THE INTRODUCTION OF A GROUP TECHNOLOGY SYSTEM AND THE ALLOCATION OF RESOURCES WITHIN THAT SYSTEM

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SUMMARY

The initial part of this thesis outlines the introduction of Group Technology into a small engineering company and gives a brief insight into the history of the company. The main part of the thesis is a critical appraisal of the allocation of resources during and after the introduction of Group Technology. Particular emphasis is placed upon the problems created by the introduction of Group Technology, especially in the areas of Production Control and Product Costing. Methods of solving these problems are analysed and the results thus obtained discussed.

The approach of this thesis is essentially a practical one. It demonstrates that running a Group Technology system in a small company with limited resources and a limited product range demands that the practical system must deviate from the theory of Group Technology in certain areas. This is especially true in its approach to 'foreign' work in cells and the methods used to obtain accuracy in capacity calculations and Product Costing. The results obtained show that even with these deviations the normal gains attributed to Group Technology, such as reduced work-in-progress and faster, more consistent throughput times etc. have been achieved and the company made to function more efficiently.

In addition, a comprehensive literature survey is included, covering all aspects of Group Technology, especially its development in the U.K.

Also included in this survey is an outline of the advances in manufacturing since the beginning of the nineteenth century, comparing Group Technology with other manufacturing systems and other methods of group working. Extensive use is made of tables, graphs, photographs and drawings to support the text.

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DECLARATION

No part of the work described in this thesis has been submitted in support of an application for another degree or other qualification of this or any other Institution.

P. G. Bunce

LIST OF FIGURES

1. INTRODUCTION

Group Technology (G.T.) has been defined as "a technique which permits jobbing and batch production to achieve similar advantages to those associated with continuous flow-line production". Many factory managers over the past decade have cast envious eyes at the economics that appear to be derived from mass production of components by the use of large and expensive special purpose machinery. Quick comparisons between this method of production and the batch production method show that the wide variety of components in batch production could never justify the kind of plant used in mass production.

At this point most managers have dismissed these thoughts to concentrate on the immediate problem of the moment, just a few managers have taken time out to consider what they are making and how they are making it. In most companies it is possible to recognise "families" of components, those which have basically similar geometric features and thus require basically similar machining operations. Having recognised this fact, it is a short step to try and arrange the machines in such a way that all those necessary to produce a family of components are grouped together. In most companies families cannot be established by haphazardly looking at the company's range of components; it must be done in a systematic manner. Some form of numerical classification is usually employed to do this, where each component is classified with a number describing its geometric form and/or its method of manufacture. From this component families can be established leading to the formation of groups or "cells" of machines - this is the basis of G.T.

Since the latter part of the 19th Century it has become the practice in virtually all batch production machine shops to group machines according to their function i.e. all lathes together, mills together, etc. This layout has now become the accepted practice and has led to the situation where each machine type is considered in isolation and no account is taken of the interaction of different machining operations. This encourages managers to seek maximum usage of each machine tool with the result that work-in-progress approaches unnacceptably high levels. Now this situation may have been excusable or even acceptable up to about 1960 when money was relatively cheap, but today when interest rates are about 17% to 20% per annum large sums of money become tied up in work-in-progress. Secondly work which is lying static on the shop floor waiting in the queue for the next operation is not speeding itself to the customer, thus throughput times are variable with the consequent risk of loss of orders.

One of the essential features of G.T. is that the groupings of component families allows large batches of similar components to be formed which in turn leads to reductions of setting times and increasing productivity with the available labour - Fig.1.1 shows the general achievements of G.T. It has been said that a G.T. cell can be likened to a mass production transfer machine but instead of each element consisting of a special purpose machine, they consist of generally available machine tools. How closely these machine tools are related is varied according to the needs of each component family as described by Thornley [I] and described in Chapter 4.

The Company used as a research vehicle was Lewmar Marine Limited, who are engaged in the design and manufacture of a range of winches and hardware for sailing yachts. Group Technology was introduced into Lewmar Marine for reasons which will be explained in Chapter 3, during its introduction and more especially the subsequent operation, many problems were encountered such as financial restrictions, changing product designs, new products etc. Many publised works were studied on the introduction of G.T. but very little was said about these subsequent problems encountered in a real situation. Thus it was decided to study how the available resources could be best utilised to minimise the problems that were encountered, at Lewmar Marine. The word "available" should be emphasised as in a small company like Lewmar Marine the available resources such as finance, labour, machine tools and space were somewhat less than that available in a large company. Also these problems had to be answered if the targets of G.T. were to be achieved.

2. MANUFACTURING AND GROUP TECHNOLOGY

2.1 Batch Production

One of the most important relationships in the design of manufacturing systems, is that of quantity produced to variety of components. Sawyer [2] has identified four types of production systems one of which, batch production, he estimates accounts for 60-70% of the total manufacturing in Great Britain. Batch production is concerned with a large variety of products produced in relatively small quantities, the manufacture of these products being repeated from time to time.

Certainly since the middle of the 19th Century it has been the practise in factories concerned with batch production to arrange their machinery and subsequent systems on a functional layout basis. The functional layout, which should be familiar to most Production Engineers, basically consists of machines grouped together according to their function (e.g. turning, drilling, milling, grinding). The theory behind this is that each section is in charge of a person highly skilled in that particular function, thus his skills can be applied to all machines in his section. In practise however this system tends to increase the organisational problems because each batch of work has to move from section to section in order to become fully machined. Moreover, each batch cannot leave a section until all the components in that batch have been processed. Thus when a batch moves from one section to another there is no guarantee that the next machine will be ready and waiting. Invariably with the functional layout there are batches of components standing on the shop floor waiting for the capacity to become available in the next section. This situation results in high work-in-progress (W.I.P.) and indeterminate throughput times, in one case they varied between 6 and 13 weeks.

Group Technology attempts to overcome most of these problems by grouping machines according to the geometric and production similarities of various components. In their comparative analysis of the G.T. and functional layout systems, Leonard and Rathmill [3] came to the conclusion that scheduling complexity and control effort is greatly reduced in the G.T. case resulting in superior overall cost performance.

Invariably with batch production and the functional layout the batch size of components is calculated from the economical batch quantity (E.B.Q.). Eilon [4] has shown that E.B.Q.s can at best be clumsy to operate and at worse totally misleading, yet they are still used greatly in industry, in spite of the problems they generate such as stock imbalance leading to high inventory costs. Also with changing values of money etc., the E.B.Q. itself is constantly changing. Skillful planning and scheduling can alleviate the problems caused by functional layouts and the E.B.Q.s but they do not strike at the heart of the problem, the system itself. G.T. is one of the very few new systems developed this century which do just that.

2.2 Manufacturing Since 1800

The Industrial Revolution, as we like to call the development of the Industrialisation of Great Britain, began during the latter part of the 18th Century. By 1800 the steam engine as a provider of power was well established together with industrialisation. The great engineer Henry Maudslay produced a steam engine in 1807 designed for standardised factory production and great portability thus providing a form of small steam power units for factories [5]. The most advanced piece of Maudslay's work, however, were 45 machines he made in 1802 to the designs of Marc Isambard Brunel (1769-1849) for manufacturing pulley-blocks for the Royal Navy. Brunel was commissioned to design equipment capable of producing 100,000 blocks per year operated by ten unskilled men [5]. Important though this was as probably the first installations in the world where machines were used for mass production; it is doubly important as possibly the first occasion when different machines were grouped together in one place to perform all the required operations on a limited range of components. It was probably not until the advent of G.T. some 150 years later that such a system occurred again. The situation at H.M. Portsmouth Naval Dockyard where these block machines were installed was brought about more by the desire to drive all machines from the shaft of one 30 h.p. steam engine than a cautious effort to improve the production system. However, a noted engineer such as Sir Marc Brunel may well have considered the wider implications of this when he positioned the machines, unfortunately there is no proof of this remaining.

The building at Portsmouth Dockyard in which these machines were located is still standing, also two of the original machines are still in situ and in working order. It has been possible to deduce from the belt drive shafts still remaining and from a photograph taken in 1901 that these machines were all grouped together. Further, the machines were divided up into three sections such that each section could completely machine a range of blocks, the block ranges being small, medium and large.

By about 1870 the principles of the bulk of machine tools had become established [6] - Figure 2 [7]. The innovations in machine tools such as the multi-spindle lathe, the universal milling machine (Brown and Sharp) and the universal grinding machine [8], all eminated from the U.S.A. [5]. The failure after about 1870 of the British engineering industry to create major innovations in machine tools, textile machinery and production equipment is very significant. From this point on Great Britain ceased to lead the world as an industrial nation, in fact some would say it has declined as a nation from 1870 onwards. After this date, most of the new innovations eminated from the U.S.A. and Germany. We still see around us evidence of this in the form of small precision mechanisms such as sewing machines (Singer), micrometers (Brown and Sharp) and tumbler locks (Yale). It is also significant that Maudslay Sons and Field closed down at about the same time as Henry Ford launched his Model 'T' car. [5]

From this time until the upsurge of interest in Group Technology in this country during the late 1950's there has not been any major changes in the types of machine tools used and the systems governing their use. Group Technology has provided British Industry with the first opportunity in years to improve their production systems, especially the batch production industries, to give them the required lead over the competition. The only other major change to affect British Industry during this period has been the growth of the large multinational corporations most of which are of U.S.A. origin. These corporations tend to treat the world as one large factory with each constituent plant feeding a number of assembly plants around the world. Of course, this has little effect on the systems of the individual factory, but it increases the pressures put on production as the component produced in a factory is very often required on 2 or 3 different assembly lines located in different countries.

Since the advent of mass production [2] for the higher volume products as pioneered by Ford in the U.S.A. and William Morris in Britain, engineers in the batch production industries have been striving to find ways in which the benefit of mass production could be brought.

to batch production [1, 9, 10]. By grouping the wide variety of components into similar families, larger batches may be formed from smaller batches which result in some of the savings normally attributed to the high volume of mass production such as short and reliable throughput time and low work-in-progress. It is interesting to note, however, that certain companies in the mass production industries are either investigating or have actually built factories where the traditional flow-line has been replaced in favour of some kind of system whereby a group of workers assemble the product together. Most of the pioneering work in this field has been related to automotive manufacture notably by Volvo [11,12, 13] and Saab [14] in Sweden and Renault [15] in France. Although these three companies have reported good results from this system in terms of higher productivity, reduced absenteeism and improved quality, not one automobile manufacturer in Great Britain has seen fit to even try a pilot group built, assembly approach. In fact the latest assembly plant built, that of Rover at Solihull, has continued with the long flow line system [16]. Other mass production companies in other industries have tried this method of group working, Wild [17] has reviewed ten case histories of such changes. These changes to group assembly in mass production or G.T. in batch production is very similar i.e. higher productivity and improved quality. Thus as the batch production industries of various countries [18] adopt G.T. to try to achieve some of the benefits of mass production so some of the mass production industries are moving towards group assembly to try to achieve some of the benefits of batch production (e.g. variety of work). Perhaps in years to come both industries will meet at a common point.

2.3 The Development of Group Technology

In his paper of the use of G.T. in the industries of various countries, Koenigsberger [18] records that "the idea of grouping components in part families appears to be much older than many people imagine. It has been reported that about 25000 B.C. for the manufacture of cutting tools made from stone of which various shapes and profiles were required, similar shapes were grouped together and then produced from one type of blank". Although the principle of G.T. appears to be older than was first thought it is generally agreed that G.T. was developed in the U.S.S.R. during the 1920's. Its progress since then and its gradual adoption in the West has been traced by Grayson [19]. The main work in the U.S.S.R. was concentrated on families of components related to capstan lathes, the most noted being the work of Mitrofanov who proposed the theoretical composite component. Mitrofanov's work, originally published in Russian in 1959 was translated and re-published in English in 1966 [20]. Mitrofanov's basic proposal was that for each family of components it was possible to produce a theoretical composite component which incorporated the major features of all the components in the family - figure 3. Having produced such a component, then tooling could be arranged to produce it, thus providing the set-ups required for each component in the family.

One of the earliest known applications of G.T. outside Eastern Europe was that of Serk-Audco [9,21] who from 1961-1971 made a complete change to G.T. with results that certainly proved the validity of the system. Since this time other companies have investigated and implemented G.T. beginning with the well documented case at Ferodo where reductions in W.I.P. of about 8 to 1 were achieved [1,22,23,43]. By the late 1960's other well known companies such as Ferranti Ltd

24,25,50 , Thomas Mercer Ltd.[26,27], Rolls Royce[28], Mather and Platt[29], have introduced G.T. Since then there have been other applications of G.T. in Great Britain such as Herbert Machine Tools[30], Rank Xerox[31], Wildt Mellor Bromley Ltd[32] and Simon Container Machinery Ltd[33]. It is also known that Moore and Wright are in an advanced stage of implementing G.T.[34]. In his paper, Koenigsberger[18] details the work being done on G.T. in the Netherlands, Switzerland, Belgium, Sweden, U.S.A., Japan and West Germany.

With any application of G.T. families of similar components have to be formed. This is usually accomplished in either one of two ways:-

a) Using a classification code
b) A technique known as Production Flow Analysis.

Considering a) first:- These classification codes usually take the form of a numeric code with anything from 4 to 26 digits which describe the components geometric form and/or its production methods, Knight[35] has identified and described 14 such codes in use throughout the world. Most companies implementing G.T. using a classification code, have used one of these 14 codes with the notable exception of Ferodo who developed their own code to suit their particular components[36]. Apart from Ferodo most of the companies in Great Britain who have used the classification codes have used either the Brisch system or the Opitz system. The Brisch system was originally conceived by E.G. Brisch and later developed by his partner Gombinski who added the polycodes which make it more suitable for G.T. applications[37] - figure 4. It is a code consisting of 4 to 6 digits which with the secondary Polycodes defines the geometric form and production requirements of each component. Although the codes have a common structure each system is tailor-made to suit each customers requirements by the consultants E.G. Brisch and Partners; a further disadvantage is the cost which may run into several thousand pounds for each application.

In the early 1960's Professor Opitz of Aachen University carried out a detailed analysis of the components produced in a number of companies which showed that from the variety of products the component spectrum of each was similar. His studies culminated in the publication of a classification system to describe the geometric form of machined components. This publication is freely available at a modest expense in many languages including English [38]. The main geometric code is of five digits with a supplementary code of four digits which categories the principle dimension and also considers the material and its in initial form - figure 5. Although this code is not as precise as the Brisch code it is simple to use and in most companies provides the necessary classification system with which to group similar families of components. As the Opitz code was originally developed for the Machine Tool Industry on occasions modifications, mainly to the secondary code, have to be made to suit it to individual companies. These modifications are usually simple and easy to make. Opitz and Wiendaal in their paper [49] have described this code's use as a classification code and how it can be used in other areas such as design standardisation. Boundy in his thesis [51] describes how the Opitz code was applied and suitably modified in two companies in Great Britain.

The method of forming similar families of components using the Production Flow Analysis has been mainly proposed by Professor

Burbidge [10,39,40] and others [41]. It is an analytical technique which finds the groups and families from the route taken through the shop as defined by the Process Layout Sheet. One of the main problems with this system is that the information produced for a whole factory is often too complex to be analysed by the human brain. Professor Burbidge has proposed, however, that this can be eased by the use of a computer[42]. The technique of Production Flow Analysis is very useful when applied to the initial groupings as defined by a classification code as it helps in further refining these groups.

The establishment of cells and the subsequent introduction of G.T. has been accomplished in various ways, most of which have been well documented [1,9,22,27,28,29,30,31,32,43]. The subsequent running of the G.T. system has only been sparsely documented, possibly because many companies having introduced G.T. are still "fine tuning" it, others due to the recent economic depression have not progressed beyond their original pilot schemes. Kruse, Swinfield and Thornley[32] have explained the production control system established at Wildt Mellar Bromley after the introduction of G.T., this gives valuable pointers for other companies. Also Craven[44] had discussed some of the problems which may be encountered by the introduction of G.T. The staff at P.E.R.A. have published several reports on different production control systems relating to G.T. and the establishment of cells[46,47,48], but although many of these appear to be based on practical cases, they are not immediately applicable to other situations, it is doubtful whether many companies would have the resources to adopt the P.E.R.A. cascade system of cells.

We are now entering the era when companies who have previously introduced G.T. are discovering not only the advantages of G.T., but the problems which sometimes result. This is to be expected, for as Leonard and Rathmill demonstrate[45], G.T. is not a panacea for the problems of industry.

3. THE COMPANY

3.1 Company History

Lewmar Marine Limited was started in 1946 by Mr. Len Lewery in a shed by the railway line at Fratton, Portsmouth to make small boat fittings to his design. The range of products and their reputation grew during the 1950's particularly with Mr. Lewery's invention of the Novex ratchet block (the design of which has since been sold), also during this time the company moved to Emsworth, Hampshire.

During the early 1960's a controlling interest in the company was acquired by H.C. Shepherd Engineering, and Mr. J.B. Wood appointed as Sales Director. This appointment is significant as, mainly due to Mr. Wood's interests and contacts in the larger boat field, many of the present lines were established including large geared winches in the latter days of the Shepherd administration. A heathy growth continued in all product lines until Mr. Wood left in 1964-65. For the following three years there appears to have been a deficiency of sales pressure and policy resulting in the established lines losing a certain amount of ground in the industry, but the introduction of the above mentioned winches compensated for this.

During 1966-67 the company again changed hands, when Mr. John Burton (the present owner) acquired it. It should be noted at this stage that the founder, Len Lewery still worked for the company. After Mr. Burton's arrival a concentrated effort was made to rationalise, productionise and market these new winches, the effort was to boost sales to astronomical proportions in terms of the existing range. However it found impossible to direct the resources and facilities of the company at both ends of its product range so therefore the original products were sold only under customer pressure.

In 1969-70 Ian Godfrey joined the Lewmar as Sales Manager and continued the effort into the U.S.A., with the birth of a subsidiary Lewmar Marine Inc., in New York, later expanded to California as well. This expansion abroad was continued with the establishment of another subsidiary, Lewmar Marin AB in Sweden in 1973. Three further branches have been established, Canada in 1973, France and Germany in 1975. As well as this activity in forming subsidiaries and branches, agencies have been appointed in Denmark, Holland, Italy, Spain, Switzerland, Japan and New Zealand. So in about 7 years, Lewmar has changed radically from a company relying mainly on the U.K. for its business to one regularly exporting between 80 and 90% of its output to at least 14 different countries. The sole function of these is selling and warehousing, the headquarters in the U.K. being the only manufacturing plant. Concurrent with this expansion and with the aims of Mr. Burton to rationalise the range, the product range changed enormously as detailed below, broadly speaking the emphasis changed from one of mostly hardware to one comprised of mainly winches.

During 1969 and 1970 a new factory was built at Havant to provide much needed extra space and improved facilities. It is indicative of the growth of the company during this period that this factory is now short of space and will soon have to be extended.

3.2 Present Product Range

For some years now the product range has been divided into two categories, winches and hardware.

3.2.1 Winches

Most of the winches manufactured by Lewmar are all hand powered and are either single speed, two or three speed, the extra speeds being obtained by reduction gearing in the base of the winch. Figure 6 shows a selection of these winches. Figures 7, 8, and 9, are exploded diagrams of one, two and three speed winches, the basic similarity of many components will be noticed as well as the increasing degree of complexity. There is another type of winch and this is the halliard winch, it differs from all the other winches in being a reel type i.e. it stores all the wire rope on its drum, the bitter end being secured in the drum.

Also included in winch components are handles which come in a variety of lengths and materials as shown in Figure 10 Handles, of course, are essential to the operation of any winch.

3.2.2. Hardware

Hardware products are far more diversified than winches as Figure 11 shows with some designs dating from an earlier period in the company's history. The main products are blocks, snap shackles, rigging screws, sliders and slider track. None of these products are as complex as winches and are produced on far simpler machine tools.

3.3 Product Changes

After Mr. Burton took control of the company in 1966/67 it was his stated intention to trim the product lines. The progress of this has been measured by researching into Sales categories for different years dating from 1965. These show that there has been a decline in the range of hardware items from 1965 until the present. In 1965 hardware accounted for 90% of the product lines, this had dropped to 85% in 1968/69 and further dropped to 63% in 1974. At present this dropped further still to 53%.

The product lines in this case are the broad headings in the catalogue for example:- 2 speed winches, 3 speed winches, blocks, snap shackles etc.

The percentages given above do not present the whole picture, they only show the decline in hardware not the ascent of winches. Figure 12 shows the variation in product lines in the years 1965, 1969, 1974 and 1976 in which hardware has declined, rapidly between 1965 and 1968, winches have increased, again fairly rapidly between 1969 and 1974. Figure 13 shows how the number of winch types have increased from 1965 to 1976, there being no increase from 1965 to 1969 then approximately 100% increase in the 5 years upto 1974 and a further 100% increase in the 2 years upto 1976. Both these figures demonstrate how winches in 7 years have completely usurped the position of hardware as the major product line of Lewmar Marine.

In 1965 when hardware predominated,fittings were largely made in bronze, stainless steel and Tufnol (synthetic resin bonded fabric) produced on a small number of relatively inexpensive and simple machine tools. With the ascendancy of winches, however, more expensive machines of a far more complex nature have had to be purchased to produce these winches in the quantities required. In fact so much has the emphasis shifted that in 1975 the Fabrication part of the company was disposed of. This part produced all the fabrications (bending, welding etc), out of tube and sheet to make such items as push-pits, pulpits and fuel tanks for boats. At present winches and their associated handles account for about 88% of the combined total turnover of winches and hardware.

3.4 Lewmar Marine & Group Technology

The preceding sections have shown that many changes have been wrought at Lewmar in the last 10 years. The increased sales efforts abroad have resulted in fuller order books, making increasing demands on production. During 1973 the management decided that as well as providing extra machining capacity investigations had to be made into better ways of organising the production to try to answer the following problems:-

(a) Falling behind with orders - customers were being lost purely because production could not meet demand.

(b) Large Work-In-Progress - the W.I.P. was high and looked like being increased if capacity was increased, thus tying up capital needed for expansion.

(c) Throughput times varied enormously making it very difficult to forecast when components would be completed, thus further aggrevating the supply situation.

(d) The need to shorten as well as predict throughput times.

Figures 14 and 15 show the general situation on the shop floor with work in progress occupying the available free space - space which would be needed for the extra machines.

During the autumn of 1973 the management team at Lewmar focussed their attention on possible solutions to these problems. It was considered that possibly some radical change in the production methods would be required as it was felt that the existing system had already been fully exploited. The Chief Production Engineer also stated there was insufficient space on the shop floor for the new machines required to increase capacity. More space had to be found within the existing factory as an extension was not feasible at this point in time. During his investigations, the

General Manager encountered several references to Group Technology and in particular to a book by Ranson which, as it was later discovered, explained G.T. and how it was introduced at Serk-Audco. A copy of this book was purchased for each manager and after an appropriate time for perusal it was discussed.

The conclusions drawn from this book were that before introducing G.T. to Serk-Audco they had suffered many of the problems from which Lewmar was presently suffering. Also the change to G.T. had not only alleviated these problems but also improved the performance of the company in no small way. The feeling of the management was that if G.T. could do this for Serk-Audio then maybe it could do the same for Lewmar Marine. It was therefore decided that the advice of leading exponents in the field of G.T. should be sought with regard to the suitability of G.T. for Lewmar and the possible benefits which could be obtained from its introduction.

Reference was made in some management periodicals to the Group Technology Centre at Blacknest and being part of a government department it was considered that this centre would be able to offer the required independent advice regarding the suitability of G.T. to Lewmar. It was thus decided to approach this centre with a view to having further discussions regarding Group Technology in general and its possible application at Lewmar in particular.

4. INTRODUCTION OF GROUP TECHNOLOGY AT LEWMAR MARINE

4.1 Initial Study

During late 1973 the G.T. centre at Blacknest was approached for further information on Group Technology. Unbeknown to Lewmar this centre had closed but we were able to contact a former member of the staff who put us in contact with Professor Thornley at the University of Aston in Birmingham.

Following a visit to Aston in January, 1974, by two members of the Lewmar Management team, Professor Thornley held a one-day seminar at Lewmar for a number of the staff who might be affected if G.T. were to be adopted. It was later decided that Lewmar Marine should embark on a feasibility study under the guidance of Professor Thornley, the writer being selected to liase between Lewmar Marine and Aston University.

It should be emphasised at this point that the decision to embark on this study had been taken by the Managing Director, Mr. Burton, and the other directors, thus this study had the blessing of the most senior management from the outset. This is an important factor in the implementation of any radical change in a company as without the backing of top management from the start, one is fighting a lost cause.

4.2 Feasibility Study

Although great similarities can be seen in many of Lewmar's components it has been the experience of other writers [10,37,52,39] on the introduction of G.T. that a more structured approach has to be made to determine the groups. There are two basic approaches, component classification and Production Flow Analysis . It was the considered opinion of the staff at Aston that some form of classification could would be the most suited to Lewmar's needs. It was considered that Production Flow Analysis was apt to be unwieldy to work when applied to the factory as a whole.

4.2.1 Classification Development

The various types of classification codes were discussed in Chapter 2. It was considered that in Lewmar's case that the Opitz system should be tried as this was the most readily available and appeared to offer all that was required. Accordingly sample numbers of components were coded using the Opitz system with encouraging results.

The system as it is published 38 did not appear to readily cover such features as the outside profile of a winch drum, pawl pockets, ratchet tracks etc. The interpretation of the code in respect of these items was entered in the appropriate space in the definitions part of the book - Figure 16.

Also the supplementory code, the standard Opitz version of which is shown in Figure 17 , did not lend itself to Lewmar's needs. After discussion between Professor Thornley and the Production and Design personnel at Lewmar, this part of the code was modified to that shown in Figure18 . In this modified form the accuracy digit was replaced with an extra dimension digit specifying the rotational length 'L' and the edge length 'C' (non-rotational). This digit was placed between the first dimension digit and the material digit. It was assumed that by dispensing with the accuracy digit that in a machined feature accuracy is an inbuilt characteristic and that useful purpose could be seen in its retention in Lewmar's case. The material selection and its initial form had to be completely changed as well as Lewmar use a completely different range of materials to those shown in Figure 17 .

Having made these modifications to the Opitz code, all the piece part drawings were coded, the code number being written on each drawing to avoid duplication and to provide a final record of the code for each part. The Opitz codes thus obtained were sorted by a local computer bureau into their ascending numerical order. Figure 19 shows a section of this computer printout; the first column is the Opitz code, the second the part number, the third a brief part description and the forth column is the product group from which the part comes. There are two product groups at Lewmar, 'A' and 'B'. 'A' is winches and 'B' is hardware, this extra information was included to enable rapid differentation between components of the different product groups, the full implication of this will be explained in the next section.

4.2.2 Cell Planning

Up to this point all the components whether eminating from winches or hardware had to be coded and sorted but from now on it was decided that winches (A) and hardware (B) should be tackled separately to reduce the work load. As at this time winches accounted for about 80% of the total turnover it was decided to start with 'A' items, these items taking up the larger part of the machine shop capacity. Thus when dividing the printout of the sorted codes into family groups all 'B' items were ignored unless they specifically fitted into an 'A' item group.

The most obvious family groups were tackled first to see if cells of machines could be arranged around these groups. Also it provided the experience needed for approaching the less obvious family groups. The three most obvious family groups were:-

(a) Small winch drums - designated G.T.1

(b) Large winch drums - designated G.T.2

(c) Centre Stems - designated G.T.3

Having roughly established these cells, they had to be refined not only to the point where the actual types of machine tools could be specified but also the numbers required. At this stage the work moved on from the classification code more into the radius of Production Flow Analysis and Component Flow Analysis. The component versus Machine chart [41] was adopted and compiled using information gained from the process layout sheets for each component, Figure 20 shows these charts for cells 1,2 and 3. In this way a picture was built up as to the machine requirements of each cell. The numbers of each machine required in each cell was decided by calculations based on the theoretical cell capacity.

4.2.3 Cell Capacity

The projected capacity requirements of each cell were calculated from the forecast of winch sales for the coming year. Key machines were selected in each cell, using the component versus machine chart, these being machines with the longest cycle time. This procedure was adopted as it was considered that these key machines would have to work all time to produce the given work, they also had the longest cycle time of any machine in the cell. Figure 23 shows a table of hourly machining rates, expressed as a ratio taking the Canavese lathe as unity, for each elemental machine for each component in cell G.T.1. This table demonstrates how both criteria have to be applied in determining the key machine and also the initial decisions that have to be made.

The Canavese Lathe at the start is required by all components and it has the slowest cycle with the exception of the gear shaper. From this one could deduce that the gear shaper is the key machine but further study shows that it is not required by all components. Also as demonstrated by Figure 24 the time required to gear cut one months output of components requiring this facility is still less than that required to turn all the components. Thus the gear shaper was not considered the key machine. However after studying these figures it was soon appreciated that for any one component, the use of the gear shaper would slow down the rate of completed components leaving the cell and create a queueing problem ahead of the gear cutter. This was considered unacceptable by the management and so two gear shapers were allocated thus definitely making the Canavese the slowest cycle and hence, key machine.

The point about this selection of the key machine is that the cycle time of the key machine controls the rate of production of the cell and thus is worked at the highest utilisation factor. Having identified the key machine in each of the cells all future capacity calculations were based on the cycle time of this key machine This system worked very well for the flowline type cells but less so in the non-flowline cells as originally envisaged, this will be explained in later chapters.

These calculations were carried out on all the projected cells for two reasons:-

(a) to see if each cell, as formulated, could cope with the expected work load.

(b) to produce a theroretical list of machine tools required by all cells.

These initial studies showed that the projected cells could cope with the expected work load although in some cases cells had been formulated with machines which were projected but not ordered. Economic constraints later dictated that certain of these machines were not ordered, this of course caused some later replanning of cells.

4.2.4 Cell Formation

Although initially it was only intended to set up cells 1, 2 and 3 as described in section 4.2.2., the remaining cells necessary for winch production had to be structured so that machine tools could be properly allocated. These other cells, however, were not considered in so much detail.

These other cells (5 in number) were formulated basically in a similar manner to the first three. The Opitz classification system was used to sort out the broad family groups but even more use was made of the process layout sheets to finally decide which components should be produced in what cell and what machines would be required. These cells are slightly different to G.T. 1,2 and 3 as the variety of components is greater. This exercise produced the plant list for each cell, Figure 25 (a to h) shows these plant lists together with a list of components to be produced in each cell. Figure 25 (g) for cell G.T.7 does not list the components to be produced as being small turned parts, they are too numerous to include. G.T.7 consists entirely of small plugboard automatic capstan lathes and it was proposed to leave these machines grouped together, as the families of components they would have to produce were those components they had always produced, both for winches and hardware.

From all these individual cell plant lists, a total plant balance sheet was drawn up for cells - Figure 26 . This was required to show up any deficiencies so that they could be investigated and corrected if possible. Figure 26 shows that these deficiencies were mainly confined to precision pillar drills, a gear shaper and a vertical mill. Subsequently the need for the extra gear shaper and vertical mill was obviated by accepting a slower throughput time in the case of the gear shaper and redesigning the milling fixtures for a horizontal mill. Later events showed that the requirements for precision pillar drills with power feed had been underestimated.

4.2.5 Monthly Reports

From the outset it was decided by the Management that a system of monthly reports should be published to keep all interested parties informed as to the progress of the feasibility study and to record discussions which may have taken place. These reports have been included in Appendix 1.

4.3 Report to Management

At the beginning of the feasibility study the Management had expressed a desire to see a full report on this study in six month's time. Accordingly, in July, 1974, a report was published entitled "Interim Report on the Introduction of Group Technology into Lewmar Marine Ltd". Although it was entitled an Interim Report, it became the only report. The need for the final report was obviated by a number of factors, such as the acceptance of the first report and the need to move all the machines during the forthcoming works shutdown.

This report outlined the following subjects:-

(a) theory of Group Technology

(b) classification system

(c) selection of groups

(d) operation of cells 1,2 and 3

(e) the effect of Work-In-Progress

(f) lead times

(g) inventory

(h) expenditure on new plant and equipment required to set up cells 1, 2 and 3.

The report concluded that there existed families of smilar components in Lewmar and that the introduction of G.T. would reduce work in progress by about 50% and cut throughput times by between 33% and 70%. It was also explained that the layout of the factory would have to be considerably modified within the next few months to accommodate new machines already on order and that this opportunity should be used to produce a layout which would be suitable when the G.T. cells would be set up, although most cells would be operating as planned for at least six months due to lack of experience in G.T. and the necessary plant.

This report was basically accepted by the Management and it was agreed that work should continue to change the factory on the lines suggested in the report, setting up cells 1, 2 and 3 as soon as possible.

4.4 Types of Cells

Three basic types of G.T. cell have been recognised by various writers[2,52] and before covering the implementation of the above these three types of cells should be explained as they have a fairly important effect on the operation of G.T. at Lewmar.

4.4.1 Group Technology Flow Line

In many families of components, there is a high degree of similarity not only of geometric form but in machining operations required. This usually means that each component need only visit a machine once. If the machines are established sequentially as determined by the order of operations, then a flow line can be established so that a component only visits each required machine once in the line and then in sequence. This differs from a conventional flow line in that as some machines will be under utilised it will be necessary for some operators to operate more than one machine. This will require them to move from one machine to another where work has accumulated. This type of flow line is balanced on the operators, rather than the machines. Often each machine is connected by roller conveyor tracks to aid movement of components.

4.4.2 Group Technology Cell

In this type of cell there is a sufficient variety of machines to carry out all the processes required by the family of components. In this system a component may have to back track to visit a particular machine more than once, causing some increases in work-in-progress. This type of cell is basically a mini machine shop and as such can cope with a wider variety of components than the G.T. flow line.

4.4.3 Single Machine Cell

This type of cell is considered when the complete family of components can be produced on one Machine. This is usually applied to small turned items produced by capstan lathes although increasingly it is also being used in the context of complex Numerically Controlled machining centres. Regarding the capstan lathes, this has been carried further by integrating the distinctive features of each member of the family into a composite component Figure 3 [20]. The capstan is then tooled up to produce this composite component and thus can produce any component in the family with the minimum of resetting.

4.4.4 Types of Cells at Lewmar

Lewmar Marine is probably fairly unusual in its application of G.T. in that it has adopted all three types of G.T. cell as follows:-

(a) G.T. Flow Line - Cells 1, 2 and 3

(b) G.T. Cell - Cells 4,5,6 and 8

(c) Single Machine Cell - Cell 7

This arose because of the varying degrees of similarity in families. The adoption of these three different types of cells has created its own special problems which will be covered in detail in later chapters.

4.5 Implementation

Having received the agreement of the Management to implement the recommendations of the Feasibility Study Report, work proceeded to produce a new factory layout and hold discussions with both middle managers and Union Representatives regarding the implementation of G.T. at Lewmar.

4.5.1 New Layout

Figure 27 shows the old layout with the machines arranged in a typical functional layout manner. The starting point of the new layout was to locate the two Canavese twin spindle chucking automatic lathes (one in use and one on order) adjacent to the stores, as these machines would process the bulk of the castings. Now each of these machines is the key machine in cells G.T.1 and 3 so these cells were than laid out. This resulted in the first complication, having laid out these cells to produce a good layout, insufficient room was left for the remaining cells. Thus began a period which lasted several weeks of rearranging and modifying successive factory layouts until the best compromise solution was reached. In laying out the other cells, space had to be left for other machines either projected or actually on order. After laying out all the cells a collection of miscellaneous machines was left unallocated. The purpose of these machines was, and still is, to process hardware components and such winch components that would not fit into families. Figure 28 shows the proposed new layout as finalised in August, 1974.

All the machines were moved during the annual works shutdown of late August, 1974, and cells G.T.1 and 3 became operational on 3rd September, 1974. Only eight months after the commencement of work on the feasibility study. This short time was achieved by virtue of the following facts:-

(a) the small size of the company

(b) the high degree of similarity of design of components

(c) the low level of manufacturing complexity

(d) the importance attached to the project by the Management.

However, it was to be a further eight months before the remaining cells become operational for reasons given in section 4.6.3.

4.5.2 <u>Trades Union and Staff Discussions</u>

Separate meetings were held with the middle managers (foremen, purchasing manager, production controller, setters etc), and the

Trades Union Representatives - Lewmar is fortunate in having only one Trades Union, the Transport and General Workers Union. The proposals were put before these meetings together with a resume of the workings of G.T. It was explained that to start with only G.T.1 and 3 would be operational as cells, the remainder of the machine shop would continue to operate on a functional layout type basis but with the machines dotted about in their eventual locations. This was accepted after discussion mainly because the factory floor at Lewmar is not very big (30m x 45m), including the stores, thus there were no great distances involved in moving work from one machine to another.

Several changes were made to the layout after suggestions made by both meetings and also the main fears regarding the operation of the new cells were allayed. These negotiations were able to proceed relatively smoothly to a conclusion as a result of three factors:-

(a) Lewmar Marine does not operate on incentive bonus scheme - each man is paid a respectable flat rate.

(b) Mobility of labour between one machine and another was already accepted and was commonplace.

(c) Being a small company, G.T. and the attendant proposals were not completely fresh ideas at these meetings. Many of these people had already had informal discussions with staff engaged on the feasibility study and some had attended Professor Thornley's original Seminar as well.

4.6 Allied Machine Tool Programme

4.6.1 The Need for Additional Machine Tools

In Chapter 3 the growth of the company has been described together with the growth in sales and type of winches. During this period the company's production capacity had not always kept pace with this growth. In 1973 the company found itself in the position of having to sub-contract large volumes of work purely for lack of capacity in its own machine shop. Decisions were taken that for the long term good of the company, extra capacity had to be bought in the form of extra machine tools to reduce the level of sub-contracting to a bare minimum. Since that time it has been the aim of Lewmar Marine to produce as many components as possible "in house" thereby reducing the cost and increasing the level of control over their manufacture. These machines were not purchased as a result of the introduction of G.T., but rather the G.T. cells were able to have greater depth and capacity by the prior decisions to purchase such machines. The lack of capacity was so great that these extra machines were required inspite of the advantages gained by introducing G.T.

4.6.2 <u>Types of Machine Tools</u>

In early 1973 when the company embarked upon this programme the most complex machines in the factory were four Herbert Senior 5 Preoptive Capstan Lathes. Two of these were filled with collets and bar feed, the other two with pneumatic power chucks. All four had hydraulic copy slides. It was appreciated that good though these machines were, they were labour intensive and required a good setter/operator to man them - a class of person not always readily found. Also little more could be done to speed up the machining of components on the existing machines.

Future machines were to be of the more modern automatic type which did not require setters/operators but rather an unskilled operator with a setter working on two or three machines. Figure 4.12 lists the major machine tools purchased since 1973 together with their purchase date and cell to which they were allocated on arrival.

The Lathes fell into two main categories - chucking for castings and collet machines for bar. To cope with the more numerous castings, the Canavese twin spindle plugboard automatics were purchased. These machines have a fast cycle, each machine performing the work of more than two Herbert 5's by virtue of the fact that each cycle is completely automatic and all tool slides work off copy templates. These machines raised the output considerably. Later it was found that there was an increasing number of castings - mostly of the larger sizes, whose numbers were somewhat smaller than could be economically machined on the Canaveses due to the long set up times of the machines (up to 8 hours). Automatic machines were still required so two Hydro Numerically Controlled chucking lathes were purchased. These are no faster than the Canaveses but have reduced the setting time from the Canaveses 6-8 hours to about 1 hour making smaller batches more viable. There was a need for high output automatic bar lathes which were satisfied by the two Wickman 3½ins diameter single spindle lathes. They are used to turn gear and spindle blanks at high rates to feed cells G.T. 4 and 6.

Prior to early 1975, all gear cutting at Lewmar had been done by vertical gear shaping on two Sykes machines. Extra capacity was used to gear cut spindles and driving gears. This was satisfied by the purchase of two Sykes gear hobbers. The advantage of hobbing over shaping in this instance was not so much a reduction in cycle time, but that the price was half that of a shaping machine.

Since 1972, the machine purchasing policy has undergone a profound change there being a marked swing to the more sophisticated and automated machine which makes the maximum use of such items as throw away tungston carbide tips.

4.6.3 Effect on G.T. Cells

When the cells were being planned in 1974, most of the machines in Figure 29 were projected if not already on order. Thus in most cases they became fundamental to the operation of the cells, often being the key machine. As the last Wickman was not delivered until March 1975, all the originally planned eight cells were not operating until April, 1975; Cell G.T. 9 was not planned until 1976. This of course imposed a delay of eight months between the start of the first cell and the start of the last cell. This time was usefully employed in improving on the already established cells and somewhat reduced the trauma that would have arisen if all eight cells had been started together.

Since the introduction of G.T. at Lewmar, the advantages relating to machine tool purchase as proposed by Thornley [1] have to a large extent been realised. It has been found that the family groups defined more clearly the types of machine tools required when replacements or extra machines are required, thus ensuring that the capital is more fully employed.

5. ALLOCATION OF RESOURCES AND RESULTING PROBLEMS

5.1 Introduction

The previous chapters have dealt mainly with the introduction of Group Technology into Lewmar Marine, this proceeded generally along the theoretical lines laid down by most writers on the subject of introducing G.T. However, when it came to running this new system it was found that in many areas the theory of introduction and the practice of running the system tended to diverge. This was caused by many factors which will be covered below. These factors and the solutions to them will not be covered in chronological order, as this will only serve to confuse, but rather as separate headings. Reference may be made to some problems and solutions more than once as many are inter-related.

Many times since introducing G.T. at Lewmar, large numbers of published work have been studied to see if they could shed any light on the problems of running a G.T. system - most did not cover this vital area. A few writers have touched on this area [31,32,44,45] but their contributions have only, at best, provided vague pointers of the direction which could be followed in overcoming these problems. In most cases at Lewmar each problem has had to be identified and attempts made to overcome it using the skills available, within the company, often more than one attempt was necessary to overcome a problem.

Lewmar Marine, like most other companies, does not have limitless resources. There is no bottomless pit from which untold numbers of machines, operators and the necessary finance can be extracted ad infinitum. Fortunately at Lewmar, finance for the purchase of new machinery is usually forthcoming if there is adequate justification. It was explained in chapter 4 how it was planned to set up each cell using the existing resources of space, labour and to a lesser extent machine tools. It was found in operation, however, that these resources tended to interact sometimes with undesirable consequences. The problems encountered in Production Control and Cost Accounting will be covered in chapters 7 and 8 respectively.

5.2 Space

Most written approaches to the introduction of G.T. have either idealised the cell layout in terms of space or have had spare factory space in which to set up the first pilot cell. This was not the case at Lewmar for although only two cells were operational at the start, 75% of all the machines were located in their allotted cell places and by April 1975 80% of the total number of machines were arranged in cells. This in reality there had been no long running pilot cells, instead all cells i.e. 80% of the productive capacity of the factory were established in eight months.

One of the greatest initial problems was that of the allocation of the resource of space. Figure 30 shows the percentage area occupied by all the various functions on the shop floor from August 1974 to September 1976. Some changes were made in May 1975 which reduced the stores area and process shop area allowing increases in the machinery space and made a separate tool stores possible. However, since May 1975, no basic changes have been made to these areas. So all the time the space allocated for production machinery has been just under half the total shop floor area and has had to remain so as the other functions could not afford to give up any more space after May 1975. In fact by January 1977, every function was hard pressed for space which meant that any changes to gain extra space for machinery were on a "rob Peter to pay Paul" basis - not very desirable. On the few occasions this was attempted, the affected departmental managers reacted strongly often retaliating with their own demands for more space!

So at Lewmar there were clearly designated areas where machinery and hence cells could be established. It could of course be argued that if the stores had been completely re-located say along the east wall then a differently shaped area would have been available. This was discounted on cost grounds. The cost of re-locating the stores would have far outweighed the doubtful advantages thus gained as 20% of the total floor area would still have been required for stores.

The other realistic problem regarding space which must surely face most companies is that of the building structure. The Lewmar factory is not a high building and thus the stores area could not be reduced by the usual method of increasing the height of the racks and stillage stacks. Also the roof structure is of a cantilever design which results in two lines of supporting columns running down the shop - figure 27. Lastly, when the factory was built, there was a need for a partitioned shop where Tufnol could be machined, (this was because of the hazardous dust generated). This partition was constructed in brick halfway along the south wall constituting a later obstacle to factory planning subsequent to the cessation of Tufnol machining. These sorts of constrictions apply to any factory layout but in a fundemental layout (i.e. figure 27) there is little relationship between one machine and another becomes important as so many factors can be affected by items such as:-

a) Work flow

b) Total cell control

c) Operator relationships with each other

d) Operator movement from one machine to another within each cell

Additionally at Lewmar there was one further factor which affected the layout, that of power supply. Most of the machines in the shop received their electrical supply from an overhead 30 ampere bus-bar system which allows for relatively simple movement of these machines. However, the three Canavese lathes (see section 4.6) have a current consumption in excess of 30 amps and thus require their own individual supply. Thus in order to keep the cost of this supply to a minimum it was considered desirable to keep these machines in contiguity. Having provided separate supplies to these machines, one is very loathe to move them at a later date when changes are made to cells. This situation applies in many factories where large machinery is installed, it is very often not moved to accommodate cells either due to power supply problems or foundation problems or both. Thus the cell layouts have to be organised around the predetermined positions on space availability for cells.

Figure 28 showed the layout of cells in September 1974 with all the open spaces left for future machinery. In contrast figure 31 shows the shop layout as of May 1975 with all these machines in position. This increase in machines from September 1974 to May 1975 was as forecasted in Chapter 4 but since May 1975, other major changes have taken place in the layouts, figures 32 and 33. These changes have taken place for the following reasons:-

a) To improve individual cell operations.
b) To create more space for getting more machines incorporated into bigger cells.
c) To accommodate new components resulting from new products.
d) To incorporate changes in production methods.
e) To incorporate new cells created since the feasibility study.

Broadly speaking, the percentage of floor area allocated to machinery has not changed greatly over the two years in question but cell areas within this have changed to a greater extent, figure 34, of the five reasons given above for changing the cell layouts, the need for extra space was probably the least important.

5.3 Machine Tools

When the first cell became operational in September 1974, it was very quickly discovered that for all the theoretical planning, minor modifications were necessary to ensure the smooth running of the cell. This situation which must be common to many companies embarking on G.T. was caused by a slight difference between the order of manufacture as laid down in the process layout sheets and the methods used on the shop floor. Fortunately in this instance, the situation was easily remedied by switching two machines around. Also in the same cell, it had been planned to accomplish a deburring operation on a special air press but this had not been produced when the cell became operational, this situation had to be quickly remedied by the addition to the cell of a spare fly press.

Although in themselves, these problems did not cause any major upsets and were quickly remedied they did highlight the following areas of detail planning which must be checked before implementing a cell:-

a) Does the process layout produced by the Planning Office agree with the methods used on the shop floor.
b) Have all the minor operations such as deburring been fully considered.

Having fallen into this trap early on, great efforts were made with the other cells not to repeat these mistakes.

In the theoretical approach to G.T. two points are made clear, one that each cell is in isolation not interacting with its neighbour, the other is that machine utilization is not considered of great importance . It has already been shown in Chapter 4 that the utilization of the key machines is usually high but the other machines less so. Lewmar started off by adopting this philosophy but found as time passed that in a practical application these ideals when carried to the ultimate can impose a heavy financial penalty which cannot always be justified.

In Chapter 4 regarding the establishment of cell G.T. 1 it was explained that there was some competition between the Canavese lathe and the gear shapers for the role of key machine which was allocated to the Canavese. This did not alter the fact, however, that Lewmar was still left with two relatively expensive machines which were under utilized. Now according to the theoretical concepts of G.T. this should have been ignored. Again theoretically, when cell G.T.2 was established, its one gear shaper had sufficient capacity: in practice, however, it was found that because this machine had a longer cycle than the key machine periodic build-ups in the work-in-progress were caused showing cell output. The best solution to this would have been to purchase another gear shaper which would have overcome this situation but at this point in time the finance for such a purchase was not forthcoming and so G.T.2 had to make do as best it could with the one gear shaper until such time as the financial situation became easier. To try and ease this situation, it was decided during 1974 to group all the gear shapers together although they belonged in different cells. This was accomplished as figure 31 shows, by splitting G.T.1 into two parts connected by roller tracking. The thinking behind this was that when the gear shapers in G.T.1 were idle (as a result of two components which did not require gear cutting) they could be used to reduce the work-in-progress and increase the output of G.T.2. This situation continued until February 1976 when it was discontinued upon the re-design of G.T.1 to accommodate the new family of single speed winch drums. - section 5.4. This method of operation was reasonably successful but it did have its problems, on numerous occasions peak work-in-progress was reached in G.T.2 when drums requiring gear cutting were being produced on G.T.1. It was very difficult to schedule the work on both G.T.1 and G.T.2 such that this did not happen at some time. This method, however unorthodox, did improve the through-put of G.T.2 without seriously impairing that of G.T.1, moreover it kept the three machines working and as they were grouped together, they could be controlled by one man. There was the further side effect that product costing became difficult as it was impossible to predict with any great degree of continuity of a drum produced in G.T.2 would be gear cut in G.T.1 or 2

The other aspect of machine tools in the G.T. environment is maintenance. With the functional layout the breakdown of a machine usually means work being put on other machines causing a general increase in the work-in-progress. When the G.T. system of a machine fails in a cell, the whole cell is in danger of coming to a halt.

Even before the first cell was set up at Lewmar this situation was recognised. It was decided that the best way to minimise this risk was to institute a programme of planned preventative maintenance for all machine tools. To this end a register of plant was established and a history of breakdowns and spares used etc. was built up. This information, together with that contained in the manufacturers handbooks, has enabled this programme to be drawn up. It has also enabled the Maintenance Section to stock a range of spare parts which will be required by each machine.

This system was put into use in late 1974 and has contained major breakdowns to a minimum - about 3 to 4 per year. These major breakdowns meant that a machine was not useable for a week or so and were usually caused by bearing failure (mainly due to age), electrical failure, such as motors burning out and damage sustained by failure of major machine components. As spare parts are now expensive to stock both in terms of money and space, the minimum normally required, determined through experience and manufacturers recommendation, are held in stock. Also when a new machine is ordered, the spare parts supply situation at the manufacturer and his agents is carefully investigated to ensure that the company will get rapid delivery of urgent spare parts. Further to this, the Maintenance Section have built up a series of contacts within about a 30 mile radius of the factory where common parts such as bearings and electrical relays can be obtained from distributors stock.

It has been the experience of Lewmar Marine that a preventative maintenance programme together with an attendant spare parts back-up is essential to the smooth operation of a G.T. system. Doubtless the same programme applied to a functional layout could produce similar results, but it is the nature of the G.T. system that functions such as machine maintenance must be considered, G.T. focuses attention on such areas which are often ignored in many factories to the detriment of throughput times and the detriment of machine tool life.

5.4 New Products

In Chapter 3 it was shown that Lewmar is not a static company, the product range is constantly changing. More importantly since 1974 there has been a mini-explosion in the number of winch types in the range, increasing 100% in two years. This increase occured at the same time as G.T. was being introduced. In other applications of G.T. [9] the impression is given that the product range remained fairly static during and after the implementation of G.T. there being only small modifications. This was not the case at Lewmar, two important changes to the winch range have been made in the last two years:-

a) New range of single speed winches to a new design - introduced in January 1976.

b) New type of winch, the self tailing winch introduced in quantity in February 1976.

The effect of the new single speed winches on the established cells was forseen. G.T.1 was re-designed to produce only this family of winch drums and G.T.3 was modified to include a new machine to put a slot in the new centre stems, also to produce the No. 16 winch drum. The 16 winch drum was moved from G.T.1 to G.T.3 as there was insufficient capacity in G.T.1 but spare capacity in G.T.3. At the same time, the two gear shapers which were now surplus to requirements in G.T.1 were allocated to G.T.2. All these changes did create one problem - although there were sufficient machines in G.T.3 to perform nearly all these operations on the No. 16 drum it could still not be gear cut in G.T.3, for that it had to be transferred to G.T.2 after G.T.3. This problem was recognised in the planning stage and so it was arranged for the roller tracking of G.T.3 to pass under the roller tracking of G.T.3 before the gear shapers. This ensured that the No. 16 drums did not have to travel a great distance before being gear cut. It also kept work-in-progress to a minimum.

The effect of the new self tailing winches was altogether different. These winches differ from the standard ones in having a completely different drum top incorporating a pair of revolving jaws to grip the rope. This entailed screw cutting the centre stems, making the drums in two halves fixed together with socket head cap screws plus producing a whole new range of components. Sales at first forecast that demand for these winches would be very small and so it was planned to produce some of these components in house and sub-contract the remainder. It was considered that production could endure the slight extra complications this would cause i.e. foreign work in cells. However, shortly after these winches appeared on the market, the demand increased markedly thus requiring much larger batches of these new components. The result was an increase in the amount of foreign work in the established cells as well as an increase in the amount of sub-contracted work. The new components on first examination did not appear to fit into existing family groupings very well, also the volumes were still much lower than the existing standard two and three speed winches. The effect on the shop floor in general was to increase the work-in-progress and cause disruption in many of the cells; by March 1976 these new self tailing winch components were seriously threatening to disrupt the whole G.T. concept at Lewmar.

The basic problem was that when the cells had been established over the period September 1974 to April 1975, self tailing winches had not even been conceived, so naturally the cells were not designed with these new components in mind. Having identified in March 1976 that it was mainly the new self tailing winch components which were causing such major disruptions on the shop the following reasons were identified:-

a) The new components did not readily fit into established cells.

b) There was insufficient capacity to produce these new components as well as the existing ones.

Further analysis showed that one of these new components, including the new single speed winch ones, had been Opitz coded and further more, there had not been a sorting of Opitz codes since April 1974, even though modifications to existing components had been re-coded. This disasterous state of affairs had obviously led to the shop floor disruption. Two points should be made at this stage:-

a) The new self tailing winches were in addition to the existing winch range and so did not replace any existing winches.

b) The shop floor disruptions reached such proportions that some managers began to question the validity of the whole G.T. concept.

Immediately all new components were Opitz coded and the resulting coded sorted as before. This new sorting enabled the planners to identify the new family groups and modify the cells as follows:-

Cell G.T.1 - Figure 35 (a) - No effect on the arrangement established in February 1976 for the new single speed winches.

Cell G.T.2 - Figure 35 (b) - Slightly replanned to produce two speed winch drums only.

Cell G.T.3 - Figure 35 (c) - No change.

Cell G.T.4 - Figure 35 (d) - Sub divided into 3 cost centres.

4A,4B,4C - G.T.4A gained another Wickman from G.T.6. This was done because the Wickman in G.T.4 was overloaded and the one in G.T.6 had the required capacity. G.T.4A became a feeder cell, feeding mainly G.T.4B, 4C, 6A and 6C plus a few components to the miscellaneous area. G.T.4B would produce the ring type gears with the internal ratchets and G.T.4C would produce the more solid gears with the pawl holes and pockets.

Cell G.T.5 - Figure 35 (e) - Relegated to a turning capacity only cell after losing turret drill to G.T.9.

Cell G.T.6 - Figure 35 (f) - Sub divided into three cost centres, 6A, 6B and 6C. G.T.6A arranged to produce three speed spindle blanks as well as producing the undercuts etc. on spindles produced in G.T.4A. G.T.6B remained as before to perform all the drilling, gear cutting, broadning etc. on the spindles. G.T.6C is a new operation - centreless plunge grinding, this was introduced on the spindles to improve their quality.

Cell G.T.7 - Figure 35 (g) - No change.

Cell G.T.8 - Figure 35 (h) - No change.

Cell G.T.9 - Figure 35 (j) - New cell created to provide necessary extra capacity to machine the lower volume castings used on existing three speed winches and new self tailing winches. Sub divided into two cost centres, 9A and 9B. G.T.9A arranged to perform all the turning feeding directly to G.T.9B, which was arranged to perform the drilling, gear shaping and broadening as necessary. These two cost centres were established as some components were fed into G.T.9B from G.T.5 rather than from G.T.9A.

The modifications to the existing cells and the formation of the new cell was accomplished during the annual works shut down of August 1976, virtually two years on from the time that the shop floor was changed to create G.T. cells. This also coincided with the delivery of the two new N.C. lathes for G.T.9.

As mentioned before, apart from these changes made to existing cells extra cpacity was required to produce these new components. When the sorted Opitz codes were studied it was found that the new self tailing winch drums filled into the existing families of two and three speed plus some of the new top end components. Cell G.T.2 provided the basis of the cell requirements for these components but it was found to have insufficient capacity. Further study of the sales forecast showed that self tailing, 3 speed and 2 speed winches were produced in the following ratio:-

Self tailing to 3 speed to 2 speed 1 : 2 : 19

Thus both the existing 3 speed winches and the new self tailing winches were to be produced in much lower volumes to the two speed winches. Lower volume means smaller batches which means more set-ups per production period. So a new cell was required which would provide the basic facilities of cell G.T.2, but owing to the smaller batch sizes, would have to be set in a shorter time. To fulfill this requirement two Numerically Controlled centre lathes were purchased to act as key machines rather than another Canavese CG1802TL. These machines can be set in a little over one hour compared with up to six hours for the Canavese. Likewise a turret drill was adopted as there was an increase in drilling and tapping resulting from the new self tailing components. So constructed, G.T.9 was also found to be ideal for machining the family of large centre-stems, work previously done in G.T.5. The result of this shift of work was that the services of the turret drill in G.T.5 were required in G.T.9. This machine was incorporated into G.T.9 thus depriving G.T.5 of its drilling capacity and furthermore causing those components still produced in G.T.5 to have to move to G.T.9B or the miscellaneous area of drilling was required. The immediate answer was to purchase extra drilling capacity but this was not thought necessary as it was planned eventually to move all the work from G.T.5 to G.T.9. Events, however, have overtaken this plan formulated as late as it was in August 1976. The plan was based on the sales forecast available at that time which indicated sufficient capacity in G.T.9 to be able to do this. Since then, demand for all winches, especially two speed and self tailing winches has increased. This has meant that at times, Cell G.T.2, machining two speed drums, has become overloaded resulting in some work being put onto G.T.9. This is because G.T.9 duplicates the services of G.T.2. The effect of this is to continue to machine components in G.T.5 rather than transfer them to G.T.9. This situation has now so loaded the drilling and gear shaping capacities of G.T.9 that an extra gear shaper has been ordered and one or more N.C. turret drills are being actively considered. If these were to be bought, the existing turret drill in G.T.9 could then return to G.T.5 thus easing the load of foreign work on G.T.9.

The events outlined above which caused a major re-think of some cells and the establishment of a new cell have highlighted several problems relating to the allocation of resources:-

a) The classification codes have to be continually updated.

b) At suitable intervals of time these updated codes have to be re-sorted. At Lewmar, the suitable interval occurs whenever one or more new products are introduced.

c) As a result of b) the existing cells will have to be modified and/or new ones established.

d) In a company which has to change its products to meet competition the manufacturing methods have to change to meet the products.

e) The manufacturing system must be matched to the sales forecast which will inevitably mean that plans made yesterday based on yesterdays forecast will have to be altered to today's changed forecast.

f) There will never come a time when the work of establishing a G.T. system is finished, for the changing product scene will always cause the planners to keep returning to the beginning.

5.5 Foreign Work in Cells

The principle of foreign work in cells is one which has to be resisted most strongly in all G.T. applications. Foreign work comprises components which do not fit into the family groups for which that cell was established and in consequence only use one or two machines in that cell. If one is not careful foreign work can easily disrupt the whole G.T. concept. This is the generally accepted theoretical viewpoint of G.T., however at Lewmar there are some cases of foreign work which can be justified. The main reason why foreign work occurs at all is that some components require special operations such as broaching or gear cutting. Because of the high cost of such machinery and often its attendant low utilization, it is usually located in the cells which will make the most use of it. In consequence, the few remaining components which also require this facility but are produced in another cell have to leave their initiating cell and be moved to the other cells for this special operation to be performed.

A survey was recently conducted in all cells to determine the amount of foreign work - figure 36. The reasons why these components constitute foreign work are as follows:-

Cell G.T.3 - foreign components require the services of a specialised milling machine to insert a slot. This could be overcome by purchasing another mill and including it in the cell which produces the main part of these components.

Cell G.T.4 - half of these foreign components require 1st operation turning on the Wickmans and the other half require the services of a broach. The Wickman operations could be done on other lathes but there is not the capacity and the cost would be greater. The broaching operations should not be required after the end of 1977 when these components should become obsolete.

Cell G.T.5 - these foreign components require second operation turning after being turned in G.T.4.

Cell G.T.6 - half of the foreign components require grooving on a lathe, the other half require vertical milling. The first half should soon be moved to the miscellaneous area due to the impending arrival of another milling machine.

Cell G.T.8 - these components require slitting on a horizontal milling machine. A study is being done to investigate the possibility of performing this operation on the lathes in G.T.7 from whence these components originate.

Cell G.T.9 - these components require the specialised services of the turret drill in this cell. This condition could be solved by the addition of more turret drilling capacity in G.T.5 and the miscellaneous area.

These foreign components have affected the cells in four ways:-

a) Capacity

b) Production Control

c) Product Costing

d) Work-in-Progress

Capacity has not been a problem, there always being a surplus on the machine in question. Production Control did cause some difficulties owing to priorities. Initially it was always understood that the foreign components would have the lowest priority - this worked well until it was discovered that on occasions the most urgent job was one of these foreign components. This situation was alleviated to some extent by progressing each of these foreign components machine by machine, a laborious task only made easier by the small numbers involved. These foreign components did pose some queuing problems which materially increased the work-in-progress levels but these varies greatly according to the overall monthly demands on each cell. Product costing was the area most affected by these foreign components for as they only used one machine in a particular cell they attracted the whole cell overhead, thus giving a high product cost - Chapter 7.

When this situation was first identified, four proposals were considered to improve it:-

a) Set up a cell for each of these foreign components - this would not be viable, as the low volume of these components could not justify the high cost involved.

b) Increase the capacity of the miscellaneous area by the addition of the necessary specialist machines - this again would not be viable and would also still give innaccurate product costs.

c) Reduce the impact on the cells by modifying their structure - this was one of the proposals adopted.

d) Re-engineer the components to bring them into line with existing families - this was the other proposal adopted.

Proposal (c) was implemented by sub dividing the cells G.T.4, 6 and 9 into sub cost centres as already outlined in section 5.4. This change was purely administrative enabling production control and product cost to be determined more accurately but had little effect on the running of the cells - the remaining 82% of components were still processed as before. Figure 37 shows the results of another survey of foreign work in the cells after the adoption of these sub-divisions - the areas where foreign work is involved have become more clearly defined and the reasons can thus be identified.

Proposal (d) was adopted at the same time as (c) but it has taken longer to implement as it has not always been possible to re-engineer components quickly. However, due to modifications and re-designs of several winches some of these foreign components are being eliminated. A good example is a winch main spindle part number 15008003 - figure 38, the original method of production was as follows:-

Op.1 Turn blank from solid stainless steel bar on Wickman - G.T. 4A.

Op.2 Countersink end and undercut - G.T. 6A.

Op.3 Broach bi-square - G.T. 9B.

Op.4 Hob ratchet track - G.T. 6B.

Clearly this component travelled a distance round the shop floor - figure 39 and was a foreign component in each cell it was led.

The new method of production did not change the basic design or function of the component but was still very different:-

Op.1 Investment cast - bought out

Op.2 Electropolish - sub contract

Op.3 Plunge grind - G.T. 6C

Op.4 Groove and face - G.T. 6B

This change in production entails a much shorter route - figure 40. Also there is no switching from one cell to another. There was no cost increase involved in this change and capacity was released from the Wickmans in G.T. 4A and the gear hobber in G.T. 6B.

This foreign work has now been reduced to manageable proportions by virtue of redesigning some components, and introducing cell modifications, however, at one stage, about February 1976, the amount of foreign work in cells started to increase mainly due to new products. It has been the experience at Lewmar that on occasions there is little choice but to accept foreign work in cells but in doing so the dangers of disruption and increased work-in-progress must be recognised. Also these foreign components must be planned into the cells, if necessary, altering the cell cost centres to enable the management to predict more accurately the production control data and the component costs. At all times all the staff must be clearly aware of why there is foreign work and rather than let it increase must strive to decrease it.

The indications at Lewmar that foreign work in cells will never completely disappear but it will drop from its present average of 12% to about 6%, this will be accomplished by some existing foreign components becoming obsolete, others being re-engineered and more sensitive modifications to cells, including plant purchases to provide the extra specialist capacity required.

5.6 Personnel

A resource that is equally as important as the machines are the people who operate them. As explained in chapter 4, discussions were held with all affected groups of people before the G.T. concept was introduced. Up until February 1976 little thought was given to the operators themselves, except for allowing for ease of access and movement of people in and around cells. With the adoption of G.T.

cells one further requirement was met, this was the ease of movement from one machine to another which an operator would be required to make.

This apparently blasé approach to personnel was probably prompted by two factors which exist at Lewmar:-

a) It has been the established practise by the supervision to move operators from one machine to another as dictated by production demands.

b) There is no incentive bonus scheme of any description in operation.

These factors resulted in a certain degree of indifference to the social interactions of people within cells. As a consequence, cells tended to be set up and moreover modified solely to meet the needs of the components produced in them rather than the people working in them.

During late 1975 and early 1976 a psychology researcher from Portsmouth Polytechnic worked on the shop floor at Lewmar as part of his study into group behaviour. In his report [53] to the Managing Director, it was made plain that this social aspect of cells had been overlooked. Both in his report and in private conversations, this researcher had indicated that the layout of some cells, whilst suiting their function did not allow for the social interaction of their operators. It was his experience that if the people in each cell wished to converse with each other they would do so whatever obstacles were put in their way. In some cells at Lewmar this meant that operators would often stop working their machines in order to move to be able to converse with their colleagues. This hypothesis was examined further by watching the activities of people in the cells over a period of several weeks and was found to be true.

In February 1976 cell G.T.1 had to be modified to cater for the manufacture of the new single speed winch drums. In the light of the above, the opportunity was taken to so design the cell that the operators could feel that they belonged to that cell and that they could interact without having to move from their machines. The difference is shown in figure 41 where the layout before the change was a long line, the layout after the change being a U-shape with the machines connected by short lengths of conveyor track. In practice, this arrangement was found to be a big improvement in performance. The result has been in subsequent cell modifications to try to continue this theme of making the individual operators feel part of a cohesive group.

When operators have spent considerable periods of time in one cell it has been found that a group feeling and loyalty does emerge, but it is still the practice to move operators from one cell to another as the demands on each cell wax and wane. Now from the standpoint of building a group feeling, a sense of belonging, within each cell, this movement is counter productive. But conversely, no company can afford to have surplus labour stood idle in one cell whilst the adjacent cell is short of people. Thus again the practicality of the situation prevails and people are moved from one cell to another as the situation demands. Over the past six months at Lewmar, it has been noticed that this practice has become less prevalent, mainly because the output is rising and each cell is fully loaded, thus each cell seldom has spare labour. Thus more and more people are finding that they tend to remain in one cell. Some researchers have cast grave doubts on this premise [45]. The experience at Lewmar is that both are right. People are not machines, we all have our own hopes and aspirations, we all have our different preferences, in short we are all individuals. Further more people all have varying intelligence levels coupled with varying ambition. The use of the word 'operator' to describe people who operate machines on the shop floor causes others to begin to think of them as automatons.

In Lewmar this generally has not been the case. The company employs 157 people with 112 working on the shop floor, these people very broadly fall into the following categories:-

a) People who will only work one type of machine.

b) People who prefer to move from one machine to another as well as one cell to another.

c) People who are quite happy if left or moved.

d) People who have to operate one type of machine because of their skills i.e. setter-operators on manual capstan lathes.

Within these four categories there are those who change according to their moods. It has been the experience at Lewmar that G.T. as practiced by Lewmar can cater for all these groups at one and the same time. Even in conditions of high work load on all cells, movement between cells for those who want it can be accomplished due to sickness and holidays etc. Again, owing to the relatively small numbers involved, the individual cell leaders and the shop foreman have soon learnt the natural leaning of each person and try to exploit this to the common advantage of both the company and the person.

Most companies have an existing hierarchical structure on the shop floor before embarking on G.T., the one at Lewmar is shown in figure 42. This type of structure is typical of most companies using a functional layout. When changing to G.T. the ideal layout would be one of individual cell leaders reporting to the shop foreman, this either entails dismissing some staff such as chargehands or downgrading them to cell leaders. At Lewmar the chargehand is a working person who has control over a large part of the shop so to make him a cell leader would diminish his responsibilities, thus when changing to G.T., there will always be the difficult problem of how to allocate shop-floor staff. The system now in use at Lewmar works satisfactorily but has occurred partly through design and partly through natural evolution.

The foreman retained his former position of being in charge of the running of each cell in matters such as work flow and labour movement within the cell. This leaves the chargehand with little to do - in theory. It took eight months to get all eight cells established and in that time a number of new, complex machine tools were delivered. The chargehand becam a kind of super-setter as well as a people organiser with the following functions:-

a) Get each new cell functioning properly.
b) Concentrate on the setting problems of the new machines.
c) Assist the foreman in re-training setters and setter-operators to become cell leaders.
d) Oversee the functions of cells G.T.1, 2 and 3.
e) To act as an extra setter and fill in where needed.
f) To assist the foreman and act as his deputy.
g) To assist cell leaders.

These functions have worked so well that it is doubtful whether G.T. could have been introduced and run as smoothly without the chargehand. This kind of person has proved invaluable providing as he does some slack in the system to be ready to act in any area at any time. This sort of dilemma faces many companies after changing to G.T., the ideal solutions detailed above are not always practical so other solutions such as the Lewmar one have to be evolved. Figure 43 shows the new shop floor structure at Lewmar after G.T. has been running for two years.

The one area which has not produced outstanding results at Lewmar was the appointment of cell leaders. The decision to appoint setters as cell leaders was basically correct. They were all retrained in setting all the machines in their particular cell, given new terms of reference and sent on their way. They were given little or no training and guidance in management and their memories were not refreshed on the function and aims of G.T. This has resulted in some cells not functioning as well as they might have done - especially the non-flow line cells which mainly due to the greater variety of components and back tracking are more difficult to control. The most obvious effect being an increase in work in progress and lack of throughput caused by each operator processing each batch on a particular machine before moving on to another machine where he re-processes the whole batch. This is instead of the usual G.T. practice of doing about half an hour's work on each machine and moving to and fro throughout the shift which gives a lower work-in-progress and ensures that components start to emerge from the cell at quite an early stage in the proceedings. In these areas more guidance must be given beforehand as to how these cells should operate to give their best. Subsequent to the commencement of operations each cell leader, the foreman, the production controller, the factory superintendant and the person in charge of the G.T. project should have a counselling session to examine the faults of their particular cell and try to correct them. This has not been done at Lewmar and shows up in the reduced performance of some cells. On the same theme retraining in the principles of G.T. must be continued for the benefit of new employees.

5.7 Tooling

In the functional layout, tooling for a particular component has to be made specifically for that component, and must be able to suit which ever machine on which that component may be machined.

It has become accepted that with the G.T. system the advantage can be taken if the family grouping of components to reduce setting time by improving tooling. Burbidge [10] re-classifies setting time reduction methods with three types:

a) Tooling family method.

b) Quick tool change method.

c) Co-ordinate setting method.

In general a) and b) are the most common either used separately or together, c) is more unusual but would often be found in conjunction with a) and b) in numerically controlled machines.

Although the advantages of such tooling changes which G.T. can bestow were clearly appreciated at Lewmar before the implementation of G.T., there was so much planning and change associated with the implementation that there was just not enough time to consider the detail benefits of tooling changes. Having established the cells there is now more time to reflect on the tooling within cells and how best it could be improved to take advantage of the cell situation. The introduction of new components resulting from new products has been the biggest spur to the re-examination of tooling. Progressively as these components have been tooled up for manufacture new tools of type a) have been designed such that after the main body of the tool is left bolted to the machine with just the top plates and spacers being changed to suit each component.

It has been found that the G.T. system provides a much more favourable climate in which the methods engineer can work. He can afford to design more costly and more accurate tools knowing that each tool will serve a greater number of components. Also each tool can be tailored to suit the exact requirements of the machine on which it will operate. This has taken place slowly over the two years since the introduction of G.T. This process has enabled better tools to be made which last longer, produce repeatedly more accurate components and are more robust.

Many companies when setting up G.T. cells give each cell its own little tooling bay where its tools (jigs, fixtures etc.) are stored. This was contemplated at Lewmar but discussed early on due to the lack of space on the shop floor and the fear that this would remove and control that might otherwise exist on tooling. Lewmar has retained the separate Tool Store attached to the Tool Room with its own store keeper. The store keeper keeps a check on consumable items such as drills and cutters, he returns blunt ones to the Tool Room for re-sharpening and re-orders new ones when necessary. Jigs which are not left permanently on machines are returned to the Tool Stores when not in use, this avoids loss and damage. The cell leader is responsible for each jig when it is booked out of the store and it is his responsibility to inform the store keeper of any faults so that it can be returned to the Tool Room for rectification. The operation of this type of system at Lewmar is helped consderably by the small size of the shop floor at Lewmar.

There are no set rules regarding the storing of tools in a G.T. system. In some companies the best solution is the indivdual cell store, in others it is the central store, others may even prefer a combination of both. Each company when introducing G.T. must examine each solution and draw their own conclusions regarding their own situation and requirements.

5.8 Conclusions

The applications of resources to G.T. at Lewmar has shown that in all areas there is always some deviation from the purely theoretical ideals of G.T. These deviations can have a major effect upon the way G.T. operates in a company, particularly in a small company such as Lewmar where they have increased the flexibility of the system and in some cases allowed cells to operate more efficiently than they would have done. These deviations have in no way affected the gains attributable to a G.T. system. In most areas the allocation of these resources has recognised the problems as they really exist rather than how they ought to exist in theory thus it has attempted to solve real problems with real solutions.

6. PRODUCTION CONTROL METHODS

6.1 Introduction

Production Control is that part of the business which plans, directs and controls the material supply and processing activities. Professor Burbidge [10] has identified these main levels at which this is performed.

(a) Programming - plans production output of finished products.

(b) Ordering - plans material input from suppliers and output of parts from processing departments.

(c) Dispatching - plans material output from machines necessary to complete order by due date.

The main input of information at the Programming stage is the sales forecast showing the number of products which may be sold in a given period. Ofter several such forecasts are produced by the Marketing staff such as five yearly, yearly and monthly, the accuracy increasing with the decreasing duration of the forecast.

At the ordering stage most companies either adopt a 'Flow Control' or a 'Stock Control' system. With the flow control system the time between the issue of orders is fixed but the order quantities are varied to regulate material flow. With the stock control system the time between issue of orders is varied, but the order quantities are fixed, again to regulate material flow. Each system has its own ordering cycle (i.e. the time between orders) and a system can be either single or multi-cycle. A single cycle system is one in which all components are ordered to the same cycle, whereas in a multi-cycle system each component is ordered to a different cycle. There is a further time relationship between cycles for different parts which Burbidge calls the Ordering Phase. With single phase system all items we ordered in the same series of order days for completion by a related series of due dates, whereas with a multi-phase system the order dates and due dates are different for each component. Flow control systems are usually single cycle and single phase, Stock control systems are usually multi-cycle and multi-phase.

Dispatching is concerned with the work to be done in each processing shop, it is the job of planning the sequence in which the operations are performed at each machine.

6.2 Stock Control and E.B.Q.

Many batch production industries throughout the world use the stock control system of ordering which as defined above, has fixed order quantities. These fixed quantities are usually calculated by Economical Batch Quantity (E.B.Q.) formulae. The stock control system has however been shown to have several disadvantages, namely:-

(a) Successful operation means high stock investment.

(b) Losses caused by material obsolence.

(c) Generation of fluctuating stock levels.

(d) Generation of unbalanced and unpredictable variations in load on the factory.

(e) Savings attainable by group processing are impossible to achieve.

These disadvantages are perpetrated by the widespread use of E.B.Q. formulae to govern the batch size of each component. A typical E.B.Q. formula is Camp's formula:-

$$E = \sqrt{\frac{2.B.F.}{C.A.}}$$

Where:-

E = Economic Batch Quantity

B = Set-up cost per batch - £

F = Number of components required per year

C = Unit Cost - £

A = Interest and storage charge - % i.e. total annual cost of storage expressed as a percentage of average value of stocks held.

Eilon [4] has suggested that most E.B.Q. models can be reduced to the following equation:-

$$Y = C + \frac{S}{Q} + K.Q.$$

Where:-

Y = Total cost per unit

Q = Batch size

c = Cost per unit not affected by batch size

s = Cost of placing on order

K = Carrying cost per unit including factors such as interest charges and holding charges in store.

Generally it becomes very difficult to closely define each constituent part of the equation; for example, in trying to fix a value for interest on storage charges a rate for borrowing money has to be fixed. Initially this would appear to be governed by the base lending rate but recently this has been changing weekly. Then the rate of interest paid on loans varies according to the amount borrowed, it becomes hard to fix a standard for this as the conditions are constantly changing. Secondly, which of the many batch quantities should be considered:-

(a) Order quantity - shown on shop order

(b) Run Quantity

(c) Set-up quantity - with tooling families this can be greater than the run quantity.

(d) Transfer quantity - quantity transported in each container between works stations.

Also for a given product each component has its own E.B.Q. which if adhered to causes high, unbalanced stocks. Further, each component has a different E.B.Q. for each machine it visits, thus either batches are split to accomodate this or the E.B.Q. calculation is only valid for one machine. It is interesting to note that the E.B.Q. is not in mass production.

The stock control system imposes a rigid discipline governed by E.B.Q.'s plus minimum and maximum storage levels. Invariably on the shop floor the batch sizes being produced and their frequency of production bear little relationship to the demands of the sales staff. This type of system is wholly incompatable with G.T. as it does not allow for similar families to be processed in sequence and it naturally tends to cause widley fluctuating throughput times.

6.3 Period Batch Control

Period Batch Control is a term used by Burbidge to describe the flow control system of the single-cycle, single phase type. In his book on the introduction of G.T. Burbidge [10] devotes chapter 5 completely to the theory and workings of Period Batch Control; a brief resume of the main points follows.

The basic steps taken in Period Batch Control are shown in figure 44. The year is divided into equal cycles and a short-term sales forecast is produced for each cycle. From this a short-term production programme is developed for the same cycle. This production programme is then 'exploded' to find the quantities of components and hence the quantities of raw materials required to build this production programme. The shorter the cycle, the shorter will be the time ahead for which the sales department must forecast future sales. Short cycles therefore produce more accurate forecasts, more frequent occasions for the correction of past errors and a system which can easily follow market trends whilst still maintaining a minimum stock level. However, cycle duration is limited by the following factors:-

(a) It must be possible to assemble in the cycle time the sales requirement for a cycle.

(b) It must be possible to make in a cycle what has to be assembled in a cycle.

(c) It cannot be less than the throughput times for any component.

(d) It must not increase the proportion of selling time so that capacity is reduced below the level required to meet demand.

One of the greatest advantages of this system is that products and their components are manufactured when they are required and in the quantity required, this is not possible with the stock control system. In every factory the cheapest way to store material is in its raw state such as castings or bar, the most expensive way is as finished goods not despatched. Between these two extremes lie the other stages such as half completed work in progress and completed finished components awaiting assembly. Period Batch Control ensures that material remains at these interim stages only as long as it takes to be processed. Used in conjunction with G.T. it ensures that once it has been decided to produce components and thus products from the raw material, they should spend as short a time as possible within the factory. Only when the customer has received the products can he be asked to pay; in the meantime from receipt of order to delivery the cost of material and processing etc. has to be funded by the company.

Period Batch Control applied to a G.T. system helps ensure that the full benefits of G.T. will be realised. These benefits are particularly important to Lewmar Marine and surely to any other company which wishes to operate in an efficient manner and keep its customers happy. Over the years both before and after G.T. Lewmar's production control systems have come closer to Burbidge's theory of Period Batch Control but most importantly they have been derived only from knowledge within the company. Thus if one company can evolve a system of production control which helps the company to operate very efficiently and to keep its customers happily supplied, a system which agrees with the theories of a noted Professor and with a system which is used extensively in Mass Production industries then it is time that stock control systems are rejected. They do not, in the long term, help the company to become efficient, they certainly do not ensure that the customer receives his goods when requested. They eventually become a means in themselves, the whole company becomes a slave to a system desperately trying to produce each component in its most economical batch size which can have little regard to the needs of the customer. It is surely the function of all companies to market and manufacture products, the systems to do that are the means to that end.

7. PRODUCTION CONTROL AT LEWMAR MARINE

7.1 Methods before Group Technology

Before the introduction of G.T. to Lewmar Marine the production control system was an amalgam of flow control and stock control and had the following theoretical sequence which is also shown diagramatically in figure 45.

1. Sales issue an annual forecast for products which is broken down into monthly quantities.
2. Each month inventory control raise assembly production orders in advance of requirements, based on the above forecast.
3. This assembly order is "exploded" and the stock position of piece parts examined.
4. If there are insufficient piece parts then Piece Part Production Orders are raised to make them.
5. When the material is received the Piece Part Production Order is sent down to the shop floor to be activated.
6. Upon completion the piece parts are put in stores and inventory control is advised daily of such receipts.
7. Stores pre-select assemblies and when all the items are complete the assembly shop requests an Assembly Production Order from inventory control. This order may have to be split into more than one batch due to shortages of piece parts and changing demands etc.
8. Upon completion the assemblies are passed into stores who advise inventory control and sales daily.

In theory this system appears to be similar to the Period Batch Control systems outlined in Chapter 6. but it has a number of subtle differences and flaws which are itemised below:-

(a) Although the cycle was fixed at one calender month, the product quantities for that month were solely obtained from the yearly forecast.

(b) The proceedure for raising assembly orders had to be done at least 3 months in advance to allow sufficient lead time for material purchase and to cover piece part manufacturing time usually between 6 and 13 weeks. The lead time of 3 months could only be reduced by increasing stocks of raw materials and piece parts.

(c) The stock position, to be accurate, should take into account the work-in-progress completion dates which were indeterminate. Thus resulting in an inaccurate picture of the piece part stock position.

(d) Owing to the functional layout system inventory control could not predict completion dates for piece parts, so advice of receipt from stores was the only indication of completion.

(e) The time interval from raising the Assembly order to its issue to the shop floor could be 2 to 3 months and in that time the actual sales demand could have changed markedly causing batches to be split. The other reason for split batches was the non-availability of piece parts due to indeterminate throughput times.

(f) In an attempt to cushion the assembly of products from the manufacture of piece parts, material and components were provisioned on a stock basis, i.e. batches of parts were made in advance, the quantities being calculated from past demand and future possible requirements. When the stocks of a piece part became low another batch was loaded into the system, the quantity being an arbitrary figure which was deemed sufficient. As well as increasing piece part stocks this also increased raw material stocks which had to be ordered further and further ahead to keep up.

The lack of liaison between sales and inventory control resulted in many cases of the factory producing products that were not required and not producing products that were required. This situation was further aggravated by the long and variable throughput times which meant that once the system had been put in motion it was difficult to stop. The net result was that priorities were established on certain batches of components and the chasing of these through the shops resulted in the extension of the throughput times of other components. Also these priorities had a habit of changing daily which produced a lack of continuity of production with jobs being broken down and new ones set-up.

The use of the yearly sales forecast as the guiding light encouraged purchasing to place long-term contracts for the supply of raw material. Also as in this situation supply could not keep pace with demand, the trend for production quantities seemed to be ever increasing which again encouraged the placing of these long-term contracts. It should be noted however, that these long-term contracts were obtained at considerably favourable prices.

The net result of this system was as follows:-

(a) High stocks of unbalanced piece parts.

(b) High stocks of raw materials, built up in an effort to cut the lead time of 3 months.

(c) High stocks of finished products as the company at times could not make what it wanted when it wanted.

(d) A small army of progress chasers were required to pursue the priority items through the shop.

(e) A large number of clerical staff to administer the system.

This situation was typical of many other batch production companies as Ranson [4] has shown at Serk-Audo and Bryan at Thomas Mercer [27]. Both these two companies and others [32, 33, 31], have chosen to adopt the G.T. approach in an attempt to overcome part, if not all of these problems. Hence it is not surprising that Lewmar Marine should also closely consider and later adopt G.T. for the same reasons.

7.2 Method after Group Technology

Having examined G.T. it became obvious that changes to the existing production control system were required to realise the full potential of G.T. However, whilst this was under consideration, after the introduction of the first cells in late 1974, other events transpired which put a new urgency into the deliberations.

By December 1974 the combined effects of cells 1 and 3 and the arrival of extra machines had increased the output of the smaller winches. This coupled with a slight downturn in the market caused some distributers to cut back on orders. It is now believed that these distributers had over ordered in the hope of obtaining what they required. This created false demand, overloading the factory, when the demand was met in full, orders were reduced to the natural level. This situation does not appear to be unique to Lewmar, it also occurred at Ferodo soon after the introduction of G.T.[58]. Also at this time the whole of the Western World went into a depression (from which it is still recovering) which resulted in distributers cancelling orders and in some cases returning unsold stocks to the factory. This resulted in a big increase in stock holdings which was further being increased by the production of yet more unwanted products. This was caused by the old production system which was difficult to halt once in motion and the lack of liaison between sales and inventory control. Further it was found extremely difficult to terminate some of the long term raw material contracts at short notice with the result that delivery of raw materials had to be accepted (and paid for) when they were not required.

The above situation produced increasingly higher inventory costs with falling sales and receipts leading to cash flow problems. These problems were reduced in a number of ways but in part by improving the production control system. The improved production control system that has evolved since January 1975 is basically Period Batch Control as proposed by Burbidge. Nothing was known of the work of Burbidge in this field at the time this system was conceived, it just seemed the most obvious and logical way to control a G.T. system. It operates as follows and as in figure 47.

7.2.1 <u>Production Cycle</u>

The production cycle or period at Lewmar is fixed at one calender month. This means that the cycle is either 4 or 5 weeks long depending on the month. This system does cause a few problems when two weeks in a month are lost due to annual holidays but it has been in use now for a number of years and has worked quite satisfactorily.

At some future stage it would be beneficial to change to 12 cycles per year each of four weeks, this would overcome the holiday periods as well as providing constant cycle times rather than the variable ones at present. It is considered that if this were introduced now in addition to G.T., a new computer system and new products, the result would be instant chaos, because the monthly cycle is so familiar, and is used and recognised by every department.

7.2.2 Forecasts

At the beginning of each production year the Sales Department produce a product forecast for the year broken down into monthly requirements. This data is only advisory as the situation could change as the year progresses but it does provide the necessary data for long term planning. It is now considered that the yachting market is too variable to try and forecast demands with any certainty for more than a year ahead. Also the product range is always changing to accomodate new trends, this again would make nonsense of forecasts for more than a year ahead. Infact because of these factors the yearly forecast is updated every quarter.

7.2.3 Monthly Revue

Every month production control and sales together revue the following:-

(a) Stock of products worldwide.

(b) Forecasts of sales for next 4 months, including firm orders.

(c) Inventory Policies, both at home and abroad.

(d) Product stocks both at the factory and distributors.

From this is derived, every month, a despatch plan (or assembly programme) for the next four months, the first two months are considered firm, the next two provisional. Thus as the year advances the provisional months move up the order to become firm as figure 46 shows. This plan is fed into a computer programme which makes access to its own files of:-

(a) Piece-part stocks

(b) Raw material stocks

(c) W.I.P. - piece part stocks

(d) W.I.P. - assemblies

(e) Material on order from supplier.

From all this information the Computer produces three main reports,

(a) Sub-assembly demand for four months.

(b) Piece Part demand for four months.

(c) Raw material demand for four months.

This computer has been available to Lewmar since late 1974 and so this improved system has always operated with some degree of computer control. The role of the computer is covered more comprehensively in section 7.4.

7.2.4 Raw Material

There are three main forms of raw material at Lewmar, castings, bright bar and sheet. Most of the casting suppliers are governed by a 3 month schedule which is firm although they are also given a non-binding indication of demand for the next six months. This 3 month schedule is advanced by one month every month as shown in figure 48. Castings are scheduled to be delivered in the month prior to their being machined. The three month schedule is drawn up from the computer raw material report and the six month indication is based on the yearly sales forecast.

Bright bar and sheet in stainless steel and aluminium alloy are usually purchased from a number of local stockholders whom it is known usually carry this material in stock, thus it is ordered monthly from the stockholder offering the best price and delivery, the quality being known from past experience. Other materials are more difficult to purchase from stockholders and are purchased from the rolling mill. To start with the mill in question for one particular material, quoted extended delivery times, this was found to be caused by production of the material to the required specification. This was overcome by giving a non-binding intention of purchasing say 40,000 kilos of bar in the next year but not specifying sizes. Immediately an order was give for say 10,000 kilos of bar with the proviso that it was to be supplied over a three month period according to a schedule which would quote sizes. Now if this order were to be given in January, the sizes for April, May and June delivery would have to be defined by the end of February - this is shown in figure 49.

With all these forms of raw material supply the company rarely has a firm commitment in excess of three months, under the old system the firm commitment was often twelve months. As the raw material stock position is evaluated every month, by computer, it is an easy task to amend forward predictions to take account of low or high stocks when changing to firm delivery schedules. All these methods ensure that long lead times for material supply are overcome without the penalty of excessive stock.

7.2.5 Shop Loading

As yet this exercise is not performed by a computer programme although it is planned to do so in the near future. The Production Controller uses as his base document the piece part kit marshalling report produced by computer - figure 56. A list is made for each cell of all the components which are produced in that cell, the quantities required in the period in question are calculated from the kit marshalling report and entered on the lost. Also on the list are the production rates for each component, from this capacity is calculated and a check made against the standard total capacity available for that cell.

Insufficient capacity is overcome in three ways:-

(a) Work overtime

(b) Work a night shift on that particular cell.

(c) Sub-contract some of the work.

As the kit marshalling report gives the likely demand for these components for the next 4 months it is relatively easy to examine the possibility of off loading overcapacity into the subsequent months. If this can be done the Sales Department would be consulted regarding the effect on the delivery schedule.

At Lewmar a very tight time scale for production is obeyed, as a general rule piece parts are machined in the same month that they are assembled. This has only been made possible by the introduction of G.T. This system has now been in operation for over a year and has proved very suitable for the high volume, high cost piece parts. Most high volume low cost piece parts such as gears, main spindles and small turned items could not be satisfactorily produced in a month. It was consistently found with these piece parts that there was insufficient capacity within the cells each month. Further investigation showed this to be caused by too high a ratio of setting to production time, even with G.T. and tooling families. In other words in trying to produce a month's supply of these components each month the setting time had increased to a point where capacity was reduced below the level required to meet demand.

Simple calculations were made, on the lines of E.B.Q. to take into account the setting time, unit time, monthly requirements, stock costing and raw material purchasing policy (usually never to order more than 3 months in advance). These calculations all averaged out to show that the components could, with advantage, be run in three monthly batches. This was tried out and it was found that the time interval of 3 months does not cause excessive stock levels and it has not caused any delays in assembly through lack of parts, further the capacity problem has disappeared. Experience of operation bears out the theoretical calculations, namely, that if the period was extended beyond 3 months, then stocks both of raw material and piece parts built up which incurred risks of obsolescent stock due to changing sales demands and design modification.

Conversly a reduction to a 2 month cycle increased the setting to production time ratio to beyond the acceptable level, thus the 3 month cycle for gears, main spindles and small turned parts has been found to be the optimum solution. Since introducing this policy there have been occasions when it has not been strictly obeyed mainly due to sudden changes in customer requirements causing a heavier than forecast demand on certain piece parts. This only happens on occasions but the penalties of lower overall production quickly assert themselves, demanding a rapid return to the three month cycle.

The shop floor are advised of the components required each month in two ways. At the beginning of each month the Production Controller and the Shop Floor Manager agree the loading and sequence for each cell (see section 7.3). A few days before a component is due to be set up in the cell, the cell leader, through the foreman, request the paperwork for the next component, this paperwork is produced by the computer on demand.

In addition, every Monday a production meeting is held attended by the following people:-

(a) Production Controller

(b) Buyer

(c) Shop Floor Manager

(d) Quality Manager

(e) Machine Shop Foreman

(f) Assembly Shop Foreman

(g) Progress Chaser.

The status of each component required for assemblies in the coming week is reviewed and action taken if required. Thus the whole system is under constant surveillance which means that the 10% of problems can be seen and action taken to speed their progress, or if that is impossible, to advise the Sales Department of a revised delivery date for the effected assembly.

It has been found that if all the products required in a particular month are not assembled, due say to late supply of components, they are usually assembled within the first few days of the next month. At all times it has been found that G.T. ensures that the majority of components and assemblies are produced when required so that management effort only has to concentrate on the odd 10% of components and assemblies which do not arrive when required. The purpose of the weekly production meeting is to sort out what is on time from that which is likely to be late. Once it has been established that components are running to programme it is assumed that they will arrive in the assembly shop when required.

7.3 Cell Scheduling

It has previously been explained that there are three different types of G.T. cell at Lewmar, G.T. Flowline, G.T. cell and Single

Machine. The scheduling of work to and within cells has to be done slightly differently with each type to suit their different characteristics.

7.3.1 G.T. Flowline

These types are th simplest of the three to schedule. As each component visits each machine in turn and there is no back tracking, it has been possible to produce a cell time for each component. This time is the hourly rate for the key machine, for by definition, the key machine is the slowest machine and sets the rate for the whole cell. This cell time is used to calculate the capacity required per month to produce the required components. In addition to this must be added the setting time for each component. The sequence of components in each cell varies from month to month and is decided by the following factors.

(a) Sales requirements - is the product required at the beginning or end of the month.

(b) Availability of material.

(c) Availability of components to make complete assemblies.

(d) Optimum tooling arrangements to give the minimum amount of re-setting.

(e) Material type - swarf is separated into stainless steel, bronze or aluminium alloy - thus components must be sequenced to keep machine cleaning to a minimum.

The sequence is determined from the above factors by the Production Controller in consultation with the Shop Floor and Sales Managers. Once written on the monthly cell schedule it can only be altered by the Production Controller usually after consulting the other two managers.

7.3.2 G.T. Cells

These types of cells have a greater variety of components than the Flowline and also some back tracking is allowed. This complicates the scheduling somewhat, especially as it is often possible to process more than one component at a time. Before the sub-divisions of cells, G.T.4 and G.T.6., it was difficult to calculate accurate capacity figures from month to month as it was not possible to find a common key machine for all components. After the sub-division, see figure 35, each sub-division has been treated separately for capacity calculations as it is now possible to identify a common key machine in each cell sub-division which has in turn made it possible to calculate the load in each sub-division. The sub-divisions are not considered when it comes to sequencing, the cells then revert to just G.T.4 or G.T.6. Each of these cells processes more than one component at a time (parallel working) and so the sequence of components issued from the first machine is of vital importance, this can best be explained by taking cell G.T.4 as an example.

Figure 50 shows diagrmatically the relationship between cells 4A, 4B and 4C. Basically cell G.T.4A is a turning facility which feeds cells G.T.4B and 4C. G.T.4B processes the ring type gear blanks (e.g. ratcher gears) and G.T.4C processes the drilled gear blanks (E.G. pawl gears). These two types of gears do form two distinct family groups. Now if G.T.4A produces all the month's requirements of ratchet gear blanks first then G.T.4C will remain idle for part of the month. More importantly, the labour is shared between G.T.4B and 4C with one man operating same machine in each sub-division, labour distribution takes no account of cell sub-divisions. Thus if either 4B or 4C are idle the labour is under utilised. The sequence on G.T.4A is therefore important to keep an even balance of work on G.T.4B and 4C. The sequence on 4A has been worked out as follows:

1. Pawl Gear
2. Ratchet gear
3. Ratchet gear
4. Pawl gear
5. Pawl gear
6. Ratchet gear

etc.

This sequence can be made up of any pawl gear or any ratchet gear, they are sequenced in this "back to back" manner because each gear type (pawl or ratchet) is a separate family. Thus similar families of gears have been grouped together whilst still continuing to keep an even work load on the subsequent parts of the cell.

It was stated in the previous section that most gears and spindles are made in three monthly batches, these types of components are produced in cells G.T.4 and G.T.6 so the majority of components produced in the G.T. cells at Lewmar are produced in 3 monthly cycles rather than the components on the G.T. Flowline which are produced in monthly cycles. The sequence of components in these cells is still a compromise between the five factors listed in section 7.3.1. but with the addition of one other. In figure 57 showing the Piece Part Kit Marshalling report, Demand is the current month in question, Demands 2, 3 and 4 are the subsequent months. Components coming at the top of the sequence list are those that are required in Demand 1, the next group on the list are those in Demand 2 and so on. Within each group the five factors are applied to decide the final sequence.

In practice it has not been found that all the components are required in Demand 1, there is usually an even balance of work which avoids this and of course the system is self generating once it has been started.

From figure 36 it can be seen that the largest percentage of foreign work is found in the G.T. cells (G.T.4, 5 and 6). This happens because the G.T. Cells have to cope with a greater variety of components than the Flowlines and thus are necessarily made up of a greater variety of machines. Hence the specialist machines required by foreign components are more likely to be found in the G.T. Cells than the G.T. Flowlines. As well as foreign components comprising a small percentage of the components in a cell, they also comprise a small percentage of the volume of components processed by a cell. As these foreign components have to move from one cell to another it has been found that they have to be treated as if a functional layout was still in use i.e. they have to be progressed within the cell. As these components are only a small percentage of the total number of components then again it is management of the exception rather than the whole.

The status of the foreign components is considered at each weekly production meeting along with the other components and from this the Shop Floor Foreman and the Progress Chaser decides the sequence in which they should be put in a particular cell.

To summarise, in the G.T. Cells there are added complications over the G.T. Flowline:-

(a) Components processed in 3 monthly cycles rather than monthly cycles.

(b) Cells, by definition, have parallel working which demands an even output from the first machine to avoid poor labour utilisation.

(c) There is usually an element of foreign work which can only be controlled on an "ad hoc" basis.

7.3.3 Single Machine Cells.

At Lewmar Marine this type of cell is treated in a manner very similar to the G.T. Cell (section 7.3.2). The sequencing is decided in the same manner from the same factors, also components in this cell (G.T.7) are producing in 3 monthly cycles in the same way and for the same reasons as those components in G.T.4 and 6. As this type of cell only involves one machine type, the sequence does not have to maintain an even balance in the subsequent machines. Thus the sequence is used solely to meet the compromise of the five factors in section 7.3.1 and the extra priority factor covered in section 7.3.2. As with all other cells the capacity available is considered before all the other factors governing the sequence.

7.4 Computerisation

Like many other companies, Lewmar Marine has been using computers to calculate the payroll and produce the pay slips for about 4 years. The computer in question has been one operated by a local computer bureau. In the latter part of 1974 the use of this computer was extended to cover some of the aspects of production control. The use of this extra facility happened to coincide with the introduction of G.T. and the new improved methods of production control, thus with this new system there has always been a measure of computer control. This computer was not "on-line" and its records as far as the production control was concerned was the "Kit Marshalling Report" which had these facets:-

(a) System Report

(b) System Files

(c) Manual Input

The elements of each of these facets are listed in more detail in figure 51. The main problem with this system was that the Input was performed at the beginning of each month and the 3-4 days that this took could render the reports slightly outdated when they were produced. However, it was extremely useful in providing the necessary data to give not only the overall picture of how the system was functioning but an in depth study as well. For the first time in Lewmar's history there was a means of quickly highlighting stock shortages and surplusses at all levels as well as reporting on the piece part usage.

During 1975 it became clear that Lewmar could gain far more from computerisation if it were 'on-line' (i.e. accessible at all times), if this was so, then information such as stock holding could be put on file and this used to give indications of stock surplus or shortage on the Kit marshalling reports.

In their paper, Koenigsberger, Caudwell, Haworth and Levy [57] considered both the tailor-made system and the proprietory system of computerised production control programmes. They draw the conclusion that the tailor-made software can be designed for a G.T. system whereas the proprietory system was designed for the more conventional functional layout system. The proprietory software schedules work on an operation by operation basis which from a G.T. point of view creates both a detailed statement of work and demands a large number of inputs. At Lewmar a priprietory software package had the advantage over tailor-made software in that it would enable the computer to become operational in as short a time as possible. The most suitable package selected could be suitably modified to cope with a G.T. system, but the main part which affects G.T., the kit marshalling reports, were not included in any of the packages offered in a desirable form. The company who prepared the proprietory package also produced a tailor made kit marshalling package added on to the end of their own proprietory package. From the production control point of view there are four main areas in which the computer operates:-

(a) Inventory Control

(b) Requirements, planning and stock recording.

(c) Factory documentation and shop loading.

(d) Kit marshalling.

The functions performed within each of these areas are listed in figures 52, 53, 54 and 55. The three reports of the Kit marshalling section for raw material, piece-parts and sub-assemblies are shown in figures 56, 57 and 58.

The stock record files are up-dated at the beginning of each day in accordance with the following sequence:-

(a) Purchase order in (Raw material, bought out parts).

(b) Raw materials received into stores.

(c) Kit issues to machine shop.

(d) Piece-parts received into stores

(e) Kit issues to assembly shop.

(f) Piece parts - out

(g) Raw materials out.

(h) Assemblies in - Finished goods.

(j) Assemblies out - Finished goods.

This sequence has to be strictly obeyed otherwise the computer would be trying to issue material that has not been received. The data from stores is received daily on record sheets; in time it is hoped that the stores will have their own input terminal which will further improve the accuracy of the system.

Piece-parts are considered to be work-in-progress once the computer is advised that the raw material has been issued. They cease to be work-in-progress when stores advise the receipt of piece parts. The same applies to the assembly work-in-progress upon the issue of kits to the assembly shop. Although the computer files record the G.T. cell in which each component is produced, this information has been sadly omitted from the Kit marshalling reports, they are arranged purely in numerical component order. This situation arose due to some misunderstandings but hopefully it will be remedied in the near future when the kit marshalling reports will be arranged in cell order. Together with this, there will be a cross reference listing in component order so that it will be possible to find out in which cell a particular component is made. Work is already in hand on both these modifications. At present the production controller works from a manually prepared list showing which components are in what cells and in conjunction with the kit marshalling reports produces the schedules for each cell for each cycle. Having the kit marshalling reports arranged in cells will reduce considerably the effort at present involved.

At present all the capacity checking is performed manually but it is envisaged that in the near future the data used in component costing (see Chapter 8) will be linked with the information on shortages from the kit marshalling reports to give an immediate indication as to the capacity required for each cell. The information for this is on file, but extra programmes will have to be written to do this.

The computer also produces the necessary paperwork required by each job in the factory, for the manufacture of piece parts, these are:-

(a) Route Card

(b) Job Card

(c) Raw Material Requisition

(d) Inspection Card.

For the assembly of products these documents are:-

(a) Job Card.

(b) Piece-part Requisition

(c) Inspection Card.

The purpose of the Route Card is to briefly state the route the component should follow e.g. Cell G.T.9A, Cell G.T.9B, subcontract polishing and subcontract anodising. It also shows the time allowed in each cell for each component and the total time for the batch. The main purpose of the job card is to record the quantities scrapped or rejected at each cell, this information being fed back to the computer for its analysis of scrap rates. The Inspection Card simply, records the quantity passed, but it is split into 8 perforated continual sections which enables a batch to be split if necessary. It is this document which advises the stores and hence the computer of the quantities finally alowed after all operations have been complete. The Raw Material Requisition records the material required for the batch and advises the stores of this, the top copy is returned to production control to advise them that material has been issued. The Piece-Part Requisition acts in a similar manner for assemblies by listing all the piece-parts required.

These documents are initiated by the monthly schedule for each cell and the demands from each cell leader for the documents for his next job. It has been found that if all these documents are run off at the beginning of the cycle then there is not enough flexibility to change quantities etc. at the last minute in response to modified requests from sales. Thus these documents are produced usually the day before they are required. This also reduces peak loads on computer time.

Because of the G.T. system it has not been found necessary to introduce further computer control to the shop floor than already exists. At present both the monthly cell etc., schedules and the documentation state the total time for the batch thus it is known when the job will start and when it will finish. The G.T. system has proved that these times can be reliably met so that instead of being hopefully optimistic they are now reasonably accurate. The weekly production meetings soon show up any components going astray. This means that because the components are fully machined in one or two cells there is little progressing of them through the shops; with consequently no information feed back by the computer.

7.5 Conclusions

The new system of production control has overcome the problems that were present with the old system by the introduction of the following proceedures:-

(a) Monthly meetings (more frequent if necessary) between Sales and Production.

(b) Never having a firm programme for more than 2 months in advance.

(c) Monthly revue of stocks of raw materials, piece parts and finished goods, enabling the company to keep stocks to a minimum.

(d) Never to be committed for raw material more than 3 months in advance.

(e) Monthly revue of stocks of products around the World enabling adherance to stock policies.

These five functions are adhered to and have enabled the new system to function properly in keeping inventory costs low and in ensuring that the right products are made at the right time. The computer had taken the drudgery out of preparing the information and it has provided even more information than would otherwise have been produceable each month. It has not been without it's problems however, the most troublesome area being the accuracy of input data. This problem has affected nearly every source of input data and caused each department to reappraise all its records and correct them, it was surprising how many errors had crept in through the years. The results of these errors led to:-

(a) Inaccurate capacity calculations.
(b) Issue of wrong material
(c) Short issue of material
(d) Wrong component routing.
(e) Piece part omitted from schedules and consequently not made.

These errors are being put right when discovered and now the computer is beginning to print more reliable information. If there had not been a concentrated effort, however, to do this, confidence in the computer reports would have been undermined to the point where people would have stopped using them.

The new production control system is not a radical innovation, it is really only a modified form of Burbidges theories on Period Bathc Control [10], although it is interesting to note Lewmar only became aware of Burbidge's work after establishing this new system.

The use of the computer again, is not a radical innovation but its application at Lewmar demonstrates that the use of an on-line computer is not restricted to the large public companies. It can make big improvements to the functions of the systems and provide a worthwhile analysis of the information.

The most radical innovation at Lewmar in production control terms was the introduction of G.T. The very fact of setting up cells to produce similar families of components had enabled Lewmar to set up a new system which is simple to understand and simple to administer. In turn the simplicity of the systen has enabled Lewmar to aquire a small computer to administer it, it is probable that had the company still been working on a functional layout system it would have required a larger computer which would not have been viable. In his recent paper Kellock [59] describes the computer based production control to the G.T. system at Thomas Mercer. They have developed a system similar in concept to that at Lewmar and it again appears to be relatively simple. Applying computers to the production control aspect is far simpler in the G.T. system than the functional layout system. Mercers draw the same conclusion as Lewmar that Computer scheduling on a monthly basis would not be practical without the application of G.T. The main difference between the Mercer computer and the Lewmar one is that Mercer use one belonging to Ronson Ltd., and thus it is not 'on line' which the Lewmar one is. Thus the Lewmar system is slightly more flexible and minimises the risk of information on computer file being out of date.

The G.T. system at Lewmar has enabled this new production control system to work with little slack in its system such as components made in the same month in which they are assembled. It has also enabled the inventory to be cut to the minimum necessary.

8. PRODUCT COSTING

8.1 Introduction

Product costs within a company are required for three purposes; profitability comparisons between products, consideration of selling price policy and stock valuation. The purpose of costing the manufacture of components is to build up the overall cost of manufacturing each product. In his book on Cost and Management Accounting, Baggett [60] defines three distinct bases for the determination of product costs; absorbtion cost, standard cost and marginal cost, and describes these different methods. At present Lewmar Marine determines product costs by a combination of absorbtion and standard costs. Basically all product and hence component costs are divided into direct (or prime) costs and indirect costs, - figure 59, each of these categories has its standard costs fixed for pre-determined intervals. Most companies adopting standard costing have usually fixed these intervals at one year but with inflation running at its present level, many companies are now reviewing these standards every six or even three months in an effort to keep the standards up to date. The absorbtion part occurs with some of the indirect costs, such as Technical overheads and administration, where their costs have to be accounted for and are absorbed into the product costs as a way of doing this; there are arguments for and against this in accounting circles but it is the method used at Lewmar Marine at present.

Of the three purposes given above for product costing, the second consideration of selling price policy is the most difficult to apply. Most companies usually start off with the premise that the selling price of its product is the works cost price (or cost of manufacture) plus additional factors such as profit. The economist usually claims that a selling price is determined by an interation of supply and demand. A customer will not pay more for a product than he feels it is worth to him in terms of the satisfaction obtained. The product however, must obtain a price which exceeds the manufacturers costs. At first glance these two approaches appear to be diametrically opposed, this is in fact more illusionary than real. The manufacturer having calculated his manufacturing costs fixes a minimum price for which he is prepared to make and sell that product, the customer is then left to decide whether or not that price is acceptable. This process basically fixes the minimum price of the product, the supply and demand concept can only cause the price to rise from this as supply fails to keep up with demand.

It has been said that the only way of accurately determining the cost of manufacturing a product is to build and equip a factory specifically to make that product, produce the quantity required and then sell off the factory and equipment. The difference would determine the unit cost of each product made. Clearly this is not practical and in any event it only gives a historical cost of production, not the current cost of production. In trying to determine the current cost of production many arbitrary decisions have to be taken regarding the factors affecting product costs.

a) Rate of depreciation.
b) Supervision levels.
c) Material costs
d) Process time.
e) Labour costs.

In order to gain some uniformity in these areas, each company defines its rules upon which these decisions will be taken. The definition of these rules will naturally govern the accuracy of the costingprocedures; well defined, and they will give a reasonably accurate cost of manufacturing a product. Because these arbitary decisions have to be made, whichever costing system is used, it is impossible to obtain the absolute true cost in an ongoing business. So each company by defining these rules tries to come as close as is practical to achieving the impossible without creating a costing system which is virtually impossible to operate. It was with this in mind that Lewmar Marine saw G.T. as a way of improving the product costing without greatly increasing the operating effort.

8.2 Product Costing at Lewmar Marine Before G.T.

It has been shown in Chapter 3 how Lewmar grew quite slowly to its present position, only increasing the growth rate in the last four years. Also during the earlier periods, the types of machines used were all relatively simple, the most complex being the Herbert Senior 5 Capstan Lathes. Thus there was not a wide difference in the values of machines used and their complexity. From this background arose a product costing system in which the whole shop floor was treated as one cost centre thus creating a single hourly rate which covered all the machines embodying all the usual factors built in to the overhead rate - figure 60. This meant whichever machine a component visited, the same hourly rate was applied and as all the machines were manually operated then the labour rate was simply added on to give a total hourly rate which applied to each and every machine in the factory.

This system was very simple to operate and gave reasonably accurate results whilst the machinery remained relatively uncomplicated and inexpensive. With the increase in volume of output resulting in the arrival of more complex and expensive machinery, such as the Canavese Twin Spindle Automatic Lathes, it became obvious that the single hourly overhead rate for all machines was becoming less relevant. The arrival of these more costly machines changed the balance of cost on the shop floor. The hourly overhead rate was adjusted to accomodate the increased value of machinery, but this was re-applied to all machines, thus in part all components had to bear a proportion of the costs of the new automatic machines, even though they never visited them.

It was obvious that the shop floor would have to be divided up into a number of smaller cost centres to try and apportion these costs more fairly, but what form these should take was another matter. The most obvious step would be to make each machine function a cost centre but then this would add to the complexity of the system as each component would then have to visit at lease 3 or 4 cost centres in its travels within the factory. With the introduction of G.T. the answer to this problem appeared simple - make each G.T. cell a cost centre.

8.3 Group Technology Cells as Cost Centres

Each cell can be likened to single, complex machine which produces finished parts from raw material. Thus with G.T. the most obvious cost centre is the cell. Now this realisation was not unique to Lewmar it has been recognised by other writers in the field of G.T. [9, 10, 61] although very few of them appear to have documented their experiences with this system of cost centres. In fact Ranson [9] explains fully why he considers Serk-Audio were correct in not adopting each cell as a cost centre but applying a single overhead rate to the factory. Equally Lewmar considered that they should move away from a single overhead rate towards splitting the factory into a number of cost centres. Each approach was adopted after considerable thought and reasoning. The fact that two companies adopting the G.T. system of manufacture should adopt diametrically oposite methods of product costing only proves that companies operating in different types of markets have different problems which do not always stand up to comparison.

In order to improve the accuracy of product costing at Lewmar it was decided to consider each cell as a cost centre. The same factors as those listed in figure 60 were used to calculate the overhead rate except that everyting was on a cell basis and not on a factory basis. Thus a separate overhead rate was calculated for each cell or cost centre.

8.4 Initial Method with Cells as Cost Centres.

The theory of using G.T. cells as cost centes as outlined above was tried out on cells 1, 2 and 3 to begin with and worked satisfactorily. The cell overhead rates calculated from the factors listed in figure 60, the labour rate being determined by the number of people normally employed in each cell. The overhead rates for all cells are shown in ratio form in figure 61. At the outset it was decided that the system could be kept simple if it used the same time data as the production control system. The time which was used with the overhead and labour rates was the cell time. Now this cell time is the longest cycle time in the cell and occurs on the key machine which is usually the most expensive machine in the cell. The overhead rate is comprised by the addition of all the factors listed in figure 60 thus to add together the process times for each machine used in the cell and then to multiply this total by the cell overhead rate would, in effect, be adding the same figures twice. Whereas using the cell time multiplyed by the overhead rate does not have this effect. This method is considered valid as it treats the cell as one complex machine, secondly the key machine is usually the most expensive machine by a large margin - figure 62.

This system of cost centres was found to work fairly well on cells 1, 2 and 3. Having tested the system on the first three cells it was extended to the other cells. In the remaining cells it was found that once the number of machines used dropped below 60% for any one component then these components attracted an abnormally high overhead cost due to the machine it had to help pay for but had no need to use. Equally with parallel working in cells (G.T.4) each family of components was helping to pay for machines used at the same time by other families of components and visa-versa. Thus each group of machines was accounted for twice incurring cost penalties on the components passing through them, Lastly the foreign components in using only one or two machines in each cell incurred inordinately high overhead costs, far and above that which could be reasonably expected.

Labour costs posed another problem, there are cases where one man operates two machines, one in each cell, this is particularly prevelant with the newer automatic cycle machines. Secondly each family of components in a cell requires a different number of machines and prople, this system could not cope with either. The resort was to take the ideal optimum labour ratio and break any difference as a variance to the cost. Unfortunately the variances became large instead of small, which was not acceptable. The problems created by the change to using cells as cost centres can best be summarised as:-

a) Components using less than 60% of machines in a cell attract a high overhead.
b) Parallel working can attract a high overhead.
c) Labour change cannot always be costed properly.
d) Shared labour cannot be costed adequately.

Clearly in ideal cells this would never happen but, as it has been detailed in Chapter 5, the G.T. system at Lewmar is a practical one not an ideal one and it cannot ignore these problems, it has to come to terms with them. In the non flowline cells the method of using each cell as a cost centre was not as successful as had been hoped yet a return to the old method of one overhead rate for the whole factory would have been less successful. It was then decided to experiment and sub-divide some of the more troublesome areas into smaller cost centres to try and achieve some of the more ideal conditions that are found in the flowline cells.

8.5 Modified Method With Sub-Divided Cells.

8.5.1 Proposal

To decide how best the cells could be sub-divided the flow of work through the cells and the machine usage was studied. It was quickly found that only two cells were affected sufficiently to warrant sub-division, cells G.T.4 and 6. Owing to the relatively small number of components at Lewmar the analysis of the flow patterns did not entail large calculations, merely an intelligent study of the process layout sheets and consultation with the Chief Production Engineer who had intimate knowledge of all the components and machines. From this cells G.T.4 and G.T.6 were sub-divided as shown in figure 35 with the slight re-allocation of functions as detailed in Chapter 5.

As before the overhead rate for each sub-division was a summation of all the factors in figure 60 and the time element was the cell time, now of course the cell time for the sub-division. Cell times had to be revised to take account of these sub-divisions. After much thought it was decided best to keep the labour time and cost separate to the overhead, this was because trying to build in the labour time and rate as a ratio of the cell times and overhead rate had only worked effectively in the flowline cells. In the non flowline cells it had masked the reality of the situation and caused some innaccuracies in labour costing to occur. By recording labour cost separately, changes to labour time and cost can be made more readily. For example when there is an increase in the rate of pay, it is a simple matter to adjust the computer and re-run the labour costs for each component, this would not be so simple if the labour was built into the overhead.

The labour cost for a component in a cell is a function of the number of people who handle it. For example in cell G.T.1 normally each component is handled by 4 people, each one for the cell time therefore the labour time is the cell time multiplied by 4. Whereas in cell G.T.4A there are two automatic machines each producing different components, the operator divides his time equally between the machines thus for each component in G.T.4A the labour time is the cell time divided by 2. This is not as complex as it may first appear. The Production Engineering Department had already worked out the number of people required in each cell to process each component, by analysing each cell it was possible to determine the number of people who handle the component in the cell. Having defined this it is simple arithmetic to determine the labour time in each cell.

Initially cell G.T.2 was sub-divided into two parts 2A and 2B. G.T.2A consisted of the Canavese CG 180 lathe and G.T.2B the remainder - figure 35(b). This was done to make it easier to cost and control some drums produced in G.T.1 and G.T.5 which needed gear cutting in G.T.2B. Shortly afterwards cell G.T.9 was established making it possible to sub-divide it into 9A and 9B for the same reasons figure 35(j) thus allowing G.T.2 to revert to its non sub-divided state.

Having determined the cell time and the cell labour time for each component, and knowing the cell overhead rate and the labour rate it is then a matter of arithmetic to produce the component cost in that cell, this is now done by computer. Working from the schedules of components for each product it is thus possible to calculate the product costs on a standard basis. With the company's own computer becoming operational in August 1976 it was important to improve on the initial method of product costing with G.T. The initial method, as well as having drawbacks which needed rectification, also was insufficiently logical for a small computer to comprehend.. So from the outset the modified method was designed to be computer operated - section 8.6.

8.5.2 Results

The cell sub-divisions were defined as detailed above and their new overhead rates calculated, these are shown in figure 62. Between the three sub-divisions of G.T.4 there is a difference of 33% between the lowest and the highest rates. In cell G.T.6 there is a difference of 71% between the lowest and the highest rates of the sub-divisions. These figures emphasis the difference of each sub-division. From the start it was planned that the split into sub-divisions would be a paper exercise to improve the accuracy of product costing and capacity planning, it was in no way intended to split up the operating of the cells. In practice this has worked as planned with the components, generally, flowing freely from one sub-division to another within the total cell as if there were no sub-divisions. Occasionally some batches of components were retained in one sub-division until the last one was finished, instead of flowing through in a steady flow. This was overcome by giving the cell leaders concerned further guidance.

With regard to product costing, there is no doubt that the modified method has overcome all the problems inherent in the initial method. It is now considered that it is providing the required degree of accuracy in terms of directly attributable costs. To state this accuracy is rather difficult since, as already discussed, implicit in the product cost are may arbitrary decisions which means that it is virtually impossible to measure the absolute, true cost of making a product. Thus there is no standard against which the accuracy of product costing can be measured. Basically the measure of accuracy is, that when results are studied by all the interested parties each considers that the individual elements have been measured to the best of the company's ability. It is now considered with the latest method that the costs that be directly attributable have been calculated as fairly as possible. These costs are:-

a) Floor area

b) Machine depreciation

c) Power consumption

d) Supervision.

These costs can be measured and directly attributed to each cost centre as they wholly apply to those cost centres. The remaining costs in figure 60 have to be absorbed by the cost centres but are not always directly attributable to them. For example the technical overheads of Production and Design Engineers are often engaged on future projects rather than that being made today. How these costs are recovered is a question of general cost accounting policy rather than how the cost centres are divided.

The initial product cost system after the introduction of G.T. proved to be more accurate and fair in operation than the old method but it did have some drawbacks such as unfairly loading parallel working and foreign components. Having accepted the reality of the situation at Lewmar and sub-divided some cells it has been proved that this has overcome the problems of the initial method. Whilst the cell construction remains relevant to the components being manufactured, the cost centres as now established have proved to provide the optimum arrangement.

8.6 Computerisation

It is generally agreed that a good product cost system follows on from a good production control system. Having computerised the production control system it was but a short step to computerise the product cost system. As part of the production control system the computer, has on file the following data:-

a) Cell time

b) Labour time

c) Product schedules

d) Component routings

e) Raw material requirements.

To use this data for product costing it was only necessary to feed in the standards for the following:-

a) Overhead rate

b) Labour rate

c) Bought-out parts cost.

d) Raw material unit cost

e) Sub-Contractors cost.

f) Scrap allowance.

From the two stores of data it is a simple matter for the computer to produce the product costs.

The computer actually produces two reports, the Product Structure Listing and the Standard/Current Costings. The product structure listing is really just a print-out of the computer files arranged in component order listing the description of the components used on each product together with their individual cell and labour times and the raw material required figure 64. The Standard/Current Costings firstly list the raw material, labour, overhead and sub-contract costs for each component - figure 65. These are then brought together and listed for each product assembly - figure 66. Thus in this simple way the computer calculates and presents the standard costs of all components and assemblies. It is planned to also present the current cost of manufacture but this cannot happen until a system has been established of feeding in current costs of raw material etc. and shop floor times. Work has already commenced on this and when completed it should be possible to compare standard and current costs and thus analyse the difference - if any.

8.7 Conclusions

It is considered that any product cost method is better than the one in use at Lewmar before the introduction of G.T. Even if G.T. had never been introduced then a number of different cost centres would have to have been established but quite what and when had never been worked out. The introduction of G.T. provided the obvious answer in making each cell a cost centre. This was the ideal solution, the company has not only had to deal with the ideal types of family groups of components but also with the odd components which lead to foreign components in cells and parallel working. How these situations arose and the solutions to them were discussed in chapter 5, but because they arose they cause the same sort of difficulties in product costing as in production control. The same solution, that of subldividing some cells, was found to be effective in both cases in allowing Lewmar to control and cost a "real-live" situation, rather than a theoretical one. This latest method of product costing costing has provided figures that appear to be reasonably accurate without any excessive "loading" of costs on some components. It has also enabled the company to computerise its product cost methods with the minimum of effort as the new method is logical and without the need for the interpretive powers of the human brain. The actual degree of accuracy of a product cost method cannot be measured as product costing is an inexact science but the cost accountant can soon tell if the product cost system is providing the right kind of information on which to base the profitability, the selling prices and the stock valuation. At Lewmar Marine it is now considered that the latest method does just this which is something neither of the previous methods could do.

This is not to say that there is no room for improvement. Some of the ways of attributing indirect costs can always be improved and the cost centres themselves need to be reviewed at least once a year to see if they are still relevant. Group Technology has enabled Lewmar Marine to establish a system of viable cost centres on which to base a workable product cost method.

9. DISCUSSIONS

9.1 Introduction

It is now nearly three years since Group Technology was introduced at Lewmar Marine in September 1974. It took eight months after this to establish the eight cells initially planned. Since that time there has already been one major change to the cell structures, planned in April 1976 and implemented in August 1976. This change was brought about by the addition of two new winch ranges, one of which replaced an existing range, the other being an addition to the existing ranges. At this point in time the Design staff are working on a new range of two-speed winches and a major modification to all the self tailing winches. Preliminary studies of these designs indicate that yet another change in the cell structure will be required during the latter part of 1977.

With this in mind, now is a good time to consider the effects and achievements of G.T. at Lewmar. For two and a half years 80% of the productive capacity of the shop floor has been grouped on G.T. principles and also other departments such as Production Control and Accounts have altered their systems to take advantage of G.T. Thus after this length of time it should be possible to gauge the total impact of G.T. on the company. This should confirm if it has achieved the desired objectives and if it is worth while to continue with G.T. at Lewmar, revamping as required and also extending it to cover all the Hardware components not yet grouped into cells.

9.2 Achievements

Figure 1 shows the possible expectations of a company embarking on G.T. Lewmar Marine introduced G.T. mainly for the following reasons.

a) Improve throughput time

b) Reduce Work-in-Progress

c) Reduce stocks

d) Increase sales

e) Increase space available for extra machine tools

f) Improve Production Control

g) Improve costing

In a report written in May 1973 [62] the throughput time at Lewmar was defined as the time allowed between the material issue for a component and its completion to stores. This report showed that the mean throughput time was 5.75 weeks but that the actual throughput time was 5-13 weeks, thus the probability of the throughput time being correct is only 46%. After cell 1 had been operating for only 3 months, one component had dropped to a consistent throughput time of 4 weeks another was consistent at 6 weeks. This included the sub-contracted operations of polishing and plating. For one particular component, a drum, a quantity of 400 had a throughput time of 763 hours before G.T. After changing to G.T. the same quantity of the same drum took only 168 hours, a reduction of 78% in throughput time. The same drum today would now have a throughput time of only 108 hours for the same quantity, a further reduction of 36%. Including polishing and plating this drum now has a throughput time of 2 weeks, this is fairly typical of all the single and two speed winch castings. The fact that the G.T. flowlines especially generate finished machined components daily has enabled the polishers to make a twice daily delivery and collection, the chrome platers deliver and collect daily and components are delivered and collected from anodising at least twice a week. The effect of this is that within 2 days of starting a batch of components, finished components are being routed into the stores. These reductions in throughput times and their consistency that has allowed production control to embark on the procedure of machining in a particular month the castings required for assembly in that month.

Before G.T. was introduced at Lewmar the machines required to process the drums turned by the first Canavese were located adjacent to this lathe. They did not, however, operate as a cell, the batches of components invariably tended to be processed as a complete batch at each machine instead of flowing through. This system was very useful in enabling comparisons to be made regarding Work-in-Progress between the old system and cell G.T.1 on the G.T. system. After G.T.1 had been running for one month it was found that the Work-in-Progress on that particular family of components had been reduced by an average of 70%. Similar reductions were found in the other flowline cells (G.T.2 and 3). It has not been possible to compare the Work-in-Progress in the remaining cells with the previous method of working owing to two factors:-

a) The complete change in the method of working

b) The arrival of new machinery coincidental with the establishment of the cells. This meant that components were produced in house rather than sub-contracted.

Because these cells have some backtracking, parallel working and foreign components, it was considered that they would not be able to make such a significant contribution to the overall reduction in the level of Work-in-Progress as the flowline cells. Also the remaining 20% of machining capacity, mainly employed on hardware components, is still working on a functional basis with the same level of W.I.P. as before.

Figure 67 shows the performance index figures from 1972 to 1977 relative to unity in 1972. Also figure 68 shows that there has been a steady decline in the work-in-progress versus sales ratio since 1972 but that this decline has become greater since 1974 when G.T. was introduced. Figure 67 shows that the value of sales over the value of work-in-progress had increased 87% in the two years from 1972 to 1974. In the two years from 1974 to 1976 the value of sales over the value of work-in-progress has increased by 55%, the last year showing the biggest increase since the introduction of G.T. in 1974. These trends show that the level of work-in-progress is still dropping in real terms and also that it is managing to fall as the value of sales increase.

It is worth noting at this point to what extent sales have increased since 1972. Figure 69 shows the index of sales value taking 1972 as unity plotted against the years. The biggest single rise in sales value was from 1973 to 1974 but a price rise partly accounts for this, the drop in 1975 (the first full year of G.T.) is attributable to the world recession and the general down turn in the leisure market. The peak of 1974 had been virtually regained in 1976 and now it is projected that 1977 will be 58% higher than 1976. The most striking figures to emerge are the sales/stock rates. Figure 70 shows that the sales/stock ratio reached its low point in 1974 and that it has steadily increased since that time. It is significant that G.T. was introduced in late 1974 and thus is making possible a big reduction in stocks compared with sales. Figure 67 also shows that the actual index if stock value is now diminishing from the high point of 1974, which, considering inflation, is a big achievement. The reduction in stock has been more marked than the reduction in work-in-progress - figure 71. This is probably the effect of the non-flowline cells where, as stated previously, modifications have had to be made to accommodate foreign components. These components have to visit more than one cell and in doing so increase the level of work-in-progress over what it might have been if they did not exist. The fact is they do exist, they have to be made and thus the facilities for their manufacture have to be provided.

Since 1972 the labour force at Lewmar has oscillated - figure 72. This shows an increase in labour of 38% from 1972 to 1974, a decrease of 30% from 1974 to 1976 and an increase of 11% in the last year. Again the high point occured just before G.T. was introduced indicating that advantage was taken of the introduction of G.T. and the world recession to trim the total labour force to a more efficient level. This is substantiated by figure 73 which relates the index of sales value to each person employed, this shows how up until 1974 the increase of sales per person was gradual but as the staff was reduced so the sales per person increased more each year. This is attributed to two reasons:

a) The introduction of G.T. requiring less indirect people and increasing the efficiency of the machine shop.

b) The introduction of modern automatic machinery.

Whereas the introduction of the automatic machinery on its own would have improved the ratio regarding direct operators, the old functional layout system would have produced an even bigger indirect labour force to control the increase in output. G.T. has enabled the gains of introducing these machines to be realised without the necessity for an increase in indirect labour. In fact the indirect labour has decreased at a higher rate than the direct labour. Thus at the end of 1976 each person in Lewmar was producing 3.5 times the value of sales they produced in 1972. Figure 67 also shows that in terms of labour costs the increase in the sales/total labour cost ratio was 70% from 1972 to 1976, thus even allowing for inflation the company has become more efficient.

Figures 14 and 15 showing views of the shop floor with large numbers of trolleys containing work-in-progress. The trolleys are occupying space that could otherwise be used to house new machine tools. This same layout without the work-in-progress, figure 27, shows just how much space there is. Figure 74 shows two views of the shop floor in February 1977, one is of cell G.T.3 and the other is part of cell G.T.6. Comparing figure 74 with figures 14 and 15 it will be noticed how dramatically the work-in-progress has dropped. Also comparing the shop layout before G.T. in figure 27 with that for

September 1976, after G.T. - figure 33, shows the increase in the number of machine tools in broadly the same area. This was made directly possible by the G.T. system reducing throughput times and reducing work-in-progress. Without G.T. it is certain that the factory would have had to be extended early in 1975 to accommodate the machinery now installed in the existing factory. This again improves the efficiency of the company and it keeps the overhead down whilst increasing the ouput.

9.3 Effects of G.T. on Individual Departments

Group Technology has not only affected the shop floor at Lewmar, its presence has been felt in every other department. In some departments it has caused a complete change in their method of working whereas in other departments it has had a lesser effect. These effects are summarised below:-

9.3.1 Sales Department

a) Closer liaison with production,

b) Verification of production promises by physically being able to see what is being produced at any time.

c) Faster throughput - enabling swifter delivery to customers.

d) Increased ability to change requirements thus keeping customers more satisfied.

9.3.2 Design Office

a) Greater encouragment to standardise components.

b) Greater understanding of production capabilities of the shop floor.

9.3.3 Production Engineering

a) Incentive to produce better composite tooling to suit a whole family of components.

b) Process layout sheets have to be kept up to date as these are used in cell planning.

c) Production times need to be substantiated by study as these affect the capacity figures for each cell.

d) Ability to predict more exactly the requirements for new machine tool purchases.

e) Increased emphasis on the need for planned machine maintenance.

9.3.4 Production Control

a) Control by groups is easier than control by operators.

b) Component batches are easier to trace and progress.

c) Better liaison with Sales and Shop Floor.

d) The need for splitting batches is eliminated.

e) Capacity surpluses and shortages are more readily indicated.

9.3.5 Production Supervision

a) Setters have had to become component orientated rather than process orientated.

b) Most setters have had to become supervisors in their new roles as cell leaders.

c) Less progressing of components is required.

d) Less cessation of part completed batches in order to run "priority" components.

9.3.6 Stores

a) Reduction in stock made possible.

b) More consistent stock issue and rotation.

9.3.7 Inspection and Quality

a) Faults produced early in the machining sequence are diagnosed quickly and can be corrected before the batch is finished.

b) Increased awareness by operators of the quality, as a component wrongly machined in one part of the cell will not fit the jig in another part of the cell. This type of problem is often corrected without involving an inspector.

c) Each inspector is now responsible for the complete machining of a component rather than individual operations - this improves the quality of each component.

d) Each inspector is instructed to patrol certain cells and is responsible for the quality in those cells.

9.3.8 Accounts

a) Greater accuracy in product costing - see chapter 8.

9.3.9 Purchasing

More reliable information from Production Control, coupled with reduced throughput time and reduction in stocks means that the purchase of raw materials need not have a firm commitment beyond 3 months.

9.3.10 Data Processing

The reduced scale of the production control problems and the fact that computer control within a cell is superfluous means that a smaller computer with simpler software can be utilised.

9.4 Problems in Allocating Resources

There are two facets to the introduction of a Group Technology system. The first and by far the easiest is the initial planning and implementation. The second is the consolidation of this and the extension to the majority of the factory, this is the most difficult part. Many researchers in G.T. have only touched on this second phase and then only in theoretical terms.

In September 1974, Lewmar Marine made a firm decision to introduce G.T. for 80% of its machinery capacity which affected 88% of its output. It also planned to do this in one year, a time scale which is much shorter than virtually any other company embarking on G.T. This was made possible by the small range of products and also by the fact that most of the high cost, high volume components fitted easily into dense family groups. In practice it was found that although the basic cells were established within the year, it took a further one and a half years to get the system running at a level deemed satisfactory. The problem was not the high volume, high cost components , these were adequately catered for in the flowline cells which functioned properly from the onset.

The problems lay with the range of components which did not readily fit into groups - the "foreign" components (see chapter 5). These components had to visit specialist machines in the non flowline cells which of course disrupted the ideal operation of these cells. The initial reaction was to ignore these components in the hope that they would go away which of course they did not. The second reaction was to accept the problem as it really was and work out a solution and try to minimise the number of these foreign components by changing the methods of production and modifying the designs. The obvious alternative of setting up cells particularly for machining these foreign components was not viable as the volume was so low it would not provide enough work to even keep the key machine working at an efficient rate. Thus these foreign components had to be accepted and integrated as far as possible into the relevant cells. In some instances of G.T. the approach to these foreign or awkward components is to establish a small group of miscellaneous machines, usually the oldest machines left over after the cells have been formed. This principle works satisfactorily where the foreign components only require the normal operations of turning, drilling and milling. Where specialist operations such as broaching and gear cutting are required it is very unlikely that there will be any spare machines of this description not required by the cell formation. To buy such machines, whether second hand or new, is often not viable as their utilization will be low. Thus the only alternative is to have these foreign components visit the specialist machines in their respective cells. As figure 36 showed, in the worst case 29% of the number of components in a cell was made up of foreign components. However, the actual volume of foreign components is much nearer 8% thus if 92% of the volume of components pass through as planned then the cell leader only has to actively persue 8% of the volume, a much smaller problem than at first it would appear to be.

The biggest impact of both foreign components and parallel working was not in the actual operation of the affected cells but in the production control and product costings. The main solution to this so far has been to sub-divide two cells each into three sub-divisions. This has had the effect of reducing the number of foreign components in a sub-division to 17% thus making the problem manageable. It has enabled the capacity calculations to be more accurate and also it has improved the product costing to an acceptable level. It has been found that the problems most likely to occur after the introduction of G.T. cells are these:-

a) Odd components which do not fit into family groups requiring the services of specialist machines located in cells.
b) Parallel working i.e. two or more components being processed at the same time in a cell.
c) Components where minor operations such as hand deburring have been overlooked.
d) Lack of ideal spaces in which to locate cells leading to cell layouts which are not ideal.

In a company such as Alfred Herbert Ltd. where there are many thousands of components, these problems may hardly arise as there is a strong likelihood of each component fitting in a family group. In a small company such as Lewmar Marine where the number of components is measured in hundreds rather than thousands and where there are fewer family groups there is a much greater chance of some components not fitting into family groups. This has been the case at Lewmar and must surely be true of other such small companies that implement G.T. This is not to say that G.T. is not applicable to small companies but rather that its method of operation has to be modified to cope with these problems. At Lewmar these problems have been recognised and the system has been modified in attempts to overcome them.

9.5 CONCLUSIONS

It is interesting to compare the performance index figures for Lewmar Marine after G.T. with those published for Mather and Platt [57]. This shows that at Mather and Platt the sales/total labour ratio had improved by an increase of 64%, at Lewmar it showed a bigger improvement by increasing 74%. The sales/stock ratio at Mather and Platt had deteriorated by 3% whereas at Lewmar it showed a significant improvement by increasing 108%. The authors of the paper concerning Mather and Platt concluded that the results justified the efforts required to implement G.T. Thus if Lewmar is able to produce results which, in many cases are better than those obtained by Mather and Platt, then the results at Lewmar must more than justify the efforts required to implement G.T., which they do.

The fact that the introduction of G.T. at Lewmar brought its own share of problems - different to those associated with a functional layout proves that G.T. is not a panacea for the problems of industry. It might be argued that introducing G.T. is just a way of exchanging one set of problems for another. This may be true but the fact that an alternative in the form of G.T. has been sought means that solutions were not forthcoming to the original set of problems. Events at Lewmar have shown that the problems posed by the introduction of G.T. into a small company do have solutions and that the benefits attributable to G.T. can still be realised even though the theory has had to be modified in order to cope with the reality of the situation.

The way in which the limited resources of a small company such as Lewmar Marine were allocated upon introducing G.T. shows a difference to methods proposed by some researchers (notably P.E.R.A. [48]). These differences are brought about by the fact that theory and practice do not always coincide. The introduction and subsequent running of a G.T. system at Lewmar have shown that in basic essence the theory of G.T. is sound but that the overlay of theoretical details on cell organisation is not always so sound. From early reading the clear message is that foreign work in cells must be resisted at all costs. Yet at Lewmar there is foreign work in cells, true it has caused problems but these have not been insurmountable, but it is there because it is the only practical way at Lewmar to operate a G.T. system which affects 80% of all components.

The results shown in section 8.2 show that the introduction of G.T. at Lewmar has brought about positive gains in terms of reduced work-in-progress, reduced stock, reduced labour and increased sales per employee. However, there are other gains less easy to quantity. The actual turnover of the business has increased considerably since the introduction of G.T. yet the machine shop and the stores have not increased in area. Thus the company is now sustaining a higher turnover with the same production and stores area and with fewer employees than it was 3 years ago. It is the view of the managers at Lewmar that this kind of increase in turnover with a functional layout would have entailed doubling the size of the factory 2 years ago and increasing the staff by at least 30%. The introduction of G.T. has ensured that each part of the company has been made to function more efficiently. This has released capital to purchase more modern machine tools to further the efficiency of the company. The experiences at Lewmar further demonstrate that G.T. can be made to operate successfully in a small company producing a limited range of products. Further, the problems generated by such an introduction can be solved by the company itself with only a small amount of outside experienced assistance. Group Technology is not a technique to be afraid of, it is not only suited to the large companies with massive resources. It is equally suited to the small companies and in fact can even make a bigger impact on the efficient operation of a small company than a large company.

10 FUTURE WORK

10.1 Improvement of the Existing G.T. Cells.

Although the existing cells are operating fairly satisfactory, like all systems devised by man there is always room for improvement. The first improvement must be to reduce the level of foreign components to a minimum. This is in hand as the Design department is at present working on a new range of two speed winches to replace the existing range. Conscious of the problems caused by these foreign components, efforts are being made to standardize, as far as possible, the production methods used for these new winches. It is expected when these new winch components have been coded that modifications will be required to some if not all the cells. Perhaps even the cell structure as it exists today will require a complete revision. If new components require changes in the cells these must be made to ensure the relevance of the cells to the components is maintained.

The computer control of the production control function can be further extended by arranging the kit marshalling report in cell order and linking in the production times with the quantity requirements and the available capacity. This would enable the computer to produce, monthly, reports showing the capacity required in each cell and whether there is a surplus or a shortage. In order to do this, new computer programmes will have to be written and the information fed into the computer must be correct. As part of the system to produce current product costs, each cell is now required to report the time spent on each batch of components and the quantity passed or scrapped etc. The system in use works quite well in most cells except G.T.4 and 6., here the level of foreign work and parallel working has caused some problems. It is hoped that these will diminish when the existing two speed winch components are replaced by new ones late in 1977 but in the meantime a solution will have to be found to these problems.

There is still some flow of work from cells to the miscellaneous area for drilling operations. This is caused by a lack of sufficient drilling capacity of the right quality being available in these cells. In the future more precision drilling machines will be required to redress the situation. Lastly the time is near when all the cell leaders will have to be re-educated in the aims and achievements of G.T. and in particular how their own cell should function. This is not to say that one is critical of the way in which these cell leaders work but it is now 2 years since they were appointed and cell structure and methods have changed since then.

10.2 Extension of G.T.

At present the application of G.T. has only covered the winch components, the majority of the hardware components are produced in the miscellaneous area which does not function on G.T. principles. The fact that winch production accounts for about 80% of the total production of Lewmar means that G.T. has had a major effect on nearly every department in the company. Now that the existing cells have been consolidated, G.T. should be extended to cover all the hardware items. It is considered, within the company that given the right conditions that Hardware could account for more than the existing 20% of the sales. If this is so, then it is imperative that its production is arranged in G.T. cells as per the winch production. The majority of hardware components, unlike winch components are either pressings or non-rotational machined components. The Opitz code as it stands at present does not cope adequately with pressings thus it will have to be modified in some way to achieve this before these components can be grouped into similar families.

11. CONCLUSIONS

1. Group Technology is a tried and proven system which can offer great benefit to companies in the batch production industry.

2. Group Technology is not a panacea for the problems of the batch production industry.

3. Group Technology can be applied as successfully in a small company as in a large company.

4. The introduction of Group Technology must have the complete support of the Managing Director.

5. The introduction of Group Technology must be a totally committed exercise on the part of all concerned.

6. Group Technology must be integrated into all departments, not just the shop floor.

7. The initial planning and the introduction of Group Technology is relatively simple.

8. The process making Group Technology operate sucessfully after introduction is somewhat more difficult.

9. Group Technology declares most of the problems associated with a functional layout system redundant.

10. Most problems associated with the introduction of a Group Technology system can be solved by the application of common sense and sound engineering principles.

11. Full consultations should take place with all concerned, both middle managers and Trades Union representatives, before Group Technology is implemented.

12. Component families must be formed by a structured analysis such as a classification code or production flow analysis.

13. Classification systems do not provide the sole answer to cell formation, some form of Production Flow Analysis is often useful to finally plan each cell in detial.

14. When planning a cell, every operation must be considered, including minor ones such as hand deburring.

15. Before all planning commences the process layout sheets should be checked against the actual shop floor routings.

16. The coding of drawings should be undertaken by the company's own staff. These people should be broadly familiar with the machining methods employed to assist in the interpretation of the classification system.

17. When introducing Group Technology into a company on a broad front (i.e. not just one pilot cell) the most obvious family groups should be tackled first as these are likely to pose the least problems and produce the best results.

18. When planning a cell the machining capacity for each operation must be checked.

19. Having established a number of cells, a company must be prepared to modify the methods of their operation in the light of operating experience.

20. The three basic types of cell, G.T. Flowline, G.T. Cells and single Machine, can work quite satisfactorily together in one company.

21. When new products and thus new components are introduced the existing cell structure must be checked to see if modifications are required and/or if new cells are required.

22. The space in factories allocated for machine tools is rarely an ideal shape or size and so cell layouts have to be a compromise with the layout of one cell often affecting those of the others.

23. Group Technology releases space, previously occupied by work-in-progress, for the siting of new machine tools.

24. After the drawings have been coded, initially, a system should be establised whereby all modified and new components are coded. At least once a year (or sooner if necessary) the codes should be re-sorted to check the relevancy of the cells.

25. Each cell can be likened to a mini machine shop and thus each manufacturing problem is diminished in scale and effect.

26. It is important to ensure maximum utilisation of the key machine in each cell which is usually a high cost machine. This is achieved by the provision of adequate secondary machining facilities which will be underutilized.

27. A degree of flexibility of labour is essential to ensure full labour utilisation. This flexibility should not just apply within cells but also between cells.

28. The establishment of cells to machine families of similar components can provide the necessary justification for the purchase of individually designed special purpose machines to perform part or all of the operations.

29. The introduction of cells has enabled the company to predict more accurately the requirements for future machine tool purchases as it highlights the areas lacking in capacity and determines exactly what type of capacity is required.

30. A small percentage of 'foreign' components can be tolerated in non-flowline cells.

31. It may not always be viable to purchase additional specialist machines, such as gear cutters, in order to render each cell independent for all operations. This in turn leads to 'foreign' work in cells.

32. If the cell structures are not up dated in line with new components then the numbers of 'foreign' components will increase to an unacceptable level causing large scale shop floor disruptions.

33. The production control of a small percentage of foreign components can be improved by sub-dividing the affected cells into smaller sections. Each section is so selected according to the needs of these 'foreign' components.

34. The sub-division of cells for production control and product costing purposes does not affect the actual operation of the cell which continues to function as one cohesive unit.

35. Cells can be used sucessfully as individual cost centres.

36. The sub-divisions of some cells improve the accuracy of product costing in respect of 'foreign' components and parallel working.

37. The stock control method of production control and its associated E.B.Q. calculations is not compatable with the aims of Group Technology.

38. The advantages accrued to Group Technology can best be exploited by changing to a Period Batch Control [10] system.

39. If possible the performance of the company for several years prior to the introduction of Group Technology should be recorded to assist in the analysis of the achievements of Group Technology.

40. Group Technology together with Period Batch Control ensures that components are manufactured when they are required and in the quantity required for assembly into products requested by Sales.

41. With any Production Control system it is essential to have frequent, regular meetings between Sales and Production Control to ensure that the production departments are in tune with the sales department.

42. When changing from a functional layout system to a Group Technology system the effects of consolidated tooling families will not be achieved immediately because existing tooling will still be in use. Only with the introduction of modified and new components will these gains become apparent.

43. When selecting the production cycle for a family of components it must be of sufficient length to allow for the required production time plus the setting time. Too short a cycle will increase the setting time to the point where it erodes the production time.

44. The scheduling of components in a cell should be arranged to take advantage of similar tooling set-ups, sales requirements, availability of raw material and material type in order that setting time is minimised and components produced when required.

45. After introducing Group Technology there is always a danger of people slipping back to thinking in a functional layout manner.

46. The introduction of Group Technology puts even greater emphasis on the necessity of a planned machine maintenance programme.

47. When using an 'on-line' computer for production control purposes Group Technology reduces the scale of the task as it is not necessary for the computer to control operations within each cell.

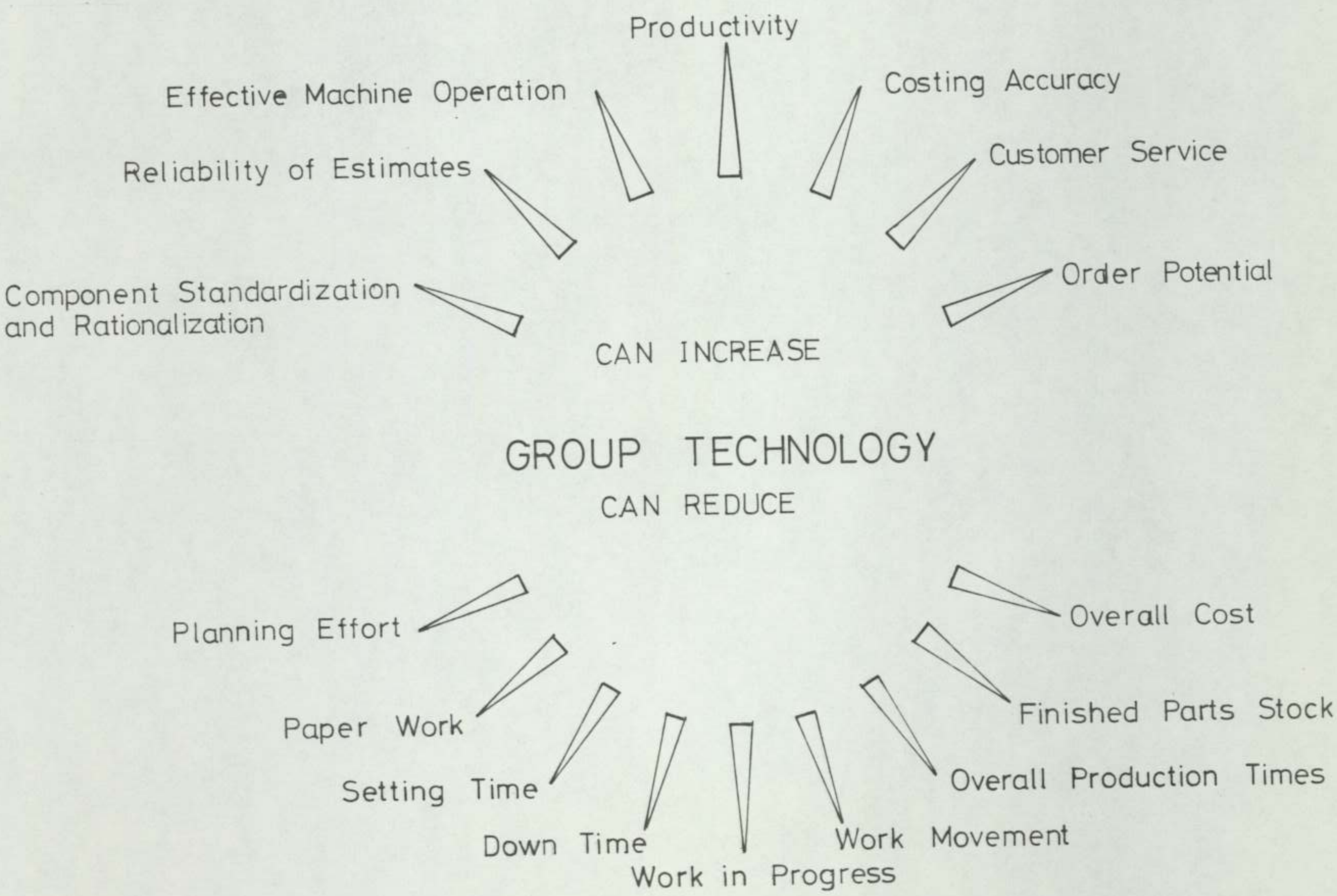
48. Group Technology can improve the quality of each component, for under G.T. each inspector is responsible for all the operations on a component rather than just one type of operation.

49. Group Technology will have an effect on every department within the company, whether in the form of an improvement in its performance or a more fundamental change in its method of operation.

50. Group Technology is an approach to group working but should not be confused with the experiments now being conducted on group working in the mass production industries.

51. No company should lose sight of the fact that it is in business to make and sell its products. The utilization of machine tools is only a means to this end not an end in itself. Group Technology encourages this aim.

52. Group Technology enables management to put each problem into its proper perspective and thus obtain a clearer understanding of the effects of their decisions.



GENERAL ACHIEVEMENTS of GROUP TECHNOLOGY
(after Thornley)

Figure 1

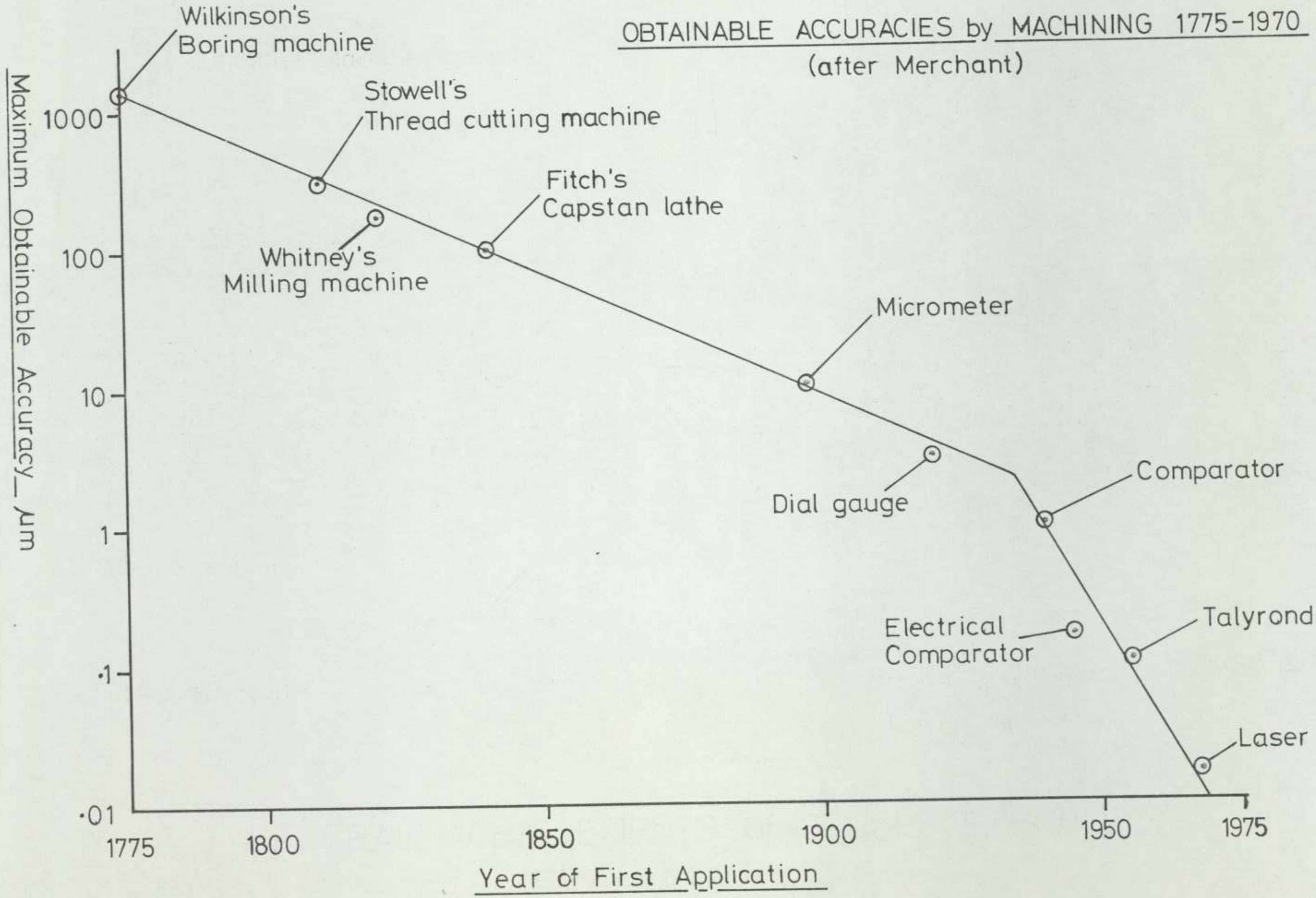
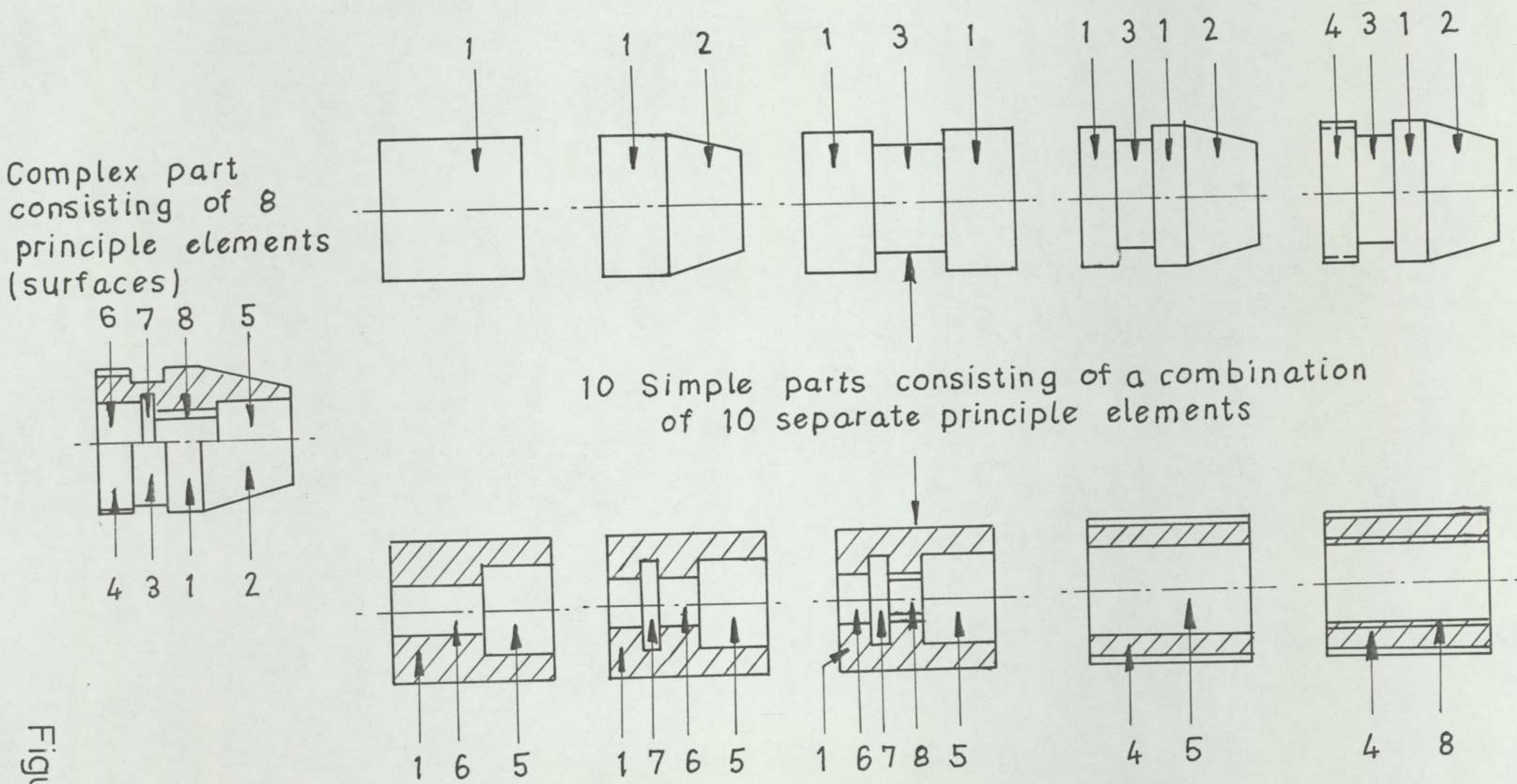
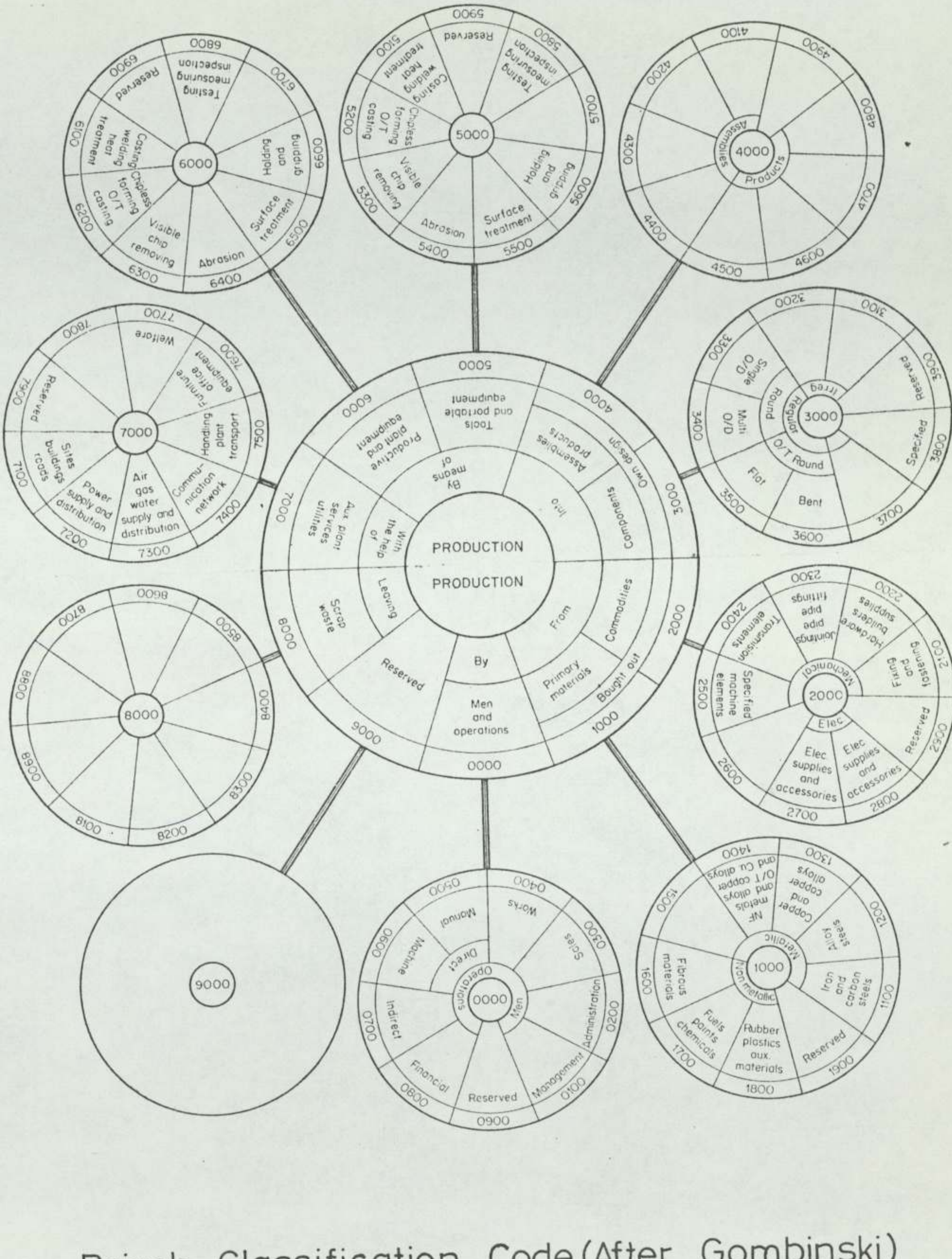

OBTAINABLE ACCURACIES by MACHINING 1775-1970
(after Merchant)
Wilkinson's
Boring machine
Stowell's
Thread cutting machine
Whitney's
Milling machine
Fitch's
Capstan lathe
Micrometer
Dial gauge
Comparator
Electrical
Comparator
Talyrond
Laser
Maximum Obtainable Accuracy_ µm
1000
100
10
1
·1
·01
1775
1800
1850
1900
1950
1975
Year of First Application

Figure 2.



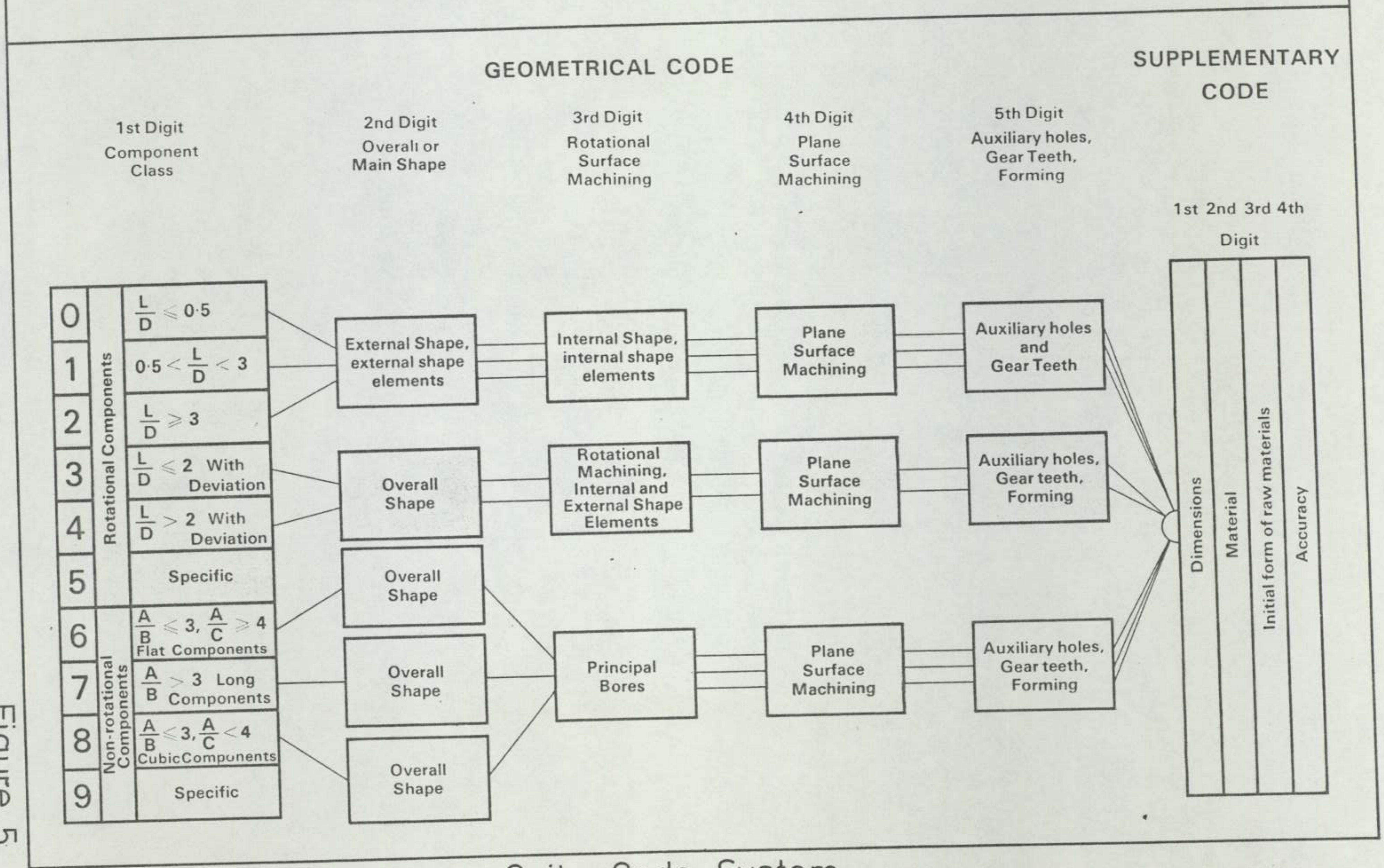
EXAMPLE OF COMPLEX COMPONENT
(AFTER MITROFANOV)

Figure 3



Brisch Classification Code (After Gombinski)

Figure 4

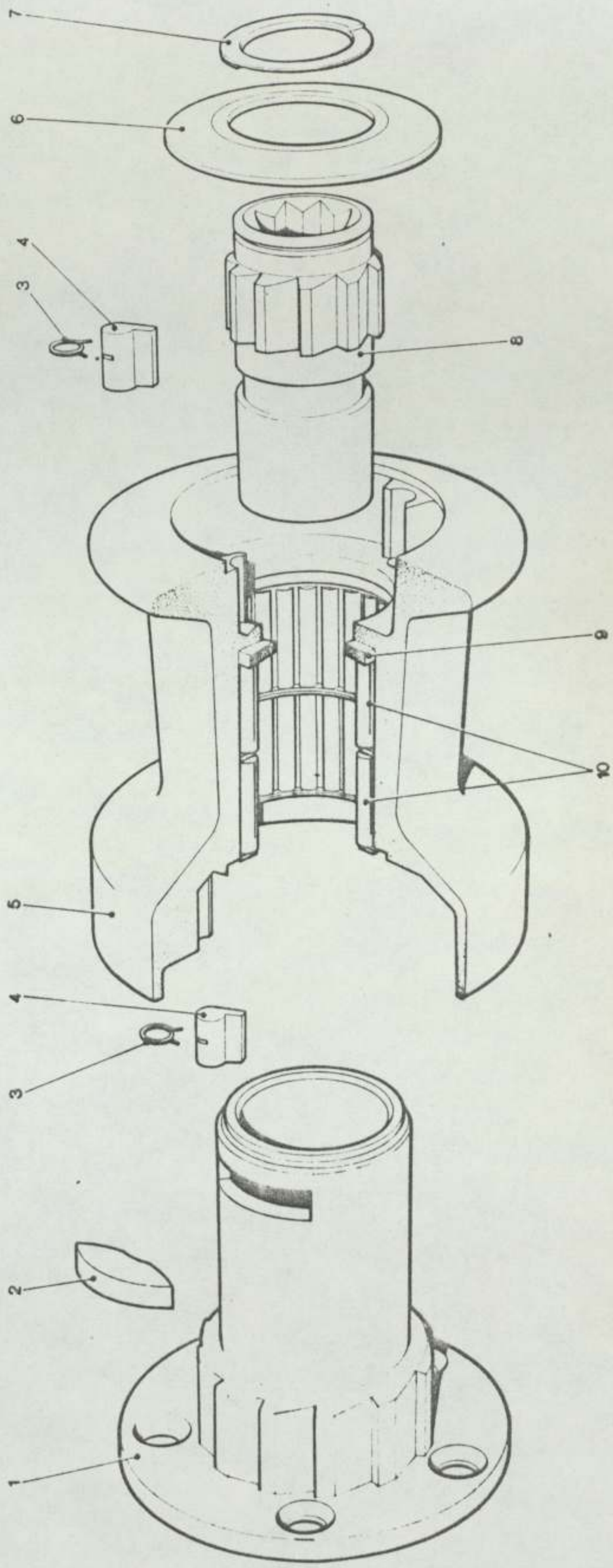


Opitz Code System

Figure 5

Examples of Lewmar Winches

Figure 6



LEWMAR No. 8 SINGLE SPEED WINCH

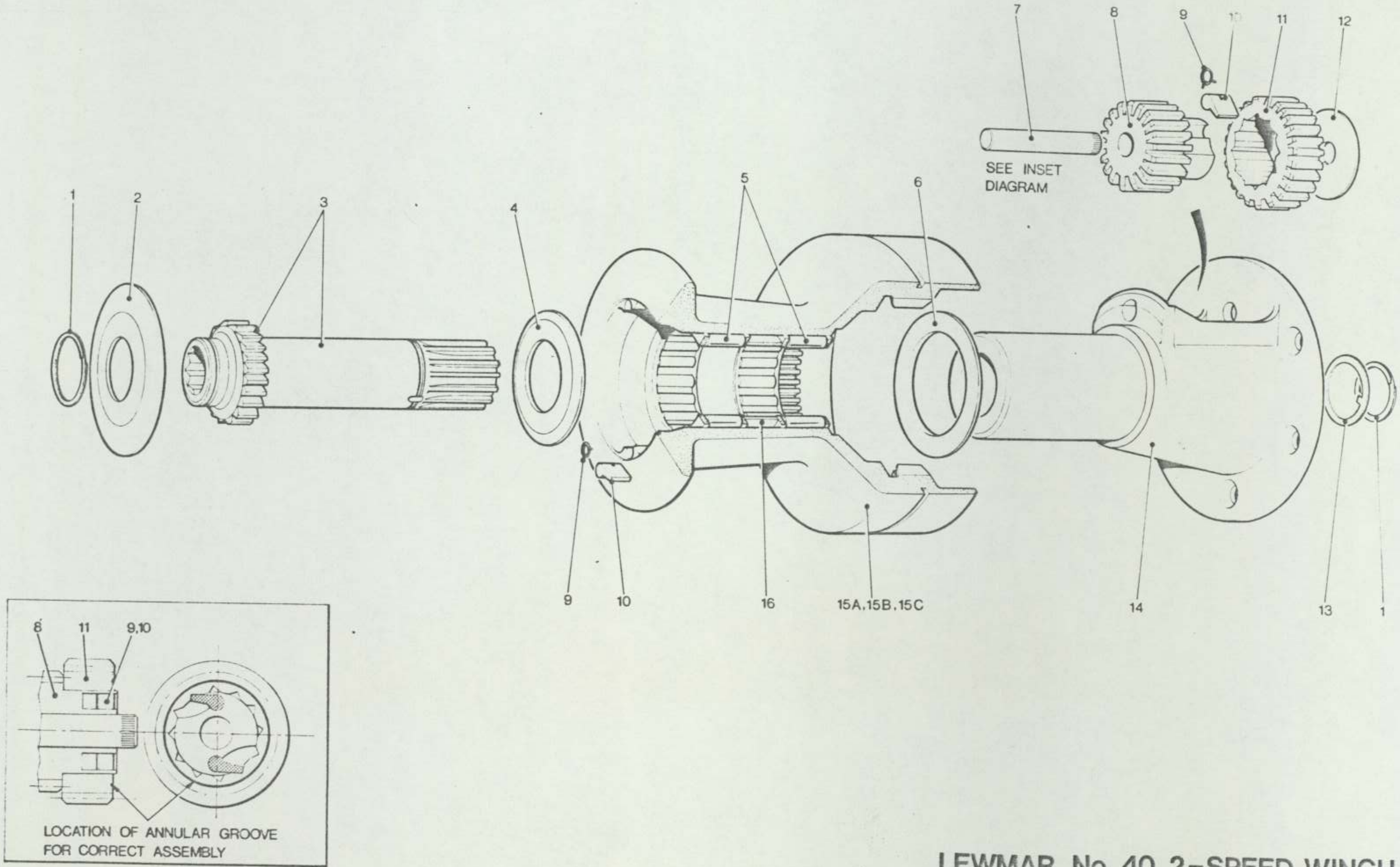
Figure 7(a)

LEWMAR No. 8 SINGLE SPEED WINCH
Parts List

ITEM No.	PART No.	DESCRIPTION	No. OFF
1	15008001	Centre Stem	1
2	15008005	Key	1
3	1260/7	Pawl Spring	4
4	1260/8	Pawl	4
5	15008102	Drum, Bronze }	1
	15008202	Drum, Alloy }	
6	15006006	Top, Cap	1
7	B2075	Circlip	1
8	15008003	Spindle	1
9	15008004	Drum Washer	1
10	15008007	Roller Bearing Assembly	2

ITEM No.	PART No.	DESCRIPTION	No. OFF

Figure 7(b)



LEWMAR No. 40 2-SPEED WINCH

Figure 8(a)

LEWMAR No. 40 2-SPEED WINCH
Parts List

ITEM No.	PART No.	DESCRIPTION	No. OFF
1	B2075	Circlip, Spirolox	2
2	15010006	Cap	1
3	1260/SA1	Spindle Assembly	1
4	1300/19	Washer	1
5	1260/SA2	Cage Assembly	2
6	1260/10	Drum Washer	1
7	1260/6	Gear Spindle	1
8	1260/4	Pawl Gear	1
9	1260/7	Spring	4
10	1260/8	Pawl	4
11	1260/5	Ratchet Gear	1
12	1260/9	Gear Washer	1
13	1260/19	Tab Washer	1
14	1260/1	Centre Stem	1
15A	1260/2	Drum, Bronze	1
15B	1255/2	Drum, Alloy	1
15C	1360/2	Drum, Stainless Steel	1
16	1260/11	Tube Spacer	1

ITEM No.	PART No.	DESCRIPTION	No. OFF

Figure 8(b)

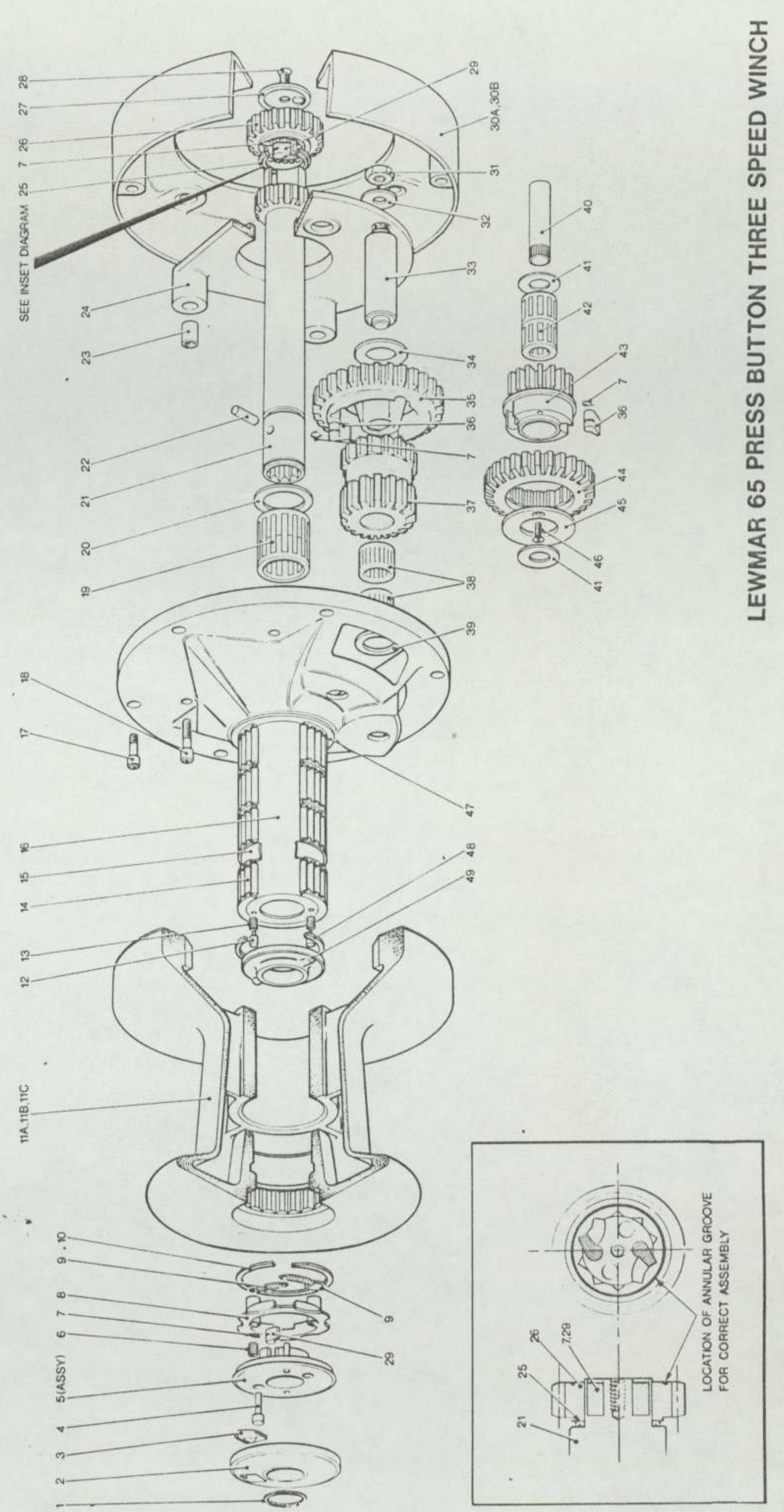
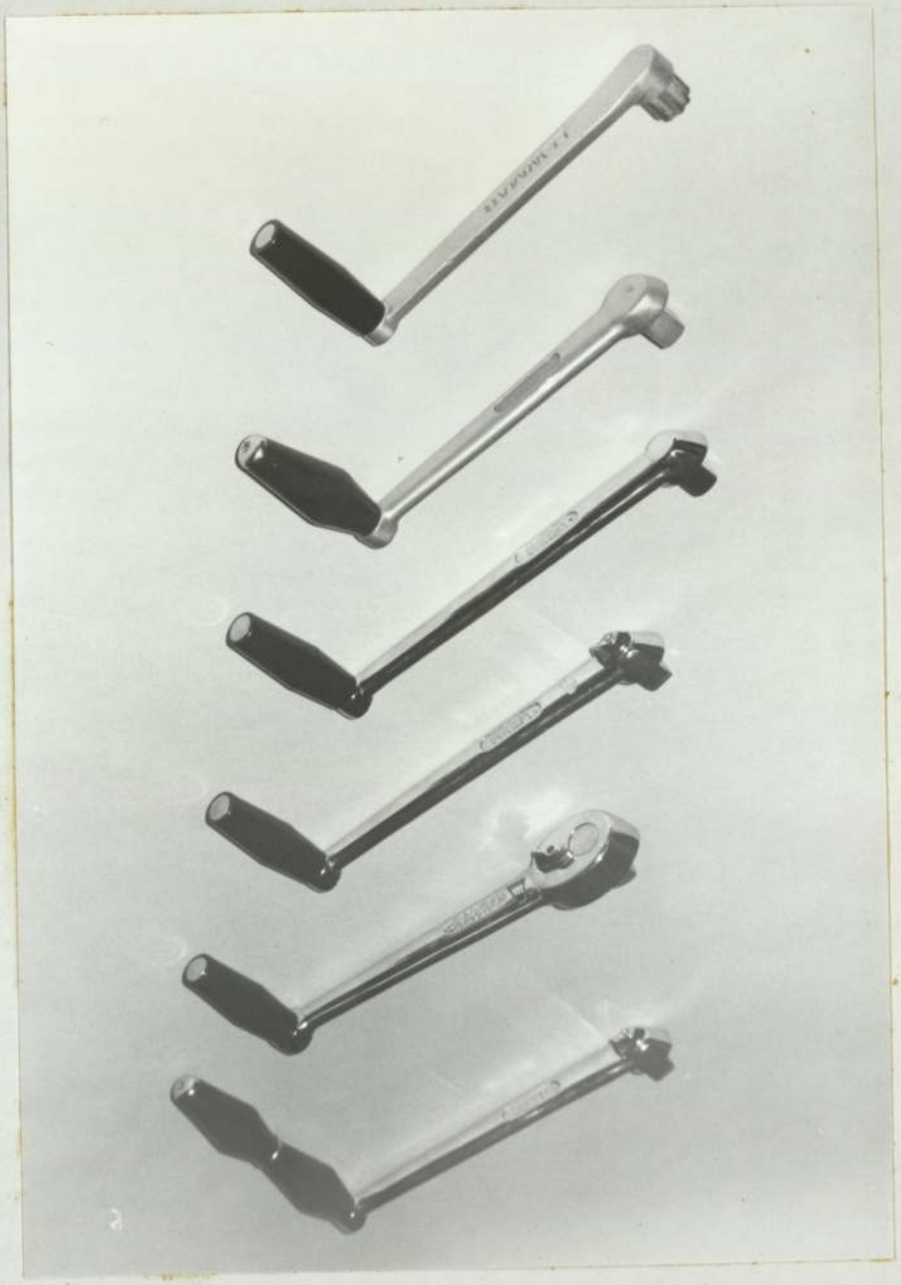

LEWMAR 65 PRESS BUTTON THREE SPEED WINCH
SEE INSET DIAGRAM
LOCATION OF ANNULAR GROOVE FOR CORRECT ASSEMBLY
1
2
3
4
5(ASSY)
6
7
8
9
9 . 10
11A,11B,11C
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30A,30B
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
7,29

Figure 9(a)

LEWMAR 65 PRESS BUTTON 3 SPEED WINCH
Parts List

ITEM No.	PART No.	DESCRIPTION	No. OFF
1	B0275	Circlip, Spirolox	1
2	15065106	Top Cap Cover	1
3	15044114	Push Button	1
4	15044111	Plunger	1
5	15044104	Top Cap Assembly	1
6	15044112	Spring	1
7	1260/7	Pawl Spring	9
8	15044106	Closing Ring	1
9	15044113	Spring	2
10	B2083	Circlip	1
11A	15065102	Drum, Bronze	1
11B	15065202	Drum, Alloy	1
11C	15065302	Drum, Stainless Steel	1
12	1300/24	Plunger	2
13	1300/20	Spring	2
14	1301/SA3	Cage Assembly	4
15	15065115	Spacer	1
16	15065201	Centre Stem	1
17	B0714	Socket Head Cap Screw 3/8" – 16 – UNC x ¾" Long	6
18	B0698	Socket Head Cap Screw 5/16" – 18 – UNC x 1½" Long	3
19	1264/SA2	Cage Assembly	1
20	1300/21	Washer	1
21	15065103	Spindle	1
22	15044119	Drive Pin	1
23	15065111	Hollow Dowel	3
24	15065105	Bridge Piece	1
25	15025107	Spacer	1
26	15065116	Ratchet Gear	1
27	15016107	Spindle End Cap	1
28	B0515	Countersunk Screw ¼" UNC x ½" Long	1
29	1260/8	Pawl	4
30A	15065104	Base, Bronze	1
30B	15065204	Base, Alloy	1
31	B1009	Locknut, ½" BSF	1
32	B1202	Washer	1
33	15080009	Spindle	1
34	B2451	Washer	1
35	15080008	Pawl Gear	1
36	1264/8	Pawl	5
37	15080007	Output Gear	1
38	1337/SA2	Cage Assembly	2
39	15080014	Washer	1
40	1302/13	Spindle	1
41	1301/19	Washer	2
42	1301/SA2	Cage Assembly	2
43	1302/8	Pawl Gear	1
44	1302/7	Ratchet Gear	1
45	1302/17	Retaining Plate	1
46	B0511	Countersunk Screw 2BA x 3/8" Long	2
47	15044116	Washer	1
48	15044118	Collet	2
49	15044105	Clutch Plate	1

Figure 9(b)



Examples of Lewmar Handles

Figure 10

Examples of Lewmar Hardware

Figure 11

Variation in Product Lines over Successive Years

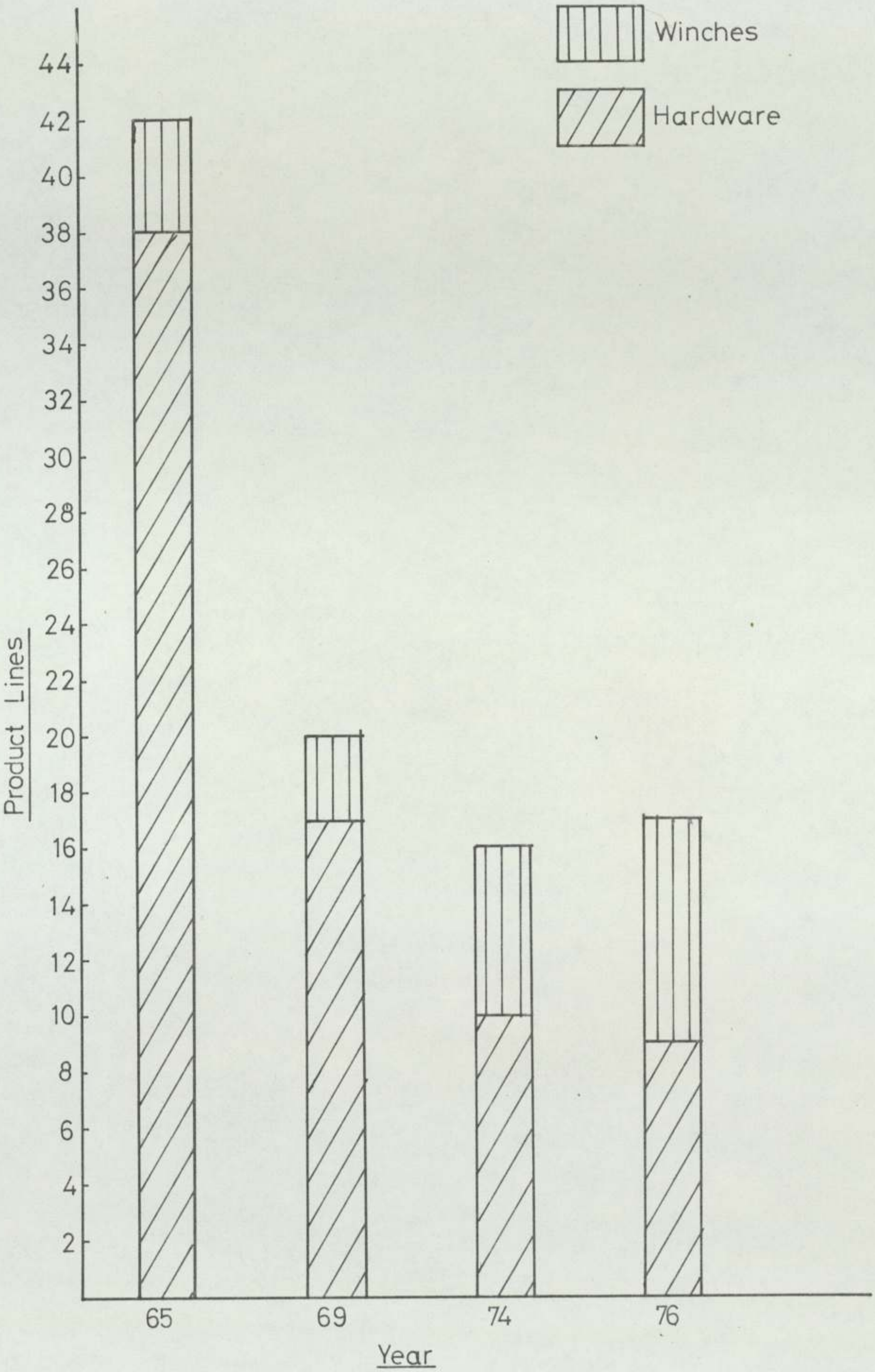


Figure 12

Increase in Winch Types From 1965 To 1976

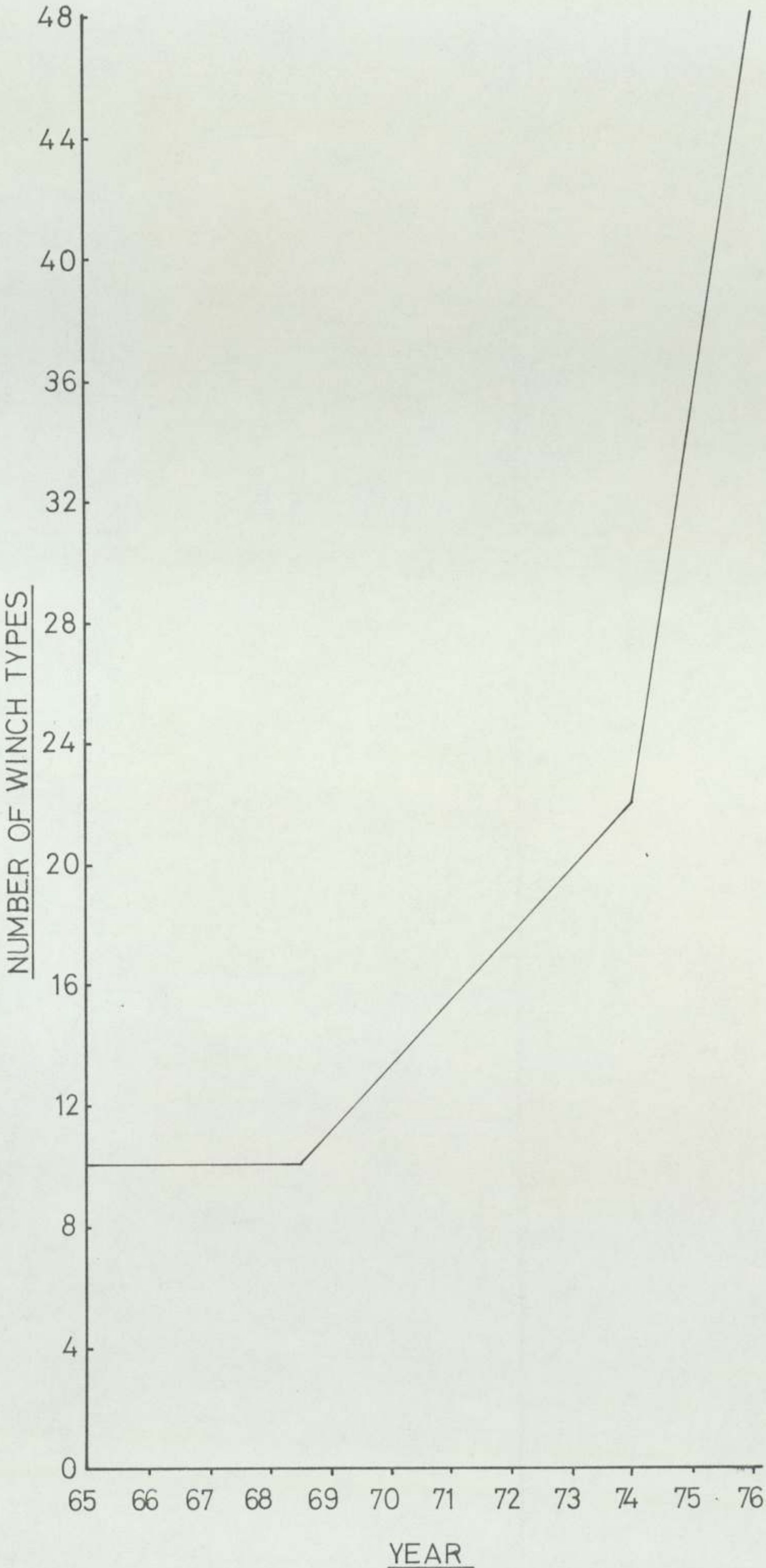
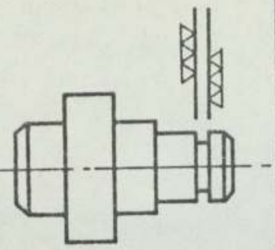
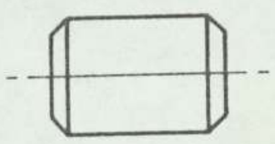
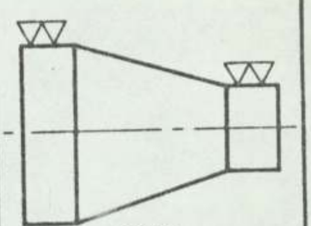
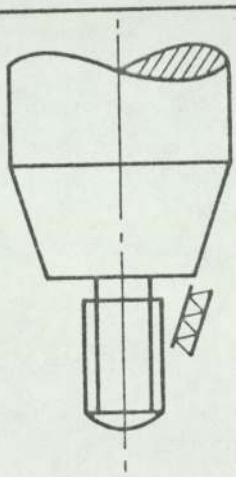
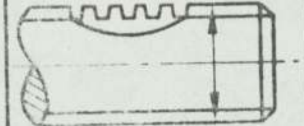


Figure 13

Figure 14

Shop Floor Prior to G.T.

Figure 15

No	Yes	Pos.	Designation	Coding digit
		6	*Stepped to both ends (multiple increases), with functional groove* Only grooves fulfilling a definite function and imposing rather high demands on production; e.g. grooves for V-belts, labyrinth glands, circlips, etc. In contrast, undercuts for threads, chamfers, etc., do not come in this position. Sheave grooves	2
 x0xxx  x1xxx		7	*Functional tapers* Tapers that fulfil a definite purpose, such as torque transmission (Morse tapers), centres, sealing, etc. Drum outside profile and all other machined profiled shapes longer than ½ ins.	
		8	*Operating threads* Threads with special profiles and higher pitch accuracy, e.g. acme threads on spindles, worms, etc.	

PAGE FROM OPITZ CODE MANUAL SHOWING MODIFICATIONS

Figure .16

1st Digit: DIAMETER 'D' or EDGE LENGTH 'A'	MM's	Inches
0	≤ 20	≤ 0·8
1	> 20 ≤ 50	> 0·8 ≤ 2·0
2	> 50 ≤ 100	> 2·0 ≤ 4·0
3	> 100 ≤ 160	> 4·0 ≤ 6·5
4	> 160 ≤ 250	> 6·5 ≤ 10·0
5	> 250 ≤ 400	> 10·0 ≤ 16·0
6	> 400 ≤ 600	> 16·0 ≤ 25·0
7	> 600 ≤ 1000	> 25·0 ≤ 40·0
8	> 1000 ≤ 2000	> 40·0 ≤ 80·0
9	> 2000	> 80·0

2nd Digit	MATERIAL
0	Cast Iron
1	Modular graphitic cast iron and malleable cast iron
2	Steel ≤ 26.5 tonf/in² Not heat treated
3	Steel > 26.5 tonf/in² Heat treatable low carbon and case hardening steel, not heat treated
4	Steels 2 and 3 Heat treated
5	Alloy Steel (Not heat treated)
6	Alloy Steel Heat treated
7	Non-ferrous Metal
8	Light Alloy
9	Other Materials

3rd Digit	INITIAL FORM
0	Round Bar, black
1	Round Bar, bright drawn
2	Bar-triangular, square, hexagonal, others
3	Tubing
4	Angle, U-, T-, and similar sections
5	Sheet
6	Plate and Slabs
7	Cast or forged Components
8	Welded Assembly
9	Pre-machined Components

4th Digit	ACCURACY IN CODING DIGIT
0	No Accuracy Specified
1	2
2	3
3	4
4	5
5	2 and 3
6	2 and 4
7	2 and 5
8	3 and 4
9	(2 + 3 + 4 + 5)

Figure 17 Opitz Supplementary Code

1st Digit	
	DIAMETER 'D' or EDGE LENGTH 'A'
	INCHES
0	$\leqslant 0.5$
1	$> 0.5 \leqslant 1.5$
2	$> 1.5 \leqslant 3.0$
3	$> 3.0 \leqslant 6.25$
4	$> 6.25 \leqslant 15.75$
5	$> 15.75 \leqslant 18.0$
6	$> 18.0 \leqslant 30.0$
7	> 30.0
8	
9	

2nd Digit	
	LENGTH 'L' Rot or EDGE LENGTH 'C' Non rot
	INCHES
0	$\leqslant 0.8$
1	$> 0.8 \leqslant 2.0$
2	$> 2.0 \leqslant 4.0$
3	$> 4.0 \leqslant 6.5$
4	$> 6.5 \leqslant 10.0$
5	$> 10.0 \leqslant 16.0$
6	$> 16.0 \leqslant 25.0$
7	$> 25.0 \leqslant 40.0$
8	$> 40.0 \leqslant 80.0$
9	> 80.0

3rd Digit	
	MATERIAL
0	High Tensile Brass
1	Aluminium Bronze
2	Brass
3	Manganese Bronze
4	Stainless Steel
5	Aluminium Alloy
6	Plastics & Tufnol
7	
8	
9	Other Materials

4th Digit	
	INITIAL FORM
0	Castings
1	Sintering
2	Forgings
3	Tube
4	Bright Bar
5	Sheet
6	Extrusion
7	
8	
9	

Figure 18 Modified Opitz Supplementary Code

OPITZ CODE		DRAWING NO	DESCRIPTION	PG
06100	2060	9211/03	SHEAVE	B
06100	2060	9111/03	SHEAVE	B
06100	3050	9393/03	SHEAVE	B
06100	3060	9311/03	SHEAVE	B
06100	3150	9493/03	SHEAVE	B
06100	3160	9411/03	SHEAVE	B
07102	3150	15040604	UP CR PLT	A
07102	3150	15048604	UP CR PLT	A
07102	3150	15044604	UP CR PLT	A
07102	4150	15055604	UP CR PLT	A
07102	4150	15065604	UP CR PLT	A
07102	4250	15080003	BASE	A
07200	2024	1024/4	CAP	B
07402	3150	15048605	LO CR PLT	A
07402	3150	15044605	LO CR PLT	A
07402	4150	15055605	LO CR PLT	A
07402	4150	15065605	LO CR PLT	A
07402	4250	15080004	DRUM TOP	A
10000	0044	15336002	DRIV PIN	A
10000	0086	1008/6	BUFFER	B
10000	0086	1006/6	BUFFER	B
10040	0044	15044614	PIN	A
10040	0044	1249/10	DOWEL	A
10100	0044	9211/06	SPACER	B
10100	0044	9111/06	TUB SPACER	B
10100	0044	TS19	SPACER	B

Sample of Opitz Code Printout

Figure 19

Machine \ Compt	1266/2	1267/2	1284/2	1291/2	1265/2	1254/2
Canavese CG 90 2T	✓	✓	✓	✓	✓	✓
Engraver	✓	✓	✓	✓	—	—
Two Spindle Drill	✓	✓	✓	✓	✓	✓
Two Spindle Drill	✓	✓	✓	✓	—	—
Air Press	✓	✓	✓	✓	—	—
Nitcher	✓	✓	✓	✓	—	—
Gear Shaper	—	—	✓	✓	✓	✓
Hand Deburr	✓	✓	✓	✓	✓	✓

Component vs. Machine Chart for Cell G.T. 1.

Figure 20 .

Compt. / Machine	15065202	1255/2	1260/2	1294/2	1264/2	15044102	15044202	15048102	15048202	15055102	15055202	15065102
Canavese CG 180 2TL	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Needle Peen	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Herbert Broach	✓	–	–	–	–	✓	✓	✓	✓	✓	✓	✓
One Speed Drill	–	✓	✓	✓	✓	–	–	–	–	–	–	–
Gear Shaper	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Hand Deburr	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Component Vs Machine Chart For Cell G.T.2.

Figure 21

Machine \ Compt	1266/1	1284/1	1265/1	1260/1	1264/1
Canavese CG 90 2T	✓	✓	✓	✓	✓
Single Spindle Drill	✓	✓	✓	✓	✓
Multi Spindle Drill	✓	✓	✓	✓	✓
Single Spindle Drill	✓	✓	✓	✓	✓
Hand Deburr	✓	✓	✓	✓	✓

Component vs Machine Chart For Cell G. T. 3.

Figure 22.

Compt	1266/2	1267/2	1284/2	1291/2	1265/2	1254/2
Canavese	1·00	1·00	1·00	1·00	1·00	1·00
Engraver	1·00	1·00	1·00	1·00	—	—
Two Spindle Drill	1·04	1·04	2·38	2·38	1·87	1·87
Two Spindle Drill	1·19	1·19	3·36	3·36	—	—
Air Press	4·14	4·14	4·80	4·80	—	—
Nitcher	6·47	6·47	12·63	12·63	—	—
Gear Shapers(3)	—	—	1·01	1·01	1·05	1·05
Hand Deburr	1·07	1·07	1·31	1·31	1·32	1·32

Ratio of Machine Rates for Components in Cell G.T.1.

Figure 23

	Canavese Hours for Month's Output	1 Gear Shaper Hours for Month's Output	2 Gear Shaper Hours for Months Output
1266/2	73·23	—	—
1267/2	43·07	—	—
1284/2	34·05	67·72	33·86
1291/2	11·06	21·99	11·00
1265/2	44·32	84·18	42·09
1254/2	11·05	21·00	10·50
Total	216·78	194·89	97·45

Cell G.T.1. – One Month's Output Hours For Canavese and Gear Shapers.

Figure 24

Drawing No.	Description	Opitz No.
1266/2	No. 8 Drum	17162-3200
1267/2	No. 8 Drum	17162-3250
1284/2	No.16 Drum	17166-3220
1291/2	No.16 Drum	17166-3250
1265/2	No.25 Drum	17406-3310
1254/2	No.25 Drum	17406-3350

PLANT

1.	Canavese CG902T	1-off
2.	Needle Peen machine	1-off
3.	Engraver	1-off
4.	3 Spindle drill	1-off
5.	4 Spindle drill	1-off
6.	1 Spindle drill	1-off
7.	Air Press	1-off
8.	Nitcher	1-off
9.	Gear Shapers	2-off

COMPONENT & PLANT LIST FOR CELL G.T.1

Figure 25(a)

Drawing No.	Description	Opitz No.
1260/2	No. 40 Drum	17406-3300
1255/2	No. 40 Drum	17406-3350
1264/2	No. 43 Drum	17406-4400
1294/2	No. 43 Drum	17406-4450
15043102	No. 43-3 Drum	17476.4400
15043202	No. 43-3 Drum	17476-4450
15045102	No. 45 Drum	17476-4400
15045202	No. 45 Drum	17476-4450
15055102	No. 55 Drum	17476-4400
15055202	No. 55 Drum	17476-4450
15065102	No. 65 Drum	17476-4400
15065202	No. 65 Drum	17476-4450

PLANT

1.	Canavese CG1802T	1-off
2.	Needle peen machine	1-off
3.	Herbert TM7 Broach	1-off
4.	3 Spindle drill	1-off
5.	Air Press	1-off
6.	Gear Shaper	2-off

COMPONENT & PLANT LIST FOR CELL G.T.2

Figure 25(b)

Drawing No.	Description	Opitz No.
1281/1	No. 1C Centre Stem	11402-3200
1266/1	No. 8 Centre Stem	11405-3200
1267/1	No. 8 Centre Stem	11405-3250
1284/1	No. 16 Centre Stem	11102-3210
1265/1	No. 25 Centre Stem	11402-3210
1260/1	No. 40 Centre Stem	11402-3310
1264/1	No. 43 Centre Stem	11402-3300
1294/1	No. 43 Centre Stem	11402-3350

PLANT

1.	Canavese CG902T	1-off
2.	Single spindle pillar drill	1-off
3.	Single spindle pillar drill	1-off
4.	Multi spindle drill	1-off

COMPONENT & PLANT LIST FOR CELL G.T.3

Figure 25(c)

Drawing No.	Description	Opitz No.
1264/5	Ratchet Gear	00176-2014
1265/5	" "	00176-2014
1260/5	" "	00176-2014
1300/5	" "	00176-2014
15016105	" "	00176-2014
1284/4	Idler Gear	11106-1034
1284/5	Ratchet Gear	01176-2024
1300/4	" "	01176-2034
1300/7	" "	01176-2014
1302/6	" "	01176-2034
1302/7	" "	01176-3012
1264/4	Pawl Gear	11116-2134
1265/4	" "	11116-1114
1260/4	" "	11116-2114
15025105	" "	11116-2114
1300/8	" "	14116-2114
15043107	" "	14116-2114
1302/8	" "	14116-2114
1300/6	" "	14116-2214
1302/9	Ratchet Gear	14146-2214
1301/6	" "	14146-2214
1238/8	Gear	00106-2014
1280/8	Gear	00106-2034

PLANT

1.	Wickman 3½ Dia. Bar auto	1-off
2.	Broach	1-off
3.	4 Spindle Drill	1-off
4.	Gear Hobber	1-off
5.	Gear Shaper	1-off

COMPONENT & PLANT LIST FOR CELL G.T.4

Figure 25(d)

Drawing No.	Description	Opitz No.
1287/1	No. 5C Centre Stem	11512-3110
1287/2	No. 5C Centre Stem	17170-3200
1281/2	No. 1C Drum	14464-3300
1282/1	No. 2C Casting	11102-4300
1282/2	No. 2C Drum	14464-3300
1280/1	No. 2 x 2C Casting	11102-4300
1280/2	No. 2 x 2C Casting	14166-3200
1283/1	No. 3C Casting	11102-4300
1283/2	No. 3C Casting	14466-4300
15043101	No. 43-3 c/Stem	11402-4300
15043201	"	11402-4350
15045101	No. 45 Centre Stem	11402-4300
15045201	"	11402-4350
15055101	No. 55 Centre Stem	31613-4400
15055201	"	31613-4450
15056101	No. 65 Centre Stem	11401-4400
15065201	"	11401-4450
15055104	No. 55 Base	01102-4200
15055204	"	01102-4250
15065104	No. 65 Base	01102-4200
15065204	"	01102.4250

PLANT

1. Herbert Senior 5 Preoptive - air chucking 2-off
2. Turret Drill 1-off
3. Vertical Mill 1-off
4. Engraver 1-off
5. Fly Press 1-off
6. Needle Peen Machine 1-off
7. Broach 1-off
8. Nitcher 1-off

COMPONENT & CELL PLANT LIST FOR CELL G.T.5 Figure 25(e)

Drawing No.	Description	Opitz No.
1265/3	Spindle	11146-1244
1260/3	Spindle	21146-1344
1264/3	Spindle	20146-1344
1300/3	Spindle	26586-2444
1301/3	Spindle	26576-2444
1302/3	Spindle	26586-2444
1265/SA1	Spindle Assy	-
1260/SA1	Spindle Assy	-
1264/SA1	Spindle Assy	-

PLANT

1.	Wickman 3½ Dia. bar auto	1-off
2.	Herbert Senior 5 Preoptive-bar feeding	1-off
3.	Ward 2A - Modified	1-off
4.	Herbert 1 - Modified	1-off
5.	Power Press	1-off
6.	Fly Press	1-off
7.	Three spindle drill	1-off
8.	Vertical Mill	1-off
9.	Gear Hobber	1-off

COMPONENT & PLANT LIST FOR CELL G.T.6

Figure 25(f)

PLANT

1.	Winchester Plugboard Capstan Lathes	6-off
2.	Disc Linisher	1-off

PLANT LIST FOR CELL G.T.7

Figure 25(g)

Drawing No.	Description	Opitz No.
1244/1	Handle Arm	75043-4150
1245/1	" "	75043-4150
1246/1	" "	75041-4150
1251/1	" "	75041-4100
1365/1	" "	75043-4150
1366/1	" "	75041-4150
1367/1	" "	75041-4110
1372/1	" "	75041-4100

PLANT

1. Cincinnati 1-18 Mill 1-off
2. 3 Spindle Drill 1-off

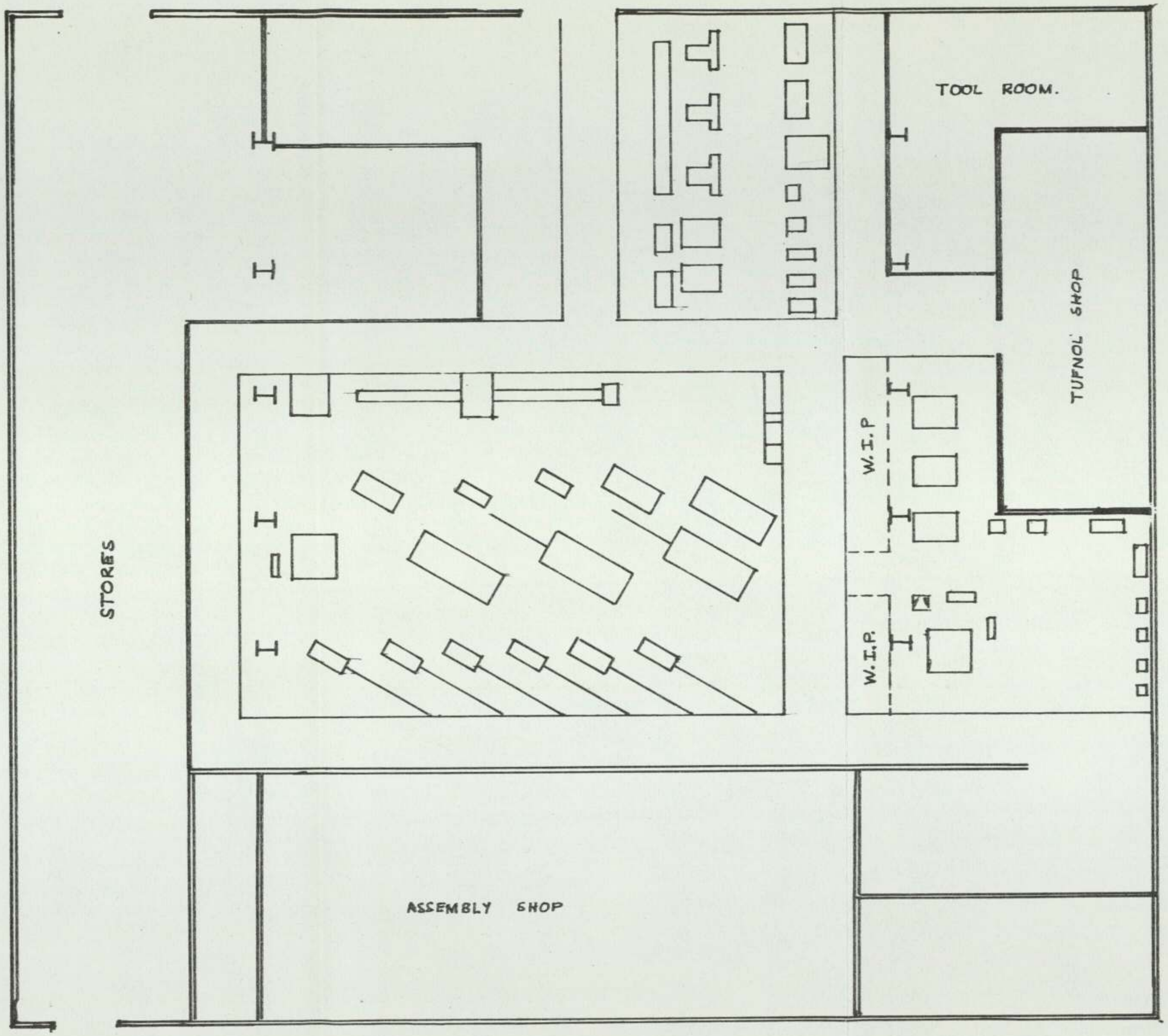
COMPONENT & PLANT LIST FOR CELL G.T.8

Figure 25(h)

Cell \ Machine	Canavese CG90	Needle Peen	Engraver	3/S Drill	4/S Drill	S/S Bench	Air Press	Nitcher	Gear Shaper	Canavese CG 180	Herb Broach	S/S Drill	Multi/S Drill	Wickman	Marlco Broach	Gear Hobber	Herbert 5 Air Chuck	Turret Drill	Vert Mill	Herbert 5 Bar Feed	Ward 2 A	Herbert 1	Power Press	3/S Drill (Auto)	Fly Press	Horiz Mill
Cell 1	1	1	1	1	1	1	1	1	2																	
Cell 2		1					1		2	1	1	1														
Cell 3												1	1													
Cell 4					1	1			1					1	1	1										
Cell 5		1	1														2	1	1						1	
Cell 6														1		1										
Cell 8				1																						1
Total Required	2	3	2	2	2	2	2	1	5	1	1	2	1	2	1	2	2	1	2	1	1	1	1	1	2	1
M/C Available	2	2	2	2	2	2	1	1	4	1	1	2	1	2	1	2	2	1	1	1	1	1	1	0	2	1
Balance	0	-1	0	0	0	0	-1	0	-1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	-1	0	0

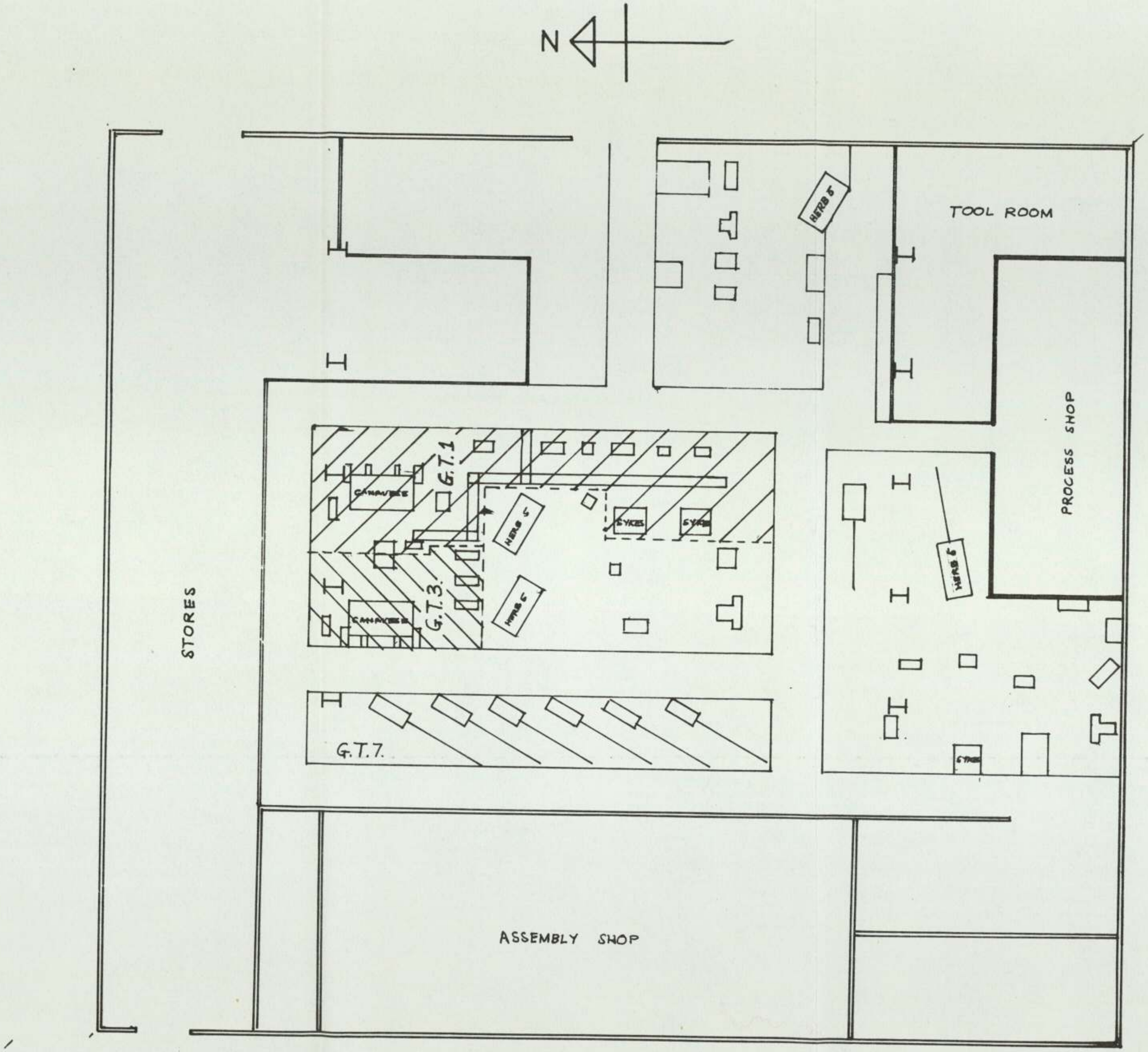
Total Machine Balance Sheet For All Cells

Figure 26



Factory Layout August 1974 - Before G.T.

Figure 27



Factory Layout September 1974 - After G.T.

Figure 28

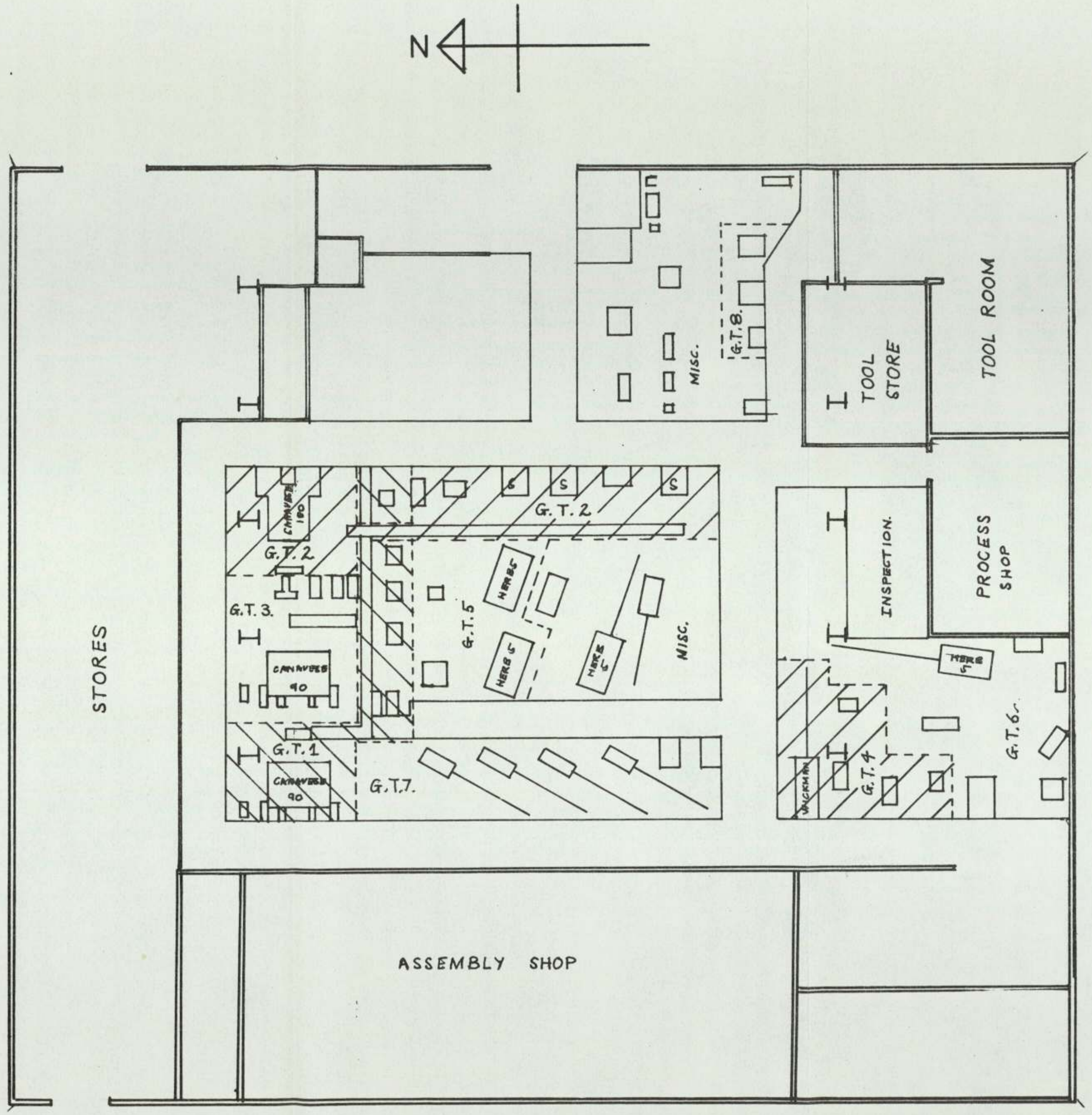
NAME	TYPE	PURCHASE DATE	CELL
Canavese CG902T	Lathe	May 73	1
Saalfeld Multi Spindle	Drill	Jan 74	3
Sykes V400	Gear Shaper	Mar 74	2
Sykes V10B	Gear Shaper	May 74	1
Canavese CG902T	Lathe	Aug 74	3
Saalfeld 1 Spindle	Drill	Oct 74	1
Saalfeld 1 Spindle	Drill	Oct 74	1
Herbert TM7	Broach	Nov 74	2
TOS OHO 20	Gear Shaper	Nov 74	4
Sykes H160	Gear Hobber	Feb 75	4
Sykes H160	Gear Hobber	Feb 75	6
Wickman 3½ Dia	Lathe	Feb 75	4
Canavese CG1802TL	Lathe	Mar 75	2
Wickman 3½ Dia	Lathe	Aug 75	6
Saalfeld 1 Spindle	Drill	Jly 75	2
Auto-Sprint	Lathe	Jan 76	7
Auto-Sprint	Lathe	Jan 76	7
Saalfeld 2 Spindle	Drill	Jan 76	3
Pollard 2 Spindle	Drill	May 76	4
Polland 2 Spindle	Drill	May 76	4
Saalfeld 2 Spindle	Drill	Aug 76	6
Wickman - Scrivener	Grinder	Aug 76	6
Hydro NC 540	Lathe	Aug 76	9
Hydro NC 540	Lathe	Aug 76	24

<u>PLANT PURCHASED 1973 to 1976</u> Figure 29

Dept. \ Date	Sept. 1974	May 1975	Feb. 1976	Sept. 1976
Stores	22	20	20	20
Process Shop	7	4	4	4
Gangways	20	20	20	20
Tool Room	6	6	6	6
Goods Inwards	6	3	3	3
Machinery	39	44	44	44
Tool Store	0	3	3	3

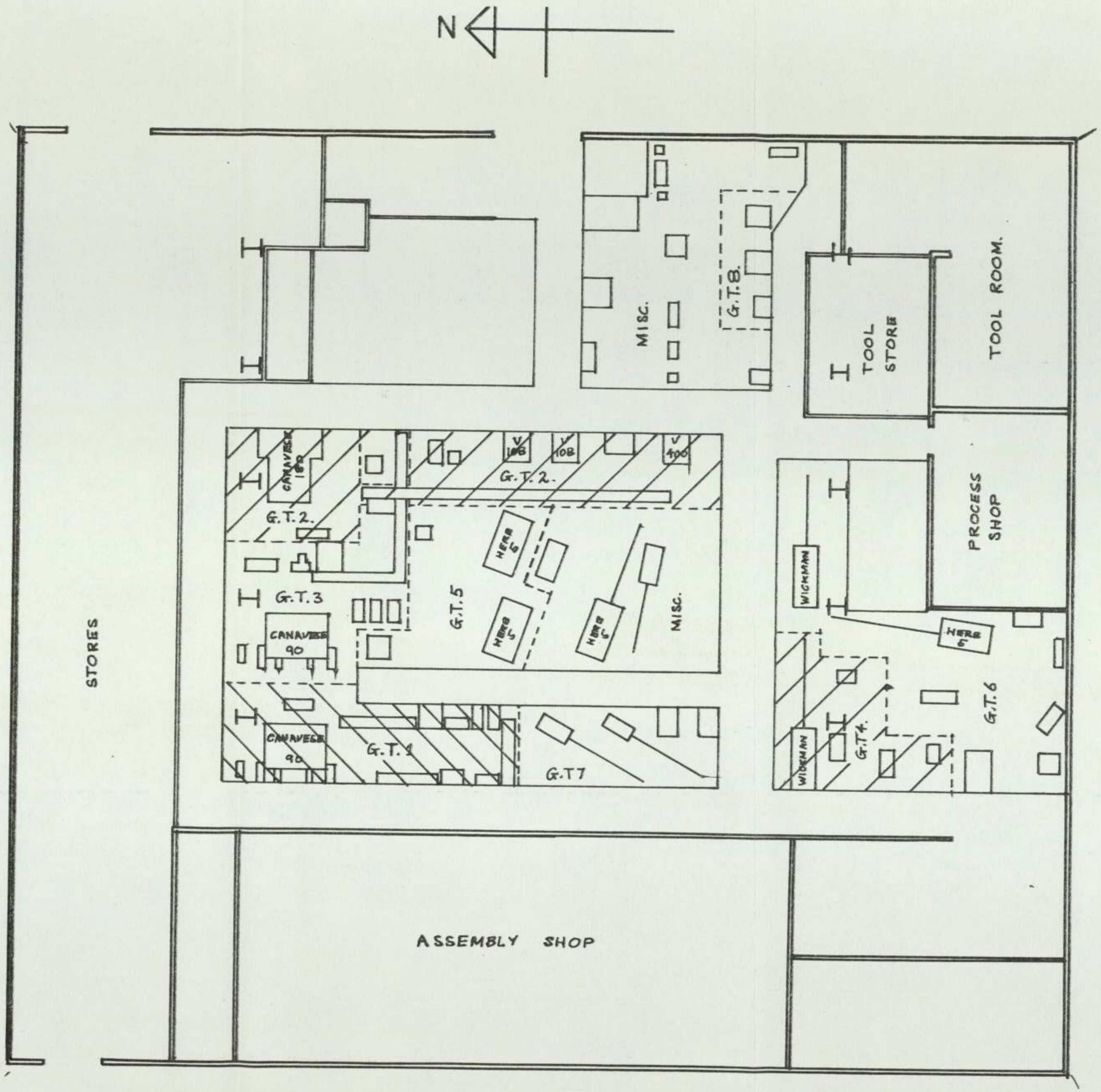
PERCENTAGE AREAS OF EACH DEPARTMENT

Figure 30



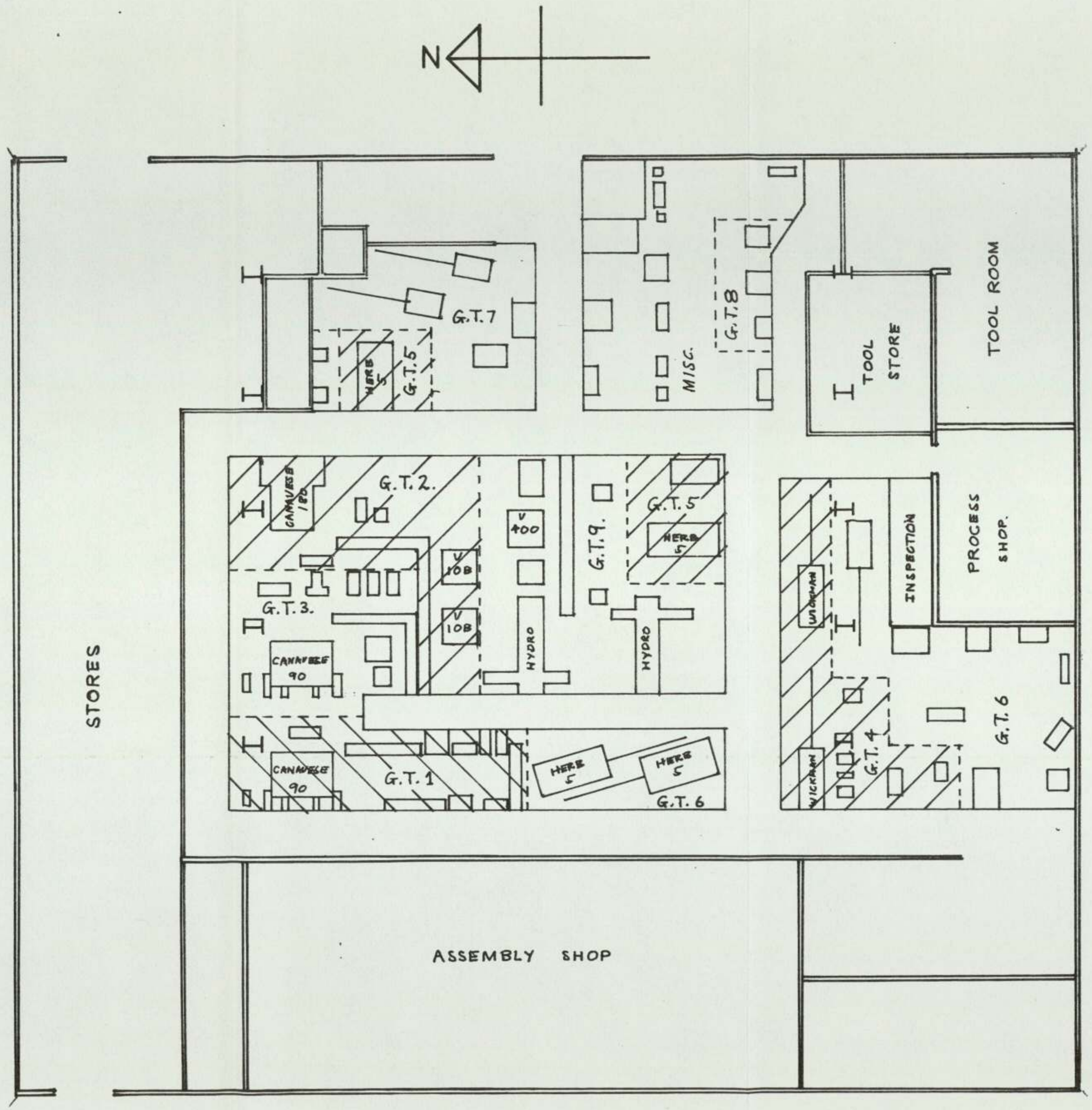
Factory Layout May 1975

Figure 31



Factory Layout February 1976

Figure 32



Factory Layout September 1976

Figure 33

Cell \ Date	Sept. 1974	May 1975	Feb. 1976	Sept. 1976
G.T.1	20	13	9	9
G.T.2	-	11	13	12
G.T.3	7	6	11	9
G.T.4	8	7	7	10
G.T.5	12	9	10	4
G.T.6	13	15	16	15
G.T.7	13	11	6	8
G.T.8	4	2	4	4
G.T.9	-	-	-	15
Miscellaneous	22	26	24	16

PERCENTAGE AREAS OF G.T. CELLS

Figure 34

MACHINE	QTY.
Canavese CG 90 2T	1
Needle Peen	1
Pollard 3 sp. drill	1
Saalfeld 1 sp. drill	2
Air Press	2
Nitching m/c	1

PLANT LIST - CELL GT1 - SEPT 1976

Figure 35(a)

MACHINE	QTY.
Canavese CG 180 2TL	1
Needle Peen	1
Saalfeld 2 sp. drill	1
Bench Drill	1
Air Press	1
Sykes Gear Shaper	2

PLANT LIST - CELL G.T.2 - SEPT 1976

Figure 35(b)

MACHINE	QTY.
Canavese CG 90 2T	1
Herbert 1 sp. drill	2
Saalfeld Multi sp. drill	1
Vertical Mill	1
Ward Lathe	1

PLANT LIST - CELL G.T. 3 - SEPT. 1976

Figure 35(c)

MACHINE		QTY.
4A	Wickman 3½ dia	2
4B	Sykes Gear Hobbs	1
	Marlco Broach	1
	Belt Linisher	1
4C	Bench Drill	1
	Pollard 2 sp. drill	2
	OHO Gear Shaper	1

PLANT LIST - CELL G.T.4 - SEPT. 1976

Figure 35(d)

MACHINE	QTY.
Herbert Sen.5 Capstan Lathe	2
Herbert 2 Capstan Lathe	1

PLANT LIST - CELL G.T.5 - SEPT. 1976

Figure 35(e)

MACHINE		QTY.
6A	Herbert 2D lathe	1
	Herbert Sen.5 lathe	2
6B	Sykes Gear Hobber	1
	Bench drill	1
	Ward lathe	1
	Fly Press	1
	Herbert 1 lathe	1
	Cincinnati Mill	1
	Rhodes Press	1
	Saalfeld 2 sp. drill	1
6C	Wickman - Scrivener Grinder	1

PLANT LIST - CELL G.T.6. - SEPT. 1976

Figure 35 (f)

MACHINE	QTY.
EMI-MEC Auto Sprint	2
Winchester lathe	2
Disc Linisher	1

PLANT LIST - CELL G.T.7 - SEPT. 1976

Figure 35 (g)

MACHINE	QTY
Cincinnati Mill	1
Edgwick Mill	1
Pollard 3 sp. drill	1
Bench Drill	1

PLANT LIST - CELL G.T.8 - SEPT 1976

Figure 35 (h)

MACHINE.		QTY
9A	Hydro NC 540 lathe	2
	Needle Peen	1
9B	Herbert Turret Drill	1
	Strigon Engraver	1
	Herbert Broach	1
	Sykes Gear Shaper	1

PLANT LIST - CELL G.T.9. - SEPT. 1976

Figure 35 (j)

CELL.	% Foreign Work
1	0
2	0
3	16
4	29
5	12
6	19
7	0
8	19
9	10

PERCENTAGE OF FOREIGN WORK IN CELLS

Figure 36

CELL	% Foreign Work
1	0
2	0
3	16
4A	16
4B	17
4C	0
5	12
6A	14
6B	6
6C	0
7	0
8	19
9A	0
9B	10

PERCENTAGE OF FOREIGN WORK IN SUB-DIVIDED CELLS

Figure 37

OLD METHOD

TURNED FROM BAR

1. Turn Blank
2. Countersink End - a
3. Broach Bi-square - b
4. Hob Ratchet Track - e

Opitz Code

16480 - 1244

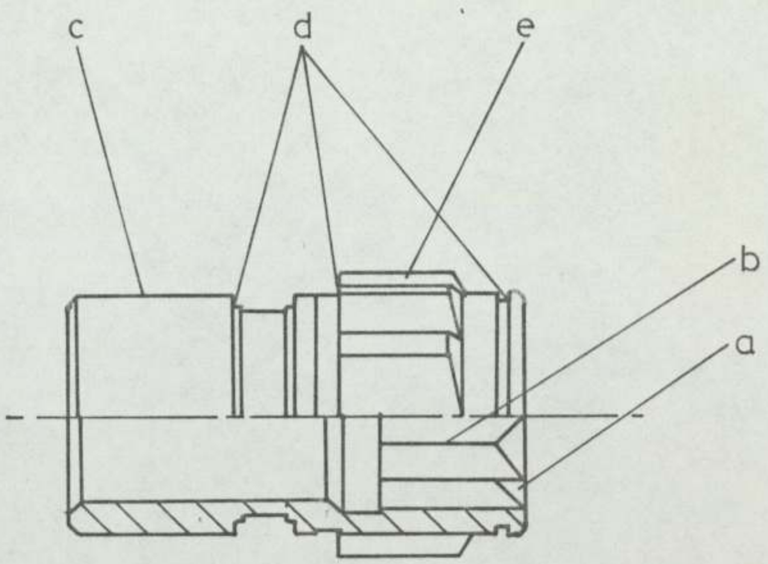
NEW METHOD

INVESTMENT CAST

1. Grind Dia. - c
2. Groove & Face - d

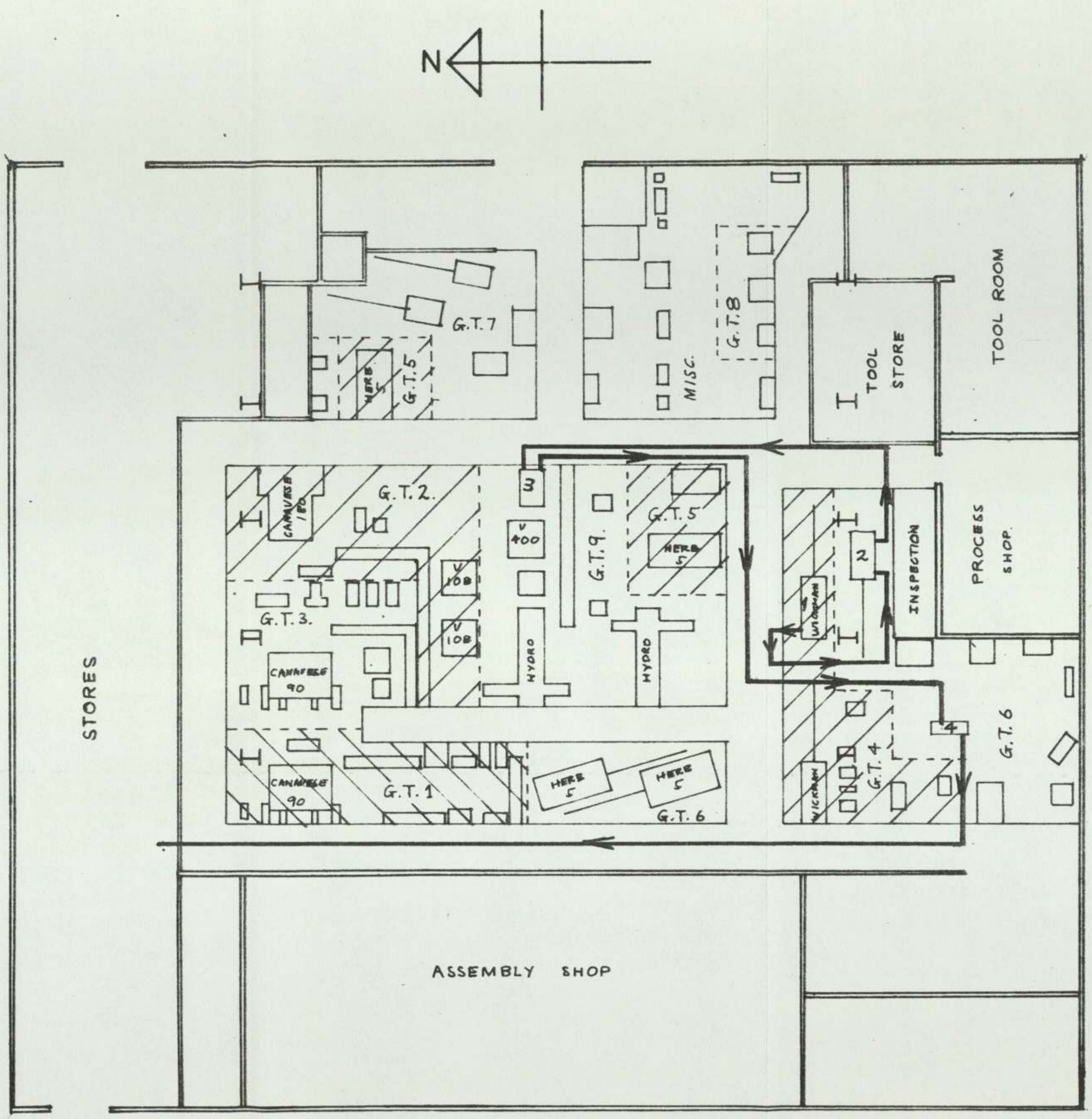
Opitz Code

16100 - 1240



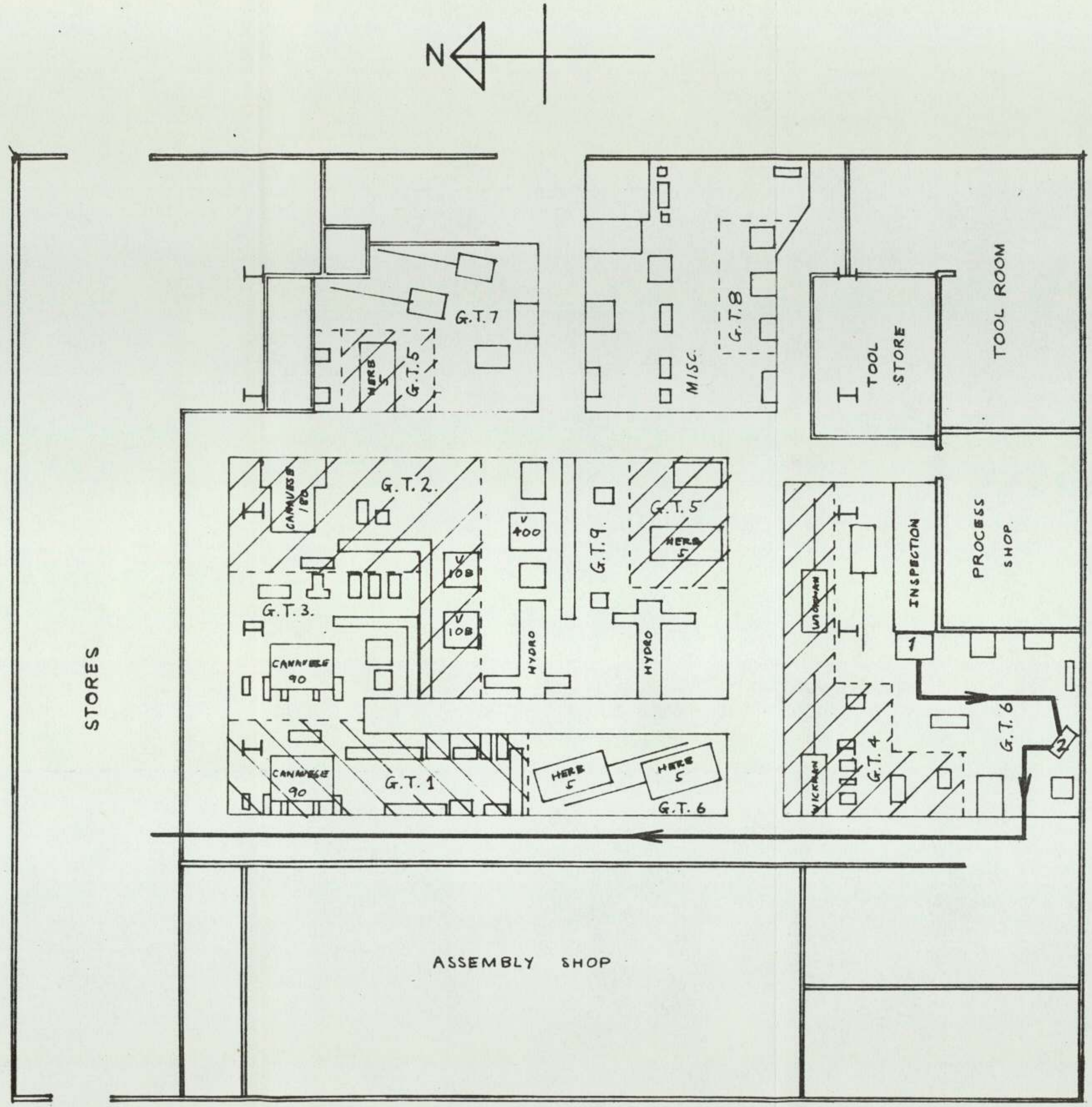
15008003 SPINDLE

Figure 38



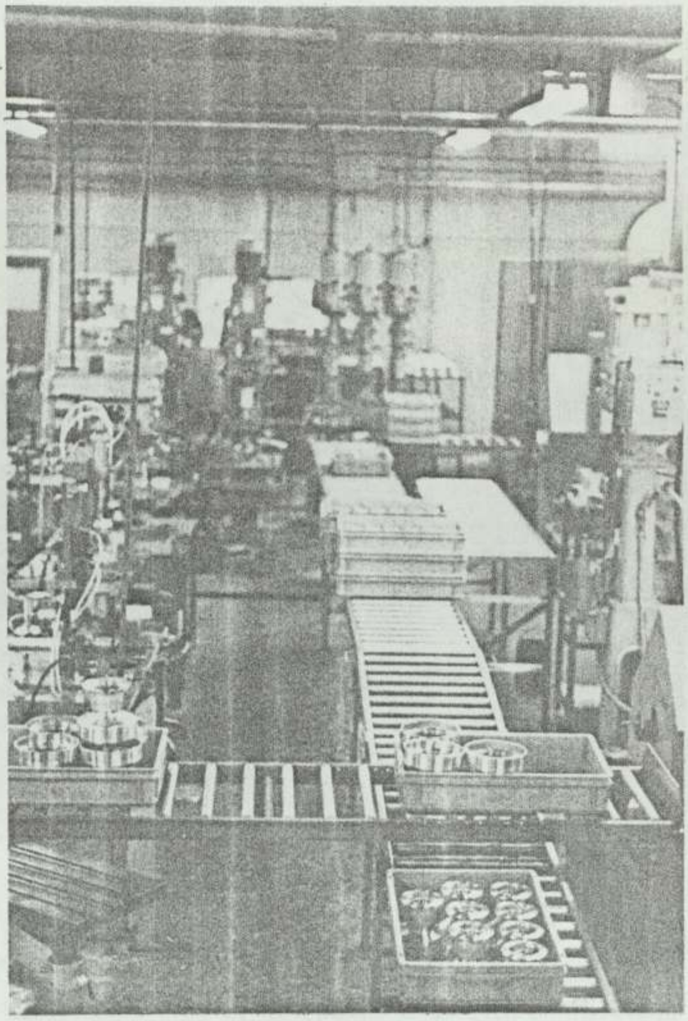
Route of Bar Turned 15008003 Spindle

Figure 39

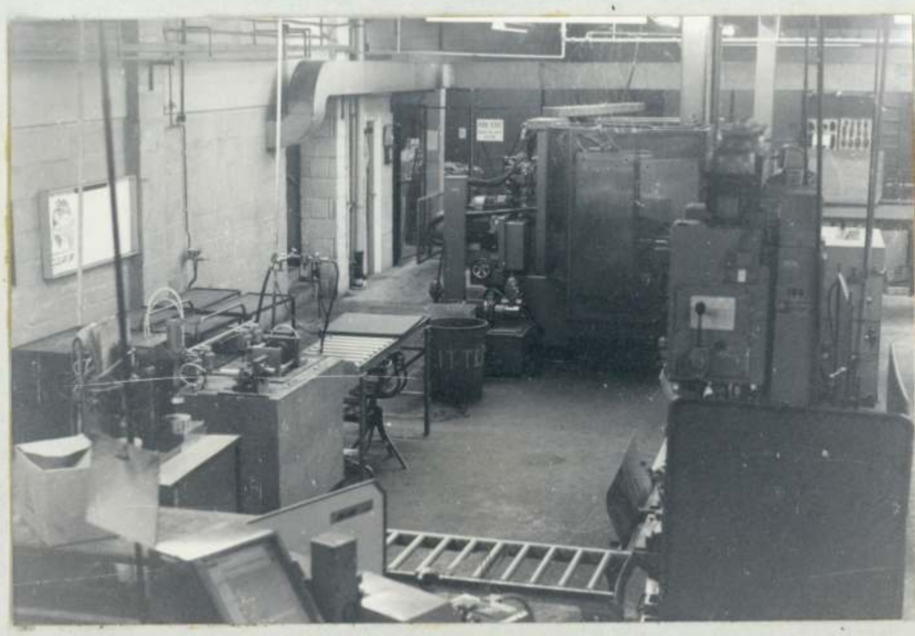


Route of Investment Cast 15008003 Spindle

Figure 40



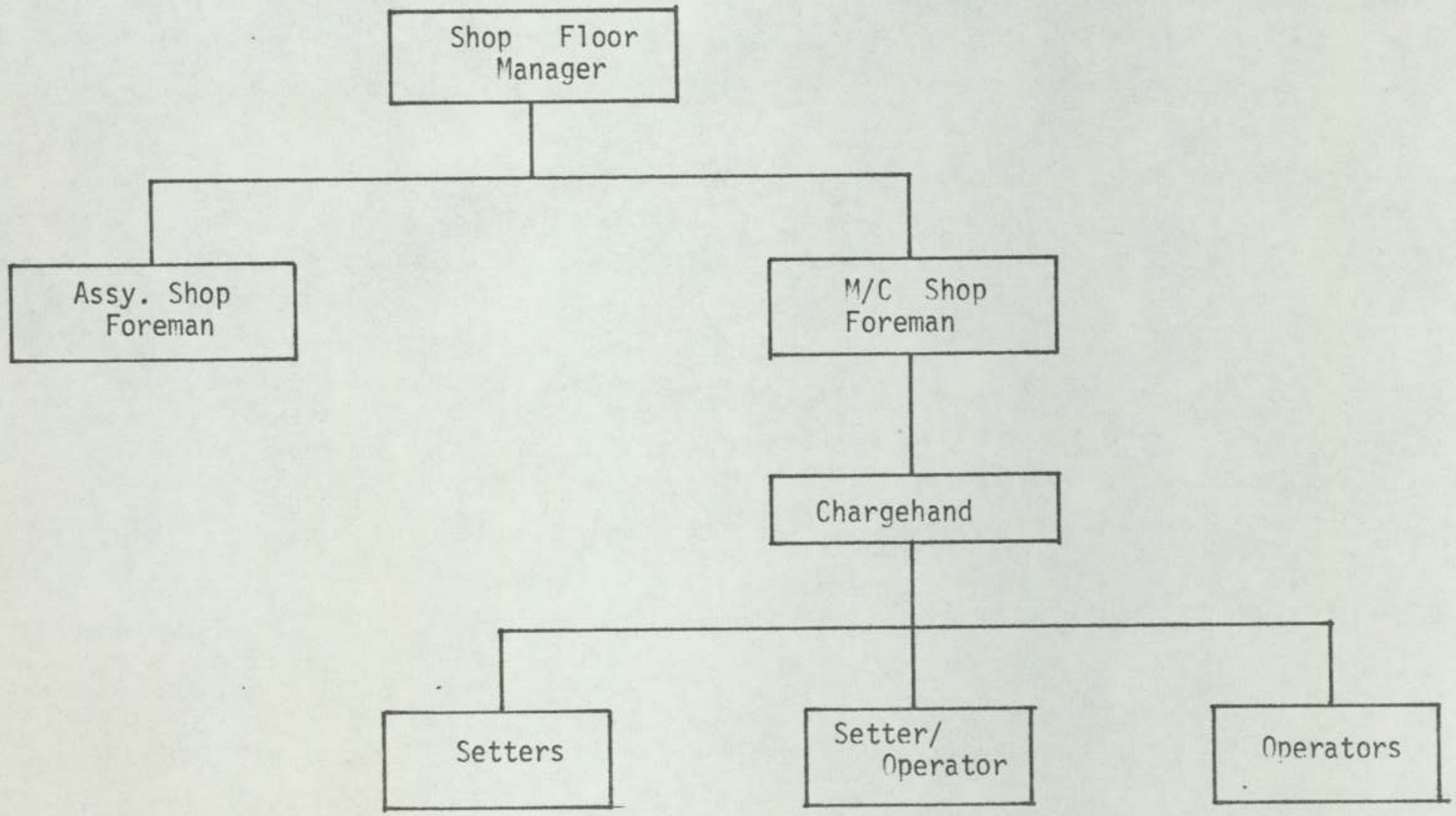
Before



After

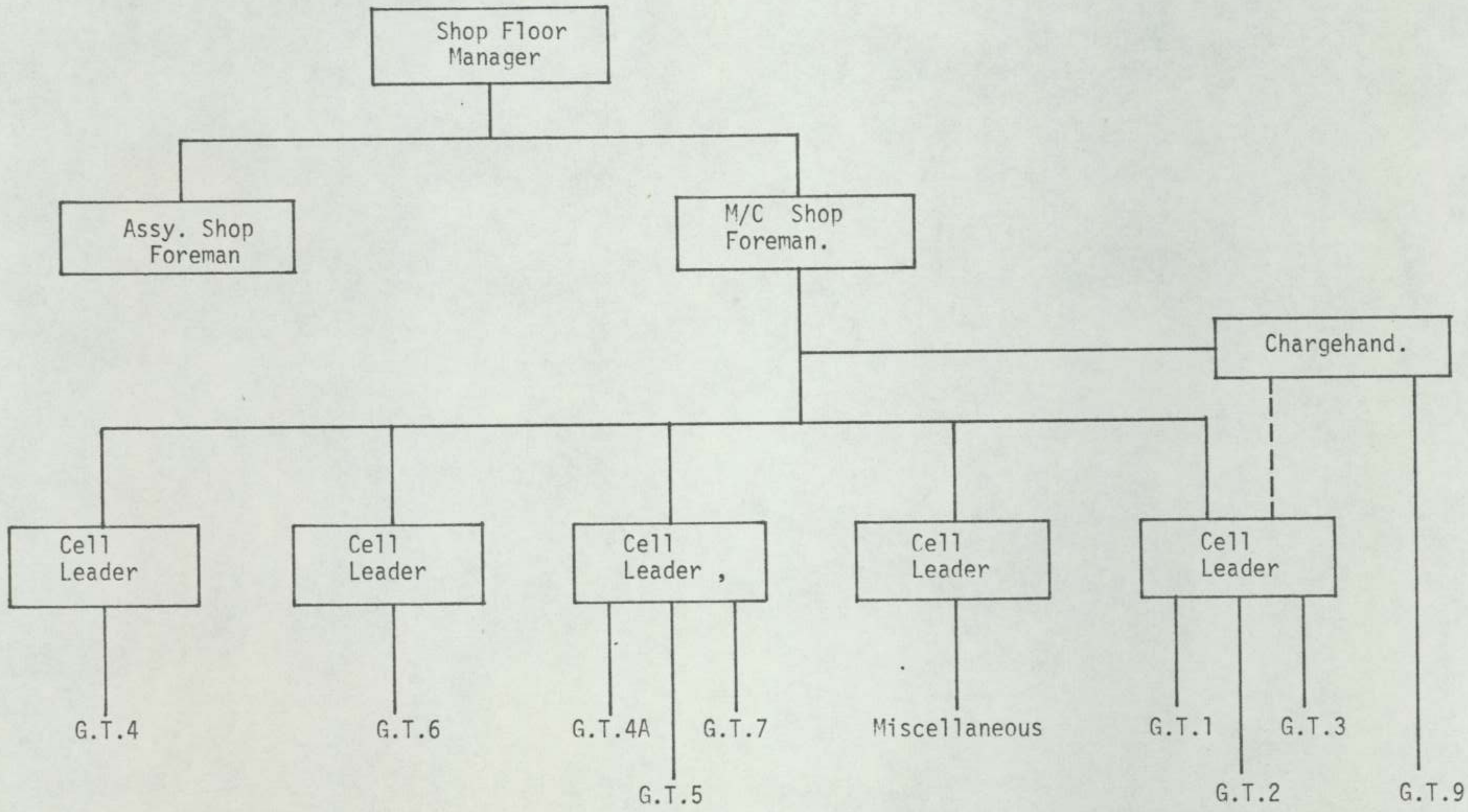
Cell G.T.1. Change to U-Shape

Figure 41



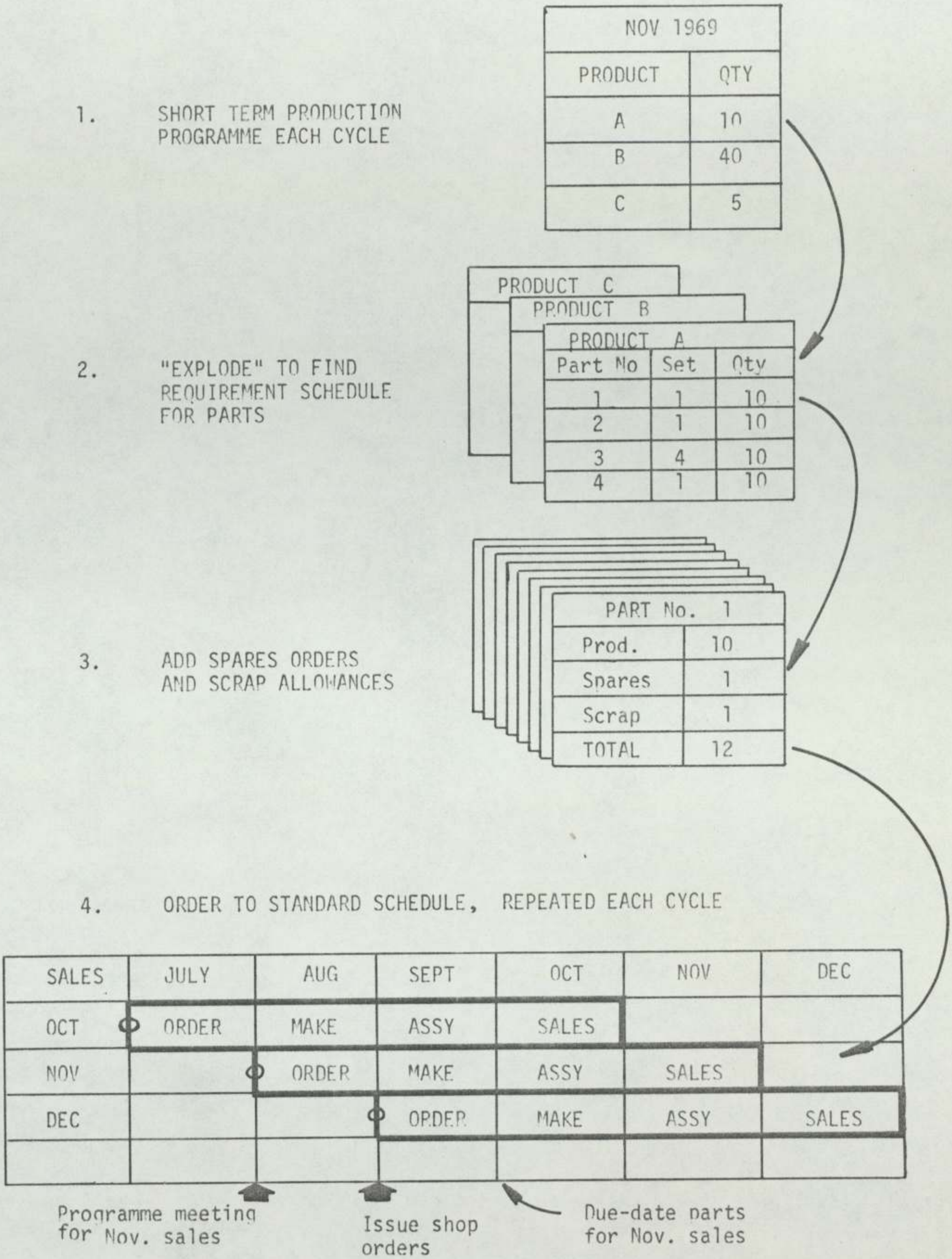
LEWMAR MACHINE SHOP STRUCTURE BEFORE G.T.

Figure 42.



LEWMAR MACHINE SHOP STRUCTURE AFTER G.T.

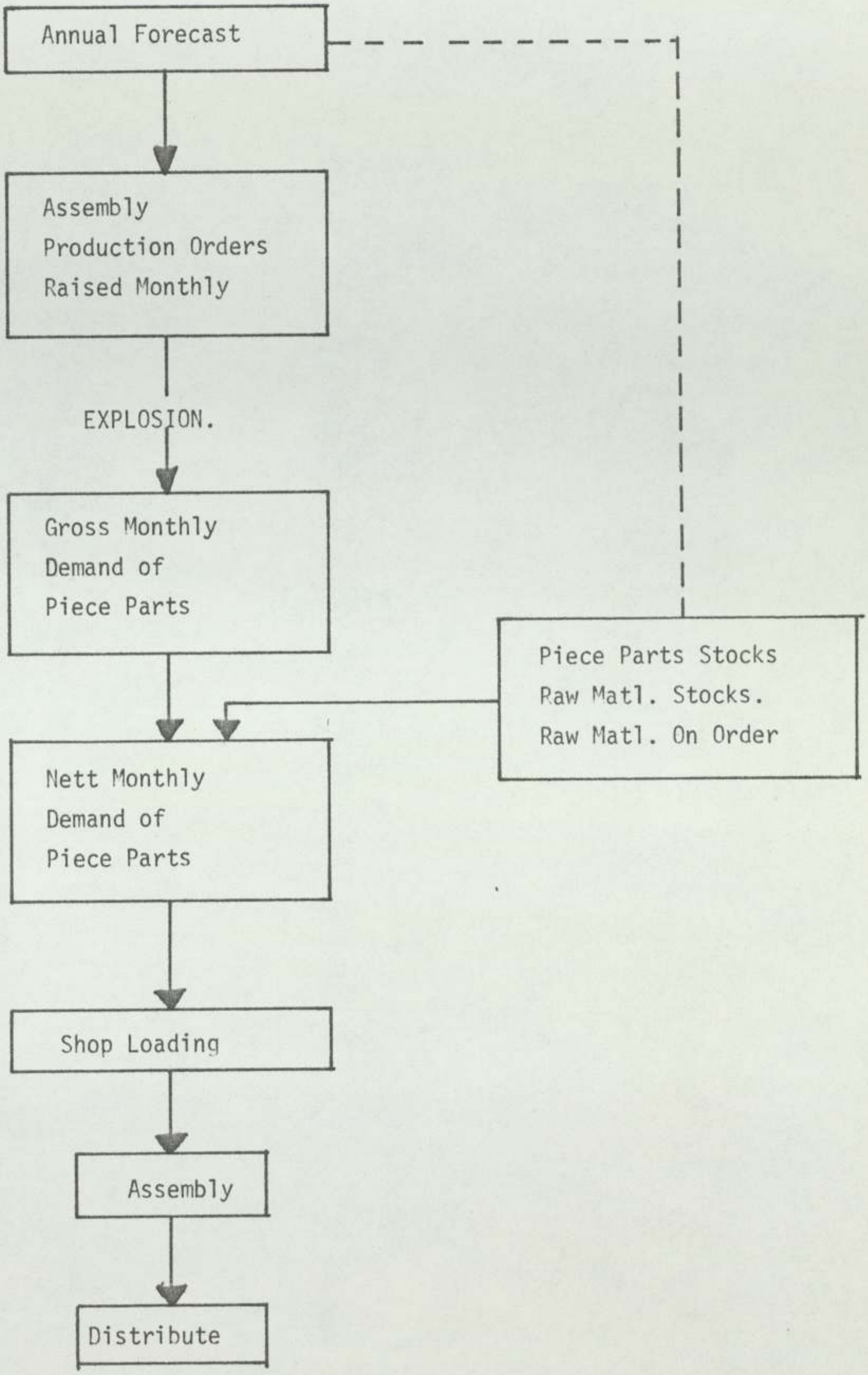
Figure 43.



Period Batch or Single Cycle Flow Control Ordering System

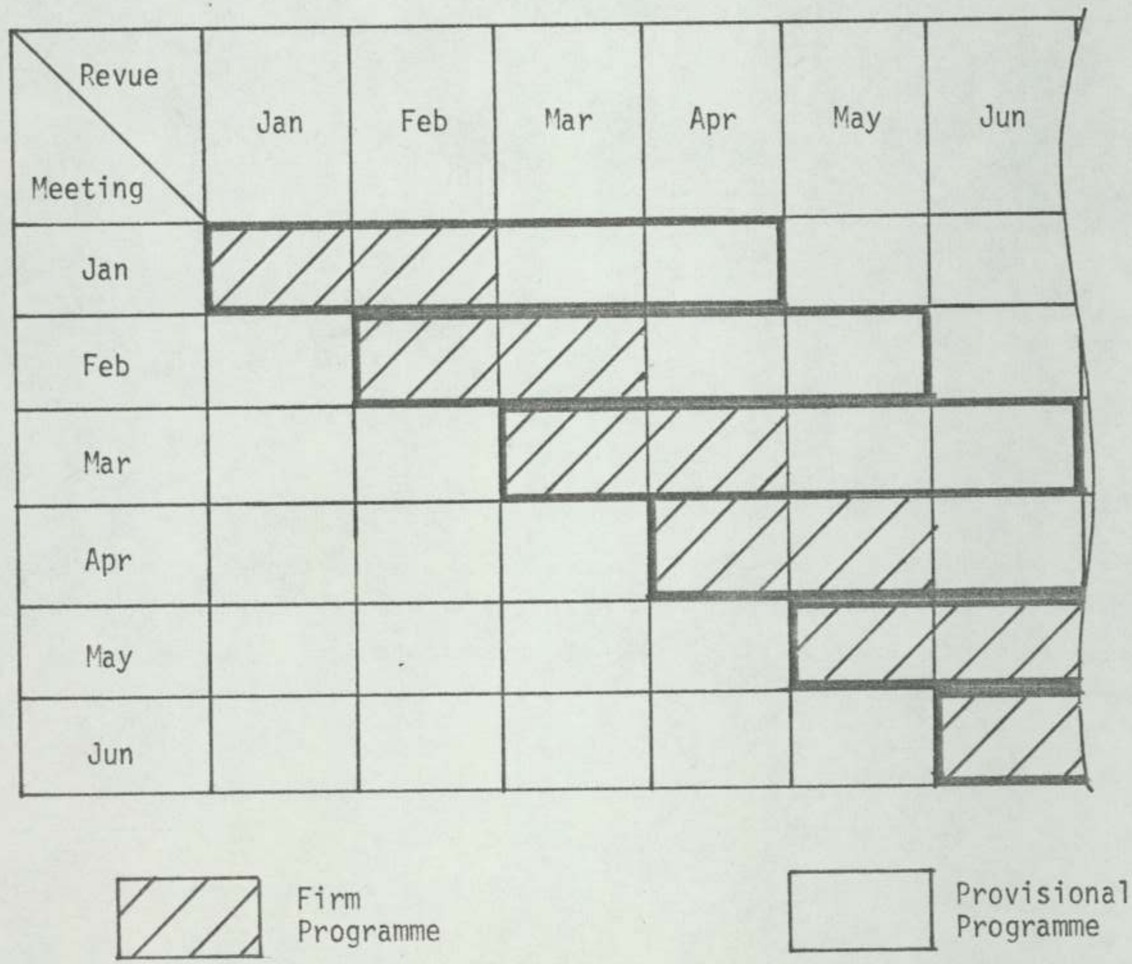
(after Burbidge)

Figure 44



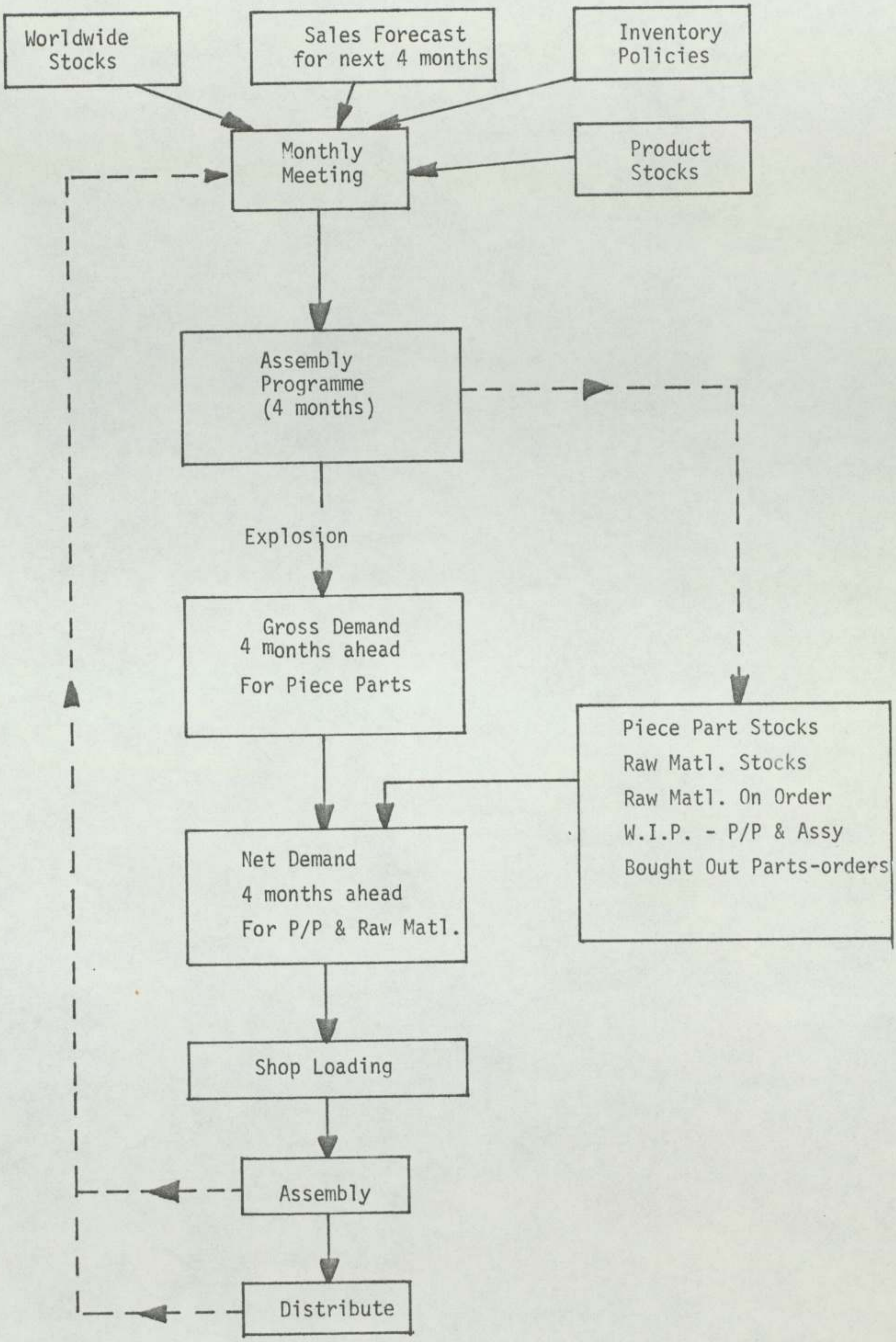
PRODUCTION CONTROL SYSTEM BEFORE G.T.

Figure 45.



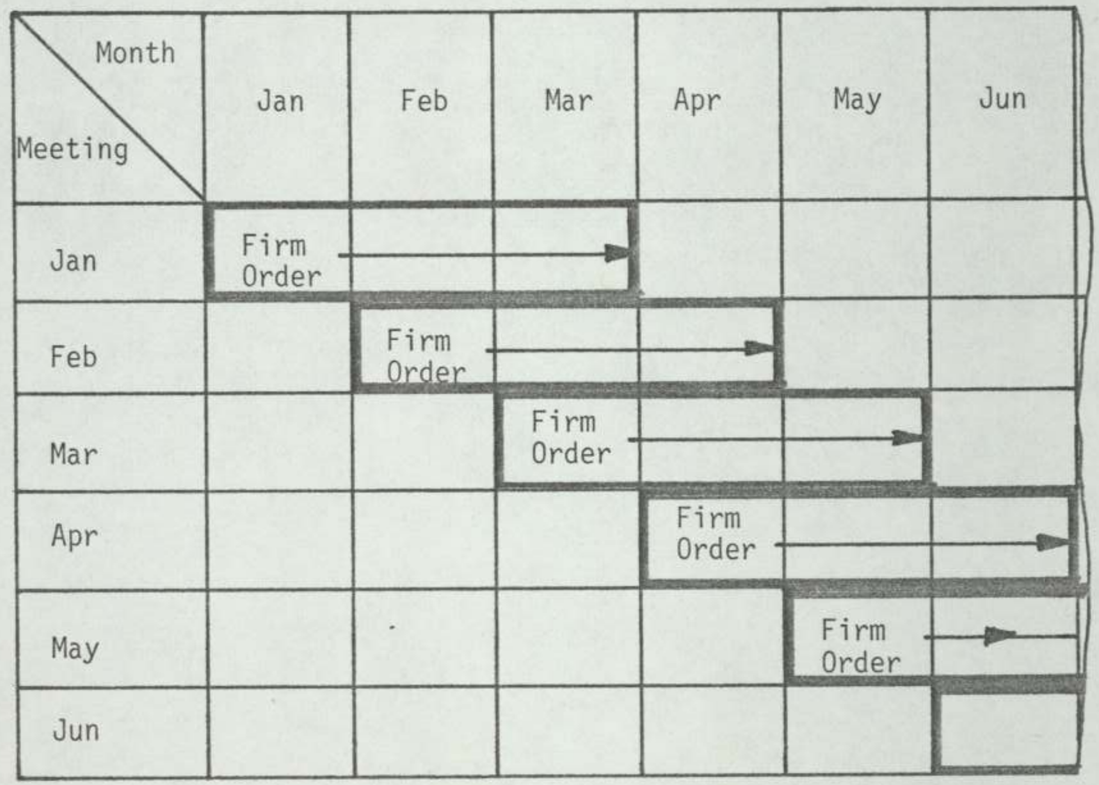
PATTERN OF SALES / PRODUCTION MONTHLY MEETINGS.

Figure 46.



GROUP TECHNOLOGY PRODUCTION CONTROL SYSTEM.

Figure 47.



RAW MATERIAL ADVANCING COMMITMENTS

Figure 48

Jan	Feb	Mar	Apr	May	Jun
Place Order (Quantity)	specify o sizes		Deliver	Deliver	Deliver

Order and Delivery Pattern for Bar Supplied by Rolling Mill

Figure 49

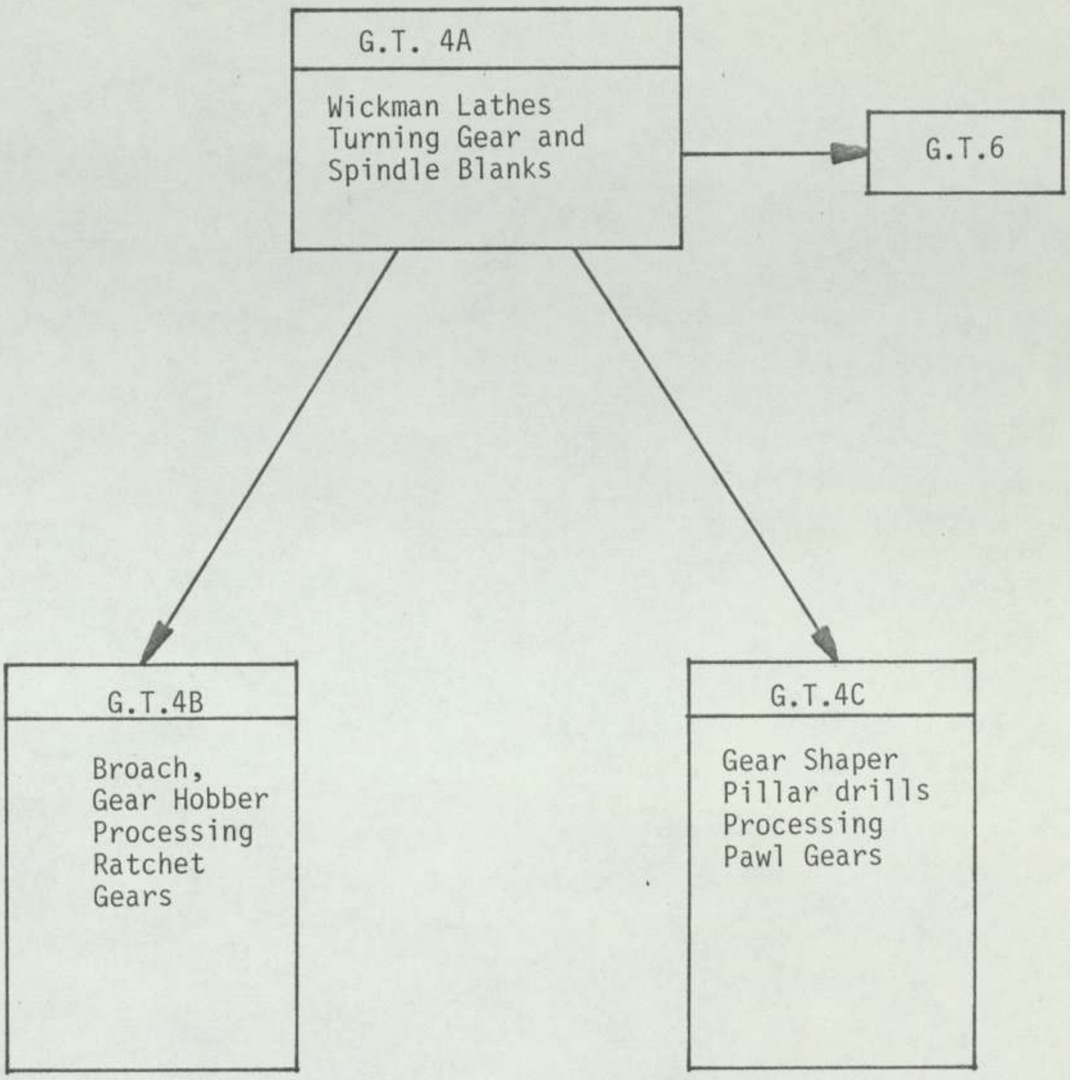


DIAGRAM SHOWING RELATIONSHIP BETWEEN SUB-DIVISIONS OF CELL G.T.4

Figure 50

SYSTEM REPORTS

1. Weekly usage update report.
2. 4 month demand - Piece Parts.
3. Inventory report - Finished Goods.
4. Piece Part Stock Report.
5. Product shortage immediate.
6. Current assembly status.
7. Inventory report - Piece Part W.I.P.
8. Inventory report - materials.
9. 4 month demand - Raw materials.

SYSTEM FILES

1. Stock file.
2. Assembly masterfile.
3. Used on file.
4. Materials file.

MANUAL INPUT

1. Assembly 4 month demand (sales).
2. Piece part stock.
3. Piece part W.I.P.
4. Finished goods stock.
5. Finished goods W.I.P.
6. Raw material stock.

ORIGINAL COMPUTER KIT MARSHALLING SYSTEM

Figure 51

FUNCTION

1. Stock evaluation
2. Stock enquiry
3. Stock listing : all parts
4. Stock listing : assemblies
5. Stock listing : sub-assemblies
6. Stock listing : piece parts
7. Stock listing : raw materials
8. Stock listing : redundant parts
9. Zeroise usage-to-date

COMPUTER INVENTORY CONTROL FUNCTIONS

Figure 52

FUNCTION

1. Stock transactions
2. Stock transactions print
3. Kit list

COMPUTER REQUIREMENTS PLANNING AND STOCK RECORDING

Figure 53

FUNCTION

1. Documentation
2. W.I.P. file layout
3. W.I.P. input
4. Time analysis
5. Scrap analysis
6. Group file maintenance
7. Group file layout

COMPUTER FACTORY DOCUMENTATION AND SHOP LOADING

Figure 54

FUNCTION

1. Input stock and W.I.P.
2. List input stock and W.I.P.
3. Demand input
4. Demand input print
5. Demand breakdown
6. Demand report - sub-assemblies
7. Demand report - piece parts
8. Demand report - raw materials
9. Demand enquiry - sub-assemblies
10. Demand enquiry - piece parts
11. Demand enquiry - raw materials
12. Stock report - assemblies
13. Stock report - sub-assemblies
14. Stock report - piece parts
15. Stock report - raw materials

LATEST COMPUTER KIT MARSHALLING FUNCTIONS

Figure 55

PROGRAM 4 MONTH DEMAND : RAW MATERIALS DATE PAGE 003

111211040 1.1/4 EN58J ROD FT

USED ON PIECE PARTS	DESCRIPTION	QUANTITY PER	DEMAND 1	DEMAND 2	DEMAND 3	DEMAND 4
1265/3	SPINDLE	0.3100	0.00	235.29	279.00	279.00
1264/3	SPINDLE	0.5450	0.00	29.43	228.90	190.75
1260/3	SPINDLE	0.4700	0.00	363.31	470.00	484.10
		TOTAL DEMAND	0.00	628.03	977.90	953.85
QTY. IN STOCK	123.00	SHORTAGE/SURPLUS	123.00	505.03-	1482.93-	2436.78-
(QTY. ON ORDER	2239.00)	VALUE AT STANDARD	369.00	1515.09	4448.79	7310.34
		VALUE AT CURRENT	0.00	0.00	0.00	0.00

Kit Marshalling Demand Report - Raw Materials

Figure 56

PROGRAM 4 MONTH DEMAND : PIECE PARTS DATE PAGE 132

15044105 CLUTCH PLATE

USED ON ASSEMBLIES	DESCRIPTION	QUANTITY PER		DEMAND 1	DEMAND 2	DEMAND 3	DEMAND 4
19044200	44/A WINCH ALLOY	1.0000		30.00	50.00	50.00	50.00
19044100	44/C WINCH BRONZE	1.0000		180.00	100.00	100.00	80.00
19044300	44/S WINCH STAINLESS	1.0000		0.00	10.00	0.00	10.00
19048200	48/C WINCH ALLOY	1.0000		70.00	40.00	40.00	30.00
19048100	48/C WINCH BRONZE	1.0000		100.00	50.00	100.00	50.00
19048300	48/S WINCH STAINLESS	1.0000		5.00	10.00	0.00	5.00
19055300	3 SPEED STAINLESS ST	1.0000		0.00	0.00	0.00	10.00
19065300	65/S WINCH STAINLESS	1.0000		6.00	0.00	0.00	4.00
19065200	65/A WINCH ALLOY	1.0000		30.00	15.00	10.00	10.00
19065100	65/C WINCH BRONZE	1.0000		0.00	0.00	0.00	10.00
19055200	55/A 3 SPEED WINCH	1.0000		50.00	30.00	30.00	20.00
19055100	55C 3 SPEED WINCH	1.0000		45.00	30.00	20.00	20.00
			TOTAL DEMAND	516.00	335.00	350.00	299.00
QTY. IN STOCK	570.00		SHORTAGE/SURPLUS	54.00	281.00-	631.00-	930.00-
WORK IN PROGRESS	486.00		SHORTAGE/SURPLUS	540.00	205.00	145.00-	444.00-

Figure 5

Kit Marshalling Demand Report - Piece Parts

PROGRAM 4 MONTH DEMAND : SUB-ASSEMBLIES DATE PAGE 008

1264/SA2 CAGE ASSY

USED ON ASSEMBLIES	DESCRIPTION	QUANTITY PER	DEMAND 1	DEMAND 2	DEMAND 3	DEMAND 4
19048600	48 SELF TAILING	1.0000	65.00	40.00	40.00	35.00
1364	43 STAINLESS WINCH	1.0000	0.00	0.00	0.00	20.00
1280	2X2 HALLIARD WINCH	1.0000	30.00	0.00	0.00	0.00
1294	43/A WINCH ALLOY	1.0000	320.00	150.00	100.00	100.00
19065500	65 SELF TAILING	1.0000	6.00	12.00	6.00	10.00
19065600	65 SELF TAILING	1.0000	5.00	10.00	10.00	10.00
19055500	55 SELF TAILING	1.0000	10.00	10.00	10.00	10.00
19055600	55 SELF TAILING	1.0000	30.00	15.00	10.00	10.00
19044200	44/A WINCH ALLOY	1.0000	30.00	50.00	50.00	50.00
19044100	44/C WINCH BRONZE	1.0000	180.00	100.00	100.00	80.00
19044300	44/S WINCH STAINLESS	1.0000	0.00	10.00	0.00	10.00
19044500	44 SELF TAILING	1.0000	65.00	50.00	40.00	40.00
19044600	44 SELF TAILING	1.0000	70.00	45.00	50.00	45.00
19048200	48/C WINCH ALLOY	1.0000	70.00	40.00	40.00	30.00
19048100	48/C WINCH BRONZE	1.0000	100.00	50.00	100.00	50.00
19048300	48/S WINCH STAINLESS	1.0000	5.00	10.00	0.00	5.00
19048500	48 SELF TAILING	1.0000	35.00	30.00	20.00	20.00
19055300	3 SPEED STAINLESS ST	1.0000	0.00	0.00	0.00	10.00
19065300	65/S WINCH STAINLESS	1.0000	6.00	0.00	0.00	4.00
19065200	65/A WINCH ALLOY	1.0000	30.00	15.00	10.00	10.00
19065100	65/C WINCH BRONZE	1.0000	0.00	0.00	0.00	10.00
1264	43/C WINCH BRONZE	1.0000	300.00	300.00	300.00	200.00
19055200	55/A 3 SPEED WINCH	1.0000	50.00	30.00	30.00	20.00
19055100	55C 3 SPEED WINCH	1.0000	45.00	30.00	20.00	20.00
		TOTAL DEMAND	1452.00	997.00	936.00	799.00
QTY. IN STOCK	1682.00	SHORTAGE/SURPLUS	230.00	767.00-	1703.00-	2502.00-
WORK IN PROGRESS	0.00	SHORTAGE/SURPLUS	230.00	767.00-	1703.00-	2502.00-

Kit Marshalling Demand Report - Sub-assemblies

Figure 58

Direct materials)		
Direct labour)	Prime Cost)	
Direct expenses)		
		Total Cost
Indirect materials)		
Indirect labour)	Overhead)	
Indirect expenses)		

TOTAL COST BREAKDOWN

Figure 59

1. Floor area occupied by cost centre.
2. Depreciation of machine in cost centre.
3. Power consumed in cost centre.
4. Proportions of total rates.
5. Supervison overhead.
6. Technical overhead (Design and Production Engineering).
7. Repairs and maintenance.
8. Heating.
9. Consumable tools.
10. Standard production hours available.

<u>FACTORS WHICH CONTRIBUTE TO OVERHEAD RATE</u>

Figure 60

CELL	OVERHEAD COST RATIO
1	11.46
2	14.12
3	6.41
4	6.68
5	7.72
6	7.23
7	2.11
8	1.00

<u>CELL OVERHEAD COST RATIO BEFORE SUB-DIVISION TAKING LOWEST AS UNITY</u>

Figure 61

Machine	Cost Ratio
Canavese lathe	150.0
Needle Peen M/C	8.5
Pollard 3 sp. drill	11.0
Saalfeld 1 sp drill	5.0
Saalfeld 1 sp drill	5.0
Air Press	1.0
Air Press	1.0
Nitching M/C	4.3

CELL G.T.1 MACHINE COST RATIO TAKING LOWEST AS UNITY.

Figure 62.

Cost Centre	Overhead Rate Ratio
Cell 1	4.43
Cell 2	7.43
Cell 3	5.66
Cell 4A	1.43
Cell 4B	2.13
Cell 4C	1.97
Cell 5	1.32
Cell 6A	1.32
Cell 6B	4.52
Cell 6C	2.41
Cell 7	1.00
Cell 8	1.79
Cell 9A	6.70
Cell 9B	5.63

CELL OVERHEAD RATES AS A RATIO TAKING THE LOWEST AS UNITY

Figure 63

PRODUCT STRUCTURE LISTING

RUN DATE

PAGE 1

PRODUCT	DESCRIPTION	TYPE	B/O	STANDARD COST DIR. MAT.	STANDARD COST DIR. LAB.	STANDARD COST VAR. O/H.	STANDARD COST FIX. O/H.	CURRENT COST DIR. MAT.	CURRENT COST DIR. LAB.	CURRENT COST VAR. O/H.	CURRENT COST FIX. O/H.
1254	25/A WINCH ALLOY	1		-.—	-.—	-.—	-.—	-.—	-.—	-.—	-.—

COMPONENT NO.	DESCRIPTION	QUANTITY
15001012	PAWL	2.0000
1265/SA2	CAGE ASSY	2.0000
R2075	CIRCLIP	1.0000
1265/SA1	25 SPINDLE SUB ASSY	1.0000
1265/5	RATCHET GEAR	1.0000
1265/1	CENTRE STEM	1.0000
1254/2	DRUM	1.0000
1265/4	PAWL GEAR	1.0000
1265/6	GEAR SPINDLE	1.0000
1265/7	GEAR WASHER	1.0000
15010006	TOP CAP	1.0000
1260/7	SPRING	4.0000
1260/10	THRUST WASHER	1.0000
1260/8	PAWL	2.0000
1260/19	TAB WASHER	1.0000
1300/19	WASHER	1.0000

OP. NO.	COST CENTRE	DESCRIPTION	MAN TIME	.MACHINE
1	CAW	ASSEMBLY WINCHES	-.—	-.—

END OF PRODUCT STRUCTURE LISTING

Assembly Product Structure Listing

Figure 64(a)

PRODUCT STRUCTURE LISTING

RUN DATE

PAGE 1

PRODUCT	DESCRIPTION	TYPE	B/O	STANDARD COST DIR. MAT.	STANDARD COST DIR. LAB.	STANDARD COST VAR. O/H.	STANDARD COST FIX. O/H.	CURRENT COST DIR. MAT.	CURRENT COST DIR. LAB.	CURRENT COST VAR. O/H.	CURRENT COST FIX. O/H.
1254/2	DRUM	3		-.—	-.—	-.—	-.—	-.—	-.—	-.—	-.—

COMPONENT NO.	DESCRIPTION	QUANTITY
13125402	1254/2C CASTING	1.0000

OP. NO.	COST CENTRE	DESCRIPTION	MAN TIME	.MACHINE
1	C2	CELL 2	-.—	-.—
2	GPL	POLISHING	-.—	-.—
3	GAN	ANODISING	-.—	-.—

END OF PRODUCT STRUCTURE LISTING

Piece Part Product Structure Listing

Figure 64(b)

PRODUCT STANDARD COST   RUN DATE   PAGE 1

PRODUCT 1254/2 DRUM

COMPONENT NO.	DESCRIPTION	DIR. MATERIAL	DIR. LABOUR	VARIABLE O/H	FIXED O/H	TOTAL
13125402	1254/2C CASTING	-.—	-.—	-.—	-.—	-.—
	TOTAL	-.—	-.—	-.—	-.—	-.—

OP. NO.	COST CENTRE	DESCRIPTION	DIR. MATERIAL	DIR. LABOUR	VARIABLE O/H	FIXED O/H	TOTAL
1	C2	CELL 2		-.—	-.—	-.—	-.—
2	GPL	POLISHING		-.—	-.—	-.—	-.—
3	GAN	ANODISING		-.—	-.—	-.—	-.—
		ASSEMBLY COST		-.—	-.—	-.—	-.—
		TOTAL COST	-.—	-.—	-.—	-.—	-.—

END OF PRODUCT STANDARD COST SHEET

Piece Part Standard Cost Sheet

Figure 65

PRODUCT STANDARD COST

RUN DATE

PRODUCT 1254 25/A WINCH ALLOY

COMPONENT NO.	DESCRIPTION	DIR. MATERIAL	DIR. LABOUR	VARIABLE O/H	FIXED O/H	TOTAL
15001012	PAWL	-.—	-.—	-.—	-.—	-.—
1265/SA2	CAGE ASSY	-.—	-.—	-.—	-.—	-.—
82075	CIRCLIP	-.—	-.—	-.—	-.—	-.—
1265/SA1	25 SPINDLE SUB ASSY	-.—	-.—	-.—	-.—	-.—
1265/5	RATCHET GEAR	-.—	-.—	-.—	-.—	-.—
1265/1	CENTRE STEM	-.—	-.—	-.—	-.—	-.—
1254/2	DRUM	-.—	-.—	-.—	-.—	-.—
1265/4	PAWL GEAR	-.—	-.—	-.—	-.—	-.—
1265/6	GEAR SPINDLE	-.—	-.—	-.—	-.—	-.—
1265/7	GEAR WASHER	-.—	-.—	-.—	-.—	-.—
15010006	TOP CAP	-.—	-.—	-.—	-.—	-.—
1260/7	SPRING	-.—	-.—	-.—	-.—	-.—
1260/10	THRUST WASHER	-.—	-.—	-.—	-.—	-.—
1260/8	PAWL	-.—	-.—	-.—	-.—	-.—
1260/19	TAB WASHER	-.—	-.—	-.—	-.—	-.—
1300/19	WASHER	-.—	-.—	-.—	-.—	-.—
	TOTAL	-.—	-.—	-.—	-.—	-.—

OP. NO.	COST CENTRE	DESCRIPTION	DIR. MATERIAL	DIR. LABOUR	VARIABLE O/H	FIXED O/H	TOTAL
1	CAW	ASSEMBLY WINCHES		-.—	-.—	-.—	-.—
		ASSEMBLY COST		-.—	-.—	-.—	-.—
		TOTAL COST	-.—	-.—	-.—	-.—	-.—

END OF PRODUCT STANDARD COST SHEET

Assembly Standard Cost Sheet

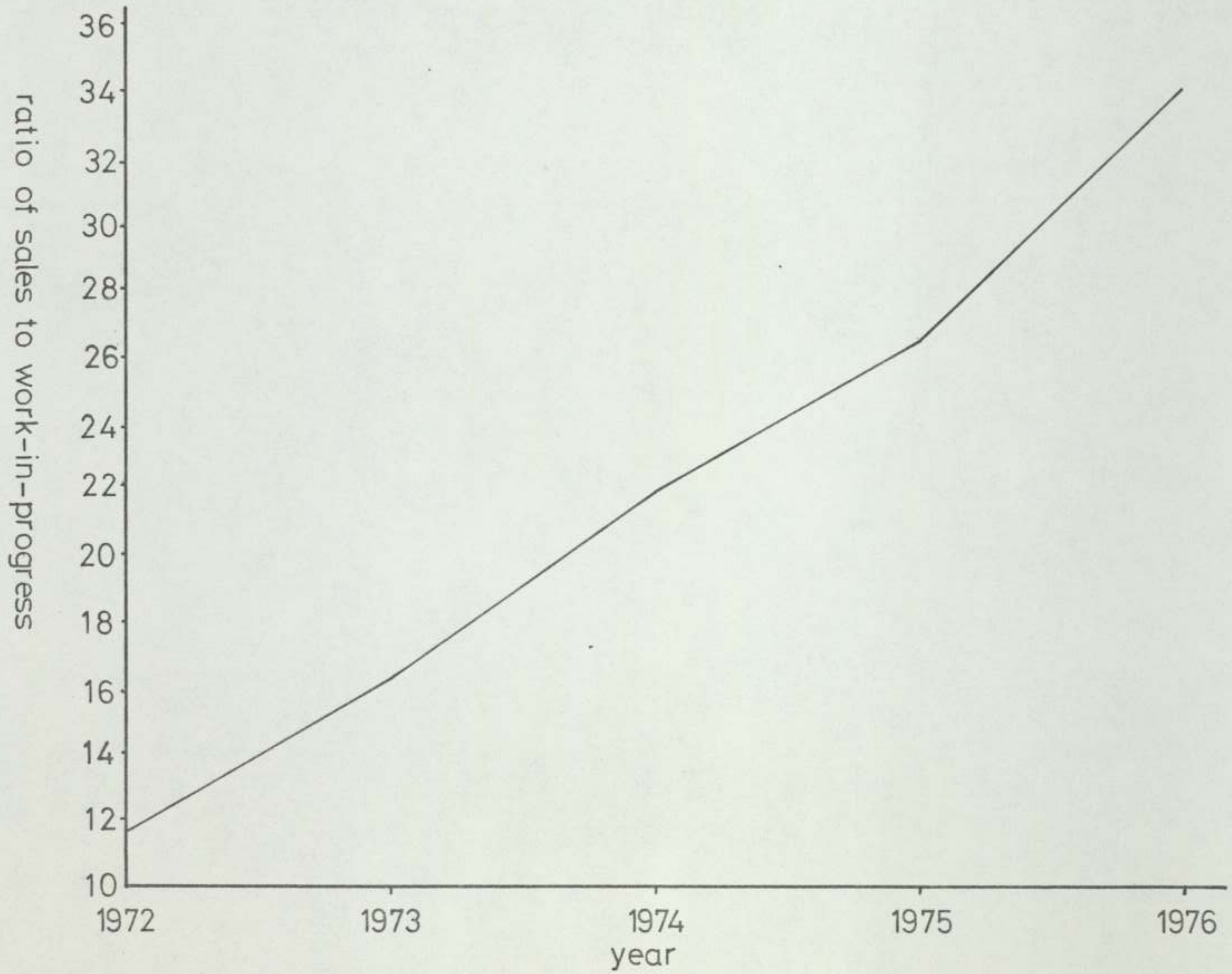
Figure 66

Year / Area of Activity	1972	1973	1974	1975	1976	1977 Projected.
Sales	1	1.49	3.4o	2.16	3.36	5.31
Labour	1	1.22	1.92	1.93	1.97	2.45
Stock	1	1.63	3.oo	2.o8	2.79	2.52
Work-in-Progress	1	1.o7	1.16	0.96	1.16	n.a.
Stock + W.I.P.	1.	1.49	2.53	1.79	2.27	n.a.
Ratios						
Sales / Labour	1	1.33	1.56	2.11	3.46	4.9
Sales / Stock	1	0.91	0.71	1.o4	1.21	2.10
Sales / W.I.P.	1	1.39	1.87	2.25	2.9o	n.a.
Sales / Stock + W.I.P.	1	1.00	0.85	1.21	1.42	n.a.

PERFORMANCE INDEX FIGURES RELATIVE TO UNITY IN 1972.

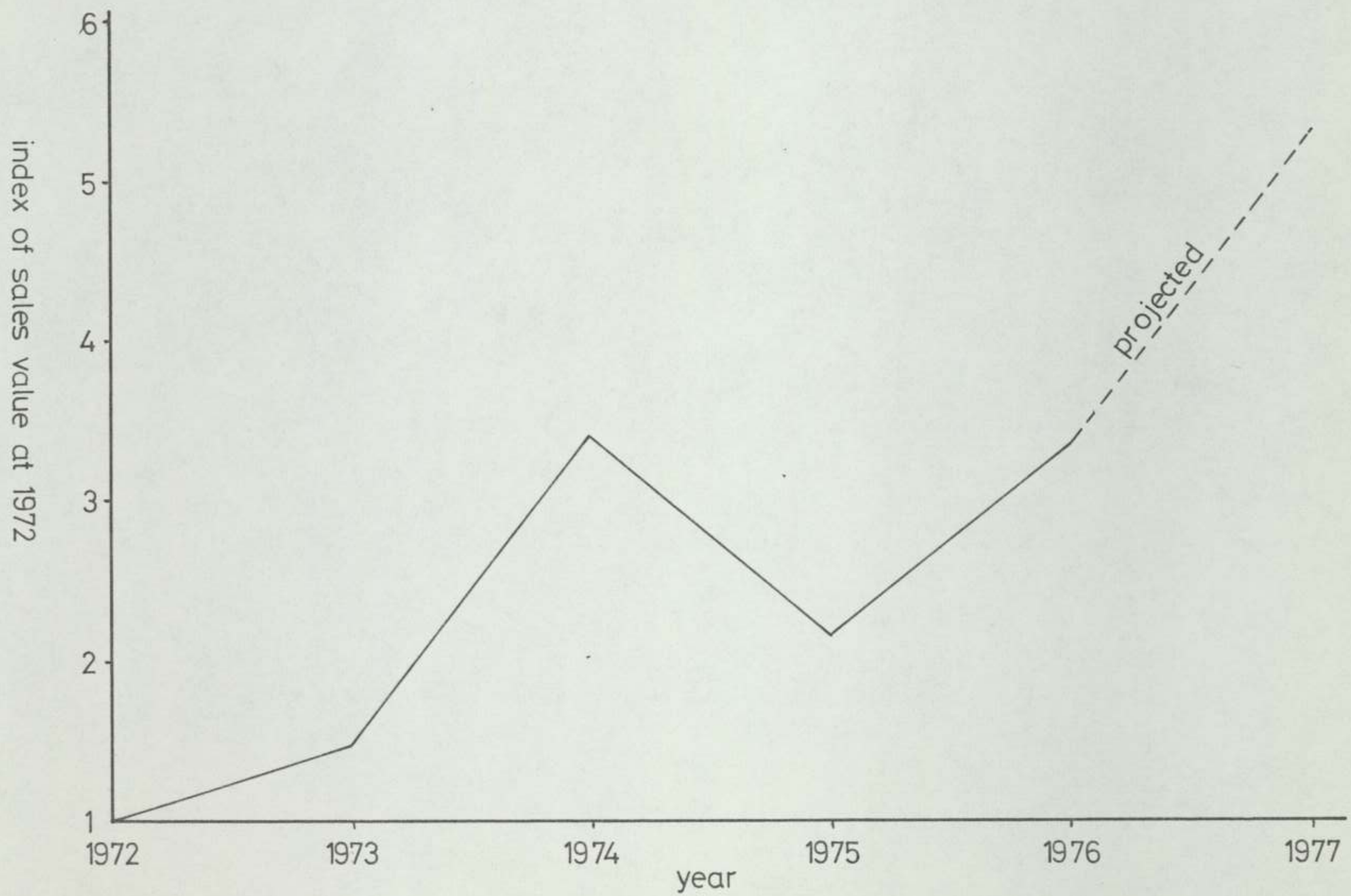
GROUP TECHNOLOGY STARTED DURING 1975

Figure 67.



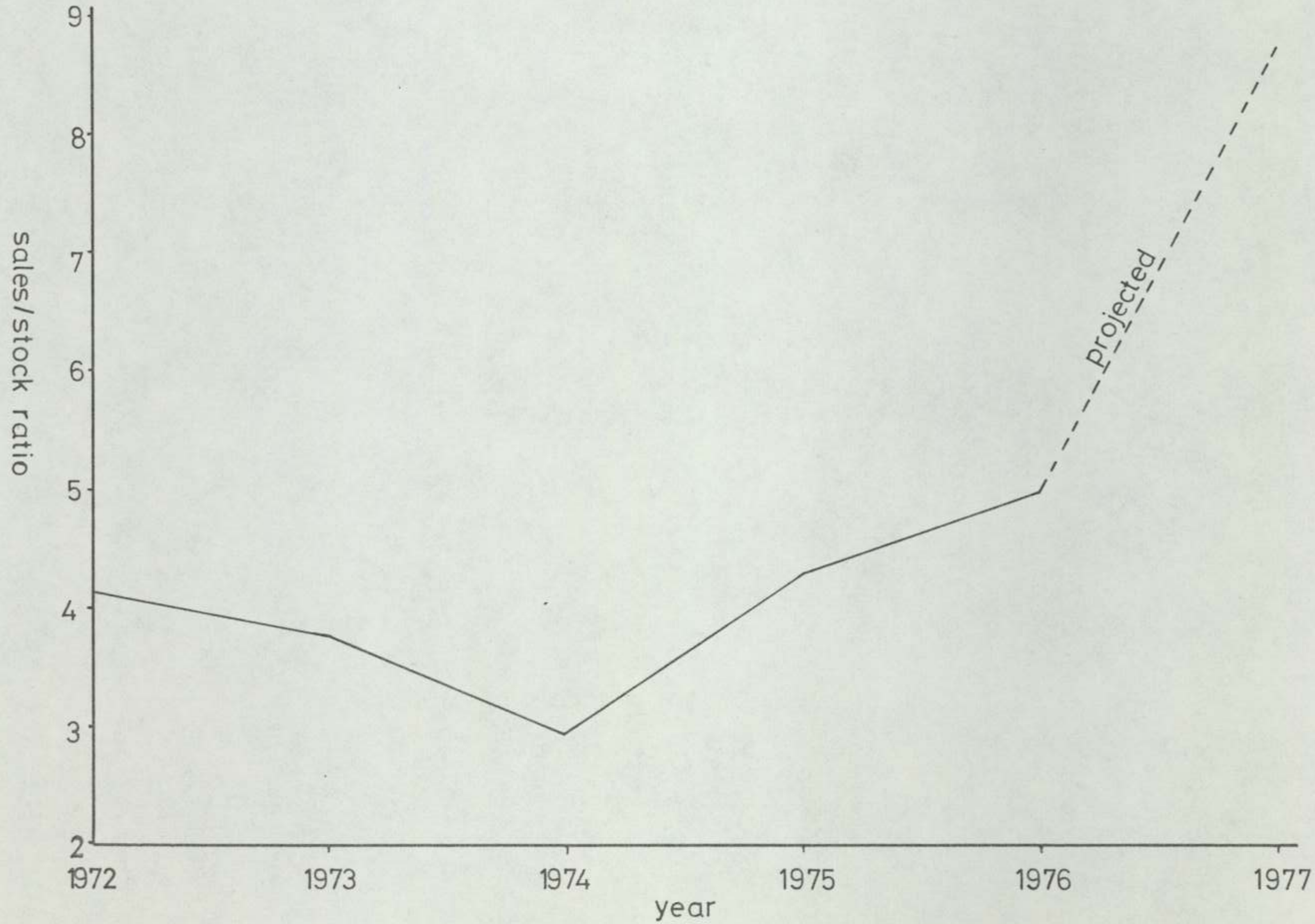
Variation of Sales/Work-in-progress Ratio From 1972 to 1976

Figure 6.8



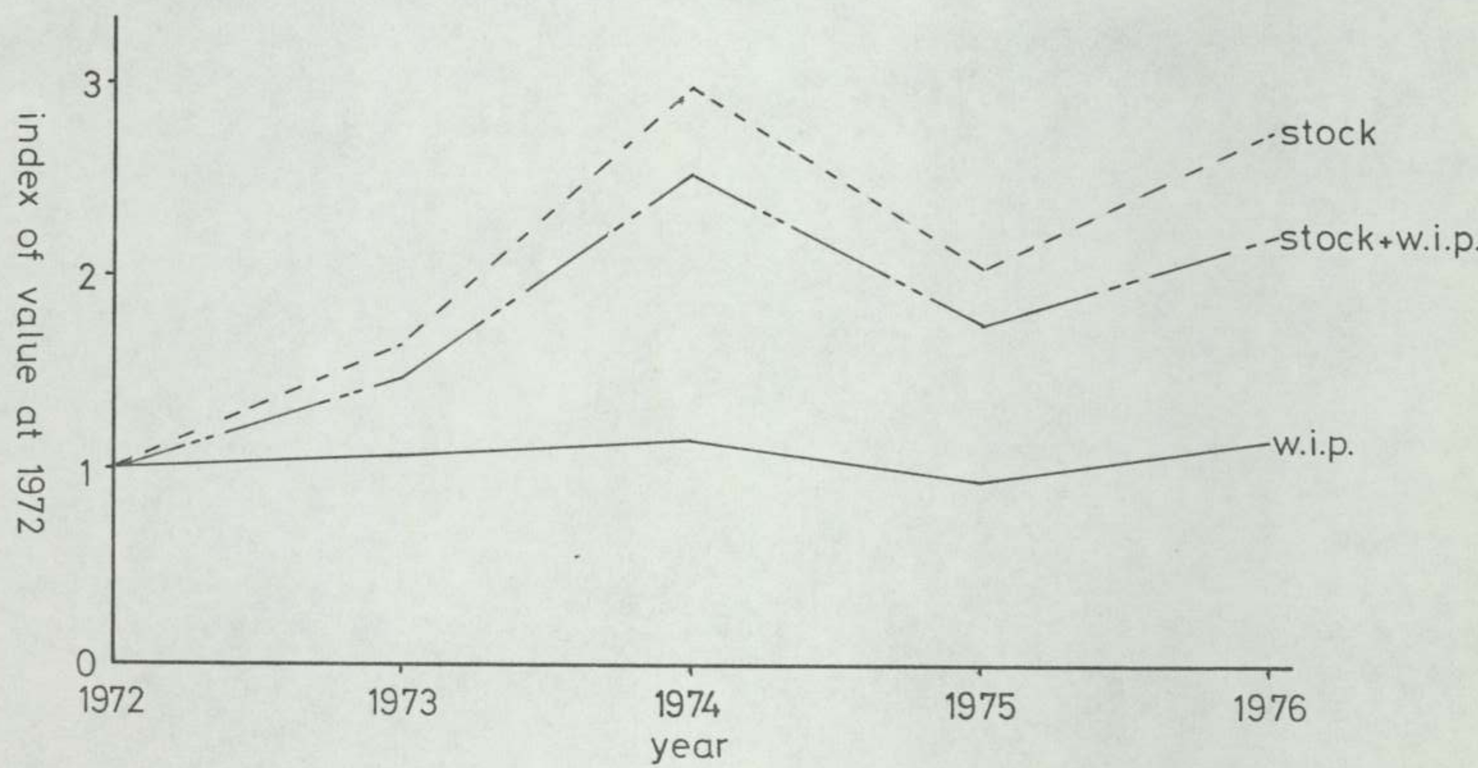
Variation in Sales Value From 1972 to 1977 Taking 1972 as Unity

Figure 69



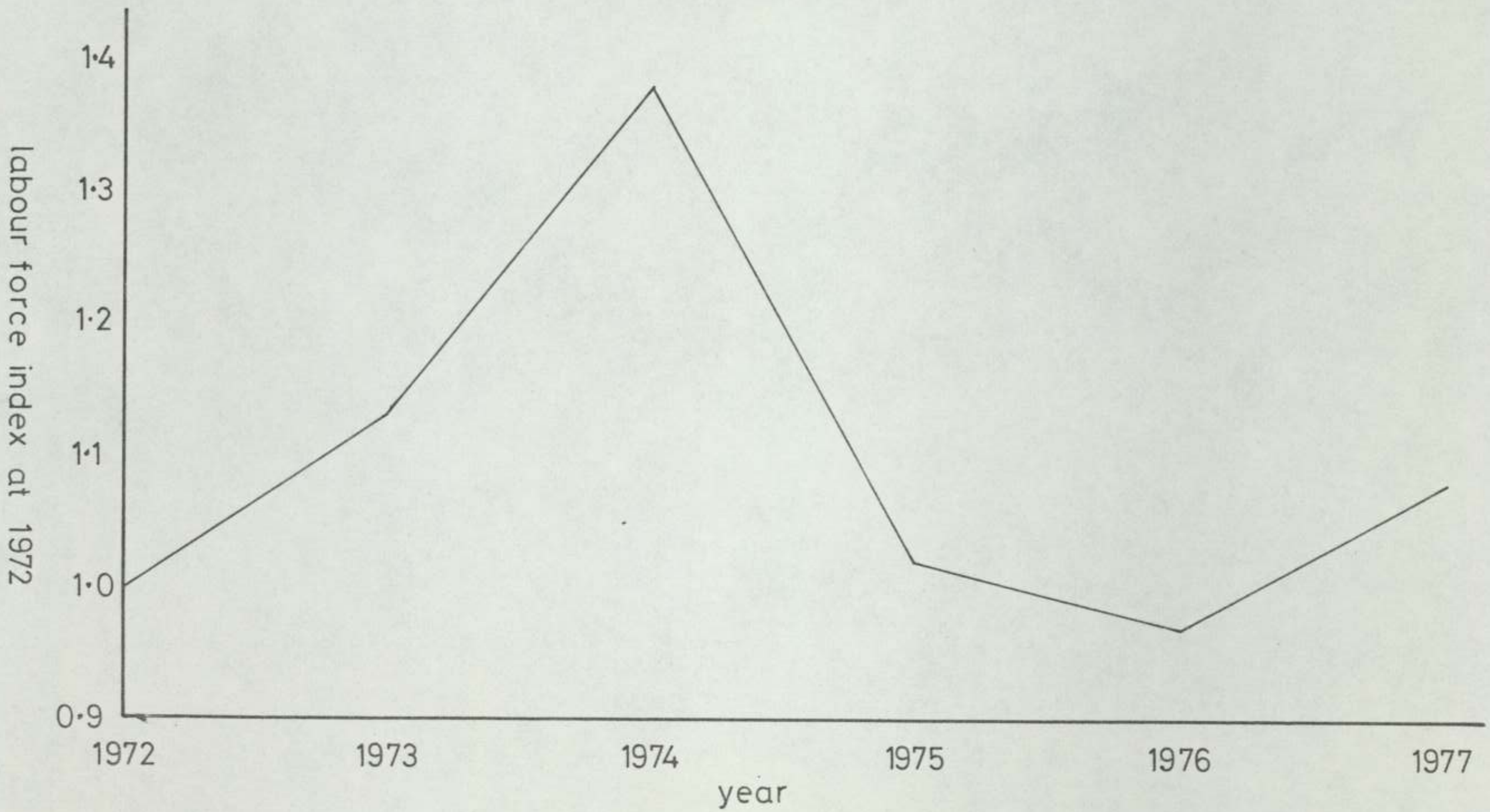
Variation of Sales/Stock Ratio From 1972 to 1977

Figure 70



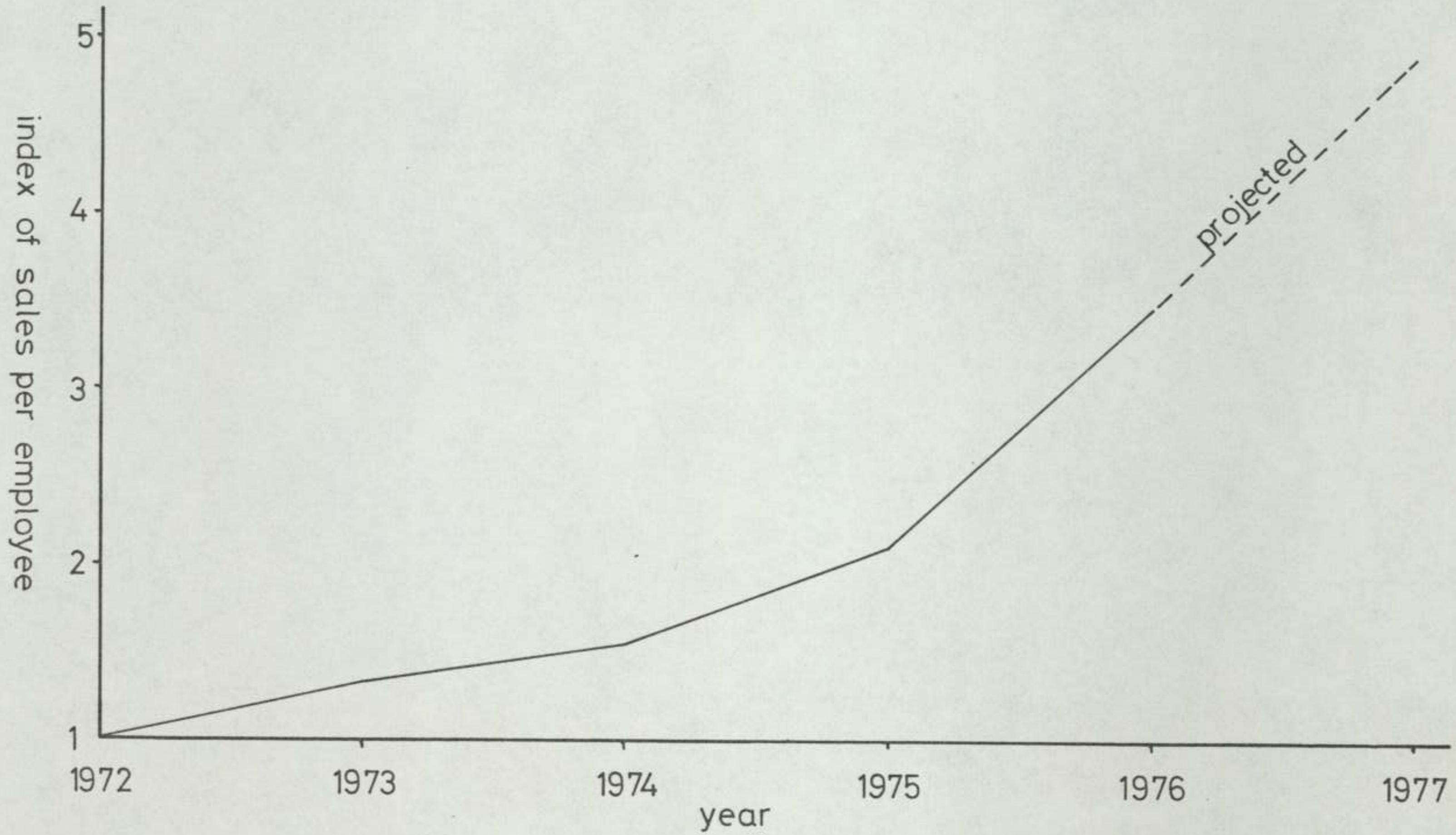
Variation of Stock, W.I.P. & Stock+W.I.P. From 1972 to 1976 Taking 1972 as Unity

Figure 71



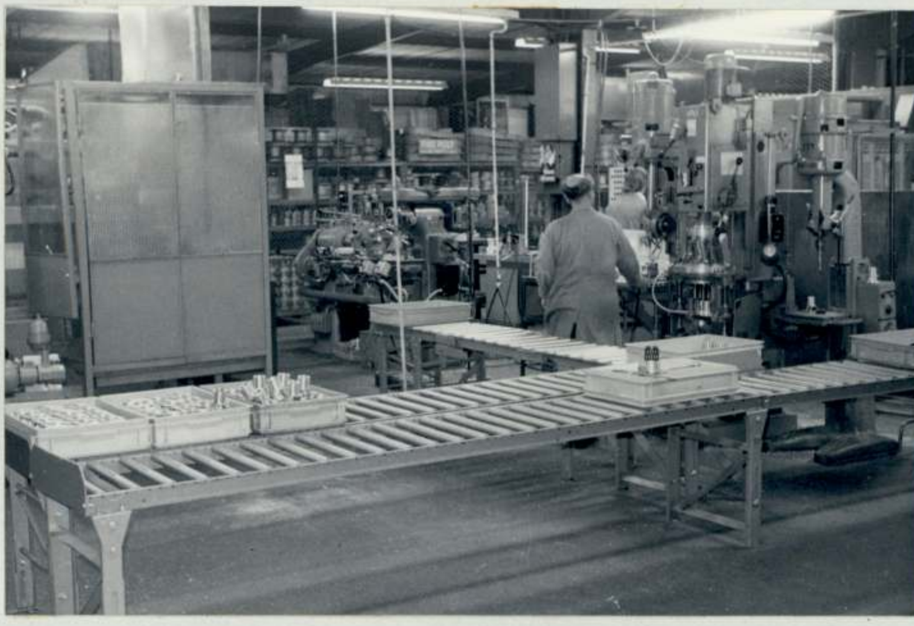
Changes In Labour Force 1972 to 1977

Figure 72



Variation of Sales per Employee From 1972 to 1977 Taking 1972 as Unity

Figure 73



Cell G.T.3

Part of Cell G.T.6

Shop Floor After G.T. February 1977

Figure 74

APPENDIX 1.

REPORT TO THE MANAGEMENT OF LEWMAR MARINE LTD.

ON THE GROUP TECHNOLOGY FEASIBILITY STUDY.

LEWMAR MARINE LIMITED

Interim Report on the Introduction of Group Technology
into Lewmar Marine Limited.

July 1974

P.G. Bunce

D.E. Vowles

CONTENTS

1 SUMMARY:

This report outlines the introduction of Group Technology into Lewmar Marine and examines the savings and expenses incurred by the first phase. It is predicted that savings in work-in-progress will be 50% of the existing; the lead times will be reduced by between 33 and 70%. Production control will be made easier by being able to produce complete components from a group in a known time. The costs incurred for the first phase (groups 1, 2 and 3) are £1,800 for new machines, £864 for roller conveyors and £180 for work trays - a total of £2,840.

2. INTRODUCTION:

This is an interim report on the viability of introducing Group Technology into Lewmar Marine. The scope of this report is to summarise the savings and expenditure caused by the first three groups. A further complete report will be issued during September, covering all aspects of this report plus the remaining work still being done on the other groups and the regions of manpower and production control.

To reduce the initial work load, it was decided to tackle Group Technology in two parts, A and B items. As at present 'A' items make up 70% of the turnover, these have been tackled first. The highest value components in a winch are the drum and the centre stem, so the effort was concentrated on the groups to produce these components - Groups 1, 2 and 3. It is envisaged that these groups will be the first groups to be set up and run as Group Technology groups.

3. GROUP TECHNOLOGY:

Group Technology can best be summarised as follows:- "Group Technology or Parts Family Manufacture is a method of achieving some degree of mass production technology in the batch production industry" (1)

cont.../2

Large batches of similar components are formed from smaller batches of identical components according to those features which influence their manufacture. In general this will bring about better utilization of the big machines but may cause the lesser machines to be under utilized. Basically three methods of applying Group Technology exist. (2)

3.1 The Single Machine System:

By using a classification system and by analysing the production requirements of the families, they may be combined together to form a production family. After examination , all the features of each component are entered on an integrated drawing to produce a composite component. Figure 1 shows an example as proposed by Mitrofanov (3).

3.2 The Group Layout System:

In this system the plant is divided into groups such that each group has a sufficient variety of machines to carry out all processes necessary as a family of components. In this system a component may have to visit a machine more than once in the cycle. It is necessary to operate a tight control system in order to prevent loading this group with foreign work from another family if decided 'convenient'; if foreign work is accepted it can soon lead to a breaking of the system.

3.3 The Group Flow Line System:

For this system the machines required for the family are arranged in order of sequence of operations and are usually connected by some form of conveyor system. A component only visits each machine once in the line, then only in sequence. As some machines are under utilized, it is necessary that some operators can operate more than one machine so that they can move from one machine to another where the work has accumulated. the conveyor length between machines acts as a buffer so catering for the out of balance condition.

4 CLASSIFICATION:

Before the types of grouping can be decided, the components have to be classified into families. This can best be done by using a coding system of which there are at least 11 published ones. In his paper on Component Classifications and Coding (4), Dr. Knight has provided an objective summary of the 11 major published systems.

After consultation with Professor Thornley, it was decided that the Opitz(5) classification system was best suited to the products and requirements of Lewmar Marine. This system consists of 5 digits plus 4 supplementary digits; the main code classifies the part shape by defining the main envelope shape and indicating the presence of various shape feature - this is shown in figure 2. In the supplementary code the first 2 digits categorises the dimensions , the 3rd digit the material form. The last four digits were modified (figure 3) to suit the requirements of Lewmar Marine.

All the components required by the current catalogue range - were coded and sorted. This produced a number of distinct families which were used as a basis for the groups.

5. SELECTION OF GROUPS:

After having sorted the components into families, a simplified version of Production Flow Analysis (6) was used to select the machines for each group and to further refine the grouping process. As stated in the introduction, only the 'A' items have been considered for grouping at present with initially only the three groups centred around the Canaveses (tables 1, 2 and 3) being worked out. Since then a further 5 group have been basically worked out, the remaining 5% being more suited to the machines allocated for the 'B' items. Of the remaining 'A' items only 11% have not yet been allocated to any of the groups but a brief examination of these shows that the bulk can be accomodated in the existing groups. It is usually found in these systems that a very small percentage of components will not fit into a family group due to either large dissimilarities or lack of quantity or a combination of both.

Groups 1, 2 and 3 are all laid out as Group Flow Line, with a Canavese at the start of each as a key machine . Tables 1, 2 and 3 show the components to be produced and the machines required for each of these groups. A roller conveyor will be used in each of these groups to connect each machine, thus enabling the work to be easily passed from one machine to another, and also as a means of controlling the work in progress.

Groups 4, 5 and 6 and 9 will be laid out as Group Layout Systems due to the greater variety and smaller batch quantities of components in them. Tables 4, 5, 6 and 7 show the components to be produced and the machines required in each group. As yet the work handling in these groups has not been fully considered.

Group 8 is different to all the other groups in that it contains all the Winchester automatic capstan lathes, it is envisaged that each of these will be tooled as a type of Single Machine System to turn a range o f both 'A' and 'B' components.

6. OPERATION OF GROUPS 1, 2 and 3:

The capacity of these groups has been done on the basis of producing one month's supply of all the components in 320 hours (4 weeks at 80 hours per week); the monthly quantity used is the peak figure from the 1974/75 sales forecast.

6.1 Group 1:

Table 1 shows the components being machined in this group - basically they are the smaller single and two speed winch drums. On examination of the individual operations it was found that they were evenly matched with the exception of the gear cutting where it was found that two gear shapers are required to maintain the rate. The table below shows the Canavese turning rates and the gear cutting rates for 1 and 2 machines.

Drum	Turning Qty /hr	Gear Cut 1/mc	Qty/hr 2m/c	4 week cycle batch
8	22.64	-	-	2,700
16	19.53	9.82	19.64	885
25	19.45	10.24	20.48	1,150

Figure 4 shows the turning rate plotted for each component in turn including an allowance for setting, this shows that this group is loaded for 75% of its time.

In operation it is thought at present that it would be best to run this group on the basis of machining each monthly batch of drums in the order of No 16, No 25 and No 8. Thus every 4 weeks a batch of each drum will be produced.

6.2 Group 2:

Table 2 shows the components being machined by this group - basically the large two and three speed winch drums. The individual operations are of shorter duration than the Canavese, with the exception of gear cutting. Here again two machines are required to maintain the rate of the Canavese as the table below shows.

Drum	Turning Qty/ hr	Gear Cut 1 M/c	Qty/hr 2m/c	8 week cycle batch
40	11.72	8.74	17.48	2,260
43	9.38	5.87	11.74	880
43-3	9.38	5.71	11.42	608
45	7.81	4.21	10.42	350
55	7.81	3.45	6.90	180
65	7.81	2.78	5.56	90

..../6

Figure 5 shows the Canavese turning rate plotted for each component in turn including an allowance for setting. This shows that this group is loaded for 83% of its time.

In operation it is envisaged that this group would operate on an 8 week cycle rather than a 4 week cycle as Group 1. This is because the quantity of drums does not justify the time and expense of 6 settings every 4 weeks. So in this case every 8 weeks a batch of each drum will be produced, except the no. 40 which will be produced on a 4 week cycle.

6.3 Group 3:

Table 3 shows the components being machined by this group - basically single and two speed winch centre stems. In a sense this group is not a true Group Flow Line System, as apart from the Canavese, the only other machines is a group of 3 drills which will be operated by one man (as at present). The conveyor track will only link the Canavese and the drills. The cycle time of the drills is less than that of the Canavese. Below are shown the turning rates of each component.

Centre Stem	8	16	25	40	43	1C
Turning Qty/hr	29.29	24.67	23.44	20.28	18.75	29.29
4 week cycle batch	2700	885	1150	1094	428	190

Figure 6 shows the Canavese turning rate plotted for each component in turn including an allowance for setting. This shows that this group is loaded for 96% of its time.

In operation it is envisaged that this group would operate on a 4 week cycle as per Group 1..

6.4 Control:

When the drums come off the roller tracking they are completely machined and will then be moved to the washing rig for washing and de-burring of the gear ring. After that they will be sent out for the subcontract operations of polishing and chrome plating/anodising. Likewise the centre stems will be completely machined and will then be moved to the Vibrator for de-burring and thence to Stores. Both the Vibrator and Washing Rig will be left in their existing positions in the old tufnol shop.

In each group each batch of components will be machined in strict rotation, the order being arranged to reduce setting to a minimum. A graph could be produced for each group for each production cycle on the lines of figures 4, 5 and 6. This would show at a glance the loading position and also enable any last minute adjustments to be made quickly by showing the effect on the other components caused by, say increasing the batch size of one component. This would be the fine control, the coarse control being to produce a graph for the year for each group based on the sales forecast.

6.5 Inspection:

With a change in the production system, changes will have to be made in the inspection systems. It is considered advisable to check the first off component from each machine in the group after setting up for a particular batch of components. Thereafter the air gauging would be used as a 100% check of the turning on the Canavese, the remaining machines being checked by random patrol inspection. The gear cutting would be checked on a percentage basis by using the Rollet gear checking equipment, located adjacent to the end of Groups 1 and 2.

6.6. Manpower Requirements:

As outlined in section 3.3, a G.T. Flow Line System does not require an operator per machine, but it does require them to move from one machine to another as the work demands. Figure 7 shows three operations which are linked and manned by two operators (7), if it is assumed that:-

a) The operators work at the same performance

b) The operations are preset for the next batch of work

c) The conveyor between operations 1 and 2 is full of work

d) The conveyor between operations 3 and 4 is empty

e) A batch of work requiring all the operations is in the process of travelling down the flow line.

Then using the rates given in fig 7 after 2 hours of continuous working by the operators on the first two operations, the work stored on the conveyor between operations 1 and 2 will have reduced to two-thirds of maximum capacity; but the conveyor between operations 2 and 3 will be full. Clearly the operator working on operation 2 is prevented from continuing work since he has no where to place his completed work. He must now move to operation 3 to relieve the bottleneck. After a further period of time the above process will be repeated again to relieve a bottleneck situation. The decision for the operators to move is inherent in the system e.g., when it is physically impossible to work at a work station the operator moves to a station where work is possible.

Using the above approach the minimum numbers of operators for each group is:

Group 1	4
Group 2	3
Group 3	2

In addition to this it is considered that 3 setters would be required, 2 to set the Canaveses and Gear Shapers and the other to set all the drills.

A brief study of the remaining groups shows that the total labour requirement is slightly less than that at present. Because all these groups will bring in a quantity of subcontracted work, it has been found that they all need to operate 2 shifts per day.

7. Work-In-Progress:

In the groups the only areas for work-in-progress (apart from raw castings) is the roller tracking and the stillage at the end of time. This of course is purely machining work in progress, the polishing and finishing work in progress would probably remain the same.

The roller tracking in each group has a fixed length and a standard plastic tray would be used to contain the components on the track. Thus it is possible to calculate the numbers of full and empty trays that can be accomodated by allowing one empty tray per work station. Table 4 shows the number of trays per track and the number of components per tray. Observation were carried out on the shop floor over several weeks, when the work in progress of a number of components from each group was counted. Table 5 shows these work-in-progress figures, the maximum projected work-in-progress in each group (not including raw castings) and the percentage savings to be gained by Group Technology. The reduction in work-in-progress on this sample averaged out at 56%. but due to the smaller batch sizes of the large drums the average accross the three groups would be more like 50%.

8. LEAD TIMES:

In a report published on 21st May 1973 by John Lewery, it was concluded that the existing lead times were 6 - 13 weeks. This was commencing with material issue and finishing with entry into Stores. There is no reason to doubt that these figures will be vastly different today.

Studying the system it is thought that the maximum time from raising an order to material issue would be 4 weeks or less. The lead time for Groups 1 and 2 could be 4 weeks including polishing and finishing and 2 weeks for Group 3. These figures are estimates and provisional

They may be modified when the final production control system has been decided. Thus using these figures, the reduction in Lead Time could vary from 33% to 70%.

9. INVENTORY:

In this area it is dangerous to imagine that the stocks of castings can be reduced to minimum quantities, e.g., a week's supply. If the foundry's next delivery is always the reserve stock, then one always runs the risk of bringing the times to a halt, due to late delivery of castings, which may happen for any number of reasons.

It would appear from discussion held with Purchasing that they are fast approaching the minimum inventory level for castings that is suitable for Lewmar Marine; any further reduction could well prejudice production and bring it to a standstill.

10. EXPENDITURE:

For Groups 1, 2 and 3, the following areas will require capital expenditure:-

1 Machine tools
2 Roller Conveyors
3 Work Trays.

10.1 Machine tools:

Listed below are the extra machine tools required for these Groups, together with the estimated purchase price. These machines are all required for Group 2:-

10.1.1	Air de-burring Press	£300
10.1.2	3 spindle auto feed drill	1,000
	total	£1,800

This may be reduced to £1,100 by buying a second hand drill.

10.2 Roller Conveyors:

10.2.1	Group 1	£444
10.2.2	Group 2	£257
10.2.3	Group 3	£82
10.2.4	Spare lengths	£81
	total	£864

10.3 Work Trays:

The tray selected as the most suitable is the W.C.B Z 200 which is made from high density polythene.

10.3.1	Group 1	40 trays	£89.20
10.3.2	Group 2	30 trays	£66.90
10.3.3	Group 3	10 trays	£23.40
	Total	80 trays	£179.50

If the 80 trays are ordered at one time, the total cost would be reduced to £170.40.

11. FURTHER WORK:

Over the next 1½ months further work will be done in the following areas:-

11.1 Production control of Groups

11.2 Manpower problems including consultations with the supervision and Union representatives.

11.3 Allocation of remaining components into groups.

11.4 Expenditure for the remaining - this includes the extra machines.

It is planned to visit Thomas Mercer & Co. Ltd., at St. Albans to study the production control systems they have evolved for their Group Technology. All the above points will be incorporated into a full report which will be published in September, 1974.

12 CONCLUSIONS:

By studying the products and the results of the classification exercise, it has become obvious that there exists a range of families of similar components, e.g. drums and centre stems. Last year a pilot group of machines was set up to machine all the drums coming from the Canavese. It included engravers and drills but not gear shapers. Study of this group has shown that this type of approach to machining components is well suited to Lewmar Marine and can certainly improve the production. The advantages are that throughput times and work-in-progress can be reduced plus production flow can be maintained more easily. The disadvantages of the present group are that there is no restriction on work in progress and little advantage has been taken of arranging the order of production to reduce the setting times. These factors can reduce the advantages drastically if not controlled effectively.

The groups proposed in this report will incorporate all the machines necessary for the family of components in each group. The roller conveyor will provide the necessary control on work-in-progress by only allowing a set number of trays to be in progress at any one time. Also production control would become more strict due to arranging the components in the most economical sequence, but in consequence it should become easier to administer. Using Group Technology, it is projected that reductions of work in progress of the order of 50% could be expected and that reductions of 33% to 70% in Lead times could also result depending on the conditions imposed. Also the G.T. Groups will be able to take full advantage of the present exercise of reducing castings inventory to the lowest practical level. It is estimated that the total expenditure (apart from plant movements) for implementing groups 1, 2 and 3 would be about £2,840.

In the Groups which will be laid out on a Group Layout System (Groups 4,5,6 and 9), the savings in work-in-progress will not be as high due to work possibly having to visit some machines more than once so as to obtain a reasonable utilisation of existing machines. Also for the same reason it may not be possible to achieve the same reduction in lead times, but at least a 15% reduction may be possible as the scale of the production control problems will have diminished.

It will be necessary to change the layout of the factory in the next few months, irrespective of G.T., to accomodate the new machines presently on order. Also it is considered that some form of layout approaching Group Technology will evolve at Lewmar Marine -given time. It is considered that the Group Technology approach outlined above would hasten this process plus providing a more complete and ordered approach to reducing the manufacturing problems of Lewmar Marine. It has been found that Lewmar Marine can expect the normal advantages associated with Group Technology and that its products are ideally suited to it.

Group Technology is the only way for Lewmar Marine to go if it is to reduce its manufacturing costs and improve its manufacturing performance.

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APPENDIX A.

Effects of Group Technology on Each Department.

1. Sales Department
   1. Benefits of closely controlled system of production i.e. knowledge of production rates and times
   2. Reduction of work load in other departments by continuing to improve the accuracy of sales forecasts.

2. Design Office
   1. Use of classification system to standardise new parts with existing.
   2. Some components to be redesigned with G.T. in mind.

3. Production Engineering
   1. Planning process and tooling closely controlled and standardised.
   2. Planned maintenance to be improved and extended.
   3. Larger stocks of machine spares to be built up and maintained.

4. Tool Room
   1. Quick turnround of tool maintenance required.
   2. More effective control on tool issue and maintenance.

5. Production Control
   1. Control by group loading is easier than control by operation.
   2. Component batches are far easier to trace and progress.
   3. The need for splitting batches is obviated.
   4. Quick diversion of components into another group is not allowed under any circumstances.

Cont..

5. Operation sequence must be followed closely.

5. Production Supervision

1. Better standard of setting required.
2. Close control on tooling and machines by setters and supervision.
3. Make full use of time by pre-setting for the next component.
4. Forward knowledge of programme giving time to prepare tooling etc.

6. Stores

1. More consistent stock issue and rotation.
2. More frequent stock issue.

DRG NO.	DESCRIPTION	OPITZ CODE
1266/2	No. 8 drum	17162 - 3200
1267/2	No. 8 drum	17162 - 3250
1284/2	No.16 drum	17166 - 3220
1291/2	No 16 drum	17166 - 3250
1265/2	No 25 drum	17406 - 3310
1254/2	No 25 drum	17406 - 3350

Components produced in Group 1

MACHINE	NO
Canavese CG90 2T	1
Needle Peen m/c	1
Engraver	1
3 spindle drill	1
4 spindle drill	1
1 spindle bench drill	1
Air press	1
Nitcher	1
Gear Shaper	2

Machines required for Group 1.

Table 1

DRG NO.	DESCRIPTION	OPITZ CODE
1260/2	No. 40 drum	17406 - 3300
1255/2	No 40 "	17406 - 3350
1264/2	No 43 "	17406 - 4400
1294/2	No. 43 "	17406 - 4450
15043102	No. 43-3 drum	17376 - 4400
15043202	No. 43-3 "	17476 - 4450
15045102	No. 45 "	17476 - 4400
15045202	No. 45 "	17476 - 4450
15055102	No. 55 "	17476 - 4400
15055202	No. 55 "	17476 - 4450
15065102	No. 65 "	17476 - 4400
15065202	No. 65 "	17476 - 4450

Components Produced in Group 2

Machine	No
Canavese CG 180 2T	1
Needle Peen m/c	1
Herbert TMT broach	1
3 spindle drill	1
Air press	1
Gear shaper	2

Machines required for Group 2

Table 2

DRG NO.	DESCRIPTION	OPITZ CODE
1281/1	No. 1 C c/stem	11402 - 3200
1266/1	No. 8 "	11405 - 3200
1267/1	No. 8 "	11405 - 3250
1284/1	No. 16 "	11102 - 3210
1265/1	No. 25 "	11402 - 3210
1260/1	No. 40 "	11402 - 3310
1264/1	No. 43 "	11402 - 3300
1294/1	No. 43 "	11402 - 3350

Components produced in Group 3.

Machine	No.
Canavese CG 90 2T	1
Single spindle pillar drill	1
Single spindle bench drill	1
Multi spindle drill	1

Machines required for Group 3.

Table 3.

Group	Length of Track M	Total No Trays	No. full trays
1	14.5	24	17
2	13.0	21	16
3	3.0	5	4

Tray type W.C. B Z200

Dimensions:- Overall length 0.6 metres.

Internal 570 x 365 x 115 mm

Drum/stem	No.in tray	Total WIP on track
8	20	340
16	15	254
25	12	204
40	12	192
43	6	96
45	4	64
55	2	32
65	2	32

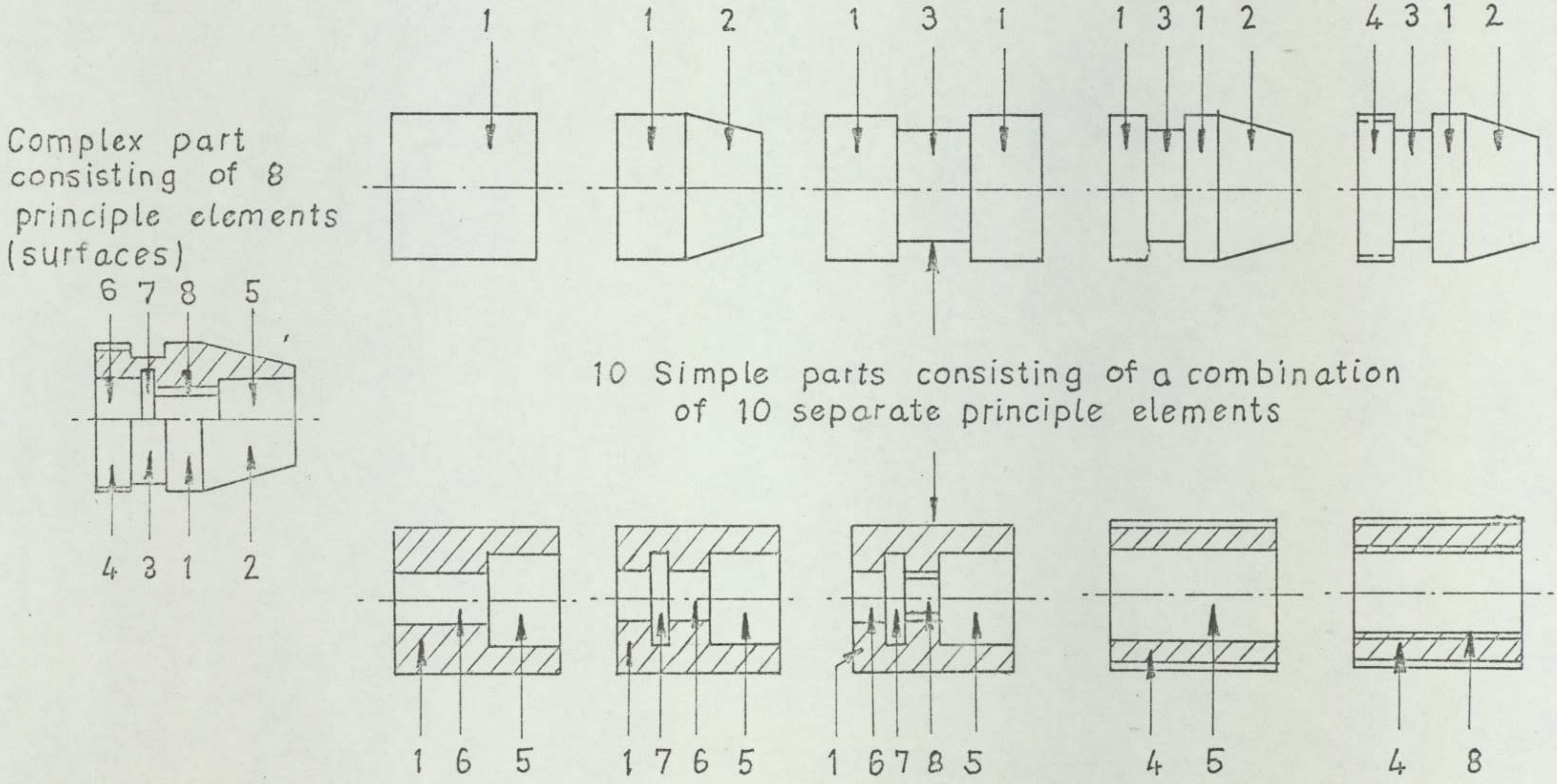
Tray and Component Quantities on Roller Conveyors

Table 4.

Component	Existing WIP	New WIP	% Reduction
8 drum	1005	540	46
25 "	807	354	56
40 "	532	292	45
55 "	98	47	52
8 c/stem	160	83	48
25 c/stem	460	51	88
		Average	56%

Work in Progress Sample

Table 5.



EXAMPLE OF COMPLEX COMPONENT
(AFTER MITROFANOV)

Fig 1

OPITZ CLASSIFICATION SYSTEM.

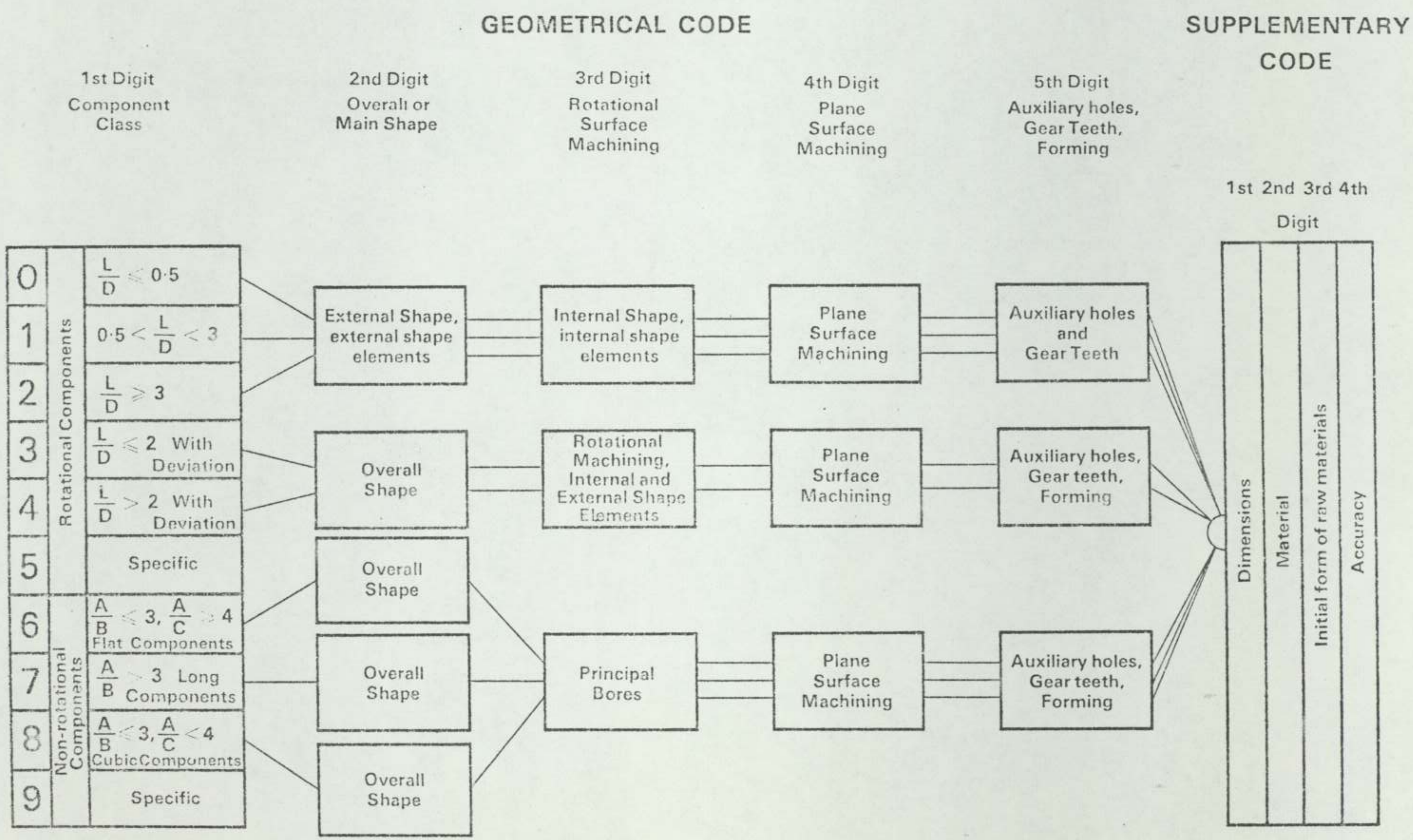


Figure 2

Code	1st Digit: DIAMETER 'D' or EDGE LENGTH 'A' (INCHES)	2nd Digit: LENGTH 'L' Rot or EDGE LENGTH 'C' Non rot (INCHES)	3rd Digit: MATERIAL	4th Digit: INITIAL FORM
0	≤ 0.5	≤ 0.8	High Tensile Brass	Castings
1	$> 0.5 \leq 1.5$	$> 0.8 \leq 2.0$	Aluminium Bronze	Sintering
2	$> 1.5 \leq 3.0$	$> 2.0 \leq 4.0$	Brass	Forgings
3	$> 3.0 \leq 6.25$	$> 4.0 \leq 6.5$	Manganese Bronze	Tube
4	$> 6.25 \leq 15.75$	$> 6.5 \leq 10.0$	Stainless Steel	Bright Bar
5	$> 15.75 \leq 18.0$	$> 10.0 \leq 16.0$	Aluminium Alloy	Steet
6	$> 18.0 \leq 30.0$	$> 16.0 \leq 25.0$	Plastics & Tufnol	Extrusion
7	> 30.0	$> 25.0 \leq 40.0$		
8		$> 40.0 \leq 80.0$		
9		> 80.0	Other Materials	

Figure 3

OPITZ SUPPLEMENTARY CODE

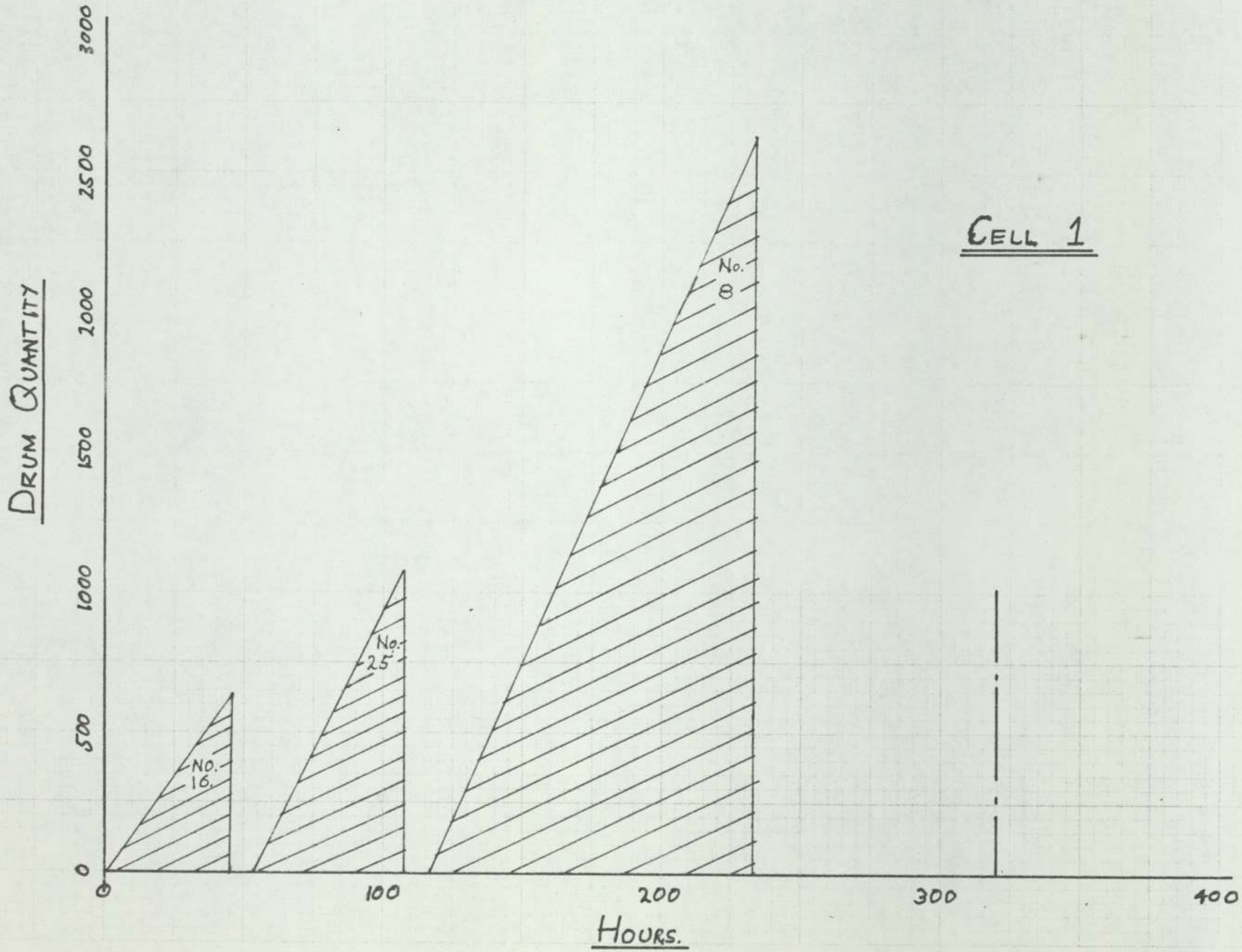
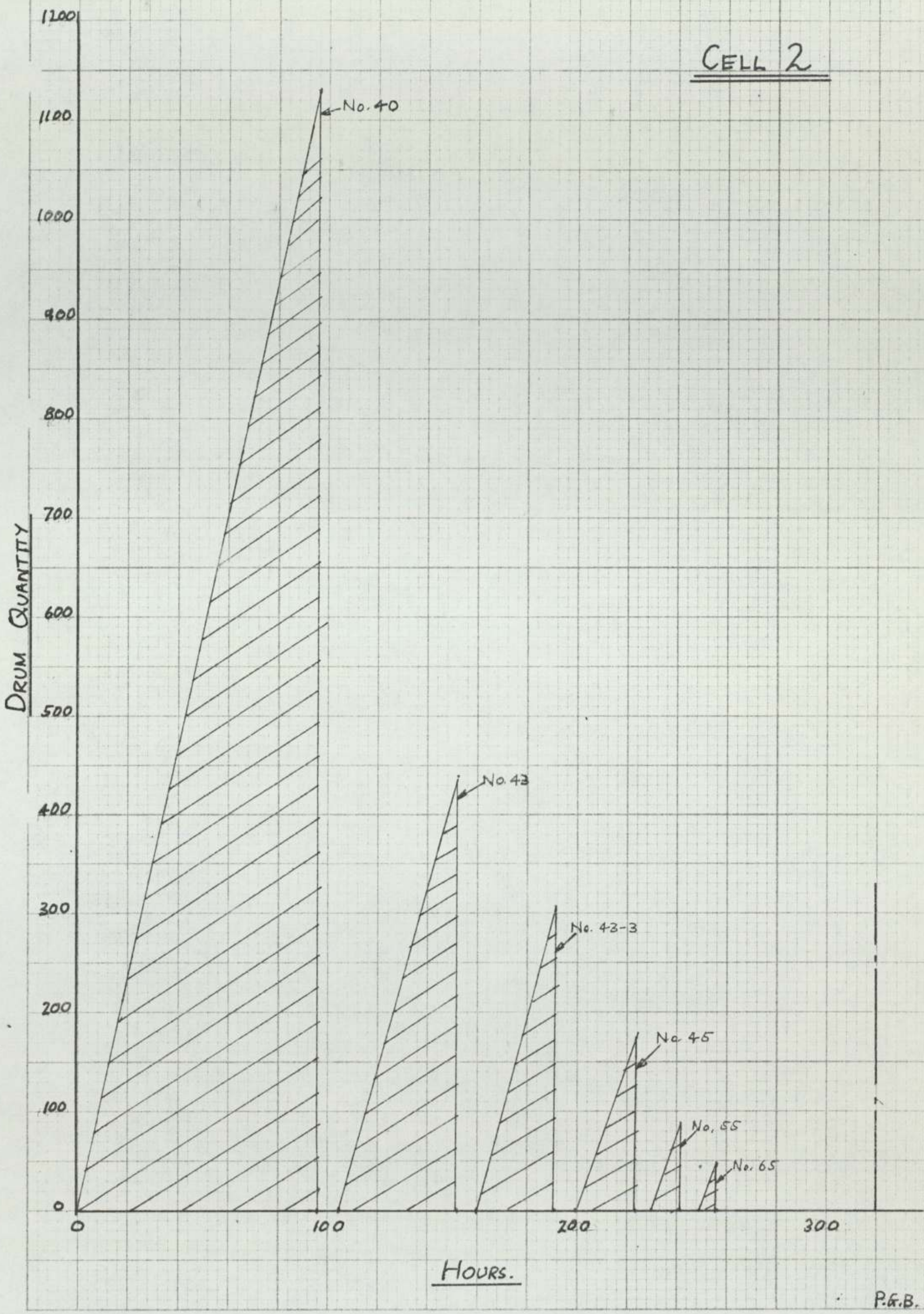

Cell 1
Drum Quantity
0
500
1000
1500
2000
2500
3000
Hours.
0
100
200
300
400
No. 16.
No. 25
No. 8

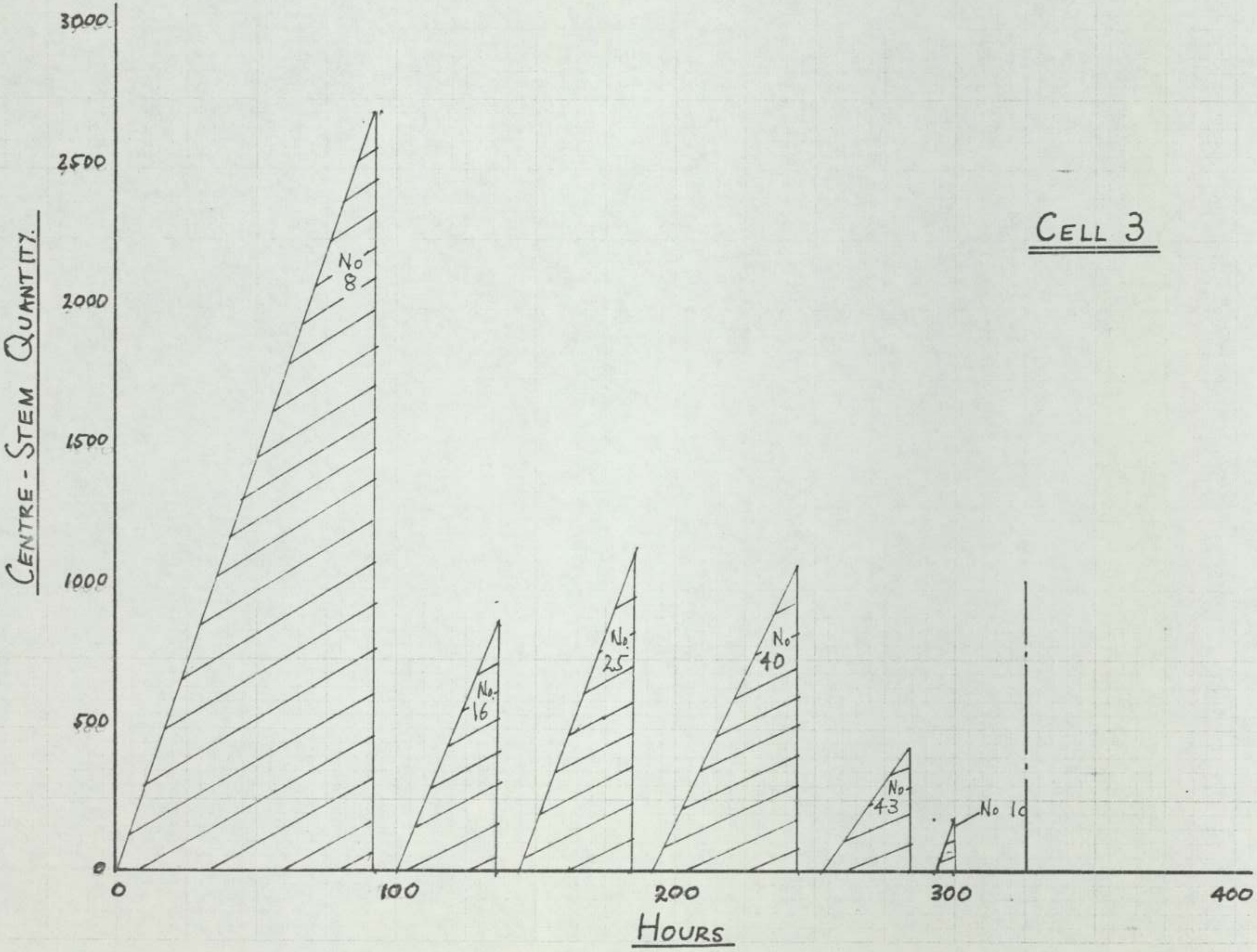
Fig. 4.

P.G.B



Cell 2
Drum Quantity
Hours.
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
No. 40
No. 43
No. 43-3
No. 45
No. 55
No. 65
P.G.B.

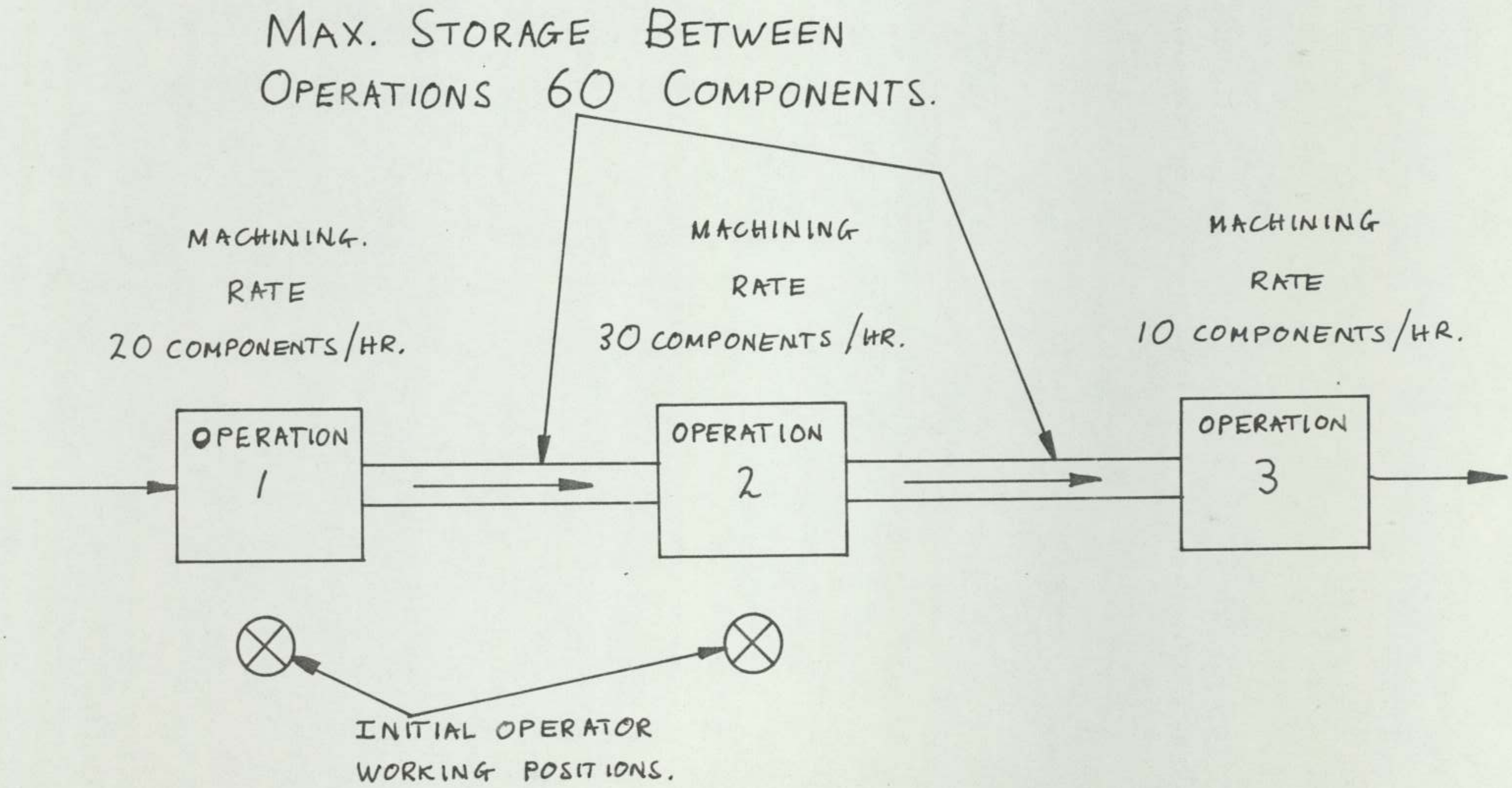
Fig 5



CELL 3
CENTRE - STEM QUANTITY.
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
HOURS
No 8
No 16
No 25
No 40
No 43
No 10

P.G.B.

Fig 6.



LINKED BATCH OPERATIONS

Figure 7.

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