THE PROGRESSIVE REGENERATION
OF A TRADITIONAL
PRODUCTION PLANT

A THESIS PRESENTED FOR THE DEGREE
OF MASTER OF PHILOSOPHY

BY

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DECLARATION

This dissertation has not been nor is currently being submitted for the award of any other degree or similar qualification.

This dissertation is entirely the work of the author unless otherwise stated.

M.D. WOODS
Author
ACKNOWLEDGEMENTS

The author wishes to thank all of the management, the staff and the operators of Van Mopps IDP. The work has been project based so exposure to a considerable number of people has been gained. Special thanks go to Peter Davies and also to Jim Curran, Ian Marsh, Steve Annettes, John Taylor, John Tunstall and Tony Green.

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Finally my thanks to Heulwen.
ABSTRACT

The programme was conducted under the auspices of the Teaching Company Scheme and involved Van Moppes-IDP, Gloucester, a manufacturer of diamond cutting tools, and The Polytechnic of Wales. The project was "to evaluate the scope for and to assist in the implementation of modern manufacturing methods."

In order to develop a planned programme of change an initial in-depth study of the Company's business and technology was undertaken which highlighted areas of particular concern. A series of interconnected projects were then undertaken.

The process of mixing and mould filling of metal powder/diamond mixture was studied and a new method of pelletisation was developed and introduced.

The machine capability of the Company was analysed and the selection of a CNC turning centre was undertaken. This machine was purchased, commissioned and brought into full production.

The problem of reducing expensive mould wear was investigated but no methods superior to those now used were identified.

The possibility of developing a novel semi-automatic manufacturing unit was explored with a cost analysis. The conceptual design was completed and has given board approval, but the project has not progressed due to a lack of resource.
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1.0 INTRODUCTION
Van Moppes IDP Limited employs some 170 and manufactures a wide range of diamond wheels and other tools for industrial cutting purposes. The company are market leader in the field of diamond tooling with a reputation for quality, precision and service.

The Company is comprised of three Divisions:

- The Rotary Truer Division
- The Stone and Construction Division
- The Superabrasives Division

This project is associated with the Superabrasives Division which produces 50% (approx) of the company turnover.

A five year Strategic Plan was devised by the Company which documented the Strategic Goal as being "To double the company turnover". However the Plan also recognised that the current manufacturing process represented a major weakness in the Company's ability to meet the goal.

To meet this goal and to increase the Company's profitability and its export market penetration, it was essential to evaluate the scope for improving the manufacturing efficiency of the Superabrasive Division. Hence the project's objective became "to evaluate the scope for and assist in the implementation of modern manufacturing methods". This was to be achieved by improvements in design and processing techniques to reduce production costs, and greater use of modern manufacturing technology to speed the introduction of new products into the production plan [1].

1.2 THE COMPANY HISTORY

L.M. Van Moppes & Sons was founded by Louis Meyer Van Moppes in 1893 after his arrival in London from Amsterdam. The operations in these early years were principally confined to diamond merchanting, although a small manufacturing facility did grow alongside the merchanting business.
The Company saw considerable expansion during and after both World Wars and by the time of the move in 1950 to Basingstoke, L.M. Van Moppes & Sons had offices in most major cities in Europe. The Van Moppes network was merged with Impregnated Diamond Products to form the Diamond Products Division of Universal Grinding Limited in 1970.

Impregnated Diamond Products was founded in 1932 by Peter Neven of Antwerp on the basis of a process which he patented for manufacturing abrasive tools for the optical, stone and engineering industries. The process involved mixing industrial diamond with iron powders, heating the mixture to the sintering point and pressing the mixture to consolidate it.

A company was formed in Antwerp under the name of Societe Anonyme Produits Bort as a result of negotiations with a London diamond organisation headed by A.E. White. The Company, was producing diamond impregnated grinding wheels, drills, cutting discs, stone cutting saws and dental tools within a short time.

Negotiations were set up with the British Admiralty because of the advent of World War Two to move key personnel and plant from Antwerp to Gloucester in England. The company changed its name to Impregnated Diamond Products and the plant itself was moved in two weeks, being completed less than a month before the German invasion.

Impregnated Diamond Products joined Universal Grindng Wheel of Stafford in 1959, the largest British owned abrasive products manufacturer in Europe.

L.M. Van Moppes & Sons (Basingstoke) and IDP (Gloucester) relocated on one site to form - Van Moppes-IDP Limited, of Gloucester, on 1st May 1981.

Van Moppes and IDP were by now both part of Unicorn Industries, where for a number of years, they had shared marketing and sales resources and contributed to the funding of the Research and Development Laboratory where many significant product developments had been born.
WM-IDP have also had welcome success in Japan where sales have risen from nothing to over £1m per annum in one year (1986)[2].

The Company now thinks of its activities in three strategic areas

1) The Rotary Truer Division
   Dressing systems for producing very fine tolerance components by grinding.

2) The Stone & Construction Division
   A range of diamond impregnated saws, drilling tubes for cutting concrete, granite, marble, etc.

3) The Superabrasives Division
   The highest quality diamond wheels, hones and tools for a wide range of engineering and glass industries.

1.3 TEACHING COMPANY SCHEME

The Teaching Company Scheme sets up active partnerships between industrial companies and academics. The scheme was devised by the Science and Engineering Research Council and the Department of Trade and Industry. The company is partnered by a nearby University or Polytechnic who must have relevant specialist expertise.

These partnerships are called Teaching Company Programmes. They work in one or more project areas identified by the company as important for improving their efficiency. The academics participate by being involved with company managers in the joint supervision and direction of the work of high quality young graduates. These graduates are called Associates. The Associates work in industry, for industry, but with the backing of the expertise and facilities of the university or polytechnic.

1.4 THE HISTORY OF SUPERABRASIVE TOOLS

The term superabrasive is only generally applied to two materials; cubic boron nitride and diamond. The conventional abrasive found in "white" and "green" grit wheels common to most workshops are
aluminium oxide and silicon carbide. Superabrasives are in the order of five times harder than conventional abrasives, as measured on the knoop scale.

It should hardly come as a surprise that the Egyptians were the first recorded users of diamond tools in the form of a diamond core drill, used during the construction of the pyramids. The modern diamond tool industry started in 1862 when a Swiss engineer, Jean Leschot, developed a hand rotated drilling machine for diamond core drilling. Within ten years, mechanical equipment of 5 - 7 horsepower had been developed, capable of driving drills at speeds up to 360 rpm [3].

Today's diamond tooling industry has grown from these humble roots into an estimated £1000M industry, employing some 20,000 people worldwide.

The last 35 years, has seen spectacular advances in superabrasive tooling technology; particularly the advent of synthetic diamond, and a material not found naturally; Cubic Boron Nitride (CBN). These materials, and their allied technology, allow more effective use of the tooling with greater increases in efficiency and productivity.

Synthetic diamonds and CBN are now mass produced in many factories where the size, purity and strength can be controlled so that the superabrasive is tailor made for its intended use.

The story of early attempts to synthesise diamonds began some 130 years ago, just after the discovery was made that diamonds were made of carbon. Hannay, Moissan, Crookes and Parsons were the 19th century scientists, equivalent to the alchemists of the Middle Ages. Unfortunately, although spectacular claims were made, each of the above, failed to turn carbon into diamond [4].

The modern quest for diamond synthesis was started in 1951 by General Electric (G.E.) who believed that the world needed a more stable supply of the industrial gem. A mere four years later on February 15th 1955 the project team headed by H. Anthoney Nerad presented to the world's press the first undisputed synthetic diamond [5]. However it was a further two years before synthetic diamonds became commercially available.
The synthesis of the superabrasive Cubic Boron Nitride began its commercial production in 1969, heralding a new era in steel grinding, which is an area of application not suitable for either natural or synthetic diamond tools [6]. In many respects diamonds and CBN are very similar to one another; they are the two hardest materials known, they have the same cubic structure and they both exhibit high thermal conductivity.

Diamond in contrast to CBN is prone to graphitisation, where the diamond degrades to form graphite at temperature, additionally, it will oxidise readily in air (at 680°C), whilst CBN is stable to higher temperatures (1400°C) both in air and whilst machining carbon containing workpieces.

The result of the above fundamental difference is a split in the areas of application of the two materials.

Diamond – for machining materials not containing carbon:– aluminium, brass, copper, wood, plastics, tungsten carbide, glass, ceramics, stone, etc.

Cubic Boron Nitride – for other applications:– tool steels, hard irons, surface hardened steels, grey cast iron, and in some cases the nickel and cobalt based superalloys.[7]

These are today's super abrasives which are held in either metal, resin, vitrified, or an electrometallic bonded matrix. These wheels and tools will generally out perform any other form of abrasive.

1.5 SUPERABRASIVE TOOLS AND THEIR APPLICATIONS

Conventional machining processes usually employ tungsten carbide or High Speed Steels as the cutting material. These cutting tool materials face serious limitations when faced with the problem of cutting hard non-metallic materials such as stone, glass, concrete or ceramics because the cutting tool needs to be even harder. Hence, diamond tools are used, where the diamonds are generally held in a matrix or bond system.
Confer stated [5] "Consider the comparisons: if a carbide was given a rating of "1" for abrasion resistance, the coated carbides would need to be rated 5 - 10, Ceramics 10 - 30, and the superabrasives, Cubic Boron Nitride (CBN) would be rated at 50 and diamond at 100." (The properties of diamond and CBN are compared to other "hard" materials in Table 1)[7]

Consequently the advantage of superabrasive tools is primarily abrasion resistance, but other advantages include high heat conductivity, good resistance to thermal shock and good price when using cost per piece economics [8].

It has been said that "diamonds are a girl's best friend" and the reason could possibly be because not only are they rare - only 130 tons of diamond has ever been recovered from an estimated sorted weight of 3000 million tons of rock, sand and gravel! However, only 20% of the recovered 130 tons is acceptable to display. The remaining industrial diamond is physically and chemically the same as the jewellery piece but it includes flaws, discolourations and inclusions.

Superabrasive tools are used in most industries in the western world. These include major markets such as the aircraft, motor vehicle, glass processing, medical, general and civil engineering industries (Fig 1).[9]

Aircraft - aero engine components and turbine blades are precision ground with grinding wheels formed and dressed by single point, multi-point and roll type diamond dressers.

Motor Vehicles - many engine parts are ground with grinding wheels formed and dressed as above, cylinder bores are honed using diamond hones, and more recently, cams and crankshafts have been ground by superabrasive CBN wheels on special purpose masterless cam grinding machines. Many more engine components are being made from low weight aluminium components, a material particularly suited to diamond grinding, turning and boring.

Glass Processing - spectacle and telescope lenses are milled with diamond milling tools, then polished with diamond powder and, finally, edged with diamond wheels.
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<th>Al₂O₃</th>
<th>Al₂O₃ +TiC</th>
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<td>16.7</td>
<td>20-25</td>
</tr>
</tbody>
</table>

Table 1: Mechanical and Thermal Properties of Cutting Tool Materials

NOTE: Syndax 3 is a Polycrystalline diamond ) De Beers
Amorite is a Polycrystalline CBN ) Tradename
Sialon is a ceramic composite Lucas Cookson Sialon Tradename

Table 1
The majority of lead crystal cut glass cut with diamond wheels to achieve the "brilliant cut". The flat glass industry uses diamond products for mirrors, coffee tables, double glazing - all edged, bevelled and drilled using diamond tools.

**Medical** - diamond knives are used almost exclusively for complicated eye surgery, diamond discs for bone sawing, diamond microtome knives for obtaining flesh samples. In the field of spare part surgery, replacement hip joints are ground and polished with diamond paste.

**General Engineering** - bearings, either plain roller or ball bearings, are all ground or polished using diamond, but the biggest users in this category are probably the carbide tool manufacturers.

**Civil Engineering** - this industry uses vast amounts of segmented diamond saws for cutting granite, marble and other rock for construction and production purposes (market size is $645m). Saws are also used for grooving motorways and aircraft runways to help prevent skidding in wet weather.

The Civil Engineering and mining industries also make use of diamond core drills for on site examination.

The above provides an insight into the current industries where diamond machining is common place. New and expanding industries where the use of diamond tooling has a very bright future are the die cast aluminium, plastics, carbon fibre and glass filled composite industries. These, coupled with the advent of CBN and other superabrasives, should ensure a continuing business for the diamond tool manufacturer.

1.6 **THE FACTORY LAYOUT**

The methods used to manufacture diamond tools at Van Moppes have remained virtually unchanged since their introduction some 40 years ago.

The processes are expensive and slow but they produce a good quality product, consequently any new process employed must be able to match the product quality currently obtained, and be capable of responding to a large number of orders being placed on a one off, made to order basis. This order intake pattern generally lends itself to the
typical jobbing/small batch setup i.e. where the plant is arranged by department or process, Van Moppes IDP is no exception [10]. This can be seen in Appendix I (the site plan) which shows the layout of each process department: mixing room, filling room, press shop, turning, fitting and grinding shops. Capacity problems are easily identified with these process arrangements, but problems in work throughput, flow, queing and routing are frequent.

1.7 PROCESSES AND PRODUCTS

The manufacture of superabrasive tools can be at best described as complicated, at least in comparison with conventional metal cutting techniques. (See Generic Product Routes Fig.2 Section 2.3.1). In its simplest form the production process for a typical diamond tool, say a metal bond product splits into four distinct stages.

Preparation of the diamond impregnated body.

Here a powder metallurgy process is employed to homogenously disperse the diamonds around a metal matrix. Powder metallurgy in general is based on the strange idea of converting stock material into a fine powder and then spending considerable time and effort sticking the powder back together again. This sticking process also consists of four operations.

- **Mixing** the powder and additives into a homogenous blend.
- **Cold Compacting** the blended powders in a mould and die set to produce a green segment where cold welding has occurred between the particles.
- **Sintering**: soaking the compacted powders still in the mould at a high temperature, in a controlled atmosphere for a pre-determined time. This creates a true metallurgical bond between the powder through a diffusion mechanism [11].
- **Hot Compacting**. The mould is removed from the furnace and whilst hot undergoes a further compaction operation. Processing in this manner ensures a component density of over 98%. This is important as it ensures that pores do not form around the diamond. Pores around the diamond results in a situation which is analogous to good teeth in bad gums, the diamonds fall out when subjected to the localised cutting forces!
Mounting the Diamond Impregnated Body

The diamond impregnated body is ejected once the mould has cooled, it can then be mounted to the tool holder which is generally a steel wheel. Mounting the impregnated body to the wheel is achieved by simple fabrication methods - adhesives, riveting, soldering, or bolting.

Forming the Tool

The use of the current range of moulds constrains the form generated on the impregnated body. This results in the majority of the moulds having a standard flat form and if any deviation from this is required a further machining operation is needed. This is presently achieved by using an Electrical Discharge Machining (E.D.M.) operation.

Dressing The Tool

The final operations are those of ensuring the diamond impregnated body runs concentricly to the bore of the tool holder and that the diamonds are exposed to give an open cutting condition. These operations are performed by dressing the tool with silicon carbide and aluminium oxide grinding sticks or wheels.

1.8 THE PROJECT

Henri Moissan, one of the early pioneers of diamond synthesis, wrote "the course of research is ever the same, analysis must precede the first gropings of synthesis" [12]. The analysis in this case, was conducted by developing an understanding of the business on two levels.

1.8.1 The Technology

Analysis was conducted on:
* product routes
* processes used
to appraise existing manufacturing techniques and methods.
This was achieved by a three month workshop experience exercise.

1.8.2 The Business & The Market Opportunity

Investigations were made using the following techniques:

* "Pareto" Type Analysis
* Financial Analysis
* Market Potential and Sales Analysis

This was achieved by the analysis of historical data and sales forecasts.

The above analysis was used to highlight areas that required a more searching study. These areas identified were then analysed in depth and alternative manufacturing processes or methods determined. The financial implications have been investigated at all times as all implementation decisions are based on business opportunity criteria, ie. increased profit, increased quality, increased manufacturing flexibility and reduced lead times.

1.8.3 Terms of Reference

The terms of reference for this project are confined to the Superabrasives Division only, which incorporates 14 of the Company's 27 Major Product Groups. The 3 major superabrasive product groups are Metal Bond, Electrometallic and Resin.

1.9 Project Objective

* To analyse all products against dimensions of their current financial performance (sales turnover/margin over materials) and their projected market potential.
* To analyse the existing production processes.
* To design new, or modify existing processes with modern alternative techniques, and subsequently
* To develop and implement those which:-
are economically viable
- speed the introduction of new products.

1.10 THE ANALYSIS OF EXISTING SYSTEMS

The existing systems were investigated during the Teaching Company mini project. A primary objective of which was to achieve a quick and effective induction by exposing the associate to the maximum number of staff in the minimum time. A summary of data recorded during this phase can be seen in Table 2. The data is a product of numerous interviews held with various staff.

The existing manufacturing and production control system used at Van Moppes-IDP Limited has evolved slowly over a period of years. The products are manufactured using conventional plant on a "one off made to order" basis. The systems support 27 major product groups made up of 14,400 special products, (see below Table 2 : General Information). The result of this diversity is:

* an inefficient small batch jobbing shop, and

* an inefficient production control system.

1.10.1 Production Control

Definition
Production control should undertake two functions: service and control.

Service - Production Control provides the (a) Manufacturing Department with details of orders, routes, tools and materials; (b) Sales Department with the progress of orders.

Control - Production Control controls by balancing the plant with effective man/machine utilisation, monitoring of performance against standards of performance and quality, and progresses orders to meet required delivery dates [13].
### General Information

<table>
<thead>
<tr>
<th><strong>Number of employees</strong></th>
<th>170</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of major product groups - manufactured</strong></td>
<td>19</td>
</tr>
<tr>
<td><strong>- factored</strong></td>
<td>8</td>
</tr>
<tr>
<td><strong>Number of products</strong></td>
<td>approx 14,400</td>
</tr>
<tr>
<td><strong>Number of standards</strong></td>
<td>Few</td>
</tr>
<tr>
<td><strong>Average number of orders per day</strong></td>
<td>55-60</td>
</tr>
<tr>
<td><strong>Quoted delivery</strong> (working days)</td>
<td>20</td>
</tr>
<tr>
<td><strong>Number of outstanding orders at any one time</strong></td>
<td>1,100-1,200</td>
</tr>
<tr>
<td><strong>Percentage of orders completed on time</strong></td>
<td>75%</td>
</tr>
<tr>
<td><strong>Are all orders completed on time</strong></td>
<td>No</td>
</tr>
<tr>
<td><strong>Average lateness (weeks)</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>Number of customers</strong></td>
<td>approx 5,500</td>
</tr>
<tr>
<td><strong>No of customers open at one time</strong></td>
<td>approx 1,300</td>
</tr>
</tbody>
</table>

### Production Information

| **Are standard parts lists used** | No |
| **Average percentage of common parts** | <10% |
| **What percentage of the time are specials drawn** | 20 per week |
| **How long are specials filed for** | >5 years |
| **Number of routes held** | >10,000 |
| **Are alternative routes used** | In emergency |
| **Average number of production operations per tool** | 10 |
| **What planning horizon is used** | 1 week |
| **Are stock orders planned to maintain load** | No |

### Stock Information

| **Number of stock locations** | 1 |
| **Are all transactions recorded** | Yes |
| **How long are transactions filed for** - customer issue | >7 years |
| **- issue to shopfloor** | Biannual |
| **How often is stock taking** | Re-order point |
| **How is re-ordering achieved** | |

---

Table 2
In short, it provides the service of developing production plans and recording results to correct the deviations from the plans.

The information gathering process is supported by a McDonnell Douglas M6830 Spirit computer and the Data Processing Department. The order information is entered into the computer at the order receipt stage and it is this information that is used to generate the production plans. The production order paperwork is generated daily and run off in the production control office overnight. The various production reports used are generated either on a weekly or monthly basis.

The evolution of the production control system has been essentially 'reactive' where solutions have been found to have particular problems as they have arisen. The global effect of this is today's production control system where duplicate or unnecessary information is processed by the computer.

1.10.2 Process Routing

The route for each product is detailed on the production paperwork route card. These routes vary from product to product, but a generic route for each major product has been compiled. The generic routes were then studied to ascertain the work flow through the factory. (see Section 2.3.1 and Fig 2).

1.10.3 Standard Times and Costings

The route cards document the standard time for each operation. The route card and the standard times are selected by the computer and issued as part of the production paperwork.

A capacity planning programme could be developed from these times. Unfortunately the standard times are out of date and the company is not presently able to update the information as it does not have the required resource. This lack of resource has lead to a situation where the times are in some cases 70% inaccurate. Capacity planning using this information would obviously be very misleading.
Costing in the short term is possibly more important. A large proportion of product cost is based upon these standard times, and their associated costs. The inaccuracy of the times will have a direct effect result on the costing data.
2.0 PROJECT PLANNING
2.1 INTRODUCTION: PROJECT PLANNING

Van Moppes IDP, has successfully emerged from a position where four years ago, £30-40K a month was being lost on a monthly turnover of £360. Today, a respectable profit is being made on a similar turnover.

The company now wants to expand from this position in order to protect its future by investing in modern production techniques.

The benefits of exploiting such technology are, according to a recent National Economic Development Organisation (N.E.D.O) report [14]:-

- **Return on capital employed** nearly doubled
- **Operating profit** increased (112 to 310%)
- **Total production costs** reduced (14 to 27%)
- **Delivery time** reduced (50 to 73%)
- **Material costs** reduced (13 to 15%)

This Chapter is concerned with the preliminary finding out and planning stages [15] that N.E.D.O. and Production Engineering Research Association (PERA) both emphasise the need for, when implementing modern production processes. These preliminary investigations become especially important if solutions to non-standard problems are being sought, as they are here.

The Project Plan was required to provide a disciplined approach to ensuring that the project objectives, the current technology and the business environment were all fully understood before any attempt was made to change the manufacturing processes.

The Strategy used to create the plan followed five clearly defined stages.

- Understanding the objectives of the project plan.
- Information retrieval
2.2 THE PROJECT PLAN OBJECTIVE

- To identify those areas most likely to yield the greatest benefit from the introduction of modern manufacturing methods.

This will also reduce the risk of project failure and maximise the benefit of the resources applied.

The criteria by which the improvements are to be measured are, as stated in section 1.8.2.

- Increased profit
- Increased quality
- Increased manufacturing flexibility; ability to respond rapidly to any new market requirements.
- Reduced lead time

2.3 Information Retrieval

It is particularly important to understand all aspects of a business before any attempt is made to change it. This was achieved by undertaking a thorough technical and financial analysis through the collation and synthesis of a vast amount of very diverse information.

2.3.1 The Current Technology

The initial analysis used to create a technical understanding, was simply one of following a generic product from each of the product groups through the production process and recording a generic product route, Fig 2. Subsequently it was decided to extend the technique to determine the time each generic product
Fig 2  GENERIC PRODUCT ROUTES
spent at each process stage. Most of the processes are used on a number of products, the shading key shows the product/process loading. (Fig. 3).

2.3.2. The Business and Market

This analysis was conducted in a number of ways, it was important because understanding the technology is not enough. The objective of this analysis was to identify which major product groups and which product lines would yield the greatest benefit from the allocation of the Teaching Company resources. Elegant and expensive solutions or processes must not be developed for businesses that have not been properly understood i.e.:-

a) product lines which could not sustain the investment
b) product lines with no future market potential.

Sales and Market Potential

The sales analysis was historical and used the previous two years accounts. The information required for this analysis needed detail for each Major Product Group and each Product Line:
- The revenue generated
- The percentage that this revenue represented for the division or group
- The average profit generated
- The estimated market potential
- The number of units manufactured per year.

The above information required the collection synthesis and documentation of information from numerous data sources and old computer reports. The result was that the author spent considerable time completely reorganising the presentation of the available data into a more useful format. This process was further hindered by the fact that the company had changed computers in 1984 and only a limited amount of hard data was still available. The empty margin over materials column in Table 3 is a direct result of this. The reorganisation of data was undertaken for all major product groups
FIG 3 SUPER-ABRASIVES PRODUCT RANGE
PROCESS TIME REQUIRED BY A GENERIC PRODUCT FROM EACH MAJOR GROUP
<table>
<thead>
<tr>
<th>Year</th>
<th>Turnover Company (%)</th>
<th>Turnover Materials (%)</th>
<th>Profit over Revenue (%)</th>
<th>&quot;S&quot;</th>
<th>Mkt. Pot.</th>
<th>Inv.</th>
<th>Fin.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986</td>
<td>44.9</td>
<td>42.8</td>
<td>53.7</td>
<td>+0.0</td>
<td>-2</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>1985</td>
<td>22.8</td>
<td>21.2</td>
<td>53.7</td>
<td>+0.0</td>
<td>0</td>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td>1984</td>
<td>16.4</td>
<td>14.8</td>
<td>53.7</td>
<td>+0.0</td>
<td>-2</td>
<td>0</td>
<td>1.5</td>
</tr>
</tbody>
</table>

**Table 3**

**FINANCE: MAJOR PRODUCT GROUP PERFORMANCE - COMPANY WIDE**
## Finance: Performance of Product Lines within Two of the Major Product Groups

<table>
<thead>
<tr>
<th>PRODUCT GROUP</th>
<th>METAL BOND GLASS</th>
<th>METAL BOND OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRODUCT</td>
<td>REVENUE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KK MB BRILL CUT WHEEL</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>KL MB PENCIL EDGE WHEEL</td>
<td>1985</td>
<td>120.00</td>
</tr>
<tr>
<td>KM MB MILLING TOOL 34H</td>
<td>1985</td>
<td>320.00</td>
</tr>
<tr>
<td>KP MB MILLING TOOL 39H</td>
<td>1985</td>
<td>180.00</td>
</tr>
<tr>
<td>KR MB V-EDGE PERI WHEEL</td>
<td>1985</td>
<td>60.00</td>
</tr>
<tr>
<td>LK MB BRILL CUT WHEEL</td>
<td>1985</td>
<td>240.00</td>
</tr>
<tr>
<td>LL MB PENCIL EDGE WHEEL</td>
<td>1985</td>
<td>180.00</td>
</tr>
<tr>
<td>LM MB MILLING TOOL 1</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>LN MB BULLNOSE WHEEL 3</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>LM MB MILLING TOOL 1</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>LR MB V-EDGE PERI WHEEL</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1985</td>
<td>1200.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>METAL BOND GLASS</th>
<th>METAL BOND OTHER</th>
<th>BNX MILLING WHEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRODUCT</td>
<td>REVENUE</td>
<td>% OF GROUP</td>
</tr>
<tr>
<td>KK MB PLAIN CUP WHEEL</td>
<td>1985</td>
<td>450.00</td>
</tr>
<tr>
<td>KL MB DOUBLE CUP WHEEL</td>
<td>1985</td>
<td>150.00</td>
</tr>
<tr>
<td>KM MB DISH WHEEL - M</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>KP MB CUP DISC - M</td>
<td>1985</td>
<td>200.00</td>
</tr>
<tr>
<td>KR MB PERI WHEEL - M</td>
<td>1985</td>
<td>100.00</td>
</tr>
<tr>
<td>LK MB PLAIN CUP WHEEL</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>LL MB CUP DISC - M</td>
<td>1985</td>
<td>200.00</td>
</tr>
<tr>
<td>LM MB PERI WHEEL - M</td>
<td>1985</td>
<td>100.00</td>
</tr>
<tr>
<td>LN MB UNILYTIC CUP WHEEL</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>LR MB UNILYTIC CUP WHEEL</td>
<td>1985</td>
<td>300.00</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1985</td>
<td>1200.00</td>
</tr>
</tbody>
</table>

### Table 4

- **FINANCE**: PERFORMANCE OF PRODUCT LINES WITHIN TWO OF THE MAJOR PRODUCT GROUPS
- **1985**
- **1986**
- **TOTAL**

**PRODUCT GROUP**
- KK MB BRILL CUT WHEEL
- KL MB PENCIL EDGE WHEEL
- KM MB MILLING TOOL 34H
- KP MB MILLING TOOL 39H
- KR MB V-EDGE PERI WHEEL
- LK MB BRILL CUT WHEEL
- LL MB PENCIL EDGE WHEEL
- LM MB MILLING TOOL 1
- LN MB BULLNOSE WHEEL 3
- LR MB V-EDGE PERI WHEEL

**METAL BOND GLASS**
- KK MB PLAIN CUP WHEEL
- KL MB DOUBLE CUP WHEEL
- KM MB DISH WHEEL - M
- KP MB CUP DISC - M
- KR MB PERI WHEEL - M
- LK MB PLAIN CUP WHEEL
- LL MB CUP DISC - M
- LM MB PERI WHEEL - M
- LN MB UNILYTIC CUP WHEEL
- LR MB UNILYTIC CUP WHEEL

**METAL BOND OTHER**
- KA MB PLAIN CUP WHEEL
- KB MB DOUBLE CUP WHEEL
- KC MB DISH WHEEL - M
- KD MB CUP DISC - M
- KE MB PERI WHEEL - M
- LF MB PLAIN CUP WHEEL

**BNX MILLING WHEEL**
- KA MB PLAIN CUP WHEEL
- KB MB DOUBLE CUP WHEEL
- KC MB DISH WHEEL - M
- KD MB CUP DISC - M
- KE MB PERI WHEEL - M
- LF MB PLAIN CUP WHEEL

**MONTHS PRODUCED**
- 20 MAX

**1985**
- 21

**1986**
- 21
Fig 4
THE REVENUE CONTRIBUTION
TO THE COMPANY TURNOVER
FOR ALL MAJOR PRODUCT GROUPS

- SUPERABRASIVE PRODUCT GROUPS
  (i.e. THOSE NUMBERED)
- PRODUCT GROUPS FROM
  REMAINING DIVISIONS

REVENUE £k

PRODUCT GROUPS
Fig 5
REVENUE GENERATED AND MARGIN OVER MATERIALS FOR EACH SUPERABRASIVE PRODUCT GROUP
The range of superabrasive Major Product Groups were considered in even more depth, that is by individual product line. This data is shown in Table 4, where for the sake of brevity only the two most important product groups have been shown.

The above required the collection, synthesis and documentation of information from numerous data sources. This proved to be considerably more time consuming than anticipated.

The results of this investigation can be seen in tabulated form in Tables 3 and 4.

2.4 Analysis

A Pareto type approach was used to evaluate which major groups and product lines provided greatest sales turnover and profit. The analysis, in this case, was also historical and conducted using the results of the sales analysis. (Figs 4 and 5 show the Graphs).

The Project Plan highlighted the Major Product groups and/or Product lines where maximum benefit would be achieved from the investment of the resources available. These highlighted areas or, Strategic Business Units (SBU's) were thought to be those generating the largest sales, but having only a small or medium profit margin; effort would be invested in increasing the SBU's profitability. The large sales high margin lines would not attract investment in time and money because increased profit would be easier to realise through greater market penetration and share.

The Project Plan must also address the forecast market potential of each SBU i.e. where both the market and competition will be in five years time. This was particularly important if any attempt was to be made to protect the Company's future. Consequently, product lines with a diminishing market potential also do not attract investment.

There is of course uncertainty in forecasting business plans five years ahead. Therefore production solutions must be capable of responding rapidly and competently to changes in market requirements.
The analysis shows that the Superabrasive Product Division is the biggest of the three product divisions within the Company. It has accrued just over 50% of the Company's sales turnover for the last three years (see Table 3 Major Group Performance and Fig 4 The Sales Turnover.)

The Metal Bond section is the largest superabrasive sales generator, it has a relatively low margin over materials, and it is believed to have a strong market potential. The Metal Bond section was therefore the ideal candidate for maximum investment of effort.

The largest sales generator in the combined Metal Bond section was the range of wheels at 45%. The next largest was the range of hones and segments commanding 41%.

The most rewarding starting point for change would usually be the largest sales generator, as maximum financial gain could be achieved with minimum effort. However, it was decided to invest most effort to improving production for the range of hones and segments. This decision was made because it was thought to be easier to improve a production process manufacturing rectangular segments, rather than one with a very diverse range of annular rings and wheels.

The improvements will be developed in two thrusts - one short term, one long term. The short term project was to develop the Pelletisation process - a process pioneered by the R & D Department, for the production of segments for the Stone & Construction Division.

The long term approach will be to develop a Flexible Manufacturing Unit (FMU) for the production of hones and segments. It is envisaged that a second machine for producing annular rings will be developed soon after implementation of the machine for the production of hones and segments.

The financial analysis highlighted the need for an investigation of
the Resin Department (Product Group 7), as approximately half of the product lines ran at a loss during 1985 and 1986. Obviously there was a need to rectify this situation.

The Resin, Resimet and Unijet product lines are all very similar and it may be that a Group Technology approach for the three sections would overcome the financial problem described above.

The Graph (Fig 5) shows product Groups 8 - 14 to be much smaller than the product groups 1 - 6. Therefore, little or no effort was invested in these, as resources were scarce and they could be used to greater effect on product groups 1 - 7.

The following product/process analysis is an oversimplification but it was used as a first approximation to give some direction to the project: Two problems were identified from the results of the analysis which recorded the time taken for the various products at each process stage (Fig.3).

- Product design problems
- Process design problems

Product Re-Design

Product re-design is to be investigated when a long time is spent at a particular process stage. Fig. 3 shows that a number of products fall into this category. The two worst offenders being

- electrometallic blanks
- crushform wheels

The result of a re-design may lead to a reduction in the time taken at a particular process stage. This would have three effects:

- increased profit
- extra capacity would be gained
- lead time would be reduced
Process Re-Design

Process re-design will be investigated for those processes which have large capacity requirements because of a large volume of production, eg.:-

- The processes used to manufacture hones and segments
- The turning process
- The diamond profiling process (presently E.D.M.)

2.5 CONCLUSION

The objective of the Project Plan was to identify those areas most likely to yield the greatest benefit from the introduction of modern manufacturing methods. The areas identified to be targeted were those generating large sales, but also having good market potential and a low margin over materials.

Some of the projects are much bigger than others, therefore, one or more projects of various sizes may be pursued at any one time, so project overlaps will occur in many instances.

The investigation undertaken and the findings lead to the following recommendations:

a) The Metal Bond Section was the ideal candidate for maximum investment of effort.

Effort should be applied to improving:-

- The manufacture of the range of hones and segments using the long and short term strategy.

- The current machining processes
  a) Turning
  b) Grinding
- The method used to manufacture profiles in the diamond impregnated body. (Electrical Discharge Machining)

- Product design.

b) The Resin Section

Effort should be applied to improving

- Overall profitability.

These areas of interest can be seen from the flowchart Fig.6

These findings have been presented in a preliminary form to the Teaching Company symposium and in a modified form to the Fourth National Conference on Production Research at Sheffield September 1988. The final updated version was presented to the Fourth International Joint Conference on Mechanical Engineering Technology in Cairo 21st - 23rd March 1989 (Appendicies XIII - XV).
THE SUPERABRASIVES DIVISION

- RESIN
  - INVESTIGATE IMPROVING THE PROFITABILITY OF THE RESIN LINES
  - INVESTIGATE ALTERNATIVE METHODS TO MACHINE DIAMOND IMPREGNATED SOLIDS
  - MIXING & FILLING
  - PRESSING & FURNACING
  - REDUCTION OF MOULD WEAR
    - MATERIALS COATINGS
  - PELLETISATION
    - SELF CONTAINED MANUFACTURING UNIT
      - HONES & WHEELS SEGMENTS
  - MACHINING
    - INVESTIGATE THE POSSIBILITIES OF CNC
      - TURNING GRINDING
    - CUTTING DISCS PENCIL EDGING WHEELS
  - PRODUCTS

FIG 6 AREAS HIGHLIGHTED AFTER INITIAL INVESTIGATION
3.0 THE MANUFACTURE OF STONE SAW SEGMENTS
3.1 INTRODUCTION

One of the major areas of production in the Metal Bond Section is the manufacture of stone saw segments which according to the results of Chapter 2 represents some 28% of the gross sales for Metal Bond products. A segment is essentially a rectangular block consisting of two layers of metal powder, one of which was impregnated with diamonds the "impreg", the other was pure metal - "the backing". The stone saw is made by mounting a series of segments to a steel blank.

The segments are traditionally manufactured by weighing out and mixing, by hand, the required amount of metal powder and diamond for both layers (see Figures 7a - d). The powders are batched up and taken to the filling room where the 30 segment moulds have each segment space individually filled by hand. This technique produces a relatively consistent product of desired quality but is very labour intensive. To weigh and mix the constituent parts for a 30 segment mould takes three quarters of an hour. A similar time was required to fill the mould.

It was felt that these times, and their corresponding costs, could be substantially reduced if the technique of pelletisation could be applied to the manufacture of metal bonded stone saw segments. This would eliminate the conventional mixing stage, and drastically reduce the filling time. It should be noted that the pelletisation technique was only ever regarded as a short term solution. The Flexible Manufacturing Unit (F.M.U.) would be unlikely to use pelletisation as this type of mixing process is an attended one. However, the planning time and the cost of the F.M.U. would be considerable, whereas pelletisation (if it is viable) would yield immediate benefits for minimal capital outlay (£5000).
Photo 7a Dispensing the segment package into the mould

Photo 7b Leveling the mix in the mould
Photo 7c: Showing the Weighing out of the bulk mix

Photo 7d Splitting the bulk mix into the individual segment packages
3.2 OBJECTIVES

The project objective was to ascertain whether pelletisation was a viable production technique for the manufacture of stone saw segments, and if it was, to:-

Ensure the quality and cost implications of the pelletising route are fully realised.

Ensure the process parameters for pelletising are understood.

Ensure that pelletisation can be successfully implemented into the main production process.

Ascertain if the potential benefits of pelletisation can be transferred to the production of other Metal Bond products.

3.3 THE ANALYSIS : THE EXISTING SYSTEM

The current routes and processes used to produce a typical Metal Bond product have been described in Chapter 1, Section 1.7. In this Chapter, a flow diagram showing a summary of the route taken to produce the range of metal bond hones and segments has been added (see Fig 8).

3.4 PELLETISATION : THE MANUFACTURING PROCESS

The key advantages with this process are that it:-

- allows large volumes of diamond impregnated powder to be mixed homogeneously;

- eliminates diamond/metal powder segregation in the mix;

- develops a flow characteristic into the mix, which allows volume filling techniques to be applied.

Pelletisation achieves the above by bonding the metal powder around the diamond particles, thus producing small pellets of metal powder
FIG 8

SUMMARY FLOWCHART OF THE CURRENT METHOD OF MANUFACTURING HONES AND SEGMENTS

1. MIXING
2. FILLING
3. FURNACE/PRESSING
4. DEMOULDING
5. DEBURRING
6. MOULD CLEANING/ASSEMBLY
7. TECTI INSPECTION (SEGMENT)
8. GRAPHITING
9. FITTING
10. MOULD ASSY

TIME (MINS)
- 45
- 45-90
- 15
- 5
- 15
- 20-90 (+5 ASSY)
- 2
- 30
- 60
- 5

SEG MOULD
and diamond [17, 18, 19].

Briefly, the pelletised segment manufacturing process is as follows:-
Also see Fig 9.

3.4.1 PELLETISATION
The pelletisation stage consists of placing the metal powder, the diamond and a binder in an angled pelletising drum (see Fig 10a). The drum is rotated and atomised water sprayed into the mix. The water and the tumbling action causes the bond to form small pellets (1-2mm diameter). The pellets are placed in an oven and allowed to dry, and then to cool.

3.4.2 PRESSING THE DIAMOND LAYER
The mix is now ready for cold pressing. The flow characteristic allows the mix to be volume filled into the die cavity of a Tablet press. The press is set up to give the correct segment weight. The green segments are produced on completion of the pressing cycle - fill die cavity, press, eject, fill die cavity...
The green segments are collected and inspected for weight. (See Fig 10b - c).

3.4.3 PRESSING THE BACKING LAYER
The backings of the segments are pressed in an identical manner, although the powder is not pelletised before pressing.

3.4.4 FILLING
The green segments produced are of such a size that sufficient clearance is given for them to be easily positioned on the conventional multi segment mould. The backing is placed on top of the impreg, and the pressing piston positioned (Fig 10d shows the pelletised mix and the hot and cold pressed segments).

3.4.5 HOT PRESSING/COMPACTING
The mould is hot pressed in the conventional manner. It is then allowed to cool. The segments are ejected deburred and inspected for weight and hardness. The segment is now ready to be brazed to the stone saw.
FIG 9

FLOW CHART OF THE PELLETISED METHOD OF MANUFACTURING HONES AND SEGMENTS

BULK MIX POWDER
WEIGH OUT POWDER 2 MINS
WEIGH OUT PEG

BULK GRIND PEG
WEIGH OUT 5 MINS

COMBINE PEG & POWDER
BALL MILL 3 MINS

DECANT INTO PELLETISING DRUM
PELLETISE
DRY & HAG
PRESS IMPREGS 45 MINS

PROCESS CONTINUES AS PER CONVENTIONAL ROUTE

PRESS BACKINGS 45 MINS
FILL MOULD 3 MINS

THE PELLETISED ROUTE REPLACES MIXING & FILLING ONLY

ADVANTAGES OF PELLETISED ROUTE
- ENABLES BULK MIXING
- FILLING BY VOLUME NOT WEIGHT
Fig 10a: Pelletising Drum and Associated Equipment

Fig 10b: 20 Ton Ajax Tablet Press
Fig 10c: Segment Pressing and Collection

Fig 10d: Cold Pressed; Hot Pressed Segments and Pelletised Powder
3.5 THE BONDS INVESTIGATED

There are a number of bonds used to manufacture the Van Moppes range of hones and segments. These bonds are described by alpha numeric codes like D31 and E51, where for security reasons the codes conceal the true metallurgical nature of the bonds. However, to simplify this presentation the bonds will simply be given alphabetical titles.

Table 5 shows the production figures for the various bonds produced during 1985. A decision was taken to pelletise bonds A - E.

Table 5 : Volume of Segments Produced

<table>
<thead>
<tr>
<th>Bond</th>
<th>Produced</th>
<th>% of Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>30,772</td>
<td>61.60</td>
</tr>
<tr>
<td>B</td>
<td>10,030</td>
<td>20.10</td>
</tr>
<tr>
<td>C</td>
<td>6,263</td>
<td>12.60</td>
</tr>
<tr>
<td>D</td>
<td>1,805</td>
<td>3.60</td>
</tr>
<tr>
<td>E</td>
<td>698</td>
<td>1.40</td>
</tr>
<tr>
<td>F</td>
<td>208</td>
<td>0.40</td>
</tr>
<tr>
<td>G</td>
<td>126</td>
<td>0.25</td>
</tr>
<tr>
<td>H</td>
<td>21</td>
<td>0.04</td>
</tr>
<tr>
<td>TOTAL</td>
<td>49,923</td>
<td></td>
</tr>
</tbody>
</table>

3.6 THE EXPERIMENTAL METHOD

The investigation was to ascertain if pelletisation was a method capable of replacing the traditional mixing and filling operations for Metal Bond segments and hones.

This was achieved by manufacturing segments using both the conventional and the pelletised methods, and then comparing segments produced by each method at two critical stages:
- The cold pressed stage: Checks were made for diamond concentration (dispersion of the diamond through the matrix), weight and standard deviation of weight.

- The final pressed stage: Checks were made for hardness, density, weight and standard deviation of weight. Checks were also made by sectioning random specimens and viewing under an electron microscope.

The initial experiments used alumina as a substitute for diamond. The reason for this was that even industrial diamonds are expensive, and for a first approximation alumina can provide a cheap substitute. However, because alumina was not a precise substitute, improvement in the results for these samples using diamond can be expected for the following reasons:-

- The diamond size investigated was at the top of the Van Moppes size range and the alumina particles were slightly larger than the sizes of diamond particle that it was required to stimulate. The best results have always previously been obtained using the middle size range of particles.

- The standard deviation of particle size within each mesh* size is greater for alumina than for diamond; due to less stringent tolerances.

- In a diamond mix, the bond pelletises more easily as the diamond has an affinity for the binder. Alumina does not have this affinity.

- Diamond particles are more uniform in shape, which tends to give better results with regard to standard deviation of concentration.

The manufacturing and testing of the pelletised segments was carried out by the author. This included pelletising the required mixes for both alumina and diamond, cold pressing the pelletized mixes, the cold pressed segment checks, mould filling, deburring and the final hot pressed segment checks.

* diamonds are graded in size by mesh sizes.
3.7 THE RESULTS

Bonds A, B and C required no modification to the bond structure, pelletisation was easily and consistently achieved. The investigations made at both checking stages gave satisfactory results. Consequently, it was felt that segments produced by these bonds, should be tested in the field immediately.

Initially, bond D would pelletise, but the pellets would lose all strength on cooling, resulting in a weak and powdery mix not capable of being handled without the diamond and metal powder separating.

Traditionally, the bond D had been a single size powder, 300 Mesh. The problem of bond weakness was discussed with the various R & D staff. It was suggested that the remedy might be to modify the powder to 50% 300 Mesh, 50% 100 Mesh. Bond D then pelletised readily and the results obtained at the checking stages were very satisfactory. Bond D should also now be tested in the field. Bond E gave unsatisfactory results. Pelletisation was eventually achieved by considerably modifying the bond by introducing a new metal powder into the bond.

The development of bond E was dropped because the bond structure was now radically different to the original, and compared to bonds A, B, C and D, the pelletised mix was still weak and powdery. Table 6 shows the results of Concentration and Yield Analysis.

3.8 GOLD PRESSING (COMPACTING)

The work carried out in pressing the pelletised segments (AJAX 20 ton press) revealed two fundamental problems.

The larger 24mm x 9.3mm x 7mm diamond impregnated segments could not be pressed to the desired green strength in one compact, as the power needed to compress the segment exceeded the power rating of the press. The solution was to press these segments in two compacts. This resulted in pressing time being twice that expected.
Table 6

CONCENTRATION/YIELD ANALYSIS

DIAMOND SIZE D601/2

SEGMENT SIZE 24 x 9.3 x 7mm LAYER : 25 CONCENTRATION

<table>
<thead>
<tr>
<th>BOND TYPE</th>
<th>STAGE CHECKED AT</th>
<th>HAND MIXED</th>
<th>PELLETISED AI₂O₃</th>
<th>PELLETISED AI₂O₃</th>
<th>PELLETISED DIAMOND</th>
<th>PELLETISED DIAMOND</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AV CONC STAND DEV YIELD %</td>
<td>25.8 2.84</td>
<td>27.2 2.64 95.7</td>
<td></td>
<td>26.7 2.55 84.9</td>
<td>28.0 2.12 84.9</td>
</tr>
<tr>
<td>B</td>
<td>AV CONC STAND DEV YIELD %</td>
<td>25.5 1.46</td>
<td>25.5 3.25 95.3</td>
<td>26.8 2.29 90.6</td>
<td>26.0 1.35 90.6</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>AV CONC STAND DEV</td>
<td>29.6 &amp; 27.8 2.68 &amp; 1.70</td>
<td>16.9 1.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>AV CONC STAND DEV YIELD %</td>
<td></td>
<td>2 REJECTS MIX TOO WEAK 71.9 &amp; 89.8</td>
<td></td>
<td>23.4 1.47</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>AV CONC STAND DEV YIELD %</td>
<td></td>
<td>24.6 3.76 98.5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NB 1 YIELD ANALYSIS : FRACTION OF MIX PASSING THROUGH 10 MESH SIEVE (DATUM ARBITRARILY SET)
The weight tolerance traditionally achieved by weighing out the individual segments by hand is the segment weight, ±0.01g. This is not realistic tolerance for the above press to work to; for example, a typical segment weight is 6.79g and the table shows the weights of fourteen consecutive pressings taken from the press.

Required Weight (g): 6.79 Pressing Tolerance ±0.05g

<p>| | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.80</td>
<td>2</td>
<td>6.76</td>
<td>3</td>
<td>6.68</td>
<td>4</td>
<td>6.76</td>
<td>5</td>
<td>6.78</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>6.76</td>
<td>9</td>
<td>6.83</td>
<td>10</td>
<td>6.78</td>
<td>11</td>
<td>6.72</td>
<td>12</td>
<td>6.79</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>6.78</td>
<td>14</td>
<td>6.74</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen from the above that readings 3, 6 & 13 are out of tolerance with a ±0.05g tolerance and one would think that an adjustment to the press would be necessary, however in each case the weight of the next pressing is adequate.

Consequently, it was decided that a realistic tolerance would be segment weight ± 0.05g, but even this can only be achieved if a high degree of care & concentration is used.

Additionally, it is believed that the tolerance band for the diamond segment is unnecessarily tight. The tolerance band should be relaxed to allow easier pressing of the diamond segment. Conversely, the backing tolerance band should be tightened as the backings press easily and consistently.

It should be realised that there is no evidence to suggest that the weight tolerance (±0.01g) for the hand mixed product is necessary. Unfortunately due to the deadline imposed for project completion no investigation was made into the effect of changing the tolerance band of the hand mixed product. Time was spent instead ensuring that the standard deviation of weight of the pelletised segment was no worse than the traditional segment.
3.9 QUALITY CONTROL

The yield of the mix was arbitrarily measured as the fraction passing through a 10 Mesh sieve. It is now believed that a 10 Mesh sieve is too fine because tests show that concentration is not adversely affected by incorporating the larger pellets. Therefore, a larger sieve could be used: 8 Mesh 22 gauge wire. A yield of above 98\% would be expected from a sieve of this size.

Recovery of sub-standard mixes and pressings is currently achieved by crushing the mix and pressings and soaking overnight in hot water, the diamond being recovered the next day by sieving through the appropriate size sieve. It is believed that the number of sub-standard mixes (ie. too large a pellet) will be in the order of 1\%. Consequently automatic recovery is not likely to prove justifiable. (Although a number of techniques could possibly be used - vibration, ultra sound and the mixing of the mix into a slurry).

Recommended Specification For Cold Pressings
Green strength: handleable, good compaction and not too dusty.
Weight accuracy:
- Impregnated Layer: $\text{wt} \pm 0.05g$
- Backings: $\text{wt} \pm 0.05g$
- Concentration\*: Concentration $\pm 2$ points.

3.10 POTENTIAL FOR OTHER PRODUCTS

The pelletisation route would certainly lend itself to the production of hones, although the larger 4 inch long hones may have to be pressed in two parts simply because the press die set could not physically incorporate a 4 inch long segment.

The conventional mixing and filling operations for the ring type moulds are generally less time consuming than the equivalent operation for the segment mould.

The time to complete the mixing operation for the ring moulds is also 90\% unattended, pelletisation it is 100\% attended. Additionally it is

\*A trade specification
### 3.11 COST COMPARISON - CONVENTIONAL & PELLETISATION

#### CONVENTIONAL

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Minutes Per Mould</th>
<th>Total Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVER. NO. OF SLOTS PER MOULD</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIXING</td>
<td>45 MINUTES</td>
<td>315</td>
<td></td>
</tr>
<tr>
<td>FILLING</td>
<td>45 MINUTES</td>
<td>315</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>630</td>
<td></td>
</tr>
</tbody>
</table>

#### PELLETISATION

<table>
<thead>
<tr>
<th>Activity</th>
<th>Description</th>
<th>Minutes Per Mould</th>
<th>Total Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PELLETISATION</td>
<td>1 BATCH × 30 MIN = 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 BATCHES × 30 MIN = 60</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 BATCHES × 30 MIN = 120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SET UP PRESS (TYPICAL)</td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>PRESS IMPEGS (INITIAL ADJUSTMENTS)</td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>PRESS BULK SEGMENTS AND CHECK</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>PRESS BACKINGS (INITIAL ADJUSTMENTS)</td>
<td></td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>PRESS BULK OF BACKINGS</td>
<td></td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>INSPECT BULK SEGMENTS</td>
<td>5 MIN PER MOULD INSPECTION</td>
<td>17 × 5 = 85</td>
<td></td>
</tr>
<tr>
<td>FILL MOULD</td>
<td>5 MIN TO FILL MOULD</td>
<td>17 × 5 = 85</td>
<td></td>
</tr>
<tr>
<td>RECOVER DIAMOND</td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>SUB TOTAL</td>
<td></td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>ADDITIONAL COSTS</td>
<td>TOCLING * 5 PENCE PER SEGMENT (0.25 MIN)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AT $12.00 PER HOUR</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>125</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>300</td>
<td></td>
</tr>
</tbody>
</table>

* BASED ON A STONE AND CONSTRUCTION COSTING FOR COMPATIBLE BONDS AND DIE SETS
not thought filling times could be drastically reduced by replacing the powdered mix with a pelletised one. This may not, however, be the case with large batch orders.

A batch of Bond A, was pelletised with very fine Diamond particles although no analysis has been undertaken. Visually, the mix has pelletised well, small pellets and little dust. Therefore, it can be concluded that pelletisation of bonds at the top and bottom of the diamond range is achievable, although the parameters for pelletisation have yet to be optimised for the smaller diamond sizes.

The problem of diamond size contamination would need to be very carefully considered if pelletisation were used for products incorporating diamonds of smaller size ranges. Small diamonds are not presently used for segment production, hence contamination by large rouge diamonds is not a problem.

3.12 DISCUSSION

Assuming the pelletised segments prove successful in the field, the pelletisation route for the production of metal bond saw segments should be adopted immediately, for D601 size diamond in the following Bonds : A, B, C, D. Concentration analysis should be undertaken before other diamond sizes are used for production orders, but the experience of other departments is that the middle size range of diamonds used at Van Moppes-IDP give the best concentration results. D601 is one of the larger sizes of diamonds used.

The results documented indicate that the standard deviations of concentration recorded are generally lower for the pelletised mixes. The results also indicate both processes produce segments of comparable quality with respect to:

Average concentration
Hardness
Density and Micro structure see Appendix III Photomicrographs

The pelletised segments also give a better standard of deviation of final pressed weight (Appendix II) and they eliminate the "dishing" sometimes seen in conventionally produced segments.
The major advantage of pelletisation over the conventional route is the cost of production.

<table>
<thead>
<tr>
<th>No. of Segments Produced in a Batch</th>
<th>200 Segs</th>
<th>500 Segs</th>
<th>1000 Segs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional time/ min</td>
<td>630</td>
<td>1530</td>
<td>3060</td>
</tr>
<tr>
<td>Pelletised time/ min</td>
<td>300</td>
<td>595</td>
<td>1100</td>
</tr>
<tr>
<td>Percent saving</td>
<td>52</td>
<td>62</td>
<td>64</td>
</tr>
</tbody>
</table>

The percentage saving can be seen to increase as the batch size increases. This is a manufactured saving. The total saving would be significantly influenced by another factor if the batch size were to be increased beyond 1000 segments. This factor is that of consignment stock. Diamond is supplied to Van Moppes in sealed jars, only when the seal is broken do Van Moppes pay for the contents. A large consignment stock available at the factory but the seals are unbroken. This allows the company ready access to diamond with minimal diamond stock cost. Consequently the manufacturing cost of very large batches of segments would fall, but the stock holding cost would drastically increase.

There are about 60,000 segments pressed each year, with batches of say 500 pressings, this represents a saving of over £20,000 working on the current overhead rate per hour.
The cost could be further reduced if:

i. One compact per segment could be produced, for all sizes.

ii. Inspection of the bulk of the pressings could be eliminated.

The above would be achieved if a replacement press could be justified.

3.13 CONCLUSION

The results and the cost analysis show saving enough to warrant immediate implementation should field trials prove conclusive. (See final discussions for field trial results).

3.14 RECOMMENDATIONS

Assuming field trials prove conclusive.

1. a) The purchase of a press pressed for the Metal Bond Section:

   b) The press selected needs to be capable of pressing one compact for one segment, to the given accuracy, thus reducing production time.

2. The development of a paperwork system to cover the orders requiring pelletised mixes.

3. Random concentration checks of the mixes, by R & D.

4. An investigation to ascertain whether the weight tolerance called for on the compacts is really required.
4.0 AN OVERVIEW OF TURNING TECHNIQUES
4.1 INTRODUCTION

The need to improve manufacturing effectiveness had been identified to meet the demands of the strategic plan.

The most effective way to increase the production output was believed to be to increase the capacity and efficiency of the largest, but most inefficient process, the earlier analysis conducted (see Section 2.3) indicated that this process was turning. The turning process is central to the running of the factory, as most products are turned at some stage. Consequently it was decided to investigate various methods to improve the efficiency of this section, as the turning methods are old, slow, and expensive.

The methods believed to be capable of increasing the capacity/efficiency of the turning section were:

- To increase sub-contracting
- To buy new or second hand conventional machines and recruit and train new operators
- To investigate the possibility of applying modern CNC techniques

4.2 OBJECTIVE

To identify and implement the most effective method of increasing the manufacturing efficiency of the superabrasives division, with regards to the turning process.

4.3 THE OPTIONS AVAILABLE

Sub-Contracting

There was only a finite amount of work that could effectively be sub-contracted without incurring massive lead time and cost penalties. This was because the work would need to first be subcontracted for machining, returned to the factory to have the diamond layer moulded on and subcontracted again for finish machining before being returned to the factory for final inspection and packaging.
Additionally at the time of the investigation the company were having problems in locating reputable sub-contractors to meet the required quality and delivery demands. This suggests that increased sub-contracting should not be the way forward.

**Conventional Machines**

The analysis undertaken (see 4.5.1) during the project quickly highlighted that the work load achievable on a CNC machine would be in the order of four times greater than that achievable on a conventional machine. Therefore, if the conventional route was adopted four conventional machines and an additional four operators would be required to achieve an output level compatible to that of one CNC machine.

However, the level of capital expenditure required for the conventional route is considerably less than the CNC route. Say, second hand machines are purchased.

\[
\begin{align*}
4 \text{ machines} @ \£3500 \text{ each (}£10000 \text{ new)} & \quad 16000 \\
4 \text{ men} @ \£10194 \text{ each (see Financial Analysis 4.5.3.)} & \quad 40776 \\
\hline
& \quad 56776
\end{align*}
\]

The above shows that the conventional route has an on-going employment cost of nearly £41K pa associated with it. It should also be noted that the company frequently had difficulty in recruiting satisfactory machine shop staff. This seems to be due to skilled labour shortages and a low local unemployment rate. Therefore, even if the conventional route looked attractive it would seem unlikely that Van Moppes IDP could easily recruit the required personnel.

The conventional route is also unable to provide most of the "built in" advantages of the modern CNC machine (Fig II) [20].
Fig 11

MANUFACTURING ADVANTAGES OF N.C.

1. FLEXIBLE
   - MIRROR IMAGE FACILITIES
   - MODIFICATIONS TO COMPONENT EASIER TO ACCOMPLISH
   - SIMPLE OR COMPLEX PARTS CAN BE MACHINED ON SAME M/C
   - "IMPOSSIBLE" PARTS MANUFACTURED
   - REDUCED LEAD TIME
2. SAVING IN TOOLING REQUIREMENTS
3. VERIFICATION
   - HIGH M/C UTILISATION/INCREASED PRODUCTION
   - ACCURACY OF OPERATION INCREASED
   - REPEATABILITY
4. PLOTTING TABLE
   - AUTOMATIC PRINT OUT OF TAPE
   - EASE OF "SETTING UP"
   - INTERPRETATION OF DRAWINGS BY M/C OPERATOR DURING PRODUCTION MINIMISED OR ELIMINATED
5. BASIC FIXTURE WILL ACT AS FIXTURE FOR MOST COMPONENTS
   - J.C.M.T. CAN BE EASILY USED FOR OTHER WORK WHILST Awaiting APPROVAL OF PART
6. ROUGHING AND FINISHING CAN BE OBTAINED FROM A SINGLE TAPE
7. ENABLES INSPECTION PROCEDURES TO BE REDUCED
CNC Machines

The next stage of the analysis was to investigate the relative merits of CNC machining techniques to see if they are appropriate for the type of work undertaken at Van Moppes IDP i.e. the production of low value, one off, made to order components. Private correspondence [20] resulted in a number of useful charts: Fig. 12 shows the circumstances under which CNC techniques can be profitably utilised. A number of these are directly relevant to Van Moppes IDP. Consequently it was decided to extend the investigation into CNC machining.

The perceived advantages of CNC machining are generally thought to be those shown in Fig. 13. There are also disadvantages, the disadvantages specific to VMIDP are discussed throughout the text.

4.4 DATA COLLECTION AND REVIEW

It had been anticipated for some time that a project involving an investigation into CNC machining might evolve, so a certain amount of background literature had already been collected. This literature came from two main sources.

- Periodicals
- CNC machine tool manufacturers literature

Once the project became 'live' a far more scientific approach was adopted. The initial task was to ascertain which products were most appropriate for CNC turning and to generate a specification for a machine to manufacture these products. Work selection and the generation of a specification were both derived using:- Polytechnic staff expertise, in house understanding of the current manufacturing methods and the information contained within the literature search and data review. The specification (see Table 14) was then used as a benchmark to judge each of the fourteen manufacturers who initially claimed to be able to provide a machine to match the specification. These manufacturers were asked to provide a quote with technical literature on the machine and user references. These users were then contacted to obtain information about machine
Fig. 12
Circumstances under which NC can be profitably utilised

* A number of different products are produced by the manufacturing process

* Batch sizes vary but are generally small (1-50)

* Lead time is important

Some of the products are of complex design

* Requires different manufacturing process or perhaps requires design changes during production

Some components require precision machining

* Some components require to be worked on by skilled labour for long periods

Close tolerance requirements or reliability or other stringent specifications

* Overall good quality product

* Indicates those advantages applicable to VMIDP
Fig 13
SPECIFIC ADVANTAGES OF N/C

COMPETITIVE ADVANTAGE

REDUCTION IN DIRECT AND INDIRECT LABOUR COSTS

REINTEGRATION OF MANAGEMENT FUNCTIONS

LESS TOOLING INVESTMENT

MORE REALISTIC PLANNING AND SCHEDULING

HIGHER QUALITY AND RELIABILITY

MORE FLEXIBILITY IN FACTORY LOCATIONS

REDUCTION IN PAPERWORK

A) QUALITY
B) REDUCTION IN LEAD TIME
C) ADDITIONAL PERFORMANCE CAPABILITIES
D) DESIGNS MORE FAITHFULLY REPRODUCED

A) REDUCTION IN LABOUR
B) SET UP TIMES REDUCED
C) HANDLING REDUCED
D) PRODUCTIVE

A) CAUSES AN EVALUATION OF THE POTENTIAL AND LIMITATIONS OF EACH OF THE MANUFACTURING FUNCTIONS

REDUCTION IN TYPES OF JIGS AND FIXTURES

SMALLER INVENTORIES

REDUCTION IN IN-PROCESS TIME

LESS DEPENDENCE ON SKILLED LABOUR

A) REDUCED IN-PROCESS TIME

A) CONSTANT TIMES
B) CONSTANT FEEDS AND SPEEDS
C) NO CALCULATIONS CARRIED OUT AT MACHINE
D) MAX UTILISATION OF EQUIPMENT

A) REDUCTION IN SCRAP
B) REDUCED INSPECTION TIME

A) REDUCED IN-PROCESS TIME
performance, installation/implementation difficulties, the quality of training and after sales service.

This phase of the project used extensively the facilities at the Polytechnic of Wales these included:-

- The Manufacturing Centre's resource of machine tools and computer systems. These were used to gain familiarisation with 
  CNC techniques, processes and nomenclature.
- The human resource, the vast amount of knowledge/expertise contained within the Department.

Attempts were also made to select the optimum machine by using an "Expertech Xi Expert" system. The system which is managed by Dr T Mileham of Bath University was at the time limited by the amount of data it contained. Unfortunately, both of the lathes selected were later found to be unsuitable.

Additionally a number of technical reports were read, a number of which provided the basis for the initial justification [20 & 21].

4.5 The Economics of CNC

The economics of CNC vs conventional machining were prepared by comparing CNC and Conventional machining times and their respective costs. (See Appendix IV : Hourly Rates)

The flow chart Fig. 14 [20] shows the stages of analysis required to compare the direct costs. This analysis was conducted for twelve products having either:-

- high turning/fitting content
- high revenue
- high sales volume i.e. Brilliant Cutting wheels, or
- Low sales volume and complex machining operations i.e. "special" electrometallic peripheral wheels
Fig 14

COMPARISON OF COSTS

CONVENTIONAL M/C
COST PER COMPONENT

COST OF JIGS AND FIXTURES
TOTAL NUMBER OF COMPONENTS

MARKING LOT
COSTS/COMPONENTS

SETTING COSTS
NO IN BATCH

MACHINING COSTS

N.C.M.T.
COST PER COMPONENT

COST OF JIGS AND FIXTURES
TOTAL NUMBER OF COMPONENTS
SOFT JAW TOOL HOLDERS

MACHINING COSTS

SETTING COSTS
NO IN BATCH

PROGRAMMING & DATA PREP COSTS
TOTAL NUMBER OF COMPONENTS
Indirect savings of reduced inspection, reduced scrap and reduced work in progress were also considered see Appendix 5.

4.5.1 The Machining Analysis

The machining analysis was developed from comparing three sets of data:

- The Costed Routes and times: the "standard" times detailed on the production paperwork route card.
- The Actual Routes and times: the shopfloor supervisors estimate of the routes and times.
- CNC Routes and estimated times: made up of an estimated CNC time, loading, unloading and a set-up times.

In an ideal world the costed and actual routes and times would be identical. However previous analysis of the production control system had revealed inaccuracies of up to ±70% on documented times (see section 1.10.3). Consequently it was decided to incorporate into the analysis the hopefully objective views of the machine shop supervisor.

The fourteen manufacturers investigated were each asked to provide time studies on the products thought to be appropriate for CNC turning. The results of these time studies were averaged for each particular product and it was these averages that were used for the CNC times as shown in Table 7. Additionally further analysis was undertaken at the Polytechnic of Wales on a Sirius CAD/CAM computer with a simulation software package which calculated the machining times therefore establishing a datum for objectivity.

The analysis then compared Costed/Actual/CNC times and costs to ascertain if there was an advantage in using CNC technology (see
Table 7 & 8). The relative costs were also compared as it can be misleading to simply compare times because CNC machining time is considerably more expensive than conventional machining time.

NOTE:— CNC cost per hour — £17.90)  
          Conventional cost per hour — £12.31) see Appendix IV

The results shown in Tables 7 & 8: show that there is a machining time advantage of 5:1 and a machining cost advantage of nearly 4:1. i.e. a CNC machine could produce the analysed work five times faster than a conventional machine which corresponds to a conventional machining cost four times the CNC machining cost.

Simple ratios are used in the following analysis of production times. In each case the CNC time has been divided into the current costed and current actual time. In doing this the CNC time is always 1 and the current costed and current actual is in a ratio to that.

The same logic has been applied to the analysis for Production Costs and subcontracted component costs.
TABLE 7

The Analysis: Production Times

Saving Ratios: In House Work

<table>
<thead>
<tr>
<th>Products/Drg No</th>
<th>Costed</th>
<th>Actual</th>
<th>CNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Metal Bond Cup</td>
<td>11.89</td>
<td>7.23</td>
<td>1</td>
</tr>
<tr>
<td>01H/150M/516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Brilliant Cutting Wheel</td>
<td>5.92</td>
<td>4.68</td>
<td>1</td>
</tr>
<tr>
<td>B07H/150M/8M/514</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Pencil Edging Wheel</td>
<td>2.17</td>
<td>2.35</td>
<td>1</td>
</tr>
<tr>
<td>P07H/200M/BM5/508</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Resimet Peri Wheel</td>
<td>5.71</td>
<td>3.81</td>
<td>1</td>
</tr>
<tr>
<td>07F/125M/3M/504</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Resimet F/C Wheel</td>
<td>3.7</td>
<td>5.56</td>
<td>1</td>
</tr>
<tr>
<td>14F/90M/10M/501</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Unijet F/C Wheel</td>
<td>3.7</td>
<td>7.4</td>
<td>1</td>
</tr>
<tr>
<td>14J/90M/10M/501</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Internal Grinder</td>
<td>8.47</td>
<td>5.6</td>
<td>1</td>
</tr>
<tr>
<td>08SL/13M/8M/503</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Cutting Disc</td>
<td>1.69</td>
<td>3.44</td>
<td>1</td>
</tr>
<tr>
<td>05SL/56/D067/3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVERAGE</td>
<td>5.11</td>
<td>5.00</td>
<td>1</td>
</tr>
</tbody>
</table>
TABLE 8

Analysis: Production Costs

Saving Ratios: In House Work

<table>
<thead>
<tr>
<th>Products/Drg No</th>
<th>Costed</th>
<th>Actual</th>
<th>CNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Metal Bond Cup</td>
<td>8.18</td>
<td>4.97</td>
<td>1</td>
</tr>
<tr>
<td>01H/150M/10M/516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Brilliant Cutting Wheel</td>
<td>2.44</td>
<td>3.21</td>
<td>1</td>
</tr>
<tr>
<td>3. Pencil Edging Wheel</td>
<td>1.87</td>
<td>1.95</td>
<td>1</td>
</tr>
<tr>
<td>P07H/200M/6M5/508</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Resimet Peri Wheel</td>
<td>3.93</td>
<td>2.62</td>
<td>1</td>
</tr>
<tr>
<td>07F/125M/3M/504</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Resimet F/C Wheel</td>
<td>2.56</td>
<td>3.83</td>
<td>1</td>
</tr>
<tr>
<td>14F/90M/6M/507</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Unijet F/C Wheel</td>
<td>2.56</td>
<td>5.13</td>
<td>1</td>
</tr>
<tr>
<td>14J/90M/10M5/501</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Internal Grinder</td>
<td>5.82</td>
<td>3.84</td>
<td>1</td>
</tr>
<tr>
<td>08SL/13M/8M/503</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Cutting Disc</td>
<td>1.00</td>
<td>2.04</td>
<td>1</td>
</tr>
<tr>
<td>05SL/56/D067/3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AVERAGE</td>
<td>3.54</td>
<td>3.45</td>
<td>1</td>
</tr>
</tbody>
</table>
Saving Ratios: Sub-contracted Component Costs

<table>
<thead>
<tr>
<th>Products/Drg No</th>
<th>Sub-contract</th>
<th>CNC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Adaptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTM/6168, 7023, 10518</td>
<td>3.85</td>
<td>1</td>
</tr>
<tr>
<td>2. EM Peri Wheels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>07SL/204M/75M/503</td>
<td>4.78</td>
<td>1</td>
</tr>
<tr>
<td>3. Mullard 0 34mm Wheels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>08SL/34M/8M/</td>
<td>4.60</td>
<td>1</td>
</tr>
<tr>
<td>4. Crushform Bodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTM/10523</td>
<td>3.59</td>
<td>1</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>4.211</strong></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>

4.5.2 The Tooling Analysis

It can be seen from the analysis (Table 9: Volumes pa are sales estimates) that many of the high volume products:

- Brilliant cutting wheels
- Pencil edging wheels
- Crushform wheels

would benefit from a CNC lathe having live tooling. The need for live tooling is further reinforced when it is realised that 25-35% of the fitting sections time is spent drilling and tapping holes; this represents £15000 pa in labour terms alone. The need for expensive jigs and fixtures and expensive marking out procedures could also be eliminated with the use of live tooling.

Consequently the live tooling would reduce or in some cases eliminate the need for secondary machining which has its own inherent advantages.

- Lead times are reduced, as queuing problems are eliminated
- Work in progress levels are reduced
<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>CNC</th>
<th>CONVENTIONAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO OF TOOLS</td>
<td>NO OF JIGS</td>
</tr>
<tr>
<td>METAL BOND</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>CUP WHEEL</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>BRILLIANT CUP WHEEL</td>
<td>300</td>
<td>6</td>
</tr>
<tr>
<td>CUT' WHEELS</td>
<td>2004</td>
<td>3</td>
</tr>
<tr>
<td>PENCIL EDGING WHEEL</td>
<td>6000</td>
<td>1</td>
</tr>
<tr>
<td>FLARING CUP WHEEL</td>
<td>100's</td>
<td>4</td>
</tr>
<tr>
<td>INT' GRINDER</td>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>CUTTING DISCS</td>
<td>100's</td>
<td>4</td>
</tr>
<tr>
<td>HABIT ADAPTERS</td>
<td>10' s</td>
<td>2</td>
</tr>
<tr>
<td>DIAMEX ADAPTER</td>
<td>10' s</td>
<td>2</td>
</tr>
<tr>
<td>QUILL ADAPTER</td>
<td>10' s</td>
<td>2</td>
</tr>
<tr>
<td>EM PERI' WHEELS</td>
<td>1500</td>
<td>4</td>
</tr>
<tr>
<td>CRUSHFORM BODIES</td>
<td>1200</td>
<td>2</td>
</tr>
</tbody>
</table>

* 3. Live Tooling Operations
4.5.3 The Financial Analysis

The Effect on Sales

The machine was justified on the increase in forecast sales alone;

The 1988 Sales Forecast (Table 10) is based on the potential market without reference to production capacity. The forecast sales level is in excess of the existing production capacity, and it will only be met by investment to increase the capacity available.

There is the possibility of exceeding these budgeted figures if a CNC machine is purchased. Conversely if a CNC machine is not purchased it is inevitable that these figures will not be met as the required turning capacity is not available.

The increase in capacity is totally consistent with the long term growth strategy. The machine is ideally suited to producing special one-off products of the Electro Metallic type, which will enable the Company to service a market where it has consistently lost out to competitors.

The Effect on Costs

In addition to the extra business derived from the purchase of a CNC lathe, the labour cost for that business will be reduced as the CNC is a more productive means of manufacturing goods. The CNC will also reduce scrap, improve quality, and improve market confidence in the company. The financial effect on costs has been documented in Table 11.
### Table 10: Sales Forecast

<table>
<thead>
<tr>
<th>Product Line</th>
<th>(a) % of line Allocatable to CNC</th>
<th>(b) Forecast (axb) 1987</th>
<th>(c)</th>
<th>(d) Budget Forecast 1988</th>
<th>(e) (axd)</th>
<th>(f) Value of Increased Sales (e-c)</th>
<th>(g) Materials Costs % of Total</th>
<th>(h) Value Increased Profit (f-g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Bond</td>
<td>94</td>
<td>£264</td>
<td>£248</td>
<td>£430</td>
<td>£404</td>
<td>£156</td>
<td>£19</td>
<td>£126</td>
</tr>
<tr>
<td>Glass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal Bond</td>
<td>77</td>
<td>£438</td>
<td>£337</td>
<td>£480</td>
<td>£370</td>
<td>£33</td>
<td>£21</td>
<td>£26</td>
</tr>
<tr>
<td>Engineering</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electro</td>
<td>37</td>
<td>£212</td>
<td>£78</td>
<td>£266</td>
<td>£98</td>
<td>£20</td>
<td>£15</td>
<td>£17</td>
</tr>
<tr>
<td>Metallic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>£209</td>
<td>£169</td>
</tr>
</tbody>
</table>

All Figures in £K

**Table 10: Sales Forecast**
### Table II
Production Costs (Annual)

- **Current Direct Labour Costs**
  - Weekly basic: £14,4832
  - Weekly O/T: £18,000
  - National Insurance: £17,016
  - Company Pensions: £13,841

  Total Cost for 19 men: £193,689
  Cost per man: £10,194

- **Proposed Machine Cost Increases**
  - Interest Charges 12%: £11,280
  - Depreciation 10%: £9,400
  - Tooling: £1,500

  Total: £22,180

- **Proposed Machine Cost Decreases**
  - Electricity: one machine instead of 4: £1,373
  - Reduced inspection (Appendix V): £1,495
  - Reduced scrap and rework (Appendix V): £2,448
  - Reduced work in progress (Appendix V): £1,224

  Total: £6,540

- **Sub-Contract Saving (Annual)**
  - £16,320 worth of work that is sub-contracted is appropriate for CNC turning. This equates to 1360 hours. Assuming a conventional/CNC cycle time ratio of 4:1, the CNC time becomes 340 hours.

  \[
  \text{Sub-contracted cost} \quad 16,320 \\
  \text{CNC cost (340 x £17.90/hr)*} \quad 6,086 \\
  \text{Saving} \quad 10,234
  \]

* See Appendix IV - Hourly Rate
Payback Period

The justification was based on the increased sales expected from the increase in capacity that would arise from a purchase of this nature. A reduction in staffing levels was not foreseen.

The financial evaluation was prepared assuming the forecast increased in sales will result if the extra capacity is made available i.e. the sales department are confident that the limiting factor affecting the bulk of the forecast sales (metal bond) is capacity alone. If capacity is increased orders will be won.

The total cost of the additional equipment was estimated and all foreseen costs included in the payback. Authorisation for the additional plant was not requested at this point. This was to be the subject of a future capital expenditure proposal.

It was envisaged that workload problems will arise in production control, variation grinding and electro discharge machining (EDM) operations during the initial stages of machine running. The production control problems will only be temporary (one year) whilst the production control system and working practices are revised to cope with the speed of production of the CNC machine. The elimination of the production control problems will be achieved by working increased overtime. The grinding and EDM problems will be due to a lack of capacity and inefficient equipment, so additional purchases may be required in the future. These are estimated to be in the order of £60,000. It was also assumed that there will be a gradual increase in the effectiveness of the machine. It was envisaged that the machine will be 100% effective after six months, but for the purpose of the justification, a conservative estimate of twelve months was used. (See tables 12 & 13).
The following effectiveness has been incorporated in the payback.

**Table 12 Machine Effectiveness**

<table>
<thead>
<tr>
<th>Months</th>
<th>% effective</th>
<th>Financial Benefit £K</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 3</td>
<td>33.3</td>
<td>14 (169 x 1/4 x 33% effective)</td>
</tr>
<tr>
<td>4 - 6</td>
<td>50</td>
<td>21</td>
</tr>
<tr>
<td>7 - 9</td>
<td>66.7</td>
<td>28</td>
</tr>
<tr>
<td>10 - 12</td>
<td>80</td>
<td>34</td>
</tr>
</tbody>
</table>

Year 1 Margin over Materials: 97
Year 2 Margin over Materials: 169

**TABLE 13 THE JUSTIFICATION**

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£(000's)</td>
<td>£(000's)</td>
</tr>
<tr>
<td>Margin over materials</td>
<td>97</td>
<td>169</td>
</tr>
<tr>
<td>(see table 12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost increase</td>
<td>(22)</td>
<td>(22)</td>
</tr>
<tr>
<td>(see table 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost decrease</td>
<td>6.5</td>
<td>6.5</td>
</tr>
<tr>
<td>(see table 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sub-contract saving</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>(see table 11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Increased overtime -</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grinding and production</td>
<td>(5)</td>
<td>(3)</td>
</tr>
<tr>
<td>planning</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spark grinding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interest, depreciation</td>
<td>(15)</td>
<td>(15)</td>
</tr>
<tr>
<td>and variable costs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Capital expenditure recovered: 71500

Capital expenditure: 
- CNC: 94000
- Other: 60000

Total Capital Expenditure: 154000

Capital Resources (Year 1): 71500
Capital to be recovered (Year 2):

Total Capital Expenditure - Capital recovered year 1
= 154000 - 71500
= 82500

which takes
82500/143500
= 0.58 yrs
= 7 mths
= 1 yr 7 mths

Therefore Payback

- 73 -
4.6 Machine Selection

The results from the various data sources investigated suggested the following manufacturers would be able to supply a machine to meet the specification, consequently they were invited to quote.

1. MHP
2. Takisawa
3. Ikegai
4. Mori Seiki
5. Nakamura
6. TI Machine Tools
7. Hitachi Seiki
8. Yamasaki
9. Traub
10. Guildermeister
11. SMT
12. Colchester
13. Tsugami
14. Hardinge

It was these manufacturers who provided the time studies for the selected components which formed the basis of the machining time/cost analysis.

The technical specification (Table 14) for a machine ideally suited to the analysed product range was drawn up after the machining analysis. The specifications of each of the quoted machines were offered against it. It can be seen from Table 15 all but three of the manufacturers could provide a machine to meet the essential requirements. The next hurdle was that of price and delivery. Six manufacturers fell at this hurdle. The penultimate hurdle was qualitative i.e. that of after sales service, and this was based on opinions of others in the market place, one company failed because they were sold by a company distributing a number of machine tools and were seen to be "jack of all trades, master of none". Bad national press at the time of the investigation gave rise to rumours about another company being dropped as an agent. Consequently this company failed to be short listed the risk of having no back up after the purchase could not be taken.
The short listed machines were the MHP, Takisawa and Ikegai whose details of cost, delivery and specification were compared using the decision matrix as shown in Table 16.

Table 14
The Technical Specification

<table>
<thead>
<tr>
<th></th>
<th>INITIAL SPEC.</th>
<th>FINAL SPEC.</th>
<th>MHP SPEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum: Component diameter [mm]</td>
<td>250</td>
<td>250</td>
<td>450</td>
</tr>
<tr>
<td>Machining diameter [mm]</td>
<td>250</td>
<td>250</td>
<td>400</td>
</tr>
<tr>
<td>Component length [mm]</td>
<td>150</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>Speed [rpm]</td>
<td>4000</td>
<td>4000</td>
<td>4500</td>
</tr>
<tr>
<td>Bar diameter [mm]</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Number of axes</td>
<td>3</td>
<td>2½</td>
<td>2½</td>
</tr>
<tr>
<td>Number of Turret Stations</td>
<td>10</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>Greatest accuracy required [mm/mm]</td>
<td>0.01/250</td>
<td>0.01/250</td>
<td>0.008/250</td>
</tr>
<tr>
<td>Power Tooling</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Three jaw 250mm chuck</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Collect Chuck</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Bar Feeder</td>
<td>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bar Puller</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>Parts catcher</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Tool Calibration probe</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
<tr>
<td>In process gauging</td>
<td>/</td>
<td>/</td>
<td></td>
</tr>
</tbody>
</table>

Table 14
### Table 15
THE HURDLES

<table>
<thead>
<tr>
<th>MANUFACTURER</th>
<th>MACHINE</th>
<th>CAN M/C MEET SPEC?</th>
<th>PRICE £K</th>
<th>DELIVERY WEEKS</th>
<th>AFTER SALES SERVICE</th>
<th>DECISION MATRIX SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>M.H.P.</td>
<td>MT50</td>
<td>YES</td>
<td>75</td>
<td>10/12</td>
<td>GOOD</td>
<td>127</td>
</tr>
<tr>
<td>TAKISAWA</td>
<td>TC3</td>
<td>YES</td>
<td>84</td>
<td>10/12</td>
<td>GOOD</td>
<td>99</td>
</tr>
<tr>
<td>IGEKAI</td>
<td>TCR15</td>
<td>YES</td>
<td>85</td>
<td>12</td>
<td>GOOD</td>
<td>89</td>
</tr>
<tr>
<td>MORI SEIKI</td>
<td>SL-25M</td>
<td>YES</td>
<td>86</td>
<td>20</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>NAKAMURA</td>
<td>TMC30</td>
<td>YES</td>
<td>87</td>
<td>12</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>T/CHURCHILL</td>
<td>SERIES3</td>
<td>YES</td>
<td>89</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HITACHI SEIKI</td>
<td>25M</td>
<td>YES</td>
<td>130</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>YAMASAKI</td>
<td>QUICKTURN10</td>
<td>YES</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRAUB</td>
<td>TNS42</td>
<td>YES</td>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GUILDERMEISTER</td>
<td>GUM65</td>
<td>YES</td>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMG</td>
<td>SWEETTURN 6</td>
<td>YES</td>
<td>138</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLCHESTER</td>
<td></td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TSUGAMI</td>
<td></td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HARDINGE</td>
<td></td>
<td>NO</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

--- ARBITRARY CUT-OFF LINE FOR FURTHER INVESTIGATION: SET AT PRICE £85K
## Table 16
### SPECIFICATION COMPARISON
#### DECISION MATRIX

<table>
<thead>
<tr>
<th>MODEL</th>
<th>WEIGHTING (POINTS)</th>
<th>IKEGAI SPEC TCR 15</th>
<th>IKEGAI SCORE</th>
<th>MHP SPEC MT50</th>
<th>MHP SCORE</th>
<th>TAKISAWA SPEC TC3</th>
<th>TAKISAWA SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRICE</td>
<td>30</td>
<td>£85000</td>
<td>10</td>
<td>£75000</td>
<td>30</td>
<td>£84000</td>
<td>20</td>
</tr>
<tr>
<td>REPUTATION</td>
<td>15</td>
<td>GOOD MACHINE</td>
<td>7</td>
<td>GOOD</td>
<td>9</td>
<td>VERY GOOD</td>
<td>12</td>
</tr>
<tr>
<td>AFTER SALES SERVICE</td>
<td>20</td>
<td>BAD IMPLEMENTATION</td>
<td>12</td>
<td>MFG IN GLOSTER</td>
<td>15</td>
<td>LOCAL ENGINEERS</td>
<td>12</td>
</tr>
<tr>
<td>LOCALITY</td>
<td>10</td>
<td>WATFORD</td>
<td>3</td>
<td>GLOUCESTER</td>
<td>10</td>
<td>REDDITCH</td>
<td>7</td>
</tr>
<tr>
<td>MAX TURNING DIA</td>
<td>10</td>
<td>WITH SPECIAL</td>
<td>5</td>
<td>400</td>
<td>7</td>
<td>500 BED SADDLE</td>
<td>10</td>
</tr>
<tr>
<td>MAX BAR DIA</td>
<td>10</td>
<td>45 mm</td>
<td>5</td>
<td>50</td>
<td>7</td>
<td>69</td>
<td>10</td>
</tr>
<tr>
<td>POWER</td>
<td>10</td>
<td>11/7.5kW</td>
<td>5</td>
<td>18kW</td>
<td>10</td>
<td>11/7.5kW</td>
<td>5</td>
</tr>
<tr>
<td>SPEED</td>
<td>10</td>
<td>4000</td>
<td>7</td>
<td>4500</td>
<td>10</td>
<td>3200</td>
<td>3</td>
</tr>
<tr>
<td>NO OF TOOLS</td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>12</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>NO DRIVEN TOOLS</td>
<td>15</td>
<td>8</td>
<td>10</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>POWER OF TOOLING</td>
<td>10</td>
<td>2.2/1.5kW</td>
<td>5</td>
<td>4.4kW</td>
<td>7</td>
<td>2.2kW</td>
<td>5</td>
</tr>
<tr>
<td>C AXIS</td>
<td>5</td>
<td>FULL</td>
<td>5</td>
<td>2.5*</td>
<td>0</td>
<td>1*</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>160</td>
<td>89</td>
<td>127</td>
<td>99</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
It can be seen from the technical specification, Table 14 that after the machining analysis the specification changed slightly, as the machine requirements were understood in considerably more detail.

The main changes to the specification were:

**Number of axes required:** Reduced from the 'X', 'Z' & a full 'C' axis, to 'X', 'Z' and incremental 'C'. The reason for this was that the extra £10,000 required for the full 'C' axis cannot be justified against the minimal work load available that would require the full 'C' axis capability.

**Bar feeder/puller:** The work undertaken at VMIDP does not warrant £10,000 for a bar feeder, therefore compromise was to purchase a bar puller for £500.

**Tool calibration/In process gauging:** Tool calibration by Renishaw LP2 probe is carried out automatically during the program cycle leaving the operator free for other tasks. It is also considerably faster than manual tool calibration.

In-process gauging will be used primarily as a "work finding" device so that once the work has been loaded, the operator can simply close the door, activate the program and let the machine do the work.
From Table 16 it can be seen that the principle advantage of the MHP machine is price, however there are also a number of technical advantages:-

- Higher spindle speed
- Higher main motor power
- Higher driven tooling power
- Quicker tool changing
- 12 tool stations - all of which can be driven. This gives greater flexibility in setting up tools.
- MHP have full spares back up and after sales service available at their local (Gloucester based) manufacturing plant.

4.7 THE FINANCIAL PERFORMANCE OF MHP

A major worry with buying a machine tool from MHP was that they are only a small company in a large and traditionally aggressive sector of the machine tool manufacturing industry. Consequently, it was thought prudent to examine their financial reports for the last three years to establish if the company was profitable, successful and likely to remain so.

The reports were scrutinised by company financial staff and an independent financial consultant. The reports were found to be in order by both parties, the only identified risk being the expectations of the parent company. That is, if the performance of the parent company was inadequate, they may expect a large profit increase from MHP. However, this was not thought to be a serious risk and, if a large profit increase did not arise, MHP because of its trading position, would be sold off rather than closed down.

4.8 THE CONCLUSION

The alternatives described during the initial investigation are not acceptable. They do not complement the growth strategy or the drive to become market-led manufacturers of quality diamond tools.
The CNC route provides the only acceptable option that:-

* Meets the strategic requirement
* Is capable of responding rapidly and flexibly to changes in demand
* Reduces lead times
* Increases quality

The conclusion drawn from the decision matrix (Table 16) points to the MHP MT50 being the best overall machine.

The order was placed with MHP for the options shown in Table 17. The negotiations with MHP for the CNC lathe resulted in the order being placed for £70,750 as opposed to the quoted price of £74,342. This was quite a dramatic saving as the basic price and the cost of the live tooling had increased by £1,500 and £800 respectively since the original quote.

Delivery was set for the week beginning 8th January 1988 with a commitment to complete machining trials by 20th November 1987. However at this stage it was made clear that the order was entirely dependent upon successful conclusion of the machining trials. A 10% deposit was made, but this was refundable if machining trials were not successful.
<table>
<thead>
<tr>
<th>1. Machine MT50</th>
<th>43300</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTA control and all options</td>
<td></td>
</tr>
<tr>
<td>- less tail stock</td>
<td></td>
</tr>
<tr>
<td>2. MHP Toolholder package</td>
<td>975</td>
</tr>
<tr>
<td>MHP Part No. 60282</td>
<td></td>
</tr>
<tr>
<td>4. 3 jaw powerchuck</td>
<td>3650</td>
</tr>
<tr>
<td>MHP Part No. 60670</td>
<td></td>
</tr>
<tr>
<td>7. Collet chuck Pratt/Crawford CDC20</td>
<td>565</td>
</tr>
<tr>
<td>MHP Part No. 60274</td>
<td></td>
</tr>
<tr>
<td>8a. Collet chucks. 9 off round.</td>
<td>450</td>
</tr>
<tr>
<td>8b. Collet chuck. 1 off hex.</td>
<td>50</td>
</tr>
<tr>
<td>10. Chuck jaws</td>
<td></td>
</tr>
<tr>
<td>a) Hard MHP Part No. 60157</td>
<td>125</td>
</tr>
<tr>
<td>b) Soft MHP Part No. 60158 3 off</td>
<td>105</td>
</tr>
<tr>
<td>c) Tee Nuts MHP Part No. 60416</td>
<td>27</td>
</tr>
<tr>
<td>12. Parts catcher</td>
<td>1350</td>
</tr>
<tr>
<td>14. Anit-vibration Pads</td>
<td>175</td>
</tr>
<tr>
<td>MHP Part No. 60166 - 001</td>
<td></td>
</tr>
<tr>
<td>19. Bar Puller</td>
<td>560</td>
</tr>
<tr>
<td>MHP Part No. 60312</td>
<td></td>
</tr>
<tr>
<td>21. In-process gauging</td>
<td>2750</td>
</tr>
<tr>
<td>MHP Part No. 60353 - 002</td>
<td></td>
</tr>
<tr>
<td>22. Tool calibration</td>
<td>3175</td>
</tr>
<tr>
<td>MHP Part No. 60764</td>
<td></td>
</tr>
<tr>
<td>25. Closed loop machining cycles</td>
<td>1500</td>
</tr>
<tr>
<td>26b. Memory extension to 46K</td>
<td>850</td>
</tr>
<tr>
<td>31. Driven tool turret.</td>
<td>9950</td>
</tr>
<tr>
<td>31b. i) Axial mill/drill tap head</td>
<td>2980</td>
</tr>
<tr>
<td>MHP Part No. 60655 (4 off)</td>
<td></td>
</tr>
<tr>
<td>ii) Tension compression (1-7mm)</td>
<td>160</td>
</tr>
<tr>
<td>MHP Part No. 60656 - 001 (1 off)</td>
<td></td>
</tr>
<tr>
<td>iii) Tension compression (4-10mm)</td>
<td>175</td>
</tr>
<tr>
<td>MHP Part No. 60656 - 002 (1 off)</td>
<td></td>
</tr>
<tr>
<td>iv) Radial mill drill head</td>
<td>1150</td>
</tr>
<tr>
<td>MHP Part No. 60654 - 00</td>
<td></td>
</tr>
<tr>
<td>33. Delivery</td>
<td>350</td>
</tr>
</tbody>
</table>

| £74342 |
5.0 PREPARATION AND PLANNING: PRIOR TO MACHINE ARRIVAL
5.1 The Planned Sequence of Events

New processes and new machines are most successfully installed if a plan is drawn up showing various stages of implementation charted against a time scale, and the time scale strictly adhered to. The planned sequence of events for this project can be seen from Fig.15.

5.2 In-Company Awareness Presentation

Objective: To explain to the shopfloor staff how the purchase of a CNC machining centre fits into the company strategy.

The presentation was made after the Group board had approved the purchase, and as a result of this decision it could be categorically stated that a machine would be ordered (see Appendix XIV).

The presentation panel contained the Engineering and Finance directors, Mr. W. Jones the Teaching Company supervisor and the author. The presentation audience included those whose day to day lives would be significantly affected by introduction of a CNC machine; i.e. union representatives, shop floor supervisors, chargehands, operators and production control staff.

A secondary objective of the presentation was to allay any fears of redundancy. This was achieved easily and effectively by demonstrating how the machine had been justified. This included making known details of; the products affected by the introduction of CNC, the cost comparisons (CNC versus conventional), the forecast effect on sales, and in conclusion how the effect on sales would pay for the machine and not job redundancies.

The presentation was well received and was concluded by each of the audience being given a CNC "information leaflet". The pack contained all the significant details relating to the presentation, and details of the capabilities of the proposed machine (Fig 16).
### FIG 15
**CNC IMPLEMENTATION SCHEDULE**
**PLANNED SEQUENCE OF EVENTS**

<table>
<thead>
<tr>
<th>Order</th>
<th>Order Materials for Trials</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Preparation</td>
<td>Supplier Training</td>
<td>P.O.W. Training</td>
</tr>
<tr>
<td>Tooling Meeting</td>
<td>Installation/Commission</td>
<td>Eng. Implementation to Production</td>
</tr>
<tr>
<td>Production Takeover Eng. Back Up</td>
<td>Back Up for 6-12 Weeks After Implementation - Back Up Remains But It is Now a Production Machine</td>
<td>In Comp'y Awareness Presentation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Week Number</td>
<td>5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 1 8 15 22 29 7 14 21</td>
<td>41 42 43 44 45 46 47 48 49 50 51 52 53 1 2 3 4 5 6 7 8 9 10 11 12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Deviations from the plan are recorded in the text.
OBJECTIVE: To increase the capacity available for turning.

The increase is required to meet the demands of the forecast increase in sales.

SOLUTIONS:

* Increase sub-contracting.
* Conventional machines.
* CNC Machine
* A further option would be to do nothing and watch market share diminish.

PROPOSED SOLUTION: CNC Machine

PROPOSED MACHINE: MHP MT50

PROJECT COST: £75,000

PAYBACK PERIOD: 19 months

PROPOSED LOADING:

<table>
<thead>
<tr>
<th>Percentage of Time Available</th>
<th>Finished turning Metal Bond Bodies 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Components currently sub-contracted 30%</td>
</tr>
<tr>
<td></td>
<td>Resin Products 20%</td>
</tr>
<tr>
<td></td>
<td>Metal Bond Wheel Bodies 10%</td>
</tr>
</tbody>
</table>

MACHINE SPEC.

- Spindle Motor 25HP (18KW)
- Max. Machining dia. 400mm
- Turret (Tool) Stations 12 Total
- Max. dia. of chuck 250 mm
- Speed (infinitely variable) 10-4500 RPM
- Max. Bar Feed 50.2 mm

OPTIONS:

- Fanuc OTA Controller
- 2.5° Indexing Turret
- Parts Catcher
- Bar Puller

- Tool pre-setter and in process gauging.
5.3 Training & Selection

It was believed that the team required to successfully implement and operate the machine, needed to contain:

- CNC operator/setter
- CNC programmers
- Design Draftsmen capable of designing for CNC production

At this time there was no one in the company with relevant experience appertaining to any of the above job functions. Consequently because of the cost of recruiting new staff, and the ease of acquiring CNC operating/programming skills it was decided to retrain in-house staff.

Initially it was thought that it would be sufficient to train two operators/programmers from each of the shop floor and the engineering office. However, because company policy is to ensure flexible working arrangements it was decided to train three operators from the shop floor, two from the engineering office and the design draftsman. In choosing the shopfloor operators a balanced team was sought; this would be most effectively provided by taking operators with varying skill and experience levels. The following were thought appropriate.

- One operator with in-company turning experience spanning many years. This in-company experience was thought necessary as many products contained diamond impregnated regions which would need to be avoided by the cutting tool.
- One operator who had recently completed an apprenticeship.
- One operator who was believed to be the most talented and versatile machinist.

It was a severe disappointment that the most experienced turner, resisted every attempt to get him to participate. However, another operator with a long company service record had asked to be part of the team. Eventually it was conceded that the first choice operator would not participate in the team and the second operator was
Training

The manufacturer was asked to provide the syllabus of their programming course. This was duly analysed and a supplementary course was designed by the Polytechnic of Wales around what the manufacturer did and did not teach: This part of the Teaching Company Project used the Polytechnic resources to the full.

The objective of the Polytechnic of Wales course was two fold:-

- To enable Van Moppes IDP to implement the CNC machine as quickly and as professionally as possible.

- To make the operators aware of 'the state of the art technology' with reference to CNC, DNC and FMS.

The Polytechnic of Wales training course was designed in three phases.

Phase 1

- The concept of NC/CNC and its applications to all spheres of industry.

- The basic principles of NC/CNC machine Tool design.
  - Machine Tool Configuration
  - Displacement measuring systems
  - Control systems
  - Machine tool communication
  - Speeds and feeds
  - Types of tooling

- Programming NC/CNC equipment-theory

- Methods
- Languages
- Part Programming

**Phase II**

- Practical experience of Programming NC/CNC equipment. This time was used to develop programmes that were tried out on the College NC/CNC equipment.
- "Hands on" Machine tool experience.
- Future trends in CNC.

**Phase III**

- Other CNC based technologies
- CAD/CAM
- FMS

The course was deliberately aimed at showing the operators what was currently achievable using CNC/CAD/CAM based technologies. This would emphasise the fact that in purchasing a CNC machine the company were not pushing the frontiers of technology, it was a matter of trying to catch up with them. Also, in showing what can be achieved in the way of CAD/CAM links, the operators would be prepared for the next stage of CNC development within the Company.

The Polytechnic of Wales also very kindly loaned the company a Fanuc System P-Mode D programming unit. This was used to generate a library of CNC programs for the selected jobs which had been analysed during the investigation phase, these would be proved during the implementation phase.

**5.4 MACHINING TRIALS**

**Objective**

1. To test the capabilities of the machine
2. To apply CNC machining techniques to the selected products (see
Thus determining if CNC machining techniques could be successfully and profitably applied to the manufacture of low value, one off made to order components.

Delays in delivery to MHP of certain critical parts resulted in the trials being two months late, with the effect that machine delivery to Van Moppes was one month late.

The trials themselves were conducted in two parts:

- The machining of a composite test piece (Appendix VI).

  The test piece was designed using the results of the machining analysis; it incorporates all the difficult to machine profiles and features that are currently manufactured. These profiles also include some that are currently sub-contracted due to the lack of in-house capacity or capability.

  The test piece will also be used to show off the capabilities of the machine thus going some way to winning the "hearts and minds" of those still doubtful of the application of CNC.

- Production Work

  A number of products have been taken from the shop floor, programmed and machined by MHP. This was partly to ensure that the carbide tips used on the machine can successfully avoid contact with regions containing diamonds.

The Composite Test Piece

The test piece was designed to test the capabilities of the machine and to mimic our production work, consequently the resulting component and the machining operations were extremely complex. The complexity of the machining resulted in four separate machining operations.
Operation One

Face off larger diameter end and bore

Operation Two

Profile and finish bore.
- Face of small diameter end, profile and finish bore.
- Initially the bore diameter was not within tolerance and the surface finishes obtained were unacceptable.

Operation Three

- Axial drilling

Operation Four

- Radial drilling
  - The drill failed to disengage on a number of operations. This was eventually found to be due to a trapped piece of swarf.

The composite piece was finally completed satisfactorily with all forms and profiles being checked for accuracy both on a 50:1 projector and a Form Talysurf.

Production Work: Habit Adaptors

The tool calibration probes were also tested during this routine. Initially the taper on the component was produced undersize. This was rectified by changing the tool offsets.

Production Work: Brilliant cutting wheels

The test here was for the turret mounted work finding probe to find the face of the work and adjust the workshift value to remove the shoulder 0.25mm proud of the diamond face, thus avoiding a diamond layer/tool tip collision. All tests proved successful.
5.5 The Estimating and Programming Procedure

The estimating systems need to be able to link with the order intake and production control systems, so when an order is placed, the original estimate and ideas for machining can be assessed easily. A basic system to achieve this can be seen from Fig 17.

The programming procedure (Fig 18) can only be described after the definition of certain terms:-

Definitions

**Parametric Programs:** These are programs that use variables to define all the dimensions and features on a component. So if one has a range of products that are exactly the same but different sizes one need only write one program which can be used to indicate the basic pattern of the piece. The sizes and dimensions are entered using a data file which can be easily changed.

**Tool suites:** The key to maximising up time for VMIDP will come through the use of standard tool suites where each suite is capable of a number of jobs, and the sequencing of jobs is achieved by tool suite priority.

The machining and tooling analysis (4.5.1, 4.5.2) undertaken by the author had vastly improved the understanding of the current machining processes. This coupled with the new skills developed through the CNC courses allowed the author to design and write all the parametric programs and to generate the tool suites.

All programs will use tools from one of a number of the standard tooling suites. Components requiring only a few tools, could possibly be machined by a number of tooling suites. However, with a manual system if the tools are in different stations the program will need to be modified. A computerised CAM system could re-generate the programs with the correct tool numbers, thus eliminating the need for manual editing at the machine. This type of system was being investigated by the manufacturing engineer.

Once written, programs will be stored on the Mainframe computer in 1 of 3 categories: (Fig 18) Standard Parametric, Standard Dedicated or New program.
THE ESTIMATING PROCEDURE

THE CUSTOMER ORDER ENQUIRY

VAN MOPPES IDP SALES DEPT

ESTIMATING DEPARTMENT

ESTIMATE PRODUCED FOR CNC
- INCLUDING
  - METHOD
    - SKELETON PROGRAM
    - TOOLS REQUIRED

INFORMATION LOGGED
- TO INCLUDE
  - ESTIMATE NUMBER
  - CUSTOMER NAME

ESTIMATING ADVISE SALES OF
- ESTIMATE/DELIVERY/PROBLEMS
THE PROGRAMMING PROCEDURE

DETERMINE WHICH OF THE FOLLOWING PROGRAMS ARE REQUIRED

STANDARD PARAMETRIC
- PRINT ROUTE CARDS
  - INFORMATION REQUIRED
    - TOOL SUITE NO.
    - DEG. ON.
    - PARAMETRIC NO./DATA
- OPERATOR ENTERS PARAMETRICS AT MACHINE
- MACHINE CUTS
- PIECE PART COMPLETE

EXISTING DEDICATED PROGRAM
- AS STD PARAMETRIC

NEW PROGRAM
- ESTIMATED
  - LOOK UP ESTIMATE
  - WRITE PROGRAM
  - ORDER TOOLS
  - RECEIVE TOOLS
  - PRINT ROUTING
  - CONTINUE AS STANDARD PARAMETRIC
- NOT ESTIMATED

IF A JOB IS TO BE PRODUCED ON THE CNC LATHE, THE PRODUCTION CARDS AND ROUTES ARE NOT TO BE RAISED UNTIL THE PROGRAM IS RECORDED AS FINISHED AND ANY NEW TOOLS HAVE BEEN RECEIVED.

* A FORMAL PROGRAMMING FORMATTING PROCEDURE HAS ALSO BEEN DEVELOPED.
Additionally, the two standard type programs can be proven or unproven all new programs will obviously be unproven.

The production cards are not to be raised until the program is recorded as finished: It will also be necessary to check that all of the tooling is available before a job is to start. This is more of a problem where new programs call for new tools.

When a program is finished the production card will state which category the program falls into, this way inspection can be notified of which jobs will require a first off inspection.

Scheduling is to be done on a daily basis, programs will be listed in tool suite sequence, with a weighting being given to priority or the order completion date.

When a job is loaded onto the CNC machine which is not a proven job, the programmer will need to be notified in order to attend the proveout.

5.6 The Shopfloor Layout

Originally the CNC machine was to be located in the turning section, the attraction being that installation here would have caused minimal disruption to the plant. However for sometime there had been an intention to rearrange the factory, changing the layout from the present process layout to a layout incorporating group technology based cells (i.e. From a layout where similar machines are all grouped together, lathes, mills, grinders, etc. to a layout where various machines are grouped together to form a product cell. This provides mini flow-lines dedicated to particular product groups).

The various staff involved with the workshop reorganisation were at this time meeting regularly to discuss the implications of any new shopfloor layout. It was soon realised that the CNC would eventually provide a service function to each of the cells as they were unlikely to be capable of fully utilizing the machine on an individual basis. The decision was then taken to locate the machine in the middle of the workshop and group the cells around it. This new shop floor plan is obviously
temporary as further plans are being made to create more cells. The shopfloor plan has catered for this by placing machines most likely to be moved in easily accessible positions.

The job of actually moving a large proportion of the machinery also gave rise to the opportunity of smartening up the factory. This was achieved by:

- steam cleaning and painting the machines,
- painting the floor,
- ordering new equipment and benches for the new work in progress and inspection areas.

5.7 Conclusion

- The company staff are now aware that the machine has been justified on the basis of growth rather than labour cutting.
- Selection and training was completed satisfactorily and on time.
- Cutting trials were delayed causing a delay in the delivery date.
- Preliminary estimating and programming procedures have been developed.
- The shop floor layout has changed giving rise to the formation of the first market led product cell: For the Glass Industry.
6.0 THE IMPLEMENTATION PHASE
6.1 **OBJECTIVES OF IMPLEMENTATION PHASE**

To ensure that the machine can be easily and fully loaded once it has been handed over to the Production Department.

To develop and rationalise a set of standard tooling suites.

To give "hands on" training to all the operators who attended the CNC course.

To develop and rationalise the systems required to control the machine.

To record and document the entire implementation phase.

6.2 **THE REASONING**

To ensure that program proving is part of the implementation phase not the subsequent production one.

To minimise down time due to tool changes.

To ensure the machine is never idle due to insufficient skill levels.

To ensure the machine runs without administrative difficulties.

To enable the appropriate staff to understand and manage the CNC systems once the implementation phase is complete.

6.3 **THE MACHINE STATUS AT HANDOVER**

6.3.1 **The Programs**

The justification was based on a selection of twelve products (see Tables 7 and 8) being suitable for CNC machining. However, because of an increased order intake for large volume products during the period between justification and implementation
only eight of the original twelve products were chosen for CNC processing. The emphasis changed again during implementation, it was realised that some components were so similar that only very minor changes would be required to prove new programs for these similar products. The machine was eventually handed over with proven programs for the following eleven products.

<table>
<thead>
<tr>
<th>No of Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brilliant Cutting Wheel Bodies</td>
</tr>
<tr>
<td>ring type 6</td>
</tr>
<tr>
<td>solid body 1</td>
</tr>
<tr>
<td>Crushform side plates 32</td>
</tr>
<tr>
<td>Crushform side plates with Clocking register 30</td>
</tr>
<tr>
<td>Disimilar side plates 32</td>
</tr>
<tr>
<td>Similar side plates * 17</td>
</tr>
<tr>
<td>Habit Adapters (2 types) 2</td>
</tr>
<tr>
<td>Resimet flaring cup wheels 1</td>
</tr>
<tr>
<td>BM 'Top Hat' blanks 1</td>
</tr>
<tr>
<td>Mullard Wheels 1</td>
</tr>
<tr>
<td>Total 123</td>
</tr>
</tbody>
</table>

Minor program modifications are required to fully prove the following products

Unijet flaring cup wheels

*The part off feed rate needs to be optimised

6.3.2 Tool Suites

The tool suites were devised so that the orders could be selected and produced by standard tool suites. Once all the orders for one tool suite are completed another tool suite is set up. Tool suite selection is by order priority. However to minimise the tool suite change over time, all orders against the
tool suite currently in use will be finished before the next tool suite is set up.

Three families of tool suites evolved resulting in a total of nine individual suites.

<table>
<thead>
<tr>
<th>The families</th>
<th>Work Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>General turning</td>
<td>Large diameter/large bore</td>
</tr>
<tr>
<td></td>
<td>Small bore</td>
</tr>
<tr>
<td>Collet chuck</td>
<td>Small diameter bar work</td>
</tr>
<tr>
<td>Live tooling</td>
<td>M5 Tapping suite</td>
</tr>
<tr>
<td></td>
<td>M5 Clearance suite</td>
</tr>
<tr>
<td></td>
<td>M6 Tapping suite</td>
</tr>
<tr>
<td></td>
<td>M6 Clearance suite</td>
</tr>
<tr>
<td></td>
<td>M8 Tapping suite</td>
</tr>
<tr>
<td></td>
<td>M8 Clearance suite</td>
</tr>
</tbody>
</table>

To further reduce down time due to 'tool setting' a tool suite probing program has been written for each tool suite. These programs are standard for each suite and save the operator having to write programs for tool setting procedures.

6.3.3 Training

It was originally intended to train a number of operators during the implementation phase. Unfortunately this soon proved to be unrealistic due to: a) Operator availability: the appropriate operators were not available at the required times b) One particular operator picking up the required skills faster than his peers therefore use of this operator alone allowed implementation to proceed at a faster pace.

It is now envisaged that this operator will train the remaining operators. This can be achieved by training the new operator when the first off of a new batch is made. It should then be possible for the new operator to run the machine for the remainder of the batch. Ultimately all CNC operators will be capable of undertaking first off production.
6.3.4 The Systems

The systems for manually creating CNC programs have been thoroughly documented in the Van Moppes CNC operations manual (see 6.3.5).

Production Control

At hand over the programs for selecting and scheduling the CNC work load were nearly complete. These programs allow a comparison between the products that can be CNC machined and the current order intake. The products that are CNC machineable are then sorted out and listed in tool suite order. All the orders that use the first tool suite listed are manufactured before the next tool suite is set up to manufacture.

Materials : Production control and the stores were made aware of all the material changes: and all the material not currently in stock was ordered.

Costings/Machining Times

The hourly rate for the CNC machine was re-calculated at £21.78 (see Appendix IX).

Unfortunately because most of the programs have been written parametrically it was not possible to establish sets of program times because the same program will machine components of various sizes whose times will be very different. It had been identified in section 5.5 that a CAM package would aid the development and management of the CNC project. A manufacturing engineer with CAM experience had recently been appointed to investigate the various CAM package available. The Production Engineering Productivity System (PEPS) was selected, this system will provide machining times, and it will eventually replace all the existing hand written parametrics.
However where possible estimates of machining times have been documented in the program body.

6.3.5 The Documentation

The Van Moppes CNC Operations Manual

The Van Moppes CNC Operations Manual contains information on how to run the computing systems used to generate the part programs for the CNC specifically:

- The hierarchy of the program numbers
- The list of dedicated parametric (MACRO) variables
- Computer access via the engineering office terminal
- Tool suites and their functions
- Generic rules for CNC machining

The CNC Programming File

The programming file documents the CNC programs on a number of levels of gradually increasing depth.

- The program directory: a list of all the programs available
- Product information: primarily for production control this section documents for each product the various programs needed for manufacture, detailing their numbers, and any special requirement
- Parametric datafile: contains the data files and the tool suites required to machine a product on the CNC.
- The CNC program bodies themselves

6.3.6 Current Operating Procedures

The few months after handover were used as a period of consolidation where the programs and the new systems were tested in a real production environment. During this time no new programs were created. Unfortunately this lost entrepreneurial
opportunities, but there was no longer a programming resource in
the superabrasives department. The author had changed jobs within the
company and a replacement production engineer had not yet been
recruited.

Operators are not allowed to create new piece part programs.

6.3.7 Forecast Production Difficulties

The return of backlash in the machine slide
caracterised by the machine not cutting to size.

Operators and managers wanting immediate solutions to get work
finished by corrupting proven programs and proven tool suites,
corruption of this nature will corrupt the system and probably
result in a collision of some kind.

Managers wanting to corrupt or by pass the new work selection
procedures.

6.4 DISCUSSION

The implementation schedule took far longer than originally
anticipated, the main reasons being:-

The technical problems took a long time to solve (this is mainly due
to level of CNC experience within the Company).

Operator availability, the most versatile operator became the CNC
operator, consequently when other work was given a higher priority
the operator was removed from the CNC. The difficulties of
integrating this type of machine into the Van Moppes V plant are
discussed in section 9.0 Final Discussions.

Production work, approximately three weeks were spent producing some
150 brilliant cutting wheels.

If a second machine were purchased tomorrow the implementation phase
would probably take about one month, as all the proving could be conducted on the present machine and PEPS.

6.5 CONCLUSION

The implementation phase took longer than expected for justifiable reasons. On completion of the implementation phase

- 123 products can be machined using CNC techniques
- 9 standard tooling suites have been generated
- Only one operator has been trained
- The production control, programming and estimating procedures are in place
- The implementation phase has been fully documented

6.6 RECOMMENDATIONS

General

1. Recruit production engineer/CNC programmer to report to the Director and General Manager of the superabrasives division:
   The job of the programmer will be to:

   Manage the system
   Write new programs

2. Investigate the need for a second machine

3. That the Data Processing department give the highest priority to completing the reports that allow CNC work to be selected and scheduled using the Mainframe Computer.

4. To develop a formal post audit of the systems set up to manage the CNC machine.
5. To train on the machine the staff who attended the original CNC training courses.

6. To send the new CNC production engineer on a special Renishaw course to develop an understanding of the probing software: To open up the EITB CNC training module for the apprentices: To select a maintenance fitter to attend the MHP maintenance course.

7. Investigate the FANUC programming option which downloads tool offset data to reduce the risk of collision and speed toolsuite changeover times.

Machining Methods

1. To reduce tip wear and the associated down time caused by using material made from flame cut blanks.

2. To reduce the tip wear found during intermittent cuts, by drilling and tapping holes after the machining is finished i.e. on the crushform programs.
7.0 REDUCTION OF MOULD WEAR
7.1 INTRODUCTION

The moulds used by the metal bond department (see sketch) are subjected to very harsh environmental conditions (see 7.4). The result is that degradation occurs through mechanisms of abrasive and adhesive wear. The worn moulds then need continual modification and refurbishment. This obviously is both time consuming and expensive (£20K pa estimate). It also has a detrimental effect on product lead times.

The problem of reducing mould wear received little attention until it was believed a real breakthrough could be made through one of two firms:

1. Metco of Chobham [23]

2. Infutec of Chesterfield [24]

It is most unusual for an engineering material to simultaneously combine optimum structural properties and optimum surface properties. This results because the bulk material performs a variety of
functions completely different from those required at the surface, and generally, one function takes precedence. In the case of the moulds used in the Metal Bond Department, the bulk function of dimensional stability at temperature takes precedence, hence surface properties suffer.

The "Wear Resistant Treatment and Coatings" [25] conference held at the National Centre of Tribology was also held at this time. The net effect of discovering Metco and Infutec and of acquiring new information from the conference allowed the project to be moved up a gear.

7.2 **The Objective**

To increase the useful life of metal bond moulds by improving the wear resistant properties of the surface, without affecting the bulk properties.

7.3 **The Problem**

**Component Ejection/Demoulding**

- During hot pressing, the powders of the metal matrix become hot welded to the mould walls. These welds are sheared during ejection and a degradation of the surface finish results. [26] see Fig 19.

- Diamonds in the metal matrix score the mould walls during the ejection process. [26] see Fig 20.

The result of the above mechanisms is excessive scoring of the mould surfaces.

- The scoring is then removed by a finishing process.

The result of the above process is that mould parts wear considerably and in doing so need continual refurbishment and replacement.
ADHESIVE WEAR

- Metal to metal rubbing
  - Galling and seizure

- Boundary lubrication
  - Scuffing
Fig 20

ABRASIVE WEAR

L

LOAD

TWO BODY

THREE BODY
(HIGH OR LOW STRESS)
7.4 SELECTION

The process of selecting the optimum solution can only begin once an analysis has determined all the engineering and environmental conditions. The conditions in this case are primarily process related.

- Operational temperature: 875°C (with temperature cycling)
- Operational atmosphere: Reducing
- Operational pressures: 150 MN/m²
- Mould body requirements:
  - Dimensionally stable at 875°C
  - Machineable on in-house equipment
- Other constraints:
  - Cost
  - Intricacy of moulds
  - Spalling of any coatings
  - Depth of any coatings
  - Frequency of refurbishment

The initial steps were to investigate:
- The material currently used for the mould;
- The formulae which led to the selection of this material.

The mould material presently used is Nimonic 80A and it was originally selected because of its inherent toughness and dimensional stability at the temperatures involved. The decision was then made to investigate modern materials to see if an alternative was available.

Initially, it was thought that Titanium may be a viable alternative, as it is easier to machine than Nimonic. Unfortunately it is susceptible to oxidation attack, dimensional instability, and it is expensive. Additionally, at 600°C, Nimonic has ten times the hot strength of pure Titanium and four times the hot strength of the stronger titanium alloys. [27]

The other alternatives briefly investigated were a range of new
engineering ceramics. However, whilst they are dimensionally stable, they are inherently brittle. The toughest engineering ceramics have fracture toughness values an order of magnitude lower than the weakest metals. Hence engineering ceramics are not at present likely to solve the wear problem.

Consequently, the engineering and environmental conditions dictate that the mould material should remain Nimonic.

7.5 SURFACE MODIFICATION

As the property of overriding importance was that of dimensional stability at the operating temperature, the next avenue was to investigate surface modification to give the desired properties. The aim of any surface modification would be to make the surface harder, as generally if hardness is increased wear resistance is also increased [26]. The surface resisting abrasion should be in the order of 1.2 times the hardness of the abrasive particle as a rule of thumb. However, this ratio is obviously not achievable as diamond is the hardest material known, but it may be possible to increase the surface hardness of the nimonic to give some advantage.

There are many ways to increase wear resistance but they can be grouped into broad categories:

- Modifying the surface without modifying the chemistry: cold deformation, machining peening.

These processes are not applicable as they do not generate the increase in hardness required.

- Modifying the surface by modifying the chemistry: chemical or thermo-chemical diffusion.

These processes introduce interstitial elements (Carbon, Nitrogen Boron) into the matrix to increase hardness, a process undertaken at temperatures in the order of 600°C. However, the moulds are required to operate at 875°C at which temperature the interstitial elements would vacate their lattice sites.
- Adding layers of material to the surface by welding, spraying, plating, bonding and dipping.

This was thought to be the only method that may offer a solution to the wear problem.

7.6 COATINGS CRITERIA

The conditions that most influence the selection of any coatings are primarily those of:-

- Coating thickness; if a coating is too thin, the aggressive wear mechanism would immediately remove it during the ejection/demoulding process. The coating thickness is thought to be in the order of 0.5mm (see Fig 21: Comparative Thickness/Depth of Treatment) [28]

- Cost: Unfortunately in the processing of moulds the batch sizes are small, the size of the components are large, the components are heavy (typically 30 Kg) and the components are complex. These criteria all serve to increase the cost of sprayed coatings (for relative cost of coatings see Fig 22).

7.7 PROCESSES INVESTIGATED

The NCT conference discussed a number of coating techniques used to improve wear resistance in harsh environments. The subsequent investigation examined the relative merits of these techniques, this was achieved by close liaison with the various suppliers (23, 24, & 29).

The techniques examined (Fig 23)
- Electrolytic hard nickel coatings
- Electroless hard nickel coatings
- Ion implantation
Fig 21 COMPARATIVE THICKNESSES/DEPTHS OF TREATMENTS
Approximate relative costs of some surface treatments.
### THE TECHNIQUES EXAMINED

#### COATINGS INVESTIGATED

<table>
<thead>
<tr>
<th>PROCESS</th>
<th>SUPPLIER</th>
<th>MAX WORKING TEMPERATURE</th>
<th>THICKNESS</th>
<th>HARDNESS VPN</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPECIFICATION REQUIRED</td>
<td></td>
<td>900°C</td>
<td>0.5mm PLUS</td>
<td>300 VPN PLUS</td>
<td></td>
</tr>
<tr>
<td>ELECTROPLATING</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>NICKEL PLATING</td>
<td>POETON</td>
<td>700°C</td>
<td>100 μm</td>
<td>1000</td>
<td>NOT ACCEPTABLE AT WORKING TEMPERATURE</td>
</tr>
<tr>
<td>ELECTROLESS NICKEL</td>
<td>POETON</td>
<td>700°C</td>
<td>1200 μm</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>ION IMPLANTATION</td>
<td></td>
<td>600°C</td>
<td>1 - 10 μm</td>
<td></td>
<td>NOT ACCEPTABLE AT WORKING TEMPERATURE</td>
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<tr>
<td>THERMAL SPRAYING</td>
<td></td>
<td></td>
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<tr>
<td>WIRE FLAME SPRAY</td>
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<tr>
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<td>BAJ</td>
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<td>PLASMA SPRAY</td>
<td>PCL</td>
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<tr>
<td>DETONATION GUN</td>
<td>UNION CARBIDE</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>LIMITING FACTOR: DEPTH CONTROLLABLE TO ± 5 THOU</td>
<td>AS (1)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>POST PROCESS MACHINING REQUIRED</td>
<td></td>
</tr>
</tbody>
</table>
7.8 DISCUSSION

The initial investigation revealed that of the processes investigated the most likely to meet the requirements would be the D-Gun process. Unfortunately however the commercial aspects to this process, that is the cost and the lead times involved make it uneconomical for our application.

The process that Metco and Infutec recommended was that of plasma spraying. All other processes could not meet the specification for working temperatures.

Unfortunately when the discussions were pursued Metco could only offer Metco 700 as the medium to be sprayed. Metco 700 undergoes particle recrystallisation at temperatures lower than 875°C, this drastically reduces its hot hardness. Consequently this powder is unlikely to meet the requirements. Additionally the process would, at least initially have to be subcontracted out. However the subcontractors are local, known to us, and have in the past acted for us as highly competent consultants in the field of coatings.

Infutec eventually declined to quote as they also did not seem to be able to offer a coating that was capable of meeting the temperature requirements.

7.9 CONCLUSION

- That the mould materials used are still the most cost effective
- It is not yet possible to supply a coating within the required commercial restraints.
7.10 RECOMMENDATIONS

- Watch for future developments in the field of materials spraying; especially thermal spraying.
- Investigate coatings that give increased wear resistance due to their being softer than the abrasive particle (i.e. like a rubber heel on a stiletto shoe).
8.0 The Development of an Original Computer Controlled Flexible Manufacturing Unit (F.M.U.)
8.1 **INTRODUCTION**

Chapter 3 describes the short term solution implemented to improve the manufacturing effectiveness of the processes required to manufacture Metal bond Hones and Segments, (essentially rectangular blocks). This chapter concerns the longer term approach, which adopts the principle, that in automating a process products are made one at a time but very quickly. The old route and the pelletisation technique (chapter 3) both ignore this, preferring instead to manufacture large quantities of segments at any one time.

8.2 **THE OBJECTIVE**

To develop a novel and original Flexible Manufacturing Unit (FMU) to replace the processes currently used to manufacture the range of Hones and Segments.

8.3 **SEGMENT SPECIFICATION**

**SCOPE**

This part of the specification covers the requirement of the segment to be manufactured.

**The Powders**

- Bronze
- Steel
- Cobalt
- Cobalt Bronze
- Iron Bronze
- Tungsten Carbide

**The Diamonds**

- Synthetic and Natural

**The Range of Diamond Sizes**

- 60 - 600 µm

**Segment Size:**

- Smallest: 15x1.5x1
- Largest: 150x12.5x18
Final Size Tolerance

- Smallest parallel to within ± 0.025mm
- Largest parallel to within ± 0.050mm

Segment weight range 0.5g - 150g

Final weight tolerance currently achieved
(in 17g segment) (3%) 0.5g

Dispensed weight tolerance
(on 17g segment) (0.0005%) 0.01g

Ratio of Dispensed weights:
Diamond to Metal Bond From 1:7.5 To 1:33

Pressed Density Above 98%

8.4 MACHINE SPECIFICATION

SCOPE

This part of the specification covers the requirements for a flexible manufacturing unit capable of manufacturing fully dense metal bonded segments and hones.

TARGET COST: £125,000

PROPOSED PHYSICAL SIZE: 2m x 0.75m x 1.2m

MACHINE REQUIREMENTS

LIFE Total machine including:-
actuators, transducers,
dispensing equipment, computer
facility and any other peripheral equipment 10 years

LIFE Carbon wall inserts, before refurbishment.
Number of refurbishments 10
Steel die punches before refurbishments 200 pressings
Number of refurbishments 10

AUTOMATIC REPLACEMENT OF INSERTS & PUNCHES TO BE COMPLETED WITHIN 3 minutes

AUTOMATIC ADJUSTMENT OF MOULD SIZE COMPLETED WITHIN 3 minutes

TOOL & MOULD WEAR ESTIMATED FROM THE MEASUREMENT OF THE PRESSED SEGMENT: MEASUREMENT FREQUENCY Every 10 segments

POSITIONAL ACCURACY OF DISPENSED BLENDED MATRIX IN THE MOULD ±0.25 mm

FREQUENCY OF PRESSINGS 15 - 20 /hr

TEMPERATURE AT PRESSING up to 900°C

ACCURACY OF TEMPERATURE ±10°C

PRESSURE APPLIED AT PRESSING (DEPENDENT ON BOND) 1 - 2 tons sq in

ACCURACY OF LOAD APPLIED ±10%

TIME PERIOD FOR WHICH LOAD & TEMPERATURE APPLIED: 1 - 2 minutes

NUMBER OF HOPPERS ON CAROUSEL Diamond 10
NEW PROCESSES (Harwell's processes which allow high hardness/wear resistance parts to be subjected to heat and not degrade).

PRODUCT LIFE SPAN    New customer requirements

STANDARDS AND SPECIFICATIONS

USER COMMENTS

QUALITY (Standards)

DEADLINES

TESTING/COMMISSIONING

MAINTENANCE - ease of access to parts

8.5 THE CONCEPT

The Flexible Manufacturing Unit (FMU Fig 24) is a "desk top" fully automatic computer controlled device capable of replacing all of the processes currently used to manufacture the range of Hones and Segments.

The "heart" of the machine will be an automatically adjustable mould
HOPPER CAROUSEL

DISPENSING TUNNEL

PICK & PLACE UNIT

ADJUSTABLE MOULD

MOULD PLATTERN

TOOL HIGHWAY

ARRAY OF MOULD WALLS

TOP RAM

BOTTOM RAM

SCHEMATIC OF THE F.M.U.

Fig 24
(Fig 25) capable of producing any size segment within a specified size range. The mould will be mounted on a plattern which can move on rails to the required process station. The process starts at order receipt stage where information is input to the mainframe. This information is down loaded to the machine's on-board computer which selects the required metal powders and diamonds. The mould is adjusted to the required size and the segment ingredients dispensed into the mould. The mould is moved to the hot pressing station where the top press tool is inserted and hot pressing occurs. Once the pressing sequence is complete the segment is ejected the mould is returned to the filling station and the sequence is resumed.

8.6 THE SEQUENCE OF EVENTS

The processes that require automation are those used to manufacture Metal bond Segments and Hones. These processes have been described in Chapter 3 (Fig 8 and 9) and do not need to be repeated here.

The sequence of automated events (Fig 26) starts with receipt of an order. The order information; customer name, order number and product code are input to the main frame computer. The order information is then processed to generate paperwork and downloaded to the machines on-board computer.

The RMU uses this information to select from a series of hopper and tool, carousels or highways, the required:-

- size and type of diamond
- metal powders
- mould size and press tools

A series of computer controlled activators select the required mould wall dimensions and the bottom press tool is positioned. Five sides to the mould are now in place. The mould is moved on a carriage or platten to the mould filling station, below the mixing funnel.

The hoppers containing the required metal bond powders and diamonds
FLOW DIAGRAM OF THE SEQUENCE OF EVENTS

Receipt of Order

Order Information into the Mainframe
Customer Name; Order Number; Product Code

THE MACHINE

Selection of
- Size & type of Diamond
- Metal powders
- Press tools

Control of
- the size of the adjustable mould
- Position the bottom press tool

The Mould Plattern is moved to the filling station
The Mould is filled from the selected hoppers
The Mould Plattern is moved to the pressing station
Heat and Pressure are applied to densify the Powder.
The Mould walls 'relax'
The press tools move up out of the mould
The Segment is ejected
Segments are sorted and labeled by order No.

Next Segment Next batch New Mould walls req'd

Mould Plattern moved to the Wall replacement Station.
The pick & place Robot replaces the Mould walls
The cycle continues as required

The Computer would also be capable of running an M.R.P. system generated from the hopper weights.
have been selected and placed on two separate "loss in weight" scales. The ingredients are released from the hoppers in the desired ratios over a fixed time period. The ingredients pass down the funnel and through a tube where a positioning device controls the position of the tube in relation to the mould thus ensuring even dispensing in the mould: Once complete metal powder without diamonds is dispersed on top of the powder and diamond composite. This is the backing layer.

The filled mould is now moved to the pressing station where the top press tool is positioned. The carbon mould walls are heated probably using a resistance field technique, and at the same time a load is applied via the press tools resulting in the segment being sinter pressed: The sintering operation consolidates the ingredients into a single solid segment.

To reduce the effects of wear on the carbon mould walls, the walls pull away (relax) from the solid segment after the sintering stage. The top and bottom press tools move up together to take the segment, held between them, out of the confines of the mould walls. Once the segment is clear of the mould walls a punch mounted at right angles to the press tools ejects the segment into the packaging carousel.

The packaging carousel sorts the finished pressed segment by order number and labels them accordingly.

The plattern returns to the filling station and the sequence is resumed, if the next segment is from the same batch.

The dispensing funnel is swung into the cleaning position if new specification segments are wanted. In the cleaning position a high pressure air jet cleans the funnel to eliminate the chance of contamination. The plattern is moved to the press tool selection station if different size segments are required, alternatively if the specification change is only a new bond or diamond size the plattern returns to the mould filling station and the sequence is resumed.
If the carbon mould walls have worn the plattern moves to the mould wall replacement station where a 'pick and place' robot replaces the walls with new or refurbished walls. The cycle then continues as required.

It should be appreciated that at this stage all of these ideas are only preliminary, and they often raise more questions than they answer. Additionally, there are many alternative ideas of achieving the results described above, but for the sake of clarity it has been decided to include only one set of ideas.

It will also be appreciated that although the machine is described as fully automatic, a 'set up' may be required to load the hoppers. It is envisaged that the machine could be made totally automatic simply by increasing the number of hoppers the machine can carry. However, this will increase the size and cost of the machine, when it may be cheaper and easier to accept the minimal set up time.

8.7 THE RISK AREAS

Moving the Mould Walls

It is thought that the bottom piston will be positioned so the four vertical walls can be positioned using hydraulic activators to force the walls against the bottom piston.

Mixing

It is believed that it may be possible to dispense the powders in the required ratios to each other over the same given time frame. This it is believed will result in a homogenous mix which can then be dispensed into the mould.

Relaxing the Mould

If the mould walls can be positioned around the bottom piston they can certainly be 'relaxed' after the pressing cycle. This is an
antiwear mechanism where the mould walls are pulled away from the segment after pressing so scoring of the walls is reduced.

It is believed that the above are the major risk areas if those "nuts" can be cracked then the project stands a good chance of reaching fruition. Unfortunately, it has not been possible to conduct extensive investigations into these problems in the time that has been allowed. Consequently, it is these tasks that will be addressed first in the second phase of the project plan, this will ensure effort is not wasted developing the remainder of the system only to find that it is not yet possible to solve problems in these areas.

The perceived achievability of each process stage can be seen from Table 18.

8.8 THE ADVANTAGES

The conceptual design of the machine clearly fulfills the objective of replacing all the processes required to manufacture the range of Hones and Segments. However, additional advantages include:

Increased
- Capacity (24 hour day if required)
- Quality/Consistency
- Flexibility - any size within the specification size range can be made
- Opportunity - Currently each time a new segment size is required an expensive (£3,000) mould has to be made. This can be replaced by a press tool at £200.
- New Market Penetration - due to increased opportunity

Reduced
- Manning (The release of three men)
- Lead times
- Heating load
- Floor space
- Mould refurbishment

Additionally the sales force will know that any size segment within the specification size range could be manufactured.
8.9 THE ANALYSIS

The initial analysis was conducted at a stage when the concept was very young, therefore, it was not thought beneficial to spend considerable time and effort investigating current processes and product specifications in minute detail.

Once the initial specifications were finalised the analysis looked at the previous years output levels, and compared these to what it was thought that the machine could achieve.

**ANALYSIS OF THE PRODUCTION OUTPUT LEVELS**

**PRODUCTION OUTPUT (HONES)**

<table>
<thead>
<tr>
<th></th>
<th>UNITS PRODUCED</th>
<th>NETT SELLING VALUE (£K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL SALES</td>
<td>6000</td>
<td>126</td>
</tr>
<tr>
<td>&quot;CAN DO&quot; By Bond² (6 bonds)</td>
<td>6000</td>
<td>126</td>
</tr>
<tr>
<td>&quot;CAN DO&quot; by size³ (6 sizes)</td>
<td>3081</td>
<td>75</td>
</tr>
</tbody>
</table>

**PRODUCTION OUTPUT (SEGMENTS)**

<table>
<thead>
<tr>
<th></th>
<th>UNITS PRODUCED</th>
<th>NETT SELLING VALUE (£K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL SALES</td>
<td>41500</td>
<td>209</td>
</tr>
<tr>
<td>&quot;CAN DO&quot; By Bond² (5 bonds)</td>
<td>41000</td>
<td>206</td>
</tr>
<tr>
<td>&quot;CAN DO&quot; by Size³ (6 sizes)</td>
<td>38000</td>
<td>186</td>
</tr>
</tbody>
</table>

Note ² is a subset of ¹ and ³ is a subset of ².

In summary only 9 bonds are required as in some cases the segments and hones used the same bond, however, 41 grit types are required as natural, synthetic and CBN grits are used.

Consequently, as a first approximation using 9 bond types and 41 grit types the FMJ could produce hones and segments to the value of £261K i.e. 80% of the combined product line.
<table>
<thead>
<tr>
<th>PROCESS</th>
<th>ACHIEVABILITY</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection of tools &amp; hoppers</td>
<td>Proven</td>
<td>CNC machine tool &amp; carousels &amp; highways</td>
</tr>
<tr>
<td>Positioning tools</td>
<td>Proven</td>
<td>Press tool technology</td>
</tr>
<tr>
<td>Moving mould walls</td>
<td>Technically achievable</td>
<td>Hydraulic rams using a feedback system</td>
</tr>
<tr>
<td>Dispensing accurate</td>
<td>Proven</td>
<td>Pharmaceutical industry</td>
</tr>
<tr>
<td>Mixing by dispensing the powders in a strict ratio to each other over a given time frame</td>
<td>Conceivable</td>
<td></td>
</tr>
<tr>
<td>Positioning powder in mould</td>
<td>Proven</td>
<td>0.1mm positional accuracy using pen plotter devices</td>
</tr>
<tr>
<td>Moving mould plattern</td>
<td>Proven</td>
<td>Dedicated A.G.V.</td>
</tr>
<tr>
<td>Pressure/heat cycle</td>
<td>Proven</td>
<td>Used by sister Company, but not automated</td>
</tr>
<tr>
<td>Relax the mould</td>
<td>Technically achievable</td>
<td>A short shock to free the segment. Presently achieved manually</td>
</tr>
<tr>
<td>Ejection of segment</td>
<td>Proven</td>
<td>Pick &amp; place robots</td>
</tr>
<tr>
<td>Mould wall replacement</td>
<td>Proven</td>
<td>Sister companies</td>
</tr>
<tr>
<td>Using carbon mould</td>
<td>Proven</td>
<td></td>
</tr>
</tbody>
</table>
THE COST ANALYSIS

The Cost Analysis investigated three routes which could produce the range of segments.

The Current route: Fully documented in Chapter 3.

The RMU route: The attended time was estimated and costed. (Appendix X): A budget price for the machine was developed by analysing the cost of the components required to build each process stage (see Appendix XI).

The "Fritish" route: Fritish are a German company specialising in manufacturing machines to produce diamond tools, and a number of the machines sold are similar in operation to parts of the proposed RMU. Hence it was thought prudent to analyse the relative merits of buying proven Fritish machines and linking them to produce a "Fritish RMU" (see Appendix XII)
**SUMMARY**

**RMM: PROJECT COST COMPARISONS**

Costs per annum: Based on Attended Times and Capital Expenditure

<table>
<thead>
<tr>
<th>Route</th>
<th>Overhead Cost</th>
<th>Labour Cost (£10194pa-man)</th>
<th>Capital Expenditure (£)</th>
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</thead>
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<tr>
<td></td>
<td>Variable Rate</td>
<td>(£)</td>
<td>(£)</td>
</tr>
<tr>
<td>CURRENT</td>
<td>223713</td>
<td>34076</td>
<td>NIL</td>
</tr>
<tr>
<td>PELLETISATION</td>
<td>179760</td>
<td>22276</td>
<td>NIL</td>
</tr>
<tr>
<td>FRITISH(^1)</td>
<td>18340(EST)</td>
<td>5000</td>
<td>130,000</td>
</tr>
<tr>
<td>RMM(^2)</td>
<td>NEGLIGIBLE(^3)</td>
<td>NEGLIGIBLE</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Notes 1, 2 & 3 overleaf
NOTE 1: THE FRITSCH ROUTE

ADVANTAGES: Off The Shelf  DISADVANTAGES: High Capital Expenditure
             Proven Equipment  : High Mould Refurbishing
                      : Dedicated Pelletised
                      : Stocks
                      : The two machines used
                      : have different batch
                      : size requirements which
                      : may result in
                      : inefficient production
                      : Minor release of labour
                      : The system is unlikely
                      : to be integrated with
                      : the main frame

NOTE 2: THE F.M.M. ROUTE

ADVANTAGES: Total Flexibility  DISADVANTAGES: High Capital Cost
            (segment size,
            diamond
            concentration etc)
            : Long gestation period
            : Stage by stage
            : Implementation (which
            : may lead to a Heath
            : Robinson device)
            : Linking sales order to
            : despatch through the
            : mainframe
            : Next day delivery

NOTE 3

The actual overhead cost will be dependant on finished design, floor
space required, the amount of set up required, mould heating cost
etc. It is not yet possible to estimate.

Additionally it is estimated that the F.M.U. system could provide
everything the Fritsch route gives for a capital cost of
approximately £60,000.
8.10 CONCLUSION

A unique Flexible Manufacturing Unit containing a number of new and revolutionary features has been conceptually designed. The F.M.U. could completely replace the existing labour intensive manufacturing processes for approximately 80% of the range of hones and segments. Initial estimates made into the cost of the machine put the budget price at about £100K excluding an estimated 2 man year development. Unfortunately the high cost of the machine means that the results of the initial justification prove inconclusive. However, it can be concluded that the F.M.U. approach is a more attractive option than buying two British machines to replace the current manufacturing processes.

8.11 RECOMMENDATIONS

1. To implement a second stage feasibility study, incorporating further analysis of:

- the cost of the system
- the running costs of the system - heating, hopper, stock costs etc.
- the product specification - i.e. full computer analysis showing the distributions by order of:
  - individual segment sizes
  - individual segment weights
  - batch segment weights
  - batch segment quantities
  - types of bond
  - sizes of diamonds

2. The development of a press tool the size of which is adjustable.

3. An investigation into the merits of using parts of the system in other production areas (i.e. using the filling or mixing stages separately).
4. An investigation into the merits of using a similar machine for cold pressed segments for stone and construction. The second stage feasibility study should culminate in a project plan to build the machine, probably in a piece meal manner so each stage can function independently of the next and thus be proven in isolation: The most difficult or technically uncertain stages should be tackled first so effort is not wasted should the project prove unsuccessful.
9.0 Final Discussions
9.0 FINAL DISCUSSIONS

The most important element of the project from the point of view of successfully meeting the company's objectives must be the financial and market analysis contained within Chapter Two. The initial analysis conducted, for 1984/6 was simply used to identify those areas that required a more searching study: A number of these areas (Fig 6) have been investigated and radical changes have been made during the course of this project.

However, in 1988 the Group Managing Director asked for the analysis to be re-calculated using the latest figures. The second analysis has then been used to provide a guide on how to break the business down into smaller more manageable Strategic Business Units (S.B.U's). These S.B.U's are market led profit centres based around manufacturing cells. The cells are run by a General Manager who is in a very strong position to grow the business, as he can very quickly become expert in his manufacturing systems and his market.

The results of the initial analysis showed the Metal Bond Product Groups and their associated processes to be the main candidate for concentrated investment of effort, time and money. The Metal Bond section has seen, the introduction of Pellitization, CNC turning, an investigation into mould wear, and the conceptual design of a flexible manufacturing unit.

Pelletisation is a process that
- allows large volumes of metal powders and diamonds to be homogenously mixed,
- introduces a flow characteristic into the mix, which in turn allows segments to be pressed semi automatically using a tablet press.

Trials for the pelletised product were conducted in the field at Penrhyn. Two blades using two different pelletised specifications were matched against the conventional Van Moppes product and a competitors product. The tests were monitored by the sales representative from Stone and Construction division.
The results indicated that the pelletised products performed at least as well as the conventional product, 36 hours cutting time, and considerably better than the competitors product (28 hours).

The five most popular bonds can now be pelletized which greatly reduces the laborious mixing and filling times. Unfortunately, just before commissioning the equipment the order intake level for the product plummeted and the equipment has never been used. However, with the advent of a single manufacturing cell to manufacture Hones and Segments (late 1989) the process is undergoing re-evaluation.

The most radical change has been the introduction of CNC turning into the plant. The use of parametric type programs make this type of equipment justifiable for the company, one program can be written to produce a number of different size but similar shape components. This is exactly the type of business the company has to address.

The justification for the machine was completed in five weeks, but the implementation took twice the two months expected. The delay in implementation was due to a number of justifiable reasons.

- Technical problems taking a long time to solve
- Operator availability
- A large batch of production work undertaken part way through implementation as a favour for production, and as a "flag waving" exercise.

The machine was handed over to production at the end of the implementation phase with 123 product programs proven. The responsibility for running the machine also passed from Engineering to Production, at this time.

The difficulties of running a machine so radically different to the traditional Van Moppes plant became apparent soon after handover. The production department were advised some months before handover to recruit a CNC production engineer. The production engineers job would be to control and manage the machine as there would still be problems to solve.
Unfortunately the machine was handed to production before a suitable candidate had been selected. Inevitably a month later the machine was handed back. This unfortunate situation was further hindered by the most experienced CNC operator deciding to leave the company.

Part of the reason misunderstandings arose was because it was not understood that the implementation period had only proved that programs worked and that they would not damage man or machine. They had not been subjected to the volume of work that production would require. Consequently the problems that were seen in production were bound to be different to those seen during implementation. A number of these production problems were even foreseen, unfortunately because production had not appointed a CNC production engineer they were not able to solve them.

The engineering director engaged one of his manufacturing engineers to manage the system. An experienced CNC operator was recruited and the machine put back to work. The manufacturing engineer linked the machine to PEPS, refined the production control system implemented bar code reading of order numbers and operation details (setting, tools, machining etc)

The production department eventually recruited a production engineer who has now taken over the system, and it is now not uncommon to see weekly uptimes of 65% - 70%.

A full post audit on the CNC has not yet been conducted, therefore it is not possible to state categorically that the CNC will pay back in the time detailed during the intial investigation.

The problem of mould wear was tackled. The investigation detailed that within the commercial constraints imposed upon the company the mould material used for the last 15 years was still the most suitable for the job.
The idea of modifying the mould walls by applying a hard abrasion resistant coating was also investigated. A number of different types of coatings and films were evaluated but not one of which could meet the operating temperature requirement of 875°C.

The idea of developing a small highly automated machine for producing hones and segments has been investigated. The investigation shows that the technology the machine requires is available, and that most of it has been proven in similar applications.

It is estimated that the cost of the machine would be in the order of £100K, but it could result in significant competitive advantage. The machine comprises of a number of process units for which summary project plans have been developed. These plans break down each unit into smaller areas of investigation detailing likely problems and proposed time scales.

Other members of the engineering team have investigated some of the other areas highlighted during the initial investigation.

For example:-

- The resin section has been reorganised into a group technology based cell.
- The relative merits of electro chemical machining to profile metal bonded wheels has been investigated. (Much of the expertise for this has been provided by the Polytechnic of Wales).
- The Metal Bond Glass Products (Pencil Edging wheels) have been organised into a strategic business unit with its own manufacturing cell.
- Production of Hones and Segments is also about to be organised in this way.
- The computer based production control system has been streamlined, and unnecessary and duplicate information has been removed.
- Standard times and costings have been investigated, updated, and remain so.
10.0 RECOMMENDATIONS
10. **RECOMMENDATIONS**

- The implementation of pelletisation should order quantities now be sufficient.

- To conduct a re-appraisal of the CNC machine to determine
  - the true payback period
  - if the skill levels need increasing
  - if the production control estimating or programming procedures need further refining

- Develop the CAD/CAM link so all programs are written by the CAM computer.

- Investigate the need for another CNC machine.

- To continue the investigation into the flexible manufacturing unit.
References

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2. Family Day Brochure. Van Moppes promotional literature, available from Van Moppes, contact Mrs M. Pegrum.


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29. Technical Sales Literature, A.T. Poeton, Eastern Avenue, Gloucester, GL4 7DN.
APPENDIX I

Site Plan
APPENDIX II

Pelletisation Results
### APPENDIX II

**PARTICIPATION RESULTS**

**MECHANICAL TESTING (SAMPLE)**

(Standard Deviation of Weight)

**Bond A**

**Hot Pressed (Pelletised)**

<table>
<thead>
<tr>
<th>Wt (g)</th>
<th>Wt (g)</th>
<th>Wt (g)</th>
<th>Wt (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.81</td>
<td>17.72</td>
<td>17.83</td>
<td>17.68</td>
</tr>
<tr>
<td>17.71</td>
<td>17.77</td>
<td>17.76</td>
<td>17.83</td>
</tr>
<tr>
<td>17.78</td>
<td>17.70</td>
<td>17.73</td>
<td>17.75</td>
</tr>
<tr>
<td>17.84</td>
<td>17.81</td>
<td>17.77</td>
<td>17.88</td>
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<td>17.79</td>
<td>17.81</td>
</tr>
<tr>
<td>17.72</td>
<td>17.87</td>
<td>17.78</td>
<td>17.89</td>
</tr>
<tr>
<td>17.82</td>
<td>17.56</td>
<td>17.70</td>
<td>17.69</td>
</tr>
</tbody>
</table>

Sample 28 \( \bar{x} = 17.77 \)

S.D. = 0.074

**Bond A**

**Hot Pressed (Conventional)**

<table>
<thead>
<tr>
<th>Wt (g)</th>
<th>Wt (g)</th>
<th>Wt (g)</th>
<th>Wt (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.02</td>
<td>17.82</td>
<td>17.81</td>
<td>17.88</td>
</tr>
<tr>
<td>17.79</td>
<td>17.80</td>
<td>17.79</td>
<td>17.78</td>
</tr>
<tr>
<td>17.73</td>
<td>17.63</td>
<td>17.78</td>
<td>17.66</td>
</tr>
<tr>
<td>17.75</td>
<td>17.74</td>
<td>17.64</td>
<td>17.71</td>
</tr>
<tr>
<td>17.76</td>
<td>17.73</td>
<td>17.39</td>
<td></td>
</tr>
<tr>
<td>18.07</td>
<td>18.10</td>
<td></td>
<td>17.68</td>
</tr>
</tbody>
</table>

Sample 22 \( \bar{x} = 17.74 \)

S.D = 0.204
Bond C
Hot Pressed (Pelletised)

<table>
<thead>
<tr>
<th>Wt(g)</th>
<th>Wt(g)</th>
<th>Wt(g)</th>
<th>Wt(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18.32</td>
<td>18.24</td>
<td>18.17</td>
<td>18.28</td>
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</tr>
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<td>18.40</td>
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<td>18.33</td>
</tr>
<tr>
<td>18.12</td>
<td>18.29</td>
<td>18.07</td>
<td>18.16</td>
</tr>
<tr>
<td>18.40</td>
<td>18.31</td>
<td>18.31</td>
<td>18.32</td>
</tr>
</tbody>
</table>

Sample 24  $x = 18.29$
S.D. = 0.104

Bond C
Hot Pressed (Conventional)

<table>
<thead>
<tr>
<th>Wt(g)</th>
<th>Wt(g)</th>
<th>Wt(g)</th>
<th>Wt(g)</th>
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<tbody>
<tr>
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<td>22.27</td>
<td>21.78</td>
</tr>
<tr>
<td>21.96</td>
<td>22.05</td>
<td>21.91</td>
<td>21.86</td>
</tr>
</tbody>
</table>

Sample 8  $x = 22.00$
S.D. = 0.163

The weights of the above segments are not intended to be the same. A comparable specification bond C was not available so a similar specification segment, having a greater depth, was used.
**DENSITY/HARDNESS ANALYSIS**

For the density analysis, the segment backing is removed and the Analysis conducted on the diamond impregnated layer only.

**Bond A**

**Pelletised**

<table>
<thead>
<tr>
<th>Impreg Wt (g)</th>
<th>Impreg Density</th>
<th>Theoretical Full Density</th>
<th>Impreg Density % of Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.7310</td>
<td>8.459</td>
<td>8.5041</td>
<td>99.5</td>
</tr>
<tr>
<td>12.8345</td>
<td>8.364</td>
<td>8.5041</td>
<td>98.4</td>
</tr>
<tr>
<td>12.7035</td>
<td>8.323</td>
<td>8.5041</td>
<td>97.9</td>
</tr>
</tbody>
</table>

**Hardness : Rockwell B Scale**

**Tolerance Range : 85 - 105**

**Actual Range : 91 - 97**

**Bond C**

**Pelletised**

<table>
<thead>
<tr>
<th>Impreg Wt (g)</th>
<th>Impreg Density</th>
<th>Theoretical Full Density</th>
<th>Impreg Density % of Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.2631</td>
<td>8.95</td>
<td>9.298</td>
<td>96.3</td>
</tr>
<tr>
<td>13.3345</td>
<td>8.97</td>
<td>9.298</td>
<td>96.5</td>
</tr>
<tr>
<td>13.4862</td>
<td>8.93</td>
<td>9.298</td>
<td>96.3</td>
</tr>
</tbody>
</table>

**Hardness : Rockwell B Scale**

**Tolerance Range : 105+**

**Actual Range : 109 - 115**

**Bond C**

**Conventional**

<table>
<thead>
<tr>
<th>Impreg Wt (g)</th>
<th>Impreg Density</th>
<th>Theoretical Full Density</th>
<th>Impreg Density % of Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td>17.7743</td>
<td>8.83</td>
<td>9.298</td>
<td>94.9</td>
</tr>
</tbody>
</table>

- 151 -
APPENDIX III

Photomicrographs
Bond A Pelletised

Bond A Hand Mixed
Bond A Pelletised

Bond A Hand Mixed
APPENDIX IV

Hourly Overhead Rates
Appendix IV
Hourly Overhead Rates

Assuming: The machine shop has 19 men allocated to it.  
- 1616 hours are worked by each man each year.  
- Four lathes could be replaced by one CNC.  
- The reallocations (for canteen, training, security etc)  
- The CNC would be run a total of 1800 hours i.e.  
with additional overtime.

Current Variable Costs: Labour

<table>
<thead>
<tr>
<th>Machine Shop</th>
<th>Total Budget (£)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Labour</td>
<td>144832</td>
</tr>
<tr>
<td>Direct Over-</td>
<td>Time 18000</td>
</tr>
<tr>
<td>Over-</td>
<td>NI Direct 17016</td>
</tr>
<tr>
<td>Co Pensions</td>
<td>13841</td>
</tr>
</tbody>
</table>

193689 - 19 (men) = 10194 per man/pa

10194 - 1616 hours £6.31/hr

Current Variable Costs: Other

<table>
<thead>
<tr>
<th>Machine Shop</th>
<th>Amount due to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Budget (£)</td>
<td>4 lathes</td>
</tr>
<tr>
<td>Consumables</td>
<td>70240</td>
</tr>
<tr>
<td>Clothing</td>
<td>2090</td>
</tr>
<tr>
<td>Maintenance</td>
<td>1690</td>
</tr>
<tr>
<td>Electricity</td>
<td>20160</td>
</tr>
<tr>
<td>Rent</td>
<td>1360</td>
</tr>
</tbody>
</table>

11281 - (1616 hrs x 4 men) £1.75/hr

Depreciation 5700 - (1616 hrs x 4 men) £0.15/hr
Current fixed Costs

Machine shop
Total Budget (£)

Indirect Labour 5907
Indirect overtime 200
NI indirect 638
Co Pensions Indirect 519
Reallocations 151921

\[
159185 - (6 \times 1616 \times 4) = \text{£}4.1/hr
\]

Current hourly overhead rate = (£6.31/hr+£1.75/hr+£0.15/hr+£4.1/hr
= £12.31/hr

The cost of Proposed Equipment

This will amount to cost of existing equipment = £12.31/hr

Plus

Pay rise .30/hr

Plus £

Depreciation 9400
Tooling 1500

Minus

Electricity 1373*
9527 - 1800 hrs = £5.29/hr
Hourly rate of proposed equipment = £17.9/hr

*Estimates made by the Finance Director
APPENDIX V
INDIRECT SAVINGS

Inspection Costs

Chief Inspector : 37 hrs/week x 46 weeks = 1702 hrs
Inspector : 39 hrs/week x 46 weeks = 1794 hrs

Time currently spent inspecting turned work
Chief Inspector 50% = 851 hrs
Inspector 25% = 448 hrs
Total = 1299 hrs

Estimated reduction of inspection time
Chief Inspector 20% = 170 hrs
Inspector 13% = 58 hrs
Total = 228 hrs

Less the efficiency rating 90% = 205 hrs
Cost Saving = 205 x £7.29/hr = £1495

Scrap and Rework
Reject rate is about 5% by value, two thirds of which is process related scrap. Therefore, assuming 2% is machining scrap.

Annual Cost of Production

- for existing equipment to produce new machine output

\[
\text{(Operating Hours)} \times \text{(the hourly)} + \text{Cost of Materials (rate)}
\]

\[
\text{(produce equiva lent output to ) (the proposed ) (machine )}
\]

Say 4:1 (conventional/CNC time ratio)

\[
4 \times 1615 \text{ hrs} \times £12.31/\text{hr} + (£1538000 \times 0.3 \times 0.3) = £217942
\]
Therefore, annual rework = annual cost of production x reject rate.

\[ = 217942 \times 0.02 = £4359 \]

*Materials bill for the company at the year end profit and loss account x 30% (materials for the superabrasives division) x (30% materials within the division that the machine will effect)

Annual Cost of Production for the New Machine

Operating hours x the hourly rate + cost of materials

\[ = 1800 \text{ hrs} \times £17.9/\text{hr} + £1538000 \times 0.3 \times 0.3 = £170640 \]

Therefore, annual rework = £170640 x 0.015 (new reject rate) = £2548

Saving (£4359 - £2548) = £1810

Work in Progress

The work in progress (WIP) cost* made up of material and labour cost would be reduced. This reduction would be due to the effect the machine would have on time required to turn the component (i.e. mould bodies, BW Blanks, finish machining etc)

According to the June stocktake, the WIP cost associated with the aforementioned products stood at :-

WIP Cost £48949

It is envisaged that this could be reduced by one quarter

WIP reduction £12237

The saving would be on the interest gained on the money saved say at 10% = £1234

Stock

It is not envisaged that there will be any measurable effect on finished stock as we generally manufacture to customer requirement.

*Material Cost - diamond and raw material
Labour cost - shop floor and press shop overheads
APPENDIX VI

Composite Test Piece
APPENDIX VII

New Shop layout
APPENDIX VII - NEW SHOP LAYOUT
APPENDIX VIII
Old Shop layout
APPENDIX VIII - OLD SHOP LAYOUT
APPENDIX IX

Actual CNC Hourly Rate
**APPENDIX IX**

**ACTUAL CNC HOURLY RATE**

<table>
<thead>
<tr>
<th>Labour Costs: Operators</th>
<th>£'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Labour £154 pw</td>
<td>8008 pa</td>
</tr>
<tr>
<td>Direct Labour Overtime 5 Hrs/w ((5 \times £3.95 \times 1.3 \times 50))</td>
<td>1284 pa</td>
</tr>
<tr>
<td>Total</td>
<td>9292 pa</td>
</tr>
<tr>
<td>NI Direct 10% labour costs</td>
<td>929 pa</td>
</tr>
<tr>
<td>Co Pensions 8% labour costs</td>
<td>743 pa</td>
</tr>
<tr>
<td>Cost to Co per man</td>
<td>10964 pa</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labour costs: Programmer/Estimator</th>
<th>£'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Labour</td>
<td>12000 pa</td>
</tr>
<tr>
<td>NI Direct</td>
<td>1200 pa</td>
</tr>
<tr>
<td>Co Pensions</td>
<td>960 pa</td>
</tr>
<tr>
<td>Cost to Co per man</td>
<td>14160 pa</td>
</tr>
</tbody>
</table>

**Machining Utilisation**

<table>
<thead>
<tr>
<th>% of time</th>
<th>Operating/Proving</th>
<th>Operating</th>
<th>Programming/Estimating</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td></td>
<td>80%</td>
<td>50%</td>
</tr>
</tbody>
</table>

**Variable Costs: Other**

<table>
<thead>
<tr>
<th>Tools/Consumables</th>
<th>£'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity ((18kw \times 1980 \text{ Hrs} \times 75% \text{ use} \times £0.041/\text{hr}))</td>
<td>1079 pa</td>
</tr>
<tr>
<td>Maintenance</td>
<td>200 pa</td>
</tr>
<tr>
<td>Filters</td>
<td>200 pa</td>
</tr>
<tr>
<td>Depreciation</td>
<td>8300 pa</td>
</tr>
</tbody>
</table>

**Fixed Costs**

<table>
<thead>
<tr>
<th>Reallocations: Training</th>
<th>£'s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>1500 pa</td>
</tr>
<tr>
<td>Inspection</td>
<td>1500 pa</td>
</tr>
<tr>
<td>Prod' Control</td>
<td>5934 pa</td>
</tr>
<tr>
<td>Canteen</td>
<td>225 pa</td>
</tr>
<tr>
<td>Stores</td>
<td>1460 pa</td>
</tr>
<tr>
<td>Buildings/Grounds</td>
<td>700 pa</td>
</tr>
</tbody>
</table>

**Total Cost to the Company**

Total No Hours Available \((39 \text{ Hrs} \times 50 \text{ wks}) + (5 \text{ Hrs O.T} \times 50 \text{ wks})\) \(2200\) hrs

Less 10% Downtime \((2200 \text{ hrs} \times 0.9)\) \(1980\) hrs

- 168 -
Therefore CNC Hourly Rate (£43142/1800 Hrs) £21.78 hrs

Note: This analysis uses revised figures, these include revised figures for hours worked.
APPENDIX X

FMU Attended Time
APPENDIX X
FMU ATTENDED TIME

Flow chart showing the estimated attended time required per day for the F.M.U.

Loading: Hoppers: Backing Powder
Impreg Powder
Diamond 20

Select program of work 10

Remove finished products 5

Total attended time for 300 segments 35 minutes
APPENDIX XI

FMU Machine Costing
## APPENDIX 1

### PAU MACHINE COSTING

### ESTIMATE COSTING PAU

**MIXING/FILLING**

| Item                           | Description                                      | Cost (£) 
|--------------------------------|--------------------------------------------------|---------
| Carousels                      | - Diamond Frame, Carousel, Motors                |         |
|                                | - Metal Powder Locator, transducer, Design       | 15000   |
|                                | - Backing Materials                              |         |
| Hoppers                        | - Diamond 10 off each = 30 off                   |         |
|                                | - Metal Powders 2 sizes, Design?                 | 6000    |
|                                | - Backing materials                              |         |
| Weighing system (+ computer?)  |                                                  | 10000   |
| Dispensing system (Vibratory? 2off) |                                                | 2000    |
| Cleaning equipment             |                                                  | 500     |
| Powder positioner              |                                                  | 500     |
| Mixing System if Required*     |                                                  |         |

**FLEXIMOULD**

| Item                           | Description                                      | Cost (£) 
|--------------------------------|--------------------------------------------------|---------
| 4 actuators and controls       |                                                  | 1500    |
| Mould walls - refurbishable - £10 each? |                                        | 200     |
| Platen                         |                                                  | 1500    |
| Rail, slepper motors, transducers controls |                                   | 1000    |

**MOULD HEATING**

| Item                           | Description                                      | Cost (£) 
|--------------------------------|--------------------------------------------------|---------
| H/M/F/?                        |                                                  |         |
| Resistance heating             |                                                  | 15000   |

**TOOL HIGHWAYS 2 off**

| Item                           | Description                                      | Cost (£) 
|--------------------------------|--------------------------------------------------|---------
| Rails, Drive transducers control |                                              | 8000    |
| Mould tools 12 off - £300 each  |                                                  | 3600    |
| Frame                          |                                                  | 6/10/87  |
| Rams (2 off)                   |                                                  | 1000    |
| Ejector ram                    |                                                  | 500     |
**REFURBISHMENT** Mould Walls

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pick &amp; Place unit, rail</td>
<td>2000 F</td>
</tr>
<tr>
<td>Array</td>
<td>500 F</td>
</tr>
<tr>
<td>Drive</td>
<td>500 F</td>
</tr>
</tbody>
</table>

**COLLECTION**

<table>
<thead>
<tr>
<th>Item</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bins</td>
<td>500 F</td>
</tr>
<tr>
<td>Chute</td>
<td></td>
</tr>
<tr>
<td>Grinding</td>
<td>3000 F</td>
</tr>
<tr>
<td></td>
<td>73800 F</td>
</tr>
</tbody>
</table>

- Extra control and software 10000 F
- Design (250 hrs @ £20) 7 man weeks 5000 F
- Extra materials 10000 F

98000 F

F = Fritsch: The RAU can supply more than what the Fritsch does for £59700 nearly £100,000 less than the Fritsch system.

**ADVANTAGES**

- Total Flexibility
- Linking from sales to order dispatch
- Next day delivery - or never catch up
APPENDIX XII

British Attended Times
APPENDIX XII
FRITISH ATTENDED TIMES

Flow chart showing the estimated attended time to produce 500 segments using the Fritish Route.

Pelletisation 180

Transfer to Fritish cold press (KP20AE) 5

Cold Press Segments 216

Collect Segments 58

Load Fritish Hot Press (SPM60) 30

Eject/Collect Finished Segments 60

Total Attended Time 549 mins = 9.15 hrs.
(Not including deburring & packaging)

No of operations required to produce segments required = \( \frac{\text{No. Segs Pa}}{\text{Batch Size}} \)

\( \frac{47500}{500} = 95 \)

Total Hours Worked 95x9.15 = 869

Cost of time at overhead rate £21.1 x 869 = £18340

Cost of time at labour cost of £10194 pa per man = £4920

NOTE 1: Capital Expenditure KP20AE = £60000
SPM60 = £70000
APPENDIX XIII

Teaching Company Symposium

London, February 16th, 1987
Van Moppes Ltd. employs some 165 employees and manufactures a wide range of diamond wheels and other tools for industrial cutting purposes. The Company has a reputation for quality, precision, and service; and enjoy the position of market leaders. The Company now comprises of three Divisions: HiTech, Stone and Construction, and Superabrasives. This project is associated with the "Superabrasives" Division, which produces some 50% of the company turnover.

A five year Strategic Plan was devised by the company, which documented the strategic goal as being "company expansion by doubling the company turnover". However, the Strategic Plan also recognised that the current manufacturing equipment represented a major weakness in the company's ability to meet this strategic goal. This results in the need to update existing manufacturing equipment with new high technology equipment.

Consequently the Teaching Company Project objectives are:

- To evaluate the scope for and assist in the implementation of modern manufacturing equipment.
- To ensure the equipment is capable of responding rapidly, flexibly and efficiently to changes in market demand.
These objectives will be met through improvements in:

- The use of modern manufacturing equipment
- Improved design and processing techniques
- Accelerating the introduction time for new products

This will result in:

- A strengthening of the company's position and protection of its future.
- Increased profitability and export market penetration.

The Manufacturing Manifesto describes the changes required to achieve the Teaching Company objectives. This paper aims briefly to discuss:

1. Understanding the objectives of the Manufacturing Manifesto
2. Creating the Manufacturing Manifesto

2.0 CREATING THE MANUFACTURING MANIFESTO

The Manifesto was required as it provided a disciplined approach to ensure that the project objectives, the current technology and the business environment were all fully understood before any changes were recommended.

The strategy used to create the Manifesto followed five clearly defined stages.

- Understanding the objective of the Manufacturing Manifesto
- Information Retrieval
- The Analysis
- The Conclusion
- Recommendations

2.1 Understanding the Objective of the Manufacturing Manifesto

The objective was to identify those areas most likely to yield the greatest benefit. The Manifesto was required to develop the manufacturing Manifesto.

The criteria by which the end result will be measured were identified. The manufacturing Manifesto describes the changes required to achieve the

Increased profitability and export market penetration.

This will result in:

- Accelerating the introduction time for new products
- Improved design and processing techniques
- The use of modern manufacturing equipment
- The objectives will be met through improved

The criteria by which the improvements are to be measured are:

- Increased profit
- Increased quality
- Increased manufacturing flexibility; ability to respond rapidly to any new market requirements.
- Reduced lead time

2.2 Information Retrieval

It is particularly important to understand all aspects of a business before any attempt is made to change it. This was achieved by a thorough technical and financial analysis through the collation and synthesis of a vast amount of very diverse information.

2.2.1 The Current Technology

The initial analysis used to create a technical understanding, was simply one of following a product from each of the product groups through the production process and recording a generic product route (see Fig. 1 Generic Product Route). Subsequently it was decided to extend the technique by determining the time each generic product spent at each process stage. The result from this are shown in Fig. 2 which plots all the processes used on the x axis, recorded against each process is the length of time spent by each product at that process stage. If one process handles more than one product, then the times spent by each product at that process are added together and recorded against that process stage.

2.2.2 The Business and Market

This analysis was conducted using a number of techniques and it is important because understanding the technology is not enough. The objective of this financial analysis is to identify which major product groups and which product lines would yield the greatest benefit from the allocation of the Teaching Company resource. If the business were not understood elegant and expensive solutions or processes may be developed for:

a) product lines which could not sustain the investment
b) product lines with no future market potential.

2.2.2.1 Sales and Market Potential

The sales analysis was historical and it used the previous two years accounts. The information required for this analysis needed detail for each Major Product Group and each Product line. This was:

- The revenue generated
- The percentage that this revenue represented for the division or group
- The average profit generated
- The estimated market potential
- The number of units manufactured per year.

The above required the collection, synthesis and documentation of information from numerous data sources. This proved to be considerably more time consuming than anticipated.
The results of this investigation can be seen in tabulated form in Fig. 3 and 4.

2.2.2.2 The Pareto Analysis

Sometimes called the "80/20 rule", where 80% of a company's profits are provided by 20% of its products. This technique was used to evaluate which major groups and product lines provided greatest revenue and profit. The analysis, in this case, was also historical and conducted using the last two years accounts.

2.3 ANALYSIS

Understanding the scope and the objectives of the project is essential if the correct information is to be assembled and synthesised. The Manifesto needed to highlight the major product groups and/or product lines where maximum benefit would be achieved from the investment of the resources available. These highlighted areas, Strategic Business Units (SBUs) were thought to be those generating the largest revenues, but having only a small or medium profit margin. The effort would be invested in increasing the SBU's profitability. The large revenue high margin lines would not attract investment in time and money as greater profit would be easier to achieve through greater market penetration and share.

The Manifesto also needs to be attentive to the forecast market potential of each market. This is particularly important if any attempt is to be made to protect the company's future. Consequently, product lines with a large potential but minimal current profitability would be exposed to increased competition. In this case, a Pareto analysis was also used to identify those product groups and product lines which were most susceptible to market attack. The analysis was used to identify which product groups and product lines had the largest revenue potential.

The largest revenue generator in the combined Metal Bond section is the range of wheels at 45%. The next largest is the range of hones and segments commanding 41%.
The most rewarding starting point for change would usually be the largest revenue generator, as maximum financial gain could be achieved with the minimum of effort. However, it was decided to gear most effort to improving production for the range of hones and segments. This decision was made as it was thought to be easier to improve a production process geared to manufacture of rectangular segments, rather than one geared to the manufacture of a very diverse range of annular rings and wheels.

The improvements will be developed in two thrusts - one short term, one long term. The short term project will be to develop the Pelletisation process - a process pioneered by our R & D Department, for the production of segments for the Stone & Construction Division. The long term approach will be to develop a self contained manufacturing unit for the production of hones and segments. It is envisaged that a second machine for producing annular rings will be developed soon after implementation of the machine for the production of hones and segments.

The financial analysis highlights the need for an investigation of the Resin Department, as for 1985/6 approximately half of the product lines ran at a loss. Obviously there is a need to rectify this situation.

The Resin, Resimet and Unijet product lines are all very similar and it may be that a Group technology approach for the three sections would overcome the financial problem described above.

The remaining financial analysis (Fig. 6) shows the other Superabrasive Major Product Groups to be much smaller than the Metal Bond and Resin groups. As a result, it is unlikely that much effort will be invested in these.

Two problems were identified from the results of the analysis which recorded the time taken for the various products at each process stage (Fig. 2).

- Product design problems
- Process design problems

Product Re-Design

Product re-design is required when a long time is spent at a particular process stage. From Fig. 2 it can be seen that a number of products fall into this category, e.g.:

- the turning of electrometallic blanks
- the fitting of crushform wheels

The result of a possible re-design could lead to a reduction in the time taken at a particular process stage. This would have three effects:

- increased profit
- extra capacity would be gained
- lead time would be reduced
Process Re-Design

Process re-design will be investigated for those processes which have large capacity requirements because of a large volume of production, e.g.:

- The range of hones and segments

Short term - Develop the Pelletisation Process
Long term - Self Contained Manufacturing Unit

Computer Numerical Controlled Machining (CNC)

Electro-chemical machining versus electro-discharge machining

(a) Grinding
(b) Turning

The range of hones and segments

2.4 CONCLUSION

In conclusion, the objective of the Manifesto was to identify those areas most likely to yield the greatest benefit from the introduction of modern manufacturing methods. In constructing the plan, the areas identified to be targeted were those generating large revenues, but also having good market potential and a low margin over materials.

It should be realised that some of the projects are much bigger than others, therefore, one or more projects of various sizes may be pursued at a time, so project overlaps will occur in many instances.

2.5 RECOMMENDATIONS

As a result of the investigation undertaken and the findings from the review and short term strategy:

- The Metal Bond Section is the short term candidate for maximum investment

Recommended that:

(a) The range of hones and segments

(b) The range of profiles in the diamond impregnated body

Current machining processes:

- Turning
- Grinding

The manufacture of the range of hones and segments using a long and short term strategy

Project overlaps will occur in many instances.

Effort should be geared towards improving:

- The manufacture of hones and segments
- The current machining processes
- The range of profiles

Recommend that:

2.5 RECOMMENDATIONS

As a result of the investigation undertaken and the findings from the review and short term strategy:

- The Metal Bond Section is the short term candidate for maximum investment

Recommended that:

(a) The range of hones and segments

(b) The range of profiles in the diamond impregnated body

Current machining processes:

- Turning
- Grinding

The manufacture of the range of hones and segments using a long and short term strategy

Project overlaps will occur in many instances.
SUPER-ABRASIVES PRODUCT RANGE

A GRAPHICAL REPRESENTATION OF THE PROCESS TIME REQUIRED BY GENERIC PRODUCT FROM EACH MAJOR GROUP
## MAJOR PRODUCT GROUP PERFORMANCE - COMPANY WIDE

### PRODUCT GROUP PERFORMANCE

<table>
<thead>
<tr>
<th>PRODUCT GROUP</th>
<th>1984</th>
<th>1985</th>
<th>1986</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REVENUE</td>
<td>% OF TOTAL</td>
<td>REVENUE</td>
</tr>
<tr>
<td>M.B. Eng.</td>
<td>11.2%</td>
<td>16.0%</td>
<td>22.8%</td>
</tr>
<tr>
<td>Tiger Saw</td>
<td>17.1%</td>
<td>10.40%</td>
<td>13.9%</td>
</tr>
<tr>
<td>Small Tools</td>
<td>9.8%</td>
<td>8.10%</td>
<td>9.20%</td>
</tr>
<tr>
<td>Resin</td>
<td>6.9%</td>
<td>6.9%</td>
<td>7.5%</td>
</tr>
<tr>
<td>Electrometallic</td>
<td>7.0%</td>
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<td>Diabond</td>
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### METAL BOND GLASS

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<tr>
<td></td>
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### TOTAL METAL BOND GLASS PERFORMANCE

## METAL BOND OTHER

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<tr>
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<td>MD</td>
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<tr>
<td>MF</td>
<td>4.39%</td>
</tr>
<tr>
<td>MG</td>
<td>8.90%</td>
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## PRODUCT LINE PERFORMANCE
THE REVENUE CONTRIBUTION TO THE COMPANY
TURNOVER FOR ALL MAJOR PRODUCT GROUPS

PRODUCT GROUPS FROM OTHER DIVISIONS

SUPERABRASIVE PRODUCT GROUPS

FIG. 6
THE SUPERABRASIVES DIVISION

METAL BOND

PROCESSES
- Investigate Alternative Methods to machine diamond impregnated solids
- Pressing & Furnacing
- Mixing & Filling
- Machining
- Reduction of Mould wear
- Materials
- Coatings
- Pelletisation
- Turning
- Grinding
- Self contained manufacturing unit
- Hones & Segments
- Wheels

PRODUCTS
- Cutting Discs
- Pencil Edging Wheels
- Hones & Segments

RESIN
- An investigation into improving the profitability of the Resin lines.

 areas highlighted after initial investigation
APPENDIX XIV

Fourth National Conference on
Production Research, Sheffield, September, 1988
A Manufacturing Manifesto for Van Moppes IDP Ltd

M Woods, P Davies, W Jones* and M B Bassett*

Van Moppes IDP Ltd and *Polytechnic of Wales, UK

ABSTRACT

The Gloucester based company, Van Moppes-IDP Ltd., had identified the need to update the existing manufacturing facility to meet the demands of management strategic plans. The company now comprises of three divisions manufacturing a wide range of diamond impregnated tools by employing processes which produce a very high quality product but these methods are slow and expensive. To accelerate the technology update required the company joined a Multigroup Teaching Company Programme with the Polytechnic of Wales, Department of Mechanical & Production Engineering.

This paper describes the techniques used to develop a planned programme of change, needed to professionally implement new manufacturing processes. These processes will be specifically designed to meet the demands of the strategic plan but it is essential that the correct order of priorities is identified so that scarce resources are optimised.

1.0 INTRODUCTION

A five year Strategic Plan was devised by the company, which documented the goal as being "company expansion by doubling the company turnover". However, the Strategic Plan also recognised that the current manufacturing equipment represented a major weakness in the company's ability to meet this goal. This resulted in the need to update existing manufacturing equipment with new high technology equipment.

Consequently the Project objectives are:-
- To evaluate the scope for and assist in the implementation of modern manufacturing equipment.
- To ensure the equipment is capable of responding rapidly, flexibly and efficiently to changes in market demand.
(SBU's) were thought to be those generating the largest revenues, but having only a small or medium profit margin. The effort would be invested in increasing the SBU's profitability. The large revenue high margin lines would not attract investment in time and money as greater profit would be easier to achieve through greater market penetration and share.

The Manifesto also needs to be attentive to the forecast market potential of each SBU i.e. where both the market and competition will be in five years time. This is particularly important if any attempt is to be made to protect the company's future. Consequently, product lines with a diminishing market potential also do not attract investment.

In addition, because of the uncertainty imposed by looking five years ahead, any solutions offered to the production problems were to cater for the future by being flexible enough to respond quickly and competently to changes in market requirements.

From Fig. 2 it can be seen that the Metal Bond section, Product Groups 1 & 5, are the largest (by revenue) major groups within the Superabrasive
Division it has a relatively low margin over materials, and it is believed to have a strong market potential. The Metal Bond section comprises of both Engineering (Product Group 1) and Glass (Product Group 5); the process routes are identical and combined they total nearly 35% of the Superabrasives Division. The Metal Bond section is therefore the ideal candidate for maximum investment of effort.

The largest revenue generator in the combined Metal Bond section is the range of wheels at 45%. The next largest is the range of hones and segments commanding 41%. The most rewarding starting point for change would usually be the largest revenue generator. However, it was decided to gear most effort to improving production for the range of hones and segments. This decision was made as it was thought to be easier to improve a production process geared to manufacture of rectangular segments, rather than one geared to the manufacture of a very diverse range of annular rings and wheels.

The improvements will be developed in two thrusts - one short term, one long term. The short term project will be to develop the Pelletisation process - a process pioneered by our R & D Department. The long term approach will be to develop a self contained manufacturing unit for the production of hones and segments.

The financial analysis (Fig.2) highlights the need for an investigation of the Resin Department (Product Group 7), as for 1985/6 approximately half of the product lines ran at a loss. Obviously there is a need to rectify this situation. The Resin, Resinet and Unijet product lines are all very similar and it may be that a Group technology approach for the three sections would overcome the financial problem described above.

Two problems were identified from the results of the analysis which recorded the time taken for the various products at each process stage (Fig. 1) which are as follows:-

- Product Re-Design is required when a long time is spent at a particular process stage. From Fig.1 it can be seen that a number of products fall into this category, e.g.:-
  - the turning of electrometallic blanks
  - the fitting of crushform wheels

The result of a possible re-design could lead to a reduction in the time taken at a particular process stage.

Process Re-Design will be investigated for those processes which have large capacity requirements because of a large volume of production, e.g.:-

- The range of hones and segments
  - Short term - Develop the Pelletisation Process
  - Long term - Self Contained Manufacturing Unit
- Computer Numerical Controlled Machining (CNC)
  a) Turning
  b) Grinding

2.3 CONCLUSION

As a result of the investigation a number of areas were highlighted (Fig.3) and from the findings it is recommended that:

a) The Metal Bond Section is the ideal candidate for maximum investment of effort.

Effort should be geared to improving:-

- The manufacture of the range of hones and segments using a long and short term strategy.
- The current machining processes: a) turning, b) grinding
- The method used to manufacture profiles in the diamond impregnated body. (Electrical Discharge Machining)
- Product design.

b) The Resin Section

Effort should be geared to improving - Overall profitability.

Implementation

Further to the investigation the following projects have been completed, installed and commissioned.

1) Pelletization
2) One CNC Machining Centre installed with a parametric CAM link and a DNC link for scheduled piece parts.
3) The Resin section has been reorganized into a group Technology based Cell, as have the production processes required to manufacture Pencil Edging Wheels.

Additionally further investigations have been made into:-

4) The feasibility of a self contained manufacturing unit to produce the range of diamond impregnated segments and hones.
5) Electrochemical Machining profiles on diamond impregnated work.
The Superabrasives Division

Advances in Manufacturing Technology
APPENDIX XV

International Joint Conference on
Mechanical Engineering Technology, Cairo, April, 1989
A MANUFACTURING MANIFESTO
FOR
VAN MOPPES IDP LIMITED

Mr. M. Woods - Van Moppes IDP Limited
Mr. P. Davies - Van Moppes IDP Limited
Mr. W. Jones - Polytechnic of Wales
Dr. M.B. Bassett - Polytechnic of Wales

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Consequently, the Project objectives are:-
- To evaluate the scope for and assist in the implementation of modern manufacturing equipment.
- To ensure the equipment is capable of responding rapidly, flexibly and efficiently to changes in market demand.

These objectives will be met through improvements in:-
- The use of modern manufacturing equipment
- Improved design and processing techniques
- Accelerating the introduction time for new products

Before these objectives could be met, two problems arise. These are "what is there now" and "where should the available resources be used". The resources of time and capital must be used effectively to maximise their benefit to the company. The solution to these problems is what is termed the "Manufacturing Manifesto" and its objective was:-

To identify those areas most likely to yield the greatest benefit from the introduction of modern manufacturing methods. Which will result in:-
- The strengthening of the companies market position and protection of its future.
- Increased profitability and export market penetration.

2.0 CREATING THE MANUFACTURING MANIFESTO
The strategy used to create the Manifesto followed five clearly defined stages.
- Understanding the objective of the Manufacturing Manifesto
- Information Retrieval
- The Analysis
- The Conclusion
- Recommendations

The criteria by which the improvements are to be measured are:-
- Increased profit
- Increased quality
- Increased manufacturing flexibility; ability to respond rapidly to any new market requirements.
- Reduced lead time
- Reduced work in progress

2.1 Information Retrieval
It is particularly important to understand all aspects of a business before any attempt is made to change it. This was achieved by developing a thorough technical and financial analysis through the collation and synthesis of a vast amount of very diverse information.
2.1.1 The Current Technology

The initial analysis used was a simple one of following a product from each of the product groups through the production processes. Subsequently it was decided to extend the technique by establishing the time each generic product spent at each process stage. The results from this are shown in Fig. 1.

2.1.2 The Business and Market

This analysis was conducted using a number of techniques and it is important because understanding the technology is not enough. The objective of this financial analysis is to identify which major product groups and product lines would yield the greatest benefit from the allocation of the resource.

2.1.2.1 Sales and Market Potential

The information for this analysis required the following detail for each Major Product Group and each Product line:

- The revenue generated.
- The percentage that this revenue represented for the division or group.
- The average profit generated.
- The estimated market potential.
- The number of units manufactured per year.

The above required the collection, synthesis and documentation of information from numerous data sources. This proved to be considerably more time-consuming than anticipated.

2.1.2.2 The Pareto Analysis (80/20 Rule)

This technique was used to evaluate which major product groups and product lines would provide the greatest revenue and profit. The analysis, in this case, was also historical and conducted using the last two years' accounts (see Fig. 2).

2.2 ASHYSYS

Understanding the scope and the objectives of the project is essential if the correct information is to be assembled and synthesised. The Manifesto needed to highlight the major product groups and product lines where the greatest benefit would be achieved from the investment of the resource.

What product groups and products should be selected to receive the greatest benefit from their investment? The selection is made on the basis of a number of factors and is as follows:

- The revenue generated.
- The percentage that this revenue represented for the division or group.
- The average profit generated.
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long term - Self Contained Manufacturing Unit

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a) Turning

b) Grinding

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The current machining processes: a) turning, b) grinding

The method used to manufacture profiles in the diamond impregnated body. (Electrical Discharge Machining)

Product design.

b) The Besin Section

Effort should be geared to improving - Overall profitability.

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3) The Resin section has been reorganized into a group Technology based Cell, as have the production processes required to manufacture Pencil Edging Kneels.

Additionally further investigations have been made into:-

4) The feasibility of a self contained manufacturing unit to produce the range of diamond impregnated segments and hones.

5) Electrochemical Machining profiles on diamond impregnated work.
engineering office staff has achieved two things. Firstly the engineering staff have been made aware of difficulties they were otherwise perhaps not aware of. Secondly the staff have been made aware of what CNC machines can easily do for them.

The analysis concluded that the use of CNC machining techniques would result in a 5:1 machining time advantage and a 4:1 cost advantage.

The Problems

The biggest problem will be that of production control. However, this should only be temporary, while the production control system and the working practices are revised to cope with the speed of production of the CNC machine.

Additionally it is believed that because of the speed at which a CNC will work capacity problems will be seen in the variation grinding and electrodischarge machining areas. These have been accounted for by including an additional £60,000 spend for buying the appropriate new machines. However at this point in time we are not requesting the authorisation for the additional plant. This will be the subject of a future capital expenditure proposal.

The Machine

Some fourteen manufacturers have been investigated and the selected machine is an MHP MT50 turning centre. The principle advantages of this machine are its price, and the manufacturer's location (Gloucester). The MT50 has:

- Higher spindle speeds
- Higher main motor power
- Higher driven tooling power
- Quicker tool changing
- 12 tooling stations

These are significant and appropriate technical advantages over the competing range of machines.

The machine has been ordered with delivery being set for 8 January 1988. At present the delivery is wholly dependent on the results of the cutting trials only if they prove conclusive will the order proceed.

The Alternatives

The alternatives investigated included the purchase of additional conventional machines. If this route were taken four conventional machines would be required to meet the increase in capacity that the CNC will provide. Additionally four operators would be required, the cost to the company per man per annum in excess of £10K, consequently the ongoing labour cost of this route would be in excess of £40K.

The remaining alternatives would be to increase the amount of work subcontracted. This is only viable for a small amount of work as massive lead time penalties are incurred. The final option would be to do nothing a watch our market share diminish.

Summary

The increase in capacity required to meet the demands of the strategic plan will only be met through plant investment.

If the CNC route is taken

The Project cost : CNC £91000
: Additional plant purchases £60000
: Total £151000

The payback period 21 months

Proposed machine MHP MT50

Conclusion

The alternatives described are not acceptable. The CNC route allows
The Justification of Implementation of the CNC Presentation

Thursday, 15th October 1987 at 11.45 am
Van Moppes IDP
The Training Room

The Presentation Committee:

S E Annetts
P H Davies
A F Green
W Jones (Poly of Wales)
R M McKenzie
R H Watkins
M D Woods Main Presenter

The Attendees:

Machine shop operators
Fitting shop operators
Inspectors
Progress Chaser Main Works
Production Controller
Mould rectification staff
Estimating Department
Design Draughtsman

The presentation will be in three stages:

1. A short video
2. The Presentation
3. Question and Answer Session

It is estimated that the complete Presentation will be approximately 45 minutes long.

THE CNC AWARENESS PRESENTATION

Introduction

The five year strategic plan documents the company goal as being "to double the size of the company whilst retaining profitability." However, the plan also recognised that the current manufacturing equipment represents a major weakness in the company's ability to meet the goal. The justification, selection and implementation of the company's first CNC machine represents an initial step being taken to redress this manufacturing weakness.

The Forecast Sales Increase

The sales department have forecast an increase in sales based on the potential market. This sales increase is in the order of £210K and it has been made with no reference to current production capacity i.e. this figure represents what we could achieve if we had the capacity.

Hopefully then it can be seen that the machine has been justified against a potential increase in sales arising from the extra capacity a CNC machine would provide. It is not envisaged that redundancies will arise. The purchase has been made to safeguard jobs, safeguard the company's future, and to preserve our market share and reputation.

The Products Affected

The products affected are those products having either:

- high turning/fitting content
- high sales volume
- complex machining operations
- subcontracted operations

The products chosen for analysis have been closely scrutinised by the shopfloor supervisor and the operator who is normally involved in their production. The involvement of various people outside the
us to meet the forecast sales increase. This route also complements our strategy for growth and our drive to becoming market led manufacturers of quality diamond tools.

CNC provides an option that

* Meets our strategic requirements
* Can respond rapidly to produce BM products effectively
* Reduces lead times
* Increases quality