DESIGNING A MAINTENANCE MANAGEMENT SYSTEM FOR A SMALL TO MEDIUM SIZED MANUFACTURING PLANT

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in partial fulfillment of the requirements
for the degree of Master in Industrial
Administration

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ABSTRACT

During the last three decades, technology has advanced at an incredible rate. Plants have become more automated and complex, and it is evident thet the quality of service provided by the maintenance department has become a cornerstone of profitability.

The idea of a Maintenance Management System is not a new one and considerable research has been carried out on various facets of the subject. However, it appears that much of this research has been directed at large organisations. This thesis covers research which is aimed at small to medium-sized plants with limited resources, and which do not have a developed Maintenance Management System.

The objectives of the research concern the design and implementation of a system which will:

a) enable engineering staff to attend to breakdowns and other work in a logical manner, which will increase the overall efficiency of the plant.

b) control artisan hours effectively and reduce overtime hours worked

c) maintain accurate service and history records

d) reduce unnecessary stoppages and obtain optimum plant availability at the minimum possible cost

e) improve the attitude of executive management towards maintenance policies and provide a safe working environment

f) identify unreliable machines which are uneconomical to maintain

g) encourage the use of maintenance manuals

These objectives were achieved by designing a Maintenance Management System which included the following:

1. A Maintenance Work Order System. This system would ensure that all work was carried out effectively. It would also produce feedback on maintenance performance, costs and equipment history.

2. A Preventive Maintenance System. Such a system would be modest to begin with and could gradually become more comprehensive to include all production equipment.

3. A Maintenance Information System. The trend nowadays is toward computerization. Therefore, a simple computer-based system was designed which could manipulate data on equipment inventory and history records. The system could be expanded to suit individual requirements.

4. Pareto Analysis. This technique could be used to identify key areas needing special attention, such as high downtime costs.

5. Performance Indices. By collecting data related to cost and performance, it was demonstrated how these indices could be calculated and plotted regularly.

The research enabled the author to design a Maintenance Management System for a small to medium sized plant. The investigation and analysis of results demonstrated that Pareto Analysis could be used to identify critical equipment, while performance indices would be useful tools for analysing maintenance or production trends. The importance of selling this system to top management was emphasised, because the success of the system would depend on their complete acceptance. For the plant under investigation, a central maintenance organisation plan was recommended because of its flexibility. The benefits of contract maintenance, and it's limits, were also highlighted.

This thesis makes a contribution to the field of maintenance management because it provides clear guidelines on how to design a suitable Maintenance Management System to satisfy individual requirements.

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CHAPTER 1

INTRODUCTION

Thirty years ago, maintenance was a matter of solving technical problems, and most maintenance managers or engineers needed little more than a high degree of technical skill. This situation has changed dramatically over the past three decades and organisations have begun to realize that Maintenance Management is a vitally important aspect of the national economy.

Huge amounts of money are allocated to maintenance each year by industrialised nations and it is estimated that some 1100 million pounds per year was being spent on direct maintenance by the British manufacturing industries as long ago as 1968[2]. In West Germany, the comparable value for 1971 was roughly 3000 million pounds. In the USA, maintenance costs amount regularly to around 4 percent of net sales from the manufacturing industries. Maintenance therefore plays a crucial role in the manufacturing process and failure to manage maintenance effectively can lead to penalty costs from downtime. The strategic importance of competent maintenance increases with increasing mechanisation and automation.

Unfortunately, maintenance is still an under-valued function within many organisations. It has an unglamorous image and is seen as a necessary evil by too many production, finance and general managers. Too often, these people regard maintenance as a financial burden which contributes nothing to the profits of the company. Fortunately, however, There is a growing awareness amongst senior industrial executives that improvements in maintenance can lead to disproportionate savings in their total factory costs.

What is maintenance? The prime purpose of maintenance is to keep equipment running so that products can be produced, shipped and a profit made. However, because making a profit is so important, it

is necessary to perform maintenance at a minimum cost in man-hours and materials. And, keeping the total capital invested in equipment at a minimum is also a necessity.

Today's technology is advancing at an incredible rate. Plants are becoming more and more automated, resulting in a decline of production workers and an increase of maintenance workers and job complexity. In the plant of tomorrow, the majority of workers will be those who are highly skilled in maintenance. Therefore, careful study to improve methods and reduce maintenance is imperative. Achieving these objectives will help save millions of rands.

Many companies have no formal Maintenance Management System. The tendency is to load the engineering workshops with job requests, both written and verbal, with little or no attention being paid to establishing priorities. In addition, no service or history files are kept, preventive maintenance is seldom carried out, maintenance manuals are non-existant, spares are inadequate and there is little control or reconciliation of artisan hours.

The idea of a Maintenance Management System is not a new one and considerable research has been carried out on various facets of the subject. However, it appears that a large proportion of the research has been aimed at large organisations and there is a need for research which is aimed at medium sized plants with limited resources and which do not have a developed Maintenance Management System. An inhibiting factor to many maintenance managers is the availability of a basic design upon which to build their individual requirements, coupled to the problems of understanding many commercial computerized maintenance packages.

The objectives of this research concern the design and implementation of a Maintenance Management System which will:

a) enable engineering staff to attend to breakdowns and other work in a logical manner,

b) obtain optimum utilisation of engineering personnel,

c) increase the overall efficiency of the plant,

d) reduce unnecessary stoppages,

e) control artisan hours effectively,

f) reduce overtime hours worked,

g) provide a safe working environment,

h) identify unreliable machines which are too uneconomical to maintain,

i) maintain accurate service and history records,

j) encourage the use of maintenance manuals,

k) improve the attitude of executive management towards maintenance policies, and

l) obtain optimum plant availability at the minimum possible cost.

Achieving these objectives requires much more then technical skill. Success requires a Maintenance Management System which will control all aspects of the maintenance function with maximum effect and minimum effort. In the South African environment, where inferior controls and inadequate procedures can cost millions, very few companies can afford to ignore the importance of a carefully designed and properly implemented Maintenance Management System.

CHAPTER 2

LITERATURE SURVEY

"Plant and Equipment maintenance does not have to be a costly, unwanted stepchild - it can easily be a highly cost-effective function. A well organised and well-managed maintenance program can help increase company profits." This statement was made by B.M.Coulter of The Emerson Consultants[9].

Maintenance normally has a poorer rate of return than any other other budget item. Yet most companies can reduce maintenance costs by at least one third, and improve the level of productivity by giving maintenance the management priority it requires. "In virtually every maintenance operation, there are sinkholes of waste that could be plugged by simply applying proper management objectives, policies and principles to all phases of the maintenance operation," says Coulter.

Preventive Maintenance (PM) means different things to different people. Management frequently sees it as "overhead that may or may not be of value;" production people usually consider it to be "something which prohibits scheduled product delivery;" line mechanics place it somewhere between corporal punishment and management stupidity[4]. In general, their attitudes are summed up by statements such as: "The machine is working fine, so why work on it?" Most plant engineers, however, see PM in a more realistic light; to them, an effective PM program is a big help in the battle to keep critical equipment in operation.

What is Preventive Maintenance? There are many definitions[48]. Ralph Renken, Principal of A.T.Kearney, Inc., New York, defines it as "That type of maintenance which inspects, adjusts, repairs or replaces equipment on an economic basis before failure could force an emergency shutdown."

Another management consultant, E.T.Newbrough, President of Albert

Raymond and Associates describes PM to be "The planned maintenance of plant and equipment resulting from periodic inspections that disclose faulty conditions."

As R.H.McCollum, Plant Engineer for The Pillsbury Co. sees it, "PM is the systematic checking of a functioning unit to determine whether it will function reliably until the next check."

In each of the three cases , the men agree that inspection lies at the heart of PM. But that says little about the concept itself as a working program. Implicit in PM is the total management technique. Thus a maintenance manager must consider the planning, organizing, implementing and controlling of all elements in any PM program he proposes to management.

The maintenance manager or plant engineer begins to obtain the control necessary to genuinely manage maintenance when a work order system is put into effect. Without a well-structured, carefully adhered-to system, the maintenance organization is likely to find that work coming in controls the organization rather than the other way around.

However, with a well-established work order system and management commitment to its use, a maintenance department will reap rewards of higher productivity, reduced costs, and an increased pride in the maintenance function. A work order system should produce quantifiable feedback on overall maintenance performance, job and plant costs and equipment history. Maintenance should be able to give its customers accurate cost information on anticipated maintenance needs, so that those using maintenance services can plan for maintenance expense. Work order control, therefore, can be considered to form the basis of the total maintenance information system, which includes interface with the inventory, purchasing and payroll functions.

CHAPTER 3

THEORY

3.1 GENERAL

In the selection of a maintenance system, top management's organizational philosophy is important, and the system should be compatible with that philosophy. Once management accepts that effective maintenance represents money, it has provided a base for establishing an efficient maintenance organization.

Firstly, a plan of operation should be developed for the entire maintenance function. This plan should not merely be a program to reduce maintenance costs, but should include all aspects of squeezing the optimum value out of the money invested in maintenance. A good maintenance plan will spell out three primary objectives for the maintenance manager[9]. They are organization, performance and supervision:

a) Organization - The maintenance manager must organize his overall program so that all necessary maintenance work is accomplished economically.

b) Performance - Maintenance labour efficiency averages less than 45 percent. Normally, maintenance managers can control no more than half the factors that determine efficiency and costs and, because of this, other managers should be made aware of the need to focus directly on improving maintenance performance while reducing the cost.

c) Supervision - Training of first line supervisors is probably the most neglected area in the maintenance function. Generally, foremen are former hourly workers in whom the company has invested time and money to train as first-class artisans. On average, in South Africa, foreman can be responsible for maintenance expenditures up to R1 000 000 per annum. Yet invariably

the company has spent very little, if any, time or money to train them as members of the management team.

Secondly, the maintenance system should optimise the maintenance performance by examining the following basic functions:

a) A sound organization structure - When staffed with competent personnel with clear areas of responsibility, such an organization will help assure that maintenance work is accomplished in an efficient manner, providing the maximum maintenance effort at the least cost.

b) Proper planning and scheduling - These are keys to an effective maintenance program. Planning determines the work that needs to be done, when it should be done (setting of priorities), and what resources will be required to complete the job. Scheduling assigns men and jobs on a daily basis to effectively utilize all resources at the jobsite. Effective scheduling involves coordinating men, material, tools and equipment shutdown to ensure that all are available at the prescribed time.

c) A preventive maintenance system - This provides opportunities to reduce costs and increase production. If preventive maintenance is successful, the cost of equipment maintenance is kept to an absolute minimum because failures are eliminated or minimised.

d) Adequate controls - These are needed to determine the overall effectiveness and progress of the maintenance program. Detailed maintenance cost records are essential if management is to manage by fact rather than opinion. The prime objective of a controls program is to measure progress made and to reveal any obstacles which could hinder the maintenance program.

e) Motivation and training - This is critical to the effectiveness of any maintenance improvement program. If the human factors which can work against maintenance cost reduction are not understood, it will be difficult to properly organize for the cost reduction. In fact,

the human factor may be the key to successful cost reduction.

f) An effective maintenance information system - This will provide details of spares, service and history records, equipment data and specifications, and manpower costs.

3.2 THE MAINTENANCE WORK ORDER SYSTEM

Most maintenance managers would agree that no attempt should be made to perform any maintenance without a written order that describes the action to be taken and which includes all pertinent job details. Verbal (or poorly written) work orders contribute to the wasted maintenance man-hours and uncompleted jobs. On the other hand, a properly organized work order system does not create an overabundance of paperwork. It is, instead, a basic means of controlling maintenance work by describing needed work in detail [12].

A work order system should produce quantifiable feedback on overall maintenance performance, job and plant costs, and equipment history. The maintenance department should be able to give its customers accurate cost information on anticipated maintenance needs, so that those using maintenance services can plan for maintenance expense.

A properly structured work order system should do all or most of the following:

- Provide a means to request maintenance service
- Identify and record maintenance work when it comes in and when it is completed
- Define the scope of each job, whether a routine repair, breakdown, preventive maintenance, project work, or other work
- Authorize work to be done
- Assign job priorities so that the most important work gets done first
- Make it possible to plan and schedule work

- Capture labour and material costs on each job
- Record the use of special tools and materials
- Assign work to artisans
- Measure the performance and efficiency of the labour force
- Generate data for equipment histories
- Provide data to analyse maintenance costs by job, equipment and cost centre.

3.2.1 Basic Information Required

The work order should be easy to use and should not ask for excessive or extraneous data. The essential information on a work order defines the job and provides for planning, scheduling, control, and accumulation of equipment history. Typical data required is shown below:

PURPOSE	INFORMATION REQUESTED
TO DEFINE THE JOB	* A unique job number * Equipment number, description and location * Account number * Budget/Project number * Priority code * Type of work code * Work requested
PLANNING SCHEDULING AND CONTROL	* Labour estimate * Material estimate * Job plan * Total estimated cost * Approvals
FOR CONTROL AND HISTORY	* Actual labour costs * Actual material costs * Actual work done * Failure codes

3.3 THE PREVENTIVE MAINTENANCE SYSTEM

The principal function of an effective preventive maintenance (PM) system is to detect and report maintenance needs. Early detection of potential maintenance problems is a vital element of preventive maintenance. Once PM reports are made, a maintenance work order system may be used to plan and schedule maintenance work, and provide feedback data for cost control, breakdown analysis, corrective maintenance and improvement of PM[39].

An effective PM system contains many elements which should be considered for its success:

1) The Manager's Role - The maintenance manager is of fundamental importance to the initiation of the PM system and he must ensure that management and production will commit their full support.

2) Work Force Motivation - The maintenance work force must be PM orientated since it is the PM system that can make work easier by early discovery of repair needs.

3) Scope - The maintenance manager should develop the scope of the PM program with the assistance of the production managers.

4) PM Compatibility With Maintenance Systems - The PM system should be compatible with the overall maintenance system and, if necessary, the maintenance system should be adjusted to ensure this compatibility.

5) Personnel in the PM Program - PM inspectors should be artisans who are selected on the basis of their knowledge and familiarity with the entire maintenance program, as well as the physical plant and its operation.

6) Equipment Designation - Using guidelines established by the maintenance manager, supervisors should prepare a basic list of equipment that is to be inspected.

7) Equipment Inspection Routes - A PM route for equipment should be prepared that minimizes travel and ensures complete coverage.

8) Standardization - After equipment checklists and inspection frequencies have been established, they must be standardized.

9) PM Manpower Requirements - Equipment inspections should be scheduled periodically, and spaced to avoid manpower conflicts throughout the year.

10) Post-Inspection Action - Once it is established that repairs are needed, the maintenance foreman should prepare a maintenance work order for the repairs.

Figure 3.1 shows various ckeckpoints which should be considered when organizing and operating a PM system[39].

To be effective, the PM system must be flexible. Effectiveness can be measured by analyzing breakdown information, available from equipment maintenance costs and reviews. In turn, the breakdown analysis will provide the decisions on corrective maintenance.

3.4 THE MAINTENANCE INFORMATION SYSTEM

The major purpose of maintenance is to maintain the reliability of the operating system at a reasonable level and still maximize profits or minimize costs. How can the maintenance manager determine whether his maintenance needs are being met at a minimum cost? Detailed information relating to the total cost of maintenance, and what maintenance services are performed on which equipment is therefore essential. In most companies, this data is available. However, because maintenance scheduling and reporting is usually handled on a manual basis, maintenance schedulers and supervisors do not have the time to re-record the manually generated and manually filed data into new formats and summaries so that they can be used for comparative or evaluative purposes.

A large amount of data is required to support a comprehensive maintenance program, even in a medium sized plant. Not only must this information be accurate, it must be of real value and be timely as well. For these reasons, many companies have turned to the computer as the nucleus of their maintenance information

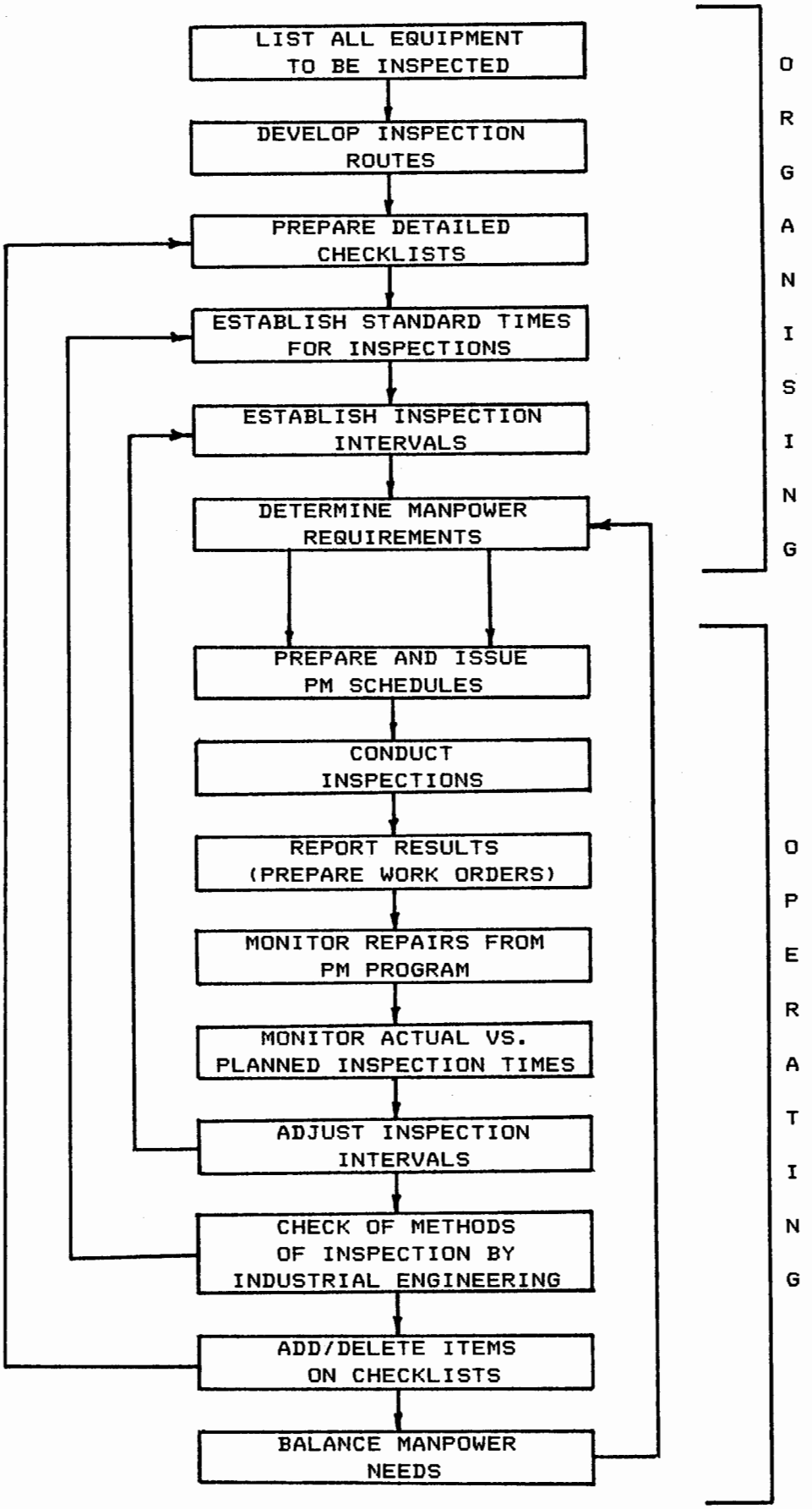


Figure 3.1: Checkpoints for organising and operating a preventive maintenance system

system. A typical comprehensive computerized system is shown in Figure 3.2.

Most organizations would probably only use various segments of the system, but it does show the full range of information systems that could be employed for any maintenance situation[1]. Essential features of the system are described below:

1) Inputs - The input to the computer can be divided into routine and special data. Routine data would include completed work orders, labour, parts and materials used, and a description of the work done. Special input data might consist of cost comparisons with other plants, breakdown distributions, time study data and so forth, which would be the basis for special output reports.

2) Files - Two types of files are used; master files for individual units and master files for resources. These files would contain data such as specifications, capacity, cost, economic age, setup costs, location, floorspace and services required for all major pieces of equipment. The resources files would contain certain information on workers such as skills, wages, etc. and on such resources such as spare parts, economic order quantities and preferred supplier.

3) Outputs - The preventive maintenance routine issues work orders for various machines on the basis of priority rules which are based upon file data. It may also prepare a list of material and parts to be reserved for a particular job. Maintenance control can be used to provide printouts of efficiency ratios, breakdown repair costs, preventive maintenance costs, budget overruns and even trends in these factors in graphical form. Individual machine control can be used for developing a report for a specific machine rather than for all machines. This would enable detailed analysis of poorly functioning machines and provide

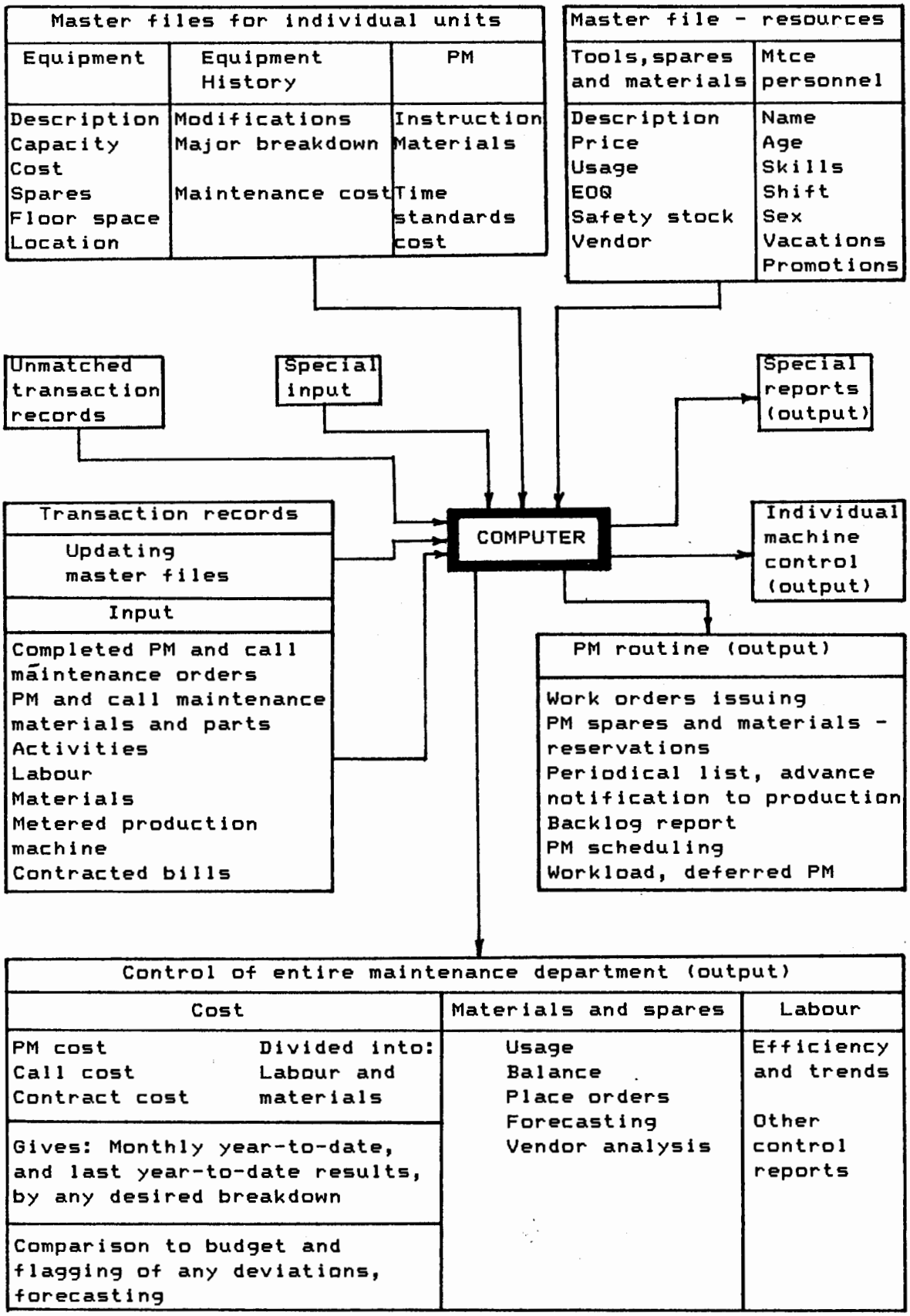


Figure 3.2: Typical Comprehensive Computerized System

preventive maintenance policy. Special reports would refer to the output from simulations, critical path studies, inventory models and output report tools that would be useful in carrying out the maintenance function.

3.5 MAINTENANCE MANUALS

The complexity of modern plant, the requirement for a logical pattern of fault diagnosis on control systems, the importance of full understanding by maintenance technicians when repairing control and instrumentation equipment , the increasing dependence on the maintenance man as automation is introduced and the high cost of down time on high output plant are all very good reasons for paying increased attention to the technical information provided for maintenance men.

The table below lists various contents which should appear in a maintenance manual:

Section	Name	Function
1	Technical data	What it does
2	Operating instructions	How to use it
3	Technical description	How it works
4	Installation procedure	How to prepare it for use
5	Maintenance procedures	How to overhaul and repair it
6	Maintenance schedules	When to maintain it
7	Parts list	What it is made of
8	Modifications	Changes and improvements

Details of each section is as follows:

Section 1 - Technical data

a) Statistics, dimensions, weights, supply requirememts, environmental factors, performance data.

b) List of source data (specifications, drawings, etc.)

c) Warnings and precautions in use.

Section 2 - Operating instructions

a) Normal operational procedures.

b) Emergency and safety measures.

c) Operator fault diagnosis and repair (if permitted).

d) Procedures for reporting failure.

Section 3 - Technical description

a) Full technical details - presented graphically if possible.

Section 4 - Installation data

a) Packing, unpacking and storage data.

b) Handling and transportation procedures.

c) Installation and connection details.

d) Testing after installation.

Section 5 - Servicing instructions

a) Fault diagnosis and repair.

b) Disassembly, inspection and reassembly.

c) Overhaul procedures - presented graphically if possible.

Section 6 - Servicing routines

a) Frequencies and procedures for routine inspections.

b) Performance monitoring.

c) Lubrication and preventive maintenance procedures.

Section 7 - Parts list

a) List of parts, cross-referenced to "exploded" illustrations.

b) Recommended spares stock.

Section 8 - Modifications

a) Variations, improvements and additions.

The serial number and other details of the product should be entered in the manual during installation. The number plates on equipment often become lost or damaged and it is difficult to obtain the correct spare parts unless a precise identification is made.

3.6 MAINTENANCE ORGANIZATION PLAN

In many industries, the maintenance operation has become a major factor influencing and determining costs. Because the impact of automation in many industries has resulted in more maintenance men on the payroll than production workers, the spotlight has inevitably focused on the maintenance function and its organization structure[6].

The selection of the best maintenance organization plan for a plant is a difficult one. Central, area, and departmental plans are typical examples, with both advantages and disadvantages.

3.6.1 Central Maintenance Plan

In a central maintenance organization (Figure 3.3), the artisans are assigned to work in any or all departments of the plant and report to the same maintenance head. Advantages include:

1) Sufficient men are available to handle the work requirements of the plant.
2) Considerable flexibility is available in assigning artisans of different trades to the various jobs.
3) Emergency jobs, breakdowns, and new work are handled quickly.
4) The total number of men can be held reasonably level, thus minimizing hirings and layoffs.
5) Specialists and special equipment are used more effectively.
6) One person is responsible for all maintenance.
7) Accounting for all maintenance costs is centralized and more control is obtained over capital or new work.

Disadvantages may include:

1) Artisans are scattered all over the plant and not properly supervised.

2) Time is lost in travelling to a job, obtaining tools and getting instructions.

3) Coordination or scheduling of several trades to a job becomes difficult.

4) More administrative controls are necessary to function effectively.

5) Different men are assigned to the same equipment and consequently, no one really becomes proficient in its repair.

6) The interval between the initial job request and completion for routine work is too long.

7) Priorities are given to the various production jobs by a maintenance man and not a production man.

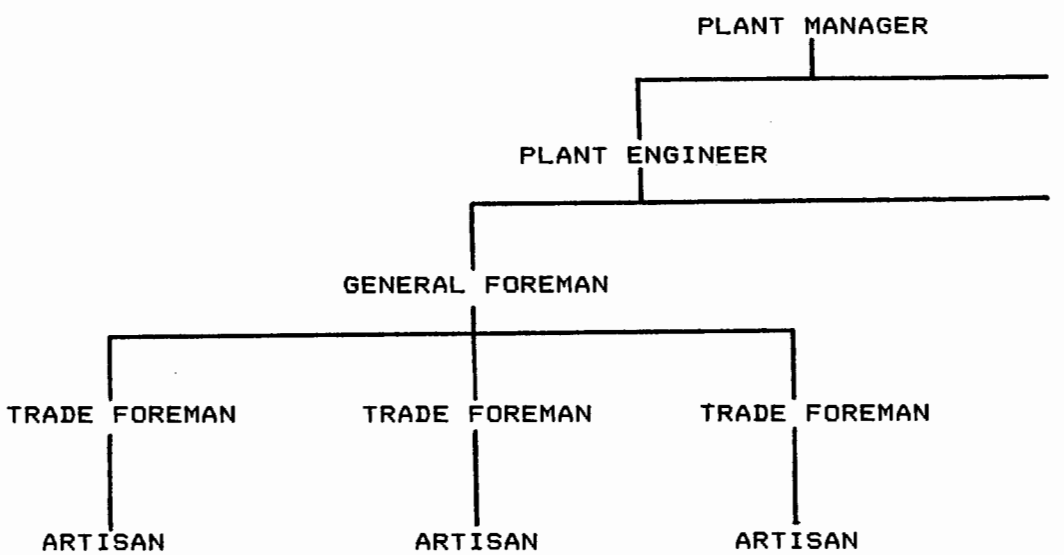


Figure 3.3: Central Maintenance Plan.

3.6.2 Area Maintenance Plan.

In area maintenance (Figure 3.4), the artisans are assigned to specific areas in the plant and still report to the same

maintenance head. The areas may be defined geographically, by product, or production department, and/or service function, such as utilities or research. The advantages include:

1) Maintenance men are readily accessible to the production men.

2) Time spent traveling to a job and obtaining tools is reduced.

3) Time lag is minimized between the issuance of the work order and its completion.

4) Maintenance supervisors and artisans become better aquainted with the equipment and its spare parts requirements.

5) Artisans are better supervised and production line or process changeover is faster.

6) Greater continuity from one shift to another is afforded.

7) Maintenance supervisors and artisans become more familiar with the production schedules, problems, special jobs, etc.

The disadvantages may include:

1) The tendency exists to overstaff the area.

2) Major repairs or servicing jobs are difficult to handle.

3) There are more personnel problems and regulations pertaining to transfer, hirings, and working overtime.

4) Special equipment may be difficult to justify because usage may be limited.

5) Duplication occurs in the area maintenance shops.

6) More clerical help is needed if the area groups are large.

7) Specialists are more difficult to employ effectively.

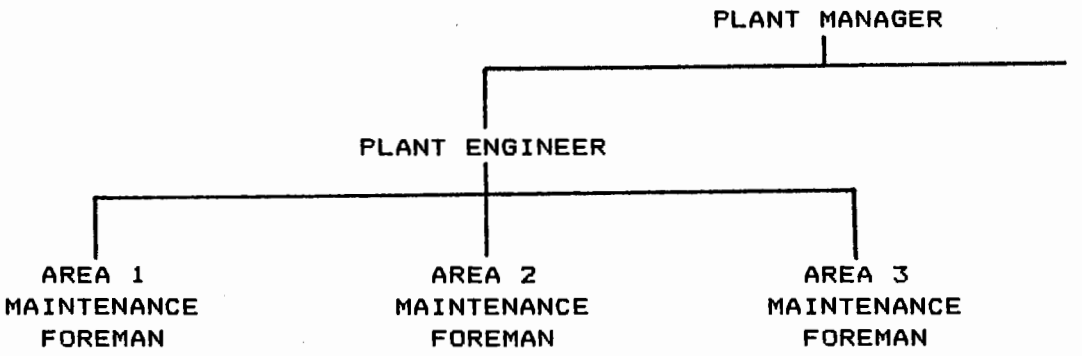


Figure 3.4: Area Maintenance Plan

3.6.3 Departmental Maintenance Plan

In the departmental maintenance organization (Figure 3.5), the artisans are assigned to a definite area or function and report to a production supervisor. Sometimes artisans report to a maintenance foreman who in turn reports to a production supervisor.

The advantages of the departmental group are similar to those of the area maintenance plan. The major difference is that the artisans report to the production supervisor.

Disadvantages are also similar to area maintenance, but may also include:

1) Production supervisors are not normally qualified to direct a maintenance job and cannot give technical assistance to an artisan.

2) The production supervisor may neglect maintenance in order to meet schedules.

3) The maintenance responsibility of the plant is divided.

4) The plant maintenance costs are harder to obtain and control.

5) Personnel problems are more pronounced than with area maintenance.

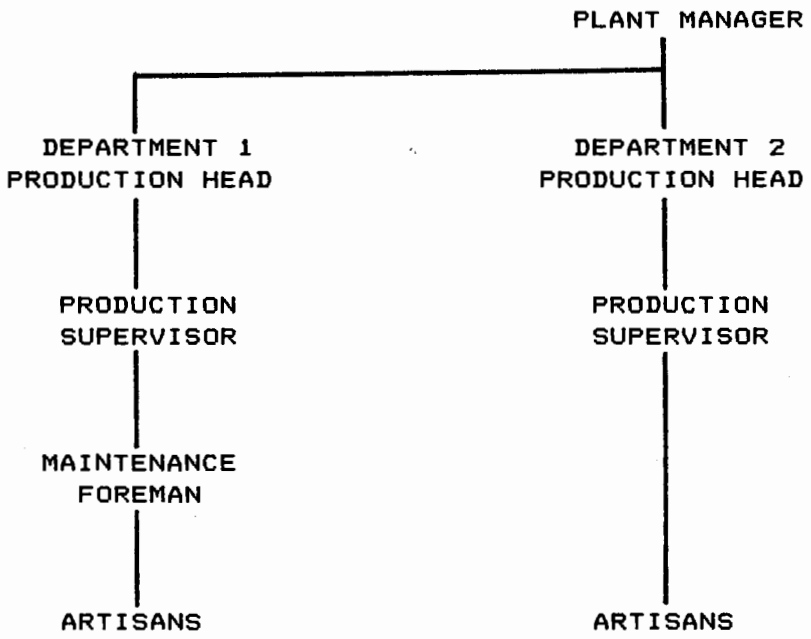


Figure 3.5: Departmental Maintenance Plan

3.6.4 Combination Maintenance Plan

Because of the difficulty in balancing service and maintenance costs, this problem may be resolved by combining a central group with an area or departmental group. There are numerous possible combinations of these basic plans. For example, in a large central moderate area maintenance organization, the advantages may still include:

1) A group of central artisans capable of handling the large projects and major repairs throughout the plant.

2) Good control of maintenance costs.

3) Area artisans available to major service and production centres.

4) Area artisans familiar with key equipment in the production centres.

The disadvantages may still include:

1) Central artisans assigned to work throughout the plant with resultant high travel time and poor job supervision.

2) Major job priorities determined by maintenance.

3) Tendency to overstaff the area.

4) Duplication of maintenance equipment.

A typical example of combination maintenance is shown in Figure 3.6.

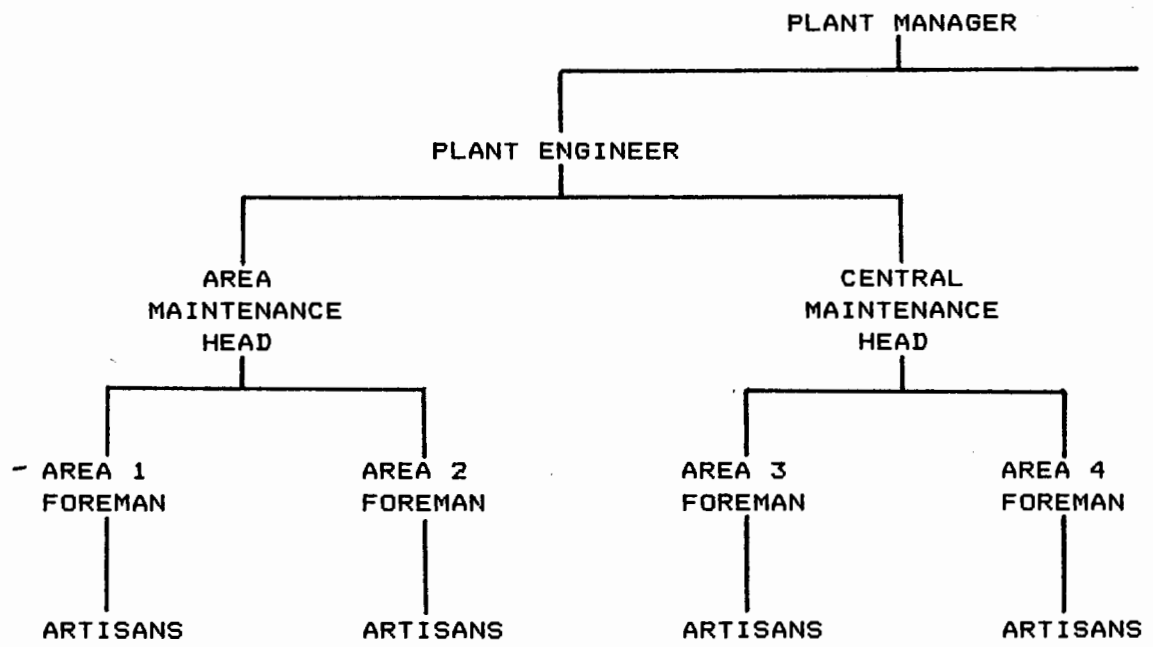


Figure 3.6: Combination Maintenance Plan

Some similarity in maintenance organization exists within an industry and comparisons may also be made between different operations located on the same plant site. Selection of the best maintenance plan for a plant therefore requires careful analysis of the maintenance function.

3.7 MAINTENANCE POLICY DETERMINATION

When considering a maintenance policy, the major operational question is whether to repair the equipment before it malfunctions (preventive maintenance) or wait and repair it after it malfunctions (corrective maintenance). This is a trade-off situation as shown in Figure 3.7[1]. Here, preventive maintenance costs consist of those costs which arise from inspecting and

adjusting equipment, replacing or repairing parts, and the loss of production time as a result of these activities. On the other hand, corrective maintenance costs are those that arise when the equipment fails or cannot be operated at a reasonable cost. These costs would also include lost production time, the costs of performing the maintenance, and, in some instances, the part of the cost of replacement equipment which, with better maintenance, would have been deferred.

The objective in dealing with this cost trade-off is to find that point in time and that amount of maintenance that minimize the total cost of the maintenance operation, as well as those productive operations that are affected by maintenance activities. Finding the optimum time and level of maintenance activities is often a complex task because the probable breakdown times for various parts of pieces of equipment must be known, the repair times must be known, and - if maintenance personnel and resources are limited - maintenance priorities among machines and among departments must be determined.

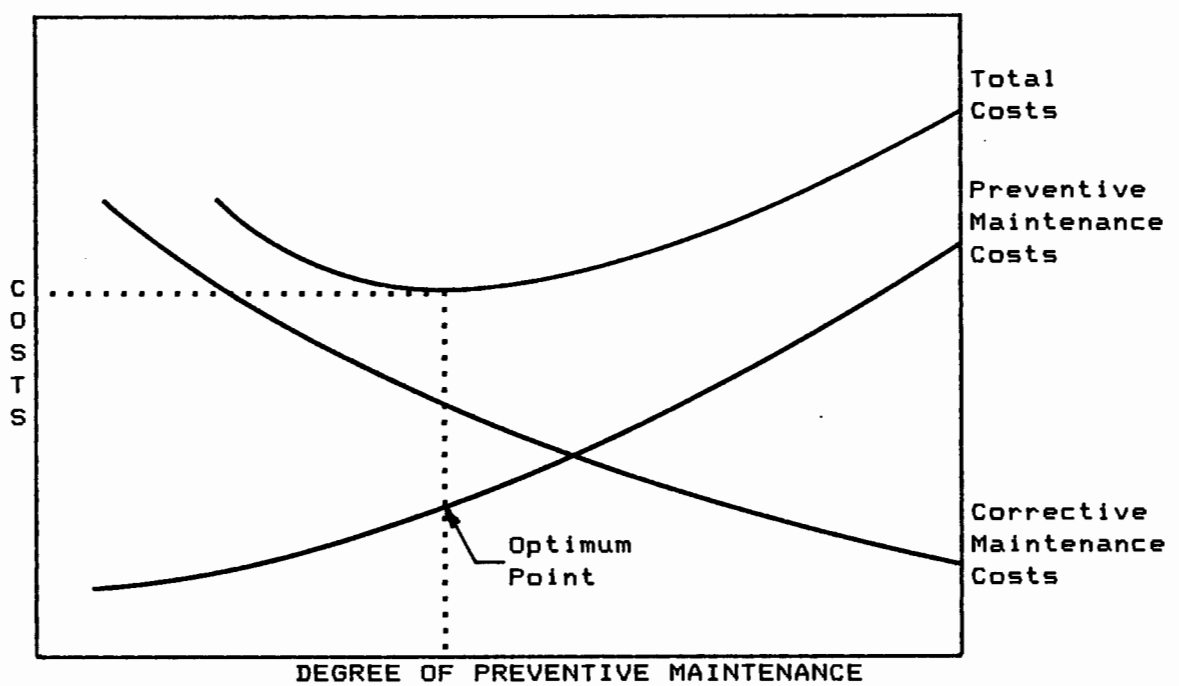


Figure 3.7: Preventive Versus Corrective Maintenance

3.7.1 Maintenance Systems

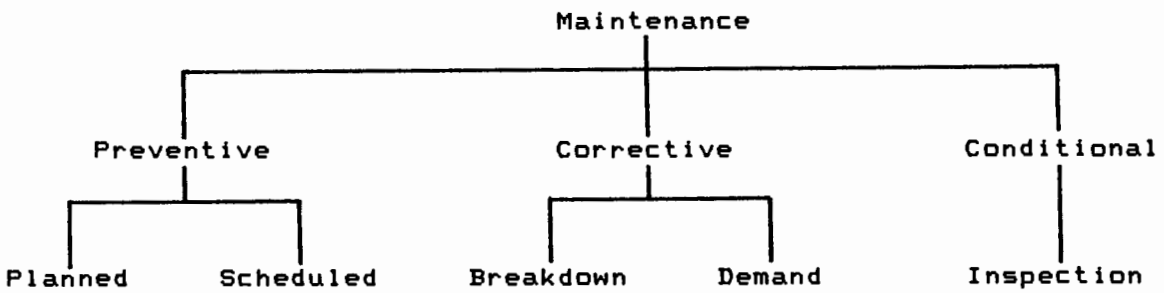
There are three main maintenance systems; preventive, corrective and conditional maintenance.

Corrective maintenance refers to carrying out a complete overhaul, or replacement, or repair of a piece of equipment when it breaks down. Such work can be performed immediately after a breakdown occurs or be placed in a queue of work that is performed at set intervals, such as every week or month. The latter policy might be followed where there is standby equipment and maintenance crews follow a specified schedule of rounds.

Preventive maintenance refers to maintenance performed prior to a breakdown and may be either minor in nature, such as a simple repair, or major, such as a complete overhaul or replacement. A preventive maintenance program may include provision for immediate repair or overhaul after a breakdown as well as for repairs or overhaul at predetermined time periods.

A conditional maintenance policy refers to overhaul or repair that is performed on the basis of inspecting and measuring the state of the equipment. If the equipment passes the test, it might be allowed to operate until it breaks down or until it has reached a certain number of operating hours, after which it is replaced, overhauled, or repaired.

These maintenance systems can be subdivided into typical categories as shown below:



Planned maintenance - the systematic servicing and inspection of equipment to ensure continuity of service through prompt

attention to defects before they develop into breakdowns, having regard at all times to the economics of the situation.

Scheduled maintenance - similar to planned maintenance, except that the equipment chosen for repair or servicing is based on priorities such as production requiremants and future needs instead of the recommended service intervals or interrupted running time.

Breakdown maintenance - no predetermined action is taken to prevent failure, the emphasis being on efficient corrective maintenance. Only those repairs necessary to return the equipment to its condition prior to breakdown are done.

Demand maintenance - a system of regular lubrication with repair and replacement only when the equipment breaks down and then, only enough to return the equipment to a working condition. Maximum life has been extracted from the component before it fails.

Inspection maintenance - random inspection of equipment, with corrective action only taking place when breakdown seems imminent or the equipment is performing unsatisfactorily.

CHAPTER 4

INVESTIGATION

4.1 THE EXISTING SYSTEM

A detailed investigation into the Maintenance Management System of a medium-sized company was carried out over a two year period.

The organization under investigation is a major manufacturer and supplier of sophisticated flexible packaging systems to selected markets in the food, liquids and medical sectors. The company's main strengths lie in its specialized and advanced design, printing and technical capabilities and its aggressive marketing orientation. The company production is orientated and geared towards efficient service and customer satisfaction.

Up until early 1982, there was no formal method for requesting work to be carried out by the engineering workshops. The tendency was to load the workshops with job requests, both written and verbal, and very little attention was paid to establishing priorities. In addition, no history or service files were kept, preventive maintenance was seldom carried out, machine downtime was unacceptably high and there was no control or reconciliation of artisan hours.

Efficiency and reliability of the highly sophisticated machines was vital, particularly in the declining South African economic climate. It is therefore against this background that it was evident that a sound maintenance management system was necessary.

4.2 COLLECTION OF INFORMATION

Prior to 1982, very little information was available regarding downtime, maintenance costs and historical data. The main source of information was obtained from records kept in the production department in the form of Unproductive Direct Labour (UDL) hours. UDL is a catch-all category for non-productive machine time and

the various categories are shown in Table 4.1.

1. Fitting Shop Repairs
2. Electrical Repairs
3. Waiting Materials/Stores
4. Waiting Inks, Adhesives, etc.
5. Waiting Instructions, Production Work Orders, etc.
6. Waiting Laboratory/Quality Control
7. Waiting Operator
8. Waiting Stereos
9. Waiting Ink Ducts
10. Changing Machine Parts
11. Cylinders
12. Waiting Temperature
13. Start and Shut Down (Extruders)
14. Die Cleaning (Extruders)
15. Waiting Material from Machines (Other)
16. Machine Idle
17. Machine Trials
18. Sundries

Table 4.1:Unproductive Direct Labour Categories

4.3 ANALYSIS OF INFORMATION

Sound maintenance planning and control demand effective analysis of past performance.

4.3.1 Pareto Analysis

The Pareto, A-B-C, or 80-20 rule is a simple, yet powerful form of analysis and can be applied to a very wide range of maintenance and control problems.

This form of analysis was applied to the Unproductive Direct Labour (UDL) which was due to Fitting Shop and Electrical Repairs (items 1 and 2 of Table 4.1). These UDL hours were tabulated for every production machine over the two year period 1983/1984 (Appendix 1.1). The total UDL hours were then tabulated in descending order, i.e. Extruder 2 had the highest UDL whereas the Lamko machine had the least. Each individual machine hourly rate was available and hence, the cumulative percentage downtime costs could be calculated and tabulated. The results are shown in Appendix 1.2 and graphically represented in Figure 4.1. By inspection, the areas A, B and C can be clearly defined and the Pareto curve is almost 80/20 in shape.

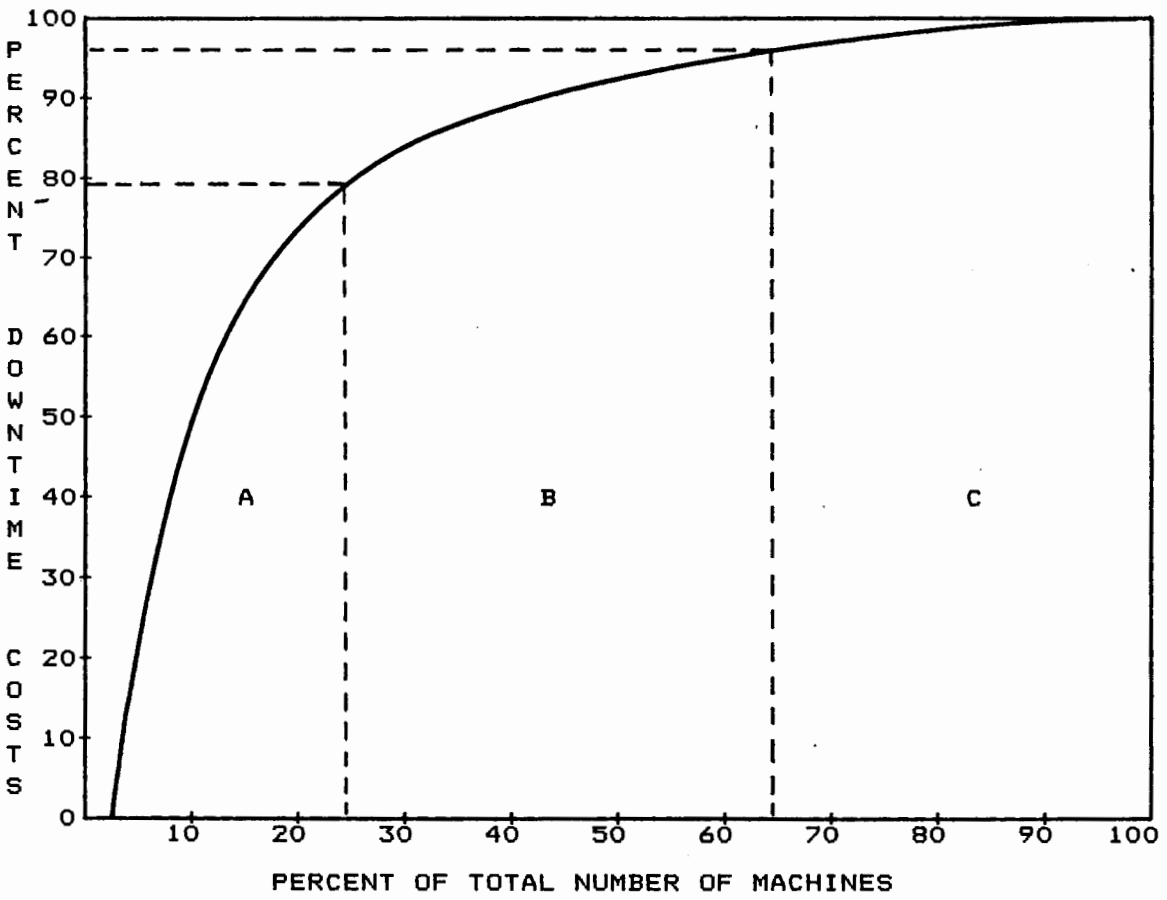


Figure 4.1:Downtime Pareto Curve

These results are interesting in that they highlight the fact that 80 percent of the maintenance downtime cost comes from 20 percent of the machines. These "area A" machines are almost exclusively from the Printing and Laminating Departments with the exception of the GN 46 machine. By the same token, "area B" consists mainly of the Bag Department machines and "area C" mainly the slitting machines. Thus the Pareto analysis will allow one to quantify the nature of demand distribution for downtime costs and consequently focus on the truly key areas.

4.3.2 Maintenance Performance Indices

The Engineering Manager needs to know if his department is doing an effective job. In many cases he simply does not know and, compared to his production management counterpart, he rarely makes use of measures of productivity. The common reason for not being able to measure maintenance department performance is that the necessary maintenance records are seldom kept.

To begin with, one should recognise the necessity for using indices of maintenance performance. The costs of maintenance (men, materials and overheads) have become too great for firms to ignore and it has become essential that maximum effectiveness be gained in return for these costs. In addition, without some formal measure of performance it is difficult to plan, control and develop the maintenance function. Indices are, therefore, essential tools of maintenance management.

In essence, indices seek to assess the general productivity of the maintenance function. But productivity is normally seen as a ratio of output to input. In this case the input is the cost of the maintenance service while the output is the effectiveness of maintenance service measured in terms of production output achieved. However, production output is not simply a function of maintenance effectiveness. It can obviously be affected by many other variables including the level of capital investment in new production plant, the level of usage and possible abuse of the production equipment and the general age of the plant. In other words the production output is only partly affected by good or bad maintenance. As a result, indices used for measuring

maintenance performance are best designed to measure the denominator of the productivity ratio. Hence, a maintenance ratio should, ideally, seek to measure aspects of the work which are solely dependent on maintenance management policy, strategy and tactics. Nevertheless, to make maintenance indices credible outside the maintenance function it is also necessary to link maintenance activity, or maintenance inputs to production delays caused by breakdown or preventive maintenance inspections.

There is a wide range of indices available and the most common ones are listed in Appendix 1.3. However, during the two year period of the investigation, very little information regarding maintenance costs was retained. Therefore two indices have been used which relate the maintenance and production levels. They are:

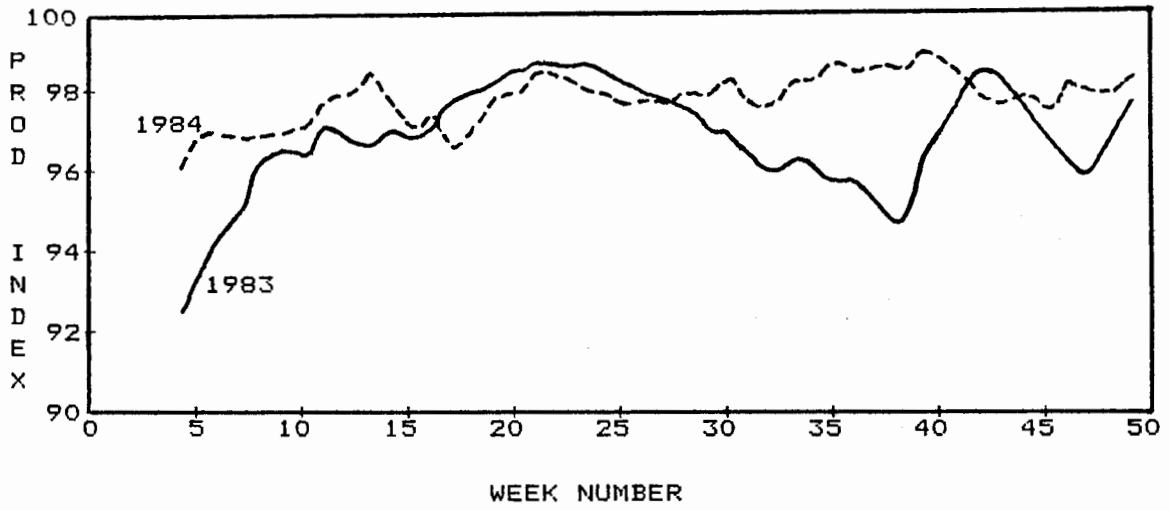
$$\text{a) Production Index PI} = \frac{\text{Production operating time}}{\text{Production operating time + downtime}}$$

$$\text{b) Maintenance Index MI} = \frac{\text{Total maintenance manhours}}{\text{Total production manhours}}$$

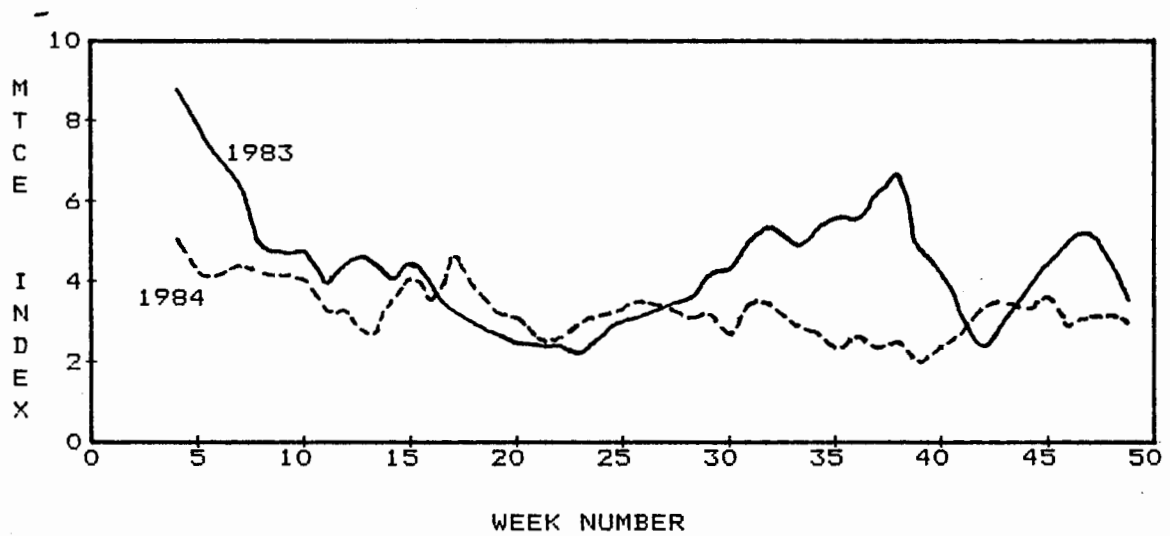
All UDL and production data for the two year investigation period were tabulated in Appendix 1.4. From this information, the Maintenance Index (MI) and Production Index (PI) could be calculated. Because maintenance loads fluctuate so widely from week to week, the four week moving average values were calculated in order to smooth the graphs of PI and MI. These graphs are shown in Figure 4.2.

The Production Index graph for 1983 shows a very wide fluctuation from 94,2 to 97,9. By the same token, the Maintenance Index graph for 1983 shows the same wide variation. Maintenance activity increased greatly by the end of the third quarter, resulting in declining production. In the last quarter, the Production index rose rapidly with a corresponding decline in the Maintenance Index. This may have been partially due to the fact that production activity is traditionally highest towards the year end and operators tend to ignore defects which would normally stop a

machine. In addition, operators have the knowledge that the machines would be overhauled during the year-end shut down.



GRAPH (i)



GRAPH (ii)

Figure 4.2: Graphs of (i) Maintenance Index (MI)

(ii) Production Index (PI)

On the other hand, the graphs for 1984 show far less fluctuation, with a higher Production Index and a correspondingly lower Maintenance Index. Also, the actual maintenance downtime hours

for 1984 were lower than 1983. This trend would suggest that maintenance control in 1984 had begun to improve and that the machines were better maintained. This, in fact, corresponds with the system of Preventive Maintenance which was introduced during the first quarter of 1984. Downtime maintenance activity dropped to a consistantly lower level during the last three quarters.

CHAPTER 5

THE SYSTEM DESIGNED

5.1 THE MAINTENANCE WORK ORDER SYSTEM

5.1.1 General Procedure

Regardless of the size or nature of the job to be carried out, it is essential that a Job Card is filled out completely by the Initiator (the person from whom the work originates). No work should be undertaken by the engineering personnel unless a Job Card has been received which has been authorized by the department manager.

The Job Card (Figure 5.1) would be white and consist of two "flimsies" backed by a third identical but stiffer card.

The procedure to be used would be as follows:

1. The Initiator would fill out the Job Card in triplicate and send all three copies to the engineering department clerk.

2. The engineering department would immediately stamp all copies with a Works Order Number and return the top copy to the Initiator as acknowledgement of having received the Job Card.

3. The remaining two copies would be retained by the engineering department until completion of the work. Once all the work has been completed, the remaining copies would be stamped "completed", signed and dated by the Engineering Foreman and the middle copy would be returned to the Initiator for his permanent records.

4. The onus would be on the individual department managers to ensure that their copy of the "completed" Job Card has been signed off by the engineering foreman.

5. The bottom card would be issued to the artisan carrying out the work and would be retained by the engineering department upon completion of the job.

JOB CARD work safely ! isolate machinery use warning signs	PRIORITY BD E PP FMS N PLAN SM DISSECTION No.	IDENTIFICATION	W.O. No.
		due date	date recd.
INITIATOR	AUTHORITY	clearance required? yes / no	DWG. No.
WORK TO BE DONE			
Special instructions or precautions			
Checked by Foreman		Date	

FRONT OF CARD

ARTISAN NAME	TRADE (F/E)	DATE	TIME START	TIME STOP	NT HOURS	OT HOURS	LABOURER NAME	CO No.	NT HOURS	OT HOURS

MATERIALS OR SPARES USED:

QTY	PART No.	DESCRIPTION

Additional history for recording or other notes:

BACK OF CARD

Figure 5.1: The Job Card

5.1.2 Details To Be Filled In By The Initiator

Referring to the sample Job Card in Figure 5.1, the following information must be supplied by the Initiator:

- INITIATOR. The name of the person from the work originates.

- DISSECTION. The Dissection Number (Cost Code) against which the costs must be allocated.

- IDENTIFICATION. What is the Factory Identification, or name of the equipment?

- PRIORITY. What priority should be assigned to the work?

- CLEARANCE REQUIRED. Is there any special procedure/supervision required? ie. welding in a hazardous area etc. Answer yes or no.

- DRAWING NUMBER. If the work to be done relates to a specific drawing, the drawing number must be provided.

- DUE DATE. What is the desired date by which time the work should be completed? This should be reasonable; the use of the terms "a.s.a.p." and "urgent" are meaningless and unacceptable. In certain cases the Due Date may have to be reviewed because of unavailability of materials, etc. It would therefore be the responsibility of the Initiator to follow up his jobs at regular intervals.

- WORK TO BE DONE. This should contain full details of the work to be carried out. If an item has to be made, a sketch should be attached, giving full dimensions and details. Terms such as "fix machine" or "make cupboard" are unacceptable. The engineering department personnel have to be in a position to estimate the artisan's time as accurately as possible in order to utilize their manpower fully. Any special instructions or precautions to be observed must also be noted.

5.1.3 Engineering Department Procedure

The bottom copy of the Job Card would be solely for engineering department use. It would contain instructions of work to be carried out by an artisan and would provide an accurate record of

hours taken, materials or spares used and other information recorded in respect of the work being carried out.

Upon receiving the Job Card, the foreman would assess what work has to be carried out. He would then assign the job to an artisan by placing the Job Card into a rack specifically designed for this purpose. The rack would be similar to that used for clock cards and would contain all the artisans' names on the left-hand side. The rack would have three columns divided into - "In Progress", "Delayed" and "Completed".

The Job card at this stage would consist of a "flimsy", backed by an identical but stiffer card. Upon commencing the work, the artisan would tear off the "flimsy" and leave it in the "In Progress" column. He would take the card with him to the workplace and fill in the required information on the rear of the card. Since the "flimsy" would always remain in the rack, this would enable the foreman to know what job each artisan is working on at all times. Once the artisan has completed his work, he would place the Job Card in the "Completed" column of the rack together with the "flimsy". The artisan would then be ready to proceed with his next job.

The engineering clerk would collect the completed Job Cards and give them to the foreman. The foreman would then check each specific job, and sign and date the "flimsy" and stiff bottom copy of the Job Card. The copies would then be stamped "Completed" and the "flimsy" would be returned to the Initiator for his records. The bottom card would be filed by the engineering clerk and used to provide data for history and service records.

5.1.4 Details To Be Filled In By Engineering Department

- W\O NO: A Works Order Number would be stamped on all three copies of the Job Card.

- DATE RECEIVED: The date on which the Job Card was received would be stamped on all three cards.

- CHECKED BY: The work must be checked by the engineering

department foreman. Once it has been approved, the foreman would sign and date the middle and bottom copies of the Job Card.

The reverse of the bottom copy of the Job Card would contain information relating to artisan hours, materials, spares and costs related to the job. Space would also be provided for any additional remarks regarding the condition or history of the machine.

5.1.5 What Work Would Require A Job Card?

The Maintenance Work Order System is designed to improve the efficiency of the engineering department. This can only be done by utilizing available artisan time to its fullest extent. Thus, every job or request made on the engineering department, regardless of size or simplicity, must be accompanied by a Job Card. This would include breakdowns and emergencies.

All work would be divided into priorities and then executed strictly in order of the assigned Works Order Number. It would be the responsibility of the departmental manager concerned to ensure that a Job Card has been completed.

5.1.6 Call-Outs

The Supervisor on duty would fill out a Job Card in detail and hand it to the artisan who has been called out. The artisan working on the job would complete the required details on the reverse of the bottom copy of the Job Card. A Works Order Number would not be assigned and the words, "Call-Out" would be written in the W\O NO space.

5.1.7 Definitions Of Priorities

Because it is obvious priority work interferes considerably with the planning of work, it is imperative that requests for priority work should be in accordance with the following definitions which are listed in order of priority:

1. Breakdown (BD) - A breakdown must be a specific job of maintenance work which must be started immediately and

worked on until completion to correct a condition which is actually holding up production.

2. Emergency (E) - An emergency job must be a specific job which must be started immediately and worked on to completion, to correct a condition which:

    a) is immediately liable to hold up production or

    b) constitutes a serious hazard or danger to life or property.

    Only work on a breakdown should have priority over an emergency job. When a breakdown or emergency job requires overtime to be worked, this must be stated on the Job Order. If no overtime is called for, the job must be worked on continuously during normal factory hours until completion.

3. Petty Priority (PP) - Petty priorities would be jobs which were expected to take up to two hours labour for the job, and:

    a) are jobs of such nuisance value in relation to the work that it is reasonable to place them ahead of other jobs, or

    b) are minor and unforseeable parts of major jobs.

    Depending on the availability of material, these jobs would normally be completed within three days.

4. Factory Made Spares (FMS) - These would be spares which are fabricated in the workshops and which must be available for repairs to ensure continuous running of equipment. Whenever factory made spares are drawn from stock, they must be replaced.

5. Normal (N) - A normal job would be one in which there is no great urgency, but which must be completed within a specified time.

6. Plan (PLAN) - A planned job would refer to installation of new equipment or modifications to existing equipment. Planned jobs would be expected to take a considerable amount of time to complete and therefore

great care would have to be taken to ensure that the target dates are met.

7. Scheduled Maintenance (SM) - This would receive priority on the due date only, because it is likely that the machine has been taken off line for such maintenance. On the due date, this would take top priority with the exception of breakdowns and emergencies.

5.2 THE PREVENTIVE MAINTENANCE SYSTEM

Before setting up the Preventive Maintenance (PM) system, the performance of all the production machines was analyzed over the previous two year period. Using the Pareto Analysis, or 80-20 rule, the machines causing the most costly downtime could be identified. By using this analysis, it would generally be established that approximately 80 percent of the downtime cost is caused by 20 percent of the machines. A full analysis of the company under investigation is shown in Appendix 1. These machines will provide a starting point from which to conduct PM inspections.

5.2.1 Procedure To Be Followed

Ideally, PM inspections should be carried out at regular intervals by a PM inspector, who would have the sole duty of inspecting machines and determining problems. He should concentrate on finding faults rather than repairing them and these faults should be noted on a worksheet for scheduling by the engineering planner. Unfortunately, in the company under investigation, there were initially no available personnel to be appointed as PM inspector and engineering planner due to the restrictions placed on the hiring of personnel in the poor economic climate.

Therefore, the initial system of PM inspections could be introduced as follows:

1. Preventive Maintenance Report Cards (Figure 5.2) would be printed. They would be almost identical to the Maintenance Work Order Job Cards discussed previously,

except that they would be pink in colour.

2. On a two-weekly basis, the engineering clerk would make out PM Report cards for the 20 percent of machines identified by the Pareto Analysis. The clerk would only be required to fill in the machine identification only, since the other information would be filled in by the various department supervisors. Every alternate Thursday, the clerk would deliver a batch of PM Report Cards to each supervisor in the factory.

3. Upon receiving the report cards, the supervisor concerned would list various items which he considers could contribute to equipment failure if it was not attended to. This would include items such as belt replacement, minor adjustments, loose nuts and bolts, greasing, motor inspections etc.

4. On the following Monday, the engineering clerk would collect all PM Report cards, regardless of whether they had been filled in or not. Where no faults were identified the cards should be marked "NIL". This would also give the engineering department some idea of which departments were being successful in reducing downtime through PM inspections.

5. As in the case of maintenance Job Cards, the Initiator would keep the top copy and the engineering department would utilize the other two copies.

6. On the right hand side of the PM Report card would be various columns which would indicate whether the job had been carried out or not and would also give an indication of the condition of a piece of equipment (good, fair, bad) which had been inspected or worked on. These columns would be ticked by the artisan carrying out the work.

7. The middle copy of the PM Report would then be returned to the Initiator with the next batch of PM Report cards. By referring to the previous cards, the Initiator could update his new PM Report to include any jobs which were not previously carried out.

JOB CARD work safely ! isolate machinery use warning signs	PREVENTIVE MAINTENANCE REPORT	IDENTIFICATION date	
INITIATOR	AUTHORITY	clearance required? yes / no	DWG. No.

WORK TO BE DONE	Done		Found		
	Yes	No	G	F	B
Special instructions					
or precautions					
Checked by Foreman Date					

FRONT OF CARD

ARTISAN NAME	TRADE (F/E)	DATE	TIME START	TIME STOP	NT HOURS	OT HOURS	LABOURER NAME	CO No.	NT HOURS	OT HOURS

MATERIALS OR SPARES USED:

QTY	PART No.	DESCRIPTION

Additional history for recording or other notes:

BACK OF CARD

Figure 5.2: The Preventive Maintenance Report Card

In the initial stages of implementing this PM System it is very likely that a large number of defects would be shown on the report cards. This is bound to be far more than the engineering department is capable of handling. Therefore, it would be reasonable to suggest that the amount of defects listed should be limited to a maximum of say, ten per report. The engineering department could then undertake to complete at least 50 percent of the jobs by the time the next report was due. If necessary, the artisans would have to work overtime in order to meet this figure.

Eventually, the information supplied on the various machines would be sufficient to enable standard PM Check Sheets to be compiled for each machine. In addition, valuable information would be supplied for building up history files. As the system progresses, it should be possible to expand it to include more of the production equipment.

5.3 THE MAINTENANCE INFORMATION SYSTEM

The lack of adequate records indicated an urgent need for devising a suitable maintenance information system. Two vital areas were considered:

a) Equipment Inventory

b) Plant History Files

Because of the large volume of information handled and manipulated, coupled to the fact that there was no existing system, it was decided to investigate computerization of these areas immediately. There are various software programs available for microcomputers which all vary in complexity. However, rather than spend money on sophisticated software in the initial stages, it was decided to design a fairly simple system using the dBASE II database program. In this way, the merits of computerization could be demonstrated to management and also allow one to assess the company needs before upgrading the system at a later date.

5.3.1 The Equipment Inventory Program

This program allows one to add, edit, list and remove equipment details from a database. To perform one of these functions, the main menu gives the user a choice of the following options:

0 - End program and return to dBASE II

1 - Enter new plant or equipment

2 - Make changes to plant or equipment records

3 - List the plant or equipment data

4 - Remove plant or equipment from the records

The full program listing is shown in Appendix 2.1.

5.3.1.1 Enter new plant equipment - Details of the equipment are entered using a predetermined format. After equipment details have been entered, the user is given the opportunity to correct data before the file is saved. Next, the user is given the option of adding further equipment or being returned to the main menu.

5.3.1.2 Make changes to plant or equipment records - The user can update plant and equipment records via full screen edit. The program will display the total number of records in the database and ask the user to enter the equipment name or the number of the equipment to be edited. If the equipment name or number is not on file, the user is given the option to try again.

5.3.1.3 List the plant or equipment data - The program allows the user to list all equipment details either numerically or alphabetically. The list can be displayed on the console or printed. In addition it is possible to list equipment in a certain department such as printing, laminating, bag-making or slitting. A typical printout is shown in Figure 5.3.

5.3.1.4 Remove plant or equipment from the records - Equipment which becomes redundant can be removed from the records. Either the equipment name or number can be selected and the program will search for the particular record. An invalid name or number will cause a prompt for the correct information to be entered.

PAGE NO. 00001

Equipment List

EQUIP#	EQUIPMENT	MANF:YR	INSTAL:YR	ELEC kw	STEAM (Y/N)	AIR (Y/N)	WATER (Y/N)	FLOOR SPACE	COST (R 000'S)
1	NINE.C CERUTTI	1982	1982	150.00	Y	Y	Y	90.75	1881
2	EIGHT.C CERUTTI	1966	1966	110.00	Y	Y	Y	78.17	240
3	SIX.C CERUTTI	1963	1980	120.00	Y	Y	Y	70.40	308
4	FIVE.C CERUTTI	1957	1959	150.00	Y	Y	Y	40.80	107
5	THREE.C CERUTTI	1957	1959	67.00	Y	Y	Y	25.20	285
6	O.6.1	1975	1975	136.00	Y	Y	Y	52.00	235
7	EXTRUDER 1	1955	1971	125.00	Y	Y	Y	129.13	153
8	EXTRUDER 2	1956	1975	156.00	Y	Y	Y	157.68	195
9	BANGERTER	1964	1964	57.00	Y	Y	Y	40.32	810
10	SOLV. LAMINATOR	1982	1982	60.00	Y	Y	Y	32.00	714
11	LANKO	1949	1955	13.50	N	Y	Y	15.00	12
12	SLITTER S1	1939	1955	3.90	N	N	N	5.75	1
13	SLITTER S31	1950	1954	4.50	N	N	N	3.64	4
14	SLITTER S32	1954	1954	4.50	N	N	N	3.64	6
15	SLITTER S33	1954	1954	4.50	N	N	N	3.64	6
16	SLITTER S35	1956	1956	6.50	N	N	N	4.48	7
17	SLITTER S36	1966	1966	6.30	N	N	N	6.80	119
18	SLITTER 41	1952	1954	9.00	N	N	N	7.26	6
19	SLITTER S43	1950	1954	9.00	N	N	N	7.26	4
20	SLITTER S45	1971	1971	10.60	N	N	N	6.29	21
21	SLITTER S48	1977	1977	9.30	N	N	Y	5.72	40
22	SLITTER S51	1955	1960	9.00	N	N	N	6.29	9

Figure 5.3: Equipment Report Listing

5.3.2 The Plant History Files Program

This program contains data related to historical information such as date, works order number, equipment name, item repaired, time taken and cost. Information from works orders would be transferred to these files. The main menu gives the user the following options:

0 - Exit back to dBASE II

1 - Add, change, delete records

2 - Search for specific maintenance information

3 - Print history records report

4 - Generate monthly work order status reports

The full program listing is shown in Appendix 2.2.

5.3.2.1 Add, change, delete records - Here the program prompts the user to make additions, changes or deletions to the files via the full screen editing feature. To add a new record, the user is prompted to enter a new number whereas, if the record is to be edited, the user is required to enter that record number. The user is also given the option of recalling any information which has been selected for deletion before final deletion takes place.

5.3.2.2 Search for specific maintenance information - This feature enables the user to search for a specific item of information, either for a works order number, or block by block. If the works order number option is selected, the console will display information related to the works number which has been input. This is a useful quick aid for checking on the status of specific works orders. If the historical data search option is

PAGE NO. 00001 'by equipment description'

Rec #	W.O.#	DATE	EQUIPMENT	ITEM REPAIRED	REPAIRS CARRIED OUT	HOURS	COST
6	0043	29/04/85	BANGERTER	GEARBOX	CLEAN AND CHANGE OIL	2.36	50.00
11	1545	14/01/85	BANGERTER	CLUTCH	CHECK FOR OVERHEATING AND RESET	2.00	50.00
14	1621	18/06/85	BANGERTER	CLUTCH	OVERHEATING - INSPECT CHILLED WATER SUPPLY	3.00	70.00
16	1659	01/06/85	EIGHT.C CERUTTI	MAIN MOTOR	REMOVE AND REWIND BURNT OUT MAIN MOTOR	3.00	230.00
7	1560	03/09/83	EXTRUDER 1	GEARBOX	CHANGE OIL ON MAIN DRIVE	3.50	50.00
17	1669	15/06/85	EXTRUDER 1	CHILL ROLL	REPAIR WATER LEAK IN L.H. ROTARY UNION	2.00	30.00
19	1733	29/07/85	EXTRUDER 1	TREATER	MOVE TREATER TO NEALAM POSITION	3.00	36.00
15	1653	29/06/85	EXTRUDER 2	ADAPTOR	CLEAN ADAPTOR AND RENEW SCREEN PACK	6.00	90.00
18	1721	23/07/85	EXTRUDER 2	BARREL	CHECK TEMPERATURE PROBE IN ZONE 2 - LOW TEMP.	1.00	15.00
13	1600	12/05/85	IVERSLEE 1	EYE	CHECK REGISTER CONTROL FOR ACCURACY	7.00	85.00
12	1643	29/01/83	MATADOR	UNWIND	CHECK NOISY BEARINGS AND RENEW IF NECESSARY	1.50	35.00
2	1102	12/04/83	NINE.C CERUTTI	UNWIND	CHECK SYNCHRONIZATION OF FLYING SPLICE	2.50	30.00
5	1105	13/03/82	NINE.C CERUTTI	ROLLERS	REPLACE BEARINGS IN 4 IDLER ROLLERS	6.00	180.00
20	1745	31/07/85	NINE.C CERUTTI	CHILL ROLL	REMOVE CHILL ROLL, FLUSH OUT AND SEAL	5.00	60.00
8	2380	29/01/85	S.53	EYE	REMOVE EYE, TEST AND ADJUST	2.00	25.00
9	2349	15/12/84	SIX C CERUTTI	ROLLERS	SKIM IMPRESSION ROLLER AT NO. 4 STATION	4.00	75.00
3	1103	12/05/82	SOLV.LAMINATOR	GEARBOX	REMOVE MAIN DRIVE GEARS FOR INSPECTION	5.00	250.00
4	1104	29/08/83	SOLV.LAMINATOR	LAM.PUMP	FLUSH OUT PUMP AND REPLACE WORN PARTS	2.50	125.00
21	1235	12/04/85	SOLV.LAMINATOR	D ROLLER	SKIM ROLLER	2.00	25.00
1	1001	26/03/84	SOLV.LAMINATOR	GEARBOX	CHECK FOR WEAR AND REPLACE WORN PARTS	2.30	260.00
10	5689	23/01/85	SOLV.LAMINATOR	D.ROLLER	CHECK BEARINGS FOR WEAR	2.00	50.00
22	1751	12/08/85	SOLV.LAMINATOR	D.ROLLER	CHECK SYCHRONIZATION WITH C.ROLLER - ADJUST POT.	4.00	48.00

Figure 5.4: History Records Report

selected, the user will be asked to identify the equipment name and item name. For example, if one wished to check the records for information on say, the Bangerter gearbox, the user would enter "Bangerter" and "Gearbox". The console would then display all data related to those items and the user has the option of printing the information.

5.3.2.3 Print history records report - The program allows the user to list the records by equipment description or by record number. The listing may be displayed on the console or printed out. A typical report is shown in Figure 5.4.

5.3.2.4 Generate monthly work order status reports - The user may obtain a report of outstanding work orders for a specific month or else a report of work orders received for a specific month. The month and year are input when requested and an option of console display or printout is offered. Again the report format will be as shown in Figure 5.4.

CHAPTER 6

DISCUSSION

6.1 IMPLEMENTING THE SYSTEM

The success in implementing a Maintenance Management System will hinge mainly on whether or not an active interest in the program is maintained. The continuing support and confidence of management is also essential.

Once convinced that a Maintenance Management System is a necessity, the first major planning step is to sell it to management. This is one of the most difficult stages and therefore sufficient research data should available so that the benefits of the system can be presented to management in terms of the data. Management will want facts such as downtime figures, overtime required, paperwork involved, spares and inventory cost. In addition, they will want to know how the system will affect the budget.

The second stage is to convince the production department that the Maintenance Management System is to their benefit. Production should be convinced that, with a few minutes of maintenance daily, weekly or monthly per machine, the results will be reduced downtime, increased production and greater safety. Accident records of badly kept machines should also be investigated. One of the most important points is to stress the fact that maintenance will be scheduled around work schedules with the minimum possible disruption to daily production. The production department must therefore be convinced that effective maintenance is to their advantage, since in the long run, they will benefit through fewer breakdowns and longer operating hours for plant equipment.

Thirdly, the Maintenance Management System must be sold to the maintenance department. Because all levels of maintenance supervision will be directly concerned, a particular effort

should be made to explain the nature of the system and the need for their contribution.

The efficiency of the Maintenance Management System will depend largely on the calibre and ability of the people involved. It must be run by conscientious, alert and well-informed personnel. Regardless of how well equipment service, adjustment and inspection checklists are compiled, the effective output of the man who is using them will determine success or failure.

There may be initial discouragement, accompanied by dwindling support and this should be avoided. Costs and manpower needs can be expected to increase during the early stages of the system, and there may be an outflow of funds and effort, with few visible returns. Personnel may have to be frequently reminded that the rewards will eventually become apparent through reduced breakdowns and trouble calls.

6.2 THE MAINTENANCE WORK ORDER SYSTEM

6.2.1 Collecting The Information

The maintenance work order is the collection point for all information in the system. To be effective, the system requires the use of written work orders with a maintenance work order assigned to each. The system also incorporates time and materials reporting, both made against individual work order numbers.

Capturing the desired cost and equipment history information on all work performed by the maintenance department is impossible without the consistent use of written work orders for both planned and unplanned jobs. Where there is more unplanned than planned work, the efficiency of the maintenance department will be low. Maintenance customers must be shown that anticipating maintenance work and requesting a job to be done before it becomes an emergency is much more efficient and cost effective for them as well as for the maintenance group.

Planned work is possible when requests are received in time for planning and scheduling the labour, material and tools needed to

complete the job when required. Unplanned work is initiated by requests made in response to emergencies that do not allow time for planning. Unplanned work may also be short duration jobs completed by an artisan while assigned to other work in the same area. For best results, non-emergency jobs that require more than say, one hour's work should fall into the planned work category, although this determination would vary according to the industry.

6.2.2 Designing The Work Order

There are many variations in printed work order forms. Work order design and content should be considered carefully, according to the actual need and use. The work order should be easy to use. Although its day-to day application should supply all the information the maintenance department requires, the work order should not ask for excessive or extraneous data. The essential information should define the job and provide for planning, scheduling, control, and accumulation of equipment history.

Smaller, pocket-sized forms usually are the most convenient to carry and use and are therefore the most likely to be used properly by supervisors and artisans. In computerized systems, a single copy printout of the work order can be given to the artisans. Everyone else can obtain desired information by using a CRT terminal.

In a manual system, a multicopy form (three or more copies) is used. Sometimes, each copy may be of a different colour and may be designated for use by different persons such as the work originator, planner/scheduler, foreman, artisan or accounting.

6.2.3 Using The Work Order

Everyone who uses a work order form must be instructed in its use. In most plants, written procedures are needed that detail use of the entire work order system. The procedures should outline the responsibilities of the customer and of maintenance. Accountability is needed on both sides.

In most systems, the work order flow is from the originator to the maintenance clerk or planner, to the maintenance foreman, to

the artisan, and back to the planner for closing. Each of these individuals must know what information he is responsible to provide on the work order.

Until the proper approval and authorization is received for a job, the work order is only a request. It becomes a written order to spend money and do work when authorization is received from the cost centre to whom expenses will be charged.

A system for authorization and approvals of maintenance work should be established by plant or corporate management. The maintenance customer should be responsible for adhering to the rules. The planner should schedule a job only when authorization is certain, the labour, parts and materials are on hand, and the equipment is shut down or otherwise available for work. Jobs with lower priority assignments would enter the work backlog. This backlog may be arranged by skill area such as mechanical, electrical or instrumentation.

The maintenance foreman should review the work orders with the clerk or planner and do the daily scheduling and assigning of work. In some organizations, a maintenance clerk or despatcher accepts orders and routes them to the maintenance foreman who does the planning, scheduling and assigning of work. The foreman would give the work order to the artisan assigned to the job.

The artisan, on completion of a job, would add information to the work order that describes the actual work performed, materials used and hours worked. He should also fill in failure analysis information. When the artisan finishes a job, he should sign the work order and return it to his foreman, who would then verify the work description, materials used, and hours spent. The clerk would return the work order to the maintenance clerk or planner for closing. This copy, which would contain all information on the job, would be filed by maintenance for its equipment history information and as a reference in planning repetitive jobs.

6.2.4 Time Reporting

Artisans must be responsible for reporting their time accurately

and by work order number. A good system would include the reporting of delay time (waiting for an assignment, tools and materials, or release of equipment), as well as time spent working on each job. An automated system using time-clock-type devices to record the time an artisan spends on each job can be used. When filling in a daily job card, the artisan should use the work orders assigned to him that day and record his hours by work order number whenever possible. The cost centre number and equipment identification number may also be included on the time card.

Many methods can be used to record time for payroll and maintenance information purposes. The timekeeping objectives of the organization and data processing resources must be considered when choosing a method.

6.2.5 Material Reporting

Other essential information connected with the work order system is a record of the spare parts and materials used to complete a job, as well as their actual or estimated cost. A stores requisition form should be used to account for material drawn from the maintenance storeroom. The requisition should be charged to a work order number, and for goods purchased from an outside source, a purchase order should be used in accordance with plant purchasing procedures.

Materials can also be recorded on the work order form or on a separate list attached to the work order. The list should describe the material used, part number and the quantity and the artisan should be instructed to fill in these details. The foreman or clerk/planner should fill in the cost information. Space on the work order can also be allotted for noting any special tools or equipment required to complete the job. The decision about how to record materials used and their cost must be made in view of the overall maintenance management system, how the information is going to be used, and in the case of a manual system, how much time can be spent on the paperwork.

6.2.6 Computerization

The positive results achieved from a manual work order system are further enhanced by computerization, provided the computer system is chosen to meet clearly defined objectives and adequate planning is done for its installation and use. In most cases, a computer system should not be introduced at a plant unless a manual system already is being used effectively. The data, procedures and training associated with the manual system provide a basis for implementing the computer system.

Basic maintenance management software covers the work order system, preventive maintenance, inventory control, and equipment history records. Software chosen should have been developed by people who understand the maintenance function and know the needs of maintenance. Computer use will be most rewarding for a maintenance department if they purchase equipment (either micro or mini on-line systems) that is dedicated to maintenance use and not dependent on a mainframe system controlled by data processing or accounting. Some maintenance software can be used only on one manufacturer's hardware. Others can be used on several hardware systems, and this is the trend of the future.

One should remember that computerization can be done in stages. A maintenance department can begin with a program to track work orders or to plan and schedule preventive maintenance. Other organizations may want to install a complete maintenance management system all at once. The route taken must fit the resources and objectives of the particular organization and plant. A computerized system may be feasible for a maintenance organization with as few as five or ten maintenance personnel.

Computerization should increase the efficiency of the maintenance operation and affect manpower, material and equipment costs. The largest cost savings should usually come from improved craft productivity, increased production uptime, and a reduction in inventory. Planned maintenance increases equipment life and minimizes unexpected breakdowns. Information stored by the computer allows faster and more accurate estimating of labour and materials needed to perform a job. Better management of resources

will result in a reduction in idle time and tool costs. Improved inventory control assures adequate quantities of needed spare parts and other materials, while unneeded items can be eliminated.

Quick access to accurate information will speed the maintenance organization's response to customer needs. With an on-line computer system, work orders can be written, planned, and scheduled at a CRT terminal. The information will immediately become available on other terminals used by foremen, artisans or the customer. The computer can produce a printout of a daily job plan and the individual work orders making up the plan. All work orders in the system would be able to be reviewed at any time, while backlogs and trade availability could be easily monitored. Computers can produce a variety of maintenance reports on the use of resources, materials and costs. Improved preventive and predictive maintenance plans can be devised. Equipment life cycle analysis can be done as repair and expense histories are established. Cost information can be tracked by cost centre, equipment and work order number.

Successful use of any computer system will require a commitment of resources, especially people, to continue development and maintenance of the system and it is therefore of utmost importance to fully train maintenance in the use and capabilities of the system.

6.2.7 The Successful System

A properly controlled work order system will allow maintenance management to obtain the information needed to analyze costs by jobs, units of equipment, priorities, trade, cost centres and account numbers. Data is generated to monitor work order status and backlogs, add to or start equipment histories, and control manning levels.

A system will not work at an optimal level, however, unless management is fully committed to its use and all appropriate employees are trained in the procedures. When a new or improved system is developed, input from all users should be requested and

- Checklist. A master checklist will help the inspector to meet all inspection requirements. The list can be used to get the inspection program underway. Once the program is operating, The maintenance manager can pick and choose the details he feels should be covered day-by-day. It would be best to keep the checklist simple. The equipment should be listed in a sensible sequence and definite inspection intervals should be prescribed. Too often, PM programs rest in limbo for many months because maintenance managers have refused to start until every nut and bolt has been considered. In the meantime, the plant could be slowly falling apart.

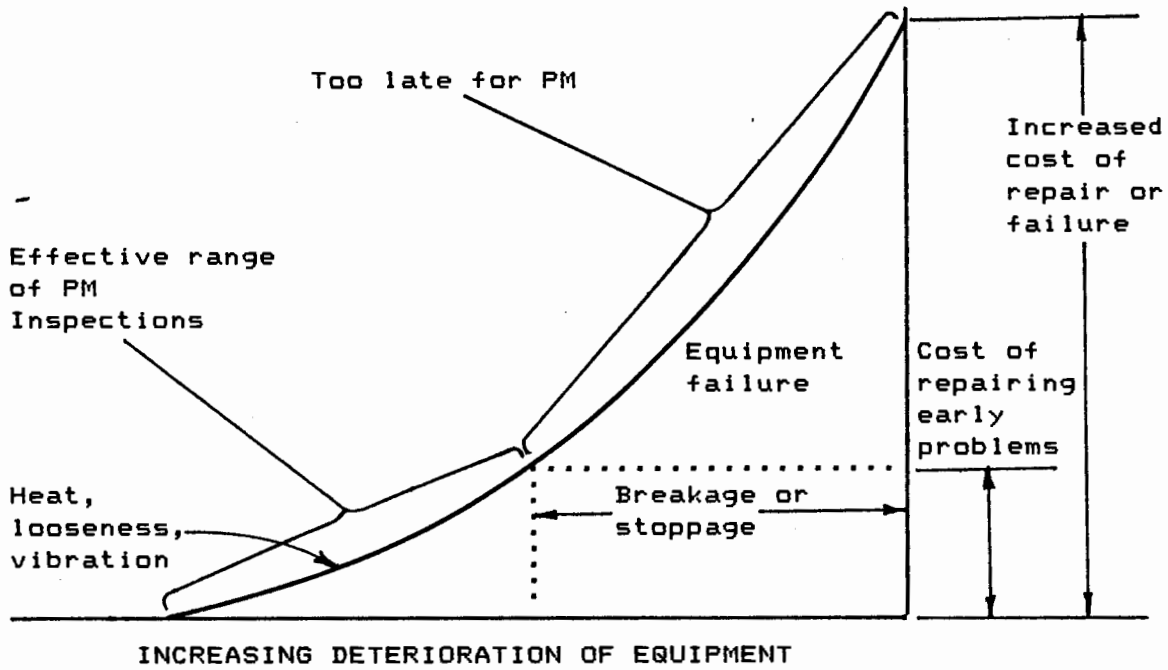


Figure 6.1: Effect Of Regular PM Inspections

- Reporting. Inspectors should be encouraged to report on both long-range and immediate problems. Long-range problem reporting will ensure the development of the appropriate lead time needed for proper planning and scheduling. Verbal reports alone should usually be discouraged. If the inspector was required to make only a verbal report, he might have the tendency to sort out the most serious problems and let the rest go unreported. The PM inspection

report is an important tool. It is the only available accurate report of equipment condition, and both the inspector who prepares the report and the foreman who receives it must recognize its value.

6.3.2.1 The PM Inspector - The key man in the PM inspection program would be the inspector. He must have a positive attitude and clearly understand that it is his duty to inspect and determine problems, and to prepare accurate reports on them. The inspector should concentrate on finding faults rather than repairing them. He may be required to make minor adjustments, but no extensive repairs should be attempted.

Operating personnel are an excellent source of information regarding the status of the equipment they work on day after day. Rather than ignore this source, the PM inspector should check with the operator at the start of the inspection tour for a report of any problems.

A good inspector should be able to sort out immediate repair needs from long-range needs and foremen should encourage inspectors to estimate the time-frame within which repair work should be done. When PM inspections are inadequate, less planned work will result, more running repairs and emergencies will take place, and maintenance costs will rise.

6.3.2.2 Control of PM Inspectors - This would vary in different maintenance organizations. In some, the foreman would be in charge whilst in others, the effort would be controlled by a PM coordinator. An examination of the current workload would be a good starting point in deciding who should be in charge. If most of the foreman's work is repair or emergency jobs, he cannot be expected to try to control PM inspections. He would not have the time to supervise them as well. If the foreman is given the responsibility for PM inspections and regular maintenance pressures become too great, he may quietly abandon the inspections. Inspectors, therefore, would soon be serving as regular repair personnel, and the breakdown maintenance concept would again take hold.

6.3.2.3 Key Points to Remember - Several points should be stressed when establishing an effective plant PM program:

- PM inspections must have the full sanction of top management, emphasized by a firm policy statement, and strict compliance by both maintenance and production.

- Results should feed directly into the planning and scheduling system so that as many maintenance jobs as possible can be planned.

- Inspection results should be reported within the framework of what is needed and not what is wrong. These needs should then be put into a time-frame which estimates when the work should be done. This would yield a basis for determining which jobs must be acted upon immediately and which should be handled more deliberately, thus ensuring maximum utilization of manpower.

- Responsibility for ensuring that PM inspections are done properly can be delegated to either the maintenance foreman or a PM coordinator, depending on the plant circumstances.

- The inspector himself must be recognized as the key man. The system that controls his efforts and the administrative tools he works with must be carefully planned and employed.

6.3.3 Equipment Maintenance Needs

A Preventive Maintenance Program may stand or fall on its effectiveness in combating the development of equipment weak points into defects, which could then lead to breakdowns. If PM is ineffective, costly production interruptions will occur.

Plant equipment maintenance needs can be determined by examining a piece of equipment's failure history. It is only after this data has been gathered and reviewed that maintenance planning steps can be taken. Unfortunately, the maintenance recommendations of equipment suppliers may often be incomplete or inappropriate. Because different manufacturers suggest different maintenance methods (varying periods between equipment inspections or lubrication, for example) these recommendations can be used only as guides to establish maintenance procedures

and schedules to suit specific plant conditions.

If all repairs were carried out at a time when defects in individual components reached permissible limits (the point of imminent failure), few breakdowns would occur. However this approach would demand numerous individual repairs. Therefore, a preventive maintenance program should be concerned with more than just routine care and attention. Above all, components must be repaired before they reach their highest permissible defect limit. Thus, all components should be maintained according to a maintenance schedule based on the degree of wear.

6.3.4 Installation Costs

What is the cost of installing and operating a preventive maintenance program[19]? In the initial PM planning stages, roughly one planner-day should be allowed for each piece of equipment worth at least R200 000. Approximately half as much planning time must be added for writing work orders and preparing the scheduling system. Actual PM performance requires approximately eight percent of the direct labour charges and indirect costs of the maintenance department. Cost of maintaining the planning system will require an average of about ten percent of the total annual cost of the planning function. The total annual cost of preventive maintenance, including planning, may be estimated at roughly 0,4 percent of the value of the equipment.

6.3.5 Expected Results

What results can be expected from a PM program? In a plant where no formal PM system was formerly employed, it could be expected that:

- The total number of equipment breakdowns will immediately decrease by 50 percent.
- The number of urgent repairs (those that have to be completed in less than 24 hours) will be reduced by half.
- The maintenance costs generally will rise as soon as a PM program is introduced, largely because of inspectors uncovering previously hidden faults. However, after the

program has been in operation for one or two years, labour and material costs could easily decrease by up to 15 percent.

- Equipment life will be extended by at least 20 percent because of the regular care given to machines in a PM program. Thus, in the long run, depreciation costs will decrease by 20 percent.

6.3.6 Limitations

What are the limitations of preventive maintenance? Every motorcar driver should be familiar with the motorcar that develops problems after being subjected to an inspection with no indicated defects. This is also the case with machinery. The probability of breakdowns is greater after needless repairs, modifications, or other changes, than after long regular periods of operation.

Because of the increased probability of breakdown after inspection, several guidelines should be noted by maintenance managers:

1. All interferences with the equipment that could contribute to its imperfections should be avoided as much as possible. i.e. dismantling, reassembling or deliberate overloading. If the principles of PM are accepted by maintenance personnel, they must also accept the fact that equipment components periodically develop defects. Most defects are time-dependent and users can differentiate between equipment "chance defects" (which occur with equal probability during any period of time) and "drift defects" (which generally develop over a period of operating time). Inspection and analysis of plant equipment would indicate that a large proportion of defects are "chance" in nature. This would be particularly true of components which are designed to have a specific lifetime.

2. Because preventive maintenance is ineffective against chance defects, it would be worthwhile to try to

identify and control by periodic maintenance only those chance defects which could cause drift defects. Chance defects develop so slowly that it would be difficult to justify inspection frequency on the basis of the cost involved. For example, it would be uneconomical to check for possible failure of the protective coatings applied to chemical vessels (a chance occurrence) in order to prevent extensive corrosion of the base metal used. Drift defects, however, develop with widely differing frequencies, even in components of essentially the same design. It would not be uncommon for similar components, in comparable plant equipment, to fail after widely varying periods of time.

3. Drift defects must be identified and checked frequently so that, despite widely varying lifetimes, there would be a high probability of discovering defects before they reached the permissible limit. The maximum defect frequency point should be used as the basis for inspection scheduling. Expensive maintenance jobs, such as replacing components or extensive dismantling should not be attempted very often in a PM program because the cost of PM would exceed the program's potential savings. It should be remembered that the principal objective of PM is to minimize the need for maintenance.

4. Cost of individual operations must be kept as low as possible. The more frequently the operation has to be performed, in relation to the defect frequency, the lower the cost should be.

Although the above guidelines could be used to identify the areas needing PM, it should be realised that there are other means of preventing or neutralizing potential defects. For example, one should deal with those defects that could lead to drift defects.

Chance defects could be handled in the following ways:

- duplication of equipment to prevent major work interruptions in case of component failure.

- modifying or strengthening of a suspect component, to reduce the probability of defect occurrence.

- installing automatic control equipment to signal impending failure.

- using alternative component designs which would change the defect's nature from chance to drift.

- taking out insurance against machine or production breakdown, thereby changing such an occurrence to a calculable risk.

6.3.7 Availability of Machines

Frequently, maintenance people complain that equipment operators will not make their machines available for inspection. However nearly all industrial equipment is frequently stopped for a variety of reasons. (Examples are listed in the UDL categories of Table 4.1). These stoppages occur often enough to allow maintenance inspections to be carried out. Maintenance operations should be scheduled to coincide with such shutdowns whenever possible rather than attempting to stick to a rigid scheduling date. Maintenance scheduling flexibility could be achieved by:

1. Allowing a fixed schedule tolerance for performing a job, i.e., ±20 percent of the scheduled period between jobs.
2. Decentralizing the scheduling operation by delegating responsibility to the production foremen.
3. Entrusting the scheduling to those workers who are best informed concerning actual shutdowns.

6.3.8 Motivation of Personnel

If a preventive maintenance program is to be effective, it is imperative that maintenance personnel receive clear job instructions. They cannot be expected to perform their tasks properly unless they are told what is needed.

Because of the relatively routine, repetitive nature of PM jobs, as compared to other maintenance and repair jobs, there is always

the possibility that personnel could become bored and inattentive to certain details. This could be extremely dangerous because PM jobs are actually amongst the most exacting, inasmuch as the workers move from one piece of equipment to another on an almost continual basis. Therefore, the following measures could assist in overcoming the problem of boredom:

- Interchanging PM inspectors occasionally to encourage a positive interest in the job.
- Checking the jobs closely to ensure that the workers retain a sense of urgency about the work.
- Encouraging equipment operators to keep a close watch on the PM program and offer constructive criticism.
- Upgrading the status of the PM man by giving him a specific title or special work clothes.
- Giving the PM man a higher rate of pay.

6.4 THE MAINTENANCE INFORMATION SYSTEM

In order to create an efficient Maintenance Management System, the individual needs of each machine must be known. Day to day servicing needs and operating experience will give some indication of the maintenance demand pattern of the machine, but many important facts may be overlooked. Often, it is the overlooked item that results in an unscheduled repair.

It is therefore of utmost importance to have a thorough method of maintenance recordkeeping that contains a usable, readable record of everything that has been done to the equipment, when it was done, costs, time taken and other pertinent information.
What should a good Maintenance Information System record? Typical information is shown below:

a. Report problems. Maintenance problems should be highlighted so that appropriate action can be instituted.

b. Simplify solutions. Problem analysis should be simplified because repetitive or major breakdowns will

be highlighted on the equipment history card.

c. Control costs. The system must indicate immediately where something is getting out of hand or when expense is likely to be incurred unless action is taken.

d. Organise maintenance intervals. By highlighting high cost areas, poor availability and unscheduled breakdowns, a good record system points out where you may need to schedule maintenance.

e. Equipment history. With full details of equipment history, it will be easier to analyse component strengths and weaknesses. Altering machine specifications when next purchasing a machine or component can reduce maintenance expense in the future.

One of the great advantages of a good record system is that it will provide definite indicators as to the capabilities and strength of a machine when required to perform a specific job. Any overworked machine demands excessive maintenance and is a reliable indication that the machine should be correctly specified when considering replacement.

By examining maintenance records, management can be greatly assisted in determining the following:

1. Is the machine or certain of its components unsuited or inadequate for the job the machine is required to perform? This problem could be remedied by more frequent maintenance, reduced workload, or perhaps by modifying a troublesome component.

2. Has the operator been abusing the machine? This could be rectified by improved operator training, more line supervision or operator replacement.

3. Have the maintenance personnel been maintaining the equipment properly and is repetitive maintenance frequent? It may be necessary to increase supervision, improve training, provide additional equipment or facilities, revise PM intervals or call in the supplier

to check the machine and report on the standard of maintenance.

Maintenance records can also assist management in determining:

- whether the current budget is adequate.
- if the correct machines are being purchased.
- the availability and cost of spares and whether pirate spares are worth using.
- if production demand is excessive or whether it can be increased.
- what machine availability can be expected.
- actual machine cost per hour.
- whether additional machine protection equipment should be fitted.

In many companies, these histories are initially recorded but are seldom kept up-to-date. Because this type of record-keeping is often delegated to clerical personnel, significant information may not be given to maintenance management for action. This problem my be greatly alleviated through the use of computers. Equipment performance records can be incorporated into a computerized maintenance system to assure transmission of data to management, while at the same time eliminating tedious paperwork.

6.5 MAINTENANCE MANUALS

Many equipment suppliers do not realise exactly what information should be provided and, consequently, it is occasionally found that no manuals or information are available at commissioning or during the first year of operation. The reasons for this often centre on the failure of suppliers to appreciate this need and to budget for it, or on a tendency to use the designers to produce the manuals after the development and commissioning tasks are complete. In this situation, the manuals not only arrive very late, but are also frequently Research and Development orientated rather than written for the user/maintainer.

It is essential to specify documentation requirements when buying equipment. For example, it is common practice to request four copies of operating and maintenance manuals which must include details of spares, lubrication schedules and detailed drawings. This cost of documentation is normally included in the equipment purchase price. These costs can be high, especially if the manuals are "made to order". However when one considers that the life maintenance cost of the equipment usually exceeds the initial purchase price, then this expenditure is worthwhile.

Plant manuals should be designed so that all staff are fully informed. These manuals should begin with outline drawings of the plant which would identify major parts and their locations, followed by functional block diagrams showing the operating states of the plant and the inter-relationship of the various parts or units. Fault-finding and calibration charts should be included, followed by spare parts identification and replacement instructions.

Even where special purpose machines are designed and built within the factory where they are to be used, there will sometimes be an information gap between the production department (who requested the machine) and the maintenance department (who design and build the machine). The solution is to supply a maintenance manual. This will provide a permanent source of information regardless of staff changes over the years of machine life and also help standardise maintenance methods between shifts on three-shift working.

Control and instrumentation manuals should not be produced as bulky volumes, full of text, with folded diagrams at the rear. Nowadays, the trend is to use graphics as far as possible with the text in block diagram form, with test data added and all test points identified.

Fault-finding charts are also important, since the time taken to locate faults is often a significant part of total downtime. As output speeds rise, expenditure in improvement of diagnostic routines becomes a good investment. Typical methods used are the

algorithm and the dependency chart. Both use a few basic symbols to indicate the logical path through a fault situation so that a fast return to service is achieved. Regular use of such charts would develop the tendency of engineers to think logically whenever problems are encountered.

In cases where planned maintenance or work measurement is used, there may be a requirement for work specification. Specifications can be prepared for preventive, corrective or overhaul maintenance tasks, listing the tools, spares, etc. which are necessary and detailing the precise order of work. Cutaway perspective drawings can be included to assist with parts identification and the working instructions can, if necessary, be overprinted on drawings, which are then issued on oil-resistant paper or plastic cards.

Maintenance instructions can be divided into mandatory and non-mandatory types. For example, spark plug maintenance for a motor car can be considered to be a non-mandatory type of instruction. A decision must be made whether to write a specific preventive maintenance instruction recommending that spark plugs be changed every 10 000km or not writing an instruction and changing the spark plug after it fails.

Consider the fact that a four cylinder car has four spark plugs which are not likely to fail simultaneously. Normally, they would all begin deteriorating at the same time. If there were no specific instructions calling for a periodic renewal of the spark plugs, the result would merely be a decline in engine performance until it was finally found to be necessary to change the spark plugs. Because nothing serious nothing serious would occur if the spark plugs were not changed on a prescribed or planned basis, the instruction is non-mandatory.

On the other hand, an example of a mandatory item would be the brakes on the car. If there were no preventive maintenance system on the brakes, there would be no assurance that brake failure would not occur without warning. Thus it would be mandatory to write a preventive maintenance instruction calling for periodic

brake inspection and a complete overhaul of the system after so many kilometers of operation. Understanding of these catagories and an intelligent appraisal of historical feedback information will help the maintenance engineer to make proper decisions concerning preventive maintenance coverage.

Another type of maintenance instruction instruction is known as pyramiding and nonpyramiding. A fuse which blows in an electric circuit is an example of a nonpyramiding type of breakdown. When the fuse blows, that is the end of it and nothing else happens.

On the other hand, an example of a pyramiding type of failure might be say, the failure of the main bearing in an engine. If it were to fail, shaft may drop and the entire engine may fail, thereby causing additional failure. In this case, instead of a R20.00 bearing failure, there might be a R1000.00 overhaul. Understanding pyramiding will assist the maintenance engineer to make decisions concerning the relative importance of maintenance tasks.

CHAPTER 7

CONCLUSION AND RECOMMENDATIONS

7.1 GENERAL

The most difficult part of starting a Maintenance Management program is convincing management that savings will result. Maintenance Management programs do not show immediate savings; visible progress along these lines will not be apparent until the system has been in effect for at least 18 months. In fact, it is most likely that costs will show increases, which can be attributed to the expense of starting a new program while the old emergency repair system is still in effect.

Because of this initial negative appearance of the Maintenance Management program, it is best to show the benefits which could be obtained in the long run. This can best be done by preparing graphs, charts and tables which show:

a) the actual costs for the 2 years immediately preceding introduction of the program.

b) projected costs for 2 years following startup of the program.

These visual displays will serve two basic functions - they will be an invaluable aid in showing what the program can do and they will provide the engineer with a budget-reduction goal.

Program projections must be realistic, however. If the figures are too extreme, management may simply elect to kill the program before it even gets started. Therefore, the engineer must plan thoroughly so that he is sure of his position before he approaches management with his idea.

The best approach for convincing management is proof-by-results; i.e. visible evidence of increased efficiency and time or money savings. For example, every industrial plant will have at least

one known problem area and, frequently, maintenance personnel can predict with a high degree of accuracy, when the next failure will occur. A Preventive Maintenance program can be planned simply by using the equipment operating records. After the PM program has been in operation for a while, the equipment breakdowns should become less frequent. Management support will generally be forthcoming once they realise the potential savings through planned and scheduled downtime.

7.2 PLAN OF ACTION

In implementing a Maintenance Management System, it is therefore recommended that the maintenance manager follows a definite plan of action. The extent to which he pursues these actions will depend on the size of his maintenance department and its economic significance within the firm.

7.2.1 Planning And Control

The maintenance manager should:

a) Collect broad survey comparisons. The company's maintenance costs and activities should be compared with those of others in the same industry.

b) Develop performance indices. Data relating to cost and performance should be collected and an appropriate set of indices should then be constructed. These indices should be plotted regularly on a moving average basis, and action should be taken when they suggest a deteriorating performance. The range and sophistication of the indices can be developed as more cost and performance data become available over time.

c) Implement a maintenance work order system. The system will produce feedback on maintenance performance, job and plant costs, and equipment history.

d) Implement a preventive maintenance system. Start with a modest system and gradually move to one with more comprehensive coverage. The optimal level of preventive maintenance, however, should first be established.

e) Develop a maintenance information system. This can be fairly modest to begin with but, as the maintenance system develops in sophistication, transfer as much of the information recording as is feasible, to a computer-based system.

f) Compile maintenance manuals. These manuals will be of great value to technical personnel and should give full operating and maintenance procedures.

g) Apply Pareto analysis. Make use of the Pareto technique to identify key areas for special attention.

7.2.2 Organising

The maintenance manager should:

a) Decide on the extent of decentralisation. He should examine the case for greater decentralisation of maintenance and evaluate the advantages of a greater use of contractors.

b) Make use of job descriptions. He must ensure that the intended authority and responsibility levels are clearly understood within the maintenance function.

7.2.3 Motivation

The maintenance manager should:

a) Implement sound foreman training and development. He should develop training schemes to suit individual needs and give special consideration to the difficulties of the foreman's role. He should also ensure that the maintenance foremen are fully consulted regarding all changes in maintenance shopfloor procedures, including wage negotiations.

b) Implement comprehensive safety training. He should arrange for safety training and fault diagnosis courses to suit specific needs of the workplace.

7.3 CRITICAL EQUIPMENT FOR PREVENTIVE MAINTENANCE

It is economically foolhardy to try and cover all equipment in the plant with a PM program. Yet, a history of machines and equipment must be compiled. The important thing is to cover the critical items, i.e. critical equipment of high cost and/or high frequency of repetitive maintenance. In selecting these pieces of equipment, the following points should be considered:

1. What would happen if a particular machine broke down? If the work could be switched to another piece of equipment, it is probably not a critical item.

2. How costly would a breakdown be? Parts, labour and the cost of downtime are only one aspect of this. Delayed or cancelled orders must be added in, as well as the idle time of production workers. The possible premium payments for rush delivery of parts or replacement equipment should also be included. In the plant under investigation, Pareto analysis identified ten machines with a high cost of breakdown.

3. How long would repairs take? It is important to know the true cost of downtime so that one can determine if additional spare parts or equipment should be stocked.

4. Would a breakdown create a health or safety hazard?

All of the above items are usable indicators of whether equipment should or should not be included in a PM program.

7.4 THE PM INSPECTOR

The inspector is a key man in all PM programs. He plans and schedules all PM inspections, repairs, overhauls and services. He notes work to be done, but doesn't necessarily have to do it, even though there is no reason why he should not make minor adjustments and repairs when he is looking over the equipment. For example, he could stop minor leaks, tighten pump packings, and fasten guards.

The inspector should be an artisan with some trouble-shooting experience if possible, since that will make him more effective in diagnosing machine ailments. In addition, moving men in and out of the job of PM inspectors is an excellent means of upgrading the artisans involved. This will ensure continuity of the PM program in the case of absence of an inspector or termination of his duties.

7.4.1 Cause and Result

One of the major problems with today's complex equipment is that the apparent cause of breakdown is almost always an end result, rather than the true cause of the breakdown[37]. For instance, if a machine loader arm breaks, the repairman immediately assumes that it weakened through use and he replaces the arm, thus solving the problem for the moment. However, this solution does not solve the real problem of the loader arm arriving at the operating point a little late in each cycle because the flow of actuating hydraulic fluid was less than it should have been. Looking further into the operation, it can be determined that the fluid flow is impeded by a partially restricted hydraulic control valve. This valve is malfunctioning because the hydraulic system filter has not been changed in months. Thus, the broken loader arm is an end result, the true cause of the problem being the partially clogged hydraulic filter. This machine will continue to have a series of annoying and costly breakdowns until this basic cause is remedied.

Thus, it is imperative that the inspector is trained to search continually for the underlying causes of breakdowns while repairing the reported end result.

7.5 MAINTENANCE ORGANISATION

In a medium sized plant, a central maintenance plan is recommended. This plan provides excellent flexibility in getting maintenance work done in the plant. New projects, emergency jobs or major repairs and servicing of equipment can be handled

quickly and efficiently and the specialist or technician can be used effectively. Many areas or departments do not have sufficient work to retain a man on a full-time basis, but they do have the occasional instrument or electronic work. Thus, the entire maintenance costs of the plant, its equipment, buildings and grounds are the responsibility of one man.

However, job priorities can be a headache. Every department feels that its jobs are the most important and department supervisors often insist that their jobs take top priority. This problem, of course, can be solved by adhering to a strict policy of carrying out jobs in the sequence of their work order numbers as discussed in Chapter 5. The backlog of work in a central group may be several weeks for effective planning of men and material. This backlog will not be appreciated by the production department and therefore, weekly planning sessions are recommended between the production departments and the Plant Manager to agree on the order of work.

In many cases, it is beneficial to combine an area group with a central group. This was evident during the investigation. The Pareto analysis identified critical machines in Area A, from the printing and laminating departments, whereas Area C contained mainly slitting machines. These critical machines require long "make ready" or "set-up" times, frequently in excess of six hours. This is usually an ideal time to carry out certain maintenance work. Unfortunately, these times do not always coincide with availability of workshop personnel. This problem could be overcome by having artisans permanently assigned both to printing and laminating. Precision work such as machining would still be carried out by the central workshops. This would also apply to major overhauls. However, these "area" artisans would be able to relieve the PM inspector of a certain amount of his workload and would be able to help identify major problems in their early stages.

The existing and proposed maintenance plans for this investigation could be as shown in Figures 7.1 and 7.2.

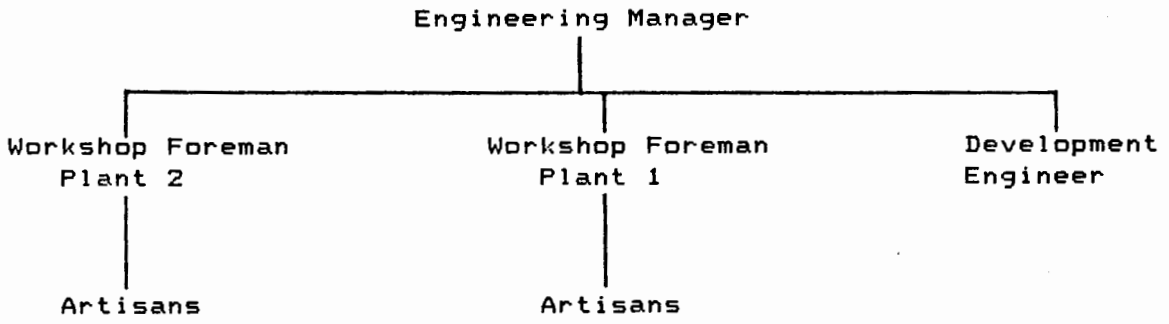


Figure 7.1: Existing Organisation Plan

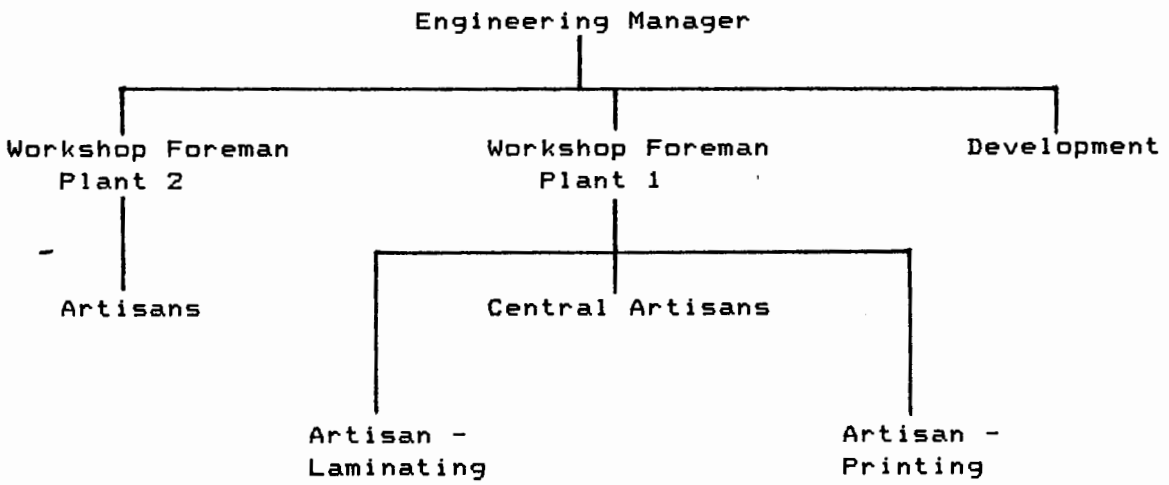


Figure 7.2: Proposed Maintenance Organisation Plan

7.6 CONTRACT MAINTENANCE

Peak demands on maintenance boost overtime charges, bloat the backlog-of-work figures and inflate the maintenance payroll. When the crests pass, one could find that the department is overstaffed. One remedy is to make use of contract maintenance. Contractors build in their own profit cushion. Their workforce has little knowledge of the plant's problems or procedures and has no loyalty to the plant. However, since contractors are expensive, their services are generally only employed where the work is of a specialised nature.

Typical areas where contract maintenance could be used are shown below:

Classification	Major Activity
Building Facilities	Roof repair, paving
Electrical facilities	Motor rewinding
Production auxiliaries	Elevators, fork trucks
Machine shop work	Sheet metal
Painting	Building
Plant services	Air-conditioning
Instruments	Recorders
Process equipment	Tanks
Miscellaneous	Rigging, carpentry

Where the maintenance is of a cyclical nature (e.g. the annual shutdown), it is often necessary to employ a contract work force to cope with the high volume of work within a short period.

7.7 CORPORATE POLICY AND STRATEGY

As companies tend to increase in size and complexity, proper maintenance becomes more and more a problem of gigantic proportions. It is not unusual for an asset to have maintenance costs that approach acquisition costs within the expected life of the equipment. When the business is in an expansionary period, the usual approach to this type of problem is to scrap the problem equipment. However, as expansion gives way to recession, there is often a tendency toward retaining the machines and maintaining them on a breakdown basis.

Such wide swings in the corporate acquisition policy should not exist, since they exaggerate corporate spending in fat years and stifle spending in lean years. Many attempts have been made to solve this dilemma. A successful program may have started with breakdown maintenance, progressed to the corrective stage, and finally arrived at true predictive or preventive maintenance.

Being able to predict the outcome of decisions made in business is, after all, the role of the successful manager.

Like all decision making process in modern industry, the management of maintenance stands to gain enormously from the development of rational strategies from systematic data or information. It is important, of course for the decision maker to use his trade knowledge or even his 'hunches'. That is why management is a difficult profession to practise - it is never simply a case of applying rigid formulae to solve complex problems. However, it is wrong, yet common for maintenance managers to reach decisions almost entirely by hunch or intuition without any recourse to any relevant quantitative information.

There is clear scope for improving planning procedures in maintenance departments by applying even basic techniques. However, it is the attitude to rational planning and control that is important and not the detailed mechanics of the exercise. Management has to become convinced of the value of rational, forward thinking compared with the reactive, firefighting strategies which are still all too common.

In the last decade or so, the biggest single move to the use of quantitative data for maintenance has been the implementation of planned maintenance techniques. By these procedures the maintenance department can develop schedules for regular inspection and repair operations which, in turn, allows the workload of maintenance operatives to be systematically scheduled.

There are also quantitative techniques and procedures of a more sophisticated nature available, such as the use of critical path analysis for the planning of large, shutdown projects, or simple computer simulation techniques to establish the ideal size of a maintenance squad or the optimal period between inspections of a specific, important piece of production plant. However, it is obvious that there is no point in a company contemplating the use of such techniques until records of downtime and other maintenance experiences and costs are maintained. The first

requirement for rational decision making is systematic data collection. Records of maintenance work in terms of cost are the raw materials for the decision maker. It is probably true that remarkably few maintenance managers can state how well their department is performing in relative, quantitative terms. Yet, this is a vital consideration for any manager. A range of indices of effectiveness are available, all of which depend on appropriate records and a valid costing system.

7.8 CONCLUDING SUMMARY

The purpose of this thesis was to design a Maintenance Management System for small to medium sized companies, in the belief that it would prove useful to managers in setting up this Maintenance Management System, whether they intend to use a commercial computer package or not.

At the time of writing this thesis, the number of commercial computer packages for maintenance management were limited, and many packages were unsuitable for smaller companies. More packages are now available on the market, but often they are highly sophisticated, difficult for maintenance personnel to understand, and in many cases include functions which will seldom be used. The author has designed a simple program which is not only easy to use, but which can be modified and developed to suit individual requirements.

The flexible packaging industry was used for this investigation. However, the actual Maintenance Management System designed is not necessarily tied to this industry and can be successfully applied to any type of operation.

CHAPTER 8

FUTURE STUDY

Today, plants can no longer tolerate unscheduled interruptions of production, particularly in those plants where automation and mechanisation is widely utilized. To keep downtime to an absolute minimum, more and more plants will have to start introducing formalised Maintenance Management Systems, and this trend has accelerated over the past few years.

Top management is beginning to realise that in view of the ever increasing production demands and tolerance requirements and more sophisticated equipment, former maintenance practices cannot stem the upward surge in maintenance costs. However, many managers have come to recognise the fact that, instead of simply seeking to improve maintenance effectiveness, a wider scope was required. The result is terotechnology[2].

Terotechnology is another word for resource or life cycle management. It describes a systems, or integrated approach to managing physical assets. It is of great significance to maintenance management, but extends across a wide range of engineering, financial and management departments. A full definition of the meaning of terotechnology is:

> a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life-cycle costs; it is concerned with the specification, and design for reliability and maintainability of plant, equipment, machinery, buildings and structures with their installation, commissioning, maintenance, modification and replacement and with feedback on information on design and performance costs.

The typical terotechnology process is shown diagrammatically in Figure 8.1.

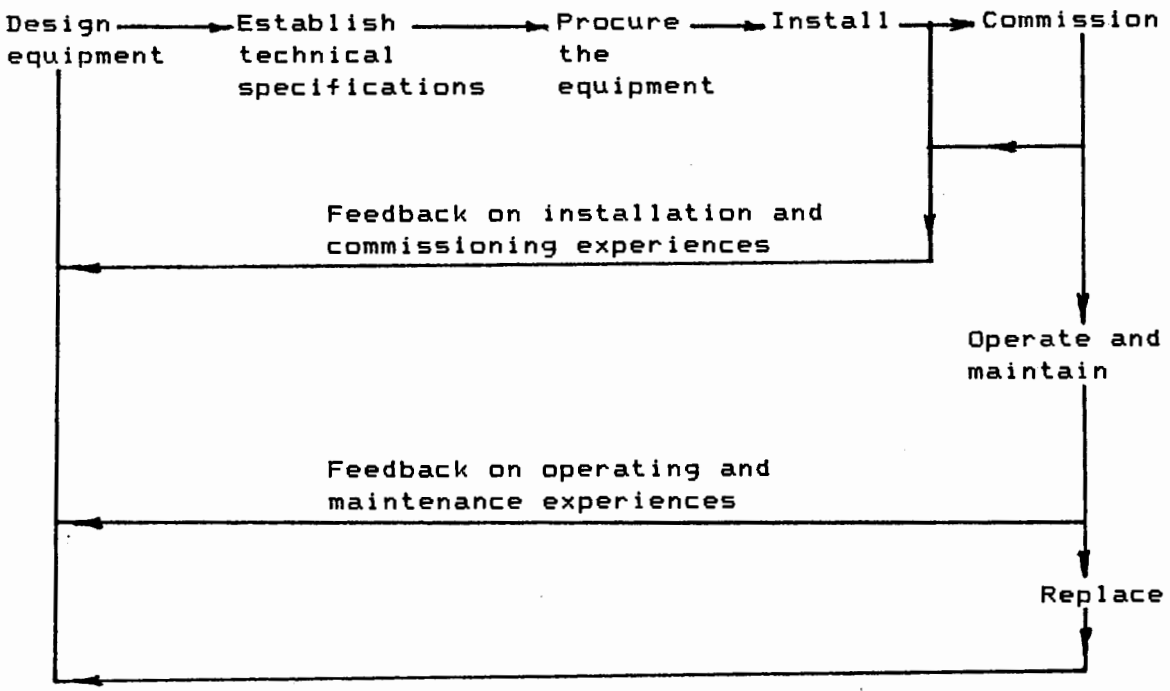


Figure 8.1: The Terotechnology Process

There is a great need for an interdisciplinary, multi-functional approach to resource management. It is essential that the cost of owning plant and equipment be minimised over its working life. To achieve this aim it is necessary to lower the traditional boundaries between the design, maintenance, finance, production and other functions. Terotechnology embraces both the aim of life cycle cost optimisation and the multi-functional approach to achieving it. It should be emphasised that maintenance is only one component of terotechnology. In fact, if terotechnology is properly applied, the need for maintenance could be eliminated or minimised. It sets out from the equipment design stage to do just that. All of the activities involved - specification, design, purchasing, commissioning, operating, maintenance, replacement - are already being carried out in industry.

Terotechnology is simply a formal approach, of an integrated nature, to resource management. No new component skills are involved. The emphasis is entirely on coordinating the existing skills of a firm's engineers, accountants and specialist managers. It is a highly significant concept for the maintenance manager. It offers the opportunity of integrating his function

into a system of general management. However, it offers much more than simply an enhanced status for maintenance. It is a philosophy of resource management every bit as fundamental as the philosophy of production management.

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APPENDIX 1

DATA AND CALCULATIONS

APPENDIX 1

1.0 USE OF THE DATA

1.0.1 Maintenance Hours - Appendix 1.1

The data in Appendix 1.1 lists the Unproductive Direct Labour (UDL) hours for all the production machines in the factory, which could be attributed to maintenance. The figures cover the 49 production weeks for the years 1983 and 1984 and the totals are used in Appendix 1.2.

1.0.2 Pareto Analysis

The total maintenance UDL hours for each machine over this two year period are listed in Appendix 1.2, starting with the machine which had the highest number of UDL hours down to the machine which had the least number. Using the machine hourly rates, each individual downtime cost could be calculated. From this information, the percentage of total number of machines and the percentage cumulative downtime costs were calculated, thus enabling the Pareto graph to be constructed.

1.0.3 Typical Maintenance Indices

Appendix 1.3 lists typical maintenance indices which could be used to measure maintenance performance. Indices (h) and (i) were calculated in Appendix 1.4.

1.0.4 Calculation of Indices

The table of results in Appendix 1.4 covers the two year period 1983 and 1984. Column A lists the UDL hours which could be attributed to maintenance for all machines for the 49 production weeks of each year. Column B lists the total UDL hours which could be attributed to the categories shown in Table 4.1 in Chapter 4. Column C lists the actual production hours and finally, column D lists the available production hours, which is the total of columns B and C. The Production and Maintenance Indices could then be calculated, followed by each respective four week moving average calculation.

APPENDIX 1.1

1983 MAINTENANCE HOURS

WEEK NO.	NINE COL	EIGHT.COL	SIX.COL	FIVE COL	THREE.COL	O.G 1	EXT. 1	EXT. 2	BANGER.	SOLV.LAM	LAMKO	S.1	S.31	S.32
1	4.75	10.75	7.25	2.50	0.00	16.75	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4.00	2.00	1.50	0.00	0.50	1.00	24.50	6.75	7.75	0.00	1.00	0.00	0.50	1.00
6	22.25	1.00	0.25	49.00	0.00	1.00	8.50	0.00	8.00	0.00	0.00	0.00	0.00	1.00
7	1.00	0.00	7.75	43.50	1.00	3.50	1.25	20.50	2.50	0.00	11.00	0.00	1.50	0.00
8	3.00	14.25	1.00	0.75	2.75	4.00	5.75	20.75	5.75	0.00	2.00	0.00	2.00	0.00
9	0.50	1.00	3.00	55.00	0.50	1.00	0.00	1.75	0.00	5.50	2.50	0.00	0.00	0.00
10	7.00	1.00	1.25	8.00	0.00	1.00	0.00	84.00	0.00	0.00	0.00	0.00	0.00	4.50
11	1.00	1.75	6.50	0.00	2.00	0.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	11.00	0.00	0.00	0.00	0.50	0.00	7.00	12.25	0.00	0.00	0.00	0.00	4.50
13	0.00	4.00	1.00	3.00	2.25	0.00	3.50	2.00	18.75	8.00	6.00	0.00	0.00	8.50
14	1.25	6.00	5.75	2.00	7.50	3.00	0.00	20.50	2.25	1.75	0.00	0.00	0.00	0.00
15	4.00	12.75	5.25	0.00	0.00	3.50	3.25	0.00	0.00	0.00	3.25	0.00	4.00	2.00
16	6.50	5.50	5.50	0.00	5.25	14.00	5.75	1.00	0.00	0.50	5.00	0.00	3.50	1.00
17	0.00	1.25	1.75	0.00	10.25	0.00	0.00	3.25	0.00	0.00	0.00	0.00	0.00	0.00
18	7.00	0.50	0.00	8.75	6.50	3.00	0.00	1.75	1.00	0.00	0.50	0.00	0.00	0.00
19	7.75	2.75	4.00	0.00	2.00	0.00	6.75	0.00	6.00	0.00	4.00	0.00	0.00	0.50
20	8.00	1.25	1.50	0.00	6.00	3.25	0.50	2.75	0.00	0.00	0.00	0.00	1.00	0.00
21	3.50	0.75	3.50	0.50	0.50	0.00	5.25	0.00	5.50	4.75	0.00	0.00	0.00	0.00
22	4.50	3.00	4.50	0.00	1.50	5.00	3.75	0.00	8.00	3.75	0.00	0.00	0.00	0.00
23	2.00	2.00	9.25	0.50	0.00	5.25	2.25	1.25	16.50	2.50	2.00	0.00	0.00	0.00
24	5.00	4.25	3.50	1.50	2.75	4.50	0.00	12.00	1.50	12.75	3.75	0.00	1.00	0.50
25	0.75	0.50	4.25	0.00	2.00	0.50	0.00	15.25	3.00	0.00	0.00	0.00	5.00	1.00
26	5.00	0.00	0.00	3.00	0.00	7.00	0.00	2.75	2.00	0.00	0.00	0.00	0.00	1.00
27	2.75	3.00	0.00	3.75	0.00	1.50	0.00	2.75	27.50	0.00	0.00	0.00	0.00	0.00
28	0.50	0.00	1.50	0.00	0.00	6.50	0.00	12.50	11.50	2.50	2.00	0.00	0.00	0.00
29	2.75	0.50	0.00	0.75	0.00	12.00	0.00	30.50	7.50	1.75	0.00	0.00	2.00	0.00
30	11.50	2.00	1.00	1.25	0.00	5.50	0.00	7.00	4.50	5.50	0.00	0.00	0.00	1.50
31	5.00	0.50	3.50	1.00	0.00	1.25	2.00	0.00	20.25	12.75	0.00	0.00	7.00	0.00
32	3.25	1.00	0.50	6.25	1.75	0.00	0.00	2.50	6.50	0.00	0.00	0.00	8.00	0.00
33	2.00	1.00	7.00	0.00	0.00	0.75	0.00	11.50	1.50	0.00	0.00	0.00	40.00	0.00
34	13.50	8.50	0.00	3.00	3.50	8.25	0.00	2.75	3.50	0.00	0.00	0.00	40.00	0.00
35	4.75	10.00	6.50	1.50	1.00	13.50	0.00	12.75	2.00	40.00	0.00	0.00	40.00	16.00
36	2.00	3.25	2.50	0.50	0.00	8.50	0.00	1.00	0.00	40.00	5.50	0.00	40.00	0.00
37	1.75	0.00	1.00	0.75	0.00	6.00	0.00	7.25	1.75	24.75	0.00	0.00	40.00	0.50
38	4.00	0.50	8.50	0.00	5.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	0.50
39	0.50	1.50	0.00	0.50	0.00	0.00	0.00	2.25	0.00	5.00	0.00	0.00	0.00	0.00
40	0.00	1.00	3.75	2.00	0.00	0.50	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00
41	8.50	0.00	0.50	0.75	0.00	0.00	7.50	4.50	10.50	2.50	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	5.25	0.00	10.25	0.50	1.25	0.50	16.50	4.75	10.25	5.25	0.00	0.00	0.00	0.00
44	6.00	1.00	0.00	2.50	0.00	8.50	15.00	5.00	8.25	1.00	1.50	0.00	0.00	0.00
45	2.00	2.00	0.00	0.50	0.00	1.75	3.50	3.50	56.00	4.75	0.00	7.00	0.00	0.50
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	9.25	1.00	2.25	2.50	0.00	2.50	5.25	6.75	7.25	4.25	0.00	0.00	0.00	5.50
48	1.50	1.50	0.00	0.00	0.25	2.50	5.00	18.50	1.50	0.00	0.00	0.00	0.00	1.50
49	0.00	0.00	0.00	0.00	0.00	1.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS	185.50	125.50	127.00	206.00	66.00	158.75	125.75	357.75	281.00	193.50	50.00	7.00	235.50	51.50

1983 MAINTENENCE HOURS (CONTD.)

WEEK NO.	S.33	S.35	S.36	S.41	S.43	S.45	S.48	S.51	S.52	S.53	S.54	S.55	S.63	BF.1
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	2.50	0.00	2.00	5.00	1.50	8.50	22.00	0.00	0.00	0.00	3.00	0.00
6	1.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	4.50	2.50	3.00	0.00	0.00	2.50
7	0.00	0.00	0.50	0.00	0.00	1.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	25.00
8	0.00	0.00	0.00	1.00	0.00	0.00	2.50	1.00	2.00	0.00	0.50	0.00	0.00	0.50
9	0.00	0.00	0.00	3.00	1.00	2.50	0.00	0.00	0.00	2.00	0.00	0.00	11.50	2.75
10	0.00	0.00	1.00	0.00	0.00	5.00	5.00	2.50	0.00	5.50	1.00	0.00	0.00	0.00
11	0.00	1.00	1.00	0.00	1.00	3.00	0.00	5.50	0.50	4.00	2.00	0.00	0.00	0.00
12	2.00	0.00	1.50	0.00	1.50	1.50	0.00	1.50	9.00	0.00	4.00	0.00	0.00	0.00
13	0.00	0.00	2.75	0.00	0.00	6.50	0.50	0.00	13.50	1.00	0.00	0.00	4.00	0.00
14	5.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.00	3.00	2.00	0.00	0.00	1.00
15	0.00	0.00	0.50	0.00	1.00	0.00	6.00	0.00	24.00	0.00	0.00	0.00	0.00	0.00
16	26.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.50	1.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.50	0.00
18	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.50	0.00	3.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	5.00	0.00	0.00	1.00	10.00	0.00	0.00	0.00	0.00	0.00
20	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	1.00	0.00	0.50	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50	0.00	4.50	0.00	0.00	0.50	7.00
23	0.00	0.50	2.00	0.00	0.00	1.00	0.00	2.00	0.00	1.50	0.00	0.00	0.00	0.00
24	0.00	1.00	1.00	1.00	0.00	5.00	0.00	0.00	11.00	0.00	0.50	0.00	2.50	0.00
25	0.00	0.00	0.00	0.00	12.00	1.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	1.00	7.00	4.00	1.00	0.00	5.00	0.00	1.50	0.00	0.00	0.00
27	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	5.50	0.00	0.00	0.00	0.00	0.00
28	47.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	5.50	0.00	0.00	0.00	0.50	0.50	0.00	3.50	1.00	8.00	0.00	40.00	2.00	2.00
30	3.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00	3.00	1.50	10.50	0.00	4.00	8.75
31	3.50	0.00	4.50	0.00	0.00	1.00	0.00	31.00	11.00	1.25	4.00	0.00	0.00	1.00
32	3.00	0.00	1.00	0.00	0.00	0.00	0.00	57.00	8.00	3.00	14.50	0.00	0.00	0.00
33	11.00	1.50	0.00	1.50	2.00	2.00	0.00	18.00	1.00	6.00	0.00	0.00	0.00	0.00
34	0.00	0.00	1.50	0.00	1.50	1.00	0.00	1.00	0.00	4.00	0.00	0.00	0.00	2.00
35	3.00	1.00	1.00	0.00	0.00	0.00	0.00	5.50	3.50	0.00	0.00	2.00	0.00	6.00
36	0.00	1.00	1.00	0.00	1.00	0.00	0.00	5.00	1.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	1.00	0.50	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00
38	0.00	2.00	0.00	1.00	1.50	0.50	0.00	1.00	7.50	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	3.50	0.00	0.00	0.00	0.00	1.00
40	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	22.50	0.00	1.00	0.00	0.00	0.00
41	0.00	0.50	3.50	0.00	0.00	1.00	0.00	4.00	14.50	5.50	2.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.50	0.50	1.50	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00
44	0.00	5.00	6.50	0.00	0.00	3.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.75
45	0.00	0.00	4.50	0.50	0.00	15.00	0.00	0.00	4.00	2.00	0.00	0.00	0.50	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	7.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	22.50	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.50	0.00	0.50	1.50	0.00	6.00	0.00	2.00	0.00	0.00	0.00	0.00
49	0.00	0.00	1.25	0.00	0.00	1.00	0.00	0.00	0.00	1.50	2.00	0.00	1.50	0.00
TOTALS	117.50	21.50	43.50	11.00	41.00	65.50	16.50	164.00	224.50	64.75	50.00	42.00	30.00	61.75

1983 MAINTENANCE HOURS (CONTD.)

WEEK NO.	BF.2	BF.5	MAT.1	CP. 2	I/LEE 1	I/LEE 2	DOYPACK	ROTO 2	ROTO 5	SCHJELD	STIEGLER	GN. 46	SOS.5	SOS.6
1	4.00	2.00	0.00	0.00	2.00	1.50	0.00	4.00	8.50	0.00	0.00	3.50	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	1.50	1.00	0.00	0.00	0.00	0.00	14.25	1.00	6.00	1.00	0.00	0.00	0.00
6	0.00	7.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	3.50	9.50	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	20.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.00	0.00	2.00	0.00	0.00	0.00	0.00
9	0.00	0.00	3.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
10	0.00	0.00	2.00	1.00	0.00	0.00	1.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00
11	0.00	4.50	2.00	2.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	26.00	0.00	0.00	5.00	0.00	0.50	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	5.50	13.50	0.00	2.50	0.00	0.00
14	0.00	0.00	0.00	2.50	2.50	0.00	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	4.50	6.50	0.00	4.00	0.00	0.00	17.00	0.00	0.00	0.00	0.00
16	2.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00
18	1.00	0.00	5.00	3.00	0.00	0.00	0.00	0.00	0.00	1.00	8.00	0.00	0.00	0.00
19	0.00	0.00	17.50	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00
21	0.00	0.00	0.00	3.00	0.00	0.00	3.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	1.00	0.00	1.50	0.00	4.00	2.00	0.00	0.00	0.00	0.00	2.75	0.00	0.00
23	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
24	0.00	0.00	4.25	5.50	0.00	0.00	0.00	11.50	0.50	0.00	0.00	0.00	0.00	1.00
25	3.50	0.00	7.50	6.50	3.00	0.00	0.00	1.50	0.00	4.50	0.00	3.75	1.00	0.00
26	0.00	0.00	0.00	12.50	0.00	0.00	0.00	18.75	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	11.00	0.00	0.00	6.00	3.50	1.00	10.00	0.00	10.00	0.00	0.00
28	0.50	0.00	0.00	0.00	6.00	0.00	0.00	8.00	0.50	0.00	0.00	2.25	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	25.50	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.50	1.00	0.00	0.00	0.00	4.00	8.00
31	1.00	0.00	3.00	2.50	0.00	0.00	0.00	24.50	1.00	5.00	5.50	0.00	0.00	3.50
32	0.00	0.00	0.00	5.00	0.00	0.00	5.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	7.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	1.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	11.50	2.00	0.00	0.00	0.00	0.50	61.75	0.00	0.00	1.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	111.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	3.00	0.00	0.00	0.00	0.00
40	0.00	1.75	0.00	0.00	3.00	1.00	2.50	0.00	8.00	2.00	0.00	1.50	0.00	0.50
41	0.00	0.00	5.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	1.50	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.50	3.00	0.00	0.00	3.00	0.00
44	0.00	0.00	0.00	3.00	50.00	1.00	0.00	0.00	1.50	40.00	1.50	1.00	0.00	1.50
45	0.00	0.00	0.00	8.50	0.00	6.00	1.00	0.00	0.00	17.00	0.00	9.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	3.00	0.00	0.00	16.00	1.00	3.00	26.50	0.00	3.00	0.00	0.00
48	0.00	0.00	0.00	5.00	0.00	0.00	5.00	0.00	0.00	5.50	0.00	8.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.75	0.00	0.00
TOTALS	13.50	17.75	73.75	84.00	78.00	23.00	101.50	103.75	239.50	184.50	33.00	60.00	15.00	20.50

1983 MAINTENANCE HOURS (CONTD.)

WEEK NO.	BF.2	BF.5	MAT.1	CP. 2	I/LEE 1	I/LEE 2	DOYPACK	ROTO 2	ROTO 5	SCHJELD	STIEGLER	GN. 46	SOS.5	SOS.6
1	4.00	2.00	0.00	0.00	2.00	1.50	0.00	4.00	8.50	0.00	0.00	3.50	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	1.50	1.00	0.00	0.00	0.00	0.00	14.25	1.00	6.00	1.00	0.00	0.00	0.00
6	0.00	7.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	3.50	9.50	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	20.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	1.50	1.00	0.00	2.00	0.00	0.00	0.00	0.00
9	0.00	0.00	3.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00
10	0.00	0.00	2.00	1.00	0.00	0.00	1.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00
11	0.00	4.50	2.00	2.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	26.00	0.00	0.00	5.00	0.00	0.50	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	5.50	13.50	0.00	2.50	0.00	0.00
14	0.00	0.00	0.00	2.50	2.50	0.00	6.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	4.50	6.50	0.00	4.00	0.00	0.00	17.00	0.00	0.00	0.00	0.00
16	2.00	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00
18	1.00	0.00	5.00	3.00	0.00	0.00	0.00	0.00	0.00	1.00	8.00	0.00	0.00	0.00
19	0.00	0.00	17.50	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00
21	0.00	0.00	0.00	3.00	0.00	0.00	3.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	1.00	0.00	1.50	0.00	4.00	2.00	0.00	0.00	0.00	0.00	2.75	0.00	0.00
23	0.00	0.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
24	0.00	0.00	4.25	5.50	0.00	0.00	0.00	11.50	0.50	0.00	0.00	0.00	0.00	1.00
25	3.50	0.00	7.50	6.50	3.00	0.00	0.00	1.50	0.00	4.50	0.00	3.75	1.00	0.00
26	0.00	0.00	0.00	12.50	0.00	0.00	0.00	18.75	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	11.00	0.00	0.00	6.00	3.50	1.00	10.00	0.00	10.00	0.00	0.00
28	0.50	0.00	0.00	0.00	6.00	0.00	0.00	8.00	0.50	0.00	0.00	2.25	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	25.50	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.50	1.00	0.00	0.00	0.00	4.00	8.00
31	1.00	0.00	3.00	2.50	0.00	0.00	0.00	24.50	1.00	5.00	5.50	0.00	0.00	3.50
32	0.00	0.00	0.00	5.00	0.00	0.00	5.00	0.00	6.75	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	1.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	7.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	1.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37	0.00	0.00	11.50	2.00	0.00	0.00	0.00	0.50	61.75	0.00	0.00	1.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	111.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	3.00	0.00	0.00	0.00	0.00
40	0.00	1.75	0.00	0.00	3.00	1.00	2.50	0.00	8.00	2.00	0.00	1.50	0.00	0.50
41	0.00	0.00	5.50	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	1.50	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	8.00	0.00	0.00	0.50	3.00	0.00	0.00	3.00	0.00
44	0.00	0.00	0.00	3.00	50.00	1.00	0.00	0.00	1.50	40.00	1.50	1.00	0.00	1.50
45	0.00	0.00	0.00	8.50	0.00	6.00	1.00	0.00	0.00	17.00	0.00	9.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	3.00	0.00	0.00	16.00	1.00	3.00	26.50	0.00	3.00	0.00	0.00
48	0.00	0.00	0.00	5.00	0.00	0.00	5.00	0.00	0.00	5.50	0.00	8.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.75	0.00	0.00
TOTALS	13.50	17.75	73.75	84.00	78.00	23.00	101.50	103.75	239.50	184.50	33.00	60.00	15.00	20.50

1984 MAINTENANCE HOURS

WEEK NO.	NINE COL	EIGHT COL	SIX COL	FIVE COL	THREE COL	O.G.1	EXT.1	EXT.2	BANGER.	SOLV.LAM	LAMKO	S.1	S.31	S.32
1	3.50	1.00	0.00	4.25	0.00	16.25	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.50	0.00	1.00	3.00	0.00	0.50	5.75	2.00	0.00	10.25	0.00	0.00	0.00	0.00
3	4.25	1.75	0.25	2.50	0.00	4.00	0.75	2.50	1.00	6.00	0.00	0.00	0.00	0.00
4	2.25	4.75	4.75	0.00	0.00	5.00	8.25	0.50	11.25	5.00	0.00	0.00	0.00	0.00
5	2.25	3.25	0.00	4.25	0.00	6.50	18.00	29.75	3.50	0.00	1.25	1.75	0.00	0.00
6	1.50	0.00	0.00	3.25	0.00	0.75	14.50	2.75	0.75	0.00	2.50	2.00	0.00	0.00
7	1.25	2.50	0.00	0.25	0.00	6.00	15.00	2.00	0.00	0.00	4.50	3.00	0.00	0.00
8	0.25	1.50	2.25	2.00	1.50	7.50	3.00	6.50	11.50	0.00	0.00	0.00	0.00	0.00
9	11.25	4.00	0.00	3.75	1.00	0.00	10.00	3.75	3.50	0.00	2.00	4.50	0.00	0.00
10	0.50	0.00	0.00	2.75	0.00	7.25	0.00	9.25	1.25	0.00	0.50	0.00	0.00	0.00
11	1.00	2.50	1.00	5.00	0.00	2.00	13.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	1.00	5.00	0.50	0.00	0.00	0.00	0.00	0.00	6.00	0.00	1.50	0.00	0.00	0.00
13	1.50	2.00	0.00	1.50	1.00	0.50	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	1.00	0.00	0.00	0.00	0.00	1.00	0.75	9.25	0.00	0.00	0.00	0.00	0.00	0.00
15	1.50	1.25	0.00	0.00	2.00	1.75	0.00	0.00	15.50	8.00	0.00	0.00	0.00	0.00
16	1.50	0.00	0.50	2.50	0.00	2.75	3.00	30.75	0.00	0.00	1.00	0.00	0.00	0.00
17	2.50	2.00	0.50	4.25	0.00	15.50	48.25	5.00	0.00	7.50	2.50	0.00	0.00	0.00
18	20.25	0.00	2.75	0.00	2.00	4.25	1.25	7.00	4.50	11.00	0.00	0.00	0.00	0.00
19	7.00	1.25	0.75	0.00	4.50	2.75	0.00	6.25	0.00	2.25	0.00	0.00	0.00	0.00
20	0.00	0.00	0.75	1.00	0.00	9.50	0.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00
21	11.75	3.25	4.50	1.50	0.00	19.25	0.00	6.00	0.00	0.00	1.50	0.00	0.00	0.00
22	1.50	0.50	1.25	2.25	0.00	1.00	27.50	12.00	0.00	0.50	0.00	0.00	0.00	0.00
23	5.25	1.50	5.00	0.00	0.75	0.00	2.00	4.75	0.00	6.75	12.00	0.00	0.00	0.00
24	3.50	0.00	3.50	8.75	6.00	2.50	4.00	3.00	8.50	0.75	0.00	0.00	0.00	0.00
25	0.00	1.50	0.50	7.75	1.00	13.25	0.00	33.25	1.50	3.75	0.00	0.00	0.00	0.00
26	0.00	1.75	2.00	6.25	0.00	3.00	19.00	13.25	11.00	5.75	0.00	2.00	0.00	0.00
27	0.75	2.75	0.00	0.00	0.00	0.25	1.75	2.00	1.50	5.00	0.00	0.00	0.00	0.00
28	3.00	3.00	2.00	4.50	0.00	0.00	1.75	6.75	8.25	3.00	0.75	0.00	0.00	0.00
29	1.00	0.50	3.25	2.75	5.50	1.75	0.00	0.00	27.25	32.00	0.00	0.00	0.00	0.00
30	4.00	4.00	0.00	1.25	0.00	0.00	0.00	0.00	4.50	5.75	0.00	0.00	0.00	0.00
31	4.00	3.00	1.50	0.00	1.00	3.00	6.00	8.00	3.75	38.50	1.00	0.00	0.00	0.00
32	1.00	4.75	11.50	1.25	0.00	4.00	0.00	4.75	2.00	4.50	0.00	0.00	0.00	0.00
33	6.75	1.50	1.50	0.00	0.00	0.25	1.50	8.00	0.00	17.50	0.00	0.00	0.00	0.00
34	4.25	2.00	1.00	0.00	1.00	1.25	6.25	0.00	0.00	1.75	0.00	0.00	0.00	0.00
35	2.00	2.50	2.00	1.75	0.00	0.75	0.00	22.75	0.00	3.50	0.00	0.00	0.00	0.00
36	0.00	10.50	2.00	1.00	0.00	1.50	0.00	3.50	0.00	2.25	0.00	0.00	0.00	0.00
37	4.50	1.00	1.00	5.25	3.00	1.50	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00
38	2.75	1.25	1.00	2.50	1.50	2.50	0.00	8.25	0.00	0.00	0.00	0.00	0.00	0.00
39	1.00	0.50	1.25	2.25	2.25	0.00	0.00	1.00	0.00	6.50	0.00	0.00	0.00	0.00
40	1.00	10.00	2.50	1.00	0.00	0.00	2.25	2.50	1.00	9.50	0.00	0.00	0.00	0.00
41	9.25	7.25	1.00	0.00	0.00	0.00	34.00	2.00	2.25	10.25	15.00	0.00	0.00	0.00
42	8.00	5.25	2.75	1.00	0.00	2.25	44.50	9.25	11.00	2.25	0.00	0.00	0.00	0.00
43	2.00	6.75	5.25	0.00	1.00	2.75	5.00	7.75	9.25	2.25	1.50	0.00	0.00	0.00
44	0.00	1.25	0.00	0.00	15.50	4.50	37.50	0.00	0.00	0.00	2.50	0.00	0.00	0.00
45	4.50	0.25	0.00	4.00	0.00	5.00	99.00	8.00	1.75	0.00	0.00	0.00	0.00	0.00
46	13.75	0.00	0.00	0.00	0.00	0.50	0.00	0.00	4.75	2.00	0.50	0.00	0.00	0.00
47	3.00	0.00	0.00	1.25	1.00	2.00	16.75	8.25	2.75	0.00	0.00	1.25	0.00	1.00
48	4.75	2.00	0.00	0.75	0.00	3.25	12.00	7.25	13.50	3.00	0.00	0.00	0.00	0.00
49	0.00	0.00	1.00	0.00	0.00	0.00	1.50	7.50	0.00	0.00	0.00	0.00	0.00	0.00
TOTALS	168.00	111.25	72.25	97.25	51.50	169.75	472.25	328.50	173.25	217.00	50.50	14.50	0.00	1.00

1984 MAINTENANCE HOURS (CONTD.)

WEEK NO.	S.33	S.35	S.36	S.41	S.43	S.45	S.48	S.51	S.52	S.53	S.54	S.55	S.63	BF.1
1	0.00	0.00	11.00	8.00	0.50	0.00	0.00	0.00	0.00	0.00	13.00	0.00	6.00	2.00
2	0.00	1.00	2.00	0.00	0.00	2.00	0.00	2.50	15.50	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	11.00	1.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	1.50	0.00	0.00	6.50	0.00	0.00	0.00	0.00	4.00	6.50
5	4.50	0.00	0.50	6.00	4.00	0.00	0.00	0.00	2.50	0.00	1.00	0.00	0.50	0.00
6	0.00	5.00	2.00	0.00	0.00	0.00	0.00	4.00	3.00	0.00	0.00	0.00	0.00	2.50
7	0.00	0.00	1.25	0.00	0.00	6.50	46.50	4.00	0.00	0.00	1.00	0.00	1.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	2.00	0.00	0.00	0.00
9	0.00	2.00	0.00	0.00	7.00	0.00	0.00	11.00	3.00	3.00	1.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.50	0.00	0.00	0.00	8.00	2.50	7.50	0.00	0.00	0.00	0.00
11	0.00	0.00	3.00	0.00	0.00	0.00	0.00	2.50	0.00	0.50	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.50	34.50	1.00	0.00	0.00	0.00	2.00
13	0.00	2.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	1.50	0.00	0.00	1.00	0.00
14	39.50	0.00	1.00	1.50	0.00	2.50	0.00	23.50	2.00	2.00	0.00	0.00	0.00	3.00
15	0.00	2.50	2.00	1.00	0.00	0.50	0.00	6.00	3.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	1.00	0.00	0.00	0.00	0.00
17	0.00	4.00	0.00	0.00	0.00	0.00	0.00	1.50	2.00	0.00	6.50	0.00	3.00	4.75
18	0.00	3.00	0.50	0.00	3.50	0.00	0.00	3.00	0.00	2.50	0.00	0.00	1.50	0.00
19	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	1.75	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	2.50	0.00	0.00	0.00	2.00	0.00
21	1.00	1.50	0.00	0.00	0.00	1.75	0.00	4.00	18.00	5.00	1.00	0.00	0.00	0.00
22	2.00	4.00	12.50	0.00	0.00	5.50	0.00	2.50	5.50	5.00	2.50	0.00	0.00	0.00
23	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	6.50	0.00
24	3.00	1.00	1.50	1.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00
25	0.00	0.00	2.00	0.00	0.00	1.00	0.00	16.50	3.00	2.00	3.50	0.00	0.00	0.00
26	0.00	3.00	2.00	0.00	0.00	5.00	1.00	8.00	4.50	0.00	2.50	0.00	0.00	0.00
27	0.00	0.00	0.50	0.00	0.00	4.50	0.00	6.00	3.50	0.00	1.00	0.00	0.00	0.00
28	0.00	0.00	0.50	0.00	0.00	0.50	0.00	3.50	0.00	3.00	0.00	0.00	0.00	0.00
29	0.00	3.00	0.50	5.50	0.00	0.00	0.00	3.00	8.50	1.00	6.00	0.00	0.00	7.50
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.50	3.50	1.00	0.00	0.50	0.00
31	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	2.50	0.00	0.00	0.00	5.50
32	0.00	0.00	1.00	0.00	12.00	0.00	0.00	0.00	1.00	0.00	1.00	0.00	0.00	1.50
33	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00
34	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	1.00	0.00	0.00	0.00	4.50
35	0.00	0.50	39.50	2.50	0.00	0.00	0.00	0.00	1.00	0.00	3.50	0.00	0.00	0.00
36	0.00	6.50	12.00	1.50	0.00	0.00	5.00	4.50	1.50	3.50	0.00	0.00	0.00	0.00
37	0.00	0.00	5.00	2.00	0.00	0.50	0.00	7.50	0.50	2.50	5.00	0.00	0.00	0.00
38	0.00	4.00	0.00	0.00	0.00	0.00	0.00	1.00	1.50	0.00	0.00	0.00	0.00	0.00
39	0.00	11.00	0.00	0.00	1.00	1.50	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
40	4.00	3.00	0.00	0.00	0.00	0.50	0.00	0.00	7.00	1.00	0.00	0.00	2.00	0.00
41	0.00	1.00	0.00	0.00	0.00	0.50	0.00	6.00	0.00	6.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
43	0.00	2.50	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.50	0.00
44	1.50	0.00	0.00	0.00	0.00	0.50	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	1.00	1.00	0.00	1.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	0.00
46	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	2.00	0.00	0.00	8.00	0.00
47	3.00	0.00	2.50	0.00	0.00	0.50	0.00	0.00	0.00	1.00	0.00	0.00	0.00	4.25
48	0.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	2.00
49	0.00	0.00	15.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	15.50
TOTALS	62.50	70.50	138.75	32.50	29.50	34.75	52.50	151.50	169.00	64.50	51.50	0.00	38.25	61.50

1984 MAINTENANCE HOURS (CONTD.)

WEEK NO.	BF.2	BF.5	MAT.1	CP.2	I/LEE 1	I/LEE 2	DOYPACK	ROTO 2	ROTO 5	SCHJELD	STIEGLER	GN. 46	SOS.5	SOS.6
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.50	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00	0.00	5.50	3.50	0.00	0.00
3	0.00	0.00	0.00	0.00	16.00	16.00	0.00	0.00	0.00	10.00	4.50	10.00	0.00	0.00
4	0.00	6.50	0.00	0.00	27.00	3.50	0.00	0.00	0.00	0.00	0.00	7.00	5.00	0.00
5	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	6.75	0.00	0.00	4.50	0.00	0.00
6	4.00	0.00	0.50	4.00	0.00	0.00	7.50	2.75	1.00	0.00	0.00	13.00	0.00	0.00
7	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	0.00	0.00	25.25	0.00	0.00
8	29.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	4.25	5.50	0.00	25.00	0.00	0.00
9	14.00	5.00	1.50	15.00	0.00	0.00	0.00	0.00	1.50	9.50	0.00	10.25	0.00	0.00
10	0.00	4.00	2.75	0.00	0.00	2.50	0.00	5.00	2.75	0.00	0.00	3.00	0.00	0.00
11	0.00	0.00	0.00	0.00	3.00	3.00	0.00	0.00	2.00	0.00	0.00	2.25	0.00	0.00
12	0.00	0.00	6.50	0.00	0.00	0.00	0.00	5.00	1.75	0.00	0.00	4.25	0.00	0.00
13	0.00	0.00	3.00	0.00	1.00	0.00	0.00	9.00	1.00	0.00	6.00	2.25	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	10.00	2.00	20.00	0.75	0.00	0.00
15	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	2.50	15.50	12.00	1.00	0.00	0.00
16	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	8.50	0.00	0.00
17	0.00	0.00	6.25	2.25	1.00	16.00	0.00	0.00	0.00	2.00	0.00	8.50	0.00	0.00
18	0.00	0.00	0.00	0.00	0.50	0.00	0.00	2.50	0.00	5.50	0.00	1.50	0.00	0.00
19	1.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00
21	0.00	0.00	0.00	0.00	1.50	0.00	0.00	3.50	0.00	0.00	0.00	2.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	10.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.25	5.50	0.00	0.00	0.00	0.00	2.00
25	0.00	6.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	1.00	0.00	1.00	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.50	0.00	0.00	23.00	6.00	0.00
28	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.50	0.50	0.00	0.00	3.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.00	0.00	3.00
30	0.00	0.00	0.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00
31	0.00	0.00	0.00	32.00	0.00	0.00	0.00	0.00	3.50	5.50	1.00	7.50	0.00	0.00
32	0.00	0.00	0.00	1.25	0.00	2.00	0.00	0.00	1.00	0.00	0.00	4.00	0.00	0.00
33	0.00	1.50	0.50	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	2.50	5.50	0.00
34	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	0.00	0.00
35	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	3.00	0.50	0.00	5.50	1.00	1.00
36	1.00	0.00	1.75	0.00	0.00	0.00	0.00	0.00	0.00	18.00	0.00	4.00	0.00	0.00
37	0.00	0.00	1.00	0.00	0.50	0.00	0.00	0.00	0.00	2.25	0.00	0.00	0.00	4.00
38	5.50	5.25	0.00	0.00	0.00	0.00	0.00	0.00	5.25	0.00	0.00	3.50	0.00	0.00
39	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
40	0.00	1.50	1.50	0.00	0.00	0.00	0.00	34.00	1.00	0.00	0.00	7.50	0.00	14.50
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	10.50	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.00	5.00	0.00	16.00	9.00	3.50	1.00
43	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	1.50	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	13.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	4.50	1.50	0.00	5.50	0.00	0.00	0.00	0.00	0.00	13.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	7.00	0.00	4.50	0.00	0.00	0.00	0.50	0.00	0.00
47	2.50	2.75	0.00	0.00	0.00	0.00	0.00	0.00	3.00	8.00	0.00	17.50	0.00	0.00
48	20.25	0.00	0.00	2.00	0.00	0.00	0.00	8.00	0.00	0.00	0.00	7.50	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
TOTALS	80.25	34.50	47.75	65.00	57.00	80.50	7.50	115.00	68.50	88.25	75.50	254.00	21.00	30.50

APPENDIX 1.2

PARETO ANALYSIS

M/C NO.	DESCRIP.	MTCE. MANHOURS	%OF TOTAL NO.OF M/C	M/C HOUR RATE	DOWNTIME COSTS ('000)	CUM/TIVE DOWNTIME COSTS	CUM/TIVE DOWNTIME COSTS(%)	
8	EXT 2	686.25	2.38	260.00	178.43	178.43	14.36	
7	EXT 1	598.00	4.76	260.00	155.48	333.91	26.88	
1	NINE COL	353.50	7.14	369.00	130.44	464.35	37.38	
9	BANGERTER	454.25	9.52	261.00	118.56	582.91	46.93	
10	SOLV.LAM	410.50	11.90	262.00	107.55	690.46	55.58	A
2	EIGHT COL	236.75	14.29	369.00	87.36	777.82	62.62	
6	O.G. 1	328.50	16.67	200.00	65.70	843.52	67.91	
4	FIVE COL	303.25	19.05	193.00	58.53	902.04	72.62	
40	GN.46	314.00	21.43	129.00	40.51	942.55	75.88	
3	SIX COL	199.25	23.81	193.00	38.46	981.01	78.97	
37	ROTO 5	308.00	26.19	83.00	25.56	1006.57	81.03	
5	THREE COL	117.50	28.57	193.00	22.68	1029.25	82.86	
38	SCHJELDAH	272.75	30.95	83.00	22.64	1051.89	84.68	
36	ROTO 2	218.75	33.33	83.00	18.16	1070.04	86.14	
23	S.52	393.50	35.71	39.00	15.35	1085.39	87.38	
32	CP. 2	149.00	38.10	83.00	12.37	1097.76	88.37	
22	S.51	315.50	40.48	39.00	12.30	1110.06	89.36	
33	I/LEE 1	135.00	42.86	83.00	11.21	1121.27	90.26	
28	BF. 1	123.25	45.24	83.00	10.23	1131.49	91.09	B
31	MATADOR 1	121.50	47.62	82.00	9.96	1141.46	91.89	
35	DOYPACK	109.00	50.00	83.00	9.05	1150.50	92.62	
13	S.31	235.50	52.38	39.00	9.18	1159.69	93.36	
39	STIEGLER	108.50	54.76	83.00	9.01	1168.69	94.08	
34	I/LEE 2	103.50	57.14	83.00	8.59	1177.29	94.77	
29	BF. 2	93.75	59.52	83.00	7.78	1185.07	95.40	
17	S.36	182.25	61.90	39.00	7.11	1192.17	95.97	
15	S.33	180.00	64.29	39.00	7.02	1199.19	96.54	
24	S.53	129.25	66.67	39.00	5.04	1204.24	96.94	
30	BF. 5	52.25	69.05	83.00	4.34	1208.57	97.29	
42	SOS 6	51.00	71.43	82.00	4.18	1212.75	97.63	
25	S.54	101.50	73.81	39.00	3.96	1216.71	97.95	
20	S.45	100.25	76.19	39.00	3.91	1220.62	98.26	
16	S.35	92.00	78.57	39.00	3.59	1224.21	98.55	
41	SOS 5	36.00	80.95	82.00	2.95	1227.16	98.79	
19	S.43	70.50	83.33	39.00	2.75	1229.91	99.01	C
21	S.48	69.00	85.71	39.00	2.69	1232.60	99.23	
27	S.63	68.25	88.10	39.00	2.66	1235.26	99.44	
14	S.32	52.50	90.48	39.00	2.05	1237.31	99.61	
18	S.41	43.50	92.86	39.00	1.70	1239.01	99.74	
26	S.55	42.00	95.24	39.00	1.64	1240.65	99.88	
12	S.1	21.50	97.62	39.00	0.84	1241.48	99.94	
11	LAMKO	88.50	100.00	8.00	0.71	1242.19	100.00	
******	TOTAL	7981.00			1242.19			

(2)

TYPICAL INDICES

Maintenance Costs

a) $$\% = \frac{\text{Total cost of maintenance}}{\text{Manhours worked by maintenance men}}$$

b) $$\% = \frac{\text{Direct cost of breakdown repairs (men and materials)}}{\text{Total direct cost of all maintenance}}$$

Maintenance Manhours

c) $$\% = \frac{\text{Overtime hours worked by maintenance employees}}{\text{Total hours worked by maintenance employees}}$$

d) $$\% = \frac{\text{Total maintenance hours on preventive maintenance work}}{\text{Total maintenance hours worked by maintenance men}}$$

e) $$\% = \frac{\text{Total maintenance hours on breakdown work}}{\text{Total maintenance hours worked by maintenance men}}$$

f) $$\% = \frac{\text{Time recorded on maintenance job cards}}{\text{Total maintenance clock card times}}$$

g) $$\% = \frac{\text{Total manhours allowed for maintenance work}}{\text{Total actual manhours recorded for the same work}}$$

Maintenance/Production Levels and Costs

$$h)\quad \% = \frac{\text{Production operating time}}{\text{Production operating time + downtime}}$$

$$i)\quad \% = \frac{\text{Total direct manhours of maintenance labour}}{\text{Total production manhours}}$$

$$j)\quad \% = \frac{\text{Number of production operating hours}}{\text{Number of breakdowns}}$$

$$k)\quad \% = \frac{\text{Total cost of maintenance}}{\text{Total cost of production}}$$

$$l)\quad \% = \frac{\text{Cost of breakdowns}}{\text{Total production cost}}$$

Maintenance Cost/Replacement Value

$$m)\quad \% = \frac{\text{Total cost of maintenance}}{\text{Total replacement cost of the plant maintained}}$$

Maintenance Crew Effectiveness

$$n)\quad \% = \frac{\text{Sum of all repair times}}{\text{Number of breakdowns}}$$

Maintenance Breakdown Severity

$$o)\quad \% = \frac{\text{Cost of breakdown repairs}}{\text{Number of breakdowns}}$$

Maintenance Improvement Justification

$$p)\quad \% = \frac{\text{(Total cost of maintenance + downtime losses) for last time period}}{\text{The same values for the current time period}}$$

Level of Maintenance Spares

$$q)\quad \% = \frac{\text{Cost of maintenance materials used}}{\text{Total cost of stock in the maintenance stores}}$$

Level of Maintenance Activity

$$r)\quad \% = \frac{\text{Number of maintenance work orders processed}}{\text{Total number of work orders on hand}}$$

APPENDIX 1.4

RESULTS- 1983

WEEK NO.	A MTCE.UDL HOURS	B TOTAL UDL HOURS	C ACTUAL PROD.HRS	D AVAIL. PROD.HRS	PI	PI 4WEEK MOV.AVGE	MI	MI 4WEEK MOV.AVGE
1	73.00	157.00	879.50	1036.50	92.34		8.30	
2	NA	NA	NA	NA	92.34		8.30	
3	NA	NA	NA	NA	92.34		8.30	
4	NA	NA	NA	NA	92.34	92.34	8.30	8.30
5	119.75	355.25	2803.50	3158.75	95.90	93.23	4.27	7.29
6	129.00	238.00	2573.25	2811.25	95.23	93.95	5.01	6.47
7	142.50	276.50	2550.25	2826.75	94.71	94.54	5.59	5.79
8	74.00	215.75	2618.00	2833.75	97.25	95.77	2.83	4.42
9	98.50	219.75	2564.25	2784.00	96.30	95.87	3.84	4.32
10	132.25	295.50	2573.25	2868.75	95.11	95.84	5.14	4.35
11	51.00	143.75	1992.75	2136.50	97.50	96.54	2.56	3.59
12	87.75	235.75	1766.00	2001.75	95.27	96.05	4.97	4.13
13	108.75	187.00	2548.25	2735.25	95.91	95.95	4.27	4.23
14	76.00	150.50	2544.50	2695.00	97.10	96.44	2.99	3.70
15	101.50	209.50	2745.00	2954.50	96.43	96.18	3.70	3.98
16	96.00	224.75	2705.50	2930.25	96.57	96.50	3.55	3.63
17	24.50	122.25	1368.00	1490.25	98.24	97.09	1.79	3.01
18	51.50	149.50	2678.00	2827.50	98.11	97.34	1.92	2.74
19	69.25	185.75	2570.50	2756.25	97.38	97.58	2.69	2.49
20	36.25	145.25	1490.00	1635.25	97.62	97.84	2.43	2.21
21	34.75	213.00	2654.25	2867.25	98.71	97.96	1.31	2.09
22	62.75	188.25	2784.00	2972.25	97.80	97.88	2.25	2.17
23	58.50	172.50	2783.25	2955.75	97.94	98.02	2.10	2.02
24	97.75	171.75	2736.00	2907.75	96.55	97.75	3.57	2.31
25	80.00	152.00	2855.50	3007.50	97.27	97.39	2.80	2.68
26	71.50	276.75	2798.00	3074.75	97.51	97.32	2.56	2.76
27	89.25	267.50	2983.25	3250.75	97.10	97.11	2.99	2.98
28	103.25	206.75	2645.25	2852.00	96.24	97.03	3.90	3.06
29	147.25	309.75	2689.25	2999.00	94.81	96.41	5.48	3.73
30	88.00	218.25	2764.25	2982.50	96.91	96.27	3.18	3.89
31	156.50	280.25	2727.00	3007.25	94.57	95.63	5.74	4.58
32	133.00	251.00	2574.50	2825.50	95.09	95.35	5.17	4.89
33	109.00	227.00	2760.00	2987.00	96.20	95.69	3.95	4.51
34	100.00	237.75	2480.75	2718.50	96.13	95.50	4.03	4.72
35	180.00	281.50	2467.75	2749.25	93.20	95.15	7.29	5.11
36	114.75	187.25	2370.50	2557.75	95.38	95.23	4.84	5.03
37	166.00	300.00	2491.25	2791.25	93.75	94.62	6.66	5.71
38	152.00	248.25	2651.00	2899.25	94.58	94.23	5.73	6.13
39	22.75	155.50	2516.50	2672.00	99.10	95.70	0.90	4.54
40	56.00	237.00	2529.25	2766.25	97.83	96.32	2.21	3.88
41	73.25	234.25	2725.75	2960.00	97.38	97.22	2.69	2.88
42	NA	NA	NA	NA	97.38	97.93	2.69	2.12
43	73.00	171.75	2895.50	3067.25	97.54	97.53	2.52	2.53
44	165.00	253.75	3327.25	3581.00	95.28	96.89	4.96	3.21
45	149.50	259.50	2765.75	3025.25	94.87	96.27	5.41	3.89
46	NA	NA	NA	NA	94.87	95.64	5.41	4.57
47	131.50	257.75	3715.50	3973.25	96.58	95.40	3.54	4.83
48	66.25	148.25	2895.00	3043.25	97.76	96.02	2.29	4.16
49	19.00	115.00	1142.25	1257.25	98.36	96.89	1.66	3.23

$$PI = \frac{C}{A + C}$$

$$MI = \frac{A}{C}$$

NA= NOT AVAILABLE

RESULTS- 1984

WEEK NO.	A MTCE.UDL HOURS	B TOTAL UDL HOURS	C ACTUAL PROD.HRS	D AVAIL. PROD.HRS	PI	PI 4WEEK MOV.AVGE	MI	MI 4WEEK MOV.AVGE
1	81.00	152.00	1032.25	1184.25	92.72		7.85	
2	62.00	151.00	2270.75	2421.75	97.34		2.73	
3	94.50	210.25	2392.50	2602.75	96.20		3.95	
4	109.25	163.50	2455.50	2619.00	95.74	95.50	4.45	4.74
5	103.75	245.25	2452.00	2697.25	95.94	96.31	4.23	3.84
6	77.25	172.75	2864.50	3037.25	97.37	96.31	2.70	3.83
7	124.75	232.75	2769.50	3002.25	95.69	96.19	4.50	3.97
8	106.75	246.75	2831.50	3078.25	96.37	96.34	3.77	3.80
9	127.50	253.50	3102.50	3356.00	96.05	96.37	4.11	3.77
10	60.00	139.50	2908.25	3047.75	97.98	96.52	2.06	3.61
11	41.25	140.75	2718.75	2859.50	98.51	97.23	1.52	2.87
12	76.50	168.25	1876.25	2044.50	96.08	97.15	4.08	2.94
13	44.25	177.75	2786.25	2964.00	98.44	97.75	1.59	2.31
14	121.75	223.50	2298.25	2521.75	94.97	97.00	5.30	3.12
15	79.50	213.00	1982.50	2195.50	96.14	96.41	4.01	3.74
16	60.50	166.00	2663.50	2829.50	97.78	96.83	2.27	3.29
17	145.75	284.50	2728.50	3013.00	94.93	95.96	5.34	4.23
18	77.00	223.75	2781.75	3005.50	97.31	96.54	2.77	3.60
19	31.00	157.00	2906.50	3063.50	98.94	97.24	1.07	2.86
20	31.25	106.50	1677.25	1783.75	98.17	97.34	1.86	2.76
21	87.00	203.00	2761.00	2964.00	96.95	97.84	3.15	2.21
22	87.50	186.00	2690.50	2876.50	96.85	97.73	3.25	2.33
23	63.50	180.25	2596.50	2776.75	97.61	97.39	2.45	2.68
24	60.25	221.25	2610.25	2831.50	97.74	97.29	2.31	2.79
25	97.50	270.00	2378.50	2648.50	96.06	97.07	4.10	3.03
26	92.50	227.75	2776.25	3004.00	96.78	97.05	3.33	3.05
27	62.00	182.50	2765.75	2948.25	97.81	97.10	2.24	3.00
28	46.50	142.50	2767.75	2910.25	98.35	97.25	1.68	2.84
29	114.50	246.50	2626.75	2873.25	95.82	97.19	4.36	2.90
30	38.50	143.50	2749.75	2893.25	98.62	97.65	1.40	2.42
31	133.25	248.75	2710.25	2959.00	95.31	97.03	4.92	3.09
32	58.50	159.00	3109.50	3268.50	98.15	96.98	1.88	3.14
33	63.00	165.00	2944.75	3109.75	97.91	97.50	2.14	2.58
34	35.50	126.00	3040.00	3166.00	98.85	97.55	1.17	2.53
35	94.25	221.00	3084.50	3305.50	97.03	97.98	3.06	2.06
36	80.00	217.25	3007.00	3224.25	97.41	97.80	2.66	2.26
37	49.50	221.50	3036.00	3257.50	98.40	97.92	1.63	2.13
38	45.75	204.50	2903.50	3108.00	98.45	97.82	1.58	2.23
39	33.25	173.50	2361.00	2534.50	98.61	98.22	1.41	1.82
40	107.25	231.25	3305.50	3536.75	96.86	98.08	3.24	1.96
41	109.00	283.50	3406.00	3689.50	96.90	97.70	3.20	2.36
42	143.75	331.25	3362.50	3693.75	95.90	97.07	4.28	3.03
43	51.50	201.00	3251.50	3452.50	98.44	97.02	1.58	3.08
44	79.75	268.75	3175.00	3443.75	97.55	97.20	2.51	2.89
45	153.50	338.00	3178.00	3516.00	95.39	96.82	4.83	3.30
46	46.50	202.00	3367.25	3569.25	98.64	97.51	1.38	2.58
47	82.25	223.75	3565.25	3789.00	97.75	97.33	2.31	2.76
48	94.75	249.25	3322.75	3572.00	97.23	97.25	2.85	2.84
49	43.00	128.25	1371.75	1500.00	96.96	97.64	3.13	2.42

$$PI = \frac{C}{A + C}$$

$$MI = \frac{A}{C}$$

NA= NOT AVAILABLE

APPENDIX 2

DESCRIPTION AND LISTING OF THE COMPUTER PROGRAMS

APPENDIX 2

2.0 DESCRIPTION, START-UP AND RUNNING THE COMPUTER PROGRAM

DBASE II is a database management tool that allows easy manipulation of medium-sized databases using simple commands. With dBASE II one can:

- Create complete database systems
- Easily add, delete, edit, display and print data from a database, with a minimum of data duplication on file
- Generate reports from one or more databases, with automatic arithmetic calculations, sub-totals, totals and other data manipulation
- Use the full-screen editing capability to set up a screen format

The following hardware and software is required:

- An 8080, 8085 or Z-80 based microprocessor system
- 48k bytes minimum of memory
- CP/M, CDOS or CROMIX operating systems
- One or more mass storage devices (usually floppy disk drives)
- Text printer

For this investigation, a 64k Apple computer, equipped with a Z-80 Softcard and 80 column card, was used.

The dBASE II program is brought up by inserting the program disk in the drive, turning on the computer and then typing "DBASE-II" when prompted. DBASE II loads into memory, displays a sign-on message, then displays the prompt dot (.) to indicate that it is ready to accept commands.

2.0.1 Equipment Inventory - ESETUP and EMAIN commands

In general, the command "DO EMAIN" is typed when the prompt dot appears. This command enters the main inventory program which displays the main menu for the user. However, when starting up the program for the first time, the command "DO ESETUP" must be used. The files will be completely erased and then the program will automatically execute the EMAIN command.

2.0.2 Plant History Files - RSETUP and RMAIN commands

Similarly, the user would normally enter the main program by typing "DO RMAIN" and only use the RSETUP command to erase old files or when starting up the system for the first time.

2.0.3 Exiting from the program

When the user wishes to exit from dBASE II, he must first exit from the Inventory or Plant History Files program by returning to the main menu and then typing in "0". When the prompt dot appears, the user must exit by typing in "QUIT". It is good practise to exit properly, rather than simply turning off the computer because the sequence of commands described above ensures that the database files are correctly indexed before being closed.

APPENDIX 2.1

```
* 06/09/84  ESETUP.CMD
*
*
*
*  Plant and equipment database setup program
*  Calls  EMAIN.cmd
set talk off
? '  Initializing the equipment database'
? '     and memory files.'
?
? 'THIS WILL DESTORY ALL OF THE RECORDS'
? '    IN THE FILE MACHINES.DBF!!!'
ACCEPT 'IS THIS WHAT YOU WANT TO DO (Y/N) ?' TO ANS
IF !(ans) ='Y'
  use machines
  delete all
  pack
  index on equip:name to e'byname
  index on equ:nmbr to e'bynmbr
  store 0 to Mequ:nmbr
  save to machines
  release all
  ?
  ?
  ? 'Loading machines main menu program.'
  do emain
endif
return
```

```
* 06/09/84   Plant and Equipment Main Menu program  EMAIN.CMD
*
*
* this is where we find what is supposed be done by the user. We display
* a menu of selections which the user may make. When a selection is made
* we try to match it to a function. If no match is made then an error
* message is displayed and we ask for the selection again. If we do find
* a match we execute the code for that match, on return we start over
* with the selection menu again.
*
SET talk OFF
SET call TO 42240
LOAD datetest
*    open the database

DO WHILE T
  ERASE
  *     do forever or until T is set to false..
  @ 2,0
  TEXT
 This is the equipment data managment
  program.

     This set of equipment management
  programs allow one to add, edit,
  list and remove plant or equipment from
  a database. To perform one of these
  functions enter one of the menu
  options.

0     End program and return to dBASE II
1     Enter new plant or equipment
2     Make changes to plant or equipment records
3     List the plant or equipment data
4     Remove plant or equipment from the records


   Enter the menu selection here
  ENDTEXT
  WAIT TO Mselect

  *   erase the error message line, just in case one was printed
  @ 20,0
  @ 21,0

  DO CASE

    CASE Mselect = "0"
  * close equipment file, release all variables and return to dBASE II
      USE
      RELEASE ALL
      RETURN

    CASE Mselect = "1"
     *   enter some new equipment
      DO equ-entr
```

```
    CASE Mselect = "2"
     *   make changes to equipment data
      DO equ-upd
    CASE Mselect = "3"
     *   list the equipment data.  But we will have to find out what
     *   to list
      DO equ-rprt

    CASE Mselect = "4"
     *   remove plant or equipment from the records
      DO equ-term

    OTHERWISE
      erase
      @ 19,3 SAY "Invalid entry"
      @ 20,3 SAY 'Please try a selection between'
      @ 21,3 SAY '       zero and four.'
      ? 'PRESS ANY KEY TO CONTINUE.'
      WAIT

  ENDCASE
  @ 22,0
ENDDO
RETURN
*   EOF
```

```
*  06/09/84 Plant and Equipment program  EQU-ENTR.CMD
*
*
*  Equipment entry routine... use the equ-scrn format screen as the
*  entry format.
*
*   the equipment file should also be indexed on the equipment name
*   this will allow the equipment data to be reported in that order
*
*   this program uses a format screen in conjunction with the edit
*   command for entering the equipment data.
*
*  Local memory variables for the function start with >Mea:<
*  Called from EMAIN.CMD
*   Uses MACHINES.DBF     Holds the equipment data
*        E'BYNMBR.NDX     Index on equip:nmbr
*        EQU-SCRN.FMT     format file for screen entry
*        MACHINES.MEM     Holds the last equipment number.
*
SET talk OFF
*  restore the equipment number from a memory file.
RESTORE FROM machines
*
*   Open the data and index files.
USE machines INDEX  e'bynmbr
 -
*  do until no more equipment to add
STORE T TO Meawork
DO WHILE Meawork

  ERASE
  IF Meawork
    STORE Mequ:nmbr +1 TO Mequ:nmbr
    APPEND BLANK
   *    this will save the equipment number and also update the index
    REPLACE equ:nmbr WITH Mequ:nmbr
    *   save the record number to edit
    STORE STR(#,4) TO Mea:newrec
    STORE F TO Mea:ok

    DO WHILE .not. Mea:ok
     *  open the format file and read the equipment data.
      SET format TO equ-scrn
      READ
     *   set the format back to screen for screen updates
      SET format TO screen
      *  test the installation date for validity
      STORE instal:yr TO Mea:date
      STORE T TO Mea:nodate
      DO WHILE Mea:nodate
     * if we get here the installation date was not valid, so try again.
        STORE F TO Mea:nodate
        CALL Mea:date
        IF Mea:date = '        '
          @ 14,05 SAY "Instal:yr      "
          @ 14,19 GET Mea:date PICTURE '9999'
          @ 15,10 SAY '** Invalid Installation Date **'
```

```
          READ
          STORE T TO Mea:nodate
        ENDIF
      ENDDO
      SET colon OFF
      @ 15,0
      @ 22,0 SAY "Is the equipment data correct (Y/N)? " GET Mea:ok
      READ
      SET colon ON
      @ 22,0
      REPLACE instal:yr WITH Mea:date NOUPDATE
    ENDDO
  ENDIF    meawork

 *   Find out if more equipment should be added
  STORE F TO Meawork
  @ 22,0 SAY "Want to add more equipment (Y/N)? " GET Meawork
  READ
 *   now clear the prompt line
  @ 22,0
ENDDO   when not adding any more equipment

*   Close the database and index files
USE
*   release local variables
RELEASE ALL LIKE Mea*
*   save the new equipment number
SAVE TO machines
*   since EMAIN does'nt clear the screen when we return,  we do it here
ERASE
RETURN
*  eof EQU-ENTR.cmd
*  Called from EMAIN.cmd
```

```
* EQU-SCRN.FMT
@  2,10 SAY 'Plant and Equipment Entry Screen'
@  4,05 SAY "Equipment number"
@  4,25 SAY EQU:NMBR
@  5,05 SAY "Equipment Name              " GET EQUIP:NAME
@  6,05 SAY "Year of Manufacture         " GET MANF:YR
@  7,05 SAY "Year Installed              " GET INSTAL:YR
@  8,05 SAY "Installed Power             " GET ELEC:KW
@  9,05 SAY "Steam Required (Y/N)        " GET STEAM:BAR
@ 10,05 SAY "Air Required (Y/N)          " GET AIR:BAR
@ 11,05 SAY "Chilled Water (Y/N)         " GET CH:WATER
@ 12,05 SAY "Floor Space                 " GET FL:SPACE
@ 13,05 SAY "Cost (R 000's)              " GET COST:R
```

```
* 10/09/84  Plant and Equipment Program EQU-UPD.CMD
*
*
*   Update Plant and Equipment Records via full screen edit.
*     Program will display total number of records in database and ask
*  user to enter the equipment name or number the equipment to be edited

*  The equipment record will be edited using full screen edit.
*
*
*   Called from EMAIN.CMD
*   LOCAL VARIABLES BEGIN WITH ^MEU^
*   Uses files MACHINES.DBF
*               E'BYNAME.NDX    Indexed on equip:name
*               E'BYNMBR.NDX    Indexed on equ:nmbr
*               EQU-UPD.FMT     Format file used to format screen for
*                               update
USE MACHINES

SET talk OFF
ERASE
DO WHILE T

  @ 0,0
  TEXT
You may edit any equipment in the database.  To select equipment for
edit, enter the equipment NAME or the equipment NUMBER.

  ENDTEXT
*the next two lines adjust the cursor so the ACCEPT will print on line 5
  @ 7,0
  @ 6,0 SAY ' '
  ACCEPT  'Enter search data ' TO Meu:srch

 *   erase the error message line
  @ 21,0

  IF Meu:srch = ' '
*time to return to the menu, Clear all local variabls, erase the screen
    RELEASE ALL LIKE Meu*
    ERASE
    USE
    *  and return...
    RETURN
  ENDIF

  *   initialize the record found variable
  STORE F TO Meu:recfnd
  *   position the cursor, so that the following messages don't print
  *   at the bottom of the screen
  @ 16,0
  @ 17,0
  @ 18,0
  @ 19,0
  @ 20,0
  @ 15,0

  IF VAL(Meu:srch) > 0
```

```
    *   Meu:srch must be an equipment number.
REMARK OK. It looks like an equipment number
REMARK WAS ENTERED, SO OPEN THE E'BYNMBR
REMARK INDEX and FIND the number.                press any key to continue

set console off
WAIT
set console on
    SET index TO e'bynmbr, e'byname
    *    have to make the search string 3 characters for the find
    *      because the index key is STR(equip:name,3)
    STORE STR(VAL(Meu:srch),3) TO Meu:srch
    *   have to put the macro within quotes because of leading spaces...
    FIND '&Meu:srch'
    IF #=0
      *   no record was found for the equipment number entered
      @ 21,0 SAY 'Equipment number not found. Try another.'
    ELSE
     *   search data was found. Be sure to remember that we found it
      STORE STR(#,4) TO Meu:rnmbr
      STORE T TO Meu:recfnd
    ENDIF
  ELSE
    *   the search data must be an equipment name...
REMARK    Well, it seems that what we have is
REMARK AN EQUIPMENT NAME. OPENING THE E'BYNAME
REMARK index, FINDing the name says...       press any key to continue.
set console off
WAIT
set console on
    SET index TO e'byname, e'bynmbr
    STORE !(Meu:srch) TO Meu:srch
    FIND &Meu:srch
    IF #=0
      *   must not be any item on the file with the name used for the
      *   search
  @ 21,5 SAY 'Equipment name is not on the file.'
     ? 'You may correct the name and try again.'
    ELSE
      *   the equipment name is on the file. so set up for the edit...
      STORE T TO Meu:recfnd
      STORE STR(#,4) TO Meu:rnmbr
    ENDIF
  ENDIF

  *   if the record was found then edit it.
  DO WHILE Meu:recfnd
    *   use EQU-UPD.FMT to format the entry screen
     SET format TO equ-upd
     READ
     SET format TO screen
     SET intensity OFF

    *
     SET colon OFF
     @ 22,0 SAY 'Are all the changes correct (Y/N) ? ' GET Meu:recfnd
     READ
```

```
      SET colon ON
      SET intensity ON
     *     store the negative of the response so that a true response will
     *    will exit the do loop
      STORE .not. Meu:recfnd TO Meu:recfnd
      ERASE
   ENDDO
ENDDO
*    release the local variables
RELEASE ALL LIKE Meu*
ERASE
RETURN
* eof   EQU-UPD.cmd
*    called from EMAIN.cmd
```

```
* 10/09/84 Plant and Equipment Program  EQU-RPRT.CMD
*
*
*  the user should be able to list equipment by name or number
*    to either the console or the printer...
*
*
*   Local variables start with >Mer<
*
CLEAR
SET talk OFF
USE MACHINES

DO WHILE T

  ERASE
  TEXT
The equipment report may be printed by equipment name or by equipment
number

Enter "1" to list by equipment name,      or   "2" to list by equipment
number, or   RETURN  to display main menu.
  ENDTEXT

  STORE "." TO Mer:type
  DO WHILE .not. Mer:type$'12 '
    *   assume we want to display the main menu again...
    STORE ' ' TO Mer:type
    SET colon OFF
    @ 11,5 SAY 'Enter the listing selection ? ' GET Mer:type PICTURE '9'
    SET colon ON
    READ
  ENDDO
  @ 11,38

  IF Mer:type = " "
    *    end the report function and return to main menu
    RELEASE ALL LIKE Mer*

    ERASE
    USE
    RETURN
  ENDIF

  *    go ahead and report on the equipment file...
REMARK  Opening the index file -

  IF Mer:type = '1'
    *   use the name index
    SET index TO e'byname
    ?? "E'BYNAME"
  ELSE
    *   use the nmbr index
    SET index TO e'bynmbr
    ?? "E'BYNMBR"
  ENDIF
```

```
  *   reuse the last variable used.  Set to assume report to console
  STORE F TO Mer:type

?
? "The report may be printed on either the console or the printer."
? "  Enter 'P' to print on the printer."
? "  Enter 'C' to list on the screen."

 *   initialize the variable and accept only 'P' or 'C'
  STORE ' ' TO Mer:type
  SET colon OFF
  DO WHILE .not. Mer:type$'PC'
    @ 21,4 SAY "Enter 'P' or 'C' " GET Mer:type PICTURE '!'
    READ
  ENDDO
  SET colon ON

  STORE ' ' TO Mer:devc
  IF Mer:type='P'

SET EJECT OFF
SET PRINT ON
??CHR(15)+CHR(14)
SET PRINT OFF

  *   if we are in here, then we must want to list to the printer
    SET console OFF

    REPORT FORM equ-prt TO print

    *  set console back on
    SET console ON
  ELSE
   IF Mer:type='C'
    *   OK, so you want to see the report on the console...
     REPORT FORM equ-cons
     ? '       Press return when ready to view the report menu.'

    *    the SET CONSOLE OFF/ON commands will hide the word WAITING from
    *   the screen and leave the cursor at the end of the prompt line
     SET console OFF
     WAIT
     SET console ON
     ?
   endif
  ENDIF    listing routine

ENDDO   doing forever
RETURN
```

```
* EQU-PRT.FRM

M=1
Y
Equipment List
n
n
6,equ:nmbr
EQUIP#
15,EQUIP:NAME
EQUIPMENT
9,MANF:YR
MANF:YR
9,INSTAL:YR
INSTAL:YR
6,ELEC:KW
ELEC;kw
6,STEAM:BAR
STEAM;(Y/N)
6,AIR:BAR
AIR;(Y/N)
6,CH:WATER
WATER;(Y/N)
6,FL:SPACE
FLOOR;SPACE
9,COST:R
COST;(R 000'S)
```

```
* EQU-CONS.FRM

M=1
Y
Equipment List
n
n
6,equ:nmbr
EQUIP#
15,EQUIP:NAME
EQUIPMENT
6,ELEC:KW
ELEC;kw
6,STEAM:BAR
STEAM;(Y/N)
6,AIR:BAR
AIR;(Y/N)
6,CH:WATER
WATER;(Y/N)
6,FL:SPACE
FLOOR;SPACE
9,COST:R
COST;(R 000'S)
```

APPENDIX 2.2

```
*  14/09/84
*  setup the History Records database and index files...RSETUP.CMD
erase
? 'Initializing data files for historey records.'
?
? ' THIS WILL DELETE ALL RECORDS FROM THE       HISTORY FILE....'
ACCEPT 'DO YOU REALLY WANT TO DO THIS (Y/N)?' TO ans
IF !(ans) ='Y'
  use mtce
  delete all
  pack
  index on !(equip:name) TO r'bydesc
  index on !(rec:nmbr) TO r'bynmbr
  do rmain
ENDIF
return
```

```
*  14/09/84
*     Plant Maintenance History Records Program RMAIN.CMD
*
*
*  Main control program. Displays a menu and takes appropriate action
*
SET talk OFF
CLEAR

STORE T TO clr:scrn
DO WHILE T
 *   ok to clear screen?
  IF clr:scrn
    ERASE
  ENDIF
  STORE " " TO inselect
  SET intensity OFF
  @  2, 7 SAY "Enter one of the following menu"
  @  3,0 SAY "selections."
  @  6, 0 SAY "0  Exit back to dBASE II"
  @  7, 0 SAY "1  Add, Change, Delete Records."
  @  8, 0 SAY "2  Search for specific Maintenance Information"
  @  9, 0 SAY "3  Print History Records Report."
  @ 10, 0 SAY "4  Generate Work Order Status Reports."

 *   print selection prompt 4 lines down from bottom of menu
  @ $+4, 5 SAY "Enter selection here ?"
  SET colon OFF
  @ $,28 GET inselect PICTURE '9'
  READ
  SET colon ON
  SET intensity ON

 *   erase the error message line
  @ 20,0
  @ 21,0

 *   reset clr:scrn flag.
  STORE T TO clr:scrn

  DO CASE
    CASE inselect = "0" .or. inselect = " "
       USE
       RELEASE ALL
       RETURN

    CASE inselect = "1"
       DO recmaint

    CASE inselect = "2"
       DO rtrial

    CASE inselect = "3"
       DO recrprt

    CASE inselect = "4"
       DO worprt
```

```
    OTHERWISE

       @ 20,5 SAY "Invalid menu option, please reenter menu selection."

      *  set the clr:scrn flag off...(so we don't ERASE the error msg)
       STORE F TO clr:scrn

    ENDCASE
ENDDO
RETURN
*  eof
```

```
* 14/09/84
*   History Records entry routine.....RECMAINT.CMD
*
*
*
*   program prompts for the records and
*      allows  ADDs, CHANGEs, and DELETEs
*
SET talk OFF
USE mtce INDEX r'bynmbr, r'bydesc
SET index TO r'bynmbr, r'bydesc
ERASE
*   Set up the format for the work screen
SET intensity OFF
@  1, 0 SAY "+-----------------------------------------------------------"
@  1,65 SAY "------------------+"
store 2 to line
do while line < 18
  @ line, 0 SAY "¦"
  @ line,76 SAY "¦"
  store line +1 to line
enddo
@ 3,0 SAY "+-----------------------------------------------------------"
@ 3,65 SAY "-----------------+"
@ 18, 0 SAY "+-----------------------------------------------------------"
@ 18,65 SAY "------------------+"
SET intensity ON

*   initialize delete flag
STORE F TO Midelete

STORE T TO Miwork
DO WHILE Miwork

  SET intensity OFF
  @ 2, 7 SAY 'History Records Maintenance Screen'
  @ 20,0 SAY 'To add a new record, enter a new number.'
  @ 21,0 SAY 'To edit a record, enter that record number.'
  @ 22,0 SAY 'Press return to display the main menu.'
  SET intensity ON

  STORE "       " TO Mirecnmbr
  @  8,10 SAY "Record Number"
  @  8,25 GET Mirecnmbr PICTURE '!!!!!!'
  READ

  @ 19,0
  @ 20,0
  @ 21,0
  @ 22,0
  STORE TRIM(Mirecnmbr) TO Mirecnmbr
  DO CASE         *Main level 0

   *    do this case if there was a record number entered...
    CASE Mirecnmbr > " "
   *   look for the record nmbr
     FIND "&Mirecnmbr"
```

```
SET intensity OFF
DO CASE         *test record type
 CASE #=0
  *  didn't find the record, so find out if a record is to be added
   @ 19, 5 SAY [Record number &Mirecnmbr not on file.]
   STORE F TO Mi:ok
   SET intensity OFF
   @ 21,0 SAY [Would you like to add the record(Y/N)?]
   @ 21,$+1 GET Mi:ok
   READ
   SET intensity ON
   @ 19,0
   @ 21,0
   IF Mi:ok
    *   initialize the temporary memory variables
    STORE '                ' TO Mirecdesc
    STORE '           ' TO Mioitem
   STORE '                                                ' TO Miowkdone
    STORE '       ' TO Miowonmbr
    STORE '         ' TO Miodate
    STORE 0.00 TO Miotime, Miocost
    STORE ' ' TO Miostat
    STORE '         ' TO Miocomp
    STORE "N" TO Mie:ok
     @ 2, 5 SAY "    Enter new records information    "
   *   read the new records information.
     DO recread
     @ 23,2 SAY 'working'
   ENDIF
   RELEASE Mi:ok
  *

 CASE *
  *    '*' means deleted,  do they still want it to be deleted?
   @ 19,1  SAY [Record &Mirecnmbr is marked for deletion]
   STORE F TO Mi:ok
   SET intensity ON
   @ 21,1 SAY [Do you want to recall the record(Y/N)?]
   SET intensity OFF
   SET colon OFF
   @ 21,$+1 GET Mi:ok
   SET colon ON
   READ
   @ 19,0
   IF Mi:ok
    *    no, guess they decided it should still be in the records
     RECALL
     @ 19, 5 SAY [Record number &Mirecnmbr recalled.]
   ENDIF
   @ 21,0

 CASE #>0
  *  display the record found and ask user what to do.
   SET intensity ON
   @  9, 2 SAY "Equipment Name"
   @  9,24 SAY equip:name
   @ 10, 2 SAY "W O Number"
```

```
      @ 10,24 SAY wo:nmbr
      @ 11, 2 SAY "Date"
      @ 11,24 SAY date
      @ 12, 2 SAY "Item"
      @ 12,25 SAY item
      @ 13, 2 SAY "Repairs Carried out"
      @ 13,25 SAY work:done
      @ 14, 2 SAY "Time Taken"
      @ 14,25 SAY time:taken
      @ 15,2  SAY "Cost"
      @ 15,25 SAY cost
      @ 16, 2 SAY "Is Job Complete Y/N ?"
      @ 16,25 SAY status
      @ 17, 2 SAY "Completion Date"
      @ 17,25 SAY compdate

      SET colon off
      STORE ' ' TO Mivar
      DO WHILE .not. Mivar$"CD/"
        @ 21, 0 SAY [Enter (C)hange, (D)elete, >/< to skip?]
        @ 21,39 GET Mivar PICTURE "!"
        READ
      ENDDO
      SET colon ON
      SET intensity OFF
-     @ 19,0
      @ 21,0

      IF Mivar = 'C'
       *   set up item in memory variables for update
        STORE rec:nmbr TO Mirecnmbr
        STORE equip:name TO Mirecdesc
        STORE wo:nmbr TO Miowonmbr
        STORE date TO Miodate
        STORE item TO Mioitem
        STORE work:done TO Miowkdone
        STORE time:taken TO Miotime
        STORE cost TO Miocost
        STORE status TO Miostat
        STORE compdate TO Miocomp
        STORE "N" TO Mie:ok
        @ 2, 5 SAY "     Update record item     "
        DO recread
        @ 23,3 SAY 'working'
      ELSE
        IF Mivar = 'D'
         * ok by user to delete record. so do it.
         DELETE
         STORE T TO Midelete
         @ 19, 0 SAY [Record &Mirecnmbr is marked for deletion.]
        ENDIF      mivar = 'c'
       ENDIF      mivar = 'd'

  ENDCASE       *level 1
  SET intensity ON
  @  9, 2 SAY '                                          '
  @ 10, 2 SAY '                                          '
```

```
    @ 11, 2 SAY '                                                '
    @ 12, 2 SAY '                                                '
    @ 13, 2 SAY '                                                '
    @ 13,38 SAY '                                                '
    @ 14, 2 SAY '                                                '
    @ 15, 2 SAY '                                                '
    @ 16, 2 SAY '                                                '
    @ 17, 2 SAY '                                                '
    @ 23,0 SAY '                                                  '
  OTHERWISE
    STORE F TO Miwork
  ENDCASE       *level 0

ENDDO

IF Midelete
  SET intensity OFF
  @ 8, 2 SAY 'Packing and re-indexing database file'
  SET intensity ON
 *   pack and reindex the file using the current index keys
  PACK
ENDIF

RELEASE ALL LIKE Mi*
RETURN
 -
```

```
* 14/09/84
*   History Records read data routine...RECREAD.CMD
*
*
*
*   Set up the screen for input, the memory variables are set up by the
*   RECMAINT program which has decided whether this is an add or a
*   change.....

DO WHILE Mie:ok = "N"
 *  setup the screen and read the data from the user
  @  9, 2 SAY "Equipment Name"
  @  9,24 GET Mirecdesc
  @ 10, 2 SAY "W O Number"
  @ 10,24 GET Miowonmbr PICTURE '999999'
  @ 11, 2 SAY "Date"
  @ 11,24 GET Miodate PICTURE '99/99/99'
  @ 12, 2 SAY "Item"
  @ 12,24 GET Mioitem
  @ 13, 2 SAY "Repairs Carried Out"
  @ 13,24 GET Miowkdone
  @ 14, 2 SAY "Time Taken"
  @ 14,24 GET Miotime PICTURE '99.99'
  @ 15, 2 SAY "Cost"
  @ 15,24 GET Miocost PICTURE '9999.99'
  @ 16, 2 SAY "Is Work Completed Y/N?"
  @ 16,24 GET Miostat
  @ 17, 2 SAY "Completion Date"
  @ 17,24 GET Miocomp PICTURE '99/99/99'
  READ



 *  is all the info correct?
  @ 20, 2 SAY [Is the inventory information correct]
  @ 21, 8 SAY "(Y-YES, N-NO, A-ABORT)?"
 *  accept only Y - N or A for a user response
  SET colon OFF
  STORE " " TO Mie:ok
  DO WHILE .not. Mie:ok$'YNA'
     @ 21,31 GET Mie:ok PICTURE '!'
     READ
  ENDDO

  SET colon ON
  @ 20,0
  @ 21,0
  @ 22,0
ENDDO

IF Mie:ok = "Y"
 * if the record pointer is at record zero, then this is probably an ADD
  IF #=0
   * adding a new record... since the find was not successful
    APPEND BLANK
  ENDIF
 *   now save the records info in the database
```

```
  REPLACE rec:nmbr WITH Mirecnmbr, equip:name WITH Mirecdesc
 * NOUPDATE skips checking for index keys(faster update)
  REPLACE wo:nmbr WITH Miowonmbr, date WITH Miodate NOUPDATE
  REPLACE item WITH Mioitem, work:done WITH Miowkdone NOUPDATE
  REPLACE time:taken WITH Miotime, cost WITH Miocost NOUPDATE
  REPLACE status WITH Miostat, compdate WITH Miocomp
ENDIF
RELEASE ALL LIKE mio*
RELEASE ALL LIKE mirec*
RETURN
```

```
*RTRIAL.CMD by G.J.Drysdale
*18 April 1985
*Search for specific maintenance by block


USE MTCE
ERASE
SET INTENSITY OFF

@ 2, 5 SAY "Enter 'W' to search for a WORKS ORDER NUMBER"
@ 3, 5 SAY "   or 'H' for a Historical Data Search"
@ 5, 0 SAY " Enter  (W/H)?"

SET COLON OFF
STORE ' ' TO Mir:type
DO WHILE .NOT. Mir:type $ 'WH'
@ 6,33 GET Mir:type PICTURE '!'
READ
ENDDO
SET COLON ON

IF Mir:type ='W'
ACCEPT "WORKS ORDER NUMBER" TO Nmbr
STORE !(Nmbr) to Nmbr
REPORT FORM SCH'CONS FOR WO:NMBR="&Nmbr"
? 'Press >return< to display main menu.'

SET CONS OFF
WAIT
SET CONS ON
ELSE

ERASE

@ 2, 5 SAY "Searching for Historical Maintenance Data on Specific"
@ 3, 5 SAY "Equipment Components."
@ 5, 0 SAY "Enter EQUIPMENT NAME followed by ITEM."
@ 6, 0 SAY "(enter one or more identification letters in each case)"

ACCEPT "EQUIPMENT NAME" TO Name
ACCEPT "ITEM" TO Bit
STORE !(Name) TO Name
STORE !(Bit) TO Bit

SET COLON OFF
STORE ' ' TO Mir:type
@ 8, 0 SAY 'Do you wish records to be printed? (Y/N)?'
DO WHILE .NOT. Mir:type $ "YN"
@ 8,39 GET Mir:type PICTURE '!'
READ
ENDDO

IF Mir:type = 'Y'
SET EJECT OFF
SET PRINT ON
?? CHR(15)+CHR(14)
SET PRINT OFF
```

```
REPORT FORM SCH'PRTR FOR EQUIP:NAME="&Name" .AND. ITEM="&Bit" TO PRINT
ELSE
REPORT FORM SCH'CONS FOR EQUIP:NAME="&Name" .AND. ITEM="&Bit"
? 'Press >return< to display main menu.'

SET cons OFF
WAIT
SET cons ON
ENDIF
SET intensity ON
RELEASE Mir:type
RELEASE Name
RELEASE Bit
RETURN
```

```
*   RECRPRT.CMD
*   17/09/84
*   Plant Maintenance History Records Program.
*   Print the records detail to a printer
USE MTCE
ERASE
SET intensity OFF
@  2, 5 SAY "Printing Maintenance History detail report."
@  4, 0 SAY "Enter 'N' to LIST report BY record number"
@  5, 0 SAY "    or 'D' for the report by equipment description"
@  6, 0 SAY "    enter report sequence (N/D)?"

SET colon OFF
STORE ' ' TO Mir:type
DO WHILE .not. Mir:type$'DN'
   @  6,33 GET Mir:type PICTURE '!'
   READ
ENDDO
SET colon ON

*   assume report by record number
SET index TO r'bynmbr
SET heading TO 'by record number'
IF Mir:type = 'D'
   SET index TO r'bydesc
   SET heading TO 'by equipment description'
ENDIF

SET colon OFF
STORE ' ' TO Mir:type
@ 8,0 SAY 'Enter destination (C)onsole, (P)rinter'
DO WHILE .NOT. Mir:type $ "PC"
   @ 8,39 GET Mir:type PICTURE '!'
   READ
ENDDO

*   initialize device macro variable
IF Mir:type = 'P'
SET EJECT OFF
SET PRINT ON
?? CHR(15)+CHR(14)
SET PRINT OFF

  REPORT FORM rec'prtr TO print
ELSE
  REPORT FORM rec'cons
  ? 'Press >return< to display main menu.'
  SET cons OFF
  WAIT
  SET cons ON
ENDIF

SET intensity ON
RELEASE Mir:type
RETURN
```

```
* REC'CONS

MAINTENANCE HISTORY RECORDS
N
N
6,REC:NMBR
Rec #
6,WO:NMBR
W.O.#
8,DATE
DATE
15,EQUIP:NAME
EQUIPMENT
15,ITEM
ITEM REPAIRED
50,WORK:DONE
REPAIRS CARRIED OUT
6,TIME:TAKEN
HOURS
8,COST
COST
```

```
* REC'PRTR

MAINTENANCE HISTORY RECORDS
N
N
6,REC:NMBR
Rec #
6,WO:NMBR
W.O.#
8,DATE
DATE
15,EQUIP:NAME
EQUIPMENT
15,ITEM
ITEM REPAIRED
50,WORK:DONE
REPAIRS CARRIED OUT
6,TIME:TAKEN
HOURS
8,COST
COST
```

```
*19/09/85
*Plant Maintenance Records Program
*by G.J.Drysdale
*WORPRT.CMD
*Generation of monthly Work Order Status Reports

USE MTCE
ERASE
SET INTENSITY OFF

@ 2, 5 SAY "Monthly Work Order Status Report."
@ 4, 0 SAY "Enter 'O' to list outstanding Work Orders"
@ 5, 0 SAY "   or 'R' to list Work Orders Received for"
@ 6, 0 SAY "   the month."
@ 7, 0 SAY "Enter (O/R)"

SET COLON OFF
STORE ' ' TO Mir:type
DO WHILE .NOT. Mir:type $ 'OR'
@ 7,33 GET Mir:type PICTURE '!'
READ
ENDDO
SET COLON ON
ACCEPT "MONTH (Letters only)  " TO Month
ACCEPT "YEAR  (Last Two Digits)" TO Year
STORE !(Month) to Month
STORE !(Year) to Year
STORE !(Year) to End

ERASE

IF MONTH = "JAN"
STORE "01" TO START
   ELSE
IF MONTH = "FEB"
STORE "02" TO START
   ELSE
IF MONTH = "MAR"
STORE "03" TO START
   ELSE
IF MONTH = "APR"
STORE "04" TO START
   ELSE
IF MONTH = "MAY"
STORE "05" TO START
   ELSE
IF MONTH = "JUN"
STORE "06" TO START
   ELSE
IF MONTH = "JUL"
STORE "07" TO START
   ELSE
IF MONTH = "AUG"
STORE "08" TO START
   ELSE
IF MONTH = "SEP"
STORE "09" TO START
```

```
   ELSE
IF MONTH = "OCT"
STORE "10" TO START
   ELSE
IF MONTH = "NOV"
STORE "11" TO START
   ELSE
IF MONTH = "DEC"
STORE "12" TO START
ENDIF
 ENDIF
  ENDIF
   ENDIF
ENDIF
 ENDIF
  ENDIF
   ENDIF
ENDIF
 ENDIF
  ENDIF
   ENDIF

IF Mir:type = 'O'
SET HEADING TO Outstanding Work Orders For &Month 19&Year
SET COLON OFF
STORE ' ' TO Mir:type
@ 8, 0 SAY "Do you wish report to be printed (Y/N)?"
DO WHILE .NOT. Mir:type $ "YN"
@ 8,39 GET Mir:type PICTURE '!'
READ
ENDDO
SET COLON ON

IF Mir:type='Y'
SET EJECT OFF
SET PRINT ON
?? CHR(15)+CHR(14)
SET PRINT OFF

REPORT FORM SCH'PRTR FOR STATUS="N" TO PRINT
ELSE
REPORT FORM SCH'CONS FOR STATUS="N"
? 'Press >return< to display main menu.'

SET CONS OFF
WAIT
SET CONS ON
ENDIF

ELSE
IF Mir:type = 'R'
SET HEADING TO Work Orders Received For &Month 19&Year

SET COLON OFF
STORE ' ' TO Mir:type
@ 8, 0 SAY "Do you wish the report to be printed (Y/N)?"
DO WHILE .NOT. Mir:type $ "YN"
```

```
@ 8,45 GET Mir:type PICTURE '!'
READ
ENDDO
SET COLON ON

IF Mir:type = 'Y'
SET EJECT OFF
SET PRINT ON
?? CHR(15)+CHR(14)
SET PRINT OFF

REPORT FORM SCH'PRTR FOR VAL($(DATE,4,2)) = &Start;
                    .AND. VAL($(DATE,7,2)) = &End TO PRINT
ELSE
REPORT FORM SCH'CONS FOR VAL($(DATE,4,2)) = &Start;
                    .AND. VAL($(DATE,7,2)) = &End
? 'Press >return< to display main menu.'

SET CONS OFF
WAIT
SET CONS ON
ENDIF
ENDIF
RELEASE Mir:type
RELEASE Month
RELEASE Year
RELEASE Start
RELEASE End
RETURN
```

```
* SCH'CONS.FRM

SPECIFIC SEARCH RECORDS
N
N
6,REC:NMBR
<Rec #
15,EQUIP:NAME
<EQUIPMENT
15,ITEM
<ITEM
35,WORK:DONE
<REPAIRS CARRIED OUT
```

```
* SCH'PRTR.FRM

MAINTENANCE HISTORY RECORDS
N
N
6,REC:NMBR
Rec #
6,WO:NMBR
W.O.#
8,DATE
DATE
15,EQUIP:NAME
EQUIPMENT
15,ITEM
ITEM REPAIRED
50,WORK:DONE
REPAIRS CARRIED OUT
6,TIME:TAKEN
HOURS
8,COST
COST
```