stock items.

3.3.7.5 Assembly

Outifit assembly is the joining of outfit. parts and subassemblies before installation on the steel structure of the vessel.

Work is done remote from the vessel in work stations equipped for the assembly work. By producing outfit assemblies and outfit units, such as equipment modules and pipe banks, the maximum amount of outfit work is brought forward in the vessel construction proqram, thus reducing the overall cycle time for the construction of the vessel. The key point here is that outfit and steel work is performed in parallel with very 1ittle effect on each other.

Outfit assembly is part joining, part installation (on frameworks) , and part fitting, followed by testing, painting and inspection. The process therefore involves a number of trades. The sequence of assembly is arranged, however, so as to avoid many different trades working on an outfit unit at the same time. For example, the steel framework is fabricated separately as a subassembly, and then heavy equipment is installed on to the framework; followed by pipes, venting, electrical equipment, painting and finally cables and delicate items such as lights.

Outfit, assembly requires overhead cranes for lifting heavv equipment items and machinery into place, and also for lifting the units on to transporters or wheeled vehicles for removal from the shop.

At the manufacturing and subassembly staqes the desiqner is aiming to utilize stock and standard items as much as possible. The manufacturing and subassembly stages are considered at the detail design level. Stock items are so designated because they are used recuently enouqh to merit either a volume purchase from an outside vecoor or laroe batch production in the shipyard.. Standard items are not used as frequently as stock stock, but. often enough to reduce the variety of choice for a particular item.

Outfit assemblies are Considered at the tactical level of production engineering and the detail design stage. It is unlikely that, these will be stock assemblies and there may even be no standard assemblies. What there will be is a standard approach to outfitting, so that it is recognized by production engineers and designers that outfit assemblies will be of a number of known types to be installed at a predefined steel production stage. The approach will be defined by strategic and tactical level production engineers with inputs from production. Once agreed, the approach will be incorporated into the company shipbuilding policy.

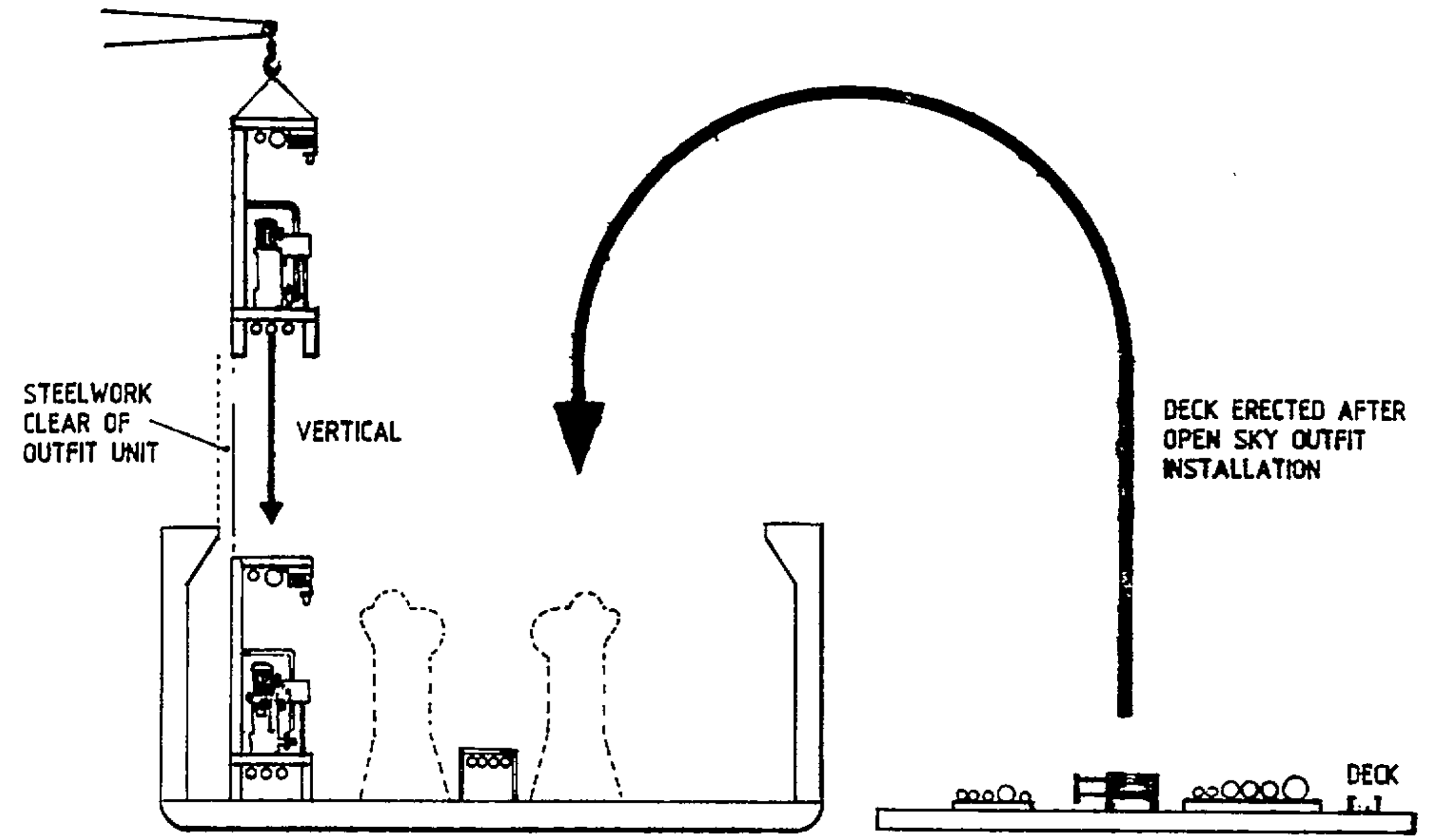
3 .3.7.7 Installation Before Erection

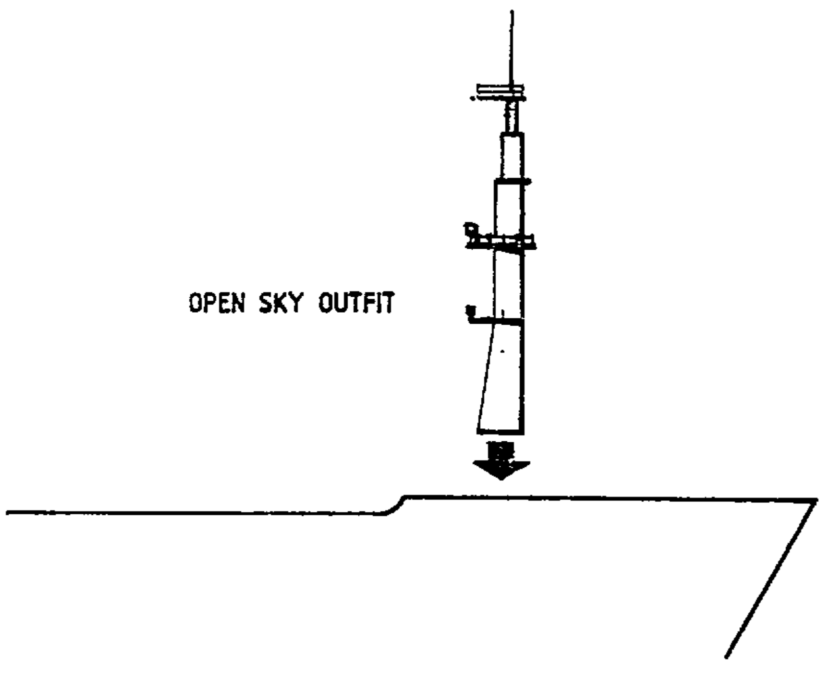
Installation of outfit. parts, subassemblies, assemhlies and units is the joining of the outfit to the steel structure of the ship. It can be done at a number of stages:

At the steel subassembly stage when outfit parts are installed, such as ladder rungs, striking plates, watertight manholes, pipe supports and penetrations. Generally the outfit. parts are small and light and involve cutting of the steel plate and welding. Installation should not interfere with the steel assembly process to an extent where delays may be caused and the steel production program upset.

At the steel assembly stage, when, for instance, the install lat. inn of parts and assemblies is carried out on a deckhead when it is in the downside-up position. Designers should be aware of early outfit installation possibilities, so that details are arranged to suit the particular stage of outfit installation. For example, installing a vent. trunk or an assembly of pipes downhand on to a deckhead will require a s1ightly different arrangement of supports clips, and other items, from an arrangement where the outfit is to be installed overhead.

At the steel unit assembly staoe where installation is the final process before erection. During this, outfit is combined with steel, and may comprise the installation of parts, assemblies and outfit units. Outfit items are brought to the steel units or blocks which may be in storage areas either remote from or alongside the dock or berth. Light mobile cranes are used to aid installation of parts and assemhlies. The construction cranes may have to he used for liftino heavier outfit units or machinery items. Paintinq is also integrated with outfitting at this stage, where access to the work is good.


STEELWORK
CLEAR OF
OUTFIT UNIT
VERTICAL
DECK ERECTED AFTER
OPEN SKY OUTFIT
INSTALLATION
DECK


OPEN SKY OUTFIT

3.3.7.8 Installation on the Ship

Installation on the ship is planned and monitored by zone.

Zones which contain large or heavy outfit items, such as the generators, or outfit units such as equipment modules, are left open for a period to al low the heavy items to be lowered verticallY into Place by crane (open sky outfitting). The zone can then be closed off by the erection of another unit or block on top. The erection program is Planned to give sufficient time between erection lifts to allow for open sky outfitting.

The designer should be aware of open sky outfit possibilities so that the structural breaks are positioned to best suit the installation requirements.

The positioning of outfit units clear of steel Unit butts is also a feature that. designers should consider. The unit breakdown is the first production engineering task carried out and will have been established when outfit units and blocks are being identified. The task of identifying outfit. units and blocks is carried out by Production engineers at the strategic level workina with production management and the contract and functional design groups.

One important stage is the completion of hot work in a zone (and on the other side of the zone bulkheads or decks). On completion of hot work, final painting can be carried out; the area becomes “clean” and the outfit trades can work in good conditions. This is particulary important for the installation of delicate/sensitive equipment and cabin furnishings.

The designer should be aware of the sequence of installation activities so that the design may best suit that. sequence. The optimum pattern and sequence of installation work will be set cut in the company shipbuilding policy.

3.3.8 BASIC RULES FOR IDENTIFICATION CODING

This chapter sets out the basic objectives of a coding system and differentiates between identification and classification codes. Examples of some of the codes required for material and work station identification are provided.

CROSS-REFERENCES

1.2.2 Basis for Shipbuilding Policy Development

2.4.2 Strategic Planning

2.4.3 Tactical Planning

2.4.4 Detail Planning

3.1.1 Implications for the Main Shipyard Functions

3.3.8.1 Objectives

Coding of information is designed tn make the task of transmitting and analysing data easier, by making it more concise and easier to handle. A code structure should make it possible to:

recognize,
sort and group,
analyze,
store,

and retrieve information without mistakes or unnecessary effort.

The structure should be designed to facilitate efficient use of coded information, by users and also by computer systems. The function of a code therefore, is twofold. Firstly, to create an unambiguous identification of a data item, and secondly, to allow meaningful collection and analysis of data.

3.3.8.2 Items to be Coded

The scope of coding systems is extremely wide and covers all aspects of the company's business. It is not the purpose of this manual to discuss the totality of coding systems. Within the context of the design for production manual material? work area and work station identification coding are nf qreatest significance.

Within these areas the items to be coded include the following:

Planning Units
Interim Products
Raw Materials
Vendor Furnished Items
Departments or Cost Centers
Production Stages
Work Stations

3.3.8.3 Coding Concepts

When considering coding systems there are two concepts that need to be understood:

Identification
Classification

Identification codes can be very simple, and in fact, many major computer based, integrated production and material control systems use the idea of unique part numbering. Using this approach, there is no structure at all to the identification code. Providing all like items have the same code and the number of digits is within the acceptable field length, any number of combination of numbers and letters can be used. The computer system keeps track of which parts go to make up which assembly, etc. by holding details of the product structure. The identification code does not have to carry that information. At the other extreme, some code systems try to pack very large amounts of information into the code; information about size, material, position, etc.

Classification codes carry information on things like:

- part type
- material type and specification
- color
- whether or not the part will be installed on a steel unit or block; or be installed onboard; or be included in an outfit assembly
- the final location of the item, the zone in which it will finally be located regardless of the stage of installation
- the number of the work package of which the item will be part.

Bar coding, with shop floor terminals can allow the extraction of additional information to that given by the code.

These are some of the areas in which information is required. They classify the item but are not needed to identify it. Information of this type can be held as attributes of the part and should not be included in the identification coding.

Different companies adopt different approaches to coding, indeed, it is possible to identify differences in national character by looking at the code systems used in the shipbuilding industry around the world. Some people are number oriented and seem able to handle long and complex codes without trouble; others require short structured codes to make the information readily understood.

It is likely that the code system will in fact carry a mix of identification and classification elements in order to make it user friendly. The codes should therefore have some structure without becoming too long or complex. The structure should reflect the hierarchy of interim products and the relationship between workstations and departments or cost centers. The way to design or assess a code system is to consider the information required out of the system and then develop the structure that will allow that information to be obtained quickly and easily. The key point to remember is the difference between identification and classification. There is no need to try and hold too much classification type information in an identification code.

3.3.8.4 Relationship to Design For Production

Designers will be most involved with the identification codes as they will have to apply the codes to drawings as they are prepared. The company shipbuilding policy will identify the interim product hierarchy and the identification code systems should be developed from the hierarchy. There must be a dialogue at all levels between designers and production engineers on the use of codes. If the code structure causes problems in use, alternatives must be developed. As a general rule it can be stated that the more structured the code and the more classification information that is embedded into identification coding, the more difficult the codes will be to use.

3.3.8.5 TYpical Examples

The followina list. gives an example of a possible code structure. The list is not. intended to be complete or exhaustive. The codes shown include a mix of identification and classification elements. The inclusion. of some classification information is acceptable to provide meaning to the code for ease of use by technical, production engineeri ng, planning and production functions.

i) Steel - Planning Unit. Codes

Structure Group Code Gaa

identifies a structure group. The code is the contract code followed by G followed by a two character structure group code,

Steel Block nn

When the planning unit is a steel block, it. is identified by the contract. code followed by the structure group code, followed by a two digit serial number representing the “s1ice” number.

When the planning unit. is a steel block, it may be further identified by a single character extension to the planning unit code, P, S, C to indicate the position of the block within the slice - Port, Starboard or Center.

ii) Outfit Planning Unit Codes

Outfitting Zone 7ann

When the planning unit is an outfitting zone, it is identified by the contract code, followed by a Z, followed by a letter and two digits.

Outfit. Block Fnnn

When the planning unit is an outfit block, it is identified with the contract code, followed by E, follnwed by a three digit serial number.

iii) System Cost Code Cnnn

The steelwork and system (outfit) cost codes are two parts of the same homogeneous cost. code structure. The code is the contract code, followed by C, followed by a three digit number.

iv) Ordering Zone PZnn

The ordering zone code, used to identify required dates for materials at an early stage in the procurement cycle, consists of the contract code, followed by PZ, followed by a two digit serial number.

v) Work Station nn

The work station code is the cost center followed by two digits.

vi) **Work Package** Wnnn or Wannn

The outfit work package is coded as an extension of the planning unit by adding “W;’, followed by a three digit serial number. A variation of this would be to insert the standard stage letter after the “14”, followed by the three digit serial number. The aim would then be to develop standard work package codes for work done at predetermined stages.

vii) **Steel Material Mark** nnn

used *to* identify steel plates and sections brought directly for a particular contract. The code is the contract code followed by a three digit extension to the block code or the structure group.

viii) **Steel Piece Part Number** Pnnn

Used to identify steel piece parts cut from steel plates or shapes. The code is a three digit extension to the block code or structure group utilizing a “P” code identifier.

iy) **Steel Assembly Number** Annnn

Used to identify steel assemblles or subassemblyies. The code is the contract code followed by “A”, and a four digit serial number.

x) **Standard Manufactured Part Number** Mnnnnnn

The standard manufactured part number is “M” ,followed by a six digit serial number. The six digits could be structured to give groups of numbers for part types rather than random serial numbers.

xi) Non Standard Manufactured Part Number Nann nnnn

The nonstandard manufactured part number is the contract code, followed by "N", and seven characters consisting of the outfitting Zone code, followed by a four digit serial number. Note: parts are identified to zone, not system. Material cost control is established through the MLS, which is structured by system.

Yii) Non Standard Manufactured Piece Part nn

A two digit serial extension of the nonstandard manufactured part number.

Xiii) Pipe Part Number Lnnn nnn nn

The pipe part number *is* used to identify individual manufactured digit system code, the three digit pipe line number, and a two digit serial number.

ziv) Outfit. Piece Part Number nn

The outfit. piece part number is a two digit extension of the non-standard manufactured part number to which it refers. In the same way piece parts for standard manufactured parts can be numbered as a two digit. extension of the standard manufactured part number. piece parts for pipes can be numbered as a two digit extension of the pipe part. number.

Xv) part Type aaaa

The part. type is four digits used tO classify both steel and outfit. materials or equipment. The part type codes, therefore, include codes for steel section types.

xvi) Material Type nnnn

The material type is four *letters* used to classify material for both steel and outfit. The material type codes, therefore, include codes for steel grades.

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GLOSSARY

GLOSSARY OF TERMS

Introduction

A number of the terms used in the manual, may be unfamiliar. In some cases, they have been given a very specific meaning and in most cases, there is a more detailed description of the term within the body of the manual. However, these detailed descriptions are not repeated in al 1 three volumes and the reader wil1 be able to refer to this glossary for definitions as required.

in some cases, there may be more than one term for a particular process or other aspect of ship production. Where appropriate, alternatives are given.

Because of the diverse nature and widespread location of the industry, it is inevitable that some terms will be used differently by some readers. In these cases, the glossary will help to resolve any problems.

ACCESS AND STAGING PLAN

Plan which shows location of temporary access holes, staging clips and attachments, access ways and staging required to facilitate construction.

ACCURACY CONTROL (A/C)

The application of various methods of controlling accuracy and dimensions during production by auditing tolerance requirements. A/C emphasizes worker checks as well as improved fitting and welding techniques at appropriate states of production to minimize problems at subsequence stages.

ADVANCED OUTFITTING (A) SO PRE-OUTFITTING)

Process of installing outfit items during assembly rather than during construction of the vessel or after launch,

ANALYSIS

Breaking a whole into parts in order to determine its nature.

AREA

A division of the production process into similar types of work problems by anything that creates a clearly different work problem which can be grouped:

by product feature (curved vs flat assemblies, steel vs. aluminum structure, small diameter vs. large diameter pipe, etc)

by kind of work (marking, cutting, bending, welding, blasting, etc)

by the physical location or facility through which a given type of work is processed (panel shop, pipe shop, etc).

ASSMEBLY ANALYSIS

Process of analyzing a planning unit and breaking it into the units, sub-assemblies and pieces from which it will be assembled.

ASSEMBLY

Process of joining pieces (steel or outfit) together prior to erection at the ship.

AN ASSEMBLY

The product of an assembly process.

The term "assembly" is usually modified to indicate which part of the process, or which element is specifically referred to.

ASSEMBLY, OUTFIT

Process, or end product, of joining together outfit items.

ASSEMBLY, STEEL

Process, or end product, of joining together steel items.

ASSEMBLY, MINOR

Process, or end result, of joining two or more pieces into a product, which will then be joined to other products to form a sub-assembly.

ASSEMBLY, SUB

Process, or end result, of joining pieces into an assembly, which will then be joined to other assemblies.

ASSEMBLY, UNIT

Process of joining sub-assemblies and pieces to form units.

ASSEMBLY, BLOCK

Process of joining units for form blocks.

ASSEMBLY LINE

A set of workstations linked by conveyors for the sequential assembly of similar units.

B L O C K

An assembly formed by joining two or more steel units. The largest assembly produced away from the erection site.

BLOCK BREAKDOWN

The process, or end result, of determining how a vessel will be split into steel blocks.

BREAKDOWN, UNIT

The process, or end result, of determining how a vessel will be split into steel units.

BUFFER STORAGE

Storage area for the products of a work station before they are transported to the next work station in their assembly sequence.

BUILD CYCLE

The time from start of production to delivery for a particular vessel.

BUILD PROGRAM

An, overall program showing the timing of key events leading up to and during the Build Cycle of a vessel.

BUILG STRATEGY, CONTRACT

A document which describes how a vessel is to be built and when key events will take place.

CLOSING PIECE (AIso MAKE-UP PIECE or CLOSER)

A piece which joins parts of two adjacent assemblies, the dimensions of which are lifted at the ship.

COMPUTER AIDED DESIGN/COMPUTER AIDED MANUFACTURING (CAD/CPW)

The application of computers to facilitate the design, engineering, lofting and fabrication processes.

COMPUTER GENERATED PARTS LIST

A computer generated list of material for a specific end use associated with a drawing. The computer generated parts list provides information pertaining to the material, catalog number, unit scope, function code, trade routing, quantity, etc, of each part,

COMPONENT

Any single item which is vendor furnished rather than shipyard manufactured.

COMPOSITE ORAWING

A drawing which depicts simultaneously the arrangements of all the individual ship systems within one zone.

CONCEPTUAL DESIGN - See DESIGN

CONTRACT

Legally binding agreement between two or more persons or parties. In shipbuilding, the contract involves a detailed specification of work and commitment to price and schedule.

CONTRACT AWARD

Date on which a customer commnits the shipyard to fulfill a negotiated contract.

CONTRACT BUILD PROGRAM - See BUILD PROGRAM

CONTRACT BUILD STRATEGY - See BUILD STRATEGY

CONTRACT CYCLE TIME

Time from contract signing to delivery of the finished vessel.

CONTRACT DESIGN - See DESIGN

CONTRACT KEY EVENT PLAN - See KEY EVENT PLAN

CONSTRUCTION (Also ERECTION)

The process of installing steel and outfit assemblies to form the vessel at the erection site.

CONSTRUCTION CYCLE (AlSO ERECTION CYCLE)

The time between the start of construction on the construction site and launch.

CONSTRUCTION SITE (Also ERECTION SITE)

The shipbuilding berth or dock from where the vessel will be launched.

DATUM LINE

A reference from which assembly and installation dimensions are measured. The datum relates to waterlines, buttocks or hull stations rather than structure.

DEFINITION, SHIP

Output of, or process of, design.

DESIGN

Process of defining the specification or relationship of any part of a vessel. Divided into stages.

DESIGN, CONCEPTUAL

The establishment of the overall features of a design to meet mission requirements.

DESIGN, CONTRACT

The establishment of the features of a design sufficient to provide the basis of a contractual arrangement.

OISIGN, FUNCTIONAL

The establishment of the functional features of a design for the purpose of classification and other approval and complete material specification.

DESIGN, TRANSITION

The translation of the features of a design from the system orientation necessary to establish functional performance to a planning unit orientation necessary to establish production requirements.

DESIGN, DETAIL

The establishment of the features of a design in sufficient detail to allow local purchasing, part manufacturing and subsequent assembly and installation to be carried out.

DESIGN /AGENT

Company or group of companies providing a design service and providing engineering, drawings and production information to a shipyard.

DESIGNEP

Any person engaged at any stage of the design process.

DESIGN LEAD TIME

The time, nominally between contract award and start of production, available to designers to meet scheduled requirements.

DETAIL PLANNING - See PLANNING

DIAGRAM

Representation of a ship system showing the system function but not its location on the vessel.

DRAWING

Pictorial representation of all or any part of a vessel, including specification and production information.

DRAWING, WORK STATION

A drawing which relates to a work package to be carried out at a specific work station. Includes production information.

ENVELOPE

A volume which is sufficient *to* contain *parts of a* ship system, or systems, and which can be used to define the location of those parts at the preliminary design stage.

ERECTION - See CONSTRUCTION

ERECTION CYCLE - See CONSTRUCTION CYCLE

ERECTION SCHEDULE (AlSO CONSTRUCTION SCHEDULE)

The timed sequence in which the steel planning units will be installed at the erection site.

ERECTION SEQUENCE (Also CONSTRUCTION SEQUENCE)

The sequence in which the steel planning units will *be* installed at the erection site.

ERECTION SITE - See CONSTRUCTION SITE

FABPICATION (Also PREPARATION)

The initial production process consisting of layout, cutting and forming to create outfit or structural piece parts,

FACILITIES

The buildings, cranes, plant and equipment available to a shipbuilder.

FAMILY

A set of parts or assemblies related by geometry and specification, which can be produced by the same work stations.

FUNCTIONAL DESIGN - See DESIGN

FUNCTIONAL SPACE

A volumetric envelope on a vessel which contains related items from one or more ship systems and which is dedicated to a specialized aspect of vessel operation.

GROUP TECHNOLOGY

A basis for production organization which allows small batch and one-of-a-kind production to gain the benefits normally obtained from flow production of large numbers of products.

GROUP - See PROCESS LANE

In group technology, a set of related production facilities applied to one or more families of products.

HOUSEKEEPING

The tidiness and cleanliness of facilities. Housekeeping is one indicator of the quality of production organization.

INDUSTRIAL ENGINEERING (Also PRODUCTION ENGINEERING)

The application of systematic methods to determine the requirements of production and to develop a production system to meet those requirements. This includes the integration of Design and Production.

INSTALLATION ANALYSIS

Analysis of the zones on a vessel to determine at what stage of production the installation of various outfit items should take place.

INSTALLATION

The process of adding outfit iterns to the vessel, either after launch or at the construction site.

The process of adding outfit iterns to the steel work of the vessel during the assembly stages. See also ADVANCED OUTFITTING.

INTERIM PRODUCT

Any part or assembly which is the output of a workstation, is complete in itself and the completion of which can be used as a measure of progress.

KEY EVENT PR0GRAM

A program which shows the most significant events between the contract award and delivery of a vessel.

KEY PLAN

A plan showing the steelwork arrangement of all or part of a vessel on which outfit systems are located.

LEAD TIME

The time between an event and another related event, during which all preparation for the second event must take place.

LEAD TIME, DESIGN - See DESIGN

MARSHALLING

The collection of parts, components and dssemblies into sets which meet the requirements of the next production stage.

MATERIAL CONTROL

The process of determining how materials should be marshalled and subsequently control led to ensure the intentions are complied with.

MINOR ASSEMBLY - See ASSEMBLY

MINOR STEEL

Non-structural steel parts and assemblies. Usually produced in the shipyard and usually related to outfitting.

MODULE

An outfit assembly consisting of functionally related components and connecting parts mounted on a steel frame and completed prior to installation. Especially in machinery spaces.

N E T W O R K

The representation of a set of logicallY connected events, or activities, which shows the sequence and inter-dependence of those events or activities.

N E T W O R K, S U B

A detailed network showing the sequence and dependence of events or activities leading to one particular event or activity on an overall network.

ON FLOW, of products

Term indicating that a product belongs to a family and is compatible with a work station or group of work stations.

OFF FLOW, of products

Term indicating that a product does not belong to a family and therefore requires non-standard production processes.

OUTFIT UNIT

An assembly of predominantly outfit items which is assembled off the vessel and then installed in one lift onto the hull structure.

PANEL

An assembly of flat plates, butt joined, together with associated stiffening.

PART- See PIECE PART

PARTS LIST

A list of all items required to complete a particular work package.

PHASE

A step in the assembly or installation process. The work in a phase constitutes a work package.

PIECE PART

Product of the fabrication stage of production. An item made in the shipyard.

PIPE BANK

An outfit assembly comparising pipes from one or more ship systems, mounted on Supports and completed prior to installation.

PLANNING

Process of determining the sequence of events in design, production and other shipyard functions, in advance of those events occurring.

PLANNING, STRATEGIC

Long term planning, beyond the current order book and generally *over* a timescale of several years.

PLANNING, TACTICA1

Medium term planning with a time horizon of about three months. The preparation of an overall program for each contract and a corresponding program for each department.

PLANNING, DETAIL

Short term planning with a time horizon of about two weeks. Planning of events at individual work stations.

PLANNING UNIT

A steel block (or pair of blocks) large outfit assembly or installation zone, the completion of which is an event at the strategic planning level. The planning unit is the basis for *more* detailed planning and engineering activity.

POLICY, COMPANY

A statement of the way in which a company plans to meet its overall business objectives.

POLICY, SHIPBUILDING

A statement of the way in which the technical and manufacturing functions in a shipyard plan to carry out company policy.

PREL IMINARY DESIGN - See DESIGN

PRE-OUTFITTING (Also ADVANCED OUTFITTING)

Instal lation of outfit items on structural assemblies prior to unit of block erection.

PREPARATION - See FABlICATION

PROCES ANALYSIS

Determination and evaluation of the proposed sequence of events leading to completion of an assembly.

PROCESS LANE - See GROUP

A group of work stations designed to produce a familY or families of products which require similar processes.

PRODUCIBILITY

An attribute of a design or product which allows it to be manufactured effectively with the available facilities.

PRODUCT, INTERIM - See INTERIM PRODUCT

PRODUCT DEVELOPMENT

Process of determining the types and sizes of vessels to be built by a shipyard, and the preparation of conceptual designs.

PRODUCT WORK BREAKDOWN STRUCTURE (PWBS)

The application of Group Technology to subdivide work into logical production categories. These categories organize shipbuilding into discrete products which are used to Plan an and control production.

PRODUCTION

Any aspect of the process of making a vessel, or of the crafts and facilities directly associated with that process.

PRODUCTION ENGINEERING - See INDUSTRIAL ENGINEERING

PRODUCTION INFORMATION

Any information which informs production how or when to carry out their function.

PRODUCTION STAGE

A particular phase of the ship production process.

PRODUCTIVITY

The ratio of output to input. Often expressed as a quantity of work achieved for given expenditure OF manhours.

RAW MATERIAL

Materia1 bought by the shipyard in made or processed form which can be converted into useful products.

SCHEDULE

A list of tasks to be performed or items to be rompleted with the associated dates by which they are to be completed.

SCHEMATIC

A single 1ine drawing showing (non-geometrically) iterns of equipment and individual inter-connections.

SHIPBUILDING POLICY - See POLICY

SHIP DEFINITION

Output of, or process of, design.

SLICE

Part of a vessel between two transverse planes. Output of the first stage of unit breakdown.

SPATIAL ANALYSIS

The process of defining at the preliminary desigr. stage, a vessel's internal layout as a series of envelopes.

STAGE

A particular phase of the design or production process.

STAGING

Upright supports and working platforms giving access to a vessel during construction.

STANDARD

An established model or example which can be broken *down* according to basic types of information. Some types of standards typically encountered are as follows:-

Design Standards - Engineering/Design data on how to perform calculations, develop a design, etc.

Application Standards - Defined service applicability of components.

Material Standards - Dimensional data for individual components which may be used for fabrication purposes.

Performance Standards - Defined minimum acceptable criteria for performance.

Standard Drawings - Standard design configurations to aid engineers and designers and to reduce design time.

Standard Procedures - Established or prescribed methods to be fol1owed routinely for the performance of designated operations such as planning, scheduling and budgeting.

STRATEGIC PLANNING - See PLANNING

SUB ASSEMBLY - See ASSEMBLY

SUB NETWORK - See NETWORK

S Y S T E M

Any set of objects or activities inter-related to form a coherent whole.

SYLY5TEM, SHIP

Set of equipment arid inter-connecting service runs which carry out a particular function in the finished vessel.

5YSTEMS

Inter-related activities which organize and control the operations of a shipyard.

TACTICAL PLANNING - Sec PLANNING

TECHNICAL

Functions of shipbuilding related to design and development of production information.

TRANSIT ROUTE

A pre-determined volume which will provide a route for services on the vessel.

TRANSITION DESIGN - See DESIGN

TYPE PLAN

A program showing the sequence of completion of planning units for a vessel type, independent of timescale.

UNIT (Also STEEL UNIT and OUTFIT UNIT)

An assembly forming part of the vessel which will be taken to the construction site to be joined to the hul1.

UNIT ASSEMBLY - See ASSEMBLY

UNIT BREAKDOWN - See BREAKDOWN