Plant Maintenance Engineering and Management

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PLANT MAINTENANCE ENGINEERING AND MANAGEMENT

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Published by :
Romesh Chander Khanna & Vineet Khanna
for **KHANNA PUBLISHERS**
2-B, Nath Market, Nai Sarak
Delhi- 110 006 (India)

Website : www.khannapublishers.in

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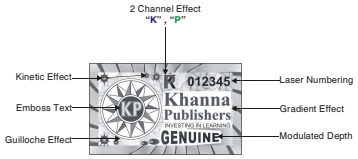

ISBN : **978-93-92549-09-0**

First Edition : **2007**

PREFACE

Rapid industrialisation and opening of Indian economy to globalisation has put stringent requirements on Indian industry, Industry has to take several measures to remain competitve. Apart from optimum designs, selection of best materials and processes, quality control, safety, etc., it is imperative that full attention is paid to maintenance aspects. Any neglect of this area can affect optimal utilisation of production capacity which industry can hardly afford. Operational security demands high quality of maintenance of plant and machinery.

Maintenance refers to all actions to be taken to keep entire sets of machines and equipment in a plant in acceptable operating condition. It is a definite science and hit and trial methods cannot help to achieve desired purpose. Maintenance science, engineering and management ensure maximised availability and reliability of all assets in a plant to enable maximum possible returns on investment. It also enables extending the useful life of all assets by minimising wear and tear and deterioration, ensuring safety, and preventing wastes of any kind.

The cost of maintenance in a plant should also be minimum and at the same time meeting all the functions.

For this purpose planned and systematic maintenance, a well defined quality management system for maintenance is essential to revive health of plant, its performance and efficiency. There are several well defined stragegies of maintenance and depending on the nature and requirements of industry, suitable strategy of maintenance need to be adopted. A maintenance engineer should be fully trained to handle his job and understand his function and objectives. He must take all steps to improve maintenance management. He must ensure proper maintenance organisationl set up and define duties of all concerned very clearly making them accountable for their job. Human factors in maintenance have to be well understood. All maintenance personnel need motivation to contribute their best. Maintenance policies and practices of organisation in its overall interest should be elaborately defined, understood by all and practised accordingly. The maintenance management programme should define methodology clearly for effectiveness. The planning process for successful implementation of maintenance management is essential. The high degree of

mechanisation and automation in industry demand top class skill both in the field of fault diagnosis and actual repair. Constant vigil and inspection during normal operation cannot be overlooked by maintenance personnel. Maintenance system needs good maintenance information system for analysis of failures, ensuring availability of materials/spare parts/consumables, keeping track of pending jobs, evaluation and control of costs, development of maintenance standards, man power utilisation, etc. Computer aided information systems help in suitable decision making in maintenance programme. Spare parts management is another area of importance for successful maintenance management.

This book attemps to cover all these important aspects of maintenance engineering and management. Various techniques are in constant advanced stage. Effort has been made to include all such methodologies like total productive maintenance, reliaibility centered maintenance, integrated maintenance techniques, and several other world class practices in this field. Failure analysis, reliability, trouble shooting and maintainability have been covered in detail. Vibration analysis is important for all mechanical and rotary machines and thus finds good deal in this book. Similarly, on line monitoring and analysis plays an important role in effective maintenance, for this a separate chapter is devoted to highlight role of non destructive testing in maintenance.

Several chapters have been devoted to cover maintenance practices for many commonly used mechanical and electrical equipments. One complete chapter covers the general maintenance and safety practices.

It is hoped that this book will be found useful by both student community as well as those working in industries, plants and factories for maintenance of plant and equipment.

In writing this book, material on maintenance practices of various organisations like NTPC, BHEL, Tata Power, Siemens, Indian Oil, HMT, Crompton, ABB etc. has been consulted.

My sincere thanks are to Sh. Vinit Khanna for his constant encouragement to me to take up this assignment. I am also grateful to my wife Sunita Jain for her total support and help in writing this book.

Any suggestion for improvement of book to serve better interest of student community and working maintenance engineers shall be welcomed and acknowledged.

R.K. Jain

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Maintenance Management

1.1. INTRODUCTION

In order to remain competitive every industry must use its production capacity optimally. For operational security, quality of maintenance is most important.

Maintenance is the total of activities serving the purpose of retaining the production means in or restoring them to a state where production function can be fulfilled. Efficient maintenance refers to the right resources at the right place at the right time. The basic aim of maintenance is to achieve high productivity, maximum utilisation of resources and acceptable safety. Maintenance actions like repair, change of components, adjustments and calibration are essential to restore the machinery and plant and reduce the losses in energy and raw materials at a minimum level.

Breakdowns constitute a major percentage of the cost attributed to the maintenance. All efforts need to be made to reduce breakdowns. One way is to modify materials, improving design, and improving manufacturing techniques. Second is the identification of failure before it actually occurs (impending failure) and this is done by inspections and following condition monitoring techniques.

1.2. REASONS TO MANAGE THE PROCESS OF MAINTENANCE

- It reduces long term costs.
- Capacity of plant can be assured if timely maintenance is done.
- Effective management of maintenance helps meeting a competitive challenge.
- Good maintenance management initiates remedial action before deterioration gets uncontrolled.
- Life of assets is increased.
- Good house keeping and properly cleaned machine enable operators to contribute their best.

— Level of perceived service to the user is increased.
— Maintenance management promotes fire and health safety.
— A maintenance managed plant is a better place to work. Quality of life is improved.

1.3. MAINTENANCE POLICY

It is a narrative statement or illustration that defines the practical means of maintaining an equipment, item or system. This is an extension of the maintenance concept with due consideration for the inherent characteristics of the equipment/system design and other constraints or limitations. In the broadest sense, a maintenance policy conveys all of the directives, procedures and resources necessary to service and maintain a equipment item or system. It sets forth the maintenance task requirements, the frequency of maintenance needs, the level of maintenance support, facility requirements, replacement part needs, support equipment and tool requirements, the required number and type of maintenance personnel, and the definition of maintenance procedures.

Maintenance Policies and Practices

(*a*) All maintenance activities requiring plant shut-down for 24 hours or other jobs of more than 24 hours duration need to be planned in detail using CPM/PERT/BAR CHART techniques. In addition to planning of the duration of the activity, materials required, internal and external services needed, manpower to be deployed etc. are also planned quite in advance of shut down.

(*b*) All breakdowns should be investigated by Technical Services for reasons of failures and remedial actions to avoid their recurrence.

(*c*) No job should be taken up without job-card. Job card serves not only as an initiating/requisition document for the job, but also serves as input document to create computerised maintenance history of various equipments.

(*d*) Inspection of rotating equipments, thickness testing of pipes and structures and technical audit of operating plants should be carried out by Technical Services at regular interval.

(*e*) The list of pending jobs requiring total shut-down or partial shut down of the plant should be kept ready all the time to take advantage of breakdown and unforeseen forced shut downs.

(*f*) Contract maintenance may be necessary for specialised jobs and to tide over peak loads during shutdowns.

(*g*) During each shut down, the actual time taken by various activities/jobs should be recorded along with problems so as to facilitate planning for subsequent shut down.

(*h*) A de-briefing report should be prepared by Industrial Engineers for each shut down of each plant to analyse the problems faced and corrective actions required.

(*i*) Preventive Maintenance schedules should be prepared after studying maintenance history of major and critical equipments by Maintenance Engineering Section.

(*j*) Computer based maintenance information system needs to be developed to analyse the pending jobs, maintenance frequency, production loss, maintenance cost, overtime incurred, manpower utilisation, inventory stock level, etc.

(*k*) Planning engineer should carry out detailed job planning, material procurement follow up, preventive maintenance follow up and for maintaining technical information of the plant.

Controlling Maintenance Down Time

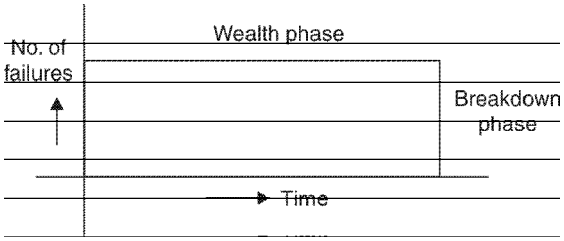
The planning and continuous progress monitoring of maintenance jobs help in reducing downtime of various plants. The day-to-day problems can be left to respective plant engineers whereas the shut downs and major jobs are planned in detail and progress is monitored with the assistance of Industrial Engineers. Since various plants are usually inter linked the shut down of each plant is judiciously planned so that total shut down duration of the plants is minimal. A master control chart is prepared to give overall view of interlinks and down time of individual plants. The movements/ allocations of facilities like cranes, welding sets, pneumatic wrenches, portable air compressors, etc. should be planned with the help of Loading Chart techniques so as to optimise their utilisation and reduce overall downtime. During the execution stage of shutdown and major maintenance jobs, round the clock monitoring is needed by Industrial Engineers so as to ensure that there is no loss at down time due to problems of co-ordination and communication. Problems need to be anticipated based on past experience and remedial actions are taken in time.

1.4. MODES OF DETERIORATION OF ASSETS

It is important to identify how various assets fail because different equipment fail in different ways and all need maintenance. We need sophisticated maintenance approach and support systems for this purpose. Once the mode of failure for any component is known, we must locate where on the critical wear curve we are and react accordingly in time.

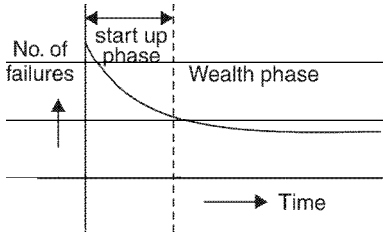
Six known and common methods of deterioration are :

(*i*) *Random*—A component may fail any time. Example is common in electronics and for components which become obsolete before their wear out phase.

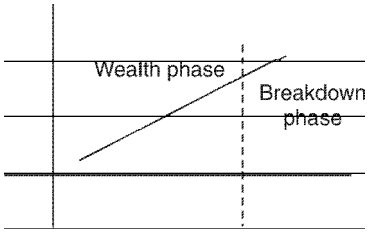


The probability of failure in any period is same and it is unrelated to life span. In such cases failure may occur by accident also.

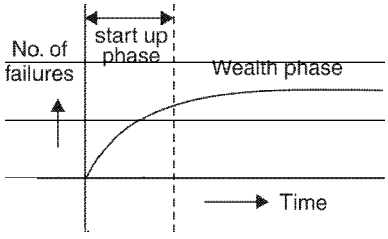
(*ii*) *Infant mortality*—In start up phase probability of failure is high and then it drops to random level. Many electronics systems failure are most frequently observed during initial burn-in.



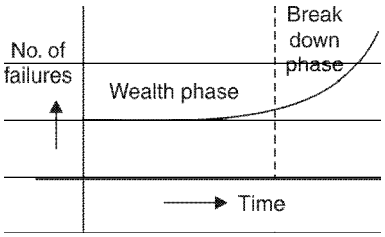
(*iii*) *Probability of failure increases with utilisation*—Most of mechanical components behave in this way as they wear out gradually. Breakdown phase could set in after about 75% of life is consumed.



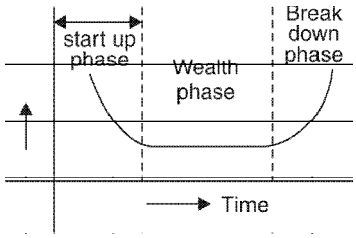
(*iv*) *Increasing and stabilising*—The probability of failure increases in initial phase and then it stabilises.



(*v*) *Ending mortality*—Probability of failure is random until end of life cycle and then it increases rapidly. Mechanical systems show such behaviour. For example corrosion can go along until the amount of metal left is marginal to support the structure.



(*vi*) *Bath tub (combination of infant mortality and ending mortality curves).*



Infant mortality in start up phase includes failures of materials, workmanship, installation, training, etc. and frequently costs are partially covered by warranty. This can be taken care of by increasing time to test run equipment, following good installation practices, training operator properly, learning from experience of other users, etc.

Wealth phase is the period when plant/machine operates profitably. This phase can be extended by following proper planned maintenance techniques, good operation and maintenance practices, quality audits, etc.

Breakdown phase is characterised by wear-out failure, break-downs, corrosion failure, fatigue, downtime, etc. One needs to be on mode of great fire fighting capability and assess the residual life of components and replace those which have worn out to extend the life of entire plant and machinery.

1.5. MAINTENANCE MANAGEMENT

The effectiveness and success of Maintenance Management depends on:

(*i*) Quality and training of men responsible for running the maintenance programme.

(*ii*) Use of scientific and properly documented methods

(*iii*) Adequate availability of funds.

The effectiveness of any programme depends on a large measure on (*i*) the men to implement it and (*ii*) how they are deployed, *i.e.* on the organisation pattern.

Considering the conflict of interest of operation men and maintenance men, it is desirable to follow an organisational structure based on the shop pattern. The head of the plant is assisted by shop chiefs who are responsible for both operation and maintenance, including major overhaul and breakdown works. The great advantage of this system of organisation is that it makes for better coordination between operation and maintenance and the entire responsibility of the equipment rests with the agency who has a large manouverability in his field of authority.

For the persons deployed for maintenance management, proper emphasis has to be laid on the qualification, caliber and background of the maintenance personnel, their initial training and periodical refresher courses, so that advantages of modern technological advances in their fields are fully derived. It is important to impart comprehensive training to the new incumbents who should actively associate themselves with the on-job training.

Another important factor which needs emphasis is the working environment and safety. Unless proper working environment is created enthusiasm will be lacking. An atmosphere of cleanliness and proper ventilation are necessary for maintenance group. Safety is ensured by proper safety permits and also by having an independent Safety Officer who has an eye for detecting hazarduous situations and who has got the necessary authority to stop work, if an unsafe act is being committed.

The effectiveness of any Maintenance Management programme is, in a very large measure, dependent on the methodology employed. Such methodology has to be imaginative, scientific and suited to the specific requirements of the job. Though the methodology can be spelt in broad terms to cover all situations of maintenance requirements, it should allow sufficient flexibility in its implementation to achieve the best end results.

1.6. PRIORITIES OF MAINTENANCE

It is necessary to have set priorities of maintenance work and such priorities have to be drawn up as a maintenance policy depending on the nature of the industry and the special characteristic of the plant. The priorities in general could be drawn up as below :

(1) *Emergency work.* Under emergency work are listed all kinds of work demanding immediate attention for preventing accident and losses in revenue. This will include (*a*) shutdown work (*b*) work to replace a critical component which will otherwise cause failure of the plant (*c*) work to prevent or avoid hazardous operating conditions, and (*d*) work which if not immediately attended, will cause very high production cost.

(2) *Scheduled preventive maintenance work*. Scheduled preventive maintenance work includes all such type of maintenance work which is meant to prolong the useful operating life of the plant without major repairs and whose periodicity is fixed on the basis of past experience on the behaviour of the plant or on the basis of manufacturer's recommendation.

(3) *Scheduled major repairs and maintenance work.* Scheduled major repairs and maintenance work include major overhaul and other repair works at stated periods as per recommended practice.

(4) *Indirect maintenance.* Indirect maintenance work includes such work taken up to incorporate modifications, improvements etc., to reduce production cost or bring about better operating conditions.

(5) *General property maintenance.* General property maintenance includes such works as painting or lining to prevent rusting and corrosion, barricading for safety, improvement to environs etc.

Preventive maintenance has its aim ensuring troublefree and smooth operation of the unit till the next scheduled major overhaul.

The operation characteristics of the equipment and the probable consequences of operating beyond the recommended parameters should be thoroughly understood, as also the stresses that components are subjected to in normal operation. Thermal stresses caused by impermissible steam parameters, load fluctuations, frequency variations, voltage dips, fault trippings all come under this category.

The maintenance man should also be aware of **new products** coming in the market which claim higher efficiency or less inspection.

Material failures should be studied in depth to ascertain the actual cause thereof—poor material, poor workmanship, poor fixing, improper operation or any other so that proper preventive action can be decided upon, including changes in design and methods of manufacture, increasing the life of the spare.

Failures caused by corrosion (including pitting and erosion), mechanical environmental processes (including stress-corrosion, cracking and hydrogen damage), fracture (including fatigue-fracture,

thermal fatigue fracture and stress rupture) and distortion (especially distortion involving thermal expansion affects or creep) should be analysed thoroughly and remedial measures for future decided.

Important stages in **analysis of failures** include collection of background data and samples, non-destructive testing, examination including analysis of metallographic sections, chemical analysis, testing under simulated service conditions and analysis of the evidence—some or all of these stages having to be gone through depending on the item under study.

Remedial methods adopted to prolong the useful life of parts between failures include change in material, design, fabrication process, heat treatment methods, change in operation procedure, strengthening of insulation etc.

Maintenance problem will be considerably simplified through **standardisation**—of tools, methods, specifications, processes, manuals, equipment and materials.

A **critical study of** monthly progress **reports**, accident reports and failure reports on equipment will throw light on areas requiring special attention. Keeping records but not making use of them is just a waste of time and effort. An analysis of equipment records will reveal items of high maintenance cost, causes of excessive downtime, and of repetitive failures. It will be advisable to fix maximum limits for annual maintenance expenditure for the plant; and when these limits are exceeded, the situation should be examined at competent levels.

Statistical analysis techniques should also be employed for establishing inspection and overhaul frequencies and for checking maintenance performance, the objective being achievement of maximum production time with minimum maintenance cost.

Ready availability of spares is the single factor exercising maximum influence on the down time of a plant.

The practice of entrusting the **maintenance work to an outside agency** on contract is useful during peak load periods of maintenance. By resorting to contract maintenance as a routine method, we can save considerably on the upkeep and administration of the maintenance work force; only a skeleton technical supervisory force will be required to plan and co-ordinate the maintenance work with the contractor and also to inspect the workmanship on a continued basis.

In case **contract maintenance** is resorted to, attention has to be paid to the proper choice of the agency. The agreement entered into with the contracting agency is the legal basis for the work and great care should be bestowed in drawing up this agreement, the

schedule of work, rate, duration and other relevant conditions.

1.7. MAINTENANCE TASKS

With increase in the degree of mechanisation and automation, a very high level of maintenance skill both in the field of fault diagnosis and actual repair is needed. In order to diagnose and restore the equipment in the shortest possible time, the present day maintenance engineers should be adept in all branches of engineering.

Womb to Tomb approach

Today plant engineering and maintenance function cover all technical tasks and physical aspects from design of plant to their replacement, including often the utility services and disposal of wastes etc. To be effective, maintenance engineers should necessarily be associated throughout the life of the equipment right from the selection of the equipment, maintenance, repair and final disposal. A typical approach would be to have a plant engineering group from the commencement of the project stage upto commissioning stage responsible for all equipment. After the commissioning of the equipment/plant in the case of sophisticated machinery, the best talents from this engineering group should be deployed for maintenance tasks.

The management should also encourage migration of talented personnel to maintenance by providing necessary incentives. The aspect of maintainability needs necessarily to be incorporated in the basic design philosophy itself of the plant right at its inception.

The primary task of maintenance is of course to ensure that equipment is available for production at the optimum capacity. The best strategy appears to be a combination of three distinct activities carried out concurrently.

(*i*) **Breakdown function—**The operational availability of plant needs to increased to above 90% level.

(*ii*) **Prevention of Breakdown—**Constant condition monitoring of the machinery should be done using all the available scientific techniques, like vibration analysis, shock pulse analysis, spectroscopic detention of wear components in spent lube oil, infra-red detection of overheating and a multitude of other techniques. The preventive actions can then be carried out at just before a predicted breakdown, saving unnecessary preventive maintenance work as well as the unnecessary preventive maintenance down time.

(*iii*) **Design out maintenance—**Breakdowns should not happen. If something breaks down, if it is not a case of negligent condition monitoring, modification of the design to prevent a

recurrence is almost imperative. It may even be a redesign of the monitoring system. Design function and maintenance function go totally hand in hand. At every failure, a design analysis is an absolute must and almost in all cases what is put back should not be just what it was. It must be redesigned part with a more reliable component which will not fail. At least, it should not fail due to the same reason as before. Frequent preventive maintenance requirement on a component also calls for redesign. Redesign of equipment is one of the constant functions of the modern maintenance engineer.

1.8. PLANNING FOR MAINTENANCE

It is a general experience that if certain maintenance factors and features are included at design stage itself, then higher plant availability and reliability, better product quality, high plant and personnel safety, environment friendly designs and more savings in terms of materials, energy, manpower plant replacements costs are possible.

To have minimum maintenance problems in a given plant it is better to review the design with respect to the maintenance of the plant. It is even better to start planning for maintenance at the conceptual stage itself. It is thus necessary to establish the basic needs first to obtain cost effectiveness in terms of savings in men, materials, machines. The incorporation of maintenance concept should contribute to the minimum outlay of funds for system acquisition and utilisation. It should accomplish basic needs such as:

(*i*) To do all tasks in a minimum amount of time, manpower, training, test equipment, contractor's services, workshop facilities, spares, variety and quantity of tools and documentation etc.

(*ii*) Provision for expansion and incorporation of modern maintenance techniques.

(*iii*) Reliable and safe operation of the plant.

Manpower Planning and Development. An organisation capability can be built by selecting personnel of all required disciplines with plant maintenance and operation experience, preferably in a similar plant. Then these personnel should be trained on the job and off the job in various aspects like maintainability, maintenance engineering and analysis, human engineering, value analysis, reliability and safety aspects. The purpose of training should be two fold *i.e.,* to train maintainability and maintenance engineers in the proper performance of tasks and to acquaint other project personnel with the purpose and importance of the concept. To acquaint various levels of personnel a familiarization course should be conducted. Design engineers should be briefed on maintainability criteria,

Plant Maintenance Engineering and Management

About the Book:

For an industry to remain competitive, it has to lay great emphasis on maintenance aspects apart from the consideration. It is today a science and engineers with good understanding of this subject are needed by industry. An attempt has been made to cover entire subject in a very simple way. This book highlights the need of timely maintenance various strategies of maintenance, duties and responsibilities of maintenance engineers, and latest world wide practices in the field of maintenance. It lays emphasis on keeping vigil on plant and machinery during normal operation by inspection and on line continuous monitoring of important parameters which have direct bearing on predicting health of plant and machinery. This book also covers as to how computers and information technology systems can assist maintenance engineers in carrying out their responsibilities in effective manner. Vibration and Vibration analysis, Failure analysis and Reliability determination have also been covered in detail. It provides information on maintenance of important mechanical and electrical equipment like motors, pumps, values, rotating machines, diesel engines, circuit breakers, transformers, etc. Safety aspects have also been covered in details.

Book has been written in a lucid manner so that beginner is able to understand the subject and implement the maintenance practice in industry.

Inside the Book:

- Maintenance Management
- Maintenance Strategies
- Failure Analysis
- Reliability
- Maintainability Criteria
- Vibration Analysis for Predictive and Preventive Maintenance
- Fault Diagnostics and Trouble Shooting
- Efficient Maintenance Management Using online Monitoring and Analysis
- Non Destructive Testing Tools for Maintenance
- Maintenance of Heat Exchangers
- Maintenance of Valves
- Maintenance of Pumps
- Maintenance of Diesel Engines
- Maintenance of Electrical Equipment
- Maintenance of Electrical Motors
- Maintenance of Circuit Breakers
- Maintenance of Transformers
- Battery Maintenance
- General Maintenance and Safety Practices in Industries.

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