Design of Systems and Implementation Stages for World-Class Maintenance at Staple Fibre Division, GRASIM Industries Limited

THESIS

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By

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CERTIFICATE

This is to certify that the thesis entitled " Design of Systems and Implementation Stages for World-Class Maintenance at Staple Fibre Division, Grasim Industries Limited " and submitted by Arun Maity ID No. 1992PHXF001 for award of Ph.D. Degree of the Institute, embodies original work done by him under my supervision.

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INTRODUCTION

1.1 The Changing World of Maintenance

Over the past twenty years, maintenance has changed perhaps more so than any other management discipline. The changes are due to a huge increase in the number and variety of physical assets (plant, equipment, and buildings) which must be maintained throughout the world, much more complex designs, new maintenance techniques and changing views on maintenance organization and responsibilities.

Maintenance is also responding to changing expectations. These include a rapidly growing awareness of the extent to which equipment failure affects safety and the environment, a growing awareness of the connection between maintenance and the product quality, and increasing pressure to achieve high plant availability and to contain costs.

The changes are changing attitudes and skills in all branches of industry to the limit. Maintenance people have to adopt completely new ways of thinking and acting, as engineers and managers. At the same time the limitations of maintenance systems are becoming increasingly apparent, no matter how much they are computerized.

In this face of this avalanche of change, there is a need for a new approach to maintenance. It is necessary to avoid the false starts and dead ends, which always accompany major upheavals and seek a strategic framework, which synthesizes the new developments into coherent pattern, so that it can, evaluate sensibly and apply scientifically to achieve higher values.

1.2 Evolution of Maintenance

Since 1930's the evolution of maintenance can be traced through three generations.

The First Generation

The First Generation covers the period up to World War II. In those days industry was not very highly mechanized, so downtime did not matter much. This meant that the prevention of equipment failure was not a high priority in the minds of most managers. At the same time, most equipment was simple and much of it was over-designed. This made it reliable and easy to repair. As a result, there was no need for systematic maintenance of any sort beyond simple cleaning, servicing and lubrication routines. The need for skills was lower than it is today.

The Second Generation

Things changed dramatically during Second World War. Wartime pressures increased the demand for goods of all kinds while the supply of industrial manpower dropped sharply. This led to increased mechanization. By the 1950's machines of all types were more numerous and more complex. Industry was beginning to depend on them.

As this dependence grew, downtime came into sharper focus. This led to the idea that equipment failures could and should be prevented, which led in turn to the concept of preventive maintenance. In the 1960's, this consisted mainly of equipment overhauls done at fixed intervals.

The cost of maintenance also started rising sharply relative to other operating costs. This led to the growth of maintenance planning and control systems. These have helped greatly to bring maintenance under control, and are now an established part of the practice of maintenance. Finally, the amount of capital tied up in fixed assets together with a sharp increase in the cost of that capital led people to start seeking ways in which they could maximize the life of the assets.

The Third Generation

Since the mid-seventies, the process of change in industry has gathered even greater momentum. Downtime has always affected the productive capability of physical assets by reducing output, increasing operating costs and interfering with customer service. By the 1960's and 1970's, this was already a major concern in the mining, manufacturing and transport sectors. In manufacturing, the effects of downtime are being aggravated by the worldwide move towards just-in-time systems, where reduced stocks of work-in-progress mean that quite small breakdowns are now much more likely to stop a whole plant. In recent times, the growth of mechanization and automation has meant that reliability, availability and maintainability have now also become key issues in sectors as diverse as health care, information systems, telecommunications and building management.

Greater automation also means that more and more failures affect our ability to sustain satisfactory quality standards. This applies as much to standards of service as it does to product quality. Equipment quality can affect consistent achievement of specified tolerances in manufacturing.

More and more failures have serious safety or environmental consequences, at a time when standards in these areas are rising rapidly. In some parts of the world, the point is approaching where organizations either conform to society's safety and environmental expectations, or they cease to operate. This adds an order of magnitude to our dependence on the integrity of our physical assets-one which goes beyond cost and which becomes a simple matter of organizational survival.

At the same time as our dependence on physical assets is growing so too is their cost - to operate and to own. To secure the maximum return on the investment which they represent, they must be kept working efficiently for as long as we want them to.

1.3 Literature Survey

Some studies have been conducted to analyze the status of maintenance in Indian Industries through a survey conducted over fifty five companies, which showed that the maintenance cost has increased in 87.2% of the organizations. The increase is more than 30% in 46.2% of the organizations.[1]

Some studies have been conducted in India as well as abroad by dealing with a type of industry separately like fertilizers, chemical industry, petrochemicals and engineering industries. The author highlights four aspects of maintenance mainly objective of maintenance, maintenance reporting, maintenance policies and responsibilities of maintenance managers. [2]

Some studies have indicated following new developments and challenges for maintenance:

New Developments

The new developments include:

- Decision support tool, such as hazard studies, failure modes and effects analyses and expert systems
- New maintenance techniques such as condition monitoring
- Designing equipment with a much greater emphasis on reliability and maintainability
- A major shift in organizational thinking towards participation, team working and flexibility.

Major Challenges Facing Maintenance

A major challenge facing maintenance people nowadays is not only what these techniques are, but to decide which are worthwhile and which are not in their own organizations. If we make the right choices, it is possible to introduce asset performance and at the same time contain and even reduce the cost of maintenance. If we make the wrong choices, new problems are created while existing problems only get worse.

The challenges facing modern maintenance managers are as follows:

- To select the most appropriate techniques to deal with each type of failure process in order to fulfill all the expectations of the owners of the assets, the users of the assets and of society as a whole
- In the most cost - effective and enduring fashion
- With the active support and cooperation of all people involved

1.4 Emergence of Total Productive Maintenance

The demand of high quality products at lower costs is driving most companies to shift focus towards equipment management programs. Leading the way is the Japanese theory known as Total Productive Maintenance (TPM), a proactive equipment maintenance strategy designed to improve overall equipment effectiveness. The goal of TPM is to increase the productivity and life cycle of equipment with a team approach that involves engineering, maintenance and operations personnel.

Total Productive Maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. TPM evolved from Total Quality Management (TQM), which evolved as a direct result of Dr. W.E.Deming's influence on Japanese industry. Dr. Deming began his work in Japan shortly after World War II. When the problems of plant maintenance were examined as a part of Quality Management program, some of the general concepts did not seem to fit or work well in the maintenance environment.

Preventive Maintenance (PM) procedure had been in place for some time and PM was practiced in most plants. Using PM techniques, maintenance schedules designed to keep machines operational were developed. However, this technique often resulted in machines being over-serviced in an attempt to improve production. There was little or no involvement of the machine operator in the maintenance program and maintenance personnel had little training beyond what was contained in often-inadequate maintenance manuals.

The need to go further than just scheduling maintenance in accordance with manufacturer's recommendations as a method of improving productivity and product quality was quickly recognized by those companies who were committed to TQM programs. To solve this problem and still adhere to the TQM concepts, modifications were made to the original TQM concepts. These modifications elevated maintenance to the status of being an integral part of overall quality program.

The first step in implementing TPM requires the assembly of teams of maintenance, operations and engineering personnel with the goal of evaluating the current performance level of the critical machines. Through this evaluation, the teams are able to identify losses in availability, performance, efficiency and quality. Once the problem has been identified, the teams clean, restore and improve those critical machines and at the same time create a model to assist future autonomous maintenance teams in evaluating, restoring and maintaining machines in other areas.

Survey revealed that most of the companies implementing TPM have reported 50% or greater reduction in downtime, reduced spare parts inventory and increased on-time deliveries. The need for out-sourcing part or all of a product line was greatly reduced in many cases. It has also been proven that the program can be adapted to work not only in industrial plants, but also in construction, building maintenance, transportation, and in a variety of other situations.

1.5 World - Class Manufacturing

World - Class Manufacturing is one of the emerging areas being adopted by the companies to strive for better quality products and better work - environment and health. The achievement of world-class manufacturing performance is essential if companies are to survive against international competition.

One vital ingredient of this is highly reliable and consistently operated machines, equipment and processes. These machines, equipment, processes together with operators are the only direct wealth creators in a manufacturing plant. Other functions like sales, marketing, design, production control, finance either feed off them or support them. To build a consistent and sustainable competitive advantage it is essential that the man / machine interface be maximized and that all associated sources of wastes are eliminated.

1.6 Statement of the Problem

Maintenance is one of the most critical areas governing any process industry. Maintenance when neglected leads to frequent breakdowns, leading to costly repairs and faster deterioration of valuable equipment, besides causing incalculable production losses.

The research work aims at designing systems and procedures for implementing World-Class Maintenance at Staple Fibre Division, Grasim Industries Limited. The study has been carried out in various departments like Viscose, Spinning & After Treatment, Auxiliaries, Acid Plant and Energy Centers of Staple Fibre Division. The existing maintenance systems have been studied and efforts were made to suggest new systems and procedures, which would help GRASIM achieve more stability, improved maintainability, maximum overall equipment effectiveness at reduced costs.

The existing Maintenance Organization structure needs a rational change, to reduce number of levels and clearly define the role and responsibilities of each level. This would help in better information flow and facilitate quicker decision-making. The existing Maintenance Information System has only become a data bank, with lots of data and information. These data need to be analyzed at different levels of the organizational hierarchy, as information required at each level is different.

The asset care management requires the determination of availability, quality, performance and thus the overall equipment effectiveness. The machine stoppages due to various reasons account for availability. The performance depends upon the target production and actual production. The quality of fibre depends upon various fibre characteristics and it has become necessary to quantify the same, as per the needs of the customer. Benchmarking of these parameters would help in continuous improvement and strive for world-class.

The main aim of maintenance is to maximize the Mean Time between Maintenance (MTBM) and minimize Mean Time to Repair (MTTR). This requires introduction of scientific maintenance procedures like Need-cum-Opportunity Based Maintenance, which helps in utilizing the opportunity to carry out all pending jobs during stoppage, thus enhancing the availability and reducing the frequency of stoppages. Guidelines need to be prepared for this new concept and the implementation procedures.

Maintenance prevention techniques should be devised which can help in preventing failures. The failure needs to be predicted much before its actual failure. The maintainability of equipment should be improved so that the equipment conditions can be maintained and the need for maintenance is reduced.

Cost has been the major factor in any maintenance activity. The replacement of equipment before achieving the actual life enhances the overall costs. Hence, reconditioning of equipment is necessary, so that the useful life of equipment can be prolonged to a greater extent. A study needs to be carried out on the factors affecting the decision of reconditioning and replacement, and prepare guidelines, by incorporating cases from various departments of Staple Fibre Division.

A need has been felt to design an autonomous maintenance system to achieve optimal equipment conditions and establish standards to sustain these conditions. It is the only way to create a failure-free and trouble-free workplace. The systems, procedures and concepts developed through scientific approach need to be followed by the operators and managers to achieve World - Class performance.

The implementation of these new concepts requires lot of skills, knowledge and good work culture. The training and development of the workers, supervisors, lower, middle and top level management becomes very necessary. The training areas need to be identified for all the levels and proper scientific methods should be adopted.

1.7 Summary of Chapters

Chapter 1 deals with an overview of advancement made in the area of maintenance in the recent years and its scenario in Indian context. Indian Industries have adopted various new concepts and technologies like Total Productive Maintenance and World – Class Manufacturing.

Chapter 2 deals with an introduction to World - Class Maintenance and highlights its various pillars. It also describes the objectives and importance of each pillar in implementing World – Class Maintenance.

Chapter 3 deals with an introduction to GRASIM Industries Limited, a flagship company of the Aditya Vikram Birla Group of Companies. It describes the process for the manufacture of Viscose Staple Fibre and gives an overview of various departments of Staple Fibre Division. It also focuses on existing working methodology of maintenance department at Staple Fibre Division.

Chapter 4 presents the maintenance organizational structure of Grasim Industries Limited and focuses on the duties and responsibilities of each level of organizational hierarchy. This proposed flat structure with reduced number of levels would definitely help in better information flow and accountability.

Chapter 5 deals with the importance of information systems in maintenance management. It describes the need of information at each level of the organizational hierarchy by means of formats and reports. It also suggests a number of maintenance formats for top, middle and lower level management of the organization. It also proposes an Executive Summary Report for Top level management, which incorporates all important maintenance parameters, to monitor department working.

Chapter 6 defines various maintenance systems applicable in a process industry. It describes the procedures for scheduling, planning & control of maintenance activities. Safety principles, guidelines and procedures have been described and new techniques for hazard identification have been explained with few cases from the department.

Chapter 7 deals with different phases of asset care management. It describes various tools and techniques of problem solving like P-M Analysis, Why-Why Analysis etc. by taking few real-life problems from various departments of Staple Fibre Division.

Chapter 8 deals with the calculation of Overall Equipment Effectiveness (O.E.E) of key equipment of various departments of Staple Fibre Division. The important parameters like downtime, mean time between maintenance etc. have been calculated and benchmarked for spinning machines for continuous improvement. Effort has also been made to devise a new empirical formula to define the fibre quality, which takes into account all aspects of fibre characteristics from production and sales point of view. This formula can be implemented to determine the actual quality of fibre.

Chapter 9 deals with an introduction of a new concept " Need-cum-Opportunity based Maintenance", which helps in maximizing the availability of machine and improving the productivity and decision-making. The daily reporting system of various departments related to process and maintenance can be made more effective through a new concept " To Inform & Confirm" as described in this chapter.

Chapter 10 deals with maintenance prevention techniques and maintainability improvement procedures. The maintenance prevention can be achieved mainly through process improvement, design change, material change and size change. The machine condition needs to be continuously monitored through condition monitoring and vibration monitoring techniques. The maintainability can be improved through improved service conditions, quality material and spares, better skills of labor and improved testing equipment and procedures.

Chapter 11 deals with the concept of Autonomous Maintenance. It describes the goals and need of Autonomous Maintenance. It emphasizes on the techniques of establishing and maintaining basic equipment conditions. Checklists have been designed for Spinning & After-Treatment departments for proper implementation.

Chapter 12 deals with the cost – reduction techniques to be adopted in maintenance. A study has been undertaken to reduce the maintenance cost through standardization, elimination of obsolete items and reconditioning of equipment. The annual maintenance contract helps to reduce the overall cost and supervision of equipment. The life value analysis of key equipment helps in prolonging the life of equipment and facilitates decision making on purchase of equipment.

Chapter 13 deals with training and development of maintenance personnel. It emphasizes on the needs of training and various training methods. Training needs at all levels have been identified. The training module for workers and the training areas for different levels of management hierarchy have been devised.

Chapter 14 discusses the findings of study undertaken and recommends ways of implementing World-Class Maintenance at Staple Fibre Division of Grasim Industries Limited, Nagda.

CHAPTER 2

WORLD – CLASS MAINTENANCE

2.1 Introduction

World-Class Maintenance is an integral part of World-Class Manufacturing, which aims at achieving world class levels of overall equipment effectiveness through scientific approach. World-Class Maintenance leads to zero defects, zero breakdowns, zero accidents, and zero pollution. The research work aims at designing systems and procedures for implementing World-Class Maintenance at Grasim Industries Limited. The study was carried out in various departments like Viscose, Spinning & After-Treatment, Auxiliaries, Acid Plant and Energy Centres of its Staple Fibre Division.

Maintenance is one of the most critical areas governing any process industry. Maintenance when neglected leads to frequent breakdowns, leading to costly repairs and faster deterioration of valuable equipment, besides causing incalculable production loss. This necessitates identifying critical equipment proned to frequent failures by analyzing the history records, finding out the causes and deciding corrective actions to be taken. The criticality of equipment depends on the nature and frequency of failures, downtime costs, safety, environmental factors etc. The most critical equipment should receive prompt attention in asset caring.

World - Class Maintenance emphasizes on following approaches:

- Adopt improvement activities designed to increase the overall equipment effectiveness
- Adopt Need-cum-Opportunity Based Maintenance
- Adopt Autonomous Maintenance

- ❖ Increase the skills and motivation of operators and engineers by individual and group development
- ❖ Initiate maintenance prevention techniques including improved design and procurement thereby increasing maintainability

2.2 Need for World-Class Maintenance

Over the last twenty years there have been a significant development in the field of maintenance and many different approaches were reinforced to improve maintenance efficiency, maintainability and maintenance prevention.

Breakdown maintenance rested on the concept of highly skilled and dedicated maintenance team poised ready to step in when plant failed for whatever reason. The maintenance team took pride in their ability to fix broken-down machine.

After the Second World War the increase in the number, variety, complexity of physical assets – plant, equipment and buildings – necessitated a different approach. At the same time the relationship of plant failure to safety, environment, and product quality and above all, cost dictated the vital necessity to achieve higher plant availability. Planned preventive maintenance rested on overhauls and checks at fixed intervals, which were applied on a scheduled maintenance basis.

Predictive Maintenance followed, and this rested heavily on systems of asset and failure records supported in the early days by cumbersome computers and somewhat primitive software. These limitations meant that the results of the data collection were not used and the systems frequently fell into disrepute due to lack of data integrity and the absence of regular disciplined data collection.

Computer-aided maintenance developed in parallel with predictive maintenance, and with it came the smaller portable computers with improved user-friendly software packages. During this period, inspection of parts and finished products gave way to quality control and quality assurance to achieve better product quality.

With the 1980's came a similar emphasis within the maintenance function to predict equipment condition. Condition-based Monitoring (CBM) is now highly developed practical aid to effective maintenance.

Reliability – Centered Maintenance (RCM) makes extensive use of statistical and mathematical techniques to predict reliability and to assess maintainability. By its nature RCM is maintenance driven because failure can be catastrophic.

Total Quality Management (TQM) rests on the elevation of the inspection function within a company to a commitment to achieve and adhere to the ISO standards and to treat every body as customers.

Total Productive Maintenance (TPM) process embodies, as an essential, the achievement of total quality and is the logical outcome of these developments in the maintenance function over the years. TPM emphasizes on the empowerment to signify the power of the operator and the maintainer, as members of a team, to ensure that the assets they own in the shape of equipment and machinery are kept always at maximum effectiveness and under permanent scrutiny for continuous improvement.

World-Class Maintenance takes into account various aspects of maintenance functions, which need to be carried out to achieve a total quality production system of world-class stature through the use of scientific methods, effective equipment and highly dedicated people.

2.3 Pillars of World-Class Maintenance

The eight pillars of World – Class Maintenance are as follows:

- Maintenance Organization
- Maintenance Information System
- Maintenance Planning, Scheduling & Control
- Overall Equipment Effectiveness and Benchmarking

- Maintenance Prevention and Maintainability Improvement
- Autonomous Maintenance
- Maintenance Cost Reduction
- Maintenance Training & Development

The above mentioned pillars will be dealt in detail in subsequent chapters, but a brief objective is summarized below:

2.3.1 Maintenance Organization:

The maintenance organization structure should be designed in such a way that the roles and responsibilities of each level should be clearly defined. All maintenance personnel should be accountable and empowered to take decisions at the lowest level. There should be proper coordination among various disciplines and instructions / information should flow as quickly as possible.

2.3.2 Maintenance Information System:

The maintenance information system should be designed in such a way that right information reaches the right person at the right time so that decisions are taken promptly. The nature of information required at each level varies, so proper formats should be prepared for each level of the organization structure. The executive summary report required by top level management should contain all the important data with deviations and corresponding action plans.

2.3.3 Maintenance Planning, Scheduling & Control:

The maintenance jobs should be scheduled in such a way that the maintenance crew has full day's work and the job is completed in time. The efficiency of the maintenance personnel should be constantly monitored and steps should be taken to reduce unproductive hours. Critical Path Method (CPM) and Programme Evaluation and Review Techniques (PERT) are useful tools in scheduling and planning of maintenance activities.

2.3.4 Overall Equipment Effectiveness & Benchmarking:

Overall Equipment Effectiveness (O.E.E) depends on the availability, performance rate and quality rate. O.E.E. is calculated for all critical equipment of Staple Fibre Division. . Benchmarking helps in continuously striving for maximum OEE, reduced MTTR and maximum MTBM. The availability of equipment can be enhanced by adopting Need-Cum-Opportunity based Maintenance (NOBM).

2.3.5 Maintenance Prevention and Maintainability Improvement:

Maintenance Prevention aims at reducing or eliminating the need of maintenance. This can be achieved through improved design, process improvement, material change and size change. The maintainability can be improved through improved service procedures, testing procedures, quality service parts and better skills. The condition monitoring and various non-destructive testing help in predicting the failure of equipment.

2.3.6 Autonomous Maintenance:

Autonomous Maintenance aims at developing a good work culture through a feeling of ownership, team building and employee participation. It is the responsibility of the operator to maintain the equipment and keep the work place clean and safe.

2.3.7 Maintenance Cost Reduction:

The maintenance of equipment requires inventory of spare parts so that right material is available at the right time thus reducing supply downtime. Efficient use of standardized material and reduction of wastage help in minimizing the inventory and eliminates accumulation of non-standard materials. The reconditioning of equipment should be preferred over the replacement, as it reduces the overall cost and prolongs the life of the equipment.

2.3.8 Maintenance Training & Development:

The basic aim of education and training is to enhance the ability of individuals to contribute to improved performance and increased values in their lives. The training areas should covers all the key aspects of maintenance and should be imparted to workers and all levels of management.

2.4 Implementing World-Class Maintenance

The implementation of World-Class Maintenance calls for participation of all levels of management and workers together in achieving a total production system of world class stature through the use of scientific methods, effective equipment and healthy work culture.

2.4.1. Steps to achieve World-Class Maintenance vision

The factors, which drive the World - Class Maintenance process forward, are as follows:

1. Measurable financial benefit
2. Higher Plant Availability & Productivity
3. Team Spirits : Speed, Self-confidence, Simplicity
4. Top-down target-driven management
5. Bottom-up shift team activity
    - Leading change
    - Linking change : Delegation, Devolution
    - Coherence: targets, responsibilities, training, wanting to change
    - Communication : understand problems, better, positive response
    - Environment: pride in workplace
6. Teams of capable, creative, self-sufficient people

2.4.2 Role of Management

The role and responsibilities of the management and supervisors in implementing World – Class Maintenance are as follows:

- Input and release of people for training
- Release of equipment for restoration and subsequent asset care
- Technical and historical information
- OEE and OPE

- Visual management and information
- Inter-shift communication
- WCM activity logistics and facilitator support
- Standardization of best practices
- Spares forecast and consumption rates
- Hygiene and safety training and policy
- Input to problem solving and solutions support

Some guidelines for helping teams to succeed are:

- Agreed priorities and strategy
- Effective planning, control and delivery systems
- Clear organization of labor, equipment and materials
- Insistence on measurable results and individual commitment to them
- Encouragement to identify and meet task and process skills needs
- Active reinforcement of team-working
- Promotion of a positive outlook to problem solving and new ideas
- Mutual trust and support
- Good communication
- Shared objectives
- Effective use of skills

2.4.3 Benefits of World-Class Maintenance

The tangible benefits of World – Class Maintenance are:

- Maximum Overall Equipment Effectiveness
- Maximum Availability & Improved Maintainability
- Reduced Costs
- Improved Inter-department Communication
- Improved Reporting Channels

- Role Clarity and Defined Responsibilities
- Improved Planning, Scheduling and Control Procedures
- Safety Conscious
- Better Time Management
- Improved Maintenance Prevention Techniques
- Improved Decision-making

The intangible benefits of World - Class Maintenance are:

- It is valued by employees and employers alike
- It is a vehicle for implementing the company's goals and vision
- It changes the attitudes of employees and create a feeling of ownership
- It creates a belief in one's own equipment protected and maintained through autonomous maintenance
- It creates clean environment and environmentally clean
- It creates a good corporate image

This chapter thus emphasized on the concept and pillars of World - Class Maintenance. The implementation of World – Class Maintenance can improve the department working, create a feeling of ownership among the employees and create a good corporate image.

The next chapter deals with an overview of Grasim Industries Limited. The Staple Fibre Division manufactures Viscose Staple Fibre. The process description and the existing maintenance procedures have been thoroughly dealt with.

CHAPTER 3

GRASIM INDUSTRIES LIMITED - AN OVERVIEW

3.1 Introduction

Grasim Industries Limited, a flagship company of the Aditya Birla Group of companies, was incorporated in Gwalior on August 25, 1947. Grasim has emerged in the process as one of Asia's largest manufacturers of Viscose Staple Fibre and Dissolving Pulp from indigenously available woods, based on its own technology and own manufactured sophisticated machinery and is truly diverse not only in terms of turnkey capabilities but also in the process of innovation and continuous improvements of system. The company also diversified in conformity with nation's priority like chemicals, cement, fertilizer, and engineering.

3.2 Manufacturing Activities of Grasim

Grasim, Nagda has three divisions namely Staple Fibre Division (SFD), Engineering & Development Division (EDD) and Chemical Division (CD). Staple Fibre Division produces Viscose Staple Fibre in various deniers, lengths and colours. Crimped Viscose Fibre, Grasi High Fibre and other Specialty Fibres are new additions to its wide range of viscose fibres. The production capacity of Viscose Staple Fibre is around 340 TPD. It also produces anhydrous sodium sulphate as a by-product.

Engineering & Development Division manufactures plant and machinery for Viscose Fibre, Filament Rayon, Paper Grade Pulp, Carbon-bi-sulphide, Sulphuric Acid, Caustic Soda etc. It also manufactures sophisticated energy-efficient equipment like Multi-Stage Flash Evaporator, Continuous Crystallizers, Continuous Filters etc. Chemical Division mainly manufactures caustic soda, stable bleaching powder, poly- aluminium chloride.

3.3 Process Description

The basic raw material in the manufacture of viscose rayon is alpha cellulose derived from wood pulp. The cellulose is converted into alkali cellulose by steeping the raw material in a solution of caustic soda (about 18 %). The excess alkali is squeezed out and recycled. The alkali cellulose is allowed to ripen and then converted to cellulose xanthate by treatment with carbon-bi-sulphide, the xanthate is subsequently dissolved in dilute caustic soda solution to give a solution of proper viscosity.

The resulting solution known as 'Viscose' is filtered by filter presses, deaerated and stored under careful conditions. The viscose is extruded under pressure into fine jets through numerous spinnerettes into spinning bath solution. The filaments so formed are cut to desired length and taken to CS_2 recovery trough where CS_2 liberated is condensed and recovered and the fibre free of CS_2 is taken to the Aftertreatment section.

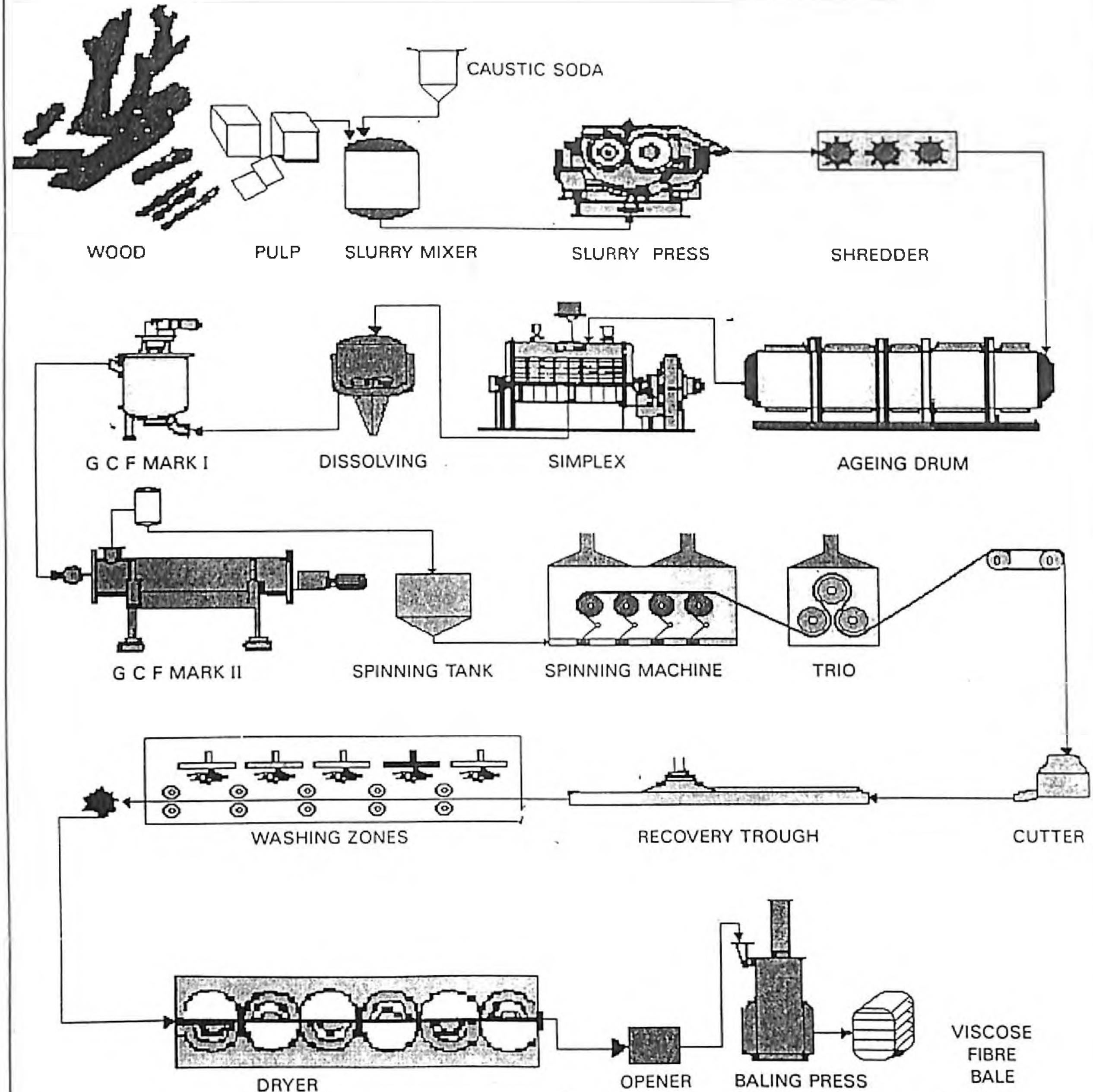
The cut filaments are first washed free of acid with water and then washed free of sulphur which is precipitated during its formation by treatment with an alkaline during its formation by treatment with an alkaline sodium sulphide solution. This is followed by washing with water and then bleached and washed. The fibre passes through a final stage of finishing and drying and is then conditioned to requisite moisture content and baled.

The spin bath used in the process gets spent due to depletion of sulphuric acid concentration by reaction as well as the addition of water from viscose. The reaction also produces sodium sulphate. The spent bath is filtered and sent to recovery plant where it is fed to evaporators to remove excess water and excess of sodium sulphate is recovered by crystallisation. The wet salt thus recovered is then dried in a rotary drum dryer and bagged. [3]

Figure 3.1 shows the process flow chart of the Viscose Rayon manufacture. The next section describes the functions of the major departments of Staple Fibre Division.

FIG 3 1

PROCESS FLOW DIAGRAM OF VISCOSE STAPLE FIBRE



3.4 Functions of Major Departments

Staple Fibre Division has five major departments, namely, Viscose, Spinning & After Treatment, Auxiliary, CS_2 and Acid Plants and Energy Centres. The functions of these departments are described below:

3.4.1 Viscose Department

The viscose department mainly consists of following sections:

- Soda station
- Slurry mixer
- Slurry Press
- Maturing Drum
- Simplex
- Dissolver
- Ripening Room

The starting point of VSF manufacturing process is viscose preparation. Pulp in the form of sheets or crumbs, flash dried pulp or pulp slurry is converted into alkali cellulose first and then to viscose solution adopting Xanthation process. The Xanthation process consists of conversion of alkali cellulose, xanthation and filtration of viscose.

The caustic received at 40-50% strength is diluted to desired strength and settled to remove iron impurities. This iron-free caustic is further diluted to 18% strength. Pulp with alpha cellulose content of 94% is hydrolyzed using 18% caustic in a slurry mixer. Manganese salt and other chemicals are added, as catalyst to assure required degree of polymerization. Excess alkali is drained in slurry press and the separated alkali cellulose is shredded and matured at a temperature of 35-45 C in a maturing drum. The recovered alkali is filtered in rotary filters to remove impurities.

The temperature of the matured alkali cellulose is brought down to about 30 C prior to batch-wise treatment using NaOH and CS_2 and chilled water. This process is known as Xanthation. CS_2 is added under vacuum and after completion of reaction, the excess CS_2 is exhausted. The viscose solution is thereafter transferred to dissolver, disintegrator and blender for uniform composition.

The viscose solution is filtered in a three-stage filter system consisting of plate and frame continuous filter. Periodic cleaning of filter presses and subsequent washing of filter cloths generate wastewater. The filtered viscose is finally deareated using four-stage vacuum flash deaerator. The filtered and deaerated viscose solution has a composition of 9.8-10.3% alpha cellulose, 5.6 -5.7 % free alkali and specific gravity 1.08-1.15.

3.4.2 Spinning & AfterTreatment Department

The spinning & aftertreatment departments have the following sections

- Spinning machine
- Jet Room
- Condenser System (CS_2 Recovery)
- After-Treatment
- Dryer
- Baling Press

The viscose solution is continuously pumped through spinerettes using gear pumps and regenerated into cellulosic fibre in contact with continuously running spinbath media. The spinning machines have cluster type spinerettes (each with 8000 - 23000 holes for filament formation) numbering 120-180 per machine. The regenerated cellulose from each spinerette is continuously drawn as Tow and cut to requisite staple length in a cutter. Tow washings and squeezing serve to recover carryover spinbath within the spinning machine and are returned to Spinbath Bottom Tank.

Following operations are carried out at the aftertreatment section:

- Hot water wash
- Caustic treatment for desulphurisation followed by washing
- Hypo treatment for bleaching followed by washing
- Addition of acetic acid for improved brightness
- Soaping and finishing
- Drying and baling

The excess water from fibre slurry is partially recycled to the cutter while the balance is drained off. The spinbath carried over along with fibre is discharged and this wastewater is called sump zone discharge. The fibre is then given first wash and the resultant wash water is discharged along with the sump zone waste water.

3.4.3 Auxiliary Department

The main functions of this department are

- Maintaining desired spinbath conditions
- Supplying spinbath to spinning machines
- Recovering anhydrous sodium sulphate from return spinbath

The Auxiliary department consists of following sections:

- Spinbath section
- Evaporation section
- Crystallization and Filtration
- Calcination, Filtration and Drying
- Sodium Sulphate Recovery

The dilute spinbath received from the spinning machine area is stored in bottom tank from where one portion is pumped to evaporator and another portion to salt recovery system so as to match the removal requirements of water and sodium sulphate. The concentrated streams from respective bottom tank for maintaining the requisite spinbath composition. The solution is also continuously filtered through quartz media in pressure filters. Make-up chemicals such as sulphuric acid, zinc and other chemicals are directly added to the bottom tank. The filtered spinbath is pumped to top tank to enable it flow by gravity to the spinning machines.

3.4.4. CS_2 and Acid Plants

Carbon bi sulphide plant supplies CS_2 to Viscose Department and receives recovered CS2 from Spinning Department. CS_2 produced by a reaction between calcined charcoal and molten sulphur is condensed, refined and stored. The uncondensed CS_2 gas is recovered in Oil Scrubber. Sulphur is recovered from H_2S gas, which is formed in Furnace by a side reaction.

The CS_2 department has the following main sections:

- Charcoal Calciner
- Sulphur Melting and Purification
- Return Sulphur Recovery and Purification
- Ventury Scrubbing
- Brine Condenser
- Oil Scrubbers
- Klaus Recovery System
- CS_2 Refinery

Sulphuric Acid Plant manufactures H_2SO_4 by DCDA Process using V_2O_5 as catalyst. It supplies acid to the Auxiliary Department and Chemical Division. Molten Sulphur is burnt to give Sulphur-di-oxide, which is converted to sulphur-tri-oxide in the presence of Vanadium Pentoxide catalyst. SO_3 is absorbed in concentrated sulphuric acid and the product is diluted to yield 98-98.5% acid.

The main sections of the acid plant are:

- Sulphur Pit
- Burners
- Converters
- SO_3 Cooler
- Absorption Tower
- Drying Tower
- Acid Circulation Tank
- Acid Cooler

3.4.5 Energy Centres

The manufacturing process of viscose staple fibre requires a steady and stable source of power supply for smooth running of the plant. In view of the substantial requirement of process steam, it is advantageous to install a co-generation facility wherein simultaneous generation of both steam and power is possible.

A modern power plant consisting of Pulverized fuel and Atmospheric fluidized bed combustion boilers and different types of turbines with high degree of performance is installed at Grasim Industries Limited, Nagda. Designed on the principle of co-generation, this power plant produces power along with high pressure (16 Kg/cm^2) and low-pressure (3 Kg/cm^2) steam to satisfy the demand of staple fibre division.

❖ ENERGY CENTRE – I

With a generation capacity of 28.5 MW, this energy centre houses turbines and 3 x 75 TPH pulverized fuel boilers. Two similar turbines with generation capacity of 16.5 MW each of back pressure-cum-extraction type is also installed of which one of them is always kept as a standby. This BHEL Turbine supplies both high and low pressure steam.

A third turbine with generation capacity of 12 MW is of extraction - cum - condensing type unit. The GDR Turbine also supplies low-pressure steam along with power.

❖ ENERGY CENTRE – II

This plant houses a 30 MW fully condensing turbine of and 3 x 75 TPH Atmosphere fluidized bed combustion boilers. This power plant fulfills the demand of power by the chemical division.

❖ ENERGY CENTRE – III

It includes a 2.85 MW topping turbine and one 12 MW BHEL turbine. Steam from the third boiler of the EC – II is used to run the topping turbine. The exhaust from the topping turbine runs a 12 MW extraction cum condensing turbine located at the old power plant.

❖ ENERGY CENTRE – IV

This power plant fulfills the demand of power for the chemicals division. It includes one 40MW fully condensing type turbine along with 2 x 100 TPH atmospheric fluidized bed combustion boilers.

The specifications of boilers and turbines at energy centres are shown below:

BOILERS	**EC-I**	**EC-II**	**EC-III**	**EC-IV**
	P .F	AFBC	-	AFBC
No: of boilers	3	3	-	2
Capacity	75 TPH each	75TPH each	-	100TPH each
Efficiency	86%	86%	-	86%
Main steam pressure	64Kg/cm^2		-	64Kg/cm^2
Main steam temp.	485^{0}C	485^{0}C	-	485^{0}C
Coal consumption	503 TPD	611 TPD	-	607 TPD

TURBINES	EC-I		EC-II	EC-III		EC-IV
	BHEL	GDR	BHEL	TOPPING	BHEL	BHEL
Generation Capacity	16.5MW	12MW	30MW	2.85MW	12MW	40MW
Generation Terminal	6.6KV	6.6KV	6.6KV	6.6.KV	6.6KV	6.6KV
Voltage Frequency	50Hz	50Hz	50Hz	50Hz	50Hz	50Hz

The main sections of the energy centres are:

- MCHP
- Coal Crushing
- Boilers
- Turbines
- Ash Handling

3.5 Maintenance Function at GRASIM

The Staple Fibre Division of GRASIM follows partially decentralized maintenance organisation system. In this system, the day-to-day maintenance activities are carried out by a group of maintenance workers who are attached to and are responsible to the Manager of that section or department. But important functions like planning, scheduling of maintenance work, major overhauls etc. are carried out by the Planning and NDT Cell.

The maintenance department comprises of following disciplines:

- Mechanical Maintenance : Department - wise
- Electrical Maintenance : Profit centre-wise
- Instrumentation : Profit centre-wise
- Civil : Centralised
- NDT: Centralised
- FRP: Centralized

In the existing system of Staple Fibre Division, each profit center is headed by a Vice President and the General Manager looks after both process and maintenance activities. Assistant General Manager looks after maintenance activities of each department.

The day-to-day working pattern of these departments are described below:

i. **Work Distribution:**

Priority is given to emergency and urgent jobs resulting out of breakdowns or any other reasons. The jobs, which are planned on the previous day / shift, are scheduled and distributed among the workers. Jobs related to day-to-day problems and routine jobs are also taken care of. Distribution of labor and materials are done on the above priority basis.

ii. Follow - Up Action

The mechanical maintenance engineers are in contact with various other departments like Civil, Electrical, Instrumentation, EDD, Mechanical & Electrical workshop to expedite their maintenance jobs.

iii. Re-planning

Redistribution of manpower and materials need to be done in case urgent job arrives and requires immediate attention.

iv. **Control**

The on-going jobs are supervised and steps are taken to expedite the same. Decisions are taken regarding overtime for workers. NDT activities on equipment are also performed like attending motors, bearing failure, lubrication, vibration checking, inspection, etc. Priority is always given to critical equipment.

v. **Materials Management**

Indents are prepared in specified formats on-line for requisition of materials. The maintenance engineers carry out spares management and inventory control.

vi. **Follow-up Round**

During the Follow-up round, planned and preventive maintenance jobs are taken. Maintenance related data entry is done on computerized on-line system.

vii. **Maintenance Register**

Maintenance Registers like Downtime Registers, Equipment History Register, Indent Register etc. are manually maintained by engineers.

viii. **Advance Planning**

Advance Planning for the next day is done and jobs are prioritised accordingly. The maintenance staff has to report to the top-level management regarding the maintenance activities performed during the day in a specified format with action plans.

The workload of a maintenance engineer may be broadly classified as corrective work, preventive work and modification work. The corrective jobs occur with almost random incidence, the emergency work occurs with little or no warning and requires urgent attention. The deferred work or the pending jobs are of varying degrees of urgency and can be scheduled accordingly.

The use of condition-based maintenance results in a shift in the workload from emergency to deferred work. The preventive work is planned in detail and scheduled well in advance with time tolerance for slotting and work-smoothing purposes. The preventive work is classified as:

i. Routine Work: Short periodicity work are carried out mainly on-line

ii. Minor off-line: Services and other minor work involving short and medium periodicity off-line work

iii. Major off-line: Overhauls and other major off-line work involving long periodicity, multi-task, multi-craft work. This mostly requires a scheduled shutdown.

Maintenance work thus carried out requires close coordination and teamwork among various disciplines like mechanical, electrical, instrumentation, civil, workshop, FRP and NDT cell. The existing maintenance practices need systematic and scientific approach for better work-environment to achieve world-class levels.

This chapter thus focussed on the manufacturing process of Viscose Staple Fibre and the functional working of maintenance department. The present departmental working has to be streamlined so that its performance improves and productivity increases. This requires a complete restructuring of the maintenance department with clearly defined duties and responsibilities.

The next chapter emphasizes on the maintenance organization structure of Staple Fibre Division and defines the duties and responsibilities of each level of management to enhance the plant working, better communication and quicker decision making.

CHAPTER 4

MAINTENANCE ORGANISATION

4.1 Introduction

World-Class Maintenance calls for a proper organization structure for deriving competitive advantage based on adoption of best-in-house practices, targeted at the following objectives:

- Increasing productivity of workers and maintenance staff
- Improving coordination between various disciplines and levels
- Assigning responsibilities and increasing accountability
- Creating healthy and competitive work environment

The maintenance organization should be designed in such a way that it has reduced number of levels. The duties and responsibilities of each level should be clearly defined. The information flow should be fast and the decision-making dynamic.

4.2 Staple Fibre Division Activities

Staple Fibre Division production capacity is 340 TPD. Production capacity of the by-product sodium sulphate is 200 TPD. Capacities of captive plants for production of carbon-bi-sulphide and sulphuric acid are 60 TPD and 320 TPD, respectively. Nearly 100 MW of power and 3000 TPD of process steam are generated at Energy Centres.

The Staple Fibre Division of Grasim Industries Limited at Nagda has the following major Departments in their profit centers:

- **Profit Center 1:**

  - Viscose I
  - Spinning & After Treatment I [7 machines]
  - Auxiliaries I
  - Textile Laboratory
  - Effluent Treatment Plant

- **Profit Center 2:**

  - Viscose II
  - Spinning & After Treatment II
  - Auxiliaries II
  - Chemical Laboratory and Quality Control
  - Water Treatment Plant

- **Profit Center 3:**

  - Carbon-bi-Sulphide Plant
  - Sulphuric Acid Plant

- **Profit Center 4:**

  - Energy Center 1
  - Energy Center 2
  - Energy Center 3
  - Energy Center 4
  - Mechanized Coal Handling Plant (MCHP)

These four profit centres are not entirely independent. Process streams flow continuously and/or intermittently, in one direction or both directions among the profit centres. Each profit centre is headed by a Vice President and are charged with responsibility of all working aspects of the plant. Each profit centre has separate profit and loss account, to measure the performance of profit centres and individual departments.

4.3 Working Complexities

Day-to-day working of SFD is rendered complex by the following factors: [4]

- Continuous chemical plant
- Age factors and old design
- Sophisticated manufacturing process, with complex inter-play between processing parameters at various stages of production
- Non-uniform and generally inferior quality of principal raw material i.e. pulp, which is received in sheet as well as flash dried forms
- Degradation tendency of flash dried pulp on storage
- Wide range of product-mix in terms of denier, length, finish, and specialty fibre
- Batch-wise continuous processes with very low unit capacities, leading to multiplicity of equipment and processing streams
- Dynamic decision making in several sections, requiring continual adjustments based on hourly data inputs
- Customers demand for continuous improvement and optimization
- More human element

4.4 Maintenance Organization Structure

In the existing maintenance organization structure, Assistant General Manager looks after the working of a particular department. General Manager looks after the working of a particular Profit Center and Vice President looks after the working of all maintenance activities of Profit Centers. Due to increased number of reporting levels, the information does not propagate as quickly as required, resulting in delay in making right decisions at the right time. In some of the cases, the information also gets distorted and the engineer at the shop floor gets puzzled in taking decision. Dual reporting also takes place, which increases the confusion among the maintenance personnel. Hence it is necessary to design an organization structure which would minimize above shortcomings.

The proposed maintenance organization structure for GRASIM includes the organization structure for following disciplines:

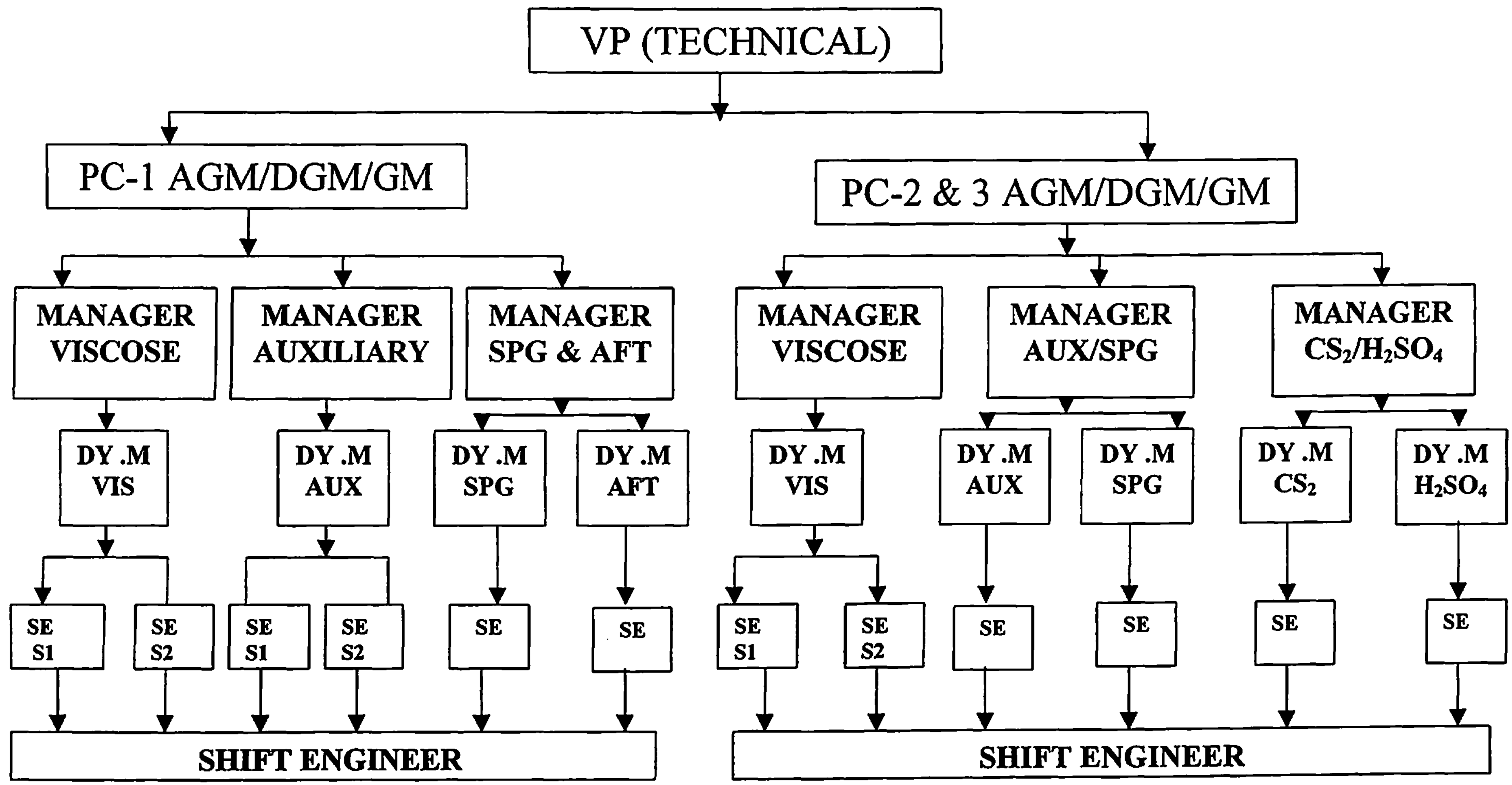
- Mechanical (Fig. No. 4.1)
- Electrical and Instrumentation (Fig. No. 4.2)
- Engineering Services (Fig. No. 4.3)

4.5 Levels & Responsibilities

The design of organization structure requires defining the number of levels, duties and responsibilities of each level and the reporting system. This would facilitate better coordination among various levels and efficient plant working.

The number of levels in the organizational hierarchy depends upon the workload of the department and the span of control. The duties and responsibilities of each level should be clearly defined so that each employee can take decisions at his/her own level.

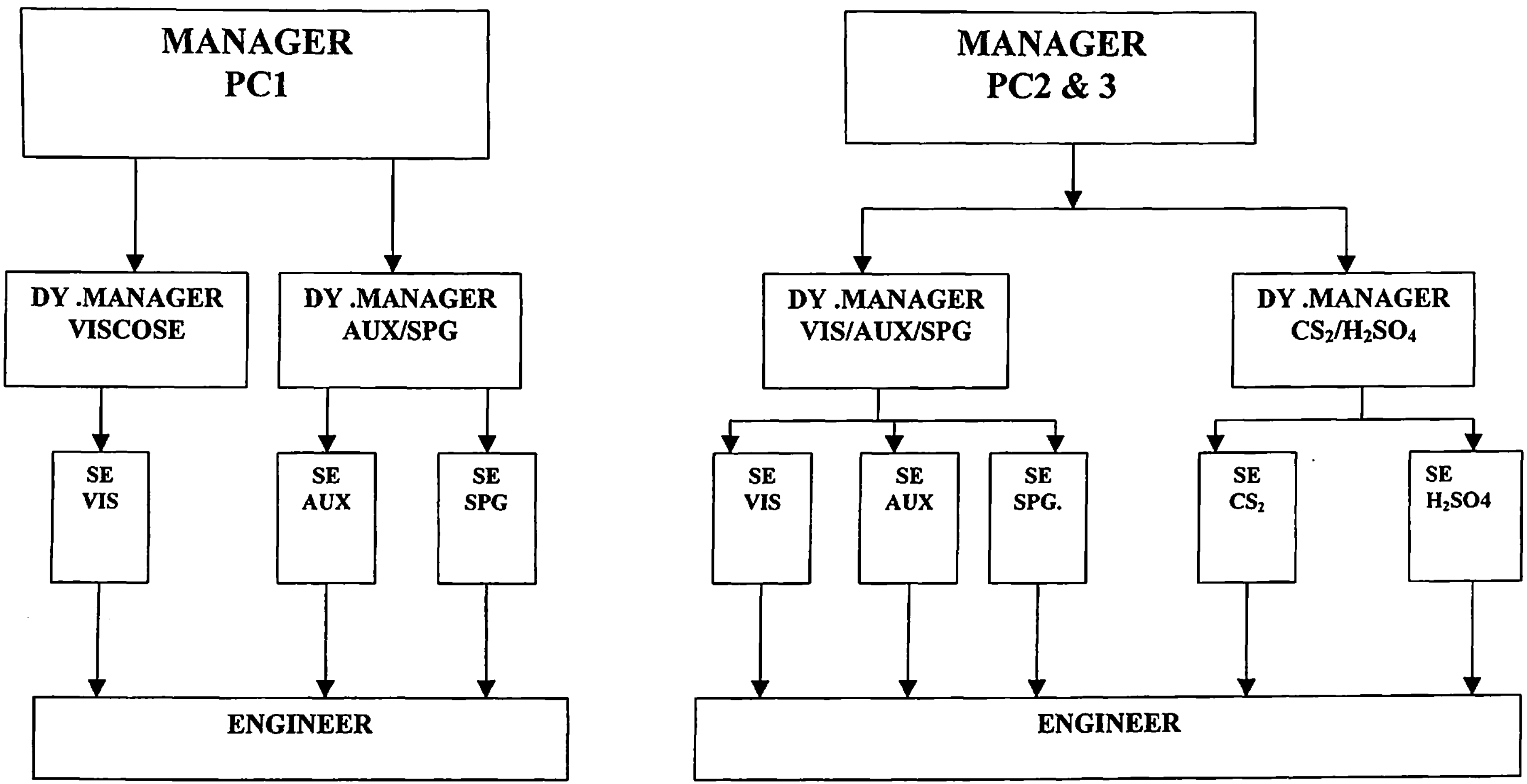
Fig 4.1 ORGANISATIONAL STRUCTURE (MECHANICAL)



LEGEND

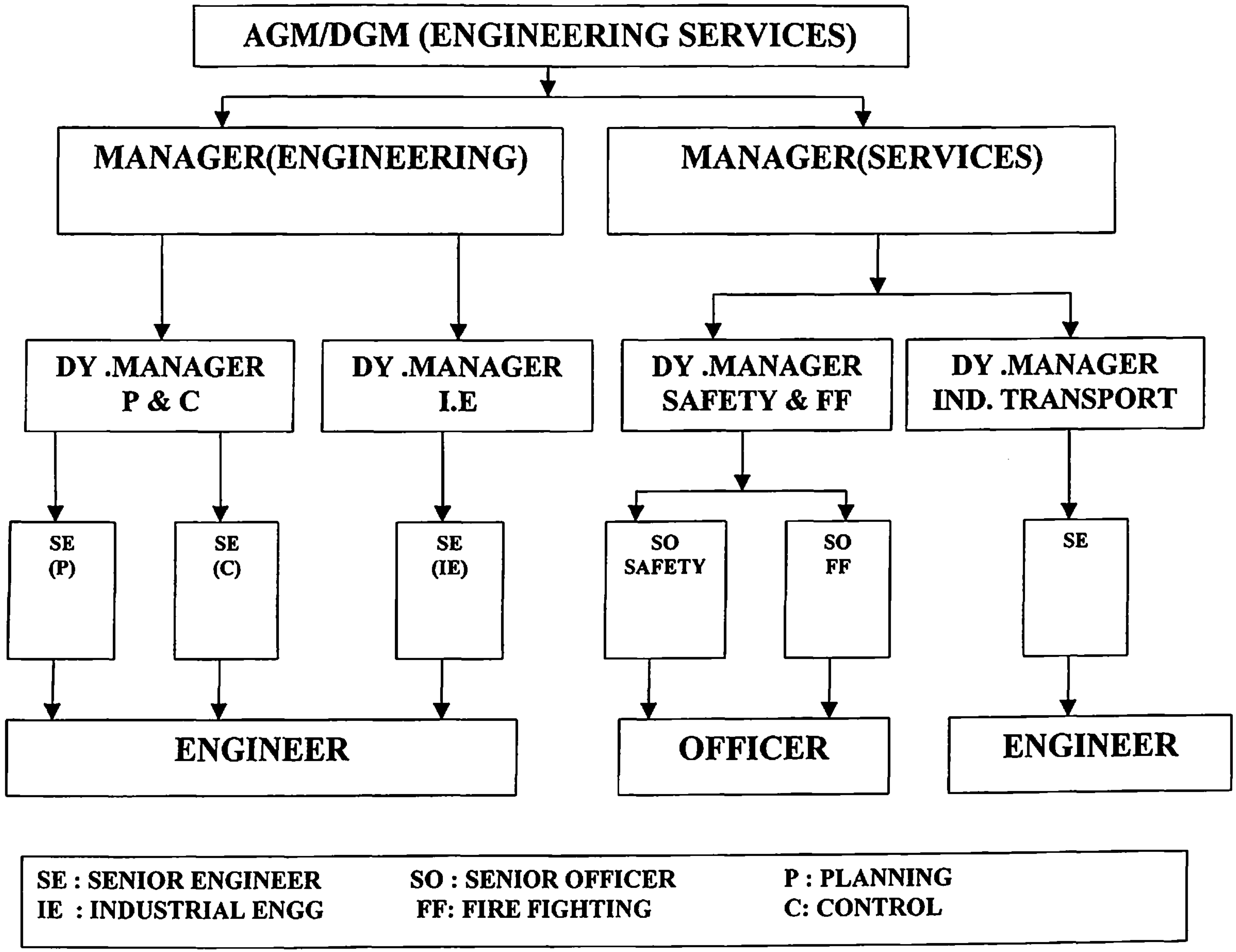
Dy.M - Deputy Manager ; SE – Senior Engineer ; VIS - Viscose ; AUX – Auxiliary; SPG – Spinning & After Treatment

Fig 4.2 ORGANISATIONAL STRUCTURE (ELECTRICAL/INSTRUMENTATION)



LEGEND
Dy.M - Deputy Manager ; SE – Senior Engineer ; VIS - Viscose ; AUX – Auxiliary; SPG – Spinning & After Treatment

Fig 4.3 ORGANISATIONAL STRUCTURE (ENGINEERING SERVICES)



4.5.1 Levels

Maintenance organization at SFD can be divided into 5 levels namely,

Level 1	:	President Sr. Executive President
Level 2	:	Vice President
Level 3	:	General Manager Dy. General Manager Asstt. General Manager
Level 4	:	Manager Dy. Manager
Level 5	:	Sr. Engineer Engineer

In the proposed system, the maintenance function of each level will be the same for each designated position. Vice President will look after the maintenance activities of the entire Staple Fibre Division. GM / DGM / AGM will be responsible for all maintenance activities of each Profit Center. Manager / Dy.Manager will look after the working of each Department and will be the Head of the Department as far as the maintenance is concerned. Sr. Engineer/Engineer will look after sections of the department.

The responsibility matrix is shown in the Table 4.1. The matrix highlights the work to be performed by each level in terms of execution, planning and control. The detailed duties and responsibilities of each level are described below and the summary of responsibilities is shown in Table 4.2.

TABLE 4.1

RESPONSIBILITIES MATRIX - LEVEL WISE

S.No	RESPONSIBILITY	1	2	3	4	5
1	EQUIPMENT MAINTENANCE					
a	Work Distribution				Planning	
b	Repair				Planning	
c	Replacement			Control	Planning	
d	Maintainability			Control	Planning	
2	BUILDING MAINTENANCE					
a	Roofs, Floors, Partitions			Control	Planning	
b	Buiilding Services Equipment			Control	Planning	
c	Minor Construction & Rearrangement			Control	Planning	
3	ROUTINE & PREVENTIVE MAINTENANCE					
a	Inspection					Planning
b	Lubrication					Planning
c	Condition Monitoring			Control	Planning	
4	MATERIALS MANAGEMENT					
a	Indent Preparation				Planning	
b	Inventory Control			Control	Planning	
c	Spares Availability			Control	Planning	
d	Stores Expenses	Control	Control	Planning		
5	VENDOR DEVELOPMENT					
a	Monitoring Jobs				Planning	
b	Contractor's Expenses	Control	Control	Planning		
6	BUDGETARY CONTROL					
a	Budget Preparation		Planning			
b	Budget Monitoring	Control				
7	EMERGENCY PLANNING	Control	Planning			
8	PERSONNEL MANAGEMENT					
a	Labour Relations			Control	Planning	
b	Overtime & Absenteeism Monitoring			Control	Planning	
9	TRAINING & DEVELOPMENT					
a	Training of workers				Control	Planning
b	Training of staff		Control	Planning		
c	Autonomous Maintenance				Control	Planning
10	RECRUITMENT & PLACEMENT					
a	Selection of staff	Control	Planning			
b	Internal Mobility	Control	Planning			
11	PERFORMANCE APPRAISAL					
a	Staff	Control	Planning			
b	Workers			Control	Planning	
12	WCM & ISO CONCEPT			Control	Planning	
13	MIS					
a	Report Generation			Control	Planning	
b	Analysis		Control	Planning		
c	Action Plan	Control	Planning			
14	COMMUNICATION					
15	AUDITING & BENCHMARKING	Control	Planning			

Execution

Planning

Control

TABLE : 4.2

RESPONSIBILITIES OF EACH LEVEL

Level	Downtime	Materials Management	Vendor Development	New Shemes	Maintainability	Productivity
1	Deviation from Norm	Stores Expenses -	Minimise Contract-	Finalise New	Improved	High Product-
	%downtime Eqpt.- wise	Department-wise	ors' Expenses	Schemes and	Maintainability	ivity of worker
	Major Breakdowns	Deviation from norm		sanction money	of Critical Eqpt.	
	Causes & Action Plan	Reasons for excess				
	Production Loss	expenditure				
2	Eqpt. and cause - wise	Stores Expenses (SE) -	Approve Bills	New Schemes/	Steps for high	High Product-
	downtime analysis, Action	Department and Eqpt-	Contractor Fixation	Modification	maintainability	ivity, Reduce
	Plan fordowntime in critica	wise, Inventory, Pending	Take Decision on	Projects, Plan &	& reliability of	overtime
	Eqpt., Production Loss	orders	renewal of contract	Set target dates	all equipment	
3	Planned Maintenance	SE - Deptt & Eqpt.-wise	Contractors' work	Conceptualise	Study failures	Sort jobs with
	for zero breakdown	Optimise High valued	Performance -	New Schemes/	of component/	highest norm
	Detail study of causes	items, Reduce no. of	Quality, Delivery	Modification	eqpt., Suggest	of manpower
	& Action Plan taken	indents, Quality of		Cost-Benefit	design change	
		materials supplied		Analysis		
4	Improve Eqpt. condition	Quality/Quantity of all	Monitor Contractor	Plan, Implement	Study and	Decide norm
	Reduce MTTR &	items received, Carry-	work - Quality,	Supervise	analyse	for each job
	Increase MTBF	out ABC Analysis,	Delivery, Material	New Schemes/	causes of	
	Suggest Plan of Action	pending orders,	Consumption	Modifications	failure	
		Sub-stores inventory				
5	Attend Breakdown,	MIS data entry, Making	Allocate optimum	Implement	Locate repetitive	Optimum use
	Efficient use of tools &	Indents, status of order-	resources	Schemes	failures-same	of resources
	tackles, Manpower and	ed items, Optimum use	Ensure Safety	Enlist difficulties	eqpt./different	
	Material Allocation	of resources, eliminate	and check	encountered	machines	
	Follow Instructions	wastage/scrap	mis-operations			

The various heads of responsibilities related to maintenance work are:

- Downtime
- Materials Management
- Vendor Development
- New Schemes
- Maintainability
- Productivity

4.5.2 Duties and Responsibilities of each Level

Level 5: Engineer / Senior Engineer

1. Study of existing process of each department
2. List the equipment details for each department-Equipment Details Register
3. Carryout method and Time Study for maintenance activities of the department
4. Getting trained in carrying out routine and preventive jobs
5. Maintain Register and get trained in MIS data entry
6. Practice Autonomous Maintenance
7. Attend breakdowns and follow instructions from superiors
8. Cordial relations with workers, peers and bosses
9. Look after one or more sections of a particular department
10. Analyze work order and requests and estimates time and material requirements
11. Schedule and assign job and materials to the workers
12. Supervises jobs to assure quality and completion times
13. Attend expeditiously to all breakdowns
14. Act to specific instructions / new assignments
15. Responsible for training of workers
16. Develop contractors and fabricators to carryout supporting work
17. Ensure efficient use of tools and tackles

18. Determines, maintains and controls inventory levels of material supplies and spare parts used by the maintenance crew and arrange discarded materials/parts
19. Responsible for improving operations to optimize inventories and speed-up service to mechanics
20. Ensure elimination of wastes, good housekeeping in work area and on jobs performed
21. Administer good relations with group and hears and settles grievances at their own level
22. Suggest methods and new equipment to improve operations
23. Responsibility for safety of workers and elimination of hazards in area and on jobs
24. Coordination with other departments
25. Follow work permit system
26. Follow ISO requirements
27. Improve problem solving skills : Observation, Formulation and Analysis
28. Implement World-Class Manufacturing Concept
29. Implement World-Class Maintenance Concept

Level 4: Dy. Manager / Manager

1. Looks after the maintenance activities of the department
2. Plans and carries out programs for optimum maintenance in area
3. Responsible for quality and quantity of work performed by subordinates
4. Responsible for inspection of facilities in area
5. Seeks improvement in methods, supplies, and equipment used in area
6. Plan routine and preventive maintenance
7. Plan and execute activities for renovation, expansion and modernization
8. Responsible for budgeting and controlling costs of operations
9. Provide good maintenance facilities
10. Responsible for deciding jobs to be assigned on contract basis
11. Analyze MIS reports as per schedule and chalk out action plans to improve working
12. Implement action plans suggested by shop floor meetings, Quality circles/WCM
13. Negotiate day-to-day problem of workers

14. Training of new recruits
15. Ensure scheduling compliance
16. Maintains fire brigade and fire prevention
17. Supervises contractor's jobs in terms of quality and scheduling compliance
18. Responsible for effective manpower utilization/control overtime for workers
19. Evolve safe procedures and practices for various operations
20. Take decisions for trouble shooting and problem solving. In the event of major abnormality, communicate to higher-ups and follow instruction
21. Monitor materials management and inventory control
22. Conceptualization of new schemes / modifications in respective areas
23. Prepare budget for the department
24. Implement World-Class Manufacturing and World-Class Maintenance concepts
25. Scrutinize indents of value less than Rs.10,000/-

Level 3: Assistant General Manager/Dy.General Manager/ General Manager

1. Looks after the maintenance activities of a particular profit center
2. Supervise the maintenance function of the plant
3. Establishes and controls budget for each department of Profit center
4. Optimize costs, quality of services performed and improve maintainability, reliability, safety
5. Vendor Development and monitor contractor's jobs and expenses for renewal
6. Monitor consumption of stores and raw material items and take steps to reduce consumption
7. Action Plan on MIS reports generated on daily, weekly, fortnightly and monthly basis
8. Selection of new engineers
9. Action Plan for implementation of new schemes/modifications
10. Prepare budget for respective profit center
11. Encourage subordinates to put best efforts to ensure short-term and long-term objectives of organization

12. Interact with Design cell/Technical cell/EDD for modification in design and improvement in operation
13. Implement World-Class Manufacturing and World-Class Maintenance concepts
14. Scrutinize indents ranging from Rs. 10,000 to Rs. 50,000/-

Level 2: Vice President

1. Shoulder responsibilities for all maintenance activities of entire profit centers
2. Take decision for overall working of PCs
3. Monitor on-going maintenance and projects for renovation, expansion and modernization
4. Optimize utilization of energy and other utilities
5. Monitor inventory levels of stores and raw materials
6. Take actions on MIS reports'
7. Scrutinize and follow-up action plans developed by various department committees / WCM
8. Approve and scrutinize contractor's quotations and bills for all services
9. Improve maintainability, reduce cost of maintenance and reduce stoppages
10. Finalize budgets for all Profit centers and sanction money to individual department
11. Implement World-Class Manufacturing and World-Class Maintenance concepts
12. Scrutinize indents of over Rs.50,000/-

Level 1: President / Sr. Executive President

1. Responsible for complete working of the plant
2. Responsible for meeting production targets, good quality products at minimum cost
3. Responsible for achieving zero breakdowns, zero accidents, zero defects and zero pollution
4. Providing full support for implementation of new concepts like World-Class Manufacturing, Total Productive Maintenance, ISO etc.
5. Responsible for profit earnings of the company and corporate image

4.6 Need for Engineering Services Department

Engineering Services Department should mainly consist of two sections namely, Engineering and Services. The Engineering Section should be responsible for Planning, Control and Industrial Engineering activities of all the departments of the profit centers. The Services section should consist of sub-sections like Safety, Fire-Fighting and Industrial Transport.

➢ **Engineering Section**

❖ **Planning:**

- Non Destructive Testing and Condition Monitoring
- Preventive Maintenance Schedule
- Lubrication and Inspection Schedule
- Status of critical equipment
- Listing of delayed jobs
- Block and special repairs: Overhauling and replacement
- Vendor Development
- Technical and Design related Jobs

❖ **Control**

- Sub-stores Management: Inventory control, Spare parts management
- Inspection of material for quality control
- Cost control
- Budget preparation
- Scheduling Compliance
- Status of ordered material
- Auditing
- Standardization

❖ **Industrial Engineering**

- Time Study
- Method Study
- Manpower Study
- Man-Material movement study

- **Safety**:

Safety is a very important aspect of any industry. Safe practices and safe handling of equipment and chemicals should be followed in order to avoid accidents. The safety personnel should carry out HAZOP and HAZAN Studies for identification and analysis of hazards. The persons working on the shop - floor should be equipped with all safety equipment and should be properly trained in the safety aspects while handling equipment and chemicals.

- **Fire-Fighting**:

It should be the responsibility of the fire-fighting personnel to train the personnel on the shop floor to operate fire-fighting equipment in case of fire. The equipment should be placed in all departments.

- **Industrial Transport**:

Industrial Transport is a service department which renders services to different departments like raw materials, warehouse, engineering division, civil, mechanical etc. and provide vehicles/equipment to the department as per their requirement. Types of services include shifting and transporting raw material, finished goods, waste, coal, heavy equipment / machinery etc. It maintains and optimizes the usage of material handling equipment. The various material handling equipment used at GRASIM Industries are forklifts, cranes, loaders, dumpers, trolleys, road rollers, tractors etc.

4.7 Role of Engineering Services Department

The Engineering Services Department should constantly monitor the entire maintenance program and seek ways to improve its effectiveness and reduce costs.

The duties of the department should be:

- Preparation of all maintenance inspection and repair procedures
- Prepare improved job plans on repetitive maintenance for the use of a planner
- Analyze the failure history, seeking out the items causing trouble and finding ways to improve their performance
- Keeping and analyzing all maintenance records
- Keep abreast of the field, seeking new materials, equipment, tools, procedures etc. and recommending those with potential benefits
- Plan, prepare and present maintenance and safety training when necessary

This chapter thus focussed on the complexities of manufacturing process and suggests for restructuring of the maintenance organization. The proposed organization structure clearly defines the duties and responsibilities of each level of management. The Engineering Services Department plays a supporting role in carrying out various maintenance activities effectively and efficiently. The department working thus gets improved with greater accountability and responsibility.

The next chapter deals with Maintenance Information System. It focuses on various formats and reports required for each level of organizational hierarchy.

CHAPTER 5

MAINTENANCE INFORMATION SYSTEMS

5.1 Systems Concept

Plant engineering management's job aims at setting goals and objectives followed by providing and supervising the means of achieving them. The task is formidable when organizations are complex, competition is stiff and a higher degree of efficiency is required.

Operations are carried out most effectively through a system, a system being a planned and orderly procedure of attaining goals. The system may be simple or complex in its scope. depending on the magnitude of the task and the difficulty of achieving it. Systems have aims of organizational growth and stability. While a specific objective is desirable with all systems, it is also advisable that the extent of their application be determinable. Systems need to be measurable in order to ascertain their effectiveness and enable them to be changed and improved.

5.2 Characteristics of Systems:

A system may have the following characteristics:

1. **Acceptable**: Users of a system must have faith and confidence on it. They must believe that it can do the job expected of it. Without this, the system may be modified, bypassed, or misused, thus diminishing its value.

2. **Simple**: Simplicity promotes understanding and acceptance. Errors are less likely to occur, if a system is easy to learn and use.

3. **Effective:** It must do the job for which it was designed. Users must be able to depend on it to produce results.

4. **Efficient**: A minimum of difficulty coupled with low cost is the signs of efficiency. Completeness and adequacy must be realized.

5. **Adaptable**: Broadness and flexibility are features required to enable a system to handle a wide range and scope of situations. Ease of adaptability contributes to usefulness and acceptability.

5.3 Requirement of Systems:

A system is devised to accomplish an objective. Although a system may be quite detailed in scope, the more specific it is, the more likely it will be to be understood and followed. A function that encompasses all possible functions of an organization may thus spell out numerous procedures relating to each. The range and type of information which it handles should be presented, along with the forms which contain this information; how the forms are used should be explained. The listing of equipment and responsibilities of the people should be properly understood.

Thus in its entirety, the system consists of three basic components: people, equipment, and procedures. All three are involved with data and information. A system is concerned with the processing of information - in how it is collected, recorded, analyzed and summarized, followed by how it is used, stored and discarded. Information is needed by the users of the systems for planning, decision making and execution. The system should also provide the means for analyzing results so that accomplishment may be assessed.

5.3.1 Creating Systems:

Since a system is originated to do a job, how it is created is determined by the type, magnitude and complexity of the task to be performed. In case of information systems, decisions must be made on the types of data or reports wanted, their number and frequency, and their detail or completeness.

The first step in the creation of any system is to do system analysis. In engineering, this would define the problem and prescribe the course or steps to be followed in solving it. Aside from problem solving, engineering management is interested also in business procedures that aid decision making and control. Thus top management want data related to their operations such as inventory, cost, capacity and personnel.

5.3.2 Data Collection:

Collecting data involves planning what information is wanted; obtaining it and then converting it into a form, which can be used by computer. Data are the raw material out of which information is made. Information is data, which have been sorted, analyzed, interpreted and arranged in a form useful for problem solving and decision making.

Plant engineering management must look to the needs of the company in planning what type of information it needs to perform its functions. The ability of management to solve problems and make good decisions depends on how accurate, complete and up to date the information is that it has to work with.

5.3.3 Data Processing:

Data processing aids management in engineering functions such as determination of work priority of the craftsmen based on cost of downtime of various production equipment; machine utilization and cost of processing as determined by machine hours; planning and scheduling operations to increase manpower efficiency; and analysis of job backlog man-hours to determine labor need.

Data processing systems will be of great help in automatically scheduling preventive maintenance, making realistic performance comparisons for cost analysis and gathering maintenance data in easily accessible form. Automatic weekly work orders can be provided for oiling and lubricating operations. The system is built around standard frequencies for servicing equipment and provides detailed instructions as to specific machines, type of service and frequency of attention.

Many systems in addition to directing the servicing function also provide feedback to management on labor time, oil consumption, repairs performed and lost operating time. Benefits from data processing of these functions include increased productivity of lubrication personnel, reduced unscheduled or emergency calls for service, reduced loss of lubricants by leakage and reduced number of lubricants needed.

5.3.4 Management Information Systems:

Information should be presented in a form that facilitates control and decision-making. Reports that used to be lengthy can now be condensed, brief and to the point. Thus the manager is able to assimilate the pertinent data he needs without being burdened by voluminous, incidental information. Reports can show percentage changes and indicate trends.

While providing management information system, only the information that is needed should be directed to manager's attention, and cost of it should not exceed its value. Control reports provide information that enable the decision maker to take corrective or preventive action in business trends, to initiate new action, or to confirm and maintain current procedures. Cost reports should present data easy to read and understand, refer to standards or norms thus facilitating budget comparisons. Special reports are also generated to assist in problem solving, planning and scheduling and unusual engineering operations. [5]

5.4 Computerized Maintenance System

Computer technology has developed extremely rapidly over the last ten years and variety of computerized documentation systems has become available. The development of on-line maintenance systems has been rendered possible by the introduction of improved data handling techniques for storing and retrieving data. A number of users can have access to the online system.

5.4.1 Basic Requirements

The implementation of computerized maintenance system requires lot of commitment and positive attitude on the part of maintenance personnel. The computerized system facilitates proper planning, execution and control of maintenance activities. The planning stage starts from scheduling i.e. CPM and PERT networks, issuing work orders etc. The execution stage requires the jobs to be carried out first, resources available, skill requirement. equipment maintenance etc. The control stage calls for control of material and labor cost, labor hours, downtime etc.

5.4.2 Predictive Maintenance

Computerized maintenance system should record the condition of all equipment. The system should be able to lists the nature of failure, repetitive failures and corrective actions taken. The life of various components of the equipment should be fed, so that the replacement due date can be determined easily. All data regarding condition and vibration monitoring can be stored. Condition monitoring checklist and the schedule can also be stored.

5.4.3 Preventive Maintenance

The computerized maintenance system can be used for routine data processing operations such as issuing work orders, keeping and updating cost records. The preventive maintenance schedule can also be prepared, which would help in carrying out the jobs at a faster rate.

5.4.4 Commissioning Data base

Commissioning of equipment requires:

- Master files
- Preventive Maintenance routines
- Plant engineering control routines

❖ **Master Files:**

The master files for individuals contain the following:

1. Facilities File: Relevant information is kept for all (or major) facilities such as building, machines, group of machines, utility systems etc.
2. Facilities History: Information about major repairs, parts replacements, and breakdown diagnoses recorded from field reports and returned work orders
3. Preventive Maintenance: All preventive maintenance instructions and frequencies are kept in this file. Also time standards for repairs, instructions and materials required can be kept here.

The master files for resources contain all the desired information about the resources available to serve the facilities: Such files include:

- Personnel : Personal data of each employee: age, education, skill, position
- Spare Parts: Spare parts that are interchangeable for different machines, usage, price, EOQ, safety stock, recommended vendor etc.
- Maintenance materials and tools: Major maintenance materials like lubricants and tools can be listed in this file with their usage, price, capacity and recommended vendor.
- Other resources: Desired maintenance resources, such as list of subcontractors can be listed here.
- Budgets and Targets: Plant engineering budgets classified in desired forms are listed here. In addition, efficiency targets such as work standards or waste rates are recorded here.

❖ **Input:**

Routine Input: The routine input includes the completed work orders for any type of work. It includes the labor, spares and materials used as well as the description of the work executed. Other routine inputs may include the running time of production machines and the sub-contractor's bills. Routine data are generally submitted at regular intervals.

❖ **Output**

- Work order issuing
- Periodic List of outstanding work orders:
- Preventive Maintenance Scheduling:
- Backlog Monitoring:

❖ **Decision Making:**

- Project Control with PERT and CPM: PERT and CPM can be used to control large plant engineering projects such as equipment installation or relocation and major plant overhauls.
- Optimizing Crew size: Queuing Theory and Simulation techniques help in balancing the idle time of the repair crew and the idle time of facilities waiting for repair.
- Facilities replacement decisions: Decisions regarding reconditioning and replacement of equipment can be taken.
- Maintenance diagnosis and self-control: Computers can process and analyze information recorded by diagnostic instruments and make the appropriate decision.
- Equipment – breakdown analysis: Equipment breakdown analysis, by type or by desired classification can be performed by computer. Causes can be listed and action plan generated.
- Revise preventive maintenance frequencies: To analyze the effect of a change in preventive maintenance frequencies on the breakdown rate and to revise these frequencies accordingly.
- Inventory decisions: Spare parts management and inventory control. Listing of slow-moving, fast moving and non-moving items, obsolete items, standardization and variety reduction.

5.5 Maintenance Management Reports:

The maintenance department can have a variety of faces in the organizational setting. To the production plants, it becomes a staff service function whose sole purpose is to support operating demands. To top management, on the other hand, maintenance may be viewed as a fact-of-life component of overhead, where costs must be minimized to achieve operating efficiency. In any case, the maintenance function must respond to both line and staff goals as well as to its own internal objectives.

The concept central to the useful design and application of maintenance management reports is that integrated communication - information flow is a requisite for effective planning, control and feedback - and thus for successful decision-making.

The overall objectives of the battery of management reports utilized relate to the whole maintenance system:

1. Operating units are to be served by keeping productive equipment operable, efficient and safe.
2. Materials, manpower and equipment will be co-ordinated to provide timely availability of resources at the work site.
3. An optimum level of maintenance will be established and provided in the most practical, low cost manner, in compliance with corporate policy regarding economics, appearance, safety and environmental standards.
4. As a guide for directing improvement, management will be provided with information on status, effectiveness and cost of maintenance activity and programs.

The usefulness of the management report lies in its objectivity and value as both a working tool and a meaningful 'report card'. Each report in itself is also intended to address specific management action on a time continuum.

Content of maintenance reports is dictated by the intended use. However, some common-sense guidelines can ensure the basic intent of objectivity and meaningfulness. The form and format for effective reporting should embrace the following points:

- Simplicity and readability
- Brevity and clarity
- Minimum paperwork and hard copy
- After-the fact summarization (result - oriented)
- Prioritized wherever meaningful
- Bottom-line accumulation (total cost, time, etc.)

- Related to stated objectives
- Exception principle (significant deviation from norm)
- Necessary action highlighted
- Timely distribution
- Comparative with own past (vs. others)
- Consistently applied parameters
- Appeal to reader's interest

5.6 Analysis of Existing Maintenance Records

The following records are maintained in the maintenance department of GRASIM:

i. Equipment Downtime Register
ii. Equipment History Card
iii. Pending Job register
iv. Breakdown and Corrective Action Plan
v. Idle and de-rated Equipment Register
vi. Indent Preparation Register
vii. Job order for EDD
viii. Lubrication norms and stock register

i. **Equipment Downtime Register**:

A register is maintained whereby the downtime of equipment is maintained each day. Every month downtime percentage is calculated for each equipment and analyzed against the norms fixed as per PARTA. The following format is used:

Equipment Downtime Register

Date	Equipment	Reason for Breakdown	Duration	Remarks

ii. **Equipment History Record**:

A register is maintained to record the major jobs done on a particular equipment. A brief description of the job done is also noted down. The following format is maintained:

Equipment History Record

Equipment Name:

S.No	Major Component	Date	Job Description

The existing equipment history card specifies only the job done on particular equipment but does not specify its reoccurrence details and the action taken. The format given below gives a detailed history about the equipment with the mean time between failures, mean to failure and corrective actions taken.

EQUIPMENT HISTORY RECORD

S. No	Eqpt	Compo-nent	Date of Install-ation	Date of failure	Life Achie-ved (TBF)	Reasons for Failure	Action Taken	Date of Commi-ssion	Time to Repair (TTR)	Remark

The format can be made more informative by adding the following column and would eliminate the requirement for maintaining unscheduled stoppage register:

- Production loss due to unscheduled stoppage
- Life Expectancy: Satisfactory / Unsatisfactory

Whenever a sudden breakdown occurs of certain component of the equipment, plant stoppage has to be taken, resulting in loss of production. This type of failures has to be given more attention, so that it does not occur frequently. Life expectancy is the life achieved by the component. If the life achieved is less than the expected life of the component, then the life expectancy has to be considered as unsatisfactory. Proper action should be taken on the components having unsatisfactory life expectancy.

iii. **Pending Job Register**:

All pending jobs on a particular day are noted down in this register. The following format is used:

Pending Job Register

S.No	Date of Reporting	Section	Equipment	Job Description	Expected duration	Date of Completion	Entry in History Register Reqd or not	Sign	Remarks

The above format can be improved by addition of following columns:

i. Type of Maintenance required: Opportunity-Based Maintenance (OBM) or Preventive Maintenance (PMT). Work can be carried out accordingly.
ii. Type of Resources Required: Manpower, Materials, and Skills
iii. Abnormality Observed: In case condition monitoring is required at a later stage, the same format can be used for pending jobs requiring condition monitoring.

iv. **Breakdown and Corrective Action**:

A register is maintained whereby the major breakdown in a particular equipment and the corrective actions taken are noted down.

Breakdown and Corrective Action

Department:

Date	Equipment	Duration	Breakdown details	Action Plan	Signature	Dept. Head	V.P (Tech)

The above format can be eliminated, as equipment history register gives all the details regarding the major breakdown occurred and the corrective actions. Sorting as per the nature and severity of the breakdown can be done through computerization and proper categorization.

v. **Idle and de-rated Equipment Register**

There are many idle equipment, which are not in use or have become obsolete. Some equipment are de-rated also. Hence the list of above equipment can help the organization to either reuse in different sections or discard them. The suggested format is as follows:

Idle and de-rated Equipment Register

Department:

S.No	Eqpt.	Subassembly	Date of isolation	Reasons for isolation	Date of commission	Equipment idle time	Remarks

vi. **Indent Preparation Register**:

The indent register helps in procuring required materials from stores. Every month the management sanctions certain fixed amount for a particular department under a specific CCN (cost center number). The following format is maintained:

Indent Preparation Register

Month: Sanction Amount:

S.No	Month	Document No./Work Order No.	Document /WorkOrder Date	CCN	Value	Cumulative Value	Signature V.P(Tech)

The advantage of this format is that it gives the cumulative value of expenditure made on items. Decisions and action plan can be made whenever the cumulative amount approaches the sanctioned amount. The format does not specify the items indented and the vendors of the supplied items. In order to incorporate the same, following format can be used:

Indent Preparation Register

Department :

S.No	Indent No.	Date	Item	Qty	Rec. Date	Rec. Qty	Vendor	Cost	Equipment	Date	Remarks

Sanction Amount: Cumulative Cost: Balance Amount:

The advantage of this format is that it helps in evaluating the efficiency of vendor regarding the supply of items of required quantity and delivery time. In the remark column, the quality of items received can be entered, whether the desired specifications are met or not, delivery is as per schedule or not.

vii. Job Order for EDD:

Certain jobs are carried out in Engineering & Development Division. To keep a track on the jobs and to expedite the same the following format is used:

Job Order for EDD

Department:

S.No	Job Order No.	Date	Description	Quantity	Unit Of measurement	Received on	Remarks

The above format does not specify the cost involved and for which equipment the work is carried out. It may happen that the entire job is not delivered at a time. So an additional column of the quantity received has to be included. The given below format incorporate the above points:

Job Order for EDD

Department:

S.No	EDD J.O No.	Date	Item	Qty	Rec. Date	Rec. Qty	Cost	Installed position	Date of installation	Remarks

The above format can further be improved by the addition of following columns:

- Quality of work received: Accepted / Rejected / Rework requirement
- Remarks should indicate whether there is any delay in delivering the job with reasons.

viii. **Lubrication Norms and Stock Register**:

A register is maintained whereby lubrication norms and the stock is maintained. The lubrication schedule with the kind of oil to be used is also maintained.

Lubricants Stock Record

Department:

Day	Equipment	Oil Specification	Stock (Amount)

Lubrication Schedule

S.No	Oil No.	Jan	Feb	Mar

Some additional records should also be maintained to make the working efficient and effectively. These reports are as follows:

i. Advance Planner

It has been found that Advance Planning Register is not maintained in the department. This is required because the process engineer specifies the job to be undertaken by the maintenance department on the next day. The jobs thus specified by the process engineer helps in maintenance planning and determining the priorities. The manpower and material distribution is based on the priority of these jobs. The priority can be indicated as follows:

E - Emergency I - Management Instruction 1- Urgent 2 - Essential 3- needed 4 - Deferrable

The advance planner format is shown below:

Advance Planner

S.No.	Eqpt.	Job Description	Priority	Manpower Requirement	Expected Duration	Overtime Requirem -ent	Remarks

ii. Equipment Details Register:

The equipment details register mainly lists the equipment with all details regarding type, make, specification, accessories/parts etc. The following format can be used:

EQUIPMENT DETAILS REGISTER

EQUIPMENT NAME:

DEPARTMENT: SECTION:

FUNCTION:

Manufacturer's Name: Order No.:

Size: Type: Drawing No.:

Purchase Order No.: Vendor:

Equipment Cost: Installation Cost: Total Cost:

Date of Installation:

Process Parameters:

Spare Parts / Accessories:

S.No	Parts	Make	Specifications	Remarks

5.7 MAINTENANCE INFORMATION SYSTEM

Maintenance Information System is one of the important pillars of World Class Maintenance. It is always necessary that right information should reach the right person at the right time, so that right decisions can be taken promptly. Hence it is mandatory to define the MIS requirements at each level of the organizational hierarchy and the frequency of reports to be generated.

5.7.1 Reports & Formats

It is evident that all levels of organizational hierarchy do not require all the information. Hence, it is necessary to categorize the information requirements at each level of the organization. The MIS reports and formats can be prepared for three levels of the organization level as described below:

Level A: Executive Reports for Level 1
Level B: Analysis Reports for Level 2 and Level 3
Level C: Data Entry Reports for Level 4 and Level 5

Table 5.1 shows the MIS requirements for each level of the organizational hierarchy.

5.7.2 Executive Summary Report

The Level A format gives an overview of the maintenance activities and the data required for decision-making. This includes production, downtime, stores expenses and inventory, contractor's jobs, accidents and overtime details, new schemes and modifications. The Executive Summary Report appears in the matrix form as shown in the Table 5.2. The supporting formats include analysis reports and data entry reports.

TABLE 5.1

MIS REQUIRMENTS - LEVEL WISE

S.No	MIS REQUIREMENTS	Level A	Level B	Level C
1	EQUIPMENT DETAILS			
2	TIME STUDY			
3	METHOD STUDY			
4	MANPOWER STUDY			
5	MAN-MATERIAL MOVEMENT STUDY			
6	DAILY PLANNER			
7	EQUIPMENT HISTORY RECORD			
8	DOWNTIME RECORDS			
9	MAJOR BREAKDOWNS WITH CAUSES			
10	PENDING JOBS			
11	LUBRICATION SCHEDULE			
12	OVERHAULING			
13	EDD / WORKSHOP JOBS			
14	SAFETY RECORDS			
15	STORES ISSUES & EXPENSES			
16	OVERTIME & ABSENTEEISM RECORDS			
17	CONTRACTOR JOBS & EXPENSES			
18	CONCEPTUALISATION OF NEW SCHEMES			
19	BUDGET			
20	STATUS OF ON-GOING SCHEMES			
21	IDLE / DERATED EQUIPMENT			
22	SPARES & INVENTORY			
23	TRAINING RECORDS			
24	APPRAISAL RECORDS			
25	WCM STATUS AND IMPLEMENTATION			

- As and when required
- Daily
- Weekly
- Monthly
- Quarterly
- Yearly

TABLE 5.2
EXECUTIVE SUMMARY REPORT (MAINTENANCE) LEVEL A

MONTH **AVERAGE FIBRE PRODUCTION:** **MACHINES:**

S.No		PARTICULARS	UNIT	PC 1			PC 2			PC 3		REMARKS
				vis	spg	aux	vis	spg	aux	CS2	H2SO4	
A		AVERAGE PRODUCTION	TPD									
B		DOWNTIME										
		Severeity Index										
		Frequency Index										
C		CRITICAL EQUIPMENT										
1		PLANNED										
	a	Preventive	%									
	b	Others	%									
2		UNPLANNED										
	a	Mechanical	%									
	b	Electrical	%									
	c	Instrumentation	%									
	d	Process	%									
	e	Power	%									
	f	Others	%									
		TOTAL (1 + 2)	%									
3		MAJOR BREAKDOWNS	Nos.									
		AFFECTING PRODUCTION										
4		PRODUCTION LOSS	Tons									
			%									
C		EXPENSES	lacs									
1		Stores Norms										
		Deviation										
		Stores Inventory										
		Pending Orders										
2		Contractor's Norm										
		Deviation										
D		LABOUR										
1		Overtime	Mandays									
	a	Absenteeism										
	b	Others										
2		Accidents										
	a	Severeity Index										
	b	Frequency Index										
E		NEW SCHEMES										
1		Total Schemes	Nos.									
	a	Schemes Completed	Nos.									
	b	Delayed Schemes	Nos.									
	c	Non-saving Schemes	Nos.									
	d	Saving Schemes	Nos.									
2		Sanction Amount	lacs									
	a	Expenditure	lacs									
	b	Deviation										

5.7.3 Analysis Reports & Formats

The Level B reports give a thorough analysis of all maintenance activities of each department. Level 2 and Level 3 persons can easily identify the problem areas of different departments and can monitor the working of these departments more efficiently. Following are the B-Level formats:

i. Downtime Formats:

The downtime formats give an insight to the stoppages taken in each equipment of a particular department. The factors like % downtime, frequency index, severity index, % production loss may help in assessing the criticality of the equipment and benchmarking the parameters. Table 5.3 shows the format for downtime records for Level B.

ii. Stores Expenses:

The stores expenses format gives a detailed summary of expenditure month-wise for each department. The planned budget, actual expenses and the deviations for process, engineering and others are indicated. The actions to be taken for overrun can be indicated in the action plan column. The format is shown in the Table 5.3.

iii. Contractors' Expenses:

The contractors' expenses format gives a detailed summary of expenditure month-wise for each department. The planned budget, actual expenses and the deviations for process, engineering and others are indicated. The actions to be taken for overrun can be indicated in the action plan column. The format is shown in the Table 5.3.

iv. Overtime Analysis:

The overtime analysis format gives the data regarding the overtime norms for each department and the deviation from the norms. It also indicates whether the overtime is due to absenteeism or for other reasons. The format is shown in the Table 5.3.

v. Accident Analysis:

The safety records helps to identify the nature of the accidents, location, causes of accident. The Accidents Analysis Report gives the number of accidents taken place in a department and the man - hour lost due to above accident. Severity Index and Frequency Index are calculated for each department. Table 5.3 shows the accident analysis report format, which gives the department and section wise accident details.

vi. New Schemes Status

Each department, as a part of modifications through improvements in the process, design changes, or rationalization of layouts develops many new schemes. Hence a database should be maintained on a monthly basis regarding the finalization of schemes and completion of schemes. Action plan should also be stated for meeting scheduling compliance. The format is shown in the Table 5.3.

vii. Departmental Expenses Summary

The departmental expense summary gives a detailed summary of the expenses of various departments with regards to stores, job orders, contractors and labor. This would help the management in pinpointing a particular department whose expenses exceeds that of budgeted. The format is shown in the Table 5.3.

TABLE 5.3

MIS (LEVEL B) FORMATS

DOWNTIME RECORDS (LEVEL B)

Department:

S.No	Equipment	Mode of Stoppage	% Downtime	Frequency Index	Severity Index	% Production Loss	Action Plan

CONTRACTOR'S REGISTER (LEVEL B)

Department:

S.No	Job Order No.	Contractor Code	Planned Expenses	Actual Expenses	Deviation	Work Slippage	Remarks

STORES EXPENSES (LEVEL B)

MONTH :

S.No	Deptt.	PLANNED BUDGET				ACTUAL EXPENSES				DEVIATION				ACTION
		Process	Engg.	Others	Total (A)	Process	Engg.	Others	Total (B)	Process	Engg.	Others	Total (A-B)	PLAN
1	Viscose 1													
2	Spinning 1													
3	Auxiliary1													
	PC 1													
	Cumulative													
	Avg.													
4	Viscose2													
5	Spinning2													
6	Auxiliary2													
	PC 2													
	Cumulative													
	Avg.													

CONTRACTOR'S EXPENSES (LEVEL B)

MONTH :

S.No	Deptt.	PLANNED BUDGET				ACTUAL EXPENSES				DEVIATION				ACTION
		Process	Engg.	Others	Total (A)	Process	Engg.	Others	Total (B)	Process	Engg.	Others	Total (A-B)	PLAN
1	Viscose 1													
2	Spinning 1													
3	Auxiliary1													
	PC 1													
	Cumulative													
	Avg													
4	Viscose2													
5	Spinning2													
6	Auxiliary2													
	PC 2													
	Cumulative													
	Avg.													

OVERTIME ANALYSIS (LEVEL B)

MONTH :

S.No	Department	OVERTIME NORM				ACTUAL O.T (MANDAYS)				DEVIATION				ACTION
		Process	Engg.	Total	% Abse-nteeism	Process	Engg.	Total	% Abs-enteeism	Process	Engg.	Total	% Abs-enteeism	PLAN
1	Viscose 1													
2	Spinning 1													
3	Auxiliary1													
	PC 1													
	Cumulative													
	Avg.													
4	Viscose2													
5	Spinning2													
6	Auxiliary2													
	PC 2													
	Cumulative													
	Avg.													

ACCIDENT ANALYSIS (LEVEL B)

Month:

S.No	Date	Department	Section	Nature of Accidents			Man-hours	Frequency	Severity
				Major	Minor	Total	Lost	Index	Index

NEW SCHEMES (LEVEL B)

Department: Equipment :

S.No	Scheme conceptualised	Amount Sanctioned	Starting Date	Completion Date	Slippage	Actual Expenditure	Cost Deviation	Saving/ Non-saving

DISCIPLINE - WISE DEPARTMENTAL EXPENSES (LEVEL B)

MONTH:

S.No	PARTICULARS	BUDGET ALLOC-ATED	PC 1			PC 2			PC 3		ACTION PLAN
			vis	spg	aux	vis	spg	aux	CS2	H2SO4	
1	PROCESS										
	Sanction Amount										
	Expenses										
	Deviation										
2	MECHANICAL										
	Sanction Amount										
	Expenses										
	Deviation										
3	ELECTRICAL										
	Sanction Amount										
	Expenses										
	Deviation										
4	INSTRUMENTATION										
	Sanction Amount										
	Expenses										
	Deviation										
5	BUILDING										
	Sanction Amount										
	Expenses										
	Deviation										
6	SERVICES										
	Sanction Amount										
	Expenses										
	Deviation										
7	SCHEMES										
	Sanction Amount										
	Expenses										
	Deviation										
	TOTAL										
	Sanction Amount										
	Expenses										
	Deviation										

viii. Discipline-wise Department Expenses

The discipline-wise department expenses gives a detailed expense summary made by the process, engineering and others of a particular department. This format would help the management in taking actions against particular discipline people for more expenditure. The format is shown in the Table 5.3.

5.7.4 Data Entry Reports

The Level C formats should be entered by individual department. The Level 4 and Level 5 persons will be responsible for the data entry and ensure all relevant details are correctly filled. The Level C formats are listed below:

i. Downtime Records:

The downtime record format for Level C is shown in Table 5.4. The data, like time of start, time of stoppage, reasons of stoppage, mode of stoppage and production loss are entered in the format.

ii. Stores Expenses:

The stores department maintains a complete record of the sanction amount and the expenses incurred by each department. Weekly and monthly statement of expenses of each department can be used for analysis. The deviations in the sanctioned amount and the actual expenses help the management to take proper actions and thus avoid overruns.

iii. Contractor's Register:

The contractor register gives a complete detail about the job to be carried out by the contractor and the expenditure involved in carrying out the said job. In the remark column, the quality of work done by the contractor and the slippage, if any, should be

TABLE 5.4

MIS (LEVEL C) FORMATS

DOWNTIME RECORDS (LEVEL C)

Department : **Equipment**

Date	Time of Stoppage	Time of Start	% Downtime	Reasons for Stoppage	Mode of Stoppage	Production loss, if any	Action Plan

CONTRACTOR'S REGISTER (LEVEL C)

Department: **Section:** **Equipment:**

S.No.	Job Order No.	Contractor Code	Date of start	Date of completion	Slippage	Actual Expenses	Quality of Work

OVERTIME ANALYSIS (LEVEL C)

Department: **Section:** **Equipment:**

Date	Total Manpower		In Attendance		% Absence		% Overtime	
	Process	Engg.	Process	Engg.	Process	Engg.	Process	Engg.

SAFETY RECORD (LEVEL C)

Department: **Month**

S.No.	Name	Card No./ Emp. Code	Date & Time	Section/ Location	Description	Nature of injury	Cause of injury	First Aid/ Hospital-isation	Witness	Mandays Lost

mentioned. This will help in thoroughly evaluating contractor's work. The contractor's register format is shown in the Table 5.4.

iv. Overtime Analysis

The overtime analysis is done for each equipment month - wise. The format can be used to identify the reasons of overtime, whether it is due to absenteeism or neglect in work. The format is shown in the Table 5.4.

v. Safety Register:

A safety register is of utmost necessity to keep a record of the accidents, their causes and nature of injury. The format is shown in the Table 5.4.

This chapter thus focussed on the requirements of maintenance information system. The study reveals that the existing reports and formats should be modified. The Executive Summary Report formats meant for Top Level Management serves as an indicator for monitoring the maintenance activities and take corrective actions. The supporting formats record all the maintenance activities and helps the department heads and shop-floor engineers to improve department working and in taking right decisions at the right time.

The next chapter deals with various maintenance systems and procedures, which would prove as a useful guideline for the maintenance department in improving the productivity of men and enhancing the overall plant effectiveness.

CHAPTER 6

MANAGING WORLD-CLASS MAINTENANCE SYSTEMS

6.1 Introduction

World - Class Maintenance calls for designing systems, which aim at organisational growth and stability with a purpose of maximising the profit and minimising the cost. Maintenance operations are carried out most effectively through planned system and orderly procedures for attaining goals and objectives. The system may be simple or complex in its scope, depending on the magnitude of the task and the difficulty of achieving it. Systems need to be measurable in order to ascertain their effectiveness and to enable them to be changed and improved. A system should be acceptable, simple, effective, efficient and adaptable. Each significant system has subsystem, which should have similar requirements.

The organization involved in plant, machinery and facilities should have clear-cut maintenance policy and should choose that maintenance system which best meets its goals and objectives.

World-Class Maintenance systems should also lay emphasis on safety aspect and a pollution-free environment. It is necessary to design policies and procedures, which will help in achieving the objective of zero accidents and zero pollution. The tools and techniques to identify the hazards and taking quick corrective actions may result in reducing accidents and create better work environment at the workplace. The new scientific techniques like HAZOP and HAZAN studies can be used for identifying and analyzing hazards at critical areas of the plant.

6.2 Types of Maintenance Systems:

The maintenance systems can be classified under the following heads: [6]

1. Breakdown Maintenance:

Breakdown maintenance is carried out only when the machine ceases to function and no servicing are carried out except for a little bit of cleaning and lubrication. The only attention the machine receives is at the time of failure. In this system, there is no maintenance man available and there are no spares kept even for immediate foreseeable needs, nor there any maintenance manuals or handbooks available. Whenever the breakdown takes place, adhoc repairs are done at tremendous costs.

2. Routine Maintenance:

Routine Maintenance is a cyclic operation recurring periodically. Routines are established by defining the frequency of the tasks and the time taken to complete the task. The advantages of this system are that it is simple to follow and establish and it achieves a higher degree of prevention by intercepting faults. It prolongs the life of equipment and facilities. The abnormalities can be easily detected and eliminated before they can cause major stoppage.

3. Planned Maintenance

Planned Maintenance is a maintenance organized and carried out with forethought, control and records, to a predetermined plan. In this system, the emphasis is on the machine needs and the expected requirements from the machine. The factors to be considered are the extent and severity of utilization of equipment and operating conditions. In the planned maintenance, the detailed instructions have to be followed strictly which include instructions for inspections, repairs, rectification and replacement of components. The data is recorded, which helps in effective planning and scheduling.

The analysis of failure data clearly brings about the reasons of failure, faulty design, and faulty operation.

4. Preventive Maintenance

Preventive Maintenance system is a system of planned servicing carried out with an objective of detecting or locating weak areas and ensuring perfect functioning by even replacing components which have not achieved their full life for enhanced reliability. In addition to this, planned inspection and servicing are also carried out between consecutive preventive maintenance for eliminating breakdowns.

5. Predictive Maintenance

Predictive Maintenance is defined as methods of surveillance used to indicate as to how well the machine is, while performing its intended tasks. The objective of this system is to predict an impending failure well in time, avoiding failures causing heavy penalty costs, health and safety hazards. Condition-based maintenance is a method of extracting information regarding the condition of the plant/machinery in quantitative terms.

6. Corrective Maintenance:

Corrective Maintenance is defined as maintenance carried out to restore machinery, which have ceased to meet acceptable conditions. Corrective Maintenance arises not only when an item fails but also when indicated by condition and vibration monitoring.

7. Design Out Maintenance

Design out maintenance is a system that strives to eliminate the cause of failure or minimize the need for maintenance to the lowest possible level. It is appropriate for items of high maintenance cost, which arises because of poor maintenance, poor design or operation outside design specification. It is applied to the product at the design stage itself, so that machinery, plant and equipment are so designed as to need the least possible amount of attention or maintenance during their economical life span. The identification of items to be designed out depends on the cost of redesign and the cost of recurring maintenance. This system helps in increasing maintainability at the design stage.

8. Contract Maintenance

Contract Maintenance is a system where for an agreed fee the contractor supplies trained manpower along with the requisite supervisory staff and the necessary tools and equipment required for carrying out the maintenance jobs. The advantage of this system is that contracting can reduce downtime by reducing the time to repair, as their manpower is more skilled and readily available. The carrying cost of trained manpower reduces to a great extent. Normally specialized jobs requiring skilled labor and sophisticated equipment are contracted. Annual maintenance contract is awarded to service agencies, which maintains the equipment throughout the year.

9. Total Productive Maintenance:

Total Productive Maintenance (TPM) process embodies, as an essential, the achievement of total quality and is the logical outcome of these developments in the maintenance function over the years. TPM emphasizes on the empowerment to signify the power of the operator and the maintainer, as members of a team, to ensure that the assets they own in the shape of equipment and machinery are kept always at maximum effectiveness and under permanent scrutiny for continuous improvement.

10. Opportunity Based Maintenance:

Maintenance turnaround is defined as the planned stoppage to completely overhaul the plant or machine and attain full operating life. At times, a major breakdown or failure forces the plant to be shut down at a time before the scheduled turnaround date. In such a situation the turnaround should be preponed to take full advantage of such a situation only if the organisation is prepared for. To convert a forced outage into a planned overhaul is quite an art and needs proper anticipation, planning and considerable managerial talent. This helps in maximizing the availability of the plant and equipment.

11. Autonomous Maintenance:

Autonomous Maintenance is a system in which operators carry out routine operation as well as inspections and maintenance to prevent accelerated deterioration of the equipment. It is implemented in a series of steps starting from initial cleaning to steps involving restoring the basic equipment conditions. It involves change of culture, sharing of vision, sustainable and innovating performance as a team, educating and motivating operating personnel.

12. Reliability - Centered Maintenance:

Reliability-Centered Maintenance is a process to determine the maintenance requirements of any physical asset in its operating context. Reliability-Centered Maintenance transforms the relationships between the undertakings, which use it, their existing physical assets and the people who operate and maintain those assets. It also enables new assets to be put into effective service with great speed, confidence and precision.

13. Quality Maintenance:

Quality Maintenance is a method for incorporating quality into products through the process and equipment rather than controlling quality by inspecting products and taking action against defects that have already occurred. This is accomplished by identifying checkpoints for the process and equipment that are affecting the desired quality characteristics, measuring those periodically and taking appropriate action.

6.3 Design of Maintenance Systems

Following factors need to be considered for designing a world-class maintenance system: [7]

- **Criticality Assessment:**

Criticality Assessment is the starting point for planning of maintenance effort. The more the equipment is critical, the more maintenance effort it will warrant to keep it in a serviceable condition. Criticality assessment is the process wherein one attempts to scientifically and systematically pinpoint and list the most important steps of a process, and importance of the equipment for safe and reliable functioning of the whole system. Various factors like reliability, maintainability, ease of repair, environment, safety, throughput velocity, cost etc. decides the criticality of equipment.

- **Downtime Costs:**

Cost of breakdown includes cost of lost production, labor cost, cost of replacements and spare parts. The impact cost should also be taken into account, which is in the form of cost of idle time of production labor and all those others who have been rendered idle by the same breakdown downstream. There may be costs related to penalty for delayed delivery of an order, or the cost of order being cancelled.

- **Severity of Utilization**

The severity of utilization is the extent of loading per day of the equipment. Its relationship with the product or production output should be ascertained and gauged correctly.

- **Standby Availability**

For critical equipment, it is always necessary to have a parallel system, which can be out to use in case of equipment failure. This is called standby availability.

- **Downstream Effects**

Downstream effects are the important criteria as they can have serious long-term implication for example a breakdown in the simplex can have far reaching repercussions on the spinning machines.

- **Hazards involved in the event of failure**

In the event of failure, breakdown or mal-functioning, certain machinery and plants can bring hazards to man, property and even the environment, for the fall-out of such failures can be very dangerous, damaging and destructive. The hazard can be of the form of poisonous, toxic or inflammable gases. In those circumstances, where failure can lead to hazardous ends, the criticality of the safety devices will be self-evident. A thoroughly efficient and well-maintained safety service must at all times be available at such sites, which can prevent and combat, if necessary.

- **Age of Plant**

An important criterion of maintenance planning to be kept in mind is the age of machinery in use. As aging occurs, the need for maintenance increases quantum-wise. The machines need to be monitored and evaluated, so that actions may be initiated accordingly without bringing on a crisis through breakdown. This can result in an increase in condition monitoring effort and perhaps also need preventive maintenance checks and frequent inspections along with planned maintenance.

❖ **Skill Availability**

With the rapid advancement in technology, skills required to cope with the state-of-the-art technology often lags behind, the effects of which are felt by all areas and functions. Initial training is a must for the production personnel before they start working on new machinery.

❖ **Maintenance support facilities and Infrastructure**

The creation of the support facilities and an infrastructure to cater to the demands of the entire range of maintenance activities is not only very expensive but also very time-consuming.

❖ **User skill, Operating environment, condition of usage and severity of utilization**

The user skill. operating environment, conditions of usage and the severity of utilization are the factors that either individually or collectively have a direct impact on the life of equipment and machinery and its performance. The factors that can lead to this state of criticality need to be looked into with care. They are operating speed, temperature, load, vibration, pressures and factors such as dirt, corrosion, pollution etc.

6.4 Maintenance Scheduling Planning & Control

World - Class Maintenance aims at utilization of the resources like labor, material, machine and money effectively and efficiently. This requires proper planning, scheduling and control of maintenance tasks and resources. Efficiency is defined as the optimum utilization of all resources to keep delays and non-productive activities to a minimum. Effectiveness is the utilization of resources at their level of proficiency to anticipate and correct problems before they call for major repairs.

An efficient and effective maintenance can take an additional workload in a period of expansion without increasing manpower. Planning and Scheduling, when properly done. will assure that equipment receives required attention at the prescribed intervals. Increased maintenance service is reflected in greater equipment reliability, maintainability reduced overall equipment costs. [8]

6.5 Requirements of Planning & Scheduling

There are five basic requirements of planning and scheduling to assure management control of the maintenance function:

- Formal procedure for defining, approving and authorizing maintenance work
- Job order system that permits effective communication of job needs and work requirements
- Priority system which classifies jobs as to urgency and need date
- Scheduling system
- Control and Follow-up

Job order:

The written job order is the principal document to plan, estimate and schedule the job and to accumulate charges for maintenance information reporting. The data provided are related to:

Financial Data: The financial data includes numbers for cost centre, account classification, capital classification, and equipment number.

Requirements Data: The requirement data includes who requested the job and when, priority and need date and a description of what is wrong or what is needed.

Approval and authorization: The approval and authorization includes blocks for approval and authorization of the work and acceptance of the completed job.

Planning and scheduling control: The planning and scheduling control includes an individual, unique number for each job, estimates of personnel, material and equipment costs and a brief description of the job

Job requirements: The job requirements include space to list the specific requirements to complete the job, which are broken down by sequential steps with labor and material estimates.

A sample format of maintenance work order is shown below:

<u>**MAINTENANCE WORK ORDER**</u>

DEPARTMENT:	SECTION:	EQUIPMENT:
TYPE: PM/BKD/OH	TAG NO. :	
PRIORITY:	FAULT: M/E/I/P	WORK PERMIT: YES/NO
DATE PLANNED:		

DETAILS OF DEFECT / PLANNED WORK

DESCRIPTION OF WORK/JOB TO BE DONE

LABOR REQUIRED:

SPARES REQUIRED:

SPECIAL TOOLS REQUIRED:

LAST DATE OF REPAIR/REPLACEMENT:

START OF MAINTENANCE:		COMPLETION OF MAINTENANCE:	
DATE:	TIME:	DATE:	TIME:
MTTF:	MTBF:	MTTR:	

ENGINEER'S SIGNATURE AND DATE: ____________________________

Changes in Job order nature:

Many times, the nature of a job changes as the work progresses. If the change is significant, then a new job order is needed from the equipment owner to change the scope of work. The newly planned and estimated job order provides the necessary information to properly schedule the job to completion.

When a repair is being done and undetected wear or damage indicates a need to complete overhaul, then the overhaul is requested on a separate job order. During an emergency, a job order is issued to correct the emergency condition, but a separate job order is necessary to make any repairs caused by the emergency.

Emergency Job order:

Prior to the start of any planning and scheduling system in maintenance, a considerable part of the work effort is expended on emergencies. Maintenance craftsmen dash from one emergency to another without completing the previous task. Emergencies are handled as special cases under the job order system. Emergencies represent the most inefficient use of maintenance resources, because there is little chance for proper planning and scheduling.

An emergency exists:

- when the situation poses grave danger for life, limb or property
- where there is immediate threat of catastrophe or rapid deterioration of the situation
- when reduced production causes unacceptable financial losses or jeopardize delivery commitments
- when the company violates legal statutes if the company is allowed to continue

The maintenance supervisor takes necessary step to pull people from scheduled jobs to correct the emergency condition with the least interruption to the daily work schedule as possible.

Job order priority system

The job order priority system establishes understanding between maintenance department and its customer regarding the urgency and importance of requested work. The equipment owner is responsible for the assignment of priorities on the job order. This is best handled in a direct negotiation with the maintenance planner.

The priority system should be as simple as possible.

Job Priority

Priority Code	Description
E-Emergency	The job must meet one of the definitions for emergency
1-Urgent	The job must be started the next day or within 24 hours or there is considerable risk of emergency condition
2- Essential	The job must be started within 5 days or there is substantial risk of equipment breakdown
3- Needed	The job is essential but can be deferred and it should start within 3 weeks. This category operates as fill-in work on the daily work schedule
4- Deferrable	These jobs are best done at the time of a major overhaul or when the equipment is under stoppages due to other reasons

The following points are essential for the proper operation of priority system:

- Once a job is scheduled, it will be worked to completion regardless of the original priority of the job order
- The maintenance planner will not change the priority classification without first consulting the equipment owner
- The priority distribution is part of the management control reports prepared to measure the effectiveness of the maintenance department

6.6 Planning equipment breakdown / plant shutdown program

This technique deals with the planning of potential maintenance work that should be performed under emergency repair work conditions. It should be recognized that it is not practical to perform preventive maintenance to the point that component parts could be replaced before failure in every case, for in some cases this is strictly uneconomical. Besides the economical evaluation, the probability of failure is always present to some degree even with new equipment. Knowing that certain failures are probable and that if the failure did occur, production would be lost, hence, some type of planned program should be developed. [8]

Since the planning covers 'possible' work, it should be kept separate from the regular planned maintenance work. The steps taken for the development of the program are as follows:

- Meeting should be held with key maintenance personnel and engineering representatives in attendance. The agenda will include a statement of the program's purpose, an outline of the format that will be followed for its development and the designation of the persons who will coordinate these efforts
- Prepare a list of major equipment whose unexpected failure would greatly cripple production
- Review the list and add possible types of failure for each piece of equipment
- Prepare action plan with various possible alternatives in case of failure
- Plan the repair action
- Provide the description of material availability and its location
- Record the amount of anticipated downtime
- Review the entire program by the group and the production personnel

Annual overhauls and major plant shutdowns pose planning problems that are quite different from those of the ongoing workload. Shutdowns consist of a multiplicity of inter-related activities, all of which needs to be coordinated if the work is to be completed in time. Overrunning the shutdown time can result in extremely high unavailability costs.

Such work is thus accomplished with network analysis, i.e. CPM and PERT. Gantt charts are prepared for shutdown programs. The list of activities, resources, cost, duration, starting time and completion time, and inter-relationships between various activities help in determining the program duration and optimizing the resources.

The major activities of plant shut down program are as follows:

- Management meets on a formal basis to agree the extent of the shut down
- A good data retrieval system, for estimating job times and resource loading for standard repetitive, is in operation
- The plant engineers actively encourage the personnel responsible for implementing the shutdown program to comment on the logic diagram for their particular areas of work
- Adequate arrangements are made using work schedules and monitoring progress
- Preparatory work is properly planned and controlled

The progress reports are normally sent to Vice President (Technical), which includes the estimated completion time of live activities, actual completion time of activities, review of pending jobs, excess or shortfall on resources, additional work arisen or arising. Work orders are issued along with the clearance certificates, instructions regarding access to special tools etc. The review and updating of program is carried out by identifying the deviation from the planned (slippages) and corrective actions are taken to complete the program on time.

6.7 Maintenance Scheduling

The scheduling function is best handled by the person, who planned the job. The planner prepares a daily work schedule based on priority designation, need date and operational requirements. The purpose of scheduling is to outline a distribution of jobs based on man-hour estimates. This assures that every maintenance craftsman is fully occupied each day. Job orders are only scheduled when all the resources needed to start the job are on hand.

The objective of scheduling is to assure that necessary material, tools and special equipment are delivered to the job site when needed and to eliminate any chance of being lost or mislaid. It also assures that craft skills are provided in proper sequence and at the correct time to prevent delays and reduced travel time between jobs. Proper scheduling and execution of jobs through a coordinated effort between operations and maintenance will keep downtime within controlled limits.

6.7.1 Scheduling Repetitive Jobs

In all maintenance operations, there are number of jobs that recur at regular intervals. Examples of these repetitive jobs are preventive maintenance inspections and / or overhauls, lubrication, inspection required by the standards. Not only must these jobs be integrated into the daily work schedule but also a procedure must be implemented to assure that all jobs are scheduled at the proper time.

The key to successful repetitive jobs scheduling is regularity. Once all the technical details have been completed - such as deciding jobs to be included and scheduling frequencies - time should be set aside on a regular basis to review all jobs. Those jobs to be scheduled are retrieved and placed on work orders. When regularity is established, then all necessary repetitive jobs will be scheduled at the proper time.

Priorities must be assigned for repetitive jobs to ensure proper progress through daily maintenance work schedules. If a job is worthy of being placed on a fixed - frequency repetitive schedule, it is a critical job. This is particularly true of jobs scheduled at weekly through monthly frequencies. Given a less than critical priority these jobs could be ready for the next scheduling period before they are actually completed, thus defeating the purpose of repetitive job-scheduling. Repetitive Jobs should never be assigned a backlog priority.

6.7.2 Preventive Maintenance Scheduling

The purpose of preventive maintenance is to minimize breakdowns and excessively rapid deterioration of equipment. In order to achieve maximum equipment effectiveness at minimum cost, the need for preventive maintenance must be analyzed and a systematic scientific approach must be adopted. The function of a preventive maintenance system, then, is to control preventive maintenance activities.

A preventive maintenance system should provide for routine inspections and provide servicing and overhaul on equipment for preventive maintenance coverage. A preventive maintenance program can be effective only if the facilities and equipment are in fairly good condition. If the equipment that must be constantly repaired is not ready for preventive maintenance, then such equipment must be reconditioned to an acceptable level of stability before preventive maintenance can be applied. If this is not done and the equipment falls at random intervals, the preventive maintenance program will most likely be ineffective.

6.7.2.1 Objectives and Principles

The objectives of a preventive maintenance system are as follows:

- To aid in minimizing the unanticipated failure of equipment in order to avoid the resulting downtime and loss of production
- To minimize the cost of emergency repair
- To minimize hazards to personnel and equipment
- To maximize the efficiency and safety of production equipment operation
- To prolong the useful life of equipment covered by the program

The following principles should be applied to preventive maintenance work:

- Preventive Maintenance work must not be interrupted by other maintenance work except that of high priority

- Workers from regular maintenance force will perform the preventive maintenance activities
- Routine work generated by a preventive maintenance system should follow the same organizational procedures as regular maintenance for authorization, accumulation of costs and reports

6.7.2.2 **Basic Elements**

The four basic elements of any preventive maintenance program are:

- Itemized listing of equipment
- A Schedule file
- A job tasks file
- An equipment history file

> **Itemized Equipment Listing**

- Preventive maintenance should be focused on the top 20% of equipment items that account for 80% of the cost of downtime or loss of production. Attention should also be given to the electrical and instrumentation equipment that controls and services these high-priority equipment items.
- Items are to be included if, after a reasonable predictable period of equivalent operating time, wear-out has been established as the cause of failure.
- Preventive Maintenance inspections are to be set by safety codes and laws
- Preventive Maintenance should include all the service-type activities, such as changing oil, changing filters, lubricating, greasing, as well as periodic inspections, using either visual examination or nondestructive testing equipment and modern diagnostic tools.
- It is up to preventive maintenance personnel to determine whether breakdown could cause serious damage to equipment.
- Care is to be exercised to assure that easily deferrable, long-term maintenance needs will not be overlooked

No preventive maintenance program should include all equipment. Items not included in the preventive maintenance program should be:

- Non-critical fractional horsepower motors
- Equipment expected to become obsolete within its normal life span
- Equipment that requires inspection which would cost more than a breakdown repair project

- **Schedule File**

This element within a preventive maintenance system includes descriptions of all equipment selected for inclusion in the preventive maintenance program, information on the frequency of preventive maintenance work for each component of equipment. It also includes a specially designated plan for preventive maintenance work orders, a historical record of interval reviews and adjustments, and a calendar schedule for the performance of preventive maintenance work.

Each file should consist of one or more of the following:

- Equipment Description
- Work order schedule
- Work order for preventive maintenance service
- Work order for preventive maintenance inspection
- Work order for preventive maintenance overhaul
- Record of interval reviews and adjustments

- **Job Tasks File**

The job tasks file provides information on how specific tasks should be done and / or a record of tasks performed. Tasks for performing preventive maintenance work are detailed and made accessible or integral with the preventive maintenance work orders for use in connection with the scheduling function.

Formal written tasks should be established for each type of equipment in the preventive maintenance program. The tasks are written so as to ensure that each particular job task can be performed on more than one equipment item. Each item or step of the job to be performed is listed with the description of the work. The manpower requirements and the duration are estimated for each step of the job.

A job task description offers the following advantages:

- It reminds the worker performing the preventive maintenance work to include all the steps necessary to complete the job.
- It provides the worker with the technical information needed to perform the work
- It ensures that preventive maintenance work being performed by different workmen will be uniform and complete

> **Equipment History File**

The equipment history file provides a means for recording and accessing histories on equipment of interest. Information from this file is used in modifying a preventive maintenance program for improved effectiveness and lower costs. The history records are dependent on a feedback procedure for reporting conditions, failures and repairs.

> **Preventive Maintenance Slippage Report**

A number of jobs to be undertaken are planned before the preventive maintenance is taken on the machine. These jobs are listed according to priority. But not all the jobs gets completed may be due to lack of resources like manpower, material or the jobs can be deferred due to its non-criticality. Hence the slippage can be recorded in the following format after the preventive maintenance gets completed.

Preventive Maintenance Slippage Report

S.No	Equipment	Planned Stoppage	Total Jobs Planned	Total Jobs Completed	% Slippage	Actual Stoppage	Reasons for Slippage

6.8 Management Controls for Maintenance

The planning and scheduling of maintenance jobs are followed by management controls, which monitors the effectiveness of the system. Various reports should be prepared, which would help the maintenance manager to effect quick controls over the maintenance operation: [9]

i. Unreported man-hours:

The maintenance foreman records on the daily work schedule the actual hours expended by the maintenance crew each day. The first control indicator is the relationship between the actual hours reported by the maintenance foreman and the direct hours paid to the craftsmen. Unreported man-hours represent the difference between reported man-hours and paid man-hours. The control parameter is unreported hours as a percent of total hours paid and the target figure is 0 %.

ii. Scheduled man-hours

The next important indicator is the percentage of available man-hours scheduled. The maintenance work force is available for work a fixed number of hours per week; on a day-to-day basis, there should be a full day's work planned and scheduled for each maintenance craftsman. The difference between regular hours available and man-hours scheduled is reported as a percent of regular hours available. The target figure is plus or minus 5 %.

iii. Scheduling Compliance

The jobs need to be completed as planned and scheduled. The indicator is the percentage of man-hours worked as scheduled and the percentage of jobs completed as scheduled. The target figure is 90 %. The maintenance manager monitors the compliance to schedule by reviewing the percentage of man-hours and jobs completed within the target range.

iv. Performance of completed jobs

The next important indicator is performance of the maintenance work force against the job estimates. This helps the equipment owner decide if the job is worth the cost, aid the planner in scheduling the job to properly align jobs and manpower availability and finally estimates are used to measure performance.

v. Backlog

Backlog helps the planner to properly balance and distribute the work force to meet all operational requirements. A backlog that is too high means that the work force cannot do the work within reasonable period and that some important jobs are not done. On the other hand, a backlog is too low means that the work force cannot be effectively utilized and the probability of excessive people is fairly high. Backlog is delivered by dividing the total outstanding man-hours on jobs ready for execution by the normal available man-hours per week. If backlog has a tendency to peak during short intervals, outside contracting is the best method to stabilize the backlog trend. Backlog trends also indicate where to schedule preventive maintenance jobs to take best advantage of dips in the workload level. A long-term rise in backlog indicates the need for additional manpower and long term drop indicates the possibility to reduce staff.

vi. Emergencies and overtime

The percentage of emergencies and percentage of overtime are the key factors in judging the performance of the maintenance function. Overtime should be kept within the range of less than 2% of all regular hours worked. Emergencies represent an interruption of the daily work schedule and work efficiency is decreased. Therefore jobs classed as emergencies should be kept to less than 10 percent of all work.

vii. Non-productive work

A review of trend patterns for non-productive time will indicate whether there are opportunities for increasing efficiency by analyzing the factors, which contribute to the non-productive work. Some of these non-productive times are unavoidable, but a percentage indicating higher than normal levels should be investigated to resolve bottlenecks to effective operations. Non productive time is expressed as a percentage of regular hours worked and includes such factors as:

- Waiting for tools and material
- Waiting for transport
- Transportation to the job site
- Waiting for equipment to be shut down
- Tea breaks
- Idle or no work available

viii. Work Classification

An analysis of the man-hours expended by work classification is a good guide toward decision making in maintenance. Preventive maintenance should represent approximately 15 to 25 percent of the work effort. The percentage of man-hours expended on re-arrangements, modifications and capital work can help the maintenance manager in manpower forecasts based on anticipated expansion and modification. A rise in safety or accident work can indicate an opportunity for changes in plant practices to reduce costs.

6.9 SAFETY MANAGEMENT & PROCEDURES

Safety in industry is well known and generally accepted by all interest groups. Accidents in industry have adversely affected not only these interest groups, but also those in the surroundings. Safety and Hygiene system establishes a work environment without accidents or near miss cases. Thus, achieving zero accidents and creating environment consciousness are the basic aims of safety & hygiene activities.

Safety in any organization has to be planned ahead and safe practices to be put into action. Safety is a discipline and requires some basic principles to be followed for its management in industry.

Principles of Safety:

The three principles of safety are:

- Philosophy and policy
- Planning
- Action

These principles are related to three groups of people in an industry, viz. owners, managers and workers. Each has different roles and responsibilities to achieve high standards of safety.

Philosophy:

Safety philosophy in an organization should have a TOP-DOWN approach. It should be a primary concern of the owner / directors as they have concern for profit, product quality and the like. Safe operation results in protecting employees, assets, surroundings and the environment. The company should be committed to spend time, money, effort for providing facility like equipment, technology, materials, etc.

Policy:

- To conduct operations safely, protecting the health of employees and all others who may be affected by its operations with due regard to the environmental protection and compliance of statutory requirements

- To implement participative management by consultation and consensus through management committees to achieve the goal of ensuring safety and preservation of environment.

Objective:

- Zero Accident
- Zero Occupational disease
- Zero Pollution

Planning:

Planning for safety starts much before operations of a company starts and continues as long as the business continues. The elements of planning of safety includes:

- Organization
- Coverage of Aspects
- Approach
- Information Systems

These elements have to be fully understood, planned and revised / upgraded to maintain safety according to the policy statement. The policy statement by the owner / directors will depend on the technology, people and money put in use by the company.

Organization and information system for safety are people-related while coverage and approach are mainly related to technology and money used by the company.

Organization:

The organization plays an important role in ensuring facility and operations for an accident – free workplace. Safety committees are formed to identify unsafe areas, practices and take appropriate prompt action.

- Management Committee: Management Committee consists of Facility-in-Charge and managers/supervisors from each department. Its function is mainly to review, implement and ensure safety according to company policy statement. It should focus on facility improvements and upgrading procedures and practices based on own experience and experience of others. The committee is chaired by Facility-in-Charge.
- Central Committee: Central Committee is represented by one manager / supervisor, workers from each department, and engineers from each discipline and chaired by Manager (Safety). Its function is not only to review safety performance and focus on procedures, practices and unsafe acts, but also to suggest improvements in facility as and when known to its members.
- Department Safety Councils: Department Safety Councils are formed by supervisors and workers of a division/department and coordinated by one of the department safety observers. Its intent is to review safety performance of the department, unsafe situations and acts and also communicate actual experience and recommendations to the central committee through its members, who are nominated to the central committee. These councils should be seen as providers of real-life situations on which management of the company has to react and communicate its serious concern on safety to all.
- Safety Observers: Safety Observers are employees on the shop-floor who are selected and trained specially by the company to critically look for potential hazards, actual unsafe situations and acts which have escaped accidents to people and / or facility. It also provides factual, independent and detailed report about a mishap in shift/department. The recommendations will have great value to take preventive actions.

6.9.1 Safety Aspects

Following aspects should be considered for planning of safety:

Personnel Safety:

Safety by their own and others acts as also by situations/facility, over which they have little/marginal control. However, their knowledge and know-how of the facility can contribute a great deal in changing situations from unsafe to safe ones.

Facility / Situational Safety:

This has relation to the design, layout, materials used and other technological factors. Accidents due to these are beyond the control of people who operate and maintain them. Situational safety depends greatly on effort and money put into building the facility and therefore is controllable by the owner/directors of the company. However, people can be responsible for unsafe situations by not maintaining and modifying the facility.

Safety of the surroundings:

Safety of the surroundings around large and hazardous plants is important as is borne out by several incidents. Hence surroundings have to be concerned in locating, designing and operating industries, besides covering the company for adequate insurance.

Environmental Effects:

Environmental Effects due to operations in industry may not be short-term, even if adequate pollution control measures and facility are provided in the plant. Disposal of wastes, which may not be in the immediate vicinity of the plant and not handled by responsible/knowledgeable agency, can create delayed and distant and unknown environmental damage, which is unsafe for people.

Information Systems on safety:

The information system on safety includes:

- Reporting of accidents, mishaps and even near-miss incidents. The latter are important to learn and possibly to prevent accidents
- Investigation reports, which give information about accidents in detail, analyze them, recommend actions for prevention and inform about actions taken. These are discussed in various forums of safety organization with a view to apprise employees.
- Record-keeping and analysis of trends
- Inter-industry and region comparisons (Benchmarking)
- Collection of published information and making it known to employees along with actions taken by the company.
- Display of company's safety performance to employees on regular basis.

Safety in action:

Having formulated the safety policy and safety plan of the company, the next principle is to act on all that has been laid down in the policy and plan. These can be achieved by nurturing these steps:

- Training in and promotion of safety through films, videos on case histories, new methods/procedures, new equipment
- Handouts, posters, bulletins, newsletters giving real-life situations, cases in the company and elsewhere
- Safety slogans, competition and awards for achievements and publicizing them within the company and outside, for others in the company to emulate
- Instituting suggestion schemes particularly for safety and awarding handsomely to good suggestions to convey that company means safety
- Organizing safety day/ week to include lectures, films, exhibition
- Publicizing safety achievements and nominations tot he state and central government awards

- Short talk on safety for specific operations by first-line supervisors in small groups every day before the work begins.[10]

6.9.2 SAFETY AUDIT

The first and foremost important step in an Accident Prevention and Emergency Preparedness Programme is the identification of hazards. In case of simple installations this does not pose any difficulty. However, as the technology, especially that of chemical industry is getting more and more complex and the operations more complexes the work of hazard identification is becoming increasingly difficult. Moreover, the actual physical hazards are also no longer immediately detectable by visual inspection.

In order to detect such latent hazards, various hazard identification techniques have been evolved and are increasingly being used. These include Management and Safety System Audit, Hazard Indices, Hazard and Operability Studies (HAZOP), Failure modes, etc. Safety Audit covers all aspects of safety of the undertaking such as organization and administration, general hazard control, process hazard control, training and motivation, accident investigation and cause analysis.

Scope of Audit:

The technique of safety audit provides a high level of surveillance of unsafe " places of work" and "action". It is a systematic critical examination of an industrial operation in its entirety to identify potential hazards and levels of risk. The audit includes every component of the total system e.g. management policy, attitude training, features of process and designs, layout and construction of the plant, operating procedures, emergency plans, personal protection standards, accident records etc.

Objectives:

The objectives of safety audit should cover examination and qualitative assessment of all facets of safety of every activity. It should be to carry out systematic critical appraisal of all variety of hazards involving personnel, plant, services and operating methods. It should also ensure that the health and safety standards fully comply with statutory standards and company's own safety policies, objectives and programmes.

The audit system should emanate from the top management. It should also be understandable and acceptable to the line management down to the humblest of workers who should be prepared to adjust his own safety and loss prevention practices in accordance with the deficiencies of the existing systems revealed by the audit.

The objective of safety audit is no doubt the identification of possible loss producing situations and their assessment. However, the motivation behind the exercise is also to select the most optimum measures, which can reduce these losses. A safety audit exercise should therefore need follow-up in seeing that these measures are actually implemented. It is also necessary to set up a system for monitoring of changes in the organization, process, training etc. [11]

Checklist:

Before carrying out an audit inspection, a checklist or questionnaire should be prepared. If the questionnaire is prepared with care it will reveal the various weak points which need greater attention to ensure loss prevention. This questionnaire forms a vital tool of successful inspection and in this sense it is as valuable as the audit itself. The checklist consists of a list of all activities, which needs to be checked in a workplace. Table 6.1 shows the audit checklist for CS_2 Condenser.

Implementation and Monitoring:

In order that the safety audit serves its desired function, institution of a monitoring system is essential. Accident investigations reveal that hazardous situations often existed undetected over a period of time before the accidents actually took place. By subjecting all the activities of the organization to a detailed safety scrutiny, safety audit aims to expose such defects before they result in an accident. It provides a method through which

TABLE : 6.1

AUDIT CHECKLIST FOR CS2 CONDENSER

S.No	CHECK POINTS	OK	DEFECTS	TARGET DATE	PERSON RESPONSIBLE
1	Physical condition of CS2 Trough				
2	Water level in CS2 recovery Trough				
3	Water Sealing at manhole of CS2 recovery Trough				
4	LP curtain for vapour before outer baffle in R/T				
5	Steam pressure / flow in CS2 recovery trough				
6	Condition of flexible steam pipe				
7	Mat Formation				
8	Condition of Off-take pipe				
9	Condition of Reflux pipe				
10	Condition of scrubber plate				
11	Flow of water in scrubber				
12	Scrubber outlet temperature				
13	Soft water inlet pressure				
14	1st condenser outlet temperature				
15	Bend Temperature				
16	Brine/Chilled water inlet pressure				
17	Brine/Chilled water inlet temperature				
18	Brine/Chilled water outlet temperature				
19	Vent Temperature				
20	Separator water overflow				
21	Condition of CS2 line				
22	Condition of ladder				
23	Availability of water and hose reel				
24	Availability of fire extinguisher				
25	Lagging of brine/chilled water line				
26	Condition of water valves				
27	Flame proof lighting provided				

the management is made aware of the status of safety of their undertaking. The exercise should be repeated at periodical intervals to derive the fullest benefits.

Assessment of safety standards:

The application of this technique incorporates a process of numerical evaluation of the findings so that the level of safety status of the company may be gauged. It is highly desirable that an external specialist should assist the auditing team so that the deficiencies, which do not immediately strike to people who might have got used to them, do not remain undetected. By giving a rating to the safety activities the audit helps better realization of the safety status of the activity studied than by describing it as good, bad or worst. Table 6.2 shows a typical format of safety audit sheet.

6.9.3 Analyzing Hazards

There are numerous types of checks and analysis that can be performed on a chemical process plant. Some are done to pinpoint the hazards while some are done to evaluate the frequency of occurrence and consequences thereof. The recent and most scientific method of analyzing the hazards are HAZOP and HAZAN described below:

- **Hazard and Operability Studies (HAZOP) Analysis:**

HAZOP is a proven technique to identify major accident and hazard potential and provide appropriate controls. Other techniques such as discipline-wise review (mechanical, electrical, controls etc.) or using checklists depend on previous experience only. They cannot effectively deal with modern complex plant with multiple interfaces.

HAZOP Study

HAZOP is a formal, structured approach to finding hazards and operability problems in a plant after its design has been frozen. A team consisting of representatives of different disciplines and varied experience carries out HAZOP. A HAZOP team of eight to ten

TABLE : 6.2

SAFETY AUDIT SHEET

S.No	Evaluation Criteria	Max. Score	Score Obtained
1	Guards,railings and insulation are in good condition	5	
2	Leakage of steam/compresses air/oil, process material wastes etc. nil	5	
3	Safety and fire fighting equipment are well maintained	5	
4	First aid box is well maintained	5	
5	All vessels/columns and motors are well grounded and electrical cable well dressed	5	
6	Fans, blowers, desert coolers and fixtures are in good condition	5	
7	Area is well ventilated and illuminated	5	
8	Floor, washroom, toilets and drainages well kept	5	
9	Easy approach to equipment, valves etc. in the area	5	
10	Walk-ways/aisles are free from obstruction	5	
11	Foundation of vessels and equipment are intact	5	
12	Noise level is within 90 db	5	
13	All employees use safety gadgets	5	
14	Vehicles are parked only in marked places	5	
15	Area has been free from accidents since last	20	
	1 year (20 marks)		
	6 months (15 marks)		
	3 months (10 marks)		
	1 month (5 marks)		
16	100 % employees are retrained in fire fighting and safety measures in the current year	10	
	Total Score	100	

different experts is an effective size. This team conducts 'brainstorming' sessions and seeks solutions, which simplify the facilities, make the design intrinsically safer and more operable in preference to adding equipment. This would result in design improvements and cost reduction.

HAZOP study is carried out with the help of Guide Words as shown in Table 6.3 a. The results of HAZOP Study undertaken at CS_2 Refinery are shown in Table 6.3 b.

➢ HAZAN: HAZARD ANALYSIS

Hazard Analysis refers to the determination of the consequences of a hazard. If the consequences are severe and if the frequency of such a hazard is high, the risk associated with the process is said to be high.

Risk = Severity of hazard x Frequency of its occurrence

If the risk is high, then steps need to be taken to minimize the frequency, reduce the severity and to contain the damage resulting from the hazard.

The Failure Mode and Cause Effect Analysis is one of the widely used techniques for Hazard Analysis:

- **Failure Mode and Cause Effect Analysis (FMCEA)**

Failure Mode and Cause Effect Analysis helps to identify the problem and its causes. The mode, effect and causes are determined for each type of failure. These are then ranked on a 10-point scale. The product of these factors determines the risk factor. Higher the risk factor, the severe is the problem. Based on the severity, the problems are prioritized and corrective actions are taken. Table 6.4 shows the FMCEA of MSFE of Auxiliaries Department (Mill-2).

TABLE 6.3 a

GUIDE WORDS FOR HAZOP STUDIES

S.No	GUIDE WORDS	MEANING	REMARKS
1	No/Not/None	Complete negation of Design intentions The activity is not carried out or it ceases	Nothing happens
2	More of	Quantitative Increase	Parameters Increasing trend
3	Less of	Quantitative Decrease	Parameters Decreasing trend
4	As well as	Alongwith the intended activity, something more happens	other materials present, ingress of air etc.
5	Part of	Only part of intention is achieved. Incomplete activity	Only partial addition/removal of product/heat. Incomplete reaction
6	Reverse	Opposite of Design intentions	Reverse flow of material, current valve wrongly installed etc.
7	Other than	Complete substitution	No part of the design intention is achieved. Something totally different happens. Different material is charged

TABLE: 6.3 b

HAZOP STUDY OF CS2 REFINERY

S.No	GUIDE WORDS	DEVIATION	POSSIBLE CAUSES	CONSEQUENCES	HAZARD	RECOMMENDATION
1	NONE	No flow of	No water pressure for	Temperature will		Always check the valve after
		Crude CS2	pressing CS2	increase		pressing the tank
			Valves not open			Check water pressure regularly
			No level of CS2 in tank			Check the level in the still
			Line getting choked			Low water pressure alarm with
			Leakage in line leading			indicator lamp may be provided
			to still			
		No steam	Sudden steam supply			
			cut off			
2	MORE	More flow of	Abnormal increase in	CS2 level may rise and	Safety flap	Check CS2 level in the still
		CS2	water pressure	pass thru' condenser,	burst, Fire	If level high, stop further feeding
			Reflux may be more	gas line, oil scrubber	Explosion	and flush out by running steam
3	LESS	Less flow of	Less water pressure	CS2 will vaporise and		Check CS2 flow rate
		CS2	Leakage in the line	still become empty		If still is empty or traces of
			Partial Choking	Suphur settles down		CS2 present, run steam
				Still Temp. increases		High temperature alarm may
						be provided
4	AS WELL AS	Water with	Condenser tube	Still temp. will increase		High temperature alarm
		CS2	leakage	more pressure, more		Check still temperature regularly
			Leakage in outlet line	gases to flow to gas		Pressure of condenser should
			of storage tank	condenser / gas holder		be tested regularly for leakage
			Steam coil leakage	Gas prodn. increase		
5	PART OF		Not Applicable			
6	REVERSE	Refined CS2	Misoperation	CS2 overflow from		Proper identification of valve in
		may pressed		condensers and still		storage tank section
		to refinery				Provision of NRV in refined CS2 line
7	OTHER THAN		Not Applicable			

TABLE 6.4

FAILURE MODE AND CAUSE EFFECT ANALYSIS (FMCEA)

DEPARTMENT : AUXILIARY 2
EQUIPMENT : MSFE

COMPONENT	FAILURE			RATINGS ON 10 POINT SCALE			RISK FACTOR	CORRECTIVE ACTION
	MODE	EFFECT	CAUSE	M	E	C		
HEATER TOP	RUBBER LINING	MSFE STOPPAGE	HIGH TEMPERATURE	8	7	6	280	TEMPERATURE REGULATION
DISH END	FAILURE	SPINBATH LEAKAGE	IMPROPER RUBBER					BETTER RUBBER LINING
			LINING AT JUNCTION					QUALITY
HEATER BOTTOM	RUBBER LINING	MSFE STOPPAGE	HIGH TEMPERATURE	6	7	4	168	TEMPERATURE REGULATION
DISH END	FAILURE	SPINBATH LEAKAGE	IMPROPER RUBBER					BETTER RUBBER LINING
			LINING AT JUNCTION					QUALITY
HEATER SHELL	LEAKAGE DUE TO	MSFE STOPPAGE	DUE TO ACID LEAKAGE	5	7	4	140	TUBES & RINGS LEAKAGE TO
	CORROSION	SPINBATH LEAKAGE	FROM TUBES AND					BE REDUCED
			RINGS					

This chapter thus focussed on various maintenance systems and the selection of best system can result in performing the maintenance activities effectively and efficiently. The maintenance activities should always be carried out with proper planning using CPM/PERT techniques. The maintenance control parameters help in monitoring the maintenance activities and help in improving productivity and reducing cost to a great extent. The maintenance procedures lay down for equipment breakdown and plant shut down should be followed strictly and serve as a useful guideline for maintenance engineers and supervisors. The safety procedures and hazard identification techniques, such as HAZOP and HAZAN help in safe running of the plant with full protection to plant personnel. The safety audit should be conducted at regular intervals to avoid accidents.

The next chapter deals with phases of asset care management and describes the means and ways to restore the equipment to its original condition by the use of scientific methods.

CHAPTER 7

ASSET CARE MANAGEMENT

7.1 Introduction

World Class Maintenance aims at maximizing the overall equipment effectiveness through the people that operate and maintain that equipment. It is of utmost importance that asset care management programme be planned to ensure that the machine condition is maintained.

7.2 Phases of Asset Care Management

There are three phases of asset care management:

❖ **Condition Cycle**

The condition cycle establishes the present condition of the equipment and identifies the areas of improvement and future care

❖ **Measurement Cycle**

The measurement cycle assesses the present effectiveness of the equipment and provides a baseline for the measurement of future improvements

❖ **Improvement Cycle**

The improvement cycle moves equipment effectiveness forward along the road to world – class.

7.3 Condition Cycle

The condition of any equipment depends on lot of factors and its impact on man, process and environment. The steps involved in the condition cycle are:

7.3.1 Criticality Assessment

The main aim of the criticality assessment is to assess the equipment production process and determine the relative criticality of each element. This will enable priority to be allocated for the refurbishment, future asset care and improvement of those elements most likely to have an effect on overall equipment effectiveness. Operators and maintainers should be involved in identifying the most critical parts of the process from their own perspective. [12]

Each element is assessed in terms of criteria listed below and a score of 1-3 is assigned to each of the criterion:

- Maintainability:

  How easy or difficult is to gain access to and work on the equipment?

  Is a specific or unusual blend of skills required to do necessary diagnostics or corrections?

- Reliability:

  How do those directly involved rate the reliability of the equipment?

  Does it suffer from chronic/continual problems?

  What is the frequency of problem / failure?

  Is it a question of breakdowns or mal-operations?

- Product Quality:

  What impact does mal-function has on the quality of finished products?

  Is the product quality impact quickly and easily identifiable, or apparent only after further deterioration?

- Throughput Velocity:

  What impact does the equipment condition and performance have on the throughput velocity of the product

- Loss of Production:

  What is the effect on the performance of the total system, production line or department, if the equipment is not running correctly, is broken down, is unreliable, or is difficult to maintain?

- Safety:

  What is the likely impact on safety considerations if the equipment is not quite right or is proving to be unreliable?

- Environment:

  What impact does the condition of equipment have on the environment, both locally and on a wider front?

- Cost:

  What are the financial consequences of failure or unreliability, or poor performance?

The significance of each criterion is assessed and allocated a score based on the impact of the process elements selected. The total score of each element is found out and arranged in the descending order. Thus the element with maximum score is the most critical element. The criticality assessment matrix of a spinning machine is shown in Table 7.1. The most critical components are cutter, bush, and trio gearbox, which require maximum attention. Table 7.2 also shows another way of determining criticality of equipment in terms of ranking.

TABLE : 7.1

CRITICALITY ASSESSMENT MATRIX: SPINNING MACHINE

S.No	DESCRIPTION	EOR	R	PQ	MI	TPV	LOP	S	ENV	C	TOTAL	REMARKS
1	GODET GEAR BOX	1	1	1	1	1	1	1	1	1	9	
2	GODET & GUIDE	1	1	1	1	1	1	1	1	1	9	
3	JET ACCESSORIES	3	1	3	1	1	1	1	3	3	17	
4	CANDLE	3	1	3	1	1	1	1	3	3	17	
5	PUMPSHAFT	3	1	1	1	1	1	1	1	1	11	
6	TRIO GEAR BOX	3	1	3	1	1	3	3	1	3	19	Most Critical
7	TRIO ROLLERS	3	1	1	1	1	3	3	1	3	17	
8	FEED ROLLERS	3	1	1	1	1	3	3	1	3	17	
9	IDLE ROLLERS	3	1	1	1	1	3	3	1	3	17	
10	REDUCTION G.B	3	1	1	1	3	1	1	1	3	15	
11	CUTTER & BUSH	1	3	3	3	3	1	3	3	3	23	Most Critical
12	CUTTER DRIVE GB	3	1	1	1	1	3	1	1	1	13	
13	FUNNEL	1	1	1	1	1	1	1	1	1	9	

	RANK	1	3
EOR	Ease of	easy	difficult
	Repair		
R	Reliability	high	low
PQ	Product	low	high
	Quality		
MI	Maintenance	long	short
	Interval		
TPV	Throughput	low	high
	Velocity		
LOP	Loss of	low	high
	Production		
S	Safety	low	high
ENV	Environment	low	high
C	Cost	low	high

TABLE 7.2

CRITERIA FOR EQUIPMENT CRITICALITY RANKING

S.No	ATTRIBUTES	EVALUATION CRITERIA	Score
1	SAFETY	Equipment failure causes explosion or other hazards	25
	Effect of failure on	Equipment failure causes serious pollution	20
	People and	Equipment failure might adversely affect the environment	15
	Environment	Other Equipment	10
2	QUALITY	Equipment failure has a major effect on quality	25
	Effect of failure on	Equipment failure produces quality variations that can be put	15
	Product Quality	right by the operator comparatively quickly	
		Other Equipment	10
3	OPERATION	Equipment with major effect on production, without standby	30
	Effect of failure on	provision, whose failure causes previous and subsequent process	
	Production	to shut down completely	
		Equipment failure causes only partial shutdown	15
		Equipment failure has little or no effect on production	10
4	MAINTENANCE	Equipment takes 4+ hours or Rs. 100000 + to repair or fails three	20
	Time and Cost	or more times per month	
	of Repair	Equipment can be repaired in under 4 hours at cost of between	10
		Rs. 7500 to Rs. 100000 or fails less than three times per month	
		Equipment costs less than Rs. 7500 to repair or can be left	5
		unrepaired until a convenient opportunity arises	

Rank	Total Score	Nature
A	65 and above	Most Critical
B	50 - 64	Critical
C	less than 50	Less Critical

7.3.2 Condition Appraisal

The objective of the condition appraisal is to make use of the same criticality assessment elements and components in order to assess the condition of equipment and to identify the refurbishment programme necessary to restore the equipment to maximum effectiveness.

Condition Appraisal

Equipment	Component	Not Appli-cable	Satis-factory	Broken Down	Needs Attention now	Needs attention later

The assessor has to put cross on the matrix as per the condition observed.

7.3.3 Refurbishment

The objective of the refurbishment programme is to set up a repair and refurbishment plan, based on the condition appraisal, and indicating the resources required. Getting the equipment back to an acceptable level is a pre-requisite to the pursuit of ideal conditions. The refurbishment matrix is shown below:

Refurbishment Chart

Description	Action Required	Estimated Refurbishment Cost	Man-hours Work
		Reqd. Reqd. Total	Reqd. Reqd. Total
		now later	now later

7.3.4 Asset Care

Asset care programme should be planned to ensure that the machine condition is maintained. Autonomous Maintenance is one of the important tools in successfully implementing this programme. This is accomplished by:

- Cleaning and inspection routines
- Checking and condition monitoring methods and routines
- Planned, preventive maintenance and service schedules

Efforts should be made to make these operations easy by using visual management techniques and training.

7.4 Measurement Cycle

The measurement cycle deals with quantifying the effectiveness of the equipment. The most effective way is to find out the overall equipment effectiveness of the equipment. For calculating overall equipment effectiveness, the data required are taken from equipment history record, quality report and production reports.

7.4.1 Equipment History Record:

The calculation of overall equipment effectiveness (O.E.E.) requires the following data from equipment history records:

- Data on equipment availability, performance and quality to enable overall equipment effectiveness to be calculated.
- Records of problems and breakdowns as a basis for problem-solving
- Process variations and data analysis from condition monitoring

All these information have the direct bearing on the asset care management and improvement programme.

7.4.2 Overall Equipment Effectiveness:

The overall equipment effectiveness is calculated as the product of availability, performance rate and the quality rate. The O.E.E. value helps to identify the parameters responsible for lower equipment effectiveness and sets the target for further improvement.

Actual Effectiveness:

It takes into consideration its availability, its performance rate when running and the quality of the product produced.

Potential Improvement:

The first improvement objective is to obtain constantly, through standardization and stabilization, the best of the best in each of the three categories: availability, performance and quality. Beyond this there must be continuous improvement towards world class levels. [12]

O.E.E = Availability x Performance rate x Quality rate

7.5 Improvement Cycle:

The Improvement cycle deals with continuous improvement of equipment effectiveness. This can be achieved through assessment of losses, using problem-solving approach and various other scientific approaches. Some of them are discussed below:

7.5.1 Assessment of six big losses:

The six big losses are:

- ❖ Breakdowns
- ❖ Setup and adjustment
- ❖ Idling and minor stoppages
- ❖ Speed
- ❖ Quality defect and rework
- ❖ Startup

Chronic losses:

- ❖ The problem by single cause, but the cause varies from one occurrence to next.
- ❖ The problem is produced by a combination of causes, which varies from one occurrence to another. Causes may be multiple and overlapping and each time a different factor may be involved.

7.5.2 Problem Solving Approach

The problem solving approach is a scientific method of solving complex problems and undergoes following steps:

1. Identify
   - ❖ Define the problem
2. Analyze
   - ❖ Do a physical analysis of the problem
   - ❖ Isolate every condition that might cause the problem
   - ❖ Evaluate equipment, material, method and environment
   - ❖ Plan the investigation
   - ❖ Investigate mal-functions
   - ❖ Generate possible solutions

3. Plan
    - ❖ List the tasks to be achieved over a reasonable period
    - ❖ Identify the best sequence including training plans
    - ❖ Identify responsibilities and resources
    - ❖ Produce an outline timetable together with resources and objective for time, cost and quality of implementation
    - ❖ Formulate improvement plans
4. Implement
5. Evaluate
    - ❖ Check and take action as required

7.5.3 P-M Analysis

The letters 'P' stands for 'Phenomenon' and 'M' stands for 'Mechanism'

P-M analysis physically analyzes chronic losses according to the inherent principles and natural laws that govern them. This analysis clarifies the mechanics of their occurrence and the conditions that must be controlled to prevent them. It emphasizes on the machine-human interface. There are phenomena, which are physical, which causes problems, which can be prevented, those are to do with materials, machines, mechanisms and manpower. [13]

P-M analysis follows the following sequence:

1. Physically analyze chronic problems such as defects and failures according to the machine's operating principle
2. Define the essential or constituent conditions underlying the abnormal phenomena
3. Identify all factors that logically contribute to the phenomena in terms of 4M's – equipment mechanisms, materials, methods, man

TABLE : 7.3

P-M ANALYSIS FOR SALT SPILLAGE

DEPARTMENT : AUXILIARY -2
EQUIPMENT: DRUM DRYERS & SEMI AUTO BAGGING SYSTEM
THEME : SALT SPILLAGE

PHENOMENON	LOGICAL	CONTRIBUTING	STANDARD	INVESTIGATIONS	ASSESS	COUNTER
	REASONING	FACTORS	CONDITION		RESULT	MEASURES
SALT SPILLAGE	Salt Accumulation	Due to improper	Proper sealing	Sealing was not	Salt	Better sealing
IN BAGGING	at exit end	sealing		proper	spillage	should be done
SECTION						
	Spillage from	No conveying system	Conveying system	Conveyor to be	Spillage	Conveyor to be
	DD-1 during			installed	reduction	installed after
	direct bagging					DD-1 lifting and
						modifications
	Spillage from	Open conveyors	Covered conveyors	Conveyors are open	Spillage	belt conveyors
	belt conveyor	Excess Air Flow	Least air flow	Air from side window	reduction	should be covered
						Perplex sheets to
						be provided for
						windows
	Spillage from	Salt feed to vibro-	Covered vibro-screen			Feed to vibro-
	vibro-screen	screen is open				screen to be closed
	Spillage while	No proper exhaust	Proper exhaust	Present system not		Exhaust to be
	bagging	system	system	working & connected		changed from 4 inch
				to DD-2 cyclone only		to 6 inch and to be
						connected to DD-1
	Miscellaneous	Pedestal fan				Better exhaust system
	Factors	Hammering of exit	No grit hammering			Cleaning to be done
		end hopper	hopper cracks			through hopper gate

TABLE : 7.4

P-M ANALYSIS FOR CELLULOSE VARIATION

DEPARTMENT: VISCOSE - 2
EQUIPMENT : SUND PRESS
THEME : CELLULOSE VARIATION

PHENOMENON	LOGICAL	CONTRIBUTING	STANDARD	INVESTIGATIONS	ASSESS	COUNTER
	REASONING	FACTORS	CONDITION		RESULT	MEASURES
CELLULOSE	Improper	Slurry	3.9-4.1 %	Variation in slurry	Normally being	Provision of balance
VARIATION OF	pressing or	inconsistency	No variation	consistency	observed	for pulp weighing
ALK-CELL OF	squeezing of					OIH of lye metering
SUND PRESS Z	alk-cell mat					pump
						Lifting of pump suction
		Slurry temperature	58 C	High or low	Not observed	Display of slurry
			No variation		but may happen	temperatures in front
						of operator
		Hemi-cellulose	30 GPL but	More than 40 GPL	Observed always	Increase dilution on
			not more		above 35 GPL	Sund Press side by
			than 40 GPL			sacrificing that of
						conventional press
		Lye Draining	Proper	Not sufficient	Insufficient	Regular checking of
						lye spray intervals
		Length-wise and	No slurry	Slurry coming out	Leakage from	Backside seal to be
		side seals	leakage	from side and back	backside seal	changed and no
						wetting of mat from sides
		Nip roll surface	Smooth	Dent on surface	Holes on surface	Strainer magnet of feed
						pumps to be checked
		Nip roll bearing	Proper	Unusual sound	Not observed	All suctions through
				from bearing		pulper's sieve

TABLE 7.5
P-M ANALYSIS FOR FIBRE DROPPINGS

EQUIPMENT : DRYER # 8 / DRUM # 1
THEME : FIBRE DROPPINGS

PHENOMENON	LOGICAL REASONING	CONTRIBUTING FACTORS	RELATIONSHIP WITH 4 M	STANDARD CONDITION	INVESTIGATIONS	ASSESS RESULT	PROPOSED COUNTER MEASURES
HEAVY FIBRE DROPPING FROM DRUM # 1	POOR FIBRE SUCTION ON SURFACE OF DRUM#1	IMPROPER FIBRE DISTRIBUTION ON FEED CONVEYOR	METHOD	UNIFORM DISTRIBUTION	SEALING WAS NOT PROPER	READILY SEEN	PROPER DISTRIBUTION ON WOODEN CONVEYOR BY PROVISION OF DEFLECTOR AT WET END
		POOR SUCTION PRESSURE	MACHINE	HIGHER	SUCTION PRESSURE INSUFFICIENT	NOT OBSERVED	FAN RPM O.K.
		ALUMINIUM NECK RING	MATERIAL	PROPER AS PER REQUIRE MENT	DAMAGED NECK RING	FOUND DAMAGED	NEW ALUMINIUM NECK RING TO BE FITTED
		WET FIBRE MOISTURE	MATERIAL	98+5%	HIGH SPEED OF FINAL ROLLER	NORMALLY BEING OBSERVED	FINAL ROLLER SPEED REDUCTION (MAX. 93% OF 1st ROLLER) PRESSURE TO BE INCREASED
		FIBRE OPENING	METHOD	FULLY OPEN	LESS STEAM PRESSURE ON RECOVERY TROUGH	NORMALLY LOW	R/T L.P. TO BE INCREASED STEAM INJECTING PIPES TO BE CHECKED FOR ANY RUPTURE
		AIR TURBULENCE BELOW DRUM # 1	METHOD	MINIMUM	VERY HIGH	ALWAYS ON HIGHER SIDE	MAVOOR DEFLECTOR TO BE REPLACED BY CONVENTIONAL DEFLECTOR
		FIBRE ACCUMULATING BELOW DRUM # 1	MAN	NIL	VERY HIGH	AT ALL TIMES	FREQUENT CLEANING DRUM SPEED ADJUSTMENT AS PER FIBRE SPEED, DISPLAY OF M/C SPEED ON DRYER
		LESS AIR AVAILABLE	METHOD	NO STARVATION	ON LOWER SIDE	NORMALLY LOW	CLEANING OF SIEVE BELOW DRUM SEALING OF SIEVE ON ALL SIDES
		FIBRE MOVEMENT ON DRUM SURFACE	METHOD	NIL	FREQUENT FROM DOOR TO FAN SIDE	AT ALL TIMES	DOOR TO BE KEPT CLOSED ALWAYS AND PROVISION OF VIEW WINDOW FOR OPERATOR'S OBSERVATION
		GAP BETWEEN FIRST DRUM AND FEED CONVEYOR	MACHINE	MINIMUM	HIGH	OBSERVED ON HIGHER SIDE	TO BE REDUCED TO FIBRE'S BED WIDTH

❖ **Steps Involved in P-M Analysis**

1. Clarify the phenomenon : Carefully define and categorize the abnormal occurrence
2. Conduct a physical analysis: Define how the parts or process conditions change in relation to each other
3. Define phenomenon's constituent conditions
4. Study production input correlation (4 M's)
5. Set optimal conditions (standard values)
6. Survey causal factors for abnormalities
7. Determine abnormalities (including slightest defects)
8. Propose and make improvements
9. Decide upon the frequency of inspection of all factors
10. Standardize and keep the record of 4M analysis sheet
11. Measure and monitor the result

Table 7.3 shows the PM Analysis for Salt Spillage in Drum Dryers & Semi–Auto-bagging System of Auxiliaries-2. Table 7.4 shows the PM Analysis for Cellulose Variation in Sund Press of Viscose–2. Table 7.5 shows the PM Analysis for fibre droppings in Drum Dryer of After-Treatment Department.

7.5.4 Why – Why Analysis

Why-Why analysis is a very effective tool for problem solving. This helps in identifying the problem and finding the root cause of the problem. At each stage the question Why? is asked and possible reasons are listed. Table 7.6 shows the Why-Why Analysis of GDR Turbine of EC-1.

TABLE : 7.6

WHY WHY ANALYSIS OF GDR TURBINE

DEPARTMENT : ENERGY CENTRE # 1
EQUIPMENT : GDR TURBINE
PROBLEM DEFINITION : TURBINE TRIPPED AT THE TIME OF SPEED RAISING AFTER MAJOR OVERHAULING

S.No	WHY	ANSWER	ACTION
1	TURBINE TRIPPED AT	SPEED MIGHT HAVE GONE UP	SPEEDOMETER SHOWN
	THE TIME OF SPEED	TO TRIP SET VALUE OF OVER	3300 RPM & HITTING
	RAISING	SPEED DEVICE (MECHANICALLY)	SOUND HEARD
2	SPEED GONE UP TO	SPEED GOVERNOR MOTORIZED	CHECKED & FOUND O.K.
	TRIP SET VALUE	PUSH(ON) BUTTON MIGHT HAVE	
		MALFUNCTIONING	
3	SPEED GONE UP TO	SPEED PULSE PRESSURE DID	SPEED PULSE PRESSURE
	TRIP SET VALUE	NOT ACT IN REVERSE AMPLIFIER	PIPE LINE & GAUGE CHECKED
			AND FUND O.K.
4	SPEED PULSE PRESSURE	MOP MAY NOT BUILD UP DESIRED	MOP SUCTION & DELIVERY OIL
	DO NOT ACT	PRESSURE	PIPELINES FOUND DRY WHEN
			MOP BLOCK ASSEMBLY
			REMOVED FROM POSITION
5	MOP NOT BUILD UP	OIL FROM AOP DID NOT GO TO	DIAMETER 3.0mm ORIFICE OF
	DESIRED PRESSURE	MOP SUCTION AND DISCHARGE	NRV FOUND CHOKED BY
		PIPELINE	COTTON WASTE

7.5.5 Best Practices Routines:

This step brings all of the developed practices for operating, maintaining and supporting the equipment, which are then standardized as the best practice routines.

Standard operation ensures:

- Reduced chance of error and risk
- Improvement of performance and removal of irregularity
- Elimination of poor operation as a cause of problem's simplified training within and between shifts

This chapter thus focussed on the asset care management, which includes determining the criticality of equipment by ranking method, refurbishment and repair activity to bring the equipment to original condition and then maintaining the equipment by adopting autonomous maintenance. Various scientific approaches and methods like P-M Analysis, Why-Why Analysis, have been illustrated with live examples from the plant, which help in identifying and rectifying the problems occurring in the equipment. The overall equipment effectiveness (O.E.E) is the best measure of equipment effectiveness which takes into account availability, performance rate and quality rate.

The next chapter deals with determining Overall Equipment Effectiveness (O.E.E) of key equipment of various departments of Staple Fibre Division. A detailed study has been undertaken for spinning machines with respect to availability, performance, quality and the maintenance parameters have been benchmarked.

CHAPTER 8

OVERALL EQUIPMENT EFFECTIVENESS & BENCHMARKING

8.1 Introduction :

This chapter deals with the calculation of Overall Equipment Effectiveness of key equipment of Staple Fibre Division. This includes Slurry Presses of Viscose Department, Spinning Machines of Spinning & After-Treatment Department, Multi-Stage Flash Evaporators of Auxiliaries Department, Acid Plant, Boiler & Turbines of Energy Centres.

The detailed O.E.E. calculations have been carried out for Spinning Machines 8 and 9 of Mill-2 of Staple Fibre Division. The availability, performance rate and quality rate of each machine month-wise is found out from downtime records maintained by maintenance department, production records maintained by process department and quality records as supplied by textile department respectively.

It is also necessary to calculate various parameters like Mean Time between Maintenance (MTBM), Mean Time to Repair (MTTR) and Mean Downtime (MDT), which helps in evaluating the performance of the maintenance department. Severity Index and Frequency Index determines the criticality of the equipment. Benchmarking of these parameters helps in comparing the best-of-best values with the achieved values and thus sets the target for further improvement.

The overall equipment effectiveness is thus the measure of equipment or system effectiveness. However, there are many factors, which affect the effectiveness of the plant. An effort has been made to identify the factors, which affect the performance and quality, which in turn affects overall plant effectiveness.

8.2 Definition of important terms

- **SYSTEM DOWNTIME:**

The System downtime is the total time for which a system is down for active maintenance. Obviously this varies from one type of failure to another. When any one (or more) of the sub-systems is not operationally available, the system is said to be down for repair.

- **MEAN TIME BETWEEN FAILURE (MTBF) :**

When a system is often unavailable due to breakdowns and is put back into operation after each breakdown with proper repairs, the mean time between breakdowns is defined as the mean time between failures.

- **MEAN TIME TO REPAIR (MTTR) :**

Mean Time to Repair is the statistical mean time for active repair. It is the total active repair time during a given period divided by the number of malfunctions during the same interval.

- **MEAN TIME BETWEEN MAINTENANCE (MTBM) :**

When preventive maintenance downtime is zero or is not considered, Mean Time between Maintenance is equal to Mean Time between Failure. The mean time between maintenance is the time of start of the machine after repair to next failure that may be caused due to any reason.

❖ PREVENTIVE MAINTENANCE DOWNTIME:

A system may become unavailable on account of periodic inspections and not because of breakdowns. The systematic inspection or preventive maintenance for the detection of defects and prevention of failures keeps the system under satisfactory operational condition. The time spent for this is termed as the Preventive Maintenance Downtime.

❖ MEAN DOWN TIME (MDT):

The statistical mean of the downtimes including supply downtime and the administrative downtime is called the mean downtime. Supply downtime is that portion of the non-active maintenance time during which maintenance is delayed solely because a required item is not readily available. The administrative downtime is that portion of the non-active maintenance time that is not included in the supply downtime. Active Repair time is that time during which the technicians are working on the item to effect a repair.

❖ INHERENT AVAILABILITY

Inherent Availability is the probability that a system or equipment shall operate satisfactorily when used under stated conditions in an ideal support environment, without consideration for any scheduled or preventive maintenance at any given time. It excludes ready time, preventive maintenance downtime, supply downtime and administrative downtime.

$$\text{Inherent Availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

❖ ACHIEVED AVAILABILITY

It is the probability that a system or equipment shall operate satisfactorily when used under stated conditions in an ideal support environment at any given time. In this case preventive maintenance downtime is also taken into consideration. Hence the formula

$$\text{Achieved Availability} = \frac{MTBM}{MTBM + M'}$$

M' is the mean active – maintenance downtime resulting from preventive and corrective maintenance.

❖ OPERATIONAL AVAILABILITY

In any real operation, we cannot reduce administrative downtime and supply downtime to zero. A certain amount of delay will always be caused by time elements. Hence operational availability is defined as the probability that a system or equipment shall operate satisfactorily when used under stated conditions and in an actual supply environment at any given time. [14]

$$\text{Operational Availability} = \frac{MTBM}{MTBM + MDT}$$

The achieved availability and operational availability have been calculated for spinning machines 8 and 9. The operational availability has also been calculated for all key equipment of various departments and is shown in O.E.E. calculation matrix.

❖ DOWNTIME ANALYSIS:

Downtime Analysis matrix is shown in the Table 8.1 and Table 8.2, for Dryer No. 8 and Dryer No. 9 of Spinning & After-Treatment Departments. The downtime analysis matrix shows the modes of stoppages like preventive, planned, mechanical, electrical, instrumentation, fire, modifications and others with their percentage contribution towards downtime.

Fig. 8.1 and Fig. 8.2 shows a graphical representation of percentage contribution to downtime of dryers 8 and 9. The downtime study of both dryers reveal that major contribution to downtime is due to mechanical reasons. Based on the downtime analysis, action plans are prepared for the causes, which greatly affects the equipment. Action plan defines the causes of breakdown, corrective actions to be taken, person responsible and target date of completion. Section 10.3 describes the measures taken to prevent maintenance in dryer by means of process improvement and change in design.

8.3 Concept of Availability

Availability is affected by the stoppages occurring due to the following reasons:

1. Preventive Maintenance: Preventive Maintenance is normally carried out at a fixed interval of 55 days in spinning machines. Sometimes the preventive maintenance has to be carried out early, in case major breakdown takes place before the scheduled date.

2. Breakdown: Failure of components / parts result in breakdown and the machine is stopped to rectify the fault. The major reasons for downtime may be due to

TABLE : 8.1

DOWNTIME ANALYSIS OF DRYER NO. 8

Month	Preventive	Planned	Mech.	Elect.	Instru.	Power	Process	Fire	Modification	Others	Total
Oct-97	0.00	1.083	7.50	2.33	0.00	0.67	4.00	0.00	0.00	0.00	15.58
Nov-97	12.00	0.00	9.67	3.6	0.00	2.42	4.00	7.00	0.00	0.00	38.69
Dec-97	0.00	0.00	0.67	0.33	0.00	0.25	0.00	0.00	0.00	0.00	1.25
Jan-98	0.00	0.92	8.67	1.25	0.00	1.50	1.67	0.42	0.00	0.00	14.43
Feb-98	0.00	3.50	11.17	1.08	0.00	0.17	0.50	0.00	0.00	0.00	16.42
Mar-98	10.25	2.83	3.75	8.42	0.00	0.17	1.17	0.42	8.00	0.00	35.01
Apr-98	0.00	1.83	3.17	2.50	0.00	2.50	2.00	1.17	0.00	1.00	14.17
May-98	18.00	5.33	17.42	5.08	0.00	0.00	5.67	0.00	0.00	0.00	51.50
Jun-98	0.00	1.25	3.00	4.67	1.17	0.33	0	2.33	0.00	0.00	12.75
Jul-98	9.50	6.00	13.00	15.83	0.00	0.67	3.25	4.08	2.00	0.00	54.33
Aug-98	0.00	2.75	14.00	6.83	0.00	3.08	6.42	2.50	0.00	0.00	35.58
Sep-98	8.00	0.00	7.92	1.17	0.00	0.92	4.50	5.92	5.17	0.00	33.60
TOTAL	**57.75**	**25.49**	**99.94**	**53.09**	**1.17**	**12.68**	**33.18**	**23.84**	**15.17**	**1.00**	**323.31**
%	0.18	0.08	0.31	0.16	0.00	0.04	0.10	0.07	0.05	0.00	1.00

FIG. 8.1 CONTRIBUTION TO DOWNTIME (DRYER 8)

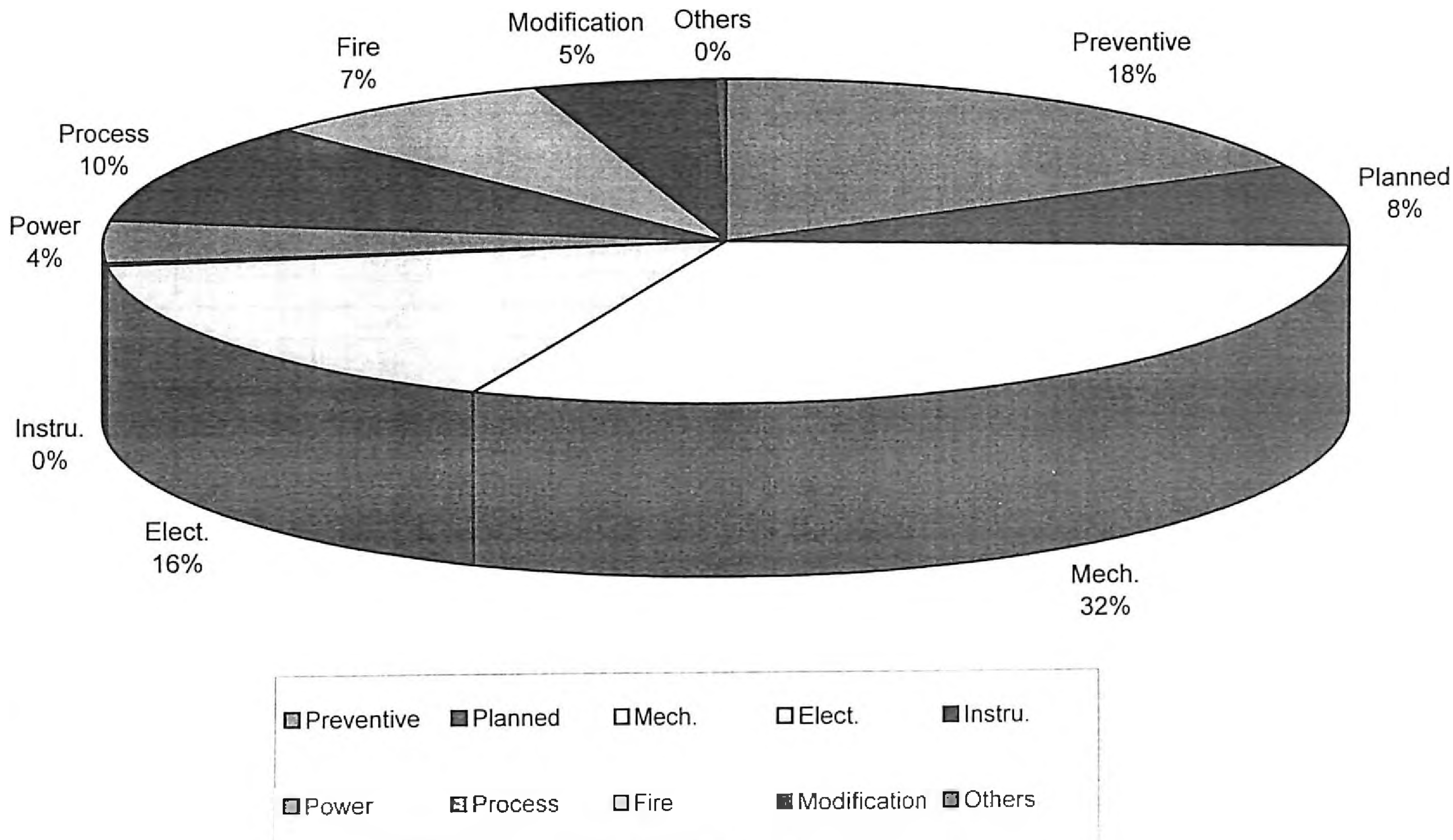
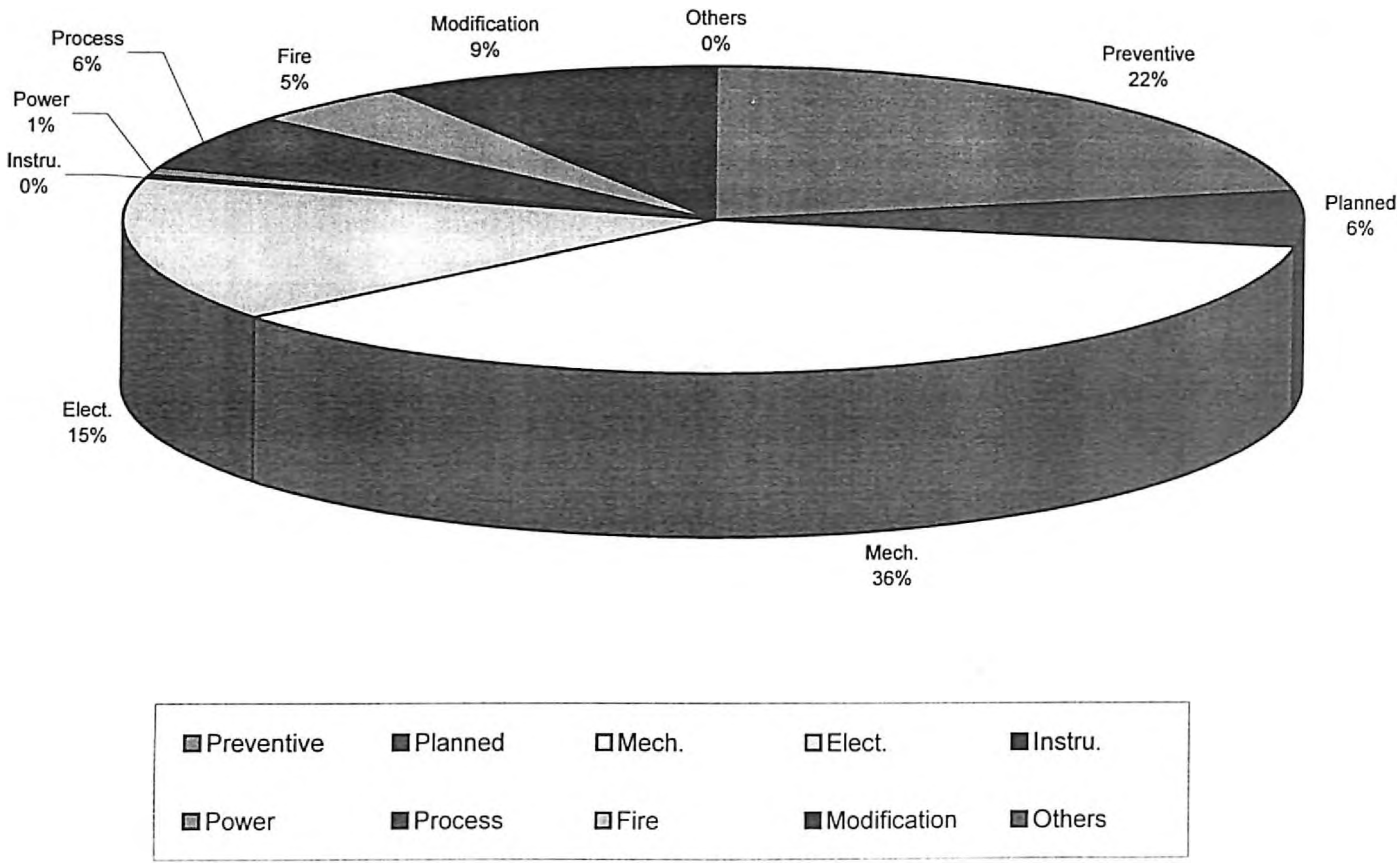


TABLE : 8.2

DOWNTIME ANALYSIS OF DRYER NO. 9

Month	Preventive	Planned	Mech.	Elect.	Instru.	Power	Process	Fire	Modification	Others	Total
Oct-97	0.00	2.17	4.92	2.67	0.00	0.00	5.50	0.00	0.00	0.00	15.26
Nov-97	12.00	3.08	8.17	3.67	0.00	0.00	1.33	1.33	0.00	0.00	29.58
Dec-97	0.00	0.00	0.00	1.08	0.00	0.00	0.00	0.00	0.00	0.00	1.08
Jan-98	0.00	0.17	6.00	0.17	0.00	0.00	0.33	0.00	0.00	0.00	6.67
Feb-98	8.00	4.17	3.08	2.60	0.00	0.00	1.17	0.00	3.83	0.00	22.85
Mar-98	0.00	0.33	7.75	4.83	0.00	0.00	0.83	0.75	0.00	0.00	14.49
Apr-98	10.00	1.92	10.60	3.62	1.08	1.67	0.00	0.00	4.4	0.00	33.29
May-98	2.92	1.67	8.75	2.83	0.00	0.00	0.00	0.00	0.00	0.00	16.17
Jun-98	8.00	0.00	10.83	6.08	0.00	0.00	0.33	0.67	6.00	0.00	31.91
Jul-98	8.25	0.17	22.67	2.75	0.0	0.17	3.75	7.25	6.00	0.00	51.01
Aug-98	8.00	1.08	6.33	5.50	0.00	0.00	1.25	1.83	3.67	0.00	27.66
Sep-98	0.00	0.00	6.08	3.75	0.00	0.00	0.40	0.00	0.00	0.00	10.23
TOTAL	**57.17**	**14.76**	**95.18**	**39.55**	**1.08**	**1.84**	**14.89**	**11.83**	**23.90**	**0.00**	**260.20**
%	0.22	0.06	0.37	0.15	0.00	0.01	0.06	0.05	0.09	0.00	1.00

FIG. 8.2 CONTRIBUTION TO DOWNTIME (DRYER 9)



- ❖ Irregular Preventive Maintenance Schedule
- ❖ Unexpected breakdown : aging, overload, non-availability of spare parts, lack of expertise during preventive maintenance and in case of major problems, oversight during regular preventive maintenance
- ❖ Machine error due to wear
- ❖ Operator error / slack

3. Planned Stoppage: Planned stoppage is normally taken in case of replacement of part/component, modifications, etc.

4. Quality Change: In order to meet sales requirement, quality of fibre needs to be changed and hence necessary stoppages are taken. It is normally of 2-hour duration.

5. Accumulation: Whenever there is quality change or problems in the After-treatment section, accumulation of fibre results in stoppages and clearing of dumped fibres become necessary.

6. Mechanical: Stoppages are taken due to mechanical faults in the machine.

7. Electrical: Stoppages are taken due to electrical faults in the machine.

8. Process : Stoppages are due to process faults in the viscose or auxiliaries

The availability of any equipment thus can be calculated by finding out the uptime and downtime. The formula used is

$$\text{Availability} = 1 - \frac{T_{down}}{T_{up} + T_{down}} \times 100$$

8.4 Concept of Performance

- **Standard Production**:

Standard Production is defined as the capacity of the machine to produce a certain quantity of fibre under ideal conditions. For example the capacity of the spinning machine is 60 TPD means that the machine can produce 60 tons of fibre per day under ideal condition,

- **Target Production**:

Target Production is the production figure to be met during a day as decided by the production-planning department based on the demand and inventory available. The capacity of the machine may be 60 TPD, but it may happen that the actual requirement of fibre is 50 TPD. So the production is reduced and the target production becomes 50 TPD.

- **Actual Production**:

Actual Production is the quantity of fibre produced during a day under actual condition of machine running. It incorporates all the stoppages taken during the day. The capacity of the machine may be 60 TPD, but due to stoppages and other reasons, the actual production might be only 52 TPD.

- **Performance**:

Performance is defined as the ratio of actual production to target production. Suppose the machine capacity is 60 TPD, the target production is 50 TPD and the actual production is 55 TPD, then the performance of the machine will be (55/50 * 100) 110 %. Hence the performance of the machine can be more than 100 %.

$$\text{Performance Rate} = \frac{\text{Actual Production}}{\text{Target Production}} \times 100$$

Based on the target production figure, all process parameters like raw material, intermediate products are set higher or lower. If the actual production is more than the target, then performance is more than 100%, otherwise it will be less than 100%.

8.5 Concept of Quality

The quality of fibre as defined by the production department is the grade obtained in the fibre characteristics like spinning fault (G+R)% and bad cutting (M+P)%. The grades assigned are G, R, S, M and P. The highest grade is G and lowest P for all fibre characteristics.

The quality rate as taken in the O.E.E. calculation is described below:

If q_1 = quality due to spinning fault (G+R)% q_2 = quality due to bad cutting (M+P)%

Hence quality of fibre (Q) = $q_1 \times (1 - q_2)$

For example for machine 8, it can be observed that

In the month of October 1997, (G+R) % = 94 and (M+P) % = 0.43

Hence, the quality of fibre is 0.94 x (1 – 0.0043) = 0.9360, i.e. 93.6 %

- **Deem Quality**

Deem Quality is defined as the ratio of actual quality achieved during production to the maximum quality achievable, based on the quality of raw material (i.e. pulp).

The quality of raw material decides the quality of fibre. If the quality of pulp is poor and the viscose quality is bad, then the quality of fibre is also poor. Normally the quality of Indian pulp is inferior to quality of Canadian pulp. For example, by using Indian Pulp, the maximum achievable quality is 97 %, but if the machine produces 100 % quality, then deem quality will be (100/97 * 100) 103 %.

❖ **Actual Quality**

The actual quality of fibre should take into account all the fibre characteristics. The weightages of each characteristic may be assigned differently as per sales requirement. The cumulative grade point average thus gives the quality of fibre.

8.6 O.E.E. Calculations for Spinning Machines

The Profit Center 2 has two spinning machines of 60 TPD and 45 TPD capacity of fibre production. The overall equipment effectiveness of spinning machines is calculated as a product of availability, performance rate and quality rate.

- **Availability:**

Availability of spinning machine is calculated by finding out the downtime month-wise. The machine stoppage occurs due to various reasons as described in section 8.3. The case-wise contribution to downtime is shown in the Table 8.3 and Fig 8.3a shows the comparison between the causes of stoppages in machine 8 and machine 9. The average downtime, best in class values and standard deviation are calculated as given in Table 8.5 and Table 8.6 for machines 8 and 9 respectively.

- **Performance Rate:**

The performance rate is calculated by finding out the actual production and the target production. The actual production is the average of production of fibre in a month by a particular machine. The target production is found out by calculating the average of the targets set in a month. The calculation of performance rate for machines 8 and 9 is shown in Table 8.4.

TABLE : 8.3

MTBM & DOWNTIME ANALYSIS : SUMMARY

A. MEAN TIME BETWEEN MAINTENANCE

MONTH	M/C 8	M/C 9
Oct-97	87.19	252.81
Nov-97	112.10	85.06
Dec-97	118.67	120.08
Jan-98	100.60	101.57
Feb-98	93.14	86.9
Mar-98	113.46	64.10
Apr-98	62.87	78.94
May-98	60.64	78.15
Jun-98	117.17	50.63
Jul-98	57.40	76.44
Aug-98	141.40	56.71
Sep-98	115.25	87.32
Oct-98	84.90	76.48
AVERAGE	**97.29**	**93.48**
STD. DEV.	**25.83**	**51.14**

B. CAUSE-WISE CONTRIBUTION TO DOWNTIME

REASONS	M/C 8	M/C 9
PREVENTIVE	19.20	16.60
PLANNED	16.70	12.60
MECHANICAL	25.00	6.06
ELECTRICAL	2.48	4.10
POWER	1.35	0.96
SALES	2.70	16.00
ACCUMULATION	25.50	31.80
PROCESS	3.34	5.70
MODIFICATION	3.67	5.90

C. BENCHMARKING PARAMETERS: SUMMARY

MACHINE NO.	FREQUENCY	MDT	MTBM	AVAILABILITY	PERFORMANCE	QUALITY	OEE
8	6.38	5.83	97.29	0.9515	0.9279	0.9434	0.8329
STD DEV.	2.36	2.37	25.83	0.0218	0.0259	0.0192	0.0352
9	7.46	4.79	93.48	0.9490	0.9688	0.9396	0.8639
STD.DEV	2.50	1.12	51.14	0.0177	0.0223	0.0342	0.0440

D. AVAILABILITY CALCULATIONS : SUMMARY

MACHINE NO.	MTBM	MDT	M' (PLANNED + PREVENTIVE)	ACHIEVED AVAILABILITY	OPERATIONAL AVAILABILITY	AVAILABILITY
8	97.29	5.83	12.60	0.8853	0.9435	0.9515
9	93.48	4.79	11.00	0.8947	0.9513	0.9490

FIG 8.3a. CAUSE WISE CONTRIBUTION TO DOWNTIME (m/c 8 Vs. m/c9)

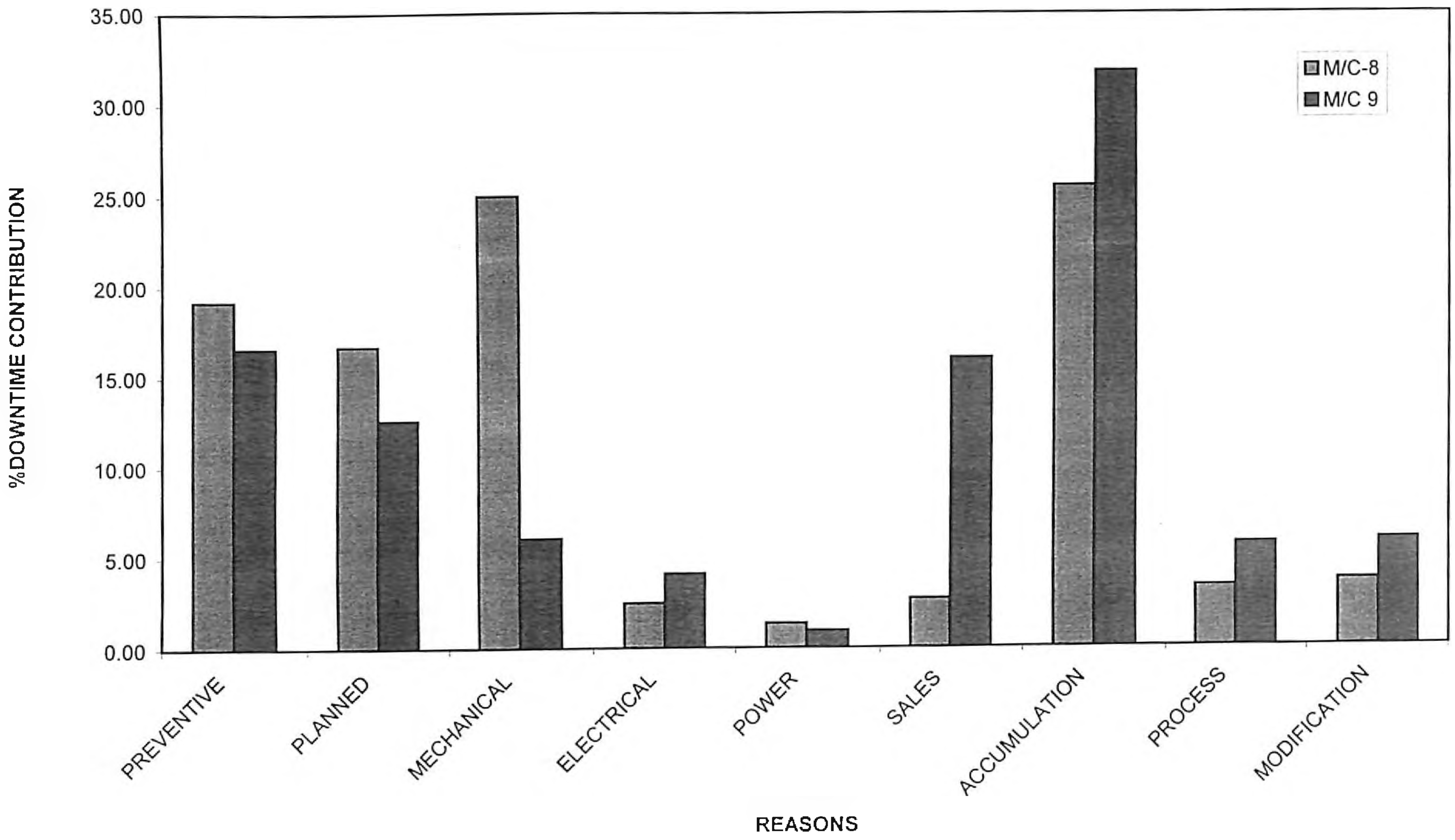


FIG. 8.3 b. MTBM OF SPINNING MACHINES 8 & 9

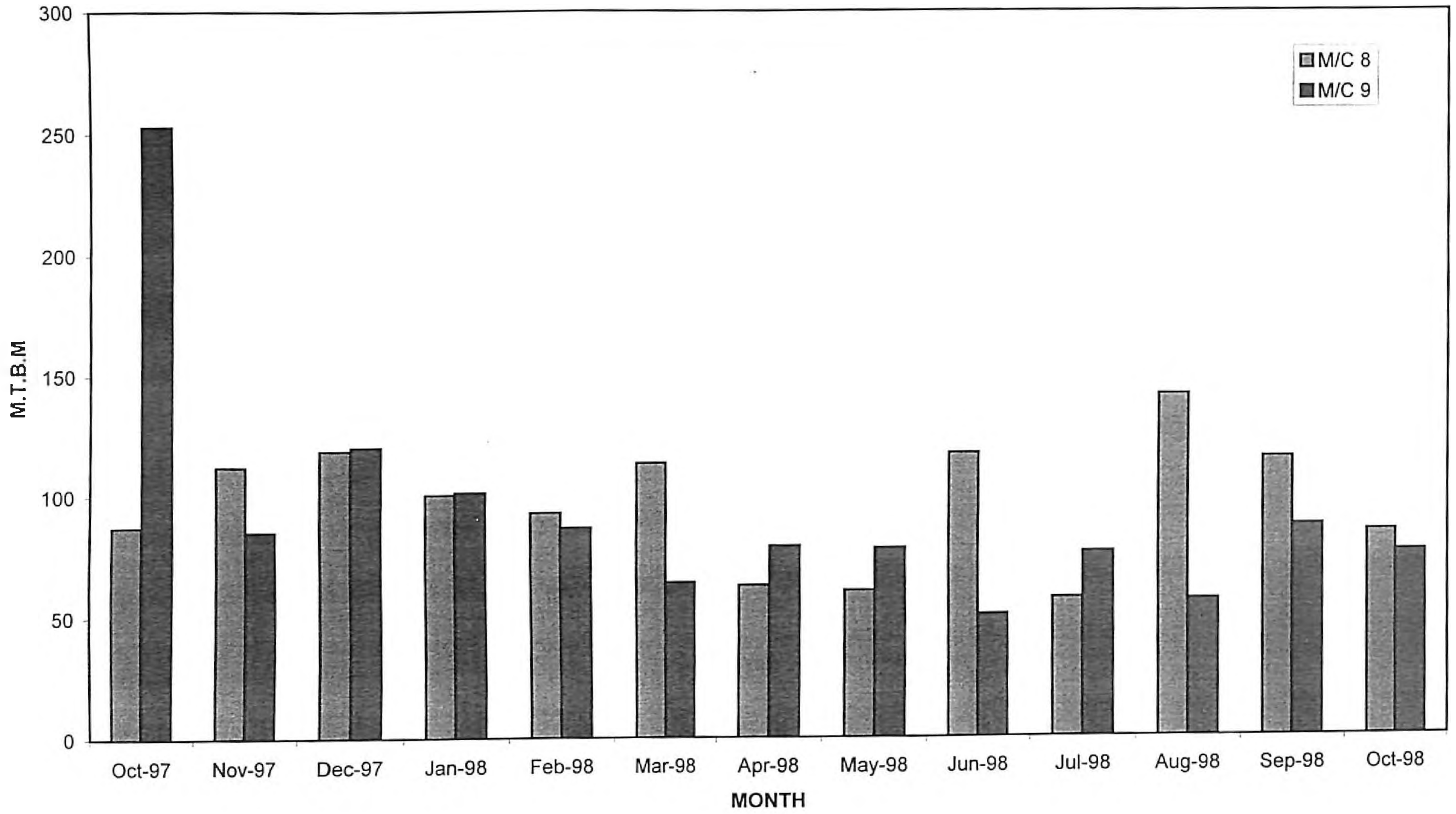


FIG. 8.3c. TRENDS IN MTBM OF MACHINE 8

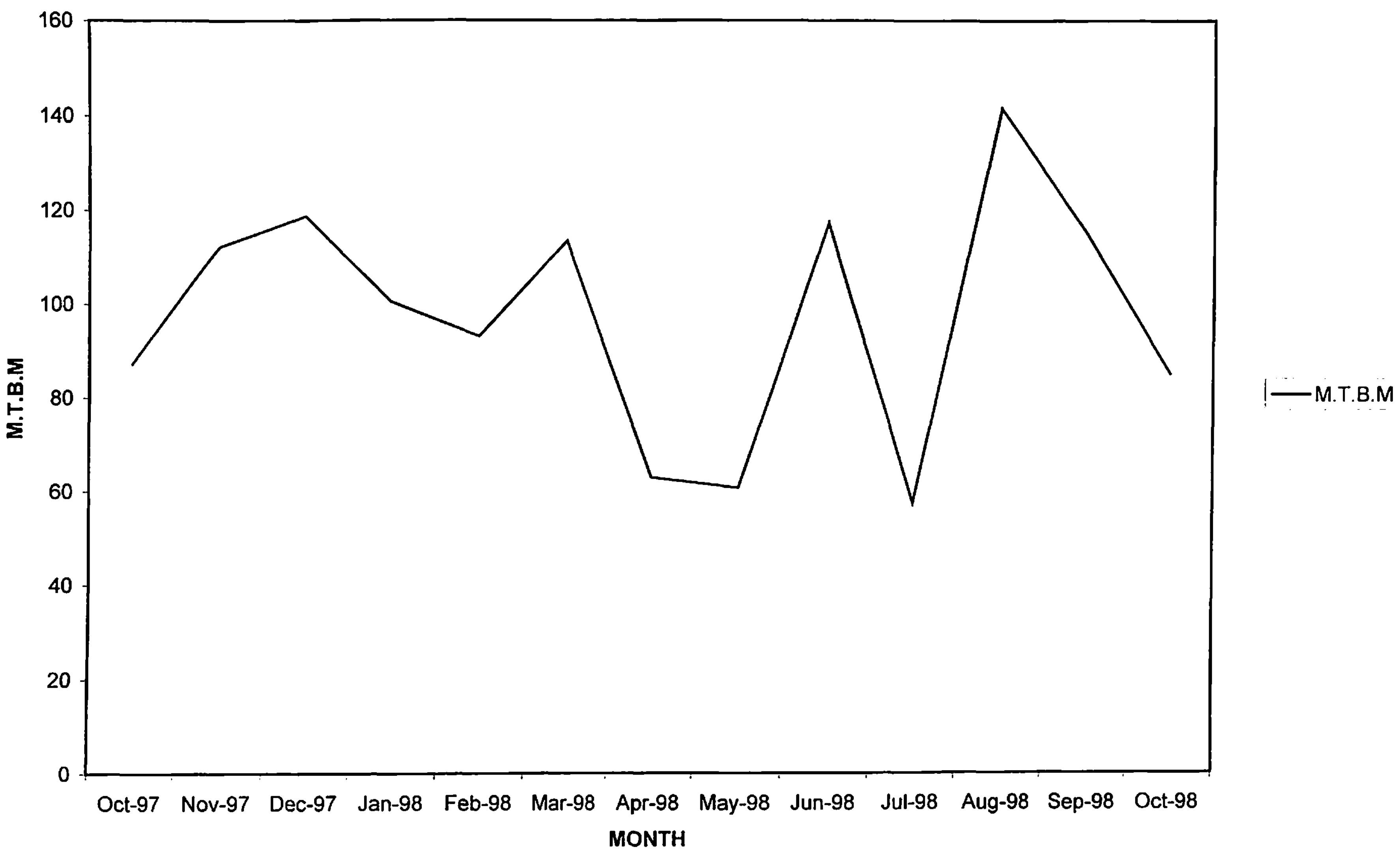


FIG 8.3d. TRENDS IN MTBM OF MACHINE 9

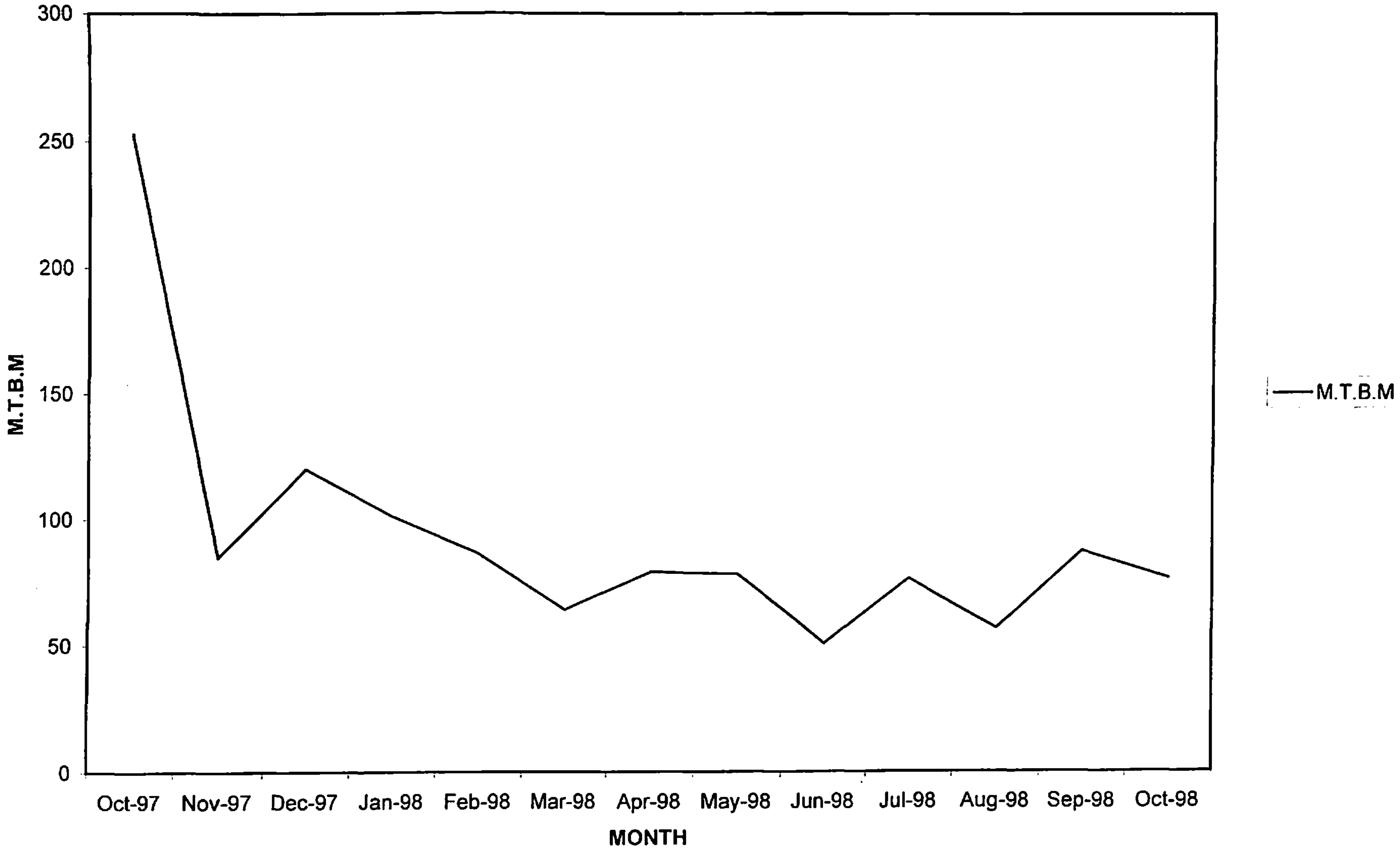


TABLE : 8.4

PERFORMANCE & QUALITY RATE CALCULATIONS
SPINNING MACHINE 8

MONTH	TARGET PRODUCTION (TPD)	ACHIEVED PRODUCTION (TPD)	PERFORMANCE	SPINNING FAULT	BAD CUTTING	QUALITY %
Oct-97	58.00	56.29	0.9705	0.94	0.0043	0.9360
Nov-97	58.00	55.68	0.9599	0.96	0.0006	0.9594
Dec-97	58.00	55.63	0.9591	0.95	0.0010	0.9490
Jan-98	58.00	54.04	0.9317	0.96	0.0006	0.9594
Feb-98	58.00	52.84	0.9110	0.93	0.0003	0.9297
Mar-98	58.00	53.25	0.9181	0.96	0.0011	0.9589
Apr-98	58.00	51.50	0.8878	0.92	0.0059	0.9145
May-98	58.00	51.81	0.8933	0.93	0.0007	0.9293
Jun-98	58.00	52.90	0.9120	0.92	0.0006	0.9194
Jul-98	58.00	53.28	0.9186	0.98	0.0006	0.9794
Aug-98	55.00	50.50	0.9181	0.96	0.0000	0.9600
Sep-98	55.00	51.16	0.9302	0.94	0.0000	0.9400
Oct-98	55.00	52.38	0.9524	0.93	0.0008	0.9293

PERFORMANCE & QUALITY RATE CALCULATIONS
SPINNING MACHINE 9

MONTH	TARGET PRODUCTION (TPD)	ACHIEVED PRODUCTION (TPD)	PERFORMANCE	SPINNING FAULT	BAD CUTTING	QUALITY
Oct-97	45.00	43.64	0.9698	0.93	0.0002	0.9298
Nov-97	45.00	42.38	0.9418	0.94	0.0016	0.9385
Dec-97	45.00	43.64	0.9699	0.95	0.0030	0.9471
Jan-98	45.00	45.16	1.0036	0.98	0.0016	0.9784
Feb-98	45.00	45.28	1.0132	0.97	0.0010	0.9690
Mar-98	45.00	42.73	0.9496	0.98	0.0011	0.9789
Apr-98	45.00	43.19	0.9597	0.96	0.0000	0.9600
May-98	45.00	43.12	0.9582	0.93	0.0019	0.9282
Jun-98	45.00	42.16	0.9369	0.92	0.0040	0.9163
Jul-98	45.00	43.25	0.9611	0.96	0.0059	0.9543
Aug-98	42.00	41.51	0.9884	0.95	0.0024	0.9477
Sep-98	42.00	40.88	0.9733	0.92	0.0034	0.9169
Oct-98	42.00	40.70	0.9689	0.85	0.0005	0.8496

- **Quality Rate:**

Quality Rate is calculated based on quality reports from Textile Laboratory. The average quality of fibre is determined on the basis of grades obtained in important fibre characteristics. The quality of fibre largely depends upon the quality of pulp used. Hence a particular kind of pulp can produce a pre-determined quality of fibre. If the quality is better than this value, then the quality rate is more than 100 %. The calculation of Quality Rate for machines 8 and 9 is shown in Table 8.4.

- **Benchmarking:**

A comparative analysis, as shown in Table 8.3, is done between the two spinning machines in terms of O.E.E., MTBM, MDT, Achieved Availability, Operational Availability and Availability. The best-in-class values of each machine in terms of availability, performance rate, quality rate, O.E.E., MDT, MTBM, severity index and frequency index achieved during the period Oct 1997 to Oct 1998 are shown in Table 8.5 and Table 8.6 for spinning machines 8 & 9 respectively. Fig. 8.5 and Fig. 8.6 shows the trends in O.E.E. of spinning machines 8 and 9 over the above period.

The analysis reflects that the machine no. 9 has greater O.E.E. than machine no. 8. The availability and quality achieved on machine 8 are more than that in machine 9. The performance of machine 9 is better than that of machine 8.

- **Calculation Procedure:**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Running Time – Total Downtime) / Running Time
PERFORMANCE RATE = Actual Fibre Production / Target Standard Production
QUALITY RATE = Quality %(G + R) x { 1 - % (M + P) }

FIG. 8.4 Trends in Frequency and Severity Indices (m/c8)

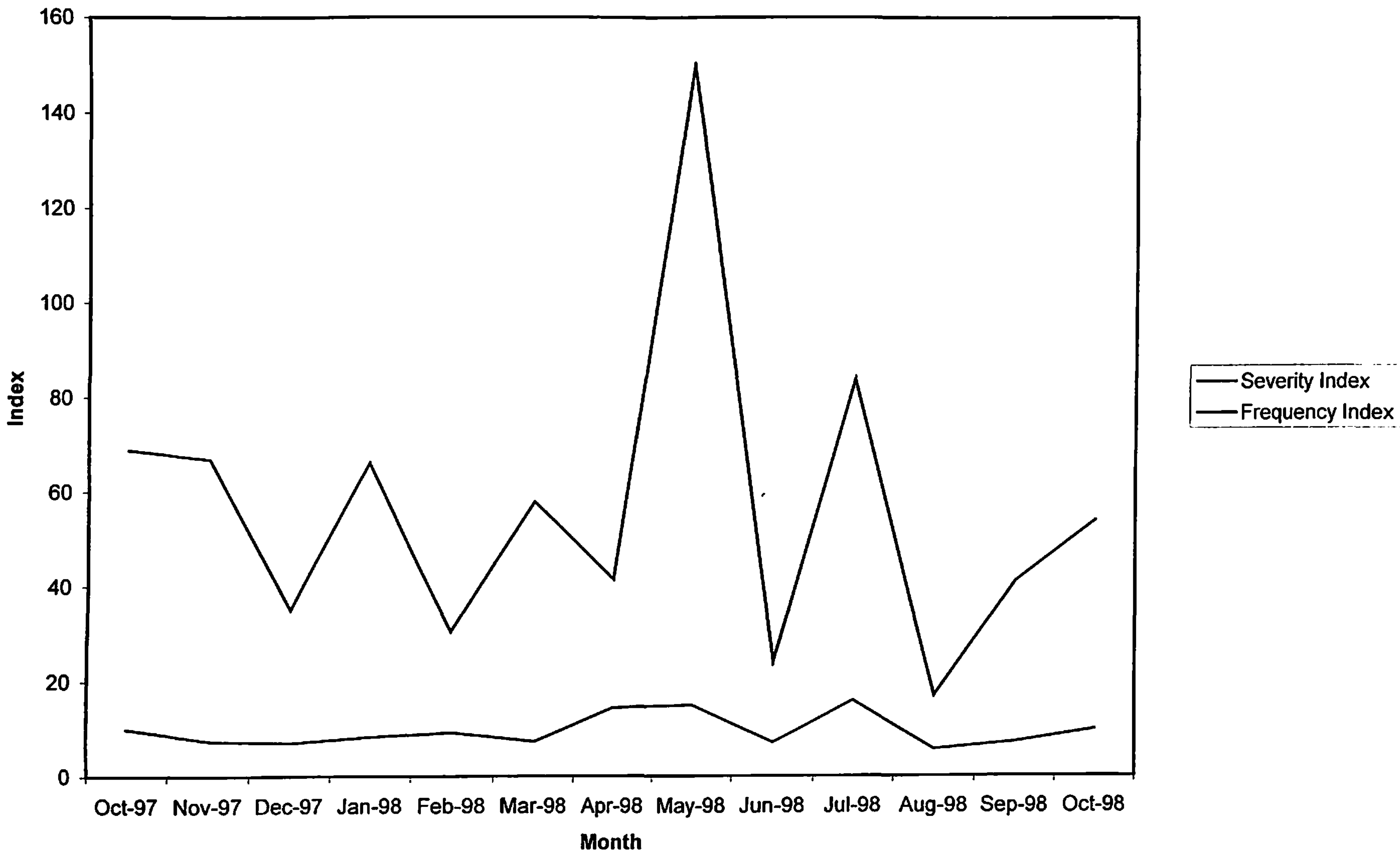


TABLE : 8.5
O.E.E CALCULATION OFSPINNING MACHINE 8

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	O.E.E	Freq. Of Stoppages	Mean Down Time (Hrs.)	M.T.B.M (Hrs.)	SEVEREITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Oct-97	0.9378	0.9705	0.9360	0.8519	7	6.90	87.19	68.83	9.98	0.9267
Nov-97	0.9394	0.9599	0.9594	0.8651	5	9.00	112.10	66.90	7.43	0.9257
Dec-97	0.9664	0.9591	0.9490	0.8796	5	5.00	118.67	35.11	7.02	0.9596
Jan-98	0.9460	0.9317	0.9594	0.8456	5	8.00	100.60	66.27	8.28	0.9263
Feb-98	0.9703	0.9110	0.9297	0.8218	6	3.33	93.14	30.64	9.20	0.9655
Mar-98	0.9469	0.9181	0.9589	0.8336	5	7.90	113.46	58.02	7.34	0.9349
Apr-98	0.9602	0.8878	0.9145	0.7796	10	2.87	62.87	41.50	14.46	0.9563
May-98	0.9055	0.8933	0.9293	0.7517	10	10.00	60.64	149.91	14.99	0.8584
Jun-98	0.9762	0.9120	0.9194	0.8185	5	3.40	117.17	24.18	7.11	0.9718
Jul-98	0.9223	0.9186	**0.9794**	0.8298	11	5.25	57.40	83.84	15.97	0.9162
Aug-98	**0.9828**	0.9181	0.9600	0.8662	4	3.00	141.40	16.97	5.66	0.9792
Sep-98	0.9604	0.9302	0.9400	0.8398	5	5.70	115.25	41.21	7.23	0.9529
Oct-98	0.9553	0.9524	0.9293	0.8455	5	5.50	84.90	53.98	9.81	0.9392
AVERAGE	0.9515	0.9279	0.9434	0.8329	6.38	5.83	97.29	56.72	9.58	0.9394
BEST IN CLASS	**0.9828**	**0.9705**	**0.9794**	**0.9342**	**4**	**2.87**	**141.40**	**16.97**	**5.66**	**0.9792**
STD. DEV	0.0218	0.0259	0.0192	0.0352	2.36	2.37	25.83	34.19	3.41	0.0314

TABLE 8.6

O.E.E. CALCULATION OF SPINNING MACHINE 9

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	OEE	Freq. Of Stoppages	Mean Down Time (Hrs.)	M.T.B.M	SEVEREITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Oct-97	0.9842	0.9698	0.9298	0.8875	3	3.92	252.81	11.63	2.97	0.9847
Nov-97	0.9451	0.9418	0.9385	0.8354	7	5.64	85.06	58.02	10.29	0.9378
Dec-97	0.9678	0.9699	0.9471	0.8890	5	4.80	120.08	33.31	6.94	0.9616
Jan-98	0.9490	1.0036	0.9784	0.9318	6	5.67	101.57	47.85	8.44	0.9471
Feb-98	0.9410	1.0132	0.9690	0.9239	6	6.62	86.90	65.29	9.86	0.9292
Mar-98	0.9517	0.9496	0.9789	0.8847	10	3.60	64.10	51.06	14.18	0.9468
Apr-98	0.9473	0.9597	0.9600	0.8728	7	5.80	78.94	64.29	11.08	0.9316
May-98	0.9456	0.9582	0.9282	0.8410	8	5.20	78.15	59.15	11.37	0.9376
Jun-98	0.9184	0.9369	0.9163	0.7884	12	3.13	50.63	57.07	18.23	0.9418
Jul-98	0.9302	0.9611	0.9543	0.8532	9	5.80	76.44	68.29	11.77	0.9295
Aug-98	0.9318	0.9884	0.9477	0.8728	11	4.61	56.71	74.52	16.16	0.9248
Sep-98	0.9702	0.9733	0.9169	0.8658	7	3.07	87.32	30.76	10.02	0.9660
Oct-98	0.9550	0.9689	0.8496	0.7861	6	4.43	76.48	49.65	11.21	0.9452
AVERAGE	0.9490	0.9688	0.9396	0.8639	7.46	4.79	93.48	51.61	10.96	0.9449
BEST IN CLASS	**0.9842**	**1.0132**	**0.9789**	**0.9762**	3	**3.07**	**252.81**	**11.63**	**2.97**	**0.9847**
STD. DEV	0.0177	0.0223	0.0342	0.0440	2.50	1.12	51.14	17.4763	3.8736	0.0171

FIG. 8.5 Trends in Frequency and Severity Indices (m/c 9)

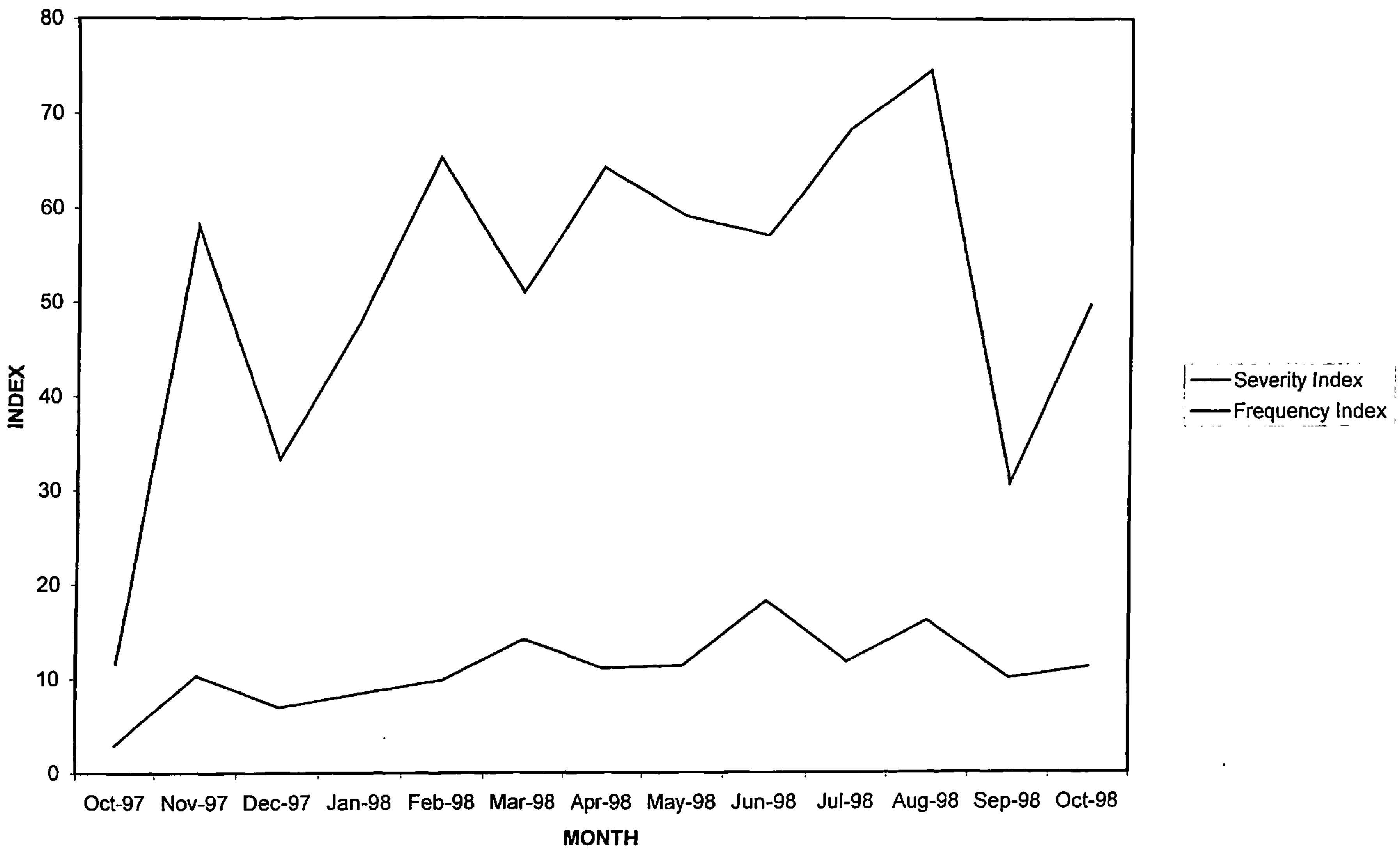


FIG. 8.6 TRENDS IN O.E.E. OF MACHINE 8

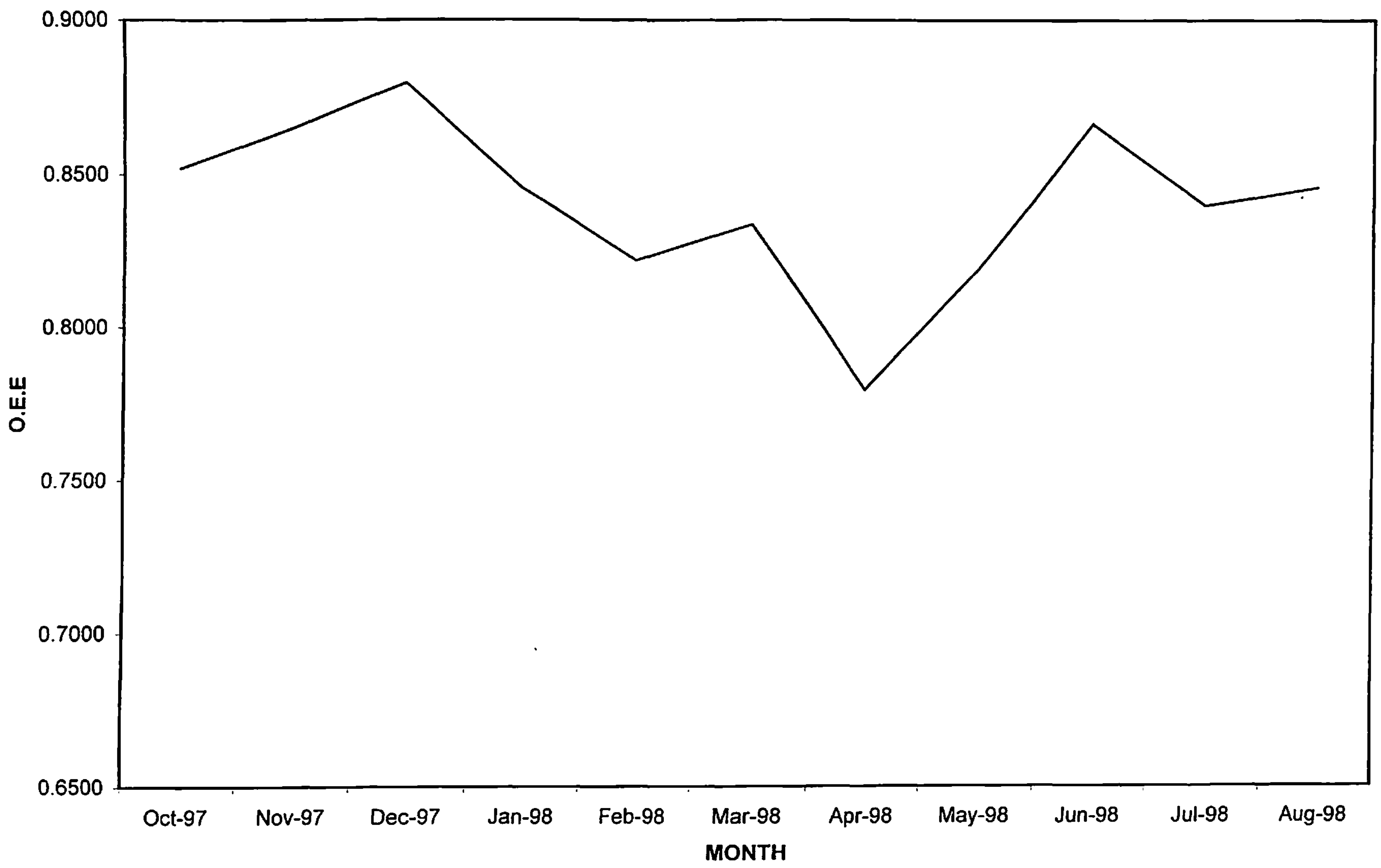
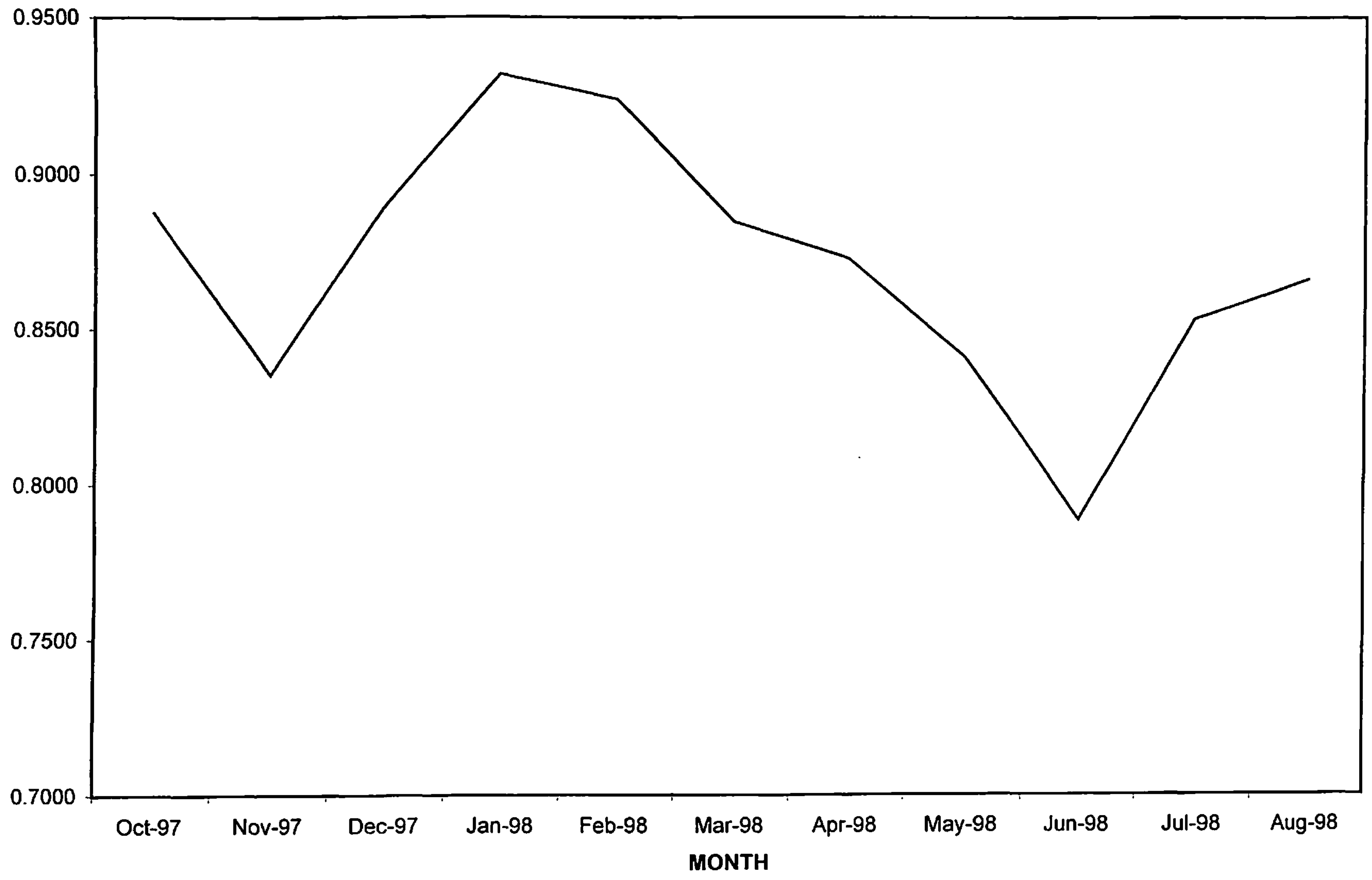


FIG. 8.7 TRENDS IN O.E.E OF MACHINE 9



$$\textbf{Frequency Index} = \frac{\text{No. of breakdowns}}{\text{Total machine running hours}} \times 1000$$

$$\textbf{Severity Index} = \frac{\text{No. Of hours lost}}{\text{Total machine running hours}} \times 1000$$

Table 8.5 and Table 8.6 give a detailed calculation of Overall Equipment Effectiveness, Mean Downtime and Mean Time between Maintenance, Frequency Index and Severity Index for Machine No. 8 and 9 of Mill – II.

Table 8.3 shows the summary of various maintenance parameters. Fig. 8.3 b shows the comparison of MTBM between machine 8 and machine 9. Fig. 8.3 c and Fig. 8.3 d shows the trends in MTBM of machine 8 and machine 9.

Fig. 8.4 and Fig. 8.5 shows the trends in frequency and severity indices of machine 8 and machine 9 respectively.

- **Preventive Maintenance Analysis:**

The preventive maintenance of spinning machines are undertaken at an average gap of 55 days. The machine stoppages do occur between two preventives. Table 8.7 shows the cause-wise analysis of stoppages occurring between consecutive preventive maintenance.

TABLE 8.7

DOWNTIME ANALYSIS BETWEEN TWO PREVENTIVE MAINTENANCE PROGRAMME FOR MACHINE NO. 8 (OCT 97 TO OCT 98)

DATE	INTERVAL (DAYS)	MECHANICAL (%)	PROCESS (%)	QC&ACC. (%)	ELECTRICAL (%)	MODIFICATION (%)	OTHERS (%)	DT(Hrs.)	Ist (Hrs.) Stoppage	Reasons
18.11.97-23.01.98	65	**55.05**	0.00	**28.82**	0.00	0.00	16.13	**63.58**	58.33	Mech.
23.01.98-19.03.98	55	**40.45**	0.00	**35.95**	0.00	0.00	23.60	**37.08**	9.50	Aux.
19.03.98-12.05.98	54	**36.85**	5.40	**36.85**	4.18	13.03	3.69	**57.91**	30.25	Accu.
12.05.98-30.05.98	18	0.81	18.68	**55.38**	0.00	19.15	5.98	**40.33**	31.00	Process
30.05.98-03.09.98	96	**33.64**	6.23	**45.80**	4.98	4.68	4.67	**80.25**	16.00	Mech.
03.09.98-14.10.98	41	**50.69**	0.00	**26.27**	0.00	16.09	6.95	**31.07**	11.75	Mech.
AVERAGE	55	**36.25**	5.05	**38.18**	1.53	8.83	10.17	**51.70**	**26.14**	

DOWNTIME ANALYSIS BETWEEN TWO PREVENTIVE MAINTENANCE PROGRAMME FOR MACHINE NO. 9 (OCT. 97 to OCT. 98)

DATE	INTERVAL (DAYS)	MECHANICAL (%)	PROCESS (%)	QC&ACC. (%)	ELECTRICAL (%)	MODIFICATION (%)	OTHERS (%)	DT(Hrs.)	I st (Hrs.) Stoppage	Reasons
11.11.97-09.01.98	59	1.83	0.74	**81.63**	0.00	8.83	6.97	45.33	56.50	QC
09.01.98-17.02.98	39	**24.02**	0.00	**46.03**	0.00	0.00	**29.95**	45.08	94.25	Accu.
17.02.98-14.04.98	56	**33.60**	5.36	27.30	8.04	0.00	**25.70**	46.66	164.33	Vis.
14.04.98-10.06.98	57	0.00	0.00	**89.79**	6.74	0.00	3.47	79.08	86.25	Aux.
10.06.98-02.07.98	22	10.21	0.00	**30.66**	14.45	0.00	**44.68**	19.58	50.00	QC
02.07.98-21.08.98	50	**23.75**	3.17	**60.16**	1.05	0.00	11.87	31.58	41.50	Accu.
21.08.98-06.10.98	46	**21.24**	0.00	**58.41**	7.08	0.00	13.27	28.25	158.75	Mech.
AVERAGE	47	**16.38**	1.32	**56.28**	5.34	1.26	**19.42**	**42.22**	**93.08**	

8.7 O.E.E. Calculations for Critical Equipment

The Overall Equipment Effectiveness (O.E.E.) calculation is done for critical equipment of Staple Fibre Division. This includes Slurry Presses of Viscose Department, Spinning Machines of Spinning & After-Treatment Department, Multi-Stage Flash Evaporator (M.S.F.E.) of Auxiliaries Department, Acid Plants, Boiler and Turbine of Energy Centre.

8.7.1 Slurry Presses

The function of the slurry press is to squeeze out the slurry formed in the homogenizer to obtain a mat of alk-cell with the help of squeeze rollers. Excess caustic solution is drained out between endless sieves and alkali to cellulose ratio is maintained to the required value in the mat.

The Slurry Press X1 of Viscose – 2 has been chosen for calculating overall equipment effectiveness.

- **Calculation Procedure**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Running Time – Total Downtime) / Running Time
PERFORMANCE RATE = Actual Alk Cell Production / Standard Production
QUALITY RATE = Weighted Average of the define quality range for Alkcell

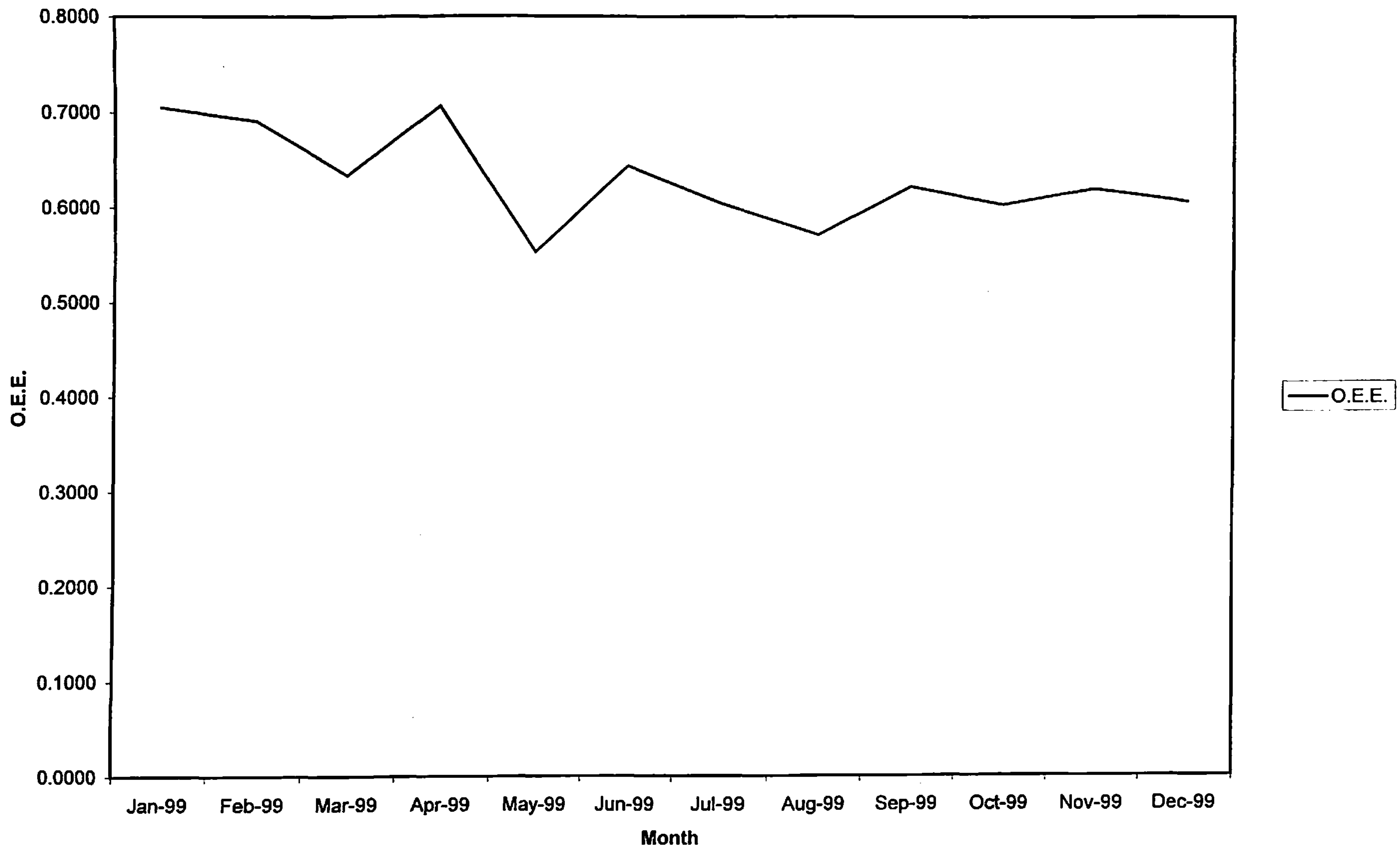
Table 8.8 shows the matrix indicating O.E.E. calculations and other maintenance parameters for Slurry Press (X1) of Viscose – 2 from the period January 1999 to December 1999. Fig 8.8 shows the trend in O.E.E. over this period. A sample calculation is shown in Annexure 1.

TABLE : 8.8

O.E.E. CALCULATION OF SLURRY PRESS

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	OEE	Freq. Of Stoppages	MDT hrs.	M.T.B.M hrs.	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Jan-99	0.9032	0.9400	0.8300	0.7047	21	3.43	30.54	107.14	31.25	0.8990
Feb-99	0.9167	0.9300	0.8100	0.6906	24	2.33	24.64	90.91	38.96	0.9136
Mar-99	0.8871	0.9150	0.7800	0.6331	21	4.00	30.00	127.27	31.82	0.8824
Apr-99	0.8875	0.9250	0.8600	0.7060	19	4.26	31.95	126.76	29.73	0.8824
May-99	0.8125	0.8350	0.8150	0.5529	30	4.65	19.50	230.77	49.63	0.8075
Jun-99	0.9189	0.9150	0.7650	0.6432	24	2.43	26.46	88.27	36.28	0.9159
Jul-99	0.8517	0.9200	0.7700	0.6033	23	4.80	26.40	174.12	36.30	0.8462
Aug-99	0.9339	0.8150	0.7500	0.5708	19	3.78	34.74	70.77	27.35	0.9019
Sep-99	0.8949	0.8850	0.7850	0.6217	26	2.91	23.87	117.44	40.35	0.8913
Oct-99	0.8264	0.9000	0.8100	0.6024	24	5.38	24.59	210.09	39.04	0.8205
Nov-99	0.8694	0.9250	0.7700	0.6192	23	4.09	26.08	150.16	36.74	0.8644
Dec-99	0.9251	0.9100	0.7200	0.6061	27	2.06	24.58	81.00	39.23	0.9227
AVERAGE	0.8856	0.9013	0.7888	0.6295	23.42	3.68	26.95	131.23	36.39	0.8790
BEST IN CLASS	**0.9339**	**0.9300**	**0.8600**	**0.7469**	**19**	**2.06**	**34.74**	**70.77**	**27.35**	**0.9227**
STD. DEV	0.0389	0.0386	0.0381	0.0494	3.23	1.06	4.16	51.1512	5.9253	0.0374

FIG. 8.8 O.E.E. OF SLURRY PRESS X1



8.7.2 Multi-Stage Flash Evaporators

Multi-Stage Flash Evaporation (MSFE) System is used for evaporating water from spin bath solution. This system replaces the conventional Double/Triple Effect Evaporator System as it offers considerable savings in steam, power and cooling water.

MSFE 6 of Auxiliaries-1 has been chosen for calculating overall equipment effectiveness.

- **Calculation Procedure:**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Calendar Time – Total Downtime) / Calendar Time
PERFORMANCE RATE = Steam Economy (Standard) / Avg. Actual Steam Economy
QUALITY RATE = Number of Quality Sulphate Reports (>350&<360) / Total Reports

Table 8.9 shows the matrix indicating O.E.E. calculations and other maintenance parameters for M.S.F.E 6 of Auxiliaries – 1 from the period January 1999 to December 1999.

Fig 8.9 shows the trend in O.E.E. over this period. A sample calculation is shown in Annexure 2.

8.7.3 Acid Plants

The Acid Plant manufactures sulphuric acid by DCDA process. It supplies acid to the Auxiliary Department and Chemical Division. Molten sulphur is burnt to give sulphur-di-oxide, which is converted to sulphur– tri – oxide in the presence of Vanadium Pentaoxide

TABLE : 8.9

O.E.E CALCULATION OF MSFE 6 OF AUX-1

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	O.E.E	Freq. Of Stoppages	MDT hrs.	M.T.B.M hrs.	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Jan-99	0.9355	0.8438	0.7888	0.6227	12	4.00	53.54	68.97	17.24	0.9305
Feb-99	0.9539	0.8182	0.9033	0.7050	8	3.88	71.22	48.36	12.48	0.9484
Mar-99	0.9603	0.7941	0.9860	0.7519	6	4.92	102.07	41.29	8.40	0.9540
Apr-99	0.9521	0.7714	0.9855	0.7238	6	5.75	97.93	50.33	8.,75	0.9445
May-99	0.9812	0.7941	0.9904	0.7717	6	2.33	104.29	19.18	8.22	0.9781
Jun-99	0.9236	0.8710	0.9756	0.7848	9	6.11	66.50	82.7	13.53	0.9159
Jul-99	0.8925	0.7105	0.9864	0.6255	14	5.71	44.27	120.48	21.08	0.8858
Aug-99	0.9193	0.7500	0.9898	0.6824	13	4.62	48.86	87.72	19.01	0.9136
Sep-99	0.8750	0.7500	0.9617	0.6311	18	5.00	33.16	142.86	28.57	0.8690
Oct-99	0.9032	0.7714	0.9940	0.6925	15	4.80	42.00	107.14	22.32	0.8974
Nov-99	0.9431	0.7500	0.9367	0.6626	13	3.15	48.50	60.38	19.14	0.9390
Dec-99	0.9483	0.8100	0.9350	0.7182	8	4.81	78.39	54.57	12.76	0.9422
AVERAGE	0.9323	0.7862	0.9528	0.6984	10.67	4.59	65.89	73.67	16.61	0.9265
BEST IN CLASS	**0.9812**	**0.8710**	**0.9940**	**0.8495**	**6**	**2.33**	**104.29**	**19.18**	**8.22**	**0.9781**
STD. DEV	0.0307	0.0450	0.0590	0.0555	4.03	1.10	24.95	35.86	6.22	0.0312

FIG: 8.9 O.E.E.OF MSFE 6

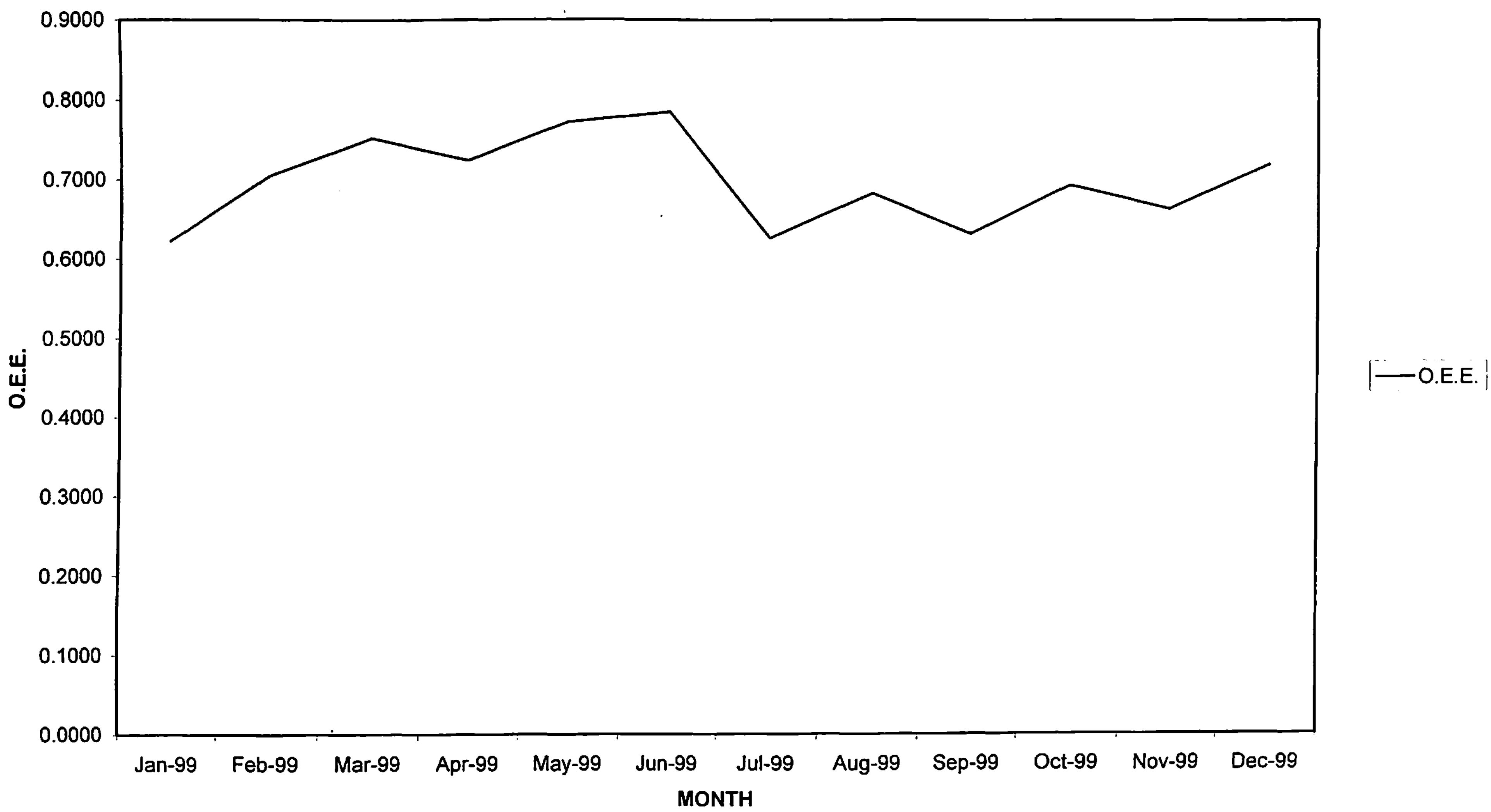
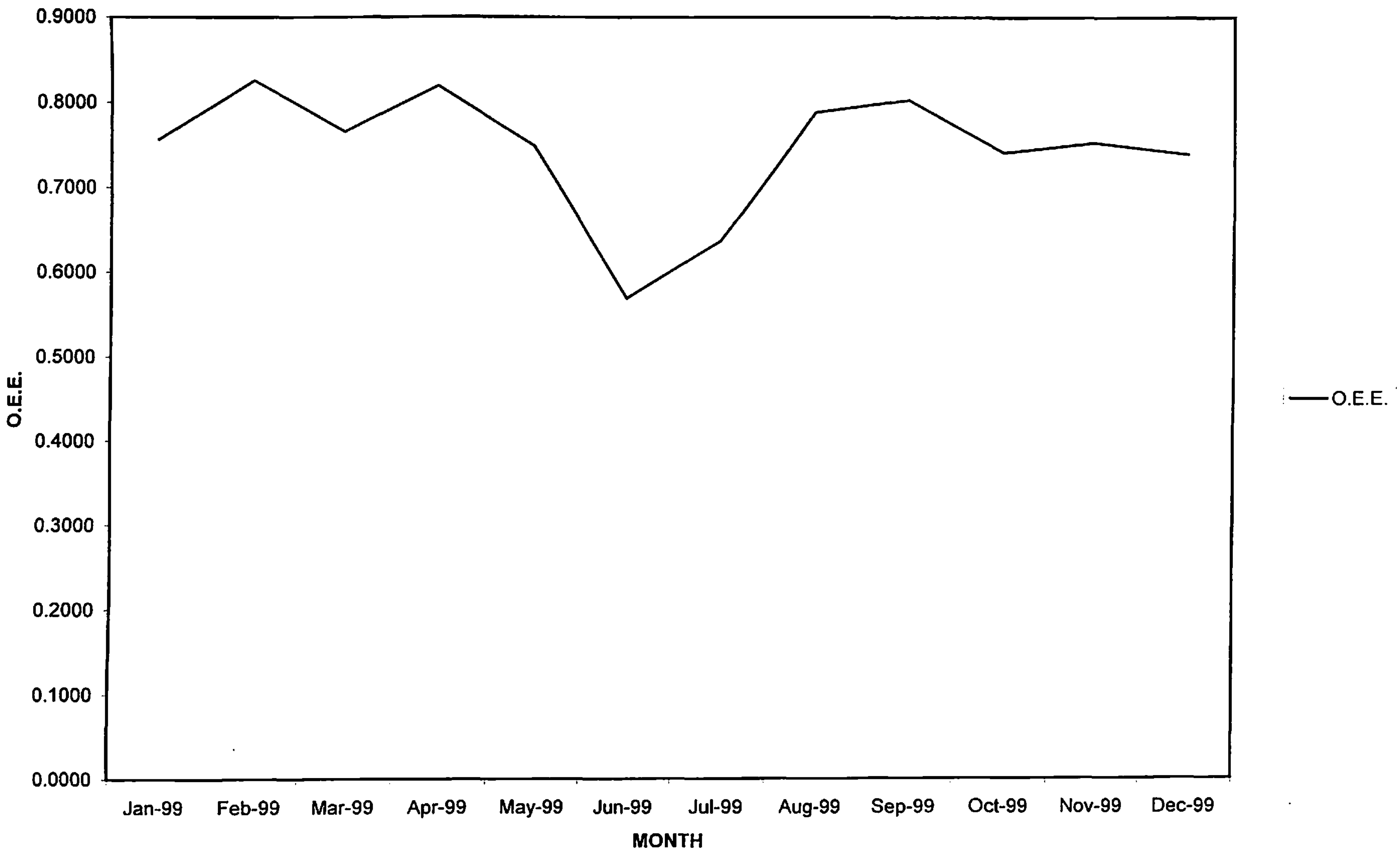


TABLE : 8.10

O.E.E CALCULATION OF ACID PLANT NO. 1

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	O.E.E	Freq. Of Stoppages	MDT hrs.	M.T.B.M hrs.	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Jan-99	0.9980	0.9650	0.7850	0.7560	2	0.75	247.5	2.02	2.69	0.9970
Feb-99	0.9921	0.9300	0.8950	0.8258	3	1.77	166.68	7.95	4.50	0.9895
Mar-99	0.9998	0.9450	0.8100	0.7653	1	0.10	371.95	0.13	1.34	0.9997
Apr-99	0.9917	0.9550	0.8650	0.8192	1	6.00	357.00	8.40	1.40	0.9835
May-99	0.9960	0.9400	0.8000	0.7490	3	1.00	185.25	4.05	4.05	0.9946
Jun-99	0.9975	0.9500	0.6000	0.5686	6	0.30	102.60	2.51	8.35	0.9971
Jul-99	0.9988	0.9800	0.6500	0.6362	7	0.13	92.89	1.21	8.07	0.9986
Aug-99	0.9906	0.8810	**0.9032**	0.7882	2	0.45	247.7	1.21	2.69	0.9982
Sep-99	0.9632	**1.0000**	0.8333	0.8026	3	1.23	179.08	5.16	4.19	0.9932
Oct-99	0.9825	0.9735	0.7742	0.7405	3	0.60	185.55	2.42	4.04	0.9968
Nov-99	0.9813	0.9581	0.8000	0.7521	7	0.27	89.77	2.65	9.75	0.9970
Dec-99	**0.9999**	0.9960	0.7419	0.7389	1	0.10	371.95	0.13	1.34	0.9997
AVERAGE	0.9910	0.9561	0.7881	0.7467	3.25	1.06	216.49	3.15	4.37	0.9954
BEST IN CLASS	**0.9999**	**1.0000**	**0.9032**	**0.9031**	**1**	**0.10**	**371.95**	**0.13**	**1.34**	**0.9997**
STD. DEV	0.0108	0.0319	0.0905	0.0744	2.22	1.64	104.50	2.76	2.88	0.0047

FIG. 8.10 O.E.E. OF ACID PLANT 1



catalyst. SO_3 is absorbed in concentrated sulphuric acid and the product is diluted to yield 98 – 98.5% acid.

The Acid Plant 1 has been chosen for calculating overall equipment effectiveness.

- **Calculation Procedure:**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Running Time – Total Downtime) / Running Time
PERFORMANCE RATE = Avg. Monthly Production / Standard Monthly Production
QUALITY RATE = Number of Quality Acid Reports (>98 %) / Total Reports

Table 8.10 shows the matrix indicating O.E.E. calculations and other maintenance parameters for Acid Plant 1 of PC-3 from the period January 1999 to December 1999.

Fig 8.10 shows the trend in O.E.E. over this period. A sample calculation is shown in Annexure 3.

8.7.4 BOILER

Energy Centre 1 has 3 boilers of capacity 75 TPH each. The main steam pressure is around 64 kg/cm2 and the main steam temperature is maintained at 485^0C. Coal consumption is around 503 TPD.

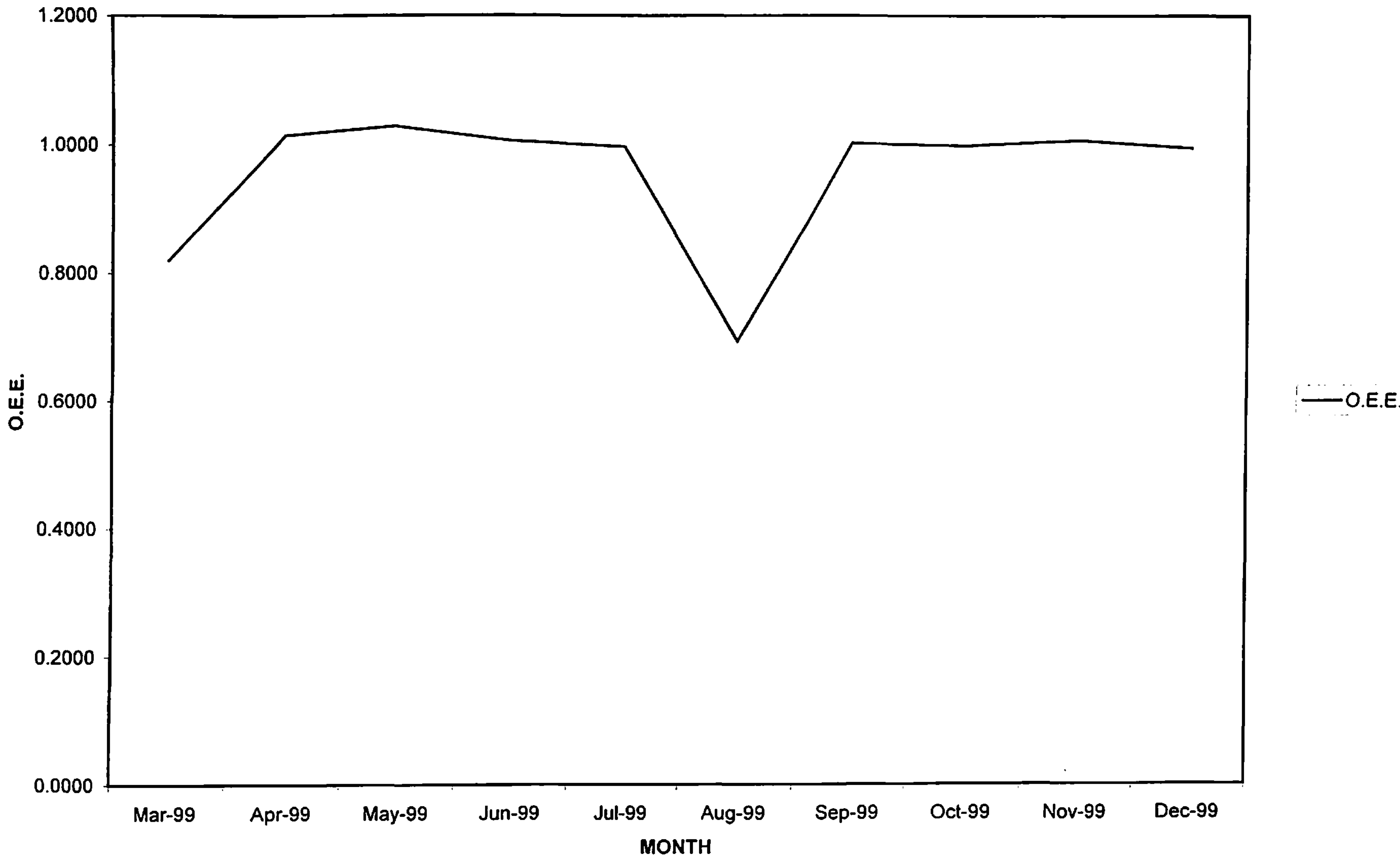
Boiler – 1 of EC-1 has been chosen for calculating overall equipment effectiveness.

TABLE : 8.11

O.E.E CALCULATION OF BOILER - 1 OF ENERGY CENTRE - 1

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	O.E.E	Freq. Of Stoppages	MDT hrs.	M.T.B.M hrs.	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Jan-99	0.0000	0.0000	0.0000	0.0000	1	744.00	0.00			0.0000
Feb-99	0.0000	0.0000	0.0000	0.0000	1	672.00	0.00			0.0000
Mar-99	0.8172	1.0027	1.0000	0.8194	1	136.00	304.00	223.68	1.65	0.6909
Apr-99	1.0000	1.0142	1.0000	1.0142	0	0.00	720.00	0	0.00	1.0000
May-99	1.0000	1.0286	1.0000	1.0286	0	0.00	744.00	0	0.00	1.0000
Jun-99	0.9993	1.0065	1.0000	1.0058	1	0.50	359.75	0.695	1.39	0.9986
Jul-99	1.0000	0.9967	1.0000	0.9967	0	0.00	744.00	0.00	0.00	1.0000
Aug-99	0.7124	0.9720	1.0000	0.6925	1	214.00	265.00	403.77	1.89	0.5532
Sep-99	0.9847	1.0178	1.0000	1.0022	1	11.00	354.50	15.514	1.41	0.9699
Oct-99	1.0000	0.9978	1.0000	0.9978	0	0.00	720.00	0	0.00	1.0000
Nov-99	0.9958	1.0104	1.0000	1.0062	1	3.00	370.50	4.1841	1.40	0.9920
Dec-99	0.9906	1.0036	1.0000	0.9942	1	7.00	368.50	9.4979	1.36	0.9814
AVERAGE	0.9500	1.0050	1.0000	0.9548	0.67	148.96	412.52	65.73	0.91	0.7655
BEST IN CLASS	**1.0000**	**1.0286**	**1.0000**	**1.0286**	**0**	**0.00**	**744.00**	**0**	**0**	**1.0000**
STD. DEV	0.1008	0.0151	0.0000	0.1099	0.49	270.24	268.43	137.52	0.80	0.3857

FIG. 8.11 O.E.E.OF BOILER 1



- **Calculation Procedure:**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Calendar Time – Total Downtime) / Calendar Time
PERFORMANCE RATE = Actual Production Rate / Standard Production Rate
QUALITY RATE = 1.0

Table 8.11 shows the matrix indicating O.E.E. calculations and other maintenance parameters for Boiler 1 of EC-1 from the period January 1999 to December 1999.

Fig 8.11 shows the trend in O.E.E. over this period. A sample calculation is shown in Annexure 5.

8.7.5 Turbines

Pressure-velocity compounded impulse turbines are used in the power plant. The pressure energy of steam is converted into kinetic energy to give rotary motion to the turbine. Alternators and exciters connected to the turbine convert it into electrical power. The BHEL Turbine has a generation capacity of 16.5 MW with terminal voltage of 6.6 KV and frequency 50 HZ.

BHEL Turbine of EC-1 has been chosen for calculating overall equipment effectiveness.

- **Calculation Procedure:**

O.E.E. = AVAILABILITY X PERFORMANCE RATE X QUALITY RATE

AVAILABILITY = (Calendar Time – Total Downtime) / Calendar Time
PERFORMANCE RATE = Actual Production Rate / Standard Production Rate
QUALITY RATE = 1.0

TABLE : 8.12

O.E.E. CALCULATION OF BHEL TURBINE OF ENERGY CENTRE - 1

MONTH	AVAILABILITY	PERFORMANCE	QUALITY	OEE	Freq. Of Stoppages	MDT hrs.	M.T.B.M hrs.	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
Jan-99	1.0000	0.9200	1.0000	0.9200	0	0.00	744.00	0	0	1.0000
Feb-99	1.0000	0.8806	1.0000	0.8806	0	0.00	672.00	0	0	1.0000
Mar-99	1.0000	0.7652	1.0000	0.7652	0	0.00	744.00	0	0	1.0000
Apr-99	1.0000	0.6729	1.0000	0.6729	0	0.00	720.00	0	0	1.0000
May-99	1.0000	0.6684	1.0000	0.6684	0	0.00	744.00	0	0	1.0000
Jun-99	0.9667	0.8774	1.0000	0.8482	1	24.00	348.00	34.48	1.44	0.9355
Jul-99	1.0000	0.9032	1.0000	0.9032	0	0.00	744.00	0	0	1.0000
Aug-99	1.0000	0.7510	1.0000	0.7510	0	0.00	744.00	0	0	1.0000
Sep-99	0.9806	0.6626	1.0000	0.6497	1	14.00	353.00	19.83	1.42	0.9619
Oct-99	1.0000	0.6303	1.0000	0.6303	0	0.00	744.00	0	0	1.0000
Nov-99	0.9972	0.6645	1.0000	0.6626	1	2.00	359.00	2.78	1.39	0.9945
Dec-99	1.0000	0.7174	1.0000	0.7174	0	0.00	744.00	0.00	0	1.0000
AVERAGE	0.9954	0.7595	1.0000	0.7559	0.25	3.33	638.33	4.76	0.35	0.9910
BEST IN CLASS	**1.0000**	**0.9032**	**1.0000**	**0.9032**	**0**	**0.00**	**744.00**	**0**	**0**	**1.0000**
STD. DEV	0.0106	0.1078	0.0000	0.1064	0.45	7.64	173.13	10.9471	0.6408	0.0206

FIG. 8.12 O.E.E.OF BHEL TURBINE

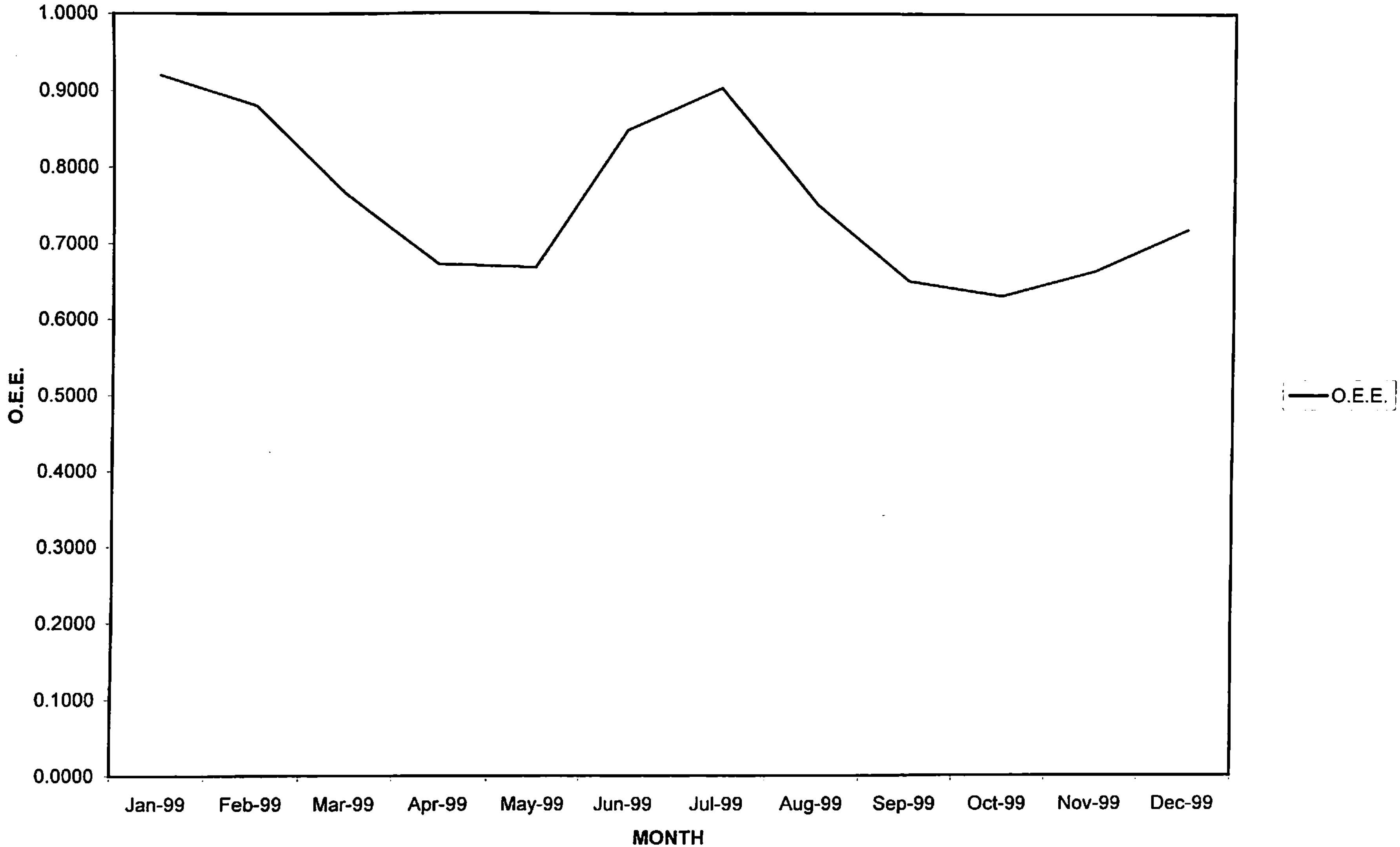


Table 8.12 shows the matrix indicating O.E.E. calculations and other maintenance parameters of BHEL Turbine 1 of EC-1 from the period January 1999 to December 1999.

Fig 8.12 shows the trend in O.E.E. over this period. A sample calculation is shown in Annexure 6.

8.7.6 Benchmarking Maintenance Parameters

The important parameters relating to maintenance are the overall equipment effectiveness, mean time between maintenance, mean downtime, severity index, frequency index and operational availability.

Table 8.13 shows the best-in-class values of the key equipment at Staple Fibre Division. Fig. 8.13 and Fig. 8.14 shows a comparison among the best-in-class values of O.E.E. and M.T.B.M.

These best-in-class values act as a benchmark for further improvement. The maintenance personnel should continuously strive for not only achieving the targets but also to create new benchmarks for the maintenance parameters, through increased availability, reduced downtime, better performance and better quality.

8.8 Overall-Plant-Effectiveness

The overall equipment effectiveness gives only the system effectiveness or the machine effectiveness. It has been observed that there are many factors, which affect the O.E.E. other than the equipment itself. The Overall Plant Effectiveness takes into account other factors related to downstream and upstream process parameters and factors which directly or indirectly affect O.E.E. The performance of spinning machines depends upon the performance of the viscose and auxiliary units. The various factors, which affect O.E.E. of spinning machines are discussed below:

TABLE 8.13

BENCHMARKING OF MAINTENANCE PARAMETERS
OF KEY EQUIPMENT IN STAPLE FIBRE DIVISION

BEST IN CLASS VALUES

S.No	EQUIPMENT	OEE	MDT	MTBM	SEVERITY INDEX	FREQUENCY INDEX	OPERATIONAL AVAILABILITY
1	SPINNING MACHINE - 8	0.9342	2.87	141.40	16.97	5.66	0.9792
2	SPINNING MACHINE - 9	0.9762	3.07	252.81	11.63	2.97	0.9847
3	SLURRY PRESS - X1	0.7469	2.06	34.74	70.77	27.35	0.9227
4	MSFE- 6	0.8495	2.33	104.24	19.18	8.22	0.9781
5	ACID PLANT- 1	0.9031	0.10	371.95	0.13	1.34	0.9997
6	BOILER-1	1.0286	0.00	744.00	0.00	0.00	1.0000
7	BHEL TURBINE-1	0.9032	0.00	744.00	0.00	0.00	1.0000

BENCHMARKING PARAMETERS : YEAR 2000-2001

S.No	PARAMETERS	NAGDA	HARIHAR	BCP	IBR	TRC	BEST
		M.P	KARNATAKA	KHARAUCH	INDONESIA	THAILAND	
1	**PULP CONSUMPTION RATIO**	**0.992**	1.002	1.018	1.019	1.014	NAGDA
2	**CAUSTIC CONSUMPTION RATIO**	**0.524**	0.555	0.544	0.551	0.552	NAGDA
3	**CS2 CONSUMPTION RATIO**	**0.149**	0.150	0.157	0.172	0.163	NAGDA
4	**ACTUAL PRODUCTION**	336.3	106.2	157.1	236.4	188.7	
5	**QUALITY**						
	% (G + R)	95.3	92.5	94.5	96.7	**98.2**	TRC
	% (M+ P)	0.13	**0.12**	1.2	0.15	**0.12**	TRC/HHR
6	**DOWNTIME**						
	Spinning Machine Downtime	2.57	**1.43**	2.61	1.55	1.85	HHR
	Dryer Downtime	1.91	2.23	2.78	0.96	**0.68**	TRC

FIG. 8.13 BEST IN CLASS O.E.E.

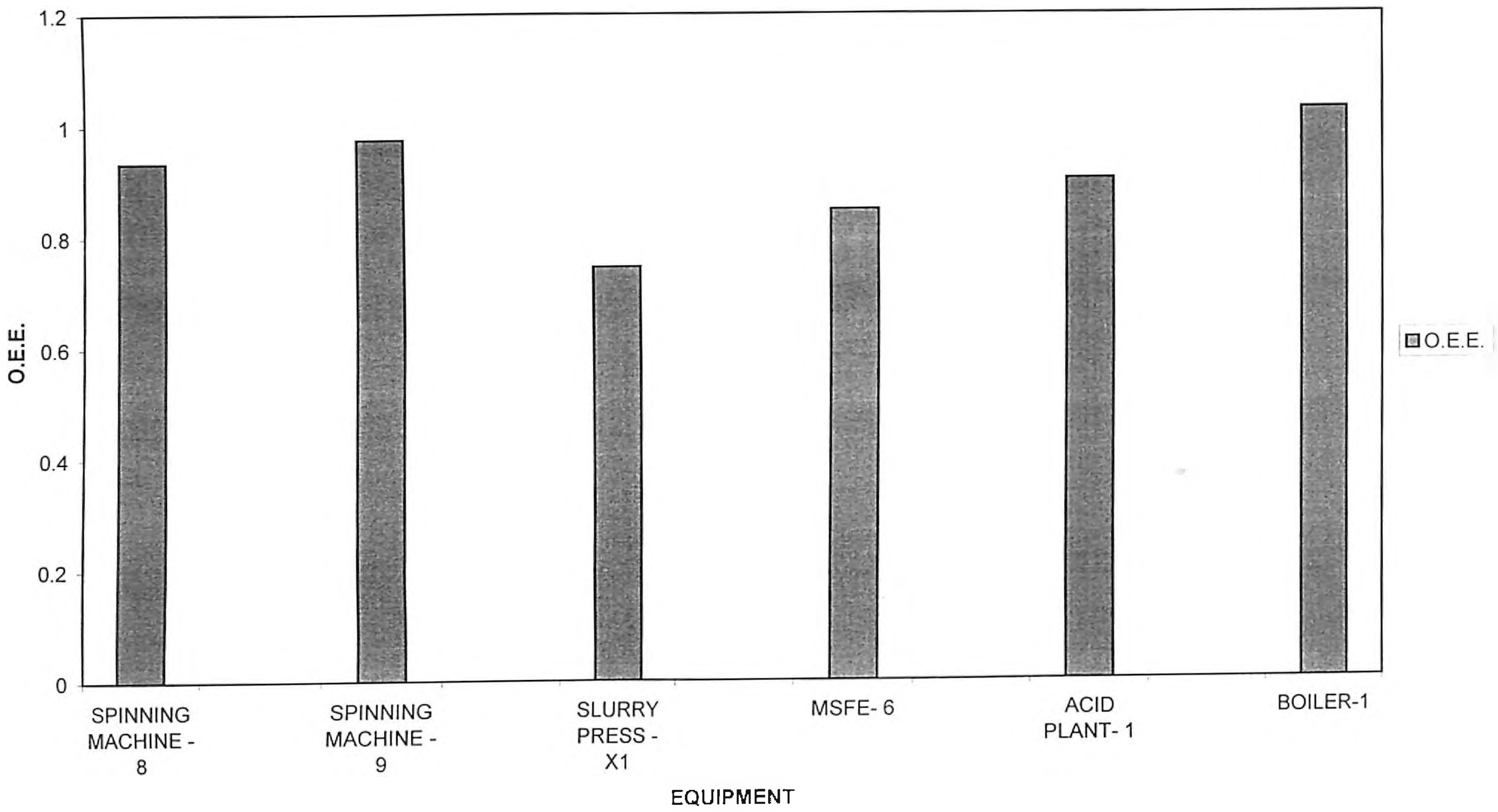
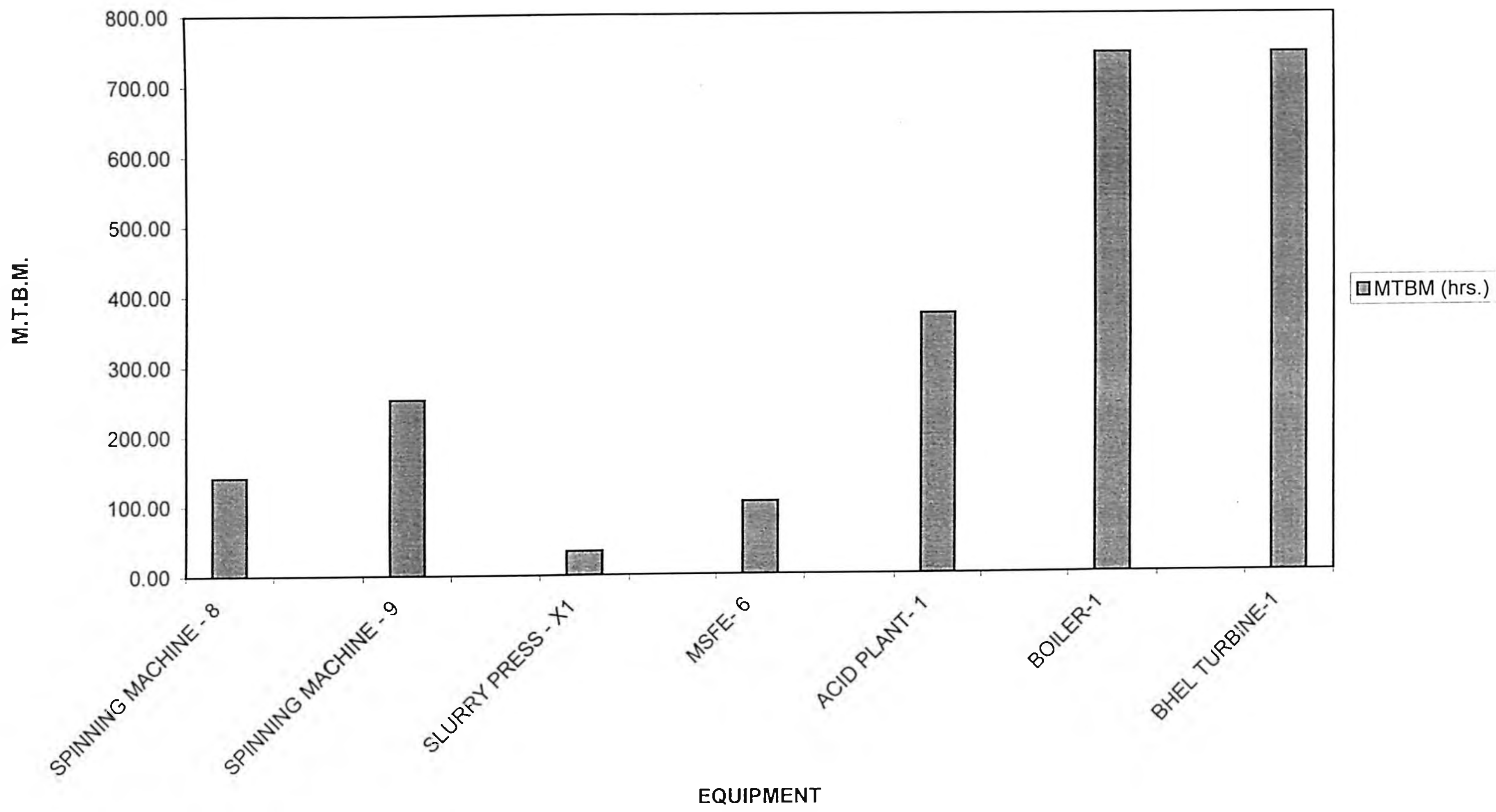


FIG. 8.14 BEST IN CLASS M.T.B.M.



8.8.1 Factors affecting Performance

The Viscose department produces viscose of certain quantity, which suits the production level of fibre in the spinning department. Hence if the viscose generation / availability is low, then automatically the production level cannot be achieved and machine has to be run at lower speeds.

The auxiliary department helps in maintaining the spin bath conditions. Hence the spin bath temperature has to be suitably maintained for better performance. It is normally maintained at 48^0 C.

8.8.2 Factors affecting Quality

The quality of fibre depends upon the quality of pulp, viscose generated and the cellulose. Hence the factor K_w is of great significance. Higher the value of K_w, lower the quality of viscose / cellulose. The other process parameters like ball-fall, ripening index, etc. should also be maintained at the desired values.

The acid percentage, sulphate percentage and spinbath clarity plays an important role in deciding the quality of fibre. Hence they have to be maintained at the desired levels.

8.9 Fibre Quality Determination

The Quality of fibre depends upon various factors. The customers value these factors at different scale at their end depending upon their purpose of use. The various characteristics of fibre are Spinning faults, OPU, Denier, Colour, Moisture Content, Bundle tenacity, Staple Length, Elongation of single fibre and Nep Potential. [3]

8.9.1 Fibre Characteristics:

❖ **Spinning Fault:**

Spinning Fault is hard mass of fused fibre. These are controlled by maintaining viscose and spin bath conditions. There are three types of spinning faults:

Big - 3/4 inch and above

Small - Between 1/2 inch and less than 3/4 inch

Speck - Less than 1/2 inch.

Norm is Fault - free fibre

❖ **Oil Pick Up (OPU):**

Oil Pick Up is the finish carry-over with the fibre.

% OPU = (Difference x 100) / 10.0

Norm: 0.30 - 0.40 %

❖ **Nep Potential:**

Neps may be considered as small tight balls of tangled fibres,which can lead to the downgrading of the fabric.

There are three types of Neps:

Large: > 2.5 mm

Medium - Between 1.5mm and 2.5 mm

Small: < 1.5 mm

The micronaire value gives an indication of the nep potential.

Norm: Neps Free Fibre

- **Colour**:

Whiteness of bright / dull fibre and shade of colour is checked for consistency point of view. The dye pick-up is also assessed in bright / dull fibre.

Norm : More or less matching to the standard sample in colour fibre.

Greater than or equal to 68 in bright / dull fibre.

- **Denier :**

The denier of a filament is the linear density expressed as the mass in gram of 9000 m length of fibre.

Denier is the fineness of fibre. It is the gram weight of 9000 m long single filament.

Norm for 1.5 denier is less than or equal to 1.50

- **Single Tenacity**:

The tenacity of a material is the mass stress at break, the unit being grams per denier. An alternative term for tenacity is specific strength, which can be defined as the force required to break a single fibre.

In technical term, it is called tenacity and denoted by gm/denier.

Norm: For 1.5 denier:

B/B (Bright Bleach) > 2.5 gm/ denier

Colour (specifically for darker shades) > 2.47 gm/denier

- **Bundle Fibre Tenacity**:

This is the strength of bunch of fibre. It is the braking load of bunch of fibre and determined by dividing the braking load with denier.

Norms: For 1.5 denier

B/B (Bright/Bleach) > 2.30

Colour Fibre > 2.25

❖ **Elongation**:

When the load is applied to a specimen a certain amount of stretching takes place. The strain is the term used to relate the stretch or elongation with the initial length.
Norm is 18 - 23 %

❖ **Moisture**:

Most textile fibres absorb more or less moisture from the surrounding atmosphere. The moisture present in a textile fibre or material is usually expressed as a percentage of the original weight of the material or its oven dry weight.

Due to hydroscopic nature of cellulosic fibre, we find out moisture regain in place of moisture. Moisture regain is calculated on dry-fibre basis.

$$\% \text{ Moisture regain} = \frac{\text{Initial Weight of Fibre} - \text{Final Weight of Fibre}}{\text{Final weight of Fibre}} \times 100$$

Norm : 13 %

❖ **Staple Length** :

Cut length is analyzed for machinery setting of textile mills for yarn making. As per customer's requirements, viscose fibre is cut in staple length of 27 mm to 120mm.

The estimate of the distance between the fibre ends when a tension applied is just sufficient to remove the crimp.
Norm : Free form long and short fibre

❖ **Effective Length**:

This value has been defined as the length of the main bulk of the longer fibres.

8.9.2 Empirical Formula

Each fibre parameters are assigned different weightages and the different grades of fibre produced is also given certain points as given below:

Fibre Parameters (U)		Fibre Grade (G)	
Spinning Fault	15	G	10
OPU	15	R	8
Colour	12	S	5
Denier	12	M	2
Moisture	10	P	0
Bundle Tenacity	10		
Neps Potential	10	**Pulp Make (K)**	
Elongation	8	Indian Pulp	97%
Staple Length	8	Canadian Pulp	99%

Based on the grades and weightages assigned to various fibre characteristics, the fibre quality can be determined by the formula:

$$\textbf{Calculated quality} = \frac{U_1G_1 + U_2G_2 + U_3G_3 + \ldots\ldots}{U_1 + U_2 + U_3 + \ldots\ldots}$$

$$\textbf{Deem Quality} = \frac{\text{Calculated Quality}}{K}$$

$$\textbf{Average Quality} = \frac{\Sigma\,(\text{No. of bales x Deem Quality})}{\Sigma(\text{No. of Bales})}$$

TABLE : 8.14

FIBRE QUALITY DETERMINATION

MONTH : MACHINE NO. :

S.No	Bale No	Make	No. Of Bales	S	O	C	N	B	D	M	L	E	Cal Quality	Deem Quality
1		Indian	20	G	G	G	G	G	G	G	G	G	100.00	103.09
2		Canadian	40	R	G	G	G	G	G	G	G	G	97.00	97.98
3		Indian	20	S	G	G	G	G	G	G	G	G	92.50	95.36
4		Indian	25	R	R	R	R	R	R	R	R	R	80.00	82.47
5		Indian	33	M	M	M	M	M	M	M	M	M	20.00	20.62
6		Indian	24	P	P	P	P	P	P	P	R	P	6.40	6.60
7		Canadian	24	S	S	G	G	G	G	G	G	G	85.00	85.86
8		Indian	21	G	M	G	G	G	G	G	G	G	88.00	90.72
9		Canadian	15	G	P	G	G	G	G	G	G	G	85.00	85.86
10		Canadian	22	G	G	R	G	G	G	G	G	G	97.60	98.59
11		Canadian	25	G	G	S	G	G	G	G	G	G	94.00	94.95
12		Indian	22	G	G	M	G	G	G	G	G	G	90.40	93.20
13		Canadian	33	G	G	R	G	G	G	G	G	G	97.60	98.59
14		Indian	31	G	G	G	R	G	G	G	G	G	97.60	100.62
15		Canadian	24	G	G	G	S	G	G	G	G	G	94.00	94.95
16		Indian	26	G	G	G	M	G	G	G	G	G	90.40	93.20
17		Canadian	28	G	G	G	P	G	G	G	G	G	88.00	88.89
18		Indian	22	G	G	G	G	R	G	G	G	G	98.00	101.03
19		Canadian	24	G	G	G	G	S	G	G	G	G	95.00	95.96
20		Canadian	25	G	G	G	G	M	G	G	G	G	92.00	92.93
21		Indian	22	G	G	G	G	P	G	G	G	G	90.00	92.78
22		Canadian	40	G	G	G	G	G	R	G	G	G	98.00	98.99
23		Indian	34	G	G	G	G	G	S	G	G	G	95.00	97.94
24		Canadian	32	G	G	G	G	G	M	G	G	G	92.00	92.93
25		Canadian	23	G	G	G	G	G	P	G	G	G	90.00	90.91
26		Indian	20	G	G	G	G	G	G	R	G	G	98.00	101.03
27		Indian	45	G	G	G	G	G	G	S	G	G	95.00	97.94
28		Canadian	44	G	G	G	G	G	G	M	G	G	92.00	92.93
29		Canadian	30	G	G	R	G	G	G	P	G	G	87.60	88.48
30		Indian	32	G	G	G	G	G	G	G	R	G	98.40	101.44
31		Canadian	21	G	G	G	G	G	G	G	S	G	96.00	96.97
32		Indian	34	G	G	G	G	G	S	G	M	G	88.60	91.34
33		Indian	50	G	P	G	M	G	G	G	P	G	67.40	69.48
34		Indian	24	G	G	R	S	M	G	P	G	G	73.60	75.88
35		Canadian	22	G	R	S	M	P	G	R	S	G	65.40	66.06
36		Indian	21	G	S	R	P	M	G	P	S	G	56.10	57.84
37		Canadian	20	R	R	S	M	P	G	S	G	G	63.40	64.04
38		Canadian	18	M	M	M	M	M	M	M	M	G	26.40	26.67
39		Indian	12	S	S	S	S	S	S	S	S	G	54.00	55.67
40		Indian	12	R	R	R	R	R	R	R	R	G	81.60	84.12
41		Indian	21	G	R	G	P	R	M	P	R	G	63.40	65.36
42		Canadian	30	R	R	R	R	R	R	R	R	G	81.60	82.42
43		Indian	18	R	G	R	G	G	G	R	R	G	91.00	93.81
44		Canadian	18	R	G	R	G	R	G	R	P	G	82.60	83.43
45		Canadian	25	G	R	G	G	G	G	G	P	G	89.00	89.90
													Avg Quality	85.06

A format has been developed in Microsoft Excel as shown in Table 8.14, in which following data are to be entered:

Bale Nos., Pulp Make, Fibre Grade and the quality of fibre in terms of calculated quality, deem quality and average quality can be directly found out.

The format serves to be useful to the textile department, sales and quality assurance departments for determining the fibre quality. The weightages of the fibre characteristics and the value of K can be altered as per the customer's needs and pulp quality respectively.

This chapter thus focussed on defining various maintenance parameters and calculated the overall equipment effectiveness of key equipment of various departments of the Staple Fibre Division. Benchmarking has also been done for further improvement.

The next chapter deals with a new concept of increasing the availability of equipment by utilizing the stoppage time for performing other maintenance work like repairs, replacement, modifications etc.

CHAPTER 9

NEED - CUM - OPPORTUNITY BASED MAINTENANCE

9.1 Introduction

Availability is an important aspect of Overall Equipment Effectiveness. The more the frequency of downtime and the duration of stoppages, the less is the availability and lower is the overall equipment effectiveness. Hence, it is necessary to achieve minimum downtime of equipment through better coordination amongst all the related departments. Any machine stoppage gives an opportunity for all the departments to carry out their jobs according to priority and availability of resources. It is always preferable to reduce the frequency index of the stoppages, so as to maximize the effectiveness and utilizing the lost time due to stoppage. Hence, whenever machine stoppage takes place, all the departments should be alert enough to utilize the downtime to the fullest.

9.2 Defining Need:

The need for maintenance is felt when certain equipment requires repair or replacement of the components. Predictive Maintenance is generally called for when there is vibration or noise on certain components. This requires immediate attention and stoppage is taken to attend the abnormality. Need also arise when certain schemes have to be implemented or modifications have to be carried out. For carrying out all these activities, machine stoppages have to be taken. It is this opportunity, which the maintenance people can make use of it in carrying out pending jobs.

Hence, the maintenance department should have a list of pending jobs, material and labor readily available during the stoppage. If the stoppage of the spinning machine is due to mechanical fault, the electrical and civil department can take this opportunity and carry out their pending work.

9.3 Defining Opportunity:

Opportunity for maintenance generally occurs during following conditions:

- **Quality Change:**

Spinning machines produce fibre of different denier, shades and color. Stoppages have to be taken when these characteristics need to be changed. Normally a stoppage of 2-hour duration is taken on the machine.

- **Accumulation Clearing:**

When there is a change in quality, the machine is stopped and the fibre produced out of previous quality has to be cleared. This results in accumulation of fibre. The fibre is also removed when there is fire or a problem occurs in dryer, spike lattice or the pneumatic handling system. The fibre gets accumulated near the dryer end. The clearing of fibre normally takes 4-6 hours.

- **Power Failure**

Whenever the power fails the machine stops. After the resumption of power, the machine can be restarted only after few hours, as the process parameters need to be set again.

- **Breakdown**

The machine stoppage takes place whenever a critical component fails. The component has to be repaired or replaced before the machine restarts.

- **Target is lower than the capacity of the machine**

Whenever the target is lower than the capacity, the machine is run at low speeds. If some jobs are pending, then the machine can be run on normal speeds and stoppages can be taken after the target production is met.

- **Viscose generation is not sufficient for full-capacity production**

If the viscose generation is not sufficient for full capacity production, then the target of fibre production is reduced or the machine is run at low speed. If required stoppages are also taken.

- **Preventive Maintenance**

Preventive maintenance on spinning machines is normally taken every 55 days. All pending jobs are carried out during this stoppage. The duration of preventive maintenance is normally for 10-12 hours.

- **Planned Stoppage**

When any critical job has to be carried out or modifications / new schemes have to be implemented, the machine stoppages are taken. During the planned stoppage, other pending jobs are also carried out.

9.4 Guidelines for Need-Cum-Opportunity Based Maintenance (NOBM)

Following guidelines should be followed for implementation of NOBM concept:

- All departments should be aware of the stoppages taking place on any equipment.
- Each department should list out the jobs to be taken under NOBM under the heads Short Term Jobs (STJ), Medium Term Jobs (MTJ) and Long Term Jobs (LTJ) and should also state whether the jobs are critical or non-critical.
- Short Term Jobs are the jobs, which can be carried out within 2 hrs. Medium Term Jobs are the jobs, which would take 2-4 hrs. And Long term Jobs are the jobs, which would take more than 4 hrs.
- Short Term Jobs should be carried out during stoppages like Quality Change, or during small breakdowns of 2 hours duration.
- Medium Term Jobs can be carried out during Accumulation Clearing and Planned Stoppages or when the viscose generation is not sufficient to give full production.
- Long term Jobs can be carried out during Preventive Maintenance.
- It will be the responsibility of the Process Department to inform other departments like Mechanical, Electrical, Instrumentation and Civil that a stoppage has been taken and their jobs can be carried out during the stoppage time.
- The manpower and spare parts requirement should also be indicated during the listing of jobs and the same should be available at once during the stoppage time to avoid any supply downtime.
- Critical Jobs will be taken first and then the other non-critical jobs.

These guidelines will help in achieving better coordination among various departments. The spares and labor can be optimally utilized and the frequency of stoppages can be greatly reduced resulting in increased availability.

9.5 Modus Operandi

Each department will maintain a register or the format as shown in Table 9.1. The engineer will enter the data as an when he identifies the need for maintenance of certain component or equipment. He would also specify the expected duration of the job to be performed in terms of STJ/MTJ/LTJ. He would also specify whether the job is critical or not. In the discipline column, he would enter the nature of the job, i.e. process, mechanical, electrical, instrumentation, civil etc. The data can also be fed in the computer in the proposed format.

The data will be sorted daily in terms of duration of the jobs, criticality, discipline and status of the job, which would help the engineers to take up the jobs on priority basis and proper planning can be done beforehand.

If an opportunity occurs due to quality change, accumulation etc. the jobs will be carried out according to the guidelines and the job duration will be entered in the scheduled stoppage column. But if there is no opportunity and the job has to wait, the following criteria will be used:

If the job can wait only upto 24 hours	:	Breakdown
Jobs can wait between 24 - 72 hours	:	NOBM
Jobs can wait more than 72 hours	:	Planned Stoppage

The above guidelines suggest that if the job cannot wait for more than 24 hours and becomes critical, then the stoppage is taken and is treated as a breakdown. However, if the job can wait between 24 and 72 hours, and there is no opportunity to carryout the job, then the opportunity has to be created and stoppage needs to be taken. This stoppage will be treated as NOBM. If the job can wait more than 72 hours, then the stoppage will be considered as planned stoppage.

TABLE : 9.1

NEED-CUM-OPPORTUNITY BASED MAINTENANCE

S.No	Need Identification			Eqpt.	Nature	Discipline	Job Duration			Job Performed	Waiting (hrs.)			Stoppage	Completion		Status
	Date	Time	Description				STJ	MTJ	LTJ	(Opportunity)	<24	24-72	> 72	SCH.NOBM B/D	Date	Time	

9.6 Advantages:

The advantages of NOBM are listed below:

- Every department can plan their work and list the jobs to be carried out during any stoppages.
- The availability of the manpower and spares can be planned and optimally utilized.
- Clubbing of planned and unplanned jobs can be done which increases equipment availability and performance.
- Each department is aware of the problems occurring in the plant and thus can contribute to finding the solution.
- Reduction in the frequency of stoppages
- Breakdowns can be greatly reduced due to periodic checking during stoppages
- Supply downtime can be reduced as spares and labor are readily available

9.7 TIC Concept

The concept of TIC (To inform & confirm) helps in transmitting important and relevant information to top management by plant personnel. The Top Management is interested with matters related to activities, which directly affect the production and thus the profitability of the organization. This concept gives a focussed information of the plant working, thus saving management time. This also helps in highlighting problems and formulating action plans during the interaction itself.

To Inform:

- Daily Production
- Important Process parameters
- Quality Change and Accumulation
- Stoppages taken and the duration
- Major Breakdown and the Remedial Action Taken

- Results of Modifications and Suggestions Implemented
- Quality and Performance
- Standard Guidelines not followed and the reasons for the same

To Confirm:

- Stoppages for emergency breakdowns / planned maintenance
- Suggestions / Modifications are to be implemented or not
- Corrective Actions for recurring problems
- Decisions affecting Production and Not Affecting Production
- Decisions necessary which violates the standard guidelines

Advantages

- ❖ Effective communication between top level and bottom level management.
- ❖ Highlighting of recurring problems
- ❖ Action plans can be quickly formulated
- ❖ Quicker Decision Making
- ❖ Enhances the confidence of shift-level engineers
- ❖ Abnormalities can be easily identified
- ❖ Saves Top management's valuable time

This chapter thus described the concept of Need-cum-Opportunity Maintenance and suggests guidelines for implementing it. This concept helps in better time management and utilization of available resources. The availability of the plant increases and all concerned departments can get their work done during this stoppage. To inform and confirm concept helps in better reporting and decisions can be taken in a focussed manner.

The next chapter deals with the methods and techniques of maintenance prevention and improving maintainability. Various non-destructive testing techniques, condition monitoring and vibration monitoring techniques help in maintaining the condition of equipment and predicting failure.

CHAPTER 10

MAINTENANCE PREVENTION & MAINTAINABILITY IMPROVEMENT

10.1 Introduction

World-Class Maintenance aims at preventing maintenance and improving the maintainability of the equipment. "Prevention is better than cure", this proverb sounds rightly in case of maintenance also. If the maintenance is prevented, then the availability of the plant increases and the overall cost reduces. Every effort should be made to avoid maintenance, which can be achieved through continuous monitoring of equipment and upgrading the sophistication of the equipment through better design and process improvement.

10.2 Methods of Maintenance Prevention

The various methods of maintenance prevention are:

- Design change
- Size change
- Material change
- Process Improvement
- Vendor change

These methods have been adopted in Spinning & After Treatment departments of Staple Fibre Division, which resulted in reduced downtime and better working of the plant.

Table 10.1 shows the various changes made in Spinning & After-Treatment departments to prevent maintenance.

10.3 Cases from Staple Fibre Division

Spinning & After Treatment Department

1. Cutter Drive Gear box:

The cutter drive gear box was prone to frequent failures caused due to excessive failure of clutch plates. There were excessive vibrations of rotating parts causing high sound level, higher set- up time, and individual drive required machine stoppage for isolation. Hence, a design change was necessary to overcome these problems.

A Separate servo-drive was coupled to each cutter along a linear RPM controller linked to machine (speed) gear box, thereby eliminating staple gear and mechanical assembly in cutter drive gear box. The results indicated that the initial investment reduced by 2 lacs/machine, downtime reduced by 0.3%, maintenance cost reduced by 3 lacs/year/machine and power consumption reduced by 1 Lac/machine/year

2. Trio Roller Shaft

It was observed that trio roller shaft was subjected to:

- High Load
- Tow stretch
- Failure of shafts due to stress and strain
- Notch sensitivity

TABLE: 10.1

MAINTENANCE PREVENTION

Spinning & After Treatment Department

S.No	Technique	Equipment/Component	From	To
1	Design Change	Cutter	Cutter drive gear box	Separate servo drive
		Godet / PP shaft drive	Fenner gear box	Reduction gear box
		Drum Drive	Stubber Gear Box	Frequency Drive
		Dryer drum drive coupling	Split couplings	Universal couplings
		Baling Press	Rotary separator	Stationary Separator
		Nip rollers, nip roller		
		conveyor, rotary separator	Existed	Removed
		wet end rubbing drum		
		Craighton Opener	Existed	Removed
		Intermeidate opener unit	Existed	Removed
2	Material Change	Trio Roller	Granite roller	DIN 1.4539/SS904L
		Sump zone Bars	Teak wood	DIN 1.4539/SS904L
		Cutter	Granite segments	Ceramic segments
		Conveyor Fix Beam	MS Rubber lined	DIN 1.4539
		Eccentric Shell	MS Rubber lined	DIN 1.4539
		Spike Lattice Lathe	MS/CRCA	SS 316L
		Shutter Conveyor	MS	SS 316
		Dryer Drum Seal	Silicon Rubber	Nomex
3	Size Change	Trio Roller	115mm dia shaft	135mm dia shaft
		Shutter Conveyor Lathe	1.2 mm thickness	1.6 mm thickness
4	Process Improvement	After treatment conveyor	Direct Drive	Servodrive
		Dryer	Steam coils existed	removed
			Fan RPM	optimized
			Inlet air area	increased
			Drying was less	Addition of two drums
5	Vendor change	Cutter arm cross pieces	M/s Maheshwari Engg.	M/s Mohta Engg.
		Bearings	FAG / others	SKF Bearings only
		Dryer Fan belts	Any	Hilton only (BX 54)
		Pulleys	Any	Fenner Only
		Hydraulic system	Any	Vickers only

- Environmental condition (acidic medium)
- Frequent pitting leading to micro blowholes

These problems necessitated a change in design of trio roller shaft and following changes have been incorporated:

- Radius at notch sensitive areas
- Locating by M-60 threads
- Size increase from 115mm to 135mm to take the high load
- Bearing changed from 232226 to 23130K

3. Dryer

Various steps have been taken to prevent maintenance in dryer. The main causes of failure in dryer are due to mechanical failure as indicated in Table 8.1 and Table 8.2. The nip rollers, nip roller conveyor, wet end rubbing drum were used for opening of fibre. These elements cause fibre-jamming, contamination of fibre leading to breakdown and bad quality of fibre. These elements have been removed so that the fibre coming from spike lattice goes straight to feed conveyor and then to dryer. This resulted in reduction in frequency of breakdowns, downtime, spillage of fibre. There was an improvement in the distribution of fibre on feed conveyor and the quality also improved significantly.

The intermediate opener unit is also removed completely as it disturbs the fibre distribution on drums causing breakdown and fibre dropping. The removal of Craighton opener has resulted in reduced breakdowns and fibre jamming.

The bottom most steam coils from whole dryer is removed to reduce system resistance. This resulted in availability of more air and reduction in fan RPM, hence saving in power. Two additional drums are added in dryer to increase heat transfer area for better drying.

10.4 Maintainability

When equipment is undertaken for repair, the ease with which it is brought back to its original operational condition is called maintainability. Maintainability is thus the probability that a unit or system will be restored to specified conditions within a given period when maintenance action is taken in accordance with prescribed procedures and resources. It is a characteristic of the design and installation of the unit or system.

The specified conditions to which the unit is required to be restored are generally with reference to its performance characteristics after it is repaired. These performance characteristics are specified in advance and are indicative of the satisfactory performance of the unit. The time within which the item is restored to the specified conditions is an important factor. The resources as if labor, tools, spares etc. should be readily available in order to minimize supply downtime.

Repair is a common operation as the cost of repair or replacement is much less than that of replacing the entire system. There are many systems, which are life supporting and critical in nature, where repair and replacement is not considered, from the point of view of safety. Ignoring such situations, repair and maintenance make a system available for use for a long period. The mean time to repair (MTTR) is the best measure for maintainability. Lower the MTTR, higher is the maintainability factor. MTTR is the statistical mean time for active repair. It is the total active repair time during a given period divided by the number of malfunctions during the same interval.

10.5 Maintainability Improvement Procedures

The maintainability improvement should be implemented right from the design stage.
The maintainability of equipment can be improved by adopting better service and testing procedures, skills, spares management and condition monitoring techniques

- **Improve service procedure**

It is mandatory to have a clear-cut procedure of services to be performed on critical equipment. The method of carrying out repair, spare parts requirement, labor requirement, skills requirement and any other sophisticated devices requirement, expected duration of repair should be clearly specified in the service procedure for each major equipment malfunction. The repairs should be done with accuracy and patience to avoid rework and wastage of time. Whenever a major repair activity takes place, work permit should be complete in all respects.

- **Improve testing procedures**

All equipment should have proper testing procedures. The instruments should be properly calibrated and the range of parameters clearly specified. The interval of calibration and testing should be strictly followed according to the plan. The instruments should be protected against environmental impacts.

- **Improve Skills of labor**

The maintenance personnel should acquire skills to operate sophisticated instruments and improve workmanship. The labor should be skilled enough to perform the job precisely and with accuracy. The rework and wastage should be avoided. Proper training should be given to labor so that they get knowledge about functioning of equipment, interpret the drawings and can operate various equipment safely within desired norms and operating conditions.

- **Availability and Quality of service parts**

The spare parts required for repair operation should be readily available. It is necessary to standardize the spare parts to reduce inventory. The quality of spare parts should be inspected on a regular basis and good vendors should be identified. The spares should be of the same quality as specified by the manufacturer. An inspection cell for material quality control would be best suited. The stocking arrangement of spares should be such that it can easily be identified, when required.

- **Adopt condition monitoring techniques**

Condition Monitoring Techniques help to identify the abnormalities in an equipment. The on-line monitoring can be carried out when the equipment is in operation and off-line monitoring can be carried out when the equipment is down. The condition monitoring helps in predicting equipment failure and taking corrective actions before the equipment fails.

10.6 Calibration and Testing

Calibration is a preventive practice, which ensures that measurement and control instruments and other test equipment/facilities are kept within, specified tolerance limits and is always kept in a fully serviceable state. Large companies usually have a central laboratory or standard facility to calibrate and maintain records of all instruments, gauges and standard reference materials. For companies requiring few instruments, calibration can be done by an accredited laboratory.

A well-run and fine tuned calibration facility provides a reliable means for the prompt detection of defects and thus enable maintenance personnel to take timely actions to rectify the abnormalities. To maintain equipment accuracy and degree of precision, the instrument should be calibrated at regular frequencies. The aim should be to have reliable means of determining process parameters commensurate with the level of accuracy prescribed in the operating manuals.

Standards:

It is necessary to lay down proper standards for calibration, once the parameter is fixed, so that maintenance personnel can perform accordingly.

ISO is a standard that clarifies principal quality-related concepts and provides guidance for the selection and use of ISO 9000 family of standards for quality assurance and management. The primary standards are laid down by Bureau of Indian Standards (BIS) and are actually the parameters for the standards. The secondary standards are available with National Test and Calibration Laboratories and are designed to the closest possible tolerance to the primary standards and put into actual use.

Calibration Procedure

The calibration of instrument at Staple Fibre Division are carried out using Fluke-702, a microprocessor based instrument. The equipment to be calibrated is connected to the Fluke – 702, which supplies the necessary input values and stores the output values from the equipment in its hard disk. Fluke 702 also calculates the error values resulting from the calibrated instrument. The uncertainty of the instrument is calculated and compared with the previously calculated value (i.e. when the instrument was last calibrated). The results are then recorded for analysis and corrective actions.

❖ **Action when the equipment is out of calibration**

During periodic calibration, equipment may sometimes be found out of calibration. As it may not be possible to pinpoint exactly when it went out of calibration, the accuracy of all measurements carried out by the equipment since its earlier calibration would be in doubt. In such situations, the following steps should be taken:

- Examine the records of the last calibration and if possible, revalidate them
- Confirm that the inaccuracy has occurred only after the last calibration

- Where possible, recheck the product parameters measured with the equipment that is out of calibration. If any parameter falls beyond specified limits, immediate actions should be taken to isolate all non-conforming products
- Assess the possible effects of the non-conformity on the final quality of the product
- Reappraise the frequency of calibration for this particular piece of equipment

❖ **Environmental effects on measurement**

Environmental conditions (such as temperature, humidity, vibration and illumination) can affect measurement to varying degrees. Environmental factors should therefore be given careful considerations, when procedures for measurements and calibrations are specified. When measurements sensitive to environmental conditions are to be carried out, suitable environmental control measures should be adopted, as well as procedures for maintaining and recording actual environmental conditions during measurements.

Calibration Interval

The inspection interval has to be laid down carefully, based on the hours of utilization in a calendar year. Initially the periodicity of checks has to be at closer intervals, but if the equipment maintains accuracy during successive checks, then the interval between the two successive calibrations may be increased. As a rule, not more than 5% of a particular type of equipment should be found beyond the specified tolerance limits at the end of the interval. [7]

Documentation

Documentation plays an important role in the process of calibration. The following list of document should be maintained:

- Equipment History record
- Calibration interval or frequency and the next due date

- Calibration procedure, checks and tolerances
- Permissible limits of error
- Environmental conditions during calibration
- Actual calibrated values of latest calibration checks
- Details of any modification, adjustments etc. carried out on the equipment
- Limitations of use, if any
- Certificate of acceptance and rejection

10.7 Non-Destructive Testing

Non-destructive testing methodologies are developed for the accurate measurement of characteristics of parts of a machine, without any damage physically or functionally. The parameters monitored are mainly the process variables like pressure, temperature, flow, etc. and mechanical running condition variables like vibration, RPM, crack detection, relative motions, wear and tear etc. The rotary machinery malfunctions include unbalance, misalignment, foundation problems, fracture, thermal loads and bearing failures.

Table 10.2 shows the various non-destructive testing methodologies adopted in a fibre industry.

10.8 Condition Based Monitoring

Condition based monitoring is one of the most efficient tool for maintenance prevention. The effectiveness of any industry depends on continuous, safe and cost effective operation of its plant, where breakdowns without any preliminary warning have to be avoided. This necessitates a felt-need to know the exact condition of the critical parts/components in a continuous running plant, which can fail, and thus cause a breakdown without warning.

TABLE: 10.2

NON-DESTRUCTIVE TESTING

S.No	Instrument	Parameters
1	Boroscope	Inaccessible points
2	Flexiscope	Contoured surfaces, U-Bends
3	Liquid-Dye Penetrant	Surface cracks, porosity
4	Magnetic particle detection	Surface discontinuity
5	Eddy current testing	Cracks, laps, seams, void
6	Ultrasonic Testing	Surface flaws, cracks, cavities
7	Radiography	Locate defects
8	Hardness tester	Hardness
9	Creep tester	Creep
10	Leak testing	Locate leakages
11	Thermal testing	temperature
12	Accoustical Emission testing	detecting minute flaws
13	Holography	Inspecting welds

TABLE 10.3

CONDITION MONITORING TECHNIQUES

S.No	Type	Method	on/off line
1	Visual	Human Eye	on
2	Temperature	Optical probes (with television)	off
		Temperature crayons, Thermomet	on
		Thermocouples	
		Infra red meter/scanner	on
3	Lubricant monitoring	Magnetic plugs, filters	on
		Ferrography, Spectroscophy	
4	Vibration	Total signal, Frequency analysis	on
		Shock pulse monitoring	on
5	Crack	Dye penetrant, Magnetic flux,	on and off
		Electric resistance, eddy current	
		Ultrasonic	
		Radiography	off
6	Corrosion Monitoring	Weight loss coupons	off
		Corrosometer	on
		Polarisation resistance	on
		Pulse indicator holes	on

The proper time of maintenance, need to be determined by monitoring condition and/or performance of the readily monitorable parameter of deterioration. The probabilistic element of failure prediction is therefore reduced, or indeed eliminated, the life of the term maximized and the effect of failure minimized. The corrective maintenance can thus be scheduled in the shorter term without any production loss.

The monitored parameter can provide information about a single element or provide information that can indicate change in any number of different components. Thus, it is necessary to monitor all the critical parameters of the machine continuously and decide the allowable tolerance levels.

The condition monitoring increases the plant availability and reliability, increases the plant and personnel safety with optimal maintenance costs.

Condition monitoring can be applied in three ways:

- **Simple checking:**

Qualitative checks based on look, listen and feel. Visual inspection helps in identifying the abnormalities of components. The periodicity of the inspection is sufficiently short to detect minor and often unexpected problems before they develop.

- **Condition monitoring:**

The condition monitoring is done routinely and measuring some parameter, which is not recorded, but is used for comparison with the control limit. Condition monitoring is carried out when the deterioration characteristic is known and inspection need not begin until well into the item's life.
Online Monitoring: Condition monitoring carried out, when the equipment is in operation
Off-line Monitoring: Condition monitoring when the equipment is shut down and not in operation.

TABLE: 10.4

CONDITION MONITORING : ROUTINE CHECKLIST FOR AFTER-TREATMENT SECTION

S.No	EQUIPMENT	PARAMETER TO BE CHECKED
1	Main Conveyor Drive	Vibration/Noise/Belt slackness/ Foundation
2	Eccentric Drive Shaft	Vibration/Noise/Lub. Flow/ Brg. Temp./Foundation
3	Ecc. & Ecc. Gear box	Vibration/Noise/Foundation Bolts/Structure
4	Lub. System and Pump	Vib./Noise/Pump Leakage/Oil condition/Line leakages
5	1st Squeeze roller drive system	Vib. /Noise/Belt/Chain/GB oil/Temp.
6	1st Squeeze roller	Vibration/Noise/Brg. Temp./Structure/Plunger Seal Leakage
7	Final Sq. roller drive system	Vib. /Noise/Belt/Chain/GB oil/Temp.
8	Final sq. roller	Vibration/Noise/Brg. Temp./Structure/Plunger Seal Leakage
9	S.F. conv. Drive	Vibration/Noise/Belt slackness/ Foundation
10	Hydraulic system	Vib./Noise/Pump plunger/Line leakage/valve leakage
11	Nip roller	Noise/Arms/Chain/Lubrication
12	Mat opener	Vib./Noise/Belts/Brg. Temp./Structure
13	Weight roller	Arms bracket/Stopper/Lubrication
14	Accumulator	Plunger seal leakage/Structure
15	Soft finish PP1	Vib./Noise/Foundation/Brg. Temp./Guard
16	Soft finish PP2	Vib./Noise/Foundation/Brg. Temp./Guard
17	Desulph PP1	Vib./Noise/Foundation/Brg. Temp./Guard
18	Desulph PP2	Vib./Noise/Foundation/Brg. Temp./Guard
19	BLeach PP1	Vib./Noise/Foundation/Brg. Temp./Guard
20	Bleach PP2	Vib./Noise/Foundation/Brg. Temp./Guard
21	Wash water PP1	Vib./Noise/Foundation/Brg. Temp./Guard
22	Wash water PP2	Vib./Noise/Foundation/Brg. Temp./Guard

- **Trend monitoring:**

Trend monitoring is most effective where little is known about the deterioration characteristics. Measurements are made and plotted in order to detect gradual departure from the norm.

Table 10.3 shows the various condition-monitoring techniques usually applied in a process industry. Table 10.4 shows the condition-monitoring checklist for After-Treatment section.

10.9 Vibration Monitoring

Vibration monitoring techniques help in maintenance prevention. The vibration monitoring equipment can identify the vibrations in the bearings, motors etc. through the signals and on-line continuous monitoring can be carried out for critical equipment. The choice of technique depends upon time, effort, level of sophistication and cost. The frequency of monitoring depends on the criticality, likely damages that can occur in case of neglect, and the equipment history of failures and its analysis.

10.9.1 Causes of vibration:

Mechanical vibration and shocks result from dynamic forces, which set up a series of motions within the system. These forced motions may be linear or angular (torsional) or a combination of both linear and angular motions.

An indication of the range of vibratory motions which generally occurs are listed below:

- Absence of lubrication
- Bent shafts
- Broken blades
- Damaged and mis-aligned drives
- Damaged bearings

- Eccentricity
- Fretting corrosion
- Incorrect assembly
- Insecure components
- Mechanical slackness
- Onset of cavitation
- Presence of solid bodies
- Static and dynamic unbalance
- Worn bearings
- Worn or damaged gears

10.9.2 Vibration Parameter selection

The choice of suitable vibration pick up involves:

- Displacement sensed by a proximity transducer with an output signal proportional to displacement
- Velocity sensed by seismic-type transducer
- Acceleration sensed by an accelerometer

The strongest influence on selection of the appropriate parameter is the frequency at which measurement is important; in any event, a large signal is required so that the signal-to-noise ratio is high. The displacement measurements record large signals at low frequencies, while acceleration measurements are effective at high frequency.

Vibration Parameter Selection Criteria

Frequency Range (Hz)	Preferred Vibration Parameter
1-50	Displacement
50-1000	Velocity
1000 upwards	Acceleration

10.9.3 Reference Standards on vibration severity level:

A good standard must represent a consensus among users and manufacturers. The following standards are generally used for measurement of vibration severity level:

- German standard VDI 2056: Criteria for assessing mechanical vibration of machines
- International Standard ISO: 2372 Mechanical vibration of machines with operating speeds 10 to 200 rev/s
- British Standard BS: 4675
- Indian Standard IS: 4729: Measurement and evaluation of vibration of rotating electrical machines.

The vibration severity level can be specified by the displacement in terms of microns, amplitude (single, double), velocity (r.m.s, peak) and RPM. These standards state the permissible vibration for 600 CPM and above. For slow speed machines, below 600 CPM, the severity is expressed in terms of displacement of vibrations.

In vibration monitoring, portable vibration spectrum analyzer, digital vector filters, oscilloscopes and the data generated can pinpoint the cause of vibration.

10.9.4 Vibration signature analysis chart:

For detecting condition of a fault and to diagnose the cause, the tables in the VDI / ISO reference standards give general guidelines. Too much reliance may not be placed on absolute levels, as the increase in any one-frequency component may not be reflected on the overall levels. Table 10.5 gives the general guidelines for identification of causes of vibrations, if frequency analysis is carried out. The frequency, at which a change in spectrum occurs, gives useful information.

TABLE 10.5

VIBRATION ANALYSIS SYMPTOMS

S.No	Cause	Frequency	Direction and Location
1	Initial unbalance	Mainly running frequency	mainly vertical and horizontal direction
	Blade failures	vibration. Rarely, higher	on shaft / bearings
	Rotor bending	multiples noticed	
2	Casing Distortion	Mostly running frequency	Mainly vertical and horizontal direction
		Sometimes half-running	located on shaft/bearings
		frequency and higher	
		multiples also	
3	Foundation Distortion	Mainly half-running	Mainly vertical and horizontal direction
		frequency and multiples	located on shaft/bearings
		upto double running frequency	
4	Seal rub	Mainly half and full running	Veritcal, horizontal & axial directions
	Rotor rub-axial	frequency. Sometimes higher	located on shaft, bearings and casings
		multiples also	
5	Misalignment	Mainly running and double	Mostly in axial direction on shaft,
	Piping forces	running frequency. Sometimes	bearings and casings
		higher multiples	
6	Bearing damage	Running frequency	Veritcal, horizontal & axial directions
		Sometimes double running	located on shaft, bearings and casings
		frequency or low frequencies	
7	Unequal Bearing stiffness	Mostly double running frequency	Vertical and Horizontal directions on
	(Looseness)	In rare cases higher multiples	shaft, bearings and casing
		also present	
8	Coupling Inaccuracy or	Running frequency	Veritcal, horizontal & axial directions
	damage		located on shaft, bearings & couplings
9	Critical Speed	Running frequency	Mostly vertical & horizontal on bearings
	resonant vibration		& shaft for critical speed & on casing,
			foundation, piping, bearings & shaft
			resonant vibration
10	Oil whirl	Half running frequency	Mainly vertical & horizontal located
			on shaft, bearings

10.9.5 Dynamic Balancing Procedure

The machine vibration signatures need to be analyzed thoroughly to determine the problem source. The analysis may indicate that the problem is due to misalignment, rotor bend, bearing damage, etc. Before balancing is attempted, it must be established that the vibration is due to unbalance.

First, analyze the vibration to determine that the vibration is due to unbalance. The unbalance in the part at the start is called the original unbalance and the vibration amount and phase, which represents that unbalance is called the original reading. The original unbalance is changed by adding a trial weight to the part. The new total unbalance in the part is represented by a new amount and phase of vibration. The change caused by the trial weight can be used to learn the size and location of the original unbalance. For balancing purpose, vibration readings are taken on the bearing housings. Locate the position, which gives the maximum vibration. Attach the vibration pickup at that location. Care must be taken to place the vibration pickup at the same point and direction for all readings if the pickup is hand held. For measuring phase angle of vibration by using a strobe light provide one reference mark on the rotating part which can be observed from outside.

Procedure

1. Measure the initial vibration and the position of the reference mark
2. Stop the machine. Add a trial weight (TW) and mark the position of the trial weight
3. Run the machine to speed. Measure the new vibration and phase angle ($\theta + T$).
4. Stop the machine and remove this trial weight
5. Construct the vector diagram
6. Measure the value of T from the construction
7. Correction weight = $TW \times \theta / T$
8. Measure the angle θ from the construction.

TABLE: 10.6

BENEFITS OF CONDITION & VIBRATION MONITORING

For the Period January 2000 - June 2000

S.No	Department	Equipment	Action	Benefits
1	Spinning	Tripple Guides	Vibration in schedule	Helps in taking corrective action
2	Spinning	Main Drive	Correct prediction of misalignment	Problem solved
3	After Treatment 7	Main conveyor	1st bearing repetitive problem	Problem solved
4	After Treatment 8	Soft Finish Drive	Foundation reinforcement	Problem solved of high vibration
5	Dryer 3	Fan's motor	Frequent shaft failure RPM reduced	Problem solved
6	Dryer 5	Whole	LLF and concentrated condition monitoring	Downtime reducing
7	Baling Press 3	Booster Fan	Foundation reinforcement	Vibration reduced from 54 to 8mm/s
8	Baling Press 5	Booster Fan	Dynamic Balancing	Reduction in vibration
9	Viscose 1	Slurry Pulper E1	Weak Foundation	Vibration reduced from 18 to 5 mm/s
10	Viscose 1	Dissolver 4	Hydraulic coupling, resilience plate found broken	Vibration reduced from 22.4 to 4.2 mm/s

S.No	Department	Equipment	Action	Benefits
11	Viscose 2	Dissolver 10	Correct prediction of Gear Box problem	Problem solved
12	Viscose 2	Slurry Press X1	Servodrive foundation reinforced	Vibration level reduced from 40 to 8mm/s
13	CS2	Venturi Scrubber Blower	Weak Foundation	Vibration level reduced from 23.4 to 2.2 mm/s
14	EC1	ID Fan 2	Weak foundation & unbalance	Vibration reduced from 8.2 to 2.8 mm/s
15	EC 4	FD fan 2 of Boiler 1	Dynamic Balancing	Vibration reduced from 8.5 to 2.3 mm/s
16	EC 4	Cooling Tower Fan 3	Dynamic Balancing	Vibration reduced from 22.5 to 8.5 mm/s

SAVINGS ACHIEVED

Month	Rs. In lacs	Hrs.
January	1.04	27
February	2.95	42
March	1.91	38
April	4.01	84
May	3.78	92
June	3.31	40
Total	**17**	**323**

The correction weight is calculated to add at the same radius where the trial weight is added. The position of the correction weight is kept opposite to the position of the trial weight.

In-situ dynamic balancing helps in directly detecting the abnormal vibrations in the machine.

10.9.6 Benefits

Table 10.6 shows the major benefits achieved by condition monitoring, vibration monitoring and ABRO's in-situ dynamic balancing for the period January 2000 to June 2000 in Staple Fibre Division. The condition monitoring and vibration monitoring have helped in predicting the failure and corrective actions were taken thereof. This has resulted in a saving of 17 lacs and downtime was reduced by 323 hours during the period of six months.

10.10 Expert Cell

An Expert cell would constitute a team of experienced maintenance personnel who would work for maintenance prevention and maintainability improvement. The expert cell will conduct brainstorming sessions weekly to identify and solve maintenance-related problems scientifically. The team will then do feasibility studies of various alternatives and perform cost-benefit analysis, return on investment (ROI), rate of return (ROR), payback etc. to select the best alternative.

The main functions of Expert Cell are listed below:

- Study Equipment History Record, failures and corrective actions taken
- Identify repetitive failures and suggest action plan
- Maintainability at the design stage
- Maintainability along the flow of material

- Adopt maintenance prevention techniques
- Evaluate the results of condition and vibration monitoring
- Decisions on Reconditioning and Replacement
- Decision on Annual Maintenance Contract
- Decision on Maintenance sub-contracting
- Life Value Analysis
- Cost-Benefit analysis, ROI, IRR, Payback calculations

10.11 Inspection Cell for Material Quality Control

The maintainability of equipment can be improved if the spares are of good quality and according to specifications of the original equipment manufacturer (OEM).

The functions of inspection cell are listed below:

- Inspection of Raw material
- Inspection of work-in-progress
- Inspection of finished products
- Inspection of spares
- Inspection of workmanship
- Study design specifications and material recommended
- Search for alternative material, if spares not available
- Vendor selection
- Warranty period by vendors

The expert cell thus focuses on the causes of problems and its corrective action right from the design stage and inspection cell focuses on quality of raw material, in progress and finished products.

This chapter thus focussed on the methods of maintenance prevention. These methods help in reducing the downtime and prolonging the life of components / equipment. The maintainability of the equipment can be improved by maintaining the condition by adopting condition and vibration monitoring techniques. The vibration monitoring symptoms help in predicting the failure and corrective actions can be taken accordingly. The expert cell helps in solving the maintenance problems scientifically and inspection cell for material quality control helps in thorough inspection of raw material, work-in-progress and finished products.

The next chapter deals with the concept and implementation procedure of Autonomous Maintenance at Grasim.

CHAPTER 11

AUTONOMOUS MAINTENANCE

11.1 Introduction:

World-Class Maintenance creates pleasant and productive work culture by changing the way people think about and work with equipment throughout the company. Autonomous maintenance is one of the most important basic building blocks which helps in shaping right attitudes among the workers by creating proper systems and procedures of doing right things, every time and on time.

As technology progresses, equipment has become increasingly powerful and complicated, and as companies become greater in scale, maintenance functions are gradually diversifying. Operators become preoccupied with production, while maintenance workers focus solely on maintenance. [17]

11.2 Goals of Autonomous Maintenance

The main function of production department is to produce good products at the optimum cost and as quickly as possible. One of its most important roles is detecting and dealing with equipment abnormalities promptly, which is the goal of good maintenance.

Autonomous Maintenance includes any activity performed by the production department that has a maintenance function and is intended to keep the plant operating efficiently and stable in order to meet production targets and plans.

Thus, the autonomous maintenance will help in creating good work culture, continuous cleaning and inspection and better asset care management.

The goals of an autonomous maintenance program are:

- Prevent equipment deterioration through correct operation and daily checks
- Bring equipment to its ideal state through restoration and proper management
- Establish the basic conditions needed to keep equipment well-maintained

To achieve the above objectives, the operators should acquire skills and expertise in

- Capability of firmly setting criteria for normalities/abnormalities
- Capability of abiding by proper condition-controlling rules
- Capability of taking proper steps in the event of abnormalities
- Capability of finding and improving machine mal-functions
- Capability of understanding equipment structure functions and finding the cause families of abnormalities
- Capability of understanding relations between equipment and quality, predicting quality abnormalities, and finding cause families.

Workers who can meet these conditions are called expert equipment operators.

11.3 Need for Autonomous Maintenance

In the past, plant operators in process industries were expected to keep their equipment working by checking it regularly and performing minor services. Although different companies had different practices, many expected operators to perform strip-down overhauls of equipment. In general, plants practiced a high degree of autonomous maintenance.

During the high growth era of 1970's and 1980's, however equipment became more sophisticated and complex as process plant grew larger and production technology advanced. With the introduction of preventive maintenance, equipment maintenance became increasingly specialized. At the same time, many companies were making significant technical progress in automation and centralization. The production departments have played an exclusively supervisory role, concentrating on production and leave maintenance to specialists. This bolstered the "I manufacture - you repair" syndrome.

Advances in computer hardware and software in 1990's are also intensifying the trend towards automation and unattended operation. It has become increasingly difficult to maintain numerous sensors and deal with leaks, spills, blocks and other problems characteristic of process industries. The best people to solve these problems are the operators, who are intimately acquainted with the workplace, so the need for autonomous maintenance is increasing.

The production department needs to change its mindset and should assume ownership of its equipment and take responsibilities for preventing deterioration. The maintenance department should not think that their job is "repair", rather they should concentrate more on measuring and restoring deterioration, so that operators can use the equipment effectively with confidence. This is the only way to create failure-free, trouble-free workplace. [17]

11.4 Classifying and Allocating Maintenance Tasks

Maintenance activities are designed to achieve optimal equipment conditions and maximise overall equipment effectiveness by maintaining or improving the equipment through prevention and rectification of failures. Table 11.1 summarizes some specific maintenance techniques and activities.

The table shows various maintenance activities to be carried out while implementing a particular type of maintenance systems. This serves as a guideline for the operators to carry out the job more efficiently.

TABLE : 11.1

MAINTENANCE TECHNIQUES AND ACTIVITIES

Normal Operation	Correct operation, correct adjustment, correct setting (prevention of human error)
Preventive Maintenance	Routine maintenance (basic equipment conditions, checking, servicing), Periodic Maintenance
Predictive Maintenance	Condition Monitoring, medium - interval and long-interval servicing
Breakdown Maintenance	Prompt abnormality detection, emergency repairs, recurrence prevention
Need-cum-Opportunity Based Maintenance	Abnormalities Identification, Opportunity utilisation, Maximising Availability and Reducing Downtime

Improvement activities on the other hand, extend equipment life, shorten the time required to perform maintenance, and make maintenance redundant. Corrective Maintenance focuses on reliability and maintainability improvement in existing equipment. Maintenance prevention activities promote the design of new equipment that is easier and less costly to operate and maintain, thus increasing maintainability of equipment.

Hence, the first step in the implementation of Autonomous Maintenance is to clarify the responsibilities of the process and maintenance departments in each of these areas and to ensure that the integrated program is free of omissions and duplications. Table 11.2 shows the responsibilities of the process and maintenance departments.

TABLE : 11.2
CLASSIFICATION AND ALLOCATION OF MAINTENANCE TASKS

TARGET	TECHNIQUES	PREVENT	MEASURE	RESTORE	PROCESS	MAINT-
		DETERIORATION	DETERIORATION	DETERIORATION		ENANCE
Maintenance	Normal Operation	Correct Operation			y	
Activities		Correct Adjustment			y	
	Daily Maintenance	Cleaning	Check Deterioration	Minor servicing	y	
		Lubricating	and conditions of		y	
		Tightening	use daily		y	
	Periodic Maintenance		Periodic Checking		y	y
			Periodic Inspection	Periodic Servicing		y
			Testing			
	Predictive Maintenance		Trend Inspection	Medium Interval		y
				and Long Interval		
				Servicing		
	Breakdown Maintenance	Prompt Identification			y	
		of abnormalities,				
		Prompt Action &				
		Reporting				
		Recurrence Prevention			y	y
				Emergency Repairs		y
IMPROVEMENT	Improve Reliability	Simplification			y	y
ACTIVITIES	(Corrective Maintenance)	Load Leveling			y	y
		Improve Control			y	y
		Precision				
	Improve Maintainability		Develop Condition -		y	y
			Monitoring equipment			
			and techniques			
			Improve inspection			
			work			
				Improve servicing		y
				work		
				Improve servicing		y
				quality		

11.5 Activities of Process Department

The process department must focus on maintaining the equipment condition and prevent failures, deterioration through cleaning, and inspection from time to time. It should build its own autonomous maintenance program around the following three kinds of activities:

11.5.1 Preventing Deterioration

- Correct Operation : preventing human errors
- Correct Adjustment: preventing process defects (quality defects)
- Basic housekeeping - cleaning, lubricating, tightening
- Early prediction and prompt detection of abnormalities - forestalling failures and accidents
- Keeping maintenance records - feeding back information for recurrence prevention and maintenance prevention design

11.5.2 Measuring Deterioration

- Daily inspection- patrol checks and five senses checks during operation
- Periodic inspection - part of overhaul inspection during plant shut-down

11.5.3 Predicting Deterioration

- Minor servicing - emergency measures when abnormal conditions arise and simple parts replacement
- Prompt, accurate reporting of failures and problems
- Assistance with repairing unexpected failures

11.6 Maintenance Department Activities:

The maintenance department plays an important role in equipment maintenance. Its main activities are:

- Planned Maintenance, Predictive Maintenance, Corrective Maintenance, NOBM
- Measuring and restoring deterioration
- To enhance maintainability, operability, and safety
- Achieve optimal equipment effectiveness and maximise OEE
- Research and develop new maintenance technologies
- Prepare maintenance standards
- Maintenance Information System
- Develop and use failure analysis techniques
- Assist equipment design and development departments

This requires advance maintenance skills and equipment technology, so maintenance department must constantly strive to increase their technical prowess. The maintenance department helps in implementing autonomous maintenance by providing proper guidance and support in the form of:

- Providing instructions in inspection skills and help operators prepare inspection standards
- Providing training in lubrication techniques, standardize lubricant types and help operators to formulate lubrication standards
- Dealing quickly with deterioration, minor flaws in equipment conditions and deficiencies in basic equipment conditions
- Contributing technical assistance in improvement activities such as eliminating contamination sources, making areas more accessible for cleaning, lubrication and inspection and boosting equipment effectiveness.
- Organising routine activities like meetings, rounds for taking orders for maintenance tasks.

11.7 Establishing Basic Equipment Condition

Autonomous Maintenance activities practiced by the process department focuses on preventing deterioration. Establishing and maintaining basic equipment conditions through cleaning, lubricating and tightening is an integral part of this program.

11.7.1 Equipment Deterioration

The cause of most of the failures is equipment deterioration. This consists of natural deterioration, which gives equipment its inherent life and accelerated deterioration, which occurs when equipment operates in an artificially created harmful environment. This is achieved through corrective maintenance which includes preventing errors by improving operability, improve maintainability and repair quality, improve safety and reliability.

The key to reducing failures is to prevent accelerated deterioration. Establishing basic equipment conditions means eliminating the causes of accelerated deterioration. It is achieved through cleaning, lubricating and tightening.

The first step is to establish minimum conditions required keeping equipment running by maintaining basic equipment condition and then striving for bringing equipment to its ideal state, that is the level where it performs optimally.

11.7.2 Cleaning

Cleaning consists of removing all dust, dirt, grime, oil, grease and other contaminants that adhere to equipment and accessories - in order to expose hidden defects. The cleaning operation should be done on a daily basis and abnormalities should be identified.

The harmful effects of inadequate cleaning are shown in Table 11.3.

TABLE 11.3

HARMFUL EFFECTS OF INADEQUATE CLEANING

Failure	Dirt and foreign matter penetrates rotating parts, sliding parts, pneumatic and hydraulic systems, electrical and control systems etc. causing loss of precision, malfunction and failure as a result of wear, blockage, frictional resistance, electrical faults etc.
Quality Defects	Quality defects are caused either directly by contamination of the product with foreign matter or indirectly as a result of equipment malfunction
Accelerated Deterioration	Accumulated dust and grime make it difficult to locate and rectify cracks, excessive play, insufficient lubrication and other disorders resulting in accelerated deterioration
Speed Losses	Dust and dirt increase wear and frictional resistance causing speed losses such as idling and under-performance

Cleaning Steps

- Clean equipment regularly as part of daily work
- Clean deeply - remove all the layers of grime and scale built up over many years
- Clean previously ignored covers, guards and so on to expose and remove every speck of dirt from every corner and crevice
- Clean attachments and accessories as well as main units
- Remove dirt at the earliest after cleaning is carried out

11.7.3 Inspection

The main aim of inspection is to detect minor flaws in equipment conditions and other abnormalities. Following points should be kept in mind for finding faults:

- ❖ Search for invisible as well as visible defects, such as looseness, subtle vibration, and slight overheating that only touch can detect
- ❖ Search carefully for worn pulleys and belts, dirty drive chains, blocked suction filters and other problems likely to lead to malfunctions
- ❖ Note whether equipment is easy to clean, lubricate, inspect, operate and adjust.
- ❖ Identify hindrances like obstructive covers, ill positioned lubricators etc.
- ❖ Ensure that all meters operate correctly and are properly calibrated
- ❖ Investigate any leaks of product, steam, water, oil, compressed air etc.
- ❖ Hunt for hidden problems such as corrosion inside insulating materials on pipes, columns and tanks, blockages in pipelines, chutes and ducts.

11.7.4 Checking

Daily checks are required to ensure that abnormalities are detected and acted upon at the earliest. But the operators in process plants perform pointless inspections based on standards others have set. The OK column is neatly ticked in advance and checklists proved meaningless.

Hence, truly the daily inspection should mean that the operator is alert enough to spot the abnormality during operating the equipment and being able to deal it and report it correctly. This requires a high degree of skill and sensitivity.

Table 11.4 shows the autonomous maintenance checklist for Spinning & After Treatment Departments.

TABLE : 11.4

AUTONOMOUS MAINTENANCE : SPINNING MACHINE

S.No	Nature of work
1	Clean the area in the vicinity of spinning machine
2	Check spinbath and viscose leakage
3	Check leakages from candle body, elbow, gooseneck
4	Check heavy leakage from metering pump
5	Check the leakage from gearbox and also check the level
6	Check the covers of moving components/equipment
7	Check the belt of exhaust fan
8	Check CS2 line leakage
9	Check the leakage from sump zone pumps
10	Check the vibration on machine
11	Check unusual sound from T gear box and cutter gear box
12	Check R/T steam leakage

AUTONOMOUS MAINTENANCE : AFTERTREATMENT SECTION

S.No	Nature of Work
1	Clean the area in the vicinity of the conveyor
2	Check the leakages from gear box and also check the level
3	Check the covers of moving components / equipment
4	Check the belt of exhaust fan, conveyor, rollers
5	Check the unusual sound from squeeze roller gear box
6	Check the moving and fixed bars of conveyor
7	Check hydraulic oil pressure
8	Check the circulation pump
9	Remove unwanted material from the vicinity of conveyor

AUTONOMOUS MAINTENANCE : DRYER

S.No	Nature of Work
1	Check the fiber droppings from drums and note dryer number
2	Check the oil leakages from gear box and also check the level
3	Check the position of fan belts and note fan number
4	Check the steam leakages
5	Chek the vibration in fans and motors
6	Clean the dryer and its vicinity
7	Remove unwanted material from dryer area
8	Check hot air leakage
9	Check steam line leakage and cladding
10	Check temperature and pressure guage recorder
11	Check conveyor, spike lattice

AUTONOMOUS MAINTENANCE : BALING PRESS

S.No	Nature of Work
1	Clean the area in the vicinity of baling press
2	Clean the housings
3	Remove unwanted material in vicinity of baling press
4	Check the leakages from hydraulic cylinder
5	Check the oil leakages from gear box
6	Check hydraulic pump
7	Check the covers of moving components / equipment
8	Check unusual sound from components/equipment
9	Check the position of compressor and booster fan belts

11.7.5 Lubrication:

Lubrication is one of the most important basic conditions for preserving equipment reliability. It prevents wear or burnout and maintains operational precision of pneumatic drives. Lubrication schedule should be prepared for each machine, indicating the components to be lubricated, type of oil to be used and lubricating frequency as shown in Table 11.5.

Table 11.5 shows the lubrication schedule for spinning machine, dryer and baling press.

TABLE 11.5

LUBRICATION SCHEDULE

A. SPINNING MACHINE

S.No	EQUIPMENT	LUBRICANT	CHECKING FREQUENCY
1	Cutter Drive Gear Box	SP 320	Daily
2	Trio Gear Box	SP 176	Daily
3	T Gear Box	SS 176	Daily
4	Main Drive Reduction Gear Box	SS 320	Daily
5	Homogenizer Reduction Gear Box	SCY 460	Daily
6	Sump zone Pump	SS 176	Weekly
7	Pump shaft gears	SC 120	Weekly
8	Pump shaft pedestal	MP Grease	PMT
9	Pump shaft reduction gear box	SS 176	PMT
10	Godet Gear Box	SS 176	PMT
11	Injection Pump Gear Box	SCY 460	Daily

B. DRYER

S.No	EQUIPMENT	LUBRICANT	CHECKING FREQUENCY
1	Drum Drive Gear Box Oil	Servo 460	Thrice a week
2	Spine Lattice Chain Oiling	Servo 176/57	Thrice a week
3	Feed Conveyor Chain Oiling	Servo 176/57	Thrice a week
4	Nip Roller Chain Oiling	Servo 176/57	Thrice a week
5	Intermediate Nip Roller Chain oiling	Servo 176/57	Thrice a week
6	Dryer Fan bearing greasing	HTXX	20 days
7	Drum Dryer stobber gear box	Servo 460	Monthly
8	Dryer Spike Lattice gear box	Servo 460	Monthly
9	Spike Lattice Roller Bearing Greasing	MP Grease	PMT

C. **BALING PRESS**

S.No	EQUIPMENT	LUBRICANT	CHECKING FREQUENCY
1	Compressor sump oil level pressure checking	Servo 150	Daily
2	Compressor Lubrication oil checking	Servo 150	Daily
3	Hydraulic oil tank, oil level & leakage checking	Servo 176	Daily
4	Separator driving gear box oil checking	Servo 460	Monthly
5	Auto rotation gear box oil checking	Servo 460	Monthly
6	Separator driving chain, nip roller lubrication	Servo 176	Thrice a week
7	Comb gear box oil checking	Servo 460	Monthly
8	Forte conveyor gear box oil checking	Servo 460	Monthly
9	Craighton Opener Bearing Greasing	MP Grease	PMT
10	Separator Exhaust Fan Greasing	MP Grease	PMT
11	Door Lock Worm Gear checking & greasing	MP Grease	PMT
12	Central column bearing checking and greasing	MP Grease	PMT

11.8 Implementing Autonomous Maintenance

The goals of cleaning as inspection are to establish basic equipment conditions, bring equipment to its ideal state, and create workplaces that are free of equipment abnormalities, failures and stoppages, and quality defects.

The step-by-step approach clearly delineates each phase of the activities, allows for regular audits that secure the gain made at each step, and gives operators a sense of achievement as they proceed through the program.

Autonomous Maintenance is implemented in seven steps, which promotes the establishment of optimal process conditions by cycling through continuous improvement management cycle. [18]

Step1: Perform Initial Cleaning

The goal of Step 1 is to raise equipment reliability through these three activities:

- Eliminate dirt, dust and grime
- Expose all abnormalities
- Correct minor flaws and establish basic equipment conditions

- **Eliminate dirt, dust and grime**

Thorough cleaning forces operators to touch every part of the equipment. They begin to recognize the importance of cleaning and resolve to keep their equipment spotless in the future. This effort in turn encourages the operator to think ways of improving their equipment to make it easier to keep clean.

- **Expose all abnormalities**

An abnormality is a deficiency, disorder, slight irregularity defect, bug or flaw – any condition that lead to other problems. Table 11.6 shows the seven steps of abnormality identification.

- **Provide one-point lesson:**

One point lesson sheets are also helpful. Operators can learn to recognize abnormalities by using specially prepared sheets with simple diagrams illustrating a single point.

- **Tag abnormalities where they occur:**

Another technique is to tag the location of each abnormality as it is spotted, using a card that shows when it was found, who found it and the nature of the problem. White tags are used for problems that operator can handle and Red tags for ones that the maintenance department will handle.

- **Correct minor flaw and establish basic equipment conditions:**

It is essential to raise the reliability of equipment by establishing basic conditions. This is achieved by correcting minor flaws as and when they occur such as damage, excessive play, deformation, wear etc. When serious damage occurs, maintenance department should be contacted immediately.

- **Lubricate:**

Lubrication is one of the most important basic conditions for preserving equipment reliability. It is designed to ensure efficient working by preventing wear or burnout, maintaining the operational precision of pneumatic drives and reducing friction.

TABLE : 11.6
SEVEN STEPS OF ABNORMALITY

S.No	Abnormality	Examples
1	MINOR FLAWS	
	Contamination	Dust, dirt, powder, oil, grease, rust, paint
	Damage	Cracking, crushing, deformation, chipping, bending
	Play	Shaking, falling out, tilting, eccentricity, wear, distortion,corrosion
	Slackness	Belts, Chains
	Abnormal Phenomena	Unusual noise, overheating, vibration, smells, discoloration
	Adhesion	Blocking, hardening, accumulation of debris, peeling, malfunction
2	UNFULFILLED BASIC CONDITIONS	
	Lubrication	Insufficient, dirty, unidentified, unsuitable, leaking lubricant
	Lubricant Supply	Dirty, damaged or deformed inlets, faulty lubricant pipes
	Oil level gauges	Dirty, damaged, leaking, no indication of correct level
	Tightening	Nuts and bolts, slackness, missing cross threaded, corroded washers
3	INACCESSIBLE PARTS	
	Cleaning	Machine construction, covers, layout, footholds, space
	Checking	Covers, construction layout, instrument position and orientation
	Lubricating	Position of lubricant inlet, construction, height, footholds
	Tightening	Covers, construction layout, size, footholds, space
	Operation	Machine layout, position of valves, switches and levers
	Adjustment	Position of pressure gauges, thermometers, flowmeters,
4	CONTAMINATION SOURCES	
	Product	Leaks, spills, spurts, scatter, overflow
	Rawmaterials	Leaks, spills, spurts, scatter, overflow
	Lubricants	Leaking, spill and seeping lubricating oils, hydraulic fluids, fuel oil
	Gases	Leaking compressed air, gases, steam, vapors, exhaust fumes
	Liquids	Leaking, split and spurting cold water, hot water, cooling water,
	Scrap	Flashes, cuttings, packaging materials and non-conforming product
	Others	Contamination brought in by people, fork-lifts, trucks, etc.

S.No	Abnormality	Examples
5	QUALITY DEFECT SOURCES	
	Foreign material	Inclusion, infiltration, entrainment of rust, chips, wirescraps etc.
	Shock	Dropping, jolting, collision, vibration
	Moisture	Too much, too little, infiltration, defective elimination
	Grain size	Abnormalities in screens, centrifugal separators,
	Concentration	Inadequate warming, heating, compounding, mixing, evaporation
	Viscosity	Inadequate warming, heating, compounding, mixing, evaporation
6	UNNECESSARY AND NON URGENT ITEMS	
	Machinery	Pumps, fans, compressors, columns, tanks
	Piping Equipment	Pipes, hoses, ducts, valves, dampers
	Measuring Instruments	Temperatures, pressure gauges, vacuum gauges
	Electrical Equipment	Wiring, piping, power leads, switches, plugs etc.
	Jigs and Tools	General tools, cutting tools, jigs, molds, dies, frames
	Spare Parts	Standby equipment, spares, permanent stocks,
	Makeshift Repairs	Tape, string, wire, metal plates
7	UNSAFE PLACES	
	Floors	Unevenness, projections, cracking, peeling, wear
	Steps	Too steep, irregular, peeling antislip covering, corrosion
	Lights	Dim, out of position, dirty, broken covers
	Rotating Machinery	Displaced, fallen off, no safety or emergency stop devices
	Lifting Gear	Wires, hooks, brakes, other parts of cranes and hoists
	Others	Special substances, solvents, toxic gases, insulating materials

- **Tighten**:

Equipment functions properly only when the fasteners are securely tightened. The machine vibration should be checked regularly and all the nuts, bolts etc. should be tightened regularly.

- **Expose Danger Points and Practice Accident Prevention Training:**

The initial cleaning and improvement activities that operators perform as part of an autonomous maintenance program are not routine tasks. Operators are not accustomed to them as they are to their regular operations. Therefore, carefully consider and assure the safety of autonomous maintenance activities. Proper accident prevention training programs should be designed using illustrations, and practice safety procedures, as discussed in Section 6.9, on the actual equipment during all autonomous maintenance activities. The effectiveness of such procedures results in achieving zero accident.

Step 2: Eliminate Sources of Contamination and Inaccessible Places

When equipment gets dirty again soon or the level of cleanliness attained through initial cleaning cannot be maintained, operators become improvement conscious. They begin to think of ways of controlling leaks, spills and other contamination sources. The goal of Step 2 is to reduce the time it takes for cleaning, checking and lubricating by introducing two types of improvement:

- **Pinpoint and Eliminate Sources of Leaks and Spills**

The workplace in process industries suffer from wide varieties of contamination sources, which often have adverse effect on equipment for example:

- ❖ Powder like sodium sulphate, grounded pulp, fibre material, vapour discharges make it difficult to maintain initial cleaning levels

- Contamination by dust and grease hampers checking bolts, oil level gauges and so on
- Powder contamination causes accelerated deterioration, such as excessive wear of V-belts and drive chains
- Contamination of limit switches, instruments and sensors causes malfunction
- Leaking liquids and vapours cause process units, stands and other structures to corrode
- Infiltration of control panels by powders makes control unreliable
- General contamination impairs the working environment and lowers product quality

Though it seems that controlling contamination is difficult, but remedial measures can be taken to reduce the extent of contamination. Following key points should be followed:

- Accurately ascertain the nature of the contamination and how and where it is generated
- Gather quantitative data on the volume of spills, leaks and other contamination
- Encourage operators to trace contamination back to its original source
- Localize the contamination and then reduce it through continuous improvement
- Consider using novel techniques and materials for seals, joints, protection devices and so on

- **Improve accessibility to reduce working time**

It is necessary to make the system easy so that cleaning, inspection, lubrication can be carried out quickly, correctly and safely. This involves the following improvement activities:

- Reduce cleaning times: Prepare and test at-a-glance cleaning charts, reduce contamination sources, make hard -to- clean places more accessible, and devise more efficient cleaning tools
- Reduce Checking times: Prepare illustrated checking charts, inspect nuts, bolts, V-belts, chains, couplings and so on to confirm whether operators can perform checks

within allotted times; devise improved inspection tools, install quick release covers etc.

- Identify hard-to-lubricate tasks: Use illustrated lubrication charts to check devices such as oil-level gauges and replenish or change lubricants
- Simplify lubrication tasks: Reposition oil-level gauges, lubricant inlets etc., standardize lubricant types, improve manual lubricating devices and take steps to prevent lubricant inlets from becoming contaminated.

Step 3: Establish Cleaning and Inspection Standards

The goal of this step is to ensure maintenance of basic conditions and keep equipment in peak condition. This calls for standardizing cleaning and inspection procedures.

The standards developed by maintenance department should strictly be followed. The guidance extended in preparing standards and establishing checkpoints motivates the operators to formulate realistic standards for preventing deterioration during their daily checking. Following points should be considered while devising standards:

- All team members should meet to decide what to clean, check and lubricate in order to maintain equipment basic conditions
- Discuss the consequences if a particular part becomes contaminated, loose or insufficiently lubricated
- Decide on the simplest and most appropriate method of checking. Devise clear visual controls that allow anybody to perform the checks correctly and reliably
- Decide which cleaning, lubricating and inspecting tools to use and label them clearly
- Decide how much time to allow for each housekeeping task and set achievable objectives.
- Decide on the frequency of inspections and monitor achievement of the objectives

- **Introduce Extensive Visual Controls**

The key to consistent performance of cleaning, checking and lubricating tasks is to make them easy to perform correctly by anybody. Hence visual controls can be placed directly on the equipment and operating conditions can be clearly indicated. Following are some examples:

- ❖ Mark each item of equipment with its name and number to make everyone aware of important units
- ❖ Put matchmarks on nuts and bolts to simplify checking for slackness
- ❖ Indicate acceptable ranges on instruments such as pressure gauges, thermometers, etc. to facilitate correct operation
- ❖ Indicate lubricant level, types and quantities to improve maintainability
- ❖ Label the cover devices such as V-belts, chains and couplings with their rotation direction and specifications to improve maintainability and simplify checking
- ❖ Label pipes with flow direction and contents to improve maintainability, operability and safety
- ❖ Provide on - off indications on valves and switches to improve maintainability, operability and safety

Step 4: Perform General Equipment Inspection

Operators should be well versed with their equipment, such as functions, construction, operating principles, so that they can identify abnormalities and rectify the flaws. General inspection training gives the operator a firm grasp of the skills required and yields tangible results through general inspection of all equipment. The general equipment inspection procedure is as follows:

- ❖ Select general inspection items
- ❖ Prepare materials for general inspection
- ❖ Draft general inspection training schedule

- Training team leaders
- Preparation by team leaders
- Relay teaching in practice
- Conducting the general equipment inspection
- Consolidation after each general inspection

Step 5: Perform General Process Inspection

In process plants, operators must operate and monitor an extremely wide range of large process units and associated equipment. The materials being handled change state frequently during the processes and the properties such as concentration, purity often vary greatly as materials are subject to high temperature and pressure. A single wrong adjustment of the process or failure to rectify an abnormality properly may cause a serious accident or produce non-conforming product.

Hence the operators must understand the performance and functions of their processes intimately. They should be able to perform adjustments and settings based on a sound knowledge of the materials being handled. They should be able to recognize signs of abnormalities and taking appropriate action.

Necessary Accomplishments for Process-Competent Operators

Level 1: Understands process performance and functions
Operates process correctly

Level 2: Understands properties of materials being handled
Performs correct adjustment and settings

Level 3: Detects abnormalities promptly
Takes emergency action against abnormalities

Level 4: Recognizes signs of abnormality
Deals with abnormalities correctly
Performs periodic overhaul checking and parts replacement correctly

This necessitates the preparation of training program for general process inspection. This includes:

- ❖ Correct operation and manipulation
- ❖ Correct adjustment and settings
- ❖ Correct handling of abnormalities

Step 6: Systematize Autonomous Maintenance

The plant that completes the first five steps of the autonomous maintenance program, achieves optimal equipment conditions and establishes a system of standards to sustain these conditions. Equipment-competent and process-competent operators are able to detect and prevent abnormalities well in advance through proper checking and operation.

One of the main goals of step 6 is to allow operators to perform sound, comprehensive autonomous maintenance of their entire process and to extend their activities into the realm of quality maintenance. Activities include standardizing various control items, preparing process flow diagrams and quality maintenance manuals, and deepening operator's understanding of the relationship between equipment and quality.

❖ **Preparing an Autonomous Maintenance Master Plan:**

- Prioritize activities by evaluating equipment
- Select PM-Equipment through equipment evaluation
  Evaluation elements: Safety, Environmental Pollution, Quality and yield, Operating status, Opportunity Cost, Failure frequency, Maintainability

- Measure the autonomous maintenance load

  Average number of items of equipment designated for autonomous maintenance per operator. Display the progress made in all equipment

- Clarification of Maintenance Responsibilities

  Responsibility for periodic maintenance

  Equipment maintenance system and policy

  Adapting the Autonomous Maintenance Development Steps

  Block Deployment and Area Deployment

- Autonomous Maintenance Audits

Step 7: Practice full self-management

The last step in the autonomous maintenance is that operators should practice full self-management, which helps them in maintaining their own equipment so that it achieves maximum overall equipment effectiveness. This can be achieved through:

- Evolve activities and standardize improvements in line with company and plant policies and objectives and reduce costs by eliminating workplace wastes
- Improve equipment further by keeping accurate maintenance records and analyze the data to improve and raise process reliability, safety, maintainability, quality and operability
- Prioritize equipment improvements and extend equipment lifetimes and checking intervals by using hard data to spot weaknesses

This chapter thus focussed on the concept of autonomous maintenance and its implementation procedure in a process industry. Autonomous Maintenance should be the key activity of all department in order to achieve maximum overall equipment effectiveness, increased productivity, better housekeeping and zero accident.

The cleaning, inspection, checking and lubrication activities should be carried out by the operator and maintenance department should be contacted only when serious abnormalities occur. The autonomous maintenance schedule should be strictly followed and each member should practice full self-management.

The next chapter deals with cost reduction techniques in maintenance and focuses on the benefits of reconditioning the equipment over its replacement.

CHAPTER 12

COST REDUCTION TECHNIQUES IN MAINTENANCE

12.1 Introduction

World-Class Maintenance calls for effective and efficient utilization of equipment and spares. It is always desirable that the equipment is utilized for its entire life span as indicated in the Original Equipment Manufacturer (OEM) specifications and spare parts are readily available whenever required. Stock-out of the spare parts should be avoided, as it results in loss of production. The ready availability of spare parts can thus help in reducing the supply downtime of equipment. The quality of materials, delivery schedule and the warranty by the supplier should be given utmost importance. Reconditioning of the equipment should be preferred over replacement, as it reduces the cost of maintenance and prolongs the life of equipment. Maintenance cost analysis helps in measuring and analyzing the effectiveness of the maintenance department. The idea simulators help in identifying the areas of cost reduction and help in taking corrective actions. The annual maintenance contract is generally awarded for low maintenance equipment and requiring specialized skills and instruments. The life value analysis is carried out for the equipment to monitor the overall cost incurred right from the installation stage until replacement and decisions on replacement can be taken accordingly.

12.2 Maintenance Cost Analysis

Maintenance cost analysis is an important tool to measure the effectiveness of the maintenance department. There is an optimum level of maintenance costs for any given plant, and exceeding this cost results in wasteful expenditure of company profits. An under- expenditure of maintenance funds can appear when some maintenance projects have been deferred until a later date, eventually resulting in an excessive overall total expenditure of funds. Under-maintenance can cause excessive production downtime and over-maintenance can reduce labor efficiency due to restriction of output.

12.2.1 Phases of Maintenance Cost Analysis:

The initial phase of an objective maintenance cost analysis is to establish a properly subdivided standard budget. The number of subdivisions in this budget can be enlarged or decreased depending upon the size of the plant and is based on past history of the department. Once this adjusted standard budget is established, then any marked deviation will serve as an early-warning indicator.

The intermediate or weekly maintenance cost analysis is accompanied by an indirect method. In this phase, maintenance labor hours is mainly monitored. The third and final phase takes place on monthly basis. The actual maintenance costs are compiled and the variation from the budget standard is reported. When these deviates from budget figure either plus or minus a predetermined percentage, then this deviation is analyzed in detail. A present deviation is allowed to prevent overwork in analyzing short-term anomalies. This analysis of a variation becomes a valuable early warning diagnostic tool for the plant engineer.

12.2.2 Maintenance Budgeting

Maintenance Budgeting helps in controlling the maintenance cost of each department. Each department is allocated certain amount on monthly and yearly basis through various profit centre accounts. Norms are then fixed and expenditure monitored frequently.

- **Monthly Basis:**

Department – wise Norms are fixed regarding

- Stores running items
- Stores Indentable items

❖ Contractors' Bill
❖ Building
❖ Painting

➢ **Yearly Basis:**

Sanction required from management as per:

❖ Replacement as per agreed life norms: Equipment – wise / Item-wise
❖ Overhauling as per life: Equipment – wise
❖ Modifications / Plant reliability as per
  - Size change
  - Material change
  - Design change
  - Process change
  - Statutory Requirements

➢ **Time to Time Scheme**

❖ Savings
❖ As per suggestion from unit persons / other unit
❖ As per life-value analysis
❖ As per technology change

➢ **Other Cost Reduction Techniques**

❖ Introduction of norms for indents
❖ Indent Norms fixed at 30 %
❖ Reduction of stores expense norms
❖ Revision of pending indents on monthly basis
❖ Review of Items lying against indent but not issued for last 6 months
❖ Review of stock positions & consumption patterns before indenting material

- Weekly stores expenses monitoring
- Identifying top 10 high value items : Department-wise
- Action Plan to reduce consumption
- Identify obsolete items

➢ **Stores Items Consumption control:**

- Regular items like raw materials, fuel, packing materials : JIT approach should be adopted
- Life Value Analysis:
    - Top 10 high value items : Plant-wise
    - Top 10 high value items : Item-wise
    - Top 10 high consumption item but low value
    - Imported items
    - Critical Items as per downtime and manpower requirements

➢ **Modifications:**

- Size change
- Material change
- Design change
- Process change
- New vendor development
- Manpower cost control
    - Skill development
    - Increasing workmen output
    - Increase maintenance reliability

12.2.3 Maintenance Budget Analysis

The following parameters should be considered for maintenance budget analysis:

- ❖ Breakdown vs. Emergency maintenance:

This is the ratio of emergency jobs to total maintenance jobs, which have been completed in a particular department. Keeping track of breakdown maintenance and/or downtime hours is one of the best ways that a maintenance department has for getting feedback to check its effectiveness.

- ❖ Future plans for equipment addition or replacement

When it is expected to replace some machinery in near future or the machinery has been recently replaced, the level of maintenance should be reduced for these units. When equipment is to be removed from a department and will not be replaced, the maintenance budget should also be adjusted downward.

- ❖ Ratio of maintenance cost to equipment value

The normal expectation is that higher the total equipment value, the greater will be the amount of maintenance cost required. This ratio is an excellent method of uncovering past imbalances in maintenance expenditures.

- ❖ Ratio of maintenance cost to use factor

A use factor is any item, which is directly proportional to the amount of use of machinery within the department. The greater the number of hours the machinery is used, the more maintenance normally required. Some use factors are direct man-hours, total machine hours or any other factor proportional to the productive capacity used.

Hence for maintenance cost reduction, it is mandatory that all norms are strictly followed and department expenditure be monitored on monthly basis. The stores should inform the department heads regarding deviations from the norms. The slow-moving items and obsolete items should be listed and proper care should be taken regarding the setting of reorder point of these items.

12.3 IDEA SIMULATOR FOR COST REDUCTION

1. **Eliminate – Combine**

- ❖ Can it be eliminated?
- ❖ Can part of it be eliminated?
- ❖ Can two parts be combined into one?
- ❖ Is there any duplication?
- ❖ Can the number of different lengths, colours, types be reduced?

2. **Standardize – Simplify**

- ❖ Could a standard part be used?
- ❖ Would a modified standard part be used?
- ❖ Does the standardization contribute to cost?
- ❖ Does anything prevent it from being standardized?
- ❖ Is it too complex?
- ❖ Can connections be simplified?
- ❖ Is it over-detailed or over-specified?

3. **Challenge – Identify**

- ❖ Does it do more than is required?
- ❖ Does it cost more than it is worth?
- ❖ Is someone else buying it at lower cost?

- What is special about it?
- Is it justified?
- Can tolerances be relaxed?
- Have drawings and specifications accurate?

4. Maintain – Operate

- Is it accessible?
- Are service calls excessive?
- Would you like to own it and pay for its maintenance?
- Is labour inordinate to the cost of materials?
- How often is it actually used?
- Does it cause problems?
- Have users established procedures to get around it?

5. Requirements – Costs

- Are any requirements excessive?
- Can less expensive materials be used?
- Is it proprietary?
- Are factors of safety too high?
- Would lighter gauge materials work?
- Can different finish be used?

12.4 Spare Parts Management

A spare part is defined as a part identical to the part of a machine, which need replacement due to wear and tear during the operating life of the equipment. Spare parts include materials such as pipes, tubes, springs, electrical cables, wires, hoses, etc. Sub-assemblies include motors, engines, compressors etc. and complete units, which are to be fitted with the machine such as water circulating pumps, panels, controls, gear- box etc.

Spares are classified into variety of ways like regular, fast moving, slow moving, non-moving, consumables, emergency, electrical, mechanical, instruments, major, minor, obsolete spares. Spare parts may also be classified as maintenance, overhauling, commissioning, insurance and capital spares.

Process plant by its nature of complexity and high degree of automation is more sensitive to breakdown of components and thus has to carry more spares. The availability of drawings and the existence of infrastructure facilities for reconditioning of major components will facilitate production of spare parts in the firm itself.

The supplier of the equipment should guarantee adequate spares for a specified time and should provide all technical details covering maintenance manuals, spares catalogue, failure data, reliability information, drawing of critical items etc.

It is always necessary to keep the ordering cost and inventory carrying cost to minimum. Hence the frequency of ordering has to be monitored and number of indents need to be reduced. The average lead-time for each spare should be determined to avoid frequent stock-outs or increased stock.

The stock-out cost arises due to non-stocking of the spare part. This is usually measured in terms of opportunity lost due to production loss by the idling cost of equipment or lost sales. In an industry producing dyed fibre, it is necessary that dyes and pigments are available on time and there is no stock-out. [7]

Codification of spare parts helps in quick identification of parts and controlling the inventory and consumption pattern. A 10-digit numeric code is being used at GRASIM for codifying the spare parts.

Value Analysis and Variety Reduction by Standardization are the important tools for cost reduction and spares planning. Value Analysis is a technique to identify and eliminate unnecessary costs without affecting the functional utility, performance, guarantee, safety and quality. Standardization is a tool to optimize the number and improve the quality of service to the user. This technique is thus useful for variety reduction and overall cost reduction. ABC analysis is a useful tool to categorize items such as high cost, high volume; high cost low volume; low cost, high volume and low cost, low volume. The Top 10 costly items are then considered for standardization and variety reduction. This method should be implemented for sub-stores management.

Table 12.1 shows the inventory control of spinning accessories by the way of standardization, listing of slow moving items and discarding obsolete items. [19]

12.5 Reconditioning Vs. Replacement

Reconditioning of equipment and spares have assumed significance in the field of spares planning and maintenance of equipment in all manufacturing industries. Reconditioning of old equipment has a significant role to play in Indian industries due to prohibitive costs of new equipment, lack of adequate foreign exchange resource for machinery imports and scarcity of capital.

Once the life span of a machine is over, its reliability decreases rapidly and planning of spares becomes a difficult task. The components have low residual life and could fail without warning. Reconditioning or partial repairs tends to strengthen certain localized areas, but the risk of breakdown in areas not reconditioned continues to remain.

12.5.1 Definition of Reconditioning

Reconditioning of equipment may be defined as a planned systematic engineering activity designed to restore the equipment to its original sound performance condition. This process involves repairs to certain problematic areas in the machine and replacement of certain parts depending upon the intended performance of the machine. [7]

TABLE : 12.1

INVENTORY CONTROL OF SPINNING ACCESSORIES

A. STANDARDIZATION

S.No	Component	Old Standards	Changed Standard
1	Elbow PP	Modified and Old	Modified
2	Candle Body	Modified and Old	Modified
3	Candle Filter	Modified and Old	Modified
4	Goose neck	with or without	with stiffner of
		stiffner 37"	37" and 40"
5	SS Flexible Pipe	35" and 42"	35"
6	FRP Godets	2 double wrap	1 double wrap
		1 triple wrap	
7	Perforated disc 32000	Two designs	One design only
8	Rubber Hose Pipe	3/4", 1", 1 1/4", 1 1/2"	1 and 1 1/4"
9	Rubber Hose clips	3/4", 1", 1 1/4", 1 1/2"	1 and 1 1/4"
10	Surgical gloves	8.5", 9",10",16",18"	9" and 16"

B. SLOW MOVING ITEMS

S.No	Component	Quantity	Value
1	Blow Off MS Valve	1243	10
2	Perforated disc 32000	422	25
3	Perforated disc 19000	450	26
4	PP Shield Ring	190	21
5	Gasket for Blow off	4500	0.8
	Valve		

C. OBSOLETE ITEMS

S.No	Component	Quantity	Value
1	Bush pp 35mm	50	250
2	Bush pp 30 mm	20	232
3	Guide 4-groove	11	213
4	Guide hexa. porc.	60	99
5	Guide square porc.	99	150
6	Guide ballard	10	110
7	Guide hexagonal ballard	192	112
8	Guide single groove	475	29
9	Guide MS Stud	126	28
10	Guide spg 122	40	150

Following activities are carried out during reconditioning:

- Stripping the machine component-wise
- Degreasing and cleaning the equipment and parts
- Total inspection of components and determining their residual life
- Replacement of all components which have residual life less than 7 years
- Replacement of all mandatory components

12.5.2 When to Recondition

Reconditioning is normally applicable when the following situations arise:

- Whenever the machine is imported, reconditioning is compulsory for not only saving the foreign exchange, but also for ensuring economy in consumption of spare parts.
- Critical components must retain dimensional and structural integrity so that performance is obtained for maximum periods of time before replacement becomes necessary due to breakage. Even if they wear they should be reconditioned and reused as long as possible
- Replacement of existing machine is costly and the choice of the new machine introduces compatibility problems with the existing machines
- Original model is a special purpose one and its tailor made to suit the one-time requirement of the specific organization.
- If rejection/rework/repair/scrap is beyond a pre-determined level
- OEM has stopped manufacturing the present model

The reconditioning activity requires complete inspection of the equipment and a list is prepared for the components, which require either repair or replacement. The total cost of reconditioning and the expected extra life to be achieved by the reconditioned equipment are determined. These are then compared with the cost and life of new equipment. Based on these factors, decision is made regarding reconditioning or replacement.

12.5.3 Factors affecting Reconditioning:

The factors influencing decisions on reconditioning are:

- Anticipated failure rate
- Susceptibility of part to damage in handling
- Operating conditions
- Manufacturer's experience
- Fabrication characteristics
- Nature of repairable items
- Salvage value
- Availability of standard repair kit
- Equipment model
- Frequency of breakdowns
- Rejection/rework due to machine defects
- Pollution/ Noise
- Technological innovations/developments
- Accuracy and precision
- Reliability and maintainability
- Economics of operation
- Profitability
- Availability of infrastructure facilities
- Logistics support

12.5.4 Economics of Reconditioning:

The literature survey indicates that the replacement cost of an indigenously produced machine tool is about five times its original cost and that of imported machine tool about fifteen times its original cost due to inflation, customs duty and difference in exchange rates.

Many organizations consider reconditioning cost - inclusive of material, labor, depreciation and outside machining cost - of up to 30 % of the price of new machine, as acceptable, provided it is guaranteed that there would be no adverse effect on its performance. This level of performance can be assessed through the hours of trouble-free service after reconditioning etc. The reconditioning will be compatible with economics only if due considerations are given to ensure quality, reliability of performance, maintainability, safety aspects, lubrication, interchangeability facility of components etc.

A critical cost-benefit analysis has to be done in deciding whether a part has to be replaced or reconditioned. The components of replacement costs are replacement spares cost, installation, other service costs, costs of manuals / drawings / catalogues, cost of ordering, logistics, test facilities, manpower charges, cost of utilities, repair procedures, updating repair catalogues, transportation charges etc.

12.5.5 Economic Analysis of equipment at SFD

A study has been undertaken in the various departments of SFD like Viscose, Spinning & After Treatment, Auxiliaries and Energy Centres to evaluate the economic analysis of reconditioning and replacement.

The major equipment / component taken for study are as follows:

Viscose Department	:	Simplex No. 2
Spinning & After Treatment	:	Exhaust Hood
Auxiliaries	:	M.S.F.E. Heaters
Energy Centre	:	Exhauster Fan (Bowl Mill)

It can be seen from Table 12.2 that the reconditioning cost of the equipment / component is less than 30 % of the replacement cost. Hence, it is advisable to consider reconditioning rather than replacement. The life of the equipment should also be

TABLE: 12.2

RECONDITIONING Vs. REPLACEMENT

S.No	Equipment	Actual Life	Jobs carried out during Reconditioning	Reconditioning Cost			Replace-ment Cost (lacs)	Expected life after reconditioning	Reconditioning Cost as % of Replacement Cost	% Extra Life Expected
				Material (lacs)	Labour (lacs)	Total (lacs)				
1	Simplex 2	20 years	Jacket,pipes,nipples	0.70	0.35	1.05	15.00	15 years	7.0	75
2	M/c 1 Denier Gear Box	20 years	Reconditioning and Modification	3.00	1.00	4.00	15.00	15 years	26.7	75
3	M/c 2 Cutter Drive Gear Box	25 years	Reconditioning	6.00	0.75	6.75	20.00	15 years	33.8	60
4	M/c 5 FRP Hood	20 years	Reconditioning	0.50	0.25	0.75	6.00	15 years	12.50	75
5	MSFE Heaters	2 years	Heater shell, Tube Plate	4.00	0.30	4.30	17.00	1.5 years	25.29	75
6	Exhauster Fan (Bowl Mill EC-1)	90 days	Hard facing by 3000D Electrode	0.20	0.10	0.30	0.50	180 days	60.00	200

considered for making decisions regarding reconditioning and replacement. The reconditioning should result in enhanced life of equipment.

12.6 Annual Maintenance Contract

Annual Maintenance Contract is a mutually agreed contract between the company and service agency, whereby the service agency agrees to maintain equipment for a full year at agreed fees. The service agency defines the scope of work and the maintenance schedule for the whole year. The contract is then reviewed by the maintenance department with respect to the scope of work, price quoted and the quality of work delivered. The annual maintenance contract helps in reducing the overall cost of maintenance for the company in terms of labor, material and skill required in maintaining particular equipment.

Following factors are taken into consideration for awarding annual maintenance contract for the equipment:

- Criticality
- High maintenance cost
- Spares not available
- Spares very costly
- Specialized tools and instrument not available
- Skills not available

The equipment considered for award of annual maintenance contract at Staple Fiber Division are listed below:

- In-motion weigh Bridge
- Avery Weigh Bridge
- Mechanical Balancing
- Precision Test Bench for calibration according to ISO requirement
- Air Compressors

The charges for annual maintenance contract is generally 0.8% of the installation costs. The service agency maintains the equipment and is responsible to bring the equipment to its operational condition in case of any breakdown. The service agency provides all the spares and tools required for the maintenance of the equipment. This helps in reducing the supply downtime, thus enhancing the availability of the equipment.

A sample contract details of the Annual Maintenance Contract for Ingersoll Rand Air Compressor is given below:

Case: Annual Maintenance Contract for Ingersoll Rand Air Compressor

The Service agency defines the scope of work, schedule of work and quotes the price.

Scope of Work:

A. Day to Day Maintenance:

A mechanic will be available for 24 hours to attend breakdown in compressor i.e. valve breakdown, loading-unloading system, seal leakage, lubrication system vibration, excessive air temperature, poor performance, air or oil leakage, excessive sound, safety valve leakage etc.

B. Periodic

1. A mechanic will inspect the compressor thoroughly for sound fit working with 100% efficiency

2. **Every Three Months**

   Checking:

   a. L.P. water pressure switch working
   b. H.P air pressure switch working

c. Oil pressure switch working
d. All safety devices cleaning

3. Six Monthly

a. Safety valve testing
b. Crank case cleaning and new oil filling
c. All tolerance checking

4. Once in a year

a. Replacement of oil
b. Cleaning of compressor jacket
c. Flushing of compressor jacket
d. Safety valve
e. Check-up of instruments & their parameters
f. Compressor overhauling & clearance checking
g. Hydraulic test of air receiver

C. Against Breakdown

In case of any breakdown, engineer / mechanic will attend the compressor within an hour of loading a complaint.

D. Following are excluded for annual maintenance contract

1. Masonry work
2. Electrical Maintenance
3. Supply of spares
4. Check up of instruments and their parameters
5. Welding works

E. Daily Check

1. Oil Level in compressor
2. Jacket water supply
3. Excessive sound in compressor
4. Excessive heat in compressor
5. Unloading system of compressor
6. Valves working
7. Lubricator working
8. Seal leakage
9. Vibration
10. Drive system

F. Monthly Checklist

1. Oil pressure switch function
2. H.P. air pressure switch function
3. Air governor function
4. Checking air filter & cleaning
5. Checking of valves operating
6. Checking of discharges & suction valves
7. Lubrication of system checking

G. Yearly

1. Overhauling of compressor as per recommendations of the manufacturer as described in the maintenance manual. Maintaining all the clearance procedure precaution to be followed strictly.

H. To check following thoroughly

a. Crank shaft clearances
b. Connecting rod clearances
c. Bearing clearances
d. Valve leakage
e. Port plate leakage
f. Lubricator overhauling
g. Oil pump overhauling
h. Jacket cleaning
i. After cooler overhauling & cleaning

The service agency may also define some other terms and conditions in the contract. Based on the contract the company decides the fees and the payment terms.

12.7 Life Cycle Costing

Life cycle costing is a combination of management, financial, engineering and other practices applied to physical assets in pursuit of economic life cycle costs. Its practice is concerned with the specification and design for reliability and maintainability of plant, machinery, equipment, buildings and structures, with their installation and replacement and with the feedback of information on design, performance and costs.

The basic aim of life cycle costing is to optimize the life cycle cost of owning and using a physical asset. It is the total cost of an asset accruing to it throughout its life. It includes:

- Specification cost
- Design cost
- Production cost
- Installation and commissioning costs
- Operating costs

- Maintenance costs
- Disposal costs

Thus the life cycle costing concept deals with optimization of total maintenance costs over the equipment life cycle. At the design stage, reliability and maintainability are important and must be considered in relation to equipment performance, capital cost and running cost. The best method of production should be adopted. The quality control during plant manufacture strongly affects the level of maintenance. At the installation stage, maintainability continues to be an important consideration because it brings forth the nature of maintenance problems. The commissioning stage is not only a period of technical performance testing but also a learning period where primary design faults that might affect equipment availability can be located and designed out.

Following points should be considered while implementing life-value analysis:

- The operator of the plant should co-operate with the designer-manufacturer-installer in a full analysis of its reliability, maintainability and safety characteristics. This includes assessment of spare part provisioning, maintenance personnel training and supplier support system.
- Decisions to buy new or replacement equipment should be based on a present value life-cycle analysis of costs. Such an analysis must take into consideration both maintenance and unavailability costs.
- The plant operator and supplier should co-operate in the collection and analysis of plant failure and maintenance data in order to identify problem areas and to determine the optimum maintenance operation of plant.

The Life Cycle Costing of Belt Press 1 in Effluent Treatment Plant of Staple Fiber Division has been carried out. The details of the Life Cycle costing are shown in Table 12.3. The manufacturing cost includes the specification cost, design cost, material cost etc., the installation cost and commissioning cost includes the cost incurred by process,

TABLE : 12.3

LIFE CYCLE COSTING OF BELT PRESS 1

EQUIPMENT : BELT PRESS 1
DEPARTMENT : EFFLUENT TREATMENT PLANT

Date of Installation: 19.03.1997

S.No	Cost Item	1997	1998	1999
		(in Rs.)	(in Rs.)	(in Rs.)
1	Manufacturing Cost	20.00		
2	Erection Cost			
	Process	0.00		
	Mechanical	1.25		
	Electrical	0.75		
	Civil	3.00		
	Instrumentation	0.00		
	Others	0.00		
3	Total Erection Cost	5.00		
4	Total Initial Cost	25.00		
5	Value (using crf)	25.00	28.00	31.36
6	Operating Cost			
	Steam Cost	0.00	0.00	0.00
	Power Cost	4.82	4.82	4.82
	Water Cost	1.49	1.49	1.49
	Maintenance Cost			
	Mech.	1.42	1.95	1.88
	Elect.	0.07	0.10	0.1
	Civil	0.00	0.00	0.00
	Instru.	0.10	0.10	0.10
	Others	0.00	0.00	0.00
7	Manpower Cost	0.60	0.60	0.60
8	Inventory Cost	0.60	0.60	1.00
9	Total Operating Expenses	9.10	9.66	9.99
10	Cumulative Operating Cost	9.10	18.76	19.65
11	Total Annual Cost	34.10	46.76	51.01
12	Average Cost Period	34.10	23.38	17.00

mechanical, electrical, civil, instrumentation and others. The operating cost includes the cost of utilities, maintenance cost, labor cost and inventory costs.

The Belt Press was installed in March 1997 and the cost of manufacturing, installation and commissioning was 25 lacs. Life cycle costing has been carried out for the year 1998 and 1999. It should be noted that 25 lacs invested in 1997 become 28 lacs in 1998 considering an interest rate of 12% using capital recovery factor. The total cost includes the initial cost and the operating cost. The annual cost is the sum of present value of initial cost and the cumulative operating cost. The average cost period is the ratio of total annual cost divided by the total running years. These calculations are made each year until the equipment is due for replacement. The replacement is done when the average cost period is greater than that of the previous year.

This chapter thus focussed on the cost reduction techniques and procedures to be implemented in the maintenance department. The standardization of components helps in reducing the inventory level and maintenance budgetary control helps in reducing the maintenance cost. The guidelines and idea simulators, if followed strictly, can help in cost reduction to a large extent. The reconditioning of equipment should be preferred as it reduces the overall cost and enhances the skills of the worker. The reconditioning activity also helps in prolonging the life of the equipment to its actual life span. The annual maintenance contract reduces the overall cost of maintaining equipment. The life value analysis helps to determine the useful life of equipment and monitors the overall cost incurred on the equipment. It also helps in taking decisions regarding replacement of equipment.

The next chapter deals with training requirements of workers, top-level, middle-level and lower-level management involved in maintenance function.

CHAPTER 13

MAINTENANCE TRAINING & DEVELOPMENT

13.1 Introduction

Maintenance Training & Development is one of the important pillars of World-Class Maintenance. The basic aim of education and training is to enhance ability of individuals to contribute to improved corporate performance and to create increased values in their lives and work through 'On the job training' and self-development.

As modern plants are precise and capable of sustained output, the equipment and machinery have become very complex with high degree of technical sophistication. These machines are in need of special kind of training. Today's maintenance personnel need a totally new set of skills and considerable knowledge in a variety of fields like Electronics, Instrumentation, Robotics, NDT, Servo-mechanism, Computers, Data Acquisition Systems etc. Hence they require better education to be able to absorb the constant upgradation of technology, and to understand the equipment, its functioning and controls, and its preventive maintenance tasks, including overhaul, trouble shooting analysis and calibration.

13.2 Need for Training:

Training is necessary to keep craft personnel and first-line supervisors abreast of the technical advances continually made in plant equipment and processes and to constantly update the knowledge of the older, more experienced workers. The spending of time, effort and money on maintenance training is justifiable for the following reasons:

- Employees are unable to perform certain jobs
- They are unable to do the jobs well enough
- They are doing a job wrong

Training can be a cure as well as a preventive to a job performance problem. Used as a preventive – before and employee starts to do a job wrong – training can save time and costly errors. Used as a cure – after mistakes become obvious – training can only get the job back to normal, not make up for the lost profits and time. [8]

13.3 Responsibility for Training:

Some plant engineers and plant managers may not think training as an essential part of their jobs. Some may insist that the training department should handle all training. However, training is the responsibility of all managerial and supervisory personnel. It is essential that employees be trained in all aspects of their craft. Training should be an integral part of job enrichment within the department and company.

13.4 Determining Training Needs:

Training need analysis should be made and used as an appraisal technique by which a training supervisor can determine the present scope of individual skills and knowledge requirements. Training needs may be determined by finding out what is going on now and matching with what should go on now or in the future. The gap, if any, gives clues to the kind as well as the amount of training needed. Clues to training needs can also come from an analysis of the behaviour of individuals or groups. Chronic absence, spoilage of work, carelessness, accidents, irritability, resistance or resentment toward instruction are symptoms of conditions that may call for corrective action involving training.

13.5 Development of Training Program:

The training needs of new workers and the benefits present craftsmen can get from additional training should be determined before a training program is developed. The scope and level of knowledge of a training program should have will be determined by the difficulty of the tasks to be learned. Training is most valid when the knowledge and skills being taught are required and will be practiced on the job. The equipment and facilities to be maintained will help in determining the needs of the training program. The basic steps for instituting a good training program are as follows:

- Accurately determine job requirements
- Accurately determine skills requirement
- Ensure that training materials are at the trainees' level of comprehension
- Use training materials that can easily be adapted to the needs of the company
- Maintain good supervision, personal contact, and follow up with trainees
- Institute good environmental conditions that encourage learning

Once the responsibility of training is accepted, the trainer should consider the best way to instruct the trainees. This involves learning about visual aids and communications and knowing how to generate involvement, motivation, interest and enthusiasm. [16]

13.6 Determining Training Objectives:

Training should be designed to fill the gap between where an employee is and that of employee's predetermined goal after training. The objectives of an in-plant maintenance-training program should provide for:

- Training of selected personnel in the knowledge and performance of tasks required for them to progress from trainee to craftsman
- A means by which they can refresh or update present knowledge
- Steps for continued development of all craftsmen
- A climate that encourages individual effort so that knowledge can be most effectively gained
- Sufficient flexibility so training will not interfere with plant work needs
- Planned work assignments that meet experience capabilities
- Scheduled participation and study time in the training program
- Help and support for overall trainee achievement

13.7 Levels of Training

There are three levels of training at which training has to be imparted:

- Worker Level
- Supervisor Level
- Executive Level

➢ **Worker level training:**

Worker level training should mainly be focussed on general training, specific trade knowledge and skills, specialized knowledge of process, plant and machinery. It should also emphasize on behavioral training and their interaction with the shop floor engineers. They should be able to follow the instructions and act accordingly. Table 13.1 shows the training module for workers of Energy Centres.

➢ **Supervisory training:**

The shop floor engineers should have a thorough technical knowledge and good inter-personal skills, so that they can tackle the workers tactfully and motivate them to get the work done. These qualities can be nurtured and cultivated during their developmental training.

➢ **Executive training:**

The top level management should be given training on role of maintenance, its costs and its operational problems, for it deepens their understanding and involvement in this crucial function.

TABLE: 13.1

WORKMEN TRAINING MODULE FOR ENERGY CENTRES

S.No	SECTION	TRAINING AREAS	Duration	Guide
1	ELECTRICAL	Control wiring of equipment	4 hrs.	Sr. Engineer
		Inter panel wiring and location of control fuses		
		Cable transmission and use of tools		
		Isolation of equipment		
2	INSTRUMENTATION	Calibration Procedures for instruments	8 hrs.	Sr. Engineer
		Field wiring layout and location of junction boxes		
		Safe and correct procedures during maintenance		
3	ASH HANDLING	Vacuum system in Ash Handling	8 hrs.	Sr. Engineer
		Dust Conditioner and Pumps		
4	DEMIN PLANT	Ion-Exchangers regeneration procedure	4 hrs.	Sr. Process
		Emergency operation during plant trouble		Chemist
		Condition monitoring and trouble shooting		
5	TURBINE	Sequence of Operation	6 hrs.	Sr. Engineer
	OPERATION &	Trouble shooting and emergency operation		
	ACCESSORIES	Condition monitoring		
		Knowledge about carious instruments		
6	COAL HANDLING	Operational Requirements	10 hrs.	Sr. Engineer
		Repair work of plant and machinery		
		Preventive Maintenance & Emergency Operation		
7	BOILER	Emergency operation during plant trouble	4 hrs	Sr. Engineer
	OPERATION &	Condition monitoring		
	ACCESSORIES	Running maintenance procedure		

The middle level maintenance executives needs more of a Management Development Programme, which will have a balanced mix of inputs like Finance, Industrial Relations, Materials Management, Cost Reduction Techniques, Leadership, Conflict Resolution, Group working, Motivation, technical knowledge of NDT, Calibration etc. They also require inter-disciplinary and inter- department training. Hence job-rotation is a must for middle level executives.

The lower level maintenance executives need a mix of technical and management training. They should go for short-term courses in Maintenance & Safety, Maintenance Management, Computer-aided Maintenance Information System, Cost control, NDT, Industrial Engineering Techniques etc.

Table 13.2 shows the matrix for the training areas for various level of management responsible for maintenance activities of the plant.

13.8 Training Methods

A variety of training aids/methods are used for training:

1. **Simulators:** Simulators can simulate faulty conditions in the system for defect diagnosis and their rectification.
2. **Sectioned models:** Sectioned models of machine or equipment can explain the entire functioning of the equipment.
3. **Wall Diagrams and charts:** These are helpful for explaining the process, flow diagrams, lubrication methods, cleaning methods etc.
4. **Maintenance Manuals:** Maintenance manuals, publications, training manuals etc.
5. **Video films:** Various video films are available which show the working of the equipment, problems and trouble shooting.
6. **Trouble-shooting charts:** Trouble-shooting charts clearly show the problems and how it can be rectified under different equipment conditions.

TABLE : 13.2

TRAINING AREAS FOR MAINTENANCE EXECUTIVES

S.No	Training Areas	Level A Top Mgmt.	Level B Middle Mgmt.	Level C Lower Mgmt.
1	Process Description and Parameters			
2	Equipment Know-how			
3	Criticality Assessment of Equipment			
4	Autonomous Maintenance			
5	Lubrication Management & Practices			
6	Cleaning and Inspection			
7	Abnormality Detection			
8	Maintenance Engineering			
9	NDT,Condition and Vibration Monitoring			
10	Maintenance Information System			
11	Maintenance Systems & Procedures			
12	Maintenance Planning & Control			
13	Safety Procedures in Maintenance			
14	Statutory Requirements			
15	Reliability, Maintainability & Availability			
16	Lubrication Management & Practices			
17	Financial & Budgetory Control			
18	Cost Reduction Techniques			
19	Trouble Shooting			
20	Minimising Scrap, Rework, Wastage			
21	Stores Management			
22	Standardization			
23	Spare Parts Management			
24	Life Value Analysis,Reconditioning & Replacement			
25	NOBM Concept and Implementation			
26	Worker's Utilisation & Contractor's Work Supervision			
27	Industrial Relations			
28	Team Building & Conflict Management			
29	Advancements in Maintenance			
30	World Class Maintenance			

Level C

Level B

Level A

7. **Classroom teaching:** Short-term courses in Maintenance & Safety, Maintenance Management, etc. can be taught in the classroom. Real-life problems can be taken up and optimal solution can be found out through brainstorming sessions.
8. **Case studies:** Case studies can be prepared on different recurring problems of the equipment and other management problems related to industrial relations and personnel management.
9. **On the job training:** On the job training under expert supervision helps in enhancing the skills, identifying the problems and finding solutions.

13.9 Determining Training Performance:

To determine the overall effectiveness of the training program, spot-checks should be made to assure that satisfactory progress are made by the trainees. Spot- check the work of the trainees out in the plant to make sure that knowledge gained in the training program is being applied to the job. A Performance Rating Sheet can be used as an appraisal tool to evaluate individual performance with respect to the quantity and quality of work. [8]

This chapter thus focussed on the importance and need of Maintenance Training and Development. The maintenance activity being a highly skilled job, it is necessary that the workers are properly trained and should acquire knowledge about equipment and entire process. The executives should be aware of recent advancements in maintenance engineering and should be able to implement it to the fullest. Training module has been designed for workers and the training areas have been identified for each level of management. Training should be imparted on a continuous basis to all cadres of management and performance in the training should be properly evaluated.

CHAPTER 14

CONCLUSION & RECOMMENDATIONS

The thesis work attempted to design systems and procedures for implementing World - Class Maintenance at Staple Fibre Division, Grasim Industries Limited. The study was undertaken at various key departments like Viscose, Spinning & After-Treatment, Auxiliaries, Sulphuric Acid Plant and Energy Centres of Staple Fibre Division.

The first step in implementing World - Class Maintenance involves study of existing organization structure and proposing a new structure with well-defined duties and responsibilities. The study of the organization structure revealed that the number of levels needs to be reduced and responsibilities clearly defined for smooth functioning of the maintenance department. The proposed structure has five levels and the duties and responsibilities have been clearly defined for each of these five levels. Role clarity thus helps the maintenance personnel to work within boundaries and helps in improving the department working. The Manager should be the Head of the Department and General Manager, the Head of Profit Centres. The Engineering Services Department will look after Industrial Engineering, Safety & Fire Fighting, Industrial Transport, Planning and Control activities of the maintenance department.

The maintenance information system has been designed to cater the needs and information requirements of various levels of the maintenance organizational hierarchy. An Executive Summary Report (Level A) gives the necessary information related to maintenance activities for top-level management. The Level B formats help the middle level management to analyze and control various maintenance parameters. The data in the Level B formats are analyzed and action plans are prepared so that the management can take right decisions at the right time. It also facilitates efficient plant working and optimum utilization of resources, thus meeting targets and deadlines. The Level C formats, entered by lower-level management, acts as a database for each equipment or department with respect to downtime, nature of breakdowns, production loss, stores expenses, contractors' expenses, modifications, new schemes, accidents etc. The Level C formats help the shop-floor engineers and supervisors to take corrective actions and plan the maintenance schedule accordingly.

The design of World - Class Maintenance systems calls for defining various maintenance systems and the factors to be considered for achieving more stability and maintainability. Maintenance Planning & Scheduling helps the maintenance engineers to plan the job in advance and take prompt action in case of any emergencies. Guidelines and procedures have been devised to facilitate decisions regarding the planning of emergency breakdown, shut down, repetitive jobs and preventive maintenance scheduling. The management control parameters such as unreported man-hours, scheduled man-hours, scheduling compliance, performance of completed jobs etc. help in monitoring the effectiveness of the maintenance system.

The World - Class Maintenance System provides guidelines and principles of attaining safety and describes the procedures for imbibing best maintenance practices. Safety Audit and Checklists help in evaluating the safety of the plant. The tools and techniques used for identifying hazards include HAZOP and HAZAN studies, which have been illustrated by an example from CS_2 and Auxiliary departments.

The Asset-Care Management emphasizes on maximizing the overall equipment effectiveness (O.E.E.) through the people that operate and maintain the equipment. The criticality of equipment depends on the ease of repair, reliability, product quality, throughput velocity, loss of production, safety, environment and cost. The criticality assessment has been carried out for spinning machine and critical components have been identified. These components require maximum attention and care and the failures can cause greater production loss. In order to improve the availability, maintainability and reliability of the equipment, various scientific problem-solving tools like P- M Analysis, Why-Why Analysis, etc. help to analyze the problem, its causes and corrective actions can be formulated. Few real-life examples from various departments have been described to understand the principles of these tools.

The Overall Equipment Effectiveness (O.E.E.) has been calculated for Spinning Machines, Slurry Press, MSFE, Acid Plant, Boiler and Turbine. The availability, performance and quality rate have been calculated for above equipment. The parameters like Availability, Performance Rate, Quality Rate, O.E.E., Mean Time Between Maintenance (M.T.B.M), Mean Down Time (M.D.T), Severity Index, Frequency Index, Operational Availability, Achieved Availability have been benchmarked for Spinning Machines for facilitating further improvement and strive for world-class.

The Quality of Fibre, as defined by production department, is the % (G + R) grade achieved for spinning faults. However, there are various other factors, which determines the quality of fibre like, colour, denier, moisture, OPU, neps etc. Hence, the quality of fibre can best be determined by considering all these factors by assigning different weightages depending on the sales requirement. An empirical formula has been devised, which best quantifies the quality of fibre.

The objective of maintenance is to maximize the availability of machine. This can be accomplished through a new concept " Need–cum-Opportunity Based Maintenance", which emphasizes on defining the need, creating or utilizing the opportunity and thus enhancing availability. This requires close coordination between various disciplines and departments so that during any stoppage, all work related to various disciplines / departments can be carried out simultaneously. This helps in effective utilization of resources and reduction in frequency of stoppages. A format has been developed which helps in identifying the pending jobs and resources required. Whenever any stoppage takes place, then the pending jobs can be carried out as per the duration of the jobs. Guidelines have been provided to categorize breakdown, NOBM and planned stoppage.

The main aim of maintenance is to make itself redundant. Hence, maintenance needs to be prevented. The prevention of maintenance can be achieved through process improvement, design change, vendor change, material change and size change. The implementation of these methods resulted in simplification of systems and reduction in downtime in Spinning & After-Treatment Departments.

The maintainability of equipment is improved by adopting improved service conditions, better testing facilities, quality material, spares and better skills. The various condition monitoring and vibration monitoring techniques have been dealt and the results show that there is a considerable saving in terms of rupees and downtime. The vibration monitoring predicts the condition of equipment and helps in taking corrective actions.

The maintenance prevention and maintainability improvement thus requires a careful and thorough analysis of different types of failures, its causes and corrective actions taken. The expert cell, constituting a team of experienced maintenance personnel and shop floor engineers, should be formed, which can identify the problems, carryout thorough analysis and take corrective actions scientifically. The inspection cell for material quality control should be established for thorough inspection of raw material, work-in-progress and finished products, so that quality is maintained and rework avoided.

Autonomous Maintenance is one of the important pillars of World-Class Maintenance, which helps in keeping the workplace clean and equipment trouble-free. All activities like cleaning, checking, inspection and lubrication can be carried out in a planned way. Guidelines have been prepared so that the operators can carryout these operations effectively. Autonomous maintenance checklists have been prepared for Spinning & After-Treatment Department, which includes checklists for Spinning Machines, After-Treatment section, Dryer and Baling Press. The implementation of Autonomous Maintenance improves work culture and imbibes feeling of ownership.

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Controlling the maintenance cost is an important aspect of World - Class Maintenance. The major expenses incurred are that of material cost, manpower cost and rework. Hence, it is mandatory that spare parts management and manpower utilization should be given utmost attention. The maintenance cost analysis should be undertaken on a weekly basis and the deviations should be properly analyzed. The budgeting should be done on an yearly basis and monitored continuously. Standardization of material and spare parts results in variety reduction and in turn reduces the inventory.

Replacement of components / equipment is the easiest job in maintenance. The replacement activity requires lot of investment and kills the skill of maintenance personnel. The replacement of equipment is often done before achieving its useful life. Hence, it is recommended that reconditioning of equipment should be carried out according to the guidelines provided and proper analysis should be done regarding the failures and its frequency. This helps in prolonging the life of equipment and saving a lot of money. This activity also helps the maintenance personnel to become more skilled in maintaining the equipment. The decisions regarding reconditioning and replacement have been described through examples from various departments of Staple Fibre Division.

The concept of annual maintenance contract for equipment is adopted to reduce the overall maintenance cost. The service agency maintains the equipment through continuous monitoring, checks and overhauls. The life cycle costing should be carried out for critical component / equipment so that the overall costs can be monitored through out its life and decisions can be taken regarding its replacement. The life cycle costing of belt press shows that the average cost period reduces over a period. When this average cost period is greater than that of the previous year, the equipment will be due for replacement.

The training and development of maintenance personnel helps to develop skills and upgrade the knowledge. It also improves the ability to take right decisions and promotes good work-culture. The training modules for workers help in enhancing the knowledge about the job and skills for performing typical jobs. The training areas identified for various levels of management like top level, middle level, lower level management, can help them in adopting scientific approach to problem solving, taking right decisions at the right time and utilizing the resources effectively and efficiently. A training module for workers has been prepared for workers at Energy Centres and the training areas have been identified for executives of all levels.

Thus, the implementation of World – Class Maintenance requires a thorough application of above systems and procedures. The top-level management should render full support. The middle-level management should analyze all the maintenance parameters and should make efforts to improve maintainability, reliability and overall equipment effectiveness. The lower-level management should be able to implement the new concepts in a scientific manner and make every effort to improve their department working by adopting best maintenance practices and upgrading their skills and knowledge. The operators and maintenance workers should understand and adopt autonomous maintenance concept, safety practices and upgrade their skills through training and development.

The Staple Fibre Division of GRASIM Industries Limited has successfully implemented the concepts of World – Class Manufacturing and achieved excellent results in all its pillars. The implementation of World – Class Maintenance would definitely help in achieving better results in equipment maintenance, enhancing the availability of plant and creating a good work culture.

ANNEXURE 1

OEE CALCULATION OF SLURRY PRESS

MONTH : DECEMBER, 1999

S.No	EQUIPMENT	CALCULATION	X1 + X2
A	Calendar Time	31 * 24	1488
B	Total Downtime		163.7
C	**Availability**	(A-B) / A	0.89
D	Avg. Actual Production		1529
E	Standard Production		1674
F	**Performance Rate**	D/E	0.91
G	**Quality Rate**		0.72
H	**OEE**	CxFxG	0.59

QUALITY CALCULATION

ALK CELL RANGE	%	No.of Days	Weighted
0.465 + 0.003	100	4	
0.465 + 0.006	90	4	
0.465 + 0.009	80	9	
0.465 + 0.012	70	4	
0.465 + 0.015	60	6	
0.465 + 0.018	50	0	
0.465 + 0.021	40	1	
0.465 + 0.024	30	2	
0.465 + 0.027	20	1	
0.465 + 0.030	10	0	
0.465 + 0.033	0	0	
		31	72%

ANNEXURE 2

OEE CALCULATION OF MSFE 6

MONTH: NOVEMBER,1999

S.No	EQUIPMENT	CALCULATION	M6
A	Calendar Time (Hrs.)	No. of days* 24	720
B	Total Downtime (Hrs.)		41
C	**Availability**	(A-B) / A	0.9431
D	Avg. Actual Steam Economy		0.36
E	Standard Steam Economy		0.27
F	**Performance Rate**	E/D	0.75
G	Number of Quality Sulphate Reports		636
H	Total Number of Reports		679
I	**Quality Rate**	G/H	0.9367
H	**OEE**	CxFxI	0.6625

ANNEXURE 3

OEE CALCULATION OF ACID PLANT 1

MONTH: DECEMBER 1999

S.No	EQUIPMENT	CALCULATION	AP1
A	Calendar Time	No. of days* 24	1488
B	Total Downtime		0.1
C	**Availability**	(A-B) / A	1.000
D	Avg. Actual Production		3242
E	Standard Production		3255
F	**Performance Rate**	D/E	0.996
G	Number of Quality Acid Reports		23
H	Total Number of Reports		31
I	**Quality Reports**	G/H	0.742
H	**OEE**	CxFxI	0.74

ANNEXURE : 4

OEE CALCULATION OF BOILER 1

S.No	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
1	CALENDAR TIME	744	672	744	720	744	720	744	744	720	744	720	744
2a	Shutdown maintenance loss (hrs.)	216	576	0	0	0	0	0	0	0	0	0	0
2b	Production adjustment loss (hrs.)	528	96	136	0	0	0	0	214	0	0	0	0
2c	Sutdown loss (2a + 2b)	744	671	136	0	0	0	0	214	0	0	0	0
3a	Equipment failure loss (hrs.)	0	0	0	0	0	0	0	0	0	0	0	0
3b	Process failure loss (hrs.)	0	0	0	0	0	0.5	0	0	11	0	3	2
3c	Major Stoppage loss (3a + 3b)	0	0	0	0	0	0.5	0	0	11	0	3	7
4	**Availability { (1-2c-3c) / 1}**	0	0	0.817	1	1	0.999	1	0.712	0.985	1	0.996	0.991
5a	Time loss due to equip/process failure	0	0	0	0	0	0	0	0	11	0	5	0
5b	Time lost due to equip stoppage for prodn. adj.	528	96	136	0	0	0	0	214	0	28	0	11
5c	Operating time (1-5a-5b-2a)	0	1	608	720	744	720	744	530	709	716	715	733
6a	Actual production (tonnes or MWH)	0	0	41150	49294	51654	48917	50053	34774	48706	49808	48904	50021
6b	Avg. actual production rate (6a/5c)	0	0	67.68	68.46	69.43	67.94	67.28	65.61	68.7	67.35	68.2	67.74
7	Standard production rate (t/h) or MW	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5	67.5
8	**Performance Rate (6b/7)**	0	0	1.003	1.014	1.029	1.007	0.997	0.972	1.018	0.998	1.010	1.004
9	**Quality Rate**	0	0	1	1	1	1	1	1	1	1	1	1
10	OEE (4 x 8 x 9)	0	0	0.819	1.014	1.029	1.006	0.997	0.692	1.002	0.998	1.006	0.994

ANNEXURE : 5

OEE CALCULATION OF BHEL TURBINE

S.No	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC
1	**CALENDAR TIME**	744	672	744	720	744	720	744	744	720	744	720	744
2a	Shutdown maintenance loss (hrs.)	0	0	0	0	0	24	0	0	14	0	0	0
2b	Production adjustment loss (hrs.)	0	0	0	0	0	0	0	0	0	0	0	0
2c	Sutdown loss (2a + 2b)	0	0	0	0	0	24	0	0	14	0	0	0
3a	Equipment failure loss (hrs.)	0	0	0	0	0	0	0	0	0	0	0	0
3b	Process failure loss (hrs.)	0	0	0	0	0	0	0	0	0	0	2	0
3c	Major Stoppage loss (3a + 3b)	0	0	0	0	0	0	0	0	0	0	2	0
4	**Availability { (1-2c-3c) / 1}**	1	1	1	1	1	0.967	1	1	0.981	1	0.997	1
5a	Time loss due to equip/process failure	0	0	0	0	0	0	0	0	0	0	0	0
5b	Time lost due to equip stoppage for prodn. adj.	0	0	0	0	0	0	0	0	0	0	0	0
5c	Operating time (1-5a-5b-2a)	744	672	744	720	744	696	744	744	720	744	720	744
6a	Actual production (tonnes or MWH)	10608	9173	8823	7510	7711	9465	10416	8664	7396	7269	7673	8286
6b	Avg. actual production rate (6a/5c)	14.26	13.65	11.86	10.43	10.36	13.6	14	11.64	10.27	9.77	10.30	11.12
7	Standard production rate (t/h) or MW	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5
8	**Performance Rate (6b/7)**	0.92	0.88	0.77	0.67	0.67	0.88	0.90	0.75	0.66	0.63	0.66	0.72
9	**Quality Rate**	1	1	1	1	1	1	1	1	1	1	1	1
10	OEE (4 x 8 x 9)	0.92	0.88	0.77	0.67	0.67	0.85	0.90	0.75	0.65	0.63	0.66	0.72

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LIST OF ABBREVIATIONS

AFBC	: Atmospheric Fluidized Bed Combustion Boilers
BHEL	: Bharat Heavy Electricals Limited
CBM	: Condition Based Monitoring
CCN	: Cost Center Number
CD	: Chemical Division
CPM	: Critical Path Method
EDD	: Engineering & Development Divisions
FMCEA	: Failure Mode and Cause -Effect Analysis
HAZAN	: Hazard Analysis
HAZOP	: Hazard Operability Studies
JIT	: Just – In – Time
LCC	: Life Cycle Cost
LTJ	: Long Term Jobs
MDT	: Mean Down Time
MIS	: Management Information System
MSFE	: Multi-Stage Flash Evaporator
MTBF	: Mean Time Between Failure
MTBM	: Mean Time Between Maintenance
MTJ	: Medium Term Jobs
MTTR	: Mean Time To Failure
MUSIC-3D	: Multi-Unit Spares Inventory Control - 3 Dimensions
NDT	: Non-Destructive Testing
NOBM	: Need-Cum-Opportunity Based Maintenance
O.E.E.	: Overall Equipment Effectiveness
O.E.M.	: Original Equipment Manufacturer
O.P.E.	: Overall Plant Effectiveness
O.P.U.	: Oil Pick Up
PCs	: Profit Centers
PERT	: Programme Evaluation & Review Techniques
P.F.	: Pulverised Fuel
P-M	: Phenomenon Mechanism
PM	: Preventive Maintenance
RCM	: Reliability Centered Maintenance
SFD	: Staple Fiber Division
STJ	: Short Term Jobs
TIC	: To Inform and Confirm
TPD	: Tons Per Day
TPH	: Tons Per Hour
TPM	: Total Productive Maintenance
TQM	: Total Quality Management
WCM	: World-Class Manufacturing

Enhancing Plant Availability and Equipment Maintainability

Arun Maity

This paper highlights the various ways and means to enhance the plant availability and equipment maintainability. The foremost aim should be to reduce the frequency of downtime and the duration of stoppages. This can be achieved through coordinated efforts of departments and better asset-care management. Need-cum-Opportunity based Maintenance serves as a useful tool to enhance plant availability. Maintenance Prevention Techniques should be adopted to increase the equipment maintainability. This can be achieved through continuous monitoring of equipment and practicing Autonomous Maintenance. The work has been carried out at Staple Fibre Division, GRASIM Industries Limited, Nagda, which is the largest manufacturer of Viscose Staple Fibre.

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Introduction

Availability is an important aspect of overall equipment effectiveness. The more the frequency of breakdown and the duration of stoppages, lower the availability and the overall equipment effectiveness. Hence it is necessary to achieve minimum downtime of equipment through better coordination amongst all the related departments. Any machine stoppage gives an opportunity for all departments to carry out their jobs according to priority and availability of resources, thus enhancing the plant availability.

Need-cum-Opportunity Based Maintenance (NOBM)

The availability of equipment can be enhanced by adopting Need-cum-Opportunity based Maintenance (NOBM), which aims at enhancing the availability through reduced stoppages and utilizing idle time of equipment for other planned activities and modifications.

Defining Need

The need for maintenance is felt when certain equipment requires repair or replacement of the components. Predictive Maintenance is generally called for when there is vibration or noise on certain components. This requires immediate attention and stoppage is taken to attend the abnormality. Need also arises, when certain schemes have to be implemented or modifications have to be carried out. For carrying out all these activities, machine stoppages have to be taken. It is this opportunity, which the maintenance people can make use of in carrying out pending jobs.

Hence, the maintenance department should have a list of pending jobs, material and labor readily available during the stoppage. If the stoppage of the spinning machine is due to mechanical fault, the electrical and civil department can take this opportunity and carry out pending work.

Defining Opportunity

Opportunity for maintenance generally occurs during following conditions:

- **Quality Change**
  Spinning machines produce fibre of different denier, shades and colour. Stoppages have to be taken when these characteristics need to be changed. Normally a stoppage of 2-hour duration is taken on the machine.

- **Accumulation Clearing**
  When there is a change in quality, the machine is stopped and the fibre produced out of previous quality has to be cleared. This results in accumulation of fibre. The fibre is also removed when there is fire or a problem occurs in dryer, spike lattice or the pneumatic handling system. The fibre gets accumulated near the dryer end. The clearing of fibre normally takes 4-6 hours.

- **Power Failure**
  Whenever the power fails the machine stops. After the resumption of power, the machine can be restarted only after few hours, as the process parameters need to be set again.

- **Breakdown**
  The machine stoppage takes place whenever a critical component fails. The component has to be repaired or replaced before the machine restarts.

- **Target being lower than the capacity of the machine**
  Whenever the target is lower than the capacity, the machine is run at low speeds. If some jobs are pending, then the machine can be run on normal speeds and stoppages can be taken after the target production is met.

- **Viscose generation being not sufficient for full-capacity production**
  If the viscose generation is not sufficient for full capacity production, then the target of fibre production is reduced or the machine is run at low speed. If required, stoppages are also taken into consideration.

- **Preventive Maintenance**
  Preventive maintenance on spinning machines is normally taken every 55 days. All pending jobs are carried out during this stoppage. The duration of preventive maintenance is normally for 10-12 hours.

- **Planned Stoppage**
  When any critical job has to be carried out or modifications / new schemes have to be implemented, the machine stoppages are taken. During the planned stoppage, other pending jobs are also carried out.

Guidelines for NOBM

Following guidelines should be followed for implementation of NOBM concept:

- All departments should be aware of the stoppages taking place on any equipment.
- Each department should list out the jobs to be taken under NOBM under the heads Short Term Jobs (STJ), Medium Term Jobs (MTJ) and Long Term Jobs (LTJ) and should also state whether the jobs are critical or non-critical.
- Short Term Jobs are the jobs, which can be carried out within 2 hrs. Medium Term Jobs are the jobs, which would take 2-4 hrs. And Long term Jobs are the jobs, which would take more than 4 hrs.
- Short Term Jobs should be carried out during stoppages like Quality Change, or during small breakdowns of 2 hours duration.
- Medium Term Jobs can be carried out during Accumulation Clearing and Planned Stoppages or when the viscose generation is not sufficient to give full production.
- Long term Jobs can be carried out during Preventive Maintenance.
- It will be the responsibility of the Process Department to inform other departments like Mechanical, Electrical, Instrumentation and Civil that a stoppage

has been taken and their jobs can be carried out during the stoppage time.

- The manpower and spare parts requirement should also be indicated during the listing of jobs and the same should be available at once during the stoppage time to avoid any supply downtime.
- Critical Jobs will be taken first and then the other non-critical jobs.

The data to be fed into the computer should be as per the format shown in Table 1. The engineer will enter the data whenever he identifies the need for maintenance of certain component or equipment. He would also specify the expected duration of the job to be performed in terms of STJ / MTJ / LTJ. He would also specify whether the job is critical or not. In the discipline column, he would enter the nature of the job, i.e. process, mechanical, electrical, instrumentation, civil etc. The data can also be fed in the computer in the proposed format.

The data will be sorted daily in terms of duration of the jobs, criticality, discipline and status of the job, which would help the engineers to take up the jobs on priority basis and proper planning can be done before hand.

If an opportunity occurs due to quality change, accumulation etc. the jobs will be carried out according to the guidelines and the jobs duration will be entered in the scheduled stoppage column. But if there is no opportunity and job has to wait, the following criteria will be used :

If the job can wait only upto 24 hours : Breakdown
Jobs can wait between 24 - 72 hours : NOBM
Jobs can wait more than 72 hours : Planned Stoppage

The above guidelines suggest that if the job cannot wait for more than 24 hours and becomes critical, then the stoppage is taken and is treated as a breakdown. However, if the job can wait between 24 and 72 hours, and there is no opportunity to carry out the job, then the opportunity has to be created and stoppage needs to be taken. This stoppage will be treated as NOBM. If the job can wait more than 72 hours, then the stoppage will be considered as planned stoppage.

Table : 1

Need-Cum-Opportunity Based Maintenance

S.No.	Need Identification			Eqpt.	Nature	Discipline	Job Duration			Job Performed	Waiting (hrs)			Stoppage			Completion		Status
	Date	Time	Description				STJ	MTJ	LTJ	(Opportunity)	<24	24-72	>72	SCH	NOBM	B/D	Date	Time	

Advantages

- Every department can plan their work and list the jobs to be carried out during any stoppages.
- The availability of the manpower and spares can be planned and optimally utilized.
- Clubbing of planned and unplanned jobs can be done which increases equipment availability and performance.
- Each department is aware of the problems occurring in the plant and thus can contribute to finding the solution.
- Reduction in the frequency of stoppages.
- Breakdowns can be greatly reduced due to periodic checking during stoppages.
- Supply downtime can be reduced as spares and labor are readily available.

These guidelines will thus help in achieving better coordination amongst various departments. The spares and labour can be optimally utilized and the frequency of stoppages can be greatly reduced resulting in increasing availability.

Asset-Care Management

The asset-care management consists of three phases namely, condition cycle, measurement cycle and improvement cycle. Criticality assessment helps to assess the equipment production process and determine the relative criticality of each element. This will enable priority to be allocated for refurbishment, future asset care and improvement of those elements most likely to have an effect on overall equipment effectiveness. The various factors, which should be considered for criticality assessment are ease of repair, reliability, product quality, maintenance interval, throughput velocity, loss of production, safety, environment and cost. Above factors can be ranked 1-3 and critical components can be determined as per the score obtained. Proper attention and care should be taken of all these critical components.

- **Phenomenon Mechanism Analysis (P-M)**

P-M analysis physically analyzes the chronic problems such as defects and failures according to the machines operating principle. It defines the essential or constituent conditions underlying the abnormal phenomena. It identifies all factors that logically contribute to the phenomena in terms of 4M's - equipment mechanisms, materials, methods, and man. Based on the above findings, optimal conditions are set, abnormalities are rectified and frequency of inspection determined.

- **Why-Why Analysis**

Why-Why Analysis is an effective tool for problem solving. This helps in identifying the problem and identifying the root cause of the problem. At each stage question Why ? is asked and possible solutions are listed. Then the optimum solution is considered for implementation.

- **Best Maintenance Practices**

Develop best maintenance practices for operation and maintenance so that there are reduced chances of error and risk, improvement of performance and removal of irregularity, elimination of poor operation and negligence in work.

Maintenance Prevention

"Prevention is better than cure", this proverb sounds rightly in case of maintenance also. If the maintenance is prevented, then the availability of the plant increases and the overall cost reduces. Every effort should be made to avoid maintenance, which can be achieved through continuous monitoring of equipment and upgrading the sophistication of the equipment through better design and process improvement .

Methods of Maintenance Prevention

The various methods of maintenance prevention are :

- Design change
- Size change
- Material change
- Process Improvement
- Vendor change

These methods have been adopted in Spinning & After Treatment departments of Staple Fibre Division, which resulted in reduced downtime and better working of the plant.

1. Cutter Drive Gear-box

The cutter drive gear-box was prone to frequent failures caused due to excessive failure of clutch plates. There were excessive vibrations of rotating parts causing high sound level, higher set-up time, and individual drive required machine stoppage for isolation. Hence, a design change was necessary to overcome these problems.

A separate servo-drive was coupled to each cutter along a linear RPM controller linked to machine (speed) gear box, thereby eliminating staple gear and mechanical assembly in cutter drive gear box. The results indicated that the initial investment reduced by Rs. 2 lacs/machine, downtime reduced by 0.3%, maintenance cost reduced by Rs. 3 lacs/year/machine and power consumption reduced by Rs. 1 Lac/machine/year.

2. Trio Roller Shaft

It was observed that trio roller shaft was subjected to :

- High Load
- Tow stretch
- Failure of shafts due to stress and strain
- Notch sensitivity

- Environmental condition (acidic medium)
- Frequent pitting leading to micro blowholes

These problems necessitated a change in design of trio roller shaft and following changes have been incorporated:

- Radius at notch sensitive areas
- Locating by M-60 threads
- Size increase from 115mm to 135mm to take the high load
- Bearing changed from 232226 to 23130K

Maintainbility

When equipment is undertaken for repair, the ease with which it is brought back to its original operational condition is called maintainability. Maintainability is thus the probability that a unit or system will be restored to specified conditions within a given period when maintenance action is taken in accordance with prescribed procedures and resources. It is characteristic of the design and installation of the unit or system.

The specified conditions to which the unit is required to be restored are generally with reference to its performance characteristics after it is repaired. These performance characteristics are specified in advance and are indicative of the satisfactory performance of the unit. The time within which the item is restored to the specified conditions is an important factor. The resources as labor, tools, spares etc. should be readily available in order to minimize supply downtime.

Repair is a common operation as the cost of repair or replacement is much less than that of replacing the entire system. There are many systems, which are life supporting and critical in nature, where repair and replacement is not considered, from the point of view of safety. Ignoring such situations, repair and maintenance make a system available for use for a long period. The mean time to repair (MTTR) is the best measure for maintainability. Lower the MTTR, higher is the maintainability factor. MTTR is the statistical mean time for active repair. It is the total active repair time during a given period divided by the number of malfunctions during the same interval.

Maintainability Improvement Procedures

The maintainability improvement should be implemented right from the design stage. The maintainability of equipment can be improved by adopting better service and testing procedures, skills, spares management and condition monitoring techniques.

- **Improve service procedure**

It is mandatory to have a clear-cut procedure of services to be performed on critical equipment. The method of carrying out repair, spare parts requirement, labor requirement, skills requirement and any other sophisticated devices requirement, and expected duration of repair, etc. should be clearly specified in the service procedure for each major equipment malfunction. The repairs should be done with accuracy and patience to avoid rework and wastage in minimum time. Whenever a major repair activity takes place, work permit should be complete in all respects.

- **Improve testing procedures**

All equipments should have proper testing procedures. The instruments should be properly calibrated and the range of parameters clearly specified. The interval of calibration and testing should be strictly followed according to the plan. The instruments should be protected against environmental impacts.

- **Improve Skills of labor**

The maintenance personnel should acquire skills to operate sophisticated instruments and improve workmanship. The labour should be skilled enough to perform the job precisely and with accuracy. The rework and wastage should be avoided. Proper training should be given to labor so that they get knowledge about functioning of equipment, interpret the drawings and can operate equipment safely within desired norms and operating conditions.

- **Availability and Quality of service parts**

The spare parts required for repair operation should be readily available. It is necessary to standardize the spare parts to reduce inventory. The quality of spare parts should be inspected on a regular basis and good vendors should be identified. The spares should be of the same quality as specified by the manufacturer. An inspection cell for material quality control would be best suited. The stocking arrangement of spares should be such that it can easily be identified, when required.

- **Condition monitoring techniques**

Condition Monitoring Techniques help to identify the abnormalities in equipment. The on-line monitoring can be carried out when the equipment is in operation and off-line monitoring can be carried out when the equipment is down. The condition monitoring helps in predicting equipment failure and taking corrective actions before the equipment fails.

- **Calibration and Testing**

Calibration is a preventive practice, which ensures that measurement and control instruments and other test equipment / facilities are kept within, specified tolerance limits and is always kept in a fully serviceable state. A well-run and fine tuned calibration facility provides a reliable means for the prompt detection of defects and thus enable maintenance personnel to take timely action to rectify the abnormalities.

- **Non-Destructive Testing**

Non-destructive testing methodologies are developed for the accurate measurement of characteristics of parts of a machine, without any damage physically or functionally. The parameters monitored are mainly the process variables like pressure, temperature, flow, etc. and mechanical running condition variables like vibration, RPM, crack detection, relative motions, wear and tear etc. The rotary machinery malfunctions include unbalance, misalignment, foundation problems, fracture, thermal loads and bearing failures.

- **Vibration Monitoring Techniques**

Vibration monitoring helps in maintenance prevention. The vibration monitoring equipment can identify the vibrations in the bearings, motors etc. through the signals and on-line continuous monitoring can be carried out for critical equipment. The choice of technique depends upon time, effort, level of sophistication and cost. The frequency of monitoring depends on the criticality, likely damages that can occur in case of neglect and the equipment history of failures and its analysis. In-situ Dynamic Balancing helps to directly detect the abnormal vibration in the machine. Vibration signature analysis also helps to detect the fault and diagnose the cause with reference to ISO standards.

- **Autonomous Maintenance**

Autonomous Maintenance includes any activity performed by the production department that has a maintenance function and is intended to keep the plant operating efficiently and stable in order to meet production targets and plans. It helps in creating good work culture, better house-keeping, continuous cleaning, inspection and better asset care management.

Expert Cell

An Expert cell would constitute a team of experienced maintenance prevention and maintainability improvement. The expert cell will conduct brainstorming sessions weekly to identify and solve maintenance-related problems scientifically. The team will then do feasibility studies of various alternatives and perform cost-benefit analysis, return on investment (ROI), rate of return (ROR), payback etc. to select the best alternative.

The main functions of Expert Cell are listed below:

- Study Equipment History Record, failures and corrective actions taken
- Identify repetitive failures and suggest action plan
- Maintainability at the design stage
- Maintainability along the flow of material
- Adopt maintenance prevention techniques
- Evaluate the results of condition and vibration monitoring
- Decisions on Reconditioning and Replacement
- Decision on Annual Maintenance Contract
- Decision on Maintenance sub-contracting
- Life Value Analysis
- Cost-Benefit analysis, ROI, IRR, Payback calculations

Inspection Cell For Material Quality Control

The maintainability of equipment can be improved if the spares are of good quality and according to specifications of the original equipment manufacturer (OEM).

The functions of inspection cell are listed below:

- Inspection of Raw material
- Inspection of work-in-progress
- Inspection of finished products
- Inspection of spares
- Inspection of workmanship
- Study design specifications and material recommended

- Search for alternative material, if spares not available.
- Vendor Selection
- Warranty period by vendors

The expert cell thus focuses on the causes of problems and its corrective action right from the design stage and inspection cell focuses on quality of raw material, work- in-progress and finished products.

Conclusion

This paper thus described various means and ways for enhancing plant availability and equipment maintainability. Need-cum-Opportunity based Maintenance should be practiced in all process industries, so that the frequency of stoppages and duration of stoppages can be reduced to a great extent. Continuous Improvement, Autonomous Maintenance and use of scientific methods help in improving the maintainability and asset care management. Maintenance Prevention methods help in reducing the downtime and prolonging the life of components / equipment. The maintainability of the equipment can be improved by maintaining the condition of equipment by adopting condition and vibration monitoring techniques. The vibration monitoring symptoms help in predicting the failure and corrective actions can be taken accordingly. The expert cell helps in solving the maintenance problems scientifically and inspection cell for material quality control helps in thorough inspection of raw material, work-in-progress and finished products.

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