UNIT 13 MAINTENANCE MANAGEMENT

Objectives

Upon completion of this unit, you should be able to:

- relate the importance and objectives of maintenance management
- understand the pattern in which failures and breakdowns take place
- realise existence of different systems of maintenance
- realise the need for letting unplanned emergency maintenance remaining an ‘exce^{p}tion rather than a rule’
- comprehend that the efforts involved in maintenance planning and control are worth it, even though this calls for greater amount of record keeping, and subsequent analysis
- realise that formal costing and budgeting would encourage prediction and preplanning of maintenance activities
- identify the need for some control indices for improving the maintenance service of an organisation.

Structure

13.1 INTRODUCTION TO MAINTENANCE MANAGEMENT

Since time immemorial when man used primitive tools and machines to carry his loads, to draw his water, to till his land and to fabricate his building materials, he has been faced with the prospect of maintaining these assets until such time as he considered their useful life to be ended. Maintenance is very important to extend the useful life of an asset. It is quite a challenge. In our country, there is no dearth of manpower but rather scarce limited capital to spend for capital equipment. Some studies have shown equipment utilisation to be as low as 30% in quite a few cases. Proper maintenance management could improve existing capacity utilisation rather than going in for additional capacities to meet the ever increasing demand of a large number of products and or services. In industry maintenance function is usually given a low status and considered to be a third rate job; this is rather unfortunate. The function of carrying out maintenance is such an obvious necessity that the subject has been taken for granted over the centuries without much thought being given to its importance in our everyday lives.

Maintenance is usually viewed only as a repair function. It is, however, "a combination of any actions carried out to retain an item in, or restore it to, an acceptance condition". In fact maintenance keeps or ensures that the entire production system is kept reliable, productive and efficient. All departments of a production system may have been designed beautifully without giving due consideration to maintenance management. The end result is obvious. Organisations like the National Productivity Council and others are playing a vital role in propagating the importance of Maintenance Management of all the assets of the organisation. In fact, all organisations must be having some assets, and hence the need for proper maintenance and `physical assets management' which is synonymous with the word `Tern-technology' which we shall discuss now.

13.2 TERO-TECHNOLOGY

The concept of tero-technology grew from the study of maintenance practices. It is synonymous with total maintenance. It takes into account all aspects of plant machinery from **Design to Discard,** viz. design, manufacture, installation, commissioning, maintenance, replacement and removal of the plant/equipment plus the. feedback of performance for the equipment manufacturer. Tero-technology envisages application of a combination of managerial, financial, engineering and other practices applied to physical assets in pursuit of economic life-cycle costs. It is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures. This total life-cycle concept enables a proper equipment evaluation and selection so as to give an overall low life cycle concept. This gives rise to huge potential for savings in terms of cost effectiveness of replacements on considerations of the whole life-cycle. `Design audit' consists of carrying out critical scrutiny of the designs by the operating and maintenance engineers independent of the design process so as to ensure reliability and maintainability of plant and machinery and to identify weaknesses in designs requiring modifications. The word `tero-technology', itself stems from the Greek root `terein'-`to look after', `to guard over', `to take care of. In fact the principles of tero-technology as discussed above can be applied, to a greater or lesser extent, to any physical asset in any organisation, no matter what the size or degree of complexity of either asset or organisation.

13.3 OBJECTIVES OF MAINTENANCE

Very loosely, some define maintenance as any work undertaken by a maintenance worker. In manufacturing organisations, the term `works engineering' has been commonly used to embrace installation, commissioning, maintenance, replacement and removal of plant, machinery etc. However, when considering service organisations, municipalities and the armed services, the term is seldom encountered. Fortunately, the term `tero-technology' covers all these situations, though it would take yet some time for an universal acceptance of a term like `tero-technology manager'. However, the manager of the maintenance function whether the job title is estates manager, works manager, chief engineer, plant engineer, building manager, maintenance manager-is attracting greater attention then ever before.

The principal objectives of maintenance activity are as follows:

a) To maximise the availability and reliability of all assets, especially plant equipment and machinery, and obtain the maximum possible return on investment.

b) To extend the useful life of assets by minimising wear and tear and deterioration. This is particularly relevant for our country as opposed to developed countries which would find replacement more economical than maintenance.

c) To ensure operational readiness of all equipment required for emergency use at all times, such as standby units, fire fighting and rescue unit etc.

d) To ensure the safety of personnel using facilities

From the line managers' point of view, the reasons for improving maintenance methods include: (i)protecting the buildings and plant, (ii)increased utilisation and reducing downtime, (iii) economising in the maintenance depot :dent, (iv) maximising utilisation of resources, (v) maintaining a safe installation, (vi) preventing wastage of tools, spares and materials, (vii) providing cost records for future budgeting.

Moreover, each day we are witnessing a trend towards increased mechanization computerisation and greater automation, though it might seem to be a distant thought in Indian conditions. Whatever be the level or degree of automation, there will always be an increasing responsibility for the maintainer of the assets. Some of the reasons for this are:

1) Plant output capacities are raised, making downtime (viz. when the plant is out of operation) more costly.

2) Dependence on control systems can produce total disruption of output when one machine or some element in a process fails.

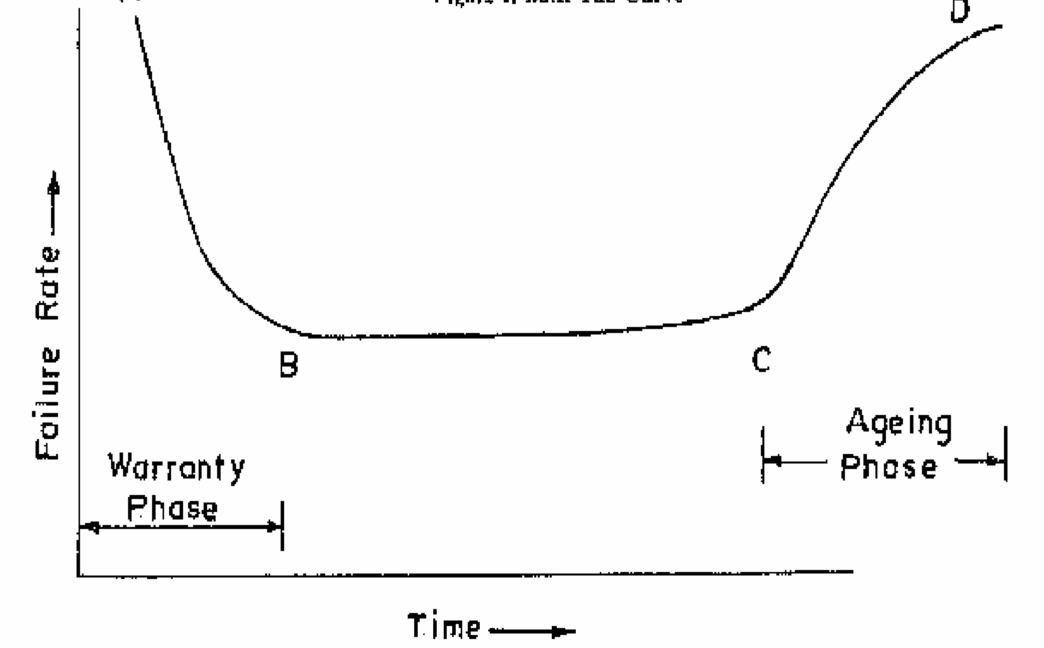
3) The possibilities for operator's intervention to compensate for machine errors or failures are decreased.

The effects upon the maintenance department include a new requirement for new skills in repair of computer controls, the need for an improved multi-disciplinary working coupled with the requirement for a systems approach to maintenance. By systematic maintenance, it is possible to achieve substantial savings in money, material and manpower, as every effort is directed towards avoiding catastrophic failure. Failure or plant breakdown could create problems such as a loss in production time, rescheduling of production, spoilt materials because of sudden stoppage of process, which could possibly damage components, failure to recover overheads because of loss in production hours, need for overtime, need for subcontracting work aid temporary work shortages etc.

13.4 FAILURE ANALYSIS

Let us now spend some time in understanding how failures take place. Failure analysis plays a vital role in taking decisions pertaining to maintenance planning and control for effective management subject to the budgetary constraining for such an activity. It is important to identify the nature and occurrence of failures with respect to time. This will be highly significant in designing and ensuring adequate reliable performance. It is seen that the failure rates pattern can be depicted as a bath tub curve as shown in Figure I.

Figure I: Bath Tub Curve



It is the usual experience with equipments that the failure rate is quite high when the equipment is new or newly installed. The failure rate is greater during the initial starting period of infancy but after this initial phase is over, the failures are relatively quite low. Such behaviour can be approximated to a `hyper exponential distribution' as shown in Figure I. Such behaviour is a sign of the design defects or installation defects. Therefore, those that had these inherent defects failed when the equipments were run. Those that failed much later were those that did not have the design or installation defects. This is somewhat similar to the infant mortality in humans.

At the other extreme, many equipments fail due to `ageing' and wear out. The failure or death may be at a 'mean' or `average' age, though some could fail earlier and some later. Such a failure pattern because of wearing out could be represented by a symmetrical bell shaped normal distribution.

We have seen the 'infancy' and the 'old age' phenomenon. In between these two extremes also equipments may fail, but it is neither due to inherent design or installation defects nor due to being worn out. The cause is external to the equipment and therefore probability of failing is constant and independent of the running time. This phenomenon can be approximated to a `negative exponential' distribution. This is again similar to the behaviour in humans, where they may die due to external causes such as an epidemic or traffic-accidents while they are neither old nor infants.

The three distributions mentioned above. namely hyper-exponential, negative exponential and normal, can be combined into one distribution, termed as the 'weibull' distribution (named after Weibull who developed it). Hence the bath tub curve depicting the failure rate can be represented by a weibull distribution. Weibull distribution calculations are very lengthy and tedious. Fortunately weibull graphs are available (though not very common) for determining mean time between failure (MTBF). This would provide good data for determining system reliabilities, availabilities, expected lives etc. Failure statistics can also be used in the diagnosis of the nature of a recurrent equipment failure and also in the prescription of solutions to maintenance problems.

The prime objective of maintenance is to increase the availability and reliability of a piece of equipment. The availability (A) of a plant can be defined as

$$A = \frac{T_{up}}{T_{up} + T_{down}}$$

where T_{up} = the cumulative time of operation in the normal working state and T_{down} =the cumulative downtime.

13.5 TYPES OF MAINTENANCE SYSTEMS

Maintenance work can be either planned or unplanned. Let us now discuss the different types of maintenance systems.

Emergency Maintenance: An unplanned maintenance which is necessary to put in hand immediately to avoid serious consequences, for instance loss of production, extensive damage to assets or for safety reasons. Emergencies should remain exceptions rather than the rule. To ensure such a possibility, it is better to have planned maintenance systems.

Planned Maintenance: Maintenance organised and carried out with forethought, control and records to a predetermined plan. Planned maintenance can be split up into essentially two main activities namely preventive and corrective.

Preventive Maintenance: Also termed `Diagnostic or Predictive Maintenance' is maintenance carried out at pre determined intervals, or to other prescribed criteria and is intended to reduce the likelihood of an equipment's condition falling below a required level of acceptability. You try to anticipate failure and then attempt to prevent its occurrence by taking preventive actions. The proverbial saying `prevention is better than cure' or `A stitch in time saves nine' is the basic philosophy of Preventive Maintenance. Preventive maintenance can be done on machines either when running or during shutdown.

Running Maintenance: Maintenance which can be carried out when the item is in service.

Shutdown Maintenance: Maintenance which can only be carried out when the item is out of service. Further preventive maintenance can be time-based or condition-based.

A Time-based Preventive Maintenance: This policy is effective when the failure of any item of an equipment is time dependent (in the third stage of the bath tub failure curve of Figure l) and the item is expected to wear out within the life of the equipment. Moreover the total costs of replacement of the item should be substantially less than those of failure replacement repair,

Condition-based Maintenance is carried out in response. to a significant deterioration in unit as indicated by a change in a monitored parameter of the unit condition or performance. It is here that one can make use of predictive maintenance by using a technique called SIGNATURE ANALYSIS which is intended to continually monitor the health of the equipment by recording systematically signals or information derived from the form of mechanical vibrations, noise signals, acoustic and thermal emissions, changes in chemical compositions, smell, pressure, relative displacement and so on. Scientific collection of these informative signals or signatures, diagnosis and detection of the faults, if any, present by a thorough analysis of these signatures based on the knowledge hitherto acquired in the field, and judging the severity of the faults for decision-making, all put together, is called `Signature Analysis'. The technique involves the use of electronic instrumentation specially designed for the purpose of varied capacities, modes of application and design features. Vibration and noise signals are *the* most versatile parameters in machine condition monitoring techniques. Periodic vibration checks reveal whether troubles are present or impending. Vibration signature analysis reveals which part of the machine is defective and why. Sound or noise analysis is somewhat similar to vibration analysis. A stock pulse meter is used to monitor the condition of roller bearings.

Condition-based maintenance thus reduces injuries and fatal accidents caused by machinery as the conditions of machinery are indicated well before hand. It enables the plant to be stopped safely when instant shutdown is not permissible. Moreover, it permits advanced planning to reduce the effect of impending breakdowns and be in time to have necessary spare parts available. However, condition monitoring is not always used because it involves high manpower and monitoring costs and, furthermore, it is difficult to monitor some parameters.

Corrective Maintenance: Maintenance carried out to restore an item which has ceased to meet an acceptable condition. It involves minor repairs, that may crop up between inspections.

Design-out Maintenance is yet another policy which is practised frequently in developed countries. This is discussed in greater detail later on in this unit. The policy here aims at minimising the effect of failure and at eliminating the cause of maintenance. In essence, an attempt is made to pinpoint the defects in the design of the equipment. Poor design of many an equipment leads to frequent breakdowns. Also an appropriate choice of tribological materials might eliminate the need for subsequent lubrication frequencies.

13.6 MAINTENANCE PLANNING AND CONTROL: PREPARATION

Total maintenance planning embraces all activities necessary to plan, control and record all work done in connection with keeping an installation to the acceptable standard by devising appropriate maintenance systems. In a fully controlled situation, the time spent on emergency work, viz. the `unplanned' portion, could well be less than ten per cent of the available man-hours in the maintenance department. The administrative control of maintenance work is very significantly altered when changing from emergency maintenance methods to a policy of planned maintenance, This brings in some increased amount of paperwork,

Maintenance Request

The most important single document in the organisation of maintenance we shall henceforth call the `maintenance request' which is alternatively termed as work order, work requisition, job card or work ticket etc. As a prerequisite for planning the 'maintenance function, it is necessary to know exactly what the labour force is doing, and how long each task takes.

The maintenance request by the production staff details the defect or work believed to be required. Hopefully, the `cause' should have been identified `before' or ‘after’ rectifying the fault so as to help planners for conducting subsequently studies for critical analysis and the all important function of `designing-out' maintenance (provided reliable documented information exists). The maintenance request provides all the information necessary as regards the type of labour employed, and the time labour has taken to do the job(Timesheets are often oriented/biased towards the worker).

Assets/Facility Register

The first step of a planned maintenance procedure is to establish **what** is to be maintained. This requires the need to establish an Assets/Facility Register. Each asset must be identified in terms of name and code; description; reference numbers pertaining to manufacturers, suppliers (if any), users, location with provision for changes if item is interchangeable or mobile and suppliers' details. When the items are recorded either in a register or in a card-index form, they could be classified and sub-divided in terms of asset usage/availability, technical groups or maintenance methods. Sometimes certain items may be subject to statutory inspections. The assets-register is the information centre of the planned maintenance system.

Maintenance Schedules

Next we must decide how these assets or facilities are to be maintained. A `maintenance schedule' must be prepared for every item listed in the assets/facility register. A typical maintenance schedule card indicates grade of labour required, frequency of the work to be done, details of the work to be done and estimated time for the execution of the work. A mistake so often made is when companies setting up a planned maintenance scheme for the first time prepare the maintenance schedules for all the plant first, and then endeavour to apply these to a maintenance programme on a specific starting date. In the absence of plant-history records, this method of approach is doomed to failure, since. it is just not possible to switch from emergency maintenance methods (which is usually the rule rather than an exception) to planned preventive maintenance overnight.

Work/Job Specifications

Having prepared our maintenance schedules we must prepare the work/job specifications which are compiled from the maintenance schedules and are a means of communication between the engineer and the tradesman (or the person who would be carrying out the job). Precise specifications for the activities on the maintenance schedule vary in depth and presentation according to the system, the local labour requirements, the complexity of the items to be maintained etc.

It should define specific items on the machine requiring attention and clearly indicate the required action e.g. inspect, check, gauge. It should give guidance in respect of **method,** however appropriate it might be. The objective is to maintain to a required standard without forgetting on the safety aspect concerning both the tradesman and operators.

Programming Annual and Weekly Planned Maintenance Programmes

Having prepared our maintenance schedules and built up a workload from our job specifications, we are now in a position to commence the preparation of an annual maintenance programme to decide when the planned productive maintenance jobs shall be carried out. Over a period of time, planned maintenance significantly reduces the demands on the maintenance department for such major overhead work to be carried out during annual shutdown periods (for which we could make use of Network Techniques like PERT/CPM). The weekly planning maintenance programme can be derived from the annual planned maintenance programme. However, tactical planning is required at the weekly level by interacting with the production planning and control section especially. Unforeseen circumstances sometimes arise, however careful the forward planning, which make it impossible to release a machine/asset according to the weekly programme charted out. It is important to communicate the weekly planning pm1•ramme, at least -a week ahead, to all concerned.

Inspection Report

One of the important forms of maintenance is to carry out inspection at the right time and duly record the data so as to produce an inspection report. This form/document is used only for reporting the results of planned productive maintenance inspections, as set out in the job/work specifications. The inspection report closely resembles the maintenance request, discussed earlier on. It is imperative that inspection reports must be used by and for maintenance supervision and planned maintenance controller and his staff prior to filling the history records (to be discussed next).

History Records

The last operation in our planned maintenance procedure is to build up a detailed historical record of the results of maintenance on every machine receiving it. Plant history records should be properly updated so that they can be referred to and made use of more meaningfully. Traditionally, history records have been `written up' by records clerks from timesheets or work orders.

The operation of an effective maintenance records system provides information about: (i) the percentage of planned work achieved in the period, (ii) ratio of planned to unplanned work, (iii) downtime for the period, (iv) maintenance requirement comparisons between individual assets, between types of asset, or between groups of assets, (v) indicators for reliability of the products of particular manufacturers, (vi) trends in spare-parts consumption, (vii) equipment failure patterns,

(viii) performance details for personnel, by individual or by trade group.

Records are kept in many different ways ranging from card files to computerised devices.

Planned Lubrication

Some form of lubrication routine is rightly considered to be an essential part of plant maintenance by most firms, yet this is a responsibility which is frequently relegated to an oiler greaser who may have little or no training before being provided with an oil can, a grease gun and a dubious supply of lubricants. Lubrication schedules are usually provided by. the planning engineers of oil companies. The schedules include information about the number of application points, frequency of each application, method to be used, e.g. grease gun, oil can etc., the amount and type of lubricant required. Planned lubrication should be an integral part of planned maintenance, and, because of its utmost importance, daily and weekly lubrication tasks should usually be carried out separately from the mechanical and electrical schedules. Monthly lubrication tasks and oil changing should be usually fully integrated with the maintenance schedules.

To ensure a smooth implementation of planned lubrication techniques, you could adopt a 3-phase procedure. In the first phase, a survey of all plant that require lubrication is carried out to establish WHAT has to be lubricated. The second phase establishes WHEN lubrication has to be done and the third phase is to conduct the OPERATION by establishing HOW lubrication is to be carried out.

Work Priority

Most of us, at some time to a greater or lesser degree, come up against the problems of deciding job priority. Obviously maintenance work of an emergency nature, required to keep production going or to reduce downtime, once incurred, should be given the first or topmost priority. However, with planned maintenance, hopefully, emergency cases are reduced to just about 10% of all cases. But still some method of priority fixing must be established preferably. After `emergency', a `machine running' priority could be thought of. In this case the machine is running, but attention is required to maintain efficient operation or for safety reasons. Yet the least priority could be labelled `not applicable' if the request for maintenance work is not relevant w a machine stoppage, and also for most work involving civil and building trades. 1t.is usually found that these three priority levels are found to be adequate and acceptable In most instances. If however, me problem persists. it becomes necessary to devise a PRIORITY. INDEX based on two important group factors, namely.

a) **Work priority** factors where all work done by maintenance department personnel

:is separated into 10 classes, most important being class 10 and the least important being class 1. Emergency Maintenance-I, II and III, Modification, Capital, Sundry aid Special Maintenance, and housekeeping are respectively ranked from 10 down to 1

b) Facility priority factor in which each facility, plant, building etc. is placed in one of 10 classes, most important being class 1. Key services, key production plant, flowline or process plant, multi-production machines, standby services, mobile transport, buildings and roads, machines (low utilisation). building, roads, offices and furniture fittings are respectively ranked from 10 down to 1.

To obtain the PRIORITY INDEX for any job, multiply `work priority' class by the 'facility/ machine priority' class. You can note that 10 classes have been chosen so that the priority index for each job can be expressed as a percentage priority.

For example, emergency maintenance for a key service sub-station equipment, the priority index would be (10x 10) = 100%. For an emergency repair to a leaking roof (building) over a production machine, the priority index would be (10x4) = 40%.

Safety

Tile observance of safety at work is essential at all times. The general rule is always ‘safety first’. Some of the main safety considerations when carrying out a maintenance management task are the following:

a) Guards are supplied by plant manufacturers or subsequently fitted by the company. Safety steps should be taken to ensure that these are not tampered with resulting in potential hazards. In fact, condition and security of easily accessible guards must always be included in job specification as items for regular checks at planned preventive-maintenance inspections.

b) Protective Clothing such as helmets, gloves, goggles, gas masks etc. must be given full consideration especially in chemical and allied industries. You must preferably include the need for wearing protective clothing in the maintenance request or the work/ job specification.

c) Power isolation by the use of appropriate fuses might be necessary while effecting certain types of maintenance tasks. Water and compressed air supplies can usually be isolated and locked off where necessary. Gas lines may have to be purged before any welding is permitted.

d) Pressure vessels, piped power, lifting appliance should have some type of a 'permit' system to open and/or blank off.

e) Permit to work for carrying out maintenance tasks should remain valid for a specific appropriate period only. A copy of the certificate should be posted or affixed in such a place that it is not possible for anyone to start up the plant or machine before referring to it.

13.7 MAINTENANCE PLANNING AND CONTROL: OPERATION

So far we have dealt with the aspects of management organisation that are related to the needs of the engineering function. Now let us come to the decision-making aspect. If management is to be truly effective and objective, it must be provided with reliable, timely, and appropriate information. This aspect is highly desirable. Unfortunately, this facility is very sadly lacking in the field of maintenance management.

Routine Analysis-Labour and Costs

Let its now discuss some of the problems that arise in the implementation of the system designed in the earlier section. It is essential to set up operational procedures for routine analysis of the results of maintenance work in order to improve the level of work planning and control through bettor control of resources in the form of labour and materials. Plant and machinery may be wearing out or be obsolete, hind inherent design faults, uptill now accepted, will be highlighted by the routine analysis. The analysis might reveal the changes in plant performance as a result of

planned productive maintenance. Many different types of analysis could be carried out, but it is good to remember that a successful operation scheme is one that retains simplicity and some amount of flexibility.
You could conduct a **weekly analysis** by scanning all completed maintenance requests, subsequent inspection reports and the total repair time and downtime costs calculated. The weekly analysis of direct maintenance labour is in hours number of jobs, and indicates:

i) Maintenance hours activity and maintenance request jobs by cost centre, types of work and trade group.
ii) Inspection reports by cost centre and trade group.
iii) Total inspection report hours by trade group.
iv) Total downtime by trade group.
v) Booked time by cost centre.
vi) Total booked time, unbooked time and clocked time by trade group.
vii) Unbooked time as a percentage of clocked time.
viii) Overtime hours worked and expressed as a percentage of clocked time.
ix) Number and total wages of maintenance personnel employ Ld by trade group.

The planned maintenance controller watches closely for any significant variations in inspection hours achieved, emergency maintenance hours incurred, downtime hours incurred, unbooked hours recorded and overtime hours worked and as a percentage of clocked hours.

It is difficult to obtain really accurate maintenance labour costs because these depend on so many diverse and variable factors, such as time booking accuracy, overtime, tradesman/unskilled labour ratios, dependent labour charges., workshop overheads, general overheads etc.

One simple approach is suggested as follows. Every four weeks, total wages paid, plus dependent labour charges, plus overhead charges are divided by the total clocked hours for the period; the resultant maintenance labour hour cost rate is directly applied to the time booked to each cost centre, and each plant number or job number during the period.

It is important to impress upon maintenance workers that they should book only the time they actually spend on a job (including travelling time, collecting tools and stores for the specific job only). Some waiting time could be unavoidable in maintenance jobs. It may be happening that unbooked or overbooked time could arise because of insufficient work to occupy a maintenance man full] time; careless or inaccurate time booking on the maintenance request or inspection report; loss of a maintenance request or inspection report; absence from shop floor Awhile attending training courses which may not have been recorded by the foreman/superintendent. It might also be helpful to prepare a weekly summary of all emergency maintenance jobs done during the period.

A plant group analysis could also be done. Machines are deliberateily placed in groups and types of sub-groups to facilitate identification and enablle the analysis of results to establish trends of breakdowns and where maintenance performance during the pre-period was unsatisfactory. By scrutinising the results of maintenance by plant/job number, it becomes a simple matter to select say the `top ten' machines that have involved the largest amount of emergency and corrective maintenance and downtime during the period. It would be worth recording chronologically the `top ten' and see which machines keep appearing in the list. For such `critical' machines drastic and long term action may be called for to `design out' the maintenance problems. It should be anticipated that the top ten analysis might reveal no significant pattern after say 2 years or so. This will leave the weekly analysis and the plant group analysis as the only two routines that will continue to be required.

Work Measurement, Manning and Workloading

Most engineering managers would agree that work planning in maintenance is both possible and desirable. However when it comes to setting certain standards or norms through work measurement for the largely non-repetitive nature of maintenance work, one encounters very divergent and strongly held views on the subject'. Incentives might motivate the maintenance workers to carry out their tasks effectively and efficiently. Different organisations have different remuneration schemes for direct production workers and indirect maintenance staff.

Certain aspects ought to be borne in mind when applying work. study techniques to maintenance engineering. It is a wasted effort to put a standard on a job that can be eliminated through `design out' maintenance. It is futile to standardise a planned preventive maintenance job if the worker does not have the correct tools, spare parts or materials. It is normally impractical or excessively costly to cover more than about 60% of the jobs. Installation and administration costs are high and can exceed the resultant benefit. Increased labour productivity remains largely a problem of reducing lost time between maintenance jobs, i. e. unbooked time.

Work measurement applied to maintenance may have advantages if applied in the right environment, but maintenance planning and control techniques must be applied first. Perhaps work sampling schemes could be employed to arrive at the total work content. Then accordingly appropriate manning levels could be estimated. An organisation that has a clear cut maintenance planning system would hopefully have a very small percentage of emergencies occurring. In such well established planned productive maintenance situations, manning and workloading are not problematic. In fact, in case of planned overhauls you could resort to the use of network techniques of PERT/CPM which you have learnt in unit 12.

13.8 MAINTENANCE PLANNING AND CONTROL: PROGRESSION

Critical Analysis: As maintenance records are being built up and sufficient statistical data become available, a point is reached when you can attempt to carry out some type of a CRITICAL ANALYSIS. It would be seen that the Pareto Principle comes in handy once again, viz. the principle of `the significant few and trivial many.' A critical breakdown analysis' (Figure Ha) reveals that a small percentage (about 10(;o) of equipment would significantly contribute to about 70% of the breakdown time. Such category of equipment could be the so called 'critical `A' type. A defect analysis (Figure ll b) could also be done. It would be seen here again that a few, say 10% defects contribute to about 70% of the breakdown times.

Figure 11 (a) : Criticality Analysis

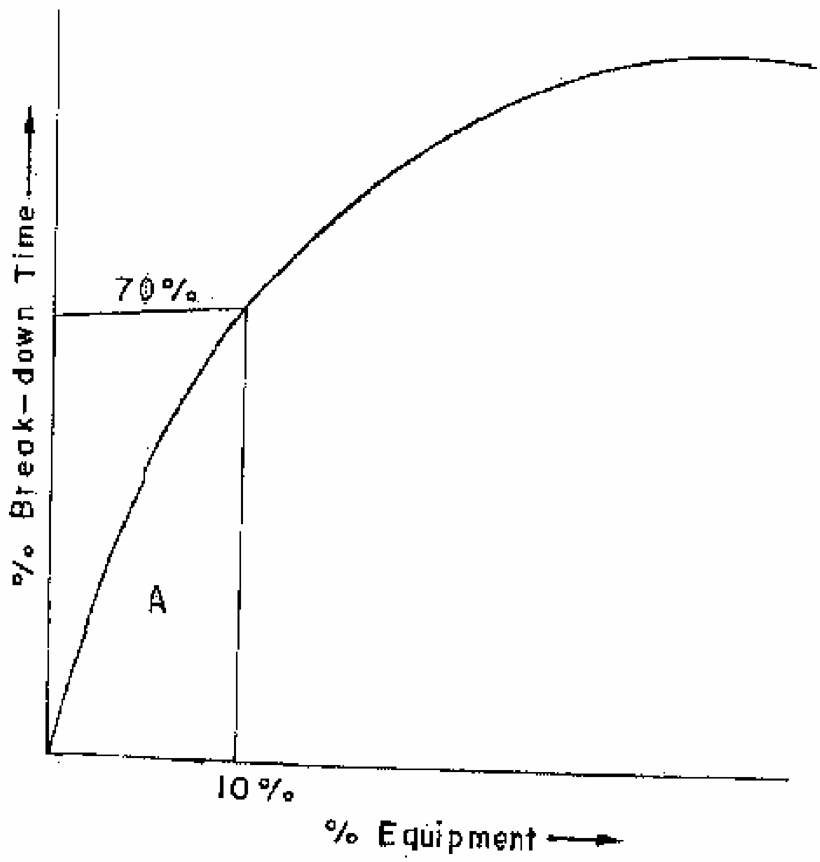
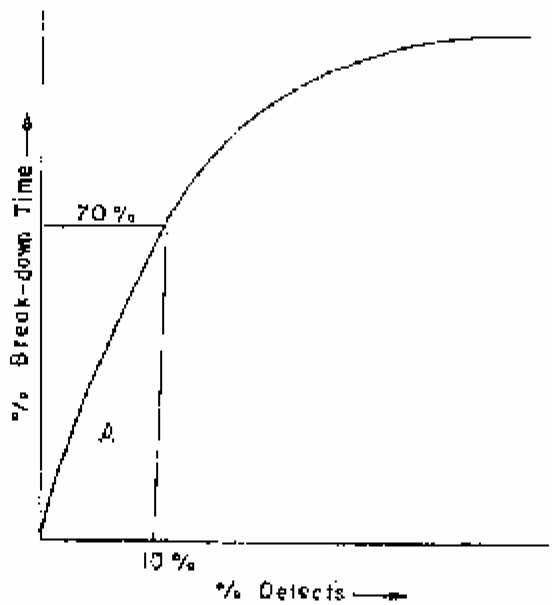


Figure II (b) : Defect Analysis



One then needs to concentrate on the critical A types of equipments and the critical A* types of defects and accordingly devise suitable preventive maintenance management schemes and design out maintenance, whenever feasible. A simple way for attacking a maintenance problem is essentially a 3 step procedure.

Step 1: Can it be eliminated? If yes, then no problem. If no, go to next step.

Step 2: Can it be simplified? If yes, then no problem. Otherwise, go to next step.

Step 3: Can it be improved? If yes, then no problem. Otherwise you have hardly any other option.

Lubrication problem-Costly and time-consuming maintenance operations of greasing the suspensions, steering and transmission components on a modern motor car, which used to number a dozen grease points or more, has now been **eliminated** by design on most models.

For machines requiring a constant supply of grease to moving parts through a multitude of often inaccessible individual grease nipples have been through the 3 step procedure, replaced by the piping of such points in groups of battery plates and thereby reducing the number of locations at which grease must be applied. Step 2 involved the piping up of all grease points to an automatic lubricator thereby simplifying maintenance and also improving quality of service. Where it proves technically impossible to design out lubrication completely or to simplify it by automatic methods, one may be confronted with grease and oil sealing problems; these can be improved by better designs of housing and sealing methods. The penny saved on capital expenditure can be pound foolish when it has to be spent ON MAINTENANCE.

13.9 MAINTENANCE COSTING AND BUDGETING

Costing and budgeting for the maintenance department embraces the provision of financial information on labour and materials expenditure, its allocation to the various cost centres together with manpower resources and the development of objectives with programmes and budgets for meeting them. The basis for cost control is provided by the use of cost account codes. Typical major code headings might include (a) capital projects, (b) planned preventive maintenance, (c) workshop services. The costs attributable to the cost codes consist broadly of wages and salaries, overhead charges, materials costs, transport costs and sundry items

The overhead charge made upon maintenance is made up of charges occurring within the maintenance department plus the overhead charges reflected from other departments like administration, general management etc. Charges arising within the department include services' rent and rates, transportation and insurance.

A budget could then be charted on the basis of the different types of costs estimated for different heads. A budget might show

Maintenance labour	20
Maintenance materials	40
Fuel costs	25
Overheads	15

When producing a departmental business plan, it is necessary to include in the budget a set of objectives and strategies for implementing the planned maintenance programmes, completion of certain capital works and the operation of a planned overhaul programme. One objective for the department ought to be the reduction of resources allocated to corrective and emergency maintenance and an increase in planned preventive work. Cost reports can be analysed for variances of actuals versus planned. In this connection it is relevant to introduce a `life-cycle cost' concept of an asset. It includes the initial costs (the total costs of procurement and setting to work), the costs of ownership during the life-cycle, and the costs of downtime. Initial costs include the costs of services, commissioning, product support and ancillary equipment. The cost of ownership include the annual costs of operation and maintenance, multiplied and factored for the life term, together with salvage value (when asset is disposed). The costs from downtime includes loss of use, repair costs and consequential damage, and will provide evidence for replacement decisions. One needs to suitably account for inflationary trends, if they exist.

Once fully understood, formal costing and budgeting would be extremely useful not only in predicting and controlling expenditure but in encouraging the prediction and preplanning of activity with the necessary resourcing to meet

13.10 MAINTENANCE PERFORMANCE INDICES

Unlike direct production which can be rated in terms of output of any particular machine, no such analytical yardstick is available for rating maintenance. In maintenance you should essentially strive to maximise availability and reliability of the machines/ assets and minimise downtime. Maintenance though a support function, is certainly linked to increase in the productivity of the system in the long run. Chandra has proposed some indices as below, which might help management achieve their objectives more effectively and efficiently.

Overtime hours worked is indicative of the failure of planning. Emergencies should be reduced to a bare minimum.

i) Maintenance productivity index $= \dfrac{\text{The output of product}}{\text{The cost of maintenance effort}}$

ii) Maintenance cost index $= \dfrac{\text{Maintenance cost} \times 100}{\text{Capital cost}}$

iii) Downtime index $= \dfrac{\text{Downtime hours} \times 100}{\text{production hours}}$

iv) Waste index $= \dfrac{\text{Quantity of Waste produced} \times 100}{\text{Quantity of total output}}$

(This is somewhat similar to 'wastivity' which, however, gives a more comprehensive conceptualisation of waste rather than just think of output waste. This would be discussed in the unit on Waste Management).

v) Breakdown Maintenance Index $= \dfrac{\text{Total hours spent on breakdown} \times 100}{\text{Total man hours available}}$

vi) Level of Maintenance $= \dfrac{\text{Total hours spent on scheduled maintenance} \times 100}{\text{Total man hours available}}$

vii) Inspection of effectiveness $= \dfrac{\text{Standard minutes of work saved on improved inspection}}{\text{Total standard minutes of inspection carried out}}$

Through inspection we should be able to reduce the volume of maintenance to the lower possible extent.

viii) Technical Competence Ratio = $\frac{\text{Annual saving in labour and material costs resulting from additions or modifications made during the year}}{\text{Total annual maintenance cost}}$

Considerable capital savings can be effected by utilising work study and value engineering techniques at the design stage.

ix) Overtime hours Ratio = $\frac{\text{Overtime hours worked}}{\text{Total maintenance man hours}}$

Overtime hours worked is indicative of the failure of planning. Emergencies should be reduced to a bare minimum.

13.11 SUMMARY

In several cases in industry, cost of unscheduled stoppage on an equipment is very high in terms of money and any breakdown or accident could cost a good deal in terms of money and human injury. Maintenance has not only to reduce scheduled stoppage time but attempt to avoid unscheduled stoppages and breakdowns by frequent performance checking, testing and providing inspection and skilful repair when required to ensure better service, availability and reliability. There are various types of maintenance management schemes. It is imperative that you use the appropriate technique by evaluating the cost-benefits of each alternative. There is a need for an effective spare parts inventory management policy and an overall necessity of adopting a systems approach. The effectiveness of production is highly dependent on the quality of maintenance service facility. Perhaps good care, caution and foresight at the design stage itself might make the concept of maintenance redundant. All effects should be to devise schemes so that emergency maintenance remains an exception rather than the rule. With the ever increasing need for reliable data and information for purposes of criticality analysis etc., computers might be in greater demand in future to help in more effective and efficient maintenance management.

13.12 KEY WORDS

Breakdown: Failure resulting in the non-availability of an item.

Corrective Maintenance: Maintenance carried out to restore (including adjustment and repair) an item which has ceased to meet an acceptable condition.

Downtime: The period of time during which an item is not in a condition to perform its intended function.

Emergency Maintenance: Maintenance which is necessary to put in hand immediately to avoid serious consequences.

History Cards: Record of usages, events and actions as appropriate relating to a particular item.

Maintenance: A combination of any actions carried out to retain an item in, or restore it to, an acceptable condition.

Maintenance Programme: A list allocating specific maintenance to a specific. period.

Maintenance Planning: Deciding in advance the jobs, methods, materials, tools, machines, labour, timing and time required.

Maintenance Schedule: A comprehensive list of maintenance and its incidence.

Overhaul: A comprehensive examination and restoration of an item, or major part thereof, to an acceptable condition.

Planned Maintenance: Maintenance organised and carried out with forethought, control and records to a predetermined plan.

Preventive Maintenance: Maintenance carrie 1 out at predetermined intervals, or to other prescribed criteria, and intended to reduce the likelihood of an item not meeting an acceptable condition.

Running Maintenance: Maintenance which can be carried out while the item is in service.

Shutdown Maintenance: Maintenance which can only be carried out when the item is out of service.

Tero-technology: It is a combination of management, financial engineering and other practices applied to physical assets in pursuit of economic life-cycle costs; it is concerned with the specification and design for reliability and maintainability of all assets, with their installation, commissioning maintenance modification and replacement, and with feedback of information of design, performance and costs.

13.13 SELF-ASSESSMENT EXERCISES

1 Should maintenance be regarded just as a repair function?

2 What do you understand by the term `tern-technology'? Is the term and concept easily acceptable?

3 If the trends of computerisation of processes continue to grow, what would be its impact on the maintenance function?

4 What are the objectives of maintenance management?

5 Can you think of some examples from your experience that either conform to or are at variance from the `bath tub curve" of failure rate phenomena.

6 What are the different types of maintenance systems? Could you give some illustrative example for each alternative system? You may take the example of a car, scooter or any other asset of your choice for elaborating your answer explicitly.

7 What is `priority index' and how would you obtain it?

8 hat precautions should you keep in mind while attempting to apply work study techniques to maintenance engineering?

9 What is `criticality analysis'? Explain how the Pareto Principle finds its application for effective maintenance planning and control.

10 Discuss the need for devising some maintenance performance indices.

11 What is the utility of maintenance performance indices? Discuss a few of them.

13.14 FURTHER READINGS

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