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THE UNIVERSITY OF DURHAM

School of Engineering and Applied Science

Planned Maintenance Systems with Respect  
to Modern Manufacturing Strategies

Thesis Submitted for the Degree of Master of Science in Engineering

BRIGID MARY QUINN, B.Sc.

October 1989

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26 JAN 1990

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## ABSTRACT

To remain competitive in today's increasingly automated environment, manufacturing industry must take a more proactive and strategic attitude towards maintenance. This thesis applies these concepts, as a case study, to Philips Components Durham - an advanced manufacturing unit for colour television tubes. Consideration is first given to modern manufacturing strategies and the business objectives which the maintenance strategy must support. Recent organisational changes are then discussed and analysis made of the maintenance information systems infrastructure. Having related the maintenance department functional requirements to proprietary equipment management packages, the area of machine breakdown data collection is further discussed.

To address the need for improved feedback on machine performance, a shop floor data collection and analysis system (Equipment Utilisation Improvement system) has been developed and commissioned. This system now provides more accurate and detailed information than was previously available. A further success of this system is that, as a pilot project, the system has highlighted many organisational and technical issues. These must be addressed before a more comprehensive equipment management package could be successfully implemented. Based on the knowledge gained from the implementation of this system, recommendations are made on the responsibilities for maintenance tasks, appropriate training for maintenance personnel and the further development of information systems to support the maintenance function.

## LIST OF TERMS

The terms listed below are for general reference. Other terms used only in one chapter are defined where they occur and are not included here.

### AQAP : Allied Forces Quality Assurance Procedure

Originally a military specification which has been adapted and is now widely used in industry.

### Availability

The fraction or percent of uptime. Availability is measured by dividing hours of uptime by scheduled running hours.

### MTTF

Mean Time To Failures. Is the average available time between equipment failure. An important characteristic with respect to machine performance and this parameter is failure pattern e.g. time based, random etc. Also of significance is the availability of suitable parameters to detect the onset of failure. The inverse of MTTF is the failure rate or the number of failures per operating hour.

### MTTR

Mean Time To Repair. Is the average time necessary to repair and return equipment to service once a failure has occurred.

### Pareto 80/20 Rule

Originally devised for stock analysis although can be readily translated to other areas. 80% of the value of stores items is held by 20% of the volume of goods.

### PPM : Parts Per Million

Number of occurrences in a given population. A commonly quoted quality parameter.

### Reliability

Is the probability that a piece of equipment or a component will operate satisfactorily for a specified period of time.

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## CHAPTER 1 : INTRODUCTION

Historically, British industry has underspent on maintenance, partially due to its low profile within the manufacturing organisation. In today's competitive environment, companies must take a much more proactive and strategic attitude towards maintenance. Poor maintenance now has implications beyond the cost of downtime; the non-availability of plant or quality problems can lead to market failure.

In Britain, it was the advent of microelectronics and the move towards capital intensive integrated manufacturing that first raised questions about the opportunity costs of under-maintaining.

In 1968, a study on engineering maintenance in British Manufacturing industry was carried out on behalf of the Ministry of Technology. It reported that :

- 1) The total direct cost of engineering maintenance was approximately £1,100 million per annum (value circa 1968).
- 2) Improved productivity of maintenance staff could have led to a reduction in maintenance expenditure of around £250 million per annum.
- 3) Better maintenance could have saved about £300 million per annum of lost production caused by unavailability.

In 1972, a steering committee, set up to examine the broader findings of this reported, concluded :

"The nature of the maintenance activity was determined by the manner in which plant and equipment was designed, selected, installed, commissioned, operated, removed and replaced. Major benefits could come to British Industry from the adoption of a broadly based technology which embraces all these areas, and because no suitable word existed to describe such a multidisciplinary concept, the name 'terotechnology' was adopted".

The extent to which the terotechnology initiative has impacted upon maintenance management is debatable. While it is accepted that integrated process technologies cut across conventional boundaries and that benefits



could be derived from more congruent maintenance and work organisations in the past, many companies have not sought to address these deep-rooted issues.

However, in Britain the changing economic climate is now bringing renewed impetus to comprehensively re-organise and formalise the maintenance process. There is now a growing belief that a more effective maintenance strategy can bring cost savings and competitive advantage in its own right.

Greater factory automation has led to a significant increase in maintenance budgets relative to other production activities. For example, the average engineering maintenance budget, as a proportion of factory operating expenses, has increased from approximately 10% to 17% during the period 1982-1986.

Companies now striving to enhance the effectiveness of their maintenance organisation tend to be active in two major areas :

1) Organisation

Notable improvements are being gained from changes in maintenance work organisation. Conventionally, British manufacturing companies have differentiated job structures in keeping with Taylorist notions of functional specialisation. The Maintenance Department is set apart from Production and typically has a different skill status.

Progressive management thinking is now to support the use of more homogenous job structures for Production and Maintenance personnel as a means of achieving improved quality of maintenance. This naturally leads to the formation of multi-disciplinary work teams.

2) Information Technology

Control of the maintenance organisation requires improved methods of measuring and quantifying maintenance activities. To support these new performance monitoring procedures requires the implementation of information gathering systems. Of particular interest are integrated asset management systems which can be valuable tools in increasing the overall level of professionalism of the maintenance function.

Philips Components Durham is one of nine Elcoma Display Components involved with the manufacture of colour television tubes. The factory was designed fifteen years ago for the production of a single type of TV tube. Today the factory employs 1,300 people and produces approximately 1.7 million tubes a year of 3 major types (Flat Square Narrow Neck, Flat Square Mini Neck and CMT). Production is carried out on a 3 shift system, 5 days a week with set/fixed plant shutdown holidays. All major engineering work is scheduled for planned shutdowns. The plant is based on a single site but is diverse and in parts, very complex, in nature. It is the responsibility of the Maintenance Department to maintain all production equipment in the plant, at an approximate annual budget of £2 million. Due to its capital intensive nature, the factory operates on a high volume, low cost principle - the cost of bottleneck equipment failure during operating hours is therefore significant. Improved effectiveness of the maintenance function can therefore play a significant part in the financial performance of the plant. With respect to lost factory capacity due to machine non availability, a 1% improvement in capacity on the FS bottleneck equates to £250,000 improved performance per annum and for the CMT bottleneck £70,000 per annum.

An effective maintenance organisation at Philips Durham is therefore most desirable. This thesis relates the above described industry developments to Philips Durham, with the overall objective of highlighting possible improvement areas.

Consideration is first given to modern manufacturing strategies and the business objectives which the maintenance strategy must support. Recent organisational changes are then discussed and analysis made of the maintenance information systems infrastructure. Having related the maintenance department functional requirements to proprietary equipment management packages, the area of machine breakdown data collection is further considered. To address the needs in this area, as a pilot project, a shop floor data collection system has been developed and is detailed. Finally, details of suitable maintenance performance indicators are given.

## CHAPTER 2 : BUSINESS ENVIRONMENT

All implementation of systems, whether computerised or manual, must be "needs driven".

To accurately determine these needs it is necessary to refer to the manufacturing strategy and the objectives that are being worked towards and from these overall objectives it is then possible to determine a suitable IT strategy, a framework in which any proposed developments can then be considered.

At the time of writing, both the manufacturing strategy and information strategy for Philips Components Durham have yet to be officially decided.

It is not within the scope of this thesis to determine these two strategies. However, consideration must be given to their direction to facilitate the appropriate environment for further developments.

### Philips Global Strategy

Recent poor trading figures for Philips (a 19% fall in profits from 1986 to 1987) have intensified pressure to improve the company's performance (Ref : Appendix 1 : Philips Earnings Blow a Fuse).

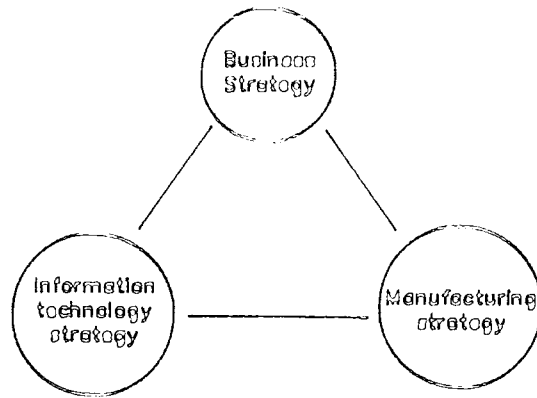
In broad terms the following requirements have been set as business targets by Company President, Mr Cor van der Klugt :

- 1) Increased Return on Capital : 8% before tax, giving 4% after tax.
- 2) Increased liquidity/cash flow.
- 3) Decreased investment.

### 2.2 Manufacturing Strategy

The interactions between various corporate strategies can be represented as in Figure 2.2.

Fig 2.2 Corporate Strategies



Strategy decisions need to take account of the impact of manufacturing on corporate objectives.

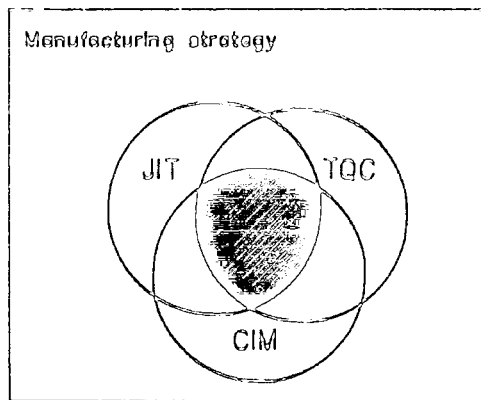
Competitive advantage can be gained through a good degree of fit between a company's marketing strategy and manufacturing's ability to support it. Both factors must be known at the business level and objectively resolved within corporate perspectives (Ref. 7).

For this to take place relevant internal information which explains the company's manufacturing capabilities needs to be available at Senior Management level, along with traditional marketing information. To be effective the ownership of its use must be vested in top management.

An information technology strategy is also required to ensure that an appropriate communications infrastructure is developed to support the business and manufacturing strategy (Ref. 6).

When determining a manufacturing strategy there are three fundamental modern manufacturing concepts which warrant further discussion : Computer Integrated Manufacturing (CIM), Total Quality Control (TQC), and Just In Time (JIT) production techniques. These are represented in Figure 2.3.

Fig 2.3 Manufacturing Strategy Concepts



The fact that these concepts are illustrated as having areas of overlap is significant. The overlap between CIM and JIT illustrates that the two concepts are not mutually exclusive - JIT concepts can be integrated with Manufacturing Resource Planning (MRP), a part of CIM. Furthermore, the fact that all three are represented on the same model, with a significant area of overlap, implies that all three must be addressed in parallel in any overall program to gain competitive advantage in manufacturing.

#### 2.2.1 Just In Time (JIT) Concept

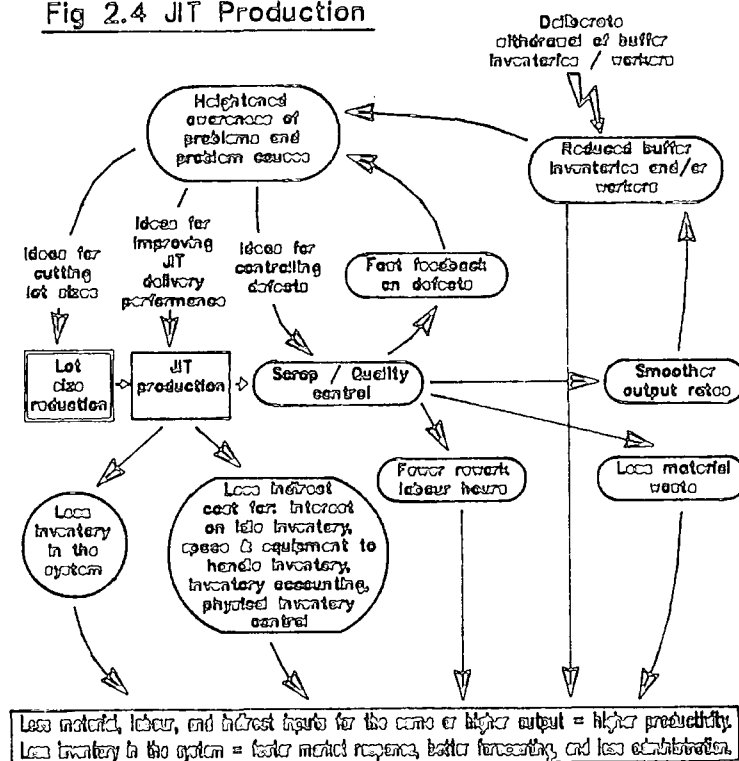
The JIT concept originated as an integral part of Japanese manufacturing philosophy, and is a cornerstone of Japanese production management and productivity improvement (Ref. 14). The fundamental JIT idea is simple : produce and deliver finished goods just in time to be sold, subassemblies just in time to be assembled into finished goods, fabricated parts just in time to go into subassemblies, and purchased material just in time to be transformed into fabricated parts. This in turn has a significant impact on batch sizes; Japanese industry tends to produce small quantities 'just in time' whereas it is not uncommon in Western industry to produce massive quantities 'just in case'.

The JIT ideal is for all materials to be in active use as elements of work in progress, never at rest incurring inventory charges - JIT therefore directly addresses the material cost component of productivity. The indirect effects are even more pronounced, effecting elements of productivity from scrap to worker motivation to process yield.

The Japanese methodology of Kanban, is a possible means to help to move towards JIT production, Kanban is simply the name of a specific Japanese inventory replenishment system developed by Toyota - stockless production is another term sometimes used. With Kanban, production output is controlled by the use of Kanban containers - a part is only manufactured if there is a demand for it and this is flagged by an empty container. If all containers are full then the production line is stopped.

The overall JIT scenario is illustrated in Figure 2.4. By deliberately reducing the level of buffer stocks there is increased awareness of problems and causes, and this can set off the chain of events as illustrated.

Fig 2.4 JIT Production



It must be stressed that JIT is a concept which will affect every area of an organisation, not simply a tool for reducing work-in-progress (Ref. 13). Moving towards JIT production is likely to involve everyone from the man on the Shop Floor through Purchasing through to Administration. For example, if a manufacturing unit has a high stock of finished goods then under JIT it would be logical to slow down production to reduce the level of finished goods stock. However, if the factory is measured on its production volume rather than sales, then a conflict of objectives arise. If JIT concepts are to be pursued, then a review of accounting and reporting procedures would be necessary.

### 2.2.2 Total Quality Control

Japanese quality improvement is partially addressed by Just-In-Time, but there are a host of other Japanese quality improvement concepts and procedures, collectively known as Total Quality Control (TQC). TQC encompasses some of the JIT techniques and improves productivity through the avoidance of waste. Collectively JIT/TQC attempts to control such costly source of waste as idle inventories, storage costs and mass production of defective components. When producing goods for a high quality, low cost market place then JIT/TQC can provide a powerful competitive advantage - producing quality goods 'right first time' is not only necessary to meet product quality criteria but also if defective products are not produced, provides a cost advantage.

Total Quality Control procedures particularly emphasise :

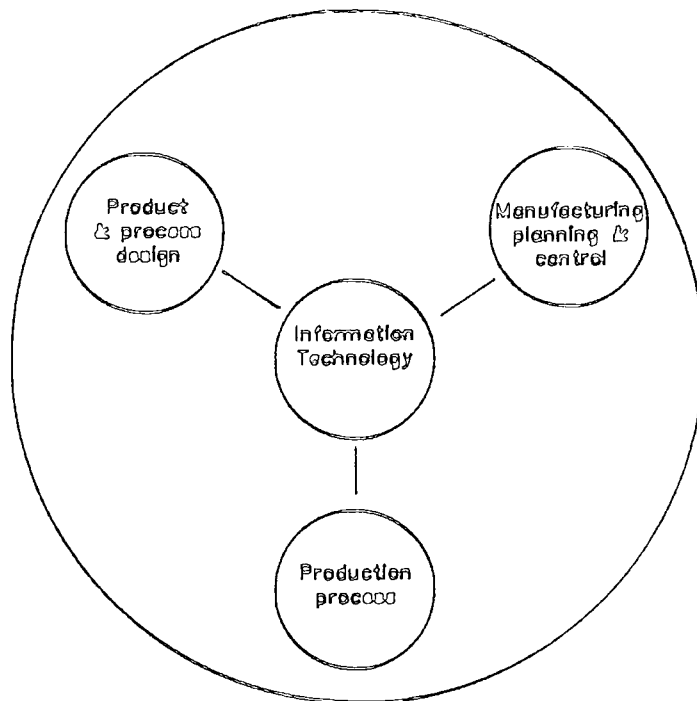
- 1) A goal of continual quality improvement.
- 2) Direct line worker responsibility for product quality rather than a separate Quality Control Department.

- 3) Quality control of every process e.g. Statistical Process Control Techniques, not reliance upon inspection of lots from selected processes. Defect prevention, not random detection.
- 4) Measures of quality that are simple, visible and readily understandable.
- 5) Automatic quality measurement devices.

### 2.2.3 Computer Integrated Manufacturing (CIM)

Figure 2.5 shows a top level framework for current definitions of CIM.

Fig 2.5 CIM Top level



The three functional nodes in this model are product and process design, manufacturing planning and control and the production process. In the case of CIM, the integrator of these three functions is information technology (Ref. 10).

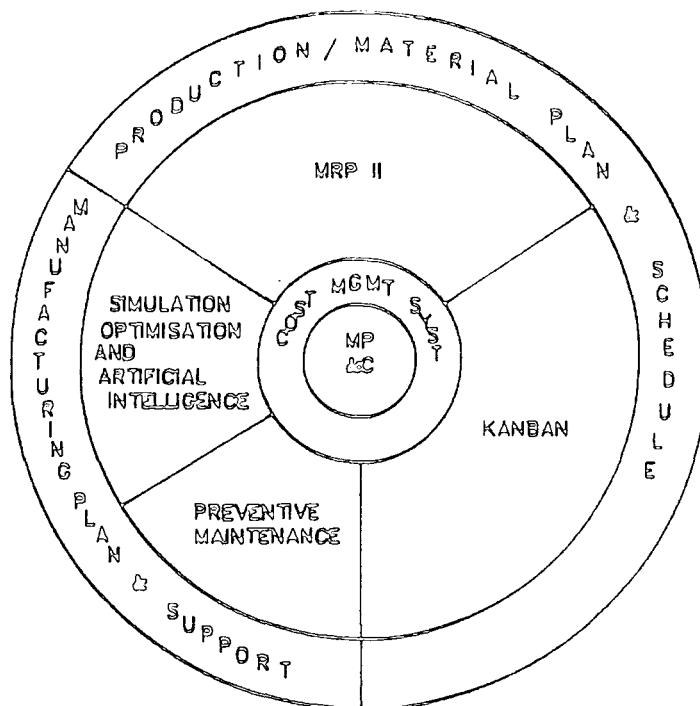
Through information technology data is defined, gathered, stored and manipulated to produce information. This in turn facilitates integration of the whole sphere of manufacturing activities.

The node manufacturing, planning and control will now be discussed in further detail.

### Manufacturing Planning and Control

Figure 2.6 shows the detail of the manufacturing planning and control area.

Fig 2.6 CIM Manufacturing Planning & Control



Underlying the basic concept of manufacturing planning and control are cost management systems which are central to any manufacturing function. Then comes production and material planning and scheduling. Two types of systems are used primarily : one is manufacturing resource planning (MRPII), and the other is the Kanban system. The Kanban system is shown in the CIM manufacturing, planning and control node because it represents the information systems side of Just-In-Time production.

Procurement, or purchasing, requires support for these systems. In the CIM framework, purchasing systems are a further module of an overall factory control system of which MRP would also be an integral part. This module, driven by MRP logic, can determine purchased item needs, create purchase orders or releases against blanket orders and serve as the basis for a vendor rating system.

Manufacturing, planning and control also includes several types of manufacturing planning and support systems. Simulation, optimisation and artificial intelligence software have become technically established products and as such are now useful tools in solving complex logistic and production process problems. A key part of any manufacturers' overall programme to gain competitive advantage in manufacturing is a preventive maintenance programme. Plant reliability must be assured before the benefits of JIT and TQC can be realised.

#### 2.2.4 Philips Durham Manufacturing Strategy

Colour televisions, especially 51FS derivatives, are now a mature product being sold in a worldwide market place of intense competition. Factory selling price and product quality are key parameters in retaining and/or improving Philips market share of sales (Ref. 7).

Similar to their competitors, Philips have high costs due to the nature of the product. Economies of scale i.e. high volumes are therefore required to absorb these fixed costs onto the product to produce at a competitive price. This makes factory results very sensitive to output : if Philips do not meet their production targets, this seriously hampers their FSP and/or profit performance (Ref. 4).

Fundamental to producing a low cost product in the present manufacturing environment are (Ref. 19) :

- 1) Manufacturable product. To achieve necessary high yields products must be designed with consideration of the manufacturing process.
- 2) Material cost reductions through redesign, substitution and standardisation.
- 3) Maintainable and reliable processes to achieve high utilisations and facilitate Just In Time principles. The design of process equipment should take into account the needs of the maintenance function. This subject is further discussed in Appendix 2.

It is difficult to review Durhams performance with respect to previously quoted company objectives on return on capital employed as industrial units within the Philips group are not directly involved in product sales. In general Philips policy is that manufacturing activity tends to take place in production units separate from the true market place.

However, some measure of return on capital employed may be gained from consideration of :

Turnover	* (1)
-----	
Net Assets Value	* (2)

\* (1) : Turnover gives a measure of the number of products sold. Profits made on sales are determined by the activity of the commercial unit. Our overall policy is to maintain a fixed price to the market place.

\* (2) : Fixed assets are calculated to be approximately £40 million - investment is being made at approximately the same rate as depreciation. Total assets, including debtors, creditors and stock varies between approximately £52 and £57 million.

For the first 6 months of 1989, this ratio is :

FS	:	2.20
CMT	:	0.99

From comparison of these figures with other data it is possible to conclude that considerable operating improvements are required by Durham, especially on the CMT range, to meet the business targets as defined by Mr van der Klugt.

More readily interpretable factory performance indicators have been set by the business unit and are detailed in Figure 2.7.

Figure 2.7 : Factory Objectives Set by the Business Unit

<u>1987</u>		<u>1990</u>
3,000 - 12,000	Quality Level - Rejects in ppm	1,000 - 2,000
100%	Cost Price	75%
95% Weekly	Delivery Reliability	100% Daily
6 Weeks	Delivery Time	1-2 Weeks

To move towards these required targets from their present position, Durham Management have outlined 7 improvement objectives, as detailed in Figure 2.8. As illustrated and in line with modern manufacturing concepts, equipment performance is seen as a key area with respect to manufacturing performance. Equipment performance and maintenance strategy will therefore be discussed further.

## 2.3 Maintenance Strategy

### 2.3.1 The Objective of a Maintenance Function

The high investment in capital equipment necessitates high utilisation of a company's assets (Ref. 20). The maintenance function has a key role to play in asset utilisation and productivity, and the overall aim of the maintenance function is to provide a cost effective and comprehensive service.

### 2.3.2 Maintenance Strategy : An Integral Part of the Manufacturing Strategy

Two factors have emerged that affect the maintenance function directly and enable it to contribute to the profitability of the company. One is asset utilisation and productivity, the other is a market driven demand for a more flexible and responsive plant (Ref. 24).

The two principal requirements of the maintenance function are to handle breakdowns effectively and to organise maintenance planning and parts replacement. To support the latter two, equipment performance data needs to be analysed so that schedules can be planned.

Equipment monitoring can be accomplished in several ways, from recording manually either downtime or productive time, through to computer based process monitoring and control mechanisms. The latter offer more accurate data recording and data processing facilities and thus faster problem diagnosis.

Stores inventory systems can record both the receipt and issue of parts and maintain stock balances. The overall objective of a such a system is to ensure that spare parts inventories are kept at optimum levels consistent with company goals for asset availability.

Finally, the maintenance function needs to input to the planned replacement of plant and equipment. Here, systems that evaluate the cost of replacing a piece of plant against the cost of keeping it properly maintained need to be adopted.

To achieve the objectives outlined above, it is essential to develop a cohesive strategy that forms part of the overall manufacturing strategy (Ref. 23).

The move from a breakdown to preventive maintenance situation demands considerable management time and effort. Fairly extensive information will need to be collected and analysed before it is possible to start developing planned schedules.

It is possible that pressures on maintenance managers to deliver short term benefits could restrict the move to a more planned maintenance scenario.

The second major challenge is the establishment of a workforce with skills appropriate to the maintenance of the installed asset base. Here, consideration should be given to the changes planned within the manufacturing environment. The trend towards increased automation will almost certainly result in the installation of equipment with logic and analogue controls. As factories introduce more intelligent systems, the need for electronic, instrumentation and control engineers will increase. The maintenance function must establish a policy, either sub-contracting these responsibilities to a third party or developing the necessary skills internally.

### 2.3.3 Analysis of Equipment

In the short term, data on breakdowns (cause, elapsed downtime, work effort and parts consumed) provides management with an analysis of the achievements of the maintenance function.

Equipment performance data can be captured in a number of ways, ranging from manual to fully automated condition monitoring devices. There is no panacea for factory maintenance - each asset needs to be treated separately and maintained on a corrective, preventive or productive basis. The strategy should reflect the priority given to each piece of equipment : process critical, safety, value etc.

#### 2.3.4 Retiring Assets

At times, maintaining a competitive advantage involves retiring some relatively young assets. By knowing the current costs of maintaining a piece of equipment and the trend since installation (increasing, decreasing or stable), management can establish and maintain an asset replacement strategy.

#### 2.4 Maintenance and Plant Capacity

To realise the maintenance business objective of minimising the long term cost of maintenance whilst achieving the planned output, consideration must be given to overall capacity limitations of a plant. Each production department cannot be viewed in isolation and therefore consideration must be given to the plant as a whole when determining the maintenance strategy for a department. To these ends the capacity, both installed and actual of each of the Departments with respect to overall production demand is the major factor in determining the level and nature of maintenance support.

As previously stated, moving towards Just In Time (JIT) manufacturing necessitates high reliability of plant equipment. However, this is a wide brief which consideration of the Optimised Production Technology (OPT) technique will help clarify (Ref. 5).

##### 2.4.1 Optimised Production Technology (OPT)

Central to the OPT approach is the way in which success is measured. The goal of a manufacturing company is defined as simply 'to make money'. In order to do this the Company must simultaneously increase throughput and reduce inventory. The key to increasing throughput is the bottleneck - the lowest capacity machine or resource in the chain of resources used to manufacture a product. A factory is viewed in OPT terms as few bottlenecks and many non bottlenecks. OPT focuses on the bottlenecks to increase output. The key OPT tenet is that bottlenecks should be

constantly producing. Non bottlenecks, however, can be employed setting up, producing or being maintained. For the whole of the production process to work in harmony the need to tolerate down time, or under utilisation, on a non bottleneck machine is vital (Ref. 18). Following the OPT approach, management attention can be drawn to the bottleneck areas. OPT is therefore a useful precursor to JIT in that it is quicker and easier to implement and also supports a process of a gradual evolution towards JIT.

The OPT approach is strongly supported by downtime cost figures. In a high volume factory lost production through bottleneck downtime is very costly. This in turn must have a strong impact on the maintenance strategies for different areas of the factory. However, before appropriate plans can be made, assessment of varying production capacities must be made.

#### 2.4.2 Bottleneck Identification

A Capacity Bottleneck Identification System (CBIS) has been set up at Durham (Ref. 22), although in practise this system is not fully utilised due mainly to problems in collecting accurate and relevant shop floor information.

For the purposes of this system the factory is set up into various production cells. For each cell or piece of equipment, the following information needs to be collected :

- Equipment Speed
- 1) Technical Speed =  $\frac{\text{-----}}{\text{Base Speed}} \times 100$
  - 2) Breakdown per equipment.
  - 3) Breakdown of equipment and following breakdowns in the cell.

- 4) Utilisation losses - for cleaning, process control etc.
- 5) Direct yield.

Obviously, to determine overall factory capacity information from the individual cells must then be linked to information about preceeding and following cells.

However, this has to take place with respect to the following 'capacity adjustors' :

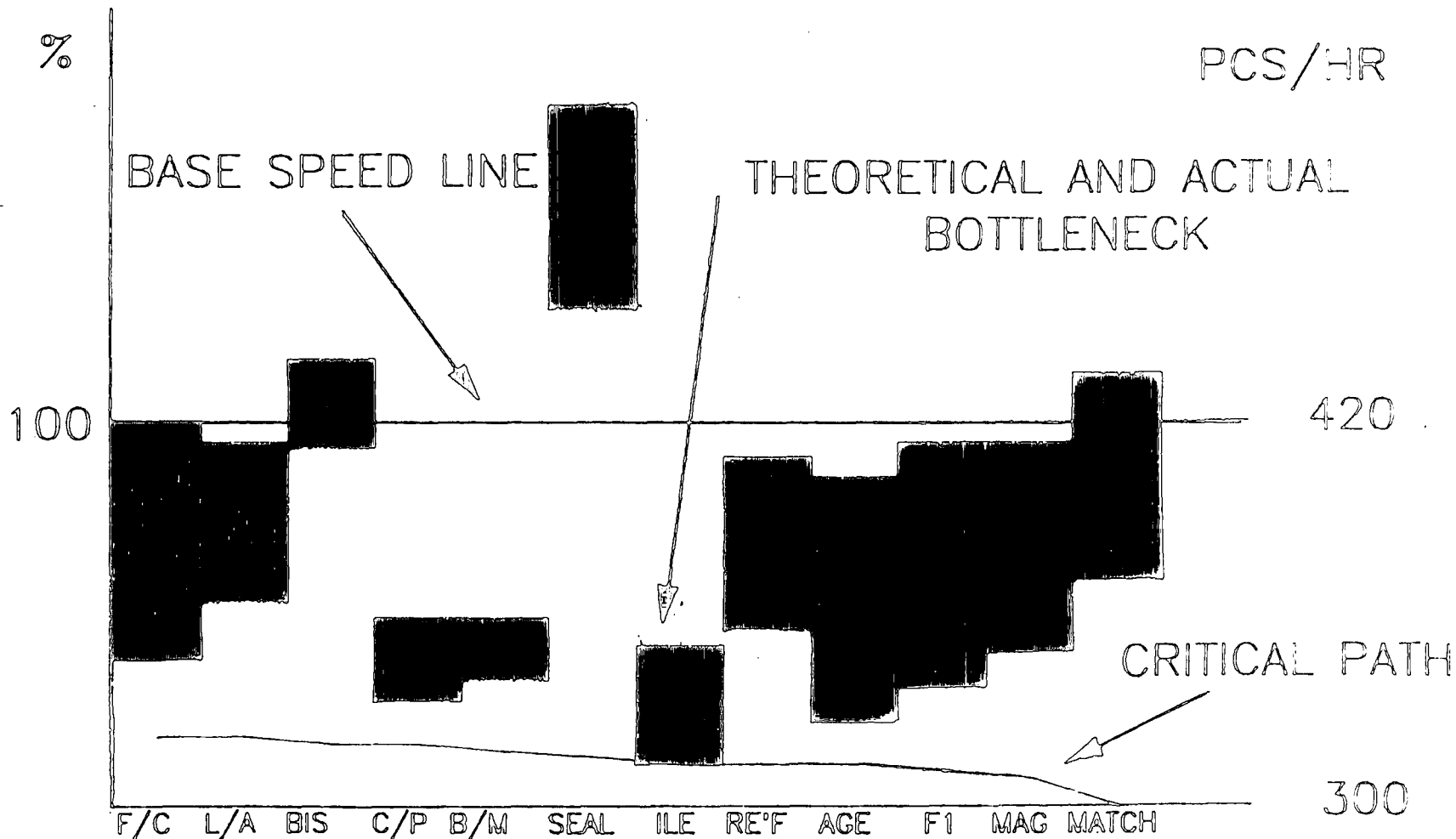
- a) Repairs : A faulty product is repaired off line within the Department where the fault arose. There is therefore no loss of capacity.
- b) Recycle : A faulty product is recycled within the Department where the fault arose. There is therefore an effect on capacity but only within this single Department.
- c) Rework : The nature of a fault on a product is such that it has to be reworked back down the line, beyond the Department where the problem arose or was identified. There is therefore an effect on capacity on all the Departments through which the rework must pass and possibly on throughput if one of these Departments is a bottleneck.

All this information is collated via a spreadsheet with an ultimate output of the CBIS chart as shown in Figure 2.9.

To further interpret this chart :

- a) The Base Speed Line : Philips policy for colour television tube factories is to use the capacity of the flowcoating process.

# CBIS CHART FS B 1989



-20-

FIGURE 2.9 : CBIS CHART

- b) For each production cell a block is shown. The top of this block represents the total capacity theoretically available. The bottom represents actual capacity. The size of the block represents lost capacity due to yield and utilisation. A further split of these boxes to show the percentage of capacity lost due to machine problems would be useful to illustrate the maintenance improvement potential for an area.
  
- c) The bottleneck is the area with the lowest actual capacity. The critical path is then determined from this cell working backwards and forwards from it, taking into account cell relationships.

NB : On the example shown target figures, rather than actual data, has been used to generate the graph.

From figure 2.9, it can be seen that a system of this nature would be a very useful tool in determining departmental maintenance policy with respect to overall factory considerations. However, on a practical level this would require the adoption of a factory wide shop floor data collection system on machine unavailability.

#### 2.4.3 Capacity Implications and Maintenance Planning

With respect to maintenance policy, areas with excess capacity and bottleneck areas have differing needs :

- a) Areas with excess capacity e.g. sealers. When the level of equipment uptime can be guaranteed, due to effective preventive maintenance, it would then be possible to create 'maintenance windows' midweek. This would serve to reduce the amount of preventive maintenance necessary at weekends, with the consequent greater availability of skilled resource for preventive maintenance for areas with critical capacity.

Reducing the total capacity of such a Department would also follow the OPT approach of synchronising the factory to the capacity of the bottleneck. Overall excess production on non-bottleneck areas creates extra work-in-progress, which is contrary to both JIT and OPT philosophies.

- b) Bottleneck areas. As well as providing an input to long term capacity development plans, the chart can highlight the actual and potential bottleneck areas. Preventive maintenance is key in these areas, as downtime will cause lost factory output. Techniques such as design out maintenance (Ref. 84 and 85) and condition monitoring (Ref. 88, 90 and 91) may be appropriate to these areas due to the high cost of failure. Resource released due to the implementation of midweek maintenance windows on non bottleneck areas may be deployed in these areas to help facilitate preventive maintenance requirements.

## 2.5 Future Trends

As manufacturing continues to automate more processes at all stages of production, there is a trend towards the introduction of more intelligent systems - artificial intelligence and expert systems. It is hoped that such investment will boost productivity within the direct production environment (Ref. 89 and 92). In some European organisations, fewer people are engaged in direct production than in support services such as maintenance and quality assurance. This trend along with strong market pressures and highly automated capital intensive industries may well serve to make the maintenance function the key to successful and profitable manufacturing.

In a complex and technical environment such as Philips Durham the success of the maintenance function will be highly dependent upon the effectiveness of its use of information systems. A broad analysis of the plant systems' infrastructure is therefore considered necessary.

## 2.6 Analysis of Information Systems Infrastructure

There is a need in a production environment for obtaining information about the overall performance of a production system (Ref. 29 and 30).

At the highest levels this information should show how well the operating directives set by the business group have been achieved.

At lower levels the production evaluation system should identify areas where improvements are possible.

A model of the hierarchy of information levels, from real time shop floor control to factory planning level, is given in Figure 2.10.

Historically data processing departments have been very active at level 1 whilst the engineering departments have usually concentrated from level 4 downwards.

These 'traditional' areas of activity have tended to produce a 'gap' at levels 2 and 3. This gap is increasingly needing to be filled by systems connecting mainframes to the shop floor, possibly via local area networks i.e. shop floor communication systems. Such systems, supporting CIM philosophies could pass order information directly from mainframes to production departments, signal completion of batches directly to planners, enable the managers to monitor yield and quality etc (Ref. 31).

As previously discussed, to improve the service given by the maintenance function to the production department it is necessary to improve shopfloor data collection of equipment failure information and produce management information for decision making. In terms of the above model a need was identified to bridge the 'gap' in maintenance information from the traditional engineering levels to the factory level.

Figure 2.10 : Information Levels Hierarchy

INFORMATION LEVELS HIERARCHY			
PROCESSING LEVEL	TYPE OF SYSTEM	PERSONNEL INVOLVED	COMPUTING ENVIRONMENT
1) FACTORY	LOGISTICS AND PLANNING	TRADITIONAL D.P. ROLE	MUCH DATA STORAGE RESPONSE IN SECONDS SHARED PROCESSOR MAINFRAMES
2) SHOP	SHOP FLOOR COMMUNICATIONS SYSTEMS	INCREASED INVOLVEMENT REQUIRED	
3) CELL/LINE			MINIS/MICROS
4) WORKSTATION		D.P./ENGINEERING INTERFACE VARYING FROM PROJECT TO PROJECT	
5) AUTOMATION MODULE CONTROL EG ROBOT			
6) DEVICE CONTROL	ENGINEERING SYSTEMS	ENGINEERING DEPARTMENTS	NEGLIGIBLE DATA STORAGE IMMEDIATE RESPONSE DEDICATED PROCESSOR PROGRAMMABLE CONTROLLERS
7) DEVICES EG SENSORS, ACTUATORS			

There are many equipment management systems now on the market (Ref. 45). Consideration of how appropriate such a system would be with respect to maintenance function requirements and plant systems infrastructure was therefore deemed necessary. However, before the requirements of the maintenance function can be determined, it is first necessary to clarify the nature of the department workload and organisational set up to carry out these tasks.

Analysis of the functionality of equipment maintenance packages can then be carried out and this then related to departmental needs and established factory systems.

3.1 The Role of the Maintenance Function

The objective of the maintenance organisation is that of achieving the optimum balance between plant availability and maintenance resource utilisation.

The ideal organisation that an individual plant may take are of many forms, often being determined by systematic consideration of such factors as :

- 1) Maintenance work load and its pattern.
- 2) Amount of emergency work.
- 3) Cost of unavailability.
- 4) Production organisation.
- 5) Maintenance resources.

For example, decentralised repair teams would probably experience a lower utilisation than centralised teams but would be able to respond, in some measure, more quickly and effectively to breakdowns and would therefore achieve a higher plant availability. Unavailability cost is the dominant factor in the design of a maintenance organisation. If this cost is high e.g. bottleneck areas, then the design should aim at effective preventive maintenance of the area and rapid response to breakdowns. If the unavailability cost is not high then the aim should be to achieve high resource utilisation in order to reduce the direct cost of maintenance.

Achieving this optimum balance is therefore key but, due to the complexity of large plant, not necessarily easy to achieve.

Due to the dynamic nature of the typical production environment the maintenance organisation may need to be modified in response to changing requirements. However, as the primary objective of the maintenance organisation is to match resources to workload, it is first necessary to clarify the nature of the workload and its effect upon the maintenance organisation (Ref. 37).

### 3.2 The Workload

The primary division is into corrective and preventive work, further classification being given in Table 3.1.

Table 3.1 : Alternative Maintenance Procedures

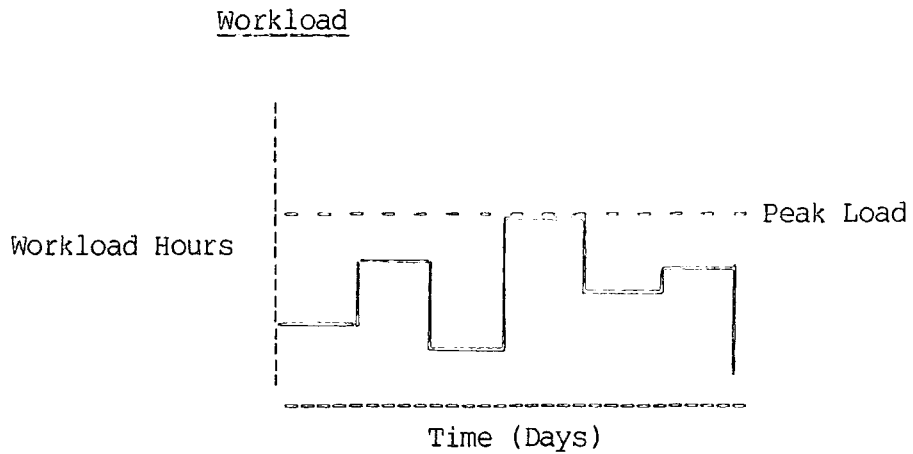
CLASS	TIMING	ACTION
Corrective	Operate to Failure	Replace or repair after failure.
Preventive	Fixed Time Maintenance	Adjust/repair/replace at fixed periods.
* Preventive	Fixed Time Inspection	Inspect via equal or variable inspection periods then adjust/repair/replace on condition.
* Preventive	Continuous Inspection	Inspect on continuous basis then adjust/repair/replace on condition.
Preventive	Opportunity Maintenance	Inspect item at time based on some other items maintenance/inspection period.

\* Further discussion of condition based monitoring is given in Appendix 3.

#### 3.2.1 Corrective Work

For the plant as a whole, corrective jobs occur with almost random incidence, the consequent daily workload varying as illustrated in Figure 3.1.

Figure 3.1 : Fluctuation of Corrective Maintenance



In the absence of condition monitoring, scheduling cannot be carried out until the work demanding event has already occurred. Part of the corrective load, the emergency work, occurs with little or no warning and requires urgent attention.

The remainder, the deferred work, is of varying degrees of urgency and can be scheduled accordingly, often being used to smooth the emergency work load. Emergency work and other high priority low warning work is difficult to plan for. At best only the average incidence can be forecast, individual jobs demanding attention during the shift in which they occur. With a large percentage of high priority work, difficulty therefore arises in the scheduling and planning of such work - if a timescale of less than a shift is available then planning must be carried out at the location of the job since it is not feasible to direct it through a centralised planning function.

Corrective action can be sub divided, according to priority, as follows :

- 1) Emergency work - high priority, on line.
- 2) Deferred work - lower order priority, off line.
- 3) Removed item work - reconditioning.

The use of condition based maintenance can result in a shift in the workload from emergency to deferred work.

This model closely fits with the present scenario at Philips Components - there is a large amount of urgent or deferred corrective work resulting in preventive work having a lower priority. The majority of tasks undertaken by the craftsmen are in response to a problem on their particular shift and are scheduled for by the Shift Engineer rather than the Engineering Planner.

### 3.2.2 Preventive Work

This can be planned in detail and scheduled in advance with time tolerances for slotting and work smoothing purposes. Such work can be further classified :

- 1) Routine. Frequently required work carried out mainly on line.
- 2) Minor off line - services and other minor work required relatively frequently and normally carried out off line. Work of this nature is often a suitable candidate for being carried out in production windows.
- 3) Major off line - overhauls etc. Work of this nature is normally infrequent and is often carried out during a scheduled shutdown.

### 3.3 Workload Type and the Effect on Maintenance Organisation

Since each type of maintenance work has different characteristics, as illustrated in Figure 3.2, the nature of the maintenance organisation will depend very much on the relative proportions of preventive and corrective work.

Figure 3.2 : Characteristics of the Maintenance Workload

WORK TYPE	PRIORITY	PLANNABILITY	COMMENTS
	HIGH	LOW	
<u>Corrective</u>			
- Emergency			On line work incurring production loss.
- Deferred Work			Off line work, possibly scheduled to a production window.
- Removed Item Work (Reconditioning)			Carried out in specialised workshop or can be used for work smoothing.
<u>Preventive</u>			
- Routines			Mainly on line, carried out as running maintenance.
- Minor Off Line			Possibly carried out in production windows.
- Major Off Line			Often carried out in shut downs.
	HIGH	LOW	

An organisation designed for a workload containing 80% planned work (mainly preventive and modification) would be totally different from that for a workload containing 80% unplanned work (mainly emergency).

The latter presents the most difficult and potentially costly organisation problem. As stated, at Philips Durham the majority of the workload is unplanned, corrective work. However, in a sophisticated plant of this nature the complexity of moving towards a more planned, preventive scenario should not be underestimated. Considerable operating experience is required if the expected level of corrective work consequent upon a given input of preventive work is to be correctly assessed. Due to time lags, the relationship between preventive work and equipment performance is always unclear.

### 3.4 Constituents of the Maintenance Function

When attempting to achieve, the aim of the maintenance organisation in matching resources to the type of workload, it is useful to consider it as being made up of three necessary and inter-related components :

- 1) Resources.
- 2) Organisation.
- 3) Work Planning and Control System.

#### 3.4.1 Resources

Men, Spares and Tools.

With respect to man power an important consideration is the level of multi skilling within the workforce.

In general, the greater the division of work the greater the skill of the individual trades. Many maintenance jobs require inputs from several different skills and this would tend to make high labour utilisation difficult. However, if a workforce holds traditional views with respect to demarcation rules, sensitive management will be required to move away from such status quo.

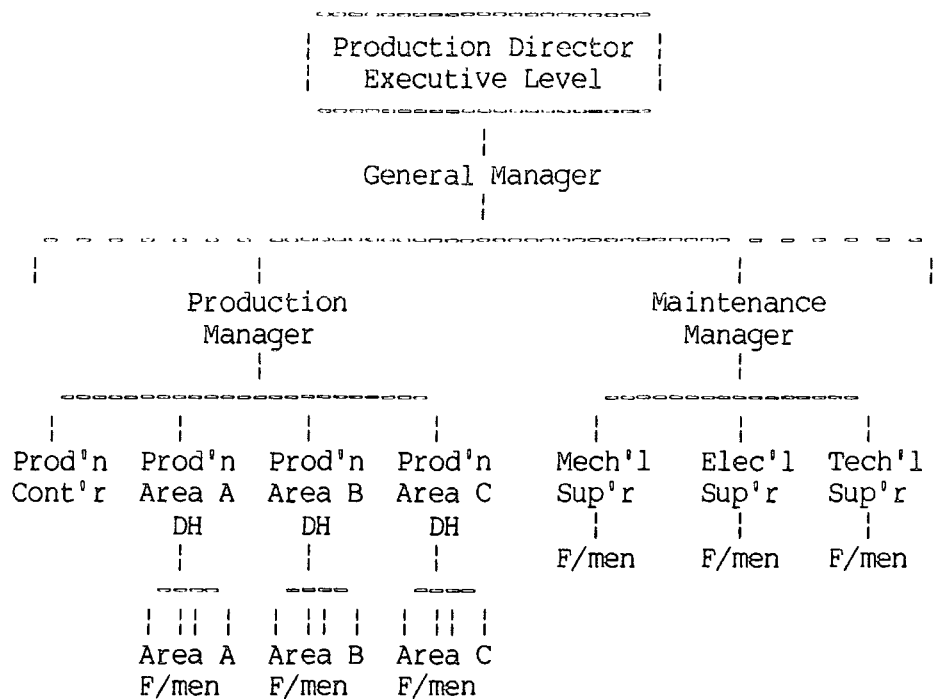
#### 3.4.2 Organisation

A hierarchy of authority and responsibility for deciding what, when and how work should be carried out.

Three organisational issues which must be addressed are :

- i) Centralisation/Decentralisation.
- ii) Reporting Structure.
- iii) Total Productive Maintenance.

Figure 3.3 : 'Traditional' Organisational Structure



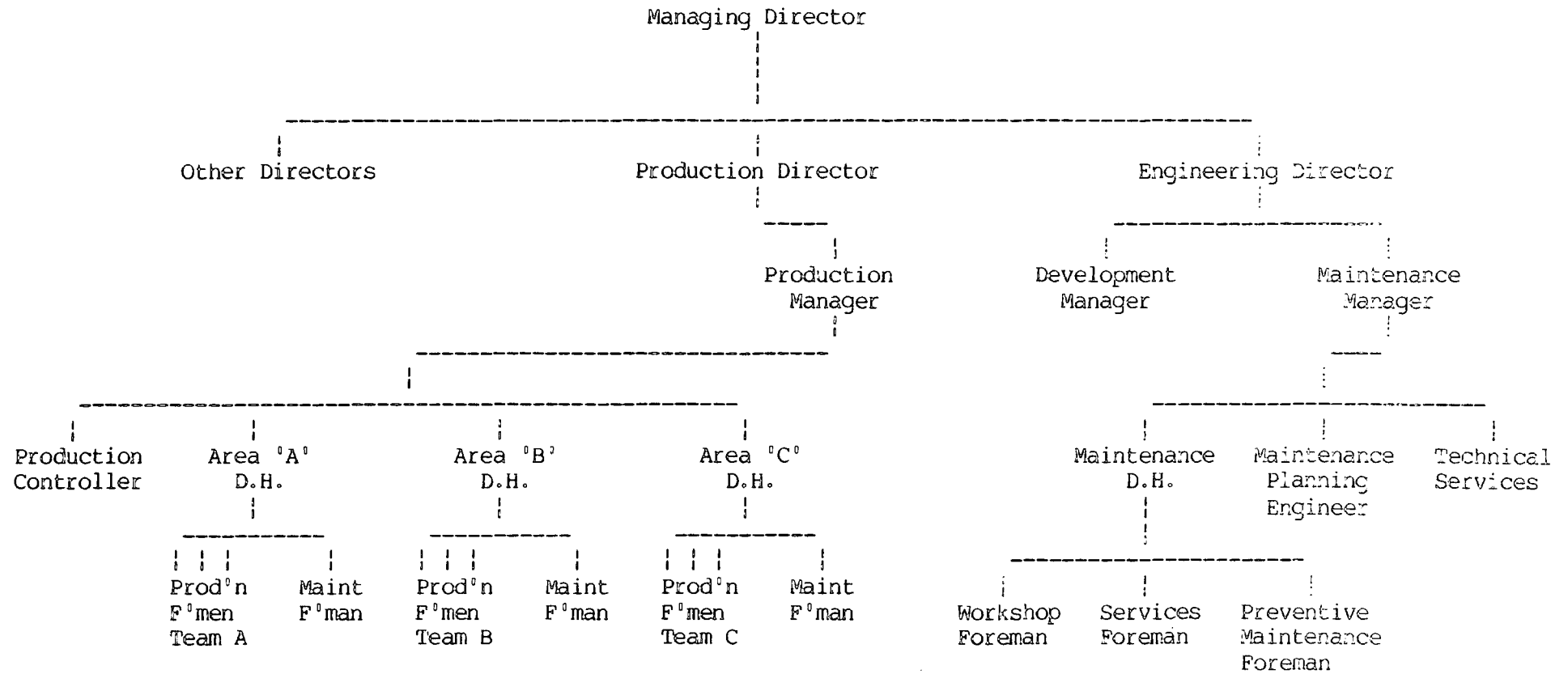
Features of the traditional organisation are typically :

- 1) The maintenance function is not represented at a high level.
- 2) The Maintenance Manager has line authority over his trade force and has the responsibility for determining the maintenance needs of the Plant.
- 3) The Production Manager has line authority over his operatives and has the responsibility for determining the production needs of the Plant.
- 4) The Commercial Manager has the responsibility for spares control.
- 5) The responsibility for maintenance work is further divided by either trade or area.
- 6) The responsibility for production work is divided by area with a separate function for production planning.

FIGURE 2.8: Durham Improvement Objectives

IMPROVEMENT OBJECTIVE (IN "RANKED" ORDER)	MANAGER WITH PRIME RESPONSIBILITY	CRITICAL ELEMENT / PROCESS	PERFORMANCE MEASURE	CURRENT LEVEL	GOAL	
					LEVEL	TIMING
YIELD	LEF	MATERIAL YIELD $Y_M$	%	90	96	END 1990
		DIRECT YIELD $Y_D$	%	53	85	END 1990
		W.I.P. VARIANCE	£			
EQUIPMENT PERFORMANCE	JW	BREAKDOWNS	NUMBER	200	50	
		PROCESS DEVIATION WAIVERS	NUMBER			
PROJECT MANAGEMENT	GS					
CUSTOMER QUALITY	LEF	SETBACK RETURNS	PPM	4500	2000	
		COMPLAINT RATE	%	3	0	
		QUARANTINED AND REWORKED BATCHES	NUMBER PER MONTH	6		
SUPPLIER PERFORMANCE	RLG	LINE REJECTION	PPM			
		DELIVERY PERFORMANCE	EG NUMBER OF LATE DELS			
		DEVIATION FROM MARKET PRICE	£			
DELIVERY PERFORMANCE	RLG	TUBEMAKING DEPT. DELS INTO BFP STOCK	CLIP CUP			
		DELIVERY INTO SUPPLY SECTOR STOCK	CLIP CUP	50	100	
		DELIVERY OUT OF SUPPLY SECTOR STOCK	CLIP CUP	98	100	
		LATE DELIVERIES AT CUSTOMERS	NUMBER	95	100	
LABOUR PRODUCTIVITY	GS	REQUIRED DIRECTS				
		VARIANCE				
		STANDARD HOURS DELIVERED PER OP PER WEEK				

Figure 3.4 : 'Progressive' Maintenance Organisation



Difficulties arise from this structure due to the division of responsibility for the plant. This results in numerous collateral relationships, committees and communication systems being used for maintenance decision making.

The more fundamental problem with an organisation of this nature is the division of responsibility for the plant operation between Production Management and Maintenance Management. Although officially Maintenance Management is responsible, after consultation with production, for the maintenance of the plant, what tends to happen in practice is that Maintenance dictates what is done, and Production dictates when. Therefore, unless there are excellent communications, considerable friction is generated. This is particularly so in a large organisation.

#### Progressive

A more progressive maintenance organisation is illustrated in Figure 3.4.

Features of a more progressive maintenance organisation are :

- 1) High level representation of the maintenance function. Where maintenance costs are a significant part of the cost of production as in a continuously operating process plant, high level representation of the maintenance function ensures that Maintenance is properly considered alongside Production when making operating decisions and when contemplating the procurement of new or replacement plant.
- 2) Improved production maintenance working relationship. Having smaller integrated groups e.g. Team 'A' with one clear reporting line and focussed responsibility helps avoid friction and encourages team spirit.

- 3) Maintenance personnel within the team deal with daily operational production problems. Responsibility for operation and maintenance is taken by the immediate Production Department Head and upwards through the Production Manager etc.
- 4) The Maintenance Department tends to provide additional maintenance assistance or technical help when required by Production. A major part of their activity is to facilitate the deferred work from breakdowns, and to provide effective preventive maintenance cover for the plant.
- 5) There is a rationalisation of the number of functions the Maintenance Manager/Department Head is expected to carry out but for which he does not necessarily have the authority to implement e.g. Production denying access to machinery for preventive maintenance purposes resulting in over budget downtime.

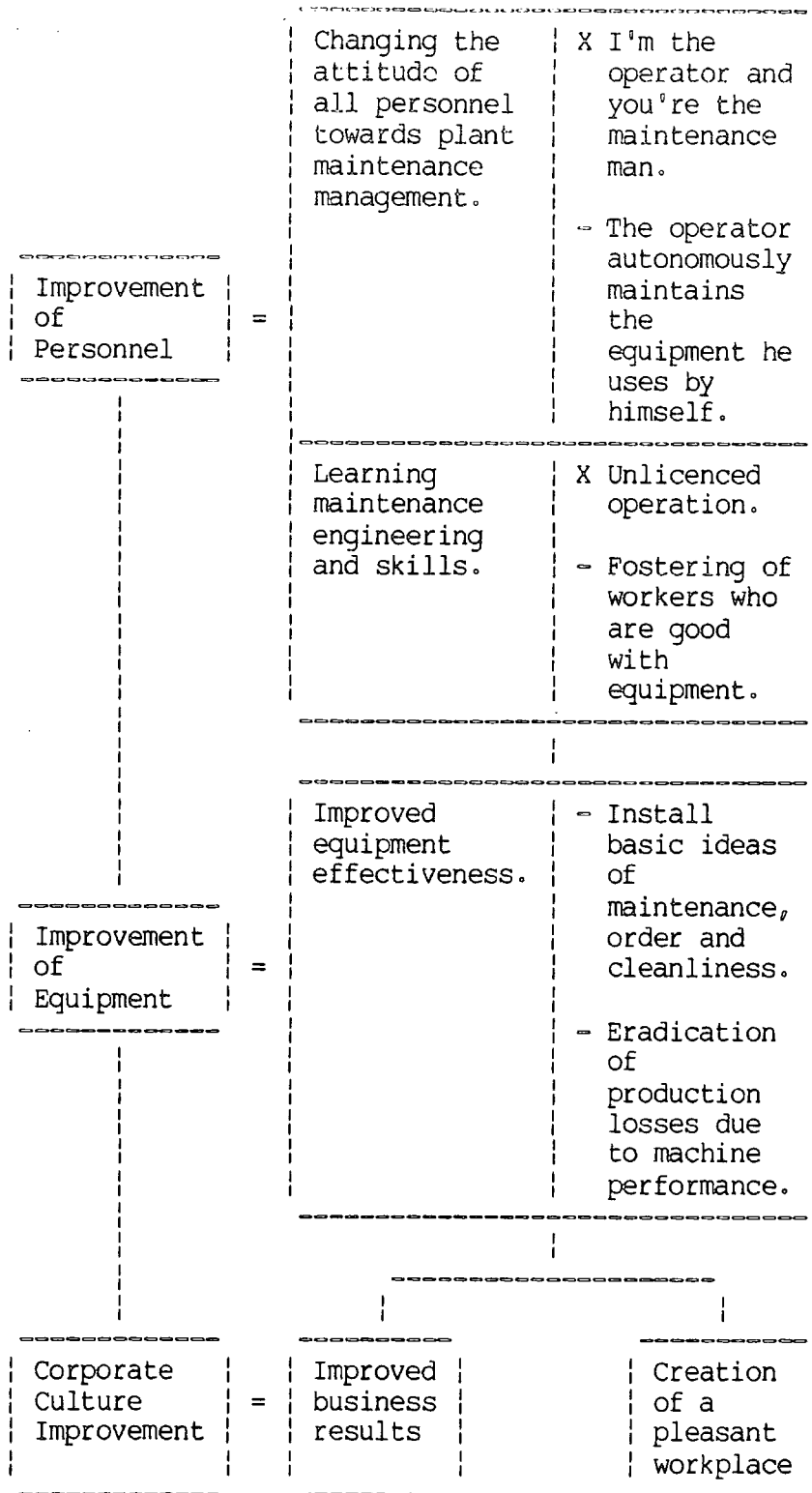
However, a potential danger of this type of organisation is that production pressure on the maintenance team member may result in the abuse of the plant to achieve short term production objectives.

iii) Total Productive Maintenance - TPM

Consideration of TPM may impact on the maintenance organisation structure in that this theory promotes that maintenance should be carried out by production rather than maintenance personnel.

TPM is a methodology developed by the Japanese company, Nippondenso, in 1969 (Ref. 39 and 40). It evolved from their systematic maintenance improvement strategy started in the early 1950's, with the introduction of preventive maintenance. TPM was initiated for the following reason : Nippondenso had

Figure 3.5 : The Basic Concepts of TPM



i) Centralisation/Decentralisation

A fundamental organisational decision for a maintenance function is the location of men, spares and tools. For any given situation there are numerous possibilities, the basic aim being to determine for each trade the arrangements which results in a reasonable balance between downtime costs and labour utilisation. Major considerations are the distribution, content, size of the workload and cost of plant unavailability. A centralised workforce tends to have a higher utilisation than a decentralised one. However, decentralisation makes for a more rapid response and localised expertise amongst Craftsmen. Decentralisation can also lead to a greater individual identification with the aims of the Maintenance Department (Ref. 34 and 38).

ii) Reporting Structure

An administration can be considered as a decision making system the aim of which is to direct available resources towards the achievement of the organisational objective.

Obviously the reporting structures within different organisations differ greatly, however two distinct and different types of reporting structure appear common in modern organisations. For the purpose of comparison they shall be called 'traditional' and 'progressive'.

Traditional

A traditional organisational structure is illustrated in Figure 3.3.

actively promoted the automation of its production facilities but as a result the maintenance of the automated equipment had become a new problem. The conventional maintenance crews could not maintain the greatly increased number of automated facilities so it was decided that the individual operator of the automated equipment would be made responsible for its routine maintenance.

The basic aim of TPM is to improve the company by improving the attitude and skills of all personnel, from top management down to shop floor workers and by improving the equipment through improving those responsible for it. A summary diagram is given in Figure 3.5.

#### 3.4.3 Work Planning and Control

The third and integral part of a maintenance organisation is the work planning and maintenance control system. The work planning system must control the 'dynamics' of maintenance - ensure that the right resources are in the right place at the right time.

For a work planning system to successfully operate, the following are pre requisites :

- 1) The right information about the work load and resources must be available to the planner at the right time.
- 2) The work planner must have the authority, or access to it, to take the decision about allocation of priorities.

The priority of work determines the level at which its initial planning takes place; the higher the priority the lower the initial planning level e.g. emergency corrective maintenance is dealt with directly by the Shift Engineer.

The plannable, low priority, work can start at a high planning level and move down the planning levels for assignment e.g. inspection maintenance is organised by the Engineering Planner with discrete jobs being allocated to the Shift Engineer.

The amount of decentralisation in a workforce is also a significant factor when designing the work planning system - decentralisation obviously results in less control from a central planning body. If there is a high degree of autonomy in the decentralised units then it may be worth considering removing all central planning activity and placing all responsibility for work planning with the individual unit. In less definite cases partially decentralised work planning may be more appropriate e.g. emergency corrective work and deferred work is the responsibility of the unit but long term preventive work is organised by a central planning function.

Major considerations with respect to establishing an effective work planning system are therefore the percentage level of corrective work and the amount of decentralisation in the workforce.

In general, where there is a high level of corrective maintenance and the workforce is decentralised, it is advisable to have corresponding levels of decentralised work planning.

### 3.5 Analysis of three Maintenance Organisations

With respect to the above criteria, 3 maintenance organisations have been analysed to determine their strengths, weaknesses and to determine possible problems when altering a maintenance organisation to support modern manufacturing strategies :

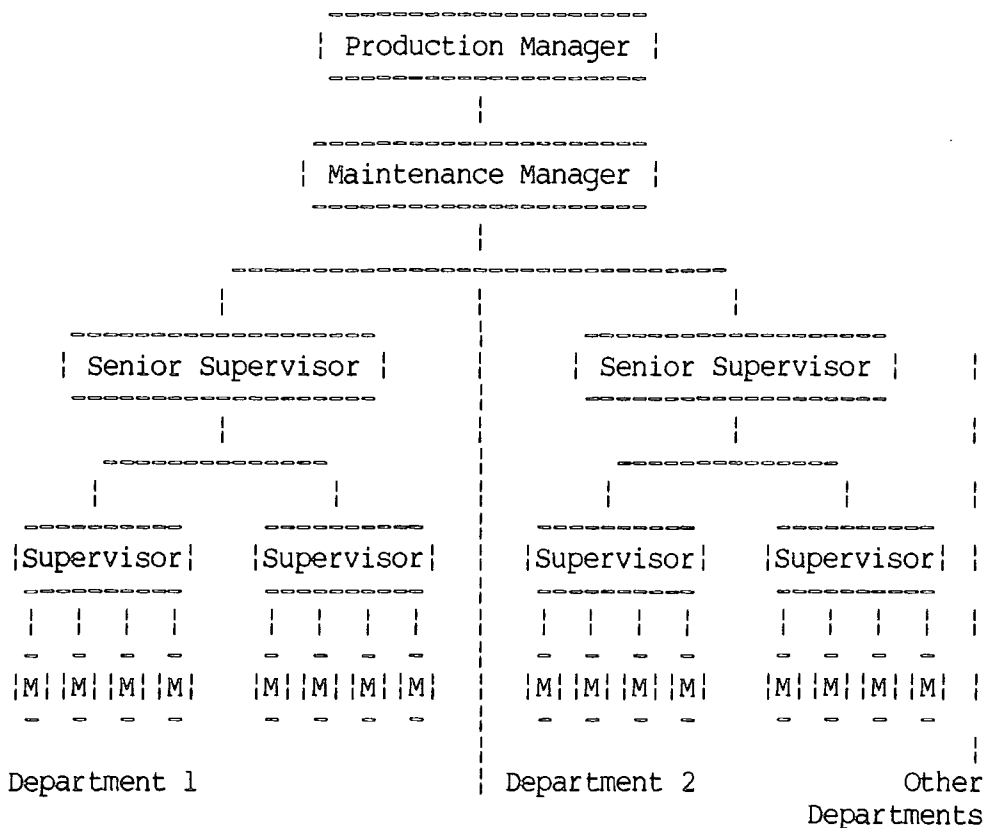
- 1) Nissan - Sunderland.
- 2) Philips Hamilton.
- 3) Philips Durham.

3.5.1 Nissan · Sunderland

The Nissan car plant is a modern, highly automated factory built on a greenfield site with a major expansion of the plant now being implemented. The workforce is young, the average age in the company is 32 and there is a strong team ethic throughout all functions in the factory.

The reporting structure of the Maintenance Department is roughly as shown in Figure 3.6. The workforce is decentralised and overall report through the production function.

Figure 3.6 : Nissan Car Plant : Structure of the Maintenance Department



As stated, a problem of decentralisation is possible low utilisation of craftsmen time. This effect has been somewhat negated by the following :

- 1) Multiskilling -- The factory was built on a greenfield site and this has facilitated management introducing flexible working practices. All Maintenance Engineers are classed as multi skilled, fitters are trained in electrical and electronic skills and vice versa. When a problem occurs whether mechanical, electrical or electronic, any of the multi skilled engineers for that specific area can be called upon to deal with it.
  
- 2) High percentage of Preventive Maintenance. A high level of plannable work obviously helps to increase the utilisation of the craftsmen. Nissan use a computerised system to control their preventive maintenance work planning. This has proved to be an important tool in facilitating the operation of the Maintenance Department.

Nissan also operate Total Productive Maintenance (TPM). The first level of inspection maintenance is done by production personnel on a formal basis. Supervision audits maintenance checks on a random basis.

### 3.5.2 Philips Hamilton

Philips Hamilton is one of the European factories of the Philips Lighting Group, involved in the mass production of electric light bulbs. At the time of investigation, December 1987, the following conclusions were drawn :

The Maintenance Department is organised along traditional lines. The reporting structure is from craftsman through Engineering Supervision to Engineering Manager. There is a very high percentage of corrective maintenance in the workload, most of the craftsmen's time is spent in fire fighting situations and breakdowns are compounded by the lack of appropriate spare parts.

The workforce is single skilled. Traditional attitudes prevail amongst the craftsmen and there is no allocation of craftsmen to specific process areas.

To attempt to address these problems and improve the maintenance work planning procedures a computerised preventive maintenance package has been implemented (Ref. 53).

The system was justified with respect to the following criteria :

- 1) Reduction in plant downtime - to within budgetted level.
- 2) Minimise maintenance costs - through effective planning.
- 3) Reduction in level of Engineering Stores Stock.

However, although having a centralised structure which would be suited to a work planning system of this nature, the following implementation problems arose :

1) Maintenance - Production Conflict

The Production Department would not allow the Maintenance Department 'maintenance windows', in which to carry out preventive maintenance work during weekly run time. At the time of this visit, the situation was further compounded by a weekend work ban in the factory. Therefore, for logistic reasons, work required as predicted by the system, could not be carried out.

Obviously a common reporting structure would have had a very positive effect with respect to this problem.

2) Traditional shop Floor Attitudes

The maintenance craftsmen would not collect information on work done. There is suspicion about what the information is to be used for i.e. man management control rather than task planning and asset management.

Without shop floor data collection , a planned maintenance system cannot function.

Organisationally, the Stores Manager, who is the system administrator, is not positioned to be able to address this problem.

NB : Follow up information : The problem of shop floor data collection has been addressed via discussions with local union representation. It is realised that communication with the craftsmen is necessary, if their concern over the intended use of this information is to allayed.

Overall, shop floor attitudes and organisational issues must be addressed before the computerised system becomes an important tool in facilitating the effective maintenance of equipment at Philips Hamilton.

### 3.5.3 Philips Durham

The organisation of the maintenance function is essentially a centralised one. The department consists of approximately 55 people, the craftsmen of which are single skilled and in general have traditional attitudes to their job functions. Although there is no official allocation of craftsmen to process areas, especially in the case of complex parts of the plant, some selectivity takes place.

The profile of trades within the department is approximately :

Mechanical	: 40%
Electrical	: 20%
Technician	: 25%
Semi-skilled	: 15%

There is a high percentage of urgent corrective work which is dealt with initially by the appropriate Shift Engineer, who organises craft resource as required. Deferred work, often resulting from a breakdown may also be dealt with by the day shift craftsmen.

If there was a move to decentralise the department, account must be taken of the following factors :

1) Number of Craftsmen

If the factory was decentralised into, say six areas, as shown in Table 3.8, then there would be a problem of adequately resourcing each area with a complete range of craft skills across each of the 3 shifts.

Table 3.8 : Possible Maintenance Areas

MAINTENANCE AREAS	TRADES LIKELY REQUIRED
1 - Precoat, Flowcoat & Frit Apply	M, E, T
2 - Lacquer, Aluminising & Bismuth	M, E, T
3 - Frit Lehrs, Sealers	M, E, T, SS
4 - ILE's, Reinforcing, Ageing	M, E, T
5 - AMH, APM	T, E
6 - Matching	T, E

M = Mechanical (22 Persons)  
 E = Electrical (10 Persons)  
 T = Technician (15 Persons)  
 SS = Semi Skilled (08 Persons)

Assuming day shift craftsmen were absorbed into shift organisation - results in the following labour resource being available on average per shift per area :

Mechanical : 1.8 (4 areas)  
 Electrical : 0.5 (6 areas)  
 Technician : 0.8 (6 areas)

---  
 3.1  
 ===

Electrical and technician skills at present level of manning could not therefore be guaranteed across the factory even assuming no day shift workshop resources are required.

A possible way of resolving this problem would be to opt for a multi skilling policy - however, the major transition required from mechanical to electrical and technician is not likely to be quickly achieved, especially given the complex nature of some parts of the plant (Ref. 41).

## 2) Nature of the Workload

As stated the present workload is one with a high percentage of corrective and deferred work.

To make effective use of a decentralised workforce and achieve high utilisation requires a significant proportion of plannable preventive work. It is likely that a high degree of decentralisation at Philips Durham would result in low utilisation of craftsmen, except during breakdown situations when there may be insufficient or incorrect resource available to deal with the incident.

For the above reasons it is therefore felt necessary to retain a somewhat centralised maintenance function at Philips Durham.

Recent organisation changes have resulted in partial decentralisation of the Maintenance Department - technicians have been assigned specifically to the AMH/APM areas. This solution is deemed to be an appropriate compromise between the 'pro's' and 'con's' of whether a maintenance organisation is centralised or decentralised. The only trades decentralised are those dealing with

emergency high cost outages, whilst other trades and functional groups remain centralised. This situation should be reviewed if the APM/AMH areas loose their bottleneck status.

#### Reporting Structure

The reporting structure of the Maintenance Department at present follows 'traditional' lines as previously described.

This has augmented underlying conflict between the Maintenance and Production Departments.

The Maintenance Department is held accountable for the number of incidents and production hours lost due to machine breakdowns. The production function is held responsible for meeting production targets and must account for all production losses - breakdowns being one possible cause. This has led to problems in the accurate reporting of equipment failure and also to what is defined as 'breakdown'. The production definition is that it is the time lost from a machine breaking down to the restart of good production, the maintenance definition is that it is the time that maintenance personnel are in attendance. At times, maintenance suspect production use machine breakdowns to account for product losses which may be due to more production orientated problems.

The proposed organisational changes to a more 'progressive' reporting structure will address the fundamental problems of the above problem. The creation of Integrated Manufacturing Teams (IMT's), with all associated personnel reporting to one Production Manager and one Production Engineering Manager responsible for the overall performance of the production area, will dramatically minimise the above conflict.

All relevant personnel will be in daily contact with each other and report to the same superior. It is therefore likely that conflict and reporting discrepancies will reduce.

A further potential benefit of this partial decentralisation is the increased feasibility of more flexible maintenance practices. The underlying philosophies of TPM may be well served by such an arrangement - realised by the implementation of the multi functional worker concept.

CHAPTER 4 : GENERAL FUNCTIONALITY OF SOFTWARE PACKAGES AVAILABLE

The maintenance management objective is to provide production with the plant availability to achieve the long and short term output at minimum resource cost subject to satisfactory levels of plant condition and safety.

Factors to be considered in the maintenance activity are resource availability, downtime/lost production, plant and equipment life and safety.

The overall functionality of a maintenance management software package must be to support these functions (Ref. 49, 51, 52, 58 and 59) through the basic areas of :

- a) Monitoring the state of the plant.
- b) Planning and controlling use of manpower to deal most effectively with the maintenance tasks required.
- c) Ensuring the availability of components so that required work can be carried out.
- d) Controlling costs.
- e) Reporting on the above.

4.1 Structure Overview

The structure of a maintenance management system may be simplified by considering the total requirements to be composed of modules linked together, each module having a definable function (Ref. 60). A structure overview diagram is given in Figure 4.1.

Figure 4.1 : Maintenance Packages : Structure Overview

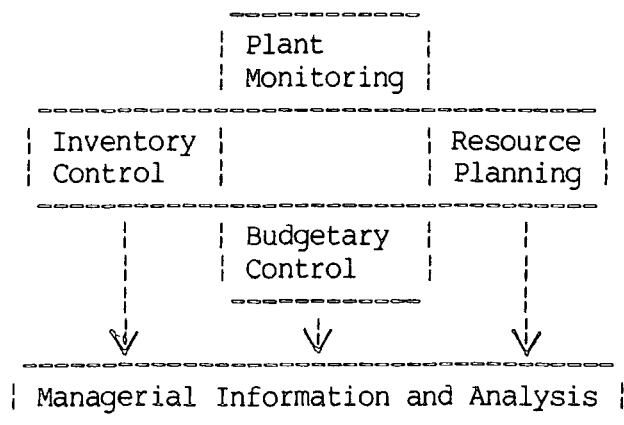
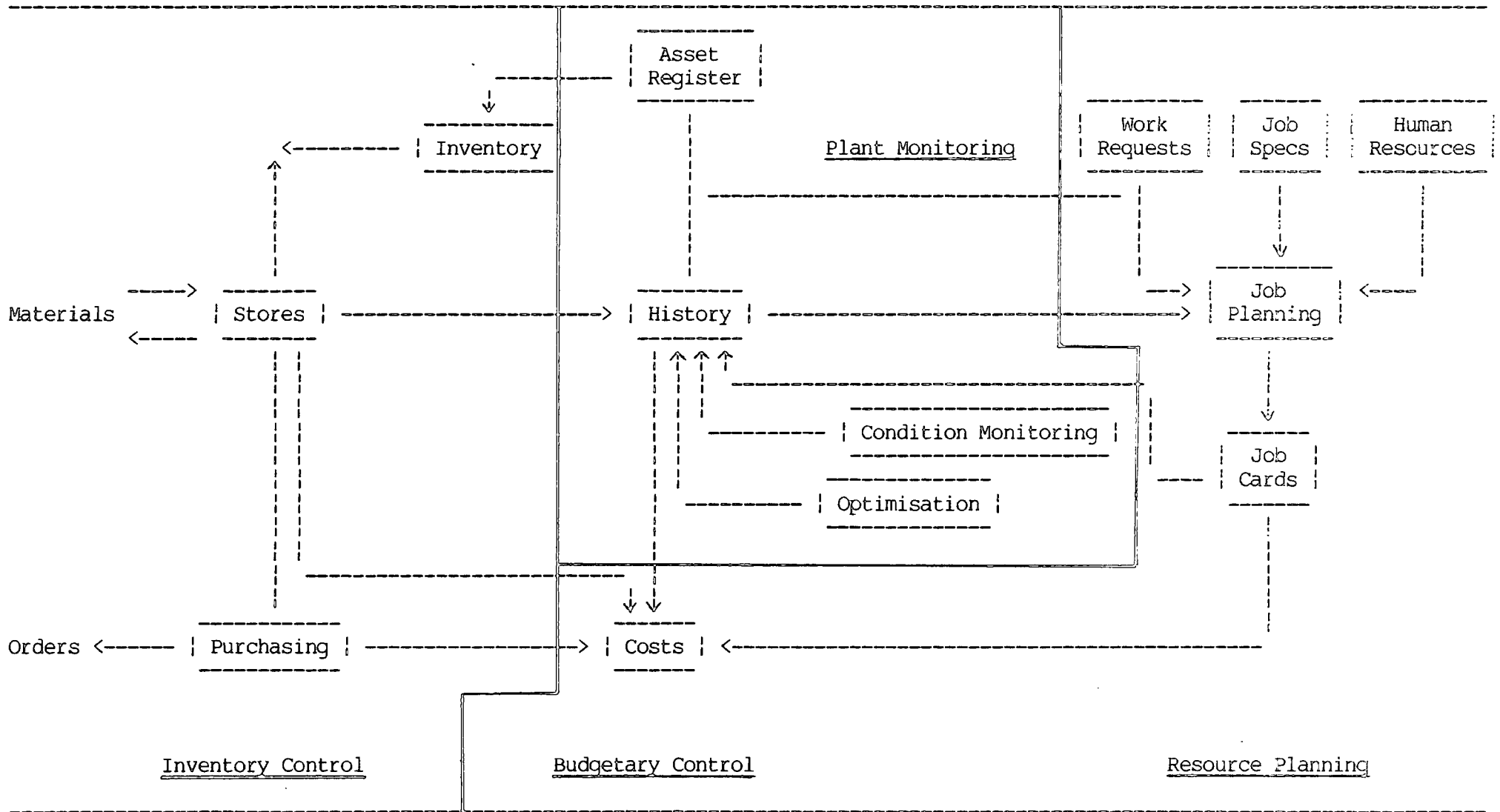


Figure 4.2 : Modules of a Maintenance Management System



As shown, the hub of such a system is the plant monitoring modules which include an asset register and asset history file. These contain all the data applicable to a particular item of plant e.g. a description, location, technical details and a history of the performance of the piece of equipment along with details of work carried out on it.

Surrounding the hub are the maintenance control aspects : inventory control of maintenance spares and consumables, work planning, and maintenance cost control. From this structure managerial reports and analysis can be obtained to give feedback on the overall performance of the plant.

A more detailed breakdown of these modules is given in Figure 4.2.

Using a computerised package, data is transmitted between the modules according to the line of communication and procedures defined by the user. Although no two organisations undertake the same maintenance procedures in an identical manner, it is possible by analysing common objectives, to identify a list of tasks which are applicable to the majority of users with provision for expansion to meet special needs.

The functionality of software in the four main areas will now be discussed in further detail :

- a) Plant Monitoring.
- b) Resource Planning.
- c) Inventory Control.
- d) Budgetary Control.

#### 4.2 Plant Monitoring

Four modules to be discussed further are :

- 1) Asset Register.
- 2) Plant History.
- 3) Condition Monitoring.
- 4) Optimisation.

## 1) Asset Register

The asset register module should include all the necessary technical information which is associated with the physical asset registered against a description, area or plant numbering system (Ref. 48).

Typical information would be key field (asset number/plant item number), identifier (model number, serial number, special facilities), manufacturer, procurement and operational costs and recommended method of inservice support (including the trades associated with this support), safety precautions appropriate to the technical specification and commonality of units/spares. Links to the stores catalogue and repetitive job specifications would provide further information.

A sub module which lists preventive maintenance details can be linked to the asset database by the key field. This would then give all the tasks which are normally scheduled for each item of plant, with the possibility of edit facilities if required. Parameters stored in a preventive maintenance module could be : asset number, last date work carried out, next date work scheduled, description, estimated work hours, spares requirements and drawing number, references.

## 2) Plant History

This is a record of all work and total costs of work carried out on each identifiable asset. It may contain information similar to that provided on completed job cards including, for example, a tradesman's comments on the condition of the plant items and problems encountered and whether preventive or corrective maintenance has been carried out. Fault and cause analysis is also possible depending on the data collection system. A type of fault may be recorded and analysed for a number of items of equivalent use, or of the same manufacturer and design, and the fault and cause codes entered onto the plant history file. Downtime analysis is also possible if data is collected on the frequency and length of downtime and the repair for a job. This

facilitates calculation of the aggregate downtime, number of breakdowns, average duration of breakdowns and statistics such as the fault rate, mean time to repair, mean time between failures and downtime percentage. Different forms of presentation for this type of information is normally available - possibly in order of performance for equipment in a group, or averaged for comparison with other similar equipment over varying durations of time. Automatic monitoring of run time may allow measurement and comparison between budgetted and actual life for pieces of plant.

### 3) Condition Monitoring

A condition monitoring module would deal with the output from sensors in the plant monitoring a parameter such as temperature, noise or vibration. Data would be analysed to produce trends and graphs, monitoring the condition of the plant according to signals transmitted from the sensors.

Typical functionality would be :

- Graphical output of different parameters over a set timespan.
- Highlight equipment which is showing an increase in the number of faults occurring within the specified timespan i.e. equipment is wearing out.
- Predict the time to failure based on previous experience by following a deviation from the norm.

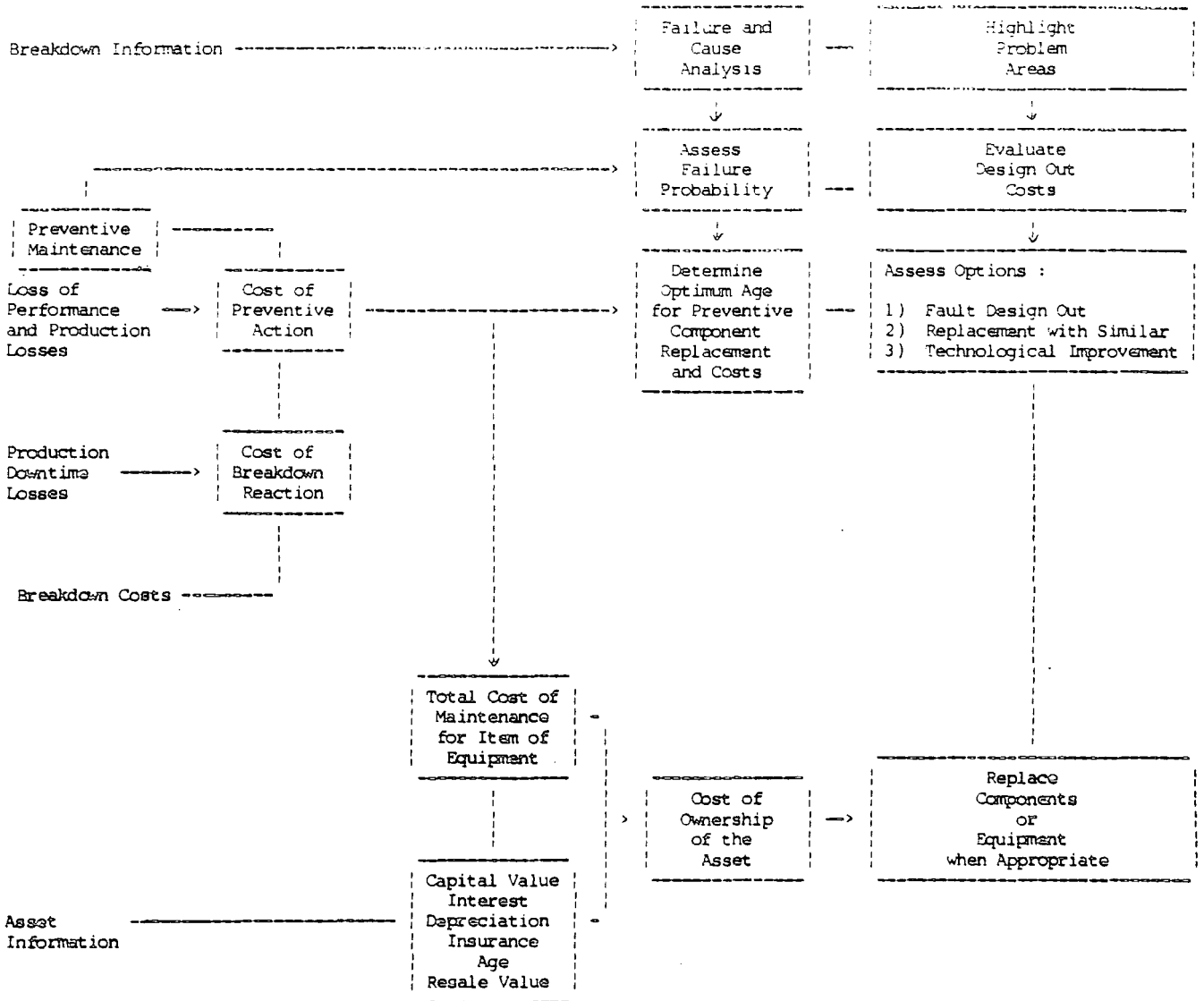
Condition monitoring facilitates reporting by exception and allows definite future failures to be actioned before failure occurs.

Further details of condition monitoring techniques are given in Appendix 3.

### 4) Optimisation

To help minimise the overall cost of the maintenance function to the organisation, an optimisation module would essentially manipulate data on :

Figure 4.3 : Functionality of Optimisation Module



- Repair on breakdown.
- Pre-determined maintenance.
- Condition monitoring.
- Replacement of plant.

The method used to address the manipulation of data concerned with these activities depends heavily on the philosophy of the maintenance management. However, computerised optimisation can greatly assist in determining the correct mix of these activities. The functionality of such a package is likely to include facilities such as the following :

- How a predetermined maintenance routine affects the probability of failure.
- Whether failure may be attributed to an isolated problem or has various causes.
- Whether the possibility of a critical failure occurring could be diagnosed by condition monitoring.
- Whether the failure should be pre-empted by preventive maintenance or dealt with as corrective maintenance.
- Optimum age replacement policy.

The data involved in providing this information includes that previously described for failure analysis, preventive maintenance, condition monitoring and also life cycle costing. Obviously the above facilities would need accurate data collection to be carried out at component level.

A module of this nature is likely to use standard maintenance techniques as illustrated in Figure 4.3.

Obviously, the technical details of any individual package must be carefully assessed to determine which, if any, of the above functions would be viable for the application being considered.

#### 4.3 Resource Planning

The resource planning modules assist the systematic control of the maintenance work within a factory, so that jobs, labour and materials may be co-ordinated at the workface in a planned and prepared manner.

The general sequence of work and resource planning cycle is :

- 1) Work request.
- 2) Authorisation and prioritisation.
- 3) Planning - labour allocation.
- 4) Scheduling.
- 5) Control and job completion.
- 6) Plant shutdown scheduling.

1) Work Request

Any newly identified work, be it of a corrective or preventive nature, requires some preparatory definition as a job or sub-division into jobs and possibly the allocation of cost codes etc.

Requests for work may be input into the system via a formatted screen. Planned preventive work would be automatically generated by the system.

2) Authorisation and Prioritisation

Planned preventive work would not require authorisation.

All work order requests could have a reference to the asset register and could be listed according to area and location till authorised and prioritised by the appropriate personnel.

On authorisation the job may proceed to a data entry facility which would possibly allow interrogation of other modules to provide further details such as costing information, plant history, drawing numbers etc. Interfacing to the stores modules may also take place in order to specify the spares and materials required.

### 3) Planning

Following authorisation and prioritisation, job requests along with planned maintenance work would then need to be planned in against trades and time required for the job. The system would review the projected labour availability for the weeks ahead and compare with the workload for major and supportive services. Job time estimation may be assisted by interrogation of the asset register to obtain standard job times.

### 4) Scheduling

The system is then ready to schedule and plan the lists of jobs and print the work programmes and job cards. All job cards with time estimates might be listed as follows :

- By trade/location/machine or plant item in order of priority.
- By trade/category of work in order of priority.
- By planned and unplanned status.

The availability and cost of the specified spare parts and materials required may be interrogated via communication with the Stores Modules with the possibility of pre-requisitioning items against the works order number/job number.

Plant availability status may be input against machine/plant number or location, allowing current status to be incorporated into the scheduling process.

Various outputs, including graphical, are normally available typically giving summaries of the estimated work hours for each week by trade, location and category of work, for comparison with the listed available hours.

By communication with the Budgetary and Costing Module, the estimated job cost can be calculated automatically and listed with the estimated cost of materials against the job number.

#### 5) Control and Job Completion

A suggested schedule of jobs may be presented at a small time in advance of commencement, detailing the major parameters of the work to be carried out. This list could be reviewed by the appropriate personnel to give final authorisation or alter where necessary.

The authorised schedule relating to each trade could be displayed showing week numbers, location, trade and job description. The estimated job time may either be displayed or maintained within the system. On completion of a job the following type of information may be entered from the job card : personnel number, time on job, work done, failure code, amount of production lost, suggestions for further work.

As part of the control mechanism the system may report backlog of work with possible automatic re-scheduling.

#### 6) Plant Shutdown Scheduling

Plant shutdown maintenance may be planned, costed, scheduled and controlled by the use of critical path network analysis. Bar charts for all areas and departments, and tables and histograms may be produced to assist in the analysis of resource usage and provide the basis of cost information.

### 4.4 Inventory Control

Interfaces to inventory control are required by a maintenance management system so that :

- 1) The availability of parts, for both corrective and predictive works can be assessed and consideration of this fact made when scheduling work.
- 2) Costing information can be updated on withdrawal of a part against a job number.

- 3) The accuracy of the stores ordering policy can be maintained/improved with respect to the current plant situation.

An inventory control system may be thought of as being made up of a stores control system and a purchasing system. A stores control system is likely to contain the following sub modules :

- 1) Stores catalogue.
- 2) Stock transaction.
- 3) Stock issues.
- 4) Stock receipt.
- 5) Stock balance.
- 6) Stock adjustments.
- 7) Cost and value information.

- 1) Stores Catalogue

The stores catalogue holds a record of all the items held in the stores. It may also contain machine pointers detailing all the spares held against a certain item of plant. It would also retain the details of re-order levels, maximum stock levels, location of item and costs. Access to these records should be possible using different search fields e.g. plant number, location etc.

A useful facility would be the correlation of stock held to preventive work planned.

- 2) Stock Transaction

Issues and receipts could be entered, edited, authorised and stock balances verified as they occur.

- 3) Stock Issues

Information relating to the issue of stock detailing each issue transacted and periodically calculating the movements of spares and the summated costs is a fundamental part of stock control system.

Operationally, the stock requisition would be presented at the issue desk, checked by a storeman and the goods issued.

Items may be issued as part of a planned requisition for project and planned maintenance work. A pre-requisition stores could be set up on the system as a separate stores location. This facility would enable transactions to be separately identified and pre-requisition stock monitored.

The information required for a stock issue might typically be as follows :

- Item identification.
- Number of units, checked against the average issue quantity.
- Unit of measure.
- Requisition number, can be allocated by the storeman, generated by the system or as pre-printed on the requisition pad.
- Stores location.
- Job number.

Various reports should be available for control and also for assisting in deciding the future stock holding requirements. Typically these may be number of issues per item, slowing moving items, average weekly issue per item, average issue quantity per requisition and issues costed by value for budget and cost control purposes.

#### 4) Stock Receipt

Stock receipts would normally be processed by entering details of the delivery into the system which would then automatically update both the purchase order file and the stock balances.

On booking in the system could check the identity and validity of the receipt and detail the bin number for the item. Items received could be reported, and the report become the authority for subsequent payment against the invoice.

The information required to be entered for a stock receipt may typically be as follows :

- Purchase order number, possibly including job number.
- Item identification code.
- Number of units.
- Unit of measure.
- Transaction date.
- Goods receipt note number.

#### 5) Stock Balance

The input of data from the requisition form and the goods received note would allow the stockholding of each item in the stores to be updated. The balance of stock held, the date of the last stock check, lead time and other information associated with the bin/stock card could be recorded as a stock status listing.

Reports showing items with a stock balance either :

- 1) Below the re-order level
- 2) Likely to reach the re-order level within a pre-defined timespan

could be produced automatically on a regular basis.

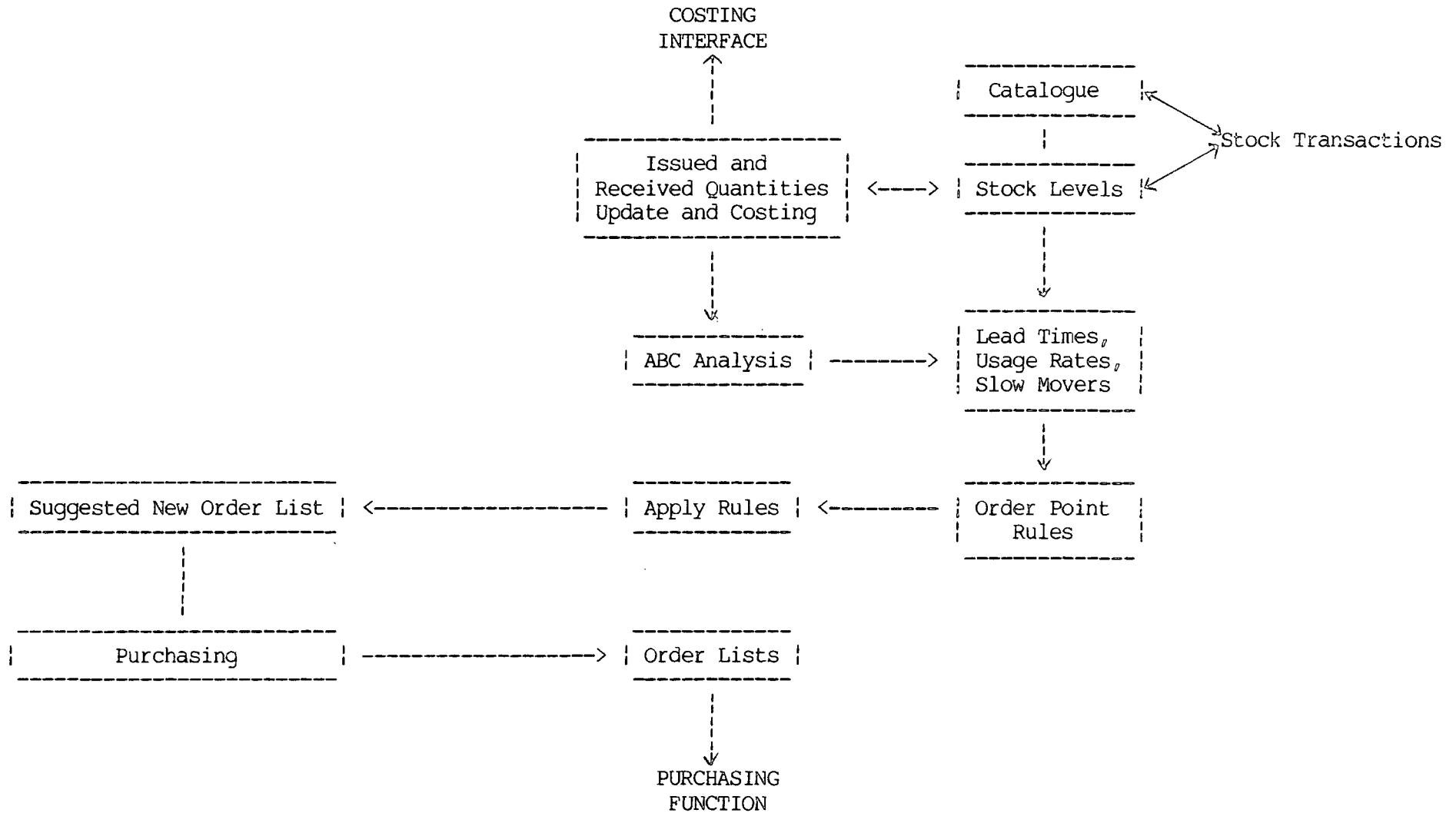
#### 6) Stock Adjustments

There are likely to be occasions when the stock balances within the system may require adjusting as a result of change of location, stock transfer etc. This need should be reflected in the functionality of the software.

##### 1) Stock Check Adjustments

As well as updating a stock balance this facility may need to update the last stock check date on the stock item file.

Figure 4.4 : Stores/Purchasing Modules



## 2) Stock Checking

The system may advise on what items should be checked, allow reconciliation and enable discrepancies to be investigated.

## 3) Timing of Physical Stock Check

If cycle counting is used, a cycle time and date of last stock check may be entered against each item on the stock item file. The system may then identify those items which require checking and list them periodically on a stock check report. Those items which require careful monitoring could be given a shorter cycle time than those which have low usage. The categorisation of items can be aided by producing a valued 'ABC Analysis' and implementation of the pareto 80/20 trend.

The interactions between the various store modules are shown in Figure 4.4.

An ABC classification report may be requested at any time. Likely parameters to be included are usage with respect to differing parameters and timebases, high value items or other customer specific criteria.

## 7) Cost and Value Information

The cost of issues against department, plant item, spare part or stores location are typical reports that may be required. The facility to carry out standard price adjustment may be a requirement, with summary printouts of the old and new stock values and the value variance.

The purchasing operations are intrinsically linked to the stores functions and can be thought of as being made up of the following sub modules :

- 1) Purchase order requirements.
- 2) Recording.

- 3) Progressing.
- 4) Reporting.
- 5) History.

- 1) Purchase Order Requirements

This sub module would highlight which items need to be purchased to overcome an expected rundown, and produce a new order or re-scheduling report. The new order report could include information such as the following :

- Item number and name.
- Required date.
- Required quantity.
- Supplier number and name.
- Order cost.
- Purchase order lead time.

- 2) Purchase Order Recording

Following receipt of purchase order requirements from the stores, a planned purchase order could be recorded into the system. The quoted item cost, if known, may be used to produce purchase order value variance information.

- 3) Purchase Order Progressing

The status of each order may be reviewed via an order re-scheduling report and if necessary the information on the purchase order file amended. Any re-scheduling may result from unexpected variances in the number of issues of receipts etc. Planned purchase orders should be reviewed on a regular timebase and orders placed on the supplier should take into account the date required and lead times.

- 4) Purchase Order Reporting

Information required to monitor the status of orders placed would typically be on the number of orders placed or outstanding, and their value.

#### 5) Purchase Order History

Following the completion of a purchase order the details could be written to a purchase order history file. Typical information would be purchase order list by stock item, purchase order list by supplier, maximum delay per item by different suppliers and mean lead time and the longest lead time per item. Information of this nature is also likely to be required for legal and internal control reasons.

#### 4.5 Cost and Budgetary Control

The functionality of such a module would typically provide information on :

##### 1) Labour Costs

The work times recorded by both inhouse or third party labour, would be translated into cost information by input of the relevant labour rate for each trade against the type of hours (normal overtime or shift) and booked to the appropriate job number.

##### 2) Material Costs

Information on maintenance costs could be gained by interrogation of the stores and purchasing modules.

##### 3) Cost and Budgetary Analysis

Analysis of the labour and material costs may be collated by area, trade and category of work, to give a weekly or cumulative summary of expenditure and commitments against budget.

Analysis of costs by plant group or plant item can allow calculation of item costs for life cycle costing techniques. Optimisation routines would help assess the effectiveness of the maintenance operation and its effects on production, by balancing the costs of preventive action taken to pre-empt a breakdown against the cost of production inefficiency or reduced overall plant life should the breakdown have occurred.

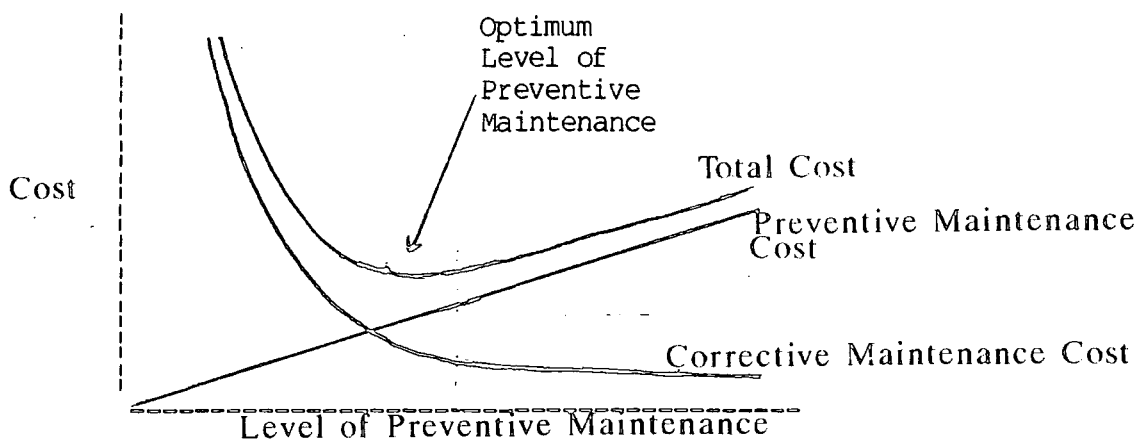
Consideration of Durham's functional requirements for a maintenance management system can now be made, with respect to the Durham organisation and the general functionality of software packages available.

With reference to Figure 4.1 - 'Modules of a Maintenance Management System', two of the major areas, plant monitoring and resource planning would require addressing. The two other major areas, inventory control and budgetary control are already covered by major systems and interfacing to, rather than replacement of these systems is likely to be the major requirement.

### 5.1 Plant Monitoring and Resource Planning

The overall objective of the plant monitoring and resource planning activity is to optimise the level of preventive maintenance as shown in Figure 5.1 (Ref. 37).

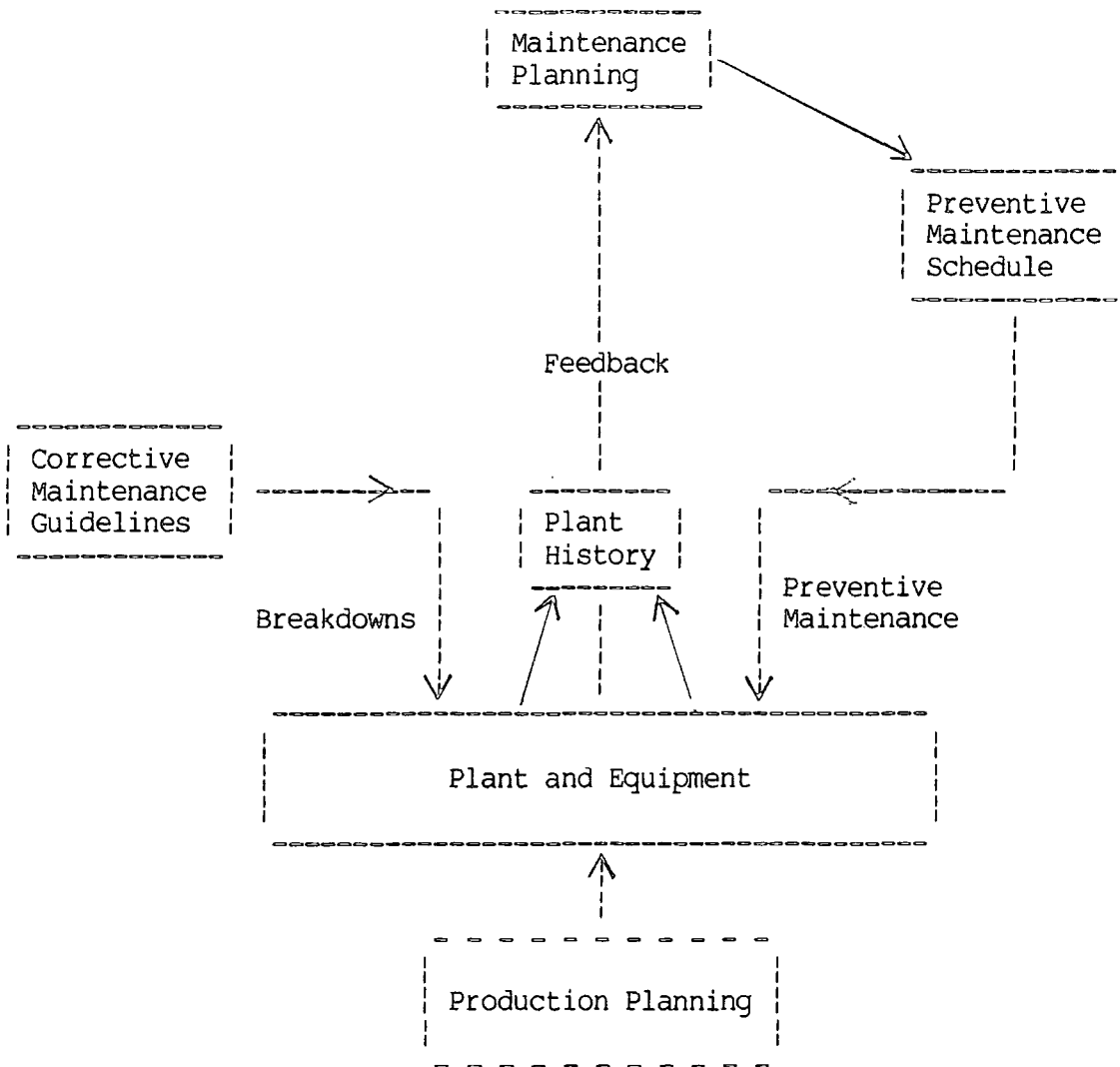
Figure 5.1 : Maintenance Planning Breakdowns vs Preventive Maintenance



However, it should be noted that in practice fixing the level and type of preventive maintenance is a complex process as consideration must be given to level of preventive maintenance resources, type of preventive maintenance, e.g. time based or inspection based, in a situation where unavailability and other influencing factors can change.

For effective maintenance planning an interactive system should be operated. Preventive maintenance routines, and their frequency, are devised from experienced personnel, manufacturers guidelines etc. The success, or lack of it, of these operations must then be measured with respect to machine performance i.e. the system must be closed loop with feedback as illustrated in Figure 5.2.

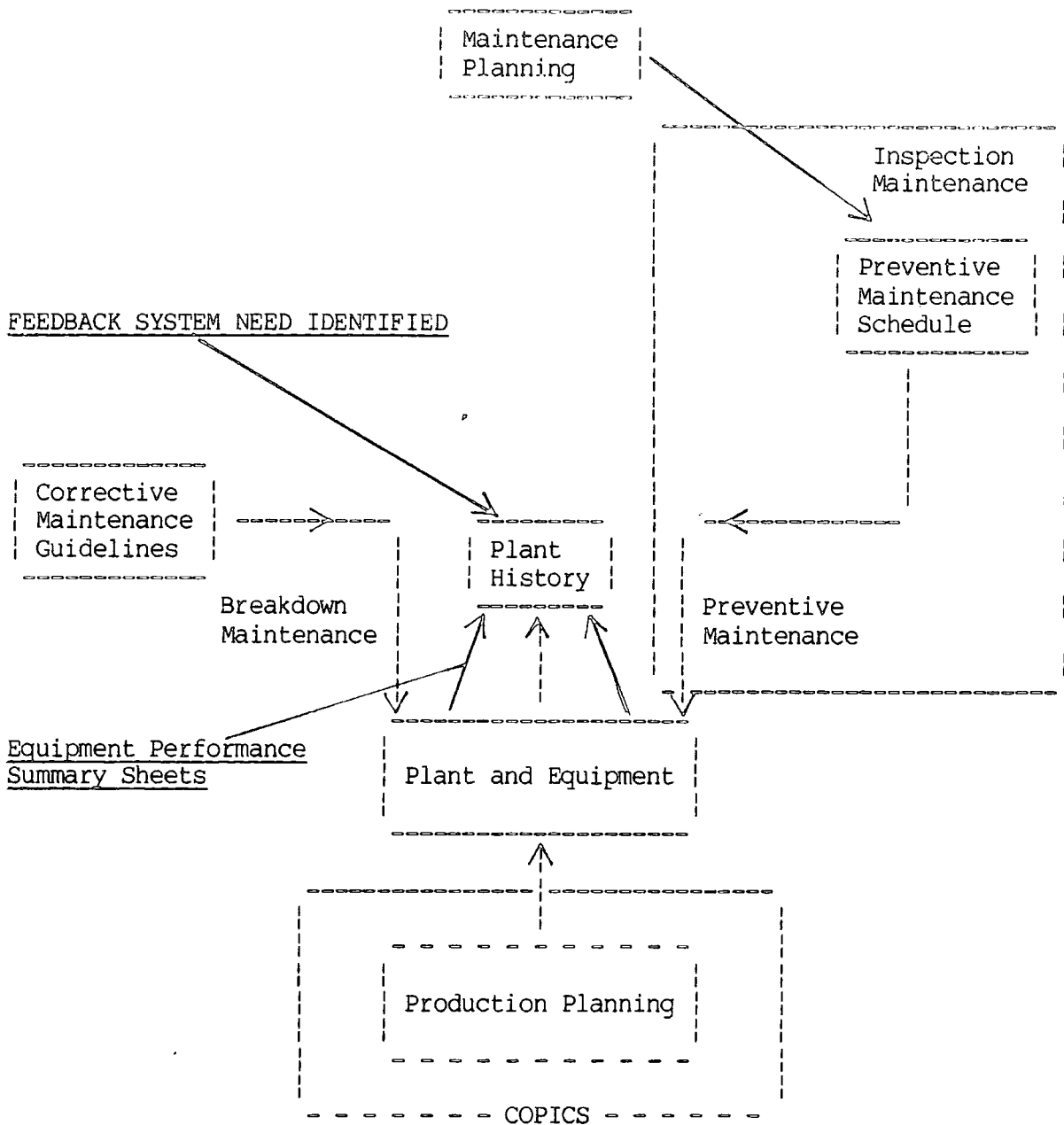
Figure 5.2 : Maintenance Planning with Feedback



With respect to the ideal model, Figure 5.3 illustrates which systems are available at Philips Durham. Major points to note are :

- i) The lack of feedback information from the plant preventing the collation of plant history data.
- ii) No link between plant history and maintenance planning.

Figure 5.3 : Philips Durham Maintenance Systems Overview



Resource Planning

Inspection maintenance is the only maintenance planning system available - dealing with the scheduling of maintenance jobs as required. An overview of the system procedures is given in Figure 5.4. The system is well documented and managed (Ref. 55). However, major problems with this system are :

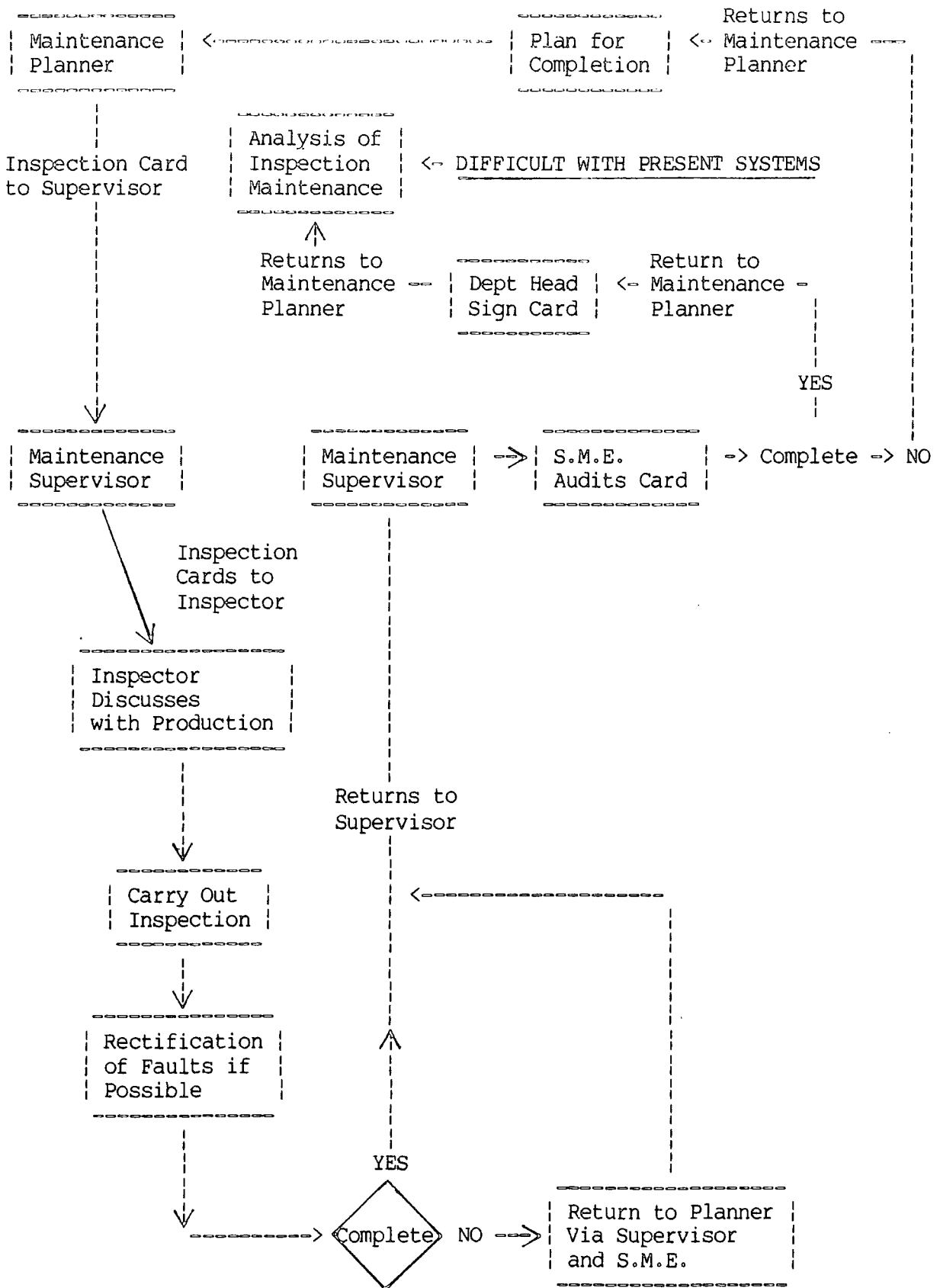
- a) It does not control the overall resource utilisation within the department. Preventive work is only a small percentage constituent of the overall workload. Planning and resource control are therefore difficult to achieve within the limitations of this system.
- b) There is no interaction with machine breakdown information. It is difficult to check effectiveness of the system making the 'analysis of inspection maintenance' (Ref : Figure 5.4) a difficult task.
- c) The frequency and content of the inspection maintenance routines are therefore difficult to update. Routines are examined only rarely and by subjective assessment of the Shift Engineer and craftsmen who may have been recently involved in the procedure. Maintenance cost optimisation is therefore not likely to be well served with this practice.
- d) Inspection maintenance is sometimes given a low priority due to more urgent corrective breakdown work.

To summarise with respect to Resource Planning, Durham's requirements are for a system which facilitates the logging, scheduling, prioritising and control of corrective jobs and planned maintenance. It would also have to cover the various trade groups available and both week and weekend operation. A further sub module on plant shutdown scheduling could also be required.

The functionality of all the sub modules as described in Section 4.3 would therefore be required in such a system. However, consideration should also be given to any additional requirements that may arise through the IMT re-organisation. If co-ordinated centralised and distributed work planning is necessary, then obviously the system should also be able to meet this requirement.

With respect to implementation, the data and schedules already developed for inspection maintenance may be a useful input, and serve to reduce the payback period for such a system.

Figure 5.4 : Inspection Maintenance System



S.M.E. = Senior Maintenance Engineer

- 3) Condition Monitoring.
- 4) Optimisation.
- 5) Interfaces to Resource Planning, Budgetary Control and Inventory Control.

## 5.2 Inventory Control

At Durham, control of the maintenance stores is carried out through the use of the inventory planning and forecasting (I P & F) module of the COPICS system. Similarly, control of the purchasing and invoice payment procedure is achieved using the Purchasing Receiving and Invoice Management (PRIM) module of the COPICS system.

Both of the modules are an integral part of the Philips approved and supported Communication Orientated Productions Information and Control System (COPICS) and are inextricably linked to various other modules e.g. MRP. As such they form an integral part of all manufacturing activity as well as providing all the necessary functions to support the stores control and purchasing operations.

Interfacing to, rather than replacement of these modules is therefore necessary. However, it may be necessary to further tune the I P & F module to use 'dependent requirement' so that certain stores items can only be issued against a pre-defined job number. This would be necessary to establish and maintain a credible preventive maintenance system since parts to carry out preventive work need to be available in stores at the prescribed work date. Reserving a part against the appropriate job number would ensure that the system could operate successfully.

## 5.3 Budgetary Control

Another major Durham system, used to control job budgets and already interfaced to COPICS is Group Job Costing (GJC). GJC is used to monitor and control expenditure against a job with respect to a predefined budget.

As this system offers all the necessary functionality for a budgetary control system as defined above, albeit subject to limitations of batch processing, and is an integral part of the Philips administration activity, interfacing to, rather than replacement of this package would be a necessary solution.

## CHAPTER 6 : THE EQUIPMENT UTILISATION IMPROVEMENT (EQUIP) SYSTEM

### 6.1 System Objectives

In summary, the previously stated benefits of a pilot system to collect machine stoppage data were :

- 1) As a necessary precursor to the successful implementation of an equipment management package. Irrespective of the package selected, accurate data on machine performance would need to be collected.
- 2) To provide information for capacity planning purposes.
- 3) To improve shop floor attitudes and highlight any problems with respect to shop floor data collection.
- 4) To provide an input to a user requirements specification for a proprietary package (Ref. 57)

On developing the specification for the EQUIP system it quickly became apparent that if the systems functionality was limited solely to its original premise of a data collection system then the system as a whole would lack credibility and its use as a learning tool would be negligible. Therefore, although it was realised that there may be some overlap with the functionality of the plant monitoring modules of any selected proprietary package, it was decided to build in a significant amount of analytical, graphical and report producing functionality into the system.

From this expanded brief, it was then possible to view the system not only as a pilot project for collection of machine breakdown information but as a viable tool for management reporting and equipment performance improvement.

Furthermore, although the initial concept of the system was to provide feedback to the maintenance planning function, it soon became apparent that further benefits could be gained from the system, in the field of capacity planning, by recording all causes of downtime i.e. whether due to production or engineering problems.

FIGURE 6.1

EQUIP REVIEW  
FUNCTIONALITY OF SHOP FLOOR DATA

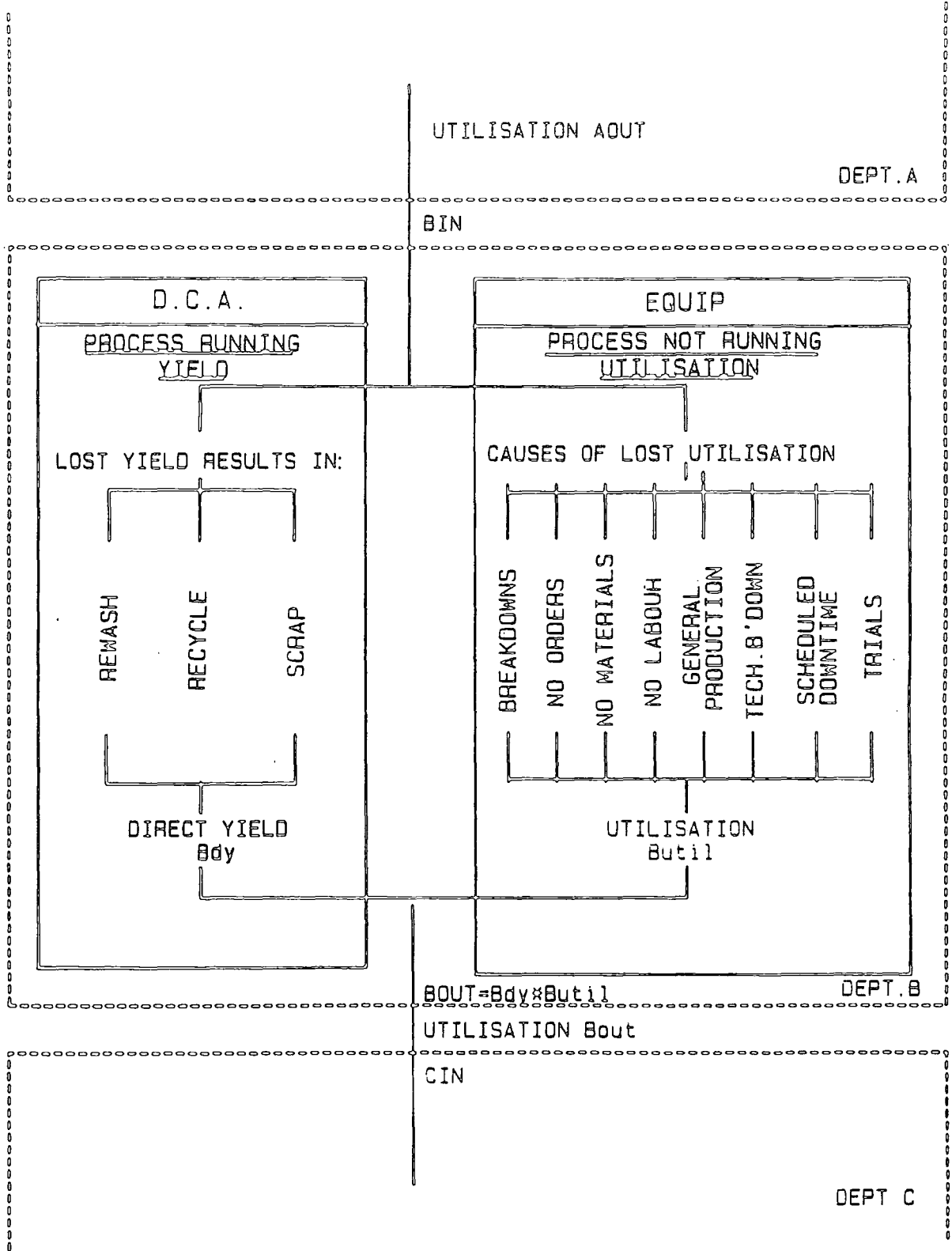
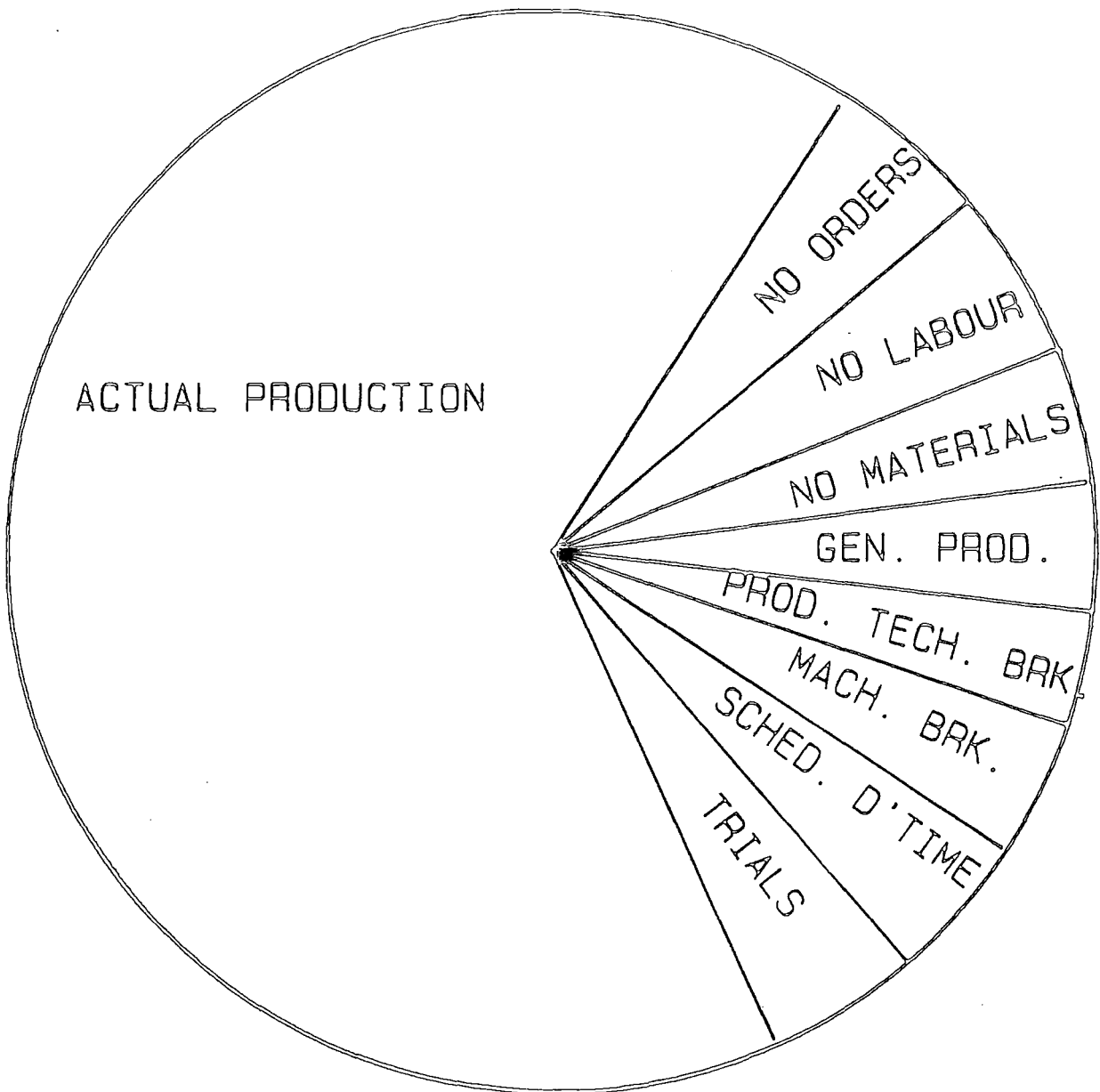


FIGURE 6.2

# EQUIP SYSTEM-DATA COLLECTED

SYSTEM CALCULATES TOTAL AVAILABLE CAPACITY FROM LINE SPEEDS AND NO. OF SHIFTS. ACTUAL PRODUCTION IS CALCULATED FROM TOTAL AVAILABLE CAPACITY SUBTRACTING ALL RECORDED DOWNTIME.



Overall objectives of the system were therefore determined as :

- 1) To diagnose major equipment utilisation problems.
- 2) To control downtime and give feedback to the maintenance planning function.

Finally, a process area of the factory had to be selected. The production of screens for computer monitor tubes is a new process for Durham and one which is highly sophisticated and complex. In general terms, after precoating, a black graphite holed matrix has to be laid down on the screen. The screen is then flowcoated to eventually develop a triad of green, blue and red phosphors in each of the matrix holes. This process technology utilises recently developed equipment and is also the factory bottleneck for CMT production. This area was therefore selected as being one in which a system of this nature would be highly desirable.

A cost benefit rationale for the proposed system was carried out and results were very favourable. It was shown that if only a 30% improvement on downtime could be achieved through improved information on the causes of downtime then savings in the region of £½ million per annum could be achieved.

## 6.2 Functionality of the System

The systems functionality and relationship with respect to other shop floor data collection systems is given in Figure 6.1. Essentially EQUIP is used to monitor causes of process downtime. Further explanation of the system operation and the data collected is given in Figure 6.2.

The complete functionality of the system is given in Appendix 4.1 - The System Functional Specification.

### 6.2.1 Failure Classification

To translate the causes of lost utilisation into a form suitable for collection and analysis by computer, machine codes and fault codes had to be determined. Analysis of data with respect to major faults and specific process machinery is then possible.

1) Machine Codes

Machine codes were allocated so that each individual piece of equipment was given its own identifying code, built up from 3 sub codes denoting :

- a) Department.
- b) Equipment Item.
- c) Position on Equipment.

For example the code for the protonising position on the precoat line would have a code of :

- a) 165P : (denoting department).
- b) S33 : (denoting precoat process equipment).
- c) 10 : (denoting process position 10).

Thus the machine identifier code would be 165P S33 10.

ii) Fault Codes

Fault code design was an important factor with respect to long term effectiveness of the system as a problem identification tool (Ref. 50).

A four digit system was decided upon and the following ranges were allocated to the different types of faults.

Maintenance

Machine Problems      0000 -> 5999    600 groups of faults

Production

Standby Time            6000 -> 7999    200 groups of faults

Scheduled Downtime    8000 -> 8999    100 groups of faults

Trials                    9000 -> 9999    100 groups of faults

Further allocation for each fault group was as follows :

- a) In each range, if appropriate, sub ranges for process equipment were determined, and fault groups were then numbered sequentially in groups of 10.
- b) Individual faults within group can then be numbered, e.g. :

4690 Wagger Arm Motor  
4700 Wagger Arm Cam  
4705 Wagger Arm Cam Follower  
4710 Wagger Arm  
4720 Timing Belts

Coding in this manner allows searches to be done on the database for individual faults and also groups of faults.

#### 6.2.2 Data Input

When there is an occurrence of lost opportunity i.e. for some reason an expected product is not made then information as to when, where, why, the significance of and who dealt with the problem is gathered.

Appendix 5.2 shows the A4 template of the data collection cards that were originally used in the system.

In detail, each time an incident occurs the following is collected :

- i) Week Number - Standard ISO numbering system widely used in Philips.
- ii) Day Number - Sunday = Day 0, Saturday = Day 6.
- iii) Shift - The factory operates a 3 shift system.
- iv) Department - In this example all 165 + Precoat, Matrix or Flowcoat.

- v) Machine Code and Process Position as previously discussed.
- vi) Fault code as previously discussed.
- vii) Number of Products Lost -- To determine the significance of the problem.
- viii) Stop and Restart Time - Useful information with respect to equipment history.
- ix) Who Took Action to Correct Problem - Maintenance, Production, Services or Other.
- x) Finally 16 digits are available for short comments by the Shop Floor Supervisor.

### 6.3 System Description

#### 6.3.1 Hardware and Software

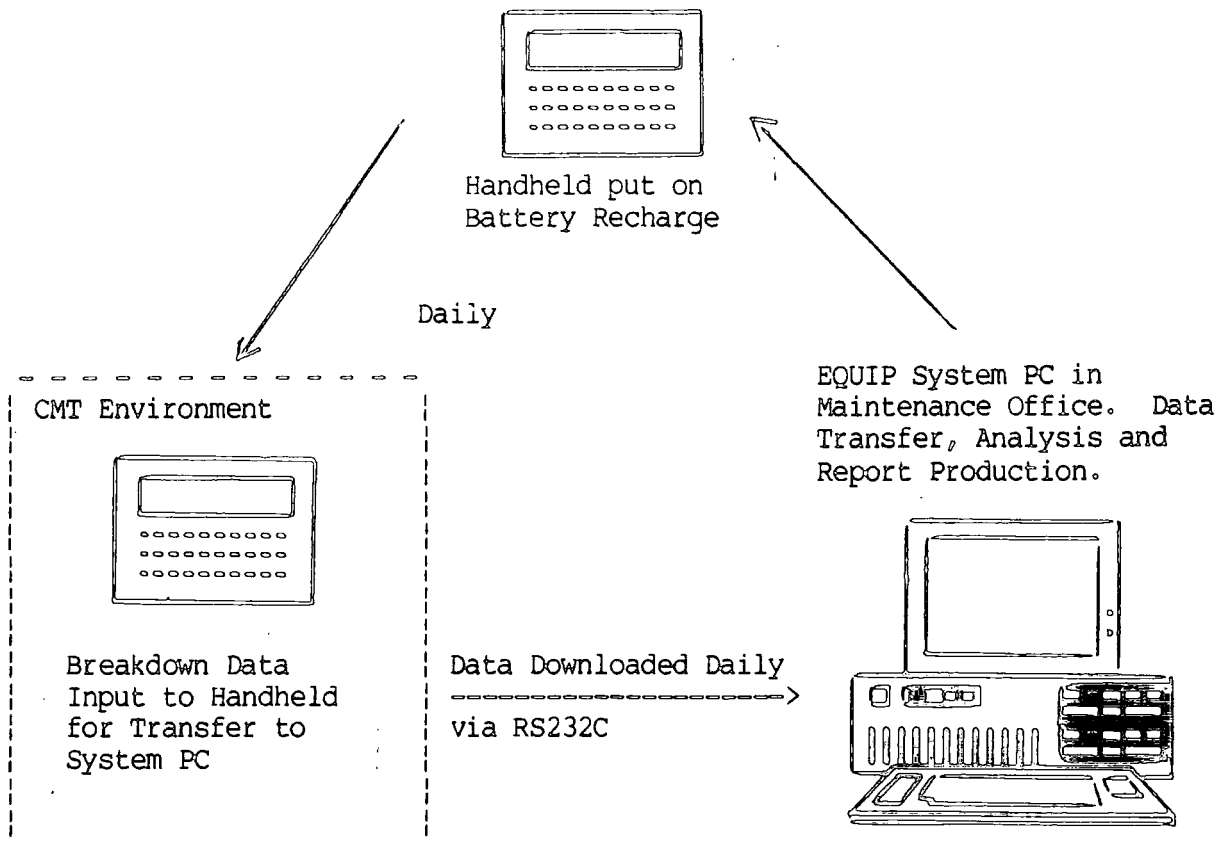
The system is based on an IBM PC AT and written in a modular form using the dBaseIII+ programming language (Ref. 66). Extra graphics macros have been used to enhance the reports and graphs produced by the system. The PC is situated in the maintenance planning office for easy access by the System Manager.

Overall the system has been designed to be easy to update and modify. DBaseIII+ was chosen as the best package to develop the system in that it has a high level programming language ideally suited to this type of application and a user friendly data query mode to facilitate ad hoc data interrogation i.e. The Assistant. DBaseIII+ is also Philips approved and supported.

### 6.3.2 System Operation

Data, on each stoppage occurrence, is input into a handheld computer by Shop Floor Supervision. This data is then down loaded daily via an RS232C interface to the EQUIP PC, as illustrated in Figure 6.3.

Figure 6.3 : System Operation Overview



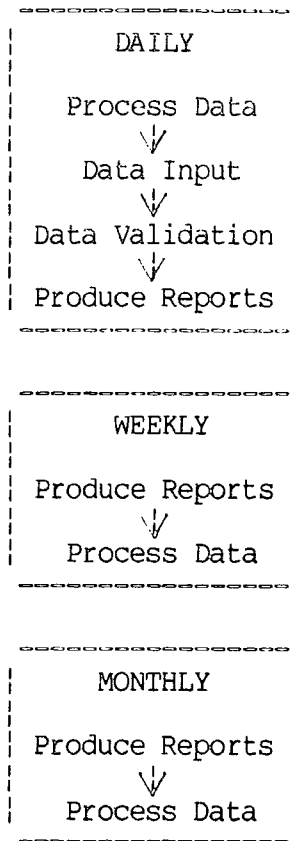
Daily operation of the system is carried out by Clerical personnel, under the supervision of the System Manager.

Broadly speaking the system has three modes of operation : Automatic, Semi Automatic and Manual.

#### Automatic

Each day, week and month set standard reports are required by the customers of the system. These are produced automatically by the system, from the day to day operation of the Clerical support.

A summary of the operating procedures is as follows :



The reports automatically produced by the system cover the majority of user requirements and an example of reports produced are given in Appendix 5.3.

#### Semi Automatic

There are some forms of data presentation required on a fairly frequent ad hoc basis. Namely, these are paretos based on machine codes or fault codes over a variable time base, or % breakdown summary detailed over a variable time base. To facilitate these needs there are routines, accessible to the System Manager, which require only the specified time base to be input.

#### Manual

There are likely to be interrogation requirements which will arise from the day to day operation of the factory and which therefore could not be predicted at the system design

**DAILY DATA INPUTTED**

**SETUP**

DATA FROM THESE REFERENCE FILES IS USED THROUGHOUT THE OPERATION OF THE SYSTEM.

**MACHINE CODE DATABASES**

NO INDEXES

**PRE-M.C**

CONTAINS ALL MACH CODES FOR PRECOAT

**MAT-M.C**

CONTAINS ALL MACH CODES FOR MATRIX

**FC-M.C**

CONTAINS ALL MACH CODES FOR FLOWCOAT

**FAULT CODE DATABASES**

NO INDEXES

**PRE-F.C**

CONTAINS ALL FAULT CODES FOR PRECOAT

**MAT-F.C**

CONTAINS ALL FAULT CODES FOR MATRIX

**FC-F.C**

CONTAINS ALL FAULT CODES FOR FLOWCOAT

**DATE CONTROL DATABASE**  
**DATE.CON**

CONTAINS WEEK AND MONTH SETUP INFORMATION. DETAILS NUMBER OF SHIFTS WORKED

**PRODUCTION UNITS MEMORY FILE**  
**PROD.MEM**

MEMORY FILE DETAILING PRODUCTION AND CAPACITY UNITS CODE IN SETUP MUST BE CHANGED AND RUN TO ALTER VALUES

**DAILY**

**DYALL**

INDEXES  
ENTRY\_ID  
PLCODE

CONTAINS ALL CURRENT DAYS INFORMATION FOR THE 3 DEPTS.  
ENTRY IDENTIFIER GENERATED.

SORTED ON DEPT.

PREMCLIM  
NO INDEXES  
TEMP DATA  
FOR DAILY  
BREAKDOWN SUM.

MATMCLIM  
NO INDEXES  
TEMP DATA  
FOR DAILY  
BREAKDOWN SUM.

FCMCLIM  
NO INDEXES  
TEMP DATA  
FOR DAILY  
BREAKDOWN SUM.

**MONTHLY**

**PREMTH**

INDEXES  
PRE-ENT  
PRE-FC

CONTAINS ALL PRECOAT PROBLEMS FOR CURRENT MONTH

**MATMTH**

INDEXES  
MAT-ENT  
MAT-FC

CONTAINS ALL MATRIX PROBLEMS FOR CURRENT MONTH

**FCMTH**

INDEXES  
FC-ENT  
FC-FC

CONTAINS ALL FLOWCOAT PROBLEMS FOR CURRENT MONTH

**LONG TERM SUMMARISED**

**PRE-DAYR**

NO INDEXES  
PRECOAT-LONG TERM STORAGE, SUMMARISED WEEKLY DATA

**MAT-DAYR**

NO INDEXES  
MATRIX-LONG TERM STORAGE, SUMMARISED WEEKLY DATA

**FC-DAYR**

NO INDEXES  
FLOWCOAT-LONG TERM STORAGE, SUMMARISED WEEKLY DATA

**YEARLY**

**PREYRPD**

INDEXES  
PRE-ENT  
PRE-FC

YEARLY DATABASE OF ALL PRODUCTION PROBLEMS IN PRECOAT AREA, PREVIOUS TO CURRENT MONTH

**PREYRMT**

INDEXES  
PRE-ENT  
PRE-FC

YEARLY DATABASE OF ALL MAINTENANCE PROBLEMS IN PRECOAT AREA, PREVIOUS TO CURRENT MONTH

**MATYRPD**

INDEXES  
MAT-ENT  
MAT-FC

YEARLY DATABASE OF ALL PRODUCTION PROBLEMS IN MATRIX AREA, PREVIOUS TO CURRENT MONTH

**MATYRMT**

INDEXES  
MAT-ENT  
MAT-FC

YEARLY DATABASE OF ALL MAINTENANCE PROBLEMS IN MATRIX AREA, PREVIOUS TO CURRENT MONTH

**FCYRPD**

INDEXES  
FC-ENT  
FC-FC

YEARLY DATABASE OF ALL PRODUCTION PROBLEMS IN FLOWCOAT AREA, PREVIOUS TO CURRENT MONTH

**FCYRMT**

INDEXES  
FC-ENT  
FC-FC

YEARLY DATABASE OF ALL MAINTENANCE PROBLEMS IN FLOWCOAT AREA, PREVIOUS TO CURRENT MONTH

FIGURE 6.4 : Schematic Overview of EQUIP Databases

stage. To make the system as flexible as possible, access to original data is required. To facilitate these needs in a user friendly way, routines are provided to load up the appropriate database required, along with relevant index files. Data is then readily available to the System Manager for further analysis with dBaseIII+ 'Assistant'.

The role of the System Manager in using these data interrogation routines is seen as critical with respect to the successful use of the EQUIP system as a maintenance planning tool.

## 6.4 System Design

The system has been developed using a top down structured approach and is written in a modular form for ease of system maintenance and to enhance software integrity (Ref. 63).

Data is sorted on a time base into various files. This is to facilitate report production and long term data analysis. As the system is PC based, consideration has been given to minimising processing time on frequently occurring operations and limiting database size on long term databases, thus maximising speed when carrying out data analysis.

### 6.4.1 Database Design

Formal structured analysis and design techniques have been used to ensure effective and elegant system design.

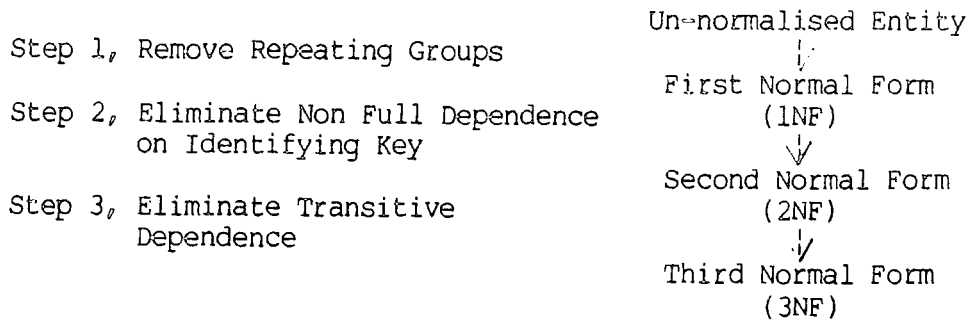
The database design encompasses criteria as defined by the 3rd form normal (3NF) analysis technique - this is essentially a set of rules for the combination of entities, attributes and relationships within a data model (Ref. 64).

An entity is in 3NF when it has :

- 1) An identifying key.
- 2) No repeating attributes or group of attributes.

- 3) No attributes which do not require the whole of the identifying key to identify them.
- 4) Attributes which are mutually independent.

Steps taken in this normalisation process are as follows :



1NF and 2NF are not important in themselves, they are merely the route to 3NF.

Some duplication has been built into the system in the form of the 'long term summarised' databases. The information in these databases is likely to be required on a fairly frequent basis and the duplication allows faster access to previously calculated summary data.

An overall schematic of the subsequent database system is given in Figure 6.4.

#### Set Up Databases

Data from these reference files is used throughout the operation of the system.

The major benefit of having these 'look up' files is that changes, which are likely to be required, need only be entered to the system in one place.

This makes modifications and changes to the system simple and relatively easy to carry out.

### Daily Databases

Daily data, from all 3 departments is input into the daily database. An entry identifier is generated by the software to give each record a unique identifier which remains with it throughout the data's lifetime in the system. The entry identifier also incorporates the week and day number.

For example : 9115001

: 9115002 = week number 911 (ISO std) +  
day number 5 + count 2

The daily downtime analysis report is produced from this data and when daily data is processed the data in the daily database is sorted by department to the monthly files.

All data in daily database is then deleted in preparation for the following days input.

Throughout the week, scratchpad files summarising data on machine breakdowns, frequency and products lost, are also kept per department.

### Monthly Databases

Data, sorted by department, is downloaded into monthly databases from the daily database during daily data processing.

Weekly and monthly report routines use these databases.

At the end of the month data from these files is sorted by fault code into the yearly maintenance and production databases.

### Long Term Summarised Databases

Summarised weekly data, as given in weekly downtime analysis report, is kept in these files for approximately 2 years before being automatically deleted during monthly processing.

## Yearly Databases

Data previously sorted by department is sorted by fault code into the 6 yearly files creating databases of maintenance or production problems per department.

### 6.4.2 Code Design

#### PC Analysis System

The PC based data manipulation, analysis and report producing software form the major part of the EQUIP system.

The programme has been written in a structured top down manner in dBaseIII+ programming language. Operation around the system is menu driven. Standard functions and procedures have been grouped together in a 'library' program, allowing access by all calling programs.

Additional graphic macros have been added (dGE graphics) for production of line graphs etc.

The functionality of the software with respect to data manipulation and automatic report generation is summarised by the data flow diagrams detailed in Appendix 5.4 (Ref. 62).

The system also provides ad hoc interrogation and graphing routines.

Entry to the system is password protected. On correct entry to the system the user is presented with the main menu. Essentially selection of an option will call a further program which in turn calls mask screens, to generate displays, and further modules, as appropriate, as shown in Figure 6.5. Figure 6.6 shows main menu screen and Figure 6.7 further illustrates the systems operating environment.

FIGURE 6.5

STRUCTURE CHART OF EQUIP

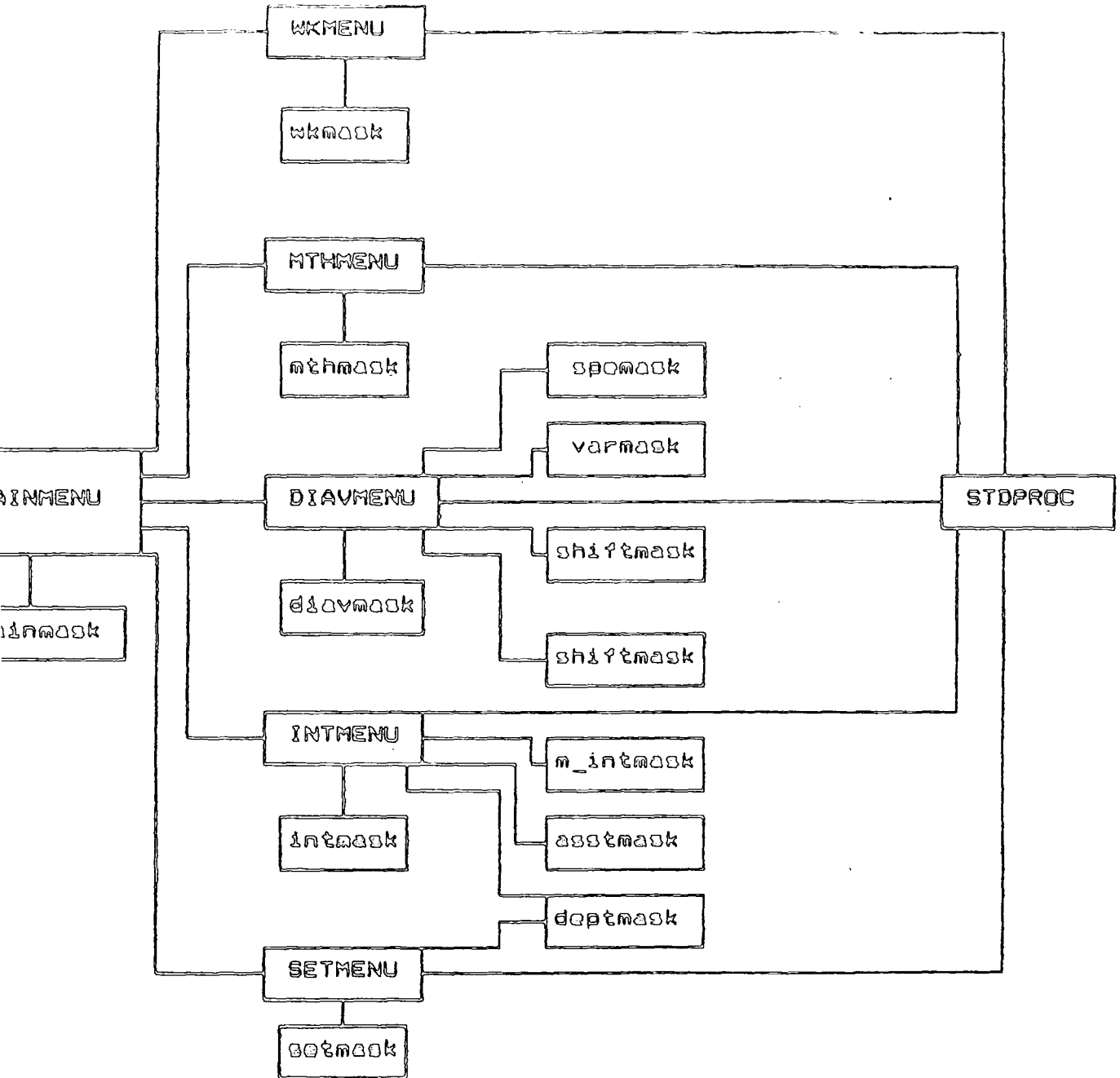


Figure 6.6

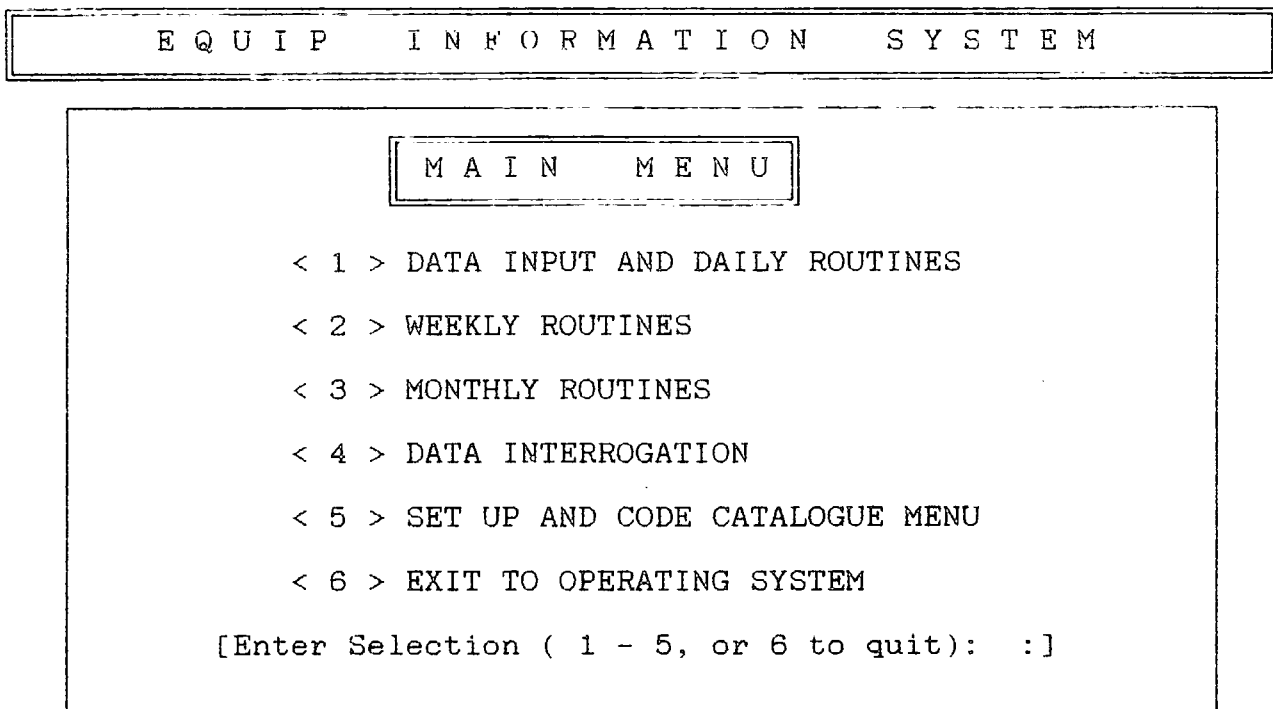
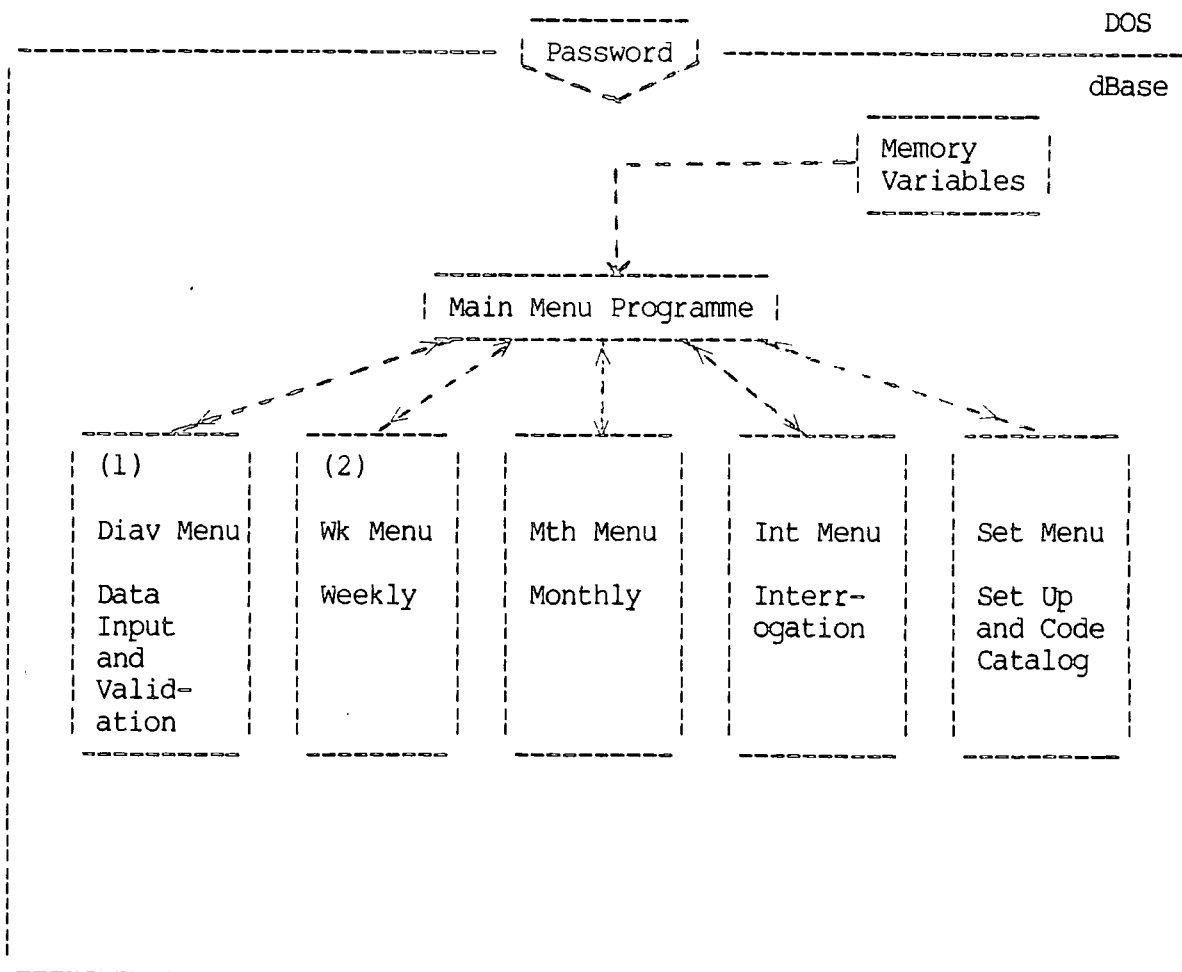


Figure 6.7



The design of all the major option programs is similar. To illustrate, the PDL (Program Description Language) and commented code of one of the smaller programs, month menu is given in Appendix 5.5. The standard procedures package provides common functions, many graphical, for all calling packages and some of the PDL and commented code for this program is also given in Appendix 5.6.

#### Handheld System

Code on the handheld is written in a structured modular form using BASIC under a CP/M operating system. Data input is validated before being written to file. This file is then transferred to the IBM PC.

### 6.5 Post Implementation Audit

The system as described above is commissioned and fully operational at Philips Durham.

Furthermore, the system has now been extended into the Lacquer and Aluminising process in the plant.

With respect to possible factory wide implementation the system has been reviewed to clarify benefits gained (see Appendix 6). Part of the brief of this audit was also to highlight any issues relating to the successful operation of such a shop floor data collection system.

#### Audit Results

##### 6.5.1 Data Accuracy

For the purposes of comparison, data from the EQUIP system was compared with that from the equipment performance summary sheets (as detailed in Chapter 3). Results of this comparison over a 3 month time period in 1988 are given in Appendix 5.7.

FIGURE 6.8

DATA COMPARISON—SUMMARY SHEETS VS EQUIP

LAC AND AL LINE 1—NO. OF BR'DOWNS

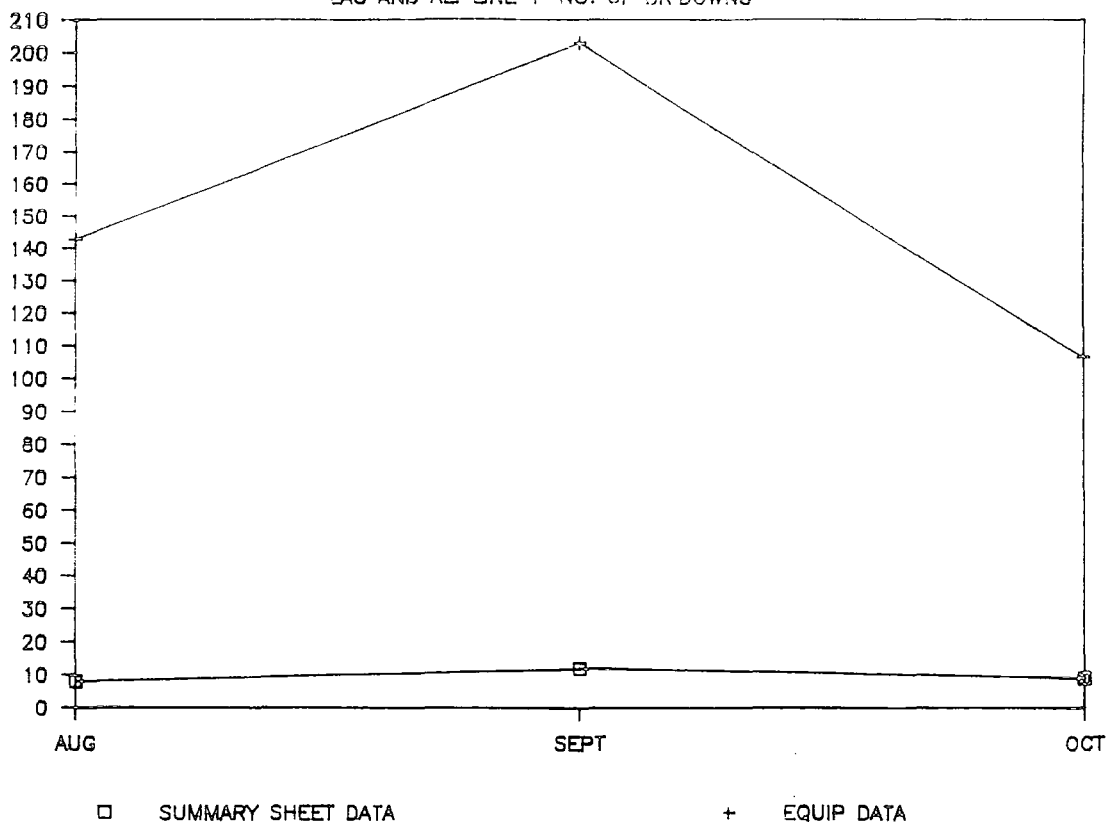
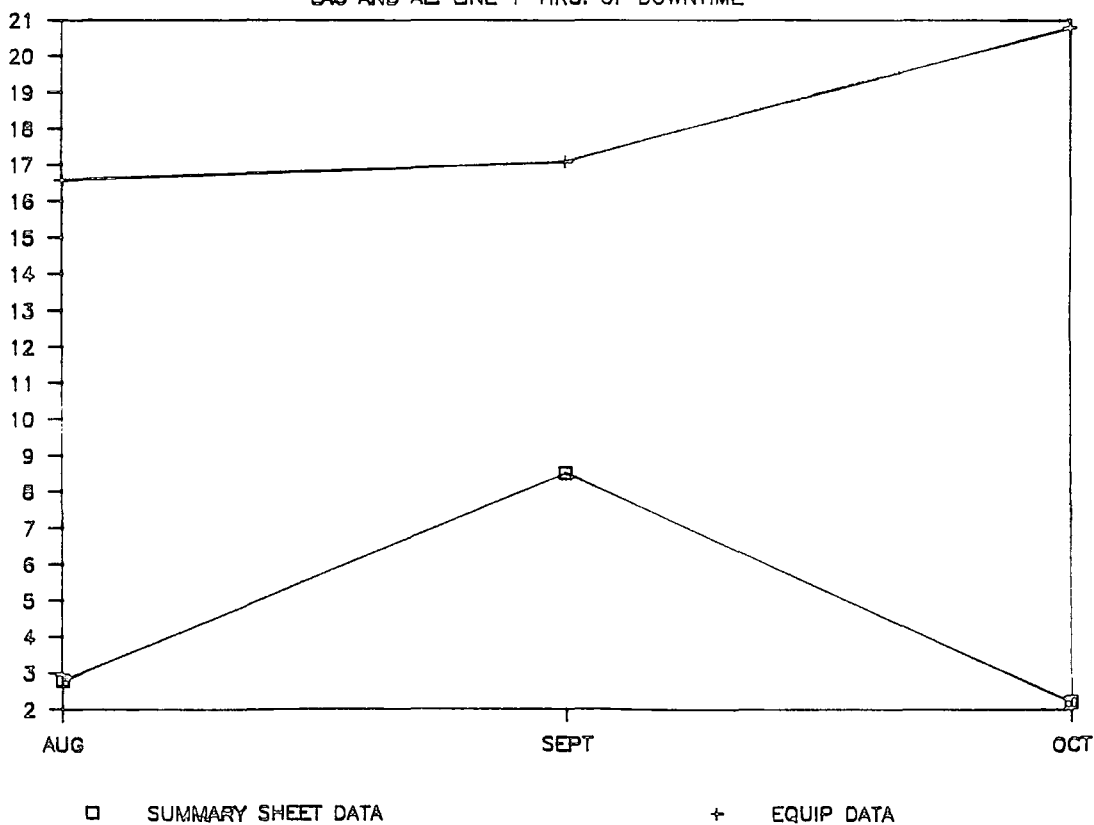


FIGURE 6.9

DATA COMPARISON—SUMMARY SHEETS VS EQUIP

LAC AND AL LINE 1—HRS. OF DOWNTIME

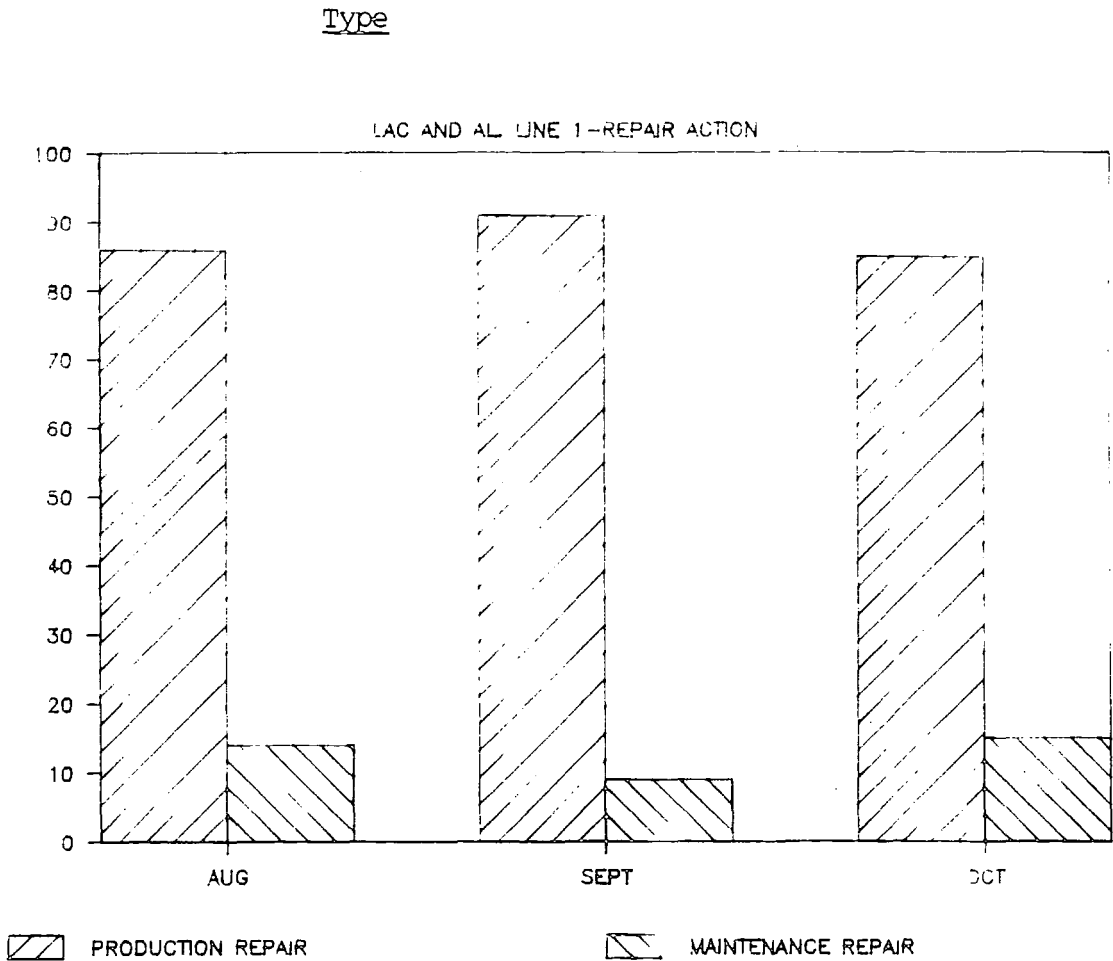


From this data it can be concluded that the system provides more accurate information on causes of lost utilisation than is otherwise available.

Graphs of one set of data, from Lacquer and Aluminising Line 1, are given in Figure 6.8 and 6.9. Although the figures and ratios vary, overall EQUIP provides very substantially improved information on machine breakdown frequency, causes and downtime - in a readily accessible form, previously unavailable.

Figure 6.10 demonstrates that it also provides a record of machine faults fixed by production, sometimes up to 90% of incidents, which would otherwise not be drawn to the attention of the maintenance department.

Figure 6.10 : Machine Incident - % Correction by Personnel



### 6.5.2 Management Issues

Management issues relating to the successful operation of a machine non availability data collection system highlighted through the implementation of this pilot project are :

- i) System Ownership. The system needs to be owned and responsibility taken for its effective operation.
- ii) Management Support. The system should be supported, and be seen to be supported, by the managers of the concerned functions i.e. production and engineering.
- iii) Duplication of Information Systems. A common failing when introducing new information systems is not to review and terminate any existing systems that were expected to be superceded. In the case of EQUIP, data on machine availability is still collected through other means e.g. engineering log. Operating duplicate systems leads to confusion and frustration for personnel charged with the task of collecting the data. It also implicitly means that no one system e.g. EQUIP has management support. Overall this tends to lead to many systems with inaccurate data, rather than one accurate and accepted system.
- iv) Data Collection Personnel. Machine breakdowns or line stoppages can happen at any time during a 24 hour shift. As only production personnel are in situ 24 hours a day then logistically it is they who must be responsible for data collection. Experience has also shown that careful consideration should be given as to whom in the production department should input the data - the person should hold a position of responsibility, be accountable for the accuracy of the data input, be physically located near the line and also have sufficient time to carry out the task in a conscientious and effective manner. In pilot areas, results indicate that process control operators are most suited to this role.

The fact that production personnel must be responsible for data input has a bearing on system ownership due to the need for accurate data input. The owner must have authority over, or influence upon, production personnel.

- v) Use of Information as a Tool. Craftsmen can readily accept spanners, multimeters etc as tools to help them perform their jobs more effectively. A much more nebulous concept is the use of information as a tool. Craftsmen do not associate information systems as tools of their trade. This is obviously a cultural barrier which must be overcome.
  
- vi) Training, in both the objectives and philosophy of the system as well as its method of use. In some ways the system is seen as a threat by maintenance personnel - "I don't need a system to tell me what has gone wrong, I keep a close eye on what is going on on the shop floor". Here the system was being perceived as a management tool, undermining the conscientiousness of the shift engineer. Improved understanding of the objectives of the system, as a tool to highlight underlying faults, has gained a much more positive response to the system. Similarly, misconceptions about the system are present with production personnel "I want to use the data to hammer maintenance about the number of breakdowns". Again this sort of perception can lead to negative attitudes about the system.

A fundamental cause for some non utilisation of the system was lack of knowledge as to what data was available and how to access it.

- vii) Access to System. An important feature for personnel who do use the system is that as it is PC based they feel in control of the system. Using the data interrogation facilities they can access the data as required.

- viii) Integrity of Data. Maintenance personnel do not completely trust the data provided by production personnel. Their concern, that time is being incorrectly booked to machine stoppages rather than to breaks etc, is symptomatic of the mistrust between the two functions. Closer working relationships and the formation of multidisciplinary teams should help resolve this problem.
- ix) Feedback to Production Personnel. Production personnel need feedback that actions are being taken by maintenance based on the data provided. Production's perception is that they provide machine breakdown information in four different ways, none of which improve the quality of the maintenance service they receive. This in turn demotivates personnel in providing accurate input data. Again improved communications between production and maintenance are required to address these issues.
- x) Benefits of the system should be visible. At a general level, for any system with preventive objectives there is difficulty in highlighting its benefits. If a major line out occurs, attention is focused at the problem and the craftsman who fixes the equipment can be seen as the 'hero of the day'. With a preventive system, thought should be given as to how to publicly praise the craftsman who prevents the problem from arising in the first place. Modified performance indicators may provide a suitable means of achieving this objective. This subject is further discussed in Chapter 9.

All the above issues have been brought to the attention of Durham management and are now being addressed.

Further discussions will therefore concentrate on the more technical issues raised by this project.

### 6.5.3 Technical Issues

Technical issues raised by EQUIP are :

- i) Although providing much improved plant history data, i.e. the feedback system, the lack of direct communication with the actuator system, inspection maintenance, makes it difficult to incorporate knowledge gained into the planning operation. Although some manual adjustments have been made to inspection maintenance based on EQUIP data, this is very much a 'hit and miss' affair. This would emphasise the need for an integrated maintenance management package for planning and feedback purposes, with optimisation routines to enhance the effectiveness of the maintenance function.
- ii) Trend analysis is carried out on the databases by the System Manager.

It is perceived that further development of the trend analysis functions and the utilisation of more statistical techniques can further enhance the benefits available from the system. Furthermore, exploration of this subject will serve greatly in helping to define user requirements for a maintenance management package. This subject is therefore further discussed in Chapter 7.

Trend analysis carried out by the System Manager, enables further clarification of machine failure modes.

A detailed review of machine component classification and further consideration of statistical techniques will serve to enhance the future functionality of the system. Such a review would also provide valuable insights into a user requirement specification for an equipment management system.

Obviously, the level down to which machine components may be classed varies for equipment type and requires consideration of what level of parts is replaced e.g. is a pump replaced on failure, or is a sub component such as a diaphragm replaced.

Ideally, though not necessarily practically, analysis should be down to smallest replaceable part.

Having clarified the level of component classification, consideration can then be given to statistical techniques available for analysing equipment performance.

However, before proceeding further, it is opportune to first define all relevant terms :

### 7.1 Clarification of Terms

#### 1) Availability

The fraction or percent of uptime. Availability is measured by dividing hours of uptime by scheduled running hours.

#### 2) MTTF

Mean Time To Failures. Is the average available time between equipment failure. An important characteristic with respect to machine performance and this parameter is failure pattern e.g. time based, random etc. Also of significance is the availability

of suitable parameters to detect the onset of failure. The inverse of MTTF is the failure rate or the number of failures per operating hour.

3) MTTR

Mean Time To Repair is the average time necessary to repair and return equipment to service once a failure has occurred.

4) Reliability

Is the probability that a piece of equipment or a component will operate satisfactorily for a specified period of time.

7.2 Significance of Failure Patterns

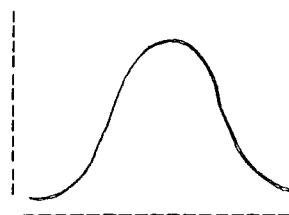
Failure mode is a vital parameter with respect to the usefulness of statistical techniques in analysing/predicting machine performance. (Ref. 73). The failure pattern of complex equipment is made up of several distinct types of failure. Obviously it would be of advantage if the failure pattern of an item of plant could be clearly described in terms of practically meaningful parameters.

Many failure causing mechanisms give rise to measured distributions of times to failure which approximate quite closely to analytical probability density functions (Ref. 72 and 74).

7.3 Description of Probability Density Functions

If many thousands of a component are tested such that the class interval of the results is such that a curve is produced, a continuous probability density distribution is obtained.

Probability Density  
Function  $f(t)$

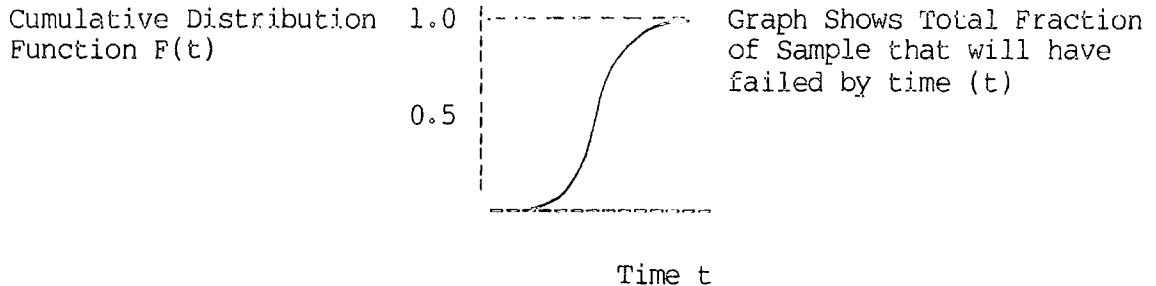


Total Area Under Graph = 1

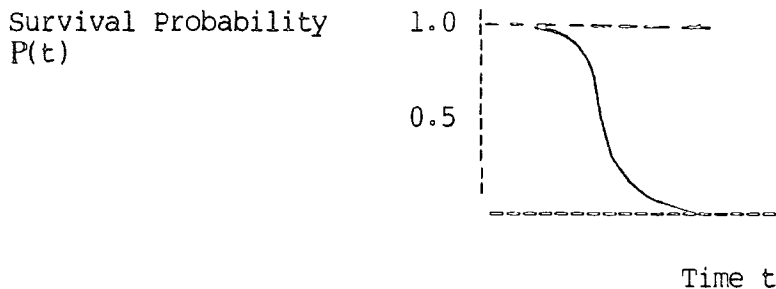
Time to Failure,  $t$

$F(t)$  = Probability of failure before a running time  $t$ .

Shown as a graph of cumulative fraction failed i.e. where  $f(t) = f(t)dt$ . the graph appears.



The survival probability,  $P(t)$ , the number of items from the sample, surviving at running time  $t$ , is clearly  $P(t) = 1 - F(t)$ .



Probability density functions that can be described by mathematical functions, are referred to as Probability Density Functions (PDF's) each of which has an associated Cumulative Distribution Function (CDF).

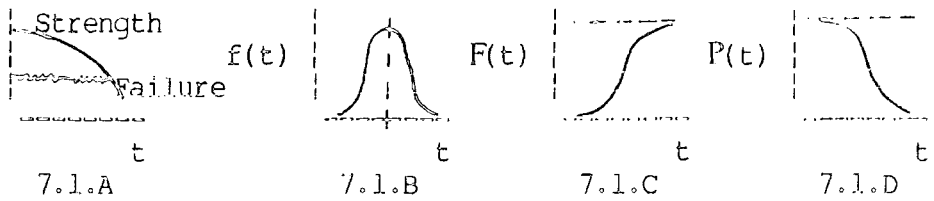
Functions such as these, provide mathematical models of failure patterns which can be used to assist maintenance decision making (Ref. 74, 75 and 78).

Three types of failure pattern will be considered further :

#### 7.4 Types of Failure Patterns :

##### 7.4.1 Age Dependent Failure (Wearout) - A Predictable Failure Model

A group of identical components operated under identical conditions will tend to wear out at the same time. A simplified model of an age dependent failure process is shown in Figure 7.1.A.



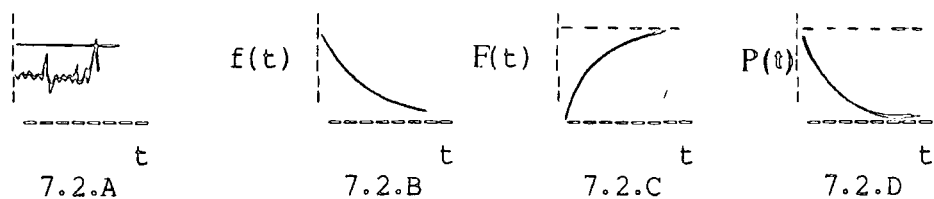
There is increasing likelihood of failure as the components grow older and the times to failure of a large number of such components would therefore be distributed as in Figure 7.1.B (where  $f(t) \therefore$  probability of failing per unit time, at running time  $t$ ). Figure 7.1.C gives fractions of items expected to have failed by time  $t$ , and 7.1.D gives the converse survival probability.

A failure pattern of this type indicates that the figure is age related and due to mechanisms such as abrasion, corrosion and fatigue. This type of pattern approximates quite closely to well known normal distribution.

#### 7.4.2 Random Failure - An Unpredictable Failure Model

These failures are the result of variations in the load imposed on any given component and the strengths of supposedly identical components. Random failures are essentially constant over the lifespan of the equipment and are normally small, being overshadowed in most cases by other failures. The probability of failure is independent of running time and such behaviour often indicates that the cause of failure is external to the item.

A simplified model of such a failure is illustrated in Figures 7.2.A to 7.2.D.



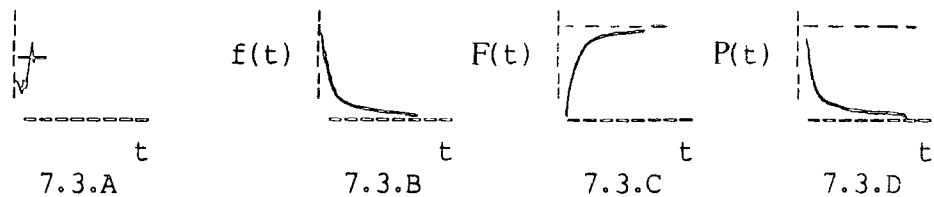
A failure pattern of this nature indicates that the failure mechanism is process related e.g. maloperation and/or poor design.

Obviously with respect to the random failure mechanism there will be no optimum replacement period for such a part.

For this type of failure, condition monitoring of a suitable parameter is a powerful technique for determining when to take maintenance action. Further details on condition monitoring are given in Appendix 3.

#### 7.4.3 Running In Failure - An Early Failure Model

Early life failures are those which occur when equipment is initially placed in service and are caused by sub standard components and/or improper installation. Their frequency is highest at initial start up and then rapidly declines. Such behaviour results in the hyper exponential PDF of time to failure, an initial rapid exponential fall and a later slower exponential fall as illustrated in Figure 7.3.B to 7.3.C.



Some items are manufactured or installed with built in defects which show up during the running in stages. Those that survive this stage were without such defects to begin with and go on to exhibit the sort of time-dependent failure probability previously discussed.

A failure pattern of this type indicates that the failure mechanism is manufacture, assembly or recondition related.

## 7.5 Analysis of Failure Modes of Items on EQUIP Databases

Items on the EQUIP database have been analysed with respect to these failure patterns to determine the viability of ascertaining their mode of failure, which in turn could aid maintenance decisions.

Unfortunately it was not possible to draw any statistical conclusions on machine performance from this analysis. However, the benefits of collecting machinery failure information in a form suitable for such analysis should not be underestimated. To pursue this objective the following points are made :

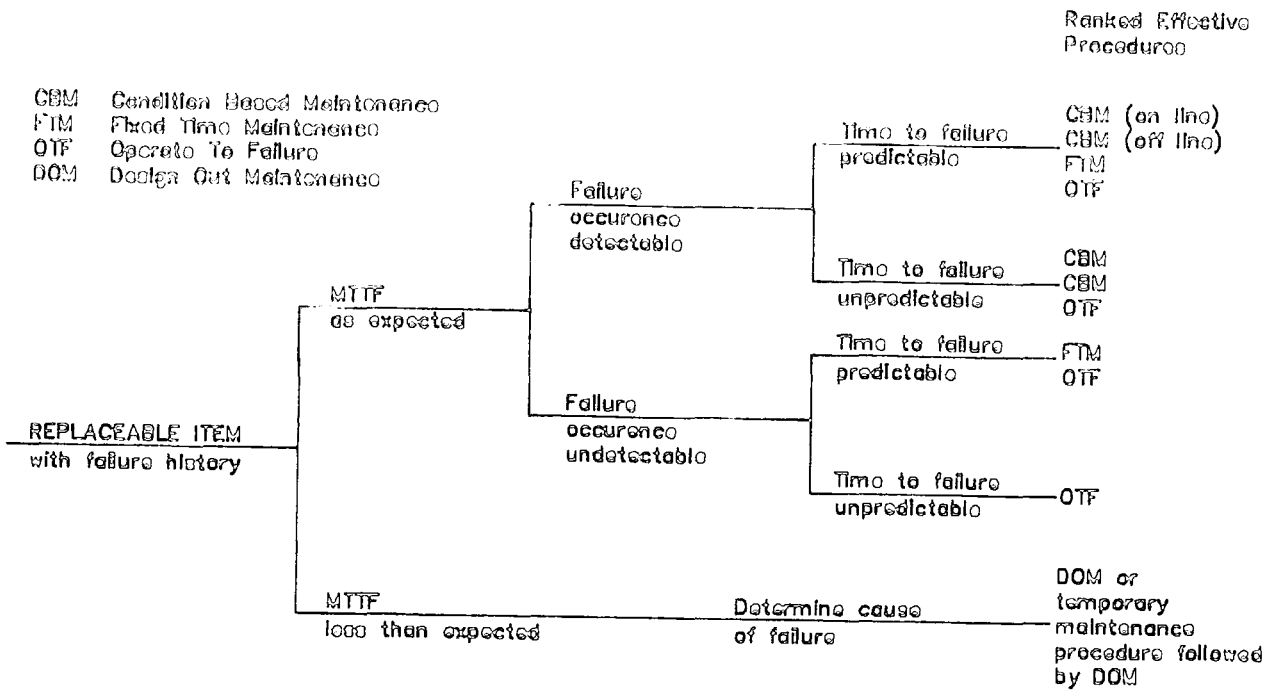
- i) Item definition is not resolute enough - fault failure codes appear to be detailed enough but machine classification does not facilitate analysis of the mode of failure for replaceable parts. For the system to become predictive this must be addressed.
- ii) There is uncertainty as to how precisely production personnel are able to diagnose the cause of failure. Durhams process equipment is complex, failure in one area may cause an effect in another area - for trend analysis purposes it is important that the cause and not the symptom of a problem is correctly diagnosed.
- iii) The system has not been operational long enough for viable statistics on mean time to failure to be obtained. Much of our process equipment is relatively unique, therefore, to collect information on the type and frequency of failure of a certain component type will be a lengthy process.

## 7.6 Potential Application of Failure Statistics to Maintenance Management

If available, failure statistics can be used to determine the best maintenance procedure for individual plant items. The different maintenance procedures possible are illustrated in Figure 7.4.



Figure 7.4 : Decision Diagram for Selection of Most Appropriate Maintenance Procedures



In many cases, the most appropriate maintenance plan can be determined without the use of failure statistics. However, where the cost of failure is high relative to the cost of fixed time replacement e.g. process bottleneck equipment, then fixed time replacement often is the best policy and failure statistics can be used to determine the optimum replacement period.

A further benefit of collecting information on failure modes is that various statistical techniques then become available to aid in maintenance decision making (Ref. 76 and 80), an example of which, the Weibull PDF is described below (Ref. 73 and 74).

The Weibull Probability Density Function (PDF)

Although conventional PDF's can be used to describe failure patterns, the Weibull PDF has been found particularly useful because it provides :

- 1) A single PDF which can be manipulated to represent the three PDF's described earlier.
- 2) Meaningful parameters of the failure pattern such as the probable minimum time to failure.
- 3) Simple graphical techniques for its practical applications.

The PDF for this distribution is :

$$f(t) = \frac{\beta (t-t_0)^{\beta-1}}{\eta^\beta} \text{Exp} \left\{ - \left[ \frac{t-t_0}{\eta} \right]^\beta \right\}$$

and the CDF is :

$$F(t) = 1 - \text{Exp} \left\{ - \left[ \frac{t-t_0}{\eta} \right]^\beta \right\}$$

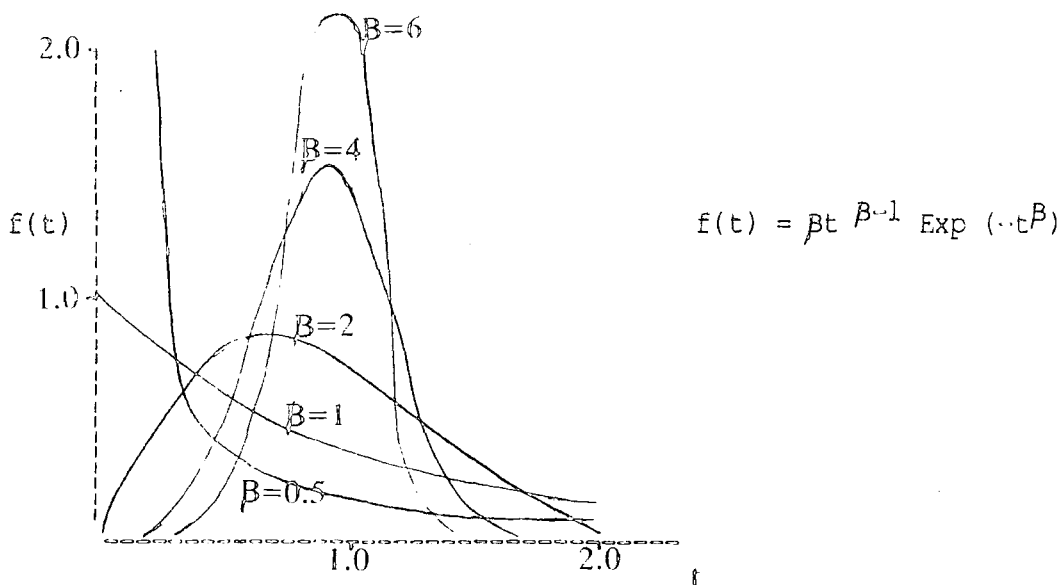
Further explanation of terms :

- 1) The threshold time to failure, or guaranteed life,  $t_0$  :

In many cases of wearout the first failure does not appear until some significant running time to has lapsed. In the Weibull expressions the time factor always occurs as the time interval  $(t-t_0)$ .

- 2) The characteristic life,  $\eta$  when  $(t-t_0) = \eta$ ,  $P(t) = \exp(-1) = 0.37$  i.e.  $\eta$  is the interval between  $t_0$  and the time at which it can be expected that 63% of the items will have failed and 37% survived.
- 3) The shape factor,  $\beta$ , Figure 7.5, shows how the various patterns of time to failure and of age specific failure rates are characterised by the value of  $\beta$ . A running in failure process is characterised by a value significantly less than one, a purely random process by a value fairly close to one, wearout by larger values, although if  $\beta$  is less than, say, 3 then a purely random factor is still significant.

Figure 7.5 : Influence of Shape Factor B on Weibull Distribution



The Weibull PDF can therefore be used as a failure diagnosis aid to help determine the cause of a recurring item failure. This is summarised in terms of the Weibull shape parameter, Figure 7.6

Figure 7.6 : Relationship Between Weibull B and Cause of Failure

	<u>Failure Pattern</u>	<u>Possible Failure Mechanisms</u>
Recurring Item Failure MTTF < Manufacturers Estimate	Age Related	
	----- Pattern $\beta > 2$	Accelerated Wear
	Time : Independent	
	----- Pattern $\beta = 1$	Process Error, Design Fault, Maloperation
	Early Failure	
	----- Pattern $\beta < 1$	Manufacturing Fault, Reconditioning Fault

CHAPTER 8 : EQUIPMENT MANAGEMENT PACKAGES .. SELECTION CONSIDERATIONS FOR  
PHILIPS DURHAM

It is outside the scope of this thesis to carry out a full user requirements specification for an equipment management package for Philips Durham.

However, it is possible to give further clarification of hardware and software requirements that will provide the functionality as detailed in Chapter 4.

8.1 Hardware Requirements

For processing purposes, the major factor to determine is whether the application would be best suited to run on a micro-computer (PC) a mini-computer or mainframe system. Essentially this will be determined not simply by the functionality of the application package but also the number of assets on the database, acceptable processing speed and the number of data terminals required.

However, as objective data on these criteria is difficult to obtain short of setting up prototypes on different systems and carrying out benchmark tests, logical assessments can only be carried out on related experience.

8.1.1 Number of Assets

Due to the large number of assets that would need to be included in the asset register and history files (there are at present over 300 major plant items on the inspection maintenance system) significant data storage would be required.

For comparison, the MTAS system at Nissan has approximately 200 assets on it and required about 20 MBytes of hard disk storage. A minimum requirement for Philips Durham, with over 300 assets giving some safety margin, would be 40 MBytes of hard disk storage. This figure is obviously highly dependent on the amount of data collected and stored

by the particular software package and to what level it is necessary to define assets. Comparison with data storage requirements for the EQUIP system would indicate that this figure is conservative.

#### 8.1.2 Speed of Processing

This is a major consideration with respect to hardware selection - if a user has to wait significant timespans for the system to process transactions - then overall the system will lack credibility.

Again, quantification of requirements is difficult. However, at Nissan the stand alone IBM AT PC based package was considered too slow and unresponsive with the resulting intention to update to a mini based version of the system. Not only were individual transactions slow and frustrating for the user, but batch style jobs were unacceptably long e.g. it took 10 hours to print the work dockets.

Comparison with the EQUIP system on its IBM AT PC would support the argument against a PC based solution. As the breakdown databases have grown over time, searches through them have become increasingly slower. If this trend were to continue then it is possible that the system would lose credibility due to its tardiness.

#### 8.1.3 Number of System Terminals

Although it is possible to determine the number of terminals required for data analysis and output purposes, the overall number of terminals is highly dependent on how data is to be input from the shopfloor. This in turn is dependent on the overall factory information strategy with respect to shopfloor data collection.

If data was to be directly input from terminals situated in the processing areas then approximately 15 terminals would be required.

For data analysis and display purposes then approximately 6 terminals would be likely :

- a) Central maintenance office. This could also be used for data input for solutions other than direct input from the shopfloor.
- b) Central Maintenance Department Head.
- c) Works Engineer.
- d) One for each of the three IMT Production Engineering Department Heads.

The selected solution would therefore have to support significant networking requirements.

With respect to the above requirements of data storage, processing speed and networking capabilities, a PC based solution for a maintenance management package is not felt to be viable.

Both mini and mainframe systems would have the technical capabilities to support our requirements. However, the overall cost of mainframe solution in terms of hardware, software, operation and maintenance costs would be much higher than a mini based solution.

As a possible part of our integrated system, special consideration has been given to the mainframe based COPICS module - plant maintenance. Although this module has excellent functionality, it is built upon another module, plant monitoring and control (Ref. 56). Plant monitoring and control is based upon a sophisticated network of shop floor systems designed to control product flow in a batch style operation. As such it has not been nor would be suitable to be implemented at Philips Durham. The COPICS plant maintenance module is therefore not a viable option for Philips Durham.

Overall, it is therefore concluded that the most appropriate hardware solution would be a mini based system.

With reference to computing facilities already installed on site with the possible availability for a package of this nature, Philips have available DEC Microvax 3300 and 3500 mini-computers. These are standard machines and obviously the selection of a package to run under VMS on one of these machines would dramatically reduce the cost of system implementation.

## 8.2 Software Requirements - Packages Comparison

With reference to the hardware requirements as detailed above, the mini based packages as summarised in Table 8.1 and further detailed in Appendix 7 have been analysed further.

Table 8.1 : Equipment Management Packages Considered

MAINPAC	Cruickshank Management Resources Ltd
MAINTENANCE MANAGEMENT SYSTEM	Hoskyns
INHAMMER MAINTENANCE MANAGEMENT SYSTEM	Idhammer
RAPIER	Resource Management Systems
TEROMAN	Scicon Limited
TEMPO	Tandem Maintenance Services Ltd
HELMSMAN	MTAS

A comparison across various relevant criteria is given in Table 8.2.

Experience gained from the EQUIP project has been used to help determine the relevant criteria and their importance when comparing various packages. These are detailed in the first and second columns of Table 8.2.

TABLE 8.2 : MAINTENANCE PACKAGES COMPARISON

Priority : (1) = Necessary, Lack would Exclude Package : (2) = Highly Desirable : (3) = Desirable

FEATURE	PRI	MAINPAC	PTS	HOSKYNS	PTS	IDHAMMAR	PTS	RAPIER	PTS	TEROMAN	PTS	TEMPO	PTS	HFI/MSMAN	PTS
<u>PACKAGE DETAILS</u>															
Hardware	N/A	DEC VAX		Portable Inc DEC VAX		DEC VAX		Portable Inc DEC VAX		Portable Inc DEC VAX		Portable Inc DEC VAX		Mini Based	
Established Supplier	3	Yes		Yes	1	Yes	1	No	0	Yes	1	No	0	Yes	
Implementation Support	2	Yes		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Post Sales Support	2	Yes - 10% of SWW Cost		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Documentation	1	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
On Line Help Facility	3	Yes		No		No	0	No	0	Yes	1	Yes	1	Yes	
UK User Group	3	No		Yes	1	Yes	1	No	0	No	0	No	0	No	
Interface to COPICS and GJC Possible (Real Time or Batch?)	1	No		Yes		Yes		Yes		Yes		Yes		No	
User Friendly Query Language	2	No		No		Yes	2	Yes	2	Yes	2	No	0	No	
Customisation Possible :															
- Fields	2	Yes		No		No	0	No	0	Yes	2	No	0	No	
- Menus	3	Yes		No		No	0	No	0	Yes	1	No	0	No	
- Report Formats	2	Yes		Yes	2	No	0	No	0	Yes	2	No	0	Yes	
Graphical Outputs	2	No * 1		Yes * 1	2	Yes	2	Yes	2	Yes	2	Yes	2	No	
Password Controlled Access	3	No		No		Yes	1	No	0	Yes	1	No	0	Yes	
Cost	N/A	£9,100		£11,000		£21,000		£21,000		£50,000		-		£10,000	

FEATURE	PRI	MAINPAC	PTS	HOSKYNS	PTS	IDHAMMAR	PTS	RAPIER	PTS	TEROMAN	PTS	TEMPO	PTS	HELMSMAN	PTS
<u>MODULES FUNCTIONALITY</u>															
<u>Plant Monitoring</u>															
Asset Register	1	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
Sub Assets/Asset Trees Clarification of Units and Modules	1	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
History File	1	Yes		Yes		Yes * 1		Yes		Yes		Yes		Yes	
Ability to Relate Machine Performance to Work Done	2	No		Yes	2	Yes	2	No	0	Yes	2	No	0	No	
Optimisation - Determine Most Cost Effective P.M. Frequency	2	No		Yes	2	No	0	No	0	No	0	No	0	No	
Failure Statistics eg MTBF	2	Yes		No		No	0	Yes	2	Yes	2	No	0	Yes	
Trend Analysis/Asset (Fault Analysis)	2	No		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Analysis of Equipment Failure by Factory, IMT, Department	2	Yes		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Ability to Add Customised Fields to History Databases	2	Yes		No		No	0	No	0	Yes	2	No	0	No	
Customised Analysis Reports eg Cusum Analysis/Machine on Lost Products	2	No		No		No	0	No	0	No	0	No	0	No	
Ability to Differentiate Between Time Spent on Preventive and Corrective Maintenance	2	Yes		Yes	2	Yes	2	No	0	Yes	2	No	0	Yes	
<u>Resource Planning</u>															
Logging and Scheduling of Jobs	1	Yes		Yes		Yes		Yes		Yes		Yes		Yes	
- Corrective															
- Planned Maintenance															

FEATURE	PRI	MAINPAC	PTS	HOSKYNs	PTS	IDHAMMAR	PTS	RAPIER	PTS	TEROMAN	PTS	TEMPO	PTS	HELMSMAN	PTS
Forecasting of Planned Maintenance with Regard to Different Bases	2	Yes		Yes	2	Yes	2	No	0	Yes	2	No	0	No	
Prioritisation of Jobs	1	No		Yes		Yes		Yes		Yes		Yes		No	
Job Scheduling Optimisation with Respect to :															
- Craft Type Required	1	No		Yes		Yes		Yes		Yes		Yes		Yes	
- Weekend or Weekday Job	2	No		No		Yes	2	No	0	No	0	No	0	No	
- Machine Status (Stopped or Running)	2	No		No		Yes	2	No	0	Yes	2	No	0	No	
Resource Analysis to Highlight Lack/Excess with Regard to Planned Workload	2	No		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Ability to Reschedule Jobs	2	No		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	No	
Docket Production	2	No		Yes	2	Yes	2	Yes	2	Yes	2	Yes	2	Yes	
Authorisation for SWO's	3	No		No		Yes	1	No	0	Yes	1	No	0	Yes	
<u>Condition Monitoring</u>															
Available	2	Yes		No		No		No	0	Yes	2	No	0	No	
Direct Link from Condition Monitoring to Job Scheduling	3	No		No		No		No	0	No	0	No	0	No	
Data Input to Condition Monitoring Module :															
1) Manual via Keyboard	2	Yes		No		No		No	0	Yes	2	No	0	No	
2) Automatically from Transducer	3	No		No		No		No	0	No	0	No	0	No	
<u>Shutdown and Project Planning</u>															
Available	3	Yes		Yes	1	Yes	1	No	0	Yes	1	Yes	1	No	

Continued ...

FEATURE	MAINPAC	HOSKYNS	IDHAMMAR	RAPIER	TERGMAN	TEMPO	BELSMAN
<u>ADDITIONAL NOTES</u>	* 1 : There is a sketching graphics module available which is used for entering drawing modifications on the plant history record.	* 1 : Requires DEC terminals and laser printers for hardcopy outputs.	* 1 : There is also a document record module which maintains a record of the location and details of drawings, instructions and manufacturer's manuals.		Significantly more expensive than other packages - is dependant on number of modules required. Approximately £10,000 per module.		
<u>SUMMARY AND POINTS SCORE</u>	Not possible to interface to COPICS. No prioritisation of jobs therefore not considered further.	Score : 29	Score : 33	Score : 20	Score : 44	Score : 18	Not possible to interface to COPICS. No prioritisation of jobs. Therefore, not considered further.

With respect to history files and failure statistics, when further clarification of requirements is necessary for more detailed decision making, consideration should be given to the points made in Chapter 7.

It was disappointing to note that as a general trend many packages do not appear to work effectively as integrated systems. Certainly packages have areas of strength but overall tend to be weak on the optimisation of functions necessary to determine cost effective levels of preventive maintenance i.e. relate work done to equipment performance and subsequently act upon the level of work done.

To provide an objective assessment of the packages against the assessment criteria a rating system was devised as follows :

Priority 1 : This is a qualifying feature. The package must contain this feature or else it is excluded from the selection. No points are given for this as it will be common to all rated packages.

Priority 2 : This is a highly desirable feature. The package is given a score of 2 if this feature is present.

Priority 3 : This is a desirable feature. The package is given a score of 1 if this feature is present.

The total possible score is 53.

Following this rating system it is recommended that the following packages should be given further consideration against a more detailed user specification :

- 1) Teroman (Score : 44).
- 2) Idhammar (Score : 33).
- 3) Hoskyns (Score : 29).
- 4) Rapier (Score : 20).

### 8.3 Implementation Requirements

To successfully implement a system of this nature (Ref. 47), consideration should also be given to the following requirements :

#### 8.3.1 Factory Wide Data Collection System

As previously stated for a system of this nature to operate there would have to be a viable factory wide data collection system on machine breakdowns. As such, the factory wide implementation of EQUIP (please see Appendix 6), albeit without some of its data analysis functions would satisfy this need. Furthermore, data already stored on the EQUIP system could usefully be transferred to the relevant assets' history files therefore reducing the payback period for any installed system.

#### 8.3.2 Implementation Considerations

Management would have to consider the following factors as well as the initial hardware and software costs if this type of system is to be implemented :

- 1) Implementation Resource : Setting up the system would involve a significant amount of clerical resource for initial data input. Engineering and computing resource would also be required (Ref. 44).
- 2) Due to the nature of a planned maintenance system a long payback period over which to cover the initial cost should be acceptable (Ref. 67 and 69).
- 3) CAM Strategy : At the time of writing no official information strategy exists. Obviously implementing shop floor data collection systems on a 'piecemeal' basis i.e. collecting equipment data but no product or process, may not fully support the long term interests and objectives of a subsequent CAM strategy.

- 4) Union Commitment : Craftsmen at Philips Durham are used to working in an environment where traditional attitudes prevail. To help prevent the data collection necessary by the craftsman from being perceived as a threat, consultation with the appropriate union bodies is necessary. The importance of gaining the craftsmen and first line supervisors acceptance of the system cannot be over emphasised.

### 8.3.3 Resource Availability for Planned Maintenance

Resource needs to be available to carry out the planned maintenance as detailed by the system. The present closed loop scenario of 'we cannot do planned maintenance because the men are busy on breakdowns' must be broken.

Possibilities are :

- 1) Production operators carry out '1st line' maintenance activities (previously discussed in Chapter 3).
- 2) Availability of mid week maintenance windows (previously discussed in Chapter 2).

### 8.3.4 Responsibility for System Operation and Maintenance

As with any other factory system, responsibility would need to be taken for system operation and maintenance as follows :

- 1) Process control operator : to be responsible for accurate and complete data input.
- 2) System operator : to do keyboard clerical tasks as necessary.
- 3) System manager : to be responsible for operational management of system.
- 4) System maintenance engineer : to provide hardware and software support.

#### 8.3.5 Audit

As with other factory systems, AQAP audits should be carried out on the system to determine if the responsibilities, as outlined above, are being undertaken.

#### 8.3.6 Performance Indicators

Performance indicators as to how well the system is being operated and maintained may also be important. Especially useful may be some measure of input data accuracy.

Performance indicators are necessary to show the effect of the system with respect to some stated factory performance figure. Regular feedback of this nature would enhance the credibility of the system by showing that the system is being used and that this is having an effect on performance. Suitable performance indicators are therefore further discussed in Chapter 9.

Introduction

In order to assess the effectiveness of an implemented change such as the introduction of an equipment management package, it is necessary to have performance measures that relate to the before and after scenarios. Performance indicators can be thought of as systematic tools to help foster and highlight improvement.

Before implementing further changes relating to the maintenance function, consideration should be given to the design and establishment of effective performance indicators (Ref. 81).

9.1 Performance Indicators : Requirements

In general, a performance indicator (PI) is a variable indicating the effectiveness and/or efficiency of a part or whole of a process or system against a given norm, target or plan.

As such, performance indicators can be extremely diverse; almost any activity can be measured. When a performance level is set and if the measurement of this performance level is quantitative, then this is classed as a performance indicator.

As well as relating to the overall objectives of the function the following conditions have to be fulfilled for the use of PI's to be meaningful :

- PI's should be well defined, understandable and available promptly. The raw data used to calculate a PI should have high integrity.
- PI's should be relevant i.e. referring to affairs or parameters that are controllable by the function.
- Targets have to be challenging but realistic.

- The presentation of PI's should be accompanied by an indicator of the target to be achieved.
- 'Supplier and customer' of a PI should agree on its relevance and meaning. In this scenario, maintenance PI's should be agreed within the Maintenance Department, between Maintenance and Production and between Maintenance and Management as appropriate.
- PI's have a relative character. Often they are specific to a unique set of conditions and therefore, in general, comparison with other PI's has little meaning and should be avoided. The most sensible comparison is with itself, at earlier instants of time.
- When implementing PI's, it is advisable to concentrate on a limited number of the most important indicators.
- PI's have to be used in combination with each other so as to cover all relevant aspects of an activity, product or service.

Therefore, to make successful use of performance indicators the maintenance function should be appraised with respect to its objectives or targets. Furthermore, each of these objectives should be prioritised. Parameters should be defined which enable actions to be monitored and related back to the overall objectives of the function.

When determining PI's for the maintenance function three broad categories should be considered :

- 1) Overall department performance.
- 2) Plant condition.
- 3) The use of any computer based maintenance system.

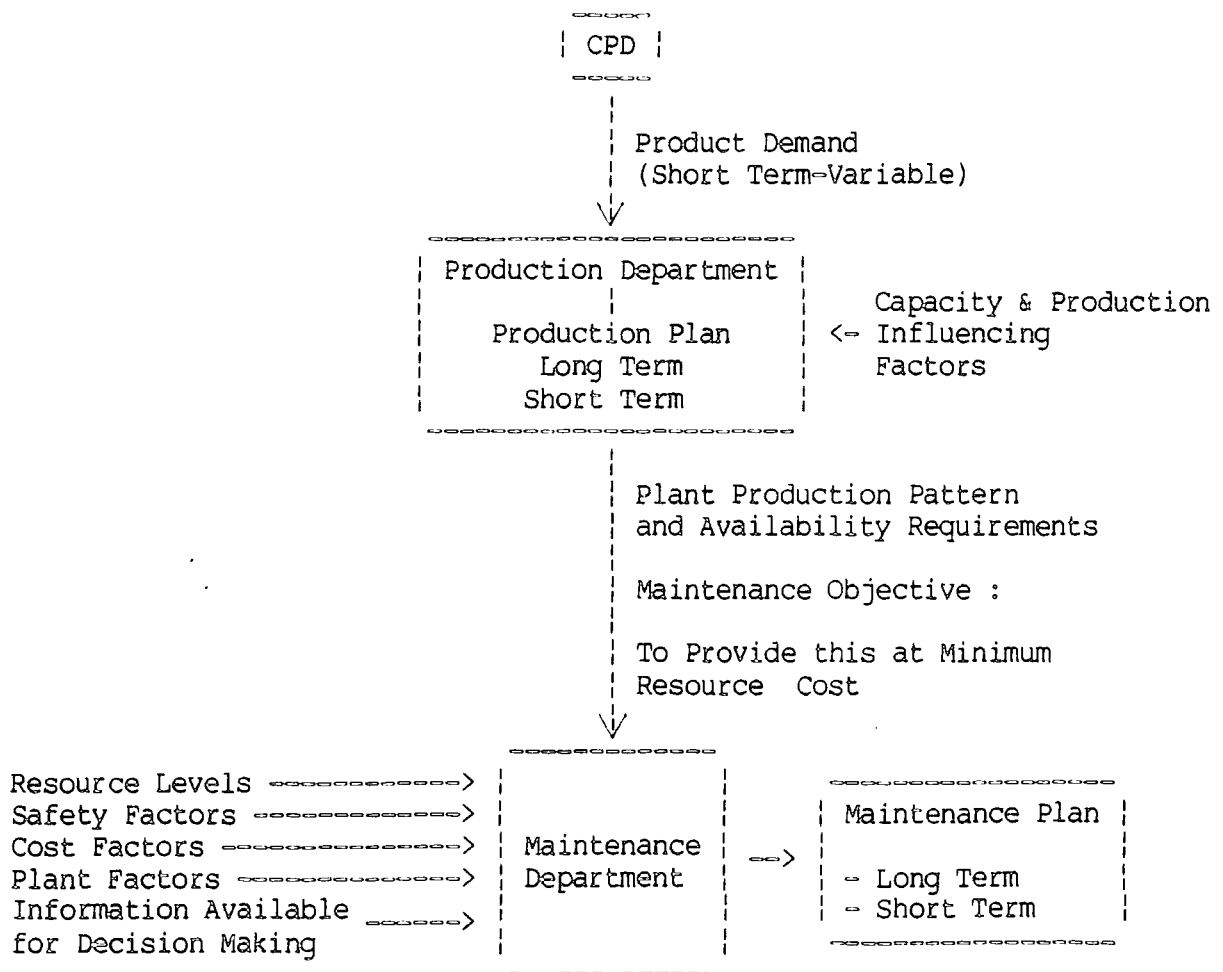
## 9.2 Overall Department Performance

### 9.2.1 Maintenance Activity and Production Capacity

As stated above, PI's should be related to the overall objectives of the function and the company, therefore, some consideration of these objectives with likely PI's will now be given.

For Durham the practical reality of the production maintenance system is that production dominates, the maintenance objective often being established as shown in Figure 9.1.

Figure 9.1 : The Production Maintenance System



The maintenance objective in this case can therefore be defined as 'to provide production with the long and short term plant availability requirements for the planned productions, at minimum direct and indirect costs.

At the top level, the direction of the maintenance function should be related to the overall financial performance of the plant.

Maintenance affects a Company's financial performance in a number of ways, the most important of which are :

- a) The relationship with availability; this is the major indirect cost of maintenance.
- b) The cost of maintenance resources; this is the direct cost of maintenance.
- c) Its relationship with the useful life of the plant; the longer the plant life, the greater is the life cycle profitability.

In general, the greater the level of maintenance resources (higher direct cost) the lower the level of unavailability (lower direct cost) and the longer the useful life of the plant. Thus, in most industrial situations the proper maintenance objective should be to minimise the sum of the direct and indirect costs, taking into consideration the long term effect of any maintenance decision. Ideally, performance indicators relating to overall department performance should reflect this relationship.

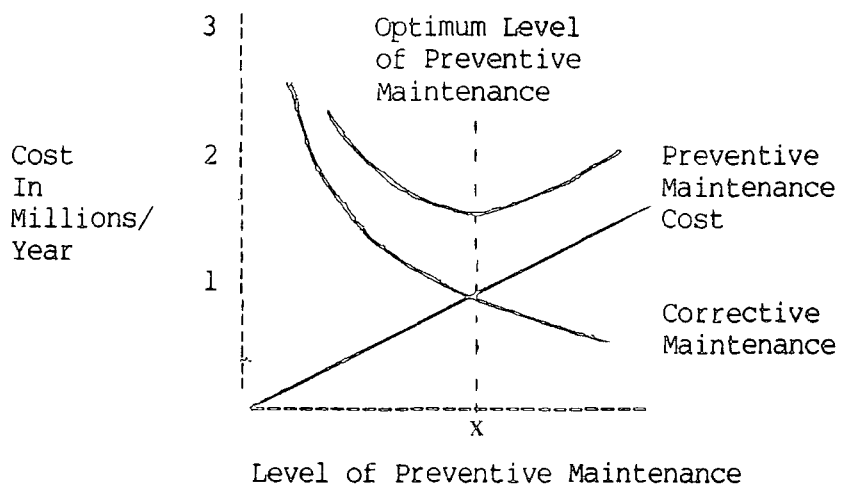
As previously discussed, the maintenance plan should consist of a schedule of preventive maintenance work and guidelines for the implementation of corrective maintenance work. Overall, it should ensure that the maintenance resources are directed so as to minimise the cost of maintenance whilst achieving the planned output. Departmental performance measures should therefore give some indication of this relationship.

i) Factory Level

The standard model of cost optimisation showing the balance between preventive and corrective maintenance costs has been interpreted for Philips Durham and is shown in Figure 9.2.

As previously stated, with respect to this model a major difficulty is fixing the level and type of preventive maintenance balanced against the cost of corrective maintenance and machine availability.

Figure 9.2 : Relationship Between Preventive Maintenance and Total Maintenance Cost for Whole Factory



It will be demonstrated that for Philips Durham there is a high cost for plant unavailability - this is normal in a high capital plant. As an indication of overall control of the plant by the Maintenance Department, it would be reasonable to expect a relatively high level of preventive maintenance thus preventing high cost outages.

Table 9.1 gives an indication of the average amount of time spent on each category of work across trades. The data represents midweek activity, sampled across three shifts, for a total sample size of 6 weeks.

Table 9.1 : Approximate Percentage of Workload Types  
by Trade

Trade	Inspection Maintenance	Corrective Maintenance Line Down	Corrective Maintenance Line Not Down	Misc
Mech'l	8	4	67	11
Elec'l	6	10	74	10
Tech'l	7	56	28	9

Data gathered for weekend work indicates a slightly higher percentage of inspection maintenance - approximately 15%.

The low inspection maintenance and high corrective maintenance figures from this table would indicate that the Maintenance Department has little control over plant activity. With respect to Figure 9.2, we are overall currently operating to the left of position x.

A further conclusion from this data is that although much of the work for the mechanical and electrical trades is of a corrective nature, much of it can be deferred and the process equipment restarted. This does not appear to be so for electronic and software problems requiring the attention of the technicians. This is therefore a key area in which preventive actions should be taken (Ref. 70).

This balance between preventive and corrective workload is a valuable indicator of overall maintenance performance. Data to generate an indicator of this nature is relatively easy to collate by Shift Engineers.

ii) Bottleneck Area

Although data on direct costs is relatively easy to obtain, accurate data on indirect costs is less readily available. The most significant problem with respect to obtaining this information is the lack of accurate downtime information in bottleneck production areas where 'EQUIP' has not been installed. Other information required i.e. bottleneck definition, throughput rates and financial data is more readily available.

Although downtime is difficult to obtain at present, this situation should be rectified so as to make PI's of this nature possible. Including the indirect costs of maintenance to the organisation has a major implication on the maintenance decision making process.

The following calculations are valid only for the bottleneck area for each of the tube types. At Durham the factory bottleneck is likely to be in one of three or four critical process areas. As PI's are used to monitor performance over time, separate details for each of these areas should be produced.

Cost Calculations

Bottleneck Area : APM/AMH

Direct Cost : The average monthly maintenance cost for this area is £20,000. This figure was obtained from the maintenance budget.

Of this approximately 80% is corrective maintenance and 20% is preventive maintenance.

Indirect Cost :

NB : The following calculation is intended only to produce a ballpark figure for machine unavailability costs.

Assuming :

- i) £13 recovery of fixed and semi fixed overheads for each FS tube produced.
- ii) £16 recovery of fixed and semi fixed overheads for each CMT tube produced
- iii) The line is fully loaded

Indirect Cost of Maintenance (i.e. Lost Output) :  
Downtime of Bottleneck x Throughput x Lost Recovery of Overheads

The downtime of equipment is estimated using data from the equipment performance summary sheets and modifying with respect to the number of process positions (APM = 4 cabinets, AMH = 5 cabinets) :

APM : FS D'time / Month : Avge No of Hrs (Jan-July 89) = 23  
: 23 x 240 x 13  
: £71,760

AMH : FS D'time / Month : Avge No of Hrs (Jan-July 89) = 39  
: 39 x 196 x 13  
: £99,372

AMH : CMT D'time / Month : Avge No of Hrs (Jan-July 89) = 39  
: 39 x 62 x 16  
: £38,688

Total : £209,820

Therefore, approximately £200,000 of production loss per month is sustained through equipment breakdown.

To summarise :

Estimated costs for APM/AMH when it is the factory bottleneck area :

Maintenance Direct Cost	: Breakdown	: £16,000
Maintenance Direct Cost	: Preventive	: £4,000
Maintenance Indirect Cost		: £200,000
		=====
Total Maintenance Cost		£220,000
		=====

Figure 9.3 (a) shows a possible graphical representation of this data.

Figure 9.3 (b) implies that the total cost of maintenance could be greatly reduced by radically increasing the amount of preventive maintenance.

From Figures 9.3 (a) and 9.3 (b) it can be seen that the optimum level of preventive maintenance changes greatly when indirect costs are taken into consideration.

Therefore to give an indication of how the maintenance function is affecting the overall plant operation, the level and type of maintenance activity in relevant bottleneck areas could be reported as in Figures 9.3 (a) and 9.3 (b). Obviously when generating the individual graphs some interpolation as to their precise loci is required. However, the value of graphs of this nature is that they illustrate the significance of the maintenance activity within the bottleneck department and relate this to overall factory performance.

Figure 9.3 (a) : Present Maintenance Costs for AMH/APM Department when Bottleneck Area

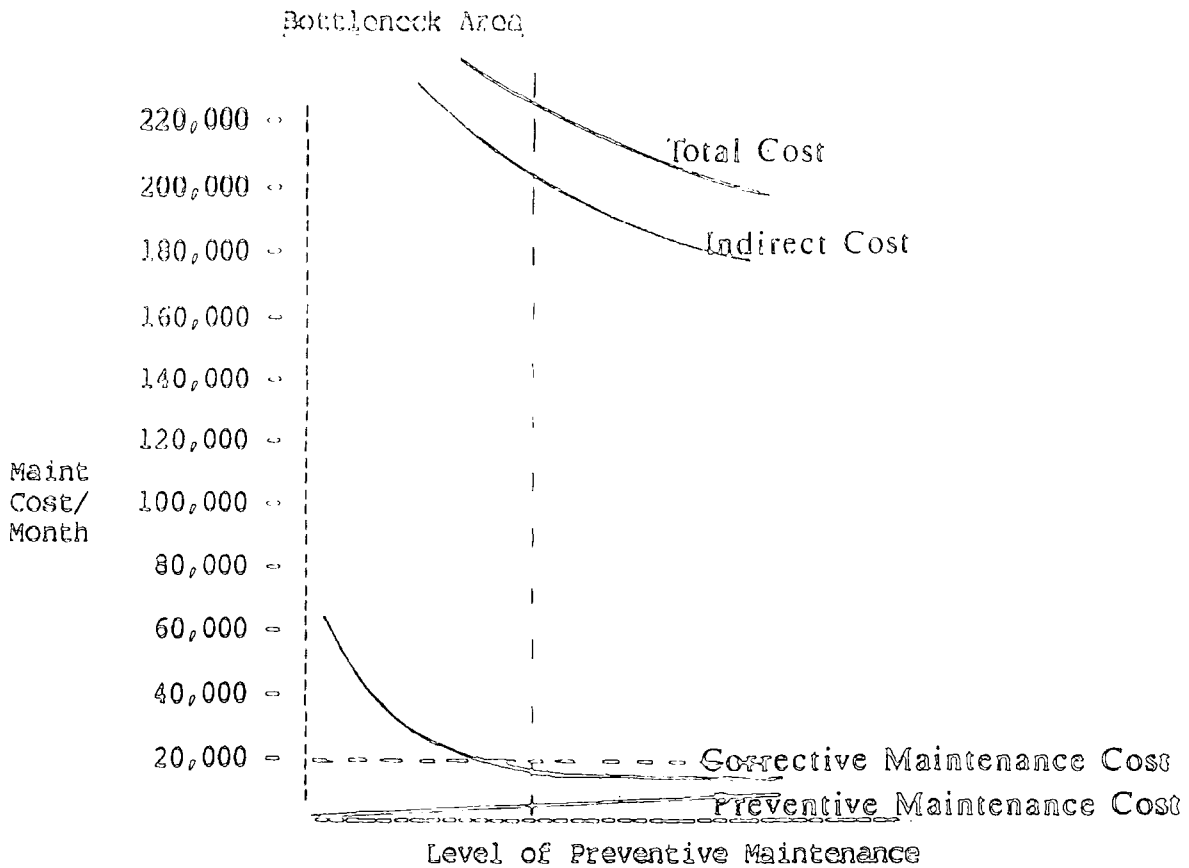
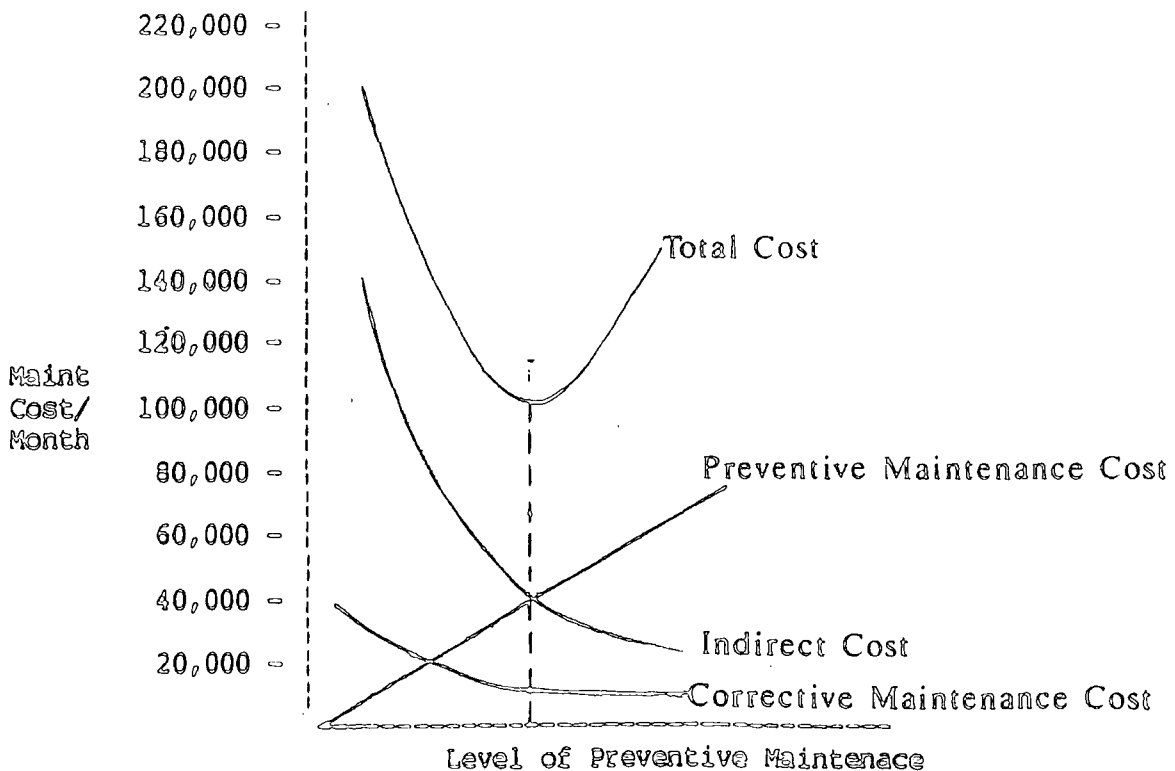


Figure 9.3 (b) : Idealised Reduced Maintenance Costs for AMH/APM Department when Bottleneck Area



9.2.2 Direct Cost Index

A further standard indicator which may be of interest with respect to monitoring overall department performance is the Direct Cost Index.

$$\text{Direct Cost Index} = \frac{\text{Direct Maintenance Costs}}{\text{Replacement Value of Maintainable Assets}}$$

All the above indicators may be calculated for the maintenance activity as a whole or broken down via trade, machine group or Production Department.

9.3 Plant Condition

As well as determining PI's to monitor the overall effectiveness of the Maintenance Department a more detailed assessment of machine performance is also necessary.

Consideration of the resolution of plant data required should be given when determining the PI's.

Comparison of machine performance across similar pieces of plant would be useful to determine if any individual machine is showing any large deviation from the mean. However, care should be taken in grouping items together that they are of similar functionality, comparable age, equivalent level of use etc.

Potential PI's are :

$$\text{a) Asset Availability} = \frac{\text{Planned Capacity} - \text{Total Downtime}}{\text{Planned Capacity}}$$

$$\text{b) Total Downtime} = \text{Breakdown Hours} + \text{Lost Production Hours}$$

$$\text{Total Downtime \%} = \frac{\text{Hours of Downtime}}{\text{Planned Capacity}} \times 100$$

Breakdown Hours

$$c) \text{ Breakdown \%} = \frac{\text{Breakdown Hours}}{\text{Planned Capacity}} \times 100$$

$$d) \text{ Utilisation \%} = \frac{\text{Planned Capacity} - \text{Total Downtime}}{\text{Planned Capacity}} \times 100$$

$$e) \text{ Mean Time Between Failure (MTBF)} =$$

$$\frac{\text{Total Running Time}}{\text{No of Breakdowns}}$$

$$\frac{\text{Planned Capacity} - \text{Breakdown Hours}}{\text{No of Breakdowns}}$$

1

$$f) \text{ Failure Rate} = \frac{1}{\text{Mean Time Between Failure}}$$

MTBF and failure rate figures are not readily available for equipment at Philips Components.

#### 9.4 Computer System Effectiveness

The overall business effectiveness of any installed computer system would intrinsically be linked to the performance indicators detailed above.

However, audits of any installed system would be necessary to ensure that the system was being used and managed effectively. Specific areas of interest may be :

- a) Integrity of data being input to system.
- b) Validity of reports automatically produced.
- c) Backup and system security.

10.1 Conclusions

1) Maintenance Strategy

Intense competitive pressure and greater factory automation is bringing renewed impetus to comprehensively re-organise and formalise the maintenance process. Due to the capital intensive nature of its plant, an effective maintenance strategy is highly desirable for Philips Components Durham.

2) JIT and Equipment Reliability

The JIT manufacturing philosophy is dependent upon an effective maintenance operation with guaranteed reliability of plant. The level of equipment/breakdowns and high percentage of corrective maintenance at Philips Components Durham is at present an obstacle to JIT production. Therefore to move towards JIT production from the present position would require improved preventive maintenance resulting in greater equipment reliability.

3) Capacity and Maintenance Planning

Unavailability cost is the dominant factor in the design of a maintenance organisation. Consideration should therefore be given to factory capacity when determining maintenance policy. Each production department should not be viewed in isolation, instead consideration must be given to the plant as a whole when determining the individual strategy for a department. It is likely to be both uneconomic and non viable to attempt to achieve an equivalent breakdown target e.g. 5% in all departments. Instead targets should be set with relative departmental capacities in mind.

4) Maintenance Resources

At Philips Components, to increase the level of preventive maintenance further resources must be identified to carry out the work.

5) Maintenance Windows

If equipment reliability could be guaranteed it would then be possible to implement midweek maintenance windows on non bottleneck areas.

6) Software and Electronics - Preventive Maintenance

Although much of the work of the mechanical and electrical trades is of a corrective nature, much of it can be deferred and the line brought back up. This is not so for work carried out by the technicians - the line tends to be down until the fault is dealt with. This equipment category should therefore be given extra consideration with respect to preventive techniques such as design out maintenance.

7) Work Planning and Control Systems

- i) To improve the effectiveness of preventive maintenance procedures an improved work planning and control system is required.
- ii) There are many equipment management systems on the market. We would require an integrated system to be used for plant monitoring and optimised resource planning with interfaces to our budgetary control system and also COPICS.
- iii) Evidence from industrial visits indicates that such a system is only viable in an appropriate environment. At Nissan, there is a 'progressive' organisation with flexible working practices. This has led to the installed system being used as an effective tool in

controlling the maintenance function. At Philips Hamilton, there was a 'traditional' organisation with inflexible working practices. Here, the system was not being used as an effective tool and had even compounded an industrial relations situation.

This would indicate that following the recent organisational changes, the environment at Philips Durham is now more suited to a system of this nature. This would therefore be a suitable opportunity to formally review the feasibility of such a system for Durham.

8) EQUIP

As a pilot project the development and implementation of the EQUIP system has been successful with respect to the following points :

- i) It provides more accurate and detailed information on causes of lost utilisation than was previously available. Analysis of EQUIP data indicates that it also provides a record of machine faults which are corrected by production, sometimes up to 90% of incidents. These would otherwise not be drawn to the attention of the maintenance department.
- ii) Perhaps most importantly, as a pilot project EQUIP has clearly highlighted the management issues which must be addressed if considering the implementation of an equipment management system. Greater benefits could be gained from the present EQUIP systems if these issues were resolved.
- iii) The system has been of some use in improving the availability of equipment in the area.

- iv) Technical issues raised by EQUIP will serve as a useful input to a user specification for a total maintenance management system. Specific areas highlighted to date are optimisation of the planning and feedback functions, statistical techniques and interfacing requirements.

9) Statistical Techniques

Mathematic models can be usefully employed in describing failure patterns. Analysis of failure data can give insights into the cause of failure and can be used to help determine the most appropriate maintenance strategy. Experience gained from the EQUIP project would indicate that, to carry out statistical analysis of this nature, the following issues must be considered :

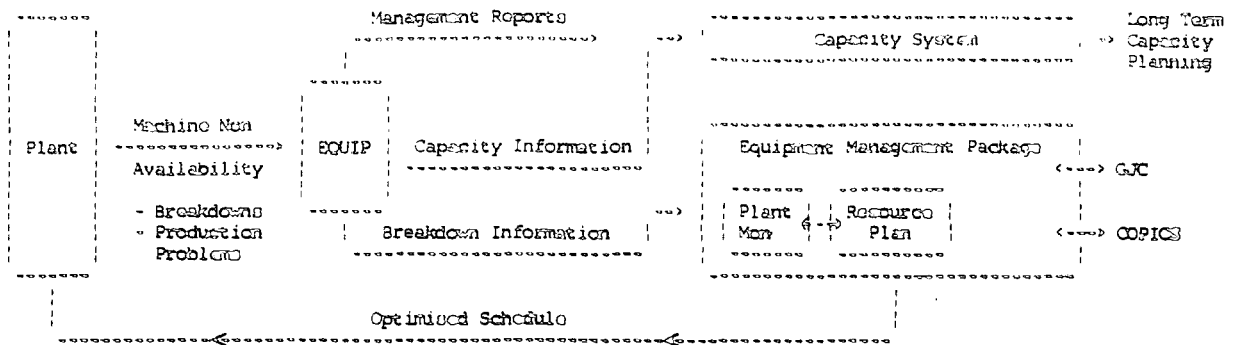
- i) Item Definition. To facilitate analysis of the mode of failure, machinery needs to be categorised down to replaceable parts.
- ii) Diagnostic Training for Production Personnel. Training in diagnostic techniques for data input personnel would be necessary to ensure that causes not symptoms are being accurately diagnosed and recorded correctly.

10) Factorywide EQUIP

The benefits of implementing EQUIP on a factory wide basis should be assessed with respect to the following areas :

- i) Factorywide EQUIP, possibly without some of its analysis functionality, would be a suitable precursor to the successful implementation of an equipment management package. Irrespective of the package selected, accurate shop floor data would be required.
- ii) A factorywide system would also be very appropriate as a data collection system for a capacity analysis package e.g. CBIS. A possible systems configuration is given in Figure 10.1.

Figure 10.1 : Factorywide EQUIP - Possible Developments



11) System Selection

With reference to technical constraints any further system development should not be done on a PC based system. Due to the cost of mainframe operations a mini based hardware solution for a equipment management package is likely to be most economic.

12) Performance Indicators

Performance indicators relating departmental performance to overall factory objectives or detailing individual machine performance are not in place.

13) Acceptance Testing

To provide quality reference 'benchmarks' and thus improve the validity of inspection maintenance routines, acceptance testing should be carried out where appropriate. As major equipment from Eindhoven is often delivered in stages, a system of this nature would also highlight any tools, drawings, test equipment or training required in order to effectively maintain the equipment.

## 10.2 Recommendations

### 1) Maintenance Strategy

A formally published maintenance strategy would be a useful document for maintenance personnel.

### 2) JIT and Equipment Reliability

A maintenance policy with greater emphasis on preventive maintenance should be formally initiated.

### 3) Capacity and Maintenance Planning

Factory capacity implications should be taken into account when setting departmental equipment performance targets.

Efforts to achieve a viable preventive maintenance operation should be intensified in bottleneck areas. In capacity critical areas techniques such as design out maintenance and condition monitoring should be considered further.

### 4) Maintenance Resources

Production personnel are a major untapped resource with respect to equipment maintenance. Due to their job function they are in a position to be closely aware of the performance of the equipment they operate. As such they are ideally suited to become more formally involved in plant maintenance.

Furthermore, it would be unrealistic not to involve production in maintenance activities - the maintenance department does not have the resources to carry out maintenance routines to the necessary level of detail.

Following the recent re-organisation, under the guidance of the Area Maintenance Engineer, production operators could be trained to :

- i) Carry out 1st line inspection maintenance on the production equipment they operate (and are possibly responsible for). There are many examples of such procedures operating successfully, the apparent key being that the system is carried out in a formal manner.
- ii) Carry out 1st line breakdown maintenance. Essentially to ensure production personnel who deal with some incidents of equipment failure are adequately trained to do so and effectively report on the situation.

The above suggestions are essentially based on the Total Preventive Maintenance philosophy which possibly could be further pursued at Durham under the multi-functional worker project. As well as proving job enlargement for production personnel the above suggestions would also improve their diagnostic skills and thus the quality of preventive and breakdown maintenance data being recorded.

This type of operation would tend to naturally lead to the formation of multidisciplinary work teams which in turn would serve to reduce the conflict that presently exists between production and maintenance.

Furthermore, some skilled craft resource would then become available, facilitating further moves to improve the quality of preventive maintenance service to the plant.

The possible problem of inappropriate skill profiles of craftsmen within the departments could be resolved by multiskilling. The trend towards greater automation will further increase Durhams need for highly skilled technicians. The retraining of mechanical trades to achieve the necessary standard of electronic and software skills is likely to be the most common requirement but due to the different technical environment this will not be easy to achieve. This course of action should therefore only be embarked upon if the above recommendations do not satisfy our resource requirements. If there is a decision to move towards multiskilled craftsmen this should be handled with diplomacy by management and the appropriate unions consulted as early as possible.

5) Maintenance Windows

A further method of increasing the quality of maintenance service with the present level of resource would be the creation of mid-week maintenance windows on areas with excess capacity. This would also support JIT and OPT philosophies.

This is essentially a two stage process :

- i) Machine reliability in areas with excess capacity needs to be guaranteed to a set level.
- ii) The excess capacity can then be utilised for maintenance purposes. Stoppages should be planned so as to minimise the effect on production and with consideration of the maintenance tasks which must be carried out.

Obviously, the use of an accurate capacity model would be necessary when making these decisions.

6) Software and Electronics - Preventive Maintenance

A high percentage of lengthy breakdowns in the factory are the result of software problems on process equipment. These problems are not quickly resolved because often the software has not been designed with consideration of maintenance requirements. The new standard IEC848, proposing modular software design, should be actively supported by Philips Durham.

This issue again highlights the need for highly skilled technicians. In areas of high complexity, the use of diagnostic expert systems may facilitate speedier problem correction.

7) Work Planning and Control Systems

A feasibility study should be formally carried out on the technical and economic viability of an equipment management system. Part of the terms of reference of this study should be to further investigate the viability of dependent requirements on maintenance stores items.

The technical issues raised by EQUIP should be incorporated into this study.

8) EQUIP

The management issues raised by EQUIP should be resolved so as to realise further benefits in the areas in which it is already implemented.

If a decision is made to proceed with the purchase of an equipment management system then these management issues should be considered in any implementation plan.

9) Statistical Techniques

Further experience of statistical techniques would be useful for maintenance personnel.

The application of modular design concepts and the use of common components in process equipment would enhance the viability of using statistical techniques.

10) Factorywide EQUIP

EQUIP should not be further expanded into the factory until a decision is reached on the possible implementation of an equipment management package.

If there is a decision to proceed with the implementation of such a package then the functionality of EQUIP should be reviewed with reference to its use as a shop floor data collection system with some simple analysis capabilities but essentially serving as a 'front end' to an equipment management and capacity planning system. Consideration at this stage should also be given to the Product Identification project.

11) System Selection

On site at Philips Durham there are Microvax systems running under VMS with capacity for a system of this nature. It is therefore recommended that a preferred solution would be to select a software package suited to this environment.

It is also recommended that a systematic selection procedure be used to assess packages against a user specification.

12) Performance Indicators

Should be reviewed and new indicators implemented as appropriate.

13) Acceptance Testing

Should be implemented as appropriate.

Financial Times Friday February 26 1988

## INTL. COMPANIES AND FINANCE

Laura Raun and David Thomas on the Dutch group's policy choices

## Philips earnings blow a fuse

THE REVELATION yesterday of a 19 per cent drop in Philips's profits for 1987 capped what has, by any standards, been a sombre year for the Dutch electronics group.

Not only was its return on sales lower than at any time during the 1980s, but key elements of overall policy ran into the sand.

Mr Cor van der Klugt, president, has fashioned a strategy based on a clear division between the group's core businesses - consumer electronics, information technology, electronic components and lighting - and its more peripheral activities, such as large domestic appliances and medical equipment.

While Philips will retain full control of the core, it is seeking

Philips blamed the collapse of its joint-venture talks on the *bête noir* which loomed over all its results - the decline of the dollar. Its fall meant that both partners had to renegotiate the value of what they were bringing to the table and, in the end, Philips was not prepared to pay the price demanded.

The dollar also played more general havoc with Philips, which has 40 per cent of its sales but only 25 per cent of its costs in dollar-linked countries. Stripping out currency factors, Philips actually managed a 7 per cent increase in sales volume last year.

The company has shown some hesitation over how to respond to these currency fluctuations.

Ideally, Mr Van der Klugt joked, Philips would have factories on supertankers steaming around the world to whichever country offered the lowest costs at a given time.

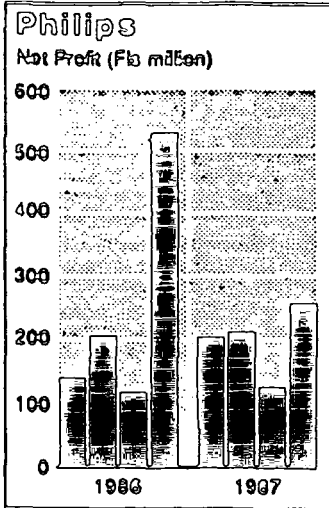
In the real world, as the Philips president wryly acknowledged, factories take longer to shift, though he gave a clear signal that Philips would site more plants in low-cost-dollar areas, such as Mexico.

Yet the dollar is only one of the multitude of problems crowding in on the Dutch multinational.

Many of these were recognised during the mid-1980s but restructuring efforts then failed to improve profitability. They include:

Overmanning: Philips's sprawling empire, marked by hundreds of factories established in the days before markets became so international and by a stifling bureaucracy symbolised by the massed numbers of workers in its Eindhoven headquarters, has long seemed ripe for rationalisation.

Mr Van der Klugt announced yesterday stern measures, with up to 20,000 jobs facing the axe over the next year or so. They will mainly be in support functions, though Philips is also set-



ting out to reduce further the number of its factories, following consolidation in recent years.

Marketing: while Philips is noted for the technical excellence of many of its consumer products, doubts linger about the speed with which goods get to the market which, under the influence of the Japanese, is marked by shorter product-life cycles.

An example is the combination CD video player, the launch of which last summer was followed by a period of deafening silence. Mr Van der Klugt named September as the new European launch date, blaming software and hardware hitches for the delay.

The US: Philips faces the urgent task of strengthening its operations in North America which last year accounted for only 22 per cent of total sales.

"We're striving to strengthen our position in North America, whether there is a higher dollar or a lower dollar," Mr Van der Klugt insisted, adding that even divisional headquarters might be moved there.

In the short term, Philips is faced with the task of increasing awareness of its brand

name in the US, now that it has bought out the minority shareholders of its North American subsidiary.

The company is planning some restructuring of its businesses in North America, which last year generated profits of just Fl 18m (80.47m) on sales of Fl 11.89bn.

Philips sees the US as a crucial market that must be fully exploited if it is to succeed as a global company. Mr Van der Klugt acknowledged, for instance, that it was looking at ways of becoming more involved in key segments of the important computer market, such as micro-computers.

Philips will also have to notch up successes in the not too distant future if its strategy of seeking partners for its

## The collapse of talks were blamed by the group on a declining dollar

joint ventures in its peripheral businesses to secure for them a world presence.

Yesterday, Mr Van der Klugt reaffirmed that vision. "We cannot achieve these high ideals for all our divisions alone," he said.

But last year saw dramatic setbacks for some of Philips's most important attempts to find partners for its peripheral activities.

Talks aimed at spinning off its large domestic appliance operations into a joint venture with Whirlpool of the US collapsed, as did negotiations with General Electric of the UK over a partnership in medical equipment.

At the same time, Philips's role in its public switching alliance with American Telephone & Telegraph was downgraded, following a failure to break into European markets as quickly as AT&T had anticipated.

## By the end of 1988 Philips will want to show it has got on top of problems

peripheral businesses is not to lose credibility.

Mr Van der Klugt stressed that the group still wanted partners for its large domestic appliance and medical businesses. He also disclosed that the group had resumed discussions with Agfa Gevaert, part of the West German Beyer group, about joining Philips's existing joint venture, with Dr Pont of the US, in audio tapes.

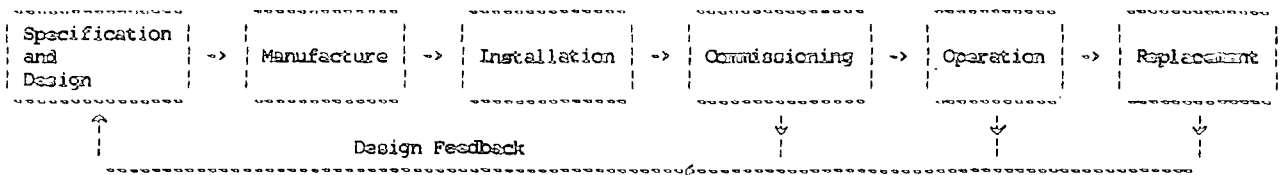
As Mr Van der Klugt implicitly acknowledged, this is a year of transition for Philips.

By the end of 1988 it will want to show it has got on top of its problems. Otherwise, the members of Philips's board will no longer be able to duct the one question which visibly unsettled them yesterday: Why have most of its Japanese counterparts adopted more swift to the ravages brought about by the dollar's decline?

## APPENDIX 2 : DESIGN FOR MAINTENANCE

The demand on maintenance resources and the achieved plant availability during the operation stage (see Figure A.2.1) are affected by factors at other stages in the equipment lifecycle.

Figure A.2.1 : Phases of the Equipment Lifecycle



At the design stage, reliability and maintainability are important and must be considered in relation to equipment performance, capital cost and running cost. Traditionally, emphasis has been put on performance and on capital cost, at the expense of reliability and maintainability. Obviously, if a piece of equipment has inherent design flaws with respect to reliability, there is little in maintenance terms the end user can do to improve the performance of such equipment. Improvements will only be achieved through modifications to the original design - 'design out maintenance'. This, however, can be a costly and protracted process.

Consideration should also be given to the type of production process the equipment is to be used in. For example, if the equipment is to be used in a continuous rather than a batch process, design criteria should encompass the much higher maintenance costs that inevitably occur.

Quality control procedures during equipment manufacture can have a strong influence on the subsequent level of maintenance during the operational phase.

Clearly, the best time to influence maintenance and unavailability costs is before the plant comes into use. It is therefore essential that systems and procedures are devised which will ensure that plant, when handed over to production, will not only perform its function but can also be serviced by the maintenance department in an efficient manner. To facilitate this the following points should be noted :

- 1) Plant production and maintenance personnel should liaise with the designer - manufacturer - installer to give a full analysis of its reliability, maintainability and safety characteristics. Such a 'plant procurement' exercise should include assessment of spare part provisioning, of maintenance personnel training and supplier support systems. The higher the potential costs of maintenance and unavailability the more vital is this exercise.
- 2) Decisions to buy new or replacement equipment should be based on a present value life cycle analysis of costs. Such an analysis must take into account both maintenance and unavailability costs.

- 3) Plant personnel and the supplier should co-operate in the collection and analysis of plant failure and maintenance data in order to identify problem areas. In certain circumstances such data could also be fed back to a central database to be shared on an inter-company basis.

The difficulties of these operations continue to pose a major obstacle to the successful implementation of a terotechnological approach; communication systems can be expensive and different organisations, with different objectives, are involved during the equipment life cycle.

Product, process and equipment design is carried out for Philips Durham by a central organisation at Philips Eindhoven. Within tube assembly plants there is evidence of insufficient integration between product, equipment and process development at Eindhoven. In general, in the factory it is thought that 'design for maintenance' requirements are not given sufficient consideration, although this type of expertise is often available in the assembly plant. Overall, Eindhoven designs tend to be complex. There appears to be philosophy of designing from first principles which results in even standard equipment eg conveyors, having little modularity, low reliability, high costs and poor delivery performance. This has resulted in a move towards the purchase of non strategic plant equipment from third party suppliers.

Examples where Eindhoven design has not accommodated maintenance requirements are :

- 1) Difficult access to replaceable parts - cone pour neck wash machines. The belt drive for this machine is not in an accessible position and therefore the machine must be dismantled to replace it.
- 2) Process control software. This is an area of particular concern as failure can result in a line remaining down until the problem is resolved. AMH and CMT plc software was written by specialist experts. The difficulty for Durham is to provide sufficient technical expertise to ensure comprehensive cover of what are often large and complex programs. This problem is now being addressed and agreement upon a modular software standard IEC848 will hopefully be made by the design and production organisations.

### Acceptance Testing

At the installation stage, maintainability issues are highlighted and it is only then that the multi dimensional nature of many of the maintenance problems become clear. The commissioning stage is not only a period of technical performance testing but also a learning period where primary design faults that might affect equipment availability can be located and designed out. At this stage an important, but sometimes overlooked, preventive maintenance practise can be carried out - acceptance testing. A major purpose of this test is to provide a quality reference or 'benchmark' for subsequent preventive maintenance tests. Future comparison of test data with this initial information can help in the detection of sudden or long term deterioration trends before equipment failure occurs. Furthermore, a procedure of this nature would also highlight any tools, drawings, test equipment or training required in order to effectively maintain the equipment.

### APPENDIX 3 : CONDITION MONITORING

When determining the maintenance strategy for a particular asset and considering the implementation of a condition based monitoring technique, five conditions should be satisfied :

- 1) The existence of failures which do not occur at regular intervals.
- 2) These failures are either a safety hazard or incur significant costs in lost production, breakdown maintenance labour and materials.
- 3) A monitoring method exists that can give sufficient advance warning of an impending failure for the maintenance/production system to act to avoid failure.
- 4) The monitoring and corrective maintenance costs are less than the lost production and breakdown maintenance.
- 5) The monitoring method is compatible with existing company procedures, workforce attitudes and expertise.

This fifth condition can lead to the specification of a condition monitoring technique :

- i) Simple to use.
- ii) Relative insensitivity to sensor location.
- iii) Insensitivity to the load condition of the machine.
- iv) Robust equipment to withstand an industrial environment.
- v) Intrinsically safe both in technical terms and manner of use.

Unfortunately it is likely that few techniques would meet all these specifications for a given situation. Care should therefore be taken with the selection of a technique to ensure that problems associated with the technique are not such that the technique becomes non viable.

### Techniques and their Applications

The major causes of plant deterioration are :

- 1) Wear at the interfaces between parts with relative motion.
- 2) Deformation or crack growth due to over stressing.
- 3) Overheating due to overload, loss of lubricant or coolant, or failure of insulation.
- 4) Corrosion or erosion.
- 5) Electrical.

These can be monitored by five main groups of monitoring techniques as shown in Table A.3.1.

Figure A.3.1 : Simple Monitoring Techniques

Cause of Deterioration	Monitored Parameter	Simple Techniques
Wear between Moving Parts	Material Content in the Lubricant	Magnetic Plugs, Filters
Deformation or Crack Growth due to Overload	Vibrations Indicating Damage in Moving Parts	Stethoscope, Shock Pulse, Total Vibration
Overheating	Temperature	Adhesive Temperature Indicators, Paints, Crayons, Hand Thermometers, Bulb and Bimetallic Thermometers
Corrosion, Erosion	Dimensional Checks	Tell-tale Holes
Electric Motors	Leakage Flux	Sensor Coil with Portable Plug In Meter

1) Wear

Damage at the interface between parts with relative movement can usually be detected from the condition of the lubricant. Here the basic technique is to examine the condition of debris in the lubricant. The size, shape and general appearance of the longer particles indicate the type of wear that is occurring. Although relatively simple to implement, this technique can be developed to provide detailed diagnostic information.

2) Deformation

Vibration analysis is a group of techniques that offer the widest potential for fault detection and diagnosis, but are limited by the complexity of most monitoring equipment.

Stethoscopes or rods may be used to transmit the sound of vibrations to the ear, but in use are limited to qualitative assessments of the characteristics of the vibrations. Commonly found are permanently located total signal vibration velocity instruments which may contain a preset alarm but unfortunately no permanent recording of data. Vibration monitoring using a portable total vibration velocity meter requires an understanding of vibration and instrumentation not normally found in the maintenance work force. One form of vibration measurement which meets most of the specification requirements is the Shock Pulse Measurement technique for monitoring rolling element bearings.

### 3) Overheating

Malfunctions that can be detected from changes in the temperature at the nearest surface, include :

- Motor overload or electrical fault.
- Damaged electrical components, switchgear etc.
- Bearings with poor lubrication, damage, overload, misalignment.
- Transmission components with poor lubrication, overload or incorrect assembly.

A simple and effective technique, satisfying many of the monitoring technique requirements, is to use temperature indicating labels, crayons or paints. An alternative technique, requiring more careful operation, is the handheld thermometer using a thermistor or thermocouple sensor. In situations where high temperatures exist infra-red radiation meters can be used by unskilled inspectors to locate hot or cold spots. Similar instruments, but portable and able to read temperatures nearer ambient, are now becoming more commonly available.

### 4) Corrosion and Erosion

Perhaps the most insidious type of plant deterioration is corrosion or erosion of the inner surfaces. Unless casing thickness is monitored, failure can occur without warning. Regular monitoring of suspicious holes enables the integrity of the plant to be ensured.

### 5) Electric Motors

Electric motors are the most common source of movement in industrial plant. Though they are relatively reliable, the numbers in use mean that they can be a common cause of plant shut down. Failures divide into two groups. Mechanical deterioration, and electrical malfunction in the form of phase failures or inter-turn shorts. By monitoring the flux leakage from the motor end it is simple to detect both these groups of motor deterioration.

## Planning

Irrespective of how simple and sensitive a monitoring technique may be, condition monitoring is incomplete without both programme planning and records.

Planning must include the selection of machines and malfunctions that are to be monitored. It is neither economic nor desirable to attempt to monitor all machines for all possible malfunctions. At the the planning stages machines should be prioritised with respect to the economic benefit to be gained by monitoring. This requires information on :

- 1) Production loss due to breakdowns.
- 2) Material and labour costs due to breakdowns.

- 3) Frequency distribution of breakdowns including correlation with maintenance work.
- 4) Causes of breakdowns and their suitability for monitoring.

### Documentation

An integral part of any successful condition monitoring programme is adequate documentation of the monitored parameters. A feature of condition monitoring, particularly at the early stages, is the accumulation of vast amounts of apparently uncorrelated data. Even with adequate records the benefits are not to be gained immediately since malfunctions can only be detected after the normal condition has been clearly established.

The purpose of appropriate records in condition monitoring is to enable trends to be adopted, even when these are small compared with the variations in the monitored parameter from machine to machine. The object of the records is to enable the normal parameter level to be established together with certainty bands. The importance of a systematic approach to record keeping when implemented condition monitoring techniques cannot be over emphasised.

APPENDIX 4 : EQUIP PERFORMANCE SUMMARY SHEET

MAINTENANCE DEPARTMENT - DAILY SUMMARY

WK. NO. 845

DAY THURSDAY

AREA	DOWN TIME	MAJOR PROBLEM AREAS	ACTION
MATRIX ROOM	25	F/C BELL W/ABLE TO RE-SET 5/STOP	RE-INITIAL. - RE-SET
PRECOAT/ FLOWCOAT	10	R2 ABSC. R/DENSH SENSORS - CALIBRATED.	
LACQUER/ ALUM	30 10	NO1 MAG M/C - NOT INITIATING - L2 TRF B. MAG-CONV. WMO CVI	RE-SET REACTO
COONE PROCESSING		OK.	
BISKUITH/LASER WELD & REFORM	10	LASER NO2 CENTER TRIPED	

APPENDIX 5.1 : CMT 'EQUIP' INFORMATION SYSTEM

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## INTRODUCTION

This EQUIP system (Equipment Utilisation Improvement Package) is designed to provide machine utilisation data, highlighting lost opportunity through :

- i) Machine performance.
- ii) Production constraints eg no labour, no material.

### i) Machine Performance

The performance of equipment influences yield, quality and capacity. Machine breakdowns effect capacity, but most breakdowns are not instantaneous. Before breakdowns there is a deterioration in performance and after breakdowns a period of settling in. Deterioration and settling in affect quality and yield. Thus, preventing deterioration, settling in and breakdowns improves quality, yield and capacity.

Effective use of EQUIP information in analysis of machine performance, should facilitate preventive maintenance and improve machine productivity.

### ii) Production Constraints

Lack of machine utilisation due to production constraints eg no labour etc gives rise to opportunity costs through lost capacity.

Use of EQUIP information will highlight problem areas for production personnel.

## SYSTEM BRIEF

The objective of the EQUIP system is to provide information on machine utilisation to :

- i) Help plan maintenance activity.
- ii) Provide production information on machine utilisation.
- iii) Give information on machine downtime.

Therefore the system will be designed to collect information on :

- i) The number of process interruptions - whether production or machine dependent.
- ii) Opportunity cost of that interruption ie number of products lost.
- iii) Downtime of machinery.

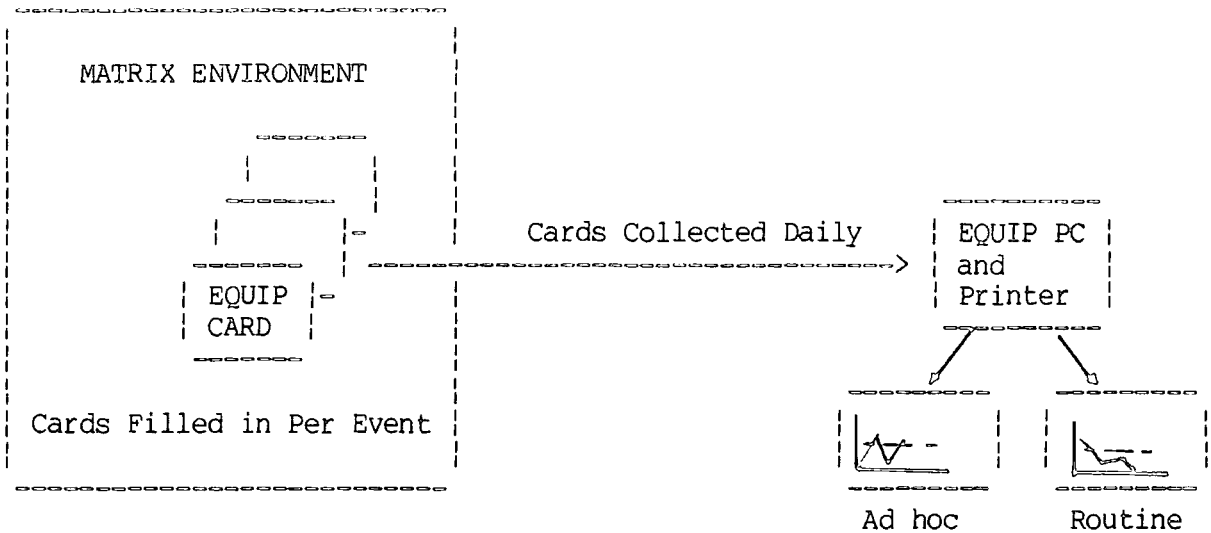
The system will not be designed to collect :

- i) Information on people.
- ii) Time taken for a repair.

## SYSTEM OVERVIEW

The system will be implemented in 2 phases as shown in Figures 1 and 2.

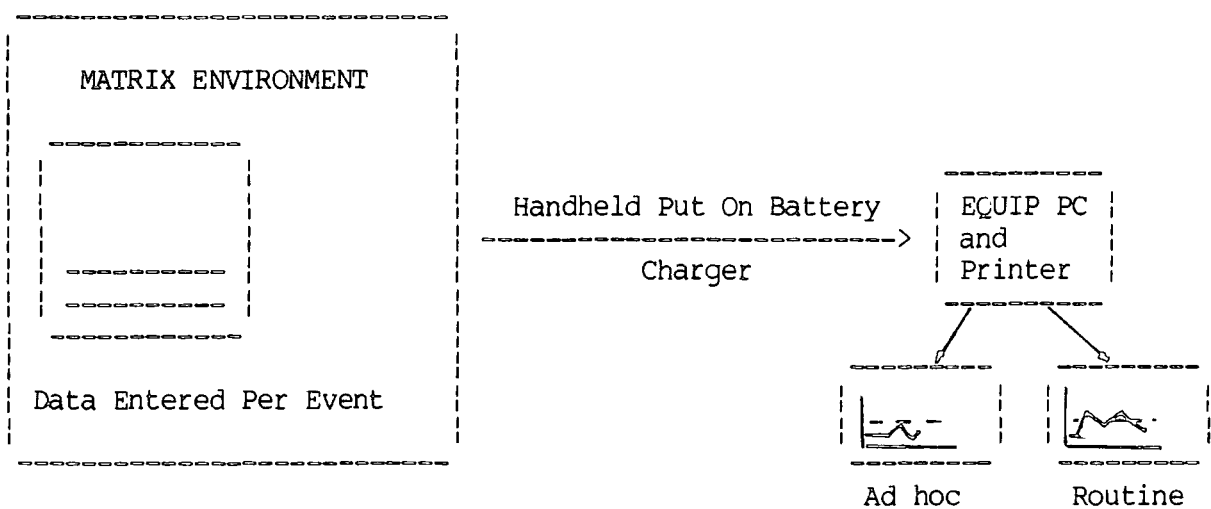
Figure 1 : Phase 1



### Description

- 1) EQUIP cards filled in per event by line supervisor/appropriate staff.
- 2) Cards collected daily from matrix hatch.
- 3) Information typed into EQUIP PC daily.
- 4) Routine reports produced.
- 5) Facilities for interrogating data for ad hoc reports if required.
- 6) Timescale for Phase 1 : September 1987.

Figure 2 : Phase 1



Description

- 1) Data typed into handheld per event by line supervisor/appropriate staff.
- 2) Information downloaded daily via RS232 link to EQUIP PC in maintenance office.
- 3) Handheld put on charge.
- 4) Routine reports produced.
- 5) Facilities for interrogating data for ad hoc reports if required.
- 6) Timescale : March 1988.

# FUNCTIONAL SPECIFICATION

## PHASE I

### 1) INTRODUCTION

This document details the functional requirements of Phase I of the EQUIP system as detailed in the system overview.

Phase II will not be discussed further in this documentation, but consideration of this phase will be incorporated into the system design.

### 2) OPERATING MODES

A password will be required to enter the system.

Where possible, decision making will be menu driven requiring the user to type in single keystrokes rather than full commands.

The system will operate under the following modes :

- 1) Daily Routines.
- 2) Weekly Routines.
- 3) Monthly Routines.
- 4) Data Interrogation.
- 5) Code Catalogue.

#### 2.1 Daily Routines

##### 2.1.1 Data Input and Validation

On selection of this option the user will be prompted to select either :

- 1) Data Input Mode.
- 2) Data Validation Mode.

##### Data Input Mode

Data can be entered in two ways, either :

- a) Individual cards can be entered.
- b) A full shift can be entered by a block entry method.

a) Individual Card Method

On selection of this option the user will be prompted to to enter the following data for each card :

- i) Year eg 7
- ii) Week eg 16
- iii) Day eg 3
- iv) Shift eg C
- v) Department eg 165P
- vi) Line eg 1
- vii) Machine Code eg GM05
- viii) Position eg 12A
- ix) Fault Code eg 1904
- x) No of Products Lost eg 0056
- xi) Stop Time : Hours eg 19  
: Minutes eg 54
- xii) Restart Time : Hours eg 20  
: Minutes eg 23
- xiii) Action Taken eg M
- xiv) Comments eg 'CAM BOLT SHEARED'

b) Block Entry Method

On selection of this option the user will be prompted to enter the following data :

- i) Year eg 7
- ii) Week eg 16
- iii) Day eg 3
- iv) Shift eg C
- v) Department eg 165P
- vi) Line eg 1
- vii) Number of Entries eg 23

and then for the appropriate number of times :

- i) Machine Code eg GM05
- ii) Position eg 12A
- iii) Fault Code eg 1904
- iv) No of Products Lost eg 0056



Details for each of the week will be given, along with a cumulative total, for each of the following parameters :

- i) Machine Code.
- ii) Machine Name.
- iii) Number of Breakdowns.
- iv) Number of Products Lost Per Day.

Copies of each of these reports are required by both the Maintenance and Production departments.

## 2.2 Weekly Routines

The user will first be prompted to input the date of the required output.

Data will be analysed in weekly units of 7 days starting from Sunday - day 0 to Saturday - day 6.

Each week two maintenance reports/process will be issued.

### 1) Machine Group Analysis

This information, presented in a bar chart form, will pareto the top five machine groups for % minutes lost per process. The number of minutes lost in real and % terms, along with the frequency of breakdown will be given.

### 2) Fault Code Analysis

This information, presented in a bar chart form, will pareto the top ten fault codes for % minutes lost per process. The number of minutes lost in real and % terms, along with the frequency of breakdown will be given.

## 2.3 Monthly Routines

The user will be prompted to choose from the following menu :

### 1) Maintenance Reports

Four monthly reports/process will be produced.

#### Monthly Summary/Process

Detailing standby time, scheduled downtime, breakdowns, productive runtime and budgeted allowances per line.

Copies of these reports are also required by the Production Department.

### Machine Group Analysis

This information presented in a bar chart form, will pareto the top ten machine groups for % minutes lost per process. The number of minutes lost in real and % terms, the number of products lost, along with the frequency of breakdown will be given.

### Fault Code Analysis

This information, presented in bar chart form, will pareto the top fifteen codes for % minutes lost per process. The number of minutes lost in real and % terms, the number of lost products along with the frequency of breakdown will be given.

### Total Percentage Breakdowns/Process

This information presented in a line graph format, will show breakdowns as a percentage of production hours available, on a weekly basis over a rotating 3 month period. The budgeted time for breakdowns will also be displayed.

## 2) Production Reports

This information presented in a line graph format will show the following as a percentage of production hours available on a monthly basis over a year :

- i) Standby Time.
- ii) Scheduled Downtime.
- iii) Breakdowns.
- iv) Startup Delay.
- v) Trials.
- vi) Actual Production.

On graphs (iii) and (iv) budgeted allowances will be shown.

## 3) Long Term Analysis

Long term analysis will be done on analysed weekly data.

The user will first be prompted to input the dates of the required output.

Facilities will then be similar to monthly facilities.

## 2.4 Data Interrogation

On selection of this option the user will be prompted to select one of the following options :

- 1) Analysis of Machine Groups.
- 2) Analysis of Fault Code.
- 3) Access Data Manager.

### 1) Analysis of Machine Groups

On selection of this option the user will be prompted to input :

- a) Process.
- b) Machine Group Classification.
- c) Time Base in Weeks.

A pareto, bar chart form, of the top five faults of this group will then be produced.

### 2) Analysis of Individual Machines

On selection of this option the user will be prompted to input :

- a) Process.
- b) Machine Classification.
- c) Time Base in Weeks.

A pareto, bar chart form, of the top five faults of this group will then be produced.

### 3) Analysis of Fault Codes

On selection of this option the user will be prompted to input :

- a) Process.
- b) Machine Classification.
- c) Time Base in Weeks.

A pareto, bar chart form, of the top five faults of this group will then be produced.

Outputs from Options (1) to (3) to be sent to :

- i) Screen.
- ii) Printer.

as requested by the user.

#### 4) Access Data Manager

On selection of this option and successful entry of a password, all files would be set up in default directories and the Database Manager would be invoked. This package can then be used to interrogate the databases as necessary.

### 2.5 Set Up and Code Catalogue

On selection of this option the user would be prompted to choose one of the following :

- 2.5.1 Set Up Data.
- 2.5.2 Code Catalogue.
- 2.5.3 Back Up Data Files.

#### 2.5.1 Set Up Data

On selection of this option the user would be able to display set up data eg week definition, downtime per machine etc.

This information will be sent to :

- i) Screen.
- ii) Printer.

as requested by the user.

#### 2.5.2 Code Catalogue

On selection of this option the user would be able to display machine and fault codes to :

- i) Screen.
- ii) Printer.

as requested by the user.

On entering a password the user would be able to update any entries.

### 2.5.3 Backup Data Files

Backing up data files onto secondary storage should be done at regular intervals at a frequency to be determined. On selection of this option backing up of all necessary files should be done automatically.

### 3) SYSTEM ATTRIBUTES

#### 1) Data Week

NB : Further clarification of shift startup is required.

For each week :

Sunday = Day 0

Monday = Day 1

.

.

.

Saturday = Day 6

#### 2) Production/Maintenance Information

Differentiation will be possible between Maintenance and Production information ie whether a stoppage was due to a breakdown or a production problem.

This requirement to be incorporated into a fault code design.

#### 3) Data Storage

##### a) Characteristics

The daily stored data will have the following characteristics attached to it :

- i) Entry identifier (7 characters) - generated by software - consists of Year, Week, Day, Entry No eg 7235001 or 7235002.
- ii) Shift (1 character).
- iii) Department (4 characters).
- iv) Line (1 character).
- v) Machine code (4 characters).
- vi) Position (3 characters).
- vii) Fault code (4 characters).
- viii) No of products lost (4 characters).

- ix) Stop time (4 characters).
- x) Start time (4 characters).
- xi) Action taken (1 character).
- xii) Comments (16 characters).

b) Storage Period

i) Daily Data

Should be stored on a rotating month basis and then be archived onto secondary storage.

ii) Analysed Weekly Data

Data should be stored for a period of at least a year, before being archived onto secondary storage.

c) Data Identification

Data from the following areas to be stored separately :

- i) Precoat.
- ii) Matrix.
- iii) Flowcoat.

4) DOCUMENTATION

The following documentation will be issued :

- 1) System Managers Manual.
- 2) Operating Procedures - Clerical Support.
- 3) Operating Procedures - Technical Supervision.
- 4) System Maintenance Engineers Manual.
- 5) PDL For All Code.
- 6) Commented Code.
- 7) Instructions For Updating Documentation.
- 8) Pocket Size and A4 Size Code Booklets.

A4 TEMPLATE OF EQUIP DATA COLLECTION CARD

CMT EQUIP DATA COLLECTION

WEEK		0	1	2	3	4	5	6	7	8	9												
DAY		0	1	2	3	4	5	6															
SHIFT		A			B				C														
DEPT.		P			M				F														
LINE		1			2																		
MACHINE			C			M				S													
CODE		0	1	2	3	4	5	6	7	8	9												
POSITION		0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
		A			B			.1		2													
FAULT		0	1	2	3	4	5	6	7	8	9												
CODE		0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
NO. OF PRODUCTS LOST	1000's	0	1	2	3	4	5	6	7	8	9												
	100's	0	1	2	3	4	5	6	7	8	9												
	10's	0	1	2	3	4	5	6	7	8	9												
	1's	0	1	2	3	4	5	6	7	8	9												
STOP TIME	HRS.	0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
	MNS	0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
RESTART TIME	HRS.	0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
	MNS	0	1	2	3	4	5	6	7	8	9												
		0	1	2	3	4	5	6	7	8	9												
ACTION BY		M			P			S			X												
COMMENTS		<table border="1" style="width: 100%; height: 20px;"> <tr> <td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td> </tr> </table>																					

APPENDIX 5.3 : EQUIP REPORTS AUTOMATICALLY PRODUCED

Daily

CMT EQUIP MANAGEMENT INFORMATION SYSTEM  
 DATA VALIDATION FOR WEEK 934 0A/ 4

SERVID	S	DEPT	L	MAC	POS	FALT	PROD	STOP	REST	A	COMMENTS
344001	C	165P	1	A99	99	6010	91	6:00	10:00	P	
344002	C	165P	1	A99	99	5990	24	11:00	12:00	P	LINE STOPPED
344003	C	165M	1	A99	99	6010	63	6:00	3:00	P	
344004	C	165M	1	A99	99	8000	21	8:00	9:00	P	
344005	C	165M	1	A99	99	6010	7	9:00	11:00	P	
344006	C	165M	1	A99	99	6030	24	11:00	12:00	P	
344007	C	165F	1	S88	12	2617	15	8:25	6:35	P	
344008	C	165F	1	S34	02	7000	12	9:00	9:09	P	
344009	C	165P	1	A99	99	6010	10	12:00	13:00	P	
344010	C	165M	1	A99	99	6010	10	12:00	13:00	P	
344011	C	165F	1	A99	99	6010	326	6:00	14:00	P	
344012	C	165P	1	A99	99	5990	9	13:00	14:00	P	
344013	C	165M	1	A99	99	6030	9	13:00	14:00	P	
344014	B	165F	1	A99	99	6010	414	14:00	22:00	P	NO ORDERS
344015	B	165P	1	S11	99	5999	110	18:00	21:00	M	CON RUN PROB
344016	B	165M	1	A99	99	6030	110	18:00	22:00	P	PRECOAT DOWN
344017	B	165M	1	A99	99	6010	189	14:00	22:00	P	NO ORDERS
344018	B	165P	1	A99	99	6010	189	14:00	22:00	P	NO ORDERS
344019	A	165M	1	A99	99	6010	37	22:00	23:00	X	
344020	A	165M	1	S55	18	1660	93	23:00	23:55	M	
344021	A	165M	1	A99	99	6030	110	: 0	1:00	X	
344022	A	165M	1	A99	99	6030	103	1:00	2:00	X	Y
344023	A	165M	1	A99	99	6030	15	2:00	3:00	X	
344024	A	165M	1	A99	99	6010	40	2:00	3:00	X	
344025	A	165M	1	A99	99	6030	22	3:00	4:00	X	
344026	A	165M	1	A99	99	6010	40	3:00	4:00	X	
344027	A	165P	1	S22	22	6010	130	22:00	: 0	X	
344028	A	165F	1	A99	99	6010	275	22:00	3:00	P	
344029	A	165F	1	A99	99	7020	299	3:00	6:00	P	GLASSCHANGE
344030	A	165M	1	A99	99	7020	187	4:20	6:00	X	
344031	A	165P	1	S22	22	1050	90	22:00	6:00	M	
344032	A	165P	1	S22	22	7020	165	3:30	5:00	P	

PRECOAT DEPT

PRODUCTION BASED STOPPAGES - No. of Incidents : 5  
 - No. of Products Lost : 325

MAINTENANCE BASED STOPPAGES - No. of Incidents : 4  
 - No. of Products Lost : 333

MAINTENANCE PERSONNEL DEALT WITH 2 INCIDENTS

Shift	Machine	Fault	Prods	Stop	Start	Comments
B	308 CONVY	NO FLT FOUND	110	18:00	21:00	CON RUN PROB
A	PROCESS LINE	CON.INDX-EPD	90	22:00	6:00	

MATRIX DEPT

PRODUCTION BASED STOPPAGES - No. of Incidents : 16  
 - No. of Products Lost : 987

MAINTENANCE BASED STOPPAGES - No. of Incidents : 1  
 - No. of Products Lost : 93

MAINTENANCE PERSONNEL DEALT WITH 1 INCIDENTS

Shift	Machine	Fault	Prods	Stop	Start	Comments
A	PROC LINE B	GRAPH PUMPS	93	23:00	23:55	

FLOWCOAT DEPT

PRODUCTION BASED STOPPAGES - No. of Incidents : 5  
 - No. of Products Lost : 1326

MAINTENANCE BASED STOPPAGES - No. of Incidents : 1  
 - No. of Products Lost : 15

MAINTENANCE PERSONNEL DEALT WITH 0 INCIDENTS

## MACHINE UTILISATION REPORT -- CMT AREA

DEPT: PRECOAT

Downtime Analysis Report for

WEEK NO. 934 DAY 4

PERIOD START TIME: WEEK 934 DAY 4 07:00 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 5 06:59 HRS  
 PRODUCTION UNITS AVAILABLE : 880 PER SHIFT 2640 PER DAY

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N U N I T S			L O S T
NO ORDERS	130	189	101	420
GENERAL PRODN.	165	0	0	165
NO MATERIAL	0	0	0	0
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	0	0
SUB TOTAL	295	189	101	585

## NON SCHEDULED DOWNTIME

BREAKDOWNS	90	110	33	233
BUDGET ( 5% )				132

## SCHEDULED DOWNTIME

PROCESS CONTROL	0	0	0	0
TRAINING/TEAM BRF.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
SUB TOTAL	0	0	0	0

MATERIALS	0	0	0	0
-----------	---	---	---	---

ACTUAL PRODUCTION	495	581	746	1822
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	56.2	66.0	84.7	69.0

SUMMARY OF BREAKDOWNS  
 DEPT: PRECOAT  
 PRODUCTS LOST/FREQUENCY OF INCIDENT

WEEK: 934

PAGE NUMBER: 1

MACHINE	SUN	MON	TUE	WED	THU	FRI	SAT	TOT
		147 12			90 1			237 13
		90 2	267 2		33 2			380 6
			440 1		110 1			550 2
				9 1				9 1

# Weekly Reports

EQUIP M A N A G E M E N T I N F O R M A T I O N S Y S T E M

## MACHINE UTILISATION REPORT -- CMT AREA

DEPT: MATRIX

Downtime Analysis Report for

WEEK NO. 934 DAY 4
--------------------

PERIOD START TIME: WEEK 934 DAY 4 07:00 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 5 06:59 HRS  
 PRODUCTION UNITS AVAILABLE : 880 PER SHIFT 2640 PER DAY

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N	U N I T S	L O S T	
NO ORDERS	117	189	80	386
GENERAL PRODN.	187	0	0	187
NO MATERIAL	250	110	33	393
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	0	0
SUB TOTAL	554	299	113	966

### NON SCHEDULED DOWNTIME

BREAKDOWNS	93	0	0	93
BUDGET ( 5% )				132

### SCHEDULED DOWNTIME

PROCESS CONTROL	0	0	21	21
TRAINING/TEAM BRK.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
SUB TOTAL	0	0	21	21

RIALS	0	0	0	0
-------	---	---	---	---

ACTUAL PRODUCTION	233	581	746	1560
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	26.4	66.0	84.7	59.0

S U M M A R Y   O F   B R E A K D O W N S

W E E K : 934

DEPT: MATRIX

PRODUCTS LOST/FREQUENCY OF INCIDENT

PAGE NUMBER: 1

MACHINE	SUN	MON	TUE	WED	THU	FRI	SAT	TOT
			278	110	93			501
			2	1	1			4

MACHINE UTILISATION REPORT -- CNT AREA

DEPT: FL'COAT

Downtime Analysis Report for

WEEK NO. 934 DAY 4

PERIOD START TIME: WEEK 934 DAY 4 07:00 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 5 06:59 HRS  
 PRODUCTION UNITS AVAILABLE : 880 PER SHIFT 2640 PER DAY

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N			L O S T
NO ORDERS	275	414	326	1015
GENERAL PRODN.	299	0	0	299
NO MATERIAL	0	0	0	0
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	0	0
<b>SUB TOTAL</b>	<b>574</b>	<b>414</b>	<b>326</b>	<b>1314</b>

NON SCHEDULED DOWNTIME

BREAKDOWNS	0	0	15	15
BUDGET ( 5% )				132

SCHEDULED DOWNTIME

PROCESS CONTROL	0	0	0	0
TRAINING/TEAM BRF.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
<b>SUB TOTAL</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

TRIALS	0	0	12	12
--------	---	---	----	----

ACTUAL PRODUCTION	306	466	527	1299
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	34.7	52.9	59.8	49.2

S U M M A R Y     I R     2 2 8 5 A 0 0 0 M 0 1 9  
DEPT: FU DURT  
PRODUCTS LOST/FREQUENCY OF INCIDENT

W E E K     0 1

P A G E     0 0 0 0 0 0

MACHINE	SUN	MON	TUE	WED	THU	FRI	SAT	TOT
		8 1						8 1
		52 1	6 1					14 2
			7 1		15 1			22 2

## MACHINE UTILICATION REPORT - CMT AREA

DEPT: PRECOAT

Weekly Downtime Analysis Report for

WEEK NO. 934

PERIOD START TIME: WEEK 934 DAY 1 7:00 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 6 7:00 HRS  
 PRODUCTION UNITS AVAILABLE : 13200 PER WEEK  
 ( A SHIFT: 4400 B SHIFT: 4400 C SHIFT: 4400 )

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N		U N I T S	L O S T
NO ORDERS	1627	1293	859	3779
GENERAL PRODN.	165	0	0	165
NO MATERIAL	0	0	0	0
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	52	52
SUB TOTAL	1792	1293	911	3996

NON SCHEDULED DOWNTIME

BREAKDOWNS	147	664	426	1237
BUDGET ( 5% )	220	220	220	660

SCHEDULED DOWNTIME

PROCESS CONTROL	0	0	0	0
TRAINING/TEAM BRP.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
SUB TOTAL	0	0	0	0

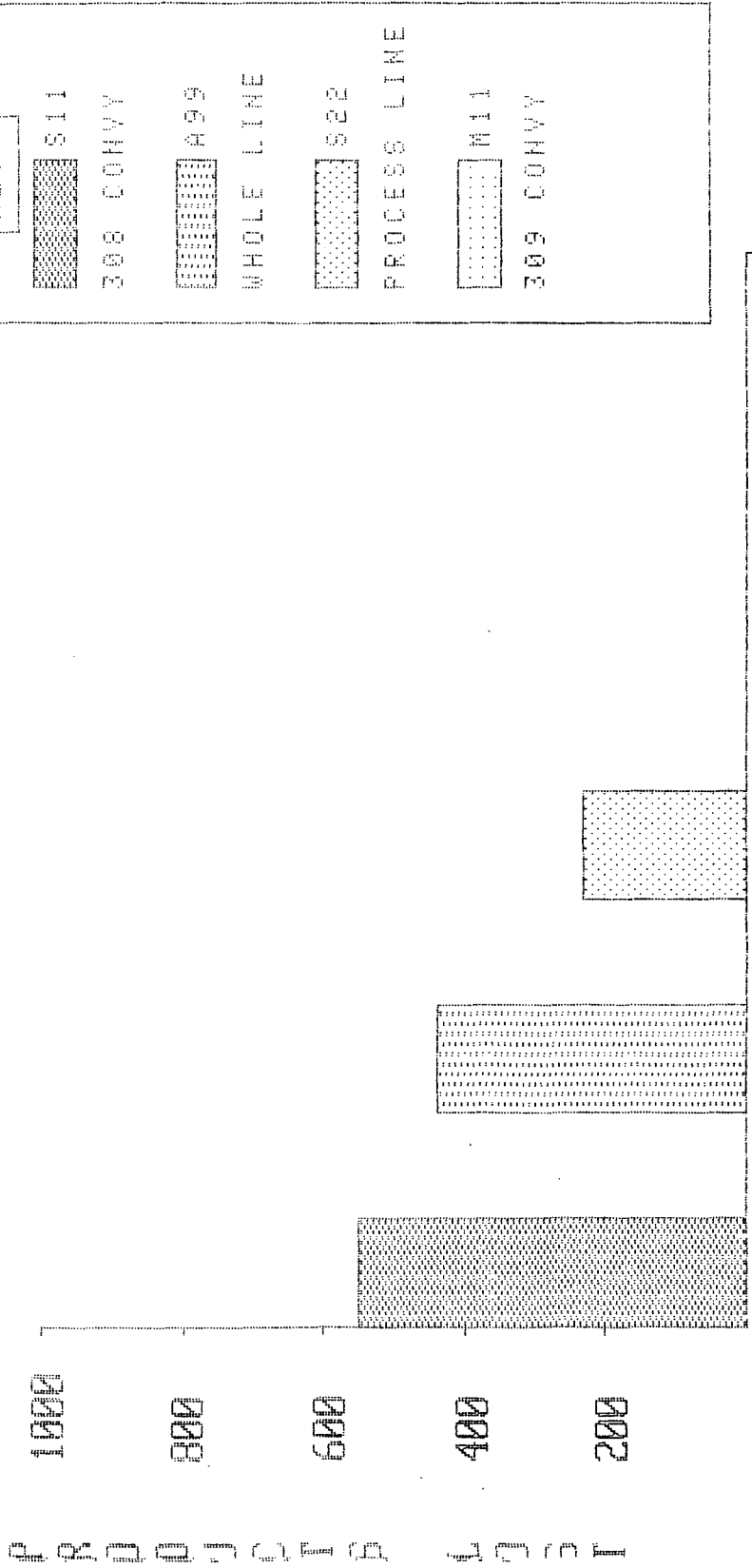
RIALS	0	0	0	0
-------	---	---	---	---

ACTUAL PRODUCTION	2461	2443	3063	7967
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	55.9	55.5	69.6	60.3

PERCENT OF THE MACHINE GROUPS CAUSING LOT PROBLEMS ARE TO BE BROKEN DOWN

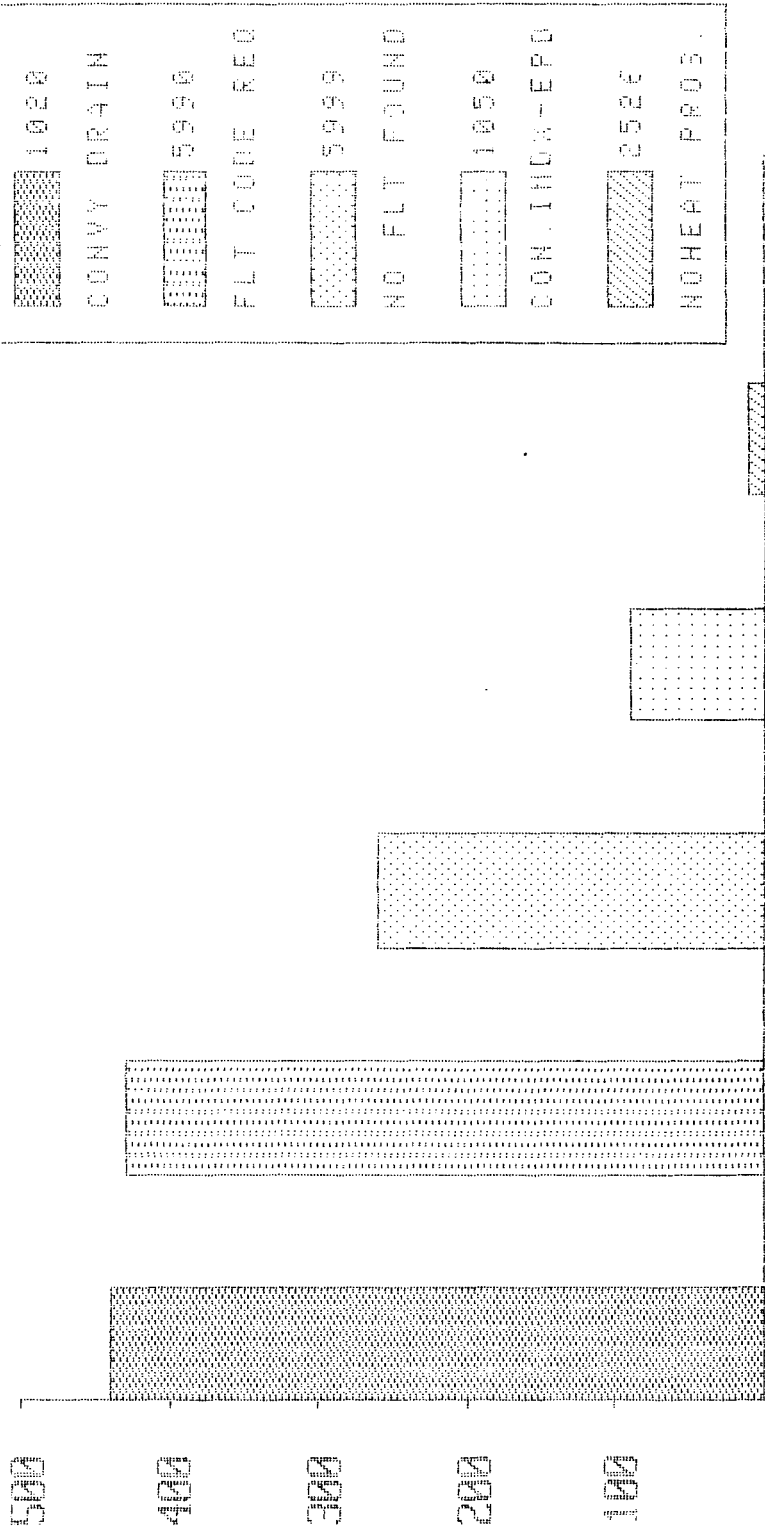
DEPARTMENT : CH1 PLANT

THE PERIOD : WEEK 934



PRODUCT LOSS

FIELD OF TOP BRANCH FALLS CANSHEE LOST PRODUCTS  
 DEPT: 1020  
 DEPARTMENT : CMT ROOM  
 TIME PERIOD : WEEK 99



KEY

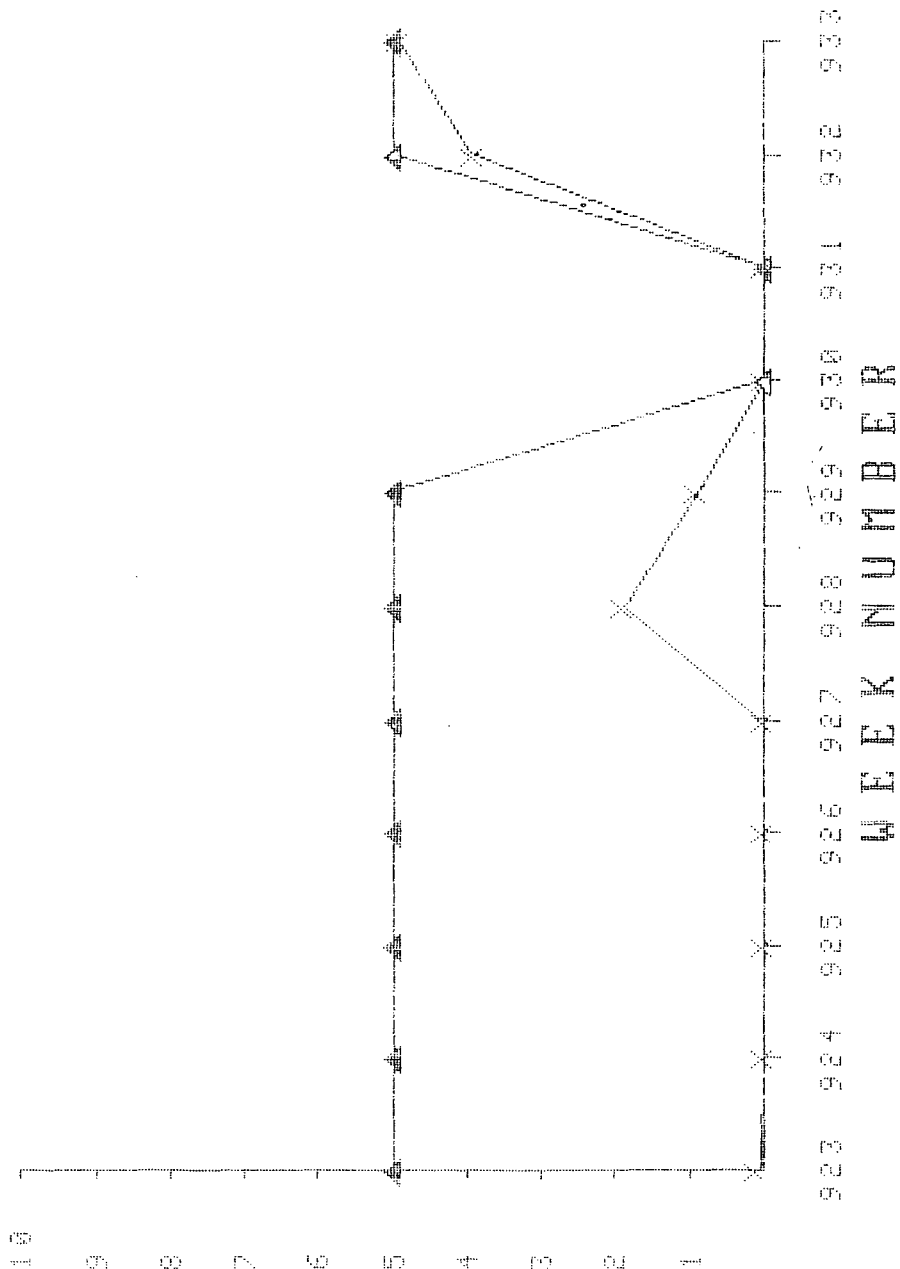
- 1020 CONVEY DRAIN
- 5990 FLT CODE REQ
- 5999 NO FLT FOUND
- 1050 CON. INDX - EPO
- 2526 NOHEAT PRODS

1020 5990 5999 1050 2526  
 FAULT CODE

COUNTY CASH OF COUNTY IN THE YEAR TO 1900

DEPARTMENT : OF THE  
 TIME PERIOD : WEEKS 923 - 933

REFERENCE



## MACHINE UTILISATION REPORT    CHT AREA

DEPT: MATRIX

Weekly Downtime Analysis Report for

WEEK NO. 934

PERIOD START TIME: WEEK 934 DAY 1        7:00    HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 6       7:00    HRS  
 PRODUCTION UNITS AVAILABLE : 13200 PER WEEK  
 ( A SHIFT: 4400    B SHIFT: 4400    C SHIFT: 4400 )

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	PRODUCTION	UNITS	LOST	
NO ORDERS	1201	1224	793	3218
GENERAL PRODN.	187	0	0	187
NO MATERIAL	467	682	300	1449
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	195	195
<b>SUB TOTAL</b>	<b>1855</b>	<b>1906</b>	<b>1288</b>	<b>5049</b>

## NON SCHEDULED DOWNTIME

BREAKDOWNS	501	0	0	501
BUDGET ( 5%)	220	220	220	660

## SCHEDULED DOWNTIME

PROCESS CONTROL	3	0	48	51
TRAINING/TEAM BRP.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
<b>SUB TOTAL</b>	<b>3</b>	<b>0</b>	<b>48</b>	<b>51</b>

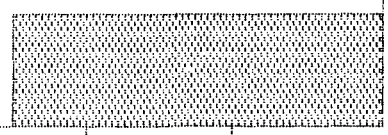
DEFECTS	0	0	0	0
---------	---	---	---	---

ACTUAL PRODUCTION	2041	2494	3064	7599
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	46.3	56.6	69.6	57.5

REPRODUCTION OF THIS DOCUMENT IS PROHIBITED WITHOUT THE WRITTEN PERMISSION OF THE NATIONAL ARCHIVES

REPRODUCTION OF THIS DOCUMENT IS PROHIBITED WITHOUT THE WRITTEN PERMISSION OF THE NATIONAL ARCHIVES

1950  
50  
50  
50  
200



KEY

555

PROVIDE

555

MACHINE CODE

THE FOLLOWING ARE THE TESTS

PERFORMED ON THE PUMPS

TEST RESULTS

1 2 3 4 5

123



1500

GEORGE PUMPS



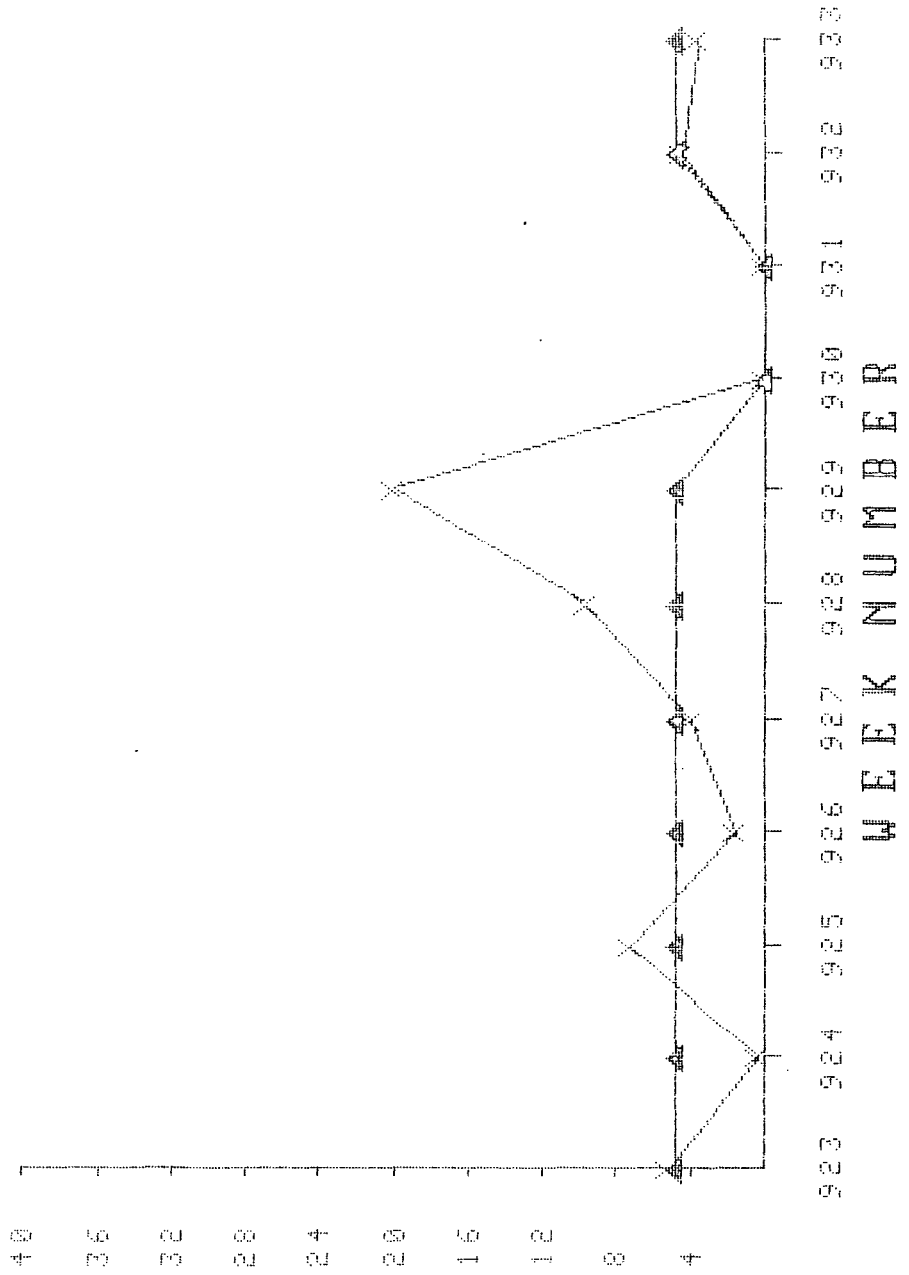
1500

FAULT CODE

SUMMARY GRAPH OF CAPACITY DOWNTIME DUE TO DEFECTS

DEPARTMENT : COT MARI X  
 TIME PERIOD : WEEKS 923 - 933

P E R C E N T A G E



## MACHINE UTILISATION REPORT - CMT AREA

DEPT: FL COAT

Weekly Downtime Analysis Report for

WEEK NO. 934

PERIOD START TIME: WEEK 934 DAY 1 7:00 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 6 7:00 HRS  
 PRODUCTION UNITS AVAILABLE : 13200 PER WEEK  
 ( A SHIFT: 4400 B SHIFT: 4400 C SHIFT: 4400 )

<u>TANDBY TIME</u>	<u>A SHIFT</u>	<u>B SHIFT</u>	<u>C SHIFT</u>	<u>TOTAL</u>
	<u>P R O D U C T I O N</u>	<u>U N I T S</u>	<u>L O S T</u>	
NO ORDERS	1986	1830	1614	5430
GENERAL PRODN.	299	0	300	599
NO MATERIAL	28	687	24	739
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	0	0
<b>SUB TOTAL</b>	<b>2313</b>	<b>2517</b>	<b>1938</b>	<b>6768</b>

NON SCHEDULED DOWNTIME

BREAKDOWNS	7	8	66	81
BUDGET ( 5% )	220	220	220	660

SCHEDULED DOWNTIME

PROCESS CONTROL	0	0	0	0
TRAINING/TEAM BRG.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
LEANING	0	0	0	0
<b>SUB TOTAL</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

REPAIRS	0	0	12	12
---------	---	---	----	----

ACTUAL PRODUCTION	2080	1875	2384	6339
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	47.2	42.6	54.1	48.0

DEPT OF THE MACHINE GROUPS MACHINE LIST REPORTS AND TO DEPARTMENTS

DEPARTMENT : OT REPORT  
 TIME PERIOD : WEEK 93

PRODUCTS LIST

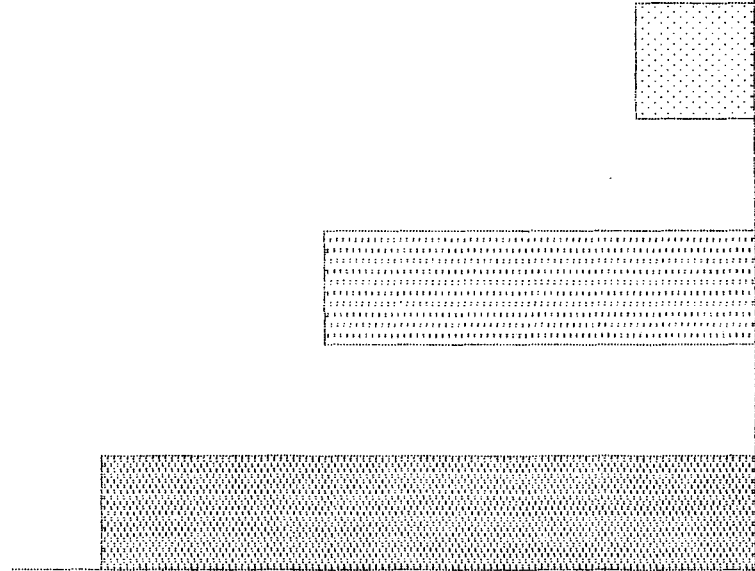
35  
 45  
 55  
 65  
 75

KEY

632  
 DURING UNIT

680  
 LONG TRAVEL

977  
 DEV PROCLINE

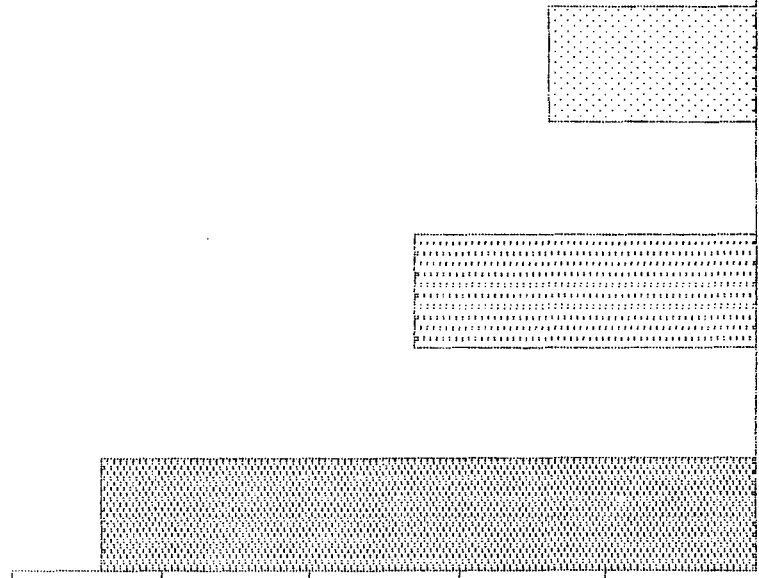
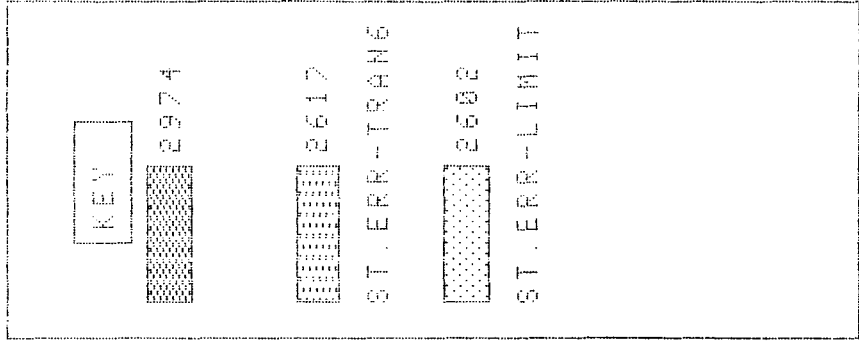


632 680 977  
 MACHINE CODE

TABLE OF BATTERY FAILS DURING LOT PROBLEMS  
 DEPT. OF DEFENSE : ON HAWAII  
 TIME PERIOD : MAY 93

LEADS OF LOSS

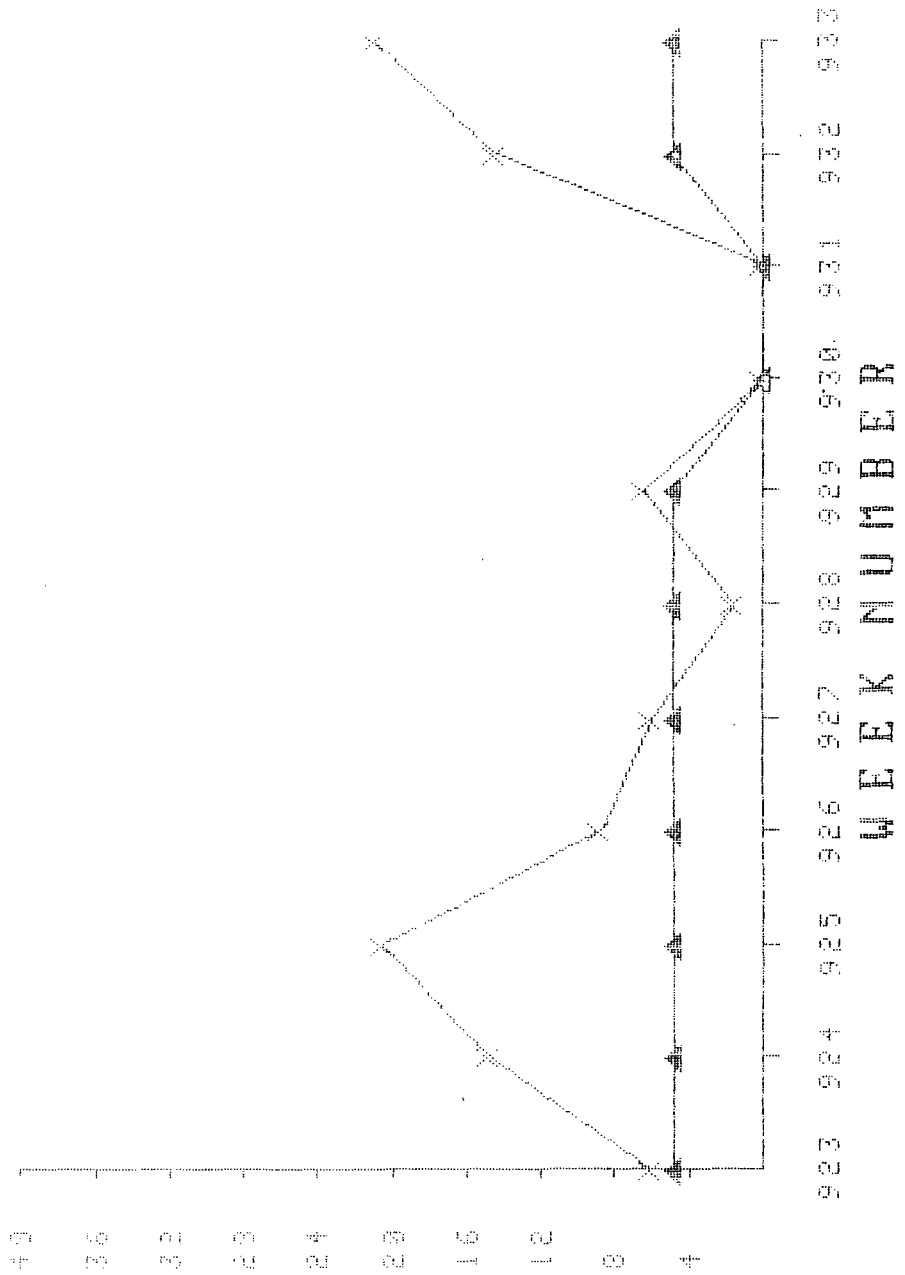
5  
4  
3  
2  
1



2974 2617 2602  
 FAULT CODE

03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33  
 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33  
 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33



# Monthly Reports

EQUIP M A N A G E M E N T I N F O R M A T I O N S Y S T E M

## MACHINE UTILISATION REPORT

DEPT: PRECOAT

Monthly Downtime Analysis Report for

MONTH : AUG
-------------

PERIOD START TIME: WEEK 931 DAY 0 : 0 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 6 7:00 HRS  
 PRODUCTION UNITS AVAILABLE : 39600 PER MONTH  
 ( A SHIFT: 13200 B SHIFT: 13200 C SHIFT: 13200 )

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N		U N I T S	L O S T
NO ORDERS	4637	4748	3024	12409
GENERAL PRODN.	165	9	408	582
NO MATERIAL	0	0	0	0
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	0	0	52	52
SUB TOTAL	4802	4757	3484	13043

### UNION SCHEDULED DOWNTIME

BREAKDOWNS	303	807	855	1965
BUDGET ( 5% )	660	660	660	1980

### SCHEDULED DOWNTIME

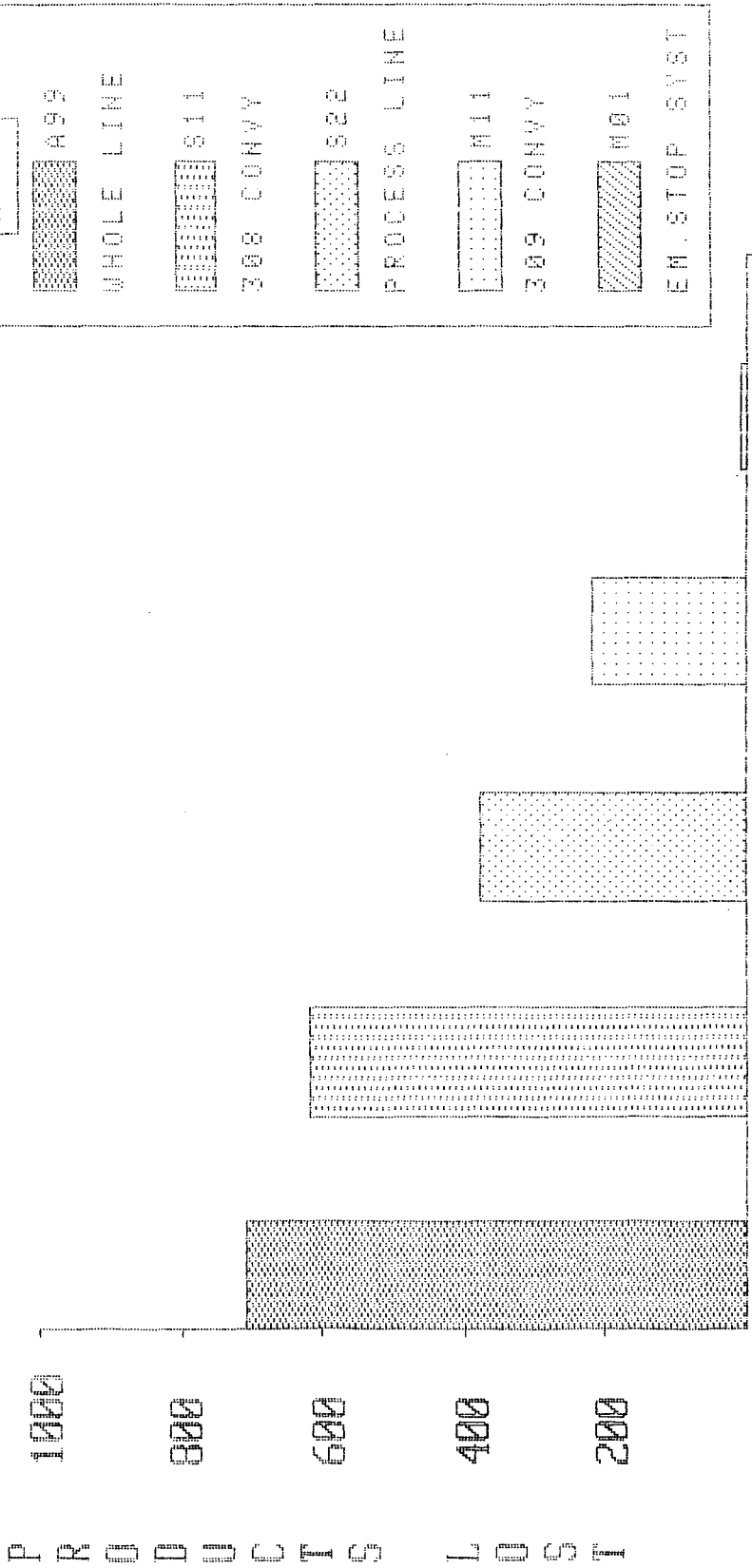
PROCESS CONTROL	2	0	0	2
TRAINING/TEAM BRG.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
SUB TOTAL	2	0	0	2

RIALS	0	0	0	0
-------	---	---	---	---

ACTUAL PRODUCTION	8093	7636	8861	24590
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	61.3	57.8	67.1	62.1

NUMBER OF TOP MACHINE GROUPS CAUSING LOSST PRODUCTS DUE TO BREAKDOWNS

DEPARTMENT : CRT PROGRAM  
 THE PERIOD : MONTH - 6/68



KEY

A99 WHOLE LINE

S11 308 CONVY

S22 PROCESS LINE

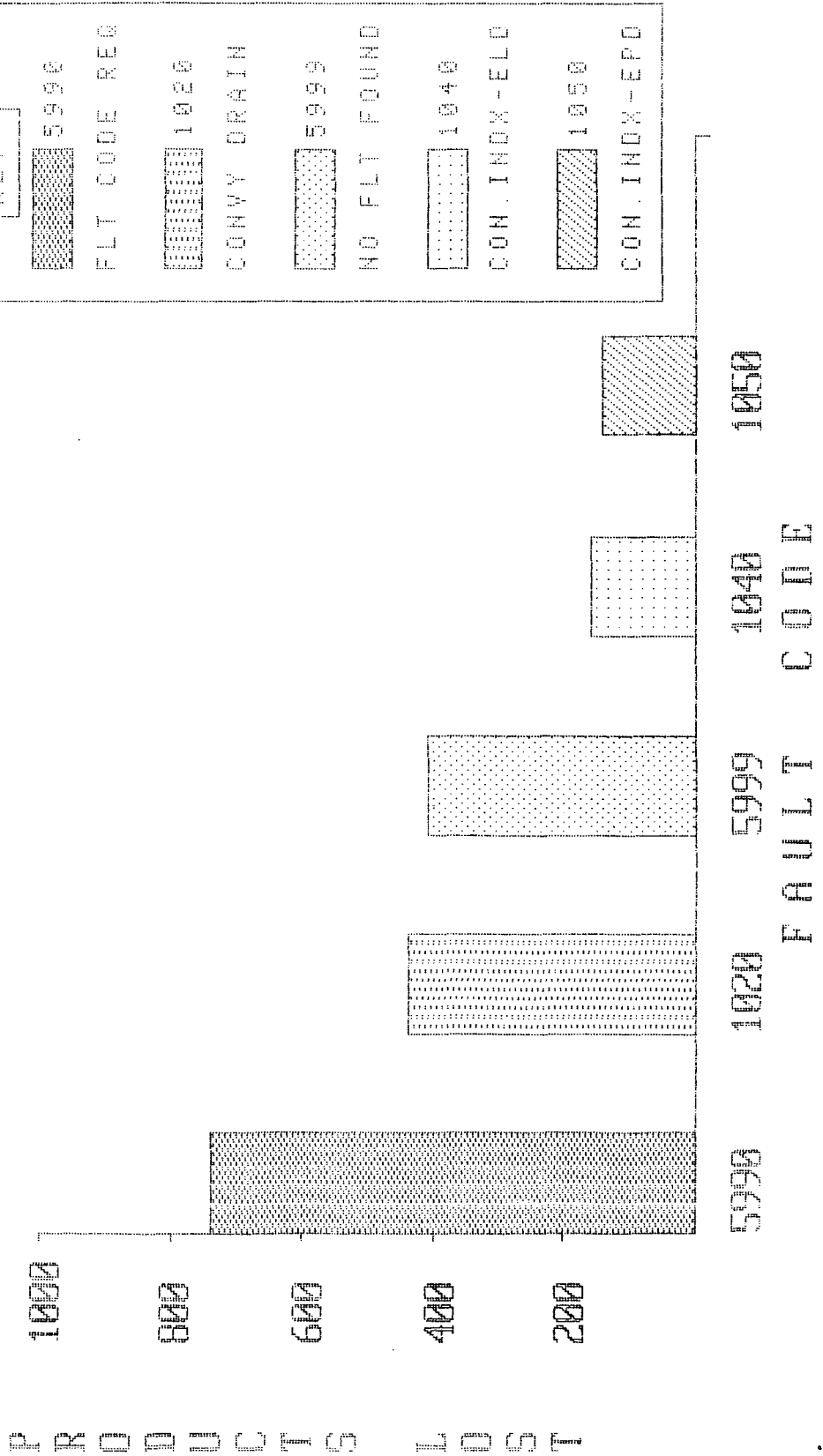
M11 309 CONVY

M01 EM. STOP SYST

STATUS OF TOP BREAKDOWN FAILURES CAUSING LOT PROBLEMS

REPORT : CRT REPORT

TIME PERIOD : MONTH - QRS



## MACHINE UTILISATION REPORT

DEPT: MATRIX

Monthly Downtime Analysis Report for

MONTH : AUG

PERIOD START TIME: WEEK 931 DAY 0 : 0 HRS

PERIOD FINISH TIME: WEEK 934 DAY 3 7:00 HRS

PRODUCTION UNITS AVAILABLE : 39600 PER MONTH

( A SHIFT: 13200 B SHIFT: 13200 C SHIFT: 13200 )

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N U N I T S			L O S T
NO ORDERS	3615	4376	2983	10974
GENERAL PRODN.	315	190	408	913
NO MATERIAL	927	904	522	2353
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	330	0	195	525
SUB TOTAL	5187	5470	4108	14765

## UNION SCHEDULED DOWNTIME

BREAKDOWNS	866	20	289	1175
BUDGET ( 5% )	660	660	660	1980

## UNION SCHEDULED DOWNTIME

PROCESS CONTROL	17	75	55	147
TRAINING/TEAM BRG.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
LEANING	0	0	0	0
SUB TOTAL	17	75	55	147

TRIALS	0	10	0	10
--------	---	----	---	----

ACTUAL PRODUCTION	7130	7625	8748	23503
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	54.0	57.7	66.2	59.3

RAIRO OF TOP MACHINE GROUPS CAUSING LOST PRODUCTS DUE TO DEFECTS

DEPARTMENT : OIT MATRX  
 TIME PERIOD : MONTH - AUG

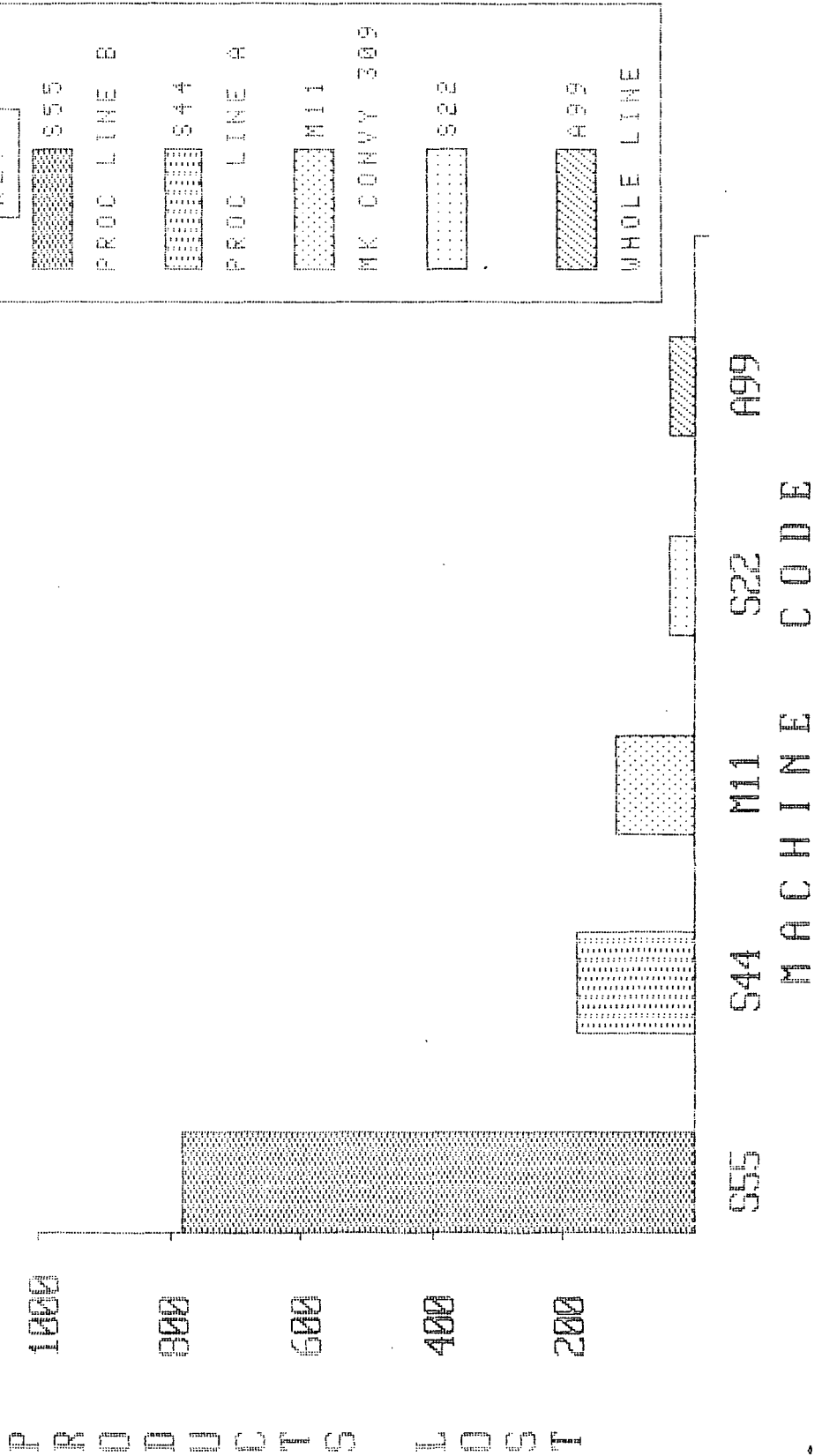
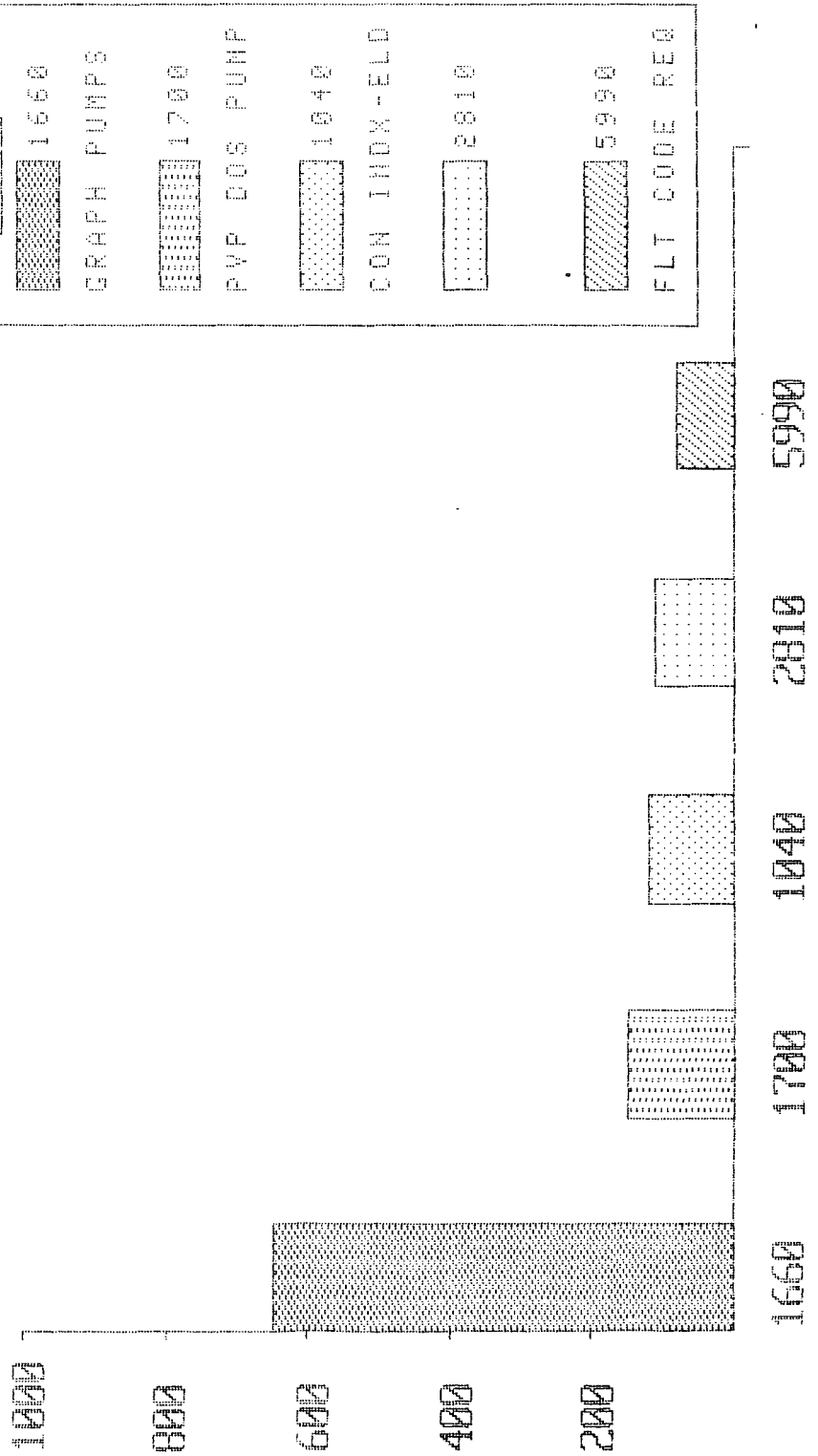


TABLE OF TOP BREAKDOWN FAILTS OASING LAST PRODUCTS

DEPARTMENT : OIT MARIX  
 THE PERIOD : NOV - 68



FAULT CODE

## MACHINE UTILISATION REPORT

DEPT: FL'COAT

Monthly Downtime Analysis Report for

MONTH : AUG

PERIOD START TIME: WEEK 931 DAY 0 : 0 HRS  
 PERIOD FINISH TIME: WEEK 934 DAY 6 7:00 HRS  
 PRODUCTION UNITS AVAILABLE : 39600 PER MONTH  
 ( A SHIFT: 13200 B SHIFT: 13200 C SHIFT: 13200 )

STANDBY TIME	A SHIFT	B SHIFT	C SHIFT	TOTAL
	P R O D U C T I O N U N I T S			L O S T
NO ORDERS	5051	5527	5522	16100
GENERAL PRODN.	381	110	300	791
NO MATERIAL	138	687	24	849
NO LABOUR	0	0	0	0
TECH. BREAKDOWN	205	0	0	205
SUB TOTAL	5775	6324	5846	17945

## NON SCHEDULED DOWNTIME

BREAKDOWNS	905	790	686	2381
BUDGET ( 5% )	660	660	660	1980

## SCHEDULED DOWNTIME

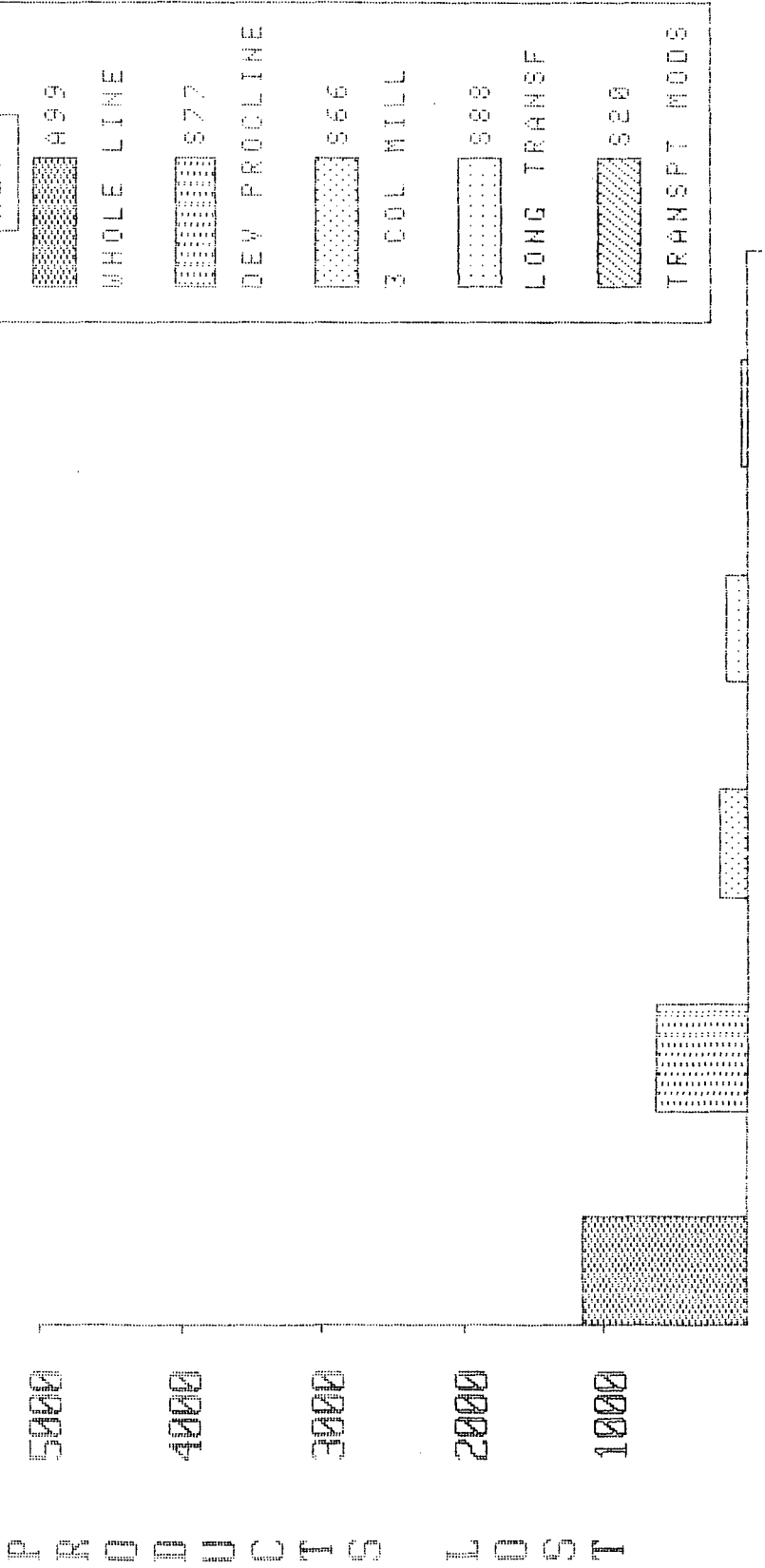
PROCESS CONTROL	0	0	24	24
TRAINING/TEAM BRF.	0	0	0	0
PLAN. MAINTENANCE	0	0	0	0
CLEANING	0	0	0	0
SUB TOTAL	0	0	24	24

TRIALS	0	0	12	12
--------	---	---	----	----

ACTUAL PRODUCTION	6520	6086	6632	19238
BUDGET UTILISATION (%)	80	80	80	80
ACTUAL UTILISATION (%)	49.3	46.1	50.2	48.5

REASON FOR TOP MACHINE GROUPOUS CAUSING LOSST PRODUCTS ARE TO BE EXAMINED

DEPARTMENT : OTT FLOUOR  
 TIME PERIOD : MONTH - AUG



999 977 966 988 920

MACHINE CODE



EQUIP System Data Flow Diagrams

LEVEL : CONTEXT

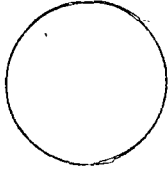
KEY



DATA FLOW



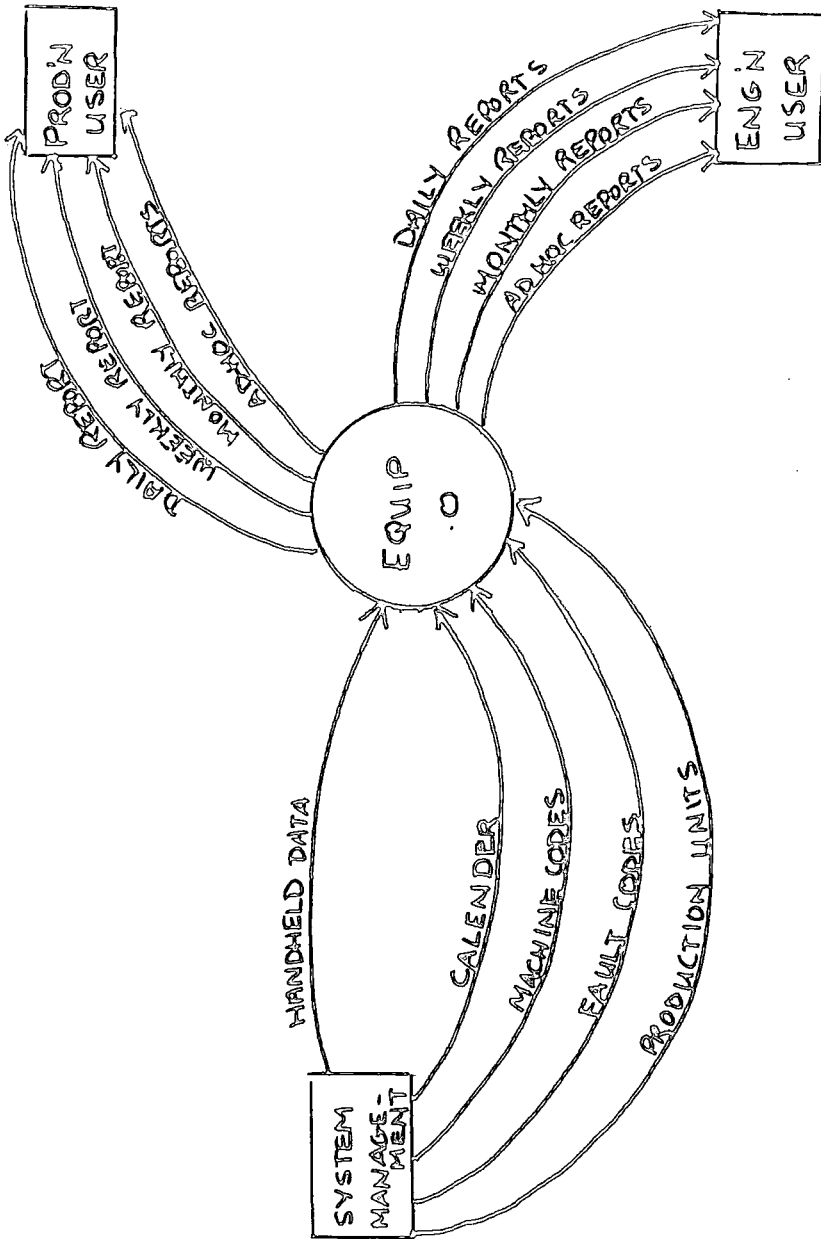
PROCESS



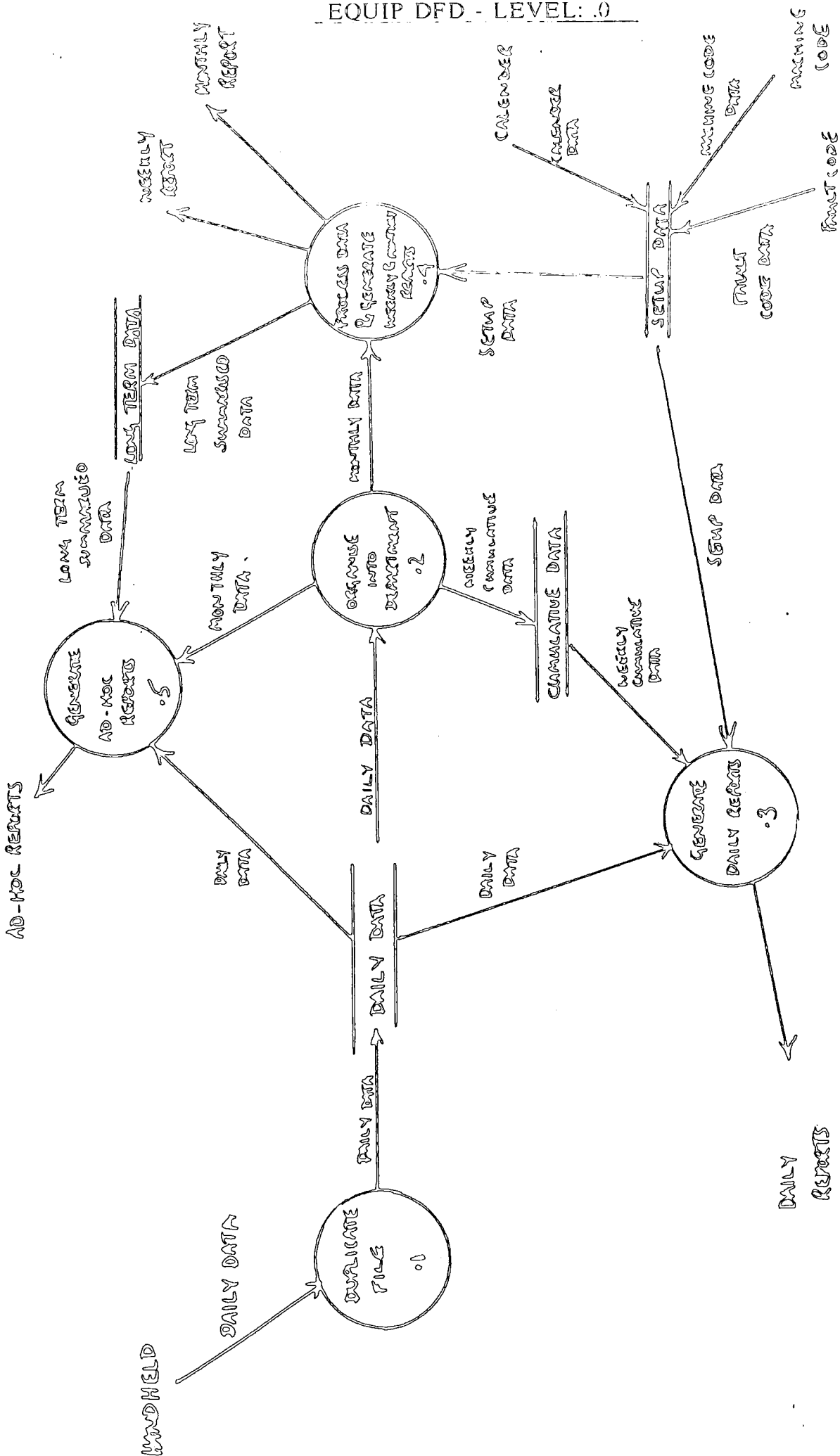
DATA STORE



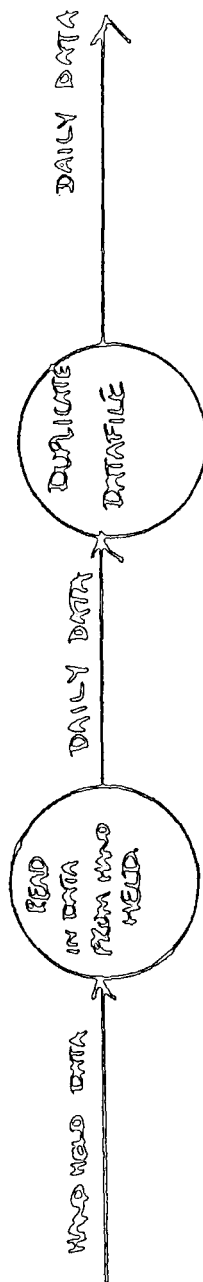
TOP LEVEL DIAGRAM (CONTEXT)



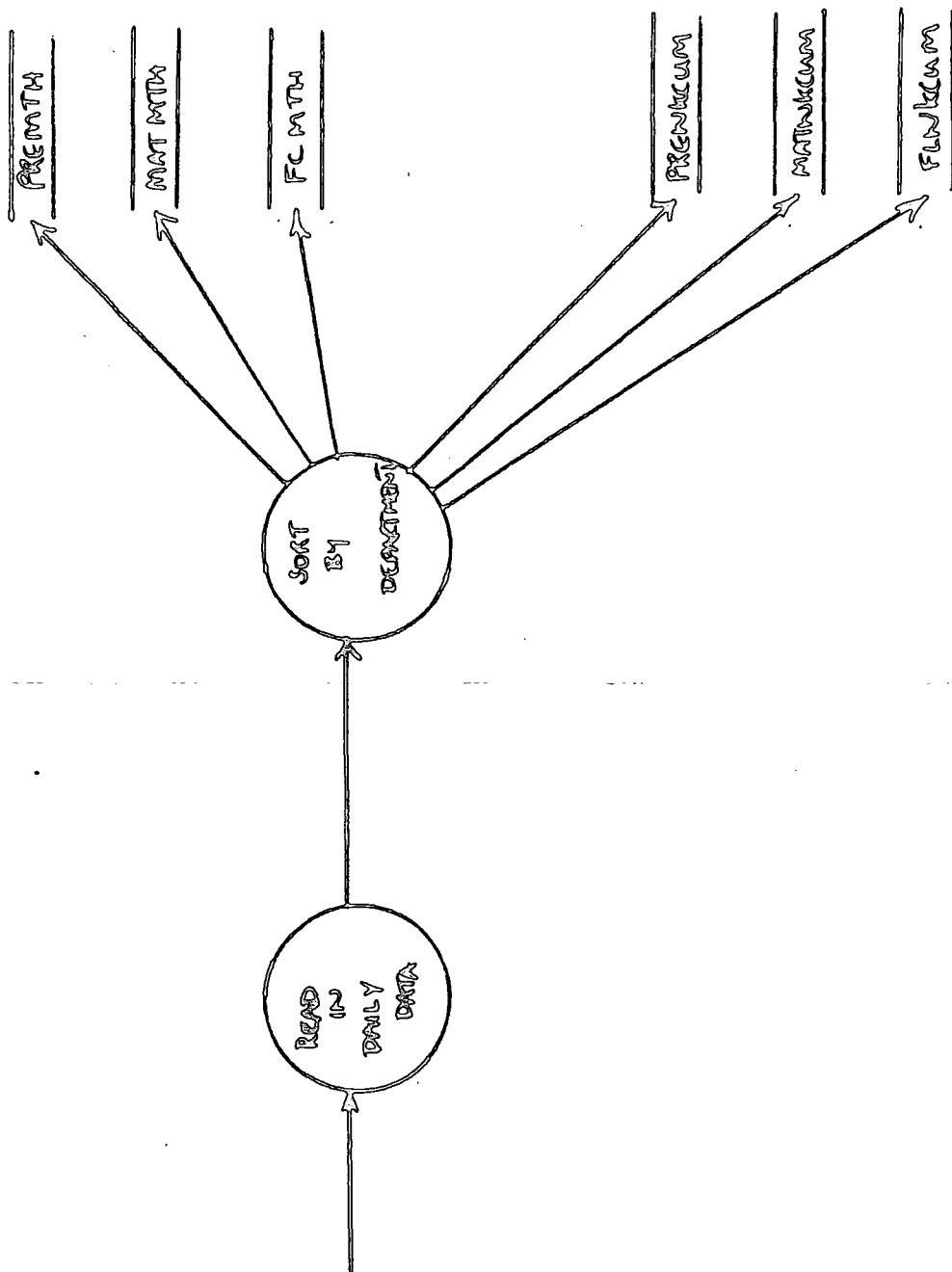
EQUIP DFD - LEVEL: .0



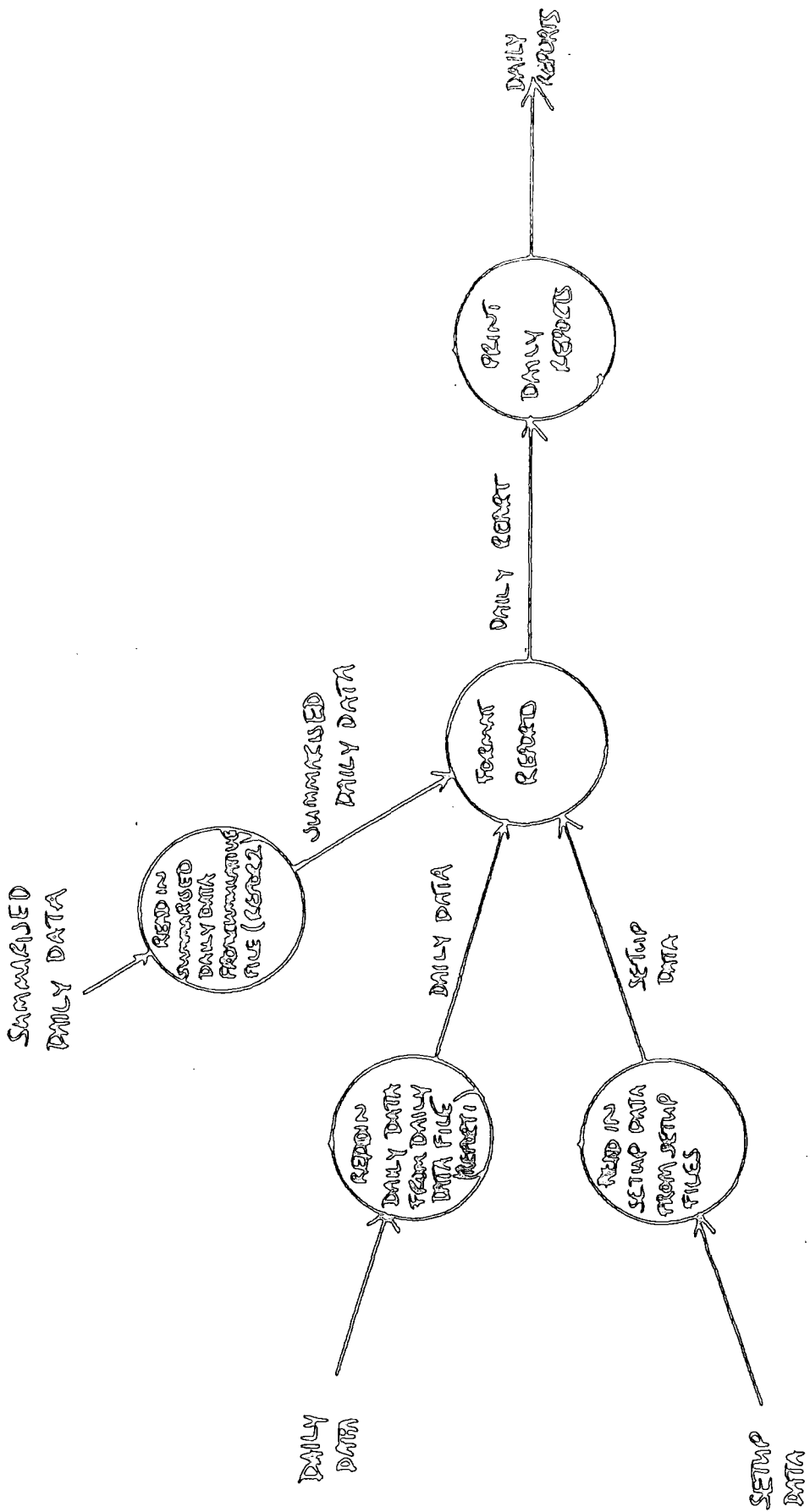
DUPLICATE FILE



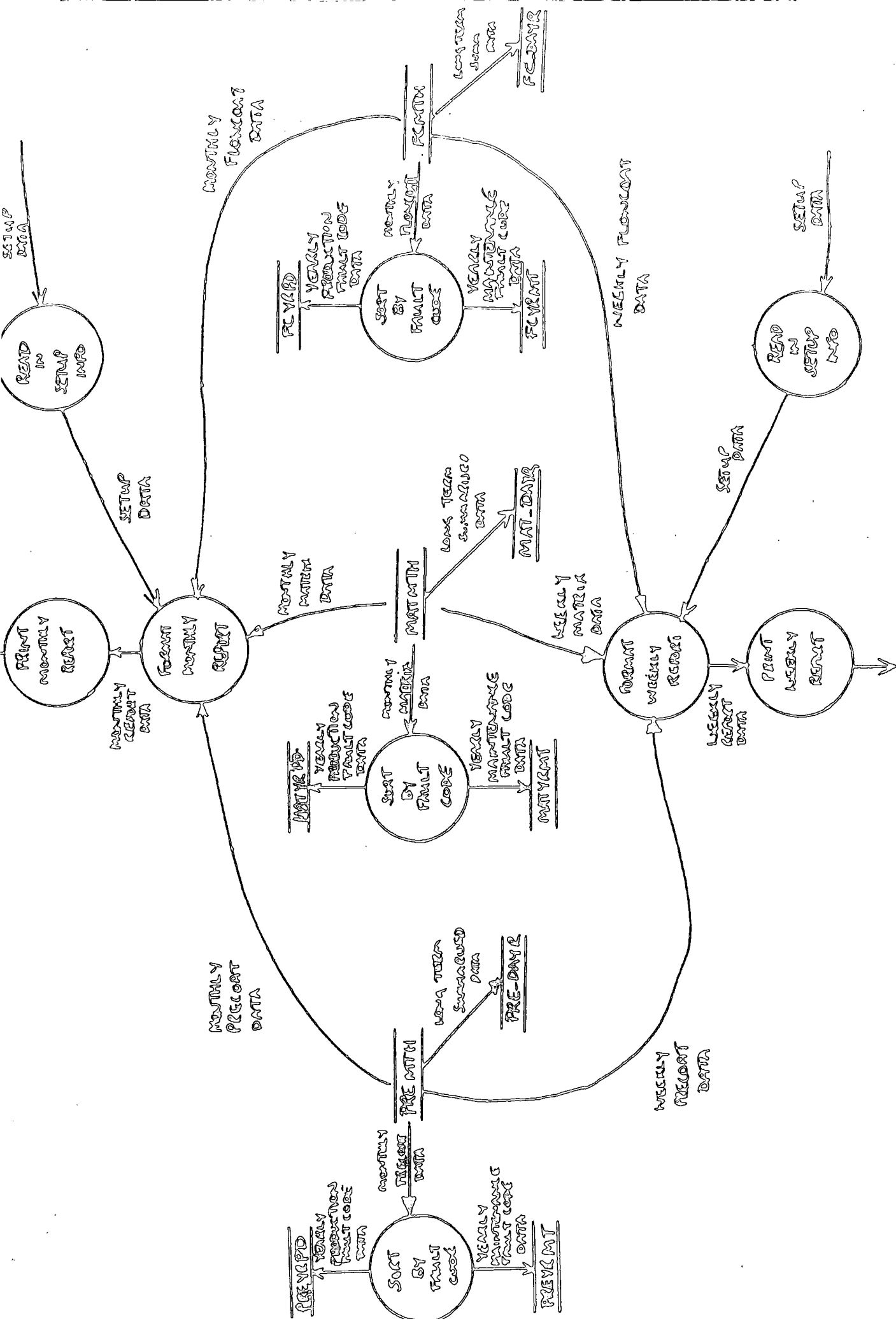
DATA INTO DEPARTMENT



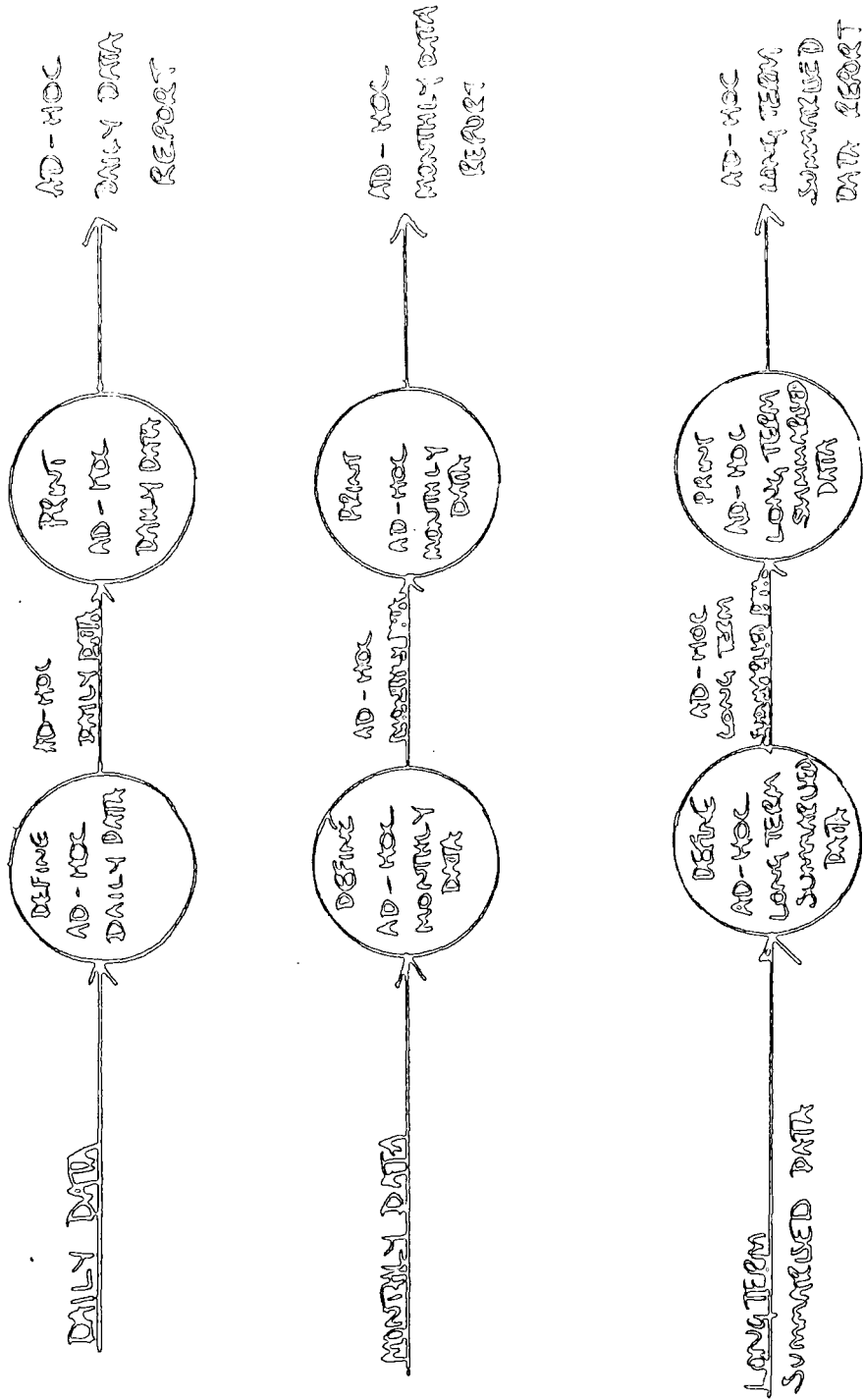
EQUIP DFD - LEVEL: 0.3  
GENERATE DAILY REPORTS



PROCESS DATA AND GENERATE WEEKLY + MONTHLY REPORTS



GENERATE AD-HOC REPORTS



APPENDIX 5.5

Program Description Language - Month Menu

Mthmenu.prg module description

=====

s module is a file to run all operational functions performed on a  
thly basis. The file will use monthly databases pmonth, matmth,  
th. Generation of monthly reports - monthly downtime analysis report  
machine group analysis (indvdl/combd)  
fault code analysis (individual/combined)  
total % breakdowns (individual/combined)  
print monthly control file for system audit

PDL for Mthmenu

\*\*\*\*\*

TART

clear screen

DO WHILE true, and run indefinitely

execute screen mask routine for monthly routines, Mthmask.pro

DO WHILE no keyboard input

IF valid input

exit from do while loop

ENDIF

ENDDO

display choice to user

do a case statement to activate the the selected option

DO CASE message type FOR

output monthly reports

this option is to contain downtime analysis report,

machine group analysis, fault code analysis,

percentage breakdown graphs.

print monthly control file for system audit purposes.

clear screen

put blanks into m\_month string variable

generate screen so as to ensure user is aware of mode

prompt user to enter month string

month should already be correctly set up from data input  
for weekly records.

read in set up info from date control database .

find first incident of month name and last incident of  
month name and update variables appropriately.

machine utilisation report

set up case statement to produce report for each dept.

IF date control flag, date\_con\_fl true

initialise loop counter

DO WHILE there is a department

DO CASE message type for

precoat monthly database, premth

store the no. of units that should have been  
made in precoat by each shift to bud\_w\_(a,b,c)

store the units of breakdown budget for each  
shift to bud\_brk\_(a,b,c)

matrix monthly database, matmth

store the no. of units that should have been  
made in matrix by 'a' shift to bud\_w\_(a,b,c)

store the units of breakdown budget for each  
shift to bud\_brk\_(a,b,c)

flexmat monthly database, femth

store the no. of units that should have been  
made in matrix by 'a' shift to bud\_w\_(a,b,c)

store the units of breakdown budget for each  
shift to bud\_brk\_(a,b,c)

```

ENDCASE
set up routine to input fault code
initialise filter variables
generate correct strings for filter command
for greater modularity of design, fault codes
should be read in at program start-up
initialise loop counters
DO WHILE there has not been 12 loops
  DO CASE message type FOR
    no orders
    general production problems
    no material
    no labour
    tech. breakdown
    breakdown - sum of various causes required
    process control
    training/team brf.
    inspection maintenance
    cleaning
    trials
  ENDCASE
  generate string for shift data
  DO WHILE there is a shift
    DO CASE message type FOR
      'A' shift
      'B' shift
      'C' shift
    ENDCASE
    generate unique variables name for each
    subtotal which also identifies position on
    machine utilisation report
    generate summary figure for all breakdown
    fault
    codes
    else
    generate figure for individual fault code
    required.
    DO CASE message type FOR
      general production problems
      b/dwn = sum of various causes required
    ENDCASE
    IF 'C' shift done
      omit for next fault code and reset
      shift pointer
    ENDIF
    increment for next shift
  ENDDO
  loop for next fault code
ENDDO

```

read in values for period definition and day  
definition from look up table - to be run when  
system initiated.

create screen to let user know what is happening  
and set up printer

clear screen

IF this is the first, proceed, report  
prompt user to ensure printer switched on  
and on line

ENDIF

IF this is the final, flowcoat, report  
inform user that data input and  
validation menu will be prompted shortly

ENDIF

suspend all output to screen

send results to the printer

set the left margin of the printer to 5

define screen layout

ENDDO

parse of machine group process/week

set up code for processing the data

code to transfer data for right month and from a  
breakdown problem from monthly files to temporary  
database

files.

parse of fault codes/process/week

process monthly data

warn user that data is going to be deleted and option to  
exit

month should already be correctly set up from data input  
for weekly records.

find first incident of month name and last incident of  
and update variables appropriately.

do a check that no data in dcall and weekly processing  
done before processing monthly data.

select each monthly database file and zap it - warning  
to user

backup procedures

. warning to user

return to main menu

ENDCASE

ENDDO

TOP

# APPENDIX 5.5 : Code- Month Menu

```

*
*          *** HTHMENU.PRG ***
**WRITTEN BY BRIGID QUINN HULLARD DURHAM. BY. 3140
*FILE TO RUN ALL OPERATIONAL FUNCTIONS TO BE PERFORMED ON A MONTHLY BASIS
*FILE WILL USE MONTHLY DATABASES PREPTH, HAPPTH, PCPTH
*GENERATION OF MONTHLY OUTPUTS -MONTHLY DOWNTIME ANALYSIS REPORT
*
*          -MACHINE GROUP ANALYSIS - INDIVIDUAL /COMBINED
*          -FAULT CODE ANALYSIS   - INDIVIDUAL /COMBINED
*          -TOTAL PERCENTAGE BREAKDOWNS-INDIVIDUAL/COMBIN
*          -TOTAL BREAKDOWN LOSS/AREA
*          -PRINT MONTHLY CONTROL FILE FOR SYSTEM AUDIT
*UPDATING OF LONG TERM DATABASES- SPLIT IN PRODUCTION AND MAINTENANCE
*PROBLEMS AND STORED IN FILES :PREYRPD, PREYRHT, HAYTRPD, HAYTRHT,
*PCYRPD, PCYRHT
*PRG SHOULD BE CALLED FROM HAINMENU AND EXIT FROM HAINMENU
*
*LAST MODIFIED ON 20TH MAR 1989 BY BHQ
*PRG HISTORY:
*10/12/87 - PRG CREATED
*30/3/88 - MODS TO PRINT OUT MONTHLY UTILISATION REPORT
*          - INDEX FILES CALLED UP WHEN FILES OPENED
*4/4/88 - MONTHLY UTILISATION REPORT N.B. USE STD UTIL_REP PROCEDURE WHEN
*          - MORE SORTED
*          - MONTHLY DATA PROCESSING CHECKED
*3/5/88 - GRAPHIC ROUTINES
*3/6/88 - BACKUP PROCEDURES, CHANGE IN MASK
*20/3/89 - DECOUPLING OF NO OF SHIFTS WORKED PER DEPT.
*-----
*generate screen mask for monthly routines (nthmask)

```

```

CLEAR
DO WHILE .T.
  DO Hthmask
    i=0
    DO WHILE i=0
      i=INKEY()
      @ 18,54 SAY ""
        IF (CHR(i))$ "1234"
          EXIT
        ENDIF
    i=0
  ENDDO

```

```
@ 18,54 SAY (CHR(i))
```

```
*do a case statement to activate the selected option
```

```
DO CASE
```

```
*output monthly reports
CASE CHR(i)$"1"
```

```

*THIS SECTION IS TO BE CONTAIN
* DOWNTIME ANALYSIS REPORT
* MACHINE GROUP ANALYSIS
* FAULT CODE ANALYSIS
* PERCENTAGE BREAKDOWN GRAPHS
* PRINT MONTHLY CONTROL FILE FOR SYTEM AUDIT PURPOSES
CLEAR
STORE SPACE(3) TO n_month

```

```

*Generate screen so as to ensure user is aware of mode
@ 0,2 to 2,70 DOUBLE

```

```

@ 1,14 SAY "E Q U I P I N F O R M A T I O N S Y S T E M"
@ 6,26 SAY "***MONTHLY PRINT OUT***"

```

```
@ 8.13 SAY "PLEASE ENTER MONTH FOR PRINTOUT (3 Chars)"
@ 10.26 SAY "MONTH:" GET n_month PICTURE 'AAA'
```

```
READ
```

```
*month should already be correctly set up from data
*input for weekly records
*read in set up info from date control database
*find 1st incident of month name and last incident of month name
*and update variables appropriately
SELECT 2
USE DATE_CON
```

```
LOCATE FOR month = UPPER(n_month)
```

```
IF .NOT. EOP()
```

```
DATE_CON_OK = .T.
```

```
STORE week_no TO n_weekst
```

```
STORE st_day TO n_dayst
```

```
STORE st_time TO n_periodst
```

```
*code to find how many weeks in month
```

```
H=1
```

```
*decouple- n<5 changed to n<15
```

```
DO WHILE H<15
```

```
CONTINUE
```

```
H=H+1
```

```
ENDDO && DO WHILE H<15
```

```
IF EOP()
```

```
STORE (n_weekst+ 3) to n_weekfn
```

```
ELSE
```

```
STORE (n_weekst+ 4) to n_weekfn
```

```
ENDIF
```

```
*load in values from last week in month
```

```
LOCATE FOR week_no = n_weekfn
```

```
STORE fin_day TO n_dayfn
```

```
STORE fin_time TO n_periodfn
```

```
*load in correct number of shifts
```

```
*decoupling-taken out
```

```
ELSE
```

```
DATE_CON_OK = .F.
```

```
@ 4,0 CLEAR
```

```
? CHR(7)
```

```
SET COLOR TO GR+,R,G,B
```

```
@ 8,9 SAY " WARNING THERE IS NO ENTRY IN THE DATE CONTROL"
```

```
@ 9,9 SAY " FILE FOR THIS MONTH NAME "
```

```
@ 12,9 SAY "TO proceed:"
```

```
@ 13,9 SAY " 1) Check that correct month name has been entered and retry."
```

```
@ 14,9 SAY " 2) Else Inform system manager of this fact"
```

```
@ 15,9 SAY " 3) AFTER date control file has been correctly "
```

```
@ 16,9 SAY " modified - reenter option and continue "
```

```
@ 17,9 SAY " 4) Report generation is now STOPPED"
```

```
SET COLOR TO G,BG,R,H
```

```
? ""
```

```
? ""
```

```
WAIT SPACE(9)+ " **Press any key to return to previous menu**"
```

```
ENDIF
```

```
USE
```

```
SELECT 1
```

```
*Machine Utilisation Report
```

```
*set up case statement to produce report for each department
```

```
IF DATE_CON_OK
```

```
STORE SPACE(7) TO This_dept
```

```
STORE SPACE(7) To Next_dept
```

```

K=1                &&initialise loop counter
DO WHILE K<4

DO CASE
CASE K=1           && all 3 files indexed on entry_i_d
  USE PREHTH INDEX Pre_ent,Pre_fc  &&and fault codes
  STORE "165P" TO n_dept
  STORE "PRECOAT" TO This_dept
  STORE "MATRIX " TO Next_dept

  *decoupling -added in 20/3/89
  SELECT 2
  USE DATE_CON

  SUM no_shift_a FOR month=n_month.AND. dept= n_dept TO no_shift_a
  SUM no_shift_b FOR month=n_month.AND. dept= n_dept TO no_shift_b
  SUM no_shift_c FOR month=n_month.AND. dept= n_dept TO no_shift_c

  SELECT 1
  **bud_w_a contains number of units that sholud of been made
  **in precoat by 'a' shift. Bud_brk_a contains units of breakdown budgetted
  ** no_shift_a etc., contain total number of shifts worked in month by each
  STORE (x_pre_cap *8 * no_shift_a) TO bud_w_a
  STORE (x_pre_cap *8 * no_shift_b) TO bud_w_b
  STORE (x_pre_cap *8 * no_shift_c) TO bud_w_c

  STORE (x_bud_brk * bud_w_a/100) TO bud_brk_a
  STORE (x_bud_brk * bud_w_b/100) TO bud_brk_b
  STORE (x_bud_brk * bud_w_c/100) TO bud_brk_c

CASE K=2
  USE HATHH INDEX Hat_ent,Hat_fc
  STORE "165H" TO n_dept
  STORE "MATRIX " TO This_dept
  STORE "FL'COAT" TO Next_dept

  *decoupling -added in 20/3/89
  SELECT 2
  USE DATE_CON

  SUM no_shift_a FOR month=n_month.AND. dept= n_dept TO no_shift_a
  SUM no_shift_b FOR month=n_month.AND. dept= n_dept TO no_shift_b
  SUM no_shift_c FOR month=n_month.AND. dept= n_dept TO no_shift_c

  SELECT 1

  STORE (x_nat_cap *8 * no_shift_a) TO bud_w_a
  STORE (x_nat_cap *8 * no_shift_b) TO bud_w_b
  STORE (x_nat_cap *8 * no_shift_c) TO bud_w_c

  STORE (x_bud_brk * bud_w_a/100) TO bud_brk_a
  STORE (x_bud_brk * bud_w_b/100) TO bud_brk_b
  STORE (x_bud_brk * bud_w_c/100) TO bud_brk_c

CASE K=3
  USE FCHTH INDEX Fc_ent,Fc_fc
  STORE "165F" TO n_dept
  STORE "FL'COAT" TO This_dept
  STORE "LACQUER" TO Next_dept

  *decoupling -added in 20/3/89
  SELECT 2
  USE DATE_CON

```

```
SUH no_shift_a FOR month=n_month.AND. dept= n_dept TO no_shift_a
SUH no_shift_b FOR month=n_month.AND. dept= n_dept TO no_shift_b
SUH no_shift_c FOR month=n_month.AND. dept= n_dept TO no_shift_c
```

```
SELECT 1
```

```
STORE (x_fc_cap *8 * no_shift_a) TO bud_m_a
STORE (x_fc_cap *8 * no_shift_b) TO bud_m_b
STORE (x_fc_cap *8 * no_shift_c) TO bud_m_c
```

```
STORE (x_bud_brk * bud_m_a/100) TO bud_brk_a
STORE (x_bud_brk * bud_m_b/100) TO bud_brk_b
STORE (x_bud_brk * bud_m_c/100) TO bud_brk_c
```

```
ENDCASE
```

```
SET ORDER TO 2      &&index on fault code
*set up routine to input fault code
```

```
*initialise filter variables
STORE 0 TO nflt_filt
STORE SPACE(1) TO n_s_filt
```

```
*generate correct strings for filter command
*for greater modularity of design, fault codes should be read in at
*program startup
```

```
I=10                &&initialise loop counters
J=1
```

```
DO WHILE I<21      &&i.e. loop 11 times
```

```
DO CASE
```

```
CASE I=10
@ 5,0 CLEAR
@ 6,26 SAY "***MONTHLY PRINT OUT***"
SET COLOR TO BG,GR+,R,G
@ 18,22 SAY "PLEASE WAIT - PROCESSING DATA "
SET COLOR TO G,BG,R,W
nflt_filt = Y_NO_ORD &&no orders -6010
```

```
CASE I=11
nflt_filt = 6020 &&not used
```

```
CASE I=12
nflt_filt = Y_NO_MAT &&no material -6030
```

```
CASE I=13
nflt_filt = Y_NO_LAB &&no labour -6040
```

```
CASE I=14
nflt_filt = Y_TECH_BRK &&tech. breakdown - 6050
```

```
CASE I=15
nflt_filt = 6000 &&breakdown --sum of various causes required
```

```
CASE I=16
nflt_filt = Y_PROC_CON &&process control -8000
```

```
CASE I=17
nflt_filt = Y_TRAINING &&training/team brf. -8010
```

```
CASE I=18
nflt_filt = Y_INSP_MAT &&inspection maintenance -8020
```

```

CASE I=19
nflt_filt = Y_CLEANING  &&cleaning -8030

CASE I=20
nflt_filt = Y_TRIALS   &&trials -9000

ENDCASE

*generate string for shift date
DO WHILE J<4
DO CASE
CASE J=1
n_s_filt = "A"

CASE J=2
n_s_filt = "B"

CASE J=3
n_s_filt = "C"

ENDCASE

*generate unique variables name for each subtotal which also
*identifies position on machine utilisation report
n_shtot = "T" + STR(I,2) + STR(J,1)

*generate summary figure for all breakdown fault codes
*else
*generate figure for individual fault code required

DO CASE

CASE I=11
*No check on week number as all entries in monthly
*files are valid for monthly reports
SUH PRODS_LOST FOR FAULT_CODE > 7000 .AND. (FAULT_CODE) < 8000;
.AND. UPPER(SHIFT)=n_s_filt .AND. UPPER(DEPT)=n_dept;
to &n_shtot

CASE I=15

SUH PRODS_LOST FOR FAULT_CODE < nflt_filt .AND. UPPER(SHIFT)=n_s_filt;
.AND. UPPER(DEPT)=n_dept to &n_shtot

OTHERWISE

SUH PRODS_LOST FOR FAULT_CODE = nflt_filt .AND. UPPER(SHIFT)=n_s_filt;
.AND. UPPER(DEPT)=n_dept to &n_shtot

ENDCASE

IF J=3          &&exit for next fault code
J=1            &&reset shift pointer
EXIT
ENDIF

J=J+1
ENDDO  && WHILE J<4

I = I+1      &&loop for next fault code
ENDDO      && WHILE I<21

```

```

*read in values for period definition and day definition from
*look up table-to be run when system initiated

```

```

STORE X_BUD_UTIL TO bud_sh_util,bud_d_util
*create screen to let user know what is happening
*and set up printer
CLEAR
@ 1,3 TO 3,69
@ 2,10 SAY " E Q U I P   I N F O R M A T I O N   S Y S T E M "

```

```

IF K=1
  @ 6,14 SAY 'PLEASE ENSURE PRINTER IS SWITCHED ON AND IS ON LINE'
  WAIT SPACE(18)+ ' AND PRESS ANY KEY TO CONTINUE'
  @ 4,0 CLEAR

```

```

ENDIF
SET COLOR TO BG,GR+,R,G
@ 10,5 SAY "PLEASE WAIT - OUTPUTTING MONTHLY UTILISATION REPORTS FOR"
@ 11,5 SAY "                               TO PRINTER"
@ 10,62 SAY d_month
SET COLOR TO G,BG,R,W

```

```

SET CONSOLE OFF
SET DEVICE TO PRINT
SET MARGIN TO 5

```

```

@ 0,0 SAY ""
@ 2,1 SAY "E Q U I P   M A N A G E M E N T   I N F O R M A T I O N   S Y S T E M"
@ 3,1 SAY "-----"

```

```

@ 5,0 SAY "                               MACHINE UTILISATION REPORT"
@ 6,0 SAY "                               "
@ 7,0 SAY "                               DEPT:"
@ 7,32 SAY this_dept
@ 8,0 SAY "                               "
@ 9,0 SAY "-----"
@ 10,0 SAY "Monthly Downtime Analysis Report for"
@ 11,0 SAY "                               "
@ 12,0 SAY "                               MONTH : "
@ 12,32 SAY d_month
@ 12,33 SAY " | "
@ 13,0 SAY "                               "
@ 14,0 SAY "PERIOD START TIME: WEEK"
@ 14,26 SAY d_weekst PICTURE "999"
@ 14,30 SAY "DAY"
@ 14,35 SAY d_dayst PICTURE "9"
@ 14,42 SAY d_periodst PICTURE "99:99"
@ 14,50 SAY "HRS"
@ 15,0 SAY "PERIOD FINISH TIME: WEEK"
@ 15,26 SAY d_weekfn PICTURE "999"
@ 15,30 SAY "DAY"
@ 15,35 SAY d_dayfn PICTURE "9"
@ 15,42 SAY d_periodfn PICTURE "99:99"
@ 15,50 SAY "HRS"
@ 16,0 SAY "PRODUCTION UNITS AVAILABLE : "
@ 16,30 SAY (bud_w_a + bud_w_b + bud_w_c) PICTURE "99999"
@ 16,37 SAY "PER MONTH"
@ 17,0 SAY " ( A SHIFT:"
@ 17,12 SAY bud_w_a PICTURE "99999"
@ 17,19 SAY "B SHIFT:"
@ 17,28 SAY bud_w_b PICTURE "99999"
@ 17,36 SAY "C SHIFT:"
@ 17,46 SAY bud_w_c PICTURE "99999"
@ 17,52 SAY ") "
@ 18,0 SAY "-----"
@ 20,0 SAY "STANDBY TIME      A SHIFT      B SHIFT      C SHIFT      TOTAL"
@ 21,0 SAY "=====          =====          =====          ====="

```

PRODUCTION UNITS LOST"

@ 22,0 SAY "  
 @ 24,0 SAY "NO ORDERS"  
 @ 24,18 SAY T101  
 @ 24,28 SAY T102  
 @ 24,42 SAY T103  
 @ 24,52 SAY T101+T102+T103  
 @ 25,0 SAY "GENERAL PRODN."  
 @ 25,18 SAY T111  
 @ 25,28 SAY T112  
 @ 25,42 SAY T113  
 @ 25,52 SAY T111+T112+T113  
 @ 26,0 SAY "NO MATERIAL "  
 @ 26,18 SAY T121  
 @ 26,28 SAY T122  
 @ 26,42 SAY T123  
 @ 26,52 SAY T121+T122+T123  
 @ 27,0 SAY "NO LABOUR"  
 @ 27,18 SAY T131  
 @ 27,28 SAY T132  
 @ 27,42 SAY T133  
 @ 27,52 SAY T131+T132+T133  
 @ 28,0 SAY "TECH. BREAKDOWN"  
 @ 28,18 SAY T141  
 @ 28,28 SAY T142  
 @ 28,42 SAY T143  
 @ 28,52 SAY T141+T142+T143  
 @ 29,0 SAY "  
 @ 30,0 SAY " SUB TOTAL"

STOT1 = T101+T111+T121+T131+T141

@ 30,18 SAY STOT1

STOT2 = T102+T112+T122+T132+T142

@ 30,28 SAY STOT2

STOT3 = T103+T113+T123+T133+T143

@ 30,42 SAY STOT3

@ 30,52 SAY STOT1+STOT2+STOT3

@ 31,0 SAY "  
 @ 32,0 SAY "  
 @ 34,0 SAY "NON SCHEDULED DOWNTIME"  
 @ 35,0 SAY "  
 @ 37,0 SAY "BREAKDOWNS"  
 @ 37,18 SAY T151  
 @ 37,28 SAY T152  
 @ 37,42 SAY T153  
 @ 37,52 SAY T151+T152+T153  
 @ 38,0 SAY "BUDGET ("  
 \* @ 38,8 SAY (x\_bud\_brk#100) PICTURE "99"  
 @ 38,8 SAY x\_bud\_brk PICTURE "99"  
 @ 38,10 SAY "%"  
 @ 38,25 SAY bud\_brk\_a PICTURE "999"  
 @ 38,35 SAY bud\_brk\_b PICTURE "999"  
 @ 38,49 SAY bud\_brk\_c PICTURE "999"  
 @ 38,60 SAY (bud\_brk\_a + bud\_brk\_b + bud\_brk\_c ) PICTURE "9999"  
 @ 40,0 SAY "  
 @ 42,0 SAY "SCHEDULED DOWNTIME"  
 @ 43,0 SAY "  
 @ 45,0 SAY "PROCESS CONTROL"  
 @ 45,18 SAY T161  
 @ 45,28 SAY T162  
 @ 45,42 SAY T163  
 @ 45,52 SAY T161+T162+T163  
 @ 46,0 SAY "TRAINING/TEAM BRP."  
 @ 46,18 SAY T171

```

@ 46,42 SAY T173
@ 46,52 SAY T171+T172+T173
@ 47,0 SAY "PLAN. MAINTENANCE"
@ 47,18 SAY T181
@ 47,28 SAY T182
@ 47,42 SAY T183
@ 47,52 SAY T181+T182+T183
@ 48,0 SAY "CLEANING"
@ 48,18 SAY T191
@ 48,28 SAY T192
@ 48,42 SAY T193
@ 48,52 SAY T191+T192+T193
@ 49,0 SAY "
@ 50,0 SAY "          SUB TOTAL"

```

```

STOT4 = T161+T171+T181+T191
@ 50,18 SAY STOT4
STOT5 = T162+T172+T182+T192
@ 50,28 SAY STOT5
STOT6 = T163+T173+T183+T193
@ 50,42 SAY STOT6
@ 50,52 SAY STOT4+STOT5+STOT6

```

```

@ 51,0 SAY "
@ 52,0 SAY "
@ 54,0 SAY "TRIALS"
@ 54,18 SAY T201
@ 54,28 SAY T202
@ 54,42 SAY T203
@ 54,52 SAY T201+T202+T203
@ 55,0 SAY "
@ 57,0 SAY "ACTUAL PRODUCTION"

```

```

ACT_A = (bud_m_a)-(STOT1+T151+STOT4+T201)
@ 57,24 SAY ACT_A PICTURE "99999"
ACT_B = (bud_m_b)-(STOT2+T152+STOT5+T202)
@ 57,34 SAY ACT_B PICTURE "99999"
ACT_C = (bud_m_c)-(STOT3+T153+STOT6+T203)
@ 57,48 SAY ACT_C PICTURE "99999"
@ 57,59 SAY ACT_A+ACT_B+ACT_C PICTURE "99999"

```

```

@ 59,0 SAY "BUDGET UTILISATION (%)"
@ 59,18 SAY bud_sh_util
@ 59,28 SAY bud_sh_util
@ 59,42 SAY bud_sh_util
@ 59,54 SAY bud_d_util

```

```

@ 60,0 SAY "ACTUAL UTILISATION (%)"

```

```

@ 60,24 SAY (ACT_A/(bud_m_a))*100 PICTURE "999.9"
@ 60,34 SAY (ACT_B/(bud_m_b))*100 PICTURE "999.9"
@ 60,48 SAY (ACT_C/(bud_m_c))*100 PICTURE "999.9"
@ 60,59 SAY ((ACT_A+ACT_B+ACT_C)/(bud_m_a+bud_m_b+bud_m_c))*100 PICTURE "999.9"
@ 61,0 SAY ""
@ 62,0 SAY ""

```

```

SET CONSOLE ON
SET DEVICE TO SCREEN

```

```

K=K+1 &&increment for next dept
RNDDO &&WHILE K<4 end of machine utilisation report code

```

```

-----
*
*          GRAPHICS ROUTINES
*Monthly printouts will be run off together
*therefore month is not prompted for again
*1)Pareto of Machine group/process/week
*2)Pareto of fault codes/process/week

*****Machine group analysis/process*****

*set up code for processing the data
*code to transfer data for right month and from a breakdown problem
*from monthly files to temporary database files

  SET PROCEDURE TO MthMenu
  DO P_Banner
  CLOSE PROCEDURE

*STORE ALL VARIABLES BEFORE PROCEDURE CALLED UP

  STORE "PREHTH" TO DFILE1
  STORE "HATHTH" TO DFILE2
  STORE "FCHTH" TO DFILE3

  STORE "PRE_ENT" TO DF1IND1
  STORE "PRE_FC" TO DF1IND2
  STORE "HAT_ENT" TO DF2IND1
  STORE "HAT_FC" TO DF2IND2
  STORE "FC_ENT" TO DF3IND1
  STORE "FC_FC" TO DF3IND2

  STORE "PRBCOAT" TO D_NAME1
  STORE "MATRIX" TO D_NAME2
  STORE "FLOWCOAT" TO D_NAME3

  STORE 4 TO LOOP_COUNT

  STORE "VAL(LEFT(ENTRY_I_D,3))>(M_WEEKST-1) .AND.;
  VAL(LEFT(ENTRY_I_D,3))<(M_WEEKFN+1)" TO TIMECOND

  STORE 5 TO NO_OF_BARS
  STORE .T. TO PRINT_REQ

  STORE "MONTH - " + SUBSTR(M_MONTH,1,3) TO TIME_STRING

  SET PROCEDURE TO STDPROC
  DO MPARETO WITH DFILE1,DF1IND1,DF1IND2,DFILE2,DF2IND1,DF2IND2,DFILE3,;
  DF3IND1,DF3IND2,TIMECOND,NO_OF_BARS,LOOP_COUNT,D_NAME1,D_NAME2,D_NAME3,TIME_STRING,PR

  CLOSE PROCEDURE

*****fault group analysis/process*****
  SET PROCEDURE TO MTHMENU
  DO P_Banner
  CLOSE PROCEDURE

*STORE ALL VARIABLES BEFORE PROCEDURE CALLED UP

  STORE "PREHTH" TO DFILE1
  STORE "HATHTH" TO DFILE2
  STORE "FCHTH" TO DFILE3

  STORE "PRE_ENT" TO DF1IND1

```

```

STORE 'PRE_FC' TO DF1IND2
STORE 'MAT_ENT' TO DF2IND1
STORE 'MAT_FC' TO DF2IND2
STORE 'FC_ENT' TO DF3IND1
STORE 'FC_FC' TO DF3IND2

```

```

STORE "PRECOAT" TO D_NAME1
STORE "MATRIX" TO D_NAME2
STORE "FLOWCOAT" TO D_NAME3

```

```

STORE 4 TO LOOP_COUNT

```

```

STORE 'VAL(LEFT(ENTRY_I_D,3))>(H_WEEKST-1) .AND.;
VAL(LEFT(ENTRY_I_D,3))<(H_WEEKST+1)' TO THRCOND

```

```

STORE 5 TO NO_OF_BARS
STORE 'MONTH - ' + SUBSTR(H_MONTH,1,3) TO TIME_STRING
STORE .F. TO PRINT_REQ

```

```

SET PROCEDURE TO STDPROC
DO FPARBTO WITH DFILE1,DF1IND1,DF1IND2,DFILE2,DF2IND1,DF2IND2,DFILE3,;
DF3IND1,DF3IND2,THRCOND,NO_OF_BARS,LOOP_COUNT,D_NAME1,D_NAME2,D_NAME3,TIME_STRING,PRINT_REQ
CLOSE PROCEDURE

```

```

ENDIF    && IF DATE_CON_OK

```

```

*-----

```

```

*process monthly data
CASE CHR(i)$"2"

```

```

* warn user that data is going to be deleted and option to exit

```

```

STORE SPACE(3) TO n_month
SET CONFIRM ON
CLEAR
@ 0,2 to 2,69 DOUBLE
@ 1,14 SAY " E Q U I P   D A T A   P R O C E S S I N G "
@ 6,26 SAY "***MONTHLY PROCESSING***"
@ 8,13 SAY "      PLEASE ENTER NAME OF MONTH (3 Chars)"
@ 10,26 SAY "      MONTH:" GET n_month PICTURE "AAA"

```

```

READ
SET CONFIRM OFF
*month should already be correctly set up from data
*input for weekly records
*find 1st incident of month name and last incident of
*and update variables appropriately
SELECT 2
USE DATE_CON

```

```

LOCATE FOR month = UPPER(n_month)
IF .NOT. EOF()
    STORE week_no TO n_weekst
    *code to find how many weeks in month
    H=1
    DO WHILE H<15
        CONTINUE
        H=H+1
    ENDDO    && DO WHILE H<15
    IF EOF()
        STORE (n_weekst+ 3) to n_weekfn
    ELSE
        STORE (n_weekst+ 4) to n_weekfn
    ENDIF
ENDIF
ENDIF    &&IF .NOT. EOF()

```

\*do a check that no data in dyall and weekly processing done before processing  
\*monthly data

```
SELECT 3
USE Dyall INDEX Entry_ID,Flt_Code
REINDEX
  IF RECCOUNT()<>0 .OR. n_weekFn >= VAL(Week_Chk)
    CLEAR
    ? CHR(7)
    SET COLOR TO GR+,BG,R,W
    @ 1,3 TO 3,69
    @ 2,10 SAY " E Q U I P   I N F O R M A T I O N   S Y S T E M "
    @ 5,10 SAY "          *****MONTHLY DATA PROCESSING***** "
    @ 8,9 SAY "***** SORRY,Monthly Processing Facilities Refused*****"
    @ 11,9 SAY "You are trying to process monthly data when data "
    @ 12,9 SAY "is present in the daily database *OR* you have not"
    @ 13,9 SAY "yet processed last weeks data"
    @ 14,9 SAY "1) Ensure daily and weekly data have been processed."
    @ 15,9 SAY "2) Contact system manager if this is not the cause of the problem."
    @ 17,0 SAY " "
    WAIT SPACE(13)+ " PRESS ANY KEY TO RETURN TO THE MAIN MENU"
    SET COLOR TO G,BG,R,W
    USE      &&Close dyall and indexes
    RETURN
  ENDF  && IF RECCOUNT()<>0
USE      &&Close dyall and indexes
SELECT 1
```

```
@ 5,0 CLEAR
SET COLOR TO GR+,R,GR,B
? "          PROCESS MONTHLY DATA"
SET COLOR TO G,BG,R,W
```

```
SET COLOR TO R,GR+,B,BG
@ 10,5 SAY " W A R N I N G - DATA FILES WILL BE ERASED IN THE FOLLOWING"
@ 11,8 SAY " OPERATION , DO YOU WISH TO CONTINUE ?      (Y/N)"
```

```
WAIT '' TO yn
IF UPPER(yn) <> 'Y'
  H_DBL_OK = .F.      &&user wishes to exit
ELSE
  H_DBL_OK = .T.      &&user wishes to continue
ENDIF
SET COLOR TO G,BG,R,W
```

```
IF H_DBL_OK          &&monthly deletion ok flag set
*message to user
CLEAR
@ 0,2 to 2,69 DOUBLE
@ 1,14 SAY " E Q U I P   D A T A   P R O C E S S I N G "
  @ 4,21 SAY "***PROCESSING MONTHLY DATA***"
  @ 6,21 SAY "*****PLEASE WAIT*****"
```

```
*update production and maintenance databases for each department
*all fault codes greater than 6000 are production problems
K=1
DO WHILE K<4
```

DO CASE

```
* precoat
CASE K=1
  SELECT 2
    USE PREYRPD INDEX Prepdent,Prepdfc
    APPEND FROM PREMTH FOR FAULT_CODE >= 6000
```

```
USE
USE PREYRHT INDEX Preitent,Prentfc
APPEND FROM PREHTH FOR FAULT_CODE < 6000
CLOSE DATABASES
```

```
* matrix
CASE K=2
SELECT 2
    USE HATYRPD INDEX Hatpdent,Hatpdfc
    APPEND FROM HATHTH FOR FAULT_CODE >= 6000
    USE
    USE HATYRHT INDEX Hatntent,Hatntfc
    APPEND FROM HATHTH FOR FAULT_CODE < 6000
    CLOSE DATABASES
```

```
* flowcoat
CASE K=3
SELECT 2
    USE FCYRPD INDEX Fcpdent,Fcpdfc
    APPEND FROM FCHTH FOR FAULT_CODE >= 6000
    USE
    USE FCYRHT INDEX Fcntent,Fcntfc
    APPEND FROM FCHTH FOR FAULT_CODE < 6000
    CLOSE DATABASES
```

```
ENDCASE
SELECT 1
```

```
K=K+1
ENDDO    &&do while k<4
```

```
*2)select each monthly database file and zap it
* Dbase automatically keeps a backup
SET SAFETY OFF
```

```
USE PREHTH INDEX Pre_Ent,Pre_Fc
ZAP
USE HATHTH INDEX Hat_Ent,Hat_Fc
ZAP
USE FCHTH INDEX Fc_Ent,Fc_Fc
ZAP
CLOSE DATABASES
SET SAFETY ON
```

```
@ 4,0 CLEAR
SET COLOR TO BG,GR+,R,G
@ 8,20 SAY "MONTHLY DATA SUCCESSFULLY PROCESSED"
?
WAIT SPACE(13)+"PRESS ANY KEY TO RETURN TO MONTHLY OPTIONS MENU"
SET COLOR TO G,BG,R,W
```

```
ENDIF    &&if n_dek_ok
```

```
*backup procedures
CASE CHR(i)%"3"
    *warning to user
```

```
CLEAR
@ 0,2 to 2,69 DOUBLE
@ 1,14 SAY "*** E Q U I P   D A T A   B A C K U P ***"
SET COLOR TO BG,R,GR+,W
@ 6,20 TO 9,50
@ 7,22 SAY "PLEASE ENSURE APPROPRIATE "
```

```

@ 9,22 SAY "BACKUP DISKS ARE AVAILABLE."
@ 13,14 SAY "ALL DATA FILES WILL : "
@ 14,15 SAY " 1)BE BACKED UP ONTO FLOPPY DISKETTES (DRIVE A)"
@ 15,15 SAY " 2)COPIED TO DIRECTORY 'CHTDATA' ON THE HARD DISK."
@ 17,14 SAY "PLEASE FOLLOW DOS PROMPTS TO CARRY OUT BACKUP"
@ 20,0 SAY " "
SET COLOR TO G,BG,R,H
WAIT SPACE(17): " PRESS ANY KEY TO RETURN TO CONTINUE"

```

```

*backup databases,fmt files and memory variable files
CLEAR
RUN BACKUP C:\DBA\*.*.A:
RUN COPY C:\DBA\*.DBF C:\CHTDATA
RUN COPY C:\DBA\*.NDX C:\CHTDATA
RUN COPY C:\DBA\*.HEM C:\CHTDATA

```

```

CLEAR
@ 0,2 to 2,69 DOUBLE
@ 1,14 SAY "*** E Q U I P   D A T A   B A C K U P ***"

```

```

SET COLOR TO BG,GR+,R,G
@ 8,19 SAY "MONTHLY BACKUP SUCCESSFULLY PROCESSED"
?
WAIT SPACE(14)+ "PRESS ANY KEY TO RETURN TO MONTHLY OPTIONS MENU"
SET COLOR TO G,BG,R,H

```

```

* return to main menu

```

```

CASE CHR(i)$"4"
  CLOSE ALL
  RETURN

```

```

ENDCASE
ENDDO      &&DO WHILE .T.

```

```

*-----
*procedure to produce a banner to let user know data being processed

```

```

PROCEDURE P_Banner
  CLEAR
  @ 0,2 to 2,69 DOUBLE
  @ 1,14 SAY " E Q U I P   D A T A   C O L L E C T I O N "
  @ 4,26 SAY "***MONTHLY PRINT OUT***"
  SET COLOR TO BG,GR+,R,G
  @ 18,12 SAY "      PLEASE WAIT - PROCESSING DATA FOR PARETO "
  @ 19,12 SAY "                GRAPH PRINTOUT"
  SET COLOR TO G,BG,R,H

```

```

* END OF P_Banner
*-----

```

```

* EOF: HTHMENU.PRG

```

Program Description Language - Standard Procedures

## MPARETO procedure description

Procedure to generate reports of machines for lost products. Parameters passed from calling programs to determine databases, time periods and conditions to sort on.

PDL for procedure MPARETO

START

```

identify the beginning of the routine MPARETO
specify memory variables that use information passed by the calling
program
do not prompt when a file is about to be overwritten
DO WHILE valid loop count
  DO CASE message type FOR
    Prometp database
      remove all records
    Matmetp database
      remove all records
    Femetp database
      remove all records
  ENDCASE
  initialise check_str
  position the record pointer to the first record that satisfies
  fault code < 6000 and time condition
  DO WHILE true, and run indefinitely
    IF a record is found
      check has not been checked already
      IF not
        update appropriate scratchpad database file
        add records to the end of the database file
        back to monthly database
        reassign check string variable so that machine code
        included
      ENDIF
      RETURN record pointer for next condition
      IF condition not met
        exit from do while loop
      ENDIF
    ENDDO
    increment for next department
  ENDDO
close databases

```

```

DO WHILE valid loop count
DO CASE according type FOR
Procstp
copy to Procscr
Matxstp
copy to Matxscr
Pcmstp
copy to Pcmscr
ENDCASE
load in graphics
execute graph-on procedure
increment for next count
ENDDO
elseo databases
return prompt when a file is about to be overwritten
return to text mode
execute graph-off procedure
TOP

```

FPARETO procedure description

procedure to generate reports of fault codes. Parameters passed from calling program to determine databases, time periods conditions to report on.

PDL for procedure FPARETO

START

```

identify the beginning of the routine FPARETO
specify memory variables that use information passed by the calling
program
do not preempt when a file is about to be overwritten
DO WHILE valid loop count
  DO CASE message type FOR
    Profetp database
      remove all records
    Matfetp database
      remove all records
    Fefetp database
      remove all records
  ENDCASE
store nothing to check_str
position the record pointer to the first record that satisfies
fault code < 6000 and time condition
DO WHILE true, and run indefinitely
  IF a record is found
    check has not been checked already
    IF not
      update appropriate scratchpad database file
      add records to the end of the database file
      back to monthly database
      reassign check string variable so fault code included
    ENDIF
    return record pointer for next continue
  ENDIF
  IF EOF ( )
    exit from do-while loop
  ENDIF
ENDDO
increment for next department
ENDDO
close databases
DO WHILE valid loop count

```

```
DO CASE MANAGE type FOR
```

```
Protect database
```

```
copy to Protec
```

```
Protect
```

```
copy to Protec
```

```
Protect
```

```
copy to Protec
```

```
ENDCASE
```

```
load in graphica
```

```
execute graph-on procedure
```

```
increment for next count
```

```
ENDDO
```

```
close database
```

```
return prompt when a file is about to be overwritten
```

```
return to text menu
```

```
execute graph-off procedure
```

```
STOP
```

LINEGRAPH procedure description

procedure to generate linegraph. Parameters passed from calling programs to  
 terminal databases, time periods conditions to sort on

PDL for procedure LINEGRAPH

```

START
  identify the beginning of the routine LINEGRAPH
  specify memory variables that use information passed by the calling
  program
  do not preempt when a file is about to be overwritten
  DO WHILE valid loop count
    DO CASE message type FOR
      Printp database
        remove all records
      MatIntp
        remove all records
      Felntp
        remove all records
    ENDCASE
    position the record pointer to the first record that satisfies
    the work required
    DO WHILE valid loop count
      IF a record is found
        check has not been checked already
      ENDIF
      IF condition not met
        exit from do while loop
      ENDIF
    ENDDO
    increment for next department
  ENDDO
  close databases
  DO WHILE valid loop count
    DO CASE message type FOR
      Printp
        copy to PreInor
      MatIntp
        copy to MatInor
      Felntp
        copy to FelInor
    ENDCASE
  
```

```
load in graphics
execute graph-on procedure
increment for next count
```

```
ENDOO
```

```
close databases
```

```
return prompt when a file is about to be overwritten
```

```
return to text mode
```

```
execute graph-off procedure
```

```
OP
```

# APPENDIX 5.6 : Code - Standard Procedures

```

*
*PROCEDURES
***WRITTEN BY BRIGID QUINN, MULLARD DURHAM, EXT. 3140***
*PROGRAM TO CONTAIN PROCEDURES WHICH ARE REQUIRED BY MORE THAN ONE
*PROGRAM. PROCEDURES FOR USE WITHIN ONE FILE ARE CONTAINED WITHIN THAT
*FILE

*PROCEDURES WITHIN THIS FILE
*2) IDENT - PASSWORD ENTRY AND CHECK ROUTINE
*3) GRAPH_ON - SET UP FOR GRAPHICS MODE
*4) GRAPH_OFF - RETURN TO TEXT MODE FROM GRAPHICS MODE
*5) MPARETO - MACHINE CODE PARETO
*6) FPARETO - FAULT CODE PARETO
*7) LINEGRAPH -LINEGRAPH ROUTINE
*
*LAST MODIFIED ON 11th MAY,1988 BY BHQ
*PRG HISTORY:
*3/11/87 - FILE CREATED. UTIL_REP CREATED
*4/11/87 - PRINTER CONTROLS ENTERED.
*11/1/88 - PROCEDURE IDENT ADDED. COPIED FROM DIAVHENU. RETURN STATEMENT
* - APPENDED TO UTIL_REP
*23/2/88 - CHANGES FOR NO ORDERS TO COVER MATRIX BREAKDOWNS
* - STOPPAGES FOR STOCK-DEPT. VARS WILL STILL BE ACTIVE
*4/4/88 - CHANGES TO UTIL_REP TO RECEIVE PARAMETERS TO INDICATE WHICH SHIFT
* - SHOULD BE ACCOUNTED FOR ON DAILY PRINTOUT.TIDYING UP OF COLUMNS
* - ON PRINTOUT
*22/4/88 - GRAPH ON AND GRAPH OFF ENTERED
*28/4/88 - PARETO OUTPUT ROUTINES
*3/5/88 - MODS TO PARETO ROUTINES
*8/5/88 - LINE GRAPH ROUTINES-INITIAL CODE
*11/5/88 - BUDGET ON LINE GRAPH
*****

```

\*Password procedure

```

*****
* IDENT - TO CHECK PASSWORD ETC. *
*****

```

PROCEDURE Ident

```

* Procedure to check password before allowing user further access
*to code . User is given opportunity to change password . Incorrect
*password -program returns to menu. Password is stored in file
*SYSCHK and is read in at startup

```

```

* give unauthorised users chance to exit
@12,14 say 'THIS ROUTINE SHOULD ONLY BE USED BY AUTHORISED USERS'
@14,21 say 'DO YOU WISH TO CONTINUE ?? (Y/N)'

```

```

WAIT '' to yn
IF UPPER(yn) <> 'Y'
    OK = .F.
    RETURN
ENDIF

```

```

@ 4,0 CLEAR
@ 10,29 SAY 'PLEASE ENTER PASSWORD'

```

```

SET EXACT ON      && ensure exact word is input
SET CONSOLE OFF  && stop output to screen

```

```

*input from user to pass
ACCEPT TO PASS

```

SET CONSOLE ON

\* Check and action on validity of user

IF UPPER(pass) = password

OK = .Y.

@10,29 SAY 'PASSWORD RECOGNISED'

@12,0 SAY ''

WAIT SPACE(19)+ 'DO YOU WISH TO CHANGE THE PASSWORD ? (Y/N)' to ans

IF UPPER(ans) = 'Y'

@ 4,0 CLEAR

@ 10,29 SAY 'TYPE NEW PASSWORD'

SET CONSOLE OFF

ACCEPT TO pass1

pass1 = UPPER(pass1)

@ 10,29 SAY 'TYPE AGAIN TO CONFIRM'

ACCEPT TO pass2

pass2 = upper(pass2)

IF pass2 = pass1

password=pass1

SET SAFETY OFF

SAVE ALL LIKE password to SYSCHK &save password in system check

SET SAFETY ON

@ 9,0 CLEAR

SET COLOR TO BG,B

@ 10,31 SAY 'PASSWORD ACCEPTED'

SET COLOR TO G,BG,R,W

@ 21,25 SAY 'PRESS ANY KEY TO CONTINUE'

WAIT

ELSE

@ 15,13 say 'ERROR - PASSWORD NOT ACCEPTED.....PASSWORD UNCHANGED.'

ENDIF

SET CONSOLE ON

ENDIF

ELSE

OK = .F.

@ 4,0 CLEAR

? CHR(7)

SET COLOR TO R,B

@10,18 say 'AUTHORISATION FAILURE.....RETURNING TO MENU.'

?

WAIT SPACE(24)+ "PRESS ANY KEY TO CONTINUE"

SET COLOR TO G,BG,R,W

ENDIF

SET EXACT OFF

@22,0 SAY ''

RETURN

\* End of procedure ident

\*\*\*\*\*

\*Procedure to set up environment of use of DGB graphics package

PROCEDURE Graph\_On

\* SUPPRESS TEXT OUTPUT

SET TALK OFF

\* INITIALISE DGB3 VARIABLES

DO DGB

```

                                * LOAD A CHARACTER 3BY
STORE 'STANDARD' TO CSBY
LOADCSBY,0,EXT,CSBY,3ND

                                * SWITCH TO HI-RES MODE
&SETHIRES,0,END

                                * CLEAR THE HI-RES SCREEN
&CLRSCEEN
&GETCHAR,2,END
ACCEPT TO VERSION

RETURN
* End of procedure Graph_on
*****
*Procedure to return to text environment from graphics DGB environment

PROCEDURE Graph_Off

&SETTEXT

RELEASE VERSION, CHAR,CSBY

RETURN
* End of procedure Graph_on
*****
***WRITTEN BY BRIGID QUINN HULLARD DURHAM. EXT. 3140
*Procedure to generate pareto of machines for lost products

*parameters passed from calling programs to determine databases,time periods
*conditions to sort on

PROCEDURE HPARETO
PARAMETERS DFILE1,DF1IND1,DF1IND2,DFILE2,DF2IND1,DF2IND2,DFILE3,DF3IND1,;
DF3IND2,TIMECOND,NO_OF_BARS,LOOP_COUNT,D_NAME1,D_NAME2,D_NAME3,TIME_STRING,PRINT_REQ

SET SAFETY OFF
P=1
DO WHILE P<LOOP_COUNT

DO CASE

CASE P=1
  SSELECT 1
  USE &DFILE1 INDEX &DF1IND1,&DF1IND2
  REINDEX
  SSELECT 2
  USE PRRHCTP
  ZAP

CASE P=2
  SSELECT 1
  USE &DFILE2 INDEX &DF2IND1,&DF2IND2
  REINDEX
  SSELECT 2
  USE HATHCTP
  ZAP

CASE P=3
  SSELECT 1
  USE &DFILE3 INDEX &DF3IND1,&DF3IND2
  REINDEX
  SSELECT 2
  USE PCHCTP
  ZAP

```

ENDCASE

STORE 10 check\_str

SELECT 1

LOCATE FOR Fault\_code < 6000 .AND. @timecond

DO WHILE .T.

IF FOUND()

STORE UPPER(MACH\_CODE) TO n\_mach\_cd

STORE RECCNO() TO rec\_return

\*check has not been checked already

IF .NOT. n\_mach\_cd \$ check\_str

SUM PRODS\_LOST FOR UPPER(MACH\_CODE)=n\_mach\_cd .ASO.;

FAULT\_CODE<6000.AND. @timecond to nachsum

\*update appropriate scratchpad dbf

SELECT 2

APPEND BLANK

REPLACE mach\_code WITH n\_mach\_cd

REPLACE Sum\_prods WITH nachsum

SELECT 1      \*\*Back to monthly database

\* reassign check string variable so that machine code in

check\_str = check\_str + n\_mach\_cd

ENDIF   \*\* if not n\_mach \$ check\_string

GOTO rec\_return   \*\*return record pointer for next continue

ENDIF

CONTINUE      \*\* goto next record that satisfies condition

IF NOT()      \*\* if condition not met

EXIT      \*\* exit-from do while loop

ENDIF

ENDDO   \*\*do while true

P = P+1 \*\*increment for next dept

ENDDO   \*\* while P < 4

CLOSE DATABASES

\* MATHCTP --> MATHCSR

\* PRMCTP --> PRMCSR

\* FCHCTP --> FCHCSR

P=1

DO WHILE P<LOOP\_COUNT

DO CASE

CASE P=1

SELECT 1

USE PRMCTP

IF RECCOUNT() >1

SORT ON SUM\_PRODS/D TO C:PRMCSR

ELSE

COPY TO C:PRMCSR

ENDIF   \*\*IF RECCOUNT() >1

SELECT 2

STRINGC = D\_NAME1

USE PRMCSR

STORE "PRE\_H\_C" TO HC\_DFILE

CASE P=2

SELECT 1

USE MATHCTP

```

IF RECCOUNT() > 1
SORT ON SUN_PRODS/D TO C:HATMCSR
ELSE
COPY TO C:HATMCSR
ENDIF &&IF RECCOUNT() > 1
SELECT 2
STRINGC = D_NAME2
USE HATMCSR
STORE "HAT_M_C" TO MC_DFILE

```

```

CASE P=3
SELECT 1
USE FCHCIP
IF RECCOUNT() > 1
SORT ON SUN_PRODS/D TO C:FCHCSR
ELSE
COPY TO C:FCHCSR
ENDIF &&IF RECCOUNT() > 1
SELECT 2
STRINGC = D_NAME3
USE FCHCSR
STORE "FC_H_C" TO MC_DFILE

```

```

ENDCASE

```

```

*load in graphics

```

```

DO Graph_On

```

```

*code could may be be used as a common routine as could perhaps sorting
*routines from above, therefore declare all variables locally

```

```

STORE 0 TO Range_Val
STORE 0 TO Scale_Val
STORE 0 TO Data_Val

```

```

GOTO TOP
STORE Sun_Prods TO Range_Val

```

```

STORE SPACE(5) TO LABEL1,LABEL2,LABEL3,LABEL4,LABEL5
DO Ranging WITH LABEL1,LABEL2,LABEL3,LABEL4,LABEL5,SCALE_VAL

```

```

IF RECCOUNT() < NO_OF_BARS
Counter = RECCOUNT()
ELSE
Counter = NO_OF_BARS
ENDIF

```

```

&DATARESET

```

```

i=0

```

```

DO WHILE i<counter

```

```

IF .NOT. EOF()

```

```

n_rec = "H" + STR(I,1)

```

```

STORE Hach_Code to &n_rec

```

```

Data_Val = 100/Scale_Val*Sun_Prods

```

```

&DATASTORE,Data_Val,i+1,0,i+1,BND

```

```

SKIP

```

```

ENDIF &&IF .NOT. EOF()

```

```

i=i+1

```

```

ENDDO &&DO WHILE i<counter

```

```

&CLRSCREEN

```

```

&BARGRAPH,35,20,30,0.1,BND

```

```

i=0

```

```

X=38

```

```

DO WHILE i<counter
  n_rec = n + STR(i,1)
  STRINGD = &n_rec
  &SAYSTRING ,2,115,0,1,1,STRINGD,END
  x=x+50
  i=i+1
ENDDO &&DO WHILE i<counter

* create axis
&XYAXIS,35,20,150,100,0,5,0,END

* create strings to output to screen
STRINGA = 'PARATO OF TOP MACHINE GROUPS CAUSING LOST PRODUCTS DUE TO BREAKDOWNS'
STRINGB = 'DEPARTMENT : '
STRINGC = 'M A C H I N E C O D E'
STRINGE = 'PRODUCTS LOST'
STRINGG = 'TIME PERIOD : '
STRINGH = 'TIME_STRING'

&SAYSTRING ,05,142,0,0,15,TXT,STRINGA,END
&SAYSTRING ,70,134,0,0,15,TXT,STRINGB,END
&SAYSTRING ,130,134,0,0,15,TXT,STRINGC,END
&SAYSTRING ,50,0,0,0,15,TXT,STRINGE,END
&SAYSTRING ,2,125,0,1,15,TXT,STRINGE,END
&SAYSTRING ,70,126,0,0,15,TXT,STRINGG,END
&SAYSTRING ,116,126,0,0,15,TXT,STRINGH,END

*label y axis
&SAYSTRING ,16,35,0,0,15,TXT,LABEL1,END
&SAYSTRING ,16,55,0,0,15,TXT,LABEL2,END
&SAYSTRING ,16,75,0,0,15,TXT,LABEL3,END
&SAYSTRING ,16,95,0,0,15,TXT,LABEL4,END
&SAYSTRING ,16,115,0,0,15,TXT,LABEL5,END

STORE 'SHALL' TO CSET
&LOADCSET,0,TXT,CSET,END

&SAYSTRING ,190,124,0,0,15,TXT,"KEY",END
&BOXFILL , 108,123,16,8,255,END
i=0
X=200
Y=115
&BOXFILL ,X-25,Y-90,45,115,255,END
DO WHILE i<counter
  n_rec = "n" + STR(i,1)
  STRINGD = &n_rec
  &SAYSTRING ,X,Y,0,0,1+1,TXT,STRINGD,END
  &BOXFILL ,X-20,Y,18,6,i+1,i+1,END
  * STORE STRING FOR MACHINE DESCRIPTION -12 CHARS MAX
  SELECT 3
  USE MHC_DFILE
  LOCATE FOR MACH_CODE = &n_rec
  STORE PRINT_NAME TO MACH_STR
  SELECT 1
  &SAYSTRING ,X-20,Y-8,0,0,1+1,TXT,MACH_STR,END
  Y=Y-20
  i=i+1
ENDDO &&DO WHILE i<counter

IF Print_Req
  &PRINTSCRN
ELSE
  &GETCHAR,END
  ACCEPT TO CHAR

```

```

      *PRINT:SERV
    ENDF
  ENDF

P=P+1
  ENDDO  ENDDO WHILE P<4
  CLOSE DATANAMES
  SET SAFETY ON

  *Return to text mode
  *SET PROCEDURE TO SYDPROC
  GO Graph_Off

*END OF PROCEDURE HPARETO

```

```

*****fault: group analysis/process*****
***WRITTEN BY BRIGID QUINN HULLARD DURHAM. 3XT. 3140
PROCEDURE ?PARETO
PARAMETERS DFILE1,DF1IND1,DF1IND2,DFILE2,DF2IND1,DF2IND2,DFILE3,DF3IND1,DF3IND2,;
TIMECOND,NO_OF_BARS,LOOP_COUNT,D_NAME1,D_NAME2,D_NAME3,TIME_STRING,PRINT_REQ

```

```

SET SAFETY OFF
P=1
DO WHILE P<LOOP_COUNT

```

```
DO CASE
```

```

  CASE P=1
  SELECT 1
  USE &DFILE1 INDEX &DF1IND1,&DF1IND2
  REINDEX
  SELECT 2
  USE PARECTP
  ZAP

```

```

  CASE P=2
  SELECT 1
  USE &DFILE2 INDEX &DF2IND1,&DF2IND2
  REINDEX
  SELECT 2
  USE HARECTP
  ZAP

```

```

  CASE P=3
  SELECT 1
  USE &DFILE3 INDEX &DF3IND1,&DF3IND2
  REINDEX
  SELECT 2
  USE FARECTP
  ZAP

```

```
ENDCASE
```

```

STORE "" TO chk_str_1
STORE "" TO chk_str_2
SELECT 1
LOCATE FOR Fault_code < 6000 .AND. &TIMECOND

```

```
DO WHILE .T.
```

```
IF FOUND()
```

STORE RECCOUNT TO rec\_return

IF NOT (trim(str(n\_fault\_cd)) & chk\_str\_1 .and. not(trim(str(n\_fault\_cd)) & chk\_str\_2

```
SUM PRODS_LOST FOR FAULT_CODE=n_fault_cd .AND.;
@TIMECOND to faultsuc
SELECT 2
APPEND BLANK
REPLACE fault_code WITH n_fault_cd
REPLACE sum_prods WITH faultsuc
```

```
SELECT 1      &&Back to monthly database
* reassign check string variable so that fault code inc.
IF LEN(chk_str_1) < 250
  chk_str_1 = chk_str_1 + ltrim(str(n_fault_cd)) + 'E'
ELSE
  chk_str_2 = chk_str_2 + ltrim(str(n_fault_cd)) + 'E'
ENDIF
```

```
ENDIF      && if not n_nach $ check_string
GOYO rec_return  &&return record pointer for next continue
ENDIF
```

CONTINUE

```
IF BOP()      && if condition not met
  EXIT      && exit-from do while loop
```

ENDIF

ENDDO &&Do while true

P = P+1 &&increment for next dept

ENDDO && while P < LOOP\_COUNT

CLOSE DATABASES

```
* HATFCTP --> HATFCSR
* PRPFCTP --> PRPFCSR
* PCFCTP --> PCFCSR
```

P=1

DO WHILE P<LOOP\_COUNT

DO CASE

CASE P=1

SELECT 1

USE PRPFCTP

IF RECCOUNT() > 1

SORT ON SUH\_PRODS/D TO C:PRPFCSR

ELSE

COPY TO C:PRPFCSR

ENDIF &&IF RECCOUNT() > 1

SELECT 2

STRINGC = D\_NAME1

USE PRPFCSR

STORE "PRF\_P\_C" TO PC\_DFILE

CASE P=2

SELECT 1

USE HATFCTP

IF RECCOUNT() >1

SORT ON SUH\_PRODS/D TO C:HATFCSR

ELSE

COPY TO C:HATFCSR

ENDIF &&IF RECCOUNT() >1

SELECT 2

```
ENDCASE  
ENDPROC
```

```
CASE 3  
SELECT 1  
USE TCCTP  
IF RECCOUNT() < NO_OF_BARS  
SORT ON SUM_PROD5/D TO @TCCTSR  
FREE  
COPY TO @TCCTSR  
DELETE WITH RECCOUNT() < NO_OF_BARS  
SELECT 2  
STRINGC = @TCCTSR  
USE TCCTSR  
STORE TCCT_C TO TC_DATA  
  
ENDCASE
```

Load in graphics

```
DO Graph_On
```

\*code could may be be used as a common routine as could perhaps sorting  
\*routines from above, therefore declare all variables locally

```
STORE 0 TO Range_Val  
STORE 0 TO Scale_Val  
STORE 0 TO Data_Val
```

```
GO TO TOP  
STORE Sum_Prods TO Range_Val
```

```
STORE SPACE(5) TO LABEL1,LABEL2,LABEL3,LABEL4,LABEL5  
DO Ranging WITH LABEL1,LABEL2,LABEL3,LABEL4,LABEL5,SCALE_VAL
```

```
IF RECCOUNT() < NO_OF_BARS  
Counter = RECCOUNT()  
ELSE  
Counter = NO_OF_BARS  
ENDIF
```

```
&DATARSKI  
i=0  
DO WHILE i < counter  
IF .NOT. EOF()  
f_rec = "F" + STR(i,1)  
STORE Fault_Code to &f_rec  
Data_Val = 100/Scale_Val*Sum_Prods  
&DATASORC,Data_Val,i+1,0,i+1,END  
SKIP  
ENDIF &&IF .NOT. EOF()  
i=i+1  
ENDDO &&DO WHILE i < counter
```

```
&CURSOR  
&BARGRAPH,35,20,30,0,1,END
```

```
i=0  
X=35  
DO WHILE i < counter  
f_rec = "f" + STR(i,1)  
STRINGX = STR(&f_rec)  
STRINGD = SUBSTR(STRINGX,7,4)  
&SAYSTRING ,X,8,15,TEXT,STRINGD,END
```

```
*****
Title
ENDDC &&DO WHILE i<counter
```

```
* create axis
&XTXAS,35,20,165,190,0,5,0,END
```

```
*create strings to output to screen
STRINGA = ' PARETO OF TOP BREAKDOWN FAULTS CAUSING LOST PRODUCTS'
STRINGB = ' DEPARTMENT : CSE'
STRINGC = ' FAULT CODE : 0 0 0 0 '
STRINGF = ' PRODUCTS LIST'
STRINGG = ' TIME PERIOD : '
STRINGH = ' TIME STRING'
```

```
&SAYSTRING ,30,142,0,0,15,TXT,STRINGA,END
&SAYSTRING ,70,134,0,0,15,TXT,STRINGB,END
&SAYSTRING ,130,134,0,0,15,TXT,STRINGC,END
&SAYSTRING ,50,0,0,0,15,TXT,STRINGE,END
&SAYSTRING ,2,126,0,1,15,TXT,STRINGF,END
&SAYSTRING ,70,126,0,0,15,TXT,STRINGG,END
&SAYSTRING ,116,126,0,0,15,TXT,STRINGH,END
```

```
*label y axis
&SAYSTRING ,18,35,0,0,15,TXT,LABEL1,END
&SAYSTRING ,18,55,0,0,15,TXT,LABEL2,END
&SAYSTRING ,18,75,0,0,15,TXT,LABEL3,END
&SAYSTRING ,18,95,0,0,15,TXT,LABEL4,END
&SAYSTRING ,18,115,0,0,15,TXT,LABEL5,END
```

```
STORE 'SHALL' TO CSET
&LOADCSET,0,TXT,CSET,END
```

```
&SAYSTRING ,190,124,0,0,15,TXT,"KEY",END
&BOXFILL , 188,123,16,8,255,END
```

```
i=0
X=200
Y=115
&BOXFILL ,X-25,Y-90,45,115,255,END
```

```
DO WHILE i<counter
f_rec = "f" + STR(i,1)
STRINGX = STR(&f_REC)
STRINGD = SUBSTR(STRINGX,7,4)
```

```
&SAYSTRING ,X,Y,0,0,I+1,TXT,STRINGD,END
&BOXFILL ,X-20,Y,18,6,i+1,i+1,END
* STORE STRING FOR FAULT DESCRIPTION -12 CHARS MAX
SELECT 3
USE &PC_DFILE
LOCATE FOR FAULT_CODE = &f_REC
STORE PRINT_NAME TO FAULT_STR
SELECT 1
&SAYSTRING ,X-20,Y-8,0,0,I+1,TXT,FAULT_STR,END
Y=Y-20
i=i+1
ENDDO &&DO WHILE i<counter
```

```
IF Print_Req
&PRINTSCRN
ELSE
&GETCHAR,END
ACCEPT TO CHAR
IF UPPER(CHAR)='P'
&PRINTSCRN
```

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70072

P=P+1

```
ENDDO &&DO WHILE P<4
  CLOSE DATABASES
  SET SAFETY ON
  *Return to text mode
  DO Graph_Off
```

-----

```
PROCEDURE LINEGRAPH
**WRITTEN BY BRIGID QUINN MULLARD DURHAM. EXT. 3140
PARAMETERS DFILE1,DFILE2,DFILE3,LOOP_COUNT,ST_WEEK,PN_WEEK,TIME_STRING,PRINT_REQ
```

```
STORE SPACE(10) TO n_actper
STORE SPACE(10) TO n_budper
STORE 0 TO n_week_no
STORE 0 TO week_req
```

```
SET SAFETY OFF
P=1
DO WHILE P<LOOP_COUNT
```

```
DO CASE
```

```
CASE P=1
  *database file1
  SELECT 1
  USE &DFILE1
  SELECT 2
  USE PRELNTP
  ZAP
```

```
CASE P=2
  SELECT 1
  USE &DFILE2
  SELECT 2
  USE HATLNTP
  ZAP
```

```
CASE P=3
  SELECT 1
  USE &DFILE3
  SELECT 2
  USE FCLNTP
  ZAP
```

```
ENDCASE
```

```
SELECT 1
I=10
```

```
week_req = st_week
```

```
LOCATE FOR VAL(WEEK_NO) = WEEK_REQ
```

```
DO WHILE I<(((PN_WEEK+1)-ST_WEEK) +10)
```

```
IF FOUND()
  STORE WEEK_NO TO n_week_no
  STORE BREAKD_PER TO n_actper
```

```

        APPEND BLANK
        REPLACE week_no WITH n_week_no
        REPLACE act_brk WITH n_actper
        REPLACE bud_brk WITH n_budper
        SELECT 1

    ENDIF &&IF FOUND()

    Week_req= Week_req+1

    I=I+1
    CONTINUE &&LOCATE FOR VAL(WEEK_NO) = WEEK_REQ

    IF EOF()          && if condition not met
        EXIT          && exit-from do while loop
    ENDIF
ENDDO &&DO WHILE I < ((FN_WEEK+1)-ST_WEEK) +10

P = P+1 &&increment for next dept
ENDDO && while P < 4

CLOSE DATABASES

*   MATLNCTP --> MATLNHR
*   PRELNTP  --> PRELNHR
*   PCLNTP   --> PCLNHR

P=1
DO WHILE P<LOOP_COUNT

DO CASE
CASE P=1
SELECT 1
USE PRELNTP
IF RECCOUNT() >1
SORT ON ACT_BRK/D TO C:PRELNHR
ELSE
COPY TO C:PRELNHR
ENDIF &&IF RECCOUNT() >1
SELECT 2
STRINGC = "PRECOAT"
USE PRELNHR

CASE P=2
SELECT 1
USE MATLNTP
IF RECCOUNT() >1
SORT ON ACT_BRK/D TO C:HATLNHR
ELSE
COPY TO C:HATLNHR
ENDIF &&IF RECCOUNT() >1
SELECT 2
STRINGC = "MATRIX"
USE MATLNHR

CASE P=3

```

```

USE FCLNTP
IF RECCOUNT() >1
SORT ON ACT_BRK/D TO C:FCLNSR
ELSE
COPY TO C:FCLNSR
ENDIF &&IF RECCOUNT() >1
SELECT 2
STRINGC = "FLOWCOAT"
USE FCLNSR

ENDCASE

DO Graph_On

*code could nay be be used as a common routine as could perhaps sorting
*routines from above, therefore declare all variables locally
STORE 0 TO Range_Val
STORE 0 TO Scale_Val
STORE 0 TO Data_Val

GOTO TOP
STORE ACT_BRK TO Range_Val

STORE SPACE(5) TO LAB1,LAB2,LAB3,LAB4,LAB5,LAB6,LAB7,LAB8,LAB9,LAB10
DO Per_Range WITH LAB1,LAB2,LAB3,LAB4,LAB5,LAB6,LAB7,LAB8,LAB9,LAB10,SCALE_VAL

SELECT 1
GOTO TOP

&DATARESET
i=10
DO WHILE i<(((FN_WEEK+1)-ST_WEEK)+ 10 )
  IF .NOT. EOF()
    p_rec = "p" + str(i,2)
    STORE week_no to &p_rec
    Data_Val = 100/Scale_Val* Act_brk
    &DATASTORE,Data_Val,1,END
    SKIP
  ENDIF &&IF .NOT. EOF()
i=i+1
ENDDO &&DO WHILE i< ((FN_WEEK+1)-ST_WEEK)+10

&CLASCREEN
&XYGRAPH,35,20,15,2,12,END

GOTO TOP

```

```

&DATAFREQSTF
i=10
DO WHILE i<(((FN_WEEK+1)-ST_WEEK)* 10 )
  IF .NOT. ROP()
    Data_Val = 100/Scale_Val* BUO.brk
    &DATASTORE,Data_Val,3,BDD
    SKIP
  ENDIF &XIF .NOT. ROP()
i=i+1
ENDDO &&DO WHILE i< ((FN_WEEK+1)-ST_WEEK)+10

&XYGRAPH,35,20,15,2,3,END

* create axis
STORE ((FN_WEEK)-ST_WEEK) * 15 TO XLENGTH
&XYAXES,35,20,XLENGTH,100,((FN_WEEK)-ST_WEEK),10,0,END

*create strings to output to screen
STRINGA = ' SUMMARY GRAPH OF CAPACITY DOWNTIME DUE TO BREAKDOWNS'
STRINGB = "DEPARTMENT : CMT"
STRINGC = " W E E K N U M B E R "
STRINGE = ' PERCENTAGE'
STRINGG = "TIME PERIOD : WEEKS"
STRINGH = TIME_STRING

&SAYSTRING ,30,142,0,0,15,TXT,STRINGA,END
&SAYSTRING ,70,134,0,0,15,TXT,STRINGB,END
&SAYSTRING ,130,134,0,0,15,TXT,STRINGC,END
&SAYSTRING ,50,0,0,0,15,TXT,STRINGE,END
&SAYSTRING ,3,125,0,1,15,TXT,STRINGF,END
&SAYSTRING ,70,126,0,0,15,TXT,STRINGG,END
&SAYSTRING ,136,126,0,0,15,TXT,STRINGH,END

STORE 'SHALL' TO CSET
&LOADCSET,0,TXT,CSET,END
*label y axis
&SAYSTRING ,22,27,0,0,15,TXT,LAB1,END
&SAYSTRING ,22,37,0,0,15,TXT,LAB2,END
&SAYSTRING ,22,47,0,0,15,TXT,LAB3,END
&SAYSTRING ,22,57,0,0,15,TXT,LAB4,END
&SAYSTRING ,22,67,0,0,15,TXT,LAB5,END
&SAYSTRING ,22,77,0,0,15,TXT,LAB6,END
&SAYSTRING ,22,87,0,0,15,TXT,LAB7,END
&SAYSTRING ,22,97,0,0,15,TXT,LAB8,END
&SAYSTRING ,22,107,0,0,15,TXT,LAB9,END
&SAYSTRING ,22,117,0,0,15,TXT,LAB10,END

i=10
X=31
DO WHILE i<(((FN_WEEK+1)-ST_WEEK)+10)
P_rec = "P" + STR(i,2)
STRINGD = &P_REC
*STRINGD = SUBSTR(STRINGX,7,4)
&SAYSTRING ,X,8,15,TXT,STRINGD,END
x=x+15
i=i+1
ENDDO &&DO WHILE i< ((FN_WEEK+1)-ST_WEEK)+10

IF Print_Req
  &PRINTSCRN
ELSE
  &GETCHAR,END
  ACCEPT TO CHAR
  IF UPPER(CHAR)='P'

```

```
        PRINT SCR  
    ENDIF  
ENDIF
```

```
P = P+1 &&increment for next dept  
REDO && while P < 4
```

```
GO GRAPH OFF
```

```
-----
```

```
*procedure to generate suitable labels and ranging for machine and  
*fault pareto  
**WRITTEN BY BRIGID QUINN MULLARD DURHAM. EXP. 3140  
PROCEDURE Ranging  
PARAMETERS LABEL1,LABEL2,LABEL3,LABEL4,LABEL5,SCALE_VAL  
*generate appropriate axis and suitable labels at correct position  
*is assumed no fault will be greater than 25000 units
```

```
*each axis will have five increments  
*create appropriate axis for the following ranges  
*0-50  
*50-100  
*101-250  
*251-500  
*501-1000  
*1001-5000  
*5000-25000
```

```
DO CASE
```

```
    CASE Range_Val < 51
```

```
        STORE 50 TO Scale_Val  
        STORE "10" TO label1  
        STORE "20" TO label2  
        STORE "30" TO label3  
        STORE "40" TO label4  
        STORE "50" TO label5
```

```
    CASE Range_Val > 50 .AND. Range_Val < 101
```

```
        STORE 100 TO Scale_Val  
        STORE "20" TO label1  
        STORE "40" TO label2  
        STORE "60" TO label3  
        STORE "80" TO label4  
        STORE "100" TO label5
```

```
    CASE Range_Val > 100 .AND. Range_Val < 251
```

```
        STORE 250 TO Scale_Val  
        STORE "50" TO label1  
        STORE "100" TO label2  
        STORE "150" TO label3  
        STORE "200" TO label4  
        STORE "250" TO label5
```

```
    CASE Range_Val > 250 .AND. Range_Val < 501
```

```
        STORE 500 TO Scale_Val  
        STORE "100" TO label1  
        STORE "200" TO label2  
        STORE "300" TO label3  
        STORE "400" TO label4
```

1000 Range\_Val > 500 .AND. Range\_Val < 1000

```
STORE 1000 TO Scale_Val
STORE "200" TO label1
STORE "400" TO label2
STORE "600" TO label3
STORE "800" TO label4
STORE "1000" TO label5
```

CASE Range\_Val > 1000 .AND. Range\_Val < 5001

```
STORE 5000 TO Scale_Val
STORE "1000" TO label1
STORE "2000" TO label2
STORE "3000" TO label3
STORE "4000" TO label4
STORE "5000" TO label5
```

CASE Range\_Val > 5000 .AND. Range\_Val < 25000

```
STORE 25000 TO Scale_Val
STORE "5000" TO label1
STORE "10000" TO label2
STORE "15000" TO label3
STORE "20000" TO label4
STORE "25000" TO label5
```

ENDCASE

```
*-----
*procedure to generate suitable labels and ranging for line graph
**WRITTEN BY BRIGID QUINN MULLARD DURHAM. EXT. 3140
PROCEDURE Per_Range
PARAMETERS LAB1,LAB2,LAB3,LAB4,LAB5,LAB6,LAB7,LAB8,LAB9,LAB10,SCALE_VAL
*generate appropriate axis and suitable labels at correct position
*is assumed no fault will be greater than 100%
```

```
*each axis will have ten increments
*create appropriate axis for the following percentage ranges
*0-10
*0-20
*0-40
*0-60
*0-80
*0-100
```

DO CASE

CASE Range\_Val < 10.1

```
STORE 10 TO Scale_Val
STORE "1" TO lab1
STORE "2" TO lab2
STORE "3" TO lab3
STORE "4" TO lab4
STORE "5" TO lab5
STORE "6" TO lab6
STORE "7" TO lab7
STORE "8" TO lab8
STORE "9" TO lab9
STORE "10" TO lab10
```

CASE Range\_Val > 10.0 .AND. Range\_Val < 20.1

STORE 20 TO Scale\_Val  
STORE "2" TO lab1  
STORE "4" TO lab2  
STORE "6" TO lab3  
STORE "8" TO lab4  
STORE "10" TO lab5  
STORE "12" TO lab6  
STORE "14" TO lab7  
STORE "16" TO lab8  
STORE "18" TO lab9  
STORE "20" TO lab10

CASE Range\_Val > 20.0 .AND. Range\_Val < 40.1

STORE 40 TO Scale\_Val  
STORE "4" TO lab1  
STORE "8" TO lab2  
STORE "12" TO lab3  
STORE "16" TO lab4  
STORE "20" TO lab5  
STORE "24" TO lab6  
STORE "28" TO lab7  
STORE "32" TO lab8  
STORE "36" TO lab9  
STORE "40" TO lab10

CASE Range\_Val > 40.0 .AND. Range\_Val < 60.1

STORE 60 TO Scale\_Val  
STORE "6" TO lab1  
STORE "12" TO lab2  
STORE "18" TO lab3  
STORE "24" TO lab4  
STORE "30" TO lab5  
STORE "36" TO lab6  
STORE "42" TO lab7  
STORE "48" TO lab8  
STORE "54" TO lab9  
STORE "60" TO lab10

CASE Range\_Val > 60.0 .AND. Range\_Val < 80.1

STORE 80 TO Scale\_Val  
STORE "8" TO lab1  
STORE "16" TO lab2  
STORE "24" TO lab3  
STORE "32" TO lab4  
STORE "40" TO lab5  
STORE "48" TO lab6  
STORE "56" TO lab7  
STORE "64" TO lab8  
STORE "72" TO lab9  
STORE "80" TO lab10

CASE Range\_Val > 80.0 .AND. Range\_Val < 100.1

STORE 100 TO Scale\_Val  
STORE "10" TO lab1  
STORE "20" TO lab2  
STORE "30" TO lab3  
STORE "40" TO lab4  
STORE "50" TO lab5  
STORE "60" TO lab6

STORE 70 TO lab7  
STORE 80 TO lab8  
STORE 90 TO lab9  
STORE 100 TO lab10

ENDCASE

\* EOP:SIDPROC.PRG

# DATA COMPARISON

## SUMMARY SHEETS - EQUIP

AREA	LINE SPEED	AUGUST						SEPTEMBER						OCTOBER					
		SUMMARY SHEET		EQUIP		ACTION BY		SUMMARY SHEET		EQUIP		ACTION BY		SUMMARY SHEET		EQUIP		ACTION BY	
		DOCS	MR.	BD	MR	PROG	MAINT. SERVICES	DOCS	MR.	BD	MR	PROG	MAINT. SERVICES	DOCS	MR	BD	MR	PROG	MAINT. SERVICES
LAC + AL 1	140/hr	8	28	143	166	85%	142	12	85	203	171	91%	97	9	22	107	208	85%	157
LAC + AL 2	140/hr	4	18	28	66	75%	25%	9	22	35	45	88%	14%	8	52	22	85	59%	41%
LAC + AL 3	220/hr	16	126	63	108	75%	23%	13	95	153	108	97%	3%	14	412	56	375	407	60%
PRECOAT	825/hr	3	22	4	46	25%	75%	3	17	8	58	75%	25%	2	22	3	17	332	67%
MATRIX	825/hr	8	52	20	155	55%	24%	17	18	39	210	72%	28%	7	72	12	69	48%	42%
FLOWCOAT	55/hr.	13	12	35	273	80%	23%	13	85	53	350	83%	17%	5	25	22	108	86%	14%

COMPARISON OF EQUIP AND SUMMARY SHEETS DATA

APPENDIX 5.7

APPENDIX 6

FEASIBILITY OF FACTORYWIDE EQUIP : TERMS OF REFERENCE

ILYPS COMPONENTS DURHAM

21 October 1988

DEPARTMENT

EQUIP

=====

Equipment utilisation systems have been implemented into 3 areas namely FS Flowchart, CMT Procoat Matrix and Flowcoat, and Lacquer and Aluminising. Although all 3 systems have the same objectives they operate on different hardware, with different software, different functionality and have different methods of collecting data.

There are also issues which need resolving around the following:-

- (1) Are the systems being used effectively and are maximum benefits being obtained.
- (2) Who are the owners of the systems.
- (3) Should the system be extended across the rest of the factory and how.

In order to help resolve these issues the following will be undertaken by Brigid Quinn and managed by a Steering Group of Simpson, J. Woods and R. Grice.

- (1) Undertake a functional study of the existing 3 EQUIP systems. This should examine.
  - (a) What each system being used for,
  - (b) What each system is not being used for but could be, and
  - (c) Are there other benefits to be obtained and how.
- (2) Undertake a functional feasibility study in how the system could be implemented factory-wide. This should identify the potential benefits, the resources required, and the method that could be employed.
- (3) Undertake a technical feasibility study. Determine the optimum hardware/software to support (a) the existing 3 systems and (b) the system if implemented factory-wide.

These 3 studies will be undertaken sequentially and at the end of each will be reported back to the Steering Group prior to continuing with the next. Timescales will be agreed with the steering group.



R. Grice

Distribution: B. Quinn, G. Simpson, J. Woods  
Copies : L.E. Foreman, D.V. Oakes

Table 8.1 : Possible Software Packages : Mini Based Systems

PACKAGE	SUPPLIER	CONTACT
MAINPAC	Cruickshank Management Resources Ltd, CAM Centre, Makerfield Way, Ince, Wigan Telephone : 0942 495483	Mr D Gillard
MAINTENANCE MANAGEMENT SYSTEM	Hoskyns, Hoskyns House, 77-79 Cross Street, Sale, Cheshire, M33 1HF Telephone : 061 9693611	Ms J Davies
IDHAMMER MAINTENANCE MANAGEMENT SYSTEM	Idhammer, Index House, Ascot, Berkshire, SL5 7EU Telephone : 0990 23404	Mr C K Cooper
RAPIER	Resource Management Systems, 51-53 Church Road, Ashford, Middlesex, TW15 2TY Telephone : 0784 253505	Mr I McCully
TEROMAN	Scicon Limited, Wavendon Tavern, Wavendon, Milton Keynes, MK17 8LX Telephone : 0908 585858	Ms P Craig
TEMPO	Tandem Maintenance Services Ltd, Moorgate Business Centre, 3 Moorgate Road, Rotherham, S60 2EN Telephone : 0709 375723	Mr K E Bonser
HELMSMAN	MTAS, 12-22 Albert Street, Birmingham, B4 7UD Telephone : 021 6324863	Mr A Giddes

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