COST EFFECTIVENESS OF PRODUCTION CONTROL SYSTEMS

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BY

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SUMMARY

This thesis deals with the problems associated with the planning and control of production, with particular reference to a small aluminium die casting company. The main problem areas were identified as:

(a) A need to be able to forecast the customers demands upon the company's facilities.

(b) A need to produce a manufacturing programme in which the output of the foundry (or die casting section) was balanced with the available capacity in the machine shop.

(c) The need to ensure that the resultant system enabled the company's operating budget to have a reasonable chance of being achieved.

At the commencement of the research work the major customers were members of the automobile industry and had their own system of forecasting, from which they issued manufacturing schedules to their component suppliers. The errors in the forecast were analysed and the distributions noted. Using these distributions the customer's forecast was capable of being modified to enable his final demand to be met with a known degree of confidence.

Before a manufacturing programme could be developed the actual manufacturing system had to be reviewed and it was found that as with many small companies there was a remarkable lack of formal control and written data.

Relevant data with regards to the component and the manufacturing process had therefore to be collected and analysed. The foundry process was fixed but the secondary machining operations were analysed by a technique similar to Component Flow Analysis and as a result the machines were arranged in a series of flow lines.

A system of manual production control was proposed and for comparison, a local computer bureau was approached and a system proposed incorporating the production of additional management information.

These systems are compared and the relative merits discussed and a proposal made for implementation.

ACKNOWLEDGEMENTS

Although only a small company, it is impossible for me to mention individually all the employees of the sponsoring company, Sage Aluminium Products Limited, both at managerial and shop floor level, for the help and comradeship extended to me during my work.

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I am most grateful to Mr. B. Griffiths, former Managing Director of the company for granting me the initial facilities and to his successors for their willingness to allow the work to continue.

My thanks are also due to Professor R. H. Thornley, my Supervisor, for his help and guidance in formulating the proposals, and to the former undergraduate students of the University of Aston who assisted in the establishment of the times required for clerical operations.

Finally, I must express my thanks to my wife for firstly her patience during the period of the work and secondly for the unenviable task of transcribing my virtually illegible scrawl and Yorkshire expressions into the present readable form.

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CHAPTER 1

INTRODUCTION

1.1. MAINLY HISTORICAL

In very early days man worked to provide for his own individual needs which in those days were mainly food and clothing for his own family.

As the individuals started to collect themselves into groups for their own protection, within the group a leader started to emerge and eventually the feudal system developed where the 'Lord of the Manor' detailed the tasks to be done by the serfs of the groups or village and in return for their labours they received goods, and in addition each had his own plot of land on which to grow additional food for his own immediate family.

Within the group some individuals tended to develop their own individual skills e.g. the smithy or miller, who in return for the exercise of their skills were also paid in goods which they in turn had to use in exchange for food and other essential items.

As groups travelled between groups so trade developed between them and from this inter-group trade a monetary system of payment for goods or services received was developed (1).

With the development of a monetary system of payment it was now possible for a person, highly skilled in some aspect, to gather around him a group of similarly skilled people and to manufacture products for sale. If the group were working as partners, then the profits from the sale might possibly be divided equally, but in all probability the leader of the group would occupy the position of employer and would distribute the money received from the sale to the other individuals in the form of wages.

With the development of methods of transport, markets became more plentiful and to cope with the increase in demand the size of the work groups had to increase and in order to supervise this larger work group, the leader had to cease working himself and take on a purely administrative role. This, together with the development of machines for performing mechanical tasks e. g. Hargreaves Spinning Jenny and Kay's Flying Shuttle in the textile industry and early machine tools or processes developed by Wilkinson and Maudsley, plus new forms of motive power in the form of the steam engine, saw the commencement of the factory system of manufacture.

As the factory system developed, so did the relationship of Master and Servant, the former being the employer and the latter the Machine Operator. The master gave his instructions and depended upon his own personal supervision or that of his appointed overseers to ensure that they were carried out. The task of supervision was also made easier because the operators were now solely dependent upon receiving a monetary wage with which to purchase the necessities of life and were therefore motivated by self-preservation into seeing that the masters instructions were carried out.

The only formal control required to be undertaken by the master was simple book-keeping to keep a record of his financial transactions. The most successful recorded attempt at comparing achieved performance with planned performance was a costing system devised by Boulton & Watt (both sons of the respective early Engineers) the main use of which was to assist the management to detect waste and inefficiency. It has been said of them 'neither Taylor, Ford nor other modern experts devised anything in the way of a plan that cannot be discovered at Soho before 1805 .... ' (2).

The development of the products and manufacturing processes had been undertaken by Engineers and it was appropriate that Engineers started to look at the organisation for production, and to this end much support was given by the American Society of Mechanical Engineers. Through papers read at Society meetings, Engineers were encouraged to pay more attention to the financial and paperwork aspects of manufacture. With regard to Production Control, a paper entitled 'A Shop Order System of Accounts' was presented by H. C. Metcalfe (3) whilst Gantt was emphasising the importance of leadership and the need to pay more attention to the human aspects of industry.

1.2. THE DEVELOPMENT OF THE MANAGEMENT SYSTEM

The control of the manufacturing companies remained within the single family unit until the demand for the product increased resulting in the company having to expand to meet this increased demand or face the alternative of being squeezed out of existence by competitors that did expand. To maintain a constant vigil on daily events, formulate managerial decisions and initiate action began to prove an impossible task for the individual to perform (4) and therefore one saw the development of the organisation structures in which subordinates were given the responsibility for decision making and in most cases the authority although some individual owners were reluctant to grant the latter (5).

As the size of the company increased the individual owner gave way to the Board of Directors with the result that the people who made the decisions within the organisation were remote from the factory floor where their decisions were finally acted upon and where activities took place which influenced their future decisions.

To make effective decisions the Senior Manager required a speedy flow of data from the Production unit and the first half of the present century saw the development of manual systems of data and information flow with mechanical accounting machines to assist with the arithmetical calculations. In the field of Production Control, Gantt (6) introduced his charting techniques for giving a visual display of a plan on which could be shown the achievement against the plan.

The systems devised were manual in operation and as such suffered from the natural time lag that occurs in such a system and consequently decisions were often made on historical data, the decision itself being outdated by the time it was finally converted into some activity in a section of the system.

The late forties and early fifties saw the development, as a commercial proposition, of the electronic computer which enabled the analysis of data to be undertaken fairly rapidly, thus reducing the time lag between an activity and a decision. This was even further reduced with the introduction of data collection systems which enabled data to be fed from the point at which the activity took place straight into the computer input device (7).

Given that the Senior Executives were remote from the production activity, then if they were to perform their function to the satisfaction of the shareholders i. e. the group to whom the Board of Directors were accountable, they had to receive and analyse data and make decisions upon this data within the shortest possible time period whilst at the same time ensuring that the methods they adopted to achieve this time were consistent with the objective of any company which is to obtain for its shareholders a satisfactory rate of return on their investment.

This thesis is concerned with the procedure leading up to the choice of system which is applicable to an individual company and whilst the final decision will be unique to an individual company, the method of procedure is applicable to other companies.

CHAPTER 2

THE VALUE OF DATA AND INFORMATION

For a person to perform a managerial role effectively (a managerial role being defined as one for which the occupant has responsibility for the work of others, and in performing the tasks associated with this role may be required to make decisions affecting the work of these subordinates), that person must receive a flow of information either verbally or in written form.

There are two basic types of information necessary to the occupant of a managerial role :

(a) A statement of past events or inputs to a system, the purpose of which is to inform.

(b) A collection of facts relating to a particular topic upon which a decision is made which will influence future events.

To differentiate between these, McRae (8) refers to type (a) as 'data' and type (b) as 'information'. Whether one can say that all data is used purely to inform is open to discussion. If it is so then the need to produce the data in the first place should be queried but in fact one often finds that data is acted upon and a decision made if the numerical value of the data falls outside set limits. The data has then become information if we accept

McRae's definitions. What we are in effect saying is that information can be type (a) or (b) which one being dependent upon the role of the person viewing the information.

Eilon (9) looks upon information as a product, considering that the terms 'data generating' and 'data processing' can be likened to work being done upon a physical product. He further highlights the similarity by likening grades of information to perishable, semi-perishable and non-perishable goods.

The value of a news item or a piece of market intelligence is a perishable item - with the passage of time (usually a relatively short interval) the value of the item depreciates rapidly.

Historical data relating to a company's sales figures or manufacturing performance have a value and are maintained on file somewhere in the organisation. The weight which is placed on this data decreases with the passage of time and so can be classed as semi-perishable information.

Non-perishable information is rarely found in a dynamic business organisation except for recording the historical development of the organisation or technical data giving the physical properties or composition of raw material.

Keller (10) defines information as 'data which has been measured or appraised as good or bad and by how much, relative to a standard believed compatible with the objectives and goals of a business enterprise. Data he considers as the raw material input from which information is produced - this conforms to McRae's definitions of data and information and from these we can assume that it is possible to collect data without necessarily requiring to produce information, but one cannot have information without first having acquired and analysed data.

If an organisation is to be run effectively and profitably then one must have information on which to base decisions. To be effective the decision must be made quickly as a decision would only have to be made on a 'live' project and in any such situation the information on which the decision is made is of a perishable nature.

Between an event happening which is recorded as data and the subsequent collection and analysis of this into information, there is a time lag which can be likened to the lead time required for the manufacture of a product.

For a product a simplification of design or manufacturing system will reduce the lead time as will the use of sophisticated manufacturing techniques for complex products.

When the product is information, removal of surplus information generated will simplify data capture and processing, resulting in reduced overall processing time or by use of more sophisticated methods of data collection, analysis and display procedures for information, this time can still be reduced for the complex organisation.

2.1 METHODS OF PROCESSING DATA

There are three basic methods that can be used to collect and analyse data:

(a) Manually where clerks collect and record data and use simple mathematical techniques to prepare the information.

(b) Manual collection and recording of the majority of the data but using data processing equipment as an aid to the analysis of this data and the preparation of the subsequent information.

(c) A computerised system capable of data collection and analysis, followed by the presentation of the resulting information.

Due to the physical limitations of the human resources used in method (a), the lead time required to produce information will be long unless the investment in these human resources is high, but this may result in a low return from the investment.

Method (c) has the potential to give a very short lead time but requires a fairly high investment in both hardware and the human resources necessary to service this hardware. The resultant short lead time may however give a good return from the investment.

2. 2 THE RETURN FROM INVESTMENT IN A DATA SYSTEM

The return from an investment can be simply stated as 'the savings resulting to the company through the investment' and the rate of return as 'the resultant savings divided by the total investment'. The amount invested in a system for producing information is usually easily quantifiable but the savings are much more difficult to quantify before a system is installed and often one finds that a procedure is installed because another, possibly similar organisation, obtained a certain percentage reduction in such things as stock levels, work in progress or throughput time. An effective method of quantifying expected savings at the system proposal stage has not yet been developed and it is the absence of this that leads to questions and doubts being raised by management as to the feasibility of applying modern data processing methods and systems to their organisations. (11)

To be able to quantify savings it must be possible to analyse an existing situation and fix values to key performance figures. Unfortunately when management seek these figures the motivation is often their inability to control their existing system due to the lack of facilities to enable these performance figures to be obtained. Their manufacturing system is a series of individual 'water-tight' compartments with no formal procedure for interchange of data and information and the initial task is therefore to create a controllable system from these individual cells. To do this one has often to increase immediately indirect costs with no immediate return visible. A willingness to do this does however reflect a company's determination to overcome its difficulties.

More effective management control is obtained if the occupant of the role is presented with live information on which to base his decision which in itself must then be rapidly transmitted to the person responsible for initiating action. (12).

The action taken must then be monitored, data being collected and analysed to give information on the effectiveness of the original decision and corrective action taken if required - this in effect gives a closed loop circuit or system. A change in the input to the system or the construction of any part of the system will affect the performance of the system when considered as a whole.

2.3 THE APPLICATION TO THE CURRENT RESEARCH

Initially the research covered by this thesis was intended to consider the cost and benefits to be derived from the production control function. Production control analyses data obtained from the company order book or forecasted order book and issues information (in the form of instructions) to the manufacturing unit(s) and monitors performance by means of despatch or progress clerks.

The extent of the monitoring required is a function of the design of the manufacturing system and therefore to be an effective system both the control and manufacturing functions must be fully integrated

The control function minimising the amount of data required but ensuring the maximum effectiveness of results from the information or instructions issued by them; the manufacturing function being designed to give optimum throughput time with minimum of control required. Both of these functions must meet the criterian of expected rate of return on investment in the system as a whole.

The initial research programme had therefore to be modified to enable this concept to be developed and to do so co-operation of an industrial organisation was required - the author being fortunate to obtain facilities with an aluminium die casting company.

CHAPTER 3

THE SPONSORING COMPANY AND ITS PRODUCT

The sponsoring company was Sage Aluminium Products Limited, an aluminium die casting company near Wolverhampton.

At the commencement of the research work it was a member of the General and Engineering Industries Group of Companies and as such was a unique company within the Group, providing no service, nor receiving any from any other member.

It buys in its raw material, aluminium, in 'liquid' form and converts this by means of conventional die casting machines into products for its customers. Some components require no further major work after the casting process, others are passed through a number of machining and finishing processes prior to despatch to the customer.

There are two grades of aluminium used by the company LM24 and LM6 - the proportion (by product) being approximately

LM24	=	95%
LM6	=	5%

For each product there is a unique tool and therefore from a casting viewpoint there is very little difficulty encountered by these differing specifications. Scrap material however can only be classified as LM24 the least pure material and also when preparing the manufacturing programme, the economics of ordering small quantities of LM6 must be taken into account. Also the machine and metal pot must be cleaned to remove any surplus inferior metal.

The major customer of the company is the motor car manufacturing industry and within this, the Ford Motor Company Limited is the major user of the available capacity. In common with the other customers, Ford place a bulk order for a component with the company (at an agreed price) and each month give to them a delivery schedule for six periods.

i. The quantity stated for the first period is a firm delivery requirement within the time period.

ii. The quantity stated for the second period is an authorisation to manufacture that number of components in anticipation of requirements and as such is a firm commitment on behalf of the customers.

iii. The quantity stated for the third period is an authorisation to purchase material for that number of components and as such is a firm commitment on behalf of the customers.

iv. The quantities stated for the fourth, fifth and sixth periods are forecasts of demand and are for planning purposes only and as such there is no firm commitment on the part of customer to accept any number of components.

Possible future obsolescence of a component is indicated by the customer on the monthly schedule as soon as this becomes apparent.

Because of its reliance upon this one major industry the financial performance of Sage Aluminium is quickly affected by any adverse condition within this industry and the company is therefore seeking to attract new customers.

In October, 1973, Gale Securities, a Financial Holding Company bought control of the company. It remained an individual and unique company within this new Group and in order to make the company more financially viable new markets were sought for its expertise and capacity. Additional markets were found that demanded on the average larger die castings than previously and also requiring less subsequent machining, only the removal of the process flash.

Unfortunately it is a highly competitive market not only from a cost aspect but also delivery performance and therefore if the company is to be successful in continuing to attract new customers and products, it must be able to offer a performance at least equal to, if not better than its competitors.

It is fair to say that at present a manufacturing programme is formulated for the foundry but not for the machine shop. As the foundry system is not a closed loop the results obtained leave much to be desired. In the machine shop the 'programme' is decided upon by the Production Control Executive by reference to his order book, but it is also influenced by the 'pressure' exerted by the customer in demanding clearance of arrears which results in changes to the 'programme' at very short notice. Information regarding the programmes is passed to both Department Heads by means of a handwritten note.

Delivery of the finished products to the customer is done by Sage Aluminium transport. Deliveries are made daily to the major customers but because of the lack of a controlled manufacturing system the lorries are often sent with only a 'part load', thus making delivery uneconomical.

No attempt has been made to produce a procedure for operating the complete system and it is the lack of a programme for the system that has led to an apparently uncontrollable situation.

CHAPTER 4

THE COST OF PROCESSING DATA

A manufacturing system can be likened to any task in as much as there are three separate phases:

(a) Get Ready.

(b) Do the task.

(c) Clear Away.

In a manufacturing system these three activities need not necessarily be done by the same individual or department and therefore in addition to the above three phases a monitoring procedure must be instituted if the actual 'doing' operation is to give the results anticipated or corrective action to be taken to ensure this is the case. This is illustrated in a diagrammatic form in Fig. 4-1

As discussed previously in Chapter 2.2, to control a system requires the feed back to generate data and/or information for decision making or to inform. The complexity of this procedure depends to a large extent upon the size of the company and the size and complexity of its production.

There are two main classes of expense in any manufacturing organisation:

(a) There are those resulting from some manipulation of the raw material and these expenses can be said to add value to a job.

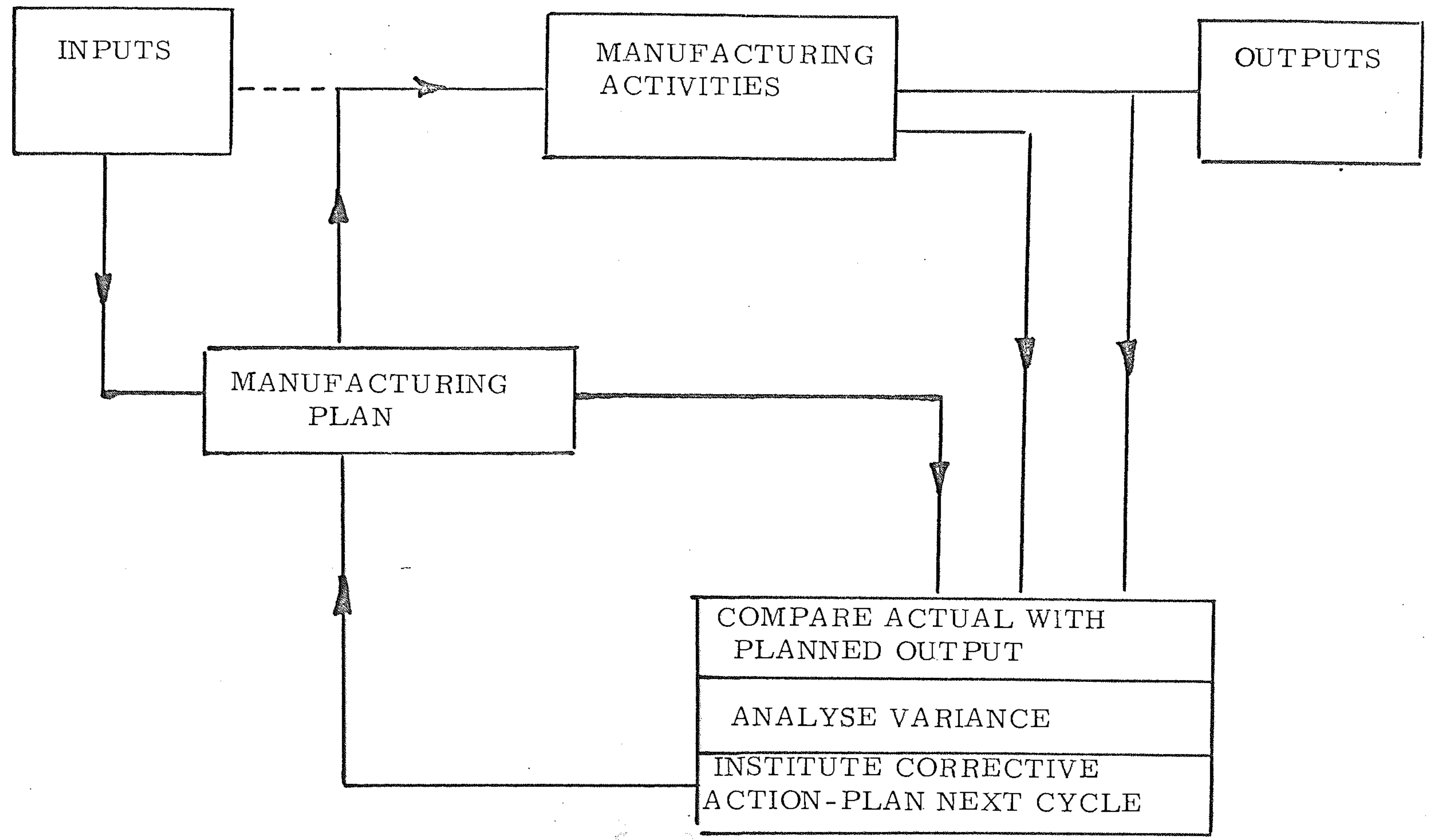


FIG. 4-1 - CLOSED LOOP CONTROL SYSTEM

(b) There are those expenses incurred in administering the organisation and as such do not add value to the job only cost.

Because they add cost and often generate paperwork, management often attempts to operate with the minimum of these 'cost additions' only activities.

The monitoring procedure essential for a closed loop manufacturing system is often classified as one of these and so management are reluctant to pursue it too vigorously.

It is generally acknowledged when considering capital investment that time has a value (13) and that the timing of cash flows may play a major part in the profitability or otherwise of a project.

This is similar to the flow of data and information - the time span required between the action and receipt of the data can seriously affect the profitability of a project. Material delayed on the shop floor awaiting a decision or further operation is in effect 'cash' left on the floor and thus a cash outflow takes place due to interest charges and loss of profit due to these.

An effective monitoring and control procedure therefore instead of adding cost by assisting to improve throughput time will reduce cost and increase the value of the contribution the product makes to the company's financial performance.

4.1 ASPECTS IN THE DEVELOPMENT OF DATA PROCESSING SYSTEMS

Systems for manual control and monitoring a production programme have been well documented by Moore (14) and Burbidge (15). The manual system depends for its effectiveness on the enthusiasm and ability of the personnel operating the system. In a small company because of the closer personal contact between management and operatives the reporting of progress is often done by a mixture of both verbal and written data and therefore the result can be a fairly efficient manufacturing system provided management is satisfied with a limited number of performance analyses.

As the size of the company increases the degree of personal contact decreases and therefore to obtain the same degree of control more written information has to be given to management and as a result the size of the indirect labour force increases and consequently the overheads. An additional requirement is some form of visual display of the proposed manufacturing programme and this could take the form of a Gantt chart or provided one is satisfied with control by a system of exception Knight (16) gives a review of a good practical and easy to operate system-

With the development of electronic data processing equipment it became possible to analyse data much more quickly and by use of collators, reproducers and card sorting machines, customers orders could be more quickly analysed, the required job cards produced and after completion of the work, progress reports more quickly produced. The cost of the equipment was often prohibitive for the smaller company and so it was left to the larger concerns to develop systems associated with EDP. Because of the complexity of the production function the earlier applications often tended to be restricted to stock control applications and parts explosion from which were produced the required job cards.

As the electronic computer was developed the ability for management to produce control systems where the programme development was quite rapid and the monitoring procedure and analysis done quickly became apparent and computer systems were developed and reported by Cox (17) and the major computer companies i. e. I. B. M., I. C. L. and Honeywell, each developed their own packages for doing certain functions but again the earlier packages dealt with stock control, sales analysis, payroll and such functions. The production control function was often left because of its complexity. Whilst no proof can be given for the statement, possibly the reason for this apparent reluctance to deal with production control may have been the obsession of the mathematicians with finding a procedure to give an optimum manufacturing schedule and it was only with the introduction of the use of priority rules GERE (18) to establish a workable schedule that computer manufacturers started to develop production control packages.

With this facility for fast analysis an obvious development was a system for fast data retrieval and thus systems were developed in which the time lag between an event happening and any action required being taken is considerably reduced, such systems have been reported in (7) (19) (20).

These developments still favoured the larger companies and so in 1966/67 the government commissioned the new developing computer bureaus to undertake feasibility studies of the practicability of producing modular package systems, a number of which could be linked together by means of a special program and thus make possible the use of computers to the smaller company as the development costs of the programs could be spread over a number of individual concerns.

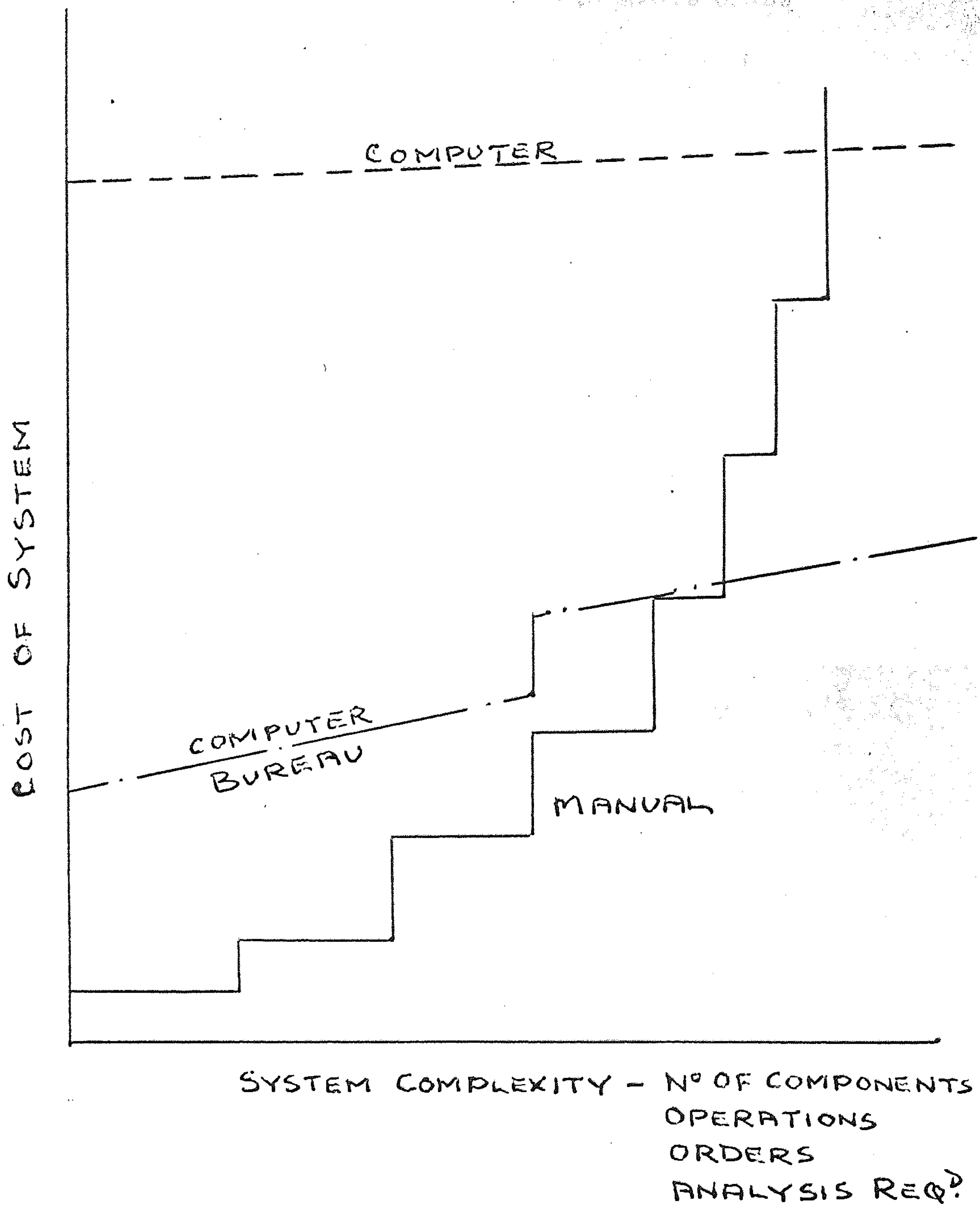
The time lag for a company using a computer bureau is still greater than a company having its own computing facilities but if one takes into account the much lower amount of capital tied up in the system then the return on the investment might be equally attractive.

In the case of the present research, the size of the sponsoring company was such as to restrict the choice to one between -

(a) A fully manual system

or

(b) A system making use of a computer bureau.



SYSTEM COSTS

FIG. 4 - 2

The costs associated with systems of control are believed to follow the pattern illustrated in Figure 4-2 and it will be seen that the horizontal independant axis includes a measure of the production system complexity in the form of the number of operations per job. This again confirms the view that the more simple one can make the manufacturing system the easier it is to control.

Edwards(21) has acknowledged that it is wrong to accept a system and formulate a procedure to control it - one should first question the system and having modified it (if found necessary) then to formulate a procedure to control this improved system.

4. 2. EVALUATING THE EFFICIENCY OF THE SYSTEM

There are two main approaches used in evaluating a system:

(a) The cost-effectiveness method.

(b) The cost-benefit analysis method.

(a) Cost-Effectiveness - Assumes the outputs from the systems to be compared to be of the same magnitude in terms of quantity and quality. The cost of producing this output is then determined for each system and the one that produces the lowest 'input to output' ratio or lowest cost is said to be the most effective system and is the one selected.

(b) Cost-Benefit Analysis - recognises that the inputs and outputs from systems may both vary or just the output vary in the terms of quantity and quality. The systems proposed are costed as before but for the system with a higher cost ratio the question is posed 'Is the higher cost justified by the improved value of its output'? If it is then the system is worth considering for adoption.

In both these methods, costs are reviewed and one must be careful only to consider relevant costs. If a cost will be eliminated or changed dependent upon the decision made then it is said to be a relevant cost and must be considered.

If the cost will not be effected by the decision then it is not relevant and should not be considered.

Of the two methods for evaluating a system, the first is by far the most simple to apply. The second requires the assessment of the added value of the output and this sometimes is dependent upon opinion and is therefore not readily quantifiable.

For the smaller company the first method is usually adopted because of its simplicity whilst the large organisation would tend to consider the Cost-Benefit approach as a small percentage increase on a large turnover is worth pursuing.

CHAPTER 5

THE INTEGRATED MANAGEMENT CONTROL SYSTEM

Starr (22) defines a system as 'a group of activities, functions or components having managerial purposes that can be bounded.' The rule for bounding he gives as 'all relevant interdependencies interactions and relationships must be enclosed within the boundaries of the system.'

Boyce (23) considers that to be an effective management control system requires 'the combining of policies, procedures and information processing, to give direction to the activities of the enterprise.'

(a) By clearly establishing goals.

(b) By measuring progress towards these goals.

(c) By indicating or initiating corrective action.

(d) By displaying the potential for further improvement.

With the growth in size of the individual company compelling the owner to delegate his responsibilities to subordinate departmental heads, he did this initially by organising them on a strictly functional basis. This often led to a series of 'water tight' compartments being created within the organisation with little or no formal contact between them. See Fig. 5-1 Boyce describes the resulting structure as a management pyramid each face of

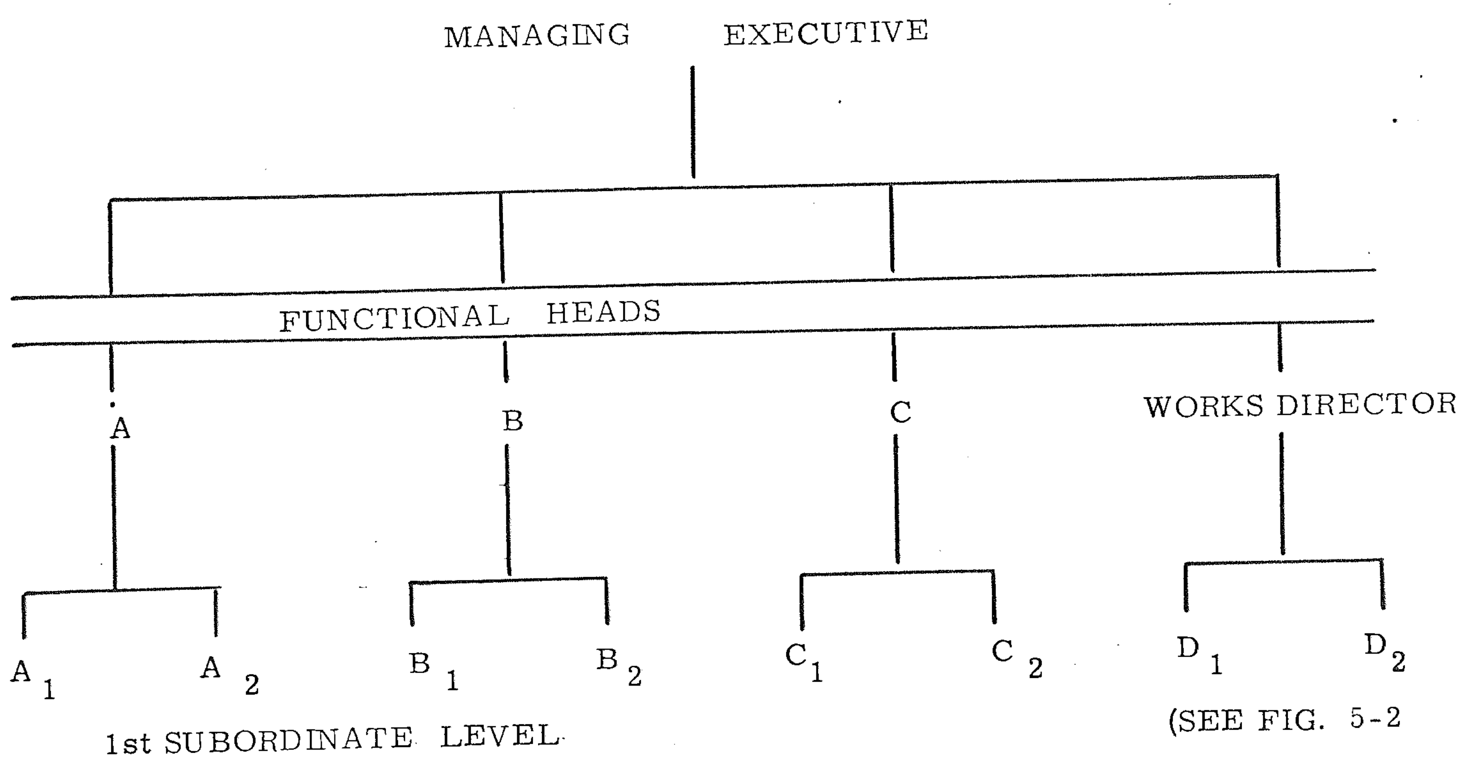
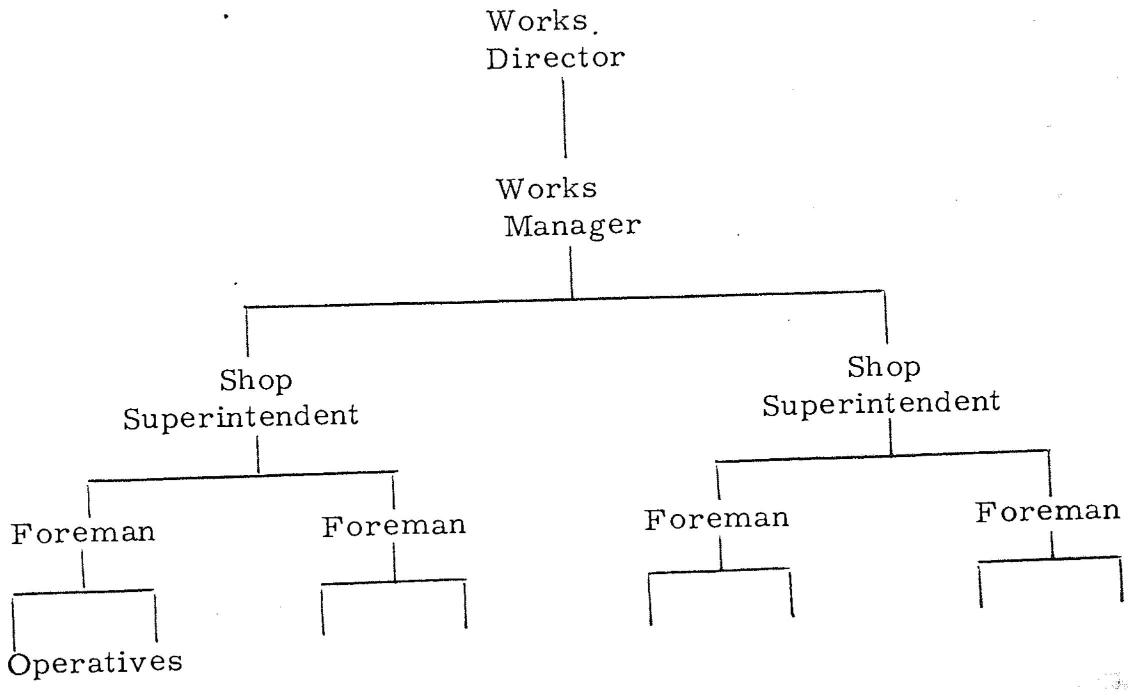


FIG. 5-1 - FUNCTIONAL OR CENTRALISED SYSTEM which represents a different facet of the organisation, the face representing the production unit possibly being as shown in Fig. 5-2



FUNCTION BREAKDOWN.

Fig. 5-2

Provided each level of command has the full authority required for the occupant of the role to carry out his task this is a simple form of organisational structure. It encounters trouble when the occupant does not have full authority to act independently in making his decisions. For example, to meet a particular production schedule the Works Manager may decide that he can only do this by using method 'A' and working 'X' hours overtime. But the Methods Department may stipulate method 'B' must be used and the Personnel Department require a limit on overtime hours to avoid unrest in other departments.

To overcome the problem could require the action of the Director at the apex of the pyramid which can distract him from his function of policy making and also result in the overloading of the channels of communication.

The purely functional type of organisation is often referred to as a centralised system and to overcome part of the problem outlined above a decentralised system is often adopted. Under this form of system a specialist from a function may be attached to the Manager of another function from whom he receives instructions on what to do but how to do the task is given in instructions from his own function head.

The above form of organisational structure is usually found to operate within a group of companies where the group head office is located away from all the member companies. The various functional heads are located at this office and from here formulate and dictate policy. Each functional head is responsible for the techniques to be used by his subordinates at the various member companies and for the efficient performance of these tasks he is accountable to the Main Board of Directors. Vertical contact therefore takes place between him and his subordinates.

At individual company level, the immediate subordinate may be considered to be at the same management level as other immediate subordinates of other functional heads and together they form an integrated management control team. Each is accountable to his own functional head as to how he performs his task but receives instructions on what to do from the person to whom the Main Board has given the responsibility and authority to decide how its given targets are to be achieved. Horizontal contact between various functions therefore takes place between the members of the management team with respect to what to do and reporting on achievements against the programme.

Fig.5-3 gives the organisational structure in diagrammatic form.

The decentralised structure therefore recognises that to be an effective system information must not only pass in the vertical line but must also pass horizontally between functions or to different levels of command in other functions.

For most manufacturing companies the functions that go to make up the managerial pyramid include:

Sales

Market Research

Product Design

Production Units

Production Units Service Departments

Finance

General Administration

Despatch and Distribution

Inventory Control

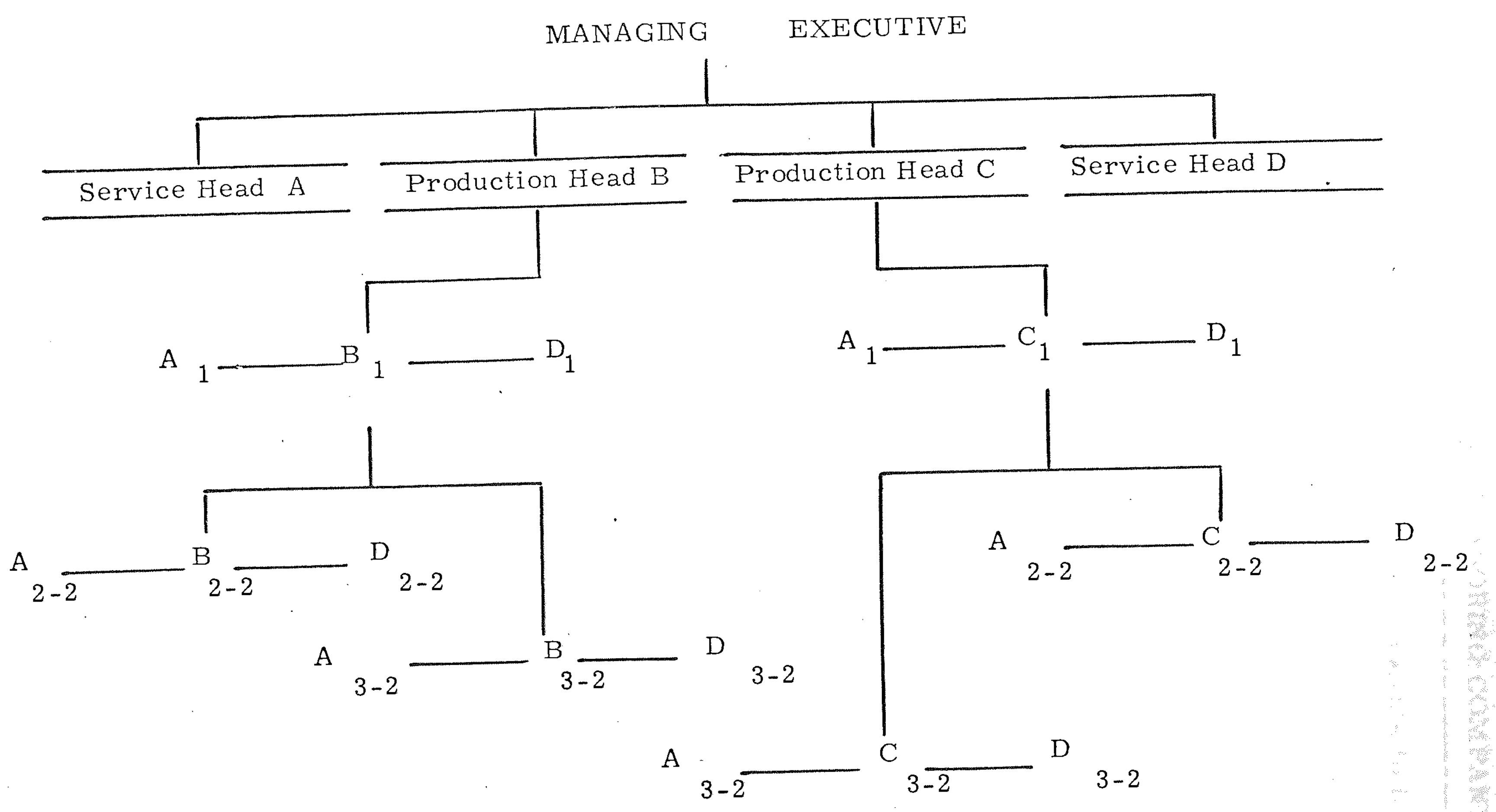


FIG. 5-3 - LINE AND STAFF OR DECENTRALISED SYSTEM

5.1 THE APPLICATION TO THE SPONSORING COMPANY

The sponsoring company did not produce components to its own design but accepted the customers design. The only design that was done was tool design for the die presses and subsequent machining operations (N. B. In certain instances the customer provided the tooling and therefore no design was required).

Because of this type of manufacture the company's managerial pyramid consisted of the following functions:

Sales

Production Units

Production Units Service Departments

Finance/General Administration

The inter-relationships were therefore kept to a minimum but because of this (and also the size of the company) there was the tendancy to remain organised on a strictly functional basis with a consequential restriction in the amount of cross flow of information which is an essential part of the integrated management system.

5.2 STAGES IN THE APPLICATION OF A CONTROL SYSTEM

For the system to be controllable the following stages are essential:

1. The customers demand must be known (either actual or forecasted).

2. This demand must be analysed and a programme originated that will meet the demand.

3. Instructions must be issued to the manufacturing departments to initiate and maintain the programme.

4. The performance of the manufacturing units must be monitored and corrective action taken as required.

5. The actual deliveries to the customer must be compared with demand.

6. The performance of the system as a whole must be checked to ensure that the criteria that affect the company's profitability are controlled.

5.3 ANALYSIS OF THE INPUT

Given a sales order giving details of the customers forecasted or actual requirements or in the case of a company producing for stock the demand which, taking into account buffer stock, the Sales Department consider will meet the requirements for a given level of service, then the first requirement of Production Control is to prepare a 'parts explosion' giving details of the components required to meet the demand and the associated man/machine hours and material requirements.

Corke (24) has outlined the procedure when done manually and all computer bureau packages dealing with ther stock or production control will include this facility.

The demand must now be analysed and a practical manufacturing schedule produced which makes optimum or near optimum use of the company's three main resources i. e. men, machines and materials. In preparing the schedules the person or persons responsible must always bear in mind that the objective of any commercial organisation is to make a profit whilst at the same time ensuring an adequate rate of return on investment.

The rate of return on investment

$$= \frac{\text{nett profit}}{\text{investment}}$$

$$= \frac{\text{Sales - (cost of sales + administration expenses + taxes)}}{\text{working capital + fixed assets.}}$$

If the organisation wishes tomaintain a given rate of return on investment then any action which causes a change to the value of any factor which goes to make up the denominator or the numerator in the above equation must be balanced by a change to a factor in the numerator or denominator as the case may be.

Machines and materials are often tightly controlled in a manufacturing system in an attempt to maintain a constant return but the human element, which can often cause the greatest variation, is not controlled to the same extent when preparing a manufacturing programme.

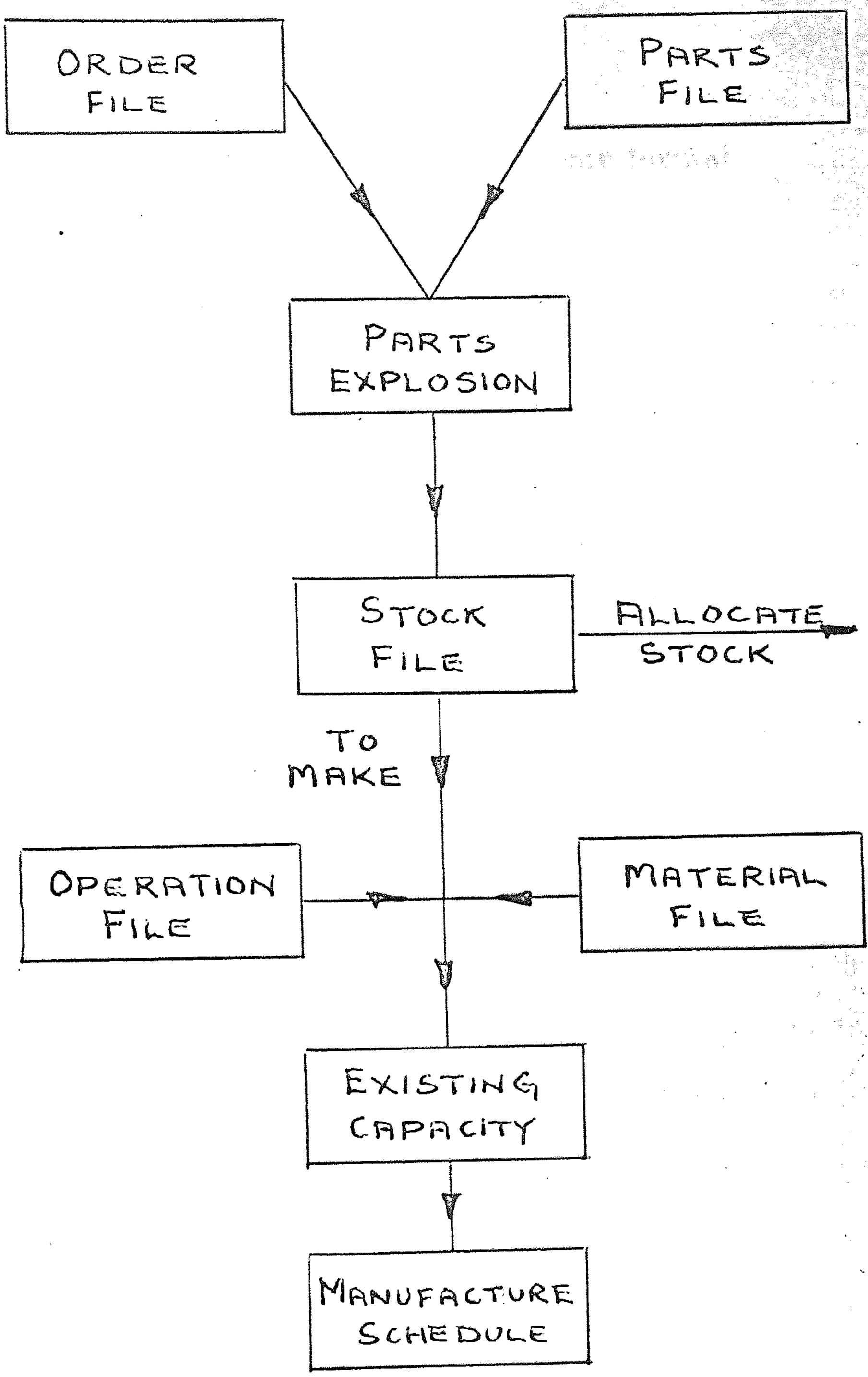
To assist the Programmer to prepare manufacturing schedules, various mathematical techniques have been developed and these have been reviewed by Conway et al (26). The major disadvantages of the mathematical approach is in the restrictions that apply i. e. that the technological sequence cannot be changed, that a batch of components must be cleared from one operation before the following operation can commence. To overcome these objections a procedure of scheduling using 'priority rules' has been developed and these are reviewed by Buffa (27) in which he reviews work of researchers into the effectiveness of different priority rules.

Most computer packages for scheduling use one of these priority rules for scheduling and in certain programs the choice is variable to suit the individual company.

The procedure for preparing the schedule is given in diagrammatic form in Fig. 5. 4.

5. 4 DOCUMENTATION AND ANALYSIS OF OUTPUT

Only in the very small company, where control is exercised closely by the owner, can instructions regarding manufacture be issued verbally and the performance monitored by visual observation and



PREPARATION OF SCHEDULES

FIG. 5-4

by analysis of the cash book.

In the larger company (above 25 employees) some formal documentation must be used:

(a) To instruct the operator on what to do.

(b) To record the time taken by the operator for payment purposes.

(c) To record issues and receipts into stores.

(d) To record despatches to customer.

Documentation does add cost to the job and not value (Chapter 4) and this is possibly the reason why one often finds that companies will use their forms or cards to pass data or information to operators or departments but they will not, at the end of the job, analyse the final data to compare performance with programme. Thus any inaccuracy in the procedure is perpetuated with each new job.

Fig. 5-5 details some of the documentation required and shows how the analysis of data on these documents is used by management whilst Fig. 4-1 shows the closed loop concept of management control.

Of the above six stages, the demand was given to the company by means of a monthly schedule; stages 2 to 5 inclusive were the responsibility of the Production Control executive; stage 6 was left to a number of individual departmental heads to issue statistics but how they affected the company's performance was not analysed. The control loop was therefore incomplete and it must be admitted that the resultant management decisions were not effective.

The demand level given to the company by the customers was liable to alteration and therefore the first requirement in producing a controllable system was a procedure to predict the error in the customers forecast of demand and knowing this to then establish the manufacturing capacity required to meet this demand.

Only when this was known could an effective manufacturing system be recommended and controls applied to the complete system.

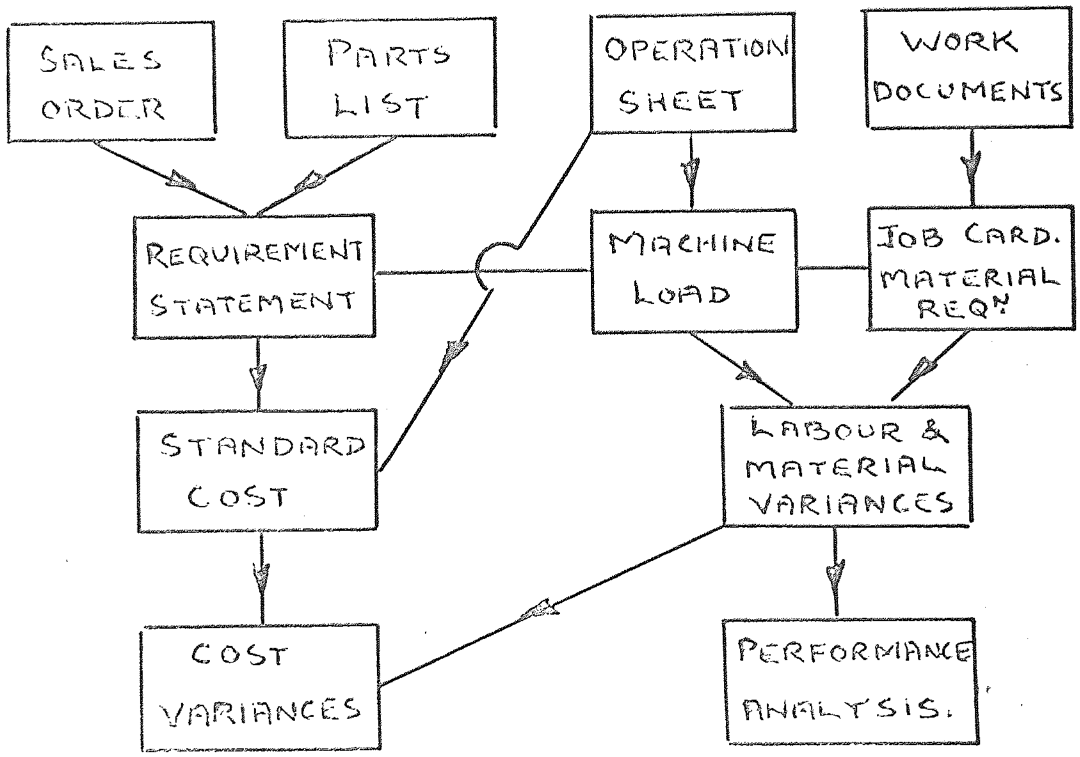


FIG. 5-5 DATA ANALYSIS

CHAPTER 6

FORECASTS OF DEMAND

Dependent upon the use to be made of a forecast so does the accurracy required of the forecast vary Magee (28). Management require forecasts covering three basic time spans if it is to carry out its role effectively.

(a) A short term forecast of requirements up to one year ahead - this enables a realistic manufacturing policy to be formulated.

(b) A medium term forecast for the period 1 - 3 years ahead - this enables short term capital programmes to be formulated.

(c) A long term forecast for periods 3- 8/10 years ahead - this enables long term company and capital projects to be appraised.

6.1 FORECASTING APPLIED TO THE RESEARCH PROJECT

For the work being undertaken it was the short term forecast that was applicable but the company was fortunate in that it was given the forecasts of future demand by its customers by means of their monthly schedules and therefore Sage Aluminium's problem was to try and predict the error in the customers forecasts.

The actual market research and analysis was done by the customer and no knowledge of the mathematical model used (if any) existed only the end results. Relationships with the major customer were good and any anticipated error was quickly passed verbally to Sage Aluminium. Close liaison by Fords also took place when mid-way through the exercise they changed their forecasting procedure. Again however, only the end result was known.

Another factor which had to be taken into account when looking at the errors in the forecast was the affect of past performance on previous delivery schedules, the cause of which was within the control of Sage Aluminium.

When arrears occurred these were shown as immediate requirements and therefore did not affect the forward schedule, but if 'over delivery' had occurred, then the forward schedules were reduced to take account of this.

A major factor causing variation in final demand was the susceptibility of the major motor car industries to industrial disputes which had the effect of immediately placing a hold on the delivery schedules. Sage Aluminium as manufacturers, were given the alternative of continuing to manufacture but holding stock for future issue, hoping that a later increased demand would take this surplus, or else holding production pending the settlement of the dispute. Whichever case was adopted they incurred a financial loss.

(a) In the first case by holding costs.

(b) By loss of contribution of the operators working hour.

To overcome this loss which could occur due to circumstances beyond their control, the company started to diversify into other industries. Although it is too early to form any firm conclusion regarding the demand pattern, it does appear that the monthly fluctuation is greatly reduced and therefore in this work products other than for the motor car industry have been assumed to be the constant monthly demand as given by the yearly budget.

To observe the error in the forecasts the final monthly demand for a product was compared with the forecast for that month in the previous two months. The distribution of the error was then plotted for the two months, the errors being -

i.	1 month previously, mean	.9669
	Standard deviation	.238
ii.	2 months previously, mean	1.018
	Standard deviation	.273

The tables in simplified form are given in Appendix A together with a histogram showing the form of distribution.

In arriving at the mean, the extreme ends of the errors were ignored as it was considered that these were due to circumstances beyond the control of both the customer and Sage Aluminium and would have to be resolved by personal intervention as is the case in most manufacturing organisations at some time.

As mentioned earlier in this section, the Ford Motor Company changed its forecasting procedure part way through this exercise which enabled a reduction in the allowance required to cover anticipated actual demand.

	Forecasting Technique old	new
Mean Error	1.042	.9669
Standard Deviation	.232	.238
Allowance Required	27.4%	20%

CHAPTER 7

THE ORIGINAL SYSTEM

The schedules were received from the customers after the commencement of the month to which the first period referred to and so in theory one had two choices -

(a) To use the previous month's forecast of demand and commence to manufacture this quantity.

(b) Wait until the schedule was received before authorising any manufacture.

In some ways the company were fortunate in that on the majority of jobs they were delivering in arrears and so invariably the schedules were received before they were in a position to commence casting.

That this position had arisen may have been due to them adopting course (b) above in the past as this would eventually lead to a position of substantial arrears. An alternative may be that the position was due to a dramatic increase in scrap percentages due to either :

(a) The company having to employ semi-skilled labour in the casting shop.

(b) The low state of maintenance of the casting machines.

(c) A combination of the above.

Or the cause may be factors beyond the control of the present company management.

It is to the credit of the management that they acknowledged their responsibility for plant maintenance and concurrently with this research work, an investigation was made into a system of planned maintenance (29) within the company.

On receipt of the schedules, the production control executive transferred the quantities to a works record book in which was recorded all component manufacture and transactions. The only form of machine loading done by the foundry was that daily the Production Controller in consultation with the Foundry Manager decided upon whether or not the jobs running on each machine should continue for a further shift or should be stopped.

If the latter was the course of action, then the Controller decided which job should be loaded next (by reference to the works record book) and wrote an instruction to the Toolroom Superintendent to the effect that a tool change was required and gave details of the new tool to be placed on the machine.

A list was also given daily to the foundry supervision stating which machines should be operated.

The output from each casting machine was recorded by means of a Kienzle counter (see Chapter 8.1) and each day the recording disc from each shift on each machine had to be analysed to give the number of shots and the hours worked.

The output, as given by this analysis was recorded in the works record book as the actual output although it was known that this would be in error.

The machine shop load was compiled by consultation between the Production Control executive and the Machine Shop Foreman who issued weekly a list of jobs to be done by each operator on which day.

The actual quantity done was passed by the operator to the Booking Clerk when she clocked off her job and her piecework earnings were calculated on this figure.

The only real check on quantities of work was after final inspection and the components were counted (by hand or weigh counting) into pallets. This quantity was then passed back to the Production Controller for entry into the book as deliveries made.

To check stock, physical stock checks were made at quarterly intervals and the quantities shown in the record book amended if required.

An additional output from the Production Controller was a statement to the Board of Directors each month giving the sales value of work schedules for the following two months.

CHAPTER 8

LIMITATIONS OF PRESENT SYSTEM

Although it is a system based upon personal contact and as such suffers greatly from the clash of personalities one often finds in management, there is a basic system that could work provided:

(a) The casting machines could be relied upon to produce a reasonably consistent good casting.

(b) The machines could be reasonably expected to have a low breakdown record.

(c) The outputs at various stages were known with a better degree of accuracy.

The company have already taken steps to improve (a) and (b) by employing a Process Controller in the foundry and by implementing a scheme of planned maintenance (29). It is the failure to record accurately the outputs and performances at various processes that causes the system to fail.

8.1 OUTPUT FROM THE FOUNDRY

Each machine is fitted with a Kienzle counter which records the number of strokes or shots of the machine. Unfortunately it only records a stroke and this does not mean that the component produced was a good component or an obviously scrap component, or whether any component was produced i. e. the machine was closed thus operating the counter but no metal was poured into the die - the operator would thus get credited with producing a component although nothing was produced.

The theoretical procedure that should have been followed was that the operator produced a die casting on the machine and on removal from the die he should inspect it and if he considered it to be a good component then it should be placed into a pallet for good components. If he considered it to be a scrap component then he should place this aside to a second pallet and at the end of a shift the scrap should be counted and the reading of the counter modified to allow for this.

In most cases there was no second pallet in which case the operator placed the scrap components on the floor but the worst feature was that no one was instructed to count the waste components and so these were simply removed by the labourer at frequent intervals. Thus the only record left to the company was the reading of the counter. Checks made with other companies operating similar processes showed that this problem was not unique to Sage Aluminium with the exception of their failure to keep a closer check on the number of supposedly good components delivered from the machine.

Whilst he acknowledged that the occasional operator would attempt to cheat by not pouring metal into the die, the Foundry Manager claimed that the occurrence of this was very small (taking into account that shift leaders , Inspectors and himself were continually moving round the foundry) and also if an operator persistently practiced this habit it would result in a non-uniform slope on the Kienzle counter disc. He admitted that in spite of this the occasional operator had been found cheating and had been severely dealt with as a result.

A series of sample checks were made by the Inspection Section on the actual quantity of components received from the foundry (the check being a physical count) and these were compaed with the figure shown on the counter. Variations of between 6% - 8%

were recorded, the mean being 6.7%.

An analysis of the value of sales and the cost of production was made by the Accounts Section and this showed an unaccountable difference of $7\frac{1}{2}\%$ or a possible loss to the company of £82 per week.

Spot checks were made by the author and the Foundry Manager and the amount of scrap produced by the operator and laid by the side of his machine or in the scrap pallet (as per instructions) noted and this amounted to approximately 6% of the output. These checks were repeated at infrequent intervals with the same result.

One can therefore say with a fair degree of confidence that the discrepancies in output figures were not in the main due to operator error but due to the company not operating its stated procedure.

Other companies with a similar problem have had to rely upon a physical count of the components or in an attempt to reduce the cost of this counting operation, a system of weigh counting has been introduced.

An alternative would be a detailed analysis of the work produced at the casting machine and a statistical analysis done to estimate the percentage scrap produced for which the operator was responsible and the percentage scrap produced for which the process was responsible.

The reading of the counter could then be taken and reduced by the total scrap to determine the actual output from the foundry but reduced by only the percentage for which the operator was responsible to determine his paid output. N. B. This assumes that any loss due to a non-working stroke is kept to a minimum by good, effective management being seen to be operated.

If a system of physical checking was introduced the cost to Sage is estimated to be £90 per week (see Appendix B) which although greater than the estimated cost of the losses (£82 per week) the £8 excess is justified because of the ability to know accurately the actual output.

8.2 MACHINE SHOP AND FINAL OUTPUT

The record of output of the machine shop depends upon the ability of the girls (and their honesty) to read the digital recorders fitted to their machines. The figure given by the operators is used by the Wages Clerk to calculate their earnings and no check is made on the quantity until after final inspection and preparation for despatch.

Assuming the girls were correct in their readings and recording, errors occurred because of poor handling and work storage facilities at the machines causing components to fall onto the floor where they were left for the labourer to clear away and pass back for re-melting with the swarf. Therefore what the operators machined and what was actually inspected could be two different total quantities. Again not the operators fault but the companys for not providing better work storage.

After inspection, the components were passed to despatch and it was only at this stage that an accurate count was passed back to Production Control for entry in the works record book.

8.3 PERFORMANCE ANALYSIS

At the end of each shift in the foundry, the Shift Leader prepared a record sheet giving the work done on each machine and the name of the operator. The details included:

1. Job number.
2. Time started.
3. Time stopped.
4. Allowed shot rate.
5. Total time actually producing components.
6. Time lost to and cause of any stoppage.

These were passed to the Production Control office and the information should have been entered onto a daily performance analysis sheet and from the data the operators performance index calculated and also the machine utilisation. An average for the whole shift was also obtainable.

The frequency with which the analysis sheet was completed was most irregular and on the majority of these occasions only the times and quantities were recorded and no attempt made to calculate performance indices.

A similar situation existed in the Machine Shop. Although the procedure was there for the recording and analysis of lost time, it was not followed.

The existing manufacturing system was therefore not a closed loop but one of the form illustrated below in Fig. 8 - 1 and the result was that the management relied upon opinion on which they based their decisions.

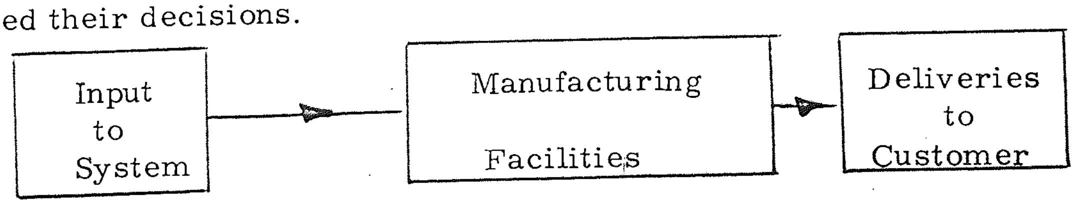


FIG. 8 - 1

CHAPTER 9

PROPOSED MANUFACTURING SYSTEM

The philosophy adopted was that Sage Aluminium was a single manufacturing unit within a Group and likewise within Sage Aluminium, although there was a number of individual manufacturing sections they had to be considered as a complete manufacturing system, the performance of any one section having a possible effect upon another.

The initial contact between the company and a prospective customer was through the Technical Sales Department who, provided the work was suitable, submitted to the customer an estimate of manufacturing costs for his individual component. The actual procedure for making the estimate appears satisfactory and no proposal is made to change this - what must be changed is the lack of feed back from the shop floor on the performance of the works compared to the estimate.

If an estimate is successful and an order is received then an operation summary sheet must be originated by the Technical Sales Department giving details of the manufacturing method they based the estimate upon, the estimated weight of material and other relevant details relating to machine and labour grade. To enable Production Control to exercise its scheduling function, the estimated times for each operation should be entered on the operation summary sheet in pencil. When the component is in actual production and correct times established these must be entered on the operation summary sheet in ink or typewritten. Thus whether a time is estimated or fixed is indicated immediately. The format of the proposed operation summary sheet is given in Appendix C .

Work is authorised by the customer by means of monthly schedules and it is proposed that the foundry be loaded on an eight week cycle (see chapter 12) covering the forward periods 2 & 3. The reason for fixing this limit is that the customer will only accept liability for machine costs in period 2 and material costs only in period 3. Further than this they will not accept any liability for costs incurred.

The figures given for periods 2 and 3 are the customers forecast of his demand and as such are liable to error. To allow for these errors the quantity stated by the customer for period 2 should be increased by an amount equal to one standard deviation above the mean (see appendix A for details of analysis of past errors) but because of the existing industrial position the quantity for period 3 should be accepted at face value.

A monitoring procedure for checking the quantities thus issued to the foundry and the quantities given on subsequent schedules is outlined in diagrammatic form in Appendix C.

9.1. AUTHORITY TO THE FOUNDRY TO PRODUCE COMPONENTS

To authorise manufacture in the foundry, a foundry job card should be introduced giving for each job :

(a) The quantity required.

(b) The estimated hours required.

(c) The shot rate and number of units per shot on which the above was based.

(d) The machine or machine groups on which the job is to be done.

(e) The starting week number for the job.

The cards should be originated by the Production Control Clerk when preparing the schedules and placed in a suitable rack in week number order, until required.

In addition to this a visual load chart should be used (this is now in use) showing the planned start and finish of each job on each machine.

At least two shifts before a job is due to finish on a machine, the Foundry Supervisor should consult the Production Control section to find out the next job due on that machine and should inform the Tool Setters of the impending tool change.

A job should finish on a machine when:

(a) The number of components required have been produced.

(b) The number of allowed hours has been reached.

The Foundry Supervisor should inform the Production Control when either of these two restraints are reached and they must make the decision if there is a large variance between actual and planned. Until they give the authority to do so, a die must not be removed from a machine.

The Foundry Supervisor knows the actual number of components per shot that is being achieved and it is his responsibility to inform Production Control of this figure when it differs from the planned output, they then can consider correcting their programme if required.

Facilities should be provided at the machine for the caster to segregate good components from scrap and his pay should be calculated on the number of good components produced. The scrap is bound to result from one of two main factors:

(a) A process defect over which the caster has little control.

(b) His own carelessness.

If he is only to be paid for good components produced then he must be given an allowance for process defects. This could have a positive effect in encouraging him to exercise his skills to keep this to a minimum and thus he would obtain some additional credited time i. e. bonus.

The quantity of good components in a pallet must be established for all work leaving the foundry (see chapter 8. 1) and this is at present the subject of negotiation between the company and unions. Each pallet should be labelled with an identification tag giving the component number, date and shift cast and the number of components contained in the pallet.

These figures will therefore give the output from the foundry and aid the batching of work ready for processing through the machine shop.

The Foundry Supervisor should still continue to complete his shift record sheet as at present but ensuring that all time on each machine is accounted for and the causes of any stoppages given. This information is transferred by Production Control into either :

(a) The works record book for control purposes.

(b) The individual operators weekly record card for wage purposes and performance calculations.

At the end of each week the performances should be summarised into a total departmental performance and a 'shift' performance. The losses should be clearly defined and caused assigned.

9. 2 AUTHORITY TO THE MACHINE SHOP TO PRODUCE COMPONENTS

The Machine Shop has been arranged into groups (see chapter 12-3) and thus work is loaded onto a group of machines and not individual machines. Appendix D gives details of the grouping and the number of operations required on each group for each component together with the hours taken for 100 components to pass through the group.

It should be noted that this is not the standard hours for the component that would have to be used for wage payment purposes. This would still be the sum of the individual operation times.

Before a batch of components is issued to the Machine Shop then not only must the machines be available but also the required number of operators to work as a group. Whenever possible the policy should be that components are taken from a pallet for the first operation and should not be replaced into a pallet until the final operation is complete.

The operators would be paid bonus as a group (this principle is already established on certain components) and the total quantity booked by the operators should correspond with the quantities shown on the pallet identification tag. Each machine is fitted with its own digital recorder therefore any discrepancy is quickly noticed. Whilst a single machine counter is open to abuse when working as a group all machines should show the same error if the discrepancy is genuine.

Work should be planned using a visual display chart constructed on Gantt chart principles thus enabling the operators and machine groups to be readily matched. Job cards (existing format) can be prepared at this stage (excluding details of the operator) and filed until required.

Stoppages, waiting time and other undesirable lost time should be recorded (again using existing cards) and these must be signed by the Machine Shop foreman giving the cause and allocating responsibility.

Each day the individual operators record card is completed giving details of work produced and lost time.

At the end of each week the individual operators performance is calculated and the departmental performance is obtained.

9.3 INSPECTION POLICY

It is company policy that all work must pass through inspection and if control is to be kept over delivery dates then consideration should be given to classing this inspection as a separate final operation for which time should be allowed for in the manufacturing programme. At present most work is inspected 100% after machining (see appendix B) but there is a proposal to introduce a sampling inspection scheme but this is dependant upon the outcome of current negotiations on the counting of work from the foundry as it is claimed that the majority of scrap would be obvious at this stage. If the negotiations are successful, the components would be 100% inspected at the actual casting machine, the Inspector separating the good from the obvious faulty castings.

This would result in a financial saving of £2191 to the company due to not having to pay the Machine Operators for machining faulty castings, the calculations being given in appendix B

9.4 DESPATCH POLICY

Assuming that the inspection process is classed as an operation, then the fact that the work is completed and available for despatch will be automatically signalled by the clearance of the operators job card.

Whilst the inspection remains 100% as at present then an accurate count can be obtained.

(a) By a physical count by the Inspector on large components.

(b) By a weigh count on the smaller components that will fit the weigh pans on the existing machine.

When the completed work is received into the despatch area the Despatch Clerk should contact the Production Controller to receive instructions.

Transportation of the components to the customer is, with few exceptions, the responsibility of Sage Aluminium using at present their own transport backed up as required by private hauliers. Negotiations are in hand to pass the entire transportation of goods to a private concern.

Although this will mean less capital tied up by Sage in lorries it does mean that if they are to avoid excess payment for 'part loads' they will have to plan the work through the Machine Shop and arrange for it to be assembled by the Despatch Clerk into economical lorry loads.

A load for a lorry is not only governed by its maximum permissible load (and as the product is aluminium this is rarely a factor) but also on the maximum cubic capacity it can carry. To enable this to be considered by the Production Control function at the scheduling stage, the quantity per standard pallet (36" x 24" x 24") is shown on the operation summary sheet.

When the Despatch Clerk has ensured that the quantity stated is in the pallet and has originated an advice note, he must supervise the loading of the pallets onto the lorry, give a copy of the advice note to the driver for the customers goods inwards record and send a copy of the note to the Production Control who will enter the despatch in the works record book and type the official invoice to the customer.

9.5 PAPERWORK

To perform these functions listed, paperwork in the way of forms and record cards must be originated. Wherever possible existing forms and cards have been used and these together with proposed new ones are shown as appendix C .

The estimated costs associated with the manual system are given as appendix E .

CHAPTER 10

FOUNDRY PROGRAMME - INITIAL BATCH SIZES

The problems associated with endeavouring to produce a workable manufacturing programme in a multi-product situation have been well documented Hull (30) Eilon (31), Wild (32).

Wild gives a good review of the work done by researchers in the application of heuristics to the scheduling problem, whilst Eilon, by contending that good management will always be prepared to recognise that optimum conditions rarely exist, makes use of an allowable increase in cost (expressed in terms of increase in variable costs or increase in total costs) to produce a production range and proposes a heuristic method to develop a workable multi-product schedule.

Magee (24) proposes a method for determining a multi-product schedule based upon a heuristic applied to the number of runs per year for the individual components as derived from the traditional economic order quantity formula. A comparison of this and other rules are contained in Griffiths (33).

As stated in Chapter 9, the foundry programme was to be based on an eight week cycle.

Although the basic calculations are done for an eight week cycle the programme should be reviewed when the customers schedule is received for the month (i + 1)and if any drastic amendments are suggested then these should be implemented, otherwise the programme as planned should be adhered to with the following as guide lines.

1. The programme is fixed for both component and quantity for two weeks ahead.

2. The programme is fixed for component but the quantity may vary for the following two weeks.

3. Both component and quantity may be varied for the following four weeks.

The basic formula used when calculating batch quantities is:-

$$Q = \sqrt{\frac{2Y\ C_s}{I\ c}}$$

from which N the number of cycles per period is given by

$$N = \sqrt{\frac{Y\ Ic}{2\ C_s}}$$

Griffiths (33) showed the advantage of using manufacturing cycles, the frequency of which is the form of a geometrical progression (see appendix F) and working on the eight week cycle for Sage this meant cycles of 1, 2 4, 8 or 16 weeks. In practice anything that required running at one or two week cycles was classed as a continuously running job.

The 800 ton press group was by company policy -

(a) Manned for twenty-four hours per day.

(b) Any changeover of tools took place at the weekend.

As these were restrictions applied only to this group and also the work did not pass through the Machine Shop (trimming being done by a male operator on a press in the Foundry), it was decided that they could safely be left out of any calculations, provided these did not use weekend working.

The responsibility for setting the tools on the die casting machine is the Toolroom Superintendents. There are two teams of two men (one day shift and one night shift). Once the tools are set then the Foundry supervision takes over for final adjustments.

Obviously setting times do vary but approximate times have been given as:

800 ton press	21 man hours
400 ton press	14 man hours
250 ton press	8 man hours
Other presses	4 man hours

The time spent by the Foundry supervision only amounts to approximately 0.5 man hours per set up and as this can easily be offset by the variability in performance of the main Tool Setters it was not included in the calculations.

Allowing a Setters rate of £1 per hour plus 100% overhead gives an applied rate of £2 per hour. The 100% overhead is only an estimated figured based upon the author's experience and one which was not violently disagreed with by the company whose present costing policy only considered one toolroom overhead, but this included machine tool depreciation, tool repair etc., the cost of which should have been allocated back to the Foundry by a budgetary control technique.

The only overheads for the Tool Setters should have been their work benches, lifting tackle proportion and trial costs.

Allowing £2 to cover the cost of paper work per order, the setting costs per machine become -

800 ton	£44
400 ton	£30
250 ton	£18
Others	£10

The holding charge covers the cost of keeping cash tied up in the form of stock or work in progress plus any storage charge. Other factors such as design changes do not readily affect Sage and can be ignored.

To borrow cash costs approximately 12% per annum (this was the figure in mid 1973 when the calculation was done) and allowing for approximately £25,000 in work storage (to be controlled by a Storeman at a rate of approximately £25 per week) gives a labour holding charge of 5%. These two factors give a total charge of 17% and to give a 10% profit after tax requires the addition of a further 3%. Thus the holding charge (I) used was 20% per annum.

The constant cost 'c' (the cost of manufacture) of the item is correctly found by the expression -

MATERIAL COST + [standard hours per unit x (hourly wage rate + overheads)]

and it is this cost which should be multiplied by the holding charge (I) to give the holding cost 'Ic' in the equation for 'N'.

Because the majority of components are fully machined before any inspection is done and any subsequent storage made it was felt that if the actual selling price for mid 1973 was used as the constant cost this would be more easily applied by the control personnel, the profit margin included in this figure covering any increase in works cost due to material price increase.

Using the above data, for each component the number of cycles (N) to achieve 'minimum' total variable costs was determined.

If $N < 1.41$ it was classed as 1.
If $1.41 \leqslant N < 2.83$ it was classed as 2.
If $2.83 \leqslant N < 5.65$ it was classed as 4.
If $5.65 \leqslant N$ it was classed as 8.

To simplify calculation, charts have been produced giving the number of cycles per eight week period when the cost per unit and quantity per eight week period are known. These are given in Appendix F .

CHAPTER 11

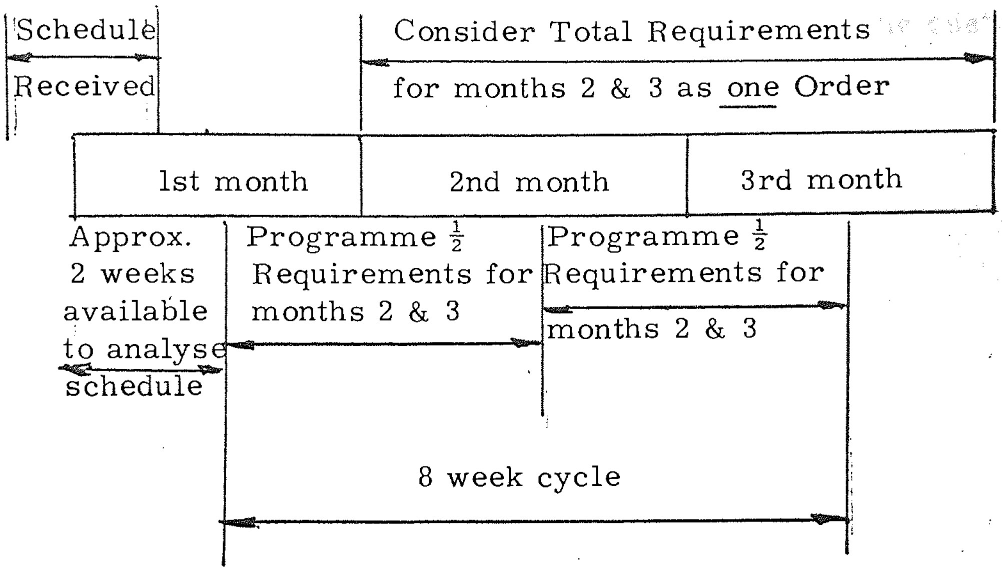
SCHEDULING OF WORK

For the purposes of scheduling work, the company was considered as two workshops but because the output from one was the input to the other, they were not independent.

The Machine Shop was the customer of the Foundry and in order to balance out demand some form of buffer stock was necessary between the Foundry and Machine Shop.

As stated in Chapter 3 the company received monthly manufacturing schedules from its customers but these only committed the customer to the demand as stated for the first, second and third period, the latter for material purchase only.

As components required to meet the first period demand should be in process in the Machine Shop, this left only the second and third period to be considered for the Foundry. To cast one month's requirements only for each item would have been expensive from a setting cost aspect, but would have kept to a minimum the variable costs associated with storage. It was therefore decided to arrange a casting programme to meet the requirements of the second and third periods, the timing of this programme being as shown in Fig. 11-1 overleaf.



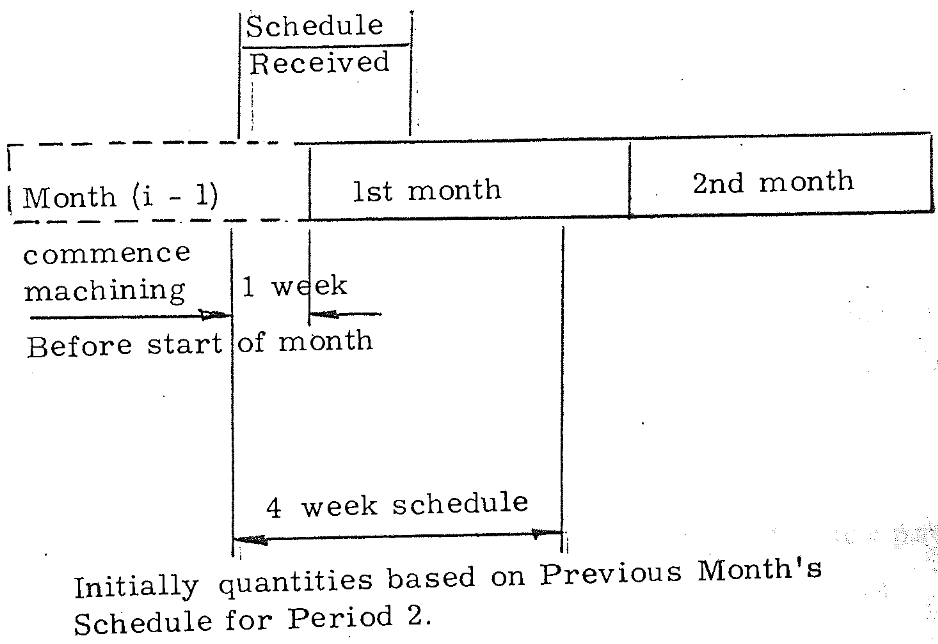
FOUNDRY PROGRAMME

FIG. 11 - 1

In theory the Machine Shop load was based upon the first period of the current customers schedule but due to the timing of the issue of these schedules by the customer anything between a quarter and a half of this first period could have elapsed by the time it was received and analysed by Sage Aluminium.

One had therefore to rely upon the previous months estimate of demand and commence production on this basis or to manufacture for stock and meet the customers requirements from this stock of finished work. This was not only expensive in terms of cash tied up in stock, bearing in mind the high interest rates prevailing, but also in the space required to store the work. It was estimated that one month's production would require 750-3' x 2' x 2' pallets to store the components.

By re-arranging the Machine Shop into group flow lines (see chapter 12. 3), the aim was to decrease the throughput time and enable the timing of the Machine Shop programme in relation to the customers schedule to be as shown in Fig. 11 - 2.



MACHINE SHOP PROGRAMME

FIG. 11 - 2

11. 1 SCHEDULING WORK TO THE CASTING MACHINES

The Foundry loads resulting from analysis of the customers schedules were calculated as described in Chapter 10. The resultant loads were listed into components required.

One per 8 week cycle

Twice per 8 week cycle

Four times per 8 week cycle } In practice both were classed as continously running.

Continuously running job }

They were also arranged into casting machine group order and for each component, the hours required for one batch to be cast was determined.

The work was loaded onto the casting machines using the following basic procedure:

1. Continuously running jobs were allocated to a machine.
2. The components that were to be scheduled once in the 8 week cycle were divided into two parts, components being allocated to each part in turn in descending order of machine hours required.

   The components in the first part were then loaded to commence to run during the first half of the 8 week period and the second part to commence during the second half of the 8 week period.

3. The components that were to be scheduled twice per cycle were then loaded to each half of the 8 week period.

In loading it was found to be an advantage to enter the works loads in a table first and then to load the machines using the following rules:

(a) The 400 ton press group had first priority (due to its restrictions on available setting time) and these were loaded first and when one became free it took priority over the other machines for re-setting.

(b) The work was loaded onto the machines in descending order of 'run time' length irrespective of the type of machine, with the proviso stated in (a) above.

(c) If the total run time for a job during an 8 week period was less than 16 hours (i. e. two shift lengths as per budget) then this should be considered for running once in every 16 weeks.

By using these rules the available setting force was effectively used, the restrictions on setting being given in chapter 11. 2.

When displayed on the wall chart it was also permissible to modify the schedule to allow for -

(a) A better operator utilisation.

(b) A more balanced load with the 4 week machine shop programme.

(c) A balanced load on the machine setters.

The procedure therefore gave an initial allocation which it was permissible to change but only when it had been displayed so that the effect of a change on one job had on another job or section could be seen before it was implemented.

11. 2 CASTING MACHINE UTILISATION

To achieve the budget targets the following machine utilisation figures were required:

	Present	Future Plan
400 ton	85%	85%
250 ton	67%	75%
Reeds	34%	1 M/c 34% 2 M/c 75%
Herberts	56%	75%
Edgwicks	9%	50%

Of the amount of under-utilisation that can be affected by a production management policy (as opposed to company selling policy) the major part comprises:

1. Losses due to machine failure.
2. Losses due to process failure.
3. Losses due to machine setting.
4. Losses due to machine tuning.
   i. e. stoppages whilst minor adjustments are made to tool setting.
5. Lost time whilst routine maintenance is carried out.

An analysis of non-productive time over a period January - February, 1973 gave a percentage non-productive time on activities other than setting of 6%. Since this date a system of planned maintenance has been introduced and it is anticipated that this 6% lost time will be decreased to reflect the effectiveness of planned maintenance. In the following calculations therefore a figure of 5% has been assumed for this non-productive factor.

Under the proposed planned maintenance scheme it is anticipated that each machine will be required for the following time periods:

Weekly - 4 hours = 5% (80 hour week)
3 monthly intervals - 3 working shifts.
= 24 hours of normal working hours.
= 2 hours per week on average
= $2\frac{1}{2}$%.

The total percentage lost time is therefore equal to 5% + 5% + $2\frac{1}{2}$%
= 12. 5%.

This means in effect that the percentage of time allowed for setting under the future plan (which was the immediate future) was:

400 ton	100 - 85 - 12.5	=	2.5%
250 ton	100 - 75 - 12.5	=	12.5%
Reeds	100 - 75 - 12.5	=	12.5%
Herberts	100 - 75 - 12.5	=	12.5%
Edgwicks	100 - 50 - 12.5	=	37.5%

This meant in terms of normal working hours available per 2 month cycle for setting:

400 ton	$2\frac{1}{2}$% of 2 x 2240	=	112
250 ton	$12\frac{1}{2}$% of 2 x 2240	=	336
Reeds	$12\frac{1}{2}$% of 2 x 960	=	240
Herberts	$12\frac{1}{2}$% of 2 x 640	=	160
Edgwicks	$37\frac{1}{2}$% of 2 x 1280	=	960

The average hours for setting these machines have been given as:

<u>400 Ton Machines</u>

Basic time (assuming no machine raising) = 6 hours.
With machine raising and hydraulics = 8 hours.

Average 7 hours

<u>250 Ton Machines</u>

Basic Time = $3\frac{1}{2}$ hours
With tie bar removal = $4\frac{1}{2}$ hours

<u>Reeds</u>

Assume same as 250 ton Average 4 hours

<u>Other Machines</u>

Basic Time 2 hours.

These were the estimated times for a team of 2 Tool Setters and there was 1 team for each shift. (N. B. The estimate was given by the Toolroom Superintendent).

Using these setting times and hours available then the maximum number of set ups permissible on each type of machine per two months cycle is:

$$\text{400 tons} = \frac{112}{7} = 16$$

$$\text{250 tons} = \frac{336}{4} = 84$$

$$\text{Reeds} = \frac{240}{4} = 60$$

$$\text{Herbert D. C.} = \frac{160}{2} = 80$$

$$\text{Edgwicks} = \frac{960}{2} = 480$$

During machine tuning (previously defined) if the tools had to be removed from the machine it was the team of Tool Setters that did this actual task. Because of this and due to their need for an appropriate relaxation allowance it is unreasonable to expect a 100% effort on original machine set ups by a team and possibly a fairer estimate would be 60%.

The figure of 60% has been arrived at by reference to the relaxation allowances quoted by Eilon (34) and is made up as follows:

Factor	% Allowance
Energy Output (4)	16
Position (2 - 5)	4
Motions (3)	3
Visual (1)	1
Personal	3
Thermal (4)	20
Atmospheric (2)	5
Environmental (8)	5
	57%

Allowing 40 minutes per day for cleaning hands and statutory breaks gives a further 6% over 10 hours which increases the above percentage to 63%, from which we can say -

$$100\% \text{ of working day} = \%\text{ working } (1 + .63)$$

$$\text{Therefore } \%\text{ working} = \frac{100}{1.63} = 61.5$$

Assuming this to be 60% makes an allowance for any machining turning which may require their assistance.

The total machine hours per week that can be allocated to setting is therefore -

$$2 \times 50 \times .6 = 60$$

N. B. This allows for a 10 hour shift by each setting team.

Over a 2 month manufacturing period this equals 480 hours.

CHAPTER 12

LAYOUT OF MANUFACTURING FACILITIES

With the formation of the early factories, the artisans were grouped together according to their individual skills and thus was developed the functional or process layout. By this system similar machines or equipment were grouped together and controlled by the same individual.

The advantages it offered included:-

(i) Flexibility of equipment and sometimes manpower within this section enabling decentralised control to be used.

(ii) A better utilisation of machines (although in the total system concept this does not necessarily mean the best rate of return on investment).

(iii) Benefit of specialist supervision.

Its disadvantages included:-

(i) Relatively long lead times due to components remaining untouched during movement between operations.

(ii) A consequential high value of work in process.

(iii) Administration costs are higher especially with regards to production planning and control.

(iv) Handling costs are higher.

The disadvantages listed are all major ones in that they affect the immediate profitability of the company and a study of the work flow in a shop organised on these lines would tend to show a series of interwoven lines which have been referred to as a 'bowl of spaghetti' (35).

With the increase in demand for components of a common design, managers recognised the limitations of the process layout and therefore the product layout was evolved. Under this form of layout the machines or processes are arranged in the correct operational sequence so that the raw material starts at one end of the line and the finished product comes off the other end.

The main advantages are:-

(i) Reduced handling between operations.
(ii) Lower levels of work in process.
(iii) Less storage space is required.
(iv) A much simplified control system can be used.
(v) Dependent upon the product a less skilled labour force is required.

The disadvantages include:-

(i) Less flexibility is available and a change in product can mean a major expense in alterations to the layout.

(ii) If one machine or process breaks down the complete line may stop unless provision is made for inter-process buffer stocks.

(iii) Identical machines may be required at different stations on the line and which are not fully utilised.

(iv) The output will be restricted to the slowest machine resulting in under-utilisation of the other machines unless the slower operation capacity is increased by the use of multiple machines.

A third type of layout is the fixed position layout which is restricted to the assembly of large immovable objects such as ships, aircraft or large electrical components. Using this method, all the individual components are brought to the fixed assembly position.

To function effectively, this type of layout requires the investment in portable machines to assist the assembly work and for each assembly position the machines could be duplicated resulting in a relatively high cost but low utilisation.

The development of numerical control for machine tools eventually saw the introduction of the machining centre concept where one complex machine tool is capable of performing the operations normally done on two or more conventional machine tools. The Molins System 24 was a similar development.

The success of this type of system relied to a large extent upon the full integration of all management functions and in the middle sixties when they were being introduced, this was not achieved - people still considering themselves as parts of separate functions.

12.1 THE DEVELOPMENT OF THE GROUP CONCEPT

For small batch production the layouts were mainly by process but in occasional instances, production engineers had analysed manufacturing methods (especially in relation to the initial operations) and where possible had grouped components together so that it was possible to use common tooling. (In the author's experience, the procedure followed at present by Mercers for their Swiss type automatic section was used by him in the mid fifties). Other instances are apparent from letters written to learned journals by practising Production Engineers.

What must be stressed is that the allocation of a component to a machine set-up group was made on practical judgement and at that time very few companies attempted any formal method of analysis to allocate components to these groups. Nor was any attempt made to incorporate the potential economic advantages into the manufacturing unit.

With the development of classification systems, the Production Engineer and indeed management as a whole (Gombinski 36) had a tool with which they could analyse components to form groups of components with similar attributes.

With this ability Production Engineers were able to turn their attention to components which required more than one type of machine to produce a finished component and from their analysis the required machines were grouped together to enable completed components to be produced.

The work content (or the time required to complete a task) varied for each operation within the group and if there was one operator to each machine gross under-utilisation of the operators occurred. With the co-operation of the operators and unions, the number of operators was reduced so that the total work content for a batch of components was approximately equal to the number of operator hours within the group. An additional feature resulting was that operators were able to exercise different skills in operating the different machines. Systems incorporating these principles have been reported by Ranson (37), Connolly (38) and Caudwell (39).

Burbidge (40) maintains that in order to form the groups or families of components as they are often called, one need only analyse the individual component operation sheet or route card as it is sometimes called. Although the technique is simple to apply it does not take into account the volume of work flowing down the resultant flow lines or through the machine cells and El-Essawy (41) together with fellow researchers from UMIST developed the technique to take this factor into account and used the term Component Flow Analysis.

12. 2 APPLICATION OF TECHNIQUES

These last techniques of Production and Component Flow Analysis are easily applied but they are restricted to the design of the actual production flow lines or cells.

As an aid to the product design and other essential functions that go to make up the complete management control system they have very limited use. For the integrated management system therefore some form of classification system is usually essential, the variable factor being the size of the company i. e. very small, or the number of different products flowing through the system is very small.

The classification systems in common use are based on original work done by Opitz (42) and systems using this technique have been applied by Thornley (43). The second is based upon work by

Brisch (44) and systems using this have been reported by Edwards (45).

The benefits to the company when the group technology principle is applied to the integrated management control system are reported by Ranson (37), Thornley (46) and Sabberwal (47). Where possible the benefits have been quantified but possibly one of the greatest benefits, improved human relations within the system cannot be readily quantified.

12.3 THE GROUPING OF MACHINES IN THE SPONSORING COMPANY

In fairness to the management of the company one must say that where they had been guaranteed a high volume production run in the past they had attempted to form a flow line for the production of the item concerned.

As demand fell the function of the flow lines ceased and a study of the flow pattern of work through the shop gave a very irregular path. This, together with a lack of a formal work programme for the Machine Shop resulted in excess movement of work between machines. The latter factor being the greatest contributory factor.

Because of the nature of the work done by the company, changes in product will take place at reasonably frequent intervals and therefore rather than set up flow lines for individual components, it was decided to analyse all the components to see if there was any definite pattern.

The number of components produced by the company (approximately 60 - 70 live components at any one time) was considered to be far too small to justify any form of component classification using a numerical coding system. It was therefore decided to analyse the components according to the manufacturing sequence using Component Flow Analysis.

The basic process done in producing a finished component at Sage is:

Die-cast and break off components from spruce.
Trim off flash from component.
Carry out any machining operations required.
Inspect (as required)

Before any form of analysis could be done, operation summary sheets had to be prepared for each item. A typical summary sheet is given in Appendix C . The compiling of these operation summary sheets again showed that a lack of reliable data was available from the shop floor which management could use to formulate a workable manufacturing programme and this possibly explains the reluctance to produce a machine shop schedule. The actual time taken to produce a workable set of operation sheets was four months.

Each component operation sheet was then analysed onto the forms as given in Appendix D , the analysis taking the following steps:

(a) Grouping components done on similar machines.
(b) Arranging the components within a group into operational sequence.

This procedure resulted in five main groups:

Group 1.
1 - 5 ton press for trimming.
1 Fobco Drill
1 Elliot pedestal drill.

Group 2.
1 - 15 ton press for trimming.
1 Fobco drill.
1 Elliot pedestal drill.

Group 3.
1 - 5 ton)
1 - 15 ton) for trimming
2 - Fobco drills, plus 1 Elliot Drill.

All the above operations were done by female operators and in addition to these operations there was certain components that had to be linished. As this was done by male labour away from the normal machining area (because of extraction problems) it was noted on the analysis sheet but not considered in the grouping.

Group 4. This was a group which required often more than one of any type of machine and also (by chance) included the few remaining flow lines.

Group 4a. This group mainly comprised components requiring a single press trimming operation with possibly some subsequent linishing or bench deburring work.

12.4 VOLUME OF WORK PASSING THROUGH THE GROUPS

The quantities of individual components stated in the proposed manufacturing budget were then linked with the appropriate group number and component volume determined. To be of real use in any further analysis this volume had to be converted into the form of standard hours.

The majority of the work done by the female operators was done on a piecework basis, a time being estimated by the Machine Shop Foreman and this given to the girls in the form of a price per 100 units. The price was often expressed in terms of 5 decimal places of a pound.

From discussion with the Company Secretary on wage payment, it was agreed reasonable to take the rate of pay per standard hour to the girls at 46.10p. All the piecework prices were therefore converted to standard hours per 100 using this conversion factor. The work load on each work group was then determined in terms of standard hours using for this initial analysis the following average standard times:

5 ton press operation	=	0.14 standard hours/100
15 ton press operation	=	0.25 standard hours/100
20 ton press operation	=	1.67 standard hours/100
Fobco Drill operation	=	0.12 standard hours/100
Elliot Drill operation	=	0.23 standard hours/100

The quantities indicated in the budget were the anticipated average monthly requirements but analysis of past orders indicated that for components required for the motor car industry an addition of 35% should be made to installed machine capacity to allow for a sudden increase in demand. This figure was obtained by plotting the distribution of the ratio.

$$\frac{\text{Highest Monthly Quantity}}{\text{Average Monthly Quantity}}$$

The mean was 1.258 and the standard deviation was 0.093. Allowing for a 35% increase in demand above the monthly budget figure therefore gave an ability to meet this 84 times out of a 100.

Components not influenced by the motor car industry were left as per budget.

All figures were increased to allow for scrap as per budget.

The budget also gave a planned increase requirement and as the company were hoping to become less dependent upon the motor car industry it was assumed that this additional market would be in any field other than the car industry. The requirements on each machine group was therefore increased by the same quantity as the output from the casting machines, whose output was machined in that group, was planned to increase. The pattern of the machine operation was also assumed to apply as also was the approximate average scrap value.

For each group then an approximate monthly work load was thus determined:

e. g. Group 1.

5 ton Press	153 standard hours.
Fobco Drill	131 standard hours.
Elliot Drill	253 standard hours.

The complete analysis of machine group loads as thus determined is given in appendix D .

From a study of the standard hours and process it was apparent that a group of machines comprising -

1 - 5 ton
1 - 15 ton
1 - Fobco Drill
2 - Elliot Drills

could perform any of the jobs classed as Group 1 and 2 and to meet all the requirements of these two groups would require at least two such machine group arrangements.

By study of the hours required for Group 3, each item could justify its own individual flow line. A similar study of the items comprising group 4 also indicated a number of flow lines were possible, some would be fully utilised on one job, others would be capable of producing a number of similar items e. g. Group 9 will produce 3 types of carburetter body.

The final grouping of the machines and the associated jobs is listed as Appendix D and shown as Fig. 12 - 1

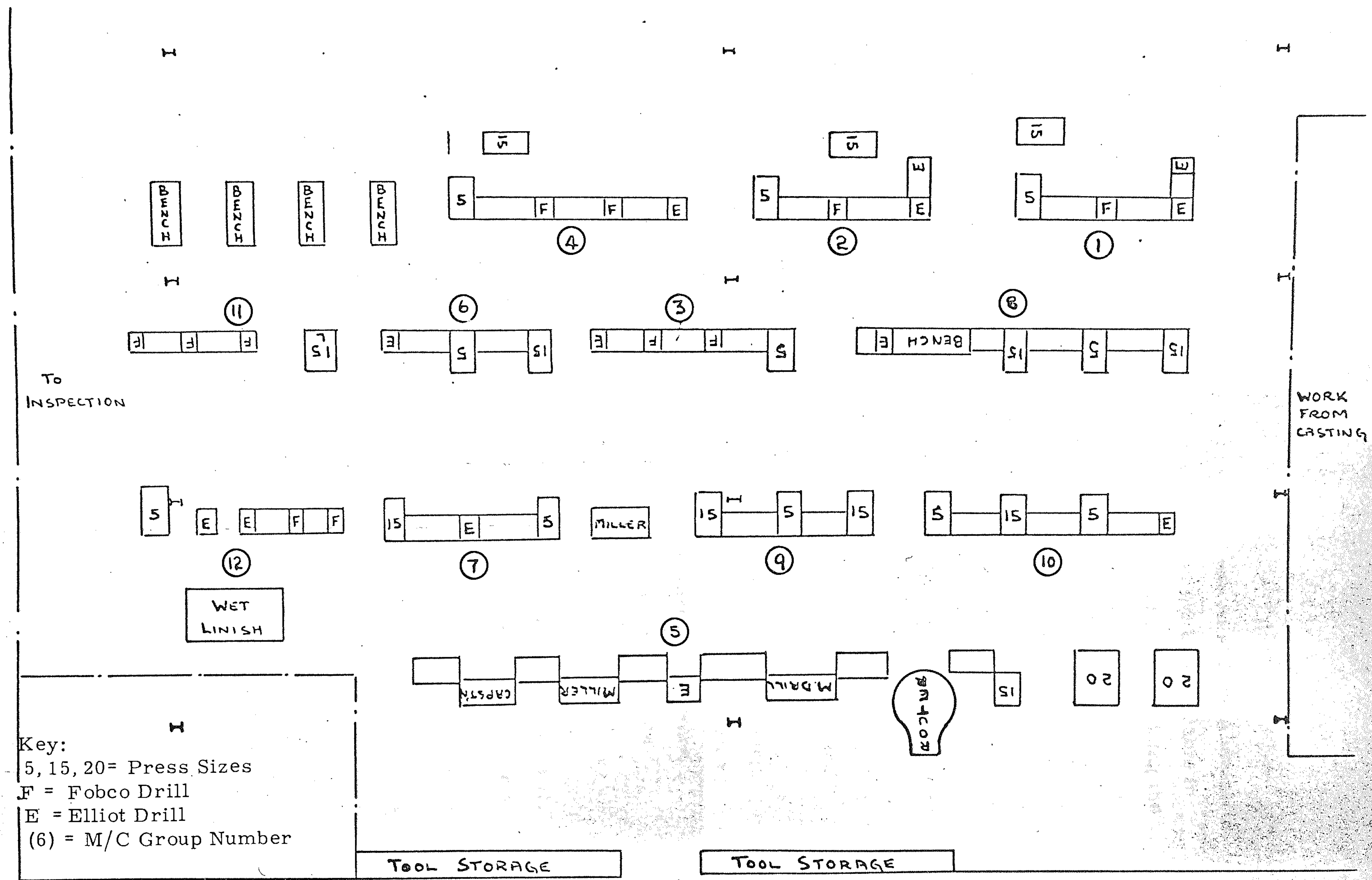


FIG. 12 - 1 MACHINE GROUPS

12.5 GROUPING FLEXIBILITY

Because of the changing nature of the work pattern at Sage Aluminium, the work groups as determined at present may not be applicable in one year's time. In changing the layout to one of cell machining the condition was given by the Managing Director that complete flexibility must be obtainable.

Fortunately the operations are of such a light nature that no fixed foundation bolts are required for the machines and so these are capable of being freely moved provided that the services i.e. electricity and compressed air, can also be freely moved.

To enable the services to be flexible electrical 'bus bars' were run down the machine shop into which it is possible to make connections at 2 ft. intervals, the cables to the machines being contained in flexible steel sheathing. The air supply was also arranged in a grid formation into which bayonet fittings were fitted for locating the flexible nylon tubing to be used for the air supply.

A machine can therefore be repositioned within ½ hour by two men and this should enable groups to be quickly changed to allow for a new work pattern.

The present layout is not fully ideal in that final inspection is still kept as a separate final operation. With improved control at the casting stage it is hoped to be able to combine this as a final sampling operation in a group of machines, the work then being passed immediately to despatch. If such a position is reqched then a slight re-arrangement of the machine groups would be required to enable an inspection point to be placed at the end of each line.

The movement of work between machines in a group is done by the operator. Roller conveyors were considered but initially it was considered that these may reduce the ability to re-arrange groups of machines and were therefore not pursued. An alternative for future evaluation is the provision of work trolleys (as illustrated in Appendix D), the objection to these at present is the feeling that the labourers will demand the right to push these trolleys between machines; the female machine operators also objecting on the grounds that they are Machine Operators and not Movement Personnel.

For this reason benches are still used between the machines, the girls having no objection to passing work by hand onto an adjacent bench.

CHAPTER 13

SIMULATED LOAD ON THE FACTORY

The basis for the simulated load was the total manufacturing budget originated by the Board of Directors. This gave details of the components they anticipated producing and the monthly quantities after they had been through a price revision exercise (which resulted in them ceasing to manufacture certain unprofitable items) with their major customer.

The budget also gave the planned machine utilisation figures for the Foundry and guide lines as to which sections they hoped to improve upon and gave the target utilisation figure for these sections.

In analysing the budget the following assumptions were made:

1. The distribution patterns previously obtained relating to orders, machine utilisation and operator performances would continue to apply to components done for the motor car industry.

2. For components done for other industries the monthly demand would be constant as given in the budget but the machine utilisation and operator performances would have the same distribution pattern as previously established for the items referred to in (1) above.

3. For the forecasted unknown components it was assumed that the pattern of secondary machining operations that applied to the present known components would also apply to these unknown components.

Provided the type of work did not change too drastically it was considered that these were reasonable assumptions to make. If there had been a drastic change in the class or type of work being done, then the figures for operator performance would have had to be adjusted to allow for the learning phenomena.

Monthly Demand - The distribution had been plotted for the ratio.

$$\frac{\text{Actual Monthly Demand}}{\text{Average Monthly Demand}}$$ - which as previously stated approximated closely to a normal distribution.

Random numbers normally distributed were generated with a mean and variance as previously obtained and this was used to represent the ratio. In place of the average monthly demand the budgeted monthly figure was used and thus a simulated monthly demand was obtained by (budget monthly figure x random number generated).

This procedure was done for all components that were considered to be affected by the motor car industry and an order book for 15 months developed. These were equivalent to the quantities given on the customers schedules as requirements for 'Period 1'.

Forecast of Demand for Periods 2 and 3

Previous analysis had shown that the ratios

$$\frac{\text{actual monthly demand}}{\text{forecast of this demand 1 month previously}}$$

and

$$\frac{\text{actual monthly demand}}{\text{forecast of this demand 2 months previously}}$$

were both approximately normally distributed although as one would expect there was a slightly different mean and variance for each.

Random numbers (normally distributed) were therefore generated to represent the forecast made of future demand as given in the customers schedule for periods 2 and 3, these being applied as follows:

For month i, the forecast for period 2

= simulated demand for month (i + 1) x random number generated

and

the forecast for period 3

= simulated demand for month (i + 2) x random number generated.

As the customer only guaranteed payment for the quantities stated for periods 1, 2 and 3 these were the only ones which were to be considered for planning purposes, the development of the quantities normally given for periods 4, 5 and 6 were not considered essential.

In Chapter 12. 4 the determination of section capacities for a given level of certainty of meeting a demand was considered. When considering the forecasts for periods 2 and 3 a similar procedure had to be considered. To allow for error it was therefore decided to increase the value given for period 2 by one standard deviation which gave an 84% certainty of being able to meet the actual demand one month ahead.

For period 3, although a similar procedure could be followed because of the prevailing uncertainty of the market (which resulted in a fairly large variance) it was decided to leave the value as given and make no further allowances. As stated in Chapter 11 manufacture in the Foundry was proposed for an eight week cycle to cover the forecasted demands for periods 2 and 3. Due to the timing of the cycle within two weeks of its implementation, a new customers schedule would be available in which the previous period 3 now became period 2, and therefore the quantity stated was more reliable. Any excessive error due to accepting the figure for period 3 could therefore be corrected fairly early on in the manufacturing cycle.

8 Week Order Size for Foundry

For the eight week period covered by month i and (i + 1) the order size was determined by:

at month i — the forecast for period 2 + 20% ($\mu + 1\sigma$) plus the forecast for period 3 plus or minus the previous eight week forecast error((i. e. for months (i-1) and (i - 2)))

The resulting order size had to be increased to allow for 'unbooked' losses in the foundry and from previous analysis a figure of $7\frac{1}{2}\%$ was considered suitable. In addition to this an allowance had to be made for recorded scrap and this was the mean figure contained in the budget.

The order size input was therefore the figure as calculated above plus the scrap percentage from the budget and the resulting total was increased by $7\frac{1}{2}\%$ to allow for foundry losses.

This order size could be issued as one batch or it could be divided into a number of batches. The procedure for making this decision is outlined in Chapter 10.

The standard hours required per batch of components passing through the Foundry was obtained by using the budgeted shot rate per hour and the actual time taken for the batch was found by generating random numbers to represent the operators performance, the distribution of past operator performances being approximately normal.

The mean scrap rate used in the budget had been assessed by the Chief Inspector by analysis of his past records. To allow for a variation in scrap (as occurs in practice) a normal distribution was assumed for the scrap rate, the mean being the budget figure and scrap rates were then generated for each batch.

Where components were inspected immediately after the casting process, then the input to the Machine Shop or Despatch Bay (as was the case) was obtained by:

(Input Quantity - $7\frac{1}{2}\%$) x (1 - Generated Scrap Rate)

Where the components were inspected after the machining operations, then the input to the Machine Shop was:

(Input Quantity to the Foundry - $7\frac{1}{2}\%$).

The Machine Shop was laid out in flow lines (see Chapter 12. 3) and work was loaded onto these lines on a monthly basis to satisfy the customers demands.

The standard times for machining the components were taken from the operation summary sheet and the operators performance index obtained by random number generation based upon the distribution of past indices. The actual time taken was then obtained from -

$$\text{Actual time} = \frac{\text{standard time x 100}}{\text{generated random performance}}$$

Where inspection occurred after machining the output from the Machine Shop was given by -

(The resultant input from the foundry) x (1 - Generated Scrap Rate)

CHAPTER 14

DISCUSSION OF SIMULATION RESULTS

In running the simulation, the components were considered as two classes -

(a) Those that were influenced by the automobile industry and thus had an increase made to the forecasted demand for period 2.

(b) Those for other industries in which the demand was always assumed constant.

The behaviour of the study was reasonably as expected.

In the first case only month 2 demand was increased although the indications were that there was a definite variation in month 3 which was slightly greater than that for month 2.

By making the allowance, one hopes to equal demand but if the increase in demand does not take place, then one creates stock. If the demand is greater than allowed for stock shortages occur and the component is in arrears.

The allowance made for month 2 was such as to satisfy demand 84 times out of a 100 but because no extra allowance was made for month 3, over the 2 month period the ability to satisfy demand would drop to approximately 67 times out of 100.

The relationship between stock and arrears would therefore have been 67: 33 approximately whereas in the simulation it is 10697:7346 i. e. slightly worse. This can be expected as by not taking account of month 3 variation which had the greater standard deviation then the chances of being in arrears would increase and the stock: arrears ratio decrease as was the case.

In case (b) when no allowance was made for variation in demand the mean scrap rate was also assumed. Because the scrap rate is a variable then failure to increase the scrap rate by a suitable figure (as illustrated in Appendix G) would result in a possibility of the result being as obtained. The final output per period will fluctuate about the mean with an equal chance of being below as above i. e. components in arrears or in stock. Volume wise the difference is small but considering the value of the work, the arrears greatly exceed the stock.

The algebraic sum of the differences for both cases combined is slightly negative thus showing that we have met approximately the mean demand. Again with a normal distribution one could expect this but it is not really a practical situation.

To be truely effective an additional buffer or safety stock should be introduced but this depends entirely upon company policy.

N. B. There is one school of thought that it pays the company to be slightly in arrears thus ensuring that the customers goods inwards inspection is realistic and not excessively rigid as is the case if they receive components in advance of their requirements.

As with most companies a small percentage of components account for a large percentage of sales. In the case of the sponsoring company, for work considered:

2% of the jobs	=	20% of sales)	)See Appendix H
25% of the jobs	=	66% of sales)	

The simulation showed that some of the larges variances occurred on these jobs and therefore it is apparent that although the plan is based upon an 8 week cycle, a close scrutiny should be made of these jobs at the end of the fourth week when the schedule is received. As one could expect with a normal distribution in the case of the 2% jobs referred to above, one job had a positive variance and the other a negative thus cancelling each other to a very great extent.

The resulting loads upon the casting machine groups were all capable of being achieved within the restrictions given with the exception of the 400 ton group, and this had to be modified. As shown in 14. 1.

The simulation gave the basic manufacturing programme and from this the hours required to complete the programme were obtained.

The small quantities resulting on some jobs had very little effect upon the Machine Shop but in the case of the Foundry small run jobs as shown by the simulation had to be considered for running once every 2 cycles (or sixteen weeks) and these jobs have been ringed in the results table given as Appendix. J.

14. 1 MODIFICATION TO 400 TON GROUP LOADING TO ALLOW FOR SETTING RESTRICTION

Working from the simulated work load for 1 year as per the budget (i. e. excluding the planned increases in certain machine utilisation figures) the average number of set ups for each machine group are as shown-

400 ton group	23 per 8 week
250 ton group	23 per 8 week
Reeds Group	5 per 8 week
D. C. 100 Group	12 per 8 week
Edgwicks	2 per 8 week

and the total setting hours 281 per 8 week period.

The restrictions applicable to machine setting were therefore met with only one exception, namely the number of set ups required on the 400 ton group of machines.

To achieve the 85% machine utilisation required of this group necessitated than an average each machine should work for

5 x 16 x 8x . 85 hours per 2 month period = 544 hours

This figure is based upon an 8 hour working shift which means that the company have additional capacity in the form of overtime hours but the use of these will entail a premium payment. Additional increased capacity is available if the operators return an individual performance better than standard (see Appendix G).

The manufacturing schedules for the 400 ton group had therefore to be changed in some form to enable the setting restrictions to be fully complied with, the alternative being to reduce the figure for machine utilisation (to 77. 5%) in order to enable the required number of set ups to be made. This latter course was obviously undesirable as it would result in a loss of contribution.

In addition to the actual tooling complexity there were two other major factors which affected the time required to set the machine.

1. Whether the machine's back end had to be raised.

   N. B. The machine had three positions in which the metal feed tube could be positioned and the position depended upon the position of the filler hole in the die. If the position of the feed tube had to be raised or lowered it was referred to as 'raising or lowering the back end.'

2. Whether major changes to the hydraulics were required.

The majority of the components required neither of the above and could therefore readily be interchanged. The components were therefore first split into groups.

(a) Those that required the machine back end to be raised.

(b) Those that required major adjustments to the hydraulics.

(c) Those that required both (a) and (b).

(d) Those that were readily interchangeable requiring none of the above.

The full modified 400 ton group load is included in appendix J but for illustration the load for July and August is given. Fig. 14 - 1 gives the load as obtained from the simulation which indicates 21 set ups are required.

	Job No.	Hours per run	No. of runs	Total hours
Back End(	25	154	1	154
Raised (	33	203	2	406
(	34	234	2	464
Hydraulics(	27	92	2	184
Changed (	29	47	1	47
Raised + Hydraulic(	30	318	2	632
	26	321	1	321
	22	165	1	165
	23	128	1	128
	31	118	1	118
	32	118	1	118
	28	116	1	116
	24	99	1	99
	20	262	2	524
	21	169	2	338

400 Ton Press Load

FIG. 14 - 1

Machine State	Job No.	Runs per Compt.	Total Hours	M/c
Raised plus Hydraulics	(34 & 29	1	511	1
	30	1	632	2
	(33 & 27	1	590	3
Raised	25 & 26	1	475	4
Basic	22, 23, 31, & 32	1	529	5
Basic	20	1	524	6
Basic	28, 24, & 21	1	553	7

Modified Press Load

FIG. 14 - 2

To enable the criterian regarding the number of set ups to be met, the individual machine loads must be modified to the form shown in Fig. 14 - 2.

Jobs that have a common machine state e. g. back end raised, have been kept together where possible but in compiling the table the timing of the component in the Machine Shop cycle had to be monitored so that components produced on the same casting machine were not processed through the machine shop at the same time on the same group. The machining periods of the above components are given in Fig.14-3.

Casting Machine No.	Job No.	Details of Machining Period
1.	) 34	No machine required
	) 29	Last five days on groups 7 & 12 plus 1st 4 on bench.
2.	30	Continuous.
3.	) 33	No machine required.
	) 27	Approx. 2nd week Group 10.
4.	) 25	Last 10 days Group 9.
	) 26	First 6 days Group 9.
	) 22	Day 5-12 Group 2
5.	) 23	Day 1-4 15T Press
	) 31	1st week 20T Press.
	) 32	2nd week 20T Press.
6.	20	Continuous
7.	) 28	Day 5-8 15T Press.
	) 24	Group 12 wks. 1 & 2
	) 21	Group 7 days 1-13

Machining Period for 400 Ton Press Work

FIG. 14-3

In Fig. 4-2 it will be seen that machine number 4 has a relatively light load for the period (475 hours) and this should always be aimed for in order that the programme of planned maintenance can be achieved.

CHAPTER 15

THE FACILITIES OFFERED BY A COMPUTER BUREAU

Both the company and Parent Holding Company are too small to be able to justify on financial grounds their own computer installation but because in a management control system where data has to be collected, analysed and issued as information, there is much duplication of effort, consideration must be given to the use of a commercial computer organisation.

With the present industrial climate still having a major effect upon the inflow of work to Sage Aluminium both machines and operators are much under-utilised and one could be excused for discounting the need to consider using the facilities of a computer bureau.

There are four main ways in which data can be transmitted to a bureau:

(a) By means of a computer terminal installed in the factory and linked by land line to the computer installation.

(b) By having either a card punch or tape punch in the factory and transfer the data from the records onto the recording medium.

(c) By sending the data on prepared forms to the computer bureau who will themselves transfer this into the computer input form.

(d) Use a form of tape recording where the data is recorded by the company onto magnetic tape held in a cassette and this is sent to the bureau for processing through the computer.

Given any of the above facilities one can often use the same basic input data to perform a number of different calculations to give varying output information.

It was undesirable to introduce a manual system of control that was not capable of being transferred to a computer with the minimum of interference or re-design and as the manual system was to be installed first this had a bearing on the approach used to transmit data.

The documents containing the data requiring transmission would be in existence by the manual system and the aim was therefore to use these where possible.

Using proposal (a) above would have satisfied the requirements but would have meant that the performance was subject to the reliability of the apparatus and also the reliability of the land link, thus the probability of the failure of the system was a function of the individual reliabilities.

Proposal (c) was the cheapest on capital outlay by the company but when the variable operating costs were considered it became less favourable.

Proposal (b) and (d) were very similar in substance but varying in ease of application.

Both enable a display to be given to the person recording the data thus enabling them to check the accuracy of the message. With proposal (b) the display was printed as the tape was punched and any error necessitated an error signal being superimposed and the correct symbol then punched. With proposal (d), as the operator entered the data through the keyboard a visual display was shown and no entry was made on the magnetic tape until the operator pressed the entry key, this only being done after the display was checked against the actual data.

It was this feature, coupled with the ease of transporting cassettes that resulted in the choice of proposal (d) to be considered in evaluating any proposal.

To calculate an operators pay, the Wages Department require to know the following data:

1. The operators identification number.
2. The time started and time finished work.
3. Time on/off individual jobs or activities.
4. Deductions i. e. tax.
5. Basic wage details.

Where the operator is on production work to calculate any bonus or performance analysis the wages section also need to know:

6. The standard time per unit.

7. The quantity produced.

If to this information is added:

8. Material details.

9. Setting time details.

10. Scrap and rectification details.

11. Cost centres applicable.

then the Cost Department can calculate costs incurred and compare performances-

Add to these items:

12. Details of machine group.

13. Quantity required per individual order.

14. Operational sequence.

15. Delivery dates.

16. Individual order numbers.

then the Production Control function can do its task.

Under the manual system proposed the majority of the above items will be shown on the proposed Operation Summary Sheet. The computer bureau could therefore form four basic files:

(a) Operator personal details.

(b) Operational summary.

(c) Machine loading and cost.

(d) Order file.

A local computer bureau who had previously approached the company with regards to payroll preparation were approached as to the feasibility of the proposal.

Being organised on a modular basis they were able to offer the following package variations:

(a) Their standard payroll analysis only.

(b) Their standard payroll modified to give not only payroll details but also operator and departmental performance analysis.

They had no production control package as such but through a consultant could have made available a package which would have analysed the order input and produced a manufacturing schedule. The actual programme could be modified to give as additional outputs:

(a) Operator and departmental performance.

(b) Forecast of the future value of sales orders based upon the customers schedules.

Being a commercial organisation, they themselves would have to work to a programme and so to be able to meet their demands, Sage Aluminium would have to more or less guarantee that data would be delivered to the bureau by the time stated or else they would run the risk of their work being left out of the bureau's computer running schedule.

This in effect is one of the benefits of a computer in that the people who create the input become disciplined into organising their resources to meet such critical factors.

Details were given to the bureau of the anticipated work volume that would be required (as used for the manual system) and an approximate cost obtained from them. This is given in Appendix E with the cost of the manual system.

CHAPTER 16

DISCUSSION OF RESULTS

The machines were re-grouped into the form shown in Fig. 12-1 during the Christmas shut-down in 1973. This period unfortunately coincided with the National emergency calling for a three day working week which so far as the sponsoring company was concerned, resulted in not only a restriction on their production facilities, but also a drastic modification to customer schedules with a number of components being shown as nil requirements.

The effect on the manufacturing system was an immediate removal of pressures for delivery by the customers which made the Managers reluctant to change tools on a machine when there was an empty machine available elsewhere, thus causing an inability to use a machine flow line when components became available because a machine was being used on another job.

The management have been provided with a list of jobs and their associated machine group number and a schedule based on average demand, in the form of a GANTT chart showing how the jobs are to be sequenced.

Implementation has commenced but full implementation is dependent upon normal working conditions being resumed. The casting plant is still running below budgeted capacity, the total casting requirements for April and May being (for all groups) 1611 and 3922 hours respectively as against a budget total of 6088 hours. There is still therefore very little pressure on the manufacturing units to meet demand and this state is forecasted to last until June/July, 1974 at the earliest.

There are plans to change the mix of casting machines (a process already started) which will possibly change the pattern of secondary machine requirements. Provided any new requirements are within the capacity of the existing machines then a move of machines can be quickly made due to the in-built flexibility and this has been shown to be achievable.

Once the volume of work has returned to normal capacity, then more effective use should be made of the machine groups.

Where operators work in groups the average performance index figure is 152 whilst when working as individuals the average is 113. Thus there is a potential increase of 34%. Taking the smallest group performance figure 135 and the highest weekly average individual performance 118, there is still a potential increase of 11%.

The few groups that are working reasonably effectively are showing a consistent output which is one of the advantages of flow line working but one cannot safetly pass comment on the operators earnings because of the present work load.

The proposal to change the point of inspection to immediately after the casting process is still the subject of senior management discussions. Working on the basis of the machines operating in groups with the number of operators as stated in this work there is a potential saving of £2191 per year on direct labour. Onto this must be added the variable overhead but as the company do not split their overhead a value for this cannot be given. As they would still have a sampling inspection after machining then possibly the cost of this could be met from the reduction in variable overhead.

Initially it was hoped that the work done by Griffiths (33) into Rota Cycle Scheduling would be applicable to the foundry but the load on the Setters and machines, as given by the simulated work load, has indicated that although in theory it could be applied because of system restrictions, it must be modified to produce components at a frequency of -

once per 8 week cycle

twice per 8 week cycle

once per 16 week cycle

or to class them as a continuously running job or at least leaving the tools set on the machine.

The number of runs of a component is a function of the square of the cost of and demand for the component. In both cases these were relatively high at Sage Aluminium in relation to the work done by Griffiths (33). It was these factors which tended to produce a demand for a component four times per eight week cycle but this was found impractical to apply due to the setting restriction.

The combination of -

(i) High component cost.

(ii) High volume demand.

(iii) Low machine setting availability -

must be considered in future attempts at producing a cyclic schedule in this type of batch producing industry.

The proposed monitoring procedure suggested for the customers schedule behaved reasonably as expected in the simulation run but to be of practical use the error must be continuously monitored and corrections made to the distribution if these are considered necessary. (This is in effect the closed loop principle being applied to the monitoring procedure).

Dependent upon the company being prepared to make the necessary financial resources available to provide for stock then the calculated demand errors should be applied to both the second and third months of the customers schedule which will enable a small buffer stock to become available to meet a sudden increased demand which the simulation study showed was required.

The proposed procedure for modifying the customers forecast of demand whilst being similar to the rule developed by Deziel (48) differs in that -

(a) Deziel was attempting to produce a rule for products which were placed into store for subsequent issue to assembly points. The forecast on which the production quantity was based was fixed by the company's own staff.
In the present work the forecast was given by the customer and delivery was made direct to him and not into a store.

(b) Incorporated into Deziel's rule was a buffer stock the value of which was entirely within the control of the company and was dependent upon the level of service required to be given. The company could increase or decrease this at will dependent upon the long term forecast of demand made internally and therefore the amount of risk involved was within their own control.

The proposed rule for the sponsoring company in attempting to meet demand 84 times out of a 100 will cause a buffer stock to be created but the size of this will be dependent upon the customers forecast of demand and the previous error. The risk incurred by the company is therefore partly controlled by an outside body.

(c) The smoothing factor proposed by Deziel was based upon the exponential forecasting technique whilst the proposal is based upon the degree of error in the forecast.

Both rules have two general points in common -

1. The primary consideration was that the rule should be simple to apply.

2. They acknowledge that some degree of subjective judgement is still required to be made by the Production Controller.

The acknowledgement of a need to continually monitor the parameters used to define the demand errors does, however, mean that the values quoted in this work cannot be immediately applied without checking against the present customer schedules. There is a possibility that in the light of experience gained during the industrial emergency that the customers may have changed their own forecasting procedures. The earliest these new parameters would be known is October/November 1974 and this will only allow three months data to be analysed.

To control the actual manufacturing system the company have the choice of either the manual system proposed or this system modified to make use of the facilities offered by a computer bureau.

On the present product mix measured in terms of cost effectiveness, the manual system is still the more attractive. because of -

(a) The cost of a female wages clerk might be saved if the payroll system was adopted but this would leave no available spare operator capacity if the full production control function was put onto the computer. There is thus a danger that the system could cease to function because of the lack of data input.

(b) To run the production control system still requires a person in the form of a Production Controller to do the initial vetting of the customers demand and to say whether the resulting computer output is practical.

(c) A liaison Clerk is still required between the customer and the company.

(d) A female Clerk, in attendance full time at the booking office is still required to issue work to the operators.

There is thus no immediate saving in operator costs and therefore on the criterian of effectiveness the manual system is preferable.

On the criterian of cost benefits (i. e. additional benefits that may accrue to the company) then these will depend to a large extent on future management policy.

If they consider adopting budgetary control then the associated costs and analysis required could be obtained with very little additional input to the computer,whereas to be done manually would involve additional manpower being employed.

Similarly stock control could easily be performed with little additional input required, the main work being required at the computer bureau to design a system of data retrieval from the present input in order to up-date the stock records. There would however be an initial high cost but the running costs would then be relatively small in comparison to a manual stock control system.

The possible benefits are therefore attractive but it depends upon future policy.

A computer does require the people operating the system to become disciplined and to make quick decisions and process these quickly, which is an additional benefit. A trivial point, but the author has had to wait 5/6 months for information from Senior Management which one cannot afford to do if a computer output is to be useful - the output is entirely dependent upon the input for its accuracy.

CHAPTER 17

FUTURE WORK

With respect to the sponsoring company a statement of the new manufacturing budget is of utmost importance to enable management to plan ahead and satisfy doubts that exist within the company as to its future viability.

The system proposed and partially installed must be fully implemented and in conjunction with this implementation tests made (possibly using a computer simulation) to establish the variation in the demand that is permissible before the distribution parameters have to be revised.

Using the operation summary sheets that have been prepared for existing jobs and are being prepared for new jobs, then a procedure must be given to the Accounts Section on how to interprete the information given and to use this to analyse cost variances on a more reliable basis rather than opinion as at present.

The additional labour cost to the company resulting from the use of a computer bureau in this instance is small because of the low product variation. The effect of the manufacturing system on the cost of operating the control system should be considered for other companies of varying size and engaged upon batch production in an attempt to formulate rules or guide lines to assist in the choice of control systems.

Whilst the individual company may be hard pressed to justify the purchase of its own computer (due not to the hardware cost but to the cost of the supporting system) this aspect should be considered in the proposal.

Work is already proceeding at the University of Aston under the author's supervision to investigate the human problems involved in introducing manufacturing systems based upon Group Technology principles. The present work has demonstrated the need to extend this work into the human aspects of all manufacturing systems in order to establish the reasons for the full or partial rejection of a system by management; this latter point also being stressed by Professor Eilon in his closing remarks to the session Chaired by himself at the 2nd International Conference on Production Research.

CHAPTER 18

CONCLUSIONS

1. If an effective economical manufacturing unit is to be formed management must recognise that the Foundry and Machine Shop are both dependent upon each other.

2. Senior Management must recognise that they are members of a team each accountable to the Managing Director for his own work, but also having a moral responsibility to fellow Managers.

3. Before a control system can be designed the manufacturing system must be designed and its limitations or applicable restrictions made known.

4. To control production an estimate must be made of the customers final demand and a programme produced on this estimate.

5. The technique proposed and checked by means of a simulation will enable this estimate to be made.

6. Because an estimate is invariably wrong the monitoring procedure must be rigidly applied to the analysis of demand.

7. The technique of rota cycle scheduling is not fully applicable to the present situation in the Foundry because of the restrictions due mainly to setting capacity.

8. Component Flow Analysis is a simple technique which can be applied to companies where the volume of work does not justify an analysis based upon some classification system.

9. To enable component flow analysis to be effectively carried out requirements and details of the product manufacturing process, component demand and machine capabilities need to be known.

10. The more accurate are the above details known, the more effective will be the resultant analysis.

11. By application of machine group principles using operators who are flexible the work load on the Production Control function is much simplified.

12. The supporting works documentation is reduced in a group technology situation due to a cell or flow line being classed as one operation.

13. Component Flow Analysis technique can be applied to the Machine Shop to formulate group flow lines.

14. Although the operators on these flow lines are fully flexible, the operation of the lines is restricted by the operators reluctance to move work.

15. To avoid stoppages in the Machine Shop due to lack of work, the work load pattern in the Foundry must be balanced to the available Machine Shop capacity.

16. The work in both the Foundry and Machine Shop should be displayed by means of GANTT charts which must be updated twice weekly and this will enable manual balancing of the work load to be more readily achieved.

17. The number of machines in the Machine Shop is greater than the number of operators. The output is therefore operator controlled.

18. Flexibility is therefore required of the operators and in preparing the Machine Shop schedule the resource 'operator availability' must be taken into account.

19. To enable an effective control system to be maintained the quantity or weight of components must be known at each stage of manufacture.

20. The policy to be adopted for counting the components must be decided by management as a matter of urgency.

21. The position of the 100% inspection should be changed from the final operation to one immediately after the component is cast and prior to machining. This will not only save cash outflow by not machining scrap but may offer a temporary solution to the counting problem.

22. To monitor performances of both operators and departments, performance analysis should be undertaken and the value of lost time allocated to the department responsible.

23. Operation summary sheets should be completed and maintained and these will then become the standard cost for the component referred to.

24. The estimate should be compared with the final operation summary sheet and variations noted which will improve the accuracy of new estimates.

25. Whilst cost-effectiveness is a simple technique to use to compare systems, cost -benefit analysis in relation to future objectives of a company should also be

considered before a final decision is made.

26. When considering costs only relevant costs must be considered.

27. Although initially a manual system of control is considered to be the most effective, the future benefits to be obtained from the use of a computer bureau are attractive dependent upon future company policy.

28. The purchase of the company's own computer would not give a suitable return on investment due to the high systems costs involved.

APPENDIX A

ERRORS IN FORECASTED DEMAND

A. 1	Demand Analysis Sheet.
A. 2	Ratio of Actual Monthly Demand to Average Monthly Demand.
A. 3	Ratio of Forecast in Period 2 to eventual Demand.
A. 4	Ratio of Forecast in Period 3 to Eventual Demand.
A. 5	Ratio of Highest Monthly Demand to Average Monthly Demand for Components Supplied to the Car Industry.
A. 6	Histogram of Errors in Forecast for Period 2.
A. 7	Histogram of Errors in Forecast for Period 3.

RELEASE NUMBER	MARCH	APRIL	MAY	JUNE	JULY	AUGUST
314	64,000	57,147	61,089	56,560	31,569	23,760
315		56,000	66,819	65,310	40,599	29,620
316			53,674	55,318	36,126	31,914
317				54,514	36,990	31,003
318					39,128	29,355
319						27,326
Demand Month (i) / Average demand	13.033	1.1404	1.093	1.1101	.7968	.5565
Actual Demand (i) / Forecast Month (i-1)	X	.980	.803	.985	1.058	.931
Actual Demand (i) / Forecast Month (i-2)	X	X	.8786	.8347	1.0831	.8814

DEMAND ANALYSIS SHEET

COMPONENT NO. F.17

RANGE			FREQUENCY
.350	-	.399	2
.400	-	.449	0
.450	-	.499	1
.500	-	.549	3
.550	-	.599	1
.600	-	.649	7
.650	-	.699	1
.700	-	.749	8
.750	-	.799	7
.800	-	.849	5
.850	-	.899	7
.900	-	.949	10
.950	-	.999	9
1.000	-	1.049	6
1.050	-	1.099	5
1.100	-	1.149	10
1.150	-	1.199	10
1.200	-	1.249	3
1.250	-	1.299	8
1.300	-	1.349	3
1.350	-	1.399	3
1.400	-	1.449	0
1.450	-	1.499	1
1.500	-	1.549	2
1.550	-	1.599	3
1.600	-	1.649	0
1.650	-	1.699	1
1.700	-	1.749	0
1.750	-	1.799	1
1.800	-	1.849	1

MEAN = 1.015

STANDARD DEVIATION = .3279

RATIO OF ACTUAL MONTHLY DEMAND TO AVERAGE MONTHLY DEMAND FOR INDIVIDUAL COMPONENTS

RANGE			FREQUENCY
.500	-	.549	5
.550	-	.599	3
.600	-	.649	2
.650	-	.699	2
.700	-	.749	3
.750	-	.799	4
.800	-	.849	6
.850	-	.899	7
.900	-	.949	11
.950	-	.999	16
1.000	-	1.049	13
1.050	-	1.099	11
1.100	-	1.149	3
1.150	-	1.199	3
1.200	-	1.249	4
1.250	-	1.299	1
1.300	-	1.349	0
1.350	-	1.399	1
1.400	-	1.449	3
1.450	-	1.449	0
1.500	-	-	3

MEAN = .9669

STANDARD DEVIATION = .238

RATIO OF FORECAST MADE IN PERIOD 2 TO EVENTUAL ACTUAL DEMAND

RANGE			FREQUENCY
.500	-	.549	0
.550	-	.599	1
.600	-	.649	1
.650	-	.699	2
.700	-	.749	3
.750	-	.799	1
.800	-	.849	4
.845	-	.899	10
.900	-	.949	8
.950	-	.999	6
1.000	-	1.049	5
1.050	-	1.099	4
1.100	-	1.149	3
1.150	-	1.199	2
1.200	-	1.249	2
1.250	-	1.299	2
1.300	-	1.349	0
1.350	-	1.399	2
1.400	-	1.449	0
1.450	-	1.499	1
1.500	-		3

MEAN = 1.018

STANDARD DEVIATION = .273

RATIO OF FORECAST MADE IN PERIOD 3 TO EVENTUAL ACTUAL DEMAND

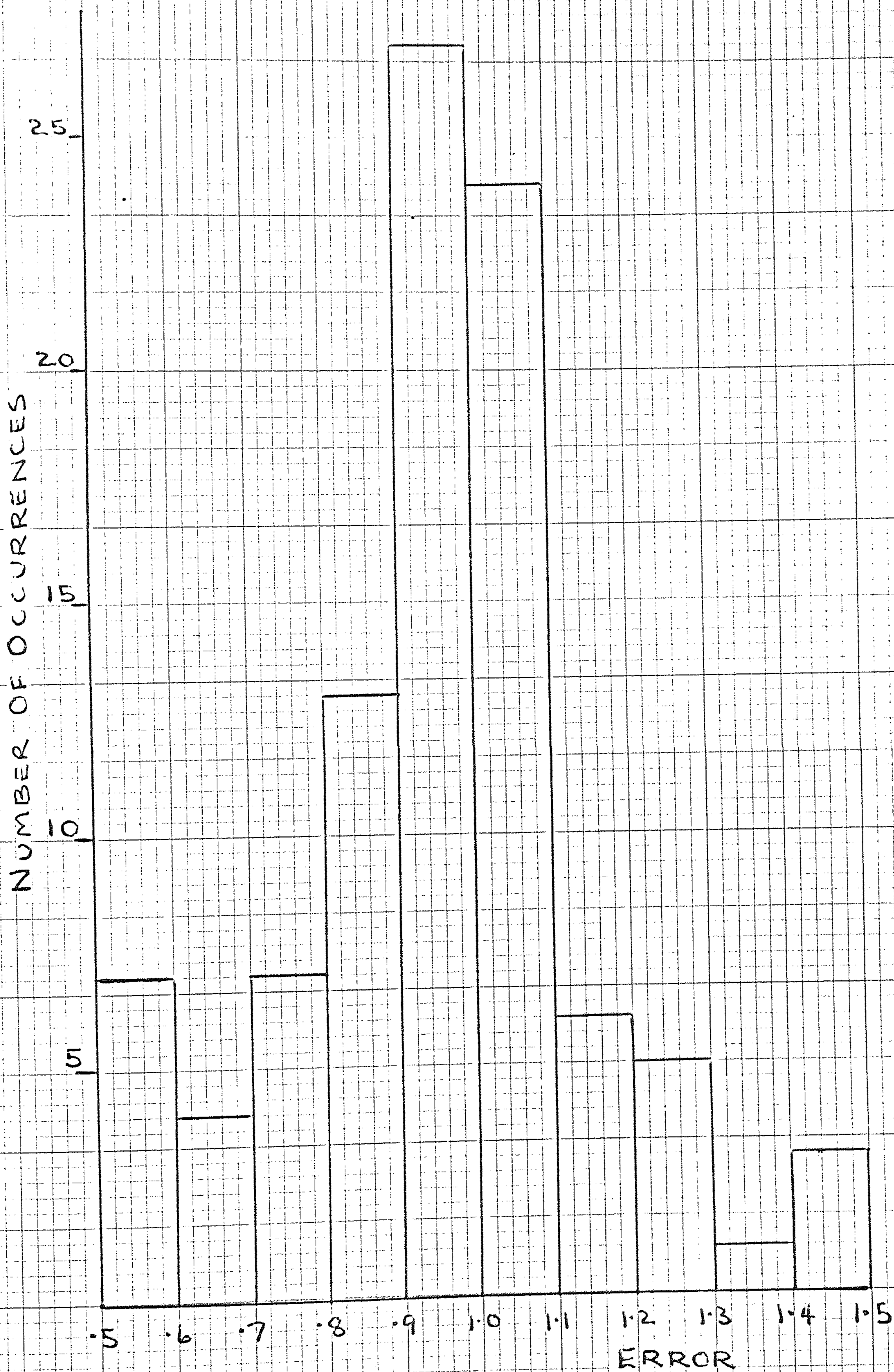
Ref. No.	Highest Q	Average Q	H.Q. / A.Q.	Remarks
-	1022	812	1.26	
54	27105	22564	1.2	
2	3185	2480	1.28	
3	17904	15245	1.17	
4	7888	6692	1.18	
9	9685	7631	1.27	
14	2104	1351	1.56	Suspect cause
17	4000	1633	2.45	Suspect cause
17	64000	49107	1.3	
22	3000	2146	1.4	
24	1500	1016	1.48	
27	40352	31999	1.26	
28	1600	1425	1.12	
31	4056	3119	1.3	
34	14916	12636	1.18	
36	20152	14924	1.35	
38	230886	200444	1.15	
40	1416	917	1.54	Suspect cause
41	23960	15420	1.55	Suspect cause
42	1256	705	1.78	Suspect cause
51a	62492	48864	1.28	
52	19522	12552	1.56	Suspect cause
56	21625	12819	1.69	Suspect cause
33	2500	2062	1.21	

MEAN VALUE = 1.258

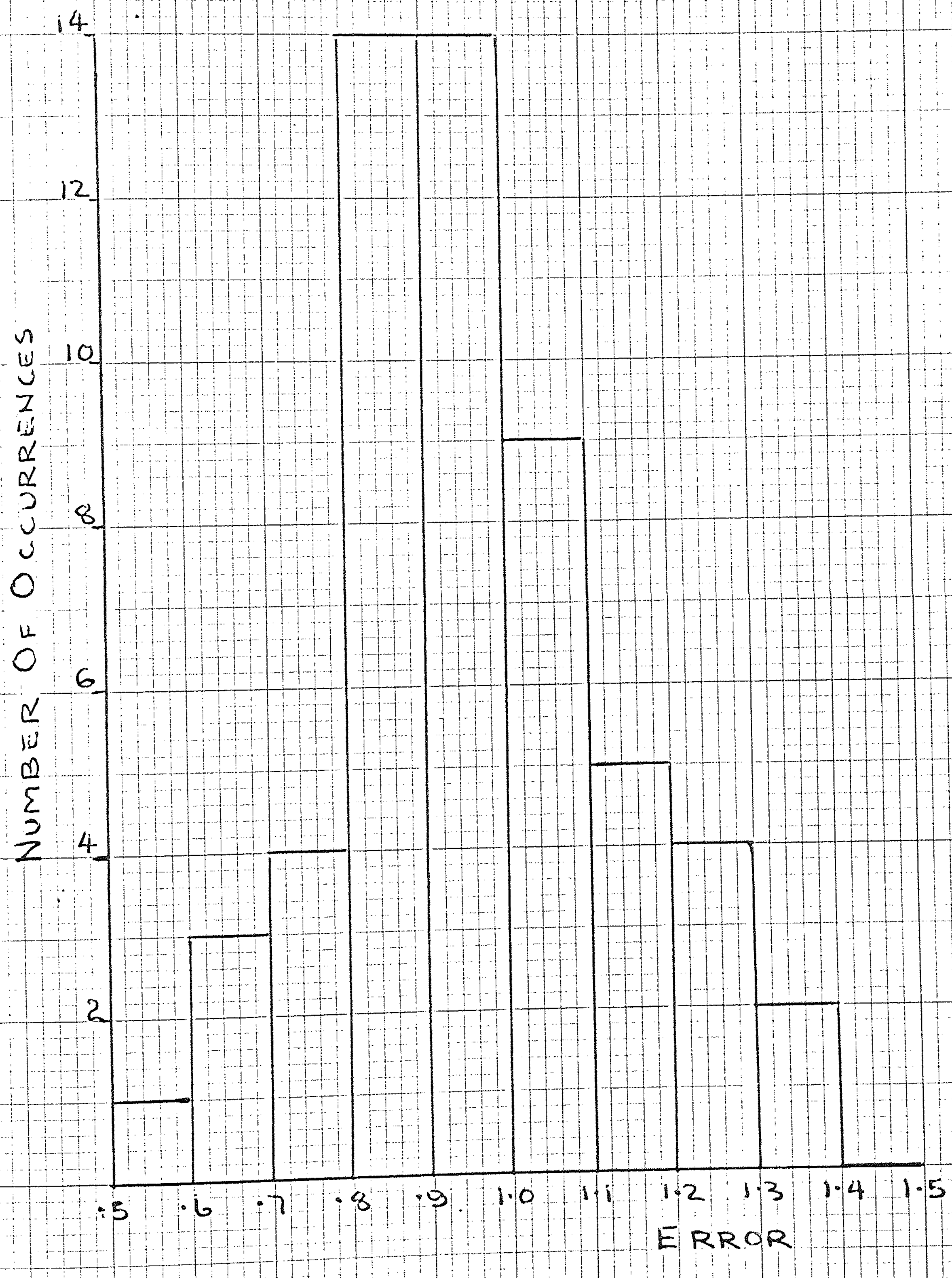
STANDARD DEVIATION = .093

1 Standard Deviation to right of mean gives value of (1.258 + .093) = 1.35

RATIO OF HIGHEST MONTHLY DEMAND TO AVERAGE MONTHLY DEMAND OF COMPONENTS SUPPLIED TO THE CAR INDUSTRY.



ERRORS IN FORECAST FOR PERIOD 2.



ERRORS IN FORECAST FOR PERIOD 3

APPENDIX B

INSPECTION

B. 1	Cost of Counting Components; Inspection as Final Operation.
B. 2	Position of Present Inspection.
B. 3	Machine Scrap losses and Resulting Cash Saving by Changing Position of inspection.

COST OF COUNTING COMPONENTS BY MANUAL AND WEIGH COUNTING METHODS IF INSPECTION REMAINS AS FINAL OPERATION

COUNTING - Hours for Fork Lift Truck

1. 60% of casting section doing work, capable of being weigh counted.

2. Allow two pallets per operator.

3. Allow 32 operators.

4. Number of operators on suitable work

   = 32 x .6
   = 19 .2

   Say 20

5. Number of pallets to count 40.

6. Estimated time per pallet is 5 mins. Therefore time = $3\frac{1}{3}$ hours.

COST OF PROPOSAL

	£/40 hr.
1 Leading Counter (Male as Storekeeper)	32
2 Female Counters (as Inspectors including timekeeping bonus)	39
Part Fork Lift Truck $\frac{(3\frac{1}{3} \times 5) \times 26}{40}$	10. 5
	81. 5
Increase in overhead for three additional staff 11% of £71	7. 9
TOTAL	£89. 4

Item	Inspection	Item	Inspection
2	2	28	1
3	2	29	2
4	2	30	2
5	2	31	2
6	2	32	2
7	2	33	1
8	1	34	1
9	1	35	2
10	1	36	2
11	1	37	2
12	1	38	2
13	1	39	1
14	1	40	1
15	1	41	2
16	1	42	2
17	1	43	2
18	2	44	2
19	1	45	2
20	1	46	2
21		47	2
22	2	48	2
23	2	49	2
24	2	50	2
25	2	51	2
26	2	52	2
27	2	53	2
		54	2

Inspection Code: 1 = Inspection after casting
2 = Inspection after machining

POSITION OF PRESENT INSPECTION

Ref. No.	Scrap from Machines	Std. Hours per 100	Std. Hours Scrap per Operator	No. of Operators in team	Total Scrap Std. Hours
2	48,539	.25	121.4	3	364.2
3	45,031	.15	67.6	4	270.4
4	11,018	1.47	162.0	2	324.
5	21,759	.25	54.4	2	108.8
6	2,606	.24	6.3	1	6.3
7	2,906	1.75	50.9	1	50.9
18	10,818	.80	86.6	1	86.6
22	9,358	.69	64.6	2	129.2
23	19,763	.28	55.4	1	55.4
24	3,600	3.80	136.8	2	273.6
25	20,322	.35	71.2	3	213.6
26	12,678	.33	41.9	1	41.9
27	4,516	.25	11.3	4	45.2
29	6,901	.50	34.5	2	69.
30	102,303	.50	511.5	4	2046.
31	3,257	.38	12.4	1	12.4
32	2,751	.38	10.5	1	10.5
36	18,130	.20	36.3	1	36.3
37	29,406	.40	117.6	1	117.6
39	1,149	.24	2.8	2	5.6
41	22,854	.22	50.3	3	150.9
42	7,057	.17	12.	2	24.0
43	3,641	.22	8.1	2	16.2
44	8,831	.17	15.1	1	15.1
45	786	.24	1.9	2	3.8
46	1,584	.24	3.8	2	7.6
47	6,369	.30	19.1	2	38.2
49	1,869	.50	9.4	1	9.4
50	10,854	.25	27.2	1	27.2
51	1,994	.35	7.0	2	14.0
52	12,746	.25	31.9	1	31.9
53	23,195	.26	60.3	2	120.6
54	7,310	.24	17.6	2	35.2
			TOTAL LOST HOURS		4,761.6

MACHINE SCRAP LOSSES OVER 14 MONTH PERIOD.
OPERATORS ON DIRECT INCENTIVE.

Ref. No.	Scrap From Machines	Allowed Hours per 100	Total Hours Scrapped	M or F	Male Hours Scrap	Female Hours Scrap
25	20,322	.50	102.	F		102.
29	6,901	1.00	69.	F		69.
30	102,302	.50	512.	F		512.
38	1,149	.20	3.	F		3.
49	1,869	.40	8.	M	8.	
52	12,746	.10	13.	M	13.	
3	45,031	.33	150.	M	150.	
6	2,606	.53	14.	M	14.	
18	10,818	.40	44.	M	44.	
		TOTAL HOURS SCRAP			229.	686.

MACHINE SCRAP LOSSES OVER 14 MONTH PERIOD
OPERATORS ON TIMEWORK

COST OF SCRAP

Operators on Direct Incentive 4761.6 std. Hrs. at 46.1p	=	£2,190
Male Operators on timework 229 hrs. at 56p.	=	£ 128
Female Operators on timework 686 hrs at 35p	=	£ 240
Cost over 14 months	=	£2,558
Therefore cost over 12 months	=	£2,191

NB. THIS TOTAL SAVING WOULD BE INCREASED IF ALLOWANCE IS MADE FOR THE RESULTANT IMPROVED CONTRIBUTION TO OVERHEAD RECOVERY.

APPENDIX C

DOCUMENTATION

C. 1	Pallet Identification Card (existing).
C. 2	Foundry Production Record (existing).
C. 3	Machine Operators Card (existing).
C. 4	Machine Operators Cards (existing) (Rectification & Indirect Work)
C. 5	Operation Summary Sheet.
C. 6	Schedule Analysis Sheet.
C. 7	Foundry Make Card.
C. 8	Operators Weekly Record Card.
C. 9	Operators Performance Summary Sheet.
C. 10	Weekly Departmental Summary Sheet.

6 a.m. - 2p.m. SHIFT

NAME

CLOCK No.

DATE

COMPONENT

PALLET No.

INSPECTION

FOREMAN'S SIGNATURE

SAGE ALUMINIUM PRODUCTS LTD. **FOUNDRY PRODUCTION RECORD** **DATE**

		PART No.	CASTER		TIME		SHOTS	HOURS WORKED			REMARKS	SHOT RATES		M/C UTIL. %	OP. PERF. %
			CLOCK No.	NAME	START	FINISH		TOTAL	CAST	DOWN		ACT.	BUDG.		
MACHINE GROUP – 400 TONS – Budgeted Plant utilisation 85%															
1															
10															
11															
12															
14															
15															
21															
							TOTAL								
MACHINE GROUP – 250 TONS – Budgeted Plant utilisation 75%															
2															
3															
4															

SAGE ALUMINIUM PRODUCTS LTD.

✱ HOLD OTHER SIDE OF CARD TOWARDS YOU ✱

NAME ______________________ NO. ________

COST CENTRE ______________________

PAY TICKET

PART NO.	DESCRIPTION

OP. NO.	OPERATION

QUANTITY	STD. RATE
MON.	
TUE.	PER 100
WED.	ACTUAL RATE IF OTHER THAN STD. RATE
THU.	
FRI.	PER ______
SAT.	RATE SIGN / COST CODE
TOTAL	

VALUE	VARIANCE +	VARIANCE −

Dataset Limited 07-29375-001 Printed in the U.K

SAGE ALUMINIUM PRODUCTS LTD.

✳ HOLD OTHER SIDE OF CARD TOWARDS YOU ✳

NAME ____________________ NO. ________

COST CENTRE ____________________

RECTIFICATION TICKET

PART NO.	DESCRIPTION

OP. NO.	OPERATION

REASON FOR RECTIFICATION	DEPT. RESPONSIBLE

QUANTITY	STD. RATE
MON.	
TUE.	PER 100
WED.	ACTUAL RATE IF OTHER THAN STD. RATE
THUR.	
FRI.	PER ____
SAT.	RATE SIGN / COST CODE
TOTAL	

VALUE	VARIANCE +	VARIANCE −

Dataset Limited 07-29375-002 Printed in the U.K.

SAGE ALUMINIUM PRODUCTS LTD.

✳ HOLD OTHER SIDE OF CARD TOWARDS YOU ✳

NAME ____________________ NO. ________

COST CENTRE ____________________

INDIRECT WORK / WAITING TICKET

PART NO.	DESCRIPTION

OP NO.	DETAILS OF WORK CARRIED OUT

IF WAITING INDICATE REASON WHY

WAITING WORK		WAITING INSPECTION	
WAITING SETTER		WAITING METAL	
WAITING TOOLROOM		MACHINE BREAKDOWN	

QUANTITY	STD. RATE
MON.	
TUE.	PER 100
WED.	ACTUAL RATE IF OTHER THAN STD. RATE
THU.	
FRI.	PER ____
SAT.	RATE SIGN / COST CODE
TOTAL	

VALUE	VARIANCE +	VARIANCE −

Dataset Limited 07-29375-003 Printed in the U.K.

OPERATION SUMMARY SHEET

Part ____________ Customer ____________ Customer Part No. ____________

Mat. Spec. ____________ Weight per 100 ____________ Standard Scrap allowed ________ % Sage Aluminium Ref.No. ____________

Quantity per Standard Pallet ____________ Date of Issue ____________

Op. No.	Operation Description	Machine	Labour Grade	Hours per 100	Scrap %	Rect. %	Remarks
10	Cast ---------- per shot						

Sheet of Sheets

SAGE ALUMINIUM PRODUCTS LTD.

Customer ____________

Customer Ref. No. ____________

Sage Aluminium Ref. No. ____________

CUSTOMER SCHEDULE NO: ________ Dated ________

ITEM	%	QUANTITY
Arrears on Date of Issue	-	
Current Month Demand	-	
2nd Month Demand	-	
2nd Month Variance Allowance		
3rd Month Demand		
Scrap Allowance		
1. Total for Schedule Available from previous schedule		
TOTAL TO MAKE		

MAKING INSTRUCTIONS

Cast ________ Batches of ________ Units

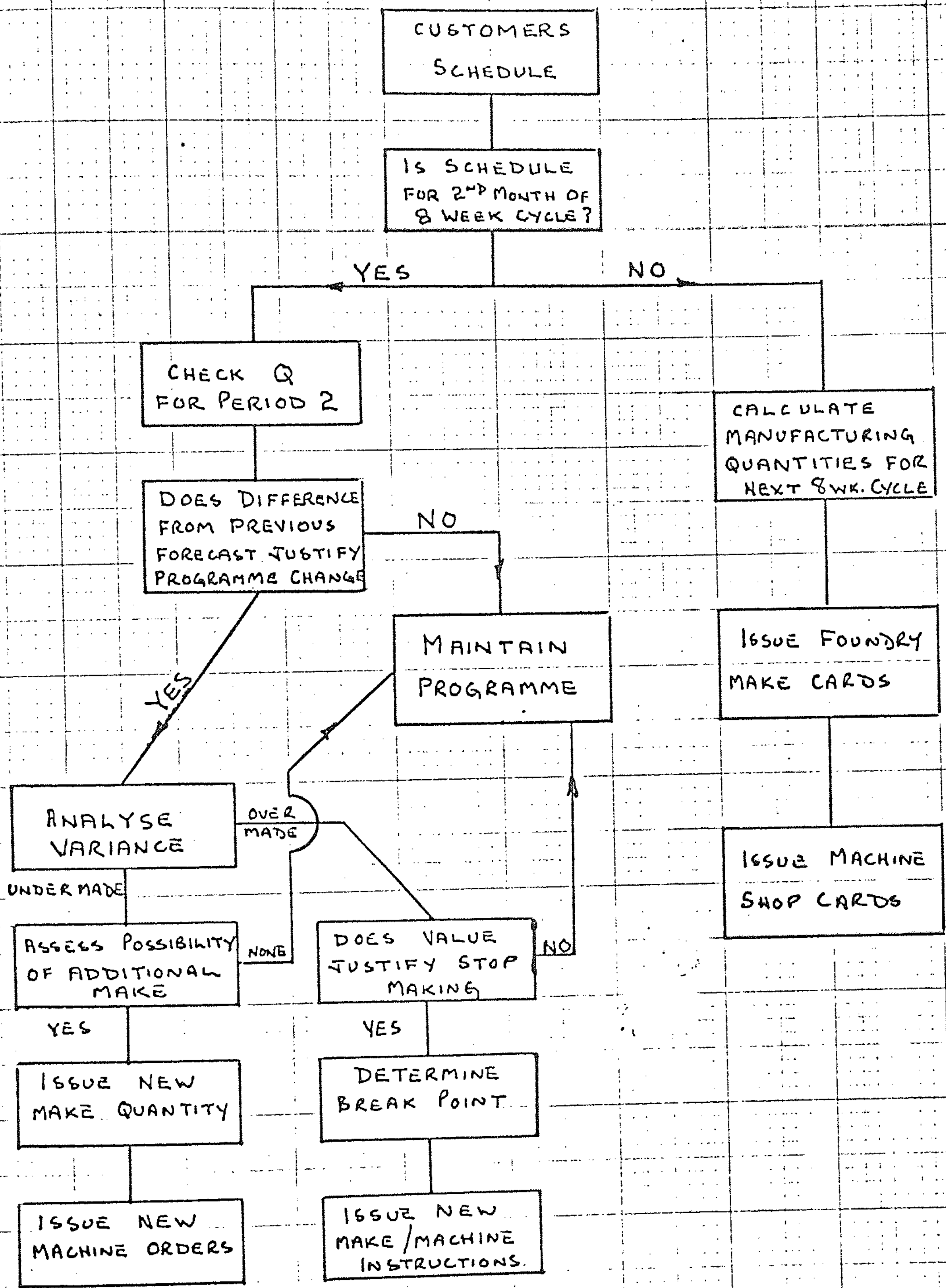
Machine ________ Batches of ________ Units

TOTAL AVAILABLE TO NEXT SCHEDULE

1. Total for this schedule = Plus returns during period of this schedule =	
Less despatched during period of this schedule =	
TOTAL AVAILABLE TO NEXT SCHEDULE	

CUSTOMER ESTIMATE OF FUTURE REQUIREMENTS

MONTH			
QUANTITY			



MONITORING PROCEDURE FOR CUSTOMERS SCHEDULES.

SAGE ALUMINIUM PRODUCTS LTD.

FOUNDRY MAKE CARD

Customer ____________________

Customer Ref. No. ____________________

Sage Ref. No. ____________________

Customer Schedule No. ____________________

BATCH SIZE ____________________ UNITS

____________________ CASTING HOURS

MACHINE GROUP ____________________ MACHINE NUMBER ____________________

MAKE PERIOD ____________________

SAGE ALUMINIUM PRODUCTS LTD.

OPERATOR ____________ CLOCK NO. ____________

WEEK ENDING ____________

Component No.	Operator No.	Clocked Hours (a)	Standard Hours Earned (b)
TOTAL HOURS			

Operator Performance $= \frac{b}{a} \times 100 =$

Overall Performance $= \frac{b}{a + c} \times 100 =$

NON - PRODUCTIVE TIME ANALYSIS

DAY	CODE NUMBER 1	2	3	4	5	6	7	Total Daily Lost Hours
Weekly Total								
(c) Total Non-Productive Hours								

PAYMENT £

Basic			=	
Bonus	Std. Hrs.	@	=	
Non-Prod. Clock Hrs.		@	=	
Premium Payment Hrs.		@	=	
----------------------------			=	
----------------------------			=	
TOTAL PAY FOR WEEK			=	

OPERATOR	DEPARTMENT				PERIOD	
Week No.	TOTAL HOURS				Operators P. I.	Av. Operator **P.** I. for Department
	P. W.	D. W.	Lost	Clocked		

OPERATORS PERFORMANCE SUMMARY SHEET

DEPARTMENT					PERIOD								
Week No.	Hours				Lost Time Analysis							Aver. Oper. P. I.	Dept. P. . I.
	P. W.	D. W.	Lost	Clock	1	2	3	4	5	6	7		

WEEKLY DEPARTMENTAL PERFORMANCE ANALYSIS

APPENDIX D

MACHINE GROUPING DETAILS

D. 1	Analysis Sheets
D. 2	Components Produced on Machine Groups.
D. 3	Hours Required per Month on Machine Groups.
D. 4	Group Combination.
D. 5	Component Allocation to Groups and Individual Machines.
D. 6	Operator Performance Indices (Individual and Group Working)
D. 7	Gantt Chart for Machine Shop.

GROUP 1.

Job No / Machine		F4	F7	F22	F27	F 28	F35	41	47	53	F25	F40	9	22				
5 Ton	A	1	1	1	1	1	1	1	1	1	1	1	1	1				
5 Ton	B																	
5 Ton	C																	
15 Ton	D																	
15 Ton	E																	
20 Ton	F																	
Fobco Dr.	G	2	2	2	2	2	2	2	3	3		2						
Fobco Dr.	H																	
Elliot Ped.	J																	
Elliot 3a	K	3	3	3	3	3	3	3	2	2	2		2	2				
Linish	L													3				
Linish	M																	
Mill(Arch)	N																	
Mill (Wad)	O																	
Bench	P																	
Special	Q																	
Special	R																	
Special	S																	

Machine \ Job No.		F8	F23	F32	F36	F37				F9	F38 (8)	F38 (10)	F24					
5 Ton	A									1	1							
5 Ton	B																	
5 Ton	C																	
15 Ton	D	1	1	1	1	1						1	1					
15 Ton	E																	
20 Ton	F																	
Fobco Dr.	G	2	2		2	2				2	2	2	4					
Fobco Dr.	H									3	3	3	5					
Elliot Ped	J																	
Elliot 3a	K			2		3				4								
Linish	L	3	3			4							2					
Linish	M												3					
Mill (Arch)	N																	
Mill(Wad)	O																	
Bench	P																	
Special	Q																	
Special	R																	
Special	S																	

GROUP 4

Job No. / Machine		F11	37	38	F10	F17	F51a	8	14	21	29	36	54	65	39	35		
5 Ton	A	1	1	1	1	1	2	1	2	2	2	1	3					
5 Ton	B	2	2	2	3	3		3		3	3	4						
5 Ton	C	3																
15 Ton	D					2	1		1	1	1		1					
15 Ton	E								3									
20 Ton	F													1	1			
Fobco Dr	G	4			5									2				
Fobco Dr	H													3				
Elliot Ped	J				2			2										
Elliot 3a	K		3	3		4	3				5	2	2		2			
Linish	L	5				5		4						4		2		
Linish	M	6																
Mill (Arch)	N				4								4					
Mill (Wad)	O																	
Bench	P						4				4		5					
Special	Q									barrel 4		3 PO spec purp.				barrel 1		
Special	R																	
Special	s																	

GROUP 4

Job No. / Machine		F33	F34	F42	F45	63	64	F31										
5 Ton	A																	
5 Ton	B																	
5 Ton	C																	
15 Ton	D	1	1	1	1	1	1	1										
15 Ton	E																	
20 Ton	F																	
Fobco Dr	G	4	4		4		3											
Fobco Dr	H																	
Elliot Ped	J																	
Elliot 3A	K	5	5	5	5	2 & 3	2 & 4	2,4,5										
Linish	L			2	2													
Linish	M			3														
Mil(Arch)	N	6	6		6													
Mill (Wad)	O	2	2															
Bench	P						5											
Special	Q	3	3	4	3 multi spin													
Special	R																	
Special	S	7turn	7turn		7turn													

GROUP 4a

Machine \ Job No.		F14	F16	F39	F41	12	13	15	19	34	62	F2	F3	78	79	40	96	93
5 Ton	A	1	1	1	1	1	1	1	1	1								
5 Ton	B																	
5 Ton	C																	
15 Ton	D										1	1	1	1	1	1	1	1
15 Ton	E																	2
20 Ton	F										2							
Fobco Dr	G																	
Fobco Dr	H																	
Elliot Ped	J																	
Elliot 3a	K																	
Linish	L											3	2	2				
Linish	M																	
Mill (Arch)	N																	
Mill (Wad)	O																	
Bench	P											2					2	
Special	Q																	
Special	R																	
Special	S																	

Machine \ Job No.		80	82	83	1	2	F52	F53	F56	92	91	88	87	86	85a	94	95	97
5 Ton	A									2	1							
5 Ton	B																	
5 Ton	C																	
15 Ton	D									1		1						
15 Ton	E											2						
20 Ton	F	1	1	1									1	1				
Fobco Dr	G																	
Fobco Dr	H																	
Elliot Ped	J																	
Elliot 3A	K																	
Linish	L				1	1						3				1		
Linish	M																	
Mill(Arch)	N																	
Mill(Wad)	O																	
Bench	P														1		1	1
								~~Large Press~~										
Special	Q						1	1	1 →									
Special	R																	
Special	S																	

Ref. No.	Budget Monthly Q	Inclusive of 35% Car Industry	Scrap %	Total make Quantity	MACHINE			Other Operations
					5T	Fobco	Elliot	
DC 100 PRESS								
42	1,500	2,025	30	2,632	x	x	x	
43	2,600	3,510	10	3,861	x	x	x	
45	600	810	10	891	x	x	x	
46	900	1,215	10	1,336	x	x	x	
47	4,400	5,940	10	6,534	x	x	x	
51	2,800	3,780	5	3,969	x	x	x	
250 TON PRESS								
5	15,500	20,925	10	23,017	x	x	x	
EDGWICK PRESS								
53	5,000	6,750	25	8,437	x	x	x	
54	4,000	5,400	10	5,940	x	x	x	

UNITS PRODUCED ON MACHINE GROUP 1

Ref. No.	Budget Monthly Q	Inclusive of 35% Car Industry	Scrap %	Total make Quantity	MACHINE			Other Operations
					15 T.	Fobco	Elliot	
400 TON PRESS								
22	8,500	11,475	8	12,393	x	x		
REED PRESS								
38	800	1,080	10	1,188	x	x	x	

UNITS PRODUCED ON MACHINE GROUP 2

Ref. No.	Budget Monthly Q	Inclusive of 35% Car Industry	Scrap %	Total make Quantity	MACHINE				Other Operations
					5 T	Fobco	Fobco	Elliot	
DC 100 PRESS									
41	9,500	12,825	12	14,364	x	x	x	x	
250 TON PRESS									
2	140,000	189,000	2.5	193,725	x *	x	x		*Part on 15 ton

UNITS PRODUCED ON MACHINE GROUP 3

Ref. No.	Budget Monthly Q	Inclusive of 35% Car Industry	Scrap %	Total Make Quantity	MACHINE					Other Operations
					5T	15T	20T	Fobco	Elliot	
400 TON PRESS										
20	30,500	41,175	8.5	44,674	x	x			x	Bench
21	13,500	18,225	7	19,500	x	x			x	Archdale Bench
25	19,100	25,785	8	27,847	x	xx				
27	4,000	-	7	4,280	xx				x	
29	3,600	4,860	10	5,346		x		x	xx	Bench
30	37,800	51,030	15	58,684	xx	x			x	Bench
250 TON PRESS										
3	29,400	39,690	10	43,659	xx	x			x	
4	6,750	9,112	10	10,023	SPECIAL LINE IN EXISTENCE					
7	1,600	2,160	10	2,376		x			xx	
18	5,500	7,425	15	8,538			x	xx		
REED PRESS										
39	2,700	3,645	10	4,009	xxx			x		
DC 100 PRESS										
48	9,000	12,150	10	13,365						Barrel & Linish

UNITS PRODUCED ON MACHINE GROUP 4

Ref. No.	Budget Monthly Q.	Inclusive of 35% Car Indy.	Scrap %	Total make Quantity	Machine			Other Operations
					5T.	15T.	20T.	
400 TON PRESS								
23	7,000	9,450	20	11,340		x		
26	10,000	13,500	8	14,580	x			
28	3,700	4,995	7	5,344		x		
31	2,000	-	10	2,200			x	
32	2,000	-	10	2,200			x	
34	28,400	-	5	29,820				Bench
250 TON PRESS								
6	2,400	3,240	6	3,434		x		
8	6,300	8,505	8	9,185				Linish
9	1,100	1,485	8	1,603				Linish
10	3,600	-	10	3,960		x		Bench
11	3,000	-	10	3,300			x	
12	2,900	-	10	3,190			x	
13	1,000	-	10	1,100			x	
14	3,600	-	10	3,960			x	
15	4,500	-	10	4,950				Bench
16	4,500	-	10	4,950				Bench
17	1,800	-	10	1,980		x		
REED PRESS								
35	3,400	-	10	3,740			x	
36	5,900	7,965	20	9,558	x			
37	7,100	9,585	25	11,981		x	x	
40	2,300	-	5	2,415	x			
DC 100 PRESS								
49	3,000	-	5	3,150		xx		
50	3,900	5,265	15	6,054	x			

UNITS PRODUCED ON MACHINE GROUP 4a

HOURS REQUIRED PER MONTH ON MACHINE GROUP TO MEET TOTAL DEMAND

GROUP 1	Present Load	Planned Increase	Total
5 Ton	80	73	153
Fobco	68	63	131
Elliot	131	120	251
GROUP 2			
15 Ton	34	2	36
Fobco	17	1	18
Elliot	3	2	5
GROUP 3			
5 Ton	292	31	323
1st Fobco	250	26	276
2nd Fobco	250	26	276
Elliot	34	4	38
GROUP 4			
5 Ton	445	15	460
15 Ton	575	20	595
20 Ton	57	2	59
Fobco	32	2	34
Elliot	429	15	444
GROUP 4a			
5 Ton	46	8	54
15 Ton	111	18	129
20 Ton	212	34	246

GROUP COMBINATION AND MANNING

GROUPS 1 & 2 COMBINED require following hours per month:

5 ton	-	153 hours
15 ton	-	36 hours
Fobco	-	151 hours
Elliot	-	292 hours

Using 4 operators gives work distribution:

1	Operator on 5 ton	=	153 hours	=	101 P.I.
1	Operator on Fobco	=	151 hours	=	102.5 P.I.
2	Operators on Elliot plus 15 ton.	=	292 hours	=	99.3 P.I.

MACHINE GROUP IS THEREFORE EITHER:

(a) 1 - 5 ton)
1 - 15 ton)
1 - Fobco)
2 - Elliots) 4 Operators

(b) 2 Groups

1 - 5 ton)
1 - 15 ton)
1 - Fobco)
1 - Elliot) 2 Operators

1 - 5 ton)
1 - Fobco)
1 - Elliot) 2 Operators

GROUP 3

HOURS PER MONTH REQUIRED:

5 ton	-	323 hours
Fobco (1)	-	276 hours
Fobco (2)	-	276 hours
Elliot	-	38 hours

Using 2 teams of 3 Operators gives work distribution per team:

1 Operator on 5 ton	= 161.5 hours	=	109 P.I.
1 Operator on Fobco (1) + $\frac{1}{2}$ Elliot	= 147.5 hours	=	100 P.I.
1 Operator on Fobco (2) + $\frac{1}{2}$ Elliot	= 147.5 hours	=	100 P.I.

N.B. 1 Group also to have a 15 ton press linked into line to allow for Item No. 2 (F.38)

Group No.	Item Ref. No.	Operation Sheet No.	Number of Operators	Standard Hours per 100	Approx. Job Duration in days/month
Group 1	42	F40	2	.17	2
	47	53	2	.30	3.5
	45	F4	2	.24	1.5
	53	F7	2	.26	2
	5	F27	2	.25	11
Group 2	43	F22	2	.22	2.5
	46	F28	2	.24	1
	22	F36	2	.69	8
	51	41	2	.35	2
	54	F35	2	.24	2
	38	F37	2	.24	1
Group 3	41	F9	3	.22	Cont.
Group 4	2	F38	3	.25	Cont.
Group 5	4	F34	2	1.47	Cont.
Group 6	20	F51a	3	.2	Cont.
Group 7	21	F54	3	.43	13
	29	64	2	.5*	5
Group 8	30	39	3	.5	Cont.
Group 9	26	15	1	.33	6
	36	13	1	.20	2
	25	14	3	.35	11
Group 10	27	37	2	.25	4
	3	F17	4	.15	9
Group 11	18	65	1	.8	8
Group 12	24	F31	1	3.8	8
	29	64	2	.5*	5

*Worked as 1 group by 2 operators.

COMPONENTS ALLOCATED TO MACHINE GROUPS

Machine Type	Item Ref. No.	Operation Sheet No.	No. of Operators	Standard Hours per 100	Approximate job duration in days/month
5 ton	50	34	1	.25	2
	39	F11	1	1.03+	4
	44	F41	1	.17	2
	40	91	1	.22	1
15 ton	23	F3	1	.28	4
	37	62	1	.40*	4
	49	88	1	.50	3
	10	96	1	.3	2
	28	40	1	.33	2
	7	63	1	1.75	1
	6	F2	1	.24	1.5
	17	78	1	.33	1
20 ton	31	86	1	.38	1
	32	87	1	.38	1
	12	83	1	.30	1.5
	13	83	1	.30	1
	37	62	1	see 15 ton*	4
	14	82	1	.30	1.5
	10	96	1	.30	1
	11	96	1	.30	1.5
Fobco	39	F11	1	see 5 ton+	1
Elliot	7	63	1	1.75	3
Bench	29	64	1	-	4
	10	96	1	-	2
	6	F2	1	-	2
	20	F51a	1	-	Cont.
	21	F54	1	-	Cont.

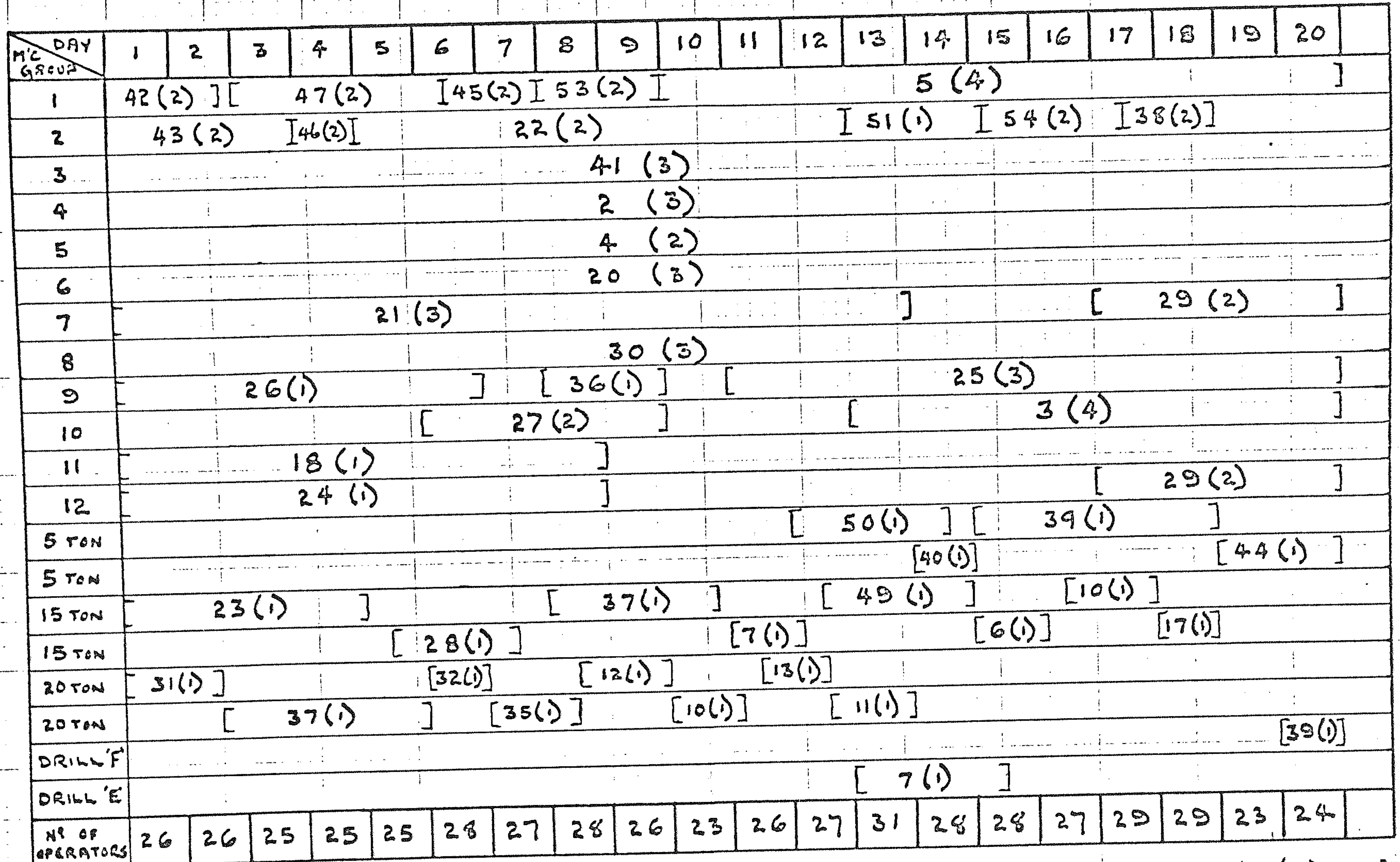
COMPONENTS ALLOCATED TO INDIVIDUAL MACHINES

RANGE	OCCURRENCES
70 - 74.9	5
75 - 79.9	5
80 - 84.9	5
85 - 89.9	11
90 - 94.9	10
95 - 99.9	20
100 -104.9	21
105 - 109.9	19
110 - 114.9	17
115 - 119.9	22
120 - 124.9	29
125 - 129.9	10
130 - 134.9	8
135 - 139.9	10
140 - 144.9	12
145 - 149.9	10
150 - 154.9	5

SAMPLE OF INDIVIDUAL MACHINE OPERATORS PERFORMANCE INDICES

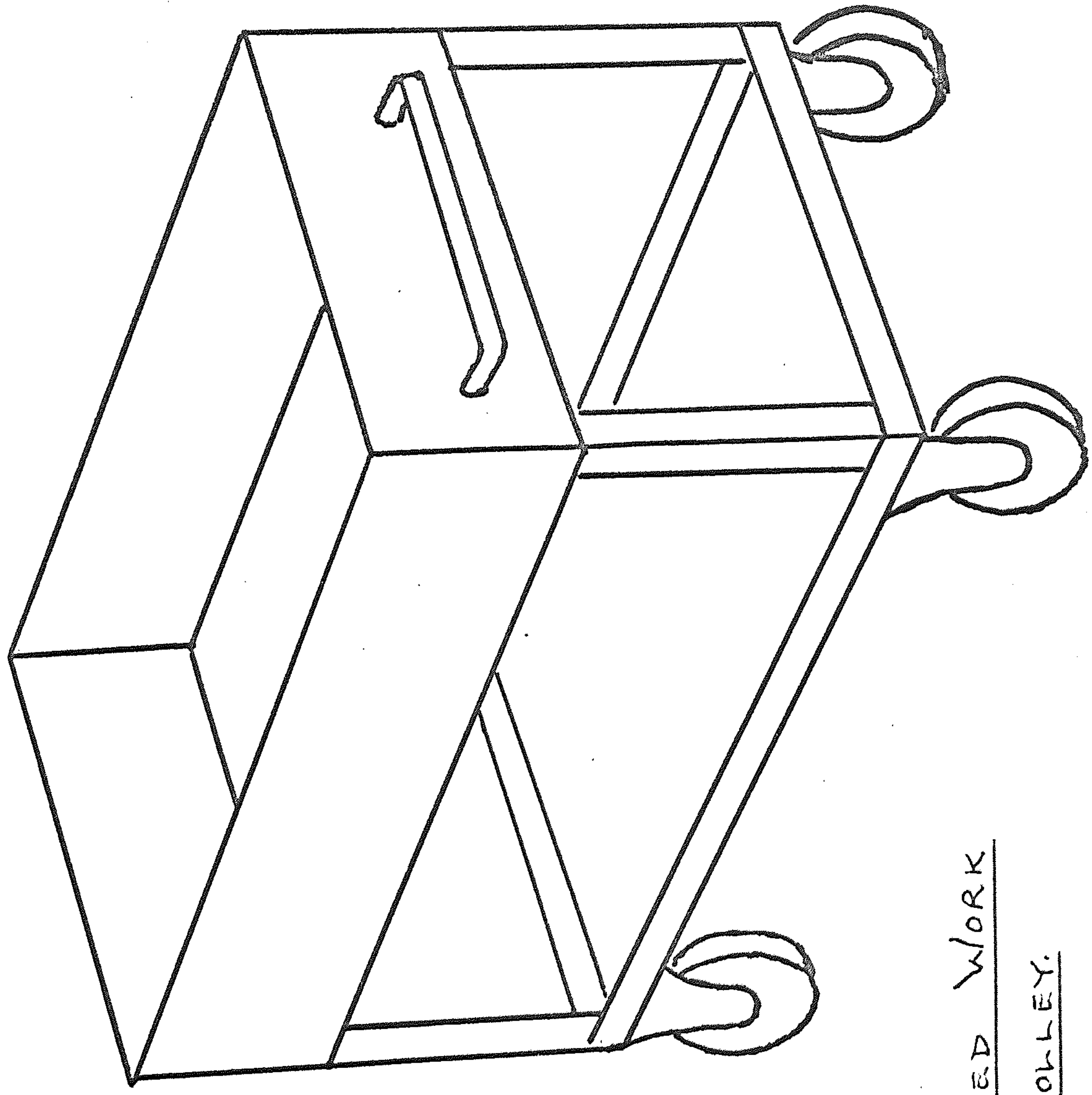
ACTUAL MEAN = 113.7

138	)	
163	)	
157	)	
137	)	
171	)	
146	)	
164	)	MEAN = 152
143	)	
161	)	
161	)	
144	)	
135	)	
147	)	
160	)	
154	)	



KEY: 42 (2) ← Nº OF OPERATORS
↑ JOB NUMBER

BASIC GANTT CHART FOR MACHINE SHOP



PROPOSED WORK TROLLEY.

APPENDIX E

COSTS ASSOCIATED WITH CONTROL SYSTEMS

E. 1 Manual System

E. 2 System Using Computer Bureau.

CALCULATION OF WORK LOAD ON PRODUCTION CONTROL PERSONNEL - MANUAL SYSTEM

Shop Booking Clerk

Basic Element		Time (secs)
1.	Once/week/operator - originate weekly card	32
2.	Per Foundry Operator - analyse Kienzle disc.	120
3.	Per M/c shop operator - originate work card.	20
4.	Per M/c shop operator - close work card.	9
5.	Per operator - fill in work card - per entry	20
6.	Per operation - find work card - per occurrence	15
7.	Per operation - file work card - per occurrence	7

... ...

Records Clerk

Basic Element		
8.	Enter Foundry output - per entry	53
9.	Enter despatch and returns - per entry	53
10.	Calculate shot rate - per entry	20

... ...

Operators (present complement)

Foundry - 42

Average number of entries/day/operator = 1. 35

Machine Shop - 34

Average number of entries/day/operator = 2. 0

RESULTANT WORKS LOADS

Shop Clerk

FOUNDRY

Element	Occurrences/day	Time per day (mins)
2	42	84
5, 6 & 7	42	30
		114
5, 6 & 7	42 x . 35	10. 5
		124. 5

MACHINE SHOP

6 & 7	34	12. 5
3, 4 & 5	68	55. 5
		68. 0

Basic work per day = 125 + 68 = 193 mins.

Weekly work

(42 + 34) x Element 1 & 7 = 50 mins.

Total weekly load = 5 (193) + 50

= 17 hours

RECORDS CLERK

Element	Occurrences/day	Time per day (mins)
8	42	37 mins
9	30	27 mins
10	42	14 mins
		68 mins

Total Weekly load = 5 x 68

= 6 hours.

Monthly Work by Records Clerk

Enter details of new schedules in book

Element 6 + Element 4 x (2x 6) = 123 secs/order

Approx. 60 orders total = 123 mins/month

Calculate value of 2 months sales

(9 + 14 + 9) as U/G study = 148 secs/item/month

= 120 x 148 for 2 months

= 296 mins.

Monthly load = 420 mins.

= 7 hours

Approximate average weekly clerical load (i. e. ignoring customerliaison)

= 6 + 7/4

= 8 hours

ADDITIONAL WORK PROPOSED FOR RECORDS CLERK

For each order received

- analyse requirements
- check stock
- consult make chart for W. I. P.
- determine batch sizes
- write on document — 15 hours/month

Formulate Foundry programme	3 hours/month
Formulate Machine Shop programme	2 hours/month
Write job cards	3 hours/month
File job cards and schedules	2 hours/month
TOTAL monthly additional work	25 hours/month

Extra for Gantt Chart Work

Proposal up date twice/week

= (2 x 75) x 60 = 150 mins.

= 10 hrs/month/department

= 20 hrs/month for two departments

Plus initial preparation (2 x 75) x 60 = $2\frac{1}{2}$ hours = 3 hrs/month

Total load on Records Clerk proposed

Existing 4 x 8	=	32 hours/month
Increase	=	48 hours/month
TOTAL	=	80 hours/month

N. B. This does not include any allowance for customer liaison or interference from other sources.

Additional Work proposed for Shop Clerk

Enter daily clock hours (5, 6 & 7) x 76 54 mins.
= 270 mins/week

Total activity hours and record on weekly card

(i) 5 to add and record

(ii) (3 to add and record) x 2

(i) (5 x 15) = 75 secs.

(ii) (3 x 15) x 2 = 90 secs.

TOTAL 165 secs. = 3 mins/M/c operator
= 126 mins/M/c shop/week

Foundry

(5 x 15) x 1. 35 = 103 secs = 2 mins/foundry operator
= 84 mins/foundry/week

Enter details on individual operators performance card.

6 entries at 9 + P. I. calculation (20 secs) = 74 secs. /operator/week
= 94 mins/week all operators.

Enter details on departmental card

6 entries at 9 secs for 76 operators = 70 mins.

Calculate P. I. for 6 activities.

Plus 1 overall = 7 x 20 = 3 mins
= 73 mins/week

Total weekly increase = 270 + 126 + 184 + 94 + 73

= $12\frac{1}{2}$ hours/week

<u>Total load on Shop Clerk</u>

Existing	4 x 17	=	68 hours/month
Increase	4 x $12\frac{1}{2}$	=	50 hours/month
	Total load	=	118 hours/month

N. B. This excludes interference.

On a 40 hour week, this means the Shop Clerk is 75% utilised which is a very good figure and the Records Clerk is 50% utilised but this does not allow for customer liaison. Therefore again this is a reasonable figure.

The Production Controller, as an executive, is responsible to the Managing Director for the efficient running of the function and will attend policy meetings and also liaise with customers and other departmental heads. Irrespective of the system his job description will remain and therefore he is not considered relevant to the exercise.

Calculation of Work Load on Production Control Personnel - using a Computer Bureau

1. Computer Bureau used for payroll and performance analysis only

The work of the Record Clerk will remain unchanged and therefore he is not relevant to the exercise.

Shop Booking Clerk

Existing load will remain 17 hours/week

Plus weekly transmit via tape

details of operator activities = 125 total

Plus clock hour details = 76 total

Final Total =201

Allow 20 characters per transmission

= 4020 characters/week

at 3 seconds per character

= 12060 seconds/week

= 4 hours/week

Total load on Shop Clerk = 21 hours/week

N. B. This does not take into account interference.

For the payroll and performance analysis only, the services of one Wages Clerk could be saved but if the company adopted full budgetary control and variance analysis then the chances are this Clerk would be required, but this is not relevant to the present proposition.

2. Computer Bureau used for Payroll, Performance Analysis and Scheduling

All the above are required plus the addition of weekly despatches and returns by customer. Monthly details of the customers order schedules will require transmitting. The former can be quite easily coped with by the Shop Clerk (approx. 5 hours per week) but she will need assistance to transmit schedule details.

3. The following salary scales are estimates for the Birmingham area:

Male Production Control Clerk	£2,200/year
Female Wages Clerk	£1,500/year
Female Shop Clerk	£1,000/year

The estimates given by the computer bureau for the systems are as follows:

Payroll Plus Performance

Initial cost	£650 non-recurring
Yearly Processing	£770
Data preparation (if required)	£750

Cost of Display unit to enable company to transmit its own data £3,500 (N. B. Data Preparation not then required)

SCHEDULING SYSTEM

Initial cost	£2,000	non-recurring
Yearly Processing	£2,000	
Data preparation (if required) per year	£1,000	

Based on the above figures, the following costs apply to the systems proposed:

Full Manual System - all aspects	£4, 700

Payroll plus performance by bureau
Production Control Manual

Initial cost including Visual Display Unit for transmission	£4, 150
Data processing per year	£ 770
Personnel	£3, 200

Payroll, performance and Scheduling by Bureau

Initial cost including Visual Display Unit for transmission	£6, 150
Yearly processing costs	£2, 770
Personnel	£3, 200

APPENDIX F

CALCULATION OF CYCLE LENGTHS IN THE FORM OF A GEOMETRICAL PROGRESSION

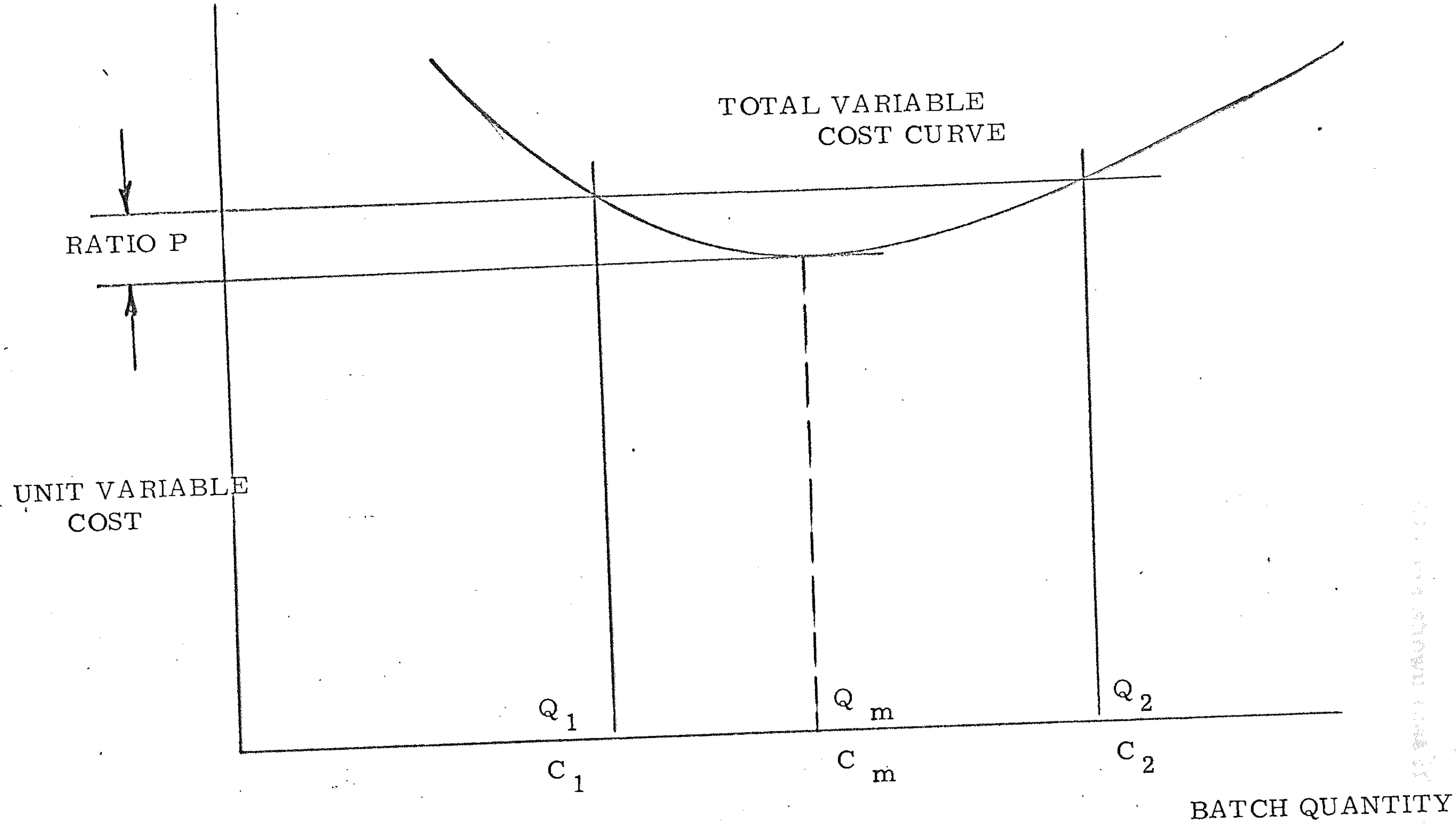

TOTAL VARIABLE
COST CURVE
RATIO P
UNIT VARIABLE
COST
Q 1
Q m
Q 2
C 1
C m
C 2
BATCH QUANTITY

FIG. F-1

Figure F. 1 shows the total cost curve as derived by application of the traditional E. O. Q. theory. Eilon (31) has shown that if

$$p = \frac{\text{batch variable costs}}{\text{Minimum variable costs}}$$

then $p = \frac{1}{2}\left(q + \frac{1}{q}\right)$

where $q = \frac{\text{Q batch size}}{\text{Q minimum batch size}}$

Referring to Fig.F-1 this gives the following values:

$$Q_1 = \text{q minimum} \times \text{Q minimum}$$

$$Q_2 = \text{q maximum} \times \text{Q minimum}$$

The number of cycles per year are given by

$$C_1 = \frac{Y}{Q_1} \qquad C_m = \frac{Y}{Q_m} \qquad C_2 = \frac{Y}{Q_2}$$

$$C_m = \frac{C_1 \quad Q_1}{Q_m} = \frac{C_2 \quad Q_2}{Q_m}$$

$$C_m^{\ 2} = C_1 \times q_{min.} \times C_2 \times q_{max.}$$

$$C_m = \sqrt{C_1 \cdot q_{min.} \times C_2 \quad q_{max.}}$$

$$q_{min.} \times q_{max.}$$

$$= \left(p - \sqrt{p^2 - 1} \right) \left(p + \sqrt{p^2 + 1} \right)$$

$$= 1 .$$

$$\therefore C_m = \sqrt{C_1 . C_2}$$

If cycles are selected in the form of a geometrical progression having a base R and such that

$$C_m = \left(R^i , R^{i+1} \right)^{\frac{1}{2}}$$

Griffiths (33) illustrates the relationship of the resulting cost curves (Fig. F-2) when this technique was applied.

DEMAND/COST CURVES - AFTER GRIFFITHS (33)

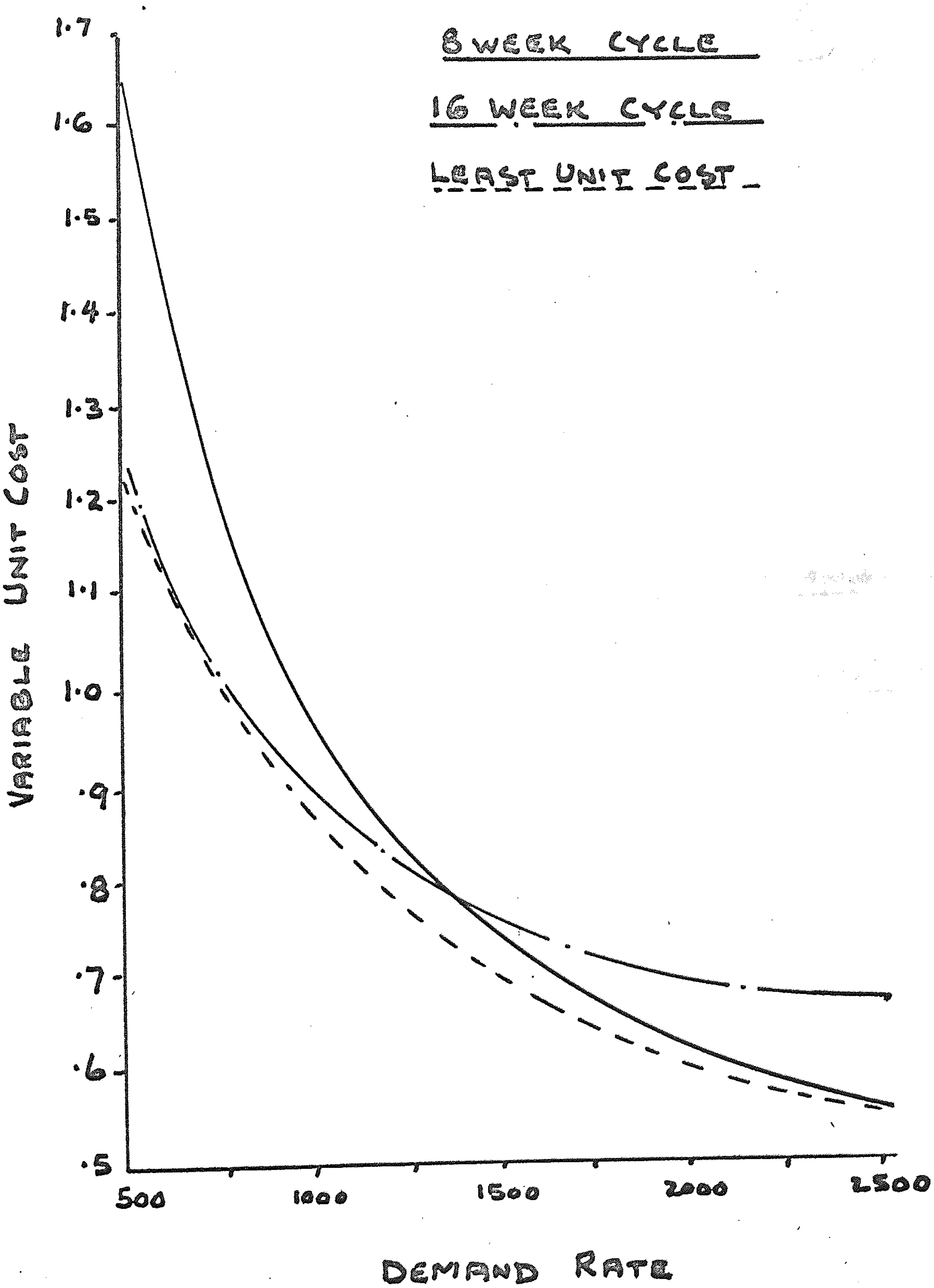
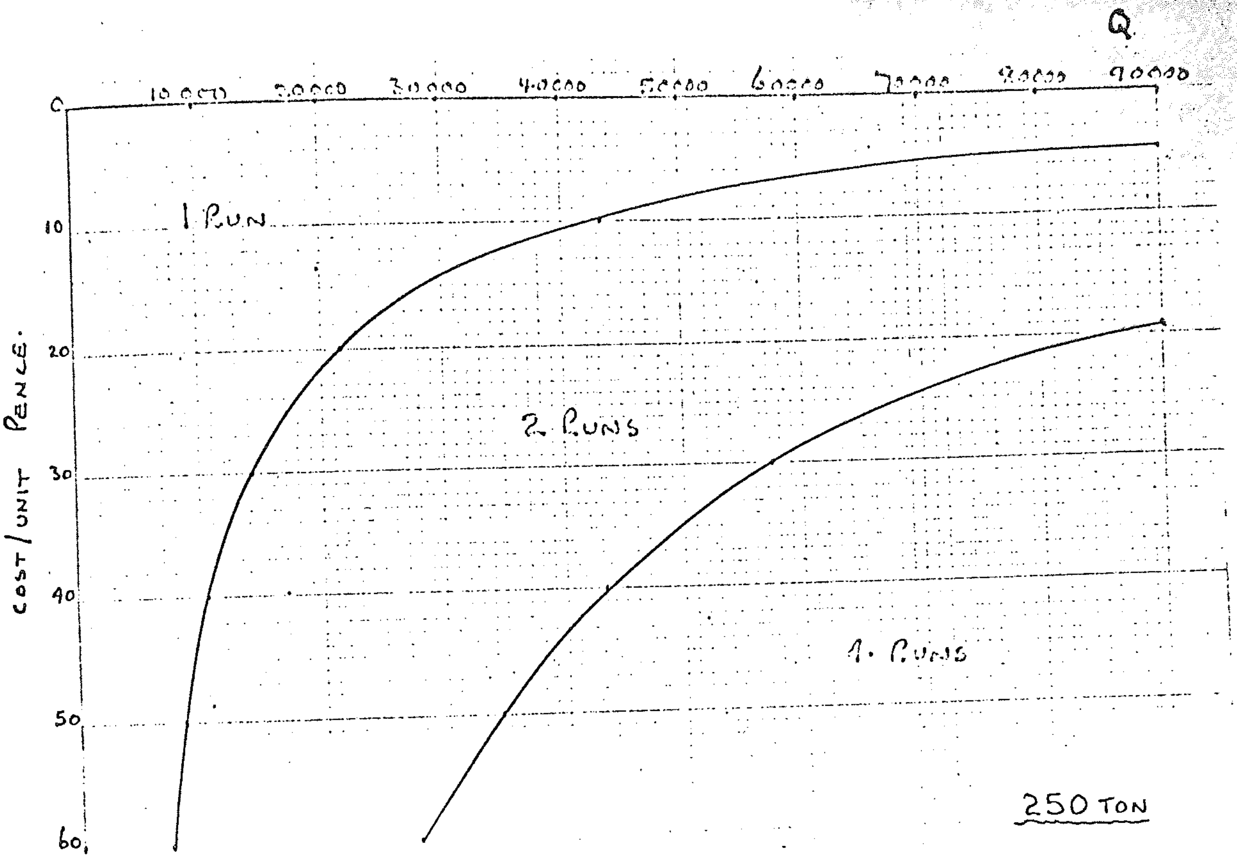
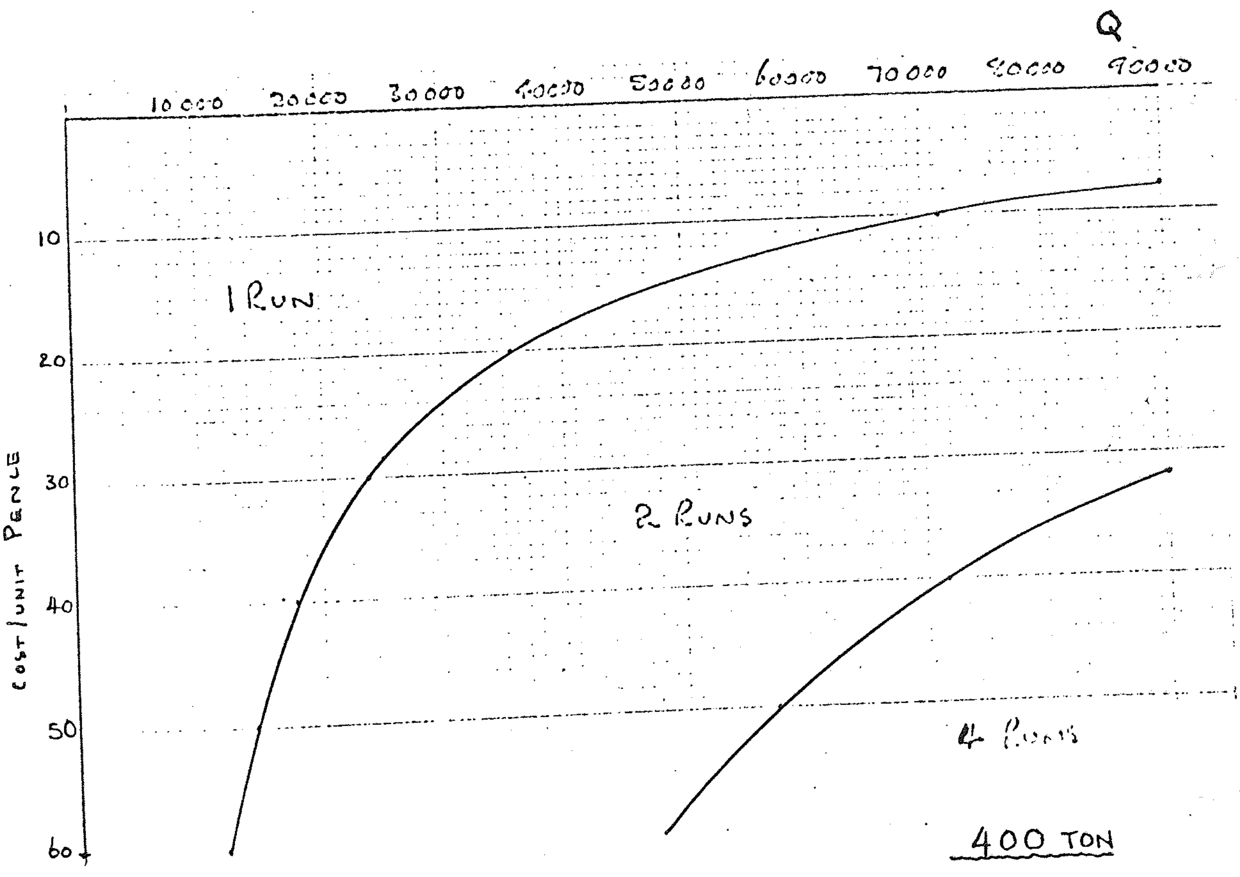
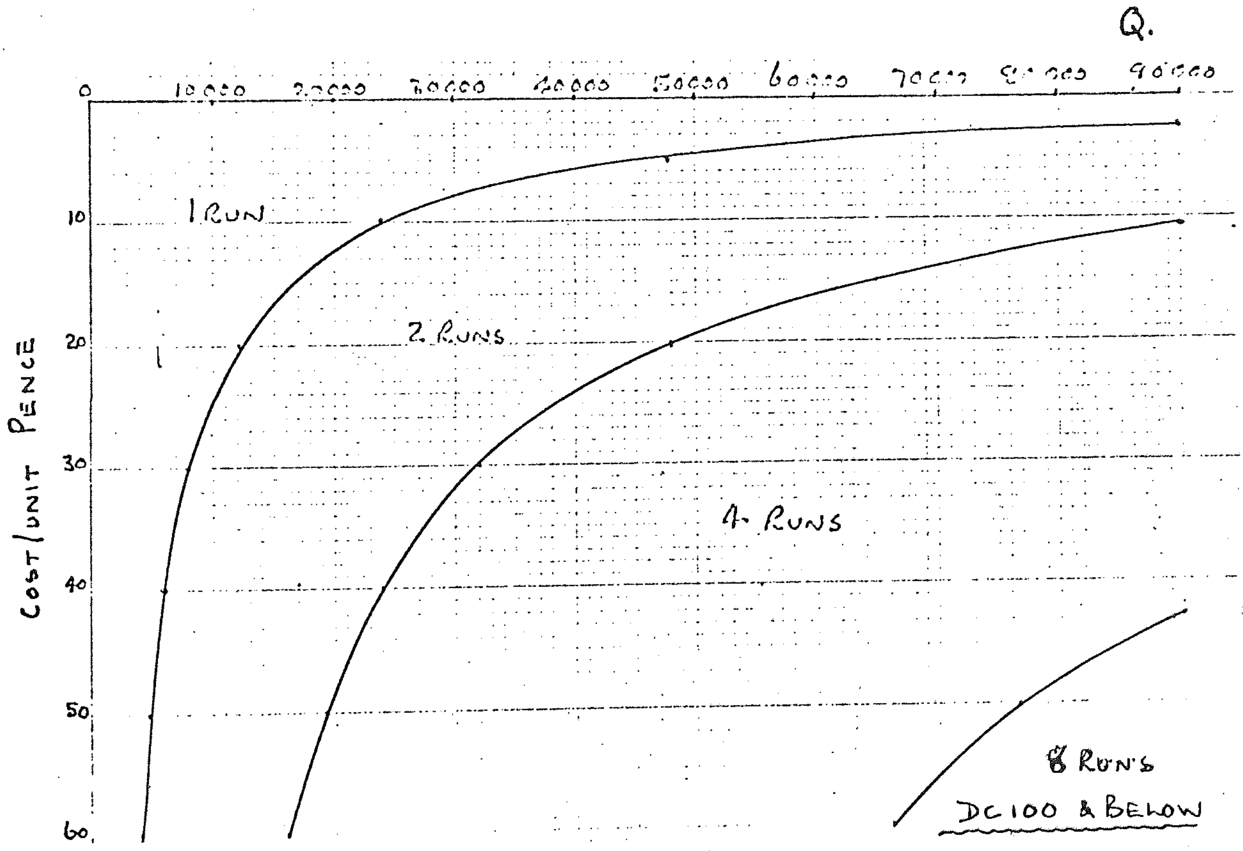


Fig. F-2





NUMBER OF RUNS FOR 8 WK. DEMAND



NUMBER OF RUNS FOR 8 WK. DEMAND

APPENDIX G

FACTORS TO CONSIDER AT PLANNING STAGE

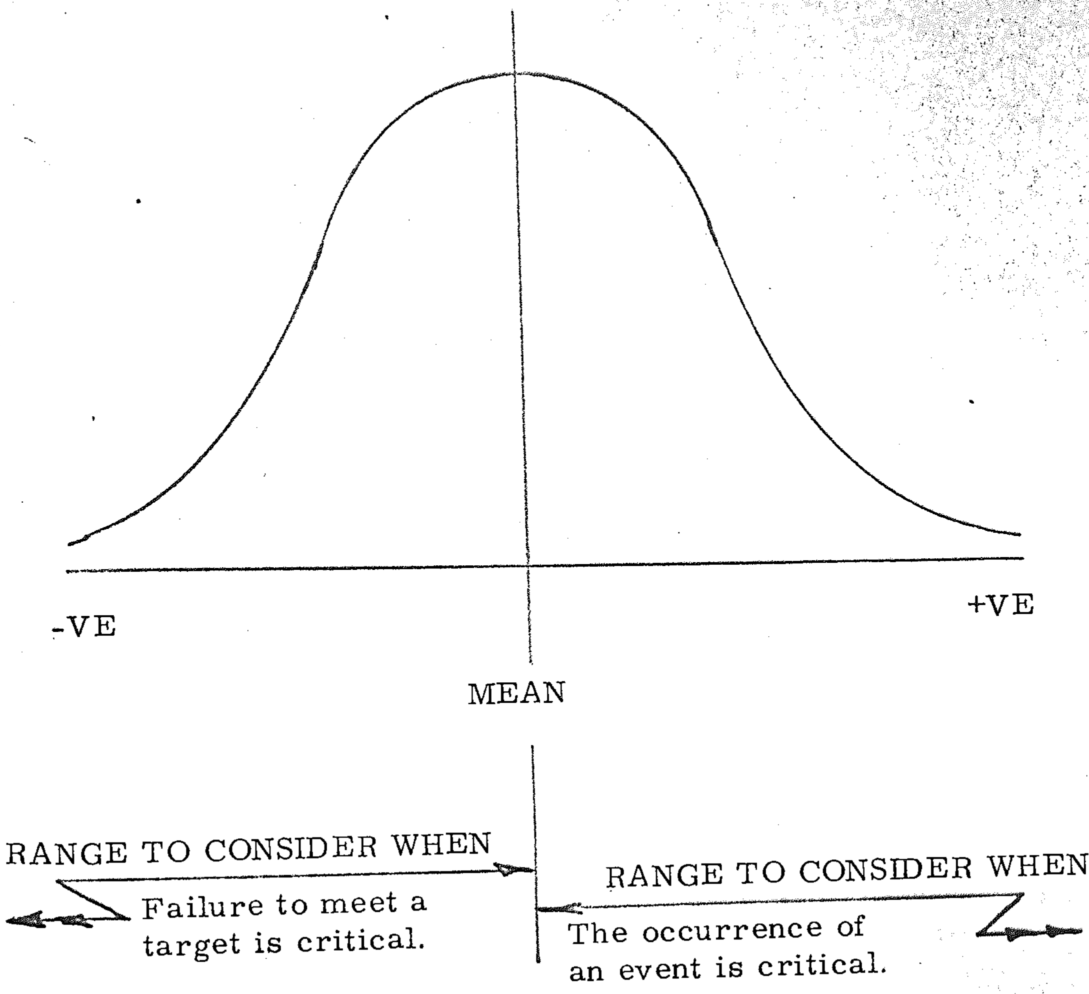
BASIC WORKING WEEK

is increased due to

OPERATOR PERFORMANCE
OVERTIME WORKED

is decreased due to

POOR OPERATOR ATTITUDE
MACHINE BREAKDOWN SCRAP
AND RECTIFICATION
ACCIDENTS
BAD MANAGEMENT



NORMAL DISTRIBUTION

APPENDIX H

BUDGET AND COMPONENT ANALYSIS

H. 1	Budget Quantities
H. 2	Budget Summary.
H. 3	Component Analysis.

BUDGET QUANTITIES

Item Ref. No.	Operation Sheet No.	Monthly Quantity	Unit Cost 'p'	Std. Scrap %	Shot Rate/Hr.	Compts per shot	Auto Ind.
1.	------------- 800 Ton machine product ----------						
2.	F.38	140000	2.86	2.5	70	10	✓
3.	F.17	29400	10.16	10	80	4	✓
4.	F.34	6750	23.79	10	60	2	✓
5.	F.27	15500	5.52	10	90	4	✓
6.	F.2	2400	18.79	6	70	2	✓
7.	63	1600	18.434	10	75	2	✓
8.	1	6300	46.846	8	75	1	✓
9.	2	1100	45.636	8	75	1	✓
10.	96	3600	45.0	10	60	1	-
11.	80	3000	57.2	10	55	1	-
12.	83	2900	32.0	10	60	2	-
13.	83	1000	34.4	10	55	2	-
14.	82	3600	19.4	10	70	1	-
15.	95	4500	53.2	10	60	1	-
16.	95	4500	46.0	10	60	1	-
17.	78	1800	39.64	10	60	1	-
18.	65	5500	19.668	15	85	1	✓
19.	89	28400	6.62	5	70	2	-
20.	F.51a	30500	24.37	8.5	58	2	✓
21.	F.54	13500	22.29	7	58	2	✓
22.	F.36	8500	21.34	8	55	3	✓
23.	F.3	7000	15.8	20	55	4	✓
24.	F.31	5000	29.82	5	60	2	✓
25.	14	19100	30.172	8	56	2	✓
26.	15	10000	19.68	8	56	2	✓
27.	37	4000	82.94	7	50	1	-
28.	40	3700	39.844	7	50	2	✓
29.	64	3600	28.979	10	45	3	✓
30.	29	37800	28.201	15	58	2	✓
31.	86	2000	76.4	10	40	1	-
32.	87	2000	76.4	10	40	1	-
33.	85	42700	11.64	6	80	3	-
34.	85a.	28400	19.0	5	70	2	-
35.	83	3400	43.8	10	70	2	-
36.	13	5900	5.782	20	70	2	✓
37.	62	7100	59.002	25	50	1	✓
38.	F.37	800	8.6	10	80	4	✓
39.	F.11	2700	30.56	10	70	1	✓
40.	91	2300	19.73	5	100	1	-
41.	F.9	9500	1.562	12	150	1	✓
42.	F.40	1500	6.33	30	100	2	✓
43.	F.22	2600	8.7	10	100	1	✓
44.	F.41	12900	9.45	5	120	2	✓

BUDGET QUANTITIES

Item Ref.	Operation Sheet	Monthly Quantity	Unit Cost 'p'	Std. Scrap %	Shot Rate/Hr	Compts per shot	Auto Ind.
45.	F.4	600	4.91	10	130	1	✓
46.	F.28	900	4.61	10	80	2	✓
47.	53	4400	8.326	10	100	2	✓
48.	35	9000	2.457	10	85	6	✓
49.	88	3000	21.06	5	90	1	–
50.	34	3900	6.993	15	75	2	✓
51.	41	2800	4.13	5	60	2	✓
52.	98	8900	5.145	10	60	4	–
53.	F.7	5000	12.97	25	70	1	✓
54.	F.35	4000	4.60	10	100	2	✓

PRESS GROUP	MACHINE GROUP				
	1	2	3	4	4a
<u>250 Ton</u>					
Present Budget Unit	15,550		140,000	43,250	34,700
Planned Increase 8/67	1,850		16,500	5,250	4,100
<u>Final Total (inc.Auto Industry Addition)</u>	24,867		210,225	69,846	45,712
<u>D.C. 100</u>					
Present Budget Units	12,800		9,500		19,800
Planned Increase 19/56	4,300		3,200		6,700
<u>Final Total (inc. Auto Industry Addition)</u>	21,600		17,564		28,804
<u>Reeds</u>					
Present Budget Units		800		2,700	18,700
Planned Increase 27/34		640		2,170	15,000
<u>Final Total (inc. Auto Industry Addition)</u>		1,892		6,179	42,694
<u>Edgwicks</u>					
Present Budget Units	9,000				
Planned Increase 41/9	41,000				
<u>Final Total (inc. Auto Industry Addition)</u>	64,377				
<u>400 Tons</u>					
<u>Final Total (inc. Auto Industry Addition)</u>		12,393		160,331	65,484
TOTAL UNITS ON MACHINE GROUP	110,844	14,285	227,789	236,356	182,694

<u>UNITS PRODUCED ON ALL MACHINE GROUPS</u>

BUDGET SUMMARY

MACHINE GROUP	NUMBER OF MACHINES	HOURS AVAILABLE	HOURS REQUIRED	UTILISATION %
400 ton	7	2240	1907	85
250 ton	7	2240	1494	67
Reeds	3	960	327	34
DC 100	2	640	357	56
EDGWICK	4	1280	114	9
Total	25	8320	5020	60

PLANNED INCREASES

250 Ton - Utilisation To Increase to 75%

Reeds - Utilisation Increase on 2 machines only to 75%

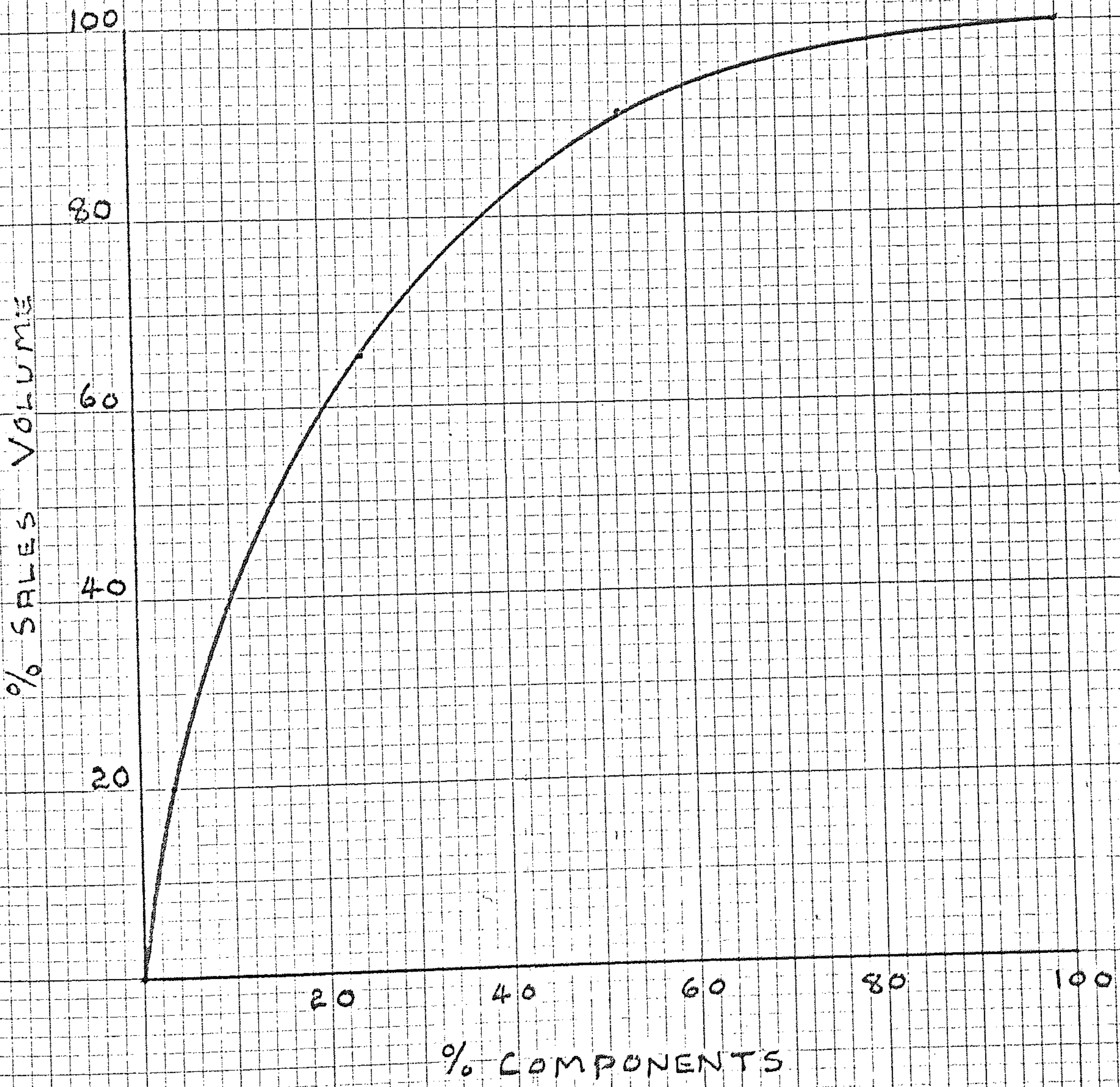
DC100 - Utilisation to Increase to 75%

EDGWICK - Utilisation to Increase to 50%

Sales Value Range	Component Reference Number.	Total Sales Value of range and %	% of Total Compts.
Up to 999	5, 6, 7, 9, 12, 13, 14, 17, 36 38, 39, 40, 41 42, 43, 45, 46 47, 48, 49, 50 51, 52, 53, 54	8390 = 9.3%	47.1
1000 - 1999	4, 10, 11, 18, 19 22, 23, 24, 26 28, 29, 31, 32 35, 44	22562 = 24.9%	28.4
2000 - 2999 3000 - 3999 4000 - 4999 5000 - 5999 6000 - 6999	3, 8, 15, 16 21, 27 2, 33, 37 25, 34 -	41051 = 45.8%	20.7
7000 - 7999 8000 - 8999 9000 - 9990 10000 - 10999	20 - - 30	18092 = 20%	3.8

CONTRIBUTION OF INDIVIDUAL COMPONENTS

TO TOTAL SALES REVENUE.



CONTRIBUTION OF COMPONENTS TO SALES VOLUME.

MACHINE GROUP	Up to 999	1000 - 1999	2000 - 2999	3000 - 3999	4000 - 4999	5000 - 5999	6000 - 6999	7000 - 7999	8000 - 8999	9000 - 9999	10000 - 10999
400 TON		XXX XXX XX		XX	X	XX		X			X
250 TON	XXX XXX XX	XXX XX	XX XX		X						
REEDS	XXX X	X			X						
DC 100	XXX XXX XXX XX	X									
EDGWICK	XX										

CONTRIBUTIONS FROM PRESS GROUPS

APPENDIX J

SIMULATION RESULTS

J. 1. Foundry Machine Loads.

J. 2 Machine Group Loads.

J. 3. Value of Stock.

J. 4 Stock Graphs for 400 & 250 ton items with variable monthly demand.

SIMULATED LOAD ON 400 TON PRESS GROUP

Item Number	January February	March April	May June	July August	September October	November December	Machine State
20	244 (4)	256 (4)	137	262 (2)	232 (2)	318 (4)	
21	231	177 (2)	-	169 (2)	182 (2)	99	
22	99	128	41	165	70	77	
23	69	99	68	128	-	62	
24	184	31	69	99	75	140	
25	173 (2)	139	295 (2)	154	230 (2)	124	Raised
26	219	114	193	321	229	128	
27	92 (2)	92 (2)	92 (2)	92 (2)	92 (2)	92 (2)	Hydraulics
28	113	45	118	116	104	82	
29	95	135	24	47	89	24	Hydraulics
30	103 (4)	244 (2)	285 (4)	318 (2)	382 (2)	97 (4)	Raise and Hydraulics
31	118	118	118	118	118	118	
32	118	118	118	118	118	118	
33	203 (2)	203 (2)	203 (2)	203 (2)	203 (2)	203 (2)	Raised
34	234 (2)	234 (2)	234 (2)	234 (2)	234 (2)	234 (2)	Raised
Total Hrs.	3676	3851	3647	3822	3913	3690	

$$\% \text{ Machine Utilisation} = \frac{\text{Total Hrs}}{\text{Hrs. per year}} \times 100$$

$$= \frac{22599}{12 \times 2240} \times 100$$

$$= 84\%$$

N.B. Figures in bracket indicate number of runs, duration of each run being preceding figure.

Period	Machine State	Item No.	Runs per Component	Total Hours	Machine
January-February	Raised+)	30,29	1	612	1
	Hydraulics)	33,27	1	590	2
	Raised	34	1	468	3
	Raised & Basic	25,28,22	2,1,1	558	4
	Basic	20	1	976	5 *
	Basic	21,24,23	1	484	6
	Basic	26,31,32	1	455	7
			16 set ups		
March-April	Raised+)	30	1	488	1
	Hydraulics)	25,27,29	1,2,1	458	2
	Raised	34	1	468	3
	Raised	33	1	406	4
	Basic	20	1	1012	5 *
	Basic	21,23,28, 24	1	529	6
	Basic	31,32,22, 26	1	478	7
			16 set ups		
May-June	Raised +)	30	1	1140	1 *
	Hydraulics)	33,27	1	590	2
	)	34,29	1	492	3
	Raised	25	1	590	4
	Basic	26,24,23	1	333	5
	Basic	20,28,22	1	296	6
	Basic	31,32	1	236	7
			14 set ups		
July-August	Raised)	34,29	1	511	1
	Plus)	30	1	632	2
	Hydraulics)	33,27	1	590	3
	Raised	25,26	1	475	4
	Basic	22,23,31 32	1	529	5
	Basic	20	1	524	6
	Basic	28,24,21	1	553	7
			15 set ups		

Period	Machine State	Item No.	Runs per Component	Total Hours	Machine
September-October	Raised + Hydraulics	30	1	632	1
		34,29	1	557	2
		33,27	1	590	3
	Raised	25	1	460	4
	Basic	20,28	2-1	568	5
	Basic	21,32,24	2-1-1	557	6
	Basic	26,31,22	1	417	7
			16 set ups		
November-December	Raised + Hydraulics	30	1	388	1
		34,29	1	552	2
		33,27	1	590	3
	Raised & Basic	25,21,28	1	305	4
	Basic	24,32,22	1	335	5
	Basic	26,31,23	1	308	6
	Basic	20	1	1272	7 *
			15 set ups		

* Indicates an overload on the individual job.

ALLOCATION OF JOBS ON 400 TON PRESS GROUP TO SATISFY SETTING RESTRICTION.

SIMULATED LOAD ON 250 TON PRESS GROUP

Item Number	January February	March April	May June	July August	September October	November December	Machine Setting
2	567	294	228	303	353	543	Tie bars out
3	131	233	202	164	291	291	Tie bars and Hydraulics
4	124	80 (2)	69	79 (2)	137	91 (2)	
5	125	104	87	152	107	61	
6	47	55	73	20	32	37	
7	34	23	29	42	33	28	
8	139 (2)	99 (2)	139 (2)	137 (2)	7	130 (2)	Tie bars and Hydraulics
9	35	26	33	33	45	44	Tie bars out
10	142	142	142	142	142	142	
11	129	129	129	129	129	129	
12	57	57	57	57	57	57	
13	22	22	22	22	22	22	
14	122	122	122	122	122	122	Tie bars and Hydraulics
15	89 (2)	89 (2)	89 (2)	89 (2)	89 (2)	89 (2)	
16	89 (2)	89 (2)	89 (2)	89 (2)	89 (2)	89 (2)	
17	71	71	71	71	71	71	
18	134	130	190	98	190	100	
19	232 (2)	232 (2)	232 (2)	232 (2)	232 (2)	232 (2)	
Total Hrs.	2838	2582	2481	2607	2558	2909	

% Machine Utilisation

$$= \frac{\text{Total hours}}{\text{Hrs. per year}} \times 100$$

$$= \frac{15975}{12 \times 2240} \times 100$$

$$= 60\%$$

N.B. Figures in bracket indicate number of runs, duration of each run being preceding figure.

Item Number	January February	March April	May June	July August	September October	November December
41	224	86	171	57	143	235
42	15	17	20	14	26	15
43	50	61	72	47	79	32
44	85 (2)	59 (2)	68 (2)	28	93	57 (2)
45	8	7	17	17	2	10
46	11	13	12	9	17	20
47	60	56	30	49	76	58
48	23	74	64	31	16	54
49	75	75	75	75	75	75
50	32	77	112	30	93	50
51	44	53	54	71	28	53
52	88	88	88	88	88	80
Total Hrs.	798	725	851	516	736	804

% Machine Utilisation

$$= \frac{\text{Total Hours}}{\text{Hrs. per year}} \times 100$$

$$= \frac{4430}{12 \times 640} \times 100$$

$$= \underline{58\%}$$

N.B. Figures in bracket indicates number of runs, duration of each run being preceding figure.

Items 45 and 46 should be considered for running once in every 2 cycles.

SIMULATED LOAD ON DC 100 PRESS GROUP

Item Number	January February	March April	May June	July August	September October	November December
35	58	58	58	58	58	58
36	79	126	65	94	95	153
37	161 (2)	228(2)	106(2)	212(2)	208(2)	226(2)
38	8	4	6	6	9	4
39	37	31	20	27	21	31
40	52	52	52	52	52	52
Total Hrs.	556	727	413	661	651	750

% Machine Utilisation

$$= \frac{3758}{12 \times 960} \times 100$$

$$= \underline{33\%}$$

N.B. Item 37 requires 2 runs per period.
Item 38 should be considered for running once in every 3 cycles.

SIMULATED LOAD ON REED MACHINES

53	164	186	153(2)	183	237	184
54	34	23	62	22	60	52
Total Hrs.	198	209	368	205	297	236

% Machine Utilisation

$$= \frac{1513}{12 \times 1280} \times 100$$

$$= \underline{10\%}$$

SIMULATED LOAD ON EDGWICK PRESS GROUP

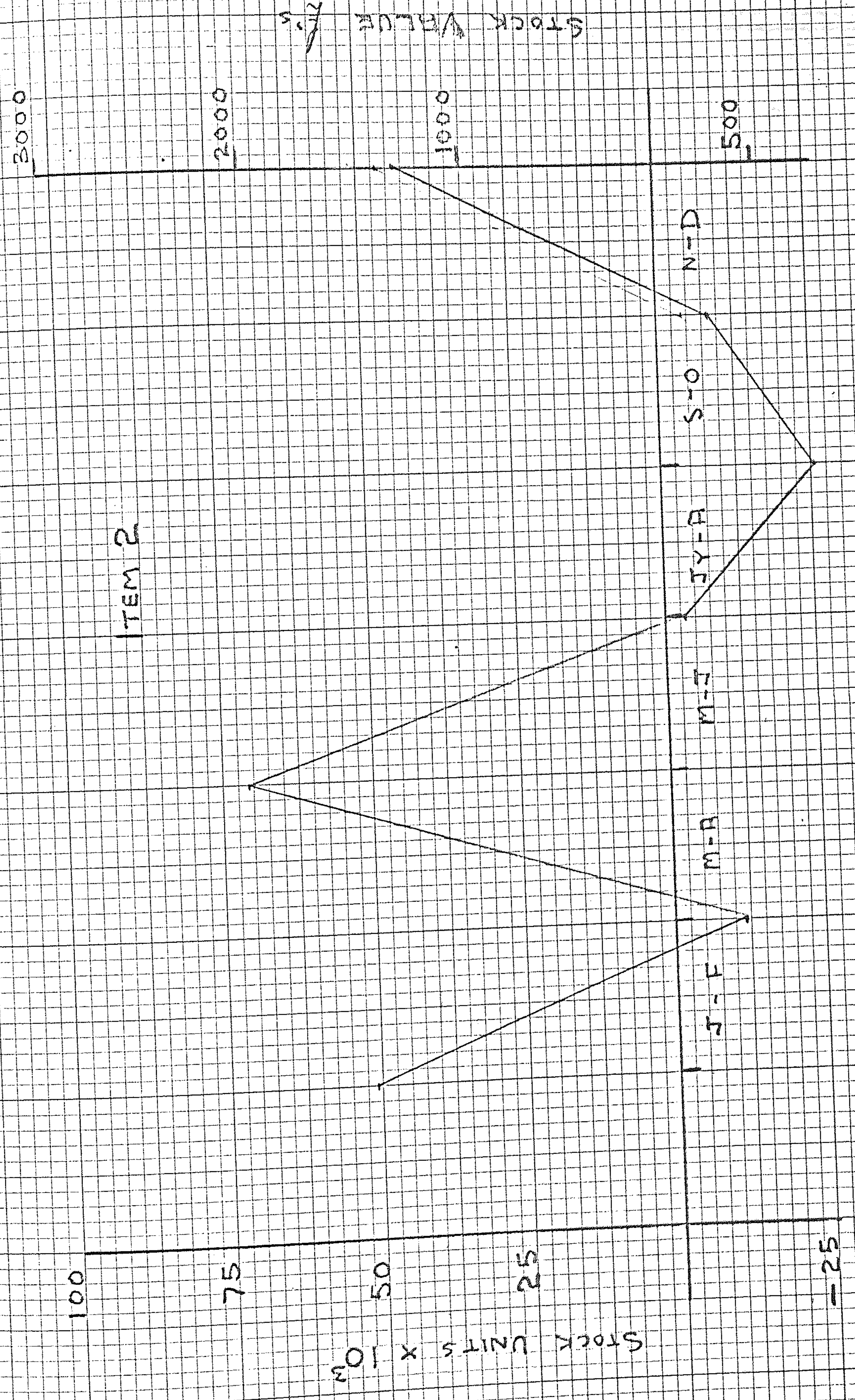
Group No.	Item Ref. No.	Jan.-Feb.	Mar.-Apr.	May-June	July-Aug.	Sept.-Oct.	Nov.-Dec.
1	42 47 45 53 5	2 17 1 14 52	3 15 1 16 43	3 8 2 26 36	2 14 2 16 63	4 21 1 20 45	2 16 1 16 25
Total Group	1	86	78	75	97	97	60
2	43 46 22 51 54 38	5 2 52 9 8 3	6 3 67 10 5 1	7 2 22 11 14 2	5 2 87 14 5 2	8 3 37 6 13 3	3 4 41 10 12 1
Total Group	2	77	92	58	115	70	71
Group 3	41	34	13	26	9	22	36
Group 4	2	492	255	198	286	306	472
Group 5	4	102	130	56	128	112	150
Group 6	20	99	97	14	50	48	125
Group 7	21 29	51 30	75 42	0 8	74 15	77 28	21 7
Total Group	7	81	117	8	89	105	28
Group 8	30	28	131	306	171	205	26
Group 9	26 36 25	34 10 63	18 16 25	30 8 107	50 12 28	36 12 101	20 20 22
Total Group	9	107	59	145	90	149	62
Group 10	27 3	11 29	11 52	11 45	11 37	11 65	11 65
Total Group	10	40	63	56	48	76	76
Group 11	18	42	41	60	31	60	31
Group 12	24 29	388 30	66 42	146 8	209 15	158 28	294 7
Total Group	12	418	108	154	224	186	301

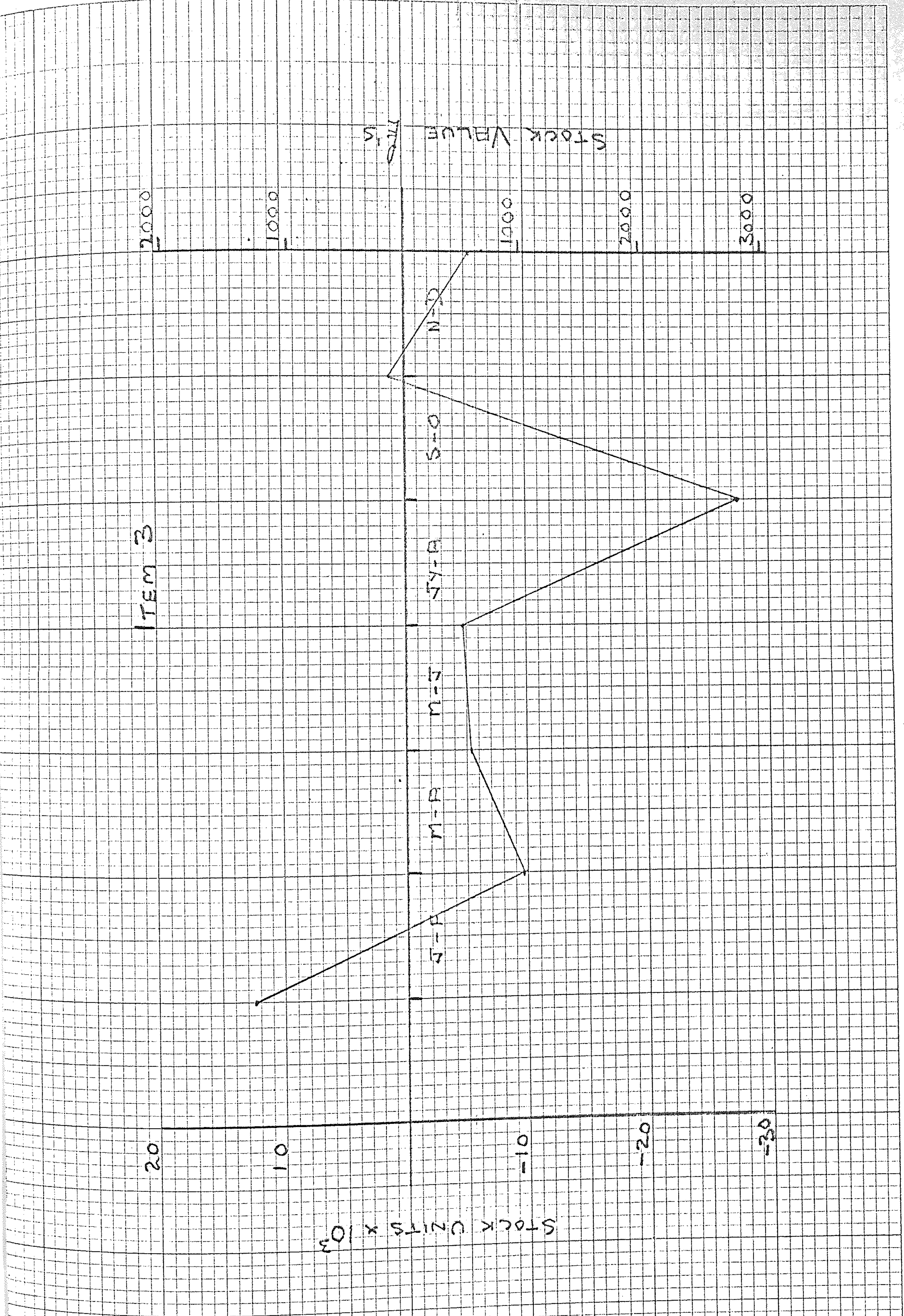
SIMULATED WORK LOADS IN STANDARD HOURS ON MAIN MACHINE GROUPS

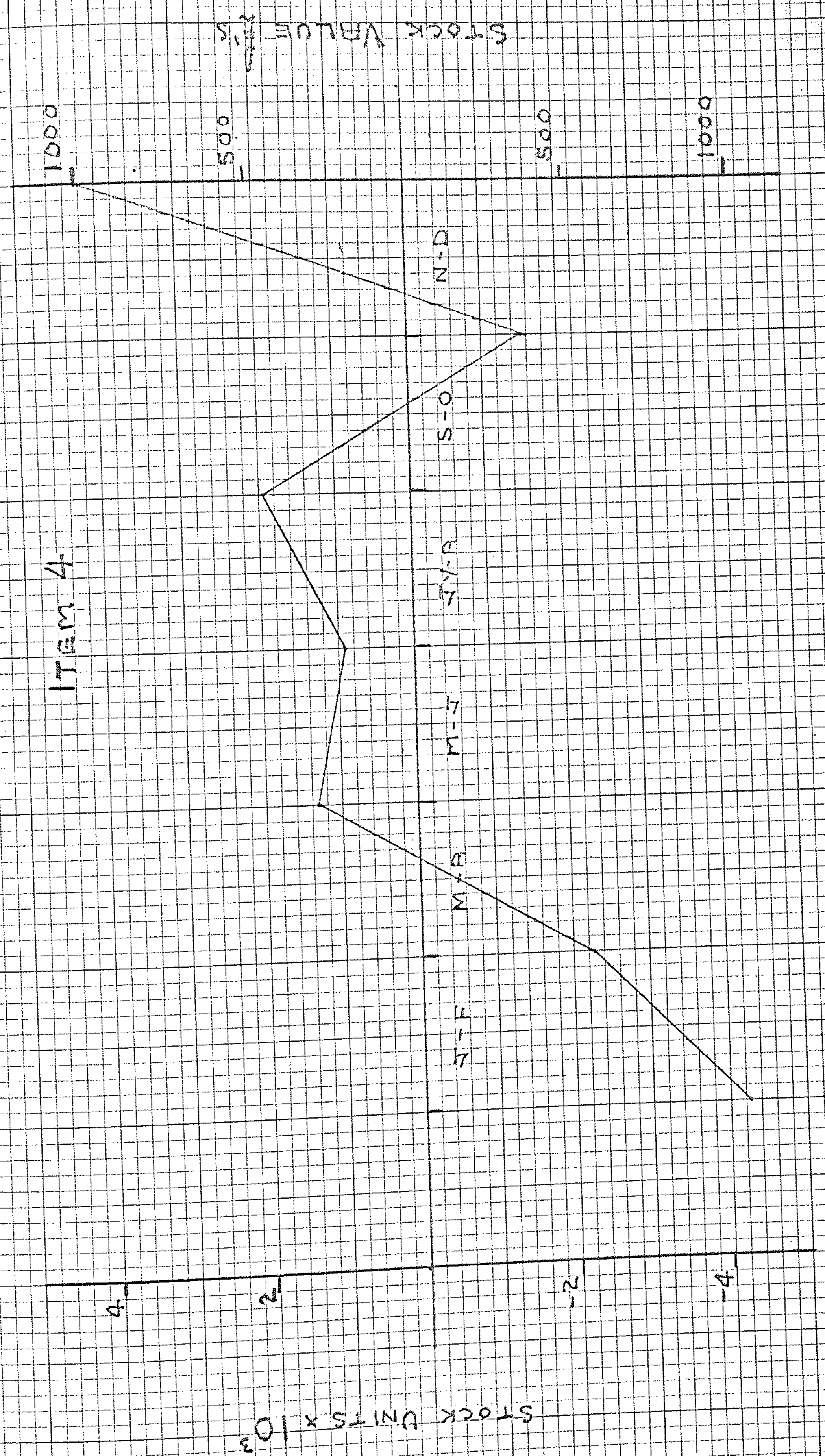
Component No.	14 month Quantity Ordered	Cumulative Quantity Made	End of 14 month period Value Stock (+) Arrears (-) (pence) (Variable Q)	Value of Stock (+) Arrears (-) (pence) (Constant Q)
2	1858430	1902381	+125708	-
3	412796	407434	- 54427	-
4	90856	95067	+100251	-
5	210596	208813	- 9814	-
6	36437	37594	+ 21777	-
7	27775	28652	+ 17143	-
8	90912	93032	+ 99500	-
9	16101	16290	+ 8762	-
10	50400	49316	-	-35280
11	42000	41500	-	-28600
12	40600	39939	-	-21152
13	14000	13549	-	-15514
14	50400	49200	-	-23280
15	63000	62230	-	-40964
16	63000	63216	-	+ 9936
17	25200	25081	-	- 4717
18	73330	72923	- 7945	-
19	397600	400436	-	+18774
20	446723	462079	+374298	-
21	168413	157999	-143235	-
22	98812	107313	+ 1771	-
23	85814	87036	+ 19323	-
24	65148	67333	+ 65275	-
25	247606	245533	- 62486	-
26	128448	130968	+ 49652	-
27	56000	55054	- 3234	-
28	52926	53850	+ 36975	-
29	54564	54328	- 6723	-
30	561937	549488	-350933	-
31	28000	27368	-	-48285
32	28000	27874	-	- 9626
33	607800	589140	-	-217389
34	397600	395036	-	-49856
35	47600	47018	-	-25492
36	72053	76532	+ 25920	-
37	99362	97913	- 85224	-
38	11856	11744	- 928	-
39	37767	38138	+ 11337	-
40	32200	32134	-	- 1302
41	132622	131700	- 1430	-
42	19633	18880	- 4741	-
43	33806	33546	- 2227	-
44	155524	159165	+ 34435	-
45	8408	8147	- 1266	-
46	12170	12627	+ 2129	-
47	58881	60626	+ 14553	-
48	132821	133397	+ 14068	-
49	42000	41965	-	- 737
50	52273	54395	+ 14860	-
51	38954	40680	+ 2193	-
52	124600	123229	-	- 7054
53	77923	79103	+ 15356	-
54	50886	54022	+ 14439	-

VALUE OF STOCK AT END OF 14 MONTH PERIOD

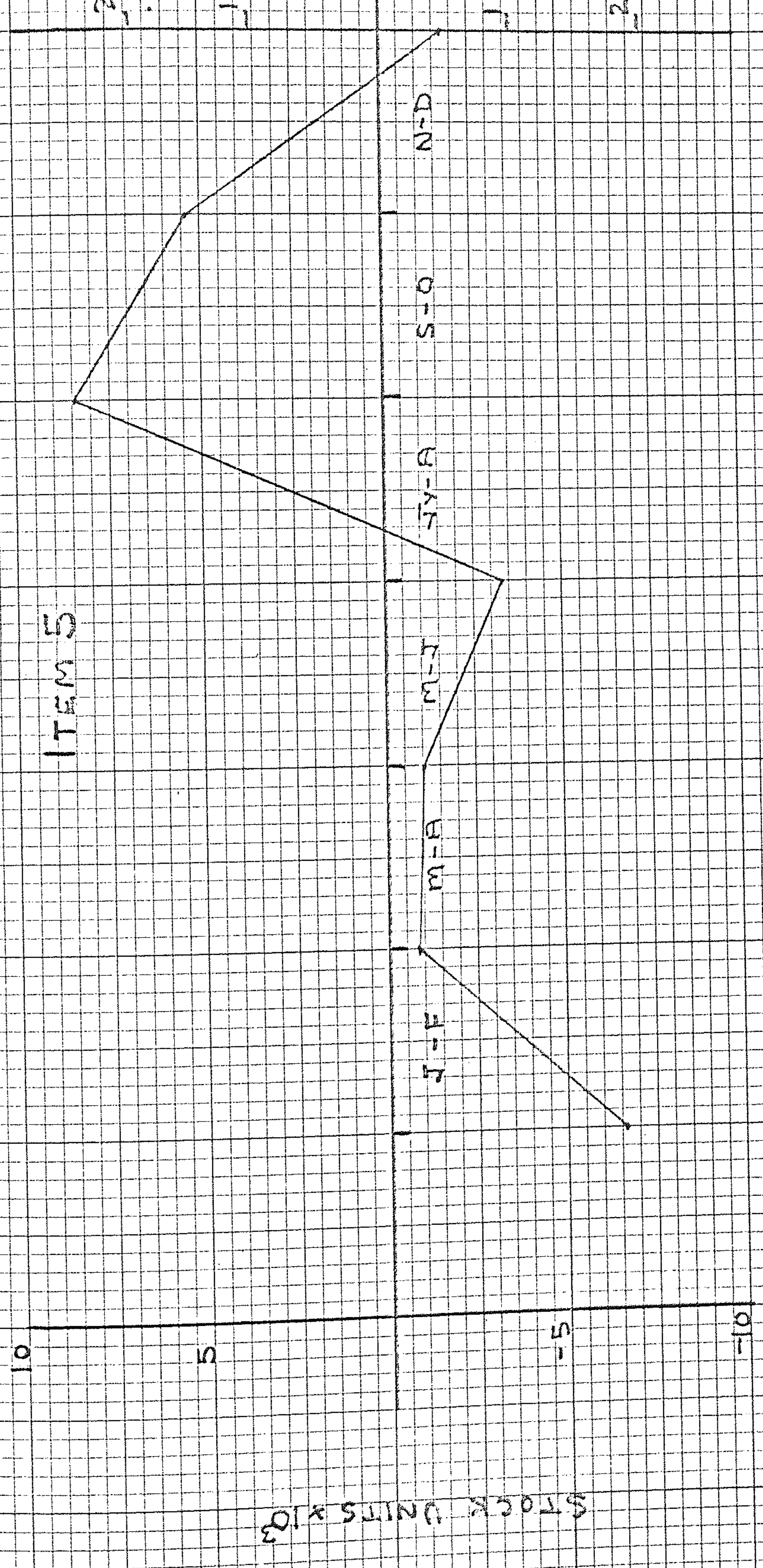
		Variable Monthly Q		Constant Monthly Q
TOTAL	+	1,069,725	+	28,710
	-	734,613	-	529,248
Algebraic Sum	+	335,112	-	490,538

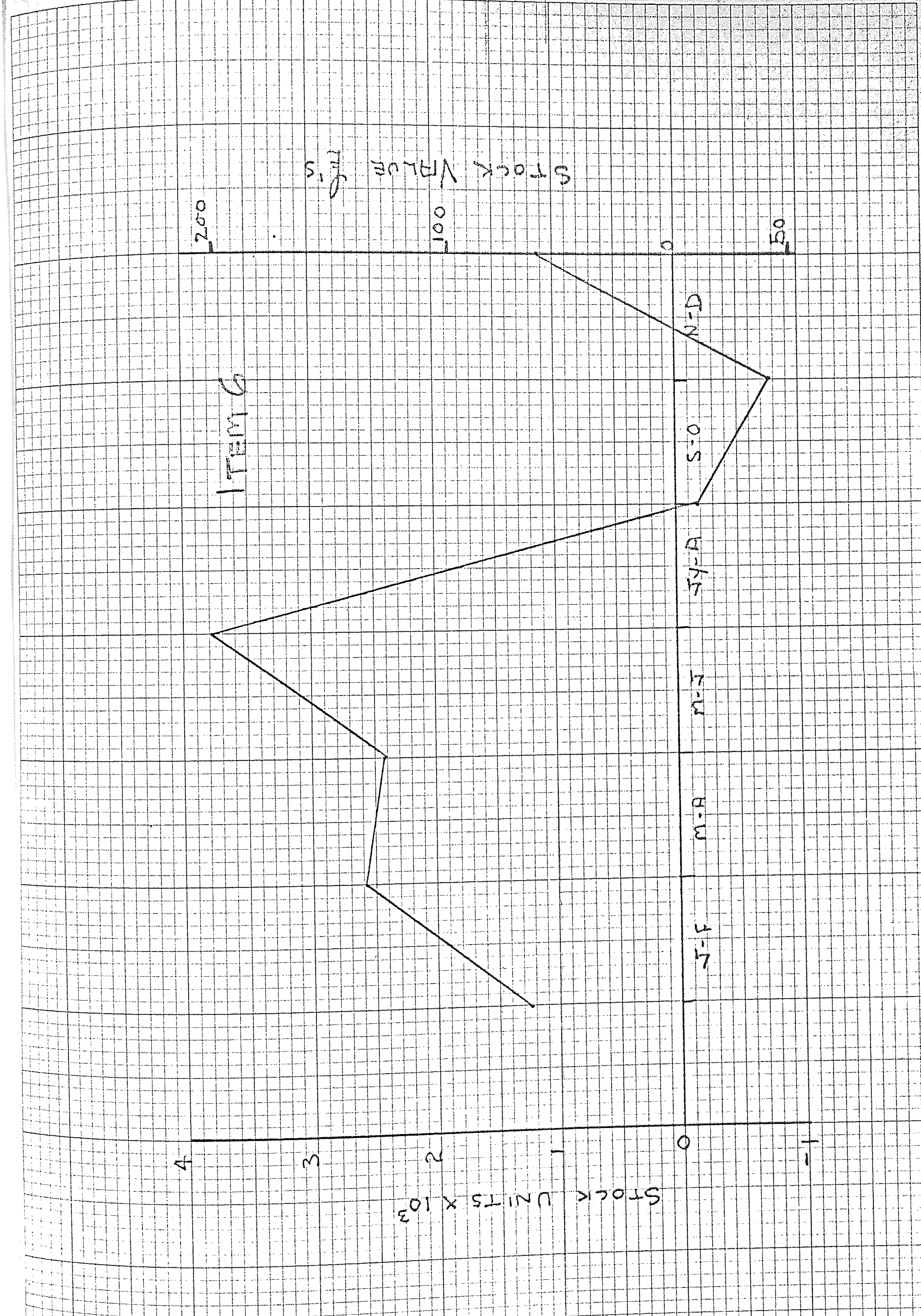

STOCK VALUE
3000
2000
1000
500
ITEM 2
N-D
S-O
JY-A
M-J
M-A
J-F
100
75
50
25
-25
STOCK UNITS x 10³

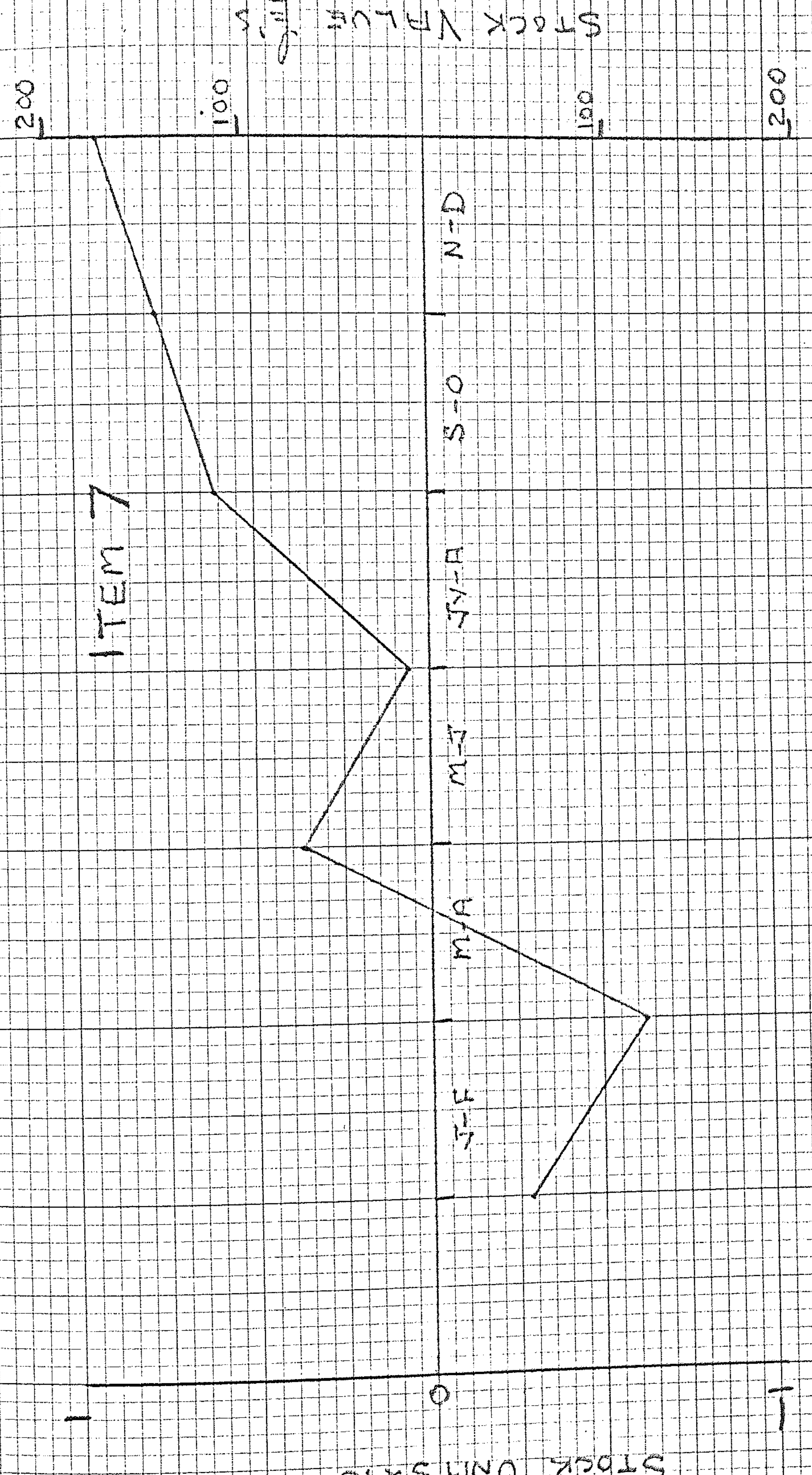

ITEM 3
STOCK VALUE £'s
3000
2000
1000
1000
2000
J-F
M-A
M-J
J-A
S-O
N-D
20
10
-10
-20
-30
STOCK UNITS x 10³

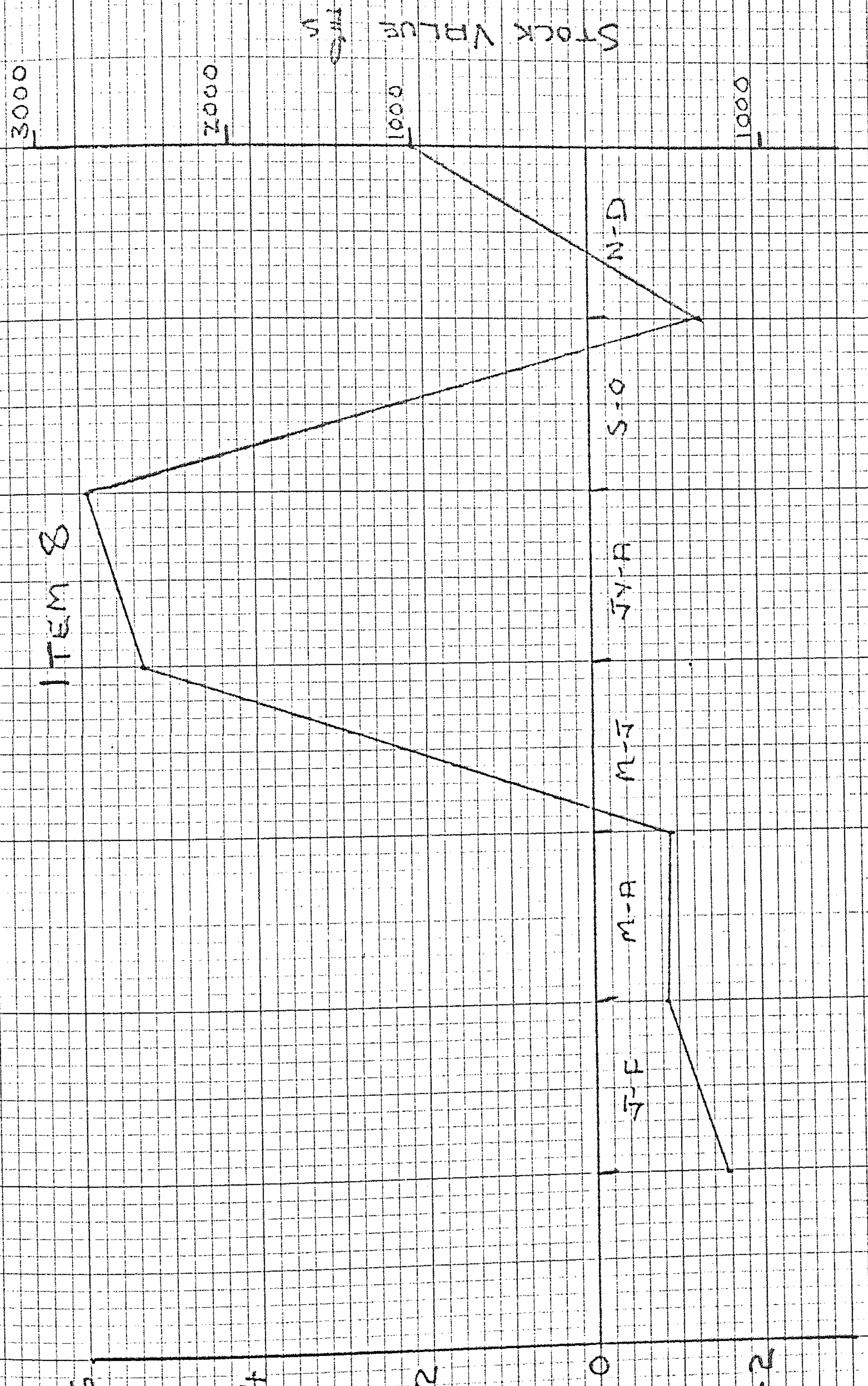


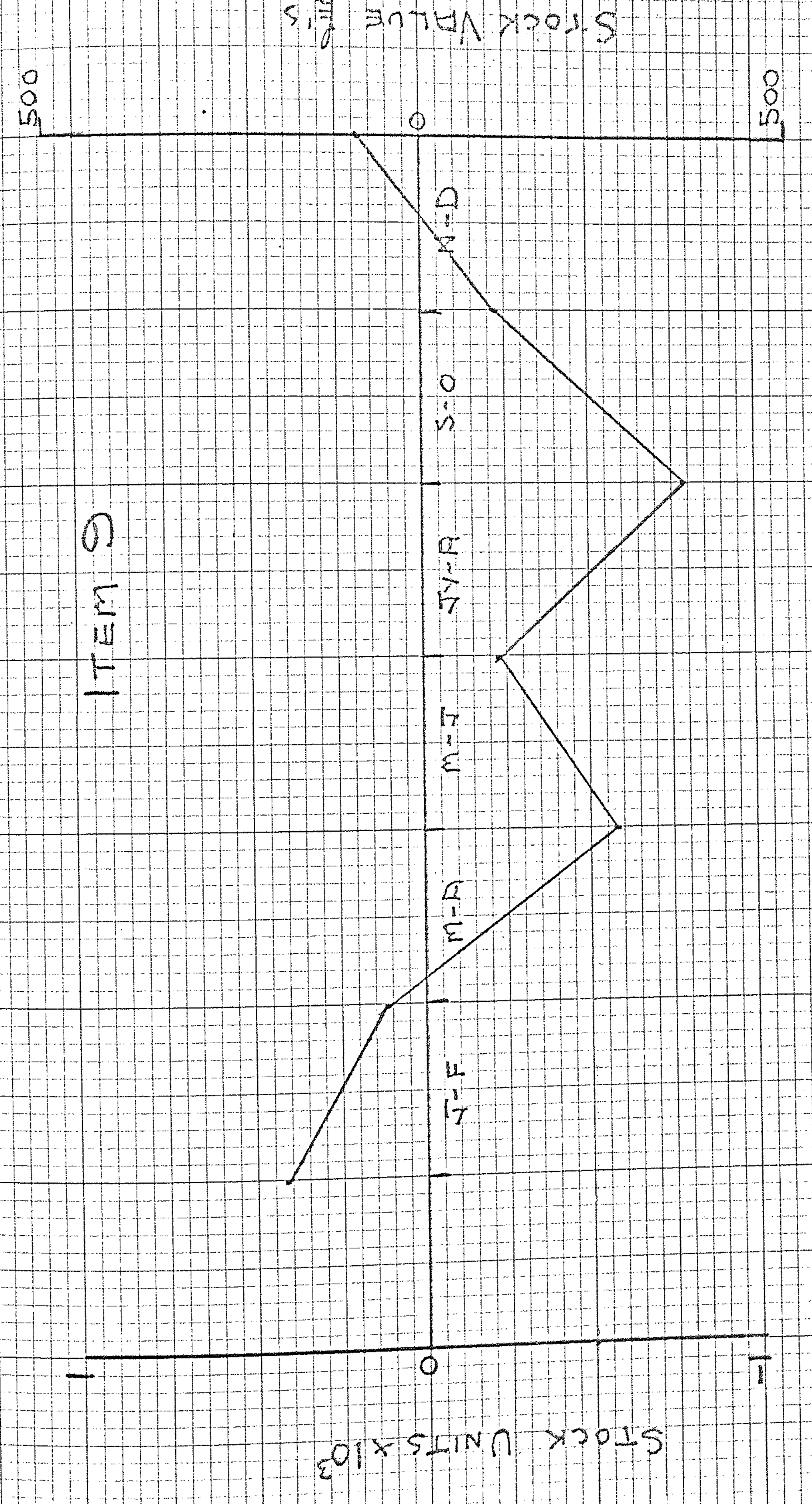
Item 4
STOCK VALUE £'s
1000
500
500
1000
N-D
S-O
J-A
M-J
M-A
J-F
4
2
-2
-4
STOCK UNITS x 10³

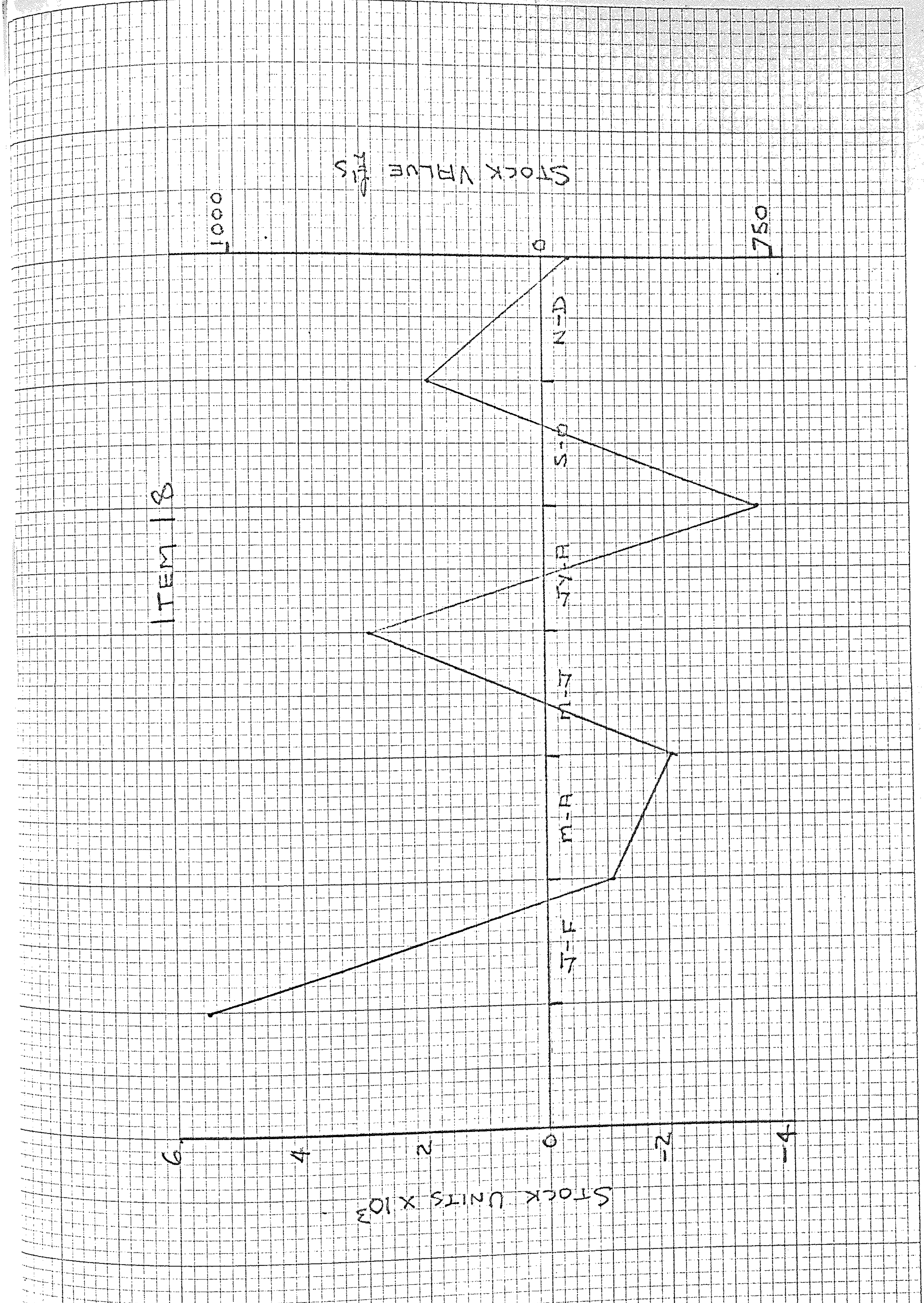

STOCK VALUE $
200
100
100
200
ITEM 5
N-D
S-O
Jy-A
M-J
M-A
J-F
10
5
-5
-10
STOCK UNITS x10³

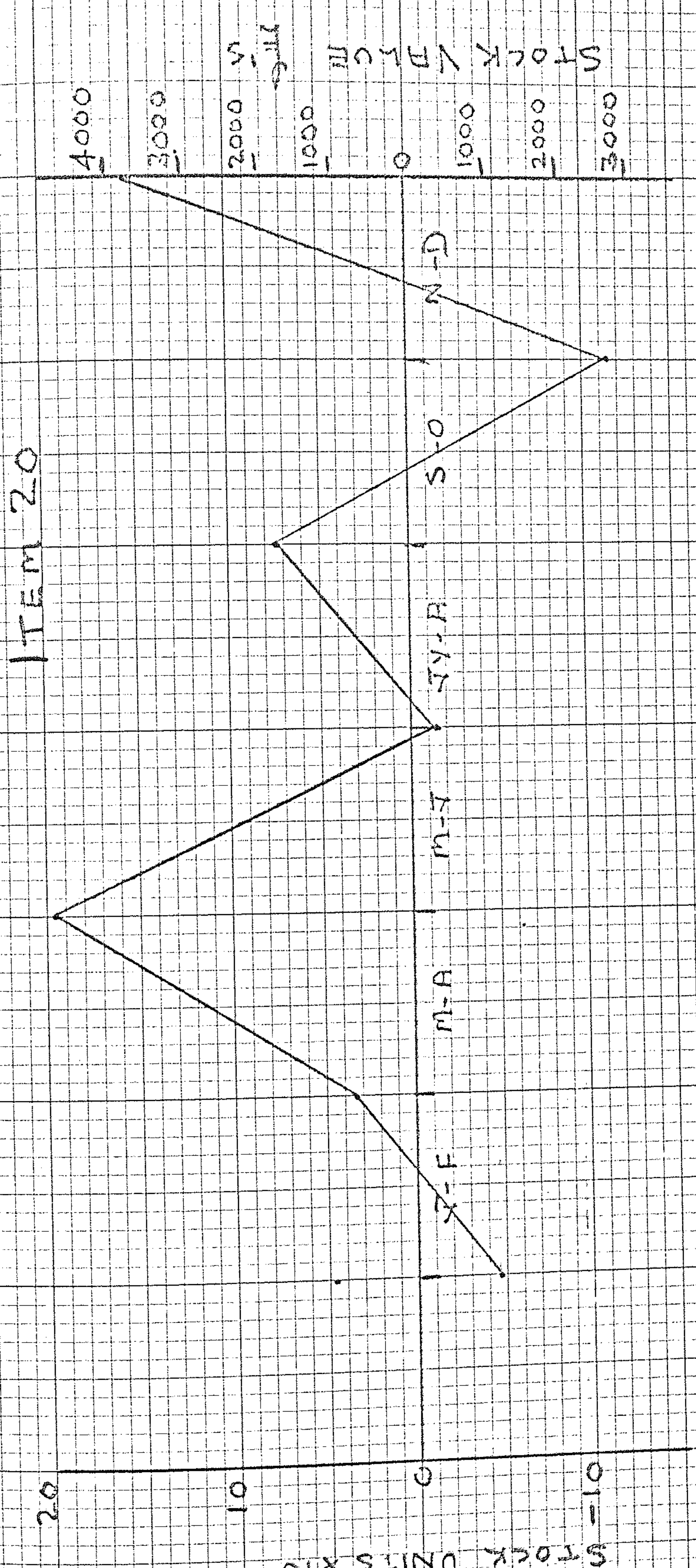

ITEM 6
STOCK VALUE £'s
200
100
0
50
N-D
S-O
JY-A
M-J
M-A
J-F
STOCK UNITS x 10³
4
3
2
1
0
-1

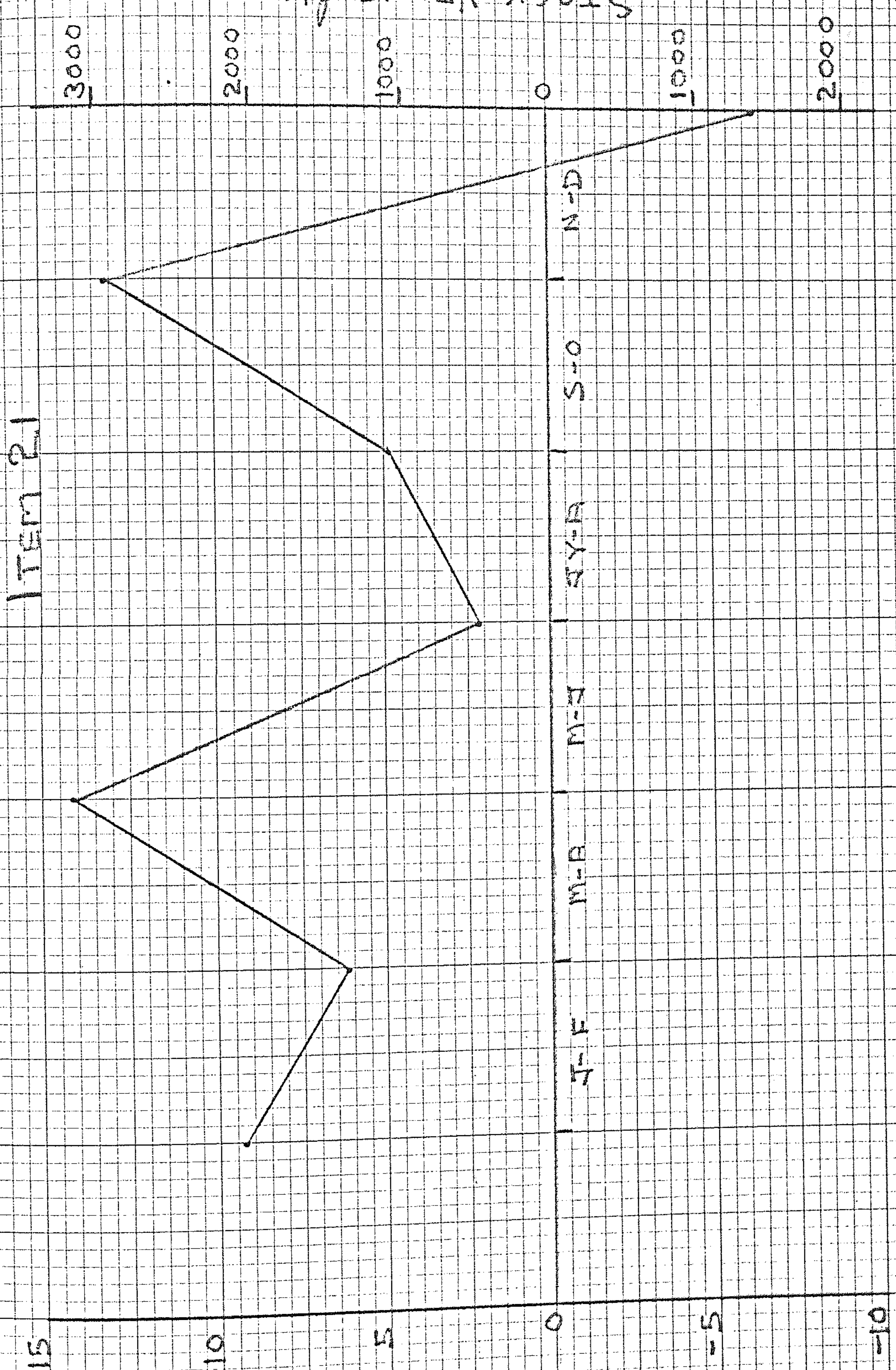

STOCK VALUE £'s
200
100
100
200
ITEM 7
N-D
S-O
JY-A
M-J
M-A
J-F
0
STOCK UNITS x10³

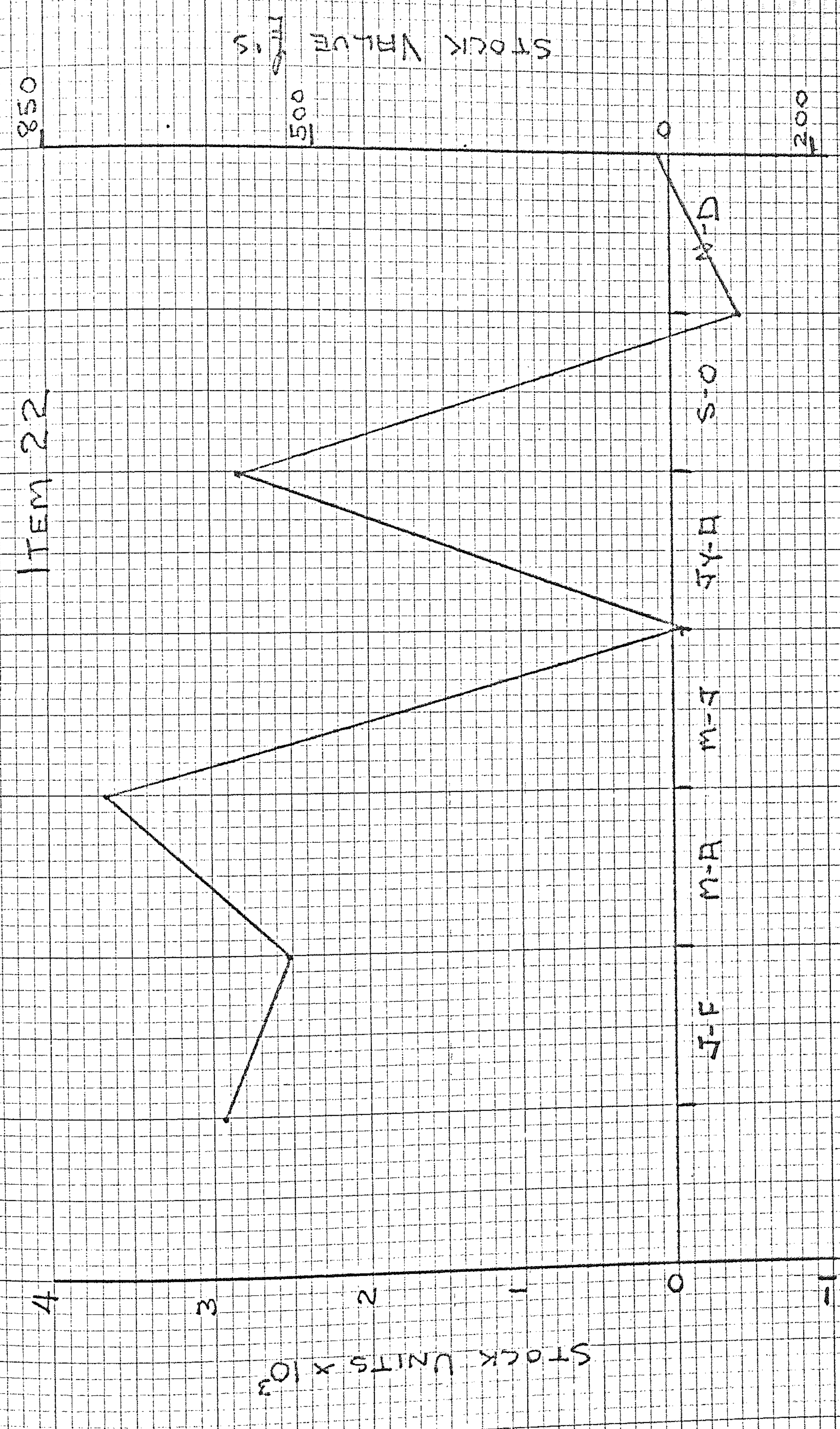

STOCK VALUE £'s
3000
2000
1000
1000
ITEM 8
N-D
S-O
JY-A
M-J
M-A
J-F
6
4
2
0
-2
STOCK UNITS x 10³

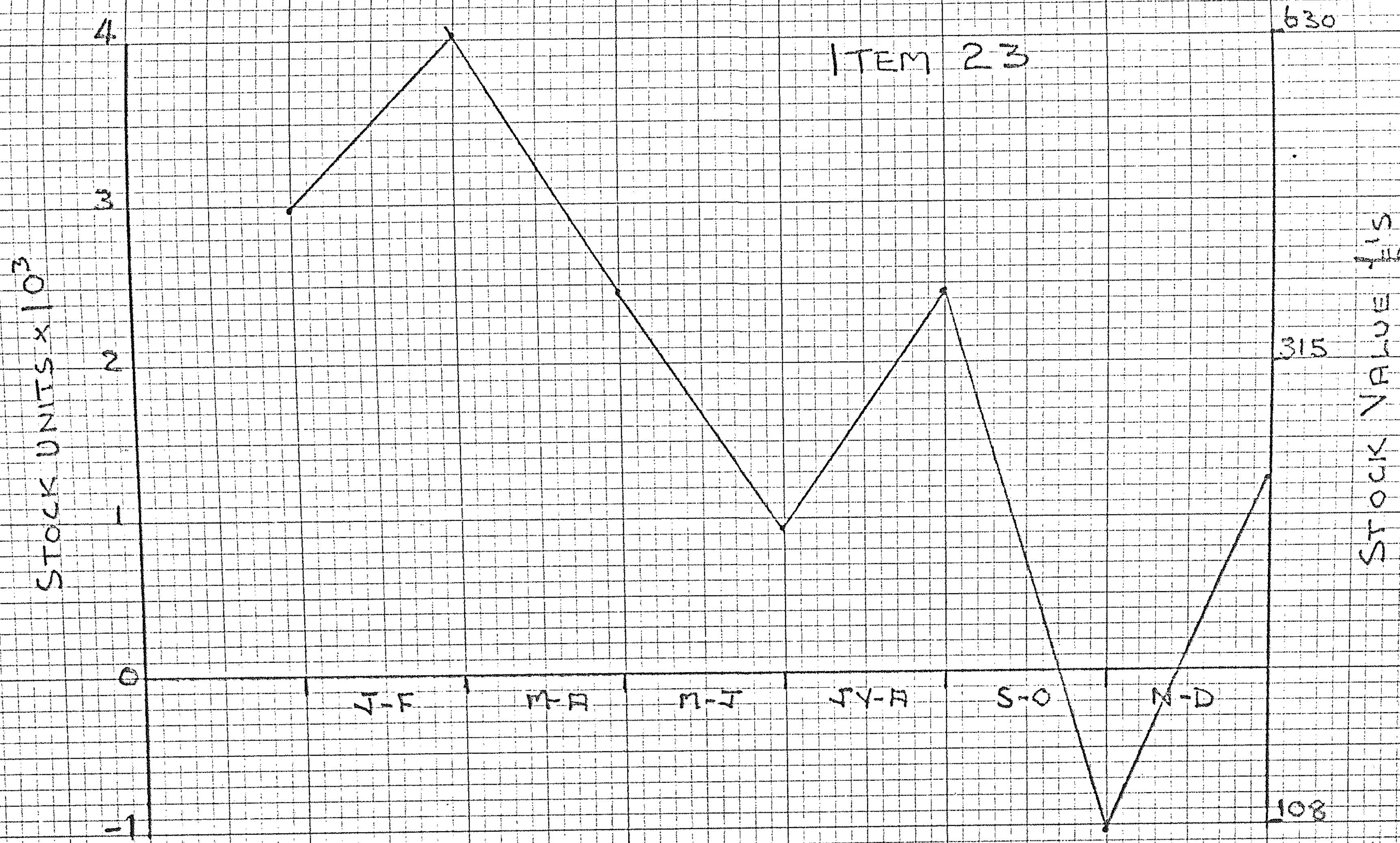

STOCK VALUE £'s
500
0
500
ITEM 9
N-D
S-O
JY-A
M-J
M-A
J-F
1
0
1
STOCK UNITS x10³

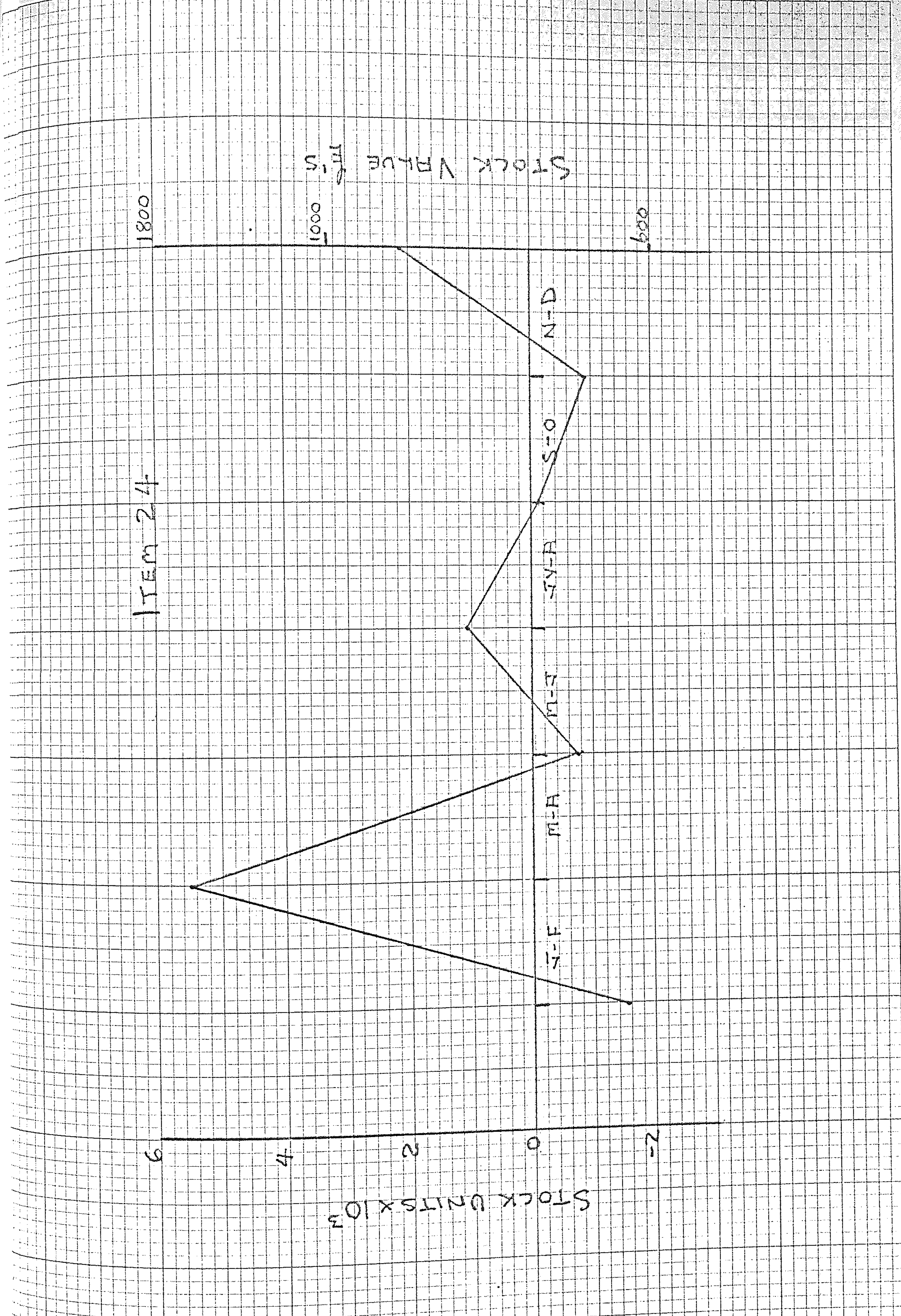

ITEM 18
STOCK VALUE £'s
1000
0
750
N-D
S-O
JY-A
M-J
M-A
J-F
6
4
2
0
-2
-4
STOCK UNITS x 10³

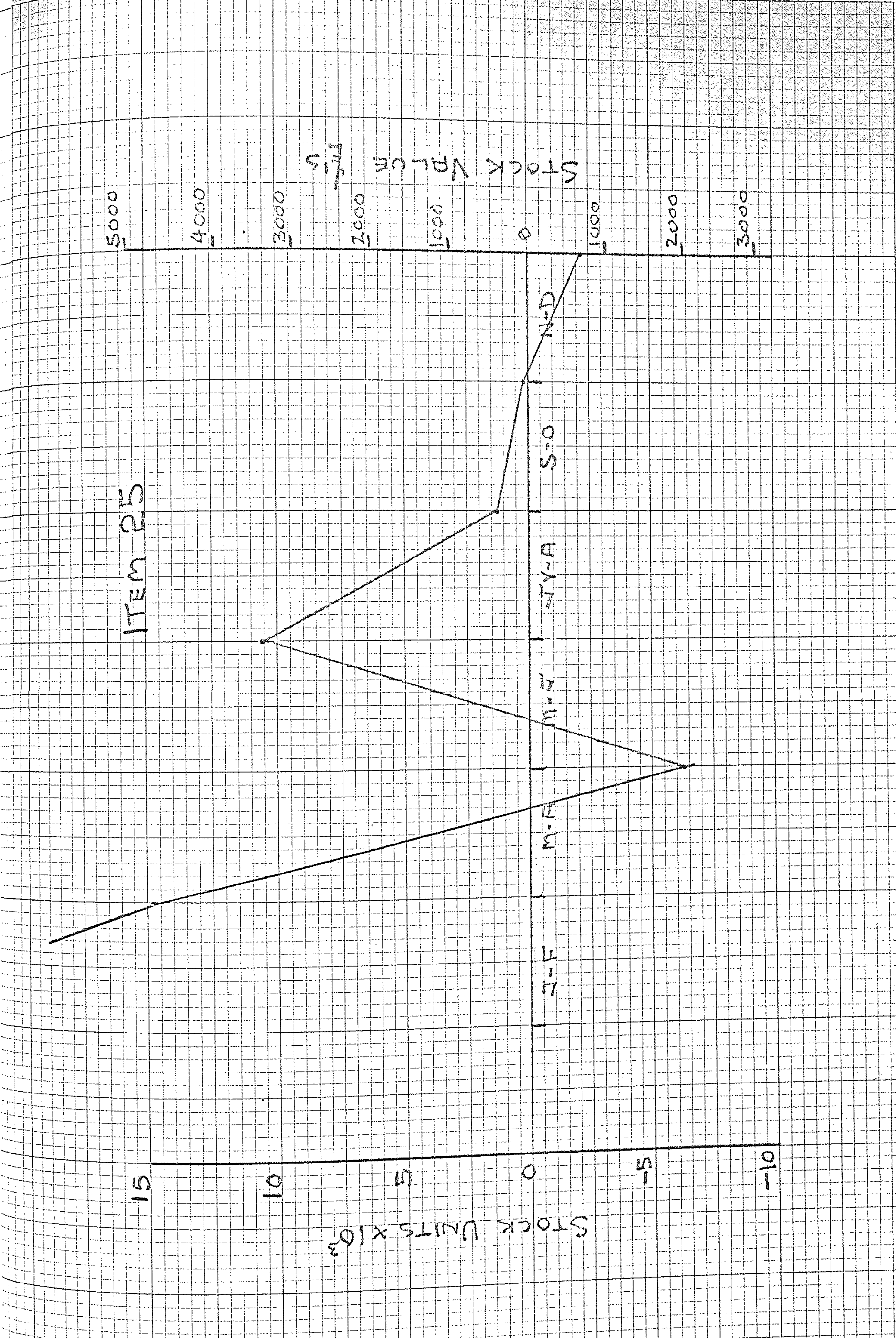

ITEM 20
STOCK VALUE
4000
3000
2000
1000
0
1000
2000
3000
N-D
S-O
JY-A
M-J
M-A
J-F
20
10
0
-10
STOCK UNITS x10³


ITEM 2
STOCK VALUE
3000
2000
1000
0
1000
2000
J-F
M-A
M-J
J-A
S-O
N-D
15
10
5
0
-5
-10
STOCK UNITS x 10^3

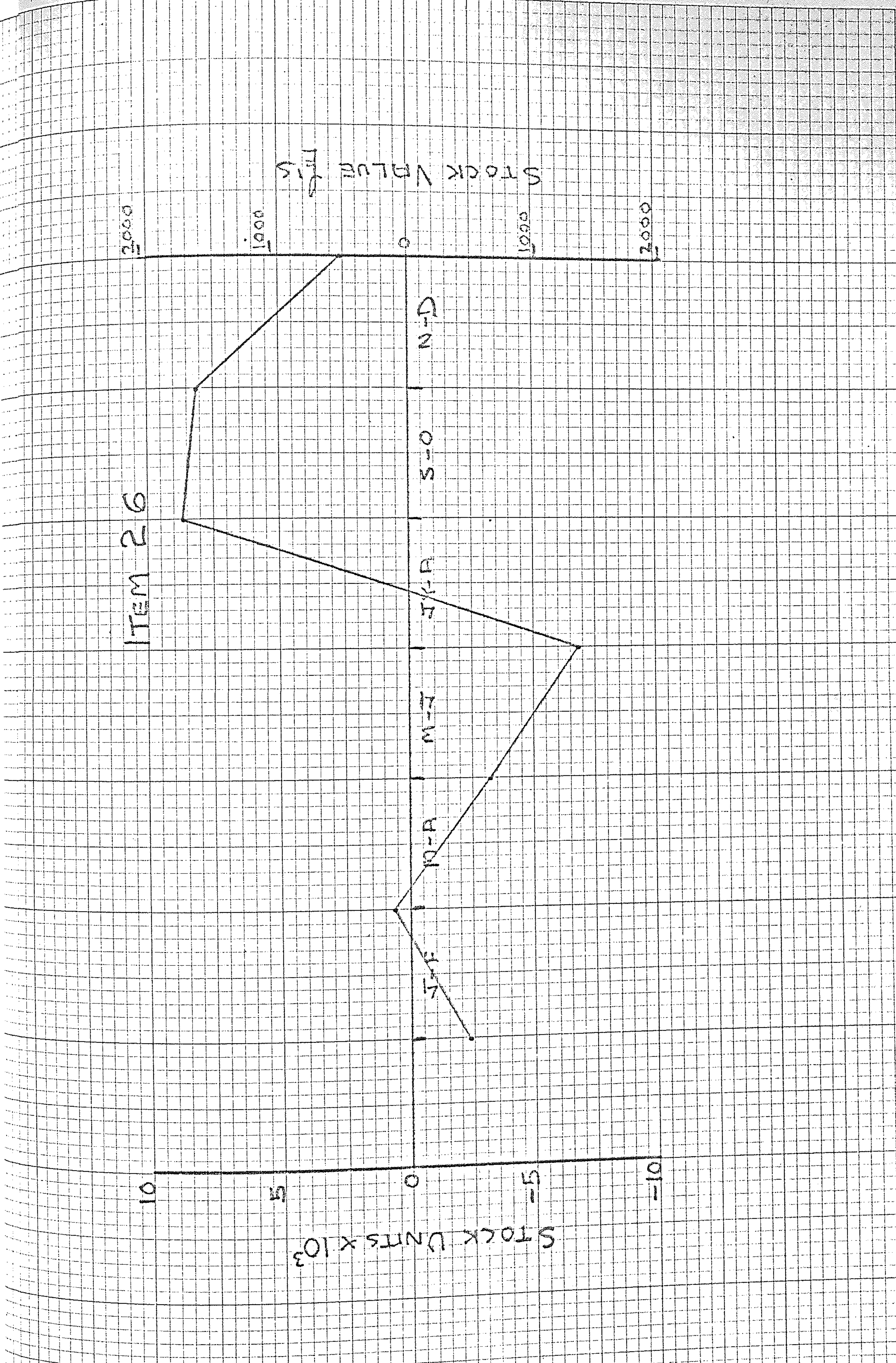

ITEM 22
STOCK VALUE £'s
850
500
0
200
N-D
S-O
JY-A
M-J
M-A
J-F
4
3
2
1
0
-1
STOCK UNITS x 10³

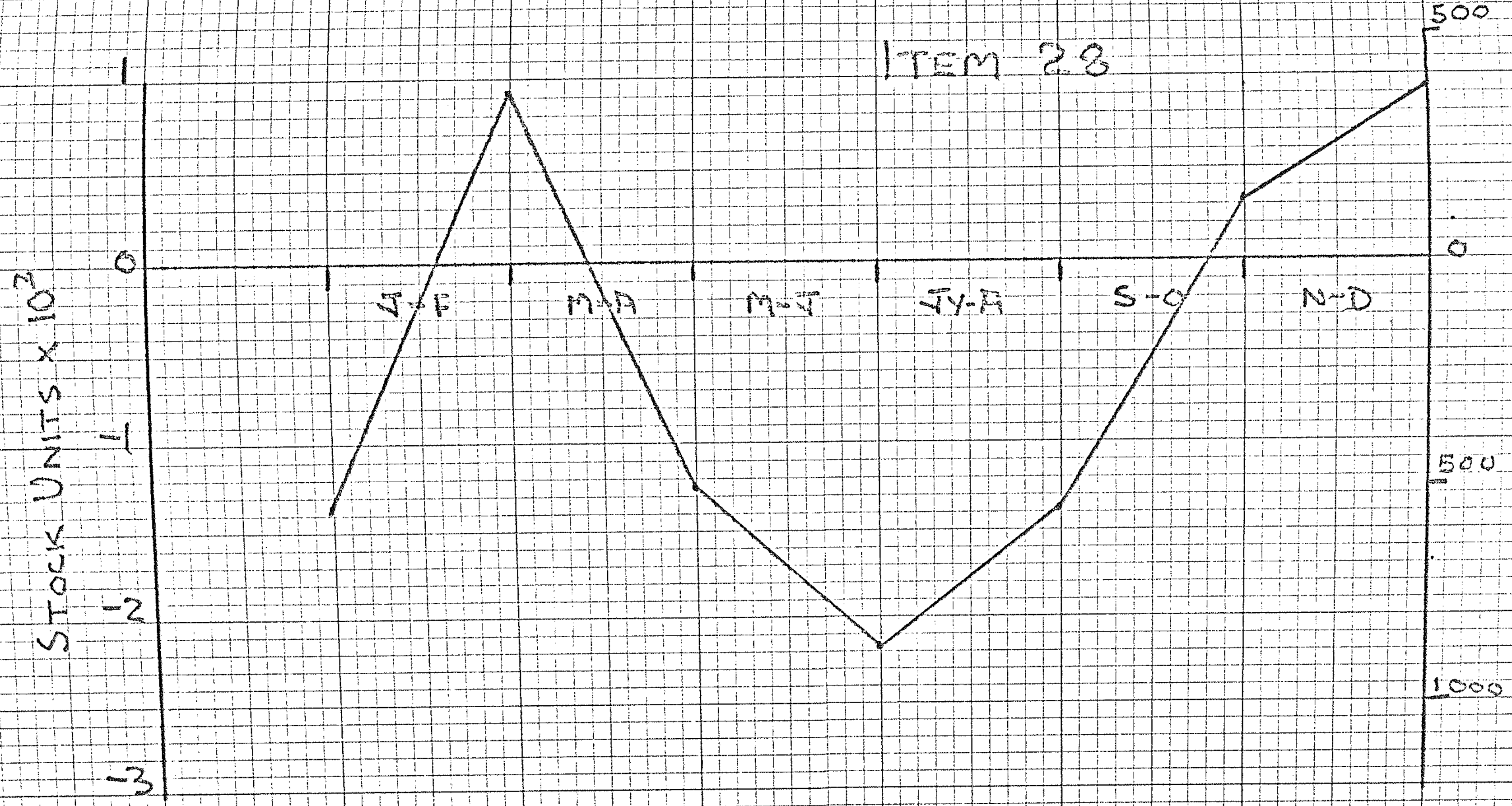

ITEM 23
STOCK UNITS x 10³
4
3
2
1
0
-1
J-F
M-A
M-J
JY-A
S-O
N-D
STOCK VALUE £'s
630
315
108


ITEM 24
STOCK VALUE £'s
1800
1000
600
N-D
S-O
Jy-A
M-J
M-A
J-F
STOCK UNITS x10³
6
4
2
0
-2

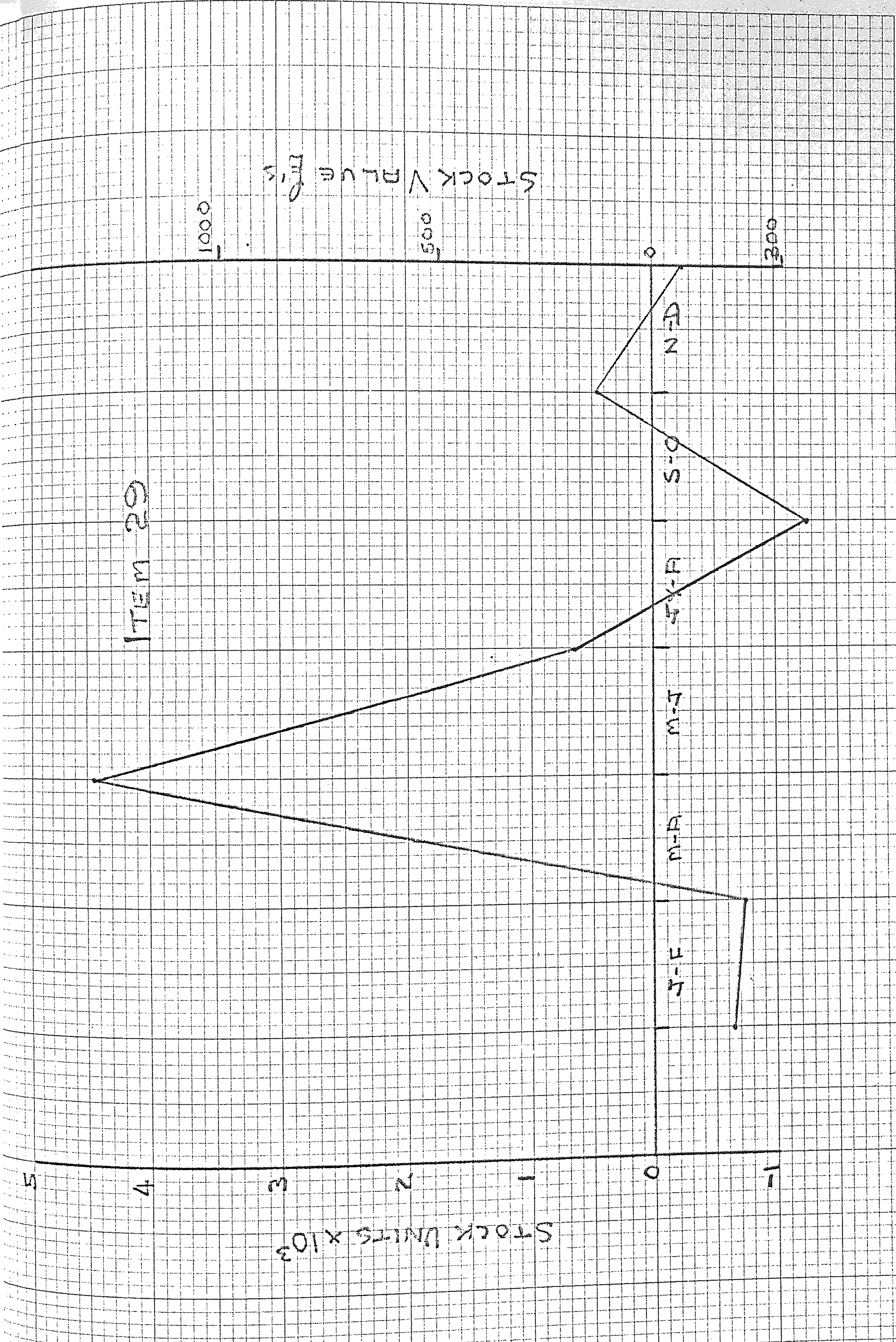


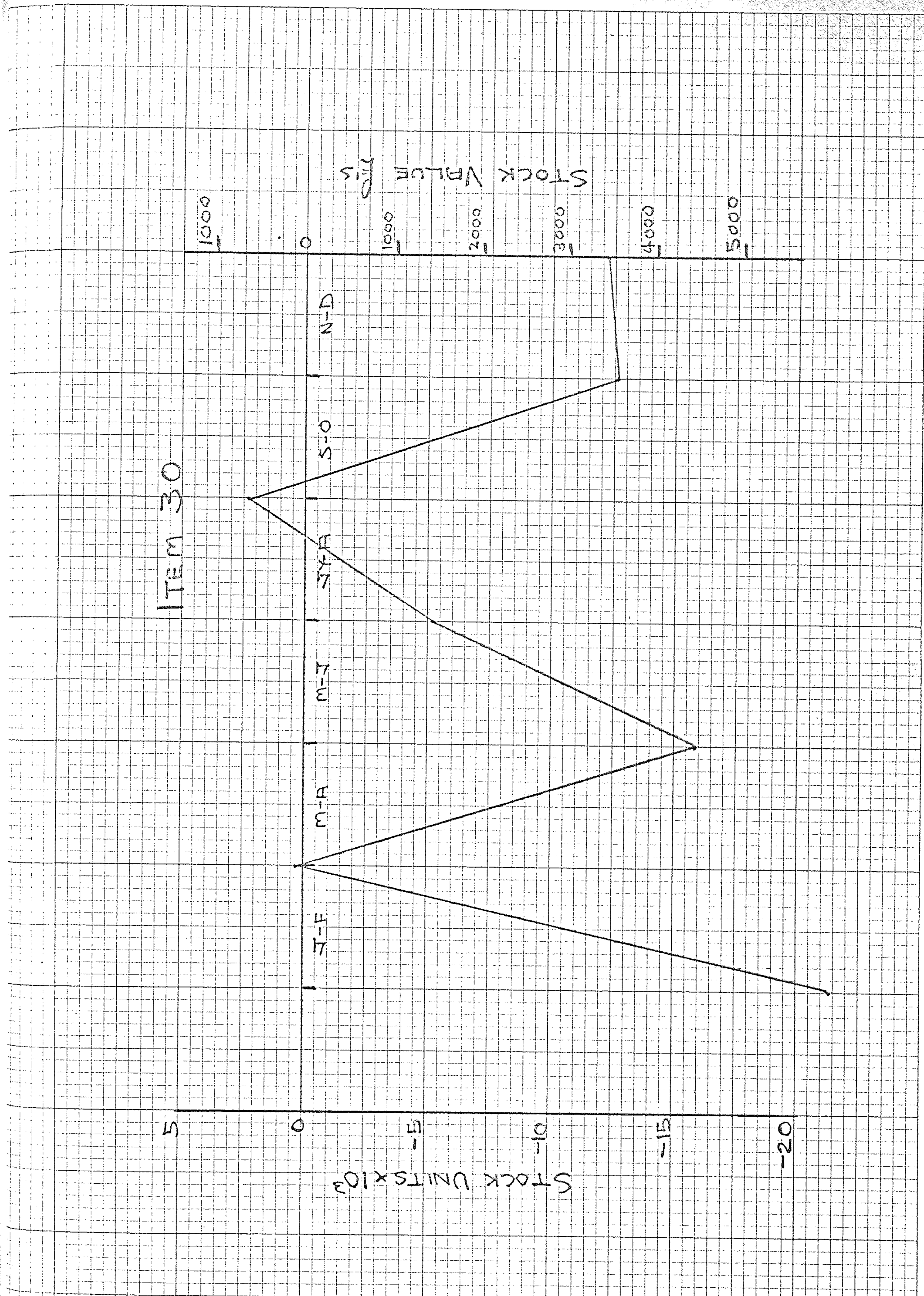
ITEM 25
STOCK VALUE £'s
5000
4000
3000
2000
1000
0
1000
2000
3000
STOCK UNITS x10³
15
10
5
0
-5
-10


ITEM 26
STOCK VALUE £'s
2000
1000
0
1000
2000
J-F
M-A
M-J
J-A
S-O
N-D
10
5
0
-5
-10
STOCK UNITS x 10³



ITEM 28
STOCK UNITS x 10²
1
0
-1
-2
-3
J-F
M-A
M-J
JY-A
S-O
N-D
STOCK VALUE £'s
500
0
500
1000


ITEM 29
STOCK VALUE £'s
1000
500
0
300
J-F
M-A
M-J
J-A
S-O
N-D
STOCK UNITS x10³
5
4
3
2
1
0
1


ITEM 30
STOCK VALUE £'s
1000
0
1000
2000
3000
4000
5000
N-D
S-O
JY-A
M-J
M-A
J-F
5
0
-5
-10
-15
-20
STOCK UNITS x10³

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