The production scheduling of the manufacture of precision moulded thermal insulation in a chemical company

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THE PRODUCTION SCHEDULING OF THE MANUFACTURE OF PRECISION MOULDED THERMAL INSULATION IN A CHEMICAL COMPANY

Thesis submitted for the
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in the
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For Betty

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University of Durham
March 1970

ABSTRACT

This thesis is concerned with the production problems in 1964/65 of a company manufacturing insulating materials. The project itself was undertaken at the request of the company, who were finding difficulty in scheduling their production, particularly of pipe insulation, in two different materials, using a semi-automatic process.

The thesis has been written in order to demonstrate the use of Operational Research Techniques, and to show that they follow the same distinct stages as are used in Scientific Method. These are:-

(1) Assessment of the problem

(2) Collection of data

(3) Analysis of data

(4) Simulation

(5) Preparation of suggested solutions

(6) Continuing check

In the application used, the author's original assessment is reproduced together with a critique, and it is shown that after the collection and analysis of data, a reassessment of the problem had to be made. The conclusion was reached that

the major problem existed in the equipment used to mould the insulation pipe-sections. The semi-automatic process included the pouring of the slurry-like raw material into "mould-blocks", which comprised a number of mould cylinders of different sizes. It was the distribution of mould cylinders to the mould-blocks which appeared to cause the main difficulty in scheduling production.

By using a scale drawing of a mould-block section, and cardboard discs to represent the range of cylinders in section, a new configuration of mould-block was designed. A simulation of production, by hand, was carried out to demonstrate that the new configuration was superior to the existing one, and a plan was prepared to carry out the changeover with the least effect on current production.

Finally, a computer simulation of production was carried out to compare two different configurations, which could have paved the way for the design of the optimum configuration.

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INTRODUCTORY NOTE

1. Arrangement of Thesis

The author has found it necessary to include a considerable number of Appendices, including diagrams, computer programs and output, and details of practical work done in the course of the project. For this reason he decided to insert these Appendices immediately following the Chapter to which they refer. A look at the Contents pages will make this arrangement clear.

2. Bibliography

The author has not employed the normal practice of annotating the text of the thesis with references to books consulted. Instead of this, the Bibliography at the end of the text includes comments on relevance and use.

3. Commercial Security

Although the author has endeavoured to conceal the identity of the Company, and other details, this information will be transparently clear to anyone connected with the Insulation industry. Reluctantly, therefore, the author cannot permit free reference to this work, if it is approved for the award of the degree of M.Sc. Persons wishing to refer to it must therefore obtain his permission, which will only be given after consultation with the Company concerned.

TITLE: The Production Scheduling of the Manufacture of Precision Moulded Thermal Insulation in a Chemical Company

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THE PRODUCTION SCHEDULING OF THE MANUFACTURE OF PRECISION MOULDED THERMAL INSULATION IN A CHEMICAL COMPANY

CHAPTER 1 : INTRODUCTION

(a) GENERAL

The project which forms the subject of this paper is one which comes under the general designation of "Operational Research". For this reason, it is convenient to introduce the paper with a short account of the science of Operational Research.

Operational Research (OR) has been described as the application of scientific method to management. Many operational research scientists are unwilling to give a more precise definition, but Sir Charles Goodeve has stated that

> "Operational Research is a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control."

This definition is examined more closely below in paragraph 1(c).

OR can usefully be employed on the smallest problems, such as the economic introduction of a new machine; but for maximum effect it should have a pervading influence throughout the whole organization.

OR does not necessarily demand the use of a computer, but there is often a need for a large amount of calculation, and manual methods may be both inaccurate and uneconomic.

OR is normally carried out by an interdisciplinary team. The team may be composed of scientists, engineers, economists, graduates in arts, and indeed anyone who is skilled in logical thinking. The wide experience of such a team has the effect of making members produce good, workable, practical solutions. Without OR training, a mathematician may reach an academic answer which would not work under practical conditions, whereas an engineer may oversimplify and reach too coarse an answer. Together they may interchange ideas and produce solutions which would not have been achieved by either in isolation.

In this project, members of the team included an engineer, a physicist, a mathematician/statistician, and research assistants trained in physics and computing.

(b) HISTORY OF OR

Before the 1939-45 war, top executives in industry found very little use for scientists except in their orthodox role. On the outbreak of war, however, scientists were turned to for assistance with military operational problems. In September 1940, PMS Blackett (later Professor Blackett), the distinguished British physicist, decided to bring together a number of men with good scientific training in a number of disciplines, such as physiologists, mathematical physicists, an astro-physicist, a surveyor, and others, to study the performance of gun control equipment in the field. The group became known as "Blackett's Circus". Because their first studies were devoted to the operational use of radar, and were carried out by scientists who had been working on radar research, their activity became known as "Operational Research". Two examples of military Operational Research, one wartime, and one postwar in which the author had firsthand experience, are shown in Appendix 1A. Until 1950, the systematic application of OR was mainly confined to military problems, but since then, with the growth in the use of computers, OR techniques have been increasingly applied to both industrial and governmental problems.

(c) OR IN PRACTICE

It is worth looking at the description of OR (see above) again. First, it is described as a "scientific method", which means that OR is an organized activity with a definite methodology of attacking a problem and finding a solution to it.

Secondly, it is a service to "executive departments", and by this is meant that OR is an applied science, using scientific techniques to solve a problem, the solution providing a basis for decisions by an executive such as the Managing Director of a Company. In the problem under investigation, it will be seen that courses of action were proposed by the OR team, it being left to the Board of Directors of the Company to decide whether or not to adopt them.

Thirdly, OR tries to provide a "quantitative basis for decisions". One of the main distinguishing features of OR is the insistence on the need - and the possibility - of quantifying any problem. In management generally, too many decisions in the past have been taken on "hunch", or with very little reliance on measurement. OR attempts to quantify as much as possible, even to the extent of measuring things which have always been considered as imponderables - such as the value to management of information. So the OR worker presents the quantitative aspects of the problem in a form that is understandable to management, indicating those other aspects which he has not been able to quantify, to enable top management to take as much as possible into account in reaching their decision.

(d) OR IN THIS PROJECT

Scientific Method is basically founded on measurement and falls into several distinct stages:-

(1) Assessment of the problem

(2) Collection of data

(3) Analysis of data

(4) Simulation, or other methods of estimating causes and effects

(5) Preparation of suggested solutions

(6) Continuing check

It will be demonstrated in the course of this paper that OR follows the same approach.

(1) Assessment of the problem

At the outset it is necessary to assess the problem, to decide exactly what it is. In this project, written appreciations of the problem were made before very much investigation had been carried out, by two members of the OR team working on the project. The author's appreciation is reproduced in this paper, together with a critique of it, written at the conclusion of the project.

In the light of further research, and particularly in considering the type and quantity of data which is available, or can be obtained, the problem may require reassessment. This was the case with the project under consideration.

(2) Collection of data

In this project a vast amount of data on production had been kept and was made available to the OR team. In addition to this, the team collected sufficient factual data on the equipment being used and its productive capability, and also data on labour potential. In a parallel study, sales figures for demand were made available, and were used later in this study. Very little planning information - such as the Company's efforts at forecasting demand - was provided, nor were any detailed costs produced, although these were in mind when the project was abruptly ended.

(3) Analysis of data

For analysing the data, the OR worker can call on a number of techniques to help him. These techniques include linear programming, critical path analysis and mathematical statistics. In the present project, the main problem was that of handling vast quantities of production statistics. Average figures were used for comparing despatches of the various "lines" being made, taking into account maximum and minimum despatches for future planning. In the main, however, most problems were handled using first principles. In OR it is the exception rather than the rule to be able to use techniques such as linear programming. This project was no exception.

(4) Simulation

The use of simulation techniques in OR is frequently necessary. This particular aspect is well demonstrated in the project. First of all, a simulation by hand of production of pipe sections was carried out, and this was followed by a computer simulation to compare different plans.

A physical "model" was also used to plan the layout of mould cylinders in a mould block.

(5) Preparation of suggested solutions

As a result of the analysis, and the simulation, the OR worker expects to be in a position to present one or more possible solutions for consideration by the executive. In this case, a possible solution was put forward, together with a plan for carrying it out.

(6) Continuing check

Normally, the OR worker must continue to check the validity of his model as new data becomes available, and will also check the carrying out of the plan in practice. In our study, this was not possible due to the termination of the contract.

The following chapters give an account of the course of the project. The final chapter discusses the results of the project, and considers what might have been achieved if the project had been allowed to continue.

TWO EXAMPLES OF MILITARY OR AND AN ANALOGY WITH INDUSTRY

1. Aircraft Anti-submarine Depth Bombs

An examination of the operational results of the first use of new equipment often indicates that a slight modification of the equipment will make it very much more effective; an example is the development of the use of aircraft as an anti-submarine weapon. The Germans underestimated the value of aircraft versus submarines. In the end aircraft played a very important part in the defeat of the U-boat in the Atlantic.

Early in World War II British Coastal Command used ordinary bombs in their attacks against submarines. They were obviously not effective, since they exploded on the surface of the water, and if they did strike the deck of the submarine, they seldom penetrated the pressurized hull. Depth charges were therefore adapted for aircraft dropping. These ensured an underwater explosion, which would be much more effective. Here, argument arose as to what should be the depth setting. It was not possible to change the setting in the aircraft just prior to attack, so that an estimate had to be made as to the best average setting for all attacks, and this setting had to be used always.

A number of squadrons set their depth bombs to explode at 150 feet: but submarines at 150 feet could not be seen, and therefore could not be attacked! Submarines near the surface which could be seen would only be somewhat shaken by an explosion at 150 feet depth. The depth setting was next reduced to 50 feet as a compromise. After a year of argument, a numerical analysis was made which settled it.

The fundamental question was the state of submergence of the submarine at the instant the attacking plane dropped its depth charge. If a great number of attacks were made when the submarine was on the surface, then even the 50 feet setting was too deep. An explosion at such a depth was too far away from the pressure hull of a surfaced submarine to have much chance of causing lethal damage. If the submarine was in the act of diving, or had just dived at the instant of attack, perhaps the 50 feet setting was right.

However, attacks after the submarine had dived were much less likely to be accurate than attacks on surfaced submarines. Even if the majority of attacks were made on submarines which had submerged a minute or more before a depth charge was dropped, it was not sensible to make the setting best for these cases, as the chance of success was low anyway. The depth setting should be determined by the type of attack which had the best chance of success. This was the attack on the surfaced submarine - unless this was a negligible fraction of the whole.

Examination of operational results indicated that in 40% of cases, the attack was made on a surfaced submarine, and in another 10% part of the submarine was visible when the depth charge was dropped: i.e., in half the cases the 50 feet setting was too deep. In the other (less accurate) half, the 50 feet setting might have been satisfactory. A numerical analysis of the chances of success of the attack as a function of the degree of submergence of the submarine indicated that a change in depth setting from 50 feet to 25 feet would at least triple the chance of success of the average attack.

The decision was then made to change the depth setting to 25 feet, and to instruct pilots not to drop depth bombs if the submarine had already submerged for more than half a minute. Within a few months of this decision, the actual effectiveness of aircraft anti-submarine attacks increased by a factor of more than 2.

2. <u>A Tactical War Game</u>

In the early 1950's it was considered important to try and find out what effects on tactical doctrine the use of nuclear weapons in the field would have. A "Tactical War Game" was set up in order to study these effects. This was an example of a very sophisticated Model, and a considerable amount of research had to be carried out before it could be set up. The historical archives of the (then) War Office had to be explored, and the statistics of such things as the outcome of battles in World War II obtained. For instance, it might be discovered that when a battalion group attacked a brigade (bigger) group, in 8 times out of 20 the battalion group was successful, each side suffering a different percentage of casualties. These statistics took into account such things as the achievement - or not - of surprise, the relative merits of the commanders, the relative fatigue or morale of the two sides, and many other imponderables. All such statistics were written into a

"Rule Book" for use when the model was set up.

At the same time, details of the effects of different sizes of nuclear weapons, exploded at various altitudes, were obtained from the United States, and these and other meteorological statistics were included in the "Rule Book".

The construction of three models was also put in hand. The models all showed the same area of European country, and were layered to show contours, and coloured to show forests, fields, towns, rivers and communications. Small pieces were also made to indicate different arms (infantry, gunners, etc.) units (companies, battalions, etc.) and weapons. The three map models were then set up in three different rooms, one for the 'Red' force, one for the 'Blue', and the third for 'Control'. Each side was in contact with 'Control', by several telephones and also by 'runner'!

All this preparatory work took several years, at the end of which the model was ready for the prospective participants, consisting of senior army officers. Two such officers would be given command of the 'Red' and 'Blue' forces, and after a practice match, to get the feel of the method of play, they would each be presented with an opening situation, telling them about their own forces in detail, and certain Intelligence information about the enemy forces. The game was usually started at the point when 'Red' forces were poised ready to attack across the frontier, and each force commander was asked to make a written "Appreciation of the Situation", which was handed in to 'Control'.

The game was then started, moves being made every hour of "game time". Force commanders, who were able to consult with "war game experts", were free to use any tactics or strategy they chose - although it was interesting to note that unconventional tactics did not pay off, with some notable exceptions. Each game lasted between three and four weeks of actual time, representing only three or four days of "game time".

By the time that a dozen or more identical games had been played, certain trends became apparent, enabling new tactical doctrines to be formulated. In addition, one game was played using conventional weapons only, and the results bore a good resemblance to actual engagements of a similar nature in Europe during the last war, which established a degree of confidence in the "Rules". It is fortunate that there has been no chance as yet to apply the lessons learnt to a real situation!

3. An Analogy with Industry

A military situation has many points which are common to industry. A military commander (a manager) may wish to stockpile shells (products) in order to lay down fire (tackle a market). The size of the stock will depend on armament supply (manufacture of goods) and expected rate of fire (sales). But now there happens to be an enemy (competitor) with a good intelligence service (market research). He plans his attack, or forms a strategy, based upon the desirability of taking his action when the other side's stocks are low, etc., etc.

CHAPTER 2 : BACKGROUND OF THE PROBLEM

(a) COMPANY ORGANIZATION

This project is concerned with a group of companies whose main business is the insulation of boilers and pipe work in Power Stations, Oil Refineries, Ships and the like. One of the group - "Company A" - is the main Thermal Insulation Contractor involved in site work, and this Company normally employed between 1,000 and 1,200 site operatives throughout the country at the time of the project. They were the major customers of "Company X", the member of the group responsible for the manufacture of insulating materials, the activities of which company provided the problem discussed in this thesis.

(b) SITE WORK FACTORS

At the same time the operations of Company "A" have an important bearing on the problem, because of the particular degree of urgency which surrounds their work. Thermal insulation is usually among the last jobs to be done on a site. Frequently, due to delays by other sub-contractors in the course of the project, the main contract will be behind schedule, and may even be overdue for completion when the Insulation Contractors arrive on site.

This factor causes a great deal of uncertainty as to exactly when the insulating materials are required, and there is also pressure from the main contractors for an uneconomically large labour force to be deployed in order to rush the completion of the project.

Due, therefore, to the difficulty of forecasting exactly when the materials are required - and in fact even the exact sizes and quantities - the manufacturing company may have a sudden, heavy demand placed on it which, under prevailing conditions, it is not capable of meeting. This causes emergency measures to be taken, which throw into chaos the production planning and scheduling which has been done. It also resulted in 'ad hoc' additions and improvements being made to the manufacturing facilities to get over each particular crisis, instead of doing this on a planned basis.

(c) MANUFACTURING PROCESS

Essentially, Company "X" employs a moulding process, similar in some ways to foundry work but very highly automated, to produce the insulation. Originally however, the insulation was made by hand, using very primitive methods; indeed, even today a small but significant proportion is made in this way, and one of the byproducts of this study could have been the possibility of finally abandoning hand methods.

For the automated process, two materials are involved (For notes on the chemical process see Appendix 2A). The first, known as "SUPERMAG", is based on magnesium carbonate;

it has been in production for several years, and demand for it remains steady. The second, called "PARATEMP", is based on calcium silicate; this has only been in production since 1963, but it can insulate up to higher temperatures; it is more costly at present, but demand for it has increased steadily, and this tendency is becoming more marked, in consequence of which its price should become lower.

The process is illustrated diagrammatically at Appendix 2B. After a chemical process carried out elsewhere in the works, the raw material for both types of insulation arrives in the form of slurry. This is stored temporarily in stock tanks high up in the building where manufacture is carried out. This slurry is drawn off into buckets suspended from a monorail system (see Appendix 2C). The operator in charge can select the weight required for the particular mould-block he is dealing with, from a central console. The required amount of slurry is then automatically weighed and tipped into a monorail bucket, and conveyed to one of the twenty-three stations which are set up to receive it. The raw material is automatically tipped from the monorail bucket into a funnel at the top of the mould-block, which is controlled by an operator on the floor below. After steam heating for a controlled period, the slurry solidifies, forming pieces of wet insulation. These are removed by hand and placed on bogies. The supermag pieces are taken straight to drying stoves, located in batteries in tunnels, each served by a separate heating system. The paratemp insulation has to go through an extra process in an autoclave to complete the chemical reaction, before being taken to the drying stoves.

The number of drying stoves has been increased from time to time as required. At one stage it was considered necessary to increase the size of the tunnels, so new ones were built to this larger size, and wider bogies were acquired, which will not fit in the older tunnels. This is an example of the way in which the facilities have been added to, making scheduling and planning more difficult.

The two materials - supermag and paratemp - must be dried in different tunnels, and the pieces of insulation remain there for about one week. As the previous process is carried out in a matter of hours, a considerable quantity of insulation is stocked in the drying tunnels, and this stock is not taken into account until it leaves the tunnels. When the drying process is complete, the pieces of insulation are put onto a conveyor for finishing. This consists of trimming, cutting to size, splitting the pipe sections in half, and very often machining the surfaces to an accurate dimension. Some of this work is done by machine, and some by hand. The finished pieces are then packed, either for despatch or for storage.

(d) LABOUR FACTORS

The plant discussed above normally used to work on a five-day, fifteen-shift week. Each shift was composed of a foreman and six men, and the shifts ran from 7 a.m. Monday through to 7 a.m. Saturday. In each 8-hour shift, the first $6\frac{1}{2}$ hours was spent on production, and the remaining $1\frac{1}{2}$ hours on cleaning out the mould-blocks and other equipment. A group bonus system was in operation, and the shifts rotated each week, so that the night work and early shifts were shared out fairly. The size of shift employed was sufficient to cope with the demand which then existed, and indeed to increase each shift by even one man would have been uneconomical, bearing in mind the extent to which the whole process had been automated. The teams did produce a large amount of insulating material, and it would have been almost impossible to obtain a pro rata increase with one extra. So the tendency was for men to work overtime at week-ends when extra production was needed, or for the extra quantities to have been made by hand methods.

(e) EQUIPMENT FACTORS

The mould-blocks used to form the insulation were extremely complex and therefore expensive pieces of equipment. Both the blocks and, in the case of pipe sections, the cores, were extensively jacketed, as steam heating is required to complete the chemical process (in the case of supermag) and to cause the slurry to solidify.

Each mould-block was designed to contain a number of individual mould sizes, each producing 3 feet lengths of insulation. There were two main types of block in existence, "slab moulds" producing slabs of insulation for flat and slightly curved surfaces, and "section moulds" producing insulation for pipes of a range of diameters from $\frac{11}{16}$" up to $8\frac{5}{8}$". The range of thicknesses produced was 1 inch, $1\frac{1}{2}$ inches, and 2 inches, with a small number at $2\frac{1}{2}$ inches and 3 inches. Out of a total of 25 mould-blocks, 9 produced slab insulation, and 16 produced sections. The blocks producing slabs were relatively simple in design, but each section block, with few exceptions, catered for a range of different sizes. The range of mould-blocks are shown diagrammatically in detail at Appendix 3C.

NOTES ON THE CHEMICAL PROCESS

1. SUPERMAG

The raw material from which supermag insulation is made arrives at the moulding process in the form of a slurry. The chemical composition of this slurry is mainly Magnesium Carbonate Trihydrate - $MgCO_3.3H_2O$ - which has a crystalline structure in the form of hexagonal prisms. This, at the time of the project, was mixed with 15% blended asbestos fibre to increase the strength.

In the moulding process, the slurry is heated under pressure to a temperature of 210°F, which causes chemical change to take place. The Magnesium Carbonate Trihydrate decomposes, giving off Carbon Dioxide, forming light basic Magnesium Carbonate - $4MgCO_3.Mg(OH)_2.4H_2O$. This material has quite a different crystalline structure, forming acicular crystals, shaped like long needles. These needle-like crystals intertwine and knit together, and with the asbestos fibre, rather like the structure of a bird's nest, and in doing so trap a large quantity of air, which is of course the insulating agent.

The lengths of time, and the temperatures, in the moulds and in the drying stoves are critical to the correct formation of the acicular crystalline structure. Drying takes place over a period of about one week, the temperature at the start being 212°F. This temperature is gradually raised to a maximum, at the end of the process, of 236°F.

This insulating material is only capable of insulating up to 600°F. Above this temperature, the water comes out of the crystals, causing the insulation to break down.

2. PARATEMP

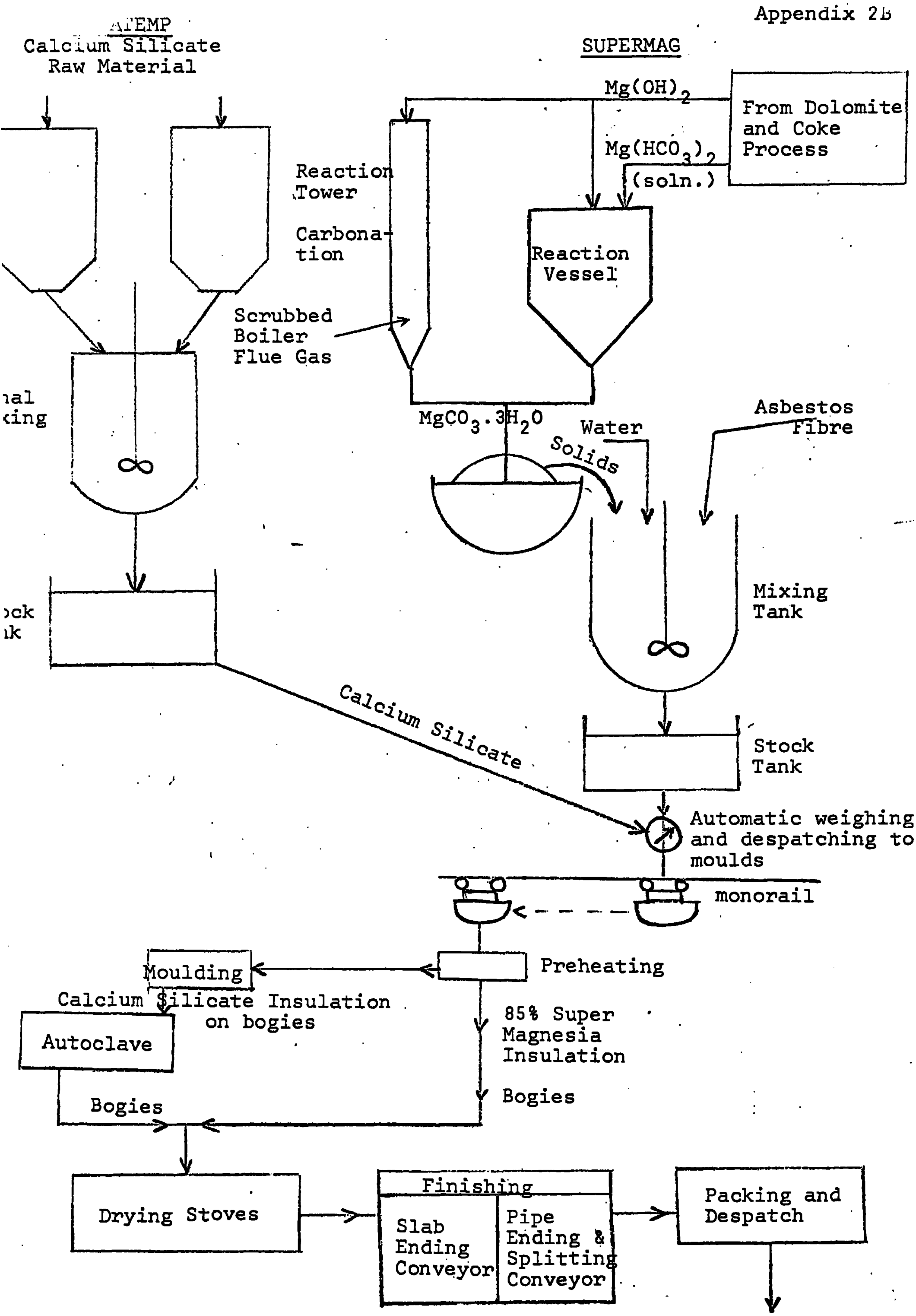
As with supermag, the raw material arrives at the moulding process as a slurry, the chemical composition being Calcium Silicate in the form of artificial Tobermorite crystals (hydrated) - so called because the natural material is found in large quantities at Tobermory in Scotland.

During the moulding process, the slurry is heated under pressure, which causes it to solidify, but no chemical change takes place at this stage. The wet pieces of paratemp, on removal from the moulds, have to be handled extremely carefully, and placed on the bogies in an interlocking pattern, and carefully supported so that they will not warp during the remainder of the process.

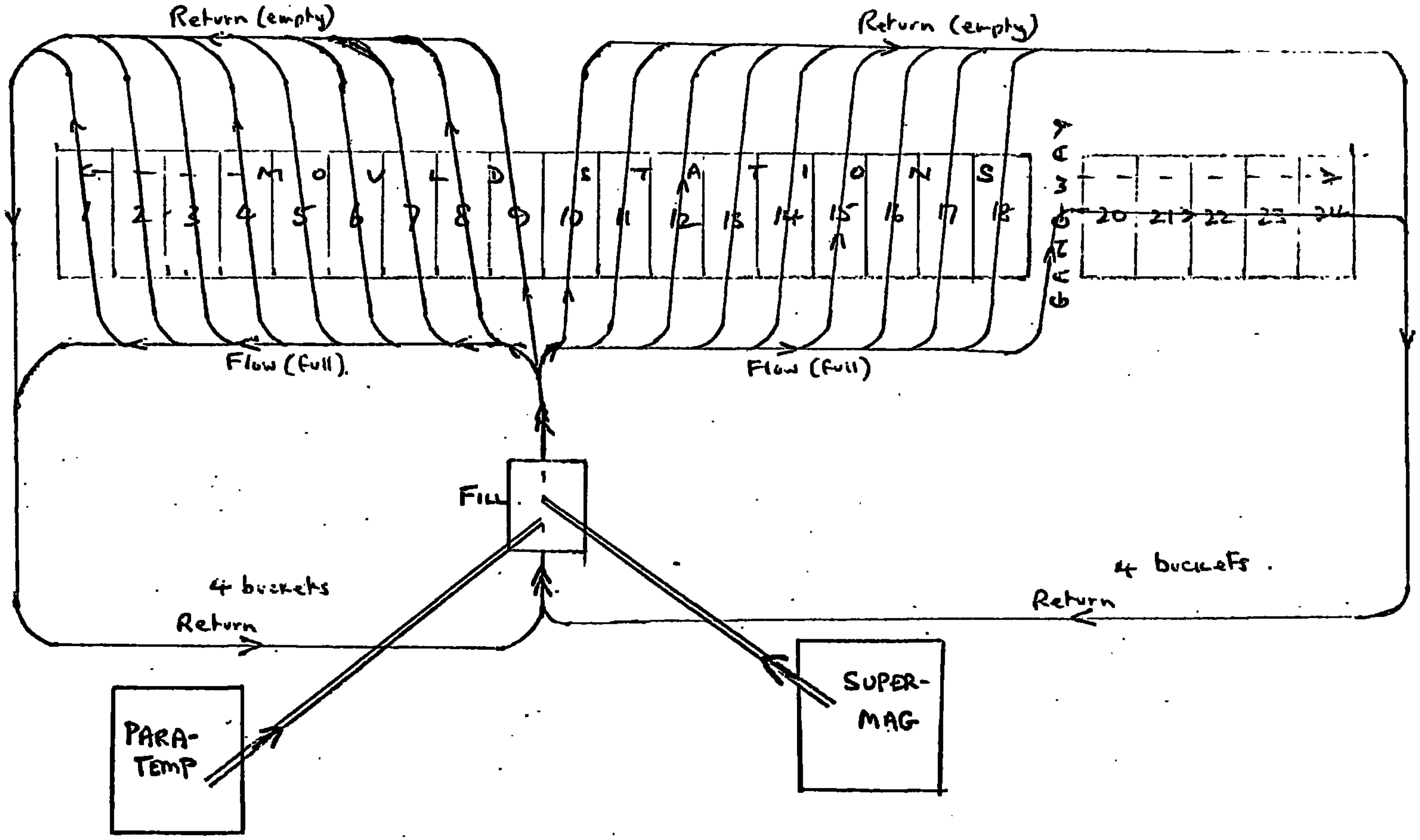
From the moulds, the pieces of insulation are conveyed on the bogies to the autoclave. Here they are subjected to a pressure of 190 p.s.i., and heated in steam at a temperature of 380°F for seven hours. During this period, chemical change takes place, from Tobermorite crystals to artificial Wollastonite crystals, which are anhydrous.

From the autoclave, the paratemp is taken through the same drying process as for supermag, although there is not the same need for rigid care with the drying temperature.

Paratemp is a satisfactory insulant up to 1200°F.


ATEMP
Calcium Silicate
Raw Material
SUPERMAG
Mg(OH)2
From Dolomite and Coke Process
Mg(HCO3)2
(soln.)
Reaction Tower
Carbonation
Reaction Vessel
Scrubbed Boiler Flue Gas
MgCO3.3H2O
Water
Solids
Asbestos Fibre
Mixing Tank
Stock Tank
Calcium Silicate
Automatic weighing and despatching to moulds
monorail
Preheating
Moulding
Calcium Silicate Insulation on bogies
Autoclave
85% Super Magnesia Insulation
Bogies
Bogies
Drying Stoves
Finishing
Slab Ending Conveyor
Pipe Ending & Splitting Conveyor
Packing and Despatch

MONORAIL SYSTEM



8 buckets -
4 serving stations 1-9,
4 serving stations 10-18 and 20-24

It is possible to achieve, from any one station, 7 lifts (cycles) of supermag in 2 hours, or 5-6 lifts of paratemp.

The buckets are normally deployed one half to each material - this may vary slightly.

CHAPTER 3 : PRELIMINARY WORK

(a) APPRECIATION OF THE PROBLEM

At a first meeting with the Managing Director and Directors of the Company the situation as presented in the first two paragraphs of section 2 of this paper was expounded, and also an explanation of the problems confronting the Company. As a result of this, and before examining the factory, an appreciation of the problem was written, a copy of which appears at Appendix 3A, together with a critique of it, written after work on the project was completed.

This paper shows the first thoughts on the subject, and the critique shows to what extent ideas were changed as a result of the investigations. In particular, attention is drawn to paragraph 4 Conclusions (a) and (b). The influence of computers on Operational Research methods was not appreciated, and these conclusions were incorrect in the light of the current facility for attacking problems on a wide front using the power of the computer.

A paper of this kind is a useful starting point for an OR study. Although some conclusions turned out to be wide of the mark, others - such as Conclusion 4(e) - pointed the way in which the project would progress.

After this first paper, work was concentrated on getting to know the complete picture of production as carried on at the factory. Visits were made and discussions held with the Works Manager and members of his staff. The production process was carefully examined from start to finish, as described in section 2. A visit was made to a typical site - a Propane Reforming Unit. This visit, which is reported in Appendix 3B, gave a valuable insight into the way in which insulating materials are used on site. The difficulty in forecasting the exact requirements of insulating materials was appreciated by this practical inspection.

(b) AVAILABLE DATA

During the visits to the works, various documents were obtained, giving details of recent and current production, and data about the equipment used. These documents, which are described briefly below and of which relevant extracts, where necessary, are appended, comprise:-

Mould Data Sheets and related papers. Appendix 3C (relevant extracts)

Chart giving location and composition of Mould Blocks

Summary Record of despatches of supermag and paratemp 1960-1964 inclusive. Appendix 3D is an example of the amount of data for one of the two materials, although the actual figures were different. This Appendix was prepared for a case study on the project.

Master Production Stock and Demand Sheets.

Appendix 3F

Utilization of Existing Moulds by Core-changing.

Appendix 3G (abridged)

<u>Mould Data Sheets</u> (Appendix 3C)

The Mould Data sheets gave details of the mould-blocks, in which the pieces of insulation are made. Relevant extracts have been taken and are recorded at Appendix 3C. As was explained in chapter 2, most of the mould-blocks are capable of making more than one size of insulation, the exceptions being blocks X, Y, Z. The details regarding thickness, size, and number of cylinders in each block, are shown in the first four columns of Appendix 3C. The next two columns show the dry weight of insulation, followed by the number of cycles per week. Less paratemp is produced due to the extra process in the autoclave, as already described. The next columns show the output per week.

<u>Chart giving Locations of Mould-blocks</u>

This chart gave a complete pictorial representation of each mould-block and the station at which it was normally used. The information, as far as pipe insulation is concerned, is shown in the last two columns of Appendix 3C.

<u>Summary Record of Despatches of Supermag and Paratemp 1960-1964</u> (Appendix 3D)

A summary of the monthly despatches of supermag for the years 1960 to 1964 inclusive was provided, together with the actual records of despatches for each cost period (4 weeks) in the 5 years concerned. The summary is shown in the form of Appendix 3D, which was produced for a case study based on this project, the figures having been corrupted to avoid prejudicing commercial security. As can be seen, there was a mass of factual data contained in these records, and the summary gave the maximum, minimum, and average quantities despatched for each pipe size in 1 inch, $1\frac{1}{2}$ inch and 2 inch thick insulation per cost period of four weeks. The summary also gave despatches of $2\frac{1}{2}$ inch and 3 inch thick insulation for 1964 only.

For paratemp, the summary was only for the two years 1963 and 1964, for each thickness from 1 inch to 3 inches, together with the actual records of despatches for each cost period of four weeks.

From these records charts were produced of despatches, the most important being the despatches of 1 inch thick and $1\frac{1}{2}$ inch thick supermag, which is shown at Appendix 3E. The main conclusions from examining these charts are:-

(a) The big variation in quantities despatched between pipe sizes.

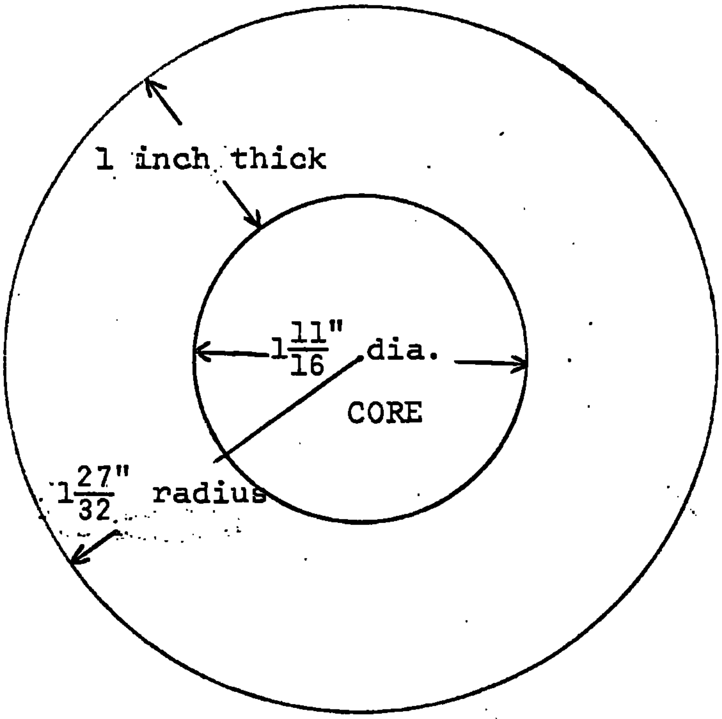
(b) The ratio of maximum despatch to average despatch is less than 2 in the case of popular sizes, but is much greater in the case of the less popular sizes. Forecasting the demand for less popular sizes will be correspondingly more difficult due to the large variations in demand.

<u>Master Production Stock and Demand Sheets</u> (Appendix 3F)

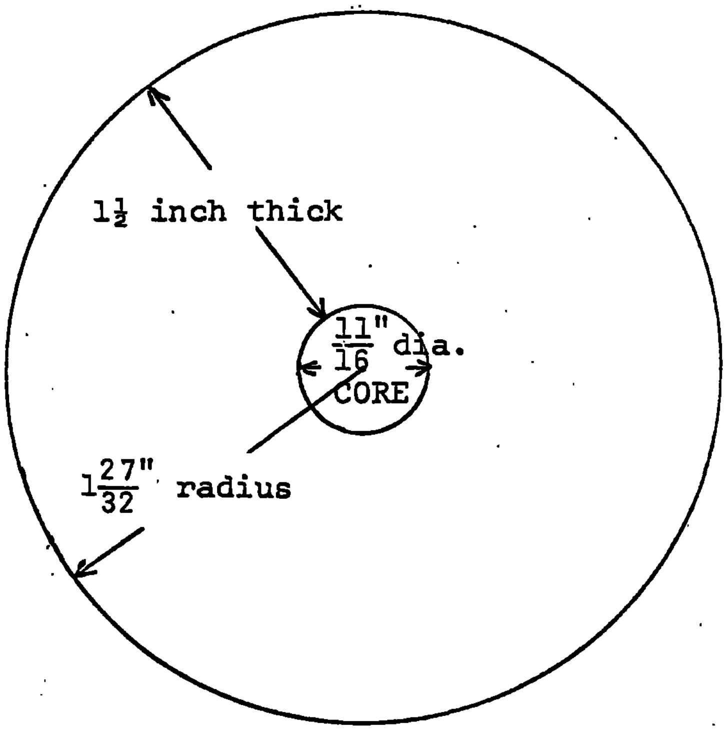
These sheets are produced by the works each week, and are supposed to show the quantity of insulating materials actually manufactured during the past week, together with the potential capacity (supermag only), the quantity in stock, and the quantity on order. The figures shown did not include the quantity in the drying stoves, which amounts to about one week's output, so although the records give an indication of the performance of the work, they do not show the whole picture. One sample sheet for supermag and one for paratemp is shown.

Utilization of existing Moulds by Core-changing (Appendix 3G)

The important concept of core-changing has already been mentioned, both at the end of chapter 2 and in Appendix 3C. The principle is that, in any mould cylinder, the core, which forms the inner surface of the moulded insulation, should be capable of easy removal, and replacement by a core of a different diameter. The diagram which follows illustrates how different thicknesses can be produced by this method.



1 inch thick by $1\frac{11}{16}''$ dia.
(pipe dia.)



$1\frac{1}{2}$ inch thick by $\frac{11}{16}''$ dia.
(pipe dia.)

The diagram shows how the same mould, of radius $1\frac{27}{32}''$, can produce insulation of either 1 inch thickness for $1\frac{11}{16}''$ diameter pipe, <u>or</u> $1\frac{1}{2}$ inch thickness for $\frac{11}{16}''$ diameter pipe. In the same way, with the larger sizes, it will be apparent that, from the same mould, 1 inch thick, $1\frac{1}{2}$ inch thick, 2 inch thick, $2\frac{1}{2}$ inch thick, and 3 inch thick insulation can be produced by merely changing the cores.

The chart at Appendix 3G shows how important this concept is, and indeed it has been a major factor in the study. Until this project was started, core-changing was used to only a very limited extent as shown in Appendix 3C, last column but one. But at Appendix 3G it can be seen that, in many cases, four and even five different sizes of core could be used in any one cylinder. Thus a cylinder producing insulation of 1 inch thickness for a 5 inch O.D. pipe could produce $1\frac{1}{2}$ inch thick insulation for a 4 inch O.D. pipe, or 2 inch thick for a 3 inch O.D. pipe, or $2\frac{1}{2}$ inch thick for a $1\frac{29}{32}''$ inch O.D. pipe, or finally 3 inch thick insulation for a $\frac{27}{32}''$ inch O.D. pipe, by using this principle. Many of these sizes were not being made by precision moulding, so the Company could have greatly increased its range of products by this method.

(c) OBSERVATIONS ON EXISTING PRODUCTION

The examination of the documents took several months, bearing in mind the need for constant consultation with the Company. It became clear that, under the arrangements then in force, it was only possible to satisfy the customer at the expense of the following:-

(i) Limiting total production to accommodate short runs for urgent orders.

(ii) Producing unwanted section sizes, or further limiting production by "blanking off" (see below) parts of mould-blocks.

(iii) Holding unduly large stocks, particularly of unpopular sizes, which mainly consisted of the larger varieties, and which therefore took up a great deal of storage space.

(iv) Not using all mould stations to the best advantage.

(d) REASSESSMENT OF THE PROBLEM

The problem now appeared as a combination of production control and stock control. Due to all the reasons already discussed, the production plan has to be modified continually to cope with rush orders, and at the same time, stocks of less popular sizes are liable to increase, and may lie dormant for months and even years.

In the case of pipe insulation, the pattern of demand, by sizes, was most irregular (see Appendices 3D and 3E), although certain lines were consistently much more popular than others. The variation between maximum, average, and minimum production in cost periods (4 weeks) is also of interest. Popular sizes show only about 100% difference between average and maximum despatches, whereas those for which demand is normally small show several hundred percent difference: e.g. from Appendix 3E

for supermag: Popular - 1 inch x $1\frac{11}{32}$"

Ratio of maximum to average is about 1.5 : 1

Unpopular - 1 inch x 7"

Ratio of maximum to average is about 8 : 1

This indicates that, for an unpopular size, a large order would arrive once in a year, whereas during the rest of the year, very little was produced.

In fact, out of the 23 stations used for both slab and pipe section production, only about 16 would be in use at any one time. There were various reasons for this, including:-

limitation in the production of the raw slurry

monorail capacity

manpower available

time required to change mould-blocks

problems connected with using two quite different raw materials

time for core-changing

time for altering "blanking off" (see below)

From this examination, the problem seemed to be as follows:-

First, what would be the best method of producing the various types and sizes of pipe insulation? <u>THE PRODUCTION PROBLEM</u>.

Secondly, what stocks of each type and size should be held as a minimum, in order to achieve the minimum delay in satisfying a customer's order? <u>THE STOCK PROBLEM</u>.

This paper is concerned mainly with the first - the Production Problem.

(e) <u>THE PRODUCTION PROBLEM</u>

The terms of reference of the study excluded detailed consideration of any part of the factory process before or after the moulding stage. (Note that it is not normal practice for OR studies to be restricted in this way.) It was therefore agreed with the Company that the main object of study in the works would be the problem of the optimum mould-block configuration. The activities of the Sales

Department, of course, have an important influence on production problems, in such things as the definition of delivery dates, but it was decided to take these as given facts of the situation. At the same time, a data-processing operation for the Sales Department was in progress, some results of which are used in this report.

From these preliminary investigations, then, it was decided that one of the basic production problems was the lack of flexibility caused by the arrangement of moulds in the mould-blocks. It was clear that, like so many other parts of the manufacturing process, the mould-block arrangement had developed through force of circumstances, and in its existing state was causing these limitations - i.e., urgent orders interfering with efficient production, unwanted - and usually large - section sizes being produced because of the particular arrangement of moulds in blocks, unduly large stocks being held, and mould stations not being used to the maximum.

It was felt that an examination of the mould-block system for pipe insulation would yield fruitful results, and first thoughts on the project were to consider the possibility of changing mould blocks as required, or of changing cores or liners in mould-blocks to vary production. A configuration of mould-blocks was required which would give at least as good service to the customer, but at the same time would

reduce costs

increase total <u>useful</u> production

enable production control to function effectively

cut down stocks if possible

increase the range of thickness which can be produced

eliminate, or minimise, production of unwanted section sizes

avoid, or minimise, "blanking off" (see below)

(f) DETAILED CONSIDERATION OF MOULD-BLOCKS

It was clear that the first task was to examine the existing distribution of moulds within mould-blocks, and see in what ways they were inefficient. To do this, a detailed explanation of the existing mould-block distribution is needed.

The size of each mould-block is: length 44 inches, normal width 16 inches, depth 48 inches. The blocks concerned with the manufacture of pipe insulation number sixteen, and are lettered as follows:-

V W Z Y X C D E I G F H M J K N

- the order in which they are listed in the Data sheet (Appendix 3C).

The composition of the mould-blocks has been re-tabulated with respect to O.D. pipe size and thickness of insulation, in the following table:-

O.D. Pipe (inches)	Thickness				
	1 inch	1½ inch	2 inch	2½ inch	3 inch
11/16	V(2)	-	N(1)		
27/32	W(9)	I(1)	N(1)		
1 1/16	W(9)	V(3)+G(1)	N^{+}(1)		
1 11/32	Z(16)	G(1)	N(1)		
1 11/16	V(7)	G(1)	N^{+}(1)		
1 29/32	Y(14)	F(1)	N(1)		
2 1/8	V(2)	I(1)	N^{+}(1)		
2 3/8	X(14)	F(1)	J(1)+N(1)		
2 5/8	C(1)	H(1)	N^{+}(1)		
3	C(3)	G(1)	F*(1)		
3½	C(3)+H*(1)	F(1)	J(1)		
4	C(1)	H(1)	H*(1)		
4½	C(2)	F(1)	J(1)		
5	D(1)	H(1)	I*(1)		
5½	D(1)	G(1)	J(1)		
6	E(1)	I(1)	M*(1)		
6 5/8	E(1)+G*(1)	F(1)	K(1)	K*(1)	K*(1)
7	E(1)	M(1)	M*(1)		
7½	E(1)	I(1)	K(1)		
8	D(1)	M(1)	M(1)		
8 5/8	D(1)+I*(1)	H(1)+K*(1)	K(1)		

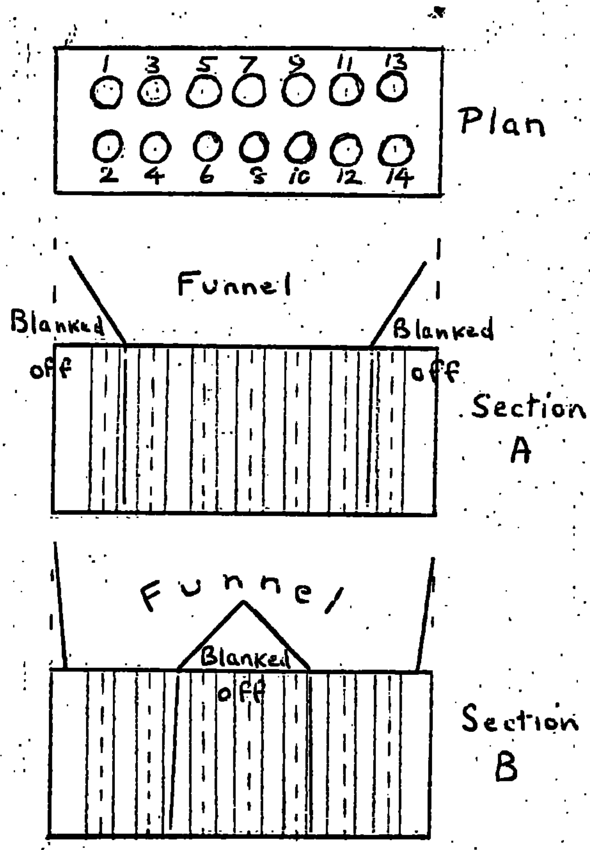
* by core change

+ by "scraping" - a machine operation which increases the internal diameter of the insulation, decreasing its thickness slightly.

From this table, and from the mould-block details given in Appendix 3C, it can be seen that mould blocks X, Y, and Z had respectively 14 x (1 inch x $2\frac{3}{8}$" O.D.), 14 x (1 inch x $1\frac{29}{32}$" O.D.), and 16 x (1 inch x $1\frac{11}{32}$" O.D.) mould cylinders in them. The remaining thirteen section moulds had a mixture of different sizes of mould cylinder in them: e.g. Block V had 2 x (1 inch x $\frac{11}{16}$" O.D.) plus 7 x (1 inch x $1\frac{11}{16}$" O.D.) plus 2 x (1 inch x $2\frac{1}{8}$" O.D.) plus 3 x ($1\frac{1}{2}$ inch x $1\frac{1}{16}$" O.D.) mould cylinders. Conversely, to make insulation to fit $3\frac{1}{2}$" O.D. pipe, 1 inch thick could be made from Mould Block C (3 cylinders) and H (1 cylinder by core-change): $1\frac{1}{2}$ inch thick from Mould Block F (1 cylinder): and 2 inch thick from Mould Block J (1 cylinder).

(g) BLANKING OFF

Although it was possible to vary production by blanking off cylinders, only certain cylinders in a block could be excluded in this way. The ones that could be blanked off most easily were those on the extreme ends of the mould-block, e.g. nos. 1 and 2, 13 and 14 in the Plan. A group in the centre could also be cut out, e.g. nos. 7 and 8, 5 and 6, 9 and 10.



(Not to scale)

The reason for this was mechanical: the extreme ends could be blanked off by narrowing the funnel through which the slurry enters the block - see Section A - whereas the central cylinders could be blanked off by dividing the funnel in two - see Section B.

The designers of the mould-blocks, therefore, had to exercise great care in selecting the physical layout of the cylinders in those blocks other than X, Y and Z, to enable any possible control over the sizes made to be exercised. At the same time, of course, the whole system of blanking off was uneconomical in that it necessarily entailed cutting down the volume of production, as the cycle time was the same however many cylinders in a block were utilized.

A CHEMICAL COMPANY STOCK CONTROL

Appreciation of the Problem

Appreciation	Critique
	The original appreciation, written in August 1964 at the beginning of the project, is examined, paragraph by paragraph, concluding with a general appraisal.

OBJECT

Appreciation	Critique
1. This paper attempts to state some of the problems which will have to be examined in this study, and hence to examine the data which will be required, and the method of tackling the study as a whole.	This was a statement of the need for writing this appreciation.

FACTORS

Appreciation	Critique
2. The problem to be examined	
The object of the whole study is to determine what, under present conditions, the level of holdings of stocks of the various sizes of pipe insulation sections	At this early stage of the project, it was desirable to keep the terms of reference as broad as possible. A better object might have been "to determine what strategy should be pursued

Appreciation	Critique
should be, and how these holdings should be made to vary in the future, when requirements alter.	in the factory in order to cope with a fluctuating demand for a wide variety of products". As will be seen, the scope of the project was in fact widened later.
<u>Conclusion (a)</u> An examination of the production and expenditure of the various sections, over the past few years, is required with particular reference to the fluctuations in the levels of stocks held, from time to time.	<u>Conclusion (a)</u> The examination of the <u>production</u> over the past few years was in fact carried out, and was the basis for many of the recommendations. We were not able, however, in the course of this project, to examine <u>expenditure</u>. This would have been the next job.
<u>Conclusion (b)</u> Some examination of any likely alterations in demand in the future is required.	<u>Conclusion (b)</u> Considerable discussion of the future requirements for insulation materials was held with the management, and our conclusions were taken into account in the final analysis.

3. <u>The demand</u>

Demand for insulation sections comes principally from sites, where work is being carried out by sister companies, or subsidiaries. Due to site working conditions -	This factor was correctly stated and needs little comment now. The conclusion is however somewhat restrictive, and tends to assume the result of the investigation.

Appreciation	Critique
especially the fact that insulation engineers being last on site, are usually late in starting work, it is not possible to anticipate requirements due to the bulky nature of the materials and the limited storage space.	
Conclusion This factor underlines the need for the study. An optimum level of stock holding is required in order that the bulk of the requirements for any particular site may be despatched with the minimum of delay, the balance being found from current production.	

4. The variety of pipe insulation sections

Appreciation	Critique
There is a huge variety of insulation sections. Pipe sizes themselves vary greatly, and then there are bends of various shapes, different thicknesses, different materials, and many other varieties.	Again, the factor is correctly stated and was verified in the course of the study.
Conclusion (a) The initial study will have to be confined	Conclusion (a) This conclusion - restricting the initial study to

Appreciation

to a small proportion only of the different varieties, as there will not be time to examine the "through-put" of every single size and type.

Conclusion (b) The method of selecting this proportion should be to sort out the whole production into classes according to total production, and then to take random samples of each class in proportion to the total number produced of that class.

Critique

a small proportion only of the different lines - was questioned at the time by the project leader, on account of the ability to tackle such problems on a broad front, with the help of a computer. In the event, although at first not much use was made of the computer, it was found necessary to consider the whole range of products, as this was the root of the problem, and entirely wrong results could have been reached if this narrow approach had been used. This also points to the advantage of team work in solving OR problems.

Conclusions (b), (c), (d) derive from conclusion (a) and were similarly put aside.

Appreciation	Critique
Conclusion (c) The storage space available would also have to be reduced proportionally.	
Conclusion (d) Referring to factor 2 (data required), an overall picture of limited production and demand will be required to set up the study, but more detailed data of the samples to be examined will be necessary.	
Conclusion (e) The wide variety points to the need, if possible, for flexible production methods (i.e. the ability to switch quickly from one size and type to another).	Conclusion (e) This was an important conclusion and had considerable effect on our thinking.
5. Site Work	
Locations of sites are widely distributed throughout the country and possibly overseas. Business has recently changed from large contracts, and consists mainly of small orders. This trend may continue.	An important factor, correctly stated.

Appreciation	Critique
Conclusion (a) The wide dispersion of sites must be taken into account, and in particular the transit time required for materials to reach sites. Data will be required from the Company of the effect this transit time has on stock holdings.	Conclusion (a) The effect of transit time on stock holdings was later found to be less significant compared with other factors.
Conclusion (b) The wider dispersion of business will make the despatch of stores more difficult, and it will also affect the type of insulation materials being used. This trend over the last few months will have to be examined as a basis for forecasting future requirements by extrapolation.	Conclusion (b) Although this conclusion was valid, the direction which our work led us made it less important than was expected at this stage.
6. Methods of manufacture	
Two methods of manufacture of the pipe sections and slabs are at present being employed concurrently. These may be described briefly as the "Hand" method	As stated, the "Hand" method of manufacture enabled a degree of flexibility to be retained in the production plan.

Appreciation

and the "Machine" method.

The intention of the Company is eventually to discontinue the "Hand" method and replace it by expanding the "Machine" method.

Conclusion (a) At first sight this alteration, although economising in labour, would make production even more inflexible than at present. (It is costly and time-wasting to change the output of machines in the "Machine" method. The "Hand" method is more flexible as it only takes a few minutes to change output. Current production is therefore geared to make the sizes in greater demand by machine, filling in wherever necessary by hand.) See also Conclusion 4(e).

Conclusion (b) Production records, it is hoped, will distinguish between "Hand" made and "Machine" made

Critique

Conclusions (a) and (b) The Company did not discontinue the "Hand" method during the course of the project. The recommended solution introduced flexibility into the "Machine" method, thus enabling the "Hand" method to be discarded later. Although desirable, the main production records did not in fact distinguish between the two methods.

Appreciation	Critique
insulation sections. The Company should be dissuaded from changing over completely to Machines until the effect on the stock problem has been assessed.	
7. Costs	
Production costs by both methods, Storage costs, Transport costs, Handling costs, and any other relevant costs will have to be examined.	This factor was indeed valid, and the next phase of the investigation would have been to examine costs.
Conclusion All these data will have to be obtained and allocated to the samples under detailed examination. Their respective effects on total costs will have to be measured. For instance, the trend to more, smaller contracts, and the Company's intention to do away with "Hand" manufacture, may both point to the need for greater storage space.	Conclusion refers again to samples - see 4(a) above.
8. Information from other sources	
In order not to have to start from "scratch", it will be necessary to obtain	It is, of course, important to examine all literature relevant to an OR investigation

Appreciation	Critique
information on the Stock Control Problem from other sources, especially from individuals and other agencies who have carried out work on the problem. Some possible sources are listed below:	before "plunging in". In this case, several reports by the DSIR Operations Unit were read (see reference at end of report) and other books on the subject.

a. DSIR Operations Unit, State House, High Holborn, London, W.C.1

b. Purchasing Officers Association, York House, Westminster Bridge Road, London, S.E.1

c. Operational Research Society

d. Other Universities
(Dr. K.B. Haley, Birmingham University, already approached)

e. Authors:
Vazsonyi: Scientific Programming in Business and Industry. Wiley 1958
Burbridge: (writes articles in journals)

Conclusion An immediate start should be made on obtaining as much help as possible from these sources.

Appreciation	Critique

SUMMARY OF CONCLUSIONS

Appreciation

9. (a) Due to the wide variety of insulation sections, it will be necessary to confine the study to a small "random" sample, which will be truly representative of the total "population".

(b) Storage space will be assumed on a "pro rata" scale.

(c) Data required

(i) To set up the study, a broad picture of production of all varieties, over 2 or 3 years, is required, in order to sort out varieties into levels of production, and hence to arrive at a "random" representative sample.

For the sample study

(ii) Production, demand, and stock levels over at least 3 years - to include trends, i.e. those items where consumption is reducing, or increasing, or tending to remain constant.

(iii) Production data must discriminate between "Hand"

Critique

This summary was, of course, written around the proposal to confine the study to a small sample. Taking the study to cover all the various "Lines", we find that paragraphs 9(c)(i), (ii) were done, (iii) the problem of flexibility was a major consideration, (iv) the effect of demand on production was constantly under review, (v) costs were not in fact examined in the part of the project that is covered by this thesis, (vi) although much reading was done, no help was actually "sought", as the problem turned out to be special.

Appreciation | Critique

method and "Machine" methods of manufacture, to assess the effect of stopping "Hand" production, and the consequent effect on flexibility.

(iv) Distribution data - the effect on stock levels required due to transit time, and the changes caused by the change in business. Will demand continue to alter, and if so how will this affect production?

(v) Costs of production, storage, transport, handling, etc. will be required over the same period, to examine their effect on storage capacity.

(vi) Other sources should be approached for help (see Factor 8).

VISIT TO A PROPANE REFORMING UNIT

Date: Thursday 6 August 1964

Conditions on site: Poor - drizzling and muddy underfoot

Object of visit: The object of the visit was to see typical site working conditions, and in particular the problems of site control and supervision

Description:

The party consisted of the local Manager of Company "X"; Mr. G.W. Hannan, Sunderland Technical College; and myself.

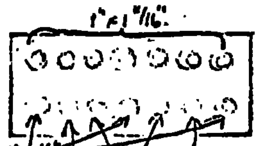
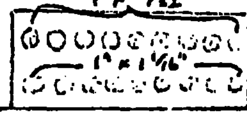
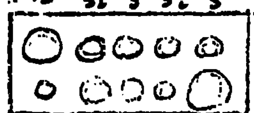
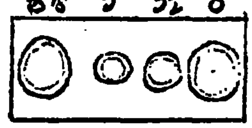
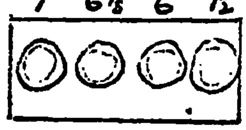
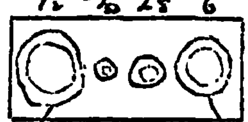
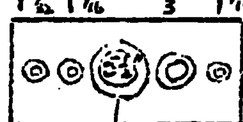
Work on site was proceeding on two main methods of insulation. First we saw a large cylindrical tank being insulated by means of foamed polyurethane. Formwork had been erected round the tank, and the insulating material, which arrives on site as two different liquids contained in drums, is pumped into the formwork in the correct proportions. On mixing the two liquids, the material sets into a hard sponge-like substance with very good insulating properties.

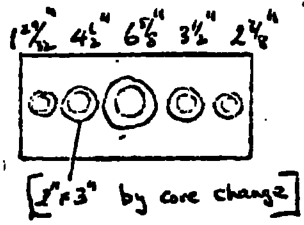
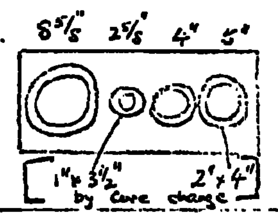
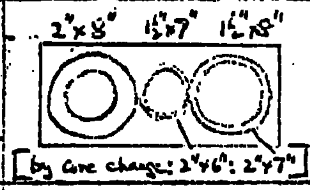
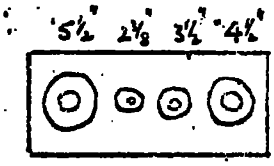
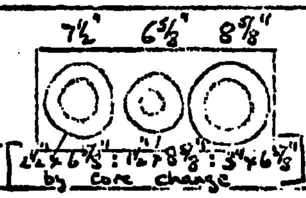
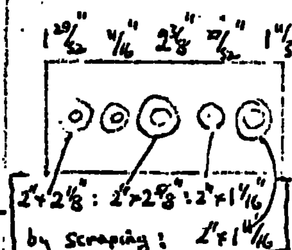
The problem with this material is connected with its high cost. Only responsible individuals can be entrusted with the job of using the material, as any mistake in the proportions of each liquid used could involve the Company in heavy losses financially. This method of insulation is comparatively new - not more than two years old.

The second method of insulation being used on the site was the use of the more standard materials, such as 85% Magnesia, and Calcium Silicate ("Paratemp") for the insulation of outdoor pipework, ducting, outlet flues, valves, fractionating towers, etc. Considerable problems exist in this sort of work. The customer usually requires work to be carried out progressively, so that the plant can be brought on stream successively, one section at a time. There are problems connected with the erection of scaffolding, and with the dangerous type of work, fixing insulation high up on a tower. There is also likely to be interaction between the pipework erectors and the insulating contractors, and frequently the shape of pipework may require modification to enable insulation to be carried out effectively.

Apart from these complications, the impression of work on site was gained of a small number of men, working very much on their own in difficult and sometimes dangerous positions.

Relevant Extract of Mould Data Sheets.

SIZES: Thickness	SIZES: O.D. of pipe	NO. OFF	DRY WEIGHT (lb): Per Piece	DRY WEIGHT (lb): Per Size	AVERAGE CYCLES PER WEEK (15 SHIFT): SUPERMAG	AVERAGE CYCLES PER WEEK (15 SHIFT): PARATEMP	OUTPUT/WEEK/SIZE: SUPERMAG Wt (lb)	OUTPUT/WEEK/SIZE: SUPERMAG Lin. Ft.	OUTPUT/WEEK/SIZE: PARATEMP Wt (lb)	OUTPUT/WEEK/SIZE: PARATEMP Lin. Ft.	LAYOUT DETAILS AND CORE CHANGE SIZES (I, G, F)	STATION
1"	11/16"	2	1.55	3.10			837	1,620	657	1,260	1"×1 11/16"  1½"×1 1/16" 1"×2 1/8" 1"×11/16"	22
1"	1 11/16"	7	2.21	15.47	270	210	4,170	5,670	3,246	4,410		
1"	2 1/8"	2	2.74	5.48			1,480	1,620	1,152	1,260		
1½"	1 1/16"	3	3.39	10.17			2,745	2,430	2,136	1,890		
				34.22			9,232	11,340	7,186	8,820		
1"	27/32"	9	1.78	16.12			4,355	7,290	3,387	5,670	1"×27/32"  1"×1 1/16"	20
1"	1 1/16"	9	1.84	16.56	270	210	4,470	7,290	3,480	5,670		
			-	32.68			8,825	14,580	6,867	11,340		
1"	1 11/32"	16	2.21	35.36	270	210	9,550	12,960	7,420	10,080	2 rows of 8.	21
1"	1 29/32"	14	2.50	35.0	270	210	9,450	11,340	7,350	8,820	2 rows of 7	23
1"	2 3/8"	14	3.10	43.4	270	210	11,720	11,340	9,120	8,820	2 rows of 7	18
1"	2 5/8"	1	3.16	3.16			853	810	663	630	4½" 3½" 3" 3½" 3"  2 5/8" 3½" 4" 3" 4½"	24
1"	3"	3	3.49	10.47	270	210	2,823	2,430	2,196	1,890		
1"	3½"	3	3.92	11.76			3,173	2,430	2,468	1,890		
1"	4"	1	4.36	4.36			1,177	810	915	630		
1"	4½"	2	4.78	9.56			2,580	1,620	2,005	1,260		
				39.31			10,610	8,100	8,250	6,300		
1"	5"	1	5.22		270	210	1,410	810	1,097	630	8 5/8" 5" 5½" 8" 	14
1"	5½"	1	5.64				1,523	810	1,186	630		
1"	8"	1	7.81				2,107	810	1,640	630		
1"	8 5/8"	1	8.17				2,206	810	1,716	630		
				26.84			7,250	3,240	5,640	2,520		
1"	6"	1	6.09				1,644	810	1,279	630	7" 6 5/8" 6" 7½" 	15
1"	6 5/8"	1	6.50		270	210	1,755	810	1,365	630		
1"	7"	1	6.94				1,873	810	1,458	630		
1"	7½"	1	7.39				1,995	810	1,551	630		
				26.92			7,270	3,240	5,655	2,520		
1½"	27/32"	1	3.32				896	810	697	630	7½" 27/32" 2 1/8" 6"  [1"×8 5/8" by core change 2"×5"]	11
1½"	2 1/8"	1	4.76		270	210	1,283	810	998	630		
1½"	6"	1	9.73				2,626	810	2,043	630		
1½"	7½"	1	11.61				3,134	810	2,438	630		
				29.42			7,940	3,240	6,175	2,520		
1½"	1 1/16"	1	3.39				916	810	712	630	1½" 1 11/16" 3" 1 1/16"  [1"×6 5/8" by core change]	17
1½"	1 11/32"	1	3.98		270	210	1,075	810	836	630		
1½"	1 11/16"	1	4.18				1,128	810	878	630		
1½"	3"	1	5.97				1,613	810	1,253	630		
1½"	5½"	1	8.41				2,270	810	1,766	630		
				25.93			7,002	4,050	5,445	3,150		

SIZES		NO.	DRY WEIGHT (lb)		AVERAGE GROSS PER WEEK (15 SHIFTS)		OUTPUT / WEEK / SIZE				LAYOUT DETAILS AND CORE CHANGE SIZES.	STATION
Thickness	O.D. of pipe	OFF	Per Piece	Per Size	SUPERMAG	PARATEMP	SUPERMAG Wt. (lb)	SUPERMAG Lin. Ft.	PARATEMP Wt. (lb)	PARATEMP Lin. Ft.		
1½"	1 29/32"	1	4·71				1,270	810	988	630		16
1½"	2⅜"	1	5·31		270	210	1,433	810	1,116	630		
1½"	3½"	1	6·53				1,763	810	1,372	630		
1½"	4½"	1	7·86				2,122	810	1,650	630		
1½"	6⅝"	1	10·40				2,807	810	2,185	630		
				34·81			9,395	4,050	7,311	3,150		
1½"	2⅝"	1	5·42				1,464	810	1,139	630		10
1½"	4"	1	7·17		270	210	1,937	810	1,506	630		
1½"	5"	1	8·41				2,270	810	1,766	630		
1½"	8⅝"	1	12·93				3,492	810	2,714	630		
				33·93			9,163	3,240	7,125	2,520		
1½"	7"	1	11·09				2,995	810	2,330	630		–
1½"	8"	1	12·39		270	210	3,344	810	2,602	630		
2"	8"	1	17·38				4,694	810	3,650	630		
				40·86			11,030	2430	8,582	1,890		
2"	2⅜"	1	7·85				2,119	810	1,647	630		9
2"	3½"	1	9·51		270	210	2,566	810	1,996	630		
2"	4½"	1	11·28				3,047	810	2,370	630		
2"	5½"	1	13·04				3,518	810	2,735	630		
				41·68			11,250	3,240	8,748	2,520		
2"	6⅝"	1	14·71				3,970	810	3,087	630		8
2"	7½"	1	16·57		270	210	4,420	810	3,440	630		
2"	8⅝"	1	18·13				4,895	810	3,806	630		
				49·21			13,285	2430	10,333	1,890		
2"	11/16"	1	4·63				1,250	810	972	630		13
2"	27/32"	1	5·35		270	210	1,443	810	1,123	630		
2"	1 11/32"	1	6·25				1,687	810	1,311	630		
2"	1 29/32"	1	7·09				1,914	810	1,489	630		
2"	2⅜"	1	7·85				2,119	810	1,647	630		
				31·17			8,413	4,050	6,542	3,150		

Metaplastic

Case Study The ~~[illegible]~~ Company Despatches.

Appendix 3D

1.0 inches thick

	1960			1961			1962			1963			1964			1960 - 1964		
dia	high	low	av	high	low	av	high	low	av	high	low	av	high	low	av	high	low	av
1	4380	421	1871	3972	117	1883	3702	474	1938	4758	566	2777	6150	678	3396	6150	117	2373
2	19036	5808	10874	18569	8493	13348	22438	6890	14720	22113	5150	12561	20291	9606	14757	22438	5150	13253
3	30426	7598	15711	26514	10607	15974	27580	10395	15118	22577	6053	13395	29258	11862	16208	30426	6063	15281
4	21187	10832	15084	27024	5614	19757	27898	10118	19560	22077	8200	18338	25981	13076	19881	27898	5614	18123
5	13453	3687	9824	14953	7668	11321	14723	9093	11970	18268	5375	9946	17615	7272	12574	18268	3687	11048
6	17249	4487	10929	15432	8792	12721	14886	5956	12452	16554	7208	12590	21256	9174	14939	21256	4487	12726
7	4778	887	3167	5880	382	3175	5150	1264	2878	6941	1193	3093	5579	1422	3082	6941	382	3078
8	20733	8715	14533	24649	10218	18766	21972	10674	15456	20899	7415	15172	28945	9577	16547	28948	7415	16108
9	4209	90	1864	3926	0	1472	2203	224	984	2070	188	1300	3870	10	1081	4209	0	1341
10	10664	3236	6468	14851	5349	7751	7372	4023	6590	8700	2106	4948	13084	4442	7697	14851	2106	6691
11	15901	5531	8615	21052	4720	11061	17758	4880	9008	13105	4319	7757	14198	5939	9717	21052	4319	9229
12	3345	203	1949	3799	41	1297	5936	40	1732	3279	316	1198	4987	418	1266	5936	40	1489
13	9256	3503	6667	9380	809	3837	13530	2912	6789	12515	3304	6618	10888	5375	7235	13530	809	6429
14	3768	0	1079	407	0	101	1545	0	418	3345	20	968	1107	0	286	3768	0	564
15	3371	600	1416	3814	15	1225	4340	127	1492	2070	107	1405	3437	790	1662	4340	15	1439
16	1101	0	492	351	0	95	1162	0	390	1203	0	236	657	0	112	1203	0	285
17	2939	457	1579	3253	448	1708	6864	183	2177	5023	826	2543	4554	842	2937	6844	183	2189
18	1244	0	316	254	0	40	1841	0	363	2381	0	498	20	0	3	2381	0	244
19	1121	0	282	647	0	134	821	61	322	780	0	287	2039	0	513	2039	0	307
20	609	0	79	209	0	42	433	0	103	627	0	106	292	0	48	627	0	74
21	3276	0	567	3110	0	894	6276	0	1521	1943	20	736	4931	35	1227	6276	0	989

Metaplastics

Case Study The ~~[illegible]~~ Company Despatches.

1.5 inches thick

Mills	1960 high	1960 low	1960 av	1961 high	1961 low	1961 av	1962 high	1962 low	1962 av
1	0	0	0	0	0	0	0	0	0
2	6884	96	1871	6339	35	1320	3564	15	1193
3	3085	0	1382	1752	0	640	4890	76	1087
4	6262	734	3192	11743	1611	3631	8838	503	3476
5	3248	0	1028	2203	101	962	2728	479	1200
6	5409	362	2740	3779	244	1665	8819	1091	2005
7	4498	40	914	1254	0	282	948	0	379
8	8153	1463	3821	4844	1606	3158	9485	974	4108
9	1983	20	533	1234	0	479	984	0	394
10	4278	1035	2813	2886	370	1535	3605	800	2158
11	10473	2565	5283	8542	1135	4464	6879	2886	4694
12	3712	0	955	2978	0	1031	2483	86	931
13	9972	2228	5400	10827	1790	5187	9696	1545	3782
14	2942	0	1206	4289	0	1086	2090	0	[illegible]
15	5462	284	1749	4508	892	2570	5054	132	[illegible]
16	1703	0	338	486	0	149	968	0	384
17	6298	2240	4295	6670	698	3272	6701	[illegible]	[illegible]
18	453	0	105	484	0	105	509	0	169
19	1817	71	911	1514	0	516	1365	0	312
20	1310	0	158	61	0	6	2179	0	290
21	4688	708	2354	6089	0	1655	3717	20	[illegible]

Mills	1963 high	1963 low	1963 av	1964 high	1964 low	1964 av	1960-1964 high	1960-1964 low	1960-1964 av
1	0	0	0	0	0	0	0	0	0
2	1438	0	659	7961	0	1686	7961	0	[illegible]
3	2238	86	889	3945	632	1890	4890	0	1174
4	4600	545	1813	3223	530	1764	11743	508	2776
5	2101	234	787	4222	443	1601	4232	0	1096
6	4994	662	1813	4895	1366	2617	8819	244	2100
7	1040	0	307	3131	0	836	4498	0	[illegible]
8	5157	1070	3134	6083	2080	3605	9485	974	3564
9	861	0	460	3779	30	890	3779	0	849
10	4054	453	2124	4605	985	2765	4605	370	2279
11	8879	1795	3741	9295	2585	4668	10873	1135	4610
12	2483	35	696	1682	0	593	3712	0	861
13	8788	866	3916	11663	2141	4413	11663	866	4538
14	1616	0	462	2677	0	581	4289	0	798
15	3299	101	1172	5171	581	2096	5462	101	[illegible]
16	489	0	113	1218	0	331	1703	0	349
17	9023	690	2861	4411	1249	2509	9083	662	[illegible]
18	423	0	118	894	0	117	894	0	124
19	1203	0	292	1693	66	467	1817	0	499
20	48	0	6	377	0	117	2179	0	118
21	5365	362	1917	3909	950	1898	9365	0	1944

Case Study The Metaplastic [redacted] Company Despatches.

Appendix 3D
(contd)

2.0 inches thick

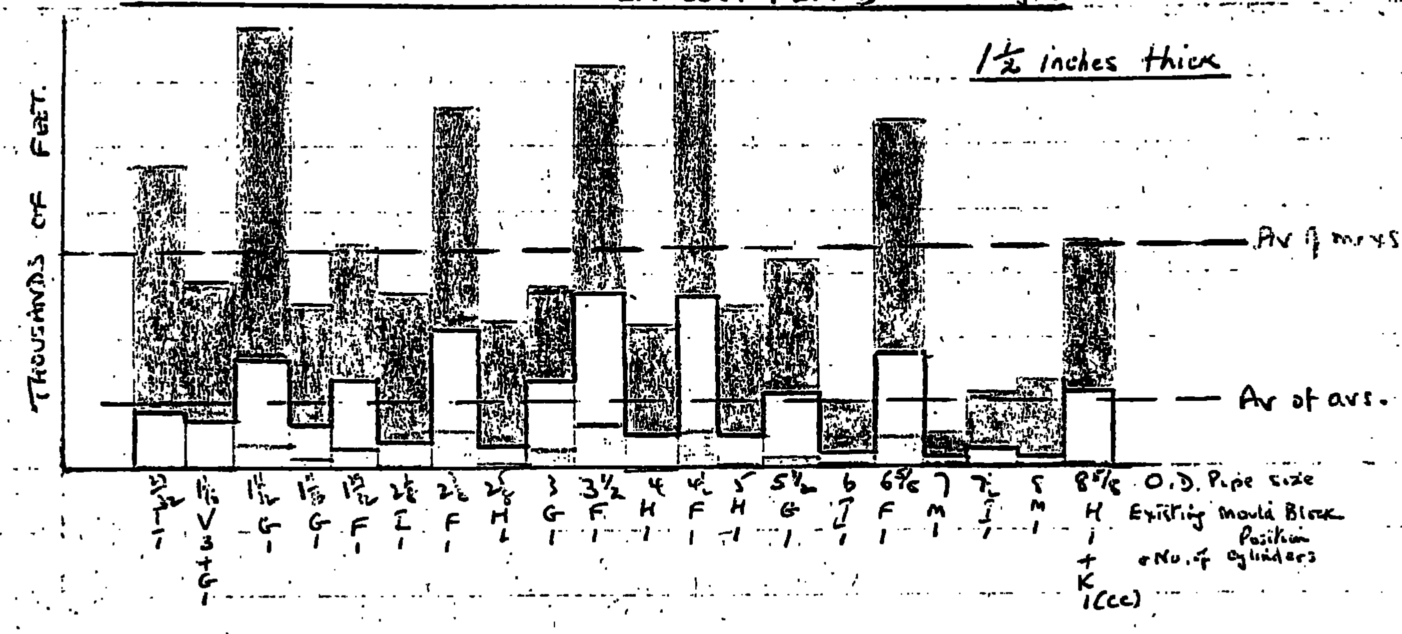
	1960			1961			1962			1963			1964			1960-1984		
dia	high	low	av	high	low	av	high	low	av	high	low	av	high	low	av	high	low	av
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	61	0	5	392	0	98	2820	0	481	84	0	59	596	0	88	2820	0	146
3	509	0	117	509	0	110	101	0	23	458	0	74	254	0	73	509	0	79
4	341	0	84	627	0	127	2682	0	350	560	0	198	407	0	154	2682	0	183
5	443	0	40	60	0	3	2769	0	387	846	0	147	683	0	112	2769	0	137
6	96	0	11	392	16	124	1616	0	428	535	0	236	2310	0	430	2310	0	246
7	203	0	44	173	0	20	190	0	39	933	0	118	504	0	81	933	0	61
8	3668	0	1230	2721	0	1132	2269	203	912	1091	76	702	2223	25	822	3668	0	960
9	474	0	93	0	0	0	418	0	61	280	0	25	254	0	44	474	0	44
10	1693	50	559	3891	0	742	3801	0	909	2498	0	591	1234	0	469	3891	0	654
11	3942	0	1495	3325	0	1004	3086	173	1361	2759	168	1268	3508	137	1225	3942	0	1271
12	1070	0	334	683	0	164	2621	0	666	1086	0	390	1274	0	297	2621	0	370
13	2509	132	1150	3100	372	1337	5360	326	1863	2912	617	1580	3962	433	1931	5360	132	1572
14	1014	0	273	958	0	159	499	0	139	912	0	125	499	0	169	1014	0	172
15	2101	0	521	1392	0	419	2764	0	1108	3274	20	1111	3228	122	1531	3274		[illegible]
16	591	0	188	455	0	79	224	0	40	494	0	122	724	0	166	724	0	118
17	3949	418	1378	2412	346	1222	4623	203	1623	4924	127	2237	3779	1285	2561	4924	127	1808
18	122	0	18	367	0	64	754	0	154	407	0	71	178	0	56	754	0	73
19	968	0	319	499	0	156	1336	0	463	2289	0	861	2988	0	508	2988	0	458
20	632	0	61	346	0	50	979	0	115	254	0	49	265	0	32	979	0	61
21	3626	152	1446	1790	30	690	3518	254	1264	3269	96	1002	2850	56	1404	3626	30	1161

CASE STUDY THE THERMICA COMPANY DESPATCHES.

1964.

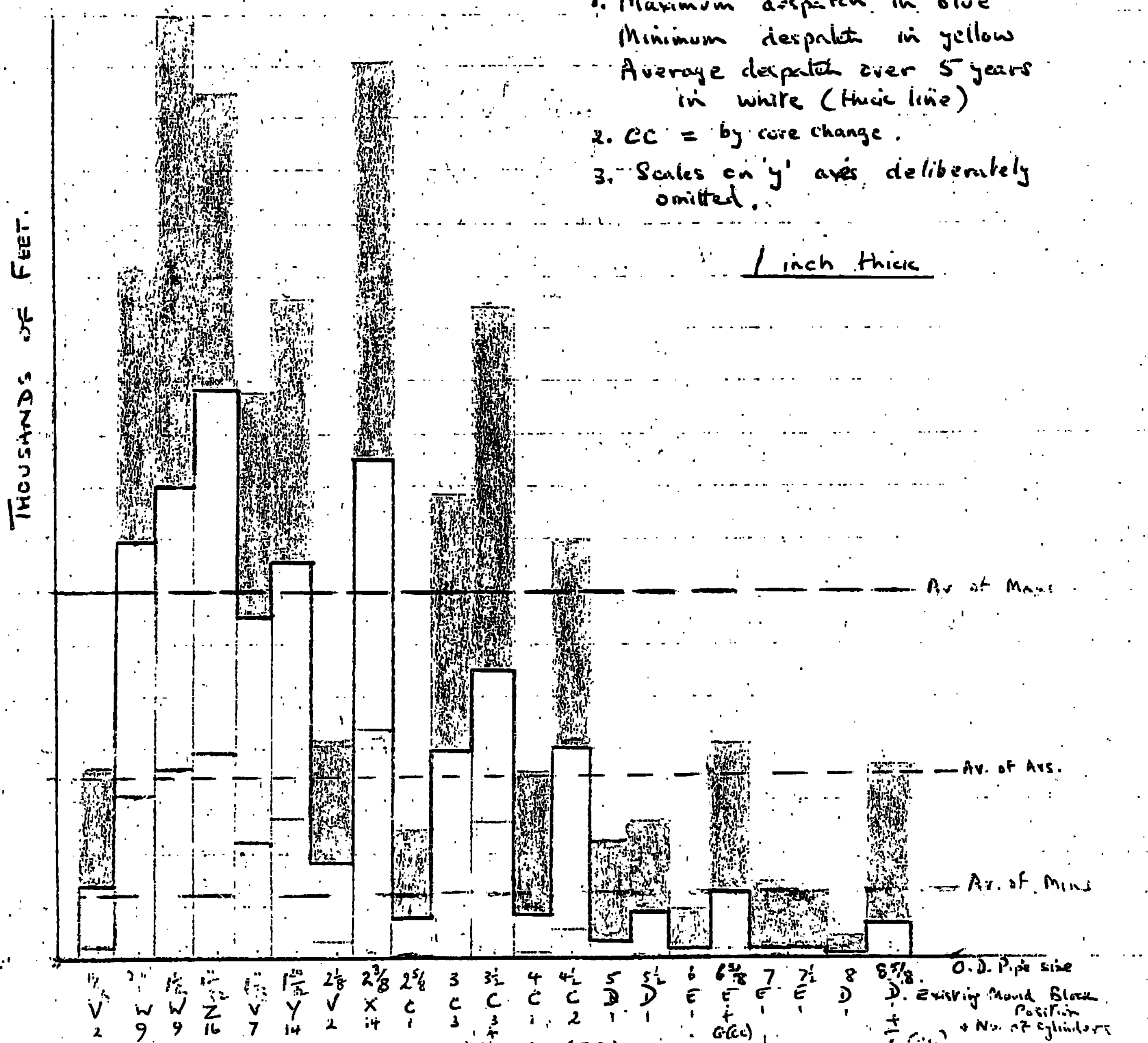
	2.5 inch thick.			3.0 inch thick.			
	High	Low	Av.	High	Low	Av.	Code
1	0	0	0	0	0	0	11/16
2	0	0	0	0	0	0	27/32
3	0	0	0	0	0	0	1 1/16
4	5	0	0	0	0	0	1 11/32
5	204	0	17	0	0	0	1 11/16
6	148	0	24	0	0	0	1 29/32
7	0	0	0	0	0	0	2 1/8
8	20	0	2	0	0	0	2 3/8
9	0	0	0	0	0	0	2 5/8
10	15	0	2	0	0	0	3
11	163	0	20	51	0	4	3 1/2
12	530	0	44	0	0	0	4
13	994	0	231	5	0	0	4 1/2
14	3	0	0	0	0	0	5
15	224	0	20	0	0	0	5 1/2
16	0	0	0	0	0	0	6
17	1697	0	663	173	0	22	6 5/8
18	0	0	0	0	0	0	7
19	1510	0	602	0	0	0	7 1/2
20	0	0	0	0	0	0	8
21	97	0	8	148	0	12	8 5/8

SUPERMAG DESPATCHES PER COST PERIOD (over 5 yrs) APPENDIX 3E



Notes.

1. Maximum despatch in blue
   Minimum despatch in yellow
   Average despatch over 5 years in white (thick line)
2. CC = by core change.
3. Scales on 'y' axes deliberately omitted.



COST PERIOD..8/..........

WEEK COMMENCING MONDAY..19/7/........

Appendix 3F

MASTER PRODUCTION STOCK & DEMAND SHEET

SUPER-MAGNESIA

	1" thick Super-Magnesia				On Order up to & incl. sub. per.	1½" thick Super-Magnesia				On Order up to & incl. sub. per.	2" thick Super-Magnesia				On Order up to & incl. sub. per.
	Ptnl. Wkly make	Act. make	Stock Rough	Stock Mach. & pkd		Ptnl. Wkly make	Act. make	Stock Rough	Stock Mach. & pkd		Ptnl. Wkly make	Act. make	Stock Rough	Stock Mach. & pkd	
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
16															
16	1200	2520		1950	2532					150		315		324	
33	5400	1958		8000	2081	600	500		1900	225				450	
16	5400	3520		4150	5120	600	1335		7300	1701					
/32	9600	5070		1300	5076	600	1515		530	810				324	
/16	4200	3340		1984	6833	600	380		530	273				351	
/32	8400	1500		4994	3022	600	540		1440	150		183		544	
8	3000	1430		9300	1941	600			864	528					
8	2400	3400		8696	2930	600	540			2647	600			3761	252
8	600	183		2134	522	600			1300						
	1800	867		1620	4189	600	380			1979				513	150
	1800	944		1558	3196	600	540			2086	600	532		1122	210
	600	319		1620	705	600	76		335	525				376	1851
	1200	688			4431	600	540		81	2691	600	532		184	1218
	600			1066	402		76		668	420				1123	303
	600				1233	600			200	471	600			794	561
	600			1932	81				935						186
	600	380		114	894	600	540		1998	1108	600	270			1175
	600			1342											
	600			692	456	600			690	27	600			411	747
	600			900											138
	600			450	186	600	347		1050	582	600	270		492	288

208 lin. ft. 6.5/8" x 2½" in stock : 30 ft. on demand

NIL. 6.5/8" x 3" in stock : 30 ft. on demand

COST PERIOD....8/.................

WEEK COMMENCING MONDAY....19.7.............

MASTER PRODUCTION STOCK & DEMAND SHEET

PARATEMP

Appendix 3F (contd)

• e e • h.	1" thick Paratemp Ptnl. Wkly Make.	1" thick Paratemp Act make	1" thick Paratemp Stock Rough	1" thick Paratemp Stock Mach. & pkd.	On Order up to & incl. sub. per.	1½" thick Paratemp Ptnl. Wkly Make.	1½" thick Paratemp Act make	1½" thick Paratemp Stock Rough	1½" thick Paratemp Stock Mach. & pkd.	On Order up to & incl. sub. per.	2" thick Paratemp Ptnl. Wkly Make.	2" thick Paratemp Act make	2" thick Paratemp Stock Rough	2" thick Paratemp Stock Mach & pkd.	On Order up to & incl. sub. per.
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
16															
16					942							158		2874	
32			330	9486	117				3000	72					60
/16				2400	2835				700	1671		158		27	135
1/32				5700	585				500	42				1600	30
/16				263	7[illegible]7				2200	354				390	210
9/32									3200	429				117	
/8				114					2300	276					270
/8				233	1359				270	882				1538	267
/8				2940	138				1800	162					
		158	148	203	1713				7500	306				1900	43
		158		713	471				172	2838				1300	258
		158	72	1956					1200	426				227	507
		158		6232	490				2140					2540	162
				1362					1070	285		155		598	
				648	375				600	120				1600	636
					330				470	288					213
		72		1594	2386				1800	222				333	30
		72		103	120										
				1420	102				1300	243				42	177
				453	417										201
				1183	315				1600	2613				1148	249

645 lin ft $6\frac{5}{8}$" x $2\frac{1}{2}$" in stock 198' in demand

45 lin ft $6\frac{5}{8}$" x 3" in stock NIL in demand

CORE CHANGE

THE RANGE OF POSSIBLE SIZES OF INSULATION WHICH COULD BE PRODUCED USING DIFFERENT SIZED CORES.

THICKNESS OF INSULATION →	1 IN	1½ IN	2 IN	2½ IN	3 IN	Coding for DATA TAPE 4 (see Chap. 6).
	11/16					1
	27/32					2
	1 1/16					3
OUTSIDE	1 11/32					4
	1 11/16	11/16				5
DIAMETER	1 29/32	27/32				6
	2 1/8	1 1/16				7
OF	2 3/8	1 11/32				8
	2 5/8	1 11/16	11/16			9
PIPE	3	1 29/32	27/32			10
		2 1/8	1 1/16			11
TO BE	3½	2 3/8	1 11/32			12
		2 5/8	1 11/16	11/16		13
INSULATED.	4	3	1 29/32	27/32		14
			2 1/8	1 1/16		15
(ie. inside	4½	3½	2 3/8	1 11/32		16
			2 5/8	1 11/16	11/16	17
diameter	5	4	3	1 29/32	27/32	18
				2 1/8	1 1/16	19
of	5½	4½	3½	2 3/8	1 11/32	20
				2 5/8	1 11/16	21
Insulation.)	6	5	4	3	1 29/32	22
					2 1/8	23
IN	6 5/8	5½	4½	3½	2 3/8	24
					2 5/8	25
INCHES.	7	6	5	4	3	26
	7½	6 5/8	5½	4½	3½	27
	8	7	6	5	4	28
	8 5/8	7½	6 5/8	5½	4½	29
		8	7	6	5	30
		8 5/8	7½	6 5/8	5½	31
			8	7	6	32
			8 5/8	7½	6 5/8	33
				8	7	not included
				8 5/8	7½	in coding
					8	list.
					8 5/8	

CHAPTER 4 : MOULD BLOCK CONFIGURATION

(a) POTENTIAL OUTPUT

Having decided to look at the configuration of each mould-block, it appeared that the first step should be to examine carefully the design of the existing mould-blocks in relation to current demand for insulating materials, and to see in what ways the design could be improved. This examination was also carried out in order to design a method, acceptable to the Company, for simulating production in the works.

Turning back to the mould data sheet (Relevant Extract - Appendix 3C) the Output/Week/Size column (Linear Feet) was converted into a "Potential Output per Shift" for supermag and paratemp, by taking 75% (giving an ample allowance for contingencies) of the figures in the Relevant Extract, and dividing them by 15, i.e. 5-day week x 3-shift. Thus, for Mould-block V, 1 inch x $\frac{11"}{16}$,

$$\underline{\text{Supermag}}\ \text{Potential Output per shift} = \frac{75}{100} \times 1620 \times \frac{1}{15} = 81$$

$$\text{Paratemp} \quad " \quad " \quad " \quad = \frac{75}{100} \times 1260 \times \frac{1}{15} = 63$$

In other words, Potential Output per Shift is equal to a fraction of $\frac{1}{20}$ of the Linear Feet figure in the mould data sheet extract.

(b) EXISTING CONFIGURATION

In this way, a table (Appendix 4A) showing Demand/Output for each size in each mould-block was built up for the present configuration. For supermag, "Demand" was taken as the Average Despatch over the five years 1960-1964 inclusive, and in order to show the situation more clearly, a period of TWELVE WEEKS (i.e. three times the normal accounting period) was chosen. Thus the figures for supermag were obtained from the Summary Record of Despatches of supermag - similar to the Table at Appendix 3D - by multiplying the figures in the final column (Average 1960-1964) on each page by three. For paratemp, a similar calculation was made to find the average figures for 1963-1964.

Going through the calculations in Appendix 4A for Mould-block V, in line 1 the Average Demand was 4,128 linear feet of supermag (col. 7) and the potential output per shift was 81 linear feet (col. 5). Hence for supermag, Demand/Output = 4128/81 = 51 - to the nearest whole number larger than the exact figure - which is shown in column 9. Similarly, for paratemp, 306 (col. 8) divided by 63 (col. 6) gives 5 (col. 10). Column 11 is the total number of shifts required to produce 4128 feet of supermag plus 306 feet of paratemp, and is found by adding the contents of columns 9 and 10 (51 + 5 = 56). In the same way, 80 shifts are required to produce the total demand of 1 inch x $1\frac{11}{16}$" insulation, 75 shifts for 1 inch by $2\frac{1}{8}$" insulation, and 40 shifts for $1\frac{1}{2}$ inch x $1\frac{1}{16}$" insulation. The last figure is shown in brackets, as it could also be produced in Mould-block G line 1 - but with only one mould as compared with three in Block V, it would take about three times as many shifts (119 instead of 40).

Examining these four totals, and ignoring for the moment the problem of the two different materials involved, where production obviously cannot be mixed, we find that, unless some of the moulds are blanked off, there will be overproduction of some sizes in order to produce the required amount of 1 inch x $1\frac{11}{16}$" insulation. The 80 shifts needed for this represent 5.3 weeks production (col. 12) and this would involve overproduction (col. 13) of the other sizes in Block V of 24, 5, and 80 shifts.

The same method was used in the case of each mould-block, and only in cases where there were no mixtures of sizes in a mould-block (Blocks Z, Y, X) was there no overproduction. As well as taking no account at present of the need to separate the production of supermag and paratemp, this tabulation also takes no accurate account of the time required for core changing, blanking off, cleaning the moulds, and other interruptions to normal production. A proportion of these is covered by the "contingencies", for which a figure of 75% of the theoretical figure of output was taken - see above.

Even using these average figures (such figures must be used with discretion when considering output rates in a factory), it appears that, on three of the mould-blocks - C, F, H - the production would be insufficient to meet demand in the twelve week period. Only 180 shifts per block would be available, and, for Block C, 1 inch x $4\frac{1}{2}$", 189 shifts would be needed. For Block F, in $1\frac{1}{2}$ inch thickness, $2\frac{3}{8}$" O.D.

would need 250 shifts, $3\frac{1}{2}$" O.D. would need 303, $4\frac{1}{2}$" O.D. would need 319, and $6\frac{5}{8}$" O.D. would need 212 shifts. In the case of Block H, the $1\frac{1}{2}$ inch x $8\frac{5}{8}$" would need 222 shifts.

As well as this failure to meet average requirements in these few cases, a considerable amount of overproduction (see col. 13) would take place, unless careful measures for blanking off were taken, with a consequent drop in total production.

The Table at Appendix 4B shows how the mould-blocks would be allotted to ten of the twenty-three stations. This Table also shows that, at stations 7, 8, 9 and 10, mould-blocks would have to be changed once each at stations 7 and 8, and twice at stations 9 and 10. As was described in section 2 under "Equipment Factors", the mould-blocks are very complicated pieces of equipment, requiring skilled plumbers to install them into position. It would be difficult, therefore, to carry out so many changes, and although, for the purposes of this comparison, it was assumed that each change would take two shifts to complete, in fact it would take longer.

Clearly the situation chosen was artificial. For one thing, only ten of the twenty-three stations were deemed to be available for the Section mould-blocks. Of the remaining thirteen, eight stations were always allotted to the production of slab insulation and the balance of five were assumed to be undergoing maintenance, repair, or core-change - a normal situation in this works.

In other words, this would be an adverse situation for

Production Control, but on the other hand they would be dealing with only the average requirement, so on half the occasions they would have to produce more than these amounts. At the same time, in practice there would not be the requirement to change mould-blocks so frequently, as the five "spare" stations could be successively brought into use, and a small stock of less popular sizes could be maintained, to cater for the sporadic nature of the demand for them.

(c) CONFIGURATION A

Having examined the results obtained from simulating production with the existing configuration, it was decided to devise a drastically changed configuration of moulds in mould-blocks, which was named "Configuration A". The basic plan behind this configuration was to go to the other extreme - each mould-block would produce only one size of section per thickness - but use would be made of core-changing as much as possible; secondly, it was decided to increase the variety of sizes which could be made - as well as all sizes of section insulation up to $8\frac{5}{8}$" diameter, of thicknesses 1 inch, $1\frac{1}{2}$, and 2 inches, the need existed for making insulation of $2\frac{1}{2}$ inches, and 3 inches thick, up to $7\frac{1}{2}$" and $6\frac{5}{8}$" diameter respectively, at least.

Configuration A is shown at Appendix 4C. Due to the basic design of the system, instead of the present 16 mould-blocks, a total of 23 blocks would be required. The facility of core-changing would enable the widest possible range of sizes to be made, but at the same time, only compatible sizes - i.e. those which could be obtained by core-change - of mould were included in any one mould-block. The effect of this would be to eliminate the need for blanking off. The time allowed for changing cores was four hours, which seemed a realistic figure.

Of the 23 mould-blocks planned, only three would be identical with the existing configuration: these were Blocks X, Y, and Z. This was because a separate mould-block was planned for each diameter of pipe at 1 inch thick, except for $2\frac{1}{8}$" and $2\frac{5}{8}$" diameter, which would be obtained by scraping. At $1\frac{1}{2}$ inch thick, four sizes - $1\frac{1}{16}$", $1\frac{11}{16}$", $2\frac{1}{8}$", $2\frac{5}{8}$" - would have to be made by scraping, and these same sizes would also have to be made by scraping at 2, $2\frac{1}{2}$, and 3 inches thick.

The number of moulds in each block was calculated from the present configuration, allowing a corresponding number of moulds to a block in proportion to the sizes to be made. So, as the diameter of each mould increased, the number which could be fitted in to a block became less. The output rates for each mould-block were based on "pro rata" figures to the first simulation. The configuration would enable complete flexibility of production to be achieved, for there was no mixing of sizes, and so no need for overproduction of unwanted sizes, or for blanking off.

Referring to Appendix 4C, the mould-blocks have been given Roman Numbers I to XXII, except for Blocks X, Y, Z, which have retained their original designations. Starting with 1 inch thick moulds, the smallest diameter ($\frac{11}{16}$") was numbered XIX, the next ($\frac{27}{32}$") XX, and $1\frac{1}{16}$" XXI. Then comes

Original Block Z ($1\frac{11}{32}$"). None of these blocks had any possibility of core-change to give different thicknesses of insulation.

The next in size (1 inch x $1\frac{11}{16}$") was numbered XXII, and was the first one in which it was possible to change the core. After this comes Original Block Y: as well as its original cores of $1\frac{29}{32}$" diameter, a new set of cores was assumed, enabling $1\frac{1}{2}$ inch thick x $\frac{27}{32}$" insulation to be made. In both cases the insulation could be scraped to fit the slightly larger diameter pipes of $2\frac{1}{8}$" and $1\frac{1}{16}$" O.D. respectively.

From then on, the mould-blocks were numbered X (letter) (an original one), and then consecutively I to XVI inclusive. Increasing use of core-changing could be made, Blocks X and I having three different sizes of core, Blocks II and III four, and Blocks IV to XII inclusive having five, making all thicknesses of insulation from 1 inch to 3 inches in steps of half an inch. Blocks XIII and XIV dropped to four sizes of core, and the last two, Blocks XV and XVI, to three - 2, $2\frac{1}{2}$, and 3 inch. The different alternative thicknesses and sizes are shown in columns 2-6 in Appendix 4C, and the number of moulds which could be arranged in each block appears in column 7.

The remainder of Appendix 4C was calculated in the same way as Appendix 4A. Columns 8 and 9 give the output rates for supermag and paratemp respectively, calculated as described at the beginning of this chapter. Columns 10 and 11 show the Average Demand for the twelve-week period, which was obtained from Appendix 4A by adding together the Average Demand for the respective sizes shown in detail there. For example, the Demand shown against Mould Block II (Appendix 4C) for supermag - 24,117 feet, including 1215 feet to be scraped, was the sum of the following demands in Appendix 4A:-

Block C,	1 inch x $3\frac{1}{2}$"	16,284
Block F,	$1\frac{1}{2}$ inch x $2\frac{3}{8}$"	6,294
Block H,	$1\frac{1}{2}$ inch x $2\frac{5}{8}$"	969
Block N,	2 inch x $1\frac{11}{32}$")	570
	2 inch x $1\frac{11}{16}$")	
plus	$2\frac{1}{2}$ inch x $\frac{11}{16}$"	-
		24,117

The 1215 feet to be scraped was made up of the 969 feet of $1\frac{1}{2}$ inch x $2\frac{5}{8}$", together with a further 246 feet ex Block N, 2 inch x $1\frac{11}{16}$".

Columns 12, 13 and 14 were obtained, as before, by dividing the Average Demand by the Potential Output per shift, first for supermag and then for paratemp; and finally entering their sum in column 14, which is the total number of shifts which would be required to produce the insulation of those sizes, again ignoring the complication of two different raw materials.

Finally, column 15 shows the number of weeks - at 15 shifts per week - required to produce the average demand. The greatest amount needed was on Mould-block X (Roman Ten), which is 7.2 weeks: this was just over half the allowed period of 12 weeks.

As in the case of the Existing Configuration, a table at Appendix 4D shows how the mould-blocks of Configuration A could be allotted to ten stations. In this case, due to the extra number of mould-blocks - 23 instead of 16 as at present - thirteen mould-block changes would be necessary, but in every case production of twelve weeks demand would be completed in less than ten weeks.

The policy on core-changes for this configuration is less clear. It could be that <u>all</u> moulds in a mould-block would be used to produce the required quantity of one thickness, then all the cores would be changed, and the required quantity of the next thickness produced, and so on. Alternatively, it is possible that two thicknesses could be produced at the same time, some moulds producing 1 inch thick insulation, say, and some $1\frac{1}{2}$ inch thick. It must be borne in mind, of course, that in practice it is likely that Production Control would not know the exact amount of each size and thickness to be made in the forthcoming 12-week period. It is likely, therefore, that a considerable amount of core-changing would be carried out, giving much greater flexibility to Production.

(d) <u>RESULTS OF THE FIRST TRIAL</u>

Examining the results of using Configuration A, it can be seen that:-

1. Production of 12 weeks demand would be completed in every case within 10 weeks. With the existing configuration (see Appendix 4B), at three stations (1, 2, 3) even the 12-week <u>average</u> demand could not be produced in the 12 weeks, and at three other stations (7, 8, 9), production of the average demand would be only just complete within the period. This means that in half the cases the situation at one or more of these stations would be worse than this.

2. There should be little, if any, overproduction of unwanted sizes (or alternatively blanking off). This compares with the considerable overproduction, or blanking off, required in the existing situation.
3. On the other hand, due to the small demand for certain sizes (e.g. Mould-blocks III, V, VII, IX, XI, XIII, XV), there would be considerable under-use of mould-blocks in this configuration.
4. 58 core-changes and 13 mould-block changes as a minimum would be required during the production period. With the existing configuration, only 9 core-changes and 6 mould-block changes would be needed. Clearly, if more use were to be made of core-changing, or mould-block changing, any reduction in the time required to carry out these changes would be worth achieving.
5. A large capital investment would be needed to convert the existing 16 mould-blocks into the new 23 mould-blocks, in which only 3 would be unchanged - i.e. a conversion of 13 existing blocks to a new layout, and the construction of an extra 7 new blocks.

(e) COMMENTS BY THE COMPANY

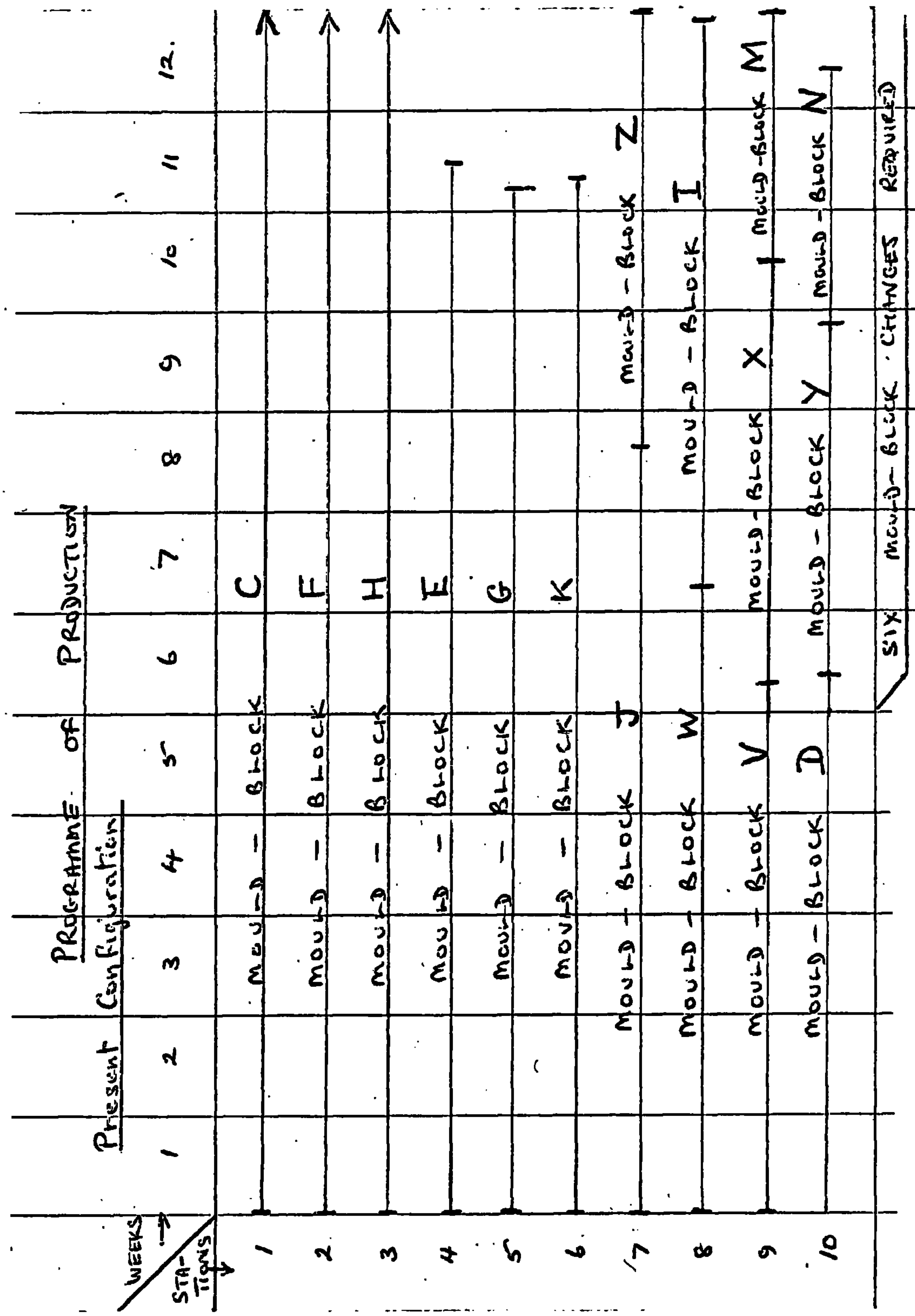
As was mentioned at the beginning of this chapter, the main object of comparing the existing configuration with Configuration A was to test out a method of hand simulation to the satisfaction of the Company. Comments from the Company included:-

1. Compatability: In carrying out this type of simulation, it is necessary to take account of the fact that it is not possible to produce from the same mould-block, at one time, pipe insulation varying in thickness by more than half an inch.
2. Mould-block changing: This is an extremely complicated operation and would take longer than had been allowed for in the simulation. It does not seem at present that this would be a feasible operation on which to plan production.
3. Storage of spare mould-blocks: Following the last comment, mould-blocks are very difficult to store safely when not in use. They take up a lot of space, and great care is needed to avoid damage. This is a further argument against frequent mould-block changing.
4. Capital cost: The cost of making twenty new mould-blocks would be prohibitive.

The conclusion from these results, and the feed-back of comments from the Company, was that a configuration was needed which would avoid the disadvantages enumerated at paragraph 4(d), which would meet the comments of the Company, and yet would possess to a large extent the advantages of Configuration A, giving flexibility and increased productive capacity to Production Control.

(1) PRESENT CONFIGURATION (Mould Data Sheet).

1	2	3	4	5	6	7	8	9	10	11	12	13
MOULD	SIZES.		NO. IN	POTENTIAL OUTPUT PER SHIFT.		AVERAGE DEMAND (12 WEEKS).		DEMAND/OUTPUT.			WEEKS REQD	OVER PRODUCTION
BLOCK.	EXISTING.	BY CORE CHANGE	BLOCK.	SuperMag	Paratemp	Supermag	Paratemp	Super Mag	Para Temp	Total (Shifts)	TO PRODUCE	(Shifts).
V	1in × 11/16	-	2	81	63	4,128	306	51	5	56		24
	× 1 11/16	-	7	284	221	19,497	2,223	69	11	80	5·3	
	× 2 1/8	-	2	81	63	5,433	441	68	7	75		5
	1½in × 1 1/16	-	3	122	95	(2,070)	(2,184)	(17)	(23)	(40)		(80)
W.	1in × 27/32	-	9	365	284	23,892	4,503	66	16	82		11
	× 1 1/16	-	9	365	284	27,021	5,073	75	18	93	6·2	
Z	1in × 1 11/32	-	16	648	504	32,496	6,633	51	13	64	4·3	–
Y	1in × 1 29/32	–	14	567	441	22,464	4,356	40	10	50	3·3	–
X	1in × 2 3/8	–	14	567	441	23,458	4,320	51	10	61	4·1	–
C	1in × 2 5/8	-	1	41	32	2,247	18	55	1	56		124
	× 3	-	3	122	95	11,808	2,301	97	25	122		58
	× 3½	-	3	122	95	16,284	3,813	134	41	175		5
	× 4	-	1	41	32	2,625	612	65	20	85		95
	× 4½	-	2	81	63	11,835	2,592	147	42	189	12 +	
D	1in × 5	-	1			999	309	25	10	35		46
	× 5½	-	1	41	32	2,544	606	62	19	81	5·4	
	× 8	-	1			135	90	4	3	7		74
	× 8 5/8	–	1			2,073	786	51	25	76		5
E	1in × 6	–	1			468	129	12	4	16		141
	× 6 5/8	-	1	41	32	3,867	1,968	95	62	157	10·5	
	× 7	-	1			432	48	11	2	13		144
	× 7½	–	1			543	375	14	12	26		131
I	1½in × 27/32	–	1			2,376	786	58	25	83	5·6	
	× 2 5/8	–	1	41	32	960	150	24	5	29		54
	× 6	2in × 5	1			747	142	19	5	24		59
	× 7½	1in × 8 5/8	1			882	651	22	21	43		40
G	1½in × 1 1/16	–	1			(2,070)	(2,184)	(51)	(68)	(119)		(9)
	× 1 11/32	–	1			4,896	1,053	120	33	153	10·2	
	× 1 9/16	–	1	41	32	1,935	492	48	16	64		89
	× 3	–	1			4,023	906	99	29	128		25
	× 5½	1in × 6 5/8	1			3,222	651	79	21	100		53
F	1½in × 1 29/32	–	1			3,828	1,521	94	48	142		38
	× 2 3/8	–	1			6,294	3,051	154	96	250	12 +	
	× 3½	–	1	41	32	8,136	3,378	200	103	303	12 +	
	× 4½	2in × 3	1			9,255	2,916	227	92	319	12 +	
	× 6 5/8	–	1			5,412	2,529	133	79	212	12 +	
H	1½in × 2 5/8	1in × 3½	1			569	42	24	2	26		154
	× 4	–	1	41	32	1,435	300	37	10	47		133
	× 5	2in × 4	1			1,995	555	49	18	67		113
	× 8 5/8	–	1			5,234	3,006	128	94	222	12 +	
M	1½in × 7	2in × 6	1			426	753	11	25	36	2·4	
	× 8	2in × 7	1	41	32	333	120	9	4	13		~~23~~
	2in × 8	-	1			111	270	3	9	12		24
J	2in × 2 3/8	–	1			(1,704)	(1,002)	(44)	(32)	(76)		(37)
	× 3½	–	1	41	32	2,244	1,059	55	34	89		24
	× 4½	-	1			2,778	1,437	68	45	113	7·6	
						[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		57
K												
N												


PROGRAMME OF PRODUCTION
Present Configuration
WEEKS
STATIONS
1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5 6 7 8 9 10
MOULD - BLOCK C
MOULD - BLOCK F
MOULD - BLOCK H
MOULD - BLOCK E
MOULD - BLOCK G
MOULD - BLOCK K
MOULD - BLOCK J
MOULD - BLOCK Z
MOULD - BLOCK W
MOULD - BLOCK I
MOULD - BLOCK V
MOULD - BLOCK X
MOULD - BLOCK M
MOULD - BLOCK D
MOULD - BLOCK Y
MOULD - BLOCK N
SIX MOULD - BLOCK CHANGES REQUIRED

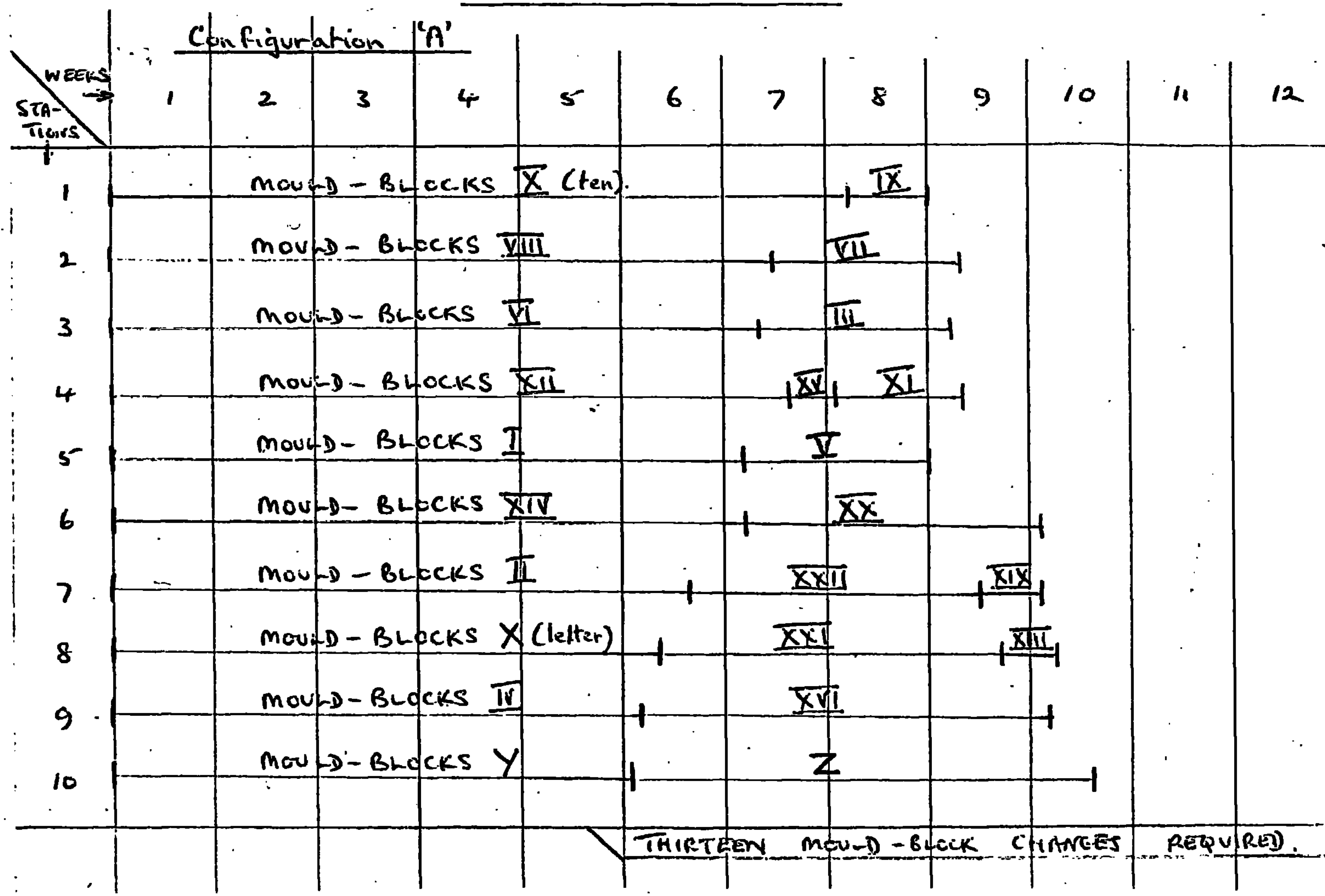
(ii) CONFIGURATION 'A'

1 Block No.	2 Moulds in Block (by one change) 1"	3 1½"	4 2"	5 2½"	6 3"	7 No in Block	8 Potential Output per Shift (75% Mould data sheet Rates ÷ 15 shifts/week) (Feet) Supermag	9 Paratemp	10 Average Demand (12 weeks) (feet) Supermag	11 Paratemp	12 Demand/Output (Shifts) Supermag	13 Paratemp	14 Total	15 Weeks Reqd to Produce	
[illegible]	11/16					18	729	567	4,128	306	6	1	7	0.5	
[illegible]	27/32					18	729	567	23,892	4,503	33	8	41	2.8	
[illegible]	1 1/16					18	729	567	27,021	5,073	38	9	47	3.2	
[illegible]	1 11/32					16	648	504	32,496	6,633	51	14	65	4.3	existing block.
[illegible]	1 11/16	11/16				14	567	441	19,497	2,223	35	6	41	2.8	
[illegible]	1 29/32 (2 1/8 S)	27/32 (1 1/16 S)				14	567	441	32,343 [incl. 7,503 S	7,767 2,625 S]	58	18	76	5.1	existing block.
[illegible]	2 3/8 (2 5/8 S)	1 11/32 (1 11/16 S)	11/16			14	567	441	37,536 [4,182 S	5,883 510 S]	67	14	81	5.4	existing block.
[illegible]	3	1 29/32 (2 1/8 S)	27/32 (1 1/16 S)			10	405	315	31,395 [1,101 S	4,548 594 S]	78	15	93	6.2	
[illegible]	3 1/2	2 3/8 (2 5/8 S)	1 11/32 (1 11/16 S)	11/16		10	405	315	24,177 [1,215 S	7,383 246 S]	60	24	84	5.6	
[illegible]	4	3	1 29/32 (2 1/8 S)	27/32 (1 1/16 S)		10	405	315	7,188 [105 S	2,217 12 S]	18	8	26	1.8	
[illegible]	4 1/2	3 1/2	2 3/8 (2 5/8 S)	1 11/32 (1 11/16 S)	11/16	10	405	315	21,765 [99 S	7,128 81 S]	54	23	77	5.2	
[illegible]	5	4	3	1 29/32 (2 1/8 S)	27/32 (1 1/16 S)	5	203	157	3,681	924	19	6	25	1.7	
[illegible]	5 1/2	4 1/2	3 1/2	2 3/8 (2 5/8 S)	1 11/32 (1 11/16 S)	5	203	157	12,894	4,785 [9 S]	64	31	95	6.3	
[illegible]	6	5	4	3	1 29/32 (2 1/8 S)	4	162	126	2,469	984	16	8	24	1.6	
[illegible]	6 5/8	5 1/2	4 1/2	3 1/2	2 3/8 (2 5/8 S)	4	162	126	9,903	4,377	62	35	97	6.5	
[illegible]	7	6	5	4	3	4	162	126	1,263	213	8	2	10	0.7	
[illegible]	7 1/2	6 5/8	5 1/2	4 1/2	3 1/2	3	121	95	8,028	3,756	67	40	107	7.2	
[illegible]	8	7	6	5	4	3	121	95	561	882	5	10	15	1.0	
[illegible]	8 5/8	7 1/2	6 5/8	5 1/2	4 1/2	3	121	95	6,174	4,563	51	49	100	6.7	
[illegible]		8	7	6	5	3	121	95	333	213	3	3	6	0.4	
[illegible]		8 5/8	7 1/2	6 5/8	5 1/2	3	121	95	5,214	4,491	44	48	92	6.2	
[illegible]			8	7	6	3	121	95	111	276	1	3	4	0.3	
[illegible]			8 5/8	7 1/2	6 5/8	3	121	95	3,153	2,964	26	32	58	3.9	

3 Mould Bl

S

PROGRAMME OF PRODUCTION



CHAPTER 5 : HAND SIMULATION

(a) RE-EXAMINATION OF CONFIGURATION A

As a first step, Configuration A was examined further, with the inclusion of extra mould-blocks to avoid the need for scraping. The new blocks were labelled YA, YB, XA, XB, IA, IB, etc., through to IVA, IVB. This configuration is shown at Appendix 5A.

In this tabulation, the 29 blocks are listed at column 1, with the main size (smallest thickness) each block would make in column 2. Sizes which could be made by core-change are apparent by reference back to Appendix 4C. Columns 3 and 4 show the potential output per shift for one mould only, of supermag and paratemp. Columns 5 and 6 show the average 4-weekly demand in feet for the two materials. Columns 7 and 8 give the Demand/Output calculations (column 7 = Column 5/ Column 3: Column 8 = Column 6/Column 4), and Column 9 sums the contents of Columns 7 and 8, giving the total number of shifts required for one mould cylinder to produce the average demand for both materials. Finally, the totals in Column 9 are divided by 60 (number of shifts in a 4-week period) to give the theoretical figure of the number of mould cylinders required to produce the average demand in the 4-week period concerned. From this could be seen the relative popularity of the particular size - or rather range of sizes - and the figures could therefore be used as a guide in planning the relative number of mould cylinders to be incorporated in any future configuration.

It should be noted that, by using average figures to compare the popularity of each range of sizes, we did not make the mistake of planning to produce these absolute quantities. At this stage we were only concerned with planning the proportional numbers of cylinders in a new configuration.

(b) PLANNING A NEW CONFIGURATION

The theoretical number of mould cylinders calculated at Column 10 of Appendix 5A were then sorted into an ascending sequence, which is shown in Column (g) of Appendix 5B. The corresponding Mould Block No. of Configuration A appears in Column (a) of the table, and Columns (b) to (f) inclusive show the respective sizes and thicknesses of the insulation sections which could be produced by core-change. In Column (h) is shown the nearest whole number greater than Column (g) plus 20%.

At the right hand side of the table, the existing configuration is set out in a way to correspond with the layout of Configuration A, thus showing where each cylinder size could be found at present. So Column (k) lists the existing Mould Block Number, and Columns (l) to (p) inclusive show the respective sizes and thicknesses of insulation sections which could in the existing scheme be produced by core-change and scraping. Finally, Column (q) lists the number of cylinders available for production under the existing configuration.

By setting out the information in the form of Appendix 5B, an impression could be obtained from Columns (h) and (q) as to where there was over- or under-capacity in the works. In particular, the existence of under-capacity (e.g. referring to Column (a), Block XVI, VI, IVA, IIA) is important to note.

Columns (i) and (j) of Appendix 5B have not so far been discussed, but will be referred to later.

(c) <u>MOULD-BLOCK MODEL</u>

At this stage in the planning of a new configuration, it was necessary to consider the geometric constraints which would determine the number and spacing of cylinders in mould-blocks. For this purpose, a half-scale model was prepared on a drawing board of the cross section of a mould-block (44" x 16"). Circles of the appropriate diameter were cut out of card to represent the external diameters of the various sizes of pipe insulation. The radius of each circular disc was increased by ¾ inch, to allow a clearance of 1½ inches between each cylinder in a mould. For the same reason, an inner rectangle, ¾ inch smaller all round, was drawn inside the cross section of the mould-block.

Bearing in mind the need to minimize the number of new mould-blocks to be made because of their high capital cost, a series of experiments was carried out on the model, on the basis of the minimum number of cylinders required (Appendix 5B, Column (h)).

It appeared possible from Column (h) of Appendix 5B to retain the existing mould-blocks V, W, X, Y, Z, but providing extra cores for blocks V, X, and Y to enable the range of sizes to be made (i.e. Block V - 1 inch x $1\frac{11}{16}''$ and $1\frac{1}{2}$ inch x $\frac{11}{16}''$, plus 1 inch x $2\frac{1}{8}''$ and $1\frac{1}{2}$ inch x $1\frac{1}{16}''$, as well as 1 inch x $\frac{11}{16}''$: Block X - 1 inch x $2\frac{3}{8}''$ and $1\frac{1}{2}$ inch x $1\frac{11}{32}''$: Block Y - 1 inch x $1\frac{29}{32}''$ and $1\frac{1}{2}$ inch x $\frac{27}{32}''$).

The remaining range of sizes were then sorted as far as possible into compatible pairs, and arranged together in the model so that the number of mould cylinders corresponded approximately to Column (h) of Appendix 5B, taking into account the constraints of the geometrical dimensions of the mould-block. Also, as far as possible, each new mould-block was designed to contain mould cylinders of roughly similar pipe size.

By this means, it was possible to fit a new configuration into 14 mould-blocks although one block (labelled QA,QB) would have to be 18 inches in width instead of the normal 16 inches. The Company already had one mould-block of this size, which would therefore be an acceptable arrangement.

(d) <u>CONFIGURATION B</u>

On the basis of this work, Configuration B was devised. This arrangement consisted of splitting the existing mould-blocks C, D, E into pairs of compatible sizes, the new blocks being labelled P and Q, R and S, T and U respectively. In addition, new mould-blocks labelled H and M were planned, the remainder being grouped into a new block L. This configuration is shown in the two centre columns (i) and (j) of

Appendix 5B - Column (i) showing the number of cylinders, and Column (j) the Block Label - the coding used being two letter. Configuration B is shown in more detail in the first seven columns of Appendix 5C headed "Hand Simulation".

It would be possible with Configuration B to manufacture insulation sections of all thicknesses from ½ inch to 3 inches, for all pipe sizes currently in use, with the exception of the following (listed by combinations which could be made by core-change):-

Thickness	$2\frac{1}{2}$ inches	3 inches
O.D. Pipe size Combinations	$2\frac{1}{8}$	$1\frac{1}{16}$
	$2\frac{5}{8}$	$1\frac{11}{16}$
		$2\frac{1}{8}$
		$2\frac{5}{8}$
	8	7
	$8\frac{5}{8}$	$7\frac{1}{2}$
		8
		$8\frac{5}{8}$

The smaller sizes ($1\frac{1}{16}$" up to $2\frac{5}{8}$") could be made by scraping the sizes $\frac{27}{32}$", $1\frac{11}{32}$", $1\frac{29}{32}$", and $2\frac{3}{8}$", at the appropriate thickness ($2\frac{1}{2}$ inch or 3 inch), which could be produced in Configuration B. At the time of the project there was very little demand for any of these sizes, possibly because they could not be precision moulded, but would have to be made by (hand) pressure moulding. Even in 1965 and 1966, the only recorded production of these sizes was as follows (quantities in feet):-

2½ inch thick	3 inch thick
$2\frac{1}{8}$" - 48 (Paratemp) 1966	$1\frac{1}{16}$" Nil
$2\frac{5}{8}$" - Nil	$1\frac{11}{16}$" (39 (Paratemp) 1965 (123 (Paratemp) 1966
	$2\frac{1}{8}$" Nil
	$2\frac{5}{8}$" Nil
8" - Nil	7" 36 (Supermag) 1966
$8\frac{5}{8}$" (201 (Supermag) 1965 (309 (Paratemp) 1966	7½" 6 (Paratemp) 1966
	8" Nil
	$8\frac{5}{8}$" 21 (Paratemp) 1965

If any appreciable demand for these thicknesses and sizes of insulation sections came about, it might be necessary to construct additional blocks to make them. The use of liners as well as different sized cores could be investigated to cut down the number of new mould-blocks necessary.

(e) <u>DEMAND</u>

Up to this point, all calculations were based on quantities of insulation sections actually <u>despatched</u> from the factory in the particular time under consideration - usually multiples of the 4-weekly Cost Periods used for accounting purposes. At this stage it was considered desirable to use <u>Sales Demand</u> quantities for the proposed simulation of production. As was stated in chapter 3 above, a data processing operation, known as "Company X Works Orders Processing I" was being carried out for the Sales Department concurrently. It was decided to use the Order quantities for Cost Periods 3 to 6 inclusive for 1965 for the simulation.

The first operation, then, was to extract the required figures from the relevant Cost Periods of the D.P. operation. These were listed under separate heads as follows (all O.D. pipe sizes):-

American standard sizes	($6\frac{5}{8}$", $7\frac{5}{8}$", $8\frac{5}{8}$")
British standard sizes	($\frac{27}{32}$" up to $8\frac{5}{8}$" inclusive)
Copper pipe sizes	($\frac{1}{2}$" up to 4" inclusive)
Non-standard sizes	(0 to $8\frac{5}{8}$" inclusive)

In itself, this calculation of total demand, by sizes, was laborious, entailing the grouping of up to three different figures for every thickness from 1 inch to 2 inch, and for a few sizes at $2\frac{1}{2}$ inch and 3 inch thickness. The calculation had to be done separately, of course, for the two materials - supermag and paratemp.

(f) HAND SIMULATION WITH CONFIGURATION B

Having obtained the correct demand figures for the four 1965 cost periods, the next requirement was to carry out the hand simulation of production, using Configuration B. For this purpose, the tabulation at Appendix 5C was prepared.

In the left hand part of the table was listed the data appertaining to Configuration B. Thus, in Column (a) appears the Mould Block No. - ZA, XA, etc. Where there was more than one range of insulation sizes produced in one block, the second, third, etc. ranges are given the suffix B, C, etc. to make reference to them easier.

In Columns (b) to (f) are listed the sizes which each range of cylinders in a mould-block could produce at the various thicknesses, 1 inch to 3 inch. In Column (g) are shown the number of cylinders of each size contained in the mould-block.

On the right hand half of the table appear the calculations necessary to support the simulation. Columns (h), (i), (j), (k) and (l) show the number of shifts required to make the quantities of insulation ordered during the cost period concerned, for supermag and paratemp respectively, of 1 inch, $1\frac{1}{2}$ inch, 2 inch, $2\frac{1}{2}$ inch and 3 inch thickness.

To explain this in detail, taking ZA, Cost Period 3, the demand for 1 inch thick x $1\frac{11}{32}$" insulation was 13,254 feet supermag, and 2,581 feet paratemp. The potential outputs per shift were 656 (16 x 41) feet and 512 (16 x 32) feet respectively. So the number of shifts required were $\frac{13,254}{656} = 21$ (to nearest whole number above the exact figure) for supermag, and $\frac{2,581}{512} = 5$ for paratemp. In the same way, each demand is turned into a number of shifts for every relevant entry.

The next wide column (m) depicts a Schedule of Production of the material. It is divided into four weeks each of 15 shifts, and bar charted for each mould-block, taking care not to mix materials when there was more than one size range involved. Also, care in scheduling was taken to ensure that the thicknesses of insulation produced in any one mould-block did not vary in size by more than $\frac{1}{2}$ inch.

This type of production scheduling would be carried out for the following cost period at least 3 weeks before the start of the cost period, based on the order forecast from the Sales Department. The schedule might require amendment to cover rush orders, but it could remain the basis of production for that period.

Some of the production scheduling was a trifle complex, particularly when there were more than two size ranges in the mould-block.

The next column (n) details "Balance carried forward to next Cost Period" - where is listed demand which has not been met in the current cost period (e.g. in cost period 3, Mould-block T, series TA has 3 shifts of 1 inch thickness paratemp outstanding, and series TB has: 9 shifts of 1 inch thickness, 8 shifts of 1½ inch thickness, and 5 shifts of 2 inch thickness paratemp outstanding.

Column (o) lists "Balance brought forward from last Cost Period" - thus the shortfall in production Block T in cost period 3 is shown again as a balance brought forward in the corresponding column against Block T in cost period 4.

Finally, Column (p) shows the percentage use made in the current cost period of each mould-block. The designation "100+" indicates that there was a shortfall in production, whereas a minus sign (e.g. Cost Period 4, Block T - "82-") indicates that this figure includes the percentage used in making up the previous cost period's shortfall.

(g) THE PRODUCTION SCHEDULE

Taking a critical look at the "Production Schedule" in Column (m) of Appendix C, it must be appreciated that this exercise was carried out in order to see how well Configuration B would cope with actual demands over a number of cost periods.

For the four here considered, the configuration would have managed extremely well - apart from the shortfall for Block T in cost period 3, there would have been a further shortfall in the same Block in cost period 6. Otherwise, only in a few cases has the usage approached 100%.

The scheduling that was carried out here, of course, would not be suitable for actual production. Looking at cost period 3 again, in weeks 1 and 2 all 14 mould-blocks are in use, in week 3 10 mould-blocks are in use, and in week 4 only 5 are in use. Clearly, this would be uneconomical in labour and overheads, and as a very simple second stage, production for Blocks Z, X, Y, M could be rescheduled to weeks 3 and 4. This would effectively level out mould-block usage to 10, 10, 14, 9.

A further rationalization would be needed to level out the quantities of the two different materials used. To illustrate this, in cost period 3 the quantities of the two materials used in mould-blocks was as follows:-

	Supermag	Paratemp	Total
Week 1	$6\frac{1}{2}$	$7\frac{1}{2}$	14 Blocks
Week 2	$6\frac{1}{2}$	$7\frac{1}{2}$	14 Blocks
Week 3	$5\frac{1}{2}$	$4\frac{1}{2}$	10 Blocks
Week 4	4	1	5 Blocks

By chance, the use of the two materials is reasonably evenly divided. But in the first week of cost period 4, for instance, $10\frac{1}{2}$ mould-blocks were turning out supermag, with only $3\frac{1}{2}$ turning out paratemp.

These operations - namely, levelling out weekly mould-block usage, and evening out the quantities of the two materials used - could be carried out most efficiently by using the correct computer program. So, having rationalized the configuration of mould-blocks to something that most nearly fits the production pattern, and having a monthly - or "running monthly" changing each week - sales demand, the logical corollary would be to make use of the facilities of a computer to schedule production in the most economical way, in terms of labour, materials and overheads.

(h) HAND SIMULATION RESULTS

Appendix 5D to this chapter summarizes the results of the Hand Simulation, as far as Percentage Usage of Mould-blocks is concerned. Over the four cost periods under examination, the most heavily used mould-block would be Block T, followed by Blocks V and S. None of the remaining mould-blocks average more than 70% usage over the four periods. Block L, with five different series contained in the one block, looks unsatisfactory, and its use would almost certainly involve the overproduction of some sizes, as it would be impossible to arrange blanking off in such a way as to avoid this happening.

Thus it can be stated that Configuration B would work more satisfactorily than the existing configuration, but is not necessarily the best, even taking into account the desirability of retaining some of the existing mould-blocks (Z, X, W, Y, V).

(i) PHASED PROGRAMME OF CHANGEOVER

Finally, in order to demonstrate the feasibility of changing over to Configuration B, a possible programme to do this, from the existing configuration, without disrupting current production, was prepared. This programme is shown at Appendix 5E, and from this it can be seen that a total of nine new mould-blocks, brought in over six phases, would be required. The final total of mould-blocks would be fourteen for the production of pipe insulation, compared with the sixteen used at present. It was felt that the smaller number should reduce the need to change mould-blocks, which was one of the objects of the configuration.

(j) CONCLUSION

The hand simulation which was carried out with Configuration B was the subject of a report to the Company, in which it was reported that the configuration would be a feasible solution to the problem of finding an arrangement of mould cylinders in blocks which would give flexibility to production control, and at the same time would provide adequate capacity, used in conjunction with a controlled inventory policy. It was pointed out that Configuration B would not necessarily be the optimum arrangement. For this, many different configurations would have to be tried out, using the computer, and compared to see which gave the best results over a larger number of cost periods.

At that stage (March 1966) the Company was urged to carry out the first phase of the conversion programme (Appendix 5E) - namely, the splitting of Mould-block C in two halves (Blocks P and Q), at the same time taking out of use Block N. This would give the Company much needed extra capacity at 1 inch thickness and 3", $3\frac{1}{2}$" and 4" O.D., and also give production control experience in scheduling production in multi-core cylinders.

CONFIGURATION II (with additional blocks to avoid scraping)

MOUND BLOCK No 1	Main Size 2.	Potential output per shift (ONE MOUND) ft. 3.		Av. Demand (4 weeks) ft. 5.	6.	DEMAND/OUTPUT 7.	8.	9.	Total/60 10.
		Supermag	Paratemp	Supermag	Paratemp	Supermag	Paratemp	TOTAL	
XIX	1" × 11/16			1,376	102	34	4	38	0·64
XX	27/32	41	32	7,964	1,501	195	47	242	4·03
XXI	1 1/16			9,007	1,691	220	53	273	4·55
Z	1 11/32			10,832	2,211	265	70	335	5·58
XXII	1 11/16			6,499	741	159	24	183	3·05
YA	1 29/32			8,280	1,714	202	54	256	4·27
YB	2 1/8			2,501	875	61	28	89	1·48
XA	2 3/8			11,118	1,791	272	56	328	5·47
XB	2 5/8			1,394	170	34	6	40	0·67
I A	3			5,298	1,318	130	42	172	2·87
I B	1½" × 2 1/8			367	198	9	7	16	0·26
II A	1" × 3½			7,634	2,379	187	75	262	4·37
II B	1½" × 2 5/8			405	82	10	3	13	0·22
III A	1" × 4			2,361	735	58	23	81	1·35
III B	2" × 2 1/8			35	4	1	1	2	0·03
IV A	1" × 4½			7,222	2,349	177	74	251	4·18
IV B	2" × 2 5/8			33	27	1	1	2	0·03
V	1" × 5			1,227	308	30	10	40	0·67
VI	5½			4,298	1,595	105	50	155	2·58
VII	6			823	328	21	11	32	0·53
VIII	6 5/8			3,301	1,459	81	46	127	2·12
IX	7			419	71	11	3	14	0·23
X	7½			2,676	1,252	66	40	106	1·77
XI	8			187	294	5	10	15	0·25
XII									
[illegible]									

CONFIGURATION 'A' GROUPED BY DEMAND

CONFIGURATION "A"								"B"		PRESENT CONFIGURATION						
Ex mould block No.	Thickness 1"	1½"	2"	2½"	3"	Total demand ÷ 60 (Table I)	No. of cylinders reqd. (+20%)	No. of cylinders proposed (Table IV)		Mould block No	Thickness 1"	1½"	2"	2½"	3"	No of cyls.
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	(q)
III B			2 1/8	1 1/16		0·03	1	1	LD	N			2 1/8 S			1
IV B			2 5/8	1 11/16		0·03	1	1	LE	N			2 5/8 S			1
XV			8	7	6	0·07	1	1	LA	M			8			1
XIII		8	7	6	5	0·10	1	1	MB	M		8	7			1
II B		2 5/8	1 11/16			0·22	1	2	LC	H + N		2 5/8	1 11/16 S			1+1
IX	7	6	5	4	3	0·23	1	1	UB	E + I	7E	6I	5I			1+1
XI	8	7	6	5	4	0·25	1	1	SB	D + M	8D	7M	6M			1+1
I B		2 1/8	1 1/16			0·26	1	2	LB	I + N		2 1/8 I	1 1/16 S			1+1
VII	6	5	4	3	1 29/32	0·53	1	2	TB	E + H	6E	5H	4H			1+1
XIX	11/16					0·64	1	2	VB	V	11/16					2
X B	2 5/8	1 11/16				0·67	1	4	HB	C + G	2 5/8	1 11/16				1+1
V	5	4	3	1 29/32	27/32	0·67	1	2	RB	D+H+F	5	4	3			1+1+1
XVI			8 5/8	7 1/2	6 5/8	0·95	2	2	MA	K			8 5/8		6 5/8	1
III A	4	3	1 29/32	27/32		1·35	2	3	QB	C+G+N	4	3	1 29/32			1+1+1
Y B	2 1/8	1 1/16				1·48	2	5	VC	V+V	2 1/8	1 1/16				2+3
XIV		8 5/8	7 1/2	6 5/8	5 1/2	1·50	2	2	HA	H+K		8 5/8 H	7 1/2 K	6 5/8 K		1+1
XII	8 5/8	7 1/2	6 5/8	5 1/2	4 1/2	1·65	2	2	SA	D+I+K	8 5/8	7 1/2	6 5/8			2+1+1
X	7 1/2	6 5/8	5 1/2	4 1/2	3 1/2	1·77	3	3	UA	E+F+J	7 1/2	6 5/8	5 1/2			1+1+1
VIII	6 5/8	5 1/2	4 1/2	3 1/2	2 3/8	2·12	3	3	TA	E+G+J	6 5/8	5 1/2	4 1/2			1+1+1
VI	5 1/2	4 1/2	3 1/2	2 3/8	1 11/32	2·58	4	4	RA	D+F+J	5 1/2	4 1/2	3 1/2			1+1+1
I A	3	1 29/32	27/32			2·87	4	5	PB	C+F+N	3	1 29/32	27/32			3+1+1
XVII	1 11/16	11/16				3·05	4	7	VA	V	1 11/16					7
XX	27/32					4·03	5	9	WA	W	27/32					9
IV A	4 1/2	3 1/2	2 3/8	1 11/32	11/16	4·18	6	7	QA	C+F+N	4 1/2	3 1/2	2 3/8			2+1+1
Y A	1 29/32	27/32				4·27	6	14	YA	Y+I	1 29/32	27/32				14+1
II A	3 1/2	2 3/8	1 11/32	11/16		4·37	6	7	PA	C+F+N	3 1/2	2 3/8	1 11/32			3+1+1
XXI	1 1/16					4·55	6	9	WB	W	1 1/16					9
K A	2 3/8	1 11/32	11/16			5·47	7	14	XA	X + G	2 3/8	1 11/32				14+1
Z	1 11/32					5·58	7	16	ZA	Z	1 11/32					16

The left hand section of this table is
used to ca
of mould b
the average
size. This
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upward to

The right hand section of this table
shows where each cylinder size is

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MOULD BLOCK	INSULATION THICKNESS 1"	1½"	2"	2½"	3"	No. IN BLOCK	SHIFTS REQ 1" S	1" P	1½" S	1½" P	2" S	2" P
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)		(i)		(j)	
Z A	1 11/32					16	21	5	–	–	–	–
X A	2 3/8	1 11/32				14	19	1	4	1	–	–
W A	27/32					9	32	17	–	–	–	–
W B	1 1/16					9	28	6	–	–	–	–
Y A	1 29/32	27/32				14	15	2	2	0	–	–
V A	1 11/16	11/16				7	27	4	1	2	–	–
V B	11/16					2	20	31	–	–	–	–
V C	2 1/8	1 1/16				5	9	4	7	8	–	–
P A	3½	2 3/8	1 11/32			7	19	4	9	8	0	1
P B	3	1 29/32	27/32			5	11	4	7	1	1	3
Q A	4½	3½	2 3/8	1 11/32		7	14	1	6	5	1	1
Q B	4	3	1 29/32	27/32		3	8	3	6	5	0	1
R A	5½	4½	3½	2 3/8	1 11/32	4	2	3	13	2	5	5
R B	5	4	3	1 29/32	27/32	2	3	4	2	15	11	14
S A	8 5/8	7½	6 5/8	5½	4½	2	1	9	3	3	8	5
S B	8	7	6	5	4	1	0	2	2	10	5	20
T A	6 5/8	5½	4½	3½	2 3/8	3	17	3	10	0	11	5
T B	6	5	4	3	1 29/32	2	5	9	5	8	7	25
U A	7½	6 5/8	5½	4½	3½	3	3	2	12	1	7	5
U B	7	6	5	4	3	1	2	1	1	10	2	7
H A		8 5/8	7½	6 5/8	5½	2	–	–	9	5	3	12
H B	2 5/8	1 11/16	11/16			4	2	6	6	5	2	3
M A			8 5/8	7½	6 5/8	2	–	–	–	–	1	14
M B		8	7	6	5	1	–	–	0	0	1	7
L A			8	7	6	1	–	–	–	–	2	6
L B		2 1/8	1 1/16			2	–	–	4	12	1	2
L C		2 5/8	1 11/16	11/16		2	–	–	5	7	0	8
L D			2 1/8	1 1/16		1	–	–	–	–	3	29
L E			2 5/8	1 11/16	11/16	1	–	–	–	–	14	21

HAN

MOULD BLOCK		INSULATION THICKNESS 1"	1½"	2"	2½"	3"	No. IN BLOCK	SHIFTS REQ 1" S	P	1½" S	P	2" S	P	S
(a)		(b)	(c)	(d)	(e)	(f)	(g)	(h)		(i)		(j)		
Z	A	1 11/32					16	21	3	–	–	–	–	
X	A	2 3/8	1 11/32				14	18	5	6	0	–	–	
W	A	27/32					9	12	3	–	–	–	–	
W	B	1 1/16					9	22	2	–	–	–	–	
Y	A	1 29/32	27/32				14	7	4	0	1	–	–	–
V	A	1 11/16	11/16				7	16	1	3	1	–	–	–
V	B	11/16					2	32	10	–	–	–	–	–
V	C	2 1/8	1 1/16				5	10	0	1	3	–	–	–
P	A	3 1/2	2 3/8	1 11/32			7	13	3	5	3	0	1	–
P	B	3	1 29/32	27/32			5	15	3	5	1	0	1	–
Q	A	4 1/2	3 1/2	2 3/8	1 11/32		7	15✓	4✓	8✓	3✓	2	1✓	0
Q	B	4	3	1 29/32	27/32		3	4✓	1✓	13✓	0	1	1✓	0
R	A	5 1/2	4 1/2	3 1/2	2 3/8	1 11/32	4	5✓	1	8✓	1	4✓	3	0
R	B	5	4	3	1 29/32	27/32	2	1✓	1	6✓	1	7✓	0	0
S	A	8 5/8	7 1/2	6 5/8	5 1/2	4 1/2	2	10	2	4	0	9	2	0
S	B	8	7	6	5	4	1	1	2	10	0	0	0	0
T	A	6 5/8	5 1/2	4 1/2	3 1/2	2 3/8	3	13✓	+3✓ 0	3✓	1✓	6	1✓	0
T	B	6	5	4	3	1 29/32	2	2✓	+4 1	11✓	+8 0	8	+5 0✓	0
U	A	7 1/2	6 5/8	5 1/2	4 1/2	3 1/2	3	5	0	11	1	3	0	1
U	B	7	6	5	4	3	1	0	0	16	0	11	0	0
H	A		8 5/8	7 1/2	6 5/8	5 1/2	2	–	–	22	1	4	1	1
H	B	2 5/8	1 11/16	11/16			4	4	0	5	1	1	0	–
M	A			8 5/8	7 1/2	6 5/8	2	–	–	–	–	4	2	0
M	B		8	7	6	5	1	–	–	0	0	0	0	0
L	A			8	7	6	1	–	–	–	–	0	1	0
L	B		2 1/8	1 11/16			2	–	–	0	0	0	0	–
L	C		2 5/8	1 11/16	11/16		2	–	–	2	0	1	1	0
L	D			2 1/8	1 1/16		1	–	–	–	–	0	0	0
L	E			2 5/8	1 11/16	11/16	1	–	–	–	–	0	0	0

HAND

MOULD BLOCK	INSULATION THICKNESS 1"	1½"	2"	2½"	3"	No. IN BLOCK	SHIFTS . RE 1" S	1" P	1½" S	1½" P	2" S	2" P	S
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)		(i)		(j)		(
Z A	1 11/32					16	16	1	—	—	—	—	—
X A	2 3/8	1 11/32				14	14	1	2	1	—	—	—
W A	27/32					9	7	1	—	—	—	—	—
W B	1 1/16					9	17	1	—	—	—	—	—
Y A	1 29/32	27/32				14	8	1	1	0	—	—	—
V A	1 11/16	11/16				7	28	1	2	0	—	—	—
V B	11/16					2	36	0	—	—	—	—	—
V C	2 1/8	1 1/16				5	16	1	3	3	—	—	—
P A	3 1/2	2 3/8	1 11/32			7	11	1	9	1	0	0	—
P B	3	1 29/32	27/32			5	16	1	3	5	1	0	—
Q A	4 1/2	3 1/2	2 3/8	1 11/32		7	9	2	6	1	1	1	0
Q B	4	3	1 29/32	27/32		3	6	1	16	0	0	0	0
R A	5 1/2	4 1/2	3 1/2	2 3/8	1 11/32	4	4	0	19	0	3	2	0
R B	5	4	3	1 29/32	27/32	2	3	1	22	3	6	0	0
S A	8 5/8	7 1/2	6 5/8	5 1/2	4 1/2	2	16	6	1	0	4	0	0
S B	8	7	6	5	4	1	0	0	5	0	0	5	0
T A	6 5/8	5 1/2	4 1/2	3 1/2	2 3/8	3	5	2	11	0	7	1	0
T B	6	5	4	3	1 29/32	2	0	2	9	1	2	6	0
U A	7 1/2	6 5/8	5 1/2	4 1/2	3 1/2	3	3	0	5	0	3	0	0
U B	7	6	5	4	3	1	0	21	3	0	0	2	0
H A		8 5/8	7 1/2	6 5/8	5 1/2	2	—	—	7	6	0	3	0
H B	2 5/8	1 11/16	11/16			4	10	1	26	4	0	1	—
M A			8 5/8	7 1/2	6 5/8	2	—	—	—	—	9	6	0
M B		8	7	6	5	1	—	—	0	8	1	2	0
L A			8	7	6	1	—	—	—	—	0	0	0
L B		2 1/8	1 1/16			2	—	—	6	0	0	0	—
L C		2 5/8	1 11/16	11/16		2	—	—	6	0	0	0	0
L D			2 1/8	1 1/16		1	—	—	—	—	0	0	0
L E			2 5/8	1 11/16	11/16	1	—	—	—	—	0	0	0

MOULD BLOCK	INSULATION THICKNESS 1"	1½"	2"	2½"	3"	No. IN BLOCK	SHIFTS 1" S	1" P	REQU… 1½" S	1½" P	2" S	2" P	S
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)		(i)		(j)		
Z A	1 11/32					16	21	2	–	–	–	–	–
X A	2 3/8	1 11/32				14	16	1	2	5	–	–	–
W A	27/32					9	29	6	–	–	–	–	–
W B	1 1/16					9	20	2	–	–	–	–	–
Y A	1 29/32	27/32				14	16	1	1	2	–	–	–
V A	1 11/16	11/16				7	28	2	1	2	–	–	
V B	11/16					2	25	11	–	–	–	–	
V C	2 1/8	1 1/16				5	9	3	1	8	–	–	
P A	3½	2 3/8	1 11/32			7	25	1	10	3	0	2	–
P B	3	1 29/32	27/32			5	25	4	4	2	0	4	–
Q A	4½	3½	2 3/8	1 11/32		7	28	4	6	1	1	1	[illegible]
Q B	4	3	1 29/32	27/32		3	7	2	13	6	0	3	[illegible]
R A	5½	4½	3½	2 3/8	1 11/32	4	3	0	8	1	9	19	[illegible]
R B	5	4	3	1 29/32	27/32	2	2	4	5	13	2	8	[illegible]
S A	8 5/8	7½	6 5/8	5½	4½	2	20	4	3	4	1	2	
S B	8	7	6	5	4	1	1	0	0	0	5	18	
T A	6 5/8	5½	4½	3½	2 3/8	3	8	1	7	1	14	0	[illegible]
T B	6	5	4	3	1 29/32	2	1	0	7	9	11	26	
U A	7½	6 5/8	5½	4½	3½	3	1	0	9	4	4	0	[illegible]
U B	7	6	5	4	3	1	1	7	18	12	0	8	[illegible]
H A		8 5/8	7½	6 5/8	5½	2	–	–	2	3	1	5	
H B	2 5/8	1 11/16	11/16			4	9	0	3	5	5	9	
M A			8 5/8	7½	6 5/8	2	–	–	–	–	10	2	
M B		8	7	6	5	1	–	–	2	0	0	2	
L A			8	7	6	1	–	–	–	–	2	11	
L B		2 1/8	1 1/16			2	–	–	3	12	0	6	
L C		2 5/8	1 11/16	11/16		2	–	–	0	7	0	8	
L D			2 1/8	1 1/16		1	–	–	–	–	0	17	
L E			2 5/8	1 11/16	11/16	1	–	–	–	–	0	11	

Appendix 5D

HAND SIMULATION RESULTS
CONFIGURATION B

MOULD BLOCK	INSULATION THICKNESS 1"	1½"	2"	2½"	3"	No. IN BLOCK	PERCENTAGE USAGE (based on 60 shifts per C.P.) CP 3	CP 4	CP 5	CP 6	Average % usage over period	REMARKS.
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)
ZA	1 11/32					16	43	40	28	38	37	Low usage due to existing Mould Blocks being retained
XA	2 3/8	1 11/32				14	43	50	32	42	42	
WA	27/32					9	82	42	30	60	54	
WB	1 1/16					9						
YA	1 29/32	27/32				14	33	22	18	38	28	
VA	1 11/16	11/16				7	100	75	68	68	78	
VB	11/16					2						
VC	2 1/8	1 1/16				5						
PA	3½	2 3/8	1 11/32			7	73	50	48	78	62	
PB	3	1 29/32	27/32			5						
QA	4½	3½	2 3/8	1 11/32		7	58	60	48	85	63	Mould Block 18 in. wide
QB	4	3	1 29/32	27/32		3						
RA	5½	4½	3½	2 3/8	1 11/32	4	97	47	65	72	70	
RB	5	4	3	1 29/32	27/32	2						
SA	8 5/8	7½	6 5/8	5½	4½	2	95	53	57	100	76	
SB	8	7	6	5	4	1						
TA	6 5/8	5½	4½	3½	2 3/8	3	100+	82−	60	100+ (+22)	91	High figures caused by sudden large demands for 2 in thick insulation.
TB	6	5	4	3	1 29/32	2						
UA	7½	6 5/8	5½	4½	3½	3	73	45	62	97	69	
UB	7	6	5	4	3	1						
HA		8 5/8	7½	6 5/8	5½	2	73	57	78	57	66	
HB	2 5/8	1 11/16	11/16			4						
MA			8 5/8	7½	6 5/8	2	37	10	33	38	30	
MB		8	7	6	5	1						
LA			8	7	6	1	75	22	20	35	38	This would be a difficult mould block to schedule: production of unwanted thicknesses would probably result
LB		2 1/8	1 1/16			2						
LC		2 5/8	1 11/16	11/16		2						
LD			2 1/8	1 1/16		1						
LE			2 5/8	1 11/16	11/16	1						

POSSIBLE PHASED PROGRAMME TO CHANGE FROM EXISTING CONFIGURATION TO CONFIGURATION "B", WITH THE LEAST INTERRUPTION TO CURRENT PRODUCTION.

Existing Configura-tion	Changes 1st	2nd	3rd	4th	5th	6th	Configura-tion "B"
V	V	V(c)	V	V	V	V	V
W	W	W	W	W	W	W	W
X	X	X(c)	X	X	X	X	X
Y	Y	Y(c)	Y	Y	Y	Y	Y
Z	Z	Z	Z	Z	Z	Z	Z
C	C_1(P)	P	P	P	P	P	P
	C_2(Q)	Q	Q	Q	Q	Q	Q
D	D	D_1(R)	R	R	R	R	R
		D_2(S)	S	S	S	S	S
E	E	E	E_1(T)	T	T	T	T
			E_2(U)	U	U	U	U
I	I	I	I	I			
G	G						
F	F	F					
H	H	H	H	H_1(H)	H	H	H
M	M	M	M	M	M	M_1(M)	M
J	J	J					
K	K	K	K	K	K		
N					N_1(L)	L	L
otal 16	16	16	15	15	15	14	14
ake C_1(P) C_2(Q)	D_1(R) D_2(S)	E_1(T) E_2(U)	H_1(H)	N_1(L)	M_1(M)		
emove	C N	D G	E F J	H	I	M K	
TES essure uld → scrape if ssible(s)	1"x2⅝(s)	1"x2⅝(s) 1½"x5½ 1½"x1$\frac{11}{16}$(s)	1"x2⅝(s) 1½"x1$\frac{11}{16}$(s)	1½"x2⅝(s)			

(c). At an early stage (after 1st change), core change facilities must be provided for certain cylinders in Blocks V, X & Y.

CHAPTER 6 : COMPUTER SIMULATION

(a) WORKS ORDER PROCESSING 1 : D.P. PROJECT (W.O.P.1)

Following the completion of the hand simulation exercise with Configuration B, work was done to pave the way for a similar investigation using the computer. The object of this simulation was to compare the efficiency of several configurations of mould-blocks over a number of cost periods.

For this purpose, the hand simulation was flow charted with the object of using part of the output of the Data Processing Project "Works Orders Processing 1". A sample of the output of this project is shown at Appendix 6A.

For this D.P. Project (W.O.P.1) a monthly program was run on the computer, the input data being all the works orders issued by the Sales Department during the previous cost period. As can be seen from Appendix 6A, these orders were sorted by material, column 1 (Magnesia or Paratemp), by thickness, column 2 (1 inch = 10, 1½ inch = 15, etc.), and by size, column 3 (using the coding shown at Appendix 6C), into orders for the six cost periods, columns 4-9 inclusive, starting with the one immediately ahead (column 4) and forecasting forward. Column 10 showed undated orders, and the final column, 11, showed the average monthly order over the previous twelve months (= cost periods).

As far as the present project was concerned, only the information for the cost period immediately ahead was required - i.e. columns 1-4 inclusive.

(b) FLOW DIAGRAM

The first necessity was to prepare a flow diagram, using the operation of the hand simulation as a guide. The whole process started from the output of W.O.P.1, which had to be sorted into production sizes; the production sizes had to be tabulated and the quantities of each size and thickness printed out as an array. This array had then to be regrouped in accordance with the tabulation at Appendix 3G, by size ranges in accordance with core-change possibilities.

This "core-change" array in turn had to be re-arranged, after reduction to "shifts required" from "quantity required", to conform with the configuration under examination. Then a simulated "production schedule" had to be carried out, taking care that where more than one size range could be produced, the thicknesses being made at one time did not differ by more than one half inch. Finally, the number of shifts required to make each size range had to be totalled for each mould-block, and the result printed out.

The flow diagram at Appendix 6B is a reconstruction of the original.

(c) THE DATA TAPES

The data tapes mentioned in the flow diagram are explained in detail at Appendices 6C, 6D, 6E.

D.T.1 (Appendix 6C) listed the W.O.P.1 sizes in a convenient order to be grouped into production sizes.

D.T.2 (Appendix 6D) showed the quantities of each W.O.P.1 size required to be produced, and are different for each cost period. These were the demand quantities against which the different configurations were being tested.

D.T.3 (Appendix 6D) listed the production sizes, against which the quantities required to be produced could be set.

D.T.4 (Appendix 6E) listed the block configuration under examination.

(d) THE PROGRAM

The computer program, written with the assistance of a Research Programmer, is shown at Appendix 6F. It is written in ALGOL, and was run successfully for two configurations, for cost periods 3 and 4, on the Elliott 803 computer at Durham.

(e) OUTPUT

The output from these runs is shown at Appendix 6G. Configuration B (modified) shows that all mould-blocks would be satisfactory (production complete in less than 60 shifts) except for - in cost period 3, Block U (UA and UB) which required 114 shifts to complete the production. In cost period 4 there were no problems.

In the case of Configuration C, in cost period 3 Block B (B1, B2, B3) completed production in 62 shifts, Block G (G1, G2) in 72 shifts, and Block H (H1, H2) in 114 shifts. In cost period 4 also there were no problems.

On the strength of these runs, Configuration B (Modified) ranks better than Configuration C, but it would be more satisfactory to run the program for several more cost periods.

Finally, the program as developed ran successfully, and could be used to try out further configurations if wanted.

APPENDIX 6A.

WORKS ORDERS PROCESSING 1

C.P.4

1. Material	2. Thickness	3. Size	10 Undated orders	11 Av. monthly o order
			87	484
Magnesia	10	AN	0	104
		AP	3018	5999
		BA	3291	7515
		BB	4857	9373
		BC	231	4672
		BD	1998	7483
		BE	1272	9771
		BF	168	2860
		BG	228	4743
		BH	216	274
		BJ	180	3638
		BK	21	31
		BL	177	503
		BM	51	1239
		BN	36	203
		BP	1602	1707
		CA	552	1224
		CB	1668	1058
		CC	582	1417
		CD	1695	1067
		CE	1632	1019
		CF	18	830
		CG	0	182
		CH	45	0
		CJ	0	2
		CK	0	95
		NA	0	78
		NB	0	649
		NC	0	363
		ND	0	432
		NE	135	353
		NF	0	224
		NG	633	261
		NH	0	160
		NJ	0	240
		NK	0	30
		NL	81	90
		NM	0	103
		NN	90	50
		NP	33349	16920
		FA	1000	8678
		TT		
			336	133
	15	AN	0	260
		AP	144	548
		BA	45	927
		BB	0	1203
		BC	0	461
		BD	231	1516
		BE	825	1053
		BF	795	960
		BG	1263	1870
		BH	0	284
		BJ	663	2346
		BK	0	60
		BL	6	781
		BN	720	939
		BP	465	54
		CA	200	162
		[illegible]	12	[illegible]

FLOW DIAGRAM

Data Tape 1

Read in integer equivalents of W.O.P.1 into an array

↓

Read in number of different thicknesses

↓

Data Tape 2

Read in for each of N thicknesses, order data consisting of W.O.P.1 size and quantity for this size. By checking against integer equivalent, place in appropriate position in array A

↓

Form array B, grouping together equivalent W.O.P.1 sizes into production sizes

↓

Data Tape 3

Read in list of production sizes in text form, and produce output tape showing quantity of each size and thickness to be produced

Output Part 1

↓

Regroup data from array B into two separate arrays for supermag and paratemp, on basis of internal diameters required: also converting quantities to be produced into equivalent shifts

↓

Data Tape 4

Read in configuration of moulds in blocks and rearrange shift data accordingly. Compare shift numbers where more than one size range is produced, and select the largest in each case. In the case of the smaller shift numbers, deal with the difficulty of producing different thicknesses simultaneously (see text, p. 82). Sum totals of largest shift numbers

→

Output Part 2

Produce output tape showing composition of each block, and the number of cylinders for each size range of the configuration, and the total shifts to complete production

DATA TAPE 1

Binary values of code letters of sizes from W.O.P.1 (see Appendix 6A).

Size	Code Letter	D.T.1
$\frac{11}{16}$	CA	4259
	NA	4270
$\frac{27}{32}$	BA	4258
	CB	4387
	NB	4398
$1\frac{1}{16}$	BB	4386
	CC	4515
	NC	4526
$1\frac{11}{32}$	BC	4514
	CD	4643
	ND	4654
$1\frac{11}{16}$	BD	4642
	CE	4771
	NE	4782
$1\frac{29}{32}$	BE	4770
$2\frac{1}{8}$	CF	4899
	NF	4910
$2\frac{3}{8}$	BF	4898
$2\frac{5}{8}$	CG	5027
	NG	5038
3	BG	5026
	CH	5155
	NH	5166

Size	Code Letter	D.T.1
$3\frac{1}{2}$	BH	5154
	CJ	5411
	NJ	5422
4	BJ	5410
	CK	5539
	NK	5550
$4\frac{1}{2}$	BK	5538
	NL	5678
5	BL	5666
	NM	5806
$5\frac{1}{2}$	BM	5794
6	NN	5934
$6\frac{1}{2}$	AN	5921
	BN	5922
7	NP	6190
$7\frac{1}{2}$	AP	6177
	BP	6178
8	NR	6446
$8\frac{1}{2}$	AR	6433
	BR	6434
Slab insulation (excluded)	(FA	4262)
	(FB	4390)
	(FT	6694)
	(TT	6708)

<u>Calculation of Binary Values</u>

$$CA = 35 + 2^7 \times 33 = 4259$$

etc. letter A to Z. Code from A=33, B=34, etc. to R=50 (Z=58)

Input - D.T.1

4259 4270 4258 4387 4398 4386 4515 4526 4514 4643 4654 4642 4771 4782 4770 4899
4910 4898 5027 5038 5026 5155 5166 5154 5411 5422 5410 5539 5550 5538 5578 5666
5806 5794 5934 5921 5922 6190 6177 6178 6446 6433 6434

DATA TAPE 2

Data tape 2 is produced from the results of "Works Order Processing 1".

The tape starts with N (no. of thickness) which equals 10 (5 thicknesses each of supermag and paratemp)

It then has pairs of figures straight from W.O.P.1 output, i.e. "Code letter value", "Quantity for C.P.3(4 etc.)".

Thus (from C.P.4 example):

```
5921 (i.e. AN)      0
6177 (i.e. AP)      0
4258 (i.e. BA)   2871
4386 (i.e. BB)   8012
```

to the end of 1 inch thicknesses of Magnesia

repeat for 1½ inch thicknesses of Magnesia

then again for 2, 2½ and 3 inch thicknesses of Magnesia

then 1 inch, 1½, 2, 2½ and 3 inch thicknesses of Paratemp.

DATA TAPE 3

Data Tape 3 gives the list of production sizes to suit O.D. pipe sizes as vulgar fractions, from $\frac{11}{16}$" through to 8½". This data tape is standard for all programs and is shown below.

Input - D.T.3

```
££l1?11/16£s4??
££L1?27/32£s4??
££l1?17/16£s4??
££L1?43/32£s4??
££L1?27/16£S4??
££L1?51/32£S4??
££L1?17/8£S5??
££L1?19/8£S5??
££L1?21/8£S5??
££L1?3£S8??
££L1?7/2£S6??
££L1?4£S8??
££L1?9/2£S6??
££L1?5£S8??
££L1?11/2£S5??
££L1?6£S8??
££L1?13/2£S5??
££L1?7£S8??
££L1?15/2£S5??
££L1?8£S8??
££L1?17/2£S5??
```

DATA TAPE 4

Data Tape 4 shows the Block Configuration under examination. For Configuration B (modified) the data tape ends with 99, and for Configuration C it ends with 999.

A configuration is shown in the data tape as follows, for each mould-block:

First figure:	number of size ranges in the block
Second figure:	coding of first size range in the block (see Appendix 3G)
Third figure:	block label of first size range
Fourth figure:	number of cylinders in first size range
Fifth figure:	coding of second size range (if any)
Sixth and Seventh:	as for third and fourth for second size range

The complete data tapes for Configuration B (modified) and Configuration C are shown overleaf. Looking at the third block for Configuration B (modified), this reads 2, 2, £WA?, 9, 3, £WB?, 9. From Appendix 3G it can be seen that coding No. 2 is $\frac{27}{32}''$ x 1 inch, and coding No. 3 is $1\frac{11}{16}''$ x 1 inch, so the entry means:- "2 size ranges in the block: first range - $\frac{27}{32}''$ x 1 inch, Block WA, 9 cylinders: second range - $1\frac{1}{16}''$ x 1 inch, Block WB, 9 cylinders", and so on.

CONFIGURATION B (MODIFIED)

```
1,  4,  £ZA?,  16,
1,  8,  £XA?,  14,
2,  2,  £WA?,  9,  8,  £WB?,  9,
1,  6,  £YA?,  14,
3,  5,  £VA?,  7,  1,  £VB?,  2,  7,  £VC?,  5,
2,  12,  £PA?,  7,  10,  £PB?,  5,
2,  16,  £QA(18ins)?,  7,  14,  £QB(18ins)?,  3,
2,  20,  £RA?,  4,  18,  £RB?,  2,
2,  29,  £SA?,  2,  28,  £SB?,  1,
2,  24,  £TA?,  3,  26,  £TB?,  1,
2,  27,  £UA?,  3,  22,  £UB?,  1,
1,  31,  £HA?,  3,
2,  33,  £MA?,  2,  30,  £MB?,  1,
6,  32,  £LA?,  1,  9,  £LB?,  2,  11,  £LC?,  2,  13,  £LD?,  2,  15,  £LE?,  1,  17,  £LF?,  1,
99
```

CONFIGURATION C

```
*2, 2,£A1?,9, 3,£A2?,9,
3, 1,£B1?,3, 4,£B2?,8,5,£B3?,5,
2, 6,£C1?,9, 7,£C2?,5,
2, 8,£D1?,8,10,£D2?,5,
2,12,£E1?,7,14,£E2?,3,
2, 9,£F1?,2,16,£F2?,7,
2,18,£G1?,2,24,£G2?,3,
2,20,£H1?,4,22,£H2?,1,
2,26,£J1?,1,27,£J2?,3,
2,28,£K1?,1,29,£K2?,2,
2,30,£L1?,1,31,£L2?,2,
2,32,£M1?,1,33,£M2?,2,
4,15,£N1?,2,17,£N2?,2,11,£N3?,4,13,£N4?,4,
999
```

CONFIGURATIONS B (mod) AND C

The two configurations which were compared in the Computer simulation are shown in detail below:-

CONFIGURATION B (modified)

MOULD BLOCK No.	THICKNESS 1 in	1½ in	2 in	2½ in	3 in	No IN BLOCK
ZA	1 1/32					16
XA	2 3/8	1 1/32				14
WA	27/32					9
WB	1 1/16					9
YA	1 29/32	27/32				14
VA	1 1/16	11/16				7
VB	11/16					2
VC	2 1/8	1 1/16				5
PA	3½	2 3/8	1 1/32			7
PB	3	1 29/32	27/32			5
QA (8in)	4½	3½	2 3/8	1 1/32		7
QB (8in)	4	3	1 29/32	27/32		3
RA	5½	4½	3½	2 3/8	1 1/32	4
RB	5	4	3	1 29/32	27/32	2
SA	8½	7½	6½	5½	4½	2
SB	8	7	6	5	4	1
TA	6½	5½	4½	3½	2 3/8	3
TB	7	6	5	4	3	1
UA	7½	6½	5½	4½	3½	3
UB	6	5	4	3	1 29/32	1
HA		8½	7½	6½	5½	3
MA			8½	7½	6½	2
MB		8	7	6	5	1
LA			8	7	6	1
LB	2 1/8	1 1/16	11/16			2
LC		2 1/8	1 1/16			2
LD		2 5/8	1 1/16	11/16		2
LE			2 1/8	1 1/16		1
LF			2 5/8	1 1/16	11/16	1

CONFIGURATION C.

MOULD BLOCK No.	THICKNESS 1 in	1½ in	2 in	2½ in	3 in	No. IN BLOCK
A1	27/32					9
A2	1 1/16					9
B1	11/16					3
B2	1 1/32					5
B3	1 1/16					5
C1	1 29/32	27/32				9
C2	2 1/8	1 1/16				5
D1	2 3/8	1 1/32				8
D2	3	1 29/32	27/32			5
E1	3½	2 3/8	1 1/32			7
E2	4	3	1 29/32	27/32		3
F1	2 5/8	1 1/16	11/16			2
F2	4½	3½	2 3/8	1 1/32		7
G1	5	4	3	1 29/32	27/32	2
G2	6½	5½	4½	3½	2 3/8	3
H1	5½	4½	3½	2 3/8	1 1/32	4
H2	6	5	4	3	1 29/32	1
J1	7	6	5	4	3	1
J2	7½	6½	5½	4½	3½	3
K1	8	7	6	5	4	1
K2	8½	7½	6½	5½	4½	2
L1		8	7	6	5	1
L2		8½	7½	6½	5½	2
M1			8	7	6	1
M2			8½	7½	6½	2
N1			2 1/8	1 1/16		2
N2			2 5/8	1 1/16	11/16	2
N3		2 1/8	1 1/16			4
N4		2 5/8	1 1/16	11/16		4
P1				8	7	1 NOT INCLUDED
P2				8½	7½	1
P3					8½	1

COMPUTER PROGRAM TO CALCULATE SHIFTS

APPENDIX 6F

```
:ALCULATION OF SHIFTS;
:egin integer char,up,word,i,j,n,m,N,SH,z,p,TS,TP,SHS,SHP;
      real array S,P[1:5,1:33];
 integer array x[1:43],A,B[1:10,1:43],SUP,PAR[1:10],J,blno[1:10],TEXT[1:100];
        switch ss:=13,14,15;

      procedure trans;
      begin switch qq:=11;
.1:     elliott(7,3,6444,0,4,0,6445);
          elliott(2,0,char,0,4,2,11);
           if char=127 or char=3 or char=64 or char=2 or char=4
           then goto 11;
        end;

        print ££s55?MAGNESIA£S72?PARATEMP£L2?Size £S16?1.0?,
           sameline,££S13?1.5£S13?2.0£S13?2.5£S13?3.0£S14?1.0£S13?1.5£S13??,
           sameline,£2.0£S13?2.5£S13?3.0£L1??;
           for j:=1 step 1 until 43 do
           for m:=1 step  1 until 10 do
           A[m,j]:=B[m,j]:=0;
           for j:=1 step  1 until 43 do read x[j];

           read N;
           for m:=1 step  1 until N do
           begin up:=word:=0;
               for i:=1,2 do
               begin trans;
                   if char=13 then goto 13;
                   elliott(3,0,char,0,0,0,0);
                   elliott(0,0,up,1,5,5,0);
                   elliott(2,4,word,0,0,0,0);
                   up:=up+7;
               end;

               for j:=1 step  1 until 43 do
               begin if word=x[j] then
                   begin read n;
                      B[m,j]:=n;  m:=m-1;
                      goto 13;
                   end;
               end;

               if word=4262 or word=4390 or word=6694 or word=6708 then
               begin read n; m:=m-1; goto 13 end;
               read n;
               print £SIZE CORRESPONDING TO?, sameline,n,
               ££s2? in group?,sameline,m,££S2?not found£L1??;
               stop;
3:        end;
```

```
            for m:=1 step 1 until N do
            begin A[m,1]:=B[m,1]+B[m,2]; A[m,2]:=B[m,3]+B[m,4]+B[m,5];
                A[m,3]:=B[m,6]+B[m,7]+B[m,8]; A[m,4]:=B[m,9]+B[m,10]+B[m,11];
                A[m,5]:=B[m,12]+B[m,13]+B[m,14]; A[m,6]:=B[m,15];
                A[m,7]:=B[m,16]+B[m,17]; A[m,8]:=B[m,18]; A[m,9]:=B[m,19]+B[m,20];
            A[m,10]:=B[m,21]+B[m,22]+B[m,23]; A[m,11]:=B[m,24]+B[m,25]+B[m,26];
                A[m,12]:=B[m,27]+B[m,28]+B[m,29]; A[m,13]:=B[m,30]+B[m,31];
                A[m,14]:=B[m,32]+B[m,33]; A[m,15]:=B[m,34]; A[m,16]:=B[m,35];
                A[m,17]:=B[m,36]+B[m,37]; A[m,18]:=B[m,38];
                A[m,19]:=B[m,39]+B[m,40]; A[m,20]:=B[m,41];
                A[m,21]:=B[m,42]+B[m,43];
            end;


            z:=p:=1;
            for j:=1 step  1 until 21 do
            begin instring(TEXT,z);
                outstring(TEXT,p);
                        p:=z;
                for m:=1 step 1 until N do
                print digits(6), sameline,££S9??,sameline,A[m,j];
            end;

print ££15?part 2 now:-£1??;


      print ££l10?BLOCK CONFIGURATION£s5?NO. IN BLOCK£s5?SHIFTS£l2??;

      for j:=1 step 1 until 33 do
      for m:=1 step 1 until N/2 do
      S[m,j]:=P[m,j]:=0;

      for m:=1 step 1 until N/2 do
      begin for j:=1 step 1 until 10 do
          begin S[m,j+4*(m-1)]:=A[m,j]/41;
              P[m,j+4*(m-1)]:=A[m+5,j]/32;
          end;
          for j:=12,j+2 while j+4*(m-1)<26 do
          begin S[m,j+4*(m-1)]:=A[m,5+j/2]/41;
              P[m,j+4*(m-1)]:=A[m+5,5+j/2]/32;
          end;
          for j:=27,j+1 while j-2*(m+3)<21 and j≤33 do
          begin S[m,j]:=A[m,j-2*(m+3)]/41;
              P[m,j]:=A[m+5,j-2*(m+3)]/32;
          end;
      end;
```

```
14:   read n;   if n=99 then goto 15;   if n=999 then
           begin print ££15?End of Programme?;    stop end;

      TS:=TP:=SHS:=SHP:=0;
      for i:=1 step 1 until n do
      begin read J[i]; print ££L1??; z:=1; instring(TEXT,z); z:=1; outstring(TEXT,z);
          read blno[i]; print££S27??,sameline, digits(2),blno[i];
      SUP[i]:=PAR[i]:=0;
      end;

      for m:=1 step 1 until N/2 do
      begin for i:=1 step 1 until n do
          begin SUP[i]:=SUP[i]+entier(S[m,J[i]]/blno[i]+0.8);
              PAR[i]:=PAR[i]+entier(P[m,J[i]]/blno[i]+0.8);
              if SUP[i]<SHS then SUP[i]:=SHS;
              if SUP[i]≥TS then TS:=SUP[i];
              SUP[i]:=checki(SUP[i]);
              if PAR[i]<SHP then PAR[i]:=SHP;
              if PAR[i]≥TP then TP:=PAR[i];
              PAR[i]:=checki(PAR[i]);
          end;
          SHS:=TS;   SHP:=TP;   TS:=TP:=0;
      end;

      SH:=SHS+SHP;   SHS:=checki(SHS);   SHP:=checki(SHP);
      print ££s13??,sameline,digits(3),SH,££l1??;
      goto 14;

15:    wait;

      print ££15??;
      goto 14;
      end of programme;
```

APPENDIX 6G.

COST PERIOD 3. OUTPUT PART 1.

MAGNESIA

Size	1.0	1.5	2.0	2.5	3.0
11/16	1566	75	219	0	0
27/32	11528	648	201	36	0
17/16	10097	1428	27	0	0
43/32	13254	2085	0	0	0
27/16	7623	828	0	0	0
51/32	8143	1359	0	0	0
17/8	1785	261	123	0	0
19/8	10572	2385	264	0	0
21/8	195	615	549	0	0
3	2265	783	880	0	0
7/2	5223	1494	837	0	0
4	897	150	516	0	0
9/2	3840	2169	1299	0	0
5	198	405	78	0	0
11/2	267	1263	879	51	0
6	381	15	189	0	0
13/2	2109	1515	621	783	0
7	75	78	30	0	0
15/2	375	219	228	111	0
8	0	0	0	0	0
17/2	0	0	0	0	0

PARATEMP

Size	1.0	1.5	2.0	2.5	3.0
11/16	1968	303	357	57	18
27/32	4617	0	408	0	0
17/16	1686	1260	102	0	0
43/32	2581	171	39	0	0
27/16	783	519	453	0	0
51/32	906	12	60	0	0
17/8	648	711	909	0	0
19/8	429	1773	114	0	0
21/8	768	441	661	0	0
3	582	444	876	0	0
7/2	774	975	654	0	0
4	300	936	1557	0	0
9/2	78	222	486	0	0
5	214	465	204	246	0
11/2	333	0	450	0	51
6	528	316	615	0	15
13/2	228	6	315	0	0
7	4	300	216	0	0
15/2	144	156	768	174	0
8	0	0	0	0	0
17/2	0	0	0	0	0

APPENDIX 6 G (cont).
Sheet 2

COST PERIOD 3. OUTPUT PART 2

CONFIGURATION B (mod)

FIGURATION	NO. IN BLOCK	SHIFTS
ZA	16	26
XA	14	25
WA	9	
WB	9	48
YA	14	17
VA	7	
VB	2	
VC	5	59
PA	7	
PB	5	39
QA(18ins)	17	
QB(18ins)	3	25
RA	4	
RB	2	54
SA	2	
SB	1	50
TA	3	
TB	1	56
UA	3	
UB	1	114
HA	3	4
MA	2	
MB	1	9
LA	1	
LB	2	
LC	2	
LD	2	
LE	1	
LF	1	59

CONFIGURATION C

CONFIGURATION	NO. IN BLOCK	SHIFTS
A1	9	
A2	9	48
B1	3	
B2	8	
B3	5	62
C1	9	
C2	5	36
D1	8	
D2	5	47
E1	7	
E2	3	40
F1	2	
F2	7	47
G1	2	
G2	3	72
H1	4	
H2	1	114
J1	1	
J2	3	40
K1	1	
K2	2	50
L1	1	
L2	2	26
M1	1	
M2	2	5
N1	2	
N2	2	
N3	4	
N4	4	23

COST PERIOD 4 OUTPUT PART I.

MAGNESIA

Size	1.0	1.5	2.0	2.5	3.0
11/16	2580	885	51	0	0
27/32	4393	0	0	0	0
17/16	8159	183	0	0	0
43/32	5754	420	0	0	0
27/16	4443	702	15	0	0
51/32	783	966	45	0	0
17/8	1968	0	0	0	0
19/8	9951	1297	525	0	0
21/8	573	87	0	0	0
3	2023	1497	549	0	0
7/2	549	2207	609	0	0
4	402	444	630	0	0
9/2	4176	1153	693	51	0
5	48	825	18	0	0
11/2	750	66	67	0	0
6	159	648	0	0	0
13/2	1554	1266	669	6	0
7	0	402	0	0	0
15/2	519	291	261	0	0
8	0	0	0	0	0
17/2	0	0	0	0	0

PARATEMP

Size	1.0	1.5	2.0	2.5	3.0
11/16	231	42	0	0	0
27/32	993	72	135	60	0
17/16	495	468	0	0	0
43/32	1131	0	3	0	0
27/16	114	3	18	0	0
51/32	1053	93	60	0	0
17/8	0	0	0	0	0
19/8	1890	654	66	21	0
21/8	0	0	0	0	0
3	471	0	0	0	0
7/2	501	498	42	252	84
4	0	3	0	0	0
9/2	708	21	78	0	51
5	3	0	0	0	0
11/2	3	42	0	0	0
6	57	0	0	0	0
13/2	3	9	102	0	0
7	0	0	0	198	0
15/2	0	0	60	0	0
8	0	0	0	0	0
17/2	0	0	0	0	0

APPENDIX 6 G (cont).
Sheet 4

COST PERIOD 4 OUTPUT PART 2

CONFIGURATION B (mod)

CONFIGURATION	NO. IN BLOCK	SHIFTS
ZA	16	12
XA	14	29
WA	9	
WB	9	25
YA	14	11
VA	7	
VB	2	
VC	5	42
PA	7	
PB	5	26
QA (18ins)	7	
QB (18ins)	3	38
RA	4	
RB	2	20
SA	2	
SB	1	15
TA	3	
TB	1	28
UA	3	
UB	1	43
NA	3	4
MA	2	
MB	1	30
LA	1	
LB	2	
LC	2	
LD	2	
LE	1	
LF	1	24

CONFIGURATION C

CONFIGURATION	NO. IN BLOCK	SHIFTS
A1	9	
A2	9	25
B1	3	
B2	8	
B3	5	34
C1	9	
C2	5	18
D1	8	
D2	5	51
E1	7	
E2	3	25
F1	2	
F2	7	32
G1	2	
G2	3	28
H1	4	
H2	1	45
J1	1	
J2	3	22
K1	1	
K2	2	15
L1	1	
L2	2	35
M1	1	
M2	2	6
N1	2	
N2	2	
N3	4	
N4	4	1

CHAPTER 7 : COMMENTS AND CONCLUSIONS

(a) GENERAL COMMENTS

Although this project was mainly concerned with the effect of mould-block configuration on production, it was clearly seen that other problems existed at the works which had a considerable bearing on the difficulties of the Production Department. Some of these problems were being tackled concurrently with this project, and others would have been tackled if the work for this Company had continued. These problems included the following:-

(1) Sales Department Information The Project "Works Order Processing", referred to particularly in chapters 5 and 6, was a Data Processing project designed to give rapid information to the Sales Department of orders received. A program had been developed and was working well to produce information in the style shown at Appendix 6A. This information would also be of value to the Production Department if grouped into "production" sizes.

(2) Demand Forecasting Another M.Sc. candidate, Mr. G.W. Hannan, was working on a sophisticated method of Demand Forecasting, using historical data and trend

information. Computer programs (entitled FORTICUM and SIMPLICUM) had been obtained from ICI Ltd. and adapted to this problem, but the thesis has not so far been presented. The present writer has himself carried out a superficial examination of the possibilities of forecasting demand reasonably accurately, this being an established OR technique. One method, using exponential smoothing is described by Robert G. Brown in his book "Statistical Forecasting for Inventory Control" (New York, McGraw Hill, 1959) pages 45 et seq. This method was explored, using the production data for supermag, 1 inch thick for $\frac{11}{16}$" pipe, starting in August 1960, and working through to 1964. Various smoothing constants ranging from $\alpha=0.1$ to $\alpha=0.5$ were used. In this method, the smoothing constant holds the key to the response - a small value (0.1) gives a slow and gradual response, whereas a high value (0.5) causes the estimates to respond quickly, not only to real changes but also to random fluctuations. In the present situation, the actual changes were so great that even with a smoothing constant of 0.5, large cumulative deficits occurred (at times production was nearly 4000 feet in arrears), followed by equally large surpluses of stock. A lot more effort would be needed in this direction to produce a reasonable forecasting service for the whole range of sizes of insulation. Another possible forecasting technique might be to analyse the Sales Department information from subparagraph (1) above, to see if a relationship exists between figures showing known orders for, say, May at the beginning of April and known orders for May at the beginning of June - i.e. if a fairly constant ratio exists for known orders forecast two months ahead for any particular size, with the completed order book for that month, this ratio could be used to base production month by month on the forecast figure - referring back to Appendix 6A, using the demand forecast for cost period 5, multiplied by the constant ratio, as a production planning figure at the beginning of cost period 4.

(3) Materials Used It was considered that the position would be greatly simplified if only one basic raw material were used. This was suggested to the Management, who did not feel that, at that time, this subject should be explored in depth.

(4) Other Methods of Manufacture Competitors were obviously using different methods of manufacture, and a comparative study would have been of great interest. However, commercial security problems would probably rule out such an investigation.

(5) Drying Process The existing system of removing the wet pieces of insulation from the moulds by hand, placing them on bogies, and so transporting them to the drying tunnels for a week, seemed to need investigation. A standard gauge for the track would have given more flexibility.

(6) Finishing It was not clear why pipe sections of insulation were cast in one piece and then split lengthwise by machine. The whole finishing process seemed to need investigation, to cut down the amount of machining required.

(7) Storage It was considered that a profitable study could have been done on the existing system of storage at the factory, in the depots, and on sites, together with the distribution system between them. Such problems as whether large stocks of less popular sizes should be held (usually consisting of the larger sizes), and what proportion of future demand should be so stored, required examination. A study to determine the size of safety stocks, using historical data, is another that could have provided useful results.

(8) Costs Preparations were in hand, at the time of the ending of the project, to investigate costs of manufacture, storage and distribution, and also the equipment overheads. Some of these costs would have had an important bearing on the mould-block configuration study. For example, in the case of those sizes for which demand was small, it might prove cheaper to produce a large quantity - say a year's requirement - and store it, rather than attempt to produce them as required. If this was the case, it might be preferable to gather together these sizes in mould-blocks, rather than distribute them as was done in the configurations designed for trial in the project.

Apart from these suggested investigations, the amount of data available at the works had a bearing on the projects actually undertaken. Although, as has been seen, a large amount of production data was forthcoming, other information was unfortunately lacking. As an example, there appeared to be no sales forecasting carried out and therefore no forecast demand figures, which would have provided a better set of data on which to base the simulations described in chapters 5 and 6.

(b) CHANGES IN THE INDUSTRY

More than three years have elapsed since the last practical work was carried out on this project. It is of interest to see what changes have taken place in the manufacture of thermal insulation since then.

The main factor which has had impact on the industry has been the effect of asbestos on health. For many years there were suspicions that workers in asbestos were at risk as far as their lungs were concerned. These suspicions have now become a near certainty, with the result that stringent precautions have to be taken where workers are exposed to these hazards.

This was a serious matter to the Insulation industry, which has always relied upon the inclusion of asbestos to provide the insulating material with the necessary strength.

A second factor has been the difficulty of obtaining supplies of the asbestos, which formerly came mainly from Rhodesia.

Accordingly, the main efforts of the R. & D. staff of thermal insulation manufacturers has been to find a suitable substitute for asbestos. Several materials have been tried out, the most promising being wood pulp - largely extracted from paper - and glass fibre. Problems still exist in the use of these materials, but many firms are using them satisfactorily, thereby making the stringent health precautions required for asbestos unnecessary. It is probably not too much to say that without the development of such substitutes, many firms would have had to go out of business due to the difficulty of complying with the health regulations.

In other respects, the particular part of the manufacturing process with which this paper is concerned has continued, and as far as Company 'X' is concerned, expanded.

(c) SUMMARY AND CONCLUSIONS

The main purpose of this thesis has been to demonstrate that Operational Research uses the same technique as Scientific Method, and follows the same distinct stages. Thus, an assessment of the problem was made at the outset, which was revised in the light of further knowledge of the production system. A large amount of data was made available on output, and further factual data regarding the detailed moulding process was collected. This data was analysed, and the general trends in production of the various sizes of pipe insulation were examined. A model of mould-block configurations was made, from which various configurations of mould-blocks could be devised.

A hand simulation of production, both using the existing configuration and a newly devised configuration, was painstakingly carried out, and a possible rearrangement of mould cylinders in the mould-blocks was suggested to Management. Finally, a computer program was developed to the stage when any configuration could be tested in order to select the most efficient one, using historical demand data. This program was actually tried out in respect of two different configurations, in order to check its method of working.

The only part of the routine, which has not been demonstrated, has been the continuing check on performance. This unfortunately was unavoidable under the circumstances.

The vehicle for this demonstration was the particular problem of the production scheduling of the manufacture of precision moulded thermal insulation in the Chemical Company. This has proved to be an interesting problem, only part of which has been tackled in this thesis. The suggested Configuration B of mould cylinders in mould-blocks would have made the job of production control much easier, and production scheduling could have been carried out on the lines used in the hand and computer simulations. More work, on the lines of the general comments listed above, remained to be done, but with an efficient demand forecasting system as indicated, Production Control could have put their scheduling problems with safety in the hands of their EDP staff, if recruited, or otherwise with a Bureau.

BIBLIOGRAPHY

An extensive search has been made of books and articles and patents concerned with the production scheduling of the manufacture of precision moulded thermal insulation, and this has resulted in the following annotated bibliography. This bibliography is divided into the following:-

(a) Operational Research methods including production scheduling and inventory control

(b) Manufacture and use of precision moulded thermal insulation

(c) Patents

In the case of (a), OR Methods, there are of course a multitude of books on Operational Research methods, many of which are known to the author. Only those books and articles are included which the author has consulted in the course of this thesis.

In the case of (b), Thermal Insulation, most of the references are concerned with either the chemical side of manufacture, or the firms producing insulation,or the design of insulation for plants requiring it.

In the case of (c), an exhaustive search at the National Reference Library for Science and Invention (formerly the Patent Office Library) was largely unproductive. The catalogue system there is a subjective one, rather than an objective one. That is to say, patents are classified by the "method of production", and not by "what is produced". This of course makes the work of the classifier easy, and probably satisfies 99% of those who use the library, who are interested in patented processes, and in any case are concerned mainly in watching for new patents as they appear. For the individual researcher, however, an investigation such as this is a lengthy process. The main heading concerned is "Moulding non-metals B5A". Probably more than 95% of the patents in this category are concerned with the moulding of rubber and plastic substances, nothing to do with insulating materials. In desperation the author turned to the Company concerned, who very generously looked out a list of all patents which have anything to do with the subject. On these are based the contents of this section of the bibliography.

(a) OPERATIONAL RESEARCH METHODS, PRODUCTION SCHEDULING, INVENTORY CONTROL

Books about OR

1. MORSE, Philip M. and KIMBALL, George E., "Methods of Operations Research". The M.I.T. Press, Cambridge, Mass., 1950

2. HOULDEN, B.T. (editor) et al (OR Group of the NCB), "Some Techniques of Operational Research", EUP Ltd., London, 1962

These two books were selected from a large amount of literature on OR, as guides in the writing of chapter 1. The Definition of OR used appears in both books, and the submarine example is in Ref. 1. Ref. 1 is mainly written round the authors' experience of OR in World War II, and the examples are therefore military ones. Ref. 2 was written by various authors commissioned by the National Coal Board, and many of the chapters refer to Ref. 1. Both books are eminently readable and together give a good account of OR in practice.

Books about Production Scheduling and Inventory Control

3. BROWN, Robert G., "Statistical Forecasting for Inventory Control", McGraw-Hill Book Co. Inc., New York, 1959

4. MAGEE, John F. and BOODMAN, David M., "Production Planning and Inventory Control", McGraw-Hill Book Co. Inc., New York, 1958 and 1967

5. BATTERSBY, Albert, "A Guide to Stock Control", Pitman, London, 1962

6. BUFFA, Elwood S., "Production-Inventory Systems: Planning and Control", Richard D. Irwin Inc., Homewood, Illinois, 1968

7. MOORE, Franklin G., "Production Control", McGraw-Hill Book Co. Inc., New York, 1959

8. RODGERS, Winston, "Production Control in a Printing Firm", DSIR Industrial Operations Unit Study Report, London, 1963

9. RODGERS, Winston, "A Case Study of stock control where steady production is desirable", DSIR Industrial Operations Unit Study Report, London, 1963

10. VAZSONYI, "Scientific Programming in Business and Industry", Wiley, 1958

Refs. 3 and 4 are really companion volumes, and together give a thorough treatment of the available techniques in this field. Ref. 3 was particularly used in the author's examination of demand forecasting (chapter 7). Ref. 5 is a very readable book, and particularly informative on such subjects as Economic Order Quantities. Refs. 6 and 7 are more lengthy books, to which reference was made. Refs. 8, 9 and 10 were found to be a very useful introduction, and were examined with interest at the beginning of the project.

(b) MANUFACTURE AND USE OF PRECISION MOULDED THERMAL INSULATION

Books

11. MALLOY, John F., "Thermal Insulation", Van Nostrand Reinhold Co., New York, 1969

12. ALLSWORTH, A.J. (editor), "Insulation Handbook 1969-70 edition", Lomax Erskine Publications, 1969

13. WESEMANN, E.J., "The Piping Handbook 1967", Chapter 6 Thermal Insulation, 5th edition, 1967

These books are mainly written for engineers concerned with the design of pipe insulation. Ref. 11 is a recent publication on this subject, and Ref. 12 a new edition of the handbook, which has the aim of bringing together as many facts and figures as possible to help those using or specifying insulating materials. Ref. 13 discusses the various types of heat insulating materials, and all three publications consider these materials and indicate which firms can supply them.

Periodicals

A total of 41 references were checked in 20 periodicals, of which the following 18 were of interest in this project.

14. Flexible Refractory Insulation, Production Equipment Digest, 11, No. 5, May 1964 (100)

15. Thermal Insulating Materials, Design and Components in Engineering, 24 September 1964 (6-12)

16. Insulation - Materials and Methods Review. The Steam and Heating Engineer, 34, No.395, October 1964 (42-57)

17. NEWALL'S INSULATION & CHEMICAL CO. LTD., Newall's Superplastic 85 - Plastic Insulation suitable for use in temperatures up to 1010°C, Production Equipment Digest, 12, No. 5, May 1965 (4)

18. Profile, Insulation, 9, No. 5, September/October 1965 (243)

19. CHAPMAN, F.S. and HOLLAND, F.A., Keep Piping Hot (by Insulation), Chemical Engineering, 72, No. 26, December 1965 (79-90)

20. Thermal Insulation (Rocksil and Caposite) - Recommended Thickness, Chemical and Process Engineering, 48, No. 1, January 1967 (72-73)

21. EDGE, Martin, High Temperature Thermal Insulation, Power and Work Engineering, 62, No.728, February 1967 (13-20)

22. Magnesia Thermal Insulation, The Steam and Heating Engineer, 37, No.425, April 1967 (62)

23. Insulation Moulded Sections, The Steam and Heating Engineer, 37, No.425, April 1967

24. McWILLIAMS, J.A., Microtherm, a new High Performance Thermal Insulation, Insulation, 11, No. 5, September/October 1967 (227)

25. SHARP, J.H., UPCHURCH, F.N. and WEST, D.E., Special Report, Introduction to the thermal insulation industry, factors affecting the selection and application of thermal insulation materials; Suppliers and Contractors, Process Engineering, January 1968 (27-39)

26. GOODSELL, D.L., Thermal Insulation, Engineering Materials and Design, 11, No. 5, May 1968 (747-755)

27. FIBREGLASS LTD., Insulation Efficiency increased without extra cost, Process Engineering, September 1968

28. DICK'S ASBESTOS CO. LTD., Mineral Wool Insulation has uses at high temperatures, Process Engineering, Sept. 1968

29. Insulation Innovations, Works Engineering, 63, No.749 November 1968 (64-68)

30. ISAACS, Max, Selecting efficient, economical insulation, Chemical Engineering, 76, No. 6, March 1969 (143-150)

31. BLAKELEY, J.D., Trends in the use of thermal insulation, Works Engineering, 64, No.750, October 1969 (19-21)

The following periodicals also contain articles on insulating materials, but not of relevance to this study:-

Heating and Ventilating News
Industrial Process Heating Review
Steel Times
Journal of American Ceramic Society
Journal of British Ceramic Society
Refractories, Russia
Chemical Processing
European Chemical News
Journal of Institute of Engineers, Australia
Mining Annual Review

The list of periodical references can be broadly divided into four categories, some appearing in more than one, as follows:-

Reviews of the use of insulation; with details and photographs of materials used; of use mainly to engineers concerned with design, but useful background to the project. Refs. 14, 15, 19, 21, 25, 26, 30.

Lists of suppliers with details of the materials they make, and insulating contractors. Refs. 16, 25, 26, 31.

Information about individual suppliers and their products. Refs. 18, 20, 22, 23.

Information about new materials, principally fibre glass and wood pulp. Refs. 17, 24, 27, 28, 29, 31

In addition to all the above, the author of this thesis had at his disposal various trade catalogues and publications produced by the Company concerned.

(c) PATENTS

The principal interest in patents lay in the preparation of chapter 7(b) - changes in the industry. Twenty British, one Canadian and sixteen US Patents were found, dealing with the manufacture of Magnesia and Calcium Silicate Insulation.

In the case of Magnesia, the patents examined stretched back to 1937 (US) and 1942 (British) and dealt with aspects of current and past methods of manufacture. The most recent (post 1964) were as follows:-

32. Br.1,112,465/May 68 Co. de St-Gobain, France - the use of a fibre mat of vitreous material for insulation

33. Br.1,133,495/Nov.68 Chemical & Insulating Co. Ltd., UK - the use of wood pulp in place of asbestos in Magnesia insulation

34. Br.1,136,811/Dec.68 Foseco Trading A.G., Switzerland - method of producing insulation in a continuous sheet or strip for subsequent cutting

35. Br.1,147,905/Apr.69 EURATOM, Belgium - a new type of insulant mainly for nuclear reactors, formed by immersing a hot tube in cold liquid

36. Br.1,154,324/June 69 Cape Insulation Ltd., UK - the use of mineral fibres - asbestos, rockwool, glasswool, slagwool

37. Br.1,157,239/July 69 Kabel und Metallwerke G.H.H.A.G., Germany - continuous method of manufacturing thermally insulated pipes complete

In the case of Calcium Silicate, the patents examined were dated from 1940 (US) and 1954 (British). The post-1964 relevant ones are as follows:-

38. Br.984,112/Feb.65 and US.3,238,052/March 66 Unilever Ltd., UK and Joseph Crossfield Ltd., UK. Not directly relevant - relates to the manufacture of silicate materials (synthetic hydrated calcium and sodium alumino-silicates)

39. US.3,317,643/May 67 Owens-Corning Fiberglass Corp. USA. The production of synthetic xonotlite and refers mainly to autoclaving

40. US.3,352,746/Nov.67 Johns-Manville Corp., USA. Relates to the reduction of shrinkage of hydrated calcium silicate bodies by controlling the effective surface area of silica reactant