SOME APPLICATIONS OF COMPUTERS

IN

GROUP TECHNOLOGY

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by

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SUMMARY

This thesis concerns principally the use and adaptation of some computer based information systems during a project to implement Group Technology in part of a large, complex, multi-product company. The approaches adopted and methods used in the implementation and operation of the new principles are discussed with particular reference to computer solutions for problems of:

* data provision, analysis and synthesis during an analytical approach to re-designing part of the company's organisation based on cellular principles

* adapting an existing production control system to support a cellular shop floor organisation and reinforce the benefits of Group Technology

* economic assessment of the benefits gained through operating a trial cell before extending the implementation to other parts of the organisation.

In addition, some particular social, technical and organisational problems that were encountered during the implementation are discussed. Some ideas are given for reducing these problems and extending the implementation to other parts of the company.

It is concluded that computer based information systems can have a considerable impact on a project to install Group Technology and on the methods used to maintain the effectiveness of the new manufacturing system.

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CHAPTER 1

SCOPE OF THE THESIS

1.1 General Hypothesis

The implementation of Group Technology in a company will require technical and sociological changes which will have effects of some significance on the company's organisation, its methods and systems. The approach to the implementation and the nature of the revised organisation and systems may depend on the degree to which the company has access to and is familiar with using computer based information systems.

1.2 Highlights of the Research

The research reported in this thesis centred on an implementation of Group Technology in one area of a large and complex multi-product company. The company had been using computers for some years to process data and provide information and, in the area of the implementation in particular, a computer based production control system was deeply entrenched. The support organisation in the area had been built up round the system which had been operating, largely unchanged for some 6 to 8 years.

An analytical approach to the implementation of Group Technology was adopted and thc company's information system provided much of the necessary data. The production control system provided a good deal of this data, but, in order to perform the analysis, other parts of the company's systems had to be linked to provide

1.2 cont'd.

all the data required. The analysis of the data and its synthesis into a design for a new organisation for Group Technology had some novel features; in particular the use of "real time" interrogation of the computer combining powerful and rapid facilities for analysis of the data with human skills in engineering and a knowledge of the area concerned.

One of the major problems encountered during the implementation was the restructuring of the production control system to support the new cellular organisation and re-inforce the use of Group Technology principles. The company's management required that the support organisations and the system's links which provided data for accounting purposes, be disturbed as little as possible. The management's requirement was met, together with the objectives of the implementation, through a re-structuring of the information provided by the system. This achievement required a novel approach to the solution of shop floor routing problems so that the information provided by the system could be properly structured.

Significant changes in the Senior Management of the company had an important influence on the project. In particular, an economic experiment became necessary to examine the cost effectiveness of the implementation. Computers played an important role in the experiment in both the measurement and analysis of data.

During the implementation, particular sociological problems were encountered which had an effect on both the speed and direction of the project so an attempt has been made to relate these problems to the project, the use of computers and the particular situation of the company.

1.2 cont'd.

Overall, the research illustrates some of the problems that the in-house production systems engineer may encounter during an implementation of Group Technology in a complex company with a significant level of computer based information systems. The philosophies brought to bear, relate to the engineer's approach of adapting and modifying existing facilities to find an effective solution to the socio-technical problems associated with the introduction of Group Technology.

1.3 Structure of the Thesis

First, to provide a context, the main concepts of Group Technology are outlined. Whilst no attempt is made to treat the subject exhaustively, the main types of Group Technology organisation are described. Some of the benefits that can be obtained and the changes that may be necessary are discussed.

Then, an outline is given of some of the main potential areas for the application of computer based information systems in Group Technology with particular emphasis on organisation design and production control. Some of the factors that may affect a company's use of such systems in the implementation of the new concepts are discussed and a survey is given of some reported methods and applications. It is important to note that the use of computers for the direct control of (N.C.) machines, is not within the scope of this thesis, which concentrates on data processing/analysis and information systems design.

1.3 cont'd.

The nature of the company's business, the complexity of its organisation and the state of its computer systems had an important effect on the project, so a description of these factors is given.

The main body of the thesis is concerned with two substantial applications of computer information systems in the project. The first concerns the analysis and synthesis of data leading up to the re-organisation based on Group Technology and the second the modifications to the production control systems necessary to support the revised organisation and the new manufacturing concepts. Whilst the main emphasis is on the use of computer information systems, some sociological problems were encountered during this work which had an important effect on the project, so these are discussed.

The economic experiment conducted round a trial Group Technology Cell is then described and the results obtained discussed with reference to the use of computers in measurement and analysis of the necessary data, the state of the implementation and the sociological problems.

Finally, after describing ideas for improving and extending the implementation, and the "state of the art" of Group Technology, the overall conclusions of the research are discussed.

CHAPTER 2

GROUP TECHNOLOGY

2.1 A Definition

Group Technology concerns the construction and association of three types of groups to perform manufacturing tasks in the best way. These groups are:

* Groups of products
* Groups of manufacturing facilities
* Groups of people.

The main applications of Group Technology have been in the production of components (rather than complete products) on a batch or jobbing basis and, as such, Group Technology has been described by Thornley (1)≠ as:

" ..... a method of achieving some degree of mass production in the batch production industry".

The concept is based on the recognition of groups or "families" of components within the total range to be manufactured (see figure 1). All the components in a family should exhibit a strong similarity regarding the facilities needed for their manufacture. By re-organising in a manner based on the manufacture of the families, a dramatic increase in the effective batch size can be achieved which makes a mass production approach with associated gains in efficiency more possible.

≠ Numbers in brackets refer to the bibliography on pages 186 to 189.

2.2 Organisation Types

Three organisational facets have been recognised which may be contrasted with the traditional organisation for the batch/jobbing production of components, where all machines of a similar type are grouped together on a functional basis.

2.2.1 Group Technology Machine Centre   The modern concept of Group Technology was first developed by Mitrofanov (2). His original approach is perhaps better described as the composite component technique whereby a single machine is equipped with sufficient pre-set tools for the complete manufacture of a component family. This concept has been developed, notably by Drurie (3) who has analysed components in a family with the object of designing a "complex component" embodying all the features of every component in the family (see figure 2). The tooling of the machine centre can then be designed for efficient manufacture of the complex component (see figure 3) and thus any component in the family can be manufactured with minimum resetting of the machine.

2.2.2 Group Technology Flow Line   When complete manufacture of a component family is not possible on one machine, it may be feasible to form a flow line of the machines necessary to manufacture the family. Each component in the family visits those machines necessary for its manufacture until completed. The machines in the line are ordered so that back tracking of components against the normal flow of work is avoided and the line is balanced to avoid bottle necks. There may, therefore, be more than one machine of each type in the line.

2.2.2 Group Technology Flow Line Cont'd.

Generally, flow line production of this type is possible only where production volumes are relatively high and where the balance of operator and machine loading is relatively easy to achieve. The advantage of the family concept is that it makes flow line production possible with much lower volumes of individual components than is conventional in the mass production industry.

2.2.3 Group Technology Cell Where neither machine centre nor flow line production is possible, the machines and operators necessary to manufacture one or more component families can be less formally grouped to form a "cell". The pattern of work flow within the cell is less important than in the case of the flow line and the load balance is easier to achieve with lower and more variable production volumes of individual components. Since the cell is equipped with all the facilities required to manufacture completely each component sent to it, the pattern of work flow in an organisation based on cells, is much simpler than that in a functionally based organisation (see figure 4).

2.3 The Benefits of Group Technology

Figure 5 summarises the improvements which can be achieved by virtue of a reorganisation based on Group Technology. Broadly speaking, these benefits fall into three main areas.

2.3.1 Technological Benefits Since component families form the basis for the design of Group Technology flow lines and cells, the benefits of the composite component technique can be incorporated into the tooling of both types of organisation. By this means, dramatic reductions in the times needed to set machines can be achieved (4).

The clearer picture of the component spectrum and the large increase in effective batch size made possible by the family approach can be used to justify the purchase of more appropriate, specialised machine tools to obtain further gains in technological efficiency.

In the longer term, the family concept can stimulate a trend towards greater standardisation of the design stage so that a reduction in both design and manufacturing costs can be achieved.

2.3.2 Sociological Benefits The aggregation of workers into cells produces many of the benefits reported for goal oriented primary groups (5). Accountability is clarified and workers can identify with the overall task of producing an item rather than merely performing an operation in isolation from the total production task. The resulting increase in job satisfaction produces happier people and consequential improvements in attendance, productivity and quality (6).

2.3.3 Organisational Benefits Figure 4 demonstrates the considerable simplification of the work flow pattern that can be achieved by virtue of a cellular organisation, when compared with that occurring in an organisation based on the function of machines.

At the operating level, this simplification can be directly reflected in a reduction of the production control problems. Scheduling/sequencing rules can be tightened to achieve a significant reduction in thru-put times and work in progress. The need for detailed paperwork diminishes along with the effort needed for progress chasing and other functions which grow from the conventional confusion of functionally based organisations.

2.4 The Place for Group Technology in the Manufacturing System

Lepper (7) has described Group Technology as:
"The only production system embodying all other systems".
Although perhaps slightly facetious in its intention, this definition is a good illustration of the extent of the Group Technology concept and how an implementation may affect many if not all areas of a company's operation if the full advantages of the new system are to be exploited.

By far the most common reason for introducing Group Technology is to improve one or more of the factors affecting the efficiency of production. However, as with any production system, the usefulness of Group Technology will depend on its suitability for a particular organisation and on where and how it is implemented. Recent research (8) has indicated that a "Total Approach" where the implementation is co-ordinated on a company wide basis by top management is more likely to produce successful results than a limited imple-

2.4 The Place for Group Technology in the Manufacturing System Cont'd.

mentation in part of a company. This may be because the full success of Group Technology required changes in many aspects of a company's manufacturing activity. Unless this need is recognised and the necessary changes properly co-ordinated, the organisational stress induced by the presence of Group Technology as a new production system, ill matched to its surrounding corporate processes, may limit any achievable results and may even produce an overall deterioration in a company's performance.

To exploit Group Technology to the full will require some, if not all of the changes listed below and illustrated in figure 6.

2.4.1 Manufacturing Technology Use of the concept of parts family manufacture and the grouping of machines for flow line or cellular production will require changes in manufacturing methods, tooling (including machine tools) and plant layout (9).

2.4.2 Design To exploit the clearer picture, both of the parts spectrum and its implied manufacturing technology will require changes in the comany's design policy affecting particularly the impact of standardisation on component design (9, 10).

2.4.3 Marketing The technological impact of Group Technology in manufacturing and design may in themselves affect a company's marketing policy. Additional affects may accrue from the improvements in lead time, delivery performance and the cost of manufacture achieved from the new system (11).

2.4.4 Systems The parts family concept and changes in design/manufacturing technology may require changes in the estimating and work study systems if the improvements in the cost of manufacture are to be properly reflected in the prices of the company's products.

Changes in systems for production control and materials management will also be necessary both to support a revised plant layout and a flow line or cellular based production organisation (12) and to exploit the potential benefits of simplified production flow and reduced lead times, work in progress and variety of parts and materials.

The full benefits of improved job satisfaction may not be possible to achieve without revision of the payment systems (13, 14).

The organisation changes and changes in the patterns of expenditure on both capital and revenue items may necessitate changes to the budgeting and accounting processes. Changes to shop floor paperwork may have significant effects on the costing systems, particularly if detailed job costing at the operation level is used.

2.4.5 Organisation Even a small implementation of Group Technology will affect the shop floor organisation and possibly its related supervisory structure and supporting methods engineering/production control organisation. A larger implementation will almost certainly have far reaching effects on supervision and the support organisations and some effect on middle management, whilst the "Total approach" may affect the whole organisational structure including senior management and the board of directors (15,16).

CHAPTER 3

SOME APPLICATIONS OF COMPUTER SYSTEMS IN GROUP TECHNOLOGY OUTLINED

3.1 Introduction

The purpose of this chapter is to outline some of the main areas of potential application for computer systems in Group Technology with reference to some reported applications and the available state of the art vis-a-vis the requirements of Group Technology.

The power of computers to process data and perform calculations much more rapidly and reliably than people has led to a dramatic increase in computer based information systems in industry in the past 20 years. Whilst it is probably fair to say that the initial promises of large reductions in clerical staff, improvements in control and hence increases in profitability have not been fulfilled, industry has been using computers on such an increasing scale and complexity of tasks, that computers must now be regarded as a common feature of modern industrial life (17).

Computing technology has improved from the early card and tape based systems of the 1950's and '60's to powerful disc based machines that can perform massive data processing and computational tasks that would otherwise be economically, if not totally, impossible. The available means of accessing a computer have improved from the relatively difficult and time consuming form filling/card punching input and tabulation outputs to direct methods involving the user and a video screen.

3.1 Introduction cont'd.

Industrial information systems development has improved, if not at the same rate as the technology, until advanced information processing has in many cases superseded the simple clerical tasks as the main function of a company's computer. In the more complex systems are to be found methods of production control and resource planning using powerful and complex algorithms that would not be feasible without the use of a computer and, in the companies using such systems, organisations have been built up round the computer systems to take advantage of the new facilities in improving control.

No longer is the computer the prerogative of large and successful companies because of the large capital investment involved in the computer and its supporting systems. Many "bureaux" now exist to lease time on computers and/or packaged systems solutions to common industrial problems and even a small company can gain access to a powerful computer and supporting systems by leasing time on a bureau's machine much more cheaply than investing in its own computer. Indeed, it is becoming wrong to assume that computers are a very major capital investment. "Mini-computers" are now available for a few thousand pounds that can perform tasks that would have required an investment of many hundreds of thousands of pounds in a "main frame" machine a few years ago.

Because computer based information systems are now common place and because their effects on a company's organisation and methods may be significant, it is important to consider their effects in applications of Group Technology.

3.1 Introduction cont'd.

A computer can have a significant effect both on the analytical and systems supporting power which can be brought to bear during the initial phases of a project to implement Group Technology and on the new organisation, systems and methods adopted after the implementation.

3.2 The Problems of a Packaged Solution

A packaged solution to the problems of installing Group Technology may well be the best for the small company which does not own its own computer. In this case, it is unlikely that any expertise in systems analysis of the required calibre exists in the company and the "package deal" used via employment of the experts providing the package on a consultative basis may be the only way to proceed if an analytical approach is desired and seen to be the most effective. Indeed, such an analysis may well be performed without the use of a computer if data samples are kept small and the analysis kept simple.

However, a number of problems exist for the medium/large company particularly if computer systems already operate in the area concerned. These problems centre on the desirability of using an externally developed package under the guidance of the organisation providing the package versus the desirability of using the available expertise in the company and include:

* the cost of using the external package
* the cost of retrieval and transcription of data from the company's systems to the external system
* problems of company security
* resentment of internal staff who may see the external solution as imposed and possibly not what they would

have developed

* unease in the management who have to accept an essentially external solution to an internal problem. They may distrust the efficacy of a solution developed by people with a small knowledge of their company.
* problems of transferring sufficient expertise to the internal staff to cope with any modifications to existing systems required by the new ways of working
* problems of keeping a new organisation up-to-date if manufacturing volumes or product mix change or if technological developments require a revision of the organisation. Such revisions may require repeated involvement of the consultants providing the package with consequential costs and lack of independence of the company using the package.

If any, or all of these problems prove too big for a company to "stomach", it may be decided to develop the necessary techniques "in-house". In this case, difficulties may arise in acquiring the necessary combination of understanding of Group Technology, the analytical techniques being used and computing expertise. The available packages are not much help to the "in-house" systems developer if, for reasons of commercial secrecy, details of the analytical techniques used in the packages are unpublished. The "in-house" system developer may also find that the published methods prove too sophisticated for his company to understand where the technique ends and where judgement must begin.

In such cases, therefore, the "in-house" developer should perhaps seek an approach which will minimise installation costs, particularly those involving data collection, and maximise the understanding of

3.2 The Problem of a Packaged Solution Cont'd.

the people involved in the project. The object is not so much an elegant solution to a mathematical problem, but more an effective solution to a socio-technical problem where the "in-house" developer aims to avoid being seen as selling another package deal and thus incurring some, if not all, of the problems outlined above.

Very little work seems to have been done in this field, but this thesis attempts to throw some light on how computers may be used by the "in-house" system developer along the lines outlined above.

3.3 Role of Computers in Analysis Prior to Implementation

3.3.1 Alternative Approaches to Analysis Following a decision to install Group Technology concepts in an organisation, two types of approach are possible, "peripatetic" and analytical.

The peripatetic approach relies on the experience of management, supervisors and operators to prepare new working methods and arrive at a better grouping of products, manufacturing facilities and people based on their knowledge of current and foreseen problems and their recognition of the aims and methods of Group Technology. Some of these organisations are regarded as successful (11) and the peripatetic approach has the advantage of speed and acceptability to the existing staff who will see the new organisation as resulting from their proposals. The main objection to the peripatetic approach is that it lacks the objectivity of the analytical approach.

3.3.1 Alternative Approaches to Analysis Cont'd.

The analytical approach seeks to form objective recommendations by numerical analysis of available data followed by a logical re-design of the organisation based on the results of the analysis, the behavioural sciences and good engineering practice. The analytical approach is generally regarded as being more likely of success and (perhaps simply because analysts publish more papers than managers) has been more widely reported (9,15).

Two types of analytical approach have been used, the most recognisable difference between them being the relative importance given to component family formation.

The "classical" approach uses component families as the most basic constituent of its recommendations for re-organisation. A classification system is used to describe components according to features which affect the design and/or production of the components. Component classification has been widely reported in the literature (9,15) and only the barest outline will be given here. Suffice it to say that many types of classification system have been developed (18) ranging from simple inspection by eye to complex digital systems describing the geometry, surface features, material and other factors important in the design and manufacture of components. Once classified, the components can be sorted to bring like components together to form families. The manufacturing routes and machine loadings of the families can then be analysed so that the new organisation can be appropriately designed and equipped to manufacture the families.

3.3.1 Alternative Approaches to Analysis Cont'd.

In spite of the many classification systems that have been developed it may be difficult to find a system ideally suited to a particular problem. In this case, development of a suitable classification system may be a long and costly exercise which may limit the applicability of the approach.

The second type of analytical approach is based on network analysis of the routing of components to the various machines needed for their production. Several attacks on the problem have been reported.

The earliest of these methods was developed by Burbidge (19,20). Burbidge's analysis is performed on three levels:

* Factory flow analysis
* Group analysis
* Line analysis

At all these levels, use is made of flow charts showing the material flow from department to department or machine to machine. The approach is similar in philosophy to the techniques of "Systematic Layout Planning" developed by Muther (21) and, whilst based on analysis, requires judgement of the "peripatetic" kind at each stage. McCauley(22) introduced a mathematical base to the problem by calculating a similarity coefficient for every pair of machines. He used single linkage cluster analysis to form groups of machines with high mutual similarity. His method suffers from the disadvantage that does not cope well with machines that may appear in several cells and it cannot take into account component quantities and machine loading.

3.3.1 Alternative Approaches to Analysis Cont'd.

El - Essawy (23) has developed techniques for successive refinement of machine groupings based on "Component flow analysis". At the first stage general combinations of machines are formed. These general combinations are then progressively refined into groups at the second stage until the final structure is determined at the third stage. El - Essawy's techniques seem similar to Burbidge's and currently are not regarded as so fundamental as they were originally claimed to be.

Rajagopalan (24) has introduced the use of graph-theoretic methods for forming cells from route card information. The batch production situation is described as a graph whose vertices are the machines and whose edges represent the relationship between the machines. Graph theory is then used to analyse such a graph to form optimal cellular machine groupings by minimising intercellular movement of components. This technique seems more able to cope with the problem of machines appearing in several cells and can take into account machine loadings, but as yet, there are no known reports of its success beyond the feasibility stage.

Whilst the techniques using network analysis based on data obtained from existing route cards do not suffer from the disadvantage of requiring a suitable classification system, they tend to lack objectivity because they tacitly assume the current working methods to be the most appropriate for the particular organisation concerned.

3.3.1 Alternative Approaches to Analysis Cont'd.

A second disadvantage of this method is that no means are provided to attack the problems of composite tool design or component standardisation from which important benefits should accrue and may be lost if no classification system is employed.

3.3.2 Roles for the Computer The role of the computer during the initial phase of a project to introduce Group Technology may vary widely according to which of the methods described above is used and what facilities are available. Whilst the computer's role will probably be minimal if a peripatetic approach is adopted, the computer can play an important part if an analytical approach is used. Clearly, the sorting of classified components into families is eased considerably if the classification system is digital and computing facilities are available. The computer can also assist in the design of an optimum re-organisation by relating the component family concept to data, on existing working methods and manufacturing facilities, available in production control and estimating systems already in use in the area concerned. A similar role exists for the computer in the analysis of production flows. The power of computer sorting techniques can ease considerably the specification of the most commonly occurring production routes from existing information and so provide the basis for the new machine groupings.

3.3.3 Some Reported Applications A computer system has been developed by Metaalinstituat TNO to support the analysis of classified components into families (25). A numerical classification system has been devised to suit, it is claimed, most types of metal components used in the electronics industry. A supporting suite of computer programs

3.3.3 Some Reported Applications Cont'd.

has also been designed to support the analysis of classified components into families. It is claimed that additional software has been developed to support synthesis of the component family data into groupings upon which to base the formation of cells taking into account machine loading and routing information. However, there is little published material available to evaluate these claims and the only known organisation based on the use of this system (26) is not regarded as embodying group technology principles to a great extent since the "cells" are very large (50 - 100 operators).

A number of computer programs have been developed to support the network analysis of production routes. PERA (27) provide a complete package based on this method which is believed to use simple sorting techniques and Burbidge has reported mechanisation of his methods (28,29). McCauley (22), El - Essawy (23) and Rajagoplan (24) all report using computers to support application of their approaches, but few details have been published to evaluate the power of their computing techniques.

3.3.4 Role of the Computer in Layout Planning Having established the optimum machine groupings during the analytical phase of the project, it is obviously necessary to produce a good, practical and workable layout of the machines on the shop floor.

An optimal layout may depend on a number of factors not simply or directly related to work flow problems (e.g. the cost of moving a machine for access to another for repair). Some of these factors are essentially intangible (e.g. the aesthetics of the layout) and consequently difficult to incorporate into a computer model. Muther (30) has developed a method based on scoring of solutions involving intangibles by the staff who will use the layout concerned in an attempt to digitise the problem.

If it should prove possible to relate all these parameters to one objective function (e.g. cost), then it might be feasible to use optimisation techniques, perhaps based on linear programming (31) or the "Out of Kilter" algorithm (32). Meanwhile, use of the computer in layout planning problems has been reported to evaluate and optimise work flow and machine movement costs (33), but at present, arrival at a practical layout seems highly dependent on the peripatetic and more simple analytical methods such as those of Muther.

3.4 Role of the Computer in Running a New Organisation

A new organisation based on Group Technology may require new or modified systems to support it and to gain maximum benefit from the new concepts.

3.4.1 Role of the Computer in Payment Systems Many companies who have a medium/large workforce use a computer (either their own or that provided by a "bureau") to calculate and print wage slips. The power of the computer to perform calculations that would otherwise be far too lengthy for manual methods has produced some quite complex incentive schemes based on operator performance. The most simple of these find their origins in the old "piecework" system whereby an

3.4.1 Role of the Computer in Payment Systems Cont'd.

operator's earnings depend simply on the amount of output he produces. This system suffers from a number of disadvantages which cause dissatisfaction in both operators and management:

* problems of waiting caused by management's failure to supply material or by machine breakdown
* problems of defining adequate quality
* problems of batch production with high job-to-job variety and consequential learning time

Many refinements of such systems are known but few have been reported which take into account the particular requirements of Group Technology, which centre on how to compensate a worker fairly, not only for doing a job within a particular range of skills with proper speed and quality, but also for being an effective member of a group with a common aim. The problem is particularly difficult in the areas where Group Technology is most appropriate, batch/jobbing production with its demands on operator flexibility and job variety.

Sawyer and Arn (34) have reported a substantial application of the computer in supporting a payment system operating in a large company with an in-depth application of Group Technology. The payment system involves a standard wage consisting of a basic rating, dependent on local conditions; a job evaluation share, dependent on mental and physical demands, educational ability, responsibility, environment, etc.; a behaviour share, dependent on cooperation, versatility, initiative, dependability, etc.; and a share based on seniority and age. Added to the standard wage is a bonus based on both quantity and

3.4.1 Role of the Computer in Payment Systems Cont'd.

quality produced. A points system is used to evaluate group performances and a series of statistically devised curves is used to evaluate a comparable operator performance for similar efforts in different types of cell. The means of calculating the wage of each operator is complex and therefore costly and unreliable if manual methods were to be used. The method is reported to be seen as fair by the operators and is viewed as a major contributor to the success of the Group Technology project concerned (34).

3.4.2 Role of the Computer in Production Control Burbidge (35) has defined production control as: "The science and art concerned with the flow of materials in production, and with the ways in which different material flow systems can be created and controlled".

The general objective of a production control system in the batch/ jobbing situation, is to achieve the best overall compromise between thruput time, delivery performance, utilisation of capacity, investment in stocks and work in progress and administrative effort.

Among the branches of production which have a significant effect on the problems of production control are organisation, design, production planning, plant layout, sales and forecasting, all of which may be affected to a greater or lesser extent by the implementation of Group Technology. It is therefore important to consider the effect of Group Technology on the design of production control systems.

3.4.2 Role of the Computer in Production Control Cont'd

The field of production control is large and has attracted a great deal of attention from workers seeking better algorithms for the solution of production control problems. The general objective of these workers seems to be to reduce the art and increase the science of production control, which has resulted in a great deal of use being made of computers.

The designer of a production control system seeks algorithms for solution to 7 main problems:

* Forecasting
* Capacity Loading
* Scheduling
* Sequencing
* Performance Measurement
* Progressing
* Optimisation

The solution to these problems must be consistent with the general objectives, and key difficulties arise because the means of achieving the general objectives are, in many situations, in mutual conflict. For instance, good delivery performance may imply poor utilisation of capacity and good utilisation of capacity may imply long queues of work between machines and result in unacceptably long lead times and a great deal of progressing effort to maintain a good delivery performance.

Forecasting algorithms endeavour to give the production controller advance notice of deviation from his optimum plan. They may, for instance, be designed to show likely variations of load beyond the time horizon of the existing order book so that the sales plan can be adjusted in time to maintain good utilization of capacity. Alternatively, they may be designed to cope with machine breakdowns via planned maintenance or operator absenteeism by adjustment to the production plan to maintain a good delivery performance. Many such algorithms are available (36) but no production control systems packages are known to be available incorporating them. Normally, the forecasting system is isolated from the production control system although it may draw upon some of the same data.

Capacity Loading and Scheduling algorithms are used to produce good utilisation of capacity within the constraints of an existing delivery plan. The simpler algorithms do not take into account the finite capacity of a real machine shop, but merely adjust the schedule of work automatically, according to simple heuristic rules, e.g. one week gap between each individual operation on each job. The most complex algorithms take into account the effects of the finite capacity and endeavour to find the production plan which will give the best compromise between delivery performance and capacity loading taking into account job priorities. Some attempts have been made to optimise the production plan (see below), but available packages use heuristic rules and simple smoothing techniques to achieve a good result within a realistic timescale and level of computer capacity and administrative effort.

A cellular production system introduces a new problem to capacity loading in that a production plan is sought that provides a good load for each cell. Lewis (37) has reported a solution to this problem by designing related cells each capable of taking on increasingly complex work. Jobs can be defined as mandatory, preferred or alternative assignments for one or more cells and the system loads the cells on a "cascade principle" so that mandatory assignments are loaded first, followed by preferred and alternative assignments in turn. The simplest work is then used to "top up" the load of each cell to its full capacity. Lewis reports some success for this method and PERA (38) provides a supporting set of computer programmes for its use. Lewis concludes that -

"The need for a loading system which is complementary to the cell system design is immediately apparent"! which is an important conclusion highlighting the inter-relationship between the design of the organisation and the systems used to run it.

Sequencing algorithms seek to improve the utilisation of capacity, shorten thruput times and reduce work in progress by optimising the sequence of jobs loaded to a given machine.

Sequencing problems in Group Technology fall into two classes -

* minimising the effect of machine interference on the queueing time of jobs
* exploitation of the parts family concept to minimise setting time.

Traditionally, optimisation of job sequences has been regarded as of academic interest only. The well known relationship of the number of possible sequences to be searched if j jobs are to be loaded to m machines is $(j!)^m$. The search becomes impossibly large even for a computer if either j or m become large as in a conventional functionally based machine shop. By dividing the organisation into cells, both j and m are reduced substantially which produces a very dramatic reduction in the number of possible sequences for work through a given cell. The use of such techniques as "branch and bound" (39) may thus become a practical reality for optimisation of intra cell job sequences to minimise the effects of machine interference.

Exploitation of the parts family concept involves taking into account a new set of criteria to arrive at the best job sequence for each particular machine. Traditional methods of calculating the load time for a particular job on a particular machine, assume that the operator starts and finishes the job with a clean, unset machine. The machine is completely reset for each new job presented to it. The parts family concept is used to reduce setting time by loading jobs that are similar in their setting requirements so that the machine need not be completely reset for each job. Consequently, the setting time is not only dependent on the particular job being manufactured, but is also dependent on the setting for the preceding job loaded to the machine in question.

There are no known practical applications of computers in either area, although Ferranti (40) have made considerable strides in reduction of setting times by exploitation of the concept of parts family manufacture, particularly on turned items and have claimed a 95% reduction in setting time by extensive use of Drurie's methods (3). This has been achieved without extensive computer help (an experiment involving linear programming was abandoned because of the computer capacity required) other than simple batching of jobs on a due date basis and provision of roughly a month's work to each cell with a supporting

3.4.2 Role of the Computer in Production Control Cont'd.

computer printout showing each tool setting required. It is up to the cell supervisor to make up the best sequence he can to minimise setting time as far as is practical, bearing in mind other constraints (operator flexibility, absenteeism, working speeds, etc.). It may be, therefore, that the use of computer algorithms in exploiting the parts family concept depends upon the design of the cellular system and the extent to which the composite component technique can cope with the degree of variety in parts loaded to a cell. In any case, a computer solution may be difficult to achieve because of the number of factors in addition to machine interference and the parts family concept which have to be taken into account to arrive at a workable sequence.

Most computer based production control systems provide progressing information by reporting deviations from the production plan in some form of "shortage list". This shortage list usually provides the basis for deploying the progressing effort to minimise the extent of the deviations from the plan. In the longer term, however, performance measurement can be important to maintain and improve the ongoing performance of the activity. In this case, measurements are needed to display many factors from operator efficiency, quality produced, etc. to the broad financial performance of the area concerned. Most proprietary packages such as the CLASS system developed by I.B.M. (41) and later derivatives, such as CAPOSS, provide some such information, but in many cases, further digestion is required before

3.4.2 Role of the Computer in Production Control Cont'd.

the information is of use to management. It is in this process that particular algorithms suited to the company's modus operandi are needed and the algorithms will depend on the management, the organisation and on the linkages between the production control and accounting systems.

Group Technology introduces problems in this field by virtue of the changes it induces in the management, organisation and systems structure of the company. The cell system may obviate the need for complex progressing information because of the dramatic simplification in work flow it makes possible, and the management reporting will need to be changed because of the new organisation promoted by Group Technology.

There appear to be no reports, either on how this situation affects the design of computer systems, or practical illustrations on how results were achieved in the field.

3.4.3 Use of the Computer to Support Design for Group Technology In a well coordinated company, the design of products should reflect the available manufacturing facilities. Technological inovation should be carefully managed to ensure that, where the "state of the art" and the market demands, the manufacturing facilities and the design of new products are updated together as far as possible.

At the component level, the parts family concept can be used as a basis for standardisation. To maximise the benefits of standardisation, 3.4.3 Use of the Computer to Support Design for Group Technology Cont'd

a drawing retrieval system is necessary to allow designers the maximum scope for using existing component designs, either in their entirety or by modification of a few features rather than by re-design of a new component from scratch. It may only take a designer a few minutes to draw a new part, but in doing so, he generates a pyramid of costs covering proving the new design, establishment of an appropriate manufacturing method together with estimating, ordering, controlling and storing of the new part, each time it is manufactured.

An interesting application has been reported by Allen (10). The use of castings was abandoned in favour of fabrication from standard billets N.C. machined to have the desired features. A mini computer is used as a drafting aid; the design process being to digitise drawings with the aid of the computer, which automatically adds the required features from a data bank of standards. N.C. tapes can be produced by the computer directly together with a tape to control automated inspection of the finished parts.

It is not within the scope of this thesis to comment on the N.C. techniques employed, but the information retrieval system reported, provides a good example of the use of information systems in Group Technology.

CHAPTER 4

PROJECT BACKGROUND

4.1 Introduction

The main body of this thesis is devoted to describing some applications of computers in Group Technology in depth. To provide a context for the work described, this chapter gives some background information on the company in which the research was done, an outline of the company's organisation and a description of some of its systems which were used or modified as a result of this research.

4.2 M.E.L's Business

The M.E.L. Equipment Co. Ltd. is a wholly owned subsidiary of the Dutch based multinational Philips Group. M.E.L. may best be described as an electronic equipment building company. At the time of writing, M.E.L. had annual sales in the region of £23M and employed about 2,200 people.

4.2.1 The Product Range M.E.L. manufactures a wide variety of equipment for both Government and Commercial customers, much of its output being for export. The products vary widely in both technical complexity and numbers produced. The variety may be illustrated by comparing two examples from extremes of the range.

The first example is a linear accelerator for radiological treatment of disease (see figure 7). A number of these products were being produced during the course of this research, each costing up to £½M.

4.2.1 The Product Range Cont'd.

Production was mainly to customer order, but, due to long lead times in manufacture, production could be initially for stock, although a specific customer might require modifications during the manufacturing process to suit the product to his particular needs. Production of these products increased steadily during the period covered by this thesis, reaching about 30 p.a. at the time of writing. The products contained components machined to "state of the art" tolerances and when finally assembled, a product could occupy the majority of a 3½ metre cube.

The second example is a module of logically arranged electronic switching elements selling for about £1 (see figure 8). These products were roughly the size of a match box and contained components which did not make high tolerance demands on the internal manufacturing facilities. Production was based on sales expectations and had remained at some 500,000 units annually for several years until the work was transferred elsewhere in the Philips Group, about half way through this project.

Between these extremes lie a large number of products varying markedly in their size and complexity, the numbers produced and the source and tolerance of their components.

M.E.L's business is characterised by a high rate of technical change, much of the annual budget being devoted to the development of new products and the improvement or tailoring of existing products for specific requirements.

4.2.2 The Organisation

Figure 9 is an outline of the organisation at the start of the project. The marketing/sales sector was divided from the technical sector, each reporting to the Managing Director. Both sectors were basically product orientated, although the product range marketed by some commercial managers could be made by more than one production division and vice versa.

The majority of the company's business was concentrated in the "Defence and Avionic Systems Group", whose technical sector had a triumvirate management team consisting of the Development Manager (responsible for the development of new products and major technical modifications to existing products), the Materials Manager (responsible for procuring all bought out supplies of raw material and components) and the Production Manager (responsible for the efficient production of developed products and the improvement/modification of products after completion of development).

At the start of the project, the production manager's organisation consisted of 4 "assembly" divisions and two component manufacturing divisions: "Manufacturing" Division (metalwork, chemical processing and painting) and "Coils and Sub-Assemblies" Division - C.A.S.A. (Coils, transformers, switching elements and potting).

The organisation was supported by various "ancillary" departments. Of particular interest were the Industrial Engineering Department, known as the Technical Efficiency Organisation - T.E.O - and the Information Systems and Automation Department - I.S.A.

4.2.2 The Organisation Cont'd.

T.E.O. was responsible for estimating the cost of manufacture upon which the company based its prices, for providing targets to guide production managers in their use of labour and for helping production managers produce improvements in their manufacturing methods.

I.S.A. was responsible for the development, maintenance and efficient running of all the company's computer systems and some manual systems, the great majority of their work being to support production and Administration.

During the course of the project, a number of organisational changes took place. The Managing Director retired and the Production Manager of D.A.S.G. left the company. The Commercial Director replaced the Managing Director and a Technical Director was appointed who ran the entire technical sector and all the auxilliary departments apart from Administration (accounting) and I.S.A. who reported to the Financial Director. One of the production assembly divisions was transferred to the Development Manager and C.A.S.A. was closed, although some of its work was transferred to one of the assembly divisions. Finally, a new senior production manager was appointed in D.A.S.G. to take charge of the three remaining Assembly Divisions (see figure 10) in this group, together with Manufacturing Division in which the majority of the work reported here took place.

4.3 Manufacturing Division

4.3.1 Its Business Manufacturing Division provided a service in pre-production metalwork and processing to six "customer" divisions in M.E.L. The service consisted of:

4.3.1 Its Business Cont'd.

* General Machining (turning, milling, drilling, grinding)
* Sheet Metalwork (cutting, bending, forming, punching, welding)
* Printed Wire Board Manufacture (cutting, drilling, plating)
* Metal Finishing (mechanical assembly, linishing, polishing, etc.)
* Plating
* Electroforming
* Painting.

The great majority of components were in the medium/small size range, but high standards of precision and quality were demanded, since the majority of Manufacturing Division's work was governed by Ministry of Defence ("05-21") quality standards (42).

M.E.L. allocated about 13% of its annual production budget to Manufacturing Division and about 26% of the total capital employed in production. Between 75% and 80% of the capital employed in Manufacturing Division was invested in metalworking machine tools which were kept in good condition and in pace with the demands of M.E.L's rapidly advancing technology by a continual programme of re-investment.

Production was organised on a batch/jobbing basis. Manufacturing Division delivered some 20,000/25,000 batches annually handling about 3,000 at once, of which about 2,000 could be on the shop floor simultaneously. Batch sizes varied between 1 and 1,000, the average being in the region of 40. The management regarded the flow of orders as random and unpredictable.

4.3.1 Its Business Cont'd.

An additional service was provided to Development areas in coping with overflows from the Development model shop. This work and the work generated by an emergency support service to the production divisions, was known as "sideways" loading. It bypassed the normal control systems and could substantially increase the number of current batches and hence the complexity of the control task.

For many years, M.E.L. had constrained the size of Manufacturing Division to cope with its base load. Extra demands on capacity or particular metalworking/processing technologies not available in Manufacturing Division were sub-contracted to other companies, Manufacturing Division coping with 1/3rd to 2/3rds the total metalwork/processing demands of M.E.L.

4.3.2 Staff Organisation and Systems M.E.L. budgeted for 127 staff to be employed in Manufacturing Division. These were organised as shown in figure 11. 61 operated machines, which cut or formed metal, whilst a further 23 were involved in processing. The shop floor was laid out on a functional basis (see figure 12) where the machine types were grouped together.

The Production Staff were supported by a Methods Engineering ("Planning") and Production Control sections who provided methods and control information to a computerised production control system (see section 4.4.3). They were assisted in this task by the T.E.O. department who provided standard time estimates for each operation on all but "sideways loaded" jobs which were loaded to the shop floor without the usual methods or control information.

4.4 The Systems

4.4.1 Introduction M.E.L. had been using computer systems for several years prior to the start of this work. Starting in a small way by leasing time on a computer owned by another company. M.E.L. acquired an I.B.M. 360-30 with 60 kilobytes of core in 1969. This machine was replaced with the faster and larger I.B.M. 370-135 with ½ megabyte of core in 1975. The software and periferal equipment was also improved during this period so that "first generation" tape based systems were being replaced by disc based systems running under the Dos - vs operating system by early 1975.

During this first phase of computerisation, M.E.L. invested over £1M in systems design and programming. Whilst some of this effort had been utilised to mechanise the payroll for hourly and weekly paid staff and latterly part of the accounting process, most of the effort had been devoted to the mechanisation of production control and requirements planning. By the start of this research, most of production divisions in the company were utilising these systems heavily.

4.4.2 The D.A.S.G. Production Control System A complex production control system was operated in D.A.S.G. (see figure 13). This system was based on the D.A.S.G. production cycle and was composed of several "stand-alone" sub-systems which communicated with each other via punched cards, "turnround documents" - computer printouts modified by hand and used to re-encode data - and by access to joint files (disc or tape). The D.A.S.G. production control system was composed of 4 main parts (see figure 14).

* Parts List Documentation - a simple form of requirements planning. In this system components were classified (manually) by supplier and the computer used to perform a limited form of bill of materials processing to break down a given number of a product into required numbers of its constituent components. This bill of materials was printed out, sorted by supplier (Manufacturing Division, C.A.S.A., purchased items, etc.) and used to plan the supply of components.
* Methodisation and Planning. This part of the system was used to plan the assembly of the finished product. The manufacture of the product was broken down into a series of operations based on the product structure. For each of these, a lead time was specified between the operation and completion of the product together with information on the assembly method and standard times for the operation (supplied by T.E.O. and used for targeting purposes). This information was digested by the computer to provide a basis for the L.o.B. system.
* The "L.o.B." progressing system was based on the well known Line of Balance production control technique. L.o.B. is really a stock maintenance system whereby the stock of each item, sub-assembly and assembly needed to make a product is kept in balanced amounts according to the lead time between its incorporation into the product and the delivery of the finished product, its place in the product

structure and likely cumulative scrap levels. A production plan is derived from the difference between actual stocks and the stock computed to be needed to maintain the balance. This difference was computed from the planning/methodising information and information on the stocks of items passed to the computer via punched cards returned from the shop floor. Progress information derived from this information was provided by the computer in both pictorial form and listings of requirements.

* Shop Floor Documentation was provided in a number of forms - feed sheets to demand items from stores, load cards to maintain the information required by the L.o.B. system and labels to identify each stocked item.

Whilst this system had both grown up and been implemented as a patchwork and had been found to be unwieldy and limiting in some areas, the company's management felt it to be invaluable in the control of a highly complex assembly process. They regarded the data in the system as the best available in the company in many areas and felt that an overall change to the system would prove a long and expensive task.

4.4.3 Manufacturing Division's Production Control System During the period covered by this thesis, Manufacturing Division operated a complex production control system separate to and different from that operating in the rest of D.A.S.G. Known as the "Huizen System", the Manufacturing Division production control system had been developed in another part of the Philips Group and transferred to M.E.L. in 1968.

4.4.3 Manufacturing Division's Production Control System Cont'd.

Appendix 1 gives a full description of the system and its links with the organisation, so only an outline will be given here.

The system was used to manage queues of work in progress in a functionally laid out machine shop. Some information was provided to aid capacity planning and materials buying. No automated scheduling was provided apart from simple back scheduling against the due date assuming infinite capacity. Manufacturing instructions were issued to the shop floor on computer documents, together with pre-punched cards for return of data on times taken, quantity made, etc. Progressing was based on due date priorities and information was provided by machine section and by customer. The only performance measure provided was a simple measure of productivity for each machine section.

The support organisations in Manufacturing Division had been built round the requirements of the system and consisted of a methods engineering section and a production control section. The methods engineering section worked out the method to be used for manufacture from the component drawing. The manufacturing effort needed to complete each operation comprising this method was estimated by T.E.O. and the due date and scheduling information was added by the production control section. This information was communicated to the computer and provided the base data for the operation of the rest of the system by the production control section.

The management felt that the system had been well implemented and had improved a messy situation which had grown steadily worse during the

4.4.3 Manufacturing Division's Production Control System Cont'd.

period immediately prior to the implementation of the system. However, some ongoing problems were experienced with the disciplines required for the accurate operation of the system which will be discussed in chapter 6.

4.5 The Group Tehnology Project

4.5.1 Factors Influencing its Creation During 1973, M.E.L's senior management recognised a number of key problems limiting the company's effectiveness:

* the reaction time required to fulfil an order
* the availability of production capacity at reasonable cost
* the efficiency of production
* a scarcity of skilled labour
* the cost of financing large amounts of work-in-progress.

The equipment manufacturing market was seen to be becoming steadily more competitive and attempts to break into new market areas were often severely restricted by the time taken to get new products to the customer or to meet new customer orders for existing products. These lengthy thru-put times were one of the prime causes of the large investment in work-in-progress.

Situated in the South East of England M.E.L had difficulty in recruiting sufficient skilled and semi-skilled labour to meet its production targets. Much of M.E.L's metalwork was sub-contracted and problems were being experienced with maintaining adequate quality and deliveries of the sub-contracted items. Shortages of metalwork items were identified as being the most common cause of production disruption.

Attempts had been made to increase production by expansion onto other sites. A firm specialising in lens manufacture with its own metalwork activity, had been taken over and more recently M.E.L. had planned to start production on sites originally belonging to other parts of the Philips organisation, but difficulties were being experienced in managing the problems posed by the geographical separation of production units from their parent organisation.

The scarcity of labour had restricted the management's scope for improving efficiency of production by conventional means. The management felt that changes would be resisted by the metalworkers, and the trade unions had succeeded in negotiating agreements which restricted the scope of work study and systems engineers to improve the efficiency of the operation.

These problems were made worse by the problems of small batch production and the high degree of technological innovation.

Group Technology was seen as a portmanteau method for tackling these problems. Some experiments had been carried out with group working in assembly areas and Group Technology was seen as a means of improving the production situation by modifying the sociological structure of the company (thus reducing the labour problem) and increasing efficiency at both the technological and administrative levels. Of particular interest were the dramatic improvements in thru-put times and increases in productivity reported in other companies involved in Group Technology (9,15).

4.5.1 Factors Influencing its Creation Cont'd.

Applications of Group Technology were seen by Senior Management to be of most interest in areas devoted to metal working. Manufacturing Division was, therefore, chosen as the area in which to experiment with Group Technology before extending into C.A.S.A., then into other areas of the company.

4.5.2 The Project Team Late in 1973, the company decided to examine the feasibility of adopting Group Technology as a basis for some of its manufacturing systems and set up a project team to conduct an experimental implementation in Manufacturing Division. The project team consisted of:

* an external consultant expert in Group Technology who was seen by the company as having the best track record of successful implementations
* the Manager of Manufacturing Division
* a member of the Methods Engineering Section of Manufacturing Division
* a member of the company's internal consulting service attached to I.S.A. Division.

The Divisional Manager represented the source of authority to "get things done" and clearly had a strong interest in helping to formulate any recommendations for change in his division.

The Methods Engineer had some 15 years experience in metalwork production, was a fully trained toolmaker (and was qualified to operate any metalworking machine on a skilled basis). His 2 years

4.5.2 The Project Team Cont'd.

experience in the Methods Engineering section had made him familiar with current working methods and his wide contacts in the factory provided good communication links with the shop floor and other production divisions at the working level.

As the nominated member of the company's internal consultancy service, the author was able to provide experience in the "Management Sciences" of numerical/analytical methods of problem solution, the use of computers and organisational/systems design. A twofold role was seen:

* to support the Group Technology project in Manufacturing Division
* to become sufficiently educated in the concept of Group Technology to act as a "link man" should it prove desirable to implement the concept elsewhere in the company.

During the early stages of the project, the I.S.A. Manager (to whom he reported) attended the project meetings and provided the authority for accessing the company's computer systems. This role was later delegated to the author.

The management felt that the project team would contain a balanced nucleus of expertise and authority. The team was created with the specific purpose of implementing Group Technology in Manufacturing Division, the perceived success of the implementation to be used as the basis for later decisions to implement the concept elsewhere in the company.

4.5.2 The Project Team Cont'd.

It seems clear that the company was primarily interested in a transfer of expertise. Package deals had been considered and rejected. The philosophy described in sections 2.3 and 3.2 served to guide the motives of the senior management, particularly the Senior Production Manager in setting up the project in the manner described above.

CHAPTER 5

USE OF COMPUTERS IN ORGANISATION DESIGN

5.1 The Project Plan

The project team decided to adopt an analytical approach to the implementation of a new organisation based on Group Technology. A three phase project was envisaged based on the methodology shown in figure 15 as follows:

* Phase 1 Building a data base containing details of components classified according to the features which should influence their method of manufacture together with details of current working methods (see figure 16).
* Phase 2 Analysing this data base to develop the Group Technology concept, to relate it to the current manufacturing system and to propose a new organisation (see figure 17).
* Phase 3 A trial implementation consisting of a simulation of the proposed new operating methods and experimentation with the actual operation of part of the trial organisation in order to refine and determine the desirability of the new system. (see figure 18). This would be followed by expansion of the concept to include the whole of Manufacturing Division and eventually other areas of M.E.L.

5.2 Phase 1 - Building the Data Base

5.2.1 Specification of Key Products In a highly diversified multi-product company such as M.E.L., a detailed analysis of all products may not be possible because of the resources required. Because of the limited resources available, the project team decided to concentrate their analysis on those products expected to comprise the majority of Manufacturing Division's load during the year 1974/75.

Accordingly, the combined experience of the Divisional Manager and Production Control Manager of Manufacturing Division, together with that of the Job Controllers of the major customer divisions, was used to specify a short list of five major product ranges on which to carry out the detailed analytical phase of the project.

5.2.2 The Coding Exercise The project team decided to use the Opitz coding system (43) as the basis for classifying components according to the features which should influence their method of manufacture. Component families could then be formed by sorting the components according to their Opitz code numbers, since similar parts would have similar codes. The Opitz code - see Figure 19 - has the advantage of being well tried and proved and is easily available.

The code consists of 9 digits, the value of each digit signifying a particular feature of the component being coded. The resulting code number provides a description of the general geometrical form of the component, (rotational, non-rotational, aspect ratios); the importance and complexity of its surface features (bores, flats, drilled holes, etc.); its approximate size and its source material. The external consultant advised that the 9th digit of the published code (signifying accuracy) should be sacrificed in favour of including a second (the 7th) digit signifying the size of the item along its

5.2.2 The Coding Exercise Cont'd.

minor axis.

The code, a sample of drawings to be coded and their current manufacturing methods were studied to determine the interpretation of the code to be used where this was not clear. (When is a bore not a bore? What constitutes a functional groove or taper? etc.). Minor modifications to the published size ranges were also made at this stage (see figure 20), to relate the classification more closely to current working methods.

A scheme was then devised to train mechanical engineering apprentices in the use of the code and to ensure the adequate quality of their work.

The Parts List Documentation system (see Section 4.4.2) was used in its standard form to specify the drawing numbers of items that were both used to make the short listed products and that were desirable to be made in the General Machine Shop area of Manufacturing Division (see figures 11 and 12). It was found that some products were not included in the P.D. system data base. In this case, the drawing code numbers were extracted by hand. These drawings were extracted from the "Master Files" and studied by the apprentices who compiled lists of drawing numbers and corresponding Optiz code (G.T.C.) numbers onto a suitably designed form (see figure 21). The completed forms were encoded onto magnetic tape by I.S.A. Department's Data Preparation staff.

5.2.2 The Coding Exercise Cont'd.

Thus lists of drawings, classified according to the features which should influence their method of manufacture were produced in a form capable of being easily handled by a computer.

5.2.3 Data Capture System In order to relate the classified components to current working methods, it was necessary to extract data on the current manufacturing method of each component. Data needed included -

* machine types used (lathes, mills, drills, etc.)
* setting times per batch
* run times per item
* quantities made

The Huizen system (see Appendix 1) contained such data, so it was decided to use this system as the source of the data required.

However, a significant difficulty was encountered. The only data held in a form capable of being easily transcribed to the computer (magnetic tape) was on jobs currently being processed by Manufacturing Division. More data on jobs previously made by Manufacturing Division was held on punched paper tape - one tape for each component - in Manufacturing Division's internal files of data on some 20,000 components made during the previous 6 to 8 years. To transfer this data onto magnetic tape would have entailed a lengthy process using more Flexowriter and filing clerk capacity than was available. Experiments to avoid the copying process by splicing the separate paper tapes together into a form capable of rapid and accurate transcription onto magnetic tape, proved abortive.

5.2.3 Data Capture System Cont'd.

To overcome the difficulty, a data capture system was devised to avoid the deletion of jobs from the Huizen system master file on the computer that took place when an item was delivered and to capture data on new jobs as they were added to the system as part of the normal production control cycle. Because the data capture system would be running during most of the Opitz coding exercise, it was hoped that significant extra data would be captured on Manufacturing Division's future load so that the extra data (and hence Flexowriter and Filing Clerk capacity) that would have to be added to the data base as a consequence of the decision to analyse products which were part of the future (rather than current) load of Manufacturing Division could be minimised.

The data capture system proved simple to design. An initial copy of the Huizen system master file was made and a program written to compare this with the "live" data base as the project proceeded. The program would add new jobs, up - date information (received via the return of operation cards) on jobs already filed and would avoid the normal deletion process occurring when jobs were delivered. The process was further simplified by the design of the Huizen system which included a speedy recognition process for each job. A "keyword" including the job number, component code number and batch identifier was included in the header record of each job. The blocks of data pertaining to each job were held in the order of this key word which simplified the decision process necessary to recognise a job as "new" or "updating".

5.2.3 Data Capture System Cont'd.

Figure 22 shows the flow diagram of system which ran each week for the duration of the classification exercise and doubled the quantity of data held on magentic tape from some 3,500 to 7,000 jobs without the need for any extra Flexowriter or Filing Clerk capacity. Computer capacity of roughly half an hour per week was required, but proved not to be a constraint. In addition to reducing the work necessary to compile data for Phase 1 of the project, the data capture system provided a valuable source of historical data for comparison and targeting of Manufacturing Division's performance during Phase 2 and 3.

5.2.4 Code Number Editing and Problems Revealed At the start of the data capture and classification exercise, it was hoped that the history file produced by the data capture system would contain data on the great majority of classified components by the time the classification exercise was complete. Accordingly, a system was devised to compare the drawing numbers in the history file with those on the magnetic tape resulting from the classification exercise. The drawing numbers in both files contained stray characters (/,;, - , , etc.) and characters that were open to misinterpretation (O and Ø, Z and 2 etc.). In addition, the last digits in certain drawing numbers proved to be non-significant. These problems could cause failures in the process of matching code numbersto combine information held in separate systems (e.g. the data base produced by the data capture system and the magnetic tape holding the drawing number and Opitz code). Accordingly, a program was written to delete the stray characters and non-significant digits and convert the characters capable of misinterpretation to a consistent format. This program followed the usual procedure for solving problems of this type and was based on a"look-up" table containing all the invalid characters and decision rules to

5.2.4 Code Number Editing and Problems Revealed Cont'd.

recognise and delete the non-significant digits and convert the other characters to the standard format. Thus, files containing compatible drawing numbers were produced.

To speed the recognition process, the file resulting from the classification exercise was sorted into code number order and read into the fast access (core) store of the computer. A program was written to compare the drawing numbers in the history file with those in the fast access store, delete those numbers recognised from the store and, after reading the whole history file, to list those items not recognised (i.e. still in store).

The classified component file contained some 1,860 items, of these only 200 were recognised before the editing programs were written. After editing the number increased to 600 leaving some 1,260 drawings on which no information on current working methods was available in a form easily handled by a computer.

This discovery had two direct consequences:

* since the sample of 600 drawings on which complete data was available was judged to be inadequate, an exercise was mounted to extract the relevant paper tapes from Manufacturing Division's files and to add these to the history file using the data capture system
* the addition of such large quantities of data not being produced as part of the normal production control cycle and hence not subject to the normal constraints of manufacturing capacity, would have produced a significant

5.2.4 Code Number Editing and Problems Revealed Cont'd.

distortion in the loading pattern. This meant that the original intention to examine the loading characteristics of a new organisation based on the load occurring in the time period covered by the history file had to be abandoned. Accordingly, the original plan was modified so that these loading characteristics could be based on a forecast of one year's output of the products specified for analysis.

5.2.5 Including Product Forecasts in the Data Base Figure 23 shows the system designed to build product forecasts in addition to the Opitz code number into the data base in a manner suitable for Phase 2 of the project.

First, Job Controllers of the Customer Divisions were interviewed to obtain the best available estimates of the specified products to be made during the implementation phase of the project. (May 1974 - May 1975).

The bill of materials processing facility of the "P.D." system was used to "explode" these forecasts to compute the number of each component required to manufacture the products. The computing process was based on the product structure (see figure 24) as follows:

A used on relationship was specified whereby the number of a particular component including a scrap allowance, required to make a particular sub-assembly was transcribed into the section of the data base allocated to that component. The sub-assembly's relationship with the main assembly was similarly specified as was the relationship of the main assembly, and the final product or "parent item". The computation of the requirement for a particular component was performed by

5.2.5 Including Product Forecasts in the Data Base Cont'd.

multiplication of the product requirement and the appropriate relationships (R(i,j) in figure 24) together through the "levels" (sub-assembly, main assembly etc.). Where the same item was used in different parts of the same product a total requirement could be computed by sorting into code number order and adding requirements at output time. If the same component was used on different products this procedure could be quickened by specification of an index or "group commoning number" to allow the computer to find the appropriate requirements directly, rather than go through a lengthy sorting procedure.

In addition to the simple calculation specified above, various embellishments were available to take into account "spares" - extra components and/or assemblies to be supplied with the main product; "free" stock - stock available as "left over" from previous orders and "E Loan" or stock already manufactured and loaned to another product on a return basis. To avoid re-specification of these embellishment quantities, a "clean sweep" option was available to compute the basic requirements by automatically setting the embellishment quantities to zero.

A limitation on the use of the P.D. system was the restriction of the computation to four levels. This restriction had required Manufacturing Division to be treated as a supplier of complete items. Where these items were assemblies, no listing was immediately available of their constituent parts. To achieve a breakdown of these

5.2.5 Including Product Forecasts in the Data Base Cont'd.

assemblies, Manufacturing Division reprocessed the "extract" specifying the items they were due to supply by re-inputting the assembly requirement and using the P.D. system to access their own separate part of the data base containing details of the constituent components and their relationships with the assemblies now defined as parent items. The P.D. system then performed a "secondary" explosion to compute the component requirements. The obvious modification to the systems design to link the two explosions directly had not been performed. However, by use of the system in the manner described above, together with a small amount of clerical effort, it was possible to generate complete lists of components, supplied by Manufacturing Division, defined in the forecast required to manufacture the set of products.

Examination of the product structure showed that on only one group of similar products was a secondary explosion necessary. In a few cases products had not had their structures included in the P.D. system's data base. These products had been controlled by similar systems and outputs were available which were used in a like manner to produce lists of component drawing numbers together with the appropriate required quantities. In all cases, the "clean sweep option" was used since modifications to requirements calculated on this basis were judged to be small and very difficult to forecast.

Meanwhile, the standard software of the computer's operating system was used to produce a deck of computer cards pre-punched with all the

5.2.5 Including Product Forecasts in the Data Base Cont'd.

drawing numbers held on the magnetic tape resulting from the classification exercise. The deck was compiled in drawing number order, each component being allocated a separate card.

The company's drawing numbering system was such that the card deck was easy to separate into blocks appropriate to each product. The component requirements were then transferred to the cards by I.S.A. Department's Data Preparation staff. A simple program was written to transfer the component requirements from the cards onto magnetic tape together with the code numbers and drawing numbers resulting from the classification exercise.

The final task was the modification of the comparison program used to specify coded items not included in the history file of information compiled from the Huizen system. The modified program was designed to match the code numbers in both files and to write the Opitz code number and forecast requirement quantities into spare space in the appropriate header record (see figure 23).

5.2.6 Discussion of Phase 1 Phase 1 lasted some 4 months. In that time some 1,860 components were classified by mechanical engineering apprentices using the Opitz system, the product forecasts obtained and the data base built. The only problem not solved during this period concerned a hard core of items on which no information on current working methods was available or which were found to be not required in the year in question. This situation was caused by four factors:

5.2.6 Discussion of Phase 1 Cont'd.

* Manufacturing Division had contracted out large volumes of work to third party suppliers wherever the work had been suited to production on capstan lathes of greater than ½ inch capacity. This policy had been followed for some years following a decision to dispense with this type of manufacturing facility. The only available methods engineering information simply specified that the item was to be "off loaded complete".
* Similar "off loading" policies had been followed on other items when capacity constraints had occurred last time the item was made. These capacity constraints had occurred in Production, Methods Engineering and Production Control areas from time to time and had resulted in a similar "off load complete" instruction as the only available methods engineering information. In some cases, copies of previous layouts with more detailed instructions were available, but the lack of the relevant paper tape and the shortage of Flexowriter capacity precluded the incorporation of these layouts in the data base.
* The requirements calculation showed the item was not required in the year in question, because some items were used only on particular customised versions of some products.
* Some information was missing from both systems (P.D. and Huizen) due to minor errors in data transcription and misfiling.

5.2.6 Discussion of Phase 1 Cont'd.

During the period covered by Phase 1 no appropriate (e.g. Methods Engineering) capacity was available to overcome this problem of missing information and consequently the project team had to manage without it.

Notwithstanding the above difficulties, at the conclusion of Phase 1, the data base contained a hard core of complete data on current manufacturing methods, forecast requirements and Opitz code for 982 items.

Investigations into the accuracy of the data showed that the Opitz classification had been carried out to a high standard of consistency (in excess of 90%). Such differences that were found were due in the main to differences in interpretation of the code rather than mistakes in coding or transcription. These differences were judged to be not significant. The product forecasts have since proved an accurate statement of the requirements placed on Manufacturing Division during the period May'74 - May'75.

The machine routing and timing information obtained from the Huizen system represented M.E.L's current standard of accuracy in methods engineering and estimating. Since no objective information was available to evaluate the accuracy of this data, it must also be categorised as best available information.

The only major question, concerning the validity of the data base as the basis for an analytical exercise resulting in a re-organisation

5.2.6 Discussion of Phase 1 Cont'd.

(Phase 2), is the degree to which the "hard core" of components on which complete data was available was representative of the work to be done by the new organisation. This question is fundamental to any scientifically based attempt to introduce Group Technology and as such receives surprisingly scant attention in the literature.

If the data used for the construction of the new organisation is historically based, then the best that can be said of any organisation resulting from its analysis is that it was most appropriate to the time when the data used was "live". Alternatively, if forecast data is used, then the new organisation may only be as good in the working situation as the relationship between the forecast and reality.

In the case of this project where historical data, representing estimated load times and recommended machine routings, forecast data representing requirements, and a potentially biased sample of components was chosen, the purest would perhaps question the scientific validity of the data.

Perhaps these difficulties can be overcome by taking an approach to this problem based on good engineering practice. No organisation can function when no flexibility is allowed and all organisations must rely on the "robustness of probability". In other words, it is extremely unlikely that the sample chosen will be far from that truly representative of reality unless either the sample is small or the business reality exhibits wide variations.

5.2.6 Discussion of Phase 1 Cont'd.

The effects of sample bias must be considered on two levels -

* The product level. Since some care was taken in the choice of products to be analysed, sample bias at this level is thought not to be serious. Additional confidence can be gained from the component family concept. Families will contain components from many products and when loading is considered from a family point of view, the products will each contribute a small part to the constituent components and loading characteristics of the family. The component spectrum thus represents an average picture obtained from a large number of products. Significant distortions will only occur when large differences in the distribution of component types between products combine with large variations in the product demand.
* At the component level, the only significant bias is thought to have been produced by a consistent trend in the off-loading policy and consequent missing methods engineering information. This trend centred on the consistent off-loading of large batch turning work of over $\frac{1}{2}$" diameter. The Manufacturing Divisional Manager had decided to buy three automatic lathes capable of producing the majority of this work in future. Since these machines would arrive during the implementation phase of the project, their affect on the loading of the new organisation would have to be taken into account. Since no methods engineering

5.2.6 Discussion of Phase 1 Cont'd.

or estimating information concerning these machines or the work to be loaded to them was available, it was decided to construct new organisational proposals by analysis of the "best available" information in the data base and to estimate the effects of the new machines during the refinement phase of Phase 2(see figure 17).

The potential problem posed by possible wide variations in the business pattern is of course fundamental and concerns the degree of flexibility required from the new organisation rather than its form at any particular time.

After consideration of these points, the project team decided to continue as planned with Phase 2 of the project, incorporating the suggestions outlined above for handling the problem posed by the new lathes.

5.3 Phase 2 - Analysis and Synthesis

5.3.1 Component Manufacturing Hours Analysis The first step in the development of the Group Technology concept was to access the data base to compute the hours required to manufacture each classified component. In order to relate the required manufacturing hours according to the current working methods with the features which should influence the manufacture of the component, the computation was designed to relate the required manufacturing hours to the Opitz code number of each classified component.

5.3.1 Component Manufacturing Hours Analysis Cont'd.

The production control system identified over 100 different manufacturing operation types. In order to clarify the results, these operation types were analysed and reduced to 8 groups of similar operations of major importance:

* turning
* milling
* numerically controlled machining
* drilling
* jig boring
* grinding (surface or cylindrical - differentiated by the Opitz code)
* "sheet metal" - deburring operations were considered to be performed by the Sheet Metal section (see Section 4.3). Note that since no sheet metal components were classified, the computation automatically excluded other types of sheet metal capacity.
* others. These were operations performed by the Processing Department, (painting, heat treatment, acid cleaning, plating, etc.), which were excluded from the potential re-organisation because the technologies were environmentally incompatible with metalworking.

A computer program was written to access the data base and calculate the manufacturing hours required, in each of the 8 major technology groupings, to meet the component requirement obtained from the product explosion. The same method of calculation was used in this program

5.3.1 Component Manufacturing Hours Analysis Cont'd.

as in the standard Huizen system, i.e. the currently accepted data on set times per batch and run times per component and the same calculation routine making due allowance for learning. A facility was incorporated to simulate the effect of debatching, but on the advice of the external consultant, this facility was not used. The flow diagram of this program is shown in figure 25 and an example of the output in figure 26.

Two attempts were made at this stage to produce family groupings of components by sorting the output according to the Opitz code number of each component. The first attempt involved simply sorting in order of the Opitz number, the second in the order of:

1. Opitz code digit 1 - major geometrical form
2. Opitz digit 6 - size range
3. Opitz digit 8 - material type
4. Complete Opitz number

In neither case were obvious component families found that were large enough to use as the basis for a re-organisation. Clearly a "wood for trees" problem was being encountered and a method was needed to compile families, large enough to use as the basis for a re-organisation, from the smaller families recognised from the sorting process. Attempts to perform this process by hand proved very lengthy and if followed would have severely restricted the number of organisational options that could have been explored. Consequently, the method described below was devised.

5.3.2 Interactive Interrogation of the Data Base   Interactive computing methods have been widely available for about 12 years in the U.K.   The usual technique is to share a large computer between a number of users on a time sharing basis.   The operating system of the computer is designed to give each user access via a remote terminal (teletype or video) to the power of the whole computer (core and peripherals) for a few milliseconds at a time.   The power of the computer has to be such that within this period significant quantities of data can be processed.   The processing for each user is done in a series of these "time slots" on a rotational basis.   Each user's time "slot" becomes available so rapidly that the interruption is hardly perceivable and each user apparently has immediate and continuous access to the whole power of the large computer.   By this means, the extensive delays of batch processing can be avoided.   An additional advantage of most time sharing systems is that sophisticated aids to program development (error flags, editing facilities and pre-written programs and sub-routines) are provided by the operating system.   By the use of such facilities it is often found that the time required for program development can be cut from a matter of weeks to a matter of hours.   Provided large volumes of printout are not required the results of a program run are available within a few seconds or minutes rather than having to wait many hours or days for the conventional batch processing system reliant on job queues.   Provided the quantities of data to be processed are not excessive, the use of such systems is comparatively cheap - say £1 per run of a developed program with say 100 lines of output and a fair amount of computation.

5.3.2 Interactive Interrogation of the Data Base Cont'd.

It was considered that interrogation of the data base by such interactive methods could be used to examine, in a short period of time, the loading characteristics of a large number of possible family combinations. These results could be combined with available knowledge of Manufacturing Division's particular situation, the social sciences and good engineering practice to establish an optimum basis for the new organisational structure.

The company's internal computer could not offer an interactive access facility. Consequently, it was necessary to transfer the relevant data to a computer offering this service. The Philips Group operated its own time sharing service, available via G.P.O. lines linked to a teletype in M.E.L. Unfortunately, speedy options for data transfer by way of direct connection of the computers, magnetic tape or machine punched cards were found to be technically infeasible. Consequently, data was transferred via the teletype using paper tape prepared manually "off line" (not connected to the computer, hence no computer charges). Data transferred was simply that contained on the output of the manufacturing load hours analysis, viz. the component drawing numbers, Opitz code numbers and the set and run times in each of the 8 major machine groupings. The apparently mammoth task of typing some 20,000 numbers accurately onto a paper tape occupied 2 people for only 3 days.

The data tape was fed into the time sharing system and validated as follows:

5.3.2 Interactive Interrogation of the Data Base Cont'd.

1. Syntax errors were eliminated using the editing facilities provided by the time sharing system.
2. A simple program was written to compute the totals per family of the set and run times. These were compared with those on the manufacturing hours output. These proved perhaps surprisingly accurate, but allowed easy correction of a few errors, again via the time sharing system editing facilities.
3. A program was written to extract and list all peculiar items, (e.g. rotational items (Opitz digit 1 $\leq$ 4) with no turning time). The data on these items was checked against the manufacturing method - no errors were found.
4. A second program was written to present a pareto of the items by total load hours. The "top twenty" items were checked against a hand calculation from basic methods engineering information - no errors were found.

The transcribed data base was now considered accurate. The entire process of transcription, writing and proving the above programs and validation took 8 man days.

A program was then developed to comb the data for items having characteristics obeying pre-set rules (e.g. similar values of particular Opitz digits, similar machines visited, etc.). This program was designed to present machine hours grouped by size and material for use as a basis for the examination of the loading characteristics of

5.3.2 Interactive Interrogation of the Data Base Cont'd.

the new organisation. Its flow diagram is shown in figure 27 and examples of the two alternative outputs available in figures 28 and 29.

5.3.3 Use of Interactive Methods in Cell Formation The facilities described above were used to examine the loading characteristics of a number of alternative organisations. The structure of each organisation was specified and appropriate decision rules to determine which-job-should-go-where incorporated into the data combing program. The system was used to compute the load, on each part of the proposed organisation, broken down by size and material into each of the 8 major machine groupings described above. The process was repeated iteratively until a number of viable alternatives had been examined fully. In order to illustrate the process, a worked example is given below:

5.3.3 1. Organisational Structure - Four production cells

* Two turning cells
* One milling cell
* One N.C. cell

5.3.3 2. Decision Rules

* Turning Cell A - devoted to machining short rotational parts of less than 1" in diameter. Appropriate selection criteria were:

  Opitz digit 1 < 2; Opitz digit 6 = 0; N.C. Hours = 0

* Turning Cell B - devoted to machining shafts, "difficult" items (awkward but basically rotational shapes) and all rotational items over 1" in diameter. Appropriate selection criteria were:

  $2 \leq$ Opitz digit $1 \leq 4$; N.C. Hours = 0 plus
  Opitz digit 1 < 2; Opitz digit 6 > 0; N.C. Hours = 0

* Milling Cell - devoted to machining all non rotational items not currently being specified for manufacture on N.C. machines. Appropriate selection criteria were:

  Opitz digit 1 $>$ 5; N.C. Hours = 0

* N.C. Cell - devoted to the complete machining of all items currently specified for manufacture on N.C. machines. Appropriate selection criteria were:

  N.C. Hours $>$ 0.

Figures 30 - 34 illustrate the depth of analysis possible and stages in the iterative process leading to the specification of a Milling Cell separate from an N.C. Cell. A similar process was followed for rotational items leading to the specification of the two Turning Cells (see figures 35 and 36).

By expanding the selection criteria it was possible to obtain rapid answers to questions such as -

> "What effect on the total loads of Turning Cells A and B is produced by sending all items requiring grinding that would normally be sent to Cell A to Cell B"?

(Grinding presented a problem because a high degree of skill was required to set the machine, but the load presented to it was too small to warrant a skilled setter in each cell).

This was simply obtained by adding the following selection criteria to the selection rules listed above.

5.3.3 Use of Interactive Methods in Cell Formation Cont'd.

Turning Cell A: Grinding Hours = 0

Turning Cell B: Opitz digit 1 $<$ 2; Opitz digit 6 = 0; Grinding Hours $>$ 0.

Another modification tried was to incorporate the effect of debatching into the loading calculation (the original calculation assumed the total component requirement for the year was produced in one batch). Whilst it could have been possible to go to the sophistication of the learning allowance described in Appendix I , a simple estimate of the effect of debatching was chosen that could be obtained by adding an extra setting time each time the load time exceeded a preset value. The relationship

$$L = S\ (1 + INT\ (R/X)\ ) + R$$

was used where the load time (L) represented the given function of the setting time per batch (S), the total run time for the quantity required to meet the year forecast (R) and the maximum batch hours allowed (X). An example of this effect is shown in figure 33.

By use of such interactive interrogation of the data base, it was possible to investigate the characteristics of a large number of organisational options both extremely rapidly and in great depth. The results described above took less than 1 hour to obtain (although the graphs shown in figures 30 - 35 took a little longer to plot).

This compares with some 5 man days to compile a single analysis by hand. The computer method has the advantage of accuracy over the hand method, when fatigue or carelessness could cause mistakes in addition and items to be missed or included wrongly. The amount of effort in a hand calculation would probably have limited the examination to one or two alternatives, with no great detail possible in the

5.3.3 Use of Interactive Methods in Cell Formation Cont'd.

investigation of alternative loading rules.

5.3.4 Evaluation of Intangibles The analyses provided by the computer painted only part of the picture. In order to evaluate the more intangible benefits and constraints produced by the various organisational proposals, the project team decided to discuss the information produced with groups of staff liable to be affected by the changes envisaged.

To limit the amount of data needed to be digested in these discussions, an "evaluation matrix" was used to select the more promising organisational proposal. This proposal could then be discussed in detail with the staff affected and information on the alternative organisations used as background if required.

Factors affecting the desirability of a new organisation were listed and weighted according to their probable relative importance (according to the author and the Methods Engineer). Each alternative organisational proposal was scored according to its desirability with respect to each factor. A total score for each proposal was obtained by summing the products of the factor weights and the scores. The most desirable organisation was defined as the one with the highest score.

This method has been used by Muther (30) to evaluate alternative layout proposals. The method was found to be a clear and speedy method of selecting an optimum. Its limitations are, of course, the subjective selection of the factors, the factor weights and the scores. It must, therefore, be classified as a quasi - objective means of

5.3.4 Evaluation of Intangibles Cont'd.

assessing a subjective thought process. However, it is believed to be at least one degree better than the even more subjective, less clear and sometimes slower process of selecting that which "seems to be best", without troubling to list the selection criteria, or considering their relative importance.

5.3.5 Interesting Considerations Apart from leading to the organisational proposals in the manner outlined above, the load analysis revealed a number of interesting considerations. Some of these are listed below.

* The 982 items analysed in depth accounted for some 28,000 hours work or the equivalent of roughly 19½ operators. (The current loading rules assumed each operator contributed 1,440 effective hours per year). The Divisional Manager and his Production Control Manager estimated this to be 60-65% of their expected load. Whilst less than the 80-85% hoped for at the product selection stage, due in the main to the missing data described in Section 5.2.6, the sample accounted for a very significant part of the expected load.
* The work was split almost evenly between rotational and non-rotational items (see figure 37) although the missing data (largely due remember to large batch turning work "off loaded") must have decreased the predicted rotational work load. The purchase of three plugboard automatic lathes would mean that this work would in future be done "in-house". To cater for this, the staff of the two Turning

5.3.5 Interesting Considerations Cont'd.

Cells was to be increased to provide more capacity on subsidiary machines. One extra operator in each cell was judged to be adequate.

* Pareto analyses (see figures 37 and 38) revealed no obvious flow lines possible in the Turning and Milling Cells. The 9,566 hours work accounted for by only 34 items combined with the tendency towards larger sized work may be indicated a potential flow line in the N.C. Cell. This area was not under the aegis of the project team, but the information was forwarded to the relevant manager.
* A large quantity of stainless steel work was shown to be required from both Turning Cells (See figures 35 and 36). Supervisors and Unions considered this to be a significant increase over the present load. The technological capability of M.E.L. to deal efficiently with this problem was questioned, and an investigation into special purpose tooling and better purchasing policies recommended.
* There was a marked lack of special purpose turning - i.e. very little screw cutting, taper turning or functional grooving. This contrasted with the provision of facilities to perform these tasks on almost every lathe in the shop.
* The items analysed were of small size (no rotational item over 16" and only 2 over 6.5" diameter). The largest non-rotational item encountered would have fitted easily into a 25" cube.

* The size range and low requirement for special purpose turning resulted in a recommendation to purchase short bed lathes with minimal facilities when replacement or expansion of the current tooling was considered.

At this stage, the proposed organisation was considered by the project team to give sufficient scope for the exploitation of the benefits of parts family manufacture without demanding too much in terms of multi-skill/flexibility or over specialisation on behalf of the operators.

5.3.6 Sociological Problems The proposed new organisation was laid out using wooden models (constructed by the ubiquitous apprentices) in a 3 dimensional layout (see figure 39). The model was used as a basis for discussions with the Supervision, the Trade Unions and the support organisation (Methods Engineering and Production Control).

Whilst accepting the proposals as good, Supervision was clearly unsure of its new role and fearful of changes that could lead to organisational independence of the cells from the Supervision. They could not see through to a new role in supporting the cells, either technically or in an entrepreneurial sense and may well have seen their jobs disappearing.

The Trade Unions were worried about the extent of specialisation to be demanded by virtue of the component family concept. Theyalso expressed concern about the possibility of management setting up a competitive situation between cells. Whilst prepared to "go along" with the change, they reserved their rights to negotiate.

5.3.6 Sociological Problems Cont'd.

The Methods Engineering and Planning Sections were asked to help in evolving their new roles in an organisation based on Group Technology. The staff involved seemed generally quite positive in their attitude to the forthcoming change but, possibly due to lack of experience, they felt unable to contribute a great deal to initial discussions.

During the period in which these discussions were taking place, many of the organisational changes mentioned in Chapter 4 took place. The most important of these was the resignation of the Senior Production Manager, who had provided much of the impetus behind the project. Without his authority, the project team lacked sufficient backing to negotiate payment for the flexibility required to support the new system. Without this payment, the Trade Unions refused to become "flexible" - to operate more than one machine in normal working hours, although they agreed to flexibility in overtime.

To cope with this problem the project team decided on the following plan:

1. the two Turning Cells would be combined into one, which would increase the load to the supporting mills and drills sufficiently to warrant one operator full time on each machine type
2. the initial implementation would be limited to the Turning Cell for a period of at least six months, which would allow all involved to become accustomed to the new system and give time for coping with some entrenched attitude problems

5.3.6 Sociological Problems Cont'd.

3. an economic experiment would be conducted to demonstrate the viability of the new organisation to management and to clarify the problem of payment for flexibility. This demonstration was also necessary because of the changes in senior management that took place during the implementation (see sections 4.2.2 and 7.1).
4. The modifications to the production control system required to support an organisation based on Group Technology, would be tried out in the Turning Cell so that extension of the concept to the rest of Manufacturing Division, could be managed more smoothly.

Agreement to proceed without flexibility was obtained from the Trade Unions, the Supervision and Support Staff agreed to give the trial cell a "fair try". A revised layout plan was produced (see figure 40) and the appropriate machines moved to create the Turning Cell.

CHAPTER 6

MODIFICATION OF A PRODUCTION CONTROL SYSTEM TO ACCOMMODATE GROUP TECHNOLOGY

6.1 Introduction

In batch/jobbing production, control systems are generally designed for the management of queues of work-in-progress in a functionally laid out shop. The implementation of Group Technology poses three particular problems to the production control systems designer. First, in the Group Technology situation, the queues of work-in-progress may be too short to make production control via their management a viable proposition. Secondly, the re-layout of the shop floor may so complicate the computer's model of the organisation that it becomes necessary to change the system to suit the organisation. Thirdly, the importance of sequencing to exploit parts family manufacture and the short thru-put times on the shop floor places a new emphasis on marshalling materials and tools before the job commences and on avoiding disruption to the production plan once the job sequence is commenced. The existing system may not be adequate to cope with this change of emphasis or give sufficient assistance in designing good job sequences.

This chapter describes how a conventionally designed production control system was modified to accommodate the changes imposed by a re-organisation based on Group Technology and how certain improvements were incorporated in the information provided by the system to cope with the problems and opportunities presented by the new methods.

6.2 "The Huizen System" - Design and General Problems

Appendix 1 describes the production control system and its links with the organisation.

The system was of fairly conventional "first generation" (tape based) design and was intended for control of jobbing production via progressing on a simple due date basis. There were no direct links with forecast sales of finished products or information on their stocks and work-in-progress in the customer divisions. The management regarded the flow of orders as random and unpredictable and so control was strictly on a jobbing basis with few efforts to minimise costs by the use of either Economic Batch Quantity or Period Batch Scheduling techniques.

In addition to problems associated with the design of the system, a number of problems were being experienced with its operation which had remained unsolved since the system had been implemented some years previously. The main such problems were:

* the capacity planning, whilst based on a good picture of the estimated load IN THE SYSTEM took no proper account of a sometimes significant amount of work loaded direct to the shop floor, bypassing the normal methodising and production control processes, for reasons of urgency but increasing the complexity of the control task. Capacity was allowed to cope with this work by degrading the amount of work assumed to be produced by each operator but no information was used to assess this capacity other

than a simple guess that each man produced 30 standard hours per week of work "in the system".

The capacity planning process was known to be suspect and customers sometimes took advantage of this by taking work turned down (for reasons of lack of capacity) by the production controller, direct to the shop floor, where they stood a good chance of getting it done.

* There was a lack of confidence in the estimating process. N.B. Estimating was done by T.E.O. - not Manufacturing Division. Factors influencing this included:
  a) insufficient detail in the methodisation for T.E.O. (see Chapter 4) particularly feeds and speeds
  b) Manufacturing Division's lack of confidence in the estimator
  c) supervision failing always to enforce the stated method and operators ignoring it at times
  d) management failing to audit the process sufficiently regularly to overcome the problems.
* Some operators failed to feed back accurate data to the system. Operations could be "clocked off" when they should have finished rather than when they actually finished. Efficient operators could thus generate some spare time and poor operators were sometimes not called to account for taking longer than they should on particular tasks. On occasions, an estimator could be asked to re-time

the job on the basis of the method being used rather than that specified. If the difference in methods was the major cause of the excess time, the next time the job was made by an efficient operator even more spare time could be generated.

* Whilst lateness in arrival of materials was recognised by the system in time for a progress chaser to take action, lateness of tools often went unrecognised. This problem was made worse by a policy of storing some tools in a warehouse 10 miles from the shop floor. No system was available to forecast which tools would be required and when.
* The company was used to jobs having a long thru-put time and to a general failure of Manufacturing Division to meet delivery dates. The customer divisions tended to ask for jobs long before they needed them which may have resulted in more work than necessary being off-loaded and a higher than necessary stock of finished parts. These problems were not visible because no information was available on them and the lack of visibility removed much of the pressure to improve from Manufacturing Division.

Notwithstanding the problems, the system coped fairly well with a complex control task. The management felt that the system had produced a good measure of control where very little had previously existed.

6.3 Particular Problems vis-a-vis Group Technology

The implementation of Group Technology produced a number of specific problems associated with the Huizen system. These problems are outlined below:

6.3.1 Organisation of Information The information output from the Huizen system was structured to support production control of a functionally organised machine shop via the management of inter-operation queues. The functional structure was also reflected in the organisation of data input to the system.

The move to a cellular organisation required some considerable re-structuring of this information to maintain and possibly improve control whilst avoiding an increase and hopefully stimulating a decrease in the administrative effort required to run the system. The restructuring was needed in most parts of the system including capacity/load planning; scheduling; progressing and performance measurement.

6.3.2 Tight Scheduling One of the main objectives in moving to a cellular organisation was to reduce the shop floor thru-put time. The achievement of this objective required a considerable reduction in the queue times allowed between operations.

The scheduling prior to the re-organisation usually allowed 1 week's queueing between each operation. The work queues generated by this rule allowed many problems to remain invisible. For example, operators taking longer than the estimated time for a job, would probably not disrupt the schedule since they would simply eat into the queue time for the next process by a small percentage (queue times were much longer than operation times). Whilst a general slackness would increase the backlog of late work, this was catered for by reducing the amount of work accepted or by sub-contracting part

6.3.2 Tight Scheduling Cont'd.

of the backlog to outside suppliers. Loose scheduling also allowed more time for coping with such problems as tool breakages, wrong materials or tools supplied, operator absenteeism, machine breakdown, etc.

A target of 1 day's queueing between operations was selected for the new organisation. This target seemed consistent with the reductions in lead times and work-in-progress claimed by other companies using Group Technology, but placed a new emphasis on Manufacturing Division's ability to solve problems fast enough to avoid disruption of the tighter schedules.

The shorter job queues also meant that the twice weekly update of information provided by the system was no longer sufficient to keep pace with one operation per day. The extra computing capacity and difficulties in speeding the flow of information to and from the computer meant that simply moving to a daily update was not possible.

6.3.3 Sequencing To exploit the concept of parts family manufacture in an environment where the families are too small (for reasons of either the lack of parts standardisation or the lack of suitable composite tool rigs) requires that some attention is paid to the sequence of jobs that are submitted to each machine. If this is not done, then little or no benefit from reductions in setting time will be obtained.

6.3.3 Sequencing Cont'd.

An additional need for a planned sequence of jobs is generated by the effects of machine interference. With long inter-operation queues, each machine is buffered from the others by the queues. If the queues are shortened without attention to the job sequence the situation may arise where a job must be idle because no machine is available to work on it or a machine must be idle because all the jobs for it are still undergoing processing on other machines. Thus machine interference can cause unplanned job queues and idle machines if no proper account is taken of the job sequence.

The Huizen system contained no facilities for sequencing. Solution of the sequencing problem by more exact scheduling was not feasible because:

* the finest schedule available from the computer could only be defined to the nearest ½ day (most operations took less than 2 hours)
* no facilities were available to examine the effects of machine interference in a job sequence
* no rules were available to design sequences in the on-going working situation. Any sequence would have to be produced by trial and error which would be very long winded if supported by batch processing in the computer.

6.4 Modifications to the System

To overcome the problems outlined above, the production control system was modified and extended as described below. There were three factors constraining the possible extent of the modifications.

6.4 Modifications to the System Cont'd.

First, some customers required proof of the actual time spent on a job. Consequently, it was not possible to consider control at any but the individual operation level. Secondly, the expense of a new or completely reorganised system was not seen to be justified by the management. Thirdly, the difficulties of implementing major perceived changes in the control system in the support organisation which had been built up round the Huizen system, were recognised as a problem to be avoided, at least until the shop floor changes had been fully implemented. The possibility of using a completely new system was therefore ruled out by the management who also felt that the reorganised Huizen system should be capable of supporting the cellular organisation with the cells treated as fairly self sufficient businesses without the necessity of significant extra modifications to the system at a later date. The objective of the modifications was therefore to modify the system to support Group Technology, minimising any basic changes to the system or to its surrounding management processes.

6.4.1 Re-organisation of Information - Basic Problems and Solutions The basic problem of reorganisation of information was that of enabling the computer to recognise a group of operations on any job as belonging to a cell. Simple solutions such as including a cell identifier in the header or operation records on input were felt to be infeasible because:

* the computer's input devices (Flexowriters) had no spare space in their input formats. Any extra information input would have necessitated extensive re-programming of the

Flexowriters and the validation and screening parts of the Huizen system.

* whilst some data on jobs previously processed by Manufacturing Division had been accumulated by use of the history file, described in section 5.2.3., much of the data was still held in the form of individual paper tapes which would have required modification if this method was adopted.
* it was hoped that extra effort associated with the cellular system in the production control and planning sections could be avoided particularly in view of the already unwieldy nature of the processes surrounding the system (see Appendix 1).

An attempt to mechanise this decision making process was therefore made.

At first it was hoped that the Opitz code could, with some minor modifications, form the basis for the processes. However, a study of some 300 sample layouts showed this to be infeasible because:

* over half the jobs studied under-went some form of painting or chemical processing. There was no information on such processing in the Opitz code.
* there was an important administrative difference between N.C. milling and ordinary milling (a different Division

and hourly rate), although both were controlled via the Huizen system. The Opitz code did not distinguish between the two types of milling

* 60% of jobs were sheetmetal. The Opitz code contained no information on sheetmetal work
* apart from processing, some 20% of jobs were required to visit more than one cell during their manufacture.

Whilst it might have been possible to overcome some of these difficulties by adjusting the cellular structure, some hard core problems would probably always have remained because of particular manufacturing problems (e.g. surface grinding on cylindrical parts) and particular, specialist machines that would have been difficult to divide amongst cells in an organisation of Manufacturing Division's size (e.g. 3 jig borers needed by 8 cells).

The Opitz code is fundamentally associated with the geometry and surface features of a component. As such, it appears unsuited to the solution of detailed routing problems.

Since the Opitz code appeared unsuited to this task, a solution was sought via the "machine group number". This three digit number was associated with each operation on every job and was the existing means whereby the computer structured its information. There were two key problems surrounding the use of the number:

6.4.1 Re-organisation of Information - Basic Problems and Solutions Cont'd.

* a single number was allocated to each machine type - Drills = 085, Jig Borers = 088. Because machines of one type could appear in more than one cell, no simple solution via the existing information structuring mechanism was available
* changes in the allocation of the machine group number were difficult because of the limit on the numbers available (200) and the large amount of data held on individual paper tapes. Any change would have required extensive editing and modification of the information both in the paper tape data bank and on the computer files. Such an exercise would have put an unacceptably large load on Production Control staff.

Consequently, an attempt was made to solve the problem of information re-structuring by building a decision process into the Huizen system whereby the cells could be recognised from their constituent (and existing) machine group numbers.

Use was made of the "rates routine file" which contained data to support another system associated with cost allocation. With some minor modifications to the existing supporting software, this file was capable of holding data structured as shown in figure 41, viz cell numbers and names together with the numbers and names of the machine groups comprising the cell.

A link was built between this file and the Huizen system input programs to build up a sorted core table (for fast access) of the machine groups in each cell e.g.

CELL NO.	NAME	CONTAINS	MACHINE	GROUP	NUMBERS		
332	Turning Team	030	052	060	061	062	
		063	064	065	066	070	
		075	076	080	085	090	095

The acceptance program of the Huizen System which passed validated data from the paper input tape to the main system data file was then modified to include the following routine.

STEP	ACTION
1.	Read a data on a job into core.
2.	List all machine groups visited up to the first inspection operation or end of cell operation (see below) into a (core) table.
3.	Sort the table into numerical order and count number of groups (N).
4.	Compare table of machine groups required for this part of the job with table of groups occurring in each cell and score "hits" (machine groups needed occuring in cell for each cell (Hj)).
5.	If a) all Hj < N reject job and record on error list b) Hj = N for one cell only,add cell number to each operation record covered in this list. c) Hj = N for more than one cell go to default option (see below) and print warning on error list.
6.	Repeat steps 2 to 6 for the next list of operations until all operations on the job have been exhausted.
7.	Repeat steps 1 to 7 for all jobs input.

6.4.1 Re-organisation of Information - Basic Problems and Solutions Cont'd.

The flow diagram of this program is shown in figure 42.

Via this process, most jobs were passed to the data files with the cell number appropriate to each operation recorded against the operation's data. Some jobs could be made by more than one cell, so a routine was designed to cope with these on the basis of a "default option". At the time of writing, the only potential confusion lay with items that required milling and/or drilling only on machines that occurred in both the Turning and Milling cells. For simplicity, it was decided to load all these jobs to the Milling Cell. Some layouts were found where a mechanical inspection did not form the natural dividing point between cells. In those cases where it was felt logical to have an inspection (because of the plan to make cells responsible for their own quality) an inspection operation was added. In some cases, an inspection operation would not have been warranted and, in these, an artificial inspection operation was added and named an "end of cell operation". This was needed in only 5% of jobs.

In both cases, no re-programming of the input devices was necessary since the information to be added had the same structure as that already entered via the Flexowriters and input programs.

Whilst the total number of jobs requiring some form of correction was in the region of 25%, very few proved necessary because of the system's decision making process, most being due to either failure to include appropriate inspection operations when jobs had been previously loaded, or new inspection requirements because of the plan for cellular accountability.

The mechanism provided the basis for the restructuring of information output from the system necessary to support Group Technology. No re-programming of the input devices was necessary and the adjustments to the input programs were minimised. The modifications to the data bank of paper tape were reduced considerably to a level that could be coped with by the existing production control staff.

Use of the rates routine file provided an independent means of adjusting the computer's model of the organisation to keep pace with any future changes without the need for modification to any programs in the Huizen (or any other) system.

Examples of the use of this solution to the routing problem, in the restructuring of the information provided by the system to support the cellular organisation and to reinforce the benefits from Group Technology, are given below.

6.4.2 Modifications to the Capacity Loading Scheduling Process

Figure 43 is an example of a "load chart" - the information used by the production controller when negotiating due dates with the customer divisions. The existing load on each machine group in a section was shown as a function of time. All overdue work was shown as "backlog". Any work due to be performed during the four weeks after the printout was produced was shown in the week concerned.

6.4.2 Modifications to the Capacity Loading Scheduling Process Cont'd.

Work planned for the next 11 (4 week) months, was shown by month and any work scheduled more than 12 months ahead was shown as "forward load". A continuous decimal week numbering system was used and the load information was derived from the estimated load time for each operation.

Figure 44 is an example of the revised format of this information used after the implementation of Group Technology. The new load charts were planned for each cell together with an overall chart displaying the total load for Manufacturing Division. As can be seen, the important concepts underlying the original version have been preserved, but some key refinements have been introduced to support Group Technology. These refinements were:

* the information was organised on a cellular basis. It was hoped that, by this means, not only would the load to the cells be better planned, but also the path to management of the cells as small business would be eased by promoting the cellular thinking of the production controllers. The new format could be used, either with the current organisation of production control staff or with an organisation based on more autonomous cells where some production control staff formed part of the cell.

6.4.2 Modifications to the Capacity Loading Scheduling Process Cont'd.

* the planned load was broken down by machine type with the machines arranged in the most likely job processing sequence reading from the left. It was hoped that this information would help the schedulers to balance the load to each machine type to minimise the requirements for operator flexibility.
* the planned load was compared with a crude estimate of available capacity (using the 30 hours/man/week rule) as before. An indicator (+) was provided to highlight the month when the notional capacity exceeded the planned load to assist the production controller in his negotiations on due dates.

A suggestion that the capacity planning process should be refined, either simply by indicating the nominal capacity of each machine type or by using a more sophisticated figure computed from an analysis of the trends of current performance was rejected as an over complication that might distort the proper running of the cell.

In addition to modifying the information supporting the negotiations of due dates and long term scheduling, a key change was made to the definition of the due date itself. Prior to Group Technology, a due week was agreed. This seemed to be an undesirable contraint because:

* dividing jobs into weekly "piles" gave insufficient scope for making parts in families
* the due date was agreed many months in advance when the planning of the customer divisions was usually not well

defined on the job concerned and, in the case of new jobs, Manufacturing Division's estimate was simply a crude guess. Considerable departures from the due date achieved by Manufacturing Division often went unnoticed by the customer divisions indicating that to tie Manufacturing Division down to a due week at this stage, was unnecessary.

Therefore, to increase the scope of parts family manufacture, the due date was defined as a due month. To allow for better planning in the customer divisions and to keep pace with changing priorities, more use was planned of an existing re-scheduling aid to change the due date of a job after it had been input to the Huizen system.

The old scheduling rule (back scheduling 1 week per operation of 30 hours or less and thereafter 1 week per 30 hours allowing 4 weeks contingency) was changed to back-scheduling of 1 month per cell visited, assuming that all operations within a cell could be completed within the month. The four weeks contingency allowance was preserved and the existing practice of down batching to keep operation times below 30 hours was encouraged. Inter-operation queue times of 1 day were allowed instead of 1 week.

6.4.3 Modifications to Tool Marshalling - The "Tool Ready Card" The existing practice of ordering materials and tools was preserved (see Appendix 1) but the control of tool requirements was tightened. Use

6.4.3 Modifications to Tool Marshalling - The "Tool Ready Card" Cont'd. was made of an existing facility indicating the availability of materials by return of a "material ready card" (see Appendix 1). This facility was extended to indicate "tools" ready. Cards similar to the material ready card were to be produced by the computer for each special tool required. The cards were returned to the tool storeman (who controlled all special tools) when he had received the appropriate tool from either the tool room (new) or the long term (existing) store. Where a tool was already in the store or (rarely) needed on more than one job in a given month, a simple labelling system was used to reserve the tool and prevent its return to the long term store. The tool ready card acted in the same way as the material ready card, i.e. preventing generation of the work packet and controlling the appearance of the item on shortage lists.

6.4.4 The Work Issue List Appendix 1 describes the "Work Issue List", the document used to guide all Manufacturing Division's short term loading and routine progress actions (see figure 45). The Work Issue List suffered from 4 disadvantages from the point of view of Group Technology:

* it was not suited to the cellular organisation because it was designed to cover progress of materials and work for the whole Division and was orientated round the old machine group concept.
* the structure of the document was not supportive to parts family manufacture because no information was given to aid division of components into families

6.4.4 The Work Issue List Cont'd.

* Production of the list each week matched the 1 weeks queue between the operations under the old scheduling rule but could not cope with the 1 day queues demanded in the new situation.
* No information was given to aid marshalling of tools

Accordingly, the information on the Work Issue List was restructured on a cellular basis and printed on separate documents produced to guide the functions of:

* material and tool marshalling/chasing
* short term loading/job sequencing
* shop floor progressing.

6.4.5 Material and Tool Marshalling/Chasing - Shortage Lists Figure 46 shows the shortage list designed for marshalling and chasing materials and tools for each cell. Items would appear on the list if their appropriate "ready" cards had not been returned within 4 weeks before they were shown to be needed. The "remarks card" facility was included to cater for known reasons for the shortage occurring outside the control and responsibility of Manufacturing Division.

6.4.6 Short Term Loading - The Work Availability Listing Figure 47 shows the document devised to aid the short term loading and sequencing processes. The Work Availability List was designed to give each cell a picture of the forward load of jobs for which materials, tools and "work packets" were available. Where items were being worked on before becoming available to the cell, the previous cell's number was provided

6.4.6 Short Term Loading - The Work Availability Listing Cont'd.

to guide progressing effort if necessary. For similar reasons, if the job was due to go to another cell, subsequent to being completed by the cell concerned, the subsequent cell's number was also shown.

To aid parts family manufacture, the Opitz code was printed. Although, at the time of writing, the concept was insufficiently developed for any decision to be made on the appropriate sort sequence of the code, an option for sorting on up to 3 digits of the code was included.

The Work Availability List allowed the shop loaders to use the work packets similarly to the way they had used them before Group Technology, whilst aiding the process of sequencing.

The combination of material and tool shortage lists and work availability lists for each cell produced a much more manageable set of information more appropriately organised to guide the necessary marshalling, loading and chasing actions and was more supportive to the concepts of parts family manufacture and cells as semi-autonomous businesses. Further assistance was, however, necessary to aid job sequencing in the cells.

6.4.7 An Aid to Job Sequencing The "Ouija Board" as this aid was dubbed by the Shop Loaders, was designed to help overcome the difficulties of job sequencing to avoid machine interference and promote parts family manufacture. It was based on the well known Gantt Chart (44) - see Figure 48.

Steel sheets 8 ft. x 4 ft. were painted white and ruled horizontally and vertically to form a grid. Each cell was provided with two of these sheets on which to plan 14 days work. Each machine in the cell was listed at the left of the sheet so that the vertical rulings could represent elapsed time in ½ hour steps. Coloured magnetic strip was cut into lengths representing various times from ½ to 4 hours and stored in divided trays for easy access.

Work packets were selected into families using the work availability list and a judgement of the likely family relationships. Initial experiments isolated change of material as the major cause of delay in re-setting a machine so the colour of the magnetic strips was made to designate material type as follows:

Green - aluminium

Yellow - brass

Red - stainless steel

Brown - fibre or plastic

Black - mild steel

White - other

Machines were then allocated to jobs by placing appropriate lengths of magnetic strip against the machine to be used to represent the time for which it was to be allocated to the particular job concerned. The job number was written on the strip for identification purposes.

The strips were placed on the boards and moved until the best looking sequence had been obtained for the 14 day's work. This program was

6.4.7 An Aid to Job Sequencing Cont'd.

agreed between the production controller and the cell supervisor and up-dated each week to allow for slippage, absenteeism, breakdowns, etc. and to incorporate the next 5 days work. Once agreed, the sequence was not to be disrupted without the agreement of the Divisional Manager.

The sequencing aid proved very successful in highlighting the conflicting problems of a short term production plan with minimum inter-operation queueing. A particular problem proved to be the lack of flexibility of operators who were at this stage unwilling to operate more than one type of machine. A key objective of the sequencing was therefore to maintain a load on the subsidiary machine operators whilst preserving the full loading of the lead machines and obtaining at least some of the benefits of parts family manufacture. Whilst this objective asked much of the production controller involved, with some assistance on technical decisions from the planning engineers and supervisors, a workable sequence soon proved relatively easy to establish after a few tries and a number of minor adjustments. Although the sequences produced in the working situation were probably not the optimum, considerable improvements were noted (see Chapter 7). The major problem proved to be more one of discipline in the operators failing to follow the agreed sequence. Other problems noted included persistently slow operators whose job over-ran the next operation's planned start time - particularly important as delays accumulated during the week - and absenteeism. The slow operators

6.4.7 An Aid to Job Sequencing Cont'd.

could be catered for by feeding them one operation jobs as far as was seen to be fair by the other operators. Problems of absenteeism proved more intractable, but centred on a few operators that were persistently absent. This problem was partially solved by re-deploying operators from one operation jobs to multi-operation jobs if absenteeism would have affected the subsidiary machine operator's load. Both problems were alleviated by the operators' willingness to become flexible in overtime, so the sequence could be maintained. It is important to note that the cells were loaded to 40 hours per man per week (less planned absence - holidays, union meetings, etc.) even though work was accepted to the level of only 30 hours per man per week. Whilst some slippage from the target was persistent, a steady improvement in productivity was noted during an experimental period, at least part of which may have been due to the new methods of production control.

6.4.8 Effects of Short Queues and Sequencing on Progressing and Customer Liaison Progressing action can be of two kinds - pull through and push through. Most production control systems contain elements of both.

Pull through progressing is the usual norm in machine shop situations where jobs that are undergoing manufacture, but are late, are actioned because of a customer's complaint or the appearance of the item on a shortage list.

6.4.8 Effects of Short Queues and Sequencing on Progressing and Customer Liaison Cont'd.

Push through progressing occurs where an item is forced through the manufacturing process by design rather than by default and is incorporated in most production control systems by basing the progressing action on due date priorities determined before the manufacturing process starts.

Group Technology changes the emphasis on the type of progressing employed because of the short lead times possible in the cellular situation and the necessity of avoiding disruption of a carefully designed job sequence. More emphasis is placed on better long/medium term planning to get overall priorities into a good order and to marshall materials and tools so that the jobs, once loaded to the shop floor will be naturally pushed through the system in a short time without disrupting the job sequence once prepared. To sum up, Group Technology requires more push and less pull through progressing.

To achieve this objective, two types of action are necessary:

* good customer liaison needs to be maintained to ensure the quality of the schedule
* the shop floor systems must support a push through rather than a pull through approach, in particular, avoiding disrupting a job sequence once started.

6.4.9 The "Micropert" The prime document used to liaise on job progress with customers, was the "Micropert" - see Figure 49. Because Customer Divisions were primarily interested in kits of components from which to assemble complete products, the micropert was based on the kitting concept, by listing all jobs for one product together. Against each job the planned operations were listed in order of action by showing their machine group numbers next to a picture showing the action plan as a function of time. As operations were completed, the machine group number was deleted from the list so only actions yet to be performed were shown. On the basis of this picture, production controllers and customers could negotiate revised priorities when jobs were late or required more urgently than had been planned in the context of other jobs required for the same product.

Production control staff were very attached to the micropert, even though it was not particularly suited to the Group Technology situation (for the usual reasons - machine groups and short thru-put times). They saw it as their main support in customer liaison. Because of their attitude, it was decided to alter the document minimally as follows:

* a tool ready indicator was included in addition to the material ready indicator to show more clearly whether the job could start.
* the cells planned to be visited by the jobs were listed in addition to the machine groups, using the decision process described in 6.4.1.

These indicators would strengthen the ordering of priorities and the marshalling of materials and tools to improve the potential for push through methods on the shop floor already strengthened by the improved capacity loading, scheduling, marshalling and progress information described above.

6.4.10 Performance Measures Whilst the new load charts and better information available to control tools and materials by cell would help create a good push through situation, it was felt that a greater consciousness of the ongoing objectives of Group Technology was necessary to ensure that due attention was paid to these on the shop floor. Consequently, two new performance measures were designed to display the thru-put times and due date delivery performance achieved to each cell and to the production control staff.

It was hoped that display of these performance measures would create a better task identity in the cells so as to improve Manufacturing Division's ability to push through jobs with minimal progressing effort or disruption to the job sequences and to improve the level of productivity.

6.4.10.1 Thru-put Times. Figure 50 is an example of the thru-put ("lead") time measurement provided by the computer for each cell. The flow diagram of the supporting program is shown in Figure 51. For each completed set of operations in the cell (determined by the decision rule discussed in 6.4.1) the elapsed time in weeks from the start of the first operation to completion of the delimiting inspection operation was computed. This information was used to update a frequency table held in core. The frequency table was a matrix α_{ij} where the rows represented the achieved thru-put time and the columns represented the week in which the inspection operations were completed. Thus, if job k had a thru-put time of i weeks and was delivered in week j, the element α_{ij} of the frequency table was increased by 1. The frequency table was compiled as described for all jobs completing a delimiting inspection in each of 32 weeks before the

6.4.10.1 Cont'd.

compilation date of the report. To compare performance over a long period of time, the report could be produced for any desired compilation date. The data source was the archive file (described in Chapter 5) which had been incorporated as an ongoing part of the system.

6.4.10.2 Due Dates. The production of the due date delivery performance measure followed a similar pattern. The difference between the planned and actual completion dates of each job was used to update a frequency table as described above. This difference defined the number of weeks early or late of the job at that point and enabled the printout shown in Figure 52 to be produced. Printouts were produced for each cell and for the whole of Manufacturing Division.

In both cases (thru-put time and due date) initial experiments displaying median, extreme and upper/lower decile indicators (between which 80% of the results would lie) were abandoned in favour of simply printing the frequency table together with an indicator (*) to show the median result for each week.

6.4.10.3 Productivity. The standard measure of productivity provided by the Huizen system was the 'M hour report' shown in Figure 53. The 'M' hour was a standard measure of productivity used throughout the Philips group and was defined as:

$$60 \times \sum_{\text{All operations}} \text{Estimated Load Time} \Big/ \sum_{\text{All operations}} \text{Measured Load Times}$$

6.4.10.3 Cont'd.

The report was provided each week and was compiled from data on operationsclocked as completed within the previous week. Various allowances were used to modify the achieved 'M' hour according to the amount of time spent on work for which no estimate was available and standard "routines" - holidays, sickness, repair, scrap, etc. The allowances allowed the time clocked on jobs by the operators to be reconciled with the attendance time of the operator and were standardised throughout the Philips Group as a "fair" measure of productivity.

From the Group Technology point of view, the item of primary importance was to organise the results to reflect the new cellular structure. The rates routine file solution described in 6.4.1 enabled a bridge to be built between the Huizen System and another system used to compute 'M' hour results in the Assembly Divisions. The report shown in figure 53 was therefore deleted and replaced with the report shown in Figure 54 provided by the alternative system. It remains to be seen whether this report will have a direct influence on the productivity of Manufacturing Division. The original Huizen system report suffered from inaccuracies in the clocking system and errors in the program used to compute productivity. Previous attempts to find the "bug" in the program had proved abortive and Manufacturing Division had used the report little. No information was (or is) provided on the performance of individual operators because the Trade Unions had negotiated an agreement to this effect. Without such a feedback link, to base the report on reality and display results to guide operators' individual improvement efforts, training, supervision or disciplinary action, the effectiveness of such performance measures must be reduced.

6.4.10.3 Cont'd.

Partial rectification of this problem may be achieved by display of all the performance measures in the cells, so at least the operators can see the overall results achieved by their cell.

6.5. <u>Conclusions on the Modified System</u> At the time of writing, many of the modifications to the Huizen System were in the early stages of implementation. The intention of this chapter has therefore been to illustrate the philosophy and methods used in the modifications rather than to measure the particular efficacy of the new system.

Figures 62 and 63 show flow diagrams of the original and modified system. The re-structured information should provide a better support for the cellular organisation and reinforce the benefits to be obtained from Group Technology. Particular benefits that have been noted were achieved through the use of:

* the lead time and due date performance measures which were the first to be implemented and attracted a good deal of interest. They provided valuable evidence in the economic experiment described in Chapter 7.
* the sequencing aid which has proved to be a valuable tool to learn about and solve some of the problems of job sequencing. Its chief defect has been the effort needed to compile alternative sequences. Chapter 8 contains some ideas for alleviating this problem.
* the "tool ready" cards and the tightening of the material and tool marshalling procedures which are diminishing (at least on a subjective basis) the disruption to job sequences.

6.5 Conclusions on the Modified System Cont'd.

Whilst these improvements show promise for the new system, it provides no direct means of solving some important ongoing problems of the original system. In particular:

* no scope existed for improving the links between the Huizen System and the customer divisions so that changes in the forecast output of finished products and stocks/ work-in-progress in the assembly divisions could be properly taken into account. Until these improvements can be incorporated, it seems unlikely that moves from strictly jobbing to batch production control with the associated economic benefits will take place
* the system remains unwieldy in the areas of initial planning/methodisation/estimating/scheduling, largely because scope for improvement in these areas was limited by the degree of change permissible in the support organisations, although management felt the objective here had been met
* the problems of inaccurate "clocking" and lack of confidence in the estimating process have been, at least, partially, alleviated although no complete solution is yet available. A solution is important because the ultimate measured productivity of Manufacturing Division depends on it and the shorter job queues make the sequences more sensitive to the differences between estimated and actual load times.

* the problems of "sideways loading" still exist. These are at least partially dependent on the speed of the methodisation/estimating process taking place before manufacture controlled by the Huizen system can start.

Chapter 8 has some suggestions for reducing these problems which are discussed in greater depth in Chapter 9. However, although it is also too early to say how effective the cellular organisation and further application of Group Technology principles will be, in solving some of the remaining problems, there would seem to be scope for:

* reduction in the "sideways loading problems" by restructuring the support organisations and delegating part of the production control problem to the cells. A better support organisation structure would also reduce the unwieldy nature of the system and improve the links between Manufacturing Division and its customers.
* reduction of the estimating and clocking problems via more effective group processes in the cells. Better task identify and a good commitment towards achieving set targets in the cells could go a long way towards solving these problems.

The philosophy and methods used in the re-design illustrate the problems that may be encountered by the in-house systems designer when faced with the task of matching an existing system to a new organisation based on Group Technology. If substantial installation

6.5 Conclusions on the Modified System Cont'd.

costs and considerable changes in the methods and tasks of the support organisations are to be avoided, then it seems better to make a serious attempt to modify the existing production control system rather than to re-design from scratch or to replace the existing system with a new one.

Other difficulties encountered illustrate the problem of installing Group Technology in one part of a large and complex company where the system has existing links with other parts of the organisation. The existing links may prove difficult to change and new links may be difficult to forge if the project is constrained to operate in one area of the company.

CHAPTER 7

COST EFFECTIVENESS OF A TRIAL IMPLEMENTATION

7.1 Implementation and Management Changes

Figure 18 is an outline of the plan for the implementation of a new organisation based on the analysis described in Chapter 5. The trial cell was to be laid out, staffed and then used to develop the new ways of working. It was hoped that the majority of the associated problems would be solved before extending the concept across the rest of Manufacturing Division. The success of a full implementation in Manufacturing Division would provide a good basis for expansion into other areas of M.E.L. and perhaps some other parts of the Philips Group.

The early stages of the implementation confirmed the seriousness of the sociological problems outlined in Chapter 5 of which the one with the most serious short term effects was the refusal of the operators to become flexible without some form of payment. Whilst wishing to compensate the operators fairly for a contribution to an improvement, the company was unwilling to proceed with this without better information on the extent of the financial benefits of the new system.

During this period, the Senior Production Manager left the company and was replaced by a Director in charge of the entire technical sector who had a particular interest in improving the cost effectiveness of the company. This management change meant that the Group Technology project lost its prime motivator and sponsor and a clear need was felt

7.1 Implementation and Management Changes Cont'd.

to demonstrate the effects of the new ways of working to the new Director. These two problems directed the efforts of the project team towards establishing the cost effectiveness (or otherwise) of the new ways of working. The computer played a significant part in this exercise which is described below.

7.2 Measurements Planned

Four factors related to the cost of production were selected for measurement, viz.:

* overall 'M' hour achieved by the cell each week.

  The 'M' hour was a standard measure of productivity used throughout the Philips group and was defined as

  $$\frac{\text{Standard hours produced}}{\text{Actual time taken (hours)}} \times 60$$

  The standard hours produced represented the sum of the estimated load times of jobs delivered by the cell each week. The actual time taken was the time recorded by the operators as having been worked on these jobs via the Huizen System. Because of some defects noted in the existing Huizen System 'M' hour reporting routine and because the report appropriate to the turning cell was not available at the time of the experiment, the actual hours were retrieved by hand from the job cards before sending them to the computer. For reasons of clarity, jobs with artificial allowances to cover rework or estimated times that were known to be in doubt were excluded.

7.2 Measurements Planned Cont'd.

* the setting time estimated to be required on jobs representing a month's work was compared, assuming
  a) simple due date priority (the pre Group Technology rules) and
  b) a work sequence designed to exploit the concept of parts family manufacture.

  Whilst no special tooling had been designed (e.g. a la Drurie (3)) it was hoped that some effects would be seen. The "Ouija" Board was used to derive the sequence (see Section 6.4.7).
* the thru-put times measured from the start of the first operation to the completion of the mechanical inspection, denoting the end of the cells responsibility, were compared on jobs delivered by the cell during two 3 month measurement periods; one pre-Group Technology and one post Group Technology. In both cases, the thru-put time data was obtained from the modified Huizen System using the report described in section 6.4.10.1. For the pre-Group Technology case, data was selected from jobs that would have gone to the Turning Cell had it been in existence, using the same selection rules as in the post-Group Technology case.
* the ability of Manufacturing Division to deliver jobs in accordance with the due date agreed with the Customer Divisions was compared using the Due Date Delivery performance report incorporated in the modified Huizen System (see section 6.10.4.2). The same comparison periods and job selection rules were used as in the thru-put time measurements.

7.2 Measurements Planned Cont'd.

In addition to the measurements described above, three intangible factors were considered, viz.:

* improvements in Industrial Relations
* simplification of the Control Problem
* increases in business flexibility.

7.3 Results of The Measurements

7.3.1 'M' Hours Results Figure 55 shows the Turning Cell's 'M' hour measured between 26th May 1975 and 15th August 1975. Prior to this period, the results showed no significant trend. Expected values for the productivity increase were derived using a standard least squares linear regression analysis as provided on the company's time sharing computer service. Defining the productivity change as:

$$\frac{\text{Productivity at the end of the Period} - \text{Productivity at the beginning of the Period}}{\text{Productivity at the Beginning of the Period}} \times 100$$

gave a probable productivity change of + 14%.

7.3.2 Setting Time Jobs producing a total turning load of 357 hours of which 91 hours would have been required for setting prior to Group Technology were sequenced to minimise setting time as described above. The sequencing exercise enabled the setting time to be reduced by an estimated 25%. The reduction was 36% on automatic lathes and 10% on centre lathes.

7.3.3 Thru-put Time Figure 56 shows histograms of the thru-put ("lead") times achieved for Turning Cell jobs delivered before and after Group Technology methods were adopted. For comparison, the histograms are shown back to back. The mean lead time is shown to have reduced by 46% and the median by 64%. Before Group Technology

7.3.3. Thru-put Time Cont'd.

was adopted, 35% of jobs took longer than 4 weeks to pass through the "cell". After Group Technology, this figure reduced to 11%.

7.3.4 Due Date Figure 57 shows similar histograms displaying the due date delivery performance achieved on turned items before and after Group Technology methods were adopted. Before Group Technology, turned items were delivered 3.7 weeks late (mean result). After Group Technology methods had been adopted, this result improved to 2.9 weks early. The number of over due orders reduced from 51% to 29%. A slight improvement in the accuracy of delivery was noted, jobs being delivered within ± 1 month of the due date increasing from 57% to 60%.

7.4 Discussion of Assumptions

As with any industrial experiment, it is difficult to show that a measured effect is due to a specific cause. It can be tacitly assumed that the measured results are due to the effects of Group Technology rather than anything else. This assumption may be dangerous and some specific factors that could have influenced the results are discussed below.

7.4.1 Hawthorne Effect It is well known (45) that conducting an industrial experiment can produce changes in performance simply by virtue of the extra interest shown in the group concerned. The usual technique adopted to isolate this effect from the measurements is to compare the results obtained by the group using the new methods with a control group using the old ones. Such a technique was considered difficult to apply in this case because:

7.4.1 <u>Hawthorne Effect</u> Cont'd.

* there was no directly comparable group of operators to those comprising the Turning Cell. Effects of load on Milling and Drilling, N.C. and Sheetmetal workers which had not adopted Group Technology methods at the time of the experiment, would not have been comparable with the effects on the Turning Cell.
* Production Control acted as one activity for the whole of Manufacturing Division. There were, therefore, no comparable control groups.
* management vetoed the extra effort that would have been entailed in the measurement of two groups rather than one.

Ellimination of the Hawthorne effect having been rejected as impractical, it had to be hoped that taking measurements via the computer system reduced the amount of special inter-actions caused by the experiment to a minimum. It was, however, not possible to conduct the experiment without the staff involved being made aware of it, so an element of the Hawthorne effect must inevitably have perturbed the results to a certain extent; the amount or direction of the perturbation being essentially unmeasurable.

7.4.2 <u>Validity of Data</u> Whilst the data surrounding the results was collected carefully, many questions surround its validity which have not yet been possible to answer. Much of the information depended on accurate clocking of the data cards returned to the computer by the operators. A detailed enforcement of clocking accuracy would

7.4.2 Validity of Data Cont'd.

have been difficult to implement and might have increased the Hawthorne effect, but such checks that were made showed some errors in clocking, missing cards and extra cards reporting unplanned and unestimated work although no deliberate mis-clocking as described in Chapter 6 was detected. The extra cards were ignored for the purpose of the 'M' hour calculation and there was no obvious reason for the lead time and due date comparison to have been altered by these effects. It is, therefore, thought that the effects of non valid data are small.

7.4.3 New Machines The Huizen clocking system assumed that each operator could only work one machine at a time. The advent of the Accuratools (see Chapter 5) meant that this was no longer true and one or two of the eight operators in the Turning Cell could (in theory at least) be operating two machines at once and thereby earning double credits towards the overall productivity of the cell. This effect may have accounted for some of the measured increase in productivity but it should be remembered that the Accuratools had been introduced six months before the start of the experiment and any false increase in the cell's productivity would have been expected to show itself earlier. A possible explanation is that an increase in productivity due to the new machines was eliminated by "Parkinson's law" until the progressive tightening of the 'M' hour measurements which led up to the experimental period prevented these losses occurring.

It should be noted that all jobs going to the Accuratools were re-planned to eliminate the possibility of a time estimated for a manually controlled lathe being compared with a time achieved on an Accuratool.

7.4.4. Effects of Load The most potentially serious perturbation of the thru-put time and due date results, could have been produced by a change in the load of turned items between the two measurement periods. A lighter load could produce at least part of the measured improvements in lead time and due date performance.

The overall load of turned items in the two measurement periods proved impossible to compare because of the unknown effects of sideways loading. Whilst a certain lightening of load could have occurred during the second (post Group Technology) period, the effect is not thought to be too significant, particularly since a real drop in load might be expected to produce a drop in productivity (the reverse was measured).

7.4.5 Variability of Productivity The variability of the productivity measurements was large. Confirmation of the results by taking measurements over a longer period would have been more satisfactory, to increase the statistical significance of the results and assure the permanence of the improvement. A longer measurement period might also have reduced any appreciable Hawthorne effect.

7.4.6 Overall Impression of the Measurements Whilst each measured item can be questioned in isolation, the overall picture appears to be one of substantial improvement due in the main to Group Technology. It is clear that the computer played a significant part in the measurement process in the following ways:

7.4.6 Overall Impression of the Measurements Cont'd

* the measurements would not have been possible without the data provided as routine to the Huizen System. In particular, the historical comparison between Group Technology and non Group Technology results would have been much more difficult and would have had to have been set up well prior to the Group Technology experiment - when management had foreseen no requirement for comparison
* a fair amount of data processing is required to achieve the lead time and due date measurements and to perform a linear regression calculation. The extra effort required to perform this process manually would have been considerable and for this reason possibly not attempted
* the existence of the computer as a measurement process familiar to the operators probably reduced what could have been a very considerable Hawthorne effect.

7.5 Worth of the Improvements

Normal commercial confidentiality prevents publication of the value of the measured improvements. However, there are a number of points worth making on the particular value of these improvements bearing in mind Manufacturing Division's position as a partial supplier of M.E.L's metalwork requirements.

7.5.1 Overall Productivity Improvements The 'M' hour and setting time measurements were conducted separately and can thus be combined to assess an overall contribution to productivity. The savings in setting time represented a 7.3% increase in productivity, bringing the overall productivity improvement to a potential 22½%.

Because Manufacturing Division had only sufficient capacity to produce 1/3 to 2/3 of M.E.L's total metalwork requirements, a two-fold gain is achieved by an increase in productivity:

* the existing load costs less to produce
* parts that would otherwise have to be sub-contracted can be made "in-house" with consequential improvements in control and more effective use of existing overheads.

7.5.2 Lead Time and Due Date Improvements Evaluation of savings from a reduction in lead time and an improvement in deliveries against due date, is more difficult. The tangible savings come from a reduction of work in progress that would not be possible to measure without a regular physical count and valuation (a costly and difficult process to implement). Two types of work in progress should be considered:

* "primary" work in progress - partially completed components on Manufacturing Division's shop floor
* "secondary" work in progress generated by a lack of confidence in Manufacturing Division's customers, causing them to order too much too early
* "tertiary" work in progress caused by Manufacturing Division's failure to deliver planned parts on time or to cope sufficiently with emergency manufacture

7.5.2 Lead Time and Due Date Improvements Cont'd.

of unexpectedly scrapped parts. The lack of the required items would cause work in progress of other items to build up in the customer divisions until Manufacturing Division could deliver the parts required to complete the assembly.

The primary work in progress can be valued from a knowledge of the average lead time, rate of material consumption and rate of added value. Assuming a linear model, the work in progress will be proportional to the lead time and will thus reduce accordingly. The values for Manufacturing Division indicated that, although worthwhile, the primary work in progress savings were probably insignificant compared with the productivity savings.

The secondary work in progress is more difficult to assess. The probability that customer divisions will order items to be delivered too early will depend on a number of factors (such as the degree to which the metalwork is on the critical path of the product manufacturing plan, the particular confidence level of the customer and Manufacturing Division's reputation). The value of secondary work in progress is higher per item since it comprises completed components, so the only control factor is the time that items remain in stores before consumption. In Manufacturing Division's position, a clear demonstration of a good delivery reputation, plus some education and direction of the customer division's job controllers who do the early ordering, would seem to be the answer to reducing secondary work in progress. It was not possible to assess any improvements achieved

7.5.2 Lead Time and Due Date Improvements Cont'd.

in the level of secondary work in progress (in fact the thru-put times and due date improvements may well have produced a temporary increase in finished part stocks).

Tertiary work in progress can be much more serious. Metalwork comprised well under 20% of the value of most of M.E.L's finished products and the "knock-on" effect of late delivery from Manufacturing Division could cause a very rapid build up of tertiary work in progress followed by a large drop in productivity caused by operators having to wait for the undelivered items and then re-learn their assembly processes. Whilst it was not possible to assess the savings produced in these factors by the implementation of Group Technology, it was noted that whereas Manufacturing Division had been identified as the major "bête noire" in M.E.L. at the start of the project, no complaints were received on turned items after the implementation of Group Technology.

7.5.3 Comparison with Other Companies Comparison of achievements in one company with published results of achievements in other companies are always dangerous because:

* bad results are rarely published (or admitted!). Surveys of achievement may produce a falsely high average
* improvements are relative and it is rarely possible to compare before and after situations between companies.

However, to give some perspective, the measured results of the turning cell experiment are compared with the results of a recently published survey (4) of over 40 firms who claim to have introduced Group Technology. The survey reports Group Technology implementations ranging in size from single cells producing a very limited number of products to complete rejection of conventional manufacturing methods in favour of Group Technology principles as demonstrated by Ferranti, Edinburgh (40). The comparison is shown in Figure 58.

The reduction in work in progress includes only an estimate of the reduction in primary work in progress in the turning cell. The reduction in overall stocks was not possible to estimate for the reasons given in Section 7.5.2. The other figures are those given in Section 7.3.

Neglecting the arguments surrounding the validity of inter-company comparisons, it would appear that M.E.L. has a long way to go in achieving the maximum benefits from Group Technology. The figures given are only those for the turning cell and represent an extremely small improvement in total company performance. Even so, according to none of the measures does the turning cell reach the average improvement claimed by other companies participating in the survey. Assuming the validity of the comparison, the below average results may have been produced because:

* the turning cell was chosen for the trial implementation more to explore and develop Group Technology methods rather than to maximise the related cost benefits. Greater benefits might have been found by a trial implementation in other metal working areas

7.5.3 Comparison with Other Companies Cont'd.

* many of the problems highlighted by the trial implementation had not been solved at the time of the experiment. These problems are discussed below.

7.6 Problems Reducing the Effectiveness of Group Technology

The operation of the trial cell highlighted a number of problems of which many were still unsolved at the time of the experiment. These problems probably reduced the benefits obtained from the new system and may be classified under three headings - sociological, technological and control.

7.6.1 Sociological Problems The supervisory and operator problems mentioned in Section 5.3.6 made a teamwork approach to the implementation difficult. New disciplines were more difficult to establish and negative reactions were produced in production control staff who were originally in favour of the new system. Attitude problems had persisted in Manufacturing Division for many years and a number of managers had failed to find adequate solutions. Indeed, a previous manager had deliberately operated a divide and rule policy which may have deepened the gap between management, supervisors, operators and support staff. An additional problem may have been the lack of a sufficiently clear policy on the role of Manufacturing Division which was required to act partially as a high speed technological problem solver to cope with last minute design changes or rectifier of quality problems on sub-contracted metalwork and partially as a low cost producer of items. These roles were essentially incompatible, given the existing organisation and supporting systems. The role conflict inevitably produced supervisory and operator problems because the staff

7.6.1 Sociological Problems Cont'd.

involved had to act for part of the time in a semi-skilled environment to detailed laid down methods and for the rest of the time in a skilled environment with little or no technological support.

It is probably unreasonable to assume that operation of a trial cell would provide a swift solution to deep rooted attitude problems that had persisted for a number of years, even though Group Technology should provide a means for their solution in the longer term by promoting teamwork approaches to problems, inproving the job satisfaction of the operators and shortening the shop floor queueing times, sufficiently to allow proper technological and control support for both roles.

The fact remains that these sociological problems were not solved by the time the experiment took place and they probably account at least partially for the lower than average benefits measured.

7.6.2 Technological Problems The concept of parts family manufacture is an important part of Group Technology. By the time of the experiment no progress had been made either on the design and use of composite component techniques or on the standardisation of components in either the design of current or future products. This lack of progress probably limited the extent to which savings in setting time could be achieved. It was noted that Ferranti (40) use Drurie's techniques (3) extensively in their turning cell and claim a 95% reduction in setting time. It is also possible that greater than average reductions in setting time could be achieved in Milling and N.C.

7.6.2 Technological Problems Cont'd.

working areas of Manufacturing Division, which would increase the total result after extensive implementation of Group Technology.

7.6.3 Control Problems The production control system had not been fully modified by the time the experiment took place. Whilst the lead time and due date performance measures and the "Ouija" board were available, no link existed to allow the long and medium term production plans to exploit the new concepts. Production control staff were having to operate two systems, one to support the functional layout and one to support the Turning Cell which inevitably diluted their efforts. Many of the disciplines - e.g. not starting a job until material and tools were available, observing the agreed job sequence, etc., were not fully established, which must have limited the potential reduction of lead times and improvement of due date delivery performance. Whilst the "Ouija" board gave some help in constructing a good sequence, a better aid might have allowed greater benefit to be obtained.

A further limitation on the reduction of lead times and work in progress was produced by the conflicting systems in that the production control staff tried to deliver kits of components, for assembly either in Manufacturing Division or the customer divisions. This task could have been more difficult given the two systems and may have reduced the potential benefits. In any case, these benefits would be expected to be smaller for turned items which had a shorter than average lead time.

7.7 Conclusions of the Experiment

It is difficult to establish an industrial experiment which will truly demonstrate that observed effects are due to a specific cause. The design is particularly difficult when the measured area is a small part of a closely related whole, since management may be unwilling to embark upon an adequate experiment because of its cost and complexity.

The computer proved to be a valuable tool in the experiment, not only by virtue of its data processing power, but also in minimising what otherwise might have been a larger Hawthorne effect.

The experiment succeeded not only in demonstrating the benefits of Group Technology to the new management, but also in focusing the attention of many people involved with some of the problems of Manufacturing Division. The work was seen to be sufficiently valuable to warrant continuation of the implementation and an increase in the involvement of other areas of M.E.L. to further increase the benefits and to minimise the boundary problems introduced into areas such as T.E.O., Accounting, Personnel and the customer divisions by the adoption of Group Technology methods on a wider scale.

CHAPTER 8

IDEAS FOR THE FUTURE

8.1 Introduction

There appears to be considerable scope for extension of the work described in this thesis both in the practical application of Group Technology principles in other areas of M.E.L. and in the development of the ideas stemming from the work reported here.

8.2 Extension at M.E.L.

8.2.1 More Cells M.E.L's real requirement is for kits of finished parts rather than individual components. The real benefits of reduced thru-put times will not be felt until all the metalwork can be obtained in less time so that the total lead time of the end product can be reduced. Clearly, there is a need to create further cells in Manufacturing Division to cater for:

* Milling and Drilling
* N.C.
* Sheetmetal
* Process

Whilst the Milling and Drilling "Cell" was almost created by exclusion when the Turning Cell was created, more attention will be needed to ensure that it can be operated as a self sufficient unit. Similar problems to those encountered with the turning cell will have to be dealt with in the provision of necessary subsidiary machines. If these and the existing sociological and control problems can be solved, then there may be considerable scope for productivity improvements and setting time reduction. There are already indications that the attention to the design of jigs and fixtures and to job sequencing

8.2.1 More Cells Cont'd.

could all make significant inroads into the current setting times which are longer than those in the Turning Cell.

Progress in the N.C. area, although outside the aegis of the existing project team, would also seem to be possible since there is evidence of long lead times and scope for improvement in the reliability of delivery and levels of work in progress. As yet no development of the techniques reported to be successful by Allen (10) has been attempted and there may be scope for a considerable cost reduction of items currently cast and N.C. machined by the use of such methods. It is indicated that there is also scope for improvements in the Sheetmetal Section along the lines explored for the Turning Cell. Two proposals for designing cells in this area are being considered, one involving production flow analysis and the other component classification. Which method is used will depend on the suitability of sheetmetal classification systems currently being studied.

The design of the process "cells" has yet to be seriously considered. There is an obvious division of processing (cleaning, plating, etc.) from painting (masking, spraying, drying) and there appears to be no alternative division of this area or any practical possibility of integrating process/painting activities with the metalworking cells because of contamination and safety considerations. Certainly, no classification system is known that would suit this area, so any further sub-division would have to be based on production flow analysis.

8.2.1 More Cells Cont'd.

There is also scope for implementation of Group Technology in another area of M.E.L. - the Watson subsidiary which manufactures glass and metal components for optical equipment. There seems to be a parallel to be drawn between work at Watson's and the implementation at Rank Taylor Hobson (15). Consideration will be given to this idea in the near future and initial indications look promising.

The rest of M.E.L. is more concerned with assembly of components into finished products where the metalwork is a minor part of mostly electrical products. To implement Group technology here, where there are few complicated and expensive machines to set up and little scope for parts family manufacture would, to the purest, seem to be more the implementation of Group Working rather than Group Technology. Whatever the semantics, there may be considerable scope for better layouts of the shop floors, for better groupings of workers and for better methods of rationalising the design and assembly of the products. A preliminary survey is to be conducted to see if a significant potential for improvement exists.

As for other areas of the Philips Group, some interest has been engendered in central departments and other plants, but as yet no plans are known for application of Group Technology in the ways being considered by M.E.L. It appears to be early days yet, although considerable strides have been made in the introduction of autonomous work groups in assembly areas which should form a valuable basis for the introduction of Group Technology in the many component manufacturing activities throughout the Philips Group.

8.2.2 Production Control The implementation of the complete, modified production control package described in Chapter 6 started in January 1977. It is too early to comment on its effectiveness. Future work on this package should be initially aimed at the simplification of its operation. There would seem to be scope for allowing "on-line" updating and interrogation of the data files which should make the package considerably easier to use and make feasible other techniques to be described later. The essence of good production control is accurate and up-to-date information and "on-line" in "real time" (files up-dated immediately) or "real-enough-time" (files up-dated periodically - say every ½ hour to every day) should improve the state of the information in the Huizen system considerably compared with the current once-a-week up-date on the majority of the data.

The availability of a data base that can provide such up to date information would make possible improvements in both the long term loading and shorter term problems of job sequencing. "Real time" operation would allow trial of alternative load plans before an optimum was chosen and would ease the re-scheduling problem. Mechanisation of the "Ouija Board" layout would be possible by allowing the job sequences to be chosen by a planner examining their effects in a conversational manner with the computer. Trial and error planning on a "what if?" basis.

Notwithstanding the availability of real time access to the Huizen system, some work is already underway to examine the potential for productivity improvements by using the computer to examine alternative sequences automatically. Initial experiments have concentrated on

8.2.2 Production Control cont'd.

sequencing jobs to the Accuratools, using a limited Monte Carlo simulation of the possible job sequences. It has been found that whilst the optimum sequence may take a considerable amount of computer time to derive, even using powerful algorithms such as "branch and bound" (39), a significant and worthwhile improvement can be obtained by simply evaluating a number of feasible sequences at random and choosing the best. The likelihood of a significant extra improvement being discovered through the generation of more sequences seems to diminish rapidly with the number of sequences generated. Work continues to extend the ideas with the intention of incorporating such a sequencing aid into the Huizen system should the savings prove worthwhile and achievable with a low overhead of computing time. These savings should be more easily achieved with such a sequencing aid available because of the complexity of the manual sequencing problem.

A combination of automated sequencing and real time operation might allow the computer to guide operators directly to the best job to start. The computer would be in possession of the up-to-date manufacturing situation and could evaluate the best sequence to follow on the basis of the information to hand when prompted by an operator seeking a new job to start.

There is also scope for improving the effectiveness of the control system through better design of its data and information links with the rest of M.E.L. Automated links to forecasts of product output and stocks in the assembly divisions could reduce what is now a considerable clerical exercise to translate the requirements of Manufacturing Division's customers into a schedule for the shop floor.

8.2.2 Production Control cont'd.

The effectiveness of this process would be further increased by more attention to the design and methods of the support organisations and on the delegation of part of the production control task to the cells together with an understanding of how moving from jobbing to batch production control could bring further economies..

8.2.3 Group Working The re-organisation of the production control system has made the creation of further cells feasible. More cells may serve to solve some of the current sociological problems, but may well create others. The problems thought likely to diminish are those connected with the special nature of the trial cell. It should prove easier to gain acceptance for a group reward scheme that would not be possible to implement in the trial cell in isolation and the operators would no longer feel themselves singled out for the attention of management. Both changes should help to reduce the current difficulties on the shop floor. It is also likely that more cells will help the supervisory problem for much the same reason although some difficulty may be expected in the conflict between imposed leadership (the supervisors) and the autonomous nature of the cells. However, moves towards the creation of further cells would be unwise without a full appreciation of the depth of the sociological problems in Manufacturing Division and without both considerable efforts to solve the problems and some clear evidence of their solution. Efforts are being made with the staff on the shop floor by holding a regular meeting between the Divisional Manager

8.2.3 Group Working cont'd.

and the operators. Although the supervisor is present at this meeting which is showing clear signs of improving communications and reducing the barriers between the shop floor and the management, there are no signs that similar improvements are being made at the supervisory level. Parallel efforts were started by holding meetings between the supervisors, production control and planning staff, two representatives of the team implementing Group Technology, and a sociologist. These meetings ceased after the unfortunate early death of the sociologist before any real improvement could be achieved. The re-creation of these meetings is thought to be highly desirable.

The creation of a fully cellularised Manufacturing Division will ease considerably the load on the supporting production control staff. With a trial cell working the production control staff are essentially operating two production control systems and are having to manage the interface between them. This extra load may be at best a partial cause of the negative reactions described in Chapter 5.

Once a fully cellularised operation has been implemented and is seen to work, the management may feel more able to move towards giving the cells more autonomy and, in effect, treating them more as businesses in their own right. Little or no modification to the Production Control system should be necessary to achieve such a situation, but careful attention would be necessary to the way planning, estimating and production control tasks were delegated to the cell. Fully autonomous working would be difficult to achieve because of the complexity in the relationships with the customer divisions that would be created. A good compromise would seem to be to delegate planning and shop floor production control to the cells, retaining a small central "customer liaison department" to handle the interface between Manufacturing Division and its customers. It would probably not prove feasible to delegate the task of estimating to the cells because of their monopoly situation and the policy of the Philips group where estimating/target setting is deliberately separated from the line management.

Another aspect of Group policy which may affect the extent to which the cells can be autonomous is the accounting process. The Philips Group operates an accounting system which is different to that of most companies in that assets are revalued and recovered at the point of added value in the amount charged for a man-hour's work. At the time of writing, only one hourly rate was used across the whole of Manufacturing Division and the setting of separate rates for the different cells could produce a heavier load for the accounting departments. The modified production control system could provide a good deal of help in the costing process via the use of the rates routine file link described in Chapter 6. This link should make automated job costing easily obtainable leaving the only extra work in the setting of the annual hourly rates. This extra work is not thought likely to be significant.

8.2.4 Standardization Currently, there is very little parts standardization at M.E.L. Whilst there are limitations imposed by customers who paid for the development leading up to many of the drawings and who demanded that their own standards be adopted, there is still considerable scope for M.E.L. to influence future designs and to take opportunities to change existing designs. The opportunities for standardization exist at three levels: methods, parts and assemblies.

Standardization of methods covers the selection and/or design of such items as threads, chamfers, undercuts, raw material sizes and grades, tolerances, etc. To illustrate the potential for methods standardization the sorted list of Opitz code numbers against part numbers described in Chapter 5 was used to retrieve drawings having a similar Opitz code number. This component family comprised pillars and spacers that were made in some quantity and with a wide variety of forms in the Turning Cell for various customers. Figure 59 shows part of this sample together with a suggested "composite component" (see figure 60) that would fulfil the purpose of the other components, but require little alteration to the setting of tools during the manufacturing process. Whilst all the components have a 4-40 UNC thread, the manufacturing method has to change, because of detail differences concerning the chamfer (size and angle) on the front of the thread; the overall length of the threaded section and; the design of the shoulder where the thread meets the main body of the component. It was also noted that the various materials chosen did not line up with those stocked as standard, although no technical reason could be found to justify this situation.

8.2.4 Standardization cont'd.

For 10 drawings selected, 8 different manufacturing methods were necessary. Using the suggested composite component, the 8 methods would be reduced to 1 with consequential savings in setting time and Planning/Production Control effort.

Standardization of components may be regarded as the use of "preferred" items wherever possibe, rather than re-designing every item from scratch. Whilst there is obvious scope for improvements in drawing office productivity by the use of preferred standard metalwork components, this saving may well be negligible compared with savings in: "debugging" new designs; production control effort; work in progress; overall lead times, etc. achieved through a reduction in the variety of items produced.

Standardization of assemblies is an extension of the preferred component concept to cover some standard metalwork assemblies. There may be scope for standardization of some equipment "racks" and "trays" but significant inroads into standardizing M.E.L's metalwork assemblies would require a substantial change in marketing and design policy that would take a long time to implement and is probably not warranted by the potential savings.

One area, falling between component and assembly standardization that might be profitable to investigate, is fabrication of machined castings and some conventional sheet metalwork items from N.C. machined standard plates. Allen (10) has claimed to have reduced lead times for metalwork items, previously cast, from 2½ years to 2 months on initial orders and from 6 months to 2 for repeats. He also claims that a

8.2.4 Standardization cont'd.

cost reduction of 64% was achieved by the use of these methods. Computing techniques are much in evidence in the achievement of these results. A mini-computer is used to digitise a drawing and produce control tapes for the N.C. machine and an automated inspection machine directly. Standard features (holes, slots, clearways, etc.) can be automatically called in at the time of digitization of the drawing and aids to visualization are provided by the computer to assist checking the tapes before cutting metal. Such techniques could well find use at M.E.L.

At the system level, the secret of effective methods and parts standardization appears to be the ease of retrieval of standard drawings. So long as it is easier for the draughtsmen to draw a new item than to use a standard, then the likelihood of a standard item being used diminishes. M.E.L. has made attempts to improve the availability of information to draughtsmen by providing manuals of standards, but with more than 500,000 drawings on file, retrieval is a large task and, so far, access by drawing number is the only system used. Access for standardization purposes would require classification of a large enough cross section of drawings to give a representative sample and a filing system organised according to the classification system. The classification system would have to strike a balance between ease of use and accuracy of description of the component's geometry, surface features and method of manufacture and the filing system would have to be very easy to use. A profitable

8.2.4 Standardization cont'd.

line of investigation would appear to be a combination of a mini-computer and a microfilm filing system.

To make the use of standards stick, not only drawings but standards manuals, tolerance/cost curves, preferred stock item lists, etc. should be available from this access system. A change to the current drawing process would be desirable so that classification is done at a very early stage in the design. The system used should ensure a constant pressure to classify and examine standards rather than draw a new item. Currently, drawings are produced first and standards thought about later. To realise the benefits of parts standardization the reverse must be the case. Figure 61 illustrates a possible change to the drawing process compared with the current methods.

8.2.5 Automated Estimating and Methodisation Given a rationalised approach to the design of metal components, the prospect of automating the estimating and methodisation process might become more feasible, perhaps along the line suggested by Arn (12). Reductions in the clerical effort and elapsed time that take place between receipt of an order and the start of component manufacture would be possible on a much greater scale than with the current level of standardization, although real benefits might still be seen with no improvements in standardization.

Apart from the obviously greater scope for standard methods and estimates resulting from standard part designs, a great benefit would accure if the estimating process could be integrated with the design process to allow examination of production costs at the design stage and build in "value engineering".

8.2.5 Automated Estimating and Methodisation cont'd.

The Philips Group has already made progress on automating methodisation and estimating (25) and the potential for the application of this work at M.E.L would appear to be significant.

8.3 Extension of Knowledge

8.3.1 Cell Design The computer is a powerful analytical tool, particularly when it can be used to manipulate existing company data. The state of the art is moving rapidly towards company data bases. Although initial results are not as promising as first hoped, it will not be long before data base systems become utilised for management of the total information in companies. The Philips Group has made strides initially based on I.C.L.NIMMS and more recently on their own data base management system which allows total computerisation of their planning, scheduling and goods movements systems. The information is derived from Commercial forecasts and product structure data and new machine shop schedules can be provided directly from input of a new Commercial forecast and up-to-date information on stocks and work-in-progress. Access to the data in such systems, particularly in real time could produce a powerful tool in the design of a new organisation embodying Group Technology principles. The process could be similar to that discussed in Chapter 5, but as yet the analytical tools have to be custom built. No packages are available.

More work needs to be done to link the classification and production flow analysis techniques of cell design. Both techniques have good and bad points and neither is ideal. Particularly important is the need to keep the cellular structure up-to-date with the parts spectrum unless a gradual increase in the in-balance of the cell load is to occur.

Classification systems are by no means ideal and their use in organisations is not yet fully thought out. A classification system for cell design and up-dating may not be suitable for drawing retrieval, shop loading, routing or sequencing purposes, but it seems unlikely that organisations will use more than one classification system. The pressure for one classification system to be all things to all parts of the system may so stress current systems, that parts classification may be abandoned. Considerable scope exists for the development of classification systems, particularly for the multi-product organisation where metalwork and in-house manufactured components may only be a small part of the final product. In particular no classification scheme is known which can help in the design of cells in an assembly area.

Production flow analysis with its heavy dependence on the current working methods in the organisation using it, is also far from ideal. There is scope for developing its objectivity and scope for easing its use. Further mechanisation of this process and the availability of computer tools that can operate with data base management systems could spread its use considerably, particularly if the technique could be extended to include automated layout planning of a revised organisation resulting from its use.

8.3.2 Production Control The solution of the production control problem in a Group Technology environment provides further scope for extension of knowledge. Existing computer packages for production control do not readily lend themselves to the Group Technology situation and development is needed in:

* The design of information systems appropriate to a cellular organisation
* The design of sequencing algorithms to exploit parts family manufacture and avoid machine interference
* The control and avoidance of disruption caused by machine or tool break-down or operator variability, sickness or absenteeism
* Design of estimating systems automated to produce job instructions and time estimates from part geometry, surface features, tolerance, etc.
* Efficient interfacing of production control with accounting systems, payment/incentive schemes and the design/estimating process.

8.3.3 Sociological Development The implementation of any new system involves people. The implementation of Group Technology poses particular problems in the organisation and restructuring of work that involves skilled operatives and supervisors. Although theories governing the motivation of people in socio-technical situations are well established (5, 14) and are being examined with particular reference to the Group Technology situation (6), as yet there is no

8.3.3 Sociological Development cont'd.

clear recipe for success involving the many problems that arise during the implementation of this new Manufacturing system. Work needs to be done in developing and transferring sufficient understanding of these theories, particularly for those responsible for managing the change from functional to group based production systems. By this means, projects may be approached in a way that guarantees a greater chance of success.

Further work in organisation development also seems necessary for better integration of cellular working with other aspects of industrial society at, supervision, middle management and Board levels (16).

The computer is an important factor in all these areas and there would seem to be considerable scope for greater understanding of the inter-relationships of people with computers in the GroupTechnology environment. Part of Group Technology is an improvement in the sociological structure of companies. In organisations possessing a computer a successful bond between man and his information systems must be sought.

CHAPTER 9

OVERALL DISCUSSION

9.1 Introduction

Arguably, the research described in this thesis produces a number of conclusions in a wider vein than simply specific applications of computer systems in Group Technology. The entry point to the research was the interaction between computer based management information systems and Group Technology, but, during the progress of the work, other areas of knowledge impinged on the research, so an attempt will be made to discuss conclusions on these wider matters as well as on some applications of computers in Group Technology.

9.2 The Project

Because the work was centered on a project to install Group Technology in one area of a large multi-product company, it is important to take this situation into account in any conclusions drawn from the research.

9.2.1 Degree of Success The success of M.E.L's project in achieving its original objective, the installation of Group Technology in Manufacturing Division, seems a bit like the curate's egg "good in parts". Whilst, as Chapter 7 shows, the project produced measurable benefits in the trial cell and indicated potential for a cost effective implementation in the rest of Manufacturing Division, progress beyond setting up the trial cell and operating it has been limited. The intention of the company is to extend cellular working, at least throughout the rest of Manufacturing Division. Other areas being considered for the installation of Group Technology are the N.C.

9.2.1 Degree of Success cont'd.

machine section, some assembly areas and the subsidiary company specialising in glass and metalwork component manufacture for optical equipments. However, the management momentum behind turning these intentions into reality does not yet appear to be large enough for real and substantial progress to be made.

9.2.2 Limiting Factors The main factors that appeared to limit the progress of the project in Manufacturing Division were the sociological problems with the operators and supervisors, the changes in senior management during the course of the project and difficulties associated with the interfaces between Manufacturing Division and other areas of M.E.L. Whilst these factors were all significant, there appear to be more fundamental causes of the problems.

First, and probably most important, was the lack of clarity of the role of Manufacturing Division in M.E.L. No clear policy existed for metalworking in M.E.L. and a succession of managers had tried to fulfil a number of conflicting requirements within some very rigid constraints. The requirements appeared to be:

* To act as an efficient producer of metalwork so as to be competitive with sub-contractors on price and delivery ("production") for the Customer Divisions of M.E.L.
* To provide a high technology production centre making parts that were too difficult for sub-contractors to make ("problem solving")

9.2.2 Limiting Factors cont'd.

* To provide a high speed rescue service to cover for delivery or quality failures in sub-contractos ("problem solving")
* To support pre-production and development metalwork requirements when the capacity of M.E.L's model shops proved inadequate ("problem solving")

The "production" and "problem solving" roles conflict because of differences in the manufacturing systems required to support them. The "production" role demands low costs which implies a high level of operator and machine utilization and imposes pressures for the use of lower levels of skill (lower cost and a greater willingness to perform repetitive jobs). The "problem solving" role demands a much higher level of skill and a greater degree of flexibility from the operators and lower machine utilization to ensure a good reaction time to solving new problems.

The prime constraint was the physical size of Manufacturing Division's shop floor which restricted Manufacturing Division's output to between 1/3rd and 2/3rds of M.E.L's production metalwork requirements.

The size of Manufacturing Division was important because:

* It was not large enough to cater for M.E.L's total metalwork requirements
* It was too large to act as a pure problem solving activity

9.2.2 Limiting Factors cont'd.

* It was not large enough to contain a problem solving activity separable from the main production activity, but spanning a sufficiently broad area of technology and having enough capacity

No opportunity arose to consider expansion of the existing shop floor because the company was already hard pressed for space.

Other constraints, which made the management of Manufacturing Division difficult, were associated with the systems and interfaces between Manufacturing Division and other areas of M.E.L. In particular, no company wide system existed to estimate the implications of changes in the required output of finished products from the Customer Divisions to changes in the likely load on Manufacturing Division which made it very difficult to obtain an adequately smooth load for efficient operation. The accounting system posed other difficulties in requiring that cost data be collected and that overheads, capital and space costs be recovered at the operation level. The effect of the accounting constraints, apart from the high level of data collection necessary, was to distort the comparison between Manufacturing Division's costs and those of sub-contractors and hence decisions to "off-load" of manufacture in-house. The distortions exacerbated the loading difficulties.

The effect of the conflicting requirements, the physical constraints and systems distortions meant that the load to the shop floor varied not only in level, but also in character. Operators and supervisors saw a load that was heavily production orientated at times and were pressurised to work efficiently to detailed and specified job instructions. At other times the load was orientated more towards problem solving, when no instructions were available, but a high degree of skill was demanded.

The continuously changing role demanded of the operators and supervisors was possibly a key underlying cause of the sociological problems of the project. The problems had existed for many years before the implementation of Group Technology was attempted and it seems likely that they were rooted in the conflict between the high level of skill demanded to fulfil the problem solving role and the lower emphasis on skill, but higher demands on measured productivity in the production role.

The role conflict did not only affect supervisors and operators. The production control staff were not provided with an adequate system to cope with the changes in level and character of the load. Because the production control system demanded so much data, not only in the form of job instructions but also in the provision of detailed time estimates, a significant amount of time elapsed between a job being given to Manufacturing Division and its effect on the load being displayed. Additionally, no system existed to take into account the load presented in problem solving. The only method open to the controllers was to degrade the assumed capacity available from each operator in the control system to allow for this "sideways loaded" work. The degraded capacity distorted the performance measuring system and made the Supervisors' and Production Controllers' jobs more difficult since work turned down by the Production Controller because of an assumed lack of capacity was sometimes taken by the Customer to the shop floor for "sideways loading" where he stood a good chance of getting it made.

9.2.2 Limiting Factors cont'd.

These difficulties could well explain a large proportion of the observed sociological problems in Manufacturing Division, although as far as the project is concerned, due consideration should be given to the failure to include representatives from the Shop Floor, Supervision and Production Control at a sufficiently early stage in the project. Such a failure could well have meant that the operational staff in Manufacturing Division saw the Group Technology project as externally imposed and to be resisted or at most, put up with, rather than feeling a sense of ownership and looking for how improvements could make their job clearer or more rewarding. Fears of Supervisors and Production Controllers that the Cells would take over large parts of their jobs may have then become more important and deepened the gulf between themselves and the project.

Although Group Technology may provide an eventual answer to this conflict, no solution is yet in sight. The answer would, however, appear to be more likely to be obtained given the clearer picture of the real requirements of M.E.L. from Manufacturing Division generated by the use of the new manufacturing system and its greater ability to cope with problems as routine.

The second underlying factor limiting the progress of the project was possibly the low level of the initial installation. Thornley (46) has advocated a total approach for the installation of Group Technology in a company and Burbidge's survey (8) of many installations has indicated that "low key" attempts starting with one or two trial cells are much less likely to suceed than a high key project initiated and

9.2.2 Limiting Factors cont'd.

led by top management. A low key project is likely to flounder when it meets difficult interface problems or has to take policy decisions into account that were made in isolation from the project.

Examples of such difficulties associated with this project were:

* The failure to obtain agreement to modify the payment system. The lack of suitable compensation was the stated reason for the operators unwillingness to cooperate and provide the flexibility necessary to obtain maximum benefits from Group Technology. The non-cooperation of the operators was a serious set-back to the implementation and was only partially overcome by the unification of the turning cells (described in Chapter 5) and the production control system modifications (described in Chapter 6). The failure seemed mainly associated with management's fear of potential difficulties with staff in areas not implementing Group Technology and exemplified the interface difficulties of a low key project.
* The policy decisions to purchase 3 automatic lathes. These new machines were the first automatic lathes to be used in Manufacturing Division and some technical difficulties were experienced with their introduction. They represented a significant change to the capacity of the trial cell and gave M.E.L. the ability to manufacture significant quantities of work previously sub-contracted. Because no methodisation or load time information existed on this work, the effect of the new machines on the capacity of the trial cell could only be roughly estimated in comparison with the careful

9.2.2 Limiting Factors cont'd.

and detailed analysis that led up to the original cell design which did not include the automatic lathes. New problems were encountered with operators who objected to their jobs being, at times, devoted to finishing large quantities of parts which could not be fully dealt with by the automatic lathes. Additional problems were generated in production control of the larger batches capable of being digested by the new machines and in achieving a good balance of work in the cell without devoting its full capacity to completing a large batch from the automatic lathes to the exclusion of most other work. The performance measurement systems were distorted because they assumed that one operator was required to work each machine which was no longer true of the automatic lathes. Even though the worst effects of distortion were eliminated from the measurements, doubt was thrown on an important part of the cost benefit analysis. Coping with these problems and helping to solve the technical problems associated with the introduction of the new machines diluted the efforts of the project team and delayed the progress of the project.

* As yet no progress has been made on persuading design departments to include Group Technology principles in the design program. Consequently, parts family manufacture and standardization of metalwork features and components does not take into account the new techniques until the parts are made by Manufacturing Division.

9.2.2 Limiting Factors cont'd.

Not only does this reduce the benefits of the new system, but it increases the load on Manufacturing Division who has to code its own drawings and take into account a perhaps unnecessarily wide spread of technology

* At least part of the delay in modifying the production control system occurred because of priorities other than the Group Technology project. However, the main delay was the need to satisfy the new Plant Director of the appropriateness of the new ideas to M.E.L's needs before the modifications were allowed to commence.
* Some key production control problems were those concerned with the interfaces with the customer divisions and the support organisation. The project as structured, was not empowered to tackle these problems.

It is, of course, sheer speculation as to whether a higher key project would have been more successful than the project conducted, which was low key in nature.

Arguments supporting such a theory include:

* High key projects tend to get more advance thinking prior to setting up. In M.E.L's situation, some form of cost justification would probably have been demanded in advance of starting the project which would have obviated the delay and change of direction half way through

9.2.2 Limiting Factors cont'd.

* High key projects get more and better people on them. It is obviously difficult to be objective about the quality of people on M.E.L's project, but representatives from Supervision, Shop Floor and Supporting staff in Manufacturing Division, plus others from the interfacing areas of design, the Customer Divisions, Personnel, Accounting, etc., if properly managed, could have produced a higher rate of progress on a broader front. Particular problems that might have been tackled more effectively by such a team include those of operator payment, interfaces with the customer divisions and incorporating Group Technology in design. It was noticed that incorporating a representative from the computing department did much to reduce any interface problems in this area.
* High key projects get taken into account when policy decisions are made. Whether or not the automatic lathes would have been purchased, is perhaps not so important to the argument as is the mechanism of a high key project that would have taken such factors into account or delayed the purchase until a full examination of the effects of the new machines had taken place.
* High key projects can tackle bigger and more fundamental problems. Arguably, it is more likely that the conflict in Manufacturing Division's role would have

9.2.2 Limiting Factors cont'd.

been tackled and solved by a high key project. It must also be recognised that no scope existed on the project for examining more fundamental groupings of products and manufacturing facilities, such as integrating part of the metalwork activity with assembly areas and combining Manufacturing Division with model shops, etc. A much higher level project would have been needed to tackle these problems.

Against these arguments for high key projects are the problems associated with the pace necessary for a project involving a large number of people and a high level of change. The rate of improvement associated with the project must be maintained or its cost will come into question. If the pace demanded is too high, stubborn problems requiring time for their solution may get overlooked. Particular dangers are to be associated with problems of the sociological type encountered on this exercise. When people are being asked to change their attitudes, it seems doubtful whether a greater number of more socially skilled people telling them to do so will have the desired effect. Whilst skilled industrial relations expertise may help, there are perhaps problems that only time will solve and there is a distinct danger that high key projects could flounder on such problems or leave them unsolved only to have their re-appearance reduce or eliminate the long term benefits accruing from the installation of Group Technology.

9.3 Effects of the Computer

The use of computers has proved to be a key influence on both the direction and progress of the project.

9.3.1 Analytical Phase Effects During the analytical phase (see Chapter 5), two main separate courses of action were followed: one applying the modified Opitz code to drawings and the other developing the data capture system and the means of accessing and analysing the file produced. Only when both exercises were complete was it possible to embark on designing a new cellular structure for Manufacturing Division. The effectiveness of such a process depends on the speed at which the desired ends are reached, the quality of the analysis produced and "spin off" benefits that were a feature of the particular approach adopted.

In many one off analytical situations, a computer approach may take longer and cost more than more simple manual methods. However, although there is no control against which to truly evaluate the M.E.L. project, a case can be made for the efficacy of the computer solution in this situation.

First, although the analysis was only carried out for the General Machining area, the computer system is equally applicable to the N.C., Sheetmetal and Process areas with little or no modification. Any modifications are likely to be restricted to coping with a different classification system which will have only small effects on the programs and no structural effects on the files generated by the system.

Secondly, the data capture system was operating before the end of the coding exercise and its development was thus not on the critical path of the project.

Thirdly, the time required to finish the analytical programs on the 360/135, to transfer data to the time sharing computer and to develop the analytical programs was small and was completed well before their use was required by the project.

Fourthly, the use of the time sharing - interactive techniques - added power to the analytical process, allowing the evaluation of a considerable number of alternatives in a very short time. A very effective man/computer interaction was observed to weld the production engineering skills of the project team and analytical power of the computer together. This part of the analytical phase was arguably both the shortest and the most effective part of the project.

Fifthly, a large measure of confidence in the results was generated by using a computer system. Once tested, the computer programs were known to produce accurate analyses and the "authenticity" of an output on computer paper in the minds of people not familiar with computing techniques should not be underestimated. Trust in the accuracy of the results and the resulting conclusions was probably important in reaching the decision to create the trial cell.

Finally, the data capture system provided the basis for an ongoing archive of computer data on every day events in Manufacturing Division, which, although previously missing from the production control system, provided a basis for the improved performance measures described in Chapter 6 and for several new and different analyses since. The cost justification experiment could not have been carried out without a much greater data collection exercise than was necessary because the data capture system existed and lately, the system has formed the basis for investment decisions on new equipment in Manufacturing Division.

9.3.1 Analytical Phase Effects cont'd.

Since none of the benefits described above would have been achieved by the use of manual methods, which in any case might well have consumed more labour than the development of the analytical system, the overall effect of the computer on both the time scale and the effectiveness of the analytical process must be regarded as beneficial with extra "spin off" benefits for the future which should not be underestimated.

9.3.2 A Packaged Alternative At the start of the project, a packaged alternative based on production flow analysis was considered and rejected. Much of the data provided by the data capture system would have been necessary to provide as input to the package and the fees that would have been necessary to pay to gain access to the package were large. Few of the "spin off" benefits that were obtained from the in-house system would seem likely to have been obtained from the package, although the support necessary to develop the use of the package in M.E.L. would probably have been similar. The experience gained in the manipulation of the data in the Group Technology data files, was valuable in improving the company's understanding of Group Technology. This experience would not have been gained through the use of the package because of the commercial secrecy surrounding its structure. The commercial secrecy might also have reduced the trust in the results provided though the use of the package. In hind-sight, the decision not to use an externally developed package was probably right.

9.3.3 Production Control System Modifications A large part of the project was devoted to modifying the production control system to reflect Group Technology principles and to allow better control of a cellular organisation to take place. In assessing the role of the computer in this part of the project, there are a number of important considerations.

At the start of the Group Technology project, the computer already had a substantial role in Manufacturing Division in the shape of the production control system. This system not only formed the basis for production control, but also provided the vehicle for the communication with the Customer Divisions and of methods engineering and timing information to the shop floor. The system was deeply entrenched in Manufacturing Division after many years of use and the support organisations of "Planning" and "Production Control" were built round the needs of the system. The routine management process of Manufacturing Division was also built round the inputs and outputs of the Huizen system, so any modifications to its use were not to be undertaken lightly.

It is claimed (46) that Group Technology reduces paperwork and since the production control system constituted the majority of the paperwork in Manufacturing Division the modifications to the production control system should be viewed in the light of this claim. Chapter 6 shows that whilst the amount of paperwork involved in the production control system did not go up significantly, it did not decrease significantly either, although the revised system would appear to be more manageable. The quantity of data collected has remained substantially unchanged. The modified Opitz code is added, but this is not essential to the operation of the system so the only real

9.3.3 Production Control System Modifications cont'd.

additional data is that necessary for description of the cells and to divide the job instructions up so that correct routing may take place. The additional load to provide this data is not significant. The information provided by the system has been modified rather than changed in volume and reorientated to:

* exploit the cellular structure of Manufacturing Division by division of the production control problem into more manageable sections
* elevate the importance of delivering to due date and achieving short lead times by providing appropriate performance measures
* provide a pressure and a means for managing the cells as semi-autonomous "businesses" by appropriate organisation of the information output from the system.

It is difficult to speculate on the future success of these modifications or on the true relative load of the new system vis-a-vis the old whilst the Production Control section has to operate both the new and the old systems at once. Only when Manufacturing Division is fully cellularised will the true effectiveness of the modified system be revealed.

If the modified system succeeds in establishing the cells as businesses it may be possible for the management to consider some more drastic surgery on the system and its associated overheads. Such a step might involve:

9.3.3 Production Control System Modifications cont'd.

* a policy decision to eliminate cost data collection at the operation level
* a demonstration that the divided production control problem can be handled without a great deal of paperwork support
* development of a more simplified means of establishing the long/medium term load in Manufacturing Division vis-a-vis that required so that good deliveries can be maintained and a rational off-loading policy followed
* development of simplified performance measures
* a demonstration that job instructions are either not needed or can be more effectively communicated to the shop floor.

At this stage, it is difficult to visualise how such extensive modifications could be successfully attempted. However, some scope is seen for reducing the time lapse between receipt of an order and issuing it to the shop floor by better systems design and a more appropriate organisation along the lines suggested in Chapter 8.

It must, therefore, be concluded that, at least, in the exercise so far, Group Technology has not so far reduced the paperwork or the associated overheads. However, the measured improvements indicate that Group Technology produced an incease in the trial cell's performance without a significant increase in the paperwork.

9.3.3 Production Control System Modifications cont'd.

There are also important underlying implications of what happened and what was achieved.

First, because the system was so deeply entrenched, the organisation was accustomed to control and costing being done in the manner indicated. A high level of control was expected and the Group Technology project was started mainly to improve the performance of Manufacturing Division to be in line with that seen to be needed by the business. A reduction in overheads was not one of the objectives but an improvement in control was. In an organisation faced with control rather than cost problems, it is probably less likely that simplification and reduction of the control system will be tackled. M.E.L. is now entering a more cost conscious phase, so it will be interesting to see if reduction of control costs and simplification of the control system becomes an important future objective.

Secondly, an important defect in M.E.L's production control process is the separate nature of the Huizen system. In building the data file to design the new organisation, special links, both computer based and manual, were forged between the Huizen system and other systems in M.E.L. These links proved too difficult to maintain on a permanent basis and so there is no direct means of assessing the implication of a change in either the product delivery or stock situation on the load on Manufacturing Division. The partial nature of M.E.L's control system may be producing effects of sub-optimisation which may be deteriorating the company's delivery performance and stock investment unnecessarily. Recently, a simple system has been installed to indicate the resource implications of a commercial forecast, which may go at least part way towards solving this problem, but a permanent solution seems more likely to lie in the company's moves towards a data base which would make a fully integrated control system more possible. Such a system would allow speedier and more effective management of the interfaces between Manufacturing Division and its customers, together with improvements in stock investment and delivery performance by more effective batch sizing and control. A related improvement might be possible in the use of Manufacturing Division and sub-contractors via a better understanding of Manufacturing Division's role along the lines suggested in section 9.2.2.

Thirdly, the modified Huizen system provides only limited help on the problem of job sequencing to exploit the benefits of parts family manufacture in M.E.L. The "Ouija boards" described in Chapter 6 are difficult to set up and provide only a modicum of assistance to solving complex sequencing problems. Chapter 8 suggests a real time computer system to evaluate more sequences more easily and quickly together with some ideas for fully automating the problem solution on a quasi-optimal basis.

It is therefore, concluded that the modified Huizen system represents an interim solution to the production control problem in Manufacturing Division. The problem of routing jobs to cells correctly has been solved with minimal change to the system and its surrounding support organisation and management processes and the information is better organised for improved control of the cells as "businesses" and for the exploitation of parts family manufacture. However, further development is necessary to fully overcome the problems associated with the interfaces between Manufacturing Division and its customers,

9.3.3 Production Control System Modifications cont'd.

the "production" and "problem solving" role conflicts and job sequencing. This development should take into account further revision of Manufacturing Division's organisation - particularly the support areas and the potential for reducing the cost of control.

It is also important to note the importance of the success of the system modifications to the Group Technology project. The Management was not prepared to go ahead with construction of further cells until the success of the system modifications had been demonstrated. Consequently, it must be concluded that, on this project, the control system was a major influence on both the direction and progress of the implementation of Group Technology in M.E.L., particularly since it provided the means of bridging a desired change to the shop floor organisation and methods within the constraints of minimal changes to the methods and structure of the support organisations and of the accounting and other systems operating in other parts of M.E.L.

9.4 Other Ideas and Conclusions

During the course of the project, several opportunities occurred both for the employment of new ideas and for observations of the effectiveness of existing techniques in Group Technology.

9.4.1 Analytical/Learning Processes Chapter 5 examines the effectiveness of the analytical process leading up to the design of the trial cell. It is clear that the analysis produced only part of the information necessary for the design of the cell. By itself, the analysis could not have achieved the end result. It was necessary to use the information from the computer in conjunction with a good deal of knowledge and judgement of both the potential benefits of Group Technology and Manufacturing Division's particular situation. At the start of the project, no one person possessed sufficient information to embark on a "peripatetic" design of a cellular system. An important aspect of the analytical approach was, therefore, a mutual learning process to combine the necessary skills for the design of the cells. In hind sight, the Opitz code was probably not the best classification system for M.E.L's future needs but, as an existing and verified system, it provided a good vehicle for the project team to get an objective view of how best to install Group Technology in the General Machining area. The combination of the classification exercise and the data gleaned from existing methods provided a powerful learning process for all involved. A particular feature was the "real time" analysis of the data which allowed a powerful learning-by-experiment process to take place.

It is only speculation to consider whether Production Flow Analysis would have achieved a similar result, but perhaps the opportunity will exist to compare the two approaches when the design of sheetmetal and process cells is attempted.

9.4.2 The Computer as a "Bridge" The use of the restructured Huizen system to bridge the reorganised shop floor with the existing Methods Engineering and Planning process has already been mentioned. The power of data processing information systems in bridging interfaces between different organisations is not to be underestimated. Good

9.4.2 The Computer as a "Bridge" cont'd.

computer systems design, however, can compensate only in part for bad organisation design. Better solutions should be looked for first in improved organisation design, rather than more clever systems. At best, a computer system can only overcome those shortcomings of the organisation that are amenable to solution by provision of better information. Such a solution is no substitute for good organisation eliminating the interface problems. It is, therefore, believed that reorganisation of the support areas in Manufacturing Division must be looked at before the full benefits of Group Technology can be realised.

9.4.3 The Computer as an Aid to Measurement The power of the computer to glean extra information from data that is collected as part of an ongoing operation provides a means of avoiding at least part of the Hawthorne effect that poses such problems in judging the improvement gained by a new organisation. The cost justification experiment illustrates this point well, but it should be noted that in an industrial situation, it is very difficult to eliminate the effects of a measurement process on the results obtained from a group of people. It is not safe to assume that, simply because the computer stands between those measured and the person doing the measuring, the Hawthorne effect is eliminated. A truely valid industrial experiment is very difficult to envisage and it is certainly not claimed that the experiment reported in Chapter 7 comes into this category. However, it seems likely that the gleaning of extra information from data provided to the computer as part of the normal process provides a significant means of reducing the impact of the measurement process on the results obtained.

9.4.4 The Computer as a Decider The most common use of computers in an industrial situation involves simple calculations and sorting processes only. In two cases on this project, the computing was extended into the area of routine decision making. The first example is the solution to the routing problem where production group numbers on jobs were matched with those occurring in the cells to specify which jobs should be loaded to each cell. It was noted that such a solution could not be obtained by the use of a classification system appropriate to the geometry and surface features of the parts themselves, although this problem certainly does not rule out such solutions in other situations. The approach used is probably not appropriate to production situations where individual machines are numbered since routing at the machine level rather than the group level might solve the routing problem more easily. However, given the particular situation in Manufacturing Division, the structure of the Huizen system and its data, the solution produced is believed to provide a good decision making process with little perturbation of either the system or its data and much less work for Manufacturing Division than if a manual decision making process was adopted.

The second example is in the simulation model mentioned in Chapter 8 that is currently being used to evaluate the potential for job sequencing and parts family manufacture. Here the essence of the computing process is to evaluate an adequately large number of possible job sequences, select the few that look the best and present the results for final selection by management. The approach is still in its infancy, but is already showing promising results and could form the basis for automated job sequencing in the future. Such uses of the computer, particularly if provided in "real time" to allow exploration of viable alternatives on a "what if"? basis (c.f. the analysis of data prior to cell design) would provide a means for considerable improvement of routine management decision making. Areas of particular interest for the future of Group Technology in M.E.L. include evaluation of in-house / sub-contracting decisions and batching decisions.

9.5 Coda

The computer has proved to be a major influence on the project to implement Group Technology in M.E.L. It has helped in the analysis of data, cell design and production control. The presence of an entrenched computer based production control system was a key influence on the methods adopted and the extent of the re-organisation. Whilst only one influence on a project that had to cope with the complexities of implementing Group Technology in a large multi-product company and in an area with some difficult pre-existing sociological problems, the presence of the computer was important. The wider use of computers in manufacturing industry means that the relationship between computers and Group Technology will have to be taken into account and it is felt that a great deal of extra work will be necessary before the areas touched on by this thesis are fully understood.

Edwards and Schmitt (48) concluded that:

"The impact of the cell system on production system design is almost unknown because the flow line and functional systems have been perceived as the only two manufacturing systems and Group Technology is being seen merely as a new technique".

9.5 Coda cont'd.

The problems encountered during this research have indicated that a total view of the manufacturing system is important in an implementation of Group Technology which must take into account the complexity of the relationships between parts, people, machines and information systems before a satisfactory implementation of a new manufacturing system can be achieved.

CHAPTER 10

CONCLUSIONS

1. Group Technology is not merely a new technique, it represents an alternative approach to the design of manufacturing systems.

2. If the full benefits of Group Technology are to be realised, far reaching changes to a company's organisation, systems and methods may be necessary.

3. If the extent of the changes required to fully exploit Group Technology is not realised at the outset and the implementation project managed accordingly, the full benefits of the new manufacturing system may not be obtained.

4. Because computer based management information systems can have a powerful influence on the design and operation of manufacturing systems and because of the wide and still spreading industrial use of computers, it is important to consider their potential application as part of a project to install Group Technology.

5. The extent to which a company has access to and is familiar with using computer based information systems can have an important effect on a project to install Group Technology.

6. Where significant computing expertise exists in a company, it appears undesirable to adopt a "package deal" approach to the implementation of Group Technology. It seems better to combine the company's own internal expertise on computing,

6. cont'd.

organisation and manufacturing methods with the required external expertise in Group Technology to install the new manufacturing system, rather than impose an externally developed system on the company.

7. A computer can be of considerable assistance in providing, analysing and synthesising data to aid the design of a new shop floor organisation.

8. It has been shown that a computer can be used to comb data from existing systems and combine it with data necessary for the incorporation of Group Technology principles to provide a data file suitable to support the design of a cellular organisation.

9. It has been shown that simple decision rules can be generated to describe a cellular shop floor organisation in a way that enables a computer to select data appropriate to each cell and synthesise a forecast of cellular loading patterns.

10. "Real Time" interrogation of the data file was found to be a powerful and effective means of combining the analytical and synthesising power of a computer with human judgement, expertise in Group Technology and knowledge of the organisation and methods of the area where implementation was being considered, to design an appropriate new shop floor organisation based on cellular principles.

11. Computer based information systems have an important role to play in supporting a manufacturing system based on Group Technology, particularly in areas of production control, design and payment.

12. The work flow in a functionally based batch/jobbing production organisation can be simplified by moving to a well designed cellular organisation, which should reduce some production control problems, but may introduce others which have to be solved before the full benefits of Group Technology can be realised.

13. Operators and supervisors may not be able to provide the increased flexibility necessary to fully exploit Group Technology. The need for flexibility can be lessened by designing larger cells and by good support from production control. However, many benefits may still be lost if sufficient flexibility cannot be obtained.

14. The faster reaction time required from Group Technology based manufacturing systems places a greater emphasis on good marshalling of resources and speedy solutions to problems of operator absenteeism and machine/tool breakdown.

15. In a Group Technology situation, control of production via the management of inter-operation job queues may no longer be possible because the queues are too short. There are also new shop floor routing and job sequencing problems to solve, all of which may pose problems for a conventionally designed production control system.

16. The new organisation may necessitate changes to the type, distribution and timing of information provided by the production control system.

17. It has been shown that a conventionally designed production control system can be modified to accommodate the particular needs of Group Technology.

18. An algorithm has been developed to enable the computer to solve the problem of routing jobs and information in a cellular organisation with minimal changes to existing data describing machine functions. The algorithm enabled an otherwise massive program of modifications to an existing bank of production control data to be brought well within manageable bounds.

19. The production control system was strengthened to provide better support for: balancing demands on flexibility by good capacity planning and scheduling aids; marshalling materials and tools prior to commencing production; aiding job sequencing to reduce setting times and avoid machine interference; performance measurement and the management of cells as businesses.

20. An appropriately designed computer based information system, properly keyed into an effective routine management process, can do much to maintain the effectiveness of a manufacturing system.

21. It is important for an information system to provide performance measures which relate to the key objectives of the area which it is supporting. Although existing information may already be provided on productivity and financial performance, in the

21. cont'd.

Group Technology situation it is important to measure thru-put time and delivery performance. Pictorial presentation of performance measures is effective and can be achieved by conventional computing facilities and algorithms which were developed as part of this research.

22. The modified production control system provided a bridge between the new cellular shop floor organisation and support areas of production control, methodization, estimating and accounting which could not be reorganised at the same time.

23. In some cases, it may not be desirable to change too many parts of a company's organisation and systems at once. Because the effects of Group Technology can be so widespread, it is important to provide a means of linking the areas where implementation has taken place with areas affected by the implementation, but which have yet to be reorganised accordingly. A computer information system can provide this bridge and thus generate the means for the more gradual spread of the new principles round a company and the avoidance of problems that might otherwise occur.

24. In designing manufacturing systems an organisational solution to problems should be sought before attempting an information systems solution.

25. The dependence of a company on its existing systems may have important ramifications for the implementation of Group Technology. The strength of the existing systems links with

25. cont'd.

the organisation may mean that modifications to the systems and the necessary re-training of the staff using them imposes high costs and long delays on the installation project. For this reason, adapting existing systems and providing bridges seems to be a better approach than re-designing from scratch or bringing in a new system on a "package deal" basis.

26. There are particular problems associated with the introduction of Group Technology into a complex multi-product company. These problems centre on difficulties of introducing changes in the areas suited to Group Technology without causing damaging effects in other areas unable, unsuited or unwilling to adopt the new methods. A particular problem is that of operator payment.

27. Because Group Technology is most suited to the production of components, in the complex company, it is most likely to be implemented in areas which are suppliers of other areas assembling finished products. Good systems links between component suppliers and users are important if the better thru-put time and delivery performance achieved by virtue of Group Technology is to be properly reflected in a reduction of stocks and work-in-progress.

28. It is important to strengthen the systems links between component design and manufacture if the full benefits of component variety reduction are to be realised.

29. It was shown that in the company studied, there was an important conflict between the production and problem solving roles of the area where Group Technology was implemented. The conflict undermined the effectiveness of the area, the relationships between the staff involved and the effectiveness of the production control system. The conflict caused extra difficulties and delays to the project to install Group Technology.

30. The full cooperation of all staff liable to be affected by the implementation is important if maximum benefits are to be obtained from the new system. Of particular importance are operators who have to provide greater flexibility of working and supervisors who have to cope with the threat to their jobs posed by autonomous cells.

31. At the working level, considerable efforts should go into building trust and understanding between management and the shop floor. Efforts should be made to reduce the threat of Group Technology by relating it in more familiar terms of changes to shop floor layout and the production control system.

32. In Group Technology, it appears that groups of products, parts and machines are often the primary consideration whereas, in other industrial group working situations, people have a greater relative importance. A better balance between the needs of people and the perceived efficiency of the system might produce more effective results.

33. Group Technology provides the means for tackling poor parts standardization via parts family manufacture and sequence technology and for improving standardization via design retrieval based on component classification.

34. Component classification systems are not yet ideal. A particular difficulty is the manifold requirement for a classification system in Group Technology viz. to support: organisation design and maintenance; parts family manufacture; job sequencing and routing in the new organisation; and information retrieval to improve parts standardization. Classification systems appear best suited to support standardization and parts family manufacture. The case for classification systems as the optimum basis for fulfilling the other needs has yet to be proven.

35. The extent of the changes required to fully exploit Group Technology and the magnitude of the benefits to be obtained warrant a strong link between the implementation project and top management. If this link is broken or changed significantly during the project, important changes to the direction of the project may ensue which can delay the implementation.

36. An industrial experiment that will truely establish that improvements in performance are specifically due to the implementation of Group Technology may be difficult to design and conduct.

37. The problem of justifying the start or continuation of a project to implement Group Technology can be eased if a computer can be used to provide the necessary data from that collected to support existing systems. Not only is the data collection task reduced, but also, Hawthorne effects may be minimised.

38. Whilst the implementation described in this thesis was only partially complete at the time of writing, significant benefits were demonstrated and opportunities for future development identified.

39. A total view of the manufacturing system is important in an implementation of Group Technology, which should take into account the complexity of the relationships between people, machines, parts and information systems in achieving the objectives of the business concerned.

APPENDIX 1

THE HUIZEN SYSTEM

The purpose of this appendix is to describe the Huizen System and its related management processes. A fully detailed description is not given, but an attempt is made to give enough understanding both of the system to support the arguments for the modifications described in Chapter 6 and of the data that was used in the analysis described in Chapter 5.

Figure 62 shows the main events in the production control process. 10 parts of the organisation inter-related with the system:

* Manufacturing Division's Production Control, Customer Liaison section who negotiated with the Customer Division on promised delivery dates on the basis of the known load in the system and the customer requirements
* Manufacturing Division's Methods Engineering ("Planning") section who detailed the methods necessary to manufacture each part and decided to which machine group the jobs should be loaded during the manufacturing process. Theyalso specified the material to be used in type (from the drawing) and quantity
* T.E.O's estimating section who worked out the standard time (set and run) for each operation

* Manufacturing Division's Scheduling Section who decided on the due dates for completion of individual operations on each job with reference to the due date agreed with the customer
* Manufacturing Division's Data Preparation section who punched data onto paper tape and liaised with the computer department. They also held the files of data previously input to the computer
* I.S.A. department who transcribed the information on paper tape onto magnetic tape for input to the computer and who ran the Huizen system
* Manufacturing Division's Production Control Progressing Section who loaded jobs to the shop floor and managed their progress until delivery was achieved
* Shop floor staff who returned data on time taken, quantity passed to the next operation, etc.
* A system liaison officer who was responsible for managing the allocation of production group numbers (signifying groups of similar machines) and "trouble shooting" any technical difficulties with the system by liaison with the I.S.A. department
* Accounting staff who used the data provided on times taken to compile "job costs" which were required by some customers.

The data needed to run the system was kept in 5 files.

* Drawing files containing drawings of all parts which were being or had been previously made by Manufacturing Division in drawing number order

* Master layout files containing a copy of the manufacturing instructions and the paper tape used last time a job was made. Master layouts were held in drawing number order
* The computer master file on magnetic tape containing all data necessary for the computer system to run on current jobs and data on time taken, start and finish dates and quantities passed to the next operation for each completed operation. For the order and structure of this file see below
* Work packets containing the drawing, the manufacturing instructions and punched cards for the return of data from the shop floor. One work packet was produced for each job and accompanied the job throughout the entire manufacturing process
* The "dead layout file" containing the job instructions on completed jobs. Comments were written on the job instructions as the job progressed and the "dead" layout was used to answer customer queries after the job had been delivered.

The computer system followed standard "first generation" (tape based) design practice. The system was based on one "master file" containing all the data on every job "in the system". The master file structure is shown in figure 64. It will be seen that data pertinent to each job was structured into a sequential series of records as follows:

* The "Header Record" containing details of the job starting with the job number and going on through such details as the quantity due to be delivered, the allowance for scrap, the planner responsible for detailing the instructions, etc. etc.
* "Operation Records" (one for each operation in sequence) containing detailed manufacturing instructions, set run and calculated total load times for the operation, due start and finish dates, the machine group on which the job was to be run, any special tools required, etc., together with space for recording actual performance (start and end times) and the clock numbers of the operator performing the operation
* A material record containing a specification of the material and quantity required together with the date when the material was needed.

The data fields within the records were similarly organised, but not identical. The system designer had clearly attempted to follow the same basic record structure for all records departing from this only when he had to. Space was allowed for further unspecified data by the provision of "filler" fields left blank until future modifications to the system might require their use. Some data was duplicated in different parts of the records to minimise processing time.

The file was held in job number order, the job number being a composite of the "works order number " (indicating the Customer Division and product, authorising expenditure and against which costs would be collected), the drawing number and batch number.

Processing was strictly sequential and required about 8 hours per week to process the data on about 3000 jobs. Core required was limited to 64K 8 bit words.

The system followed for data input depended on whether or not Manufacturing Division had made the part before. A description of the process appropriate to a new job will be given, followed by indications on the changes to the process if the job had been made before.

Step 1 Customer Liaison - Input

Customers would approach Manufacturing Division armed with a works order number, a full set of drawings for the parts they needed and a list of the quantities required obtained from the P.D. system (see section 4.4.2). After studying the drawings in conjunction with the Head of the Planning Section, the Head of Production Control would estimate the total load represented by the job and negotiate a delivery date on the basis of the known existing load (provided by the system on a tabulation formulated as shown in figure 43) and his estimate of the load represented by the new job.

Step 2 Initial Data Input - Material Ordering

Having obtained agreement on the due date, a Planner would open a layout form (see figure 65) and supply basic data on the job and the material required. The form would then be passed to Manufacturing Division's data preparation staff who would punch a paper tape from this information on "Flexowriters". The information would be passed to the computer which would consolidate the information on all new jobs submitted onto a weekly tabulation listing the material required (see figure 66). The Production Controller's Material Control Clerk would check material stocks and order any new material requirements via a Purchasing Department Instruction form.

Step 3 Methodization

The master layout form and the drawing would be passed back to the Planning Section who would detail instructions for each process necessary to complete the part and decide on what machine group each process should be conducted. Any special tools were listed at this point and the requirements communicated to the Tool Room in Manufacturing Division (see below and figure 67).

Step 4 Standard Times

The master layout and the drawing were then passed to the T.E.O. department where standard times (set and run) were worked out and added to the form.

Step 5 Scheduling

The completed layout form was then passed to the Production Control Section who decided on the due dates for each operation with respect to the due date for delivery of the completed part and on any necessary down batching with reference to the existing load and operation times per machine group.

Step 6 Computer Input

The layout form was transcribed onto paper tape by the Data Preparation staff and then onto magnetic tape and into the computer. The Huizen system contained two levels of screening programs: one to check for invalid characters and parity errors and another to check that certain specified fields were within allowed ranges. Any errors were passed back to the Data Preparation staff for correction. The completed information was matched with the job and material data already input by means of the job number.

Step 8 Material Progressing

Each week the entire system was run twice, but not all the tabulations were generated at each run. In particular, the major progressing document was generated once each week. This document was known as the "work issue list" - see figure 45. The work issue list contained details of each operation on all jobs from 4 weeks before their due start date until they were recorded as delivered. An indicator showed whether material was available, being set by return of a "material ready" punched card to the system when the material arrived. Any jobs "held" for lack of material and hence unable to start their first operation would have their "material ready" indicator shown as zero. Each week a progress clerk chased any material needed within the next few weeks on the basis of the information on the work issue list.

Step 9 Shop Loading

Each week, the computer would generate a set of pre-punched cards for all jobs due to start 4 weeks hence. The cards were:

* A material ready card
* A start card for each operation
* A finish card for each operation
* Three "remarks cards" for notifying any particular reason for a job being held up at a particular operation - e.g. tool failure
* 2 delivery cards.

The cards were sorted into operation order and placed in a wallet with a copy of the operation instructions generated at the same time as the cards (see figure 68) and a copy of the drawing retrieved from the file. The "work packets" as these jobs were known, were then stacked according to the due start week and the machine groups where they were to be worked on. Each week the "shop loader" distributed the work packets due to start and re-distributed jobs that had been completed by one section, together with the part-finished items, to the next section shown on the operation instructions using the work issue list as his overall guide.

Step 10 Manufacture and Data Recording

Operators either collected a new job from the waiting stock of work packets or the trays of work-in-progress. Their first action was to punch the start card for return to the computer. The start card contained details of the job and operation to be started and the "clocking" action recorded the start time of the job. The operator would set up his machine and run it to complete the operation. Once completed, the operator would record the mumber passed to the next operation on the "finish card" together with his clock number and "clock off" the job.

Step 11 Progressing

The work issue list (figure 45) was the prime document used for progressing as well as details describing the job and the operation immediately due, the previous and next machine groups processing the job were shown. The work issue list was shown in order of the due week of the current operation. The other printout used for progressing was known as the "micropert" (see figure 49). The micropert was printed in job number order to group jobs by Customer Division. A list of the machine group numbers to be visited by the job before its completion was given (any completed operations were shown as dashes) together with a pictorial representation of the state of progress against the delivery schedule. The "micropert" was easy to read and gave an immediate picture of any late jobs liable to slip beyond the due date. The micropert was the prime document used to liaise with customers when jobs slipped or re-scheduling was required by either Manufacturing Division or the customers for other reasons.

Step 12 Inspection

After completion of manufacture, jobs were inspected to ensure that they met the specification. Any rejects were either repaired by "sideways loading" - negotiated between the inspector and a supervisor direct without notification to the system or rejected for replacement by a new batch after Production Control had been notified and had made appropriate negotiations with the customer. The quantity passed for delivery was marked on the delivery card which was stamped by the inspector who also sent the operation instructions to the dead layout file and the drawing, back to the drawing file.

Step 13 Delivery

The job was sent to stores with 2 delivery cards. The first card was kept with the job for eventual use by the customer, the second card was used to up-date the stock records and was then returned to the computer. On receipt of the delivery card, the computer would delete the data on the job from the master file and hence from any future tabulations.

Step 14 Performance Measures and Job Costing

Each week a tabulation for each machine section was produced showing the achieved productivity, which was computed by comparison of the standard and actual times for the operations (see figure 53). The standard time included a percentage learning allowance (computed from a look-up table) dependent on the batch size and credit was given for work on which no proper standard time was available at an agreed rate. The actual times were accumulated under each works order number and the total charge notified to the accounts department each month on an "Admin. Routines" report. The job cost was worked out as simply the product of the hours worked and an hourly charge inclusive of wages, salaries and overheads, and an allowance to recover capital and space employed in the manufacturing process.

In cases where Manufacturing Division had made particular parts before, the planning and estimating stages were omitted, unless the Production Controller felt that re-planning was called for. The master layout and paper tape used the last time the job was made, was retrieved from the master layout file and after any appropriate amendments, particularly to the due date, transcribed into the computer. The Huizen system contained a facility for automatically amending all the operation scheduled dates according to the new due date and the time lapse between the old and new due dates.

BIBLIOGRAPHY

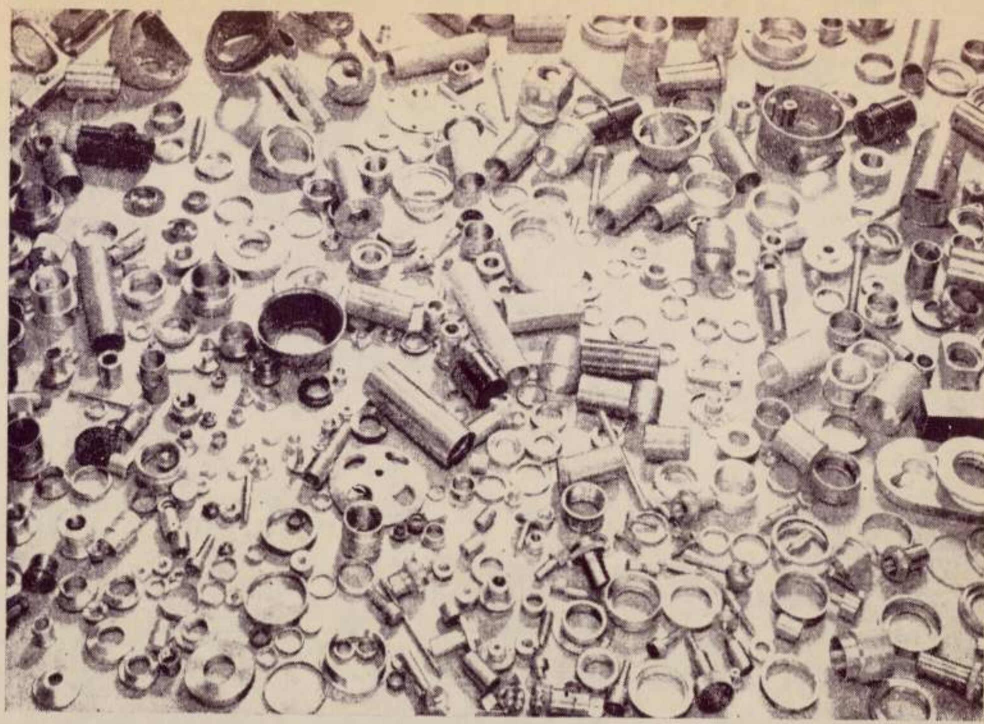
Thesis Ref. Number	Author(s)	Where and When Published
1.	Thornley R.H.	"An Introduction to Group Technology". Conference: Group Technology UMIST 4th - 6th July 1972
2.	Mitrofanov S.P.	"Scientific Principles of Group Technology" English Translation Published by the National Lending Library 1966
3.	Drurie F.R.E.	"A Survey of Group Technology and its Potential for User Application in the U.K.". The Production Engineer 49, 51, 1970.
4.	Hall P.D.	Metal Working Production, February 1975 pp. 45 - 51.
5.	Brown J.A.L.	"The Social Psychology of Industry" Penguin Books Ltd. 1964.
6.	Fazakerley M.	"A research report on the human aspects of Group Technology and Cellular Manufacture". Institution of Production Engineers - Group Technology Division - November 1975.
7.	Lepper C.	"G.T. Methods at Rolls Royce (1971) Ltd." The Institution of Production Engineers Group Technology Division 3rd Annual Conference. November 1973.
8.	Burbidge J.	"Group Technology" - A course for industry. INCOMTECH. October 1975.
9.	Edwards G.A.B.	"Readings in Group Technology". The Machinery Publishing Co.Ltd. 1971.
10.	Allen C.	"Computer Aided Design, Drafting and Manufacture in Avionics" - Computer aided design 6.4 October 1974.
11.	-	"Group Technology Case Study and Works Visit to Mercer Gauges Ltd. The Institution of Production Engineers May 1974.

Thesis Ref. Number	Author(s)	Where and When Published
12.	Arn E.A.	"Applications of Systems Engineering to Group Technology" Ph.D thesis submitted to the University of Aston in Birmingham March 1974.
13.	Sawyer J.F.H. and Arn E.A.	"Payment Systems" Institution of Production Engineers, Group Technology Division, 3rd Annual Conference November 1973.
14.	Hertzberg F.	"Work and the Nature of Man" World Publishing Co. 1966.
15.	Gallagher C.C. and Knight N.A.	"Group Technology" Butterworth & Co. 1973.
16.	Schmitt J.P.	"Management Structure as applied to G.T.". Third Annual Conference of the Group Technology Division of the Institution of Production Engineers. November 1973.
17.	-	"Computercrime" B.B.C. Radio 4 August 4th 1976.
18.	Couling A.J.	"A Comparison of Classification Systems in the Machined Components Industry". University of Aston in Birmingham. Department of Production Engineering B.Sc. Final Year Project March 1974.
19.	Burbidge J.L.	"Production Flow Analysis". Production Engineer 42, 742.
20.	Burbidge J.L.	"Production Flow Analysis" Production Engineer 50,139.
21.	Muther R.	Systematic Layout Planning.
22.	McCauley J.	"Machine Groupings for Efficient Production". The Production Engineer pp. 53 - 57 February 1972.
23.	El-Essawy I.G.K. and Torrance J.	"Component Flow Analysis - an Effective Approach to Production Systems Design". Production Engineer 1972. 51, 165.
24.	Rajagopalan R. and Batra J.L.	"Design of Cellular Production Systems". International Journal of Production Research. 13, 6, November 1975 pp 567.

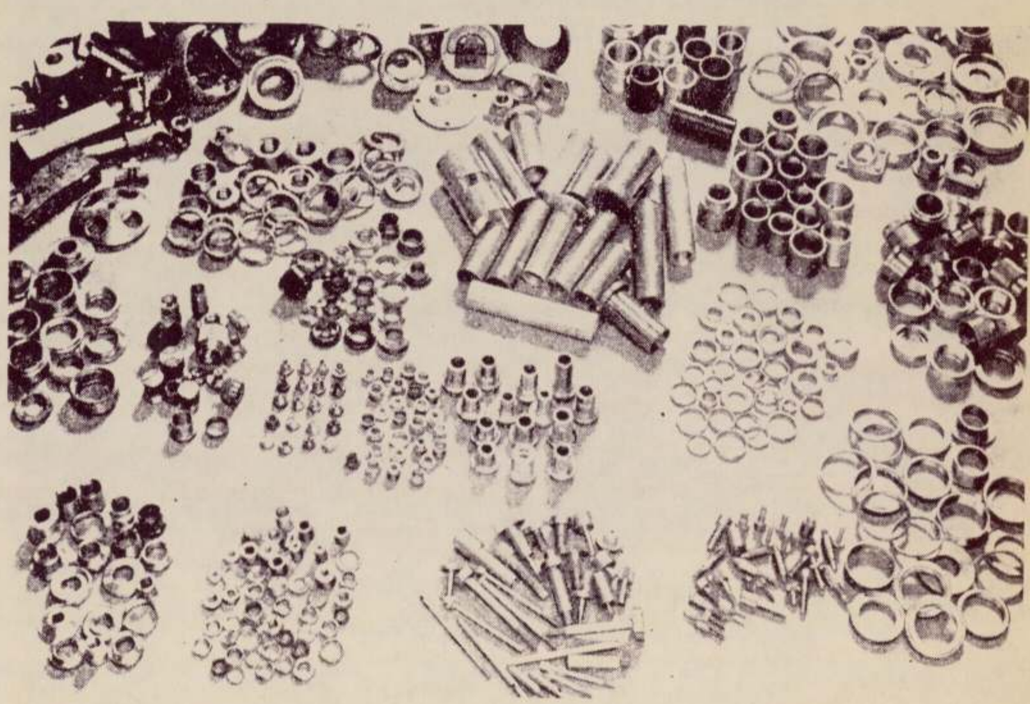
Thesis Ref. Number	Author(s)	Where and When Published
25.	-	"An introduction to the Miclass System". TNO Metal Research Institute for Metalworking Report. Technical Centre for Metalworking. Laan van Westanenk 501, Apeldoorn, The Netherlands.
26.	-	Visit to TNO Metalwork Laboratories 1976. Unpublished.
27.	-	"Group Production - Methods of Flow Analysis" PERA Report No. 243. September 1971.
28.	Burbidge J.L.	"Production Flow Analysis and the Computer". Third Annual Conference of the Institution of Production Engineers November 1975.
29.	Burbidge J.L.	"Group Technology". INCOMTECH course for industry. October 1974.
30.	Muther R.	"Introduction to Layout Planning" Seminar given in July 1974.
31.	Churchman et al.	"Introduction to Operations Research". John Wiley and Sons 1957.
32.	Philips D.T.	"The Out of Kilter Algorithm" Industrial Engineering 1974 February. pp 36 - 44.
33.	Driscoll J.	Preparation for Ph.D. thesis discussed. July 1974.
34.	Sawyer J.F.H. and Arn E.	"Payment Systems" Institution of Production Engineers Third Annual Conference. November 1973.
35.	Burbidge J.L.	"The Principles of Production Control". Macdonald and Evans 1962.
36.	Brown R.G.	"Statistical Forecasting for Inventry Control". McGraw Hill 1959.
37.	Lewis F.A.	"The Design and Operation of Flexible Cell Systems". The Institution of Production Engineers Group Technology Division. November 1975.
38.	-	"Sequence Technology" PERA Report No. 18.

Thesis Ref. Number	Author(s)	Where and When Published
39.	Nicholson T.A.J.	"Optimisation in Industry" Volumes 1 and 2. Langman Press London 1971.
40.	-	Visit to Ferranti Edinburgh 23rd October 1974. Organised by C. Allen and A.J. Page.
41.	-	"Class 25" I.B.M. U.K. Ltd. August 1969.
42.	-	"Defence Standard 05-21". Ministry of Defense Directorate of Standardization 1973.
43.	Opitz H.	"A Classification System to Describe Work Pieces". English Edition - Permagon Press 1970.
44.	Gannt H.	"Gannt on Management". New York: American Management Association 1960.
45.	Urwick L. and Brech E.F.L.	"The Making of Scientific Management". Vol. III. Pitman London 1948.
46.	Thornley R.H.	"Group Technology - A Complete Manufacturing System" Inaugural Lecture published in the British Engineer May 1972.
47.	Kast F.E. and Rosenzwig J.E.	"Organisation and Management: A Systems Approach". McGraw Hill 1970.
48.	Edwards G. and Schmitt J.P.	"Manufacturing - Not so much a technology more a way of life". pp 15 - 28.

FIGURE 1 ILLUSTRATION OF COMPONENT FAMILIES



A RANGE OF COMPONENTS TO BE MACHINED



THE SAME COMPONENTS ARRANGED IN GROUPS

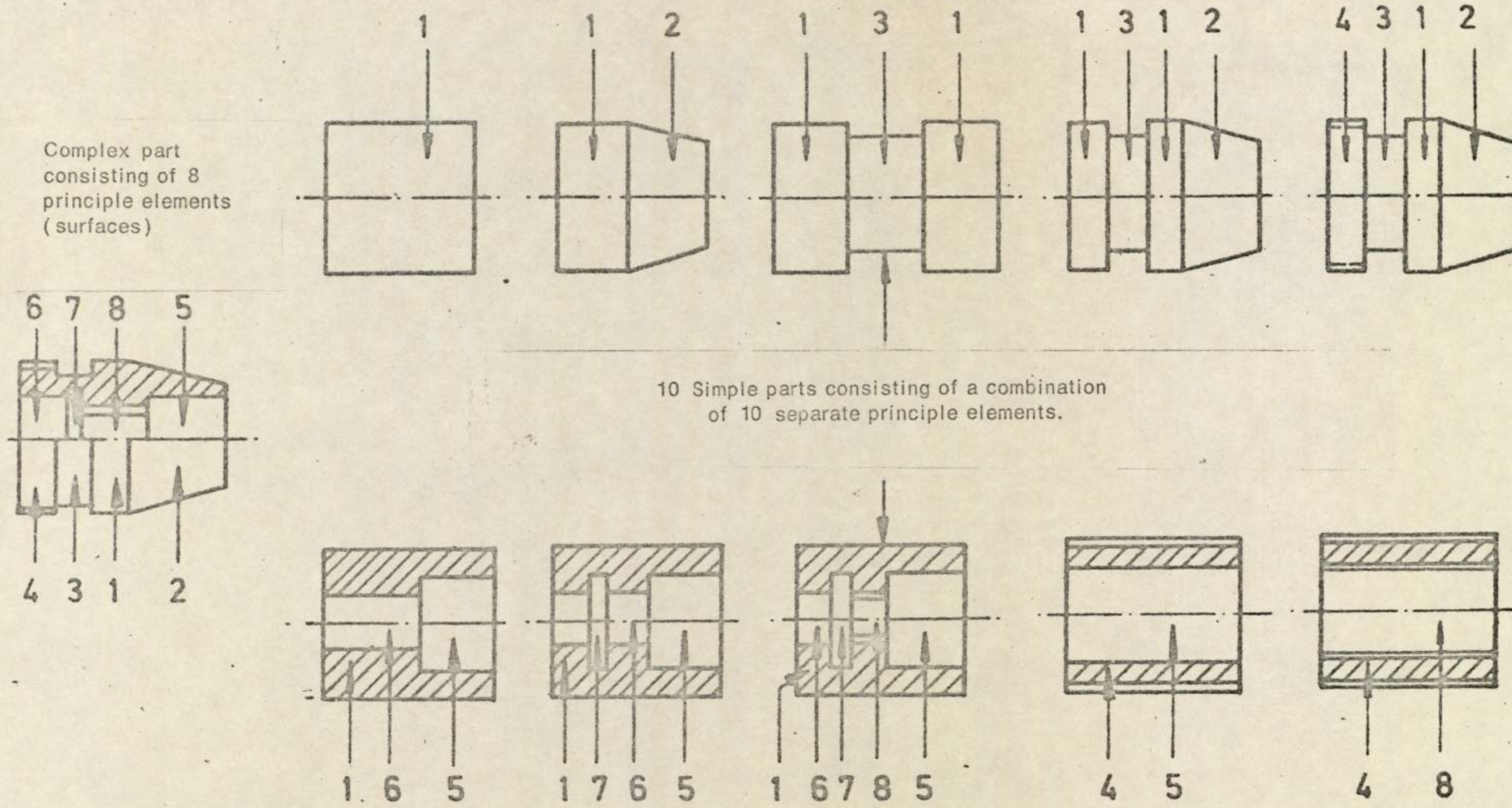
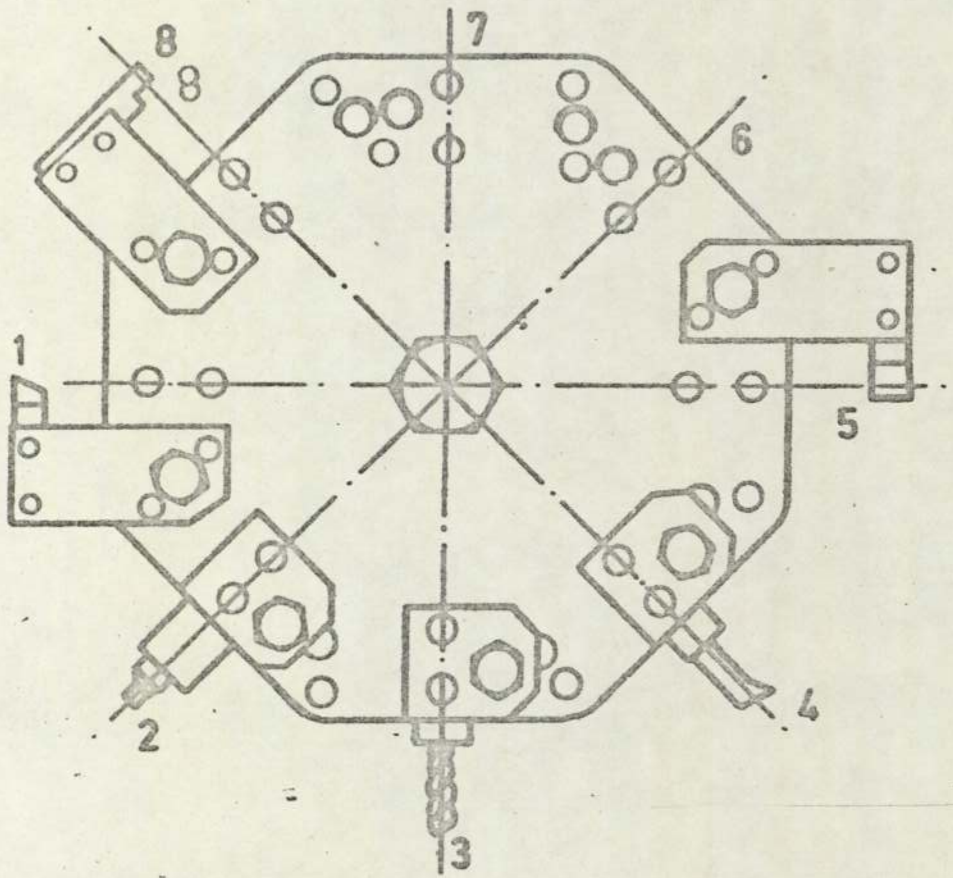
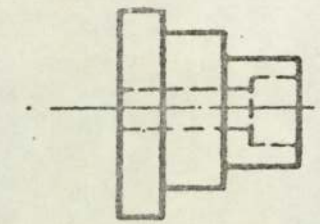


FIGURE 2 EXAMPLE OF COMPLEX COMPONENT
(AFTER MITROFANOV)

Ferrous, 2 or more 0/Dias. (successively increasing)

1 or more 1/Dia.





Turret Posn.	Tool Description
1	Face & Rgt. Turn (use as stop)
2	Centre
* 3	Drill
* 4	Boring
5	Finish Turn
6	Free
7	Free
8	Part Off

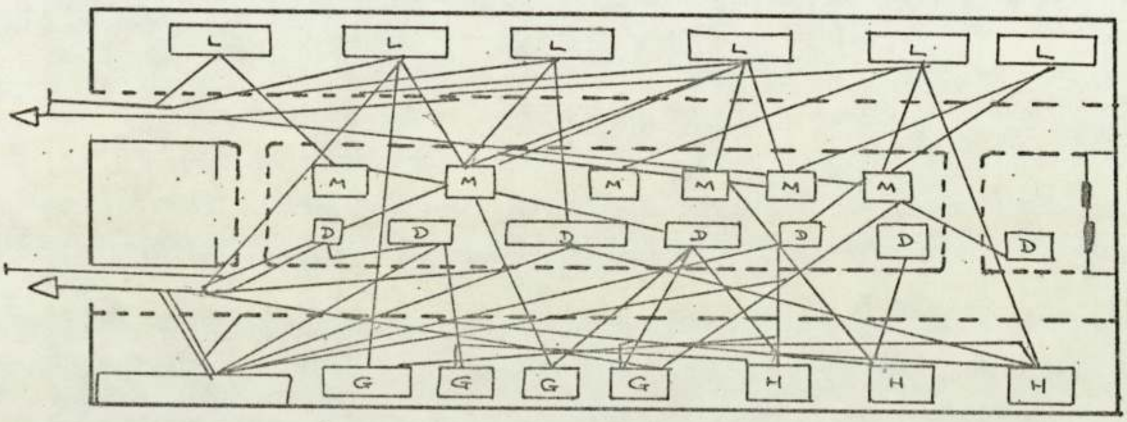
* Change to suit requirements

NOTE:- Additional tools should be placed in a free position where possible thus preserving the basic settings

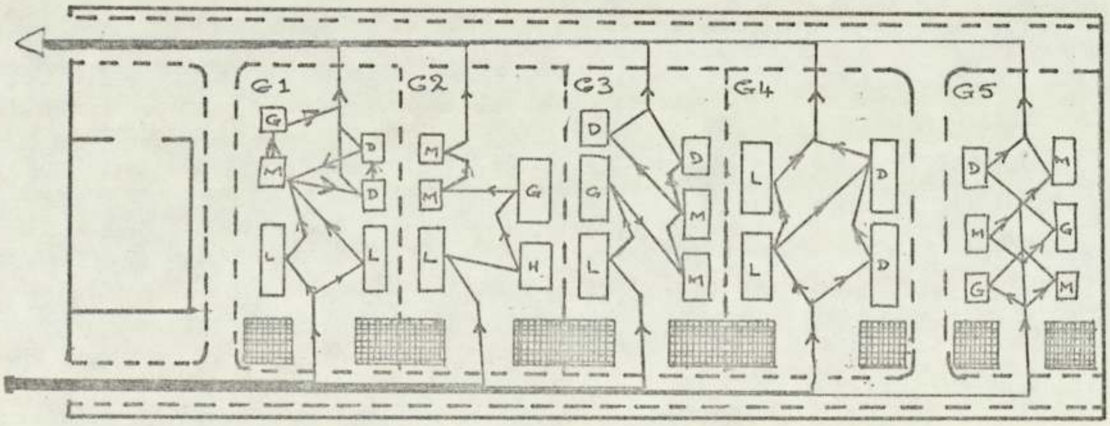
FIGURE 3 TOOLING SET-UP AND THE COMPLEX COMPONENT (AFTER DURIE)

FIGURE 4 SIMPLIFICATION OF MATERIAL FLOW WITH GROUP LAYOUT

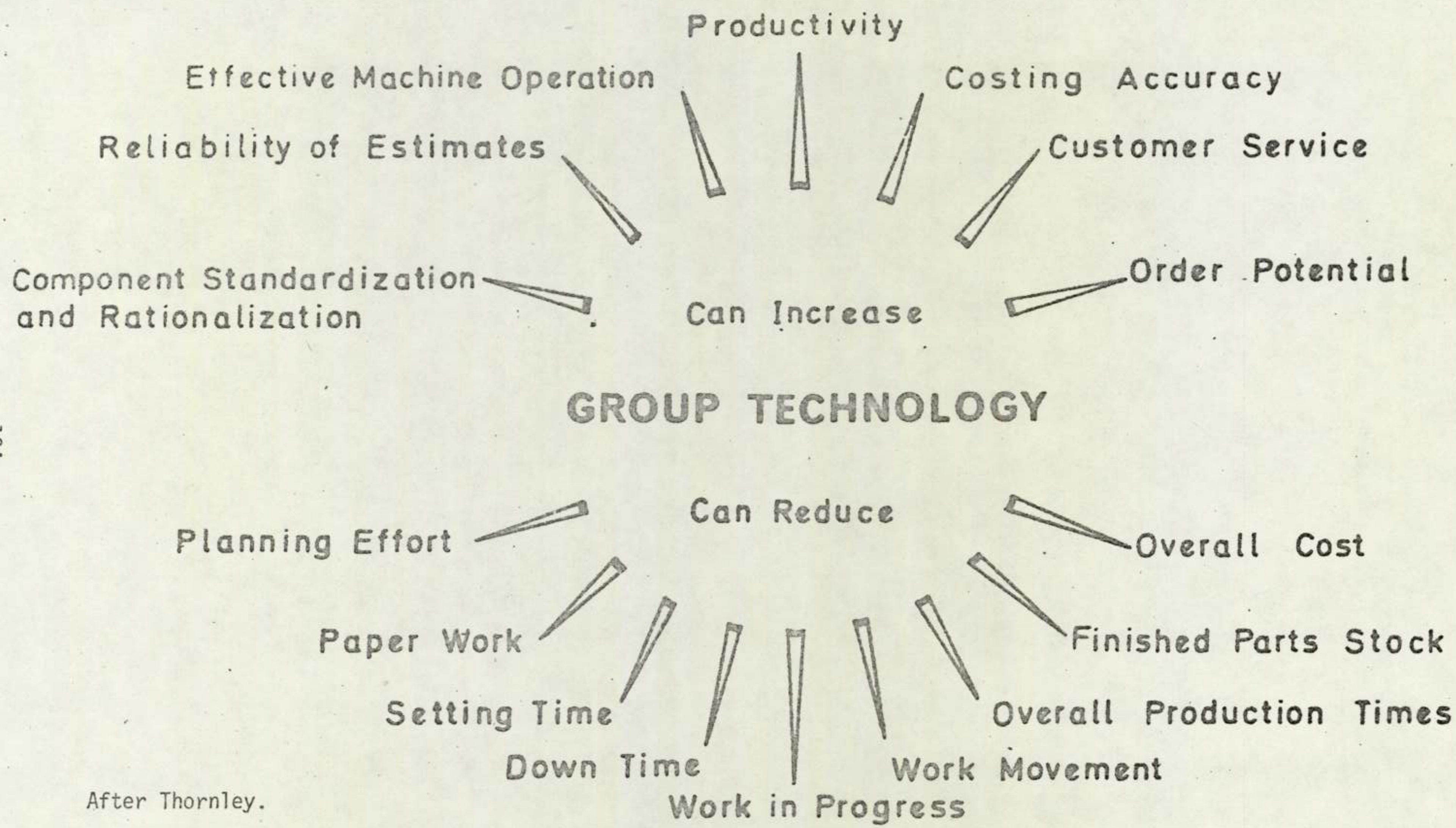
1. COMPLICATED MATERIAL FLOW SYSTEM (FUNCTIONAL LAYOUT)



2. SIMPLE MATERIAL FLOW SYSTEM (GROUP LAYOUT)



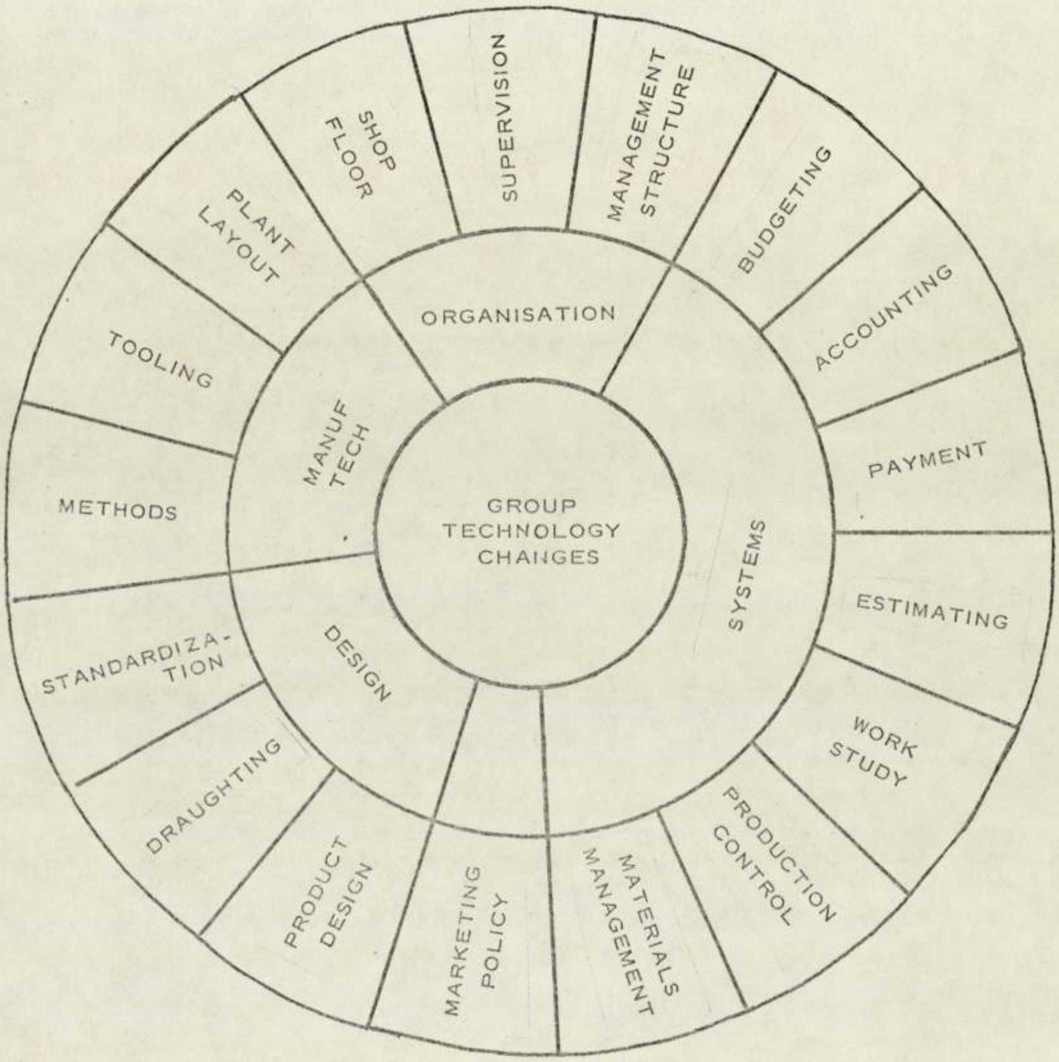
AFTER BURBRIDGE



After Thornley.

FIGURE 5 GENERAL ACHIEVEMENTS OF GROUP TECHNOLOGY

FIGURE 6 GROUP TECHNOLOGY AND ORGANISATIONAL CHANGE



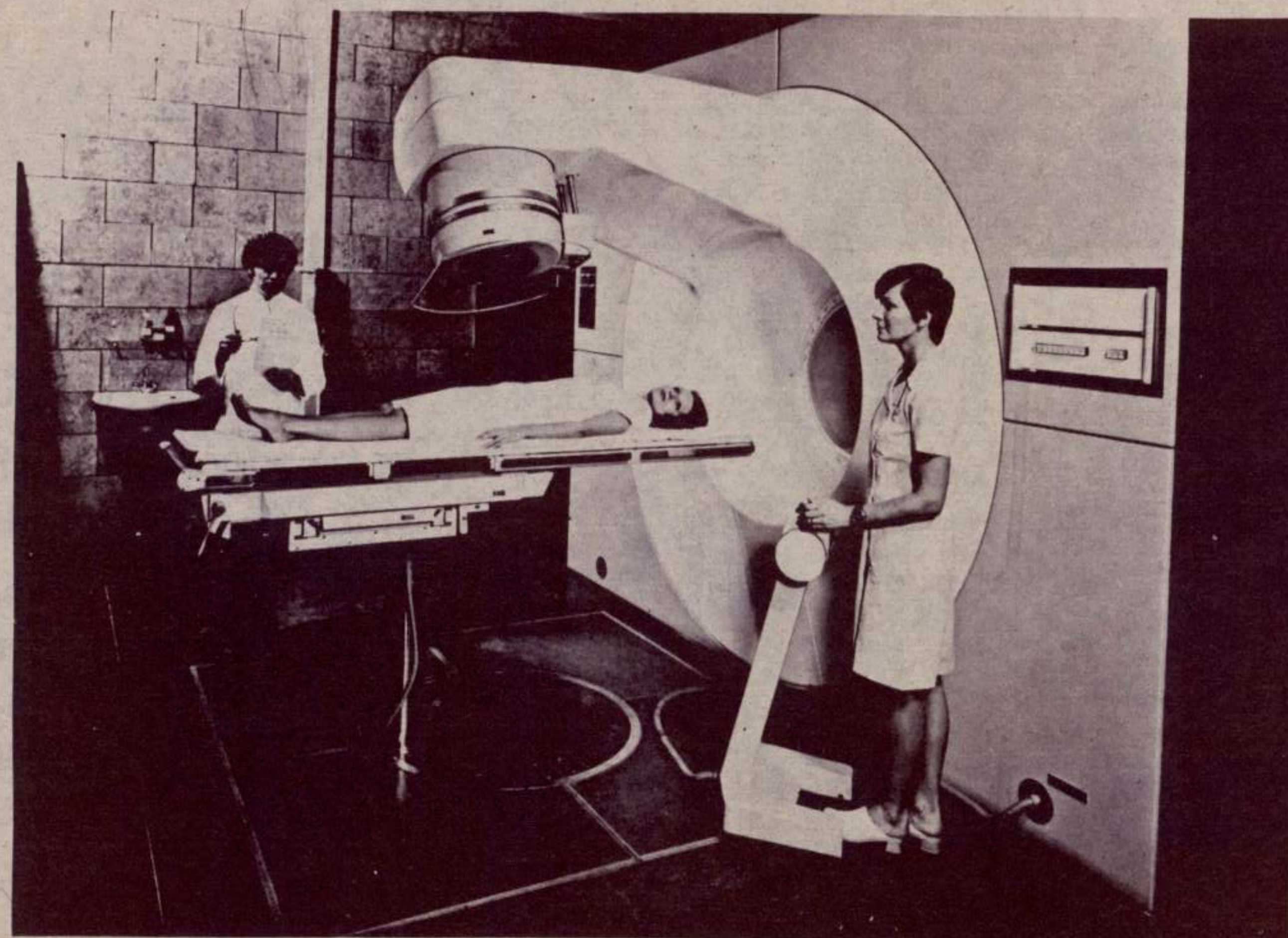
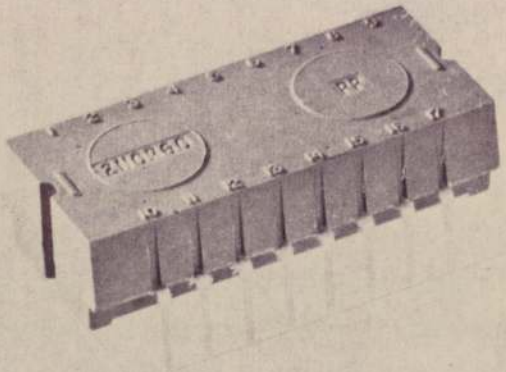


FIGURE 7

MACHINE FOR RADIOLOGICAL
TREATMENT OF DISEASE

FIGURE 8 A MODULE OF SWITCHING ELEMENTS



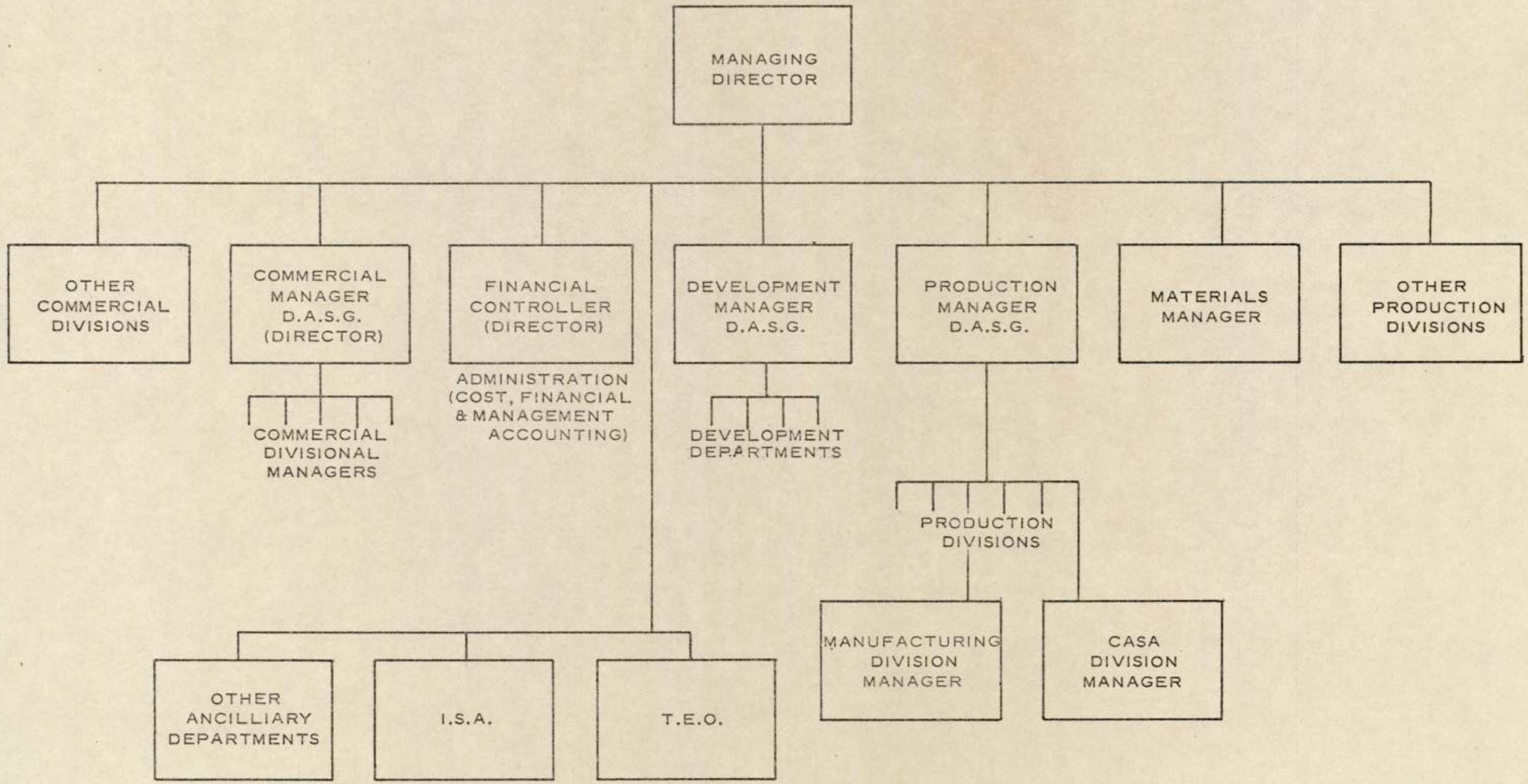


FIGURE 9 OUTLINE OF M.E.L.'S ORGANISATION AT THE START OF THE RESEARCH

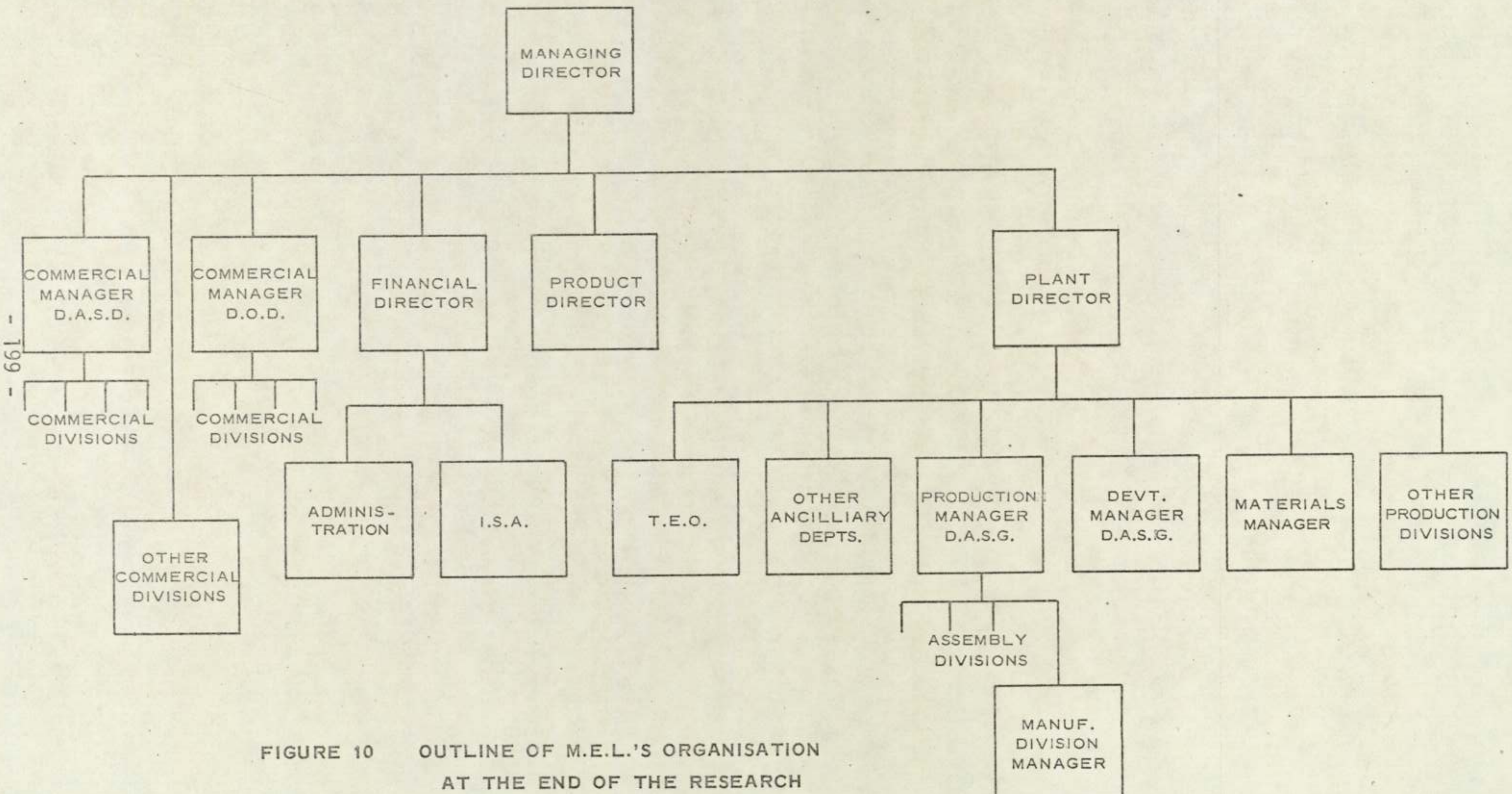


FIGURE 10 OUTLINE OF M.E.L.'S ORGANISATION AT THE END OF THE RESEARCH

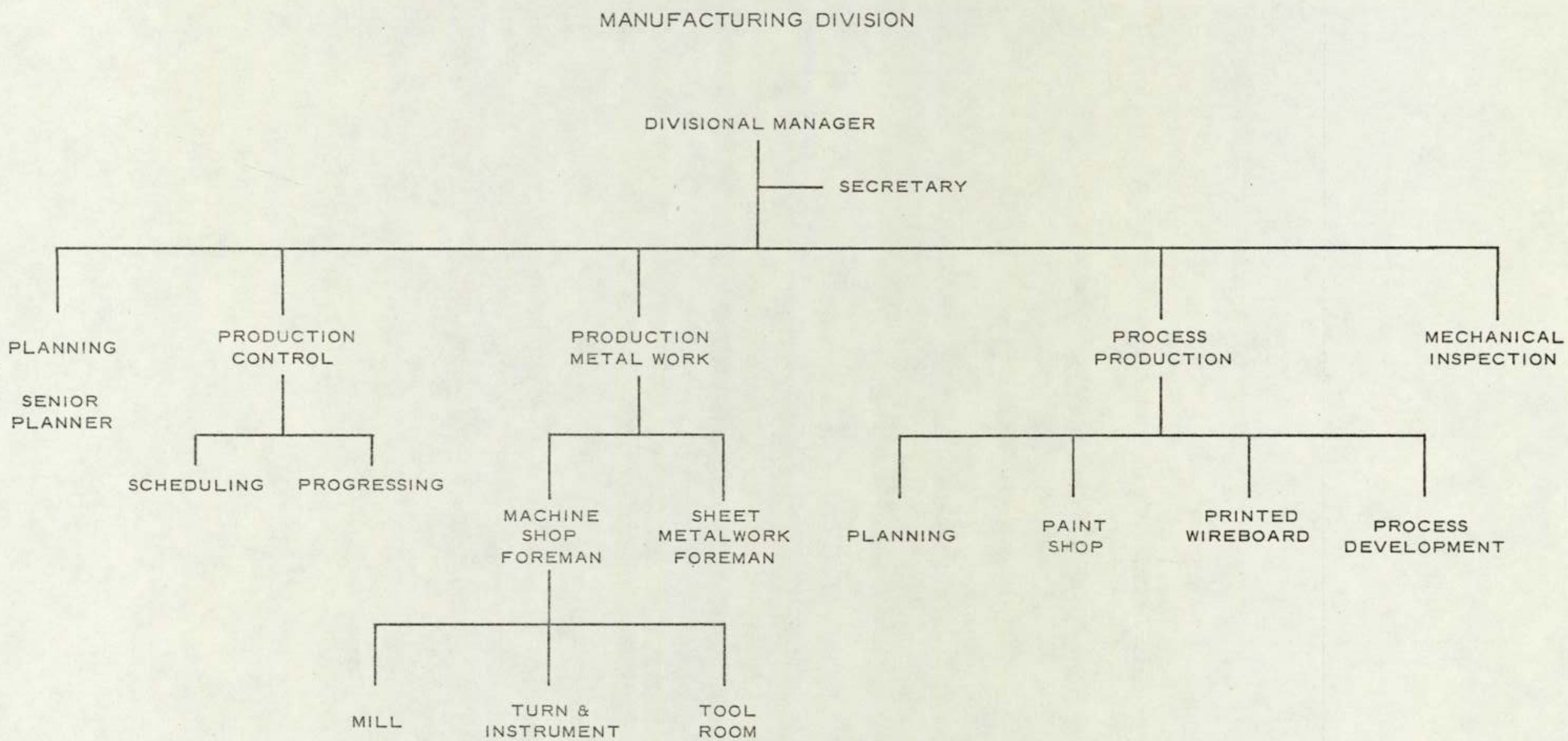


FIGURE 11 MANUFACTURING DIVISION'S ORGANISATION
PRIOR TO GROUP TECHNOLOGY

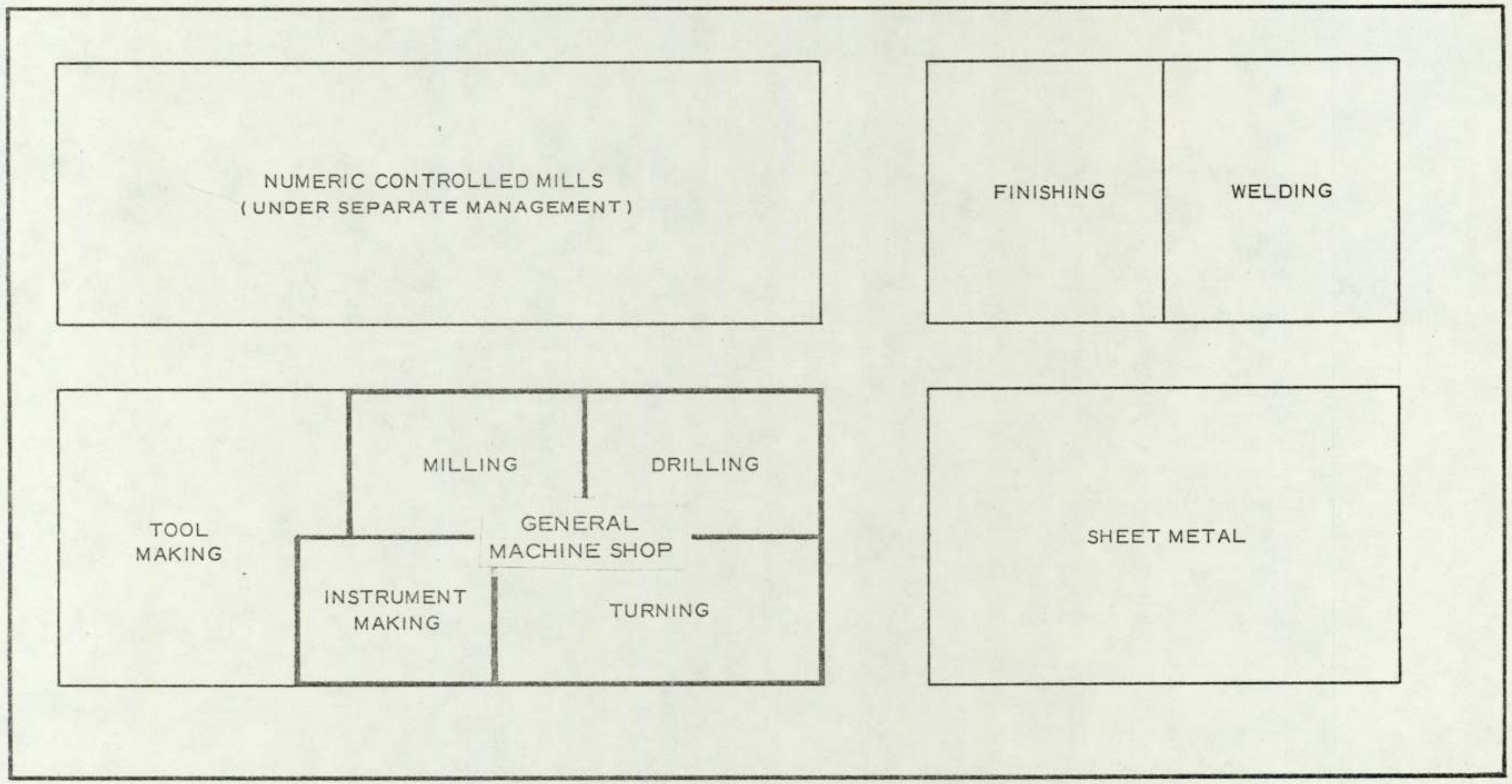


FIGURE 12 LAYOUT OF MANUFACTURING DIVISION'S METALWORK ACTIVITY PRIOR TO GROUP TECHNOLOGY

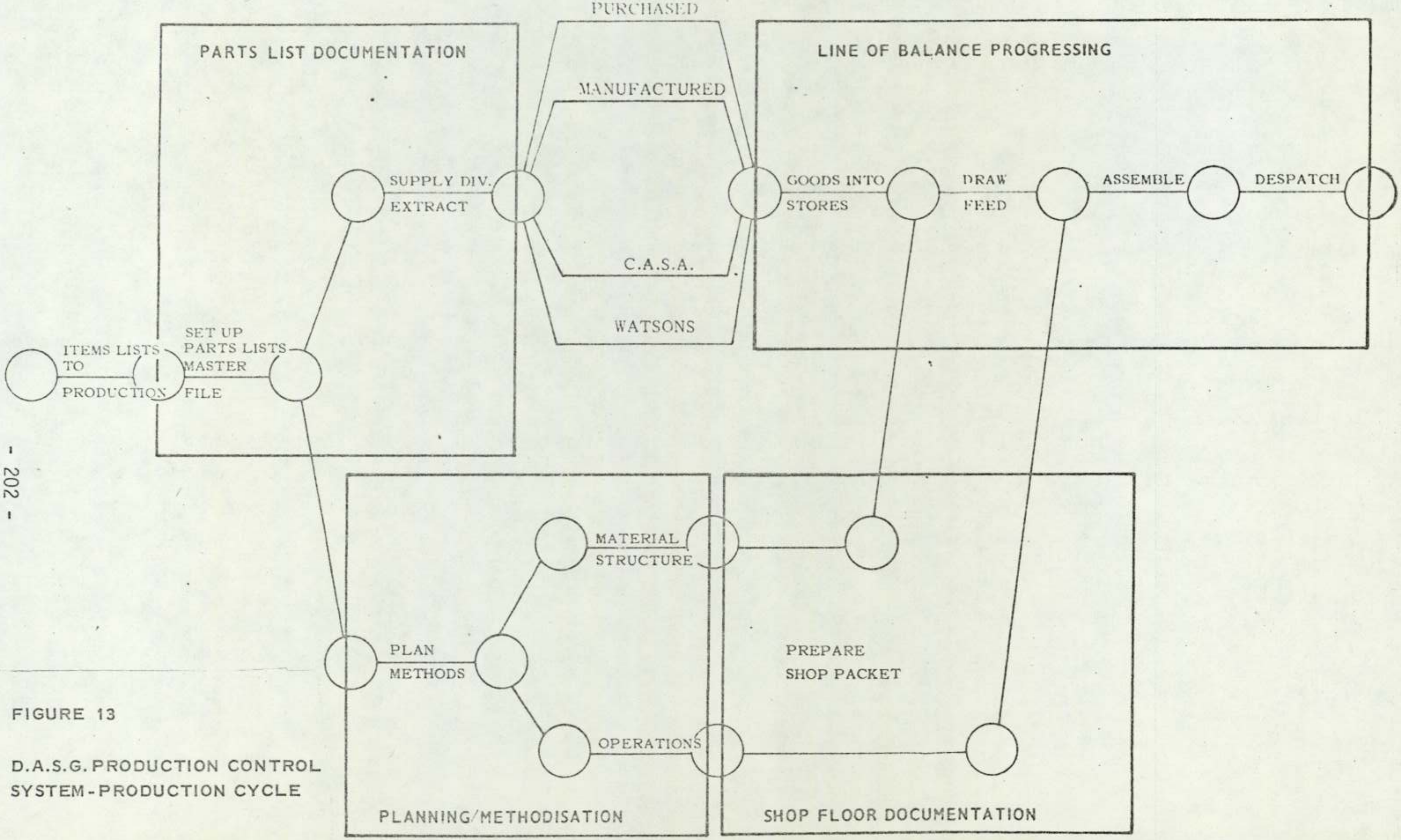


FIGURE 13

D.A.S.G. PRODUCTION CONTROL
SYSTEM - PRODUCTION CYCLE

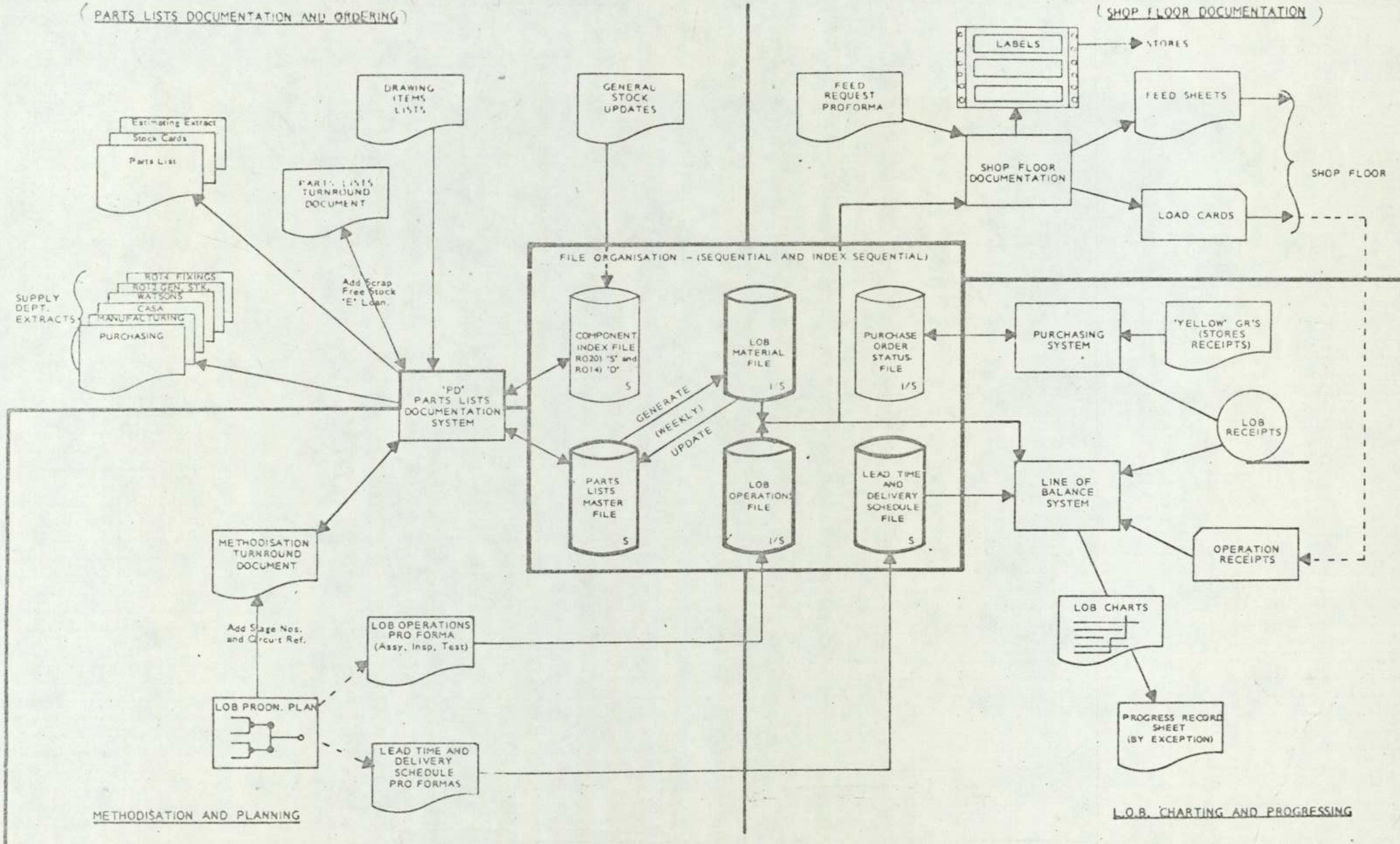


FIGURE 14 D.A.S.G. PRODUCTION CONTROL SYSTEM - SYSTEM STRUCTURE

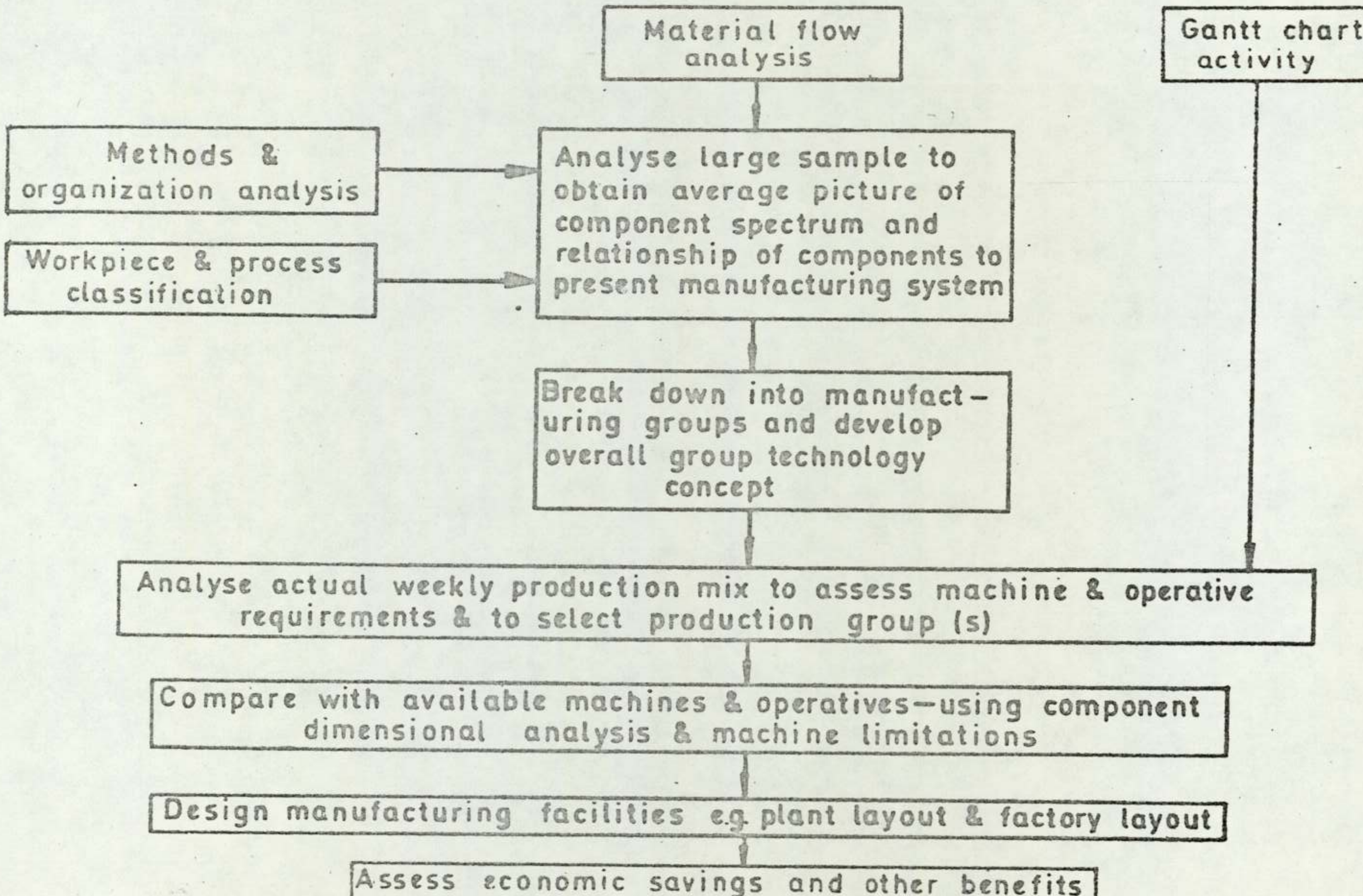


FIGURE 15 METHODOLOGY FOR THE IMPLEMENTATION OF GROUP TECHNOLOGY

FIGURE 16 PHASE 1 PROJECT PLAN

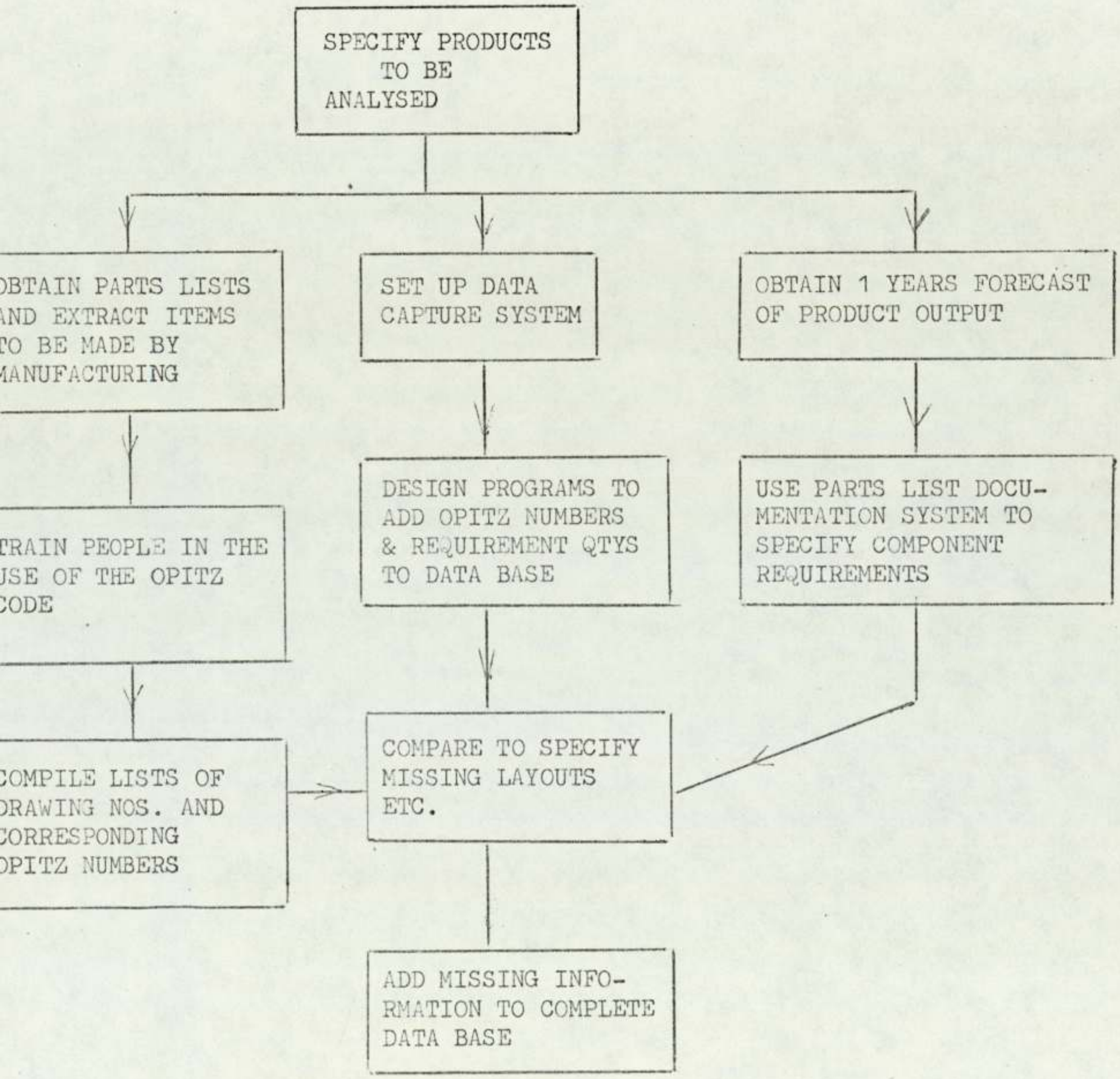


FIGURE 17 PHASE 2 PROJECT PLAN

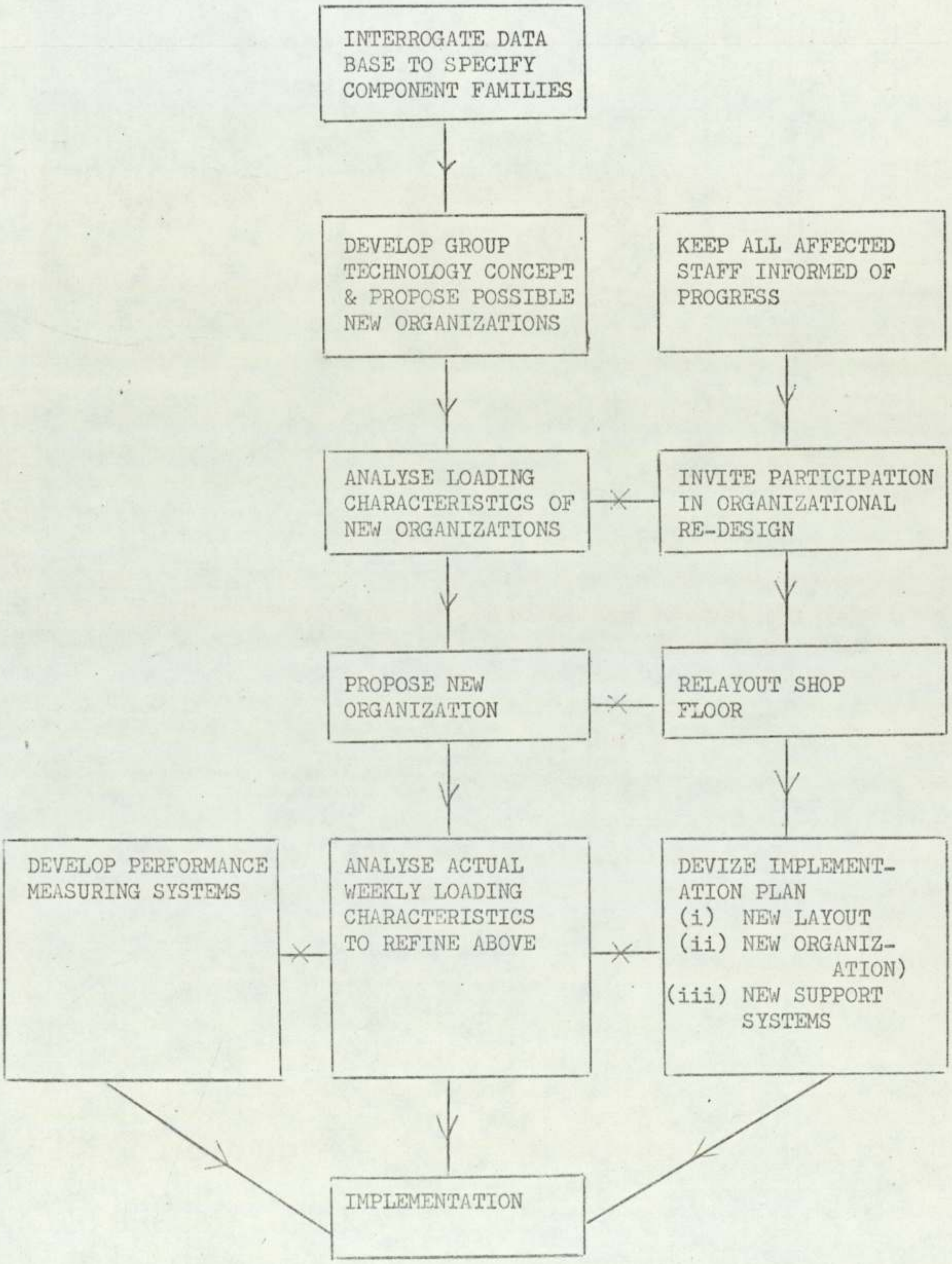
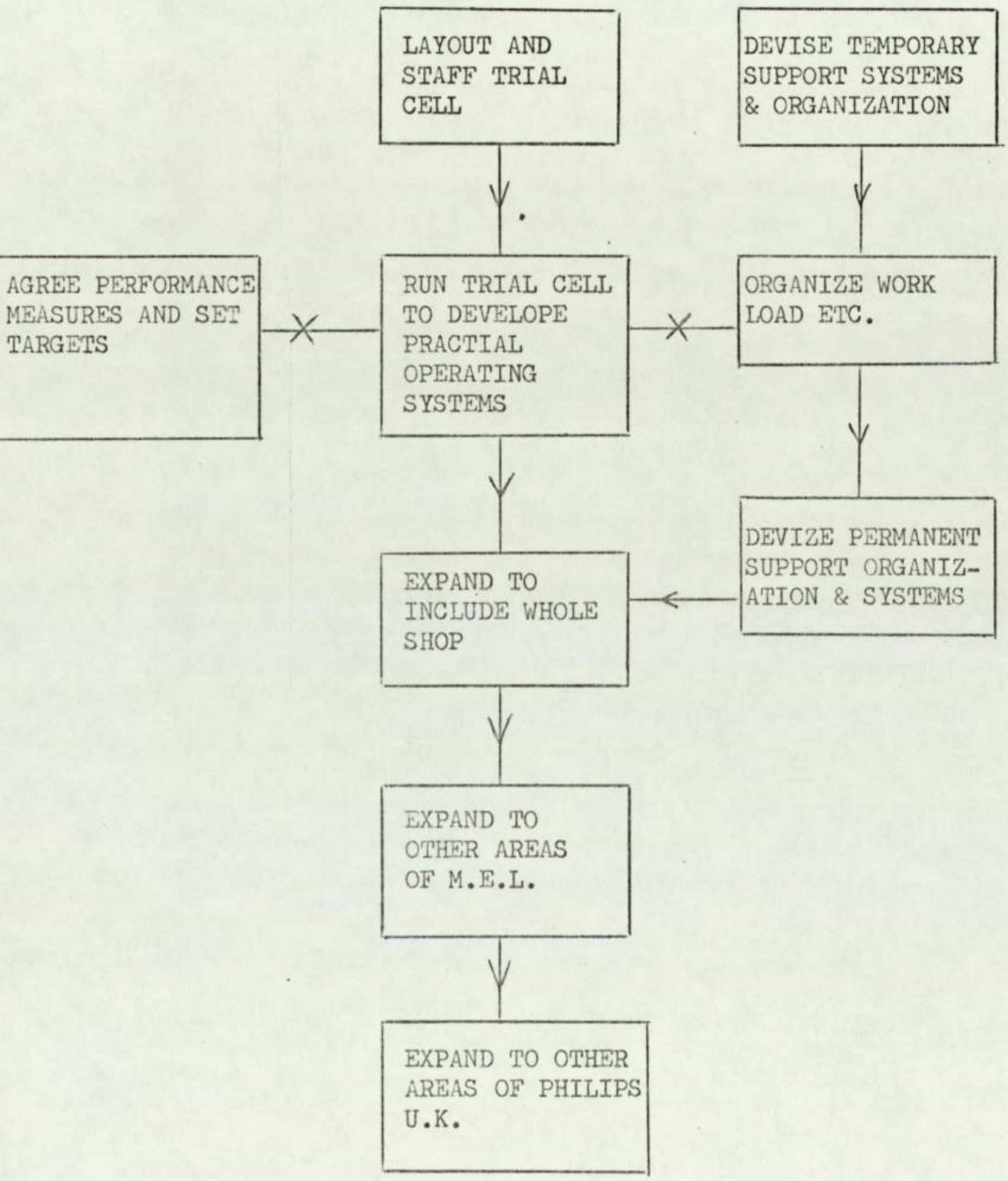


FIGURE 18 OUTLINE PHASE 3 PROJECT PLAN



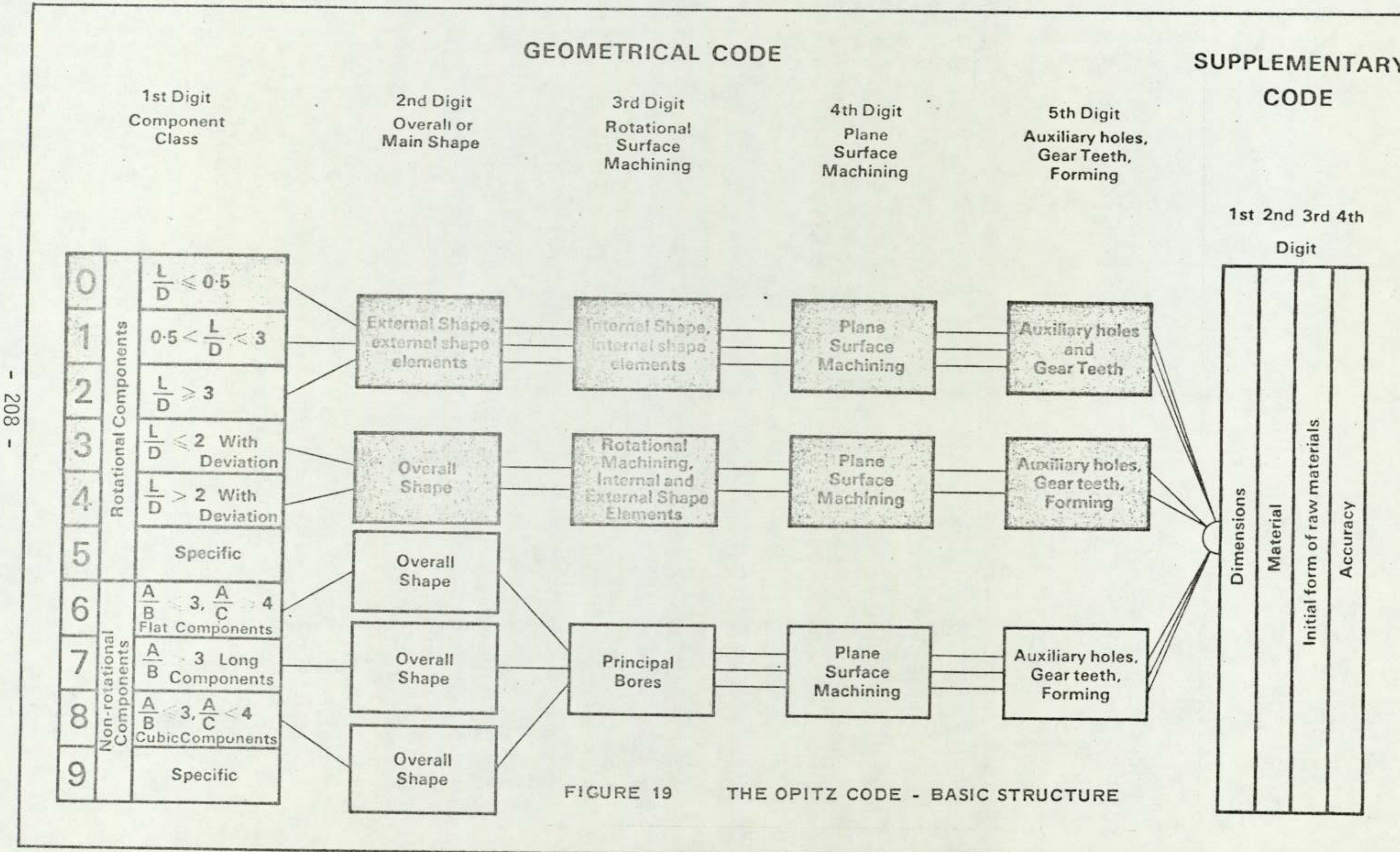


FIGURE 19 THE OPITZ CODE - BASIC STRUCTURE

6TH DIGIT

	DIAMETER 'D' OR EDGE LENGTH 'A'	
	M.M.'s	Inches
0	Under 25.4	Under 1.0
1	25.4 - 51	1.0 - 2.0
2	51 - 102	2.0 - 4.0
3	102 - 160	4.0 - 6.5
4	160 - 250	6.5 - 10
5	250 - 400	10 - 16
6	400 - 600	16 - 25
7	600 - 1000	25 - 40
8	1000 - 2000	40 - 80
9	Over 2000	Over 80.0

7TH DIGIT

	LENGTH 'L' ROTATIONAL OR EDGE LENGTH 'C' (NON.R)	
	M.M.'s	Inches
0	Under 25.4	Under 1.0
1	25.4 - 51	1.0 - 2.0
2	51 - 102	2.0 - 4.0
3	102 - 160	4.0 - 6.5
4	160 - 250	6.5 - 10
5	250 - 400	10 - 16
6	400 - 600	16 - 25
7	600 - 1000	25 - 40
8	1000 - 2000	40 - 80
9	Over 2000	Over 80.0"

8TH DIGIT

	MATERIAL
0	Aluminium
1	Brass (Bar or Rod)
2	Mild Steel
3	Stainless Steel
4	High Tensile or High Carbon Stl.
5	Fibres or Plastics
6	Cast or S.G. Iron
7	Precious Metals
8	Other Non-Ferrous H.T. Brass etc.
9	Others

9TH DIGIT

	INITIAL FORM
0	Round or Hexagon Rod, Stud etc.
1	Round Rod Billets
2	Tube
3	Flat, Bar, Angle, Sq. etc.
4	Castings or Mouldings
5	Plate or Slabs
6	Pre-Machined or Extruded Section
7	Welded or Pre-formed
8	Sheet (under $\frac{1}{8}$ ins)
9	Any apart from above

FIGURE 20 MODIFIED OPITZ CODE

G.T. CODING SHEET

GROUP TECHNOLOGY

PRODUCT	
ANALYST	
SHEET	OF

PUNCH EXACTLY AS MARKED

	DRAWING NUMBER	G.T.C. NUMBER		DRAWING NUMBER	G.T.C. NUMBER		DRAWING NUMBER	G.T.C. NUMBER	
1 2	3 4 5 6 7 8 9 10 11 12 13 14	15 16 17 18 19 20 21 22 23	24 25	26 27 28 29 30 31 32 33 34 35 36 37	38 39 40 41 42 43 44 45 46	47 48	49 50 51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69	70 71 72
G T									
G T									
G T									
G T									
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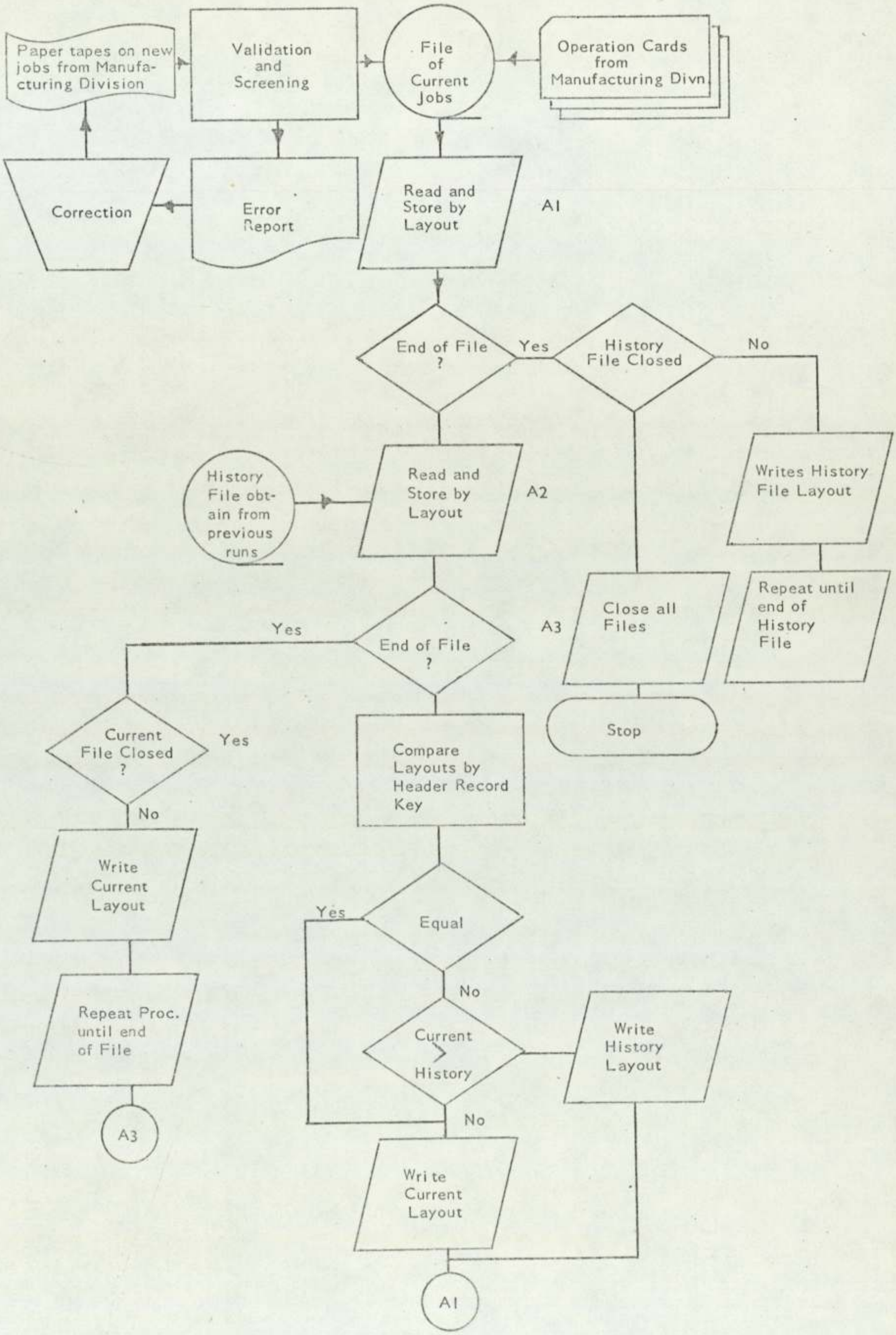
G T									
G T									
G T									
1 2	3 4 5 6 7 8 9 10 11 12 13 14	15 16 17 18 19 20 21 22 23	24 25	26 27 28 29 30 31 32 33 34 35 36 37	38 39 40 41 42 43 44 45 46	47 48	49 50 51 52 53 54 55 56 57 58 59 60	61 62 63 64 65 66 67 68 69	70 71 72

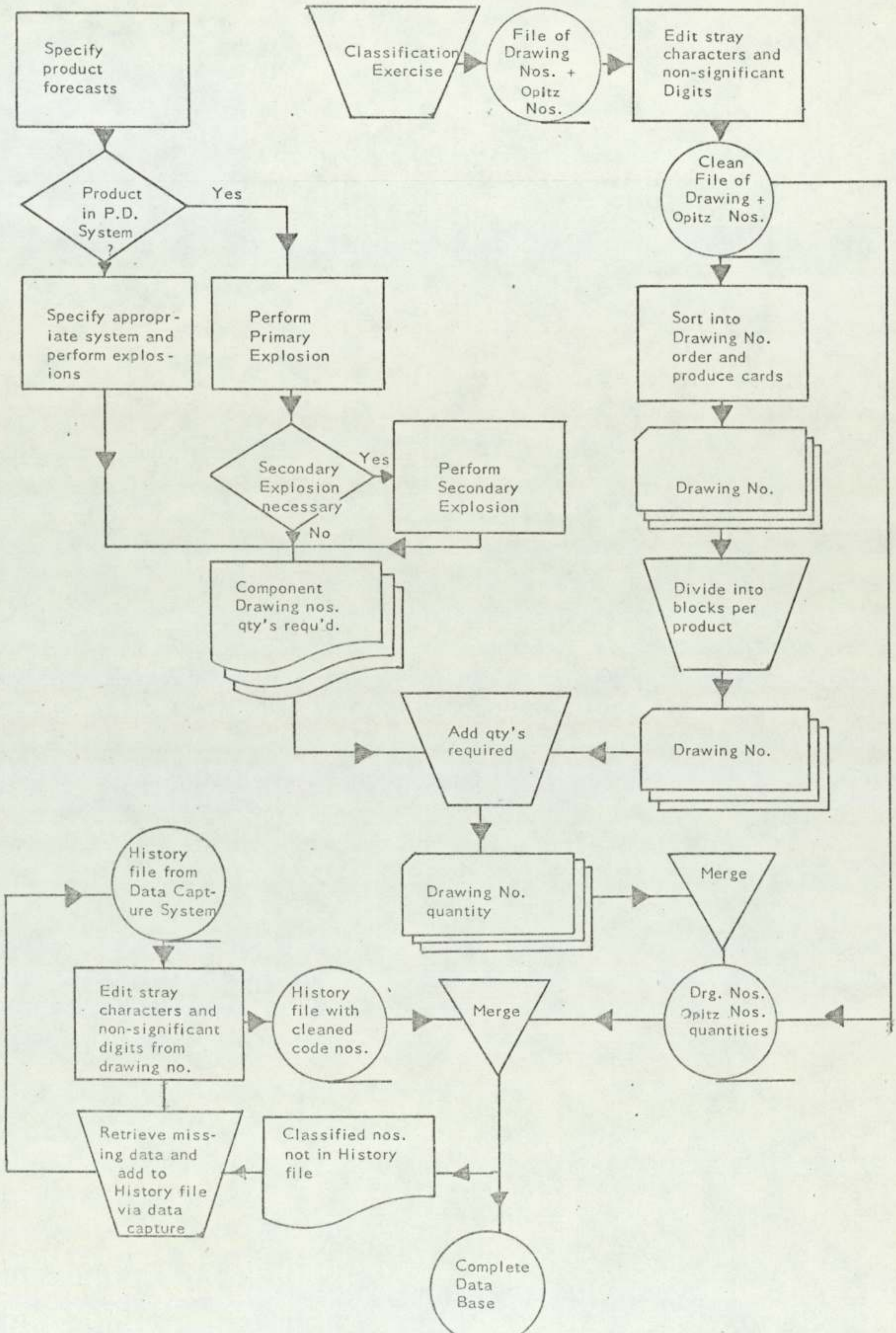
FIGURE 21 ENCODING FORM

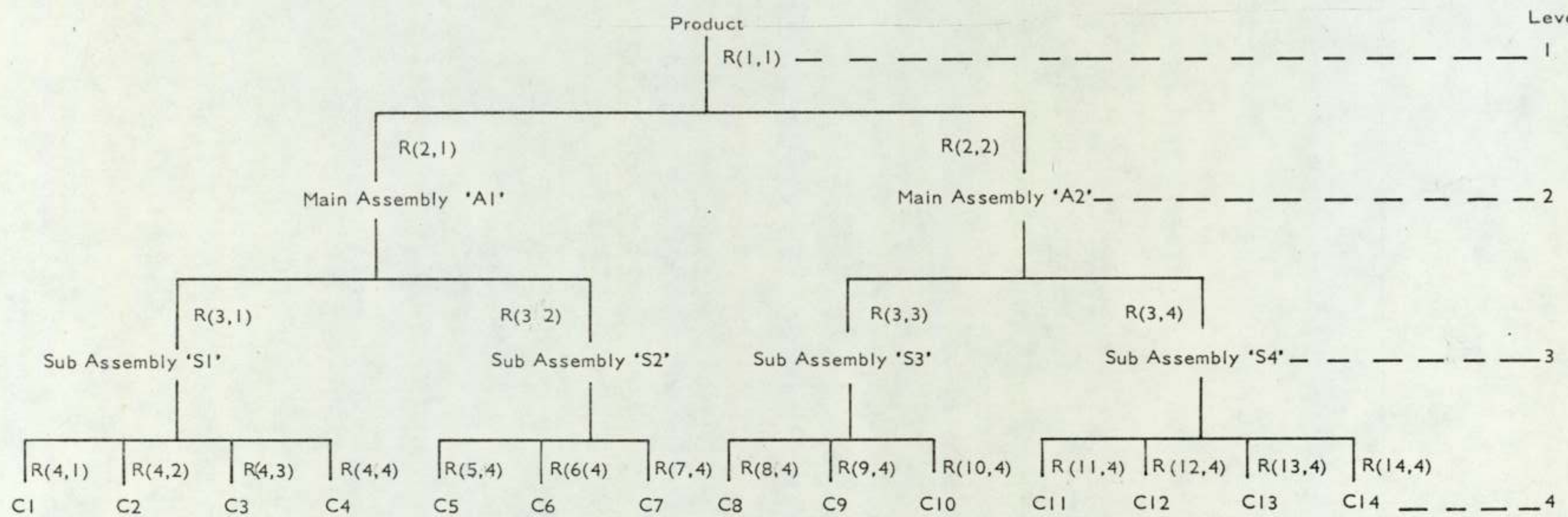
FIGURE 22 DATA CAPTURE SYSTEM



TO BE PERFORMED EACH WEEK

FIGURE 23 SYSTEM FOR COMPLETING THE DATA BASE



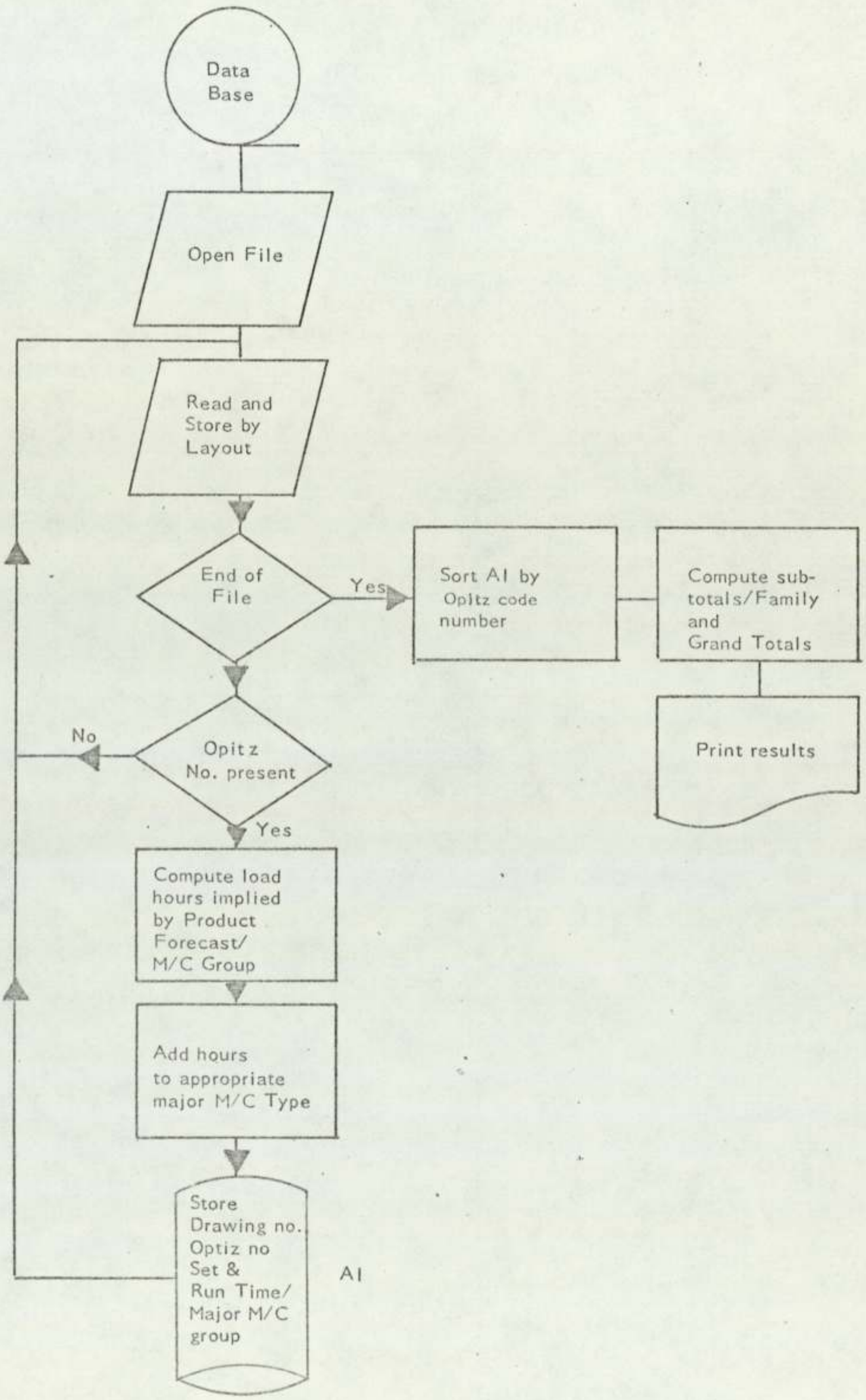


Requirement for Component 'X' used in positions C3 and C10 is:-

R(1,1) x (R(2,1) x R(3,1) x R(4,3) + R(2,2) x R(3,3) x R(10,4))

FIGURE 24 PRODUCT EXPLOSION

FIGURE 25 FLOW DIAGRAM OF THE MANUFACTURING HOURS CALCULATOR



MACHINE GROUP HOURS PER GTC AND CODE NUMBER PAGE 1 17/06/74

GTC NUMBER	CODE NUMBER	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	N.C.SECTION SET	N.C.SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
001000000	B104837	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	B116753	.7	2.9	.0	.0	.0	.0	.1	.4	.0	.0	.0	.0	.0	.0	.0	.0
001000000	B116779	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	RRA825129	.8	7.9	.0	.0	.0	.0	.1	.8	.0	.0	.0	.0	.0	.0	.0	.0
001000000	RRA825222	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	35131283257	.8	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001020000	55114571	1.2	1.3	.0	.0	.0	.0	.2	1.0	.0	.0	.0	.0	.1	.6	.0	.0
002000000	B116877	1.2	17.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
002000000	RRA825351	.8	3.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
010100000	B147672	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000000	B102982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000000	B119180	1.0	5.7	.0	.0	.0	.0	.1	.7	.0	.0	.0	.0	.0	.0	.0	.0
011000000	35131282778	.7	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000000	FV282052	2.0	7.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
021300000	B104856	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTALS THIS GTC		9.2	48.9	.0	.0	.0	.0	.5	2.9	.0	.0	.0	.0	.1	.6	.0	.0
CUMULATIVE TOTALS		9.2	48.9	.0	.0	.0	.0	.5	2.9	.0	.0	.0	.0	.1	.6	.0	.0
000000016	FV720964	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
000000016	FV720965	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	FV700259	1.5	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	FV700260	1.5	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	0S81889	.8	2.1	.0	.0	.0	.0	.1	.3	.0	.0	.0	.0	.1	.3	.0	.0
001000010	0S82124	.9	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	.6	.0	.0
001000010	RRA828611	.7	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	35131282287	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	55114720	.5	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.4	.0	.0
001000016	FV720973	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000016	FV720974	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001030010	0S81876	1.0	1.2	.0	.0	.0	.0	.6	2.5	.0	.0	.0	.0	.0	.0	.0	.0
002000010	35131200004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
002000010	55197543	1.2	2.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	RRA825253	1.2	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	35131282821	1.2	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55113521	1.2	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55114744	1.0	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55147670	1.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2*
011030010	35131282335	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011120010	0S82091	1.9	3.4	.5	.5	.0	.0	.2	1.1	.0	.0	.0	.0	.0	.0	.1	.6
011120010	35131282617	1.0	65.1	.0	.0	.0	.0	.2	14.4	.0	.0	.0	.0	.1	20.9	.6	19.6
011120010	35131282785	1.0	12.0	.6	4.3	.0	.0	.5	5.1	.0	.0	.0	.0	.1	4.6	.0	.0
011130010	0S81892	2.0	3.1	.5	1.4	.0	.0	.2	.9	.0	.0	.0	.0	.0	.0	.1	.5
011220010	35131282619	1.0	14.5	.8	10.3	.0	.0	.2	3.8	.0	.0	.0	.0	.1	5.9	.0	.0
011310010	0S82110	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000010	55144526	1.5	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000010	55193716	1.0	.7	.0	.0	.0	.0	.3	.5	.0	.0	.0	.0	.0	.0	.0	.0

FIGURE 26 EXAMPLE OUTPUT FROM THE MANUFACTURING HOURS CALCULATOR

FIGURE 27 FLOW DIAGRAM OF THE LOAD ANALYSER

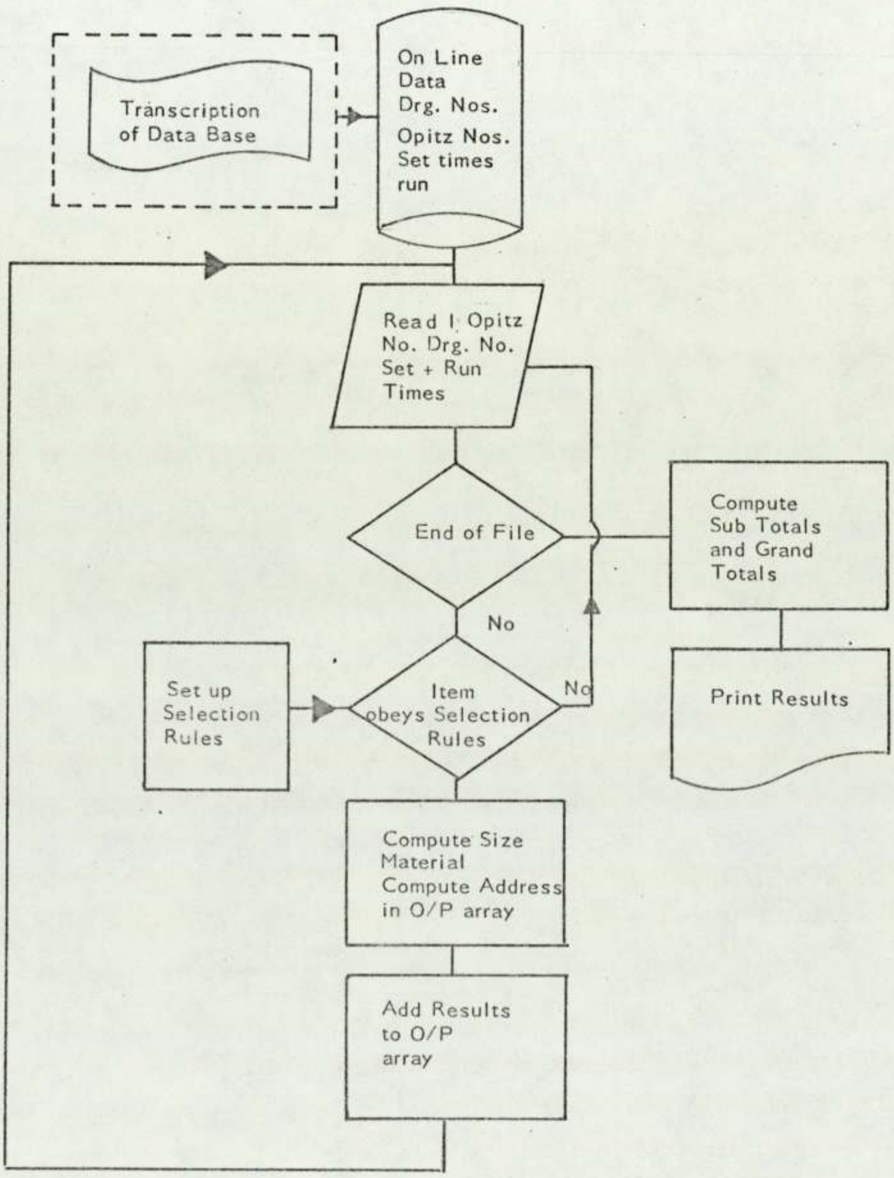


FIGURE 28 OPTION 1 OUTPUT FROM THE LOAD ANALYSER

0- 1"DIA

MATERIAL	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
ALUMINIUM	19	15	192	2	1	0	0	1	13	0	0	0	0	1	27	5	24
BRASS	38	47	287	9	20	0	0	4	60	0	0	0	0	1	14	0	0
MILD STEEL	38	39	197	7	43	0	0	2	18	0	0	3	22	4	31	0	0
STAINLESS	93	119	1503	25	117	2	6	4	27	0	0	21	173	5	57	3	9
HT STEEL	8	5	10	0	3	0	0	0	0	0	0	3	6	0	2	0	2
PLASTICS	3	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
HT BRASS	1	1	2	1	3	0	0	0	3	0	0	0	0	0	0	0	1
OTHERS	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	202	232	2202	47	201	2	6	14	124	0	0	28	201	14	136	9	40
		2435		249		9		138		0		229		151		50	
PEOPLE		1.691		0.173		0.007		0.096		0.000		0.160		0.105		0.035	

1- 2"DIA

MATERIAL	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
ALUMINIUM	14	17	311	8	29	0	0	5	81	0	0	0	0	1	42	0	5
BRASS	12	15	63	3	18	0	0	4	27	0	0	0	0	1	15	3	13
MILD STEEL	9	9	79	7	43	0	0	1	14	0	0	1	27	2	13	0	2
STAINLESS	27	41	[illegible]	13	86	0	0	8	110	9	59	24	113	0	11	0	15
HT STEEL	1	1	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0
PLASTICS	3	5	55	0	1	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	5	8	25	7	10	0	0	2	7	0	0	0	0	0	5	0	3
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	72	98	999	39	193	0	0	22	242	9	59	25	140	6	[illegible]	4	40
		1098		232		0		265		68		165		95		45	
PEOPLE		0.763		0.162		0.000		0.185		0.048		0.115		0.066		0.032	

2- 4"DIA

MATERIAL	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
ALUMINIUM	18	29	311	6	24	6	115	9	117	0	0	0	0	3	35	5	162
BRASS	6	6	28	3	1	0	0	2	6	0	0	0	0	1	4	0	0
MILD STEEL	4	7	46	4	14	1	20	1	9	0	0	0	0	0	9	0	0
STAINLESS	6	13	290	3	82	0	0	1	19	1	2	1	0	0	3	0	27
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	1	2	24	1	7	0	0	0	3	0	0	0	0	0	3	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	2	1	5	1	2	0	0	0	1	0	0	0	0	0	0	0	1
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	37	61	707	21	133	10	135	15	157	1	2	1	1	6	54	6	191
		708		154		146		173		3		3		61		198	
PEOPLE		0.534		0.108		0.102		0.121		0.002		0.002		0.043		0.138	

4-6.5"DIA

MATERIAL	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
ALUMINIUM	4	5	17	1	3	0	0	1	3	0	0	0	0	1	5	8	47
BRASS	1	1	15	0	0	0	0	0	3	0	0	0	0	0	3	0	0
MILD STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAINLESS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	5	6	34	1	3	0	0	2	6	0	0	0	0	1	9	8	47
		40		4		0		9		0		0		11		55	
PEOPLE		0.028		0.003		0.000		0.006		0.000		0.000		0.008		0.039	

6.5- 10"DIA

MATERIAL	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
ALUMINIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MILD STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAINLESS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0		0		0		0		0		0		0		0	
PEOPLE		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

10- 16"DIA

FIGURE 29 OPTION 2 OUTPUT FROM THE LOAD ANALYSER

ALUMINIUM

SIZE RANGE	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
0- 1"DIA	19	15	192	2	4	0	0	1	13	0	0	0	0	1	27	5	24
1- 2"DIA	14	17	311	3	29	0	0	5	31	0	0	0	0	1	42	0	5
2- 4"DIA	18	29	311	6	24	8	115	9	117	0	0	0	0	3	35	5	162
4-6.5"DIA	4	5	17	1	3	0	0	1	3	0	0	0	0	1	5	3	47
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	55	68	833	18	61	8	115	18	217	0	0	0	0	7	111	19	239
		901		80		124		235		0		0		113		259	
PEOPLE		0.628		0.056		0.086		0.164		0.000		0.000		0.083		0.180	

BRASS

SIZE RANGE	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
0- 1"DIA	38	47	287	9	20	0	0	4	60	0	0	0	0	1	14	0	0
1- 2"DIA	12	15	53	3	13	0	0	4	2	0	0	0	0	1	15	3	13
2- 4"DIA	6	5	28	3	1	0	0	2	5	0	0	0	0	1	4	0	0
4-6.5"DIA	1	1	16	0	0	0	0	0	3	0	0	0	0	0	3	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	57	70	395	16	41	0	0	12	97	0	0	0	0	4	38	3	13
		465		57		0		110		0		0		42		16	
PEOPLE		0.324		0.040		0.000		0.077		0.000		0.000		0.030		0.012	

MILD STEEL

SIZE RANGE	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
0- 1"DIA	33	39	197	7	43	0	0	2	13	0	0	3	22	4	31	0	0
1- 2"DIA	9	9	79	7	43	0	0	1	14	0	0	1	27	2	13	0	2
2- 4"DIA	4	7	45	4	14	1	20	1	9	0	0	0	0	0	9	0	0
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	52	57	324	19	102	1	20	5	42	0	0	5	50	3	55	0	2
		381		121		21		47		0		55		64		2	
PEOPLE		0.265		0.084		0.015		0.033		0.000		0.038		0.045		0.002	

STAINLESS

SIZE RANGE	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
0- 1"DIA	93	119	1503	25	117	2	5	4	27	0	0	21	173	5	57	3	9
1- 2"DIA	27	41	452	13	86	0	0	8	110	9	59	24	113	0	11	0	15
2- 4"DIA	6	13	290	3	82	0	0	1	19	1	2	1	0	0	3	0	27
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	1	1	2	0	1	0	0	0	1	3	7	1	0	0	0	1	1
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	127	176	2254	42	238	2	5	14	153	13	53	47	233	7	71	5	53
		2431		331		9		173		82		335		79		58	
PEOPLE		1.683		0.230		0.007		0.120		0.057		0.233		0.055		0.041	

HT STEEL

SIZE RANGE	ITEMS	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	NC SECTION SET	NC SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
0- 1"DIA	3	5	10	0	3	0	0	0	0	0	0	3	6	0	2	0	2
1- 2"DIA	1	1	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2- 4"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	9	5	21	0	3	0	0	0	1	0	0	3	6	0	2	0	2
		28		4		0		1		0		9		3		3	
PEOPLE		0.020		0.003		0.000		0.001		0.000		0.007		0.002		0.002	

PLASTICS

SIZE RANGE ITEMS	TURNING	MILLING	NC SECTION	DRILLING	JIG BORING	GRINDING	SHEET METAL	OTHERS

Analysis by Items - Sample Size Total = 982 Non-Rotational = 253
%ages quoted are of the Non-Rotational Items

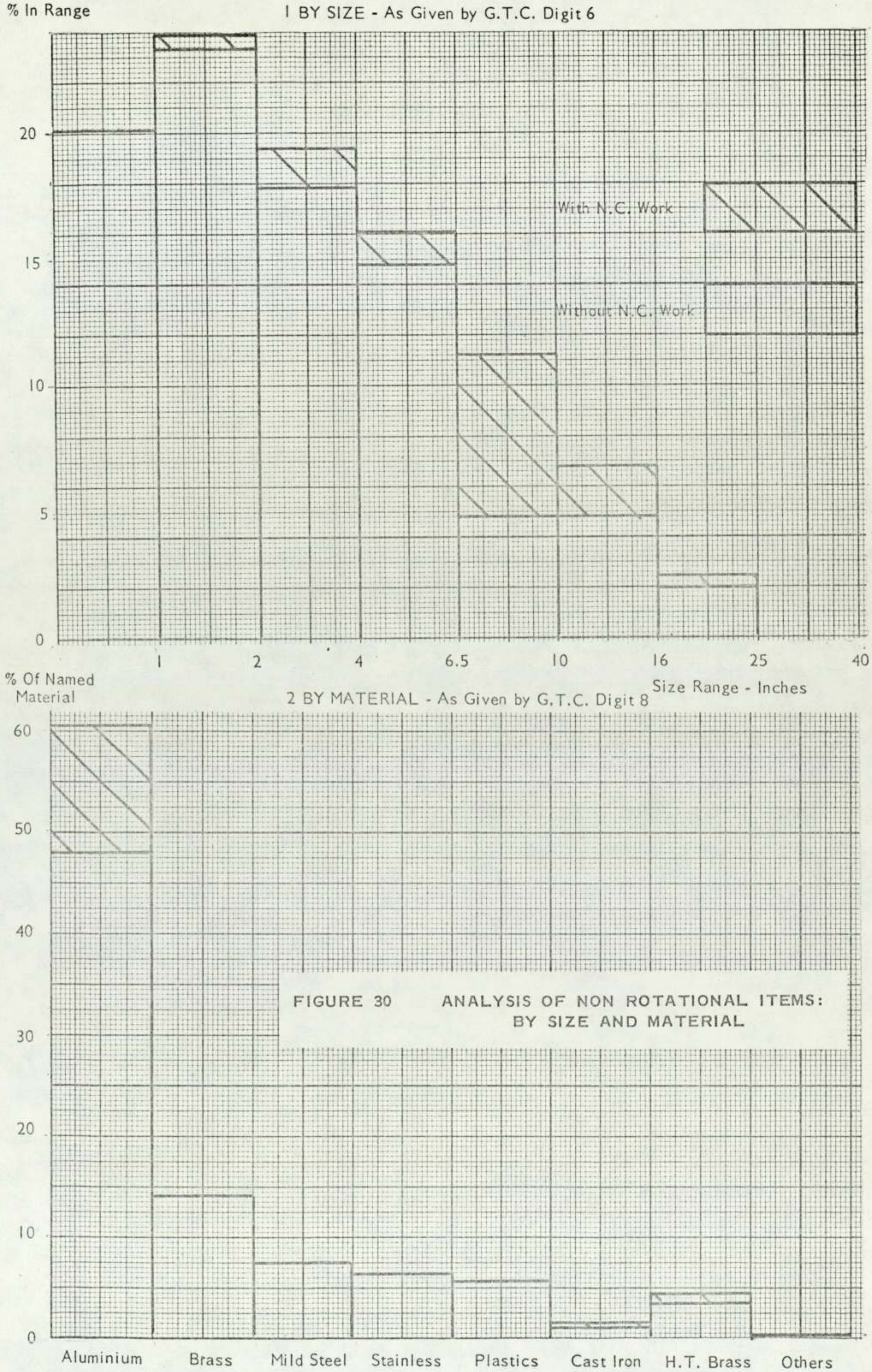
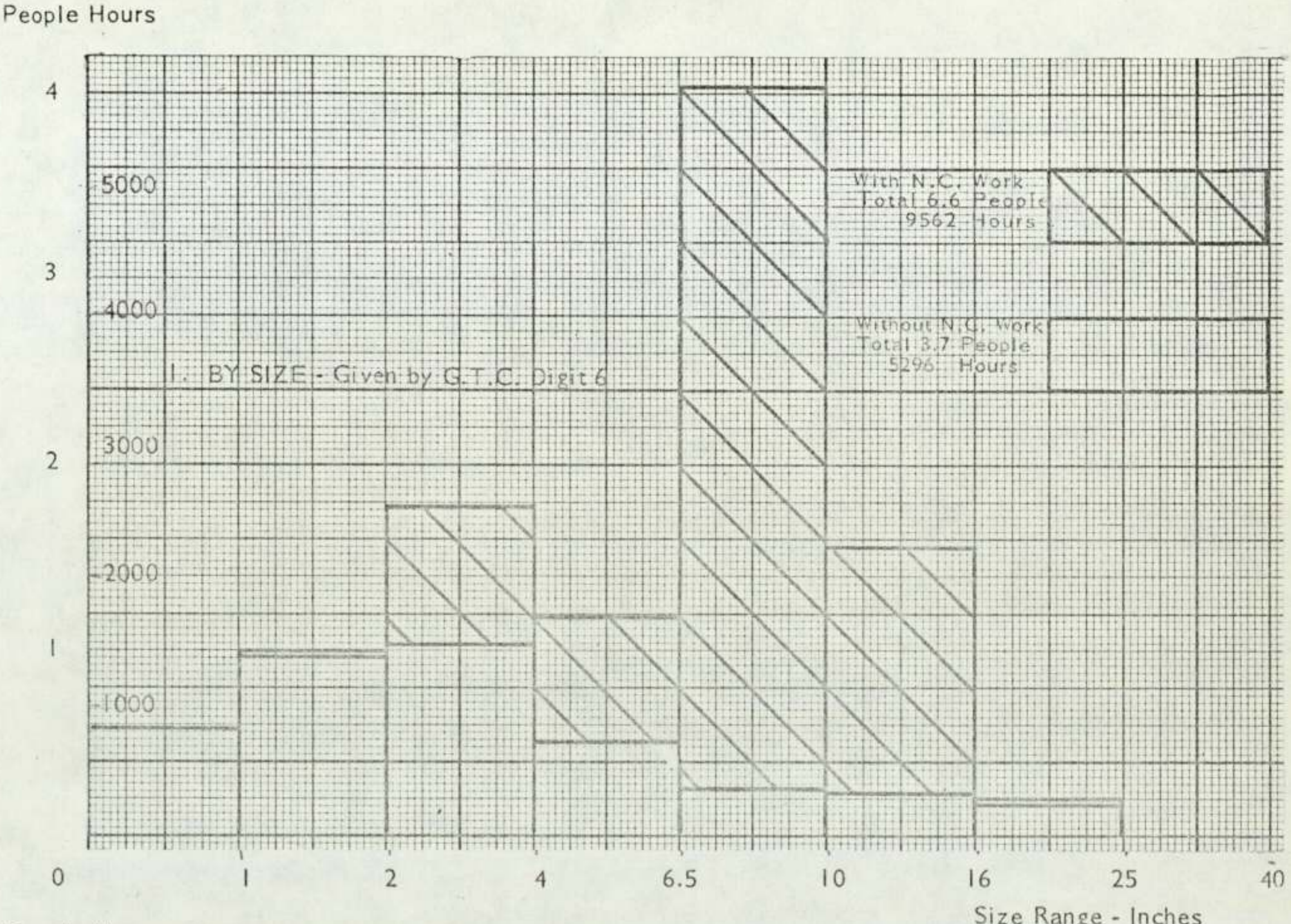


FIGURE 30 ANALYSIS OF NON ROTATIONAL ITEMS: BY SIZE AND MATERIAL

FIGURE 31 AS FIGURE 30 BUT BY WORK CONTENT

Analysis by Hours - Sample Total 27910 Non Rotational 14865 Hours
and People 19.4 10.3 People

N.B. This Analysis Assumes that Each Item is Manufactured in One Batch



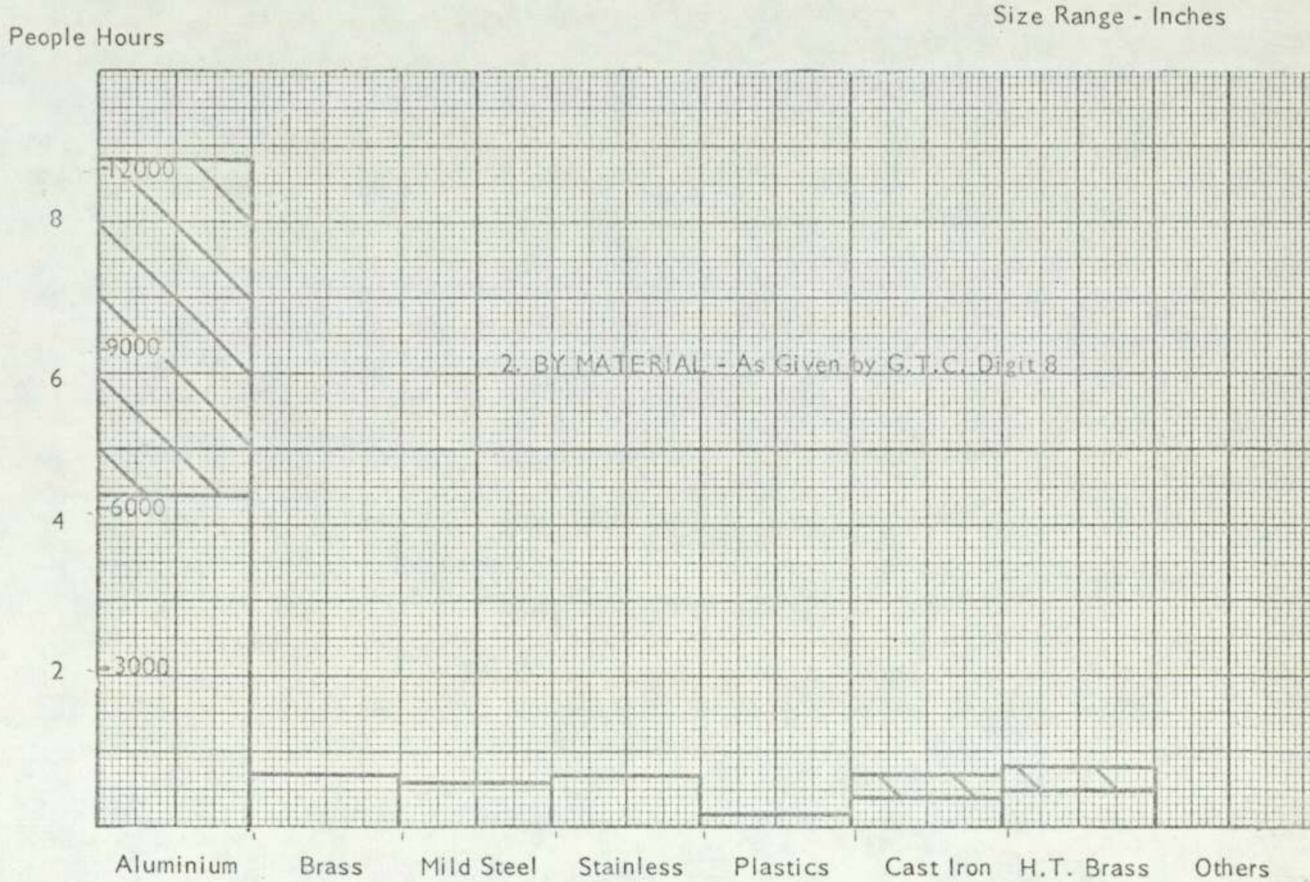
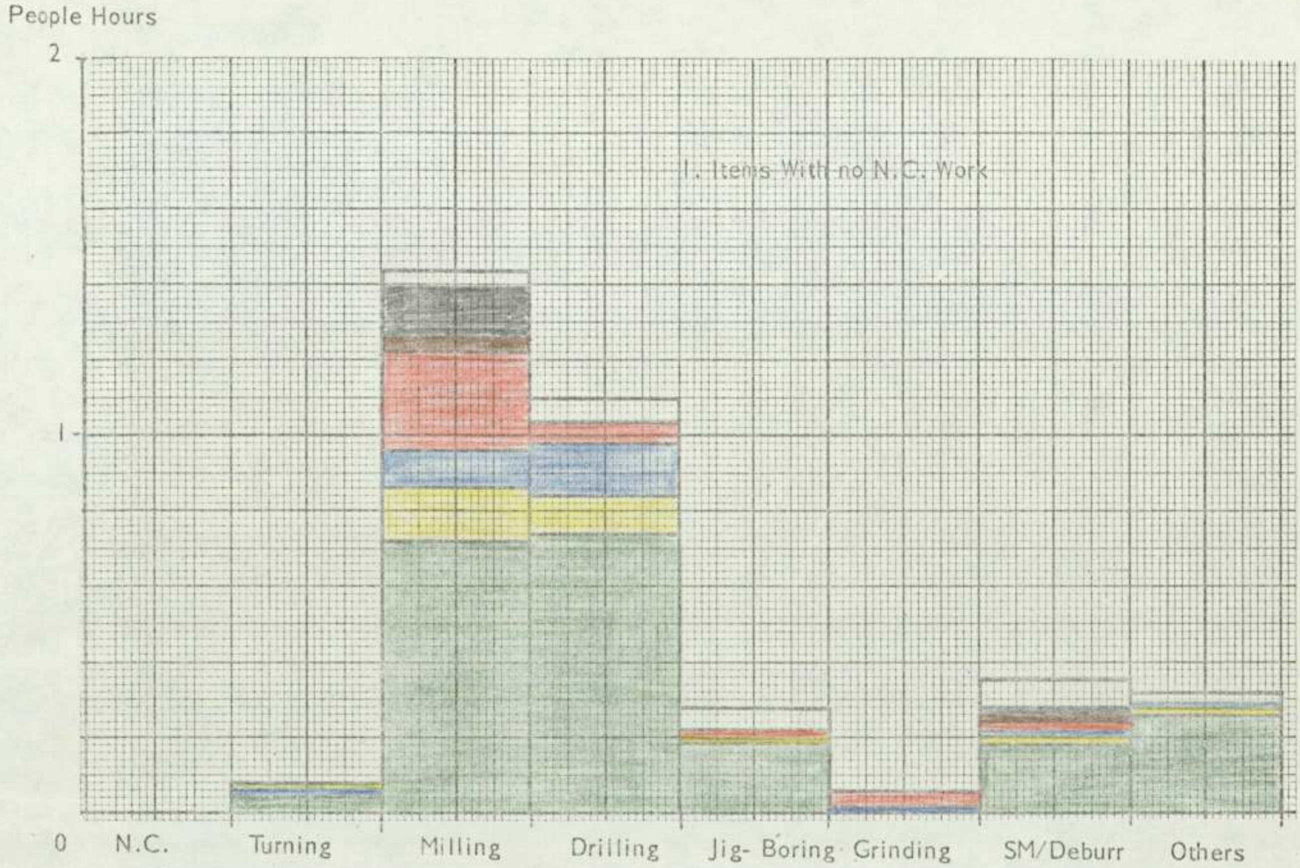


FIGURE 32 ANALYSIS OF NON ROTATIONAL ITEMS BY MACHINE TYPE

Analysis by Machine by Material - Sample Total 27910 Non Rotational 14865 Hours
19.3 10.3 People

1. Non-N.C. Items



2. N.C. Items

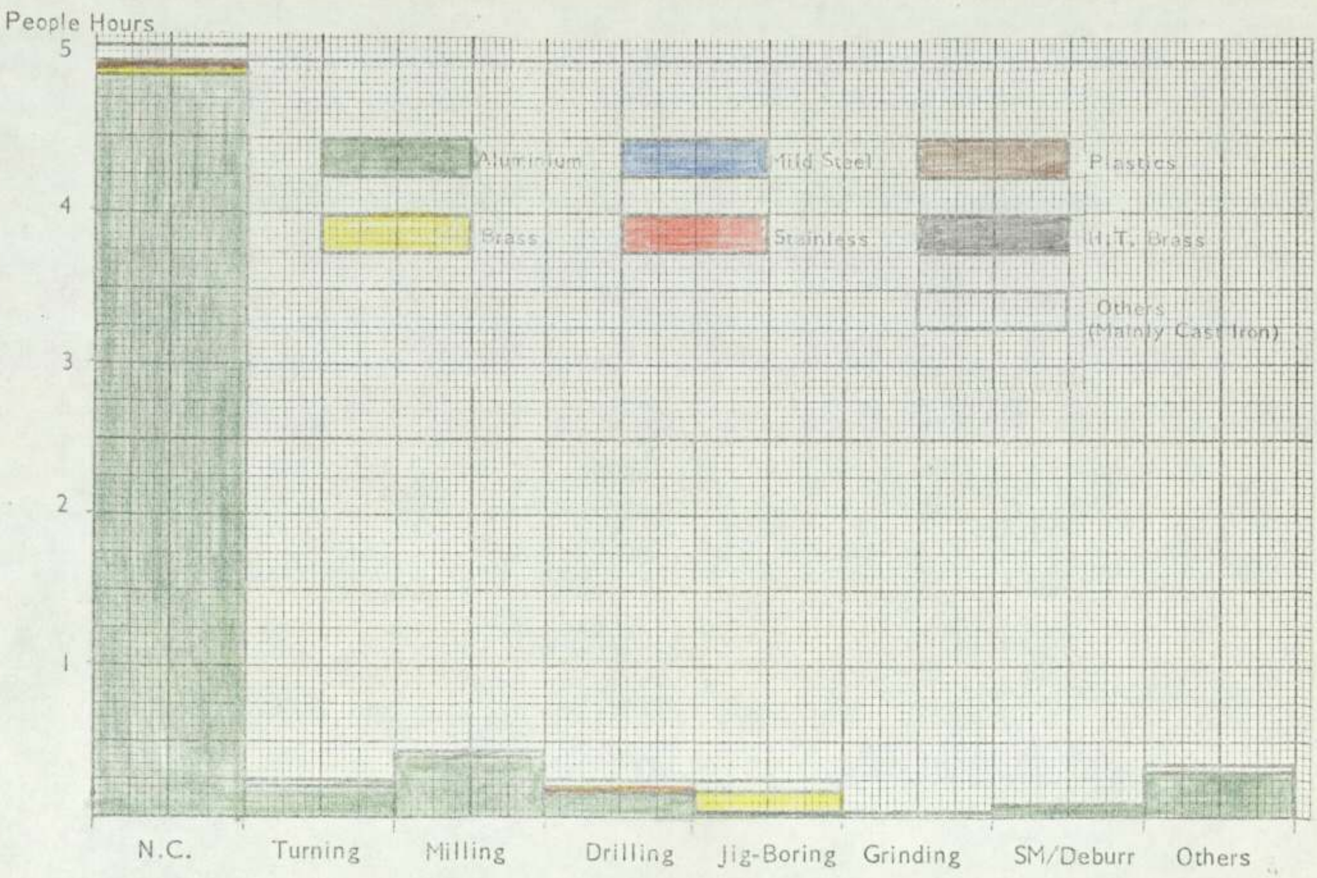
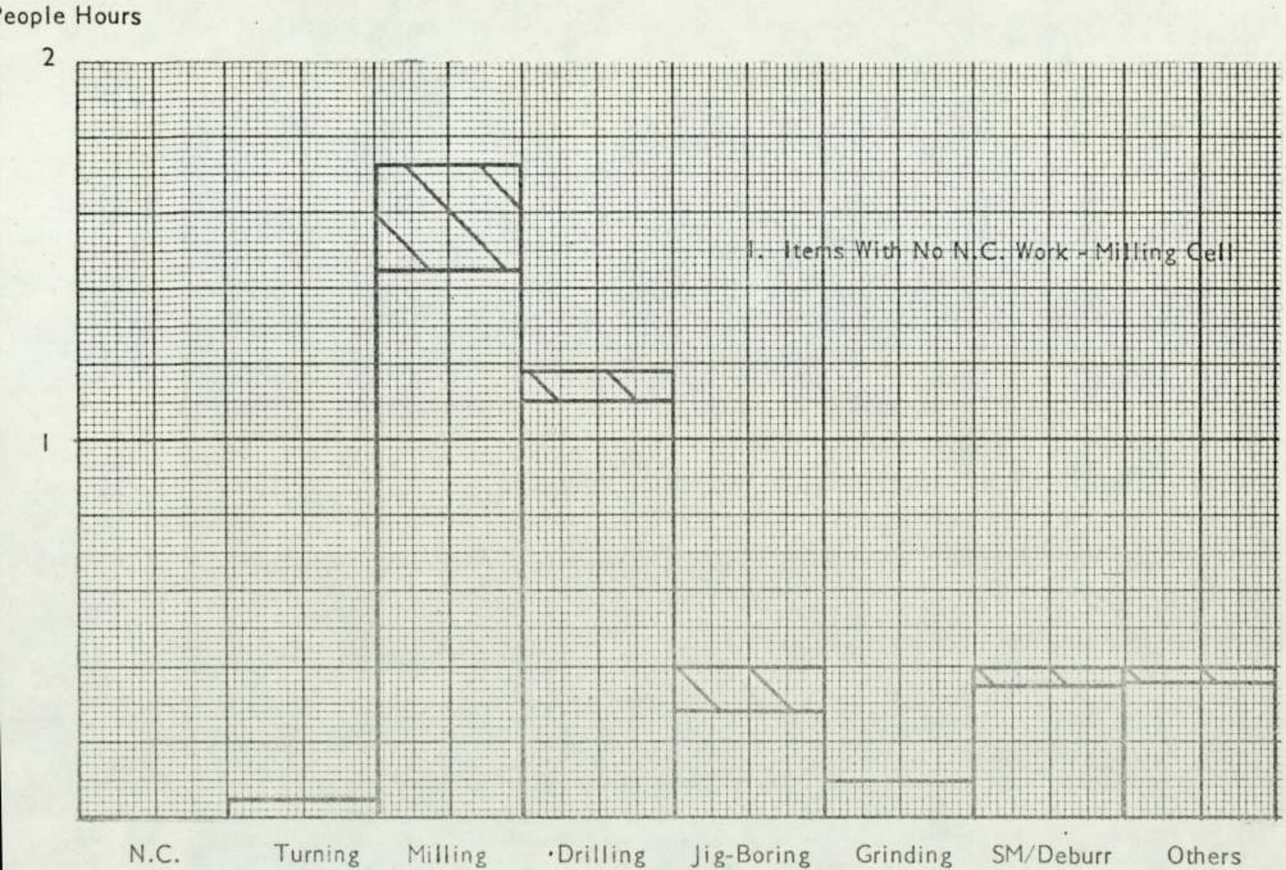


FIGURE 33 EFFECT OF DE-BATCHING

Analysis by Machine Type - Sample Total 27910 Non Rotational 14865 Hours
19.4 10.3 People



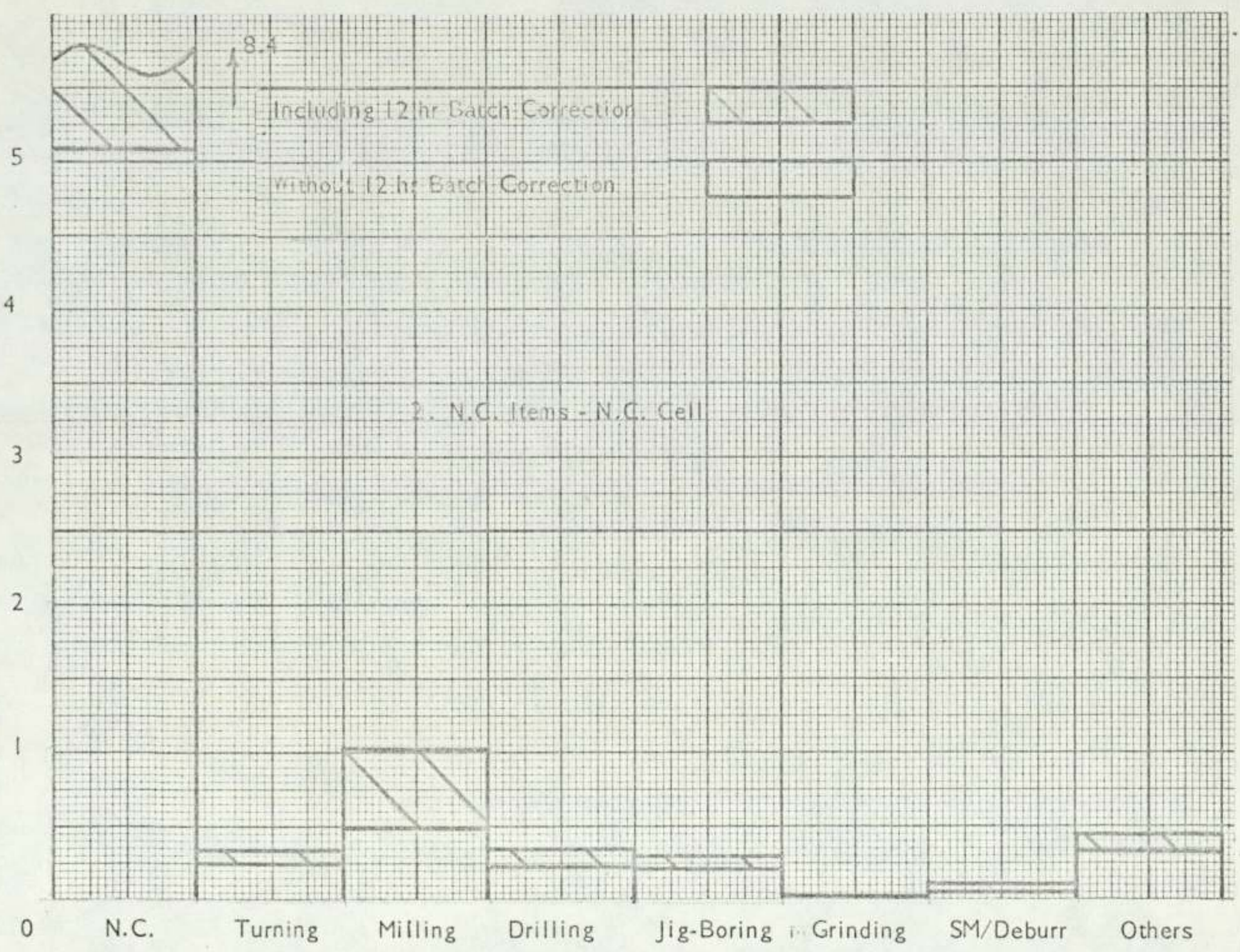
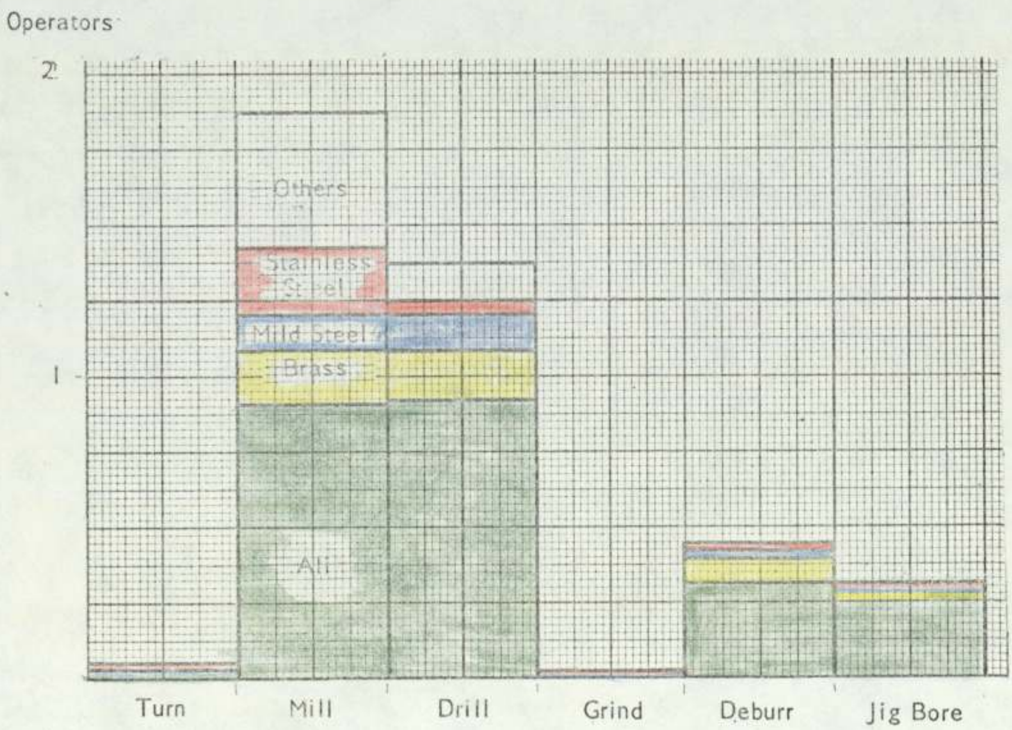


FIGURE 34 LOAD CHARACTERISTICS OF THE MILLING CELL

Components All those opitz code Ist Digit op 6, 7 or 8.
Typical components:- BLOCK SHAPES and CASTINGS.

Work Load for 3 Operators :- 3 Universal Millers
or 2 Millers and 1 Driller

Machines Required	2/3	ABENE UNIVERSAL MILLS
	I	SMALL UNIVERSAL MILL for slotting etc.
	I	MULTI SPINDLE DRILL & TAPPING MACHINE
	2	SINGLE SPINDLE DRILLS
	2	TAPPING MACHINES
	I	BENCH for DEBURR and INSPECTION
	I	TUMBLER or perhaps a small ROTO-FINISHER



Components: All those with Opitz Code 1st digit of 0 or 1 under 1" diameter.
Typical shape bushes and spacers.

Work load for 4 operators. 2 Turners, 1 Capstan Setter Operator, 1 Driller.

Machines required:
- 2 Conventional Centre Lathes (C.V.A.)
- 1 Reverse Operation Lathe
- 1 Small Capstan
- 1 Small Universal Mill
- 1 Multi Spindle Drill
- 1 Single Spindle Drill
- 1 Bench for inspection and deburr
- 1 Tumbler (deburr)

FIGURE 35 LOAD CHARACTERISTICS OF TURNING CELL A

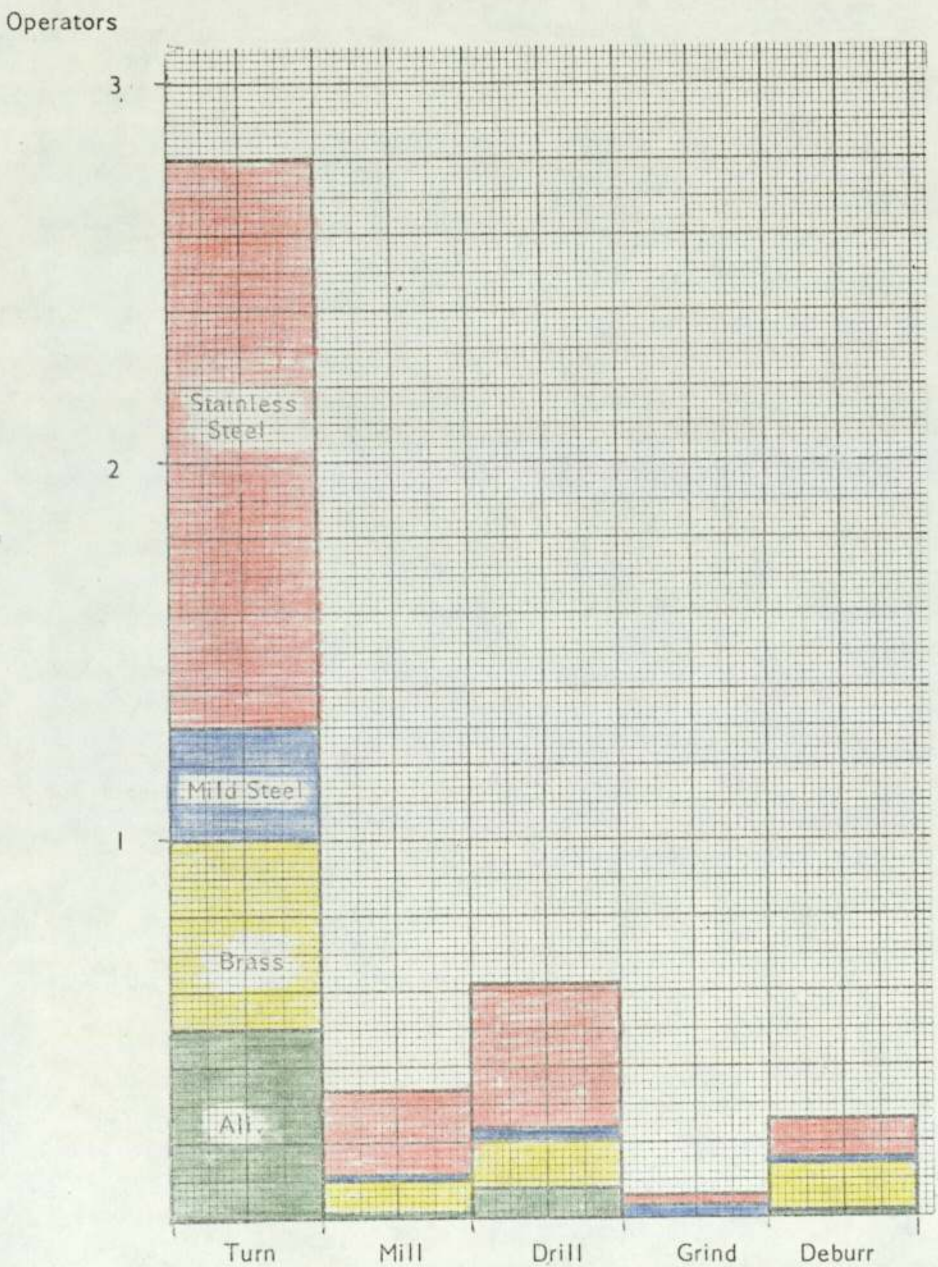
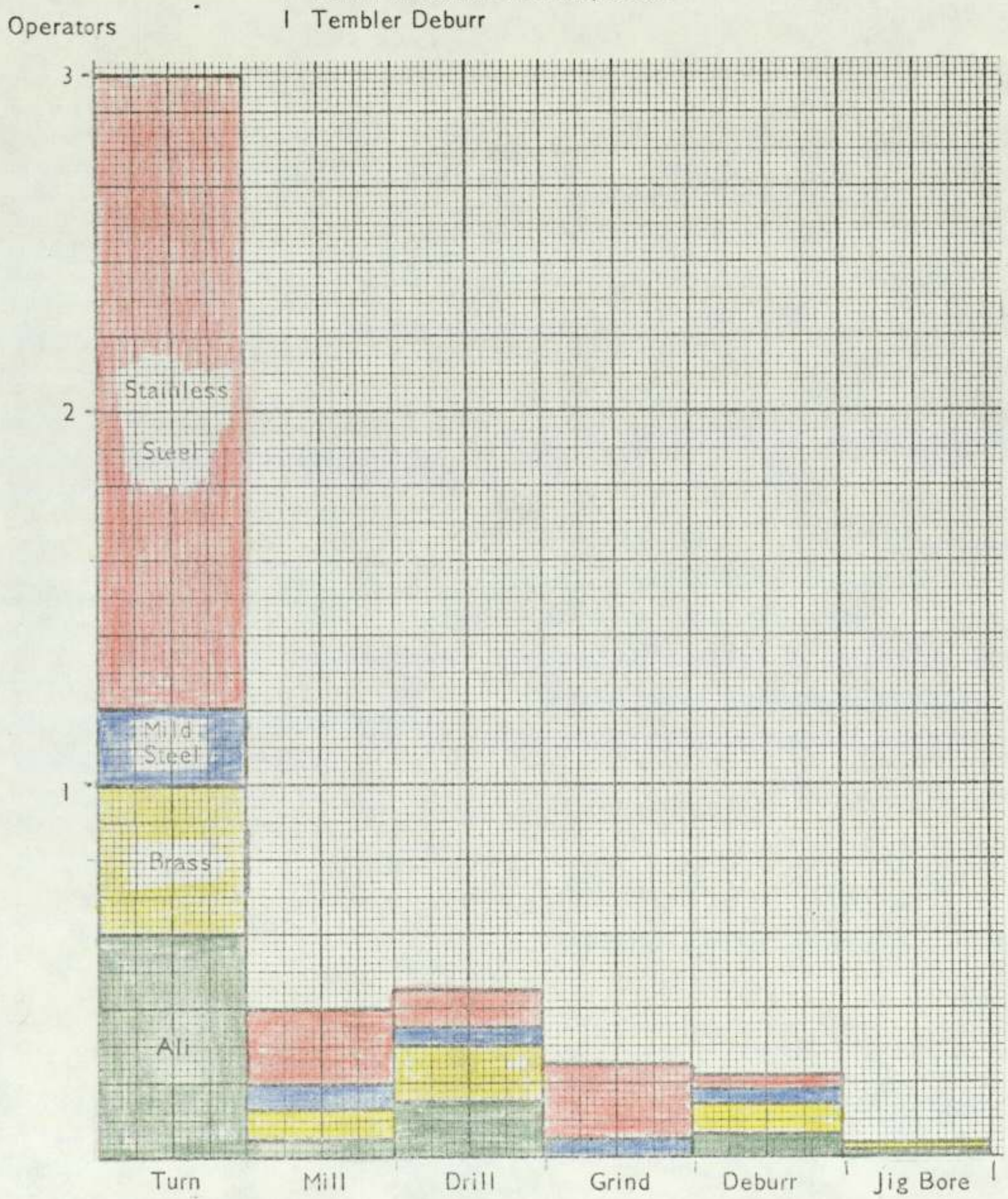


FIGURE 36 LOAD CHARACTERISTICS OF TURNING CELL B

COMPONENTS All those with Opitz Code 1st digit of 2, 3 or 4.
All components over 1" diameter. Typical shape shaft or spindle.
Irregular shapes, e.g. castings, bar stock over 1" diameter.

Work load for 4 operators. (3 Turners and 1 Miller/Driller)

Machines Required:
1 Cazeneuve Lathe (Large)
2 Centre Lathes. 1" diameter capacity
2 Second Operation Lathes
1 Abene Universal Mill
1 Small Universal Mill
1 Multi Spindle Drill & Tapping Machine
1 Single Spindle Drill
1 Bench for deburr and Inspection
1 Tembler Deburr



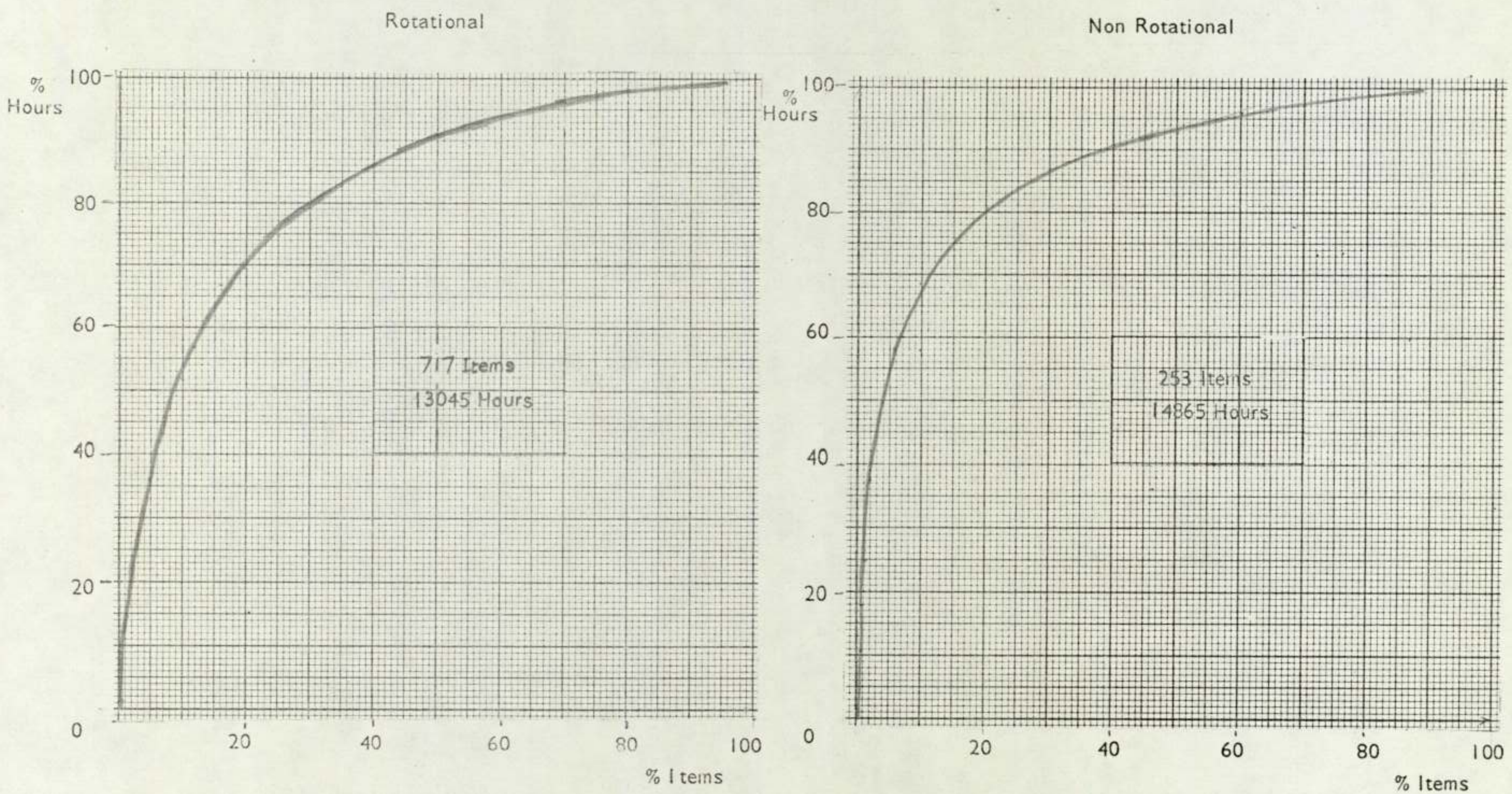
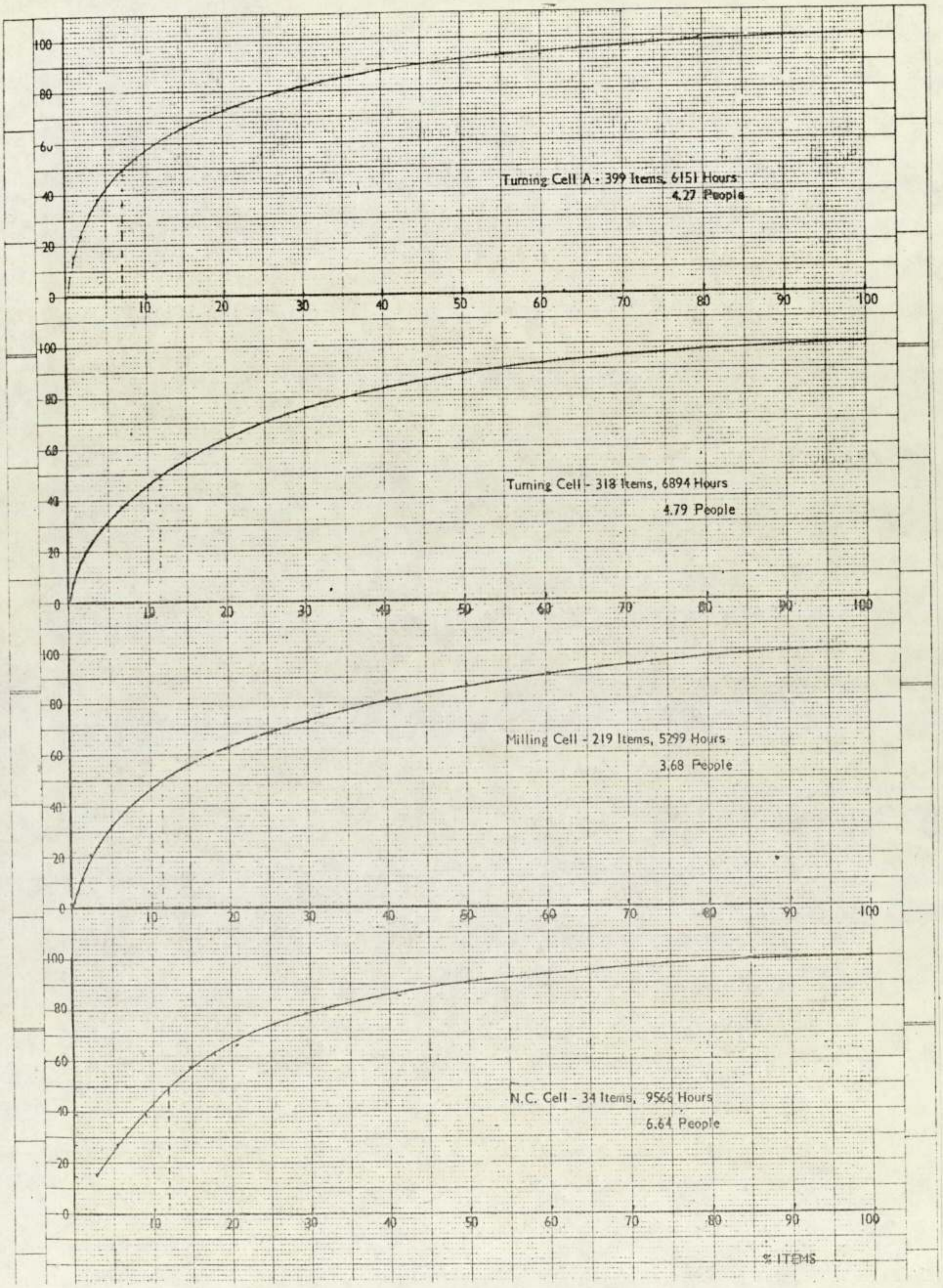


FIGURE 37 PARETO ANALYSIS OF ROTATIONAL AND NON ROTATIONAL ITEMS

FIGURE 38   PARETO ANALYSIS OF CELL LOADING



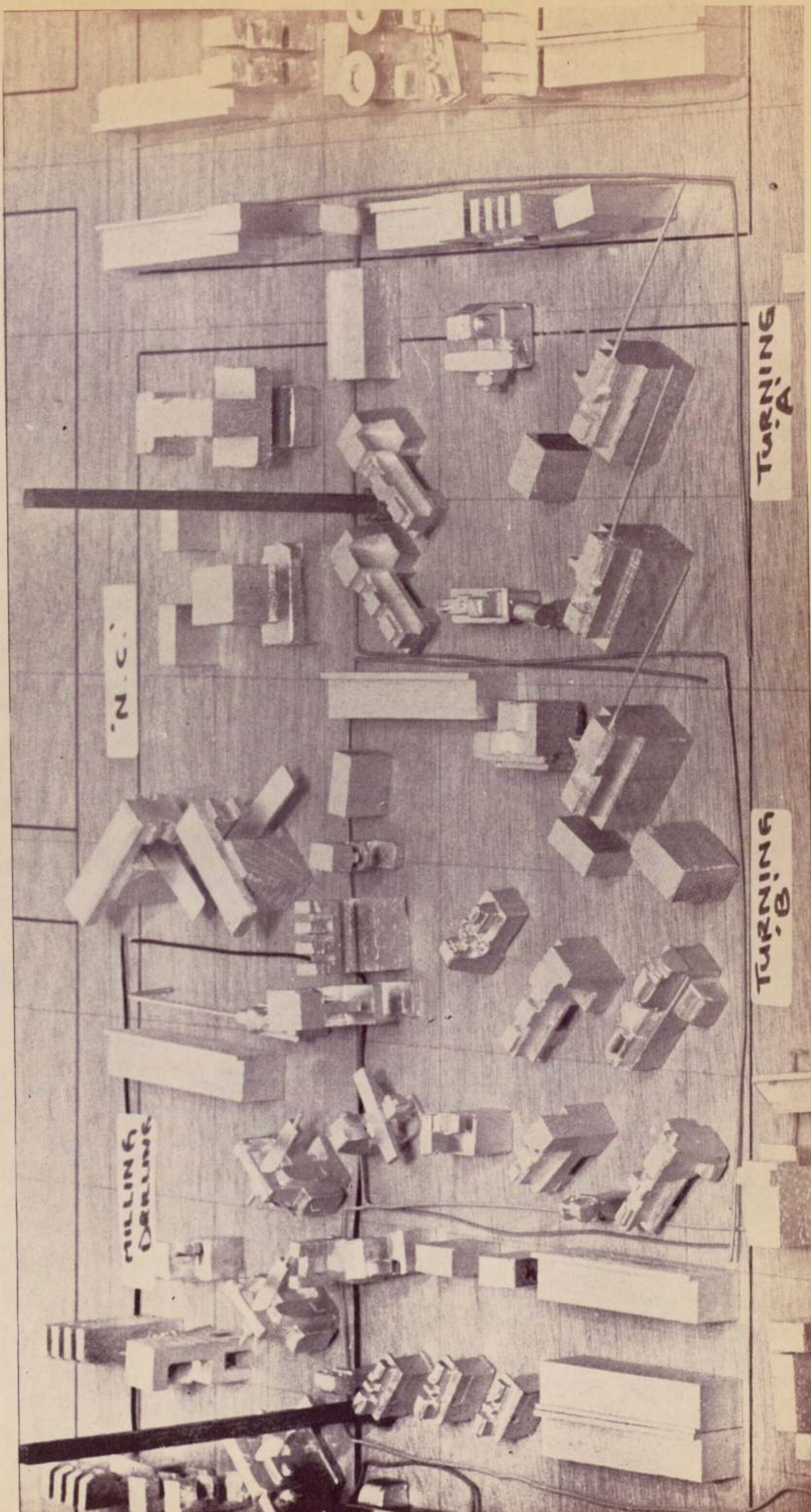


FIGURE 39 LAYOUT USED FOR INITIAL DISCUSSIONS

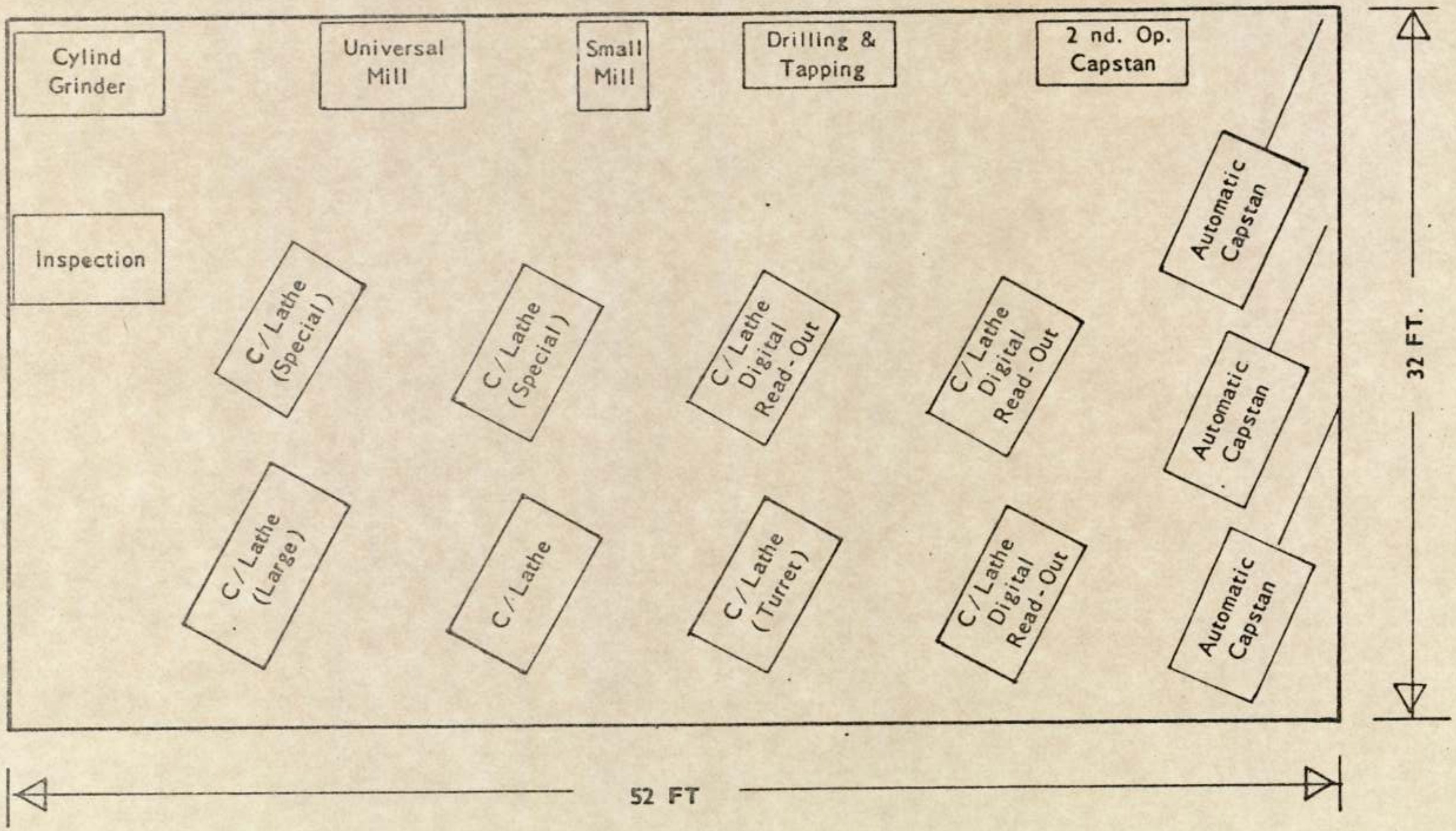


FIGURE 40 LAYOUT FINALLY CHOSEN FOR THE TURNING CELL

SAMPLE DATA FROM MANUFACTURING DIVISION

	B	C	D	E		F		G	H	J	K
				PERFORMANCE REPORT		CAPACITY/LOAD REPORT					
DEPT. NO.	PRODN. GROUP	DESCRIPTION	CELL/PROD'CT ORGANISATION	COLL-ECTION	LINE NO.	COLL-ECTION	LINE NO.	END CELL PRODN. GROUP	DUMMY	CAPAC-ITY	SPARE INDICATORS
321	bbb	TURNING CELL	C	321	00	321	00		D	180	
	030	DEBURR/BENCH WORK		321	01	321	11			30	
	052	MILLS		321	01	321	08			30	
	060	MEDIUM CENTRE LATHES		321	01	321	01			30	
	061	MEDIUM CENTRE LATHES		321	01	321	01			30	
	062	MEDIUM CENTRE LATHES		321	01	321	01			30	
	063	MEDIUM 2ND OP CENTRE		321	01	321	02			30	
	064	LARGE CENTRE LATHE		321	01	321	03			30	
	065	LARGE 2ND OP CENTRE		321	01	321	04			30	
	066	IRIS LATHE		321	01	321	05			30	
	070	MEDIUM CENTRE LATHES		321	01	321	01			30	
	075	2ND OP CAPSTAN		321	01	321	07			30	
	076	ACCURATOOL		321	01	321	06			30	
	080	MEDIUM CENTRE LATHES		321	01	321	01			30	
	085	DRILLS		321	01	321	09			30	
	090	CYL. GRIND		321	01	321	10			30	
	095	DEBURR/BENCH WORK		321	01	321	11			30	
322	bbb	OFF-LOAD CELL	C	bbb	00	bbb	00		D	0	
	190	OFF-LOAD		bbb	00	bbb	00		D	0	
323	bbb	INSPECTION TEAM	C	323	00	bbb	00		D	150	
	121	MACHINING INSPECTION		323	01	bbb	00	E		75	
	122	PROCESS INSPECTION		323	02	bbb	00	E		75	

A The Cell No.

B Those Prodn. Groups which constitute the cell

C The Description of the Cell or the Production Groups within the Cell. It may be preferable to have more than one Description leg, one for the Performance Report and one for the Capacity/Load Report.

D Indicates whether the Department is organised by Cell or by Product Team and thus how Performance Reports should be structured.

E Indicates how hours should be collected on Performance Report.

Turning Cell:-
All hours against Prodn. Groups collected under Cell 321 as collection field 321 and analysed collectively as Line no 01

Off-Load Cell:-
No hours for cell printed as collection fiels 'bbb'

Inspection Team
All hours against Prodn. Groups collected under Cell 323 as collection fields 323 and analysed separately as each Line no. is unique.

F Serves the same purpose as E above for Capacity/Load Report.

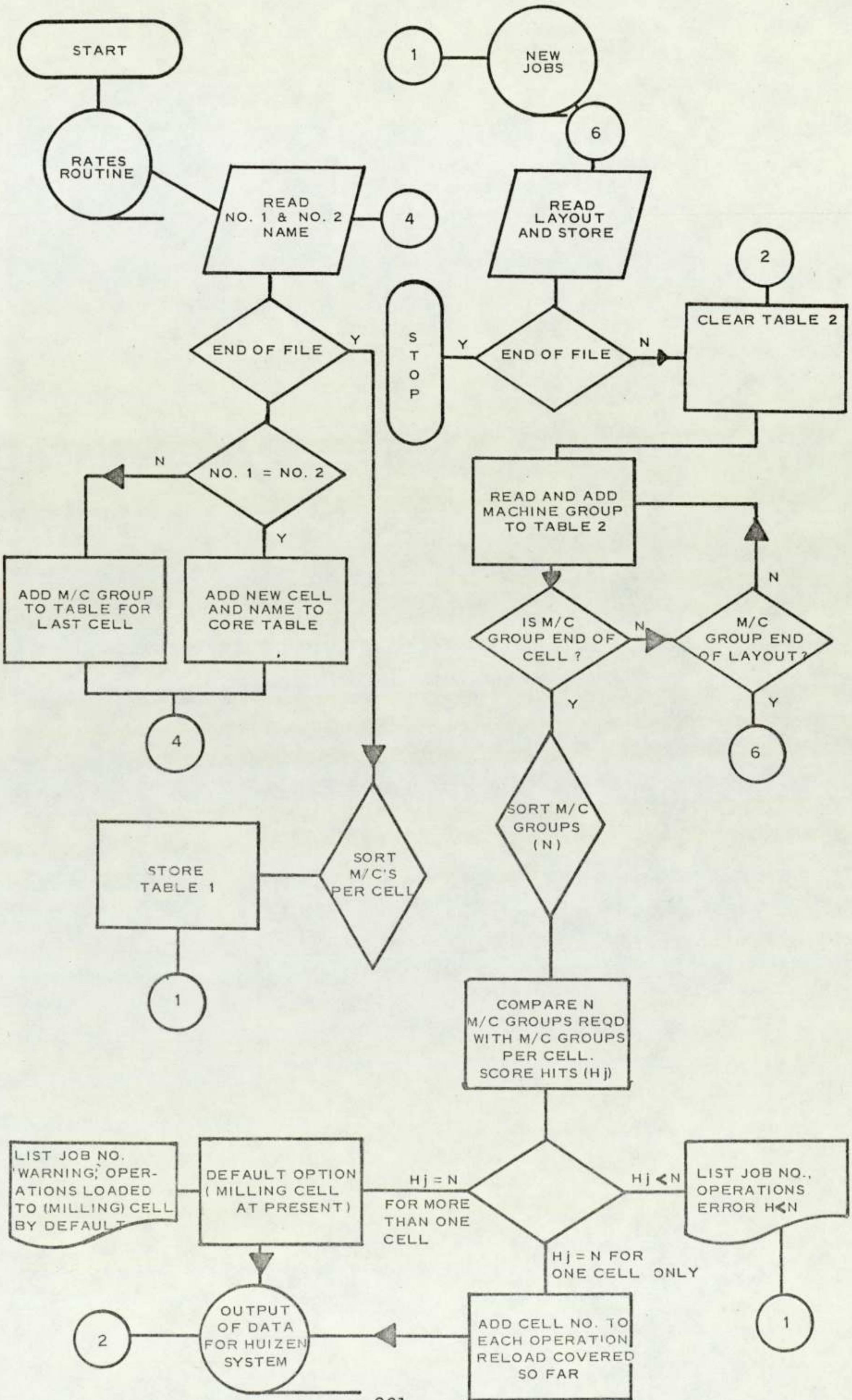
G Indicates those Production Groups which, when processed on a layout, de-limit the cell.

H Indicates those Rates/Routine records which are 'dummy', i.e. for descriptive purposes only. In theory, (although in practice this may not be true) no labour bookings should quote the Dept. No. excluding the Prodn. Group.

J Indicates total Capacity for cell and individual capacities for Prodn. Groups. Former figure used on Capacity/Load Report, latter figure not used as yet.

FIGURE 41 STRUCTURE OF THE RATES ROUTINE FILE

FIGURE 42 FLOW DIAGRAM OF THE CELL ALLOCATION PROGRAM



DATE 365.6 PAGE 001

4X1 WEEK AND 11X1 MONTH	CAPSTANS 0 075	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD	TURNING SMALL 070 083	MEDIUM 060 061 062	LARGE 064	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD
BACKLOG	258	258*		282*	1[illegible]1	31[illegible]	176	587*		162
365.6	45	303*	30	308*	71	77	34	769*	240	294
366.6	83	386*	60	324*	60	68	24	921*	480	354
367.6	47	433*	9[illegible]	329*	23	135	25	1104*	720	372
368.6	12	445*	12[illegible]	329*	16	115	43	1278*	960	393
369.6	118	563*	240		105	473	50	1566*	1920	
373.6	108	671*	36[illegible]		191	236	72	2405*	2880	
377.6	49	720*	480		44	154	5	2608*	3840	
381.6	36	756*	600		42	122	30	2802*	4800	
385.6	25	781*	720		13	6[illegible]	-	2875*	5760	
389.6	5	786*	840		2	1	15	2853*	6720	
393.6	-	786*	960		-	-	-	2893*	7680	
397.6	-	786*	1080		-	-	-	2893*	8640	
401.6	-	786*	1200		-	-	-	2893*	9600	
405.6	-	786*	1320		-	-	-	2893*	10560	
409.6	-	786*	1440		-	-	-	2893*	11520	
FORWARD LOAD	180	966*			461	467	23	3844*		
TOTAL	966				1129	2218	497			

4X1 WEEK AND 11X1 MONTH	MILLS DATUM 050	SMALL 051	MEDIUM 052	LARGE 053	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD	DRILLS DRILL & TAP 085	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD
BACKLOG	8	24	847	244	1123*		1[illegible]7	652	652*		68
365.6	-	2	133	-	1250*	210	148	104	756*	90	70
366.6	-	17	92	6	1373*	420	156	157	913*	180	77
367.6	-	16	89	11	1409*	630	166	148	1061*	270	85
368.6	-	10	140	-	1639*	840	169	115	1176*	360	85
369.6	-	4	530	54	2217*	1680		459	1635*	720	
373.6	-	25	354	-	2596*	252[illegible]		581	2216*	1080	
377.6	3	47	122	-	2768*	3360		205	2421*	1440	
381.6	-	-	248	-	3016*	4200		179	2600*	1800	
385.6	-	5	40	-	3061*	5040		103	2703*	2160	
389.6	-	47	30	-	3146*	5880		59	2762*	2520	
393.6	-	-	27	-	3173*	6720		29	2791*	2880	
397.6	-	-	10	-	3183*	7560		23	2814*	3240	
401.6	-	-	17	-	32[illegible]*	8400		10	2824*	3600	
405.6	-	-	-	-	32[illegible]*	9240		-	2824*	3960	
409.6	-	-	13	-	3213*	10080		-	2824*	4320	
FORWARD LOAD	1	26	590	-	383[illegible]*			387	3211*		
TOTAL	12	223	3280	315				3211			

FIGURE 43 LOAD CHART USED PRIOR TO GROUP TECHNOLOGY

REPORT RMD01(GT) THE MEL EQUIPMENT CO. LTD. PAGE 0001

MD CAPACITY LOAD REPORT WK. 418.7

4X1 WEEK AND 11X1 MONTH	ACCURA TOOL 076	2ND-OP CAPSTAN 075	LARGE CENTRE LATHE 064	LARGE 2ND-OP CENTRE 065	MEDIUM /SMALL CENTRE 060 062	MEDIUM 2ND-OP CENTRE 063	IRIS LATHE 066	MILLS 052	DRILLS 085	GRIND CYL. 090	DEBURR 095	OTHERS ---	CUM LOAD HRS	CUM AVAIL. CAPACITY	CUM AVAIL. LOAD
	TURNING TEAM MACHINE GROUPS														
BACKLOG	102	11	91	237	78	62	91	32	275	614	1009	-	3094		651
418-7	90	6	24	82	26	35	17	-	28	72	75	-	3549	300	694
419-7	81	1	21	87	33	9	21	-	26	109	70	-	4101	600	727
420-7	105	2	21	94	10	-	43	-	18	140	148	-	4698	900	747
421-7	69	5	26	63	12	43	26	1	56	169	83	-	5294	1200	
422-7	132	13	38	146	23	47	76	4	91	474	443	-	6952	2400	
426-7	93	6	41	75	10	11	15	-	55	198	322	-	7836	3600	
430-7	39	36	9	18	15	1	7	-	48	51	265	-	8340	4800	
434-7	12	-	10	12	3	-	4	1	12	26	10	-	8446	6000	
438-7	12	2	4	18	6	-	7	-	26	23	107	-	8660	7200	
442-7	33	7	6	7	2	1	1	-	10	19	78	-	8826	8400	
446-7	30	1	7	42	4	-	5	-	1	25	27	-	8973	9600+	
450-7	9	-	6	29	-	-	3	-	4	1	30	-	9064	10800	
454-7	12	-	6	26	-	-	3	-	31	-	-	-	9152	12000	
458-7	15	-	-	16	-	-	3	-	9	9	6	-	9200	13200	
462-7	18	-	-	24	-	-	3	-	13	9	256	-	9511	14400	
FORWARD LOAD	357	11	187	316	60	-	80	1	416	438	934	-	12611		
TOTAL	1215	101	497	1292	282	209	405	39	1119	2377	3863	-			

NB 1)FIGURE OF 300 HOURS CAPACITY IS ARBITRARY

2)BLANK COLUMN MAY BE HELPFUL FOR UNALLOCATED MACHINE GROUPS

SEE NEXT PAGE

ISSUE 1 20/03/75

FIGURE 44 LOAD CHART USED AFTER GROUP TECHNOLOGY

0227 PRODUCTION GROUP C76 ACCURATOOL WORK ISSUE LIST MANUFACTURING DIVISION WEEK NO 473.1 PAGE NO 001

STRT DATE	UR	A C	RC	ISS DATE	NAME	CODE NUMBER	DESCRIPTION	FAMLY TREE	CC	W.O.NUMBER	OP NO	QUANT AVAIL	LOAD TIME	PROD.GP BEF	PROD.GP AFT	CW	T I	REMARKS
4530	5	0	NB	4551	OTHER	35131283217202	SCREW	A1001A	00	999997 291 0	060	110	106	002	052			LOADED TO ACCURATOOL
4530	5	0		4731	APPRENTI	43220813769003	COLLAR	BB007A	00	652997 000 0	050	167	67	002	075			
4580	5			4707	OTHER	43220813802001	BUSH	B1048H	00	651656 004 2	040		233	002	075			JOB CARD NOT SENT IN
4650	5	0				FV/397348 02	SHOULDER SCREW	01383B	00	651915 010 0	050	205	85	002	075			
4670	1	0				35131283001001	SHORT CIRC CLMP	YK837A	00	226408 285 0	080	199	48	002	085		2	
4670	5	0				RR/A825907 03	WASHER FLAT	A1003A	SZ	289051 116 0	030	158	40	002	030			
468C	1	0				35131248006002	SPECIAL SCREW	UD167A	00	226408 275 0	060	135	80	002	052			
4680	1	0		4731	ALLEN	35131282879202	SPRING PIN	MB007A	S1	226408 281 0	030	815	80	002	097		1	
4680	5	0				SD/A141765 02	SPACER	M2361A	00	333913 000 0	050	114	42	002	075			
4680	5	0				SD/A141764/103	HANK BUSH	M2359A	00	333913 000 0	050	60	44	002	075			
4680	5	0				4322C815550002	BUSH	BA010A	SZ	652997 000 0	030	75	78	002	085			
4680	5	0				SD/A141764/203	HANK BUSH	M2227A	00	333913 000 0	060	367	108	002	075			
4690	5	0				SD/A141739 04	PILLAR	M2221A	00	333913 000 0	050	312	112	002	075			
4690	5	0				35131282172 01	TUNING PIN	A0010A	00	724807 417 0	050	1030	354	002	051			
4700	1	0				SD/A141740 04	PILLAR	M2222A	00	333913 000 0	050	108	47	002	075			
470C	1	0				35131283263001	BUSH	MB002A	00	260037 120 0	050	70	51	002	085			
4700	1	0		4731	TRILL	35131283283001	BUSH	MB011A	00	305006 020 0	050	410	145	002	085			
4700	5	0				35131283347201	SHORT CLAMP	YL118A	SZ	226408 285 0	050	69	33	002	052			
4700	5	0		4727	TRILL	43220813815001	BUSH	BC026A	SZ	652997 000 0	030	650	141	002	085			
4710	5	0				35131283056201	RIVET BUSH	UB893A	00	226408 275 0	030	253	121	002	085			
4720	1	1				35131250011202	CAPTIVE SCREW	FG001A	00	226408 281 0	070	415	101	002	052			
4720	5	1				35136101048 0B	PIN DOWEL	MB026B	00	298077 070 0	020	75	28	002	121			
4720	5	0				35131283079201	WASHER	FG002A	00	226408 281 0	030	415	81	002	085			
4720	5	0				35131282963201	BOLLARD	UD151A	00	226408 275 0	050	101	90	002	061			
4720	5	0				35131282177 01	INSERT	A0002A	00	724807 417 0	030	335	226	002	051			
4740	1	0				B116545 03	SCREW	MB016A	00	281204 425 0	040	27	25	002	052			
4740	1	0				A147728 01	SPACER	A1001A	00	289035 156 0	050	108	43	002	085			
4740	1	0				35131283065201	PATH ADJUSTER	UB765A	00	226408 275 0	070	85	66	002	085		1	
4740	5	0				RR/A828500 2A	FERRULE ELT CON	BB489A	00	282804 490 0	060	168	81	002	052			
4740	5	0				35131282574201	BOLLARD	UD145A	00	226408 275 0	030	101	90	002	052			
4740	5	1				RR/A825022 03	PILLAR ASSY	01891B	00	724807 404 0	080	610	99	004	075			
4750	5	0				RR/A826083 03	SCREW MACHINE	01072A	00	724807 404 0	040	175	80	002	052			
4760	1	0				35131253508201	SPACER	MB066A	00	226459 002 0	040	270	60	002	085			
4760	5	1	RM			B115762 03	SPACER	A1006A	00	281204 428 0	040	210	32	002	030			
4760	5	1	RM			35131283425201	PIN	MB005A	00	226408 283 0	040	101	37	002	121			
4760	5	1	RM			B115599 03	SPIGOT	A1003A	00	281204 428 0	030	105	46	002	061			
4760	5	0				RP/A825301 04	PILLAR ASSY	01839A	00	724807 404 0	080	652	94	004	075			
4770	1	0				RP/A827293 07	SCREW SHOULDER	BB354A	00	282804 492 0	050	135	66	002	075			
4770	1	0				A147735 01	SPACER	A1004A	00	289035 156 0	030	106	67	002	060			
4770	5	1				RR/A825299 03	PILLAR ASSY	01436A	00	724807 404 0	080	168	40	004	075			
4770	5	1				RR/A825352 04	POST ELECT	01552A	00	724807 404 0	080	346	64	004	075			
4770	5	0				RR/A828541 04	WASHER PACKING	01098A	00	724807 404 0	030	175	65	002	085			
4770	5	1				RR/A825022 03	PILLAR ASSY	01891A	00	724807 404 0	080	710	113	004	075			

SEE FOLLOWING PAGE

FIGURE 45 THE 'WORK ISSUE LIST' USED BEFORE GROUP TECHNOLOGY

APPENDIX 4
REPORT RMDC5(GT)
****

THE MEL EQUIPMENT CO.LTD
****

MD MATERIAL AND TOOL CHASING LIST
****

PAGE 0001
****
WK.424.7
****

START DATE	RC	MAT'L ITEM NO.	MATERIAL DESCRIPTION OR TOOL NO.		PREV CELL	OP NO	PART CODE NO.	ITEM NO	WORKS ORDER	REMARKS
3890		A1017	D145438	REAR SUPPORT	327		DP19057	A1001A	289078 025 0	
3970	MS	CF/IO	RR/B82845C/2	BLANKING GROMMET F/ISSUE	327		RR/A82488	BB326A	282707 492 0	HELD AVIONICS
3970	MS	CF/IO	RR/B828450/3	JUNCTION BOX.F/ISSUE	327		RR/A828466	BB325A	282707 492 0	HELD AVIONICS
3990	TN		MRS51C44		327	080	RR/A824978	A1166A	284653 410 0	
3990	TN		MCT29924			040	B115826	B2053A	289027 111 0	
4090		MB018	041301800002	22 SWG AL ALLOY SHT L81			RR/B825178	MB018A	284750 409 0	
4160	RM	B1062	011304405004	1/4 X 1/4 SQ ST/STL BAR EN57			B115490	B1062A	280909 470 0	PD324742RAPPS
4180	RM	A1002	041301109012	.812 A/F HEX AL ALLOY BAR			B116875	A1002A	289027 222 0	PD324754APP
4200	RM	A1002	A/F	7/32 DIA STL ROD BS970 EN3B			A436283	A1002A	293237 008 0	PD324737TEDD
4210	TN		ERT 1881.			120	RR/B827673	01954A	284653 402 0	
4220	TN		MCT30165		327	040	B118594	A1197C	283126 478 0	
4230	RM	B1208	031309501001	38SWG COPPER SHT BS899			A148667	B12C8B	280909 431 0	GOODS IN 2810
4245		A1004	B117497/UNF	CASTING			B117497	A1004A	289027 172 0	

NB 1) THIS IS A CHASING LIST FOR THE CELL CHASER. IT ONLY SHOWS BACKLOG, BUT COULD BE EXTENDED TO SHOW REQUIREMENTS FOR, SAY, THE NEXT 4 WEEKS

ISSUE 1 24/03/75

FIGURE 46 SHORTAGE LIST OF MATERIALS AND TOOLS

REPORT RMD03(GT) THE MEL EQUIPMENT CO.LTD. PAGE 0001

MD WORK AVAILABILITY LIST WK. 424.7

TURNING.TEAM WORK-FIRST 300 HOURS UNHELD LOAD

FINISH DATE	CODE NO.	IS NO	DESCRIPTION	WORKS ORDER	ITEM NO	QTY AVAIL	LOAD HOURS	PROD-GRP BEF	PROD-GRP AFT	OPITZ CODE	REMARKS
3820	FV397349	02	SHOULDER SCREW	651915 010 0	01383B	220	7.2	002		120300020	
3940	FV 720733	02	SHAFT LOCATING	651915 010 0	02516C	175	8.8	002		220300130	5/16 S/S EN57 GS.
3960	FV 692328	0C	BUSH	651915 010 0	01184D	51	2.0	002		101030030	
4010	B115539/3	05	SPACER	280704 405 0	A1586A	80	3.1	002		202000000	
4050	B117422	03	SPACER	280704 405 0	A1069A	182	24.0	002		222000030	
4090	B115649	01	HANDLE	283207 479 0	B1017A	55	5.1	002		425050030	
4095	A148216/2	04	PILLAR	280909 464 0	A1773A	32	2.2	002		202000000	
4100	RR/AB25985	03	INSULATING BUSH	284750 404 0	A1844A	56	0.5	002		111000050	
4160	RR/AB25981	03	PILLAR	284610 404 0	A2563A	31	8.5	002		205030000	
4160	RR/AB25039	04	PILLAR	284750 404 0	A1411A	215	0.6	002		202000000	
4160	35131283182	01	SCREW	226289 217 0	CC393A	192	8.3	002		120300030	
4160	RR/AB27446	03	SPACER SCREWED	284750 409 0	A1391A	180	24.7	002		222000030	
4160	RP/AB27579	1A	SPACER	284750 402 0	A1163A	120	2.7	002		101000000	
4160	432208137630	04	SPINDLE	651656 004 0	B1054C	260	6.4	002		200000230	
4160	RR/AB25306	03	SCREW SHOULDER	284750 404 0	A2158A	125	14.0	002		120000030	
4160	RR/AB27753	1A	BOSS	284750 402 0	W1183A	110	15.0	002		142000010	
4160	RR/AB27546	05	SCREW SPECIAL	284750 404 0	A1068A	120	16.2	002		220330130	
4170	A147098	01	SPACER	280909 431 0	B1182A	105	4.6	002		205000100	
4170	RR/AB25038	03	SCREW MACHINE	284750 402 0	A1973A	113	7.5	002		120330030	
4170	B145321/2	03	SPACER	284750 402 0	A1200A	475	9.4	002		101000002	
4170	RR/AB28699	1A	SCREW MACHINE	284750 402 0	A1155A	310	13.9	002		222000030	
4170	RR/AB28545	02	BOLT SPECIAL	284750 404 0	A1079A	130	17.5	002		120300030	
4170	RR/AB26083	03	SCREW MACHINE	284750 404 0	A1072A	130	18.4	002		220000130	
4170	RR/AB25992	2A	SCREW MACHINE	284750 402 0	A1163A	260	25.9	002		220000030	
4170	RR/AB26081	03	SCREW MACHINE	284750 404 0	A1071A	240	29.9	002		120300030	

SEE NEXT PAGE

NB 1.LOAD HOURS ON LIST ARE NOT ACCURATE AND FIGURE OF 300 HOURS CAPACITY IS ARBITRARY

2.IN ORDER TO PROVE THE CONTENT AND SEQUENCE OF LIST,IT MAY BE DESIRABLE TO SET UP DUMMY EXERCISE TO SEQUENCE WORK ON LIST USING OUIJA BOARD

3.LIST WILL BE AVAILABLE BEFORE TOOL READY FACILITIES,SO THAT IN FIRST INSTANCE ONLY MATERIAL AVAILABILITY WILL BE DEFINITELY KNOWN.

ISSUE 01 23/03/75

FIGURE 47 THE 'WORK AVAILABILITY LISTING'

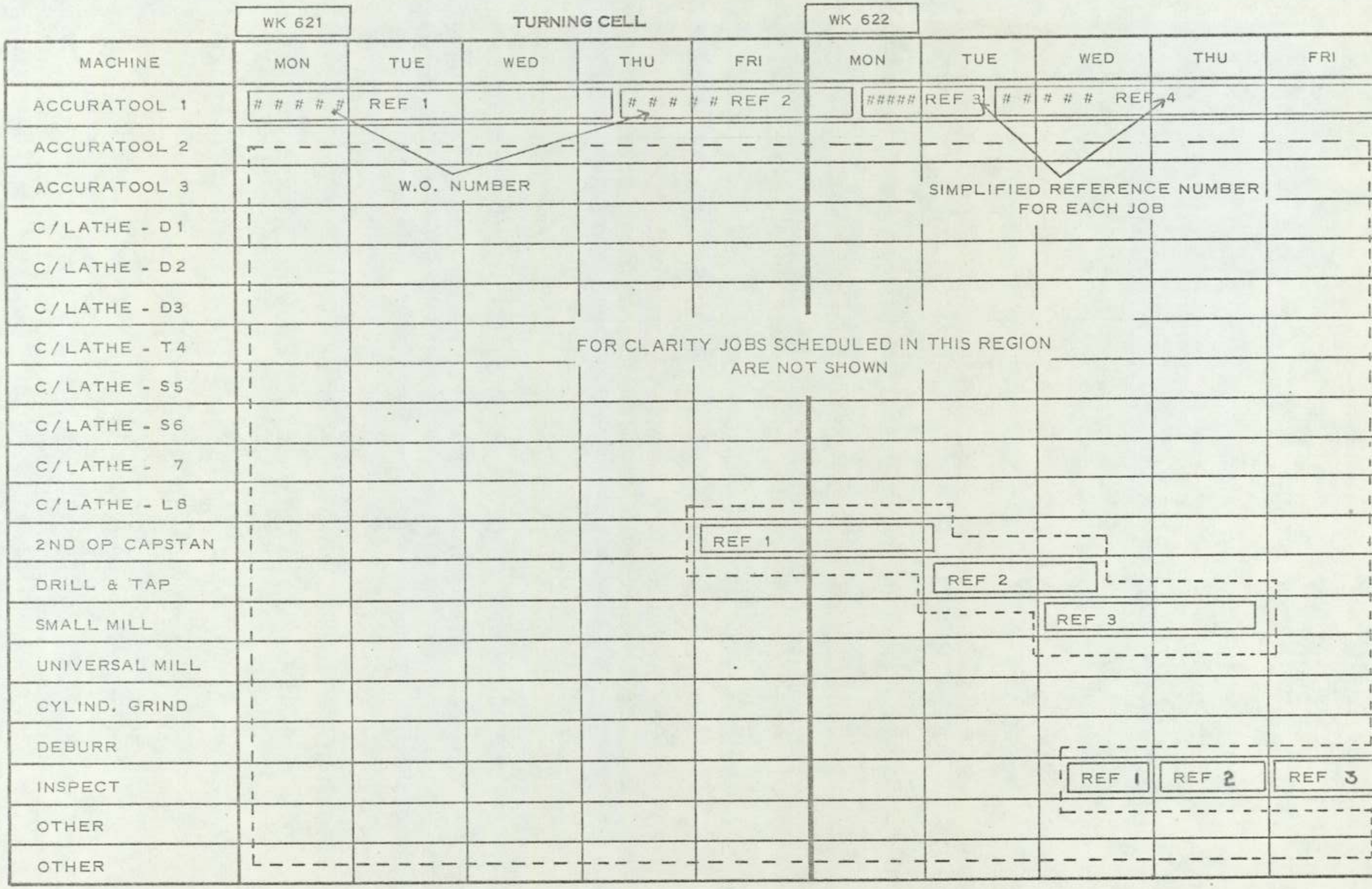


FIGURE 48 DIAGRAM OF A 'OUIJA BOARD'

```
0766 MICROPERT FOR W.O.NO.999957 291 0 0000 EQUIPMENT     SPARES          WEEK NOS 451/483 (451/483)          WEEK 473.1  PAGE   1

      PART NUMBER        QTY      DESCRIPTION        I BEG ACCUM ACCUMUR RC R        470       480       490       500       510    R
      COMB  CC ITEM                                          LOAD   ACT           ..I....I....I....I....I....I....I....I....I....I...
                                                                                   .       .                                       .
      3513 128 32172       100  SCREW                02              \     5       .       .                                       .
                                                     2/-----   076-011             .       .                                       .
483        OC A1001A 052/003  C30/001   122/000   142/000   120/000       6.       .                                       .
                                                         0       0      0          .       .                                       .
                                                                                   .       .                                       .
      3513 132 16852        12  HEATSINK             01                    1       .       .                                       .
                                         1/OG/SO  010/000   013/001             .       .                                       .
483        CC A1002A 013/C01  03C/000   122/C00   141/000   120/000             .       .             1112111 A *               .
                                                         0       0      0          .       .                                       .
                                                                                   .       .                                       .
      3513 132 18802        24  LATCH                01                    5       .       .                                       .
                     1/A1003 -C20/C00   052/C02   C85/002   014/000             .       .                                       .
483        OC A1003A 052/002  C30/002   122/000   141/000   120/000             .       .          1111111111= A *               .
                                                         0       0      0          .       .                                       .
                                                                                   .       .                                       .
      3513 152 1C872         6  FFCNT PANEL          02                    1       .       .                                       .
                                                     5/A1004   4/OG/SO             .       .                                       .
483        CC A1004A 4/OG/SO  C25/001   052/008   088/006   034/000             .       .                                       .
                     085/004  121/000   141/000   120/000   094/003             .       .                                       .
                     035/000  036/002   038/005   036/001   120/000             .       .     3111121211111 A *               .
                                                         0       0      0          .       .                                       .
                                                                                   .       .                                       .
      3513 160 11012        12  REGU. PABEL          03                    5       .       .                                       .
                     4/MB008  4/MB009   4/PB010   027/001   122/000             .       .                                       .
483        CO A1005A                                                               .       .                 311= A *               .
                                                         0       0      0          .       .                                       .
                                                                                   .       .                                       .
      3513 128 32172       10C  SCREW                02                    5       .       .                                       .
                                                     2/OG/SO   060/011             .       .                                       .
463        OC A1001C 052/003  C30/001   122/000   142/000   120/000             .       .             1111111= A *               .
                                                         0       0      0          .       .                                       .
                                                                                  ..I....I....I....I....I....I....I....I....I....I...
                                                                             R        470       480       490       500       510    R
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FIGURE 49   THE 'MICROPERT'

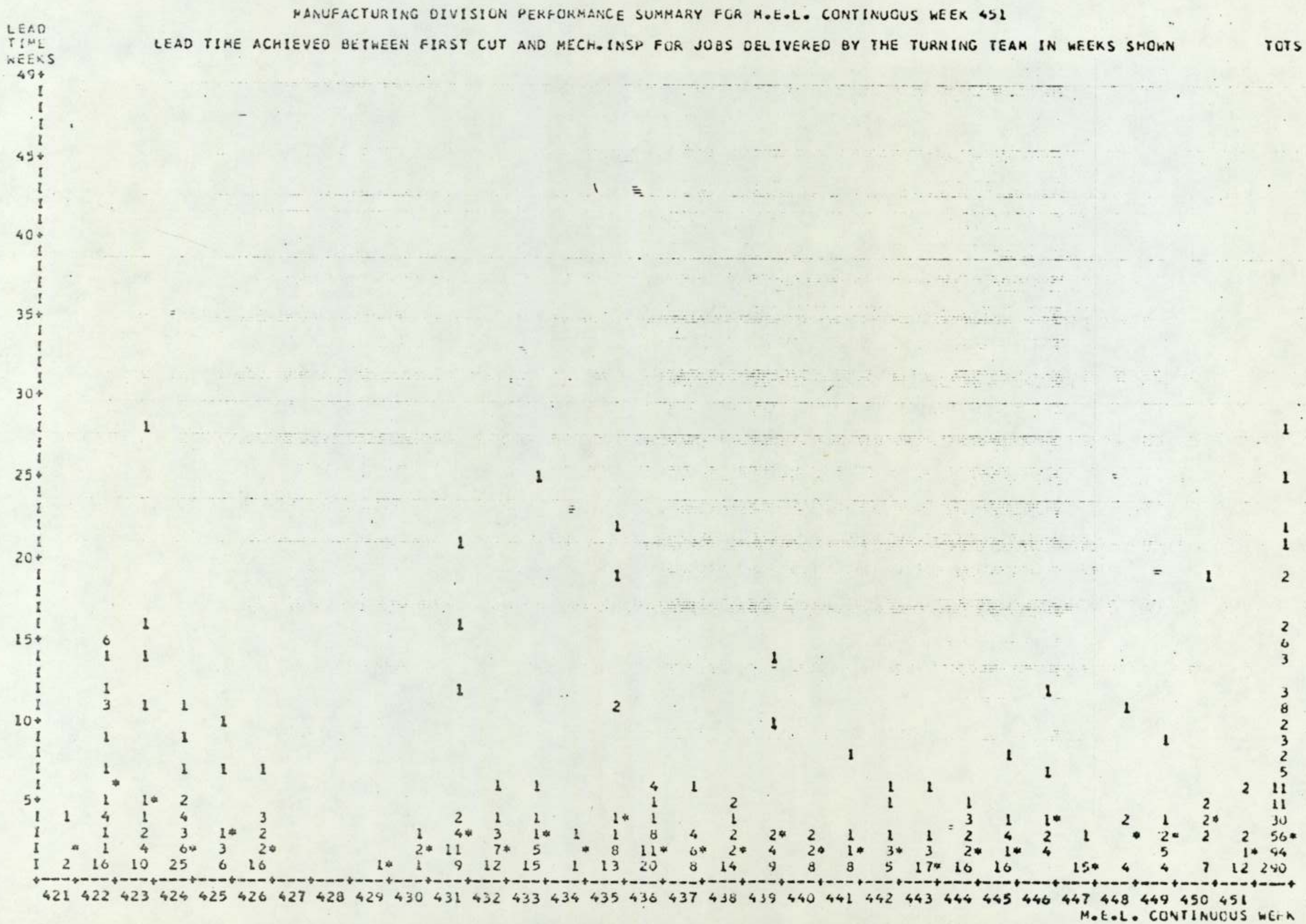
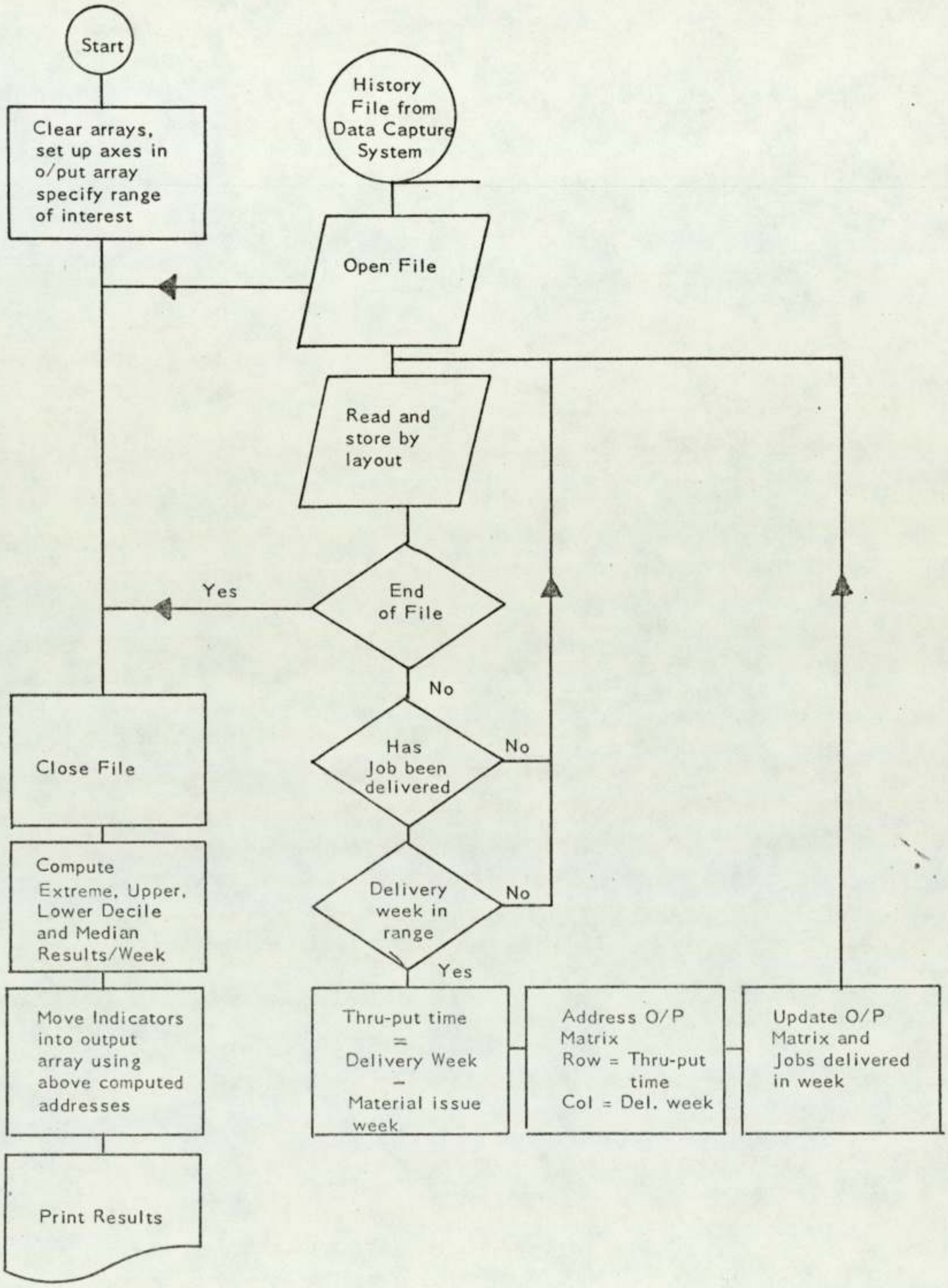


FIGURE 50 THRU-PUT TIME PERFORMANCE MEASURE

FIGURE 51 FLOW DIAGRAM OF THE THRU-PUT TIME CALCULATOR



MANUFACTURING DIVISION PERFORMANCE SUMMARY FOR M.E.L. CONTINUOUS WEEK 451

DELIVERIES AGAINST DUE DATE FOR JOBS DELIVERED BY THE TURNING TEAM IN WEEK SHOWN

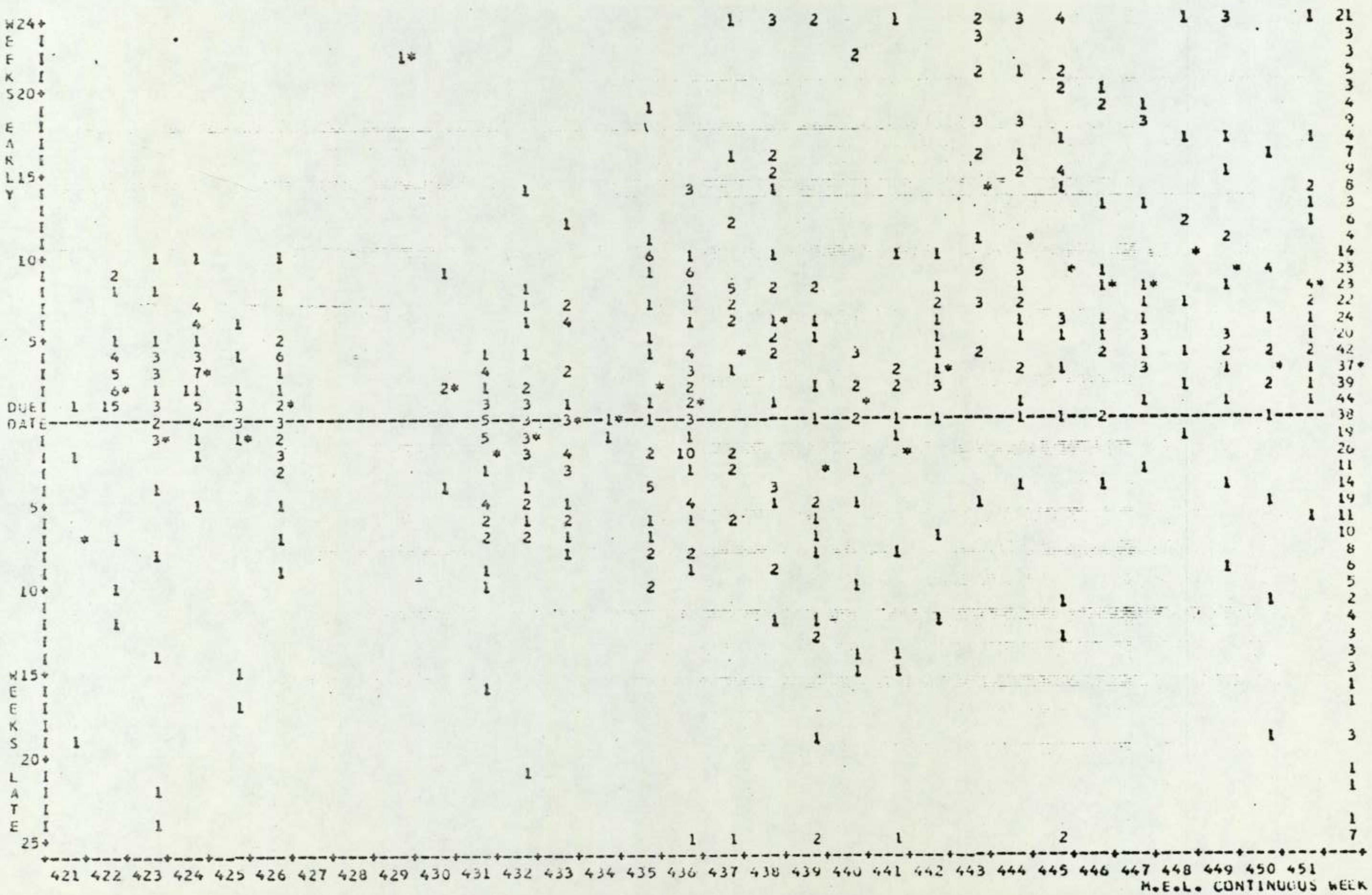


FIGURE 52 DUE DATE PERFORMANCE MEASURE

REPORT RLMD5501 THE MEL EQUIPMENT CO.LTD 21/10/76

PAGE NO 2 MANUFACTURING DIVISION PRODUCTION CONTROL SYSTEM - ADMINISTRATION ROUTINES WEEK NO. 43

ANALYSIS OF PERFORMANCE GENERAL M/C 325

PROD GROUP RANGE	DESCRIPTION	HOURS ALLOWED MS/60	ANALYSIS OF HOURS: TIME TAKEN: ON TARGET	NOT ON TARGET	WAITING TIME	TRAINING TIME	OTHER ROUTINES	WEEKLY WORKED HOURS	SUPPLEMENTARY HOURS: S1	S2 CUST	S2 MANF	AVERAGE OPERATOR PERF	DEPT PERF
050-059 EXCL. NC M/C	MILLS	186.	220.	9.			42.	270.	4.		10.	51.	50.
			81%	3%			15%		2%		4%		
060-080 EXCL. NC WORK	TURNING	167.	179.	119.	1.		11.	309.	15.	6.	1.	56.	51.
			58%	38%			3%		5%	2%			
085-086	DRILLS	151.	163.	1.				163.			9.	56.	55.
			100%								6%		
087-099	OTHERS	338.	267.	165.			48.	479.	2.	3.	6.	76.	71.
			56%	34%			10%			1%	1%		
058	REFURBISH N/C												
DEPARTMENTAL TOTALS		844.	829.	292.	1.		100.	1221.	21.	9.	27.	61.	58.
			68%	24%			8%		2%	1%	2%		
CUMULATIVE PERFORMANCE		33578.	32534.	4012.	181.	72.	6492.	43290.	717.	136.	1748.	62.	BUDGET. 61.
			75%	9%			15%		2%		4%		

FIGURE 53 PERFORMANCE MEASURES PRE GT

WEEKLY PERFORMANCE ANALYSIS - MANUFACTURING DIVISION

DATE 21/ 1/1977 *** WEEK NO. 702

**** M01-TURNING CELL

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	247.4	30.5	.0	.0	3.1	.0	.0	65.3	.9	347.2	218.3	21.9	.0	240.2	53	42	56
WEEK %	71.3	8.8	.0	.0	.9	.0	.0	18.8	.3	100.0	90.9	9.1	.0	100.0			
CUM.	247.4	30.5	.0	.0	3.1	.0	.0	65.3	.9	347.2	218.3	21.9	.0	240.2	59	44	58
CUM.%	71.3	8.8	.0	.0	.9	.0	.0	18.8	.3	100.0	90.9	9.1	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M02-MILL/DRILL CELL

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	489.7	67.3	.0	.0	6.0	.4	6.2	93.4	3.1	666.1	500.7	57.2	.0	557.9	61	50	65
WEEK %	73.5	10.1	.0	.0	.9	.1	.9	14.0	.5	100.0	89.7	10.3	.0	100.0			
CUM.	489.7	67.3	.0	.0	6.0	.4	6.2	93.4	3.1	666.1	500.7	57.2	.0	557.9	60	45	59
CUM.%	73.5	10.1	.0	.0	.9	.1	.9	14.0	.5	100.0	89.7	10.3	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M03-INSTRUMENT CELL

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	56.4	.0	.0	.0	.0	.0	.0	27.7	1.0	85.1	54.7	.0	.0	54.7	58	39	53
WEEK %	66.3	.0	.0	.0	.0	.0	.0	32.5	1.2	100.0	100.0	.0	.0	100.0			
CUM.	56.4	.0	.0	.0	.0	.0	.0	27.7	1.0	85.1	54.7	.0	.0	54.7	60	43	57
CUM.%	66.3	.0	.0	.0	.0	.0	.0	32.5	1.2	100.0	100.0	.0	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M04-SHEET METAL CELL

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	753.8	284.4	20.8	26.4	75.1	51.7	9.0	181.5	14.5	1417.2	750.4	237.0	13.9	1001.3	60	42	57
WEEK %	53.2	20.1	1.5	1.9	5.3	3.6	.6	12.8	1.0	100.0	74.9	23.7	1.4	100.0			
CUM.	753.8	284.4	20.8	26.4	75.1	51.7	9.0	181.5	14.5	1417.2	750.4	237.0	13.9	1001.3	56	40	55
CUM.%	53.2	20.1	1.5	1.9	5.3	3.6	.6	12.8	1.0	100.0	74.9	23.7	1.4	100.0			
TARGET %	55.0	20.0	.5	.8	3.0	3.5	.0	14.2	3.0	100.0					55	39	54

**** M07-PROCESS CELL

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	0	0
WEEK %	.0	.0	.0	.0	.0	.0	.0	.0	.0	100.0	.0	.0	.0	100.0			
CUM.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	60	39	55
CUM.%	.0	.0	.0	.0	.0	.0	.0	.0	.0	100.0	.0	.0	.0	100.0			
TARGET %	20.0	53.2	.2	.4	3.0	3.5	.0	15.9	3.8	100.0					60	39	55

DIVISION OR TEAM TOTALS

****

	BOOKED HOURS OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	CREDIT HOURS OT	NOT	TT	TOTAL	PERFORMANCES AOP	DEPT	BU2
WEEK	1547.3	382.2	20.8	26.4	84.2	52.1	15.2	367.9	19.5	2515.6	1524.1	316.1	13.9	1854.0	59	44	59
WEEK %	61.5	15.2	.8	1.0	3.3	2.1	.6	14.6	.8	100.0	82.2	17.0	.7	100.0			
CUM.	1547.3	382.2	20.8	26.4	84.2	52.1	15.2	367.9	19.5	2515.6	1524.1	316.1	13.9	1854.0	60	44	57
CUM.%	61.5	15.2	.8	1.0	3.3	2.1	.6	14.6	.8	100.0	82.2	17.0	.7	100.0			

***** ISSUED BY TEO DEPARTMENT *****

FIGURE 54 PERFORMANCE FIGURES POST GT

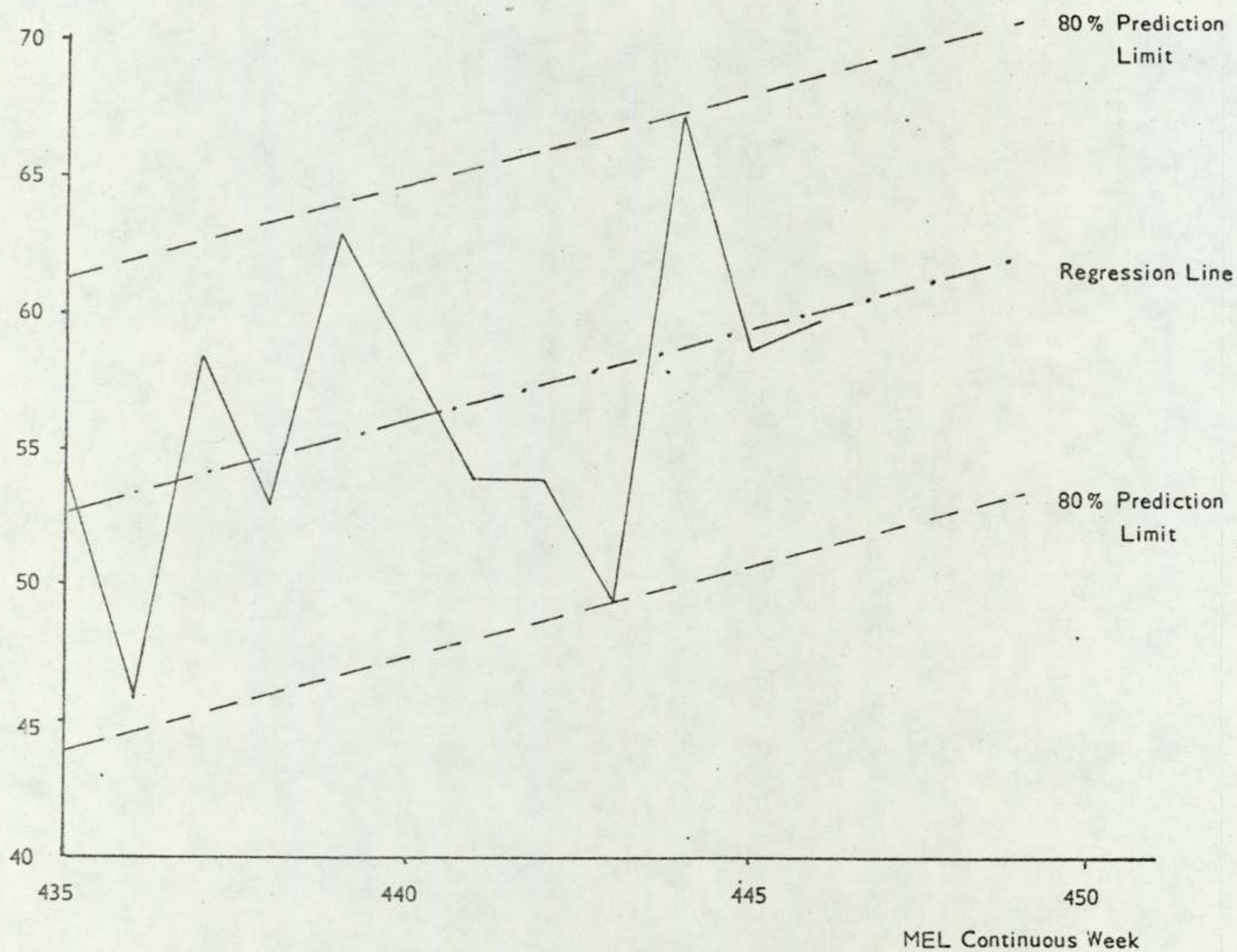


FIGURE 55 TURNING CELLS 'M' HOUR PERFORMANCE

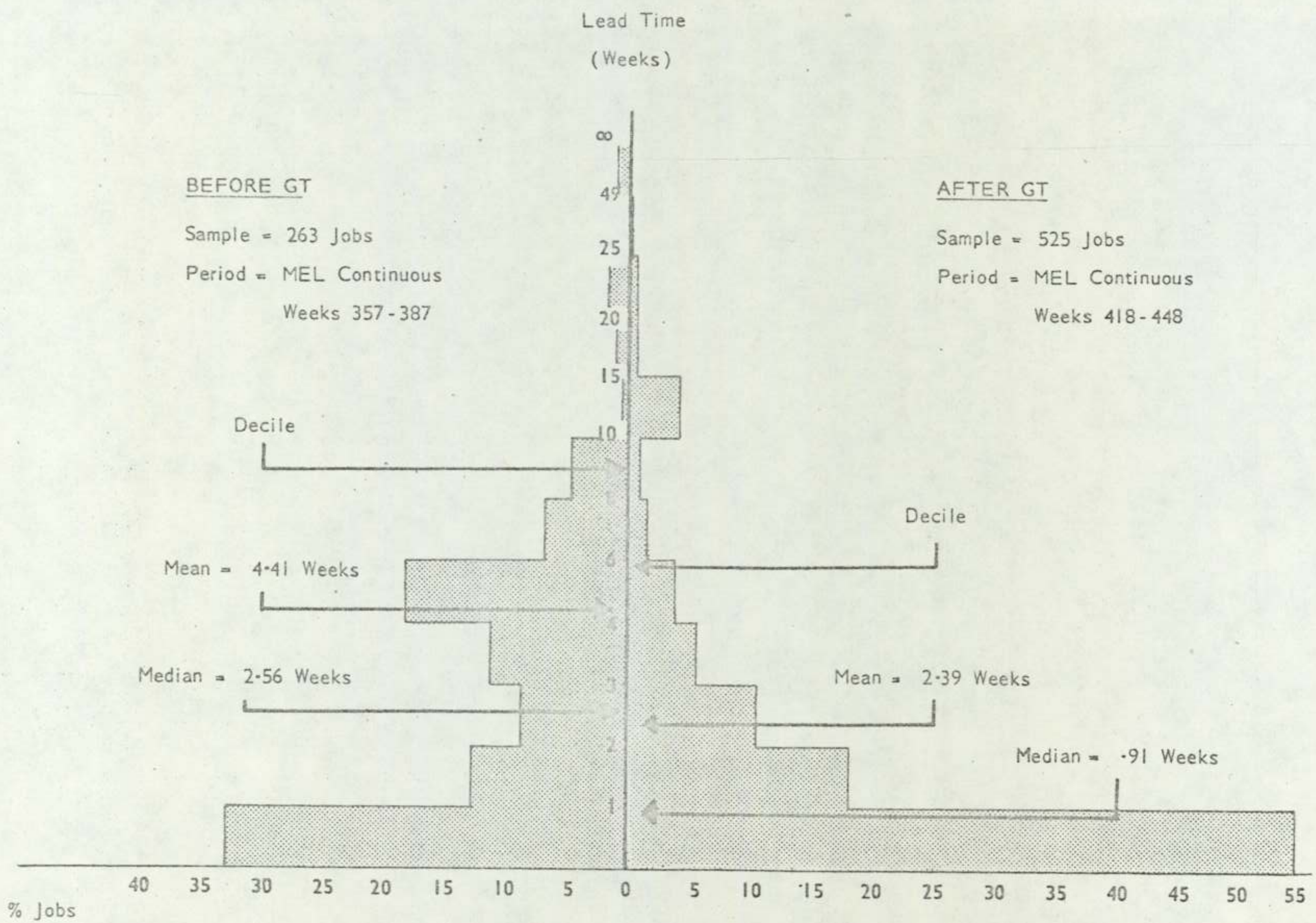


FIGURE 56 TURNING CELL LEAD TIME PERFORMANCE PRE AND POST GROUP TECHNOLOGY

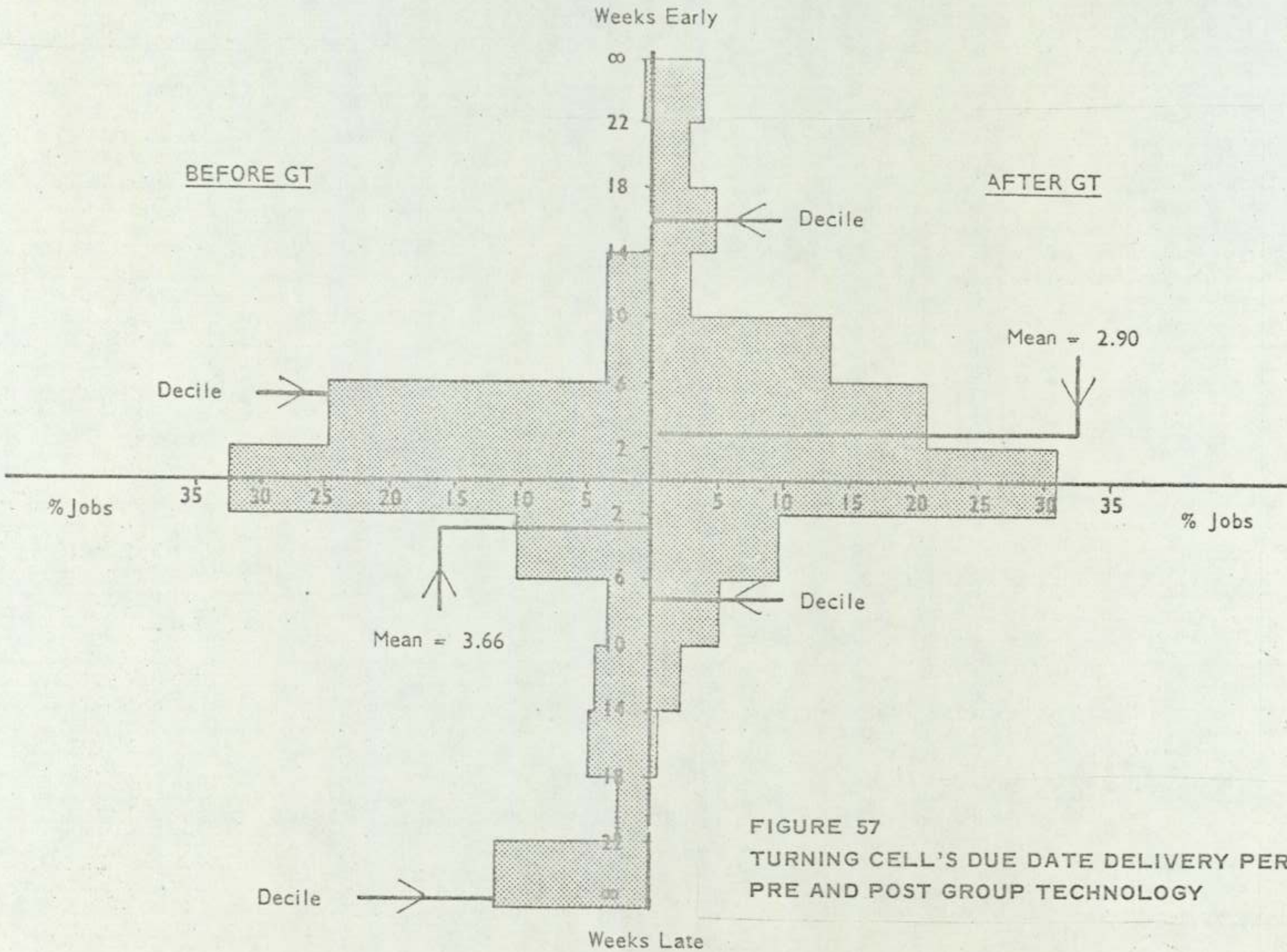


FIGURE 57
TURNING CELL'S DUE DATE DELIVERY PERFORMANCE
PRE AND POST GROUP TECHNOLOGY

FACTOR	TURNING CELL IMPROVEMENT (%)	SURVEYED IMPROVEMENT (%)
REDUCTION OR WORK IN PROGRESS	46	62
REDUCTION IN OVERALL STOCKS	NOT MEASURED	42
REDUCTION IN SETTING TIME	25	69
REDUCTION IN THRU-PUT TIME	46	70
INCREASE OUTPUT PER EMPLOYEE	$22\frac{1}{2}$	33
REDUCTION IN OVERDUE ORDERS	33	82

FIGURE 58 COMPARISON OF BENEFITS SEEN IN THE TURNING CELL WITH THOSE REPORTED BY A SURVEY OF OTHER COMPANIES

FIGURE 59 SAMPLE OF CANDIDATES FOR STANDARDISATION

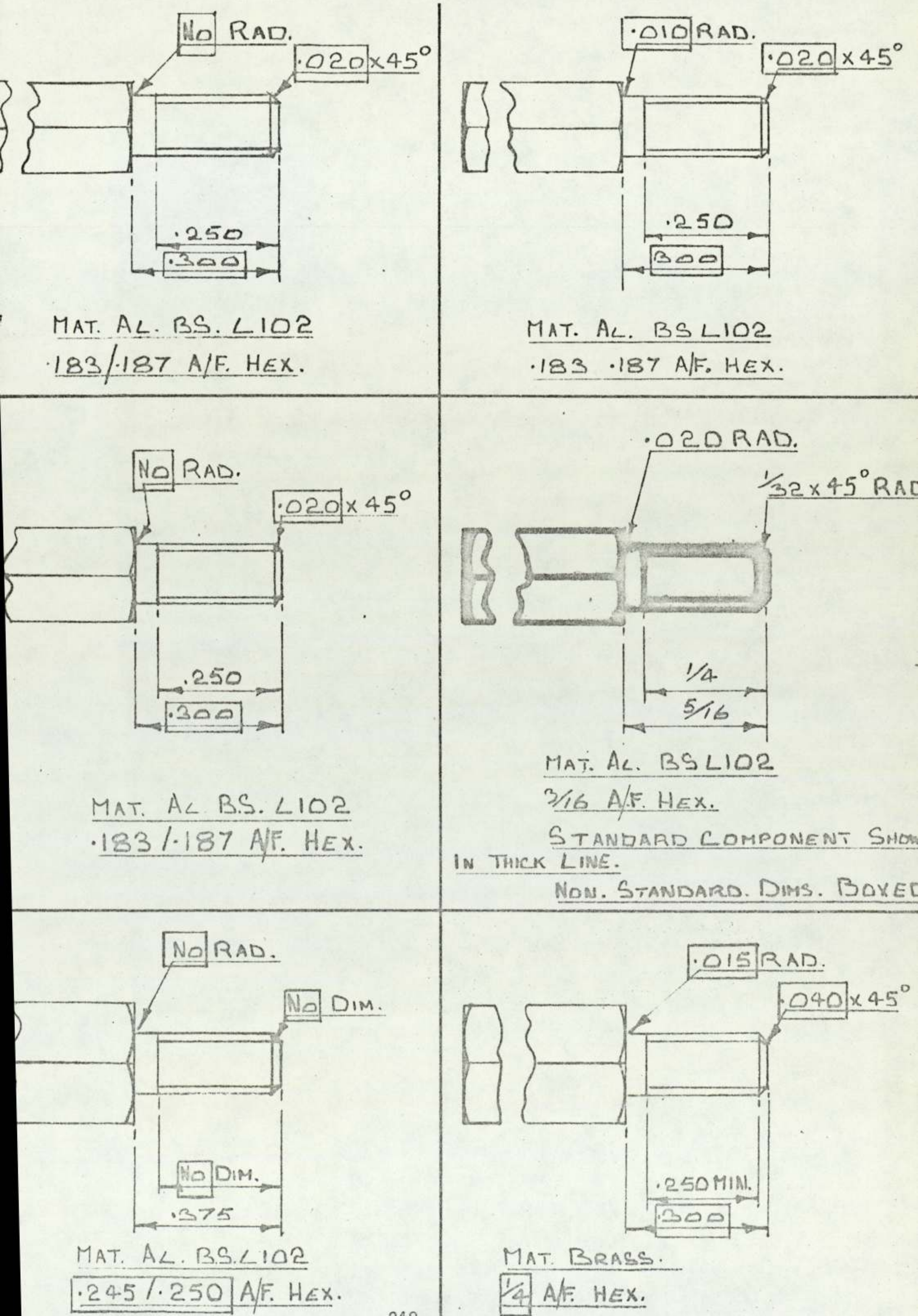


FIGURE 60 SUGGESTED COMPOSITE COMPONENT

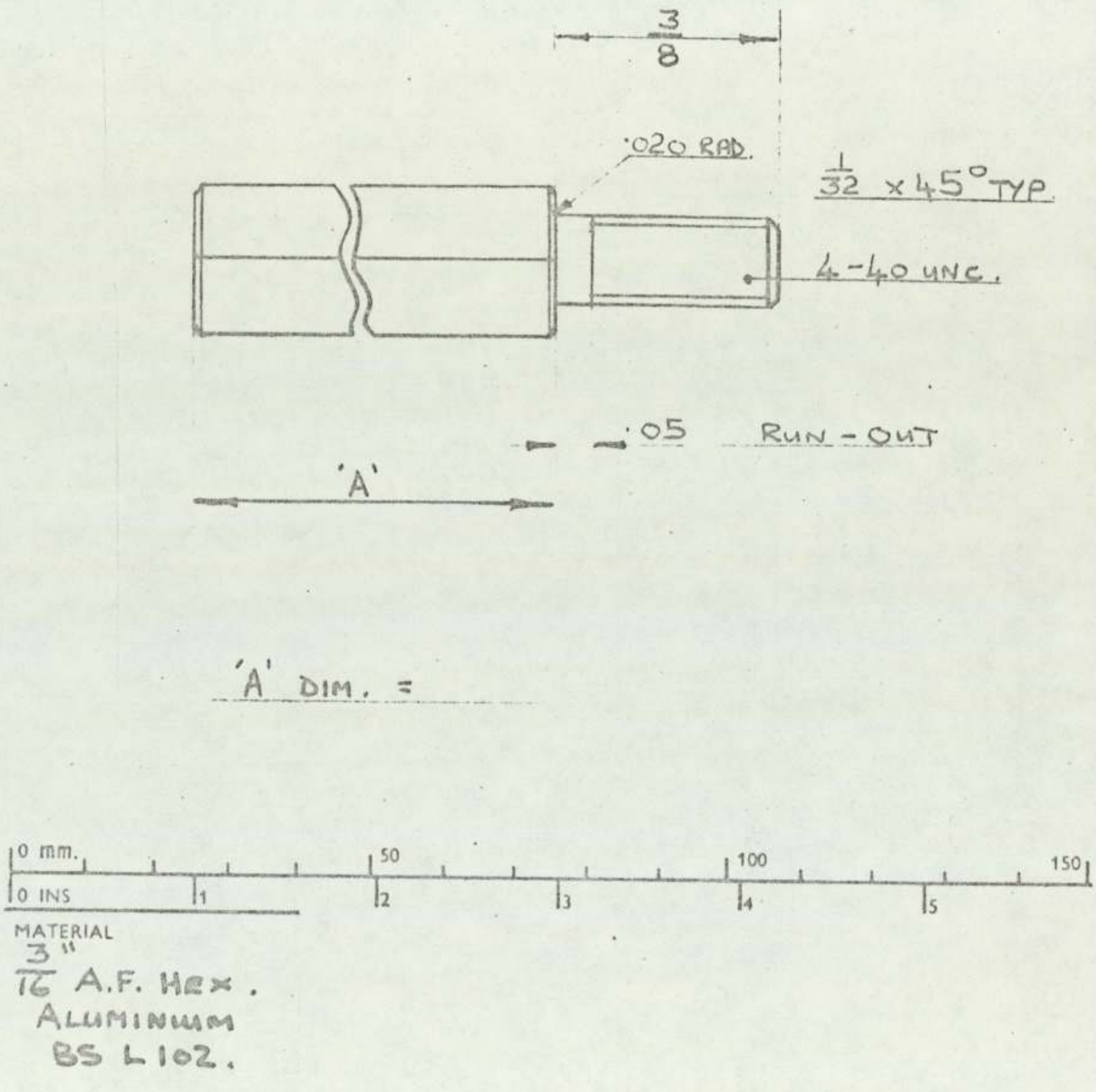
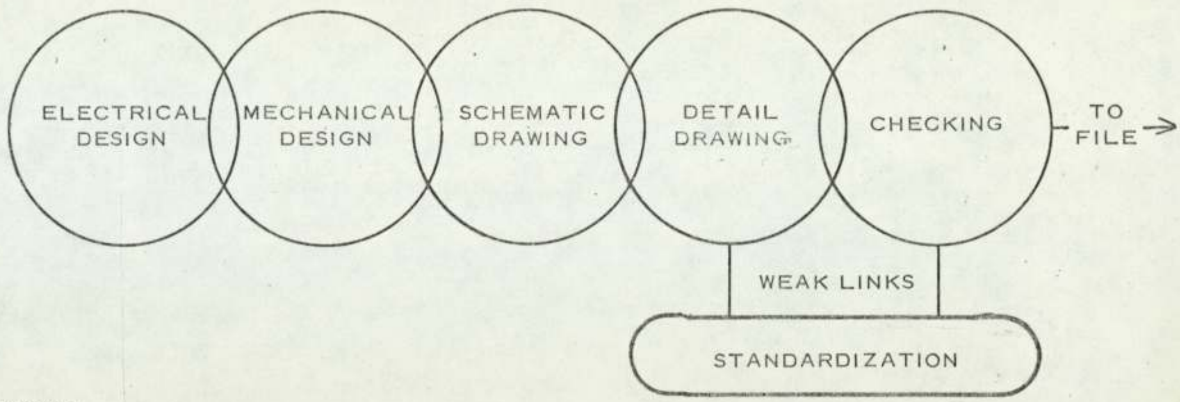


FIGURE 61 COMPARISON OF EXISTING DESIGN PROCESS WITH A SUGGESTED ALTERNATIVE TO IMPROVE PARTS STANDARDIZATION

1. EXISTING PROCESS



NOTES

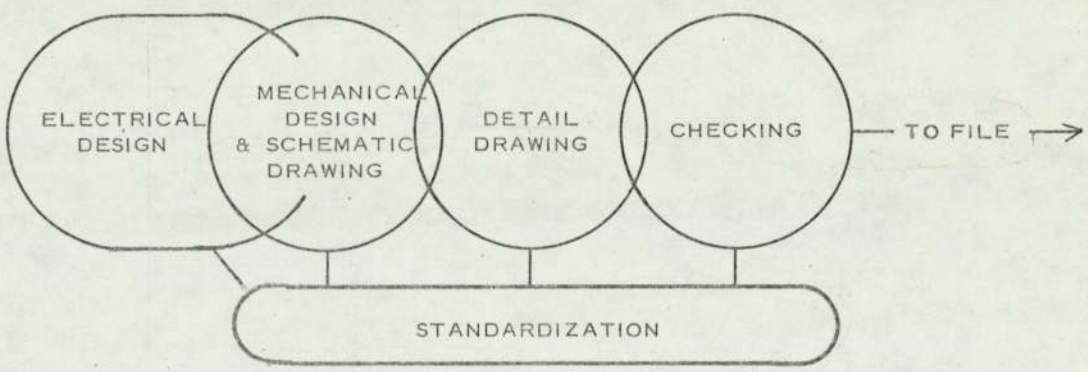
1. Electrical and mechanical design usually loosely linked at concept stage.

2. Schematic and detail drawing done by different draughtsmen.

3. Conceptual design and drawing are done by different parts of the organization.

4. No geometric coding used.

2. PROPOSED PROCESS



NOTES

1. Reorganize to site Mechanical Designers in Electrical Laboratories.

2. Mechanical Designers to do schematic drawings and to apply geometric code to items designed.

3. Technical Clerk to assist Mechanical Designers and to check that all parts have geometric code applied before detailed draughting commences.

4. Mechanical Designers and Technical Clerks to have access to computer/microfilm drawing library organized by geometric code, stock book of preferred components, cost/tolerance curves, machine capability information.

5. Technical Clerks responsible to Head of Standardization for enforcing parts standardization.

6. No parts detailed until head of Standardization approves design as making proper use of standard parts.

7. Only non standard parts drawn.

8. Vetting process, after parts standardization and drawing of non standard parts, to ensure that no non standard parts are used where a standard alternative is available.

9. Drawing of blanks showing standard components with options on dimensions available. See Figure 60.

FIGURE 62 MAIN ELEMENTS OF THE HUIZEN SYSTEM BEFORE MODIFICATION TO ACCOMODATE GROUP TECHNOLOGY

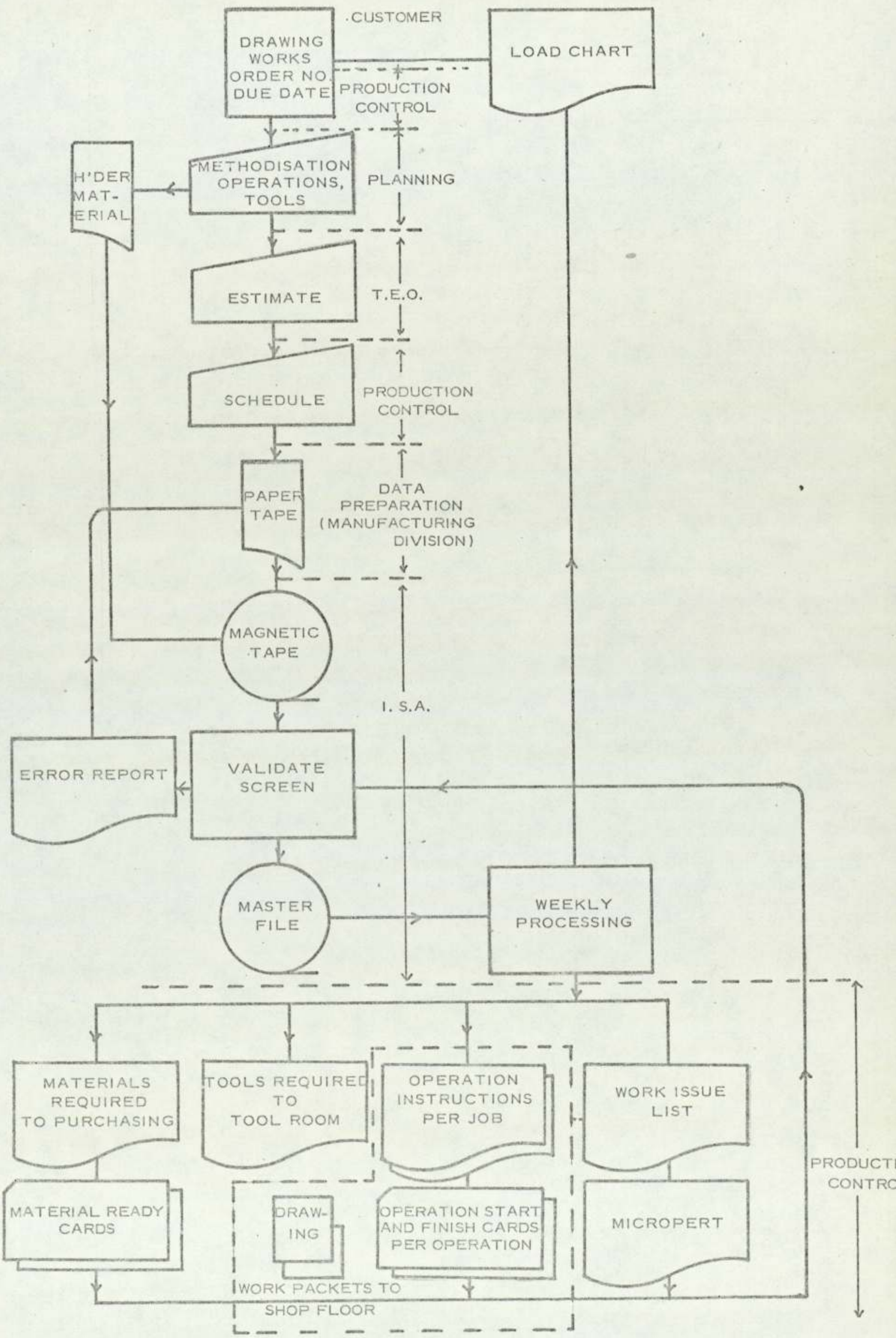
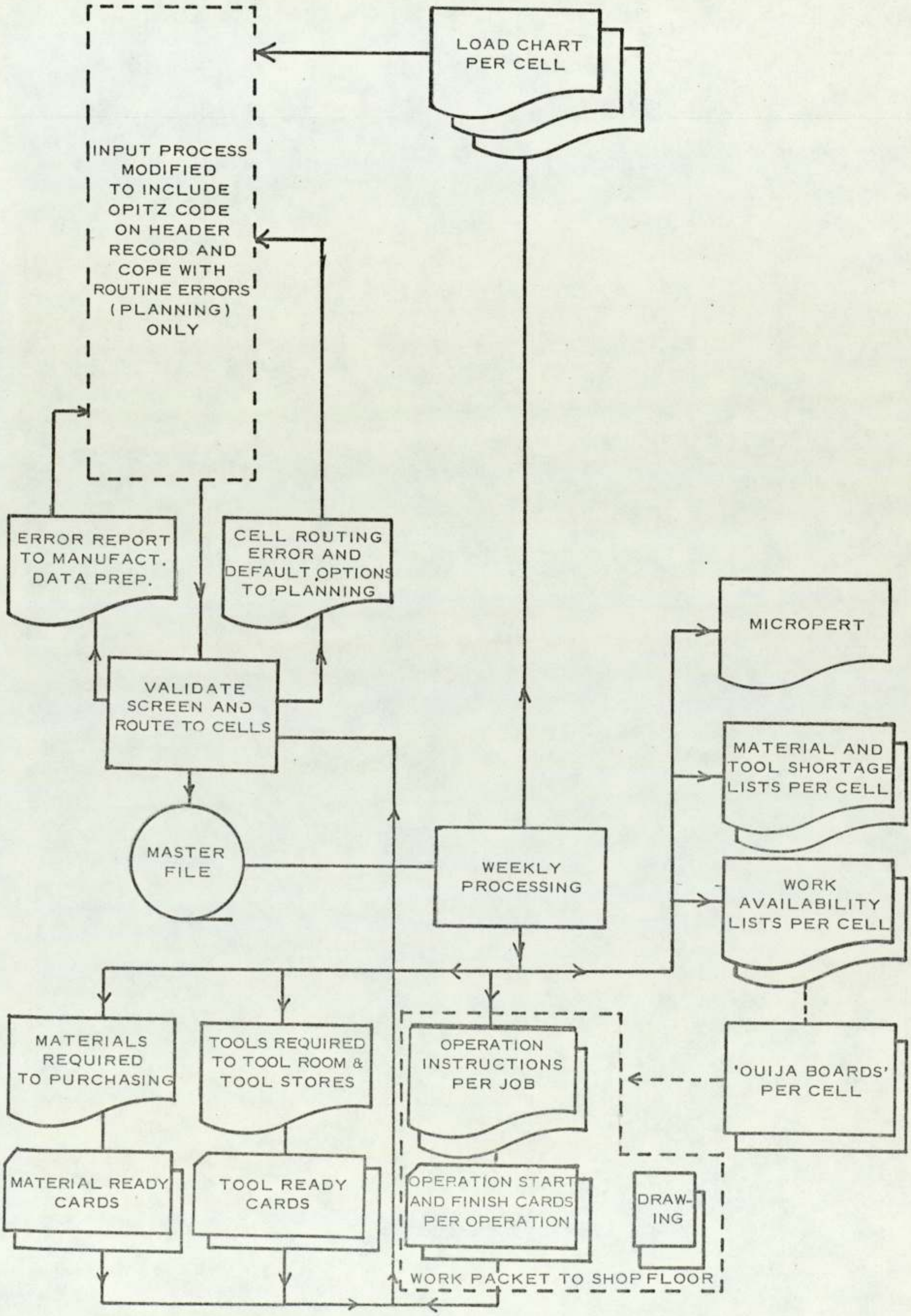


FIGURE 63 MAIN ELEMENTS OF THE HUIZEN SYSTEM AFTER MODIFICATION TO ACCOMODATE GROUP TECHNOLOGY



Record	Card	Fields (in column order, positions 1–96+)
HEAD RECORD	RS 21	IDENT · WORKS ORDER NUMBER · P-SORT-WORD: EVENT NOS. 1 / 2, W.O. SUFFIX · COST CODE · FAMILY TREE NUMBER · PART NUMBER · FILLER · OPER NO. · RS. · BEGIN WEEK · FILLER · END WEEK · RE-PLAN STRT WEEK · FILLER · RE-PLAN END WEEK · FILLER · DATE PLAN'D · PLANNERS NAME · FILLER · USED ON NUMBER (EQUIPMENT) · FILLER · DEST STRS CD · AM · FILLER · ITEM NO.
HEAD RECORD		ITEM NO CONT. · FILLER · LEVEL · FILLER · ORDERED QUANTITY · DRAWING ISSUE · FILLER · COMBINE WITH PART NUMBER · FAMILY TREE NUMBER · SCRAP ALLOW · PART DESCRIPTION · FILLER · DEST. STORE · FILLER · DATE REC. ACCTD · FILLER · CHNGE IND · FILLER · QTY. DEL'D · CHANGE COUNT · FILLER · DATE DEL'D · PRINT IND · W.O. PRT · EVCHNG 1 · PL CHNG 1 · DATE BEGUN
HEAD RECORD		FILLER · INSP REQD · IND 3 · IND 2 · START IND · ENTRY IND · FILLER · START DATE · REMARKS · FILLER · PROD HCSK · IND 1 · IND 2 · IND 3 · IND 4 · GTC · FILLER UP TO 320 POSITIONS
OPERATION RECORD	RS 22	IDENT · FILLER · OPER NO. · RS · SET UP TIME · IND OP. · INDOP 2 · PROD GRP · COMB WITH · FILLER · RATE · TOOL NUMBER · OPERATION DESCRIPTION · URG FCT · IND HG · REQD DATE · REQD DATE · R.G. P.M. · FILLER · DATE RC(PM) ENTRD · RE-MARKS PM
OPERATION RECORD		REMARKS (P.M.) CONT. · FILLER · IND PM · R.C · FILLER · DATE R.C. ENTRD · REMARKS · FILLER · REMKSING · FILLER · CLOCK NUMBER · MANS NAME · NEW PROD GRP · CHNGE IND · FILLER · QTY. PASSED · CHANGE COUNT · FILLER · DATE FIN'SHD · PRINT IND · CHNG OP IN · FILLER · DATE BEGUN
OPERATION RECORD		URG FAC · FILLER · IND 1 · CHNGD REQD DATE · SUPPLEMENTARY REMARKS · TIME TAKEN · START DATE · IND ADMIN · FILLER · SUPPLEMENTARY TABLE: 1 ST SUPPL EXTRA TIME, CC · 2ND SUPPL EXTRA TIME, CC · 3 RD SUPPL EXTRA TIME, CC · 4 TH SUPPL EXTRA TIME, CC · 5 TH SUPPL EXTRA TIME, CC · LOAD TIME · FILLER UP TO 320 POSITIONS
MATERIAL RECORD	RS 24	IDENT · FILLER · OPER NO. · RS · FILLER · MATL IND · PROD GRP · FILLER · TOOL NUMBER · MATERIAL DESCRIPTION · URG FAC · IND HG · FILLER · REQD DATE · RC PM · FILLER · DATE RC(PM) ENTRD · RE-MARKS PM
MATERIAL RECORD		REMARKS (P.M.) CONT. · FILLER · IND RC PM · RC · FILLER · DATE RC ENTRD · REMARKS · FILLER · IND RC · FILLER · NO. PER PIECE · FILLER · DIMENSION 1 · FILLER · DIMENSION 2 · FILLER · CHNGE IND · FILLER · CHANGE COUNT · FILLER · DATE FIN'SHD · PRINT IND · CHNG OP IN · FILLER · DATE BEGUN
MATERIAL RECORD		URG FAC · FILLER · IND 1 · MATL IND · REQD · FILLER · MATL. QTY. · MATL D IN · PIECES REQD · FILLER UP TO 320 POSITIONS

FIGURE 64 MASTER FILE STRUCTURE

MANUFACTURING LAYOUT

RS	START WEEK	FIN. WEEK	W.O. SUFFIX XXX X	EVENT XXXX	PART DESCRIPTION	BATCH NO.	REPLAN IND.	PLANNED DATE	PLANNED BY	PLANNED LOB	INSP. REQD	DRAWING ISSUE	REPEAT PROCEDURE REMARKS	COMMENTS
21	5215	8200	000000		DISTANCE PCE	A	0000	5210	MT.	99	A	01	SSA	

A/M	DEST. STORE	CODE NUMBER	USED ON NUMBER	MINIMUM QUANTITY	SCRAP ALLOWANCE	COST CODE	WORKS ORDER No.	LEVEL	ITEM NO.	COMBINE WITH ITEM NO.	COMBINE WITH CODE NUMBER
MAM		55164731		80	4	00	315125	F	F2539		

RS	OP. NO.	PROD. GRP.	MATERIAL DESCRIPTION / OPERATION DESCRIPTION	QTY. / SET UP	DIMENSION 1 / RATE	1	DIMENSION 11 / C.W.	ITEM NO. / TOOL NUMBER	REQ'D DATE	URG. FACT	
24	3000	02	+031300102007 1/8 DIA BRASS ROD CZ 121	16	10	II		OG/SO	5380	5	
22	0400	62	FACE TURN 1.0 MM DIA FOR 2.5 LONG	60	600	D1			5390	5	
23	040		TURN 2 MM H11 O/D PLUNGE TO 1.0 MM DIA X 6.0								
23	040		MM LONG. BACK TURN TO 1.0 MM DIA. DEBURR								
23	040		P/OFF TO LENGTH NO.T PLATING ALLOWANCE								
22	0301	21	INSPECT						5400	5	
22	0201	45	SILVER PLATE						5410	5	
22	0101	20	INSPECT						5420	5	

FIGURE 65 MASTER LAYOUT FORM

0355 MATERIAL RESERVATION LIST WEEK NO 474.1 PAGE NO 1

MATERIAL	DESCRIPTION	QUANTY	M/F	TOT QTY	WK.	CC	W.O.NUMBER	EVENT	FAMTREE	CODE NUMBER	OP.NO
+011309308003	23SWG BMS SHEET B	0.5	F	0.5	482	00	226459 002	0 0000	MB509A	35131321211202	300
+011309308008	S1449 EN2 18SWG BMS BS1449	0.5	F		477	00	226459 002	0 0000	MB534A	81130101534001	300
		3.0	F		473	00	226459 002	0 0000	MB533A	81130101533001	300
		6.0	F		475	00	226459 002	0 0000	MB531A	81130101531001	300
		6.0	F	15.5	475	00	226459 C02	0 0000	MB532A	81130101532001	300
	449 EN2	8.2	F		477	00	260037 11C	0 0000	MB005A	35131323717 0C	300
		1.7	F		474	00	260037 11C	0 0000	MB009A	35131323659 0B	300
		37.8	F		473	00	260037 11C	0 0000	MB010A	35131323657 0F	300
		10.5	F		474	00	260037 110	0 0000	MB011A	35131602796 0A	310
		3.1	F		476	00	260037 11C	0 0000	MB007A	35131323706 0D	300
		21.0	F		477	00	260037 11C	0 0000	MB006A	35131323716 0A	300
		63.0	F		477	00	260037 11C	0 0000	MB008A	35131323704 0E	300
		1.4	F	146.7	474	00	260037 110	0 0000	MB012A	35131602797 0A	310
+011309308009	S2449 EN2 16SWG BMS SHT BS	2.4	F		475	00	226459 002	0 0000	MB535A	35131323846201	300
		0.5	F		475	00	226459 002	0 0000	MB537A	81130101609001	300
		1.2	F	4.1	475	00	226459 002	0 0000	MB536A	35131323847201	300
	449 EN2	4.0	F		475	00	260037 11C	0 0000	MB003A	35131602529 0B	310
		0.5	F	4.5	475	00	260037 110	0 0000	MB002A	35131602528 0B	310
+031300101008	1449 EN2 .324 A/F BRASS HE	0.7	F	0.7	480	00	293652 004	0 0000	MB018A	A95101 03	300
	X ROD	0.6	F	0.6	480	00	293660 014	0 0000	MB018A	A95101 03	300
	X ROD	0.5	F	0.5	480	00	293679 008	0 0000	MB018A	A95101 03	300
	X ROD	0.5	F	0.5	480	00	293687 008	0 0000	MB018A	A95101 03	300
	X ROD	0.5	F	0.5	480	00	..3709 001	0 0000	MB018A	A95101 03	300
...3011	X ROD 3/16 DIA BRASS RO	0.5	F						A2018A	B95126 02	
		0.6									

FIGURE 66 MATERIAL REQUIREMENTS LISTING

TOOL EXTRACT

TOOLS REQUIRED FOR OPERATION SHEETS PRINTED WEEK 474.1

WORKS ORDER	W/O SUFF	CC	START WEEK	PART CODE NUMBER	ISS	PAPT DESCRIPTION	FAMILY TPEE	OPER NO	TOOL NUMBER
226408	283	00	4720	351316024282	1	BRACKET DET ASS	TE560	160	MCT39766
226408	283	00	4721	351316024282	1	BRACKET DET ASS	TE560	150	MCT39766
226459	002	00	4740	811301015330	1	BASE	MB533	100	MCT35498
260037	110	0C	4740	35131323657	0F	TRAY	MB010	110	MCT35137
520675	000	00	4740	40131006645	1B	CAN	MB091	070	MCT28187
260037	110	00	4743	35131323657	0F	TRAY	MB010	100	MCT35137
226459	002	00	4750	811301015330	1	BASE	MB533	090	MCT35498
260037	110	0C	4750	35131323657	0F	TRAY	MB010	080	MRS51028
260037	110	00	4750	35131602796	0A	TRAYTOP	MB011	140	MCT35950
293652	004	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293660	014	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293679	008	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293687	008	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293709	001	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
260037	110	0C	4753	35131602796	0A	TRAYTOP	MB011	130	MCT35950
226459	002	00	4760	351313238472	1	SUPPORT BAR	MB536	080	MCT35500
226459	002	0C	4760	351313238462	1	SUPPORT BAR	MB535	080	MCT35500
226459	002	00	4760	811301016090	1	SUPPORT BAR	MB537	080	MCT35901
226459	002	00	4760	811301015320	1	BOTTOM SECN	MB532	130	MCT35907
226459	002	00	4760	811301015310	1	TOP SECTION	MB531	130	MCT35904
260037	110	00	4760	35131602796	0A	TRAYTOP	MB011	110	MRS51028
260037	110	00	4760	35131602529	0B	PLATFORM ASSY	MB003	110	MCT35134
260037	110	0C	4760	35131323657	0F	TRAY	MB010	060	SA002155
260037	110	00	4760	35131602528	0B	BRACKET ASSY	MB002	110	SA002097
293652	004	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293660	014	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293679	008	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293687	008	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293709	001	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
724807	410	SZ	4760	RR/A827546	06	SCREW	AI012	030	ERT.4626
260037	110	00	4765	35131602528	0B	BRACKET ASSY	MB002	100	SA002097
260037	110	00	4765	35131602529	0B	PLATFORM ASSY	MB003	100	MCT35134
226408	285	00	4770	351313242070	1	DIODE CLAMP	YK740	050	MCT39738
226459	002	00	4770	351313238472	1	SUPPORT BAR	MB536	070	MCT35500
226459	002	00	4770	811301016090	1	SUPPORT BAR	MB537	070	MCT35901
226459	002	00	4770	811301015320	1	BOTTOM SECN	MB532	120	MCT35907
226459	002	00	4770	351313238462	1	SUPPORT BAR	MB535	070	MCT35500
226459	002	00	4770	811301015310	1	TOP SECTION	MB531	120	MCT35904
260037	110	00	4770	35131323706	0D	BRACKET	MB007	110	MCT35133
260037	110	00	4770	35131602796	0A	TRAYTOP	MB011	080	SA002155
260037	110	00	4775	35131323706	0D	BRACKET	MB007	100	MCT35133
260037	110	00	4776	35131323549	0C	FRAME SIDE	MC003	020	MCT35141
260037	110	00	4780	35131323717	0C	PLATE DEFLECTOR	MB005	080	MCT35132
260037	110	00	4780	35131323704	0E	PANEL REAR	MB008	080	MCT35129
260037	110	00	4780	35131323716	0A	PLATE BASE	MB006	070	MCT35131
520675	000	00	4780	40131006645	1B	CAN	MB091	030	MCT36328

FIGURE 67 TOOL REQUIREMENTS LISTING

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0165     OPERATION SHEET MANUFACTURING DIVISION M E L CRAWLEY PRINTED WEEK NO. 529.1 SHEET   1

     I----------------------------------------------------------------------------------------I
     I W.O.NUMBER CC EVENT  FAMTREE LEV  CODE NUMBER    INSP ITEM   USED ON NO.  A/M MIN.QTY. SCRAP I
     I                                                                                        I
     I 315125 000 00 0-0000  F2539A  F  55164731    01    A  F2539              M      80      4  I
     I----------------------------------------------------------------------------------------I
     I  COMBINATION NUMBER          PART DESCRIPTION          STORES      REMARKS         PLAN.BY-DATE I
     I FAMTRE  CODE NUMBER                                                                    I
     I                              DISTANCE PCE               A MANF     SSA             MT.    521.0 I
     I----------------------------------------------------------------------------------------I
     I OPNO  PG  MATERIAL DESCRIPTION                         .ITEN NO .QUANT.QNTY.DIM 1 .DIM2  .INDI
     I GT NO  240000010    CELL  B                             .        .PIECE. PER.      .      .   I
     I                                                         .        .     .    .      .      .   I
323  I 300  002 +031300102007     1/8 DIA BRASS ROD CZ 121    .OG/SO   .    6.  16.  10.0.      .II I
     I----------------------------------------------------------------------------------------I
     I OPNO  PG  OPERATION DESCRIPTION                        .TOOL NO . SET. RATE. IND. LOAD. CW   I
     I                                                         .        . UP .     .     . TIME.      I
     I                                                         .        .    .     .     .     .      I
323  I 040  062 FACE TURN 1.0 MM DIA FOR 2.5 LONG              .        .  60.  600. D1 .  101.      I
     I              TURN 2 MM H11 O/D PLUNGE TO 1.0 MM DIA X 6.0 .      .    .     .     .     .      I
     I              MM LONG. BACK TURN TO 1.0 MM DIA. DEBURR   .        .    .     .     .     .      I
     I              P/OFF TO LENGTH NO.T PLATING ALLOWANCE     .        .    .     .     .     .      I
     I                                                         .        .    .     .     .     .      I
323  I 030  121 INSPECT                                        .        .    .     .     .     .      I
     I                                                         .        .    .     .     .     .      I
336  I 020  145 SILVER PLATE                                   .        .    .     .     .     .      I
     I                                                         .        .    .     .     .     .      I
336  I 010  120 INSPECT                                        .        .    .     .     .     .      I
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FIGURE 68   JOB INSTRUCTIONS

SOME APPLICATIONS OF COMPUTERS

IN

GROUP TECHNOLOGY

A thesis submitted to the University of Aston in Birmingham

as part of the requirements for the degree of Master of Philosophy

by

A.J. Page B.Sc. Hons. (Physics)
Dip.Ed.

February 1977

SUMMARY

This thesis concerns principally the use and adaptation of some computer based information systems during a project to implement Group Technology in part of a large, complex, multi-product company. The approaches adopted and methods used in the implementation and operation of the new principles are discussed with particular reference to computer solutions for problems of:

* data provision, analysis and synthesis during an analytical approach to re-designing part of the company's organisation based on cellular principles

* adapting an existing production control system to support a cellular shop floor organisation and reinforce the benefits of Group Technology

* economic assessment of the benefits gained through operating a trial cell before extending the implementation to other parts of the organisation.

In addition, some particular social, technical and organisational problems that were encountered during the implementation are discussed. Some ideas are given for reducing these problems and extending the implementation to other parts of the company.

It is concluded that computer based information systems can have a considerable impact on a project to install Group Technology and on the methods used to maintain the effectiveness of the new manufacturing system.

ACKNOWLEDGEMENTS

The author is indebted to Professor R.H. Thornley, his staff and research students of the Department of Production Engineering at the University of Aston in Birmingham for many helpful discussions on subjects related to those contained in this thesis.

Thanks are also due to the management and staff of the M.E.L. Equipment Co.Ltd. and particularly to Mr. D.H.O. Allen, Plant Director; Mr. P.B. Crewe, Manager, Manufacturing Division; Mr. J. Duncan, Manager, Information Systems and Automation Department; Mr. P. Moyes, Group Production Manager, Defence Systems and Avionics Group; the late Mr. L. Trodd, Staff Development Officer and Mr. D.B. Whinder, Planning Engineer; without whose helpful co-operation and support none of the work reported here would have been possible.

Finally, I should like to thank Mrs. P.A. Barry for typing this thesis, above and beyond the call of duty.

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LIST OF FIGURES (Cont'd.)

CHAPTER 1

SCOPE OF THE THESIS

1.1 General Hypothesis

The implementation of Group Technology in a company will require technical and sociological changes which will have effects of some significance on the company's organisation, its methods and systems. The approach to the implementation and the nature of the revised organisation and systems may depend on the degree to which the company has access to and is familiar with using computer based information systems.

1.2 Highlights of the Research

The research reported in this thesis centred on an implementation of Group Technology in one area of a large and complex multi-product company. The company had been using computers for some years to process data and provide information and, in the area of the implementation in particular, a computer based production control system was deeply entrenched. The support organisation in the area had been built up round the system which had been operating, largely unchanged for some 6 to 8 years.

An analytical approach to the implementation of Group Technology was adopted and the company's information system provided much of the necessary data. The production control system provided a good deal of this data, but, in order to perform the analysis, other parts of the company's systems had to be linked to provide

1.2 cont'd.

all the data required. The analysis of the data and its synthesis into a design for a new organisation for Group Technology had some novel features; in particular the use of "real time" interrogation of the computer combining powerful and rapid facilities for analysis of the data with human skills in engineering and a knowledge of the area concerned.

One of the major problems encountered during the implementation was the restructuring of the production control system to support the new cellular organisation and re-inforce the use of Group Technology principles. The company's management required that the support organisations and the system's links which provided data for accounting purposes, be disturbed as little as possible. The management's requirement was met, together with the objectives of the implementation, through a re-structuring of the information provided by the system. This achievement required a novel approach to the solution of shop floor routing problems so that the information provided by the system could be properly structured.

Significant changes in the Senior Management of the company had an important influence on the project. In particular, an economic experiment became necessary to examine the cost effectiveness of the implementation. Computers played an important role in the experiment in both the measurement and analysis of data.

During the implementation, particular sociological problems were encountered which had an effect on both the speed and direction of the project so an attempt has been made to relate these problems to the project, the use of computers and the particular situation of the company.

1.2 cont'd.

Overall, the research illustrates some of the problems that the in-house production systems engineer may encounter during an implementation of Group Technology in a complex company with a significant level of computer based information systems. The philosophies brought to bear, relate to the engineer's approach of adapting and modifying existing facilities to find an effective solution to the socio-technical problems associated with the introduction of Group Technology.

1.3 Structure of the Thesis

First, to provide a context, the main concepts of Group Technology are outlined. Whilst no attempt is made to treat the subject exhaustively, the main types of Group Technology organisation are described. Some of the benefits that can be obtained and the changes that may be necessary are discussed.

Then, an outline is given of some of the main potential areas for the application of computer based information systems in Group Technology with particular emphasis on organisation design and production control. Some of the factors that may affect a company's use of such systems in the implementation of the new concepts are discussed and a survey is given of some reported methods and applications. It is important to note that the use of computers for the direct control of (N.C.) machines, is not within the scope of this thesis, which concentrates on data processing/analysis and information systems design.

1.3 cont'd.

The nature of the company's business, the complexity of its organisation and the state of its computer systems had an important effect on the project, so a description of these factors is given.

The main body of the thesis is concerned with two substantial applications of computer information systems in the project. The first concerns the analysis and synthesis of data leading up to the re-organisation based on Group Technology and the second the modifications to the production control systems necessary to support the revised organisation and the new manufacturing concepts. Whilst the main emphasis is on the use of computer information systems, some sociological problems were encountered during this work which had an important effect on the project, so these are discussed.

The economic experiment conducted round a trial Group Technology Cell is then described and the results obtained discussed with reference to the use of computers in measurement and analysis of the necessary data, the state of the implementation and the sociological problems.

Finally, after describing ideas for improving and extending the implementation, and the "state of the art" of Group Technology, the overall conclusions of the research are discussed.

CHAPTER 2

GROUP TECHNOLOGY

2.1 A Definition

Group Technology concerns the construction and association of three types of groups to perform manufacturing tasks in the best way. These groups are:

* Groups of products
* Groups of manufacturing facilities
* Groups of people.

The main applications of Group Technology have been in the production of components (rather than complete products) on a batch or jobbing basis and, as such, Group Technology has been described by Thornley (1)≠ as:

" ..... a method of achieving some degree of mass production in the batch production industry".

The concept is based on the recognition of groups or "families" of components within the total range to be manufactured (see figure 1). All the components in a family should exhibit a strong similarity regarding the facilities needed for their manufacture. By re-organising in a manner based on the manufacture of the families, a dramatic increase in the effective batch size can be achieved which makes a mass production approach with associated gains in efficiency more possible.

≠ Numbers in brackets refer to the bibliography on pages 186 to 189.

2.2 Organisation Types

Three organisational facets have been recognised which may be contrasted with the traditional organisation for the batch/jobbing production of components, where all machines of a similar type are grouped together on a functional basis.

2.2.1 Group Technology Machine Centre The modern concept of Group Technology was first developed by Mitrofanov (2). His original approach is perhaps better described as the composite component technique whereby a single machine is equipped with sufficient pre-set tools for the complete manufacture of a component family. This concept has been developed, notably by Drurie (3) who has analysed components in a family with the object of designing a "complex component" embodying all the features of every component in the family (see figure 2). The tooling of the machine centre can then be designed for efficient manufacture of the complex component (see figure 3) and thus any component in the family can be manufactured with minimum resetting of the machine.

2.2.2 Group Technology Flow Line When complete manufacture of a component family is not possible on one machine, it may be feasible to form a flow line of the machines necessary to manufacture the family. Each component in the family visits those machines necessary for its manufacture until completed. The machines in the line are ordered so that back tracking of components against the normal flow of work is avoided and the line is balanced to avoid bottle necks. There may, therefore, be more than one machine of each type in the line.

2.2.2 Group Technology Flow Line Cont'd.

Generally, flow line production of this type is possible only where production volumes are relatively high and where the balance of operator and machine loading is relatively easy to achieve. The advantage of the family concept is that it makes flow line production possible with much lower volumes of individual components than is conventional in the mass production industry.

2.2.3 Group Technology Cell Where neither machine centre nor flow line production is possible, the machines and operators necessary to manufacture one or more component families can be less formally grouped to form a "cell". The pattern of work flow within the cell is less important than in the case of the flow line and the load balance is easier to achieve with lower and more variable production volumes of individual components. Since the cell is equipped with all the facilities required to manufacture completely each component sent to it, the pattern of work flow in an organisation based on cells, is much simpler than that in a functionally based organisation (see figure 4).

2.3 The Benefits of Group Technology

Figure 5 summarises the improvements which can be achieved by virtue of a reorganisation based on Group Technology. Broadly speaking, these benefits fall into three main areas.

2.3.1 <u>Technological Benefits</u> Since component families form the basis for the design of Group Technology flow lines and cells, the benefits of the composite component technique can be incorporated into the tooling of both types of organisation. By this means, dramatic reductions in the times needed to set machines can be achieved (4).

The clearer picture of the component spectrum and the large increase in effective batch size made possible by the family approach can be used to justify the purchase of more appropriate, specialised machine tools to obtain further gains in technological efficiency.

In the longer term, the family concept can stimulate a trend towards greater standardisation of the design stage so that a reduction in both design and manufacturing costs can be achieved.

2.3.2 <u>Sociological Benefits</u> The aggregation of workers into cells produces many of the benefits reported for goal oriented primary groups (5). Accountability is clarified and workers can identify with the overall task of producing an item rather than merely performing an operation in isolation from the total production task. The resulting increase in job satisfaction produces happier people and consequential improvements in attendance, productivity and quality (6).

2.3.3 Organisational Benefits Figure 4 demonstrates the considerable simplification of the work flow pattern that can be achieved by virtue of a cellular organisation, when compared with that occurring in an organisation based on the function of machines.

At the operating level, this simplification can be directly reflected in a reduction of the production control problems. Scheduling/sequencing rules can be tightened to achieve a significant reduction in thru-put times and work in progress. The need for detailed paperwork diminishes along with the effort needed for progress chasing and other functions which grow from the conventional confusion of functionally based organisations.

2.4 The Place for Group Technology in the Manufacturing System

Lepper (7) has described Group Technology as:

"The only production system embodying all other systems".

Although perhaps slightly facetious in its intention, this definition is a good illustration of the extent of the Group Technology concept and how an implementation may affect many if not all areas of a company's operation if the full advantages of the new system are to be exploited.

By far the most common reason for introducing Group Technology is to improve one or more of the factors affecting the efficiency of production. However, as with any production system, the usefulness of Group Technology will depend on its suitability for a particular organisation and on where and how it is implemented. Recent research (8) has indicated that a "Total Approach" where the implementation is co-ordinated on a company wide basis by top management is more likely to produce successful results than a limited implementation in part of a company. This may be because the full success of Group Technology required changes in many aspects of a company's manufacturing activity. Unless this need is recognised and the necessary changes properly co-ordinated, the organisational stress induced by the presence of Group Technology as a new production system, ill matched to its surrounding corporate processes, may limit any achievable results and may even produce an overall deterioration in a company's performance.

To exploit Group Technology to the full will require some, if not all of the changes listed below and illustrated in figure 6.

2.4.1 Manufacturing Technology Use of the concept of parts family manufacture and the grouping of machines for flow line or cellular production will require changes in manufacturing methods, tooling (including machine tools) and plant layout (9).

2.4.2 Design To exploit the clearer picture, both of the parts spectrum and its implied manufacturing technology will require changes in the comany's design policy affecting particularly the impact of standardisation on component design (9, 10).

2.4.3 Marketing The technological impact of Group Technology in manufacturing and design may in themselves affect a company's marketing policy. Additional affects may accrue from the improvements in lead time, delivery performance and the cost of manufacture achieved from the new system (11).

2.4.4 Systems The parts family concept and changes in design/ manufacturing technology may require changes in the estimating and work study systems if the improvements in the cost of manufacture are to be properly reflected in the prices of the company's products.

Changes in systems for production control and materials management will also be necessary both to support a revised plant layout and a flow line or cellular based production organisation (12) and to exploit the potential benefits of simplified production flow and reduced lead times, work in progress and variety of parts and materials.

The full benefits of improved job satisfaction may not be possible to achieve without revision of the payment systems (13, 14).

The organisation changes and changes in the patterns of expenditure on both capital and revenue items may necessitate changes to the budgeting and accounting processes. Changes to shop floor paperwork may have significant effects on the costing systems, particularly if detailed job costing at the operation level is used.

2.4.5 Organisation Even a small implementation of Group Technology will affect the shop floor organisation and possibly its related supervisory structure and supporting methods engineering/production control organisation. A larger implementation will almost certainly have far reaching effects on supervision and the support organisations and some effect on middle management, whilst the "Total approach" may affect the whole organisational structure including senior management and the board of directors (15,16).

CHAPTER 3

SOME APPLICATIONS OF COMPUTER SYSTEMS IN GROUP TECHNOLOGY OUTLINED

3.1 Introduction

The purpose of this chapter is to outline some of the main areas of potential application for computer systems in Group Technology with reference to some reported applications and the available state of the art vis-a-vis the requirements of Group Technology.

The power of computers to process data and perform calculations much more rapidly and reliably than people has led to a dramatic increase in computer based information systems in industry in the past 20 years. Whilst it is probably fair to say that the initial promises of large reductions in clerical staff, improvements in control and hence increases in profitability have not been fulfilled, industry has been using computers on such an increasing scale and complexity of tasks, that computers must now be regarded as a common feature of modern industrial life (17).

Computing technology has improved from the early card and tape based systems of the 1950's and '60's to powerful disc based machines that can perform massive data processing and computational tasks that would otherwise be economically, if not totally, impossible. The available means of accessing a computer have improved from the relatively difficult and time consuming form filling/card punching input and tabulation outputs to direct methods involving the user and a video screen.

3.1 Introduction cont'd.

Industrial information systems development has improved, if not at the same rate as the technology, until advanced information processing has in many cases superseded the simple clerical tasks as the main function of a company's computer. In the more complex systems are to be found methods of production control and resource planning using powerful and complex algorithms that would not be feasible without the use of a computer and, in the companies using such systems, organisations have been built up round the computer systems to take advantage of the new facilities in improving control.

No longer is the computer the prerogative of large and successful companies because of the large capital investment involved in the computer and its supporting systems. Many "bureaux" now exist to lease time on computers and/or packaged systems solutions to common industrial problems and even a small company can gain access to a powerful computer and supporting systems by leasing time on a bureau's machine much more cheaply than investing in its own computer. Indeed, it is becoming wrong to assume that computers are a very major capital investment. "Mini-computers" are now available for a few thousand pounds that can perform tasks that would have required an investment of many hundreds of thousands of pounds in a "main frame" machine a few years ago.

Because computer based information systems are now common place and because their effects on a company's organisation and methods may be significant, it is important to consider their effects in applications of Group Technology.

3.1 Introduction cont'd.

A computer can have a significant effect both on the analytical and systems supporting power which can be brought to bear during the initial phases of a project to implement Group Technology and on the new organisation, systems and methods adopted after the implementation.

3.2 The Problems of a Packaged Solution

A packaged solution to the problems of installing Group Technology may well be the best for the small company which does not own its own computer. In this case, it is unlikely that any expertise in systems analysis of the required calibre exists in the company and the "package deal" used via employment of the experts providing the package on a consultative basis may be the only way to proceed if an analytical approach is desired and seen to be the most effective. Indeed, such an analysis may well be performed without the use of a computer if data samples are kept small and the analysis kept simple.

However, a number of problems exist for the medium/large company particularly if computer systems already operate in the area concerned. These problems centre on the desirability of using an externally developed package under the guidance of the organisation providing the package versus the desirability of using the available expertise in the company and include:

* the cost of using the external package
* the cost of retrieval and transcription of data from the company's systems to the external system
* problems of company security
* resentment of internal staff who may see the external solution as imposed and possibly not what they would

have developed

* unease in the management who have to accept an essentially external solution to an internal problem. They may distrust the efficacy of a solution developed by people with a small knowledge of their company.
* problems of transferring sufficient expertise to the internal staff to cope with any modifications to existing systems required by the new ways of working
* problems of keeping a new organisation up-to-date if manufacturing volumes or product mix change or if technological developments require a revision of the organisation. Such revisions may require repeated involvement of the consultants providing the package with consequential costs and lack of independence of the company using the package.

If any, or all of these problems prove too big for a company to "stomach", it may be decided to develop the necessary techniques "in-house". In this case, difficulties may arise in acquiring the necessary combination of understanding of Group Technology, the analytical techniques being used and computing expertise. The available packages are not much help to the "in-house" systems developer if, for reasons of commercial secrecy, details of the analytical techniques used in the packages are unpublished. The "in-house" system developer may also find that the published methods prove too sophisticated for his company to understand where the technique ends and where judgement must begin.

In such cases, therefore, the "in-house" developer should perhaps seek an approach which will minimise installation costs, particularly those involving data collection, and maximise the understanding of

3.2 The Problem of a Packaged Solution Cont'd.

the people involved in the project. The object is not so much an elegant solution to a mathematical problem, but more an effective solution to a socio-technical problem where the "in-house" developer aims to avoid being seen as selling another package deal and thus incurring some, if not all, of the problems outlined above.

Very little work seems to have been done in this field, but this thesis attempts to throw some light on how computers may be used by the "in-house" system developer along the lines outlined above.

3.3 Role of Computers in Analysis Prior to Implementation

3.3.1 Alternative Approaches to Analysis Following a decision to install Group Technology concepts in an organisation, two types of approach are possible, "peripatetic" and analytical.

The peripatetic approach relies on the experience of management, supervisors and operators to prepare new working methods and arrive at a better grouping of products, manufacturing facilities and people based on their knowledge of current and foreseen problems and their recognition of the aims and methods of Group Technology. Some of these organisations are regarded as successful (11) and the peripatetic approach has the advantage of speed and acceptability to the existing staff who will see the new organisation as resulting from their proposals. The main objection to the peripatetic approach is that it lacks the objectivity of the analytical approach.

3.3.1 Alternative Approaches to Analysis Cont'd.

The analytical approach seeks to form objective recommendations by numerical analysis of available data followed by a logical re-design of the organisation based on the results of the analysis, the behavioural sciences and good engineering practice. The analytical approach is generally regarded as being more likely of success and (perhaps simply because analysts publish more papers than managers) has been more widely reported (9,15).

Two types of analytical approach have been used, the most recognisable difference between them being the relative importance given to component family formation.

The "classical" approach uses component families as the most basic constituent of its recommendations for re-organisation. A classification system is used to describe components according to features which affect the design and/or production of the components. Component classification has been widely reported in the literature (9,15) and only the barest outline will be given here. Suffice it to say that many types of classification system have been developed (18) ranging from simple inspection by eye to complex digital systems describing the geometry, surface features, material and other factors important in the design and manufacture of components. Once classified, the components can be sorted to bring like components together to form families. The manufacturing routes and machine loadings of the families can then be analysed so that the new organisation can be appropriately designed and equipped to manufacture the families.

3.3.1 Alternative Approaches to Analysis Cont'd.

In spite of the many classification systems that have been developed it may be difficult to find a system ideally suited to a particular problem. In this case, development of a suitable classification system may be a long and costly exercise which may limit the applicability of the approach.

The second type of analytical approach is based on network analysis of the routing of components to the various machines needed for their production. Several attacks on the problem have been reported.

The earliest of these methods was developed by Burbidge (19,20). Burbidge's analysis is performed on three levels:

* Factory flow analysis
* Group analysis
* Line analysis

At all these levels, use is made of flow charts showing the material flow from department to department or machine to machine. The approach is similar in philosophy to the techniques of "Systematic Layout Planning" developed by Muther (21) and, whilst based on analysis, requires judgement of the "peripatetic" kind at each stage. McCauley(22) introduced a mathematical base to the problem by calculating a similarity coefficient for every pair of machines. He used single linkage cluster analysis to form groups of machines with high mutual similarity. His method suffers from the disadvantage that does not cope well with machines that may appear in several cells and it cannot take into account component quantities and machine loading.

3.3.1 Alternative Approaches to Analysis Cont'd.

El - Essawy (23) has developed techniques for successive refinement of machine groupings based on "Component flow analysis". At the first stage general combinations of machines are formed. These general combinations are then progressively refined into groups at the second stage until the final structure is determined at the third stage. El - Essawy's techniques seem similar to Burbidge's and currently are not regarded as so fundamental as they were originally claimed to be.

Rajagopalan (24) has introduced the use of graph-theoretic methods for forming cells from route card information. The batch production situation is described as a graph whose vertices are the machines and whose edges represent the relationship between the machines. Graph theory is then used to analyse such a graph to form optimal cellular machine groupings by minimising intercellular movement of components. This technique seems more able to cope with the problem of machines appearing in several cells and can take into account machine loadings, but as yet, there are no known reports of its success beyond the feasibility stage.

Whilst the techniques using network analysis based on data obtained from existing route cards do not suffer from the disadvantage of requiring a suitable classification system, they tend to lack objectivity because they tacitly assume the current working methods to be the most appropriate for the particular organisation concerned.

3.3.1 Alternative Approaches to Analysis Cont'd.

A second disadvantage of this method is that no means are provided to attack the problems of composite tool design or component standardisation from which important benefits should accrue and may be lost if no classification system is employed.

3.3.2 Roles for the Computer The role of the computer during the initial phase of a project to introduce Group Technology may vary widely according to which of the methods described above is used and what facilities are available. Whilst the computer's role will probably be minimal if a peripatetic approach is adopted, the computer can play an important part if an analytical approach is used. Clearly, the sorting of classified components into families is eased considerably if the classification system is digital and computing facilities are available. The computer can also assist in the design of an optimum re-organisation by relating the component family concept to data, on existing working methods and manufacturing facilities, available in production control and estimating systems already in use in the area concerned. A similar role exists for the computer in the analysis of production flows. The power of computer sorting techniques can ease considerably the specification of the most commonly occurring production routes from existing information and so provide the basis for the new machine groupings.

3.3.3 Some Reported Applications A computer system has been developed by Metaalinstituat TNO to support the analysis of classified components into families (25). A numerical classification system has been devised to suit, it is claimed, most types of metal components used in the electronics industry. A supporting suite of computer programs

3.3.3 Some Reported Applications Cont'd.

has also been designed to support the analysis of classified components into families. It is claimed that additional software has been developed to support synthesis of the component family data into groupings upon which to base the formation of cells taking into account machine loading and routing information. However, there is little published material available to evaluate these claims and the only known organisation based on the use of this system (26) is not regarded as embodying group technology principles to a great extent since the "cells" are very large (50 - 100 operators).

A number of computer programs have been developed to support the network analysis of production routes. PERA (27) provide a complete package based on this method which is believed to use simple sorting techniques and Burbidge has reported mechanisation of his methods (28,29). McCauley (22), El - Essawy (23) and Rajagoplan (24) all report using computers to support application of their approaches, but few details have been published to evaluate the power of their computing techniques.

3.3.4 Role of the Computer in Layout Planning Having established the optimum machine groupings during the analytical phase of the project, it is obviously necessary to produce a good, practical and workable layout of the machines on the shop floor.

An optimal layout may depend on a number of factors not simply or directly related to work flow problems (e.g. the cost of moving a machine for access to another for repair). Some of these factors are essentially intangible (e.g. the aesthetics of the layout) and conse-

3.3.4 Role of the Computer in Layout Planning Cont'd.

quently difficult to incorporate into a computer model. Muther (30) has developed a method based on scoring of solutions involving intangibles by the staff who will use the layout concerned in an attempt to digitise the problem.

If it should prove possible to relate all these parameters to one objective function (e.g. cost), then it might be feasible to use optimisation techniques, perhaps based on linear programming (31) or the "Out of Kilter" algorithm (32). Meanwhile, use of the computer in layout planning problems has been reported to evaluate and optimise work flow and machine movement costs (33), but at present, arrival at a practical layout seems highly dependent on the peripatetic and more simple analytical methods such as those of Muther.

3.4 Role of the Computer in Running a New Organisation

A new organisation based on Group Technology may require new or modified systems to support it and to gain maximum benefit from the new concepts.

3.4.1 Role of the Computer in Payment Systems

Many companies who have a medium/large workforce use a computer (either their own or that provided by a "bureau") to calculate and print wage slips. The power of the computer to perform calculations that would otherwise be far too lengthy for manual methods has produced some quite complex incentive schemes based on operator performance. The most simple of these find their origins in the old "piecework" system whereby an operator's earnings depend simply on the amount of output he produces. This system suffers from a number of disadvantages which cause dissatisfaction in both operators and management:

* problems of waiting caused by management's failure to supply material or by machine breakdown
* problems of defining adequate quality
* problems of batch production with high job-to-job variety and consequential learning time

Many refinements of such systems are known but few have been reported which take into account the particular requirements of Group Technology, which centre on how to compensate a worker fairly, not only for doing a job within a particular range of skills with proper speed and quality, but also for being an effective member of a group with a common aim. The problem is particularly difficult in the areas where Group Technology is most appropriate, batch/jobbing production with its demands on operator flexibility and job variety.

Sawyer and Arn (34) have reported a substantial application of the computer in supporting a payment system operating in a large company with an in-depth application of Group Technology. The payment system involves a standard wage consisting of a basic rating, dependent on local conditions; a job evaluation share, dependent on mental and physical demands, educational ability, responsibility, environment, etc.; a behaviour share, dependent on cooperation, versatility, initiative, dependability, etc.; and a share based on seniority and age. Added to the standard wage is a bonus based on both quantity and

3.4.1 Role of the Computer in Payment Systems Cont'd.

quality produced. A points system is used to evaluate group performances and a series of statistically devised curves is used to evaluate a comparable operator performance for similar efforts in different types of cell. The means of calculating the wage of each operator is complex and therefore costly and unreliable if manual methods were to be used. The method is reported to be seen as fair by the operators and is viewed as a major contributor to the success of the Group Technology project concerned (34).

3.4.2 Role of the Computer in Production Control Burbidge (35) has defined production control as: "The science and art concerned with the flow of materials in production, and with the ways in which different material flow systems can be created and controlled".

The general objective of a production control system in the batch/ jobbing situation, is to achieve the best overall compromise between thruput time, delivery performance, utilisation of capacity, investment in stocks and work in progress and administrative effort.

Among the branches of production which have a significant effect on the problems of production control are organisation, design, production planning, plant layout, sales and forecasting, all of which may be affected to a greater or lesser extent by the implementation of Group Technology. It is therefore important to consider the effect of Group Technology on the design of production control systems.

3.4.2 Role of the Computer in Production Control Cont'd

The field of production control is large and has attracted a great deal of attention from workers seeking better algorithms for the solution of production control problems. The general objective of these workers seems to be to reduce the art and increase the science of production control, which has resulted in a great deal of use being made of computers.

The designer of a production control system seeks algorithms for solution to 7 main problems:

* Forecasting
* Capacity Loading
* Scheduling
* Sequencing
* Performance Measurement
* Progressing
* Optimisation

The solution to these problems must be consistent with the general objectives, and key difficulties arise because the means of achieving the general objectives are, in many situations, in mutual conflict. For instance, good delivery performance may imply poor utilisation of capacity and good utilisation of capacity may imply long queues of work between machines and result in unacceptably long lead times and a great deal of progressing effort to maintain a good delivery performance.

Forecasting algorithms endeavour to give the production controller advance notice of deviation from his optimum plan. They may, for instance, be designed to show likely variations of load beyond the time horizon of the existing order book so that the sales plan can be adjusted in time to maintain good utilization of capacity. Alternatively, they may be designed to cope with machine breakdowns via planned maintenance or operator absenteeism by adjustment to the production plan to maintain a good delivery performance. Many such algorithms are available (36) but no production control systems packages are known to be available incorporating them. Normally, the forecasting system is isolated from the production control system although it may draw upon some of the same data.

Capacity Loading and Scheduling algorithms are used to produce good utilisation of capacity within the constraints of an existing delivery plan. The simpler algorithms do not take into account the finite capacity of a real machine shop, but merely adjust the schedule of work automatically, according to simple heuristic rules, e.g. one week gap between each individual operation on each job. The most complex algorithms take into account the effects of the finite capacity and endeavour to find the production plan which will give the best compromise between delivery performance and capacity loading taking into account job priorities. Some attempts have been made to optimise the production plan (see below), but available packages use heuristic rules and simple smoothing techniques to achieve a good result within a realistic timescale and level of computer capacity and administrative effort.

A cellular production system introduces a new problem to capacity loading in that a production plan is sought that provides a good load for each cell. Lewis (37) has reported a solution to this problem

by designing related cells each capable of taking on increasingly complex work. Jobs can be defined as mandatory, preferred or alternative assignments for one or more cells and the system loads the cells on a "cascade principle" so that mandatory assignments are loaded first, followed by preferred and alternative assignments in turn. The simplest work is then used to "top up" the load of each cell to its full capacity. Lewis reports some success for this method and PERA (38) provides a supporting set of computer programmes for its use. Lewis concludes that -
"The need for a loading system which is complementary to the cell system design is immediately apparent"! which is an important conclusion highlighting the inter-relationship between the design of the organisation and the systems used to run it.

Sequencing algorithms seek to improve the utilisation of capacity, shorten thruput times and reduce work in progress by optimising the sequence of jobs loaded to a given machine.

Sequencing problems in Group Technology fall into two classes -

* minimising the effect of machine interference on the queueing time of jobs
* exploitation of the parts family concept to minimise setting time.

Traditionally, optimisation of job sequences has been regarded as of academic interest only. The well known relationship of the number of possible sequences to be searched if j jobs are to be loaded to m machines is $(j!)^m$. The search becomes impossibly large even for a computer if either j or m become large as in a conventional functionally based machine shop. By dividing the organisation into cells, both j and m are reduced substantially which produces a very dramatic reduction in the number of possible sequences for work through a given cell. The use of such techniques as "branch and bound" (39) may thus become a practical reality for optimisation of intra cell job sequences to minimise the effects of machine interference.

Exploitation of the parts family concept involves taking into account a new set of criteria to arrive at the best job sequence for each particular machine. Traditional methods of calculating the load time for a particular job on a particular machine, assume that the operator starts and finishes the job with a clean, unset machine. The machine is completely reset for each new job presented to it. The parts family concept is used to reduce setting time by loading jobs that are similar in their setting requirements so that the machine need not be completely reset for each job. Consequently, the setting time is not only dependent on the particular job being manufactured, but is also dependent on the setting for the preceding job loaded to the machine in question.

There are no known practical applications of computers in either area, although Ferranti (40) have made considerable strides in reduction of setting times by exploitation of the concept of parts family manufacture, particularly on turned items and have claimed a 95% reduction in setting time by extensive use of Drurie's methods (3). This has been achieved without extensive computer help (an experiment involving linear programming was abandoned because of the computer capacity required) other than simple batching of jobs on a due date basis and provision of roughly a month's work to each cell with a supporting computer printout showing each tool setting required. It is up to the cell supervisor to make up the best sequence he can to minimise setting time as far as is practical, bearing in mind other constraints (operator flexibility, absenteeism, working speeds, etc.). It may be, therefore, that the use of computer algorithms in exploiting the parts family concept depends upon the design of the cellular system and the extent to which the composite component technique can cope with the degree of variety in parts loaded to a cell. In any case, a computer solution may be difficult to achieve because of the number of factors in addition to machine interference and the parts family concept which have to be taken into account to arrive at a workable sequence.

Most computer based production control systems provide progressing information by reporting deviations from the production plan in some form of "shortage list". This shortage list usually provides the basis for deploying the progressing effort to minimise the extent of the deviations from the plan. In the longer term, however, performance measurement can be important to maintain and improve the ongoing performance of the activity. In this case, measurements are needed to display many factors from operator efficiency, quality produced, etc. to the broad financial performance of the area concerned. Most proprietary packages such as the CLASS system developed by I.B.M. (41) and later derivatives, such as CAPOSS, provide some such information, but in many cases, further digestion is required before

3.4.2 Role of the Computer in Production Control Cont'd.

the information is of use to management. It is in this process that particular algorithms suited to the company's modus operandi are needed and the algorithms will depend on the management, the organisation and on the linkages between the production control and accounting systems.

Group Technology introduces problems in this field by virtue of the changes it induces in the management, organisation and systems structure of the company. The cell system may obviate the need for complex progressing information because of the dramatic simplification in work flow it makes possible, and the management reporting will need to be changed because of the new organisation promoted by Group Technology.

There appear to be no reports, either on how this situation affects the design of computer systems, or practical illustrations on how results were achieved in the field.

3.4.3 Use of the Computer to Support Design for Group Technology In a well coordinated company, the design of products should reflect the available manufacturing facilities. Technological inovation should be carefully managed to ensure that, where the "state of the art" and the market demands, the manufacturing facilities and the design of new products are updated together as far as possible.

At the component level, the parts family concept can be used as a basis for standardisation. To maximise the benefits of standardisation, 3.4.3 Use of the Computer to Support Design for Group Technology Cont'd

a drawing retrieval system is necessary to allow designers the maximum scope for using existing component designs, either in their entirety or by modification of a few features rather than by re-design of a new component from scratch. It may only take a designer a few minutes to draw a new part, but in doing so, he generates a pyramid of costs covering proving the new design, establishment of an appropriate manufacturing method together with estimating, ordering, controlling and storing of the new part, each time it is manufactured.

An interesting application has been reported by Allen (10). The use of castings was abandoned in favour of fabrication from standard billets N.C. machined to have the desired features. A mini computer is used as a drafting aid; the design process being to digitise drawings with the aid of the computer, which automatically adds the required features from a data bank of standards. N.C. tapes can be produced by the computer directly together with a tape to control automated inspection of the finished parts.

It is not within the scope of this thesis to comment on the N.C. techniques employed, but the information retrieval system reported, provides a good example of the use of information systems in Group Technology.

CHAPTER 4

PROJECT BACKGROUND

4.1 Introduction

The main body of this thesis is devoted to describing some applications of computers in Group Technology in depth. To provide a context for the work described, this chapter gives some background information on the company in which the research was done, an outline of the company's organisation and a description of some of its systems which were used or modified as a result of this research.

4.2 M.E.L's Business

The M.E.L. Equipment Co. Ltd. is a wholly owned subsidiary of the Dutch based multinational Philips Group. M.E.L. may best be described as an electronic equipment building company. At the time of writing, M.E.L. had annual sales in the region of £23M and employed about 2,200 people.

4.2.1 The Product Range M.E.L. manufactures a wide variety of equipment for both Government and Commercial customers, much of its output being for export. The products vary widely in both technical complexity and numbers produced. The variety may be illustrated by comparing two examples from extremes of the range.

The first example is a linear accelerator for radiological treatment of disease (see figure 7). A number of these products were being produced during the course of this research, each costing up to £½M.

4.2.1 The Product Range Cont'd.

Production was mainly to customer order, but, due to long lead times in manufacture, production could be initially for stock, although a specific customer might require modifications during the manufacturing process to suit the product to his particular needs. Production of these products increased steadily during the period covered by this thesis, reaching about 30 p.a. at the time of writing. The products contained components machined to "state of the art" tolerances and when finally assembled, a product could occupy the majority of a $3\frac{1}{2}$ metre cube.

The second example is a module of logically arranged electronic switching elements selling for about £1 (see figure 8). These products were roughly the size of a match box and contained components which did not make high tolerance demands on the internal manufacturing facilities. Production was based on sales expectations and had remained at some 500,000 units annually for several years until the work was transferred elsewhere in the Philips Group, about half way through this project.

Between these extremes lie a large number of products varying markedly in their size and complexity, the numbers produced and the source and tolerance of their components.

M.E.L's business is characterised by a high rate of technical change, much of the annual budget being devoted to the development of new products and the improvement or tailoring of existing products for specific requirements.

4.2.2 The Organisation

Figure 9 is an outline of the organisation at the start of the project. The marketing/sales sector was divided from the technical sector, each reporting to the Managing Director. Both sectors were basically product orientated, although the product range marketed by some commercial managers could be made by more than one production division and vice versa.

The majority of the company's business was concentrated in the "Defence and Avionic Systems Group", whose technical sector had a triumvirate management team consisting of the Development Manager (responsible for the development of new products and major technical modifications to existing products), the Materials Manager (responsible for procuring all bought out supplies of raw material and components) and the Production Manager (responsible for the efficient production of developed products and the improvement/modification of products after completion of development).

At the start of the project, the production manager's organisation consisted of 4 "assembly" divisions and two component manufacturing divisions: "Manufacturing" Division (metalwork, chemical processing and painting) and "Coils and Sub-Assemblies" Division - C.A.S.A. (Coils, transformers, switching elements and potting).

The organisation was supported by various "ancillary" departments. Of particular interest were the Industrial Engineering Department, known as the Technical Efficiency Organisation - T.E.O - and the Information Systems and Automation Department - I.S.A.

4.2.2 The Organisation Cont'd.

T.E.O. was responsible for estimating the cost of manufacture upon which the company based its prices, for providing targets to guide production managers in their use of labour and for helping production managers produce improvements in their manufacturing methods.

I.S.A. was responsible for the development, maintenance and efficient running of all the company's computer systems and some manual systems, the great majority of their work being to support production and Administration.

During the course of the project, a number of organisational changes took place. The Managing Director retired and the Production Manager of D.A.S.G. left the company. The Commercial Director replaced the Managing Director and a Technical Director was appointed who ran the entire technical sector and all the auxilliary departments apart from Administration (accounting) and I.S.A. who reported to the Financial Director. One of the production assembly divisions was transferred to the Development Manager and C.A.S.A. was closed, although some of its work was transferred to one of the assembly divisions. Finally, a new senior production manager was appointed in D.A.S.G. to take charge of the three remaining Assembly Divisions (see figure 10) in this group, together with Manufacturing Division in which the majority of the work reported here took place.

4.3 Manufacturing Division

4.3.1 Its Business Manufacturing Division provided a service in pre-production metalwork and processing to six "customer" divisions in M.E.L. The service consisted of:

4.3.1 Its Business Cont'd.

* General Machining (turning, milling, drilling, grinding)
* Sheet Metalwork (cutting, bending, forming, punching, welding)
* Printed Wire Board Manufacture (cutting, drilling, plating)
* Metal Finishing (mechanical assembly, linishing, polishing, etc.)
* Plating
* Electroforming
* Painting.

The great majority of components were in the medium/small size range, but high standards of precision and quality were demanded, since the majority of Manufacturing Division's work was governed by Ministry of Defence ("05-21") quality standards (42).

M.E.L. allocated about 13% of its annual production budget to Manufacturing Division and about 26% of the total capital employed in production. Between 75% and 80% of the capital employed in Manufacturing Division was invested in metalworking machine tools which were kept in good condition and in pace with the demands of M.E.L's rapidly advancing technology by a continual programme of re-investment.

Production was organised on a batch/jobbing basis. Manufacturing Division delivered some 20,000/25,000 batches annually handling about 3,000 at once, of which about 2,000 could be on the shop floor simultaneously. Batch sizes varied between 1 and 1,000, the average being in the region of 40. The management regarded the flow of orders as random and unpredictable.

4.3.1 Its Business Cont'd.

An additional service was provided to Development areas in coping with overflows from the Development model shop. This work and the work generated by an emergency support service to the production divisions, was known as "sideways" loading. It bypassed the normal control systems and could substantially increase the number of current batches and hence the complexity of the control task.

For many years, M.E.L. had constrained the size of Manufacturing Division to cope with its base load. Extra demands on capacity or particular metalworking/processing technologies not available in Manufacturing Division were sub-contracted to other companies, Manufacturing Division coping with 1/3rd to 2/3rds the total metalwork/processing demands of M.E.L.

4.3.2 Staff Organisation and Systems M.E.L. budgeted for 127 staff to be employed in Manufacturing Division. These were organised as shown in figure 11. 61 operated machines, which cut or formed metal, whilst a further 23 were involved in processing. The shop floor was laid out on a functional basis (see figure 12) where the machine types were grouped together.

The Production Staff were supported by a Methods Engineering ("Planning") and Production Control sections who provided methods and control information to a computerised production control system (see section 4.4.3). They were assisted in this task by the T.E.O. department who provided standard time estimates for each operation on all but "sideways loaded" jobs which were loaded to the shop floor without the usual methods or control information.

4.4 The Systems

4.4.1 Introduction M.E.L. had been using computer systems for several years prior to the start of this work. Starting in a small way by leasing time on a computer owned by another company. M.E.L. acquired an I.B.M. 360-30 with 60 kilobytes of core in 1969. This machine was replaced with the faster and larger I.B.M. 370-135 with ½ megabyte of core in 1975. The software and periferal equipment was also improved during this period so that "first generation" tape based systems were being replaced by disc based systems running under the Dos - vs operating system by early 1975.

During this first phase of computerisation, M.E.L. invested over £1M in systems design and programming. Whilst some of this effort had been utilised to mechanise the payroll for hourly and weekly paid staff and latterly part of the accounting process, most of the effort had been devoted to the mechanisation of production control and requirements planning. By the start of this research, most of production divisions in the company were utilising these systems heavily.

4.4.2 The D.A.S.G. Production Control System A complex production control system was operated in D.A.S.G. (see figure 13). This system was based on the D.A.S.G. production cycle and was composed of several "stand-alone" sub-systems which communicated with each other via punched cards, "turnround documents" - computer printouts modified by hand and used to re-encode data - and by access to joint files (disc or tape). The D.A.S.G. production control system was composed of 4 main parts (see figure 14).

4.4.2 The D.A.S.G. Production Control System Cont'd.

* Parts List Documentation - a simple form of requirements planning. In this system components were classified (manually) by supplier and the computer used to perform a limited form of bill of materials processing to break down a given number of a product into required numbers of its constituent components. This bill of materials was printed out, sorted by supplier (Manufacturing Division, C.A.S.A., purchased items, etc.) and used to plan the supply of components.
* Methodisation and Planning. This part of the system was used to plan the assembly of the finished product. The manufacture of the product was broken down into a series of operations based on the product structure. For each of these, a lead time was specified between the operation and completion of the product together with information on the assembly method and standard times for the operation (supplied by T.E.O. and used for targeting purposes). This information was digested by the computer to provide a basis for the L.o.B. system.
* The "L.o.B." progressing system was based on the well known Line of Balance production control technique. L.o.B. is really a stock maintenance system whereby the stock of each item, sub-assembly and assembly needed to make a product is kept in balanced amounts according to the lead time between its incorporation into the product and the delivery of the finished product, its place in the product

4.4.2 The D.A.S.G. Production Control System Cont'd.

structure and likely cumulative scrap levels. A production plan is derived from the difference between actual stocks and the stock computed to be needed to maintain the balance. This difference was computed from the planning/methodising information and information on the stocks of items passed to the computer via punched cards returned from the shop floor. Progress information derived from this information was provided by the computer in both pictorial form and listings of requirements.

* Shop Floor Documentation was provided in a number of forms - feed sheets to demand items from stores, load cards to maintain the information required by the L.o.B. system and labels to identify each stocked item.

Whilst this system had both grown up and been implemented as a patchwork and had been found to be unwieldy and limiting in some areas, the company's management felt it to be invaluable in the control of a highly complex assembly process. They regarded the data in the system as the best available in the company in many areas and felt that an overall change to the system would prove a long and expensive task.

4.4.3 Manufacturing Division's Production Control System During the period covered by this thesis, Manufacturing Division operated a complex production control system separate to and different from that operating in the rest of D.A.S.G. Known as the "Huizen System", the Manufacturing Division production control system had been developed in another part of the Philips Group and transferred to M.E.L. in 1968.

4.4.3 Manufacturing Division's Production Control System Cont'd.

Appendix 1 gives a full description of the system and its links with the organisation, so only an outline will be given here.

The system was used to manage queues of work in progress in a functionally laid out machine shop. Some information was provided to aid capacity planning and materials buying. No automated scheduling was provided apart from simple back scheduling against the due date assuming infinite capacity. Manufacturing instructions were issued to the shop floor on computer documents, together with pre-punched cards for return of data on times taken, quantity made, etc. Progressing was based on due date priorities and information was provided by machine section and by customer. The only performance measure provided was a simple measure of productivity for each machine section.

The support organisations in Manufacturing Division had been built round the requirements of the system and consisted of a methods engineering section and a production control section. The methods engineering section worked out the method to be used for manufacture from the component drawing. The manufacturing effort needed to complete each operation comprising this method was estimated by T.E.O. and the due date and scheduling information was added by the production control section. This information was communicated to the computer and provided the base data for the operation of the rest of the system by the production control section.

The management felt that the system had been well implemented and had improved a messy situation which had grown steadily worse during the

4.4.3 Manufacturing Division's Production Control System Cont'd.

period immediately prior to the implementation of the system. However, some ongoing problems were experienced with the disciplines required for the accurate operation of the system which will be discussed in chapter 6.

4.5 The Group Tehnology Project

4.5.1 Factors Influencing its Creation During 1973, M.E.L's senior management recognised a number of key problems limiting the company's effectiveness:

* the reaction time required to fulfil an order
* the availability of production capacity at reasonable cost
* the efficiency of production
* a scarcity of skilled labour
* the cost of financing large amounts of work-in-progress.

The equipment manufacturing market was seen to be becoming steadily more competitive and attempts to break into new market areas were often severely restricted by the time taken to get new products to the customer or to meet new customer orders for existing products. These lengthy thru-put times were one of the prime causes of the large investment in work-in-progress.

Situated in the South East of England M.E.L had difficulty in recruiting sufficient skilled and semi-skilled labour to meet its production targets. Much of M.E.L's metalwork was sub-contracted and problems were being experienced with maintaining adequate quality and deliveries of the sub-contracted items. Shortages of metalwork items were identified as being the most common cause of production disruption.

Attempts had been made to increase production by expansion onto other sites. A firm specialising in lens manufacture with its own metalwork activity, had been taken over and more recently M.E.L. had planned to start production on sites originally belonging to other parts of the Philips organisation, but difficulties were being experienced in managing the problems posed by the geographical separation of production units from their parent organisation.

The scarcity of labour had restricted the management's scope for improving efficiency of production by conventional means. The management felt that changes would be resisted by the metalworkers, and the trade unions had succeeded in negotiating agreements which restricted the scope of work study and systems engineers to improve the efficiency of the operation.

These problems were made worse by the problems of small batch production and the high degree of technological innovation.

Group Technology was seen as a portmanteau method for tackling these problems. Some experiments had been carried out with group working in assembly areas and Group Technology was seen as a means of improving the production situation by modifying the sociological structure of the company (thus reducing the labour problem) and increasing efficiency at both the technological and administrative levels. Of particular interest were the dramatic improvements in thru-put times and increases in productivity reported in other companies involved in Group Technology (9,15).

4.5.1 Factors Influencing its Creation Cont'd.

Applications of Group Technology were seen by Senior Management to be of most interest in areas devoted to metal working. Manufacturing Division was, therefore, chosen as the area in which to experiment with Group Technology before extending into C.A.S.A., then into other areas of the company.

4.5.2 The Project Team Late in 1973, the company decided to examine the feasibility of adopting Group Technology as a basis for some of its manufacturing systems and set up a project team to conduct an experimental implementation in Manufacturing Division. The project team consisted of:

* an external consultant expert in Group Technology who was seen by the company as having the best track record of successful implementations
* the Manager of Manufacturing Division
* a member of the Methods Engineering Section of Manufacturing Division
* a member of the company's internal consulting service attached to I.S.A. Division.

The Divisional Manager represented the source of authority to "get things done" and clearly had a strong interest in helping to formulate any recommendations for change in his division.

The Methods Engineer had some 15 years experience in metalwork production, was a fully trained toolmaker (and was qualified to operate any metalworking machine on a skilled basis). His 2 years

4.5.2 The Project Team Cont'd.

experience in the Methods Engineering section had made him familiar with current working methods and his wide contacts in the factory provided good communication links with the shop floor and other production divisions at the working level.

As the nominated member of the company's internal consultancy service, the author was able to provide experience in the "Management Sciences" of numerical/analytical methods of problem solution, the use of computers and organisational/systems design. A twofold role was seen:

* to support the Group Technology project in Manufacturing Division
* to become sufficiently educated in the concept of Group Technology to act as a "link man" should it prove desirable to implement the concept elsewhere in the company.

During the early stages of the project, the I.S.A. Manager (to whom he reported) attended the project meetings and provided the authority for accessing the company's computer systems. This role was later delegated to the author.

The management felt that the project team would contain a balanced nucleus of expertise and authority. The team was created with the specific purpose of implementing Group Technology in Manufacturing Division, the perceived success of the implementation to be used as the basis for later decisions to implement the concept elsewhere in the company.

4.5.2 The Project Team Cont'd.

It seems clear that the company was primarily interested in a transfer of expertise. Package deals had been considered and rejected. The philosophy described in sections 2.3 and 3.2 served to guide the motives of the senior management, particularly the Senior Production Manager in setting up the project in the manner described above.

CHAPTER 5

USE OF COMPUTERS IN ORGANISATION DESIGN

5.1 The Project Plan

The project team decided to adopt an analytical approach to the implementation of a new organisation based on Group Technology. A three phase project was envisaged based on the methodology shown in figure 15 as follows:

* Phase 1 Building a data base containing details of components classified according to the features which should influence their method of manufacture together with details of current working methods (see figure 16).
* Phase 2 Analysing this data base to develop the Group Technology concept, to relate it to the current manufacturing system and to propose a new organisation (see figure 17).
* Phase 3 A trial implementation consisting of a simulation of the proposed new operating methods and experimentation with the actual operation of part of the trial organisation in order to refine and determine the desirability of the new system (see figure 18). This would be followed by expansion of the concept to include the whole of Manufacturing Division and eventually other areas of M.E.L.

5.2 Phase 1 - Building the Data Base

5.2.1 Specification of Key Products In a highly diversified multi-product company such as M.E.L., a detailed analysis of all products may not be possible because of the resources required. Because of the limited resources available, the project team decided to concentrate their analysis on those products expected to comprise the majority of Manufacturing Division's load during the year 1974/75.

Accordingly, the combined experience of the Divisional Manager and Production Control Manager of Manufacturing Division, together with that of the Job Controllers of the major customer divisions, was used to specify a short list of five major product ranges on which to carry out the detailed analytical phase of the project.

5.2.2 The Coding Exercise The project team decided to use the Opitz coding system (43) as the basis for classifying components according to the features which should influence their method of manufacture. Component families could then be formed by sorting the components according to their Opitz code numbers, since similar parts would have similar codes. The Opitz code - see Figure 19 - has the advantage of being well tried and proved and is easily available.

The code consists of 9 digits, the value of each digit signifying a particular feature of the component being coded. The resulting code number provides a description of the general geometrical form of the component, (rotational, non-rotational, aspect ratios); the importance and complexity of its surface features (bores, flats, drilled holes, etc.); its approximate size and its source material. The external consultant advised that the 9th digit of the published code (signifying accuracy) should be sacrificed in favour of including a second (the 7th) digit signifying the size of the item along its minor axis.

The code, a sample of drawings to be coded and their current manufacturing methods were studied to determine the interpretation of the code to be used where this was not clear. (When is a bore not a bore? What constitutes a functional groove or taper? etc.). Minor modifications to the published size ranges were also made at this stage (see figure 20), to relate the classification more closely to current working methods.

A scheme was then devised to train mechanical engineering apprentices in the use of the code and to ensure the adequate quality of their work.

The Parts List Documentation system (see Section 4.4.2) was used in its standard form to specify the drawing numbers of items that were both used to make the short listed products and that were desirable to be made in the General Machine Shop area of Manufacturing Division (see figures 11 and 12). It was found that some products were not included in the P.D. system data base. In this case, the drawing code numbers were extracted by hand. These drawings were extracted from the "Master Files" and studied by the apprentices who compiled lists of drawing numbers and corresponding Optiz code (G.T.C.) numbers onto a suitably designed form (see figure 21). The completed forms were encoded onto magnetic tape by I.S.A. Department's Data Preparation staff.

5.2.2 The Coding Exercise Cont'd.

Thus lists of drawings, classified according to the features which should influence their method of manufacture were produced in a form capable of being easily handled by a computer.

5.2.3 Data Capture System In order to relate the classified components to current working methods, it was necessary to extract data on the current manufacturing method of each component. Data needed included -

* machine types used (lathes, mills, drills, etc.)
* setting times per batch
* run times per item
* quantities made

The Huizen system (see Appendix 1) contained such data, so it was decided to use this system as the source of the data required.

However, a significant difficulty was encountered. The only data held in a form capable of being easily transcribed to the computer (magnetic tape) was on jobs currently being processed by Manufacturing Division. More data on jobs previously made by Manufacturing Division was held on punched paper tape - one tape for each component - in Manufacturing Division's internal files of data on some 20,000 components made during the previous 6 to 8 years. To transfer this data onto magnetic tape would have entailed a lengthy process using more Flexowriter and filing clerk capacity than was available. Experiments to avoid the copying process by splicing the separate paper tapes together into a form capable of rapid and accurate transcription onto magnetic tape, proved abortive.

5.2.3 Data Capture System Cont'd.

To overcome the difficulty, a data capture system was devised to avoid the deletion of jobs from the Huizen system master file on the computer that took place when an item was delivered and to capture data on new jobs as they were added to the system as part of the normal production control cycle. Because the data capture system would be running during most of the Opitz coding exercise, it was hoped that significant extra data would be captured on Manufacturing Division's future load so that the extra data (and hence Flexowriter and Filing Clerk capacity) that would have to be added to the data base as a consequence of the decision to analyse products which were part of the future (rather than current) load of Manufacturing Division could be minimised.

The data capture system proved simple to design. An initial copy of the Huizen system master file was made and a program written to compare this with the "live" data base as the project proceeded. The program would add new jobs, up - date information (received via the return of operation cards) on jobs already filed and would avoid the normal deletion process occurring when jobs were delivered. The process was further simplified by the design of the Huizen system which included a speedy recognition process for each job. A "keyword" including the job number, component code number and batch identifier was included in the header record of each job. The blocks of data pertaining to each job were held in the order of this key word which simplified the decision process necessary to recognise a job as "new" or "updating".

5.2.3 Data Capture System Cont'd.

Figure 22 shows the flow diagram of system which ran each week for the duration of the classification exercise and doubled the quantity of data held on magentic tape from some 3,500 to 7,000 jobs without the need for any extra Flexowriter or Filing Clerk capacity. Computer capacity of roughly half an hour per week was required, but proved not to be a constraint. In addition to reducing the work necessary to compile data for Phase 1 of the project, the data capture system provided a valuable source of historical data for comparison and targeting of Manufacturing Division's performance during Phase 2 and 3.

5.2.4 Code Number Editing and Problems Revealed At the start of the data capture and classification exercise, it was hoped that the history file produced by the data capture system would contain data on the great majority of classified components by the time the classification exercise was complete. Accordingly, a system was devised to compare the drawing numbers in the history file with those on the magnetic tape resulting from the classification exercise. The drawing numbers in both files contained stray characters (/,;, - , , etc.) and characters that were open to misinterpretation (O and Ø, Z and 2 etc.). In addition, the last digits in certain drawing numbers proved to be non-significant. These problems could cause failures in the process of matching code numbersto combine information held in separate systems (e.g. the data base produced by the data capture system and the magnetic tape holding the drawing number and Opitz code). Accordingly, a program was written to delete the stray characters and non-significant digits and convert the characters capable of misinterpretation to a consistent format. This program followed the usual procedure for solving problems of this type and was based on a"look-up" table containing all the invalid characters and decision rules to recognise and delete the non-significant digits and convert the other characters to the standard format. Thus, files containing compatible drawing numbers were produced.

To speed the recognition process, the file resulting from the classification exercise was sorted into code number order and read into the fast access (core) store of the computer. A program was written to compare the drawing numbers in the history file with those in the fast access store, delete those numbers recognised from the store and, after reading the whole history file, to list those items not recognised (i.e. still in store).

The classified component file contained some 1,860 items, of these only 200 were recognised before the editing programs were written. After editing the number increased to 600 leaving some 1,260 drawings on which no information on current working methods was available in a form easily handled by a computer.

This discovery had two direct consequences:

* since the sample of 600 drawings on which complete data was available was judged to be inadequate, an exercise was mounted to extract the relevant paper tapes from Manufacturing Division's files and to add these to the history file using the data capture system
* the addition of such large quantities of data not being produced as part of the normal production control cycle and hence not subject to the normal constraints of manufacturing capacity, would have produced a significant

5.2.4 Code Number Editing and Problems Revealed Cont'd.

distortion in the loading pattern. This meant that the original intention to examine the loading characteristics of a new organisation based on the load occurring in the time period covered by the history file had to be abandoned. Accordingly, the original plan was modified so that these loading characteristics could be based on a forecast of one year's output of the products specified for analysis.

5.2.5 Including Product Forecasts in the Data Base Figure 23 shows the system designed to build product forecasts in addition to the Opitz code number into the data base in a manner suitable for Phase 2 of the project.

First, Job Controllers of the Customer Divisions were interviewed to obtain the best available estimates of the specified products to be made during the implementation phase of the project. (May 1974 - May 1975).

The bill of materials processing facility of the "P.D." system was used to "explode" these forecasts to compute the number of each component required to manufacture the products. The computing process was based on the product structure (see figure 24) as follows:

A used on relationship was specified whereby the number of a particular component including a scrap allowance, required to make a particular sub-assembly was transcribed into the section of the data base allocated to that component. The sub-assembly's relationship with the main assembly was similarly specified as was the relationship of the main assembly, and the final product or "parent item". The computation of the requirement for a particular component was performed by multiplication of the product requirement and the appropriate relationships (R(i,j) in figure 24) together through the "levels" (sub-assembly, main assembly etc.). Where the same item was used in different parts of the same product a total requirement could be computed by sorting into code number order and adding requirements at output time. If the same component was used on different products this procedure could be quickened by specification of an index or "group commoning number" to allow the computer to find the appropriate requirements directly, rather than go through a lengthy sorting procedure.

In addition to the simple calculation specified above, various embellishments were available to take into account "spares" - extra components and/or assemblies to be supplied with the main product; "free" stock - stock available as "left over" from previous orders and "E Loan" or stock already manufactured and loaned to another product on a return basis. To avoid re-specification of these embellishment quantities, a "clean sweep" option was available to compute the basic requirements by automatically setting the embellishment quantities to zero.

A limitation on the use of the P.D. system was the restriction of the computation to four levels. This restriction had required Manufacturing Division to be treated as a supplier of complete items. Where these items were assemblies, no listing was immediately available of their constituent parts. To achieve a breakdown of these

5.2.5 Including Product Forecasts in the Data Base Cont'd.

assemblies, Manufacturing Division reprocessed the "extract" specifying the items they were due to supply by re-inputting the assembly requirement and using the P.D. system to access their own separate part of the data base containing details of the constituent components and their relationships with the assemblies now defined as parent items. The P.D. system then performed a "secondary" explosion to compute the component requirements. The obvious modification to the systems design to link the two explosions directly had not been performed. However, by use of the system in the manner described above, together with a small amount of clerical effort, it was possible to generate complete lists of components, supplied by Manufacturing Division, defined in the forecast required to manufacture the set of products.

Examination of the product structure showed that on only one group of similar products was a secondary explosion necessary. In a few cases products had not had their structures included in the P.D. system's data base. These products had been controlled by similar systems and outputs were available which were used in a like manner to produce lists of component drawing numbers together with the appropriate required quantities. In all cases, the "clean sweep option" was used since modifications to requirements calculated on this basis were judged to be small and very difficult to forecast.

Meanwhile, the standard software of the computer's operating system was used to produce a deck of computer cards pre-punched with all the

5.2.5 Including Product Forecasts in the Data Base Cont'd.

drawing numbers held on the magnetic tape resulting from the classification exercise. The deck was compiled in drawing number order, each component being allocated a separate card.

The company's drawing numbering system was such that the card deck was easy to separate into blocks appropriate to each product. The component requirements were then transferred to the cards by I.S.A. Department's Data Preparation staff. A simple program was written to transfer the component requirements from the cards onto magnetic tape together with the code numbers and drawing numbers resulting from the classification exercise.

The final task was the modification of the comparison program used to specify coded items not included in the history file of information compiled from the Huizen system. The modified program was designed to match the code numbers in both files and to write the Opitz code number and forecast requirement quantities into spare space in the appropriate header record (see figure 23).

5.2.6 Discussion of Phase 1 Phase 1 lasted some 4 months. In that time some 1,860 components were classified by mechanical engineering apprentices using the Opitz system, the product forecasts obtained and the data base built. The only problem not solved during this period concerned a hard core of items on which no information on current working methods was available or which were found to be not required in the year in question. This situation was caused by four factors:

5.2.6 Discussion of Phase 1 Cont'd.

* Manufacturing Division had contracted out large volumes of work to third party suppliers wherever the work had been suited to production on capstan lathes of greater than ½ inch capacity. This policy had been followed for some years following a decision to dispense with this type of manufacturing facility. The only available methods engineering information simply specified that the item was to be "off loaded complete".
* Similar "off loading" policies had been followed on other items when capacity constraints had occurred last time the item was made. These capacity constraints had occurred in Production, Methods Engineering and Production Control areas from time to time and had resulted in a similar "off load complete" instruction as the only available methods engineering information. In some cases, copies of previous layouts with more detailed instructions were available, but the lack of the relevant paper tape and the shortage of Flexowriter capacity precluded the incorporation of these layouts in the data base.
* The requirements calculation showed the item was not required in the year in question, because some items were used only on particular customised versions of some products.
* Some information was missing from both systems (P.D. and Huizen) due to minor errors in data transcription and misfiling.

5.2.6 Discussion of Phase 1 Cont'd.

During the period covered by Phase 1 no appropriate (e.g. Methods Engineering) capacity was available to overcome this problem of missing information and consequently the project team had to manage without it.

Notwithstanding the above difficulties, at the conclusion of Phase 1, the data base contained a hard core of complete data on current manufacturing methods, forecast requirements and Opitz code for 982 items.

Investigations into the accuracy of the data showed that the Opitz classification had been carried out to a high standard of consistency (in excess of 90%). Such differences that were found were due in the main to differences in interpretation of the code rather than mistakes in coding or transcription. These differences were judged to be not significant. The product forecasts have since proved an accurate statement of the requirements placed on Manufacturing Division during the period May'74 - May'75.

The machine routing and timing information obtained from the Huizen system represented M.E.L's current standard of accuracy in methods engineering and estimating. Since no objective information was available to evaluate the accuracy of this data, it must also be categorised as best available information.

The only major question, concerning the validity of the data base as the basis for an analytical exercise resulting in a re-organisation

(Phase 2), is the degree to which the "hard core" of components on which complete data was available was representative of the work to be done by the new organisation. This question is fundamental to any scientifically based attempt to introduce Group Technology and as such receives surprisingly scant attention in the literature.

If the data used for the construction of the new organisation is historically based, then the best that can be said of any organisation resulting from its analysis is that it was most appropriate to the time when the data used was "live". Alternatively, if forecast data is used, then the new organisation may only be as good in the working situation as the relationship between the forecast and reality.

In the case of this project where historical data, representing estimated load times and recommended machine routings, forecast data representing requirements, and a potentially biased sample of components was chosen, the purest would perhaps question the scientific validity of the data.

Perhaps these difficulties can be overcome by taking an approach to this problem based on good engineering practice. No organisation can function when no flexibility is allowed and all organisations must rely on the "robustness of probability". In other words, it is extremely unlikely that the sample chosen will be far from that truly representative of reality unless either the sample is small or the business reality exhibits wide variations.

5.2.6 Discussion of Phase 1 Cont'd.

The effects of sample bias must be considered on two levels -

* The product level. Since some care was taken in the choice of products to be analysed, sample bias at this level is thought not to be serious. Additional confidence can be gained from the component family concept. Families will contain components from many products and when loading is considered from a family point of view, the products will each contribute a small part to the constituent components and loading characteristics of the family. The component spectrum thus represents an average picture obtained from a large number of products. Significant distortions will only occur when large differences in the distribution of component types between products combine with large variations in the product demand.
* At the component level, the only significant bias is thought to have been produced by a consistent trend in the off-loading policy and consequent missing methods engineering information. This trend centred on the consistent off-loading of large batch turning work of over ½" diameter. The Manufacturing Divisional Manager had decided to buy three automatic lathes capable of producing the majority of this work in future. Since these machines would arrive during the implementation phase of the project, their affect on the loading of the new organisation would have to be taken into account. Since no methods engineering

5.2.6 Discussion of Phase 1 Cont'd.

or estimating information concerning these machines or the work to be loaded to them was available, it was decided to construct new organisational proposals by analysis of the "best available" information in the data base and to estimate the effects of the new machines during the refinement phase of Phase 2(see figure 17).

The potential problem posed by possible wide variations in the business pattern is of course fundamental and concerns the degree of flexibility required from the new organisation rather than its form at any particular time.

After consideration of these points, the project team decided to continue as planned with Phase 2 of the project, incorporating the suggestions outlined above for handling the problem posed by the new lathes.

5.3 Phase 2 - Analysis and Synthesis

5.3.1 Component Manufacturing Hours Analysis The first step in the development of the Group Technology concept was to access the data base to compute the hours required to manufacture each classified component. In order to relate the required manufacturing hours according to the current working methods with the features which should influence the manufacture of the component, the computation was designed to relate the required manufacturing hours to the Opitz code number of each classified component.

5.3.1 Component Manufacturing Hours Analysis Cont'd.

The production control system identified over 100 different manufacturing operation types. In order to clarify the results, these operation types were analysed and reduced to 8 groups of similar operations of major importance:

* turning
* milling
* numerically controlled machining
* drilling
* jig boring
* grinding (surface or cylindrical - differentiated by the Opitz code)
* "sheet metal" - deburring operations were considered to be performed by the Sheet Metal section (see Section 4.3). Note that since no sheet metal components were classified, the computation automatically excluded other types of sheet metal capacity.
* others. These were operations performed by the Processing Department, (painting, heat treatment, acid cleaning, plating, etc.), which were excluded from the potential re-organisation because the technologies were environmentally incompatible with metalworking.

A computer program was written to access the data base and calculate the manufacturing hours required, in each of the 8 major technology groupings, to meet the component requirement obtained from the product explosion. The same method of calculation was used in this program

5.3.1 Component Manufacturing Hours Analysis Cont'd.

as in the standard Huizen system, i.e. the currently accepted data on set times per batch and run times per component and the same calculation routine making due allowance for learning. A facility was incorporated to simulate the effect of debatching, but on the advice of the external consultant, this facility was not used. The flow diagram of this program is shown in figure 25 and an example of the output in figure 26.

Two attempts were made at this stage to produce family groupings of components by sorting the output according to the Opitz code number of each component. The first attempt involved simply sorting in order of the Opitz number, the second in the order of:

1. Opitz code digit 1 - major geometrical form
2. Opitz digit 6 - size range
3. Opitz digit 8 - material type
4. Complete Opitz number

In neither case were obvious component families found that were large enough to use as the basis for a re-organisation. Clearly a "wood for trees" problem was being encountered and a method was needed to compile families, large enough to use as the basis for a re-organisation, from the smaller families recognised from the sorting process. Attempts to perform this process by hand proved very lengthy and if followed would have severely restricted the number of organisational options that could have been explored. Consequently, the method described below was devised.

5.3.2 Interactive Interrogation of the Data Base   Interactive computing methods have been widely available for about 12 years in the U.K. The usual technique is to share a large computer between a number of users on a time sharing basis. The operating system of the computer is designed to give each user access via a remote terminal (teletype or video) to the power of the whole computer (core and peripherals) for a few milliseconds at a time. The power of the computer has to be such that within this period significant quantities of data can be processed. The processing for each user is done in a series of these "time slots" on a rotational basis. Each user's time "slot" becomes available so rapidly that the interruption is hardly perceivable and each user apparently has immediate and continuous access to the whole power of the large computer. By this means, the extensive delays of batch processing can be avoided. An additional advantage of most time sharing systems is that sophisticated aids to program development (error flags, editing facilities and pre-written programs and sub-routines) are provided by the operating system. By the use of such facilities it is often found that the time required for program development can be cut from a matter of weeks to a matter of hours. Provided large volumes of printout are not required the results of a program run are available within a few seconds or minutes rather than having to wait many hours or days for the conventional batch processing system reliant on job queues. Provided the quantities of data to be processed are not excessive, the use of such systems is comparatively cheap - say £1 per run of a developed program with say 100 lines of output and a fair amount of computation.

5.3.2 Interactive Interrogation of the Data Base Cont'd.

It was considered that interrogation of the data base by such interactive methods could be used to examine, in a short period of time, the loading characteristics of a large number of possible family combinations. These results could be combined with available knowledge of Manufacturing Division's particular situation, the social sciences and good engineering practice to establish an optimum basis for the new organisational structure.

The company's internal computer could not offer an interactive access facility. Consequently, it was necessary to transfer the relevant data to a computer offering this service. The Philips Group operated its own time sharing service, available via G.P.O. lines linked to a teletype in M.E.L. Unfortunately, speedy options for data transfer by way of direct connection of the computers, magnetic tape or machine punched cards were found to be technically infeasible. Consequently, data was transferred via the teletype using paper tape prepared manually "off line" (not connected to the computer, hence no computer charges). Data transferred was simply that contained on the output of the manufacturing load hours analysis, viz. the component drawing numbers, Opitz code numbers and the set and run times in each of the 8 major machine groupings. The apparently mammoth task of typing some 20,000 numbers accurately onto a paper tape occupied 2 people for only 3 days.

The data tape was fed into the time sharing system and validated as follows:

5.3.2 Interactive Interrogation of the Data Base Cont'd.

1. Syntax errors were eliminated using the editing facilities provided by the time sharing system.
2. A simple program was written to compute the totals per family of the set and run times. These were compared with those on the manufacturing hours output. These proved perhaps surprisingly accurate, but allowed easy correction of a few errors, again via the time sharing system editing facilities.
3. A program was written to extract and list all peculiar items, (e.g. rotational items (Opitz digit 1 $\leq$ 4) with no turning time). The data on these items was checked against the manufacturing method - no errors were found.
4. A second program was written to present a pareto of the items by total load hours. The "top twenty" items were checked against a hand calculation from basic methods engineering information - no errors were found.

The transcribed data base was now considered accurate. The entire process of transcription, writing and proving the above programs and validation took 8 man days.

A program was then developed to comb the data for items having characteristics obeying pre-set rules (e.g. similar values of particular Opitz digits, similar machines visited, etc.). This program was designed to present machine hours grouped by size and material for use as a basis for the examination of the loading characteristics of the new organisation. Its flow diagram is shown in figure 27 and examples of the two alternative outputs available in figures 28 and 29.

5.3.3 Use of Interactive Methods in Cell Formation The facilities described above were used to examine the loading characteristics of a number of alternative organisations. The structure of each organisation was specified and appropriate decision rules to determine which-job-should-go-where incorporated into the data combing program. The system was used to compute the load, on each part of the proposed organisation, broken down by size and material into each of the 8 major machine groupings described above. The process was repeated iteratively until a number of viable alternatives had been examined fully. In order to illustrate the process, a worked example is given below:

5.3.3 1. Organisational Structure - Four production cells

- Two turning cells
- One milling cell
- One N.C. cell

5.3.3 2. Decision Rules

- Turning Cell A - devoted to machining short rotational parts of less than 1" in diameter. Appropriate selection criteria were:

  Opitz digit 1 $<$ 2; Opitz digit 6 = 0; N.C. Hours = 0

- Turning Cell B - devoted to machining shafts, "difficult" items (awkward but basically rotational shapes) and all rotational items over 1" in diameter. Appropriate selection criteria were:

  2 $\leqslant$ Opitz digit 1 $\leqslant$ 4; N.C. Hours = 0 plus
  Opitz digit 1 $<$ 2; Opitz digit 6 $>$ 0; N.C. Hours = 0

5.3.3 Use of Interactive Methods in Cell Formation Cont'd.

* Milling Cell - devoted to machining all non rotational items not currently being specified for manufacture on N.C. machines. Appropriate selection criteria were:

  Opitz digit 1 > 5; N.C. Hours = 0

* N.C. Cell - devoted to the complete machining of all items currently specified for manufacture on N.C. machines. Appropriate selection criteria were:

  N.C. Hours > 0.

Figures 30 - 34 illustrate the depth of analysis possible and stages in the iterative process leading to the specification of a Milling Cell separate from an N.C. Cell. A similar process was followed for rotational items leading to the specification of the two Turning Cells (see figures 35 and 36).

By expanding the selection criteria it was possible to obtain rapid answers to questions such as -

> "What effect on the total loads of Turning Cells A and B is produced by sending all items requiring grinding that would normally be sent to Cell A to Cell B"?

(Grinding presented a problem because a high degree of skill was required to set the machine, but the load presented to it was too small to warrant a skilled setter in each cell).

This was simply obtained by adding the following selection criteria to the selection rules listed above.

5.3.3 Use of Interactive Methods in Cell Formation Cont'd.

Turning Cell A: Grinding Hours = 0

Turning Cell B: Opitz digit 1 < 2; Opitz digit 6 = 0;

Grinding Hours > 0.

Another modification tried was to incorporate the effect of debatching into the loading calculation (the original calculation assumed the total component requirement for the year was produced in one batch). Whilst it could have been possible to go to the sophistication of the learning allowance described in Appendix I , a simple estimate of the effect of debatching was chosen that could be obtained by adding an extra setting time each time the load time exceeded a preset value. The relationship

$$L = S\ (1 + \mathrm{INT}\ (R/X)\ ) + R$$

was used where the load time (L) represented the given function of the setting time per batch (S), the total run time for the quantity required to meet the year forecast (R) and the maximum batch hours allowed (X). An example of this effect is shown in figure 33.

By use of such interactive interrogation of the data base, it was possible to investigate the characteristics of a large number of organisational options both extremely rapidly and in great depth. The results described above took less than 1 hour to obtain (although the graphs shown in figures 30 - 35 took a little longer to plot).

This compares with some 5 man days to compile a single analysis by hand. The computer method has the advantage of accuracy over the hand method, when fatigue or carelessness could cause mistakes in addition and items to be missed or included wrongly. The amount of effort in a hand calculation would probably have limited the examination to one or two alternatives, with no great detail possible in the

5.3.3 Use of Interactive Methods in Cell Formation Cont'd.

investigation of alternative loading rules.

5.3.4 Evaluation of Intangibles The analyses provided by the computer painted only part of the picture. In order to evaluate the more intangible benefits and constraints produced by the various organisational proposals, the project team decided to discuss the information produced with groups of staff liable to be affected by the changes envisaged.

To limit the amount of data needed to be digested in these discussions, an "evaluation matrix" was used to select the more promising organisational proposal. This proposal could then be discussed in detail with the staff affected and information on the alternative organisations used as background if required.

Factors affecting the desirability of a new organisation were listed and weighted according to their probable relative importance (according to the author and the Methods Engineer). Each alternative organisational proposal was scored according to its desirability with respect to each factor. A total score for each proposal was obtained by summing the products of the factor weights and the scores. The most desirable organisation was defined as the one with the highest score.

This method has been used by Muther (30) to evaluate alternative layout proposals. The method was found to be a clear and speedy method of selecting an optimum. Its limitations are, of course, the subjective selection of the factors, the factor weights and the scores. It must, therefore, be classified as a quasi - objective means of

5.3.4 Evaluation of Intangibles Cont'd.

assessing a subjective thought process. However, it is believed to be at least one degree better than the even more subjective, less clear and sometimes slower process of selecting that which "seems to be best", without troubling to list the selection criteria, or considering their relative importance.

5.3.5 Interesting Considerations Apart from leading to the organisational proposals in the manner outlined above, the load analysis revealed a number of interesting considerations. Some of these are listed below.

* The 982 items analysed in depth accounted for some 28,000 hours work or the equivalent of roughly 19½ operators. (The current loading rules assumed each operator contributed 1,440 effective hours per year). The Divisional Manager and his Production Control Manager estimated this to be 60-65% of their expected load. Whilst less than the 80-85% hoped for at the product selection stage, due in the main to the missing data described in Section 5.2.6, the sample accounted for a very significant part of the expected load.
* The work was split almost evenly between rotational and non-rotational items (see figure 37) although the missing data (largely due remember to large batch turning work "off loaded") must have decreased the predicted rotational work load. The purchase of three plugboard automatic lathes would mean that this work would in future be done "in-house". To cater for this, the staff of the two Turning

5.3.5 Interesting Considerations Cont'd.

Cells was to be increased to provide more capacity on subsidiary machines. One extra operator in each cell was judged to be adequate.

* Pareto analyses (see figures 37 and 38) revealed no obvious flow lines possible in the Turning and Milling Cells. The 9,566 hours work accounted for by only 34 items combined with the tendency towards larger sized work may be indicated a potential flow line in the N.C. Cell. This area was not under the aegis of the project team, but the information was forwarded to the relevant manager.
* A large quantity of stainless steel work was shown to be required from both Turning Cells (See figures 35 and 36). Supervisors and Unions considered this to be a significant increase over the present load. The technological capability of M.E.L. to deal efficiently with this problem was questioned, and an investigation into special purpose tooling and better purchasing policies recommended.
* There was a marked lack of special purpose turning - i.e. very little screw cutting, taper turning or functional grooving. This contrasted with the provision of facilities to perform these tasks on almost every lathe in the shop.
* The items analysed were of small size (no rotational item over 16" and only 2 over 6.5" diameter). The largest non-rotational item encountered would have fitted easily into a 25" cube.

* The size range and low requirement for special purpose turning resulted in a recommendation to purchase short bed lathes with minimal facilities when replacement or expansion of the current tooling was considered.

At this stage, the proposed organisation was considered by the project team to give sufficient scope for the exploitation of the benefits of parts family manufacture without demanding too much in terms of multi-skill/flexibility or over specialisation on behalf of the operators.

5.3.6 Sociological Problems The proposed new organisation was laid out using wooden models (constructed by the ubiquitous apprentices) in a 3 dimensional layout (see figure 39). The model was used as a basis for discussions with the Supervision, the Trade Unions and the support organisation (Methods Engineering and Production Control).

Whilst accepting the proposals as good, Supervision was clearly unsure of its new role and fearful of changes that could lead to organisational independence of the cells from the Supervision. They could not see through to a new role in supporting the cells, either technically or in an entrepreneurial sense and may well have seen their jobs disappearing.

The Trade Unions were worried about the extent of specialisation to be demanded by virtue of the component family concept. Theyalso expressed concern about the possibility of management setting up a competitive situation between cells. Whilst prepared to "go along" with the change, they reserved their rights to negotiate.

5.3.6 Sociological Problems Cont'd.

The Methods Engineering and Planning Sections were asked to help in evolving their new roles in an organisation based on Group Technology. The staff involved seemed generally quite positive in their attitude to the forthcoming change but, possibly due to lack of experience, they felt unable to contribute a great deal to initial discussions.

During the period in which these discussions were taking place, many of the organisational changes mentioned in Chapter 4 took place. The most important of these was the resignation of the Senior Production Manager, who had provided much of the impetus behind the project. Without his authority, the project team lacked sufficient backing to negotiate payment for the flexibility required to support the new system. Without this payment, the Trade Unions refused to become "flexible" - to operate more than one machine in normal working hours, although they agreed to flexibility in overtime.

To cope with this problem the project team decided on the following plan:

1. the two Turning Cells would be combined into one, which would increase the load to the supporting mills and drills sufficiently to warrant one operator full time on each machine type
2. the initial implementation would be limited to the Turning Cell for a period of at least six months, which would allow all involved to become accustomed to the new system and give time for coping with some entrenched attitude problems

5.3.6 Sociological Problems Cont'd.

3. an economic experiment would be conducted to demonstrate the viability of the new organisation to management and to clarify the problem of payment for flexibility. This demonstration was also necessary because of the changes in senior management that took place during the implementation (see sections 4.2.2 and 7.1).
4. The modifications to the production control system required to support an organisation based on Group Technology, would be tried out in the Turning Cell so that extension of the concept to the rest of Manufacturing Division, could be managed more smoothly.

Agreement to proceed without flexibility was obtained from the Trade Unions, the Supervision and Support Staff agreed to give the trial cell a "fair try". A revised layout plan was produced (see figure 40) and the appropriate machines moved to create the Turning Cell.

CHAPTER 6

MODIFICATION OF A PRODUCTION CONTROL SYSTEM TO ACCOMMODATE GROUP TECHNOLOGY

6.1 Introduction

In batch/jobbing production, control systems are generally designed for the management of queues of work-in-progress in a functionally laid out shop. The implementation of Group Technology poses three particular problems to the production control systems designer. First, in the Group Technology situation, the queues of work-in-progress may be too short to make production control via their management a viable proposition. Secondly, the re-layout of the shop floor may so complicate the computer's model of the organisation that it becomes necessary to change the system to suit the organisation. Thirdly, the importance of sequencing to exploit parts family manufacture and the short thru-put times on the shop floor places a new emphasis on marshalling materials and tools before the job commences and on avoiding disruption to the production plan once the job sequence is commenced. The existing system may not be adequate to cope with this change of emphasis or give sufficient assistance in designing good job sequences.

This chapter describes how a conventionally designed production control system was modified to accommodate the changes imposed by a re-organisation based on Group Technology and how certain improvements were incorporated in the information provided by the system to cope with the problems and opportunities presented by the new methods.

6.2 "The Huizen System" - Design and General Problems

Appendix 1 describes the production control system and its links with the organisation.

The system was of fairly conventional "first generation" (tape based) design and was intended for control of jobbing production via progressing on a simple due date basis. There were no direct links with forecast sales of finished products or information on their stocks and work-in-progress in the customer divisions. The management regarded the flow of orders as random and unpredictable and so control was strictly on a jobbing basis with few efforts to minimise costs by the use of either Economic Batch Quantity or Period Batch Scheduling techniques.

In addition to problems associated with the design of the system, a number of problems were being experienced with its operation which had remained unsolved since the system had been implemented some years previously. The main such problems were:

* the capacity planning, whilst based on a good picture of the estimated load IN THE SYSTEM took no proper account of a sometimes significant amount of work loaded direct to the shop floor, bypassing the normal methodising and production control processes, for reasons of urgency but increasing the complexity of the control task. Capacity was allowed to cope with this work by degrading the amount of work assumed to be produced by each operator but no information was used to assess this capacity other

than a simple guess that each man produced 30 standard hours per week of work "in the system".

The capacity planning process was known to be suspect and customers sometimes took advantage of this by taking work turned down (for reasons of lack of capacity) by the production controller, direct to the shop floor, where they stood a good chance of getting it done.

* There was a lack of confidence in the estimating process. N.B. Estimating was done by T.E.O. - not Manufacturing Division. Factors influencing this included:
  a) insufficient detail in the methodisation for T.E.O. (see Chapter 4) particularly feeds and speeds
  b) Manufacturing Division's lack of confidence in the estimator
  c) supervision failing always to enforce the stated method and operators ignoring it at times
  d) management failing to audit the process sufficiently regularly to overcome the problems.
* Some operators failed to feed back accurate data to the system. Operations could be "clocked off" when they should have finished rather than when they actually finished. Efficient operators could thus generate some spare time and poor operators were sometimes not called to account for taking longer than they should on particular tasks. On occasions, an estimator could be asked to re-time

the job on the basis of the method being used rather than that specified. If the difference in methods was the major cause of the excess time, the next time the job was made by an efficient operator even more spare time could be generated.

* Whilst lateness in arrival of materials was recognised by the system in time for a progress chaser to take action, lateness of tools often went unrecognised. This problem was made worse by a policy of storing some tools in a warehouse 10 miles from the shop floor. No system was available to forecast which tools would be required and when.
* The company was used to jobs having a long thru-put time and to a general failure of Manufacturing Division to meet delivery dates. The customer divisions tended to ask for jobs long before they needed them which may have resulted in more work than necessary being off-loaded and a higher than necessary stock of finished parts. These problems were not visible because no information was available on them and the lack of visibility removed much of the pressure to improve from Manufacturing Division.

Notwithstanding the problems, the system coped fairly well with a complex control task. The management felt that the system had produced a good measure of control where very little had previously existed.

6.3 Particular Problems vis-a-vis Group Technology

The implementation of Group Technology produced a number of specific problems associated with the Huizen system. These problems are outlined below:

6.3.1 Organisation of Information The information output from the Huizen system was structured to support production control of a functionally organised machine shop via the management of inter-operation queues. The functional structure was also reflected in the organisation of data input to the system.

The move to a cellular organisation required some considerable re-structuring of this information to maintain and possibly improve control whilst avoiding an increase and hopefully stimulating a decrease in the administrative effort required to run the system. The restructuring was needed in most parts of the system including capacity/load planning; scheduling; progressing and performance measurement.

6.3.2 Tight Scheduling One of the main objectives in moving to a cellular organisation was to reduce the shop floor thru-put time. The achievement of this objective required a considerable reduction in the queue times allowed between operations.

The scheduling prior to the re-organisation usually allowed 1 week's queueing between each operation. The work queues generated by this rule allowed many problems to remain invisible. For example, operators taking longer than the estimated time for a job, would probably not disrupt the schedule since they would simply eat into the queue time for the next process by a small percentage (queue times were much longer than operation times). Whilst a general slackness would increase the backlog of late work, this was catered for by reducing the amount of work accepted or by sub-contracting part

6.3.2 Tight Scheduling Cont'd.

of the backlog to outside suppliers. Loose scheduling also allowed more time for coping with such problems as tool breakages, wrong materials or tools supplied, operator absenteeism, machine breakdown, etc.

A target of 1 day's queueing between operations was selected for the new organisation. This target seemed consistent with the reductions in lead times and work-in-progress claimed by other companies using Group Technology, but placed a new emphasis on Manufacturing Division's ability to solve problems fast enough to avoid disruption of the tighter schedules.

The shorter job queues also meant that the twice weekly update of information provided by the system was no longer sufficient to keep pace with one operation per day. The extra computing capacity and difficulties in speeding the flow of information to and from the computer meant that simply moving to a daily update was not possible.

6.3.3 Sequencing To exploit the concept of parts family manufacture in an environment where the families are too small (for reasons of either the lack of parts standardisation or the lack of suitable composite tool rigs) requires that some attention is paid to the sequence of jobs that are submitted to each machine. If this is not done, then little or no benefit from reductions in setting time will be obtained.

6.3.3 Sequencing Cont'd.

An additional need for a planned sequence of jobs is generated by the effects of machine interference. With long inter-operation queues, each machine is buffered from the others by the queues. If the queues are shortened without attention to the job sequence the situation may arise where a job must be idle because no machine is available to work on it or a machine must be idle because all the jobs for it are still undergoing processing on other machines. Thus machine interference can cause unplanned job queues and idle machines if no proper account is taken of the job sequence.

The Huizen system contained no facilities for sequencing. Solution of the sequencing problem by more exact scheduling was not feasible because:

* the finest schedule available from the computer could only be defined to the nearest ½ day (most operations took less than 2 hours)
* no facilities were available to examine the effects of machine interference in a job sequence
* no rules were available to design sequences in the on-going working situation. Any sequence would have to be produced by trial and error which would be very long winded if supported by batch processing in the computer.

6.4 Modifications to the System

To overcome the problems outlined above, the production control system was modified and extended as described below. There were three factors constraining the possible extent of the modifications.

6.4 Modifications to the System Cont'd.

First, some customers required proof of the actual time spent on a job. Consequently, it was not possible to consider control at any but the individual operation level. Secondly, the expense of a new or completely reorganised system was not seen to be justified by the management. Thirdly, the difficulties of implementing major perceived changes in the control system in the support organisation which had been built up round the Huizen system, were recognised as a problem to be avoided, at least until the shop floor changes had been fully implemented. The possibility of using a completely new system was therefore ruled out by the management who also felt that the reorganised Huizen system should be capable of supporting the cellular organisation with the cells treated as fairly self sufficient businesses without the necessity of significant extra modifications to the system at a later date. The objective of the modifications was therefore to modify the system to support Group Technology, minimising any basic changes to the system or to its surrounding management processes.

6.4.1 Re-organisation of Information - Basic Problems and Solutions The basic problem of reorganisation of information was that of enabling the computer to recognise a group of operations on any job as belonging to a cell. Simple solutions such as including a cell identifier in the header or operation records on input were felt to be infeasible because:

* the computer's input devices (Flexowriters) had no spare space in their input formats. Any extra information input would have necessitated extensive re-programming of the

Flexowriters and the validation and screening parts of the Huizen system.

* whilst some data on jobs previously processed by Manufacturing Division had been accumulated by use of the history file, described in section 5.2.3., much of the data was still held in the form of individual paper tapes which would have required modification if this method was adopted.
* it was hoped that extra effort associated with the cellular system in the production control and planning sections could be avoided particularly in view of the already unwieldy nature of the processes surrounding the system (see Appendix 1).

An attempt to mechanise this decision making process was therefore made.

At first it was hoped that the Opitz code could, with some minor modifications, form the basis for the processes. However, a study of some 300 sample layouts showed this to be infeasible because:

* over half the jobs studied under-went some form of painting or chemical processing. There was no information on such processing in the Opitz code.
* there was an important administrative difference between N.C. milling and ordinary milling (a different Division

and hourly rate), although both were controlled via the Huizen system. The Opitz code did not distinguish between the two types of milling

* 60% of jobs were sheetmetal. The Opitz code contained no information on sheetmetal work
* apart from processing, some 20% of jobs were required to visit more than one cell during their manufacture. Whilst it might have been possible to overcome some of these difficulties by adjusting the cellular structure, some hard core problems would probably always have remained because of particular manufacturing problems (e.g. surface grinding on cylindrical parts) and particular, specialist machines that would have been difficult to divide amongst cells in an organisation of Manufacturing Division's size (e.g. 3 jig borers needed by 8 cells).

The Opitz code is fundamentally associated with the geometry and surface features of a component. As such, it appears unsuited to the solution of detailed routing problems.

Since the Opitz code appeared unsuited to this task, a solution was sought via the "machine group number". This three digit number was associated with each operation on every job and was the existing means whereby the computer structured its information. There were two key problems surrounding the use of the number:

6.4.1 Re-organisation of Information - Basic Problems and Solutions Cont'd.

* a single number was allocated to each machine type - Drills = 085, Jig Borers = 088. Because machines of one type could appear in more than one cell, no simple solution via the existing information structuring mechanism was available
* changes in the allocation of the machine group number were difficult because of the limit on the numbers available (200) and the large amount of data held on individual paper tapes. Any change would have required extensive editing and modification of the information both in the paper tape data bank and on the computer files. Such an exercise would have put an unacceptably large load on Production Control staff.

Consequently, an attempt was made to solve the problem of information re-structuring by building a decision process into the Huizen system whereby the cells could be recognised from their constituent (and existing) machine group numbers.

Use was made of the "rates routine file" which contained data to support another system associated with cost allocation. With some minor modifications to the existing supporting software, this file was capable of holding data structured as shown in figure 41, viz cell numbers and names together with the numbers and names of the machine groups comprising the cell.

6.4.1 Re-organisation of Information - Basic Problems and Solutions Cont'd.

A link was built between this file and the Huizen system input programs to build up a sorted core table (for fast access) of the machine groups in each cell e.g.

CELL NO.	NAME	CONTAINS	MACHINE	GROUP	NUMBERS		
332	Turning Team	030	052	060	061	062	
		063	064	065	066	070	
		075	076	080	085	090	095

The acceptance program of the Huizen System which passed validated data from the paper input tape to the main system data file was then modified to include the following routine.

STEP	ACTION
1.	Read a data on a job into core.
2.	List all machine groups visited up to the first inspection operation or end of cell operation (see below) into a (core) table.
3.	Sort the table into numerical order and count number of groups (N).
4.	Compare table of machine groups required for this part of the job with table of groups occurring in each cell and score "hits" (machine groups needed occuring in cell for each cell (Hj)).
5.	If a) all Hj < N reject job and record on error list b) Hj = N for one cell only, add cell number to each operation record covered in this list. c) Hj = N for more than one cell go to default option (see below) and print warning on error list.
6.	Repeat steps 2 to 6 for the next list of operations until all operations on the job have been exhausted.
7.	Repeat steps 1 to 7 for all jobs input.

6.4.1 Re-organisation of Information - Basic Problems and Solutions Cont'd.

The flow diagram of this program is shown in figure 42.

Via this process, most jobs were passed to the data files with the cell number appropriate to each operation recorded against the operation's data. Some jobs could be made by more than one cell, so a routine was designed to cope with these on the basis of a "default option". At the time of writing, the only potential confusion lay with items that required milling and/or drilling only on machines that occurred in both the Turning and Milling cells. For simplicity, it was decided to load all these jobs to the Milling Cell. Some layouts were found where a mechanical inspection did not form the natural dividing point between cells. In those cases where it was felt logical to have an inspection (because of the plan to make cells responsible for their own quality) an inspection operation was added. In some cases, an inspection operation would not have been warranted and, in these, an artificial inspection operation was added and named an "end of cell operation". This was needed in only 5% of jobs.

In both cases, no re-programming of the input devices was necessary since the information to be added had the same structure as that already entered via the Flexowriters and input programs.

Whilst the total number of jobs requiring some form of correction was in the region of 25%, very few proved necessary because of the system's decision making process, most being due to either failure to include appropriate inspection operations when jobs had been previously loaded, or new inspection requirements because of the plan for cellular accountability.

The mechanism provided the basis for the restructuring of information output from the system necessary to support Group Technology. No re-programming of the input devices was necessary and the adjustments to the input programs were minimised. The modifications to the data bank of paper tape were reduced considerably to a level that could be coped with by the existing production control staff.

Use of the rates routine file provided an independent means of adjusting the computer's model of the organisation to keep pace with any future changes without the need for modification to any programs in the Huizen (or any other) system.

Examples of the use of this solution to the routing problem, in the restructuring of the information provided by the system to support the cellular organisation and to reinforce the benefits from Group Technology, are given below.

6.4.2 Modifications to the Capacity Loading Scheduling Process

Figure 43 is an example of a "load chart" - the information used by the production controller when negotiating due dates with the customer divisions. The existing load on each machine group in a section was shown as a function of time. All overdue work was shown as "backlog". Any work due to be performed during the four weeks after the printout was produced was shown in the week concerned.

6.4.2 Modifications to the Capacity Loading Scheduling Process Cont'd.

Work planned for the next 11 (4 week) months, was shown by month and any work scheduled more than 12 months ahead was shown as "forward load". A continuous decimal week numbering system was used and the load information was derived from the estimated load time for each operation.

Figure 44 is an example of the revised format of this information used after the implementation of Group Technology. The new load charts were planned for each cell together with an overall chart displaying the total load for Manufacturing Division. As can be seen, the important concepts underlying the original version have been preserved, but some key refinements have been introduced to support Group Technology. These refinements were:

* the information was organised on a cellular basis. It was hoped that, by this means, not only would the load to the cells be better planned, but also the path to management of the cells as small business would be eased by promoting the cellular thinking of the production controllers. The new format could be used, either with the current organisation of production control staff or with an organisation based on more autonomous cells where some production control staff formed part of the cell.

6.4.2 Modifications to the Capacity Loading Scheduling Process Cont'd.

* the planned load was broken down by machine type with the machines arranged in the most likely job processing sequence reading from the left. It was hoped that this information would help the schedulers to balance the load to each machine type to minimise the requirements for operator flexibility.
* the planned load was compared with a crude estimate of available capacity (using the 30 hours/man/week rule) as before. An indicator (+) was provided to highlight the month when the notional capacity exceeded the planned load to assist the production controller in his negotiations on due dates.

A suggestion that the capacity planning process should be refined, either simply by indicating the nominal capacity of each machine type or by using a more sophisticated figure computed from an analysis of the trends of current performance was rejected as an over complication that might distort the proper running of the cell.

In addition to modifying the information supporting the negotiations of due dates and long term scheduling, a key change was made to the definition of the due date itself. Prior to Group Technology, a due <u>week</u> was agreed. This seemed to be an undesirable contraint because:

* dividing jobs into weekly "piles" gave insufficient scope for making parts in families
* the due date was agreed many months in advance when the planning of the customer divisions was usually not well

6.4.2 Modifications to the Capacity Loading Scheduling Process Cont'd.

defined on the job concerned and, in the case of new jobs, Manufacturing Division's estimate was simply a crude guess. Considerable departures from the due date achieved by Manufacturing Division often went unnoticed by the customer divisions indicating that to tie Manufacturing Division down to a due week at this stage, was unnecessary.

Therefore, to increase the scope of parts family manufacture, the due date was defined as a due month. To allow for better planning in the customer divisions and to keep pace with changing priorities, more use was planned of an existing re-scheduling aid to change the due date of a job after it had been input to the Huizen system.

The old scheduling rule (back scheduling 1 week per operation of 30 hours or less and thereafter 1 week per 30 hours allowing 4 weeks contingency) was changed to back-scheduling of 1 month per cell visited, assuming that all operations within a cell could be completed within the month. The four weeks contingency allowance was preserved and the existing practice of down batching to keep operation times below 30 hours was encouraged. Inter-operation queue times of 1 day were allowed instead of 1 week.

6.4.3 Modifications to Tool Marshalling - The "Tool Ready Card" The existing practice of ordering materials and tools was preserved (see Appendix 1) but the control of tool requirements was tightened. Use

6.4.3 Modifications to Tool Marshalling - The "Tool Ready Card" Cont'd.

was made of an existing facility indicating the availability of materials by return of a "material ready card" (see Appendix 1). This facility was extended to indicate "tools" ready. Cards similar to the material ready card were to be produced by the computer for each special tool required. The cards were returned to the tool storeman (who controlled all special tools) when he had received the appropriate tool from either the tool room (new) or the long term (existing) store. Where a tool was already in the store or (rarely) needed on more than one job in a given month, a simple labelling system was used to reserve the tool and prevent its return to the long term store. The tool ready card acted in the same way as the material ready card, i.e. preventing generation of the work packet and controlling the appearance of the item on shortage lists.

6.4.4 The Work Issue List Appendix 1 describes the "Work Issue List", the document used to guide all Manufacturing Division's short term loading and routine progress actions (see figure 45). The Work Issue List suffered from 4 disadvantages from the point of view of Group Technology:

* it was not suited to the cellular organisation because it was designed to cover progress of materials and work for the whole Division and was orientated round the old machine group concept.
* the structure of the document was not supportive to parts family manufacture because no information was given to aid division of components into families

6.4.4 The Work Issue List Cont'd.

* Production of the list each week matched the 1 weeks queue between the operations under the old scheduling rule but could not cope with the 1 day queues demanded in the new situation.
* No information was given to aid marshalling of tools

Accordingly, the information on the Work Issue List was restructured on a cellular basis and printed on separate documents produced to guide the functions of:

* material and tool marshalling/chasing
* short term loading/job sequencing
* shop floor progressing.

6.4.5 Material and Tool Marshalling/Chasing - Shortage Lists Figure 46 shows the shortage list designed for marshalling and chasing materials and tools for each cell. Items would appear on the list if their appropriate "ready" cards had not been returned within 4 weeks before they were shown to be needed. The "remarks card" facility was included to cater for known reasons for the shortage occurring outside the control and responsibility of Manufacturing Division.

6.4.6 Short Term Loading - The Work Availability Listing Figure 47 shows the document devised to aid the short term loading and sequencing processes. The Work Availability List was designed to give each cell a picture of the forward load of jobs for which materials, tools and "work packets" were available. Where items were being worked on before becoming available to the cell, the previous cell's number was provided

6.4.6 Short Term Loading - The Work Availability Listing Cont'd.

to guide progressing effort if necessary. For similar reasons, if the job was due to go to another cell, subsequent to being completed by the cell concerned, the subsequent cell's number was also shown.

To aid parts family manufacture, the Opitz code was printed. Although, at the time of writing, the concept was insufficiently developed for any decision to be made on the appropriate sort sequence of the code, an option for sorting on up to 3 digits of the code was included.

The Work Availability List allowed the shop loaders to use the work packets similarly to the way they had used them before Group Technology, whilst aiding the process of sequencing.

The combination of material and tool shortage lists and work availability lists for each cell produced a much more manageable set of information more appropriately organised to guide the necessary marshalling, loading and chasing actions and was more supportive to the concepts of parts family manufacture and cells as semi-autonomous businesses. Further assistance was, however, necessary to aid job sequencing in the cells.

6.4.7 An Aid to Job Sequencing The "Ouija Board" as this aid was dubbed by the Shop Loaders, was designed to help overcome the difficulties of job sequencing to avoid machine interference and promote parts family manufacture. It was based on the well known Gannt Chart (44) - see Figure 48.

6.4.7 An Aid to Job Sequencing Cont'd.

Steel sheets 8 ft. x 4 ft. were painted white and ruled horizontally and vertically to form a grid. Each cell was provided with two of these sheets on which to plan 14 days work. Each machine in the cell was listed at the left of the sheet so that the vertical rulings could represent elapsed time in ½ hour steps. Coloured magnetic strip was cut into lengths representing various times from ½ to 4 hours and stored in divided trays for easy access.

Work packets were selected into families using the work availability list and a judgement of the likely family relationships. Initial experiments isolated change of material as the major cause of delay in re-setting a machine so the colour of the magnetic strips was made to designate material type as follows:

Green - aluminium

Yellow - brass

Red - stainless steel

Brown - fibre or plastic

Black - mild steel

White - other

Machines were then allocated to jobs by placing appropriate lengths of magnetic strip against the machine to be used to represent the time for which it was to be allocated to the particular job concerned. The job number was written on the strip for identification purposes.

The strips were placed on the boards and moved until the best looking sequence had been obtained for the 14 day's work. This program was agreed between the production controller and the cell supervisor and up-dated each week to allow for slippage, absenteeism, breakdowns, etc. and to incorporate the next 5 days work. Once agreed, the sequence was not to be disrupted without the agreement of the Divisional Manager.

The sequencing aid proved very successful in highlighting the conflicting problems of a short term production plan with minimum inter-operation queueing. A particular problem proved to be the lack of flexibility of operators who were at this stage unwilling to operate more than one type of machine. A key objective of the sequencing was therefore to maintain a load on the subsidiary machine operators whilst preserving the full loading of the lead machines and obtaining at least some of the benefits of parts family manufacture. Whilst this objective asked much of the production controller involved, with some assistance on technical decisions from the planning engineers and supervisors, a workable sequence soon proved relatively easy to establish after a few tries and a number of minor adjustments. Although the sequences produced in the working situation were probably not the optimum, considerable improvements were noted (see Chapter 7). The major problem proved to be more one of discipline in the operators failing to follow the agreed sequence. Other problems noted included persistently slow operators whose job over-ran the next operation's planned start time - particularly important as delays accumulated during the week - and absenteeism. The slow operators

6.4.7 An Aid to Job Sequencing Cont'd.

could be catered for by feeding them one operation jobs as far as was seen to be fair by the other operators. Problems of absenteeism proved more intractable, but centred on a few operators that were persistently absent. This problem was partially solved by re-deploying operators from one operation jobs to multi-operation jobs if absenteeism would have affected the subsidiary machine operator's load. Both problems were alleviated by the operators' willingness to become flexible in overtime, so the sequence could be maintained. It is important to note that the cells were loaded to 40 hours per man per week (less planned absence - holidays, union meetings, etc.) even though work was accepted to the level of only 30 hours per man per week. Whilst some slippage from the target was persistent, a steady improvement in productivity was noted during an experimental period, at least part of which may have been due to the new methods of production control.

6.4.8 Effects of Short Queues and Sequencing on Progressing and Customer Liaison Progressing action can be of two kinds - pull through and push through. Most production control systems contain elements of both.

Pull through progressing is the usual norm in machine shop situations where jobs that are undergoing manufacture, but are late, are actioned because of a customer's complaint or the appearance of the item on a shortage list.

6.4.8 Effects of Short Queues and Sequencing on Progressing and Customer Liaison Cont'd.

Push through progressing occurs where an item is forced through the manufacturing process by design rather than by default and is incorporated in most production control systems by basing the progressing action on due date priorities determined before the manufacturing process starts.

Group Technology changes the emphasis on the type of progressing employed because of the short lead times possible in the cellular situation and the necessity of avoiding disruption of a carefully designed job sequence. More emphasis is placed on better long/medium term planning to get overall priorities into a good order and to marshall materials and tools so that the jobs, once loaded to the shop floor will be naturally pushed through the system in a short time without disrupting the job sequence once prepared. To sum up, Group Technology requires more push and less pull through progressing.

To achieve this objective, two types of action are necessary:

* good customer liaison needs to be maintained to ensure the quality of the schedule
* the shop floor systems must support a push through rather than a pull through approach, in particular, avoiding disrupting a job sequence once started.

6.4.9 The "Micropert" The prime document used to liaise on job progress with customers, was the "Micropert" - see Figure 49. Because Customer Divisions were primarily interested in kits of components from which to assemble complete products, the micropert was based on the kitting

6.4.9 The "Micropert" Cont'd.

concept, by listing all jobs for one product together. Against each job the planned operations were listed in order of action by showing their machine group numbers next to a picture showing the action plan as a function of time. As operations were completed, the machine group number was deleted from the list so only actions yet to be performed were shown. On the basis of this picture, production controllers and customers could negotiate revised priorities when jobs were late or required more urgently than had been planned in the context of other jobs required for the same product.

Production control staff were very attached to the micropert, even though it was not particularly suited to the Group Technology situation (for the usual reasons - machine groups and short thru-put times). They saw it as their main support in customer liaison. Because of their attitude, it was decided to alter the document minimally as follows:

* a tool ready indicator was included in addition to the material ready indicator to show more clearly whether the job could start.
* the cells planned to be visited by the jobs were listed in addition to the machine groups, using the decision process described in 6.4.1.

These indicators would strengthen the ordering of priorities and the marshalling of materials and tools to improve the potential for push through methods on the shop floor already strengthened by the improved capacity loading, scheduling, marshalling and progress information described above.

6.4.10 Performance Measures   Whilst the new load charts and better information available to control tools and materials by cell would help create a good push through situation, it was felt that a greater consciousness of the ongoing objectives of Group Technology was necessary to ensure that due attention was paid to these on the shop floor. Consequently, two new performance measures were designed to display the thru-put times and due date delivery performance achieved to each cell and to the production control staff.

It was hoped that display of these performance measures would create a better task identity in the cells so as to improve Manufacturing Division's ability to push through jobs with minimal progressing effort or disruption to the job sequences and to improve the level of productivity.

6.4.10.1 Thru-put Times. Figure 50 is an example of the thru-put ("lead") time measurement provided by the computer for each cell. The flow diagram of the supporting program is shown in Figure 51. For each completed set of operations in the cell (determined by the decision rule discussed in 6.4.1) the elapsed time in weeks from the start of the first operation to completion of the delimiting inspection operation was computed. This information was used to update a frequency table held in core. The frequency table was a matrix α_{ij} where the rows represented the achieved thru-put time and the columns represented the week in which the inspection operations were completed. Thus, if job k had a thru-put time of i weeks and was delivered in week j, the element α_{ij} of the frequency table was increased by 1. The frequency table was compiled as described for all jobs completing a delimiting inspection in each of 32 weeks before the

6.4.10.1 Cont'd.

compilation date of the report. To compare performance over a long period of time, the report could be produced for any desired compilation date. The data source was the archive file (described in Chapter 5) which had been incorporated as an ongoing part of the system.

6.4.10.2 Due Dates. The production of the due date delivery performance measure followed a similar pattern. The difference between the planned and actual completion dates of each job was used to update a frequency table as described above. This difference defined the number of weeks early or late of the job at that point and enabled the printout shown in Figure 52 to be produced. Printouts were produced for each cell and for the whole of Manufacturing Division.

In both cases (thru-put time and due date) initial experiments displaying median, extreme and upper/lower decile indicators (between which 80% of the results would lie) were abandoned in favour of simply printing the frequency table together with an indicator (*) to show the median result for each week.

6.4.10.3 Productivity. The standard measure of productivity provided by the Huizen system was the 'M hour report' shown in Figure 53. The 'M' hour was a standard measure of productivity used throughout the Philips group and was defined as:

$$60 \times \sum_{\text{All operations}} \text{Estimated Load Time} \Big/ \sum_{\text{All operations}} \text{Measured Load Times}$$

6.4.10.3 Cont'd.

The report was provided each week and was compiled from data on operationsclocked as completed within the previous week. Various allowances were used to modify the achieved 'M' hour according to the amount of time spent on work for which no estimate was available and standard "routines" - holidays, sickness, repair, scrap, etc. The allowances allowed the time clocked on jobs by the operators to be reconciled with the attendance time of the operator and were standardised throughout the Philips Group as a "fair" measure of productivity.

From the Group Technology point of view, the item of primary importance was to organise the results to reflect the new cellular structure. The rates routine file solution described in 6.4.1 enabled a bridge to be built between the Huizen System and another system used to compute 'M' hour results in the Assembly Divisions. The report shown in figure 53 was therefore deleted and replaced with the report shown in Figure 54 provided by the alternative system. It remains to be seen whether this report will have a direct influence on the productivity of Manufacturing Division. The original Huizen system report suffered from inaccuracies in the clocking system and errors in the program used to compute productivity. Previous attempts to find the "bug" in the program had proved abortive and Manufacturing Division had used the report little. No information was (or is) provided on the performance of individual operators because the Trade Unions had negotiated an agreement to this effect. Without such a feedback link, to base the report on reality and display results to guide operators' individual improvement efforts, training, supervision or disciplinary action, the effectiveness of such performance measures must be reduced.

6.4.10.3 Cont'd.

Partial rectification of this problem may be achieved by display of all the performance measures in the cells, so at least the operators can see the overall results achieved by their cell.

6.5. Conclusions on the Modified System At the time of writing, many of the modifications to the Huizen System were in the early stages of implementation. The intention of this chapter has therefore been to illustrate the philosophy and methods used in the modifications rather than to measure the particular efficacy of the new system.

Figures 62 and 63 show flow diagrams of the original and modified system. The re-structured information should provide a better support for the cellular organisation and reinforce the benefits to be obtained from Group Technology. Particular benefits that have been noted were achieved through the use of:

* the lead time and due date performance measures which were the first to be implemented and attracted a good deal of interest. They provided valuable evidence in the economic experiment described in Chapter 7.
* the sequencing aid which has proved to be a valuable tool to learn about and solve some of the problems of job sequencing. Its chief defect has been the effort needed to compile alternative sequences. Chapter 8 contains some ideas for alleviating this problem.
* the "tool ready" cards and the tightening of the material and tool marshalling procedures which are diminishing (at least on a subjective basis) the disruption to job sequences.

6.5 Conclusions on the Modified System Cont'd.

Whilst these improvements show promise for the new system, it provides no direct means of solving some important ongoing problems of the original system. In particular:

* no scope existed for improving the links between the Huizen System and the customer divisions so that changes in the forecast output of finished products and stocks/ work-in-progress in the assembly divisions could be properly taken into account. Until these improvements can be incorporated, it seems unlikely that moves from strictly jobbing to batch production control with the associated economic benefits will take place
* the system remains unwieldy in the areas of initial planning/methodisation/estimating/scheduling, largely because scope for improvement in these areas was limited by the degree of change permissible in the support organisations, although management felt the objective here had been met
* the problems of inaccurate "clocking" and lack of confidence in the estimating process have been, at least, partially, alleviated although no complete solution is yet available. A solution is important because the ultimate measured productivity of Manufacturing Division depends on it and the shorter job queues make the sequences more sensitive to the differences between estimated and actual load times.

6.5 Conclusions on the Modified System Cont'd.

* the problems of "sideways loading" still exist. These are at least partially dependent on the speed of the methodisation/estimating process taking place before manufacture controlled by the Huizen system can start.

Chapter 8 has some suggestions for reducing these problems which are discussed in greater depth in Chapter 9. However, although it is also too early to say how effective the cellular organisation and further application of Group Technology principles will be, in solving some of the remaining problems, there would seem to be scope for:

* reduction in the "sideways loading problems" by restructuring the support organisations and delegating part of the production control problem to the cells. A better support organisation structure would also reduce the unwieldy nature of the system and improve the links between Manufacturing Division and its customers.
* reduction of the estimating and clocking problems via more effective group processes in the cells. Better task identify and a good commitment towards achieving set targets in the cells could go a long way towards solving these problems.

The philosophy and methods used in the re-design illustrate the problems that may be encountered by the in-house systems designer when faced with the task of matching an existing system to a new organisation based on Group Technology. If substantial installation

6.5 Conclusions on the Modified System Cont'd.

costs and considerable changes in the methods and tasks of the support organisations are to be avoided, then it seems better to make a serious attempt to modify the existing production control system rather than to re-design from scratch or to replace the existing system with a new one.

Other difficulties encountered illustrate the problem of installing Group Technology in one part of a large and complex company where the system has existing links with other parts of the organisation. The existing links may prove difficult to change and new links may be difficult to forge if the project is constrained to operate in one area of the company.

CHAPTER 7

COST EFFECTIVENESS OF A TRIAL IMPLEMENTATION

7.1 Implementation and Management Changes

Figure 18 is an outline of the plan for the implementation of a new organisation based on the analysis described in Chapter 5. The trial cell was to be laid out, staffed and then used to develop the new ways of working. It was hoped that the majority of the associated problems would be solved before extending the concept across the rest of Manufacturing Division. The success of a full implementation in Manufacturing Division would provide a good basis for expansion into other areas of M.E.L. and perhaps some other parts of the Philips Group.

The early stages of the implementation confirmed the seriousness of the sociological problems outlined in Chapter 5 of which the one with the most serious short term effects was the refusal of the operators to become flexible without some form of payment. Whilst wishing to compensate the operators fairly for a contribution to an improvement, the company was unwilling to proceed with this without better information on the extent of the financial benefits of the new system.

During this period, the Senior Production Manager left the company and was replaced by a Director in charge of the entire technical sector who had a particular interest in improving the cost effectiveness of the company. This management change meant that the Group Technology project lost its prime motivator and sponsor and a clear need was felt

7.1 Implementation and Management Changes Cont'd.

to demonstrate the effects of the new ways of working to the new Director. These two problems directed the efforts of the project team towards establishing the cost effectiveness (or otherwise) of the new ways of working. The computer played a significant part in this exercise which is described below.

7.2 Measurements Planned

Four factors related to the cost of production were selected for measurement, viz.:

* overall 'M' hour achieved by the cell each week.

  The 'M' hour was a standard measure of productivity used throughout the Philips group and was defined as

  $$\frac{\text{Standard hours produced}}{\text{Actual time taken (hours)}} \times 60$$

  The standard hours produced represented the sum of the estimated load times of jobs delivered by the cell each week. The actual time taken was the time recorded by the operators as having been worked on these jobs via the Huizen System. Because of some defects noted in the existing Huizen System 'M' hour reporting routine and because the report appropriate to the turning cell was not available at the time of the experiment, the actual hours were retrieved by hand from the job cards before sending them to the computer. For reasons of clarity, jobs with artificial allowances to cover rework or estimated times that were known to be in doubt were excluded.

7.2 Measurements Planned Cont'd.

* the setting time estimated to be required on jobs representing a month's work was compared, assuming
  a) simple due date priority (the pre Group Technology rules) and
  b) a work sequence designed to exploit the concept of parts family manufacture.

  Whilst no special tooling had been designed (e.g. a la Drurie (3)) it was hoped that some effects would be seen. The "Ouija" Board was used to derive the sequence (see Section 6.4.7).

* the thru-put times measured from the start of the first operation to the completion of the mechanical inspection, denoting the end of the cells responsibility, were compared on jobs delivered by the cell during two 3 month measurement periods; one pre-Group Technology and one post Group Technology. In both cases, the thru-put time data was obtained from the modified Huizen System using the report described in section 6.4.10.1. For the pre-Group Technology case, data was selected from jobs that would have gone to the Turning Cell had it been in existence, using the same selection rules as in the post-Group Technology case.

* the ability of Manufacturing Division to deliver jobs in accordance with the due date agreed with the Customer Divisions was compared using the Due Date Delivery performance report incorporated in the modified Huizen System (see section 6.10.4.2). The same comparison periods and job selection rules were used as in the thru-put time measurements.

7.2 Measurements Planned Cont'd.

In addition to the measurements described above, three intangible factors were considered, viz.:

* improvements in Industrial Relations
* simplification of the Control Problem
* increases in business flexibility.

7.3 Results of The Measurements

7.3.1 'M' Hours Results Figure 55 shows the Turning Cell's 'M' hour measured between 26th May 1975 and 15th August 1975. Prior to this period, the results showed no significant trend. Expected values for the productivity increase were derived using a standard least squares linear regression analysis as provided on the company's time sharing computer service. Defining the productivity change as:

$$\frac{\text{Productivity at the end of the Period} - \text{Productivity at the beginning of the Period}}{\text{Productivity at the Beginning of the Period}} \times 100$$

gave a probable productivity change of + 14%.

7.3.2 Setting Time Jobs producing a total turning load of 357 hours of which 91 hours would have been required for setting prior to Group Technology were sequenced to minimise setting time as described above. The sequencing exercise enabled the setting time to be reduced by an estimated 25%. The reduction was 36% on automatic lathes and 10% on centre lathes.

7.3.3 Thru-put Time Figure 56 shows histograms of the thru-put ("lead") times achieved for Turning Cell jobs delivered before and after Group Technology methods were adopted. For comparison, the histograms are shown back to back. The mean lead time is shown to have reduced by 46% and the median by 64%. Before Group Technology

7.3.3. Thru-put Time Cont'd.

was adopted, 35% of jobs took longer than 4 weeks to pass through the "cell". After Group Technology, this figure reduced to 11%.

7.3.4 Due Date Figure 57 shows similar histograms displaying the due date delivery performance achieved on turned items before and after Group Technology methods were adopted. Before Group Technology, turned items were delivered 3.7 weeks late (mean result). After Group Technology methods had been adopted, this result improved to 2.9 weks early. The number of over due orders reduced from 51% to 29%. A slight improvement in the accuracy of delivery was noted, jobs being delivered within ± 1 month of the due date increasing from 57% to 60%.

7.4 Discussion of Assumptions

As with any industrial experiment, it is difficult to show that a measured effect is due to a specific cause. It can be tacitly assumed that the measured results are due to the effects of Group Technology rather than anything else. This assumption may be dangerous and some specific factors that could have influenced the results are discussed below.

7.4.1 Hawthorne Effect It is well known (45) that conducting an industrial experiment can produce changes in performance simply by virtue of the extra interest shown in the group concerned. The usual technique adopted to isolate this effect from the measurements is to compare the results obtained by the group using the new methods with a control group using the old ones. Such a technique was considered difficult to apply in this case because:

7.4.1 Hawthorne Effect Cont'd.

* there was no directly comparable group of operators to those comprising the Turning Cell. Effects of load on Milling and Drilling, N.C. and Sheetmetal workers which had not adopted Group Technology methods at the time of the experiment, would not have been comparable with the effects on the Turning Cell.
* Production Control acted as one activity for the whole of Manufacturing Division. There were, therefore, no comparable control groups.
* management vetoed the extra effort that would have been entailed in the measurement of two groups rather than one.

Ellimination of the Hawthorne effect having been rejected as impractical, it had to be hoped that taking measurements via the computer system reduced the amount of special inter-actions caused by the experiment to a minimum. It was, however, not possible to conduct the experiment without the staff involved being made aware of it, so an element of the Hawthorne effect must inevitably have perturbed the results to a certain extent; the amount or direction of the perturbation being essentially unmeasurable.

7.4.2 Validity of Data Whilst the data surrounding the results was collected carefully, many questions surround its validity which have not yet been possible to answer. Much of the information depended on accurate clocking of the data cards returned to the computer by the operators. A detailed enforcement of clocking accuracy would

7.4.2 Validity of Data Cont'd.

have been difficult to implement and might have increased the Hawthorne effect, but such checks that were made showed some errors in clocking, missing cards and extra cards reporting unplanned and unestimated work although no deliberate mis-clocking as described in Chapter 6 was detected. The extra cards were ignored for the purpose of the 'M' hour calculation and there was no obvious reason for the lead time and due date comparison to have been altered by these effects. It is, therefore, thought that the effects of non valid data are small.

7.4.3 New Machines The Huizen clocking system assumed that each operator could only work one machine at a time. The advent of the Accuratools (see Chapter 5) meant that this was no longer true and one or two of the eight operators in the Turning Cell could (in theory at least) be operating two machines at once and thereby earning double credits towards the overall productivity of the cell. This effect may have accounted for some of the measured increase in productivity but it should be remembered that the Accuratools had been introduced six months before the start of the experiment and any false increase in the cell's productivity would have been expected to show itself earlier. A possible explanation is that an increase in productivity due to the new machines was eliminated by "Parkinson's law" until the progressive tightening of the 'M' hour measurements which led up to the experimental period prevented these losses occurring.

It should be noted that all jobs going to the Accuratools were re-planned to eliminate the possibility of a time estimated for a manually controlled lathe being compared with a time achieved on an Accuratool.

7.4.4. Effects of Load The most potentially serious perturbation of the thru-put time and due date results, could have been produced by a change in the load of turned items between the two measurement periods. A lighter load could produce at least part of the measured improvements in lead time and due date performance.

The overall load of turned items in the two measurement periods proved impossible to compare because of the unknown effects of sideways loading. Whilst a certain lightening of load could have occurred during the second (post Group Technology) period, the effect is not thought to be too significant, particularly since a real drop in load might be expected to produce a drop in productivity (the reverse was measured).

7.4.5 Variability of Productivity The variability of the productivity measurements was large. Confirmation of the results by taking measurements over a longer period would have been more satisfactory, to increase the statistical significance of the results and assure the permanence of the improvement. A longer measurement period might also have reduced any appreciable Hawthorne effect.

7.4.6 Overall Impression of the Measurements Whilst each measured item can be questioned in isolation, the overall picture appears to be one of substantial improvement due in the main to Group Technology. It is clear that the computer played a significant part in the measurement process in the following ways:

7.4.6 Overall Impression of the Measurements Cont'd

* the measurements would not have been possible without the data provided as routine to the Huizen System. In particular, the historical comparison between Group Technology and non Group Technology results would have been much more difficult and would have had to have been set up well prior to the Group Technology experiment - when management had foreseen no requirement for comparison
* a fair amount of data processing is required to achieve the lead time and due date measurements and to perform a linear regression calculation. The extra effort required to perform this process manually would have been considerable and for this reason possibly not attempted
* the existence of the computer as a measurement process familiar to the operators probably reduced what could have been a very considerable Hawthorne effect.

7.5 Worth of the Improvements

Normal commercial confidentiality prevents publication of the value of the measured improvements. However, there are a number of points worth making on the particular value of these improvements bearing in mind Manufacturing Division's position as a partial supplier of M.E.L's metalwork requirements.

7.5.1 Overall Productivity Improvements The 'M' hour and setting time measurements were conducted separately and can thus be combined to assess an overall contribution to productivity. The savings in setting time represented a 7.3% increase in productivity, bringing the overall productivity improvement to a potential 22½%.

Because Manufacturing Division had only sufficient capacity to produce 1/3 to 2/3 of M.E.L's total metalwork requirements, a two-fold gain is achieved by an increase in productivity:

* the existing load costs less to produce
* parts that would otherwise have to be sub-contracted can be made "in-house" with consequential improvements in control and more effective use of existing overheads.

7.5.2 Lead Time and Due Date Improvements Evaluation of savings from a reduction in lead time and an improvement in deliveries against due date, is more difficult. The tangible savings come from a reduction of work in progress that would not be possible to measure without a regular physical count and valuation (a costly and difficult process to implement). Two types of work in progress should be considered:

* "primary" work in progress - partially completed components on Manufacturing Division's shop floor
* "secondary" work in progress generated by a lack of confidence in Manufacturing Division's customers, causing them to order too much too early
* "tertiary" work in progress caused by Manufacturing Division's failure to deliver planned parts on time or to cope sufficiently with emergency manufacture

of unexpectedly scrapped parts. The lack of the required items would cause work in progress of other items to build up in the customer divisions until Manufacturing Division could deliver the parts required to complete the assembly.

The primary work in progress can be valued from a knowledge of the average lead time, rate of material consumption and rate of added value. Assuming a linear model, the work in progress will be proportional to the lead time and will thus reduce accordingly. The values for Manufacturing Division indicated that, although worthwhile, the primary work in progress savings were probably insignificant compared with the productivity savings.

The secondary work in progress is more difficult to assess. The probability that customer divisions will order items to be delivered too early will depend on a number of factors (such as the degree to which the metalwork is on the critical path of the product manufacturing plan, the particular confidence level of the customer and Manufacturing Division's reputation). The value of secondary work in progress is higher per item since it comprises completed components, so the only control factor is the time that items remain in stores before consumption. In Manufacturing Division's position, a clear demonstration of a good delivery reputation, plus some education and direction of the customer division's job controllers who do the early ordering, would seem to be the answer to reducing secondary work in progress. It was not possible to assess any improvements achieved

7.5.2 Lead Time and Due Date Improvements Cont'd.

in the level of secondary work in progress (in fact the thru-put times and due date improvements may well have produced a temporary increase in finished part stocks).

Tertiary work in progress can be much more serious. Metalwork comprised well under 20% of the value of most of M.E.L's finished products and the "knock-on" effect of late delivery from Manufacturing Division could cause a very rapid build up of tertiary work in progress followed by a large drop in productivity caused by operators having to wait for the undelivered items and then re-learn their assembly processes. Whilst it was not possible to assess the savings produced in these factors by the implementation of Group Technology, it was noted that whereas Manufacturing Division had been identified as the major "bête noire" in M.E.L. at the start of the project, no complaints were received on turned items after the implementation of Group Technology.

7.5.3 Comparison with Other Companies Comparison of achievements in one company with published results of achievements in other companies are always dangerous because:

* bad results are rarely published (or admitted!). Surveys of achievement may produce a falsely high average
* improvements are relative and it is rarely possible to compare before and after situations between companies.

However, to give some perspective, the measured results of the turning

7.5.3 Comparison with Other Companies Cont'd.

cell experiment are compared with the results of a recently published survey (4) of over 40 firms who claim to have introduced Group Technology. The survey reports Group Technology implementations ranging in size from single cells producing a very limited number of products to complete rejection of conventional manufacturing methods in favour of Group Technology principles as demonstrated by Ferranti, Edinburgh (40). The comparison is shown in Figure 58.

The reduction in work in progress includes only an estimate of the reduction in primary work in progress in the turning cell. The reduction in overall stocks was not possible to estimate for the reasons given in Section 7.5.2. The other figures are those given in Section 7.3.

Neglecting the arguments surrounding the validity of inter-company comparisons, it would appear that M.E.L. has a long way to go in achieving the maximum benefits from Group Technology. The figures given are only those for the turning cell and represent an extremely small improvement in total company performance. Even so, according to none of the measures does the turning cell reach the average improvement claimed by other companies participating in the survey. Assuming the validity of the comparison, the below average results may have been produced because:

* the turning cell was chosen for the trial implementation more to explore and develop Group Technology methods rather than to maximise the related cost benefits. Greater benefits might have been found by a trial implementation in other metal working areas

7.5.3 Comparison with Other Companies Cont'd.

* many of the problems highlighted by the trial implementation had not been solved at the time of the experiment. These problems are discussed below.

7.6 Problems Reducing the Effectiveness of Group Technology

The operation of the trial cell highlighted a number of problems of which many were still unsolved at the time of the experiment. These problems probably reduced the benefits obtained from the new system and may be classified under three headings - sociological, technological and control.

7.6.1 Sociological Problems The supervisory and operator problems mentioned in Section 5.3.6 made a teamwork approach to the implementation difficult. New disciplines were more difficult to establish and negative reactions were produced in production control staff who were originally in favour of the new system. Attitude problems had persisted in Manufacturing Division for many years and a number of managers had failed to find adequate solutions. Indeed, a previous manager had deliberately operated a divide and rule policy which may have deepened the gap between management, supervisors, operators and support staff. An additional problem may have been the lack of a sufficiently clear policy on the role of Manufacturing Division which was required to act partially as a high speed technological problem solver to cope with last minute design changes or rectifier of quality problems on sub-contracted metalwork and partially as a low cost producer of items. These roles were essentially incompatible, given the existing organisation and supporting systems. The role conflict inevitably produced supervisory and operator problems because the staff

7.6.1 Sociological Problems Cont'd.

involved had to act for part of the time in a semi-skilled environment to detailed laid down methods and for the rest of the time in a skilled environment with little or no technological support.

It is probably unreasonable to assume that operation of a trial cell would provide a swift solution to deep rooted attitude problems that had persisted for a number of years, even though Group Technology should provide a means for their solution in the longer term by promoting teamwork approaches to problems, inproving the job satisfaction of the operators and shortening the shop floor queueing times, sufficiently to allow proper technological and control support for both roles.

The fact remains that these sociological problems were not solved by the time the experiment took place and they probably account at least partially for the lower than average benefits measured.

7.6.2 Technological Problems The concept of parts family manufacture is an important part of Group Technology. By the time of the experiment no progress had been made either on the design and use of composite component techniques or on the standardisation of components in either the design of current or future products. This lack of progress probably limited the extent to which savings in setting time could be achieved. It was noted that Ferranti (40) use Drurie's techniques (3) extensively in their turning cell and claim a 95% reduction in setting time. It is also possible that greater than average reductions in setting time could be achieved in Milling and N.C.

7.6.2 Technological Problems Cont'd.

working areas of Manufacturing Division, which would increase the total result after extensive implementation of Group Technology.

7.6.3 Control Problems The production control system had not been fully modified by the time the experiment took place. Whilst the lead time and due date performance measures and the "Ouija" board were available, no link existed to allow the long and medium term production plans to exploit the new concepts. Production control staff were having to operate two systems, one to support the functional layout and one to support the Turning Cell which inevitably diluted their efforts. Many of the disciplines - e.g. not starting a job until material and tools were available, observing the agreed job sequence, etc., were not fully established, which must have limited the potential reduction of lead times and improvement of due date delivery performance. Whilst the "Ouija" board gave some help in constructing a good sequence, a better aid might have allowed greater benefit to be obtained.

A further limitation on the reduction of lead times and work in progress was produced by the conflicting systems in that the production control staff tried to deliver kits of components, for assembly either in Manufacturing Division or the customer divisions. This task could have been more difficult given the two systemsand may have reduced the potential benefits. In any case, these benefits would be expected to be smaller for turned items which had a shorter than average lead time.

7.7 Conclusions of the Experiment

It is difficult to establish an industrial experiment which will truly demonstrate that observed effects are due to a specific cause. The design is particularly difficult when the measured area is a small part of a closely related whole, since management may be unwilling to embark upon an adequate experiment because of its cost and complexity.

The computer proved to be a valuable tool in the experiment, not only by virtue of its data processing power, but also in minimising what otherwise might have been a larger Hawthorne effect.

The experiment succeeded not only in demonstrating the benefits of Group Technology to the new management, but also in focusing the attention of many people involved with some of the problems of Manufacturing Division. The work was seen to be sufficiently valuable to warrant continuation of the implementation and an increase in the involvement of other areas of M.E.L. to further increase the benefits and to minimise the boundary problems introduced into areas such as T.E.O., Accounting, Personnel and the customer divisions by the adoption of Group Technology methods on a wider scale.

CHAPTER 8

IDEAS FOR THE FUTURE

8.1 Introduction

There appears to be considerable scope for extension of the work described in this thesis both in the practical application of Group Technology principles in other areas of M.E.L. and in the development of the ideas stemming from the work reported here.

8.2 Extension at M.E.L.

8.2.1 More Cells M.E.L's real requirement is for kits of finished parts rather than individual components. The real benefits of reduced thru-put times will not be felt until all the metalwork can be obtained in less time so that the total lead time of the end product can be reduced. Clearly, there is a need to create further cells in Manufacturing Division to cater for:

* Milling and Drilling
* N.C.
* Sheetmetal
* Process

Whilst the Milling and Drilling "Cell" was almost created by exclusion when the Turning Cell was created, more attention will be needed to ensure that it can be operated as a self sufficient unit. Similar problems to those encountered with the turning cell will have to be dealt with in the provision of necessary subsidiary machines. If these and the existing sociological and control problems can be solved, then there may be considerable scope for productivity improvements and setting time reduction. There are already indications that the attention to the design of jigs and fixtures and to job sequencing

8.2.1 More Cells Cont'd.

could all make significant inroads into the current setting times which are longer than those in the Turning Cell.

Progress in the N.C. area, although outside the aegis of the existing project team, would also seem to be possible since there is evidence of long lead times and scope for improvement in the reliability of delivery and levels of work in progress. As yet no development of the techniques reported to be successful by Allen (10) has been attempted and there may be scope for a considerable cost reduction of items currently cast and N.C. machined by the use of such methods. It is indicated that there is also scope for improvements in the Sheetmetal Section along the lines explored for the Turning Cell. Two proposals for designing cells in this area are being considered, one involving production flow analysis and the other component classification. Which method is used will depend on the suitability of sheetmetal classification systems currently being studied.

The design of the process "cells" has yet to be seriously considered. There is an obvious division of processing (cleaning, plating, etc.) from painting (masking, spraying, drying) and there appears to be no alternative division of this area or any practical possibility of integrating process/painting activities with the metalworking cells because of contamination and safety considerations. Certainly, no classification system is known that would suit this area, so any further sub-division would have to be based on production flow analysis.

8.2.1 More Cells Cont'd.

There is also scope for implementation of Group Technology in another area of M.E.L. - the Watson subsidiary which manufactures glass and metal components for optical equipment. There seems to be a parallel to be drawn between work at Watson's and the implementation at Rank Taylor Hobson (15). Consideration will be given to this idea in the near future and initial indications look promising.

The rest of M.E.L. is more concerned with assembly of components into finished products where the metalwork is a minor part of mostly electrical products. To implement Group technology here, where there are few complicated and expensive machines to set up and little scope for parts family manufacture would, to the purest, seem to be more the implementation of Group Working rather than Group Technology. Whatever the semantics, there may be considerable scope for better layouts of the shop floors, for better groupings of workers and for better methods of rationalising the design and assembly of the products. A preliminary survey is to be conducted to see if a significant potential for improvement exists.

As for other areas of the Philips Group, some interest has been engendered in central departments and other plants, but as yet no plans are known for application of Group Technology in the ways being considered by M.E.L. It appears to be early days yet, although considerable strides have been made in the introduction of autonomous work groups in assembly areas which should form a valuable basis for the introduction of Group Technology in the many component manufacturing activities throughout the Philips Group.

8.2.2 <u>Production Control</u> The implementation of the complete, modified production control package described in Chapter 6 started in January 1977. It is too early to comment on its effectiveness. Future work on this package should be initially aimed at the simplification of its operation. There would seem to be scope for allowing "on-line" updating and interrogation of the data files which should make the package considerably easier to use and make feasible other techniques to be described later. The essence of good production control is accurate and up-to-date information and "on-line" in "real time" (files up-dated immediately) or "real-enough-time" (files up-dated periodically - say every ½ hour to every day) should improve the state of the information in the Huizen system considerably compared with the current once-a-week up-date on the majority of the data.

The availability of a data base that can provide such up to date information would make possible improvements in both the long term loading and shorter term problems of job sequencing. "Real time" operation would allow trial of alternative load plans before an optimum was chosen and would ease the re-scheduling problem. Mechanisation of the "Ouija Board" layout would be possible by allowing the job sequences to be chosen by a planner examining their effects in a conversational manner with the computer. Trial and error planning on a "what if?" basis.

Notwithstanding the availability of real time access to the Huizen system, some work is already underway to examine the potential for productivity improvements by using the computer to examine alternative sequences automatically. Initial experiments have concentrated on

8.2.2 Production Control cont'd.

sequencing jobs to the Accuratools, using a limited Monte Carlo simulation of the possible job sequences. It has been found that whilst the optimum sequence may take a considerable amount of computer time to derive, even using powerful algorithms such as "branch and bound" (39), a significant and worthwhile improvement can be obtained by simply evaluating a number of feasible sequences at random and choosing the best. The likelihood of a significant extra improvement being discovered through the generation of more sequences seems to diminish rapidly with the number of sequences generated. Work continues to extend the ideas with the intention of incorporating such a sequencing aid into the Huizen system should the savings prove worthwhile and achievable with a low overhead of computing time. These savings should be more easily achieved with such a sequencing aid available because of the complexity of the manual sequencing problem.

A combination of automated sequencing and real time operation might allow the computer to guide operators directly to the best job to start. The computer would be in possession of the up-to-date manufacturing situation and could evaluate the best sequence to follow on the basis of the information to hand when prompted by an operator seeking a new job to start.

There is also scope for improving the effectiveness of the control system through better design of its data and information links with the rest of M.E.L. Automated links to forecasts of product output and stocks in the assembly divisions could reduce what is now a considerable clerical exercise to translate the requirements of Manufacturing Division's customers into a schedule for the shop floor.

8.2.2 Production Control cont'd.

The effectiveness of this process would be further increased by more attention to the design and methods of the support organisations and on the delegation of part of the production control task to the cells together with an understanding of how moving from jobbing to batch production control could bring further economies..

8.2.3 Group Working The re-organisation of the production control system has made the creation of further cells feasible. More cells may serve to solve some of the current sociological problems, but may well create others. The problems thought likely to diminish are those connected with the special nature of the trial cell. It should prove easier to gain acceptance for a group reward scheme that would not be possible to implement in the trial cell in isolation and the operators would no longer feel themselves singled out for the attention of management. Both changes should help to reduce the current difficulties on the shop floor. It is also likely that more cells will help the supervisory problem for much the same reason although some difficulty may be expected in the conflict between imposed leadership (the supervisors) and the autonomous nature of the cells. However, moves towards the creation of further cells would be unwise without a full appreciation of the depth of the sociological problems in Manufacturing Division and without both considerable efforts to solve the problems and some clear evidence of their solution. Efforts are being made with the staff on the shop floor by holding a regular meeting between the Divisional Manager

8.2.3 Group Working cont'd.

and the operators. Although the supervisor is present at this meeting which is showing clear signs of improving communications and reducing the barriers between the shop floor and the management, there are no signs that similar improvements are being made at the supervisory level. Parallel efforts were started by holding meetings between the supervisors, production control and planning staff, two representatives of the team implementing Group Technology, and a sociologist. These meetings ceased after the unfortunate early death of the sociologist before any real improvement could be achieved. The re-creation of these meetings is thought to be highly desirable.

The creation of a fully cellularised Manufacturing Division will ease considerably the load on the supporting production control staff. With a trial cell working the production control staff are essentially operating two production control systems and are having to manage the interface between them. This extra load may be at best a partial cause of the negative reactions described in Chapter 5.

Once a fully cellularised operation has been implemented and is seen to work, the management may feel more able to move towards giving the cells more autonomy and, in effect, treating them more as businesses in their own right. Little or no modification to the Production Control system should be necessary to achieve such a situation, but careful attention would be necessary to the way planning, estimating and production control tasks were delegated to

8.2.3 Group Working cont'd.

the cell. Fully autonomous working would be difficult to achieve because of the complexity in the relationships with the customer divisions that would be created. A good compromise would seem to be to delegate planning and shop floor production control to the cells, retaining a small central "customer liaison department" to handle the interface between Manufacturing Division and its customers. It would probably not prove feasible to delegate the task of estimating to the cells because of their monopoly situation and the policy of the Philips group where estimating/target setting is deliberately separated from the line management.

Another aspect of Group policy which may affect the extent to which the cells can be autonomous is the accounting process. The Philips Group operates an accounting system which is different to that of most companies in that assets are revalued and recovered at the point of added value in the amount charged for a man-hour's work. At the time of writing, only one hourly rate was used across the whole of Manufacturing Division and the setting of separate rates for the different cells could produce a heavier load for the accounting departments. The modified production control system could provide a good deal of help in the costing process via the use of the rates routine file link described in Chapter 6. This link should make automated job costing easily obtainable leaving the only extra work in the setting of the annual hourly rates. This extra work is not thought likely to be significant.

8.2.4 Standardization Currently, there is very little parts standardization at M.E.L. Whilst there are limitations imposed by customers who paid for the development leading up to many of the drawings and who demanded that their own standards be adopted, there is still considerable scope for M.E.L. to influence future designs and to take opportunities to change existing designs. The opportunities for standardization exist at three levels: methods, parts and assemblies.

Standardization of methods covers the selection and/or design of such items as threads, chamfers, undercuts, raw material sizes and grades, tolerances, etc. To illustrate the potential for methods standardization the sorted list of Opitz code numbers against part numbers described in Chapter 5 was used to retrieve drawings having a similar Opitz code number. This component family comprised pillars and spacers that were made in some quantity and with a wide variety of forms in the Turning Cell for various customers. Figure 59 shows part of this sample together with a suggested "composite component" (see figure 60) that would fulfil the purpose of the other components, but require little alteration to the setting of tools during the manufacturing process. Whilst all the components have a 4-40 UNC thread, the manufacturing method has to change, because of detail differences concerning the chamfer (size and angle) on the front of the thread; the overall length of the threaded section and; the design of the shoulder where the thread meets the main body of the component. It was also noted that the various materials chosen did not line up with those stocked as standard, although no technical reason could be found to justify this situation.

8.2.4 Standardization cont'd.

For 10 drawings selected, 8 different manufacturing methods were necessary. Using the suggested composite component, the 8 methods would be reduced to 1 with consequential savings in setting time and Planning/Production Control effort.

Standardization of components may be regarded as the use of "preferred" items wherever possibe, rather than re-designing every item from scratch. Whilst there is obvious scope for improvements in drawing office productivity by the use of preferred standard metalwork components, this saving may well be negligible compared with savings in: "debugging" new designs; production control effort; work in progress; overall lead times, etc. achieved through a reduction in the variety of items produced.

Standardization of assemblies is an extension of the preferred component concept to cover some standard metalwork assemblies. There may be scope for standardization of some equipment "racks" and "trays" but significant inroads into standardizing M.E.L's metalwork assemblies would require a substantial change in marketing and design policy that would take a long time to implement and is probably not warranted by the potential savings.

One area, falling between component and assembly standardization that might be profitable to investigate, is fabrication of machined castings and some conventional sheet metalwork items from N.C. machined standard plates. Allen (10) has claimed to have reduced lead times for metalwork items, previously cast, from 2½ years to 2 months on initial orders and from 6 months to 2 for repeats. He also claims that a

8.2.4 Standardization cont'd.

cost reduction of 64% was achieved by the use of these methods. Computing techniques are much in evidence in the achievement of these results. A mini-computer is used to digitise a drawing and produce control tapes for the N.C. machine and an automated inspection machine directly. Standard features (holes, slots, clearways, etc.) can be automatically called in at the time of digitization of the drawing and aids to visualization are provided by the computer to assist checking the tapes before cutting metal. Such techniques could well find use at M.E.L.

At the system level, the secret of effective methods and parts standardization appears to be the ease of retrieval of standard drawings. So long as it is easier for the draughtsmen to draw a new item than to use a standard, then the likelihood of a standard item being used diminishes. M.E.L. has made attempts to improve the availability of information to draughtsmen by providing manuals of standards, but with more than 500,000 drawings on file, retrieval is a large task and, so far, access by drawing number is the only system used. Access for standardization purposes would require classification of a large enough cross section of drawings to give a representative sample and a filing system organised according to the classification system. The classification system would have to strike a balance between ease of use and accuracy of description of the component's geometry, surface features and method of manufacture and the filing system would have to be very easy to use. A profitable

8.2.4 Standardization cont'd.

line of investigation would appear to be a combination of a mini-computer and a microfilm filing system.

To make the use of standards stick, not only drawings but standards manuals, tolerance/cost curves, preferred stock item lists, etc. should be available from this access system. A change to the current drawing process would be desirable so that classification is done at a very early stage in the design. The system used should ensure a constant pressure to classify and examine standards rather than draw a new item. Currently, drawings are produced first and standards thought about later. To realise the benefits of parts standardization the reverse must be the case. Figure 61 illustrates a possible change to the drawing process compared with the current methods.

8.2.5 Automated Estimating and Methodisation Given a rationalised approach to the design of metal components, the prospect of automating the estimating and methodisation process might become more feasible, perhaps along the line suggested by Arn (12). Reductions in the clerical effort and elapsed time that take place between receipt of an order and the start of component manufacture would be possible on a much greater scale than with the current level of standardization, although real benefits might still be seen with no improvements in standardization.

Apart from the obviously greater scope for standard methods and estimates resulting from standard part designs, a great benefit would accure if the estimating process could be integrated with the design process to allow examination of production costs at the design stage and build in "value engineering".

8.2.5 Automated Estimating and Methodisation cont'd.

The Philips Group has already made progress on automating methodisation and estimating (25) and the potential for the application of this work at M.E.L would appear to be significant.

8.3 Extension of Knowledge

8.3.1 Cell Design The computer is a powerful analytical tool, particularly when it can be used to manipulate existing company data. The state of the art is moving rapidly towards company data bases. Although initial results are not as promising as first hoped, it will not be long before data base systems become utilised for management of the total information in companies. The Philips Group has made strides initially based on I.C.L.NIMMS and more recently on their own data base management system which allows total computerisation of their planning, scheduling and goods movements systems. The information is derived from Commercial forecasts and product structure data and new machine shop schedules can be provided directly from input of a new Commercial forecast and up-to-date information on stocks and work-in-progress. Access to the data in such systems, particularly in real time could produce a powerful tool in the design of a new organisation embodying Group Technology principles. The process could be similar to that discussed in Chapter 5, but as yet the analytical tools have to be custom built. No packages are available.

More work needs to be done to link the classification and production flow analysis techniques of cell design. Both techniques have good

8.3.1 Cell Design cont'd.

and bad points and neither is ideal. Particularly important is the need to keep the cellular structure up-to-date with the parts spectrum unless a gradual increase in the in-balance of the cell load is to occur.

Classification systems are by no means ideal and their use in organisations is not yet fully thought out. A classification system for cell design and up-dating may not be suitable for drawing retrieval, shop loading, routing or sequencing purposes, but it seems unlikely that organisations will use more than one classification system. The pressure for one classification system to be all things to all parts of the system may so stress current systems, that parts classification may be abandoned. Considerable scope exists for the development of classification systems, particularly for the multi-product organisation where metalwork and in-house manufactured components may only be a small part of the final product. In particular no classification scheme is known which can help in the design of cells in an assembly area.

Production flow analysis with its heavy dependence on the current working methods in the organisation using it, is also far from ideal. There is scope for developing its objectivity and scope for easing its use. Further mechanisation of this process and the availability of computer tools that can operate with data base management systems could spread its use considerably, particularly if the technique could be extended to include automated layout planning of a revised organisation resulting from its use.

8.3.2 Production Control The solution of the production control problem in a Group Technology environment provides further scope for extension of knowledge. Existing computer packages for production control do not readily lend themselves to the Group Technology situation and development is needed in:

* The design of information systems appropriate to a cellular organisation
* The design of sequencing algorithms to exploit parts family manufacture and avoid machine interference
* The control and avoidance of disruption caused by machine or tool break-down or operator variability, sickness or absenteeism
* Design of estimating systems automated to produce job instructions and time estimates from part geometry, surface features, tolerance, etc.
* Efficient interfacing of production control with accounting systems, payment/incentive schemes and the design/estimating process.

8.3.3 Sociological Development The implementation of any new system involves people. The implementation of Group Technology poses particular problems in the organisation and restructuring of work that involves skilled operatives and supervisors. Although theories governing the motivation of people in socio-technical situations are well established (5, 14) and are being examined with particular reference to the Group Technology situation (6), as yet there is no

8.3.3 Sociological Development cont'd.

clear recipe for success involving the many problems that arise during the implementation of this new Manufacturing system. Work needs to be done in developing and transferring sufficient understanding of these theories, particularly for those responsible for managing the change from functional to group based production systems. By this means, projects may be approached in a way that guarantees a greater chance of success.

Further work in organisation development also seems necessary for better integration of cellular working with other aspects of industrial society at, supervision, middle management and Board levels (16).

The computer is an important factor in all these areas and there would seem to be considerable scope for greater understanding of the inter-relationships of people with computers in the GroupTechnology environment. Part of Group Technology is an improvement in the sociological structure of companies. In organisations possessing a computer a successful bond between man and his information systems must be sought.

CHAPTER 9

OVERALL DISCUSSION

9.1 Introduction

Arguably, the research described in this thesis produces a number of conclusions in a wider vein than simply specific applications of computer systems in Group Technology. The entry point to the research was the interaction between computer based management information systems and Group Technology, but, during the progress of the work, other areas of knowledge impinged on the research, so an attempt will be made to discuss conclusions on these wider matters as well as on some applications of computers in Group Technology.

9.2 The Project

Because the work was centered on a project to install Group Technology in one area of a large multi-product company, it is important to take this situation into account in any conclusions drawn from the research.

9.2.1 Degree of Success The success of M.E.L's project in achieving its original objective, the installation of Group Technology in Manufacturing Division, seems a bit like the curate's egg "good in parts". Whilst, as Chapter 7 shows, the project produced measurable benefits in the trial cell and indicated potential for a cost effective implementation in the rest of Manufacturing Division, progress beyond setting up the trial cell and operating it has been limited. The intention of the company is to extend cellular working, at least throughout the rest of Manufacturing Division. Other areas being considered for the installation of Group Technology are the N.C.

9.2.1 Degree of Success cont'd.

machine section, some assembly areas and the subsidiary company specialising in glass and metalwork component manufacture for optical equipments. However, the management momentum behind turning these intentions into reality does not yet appear to be large enough for real and substantial progress to be made.

9.2.2 Limiting Factors The main factors that appeared to limit the progress of the project in Manufacturing Division were the sociological problems with the operators and supervisors, the changes in senior management during the course of the project and difficulties associated with the interfaces between Manufacturing Division and other areas of M.E.L. Whilst these factors were all significant, there appear to be more fundamental causes of the problems.

First, and probably most important, was the lack of clarity of the role of Manufacturing Division in M.E.L. No clear policy existed for metalworking in M.E.L. and a succession of managers had tried to fulfil a number of conflicting requirements within some very rigid constraints. The requirements appeared to be:

* To act as an efficient producer of metalwork so as to be competitive with sub-contractors on price and delivery ("production") for the Customer Divisions of M.E.L.
* To provide a high technology production centre making parts that were too difficult for sub-contractors to make ("problem solving")

9.2.2 Limiting Factors cont'd.

* To provide a high speed rescue service to cover for delivery or quality failures in sub-contractos ("problem solving")
* To support pre-production and development metalwork requirements when the capacity of M.E.L's model shops proved inadequate ("problem solving")

The "production" and "problem solving" roles conflict because of differences in the manufacturing systems required to support them. The "production" role demands low costs which implies a high level of operator and machine utilization and imposes pressures for the use of lower levels of skill (lower cost and a greater willingness to perform repetitive jobs). The "problem solving" role demands a much higher level of skill and a greater degree of flexibility from the operators and lower machine utilization to ensure a good reaction time to solving new problems.

The prime constraint was the physical size of Manufacturing Division's shop floor which restricted Manufacturing Division's output to between 1/3rd and 2/3rds of M.E.L's production metalwork requirements.

The size of Manufacturing Division was important because:

* It was not large enough to cater for M.E.L's total metalwork requirements
* It was too large to act as a pure problem solving activity

9.2.2 Limiting Factors cont'd.

* It was not large enough to contain a problem solving activity separable from the main production activity, but spanning a sufficiently broad area of technology and having enough capacity

No opportunity arose to consider expansion of the existing shop floor because the company was already hard pressed for space.

Other constraints, which made the management of Manufacturing Division difficult, were associated with the systems and interfaces between Manufacturing Division and other areas of M.E.L. In particular, no company wide system existed to estimate the implications of changes in the required output of finished products from the Customer Divisions to changes in the likely load on Manufacturing Division which made it very difficult to obtain an adequately smooth load for efficient operation. The accounting system posed other difficulties in requiring that cost data be collected and that overheads, capital and space costs be recovered at the operation level. The effect of the accounting constraints, apart from the high level of data collection necessary, was to distort the comparison between Manufacturing Division's costs and those of sub-contractors and hence decisions to "off-load" of manufacture in-house. The distortions exacerbated the loading difficulties.

The effect of the conflicting requirements, the physical constraints and systems distortions meant that the load to the shop floor varied not only in level, but also in character. Operators and supervisors saw a load that was heavily production orientated at times and were pressurised to work efficiently to detailed and specified job instructions. At other times the load was orientated more towards problem solving, when no instructions were available, but a high degree of skill was demanded.

The continuously changing role demanded of the operators and supervisors was possibly a key underlying cause of the sociological problems of the project. The problems had existed for many years before the implementation of Group Technology was attempted and it seems likely that they were rooted in the conflict between the high level of skill demanded to fulfil the problem solving role and the lower emphasis on skill, but higher demands on measured productivity in the production role.

The role conflict did not only affect supervisors and operators. The production control staff were not provided with an adequate system to cope with the changes in level and character of the load. Because the production control system demanded so much data, not only in the form of job instructions but also in the provision of detailed time estimates, a significant amount of time elapsed between a job being given to Manufacturing Division and its effect on the load being displayed. Additionally, no system existed to take into account the load presented in problem solving. The only method open to the controllers was to degrade the assumed capacity available from each operator in the control system to allow for this "sideways loaded" work. The degraded capacity distorted the performance measuring system and made the Supervisors' and Production Controllers' jobs more difficult since work turned down by the Production Controller because of an assumed lack of capacity was sometimes taken by the Customer to the shop floor for "sideways loading" where he stood a good chance of getting it made.

9.2.2 Limiting Factors cont'd.

These difficulties could well explain a large proportion of the observed sociological problems in Manufacturing Division, although as far as the project is concerned, due consideration should be given to the failure to include representatives from the Shop Floor, Supervision and Production Control at a sufficiently early stage in the project. Such a failure could well have meant that the operational staff in Manufacturing Division saw the Group Technology project as externally imposed and to be resisted or at most, put up with, rather than feeling a sense of ownership and looking for how improvements could make their job clearer or more rewarding. Fears of Supervisors and Production Controllers that the Cells would take over large parts of their jobs may have then become more important and deepened the gulf between themselves and the project.

Although Group Technology may provide an eventual answer to this conflict, no solution is yet in sight. The answer would, however, appear to be more likely to be obtained given the clearer picture of the real requirements of M.E.L. from Manufacturing Division generated by the use of the new manufacturing system and its greater ability to cope with problems as routine.

The second underlying factor limiting the progress of the project was possibly the low level of the initial installation. Thornley (46) has advocated a total approach for the installation of Group Technology in a company and Burbidge's survey (8) of many installations has indicated that "low key" attempts starting with one or two trial cells are much less likely to suceed than a high key project initiated and led by top management. A low key project is likely to flounder when it meets difficult interface problems or has to take policy decisions into account that were made in isolation from the project.

Examples of such difficulties associated with this project were:

* The failure to obtain agreement to modify the payment system. The lack of suitable compensation was the stated reason for the operators unwillingness to cooperate and provide the flexibility necessary to obtain maximum benefits from Group Technology. The non-cooperation of the operators was a serious set-back to the implementation and was only partially overcome by the unification of the turning cells (described in Chapter 5) and the production control system modifications (described in Chapter 6). The failure seemed mainly associated with management's fear of potential difficulties with staff in areas not implementing Group Technology and exemplified the interface difficulties of a low key project.
* The policy decisions to purchase 3 automatic lathes. These new machines were the first automatic lathes to be used in Manufacturing Division and some technical difficulties were experienced with their introduction. They represented a significant change to the capacity of the trial cell and gave M.E.L. the ability to manufacture significant quantities of work previously sub-contracted. Because no methodisation or load time information existed on this work, the effect of the new machines on the capacity of the trial cell could only be roughly estimated in comparison with the careful

9.2.2 Limiting Factors cont'd.

and detailed analysis that led up to the original cell design which did not include the automatic lathes. New problems were encountered with operators who objected to their jobs being, at times, devoted to finishing large quantities of parts which could not be fully dealt with by the automatic lathes. Additional problems were generated in production control of the larger batches capable of being digested by the new machines and in achieving a good balance of work in the cell without devoting its full capacity to completing a large batch from the automatic lathes to the exclusion of most other work. The performance measurement systems were distorted because they assumed that one operator was required to work each machine which was no longer true of the automatic lathes. Even though the worst effects of distortion were eliminated from the measurements, doubt was thrown on an important part of the cost benefit analysis. Coping with these problems and helping to solve the technical problems associated with the introduction of the new machines diluted the efforts of the project team and delayed the progress of the project.

* As yet no progress has been made on persuading design departments to include Group Technology principles in the design program. Consequently, parts family manufacture and standardization of metalwork features and components does not take into account the new techniques until the parts are made by Manufacturing Division.

9.2.2 Limiting Factors cont'd.

Not only does this reduce the benefits of the new system, but it increases the load on Manufacturing Division who has to code its own drawings and take into account a perhaps unnecessarily wide spread of technology

* At least part of the delay in modifying the production control system occurred because of priorities other than the Group Technology project. However, the main delay was the need to satisfy the new Plant Director of the appropriateness of the new ideas to M.E.L's needs before the modifications were allowed to commence.
* Some key production control problems were those concerned with the interfaces with the customer divisions and the support organisation. The project as structured, was not empowered to tackle these problems.

It is, of course, sheer speculation as to whether a higher key project would have been more successful than the project conducted, which was low key in nature.

Arguments supporting such a theory include:

* High key projects tend to get more advance thinking prior to setting up. In M.E.L's situation, some form of cost justification would probably have been demanded in advance of starting the project which would have obviated the delay and change of direction half way through

9.2.2 <u>Limiting Factors</u> cont'd.

* High key projects get more and better people on them. It is obviously difficult to be objective about the quality of people on M.E.L's project, but representatives from Supervision, Shop Floor and Supporting staff in Manufacturing Division, plus others from the interfacing areas of design, the Customer Divisions, Personnel, Accounting, etc., if properly managed, could have produced a higher rate of progress on a broader front. Particular problems that might have been tackled more effectively by such a team include those of operator payment, interfaces with the customer divisions and incorporating Group Technology in design. It was noticed that incorporating a representative from the computing department did much to reduce any interface problems in this area.
* High key projects get taken into account when policy decisions are made. Whether or not the automatic lathes would have been purchased, is perhaps not so important to the argument as is the mechanism of a high key project that would have taken such factors into account or delayed the purchase until a full examination of the effects of the new machines had taken place.
* High key projects can tackle bigger and more fundamental problems. Arguably, it is more likely that the conflict in Manufacturing Division's role would have

been tackled and solved by a high key project. It must also be recognised that no scope existed on the project for examining more fundamental groupings of products and manufacturing facilities, such as integrating part of the metalwork activity with assembly areas and combining Manufacturing Division with model shops, etc. A much higher level project would have been needed to tackle these problems.

Against these arguments for high key projects are the problems associated with the pace necessary for a project involving a large number of people and a high level of change. The rate of improvement associated with the project must be maintained or its cost will come into question. If the pace demanded is too high, stubborn problems requiring time for their solution may get overlooked. Particular dangers are to be associated with problems of the sociological type encountered on this exercise. When people are being asked to change their attitudes, it seems doubtful whether a greater number of more socially skilled people telling them to do so will have the desired effect. Whilst skilled industrial relations expertise may help, there are perhaps problems that only time will solve and there is a distinct danger that high key projects could flounder on such problems or leave them unsolved only to have their re-appearance reduce or eliminate the long term benefits accruing from the installation of Group Technology.

9.3 Effects of the Computer

The use of computers has proved to be a key influence on both the direction and progress of the project.

9.3.1 Analytical Phase Effects During the analytical phase (see Chapter 5), two main separate courses of action were followed: one applying the modified Opitz code to drawings and the other developing the data capture system and the means of accessing and analysing the file produced. Only when both exercises were complete was it possible to embark on designing a new cellular structure for Manufacturing Division. The effectiveness of such a process depends on the speed at which the desired ends are reached, the quality of the analysis produced and "spin off" benefits that were a feature of the particular approach adopted.

In many one off analytical situations, a computer approach may take longer and cost more than more simple manual methods. However, although there is no control against which to truly evaluate the M.E.L. project, a case can be made for the efficacy of the computer solution in this situation.

First, although the analysis was only carried out for the General Machining area, the computer system is equally applicable to the N.C., Sheetmetal and Process areas with little or no modification. Any modifications are likely to be restricted to coping with a different classification system which will have only small effects on the programs and no structural effects on the files generated by the system.

Secondly, the data capture system was operating before the end of the coding exercise and its development was thus not on the critical path of the project.

Thirdly, the time required to finish the analytical programs on the 360/135, to transfer data to the time sharing computer and to develop the analytical programs was small and was completed well before their

9.3.1 Analytical Phase Effects cont'd.

use was required by the project.

Fourthly, the use of the time sharing - interactive techniques - added power to the analytical process, allowing the evaluation of a considerable number of alternatives in a very short time. A very effective man/computer interaction was observed to weld the production engineering skills of the project team and analytical power of the computer together. This part of the analytical phase was arguably both the shortest and the most effective part of the project.

Fifthly, a large measure of confidence in the results was generated by using a computer system. Once tested, the computer programs were known to produce accurate analyses and the "authenticity" of an output on computer paper in the minds of people not familiar with computing techniques should not be underestimated. Trust in the accuracy of the results and the resulting conclusions was probably important in reaching the decision to create the trial cell.

Finally, the data capture system provided the basis for an ongoing archive of computer data on every day events in Manufacturing Division, which, although previously missing from the production control system, provided a basis for the improved performance measures described in Chapter 6 and for several new and different analyses since. The cost justification experiment could not have been carried out without a much greater data collection exercise than was necessary because the data capture system existed and lately, the system has formed the basis for investment decisions on new equipment in Manufacturing Division.

9.3.1 Analytical Phase Effects cont'd.

Since none of the benefits described above would have been achieved by the use of manual methods, which in any case might well have consumed more labour than the development of the analytical system, the overall effect of the computer on both the time scale and the effectiveness of the analytical process must be regarded as beneficial with extra "spin off" benefits for the future which should not be underestimated.

9.3.2 A Packaged Alternative At the start of the project, a packaged alternative based on production flow analysis was considered and rejected. Much of the data provided by the data capture system would have been necessary to provide as input to the package and the fees that would have been necessary to pay to gain access to the package were large. Few of the "spin off" benefits that were obtained from the in-house system would seem likely to have been obtained from the package, although the support necessary to develop the use of the package in M.E.L. would probably have been similar. The experience gained in the manipulation of the data in the Group Technology data files, was valuable in improving the company's understanding of Group Technology. This experience would not have been gained through the use of the package because of the commercial secrecy surrounding its structure. The commercial secrecy might also have reduced the trust in the results provided though the use of the package. In hind-sight, the decision not to use an externally developed package was probably right.

9.3.3 Production Control System Modifications A large part of the project was devoted to modifying the production control system to reflect Group Technology principles and to allow better control of a cellular organisation to take place. In assessing the role of the computer in this part of the project,there are a number of important considerations.

At the start of the Group Technology project, the computer already had a substantial role in Manufacturing Division in the shape of the production control system. This system not only formed the basis for production control, but also provided the vehicle for the communication with the Customer Divisions and of methods engineering and timing information to the shop floor. The system was deeply entrenched in Manufacturing Division after many years of use and the support organisations of "Planning" and "Production Control" were built round the needs of the system. The routine management process of Manufacturing Division was also built round the inputs and outputs of the Huizen system, so any modifications to its use were not to be undertaken lightly.

It is claimed (46) that Group Technology reduces paperwork and since the production control system constituted the majority of the paperwork in Manufacturing Division the modifications to the production control system should be viewed in the light of this claim. Chapter 6 shows that whilst the amount of paperwork involved in the production control system did not go up significantly, it did not decrease significantly either, although the revised system would appear to be more manageable. The quantity of data collected has remained substantially unchanged. The modified Opitz code is added, but this is not essential to the operation of the system so the only real additional data is that necessary for description of the cells and to divide the job instructions up so that correct routing may take place. The additional load to provide this data is not significant. The information provided by the system has been modified rather than changed in volume and reorientated to:

* exploit the cellular structure of Manufacturing Division by division of the production control problem into more manageable sections
* elevate the importance of delivering to due date and achieving short lead times by providing appropriate performance measures
* provide a pressure and a means for managing the cells as semi-autonomous "businesses" by appropriate organisation of the information output from the system.

It is difficult to speculate on the future success of these modifications or on the true relative load of the new system vis-a-vis the old whilst the Production Control section has to operate both the new and the old systems at once. Only when Manufacturing Division is fully cellularised will the true effectiveness of the modified system be revealed.

If the modified system succeeds in establishing the cells as businesses it may be possible for the management to consider some more drastic surgery on the system and its associated overheads. Such a step might involve:

9.3.3 Production Control System Modifications cont'd.

* a policy decision to eliminate cost data collection at the operation level
* a demonstration that the divided production control problem can be handled without a great deal of paperwork support
* development of a more simplified means of establishing the long/medium term load in Manufacturing Division vis-a-vis that required so that good deliveries can be maintained and a rational off-loading policy followed
* development of simplified performance measures
* a demonstration that job instructions are either not needed or can be more effectively communicated to the shop floor.

At this stage, it is difficult to visualise how such extensive modifications could be successfully attempted. However, some scope is seen for reducing the time lapse between receipt of an order and issuing it to the shop floor by better systems design and a more appropriate organisation along the lines suggested in Chapter 8.

It must, therefore, be concluded that, at least, in the exercise so far, Group Technology has not so far reduced the paperwork or the associated overheads. However, the measured improvements indicate that Group Technology produced an incease in the trial cell's performance without a significant increase in the paperwork.

9.3.3 Production Control System Modifications cont'd.

There are also important underlying implications of what happened and what was achieved.

First, because the system was so deeply entrenched, the organisation was accustomed to control and costing being done in the manner indicated. A high level of control was expected and the Group Technology project was started mainly to improve the performance of Manufacturing Division to be in line with that seen to be needed by the business. A reduction in overheads was not one of the objectives but an improvement in control was. In an organisation faced with control rather than cost problems, it is probably less likely that simplification and reduction of the control system will be tackled. M.E.L. is now entering a more cost conscious phase, so it will be interesting to see if reduction of control costs and simplification of the control system becomes an important future objective.

Secondly, an important defect in M.E.L's production control process is the separate nature of the Huizen system. In building the data file to design the new organisation, special links, both computer based and manual, were forged between the Huizen system and other systems in M.E.L. These links proved too difficult to maintain on a permanent basis and so there is no direct means of assessing the implication of a change in either the product delivery or stock situation on the load on Manufacturing Division. The partial nature of M.E.L's control system may be producing effects of sub-optimisation which may be deteriorating the company's delivery performance and stock investment unnecessarily. Recently, a simple system has been installed to indicate the resource implications of a commercial forecast, which may go at least part way towards solving this problem, but a permanent solution seems more likely to lie in the company's moves towards a data base which would make a fully integrated control system more possible. Such a system would allow speedier and more effective management of the interfaces between Manufacturing Division and its customers, together with improvements in stock investment and delivery performance by more effective batch sizing and control. A related improvement might be possible in the use of Manufacturing Division and sub-contractors via a better understanding of Manufacturing Division's role along the lines suggested in section 9.2.2.

Thirdly, the modified Huizen system provides only limited help on the problem of job sequencing to exploit the benefits of parts family manufacture in M.E.L. The "Ouija boards" described in Chapter 6 are difficult to set up and provide only a modicum of assistance to solving complex sequencing problems. Chapter 8 suggests a real time computer system to evaluate more sequences more easily and quickly together with some ideas for fully automating the problem solution on a quasi-optimal basis.

It is therefore, concluded that the modified Huizen system represents an interim solution to the production control problem in Manufacturing Division. The problem of routing jobs to cells correctly has been solved with minimal change to the system and its surrounding support organisation and management processes and the information is better organised for improved control of the cells as "businesses" and for the exploitation of parts family manufacture. However, further development is necessary to fully overcome the problems associated with the interfaces between Manufacturing Division and its customers,

9.3.3 Production Control System Modifications cont'd.

the "production" and "problem solving" role conflicts and job sequencing. This development should take into account further revision of Manufacturing Division's organisation - particularly the support areas and the potential for reducing the cost of control.

It is also important to note the importance of the success of the system modifications to the Group Technology project. The Management was not prepared to go ahead with construction of further cells until the success of the system modifications had been demonstrated. Consequently, it must be concluded that, on this project, the control system was a major influence on both the direction and progress of the implementation of Group Technology in M.E.L., particularly since it provided the means of bridging a desired change to the shop floor organisation and methods within the constraints of minimal changes to the methods and structure of the support organisations and of the accounting and other systems operating in other parts of M.E.L.

9.4 Other Ideas and Conclusions

During the course of the project, several opportunities occurred both for the employment of new ideas and for observations of the effectiveness of existing techniques in Group Technology.

9.4.1 Analytical/Learning Processes Chapter 5 examines the effectiveness of the analytical process leading up to the design of the trial cell. It is clear that the analysis produced only part of the information necessary for the design of the cell. By itself, the analysis could not have achieved the end result. It was necessary to use the information from the computer in conjunction with

9.4.1 Analytical/Learning Processes cont'd.

a good deal of knowledge and judgement of both the potential benefits of Group Technology and Manufacturing Division's particular situation. At the start of the project, no one person possessed sufficient information to embark on a "peripatetic" design of a cellular system. An important aspect of the analytical approach was, therefore, a mutual learning process to combine the necessary skills for the design of the cells. In hind sight, the Opitz code was probably not the best classification system for M.E.L's future needs but, as an existing and verified system, it provided a good vehicle for the project team to get an objective view of how best to install Group Technology in the General Machining area. The combination of the classification exercise and the data gleaned from existing methods provided a powerful learning process for all involved. A particular feature was the "real time" analysis of the data which allowed a powerful learning-by-experiment process to take place.

It is only speculation to consider whether Production Flow Analysis would have achieved a similar result, but perhaps the opportunity will exist to compare the two approaches when the design of sheetmetal and process cells is attempted.

9.4.2 The Computer as a "Bridge" The use of the restructured Huizen system to bridge the reorganised shop floor with the existing Methods Engineering and Planning process has already been mentioned. The power of data processing information systems in bridging interfaces between different organisations is not to be underestimated. Good

9.4.2 The Computer as a "Bridge" cont'd.

computer systems design, however, can compensate only in part for bad organisation design. Better solutions should be looked for first in improved organisation design, rather than more clever systems. At best, a computer system can only overcome those shortcomings of the organisation that are amenable to solution by provision of better information. Such a solution is no substitute for good organisation eliminating the interface problems. It is, therefore, believed that reorganisation of the support areas in Manufacturing Division must be looked at before the full benefits of Group Technology can be realised.

9.4.3 The Computer as an Aid to Measurement The power of the computer to glean extra information from data that is collected as part of an ongoing operation provides a means of avoiding at least part of the Hawthorne effect that poses such problems in judging the improvement gained by a new organisation. The cost justification experiment illustrates this point well, but it should be noted that in an industrial situation, it is very difficult to eliminate the effects of a measurement process on the results obtained from a group of people. It is not safe to assume that, simply because the computer stands between those measured and the person doing the measuring, the Hawthorne effect is eliminated. A truely valid industrial experiment is very difficult to envisage and it is certainly not claimed that the experiment reported in Chapter 7 comes into this category. However, it seems likely that the gleaning of extra information from data provided to the computer as part of the normal process provides a significant means of reducing the impact of the measurement process on the results obtained.

9.4.4 <u>The Computer as a Decider</u> The most common use of computers in an industrial situation involves simple calculations and sorting processes only. In two cases on this project, the computing was extended into the area of routine decision making. The first example is the solution to the routing problem where production group numbers on jobs were matched with those occurring in the cells to specify which jobs should be loaded to each cell. It was noted that such a solution could not be obtained by the use of a classification system appropriate to the geometry and surface features of the parts themselves, although this problem certainly does not rule out such solutions in other situations. The approach used is probably not appropriate to production situations where individual machines are numbered since routing at the machine level rather than the group level might solve the routing problem more easily. However, given the particular situation in Manufacturing Division, the structure of the Huizen system and its data, the solution produced is believed to provide a good decision making process with little perturbation of either the system or its data and much less work for Manufacturing Division than if a manual decision making process was adopted.

The second example is in the simulation model mentioned in Chapter 8 that is currently being used to evaluate the potential for job sequencing and parts family manufacture. Here the essence of the computing process is to evaluate an adequately large number of possible job sequences, select the few that look the best and present the results for final selection by management. The approach is still in its infancy, but is already showing promising results and could form the basis for automated job sequencing in the future. Such uses of the computer, particularly if provided in "real time" to allow exploration of viable alternatives on a "what if"? basis (c.f. the analysis of data prior to cell design) would provide a means for considerable improvement of routine management decision making. Areas of particular interest for the future of Group Technology in M.E.L. include evaluation of in-house / sub-contracting decisions and batching decisions.

9.5 Coda

The computer has proved to be a major influence on the project to implement Group Technology in M.E.L. It has helped in the analysis of data, cell design and production control. The presence of an entrenched computer based production control system was a key influence on the methods adopted and the extent of the re-organisation. Whilst only one influence on a project that had to cope with the complexities of implementing Group Technology in a large multi-product company and in an area with some difficult pre-existing sociological problems, the presence of the computer was important. The wider use of computers in manufacturing industry means that the relationship between computers and Group Technology will have to be taken into account and it is felt that a great deal of extra work will be necessary before the areas touched on by this thesis are fully understood.

Edwards and Schmitt (48) concluded that:
"The impact of the cell system on production system design is almost unknown because the flow line and functional systems have been perceived as the only two manufacturing systems and Group Technology is being seen merely as a new technique".

9.5 Coda cont'd.

The problems encountered during this research have indicated that a total view of the manufacturing system is important in an implementation of Group Technology which must take into account the complexity of the relationships between parts, people, machines and information systems before a satisfactory implementation of a new manufacturing system can be achieved.

CHAPTER 10

CONCLUSIONS

1. Group Technology is not merely a new technique, it represents an alternative approach to the design of manufacturing systems.

2. If the full benefits of Group Technology are to be realised, far reaching changes to a company's organisation, systems and methods may be necessary.

3. If the extent of the changes required to fully exploit Group Technology is not realised at the outset and the implementation project managed accordingly, the full benefits of the new manufacturing system may not be obtained.

4. Because computer based management information systems can have a powerful influence on the design and operation of manufacturing systems and because of the wide and still spreading industrial use of computers, it is important to consider their potential application as part of a project to install Group Technology.

5. The extent to which a company has access to and is familiar with using computer based information systems can have an important effect on a project to install Group Technology.

6. Where significant computing expertise exists in a company, it appears undesirable to adopt a "package deal" approach to the implementation of Group Technology. It seems better to combine the company's own internal expertise on computing,

6. cont'd.

organisation and manufacturing methods with the required external expertise in Group Technology to install the new manufacturing system, rather than impose an externally developed system on the company.

7. A computer can be of considerable assistance in providing, analysing and synthesising data to aid the design of a new shop floor organisation.

8. It has been shown that a computer can be used to comb data from existing systems and combine it with data necessary for the incorporation of Group Technology principles to provide a data file suitable to support the design of a cellular organisation.

9. It has been shown that simple decision rules can be generated to describe a cellular shop floor organisation in a way that enables a computer to select data appropriate to each cell and synthesise a forecast of cellular loading patterns.

10. "Real Time" interrogation of the data file was found to be a powerful and effective means of combining the analytical and synthesising power of a computer with human judgement, expertise in Group Technology and knowledge of the organisation and methods of the area where implementation was being considered, to design an appropriate new shop floor organisation based on cellular principles.

11. Computer based information systems have an important role to play in supporting a manufacturing system based on Group Technology, particularly in areas of production control, design and payment.

12. The work flow in a functionally based batch/jobbing production organisation can be simplified by moving to a well designed cellular organisation, which should reduce some production control problems, but may introduce others which have to be solved before the full benefits of Group Technology can be realised.

13. Operators and supervisors may not be able to provide the increased flexibility necessary to fully exploit Group Technology. The need for flexibility can be lessened by designing larger cells and by good support from production control. However, many benefits may still be lost if sufficient flexibility cannot be obtained.

14. The faster reaction time required from Group Technology based manufacturing systems places a greater emphasis on good marshalling of resources and speedy solutions to problems of operator absenteeism and machine/tool breakdown.

15. In a Group Technology situation, control of production via the management of inter-operation job queues may no longer be possible because the queues are too short. There are also new shop floor routing and job sequencing problems to solve, all of which may pose problems for a conventionally designed production control system.

16. The new organisation may necessitate changes to the type, distribution and timing of information provided by the production control system.

17. It has been shown that a conventionally designed production control system can be modified to accommodate the particular needs of Group Technology.

18. An algorithm has been developed to enable the computer to solve the problem of routing jobs and information in a cellular organisation with minimal changes to existing data describing machine functions. The algorithm enabled an otherwise massive program of modifications to an existing bank of production control data to be brought well within manageable bounds.

19. The production control system was strengthened to provide better support for: balancing demands on flexibility by good capacity planning and scheduling aids; marshalling materials and tools prior to commencing production; aiding job sequencing to reduce setting times and avoid machine interference; performance measurement and the management of cells as businesses.

20. An appropriately designed computer based information system, properly keyed into an effective routine management process, can do much to maintain the effectiveness of a manufacturing system.

21. It is important for an information system to provide performance measures which relate to the key objectives of the area which it is supporting. Although existing information may already be provided on productivity and financial performance, in the

21. cont'd.

Group Technology situation it is important to measure thru-put time and delivery performance. Pictorial presentation of performance measures is effective and can be achieved by conventional computing facilities and algorithms which were developed as part of this research.

22. The modified production control system provided a bridge between the new cellular shop floor organisation and support areas of production control, methodization, estimating and accounting which could not be reorganised at the same time.

23. In some cases, it may not be desirable to change too many parts of a company's organisation and systems at once. Because the effects of Group Technology can be so widespread, it is important to provide a means of linking the areas where implementation has taken place with areas affected by the implementation, but which have yet to be reorganised accordingly. A computer information system can provide this bridge and thus generate the means for the more gradual spread of the new principles round a company and the avoidance of problems that might otherwise occur.

24. In designing manufacturing systems an organisational solution to problems should be sought before attempting an information systems solution.

25. The dependence of a company on its existing systems may have important ramifications for the implementation of Group Technology. The strength of the existing systems links with

25. cont'd.

the organisation may mean that modifications to the systems and the necessary re-training of the staff using them imposes high costs and long delays on the installation project. For this reason, adapting existing systems and providing bridges seems to be a better approach than re-designing from scratch or bringing in a new system on a "package deal" basis.

26. There are particular problems associated with the introduction of Group Technology into a complex multi-product company. These problems centre on difficulties of introducing changes in the areas suited to Group Technology without causing damaging effects in other areas unable, unsuited or unwilling to adopt the new methods. A particular problem is that of operator payment.

27. Because Group Technology is most suited to the production of components, in the complex company, it is most likely to be implemented in areas which are suppliers of other areas assembling finished products. Good systems links between component suppliers and users are important if the better thru-put time and delivery performance achieved by virtue of Group Technology is to be properly reflected in a reduction of stocks and work-in-progress.

28. It is important to strengthen the systems links between component design and manufacture if the full benefits of component variety reduction are to be realised.

29. It was shown that in the company studied, there was an important conflict between the production and problem solving roles of the area where Group Technology was implemented. The conflict undermined the effectiveness of the area, the relationships between the staff involved and the effectiveness of the production control system. The conflict caused extra difficulties and delays to the project to install Group Technology.

30. The full cooperation of all staff liable to be affected by the implementation is important if maximum benefits are to be obtained from the new system. Of particular importance are operators who have to provide greater flexibility of working and supervisors who have to cope with the threat to their jobs posed by autonomous cells.

31. At the working level, considerable efforts should go into building trust and understanding between management and the shop floor. Efforts should be made to reduce the threat of Group Technology by relating it in more familiar terms of changes to shop floor layout and the production control system.

32. In Group Technology, it appears that groups of products, parts and machines are often the primary consideration whereas, in other industrial group working situations, people have a greater relative importance. A better balance between the needs of people and the perceived efficiency of the system might produce more effective results.

33. Group Technology provides the means for tackling poor parts standardization via parts family manufacture and sequence technology and for improving standardization via design retrieval based on component classification.

34. Component classification systems are not yet ideal. A particular difficulty is the manifold requirement for a classification system in Group Technology viz. to support: organisation design and maintenance; parts family manufacture; job sequencing and routing in the new organisation; and information retrieval to improve parts standardization. Classification systems appear best suited to support standardization and parts family manufacture. The case for classification systems as the optimum basis for fulfilling the other needs has yet to be proven.

35. The extent of the changes required to fully exploit Group Technology and the magnitude of the benefits to be obtained warrant a strong link between the implementation project and top management. If this link is broken or changed significantly during the project, important changes to the direction of the project may ensue which can delay the implementation.

36. An industrial experiment that will truely establish that improvements in performance are specifically due to the implementation of Group Technology may be difficult to design and conduct.

37. The problem of justifying the start or continuation of a project to implement Group Technology can be eased if a computer can be used to provide the necessary data from that collected to support existing systems. Not only is the data collection task reduced, but also, Hawthorne effects may be minimised.

38. Whilst the implementation described in this thesis was only partially complete at the time of writing, significant benefits were demonstrated and opportunities for future development identified.

39. A total view of the manufacturing system is important in an implementation of Group Technology, which should take into account the complexity of the relationships between people, machines, parts and information systems in achieving the objectives of the business concerned.

APPENDIX 1

THE HUIZEN SYSTEM

The purpose of this appendix is to describe the Huizen System and its related management processes. A fully detailed description is not given, but an attempt is made to give enough understanding both of the system to support the arguments for the modifications described in Chapter 6 and of the data that was used in the analysis described in Chapter 5.

Figure 62 shows the main events in the production control process. 10 parts of the organisation inter-related with the system:

* Manufacturing Division's Production Control, Customer Liaison section who negotiated with the Customer Division on promised delivery dates on the basis of the known load in the system and the customer requirements
* Manufacturing Division's Methods Engineering ("Planning") section who detailed the methods necessary to manufacture each part and decided to which machine group the jobs should be loaded during the manufacturing process. Theyalso specified the material to be used in type (from the drawing) and quantity
* T.E.O's estimating section who worked out the standard time (set and run) for each operation

* Manufacturing Division's Scheduling Section who decided on the due dates for completion of individual operations on each job with reference to the due date agreed with the customer
* Manufacturing Division's Data Preparation section who punched data onto paper tape and liaised with the computer department. They also held the files of data previously input to the computer
* I.S.A. department who transcribed the information on paper tape onto magnetic tape for input to the computer and who ran the Huizen system
* Manufacturing Division's Production Control Progressing Section who loaded jobs to the shop floor and managed their progress until delivery was achieved
* Shop floor staff who returned data on time taken, quantity passed to the next operation, etc.
* A system liaison officer who was responsible for managing the allocation of production group numbers (signifying groups of similar machines) and "trouble shooting" any technical difficulties with the system by liaison with the I.S.A. department
* Accounting staff who used the data provided on times taken to compile "job costs" which were required by some customers.

The data needed to run the system was kept in 5 files.

* Drawing files containing drawings of all parts which were being or had been previously made by Manufacturing Division in drawing number order

* Master layout files containing a copy of the manufacturing instructions and the paper tape used last time a job was made. Master layouts were held in drawing number order
* The computer master file on magnetic tape containing all data necessary for the computer system to run on current jobs and data on time taken, start and finish dates and quantities passed to the next operation for each completed operation. For the order and structure of this file see below
* Work packets containing the drawing, the manufacturing instructions and punched cards for the return of data from the shop floor. One work packet was produced for each job and accompanied the job throughout the entire manufacturing process
* The "dead layout file" containing the job instructions on completed jobs. Comments were written on the job instructions as the job progressed and the "dead" layout was used to answer customer queries after the job had been delivered.

The computer system followed standard "first generation" (tape based) design practice. The system was based on one "master file" containing all the data on every job "in the system". The master file structure is shown in figure 64. It will be seen that data pertinent to each job was structured into a sequential series of records as follows:

* The "Header Record" containing details of the job starting with the job number and going on through such details as the quantity due to be delivered, the allowance for scrap, the planner responsible for detailing the instructions, etc. etc.
* "Operation Records" (one for each operation in sequence) containing detailed manufacturing instructions, set run and calculated total load times for the operation, due start and finish dates, the machine group on which the job was to be run, any special tools required, etc., together with space for recording actual performance (start and end times) and the clock numbers of the operator performing the operation
* A material record containing a specification of the material and quantity required together with the date when the material was needed.

The data fields within the records were similarly organised, but not identical. The system designer had clearly attempted to follow the same basic record structure for all records departing from this only when he had to. Space was allowed for further unspecified data by the provision of "filler" fields left blank until future modifications to the system might require their use. Some data was duplicated in different parts of the records to minimise processing time.

The file was held in job number order, the job number being a composite of the "works order number " (indicating the Customer Division and product, authorising expenditure and against which costs would be collected), the drawing number and batch number.

Processing was strictly sequential and required about 8 hours per week to process the data on about 3000 jobs. Core required was limited to 64K 8 bit words.

The system followed for data input depended on whether or not Manufacturing Division had made the part before. A description of the process appropriate to a new job will be given, followed by indications on the changes to the process if the job had been made before.

Step 1 Customer Liaison - Input

Customers would approach Manufacturing Division armed with a works order number, a full set of drawings for the parts they needed and a list of the quantities required obtained from the P.D. system (see section 4.4.2). After studying the drawings in conjunction with the Head of the Planning Section, the Head of Production Control would estimate the total load represented by the job and negotiate a delivery date on the basis of the known existing load (provided by the system on a tabulation formulated as shown in figure 43) and his estimate of the load represented by the new job.

Step 2 Initial Data Input - Material Ordering

Having obtained agreement on the due date, a Planner would open a layout form (see figure 65) and supply basic data on the job and the material required. The form would then be passed to Manufacturing Division's data preparation staff who would punch a paper tape from this information on "Flexowriters". The information would be passed to the computer which would consolidate the information on all new jobs submitted onto a weekly tabulation listing the material required (see figure 66). The Production Controller's Material Control Clerk would check material stocks and order any new material requirements via a Purchasing Department Instruction form.

Step 3 Methodization

The master layout form and the drawing would be passed back to the Planning Section who would detail instructions for each process necessary to complete the part and decide on what machine group each process should be conducted. Any special tools were listed at this point and the requirements communicated to the Tool Room in Manufacturing Division (see below and figure 67).

Step 4 Standard Times

The master layout and the drawing were then passed to the T.E.O. department where standard times (set and run) were worked out and added to the form.

Step 5 Scheduling

The completed layout form was then passed to the Production Control Section who decided on the due dates for each operation with respect to the due date for delivery of the completed part and on any necessary down batching with reference to the existing load and operation times per machine group.

Step 6 Computer Input

The layout form was transcribed onto paper tape by the Data Preparation staff and then onto magnetic tape and into the computer. The Huizen system contained two levels of screening programs: one to check for invalid characters and parity errors and another to check that certain specified fields were within allowed ranges. Any errors were passed back to the Data Preparation staff for correction. The completed information was matched with the job and material data already input by means of the job number.

Step 8 Material Progressing

Each week the entire system was run twice, but not all the tabulations were generated at each run. In particular, the major progressing document was generated once each week. This document was known as the "work issue list" - see figure 45. The work issue list contained details of each operation on all jobs from 4 weeks before their due start date until they were recorded as delivered. An indicator showed whether material was available, being set by return of a "material ready" punched card to the system when the material arrived. Any jobs "held" for lack of material and hence unable to start their first operation would have their "material ready" indicator shown as zero. Each week a progress clerk chased any material needed within the next few weeks on the basis of the information on the work issue list.

Step 9 Shop Loading

Each week, the computer would generate a set of pre-punched cards for all jobs due to start 4 weeks hence. The cards were:

* A material ready card
* A start card for each operation
* A finish card for each operation
* Three "remarks cards" for notifying any particular reason for a job being held up at a particular operation - e.g. tool failure
* 2 delivery cards.

The cards were sorted into operation order and placed in a wallet with a copy of the operation instructions generated at the same time as the cards (see figure 68) and a copy of the drawing retrieved from the file. The "work packets" as these jobs were known, were then stacked according to the due start week and the machine groups where they were to be worked on. Each week the "shop loader" distributed the work packets due to start and re-distributed jobs that had been completed by one section, together with the part-finished items, to the next section shown on the operation instructions using the work issue list as his overall guide.

Step 10 Manufacture and Data Recording

Operators either collected a new job from the waiting stock of work packets or the trays of work-in-progress. Their first action was to punch the start card for return to the computer. The start card contained details of the job and operation to be started and the "clocking" action recorded the start time of the job. The operator would set up his machine and run it to complete the operation. Once completed, the operator would record the mumber passed to the next operation on the "finish card" together with his clock number and "clock off" the job.

Step 11 Progressing

The work issue list (figure 45) was the prime document used for progressing as well as details describing the job and the operation immediately due, the previous and next machine groups processing the job were shown. The work issue list was shown in order of the due week of the current operation. The other printout used for progressing was known as the "micropert" (see figure 49). The micropert was printed in job number order to group jobs by Customer Division. A list of the machine group numbers to be visited by the job before its completion was given (any completed operations were shown as dashes) together with a pictorial representation of the state of progress against the delivery schedule. The "micropert" was easy to read and gave an immediate picture of any late jobs liable to slip beyond the due date. The micropert was the prime document used to liaise with customers when jobs slipped or re-scheduling was required by either Manufacturing Division or the customers for other reasons.

Step 12 Inspection

After completion of manufacture, jobs were inspected to ensure that they met the specification. Any rejects were either repaired by "sideways loading" - negotiated between the inspector and a supervisor direct without notification to the system or rejected for replacement by a new batch after Production Control had been notified and had made appropriate negotiations with the customer. The quantity passed for delivery was marked on the delivery card which was stamped by the inspector who also sent the operation instructions to the dead layout file and the drawing, back to the drawing file.

Step 13 Delivery

The job was sent to stores with 2 delivery cards. The first card was kept with the job for eventual use by the customer, the second card was used to up-date the stock records and was then returned to the computer. On receipt of the delivery card, the computer would delete the data on the job from the master file and hence from any future tabulations.

Step 14   Performance Measures and Job Costing

Each week a tabulation for each machine section was produced showing the achieved productivity, which was computed by comparison of the standard and actual times for the operations (see figure 53). The standard time included a percentage learning allowance (computed from a look-up table) dependent on the batch size and credit was given for work on which no proper standard time was available at an agreed rate. The actual times were accumulated under each works order number and the total charge notified to the accounts department each month on an "Admin. Routines" report. The job cost was worked out as simply the product of the hours worked and an hourly charge inclusive of wages, salaries and overheads, and an allowance to recover capital and space employed in the manufacturing process.

In cases where Manufacturing Division had made particular parts before, the planning and estimating stages were omitted, unless the Production Controller felt that re-planning was called for. The master layout and paper tape used the last time the job was made, was retrieved from the master layout file and after any appropriate amendments, particularly to the due date, transcribed into the computer. The Huizen system contained a facility for automatically amending all the operation scheduled dates according to the new due date and the time lapse between the old and new due dates.

BIBLIOGRAPHY

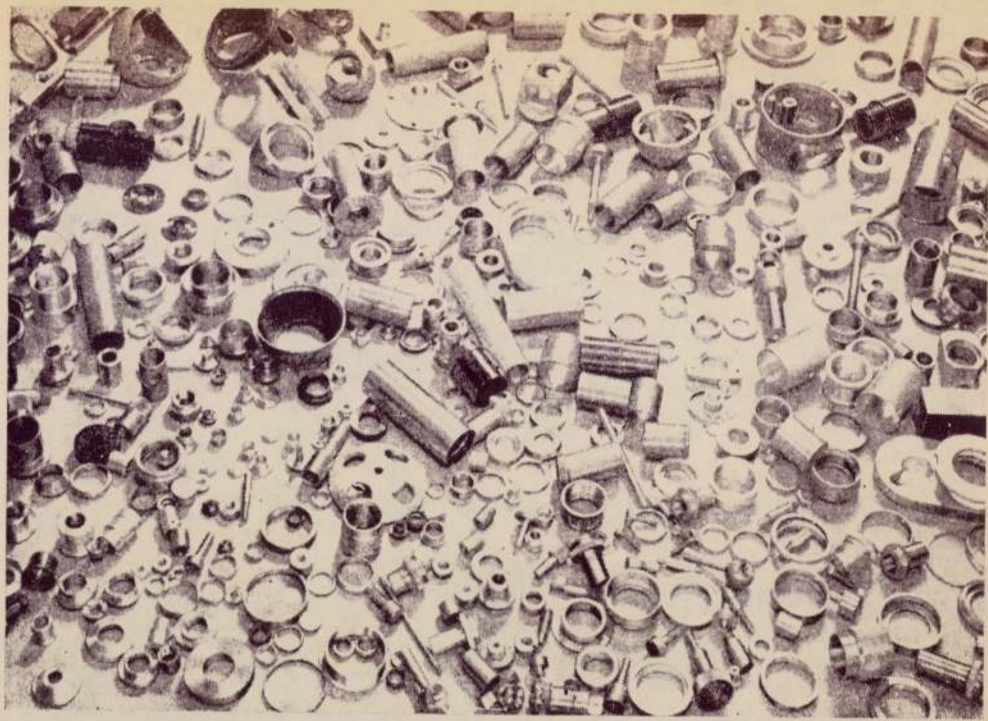
Thesis Ref. Number	Author(s)	Where and When Published
1.	Thornley R.H.	"An Introduction to Group Technology". Conference: Group Technology UMIST 4th - 6th July 1972
2.	Mitrofanov S.P.	"Scientific Principles of Group Technology" English Translation Published by the National Lending Library 1966
3.	Drurie F.R.E.	"A Survey of Group Technology and its Potential for User Application in the U.K.". The Production Engineer 49, 51, 1970.
4.	Hall P.D.	Metal Working Production, February 1975 pp. 45 - 51.
5.	Brown J.A.L.	"The Social Psychology of Industry" Penguin Books Ltd. 1964.
6.	Fazakerley M.	"A research report on the human aspects of Group Technology and Cellular Manufacture". Institution of Production Engineers - Group Technology Division - November 1975.
7.	Lepper C.	"G.T. Methods at Rolls Royce (1971) Ltd." The Institution of Production Engineers Group Technology Division 3rd Annual Conference. November 1973.
8.	Burbidge J.	"Group Technology" - A course for industry. INCOMTECH. October 1975.
9.	Edwards G.A.B.	"Readings in Group Technology". The Machinery Publishing Co.Ltd. 1971.
10.	Allen C.	"Computer Aided Design, Drafting and Manufacture in Avionics" - Computer aided design 6.4 October 1974.
11.	-	"Group Technology Case Study and Works Visit to Mercer Gauges Ltd. The Institution of Production Engineers May 1974.

Thesis Ref. Number	Author(s)	Where and When Published
12.	Arn E.A.	"Applications of Systems Engineering to Group Technology" Ph.D thesis submitted to the University of Aston in Birmingham March 1974.
13.	Sawyer J.F.H. and Arn E.A.	"Payment Systems" Institution of Production Engineers, Group Technology Division, 3rd Annual Conference November 1973.
14.	Hertzberg F.	"Work and the Nature of Man" World Publishing Co. 1966.
15.	Gallagher C.C. and Knight N.A.	"Group Technology" Butterworth & Co. 1973.
16.	Schmitt J.P.	"Management Structure as applied to G.T.". Third Annual Conference of the Group Technology Division of the Institution of Production Engineers. November 1973.
17.	-	"Computercrime" B.B.C. Radio 4 August 4th 1976.
18.	Couling A.J.	"A Comparison of Classification Systems in the Machined Components Industry". University of Aston in Birmingham. Department of Production Engineering B.Sc. Final Year Project March 1974.
19.	Burbidge J.L.	"Production Flow Analysis". Production Engineer 42, 742.
20.	Burbidge J.L.	"Production Flow Analysis" Production Engineer 50,139.
21.	Muther R.	Systematic Layout Planning.
22.	McCauley J.	"Machine Groupings for Efficient Production". The Production Engineer pp. 53 - 57 February 1972.
23.	El-Essawy I.G.K. and Torrance J.	"Component Flow Analysis - an Effective Approach to Production Systems Design". Production Engineer 1972. 51, 165.
24.	Rajagopalan R. and Batra J.L.	"Design of Cellular Production Systems". International Journal of Production Research. 13, 6, November 1975 pp 567.

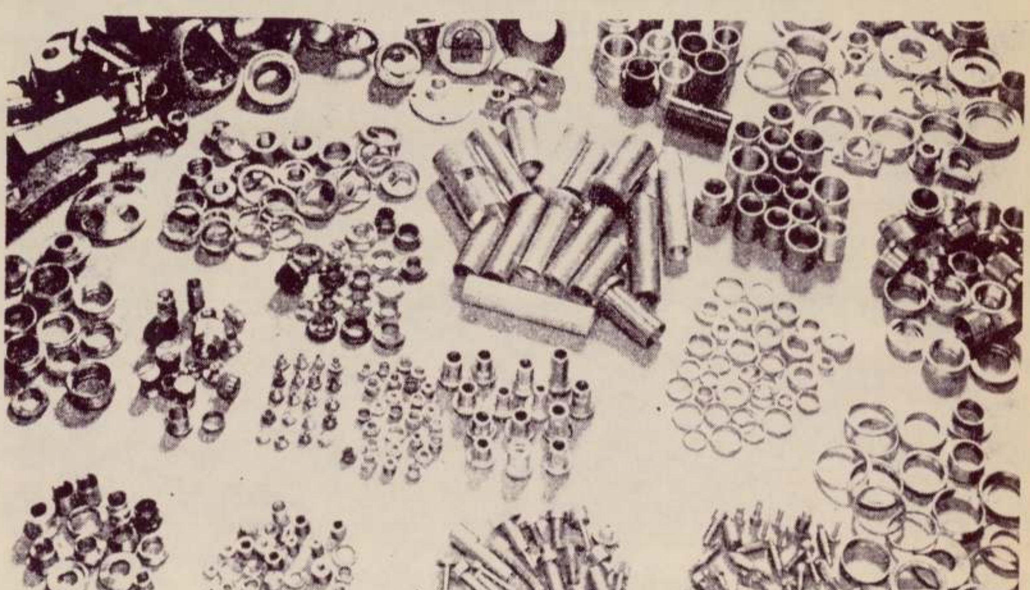
Thesis Ref. Number	Author(s)	Where and When Published
25.	-	"An introduction to the Miclass System". TNO Metal Research Institute for Metalworking Report. Technical Centre for Metalworking. Laan van Westanenk 501, Apeldoorn, The Netherlands.
26.	-	Visit to TNO Metalwork Laboratories 1976. Unpublished.
27.	-	"Group Production - Methods of Flow Analysis" PERA Report No. 243. September 1971.
28.	Burbidge J.L.	"Production Flow Analysis and the Computer". Third Annual Conference of the Institution of Production Engineers November 1975.
29.	Burbidge J.L.	"Group Technology". INCOMTECH course for industry. October 1974.
30.	Muther R.	"Introduction to Layout Planning" Seminar given in July 1974.
31.	Churchman et al.	"Introduction to Operations Research". John Wiley and Sons 1957.
32.	Philips D.T.	"The Out of Kilter Algorithm" Industrial Engineering 1974 February. pp 36 - 44.
33.	Driscoll J.	Preparation for Ph.D. thesis discussed. July 1974.
34.	Sawyer J.F.H. and Arn E.	"Payment Systems" Institution of Production Engineers Third Annual Conference. November 1973.
35.	Burbidge J.L.	"The Principles of Production Control". Macdonald and Evans 1962.
36.	Brown R.G.	"Statistical Forecasting for Inventry Control". McGraw Hill 1959.
37.	Lewis F.A.	"The Design and Operation of Flexible Cell Systems". The Institution of Production Engineers Group Technology Division. November 1975.
38.	-	"Sequence Technology" PERA Report No. 18.

Thesis Ref. Number	Author(s)	Where and When Published
39.	Nicholson T.A.J.	"Optimisation in Industry" Volumes 1 and 2. Langman Press London 1971.
40.	-	Visit to Ferranti Edinburgh 23rd October 1974. Organised by C. Allen and A.J. Page.
41.	-	"Class 25" I.B.M. U.K. Ltd. August 1969.
42.	-	"Defence Standard 05-21". Ministry of Defense Directorate of Standardization 1973.
43.	Opitz H.	"A Classification System to Describe Work Pieces". English Edition - Permagon Press 1970.
44.	Gannt H.	"Gannt on Management". New York: American Management Association 1960.
45.	Urwick L. and Brech E.F.L.	"The Making of Scientific Management". Vol. III. Pitman London 1948.
46.	Thornley R.H.	"Group Technology - A Complete Manufacturing System" Inaugural Lecture published in the British Engineer May 1972.
47.	Kast F.E. and Rosenzwig J.E.	"Organisation and Management: A Systems Approach". McGraw Hill 1970.
48.	Edwards G. and Schmitt J.P.	"Manufacturing - Not so much a technology more a way of life". pp 15 - 28.

FIGURE 1 ILLUSTRATION OF COMPONENT FAMILIES



A RANGE OF COMPONENTS TO BE MACHINED



THE SAME COMPONENTS ARRANGED IN GROUPS

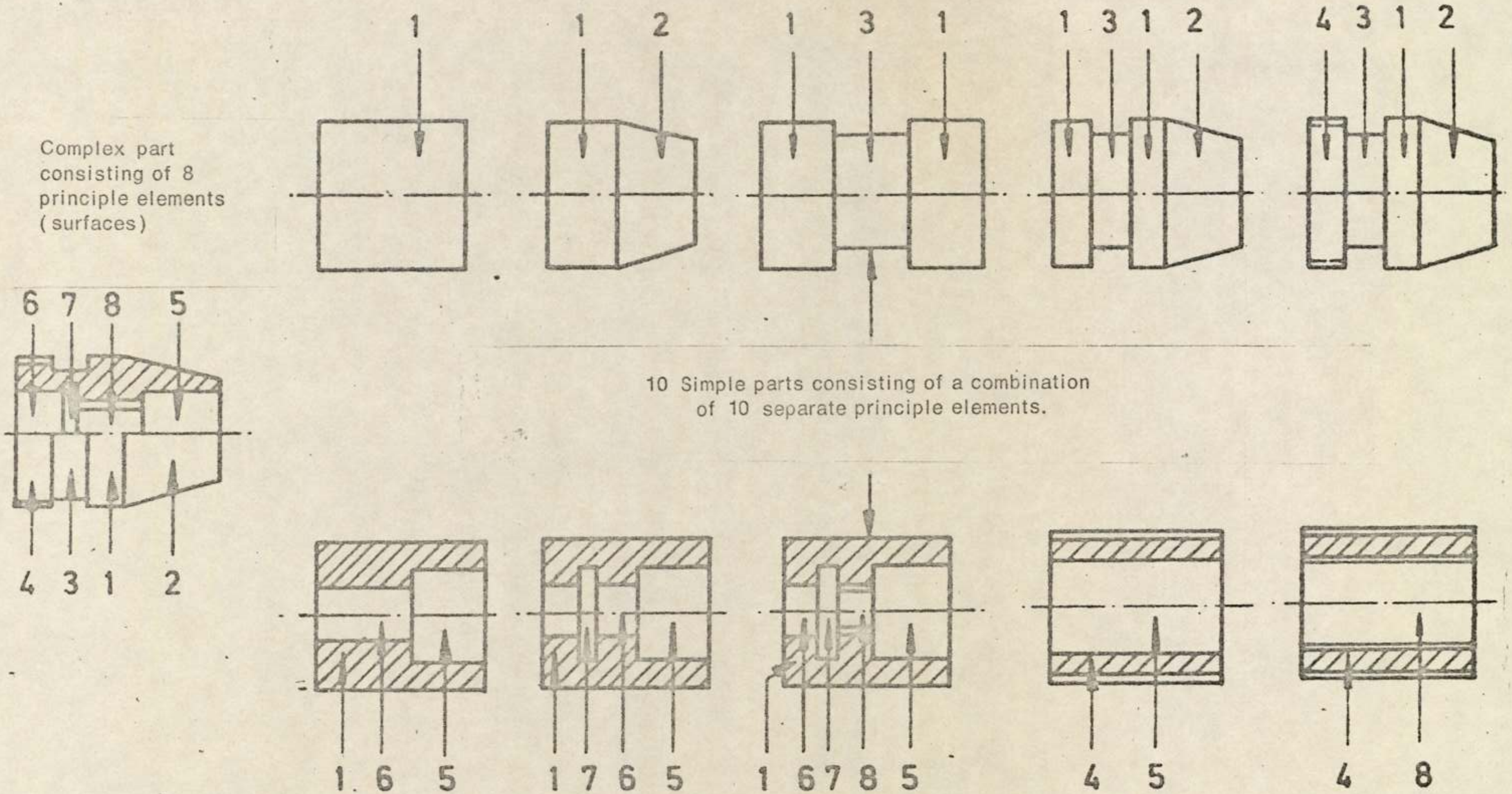
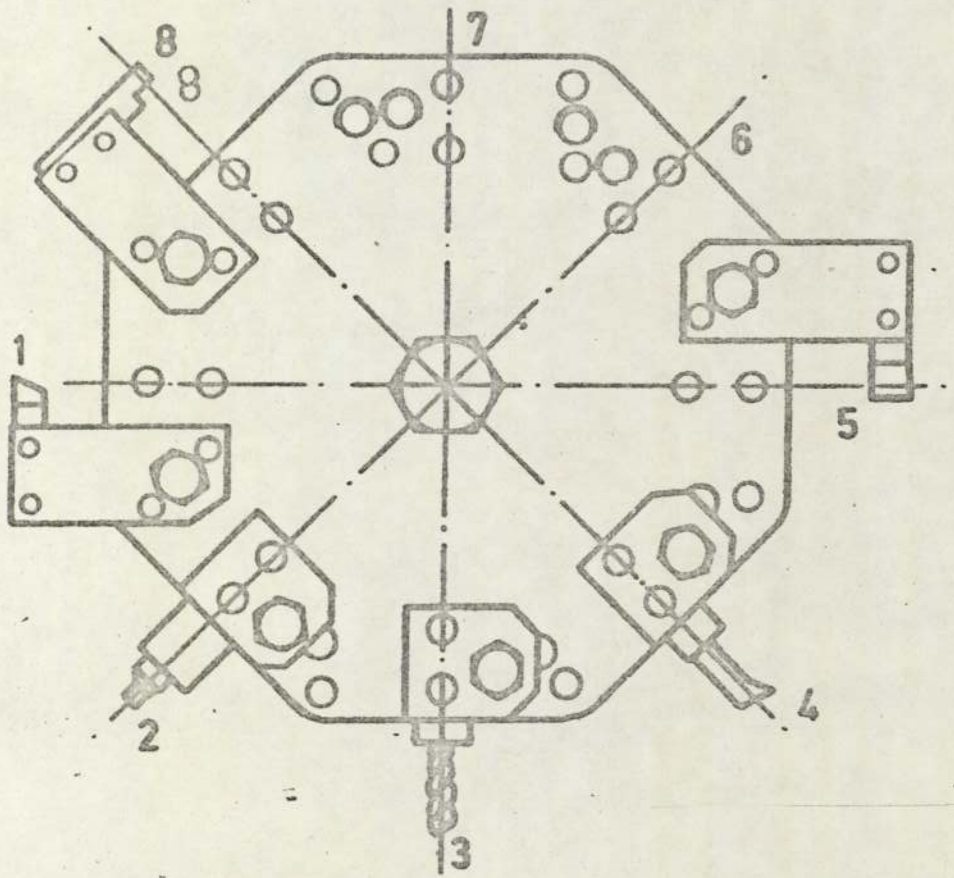
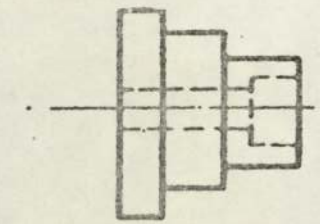


FIGURE 2 EXAMPLE OF COMPLEX COMPONENT
(AFTER MITROFANOV)

Ferrous, 2 or more 0/Dias. (successively increasing)

1 or more 1/Dia.





Turret Posn.	Tool Description
1	Face & Rgt. Turn (use as stop)
2	Centre
* 3	Drill
* 4	Boring
5	Finish Turn
6	Free
7	Free
8	Part Off

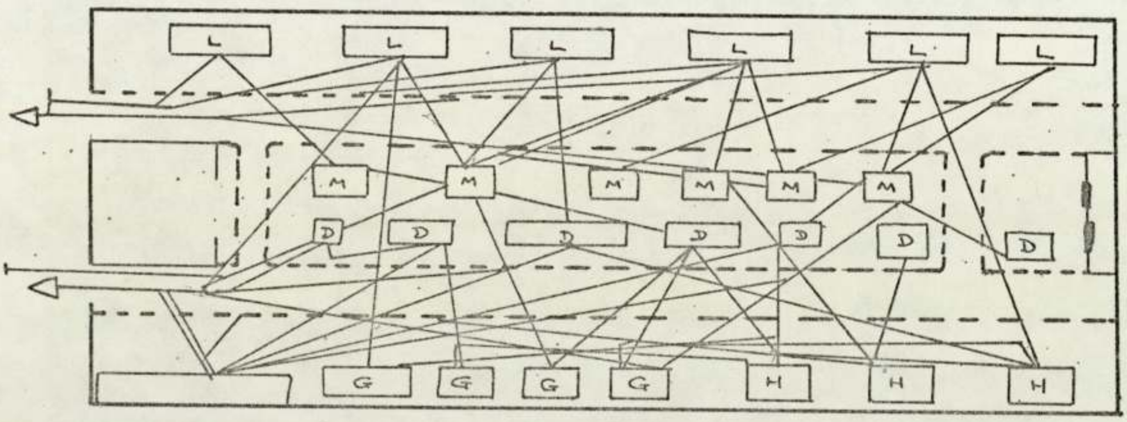
* Change to suit requirements

NOTE:- Additional tools should be placed in a free position where possible thus preserving the basic settings

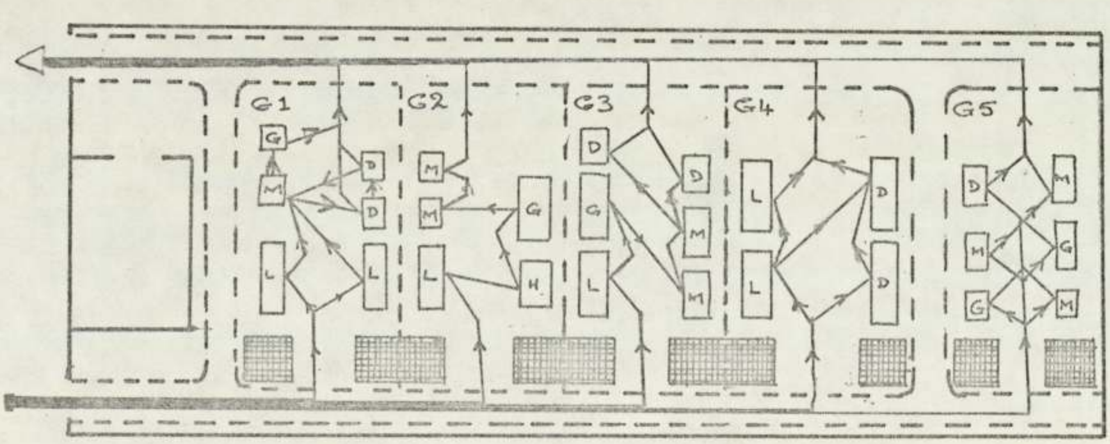
FIGURE 3 TOOLING SET-UP AND THE COMPLEX COMPONENT (AFTER DURIE)

FIGURE 4 SIMPLIFICATION OF MATERIAL FLOW WITH GROUP LAYOUT

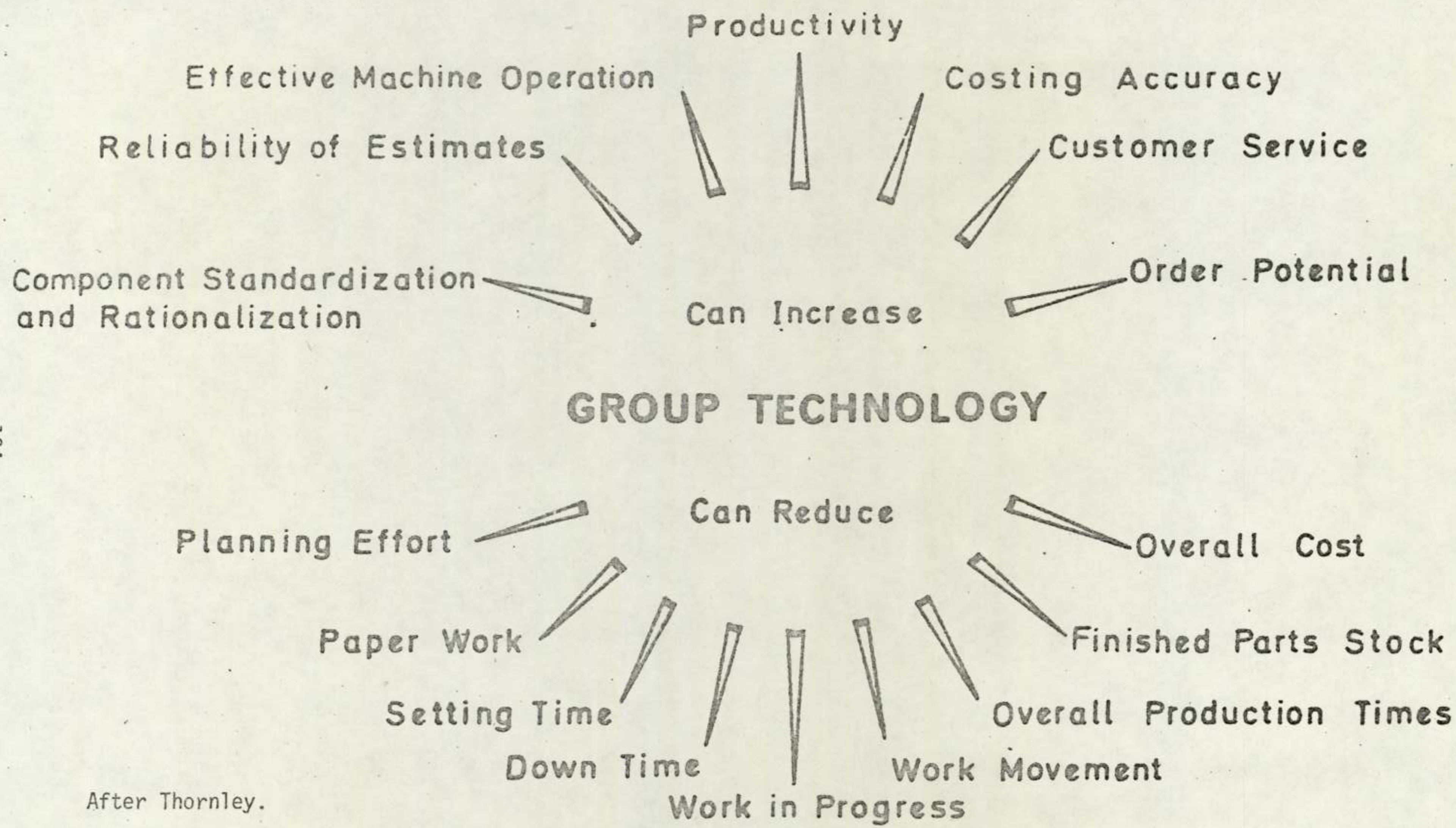
1. COMPLICATED MATERIAL FLOW SYSTEM (FUNCTIONAL LAYOUT)



2. SIMPLE MATERIAL FLOW SYSTEM (GROUP LAYOUT)



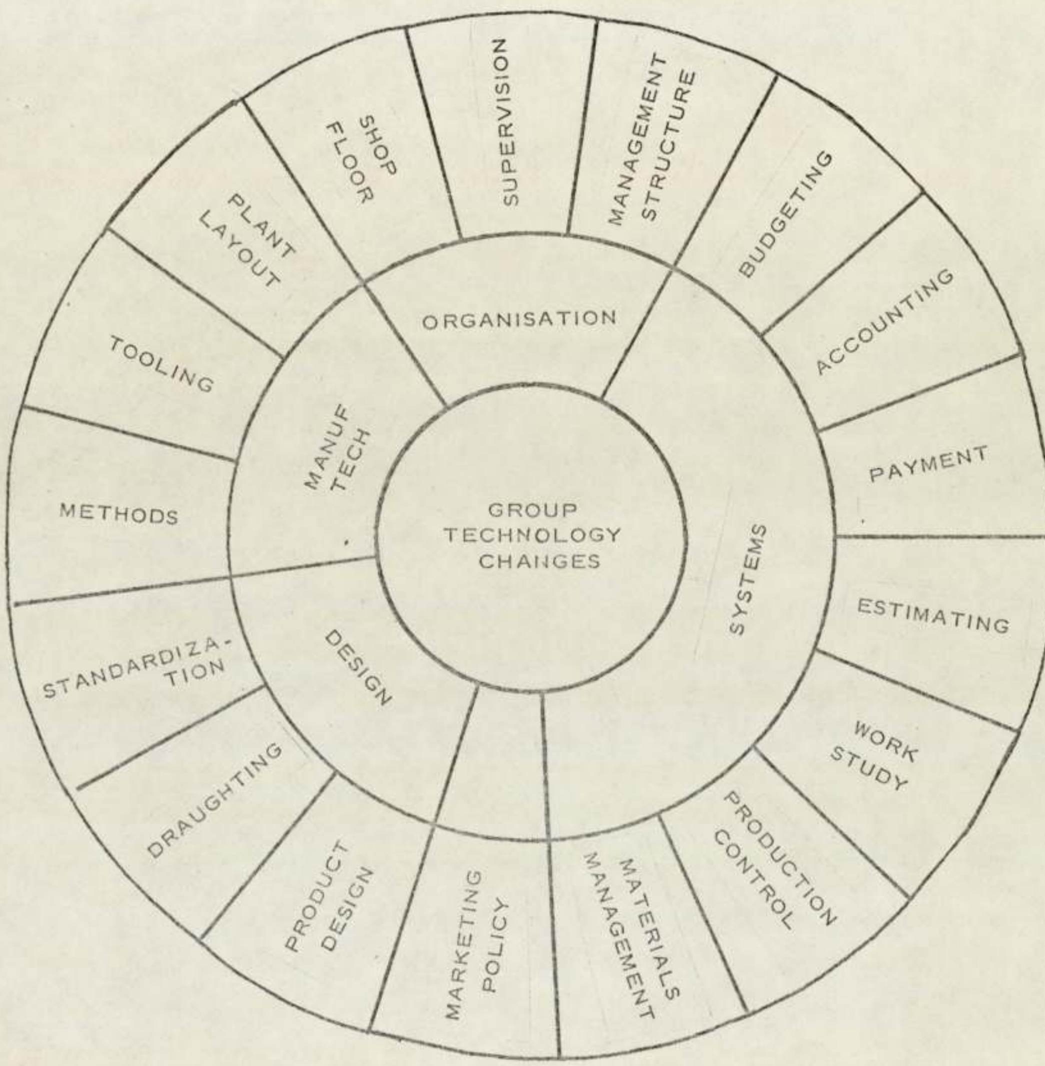
AFTER BURBRIDGE



After Thornley.

FIGURE 5 GENERAL ACHIEVEMENTS OF GROUP TECHNOLOGY

FIGURE 6 GROUP TECHNOLOGY AND ORGANISATIONAL CHANGE



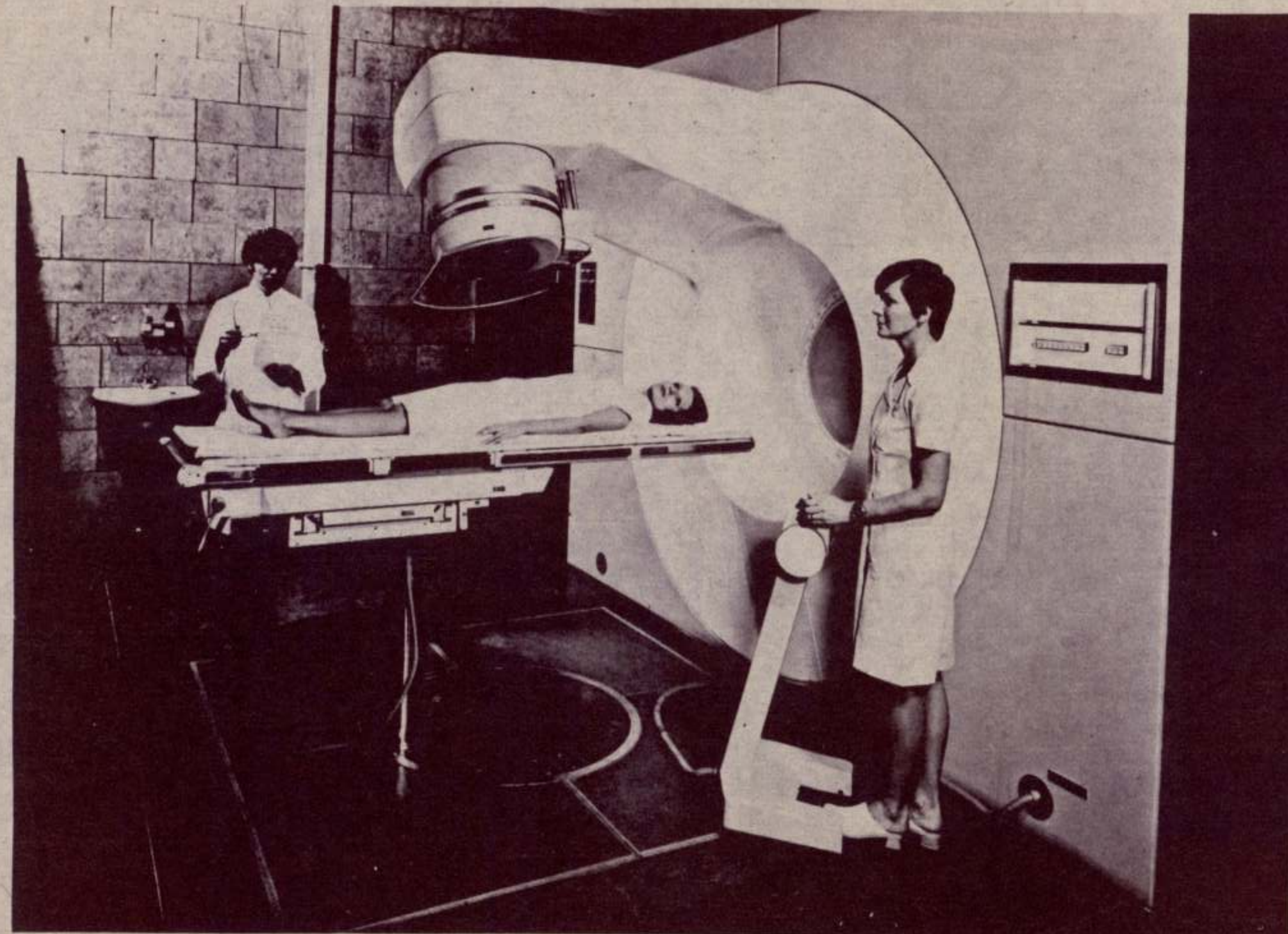
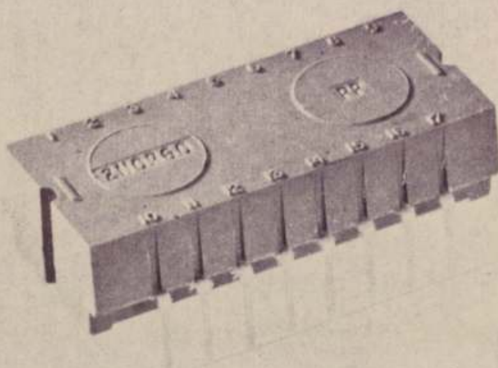


FIGURE 7

MACHINE FOR RADIOLOGICAL
TREATMENT OF DISEASE

FIGURE 8 A MODULE OF SWITCHING ELEMENTS



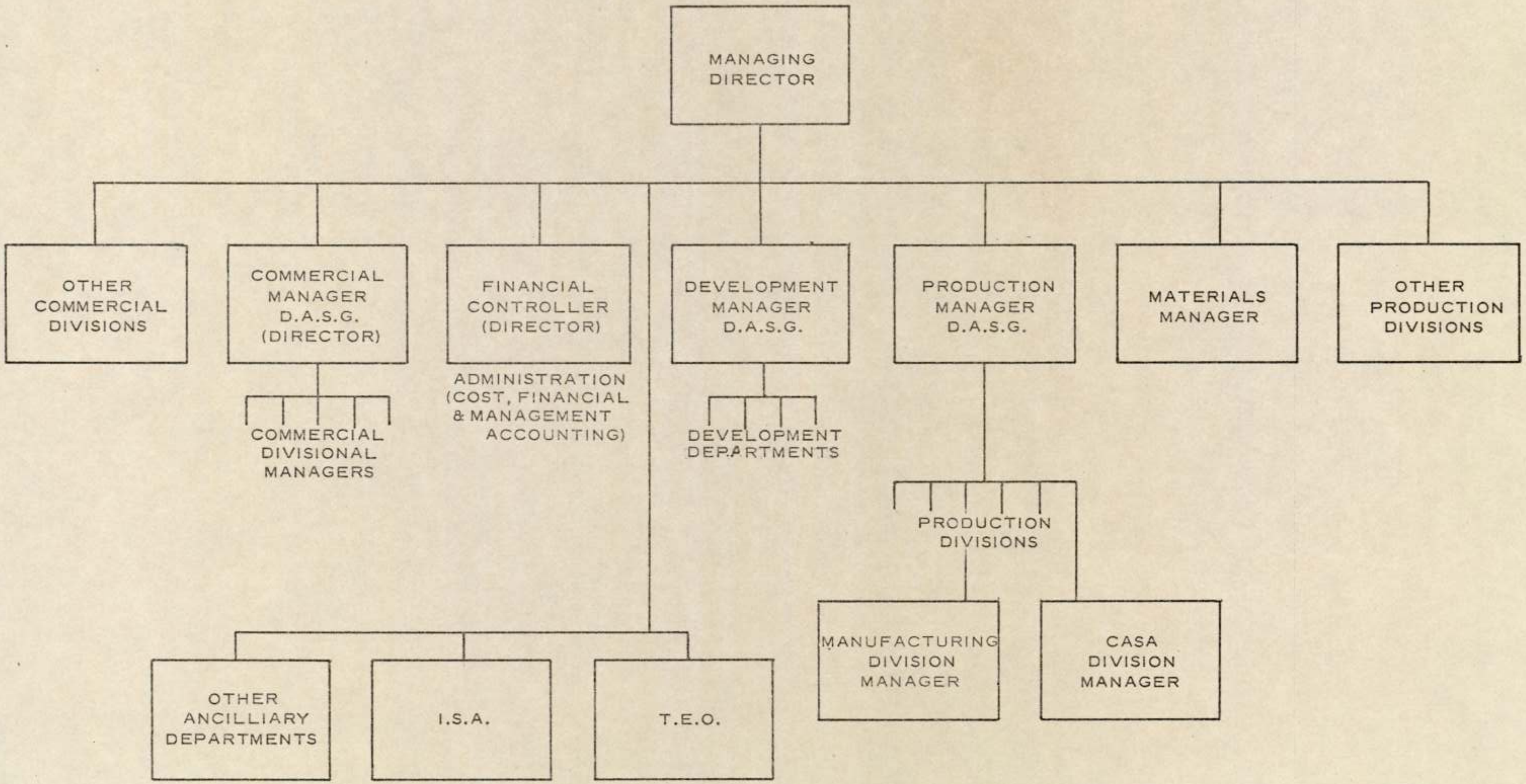


FIGURE 9 OUTLINE OF M.E.L.'S ORGANISATION AT THE START OF THE RESEARCH

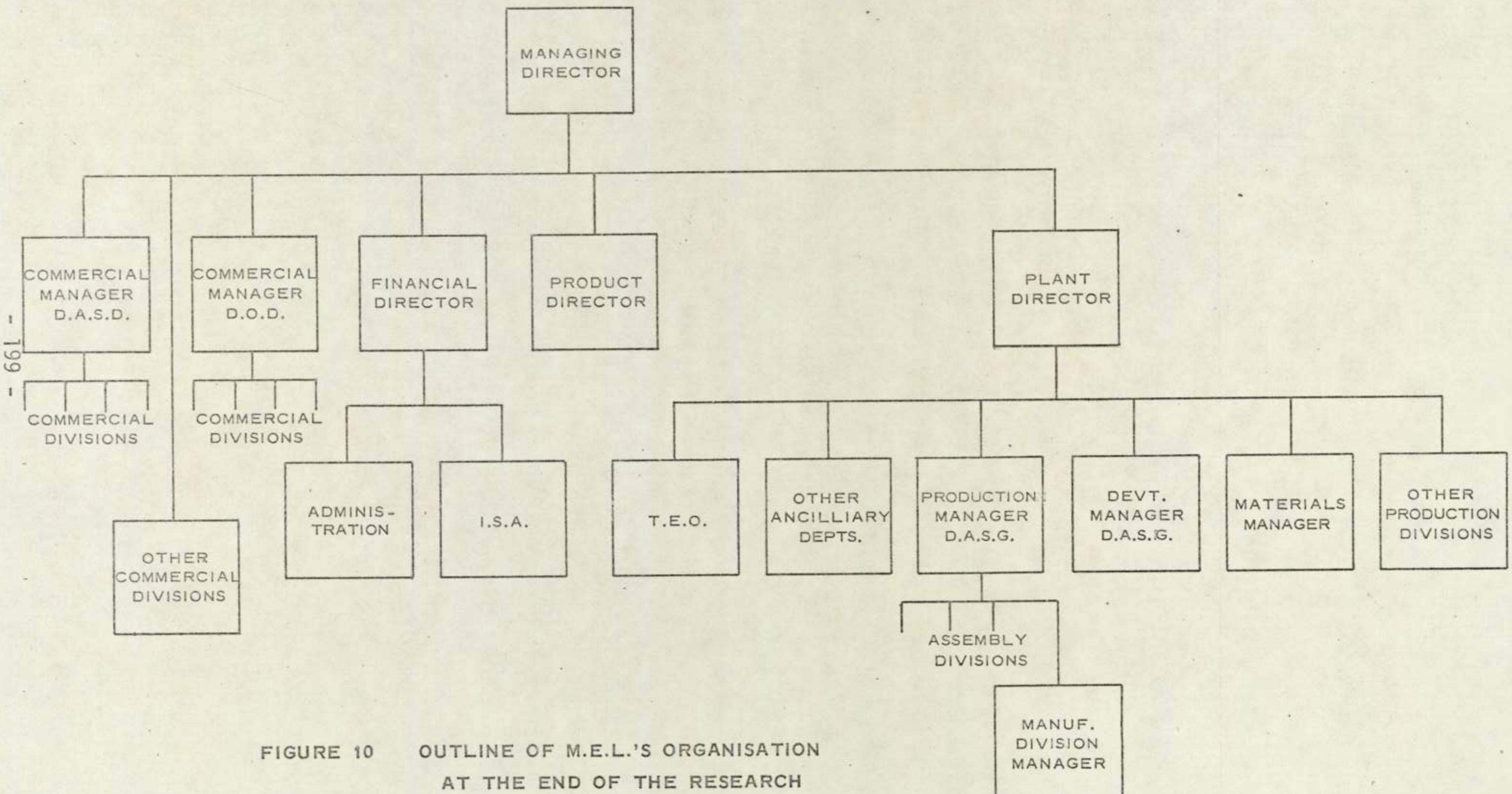


FIGURE 10 OUTLINE OF M.E.L.'S ORGANISATION AT THE END OF THE RESEARCH

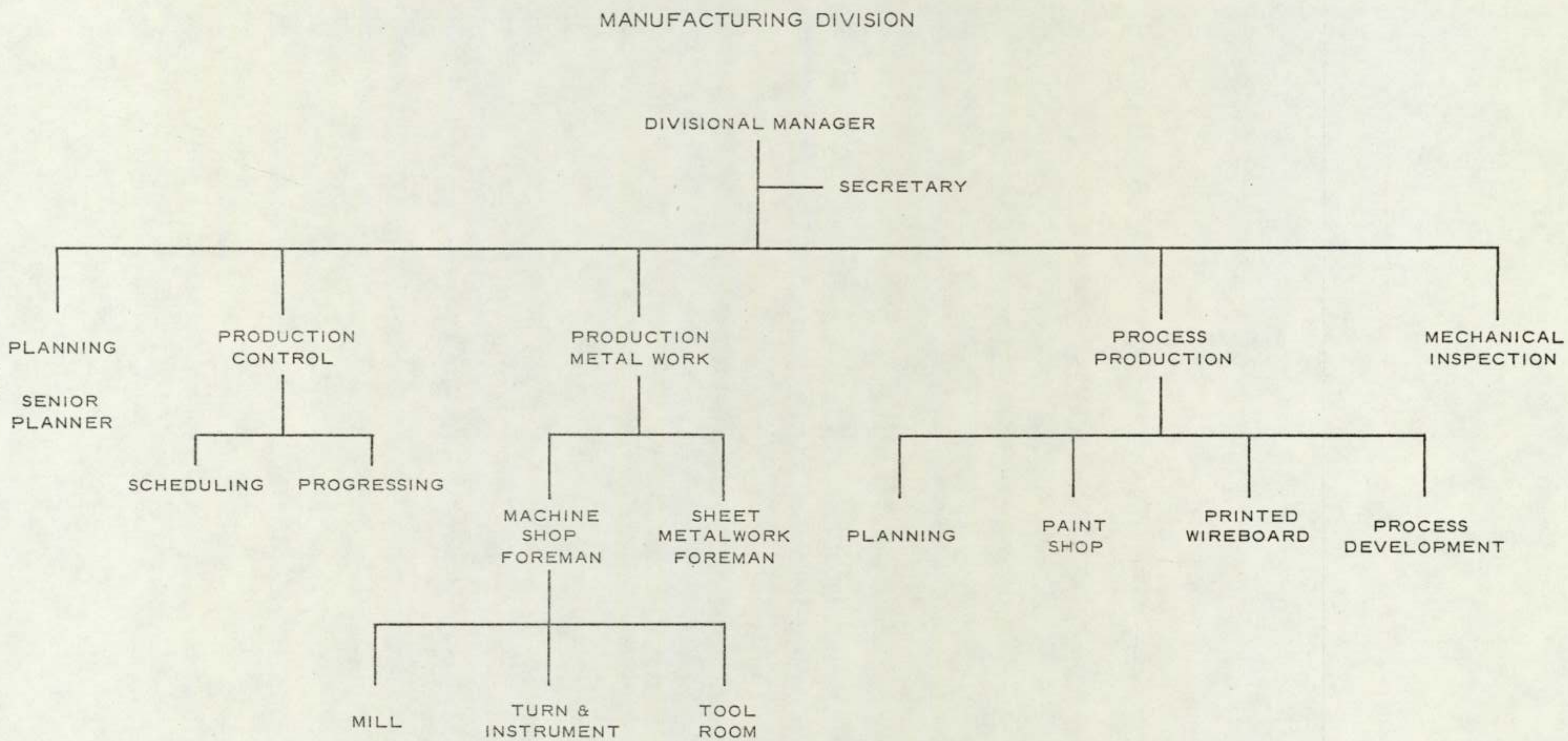


FIGURE 11 MANUFACTURING DIVISION'S ORGANISATION
PRIOR TO GROUP TECHNOLOGY

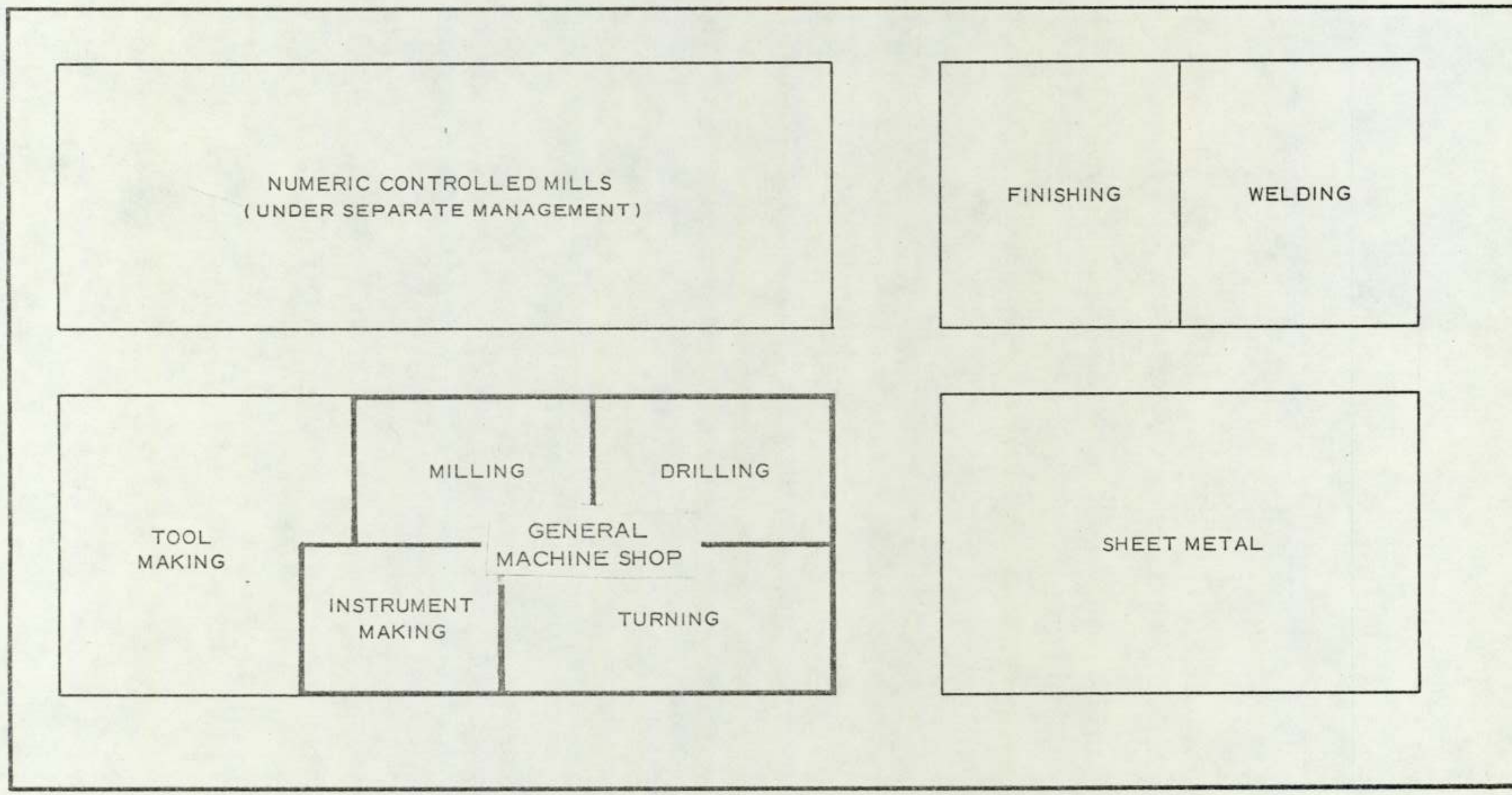


FIGURE 12 LAYOUT OF MANUFACTURING DIVISION'S METALWORK ACTIVITY PRIOR TO GROUP TECHNOLOGY

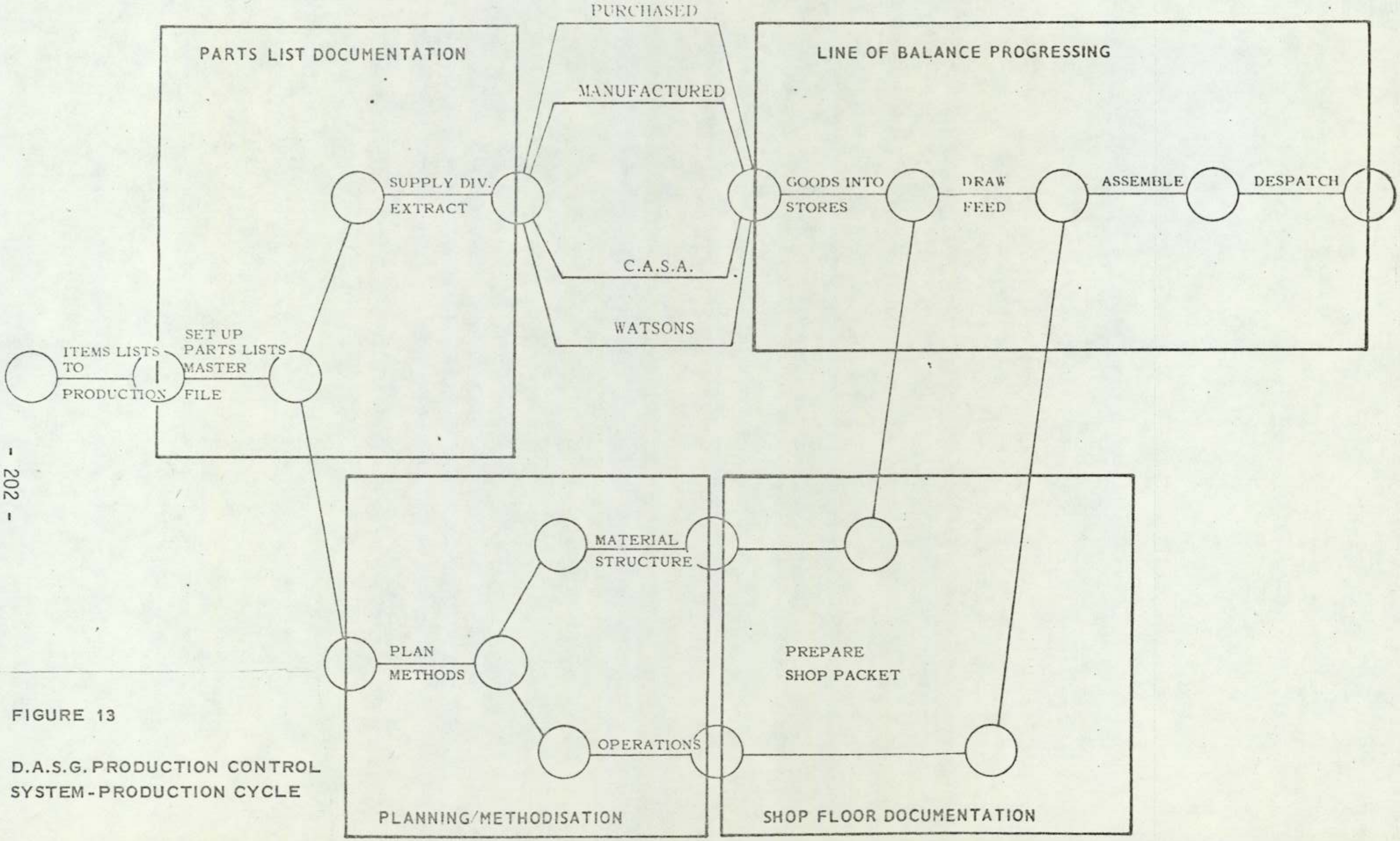


FIGURE 13

D.A.S.G. PRODUCTION CONTROL
SYSTEM - PRODUCTION CYCLE

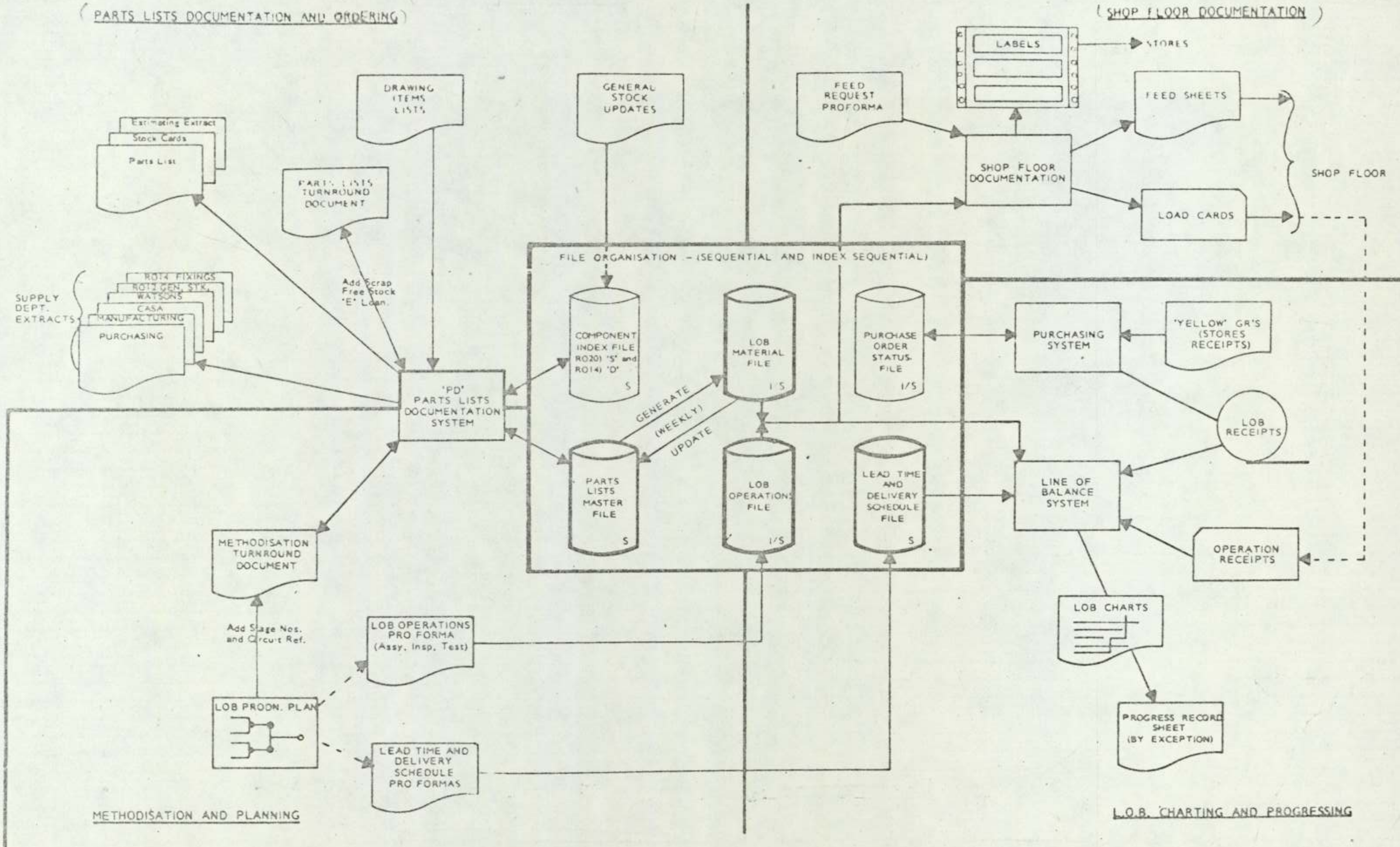


FIGURE 14 D.A.S.G. PRODUCTION CONTROL SYSTEM - SYSTEM STRUCTURE

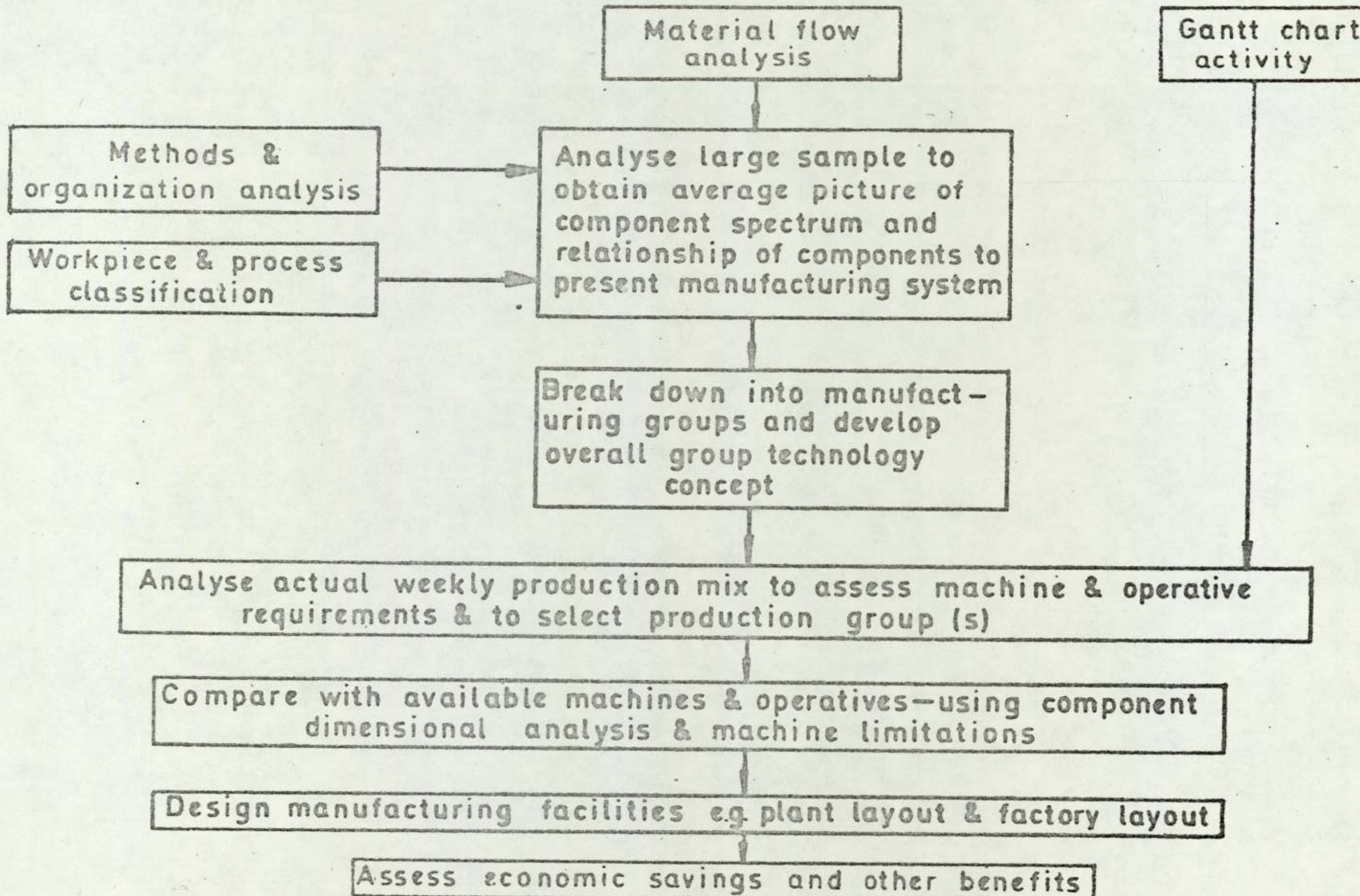


FIGURE 15 METHODOLOGY FOR THE IMPLEMENTATION OF GROUP TECHNOLOGY

FIGURE 16 PHASE 1 PROJECT PLAN

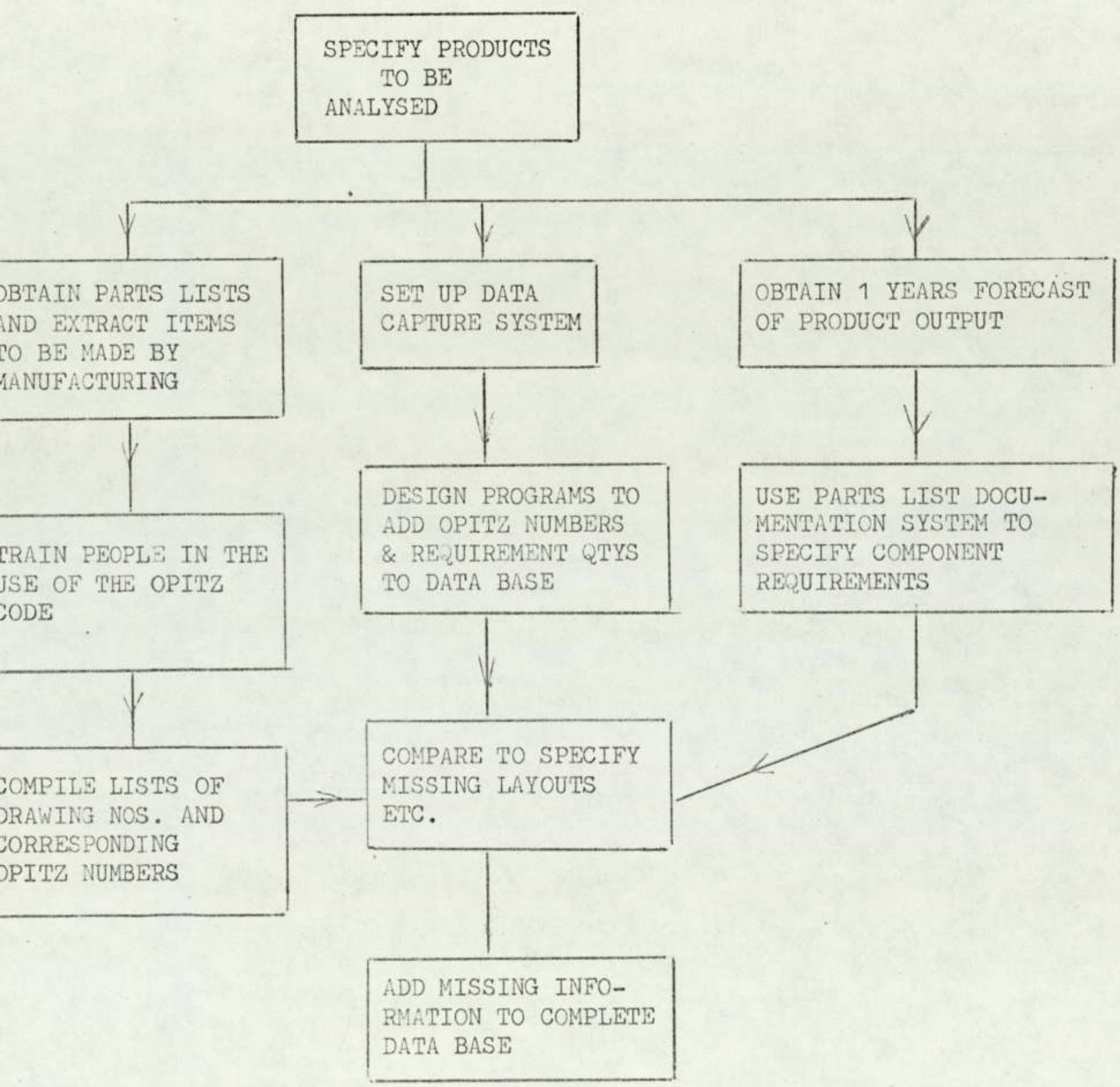


FIGURE 17 PHASE 2 PROJECT PLAN

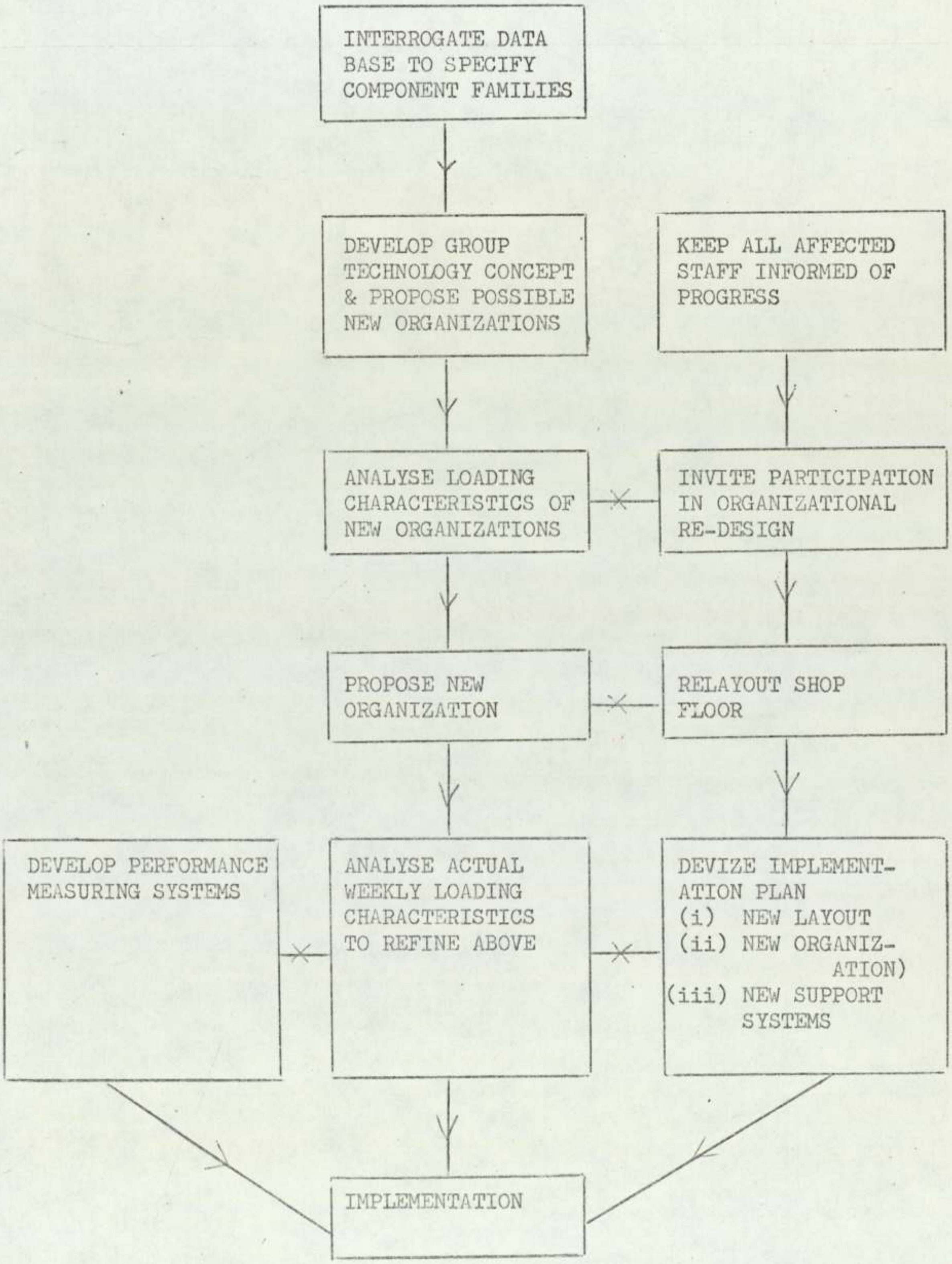
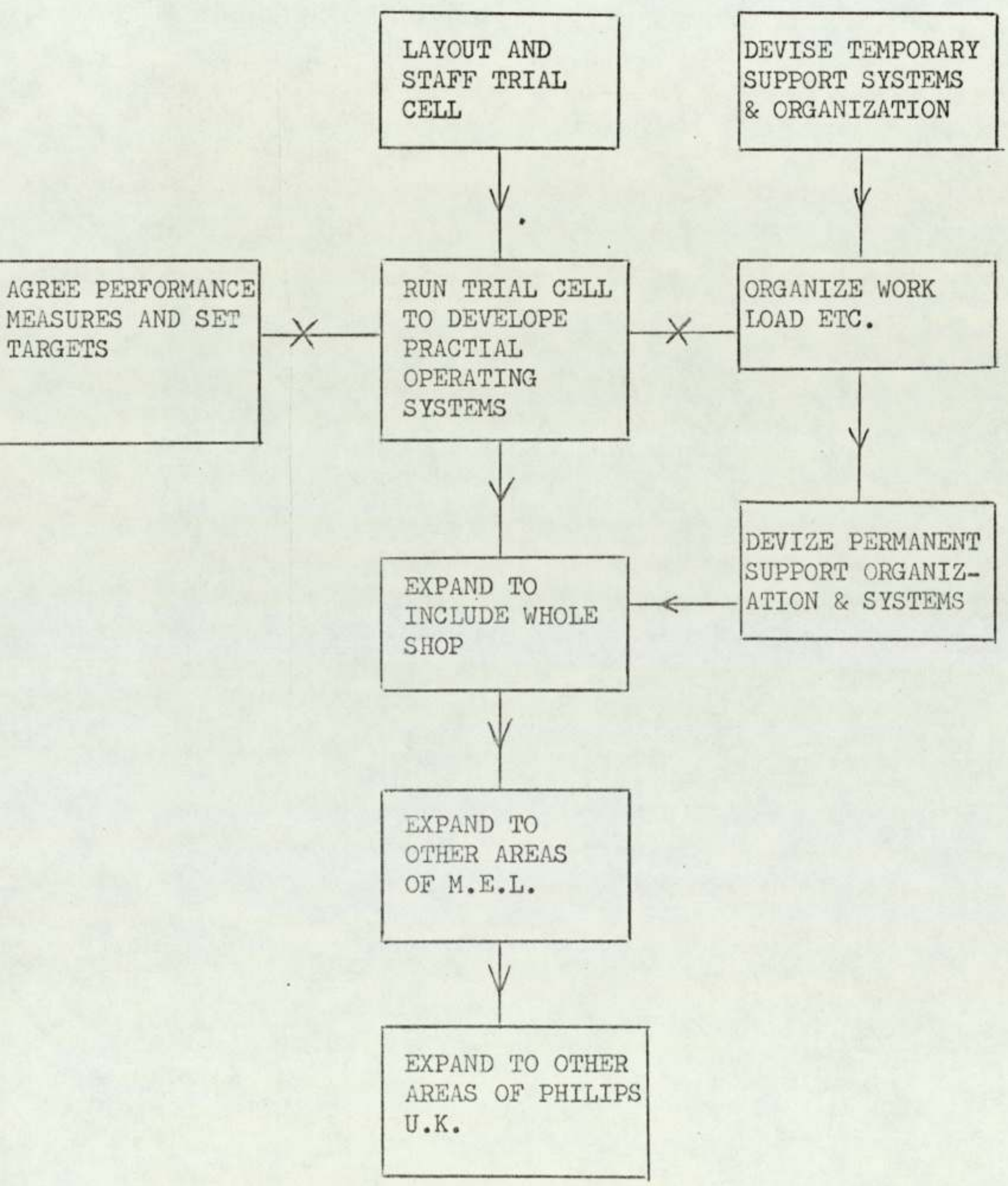


FIGURE 18 OUTLINE PHASE 3 PROJECT PLAN



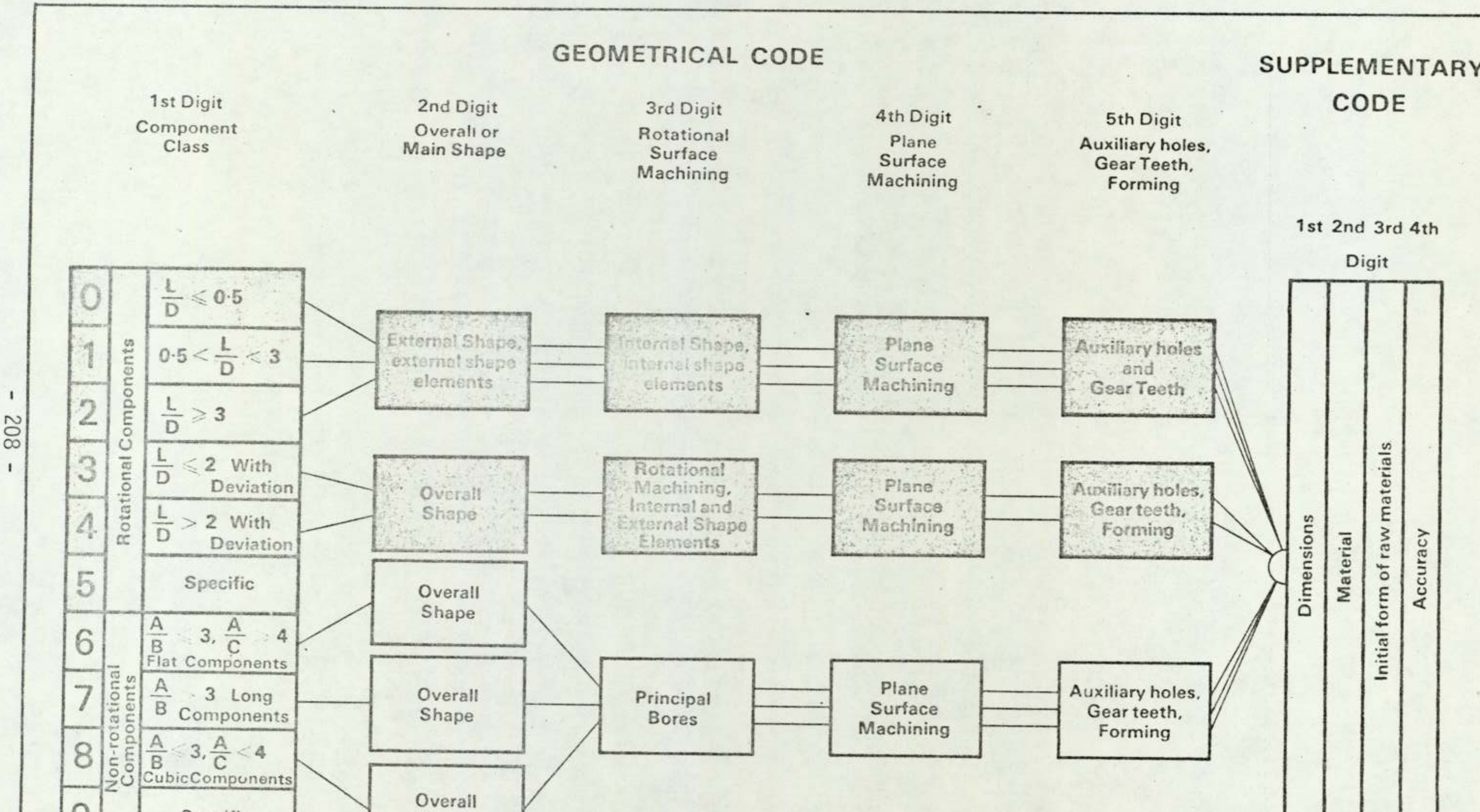


FIGURE 19 THE OPITZ CODE - BASIC STRUCTURE

6TH DIGIT

	DIAMETER 'D' OR EDGE LENGTH 'A'	
	M.M.'s	Inches
0	Under 25.4	Under 1.0
1	25.4 - 51	1.0 - 2.0
2	51 - 102	2.0 - 4.0
3	102 - 160	4.0 - 6.5
4	160 - 250	6.5 - 10
5	250 - 400	10 - 16
6	400 - 600	16 - 25
7	600 - 1000	25 - 40
8	1000 - 2000	40 - 80
9	Over 2000	Over 80.0

7TH DIGIT

	LENGTH 'L' ROTATIONAL OR EDGE LENGTH 'C' (NON.R)	
	M.M.'s	Inches
0	Under 25.4	Under 1.0
1	25.4 - 51	1.0 - 2.0
2	51 - 102	2.0 - 4.0
3	102 - 160	4.0 - 6.5
4	160 - 250	6.5 - 10
5	250 - 400	10 - 16
6	400 - 600	16 - 25
7	600 - 1000	25 - 40
8	1000 - 2000	40 - 80
9	Over 2000	Over 80.0"

8TH DIGIT

	MATERIAL
0	Aluminium
1	Brass (Bar or Rod)
2	Mild Steel
3	Stainless Steel
4	High Tensile or High Carbon Stl.
5	Fibres or Plastics
6	Cast or S.G. Iron
7	Precious Metals
8	Other Non-Ferrous H.T. Brass etc.
9	Others

9TH DIGIT

	INITIAL FORM
0	Round or Hexagon Rod, Stud etc.
1	Round Rod Billets
2	Tube
3	Flat, Bar, Angle, Sq. etc.
4	Castings or Mouldings
5	Plate or Slabs
6	Pre-Machined or Extruded Section
7	Welded or Pre-formed
8	Sheet (under $\frac{1}{8}$ ins)
9	Any apart from above

FIGURE 20 MODIFIED OPITZ CODE

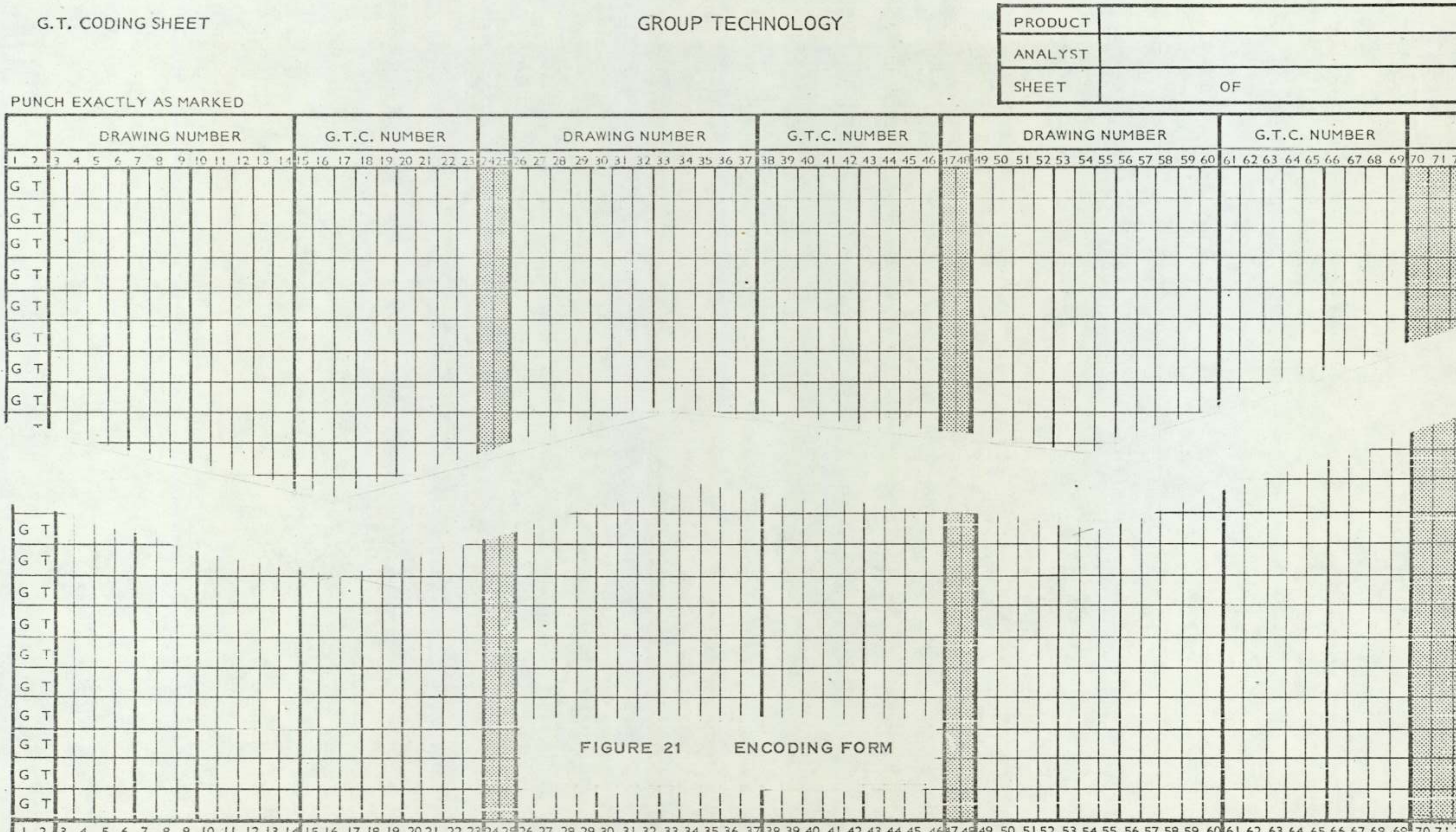
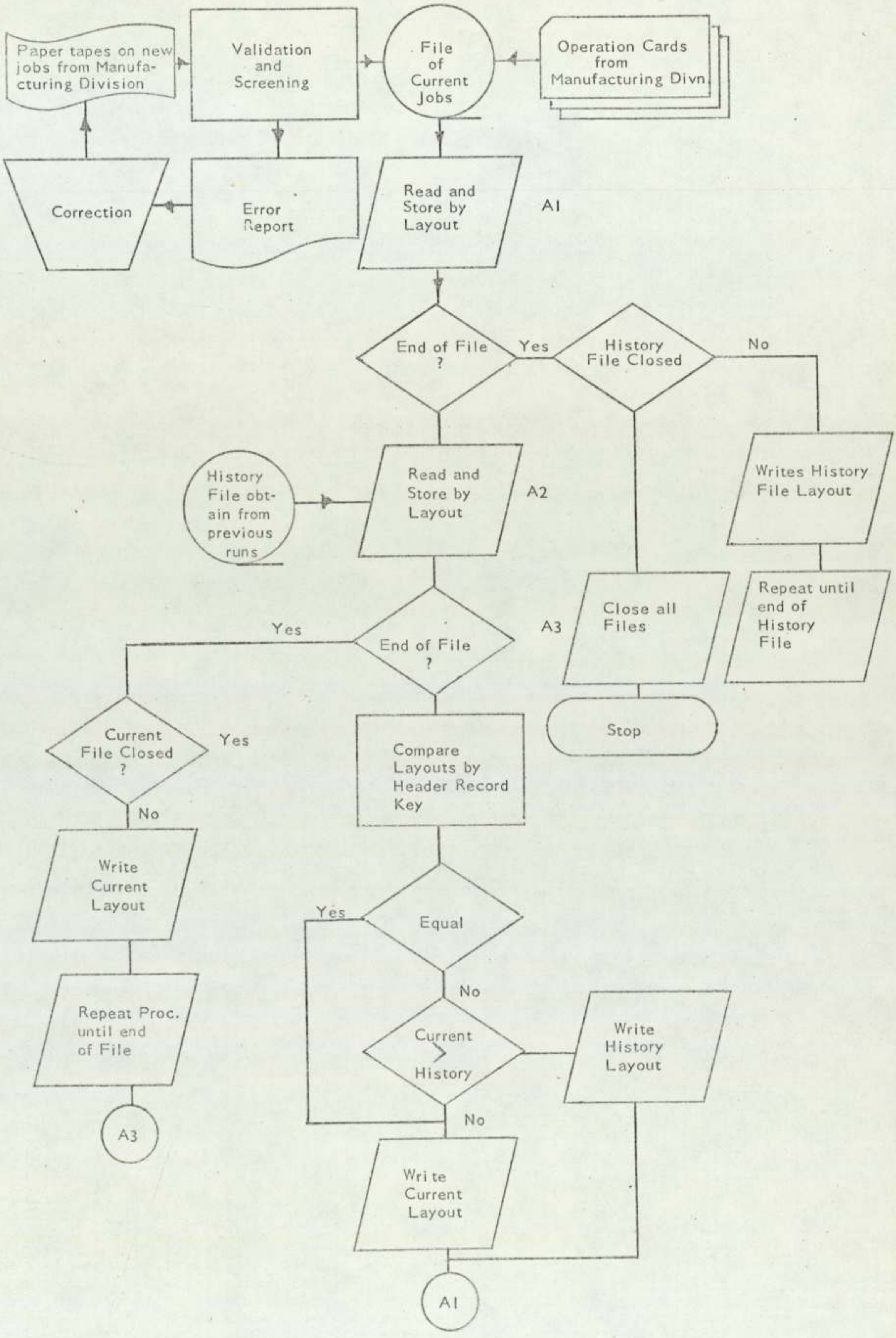


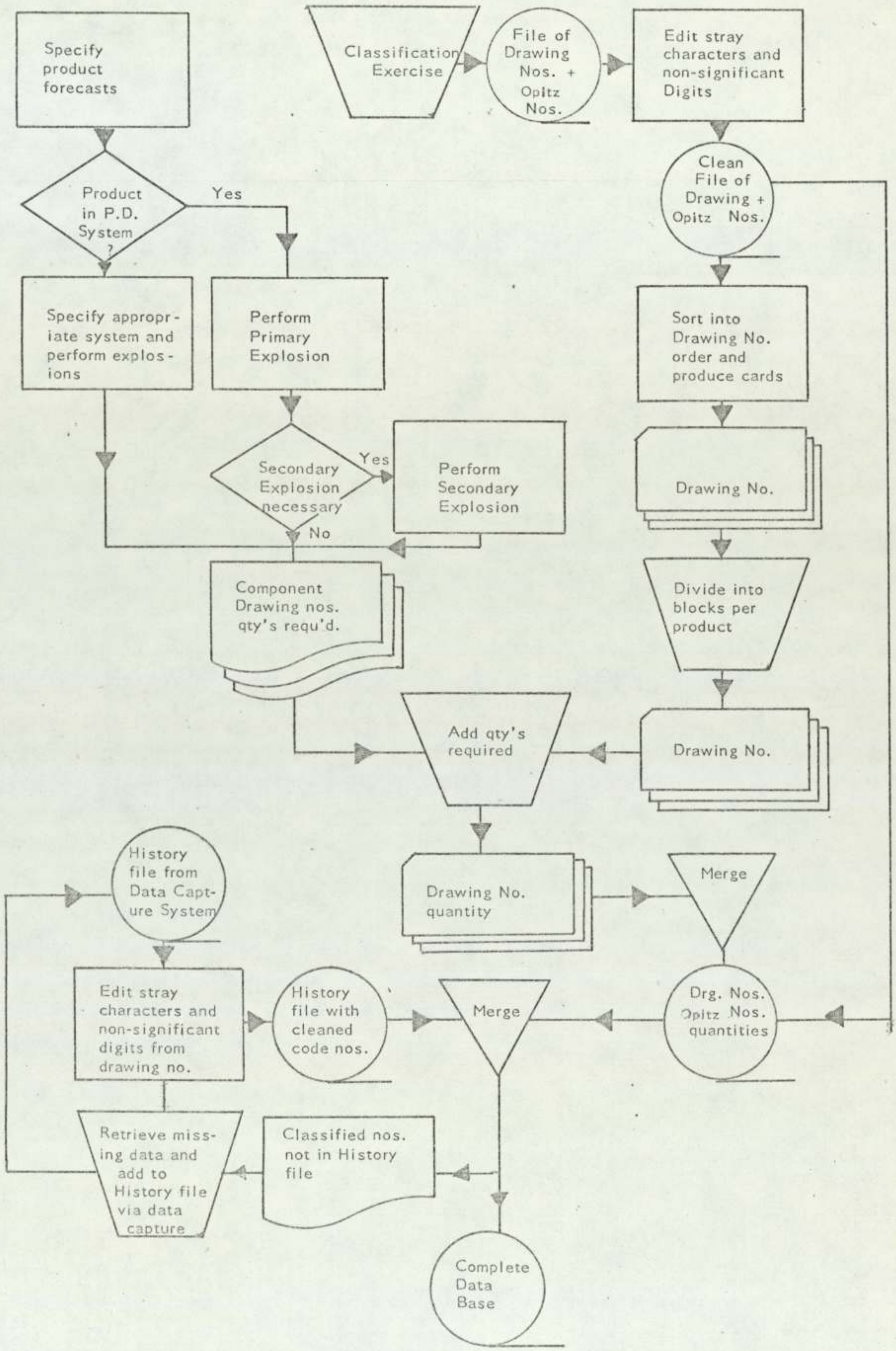
FIGURE 21 ENCODING FORM

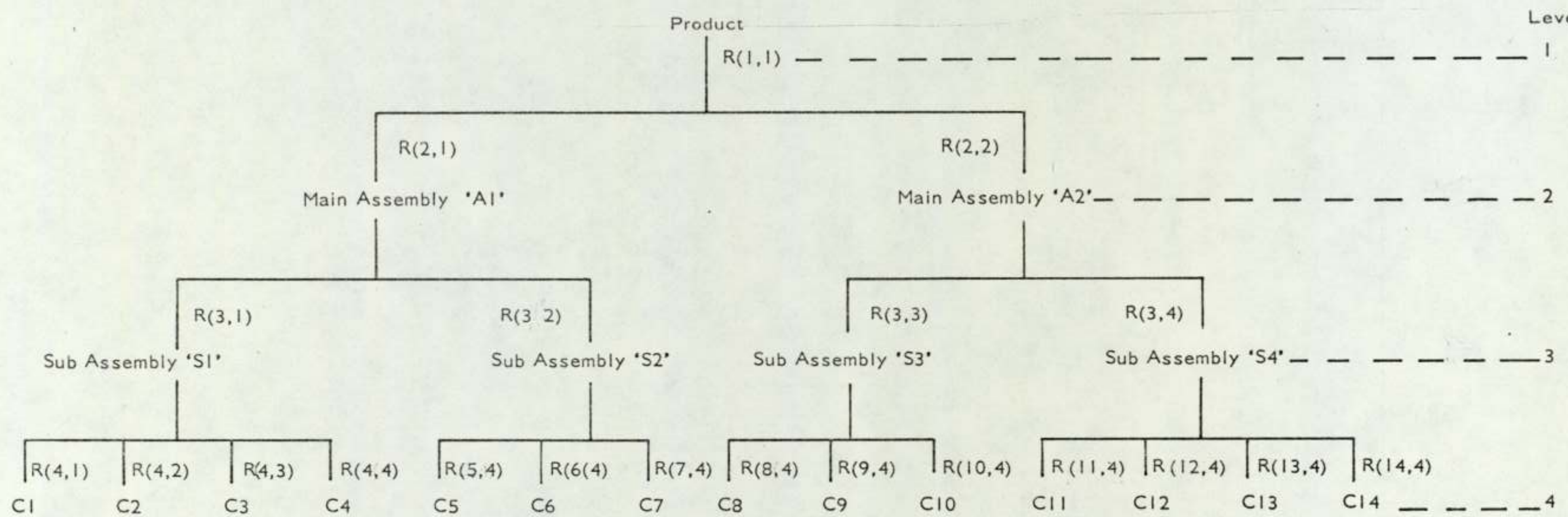
FIGURE 22 DATA CAPTURE SYSTEM



TO BE PERFORMED EACH WEEK

FIGURE 23 SYSTEM FOR COMPLETING THE DATA BASE



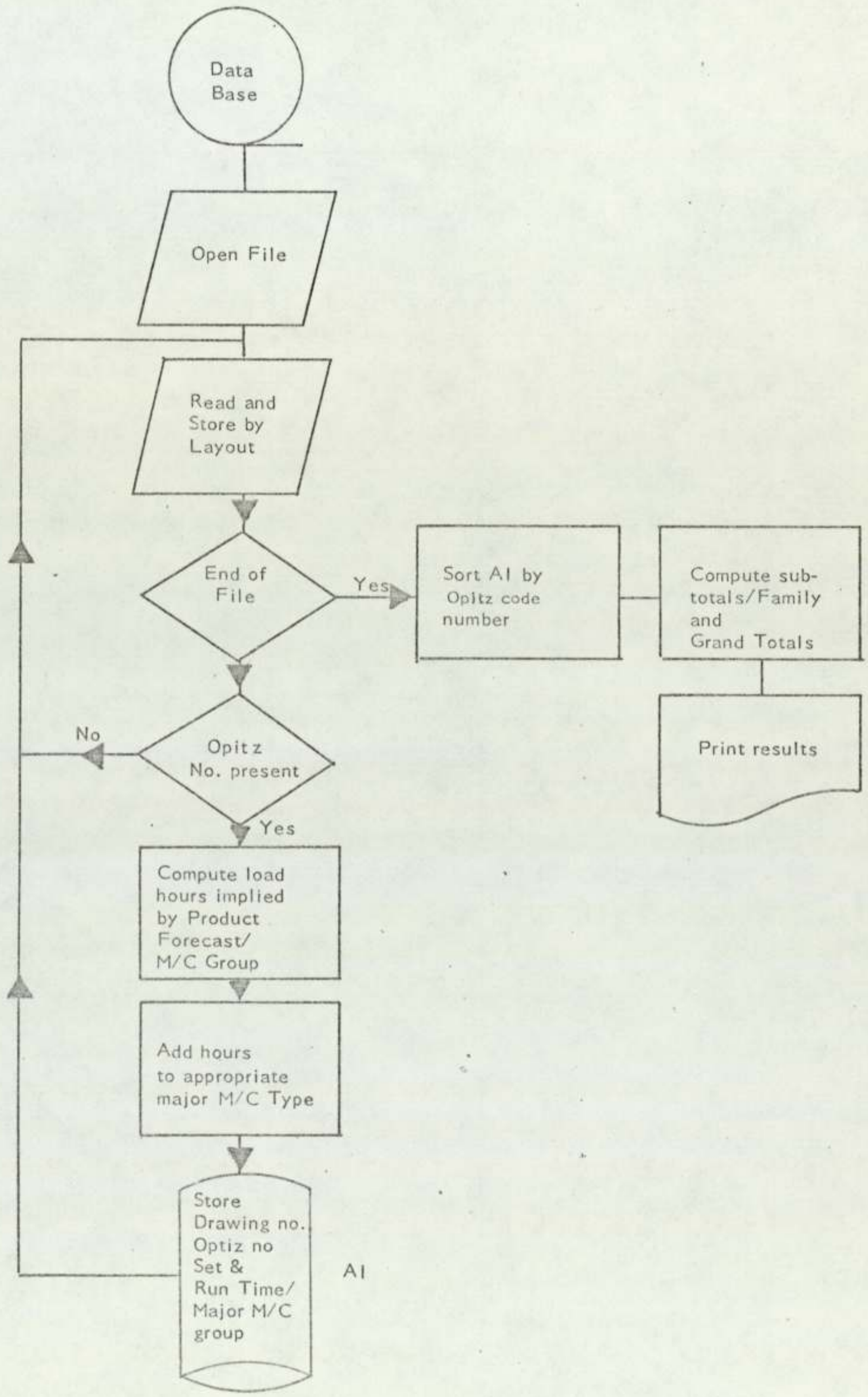


Requirement for Component 'X' used in positions C3 and C10 is:-

R(1,1) x (R(2,1) x R(3,1) x R(4,3) + R(2,2) x R(3,3) x R(10,4))

FIGURE 24 PRODUCT EXPLOSION

FIGURE 25 FLOW DIAGRAM OF THE MANUFACTURING HOURS CALCULATOR



MACHINE GROUP HOURS PER GTC AND CODE NUMBER PAGE 1 17/06/74

GTC NUMBER	CODE NUMBER	TURNING SET	TURNING RUN	MILLING SET	MILLING RUN	N.C.SECTION SET	N.C.SECTION RUN	DRILLING SET	DRILLING RUN	JIG BORING SET	JIG BORING RUN	GRINDING SET	GRINDING RUN	SHEET METAL SET	SHEET METAL RUN	OTHERS SET	OTHERS RUN
001000000	B104837	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	B116753	.7	2.9	.0	.0	.0	.0	.1	.4	.0	.0	.0	.0	.0	.0	.0	.0
001000000	B116779	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	RRA825129	.8	7.9	.0	.0	.0	.0	.1	.8	.0	.0	.0	.0	.0	.0	.0	.0
001000000	RRA825222	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000000	35131283257	.8	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001020000	55114571	1.2	1.3	.0	.0	.0	.0	.2	1.0	.0	.0	.0	.0	.1	.6	.0	.0
002000000	B116877	1.2	17.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
002000000	RRA825351	.8	3.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
010100000	B147672	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000000	B102982	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000000	B119180	1.0	5.7	.0	.0	.0	.0	.1	.7	.0	.0	.0	.0	.0	.0	.0	.0
011000000	35131282778	.7	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000000	FV282052	2.0	7.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
021300000	B104856	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTALS THIS GTC		9.2	48.9	.0	.0	.0	.0	.5	2.9	.0	.0	.0	.0	.1	.6	.0	.0
CUMULATIVE TOTALS		9.2	48.9	.0	.0	.0	.0	.5	2.9	.0	.0	.0	.0	.1	.6	.0	.0
000000016	FV720964	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
000000016	FV720965	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	FV700259	1.5	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	FV700260	1.5	3.2	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	OS81889	.8	2.1	.0	.0	.0	.0	.1	.3	.0	.0	.0	.0	.1	.3	.0	.0
001000010	OS82124	.9	2.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2	.6	.0	.0
001000010	RRA828611	.7	1.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	35131282287	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000010	55114720	.5	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.4	.0	.0
001000016	FV720973	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001000016	FV720974	.8	8.7	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
001030010	OS81876	1.0	1.2	.0	.0	.0	.0	.6	2.5	.0	.0	.0	.0	.0	.0	.0	.0
002000010	35131200004	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
002000010	55197543	1.2	2.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	RRA825253	1.2	1.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	35131282821	1.2	1.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55113521	1.2	.5	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55114744	1.0	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011000010	55147670	1.0	.8	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.2*
011030010	35131282335	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
011120010	OS82091	1.9	3.4	.5	.5	.0	.0	.2	1.1	.0	.0	.0	.0	.0	.0	.1	.6
011120010	35131282617	1.0	65.1	.0	.0	.0	.0	.2	14.4	.0	.0	.0	.0	.1	20.9	.6	19.6
011120010	35131282785	1.0	12.0	.6	4.3	.0	.0	.5	5.1	.0	.0	.0	.0	.1	4.6	.0	.0
011130010	OS81892	2.0	3.1	.5	1.4	.0	.0	.2	.9	.0	.0	.0	.0	.0	.0	.1	.5
011220010	35131282619	1.0	14.5	.8	10.3	.0	.0	.2	3.8	.0	.0	.0	.0	.1	5.9	.0	.0
011310010	OS82110	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000010	55144526	1.5	.9	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
012000010	55193716	1.0	.7	.0	.0	.0	.0	.3	.5	.0	.0	.0	.0	.0	.0	.0	.0

FIGURE 26 EXAMPLE OUTPUT FROM THE MANUFACTURING HOURS CALCULATOR

FIGURE 27 FLOW DIAGRAM OF THE LOAD ANALYSER

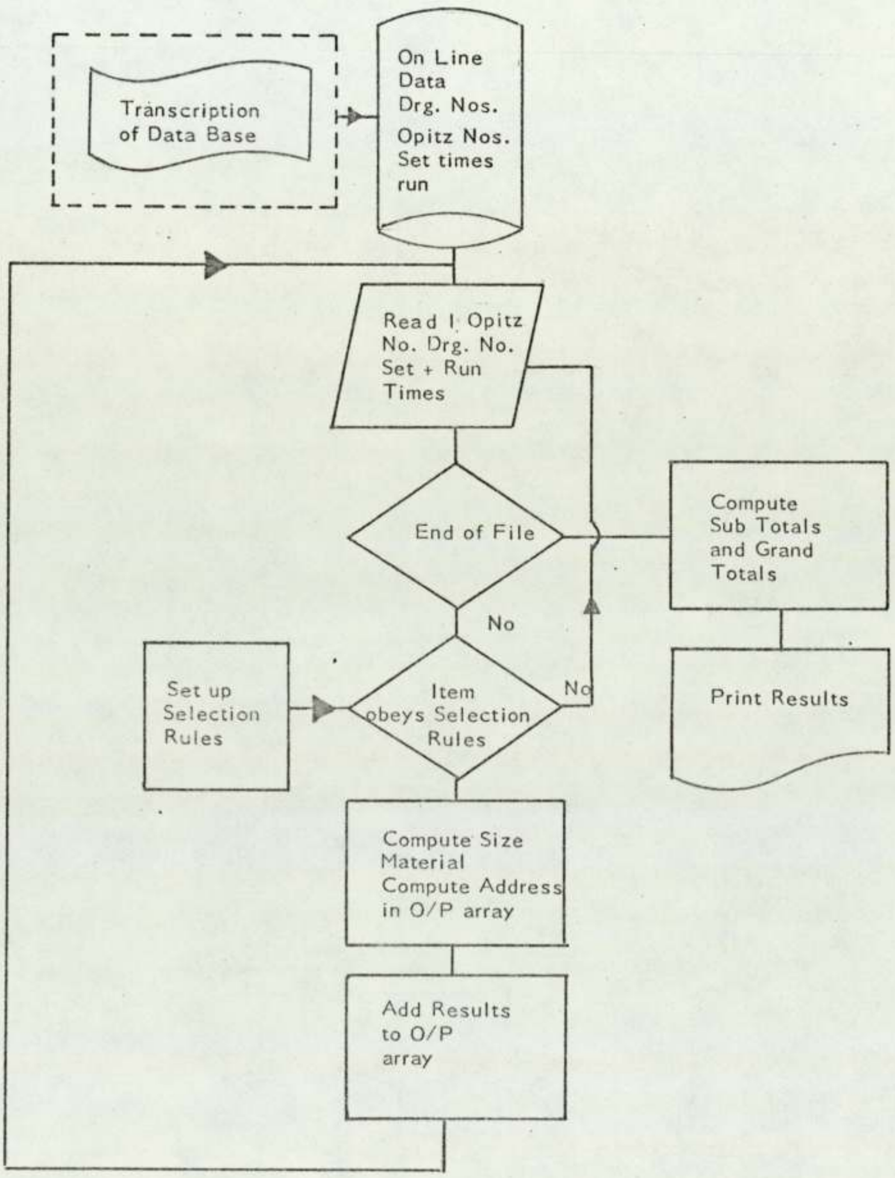


FIGURE 28 OPTION 1 OUTPUT FROM THE LOAD ANALYSER

0- 1"DIA

MATERIAL	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
ALUMINIUM	19	15	192	2	1	0	0	1	13	0	0	0	0	1	27	5	24
BRASS	38	47	287	9	20	0	0	4	60	0	0	0	0	1	14	0	0
MILD STEEL	38	39	197	7	43	0	0	2	18	0	0	3	22	4	31	0	0
STAINLESS	93	119	1503	25	117	2	6	4	27	0	0	21	173	5	57	3	9
HT STEEL	8	5	10	0	3	0	0	0	0	0	0	3	6	0	2	0	2
PLASTICS	3	2	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
HT BRASS	1	1	2	1	3	0	0	0	3	0	0	0	0	0	0	0	1
OTHERS	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	202	232	2202	47	201	2	6	14	124	0	0	28	201	14	136	9	40
		2435		249		9		138		0		229		151		50	
PEOPLE		1.691		0.173		0.007		0.096		0.000		0.160		0.105		0.035	

1- 2"DIA

MATERIAL	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
ALUMINIUM	14	17	311	8	29	0	0	5	81	0	0	0	0	1	42	0	5
BRASS	12	15	63	3	18	0	0	1	27	0	0	0	0	1	15	3	13
MILD STEEL	9	9	79	7	43	0	0	1	14	0	0	1	27	2	13	0	2
STAINLESS	27	41	[illegible]	13	86	0	0	8	110	9	59	24	113	0	11	0	15
HT STEEL	1	1	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0
PLASTICS	3	5	55	0	4	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	5	8	25	7	10	0	0	2	7	0	0	0	0	0	5	0	3
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	72	98	999	39	193	0	0	22	242	9	59	25	140	6	[illegible]	4	40
		1098		232		0		265		68		165		95		45	
PEOPLE		0.763		0.162		0.000		0.185		0.048		0.115		0.066		0.032	

2- 4"DIA

MATERIAL	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
ALUMINIUM	18	29	311	6	24	6	115	9	117	0	0	0	0	3	35	5	162
BRASS	6	6	28	3	1	0	0	2	6	0	0	0	0	1	4	0	0
MILD STEEL	4	7	46	4	14	1	20	1	9	0	0	0	0	0	9	0	0
STAINLESS	6	13	290	3	82	0	0	1	19	1	2	1	0	0	3	0	27
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	1	2	24	1	7	0	0	0	3	0	0	0	0	0	3	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	2	1	5	1	2	0	0	0	1	0	0	0	0	0	0	0	1
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	37	61	707	21	133	10	135	15	157	1	2	1	1	6	54	6	191
		768		154		146		173		3		3		61		198	
PEOPLE		0.534		0.108		0.102		0.121		0.002		0.002		0.043		0.138	

4-6.5"DIA

MATERIAL	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
ALUMINIUM	4	5	17	1	3	0	0	1	3	0	0	0	0	1	5	8	47
BRASS	1	1	15	0	0	0	0	0	3	0	0	0	0	0	3	0	0
MILD STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAINLESS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	5	6	34	1	3	0	0	2	6	0	0	0	0	1	9	8	47
		40		4		0		9		0		0		11		55	
PEOPLE		0.028		0.003		0.000		0.006		0.000		0.000		0.008		0.039	

6.5- 10"DIA

MATERIAL	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
ALUMINIUM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MILD STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STAINLESS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT STEEL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PLASTICS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CAST IRON	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PRECIOUS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
HT BRASS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OTHERS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		0		0		0		0		0		0		0		0	
PEOPLE		0.000		0.000		0.000		0.000		0.000		0.000		0.000		0.000	

10- 16"DIA

FIGURE 29 OPTION 2 OUTPUT FROM THE LOAD ANALYSER

ALUMINIUM

SIZE RANGE	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
0- 1"DIA	19	15	192	2	4	0	0	1	13	0	0	0	0	1	27	5	24
1- 2"DIA	14	17	311	3	29	0	0	5	31	0	0	0	0	1	42	0	5
2- 4"DIA	18	29	311	6	24	8	115	9	117	0	0	0	0	3	35	5	162
4-6.5"DIA	4	5	17	1	3	0	0	1	3	0	0	0	0	1	5	8	47
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 15"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	55	68	833	18	61	8	115	18	217	0	0	0	0	7	111	19	239
		901		80		124		235		0		0		113		259	
PEOPLE		0.626		0.056		0.086		0.164		0.000		0.000		0.083		0.180	

BRASS

SIZE RANGE	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
0- 1"DIA	38	47	287	9	20	0	0	4	60	0	0	0	0	1	14	0	0
1- 2"DIA	12	15	53	3	13	0	0	4	2	0	0	0	0	1	15	3	13
2- 4"DIA	6	6	28	3	1	0	0	2	5	0	0	0	0	1	4	0	0
4-6.5"DIA	1	1	16	0	0	0	0	0	3	0	0	0	0	0	3	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 15"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	57	70	395	16	41	0	0	12	97	0	0	0	0	4	38	3	13
		465		57		0		110		0		0		42		16	
PEOPLE		0.324		0.040		0.000		0.077		0.000		0.000		0.030		0.012	

MILD STEEL

SIZE RANGE	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
0- 1"DIA	33	39	197	7	43	0	0	2	18	0	0	3	22	4	31	0	0
1- 2"DIA	9	9	79	7	43	0	0	1	14	0	0	1	27	2	13	0	2
2- 4"DIA	4	7	45	4	14	1	20	1	9	0	0	0	0	0	9	0	0
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 15"DIA	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
15- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	52	57	324	19	102	1	20	5	42	0	0	5	50	8	55	0	2
		381		121		21		47		0		55		64		2	
PEOPLE		0.265		0.084		0.015		0.033		0.000		0.038		0.045		0.002	

STAINLESS

SIZE RANGE	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
0- 1"DIA	93	119	1508	25	117	2	5	4	27	0	0	21	173	5	57	3	9
1- 2"DIA	27	41	452	13	86	0	0	8	110	9	59	24	113	0	11	0	15
2- 4"DIA	6	13	290	3	82	0	0	1	19	1	2	1	0	0	3	0	27
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 15"DIA	1	1	2	0	1	0	0	0	1	3	7	1	0	0	0	1	1
15- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	127	176	2254	42	238	2	5	14	153	13	63	47	233	7	71	5	53
		2431		331		9		173		82		335		79		58	
PEOPLE		1.633		0.230		0.007		0.120		0.057		0.233		0.055		0.041	

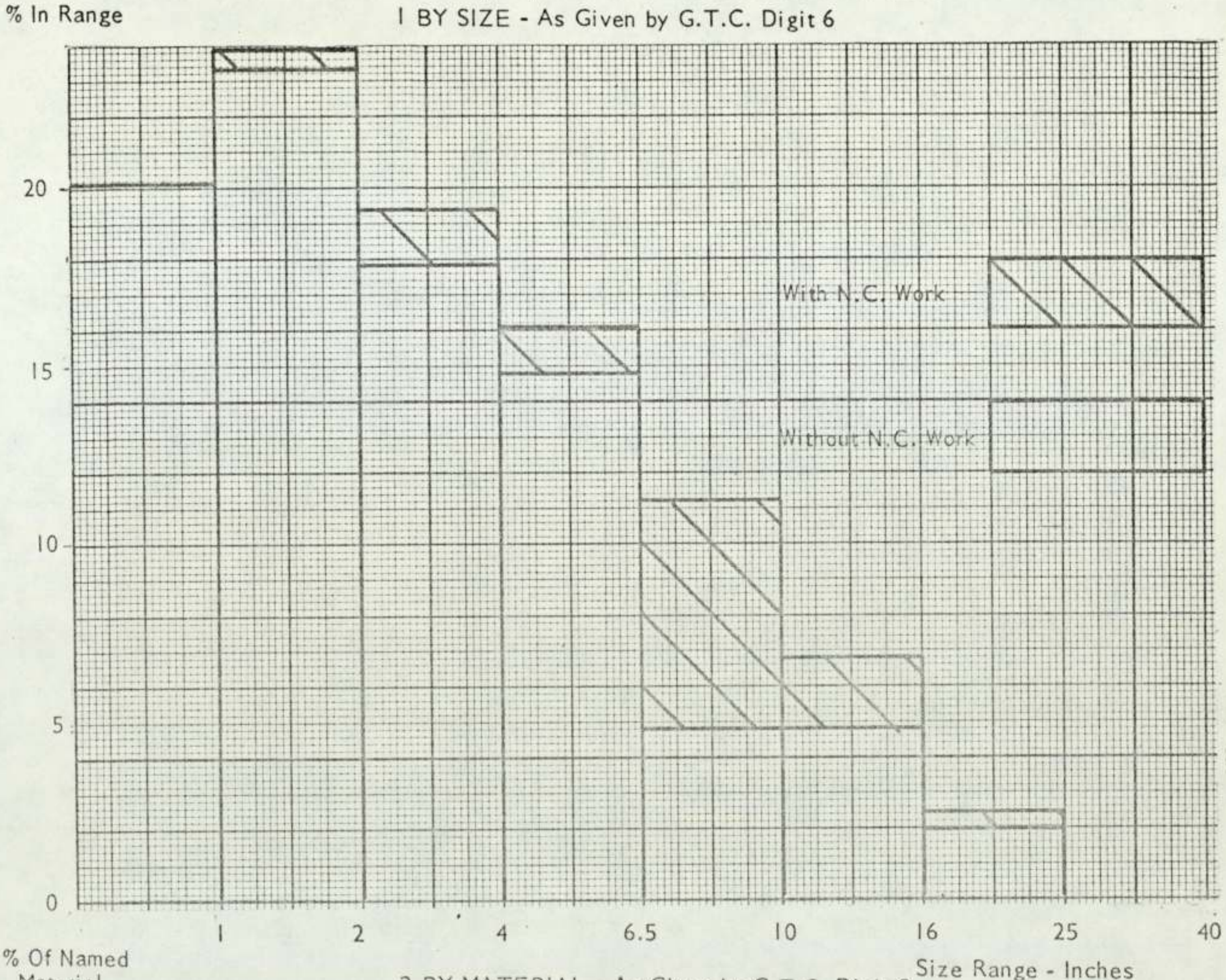
HT STEEL

SIZE RANGE	ITEMS	TURNING		MILLING		NC SECTION		DRILLING		JIG BORING		GRINDING		SHEET METAL		OTHERS	
		SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN	SET	RUN
0- 1"DIA	3	5	10	0	3	0	0	0	0	0	0	3	5	0	2	0	2
1- 2"DIA	1	1	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2- 4"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4-6.5"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6.5- 10"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10- 16"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15- 25"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25- 40"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40- 80"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
80+"DIA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	9	5	21	0	3	0	0	0	1	0	0	3	6	0	2	0	2
		28		4		0		1		0		9		3		3	
PEOPLE		0.020		0.003		0.000		0.001		0.000		0.007		0.002		0.002	

PLASTICS

SIZE RANGE	ITEMS	TURNING	MILLING	NC SECTION	DRILLING	JIG BORING	GRINDING	SHEET METAL	OTHERS

Analysis by Items - Sample Size Total = 982 Non-Rotational = 253
%ages quoted are of the Non-Rotational Items



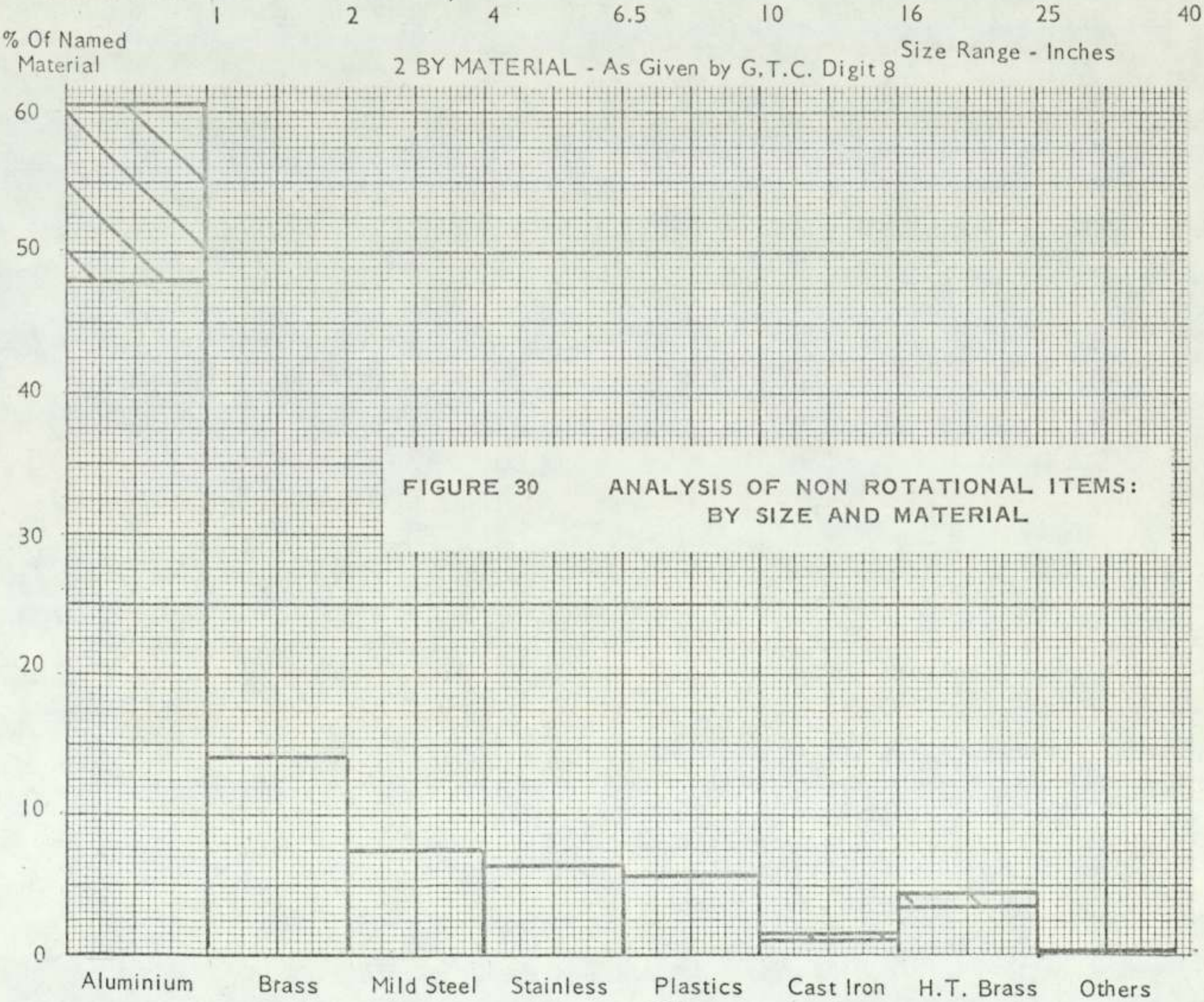
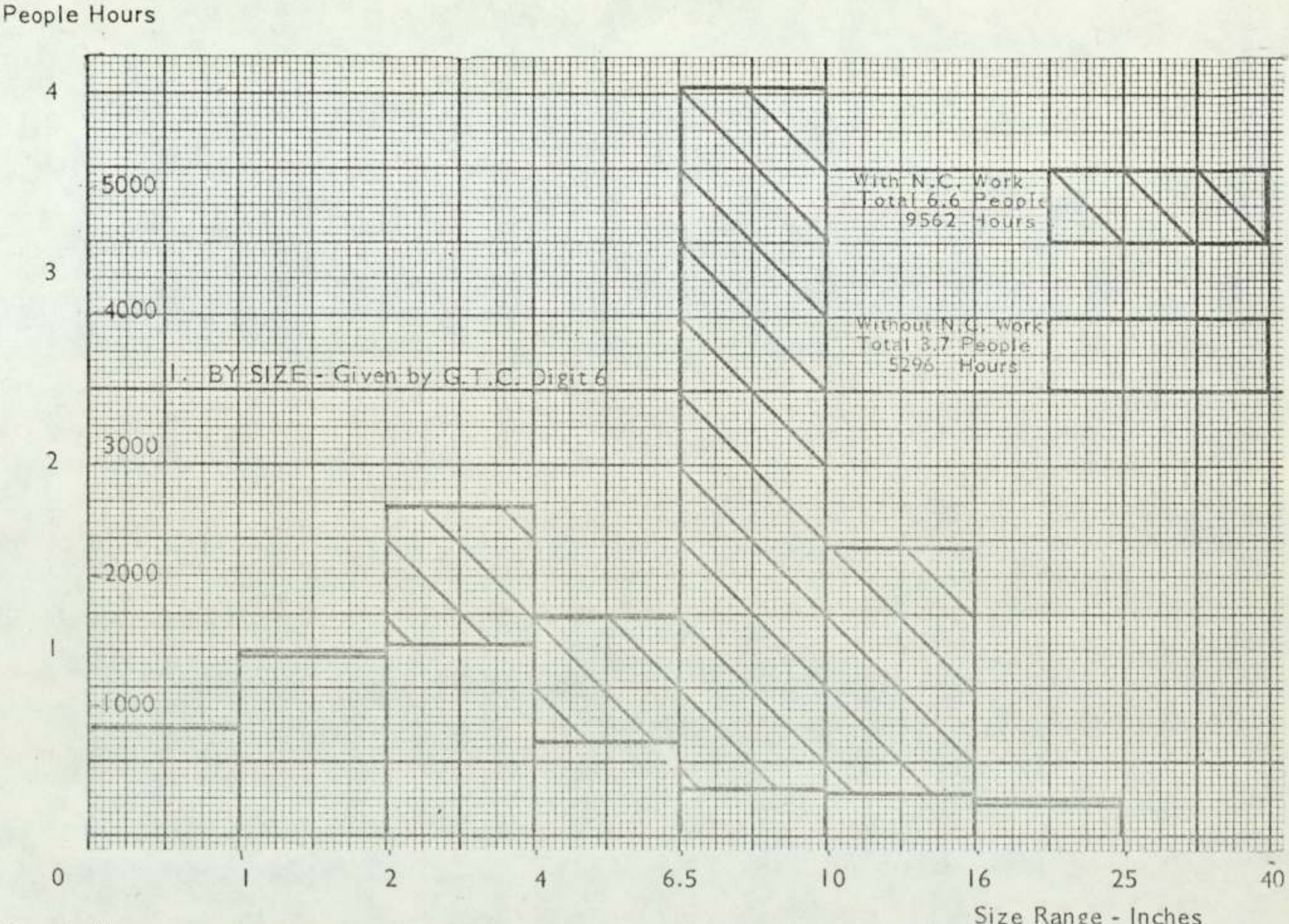


FIGURE 30 ANALYSIS OF NON ROTATIONAL ITEMS: BY SIZE AND MATERIAL

FIGURE 31 AS FIGURE 30 BUT BY WORK CONTENT

Analysis by Hours - Sample Total 27910 Non Rotational 14865 Hours
and People 19.4 10.3 People

N.B. This Analysis Assumes that Each Item is Manufactured in One Batch



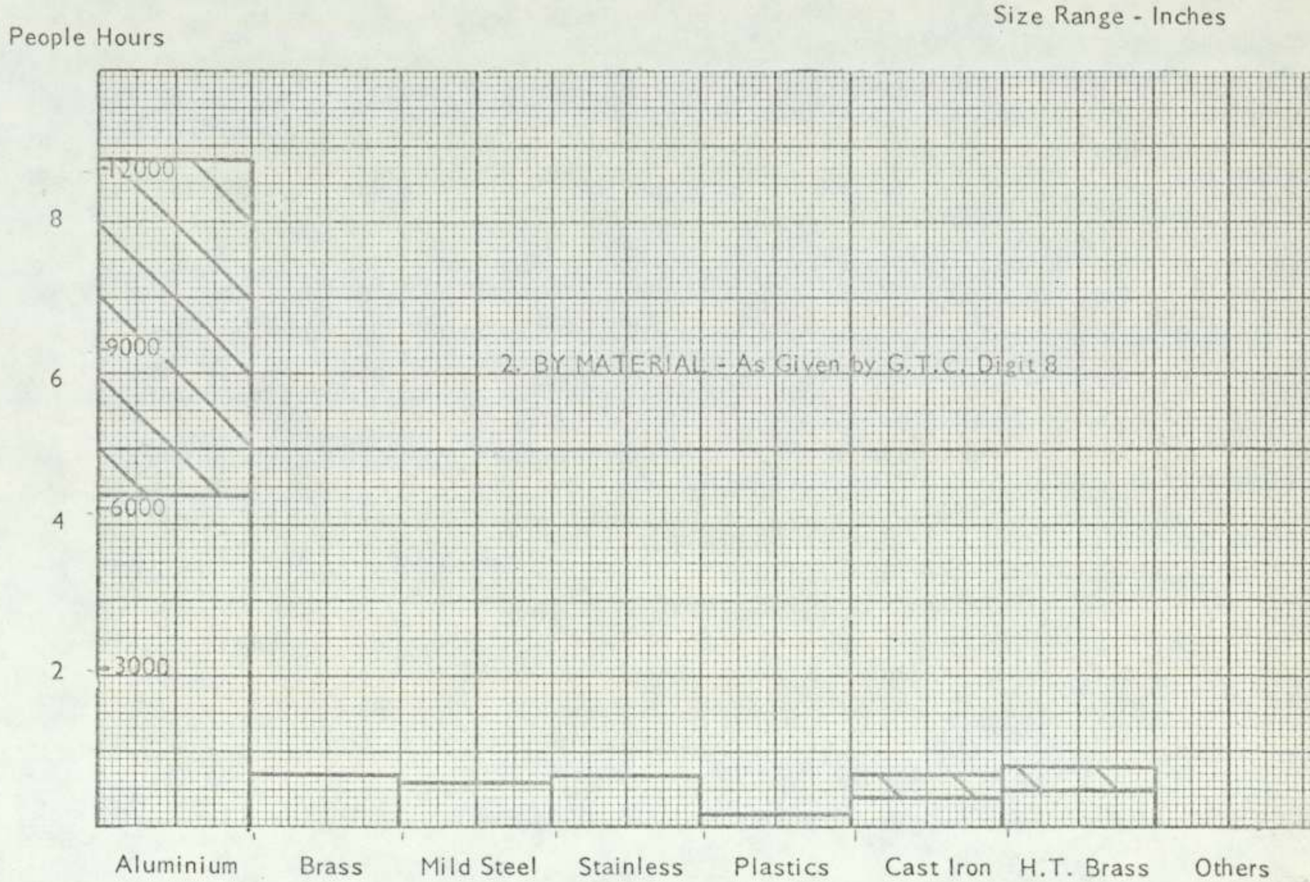
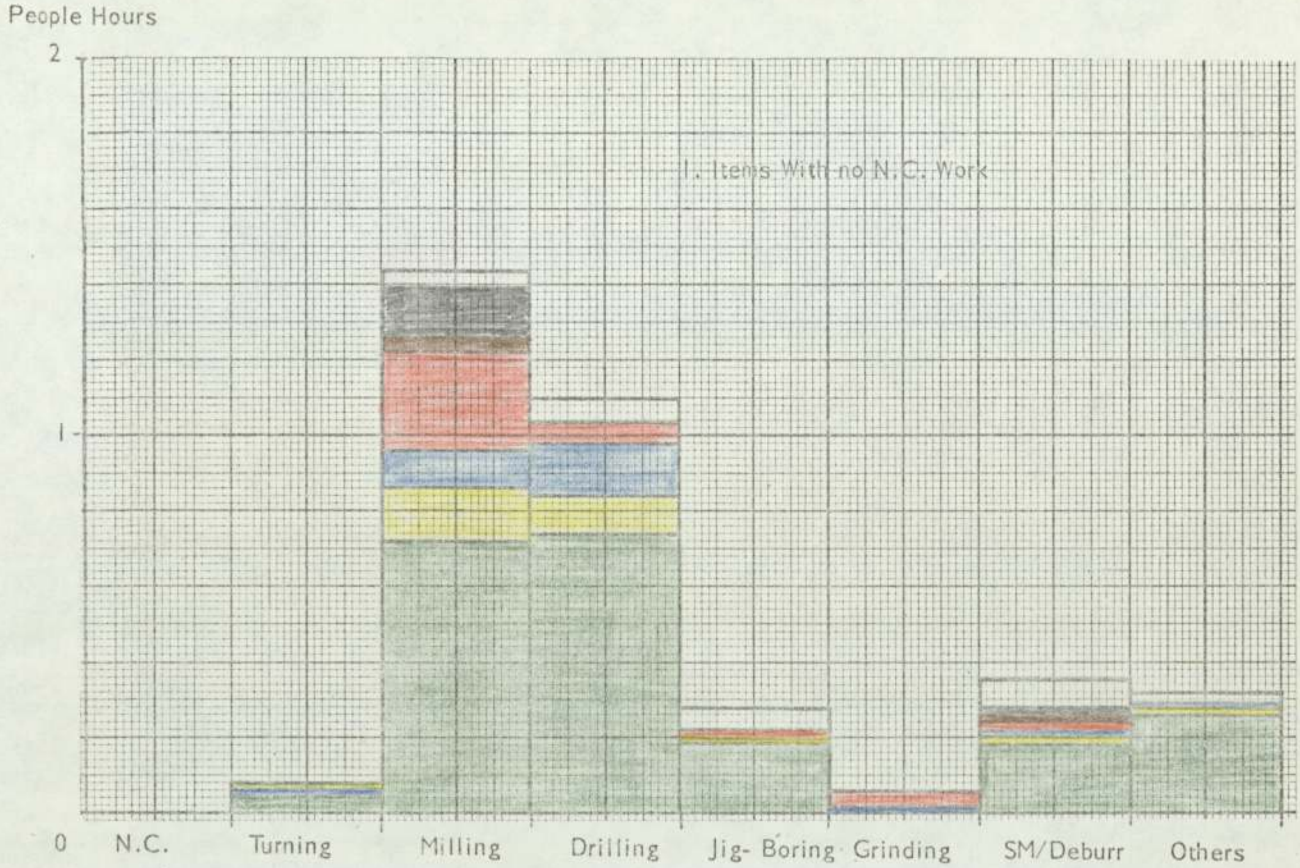


FIGURE 32 ANALYSIS OF NON ROTATIONAL ITEMS BY MACHINE TYPE

Analysis by Machine by Material - Sample Total 27910 Non Rotational 14865 Hours
1. Non-N.C. Items 19.3 10.3 People



2. N.C. Items

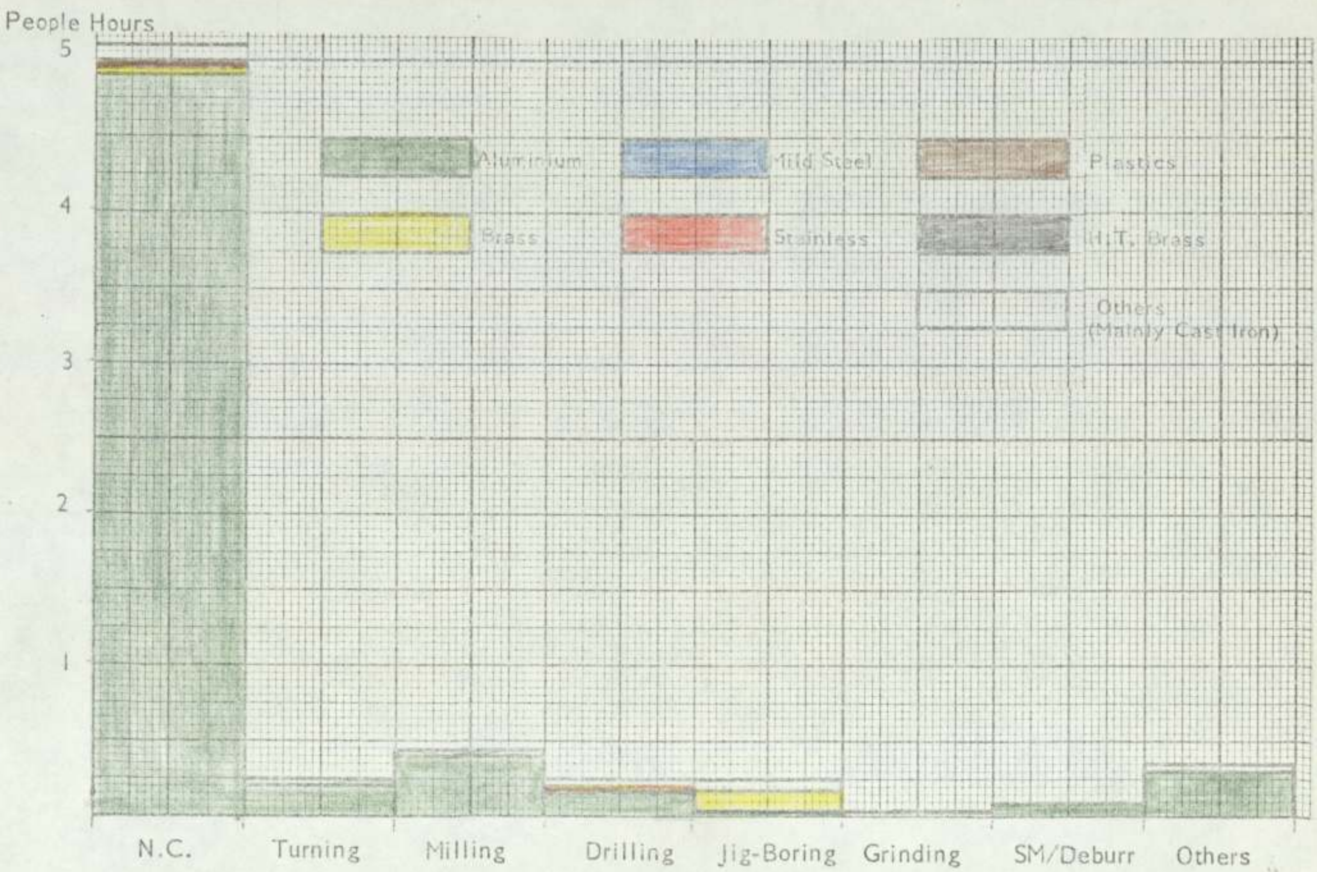


FIGURE 33 EFFECT OF DE-BATCHING

Analysis by Machine Type - Sample Total 27910 Non Rotational 14865 Hours
19.4 10.3 People

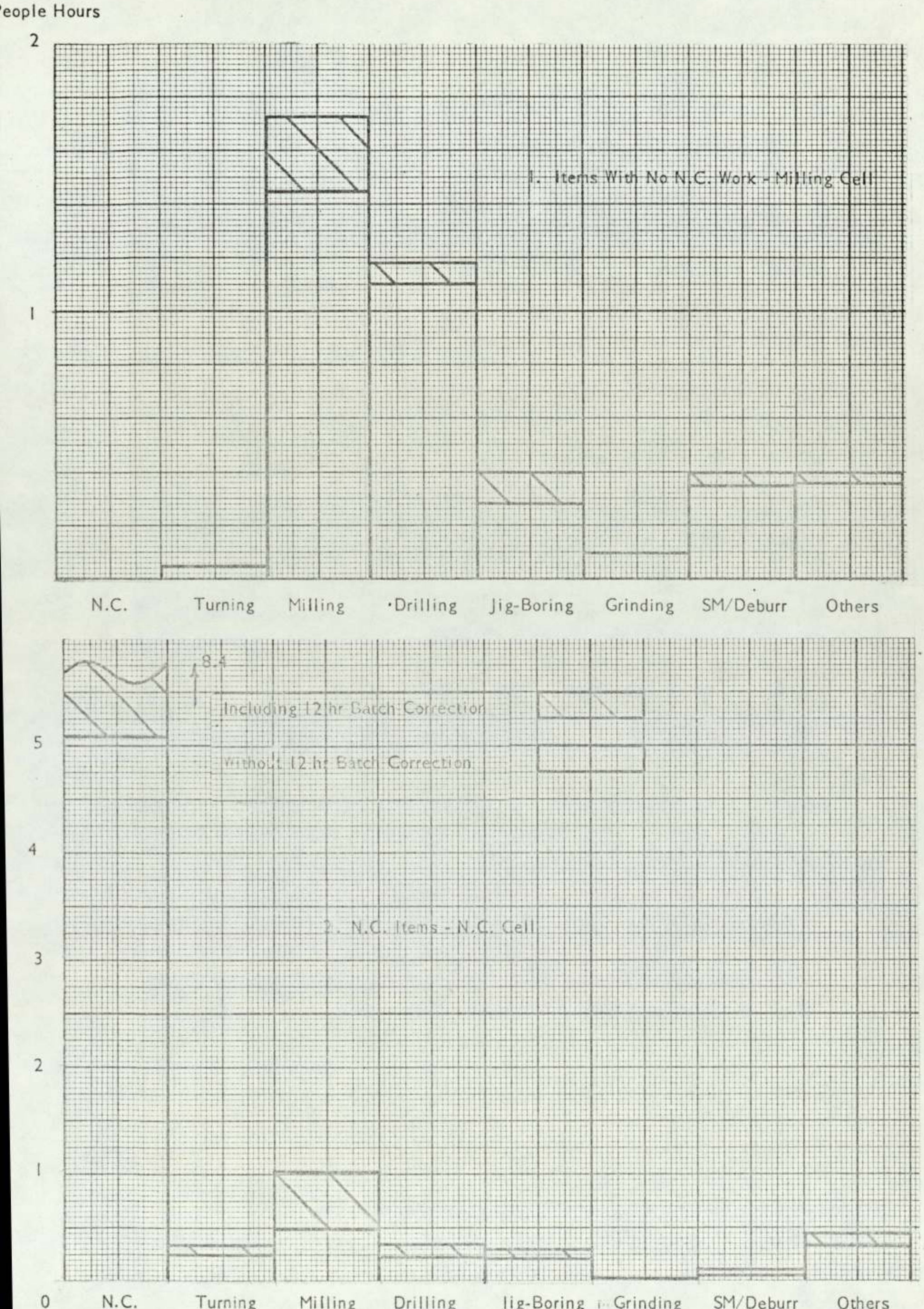


FIGURE 34 LOAD CHARACTERISTICS OF THE MILLING CELL

Components — All those opitz code Ist Digit op 6, 7 or 8.
Typical components:- BLOCK SHAPES and CASTINGS.

Work Load for 3 Operators :- 3 Universal Millers
or 2 Millers and 1 Driller

Machines Required

2/3	ABENE UNIVERSAL MILLS
I	SMALL UNIVERSAL MILL for slotting etc.
I	MULTI SPINDLE DRILL & TAPPING MACHINE
2	SINGLE SPINDLE DRILLS
2	TAPPING MACHINES
I	BENCH for DEBURR and INSPECTION
I	TUMBLER or perhaps a small ROTO-FINISHER

Components: All those with Opitz Code Ist digit of 0 orl under I" diameter.
Typical shape bushes and spacers.

Work load for 4 operators. 2Turners, I Capstan Setter Operator, I Driller.

Machines required:
- 2 Conventional Centre Lathes (C.V.A.)
- I Reverse Operation Lathe
- I Small Capstan
- I Small Universal Mill
- I Multi Spindle Drill
- I Single Spindle Drill
- I Bench for inspection and deburr
- I Tumbler (deburr)

FIGURE 35 LOAD CHARACTERISTICS OF TURNING CELL A

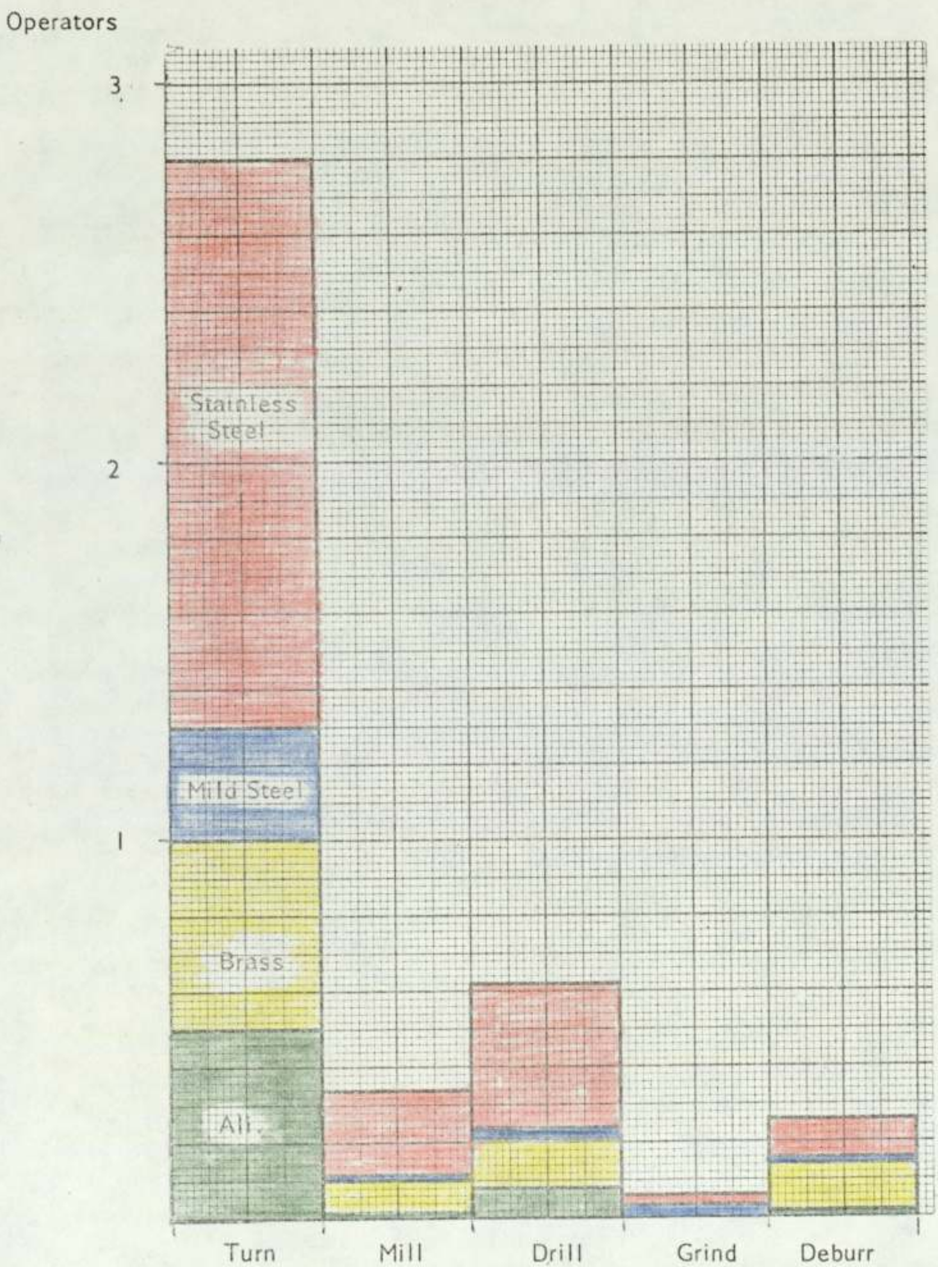
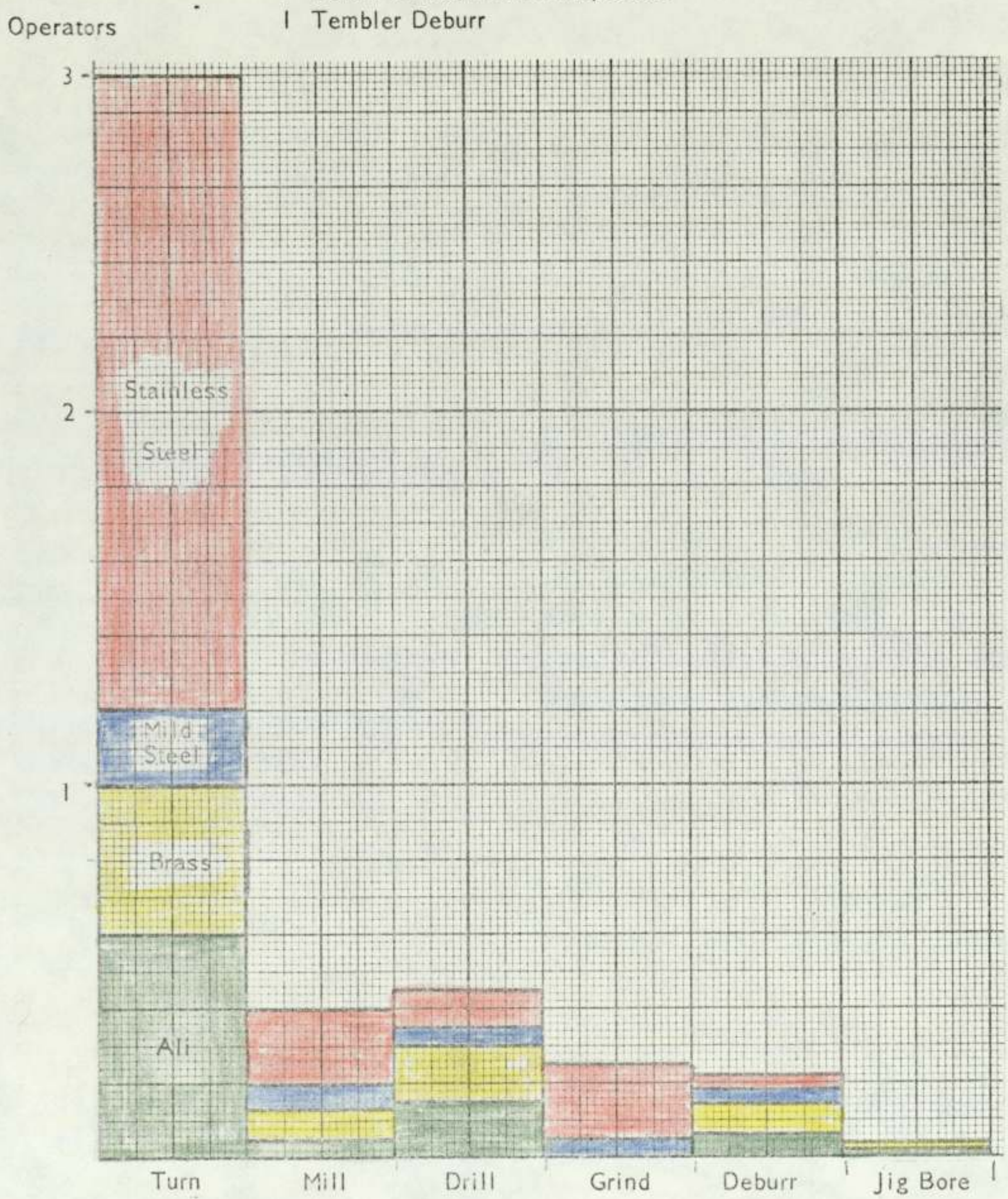


FIGURE 36 LOAD CHARACTERISTICS OF TURNING CELL B

COMPONENTS All those with Opitz Code 1st digit of 2, 3 or 4.
All components over 1" diameter. Typical shape shaft or spindle.
Irregular shapes, e.g. castings, bar stock over 1" diameter.

Work load for 4 operators. (3 Turners and 1 Miller/Driller)

Machines Required:
- 1 Cazeneuve Lathe (Large)
- 2 Centre Lathes. 1" diameter capacity
- 2 Second Operation Lathes
- 1 Abene Universal Mill
- 1 Small Universal Mill
- 1 Multi Spindle Drill & Tapping Machine
- 1 Single Spindle Drill
- 1 Bench for deburr and Inspection
- 1 Tembler Deburr



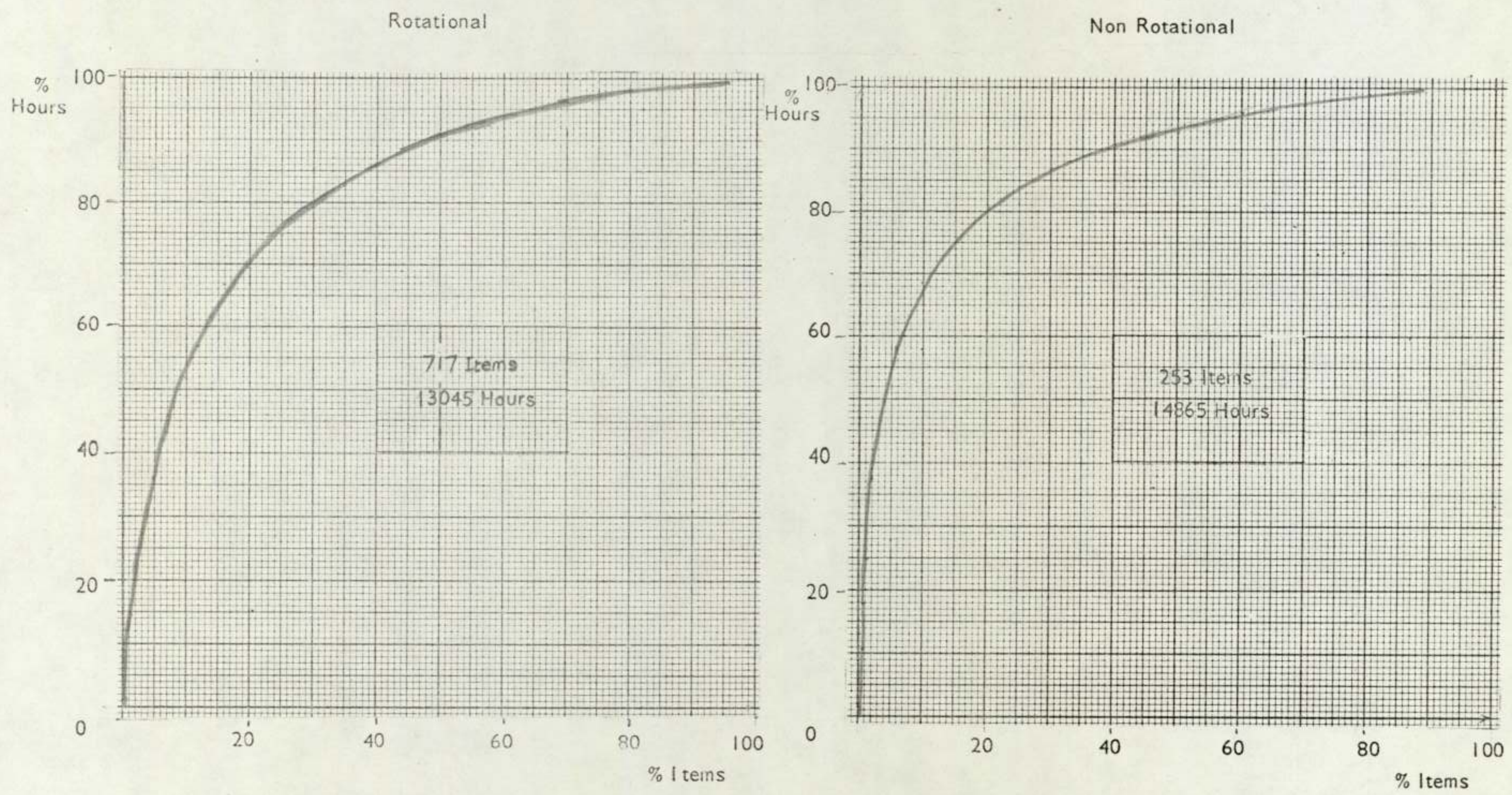
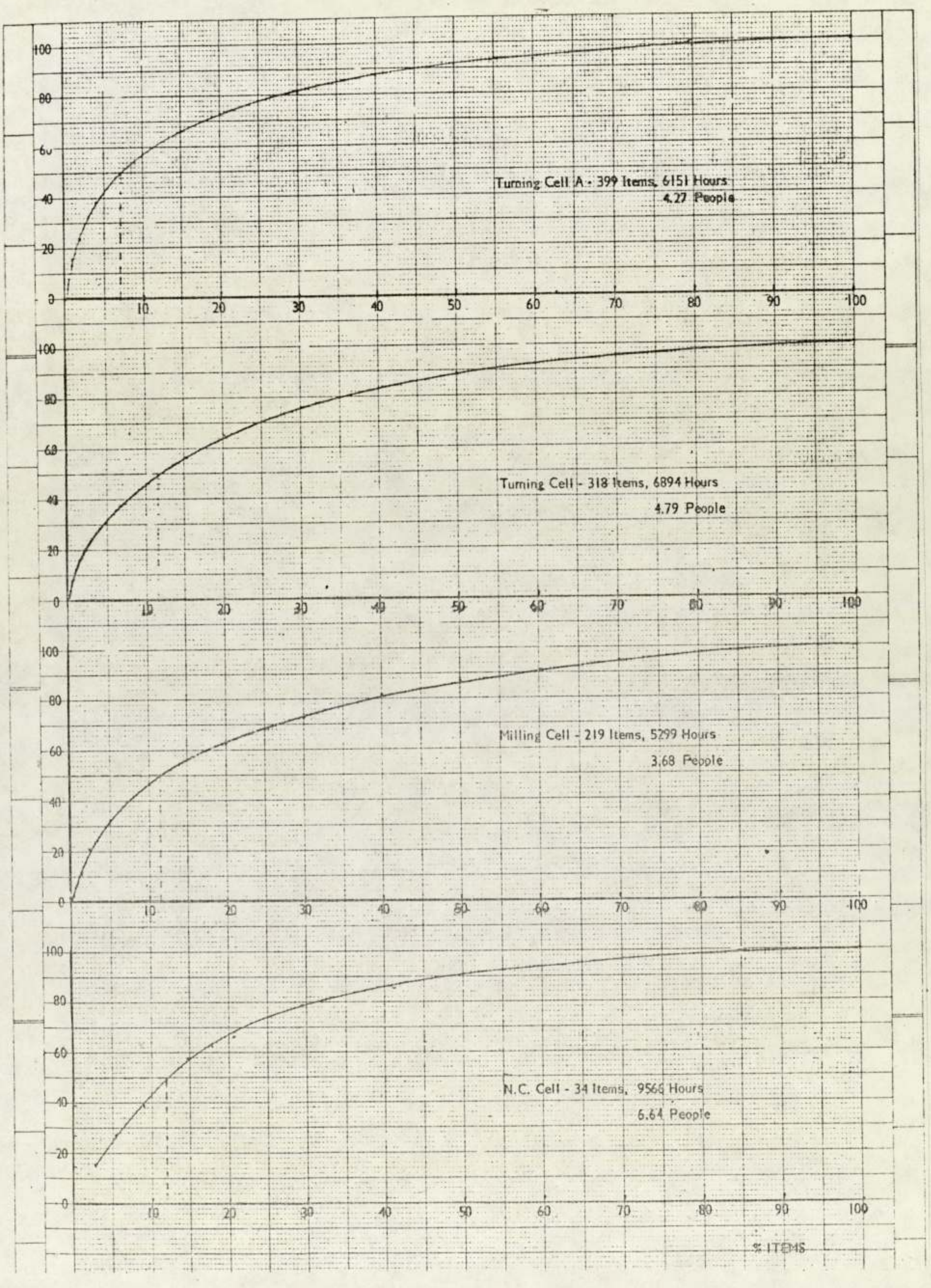


FIGURE 37 PARETO ANALYSIS OF ROTATIONAL AND NON ROTATIONAL ITEMS

FIGURE 38 PARETO ANALYSIS OF CELL LOADING



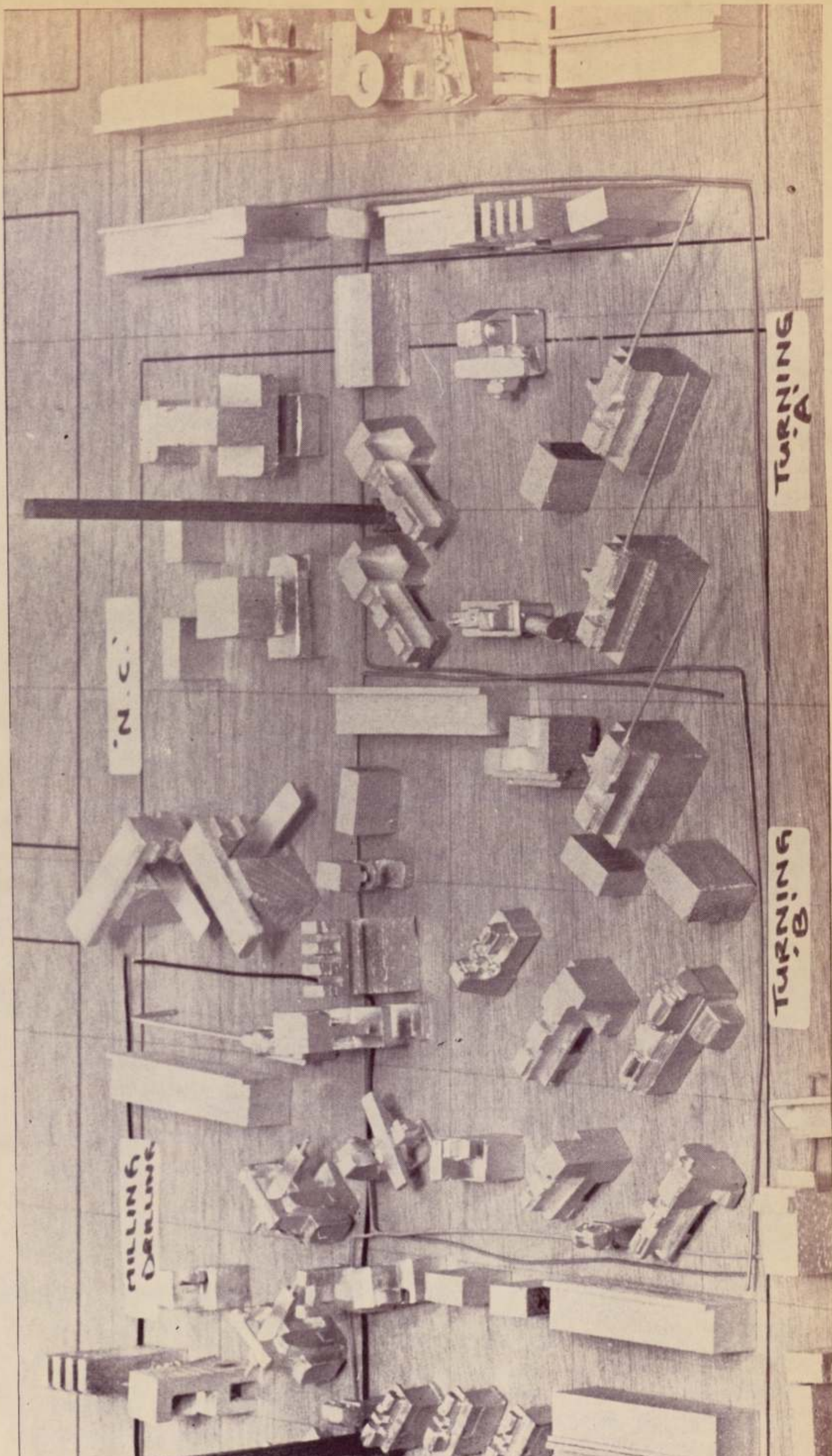


FIGURE 39 LAYOUT USED FOR INITIAL DISCUSSIONS

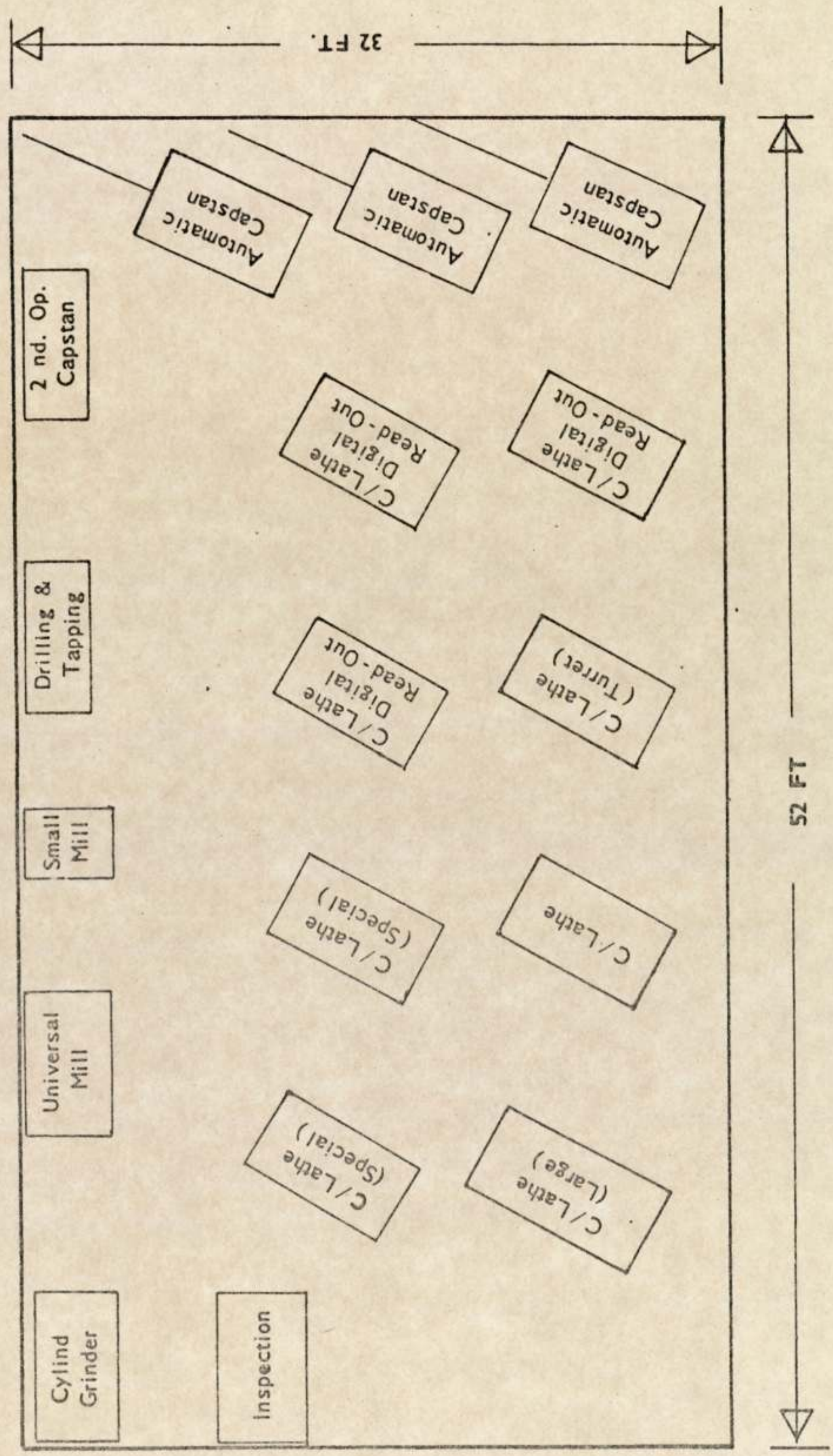


FIGURE 40 LAYOUT FINALLY CHOSEN FOR THE TURNING CELL

SAMPLE DATA FROM MANUFACTURING DIVISION

A	B	C	D	E	E	F	F	G	H	J	K
				PERFORMANCE REPORT		CAPACITY/LOAD REPORT					
DEPT. NO.	PRODN. GROUP	DESCRIPTION	CELL/ PROD'CT ORGANI-SATION	COLL-ECTION	LINE NO.	COLL-ECTION	LINE NO.	END CELL PRODN. GROUP	DUMMY	CAPAC-ITY	SPARE INDICATORS
321	bbb	TURNING CELL	C	321	00	321	00		D	180	
	030	DEBURR/ BENCH WORK		321	01	321	11			30	
	052	MILLS		321	01	321	08			30	
	060	MEDIUM CENTRE LATHES		321	01	321	01			30	
	061	MEDIUM CENTRE LATHES		321	01	321	01			30	
	062	MEDIUM CENTRE LATHES		321	01	321	01			30	
	063	MEDIUM 2ND OP CENTRE		321	01	321	02			30	
	064	LARGE CENTRE LATHE		321	01	321	03			30	
	065	LARGE 2ND OP CENTRE		321	01	321	04			30	
	066	IRIS LATHE		321	01	321	05			30	
	070	MEDIUM CENTRE LATHES		321	01	321	01			30	
	075	2ND OP CAPSTAN		321	01	321	07			30	
	076	ACCURATOOL		321	01	321	06			30	
	080	MEDIUM CENTRE LATHES		321	01	321	01			30	
	085	DRILLS		321	01	321	09			30	
	090	CYL. GRIND		321	01	321	10			30	
	095	DEBURR / BENCH WORK		321	01	321	11			30	
322	bbb	OFF-LOAD CELL	C	bbb	00	bbb	00		D	0	
	190	OFF-LOAD		bbb	00	bbb	00		D	0	
323	bbb	INSPECTION TEAM	C	323	00	bbb	00		D	150	
	121	MACHINING INSPECTION		323	01	bbb	00	E		75	
	122	PROCESS INSPECTION		323	02	bbb	00	E		75	

A The Cell No.

B Those Prodn. Groups which constitute the cell

C The Description of the Cell or the Production Groups within the Cell. It may be preferable to have more than one Description leg, one for the Performance Report and one for the Capacity / Load Report.

D Indicates whether the Department is organised by Cell or by Product Team and thus how Performance Reports should be structured.

E Indicates how hours should be collected on Performance Report.

Turning Cell :- All hours against Prodn. Groups collected under Cell 321 as collection field 321 and analysed collectively as Line no 01

Off-Load Cell :- No hours for cell printed as collection fiels 'bbb'

Inspection Team All hours against Prodn. Groups collected under Cell 323 as collection fields 323 and analysed separately as each Line no. is unique.

F Serves the same purpose as E above for Capacity / Load Report.

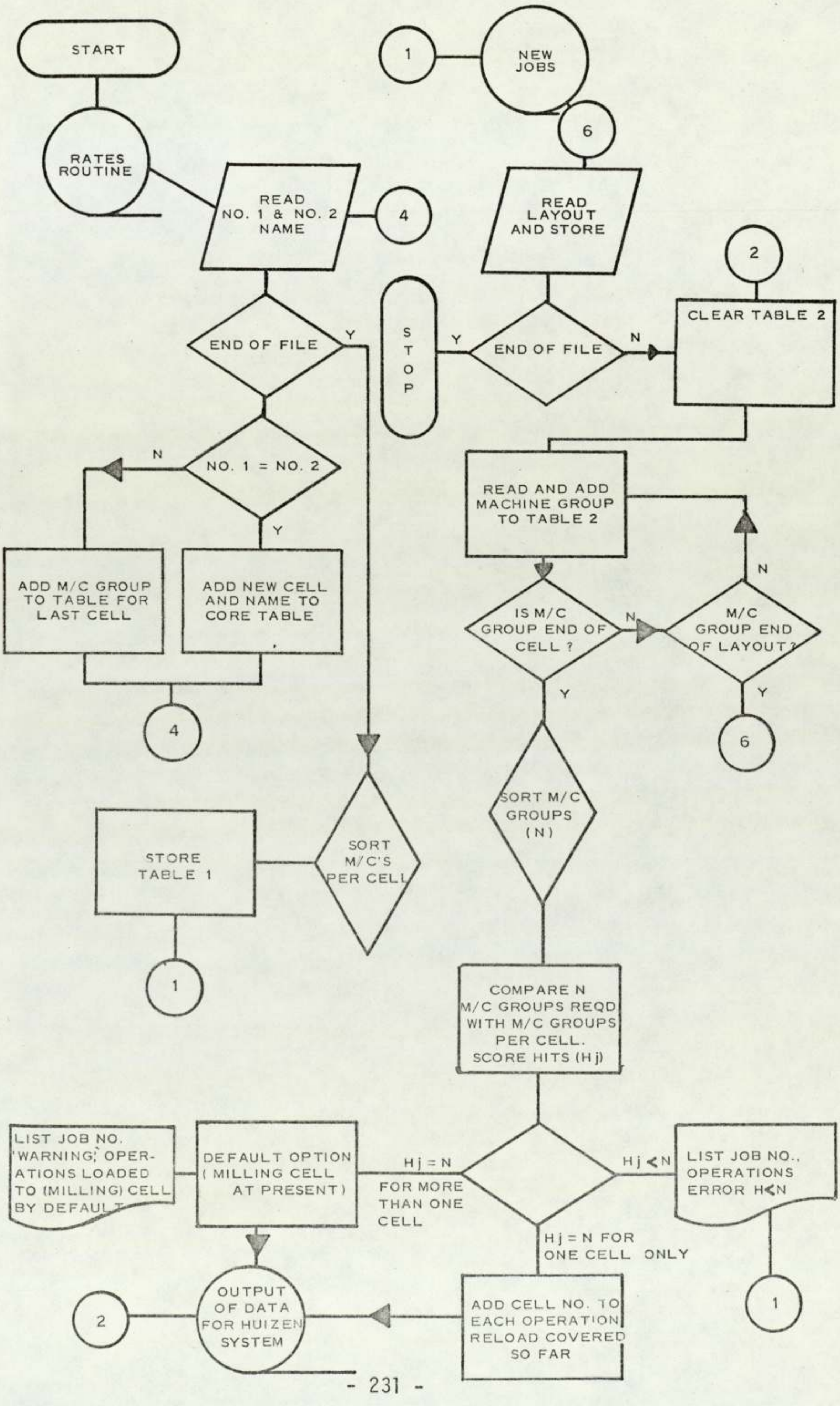
G Indicates those Production Groups which, when processed on a layout, de-limit the cell.

H Indicates those Rates/Routine records which are 'dummy', i.e. for descriptive purposes only. In theory, (although in practice this may not be true) no labour bookings should quote the Dept. No. excluding the Prodn. Group.

J Indicates total Capacity for cell and individual capacities for Prodn. Groups. Former figure used on Capacity / Load Report, latter figure not used as yet.

FIGURE 41 STRUCTURE OF THE RATES ROUTINE FILE

FIGURE 42 FLOW DIAGRAM OF THE CELL ALLOCATION PROGRAM



DATE 365.6 PAGE [illegible]

4X1 WEEK AND 11X1 MONTH	CAPSTANS 0 075	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD	TURNING SMALL 070 081	MEDIUM 060 061 062	LARGE 064	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD
BACKLOG	258	258		282	1[illegible]1	31[illegible]	176	587		162
365.6	45	303	30	308	71	77	34	769	240	294
366.6	83	3[illegible]6	60	324	60	68	24	921	490	354
367.6	47	433	9[illegible]	329	23	135	25	11[illegible]4	72[illegible]	372
368.6	12	445	12[illegible]	329	16	115	43	1278	960	393
369.6	118	563	240		105	473	50	15[illegible]6	192[illegible]	
373.6	1[illegible]8	671	36[illegible]		191	236	72	24[illegible]5	2880	
377.6	49	720	480		44	154	5	2608	3840	
381.6	36	756	60[illegible]		42	122	30	2802	4800	
385.6	25	781	720		13	6[illegible]	-	2875	576[illegible]	
389.6	5	786	84[illegible]		2	1	15	2853	672[illegible]	
393.6	-	786	960		-	-	-	2893	7680	
397.6	-	786	1[illegible]80		-	-	-	2893	8640	
401.6	-	786	1200		-	-	-	2893	96[illegible]	
405.6	-	786	132[illegible]		-	-	-	2893	1[illegible]560	
409.6	-	786	144[illegible]						11520	
FORWARD LOAD	18[illegible]	966			461	467	23	3844		
TOTAL	966				1129	2218	497			

4X1 WEEK AND 11X1 MONTH	MILLS DATUM 050	SMALL 051	MEDIUM 052	LARGE 053	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD	DRILLS DRILL & TAP 085	CUM LOAD HRS	CUM AVAILABLE CAPACITY	CUM AVAILABLE LOAD
BACKLOG	8	24	847	244	1123		1[illegible]7	652	652		68
365.6	-	2	133	-	1253	210	148	104	756	90	7[illegible]
366.6	-	17	92	6	1373	420	156	157	913	18[illegible]	7[illegible]
367.6	-	16	89	11	1409	63[illegible]	166	148	1[illegible]61	27[illegible]	85
368.6	-	1[illegible]	140	-	1639	840	169	115	1176	360	85
369.6	-	4	520	54	2217	1680		459	1635	72[illegible]	
373.6	-	25	354	-	2596	[illegible]252		581	2216	108[illegible]	
377.6	3	47	122	-	2768	3360		205	2421	1440	
381.6	-	-	248	-	3[illegible]16	420[illegible]		179	2600	1800	
385.6	-	5	40	-	3061	5[illegible]4[illegible]		1[illegible]3	27[illegible]3	216[illegible]	
389.6	-	47	38	-	3146	588[illegible]		59	2762	2520	
393.6	-	-	27	-	3173	6720		29	2791	2880	
397.6	-	-	1[illegible]	-	3183	7560		23	2814	3240	
401.6	-	-	17	-	32[illegible]	84[illegible]		1[illegible]	2824	3600	
405.6	-	-	-	-	32[illegible]	924[illegible]		-	2824	3960	
409.6	-	-	13	-	3213	10080		-	2824	4320	
FORWARD LOAD	1	26	59[illegible]	-	383[illegible]			387	3211		
TOTAL	12	223	3280	315				3211			

FIGURE 43 LOAD CHART USED PRIOR TO GROUP TECHNOLOGY

REPORT RMD01(GT) THE MEL EQUIPMENT CO. LTD. PAGE 0001

MD CAPACITY LOAD REPORT WK. 418.7

TURNING TEAM MACHINE GROUPS

4X1 WEEK AND 11X1 MONTH	ACCURA TOOL 076	2ND-OP CAPSTAN 075	LARGE CENTRE LATHE 064	LARGE 2ND-OP CENTRE 065	MEDIUM /SMALL CENTRE 060 062	MEDIUM 2ND-OP CENTRE 063	IRIS LATHE 066	MILLS 052	DRILLS 085	GRIND CYL. 090	DEBURR 095	OTHERS ---	CUM LOAD HRS	CUM AVAIL. CAPACITY	CUM AVAIL. LOAD
BACKLOG	102	11	91	237	78	62	91	32	275	614	1009	-	3094		651
418-7	90	6	24	82	26	35	17	-	28	72	75	-	3549	300	694
419-7	81	1	21	87	33	9	21	-	26	109	70	-	4101	600	727
420-7	105	2	21	94	10	-	43	-	18	140	148	-	4698	900	747
421-7	69	5	26	63	12	43	26	1	56	169	83	-	5294	1200	
422-7	132	13	38	146	23	47	76	4	91	474	443	-	6952	2400	
426-7	93	6	41	75	10	11	15	-	55	198	322	-	7836	3600	
430-7	39	36	9	18	15	1	7	-	48	51	265	-	8340	4800	
434-7	12	-	10	12	3	-	4	1	12	26	10	-	8446	6000	
438-7	12	2	4	18	6	-	7	-	26	23	107	-	8660	7200	
442-7	33	7	6	7	2	1	1	-	10	19	78	-	8826	8400	
446-7	30	1	7	42	4	-	5	-	1	25	27	-	8973	9600+	
450-7	9	-	6	29	-	-	3	-	4	1	30	-	9064	10800	
454-7	12	-	6	26	-	-	3	-	31	-	-	-	9152	12000	
458-7	15	-	-	16	-	-	3	-	9	9	6	-	9200	13200	
462-7	18	-	-	24	-	-	3	-	13	9	256	-	9511	14400	
FORWARD LOAD	357	11	187	316	60	-	80	1	416	438	934	-	12611		
TOTAL	1215	101	497	1292	282	209	405	39	1119	2377	3863	-			

NB 1)FIGURE OF 300 HOURS CAPACITY IS ARBITRARY

2)BLANK COLUMN MAY BE HELPFUL FOR UNALLOCATED MACHINE GROUPS

SEE NEXT PAGE

ISSUE 1 20/03/75

FIGURE 44 LOAD CHART USED AFTER GROUP TECHNOLOGY

0227 PRODUCTION GROUP C76 ACCURATOOL WORK ISSUE LIST MANUFACTURING DIVISION WEEK NO 473.1 PAGE NO 001

STRT DATE	UR	A C	RC	ISS DATE	NAME	CODE NUMBER	DESCRIPTION	FAMLY TREE	CC	W.O.NUMBER	OP NO	QUANT AVAIL	LOAD TIME	PROD.GP BEF	PROD.GP AFT	CW	T I	REMARKS
4530	5	0	NB	4551	OTHER	35131283217202	SCREW	A1001A	00	999997 291 0	060	110	106	002	052			LOADED TO ACCURATOOL
4530	5	0		4731	APPRENTI	43220813769003	COLLAR	BB007A	00	652997 000 0	050	167	67	002	075			
4580	5			4707	OTHER	43220813802001	BUSH	B1048H	00	651656 004 2	040		233	002	075			JOB CARD NOT SENT IN
4650	5	0				FV/397348 02	SHOULDER SCREW	01383B	00	651915 010 0	050	205	85	002	075			
4670	1	0				35131283001001	SHORT CIRC CLMP	YK837A	00	226408 285 0	080	199	48	002	085		2	
4670	5	0				RR/A825907 03	WASHER FLAT	A1003A	SZ	289051 116 0	030	158	40	002	030			
468C	1	0				35131248006002	SPECIAL SCREW	UD167A	00	226408 275 0	060	135	80	002	052			
4680	1	0		4731	ALLEN	35131282879202	SPRING PIN	MB007A	S1	226408 281 0	030	815	80	002	097		1	
4680	5	0				SD/A141765 02	SPACER	M2361A	00	333913 000 0	050	114	42	002	075			
4680	5	0				SD/A141764/103	HANK BUSH	M2359A	00	333913 000 0	050	60	44	002	075			
4680	5	0				43220815550002	BUSH	BA010A	SZ	652997 000 0	030	75	78	002	085			
4680	5	0				SD/A141764/203	HANK BUSH	M2227A	00	333913 000 0	060	367	108	002	075			
4690	5	0				SD/A141739 04	PILLAR	M2221A	00	333913 000 0	050	312	112	002	075			
4690	5	0				35131282172 01	TUNING PIN	A0010A	00	724807 417 0	050	1030	354	002	051			
4700	1	0				SD/A141740 04	PILLAR	M2222A	00	333913 000 0	050	108	47	002	075			
470C	1	0				35131283263001	BUSH	MB002A	00	260037 120 0	050	70	51	002	085			
4700	1	0		4731	TRILL	35131283283001	BUSH	MB011A	00	305006 020 0	050	410	145	002	085			
4700	5	0				35131283347201	SHORT CLAMP	YL118A	SZ	226408 285 0	050	69	33	002	052			
4700	5	0		4727	TRILL	43220813815001	BUSH	BC026A	SZ	652997 000 0	030	650	141	002	085			
4710	5	0				35131283056201	RIVET BUSH	UB893A	00	226408 275 0	030	253	121	002	085			
4720	1	1				35131250011202	CAPTIVE SCREW	FG001A	00	226408 281 0	070	415	101	002	052			
4720	5	1				35136101048 0B	PIN DOWEL	MB026B	00	298077 070 0	020	75	28	002	121			
4720	5	0				35131283079201	WASHER	FG002A	00	226408 281 0	030	415	81	002	085			
4720	5	0				35131282963201	BOLLARD	UD151A	00	226408 275 0	050	101	90	002	061			
4720	5	0				35131282177 01	INSERT	A0002A	00	724807 417 0	030	335	226	002	051			
4740	1	0				B116545 03	SCREW	MB016A	00	281204 425 0	040	27	25	002	052			
4740	1	0				A147728 01	SPACER	A1001A	00	289035 156 0	050	108	43	002	085			
4740	1	0				35131283065201	PATH ADJUSTER	UB765A	00	226408 275 0	070	85	66	002	085		1	
4740	5	0				RR/A828500 2A	FERRULE ELT CON	BB489A	00	282804 490 0	060	168	81	002	052			
4740	5	0				35131282574201	BOLLARD	UD145A	00	226408 275 0	030	101	90	002	052			
4740	5	1				RR/A825022 03	PILLAR ASSY	01891B	00	724807 404 0	080	610	99	004	075			
4750	5	0				RR/A826083 03	SCREW MACHINE	01072A	00	724807 404 0	040	175	80	002	052			
4760	1	0				35131253508201	SPACER	MB066A	00	226459 002 0	040	270	60	002	085			
4760	5	1	RM			B115762 03	SPACER	A1006A	00	281204 428 0	040	210	32	002	030			
4760	5	1	RM			35131283425201	PIN	MB005A	00	226408 283 0	040	101	37	002	121			
4760	5	1	RM			B115599 03	SPIGOT	A1003A	00	281204 428 0	030	105	46	002	061			
4760	5	0				RP/A825301 04	PILLAR ASSY	01839A	00	724807 404 0	080	652	94	004	075			
4770	1	0				RP/A827293 07	SCREW SHOULDER	BB354A	00	282804 492 0	050	135	66	002	075			
4770	1	0				A147735 01	SPACER	A1004A	00	289035 156 0	030	106	67	002	060			
4770	5	1				RR/A825299 03	PILLAR ASSY	01436A	00	724807 404 0	080	168	40	004	075			
4770	5	1				RR/A825352 04	POST ELECT	01552A	00	724807 404 0	080	346	64	004	075			
4770	5	0				RR/A828541 04	WASHER PACKING	01098A	00	724807 404 0	030	175	65	002	085			
4770	5	1				RR/A825022 03	PILLAR ASSY	01891A	00	724807 404 0	080	710	113	004	075			

FIGURE 45 THE 'WORK ISSUE LIST' USED BEFORE GROUP TECHNOLOGY

SEE FOLLOWING PAGE

APPENDIX 4
REPORT RMDC5(GT)
****

THE MEL EQUIPMENT CO.LTD
****

MD MATERIAL AND TOOL CHASING LIST
****

PAGE 0001
****
WK.424.7
****

START DATE	RC	MAT'L ITEM NO.	MATERIAL DESCRIPTION OR TOOL NO.		PREV CELL	OP NO	PART CODE NO.	ITEM NO	WORKS ORDER	REMARKS
3890		A1017	D145438	REAR SUPPORT	327		DP19057	A1001A	289078 025 0	
3970	MS	CF/IO	RR/B82845C/2	BLANKING GROMMET F/ISSUE	327		RR/A82488	BB326A	282707 492 0	HELD AVIONICS
3970	MS	CF/IO	RR/B828450/3	JUNCTION BOX.F/ISSUE	327		RR/A828466	BB325A	282707 492 0	HELD AVIONICS
3990	TN		MRS51C44		327	080	RR/A824978	A1166A	284653 410 0	
3990	TN		MCT29924			040	B115826	B2053A	289027 111 0	
4090		MB018	041301800002	22 SWG AL ALLOY SHT L81			RR/B825178	MB018A	284750 409 0	
4160	RM	B1062	011304405004	1/4 X 1/4 SQ ST/STL BAR EN57			B115490	B1062A	280909 470 0	PO324742RAPPS
4180	RM	A1002	041301109012	.812 A/F HEX AL ALLOY BAR			B116875	A1002A	289027 222 0	PO324754APP
4200	RM	A1002	A/F	7/32 DIA STL ROD BS970 EN3B			A436283	A1002A	293237 008 0	PO324737TEDO
4210	TN		ERT 1881.			120	RR/B827673	01954A	284653 402 0	
4220	TN		MCT30165		327	040	B118594	A1197C	283126 478 0	
4230	RM	B1208	031309501001	38SWG COPPER SHT BS899			A148667	B12C8B	280909 431 0	GOODS IN 2810
4245		A1004	B117497/UNF	CASTING			B117497	A1004A	289027 172 0	

NB 1) THIS IS A CHASING LIST FOR THE CELL CHASER.IT ONLY SHOWS BACKLOG,
BUT COULD BE EXTENDED TO SHOW REQUIREMENTS FOR,SAY,THE NEXT 4 WEEKS

ISSUE 1 24/03/75

FIGURE 46 SHORTAGE LIST OF MATERIALS AND TOOLS

REPORT RMD03(GT)
****

THE MEL EQUIPMENT CO.LTD.
****
MD WORK AVAILABILITY LIST
****

PAGE 0001
****
WK. 424.7
****

TURNING.TEAM WORK-FIRST 300 HOURS UNHELD LOAD
****

FINISH DATE	CODE NO.	IS NO	DESCRIPTION	WORKS ORDER	ITEM NO	QTY AVAIL	LOAD HOURS	PROD-GRP BEF	PROD-GRP AFT	OPITZ CODE	REMARKS
3820	FV397349	02	SHOULDER SCREW	651915 010 0	01383B	220	7.2	002		120300020	
3940	FV 720733	02	SHAFT LOCATING	651915 010 0	02516C	175	8.8	002		220300130	5/16 S/S EN57 GS.
3960	FV 692328	0C	BUSH	651915 010 0	01184D	51	2.0	002		101030030	
4010	B115539/3	05	SPACER	280704 405 0	A1586A	80	3.1	002		202000000	
4050	B117422	03	SPACER	280704 405 0	A1069A	182	24.0	002		222000030	
4090	B115649	01	HANDLE	283207 479 0	B1017A	55	5.1	002		425050030	
4095	A148216/2	04	PILLAR	280909 464 0	A1773A	32	2.2	002		202000000	
4100	RR/A825985	03	INSULATING BUSH	284750 404 0	A1844A	56	0.5	002		111000050	
4160	RR/A825981	03	PILLAR	284610 404 0	A2563A	31	8.5	002		205030000	
4160	RR/A825039	04	PILLAR	284750 404 0	A1411A	215	0.6	002		202000000	
4160	35131283182	01	SCREW	226289 217 0	CC393A	192	8.3	002		120300030	
4160	RR/A827446	03	SPACER SCREWED	284750 409 0	A1391A	190	24.7	002		222000030	
4160	RR/A827579	1A	SPACER	284750 402 0	A1163A	120	2.7	002		101000000	
4160	432208137630	04	SPINDLE	651656 004 0	B1054C	260	6.4	002		200000230	
4160	RR/A825906	03	SCREW SHOULDER	284750 404 0	A2158A	125	14.0	002		120000030	
4160	RR/A827753	1A	BOSS	284750 402 0	W1183A	110	15.0	002		142000010	
4160	RR/A827546	05	SCREW SPECIAL	284750 404 0	A1068A	120	16.2	002		220330130	
4170	A147098	01	SPACER	280909 431 0	B1182A	105	4.6	002		205000100	
4170	RR/A825038	03	SCREW MACHINE	284750 402 0	A1973A	113	7.5	002		120330030	
4170	B145321/2	03	SPACER	284750 402 0	A1200A	475	9.4	002		101000002	
4170	RR/A828699	1A	SCREW MACHINE	284750 402 0	A1155A	310	13.9	002		222000030	
4170	RR/A828545	02	BOLT SPECIAL	284750 404 0	A1079A	130	17.5	002		120300030	
4170	RR/A826083	03	SCREW MACHINE	284750 404 0	A1072A	130	18.4	002		220000130	
4170	RR/A925992	2A	SCREW MACHINE	284750 402 0	A1163A	260	25.9	002		220000030	
4170	RR/A826081	03	SCREW MACHINE	284750 404 0	A1071A	240	29.9	002		120300030	

SEE NEXT PAGE

NB 1.LOAD HOURS ON LIST ARE NOT ACCURATE AND FIGURE OF 300 HOURS CAPACITY IS ARBITRARY

2.IN ORDER TO PROVE THE CONTENT AND SEQUENCE OF LIST,IT MAY BE DESIRABLE TO SET UP DUMMY EXERCISE TO SEQUENCE WORK ON LIST USING OUIJA BOARD

3.LIST WILL BE AVAILABLE BEFORE TOOL READY FACILITIES,SO THAT IN FIRST INSTANCE ONLY MATERIAL AVAILABILITY WILL BE DEFINITELY KNOWN.

ISSUE 01 23/03/75

FIGURE 47 THE 'WORK AVAILABILITY LISTING'

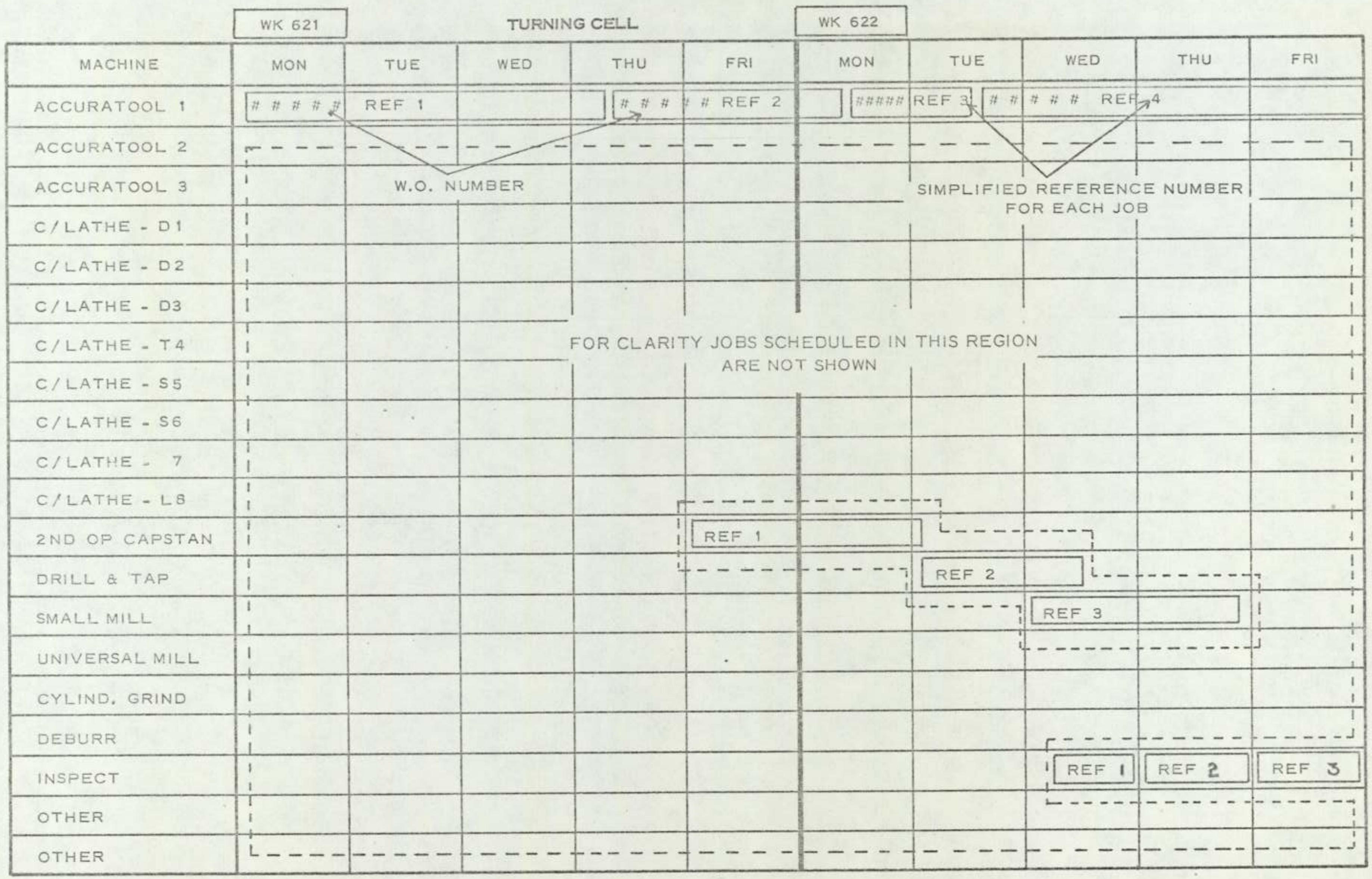


FIGURE 48 DIAGRAM OF A 'OUIJA BOARD'

```
0766 MICROPERT FOR W.O.NO.999957 291 0 0000 EQUIPMENT     SPARES           WEEK NOS 451/483 (451/483)          WEEK 473.1  PAGE   1

         PART NUMBER        QTY     DESCRIPTION      I BEG ACCUM ACCUMUR RC R       470       480       490       500       510   R
         COMB  CC ITEM                                       LOAD   ACT          ..I....I....I....I....I....I....I....I....I....I...

         3513 128 32172       100  SCREW              02                 5        .         .                                       .
                                                      2/-----  076-011            .         .                                       .
 483          OC A1001A 052/003  C30/001   122/000    142/000  120/000         6. .         .                                       .
                                                          0       0      0        .         .                                       .
                                                                                  .         .                                       .
         3513 132 16852        12  HEATSINK           01                 1        .         .                                       .
                                           1/OG/SO    010/000  013/001            .         .                                       .
 483          CC A1002A 013/C01  03C/000   122/C00    141/000  120/000            .         .           1112111 A *                 .
                                                          0       0      0        .         .                                       .
                                                                                  .         .                                       .
         3513 132 18802        24  LATCH              01                 5        .         .                                       .
                         1/A1003 -C20/C00  052/C02    C85/002  014/000            .         .                                       .
 483          OC A1003A 052/002  C30/002   122/000    141/000  120/000            .         .       1111111111= A *                 .
                                                          0       0      0        .         .                                       .
                                                                                  .         .                                       .
         3513 152 10872         6  FRCNT PANEL        02                 1        .         .                                       .
                                                      5/A1004  4/OG/SO            .         .                                       .
 483          CC A1004A 4/OG/SO  C25/001   052/008    088/006  034/000            .         .                                       .
                        085/004  121/000   141/000    120/000  094/003            .         .                                       .
                        035/000  036/002   038/005    036/001  120/000            .         .  3111121211111 A *                    .
                                                          0       0      0        .         .                                       .
                                                                                  .         .                                       .
         3513 160 11012        12  REGU. PABEL        03                 5        .         .                                       .
                        4/MB008  4/MB009   4/PB010    027/001  122/000            .         .                                       .
 483          CO A1005A                                                           .         .                 311= A *              .
                                                          0       0      0        .         .                                       .
                                                                                  .         .                                       .
         3513 128 32172       10C  SCREW              02                 5        .         .                                       .
                                                      2/OG/SO  060/011            .         .                                       .
 463          OC A1001C 052/003  C30/001   122/000    142/000  120/000            .         .             1111111= A *              .
                                                          0       0      0        .         .                                       .
                                                                               ..I....I....I....I....I....I....I....I....I....I...
                                                                             R       470       480       490       500       510   R
```

FIGURE 49   THE 'MICROPERT'

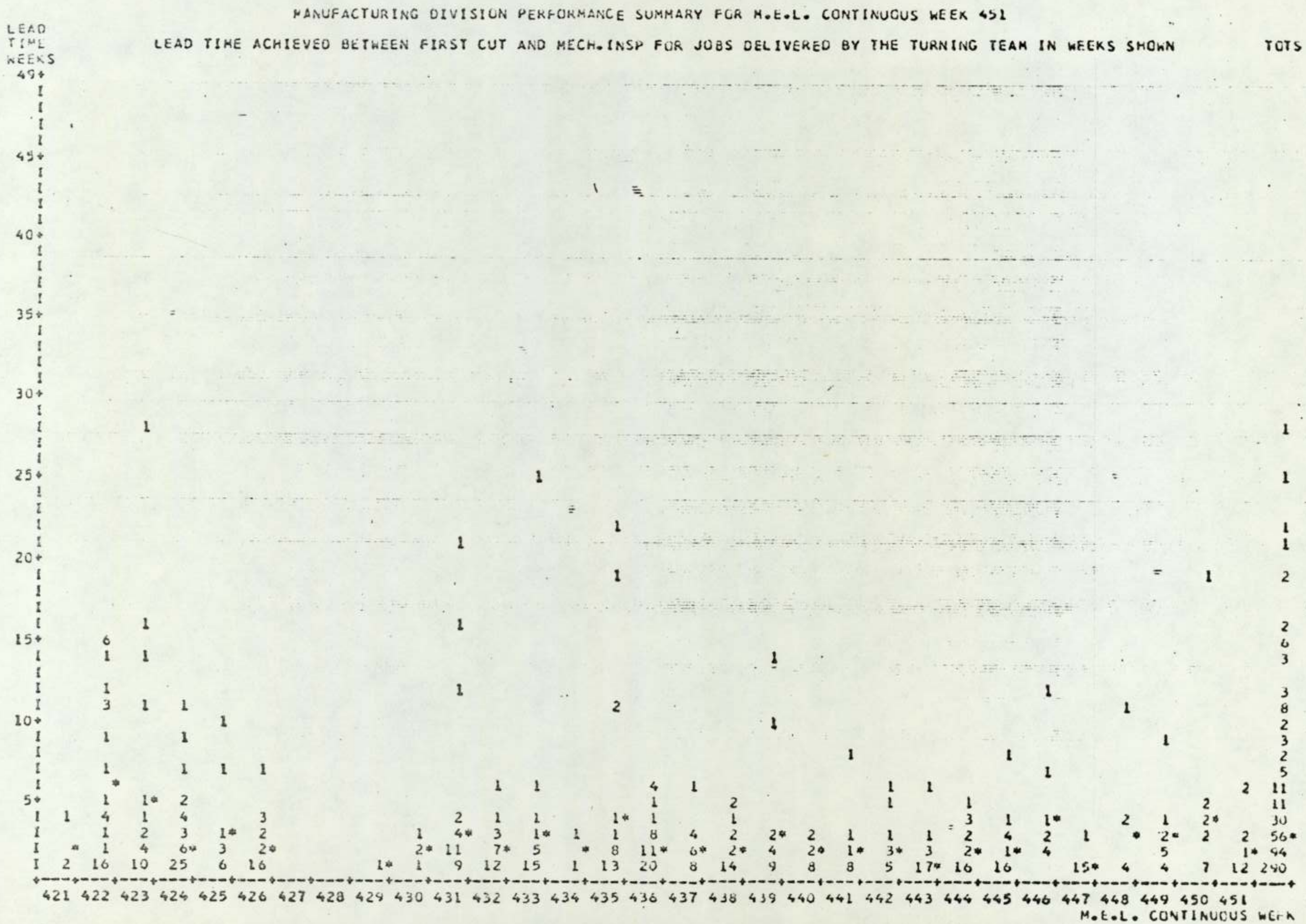
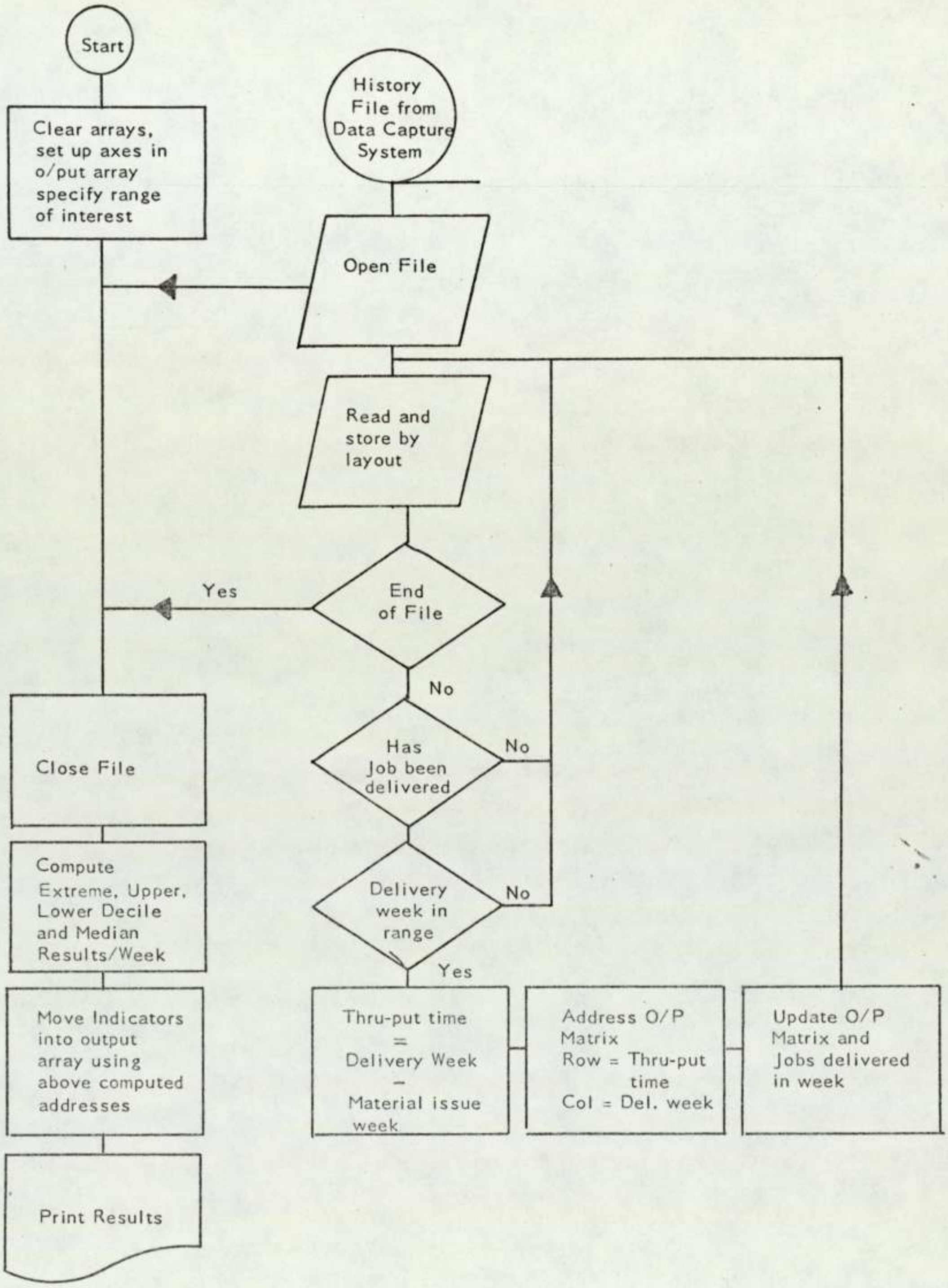


FIGURE 50 THRU-PUT TIME PERFORMANCE MEASURE

FIGURE 51 FLOW DIAGRAM OF THE THRU-PUT TIME CALCULATOR



MANUFACTURING DIVISION PERFORMANCE SUMMARY FOR M.E.L. CONTINUOUS WEEK 451

DELIVERIES AGAINST DUE DATE FOR JOBS DELIVERED BY THE TURNING TEAM IN WEEK SHOWN

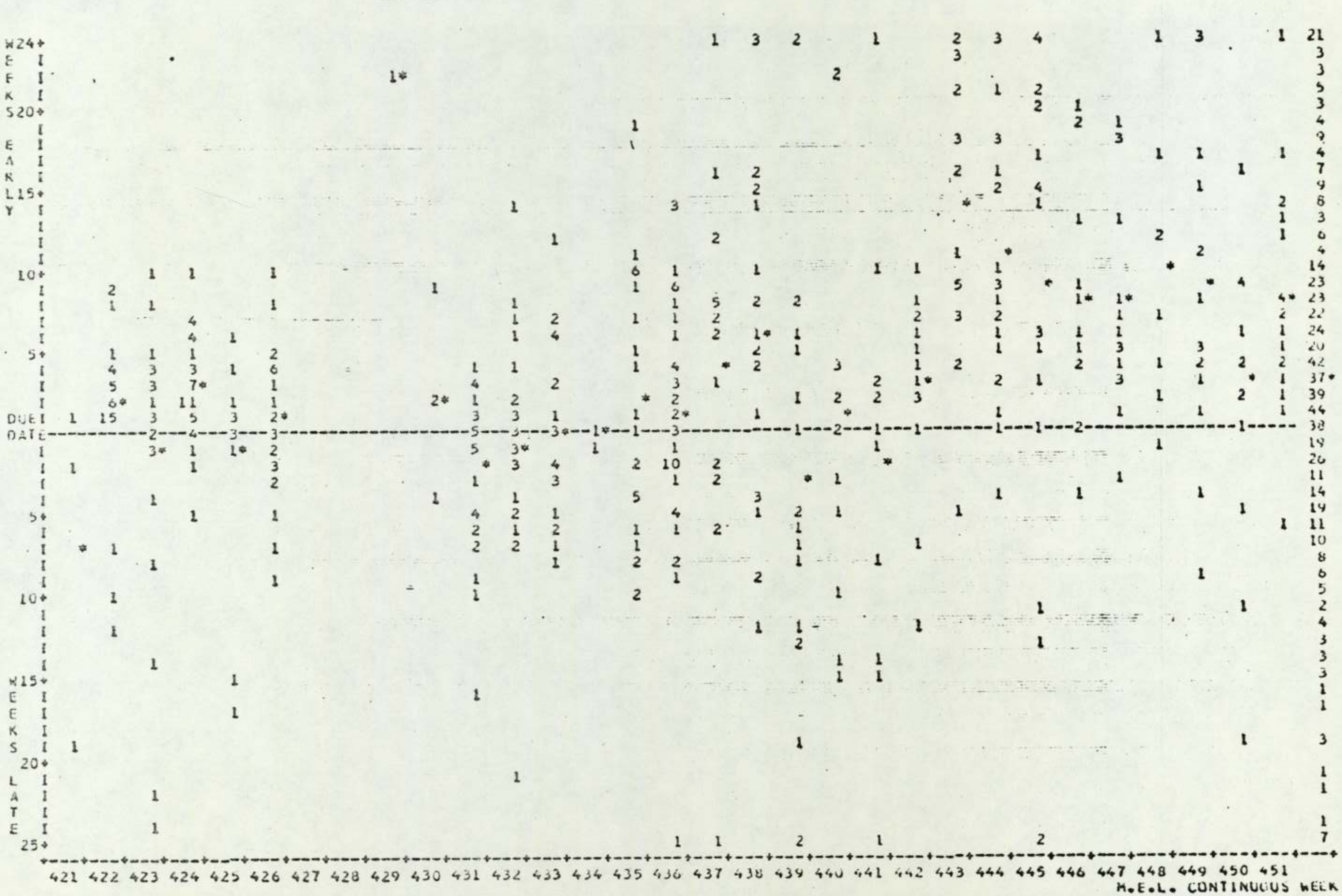


FIGURE 52 DUE DATE PERFORMANCE MEASURE

REPORT RLMD5501 THE MEL EQUIPMENT CO.LTD 21/10/76

PAGE NO 2 MANUFACTURING DIVISION PRODUCTION CONTROL SYSTEM - ADMINISTRATION ROUTINES WEEK NC. 43

ANALYSIS OF PERFORMANCE GENERAL M/C 325

PROD GROUP RANGE	DESCRIPTION	HOURS ALLOWED MS/60	ANALYSIS OF HOURS: TIME TAKEN: ON TARGET	NOT ON TARGET	WAITING TIME	TRAINING TIME	OTHER ROUTINES	WEEKLY WORKED HOURS	SUPPLEMENTARY HOURS: S1	S2 CUST	S2 MANF	AVERAGE OPERATOR PERF	DEPT PERF
C50-059. EXCL. NC M/C	MILLS	186.	220.	9.			42.	270.	4.		10.	51.	50.
			81%	3%			15%		2%		4%		
060-C80. EXCL. NC WORK.	TURNING	167.	179.	119.	1.		11.	309.	15.	6.	1.	56.	51.
			58%	38%			3%		5%	2%			
C85-C86.	DRILLS	151.	163.	1.				163.			9.	56.	55.
			100%								6%		
087-C99.	OTHERS	338.	267.	165.			48.	479.	2.	3.	6.	76.	71.
			56%	34%			10%			1%	1%		
058	REFURBISH N/C												
DEPARTMENTAL TOTALS		844.	829.	292.	1.		100.	1221.	21.	9.	27.	61.	58.
			68%	24%			8%		2%	1%	2%		
CUMULATIVE PERFORMANCE		33578.	32534.	4012.	181.	72.	6492.	43290.	717.	136.	1748.	62.	BUDGET. 61.
			75%	9%			15%		2%		4%		

FIGURE 53 PERFORMANCE MEASURES PRE GT

WEEKLY PERFORMANCE ANALYSIS - MANUFACTURING DIVISION

DATE 21/ 1/1977 WEEK NO. 702

**** M01-TURNING CELL

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	247.4	30.5	.0	.0	3.1	.0	.0	65.3	.9	347.2	218.3	21.9	.0	240.2	53	42	56
WEEK %	71.3	8.8	.0	.0	.9	.0	.0	18.8	.3	100.0	90.9	9.1	.0	100.0			
CUM.	247.4	30.5	.0	.0	3.1	.0	.0	65.3	.9	347.2	218.3	21.9	.0	240.2	59	44	58
CUM.%	71.3	8.8	.0	.0	.9	.0	.0	18.8	.3	100.0	90.9	9.1	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M02-MILL/DRILL CELL

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	489.7	67.3	.0	.0	6.0	.4	6.2	93.4	3.1	666.1	500.7	57.2	.0	557.9	61	50	65
WEEK %	73.5	10.1	.0	.0	.9	.1	.9	14.0	.5	100.0	89.7	10.3	.0	100.0			
CUM.	489.7	67.3	.0	.0	6.0	.4	6.2	93.4	3.1	666.1	500.7	57.2	.0	557.9	60	45	59
CUM.%	73.5	10.1	.0	.0	.9	.1	.9	14.0	.5	100.0	89.7	10.3	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M03-INSTRUMENT CELL

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	56.4	.0	.0	.0	.0	.0	.0	27.7	1.0	85.1	54.7	.0	.0	54.7	58	39	53
WEEK %	66.3	.0	.0	.0	.0	.0	.0	32.5	1.2	100.0	100.0	.0	.0	100.0			
CUM.	56.4	.0	.0	.0	.0	.0	.0	27.7	1.0	85.1	54.7	.0	.0	54.7	60	43	57
CUM.%	66.3	.0	.0	.0	.0	.0	.0	32.5	1.2	100.0	100.0	.0	.0	100.0			
TARGET %	60.0	15.8	.4	.7	3.0	3.5	.0	14.2	2.4	100.0					60	44	58

**** M04-SHEET METAL CELL

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	753.8	284.4	20.8	26.4	75.1	51.7	9.0	181.5	14.5	1417.2	750.4	237.0	13.9	1001.3	60	42	57
WEEK %	53.2	20.1	1.5	1.9	5.3	3.6	.6	12.8	1.0	100.0	74.9	23.7	1.4	100.0			
CUM.	753.8	284.4	20.8	26.4	75.1	51.7	9.0	181.5	14.5	1417.2	750.4	237.0	13.9	1001.3	56	40	55
CUM.%	53.2	20.1	1.5	1.9	5.3	3.6	.6	12.8	1.0	100.0	74.9	23.7	1.4	100.0			
TARGET %	55.0	20.0	.5	.8	3.0	3.5	.0	14.2	3.0	100.0					55	39	54

**** M07-PROCESS CELL

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	0	0	0
WEEK %	.0	.0	.0	.0	.0	.0	.0	.0	.0	100.0	.0	.0	.0	100.0			
CUM.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	60	39	55
CUM.%	.0	.0	.0	.0	.0	.0	.0	.0	.0	100.0	.0	.0	.0	100.0			
TARGET %	20.0	53.2	.2	.4	3.0	3.5	.0	15.9	3.8	100.0					60	39	55

DIVISION OR TEAM TOTALS

****

	Booked hours OT	NOT	TT	WT	S1	OWN S2	CUS.S2	OR1	OR2	TOTAL	Credit hours OT	NOT	TT	TOTAL	Performances AOP	DEPT	BU2
WEEK	1547.3	382.2	20.8	26.4	84.2	52.1	15.2	367.9	19.5	2515.6	1524.1	316.1	13.9	1854.0	59	44	59
WEEK %	61.5	15.2	.8	1.0	3.3	2.1	.6	14.6	.8	100.0	82.2	17.0	.7	100.0			
CUM.	1547.3	382.2	20.8	26.4	84.2	52.1	15.2	367.9	19.5	2515.6	1524.1	316.1	13.9	1854.0	60	44	57
CUM.%	61.5	15.2	.8	1.0	3.3	2.1	.6	14.6	.8	100.0	82.2	17.0	.7	100.0			

***** ISSUED BY TEO DEPARTMENT *****

FIGURE 54 PERFORMANCE FIGURES POST GT

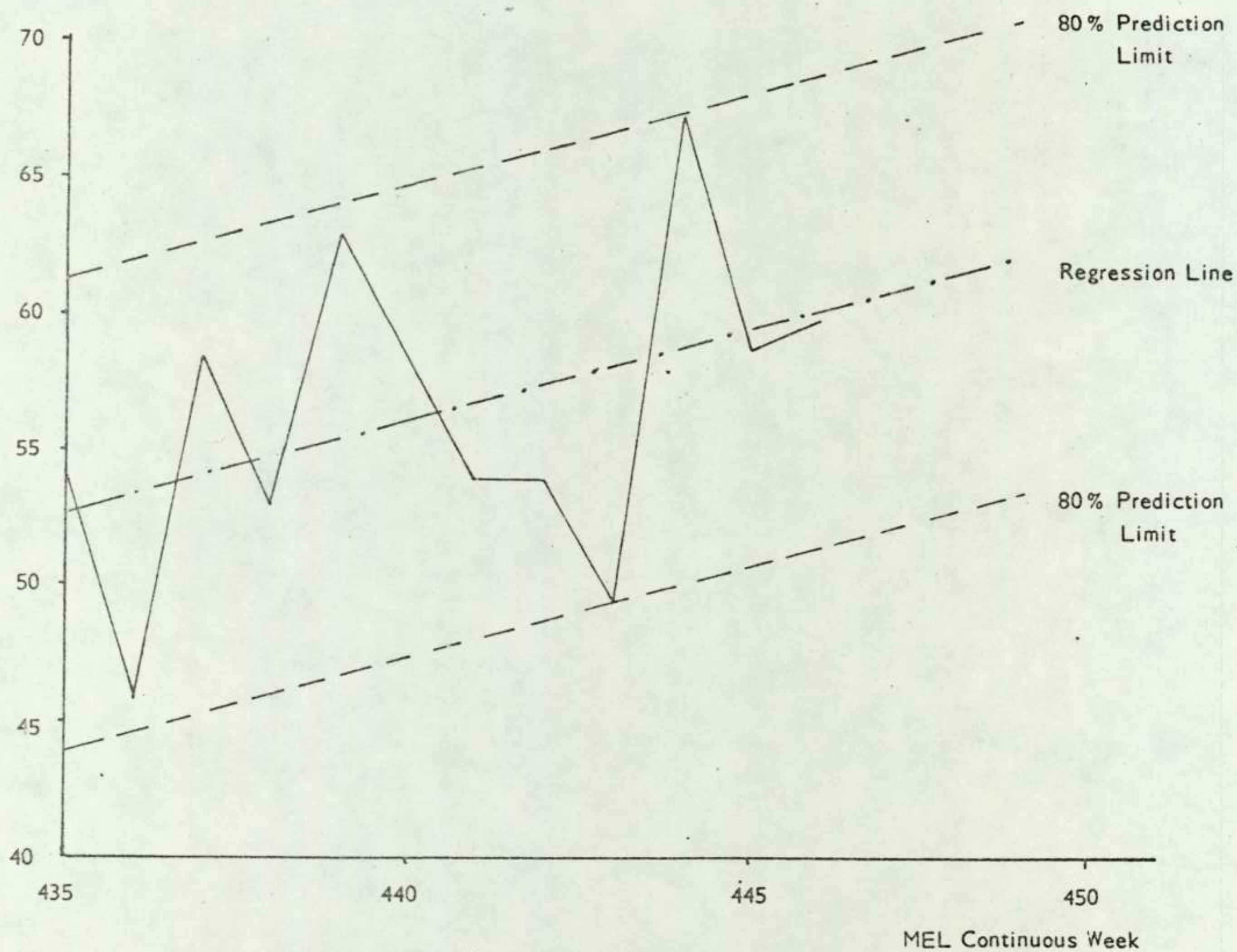


FIGURE 55 TURNING CELLS 'M' HOUR PERFORMANCE

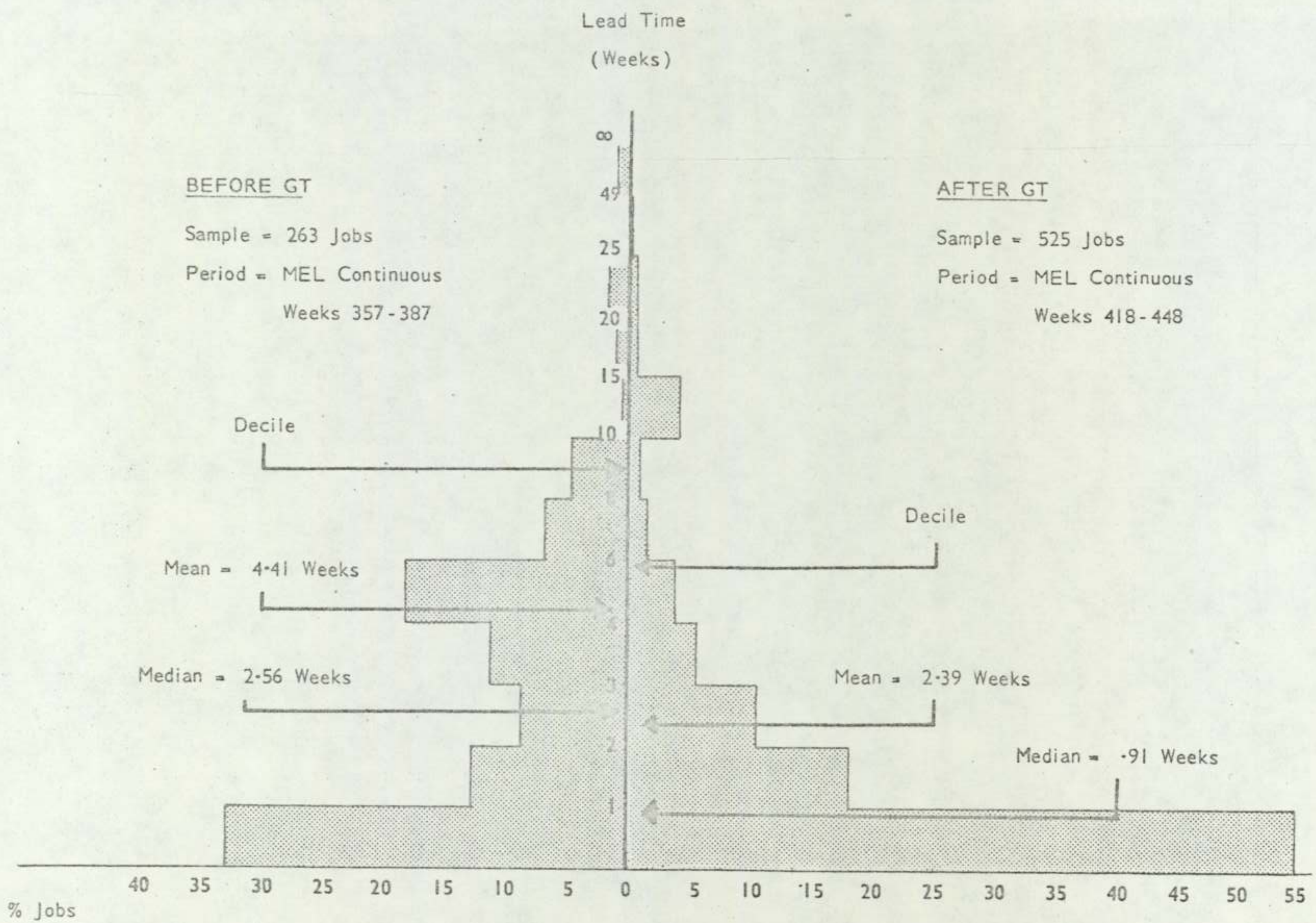


FIGURE 56 TURNING CELL LEAD TIME PERFORMANCE PRE AND POST GROUP TECHNOLOGY

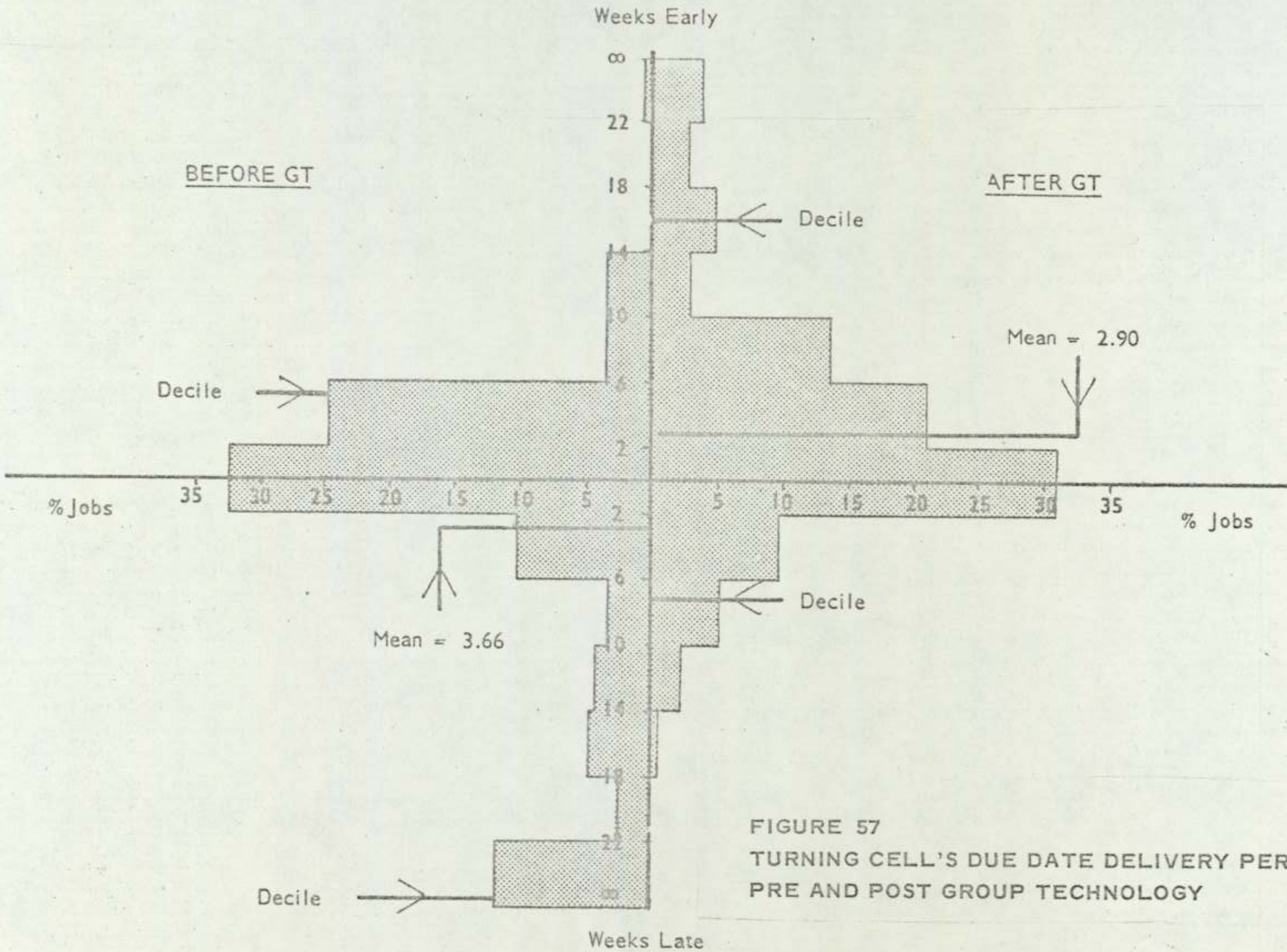


FIGURE 57
TURNING CELL'S DUE DATE DELIVERY PERFORMANCE
PRE AND POST GROUP TECHNOLOGY

FACTOR	TURNING CELL IMPROVEMENT (%)	SURVEYED IMPROVEMENT (%)
REDUCTION OR WORK IN PROGRESS	46	62
REDUCTION IN OVERALL STOCKS	NOT MEASURED	42
REDUCTION IN SETTING TIME	25	69
REDUCTION IN THRU-PUT TIME	46	70
INCREASE OUTPUT PER EMPLOYEE	$22\frac{1}{2}$	33
REDUCTION IN OVERDUE ORDERS	33	82

FIGURE 58 COMPARISON OF BENEFITS SEEN IN THE TURNING CELL WITH THOSE REPORTED BY A SURVEY OF OTHER COMPANIES

FIGURE 59 SAMPLE OF CANDIDATES FOR STANDARDISATION

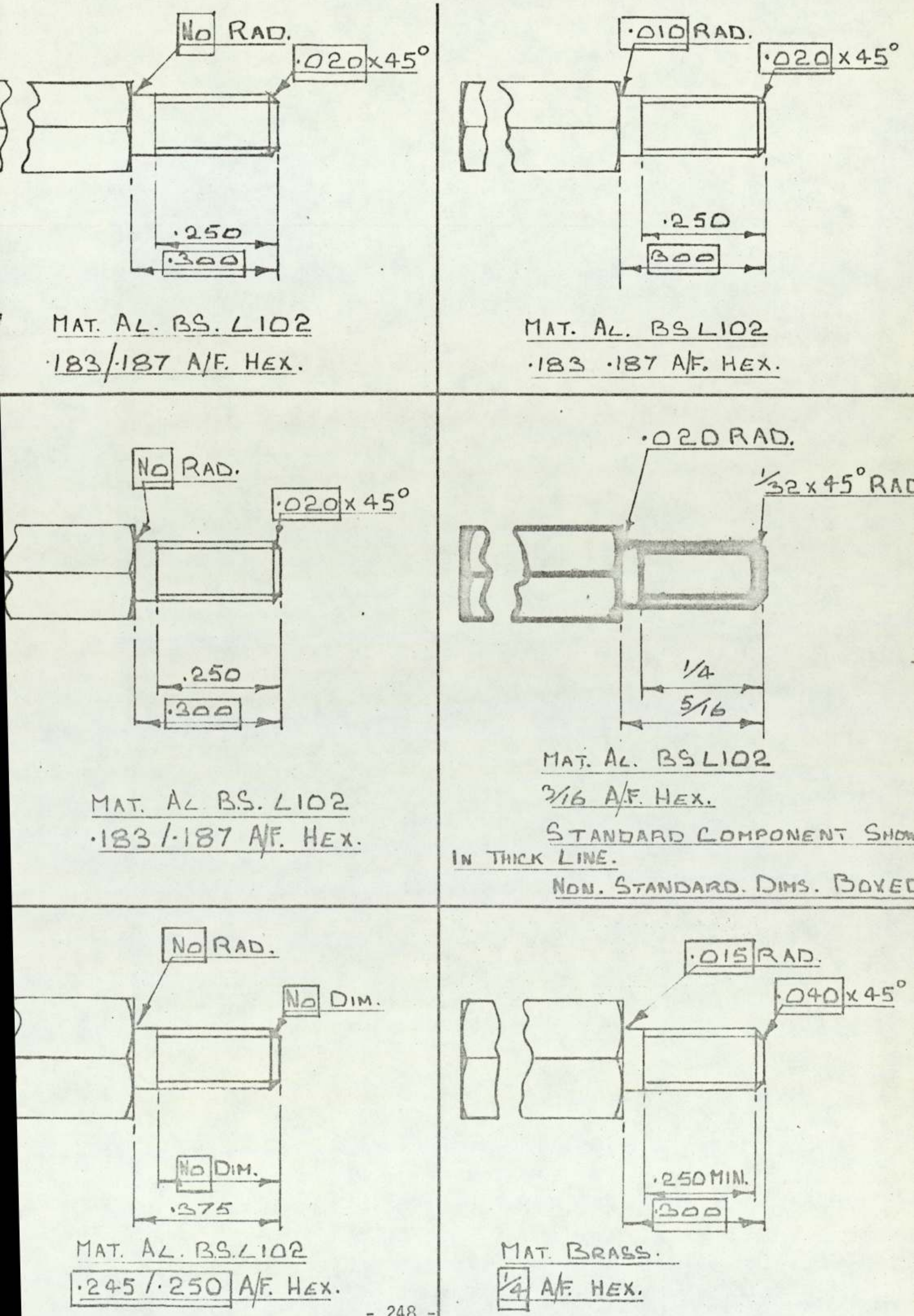


FIGURE 60 SUGGESTED COMPOSITE COMPONENT

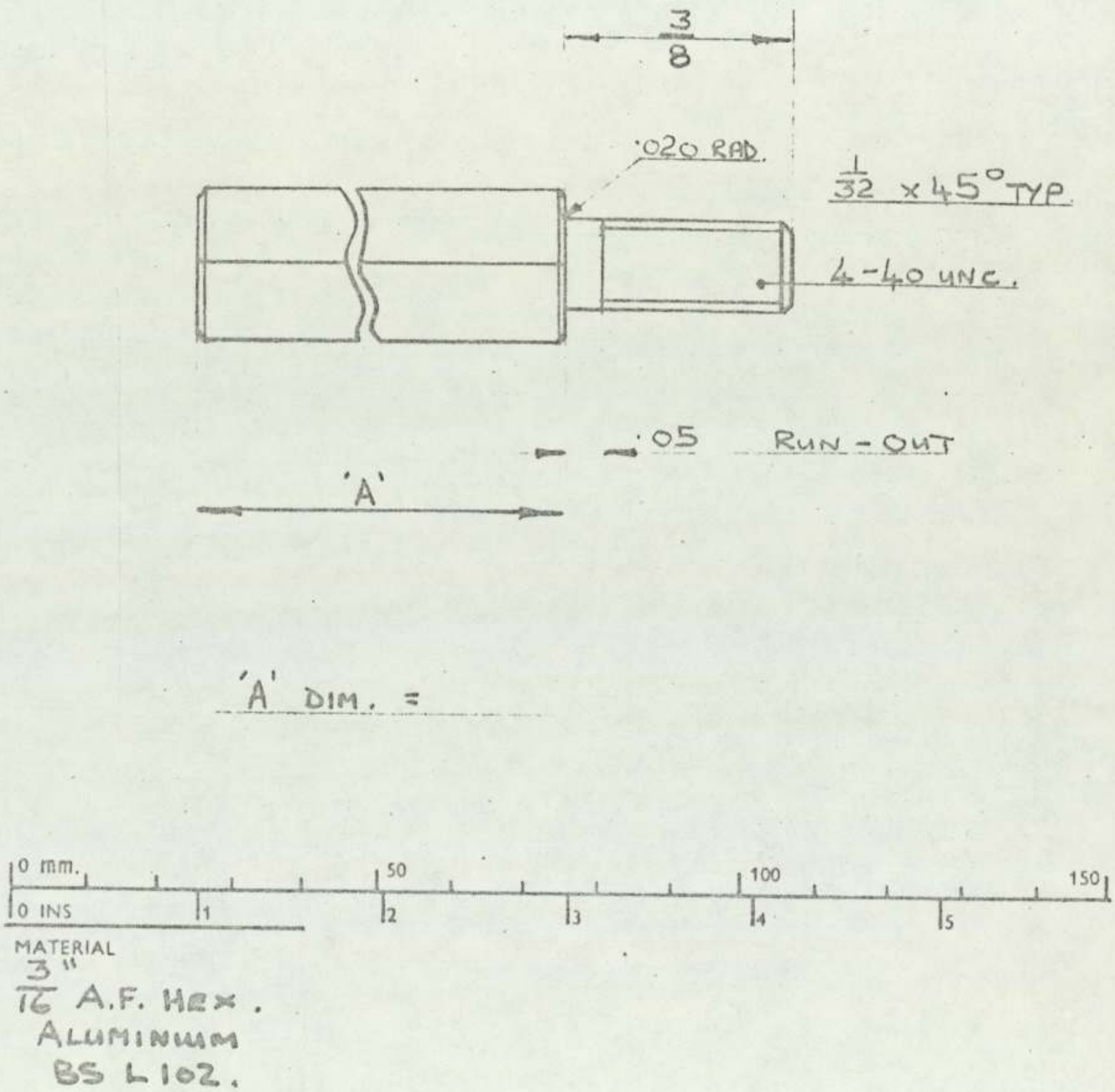
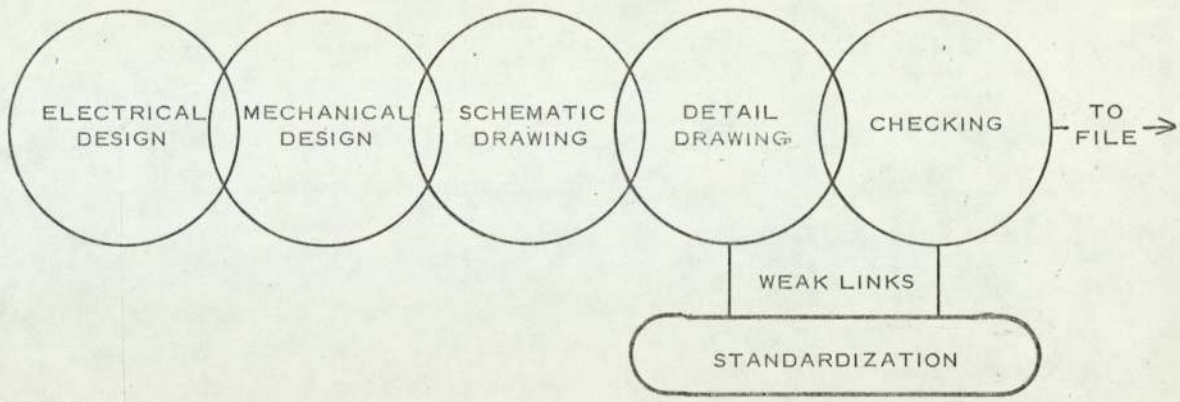


FIGURE 61 COMPARISON OF EXISTING DESIGN PROCESS WITH A SUGGESTED ALTERNATIVE TO IMPROVE PARTS STANDARDIZATION

1. EXISTING PROCESS



NOTES

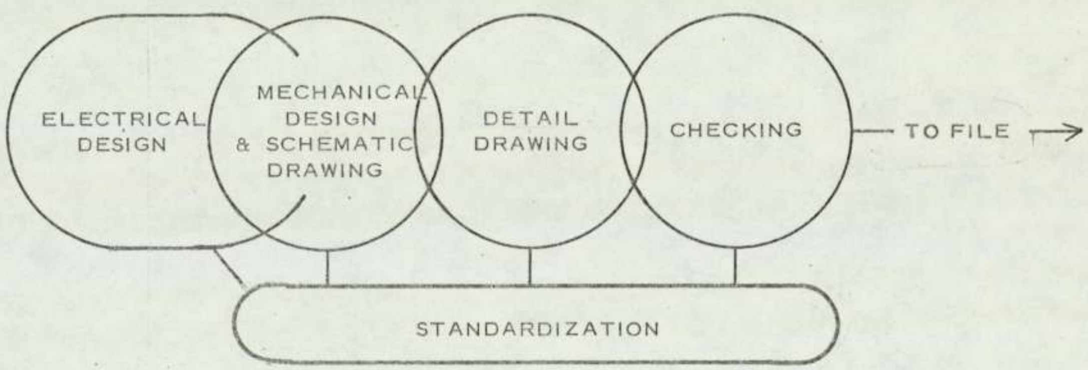
1. Electrical and mechanical design usually loosely linked at concept stage.

2. Schematic and detail drawing done by different draughtsmen.

3. Conceptual design and drawing are done by different parts of the organization.

4. No geometric coding used.

2. PROPOSED PROCESS



NOTES

1. Reorganize to site Mechanical Designers in Electrical Laboratories.

2. Mechanical Designers to do schematic drawings and to apply geometric code to items designed.

3. Technical Clerk to assist Mechanical Designers and to check that all parts have geometric code applied before detailed draughting commences.

4. Mechanical Designers and Technical Clerks to have access to computer/microfilm drawing library organized by geometric code, stock book of preferred components, cost/tolerance curves, machine capability information.

5. Technical Clerks responsible to Head of Standardization for enforcing parts standardization.

6. No parts detailed until head of Standardization approves design as making proper use of standard parts.

7. Only non standard parts drawn.

8. Vetting process, after parts standardization and drawing of non standard parts, to ensure that no non standard parts are used where a standard alternative is available.

9. Drawing of blanks showing standard components with options on dimensions available. See Figure 60.

FIGURE 62 MAIN ELEMENTS OF THE HUIZEN SYSTEM BEFORE MODIFICATION TO ACCOMODATE GROUP TECHNOLOGY

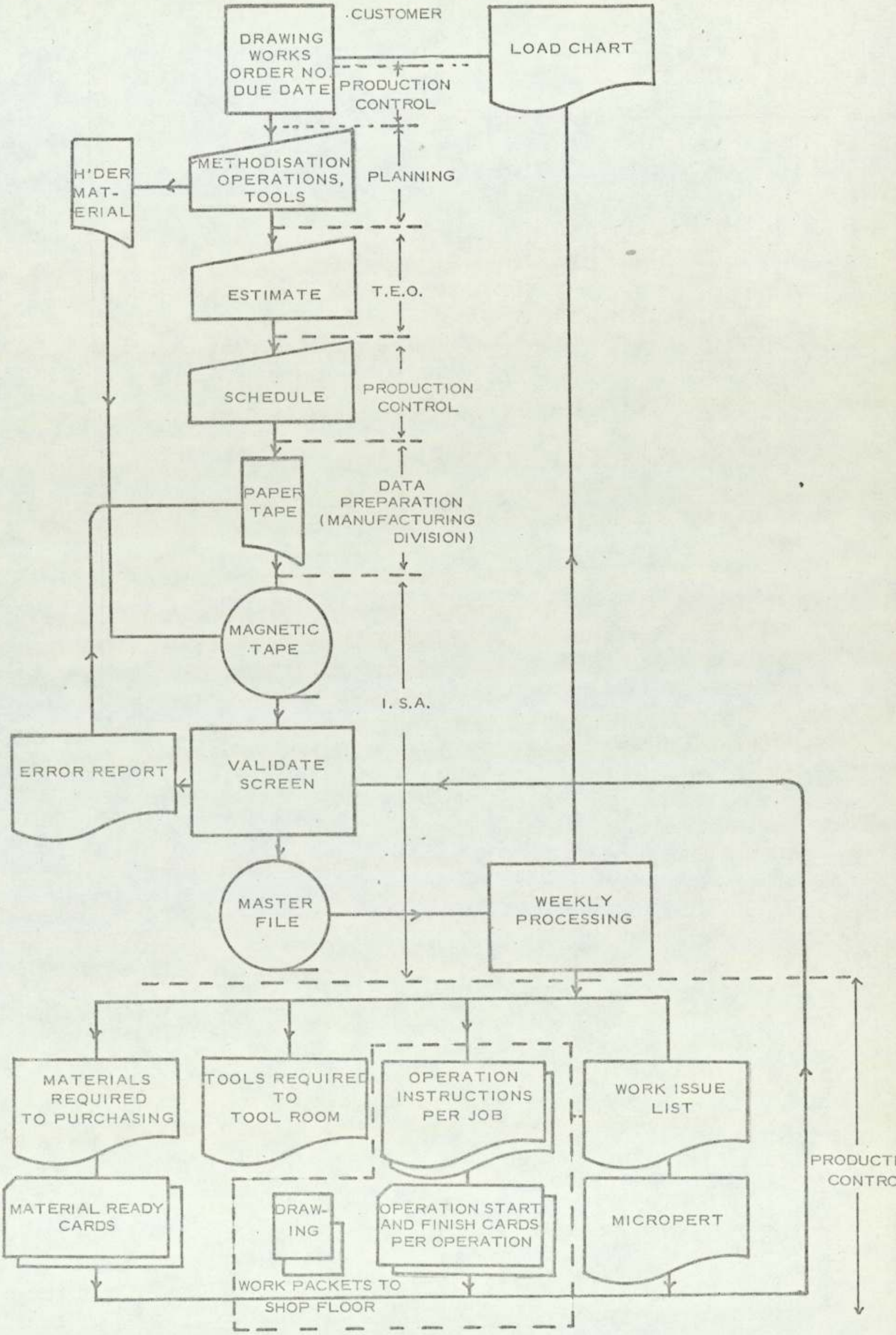
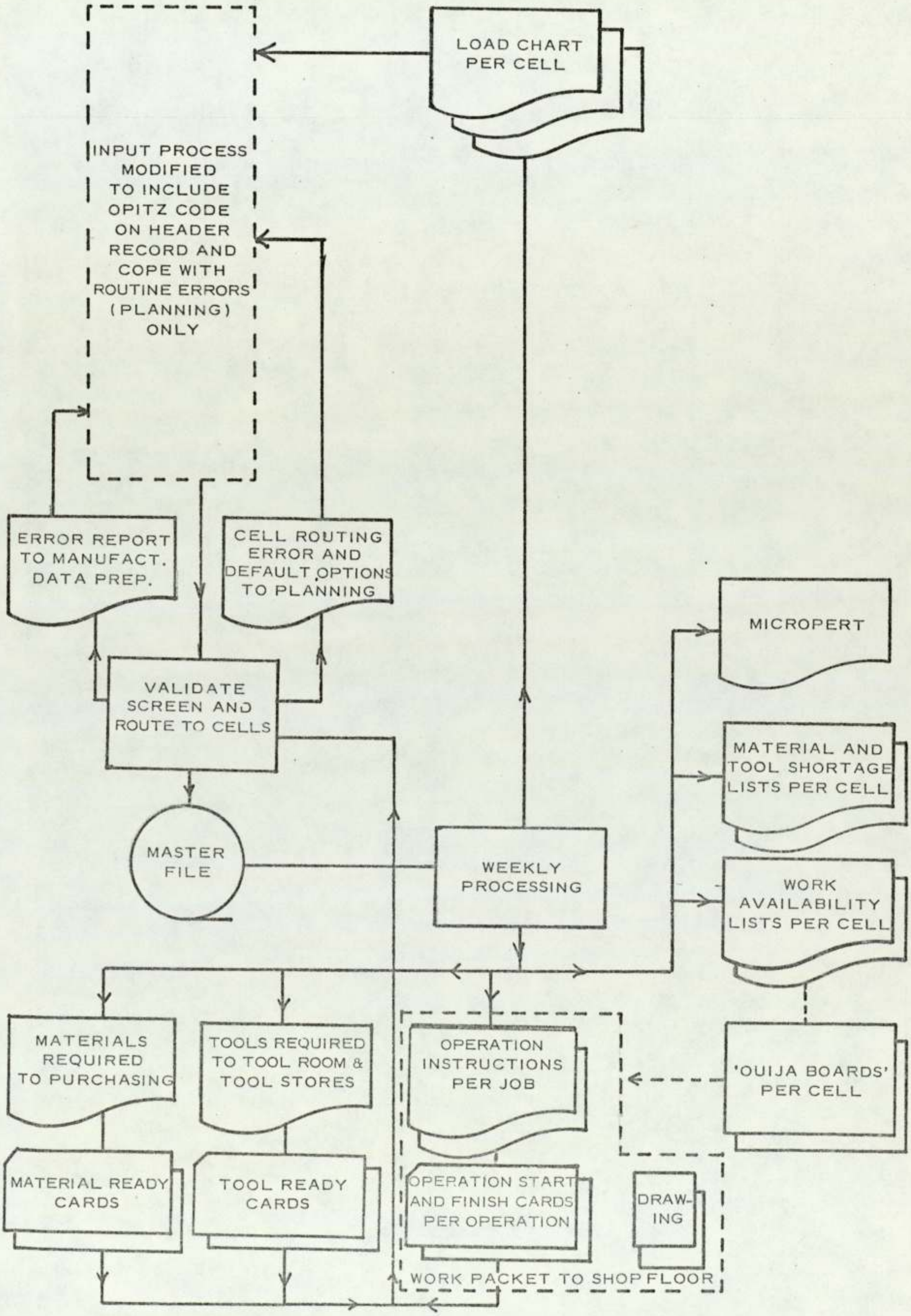


FIGURE 63 MAIN ELEMENTS OF THE HUIZEN SYSTEM AFTER MODIFICATION TO ACCOMODATE GROUP TECHNOLOGY



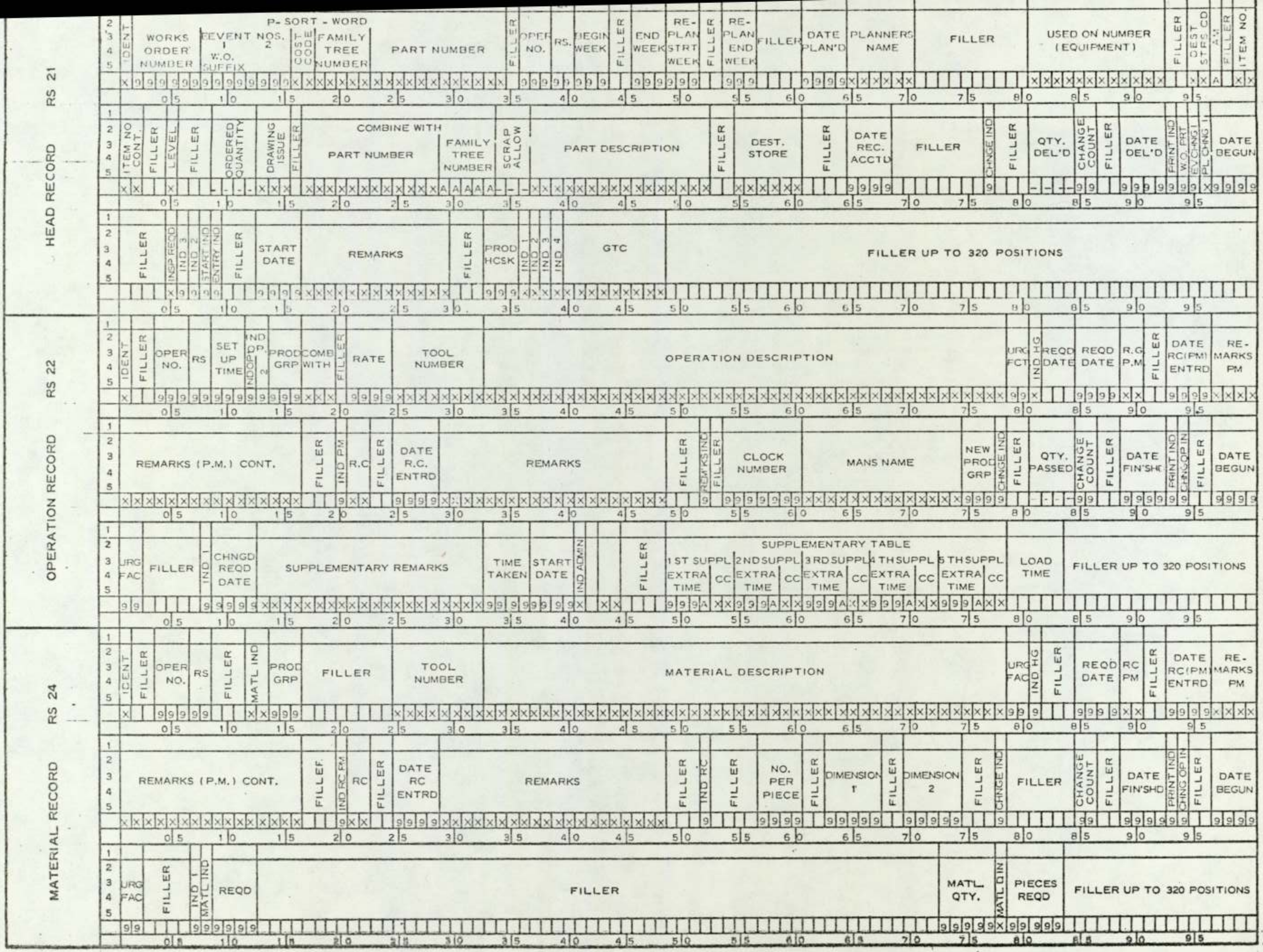


FIGURE 64 MASTER FILE STRUCTURE

MANUFACTURING LAYOUT

RS	START WEEK	FIN. WEEK	W.O. SUFFIX XXX X EVENT XXXX	PART DESCRIPTION	BATCH NO.	REPLAN IND.	PLANNED DATE	PLANNED BY	PLANNED LOB	INSP. REQD	DRAWING ISSUE	REPEAT PROCEDURE REMARKS	COMMENTS
21	5215	8200	000000	DISTANCE PCE	A	0000	5210	MT.	99	A	01	SSA	

A/M	DEST. STORE	CODE NUMBER	USED ON NUMBER	MINIMUM QUANTITY	SCRAP ALLOWANCE	COST CODE	WORKS ORDER No.	LEVEL	ITEM NO.	COMBINE WITH ITEM NO.	COMBINE WITH CODE NUMBER
MAM		55164731		80	4	00	315125	F	F2539		

RS	OP. NO.	PROD. GRP.	MATERIAL DESCRIPTION / OPERATION DESCRIPTION	QTY. / SET UP	DIMENSION 1 / RATE	1	DIMENSION 11 / C.W.	ITEM NO. / TOOL NUMBER	REQ'D DATE	URG. FACT
24	3000	02	+031300102007 1/8 DIA BRASS ROD CZ 121	16	10	II		OG/SO	5380	5
22	0400	62	FACE TURN 1.0 MM DIA FOR 2.5 LONG	60	600	D1			5390	5
23	040		TURN 2 MM H11 O/D PLUNGE TO 1.0 MM DIA X 6.0							
23	040		MM LONG. BACK TURN TO 1.0 MM DIA. DEBURR							
23	040		P/OFF TO LENGTH NO.T PLATING ALLOWANCE							
22	0301	21	INSPECT						5400	5
22	0201	45	SILVER PLATE						5410	5
22	0101	20	INSPECT						5420	5

FIGURE 65 MASTER LAYOUT FORM

0355	MATERIAL RESERVATION LIST				WEEK NO 474.1 PAGE NO I					

MATERIAL	DESCRIPTION	QUANTY	M/F	TOT QTY	WK.	CC	W.O.NUMBER	EVENT	FAMTREE	CODE NUMBER	OP.NO
+011309308003	23SWG BMS SHEET B	0.5	F	0.5	482	00	226459 002	0 0000	MB509A	35131321211202	300
	S1449 EN2										
+011309308008	18SWG BMS BS1449	0.5	F		477	00	226459 002	0 0000	MB534A	81130101534001	300
		3.0	F		473	00	226459 002	0 0000	MB533A	81130101533001	300
		6.0	F		475	00	226459 002	0 0000	MB531A	81130101531001	300
		6.0	F	15.5	475	00	226459 002	0 0000	MB532A	81130101532001	300
	449 EN2										
		8.2	F		477	00	260037 110	0 0000	MB005A	35131323717 0C	300
		1.7	F		474	00	260037 110	0 0000	MB009A	35131323659 0B	300
		37.8	F		473	00	260037 110	0 0000	MB010A	35131323657 0F	300
		10.5	F		474	00	260037 110	0 0000	MB011A	35131602796 0A	310
		3.1	F		476	00	260037 110	0 0000	MB007A	35131323706 0D	300
		21.0	F		477	00	260037 110	0 0000	MB006A	35131323716 0A	300
		63.0	F		477	00	260037 110	0 0000	MB008A	35131323704 0E	300
		1.4	F	146.7	474	00	260037 110	0 0000	MB012A	35131602797 0A	310
	S2449 EN2										
+011309308009	16SWG BMS SHT BS	2.4	F		475	00	226459 002	0 0000	MB535A	35131323846201	300
		0.5	F		475	00	226459 002	0 0000	MB537A	81130101609001	300
		1.2	F	4.1	475	00	226459 002	0 0000	MB536A	35131323847201	300
	449 EN2										
		4.0	F		475	00	260037 110	0 0000	MB003A	35131602529 0B	310
		0.5	F	4.5	475	00	260037 110	0 0000	MB002A	35131602528 0B	310
	1449 EN2										
+031300101008	.324 A/F BRASS HE	0.7	F	0.7	480	00	293652 004	0 0000	MB018A	A95101 03	300
	X ROD										
		0.6	F	0.6	480	00	293660 014	0 0000	MB018A	A95101 03	300
	X ROD										
		0.5	F	0.5	480	00	293679 008	0 0000	MB018A	A95101 03	300
	X ROD										
		0.5	F	0.5	480	00	293687 008	0 0000	MB018A	A95101 03	300
	X ROD										
		0.5	F	0.5	480	00	[illegible]709 001	0 0000	MB018A	A95101 03	300
	X ROD										
[illegible]011	3/16 DIA BRASS RO	0.5	F						A2018A	B95126 02	
		0.6									

FIGURE 66 MATERIAL REQUIREMENTS LISTING

TOOL EXTRACT

TOOLS REQUIRED FOR OPERATION SHEETS PRINTED WEEK 474.1

WORKS ORDER	W/O SUFF	CC	START WEEK	PART CODE NUMBER	ISS	PART DESCRIPTION	FAMILY TPEE	OPER NO	TOOL NUMBER
226408	283	00	4720	351316024282	1	BRACKET DET ASS	TE560	160	MCT39766
226408	283	00	4721	351316024282	1	BRACKET DET ASS	TE560	150	MCT39766
226459	002	00	4740	811301015330	1	BASE	MB533	100	MCT35498
260037	110	0C	4740	35131323657	0F	TRAY	MB010	110	MCT35137
520675	000	00	4740	40131006645	1B	CAN	MB091	070	MCT28187
260037	110	00	4743	35131323657	0F	TRAY	MB010	100	MCT35137
226459	002	00	4750	811301015330	1	BASE	MB533	090	MCT35498
260037	110	0C	4750	35131323657	0F	TRAY	MB010	080	MRS51028
260037	110	00	4750	35131602796	0A	TRAYTOP	MB011	140	MCT35950
293652	004	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293660	014	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293679	008	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293687	008	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
293709	001	00	4750	B95096	02	MOUNT	MC004	030	MCT23065
260037	110	00	4753	35131602796	0A	TRAYTOP	MB011	130	MCT35950
226459	002	00	4760	351313238472	1	SUPPORT BAR	MB536	080	MCT35500
226459	002	0C	4760	351313238462	1	SUPPORT BAR	MB535	080	MCT35500
226459	002	00	4760	811391016090	1	SUPPORT BAR	MB537	080	MCT35901
226459	002	00	4760	811301015320	1	BOTTOM SECN	MB532	130	MCT35907
226459	002	00	4760	811301015310	1	TOP SECTION	MB531	130	MCT35904
260037	110	00	4760	35131602796	0A	TRAYTOP	MB011	110	MRS51028
260037	110	00	4760	35131602529	0B	PLATFORM ASSY	MB003	110	MCT35134
260037	110	0C	4760	35131323657	0F	TRAY	MB010	060	SA002155
260037	110	00	4760	35131602528	0B	BRACKET ASSY	MB002	110	SA002097
293652	004	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293660	014	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293679	008	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293687	008	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
293709	001	00	4760	B95096	02	MOUNT	MC004	020	MCT23065
724807	410	SZ	4760	RR/A827546	06	SCREW	AI012	030	ERT.4626
260037	110	00	4765	35131602528	0B	BRACKET ASSY	MB002	100	SA002097
260037	110	00	4765	35131602529	0B	PLATFORM ASSY	MB003	100	MCT35134
226408	285	00	4770	351313242070	1	DIODE CLAMP	YK740	050	MCT39738
226459	002	00	4770	351313233472	1	SUPPORT BAR	MB536	070	MCT35500
226459	002	00	4770	811301016090	1	SUPPORT BAR	MB537	070	MCT35901
226459	002	00	4770	811301015320	1	BOTTOM SECN	MB532	120	MCT35907
226459	002	00	4770	351313238462	1	SUPPORT BAR	MB535	070	MCT35500
226459	002	00	4770	811301015310	1	TOP SECTION	MB531	120	MCT35904
260037	110	00	4770	35131323706	0D	BRACKET	MB007	110	MCT35133
260037	110	00	4770	35131602796	0A	TRAYTOP	MB011	080	SA002155
260037	110	00	4775	35131323706	0D	BRACKET	MB007	100	MCT35133
260037	110	00	4776	35131323549	0C	FRAME SIDE	MC003	020	MCT35141
260037	110	00	4780	35131323717	0C	PLATE DEFLECTOR	MB005	080	MCT35132
260037	110	00	4780	35131323704	0E	PANEL REAR	MB008	080	MCT35129
260037	110	00	4780	35131323716	0A	PLATE BASE	MB006	070	MCT35131
520675	000	00	4780	40131006645	1B	CAN	MB091	030	MCT36328

FIGURE 67 TOOL REQUIREMENTS LISTING

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0165     OPERATION SHEET MANUFACTURING DIVISION M E L CRAWLEY PRINTED WEEK NO. 529.1 SHEFT   1

     I---------------------------------------------------------------------------------------I
     I W.O.NUMBER CC EVENT  FAMTREE LEV  CODE NUMBER    INSP ITEM   USED ON NO.  A/M MIN.QTY. SCRAP I
     I                                                                                       I
     I 315125 000 00 0-0000  F2539A  F  55164731    01    A  F2539               M      80     4  I
     I---------------------------------------------------------------------------------------I
     I  COMBINATION NUMBER          PART DESCRIPTION           STORES      REMARKS        PLAN.BY-DATE I
     I FAMTRE  CODE NUMBER                                                                   I
     I                              DISTANCE PCE               A MANF    SSA             MT.    521.0 I
     I---------------------------------------------------------------------------------------I
     I OPNO  PG  MATERIAL DESCRIPTION                          .ITEN NO .QUANT.QNTY.DIM 1 .DIM2  .INDI
     I GT NO  240000010    CELL  B                            .        .PIECE. PER.      .      .   I
     I                                                        .        .     .    .      .      .   I
323  I 300  002 +031300102007     1/8 DIA BRASS ROD CZ 121    .OG/SO   .    6.  16.  10.0.       .II I
     I---------------------------------------------------------------------------------------I
     I OPNO  PG  OPERATION DESCRIPTION                         .TOOL NO . SET. RATE. IND. LOAD. CW   I
     I                                                        .        . UP .      .    . TIME.      I
     I                                                        .        .     .     .    .     .      I
323  I 040  062 FACE TURN 1.0 MM DIA FOR 2.5 LONG             .        .  60.  600. D1 .  101.      I
     I              TURN 2 MM H11 O/D PLUNGE TO 1.0 MM DIA X 6.0 .     .     .     .    .     .      I
     I              MM LONG. BACK TURN TO 1.0 MM DIA. DEBURR  .        .     .     .    .     .      I
     I              P/OFF TO LENGTH NO.T PLATING ALLOWANCE    .        .     .     .    .     .      I
     I                                                        .        .     .     .    .     .      I
323  I 030  121 INSPECT                                       .        .     .     .    .     .      I
     I                                                        .        .     .     .    .     .      I
336  I 020  145 SILVER PLATE                                  .        .     .     .    .     .      I
     I                                                        .        .     .     .    .     .      I
336  I 010  120 INSPECT                                       .        .     .     .    .     .      I
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FIGURE 68   JOB INSTRUCTIONS