EFFECTIVE SHUTDOWN MAINTENANCE PROJECT MANAGEMENT

B. E. Klingenberg

June 1986

Submitted to the University of Cape Town in partial fulfilment for the degree of Master of Science in Engineering

I, BERNARD EKHARD KLINGENBERG, submit this thesis in partial fulfilment of the requirements for the degree of Master of Science in Engineering. I claim that this is my original work and that it has not been submitted for a degree at any University.

ABSTRACT

Shutdown maintenance projects are an intergral part of any plant maintenance system. When a plant is shutdown, production stops and major maintenance work and modification of components is carried out. Whatever the size and scope of the shutdown, component project **management** is vital if the shutdown project is to be completed successfully.

This author has found that there is little or no literature available that treats shutdown maintenance projects as a complete study. The study of the management organisation and structure, as well as the associated resources and services required by a shutdown project manager has been neglected.

The aim of this thesis project is to research and investigate shutdown maintenance and to present it as a complete study. **All** the aspects of shutdown maintenance project management are dealt with.

This is done in the following way. Shutdown maintenance is defined with specific objectives. Then the management organisation and structure, as well as the resources and services required for shutdown projects are discussed. The shutdown project management procedure and techniques are dealt with next, and finally there is a section on the effect of condition based maintenance on shutdown maintenance projects.

This thesis project serves to provide a complete perspective on shutdown projects where this was found to be lacking in previous literature on maintenance management. This thesis provides a useful source of instruction and information to an engineer who for the first time has been given a shutdown project to complete.

ACKNOWLEDGEMENTS

The author wishes to thank Mr W Jervis as supervisor of this thesis for his guidance and help throughout.

Thanks are also extended to Mr R S Dent for his advice and Ms P Beazley for doing the typing.

TABLE OF CONTENTS

CONTENTS | PAGE

CONTENTS PAGE

LIST OF ILLUSTRATIONS

CHAPTER ONE

INTRODUCTION

For many years, certainly up until the first world war, maintenance work was given little if any recognition as an important aid to productivity in industry. Planned maintenance has developed in the twentieth century to a stage now, where most industries have begun to invest more time and effort on the management of maintenance as industrialists have become aware of its economic benefits. Many companies are beginning to view the maintenance department as a profit centre, whereas previously it has been considered a cost centre. By introducing and improving maintenance systems, more profits can be generated through higher plant productivity, reliability and improved product quality. An important development today is that qualified engineers are being employed in maintenance instead of leaving its problems to skilled artisans who lack training in management. Maintenance has emerged and is still developing into an engineering science requiring good management, with more and more research and effort being spent to upgrade and improve maintenance systems.

Shutdown maintenance projects are a specific part of this field in industry. However, while maintenance in general has gained recognition, it appears that shutdown projects are still viewed as a necessary evil in industry. In fact while conducting a literature survey, the author was unable to find a complete and comprehensive study on shutdown maintenance projects and procedures. In most maintenance books and papers, shutdown maintenance is afforded a paragraph or maybe a chapter at best, which serve only to state that it exists and provide a superficial description of it.

Because of this many engineers who are confronted with the prospect of conducting a shutdown maintenance project for the first time (and indeed maybe not only the first time), find themselves faced with a huge task, but are not very sure as to how they should go about it. Where do I start? What organisational structure do I need? Who must be involved? What management tools are at my disposal? These and other questions must be answered if the shutdown project manager is to be successful in accomplishing the task.

This then is the subject and aim of this disertation. To research and investigate shutdown maintenance and to present it as a **whole** study. i.e. all aspects of shutdown maintenance are dealt with. This thesis does not attempt to provide a step-by-step procedure for shutdown maintenance, but studies the principles and policies involved in shutdown maintenance projects.

This is done in the following way. Firstly, shutdown maintenance is defined with needs and objectives (Chapter 2). Then secondly, the ingredients, components and structures required for shutdown projects are discussed (Chapter 3). Thirdly, the planning, implementing and finishing phases of a shutdown project are considered (Chapters 4,5, & 6). Chapter 7 deals with common problems associated with shutdown maintenance projects.

Finally, also included in this thesis is a look at the future of shutdown maintenance projects in the light of developments in maintenance techniques and systems.

CHAPTER TWO

DEFINING SHUTDOWN MAINTENANCE

In chapter 1 shutdown maintenance is introduced briefly and in general terms. This chapter deals specifically with **defining** shutdown maintenance so that the reader and author are at one with the subject of this project.

2.1 DEFINING SHUTDOWN MAINTENANCE

Maintenance can be defined as that function which seeks to keep or restore a physical component or system so that it can perform its original function safely and effectively. Usually this means restoring it to its original state or as near as possible to its original state, but could also involve modification or replacement of parts of the system.

According to Mann [11] "Maintenance can be defined as the activities required to keep a facility in as-built condition, continuing to have its original productive capacity."

Shutdown used in this thesis is used with reference to the whole plant, production line or facility. That is, the whole system is "shut down" or "closed off" or production stops and the facility becomes non-operational.

Thus **shutdown maintenance** refers to that maintenance function carried out on the whole system while the plant, production line or facility is shut down.

Some other authors have referred to shutdown maintenance as follows:

According to Patton [10] "Many operations halt for a period of time in order to consolidate all maintenance activities, accomplish inspections that cannot be done during operation and accommodate seasonal raw materials or personnel situations."

According to White (12), "In many plants a six-monthly, annual or five-yearly closure is planned during which essential maintenance of plant replacement is carried out."

Reasons which determine the time of the shutdown may vary. Firstly, a shutdown may be scheduled as part of a preventative maintenance system. Secondly, the shutdown may be forced due to critical faliure of some component(s). Thirdly, shutdown often occurs when there is a so called turnaround which is a product change, and equipment and components need to be changed to accommodate the new product. It is during these shutdowns that overall maintenance is carried out and requires planning scheduling and project control. While in the case of equipment failure it may be "unplanned", often a company's policy is to institute a pre-planned shutdown maintenance ("package") programme while the plant is down.

The question of overhauls arises. When a pump or a turbine is overhauled (in the true sense of the word), it does in fact need to be "shut down" and will cease to function. So then, the overhaul of any component can be seen as minor or localised shutdown maintenance. Often that component forms an important link in a system and the overhaul of that component (e.g. a steam turbine) will cause a whole system to stop functioning.

This can be seen to be a form of shutdown but for the scope of this thesis would not be defined as a shutdown maintenance project. This is because only the one component is repaired, while maybe minor services (e.g. lubrication etc) are done on other components, if any work at all, and as soon as the major work is complete, the "shutdown" will end.

A simple example is given which will illustrate some of the definitions and examples above.

> If a large truck is being used extensively and needs a gear box replaced, it would have to "come off production". During repair the truck is non-functional but little or no work other than the gear box replacement is done and it does not constitute shutdown maintenance.
>
> However once in three years the truck may be scheduled for complete stripping and repair and is taken out of service for a few weeks or months. This clearly would constitite a shutdown maintenance project. For this planning and scheduling are required which involve the implementation of a maintenance procedure.
>
> Another situation which may arise is that after 2 years, the truck's engine seizes up. Here the fleet management may decide to implement a complete shutdown maintenance programme to coincide with the breakdown. (Thus bringing forward the planned shutdown if resources allow them to.)

Finally then, it should be clear that for this thesis shutdown maintenance is defined as an overall maintenance programme of a whole plant, production line or facility.

2.2 THE NEED FOR SHUTDOWN MAINTENANCE

There are some specific needs for shutdown maintenance. These are the following and are discussed in this section.

Safety/Law
Mechanical Efficiency/Productivity
Turnaround
Other

2.2.1 Safety/Law

Many components and installations may **by law** require an inspection or specific maintenance. An example of such a case is an air compressor which has to be shut down every three months for an inspection and repair if necessary. Boilers are another example of law-enforced shutdown and usually then for industries and factories which rely on these components, the shutdown maintenance programme is scheduled to coincide with the inspection period.

2.2.2 Mechanical Efficiency/Productivity

According to Mann [11] "Most equipment eventually deteriorates to such an extent that routine servicing and component replacements are insufficient to ensure good performance." It is at this stage (when the above applies to the whole system) that a shutdown maintenance programme needs to be implemented in order to restore that system so that productivity can be increased to original levels.

It is the "mechanical efficiency" of the system that needs to be increased after it has been "lost" through deterioration or failure of various components. Manufacturing plants are prone to this type of shutdown when due to wear and deterioration, tolerances and the quality of products become unaccepatble.

2.2.3 **Turnaround**

In many industries there are major product changes which require alteration or modification to existing systems. A typical example of this is in the chemical industry where a system may need to be altered to accommodate different raw products in order to achieve different end products. Here again a shutdown maintenance programme is often planned to coincide with the turnaround. The turnaround programme in itself constitutes a major project.

Turnaround projects are common in process plants where the product change involves significant plant modification. In the manufacturing (discrete part) industry, turnaround would not usually constitute a major shutdown, except where there are extensive modifications to manufacturing machinery.

(This should not be confused with preventative maintenance carried out on a regular basis in industrial applications where product change is frequent (e.g. food packaging). The hold up and changes must be sufficient to allow a team to implement a complete shutdown maintenance program.)

2.2.4 **Other**

Failure of one or a few vital components in a system can cause a shutdown. As has been discussed this may not be classed as a shutdown maintenance project but if the nature of the failure is such that it will cause a major delay, a shutdown maintenenace programme is usually implemented. In the mining industry for example, the failure of the hoisting system could be serious enough to cause a shutdown.

There is one other type or need for a shutdown. For a nuclear reactor, there comes a time when the catalyst needs to be replaced as it is spent. This constitutes a major shutdown and will be accompanied with major maintenance (shutdown). It is possible to see this in the same light as efficiency loss or productivity loss, but is different however in that the cause for shutdown is an ingredient in the process and not necessarily a component (mechanical), such as a turbine or a compressor.

2.3 OBJECTIVES OF SHUTDOWN MAINTENANCE

The definition of shutdown maintenance gives a broad view of the overall aim of a shutdown maintenance project. However like any other project it is useful to break down the overall aim into definite objectives and goals that one can visualise, plan and implement. This helps project managers to define the project so that it becomes manageable. For shutdown maintenance projects the objectives are as follows:

1. Essential repairs to deferred defects
2. Manufacture recommended maintenance
3. Inspection
4. Modification
5. Standardisation
6. Overruns
7. Successful start-up

2.3.1 Essential Repairs to Deferred Defects

In many plants or industries there are deferred defects which need to be repaired at shutdown. These are defects which have been fixed temporarily, or which may not have been critical to the functioning of the system.

it is important that these defects be included in the work load planned and scheduled at shutdown and that they are not overlooked. This emphasises the importance of an efficient recording system and information gathering system as a maintenance support (discussed in chapter 3).

2.3.2 <u>**Manufacturers Recommended Maintenance**</u>

An important aspect to be dealt with during shutdown is completing outstanding recommended maintenance on components. Most components are supplied with specific instructions regarding maintenance but often during production or operation, this maintenance work is neglected. Once again the planning must incorporate this work into a shutdown period and hence a good information retaining system is imperative.

2.3.3 <u>**Inspection**</u>

As has already been discussed many shutdowns occur when specific components have to be inspected or overhauled by law. During shutdown projects, inspection and testing of other components for leaks and defects is an important objective even if these have no known defects. Often inspection will reveal faults which may need additional repair.

2.3.4 <u>**Modification**</u>

This may be one of the most important objectives of a shutdown maintenance program. During a shutdown, modifications are usually carried out in order to improve the availability of existing equipment. This is particularly important for components which have proved to be unreliable or difficult to maintain.

In a shutdown period then, it is important to carry out these modifications and replacements if necessary, as this is not usually possible while the plant is in operation.

Obviously this would involve the design and development departments of a plant and the design and pre-fabrication must be completed before the shutdown. This means that there must be co-ordination between the maintenance and design departments long before the shutdown.

Of vital importance for any modification or redesign or replacement is the need for full documentation. These may include operating and maintenance instructions, drawings and spare parts listing and any other technical specifications. Then before commissioning it is important that modified or replacement equipment is tested and passes inspection.

2.3.5 Standardisation

Standardisation often includes modification but is not aimed at achieving the same objective. Here the availability of spares and ease of maintenance functions are involved and a component which may be functioning correctly but is non-standard may be replaced. Standardisation is also important in reducing the number of spares that need to be held.

Very often lack of standardisation may be a result of so-called "turn-key projects". This is where a plant has been designed and built by contractors and then "handed over" for production. At this stage and as the maintenance system develops, the plant managers come across many non-standard components. For example, contract managers may have included more than one kind of pump in the design.

The contractors are often guilty of neglecting the need to standardise during design and then it may be necessary for plant managers to accomplish this in subsequent shutdown maintenance programs.

Often changes in the local market and availability of spares make standardisation necessary. For example, a pump which has previously been supplied only by overseas companies may become available locally and spares may be so much cheaper that it becomes economically beneficial to standardise.

To quote from White [12], "In one plant , for example, it was found that the replacement of non-standard pumps, accompanied with the resale of unwanted pumps and spares would produce significant reductions in spares stocks and in maintenance costs and would facilitate an overhaul-by-exchange programme reducing the needs for shutdown during pump maintenance."

The questions of modification, procurement and standardisation are part of the design and development function and what effect these can have on the maintenance function and in particular on shutdown maintenance are dealt with in greater detail in chapter 3.

2.3.6 <u>Overruns</u>

Possibly the most important economic implications for shutdowns occur when there is overrun on the project i.e. the shutdown is longer than necessary. It is of vital importance that the project runs on schedule and finishes on time. To best illustrate this, from Patton [10], "The epitome of inspections and preventative maintenance done at a shutdown is a nuclear power generating station.

Even a relatively small 500 megawatt plant produces $250 000,00 worth of electricity a day (1982). When such a station is not generating electricity, that power must be purchased from other sources."

2.3.7 Successful Start Up

"Quality control" is a term usually used in production lines. However, it is important that the quality of work done during shutdown is controlled and inspected. This is so that commissioning and restart can be accomplished with the greatest possible success. Thus it is important that the work done conforms to standards and procedeures laid out during planning. This is essentially a discipline problem and requires competent supervision and inspection. How well and reliably the system runs after start up is a measure of the success of the shutdown maintenance programme.

CHAPTER THREE

THE SHUTDOWN MAINTENANCE ORGANISATION AND MANAGEMENT STRUCTURE

3.1 INTRODUCTION

Very often an engineer may be faced for the first time with having to do a shutdown maintenance project. The question that he or she would have to ask is - where do I start?

A common method of approach may be described as follows. The first thing that a project manager must do is define the scope and extent of the shutdown project. Once this is done, a provisional plan and rough schedule should be constructed. It is important for the project manager to find out what maintenance work needs to be done and what modifications should be made. Thus the shutdown project manager, together with the one or two assistants, gathers information from various departments on the resources available and the shutdown work load requirements. All this information is used to construct the final network or plan. Then before the shutdown period starts, all the departments are informed of the shutdown plan detail and of the role that each will have to play during the shutdown. This procedure is depicted in Figure 3.1.

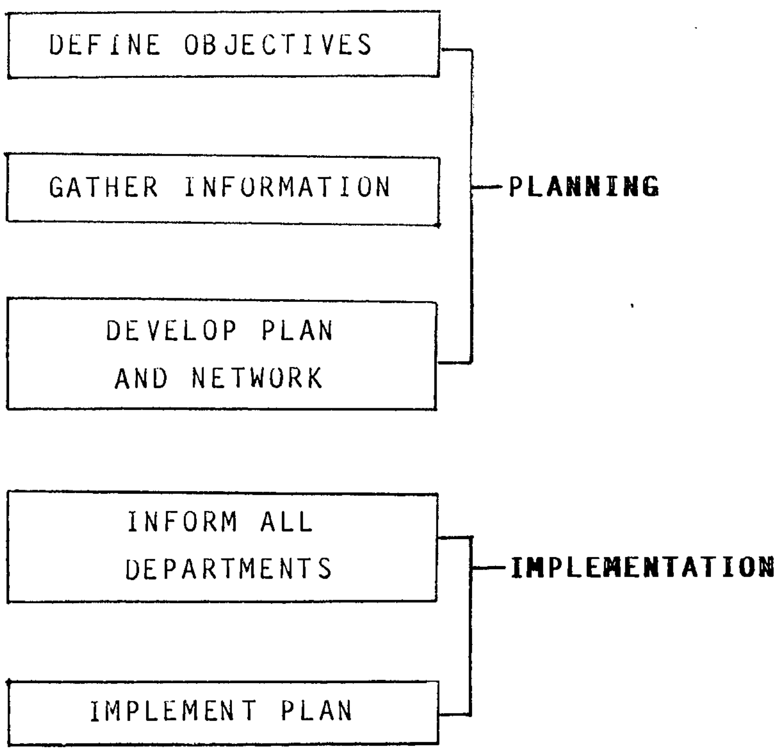

Figure 3.1 Conventional Planning Procedure

This is the pattern which is followed in usual shutdown projects. The **planning** organisation includes only the project manager and planners and the various other departments only become actively involved at the implementation stage of the shutdown project. In other words, they are part of the **implementing** organisation.

While this may be viewed as common practice, this author feels that this is not the best approach. More participation from various departments during the planning stage is important, and they should be part of the planning organisation as well as the implementing organisation. This is shown in Figure 3.2.

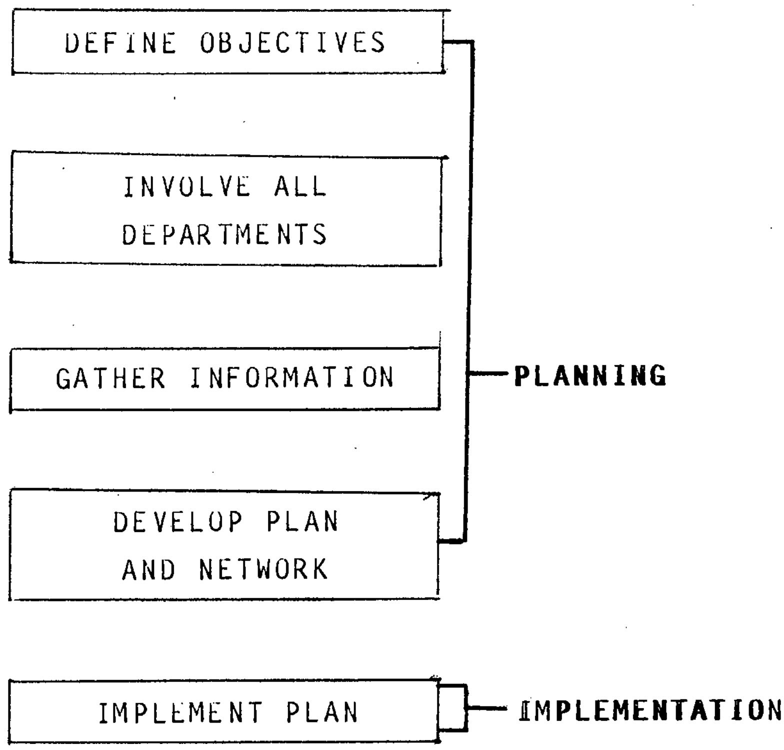

Figure 3.2 Modified Planning Procedure

At a very early stage in the planning of a shutdown project, various department managers (or their representatives) must be drawn into the planning procedure. This has two significant advantages.

Firstly, these department managers become an **integral part** of the shutdown project itself. The project becomes their project. Secondly, the inclusion of various departments in the planning phase will cause the overall schedule and plan to be more effective. The shutdown manager will have limited knowledge of all the departments, while the specific knowledge of each department manager and his input in the planning process will mean that his department is accommodated for properly in the schedule. This will help to avoid clashes between shutdown work and other work, during the shutdown period. For example, the modification department will be able to plan their workload to accommodate for shutdown work more effectively if somebody from the modification department is involved in the planning stage.

This chapter describes the organisation and management structures and the requirements which are all needed for successful shutdown projects.

3.2 SHUTDOWN MAINTENANCE MANAGEMENT STRUCTURE AND ORGANISATION

Shutdown projects require the involvement of various departments (e.g. design and production) and the implementation of many resources. In order to utilise these a project manager needs to ensure that the departments are involved in the planning and that **during** the shutdown, the project manager is given some control over the implementation and scheduling of resources in other departments.

3.2.1 Authority

One of the most important aspects of an organisation is that which assigns authority to various people to make decisions. Thus if a system is to operate successfully there must be control and in order to control, one must be able to make decisions which will be carried out. It is obviously important that competent people are assigned to positions of authority.

It is important that the project manager sets up a management team organisation which have suitable authority over the men and resources needed in various departments throughout the project. For example, the project manager will not assume control of the design department, but at the same time does not want to "wait his turn" when he requires design work for the shutdown project. In this sense, he has "authority" or control in that he can get work done as and when he needs it. Top management must recognise his need and allow the project manager this "control".

As in any organisation, a shutdown maintenance team will have various levels of control. The type of structure will of course vary depending on the type of industry, size and extent of the shutdown. Which structure is best for each application is a field of study on its own and falls beyond the scope of this project.

An important aspect to be considered is that of supervision density. The number of people who work under one foreman will affect the time he has to supervise work and will therefore have a bearing on the quality of work that is done.

Also important is the supervision situation. In some applications, area supervision is best applied while elsewhere central supervision is desirable. For very large shutdown projects, on-the-job supervision is a must (area supervision).

3.2.2 Scope and Designation

Directly related to authority is the need to define the scope of authority and control. It is important that everybody involved knows what he is responsible for and to whom, and who is responsible to him.

Equally important is the need for job specification. Each member of the project must be certain as to the function and role that he plays and the scope of his work.

3.3 COMMUNICATION AND FLOW OF INFORMATION

For any system to be able to operate, there must be defined channels for information flow and feedback and a suitable means of carrying that information.

An analogy is the human body. Consider the structure or network of veins and arteries as being the organisation and channels and the blood they carry as being the information flow. Without veins the heart would be unable to supply various parts of the body with life-giving blood, but equally dependant for life the body must have blood to fill the veins and arteries. It is impoprtant that a structure and organisation exists which is designed to aid communication and information flow. What this information is actually used for is described by Versteeg [20].

"Recorded and process data can be used for a host of reasons. The most essential uses however, are in areas of planning and controlling. One of the most basic requirements of any control system is that it has to be preceded by a plan. The information is used to indicate a deviation from a plan. The second prerequisite of a control system is that is must be backed by an organisational structure."

The importance of information flow to management is illustrated by Versteeg [20], who depicts the relationship between information and action in figure 3.3.

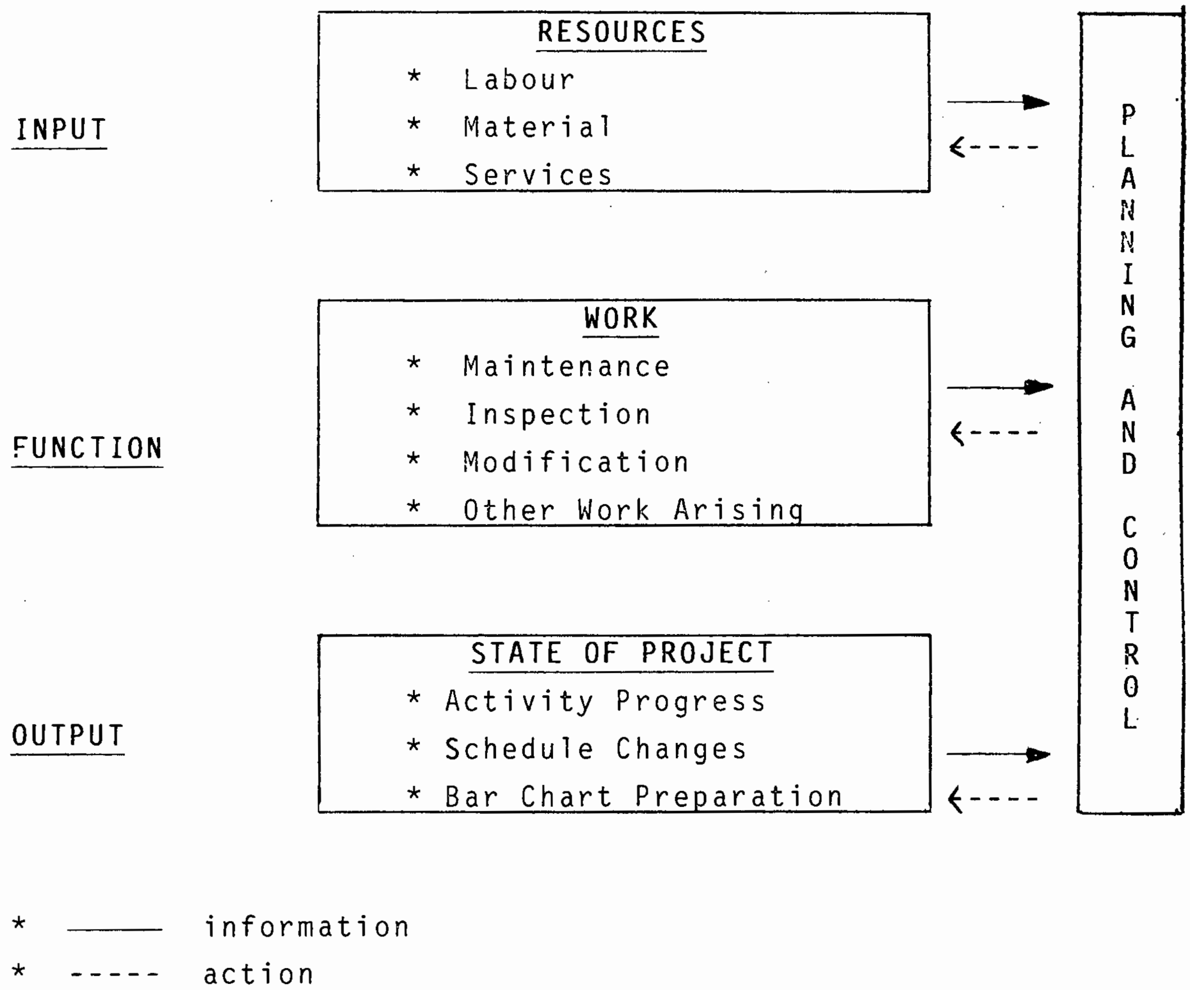

Figure 3.3 Information Flow and Action

An important principle demonstrated by figure 3.3 is that the planning and control function is entirely dependant on the information system and it follows then that the success of the planning and control of a shutdown maintenance project is directly related to the effectiveness of the information system.

Finally a sophisticated, good organisational structure becomes useless unless there is useful information flow between departments and equally important is that a mass of information without an organisation or structure which can use that information, is also worthless.

3.3.1 Feedback Information

What are the types of information which are vital for effective feedback and successful management control? This question relates to any type of project, but here is considered with particular reference to shutdown maintenance. Here a maintenance project manager must make provision in planning a project management structure for specific information required during and before a shutdown.

1. Once started, a shutdown maintenance programme is crippled without an effective feedback to management of the work progress of jobs. Outstanding work that is scheduled is dependant on the completion of old work. Thus incomplete jobs due to labour, incorrect spares or any other unforseen problem or on the other hand jobs completed earlier than scheduled have a profound effect on the project schedule.

Work progress is important to be able to inform other departments, timeously of changes or inadequate service or additional needs. Feedback on job progress should be immediate and accurate.

2. Additional Resources - An important feature of work progress reporting is not only waiting for completion of work before reporting but being able to predict during the job whether and when the job will be complete. This enables corrective action to be taken if necessary so that delays can be avoided (i.e. additional labour).

   Often during work or job the need arises to acquire special spares or specific materials may be required and these were overlooked in the planning stage. The sooner this information is fedback to the management and purchasing departments the less serious the consequences of the delay will be.

3.3.2 **Technical Information**

In order to be able to make an objective and accurate decision one must have access to facts and information concerning the subject of the decision. So if the maintenance function is to operate effectively it is important that staff have up-to-date information about the plant and equipment.

3.3.2.1 Equipment - Information on equipment could be classed in two categories. Firstly permanent data or that which is supplied with the equipment when it is supplied. Secondly that information about equipment which is acquired during its operation, often referred to as equipment history.

The information that is permanent is the following :

- Information on the manufacturer or supplier which is required for ordering replacement parts and spares and obtaining specialist help in the case of failure.
- Designed and actual duty, designed and actual service power specifications are required so that equipment performances can be monitored.
- Data on costs which will enable maintenance staff to make replacements or repair decisions. It should be noted that these would probably change considerably and thus updates should be requested from suppliers.
- Drawings are always useful for the identification of equipment.
- Other specifications, lubricants, raw materials, bolt tension requirements and a host of other technical specifications are all needed.

All the above are generally available in the equipment manuals which are supplied with the equipment. However, the filing and storing system for this information is of vital importance if these are going to be useful as they must be readily available and easy to find.

Equipment Coding and Identification

In any organisation it is very important that each component is clearly and easily identifiable. A coding system which is simple and clear and leaves no doubt as to which component is being referred to is vital. This coding system must be consistent throughout the system. All documentation must be related to corresponding codes.

3.3.2.2 Maintenance Instruction - The procedures which need to be followed when maintaining equipment and especially for overhauling equipment during shutdowns must be clearly set out. Complete job inspections go a long way in helping to achieve objectives in maintenance work. Maintenance instructions are supplied with the equipment, but invariably these are supplemented with additional information gained during the operation and maintenance of equipment. (This aspect is dealt with separately.)

Coupled with job instruction is the aspect of training. Maintenance staff must be adequately qualified and trained to do the work. Often equipment requires specialised attention and it may be that some staff need to attend courses for maintenance specific equipment to obtain the expertise required.

From ref [1], the type of information which must be included in job instruction is "special tools to be used; tolerances and similar limits if not specified on drawings; special precautions to be taken during operation and maintenance; diagnostic equipment and precedures used for faults; changes made to design (modification) and materials of construction; changes made during previous repairs."

3.2.2.3 Historical Records - During the life of equipment invaluable information is obtained concerning the operation and maintenance of the equipment. It is important that this information is documented correctly and efficiently so that it is useful to maintenance staff in planning and determining work procedures and work loads. This historical information is obtained via feedback from maintenance staff after completion of work on equipment.

It should be stressed though that routine work which does not reveal anything new about equipment should not be recorded as historical data. Historical data falls into two categories (ref Mann [11]), equipment and jobs.

Equipment :

Record history for those items of equipment

1. Which are trouble spots, expensive to maintain, require much attention.
2. Which have major long term overhauls and where information findings from one overhaul are unlikely to be remembered at the next.
3. Which have been developed, modified or tested or which operate under revised operating or maintenance conditions.
4. That are interchangeable and complimentary.
5. Which prohibit unusual frequency and types of failure so that improvements can be made.
6. Which are new and no previous experience is available.

Jobs :

Record history for those jobs :

1. Which are complex so that proved maintenance procedures are not forgotten.
2. Which contribute knowledge for assessing the merits of revised procedures, designs.
3. Which give an indication of work to be done in the future.

This historical information is very useful and used by the planning department when scheduling workloads, determining labour requirements and identifying unique areas of interest.

While the information is gathered long before shutdown periods the lessons learnt should be used during shutdown maintenance. During shutdown projects **more** information related to the overhauling of components and of the nature of the data described above, with specific reference to shutdowns, will be gathered so that it can be used for subsequent shutdown projects.

3.3.3 Information Destination

The organisation of the information flow must ensure that the correct information reaches the correct places quickly. It would be of no use say, if the electrical department received certification that the inspector would be required on the following day, or that the inspector is notified to be in place B, if in fact he is to be at place A.

Thus an information system must be designed which directs information to the people that need it so that they can in fact make decisions and control effectively. The quicker this information reaches its destination the better. It should be realised that too much information, especially in a project context is unuseful and the feedback should be limited to useful relevant information.

Finally, to be effective the actual presentation of information should adhere to some simple rules [ref from Hughes 20].

- it should be easy to read and easy to understand
- it should be concise, relevant and completely accurate
- it should be prepared with clockwork regularity and as soon as possible
- it should point out specific areas of interest and deviations
- it should evaluate project progress.

3.4 OTHER DEPARTMENTS

During a shutdown operation it is obvious that not only the maintenance department is affected. The production, sales, procurement, design, personnel and in fact most departments within an industry will be affected by a shutdown in some way. This implies that the liaison between these departments and the co-ordination of them is vital to the successful completion of the project. The importance of the involvement of these departments in the planning phase has already been discussed.

In this section of this report some of the effects that a major shutdown will have on these departments and the scope of each department's involvement in the shutdown project are discussed.

This section deals with those departments which support or supplement the maintenance department and which are required to conduct a shutdown maintenance project. The aspects dealt with would apply to any maintenance organisation or function, but here they are discussed with particular reference to shutdown maintenance projects.

3.4.1 Stores and Spares

The need for materials and spare parts in a shutdown maintenance project is obvious. But the procurement, storing and distribution system and its organisation will differ from one industrial application to another. For any maintenance function to be fulfilled there needs to be an efficient stores system. This is particularly relevant for a shutdown operation where parts and spares need to be supplied on time and to the correct places.

Some important features of a stores system are:

1. Stores and spares must be coded and easily identified.
2. Important documentation required for effective control and usage of spares are :
   - requisition forms
   - issue sheets
   - stock record records
   - for shutdown projects capital item request forms for replacement and modification is important
3. Stores must be kept in good condition and supplied in working order.

There must be a liaison between the planning departments of a shutdown and the stores and spares department to ensure that the spares required for the work scheduled and the consumable stores (paint, lubricants etc) are in full supply and readily available.

The stores facility has a vital function and if inadequate can lead to hold ups and set-backs which could cause overruns of the shutdown period. The spares that need to be supplied must be :

- supplied on time
- the correct spares
- supplied to the correct place
- supplied with all relevant accessories (e.g. special tools, lubricants, gaskets etc)
- accounted for (documentation)

3.4.2 Contract Servicing

While some companies have contractors which carry out all their own maintenance, others have their own maintenance organisation but may need to supplement it during periods of shutdown.

There are two alternatives for a company :

1. A service contractor is called in to complete the whole shutdown project and supplies project management personnel, artisans, inspections etc. The contractor is given a mandate to complete the shutdown by a specific date.

2. The company obtains contract labour only. The company controls the project itself and contract lavour is required to supplement the existing labour because of the excessive workload.

3.4.2.1 Contracting Out Whole Shutdown Project - In the case where the whole project is contracted out a company must be sure that :

1. The contractor is large enough to guarantee adequate technical resources and qualified personnel.
2. There are specific (named) contact personnel and a direct link between contractor and buyer so that requirements are understood.
3. The contractor has a stable work force.
4. Modification and redesign specifications must be controlled and documented to enable normal maintenance policies to be carried out once the shutdown is completed.

5. The contractors adhere to company policies regarding coding, documentation and testing procedures. Standardisation and compliance with equipment procurement policies is also very important.

Some of the disadvantages of contracting the whole project are :

1. The possibility of undocumented (or badly documented) modifications of the plant.
2. Inadequate disclosure of technical information of new plant for plant maintenance after completion.
3. Failure of the host company to acquire plant expertise on special equipment and hence continued reliance on contractors for spectific maintenance tasks conducted during normal (routine) maintenance.

3.4.2.2 Contracting Supplementary Labour - This form of contracting is a very common one. Most companies (except for those which have regular shutdowns in different departments) would need to supplement their labour for major shutdown operations in order to cope with the vast workload.

In this case a major issue is that of supervision. It must be assured that contracted personnel :

- follow all the intructions in job procedures
- adequately document the work they have done, noting any pecularities.
- finish on time and are controlled in so far as schedules are maintained.
- receive qualified supervision and that there is adequate supervision so that contracted labour is not left idle.

To this end the important decision that must be made within the company is who does the supervision? For example in a large process plant a competent foreman could be promoted to acting engineer and a number of artisans promoted to acting foremen for the duration of the shutdown.

Before contracting labour the host company must ensure that for the project there is enough qualified supervision and may have to include engineers and/or foremen in the contracted labour. The requirements and hence decisions for each situation would be different and would therefore require different organisational structures.

While the advantages and disadvantages of contracting services may be argued it cannot be denied that these are essential to shutdown projects on the whole. In South Africa in the past there may have been some doubt as to the competence of contractors. This fear is losing ground in the face of the development of specialised engineering and technical personnel in contracting companies which have given them more credibility with industry.

3.4.3 Design Department

As has been discussed, in many shutdown maintenance projects there is a need to do modification in order to improve plant availability effectiveness. An important objective of modification is to increase the output by "de-bottlenecking" a system i.e. strengthening a weak link in the system. Other reasons are for standardisation for which the advantages have already been discussed. It is important that the components which have to be designed are complete so that the installation of modified parts can be done timeously during the shutdown.

This implies that there must be adequate time given before the shutdown or enough "warning" so that the design department has enough time to do a complete modification design.

There is an important function that the design department plays long before the shutdown and in fact could be in the initial design and development of the whole plant. This is such that the designers must be aware of the maintenance and must in fact design for ease of maintenance. Thus accessibility and simplicity are important, and when designing modifications the same factors apply.

3.4.4 Production Department

Since in the shutdown, of necessity all production stops it is important that there be close liaison with the production department. This means that production plans can be adopted to suit the shutdown or the shutdown to be delayed or brought forward to suit production needs. The production department can then also organise its staff vacations to coincide with the shutdown if need be, or be in a position to plan for training programmes for staff during the shutdown period.

The production department may also have modifications and updating to do to their system or to the process which would involve substantial pre-planning and also effective co-ordination between maintenance, design and production departments.

Also important to the shutdown is the involvement of production in planning the physical shutting off of the plant and then of course their involvement in actually starting up again.

Often because of the knowledge that production staff have of the plant it is possible that they could also be invloved in the shutdown maintenance project itself.

3.4.5 **Services Departments**

(Instrumentation, Electrical , Riggers)

These facilities or departments may be part of the maintenance department but where they are separate services they need to be informed and be involved in the planning stage of the operation so that they can be accurately scheduled as part of the project.

Their availability at the times and places provided in the schedule is of vital importance to the project as they usually form a direct link in the progress (e.g. the electrical connections must be taken off before a motor can be removed etc)

As the project progresses these departments must be aware of changes in the scheduled workload and be able to accommodate for them.

3.4.6 **Sales and purchases.**

The sales and purchases department is affected in two ways. Firstly the sale and purchase of the raw material or finished goods changes because production rate changes or stops and secondly the purchasing department through stores has to obtain spares and replacement parts for the actual shutdown project.

Thus in the case of perishable raw material, the purchasing must stop or be reduced accordingly and for turnaround projects planning for new raw materials procurement and storage must be done.

Stockpiling and hence purchases will be affected by shutdown. Also since there is no production there will be no, or restricted sale of those goods which are affected.

For all this, planning and estimating needs to be done and hence information flow is important so that the sales /purchases department is fully aware of the needs long before they arise. It is important that these be defined clearly and accurately so that the correct purchases are made.

3.4.7. Personnel

As has been noted already, the need for the labour force to be supplemented often arises. The hiring of contract labour would affect the personnel department who need to be made aware (in advance) of the needs and requirements of personnel during the shutdown. Specific details on the kind of labour skills required and also the extra amount of skilled labour required must be supplied to personnel.

CHAPTER 4

PHASE 1 - PREPARING FOR SHUTDOWN MAINTENANCE PROJECTS

As for any project, good ground work and preparatory work is essential for the successful implementation of a shutdown maintenance project. The availability of parts, materials or services at specific places and times of the shutdown operation will depend on how effective the planning and preparation work has been done.

In the previous chapter, the structure and organisation required for a shutdown maintenance project are discussed. In this chapter, the first and most important phase of a shutdown maintenance project is discussed, that of PLANNING THE PROJECT. While it may seem that there is some overlap with the previous chapter, this chapter deals specifically with the **planning procedure** and requirements, and sets out some techniques and tools used in planning. The co-ordination, scheduling and planning of the maintenance operations is the most vital step of a whole shutdown maintenance project.

In this chapter the following aspects are dealt with in the given order:

1. Planning - general comments
2. Information flow during planning
3. Management tools for Project Planning
4. Computers and Shutdown Planning

4.1 PLANNING - GENERAL COMMENTS

Planning can be defined as the process of preparing for the committment of resources in the most effective fashion. For a shutdown maintenance project this involves combining the efforts of various departments, to make use of resources in order to achieve the objectives of the specific project. For a shutdown project the planning process needs to start some time in advance of the shutdown. According to Kelly [13] this process should start at least 10 weeks before the actual shutdown. In some situations, where for example imported components are required, planning and ordering may have to be done well in advance of even this 10 week period. Features of this preparatory period are discussed here.

4.1.1 Management Meetings

The management and supervision staff must meet on a formal basis to discuss and plan the whole operation. Representatives from different departments need to be present to ensure that all those departments involved have the same goals and objectives. Together they need to :

- define and decide on the extent of the shutdown.
- define the needs and objectives of the shutdown.
- evaluate resources and determine additional resource requirements.
- prepare work schedules construct for client, critical path networks or other control systems.
- each department must anaylse and comment on the logic diagram for their particular areas of work.
- give feedback as to the progress of work being done in preparation for the shutdown.

In order to make good decisions which will satisfy the objectives of the shutdown maintenance project, the management must be suitably qualified. The following are specific prerequisites :

- a good knowledge of the plant, the process and its function
- an awareness of the economic significance of decisions
- access to information and feedback, and adequate experience and knowledge to draw conclusions from that information and use it effectively
- an adequate knowledge of engineering techniques applicable to maintenance of assets
- a knowledge of when to call in specialist assistance and ability to anticipate problems and to be able to deal with them
- the ability to work under increased workloads and economic pressure

4.1.2 **Support Function**

It is important that the supports for the shutdown project are complete and readily available when they are needed. These need to be controlled and included in the planning before the actual shutdown and include the following aspects :

1. Modified and replacement parts must be available and complete. Thus control and feedback on the progress of the fabrication of components or procurement of spare parts is important.

2. Job cards and job instructions need to be completed ahead of time and there must be control to ensure that these are in fact completed. Detailed job lists must be compiled with estimated job times.
3. Equipment required to do the work in the shutdown must be available and in working order. (Testing equipment and tools etc.)
4. Special instructions for contract staff in order to familiarise them with plant practice and procedures need to be prepared.
5. Spare parts and materials must be obtained for the work that is to be done and there must be control that these are actually available before the need for them arises.

4.1.3 Personnel Instruction and Motivation

For many shutdown maintenance projects, it is necessary that during the shutdown the organisational structure changes. This is usually done to accommodate contract labour. For times such as these, a foreman may be temporarily appointed as an acting maintenance engineer and a number of artisans appointed to acting foremen. In these situations the people concerned must be made aware of the scope of their new authority and be instructed as to the responsibilities they will assume. This must be done ahead of time so that everybody involved will know in advance what his function will be, to whom he will be directly responsible and who he will be responsible for during the shutdown period.

Shutdown maintenance projects often exact greater demands from personnel than during normal periods and thus motivation and preparation for the shutdown periods is important. Employees involved in the shutdown operation must be prepared for possible overtime work, and must plan to take their vacations at other times.

An important aspect of shutdown is to inform the relevant unions of shutdown details where necessary. While in the past this may not have been significant, unions have become increasingly more prominent and need to be considered. Accordingly, one must also ensure that the physical needs of the workforce are met. Additional canteens, ablution blocks etc. must be catered for.

4.2 INFORMATION FLOW DURING PLANNING

During the time leading up to when a shutdown maintenance project is to start, there may be changes in the situations and conditions which will cause considerable deviations from the planned schedule. It is important that the various departments are kept up to date with all these changes so that the scheduling and planning can be changed accordingly. They may be delayed or on the other hand brought forward.

Times where the whole operation is brought forward can arise due to any of the following :

- a breakdown, where a major failure causes the plant to "come down".
- a power failure, where production has stopped and would take some time to come back on line.
- an unexpected drop in product demand may also initiate a decision to implement shutdown procedures ahead of schedule.

Whether the system will be brought back on line or the shutdown maintenance project implemented immediately, will be an economic consideration and obviously will depend on the facts of each situation.

Times where shutdown may be delayed could be :

- an unexpected increase in product demand may be of such a nature that it could be beneficial to delay the shutdown.
- the incomplete modification design or unavailablity of vital spares.

For all these situations, information flow and re-scheduling are important to achieve success in implementing the shutdown project.

4.3 MANAGEMENT TOOLS FOR PROJECT PLANNING

There are systems that have been developed which are intended to aid project managers in the planning, scheduling and control of projects. Essentially these systems provide a means of planning, scheduling and then finally controlling the shutdown maintenance projects. The basic objective of these systems is to help the project manager to complete the tasks defined within the specified time limits, using the resources available.

It is before that shutdown occurs that such a plan or schedule must be complete, and that the project manager uses the system to achieve effective project monitoring and control.

In this section, the development of control techniques is discussed, with some detail given to CPM/PERT systems. A final note on the usefulness of these systems is included, with specific reference to the role that such a system should play in shutdown project management.

Development of Planning and Control Techniques

The oldest or first form of project planning and control was formulated in World War 1 by Gantt and is still in use today. Gantt bar charts were used primarily for military projects and provide a good visual representation of project status. Gantt charts are discussed in section 4.3.1 in greater detail. Development from the Gantt Bar charts lead to CPM (Critical Path Analysis) and PERT (Program Evaluation Research Techniques).

CPM and PERT are very similar even though they were developed separately. However there is one difference which is significant if considering the maintenance function. The PERT system uses a statistical approach to project activity analysis. Scheduling systems have, traditionally, been based upon the idea of a fixed time for each task. However in the PERT system, three time estimates are obtained for each activity.

- an optimistic time (minimum)
- a most likely time (modal)
- a pessimistic time (maximum)

Two different types of activities have been defined. Firstly variable activities are those "which have possibly never been performed before, and which contain a considerable number of chance elements." Secondly there are deterministic activities which are those "whose mean value is accurately known and whose variance in performance time is negligible." (Definitions from Moder [22])

Because of the statistical nature of the PERT system, it follows that projects which involve variable activities would use PERT. Examples of these could be the excavation of unsampled soil or the performance of outdoor activities during heavy rainfall seasons.

On the other hand, CPM omits the statistical considerations and is based on the single estimate of the average time to perform an activity. Maintenance work is often repetitive and therefore on the whole can be considered to be deterministic. Traditionally it has been said that shutdown maintenance projects would generally employ CPM and not PERT. (Ref Moder [22])

This conclusion certainly is valid for those maintenance situations which do have deterministic activities. However, a compromise between the two may have an advantage in some applications. This would be that a PERT system is employed for all activities, but where the activities are well defined, the pessimistic, probable and optimistic times are made the same, and this enables the project planner to assign pessimistic, probable and optimistic times to those maintenance activities which are in fact **not** deterministic.

Having commented on the development of these planning and control tools, the next section of the report will describe the principles employed by them. It is of vital importance that the project manager and his team understand the techniques and structures of these tools.

The description of the methodology gives invaluable insight into the planning process and requirements for planning.

4.3.1 Gantt Bar Charts

Bar charts for project planning and control have been in use for some time. The bar chart is principally designed for the purpose of controlling the time element of a program. The essential components of a bar chart are the following :

- the scheduled start times of activities
- the scheduled finish times of activities
- the current status of projects (during implementation)

For a shutdown project then each activity (i.e. section of the work e.g. pump, turbine and motor overhaul) has estimated times and these are used to place activities in sequence. This process must take into account the requirements that certain activities must be performed sequentially (i.e. that activity B can only be done once A has been completed) while other activities can be performed simultaneously.

Thus when loading such a bar chart, the optimum combination must be chosen until the project satisfies a time limit and is scheduled to be completed by a specific date. Obviously here it is good if the planning can include some "slack" for unforseen problems which would cause delays.

A very simple example of a Gantt Bar Chart is given here to illustrate the principles included. The discussion presented relates to figure 4.1.

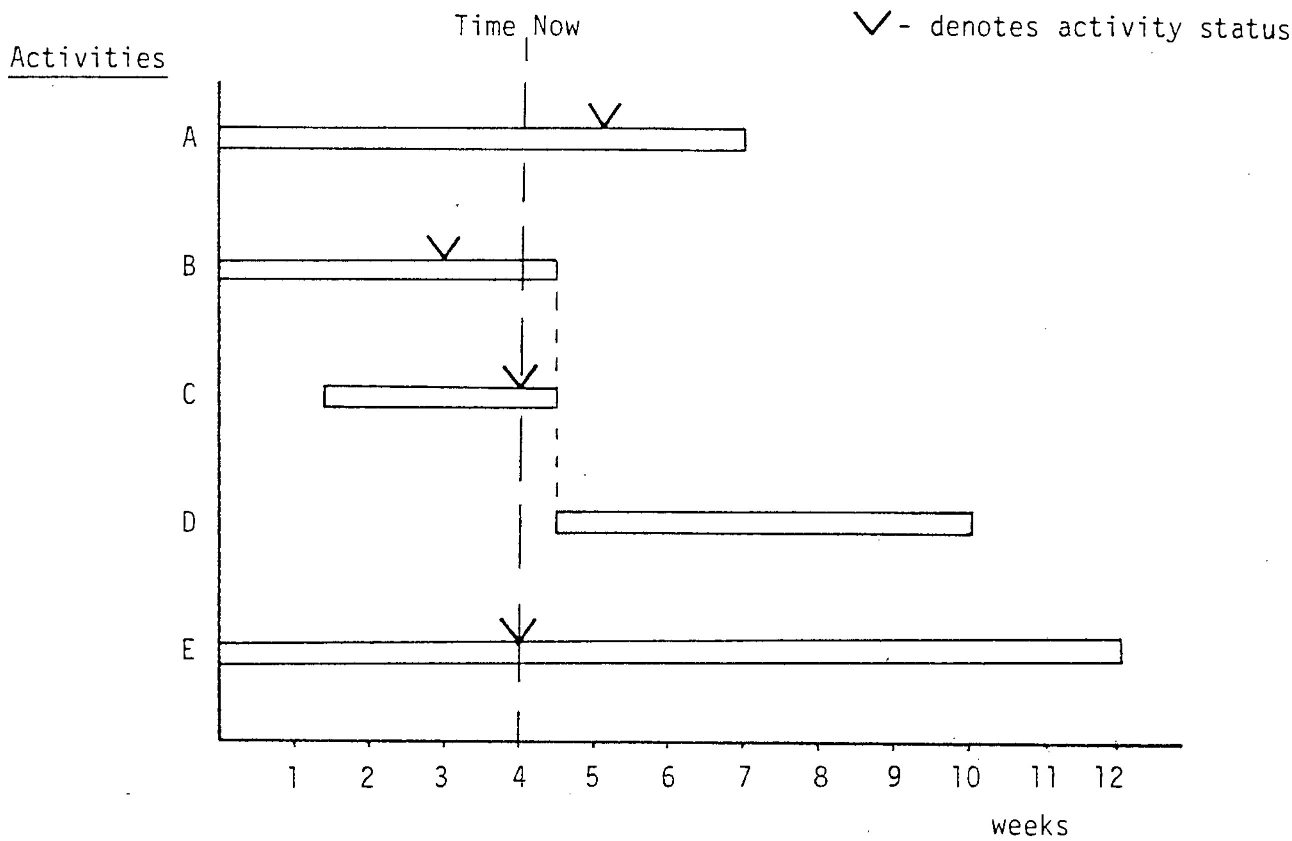

Figure 4.1 Gantt Bar Chart

The Gantt Chart is shown four weeks after implementation of the shutdown project. The bar chart itself however, is planned and completed before the shutdown starts.

From the bar chart it can be seen immediately that activity A is ahead of schedule, B is behind schedule, while C and E are exactly on schedule. Activity D can only start once activities B and C are complete.

An important advantage of this system is that it provides immediate (simple) visual information to the planner on the project status. The plan, schedule and progress of the project are all portrayed graphically together.

There are however, very real disadvantages to this system which cannot be ignored and which restrict its usefulness considerably. These are the following :

1. The bar chart does not show explicitly the dependency relationships among the activities. Thus it is difficult to calculate the effect that progress delays in specific activities will have on project completion. For the example given, this may not be obvious as there are only 5 activities, but realistic projects have many more activities and a more complicated dependency relationship.
2. The bar chart does not enable sufficient activity detail to be shown, so that for activities which have a long duration, schedule stoppages are not detected.
3. The bar chart is essentially a manual graphic procedure and for large projects will become very awkward and difficult to maintain.

The third aspect needs further discussion. Normal modern-day projects have many activities, often well over 1 000, with complex dependency relationships. The bar chart method does not in fact provide a logical systematic procedure which enables a planner to schedule effectively. That is, by the time he is placing activity "75" say on the bar chart, he has lost track of the first few activities, and then every time he needs to reschedule during the project, or when allocating resources, it becomes very difficult for him to pick up every outstanding dependant activity. The greater the number of activities, the more difficult and complicated this procedure will become. Essentially then, the point is that this method does not provide a logical systematic procedure or means whereby a planner can easily and quickly accommodate any changes, which reflect automatically on the dependency relationship of subsequent activities.

Thus it would appear that the usefulness of the Gantt Bar Chart as a controlling and scheduling tool is limited to projects which have a small number of activities and which have a simple dependency "structure". However, it should be noted that the fundamental principles of the Gantt Bar Chart system formed a basis for what is referred to as a network concept and hence CPM. In section 4.3.4 the use of Bar Charts in relation to CPM is discussed as a conclusion to this chapter. However, first CPM (Critical Path Method) is described.

4.3.2 Critical Path Method - Discussion

As has been discussed, network based planning methods emerged as a result of a need to be able to plan and control projects that contain thousands of activities which could take place in widely dispersed locations. One of the most significant objectives was to show the dependency relationship between project activities. Since many of these occur after one another, a path-like structure can be formed and the phrase "critical path methods" or CPM has since come into use. The **critical path**, can be defined as the activities, each of which depend on the completion of a preceding activity, that runs from start to finish of the project. Those activities which form part of this critical path are referred to as critical activities, while those that do not are referred to as non-critical activities.

Activities can be defined as any portion of a project which consumes time and resources and has a definable beginning and ending.

Moder [22] makes the following comment of CPM and maintenance and shutdown. "Maintenance and shutdown procedures, an area in which CPM was initially developed, continues to be a most productive area of application of critical path methods."

Moder [22] also lists some advantages of CPM:

1. **Planning** - Critical path methods first require the establishment of project objectives and specifications and then provide a realistic and disciplined basis for determining how to attain these objectives, considering pertinent time and resource constraints. It reduces the risk of overlooking tasks necessary to complete a project and it also provides a realistic way of carrying out detailed planning of projects, including their co-ordination at all levels of management.
2. **Communication** - Critical path methods provide a clear and unambiguous way of documenting and communicating project plans, schedules and time and cost performance.
3. **Control** - Critical path methods facilitate the application of the principle of management by exception, by identifying the most critical elements of the plan and by focusing attention on those activities which have a high priority. It continually defines new schedules and illustrates the effects of technical and procedural changes on the overall schedule.
4. **Training** - Critical path methods are useful in training new project managers and in the introduction and motivation of other personnel that may be connected from time to time.

5. **Psychological** - Critical path methods, if properly developed and applied can encourage a team feeling. The role that individuals play in the whole project is easily recognised and members thus can be made to feel important. The degree of progress can serve to encourage participants. It is good for empolyees to be able to see new plan fit together and how they fit into the plan.

An important aspect of project management is deciding who should be involved in CPM planning. Firstly there must be one shutdown maintenance project manager, who has control of the whole operation, and to assist him, various engineers need to be involved in the planning, construction and control of the project. These should represent all the various disciplines or departments involved during the shutdown. All the information and feedback must pass through this control centre so that the project progress can be monitored and the network modified where necessary.

An important aspect that is considered is that often the project manager assumes authority and responsibility which may differ from the traditional structure. When considering a maintenance shutdown project, various departments are involved and often this implies that the project manager will assume authority in some other departments during the shutdown period itself. This could be in conflict with traditional vertical lines of authority and responsibility relationships. Here then the project manager's managerial skills and tact would be tested in dealing with this situation.

4.3.3 Critical Path Method - Management Methodology

A summary of the steps involved in applying a CPM system to maintenance shutdown projects is given in this section. Figure 4.2 gives a diagramatic view of these steps and how they are connected. Each step is then described in greater detail.

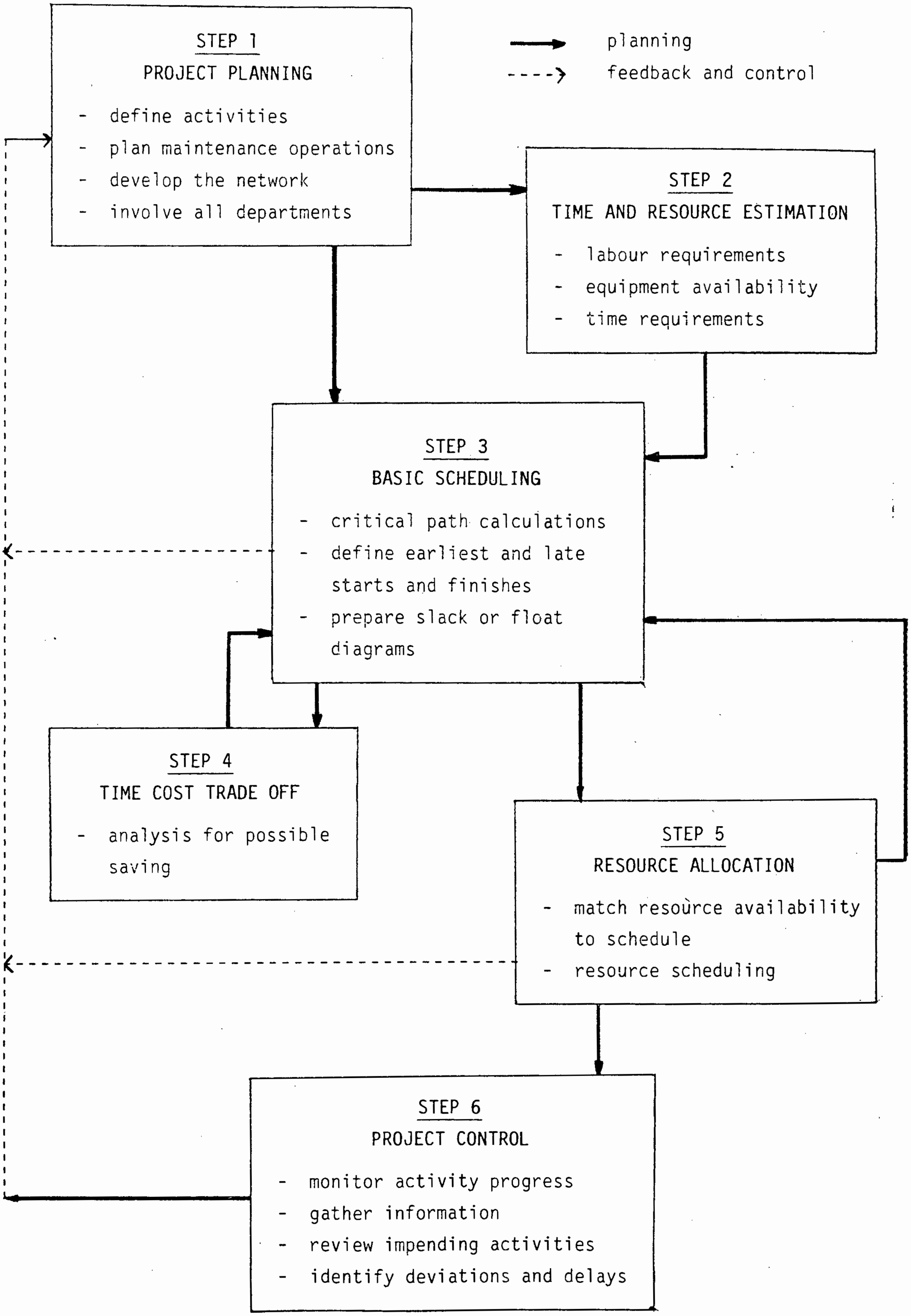

Figure 4.2 CPM Planning and Control

Step One - Project Planning

This first step involves defining all the maintenance operations and activities and their technological dependencies upon one another are shown in the form of a network diagram. This step involves setting up or developing the network. The network is essentially a plan or a sequence of activities which shows all the dependencies. This network should include all relevant details. This step is possibly the most important, because omitting some activities which have to be included later could have disasterous effects on the project progress and scheduling.

Step Two - Time and Resource Estimation

The time required to do the work that is planned and of course the resources to complete the work in this time must be estimated. As has been discussed a single time estimation is used for well defined jobs (deterministic), while a three time estimation method is associated with unknown, unpredictable (variable) activities. These estimates are necessary in determining earliest and latest starts and dependency relationships. Once incorporated in the schedule, these times will give an indication of the slack and float available for non-critical activities.

Step Three - Basic Scheduling

The basic scheduling computations give the earliest and latest starts for each activity. Here the critical path is identified. Once this is completed activites can be assigned priorities.

Step Four - Time/Cost Trade offs

For shutdown projects the shutdown period is often fixed and thus there is no real need for a time/cost trade off. However, once the basic scheduling has been done, the critical path will identify those activities which determine the completion date. In situations where this critical path is very dominant, that is, other non-critical activities have a lot of slack, a time/cost trade-off can easily be done. e.g. by doubling the workforce on one activity, the time could be reduced by say two weeks, which in terms of cost production may be R7 million (14 x 500 000 per day). This is weighed up against additional costs etc. Essentially the scheduling process provides a means of identifying areas of possible saving. This is an almost "separate" part of the system, or a by-product, as is seen in figure 4.2.

Step Five - Resource Allocation

The feasibility of each schedule must be decided with respect to resource availability. In step three the scheduling indicates the slack available on each path. By moving these activities forward or backwards the completion time is not affected. This enables the planners to allocate resources. **Resource levelling** is a valuable by-product of this planning system. This enables a project manager to reduce excessive "peaks" or "troughs" on resource demand curves. In order to obtain complete feasibility, recalculating and rescheduling may have to be done. This relationship can be seen clearly in figure 4.2. It may become necessary if no acceptable schedule can be achieved, to make changes in the project planning stage (step one).

Step Six - Project Control

Once the project is implemented, the CPM system becomes an effective way of maintaining and controlling the project's progress. Thus the progress of each activity is checked against the schedule and where necessary, changes are made. Feedback on all the activities is digested and the following information collected :

- periodic status reports
- elapsed status reports
- measured progress
- expected delays
- additional labour requirements

It is in this step that the loop to step one is closed and as required, various of the steps are involved in the whole process of monitor and control, and will be employed to accommodate deviations in the original plan.

This aspect falls into Phase 2 - Implementation which is discussed in greater detail in the following chapter.

4.3.4 <u>Gantt Bar Charts and CPM</u>

An important part of project planning and then project control, is being able to illustrate and present schedules and plans. In this sense bar charts have never become obsolete. Even though bar charts may not be useful as a planning tool, once a path network system has been established, the schedules can be transferred to bar charts to provide an accurate visual display of the whole plan.

Here it should be noted that this thesis has not attempted to educate the reader in CPM or PERT techniques. The reader may refer to many books, one of which is "Project Management with CPM and PERT" by Joseph J Moder and Cecil R Phillips.

4.4 COMPUTERS AND SHUTDOWN MAINTENANCE

The role of computers and their very profound influence on maintenance management and shutdown projects is a field of study on its own. Some significant advantages are mentioned here.

Simulation

The use of computers has enabled project planners and managers to determine the effects that specific situations would have on project progress. This is because by changing the information input, it is possible to simulate a variety of possibilities and to test numerous determinants. In the past this would have been far too time consuming as this simulation would have had to have been done manually. A result is that it has become possible to obtain the best possible schedule, or optimise resource allocation.

Presentation

The use of computers has also enabled project managers and planners to obtain graphical presentation (bar charts, resource curves) easily and of course more accurately. The frequency with which these can be generated is also increased.

Computers have on the whole been very useful to project managers, but it should always be remembered that they are still only a tool and can only be effective if used correctly. The networks that are available commercially are developing and being improved continually. More and more software on different computer systems is now available. Personal computers (PC's) in particular, which have been developed in the last 10 years, have become indispensible to project managers.

CHAPTER 5

PHASE 2 - IMPLEMENTING AND CONTROL OF SHUTDOWN PROJECTS

When the time of the shutdown is reached, the planning and preparation should be complete. The plan and schedule are put into operation as the plant or facility is shut down. The first work is started and the value of the planning and preparation is put to the test. The success of the implementation and shutdown stage of the project depends entirely on the success achieved in phase 1, the planning stage. Project monitoring and control are an essential ingredient in achieving success in the implementation of the plan and schedule.

This chapter deals with the implementation and control of the project. There are many factors which influence the progress of shutdown projects and it would be important for any shutdown project manager to be aware of these so that they are identified as soon as they occur.

5.1 FEEDBACK

The only way that project managers can monitor or control the project progress is through feedback. From Kelly [13] "Large shutdowns are normally planned in one-hour time units; ideally progress reports should be made every two hours. They should be delivered to centrally located planning engineers and should include the following information :

1. The estimated completion time of all live activities
2. The actual completion time of activities
3. A review of impending activities and resources required
4. Excess or short falls in resources
5. Additional work arisen and arising."

It is essential that the project managemer is informed of all deviations and problems etc as they occur. This enables the manager to make decisions as to what corrective action should be taken.

Documentation

A simple but effective form of documentation for all the work is of vital importance to effective project management. At any stage of the project the project manager must be able to trace all scheduled job cards and the system must ensure that no job cards can get lost. A simple system that is used effectively is that for each operation there are 3 copies of the job card. (See Figure 5.1) Copy 1 stays in the planning centre and copy 2 and 3 are both signed for by a foreman (supervisor). The artisan signs for copy 3, while copy 2 stays with the supervisor. When the job is complete, copy 3 is returned to the supervisor, who then returns copy 2 and 3 to the planning centre.

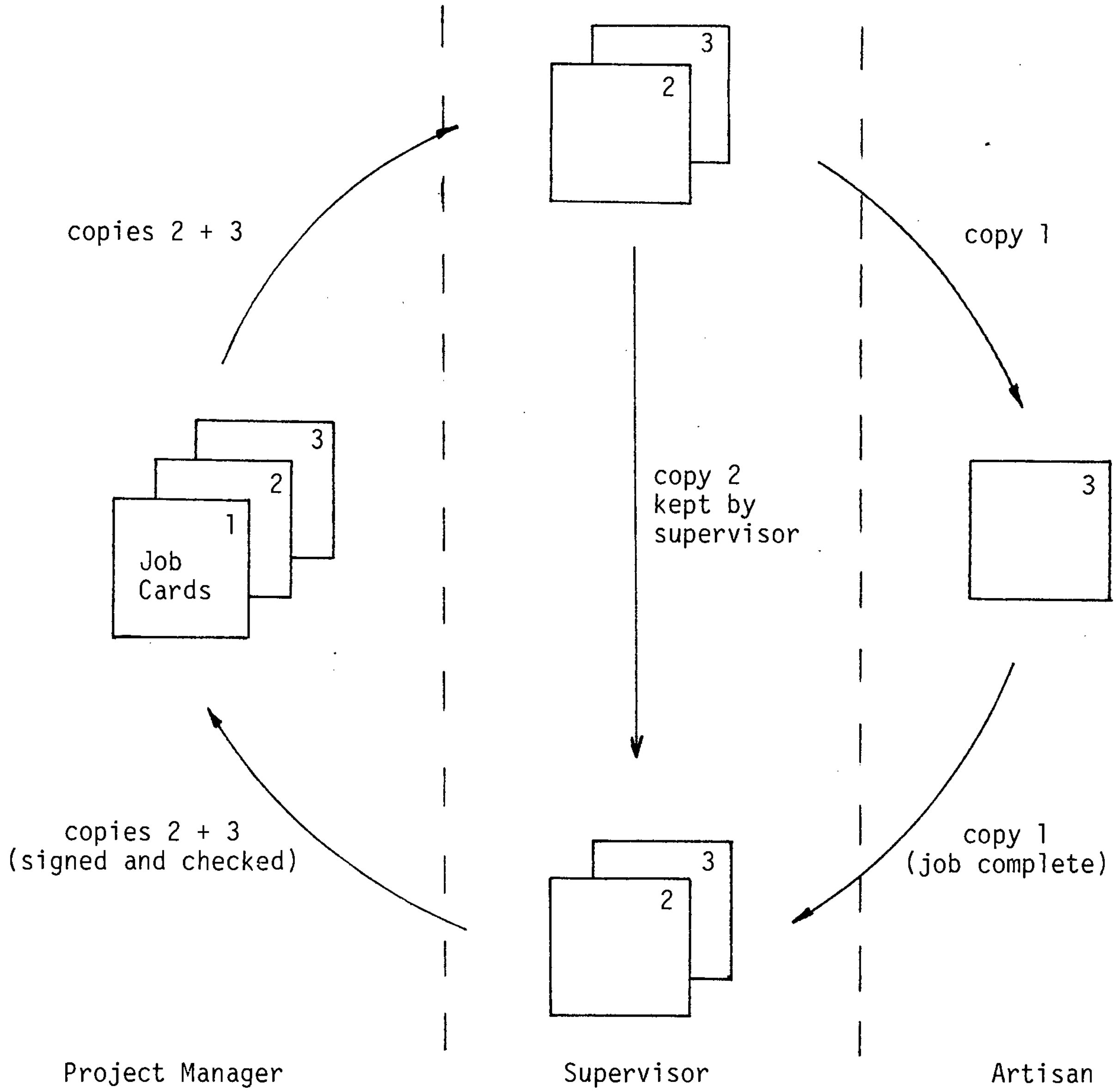

Figure 5.1 Simple Job Card System

The most important objective of such a system is to ensure that all work is accounted for. This is particularly important when assessing the project status, or even when the start-up stage is reached. The plant cannot be restarted until all job cards have been returned or accounted for.

5.2 RE SCHEDULING

Once such a maintenance shutdown project gets under way, changes in the time and resource requirements will cause the schedule to become inaccurate in places. As these changes occur, the project managers will have to make appropriate changes to the schedules and plan for additional work and resources. This control procedure is illustrated in Figure 4.2.

5.3 SHIFT WORK

An aspect of project work which deserves mention here is that of shift work communication. For shutdown projects it is inevitable that there will be shift work, and it is crucial that information is carried from one shift to the next. All changes in the schedule must be noted and all oustanding work and job cards must be carried over so that there are no gaps in the system after a shift change over. It is vital that the new shift workers know exactly what needs to be done as soon as they come on duty. Feedback to the "control centre" must be **documented** and carried over if it has not yet been taken into account and does not reflect on the schedule by the time change over occurs. It is often in this shift change that special tools and spare parts are misplaced, which can cause costly delays in the work progress.

5.4 PROJECT STATUS

Throughout the project the project management must assess the project status. This should be done as often as possible. Assessing the project status means to identify each critical ("Line") activity and to determine whether or not it is running on schedule. This highlights good and bad areas and thus enables the project manager to take corrective action. Other activities (non-critical) are also monitored.

The status of the project should be communicated to all levels of the organisation to provide as an encouragement when on schedule and as an incentive when the project is lagging behind. In this respect, graphical and visual displays (bar charts) are very useful and should be used as much as possible.

CHAPTER 6

PHASE 3 - COMMISSIONING AND RESTART

Once all the activities on the schedule have been completed there is one more activity which must be done before the whole shutdown is complete. The plant or facility must be brought back on line. While this chapter treats this as phase 3, this activity must be scheduled for in the planning stage as part of the shutdown project. The work that needed doing must stop before the end on the shutdown period and some time must be allowed for the process of actually starting up. At start up, the question everybody asks themselves is, is it going to work?

6.1 JOB CARDS AND LOCK OUTS

Before any restart is allowed, every job card must be accounted for. It must be certain that all the work is complete, and if not that it has been accounted for.

Lock outs are described as follows: Before some work on specific components can be done, the equipment must be "made safe". Often this involves locking up an electrical switch board, or uncoupling a drive. The artisan will then keep the key to the lock and the supervisor must be aware of the situation. Once complete, the lock must be removed or the drive recoupled before the job card is returned. This has two obvious implications. Firstly that at start up the safety of all the workers is ensured and secondly that no damage can be caused unnecessarily.

6.2 INFANT MORTALITY

There is an old adage which states "if it works don't touch it". This is because often components which are replaced or serviced are prone to early failure due to mechanical fault or faulty workmanship. It is not always possible to ensure that every component worked on during a shutdown will not fail. In fact it is true that often it will fail soon after start up, or not at all. Hence the term infant mortality and a need to be prepared.

Because of this, problems may arise and there is a need for the following to be on stand-by during the start up and for some period after start up:

- electrical department
- fire fighting department
- anti-gas equipment on hand
- first aid

6.3 POWER CONSUMPTION AT START UP

Because of the way in which electrical expenses are calculated, it may be important for some installations to do the start up during a trough in their electricity demand curve. The reason for this is because one electrical change, called a maximum demand charge depends on the highest peak of the demand curve of a plant. Thus if the start up is scheduled to occur during a peak demand period it could cause an even greater peak, thus increasing the maximum demand charge.

6.4 POST MORTEM AND REPORTING

An important activity to be done after the start up is completed is that of critically assessing the shutdown project. What went wrong? Information and experience gained during shutdowns should be collected. Here different departments need to be involved and at a meeting the success and failures of various aspects of the project should be discussed in an attempt to accommodate them in subsequent shutdown projects.

It is important that all those included in the shutdown have an opportunity to provide feedback after the shutdown. Employees at various levels can often offer invaluable information because of their more direct involvement with the actual work.

6.4.1 Modifications and Replacements

All documentation on modified and replaced parts must be compiled and included in the plant data system. Special information regarding maintenance procedures, spare parts and operating instructions need to be included.

6.5 HOUSE KEEPING AND FINAL CONSIDERATIONS

6.5.1 House Keeping

During shutdown periods house keeping is often neglected. Also, becuase of the volume of work, materials and spares (used) accumulate in production areas. These need to be cleared away and restored if new or reusable, or discarded.

6.5.2 <u>Recognition by Management</u>

Because shutdown periods usually involve tremendous work input by employees and also accrue massive economic benefits if successful (i.e. no overruns) it is important that management acknowledge the efforts of workers. This can be done in a number of ways. Congratulatory letters to all departments, or special leave (long weekends) or other bonuses are some of them. This is vital for future shutdowns as motivation and committment are essential if shutdown works are to be successful.

CHAPTER 7

SOME REASONS WHY SHUTDOWN PROJECTS FAIL

Finally, to conclude the discussion on conducting shutdown maintenance projects, one should take a look at common problems which cause such projects to fail. This information is found in case studies where specific areas have been pin-pointed as being the reason that the project did not succeed in all its objectives. These are things which the project manager should be specifically aware of throughout the project. The discussion is divided into two parts; those problems related to project management and those related to people management.

7.1 PROJECT MANAGEMENT

7.1.1 Improper Focus of Project Management

It is important that during a maintenance shutdown the project manger keeps his focus on the project objectives. There is often a danger that he becomes absorbed in the project management **system** that is being used to monitor and control the project. When this happens he becomes a network manager and no longer a project manager. Here, the schedule or network becomes the project, whereas it should be helping to manage the project. It is important to remember, the shutdown manager must manage the shutdown project and not a project management **system**.

7.1.2 Information Indigestion

It is important that only information which is useful to manage and control reaches the project manager. Too much detail will tend to bog down a manager while too little will make it difficult to make decisions.

7.1.3 Understand Project Management System

Many good and effective management systems are rendered useless because the people using them do not completely understand the principles and techniques involved in using them. The project manager must ensure that all those involved in project management know how to use the management system. Some training may be necessary to ensure that this is not a problem.

7.2 PEOPLE MANAGEMENT

This aspect of project management is an important one and is a study field in its own right. Successful people management is vital if a project is to succeed. Some points of special interest are mentioned.

7.2.1 Creating a Communication Environment

A basic principle of project control is that of feedback so that corrective action can be taken. To this end it is important that the project manager creates an environment which makes it easy for people working to share all difficulties they have. If this is not so, often problems arise and because they are not reported quickly, they soon become unmanageable and then cause unnecessary delay.

Another vital aspect is that of communicating project goals to those involved and keeping workers informed of the progress of the project. A lack of this easily causes low motivation. From Hughes [23], "An employee's perception of his or her job can be greatly influenced by a project manager. Fitzens (1978), in his job satisfaction study, ranked factors of job satisfaction in order of importance to employees. The top five were 1) achievement, 2) possibility of growth, 3) work itself, 4) recognition and 5) advancement."

This also illustrates another point, that of acknowledgement. It is important that employees are acknowledged for their efforts and successes. Simple "good work" memos are one example of such acknolwedgement.

7.2.2 Number of People in Management

Never have too many people in control. As soon as there are a number of managers whose interests clash, a potential conflict area arises. The number of managers must be limited to those that are required and the scope of their authority must be clearly defined with no or very little overlap. Conflicting decisions and opinions are a sure way of retarding project progress.

CHAPTER 8

INTRODUCING CONDITION BASED MAINTENANCE AND THE EFFECT IT IS HAVING ON SHUTDOWN MAINTENANCE

Shutdown maintenance is and always will be very expensive. The need to do it and the implications of poor shutdown project management have already been discussed in detail. A question which does arise is how often is shutdown necessary and what can be done about reducing the costs and impact that shutdown projects have on a company's profits?

This chapter looks at a development in maintenance thinking and which has made a large impact on maintenance and has definite advantages and benefits in minimising the impact of shutdown maintenance projects. This is called **condition based** or **on-condition** maintenance.

8.1 INTRODUCTION

What had by the late 1960's become a traditional view of failure patterns, was that most components would last for a given period X, after which one could expect a rapid increase in the incidence of failure. Preventative maintenance theory suggested that all one needed to do was to accumulate masses of records which would eventually reveal what the life of a component was, and then to undertake to replace that component shortly before it was destined to fail the next time.

However, while this theory may hold true for simple components and equipment, the same cannot be said for complex equipment. This is particularly significant because, along with industrial growth over the last two decades, has come the development of more sophisticated and complex equipment and its use in industry.

A pertinent study on the failure pattern of components in an aircraft industry illustrates these concepts well. (From Patton [10] Six failure patterns were identified and are presented as reliability failure plots. Corresponding values of the percentages of components exhibiting each failure pattern are also given. These are shown on Figure 8.1.

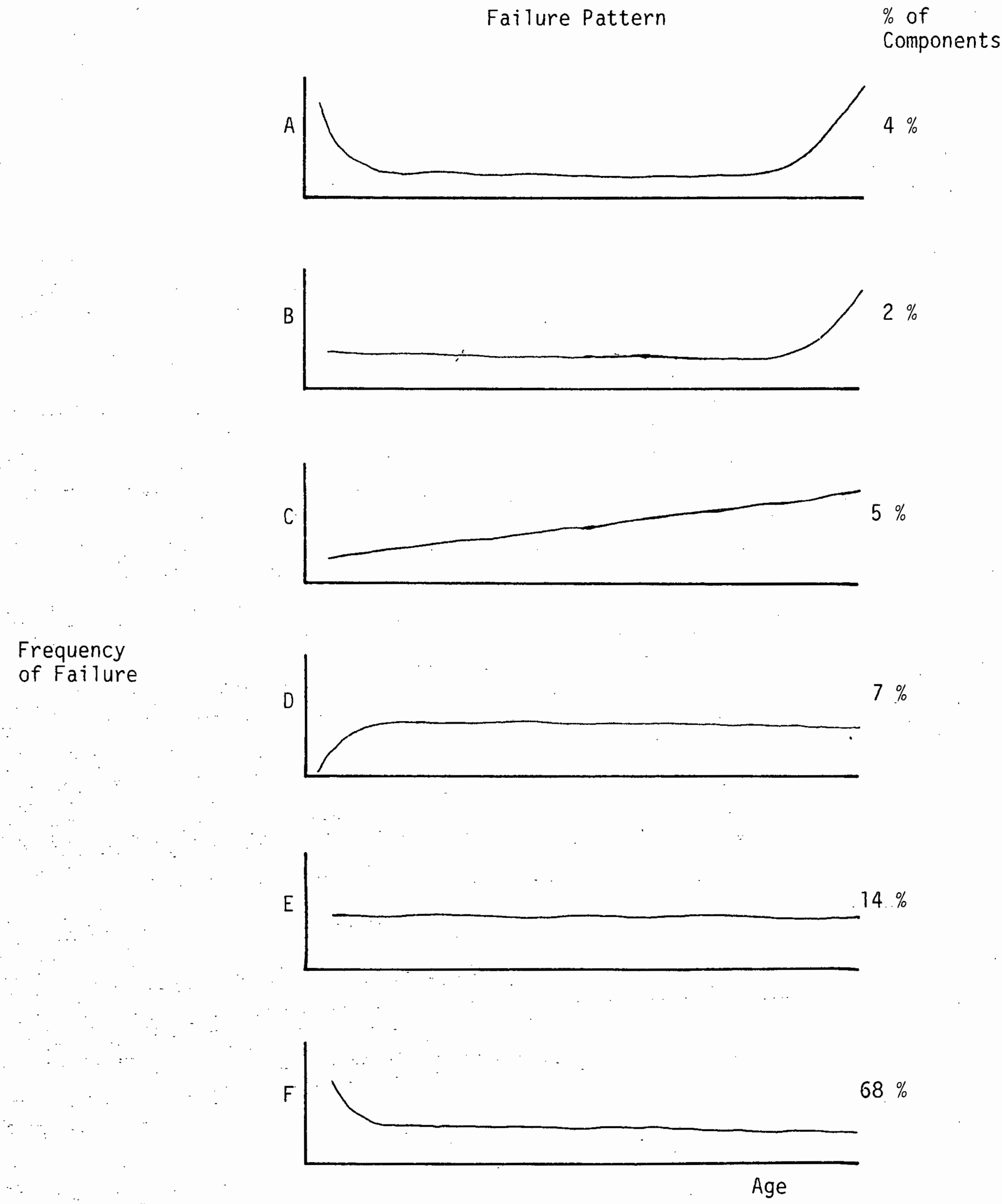

Figure 8.1 Failure Patterns in Aircraft Components

Only the first two of these patterns, A and B, exhibit the "traditional" view of component failure i.e. show a pronounced "wear-out" region. Together they form a mere 6 %. Pattern D, E and F in particular show a marked deviation with no apparent "wear-out" range. Together these contribute 89 %.

Thus for 89 % of the components no age as such can be defined as the beginning of a "wear-out" zone. For this reason, an age limit does little or nothing to improve the overall reliability of a complex item. "In fact in many cases scheduled overhaul actually increases the overall failure rate in an otherwise stable system." (From Moubray [16])

Moubray [16], also goes on to say that "An important point to emerge from this research is that in many cases, in fact in most industries, the concept of regular scheduled overhauls of complex equipment is not only obsolete, but actually counter-productive,"

Because of this development there has been a move away from trying to find fixed time intervals at which scheduled work or replacement of components should be carried out. Instead there is an increasing trend towards inspection procedures designed to detect imminent failure and then to take corrective action. Thus condition based or on-condition maintenance has become an important part of maintenance technology. What it is and how it affects maintenance is discussed in the following section.

8.2 CONDITION BASED MAINTENANCE

Condition based maintenance is adequately described as **predictive** maintenance. By monitoring the condition of equipment and components, maintenance personnel do shutdown maintenance only when they have to.

In order to do this, maintenance personnel must have ways of knowing and determining the condition of the plant. Many associated **condition monitoring** techniques have developed.

The basic principle of condition monitoring is to select a suitable measurement or measurements, which are sensitive to component deterioration and then to take readings of this measurement so that any changes in the condition are noticed. Techniques are aimed at achieving two things. Firstly, to detect that a problem exists and secondly to determine the exact nature of a problem.

Condition monitoring is a wide and developing field in industry with much work being done in establishing condition monitoring techniques. However, there are four basic types of methods used for condition monitoring. (From Neale [17])

" 1. Directly checking that components are correctly performing their basic function. For example structural components may be checked for cracks, or bearings' temperature measured.
2. Vibration measurement of machinery to check if incipient defects in moving parts are giving rise to increased vibration levels.

3. Wear debris analysis which uses the fact that the machine components are washed by the lubricating oil and any distress, particularly at relatively moving parts, is likely to give rise to wear debris particles.
4. Monitoring the performance of a machine as a whole to see whether its operating characterisitcs have changed."

8.3 THE EFFECT ON SHUTDOWN MAINTENANCE

The aims of condition based maintenance are firstly that the plant is only shutdown when it needs to be and secondly that all breakdowns during actual operation are avoided. Thus only those components which require attention are worked on.

The effect that such a policy would have on shutdown maintenance would be to reduce the time required for shutdown as well as the extent of the shutdown. This is illustrated in figure 8.1. The economic implication can easily be seen. The money saved due to smaller shutdown results from reduced loss of production and smaller maintenance effort.

Another result of on-condition maintenance is that due to reduced routine maintenance there is less "infant-mortality" and the plant availibility and condition is increased. Refer to figure 8.3.

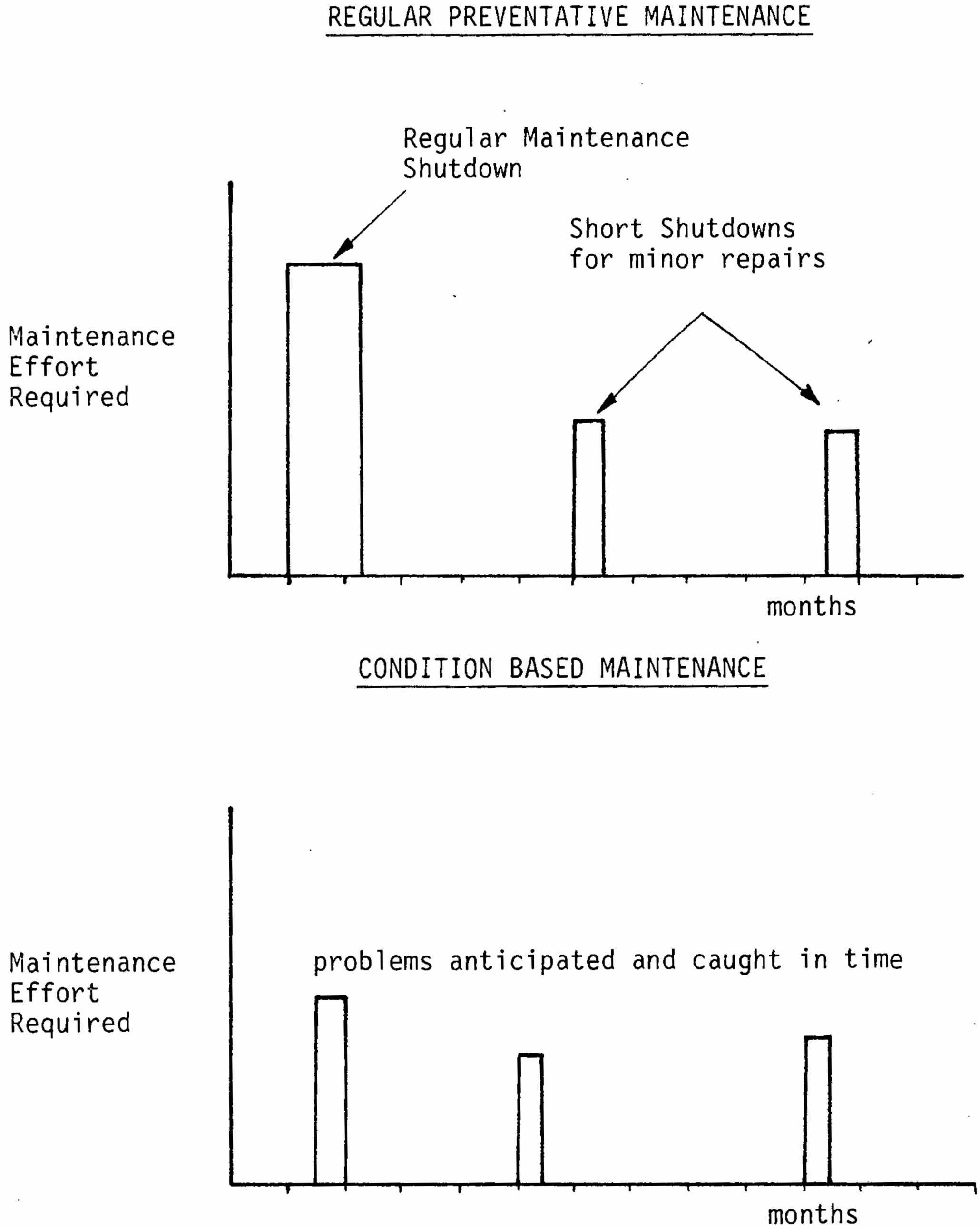

Figure 8.2 The Effect of Condition Based Maintenance on Shutdown

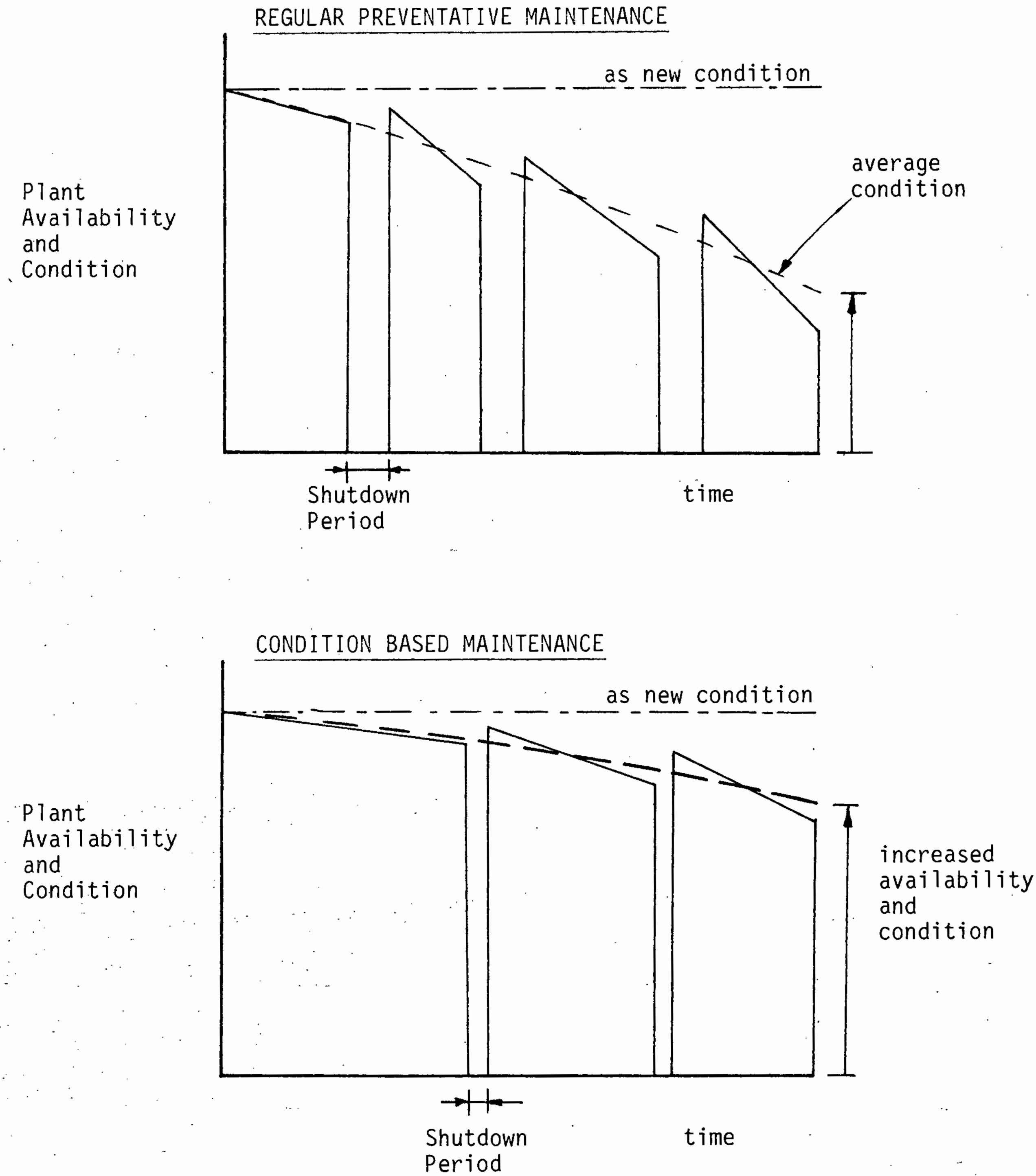

Figure 8.3 Increased Availability and Condition Due to Condition Based Maintenance

This has the effect of decreasing the rate of the deterioriation of plant and equipment. Consequently the time intervals between overhaul and shutdown are lengthened and the associated immediate drop in equipment condition after shutdown delayed. This results in increased plant availibility and because the condition of the plant and equipment is higher, improved product quality on company profits.

Finally then, even though the need for shutdown projects will not be eliminated, it can be seen that **on-condition** maintenance certainly has had and can have a profound effect in reducing the negative impact that shutdown maintenance projects have on company profits.

REFERENCE

1. "Schedule Maintenance Code of Practise", Somerset West Factory, AECI.

2. AMOS, John.M. and SARCHET, Bernard.R., "Management for Engineers", Prentice Hall (1981).

3. ROBINSON, N., "Making Maintenance Work", Industrial Management and Data Systems, May/June (1982) p. 6-7.

4. KELLY, A.G., "A plan to reduce forced outages in power stations", Proc. Instu, Mech Engrs., Vol 198A, No 1 (1984).

5. SHERWIN, D.J., "An investigation of the application of failure analysis to decision making in maintenance of process plants, PART 1", Proc. Instu. Mech. Engrs. Vol 194 (1980).

6. SHERWIN, D.J., "An investigation of the application of failure analysis to decision making in maintenance of process plants, PART 2", Proc. Instu. Mech. Engrs. Vol 194 (1980).

7. PATNAICK, S.P. and MOHANTY, R.P., "Setting a design-out-maintenance programme in an integrated steel plant", Maintenance Management International, 5, (1985), p. 155 - 160.

8. JARDINE, A.K.S., "Operational Research in Maintenance, Manchester University Press, (1970), p 44 - 60.

9. JARDINE, A.K.S., "Maintenance, Replacement and Reliability", Pitman Publishing (1973), p. 116 - 134.

10. PATTON, J.D.(Jr), "Preventative Maintenance", Prentice Hall Inc. (1983).

11. MANN, L.(Jr), "Maintenance Management", Lexington Books (1983).

12. WHITE, E.N., "Maintenance Planning, Control and Documentation", Gower Press (1973), p. 16, 22.

13. KELLY, A. and HARRIS, M.J., "Management of Industrial Maintenance", Butterworth & Co (Publishers) Ltd, London, (1978).

14. HUSKINS, T. "The Dilemma of Contract Industrial Staff", Industrial Management and Data Systems, JULY/AUGUST (1984), p. 3 - 4.

15. MITCHELL, J.S., "Condition Monitoring", Mechanical Engineering, December (1985), p. 32 - 37.

16. MOUBRAY, J.M., "A Strategic Framework for Maintenance Management", The 1985 Maintenance Management Convention, Proceedings, Johannesburg, SAIME, Keynote Session 1.

17. NEALE, M.J., "Condition Monitoring Principles and Methods", The 1985 Maintenance Management Convention, Proceedings, Johannesburg, SAIME, Session A1.

18. BROOKS, A.M., "Condition Monitoring - An Historical Approach", The 1985 Maintenance Management Convention, Proceedings, Johannesburg, SAIME, Session A8.

19. McELROY, B.R., "Contracting of plant services", The 1985 Maintenance Management Convention, Proceedings, Johannesburg, SAIME, Session B9.

20. VERSTEEG, J.A.J., "Establishing the Essential Maintenance Management Information Requirements", The 1985 Maintenance Management Convention, Proceedings, Johannesburg, SAIME, Session C7.

21. HUGHES, P.E., "Why Projects Fail; The Effects of Ignoring the Obvious", Industrial Engineering, 18, April (1986), p 14 -18.

22. MODER, J.J., "Project Management With CPM and PERT", Van Nostrand Reinhold Publishers, 2nd Ed, 1970.