

# 8

## MAINTENANCE MANAGEMENT

### CHAPTER OUTLINE

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### 8.1 INTRODUCTION AND MEANING

Past and current maintenance practices in both the private and Government sectors would imply that maintenance is the actions associated with equipment repair after it is broken. The dictionary defines maintenance as “the work of keeping something in proper condition, upkeep.” This would imply that maintenance should be actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order. Data obtained in many studies over the past decade indicates that most private and Government facilities do not expend the necessary resources to maintain equipment in proper working order. They wait for equipment failure to occur and then take whatever actions are necessary to repair or replace the equipment. Nothing lasts forever and all equipment has associated with it some predefined life expectancy or operational life.

### 8.2 OBJECTIVES OF MAINTENANCE

Equipments are an important resource which is constantly used for adding value to products. So, it must be kept at the best operating condition. Otherwise, there will be excessive downtime and also interruption of production if it is used in a mass production line. Poor working of equipments

will lead to quality related problems. Hence, it is an absolute necessity to maintain the equipments in good operating conditions with economical cost. Hence, we need an integrated approach to minimize the cost of maintenance. In certain cases, the equipment will be obsolete over a period of time. If a firm wants to be in the same business competitively, it has to take decision on whether to replace the equipment or to retain the old equipment by taking the cost of maintenance and operation into account.

### 8.3 TYPES OF MAINTENANCE

The design life of most equipment requires periodic maintenance. Belts need adjustment, alignment needs to be maintained, proper lubrication on rotating equipment is required, and so on. In some cases, certain components need replacement, *e.g.*, a wheel bearing on a motor vehicle, to ensure the main piece of equipment (in this case a car) last for its design life. Different approaches have been developed to know how maintenance can be performed to ensure equipment reaches or exceeds its design life. In addition to waiting for a piece of equipment to fail (reactive maintenance) the other approaches are preventive maintenance, predictive maintenance, or reliability centered maintenance.

#### 8.3.1 Breakdown (Reactive) Maintenance

Breakdown maintenance is basically the 'run it till it breaks' maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended to ensure design life is reached. Studies as recent indicate that, this is still the predominant mode of maintenance.

Advantages to breakdown maintenance can be viewed as a double-edged sword. If we are dealing with new equipment, we can expect minimal incidents of failure. If our maintenance program is purely reactive, we will not expend manpower or incur capital cost until something breaks. Since we do not see any associated maintenance cost, we could view this period as saving money. In reality, during the time we believe we are saving maintenance and capital cost, we are really spending more money than we would have under a different maintenance approach. We are spending more money associated with capital cost because, while waiting for the equipment to break, we are shortening the life of the equipment resulting in more frequent replacement. We may incur cost upon failure of the primary device associated with its failure causing the failure of a secondary device. This is an increased cost we would not have experienced if our maintenance program was more proactive.

Our labour cost associated with repair will probably be higher than normal because the failure will most likely require more extensive repairs than would have been required if the piece of equipment had not been run to failure. Chances are the piece of equipment will fail during off hours or close to the end of the normal workday. If it is a critical piece of equipment that needs to be back on-line quickly, we will have to pay maintenance overtime cost. Since we expect to run equipment to failure, we will require a large material inventory of repair parts. This is a cost we could minimize under a different maintenance strategy.

**Advantages**

1. Involves low cost investment for maintenance.
2. Less staff is required.

**Disadvantages**

1. Increased cost due to unplanned downtime of equipment.
2. Increased labour cost, especially if overtime is needed.
3. Cost involved with repair or replacement of equipment.
4. Possible secondary equipment or process damage from equipment failure.
5. Inefficient use of staff resources.

**8.3.2 Preventive Maintenance**

Preventive maintenance can be defined as, "Actions performed on a time or machine-run-based schedule that detect, preclude, or mitigate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level."

Preventive maintenance is a means to increase the reliability of their equipment. By simply expending the necessary resources to conduct maintenance activities intended by the equipment designer, equipment life is extended and its reliability is increased. In addition to an increase in reliability, lot of amount will be saved over that of a program just using reactive maintenance. Studies indicate that this savings can amount to as much as 12% to 18% on the average.

**Advantages**

1. Cost effective in many capital intensive processes.
2. Flexibility allows for the adjustment of maintenance periodicity.
3. Increased component life cycle.
4. Energy savings.
5. Reduced equipment or process failure.
6. Estimated 12% to 18% cost savings over reactive maintenance program.

**Disadvantages**

1. Catastrophic failures still likely to occur.
2. Labour intensive.
3. Includes performance of unneeded maintenance.
4. Potential for incidental damage to components in conducting unneeded maintenance.

Depending on the facilities current maintenance practices, present equipment reliability, and facility downtime, there is little doubt that many facilities purely reliant on reactive maintenance could save much more than 18% by instituting a proper preventive maintenance program.

While preventive maintenance is not the optimum maintenance program, it does have several advantages over that of a purely reactive program. By performing the preventive maintenance

as the equipment designer envisioned, we will extend the life of the equipment closer to design. This translates into dollar savings. Preventive maintenance (lubrication, filter change, etc.) will generally run the equipment more efficiently resulting in dollar savings. While we will not prevent equipment catastrophic failures, we will decrease the number of failures. Minimizing failures translate into maintenance and capital cost savings.

### 8.3.3 Predictive Maintenance

Predictive maintenance can be defined as “Measurements that detect the onset of a degradation mechanism, thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state. Results indicate current and future functional capability”.

Basically, predictive maintenance differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some preset schedule. Preventive maintenance is time-based. Activities such as changing lubricant are based on time, like calendar time or equipment run time. For example, most people change the oil in their vehicles every 3,000 to 5,000 miles travelled. This is effectively basing the oil change needs on equipment run time. No concern is given to the actual condition and performance capability of the oil. It is changed because it is time. This methodology would be analogous to a preventive maintenance task. If, on the other hand, the operator of the car discounted the vehicle run time and had the oil analyzed at some periodicity to determine its actual condition and lubrication properties, he may be able to extend the oil change until the vehicle had travelled 10,000 miles. This is the fundamental difference between predictive maintenance and preventive maintenance, whereby predictive maintenance is used to define needed maintenance task based on quantified material/equipment condition.

There are many advantages of predictive maintenance. A well-orchestrated predictive maintenance program will eliminate catastrophic equipment failures. Schedule of maintenance activities can be made to minimize or delete overtime cost. It is possible to minimize inventory and order parts, as required, well ahead of time to support the downstream maintenance needs and optimize the operation of the equipment, saving energy cost and increasing plant reliability. Past studies have estimated that a properly functioning predictive maintenance program can provide a savings of 8% to 12% over a program utilizing preventive maintenance alone. Depending on a facility's reliance on reactive maintenance and material condition, it could easily recognize savings opportunities exceeding 30% to 40%. Independent surveys indicate the following industrial average savings resultant from initiation of a functional predictive maintenance program:

1. Return on investment—10 times
2. Reduction in maintenance costs—25% to 30%
3. Elimination of breakdowns—70% to 75%
4. Reduction in downtime—35% to 45%
5. Increase in production—20% to 25%.

**Advantages**

1. Increased component operational life/availability.
2. Allows for pre-emptive corrective actions.
3. Decrease in equipment or process downtime.
4. Decrease in costs for parts and labour.
5. Better product quality.
6. Improved worker and environmental safety.
7. Improved worker moral.
8. Energy savings.
9. Estimated 8% to 12% cost savings over preventive maintenance program.

**Disadvantages**

1. Increased investment in diagnostic equipment.
2. Increased investment in staff training.
3. Savings potential not readily seen by management.

**Concept of Reliability in Maintenance**

Reliability is the probability of survival under a given operating environment. For example, the time between consecutive failures of a refrigerator where continuous working is required is a measure of its reliability. If this time is more, the product is said to have high reliability.

In a textile mill, generally the light is maintained at a minimum specified level. To achieve this, let us assume that there are 100 bulbs in use and the guaranteed life time of these bulbs is 5000 hours. If we collect statistics about the number of bulbs survived till 5000 hours, we can compute the reliability of the bulbs. In this case,

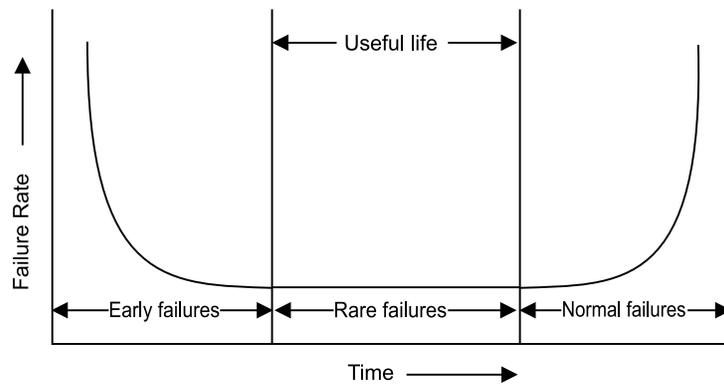
$$\text{Reliability} = \text{Failurerate} = \frac{\text{Number of bulbs survived till the specified time limit}}{\text{Number of bulbs used}}$$

If the number of bulbs survived till 5000 hours is 80, then we can say that the reliability is 0.8 (*i.e.*, 80/100)

The reliability of railway signalling system, aircraft, and power plant are some of the interesting examples for demonstrating the reliability concept. In these cases, a failure will lead to heavy penalty.

The concept of reliability can be matched with systems concept. Generally, products/equipments will have many components which may function with serial relationship or parallel relationship. So, the individual component's reliability affects the reliability of the product. Hence, enough attention must be given at the design, stage such that the product's reliability is maximized. The cost of maintenance is also to be considered along with the reliability while improving it.

The general failure pattern of any product is given in Fig. 8.1. This is called bath-tub curve. In Fig. 8.1, there will be large number of failures in the early period. This is mainly due to non-alignment while shipping the product, or misfit while manufacturing (assembling), or very high initial friction between moving parts, etc.



**Fig. 8.1** Product failure rate

### Reliability Improvement

The reliability of a system/product depends on many factors. So, we should concentrate at the grassroot level to improve product's reliability.

Some of the ways of improving systems reliability are listed below:

- Improved design of components
- Simplification of product structure
- Usage of better production equipments
- Better quality standards
- Better testing standards
- Sufficient number of standby units
- Usage of preventive maintenance if necessary at appropriate time.

## 8.4 MAINTENANCE PLANNING

Planning of maintenance jobs basically deals with answering two questions, 'what' and 'How' of the job; 'what activities are to be done?' and 'how those jobs and activities are to be done?' While answering these two questions, other supplementary questions are to be answered, *e.g.*, 'where the jobs is to be done?' and 'why the job is to be done?' etc., but all these will be helping in developing 'what' and 'how' of the job. It is very essential that engineering knowledge must be applied extensively to maintenance jobs for development of appropriate job plans using most suited techniques, tools materials and special facilities etc.

As the job planning forms the basic foundations, over which the efficiency and cost of actions depends, persons responsible for job planning should have adequate capabilities, such as, knowledge about jobs and available techniques, facilities and resources, analytical ability, conceptual logical ability and judgmental courage etc.

## Steps of Job Planning

The main steps to be followed for proper job planning are:

1. **Knowledge base:** It includes knowledge about equipment, job, available techniques, materials and facilities.
2. **Job investigation at site:** It gives a clear perception of the total jobs.
3. **Identify and document the work:** Knowing the earlier two steps and knowing the needs of preventive, predictive and other maintenance jobs.
4. **Development of repair plan:** Preparation of step by step procedures which would accomplish the work with the most economical use of time, manpower and material.
5. **Preparation tools and facilities list** indicating the needs of special tools, tackles and facilities needed.
6. **Estimation of time required to do the job** with work measurement technique and critical path analysis.

## 8.5 MAINTENANCE SCHEDULING

Scheduling is the function of coordinating all of the logistical issue around the issues regarding the execution phase of the work. Scheduled of maintenance jobs basically deals with answering two questions—‘Who’ and ‘When’ of job, *i.e.*, “who would do the job” and “when the job would be started and done”.

Effective scheduling essentially needs realistic thinking, based on substantial data and records. Majority of scheduling work needs to occur in areas such as overhead labour hours safety and toolbox meetings, break times and training times etc. Addition of corrective and approved improvement actions as dictated by the prioritization system and operations plan etc.

### Requirements for Schedulers

A scheduler should also have knowledge about job, techniques, facilities, analytical ability and judgmental courage. The scheduler must obtain knowledge/information about following ability and judgmental courage. The scheduler must obtain information about following facts, before starting his job:

1. Manpower availability by trade, location, shift, crew arrangement and permissible overtime limit etc.
2. Man hour back log on current or unfinished jobs.
3. Availability of the equipment or area where the work has to be performed.
4. Availability of proper tools, tackles, spares, consumables, structural and other required materials.
5. Availability of external manpower and their capabilities; these may be from other shops/ departments of the plant or from contractors (local, nearby, ancillary etc).
6. Availability of special equipments, jigs/fixtures, special lifting and handling facilities and cranes etc. This should also include labour and time saving devices like pneumatic hammers and excavators etc.

7. Starting date of the job; also often completion time of total job is predetermined and, in that case, resources are to be arranged accordingly.
8. Past schedules and charts (updated) if the same job has been done earlier, etc.

## 8.6 MAINTENANCE SCHEDULE TECHNIQUES

Different types of schedules are made suiting the respective job plans and different techniques are used for making and following those schedules. The first step of all scheduling is to break the job into small measurable elements, called activities and to arrange them in logical sequences considering the preceding, concurrent and succeeding activities so that a succeeding activity should follow preceding activities and concurrent activities can start together.

Arranging these activities in different fashion makes different types of schedules. They are as follows:

1. **Weekly general schedule** is made to provide weeks worth of work for each employee in an area.
2. **Daily schedule** is developed to provide a day's work for each maintenance employee of the area.
3. **Gantt charts** are used to represent the timings of tasks required to complete a project.
4. **Bar charts** used for technical analysis which represents the relative magnitude of the values.
5. **PERT/CPM** are used to find the time required for completion of the job and helps in the allocation of resources.

[Note: Discussed in detail in Chapter 5.]

### 8.6.1 Modern Scientific Maintenance Methods

**Reliability centered maintenance:** Reliability centered maintenance (RCM) is defined as “a process used to determine the maintenance requirements of any physical asset in its operating context”.

Basically, RCM methodology deals with some key issues not dealt with by other maintenance programs. It recognizes that all equipment in a facility is not of equal importance to either the process or facility safety. It recognizes that equipment design and operation differs and that different equipment will have a higher probability to undergo failures from different degradation mechanisms than others. It also approaches the structuring of a maintenance program recognizing that a facility does not have unlimited financial and personnel resources and that the use of both need to be prioritized and optimized. In a nutshell, RCM is a systematic approach to evaluate a facility's equipment and resources to best mate the two and result in a high degree of facility reliability and cost-effectiveness.

RCM is highly reliant on predictive maintenance but also recognizes that maintenance activities on equipment that is inexpensive and unimportant to facility reliability may best be left to a reactive maintenance approach. The following maintenance program breakdowns of continually

top-performing facilities would echo the RCM approach to utilize all available maintenance approaches with the predominant methodology being predictive.

- <10% Reactive
- 25% to 35% Preventive
- 45% to 55% Predictive.

Because RCM is so heavily weighted in utilization of predictive maintenance technologies, its program advantages and disadvantages mirror those of predictive maintenance. In addition to these advantages, RCM will allow a facility to more closely match resources to needs while improving reliability and decreasing cost.

### **Advantages**

- (a) Can be the most efficient maintenance program.
- (b) Lower costs by eliminating unnecessary maintenance or overhauls.
- (c) Minimize frequency of overhauls.
- (d) Reduced probability of sudden equipment failures.
- (e) Able to focus maintenance activities on critical components.
- (f) Increased component reliability.
- (g) Incorporates root cause analysis.

### **Disadvantages**

- (a) Can have significant startup cost, training, equipment, etc.
- (b) Savings potential not readily seen by management.

### **How to Initiate Reliability Centered Maintenance?**

The road from a purely reactive program to a RCM program is not an easy one. The following is a list of some basic steps that will help to get moving down this path.

1. Develop a master equipment list identifying the equipment in your facility.
2. Prioritize the listed components based on importance to process.
3. Assign components into logical groupings.
4. Determine the type and number of maintenance activities required and periodicity using:
  - Manufacturer technical manuals
  - Machinery history
  - Root cause analysis findings—Why did it fail?
  - Good engineering judgment
5. Assess the size of maintenance staff.
6. Identify tasks that may be performed by operations maintenance personnel.
7. Analyze equipment failure modes and effects.
8. Identify effective maintenance tasks or mitigation strategies.

### 8.6.2 Six Sigma Maintenance

It is the application of six sigma principles in maintenance. Six sigma is a maintenance process that focuses on reducing the variation in business production processes. By reducing variation, a business can achieve tighter control over its operational systems, increasing their cost effectiveness and encouraging productivity breakthrough.

Six sigma is a term created at Motorola to describe the goal and process used to achieve breakthrough levels of quality improvement. Sigma is the Greek symbol used by statisticians to refer to the six standard deviations. The term six sigma refers to a measure of process variation (six standard deviations) that translates into an error or defect rate of 3.4 parts per million. To achieve quality performance of six sigma level, special sets of quality improvement methodologies and statistical tools developed. These improvement methods and statistical tools are taught to a small group of workmen known as six sigma champions who are assigned full-time responsibility to define, measure, analyze, improve and control process quality. They also facilitate the improvement process by removing the organizational roadblocks encountered. Six sigma methodologies improve any existing business process by constantly reviewing and re-tuning the process. To achieve this, six sigma uses a methodology known as DMAIC (Define opportunities, Measure performance, Analyse opportunity, Improve performance, Control performance). This six sigma process is also called DMAIC process.

Six sigma relies heavily on statistical techniques to reduce failures and it incorporates the basic principles and techniques used in Business, Statistics, and Engineering. Six sigma methodologies can also be used to create a brand new business process from ground up using design for six sigma principles.

#### **SIX SIGMA MAINTENANCE PROCESS**

The steps of six sigma maintenance are same as DMAIC process. To apply six sigma in maintenance, the work groups that have a good understanding of preventive maintenance techniques in addition to a strong leadership commitment. Six sigma helps in two principal inputs to the maintenance cost equation: Reduce or eliminate the need to do maintenance (reliability of equipment), and improve the effectiveness of the resources needed to accomplish maintenance. Following are the steps involved in six sigma maintenance process.

#### **Define**

This step involves determining benchmarks, determining availability and reliability requirements, getting customer commitments and mapping the flow process.

#### **Measure**

This step involves development of failure measurement techniques and tools, data collection process, compilation and display of data.

#### **Analysis**

This step involves checking and verifying the data and drawing conclusions from data. It also involves determining improvement opportunities, finding root causes and map causes.

#### **Improve**

This step involves creating model equipment and maintenance process, total maintenance plan and schedule and implementing those plans and schedule.

## Control

This step involves monitoring the improved programme. Monitor improves performance and assesses effectiveness and will make necessary adjustments for the deviation if exists.

### 8.6.3 Enterprise Asset Management (EAM)

**Enterprise asset management** is an information management system that connects all departments and disciplines within a company making them an integrated unit. EAM is also referred as computerised maintenance management system. It is the organized and systematic tracking of an organization's physical assets *i.e.*, its plant, equipment and facilities. EAM aims at best utilisation of its physical assets. It ensures generation of quality data and timely flow of required data throughout the organization. EAM reduces paper work, improves the quality, quantity and timeliness of the information and provides information to technicians at the point of performance and gives workers access to job specific information at the work site.

### 8.6.4 Lean Maintenance

**Lean maintenance** is the application of lean principle in maintenance environments. Lean system recognises seven forms of waste in maintenance. They are over production, waiting, transportation, process waste, inventory, waste motion and defects. In lean maintenance, these wastes are identified and efforts are made for the continuous improvement in process by eliminating the wastes. Thus, lean maintenance leads to maximise yield, productivity and profitability.

Lean maintenance is basically equipment reliability focussed and reduces need for maintenance troubleshooting and repairs. Lean maintenance protects equipments and system from the route causes of malfunctions, failures and downtime stress. From the sources of waste uptime can be improved and cost can be lowered for maintenance.

### 8.6.5 Computer Aided Maintenance

For effective discharge of the maintenance function, a well designed information system is an essential tool. Such systems serve as effective decision support tools in the maintenance planning and execution. For optimal maintenance scheduling, large volume of data pertaining to men, money and equipment is required to be handled. This is a difficult task to be performed manually. For a planned and advanced maintenance system use of computers is essential. Here programmes are prepared to have an available inputs processed by the computer. Such a computer based system can be used as and when required for effective performance of the maintenance tasks. There are wide varieties of software package available in the market for different types of maintenance systems.

A computerised maintenance system includes the following aspects:

- Development of a database
- Analysis of past records if available
- Development of maintenance schedules
- Availability of maintenance materials

- Feedback control system
- Project management.

Following are some computer based maintenance systems which can be implemented:

**Job card system:** It is essential to prepare a job card for each component to record the maintenance work carried out or the work to be done. Job card shows the plant code, equipment code, the job code, the nature of the jobs, the start time and finishing time of the card, man-hour spent and etc. The use of computers facilitates the issue of job cards, recording of job history and control of manpower.

**Spare part life monitoring system:** Under this system, information about a spare part such as its description, anticipated life and date of its installation in equipment is recorded. As and when a particular sparepart is replaced during breakdown failures or scheduled maintenance, the updating of this information is done in their respective files stored in the computer. This helps to prepare the following reports:

- Spares repeatability in various machines indicating the performance of such spare parts.
- Comparisons of the actual life with the estimated life of the spare parts.

**Spare parts tracking system:** In most of the cases maximum time is consumed in procurement of spare parts. The total time required to rectify the breakdown is summation of the time to identify the cause of the failure, time to determine the requirements of spare parts, time to procure spare parts and the time to rectify the failure. In a computerised system, the spare part tracking system is beneficial in getting required material at the earliest. A spare part file is created that contains the information about the material code, spare part identification number, the assembly or sub-assembly number and the place where the spare part is used. This helps in knowing the current position about a particular spare part and facilitates timely requirement for future demands.

## 8.7 TOTAL PRODUCTIVE MAINTENANCE (TPM)

Total productive maintenance (TPM) is a maintenance program, which involves a newly defined concept for maintaining plants and equipment. The goal of the TPM program is to markedly increase production while, at the same time, increasing employee morale and job satisfaction. It can be considered as the medical science of machines.

TPM brings maintenance into focus as a necessary and vitally important part of the business. It is no longer regarded as a non-profit activity. Downtime for maintenance is scheduled as a part of the manufacturing day and, in some cases, as an integral part of the manufacturing process. The goal is to hold emergency and unscheduled maintenance to a minimum.

TPM was introduced to achieve the following objectives. The important ones are listed below.

- Avoid wastage in a quickly changing economic environment.
- Producing goods without reducing product quality.
- Reduce cost.

- Produce a low batch quantity at the earliest possible time.
- Goods send to the customers must be non-defective.

**8.7.1 Similarities and Differences between TQM and TPM**

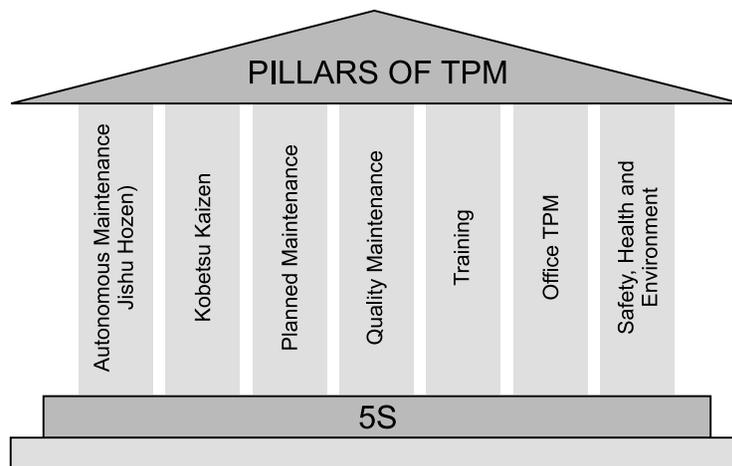
The TPM program closely resembles the popular Total Quality Management (TQM) program. Many of the tools such as, employee empowerment, benchmarking, documentation, etc. used in TQM are used to implement and optimize TPM. Following are the similarities between the two:

1. Total commitment to the program by upper level management is required in both programmes,
2. Employees must be empowered to initiate corrective action, and
3. A long-range outlook must be accepted as TPM may take a year or more to implement and is an on-going process. Changes in employee mind-set toward their job responsibilities must take place as well.

The differences between TQM and TPM are summarized below.

<i>Category</i>	<i>TQM</i>	<i>TPM</i>
Object	Quality (Output and effects)	Equipment (Input and cause)
Mains of attaining goal	Systematize the management. It is software oriented	Employees participation and it is hardware oriented
Target	Quality for PPM	Elimination of losses and wastes.

**8.7.2 Pillars of TPM**



**PILLAR 1-5S**

TPM starts with 5S. Problems cannot be clearly seen when the work place is unorganized. Cleaning and organizing the workplace helps the team to uncover problems. Making problems visible is the first step of improvement.

<i>Japanese term</i>	<i>English translation</i>	<i>Equivalent 'S' term</i>
Seiri	Organization	Sort
Seiton	Tidiness	Systematise
Seiso	Cleaning	Sweep
Seiketsu	Standardisation	Standardise
Shitsuke	Discipline	Self-discipline

**SEIRI—Sort out**

This means sorting and organizing the items as critical, important, frequently used items, useless, or items that are not need as of now. Unwanted items can be salvaged. Critical items should be kept for use nearby and items that are not be used in near future, should be stored in some place. For this step, the worth of the item should be decided based on utility and not cost. As a result of this step, the search time is reduced.

Priority	Frequency of use	How to use
Low	Less than once per year, Once per year<	Throw away, Store away from the workplace
Average	At least 2/6 months, Once per month, Once per week	Store together but offline
High	Once per day	Locate at the workplace

**SEITON—Organise**

The concept here is that “Each items has a place, and only one place”. The items should be placed back after usage at the same place. To identify items easily, name plates and coloured tags has to be used. Vertical racks can be used for this purpose, and heavy items occupy the bottom position in the racks.

**SEISO—Shine the Workplace**

This involves cleaning the work place free of burrs, grease, oil, waste, scrap etc. No loosely hanging wires or oil leakage from machines.

**SEIKETSU—Standardization**

Employees has to discuss together and decide on standards for keeping the work place/ machines/pathways neat and clean. This standards are implemented for whole organization and are tested/inspected randomly.

**SHITSUKE—Self-discipline**

Considering 5S as a way of life and bring about self-discipline among the employees of the organization. This includes wearing badges, following work procedures, punctuality, dedication to the organization etc.

**PILLAR 2—JISHU HOZEN (AUTONOMOUS MAINTENANCE)**

This pillar is geared towards developing operators to be able to take care of small maintenance tasks, thus freeing up the skilled maintenance people to spend time on more value added activity

and technical repairs. The operators are responsible for upkeep of their equipment to prevent it from deteriorating.

### Steps in JISHU HOZEN

1. **Train the employees:** Educate the employees about TPM, its advantages, JH advantages and steps in JH. Educate the employees about abnormalities in equipments.

#### 2. Initial cleanup of machines

- Supervisor and technician should discuss and set a date for implementing step 1.
- Arrange all items needed for cleaning.
- On the arranged date, employees should clean the equipment completely with the help of maintenance department.
- Dust, stains, oils and grease has to be removed.
- Following are the things that have to be taken care while cleaning. They are oil leakage, loose wires, unfastened nuts and bolts and worn out parts.
- After clean up problems are categorized and suitably tagged. White tags are place where operators can solve problems. Pink tag is placed where the aid of maintenance department is needed.
- Contents of tag are transferred to a register.
- Make note of area, which were inaccessible.
- Finally close the open parts of the machine and run the machine.

#### 3. Counter measures

- Inaccessible regions had to be reached easily, *e.g.*, if there are many screw to open a flywheel door, hinge door can be used. Instead of opening a door for inspecting the machine, acrylic sheets can be used.
- To prevent work out of machine parts necessary action must be taken.
- Machine parts should be modified to prevent accumulation of dirt and dust.

#### 4. Tentative standard

- JH schedule has to be made and followed strictly.
- Schedule should be made regarding cleaning, inspection and lubrication and it also should include details like when, what and how.

#### 5. General inspection

- The employees are trained in disciplines like pneumatics, electrical, hydraulics, lubricant and coolant, drives, bolts, nuts and safety.
- This is necessary to improve the technical skills of employees and to use inspection manuals correctly.
- After acquiring this new knowledge the employees should share this with others.
- By acquiring this new technical knowledge, the operators are now well aware of machine parts.

### 6. Autonomous inspection

- New methods of cleaning and lubricating are used.
- Each employee prepares his own autonomous chart/schedule in consultation with supervisor.
- Parts which have never given any problem or part which don't need any inspection are removed from list permanently based on experience.
- Including good quality machine parts. This avoid defects due to poor JH.
- Inspection that is made in preventive maintenance is included in JH.
- The frequency of cleanup and inspection is reduced based on experience.

### 7. Standardization

- Up to the previous stem only the machinery/equipment was the concentration. However, in this step the surroundings of machinery are organized. Necessary items should be organized, such that there is no searching and searching time is reduced.
- Work environment is modified such that there is no difficulty in getting any item.
- Everybody should follow the work instructions strictly.
- Necessary spares for equipments is planned and procured.

### 8. Autonomous management

- OEE and OPE and other TPM targets must be achieved by continuous improve through Kaizen.
- PDCA (Plan, Do, Check and Act) cycle must be implemented for Kaizen.

## **PILLAR 3—KAIZEN**

'Kai' means change, and 'Zen' means good (for the better). Basically Kaizen is for small improvements, but carried out on a continual basis and involve all people in the organization. Kaizen is opposite to big spectacular innovations. Kaizen requires no or little investment. The principle behind is that "a very large number of small improvements are more effective in an organizational environment than a few improvements of large value." This pillar is aimed at reducing losses in the workplace that affect our efficiencies. By using a detailed and thorough procedure we eliminate losses in a systematic method using various Kaizen tools. These activities are not limited to production areas and can be implemented in administrative areas as well.

### **Kaizen Policy**

1. Practice concepts of zero losses in every sphere of activity.
2. Relentless pursuit to achieve cost reduction targets in all resources.
3. Relentless pursuit to improve overall plant equipment effectiveness.
4. Extensive use of PM analysis as a tool for eliminating losses.
5. Focus of easy handling of operators.

### **Kaizen Target**

Achieve and sustain zero loses with respect to minor stops, measurement and adjustments, defects and unavoidable downtimes. It also aims to achieve 30% manufacturing cost reduction.



3. Corrective maintenance
4. Maintenance prevention

With planned maintenance, we evolve our efforts from a reactive to a proactive method and use trained maintenance staff to help train the operators to better maintain their equipment.

### **Policy**

1. Achieve and sustain availability of machines;
2. Optimum maintenance cost;
3. Reduces spares inventory; and
4. Improve reliability and maintainability of machines.

### **Target**

1. Zero equipment failure and breakdown;
2. Improve reliability and maintainability by 50%;
3. Reduce maintenance cost by 20%; and
4. Ensure availability of spares all the time.

### **Six Steps in Planned Maintenance**

1. Equipment evaluation and recoding present status;
2. Restore deterioration and improve weakness;
3. Building up information management system;
4. Prepare time based information system, select equipment, parts and members and map out plan;
5. Prepare predictive maintenance system by introducing equipment diagnostic techniques; and
6. Evaluation of planned maintenance.

## **PILLAR 5—QUALITY MAINTENANCE**

It is aimed towards customer delight through highest quality through defect free manufacturing. Focus is on eliminating non-conformances in a systematic manner, much like Focused Improvement. We gain understanding of what parts of the equipment affect product quality and begin to eliminate current quality concerns, then move to potential quality concerns. Transition is from reactive to proactive (Quality Control to Quality Assurance).

QM activities is to set equipment conditions that preclude quality defects, based on the basic concept of maintaining perfect equipment to maintain perfect quality of products. The conditions are checked and measure in time series to very that measure values are within standard values to prevent defects. The transition of measured values is watched to predict possibilities of defects occurring and to take counter measures before hand.

### **Policy**

1. Defect free conditions and control of equipments;
2. QM activities to support quality assurance;

3. Focus of prevention of defects at source;
4. Focus on poka-yoke (fool proof system);
5. In-line detection and segregation of defects; and
6. Effective implementation of operator quality assurance.

**Target**

1. Achieve and sustain customer complaints at zero;
2. Reduce in-process defects by 50%; and
3. Reduce cost of quality by 50%.

**Data Requirements**

Quality defects are classified as *customer end* defects and *in house* defects. For customer-end data, we have to get data on:

1. Customer end line rejection; and
2. Field complaints.

In-house, data include data related to products and data related to process.

**Data Related to Product**

1. Product-wise defects;
2. Severity of the defect and its contribution—major/minor;
3. Location of the defect with reference to the layout;
4. Magnitude and frequency of its occurrence at each stage of measurement;
5. Occurrence trend in beginning and the end of each production/process/changes (like pattern change, ladle/furnace lining etc.); and
6. Occurrence trend with respect to restoration of breakdown/modifications/periodical replacement of quality components.

**Data Related to Processes**

1. The operating condition for individual sub-process related to men, method, material and machine;
2. The standard settings/conditions of the sub-process; and
3. The actual record of the settings/conditions during the defect occurrence.

**PILLAR 6—TRAINING**

It is aimed to have multi-skilled revitalized employees whose morale is high and who has eager to come to work and perform all required functions effectively and independently. Education is given to operators to upgrade their skill. It is not sufficient know only 'Know-How' by they should also learn 'Know-Why'. By experience they gain, 'Know-How' to overcome a problem what to be done. This they do without knowing the root cause of the problem and why they are doing so. Hence, it becomes necessary to train them on knowing 'Know-Why'. The employees should be trained to achieve the four phases of skill. The goal is to create a factory full of experts. The different phase of skills is:

Phase 1: Do not know.

Phase 2: Know the theory but cannot do.

Phase 3: Can do but cannot teach.

Phase 4: Can do and also teach.

### **Policy**

1. Focus on improvement of knowledge, skills and techniques;
2. Creating a training environment for self-learning based on felt needs;
3. Training curriculum/tools/assessment etc. conducive to employee revitalization; and
4. Training to remove employee fatigue and make work enjoyable.

### **Target**

1. Achieve and sustain downtime due to want men at zero on critical machines;
2. Achieve and sustain zero losses due to lack of knowledge/skills/techniques; and
3. Aim for 100% participation in suggestion scheme.

### **Steps in Educating and Training Activities**

1. Setting policies and priorities and checking present status of education and training;
2. Establish of training system for operation and maintenance skill upgradation;
3. Training the employees for upgrading the operation and maintenance skills;
4. Preparation of training calendar;
5. Kick-off of the system for training; and
6. Evaluation of activities and study of future approach.

### **PILLAR 7—OFFICE TPM**

Office TPM should be started after activating four other pillars of TPM (JH, KK, QM, PM). Office TPM must be followed to improve productivity, efficiency in the administrative functions and identify and eliminate losses. This includes analyzing processes and procedures towards increased office automation. Office TPM addresses twelve major losses. They are:

1. Processing loss;
2. Cost loss including in areas such as, procurement, accounts, marketing, sales leading to high inventories;
3. Communication loss;
4. Idle loss;
5. Set-up loss;
6. Accuracy loss;
7. Office equipment breakdown;
8. Communication channel breakdown, telephone and fax lines;
9. Time spent on retrieval of information;
10. Non availability of correct on-line stock status;

11. Customer complaints due to logistics; and
12. Expenses on emergency dispatches/purchases.

### **Office TPM and its Benefits**

1. Involvement of all people in support functions for focusing on better plant performance;
2. Better utilized work area;
3. Reduce repetitive work;
4. Reduced inventory levels in all parts of the supply chain;
5. Reduced administrative costs;
6. Reduced inventory carrying cost;
7. Reduction in number of files;
8. Reduction of overhead costs (to include cost of non-production/non-capital equipment);
9. Productivity of people in support functions;
10. Reduction in breakdown of office equipment;
11. Reduction of customer complaints due to logistics;
12. Reduction in expenses due to emergency dispatches/purchases;
13. Reduced manpower; and
14. Clean and pleasant work environment.

### **PILLAR 8—SAFETY, HEALTH AND ENVIRONMENT**

#### **Target**

1. Zero accident,
2. Zero health damage, and
3. Zero fires.

In this area focus is on to create a safe workplace and a surrounding area that is not damaged by our process or procedures. This pillar will play an active role in each of the other pillars on a regular basis.

A committee is constituted for this pillar, which comprises representative of officers as well as workers. The committee is headed by senior vice President (Technical). Utmost importance to safety is given in the plant. Manager (safety) is looking after functions related to safety. To create awareness among employees various competitions like safety slogans, quiz, drama, posters, etc. related to safety can be organized at regular intervals.

Today, with competition in industry at an all time high, TPM may be the only thing that stands between success and total failure for some companies. It has been proven to be a program that works. It can be adapted to work not only in industrial plants, but also in construction, building maintenance, transportation, and in a variety of other situations. Employees must be educated and convinced that TPM is not just another 'program of the month' and that management is totally committed to the program and the extended time frame necessary for full implementation. If everyone involved in a TPM program does his or her part, an unusually high rate of return compared to resources invested may be expected.

## EXERCISES

### Section A

1. Define maintenance.
2. What is reactive maintenance?
3. What is preventive maintenance?
4. What is predictive maintenance?
5. What is maintenance planning?
6. What is scheduling?
7. What is reliability centred maintenance?
8. What is six sigma maintenance?

### Section B

1. Explain the steps of job planning.
2. What are the requirements of schedules?
3. What are the maintenance techniques used?
4. Explain the six sigma maintenance process.

### Section C

1. Discuss the different types of maintenance.
2. Discuss the enterprise asset management.

### Skill development

**FAST FOOD RESTAURANT VISIT:** Get the information for the following questions:

1. Method of maintenance of equipment. (i.e. preventive maintenance or Breakdown maintenance)
2. Maintenance schedule followed.