Reliability Engineering

Notes 7

Maintainability

- Maintainability is 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.
- Maintainability is a measure of the speed with which loss of performance is detected, diagnosed and made good.
- The ‘availability’ or time an equipment is functioning correctly while in use depends both on reliability and on maintainability.

- *Maintainability , M(t)*, is a measure of the ease with which a system can be repaired, once it has failed. The restoration process includes locating the problem, physically repairing the system, and bringing the system back to its operational condition.

Maintainability

- Maintainability in a system is represented with these terms.
- MTTR: Mean time to repair. This is the expected value of the repair time *R*.

- MEAN TIME TO REPAIR (MTTR) : A measure of system maintainability equal to the average system repair time, and this value is the reciprocal of repair rate in the exponential case.

$$\text{MTTR} = \frac{\text{Total diagnose, repair, and test hours for specified units}}{\text{Total number of completed repair actions for those units}}$$

- An important parameter in maintainability modeling is the repair rate, μ .
- The repair rate is the average number of repairs that can be performed per time unit. The inverse of the repair rate is the *MTTR* which is the average time required to perform a single repair.

$$MTTR = \frac{1}{\mu}$$

$$M(t) = 1 - e^{-\mu t}$$

- First, if the repair rate is zero, the maintainability will also be zero since the system cannot be repaired in any length of time.
- Second, if the repair rate is infinite, the maintainability will be 1.0 since repair can be performed in zero time.

Example

- An electronic equipment has the total number of failures is 106. The total number of maintenance hours used to correct the 106 failures is 646. Calculate maintainability for 1, 2 and 10 hr.

$$\mu = \frac{106}{646} = 0.164$$

$$M\,(1\text{ hr}) = 1 - e^{-\mu t}$$

$$= 1 - e^{-(0.164)(1)}$$

$$= 1 - e^{-0.164}$$

$$= 1 - 0.8487$$

$$= 0.1513 \text{ or } 15\%$$

Maintainability for 2 hours

$$M\,(2\text{ hr}) = 1 - e^{-0.164(2)}$$

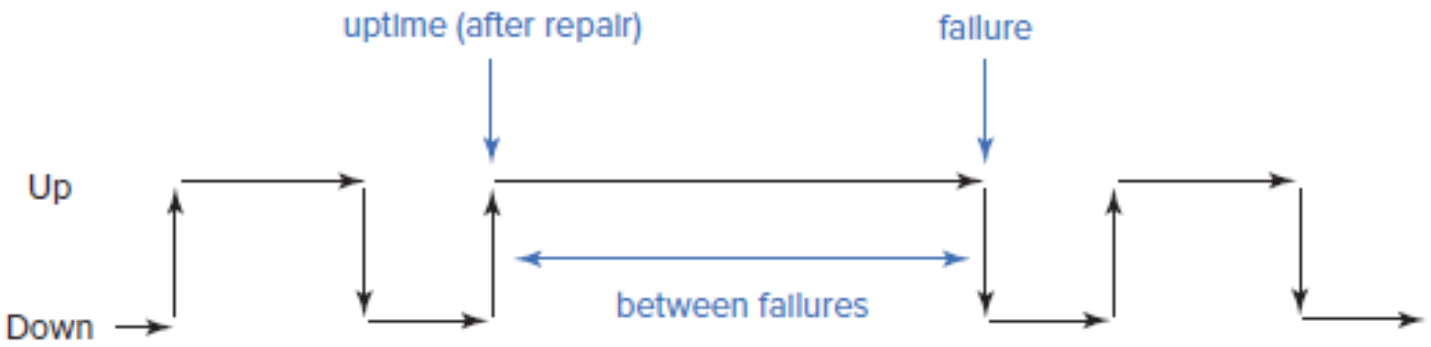
$$= 0.2796 \text{ or } 28\%$$

Maintainability for 10 hours

$$M\,(10\text{ hr}) = 1 - e^{-0.164(10)}$$

$$= 0.8060 \text{ or } 80.6\%$$

Maintainability



Maintenance

- Maintenance is any activity that is carried out on any facility either to restore or to retain the facility in a good and acceptable working conditions. Maintenance involves all technical and other procedures performed in order to retain the satisfactory working condition of a machine or part or restoring it to an acceptable working condition so that the set tasks can be performed at the scheduled time and under given conditions.

Maintenance

- Maintenance is concerned with avoiding or minimizing downtime or to avoid undesirable results due to system failure.
- The most important function of maintenance is to provide system reliability that is to ensure that a specific machine continues to function for a specified period of time with minimum chances of breaking down and at minimum costs.

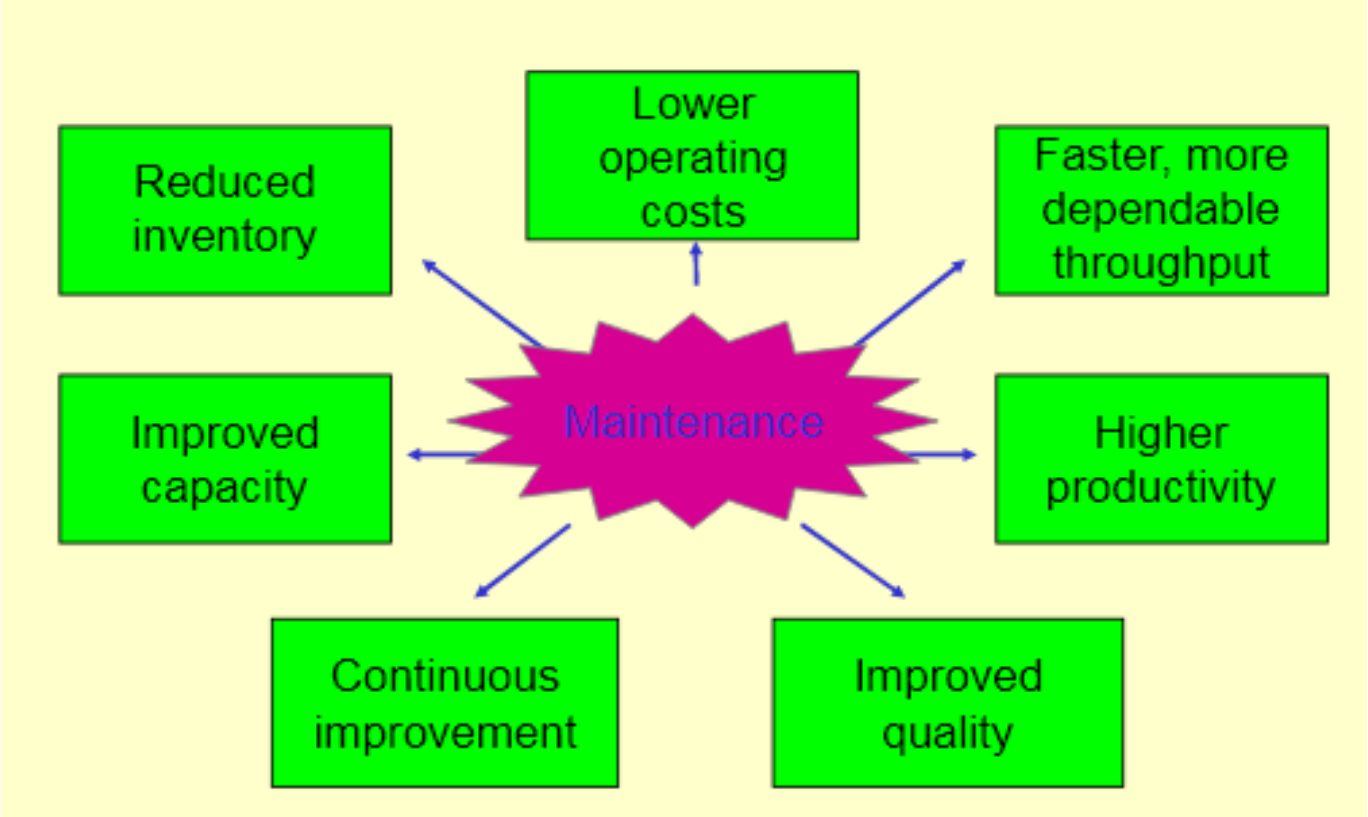
Maintenance

- The primary functions of maintenance are:
- (i) Maintenance of existing machines and equipment
- (ii) Maintenance of existing buildings
- (iii) Inspection of machine and equipment
- (iv) Generation and distribution of utilities e.g. water, electricity etc.
- (v) Installation of new machines and equipment
- (vi) Modifications of existing machines, equipment and buildings

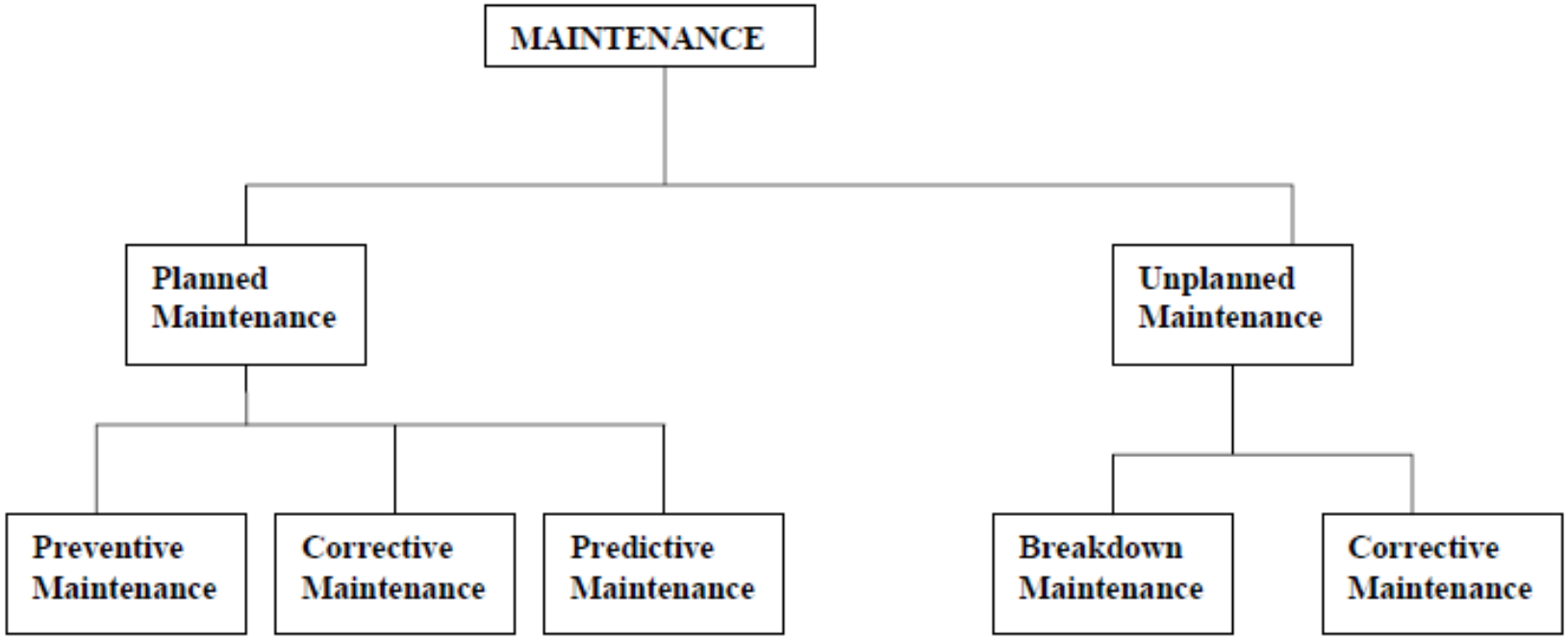
Maintenance

- Maintenance Management involves all activities in keeping a system's equipment working.
- The objective is to maintain system capability & minimize total costs.

Benefits of Maintenance



- Inadequate or lack of effective and efficient maintenance system especially in a manufacturing enterprise gives rise to several undesirable consequences. These consequences include:
- (i) Excessive machine breakdown
- (ii) Frequent emergency maintenance work
- (iii) Shortened life-span of the facility
- (iv) Poor use of maintenance staff
- (v) Loss in production output
- (vi) Inability to meet delivery dates
- (vii) Excessive overtime
- (viii) Loss of lives
- These factors may contribute to high costs of production and consequently loss in profitability.


MAINTENANCE
Planned Maintenance
Unplanned Maintenance
Preventive Maintenance
Corrective Maintenance
Predictive Maintenance
Breakdown Maintenance
Corrective Maintenance

Types of Maintenance

- **Breakdown maintenance:** It is also called as many different names: reactive maintenance, repair, fix when-fail, and run-to-failure (RTF) maintenance.
- When applying this maintenance strategy, a piece of equipment receives maintenance (e.g., repair or replacement) only when the deterioration of the equipment's condition causes a functional failure. The strategy of breakdown maintenance assumes that failure is equally likely to occur in any part, component, or system.

Breakdown maintenance

- It is generally considered to be the most expensive option. It should only be used on low-cost and easy to replace components that are not critical to operations.
- The major downside of breakdown maintenance is unexpected and unscheduled equipment downtime. If a piece of equipment fails and repair parts are not available, delays occur while the parts are ordered and delivered.

Preventive Maintenance (PM):

- Maintenance repairs performed on a regular schedule to minimize component degradation and extend the life of equipment. Preventive maintenance is performed after a set amount of elapsed calendar time or machine run time, regardless of whether the repair is needed. While more cost effective than reactive maintenance, preventive maintenance still requires substantial human resources and replacement parts inventories.

- It may be a daily maintenance (cleaning, inspection, oiling and re-tightening), designed to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration.
- The intent of PM is to “prevent” maintenance problems or failures before they take place by following routine and comprehensive maintenance procedures. The goal is to achieve fewer, shorter, and more predictable outages.

- The objective is to reduce frequency and severity of interruptions to production caused by machine malfunctions and to detect potential problems earlier and avoid the associate cost.

- **Periodic Maintenance**
- Time based maintenance consists of periodically inspecting, servicing and cleaning equipment and replacing parts to prevent sudden failure and process problems.

- **Predictive Maintenance**
- This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Predictive maintenance programs measure equipment on a regular basis, track the measurements over time, and take corrective action when measurements are about to go outside the equipment operating limits.

- **Proactive Maintenance**
- Proactive maintenance concentrate on the monitoring and correction of root causes to equipment failures. The proactive maintenance strategy is also designed to extend the useful age of the equipment to reach the wear-out stage by adaptation a high mastery level of operating precision.

Preventive

- Routine inspection & servicing
- Prevents failures
- Bases for doing
  - Time: Every day
  - Usage: Every 300 pieces
  - Inspection: Control chart deviations

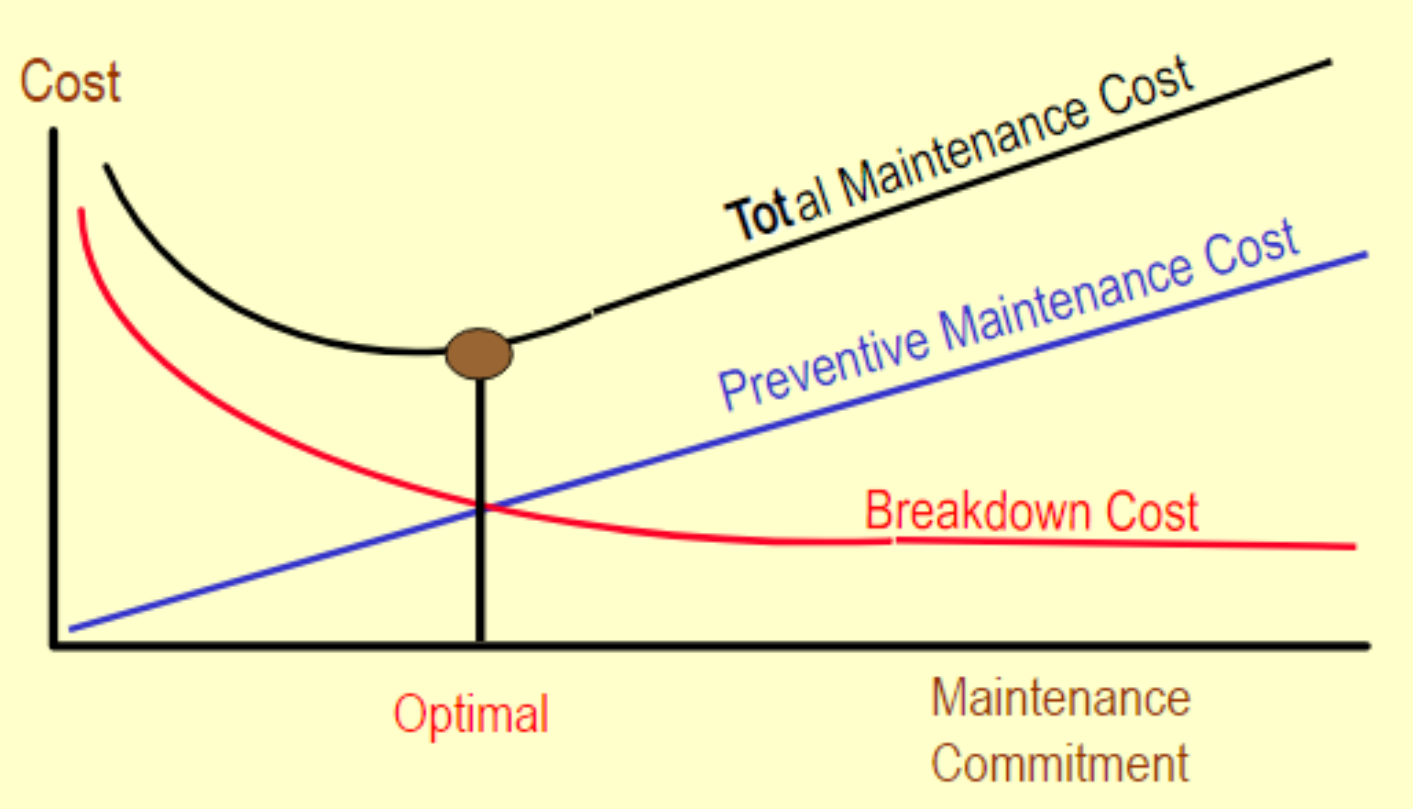
Breakdown

- Non-routine inspection & servicing
- Remedial
- Basis for doing
  - Equipment failure

Features of A Good Maintenance Facility

- Well-trained personnel
- Adequate resources
- Ability to establish a repair plan and priorities
- Ability and authority to do material planning
- Ability to identify the cause of breakdowns
- Ability to design ways to extend MTBF

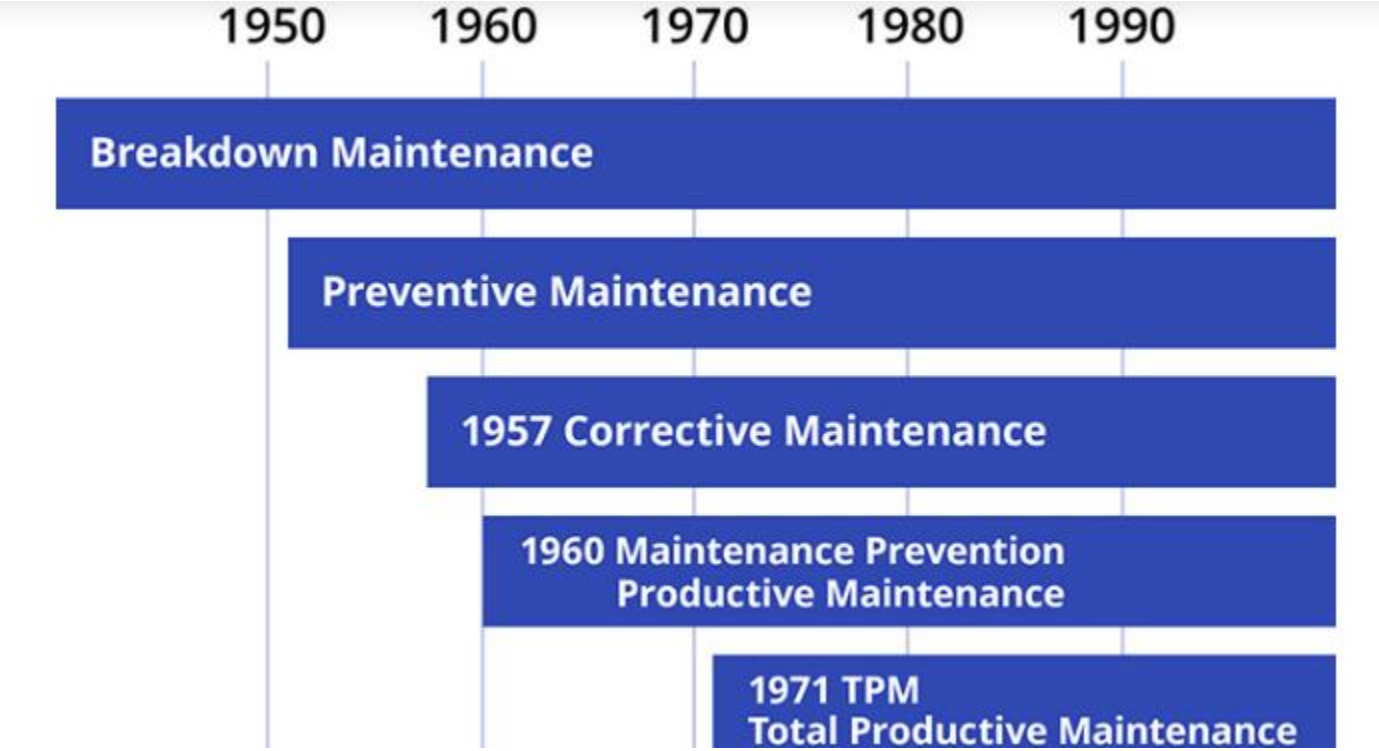
Cost (Traditional)



Total Productive Maintenance (TPM)

- Total Productive Maintenance (TPM) has been developed from the original PM (preventive maintenance concept. The history can be traced back to 1951 and first implemented in Japan (1971).
- The first example of TPM used in Europe to deliver world class performance was by Volvo in Ghent, Belgium.

Total Productive Maintenance (TPM)



Total Productive Maintenance (TPM)

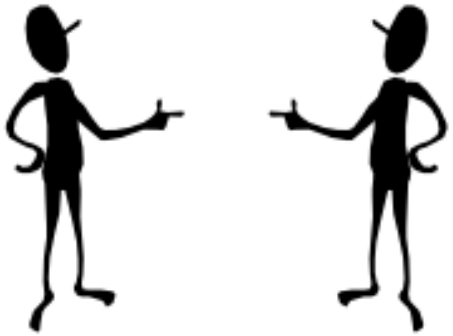
- TPM that is a set of activities for restoring equipment to its optimal condition, and changing the work environment to maintain those conditions through daily maintenance activities.

Total Productive Maintenance (TPM)

- **Total:** Participation of all employees
- Includes all departments operations equipment and process.
- **Productive:** Effective utilisation of all resources.
- **Maintenance:** Keeping the Man-Machine-Material system in optimum condition.

Old Attitude

"I operate, you fix."
"I fix, you design."
"I design, you operate."



TPM Attitude

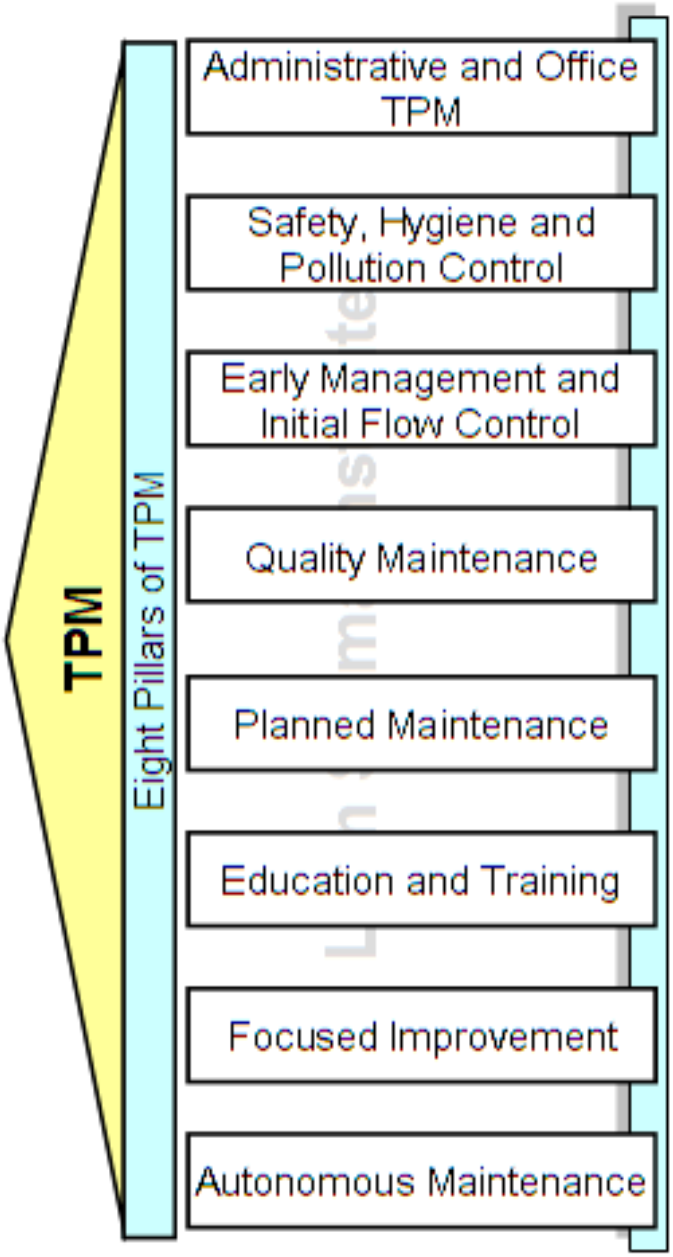
"We are all responsible for our equipment."

Management…Operators….Maintenance…
Engineers…EVERYONE!

- TPM focused on achieving:
- • Zero Accidents
- • Zero Break-downs
- • Zero Defects

TPM Objectives

- Increase the production while at the same time increasing job satisfaction.
- Hold emergency and unscheduled maintenance to a minimum.
- Provide the safe and good working environment to the worker.


TPM
Eight Pillars of TPM
Administrative and Office TPM
Safety, Hygiene and Pollution Control
Early Management and Initial Flow Control
Quality Maintenance
Planned Maintenance
Education and Training
Focused Improvement
Autonomous Maintenance

Reliability Centered Maintenance (RCM)

- A RCM strategy employs preventive, predictive and proactive maintenance technologies in an integrated manner to increase confidence that a machine will operate dependably over an extended life cycle.
- The integrated approach of various techniques is required, as no single technique is sufficient to accurately understand the problems of complex equipment.

Reliability Centered Maintenance (RCM)

- The ability to use the various techniques focused around reliability affords an opportunity to move beyond fault detection towards developing a meaningful and valuable tool for a maintenance improvement program. The focus shifts on the elimination of machine failure, rather than the prediction of failures.

Reliability Centered Maintenance (RCM)

- RCM was developed in 1970s by the maintenance steering group of commercial airline industry in order to reduce maintenance downtime, maintenance cost and improve flight safety. It has also been successfully employed in grain terminals, coal mining, oil refinery, gas plants and paper industry.

Reliability-centered maintenance (RCM)

- Reliability-centered maintenance (RCM) is a systematic consideration of system functions, the way functions can fail, and a priority-based consideration of safety and economics that identifies applicable and effective PM (preventive maintenance)tasks.
- Objective: To reduce the maintenance cost, by focusing on the most important functions of the system, and avoiding or removing maintenance actions that are not strictly necessary.

Reliability Centered Maintenance (RCM)

- It provides a methodology targeted on system functions, the failures relating to that function, and in particular to the effects of dominant functional system failures.
- RCM is a method for developing and selecting maintenance design alternatives based on safety, operational and economic criteria. It employs a system perspective in its analysis of system functions.

Benefits of RCM

- High quality, cost effective maintenance plans in less time
- • Assurance that all maintenance important parts and their failure mode are critically considered in the development of maintenance programs
- • Increased probability that the level and content of the maintenance requirement is optimally specified
- • Provides the basis for routine, on-line information sharing among engineering, operations and maintenance staff
- • Longer useful life of expensive assets
- • Improved safety of equipment and plant personnel

Problems in Implementing RCM

- **Insufficient Equipment Failure Data**

Historical data about equipment failure is required for the RCM program to be effective. Without the data about the failure, frequency of failure and root cause of the failures, the RCM programs are based on guesswork.

Poor Training in the RCM Methodology

RCM consists of many methodologies, some have flexibility, whereas others are more rigid. After selection of the appropriate approach, all the employees involved in RCM efforts should be trained to a high degree of proficiency in the appropriate RCM techniques.

- **Lack of Understanding at Top Management Level**
- The lack of understanding about the benefits that can be achieved from a successful RCM program results in poor support from top management.
- **Short Term RCM Efforts**
- RCM is a valuable tool, especially when coupled with a disciplined maintenance improvement program.
- **Lack of Focus**
- The organization need to be focused on its vision, the improvement plan and the implementation methodology needed to achieve the goals.

Basic questions

- 1. What are the functions and associated performance standards of the equipment in its present operating context?
- 2. In what ways can it fail to fulfill its functions?
- 3. What is the cause of each functional failure?
- 4. What happens when each failure occurs?
- 5. In what way does each failure matter?
- 6. What can be done to prevent each failure?
- 7. What should be done if a suitable preventive task cannot be found?

System selection

- We should consider which systems are beneficial for RCM compared with more traditional maintenance planning?
- At what level of assembly (plant, system, subsystem) should the analysis be conducted?
- The following system hierarchy levels are used:
- 1. Plant (e.g., process plant)
- 2. System (e.g., gas compression system)
- 3. Subsystem (e.g., one gas compressor)
- 4. Maintainable item (is an item that is able to perform at least one significant function as a stand alone item (e.g., pumps, valves electric motors)

Resources

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- Operations Management Lecture – 48 Total Productive Maintenance Lecture Notes, Dr. Inderdeep Singh Department of Mechanical & Industrial Engineering
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