UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING AND APPLIED SCIENCE

Department of Ship Science

STRUCTURAL DESIGN FOR PRODUCTION

ON A MICRO-COMPUTER

by

A. Emmerson, B.Sc., C.Eng., M.R.I.N.A.

A Thesis Submitted for the Degree of M.Phil

1987

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ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE

DEPARTMENT OF SHIP SCIENCE

Master of Philosophy

STRUCTURAL DESIGN FOR PRODUCTION ON A MICRO-COMPUTER

by Andrew Emmerson

Details are presented of the development of a suite of computer programs for use on a micro-computer. These are used for the prediction of the production costs associated with different structural designs. Since, for merchant ships, the costs associated with steelwork form a significant component, the software calculates these figures.

To maximise the potential cost savings the design appraisal is undertaken at an early stage in the design process, viz. midship section design. Typical inputs for the programs are the geometry and scantlings of the production unit.

Production costs comprise labour, materials and overheads. Whilst work study data is used in the calculations of fabrication and erection manhours, regression techniques form those pertinent to preparation.

Examples are given for a production unit and stiffened deck panel and comparisons are made with previously published work.

ACKNOWLEDGEMENTS

The author wishes to thank:

- Professor G.J. Goodrich, Dr. R.A. Shenoi and other staff in the Department of Ship Science for their support and guidance throughout the work.

- British Shipbuilders and the Science and Engineering Research Council who funded the project on which this thesis is based.

- Management and Staff in Design, Drawing and Production Engineering Departments at Austin and Pickersgill Ltd.

- Mr. Jack Rosser of B.S. for guidance relating to the use of the workstudy data.

- My wife, Mary, for the endless encouragement she has given during the preparation of this thesis.

LIST OF ILLUSTRATIONS

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1. INTRODUCTION

The Author was engaged by the Department of Ship Science at Southampton University on a two year research project; "Production Orientated Structural Design" [9 & 32] which was jointly funded by British Shipbuilders (BS) and the Science and Engineering Research Council (SERC). The aims of the project were to:

1. Evaluate the influence of major production factors on structural design variables.

2. Develop a method (with simple algorithms) of using the results of the evaluation and applying them to structural design.

3. Verify the method and algorithms by trial demonstrations.

This thesis describes the development of the algorithms and subsequent computer programs for use on an IBM-XT personal computer. They enable production details and costs to be analysed and compared for design alternatives.

The following details are included in this document:

1. The background to the work.

2. An explanation of what design for production is and the need for it.

3. Details of previous work associated with the subject.

4. The use of work study data.

5. The development of the computer model, algorithms and software.

6. Software testing and case studies.

Appendix A details more fully the tasks which were necessary to complete the project.

2. BACKGROUND TO THE WORK

During the past few years the world recession has led to a reduction in a) the world shipping fleet and b) orders for new vessels. Concurrent with this, several nations have increased their share of what new building market there has been. Comparisons between 1974 and 1984 are striking:

	1974	1984
Europe	27%	10%
Japan	38.4%	56%
South Korea	2.8%	17.5%

One of the fundamental reasons for the decline in the EEC (and UK) share is the gap in shipyard productivity as shown in figure 2-1. Although this indicates the need to improve the working efficiency of the workforce, it also shows the need to find and use cheaper production methods.

Whilst this can be achieved by introducing new technology, machinery and reorganising the physical facilities of production, it requires capital expenditure which might not be available. An alternative is to rationalise ship design and production within the constraints of the existing facilities.

It has been estimated that in a UK/EEC context such a process could lead to savings of up to 15% of total production costs. The process would need inputs from the following functions as illustrated in figure 2-2:

1. Organisational e.g. better planning.

2. Manpower resourcing eg. flexible work patterns.

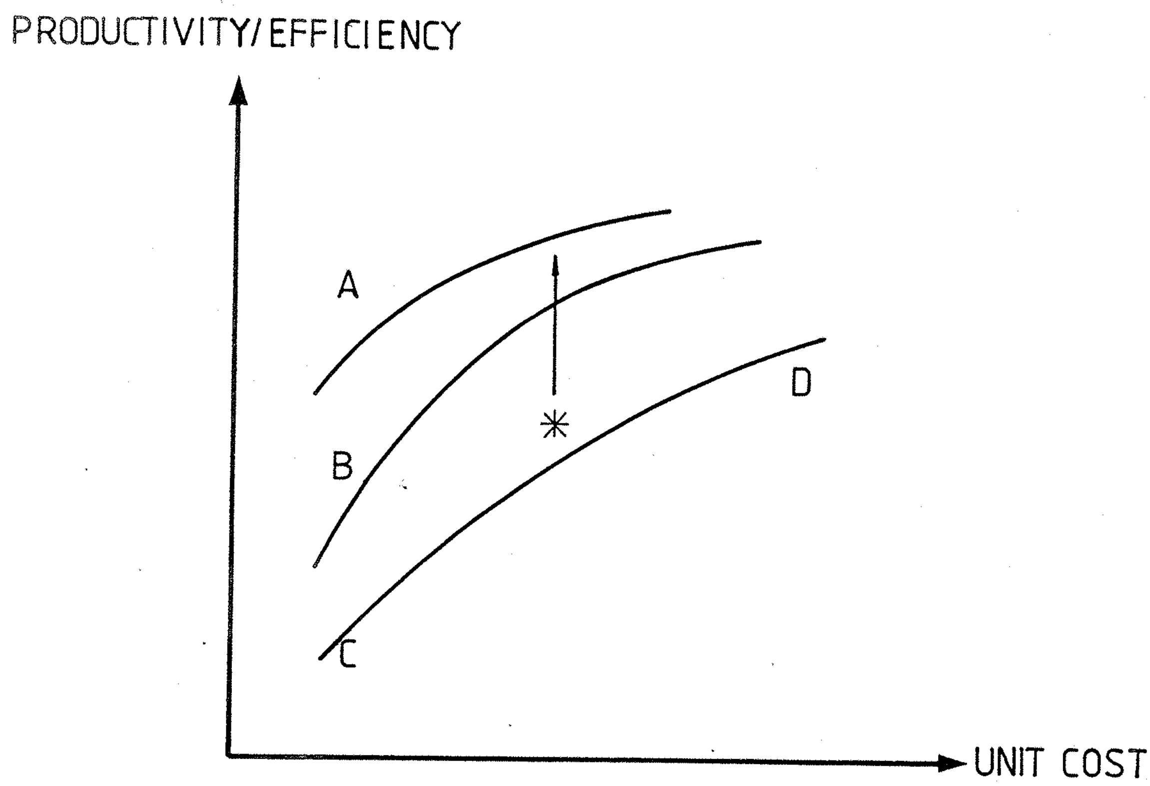
3. Engineering eg. maximising the use of existing facilities.

4. Design eg. design simplification.

Such an interaction falls in the domain of Production Engineering one aspect of which is termed "design for production".

FIGURE 2-1 THE PRODUCTIVITY GAP

Source: Ref. 28



A - Emerging competition

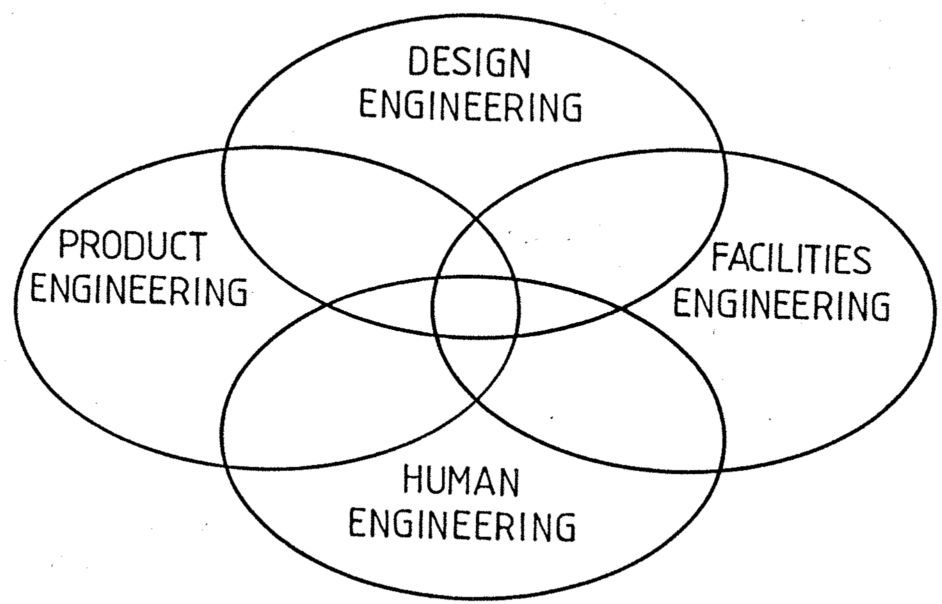
B - Existing competition

C - Low cost/low productivity developing countries

D - High cost/high productivity developed countries

* - U.K., need to improve

FIGURE 2-2 PRODUCTION ENGINEERING INTERACTIONS



3. DESIGN FOR PRODUCTION

The Naval Architect has traditionally been involved in the development of a design for a vessel which satisfies the owner's performance requirements. This is achieved by working through preliminary designs and feasibility studies to a detailed solution. The typical information available at these stages is given in figure 3-1.

The concept of design for production requires that besides complying with the owner's requirements, the design should also be easy to produce. Therefore, a compromise must be reached which takes account of production and performance. Design for production is necessary if production costs are to be reduced and, hence, more orders won. Maintenance and operational constraints will also figure in the final solution as shown in figure 3-2.

In order to achieve design for production for the whole boat, each design sub-system has to be analysed. Of these, steelwork has been considered the dominant area since it generally accounts for the majority of the labour cost for merchant ships as shown in figure 3-3. Although the cost for outfit on a frigate is greater than that relating to steelwork, this is attributable to the installation of the weapon systems.

3.1 Levels of Decision Making

The design development process, where decisions have to be made at different levels, has a number of implications vis-a-vis designing for production.

Firstly, production considerations interact with design at all levels. For example, the choice of a block coefficient at the concept stage influences the cost of production. A slender ship (i.e. a low block coefficient) will require more shaped/rolled plates than a full one. Consequently, the slender vessel will need more time to construct, leading to increased costs. The potential for the simplification of structural designs at an early stage is illustrated by the choice of a midship section configuration, as shown in figure 3-4. Figure 3-5 shows how the detailed design of brackets and minor assemblies lend themselves to easier production if alternative solutions are thoroughly appraised.

The second important implication is that the impact of design decisions on the production process is dependent on how far the design is advanced ie. the maximum scope for increasing producability (and, hence, reducing costs) is in decisions made at the very early stages of design. As illustrated in figure 3-6, the choice of the value of a block coefficient or the overall layout and geometry of a midship section structure has far more impact on production than the choice of an individual bracket.

Finally, the irreversible nature of design decisions has to be recognised. For example, it would impractical to change the block coefficient late in the design process even though existing jigs could be used if it was. This type of information must be appraised at the beginning of the design cycle - the designer must get it right from the outset.

3.2 Quantifying Design for Production.

Although a design proposal can be readily evaluated against the owner's requirements, it is more difficult, however, to judge quantitatively if it is easy to produce. One measure which can be used is total production cost which comprises:

material,

labour, and

overhead

components which are, unfortunately, inter-dependent. For example, a reduced material cost might result in poorer quality resulting in increased labour costs through rectification work. Alternatively, overheads could be reduced by a reduction in the size of support departments although this might increase labour manhours through inadequate planning and production control.

3.2.1 Material Costs

The cost of steel in a design can be readily determined from the steelweight estimates used in deadweight calculations. Although weight/unit length is used, historical data from previous contracts can also be useful.

3.2.2 Labour Costs

At the preliminary design stage empirical relationships linking work content and design parameters are used as the basis for labour cost estimation. Typical of these are manhours/tonne of steelweight or manhours/unit length, based generally on historical data ie. the manpower returns for previous vessels of similar design (arrangement).

Historical data has the following inherent disadvantages:

1. It relates to a particular ship type, size and construction.

2. It contains the deficiencies of the labour reporting systems.

3. It contains the effect of the productivity of the workforce on the previous vessel.

4. It is not detailed enough to allow the effects of changes to minor variables to be assessed.

Also, the reduction of new building contracts has led to yards tendering for ship types they are unfamiliar with. Combined with the lack of extensive series of vessels the problems highlighted above have been exacerbated.

One alternative to using the type of historical information as outlined above is to utilise standard data obtained through workstudy techniques. Although it is collected from the shipyard initially, the inherent problems are calculated out to give "basic" and "standard" times. This solution is discussed further in Chapter 5.

3.2.3 Overheads

Overheads can be defined as the "aggregate of indirect material cost, indirect labour wages, and other indirect expenses". They can be fixed or variable and can be conveniently recovered by apportioning them to the direct manhours worked on a contract. For example, overhead costs of a job might be 150% of direct costs.

3.3 Design for Production Practices

Design for production can be defined as "design to reduce production costs to a minimum compatible with the requirements of the ship to fulfil its operational functions with acceptable reliability and efficiency".# This is achieved through reducing the work content of a design whilst ensuring the maximum amount of work can be conducted in the downhand position with the minimum of inconvenience and discomfort.

Whilst it is difficult to quantify the work content in a design it is possible to suggest methods through which;

a) the amount of work is reduced,

or b) the work can be completed in an easier position or location.

Examples include:

1. Simplification of the design with a reduction in the total joint length and number of components.

2. Subdivision of the vessel into steelwork and outfit assemblies which would improve the access and working position whilst allowing the maximum amount of work to be completed in the shop.

3. Utilise the most effective production proccesses, welding and assembly techniques.

4. Compatability with existing and projected shipbuilding facilities.

 # Source: Ref. 36

5. Standardisation to reduce the number of drawings required and to take full benefit of the learning curve.

6. Maximise the use of straight materials and components and minimise the use of double curvature items.

7. Zone orientated studies to allow the maximum use of space whilst pipe and cable requirements are minimised. [26].

Specific details pertaining to the production stages are given in Appendix B.

3.4 Synopsis

Although the need for design for production has been stressed, it is currently difficult to evaluate it in other than qualitative terms. Since good design for production results in a cheaper vessel, one measure might be total build cost which comprises material, labour and overheads. Material cost can be readily determined and overheads are generally recovered by the addition of a percentage of the direct labour costs.

At the early design stage when the design and, hence, production costs can be influenced most, work content ie. labour cost, is difficult to calculate. Historical data from previous vessels is not detailed enough to show the advantages associated with changes in minor design variables. Also, it contains inherent inaccuracies.

Therefore, a method is needed by which design alternatives can be appraised at an early stage, with reference to more accurate figures than obtainable from historical data.

FIGURE 3-1 INFORMATION AVAILABLE AT EACH DESIGN STAGE

Source: Molland, Ref. 30

Enquiry

Stage	TYPICAL CONTENT	EXAMPLES OF TYPICAL DESIGN - PRODUCTION INTERRELATIONS
CONCEPT/PRELM DESIGN	operational considerations : Dw, speed, range etc. Derive feasible design : Principal dimensions, Outline GA. Prelim. power, masses, volumes Prelim cost	camber/sheer Hull shape Hold lengths Accomm. Block
TENDER	Given: Dw,cap.,speed,range (Dimensions +GA) Derive(check) dimensions,power, masses, stab., GA etc. Outline planning Estimate cost	Block unit type/sizes/masses, crane cap. Advance and modular outfitting
CONTRACT	Detailed design Detailed planning Working Drawings Monitor/feedback	Detailed level of analysis Design alternatives, stiffening arrgts etc Max level of interaction between design and production.

Delivery/operation

FIGURE 3-2 COMPROMISE BETWEEN ECONOMY, EFFICIENCY AND RELIABILITY IN DESIGN

Source: Ref. 36

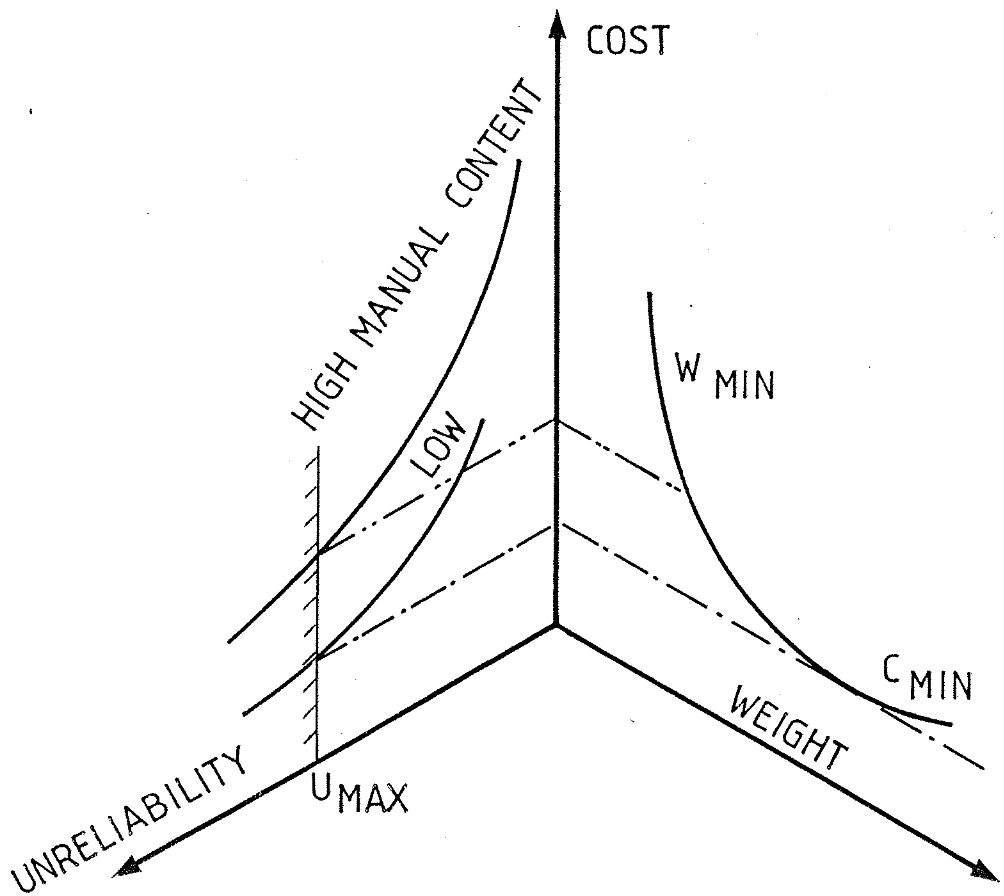


FIGURE 3-3 STEELWORK LABOUR COSTS

Source: Goodrich, Ref. 29 & McIver, Ref. 30

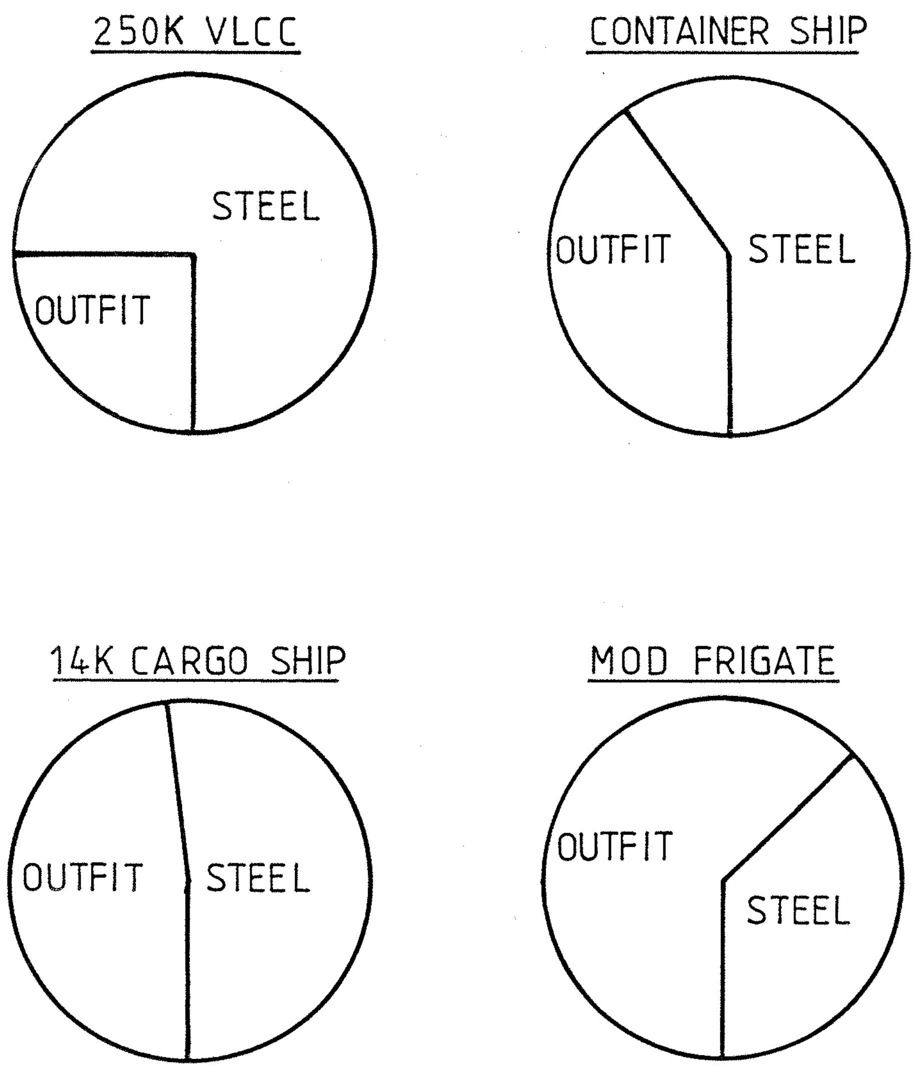
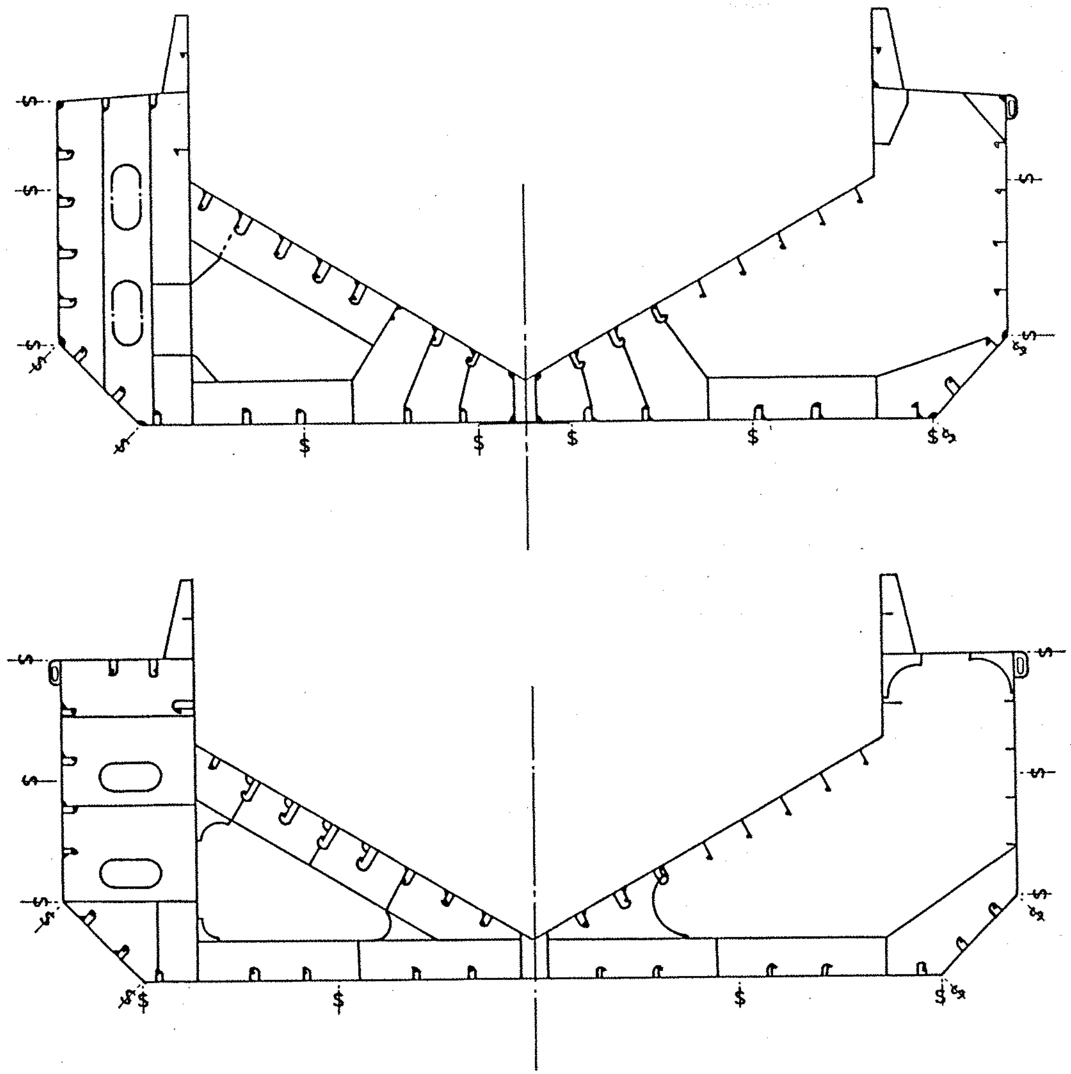


FIGURE 3-4 PRODUCTION DESIGN ANALYSIS - EARLY DESIGN STAGE

Source: Hargroves, Ref.30



It is worthwhile noting the significant differences between these two design sequences:

(a) The numbers of different types of stiffener have been reduced from eight to three.

(b) The bottom shell plating arrangement has been simplified with the elimination of the thickened keel plate.

(c) The chine bars have been removed thereby simplifying assembly operations and achieving a reduction in joint length.

(d) The connections between webs and longitudinal stiffeners have been simplified.

(e) The deck camber has been eliminated.

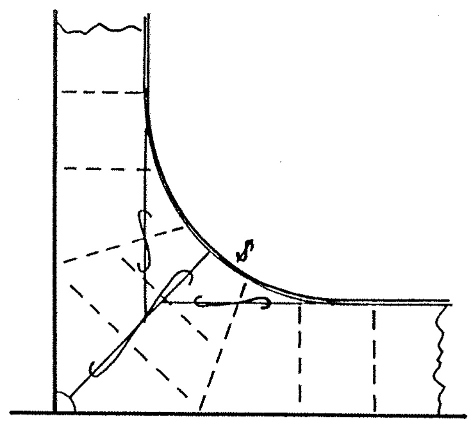
(f) A minimum variation has been achieved in plate breadths.

(g) Symmetrical "T" girders have been adopted as far as possible.

(h) The bilge bracket design connections have been simplified to made them self-jigging.

FIGURE 3-5 PRODUCTION DESIGN ANALYSIS - DETAIL DESIGN STAGE

Source: Molland, Ref. 30



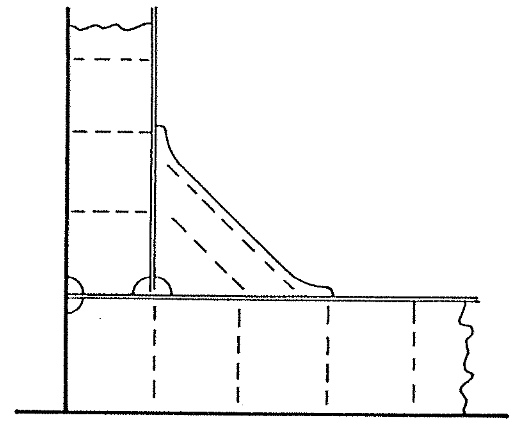
GROSS WEIGHT HIGHER

MORE DIFFICULT SCRAP ARRANGEMENT

SUBJECT TO BUCKLING FAILURE, FAILURE OFTEN SEEN AT EARLY STAGE OF HYDROSTATIC TEST BEFORE SHIP LEAVES YARD

MORE DIFFICULT ERECTION BUTT AND FACE PLATE WELDING

USE OF ALTERNATIVE ERECTION JOINTS, E.G. LAPS



NET WEIGHT HIGHER

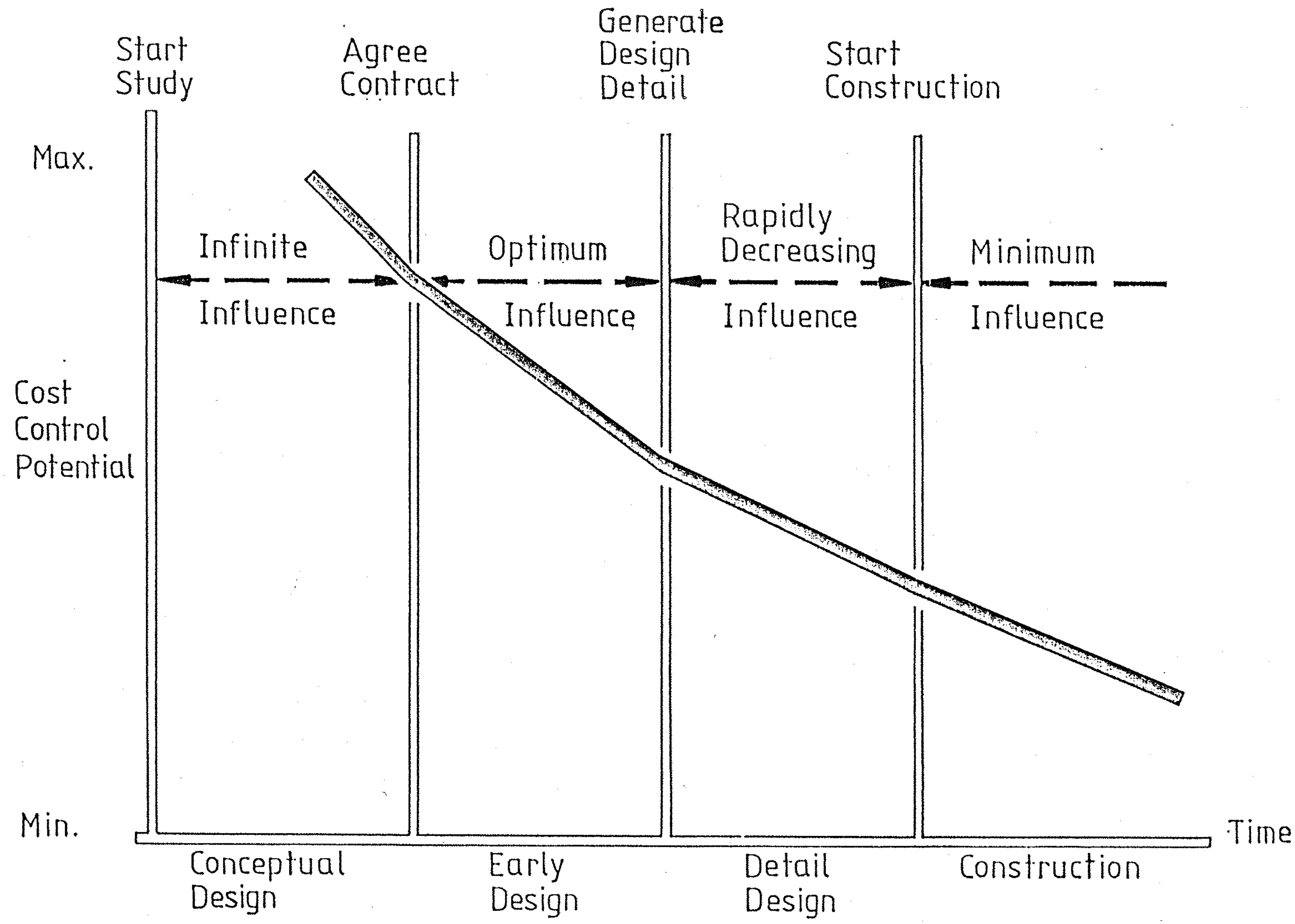
CLAIMED LOWER PRODUCTION HOURS DUE TO STRAIGHT LINES AND MACHINE APPLICATION

SUBJECT TO FATIGUE FAILURE, FAILURE SEEN AFTER A NUMBER OF YEARS IN SERVICE

GOOD FOR FAST ERECTION, ALTHOUGH ACCURATE ALIGNMENT SHOULD BE MAINTAINED

LENDS ITSELF TO FUTURE MORE FUNDAMENTAL DESIGN APPROACH, E.G. PLASTIC DESIGN OR BRACKETLESS

FIGURE 3-6 COST CONTROL POTENTIALS



4. PREVIOUS WORK

This section of the thesis describes some of the previously published work associated with design for production. Although most of the papers acknowledge the need to consider production costs in addition to material weight, few have tackled the problem. Of those which have the methods of calculating work content, and hence production costs, vary between the use of inaccurate historical data and the application of detailed workstudy information.

4.1 Harlander 1960 [14]

In his paper to SNAME in 1960, Harlander attempted to establish criteria which would optimise the design of stiffened panels for minimum weight. Although various loading conditions were considered, he did not address the issue of minimum weight not necessarily representing minimum production cost.

4.2 Evans and Khousy 1963 [11]

The two authors considered the problem of optimising a midship section structure for least weight and minimum construction cost. The implications of a lower steelweight design are twofold. Firstly, it gives a higher deadweight and, hence, revenue earning capacity. Secondly, since steel costs are roughly proportional to steelweight, the material costs for the design are also lower.

Labour costs were based on an equivalent surface:

$$\frac{\text{net weight of plates and sections}}{\text{average thickness of plates}}$$

Historical figures for manhours per square foot of equivalent surface were applied to each major structural component;

bottom shell	0.329 manhrs/sq ft of equiv. surf.
side shell	0.610
bilge (and bilge keel)	0.839

and are summed to give the total labour cost for the design.

The parametric studies in the paper suggested that in any particular case, the most economic solution was likely to lie between the minimum cost and least weight solutions. As the labour rate was reduced, the gap between the two solutions narrowed.

Although this work did consider that minimum cost was not necessarily synonimous with least weight, the labour rate data used was of an historical nature with all its detractions. Also, the effects of changes in minor design variables could not be appraised.

4.3 Moe and Lund 1967 [20]

Moe and Lund described a general method of non-linear programming with an extensive study of longitudinal strength members of tankers. The method contained the following steps:

1. Formulate the functional requirements eg. types of loadings, in service requirements.

2. Select the topography eg. structural arrangement.

3. Describe the structure by design variables $y_1 \ldots y_n$, eg. diameters, lengths, thicknesses which cause certain behaviours when under loads $\sigma_1 \ldots \sigma_t$, eg. stresses, deflections.

4. Develop the relationships between design variables and behaviours $h_j(y_1 \ldots y_n, \sigma_1 \ldots \sigma_t)=0$, $j=1 \ldots t$

5. Determine the unfeasible solutions ie. those outside the restrictions $g_i(y_1 \ldots y_n, \sigma_1 \ldots \sigma_t) \geqslant 0$, $i=1 \ldots m$

6. If the solutions comply with 4 and 5 above then judge them against a certain criteria F(y), the object function, as to which is the optimum.

The optimum can be calculated by iterative techniques on a computer.

This approach requires the geometric description of each element in the midship section in a manner consistent with calculating the section modulus. Constants, derived from the input data, are used in formulae to calculate material costs (£/tonne), welding rates (£/metre) and unit costs of intersections between longitudinal/transverse elements.

The individual cost elements are summed to give the total building cost which is rationalised to give the cost of production per m^3 of cargo volume.

Although this work does not represent absolute design for production, it provides a technique to design for strength at minimum cost. The ratio $k=P_a/P_s$ is used to relate the unit cost of labour to the unit cost of mild steel.

The equations apply to the midship section only, with no account taken of fore or aft end construction. Changes in the basic design could not be accommodated unless further optimisation routines were developed.

4.4 Caldwell and Hewitt 1976 [5]

The authors drew attention to two aspects which are necessary for design for production:

1. The need to consider the "as built" structure with its inherent imperfections and irregularities.

2. The design of these real structures must be synthesised to meet the appropriate criteria eg. weight, cost, reliability.

Despite these thoughts, cost effective design was considered difficult due to the lack of data on unit costs.

An equation was, however, developed which allowed both material weight and production costs to be included in the optimisation process. Production costs were assumed to comprise labour, materials, fixed and variable overheads. Together with the weight element in the equation, they were considered proportional to the known figures for a basis design.

The examples showed that to ensure minimum production costs for a flat stiffened panel, the stiffener spacing should increase as the cost ratio increases. The cost ratio was defined as:

$$\log_{10}\left(\frac{\text{production cost}}{\text{material cost}}\right)$$

Further conclusions were that a design to minimise costs led to simpler structures with fewer pieceparts but thicker plating. Also, as the cost ratio increased the difference between minimum cost and minimum weight designs behaved similarly. Despite these findings, the paper only contained detailed examples of grillages/panels and did not address "whole ship" design for production.

4.5 Carreyette 1977 [8]

Carreyette's paper presented a method of assessing the approximate capital cost of a new vessel at the early design stage. In particular it enabled comparisions to be made of building cost when principal design variables were changed.

In the parametric approach suggested, labour hours, H, were represented by curves $H = \alpha x^n$ where α and n are constants $(n \leqslant 1)$, and x is the size variable. The constants were determined from Carreyette's study of shipyards and were, therefore, based on historical data.

The total cost, found by summing the various components, could be modified to take account of variation of ship form (block coefficient), speed (propulsion machinery size), wage rates and overhead recovery rates.

Since the equations are best used in studies of cost changes due to changes in major variables, they are not suitable for use in design for production work where, perhaps, structural details are under consideration. Also, the curves are dependent on observed shipyard results and simplify the relationships between design variables and production factors.

4.6 Southern 1979 [24]

Southern accepted the problems associated with using empirical factors and steelweight in calculations for work content. Cutting length and weld length were thought more suitable since empirical factors did not have to be applied to them. The disadvantage of this "way ahead" was the necessity to extract details of the type, size and length of weld from the assembly drawings.

To overcome these problems Southern analysed two ships. Using a system of codes, each piecepart was modelled by computer programs in order to calculate the work content in terms of labour for welding processes.

Since the data had to be extracted from previous vessels its applicability to other contracts is considered unsuitable. Questions were raised at the time regarding the accuracy of the work content predictions.

4.7 Keil 1982 [15]

This paper shows the methods used in Blohm and Voss for determining the production costs of design options at the pre-contract phase, enabling comparisons to be made of alternative arrangements and build methods. The construction work was grouped into four stages:

1. "Fabrication" - preparation of components.

2. Sub- assembly construction - The components are assembled into panels etc.

3. Block construction - from the combination of sub-assemblies.

4. Shipboard or slipway installation - the erection of blocks on the slipway.

The scantlings for a number of "frame sections" along the length of the ship were generated from classification society rules. Unit and block breakdown decisions at that time permitted the work content to be established from simple equations for each block at each build stage, in terms of manhours/metre. The total build cost was found from integrating the area enclosed by the curve of manhours/metre for frame sections against ship length (figure 4-1).

This method allows quick comparisons to be made of alternative structures at the pre-contract stage. However, the method is simplistic and its applicability "across the board" of ship types is uncertain. The equations seem to be based on historical data.

4.8 Kuo, MacCallum and Shenoi 1983 [16]

The authors described the development of a production costing tool which would enable a range of feasible designs to be compared. A suite of computer programs estimated the material, labour, overhead and total costs of production.

The main difference to other costing tools was the use of workstudy data to determine labour costs. This enabled the use of historical data, which had possibly been corrupted, being avoided. The work content of a design was built up from elemental workstudy data which was collected at Govan Shipbuilders.

The routines developed by the authors covered double bottom units and grillages both of which were examined quite extensively. However, further routines would be necessary to cover other areas.

Although this approach has led to a quantitative method for comparing arrangements, it is necessary to specify the fabrication procedure in detail, and have a working knowledge of how to use the workstudy data if the solution is to be meaningful. This solution does, however, permit production costs to be related to minor design variables.

4.9 Baird and Winkle 1985 [2]

The basis for this work is that described in 4.8 but with specific modifications to cover, initially, offshore type structures. The elemental workstudy data from Govan covering assembly and welding, was converted to form a database on a micro-computer. Also included was synthesised data from Sunderland Shipbuilders.

A number of tasks were synthesised from the elemental data and stored on datafile. These were used to build up the total work content of ship-type structures very quickly. However, since they only represent one build procedure, other files would have to be developed to cover different build methods. The tasks have been optimised by other computer programs.

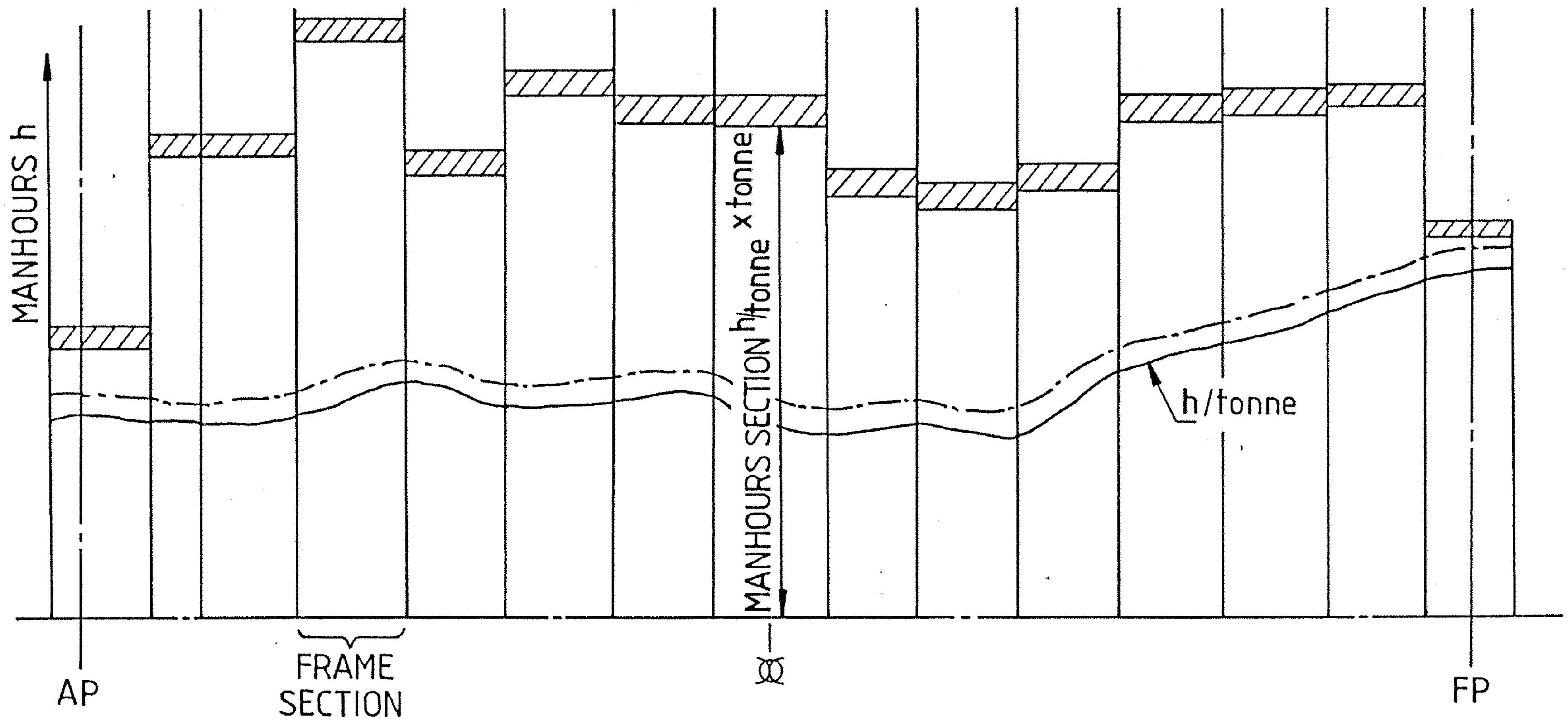
The major step achieved by this work was the establishment of a micro-computer database. However, since only a limited number of synthesised tasks are available a designer is restricted to using these standards unless the elemental data is used to work up other arrangements.

4.10 Summary

The methods of calculating work content and production costs at the early design stage of a vessel generally use inaccurate data of an historical nature. The alternative is to use workstudy techniques which require substantial data input. Since this might not be available, assumptions regarding the structural arrangement might have to be made.

FIGURE 4-1 MANHOURS vs FRAME SECTION FOR A 35,000 TONNE CONTAINER SHIP

Source: Ref. 15



5. WORKSTUDY METHODS

The need for an accurate method by which to calculate the work content and, hence, labour and total costs of design alternatives has been stressed earlier in this thesis. This section discusses how workstudy data can form the basis of determining work content.

Work measurement is the branch of workstudy which will be used and can be of two types:

- Methods-Time Measurement
- Stopwatch studies

5.1 Methods-Time Measurement

Methods-time measurement includes pre-determined motion time study (PMTS) which is perhaps the most complex method of estimating work content. The fabrication process is considered to comprise tasks, each of which have to be analysed as individual movements. The time to complete these can be extracted from tables of standard data. Typical examples of these movements are:

move
grasp
position
reach
turn.

They are shown in figure 5-1 from where it can be seen that the times are dependent on factors such as object size and weight, and the distance moved.

Whilst the simple task of removing a nut from a bearing is shown in figure 5-2, a fabrication process in a shipyard could be made up of thousands of movements. The total time for a task is obtained by summing the individual elements. Although allowances can be made for the differences between actual and theoretical working conditions, these do not always produce accurate estimates.

5.2 Stopwatch Studies

These are when workers are studied at length, and the time taken to complete a task is measured on a number of occasions to give an average. This raw data must be corrected to give a time in "basic" minutes - the time a trained worker would take to complete the task under perfect conditions. A more realistic value is the "standard" minute which includes allowances for rest, fatigue, temperature, humidity etc.

The first of two studies to be evaluated was that reported on in 1973 and covered welding only. Both ship and shop work were detailed in normal and difficult positions [17].

Also evaluated was the work measurement data collected at Govan Shipbuilders on the Clyde during the 1970's and which forms the basis of the workstudy data which was used in the BS project. This work still represents the most extensive investigation of its kind in the UK shipbuilding industry.

5.2.1 The Govan Work Measurement Data

The studies at Govan covered the departments shown in figure 5-3. Since the research project concentrated on the steelwork aspects of design for production, only this data was used in the programs. In particular, that pertaining to the plating, and hand and machine welding functions of the fabrication process.

A typical fabrication activity comprises fairing and welding. The former includes the work involved with collecting materials and tools, setting out, and temporarily fixing the piece-parts (tack welding) prior to the permanent welding process starting. These details are contained in the plating serials the range of which is given in figure 5-4.

The serials represent the work necessary to complete tasks which comprise elements, each of which were timed on a number of occasions to produce an average. The frequency of each element was also noted eg. per job, per plate or section, per linear foot. The "as recorded" times were modified to give the basic minutes a perfect worker would take to complete the job in ideal conditions. An example of elemental data is shown in figure 5-5.

On completion of the work measurement the serials were redivided with the elements grouped and totalled with respect to their frequency as shown in figure 5-6. Relaxation allowances were applied to the basic minutes figures to give composite tables of standard minutes (figure 5-7).

After consultation with British Shipbuilders (BS), the holders of the serials, and in particular their Industrial Relations Manager who was involved in the original work, the project used the composite tables of standard manhours.

5.2.2 Application of the Data

The total time to complete a task comprises:

a) Time which occurs once only eg. receiving instructions clearing the working area.

b) Time relating to the number of pieces of material (or number of joints in the case of welding processes).

c) Time proportional to the length of a joint.

Therefore, if the joint lengths and number of pieceparts were known, the work content of a task could be calculated.

The computer programs do this and also generate the necessary production parameters, ie. controls, to enable the workstudy data to be extracted from computer datafiles on which it is stored. The options for completing the tasks are extensive, varying between serials. For example,

Restrictions .... Restricted / Unrestricted #

Working position .... Downhand / Vertical

Type of lift .... Manual / Crane

Material thickness .... ⩽13mm / >13mm

The flow diagram in figure 5-8 gives an indication of the production parameters which must be generated.

An example of a task is given in Appendix C.

Note: The access is considered restricted if the work is undertaken in areas of reduced headroom or elbow room.

TABLE II—MOVE—M

Distance Moved Inches	Time TMU A	Time TMU B	Time TMU C	Time TMU Hand In Motion B
3/4 or less	2.0	2.0	2.0	1.7
1	2.5	2.9	3.4	2.3
2	3.6	4.6	5.2	2.9
3	4.9	5.7	6.7	3.6
4	6.1	6.9	8.0	4.3
5	7.3	8.0	9.2	5.0
6	8.1	8.9	10.3	5.7
7	8.9	9.7	11.1	6.5
8	9.7	10.6	11.8	7.2
9	10.5	11.5	12.7	7.9
10	11.3	12.2	13.5	8.6
12	12.9	13.4	15.2	10.0
14	14.4	14.6	16.9	11.4
16	16.0	15.8	18.7	12.8
18	17.6	17.0	20.4	14.2
20	19.2	18.2	22.1	15.6
22	20.8	19.4	23.8	17.0
24	22.4	20.6	25.5	18.4
26	24.0	21.8	27.3	19.8
28	25.5	23.1	29.0	21.2
30	27.1	24.3	30.7	22.7

Wt. Allowance Wt. (lb.) Up to	Factor	Constant TMU
2.5	1.00	0
7.5	1.06	2.2
12.5	1.11	3.9
17.5	1.17	5.6
22.5	1.22	7.4
27.5	1.28	9.1
32.5	1.33	10.8
37.5	1.39	12.5
42.5	1.44	14.3
47.5	1.50	16.0

CASE AND DESCRIPTION
A Move object to other hand or against stop.
B Move object to approximate or indefinite location.
C Move object to exact location.

TABLE IV—GRASP—G

Case	Time TMU	DESCRIPTION
1A	2.0	Pick Up Grasp—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than 1/2".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter 1/4" to 1/2".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than 1/4".
2	5.6	Regrasp.
3	5.6	Transfer Grasp.
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. 1/4" x 1/4" x 1/8" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than 1/4" x 1/4" x 1/8".
5	0	Contact, sliding or hook grasp.

TABLE V—POSITION*—P

CLASS OF FIT		Symmetry	Easy To Handle	Difficult To Handle
1—Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2—Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3—Exact	Heavy pressure required.	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage—1" or less.

FIGURE 5-2 PMTS SYNTHESISED TASK

METHODS ANALYSIS CHART No: ______

Department: ______ Section: ______

Operator's Name: B.A.T. Mann Taken by: R.O. Bin Date: ______

Operation: Remove Nut from Bearing

	Description - Left Hand	No.	L.H.	TMU	R.H.	NO.	Description - Right Hand
	Hold Bearing			23	GC30		Spanner
	" "			30	PC30		To Nut
	" "			14	A		Loosen
	" "			6	PA15		Over travel
	" "			11	PA30		Spanner aside
	" "			14	GB30		Hand to Nut
	" "			3	PA5		1st Turn
	" "			42	GB5	6	Unscrew
	" "			18	PA5	6	"
	" "			11	PA30		Nut Aside
				172	tmu		

FIGURE 5-3 EXTENT OF THE GOVAN WORKSTUDY DATA

DEPARTMENT	SECTION	TYPE OF WORK	Page No.	Code (B.Ms)
Steelwork	Fabrication	Plating		A
	Fabrication	Hand Burning		1A
	Fabrication	Hand Welding		C
	Fabrication	M/C Welding		1C
Steelwork	Preparation	All M/C		B
Steelwork	Berth	Erection		D
	Berth	Hand Welding		5D
Joinery	Ship	Various		E
	Shop	Various		F
Ironworks	Sheet Iron	Shop - Various		G
	Sheet Iron	Ship - Various		H
	Blacksmith	Shop - Various		I
M.I.D.	Shop	Various		L
	Ship	Various		M
Pipework	Shop	Various		N
	Ship	Pipe Installation		O
Electrical	Ship	Various		P
Paint	Ship	Various		R

FIGURE 5-4 INDEX OF STEELWORK SERIALS

DEPARTMENT:	SECTION:	TYPE OF WORK:	CODE:
Steelwork	Fabrication	Plating	A

CODE NO.	SERIAL DESCRIPTION	SERIAL NO.
A1	OBP up to 12"	SFP2 - 401
	Slab & OBP 12" shaped	SFP2- 403
	OBP & Slab Over 12" shaped	SFP2- 404
A2	OBP up to 12" manually	SFP2 - 405
A3	OBP & Slab Over 12"	SFP2 - 402
	OBP & Slab Over 12" manually	SFP2 - 406
	Flat Bar & Angle Bar 6"	SFP2 - 411
A4	Solid Round Bar up to 3" dia.	SFP2 - 421
	Solid Round Bar up to 3" dia. Shaped.	SFP2 - 422
A5	Flat Plates up to 1"	SFP3 - 401
	Flat plates, loose seams 1/4" up to 1"	SFP3 - 406
A6	Shaped plates 1/4" up to 1"	SFP3 - 411
	Corrugated bulkheads up to ½"	SFP3 - 421
A7	Swedge bulkheads up to ½"	SFP3 - 422
A8	Brackets, girders etc. "T" fashion	SFP4- 401
	Brackets, girders etc. "T" fashion Manually positioned.	SFP4 - 403

FIGURE 5-5 TYPICAL WORK ELEMENTS

ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
ELEMENT 6 - COLLECT SECTION SUPPORTS - (SOLDIERS) : Collect box and walk approximately 200 feet to where section supports are stored. Load 15 pairs of supports into box, carry box 200 feet back to job and deposit supports.	2.64	Per Job
ELEMENT 7 - ERECT SECTION SUPPORTS : Position and tack one pair of supports and move to next position.	1.14	Per Section
ELEMENT 8 - POSITION SECTIONS (OVER 8 FEET LONG) BY CRANE : Summon crane. Attach grab or jigs to section. Lift to position (approx. 25 feet) between supports. Remove grab or jigs and return to next section.	4.44	Per Section
ELEMENT 9 - LAYOUT SECTIONS (UP TO 8 FEET LONG) MANUALLY : Lift section, carry to position (approx. 25 feet) deposit and return for next section.	0.66	Per Section
ELEMENT 10 - COLLECT FAIRING AIDS : Collect box, walk approx. 200 feet to where fairing aids are stored. Load 15 fairing aids (6 bridges, 4 stoppers and 5 stays) into box. Carry box 200 feet to job and deposit fairing aids.	2.64	Per 27'-0" Of Section

FIGURE 5-6 ELEMENT GROUPINGS BY FREQUENCY

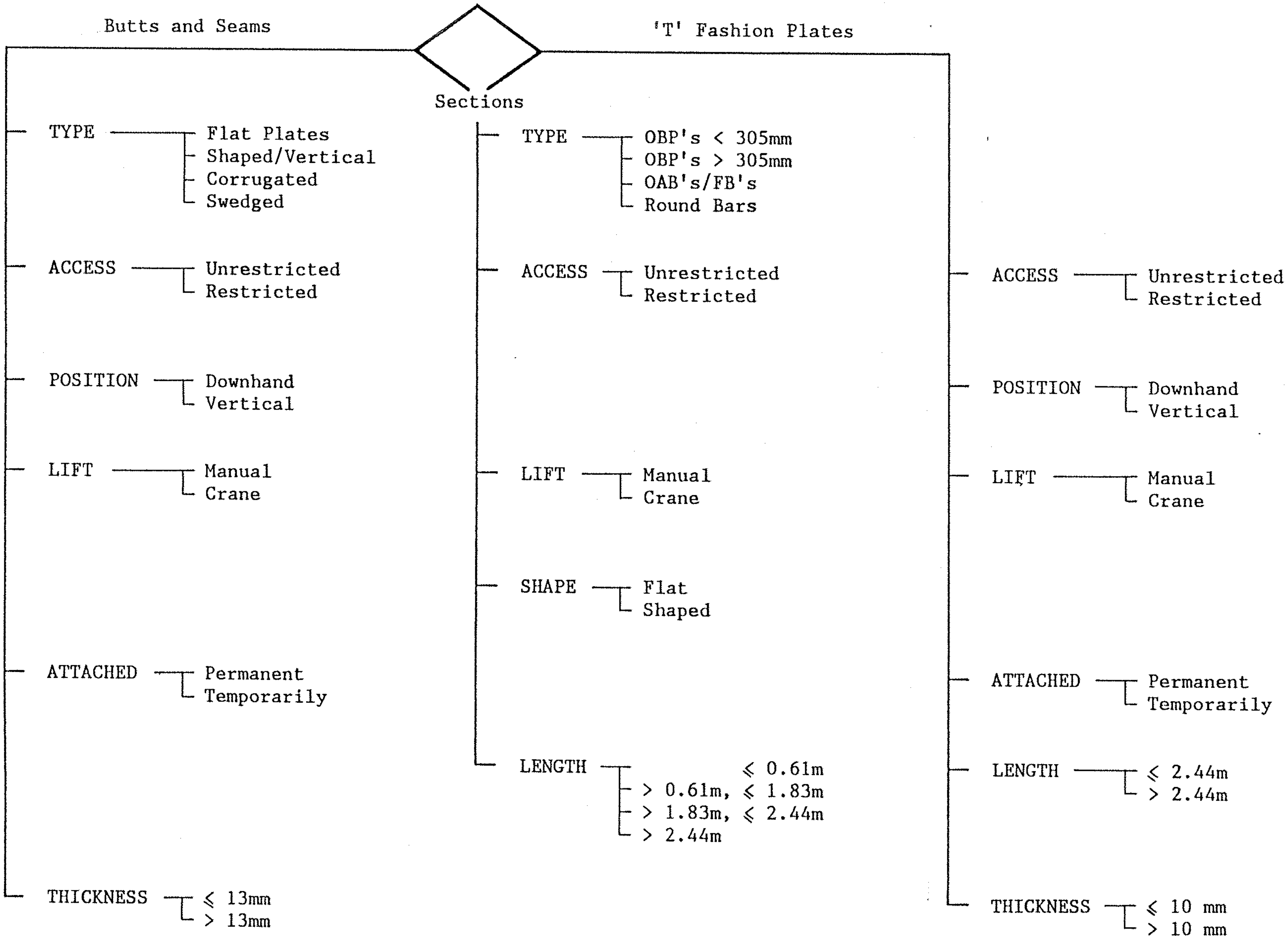
JOB CONSTANT (RESTRICTED)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
1	Receive Instructions	4.98	Per Job
2	Collect and Layout Tools and Equipment.	3.60	Per Job
3	Make Initial Inspection	3.48	Per Job
4	Collect and Layout Gear and Replace.	1.26	Per Job
5	Transport Sections By Crane.	4.80	Per Job
6	Collect Section Supports (Soldiers)	2.64	Per Job
12	Make Final Inspection	3.48	Per Job
	Total-Job Constant	24.24	Per Job

SECTION CONSTANT (OVER 8'-0" LONG)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
7	Erect Section Supports	1.14	Per Section.
8	Position Sections (Over 8'-0" Long) By Crane.	4.44	Per Section
10	Collect Fairing Aids	2.64	Per Section
	Total-Section Constant	8.22	Per Section.

FIGURE 5-7 COMPOSITE TABLE OF STANDARD MANHOURS

* TIMES ARE IN MINUTES *		FAIR & TACK O.B.P's UP TO 305 MANUALLY (UNRESTRICTED)	FAIR & TACK O.B.P's UP TO 305 MANUALLY (RESTRICTED).
JOB CONSTANT UP TO 1830mm. LONG.	PER JOB	12.21	17.46.
JOB CONSTANT OVER 1830mm UP TO 2440mm.	PER JOB	15.49	21.09.
SECTION CONSTANT UP TO 610 mm.	PER SECT.	0.63	0.69.
SECTION CONSTANT. 610mm UP TO 1830 mm.	PER SECT	1.55	1.71.
SECTION CONSTANT. 1830mm. UP TO 2440mm.	PER SECT	2.52	2.76.
FAIR AND TACK UP TO 610mm.	PER MTR	8.59	9.48.
FAIR AND TACK 610mm UP TO 1830mm.	PER MTR.	5.48	6.04
FAIR AND TACK 1830mm. UP TO 2440 mm.	PER MTR.	5.28	5.81.

FIGURE 5-8 PRODUCTION PARAMETERS INFLUENCING WORKSTUDY FAIRING DATA



6. THE RATIONAL COMPUTER BASED APPROACH

As discussed in Chapter 3, the multi-faceted nature of ship design and production makes the advantages of a particular layout or structural arrangement difficult to quantify. Often decisions are left soley to the designers' experience and result in "I think" or "I feel" choices. The project for BS produced a computer based approach to avoid these problems. Typical design/production interactions are shown in figure 6-1.

6.1 Structural Producability

Although in the work funded by BS/SERC total production cost was considered to be an adequate measure of structural producability, other parameters are needed for comparison eg. weight, number of pieceparts etc.

6.2 The Quantification of the Production Criteria

In order to quantify the criteria outlined above it was necessary to consider the following:

1. The equipment and facilities used in the production procedure.

2. Production and shipyard standards.

3. The construction sequence adopted in fabricating a structure.

6.3 Design Information

The method had to utilise the design information available. Since this increases as the design progresses, in order to obtain an accurate estimate of construction costs it is necessary to have completed the design to a fairly advanced level. This, however, suggests that time and money will have already been spent on the preparation of drawings and calculations. A change in the structural arrangement at this stage would create expensive re-work. Alternatively, attempting to determine costs accurately at an earlier stage is not possible. Therefore, the optimum point in the design cycle was considered to be the time of the midship section calculations. The programs are for use at this stage, at which time the following should be known:

general layout

scantlings of structural members.

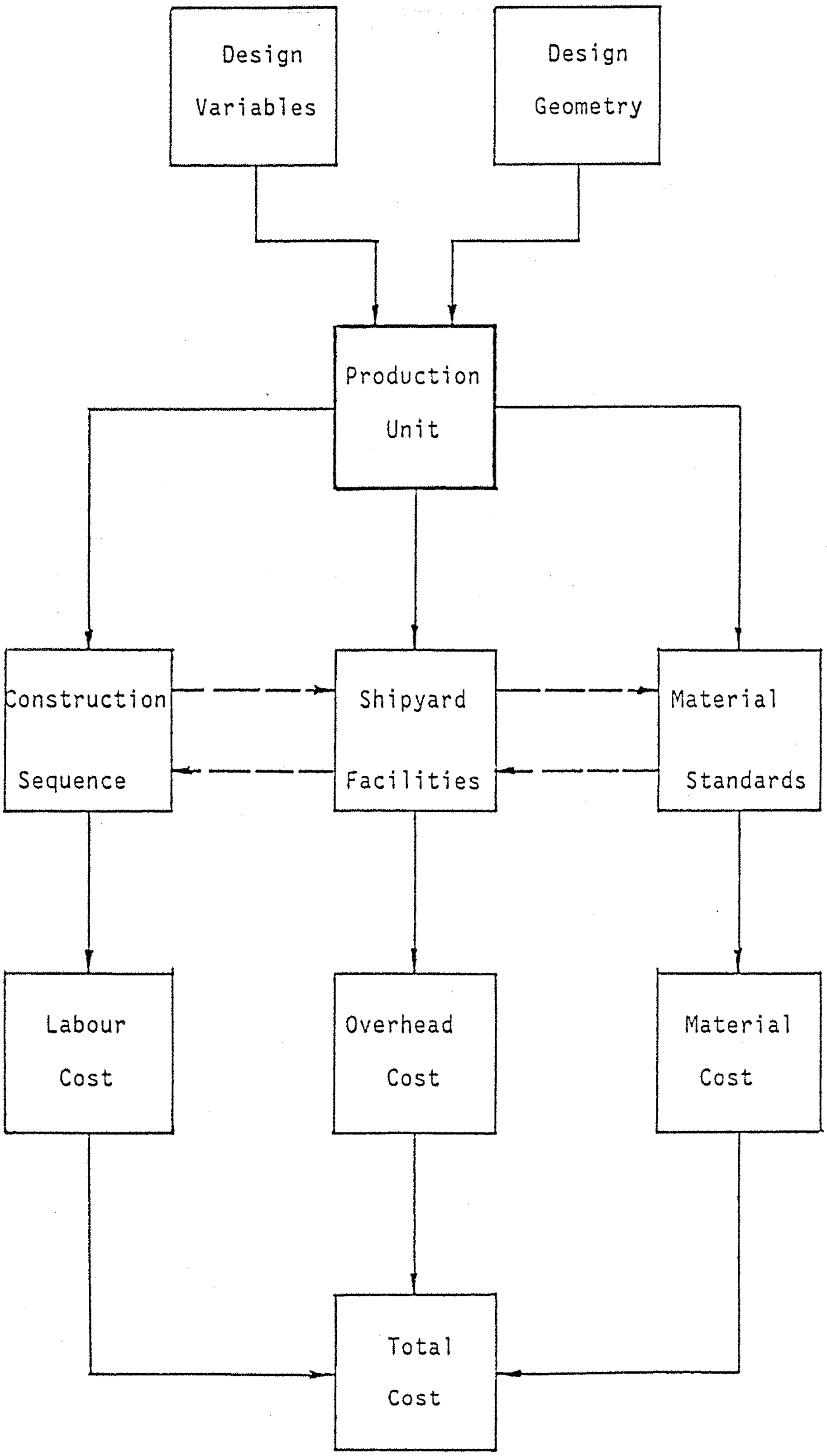
These enable the production parameters to be calculated.

6.4 Design/Production Interaction

Since design for production is an attempt to compromise performance and production constraints, there needs to be a link between the two. This link is known as the production unit as originally described in Reference 16. At the midship design stage it can be considered as a fabricated module or unit.

FIGURE 6-1 DESIGN/PRODUCTION INTERACTION

Source: Ref. 22



7. THE COMPUTER MODEL

Details of the computer model for calculating production costs and parameters, as developed during the BS project, are outlined in this chapter. The flow diagrams are contained in figures 7-1 and 7-2. Whilst brief details of the programs are contained in figure 7-3, they are described more fully in Chapters 9 and 10.

7.1 Product Work Breakdown

An appropriate vehicle for determining the producability of a design is the production unit based on the midship section details. The mathematical model had to break the production unit down into discrete elements which would enable the calculation of production parameters and, hence, work content and production costs. It was also necessary to model the process of the berth erection of the units into "blocks". An hierarchical product work breakdown was developed for use on the computer (figure 7-4).

Each unit comprises modules eg. deck, bulkhead and side shell panels as detailed in figure 7-4. These are made up of structural elements eg. plates, longitudinals and transverses. Any number of units can be erected to form a block.

7.2 The Production Unit

The task of the programs is to calculate the cost of production which includes labour, material and overhead costs of design alternatives. To accomplish this the algorithms and programs are divided into the following stages:

1. Input of the unit layout.

2. Input of the scantlings.

3. Calculation of the production parameters.

4. Calculation of standard manhours.

5. Calculation of cost data.

Additionally, information pertaining to manning, productivity and yard standards has to be input at an early stage. Stages 3, 4 and 5 are repeated for the block erection process.

The first step is to use the general characteristics of the unit eg. length, width, number of decks (figure 7-5) as the layout input. The programs use these as the basis for the input prompts for the scantlings data.

The number off, scantlings and weld preparation details are input for the structural elements which make up the appropriate modules. The calculations in the later programs are completed for each type of element.

The production parameters determined for the elements during the next phase include joint length, number of pieceparts, weight and surface area and codes pertaining to length, depth and shape. This data is held on a random access data file with each record representing a structural element.

These records are used to calculate the standard manhours for the fabrication process ie. fairing and welding. The times are sub-divided into those for in-plane and 'T' fashion (fillet) work.

Before summing the costs associated with labour, materials and overheads, the standard manhours have to be corrected for manning and productivity factors. Overhead costs are derived as a percentage of the labour figure. Therefore, either the total production cost or its components can be used as a base for comparing design options. Alternatively, the analysis of another parameter eg. weight might be thought beneficial.

7.3 The Philosophy for Block Erection

Figure 7-6 shows an arrangement of four deck/side shell units. During the design phase these will have been given identification numbers eg. 501, 502, 503, 504. The ".1" indicates which structural alternative which is being considered. The erected block is given a further designation number, in this case 900.

Since each inter-unit joint must be analysed separately, they are given identifiers eg. 900.10, 900.11. The individual elements which comprise the joint eg. plate butts and seams, connections between longitudinals, have their production parameters calculated by the block erection programs.

The costs and production details for the erected block can be analysed by summing the details for the appropriate units and inter-unit joints.

FIGURE 7-1 FLOW DIAGRAM FOR UNIT CALCULATIONS

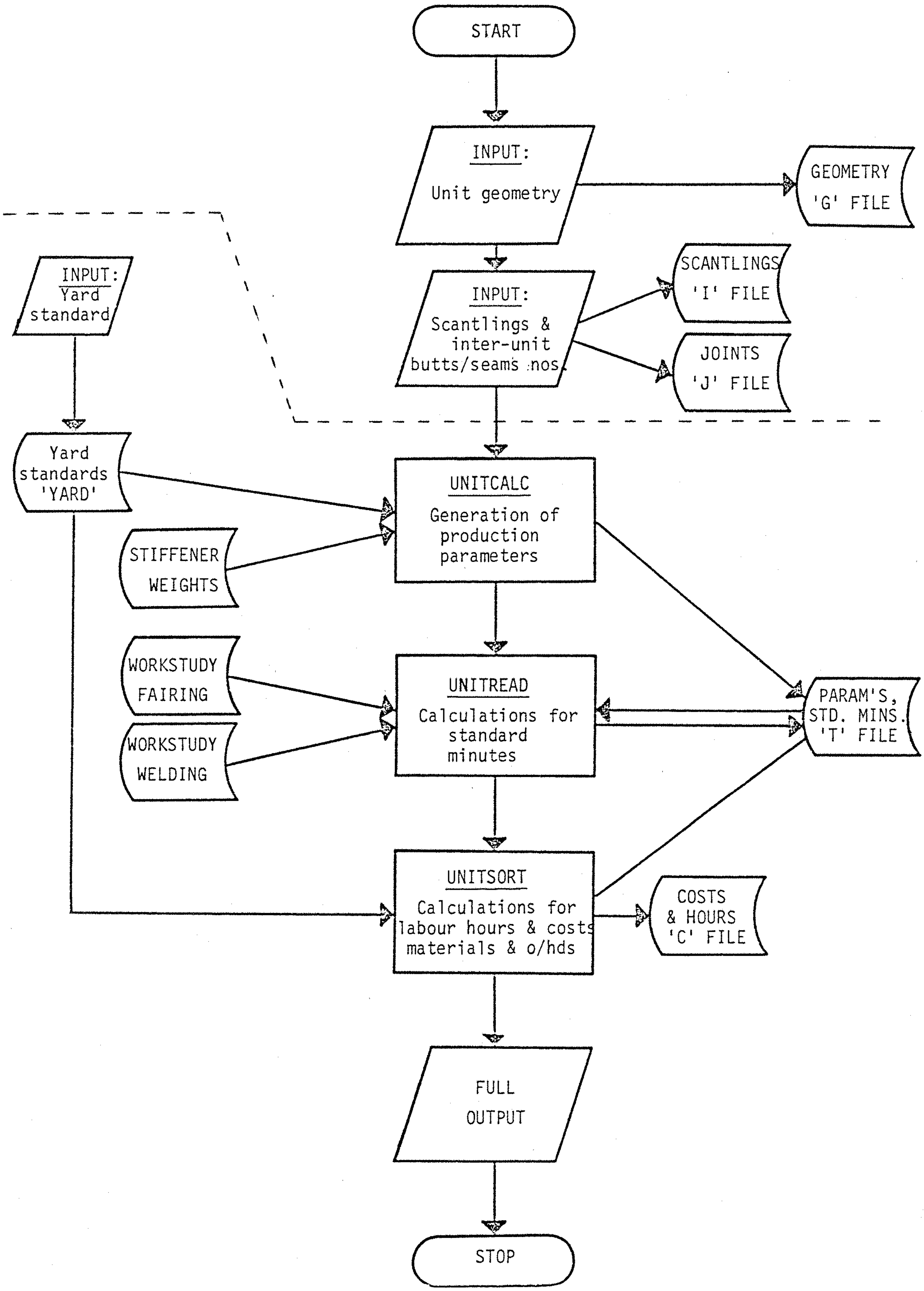


FIGURE 7-2 FLOW DIAGRAM FOR BLOCK ERECTION CALCULATIONS

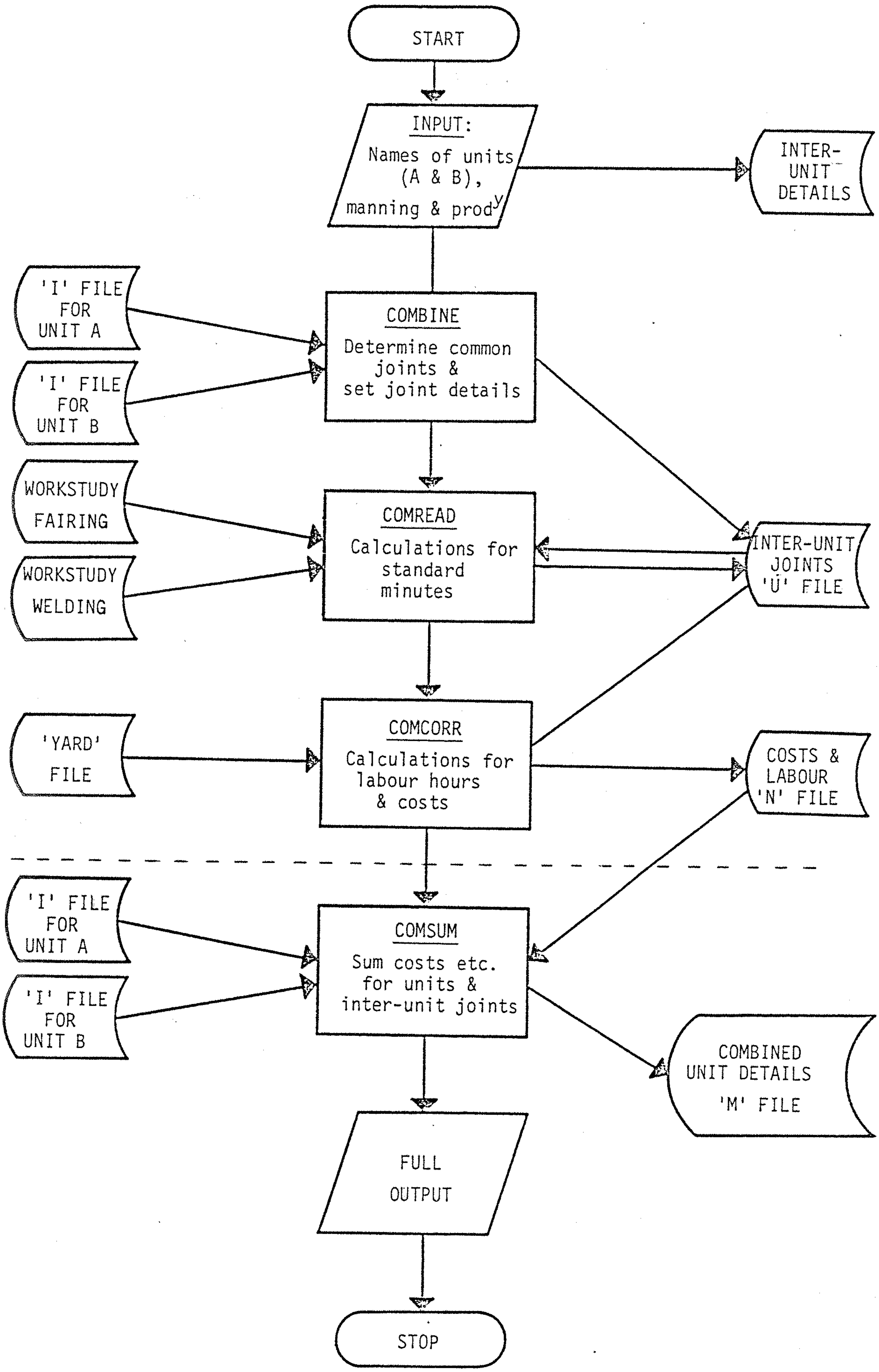


FIGURE 7-3 PROGRAM DETAILS

NAME	SIZE	
DATA INPUT		
Yardstds	7385	Input of yard data e.g. wages, overhead rates, standard material sizes.
Layout	4469	Geometrical details of the unit.
Scantlin	37792	Scantlings of the unit.
UNITS		
Unitcalc	48046	Generation of production parameters.
Unitread	13071	Determination of standard times.
Unitsort	28754	Calculation of manhours and costs.
INTER-UNIT JOINTS		
Combine	38381	Generation of production parameters.
Comread	8573	Determination of standard times.
Comcorr	15647	Calculations of manhours and costs
COMBINATIONS/BLOCKS		
Comsum	35753	Summation of appropriate units and inter-unit joints.

FIGURE 7-4 PRODUCT WORK BREAKDOWN

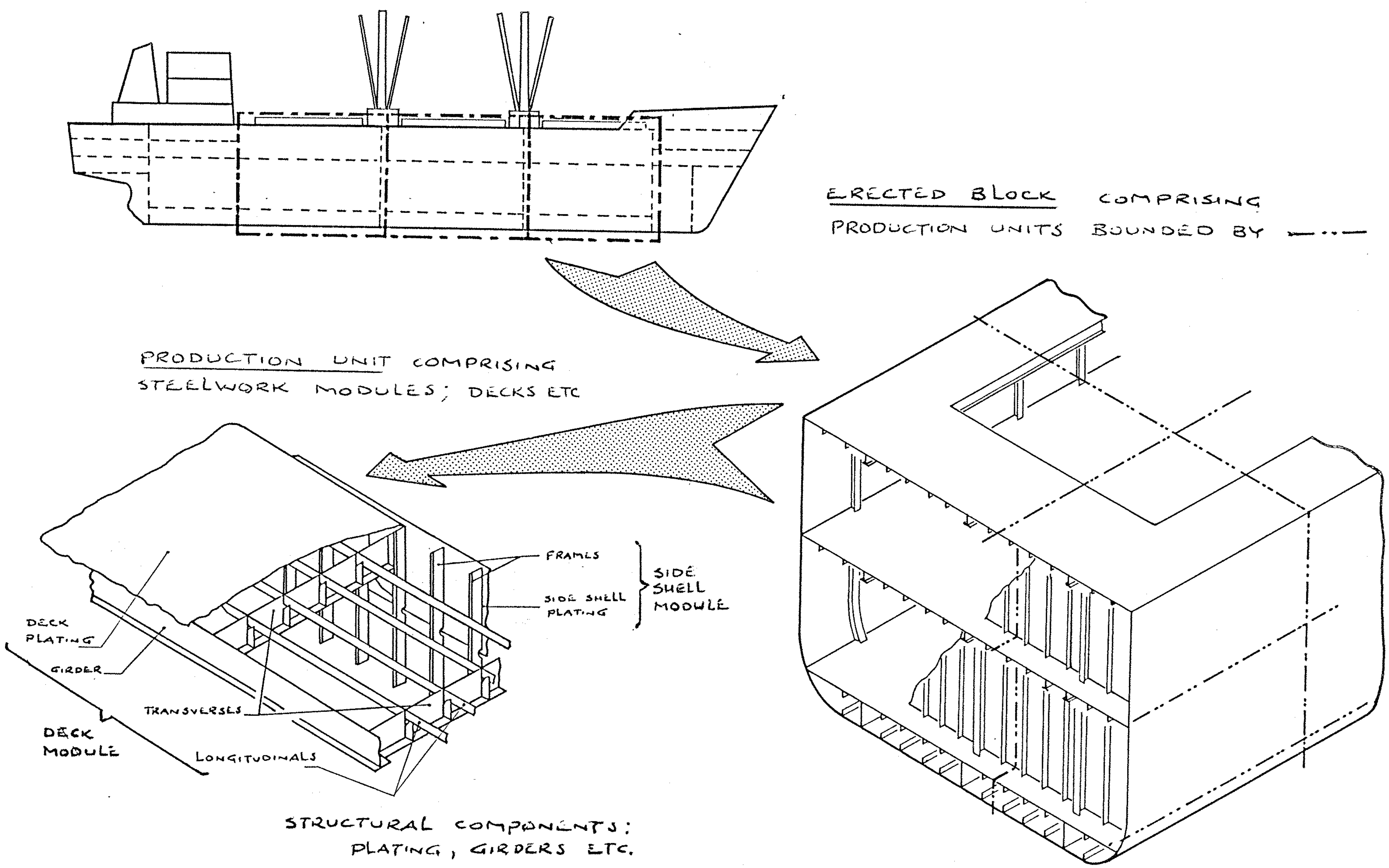


FIGURE 7-5 UNIT LAYOUT

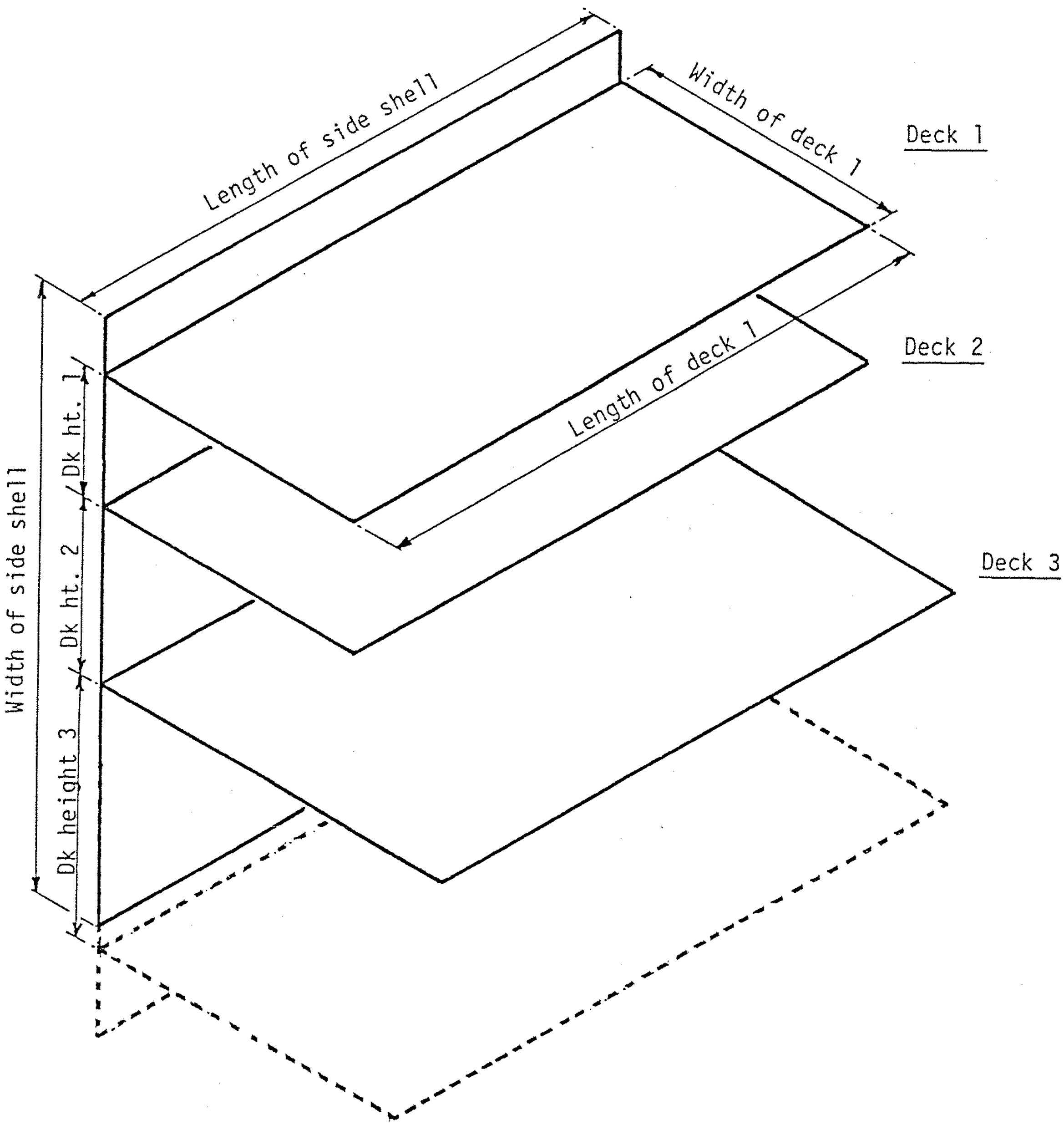
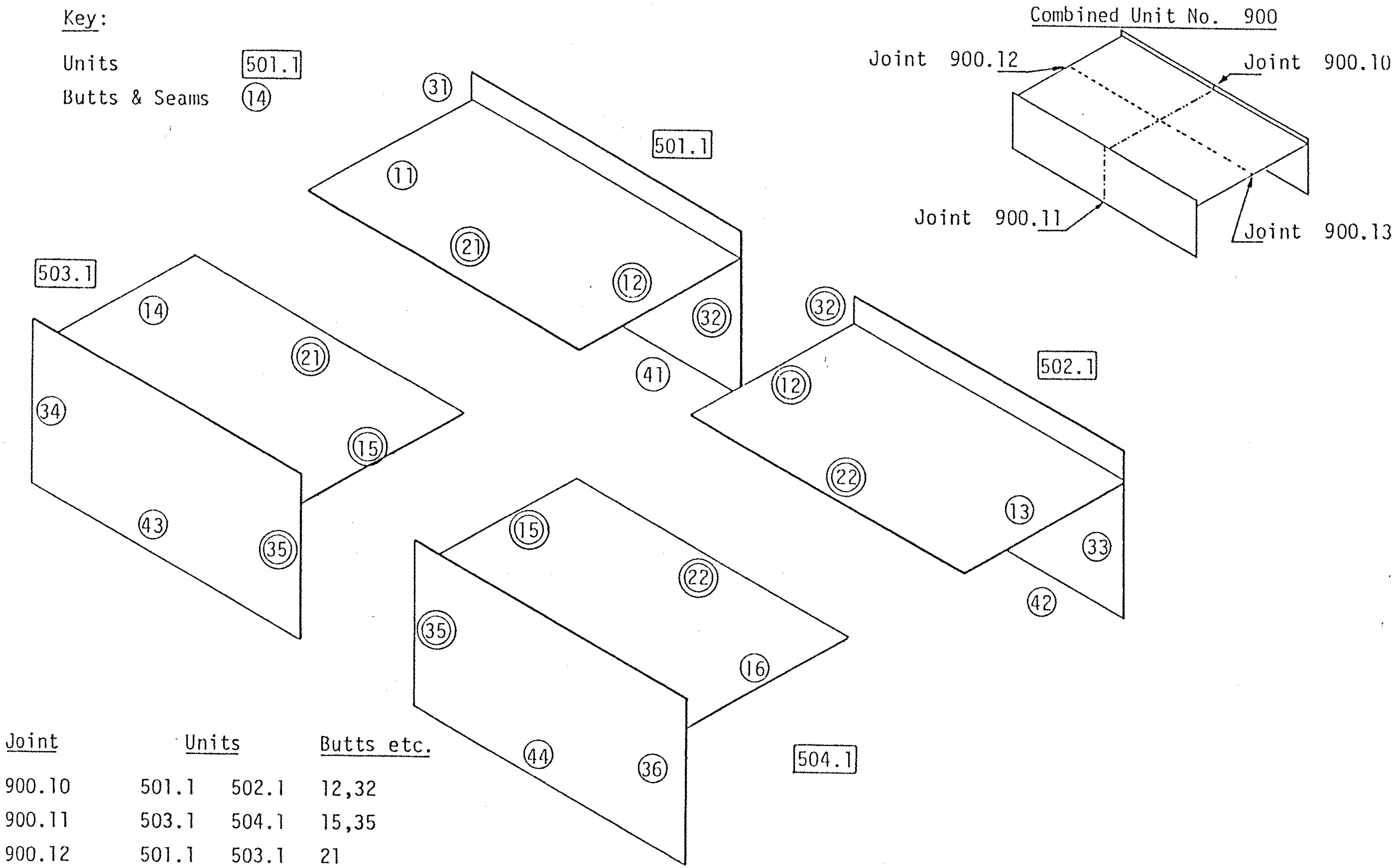


FIGURE 7-6 BLOCK ERECTION LOGIC



Joint	Units		Butts etc.
900.10	501.1	502.1	12,32
900.11	503.1	504.1	15,35
900.12	501.1	503.1	21
900.13	502.1	504.1	22

8. HARDWARE AND SOFTWARE

This chapter outlines the reasons for developing the programs on a microcomputer and discusses the choice of machine. A general overview of the system is included as are details of the programming language.

8.1 Hardware Choice

VDU terminals to mainframe computers have been a familiar part of the drawing/design office environment for a number of years. Unfortunately, they are often "overworked" leading to department members "queuing" for their use only to experience slow response times due to the heavy workload the central processor is under.

The advent of powerful microcomputers has led to some of the tasks previously performed by the mainframe now being run on these smaller machines. There are also extensive ranges of proprietary software which produce "reports" similar to those required by management services departments. These reasons combined with the policies of many companies of reducing overheads eg. reducing the size of computing/data processing departments, has led to a greater reliance on microcomputers.

Consequently, it was decided that since the design for production programs developed during the BS project were for industry, they should be for use on a microcomputer. Before a final choice of machine was made, two areas of compatibility were examined:

1. Although mainframe computers were not a direct part of the system included in this project, they might well have held information which could have been useful in the microcomputer programs. For example, details generated by CAD programs. Therefore, the choice of machine had some dependence on the mainframe system in the Company in which the investigation was undertaken.

2. The chosen micro also had to be directly compatible with the small machines already in use in the organisation.

The machine finally chosen was an IBM-XT Personal Computer. Although it is slower than some of the other micros considered, it did meet the compatibility requirements. Also, it had the advantage of an integral hard disk. This reduced a) the time for accessing datafiles and b) the role of the relatively delicate floppy disks to one of back-up.

8.2 Programming Language

Despite the use of a microcomputer, a number of programming languages could have been used, eg. Basic, Fortran, Pascal. Additionally, commercial software packages such as "Dbase" and "Lotus 1-2-3" were available. After careful consideration and "testing", Microsoft Advanced Basic (BASICA) was chosen for the following reasons.

Advantages:

1. Convenient and quick to use ie. no need for long compilation times which are necessary for Fortran.

2. Reasonably high level language.

3. Use of colours eg. highlighting data input.

4. Use of graphics.

Disadvantages:

1. Not as powerful or as fast as Fortran.

2. Restricted to 64k bytes random access memory (RAM).

Solutions to disadvantages:

Commercial software is available which can compress basic programs by 40% to 50% by removing "rem" statements and reducing long variable names etc. Consequently, the programs run faster. Also, the useable RAM can be increased through machine language sub-routines.

Although the use of Fortran was ruled out due to the long and tedious compilation process, a Basic compiler was used after program development was complete. Very few changes were necessary to the interpreted basic programs to enable compilation, and subsequent run times were on average 40% of those previously.

8.3 Datafiles

There are considerable amounts of data, both input and program generated, which must be stored in the computer. The datafiles which hold it are of two types; sequential and random access more details of which are given in Appendix D. The differences are outlined below.

8.3.1 Sequential Files

Sequential datafiles are accessed by reading them into the machine's memory as a whole. Therefore, they are most suited to the storage of limited quantities of information all of which, preferably, needs to be accessed at the same time. If large quantities of unnecessary data was held on such files, there would be ineffeciences due to:

1. The time taken to read and write data from and to the file.

2. The amount of working memory needed to hold the data in the program.

Consequently, these files have only been used for holding the input data eg. yard standards, unit layout, scantlings and inter-unit butt/seam details.

8.3.2 Random Access Files

As the name suggests, discrete pieces of information can be accessed from the file without interrogating it in total. Therefore, the time taken to read in the appropriate data is much reduced as is the amount of storage needed in the working memory.

Each piece of data is stored in a field, a number of which make up a record. The length of the fields and records must be defined in the program, and are constant throughout the file. Since the records are referred to by unique numbers, it is possible to access one part of the file at a time.

Random access files have been used in the programs for the storage of data pertaining to structural elements. They are also used to store reference data which is accessed frequently during the calculation routines in the programs eg. stiffener weight and workstudy composite tables.

FIGURE 8-1 DETAILS OF DATAFILES

	PREFIX	COMPLETE FILENAME	DETAILS OF FILE DATA	FILE TYPE
FREQUENTLY ACCESSED		STIFFWT.RAN	Weights of rolled sections	RANDOM ACCESS
		WKSTDYF.RAN	Workstudy standard times for fairing processes	RAN
		WKSTDYW.RAN	Work study, standard times for welding processes	RAN
INPUT DATA	YARD	+ 1 - 99	Yard standards	SEQUENTIAL
	G	+ Ship name + unit no.	General layout of unit	SEQ
	I	+ Ship name + unit no. + "." + Alt've no.	Scantlings of unit	SEQ
	J	+ Ship name + unit no. + "." + Alt've no.	Inter-unit butts & seams details for unit	SEQ
CALCULATED DATA	T	+ Ship name + unit no. + "." + Alt've no	Production parameters & std minutes for unit	RAN
	C	+ Ship name + unit no. + "." + Alt've no.	Hours and costs for unit	RAN
	U	+ Ship name + combination no. + "." + i/u joint no.	Production parameters & std minutes for i/u joint	RAN
	N	+ Ship name + combination no. + "." + i/u joint no.	Hours and costs for i/u joint	RAN
	M	+ Ship name + combination no.	Totals for hours and costs for combination	RAN

9. DATA INPUT AND UNIT CALCULATION PROGRAMS

The details of the programs which are used in calculations pertaining to production units are given in this chapter. Those pertinent to the combination of units into blocks are detailed in Chapter 10.

9.1 "Yardstds"

The number of pieceparts and, hence, joint length and number of welds which make up a unit are dependent on the size of the plates and sections used in the yard. The manhours and costs are determined by applying the relevant wage and overhead rates to the standard manhour figures. "Yardstds" enables this standard information to be entered from the keyboard and stored on a sequential datafile with the prefix "YARD" and a number 1 to 99 eg. "YARD2".

9.2 "Layout"

A production unit is initially defined by its dimensions eg. length of side shell, height of side shell etc. (figure 9-1). This information is input during the "Layout" program prior to storage as a sequential file. The filename prefix is "G", whilst the complete name comprises:

"G" + Ship name + Unit no.

9.3 "Scantlin"

The information stored in the "G" file is accessed in order to enable the "Scantlin" program to display the correct prompts for the input of structural data. The scantlings are taken from the calculations, or drawings for the midship structure (figure 9-2), or the appropriate frame section.

The details, shown in figures 9-3 and 9-4, include:

Frames Deep frames Longitudinals Girders	} No. off, scantlings

Plate thicknesses
Beam knee connection types (figure 9-5)
Longitudinal/transverse connection types.

Weld preparation data must also be input at this juncture in the form of codes as shown in figure 9-6.

The longest edges of the individual plates are orientated with the length of the panel whilst the stiffening can be either lengthwise or widthwise to the panel. Therefore, all combinations of plate and stiffener alignment can be accommodated. (figure 9-7).

The following maximum values must, however, be observed:

Side shell - no. of plating groups 4

Decks - no. off 4

- no. of plating groups per dk .. 4

- no. of longl groups per dk 4

- no. of girder groups per dk ... 3

The data for each production unit is held on a sequential file named:

"I" + Ship name + Unit no. + "." + Alternative no.

This is the standard format of the file names created by the programs. They are subsequently referred to in this thesis by their prefix only.

In order to reduce the quantity of information input at this stage for similar units, the main menu enables a copy facility to be invoked. For example, an existing set of data can be used as a basis for another structural unit. Modifications are made through a menu system contained in the program "Scantchg" which is automatically accessed when required. The menu's also permit individual items of data held on a unit's "I" file to be changed easily and quickly prior to recalculating the production parameters etc.

"Scantlin" is also used for the input of data pertaining to inter-unit weld preparations for the appropriate plates, longitudinals etc. This data is held on the "J" file for the unit.

A complete list of the input data is given in Appendix E.

9.4 "Unitcalc"

The first process the input data undergoes is the generation of production details.

The types of information calculated at this stage are given below:

Plates (figure 9-8)

- Number of plates, full and cut
- Number of butts and seams
- Joint lengths of butts and seams
- Number and lengths of burns
- Weight
- Surface area

Stiffening (figure 9-9)

- Number of stiffeners (primary and secondary)
- Number of welds - stiffeners to plates
- Joint lengths of welds - stiffeners to plates

- Number of pieceparts per stiffener
- Number of piecepart welds per stiffener
- Joint length of piecepart welds

- Number of connections - primary to secondary stiffeners
- Joint length of connections
- Number and length of burns
- Weight
- Surface area

These are calculated for each structural element contained in the unit as given in figure 9-10. For example, deck plate butts, deck plate seams, transverse webs, transverse flanges.

"G" and "I" files are accessed prior to these calculations which use the standard plate and section size data held on the "YARD" file selected by the designer. The weight of rolled stiffeners are determined from the stiffener weight random access datafile "STIFFWT.RAN". For other structural elements and rolled stiffeners not held on this file, calculation routines give the weight details.

The generated data is stored on a random access file prefixed "T" (figure 9-11). Each record represents a different structural element as shown in figure 9-10 and discussed in Chapter 8.

9.5 "Unitread"

The production details generated in "Unitcalc" are used as the basis for calculating the manhours and costs of production alternatives. The initial task is to use the workstudy data to determine the standard hours necessary for fabrication ie. fairing and welding processes.

The "T" file is accessed and each record checked for data. If data exists the workstudy datafiles are interrogated for the correct record to match the production details in the "T" file record. Typically these details are:

Material type
shape
length
thickness

Working position
restrictions

As described in Chapter 5, the standard time for each process comprises:

Job constant
+ plate/section constant
+ rate

as described in Chapter 5. This program sums the constants and rates for each record (structural element) prior to four new fields of data being written to the "T" file. These represent the standard minutes for:

Fillet arrangement	-	fairing
		welding
In-plane arrangement	-	fairing
		welding

Figure 9-12 shows a typical "T" file after being processed in "Unitread".

9.6 "Unitsort"

Productivity, wage, material and overhead recovery rates have a bearing on the overall cost of a structural alternative and are taken into account in this program. The records in the "T" file which hold data are extracted and the standard times corrected for:

1. manning

and 2. productivity

prior to the application of wage rates etc. (figures 9-13 to 9-15). The material weight data is used to determine material cost (figure 9-16). The record values are summed to give plate totals and section totals from which the overhead and preparation costs are determined.

Although it was hoped to use further workstudy data to calculate the preparation costs, this has not been possible and instead regression techniques have been used. Campsey and Gedling [6] produced equations of preparation manhours against the number of plates and sections ordered. After contacting the authors of this work, a new line was put through the data:

Preparation manhours = 3.402 x No. of plates and sections ordered

Discussions with the shipyard suggested:

no. of plts and sections ordered = 0.75 x the total number of pieceparts.

The manhour and cost data for each unit is written to a random access file with the filename prefix "C". The record numbers match those in the "T" file and hold the data shown in figure 9-9. Additionally, the total cost and main production details are also held.

The type of output from this program can be selected. A summary (figure 9-16) gives:

1. Details of the "YARD" file used.

2. Productivity and manning data used.

3. Production details - no. of pieceparts
   - In-plane and fillet joints; lengths, no. off
   - burn lengths, no. off
   - weight and surface area for plates, sections and total.

4. Cost summary for - labour (preparation and fabrication)
- materials (plates and sections)
- overheads (prep'n and fabrication)
- total

A fuller output (figures 9-13 to 9-15) is available which gives the intermediate figures for:

1. Manhours corrected for manning.

2. Manhours corrected for productivity.

3. Labour costs.

These are generated for each component in terms of

fairing processes - in-plane and 'T' fashion processes, skilled and unskilled labour.

welding processes - in-plane and fillet welds, skilled and unskilled labour

Also printed are the costs attributable to each component in terms of:

1. Materials - sections, plates, total.

2. Overheads - fairing, welding, total.

At this stage, unit fabrication, it is assumed there are no erection processes or costs. These are covered in the programs for block erection.

FIGURE 9-1 UNIT LAYOUT

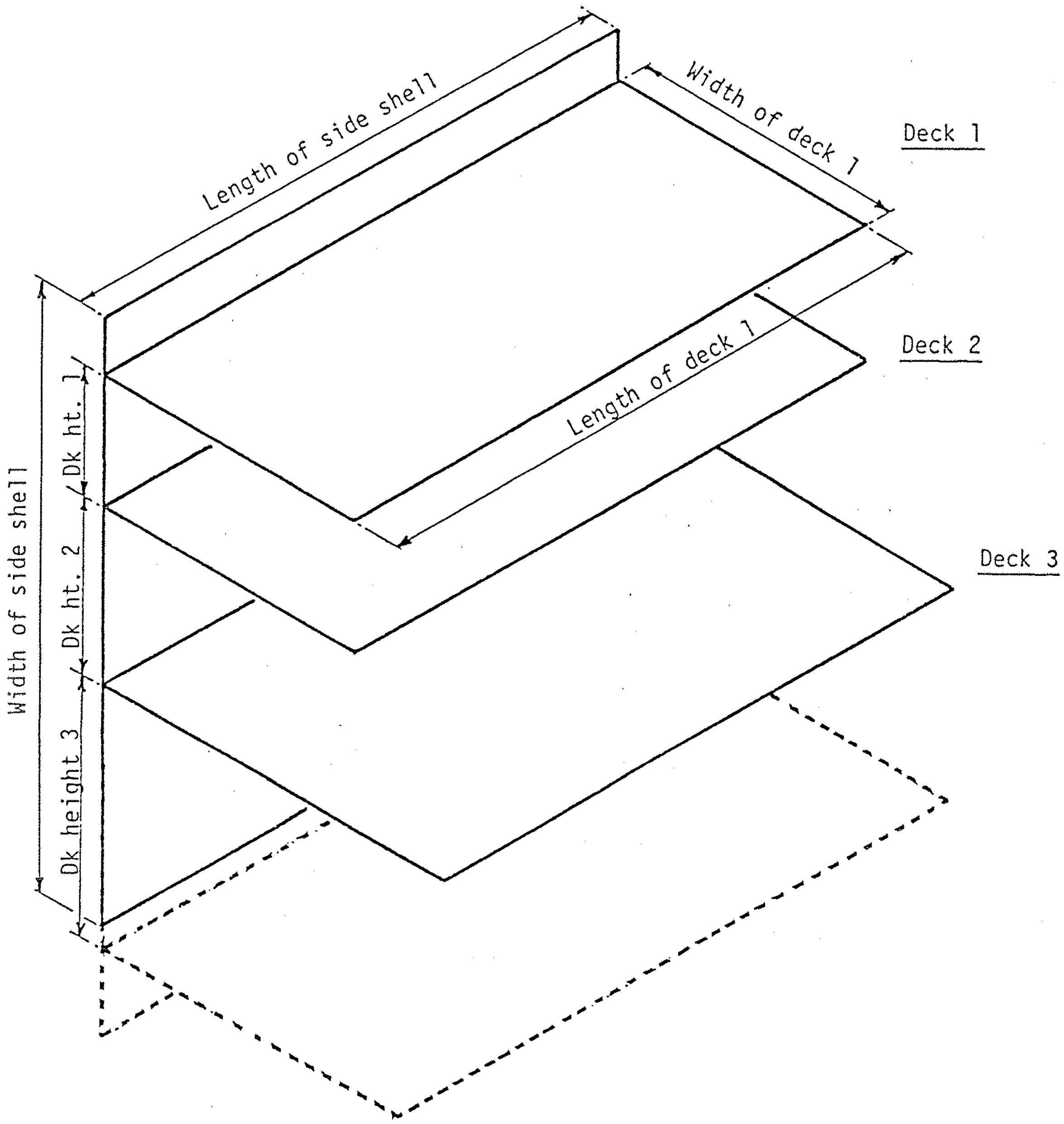


FIGURE 9-2 MIDSHIP SECTION DRAWING

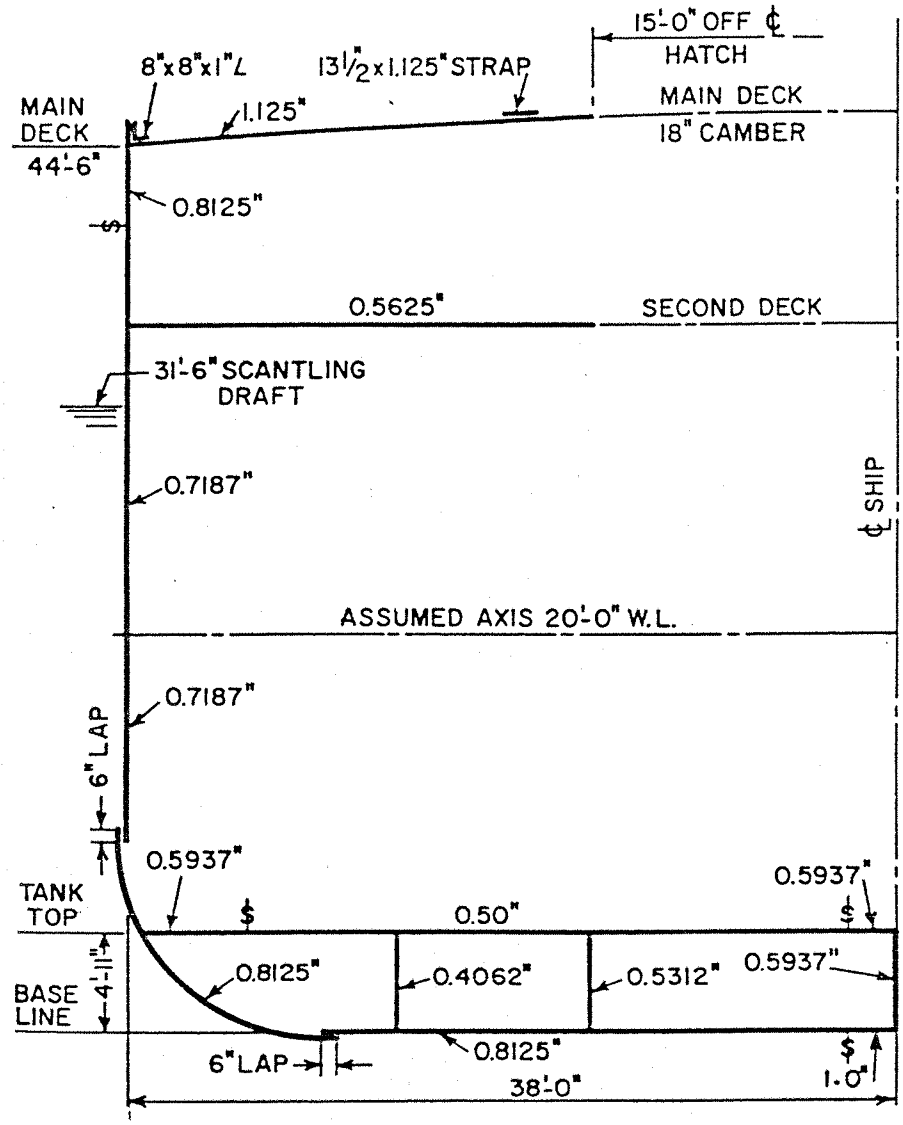


FIGURE 9-3 SCANTLINGS ARRANGEMENT OF SIDE SHELL

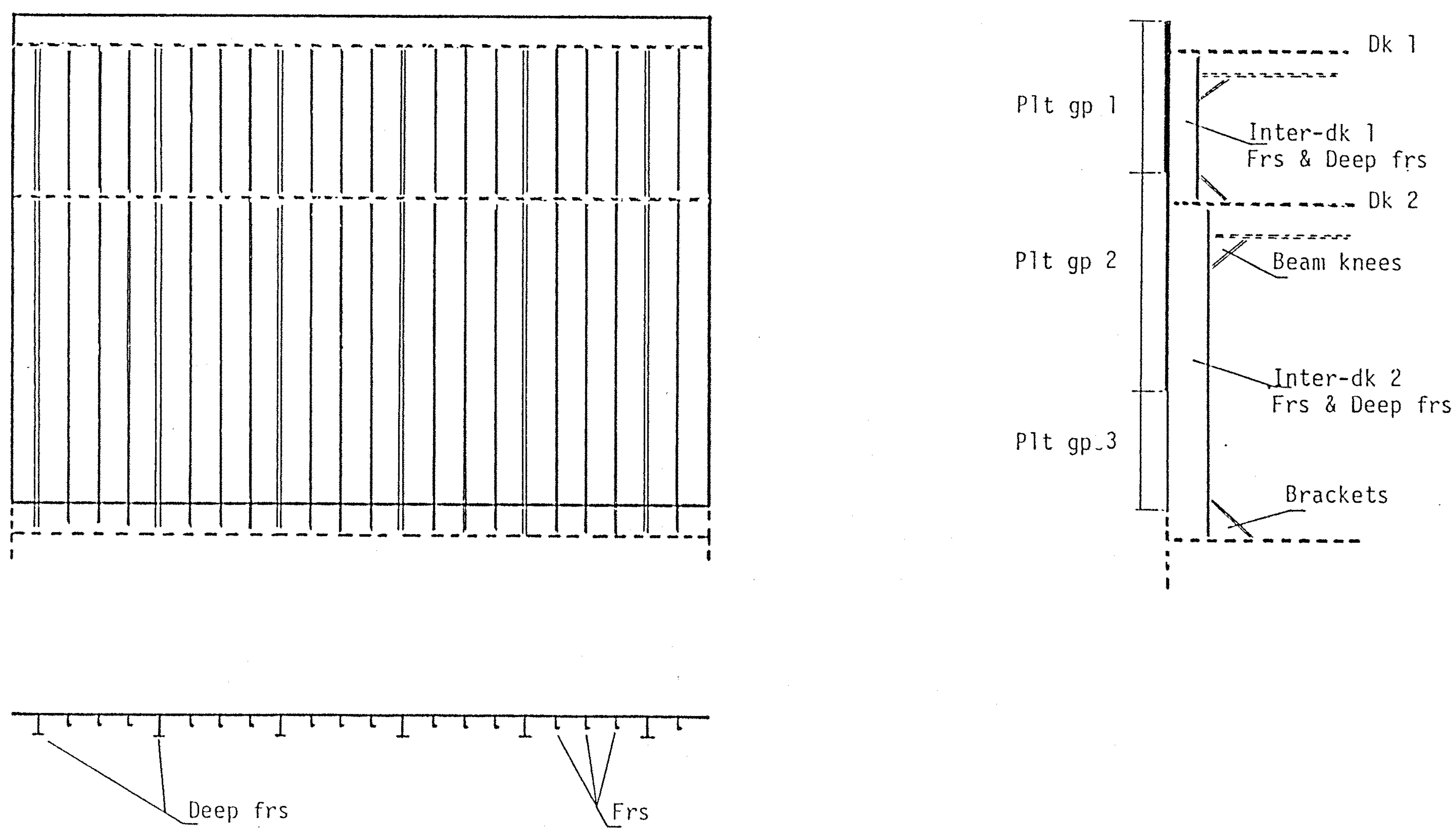


FIGURE 9-4 SCANTLINGS ARRANGEMENT OF DECK

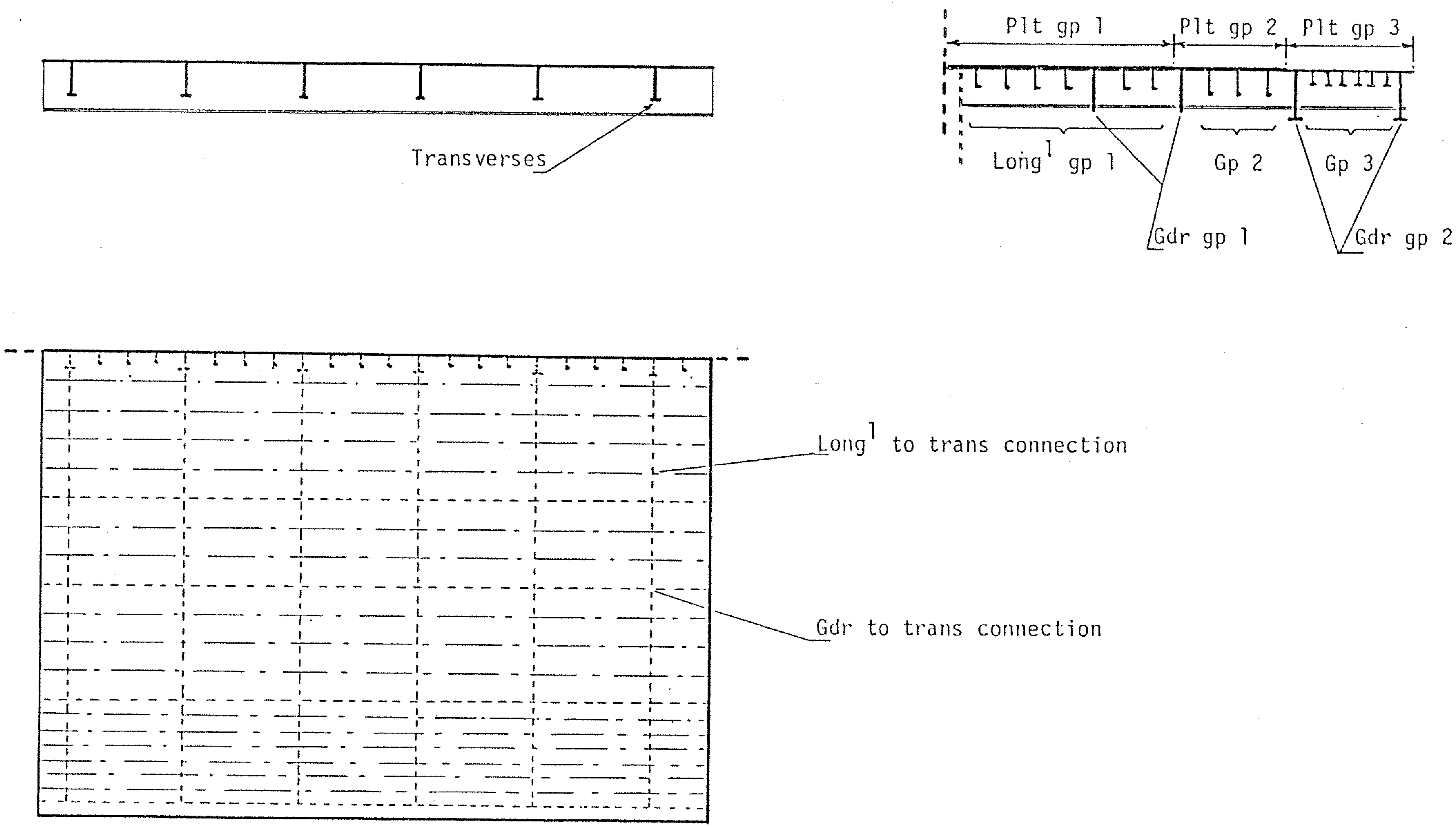


FIGURE 9-5 BEAM KNEE AND BRACKET TYPES

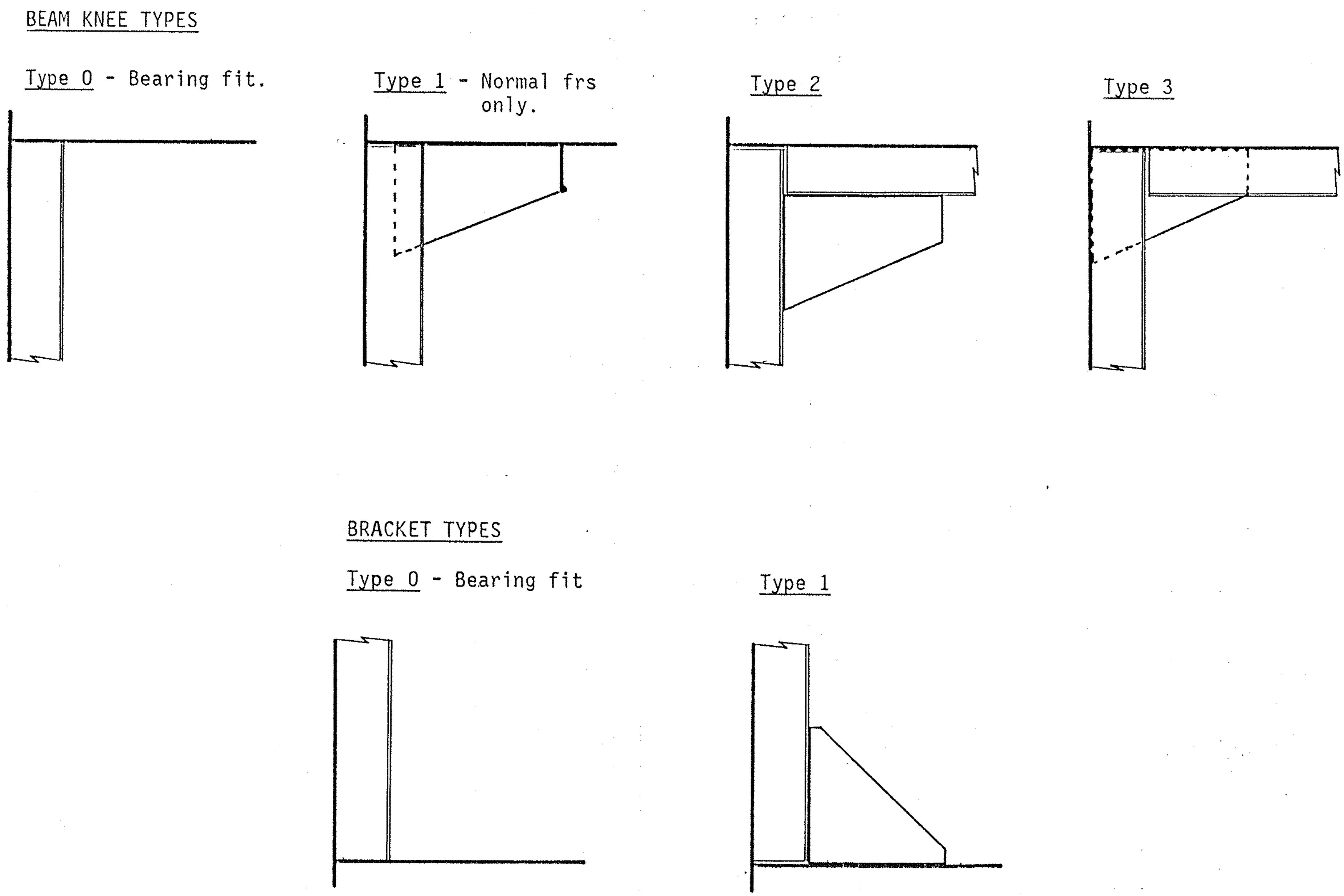
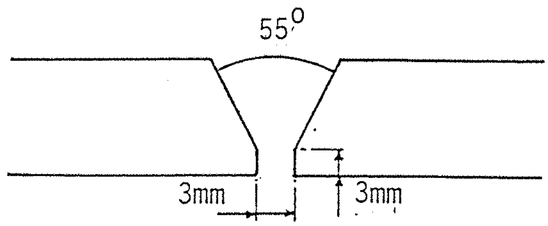


FIGURE 9-6 WELD PREPARATION TYPES

MANUAL WELDING

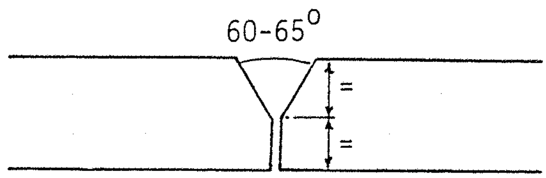
Code=2 K-Preparation

8mm - 20mm



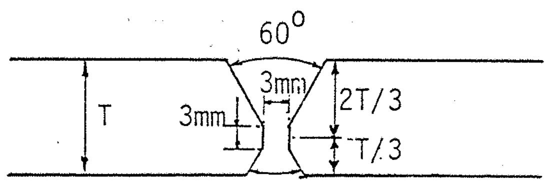
Code=3 SK-Preparation

10mm - 19mm



Code=4 M-Preparation

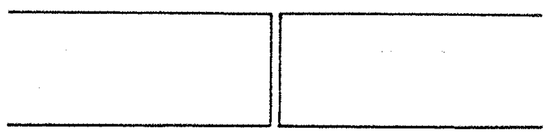
19mm - 38mm



MINI-DECK WELDING

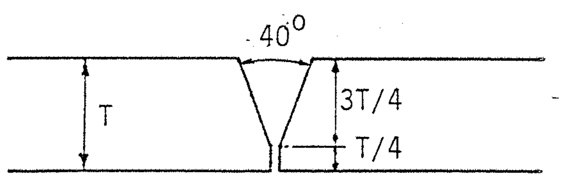
Code=8 J-Preparation

≤17.5mm



Code=9 KM-Preparation

≤25mm



Code=10 L-Preparation

≤31.5mm

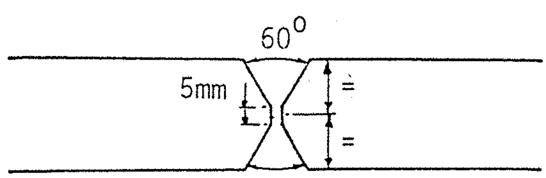


FIGURE 9-7 PLATE ORIENTATION AND STRUCTURAL ALIGNMENT

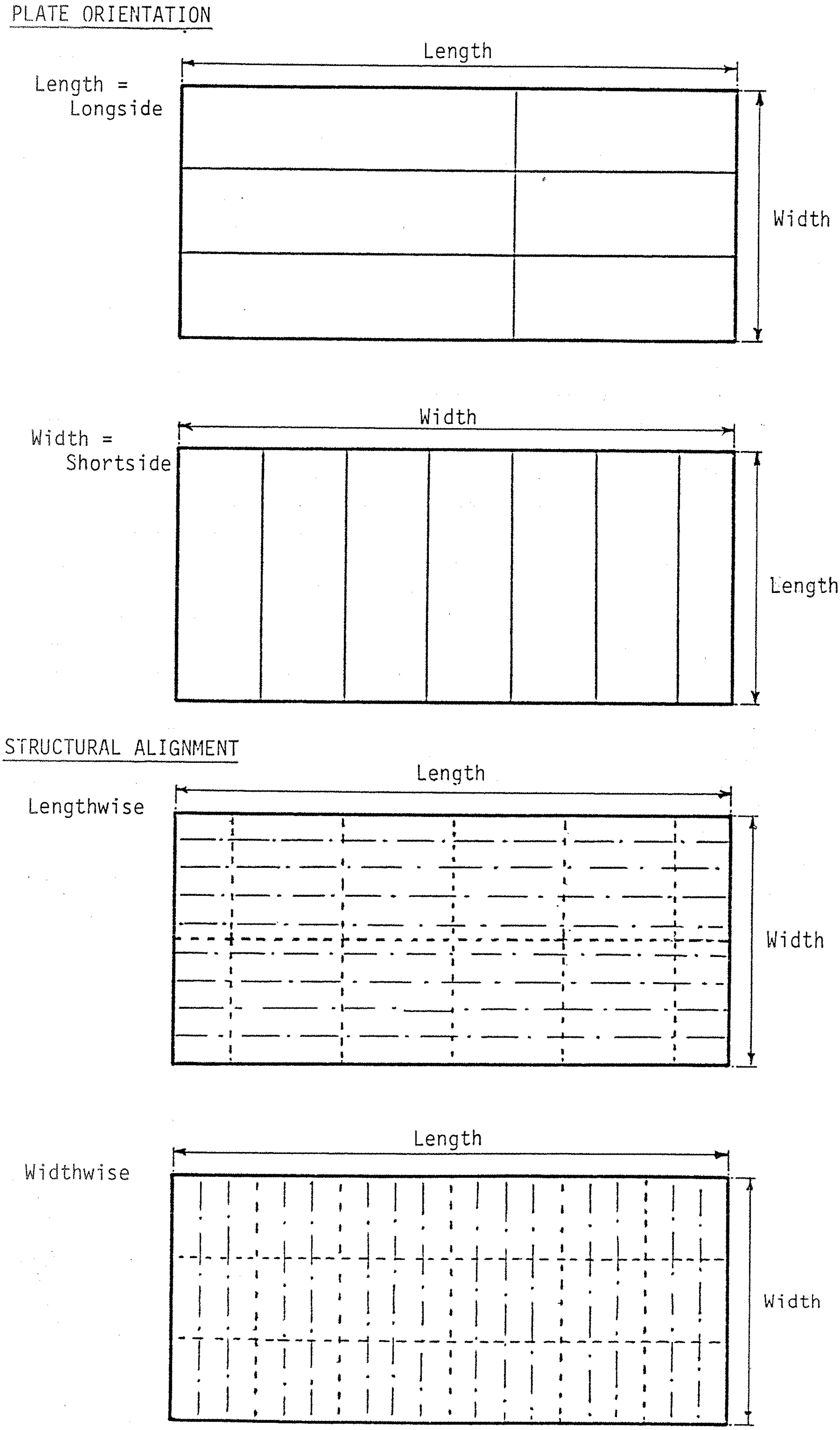


FIGURE 9-8 <u>CONFIGURATION</u> <u>OF</u> <u>PLATE</u> <u>VARIABLES</u>

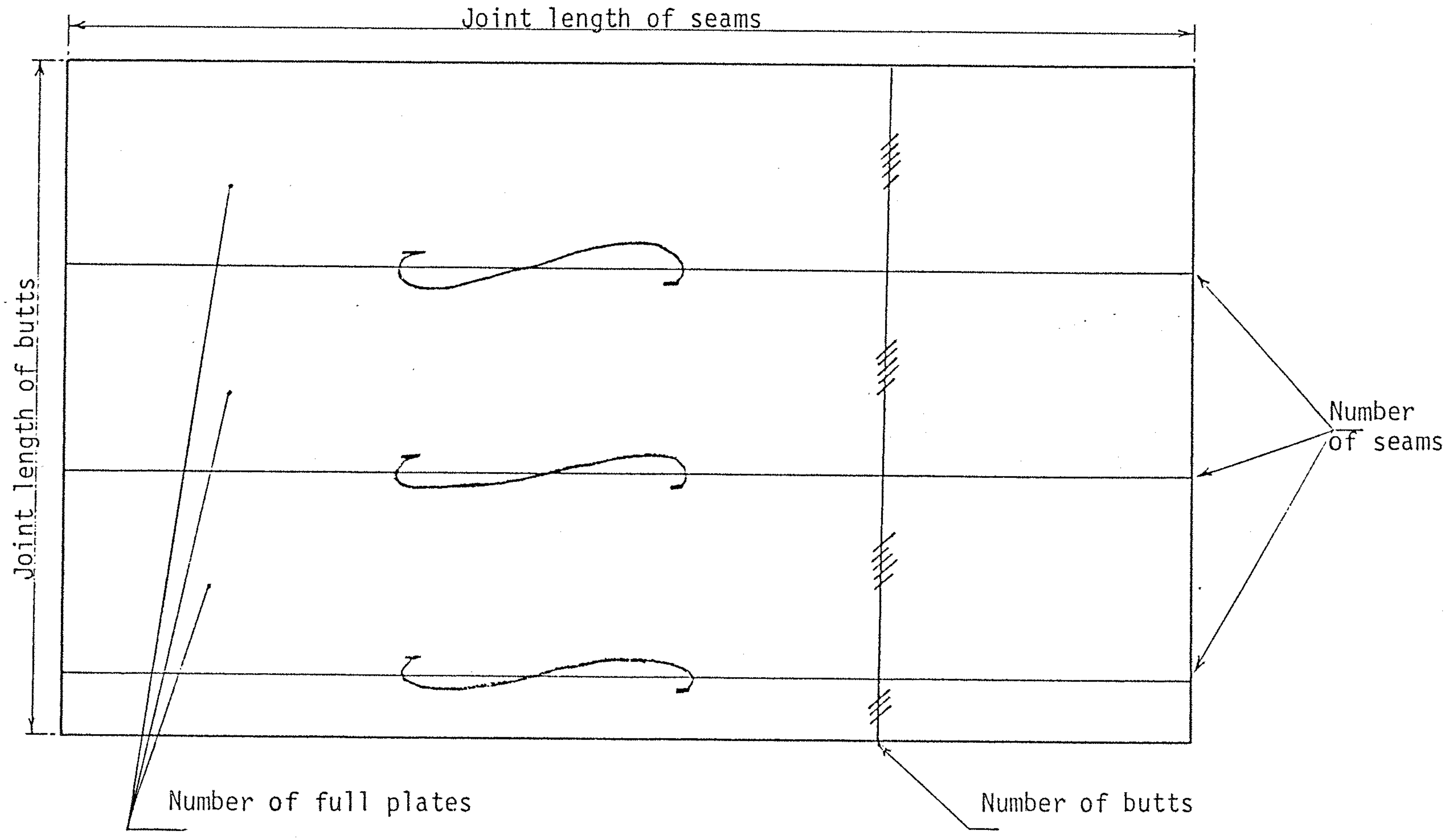


FIGURE 9-9 CONFIGURATION OF STIFFENER VARIABLES

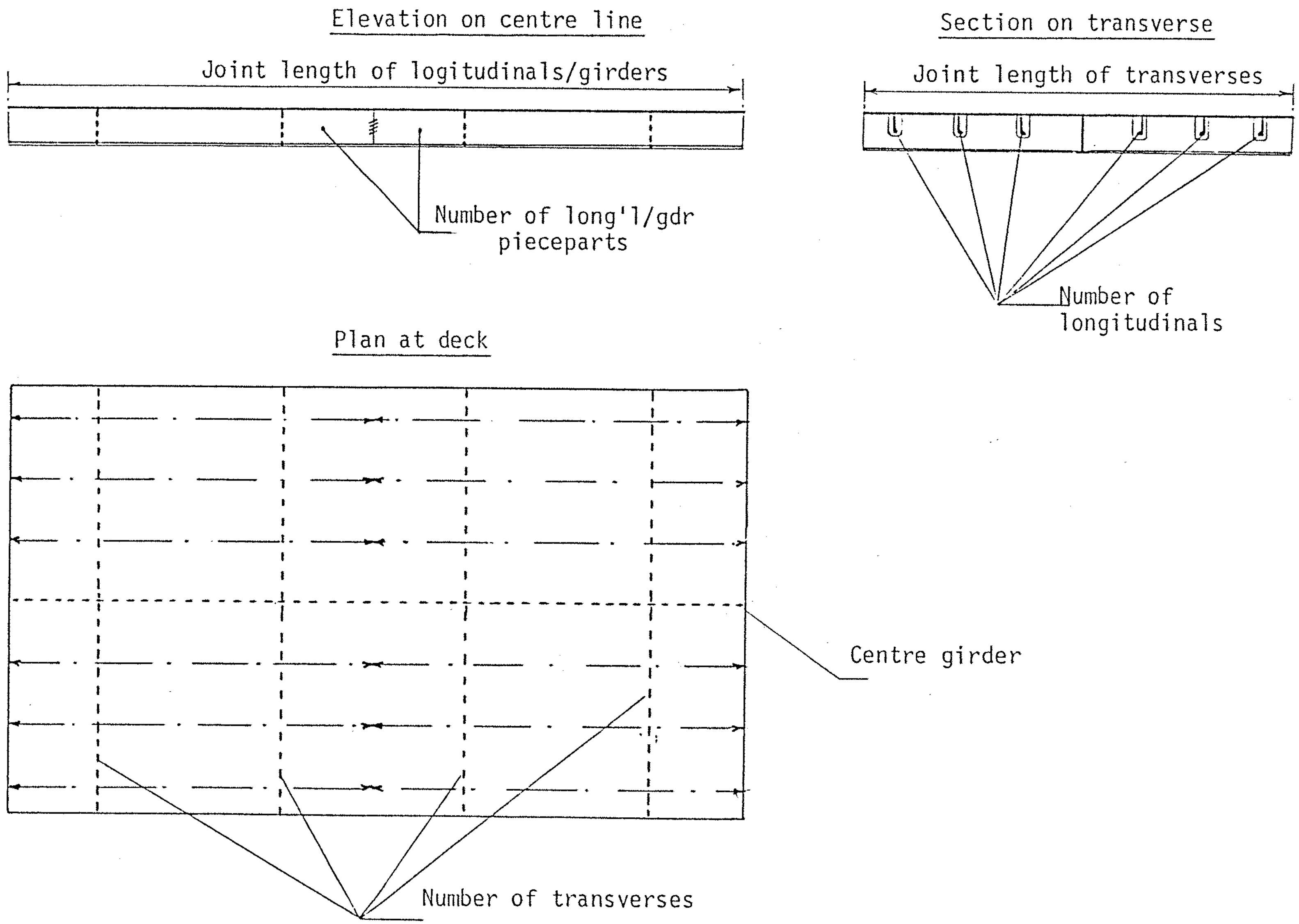


FIGURE 9-10 DATAFILE RECORD NUMBERS FOR "T" AND "C" FILES

				Codes			
SIDE SHELL				*IS=1*	*2*	*3*	*4*
Plating -	seams	IS		1	2	3	4
	butts	4+IS		5	6	7	8
	inter-plt gp seams	9					
Frames -		(10*ID)+1		11	21	31	41
Deep frames -	webs	(10*ID)+2		12	22	32	42
	flanges	(10*ID)+3		13	23	33	43
DECKS			*IDP=*	*ID=1*	*2*	*3*	*4*
Plating -	seams	(30*ID)+20+IDP	*1*	51	81	111	141
			2	52	82	112	142
			3	53	83	113	143
			4	54	84	114	144
	butts	(30*ID)+24+IDP	*1*	55	85	115	145
			2	56	86	116	146
			3	57	87	117	147
			4	58	88	118	148
	inter-plt gp seams	(30*ID)+29		59	89	119	149
			IDL=				
Longitudinals -		(30*ID)+3)+IDL	*1*	61	91	121	151
			2	62	92	122	142
			3	63	93	123	143
			4	64	94	124	144
			IDG=				
Girders -	webs	(30*ID)+35+IDG	*1*	66	96	126	146
			2	67	97	127	147
			3	68	98	128	148
	flanges	(30*ID)+38+IDG	*1*	69	99	129	149
			2	70	100	130	150
			3	71	101	131	151
Transverses -	webs	(30*ID)+43		73	103	133	163
	flanges	(30*ID)+44		74	104	134	164
Longl/trans conn		(30*ID)+45		75	105	135	165
Gdr/trans conn		(30*ID)+46		76	106	136	166
DECK/SIDE SHELL CONNECTION							
Plates		(30*ID)+47		77	107	137	167
Beam knees -	normal frames	(30*ID)+48		78	108	138	168
	deep frames	(30*ID)+49		79	109	139	169
Brackets -	normal frames	170+ID		171	172	173	174
	deep frames	174+ID		175	176	177	178

9

FIGURE 9-11 <u>"T" FILE AFTER "UNITCALC" (BEFORE "UNITREAD")</u>

SUMMARY OF PARAMETERS

03-04-1987   19:48:34

SHIP NAME: THES

UNIT NO: 300

ALTERNATIVE No: 1

OUTPUT FILENAME: TTHES300.1

```
D P   N  T  N  PPS PPS   MAIN     WELD     PP's     WELD       BURNS     WT    SURF S  LNTH DPTH  THK COD
E A   A  Y  o  TOT CUT   N T  P  Lnth     N T  P  Lnth    N   Lnth              H               L T
C R   M  P               o y  r           o y  r          o                                       e h

K T   E  E                 p  p             p  p                                                  n k
 51
DECK  1 Plts-group  1,sea
1 1 210 10   2   4   4   0 0  0   0.00   1 4  2  18.50   8  74.00 10.02 268.25 1 18.50    0  9.5 5 1


 55
DECK  1 Plts-group  1,but
1 1 210 10   0   0   0   0 0  0   0.00   1 4  2   7.25   8  29.00  0.00   0.00 1  7.25    0  9.5 5 1


 61
DECK  1 Longl gp  1
1 1 220 31  10  20  10  10 2  5 185.00  10 4  2   1.26  10   1.26  1.65  49.03 1 18.50  125  6.5 5 1


 73
DECK  1 Trans, web
1 1 241 31   6  12   6   6 2  5 111.00   6 4  2   1.14  66  30.99  1.64  44.14 1 18.50  190 10.0 5 1


 74
DECK  1 Trans, flg
1 1 242 31   6  12   6   6 2  5 111.00   6 4  2   0.57   6   0.57  0.83  23.31 1 18.50   95 10.0 5 1


 75
DK 1 Longl/trans conn
1 0 251 20   0   0   0 120 1  5  24.00   0 0  0   0.00   0   0.00  0.00   0.00 1  0.10    0 10.0 1 1
```

FIGURE 9-12 "T" FILE AFTER "UNITREAD"

SUMMARY OF PARAMETERS & STANDARD TIMES

03-04-1987 19:48:34

SHIP NAME: THES

UNIT NO: 300

ALTERNATIVE No: 1

OUTPUT FILENAME: TTHES300.1

DECK	PART	NAME	TYPE	No	PPS TOT	PPS CUT	MAIN No	MAIN Typ	MAIN Prp	WELD Lnth	PP's No	PP's Typ	PP's Prp	WELD Lnth	BURNS No	BURNS Lnth	WT	SURF	SH	LNTH	DPTH	THK	COD Len	COD Thk	STANDARD MINUTES Fllts(Main) Fair'g	Fllts(Main) Weld'g	In-pl(pp's) Fair'g	In-pl(pp's) Weld'g
51 DECK 1 Plts-group 1,sea																												
1	1	210	10	2	4	4	0	0	0	0.00	1	4	2	18.50	8	74.00	10.02	268.25	1	18.50	0	9.5	5	1	0.00	0.00	125.65	1211.76
55 DECK 1 Plts-group 1,but																												
1	1	210	10	0	0	0	0	0	0	0.00	1	4	2	7.25	8	29.00	0.00	0.00	1	7.25	0	9.5	5	1	0.00	0.00	73.68	494.79
61 DECK 1 Longl gp 1																												
1	1	220	31	10	20	10	10	2	5	185.00	10	4	2	1.26	10	1.26	1.65	49.03	1	18.50	125	6.5	5	1	973.43	2699.50	60.12	67.99
73 DECK 1 Trans, web																												
1	1	241	31	6	12	6	6	2	5	111.00	6	4	2	1.14	66	30.99	1.64	44.14	1	18.50	190	10.0	5	1	596.97	4785.56	37.85	72.65
74 DECK 1 Trans, flg																												
1	1	242	31	6	12	6	6	2	5	111.00	6	4	2	0.57	6	0.57	0.83	23.31	1	18.50	95	10.0	5	1	596.97	4785.56	35.21	36.33
75 DK 1 Longl/trans conn																												
1	0	251	20	0	0	0	120	1	5	24.00	0	0	0	0.00	0	0.00	0.00	0.00	1	0.10	0	10.0	1	1	286.79	532.52	0.00	0.00

FIGURE 9-13 "UNITSORT" OUTPUT - MANHOURS CORRECTED FOR MANNING

MANHOURS CORRECTED FOR MANNING

	FABRICATION					WELDING					
	Sections		Plates		Total	Fillet welds		In-plane welds		Total	TOTAL
	Skilled	Unskilled	Skilled	Unskilled		Skilled	Unskilled	Skilled	Unskilled		
51	0.00	0.00	4.19	2.09	6.28	0.00	0.00	20.20	0.00	20.20	26.48
55	0.00	0.00	2.46	1.23	3.68	0.00	0.00	8.25	0.00	8.25	11.93
61	32.45	16.22	2.00	1.00	51.68	44.99	0.00	1.13	0.00	46.12	97.80
73	19.90	9.95	1.26	0.63	31.74	79.76	0.00	1.21	0.00	80.97	112.71
74	19.90	9.95	1.17	0.59	31.61	79.76	0.00	0.61	0.00	80.36	111.97
75	9.56	4.78	0.00	0.00	14.34	8.88	0.00	0.00	0.00	8.88	23.21

FIGURE 9-14 "UNITSORT" OUTPUT - MANHOURS CORRECTED FOR PRODUCTIVITY

Note: Productivity in this example is 100%

MANHOURS CORRECTED FOR PRODUCTIVITY

	FABRICATION					WELDING					
	Sections		Plates		Total	Fillet welds		In-plane welds		Total	TOTAL
	Skilled	Unskilled	Skilled	Unskilled		Skilled	Unskilled	Skilled	Unskilled		
51	0.00	0.00	4.19	2.09	6.28	0.00	0.00	20.20	0.00	20.20	26.48
55	0.00	0.00	2.46	1.23	3.68	0.00	0.00	8.25	0.00	8.25	11.93
61	32.45	16.22	2.00	1.00	51.68	44.99	0.00	1.13	0.00	46.12	97.80
73	19.90	9.95	1.26	0.63	31.74	79.76	0.00	1.21	0.00	80.97	112.71
74	19.90	9.95	1.17	0.59	31.61	79.76	0.00	0.61	0.00	80.36	111.97
75	9.56	4.78	0.00	0.00	14.34	8.88	0.00	0.00	0.00	8.88	23.21

FIGURE 9-15 "UNITSORT" OUTPUT - LABOUR COSTS

LABOUR COSTS

	FABRICATION					WELDING					
	Sections		Plates		Total	Fillet welds		In-plane welds		Total	TOTAL
	Skilled	Unskilled	Skilled	Unskilled		Skilled	Unskilled	Skilled	Unskilled		
51	0.00	0.00	12.44	5.44	17.88	0.00	0.00	51.04	0.00	51.04	68.93
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	88.44	38.69	0.00	0.00	127.14	112.30	0.00	0.00	0.00	112.30	239.44
73	37.96	16.61	0.00	0.00	54.57	132.88	0.00	0.00	0.00	132.88	187.44
74	37.96	16.61	0.00	0.00	54.57	132.88	0.00	0.00	0.00	132.88	187.44
75	27.33	11.96	0.00	0.00	39.28	24.05	0.00	0.00	0.00	24.05	63.33
179	191.69	83.86	12.44	5.44	293.44	402.10	0.00	51.04	0.00	453.14	746.58

FIGURE 9-16 "UNITSORT" OUTPUT - SUMMARY

SUMMARY OF PRODUCTION DETAILS
=============================

	No. pcs Cut	No. pcs Tot	No. jts	Fillets No.	Fillets Jt.len m	In-plane No.	In-plane Jt.len m	Burns No.	Burns Len. m	Weight tonnes	Surf. area m^2
Sections	22	44	22	22	407.00	22	2.97	82	32.82	4.12	116.48
Plates	4	4	2	120	24.00	2	25.75	16	103.00	10.02	268.25
TOTAL	26	48	24	142	431.00	24	28.72	98	135.82	14.14	384.73

SUMMARY OF COSTS
================

LABOUR	- Preparation		489.89	
	Fairing	534.11		
	Welding	979.11		
	- Fabrication		1513.22	
	- Total			2003.11
MATERIALS	- Sections		1030.05	
	- Plates		2754.16	
	- Total			3784.21
OVERHEADS	- Preparation		734.83	
	- Fabrication		2269.83	
	- Total			3004.66
TOTAL				8791.98

10. BLOCK ERECTION

The programs described in this Chapter cover the activity of combining production units. This comprises the calculation of data pertaining to inter-unit joints ("Combine", "Comread" and "Comcorr") and the summation of the approprate unit and inter-unit joint data to give the block erection totals ("Comsum"). The logic for this process is described in Section 7.3 and shown in figure 10-1.

10.1 "Combine"

The main menu of "Scantlin" has an option to input the details of the inter-unit butts and seams. In particular, these relate to the butt/seam identification numbers and appropriate weld preparations. As discussed in section 9.3, this information is held on a "J" file.

"Combine" enables the designer to choose which units he wishes to combine during an erection process. He must input the identification numbers of the files pertaining to:

a) Scantlings "I",

b) Inter-unit butts and seams "J",

c) Unit costs "C",

for each of the units. Also required are the erected block identification and inter-unit joint numbers.

After ensuring the selected files exist, the program lists the joint numbers of those common to both units. Next, the designer must enter the manning and productivity values to be used in the calculations.

The joint length and production parameters are calculated for each element in the butt/seam configuration eg. plates, stiffeners etc. This data and the manning and productivity data, is held on a random access file:

"U" + Ship name + Erected block no. + "." + Inter-unit joint no.

10.2 "Comread"

As in "Unitread", the production details are used as the basis for interrogating the workstudy data files. Although it was initially planned to use data specific to the erection process, this was not available so a factor of 1.6# was applied to the composite tables of standard manhours for fabrication. This was determined from other work relating cost factors at each build stage, and gives a notional allowance for the reduced efficiecy during erection.

The standard times for fairing and welding processes (in-plane joints only) are stored on two additional fields in the "U" file.

Note: This factor is derived from shipyard data based on the relative efficiency of the fabrication and erection processes.

10.3 "Comcorr"

The standard times calculated in "Comread" are used as the basis for calculating the production costs of the inter-unit joints. The appropriate "YARD" file is accessed and, together with the "U" file, enables the costing of the labour and overheads. It is assumed there are no material costs at this stage.

The production and cost details are written to an "N" file as shown in figure 10-2.

10.4 "Comsum"

The calculations so far have covered individual units and inter-unit joints, the details of which are held on "C" and "N" files respectively. The final program in the suite, "Comsum", enables any number of units to be combined to form an erected block. The designation number of the block is selected at this stage.

The number of the inter-unit joint is input first which leads to the interrogation of the appropriate "N" file which holds the names of the component units.

The materials, manhours and cost details for the block are held on an "M" file:

"M" + Ship name + Erected block no.

If units have previously been combined for the block, the file is re-accessed. Otherwise it is created during "Comsum". A back-up of the "M" file is automatically taken before further details are added and calculations performed.

The calculations fall into three areas:

a) Units - "C" files

b) Inter-unit joints - "N" files

c) Total

For a) and b) the details for the current units and inter-unit joints are added to the existing totals for "C" and "N" files respectively. A new total c) is determined from the addition of the current details to the existing total. For example:

New total for "C" files = Existing "C" total + 1st unit "C" file
+ 2nd unit "C" file

New total for "N" files = Existing "N" total + current inter-unit joint file

New total = Existing total + 1st Unit "C" file
+ 2nd unit "C" file
+ current inter-unit joint file

If a unit's details are already on the "M" file from a previous combination of units, it is not added at this juncture.

Details of the current files and the new totals are sent to the modified "M" file. These figures and the existing totals are given as hard copy printout (figures 10-3 to 10-5) which includes:

1. Labour costs.
2. Material costs.
3. Overhead costs.
4. Total costs.
5. Production data.

These are given for:

a) Existing "M" file totals for units
inter-unit joints
total.

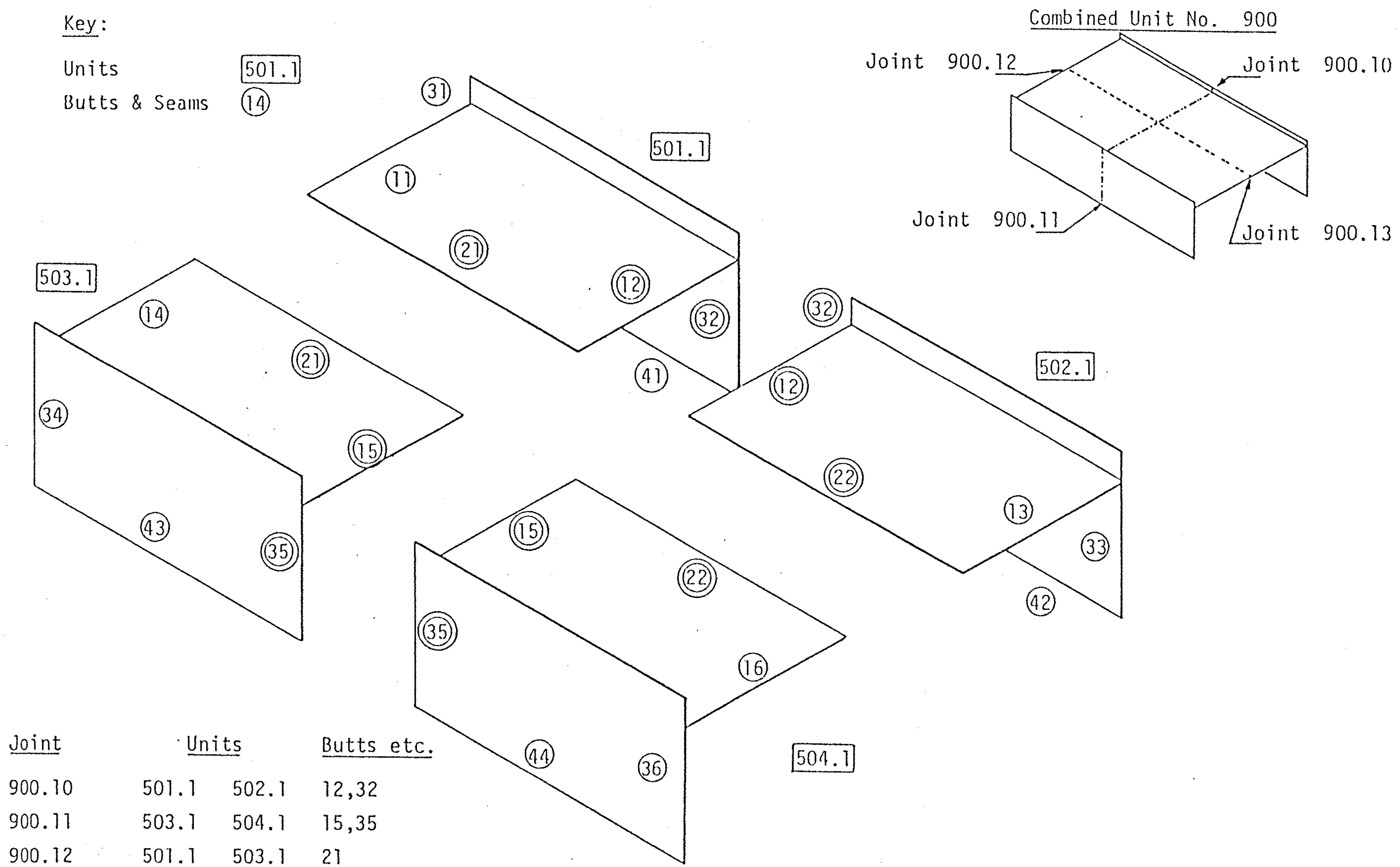
b) Each new unit in the block.

c) The new inter-unit joint.

d) The new "M" file totals for units,
inter-unit joints,
total.

The summary sheet (figure 10-6) also lists the names of the files included.

FIGURE 10-1 BLOCK ERECTION LOGIC



Joint	Units		Butts etc.
900.10	501.1	502.1	12,32
900.11	503.1	504.1	15,35
900.12	501.1	503.1	21
900.13	502.1	504.1	22

FIGURE 10-2 "COMCORR" OUTPUT

Manning levels				
	Fairing	skilled,unskilled	2.0	1.0
	Welding	skilled,unskilled	1.0	0.0
Productivity				
	Erection		100 %	
Wage rates				
	Skilled		£ 4.00 /hour	
	Unskilled		£ 3.50 /hour	
Material prices				
	Plates		£275.00 /tonne	
	Sections		£250.00 /tonne	
Overhead recovery rate				
	For erection		150 %	

SUMMARY OF COSTS
================

LABOUR -	Fairing	33.37	
	Welding	36.24	
	- Erection total		69.61
OVERHEADS	- Erection total		104.42
-----			-----------
TOTAL			174.03
=====			===========

FIGURE 10-3 "COMSUM" OUTPUT - INDIVIDUAL UNITS

INDIVIDUAL UNITS

COST TOTALS

LABOUR

	Preparation	Fabrication: Fairing	Fabrication: Welding	Fabrication: Total	Total
Existing totals	0	0	0	0	0
First unit	490	534	979	1513	2003
Second unit	204	293	453	747	951
New Totals	694	828	1432	2260	2954

	MATERIALS: Sections	MATERIALS: Plates	MATERIALS: Total	OVERHEADS: Prep'n	OVERHEADS: Fab'n	OVERHEADS: Total	TOTALS
Existing totals	0	0	0	0	0	0	0
First unit	1030	2754	3784	735	2270	3005	8792
Second unit	511	1712	2223	306	1120	1426	4600
New Totals	1541	4466	6008	1041	3390	4431	13392

PARAMETER TOTALS

	Pieceparts: Sect	Pieceparts: Plt	Pieceparts: Cut	Pieceparts: Total	Joints: Fllt No.	Joints: Fllt Length	Joints: Inpl No.	Joints: Inpl Length	Joints: Total	Burns: No.	Burns: Length	Weight	Area
Existing totals	0	0	0	0	0	0.00	0	0.00	0	0	0.00	0.00	0.00
First unit	44	4	26	48	142	431.00	24	28.72	24	98	135.82	14.14	384.73
Second unit	18	2	20	20	98	223.00	1	11.50	20	66	82.80	8.27	225.11
New totals	62	6	46	68	240	654.00	25	40.22	44	164	218.62	22.41	609.84

FIGURE 10-4 "COMSUM" OUTPUT - COMBINATION DETAILS

COMBINATION DETAILS

COSTS AND PARAMETERS

	COSTS					PARAMETERS	
	LABOUR			OVERHEADS	TOTAL	In-Plane Joints	
	Fab'n	Welding	Total			No.	Length
Existing Totals	0	0	0	0	0	0	0.00
Additions	33	36	70	104	174	52	8.51
New Totals	33	36	70	104	174	52	8.51

FIGURE 10-5 "COMSUM" OUTPUT - TOTALS

TOTALS

COST TOTALS

LABOUR

	Preparation	Fabrication/Erection			Total
		Fairing	Welding	Total	
Existing totals	0	0	0	0	0
Additions	694	861	1468	2329	3023
New totals	694	861	1468	2329	3023

	MATERIALS			OVERHEADS			TOTALS
	Sections	Plates	Total	Prep'n	Fab'n	Total	
Existing totals	0	0	0	0	0	0	0
Additions	1541	4466	6008	1041	3494	4535	13566
New Totals	1541	4466	6008	1041	3494	4535	13566

PARAMETER TOTALS

	Pieceparts				Joints					Burns		Weight	Area
	Sect	Plt	Cut	Total	Fllt		Inpl		Total	No.	Length		
					No.	Length	No.	Length					
Existing totals	0	0	0	0	0	0.00	0	0.00	0	0	0.00	0.00	0.00
Additions	62	6	46	68	240	654.00	77	48.73	44	164	218.62	22.41	609.84
New totals	62	6	46	68	240	654.00	77	48.73	44	164	218.62	22.41	609.84

FIGURE 10-6 "COMSUM" OUTPUT - SUMMARY

SUMMARY

EXISTING TOTALS

LABOUR	0	
MATERIALS	0	
OVERHEADS	0	
TOTAL		0

ADDITIONS

LABOUR	3023	
MATERIALS	6008	
OVERHEADS	4535	
TOTAL		13566

NEW TOTALS

LABOUR	3023	
MATERIALS	6008	
OVERHEADS	4535	
TOTAL		13566
		========

11. USE OF THE PROGRAMS

The programs which have been developed by the BS/SERC project enable designers to compare structural designs at an early stage in the design cycle. However, care must be taken to interpret the output as detailed below.

11.1 Output

In order to give the designers as many parameters as possible on which to base their judgement, the programs endeavour to provide a full range of output.

For example:

- No. of pieceparts
  - plates
  - sections
- No., type and lengths of welds
- Weight of materials
- Surface area of materials
- Corrected manhours
  - for manning
  - for productivity
- Costs
  - labour
  - materials
  - overheads
  - total

The exact format may vary between programs depending on the calculation type, phase of construction and available file space.

11.2 Interpretation

It must be stressed that the output from the programs is meant to be used solely for comparisons of alternative structural designs within a particular shipyard. Earlier in this thesis there is mention of the problems which arise if historical data is used in work content estimation. This project does rely slightly on a historical value for productivity during the construction of the different units and blocks. This will be reflected in the relative sizes of labour, materials and overheads. However, since only comparisons are being made it is sufficient to enter a notional value.

Another factor influencing production manhours and costs is the manning level. However, this input is not meant to be a variable the designer can alter at will. It is the minimum number of men necessary to complete a task in the shipyard. For example, if a yard currently uses one plater, one platers helper and one tack welder for a fairing task, the manning would be two skilled and one unskilled. The introduction of flexible work practices in the yard might permit the job to be completed without a dedicated tack welder, i.e. the manning would be reduced to one skilled and one unskilled only.

Although the final outputs are in pounds stirling, these values should not be taken for estimating purposes. They should, more correctly, be interpreted as cost factors; percentage differences being considered most important.

12. PROGRAM TESTING

The programs have been tested, as far as reasonably possible, by checking the results they produce against manual calculations. However, since it is difficult to ensure all possible combinations of sub-routines are verified there may, as in all computer programs, still be "bugs".

Additional to the manual checks described above, the programs have been used in the following work:

1. Production unit case study (Appendix F)
2. Stiffened deck panel design (Appendix G)
3. Comparisons with published work (Appendix H)

It is envisaged that there should be a further period of testing in an industrial environment. These tests could take the form of comparing standard ships with varying structures or, alternatively, existing designs could be re-appraised or perhaps current contracts examined.

13. CONCLUSIONS

The BS project has produced tools which will increase the amount of science as against historical judgement in the evaluation of structural designs. On completion of the work the programs were, on the whole, user friendly with a high standard of technical documentation. Although the initial programs were written in interpreted basic, further versions were in compiled basic which had run times of 1/4 to 1/3 of the interpreted times. Examples of run times for interpreted programs:

	Unitcalc	Unitread	Unitsort
One dk/side shell structure	1 min	1 min	1 min
Four dks/side shell structure with maximum no. of dks/panels etc	4 mins	4 mins	4 mins

The work study data from Govan Shipbuilders has been accepted by BS as generally relevant to its member shipyards including Austin and Pickersgill who have, in fact, been using the data in its detailed form within their Production Engineering Department [19].

The case studies show how the output from the programs can be used to assess the merits of different structural designs in terms of production costs or other production parameters.

14. FURTHER WORK

The suite of computer programs provide a tool for designers to evaluate structural designs. It would be beneficial if the programs were used to consider parametric variations throughout the ship. The results might lead to even simpler methods of estimating work content with factors based on the production area e.g. double bottoms, side shell, deck etc.

Currently, workstudy data has only been used for the calculation routines associated with fairing and welding processes in fabrication. Historical data (from Campsey) is used for preparation, whilst erection times are determined from 'factored' fabrication data. There is further workstudy data available for these two phases of construction as shown in Figure 5-3, however, there was insufficient time to extract this information from the BS datafiles and subsequently use it in the calculation routines. Although not used, there should be sufficient production parameters in the "T" and "U" files to enable preparation and erection workstudy data to be used at a later stage.

Finally, similar programs would be useful for outfitting trades, e.g. joinery, sheet metal working and pipework manufacture.

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APPENDIX A THE TASKS INVOLVED IN THE IMPLEMENTATION OF THE PROJECT

Source: Ref. 32

The tasks for this project were considered under four categories, details of which are outlined below.

1. Study Phase

This was carried out on the basis of practices and facilities available in the shipyard collaborating in this project. The main areas of the study were as follows:

1. Key decisions affecting designs/drawings vis-a-vis Build Strategy.

2. Production processes and facilities available in the steelwork shops.

3. Data concerning work content estimation.

4. Information flow and communication channels within the shipyard.

2. Evaluation Phase

Information gathered in the course of the study was then evaluated with respect to the following items.

2.1 Design Procedure

- Information content of drawings/designs.
- Interaction of design variables and parameters
- Impact on structural design of production processes.

2.2 Production Factors

- Shipyard standards (eg. steelwork details, maximum plate sizes, preferred scantlings of rolled sections, etc.)
- Production equipment and facilities.
- Construction sequences and procedure.
- Identification of indirect costs.

2.3 Information Reporting Systems

- Availability of data.
- Identification of data items.
- Methods of representing information.

3. Development Phase

3.1 Method of Appraisal

The logic in the method was such as to:

1. Incorporate steelwork preparation, fabrication and erection activities.

2. Be applicable at a preliminary (midship section) design stage as well as for detailed design work.

3. Ensure that the method suits the existing/planned shipyard systems.

3.2 Development of Algorithms

Simple algorithms based on the above method were developed for application on an IBM PC-XT micro-computer.

4. Test Phase

The algorithms and programs were tested:

1. Using an existing scantlings determination algorithm based on Lloyd's Rules available in the University. This was particularly relevant for application of the approach to preliminary design stages.

2. On some published designs of panel structures, ie. application for detailed design work.

APPENDIX B OBJECTIVES IN THE PRODUCTION PROCESS

Source: Ref. 22 & 35

For those designs developed with the principles developed in Chapter 3 in mind, production advantages may be gained within each of the following major production stages:

- Steelwork manufacture
- Outfit manufacture
- Block and Module assembly
- Berth construction

Considering these work stages in turn, the principal objectives within each category may be set down as follows:

1. Steelwork manufacture

- Utilisation of maximum size materials within yard constraints.

- Minimisation of the numbers of materials.

- Effective machine utilisation for the major cutting machines.

- Effective production of standard component piece parts which may be handled readily and stored as unit loads (prior to delivery to the designated unit and block assembly work stations).

- Effective dimensional and quality control of component manufacture.

2. <u>Outfit Manufacture</u>

- Maximum use of standard size materials, hence, minimum number of piece parts and joints.

- Maximisation of predetermined component and piece part production.

- Effective systems grouping to form pipework sub-assemblies within the workshop environment, which may possibly be installed within a block prior to erection.

- Effective use of palletisation and unit loads as appropriate for standard piece parts and components within a specific area, zone or block.

3. <u>Block and module assembly</u>

- Maximum use of mechanised and semi-automatic assembly facilities; maximum use of downhand working.

- Standardisation of assembly joints within structures to facilitate the use of jigs and other labour saving devices.

- Effective block assembly operations involving the build-up of self-supporting structures which may also be readily self-fairing.

- Effective assembly of minor structure, outfit systems and equipment into modules which may be completed and tested as far as possible within the workshop environment.

- Effective final assembly of major machinery modules within the workshop environment involving elements of structure, machinery, outfit systems and sub-assemblies.

4. Berth construction

- Adoption of a natural block breakdown philosophy which enables blocks to be effectively self-supporting at the erection stage. This involves the maximum use of downhand fairing and welding as well as providing good access to the required working locations.

- Development of a block breakdown which enables maximum advantage to be taken of the lifting capabilities of the ship construction craneage for:

  a) the main hull building operations

  and b) the final block assembly activities.

- Development of a natural block breakdown which results in a similarity of process, sequence, methods and dimensions between blocks as far as is practicable.

APPENDIX C WORKSTUDY DATA

Details of a typical workstudy serial are given together with an example showing how the composite table information is used. Due to the confidential nature of the data, the figures given for the basic minutes have been changed. All other details are, however, correct.

DATA BANK	STEELWORK FABRICATION	SERIAL	SECTION S. F. P. 2	NUMBER 401
PLATING : Fair and Tack O. B. P. 's Up To 12"			DATE Aug. '75	PAGE 1 OF 11

TOOLS AND EQUIPMENT :

Tool Box
7 lb. Hammer
2 lb. Hammer
Pinch
Steel Wedges
Bridges, Stoppers, Section Supports and Stays
Section Lifting Jigs or Spring Grab Chains
Crane
Manual Welding Regulator (Choke) 300 to 600 Amps
Manual Welding Helmet and Tongs; Gloves
Rule.

MATERIAL :

Worked On : Mild Steel O. B. P. 's of Varying Dimensions.

Expendable : Bridges, Stoppers, Stays and Section Supports (Soldiers).
Manual Welding Electrodes Conforming To B. S. 639 and B. S. 1719.

METHOD : See Pages 2, 3 and 4

LOCATION : Indoor, ground level reasonably clean and free from obstruction.

OPERATOR : Male, suitably trained and accustomed to the job.

DATA : The Data are expressed in basic time in minutes (i. e. the time required at the standard rate of working, excluding Relaxation Allowance).

DATA BANK	STEELWORK FABRICATION	SERIAL	SECTION	NUMBER
			S. F. P. 2	401
PLATING :			DATE	PAGE
Fair and Tack O. B. P.'s Up To 12"			Aug. 75	2 OF 11

METHOD

ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
ELEMENT 1 - RECEIVE INSTRUCTIONS :		
Operator approaches Foreman or Leading Hand. Receives instructions pertaining to the job.	6.0	Per Job
ELEMENT 2 - COLLECT AND LAYOUT TOOLS AND EQUIPMENT :		
Collect tools from previous work area. Pick up tools and carry to job location and layout tools. Tools carried; 7 lb. hammer, 2 lb. hammer, 3/4" screw key, 6 steel wedges etc.,	3.5 4.0	Per Job Per Job*
ELEMENT 3 - MAKE INITIAL INSPECTION :		
Check job prior to starting work. Check for fairing aids required to fair job to position.	2.0 3.5	Per Job Per Job*
ELEMENT.4 - COLLECT AND LAYOUT GEAR AND REPLACE :		
Operator walks from job to locker, collects reeving chains, spring grab, lifting jigs and pinch and returns to job. Replace equipment on completion of job.	1.0	Per Job
ELEMENT 5 - TRANSPORT SECTIONS BY CRANE :		
Summon crane, attach chains to sections, raise sections and transport 300 feet to work area. Deposit sections and release chains.	5.0	Per Job
* Restricted		

PLATING :

Fair and Tack O.B.P.'s Up To 12"

METHOD

ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
ELEMENT 6 - COLLECT S@CTION SUPPORTS - (SOLDIERS) :		
Collect box and walk approximately 200 feet to where section supports are stored. Load 15 pairs of supports into box, carry box 200 feet back to job and deposit supports.	3.0	Per Job
ELEMENT 7 - ERECT SECTION SUPPORTS :		
Position and tack one pair of supports and move to next position.	1.5	Per Section
ELEMENT 8 - POSITION SECTIONS (OVER 8 FEET LONG) BY CRANE :		
Summon crane. Attach grab or jigs to section. Lift. to position (approx. 25 feet) between supports. Remove grab or jigs and return to next section.	5.0	Per Section
ELEMENT 9 - LAYOUT SECTIONS (UP TO 8 FEET LONG) MANUALLY :		
Lift section, carry to position (approx. 25 feet) deposit and return for next section.	1.0	Per Section
ELEMENT 10 - COLLECT FAIRING AIDS :		
Collect box, walk approx. 200 feet to where fairing aids are stored. Load 15 fairing aids (6 bridges, 4 stoppers and 5 stays) into box. Carry box 200 feet to job and deposit fairing aids.	3.0	Per 27'-0" Of Section

DATA BANK	STEELWORK FABRICATION	SERIAL	SECTION	NUMBER
PLATING :			S. F. P. 2	401
Fair and Tack O. B. P. 's Up To 12"			DATE: Aug. '75	PAGE: 4 OF 11

METHOD

ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
ELEMENT 11 - FAIR AND TACK SECTIONS :		
Fair Section attaching one bridge approx. every 4'-6". One stopper approx. every 6'-9" and one stay approx. every 5'-6". Tack weld sections approx. one tack every 12".	1.0	Per Foot.
ELEMENT 12 - MAKE FINAL INSPECTION :		
Make final inspection of job on completion of work as described on job card, i.e. checking for articles missed during fairing operation.	3.0 4.0	Per Job Per Job *

* Restricted

PLATING :

Fair and Tack O.B.P.'s Up To 12"

Table 1 - Job Constants (Unrestricted) :

JOB CONSTANT (UNRESTRICTED)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
1	Receive Instructions.	6.0	Per Job
2	Collect and Layout Tools and Equipment.	3.5	Per Job
3	Make Initial Inspection.	2.0	Per Job
4	Collect and Layout Gear and Replace.	1.0	Per Job
5	Transport Sections By Crane.	5.0	Per Job
6	Collect Section Supports (Soldiers)	3.0	Per Job
12	Make Final Inspection.	3.0	Per Job
	Total-Job Constant	23.5	Per Job

Table 2 - Job Constants (Restricted) :

JOB CONSTANT (RESTRICTED)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
1	Receive Instructions	6.0	Per Job
2	Collect and Layout Tools and Equipment.	4.0	Per Job
3	Make Initial Inspection	3.5	Per Job
4	Collect and Layout Gear and Replace.	1.0	Per Job
5	Transport Sections By Crane.	5.0	Per Job
6	Collect Section Supports (Soldiers)	3.0	Per Job
12	Make Final Inspection	4.0	Per Job
	Total-Job Constant	26.5	Per Job

Table 3 - Section Constants (Over 8'-0" Long) :

SECTION CONSTANT (OVER 8'-0" LONG)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
7	Erect Section Supports	1.5	Per Section.
8	Position Sections (Over 8'-0" Long) By Crane.	5.0	Per Section
10	Collect Fairing Aids	3.0	Per Section
	Total-Section Constant	9.5	Per Section.

Table 4 - Section Constant (Up To 8'-0" Long) :

SECTION CONSTANT (UP TO 8'-0" LONG.)			
EL. NO.	ELEMENT DESCRIPTION	BASIC MINS.	FREQY.
7	Erect Section Supports.	1.5	Per Section
9	Layout Sections (Up To 8'-0" Long) Manually.	1.0	Per Section
10	Collect Fairing Aids	3.0	Per Section
	Total - Section Constant	5.5	Per Section

PLATING :

Fair and Tack O.B.Ps. up To 12".

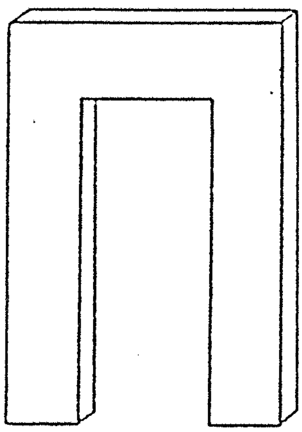
DATA :

Fair and Tack Values :

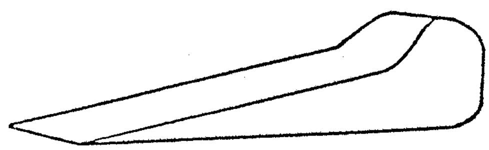
	Basic Minutes	Details	Reference
Job Constant (Unrestricted)	23.5	El. 1 - 6 & 12 Table 1	Page 5
Job Constant (Restricted)	26.5	El. 1 - 6 & 12 Table 2	Page 6
Section Constant (Over 8'-0" Long)	9.5	El. 7 - 8 - 10 Table 3	Page 7
Section Constant (Up to 8'-0" Long)	5.5	El. 7 - 9 - 10 Table 4	Page 7
Fair and Tack	1.0 / Feet	El. 11	Page 4

DATA BANK	STEELWORK FABRICATION	SERIAL	SECTION	NUMBER
			S. F. P. 2	401
PLATING :			DATE	PAGE
Fair and Tack O. B. P.'s Up To 12"			Aug. '75	9 OF 11

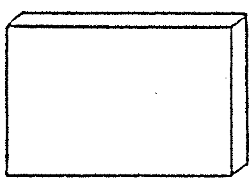
Typical Fairing Aids:



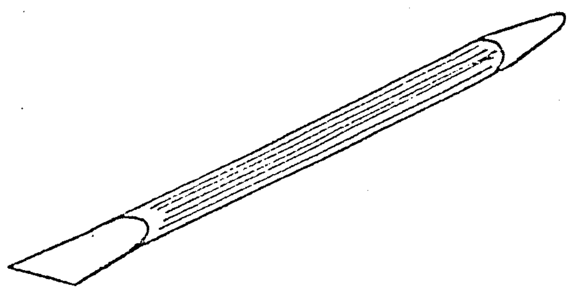
'Bridge'



'Steel Wedge'



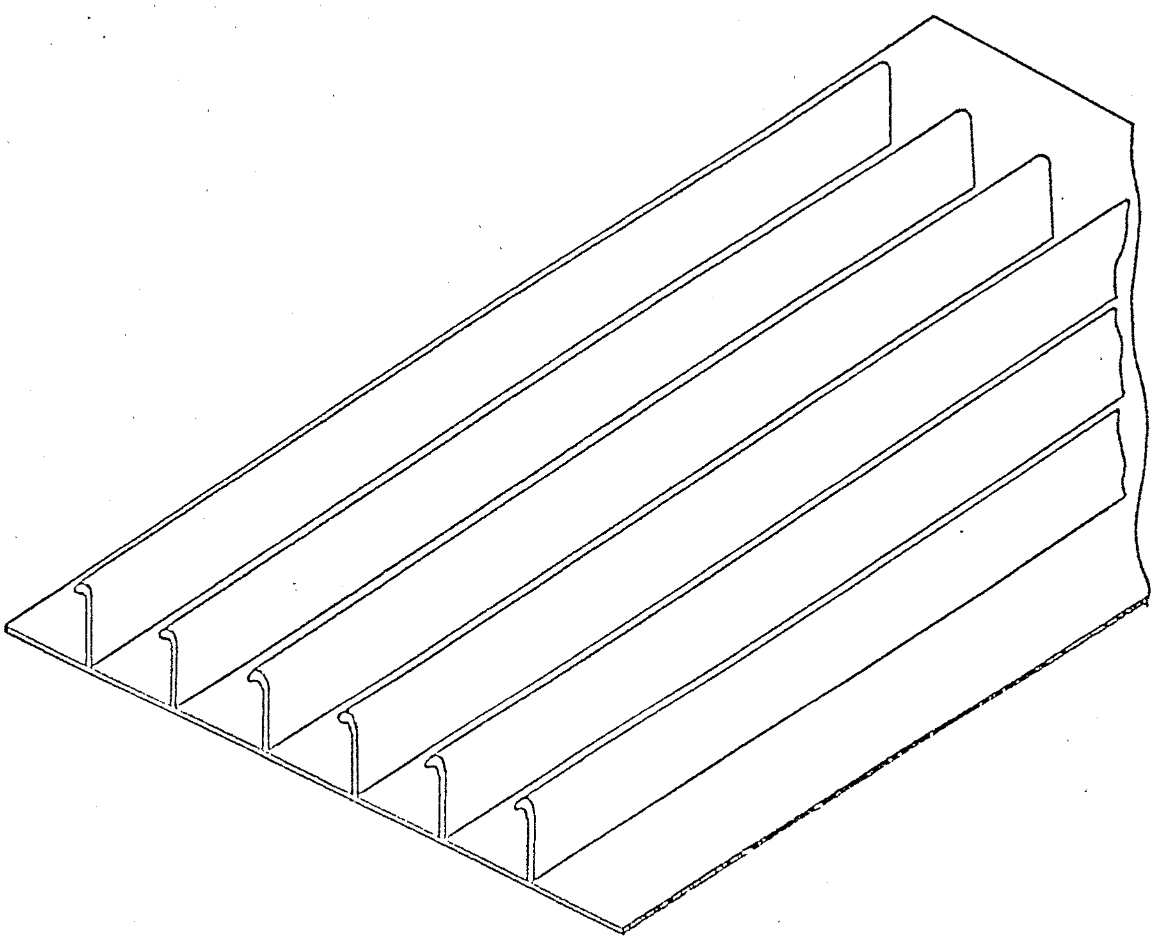
'Stopper'



'Pinch'

Typical O. B. P. 's Faired and Tacked to Deck Panel.

O. B. P. : Offset Bulb Plate.



Example On How To Use Data :

Fair and Tack to Deck Panel 4 - O. B. P. 's 7" x 30'-0" Long
4 - O. B. P. 's 10" x 20'-0" Long
4 - O. B. P. 's 12" x 7'-0" Long
(Unrestricted)

Job Constant	Page 5	=	23.5	
Section Constant x 8	Page 7	=	9.5	x 8
Section Constant x 4	Page 7	=	5.5	x 4
Element 11 x 228'-0"	Page 4	=	1.0	x 228'-0"

= 23.5 + (9.5 x 8) + (5.5 x 4) + (1.0 x 228'-0")

= 23.5 + 76.0 + 22.0 + 228.0

∴ Total B. M. 's for above O. B. P. 's

= 349.5 B. M. 's

APPENDIX D FILE DETAILS

This appendix gives further details of the files discussed in earlier Chapter 8 of this thesis. In particular,

- File name prefixes,

- Workstudy data files - fairing
  - welding

- Stiffener weight data file,

- Record and field information for "T", "C", "U", "N" and "M" files.

FIGURE D-1 FILENAME PREFIXES

PREFIX	COMPLETE FILENAME	DETAILS OF FILE DATA	CREATED IN:	USED IN:
YARD	+ 1 - 99	Yard standards	YARDSTDS	UNITCALC UNITSORT COMCORR
G	+ Ship name + unit no.	General layout of unit	LAYOUT	SCANTLIN SCANTCHG
I	+ Ship name + unit no. + "." + Alt've no.	Scantlings of unit	SCANTLIN	SCANTCHG UNITCALC COMBINE
J	+ Ship name + unit no. + "." + Alt've no.	Inter-unit butts & seams details for unit	SCANTLIN	COMBINE
T	+ Ship name + unit no. + "." + Alt've no	Production parameters & std minutes for unit	UNITCALC (UNITREAD)	UNITREAD UNITSORT STDHRPRN
C	+ Ship name + unit no. + "." + Alt've no.	Hours and costs for unit	UNITSORT	COMSUM
U	+ Ship name + combination no. + "." + i/u joint no.	Production parameters & std minutes for i/u joint	COMBINE (COMREAD)	COMREAD COMCORR
N	+ Ship name + combination no. + "." + i/u joint no.	Hours and costs for i/u joint	COMCORR	COMSUM
M	+ Ship name + combination no.	Totals for hours and costs for combination	COMSUM	

FIGURE D-2 DETAILS OF DATAFILES

	PREFIX	COMPLETE FILENAME	DETAILS OF FILE DATA	FILE TYPE
FREQUENTLY ACCESSED		STIFFWT.RAN	Weights of rolled sections	RANDOM ACCESS
		WKSTDYF.RAN	Workstudy standard times for fairing processes	RAN
		WKSTDYW.RAN	Work study, standard times for welding processes	RAN
INPUT DATA	YARD	+ 1 - 99	Yard standards	SEQUENTIAL
	G	+ Ship name + unit no.	General layout of unit	SEQ
	I	+ Ship name + unit no. + "." + Alt've no.	Scantlings of unit	SEQ
	J	+ Ship name + unit no. + "." + Alt've no.	Inter-unit butts & seams details for unit	SEQ
CALCULATED DATA	T	+ Ship name + unit no. + "." + Alt've no	Production parameters & std minutes for unit	RAN
	C	+ Ship name + unit no. + "." + Alt've no.	Hours and costs for unit	RAN
	U	+ Ship name + combination no. + "." + i/u joint no.	Production parameters & std minutes for i/u joint	RAN
	N	+ Ship name + combination no. + "." + i/u joint no.	Hours and costs for i/u joint	RAN
	M	+ Ship name + combination no.	Totals for hours and costs for combination	RAN

FIGURE D-3 WORKSTUDY DATAFILE - FAIRING FILE VARIABLES

FAIR AND TACK: WKSTDYF.RAN

Variable		Description	Options	
F1$	2	Material type	10	Plates - in plane
			20	Plates - T fashion
			31	OBP ⩽ 305mm
			32	OBP > 305mm
			33	F.B's, OAB's ⩽ 152mm
			34	Round bars
F2$	2	Shape	1	Straight
			2	Shaped
F3$	2	Fastening	1	Permanent
			2	Temporary
F4$	2	Lift	1	Manual
			2	Crane
F5$	2	Restrictions	1	Unrestricted
			2	Restricted
F6$	2	Length	1	⩽0.61m
			2	>0.61m, ⩽1.83m
			3	>1.83m, ⩽2.44m
			4	>2.44m, ⩽3.66m
			5	>3.66m
F7$	2	Position	1	Downhand
			2	Vertical
F8$	2	Thickness	1	⩽10mm
			2	>10mm, ⩽13mm
			3	>13mm
F9$	5	Job constant		
F10$	5	Material constant		
F11$	5	Rate		

FIGURE D-4 WORKSTUDY DATAFILE - FAIRING FILE LISTING

Rec. No.	Mat'l type	Shape	Fast'g	Lift	Restrict'n	Length code	Posn.	Thk.	Job const.	Material const.	Rate
1	10	1	1	0	0	0	0	1	34.75	5.43	4.62
2	10	1	1	0	0	0	0	2	34.75	5.43	4.62
3	10	1	1	0	0	0	0	3	34.75	5.43	6.26
4	10	2	0	0	0	0	0	1	35.45	21.56	6.07
5	10	2	0	0	0	0	0	2	35.45	21.56	6.07
6	10	2	0	0	0	0	0	3	35.45	22.63	9.15
7	20	0	0	2	1	1	1	1	41.27	8.12	10.23
8	20	0	0	2	1	2	1	1	41.27	8.12	10.23
9	20	0	0	2	1	3	1	1	41.27	8.12	10.23
10	20	0	0	2	1	1	1	2	41.27	8.12	9.45
11	20	0	0	2	1	1	1	3	41.27	8.12	9.45
12	20	0	0	2	1	2	1	2	41.27	8.12	9.45
13	20	0	0	2	1	2	1	3	41.27	8.12	9.45
14	20	0	0	2	1	3	1	2	41.27	8.12	9.45
15	20	0	0	2	1	3	1	3	41.27	8.12	9.45
16	20	0	0	2	1	4	1	1	41.27	13.64	10.23
17	20	0	0	2	1	5	1	1	41.27	13.64	10.23
18	20	0	0	2	1	4	1	2	41.27	13.64	9.45
19	20	0	0	2	1	4	1	3	41.27	13.64	9.45
20	20	0	0	2	1	5	1	2	41.27	13.64	9.45
21	20	0	0	2	1	5	1	3	41.27	13.64	9.45
22	31	1	0	1	1	1	0	0	12.21	0.63	8.59
23	31	1	0	1	1	2	0	0	12.21	1.55	5.48
24	31	1	0	1	1	3	0	0	15.49	2.52	5.28
25	31	1	0	2	1	4	0	0	32.28	12.16	4.43
26	31	1	0	2	1	5	0	0	32.28	12.16	4.43
27	31	2	0	2	1	4	0	0	34.99	13.65	6.72
28	31	2	0	2	1	5	0	0	34.99	13.65	6.72
29	32	1	0	0	1	0	0	0	32.28	12.25	6.63
30	32	2	0	0	1	0	0	0	34.99	13.73	9.09
31	33	0	0	0	1	1	0	0	32.28	6.90	3.80
32	33	0	0	0	1	2	0	0	32.28	6.90	3.80
33	33	0	0	0	1	3	0	0	32.28	6.90	3.80
34	33	0	0	0	1	4	0	0	32.28	6.90	3.80
35	33	0	0	0	1	5	0	0	32.28	12.16	3.80
36	34	1	0	0	0	0	0	0	28.27	14.13	4.95
37	34	2	0	0	0	0	0	0	30.36	16.34	7.31

FIGURE D-5 WORKSTUDY DATAFILE - WELDING FILE VARIABLES

WELDING: WKSTDYW.RAN

Variable	Description	Options	
W1$	Weld type	1	Single sided fillet
		2	Double sided fillet
		3	Single sided in-plane
		4	Double sided in-plane
W2$	Preparation	1	In-place - deep penetration
		2	- rutile - K prep
		3	- rutile - SK prep
		4	- rutile - M prep
		5	Fillet - rutile
		6	- Iron powder
		7	- Low hydrogen
		8	In-plane - minideck - J prep
		9	- KM prep
		10	- L prep
W3$	Side	1	First side
		2	Second side
W4$	Gauge of rod	12	SWG
		10	SWG
		8	SWG
		6	SWG
		4	SWG
W5$	Restrictions	1	Unrestricted
		2	Restricted
W6$	Working position	1	Downhand
		2	Vertical
		3	Overhead
		4	Horizontal
W7$	Material thickness (mm)		
W8$	Job constant		
W9$	Seam costant		
W10$	Rate		

FIGURE D-6 WORKSTUDY DATAFILE - WELDING FILE LISTING

Rec. No.	Weld type	Prep.	Side	Rod size	Rest'n	Posn.	Thk.	Job const.	Seam const.	Rate
495	1	7	0	8	1	2	5.0	14.04	0.00	9.64
496	1	7	0	10	1	2	6.5	14.04	0.00	22.37
497	1	7	0	8	1	2	6.5	14.04	0.00	17.71
498	1	7	0	10	1	2	8.0	14.04	0.00	29.91
499	1	7	0	8	1	2	8.0	14.04	0.00	26.80
500	1	7	0	10	1	2	9.5	14.04	0.00	40.54
501	1	7	0	8	1	2	9.5	14.04	0.00	36.21
502	1	7	0	8	1	2	11.0	14.04	0.00	43.30
503	1	7	0	8	1	2	12.5	14.04	0.00	52.15
504	1	7	0	12	1	3	3.0	14.04	0.00	13.78
505	1	7	0	10	1	3	5.0	14.04	0.00	14.69
506	1	7	0	8	1	3	5.0	14.04	0.00	12.00
507	1	7	0	10	1	3	6.5	14.04	0.00	23.12
508	1	7	0	8	1	3	6.5	14.04	0.00	15.22
509	1	7	0	10	1	3	8.0	14.04	0.00	31.13
510	1	7	0	8	1	3	8.0	14.04	0.00	20.73
511	1	7	0	8	1	3	9.5	14.04	0.00	35.62
512	1	7	0	8	1	3	11.0	14.04	0.00	48.81
513	1	7	0	8	1	3	12.5	14.04	0.00	66.12
514	1	7	0	12	2	1	3.0	14.04	0.00	11.35
515	1	7	0	10	2	1	5.0	14.04	0.00	11.91
516	1	7	0	8	2	1	5.0	14.04	0.00	9.64
517	1	7	0	10	2	1	6.5	14.04	0.00	20.27
518	1	7	0	8	2	1	6.5	14.04	0.00	16.43
519	1	7	0	6	2	1	6.5	14.04	0.00	10.86
520	1	7	0	4	2	1	6.5	14.04	0.00	7.25
521	1	7	0	8	2	1	8.0	14.04	0.00	29.72
522	1	7	0	6	2	1	8.0	14.04	0.00	20.30
523	1	7	0	4	2	1	8.0	14.04	0.00	12.20
524	1	7	0	6	2	1	9.5	14.04	0.00	28.54
525	1	7	0	4	2	1	9.5	14.04	0.00	21.25
526	1	7	0	6	2	1	11.0	14.04	0.00	36.01
527	1	7	0	4	2	1	11.0	14.04	0.00	32.86

FIGURE D-7 STIFFENER WEIGHT DATAFILE - FILE VARIABLES

Variable	Description	Options
TYPE$	Section type	OAB Ordinary angle bar OBP Offset Bulb Plate FB Flat Bar
DEPTH$	Section depth	(mm)
FLANGE$	Flange width	(mm) 0 Flat bar 1 Offset bulb plate
WEIGHT$	Weight per unit length	kg/m

FIGURE D-8 STIFFENER WEIGHT DATAFILE - FILE LISTING

Stiff'r	Depth	Flange	Thk.	kg/m
OAB	120	120	8.0	14.700
OAB	120	120	10.0	18.200
OAB	120	120	12.0	21.600
OAB	120	120	15.0	26.600
OAB	150	150	10.0	23.000
OAB	150	150	12.0	27.300
OAB	150	150	15.0	33.800
OAB	150	150	18.0	40.100
OAB	200	200	16.0	48.500
OAB	200	200	18.0	54.200
OAB	200	200	20.0	59.900
OAB	200	200	24.0	71.100
OAB	40	25	4.0	1.910
OAB	60	30	5.0	3.370
OAB	60	30	6.0	3.990
OAB	65	50	5.0	4.350
OAB	65	50	6.0	5.160
OAB	65	50	8.0	6.750
OAB	75	50	6.0	5.650
OAB	75	50	8.0	7.390
OAB	80	60	6.0	6.370
OAB	80	60	7.0	7.360
OAB	80	60	8.0	8.340
OAB	100	65	7.0	8.770
OAB	100	65	8.0	9.940
OAB	100	65	10.0	12.300
OAB	100	75	8.0	10.600
OAB	100	75	10.0	13.000
OAB	100	75	12.0	15.400
OAB	125	75	8.0	12.200
OAB	125	75	10.0	15.000
OAB	125	75	12.0	17.800
OAB	150	75	10.0	17.000
OAB	150	75	12.0	20.200
OAB	150	75	15.0	24.800
OAB	150	90	10.0	18.200
OAB	150	90	12.0	21.600

FIGURE D-9 <u>DATAFILE RECORD NUMBERS FOR "T" AND "C" FILES</u>

				Codes				
SIDE SHELL				*IS=1*	*2*	*3*	*4*	
Plating -	seams	IS		1	2	3	4	
	butts	4+IS		5	6	7	8	
	inter-plt gp seams	9						9
Frames -		(10*ID)+1		11	21	31	41	
Deep frames -	webs	(10*ID)+2		12	22	32	42	
	flanges	(10*ID)+3		13	23	33	43	
DECKS			*IDP=*	*ID=1*	*2*	*3*	*4*	
Plating -	seams	(30*ID)+20+IDP	*1*	51	81	111	141	
			2	52	82	112	142	
			3	53	83	113	143	
			4	54	84	114	144	
	butts	(30*ID)+24+IDP	*1*	55	85	115	145	
			2	56	86	116	146	
			3	57	87	117	147	
			4	58	88	118	148	
	inter-plt gp seams	(30*ID)+29		59	89	119	149	
			IDL=					
Longitudinals -		(30*ID)+3)+IDL	*1*	61	91	121	151	
			2	62	92	122	142	
			3	63	93	123	143	
			4	64	94	124	144	
			IDG=					
Girders -	webs	(30*ID)+35+IDG	*1*	66	96	126	146	
			2	67	97	127	147	
			3	68	98	128	148	
	flanges	(30*ID)+38+IDG	*1*	69	99	129	149	
			2	70	100	130	150	
			3	71	101	131	151	
Transverses -	webs	(30*ID)+43		73	103	133	163	
	flanges	(30*ID)+44		74	104	134	164	
Longl/trans conn		(30*ID)+45		75	105	135	165	
Gdr/trans conn		(30*ID)+46		76	106	136	166	
DECK/SIDE SHELL CONNECTION								
Plates		(30*ID)+47		77	107	137	167	
Beam knees -	normal frames	(30*ID)+48		78	108	138	168	
	deep frames	(30*ID)+49		79	109	139	169	
Brackets -	normal frames	170+ID		171	172	173	174	
	deep frames	174+ID		175	176	177	178	

FIGURE D-10 "T" FILE VARIABLES - RECORDS 1 TO 179

VARIABLES	FIELD LENGTH	RECORDS 1 - 179	
T1$	2	LSD$	Check for data in record "£$"
T2$	25	TITLE$	Title
T3$	2	AREA	'Area' e.g. Dk no.
T4$	2	SUBAREA	'Sub-area' e.g. Longl. group no.
T5$	3	NME	Component type identifier
T6$	2	TY	Material type identifier
T7$	3		No. of items
T8$	3		No. of pieceparts - total
T9$	3		- cut
T10$	3		Fillet welds - no
T11$	3		type
T12$	2		prep
T13$	8		length
T14$	3		In-plane welds - no
T15$	3		type
T16$	2		prep
T17$	8		length
T18$	3		Burns - no
T19$	8		length
T20$	8		Weight
T21$	8		Surface area
T22$	2		Shape
T23$	6		Length of item
T24$	4		Depth of item
T25$	4		Thickness of item
T26$	2		Code - length
T27$	2		thickness
T28$	8	*FABTOT	Fillet processes - fairing std. minutes
T29$	8	*WLDTOT	- welding std. minutes
T30$	8	*PFABTOT	In-plane processes - fairing std. minutes
T31$	8	*PWLDTOT	- welding std. minutes
	156		

Values marked * are added to the file during 'UNITREAD'

FIGURE D-11 "T" FILE VARIABLES - RECORD 180

FIELD VARIABLES	RECORD 180	
T1$	LSD$	Check for data in record "£$"
T2$		
T3$	ND	No. of decks
T4$	NS	No. of side shell plate groups
T5$		
T6$		
T7$		
T8$		
T9$		
T10$		
T11$		
T12$		
T13$	MANFS	Manning - fairing, skilled
T14$		
T15$		
T16$		
T17$	MANFU	- fairing, unskilled
T18$		
T19$	MANWS	- welding, skilled
T20$	MANWS	- welding, unskilled
T21$	PRODP	Productivity - preparation
T22$		
T23$	PRODF	- fairing
T24$		
T25$	PRODW	- welding
T26$		
T27$		
T28$		
T29$		
T30$		
T31$		

FIGURE D-12 OPTIONS FOR COMPONENT VARIABLE - "NME"

110	Side shell plates		
120	Side shell frames		
131	Side shell deep frames	-	webs
132		-	flanges
210	Deck plates		
220	Deck longitudinals		
231	Deck girders	-	webs
232		-	flanges
241	Deck transverses	-	webs
242		-	flanges
251	Longitudinal/transverse connections		
252	Girders/transverse connections		
310	Deck/side shell connections	-	plates
320		-	beam knees
330		-	brackets

FIGURE D-13 OPTIONS FOR MATERIAL VARIABLE - "TY"

10	In-plane butts and seams
20	'T' fashion arrangement
31	OBP's < 305 mm
32	OBP's > 305 mm
33	OAB's and FB's
34	Round bars

FIGURE D-14 "C" FILE VARIABLES - RECORDS 1 TO 179

VARIABLES	FIELD LENGTHS	RECORD 1 - 179	Values are per component
C1$	2	"£$"	Check for data in record
C2$	9	L1FS	Lab. hrs. corrected for manning - fair, skilled
C3$	9	L1FU	- fair, unskilled
C4$	9	L1PFS	- piecepart, fair, skilled
C5$	9	L1PFU	- piecepart, fair, unskilled
C6$	9	L1WS	- weld, skilled
C7$	9	L1WU	- weld, unskilled
C8$	9	L1PWS	- piecepart, weld, skilled
C9$	9	L1PWU	- piecepart, weld, unskilled
C10$	9	L2FS	Lab. hrs. corrected for productivity - fair, skilled
C11$	9	L2FU	- fair, unskilled
C12$	9	L2PFS	- piecepart, fair, skilled
C13$	9	L2PFU	- piecepart, fair, unskilled
C14$	9	L2WS	- weld, skilled
C15$	9	L2WU	- weld, unskilled
C16$	9	L2PWS	- piecepart, weld, skilled
C17$	9	L2PWU	- piecepart, weld, unskilled
C18$	10	L3FS	Labour costs - fair skilled
C19$	10	L3FU	- fair, unskilled
C20$	10	L3PFS	- piecepart, fair, skilled
C21$	10	L3PFU	- piecepart, fair, unskilled
C22$	10	L2WS	- weld, skilled
C23$	10	L3WU	- weld, unskilled
C24$	10	L3PWS	- piecepart, weld, skilled
C25$	10	L3PWU	- piecepart, weld, unskilled
C26$	10	CSECT	Cost of material - sections
C27$	10	CPLT	Cost of material - plates
C28$	10	OFAB	Overhead cost - fairing
C29$	10	OWLD	Overhead cost - welding
	266		

FIGURE D-15 "C" FILE VARIABLES - RECORD 180

FIELD VARIABLES	RECORD 180	Values are per unit
C1$	"£$"	Check for data in record
C2$	TFS	Lab. cost - fair, skilled
C3$	TFU	- fair, unskilled
C4$	TPFS	- piecepart, fair, skilled
C5$	TPFU	- piecepart, fair, unskilled
C6$	TWS	- weld, skilled
C7$	TWU	- weld, unskilled
C8$	TPWS	- piecepart, weld, skilled
C9$	TPWU	- piecepart, weld, unskilled
C11$	LABF	Lab. cost - fair total
C11$	LABW	- weld total
C12$	TLAB	- total
C13$	TSECT	Material cost - sections
C14$	TPLT	- plates
C15$	TMAT	- total
C16$	TOFAB	Overhead cost - fair
C17$	TOWLD	- weld
C18$	TOTOT	- total
C19$	TOTAL	Total cost
C20$	NJTSECT	Sections - no. of items
C21$	NPPTSECT	- total no. of pieceparts
C22$	NPPCSECT	- no. of cut pieceparts
C23$	NFLLTS	Section fillet welds - total no.
C24$	LFLLTS	- total length
C25$	NINPLS	Section in-plane welds - total no.
C26$	LINPLS	- total length
C27$	NBSECT	Sections - total no. of burns
C28$	LBSECT	- length of burns
C29$	WTSECT	- total weight

FIGURE D-16 <u>"C" FILE VARIABLES - RECORD 181</u>

FIELD VARIABLES	RECORD 181	Values are per unit
C1$	"£$"	Check for data in record
C2$	SASECT	Sections - total surface area
C3$	NJTPL	Plates - No. of items
C4$	NPPTPLT	- total no. of pieceparts
C5$	NPPCPLT	No. of cut pieceparts
C5$	NFLLTP	Plate fillet welds - total no.
C7$	LFLLTP	- total length
C8$	NINPLP	Plate in-plane welds - total no.
C9$	LINPLP	- total length
C10$	NBPLT	Plates - total no. of burns
C11$	LBPLT	- total length of burns
C12$	WTPLT	- total weight
C13$	SAPLT	- total surface area
C14$	NJTTOT	Total no. of items
C15$	NPPTTOT	Total no. of pieceparts
C16$	NPPCTOT	No. of cut pieceparts
C17$	NFLLT	Fillet welds - total no.
C18$	LFLLT	- total length
C19$	NINPL	In-plane welds - total no.
C20$	LINPL	- total length
C21$	NB	Burns - total no.
C22$	LB	- total length
C23$	WT	Total weight
C24$	SA	Total surface area
C25$	LABP	Lab. cost - preparation total
C26$	OPREP	Overhead cost - preparation total
C27$	LAB	Total labour cost
C28$	O ,D	Total overhead cost
C29$		

FIGURE D-17 DATAFILE RECORD NUMBERS FOR "U" AND "N" FILES

Side Shell:

Top seam	-	plates	1
Bottom seam	-	plates	2
Forward butt	-	plates	3
Aft butt	-	plates	4

Decks:

			ID = 1	2	3	4
Outer seam	- plates	(10*ID) + 0	10	20	30	40
	- transverses	(10*ID) + 1	11	21	31	41
Inner seam	- plates	(10*ID) + 2	12	22	32	42
	- transverses	(10*ID) + 3	13	23	33	43
Forward butt	- plates	(10*ID) + 4	14	24	34	44
	- longls	(10*ID) + 5	15	25	35	45
	- girders	(10*ID) + 6	16	26	36	46
Aft butt	- plates	(10*ID) + 7	17	27	37	47
	- longls	(10*ID) + 8	18	28	38	48
	- girders	(10*ID) + 9	19	29	39	49

FIGURE D-18 "U" FILE VARIABLES - RECORDS 1 TO 49

VARIABLES	FIELD LENGTHS		
U1$	2	LSD$	Check for data in record "£$"
U2$	4	NAMJT(IJT)	Designation no. of 'butt & seam'
U3$	20	TITLE$	Description of 'butt & seam'
U4$	4	DK	Dk no. ('5' for side shell)
U5$	4		No. of items
U6$	2		In-plane weld - no.
U7$	2		- type
U8$	4		- prep
U9$	7		- length
U10$	4		Material thickness
U11$	2		Working position
U12$	2		Shape
U13$	2		Code - thickness
U14$	8	PFABTOT	Standard time for fairing processes
U15$	8	PWLDTOT	Standard time for welding processes
U16$	2	EXCLAM$	If data in record then "!"
	77		

FIGURE D-19 "U" FILE VARIABLES - RECORD 50

FIELD VARIABLES	RECORD 50		
U1$	LSD$	Check for data in record "£$"	
U2$	AUN1$	First unit -	unit no.
U3$	I1$	-	alt've no. for scantlings file
U4$	J1$		for joints file
U5$	CS1$		for cost file
U6$			
U7$			
U8$	AUN2$	Second unit -	unit no.
U9$	I2$	-	alt've no. for scantlings file
U10$	J2$		for joints file
U11$	CS2$		for cost file
U12$			
U13$			
U14$			
U15$			
U16$			

FIGURE D-20 "N" FILE VARIABLES - RECORDS 1 TO 49

VARIABLES	FIELD LENGTH		RECORD 1 - 49 Values are per component i.e. record
N1$	2	LSD$	Check for data in record "£$"
N2$	8	L1PFS	Lab hrs corrected for manning - in-plane, fair, skilled
N3$	8	L1PFU	in-plane, fair, unskilled
N4$	8	L1PWS	in-plane, weld, skilled
N5$	8	L1PWU	in-plane, weld, unskilled
N6$	9	L2PFS	Lab hrs corrected for prodictuvity - in-plane, fair, skilled
N7$	9	L2PFU	in-plane, fair, unskilled
N8$	9	L2PWS	in-plane, weld, skilled
N9$	9	L2PWU	in-plane, weld, unskilled
N10$	10	L3PFS	Lab costs - in-plane, fair, skilled
N11$	10	L3PFU	in-plane, fair, unskilled
N12$	10	L3PWS	in-plane, weld, skilled
N13$	10	L3PWU	in-plane, weld, unskilled
N14$	10	OFAB	Overhead cost - fairing
N15$	10	OWLD	Overhead cost - welding
N16$	10	CITEM	Total cost (lab & ohd)
N17$	4		In-plane weld - no. (U6$)
N18$	9		- length (U9$)
N19$	4		
	157		

FIGURE D-21 "N" FILE VARIABLES - RECORD 50

FIELD VARIABLES		RECORD 50 Totals for the inter-unit joint
N1$	U1$ (LSD$)	Check for data in record "£$"
N2$	U2$ (AUN1$)	First unit - unit no
N3$	U3$ (I1$)	alternative no. for scantlings
N4$	U4$ (J1$)	for joints
N5$	U5$ (CS1$)	for costs
N6$	L2ST	Lab. hrs corrected for production - skilled
N7$	L2UT	unskilled
N8$	U8$ (AUN2$)	Second unit - unit no.
N9$	U9$ (I2$)	- alternative no. for scantlings
N10$	U10$ (J2$)	for joints
N11$	U11$ (CS2$)	for costs
N12$	LABF	Labour cost - fairing
N13$	LABW	welding
N14$	TLAB	total
N15$	TOTOT	Overhead cost
N16$	TOTAL	Total cost
N17$	NINPL	In-plane welds - no.
N18$	LINPL	length
N19$		

FIGURE D-22 "N" FILE VARIABLES - RECORD 51

FIELD VARIABLES		RECORD 51 Totals for inter-unit joints	
N1$	LSD$	Check for data in record "£$"	
N2$	L1PFST	Lab hrs corrected for manning	- in-plane, fair, skilled
N3$	L1PFUT		- in-plane, fair, unskilled
N4$	L1PWST		- in-plane, weld, skilled
N5$	L1PWUT		- in-plane, weld, unskilled
N6$	L2PFST	Lab hrs corrected for production	- in-plane, fair, skilled
N7$	L2PFUT		- in-plane, fair, unskilled
N8$	L2PWST		- in-plane, weld, skilled
N9$	L2PWUT		- in-plane, weld, unskilled
N10$	L3PFST	Lab costs	- in-plane, fair, skilled
N11$	L3PFUT		- in-plane, fair, unskilled
N12$	L3PWST		- in-plane, weld, skilled
N13$	L3PWUT		- in-plane, weld, unskilled
N14$	TOFAB	Overhead costs	- fairing
N15$	TOWLD		- welding
N16$	TOTAL	Total cost	
N17$	L2ST	Lab hrs corrected for production	- skilled
N18$	L2UT		- unskilled
N19$	L2T		- total

FIGURE D-23 "M" FILE VARIABLES - RECORD 1

FIELD VARIABLES	LENGTHS	RECORD 1 - TOTAL FOR ALL UNITS			
M1$	2	LSD$	Check for data in record "£$"		
M2$	2	TYPE$	Type of record	-	"TC"
M3$	4	NUL$	""		
M4$	3	NUL$	""		
M5$	7	CLABP	Labour cost	-	preparation
M6$	7	COPREP	Overhead cost	-	preparation
M7$	7	CLABF	Labour cost	-	fairing
M8$	7	CLABW		-	welding
M9$	7	CTLAB		-	fabrication (fair & weld)
M10$	7	CLAB		-	total (prep & fab)
M11$	7	CTSECT	Material cost	-	sections
M12$	7	CTPLT		-	plates
M13$	7	CTMAT		-	total
M14$	7	CTOTOT	Overhead cost	-	fabrication (fair & weld)
M15$	7	COHD		-	total (prep & fab)
M16$	8	CTOTAL	Total cost	-	(Lab & Mat'l & Ohd)
M17$	5	CNPPS	No of pieceparts	-	sections
M18$	5	CNPPP		-	plates
M19$	5	CNPPC		-	cut
M20$	6	CNPPT		-	total
M21$	6	CNJT	No of joints	-	total
M22$	5	CNFLLT	Fillet welds	-	no
M23$	9	CLFLLT		-	length
M24$	5	CNINPL	In-plane welds	-	no
M25$	9	CLINPL		-	length
M26$	6	CNB	Burns	-	no
M27$	9	CLB		-	length
M28$	9	CWT	Weight		
M29$	9	CSA	Surface area		
	184				

FIGURE D-24 "M" FILE VARIABLES - RECORD 2

FIELD VARAIBLES		RECORD 2 - TOTAL FOR ALL I/U JOINTS		
M1$	LSD$	Check for data in record "£$"		
M2$	TYPE$	Type of record	-	"TN"
N3$	NUL$	""		
M4$	NUL$	""		
M5$	NIL	0		
M6$	NIL	0		
M7$	NLABF	Labour cost	-	fairing
M8$	NLABW		-	welding
M9$	NTLAB		-	fabrication (fair & weld)
M10$	NIL			
M11$	NIL			
M12$	NIL			
M13$	NIL			
M14$	NTOTOT	Overhead cost	-	fabrication (fair & weld)
M15$	NOHD		-	total (fab.)
M16$	NTOTAL	Total cost		
M17$	NIL			
M18$	NIL			
M19$	NIL			
M20$	NIL			
M21$	NIL			
M22$	NIL			
M23$	NIL			
M24$	NNINPL	In-plane welds	-	no.
M25$	NLINPL		-	length
M26$	NIL			
M27$	NIL			
M28$	NIL			
M29$	NIL			

FIGURE D-25 "M" FILE VARIABLES - RECORD 3

FIELD VARIABLES	RECORD 3 - TOTALS FOR 'BLOCK' (UNIT & I/U JOINTS			
M1$	LSD$	Check for data in record		
M2$	TYPE$	Type of record "T"		
M3$	NUL$	""		
M4$	NUL$	""		
M5$	LABP	Labour cost	-	preparation
M6$	OPREP	Overhead cost	-	preparation
M7$	LABF	Labour cost	-	fairing
M8$	LABW		-	welding
M9$	TLAB		-	fabrication (fair & weld)
M10$	LAB		-	total (prep & fab)
M11$	TSECT	Material cost	-	sections
M12$	TPLT		-	plates
M13$	TMAT		-	total
M14$	TOTOT	Overhead cost	-	fabrication (fair & weld)
M15$	OHD		-	total (prep & fab)
M16$	TOTAL	Total cost		(Lab & Mat'l & Ohd)
M17$	NPPS	No of pieceparts	-	sections
M18$	NPPP		-	plates
M19$	NPPC		-	cut
M20$	NPPT		-	total
M21$	NJT	No of joints	-	total
M22$	NFLLT	Fillet welds	-	no.
M23$	LFLLT		-	length
M24$	NINPL	In-plane welds	-	No.
M25$	LINPL		-	length
M26$	NB	Burns	-	no.
M27$	LB		-	length
M28$	WT	Weight		
M29$	SA	Surface area		

FIGURE D-26 "M" FILE VARIABLES - RECORDS 4 TO 200 UNIT DETAILS

FIELD VARIABLES				
M1$	LSD$		Check for data in record "£$"	
M2$	TYPE$		Type of record "C"	
M3$	AUNA$/AUNB$		Unit no	
M4$	C5A$/C5B$		Alternative no.	
M5$	A5/B5		Labour cost	- preparation
M6$	A6/B6		Overhead cost	- preparation
M7$	A7/B7	*	Labour cost	- fairing
M8$	A8/B8	*		- welding
M9$	A9/B9	*		- fabrication (fair & weld)
M10$	A10/B10			- total (prep & fab)
M11$	A11/B11	*	Material cost	- sections
M12$	A12/B12	*		- plates
M13$	A13/B13	*		- total
M14$	A14/B14	*	Overhead cost	- fabrication (fair & weld)
M15$	A15/B15			- total (prep & fab)
M16$	A16/B16	*	Total cost	(Lab & Mat'l & Ohd)
M17$	A17/B17		No of pieceparts	- sections
M18$	A18/B18			- plates
M19$	A19/B19			- cut
M20$	A20/B20			- total
M21$	A21/B21		No of joints	- total
M22$	A22/B22		Fillet welds	- no
M23$	A23/B23			- length
M34$	A24/B24		In-plane welds	- no.
M25$	A25/B25			- length
M26$	A26/B26		Burns	- no.
M27$	A27/B27			- length
M28$	A28/B28		Weight	
M29$	A29/B29		Surface area	

Values marked * are from record 181 of the appropriate 'C' file. Others are from record 182.

FIGURE D-27 "M" FILE VARIABLES -
RECORDS 4 TO 200 INTER-UNIT JOINT DETAILS

FIELD VARIABLES			
M1$	LSD$	Check for data in record "£$"	
M2$	TYPE$	Type of record - "N"	
M3$		Combination (block) no.	
M4$		I/U joint no.	
M5$	NIL		
M6$	NIL		
M7$	D7	Labour cost -	fairing
M8$	D8	-	welding
M9$	D9	-	fabrication (fair & weld)
M10$	NIL		
M11$	NIL		
M12$	NIL		
M13$	NIL		
M14$	D14	Overhead cost -	fabrication (fair & weld)
M15$	NIL		
M16$	D16	Total cost	
M17$	NIL		
M18$	NIL		
M19$	NIL		
M20$	NIL		
M21$	NIL		
M22$	NIL		
M23$	NIL		
M24$	D24	In-plane welds -	no.
M25$	D25	-	length
M26$	NIL		
M27$	NIL		
M28$	NIL		
M29$	NIL		

APPENDIX E   INPUT DATA

This appendix gives a quantitative list of the data input required during the "Layout" and "Scantlin" programs.

"LAYOUT"

- Side Shell — Plating
  - Length
  - Width
  - Shape
- Decks — No. off
  - Deck height
  - Plating
    - Length
    - Width
    - Shape

"SCANTLIN"

Side Shell

- Plating
  - No. of plate groups
    - Width
    - Thickness
    - Shape
    - Weld preps
      - Butts
      - Seams
  - Inter-group weld prep
- ⋮

- <u>Stiffening</u>
  - Alignment of stiffening
  - Frame spacing
  - Frames
    - No. off
    - Scantlings
    - Shape
    - Bracket type
    - Knee type
    - Weld preps
      - Fillet
      - In-plane
  - Deep frames
    - No. off
    - Scantlings
    - Shape
    - Weld preps
      - Fillet
      - In-plane

<u>Decks</u>

- <u>Plating</u>
  - No. of plate groups
    - Width
    - Thickness
    - Shape
    - Weld preps
      - Butts
      - Seams
  - Inter-group weld prep
  - Weld prep for deck/side shell connection

- <u>Stiffening</u>
  - Stiffening alignment
  - Longitudinals
    - No. of groups
      - No. of longls
      - Spacing
      - Scantlings
      - Shape
      - Weld preps
        - Fillet
        - In-plane
  - Girders
    - No. of groups
      - No. of girders
      - Scantlings
      - Shape
      - Continuity
      - Weld preps
        - Fillet
        - In-plane
  - Transverses
    - No. off
    - Shape
    - Continuity
    - Scantlings
    - Weld preps
      - Fillet
      - In-plane
    - Connections
      - Trans/longl
        - Type
        - Prep
      - Trans/gdr
        - Type
        - Prep
    - Beam knee type

Inter-Unit Joints

- Outer Seam — Joint no.
  - Plates
    - Weld type
    - Weld prep
  - Transverses
    - Weld prep
- Inner Seam — Joint no.
  - Plates
    - Weld type
    - Weld prep
  - Transverses
    - Weld prep
- Forward Butt — Joint no.
  - Plates
    - Weld type
    - Weld prep
  - Longls
    - Weld prep
  - Girders
    - Weld prep
- Aft Butt — Joint no.
  - Plates
    - Weld type
    - Weld prep
  - Longls
    - Weld prep
  - Girders
    - Weld prep

Manning and Productivity

- Manning
  - Fairing
    - Skilled
    - Unskilled
  - Welding
    - Skilled
    - Unskilled
- Productivity
  - Preparation
  - Fabrication
  - Erection

APPENDIX F <u>PRODUCTION UNIT CASE STUDY</u>

An example of a deck/side shell unit is considered in this appendix as shown in Figure F-1. The production costs etc. have been calculated for the options given below:

CASE STUDY STRUCTURAL ARRANGEMENTS

	No. 1 A & B As built	No. 2 A & B Reduced Deck Longl. Specg.	No. 3 A & B Alternative Longl. Type	No. 4 A & B Reduced Plt & Stiffr Size (Matl Stds)
Frame Spcg. mm	762	762	762	762
Scantlings mm	400x13 OBP	400x13 OBP	400x13 OBP	400x13 OBP
Longls. Spcg. mm	850	*700	850	850
Scantlings mm	180x11.5 OBP	*180x8 OBP	*150x90x10 OAB	180x11.5 OBP
Transverses mm	400x13 OBP	400x13 OBP	400x13 OBP	400x13 OBP
Plate size m	12x3	12x3	12x3	*8x2
Stiffr size m	12	12	12	*8

* - Changed values

Weld alternative A: Fillets - Manual, Seams - Manual

B: Fillets - Manual, Seams - Semi-Auto

Results

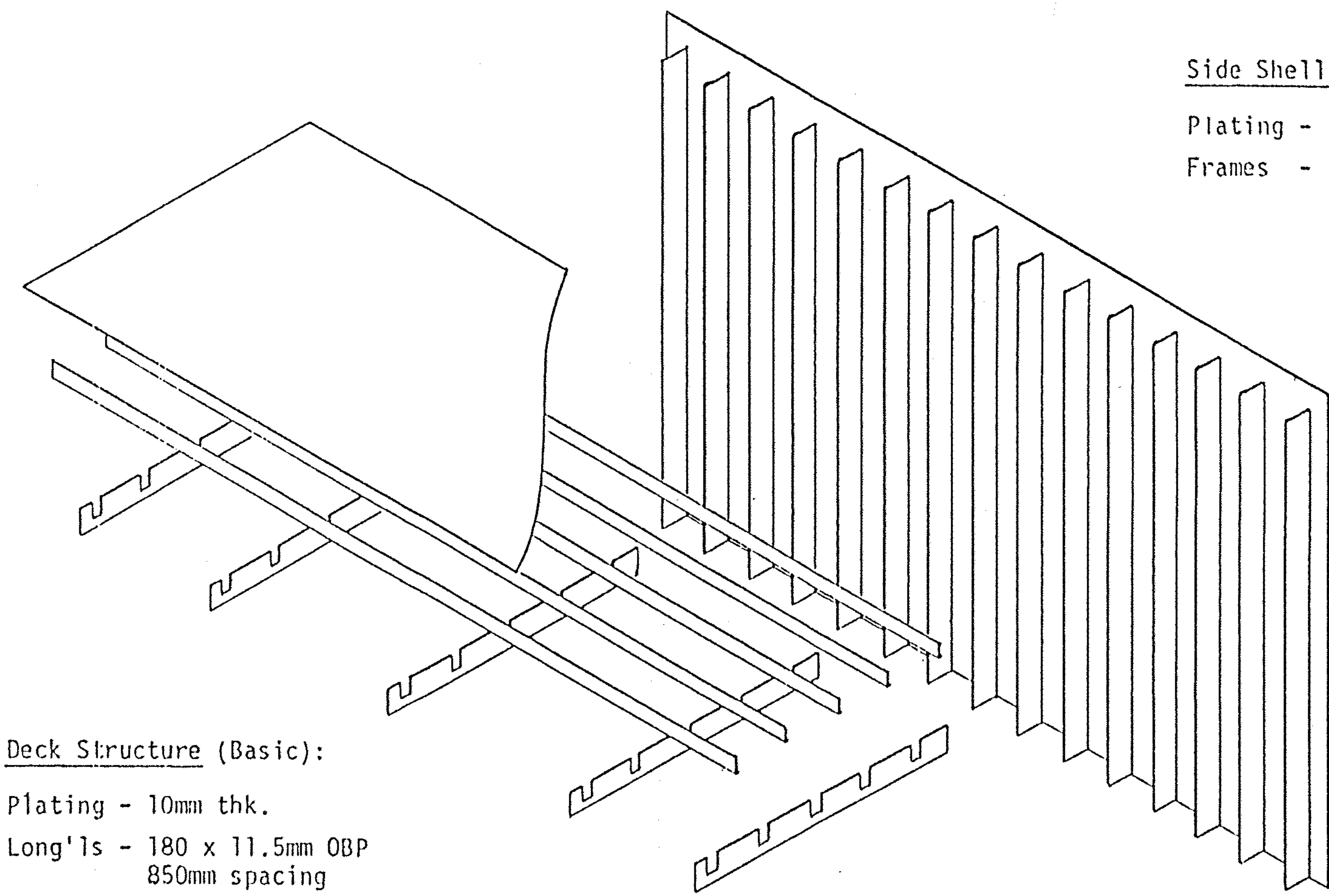
The results of the analysis are shown in figure F-2.

Of interest is the reduction in total cost when OBP's are used rather than OAB's. This amounts to 4% when total costs, including or excluding overheads, are considered.

The use of an automatic welding process for the butts and seams shows a reduction in total costs of approximately 3%. A greater saving would be experienced if fillet welds are completed by automatic or semi-automatic processes.

Finally, by reducing the size of plates and section used from 12m x 3m and 12m respectively to 8m x 2m and 8m, whilst retaining the panel size, the total costs increase by approximately 6%. Hence, it is essential to maximise the size of the materials used in the yard.

FIGURE F-1 CASE STUDY ARRANGEMENT



Side Shell Structure:

Plating - 13.5mm thk.

Frames - 400 x 13mm OBP
762mm spacing

Deck Structure (Basic):

Plating - 10mm thk.

Long'ls - 180 x 11.5mm OBP
850mm spacing

Trans. - 400 x 13mm
5 in No.

Unit length	11.50m
Side Shell Height	7.52m
Deck Width	4.75m

FIGURE F-2 CASE STUDY ANALYSIS

DESIGN OPTIONS

	1		2		3		4	
	Manual	Auto	Manual	Auto	Manual	Auto	Manual	Auto
PRODUCTIVITY = 100%								
Labour	1961	1868	1877	1785	1910	1817	2237	2066
Materials	4571	4571	4404	4404	4545	4545	4571	4571
Total EXCL. O/HD	6532	6439	6201	6189	6455	6362	6808	6637
Overheads	2941	2802	2816	2677	2865	2727	3356	3099
TOTALS INCL O/HD	9473	9241	9097	8866	9320	9088	10164	9736
PRODUCTIVITY = 66%								
Labour	2971	2830	2845	2704	2894	2754	3390	3131
Materials	4571	4571	4404	4404	4545	4545	4571	4571
Totals EXCL. O/HD	7542	7401	7249	7108	7439	7299	7691	7826
Overheads	4456	4245	4267	4057	4342	4132	5085	4696
TOTALS INCL. O/HD	11998	11646	11516	11165	11781	11431	13946	12398

APPENDIX G STIFFENEND DECK PANEL DESIGN

This case study is based on the structure associated with the second deck, outside the line of openings, of a 175m LBP cargo ship. The panel under consideration has constant dimensions of 11.0m x 3.7m. As shown in figure G-1, the deck structure comprises:

Longitudinals - spacing varies between 500mm and 1000mm.

Girders - approx. 4m apart depending on the longitudinals.

Transverses - spaced 3m apart.

The hardcopy output from "Scantlin" and "Yardstds" are given in figures G-2 and G-3.

The scantlings for the designs were generated from Lloyds' Rules for both OAB and OBP longitudinals. The latter were "overdesigned" due to the range of standard sections available. Therefore, only the OAB results were used in the cost comparisons.

The cost factor,

$$k = \frac{\text{labour rate} \quad (\pounds \text{ per manhour})}{\text{material rate} \quad (\pounds \text{ per tonne of steel})}$$

varies between 0.01 and 0.05.

Results

The consequencies on the production cost of varying the cost factor and efficiency can be seen from figures G-4 to G-14.

A note must first be taken of the minimum weight option - design number 2. This criteria is often used to determine which design should be pursued. The weight curve for the designs is given in figure G-4.

The stiffener spacing increases with the design number as detailed in figure G-1, and the number of longitudinals on the panel decreases. The joint length and work content decreases similarly. Hence, as the cost factor (labour rate/materials rate) increases, the spacing associated with the minimum cost design also increases.

The effect of the cost factor on the ranking of designs is dependent on whether overheads are included.

Excluding Overheads

Figures G-5 to G-9 show that as k increases, the differences in in cost of the designs decrease. Also, the optimum stiffener spacing increases. A reduction in the efficiency of the workforce has a similar effect on the optimum stiffener spacing.

Ranking of the designs

	k=0.01			k=0.05		
Cost ranking	Option	Cost	%	Option	Cost	%
1st	2	1.52	100.0	7	3.20	100.0
2nd	7	1.56	102.5	10	3.30	103.0
3rd	6	1.57	103.0	6	3.40	106.3
4th	4	1.59	104.6	8	3.45	107.8
5th	3	1.63	107.2	11	3.50	109.4
Minimum weight	2	1.52	100.2	2	3.60	112.5

At the higher cost factor the total cost of production of the minimum weight design is 12% greater than the minimum cost option. With the lower cost factor the minimum weight design is synonymous with minimum cost.

Including Overheads

Figures G-10 to G-14 demonstrate that although the cost curves flatten as k increases, the ranking does not necessarily change.

Ranking of the designs

	k=0.01			k=0.05		
Cost ranking	Option	Cost	%	Option	Cost	%
1st	7	2.48	100.0	7	4.10	100.0
2nd	6	2.55	102.8	10	4.15	101.2
3rd	10	2.57	103.6	6	4.35	106.1
4th	8	2.66	107.3	8	4.40	107.3
5th	2	2.67	107.7	11	4.45	108.0
Minimum weight	2	2.67	107.7	2	4.70	114.6

The size of the overheads has been taken as 150% of the direct labour costs. Reference 5 suggests that a more realistic figure is 80%. The results with the latter value would probably show a change in ranking.

For both high and low cost factors the cost of the minimum weight design is greater than that associated with the minimum cost option. Typically, the differences are greater than 7% and 14% for k=0.01 and k=0.05 respectively.

FIGURE G-1 STRUCTURAL ARRANGEMENT OF STIFFENED DECK PANELS

DESIGN OPTION	LONGL. SPACG. mm	LONGL. NO.OFF	GDR SPCG. m
1	500	7	4·00
2	550	6	3·85
3	600	6	4·20
4	650	5	3·90
5	700	5	4·20
6	750	4	3·75
7	800	4	4·00
8	850	4	4·25
9	900	4	4·50
10	950	3	3·80
11	1000	3	4·00

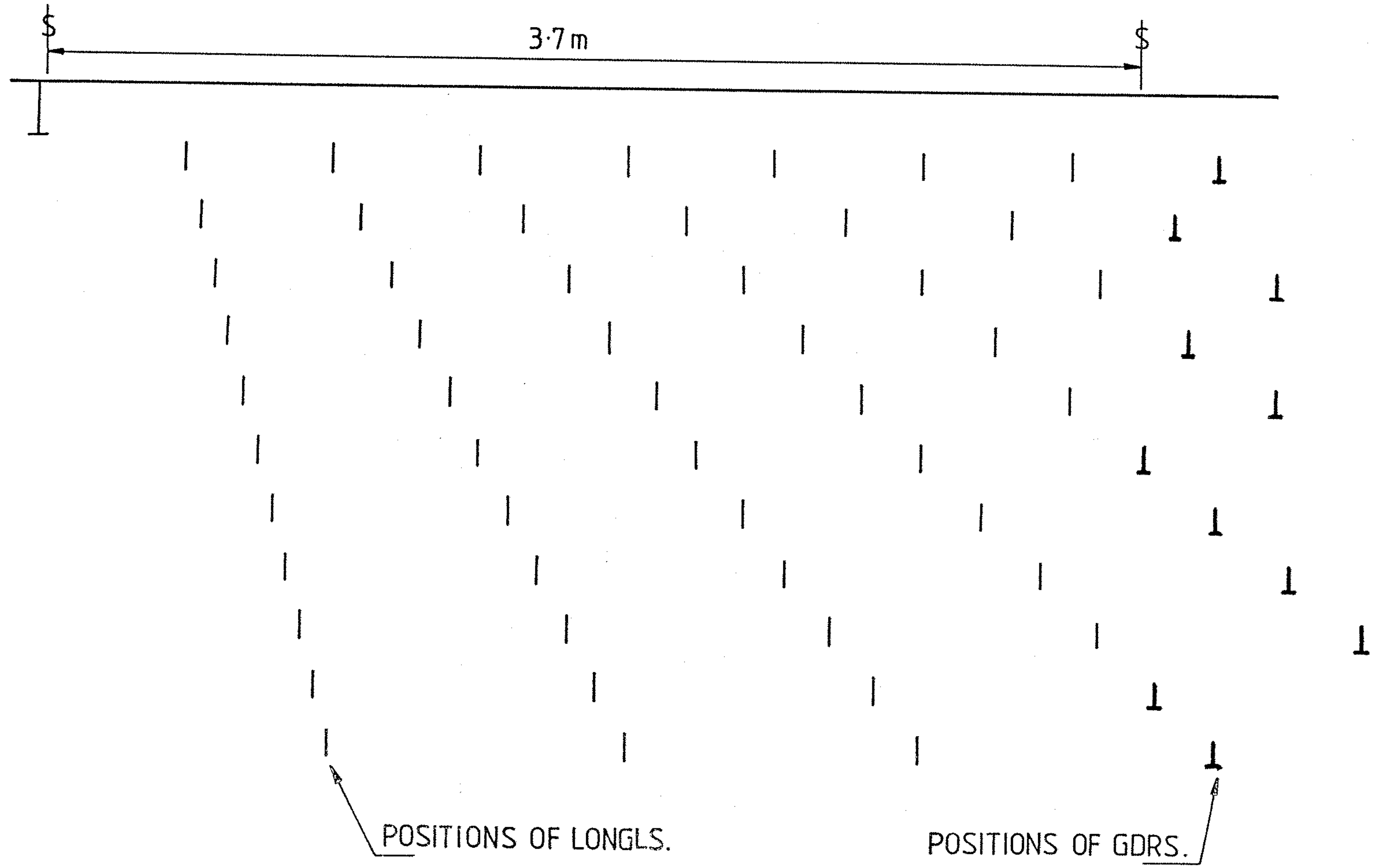


FIGURE G-2 HARDCOPY OUTPUT FROM "SCANTLIN"

SUMMARY OF SCANTLINGS

DECK No: 1

PLATING

Total plating width = 3.7 (m)

Number of Plating Groups 1

Dk.	Sp.	Length m	Width m	Thk. mm	Shp	Preps Seam	Butt	Dk-SS
1	1	11.00	3.70	6.5	1	0	0	0

Alignment of structure L

LONGITUDINALS

No. of groups of longls 1

Dk.	Sp.	Spcg	No.	Dpth mm	Wdth mm	Thk. mm	Shp	Preps Flt	I-p	L-T
1	1	500	7	80	60	10.0	1	5	0	5

TRANSVERSES

Dk.	No.	Dpth mm	Thk mm	Flg. mm	Thk. mm	Shp	Cty	Con L	K	Preps Web Flt	Web I-p	Flg. Flt	Flg. I-p
1	4	150	15.0	125	10.0	1	1	1	0	5	0	5	0

MANNING AND PRODUCTIVITY

MANNING

Fairing -Sklld 2.0 Unsk 1.0

Welding -Sklld 1.0 Unsk 0.0

PRODUCTIVITY

Preparation 100 %

Fairing 100 %

Welding 100 %

FIGURE G-3 HARDCOPY OUTPUT FROM "YARDSTDS"

YARD1

11-18-1986 17:31:02

Wage rates

Skilled	£ 4.00 /hour
Unskilled	£ 3.50 /hour

Material prices

Plates	£275.00 /tonne
Sections	£250.00 /tonne

Overhead_recovery rate

For preparation	150 %	£ 6.00 per manhour
For fairing	150 %	£ 6.00 per manhour
For welding	150 %	£ 6.00 per manhour
For erection	150 %	£ 6.00 per manhour

Standard sizes

Plates - Length, Width	12.0 x 4.0 (m)
Sections - Length	12.0 (m)

FIGURE G-4 WEIGHT CURVE

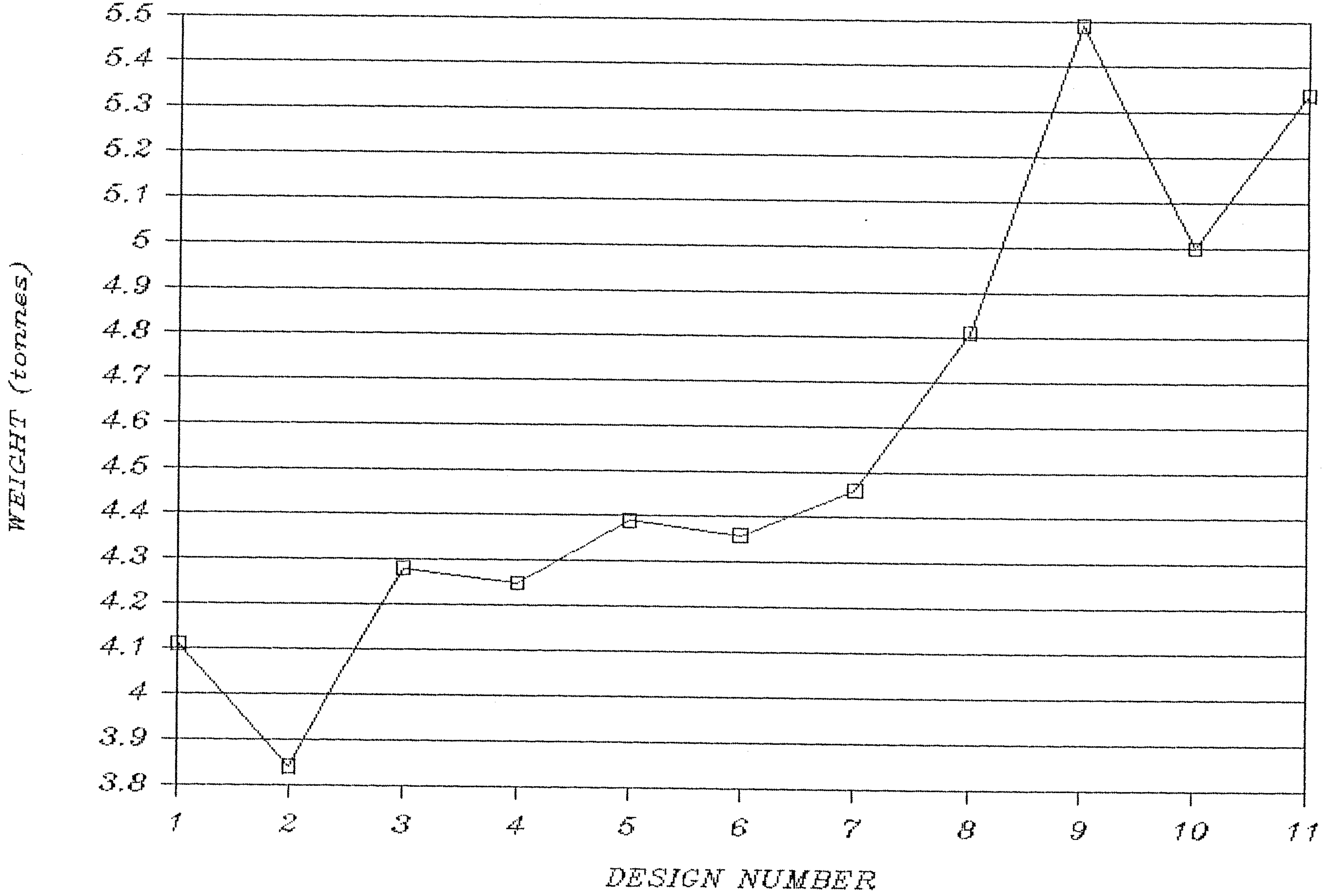


FIGURE G-5 TOTAL COSTS (EXCLUDING OVERHEADS)

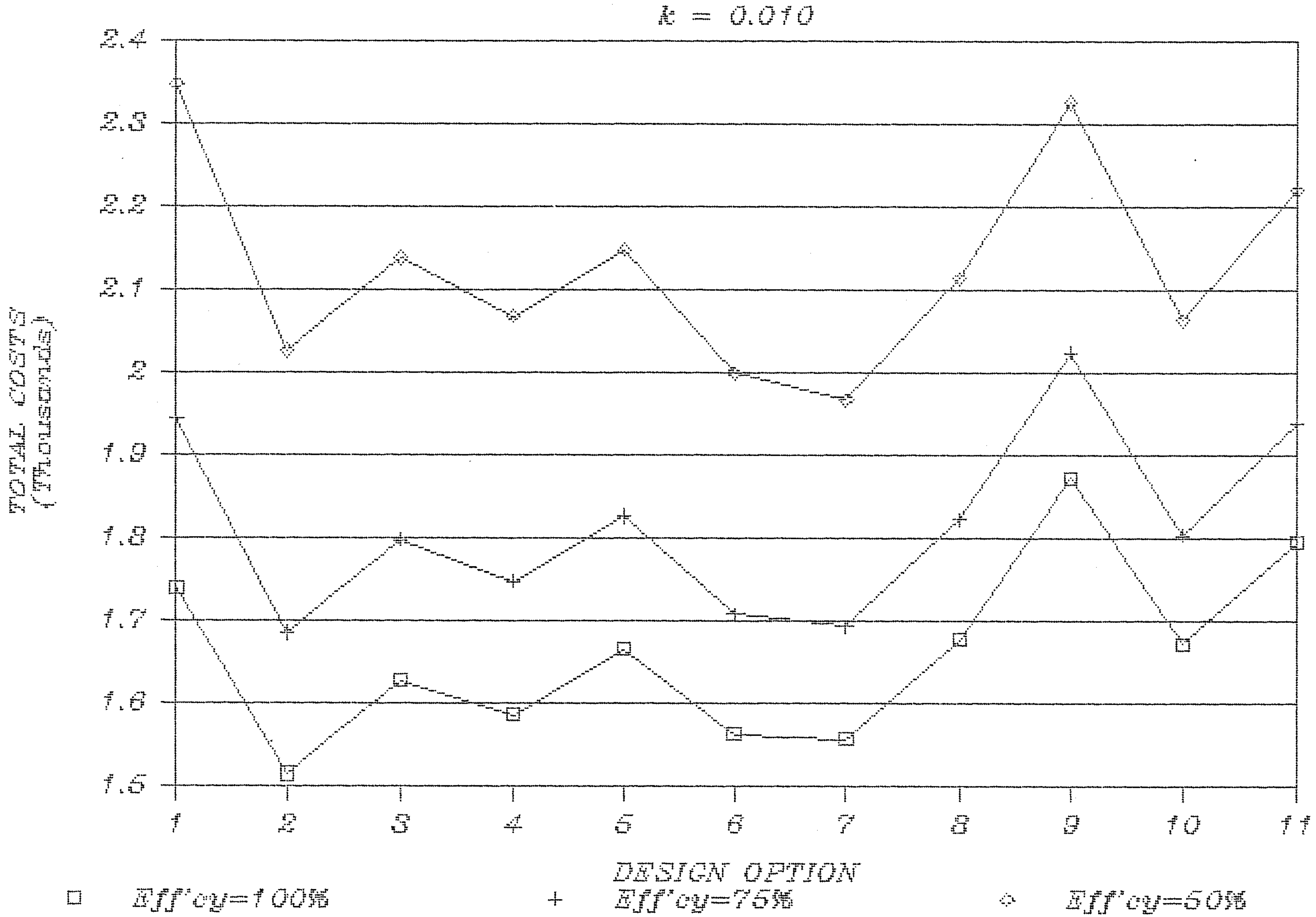


FIGURE G-6 TOTAL COSTS (EXCLUDING OVERHEADS)

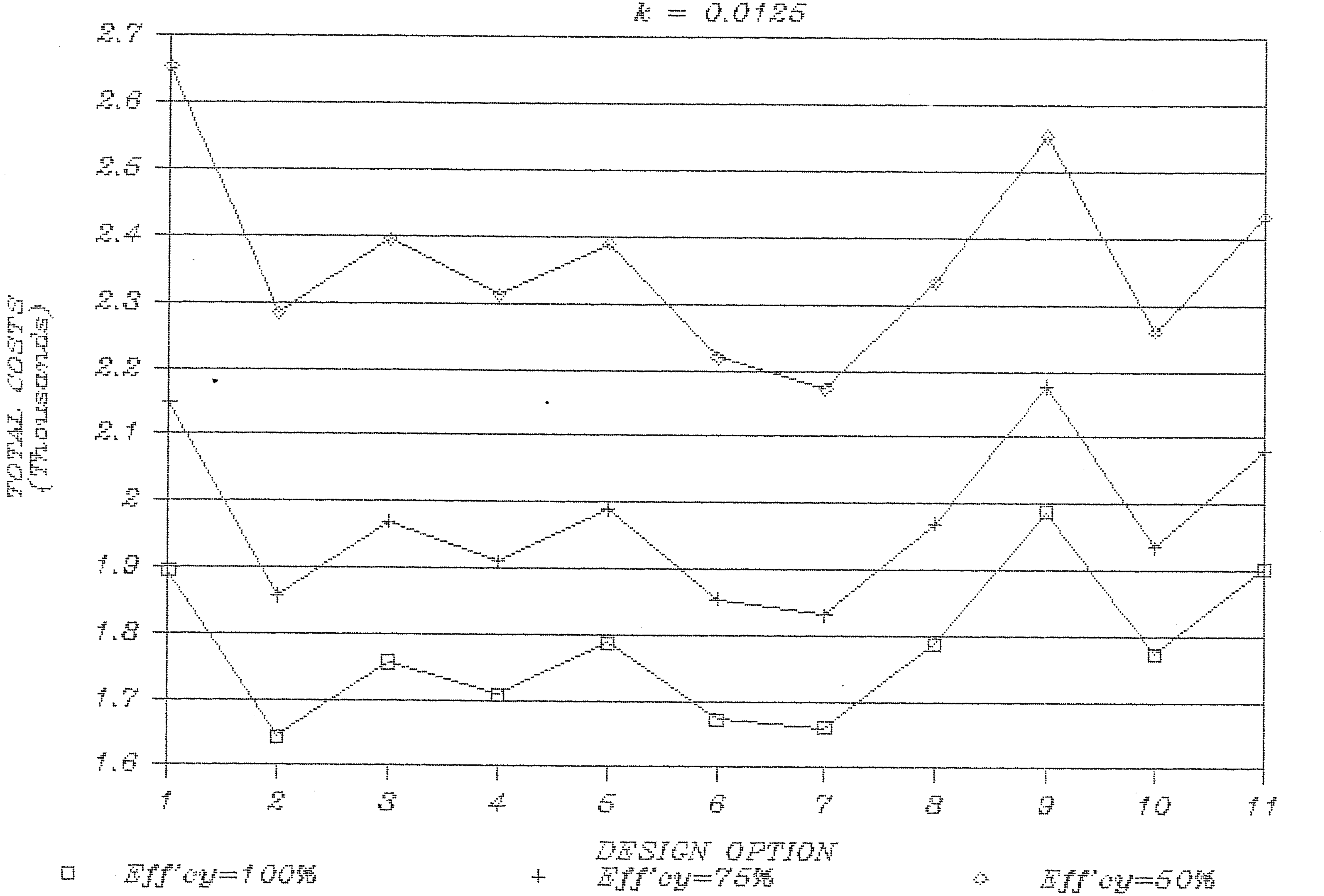


FIGURE G-7 TOTAL COSTS (EXCLUDING OVERHEADS)

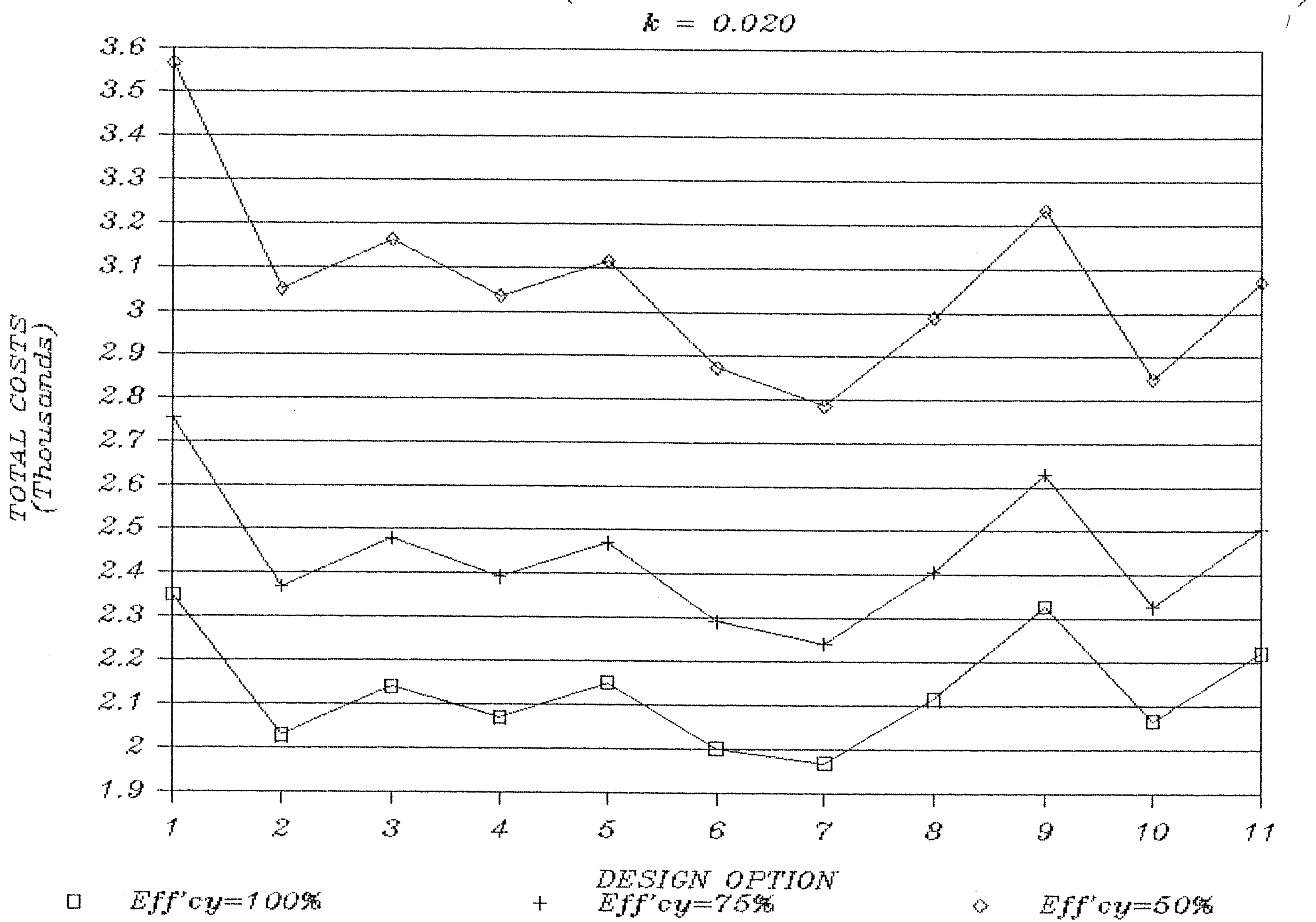


FIGURE G-8 TOTAL COSTS (EXCLUDING OVERHEADS)

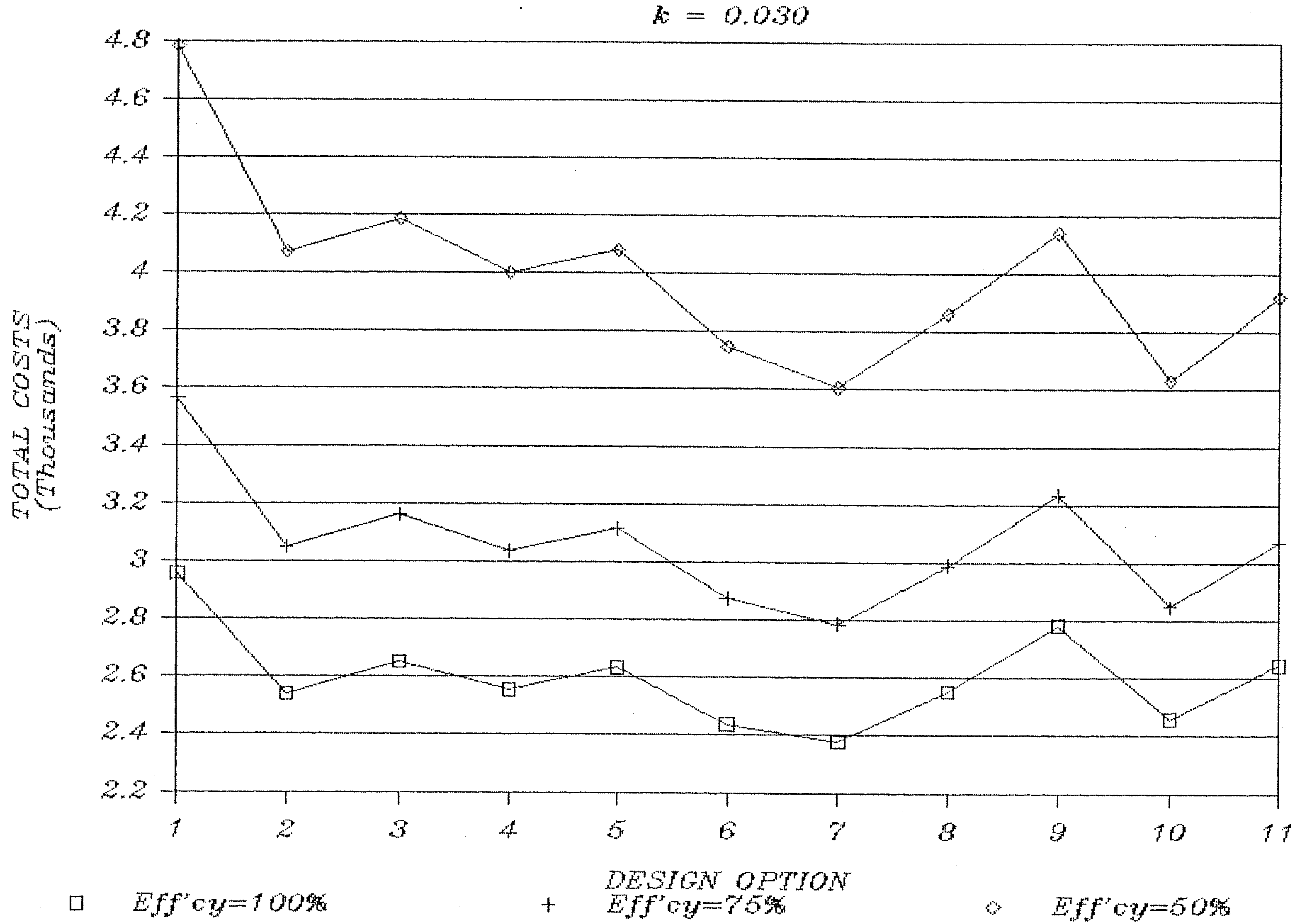


FIGURE G-9 TOTAL COSTS (EXCLUDING OVERHEADS)

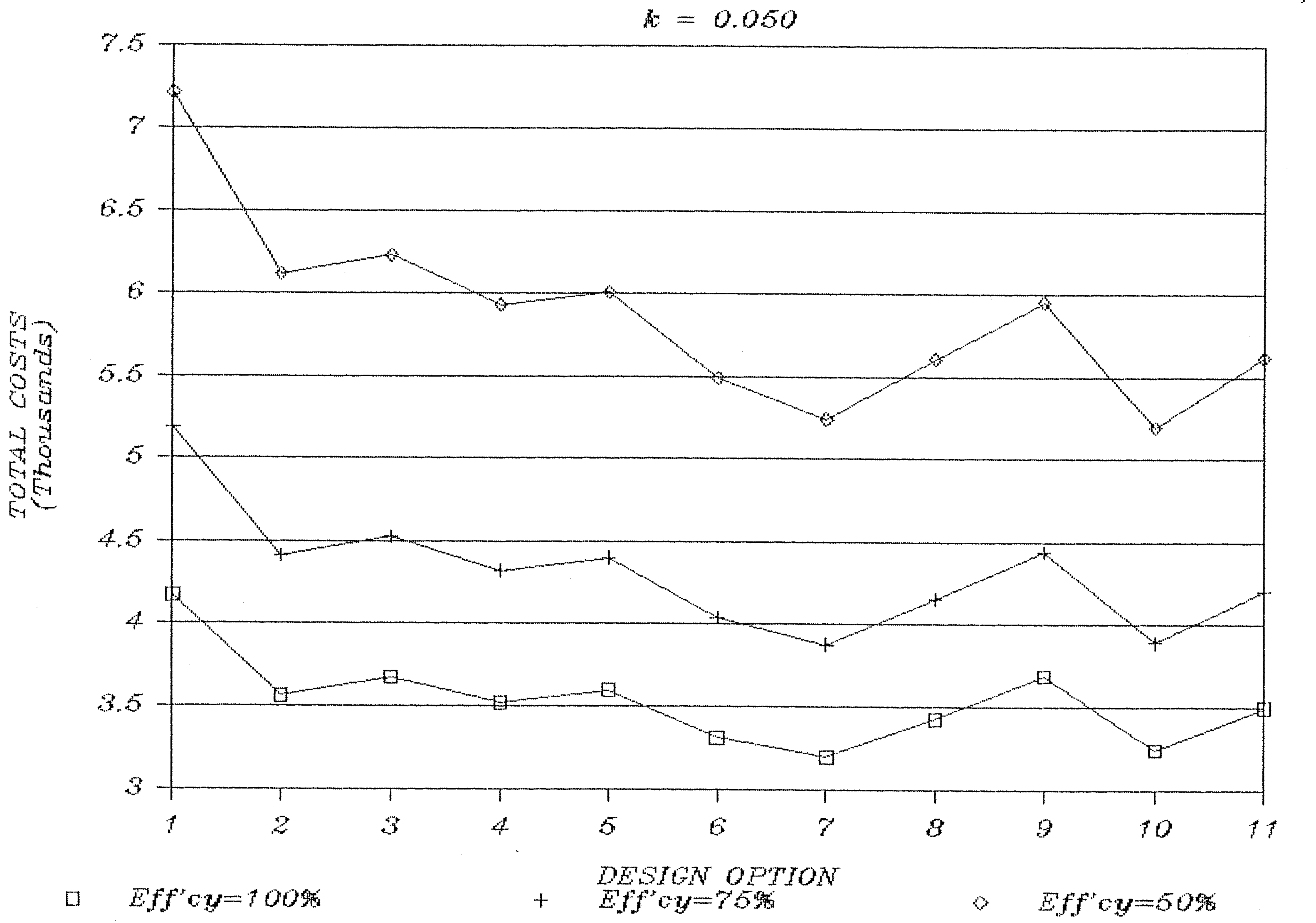


FIGURE G-10

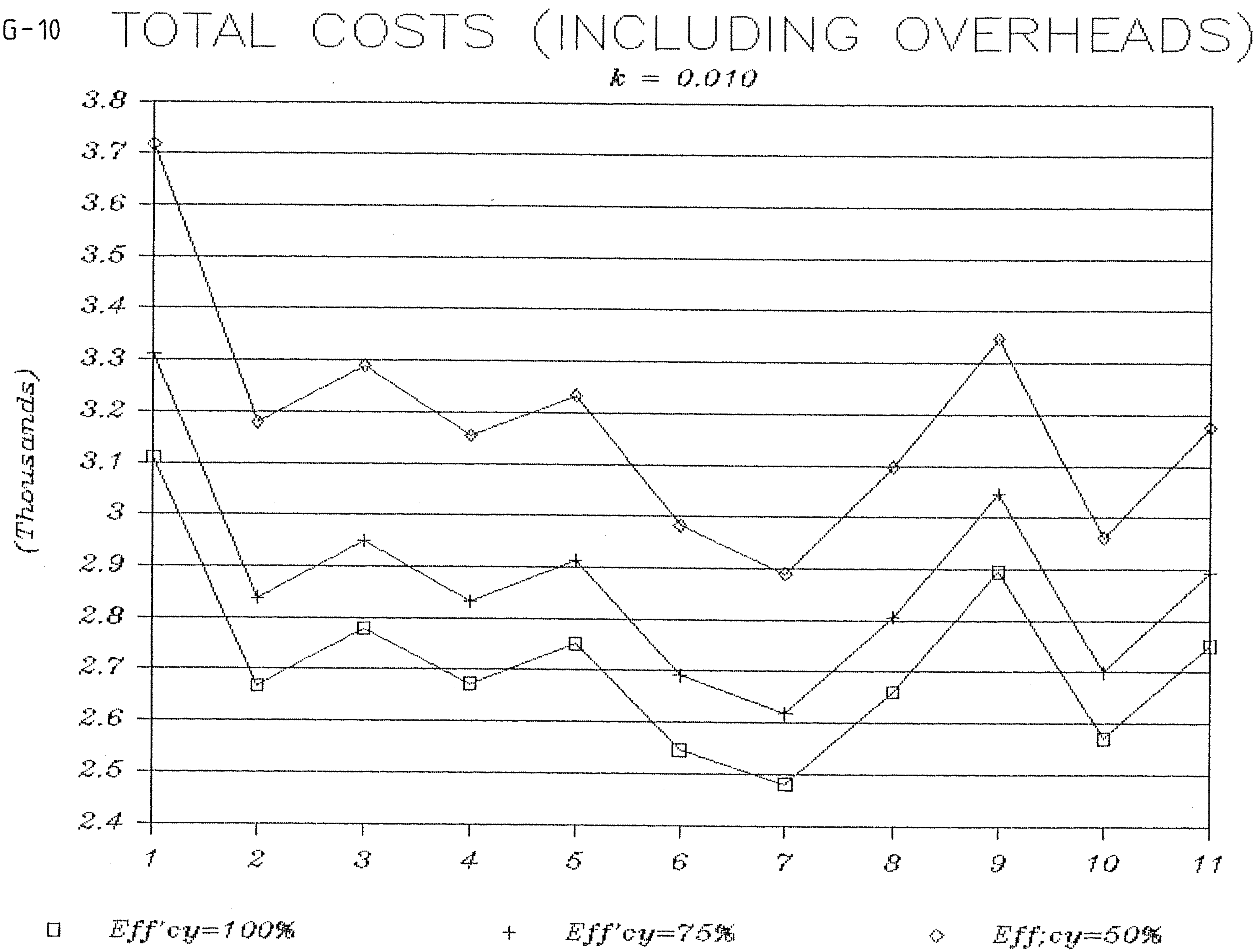

TOTAL COSTS (INCLUDING OVERHEADS)
k = 0.010
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
2.4
(Thousands)
1
2
3
4
5
6
7
8
9
10
11
Eff'cy=100%
Eff'cy=75%
Eff;cy=50%

FIGURE G-11

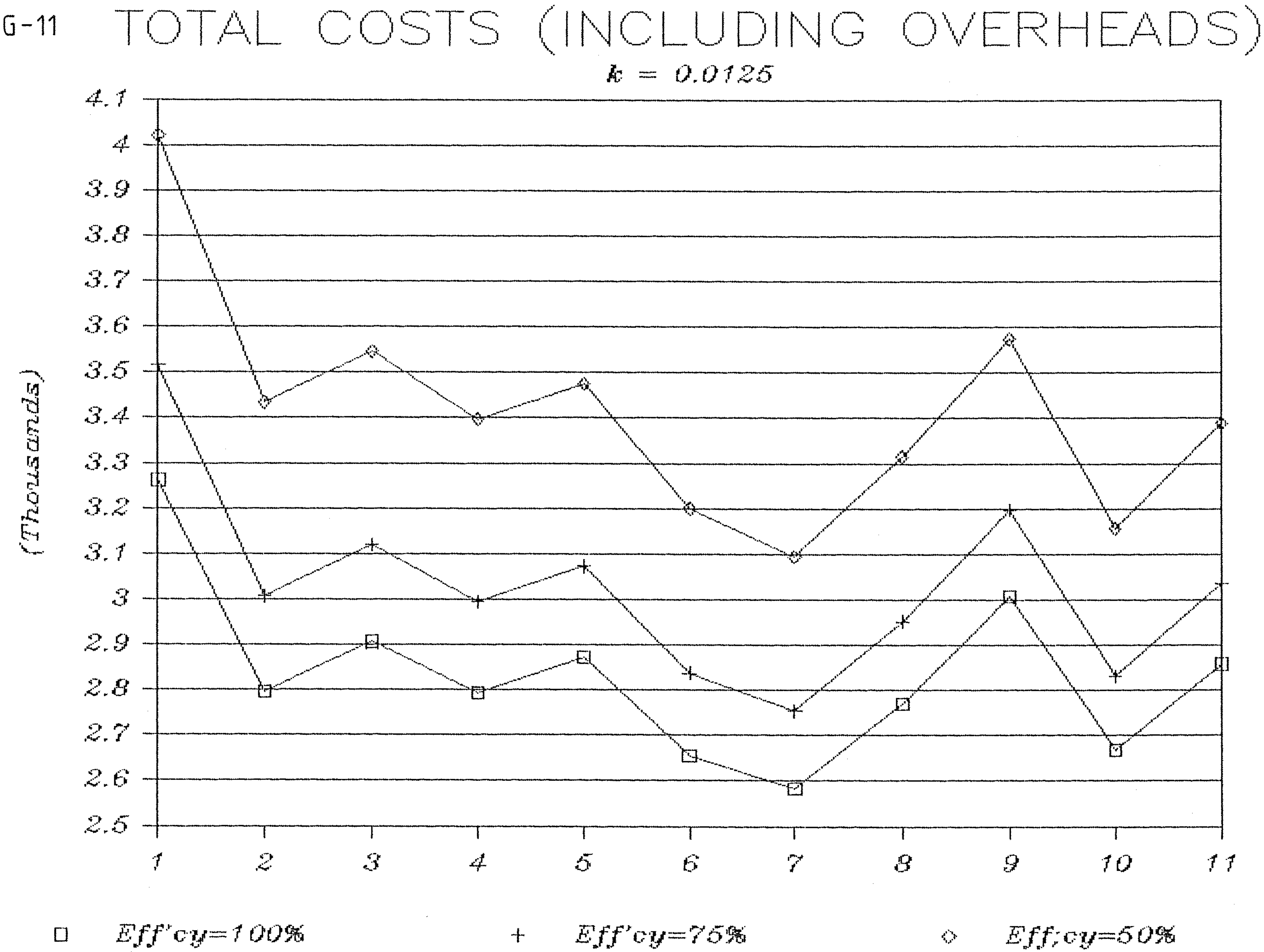

TOTAL COSTS (INCLUDING OVERHEADS)
k = 0.0125
(Thousands)
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
2.7
2.6
2.5
1
2
3
4
5
6
7
8
9
10
11
Eff'cy=100%
Eff'cy=75%
Eff;cy=50%

FIGURE G-12

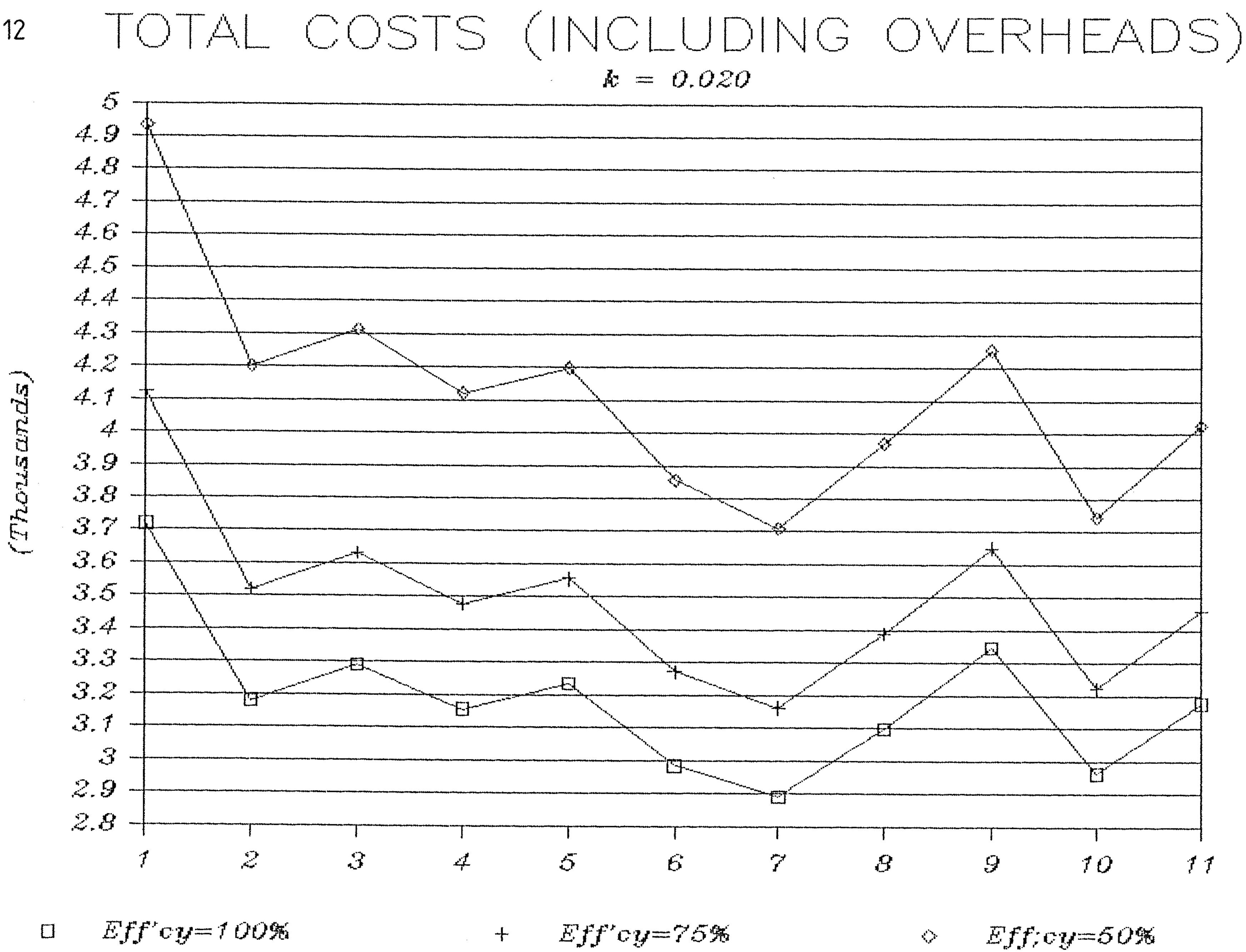

TOTAL COSTS (INCLUDING OVERHEADS)
k = 0.020
(Thousands)
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3
2.9
2.8
1
2
3
4
5
6
7
8
9
10
11
Eff'cy=100%
Eff'cy=75%
Eff;cy=50%

FIGURE G-13

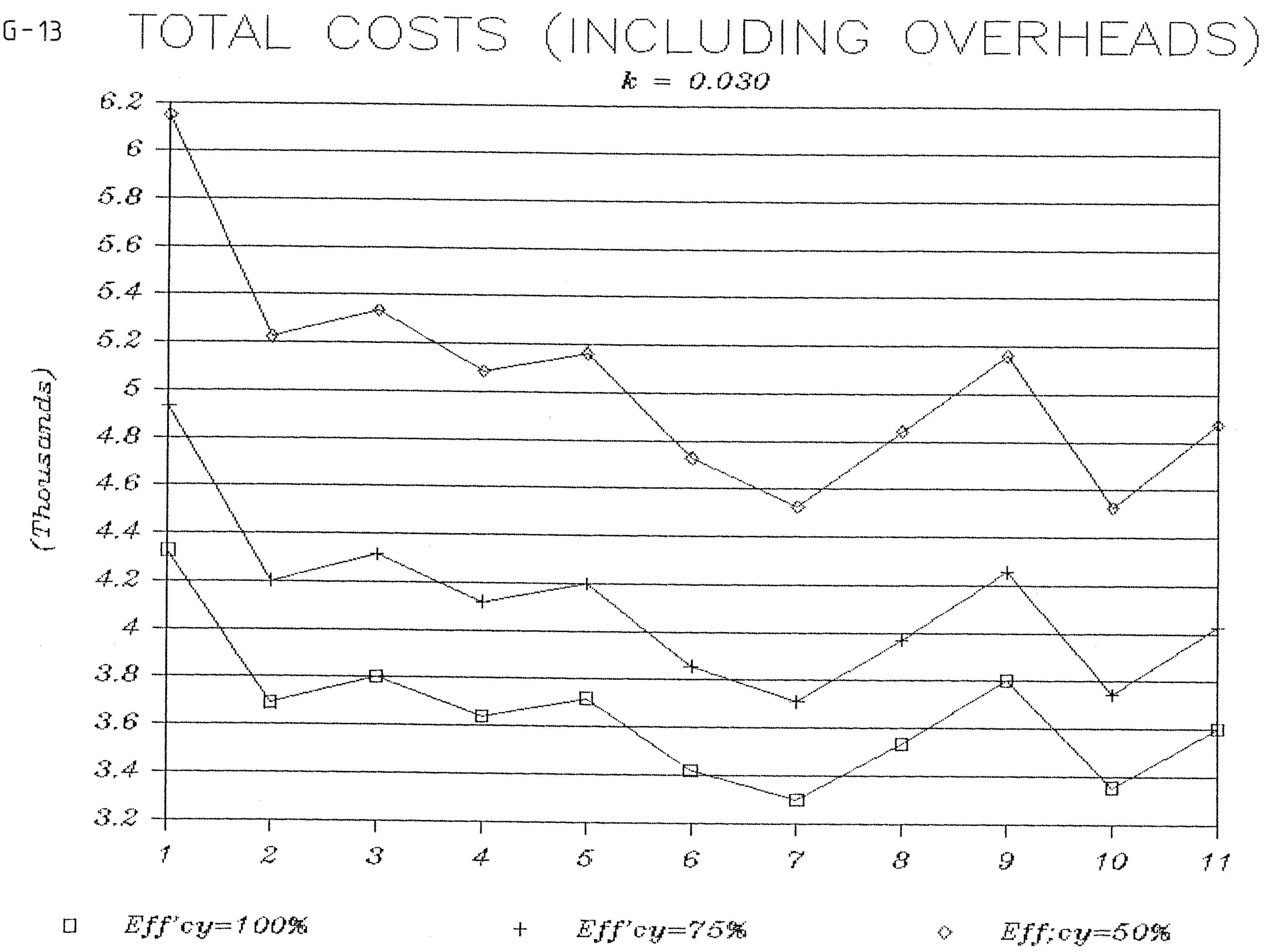
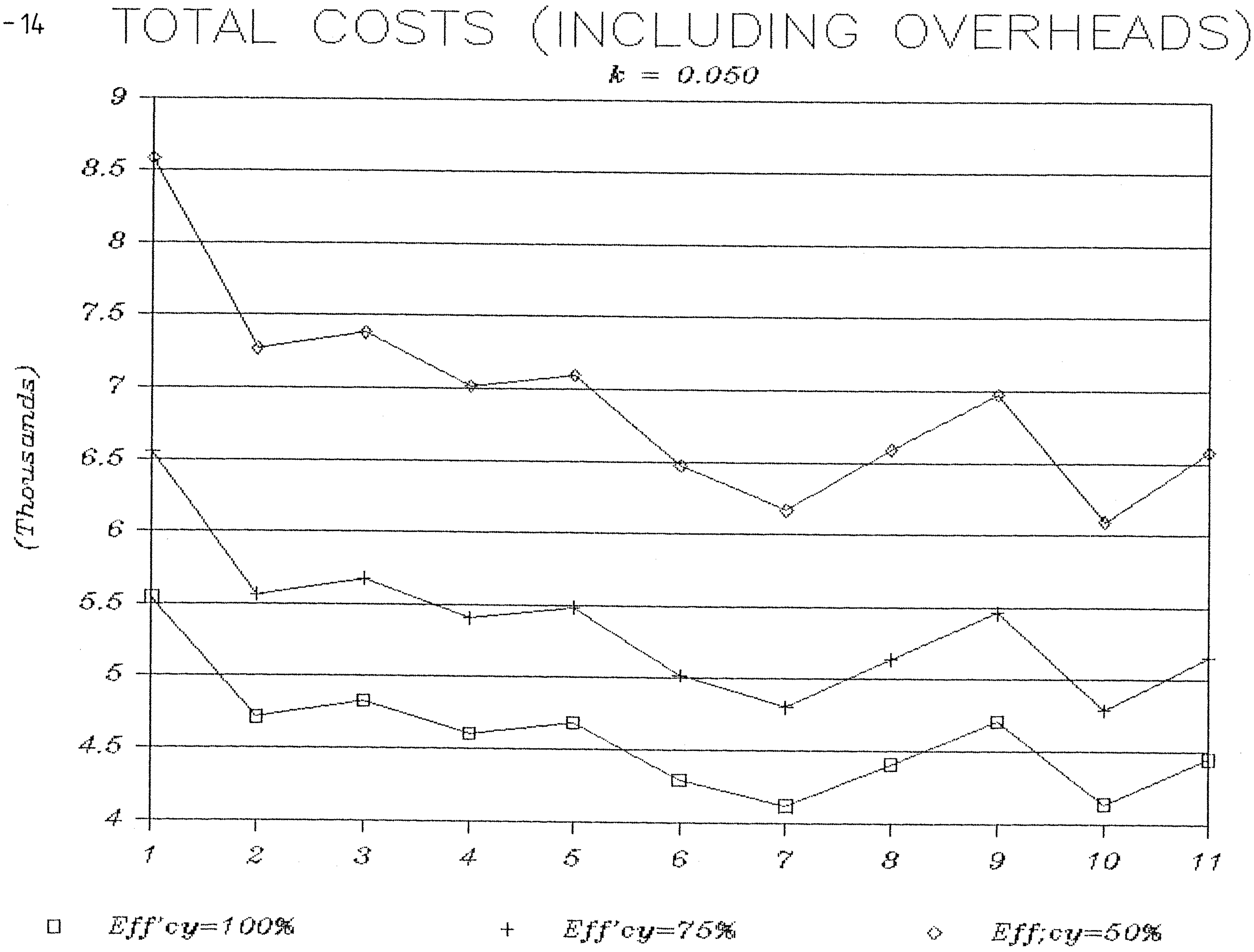

TOTAL COSTS (INCLUDING OVERHEADS)
k = 0.030
(Thousands)
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
1
2
3
4
5
6
7
8
9
10
11
Eff'cy=100%
Eff'cy=75%
Eff;cy=50%

FIGURE G-14



TOTAL COSTS (INCLUDING OVERHEADS)
k = 0.050
(Thousands)
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
1
2
3
4
5
6
7
8
9
10
11
Eff'cy=100%
Eff'cy=75%
Eff;cy=50%

APPENDIX H COMPARISONS WITH PUBLISHED WORK

Baird and Winkle [2], from Glasgow University, examined a number of grillage arrangements (figures H-1 & H-2), suitable for a warship's double bottom, and have determined production costs using their own computer based techniques. The same examples have been run through the programs described in this thesis and construction parameters obtained. The comparisons are detailed in this appendix.

The answers (figures H-3, H-4 and H-5) are rationalised using the Glasgow technique of relating labour rates to material rates:

$$k = \frac{\text{labour rate}}{\text{material rate}}$$

and, hence, their overall cost factor; Cost Equivalent Relative Weight (CERW) is defined as:

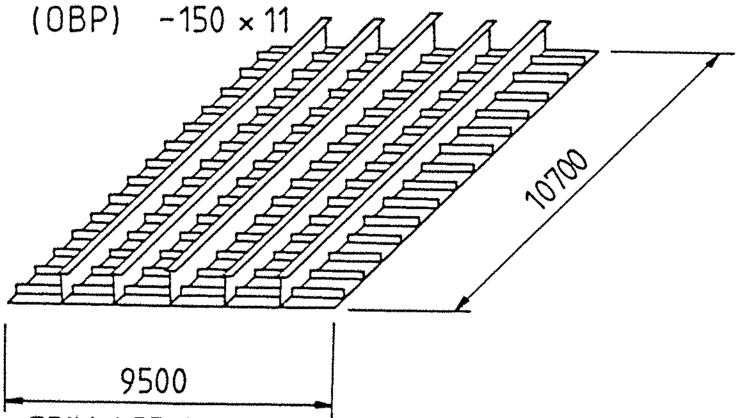
$$\text{CERW} = \text{manhours} \times k + \text{weight(tonne)}$$

Although some of the differences can be accounted for by the Glasgow practice of assuming preparation costs are overheads, there appears to be inconsistencies in the results generated by the programs described in this thesis.

Subsequent to the analysis of Glasgow's work, "bugs" have been found in the BS programs. Therefore, the grillages need to be re-examined to check that the original results are still valid. Despite this, the results show how the ranking of the designs varies with the different criteria (figures H-6 and H-7).

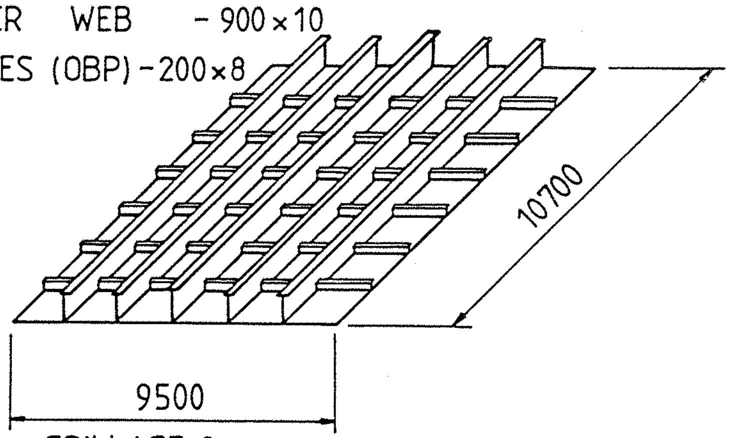
FIGURE H-1 GRILLAGE ARRANGEMENTS

PLATING 11mm. (14 mm. AT KEEL)
GIRDERS FLANGE - 360 × 30
WEB - 870 × 12
KEEL GIRDER FLANGE - 400 × 30
WEB - 1200 × 12
FRAMES (OBP) - 150 × 11



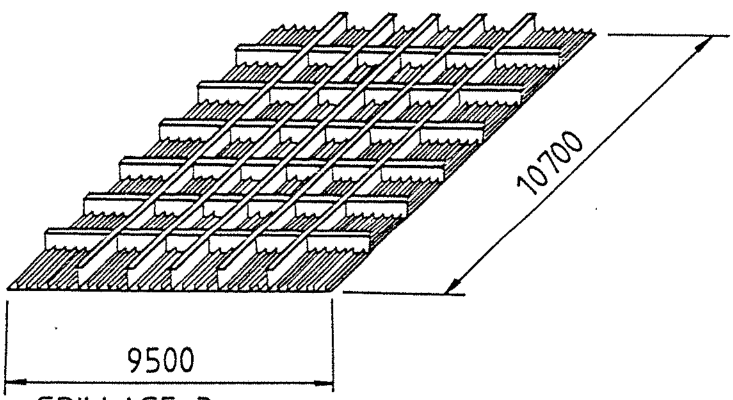
GRILLAGE 1

PLATING 21mm.
GIRDERS FLANGE - 250 × 30
WEB - 700 × 10
KEEL GIRDER FLANGE - 400 × 30
WEB - 900 × 10
FRAMES (OBP) - 200 × 8



GRILLAGE 2

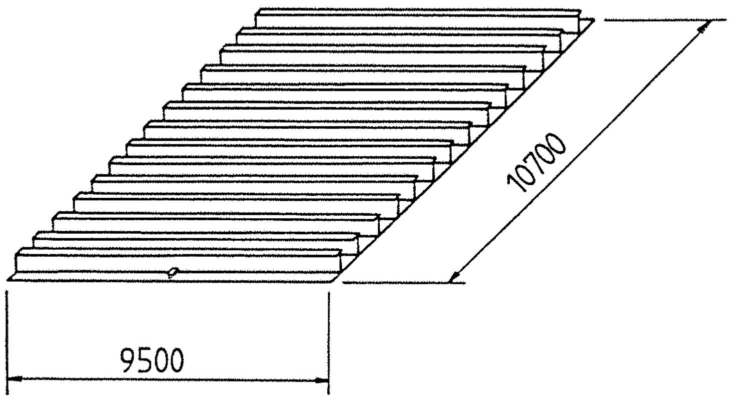
PLATING 8mm. (9 AT KEEL)
GIRDER FLANGE - 200 × 8
WEB - 600 × 6
TRANSVERSE FLANGE - 150 × 8
WEB - 600 × 6
FRAME (TEE) - 42 × 114



GRILLAGE 3

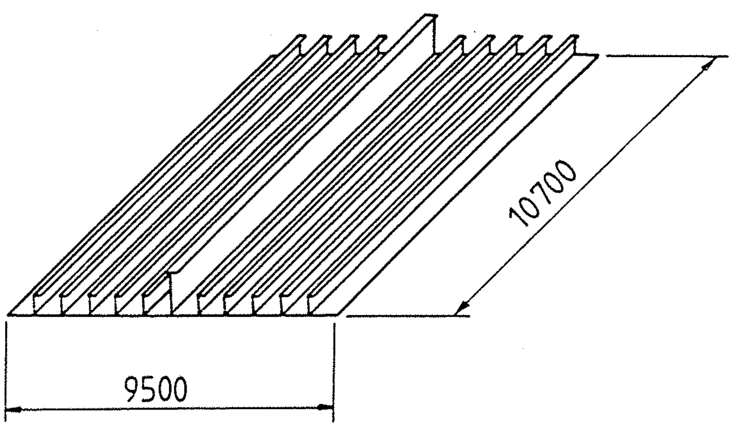
FIGURE H-2 GRILLAGE ARRANGEMENTS

PLATING 11mm.		
TRANSVERSE	FLANGE	- 250 × 20
	WEB	- 600 × 10
KEEL	FLANGE	- 150 × 15
GIRDER	WEB	- 250 × 8



GRILLAGE 4

PLATING 11mm. (14mm. AT KEEL)		
GIRDERS	FLANGE	- 250 × 20
	WEB	- 550 × 10
KEEL	FLANGE	- 400 × 30
GIRDER	WEB	- 1200 × 2



GRILLAGE 5

FIGURE H-3 COMPARISON OF RESULTS - SOUTHAMPTON AND GLASGOW

i) SOUTHAMPTON

Design	Piece-parts			Weld length (m)			Weight	Manhours			CERW k=0.05	
	P/F	Section	Total	Fillets	In-Plane	Total	(t)	Fab 1	Prep 2	Total	(1)	(2)
1	18	38	56	298.8	50.22	349.02	20.45	415.43	142.89	558.32	48.37	41.20
2	18	22	40	195.2	47.9	243.10	24.71	293.41	102.06	395.47	44.48	39.36
3	30	74	104	672.96	53.22	726.18	13.27	460.36	265.35	725.71	49.55	36.28
4	32	36	68	344.24	53.90	398.14	22.10	449.71	168.35	618.06	53.00	44.59
5	30	22	52	235.4	51.20	286.60	19.84	340.71	132.68	473.39	43.51	36.88

ii) GLASGOW

Design	Weight (t)	Manhours-Total	CERW k=0.05 (2)
1	19.61	211.6	30.19
2	24.41	165.2	32.67
3	12.98	526.2	39.29
4	20.43	271.1	31.98
5	19.62	243.4	31.78

NOTE:

CERW type (1) treats prep costs as direct labour

CERW type (2) treats prep costs as overheads

FIGURE H-4 PRODUCTION PARAMETERS

	Design No. 1		2		3		4		5	
Pieceparts:										
Plates	19		11		37		16		11	
Sections	9		9		15		18		15	
TOTAL	28		20		52		34		26	
Welds:										
Fillets: No., Length(m)	164	298.80	76	195.20	420	672.96	58	344.24	22	235.40
In-pl.: No., Length(m)	3	32.10	3	32.10	3	32.10	3	32.10	3	32.10
TOTAL	167	330.90	79	227.30	423	705.06	61	376.34	25	267.50
Weight (tonnes):		20.45		24.71		13.27		22.10		19.84
Surface Area (m^2):		396.16		344.04		458.52		476.00		416.06
Production Costs (£):										
Labour - Prep'n	500.09		357.21		928.75		607.26		464.37	
Fab'n	2700.98		1874.55		3022.10		2936.01		2193.99	
Total		3201.07		2231.76		3950.85		3543.26		2658.36
Materials		4090.05		4942.85		2653.28		4419.56		3967.93
Overheads		1371.89		956.47		1693.22		1518.54		1139.30
TOTAL		8663.01		8131.07		8297.35		9481.36		7765.59

FIGURE H-5 COMPARISON CERW - SOUTHAMPTON AND GLASGOW METHODS

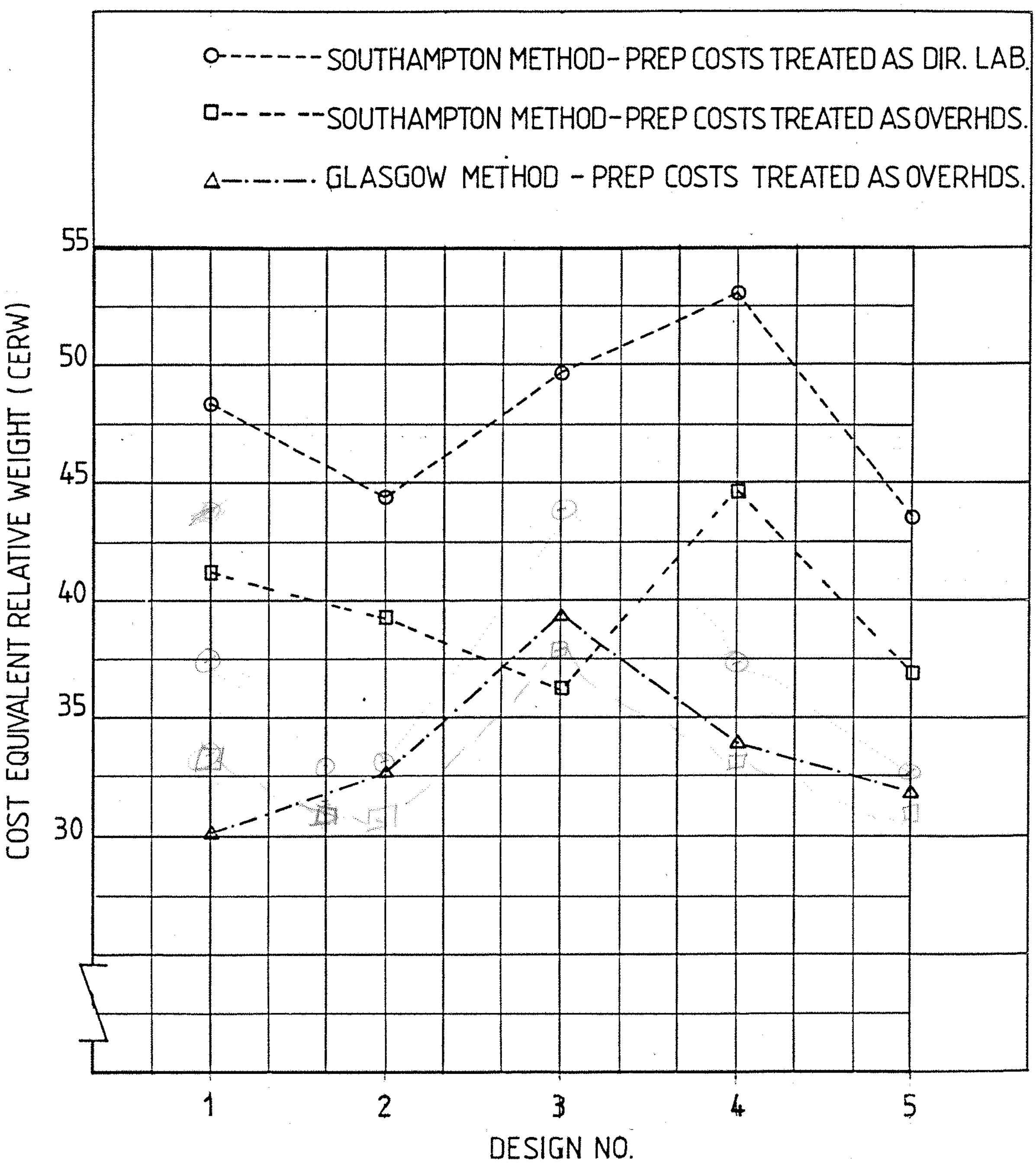


FIGURE H-6 PRODUCTION PARAMETERS FOR THE DESIGNS

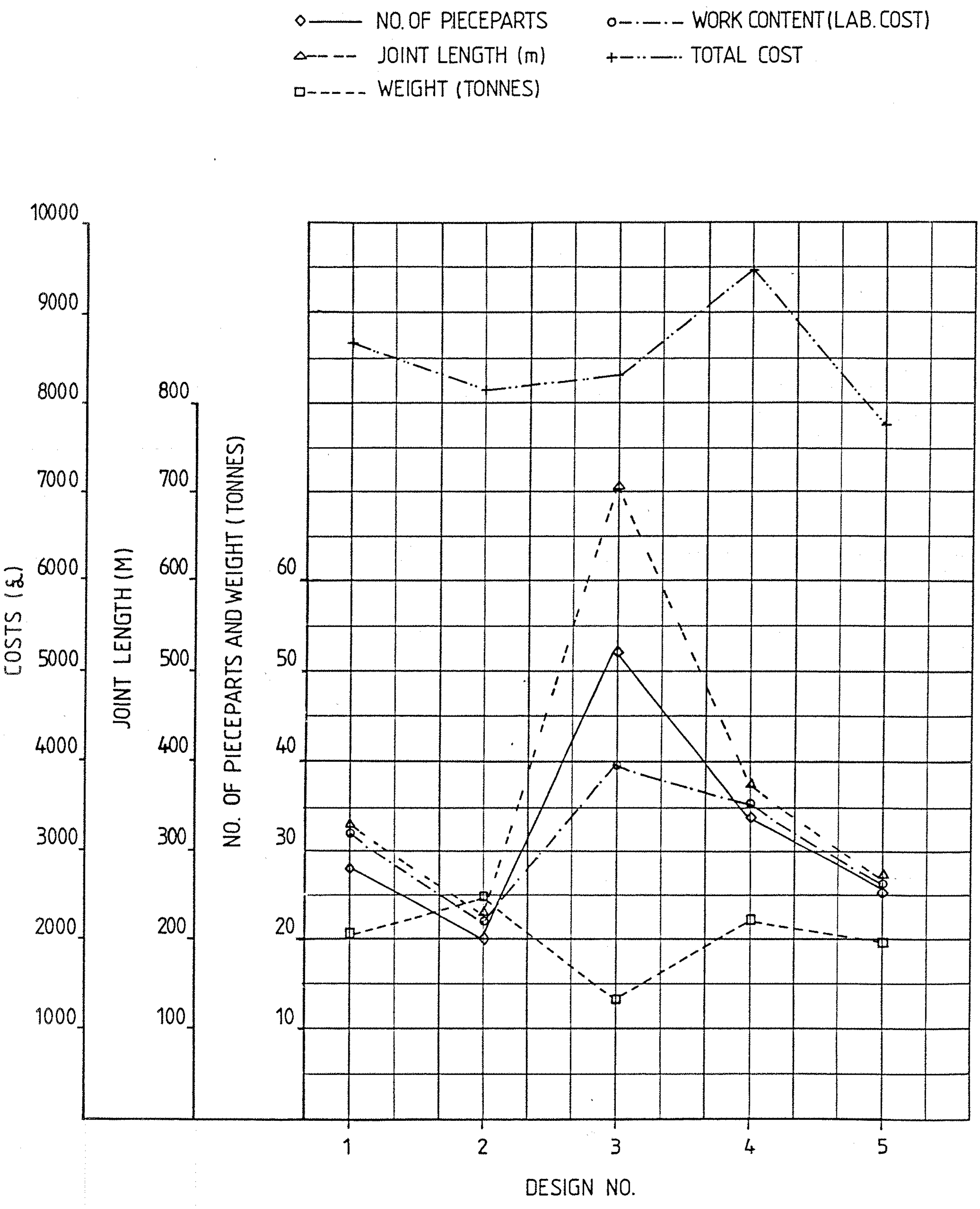


FIGURE H-7 CHOICE OF JUDGEMENT CRITERIA

Design	Ranking with respect to: No. of Pieceparts	Joint length	Weight	Work Content Lab. Cost	Total Prodn. Cost
1	3	3	3	3	4
2	1	1	5	1	2
3	5	5	1	5	3
4	4	4	4	4	5
5	2	2	2	2	1