UNIT 2 MAINTENANCE OBJECTIVES AND STRATEGIES

Objectives

After studying this unit, you will be able to:

- understand functions and objectives of maintenance,
- understand the scope and limitations of different maintenance strategies,
- decide the best maintenance strategy for a given item,
- understand the scope of new maintenance approaches like proactive maintenance, reliability centred maintenance and total productive maintenance.

Structure

2.1 INTRODUCTION

In recent times industrial plants have come up with large number of automated and sophisticated machinery with complex control systems. With the coming of large size plants, investment costs have increased. Maintenance expenditure forms 3.5% to 5 % of the sales turnover. The poor functioning of many industries is generally because of lack of efficient maintenance of production plant and equipment.

The increased emphasis on equipment availability, performance, quality, environment conditions and safety considerations has made maintenance function very important. Maintenance involves a combination of activities by which equipment or system is kept in, or restored to, a state in which it can perform its designated functions. The rationalization of maintenance function requires a deep insight into what maintenance really is. Raising the efficiency of maintenance does not entail carrying out the wrong kind of work efficiently. Efficient maintenance is a matter of having the right resources at the right place at the right time, to do the right job, in the right way.

To achieve this one has to understand the nature of maintenance, its relationship with production, and the functions and objectives of the maintenance department.

2.2 FUNCTIONS AND OBJECTIVES OF MAINTENANCE

As discussed earlier industrial maintenance could be considered as a sub-system of an industrial organization enabling the plant to fulfill its specified function for specified time. To enable the plant to achieve this the main functions performed by the maintenance are:

- Cleaning, lubrication and topping up
- Adjustment/Calibration
- Condition assessment
- Repairs and
- Replacements

Maintenance sub-system requires input of resources and information and provides outputs in the form of plant useful-life, availability, performance, quality and safety. Maintenance management finds the most economical ways of performing the desired maintenance functions. Figure 2.1 explains the functions of a maintenance sub-system.

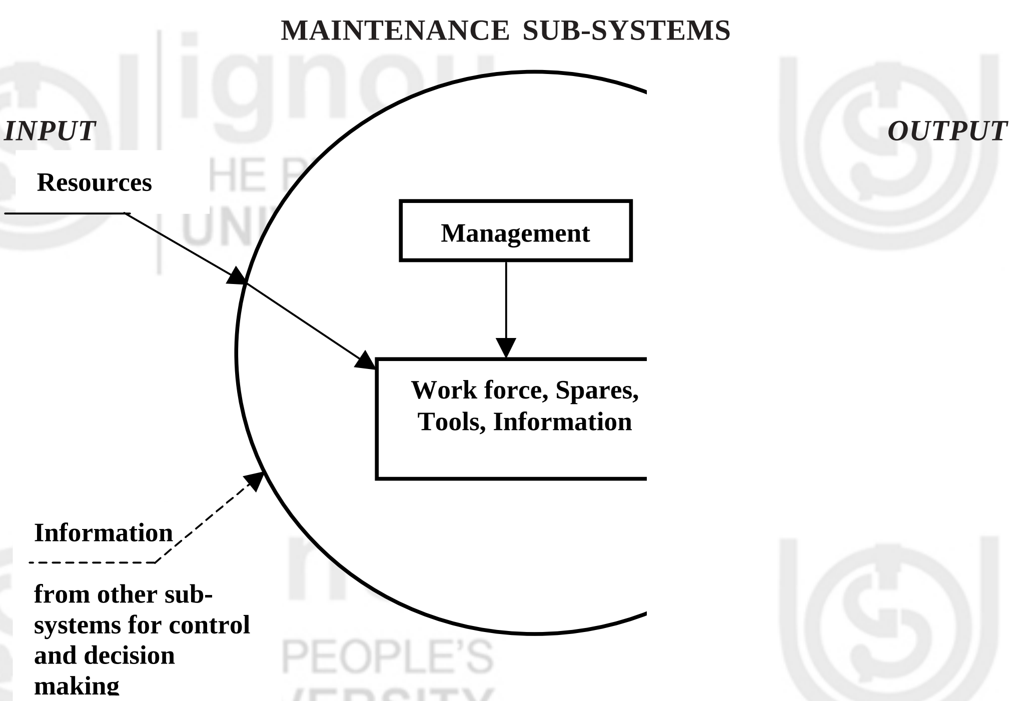

Figure 2.1 : Functions of a Maintenance sub-System

The objective of a production department in any industrial plant is to achieve a planned output in a specified time. This planned output is normally a function of sales demand. It determines the long term and short term production plans fixing the availability requirements of the plant. At any point of time the condition of production units of a plant can be represented as in Figure 2.2. The plant, or some part of it, may be in one of the following states:

a) In production and only 'running maintenance' can be carried out.

b) Not being used for production and is available for maintenance without any production loss. This is the 'production window' where 'shut down maintenance' will not incur production loss. These production windows may be scheduled or may occur with random incidence. The example of production windows are week ends, night shifts, or during feedstock shortage.

c) Out of production because of scheduled maintenance and will incur production loss.

d) Unexpected breakdown and undergoing emergency maintenance. It incurs production loss and the maintenance is difficult to plan.

e) Unexpected breakdown and waiting for maintenance because of shortage of m[...]t incurs production loss.

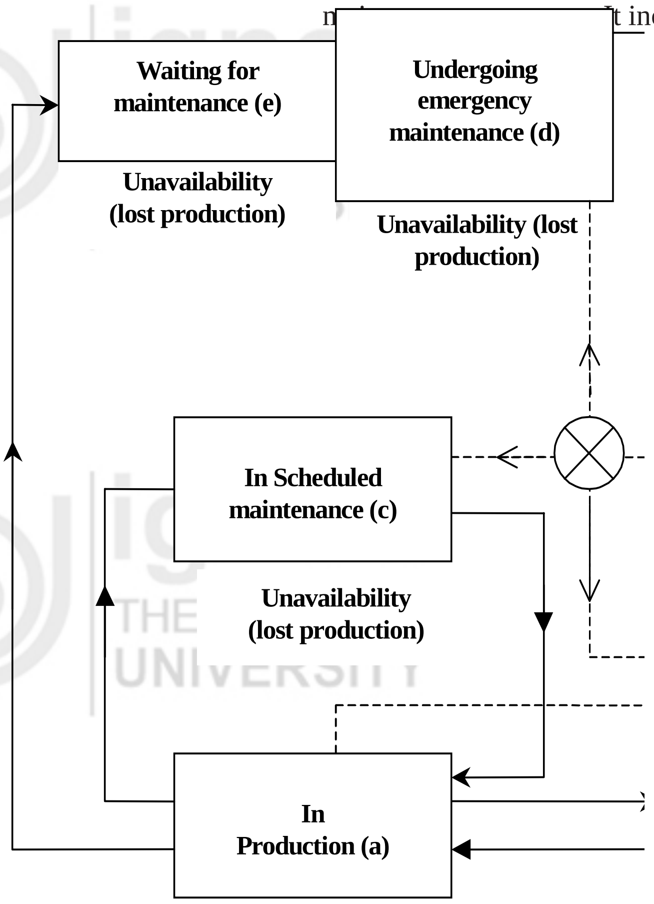

Figure 2.2 : The Maintenance/Production System

In *Fig. 2.2* maintenance is shown as pool of resources (men, spares, tools and information) directed towards achieving desired availability and plant condition following a maintenance plan. To decide on a maintenance plan it is necessary to establish maintenance objectives. These objectives should be compatible with the company objective and must be linked to profitability.

Maintenance resources are used to prevent failure or to respond to failure or unacceptable deterioration. Maintenance resource cost (direct cost of maintenance) and un-availability cost (indirect cost of maintenance) affects company profits. In general, greater the level of maintenance resources the lower the level of unavailability and longer the useful life of the plant. Thus the maintenance objective should be to minimize the sum of the direct and indirect costs taking into consideration the long-term effect of maintenance decisions.

Thus the main maintenance objectives can be stated as follows:

a) To enhance overall equipment effectiveness by maximizing availability, performance and quality rates and obtaining maximum return on investments.

b) To extend the useful life of assets by minimizing wear and deterioration.

c) To ensure operational readiness of all equipment at all times and for emergency use.

d) To ensure safety of personnel using facilities and achieve acceptable safety.

e) To provide all this at minimum resource cost.

Activity A

Are the above objectives at par with objectives of your maintenance department? If no, then write down the objectives of your maintenance department.

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2.3 MAINTENANCE STRATEGY

Any industrial plant consists of different functional units. These units are divided into sections and each section may have number of machines. These machines are further sub-divided into sub-assemblies and finally into the lowest level, *i.e.* components.

Maintenance is generated from component level. When a component is unable to perform its desired function, it is said to have failed. The loss of function could be contained at component level or have consequences at plant level, depending on the design of the plant, e.g. on the amount of interstage storage or redundancy. The loss of function could also have safety consequences.

Many of the machine components are designed with a useful life greater than the longest plant production cycle. In most cases such short life components will have to be identified at the design stage and made easily maintainable at component level without affecting plant availability and safety.

Other machine components will fail for reasons such as poor design, poor maintenance or mal-operation and may be expensive to maintain. It may require replacement of a higher-level assembly. In addition, as the plant ages component and assembly failures may increase. To keep the plant operating at desired level of output and safety proper maintenance strategy is required.

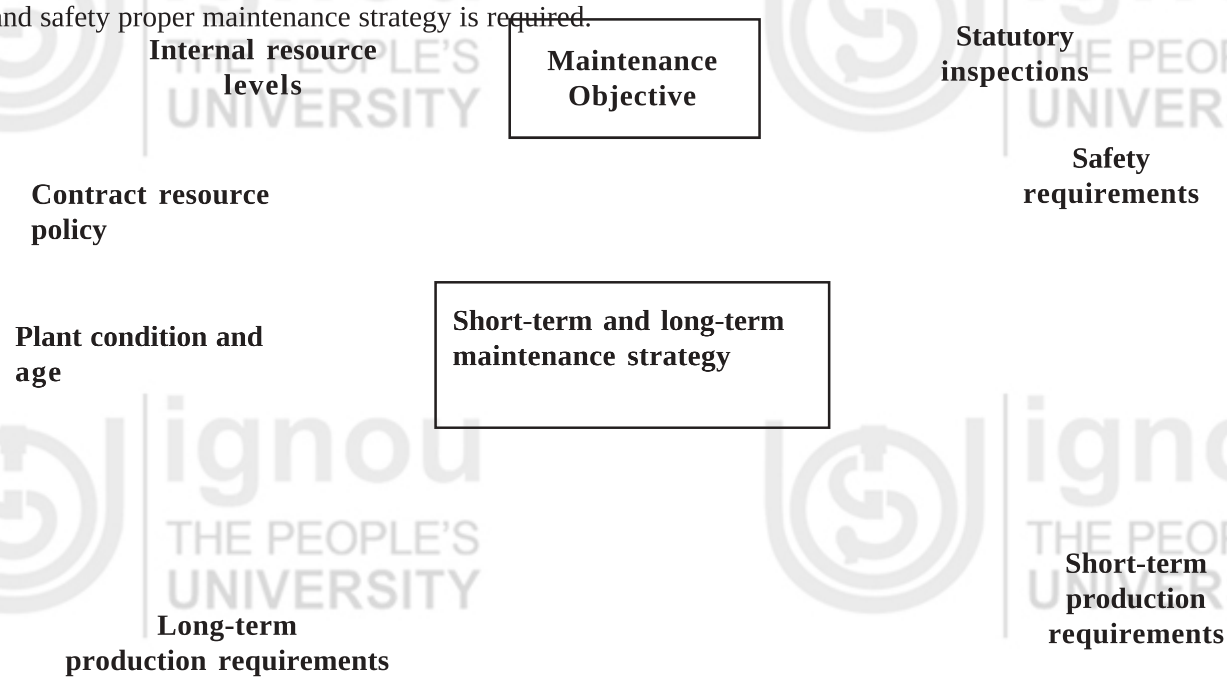

Figure 2.3 : Factors Affecting Maintenance Strategy

Maintenance strategy is concerned with identifying the components of the plant, which might require maintenance, determining the most appropriate maintenance procedure and then listing the procedures in the form of a schedule for a plant.

The maintenance strategy is a function of the production-maintenance relationship and therefore in most situations will be subject to change. The factors that influence the maintenance strategy are shown in Figure 2.3.

The commonly used maintenance strategies are as follows :

a) Break-down maintenance/Corrective maintenance
b) Fixed time maintenance/Preventive maintenance
c) Condition based maintenance
d) Opportunistic maintenance
e) Design-out maintenance

2.4 BREAK-DOWN MAINTENANCE /CORRECTIVE MAINTENANCE

In breakdown maintenance the equipment is allowed to run till it breaks down and then maintaining it and putting back to operation. Here most of the maintenance tasks are reactive to breakdowns or production interruptions and the only focus of these tasks is how quickly the machine or system can be returned to service. The failures may often cause large secondary damages to surrounding machinery before they are discovered.

In breakdown maintenance most of the corrective maintenance work is poorly planned because of the time constraint imposed by production and plant management. As a result, manpower utilization and effective use of maintenance resources are minimal. Breakdown or reactive maintenance may cost three to four times more than the same corrective maintenance work when it is well planned. Another limitation of breakdown maintenance is that it concentrates maintenance work on obvious symptoms of the failure and not on the root cause. As a result, the reliability of the machine or system is severely reduced.

Corrective maintenance is limited to those tasks performed in order to restore the machine or system to acceptable operating condition after a failure has occurred.

All corrective maintenance tasks are generally accomplished in four steps :

i) Fault detection
ii) Fault isolation
iii) Fault elimination and
iv) Verification that the fault has been eliminated

Fault elimination may be accomplished in any one of the three ways, depending on the nature of the fault :

a) **Adjust/align/calibrate**

Restoring the equipment or the system to acceptable functional condition by adjustment, alignment or calibration of a circuit or component controlling a critical performance parameter. To adjust is to vary the setting a controller until the performance parameter that it controls is brought into an acceptable state or falls within an acceptable range. Adjusting the carburetor of an automobile for minimum fuel consumption at cruising speed is an example of carrying out adjustment.

Figure 2.4 shows the work flow in a correcitve maintenance cycle.

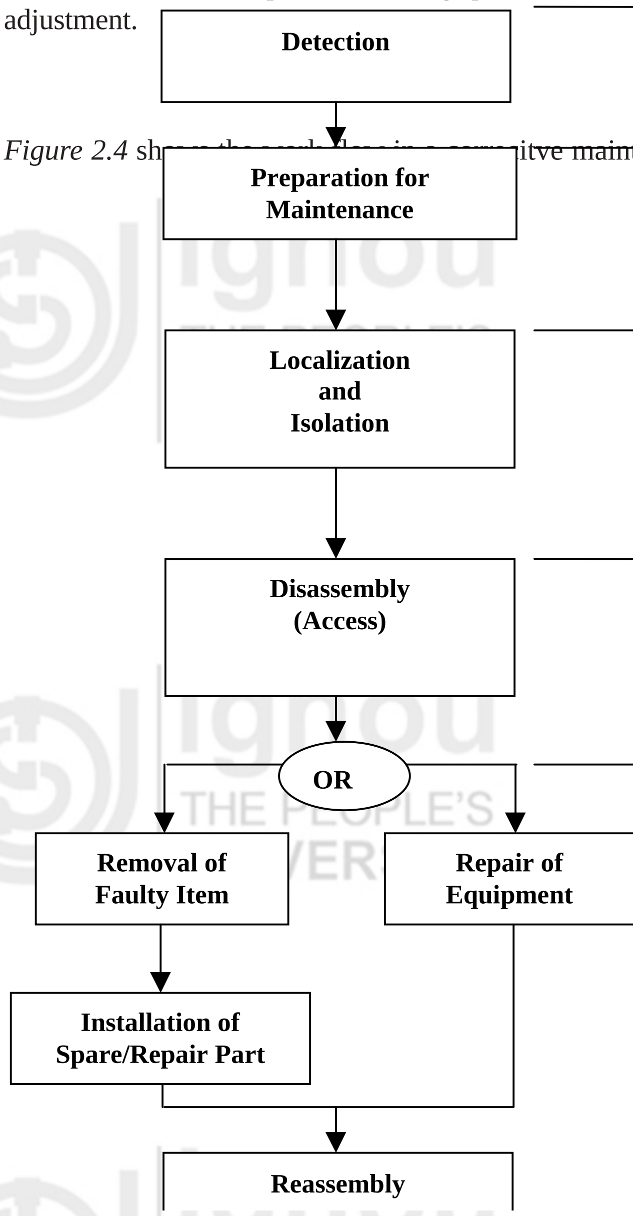

Figure 2.4 : Corrective Maintenance Cycle

To align is to bring a subsystem or circuit to a designated position. Example is the aligning the front suspension of an automobile.

To calibrate is to verify, for a variable controller, the actual performance value of the parameter controlled at a number of pre-designated controller settings, and correcting any discrepancies found.

b) ***Repair***

Physically altering a faulty component to restore it to its originally designated structure or functional condition or to another condition deemed acceptable. Commonly used rework methods include welding, soldering, patching, splicing, bonding and reinforcing. Repair is particularly applicable to the correction of failures originating in faulty interconnections utilizing media such as wiring, piping, hoses, mechanical linkages, or optical fibres.

c) ***Remove–and-replace***

Restoring a malfunctioning machine or system to proper operating condition by removing the faulty component or subassembly and replacing it with a properly functioning spare component or subassembly, with no repairs involved.

Activity B

Visit your maintenance department. Out of the above breakdown maintenance, which one is in practice? Do you agree to the present practice or differ? What is your suggestion to improve upon the present practice?

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2.5 FIXED TIME MAINTENANCE/ PREVENTIVE PERIODIC MAINTENANCE

Here maintenance is carried out at predetermined intervals, or to other prescribed criteria to reduce the likelihood of an equipment or system not meeting an acceptable condition. Other prescribed criteria for determining the intervals could be based on fixed cumulative output, fixed number of cycles of operation or usage hours. Here it is assumed that the mechanical failure and deterioration processes are depending on time in a predictable way. The advantages of this maintenance strategy as compared to breakdown maintenance are :

- Number of unexpected shut-downs are reduced
- Risk of secondary damages caused by initial failures is reduced
- Better resource utilization
- Reduced overtime costs and more economical use of maintenance workers due to working on a scheduled basis instead of a crash basis to repair breakdowns
- Reduced product rejects, rework, and scrap due to better overall equipment condition
- Improved safety and quality conditions

But the actual life span varies from component to component. It depends on several factors like load, lubrication, material quality, environmental conditions etc. The limitations of preventive periodic maintenance are :

- The method does not give full protection from unexpected shut-downs
- Some of the maintenance actions may not be necessary
- Periodic maintenance cause increased number of running in failures
- If incidental failures are predominant, periodic replacement may not have any positive effect on reliability

The decision regarding the level of preventive maintenance required to bring the plant output factors and the maintenance resource levels under control is important. The various possible strategies ranging from 100% preventive to 100% corrective are possible. The aim is to establish the best strategy to achieve the maintenance objective. Figure 2.5 shows a model describing the relationship between the level of ost for any production unit. There the sum of the resource cost and intenance is very sensitive to the work should be carried out in the

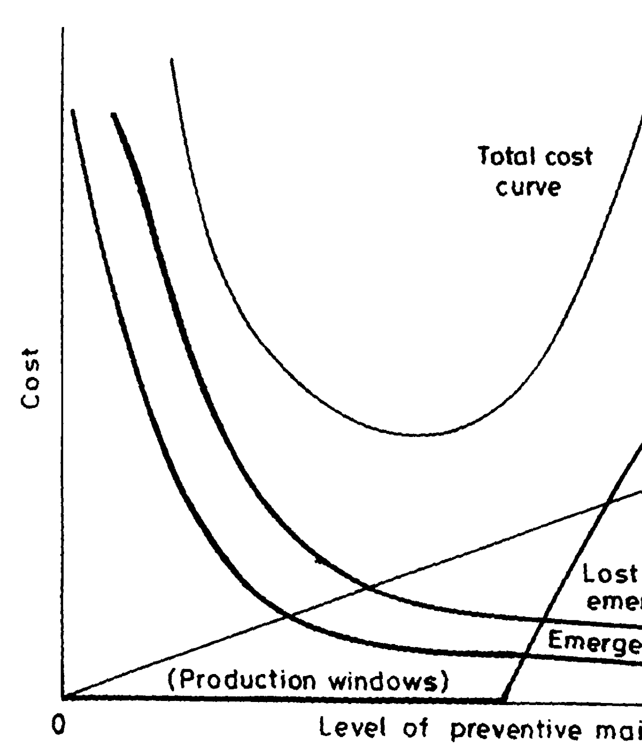

Figure 2.5 : Possible relationship between level of preventive maintenance and total maintenance cost.

Commonly used preventive maintenance tasks are as follows:

a) ***Servicing***

Tasks that must be performed periodically to assure that equipment will remain in proper operating condition. Servicing includes (but is not necessarily limited to) :

i) Replenishment of consumables such as fuel and of depletables like lubricants, battery electrolyte, coolant fluids, and air in pneumatic tyres

ii) Minor adjustments and alignments

iii) Cleaning of permanent filters and other critical surfaces subject to contamination

iv) Replacement of expendable filters and other short-lived items

A servicing task consists of an inspection to determine the extent of work required, followed by performance of that work.

b) ***Condition Assessment and On-Condition Remedial Action***

Condition assessment is evaluation of the physical condition of equipment components known to be subject to wear or other forms of deterioration. It is performed during scheduled inspections of the equipment. On the basis of this evaluation, it is decided whether the item can safely be permitted to remain in use as-is until the next scheduled inspection or should be subjected to remedial action. The remedial action can consist of replacing a suspect component, or of adjusting, aligning, calibrating, refurbishing, renovating, or repairing the equipment in-place.

Normally condition assessment is performed on :

i) Surfaces that wear out or corrode e.g. bearings, tyre treads, DC motor commutators and brushes.

ii) Mechanisms subject to misalignment or excessive play e.g. mechanical operating controls

iii) Items that accumulate contaminants interfering with operation e.g. radiator cores through which fluid coolant circulates

For electronic equipment, however, the bulk of condition-assessment tasks may consist of measuring the performance parameter drift, to assess the need for adjustment, alignment or calibration.

If component replacement is found to be necessary, it is designated as on-condition remedial action, as distinguished from scheduled replacement. If in-place repair is found necessary, it is also designated as on-condition remedial action.

Methods used for condition assessment include visual examination (with or without an optical instrument), measurement of physical and/or functional attributes using appropriate test equipment, and various special non-destructive techniques. Condition assessment is done only for attributes subject to degradation that ultimately leads to failure.

c) ***Verification of Hidden Functions***

Hidden functions are functions not exercised during normal operation of the equipment or system. The circuit or sub-system performing the hidden function must be exercised periodically to verify that it is still capable of performing the function.

Typically, hidden functions are emergency or redundant functions. A circuit breaker performs an emergency function and a back-up power supply performs a redundant function that enhances the reliability of the system. Both are hidden functions that require special techniques and, where feasible built-in-test provisions for verifying that the capability is available when needed. If at all possible, verification of the function should exercise the corresponding circuit or sub-system in every one of its operating modes. If this is not feasible, some sort of indirect test method is needed. Unfortunately, indirect methods do not always provide absolute verification. In the case of a fuse, the function cannot be exercised directly, and the only economically feasible indirect methods are non-destructive examination and verification of electrical continuity.

d) ***Scheduled Replacement***

Scheduled replacement applies to the components that meet all of the following criteria:

i) Failure of the component would endanger personnel or equipment, or would reduce the operational availability of the equipment below the minimum acceptable level.

ii) The failure mode is not suitable for condition assessment, which is the preferred preventive maintenance method.

iii) The useful life span of the component is substantially less than the intended operating life of the product, and can be determined accurately.

The proper selection and scheduling of preventive maintenance tasks required a planned maintenance management approach.

Activity C

Which type of preventive maintenance is prevailing in your organization/ maintenance department? Critically analyze and comment.

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2.6 CONDITION BASED MAINTENANCE

In condition based maintenance the equipment is maintained when measurements indicate an incipient failure. The condition of the machine may be determined continuously or at regular intervals by monitoring vibration, wear debris, temperature and performance parameters. Any change in any of these parameters would mean a change in the condition or health of the machine.

Table 2.1 : Various methods for conditions monitoring of rotating machinery and their fields of application

Methods → / Field of Application ↓	Overall vibration level	Frequency analysis	Acoustic emission	Kurtosis	Crest factor	SPM	Cepstrum analysis	Spectrometric oil analysis	Wear particle analysis	Particle Counting	Magnetic plugs	Temperature measurements	Shaft alignment	Stroboscope	Ultrasonic measurements	Sound measurement
Unbalance	1	1	--	--	--	--	--	--	--	--	--	--	x	--	--	--
Misalignment fault	1	1	--	--	--	--	--	--	--	--	--	--	x	x	--	--
Rolling bearing	x	x	0	x	x	1	x	x	x	x	x	x	--	--	x	x
Sliding bearing	x	x	x	--	--	--	--	x	x	x	x	x	1	--	x	--
Gears	x	1	0	0	0	x	1	x	x	x	x	--	--	--	x	x
Resonance	x	1	--	--	--	--	--	--	--	--	--	--	x	x	--	x
Cavitation	x	x	x	0	0	x	--	--	--	--	--	--	--	--	x	x
Mechanical tolerances	x	x	--	--	--	--	--	--	--	--	--	--	x	x	--	--
Electrical unbalance	1	1	--	--	--	--	--	--	--	--	--	--	x	--	--	--
Bent shaft	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oil whil	x	1	--	--	--	--	--	0	--	--	--	--	1	--	--	--
Friction	x	x	x	--	--	x	--	--	--	--	--	x	x	--	x	x
Faulty driving belts	x	x	--	--	--	--	--	--	--	--	--	--	--	1	--	--
Dirt	1	1	--	--	--	--	--	--	--	--	--	--	x	x	--	--
Contamination	--	--	--	--	--	--	--	1	x	x	x	--	--	--	--	--

of oil																
Speed of wear	--	--	--	--	--	--	--	x	1	x	x	--				
Insufficient lubrication	x	x	x	--	0	1	--	x	x	--	--	x	x	--	x	x

1 = Normally applicable

x = Applicable with limitations

o = Requires a case-to-case study

-- = Not normally used

Implementing condition based easurement or monitoring of appropriate physical variables or signatures of the machine using instrumentation and interpretating the signatures to indicate if maintenance of the machine is called for or not.

Flow diagram of the condition monitoring procedure is as shown in *Figure 2.6*. Table 2.1 gives various metho ng of rotating machinery and their fields of application.

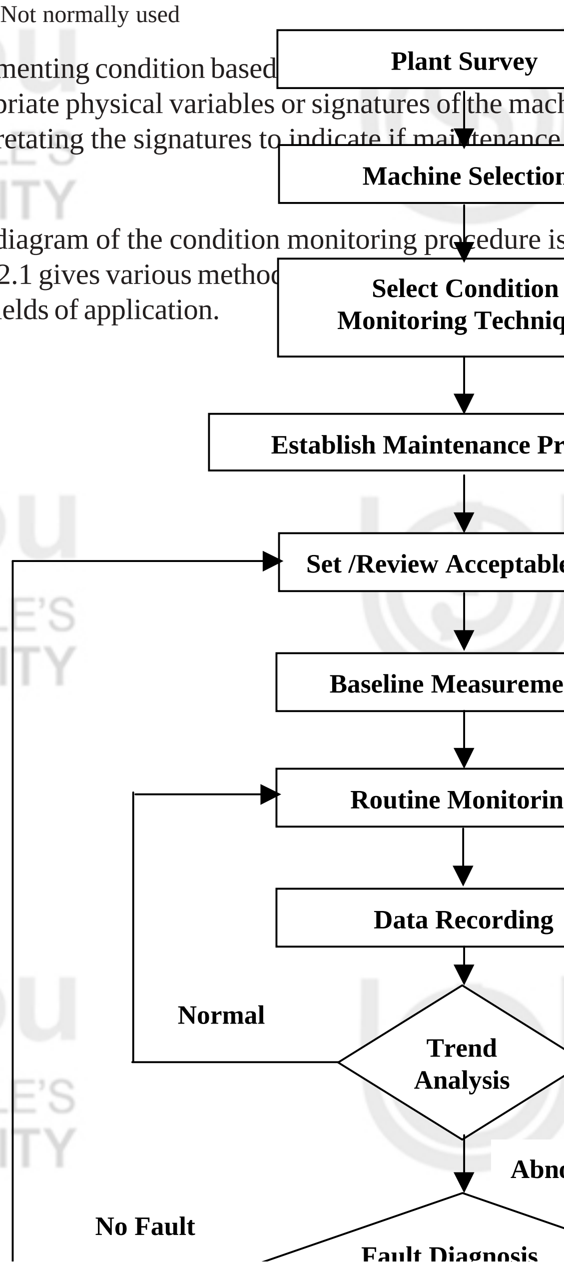

Figure 2.6 : Flow Diagram of a Condition Monitoring Procedure

The advantages of condition based maintenance are :

- It gives fairly effective protection from unexpected shutdowns.
- The machine is rarely stopped for unnecessary maintenance work compared to that in periodic maintenance.
- Damages may be prevented by reducing stress on the machine in case of incipient failure.
- Condition checking after completion of maintenance helps in checking the quality of maintenance work.

But there is always some degree of subjectivity involved in the interpretation of the measurements and thus there is always a risk of planning maintenance too early or too late. The use of condition based maintenance is justified where benefits prove to be larger than the costs on instrumentation, measurement routines, analysis and follow-up work.

Activity D

What are the advantages of condition based maintenance over preventive maintenance? Which one would you like to implement in your maintenance department and why?

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2.7 OPPORTUNISTIC MAINTENANCE

Here decision to perform maintenance is taken neither on the basis of condition assessment nor on the basis of elapsed time since the last maintenance, but is carried out in the event of a machine shutdown for maintenance or other reasons (i.e. change of gauge or die). The decision to prepone maintenance to the available opportunity is mostly based on the economics of preponing maintenance to that of sticking to scheduled maintenance and going for another downtime.

2.8 DESIGN-OUT MAINTENANCE

During the design stages of production equipment, designers are primarily concerned with creating mechanisms to carry out set functions. Very often and inadvertently, potential maintenance factors are not fully apparent, otherwise alternative designs would have been incorporated to reduce or eliminate them. These maintenance requirements could become fully apparent during operation, and when highlighted by critical analysis should be viewed with possibility of applying designing-out techniques.

Design-out aims to eliminate the cause of maintenance. This is an engineering design problem but it is often part of maintenance department's responsibility. It is appropriate for items of high maintenance cost where such costs arise either because of poor maintenance, poor design or operation outside design specification. In many cases design-out is aimed at items that were not expected to require maintenance. To effectively implement this policy an information system is required which may help in the identification of such items. The choice is to be made between the cost of re-design plus reduced (or eliminated) maintenance cost and the recurring cost of best maintenance procedure.

Important steps involved in design-out maintenance are :

a) Identifying the defects causing high maintenance costs

b) To look into the possible causes of the defect

c) To identify the possible solutions to eliminate the cause

d) To suggest the necessary modification eliminating or reducing the effect of the defect

e) To compare financial benefits against investments required

f) To assess the degree of risk with the new modification.

2.9 GUIDELINES FOR SELECTING BEST MAINTENANCE STRATEGY

The decision to select the best maintenance strategy for a given item is very important. Selection of strategy is influenced by following factors :

a) Deterioration characteristics of item like mean time to failure, nature of deterioration parameter if any

b) Repair characteristics like mean time to repair, time after failure before unit function is affected

c) Economic factors like material cost, repair cost, cost of unexpected failure, cost of replacement prior to failure, monitoring cost

d) Internal, environmental and statutory safety regulations if any

When the mean life of any item is considerably less than expected the problem boils down to establishing the cause of this and, if possible, designing it out. Often a temporary maintenance procedure is adopted until a more permanent solution is found out. Normally the ranking of the maintenance strategies is in the following order :

i) Condition based maintenance (on-line)

ii) Condition based maintenance (off-line)

iii) Fixed-time-maintenance

iv) Operate-to-failure

Based on the above ranking, *Figure 2.7* gives a decision model for selection of best maintenance strategy. Idhammar decision diagram given in Figure 2.8 is also based on idea that, wherever possible, a condition monitoring procedure should be used.

2.10 RECENT DEVELOPMENTS IN MAINTENANCE APPROACH

a) ***Proactive Maintenance***

Proactive maintenance is receiving much attention as compared to other conventional maintenance strategies. It is based on the maintenance philosophy, which is 'failure proactive' rather than 'failure reactive' and avoids the underlying conditions that lead to machine faults and degradation. Unlike predictive/preventive maintenance, Proactive maintenance commissions corrective actions aimed at failure root causes, not just symptoms. Its central theme is to extend the life of mechanical machinery as opposed to:

i) making repair when often nothing is bro

ii) accommodating failures as routine or n

iii) pre empting crises failure maintenance of scheduled failure maintenance.

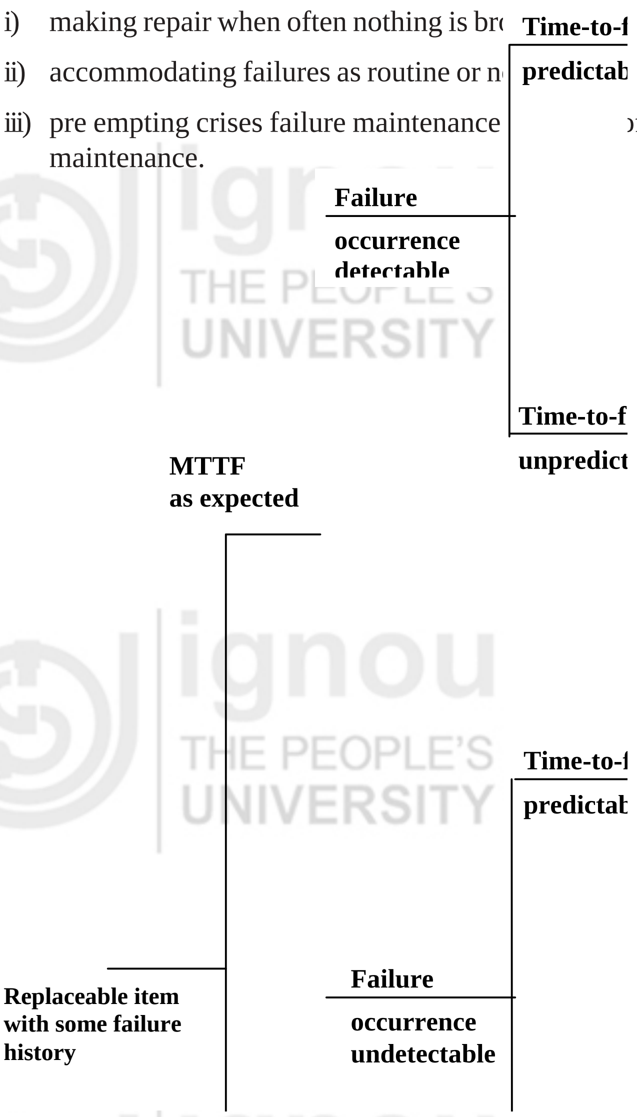
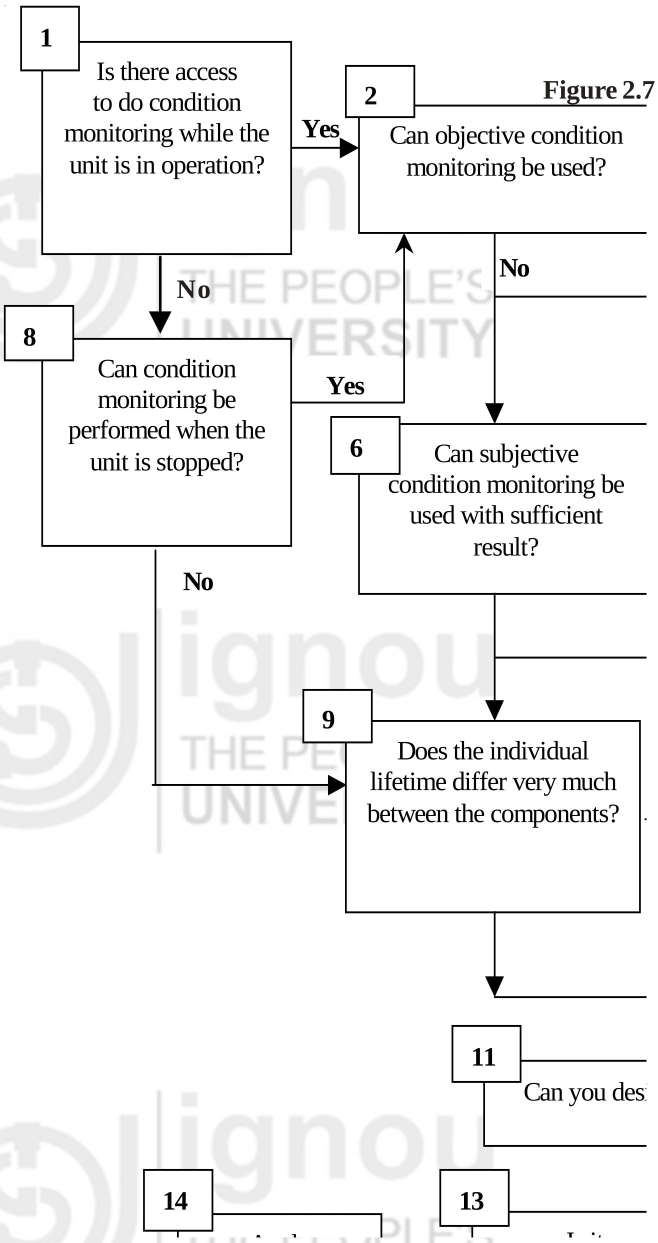


Figure 2.7 : Decision Diagram for Selection of Best Maintenance Strategy



If operating to failure:
Establish corrective maintenance standards to reduce dow

- *Drawings* • *Pr*
- *Unit record* • *Pl*
- *Spare part records* • *Sp*
- *Logical fault finding schedules etc.*

Figure 2.8 : Idhammar Decision Diagram

The root causes of machine failure are too many. But it is well accepted that only 10 per cent of the causes of failure are responsible for 90 per cent of occurrences. Most often the symptoms of failure mask the root cause or they are presumed themselves to be the cause.

When a machine is well designed and well manufactured, the causes of failure can generally be reduced to machine misapplication or contamination. And, among these two, contamination is clearly the most common and serious failure culprit. Therefore, the logical first-approach to proactive maintenance is the implementation of rigorous contamination control programs for lubrication fluids, hydraulic fluids, coolants, air, and fuel.

Heat, moisture, air, and particles literally rob fluids and lubricants of life. But with rigid contamination control practices, these fluids and lubricants can last indefinitely which, in turn, prolongs the life of the machine's components and keeps the machine running at the highest level of efficiency. The costs to begin a proactive contamination control program are quickly absorbed in maintenance cost savings. A basic contamination control program could be implemented in three steps :

i) Establish the target fluid cleanliness levels for each machine fluid system.

ii) Select and install filtration equipment (or upgrade current filter rating) and contaminant exclusion techniques to achieve target cleanliness.

iii) Monitor fluid cleanliness at regular intervals to achieve target cleanliness levels.

b) ***Reliability Centred Maintenance***

Reliability Centred Maintenance approach was initially developed in 1978 to better assure the reliability of the aircraft.

It is a systematic approach to determine maintenance requirements of any physical asset in its operating context. It focuses on preserving the functions of equipment not on preserving the equipment itself. By identifying the nature of equipment failures, it specifies actions that reduce the consequences of equipment failure like damaged equipment, possible injury, unnecessary downtime resulting in production loss and, ultimately, reduction in profits.

Implementing reliability centred maintenance requires team effort, especially from operations and maintenance. Operations identify the functions and the performance standards while maintenance identifies the type of failures. Both collaborate on the consequences of identified failures. Maintenance then defines the most appropriate maintenance strategies to predict or prevent each failure and brings them together as a planned maintenance program. Both then cooperate in carrying out the program, often with specific operator tasks. Thus, the implementing team can attain better understanding of how equipment functions and generate quality information for future use. This information is used to monitor progress, measure gains, analyze results and record events to identify ... and benefits of reliability centred maintenance. The impo... lementing reliability centred maintenance are as shown in *Figure*

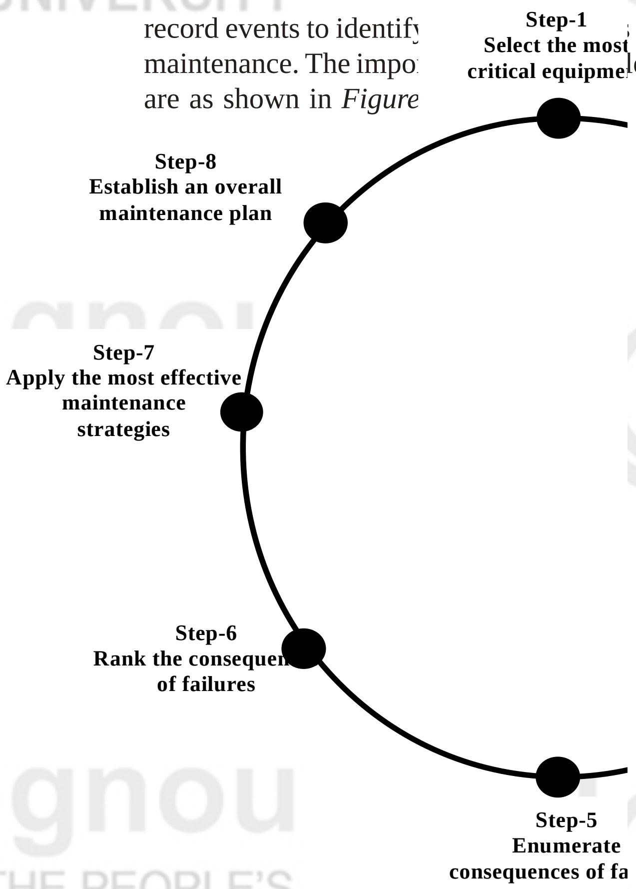


Figure 2.9 : Important steps in implementing Reliability Centered Maintenance

c) ***Total Productive Maintenance***

Japanese in 1971 introduced the concept of Total Productive Maintenance (TPM), which is in fact productive maintenance implemented by all employees from line operator to top management. Contribution of operation and maintenance cost to life cycle cost of the system is reduced through participative programs designed to increase equipment effectiveness. The term TPM was defined by the Japan Institute of Plant Engineers to include the following five goals :

a) Maximize equipment effectiveness (improve overall efficiency).

b) Develope a system of productive maintenance for the life of the equipment.

c) Involve all departments that plan, design, use, or maintain equipment in implementing TPM.

d) Actively involve all employees-from top management to shop-floor workers.

e) Promote TPM through motivation management: autonomous small group activities.

The word total in "Total Productive Maintenance" has three meanings related to three important features of TPM :

- Total effectiveness – pursuit of economic efficiency or profitability.
- Total PM – maintenance prevention and activity to improve maintainability as well as preventive maintenance.
- Total participation – autonomous maintenance by operators and small group activities in every department and at every level.

Overall equipment effectiveness is the product of the availability, performance rate and quality rate. It can be maximized and life cycle cost minimized through company-wide efforts to eliminate the six big losses that reduce equipment effectiveness :

i) Break-downs due to equipment failure

ii) Set-up and adjustment (exchange of tools)

iii) Idling and minor stoppages due to abnormal operation of machine components

iv) Reduced speed (discrepancies between designed and actual speed of equipment)

v) Defects in process and rework (scrap and quality defects requiring repair)

vi) Reduced yield between machine start-up and stable production

First two losses contribute to downtime, third and fourth contribute towards speed losses and the last two contribute towards quality defects. The specific steps necessary to develop a TPM program must be determined for each company individually, adjusted to fit individual requirements and production details.

Activity E

How does Total Productive Maintenance (TPM) differ from preventive maintenance? Explain with the help of an example from your maintenance department?

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2.11 SUMMARY

With the coming of large plants, investment costs have increased. The poor functioning of many industries is generally because of lack of efficient maintenance of production plant and equipment. Maintenance requires input of resources and information and provides outputs in the form of plant useful-life, availability, performance, quality and safety. Maintenance resources are used to prevent failure or to respond to failure or unacceptable deterioration. Maintenance management finds the most economical ways of performing the desired maintenance functions. To keep the plant operating at desired level of output and safety proper maintenance strategy is required. Guidelines are available for selecting the best maintenance strategy for a given item. Some of the recent developments in the maintenance approach are proactive maintenance, reliability centred maintenance and total productive maintenance.

2.12 KEY WORDS

Breakdown Maintenance: Maintenance performed in response to a breakdown.

Condition Based Maintenance: The preventive maintenance initiated as a result of knowledge of the condition of equipment observed through routine or continuous monitoring.

Corrective Maintenance: The maintenance carried out after a failure has occurred and intended to restore equipment to a state in which it can perform its required function.

Preventive Maintenance: Maintenance carried out at predetermined intervals and intended to minimize the probability of failure or the performance degradation of equipment.

Proactive Maintenance: Maintenance actions are aimed at failure root causes and avoids the underlying conditions that lead to machine faults and degradation.

Reliability Centred Maintenance: It is a systematic approach to determine maintenance requirements of any physical asset in its operating context and focuses on preserving the functions of equipment.

Total Productive Maintenance: It is a maintenance system focusing on maximizing overall equipment effectiveness. It uses autonomous maintenance by operator and full organizational participation.

2.13 SELF ASSESSMENT QUESTIONS

1) What is maintenance objective?
2) What are the functions of a maintenance system?
3) What type of information you will be looking into before deciding for a proper maintenance strategy?
4) Explain the procedure you will recommend for choosing a suitable maintenance strategy?
5) What are the important steps required to accomplish a corrective maintenance task?
6) What is preventive maintenance? Explain different preventive maintenance tasks?
7) How is the total maintenance cost affected by the level of preventive maintenance?
8) What do you understand by preventive predictive maintenance? How can it be implemented in any plant?
9) What is opportunistic maintenance?
10) What is design-out maintenance? Explain the situations and the steps in which it should be applied?
11) What do you understand by proactive maintenance?
12) What is reliability centred maintenance? What are the important steps involved in implementing it in any plant?
13) What do you understand by total productive maintenance?
14) What is overall equipment effectiveness? How can it be maximized?

2.14 BIBLIOGRAPHY AND SUGGESTED READINGS

1) Kelly, A., "*Maintenance Planning and Control*", Butterworths, 1984.