AALIM MUHAMMED SALEGH COLLEGE OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

ME 2037 – MAINTENANCE ENGINEERING

TWO MARKS, 16 MARKS – Q + A

HEAD OF THE DEPARTMENT

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ME 2037 - MAINTENANCE ENGINEERING
2 MARKS - QUESTIONS AND ANSWERS

Unit I

1. Define maintenance?

Maintenance is the routine and recurring process of keeping a particular machine or asset in its normal operating conditions, So that it can deliver the expected performance or service without any loss or damage.

2. Define reliability?

Reliability is defined as the probability that a component /system, when operating under given condition, will perform its intended functions adequately for a specified period of time. It refers to the like hood that equipment will not fail during its operation.

3. State the benefits of reliability analysis in industries?

The main advantages of imposing reliability requirements are increased productivity and reductions in forced outage equipment due to planned maintenance activity.

4. Define failure rate?

Failure rate is the ratio of the number of failures during particular unit interval to the average population during that interval. This failure rate is also known as hazard rate and instantaneous failure rate.

5. What is Mean Failure Rate?

The mean failure rate h is obtained by finding the mean of the failures rates for Specified period of time.

$$h = \frac{(Z_1 + Z_2 + Z_3 + ... + Z_T)}{T}$$

Where, 'Z_T' represents failure rates over the specified period of time T.

6. Define Mean Time to Failure.

Let t_1 is the time to failure for the first specimen, t_2 is the time to failure for the second specimen and t_N is the time to failure for the N^{th} specimen. Hence the mean time to failure for N specimens are

$$MTTR = (t_1 + t_2 + ... + t_N) / N$$

7. What is Mean Time between Failures (MTBF)?

Mean Time between Failures (MTBF) is the mean or average time between successive failures of a product. Mean time between failures refers tom the average time of breakdown until the device is beyond repair.

8. Define Mean Time to Repair (MTTR)?

Mean Time to Repair is the arithmetic mean of the time required to perform maintenance action. MTTR is defined as the Ratio of total maintenance time to Number of maintenance action.

MTTR = Total maintenance time/ Number of maintenance action.

9. Define Maintenance Action Rate?

Maintenance action rate is the number of maintenance action that can be carried out on equipment per hour.

10. Define Failure Density?

Failure Density is the ratio of the number of failures during a given unit interval of time to the total number of items at the very beginning of the test.

11. State the types of reliability?

Reliability can be generally of two types:

(i) Inherent Reliability: It is associated with the quality of the material and design of machine parts.

(ii) Achievable Reliability: It depends upon other factors such as maintenance and operation of the equipment.

12. Draw the equipment life cycle and name the various phases in it?

Phase I - Failure pattern inherent in a new product because of manufacturing or design defects.

Phase II - Life period of an equipment.

Phase III - Failures due to wear out conditions because of aging of the equipment.

13. Define maintainability?

Maintainability is defined as the probability that a unit or system will be restored to specified working conditions within a given period when maintenance action is taken in accordance with the prescribed procedures and resources.

14. Define availability?

Availability is the ratio of the time at which equipment is available for the designated operation/service to the total time of operation and maintenance of the equipment. It is also defined as the ratio of equipments uptime to the equipment uptime and downtime over a specified period of time.

15. State the advantages of life cycle cost analysis.

(i) Integration of engineering, economics and financial aspects lead to the way of robust metric for the selection and purchase equipment required for the industry.

(ii) Reduced operating and maintenance cost of equipments due to cost analysis over span of time.

(iii) It leads to the selection of proper and economically viable equipment.

16. Draw the curve to determine the economic life of equipment?

The economic life of equipment depends on the maintenance and repair costs, availability and operational efficiency. A plot of cumulative efficiency and maintenance and repair cost per cumulative hours Vs operating hours of the equipment to find the economic life of the equipment is shown in the figure.

17. State the components of maintenance cost?

The maintenance cost is comprised of two factors:

(i) Fixed cost: This includes the cost of support facilities including the maintenance staff.

(ii) Variable cost: This includes the consumption of spare parts, replacement of components and cost other facilities requirements of maintenance.

18. State the role of maintenance budget.

The maintenance budget is used to set aside certain amount of money to meet the expenditures incurred in achieving the objectives of maintenance.

19. State the types of maintenance budget?

(i) Appropriation Budget: Budget used to allocate money for each activity independently.

(ii) Fixed Budget: Fixed used to allocate money for a specified period of time.

(iii)Variable Budget: Dynamic allocation of expenditure based on maintenance requirements and activities.

20. List the main factors of maintenance cost?

The maintenance cost is comprised of two factors:

(i) Fixed cost: This includes the cost of support facilities including the maintenance staff.

(ii) Variable cost: This includes the consumption of spare parts, replacement of components and cost other facilities requirements of maintenance.

Unit – II

1. Define the term Preventive Maintenance?

It is a maintenance program which is committed to the elimination or prevention of corrective and breakdown maintenance. It is designed for day to day maintenance like cleaning, inspection, lubricating, retightening etc. to retain the healthy condition of equipments.

2. Define predictive maintenance?

Predictive maintenance is a management technique that uses regular evaluation of the actual operating conditions of plant equipment, production systems and plant management function to optimize total plant operation.

3. What is meant by Breakdown maintenance approach?

It is a type of maintenance approach in which equipment is allowed to function / operate till no failure occurs (i.e.) no maintenance work is carried out in advance to prevent failure.

4. Classify various planned maintenance approach.

- Preventive Maintenance
- Corrective Maintenance
- Predictive Maintenance
- Condition Based Maintenance

5. Define corrective maintenance approach.

Corrective maintenance is the program focused on regular planed tasks that will maintain all critical machinery and system in optimum operation conditions.

6. What is meant by preventive maintenance approach?

A comprehensive preventive maintenance program involves periodical evaluation of critical equipment, machinery to detect problem and schedule maintenance task to avoid degradation in operating conditions. It is designed for day to day maintenance like cleaning inspection, lubricating, retightening etc. to retain the healthy condition of equipments.

7. List the objectives of corrective maintenance?

- Elimination break downs
- Elimination deviations from optimum operating condition
- Elimination unnecessary repairs

8. What is meant by predictive Maintenance?

Predictive maintenance is a management technique that uses regular evaluation of the actual operating conditions of plant equipment production systems and plant management functions to optimize total plant operation.

9. List out some condition based monitoring techniques and briefly discuss on them.

- Vibration Monitoring
- Thermograph
- Tribology
- Electrical Motor Analysis

10. What is meant by reliability centered maintenance (RCM)?

Reliability centered maintenance is one of the well established systematic and a step by step instructional tool for selecting applicable and appropriate maintenance operation types. It helps in how to analyze all failure modes in a system and define how to prevent or find those failures early.

11. What is Total Productive Maintenance (TPM) and discuss its similarities with TQM?

Total Productive Maintenance (TPM) is a maintenance program which involves a newly defined concept of maintaining plants and equipments. The goal of TPM program is to significantly increase the production, at the same time increasing employee morale and job satisfaction.

CATEGORY	TQM	TPM
Objective	To have Quality Output	To have Reliable Equipment
Means of Achieving	Through Systematized Management	Through Active Participation of employees
Target	Minimized defects through Planned Preventive Maintenance	Elimination of losses and Wastes

12. What is meant by Reliability Centered Maintenance (RCM)?

Reliability centered maintenance is one of the well established systematic and a step by step instructional tool for selecting applicable and appropriate maintenance operational types.

13. What does safety, health and environment pillar of TPM aims at?

This pillar aims at achieving Zero accident, Zero health damage and Zero fires.

14. What is limitation of breakdown maintenance?

- Most repairs are poorly planned due to time constraint caused by production and plant management. This will cost three to four times than the same repair when it is well planned.
- This approach focus only on repair or the symptoms of failure and not on the root cause of failure. This results only in increase in the frequency of repair and correspondingly the maintenance costs.

15. List the benefits of implementing preventive maintenance.

- It maintains the equipment in good condition to prevent them from bigger problems
- Prolongs the effective life of the equipments
- Detects the problem at earlier stages
- minimizes/eliminates the rework/scrap and helps in reducing the process variability
- Significantly reduces unplanned downtime

16. Name the five S principles used for implementations of TPM.

- SEIRI – Sort Out
- SEITON –Organize
- SEISO – Shine Workplace
- SEIKETSU – Standardization
- SHITSUKE – Self Discipline

17. List the various pillars of TPM?

- 5-S Principle
- JISHU HOZEN(JH)
- KAIZEN
- Planned Maintenance
- Quality Maintenance
- Training
- Office TPM
- Safety, Health and Environment

18. What are the objectives of TPM?

The main objectives of TPM are

- To achieve zero defects
- Achieve zero accidents and zero break downs in all areas of an organization
- To create different team of people to have active participation.
- To aim at minimization of defects and
- To inculcate autonomous policy

19. Name the various stakeholders of maintenance scheduling.

- Operators
- Planners
- Schedulers
- Maintenance Supervisors
- Craftsman
- Store's In Charge
- Operation Superintendent

20. Define Maintenance Scheduling.

Maintenance scheduling is a joint maintenance operations activity in which maintenance agrees to make the recourses available at a specific time when the unit can also be made available by operations.

Unit – III

1. What is equipment health monitoring?

Conditions monitoring is one of the maintenance methods which are used to assess the health and condition of equipments machines, systems or process by absorbing checking, measuring and monitoring several parameters. This technique is also called as equipment health monitoring.

2. List down the factors for increasing the demand condition monitoring.

- Increased quality expectations reflected in produces liability legislation
- Increased automation to improve profitability and maintain competitiveness
- Increased safety and reliability expectations
- Increased cost of maintenance due to labour and material cost

3. List down the key features of condition monitoring.

- Links between cause and effect
- Systems with sufficient response
- Mechanisms for objective data assessment
- Benefits outweighing cost
- Data storage and review facilities

4. Write down the basic steps in condition monitoring

- Identifying critical systems
- Selecting suitable techniques for condition monitoring
- Setting baselines
- Data collection
- Data assessment
- Fault diagnosis and repair
- System review

5. What are three types of condition monitoring?

- Subjective condition monitoring
- Minimized breakdown costs
- Improved morality of the operating personnel and safety

6. State the advantages and disadvantages and disadvantages of condition monitoring.

Advantages

- Improved availability of equipment
- Minimized breakdown cost
- Improved reliability

Disadvantages

- Gives only marginal benefits
- Increased running cost
- Sometimes difficult to organize

7. Mention the various costs involved in costing of condition monitoring.

I. Installation cost
II. Operating cost

8. State the methods of measuring vibration.

- Amplitude
- Frequency
- Phase

9. Name the types of pyrometers.

- Total radiation pyrometers
- Infra red pyrometers
- Optical radiation pyrometers

10. Mention the application of bimetallic strip.

- Bimetallic strips are frequently used in simple ON – OFF switches
- The bimetal strips are also used in control switches

11. List down the features of RTD.

- High degree of accuracy
- Resistance thermometer is interchangeable in a process without compensation or recalibration

12. State the application and limitation of thermisters.

Applications:

- It is used for varying temperatures
- it is used in time delay circuits
- Thermistors are used for temperature compensation

13. What are two main types of Infrared Themography?

- Passive Thermography
- Active Thermography

14. What are the principles very important for the study of eddy current test?

- Permeability
- Conductivity
- Material thickness
- Edge effect and end effect
- Lift off
- Fill factor

15. Describe the limitation of eddy current test.

The main limitation is the low penetration of parts being examined, using limited to thin walls or near surface flaws. It is difficult to use on ferromagnetic materials. False indications are possible because of mixed variables, edge effects and lift-off effects. Extensive technical knowledge is required for the development of inspection procedures, specific probes and to interpret the inspection data.

16. Mention the effect of X-rays to human body?

- ❖ Injuries to superficial tissue
- ❖ General effects on the body, particularly the blood forming organs; eg. Producers of anaemia and leukaemia
- ❖ Induction of malignant tumours
- ❖ Genetic effects

17. What are the limitations of ultrasonic test?

- Unfavourable geometries and coarse anisotropic grain structures are difficult to inspect
- Extensive technical knowledge is required for the development of inspection procedure
- Parts that are rough, irregular in shape, very small or thin or not homogenous are difficult to examine, specific probes and to interpret the inspection data

18. Name some of the methods of leakage monitoring.

- Interstitial Monitoring
- Level Monitoring
- Vapour Monitoring
- Liquid Monitoring

19. Define see back effect?

The basic principle of thermocouple is ‘when two dissimilar metals are joined together and emf will exist between the two points A and B, which is primarily a function of the junction temperature. The above said to be principle of see back effect.

20. State the various methods of corrosion monitoring?

- Weight loss method
- Electrical resistance method
- Linear polarization method
- Corrosion potential measurement
- Ultrasonic testing
- Sentinel hole method

Unit –IV

1. Define the term failure.

The term failure may be defined as

- any loss that interrupts the continuity of production
- a loss of assets availability
- the unavailability of equipment
- a deviation from the status quo
- not meeting target expectations
- Any secondary defect

2. What are the various possible causes for a failure?

- Unexpected and unintentional damage \
- Workmanship
- Improper design
- Manufacturing defects
- Incorrect usage of equipment

3. Define failure analysis?

Failure analysis is the process by which information/data about failure occurring in equipments/ systems are collected and analyzed to find the root cause of failures, and the causes are addressed to prevent recurrence of failures.

4. Name the three types of failure models?

- Predictable failure model
- Unpredictable failure model
- Running-In-Failure model

5. What are called age-dependent failures?

Time dependent failures are called age dependent failures.

6. What are predictable failures?

In spite of all the working conditions maintained at same level, the cause of failure will be random in nature and cannot be assigned to any particular mechanism of failure. This type of failures is called Unpredictable Failures.

7. What are running In Failures?

Suppose if some components/ equipments are installed with unnoticed defects, may fail in a short duration after installation than during its useful life. This type of failures is Running In Failures.

8. Define Fault tree diagrams.

Fault tree diagrams are logic block diagrams that display the state of a system in terms of the states of its components.

9. Write down the capabilities of Fault Tree Diagram.

- Fault tree analysis and failure modes and effects analysis,
- Design for reliability
- Design for safety

10. Define Event tree Analysis

An event tree is a visual representation of all the events which can occur in a system. As the number of events increases, the pictures fans out like the branches of a tree.

11. What is the aim of event tree analysis?

The aim of event tree is to determine the probability of an event based on the outcomes of each event in the chronological sequence of events leading up to it. By analyzing all possible outcomes, we can determine the percentage of outcomes which lead to the desired result.

12. Define Root cause analysis?

RCA is a step by step method that leads to the discovery of faults first or root cause. Every equipment failure happens for a number of reasons. There is a definite progression of actions and consequences that lead to a failure. An RCA investigation from the end failure is back to the root cause.

13. Define FMEA?

FMEA is methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome the issues, thereby enhancing reliability through design.

14. Define Risk Priority Number (RPN).

Risk priority numbers is the product of the numerical Severity, Occurrence and Detection ratings.

$$RPN = (S) \times (O) \times (D)$$

15. Name the factors based on the satisfactory performance of gears/drives.

- Proper design and manufacture of drive
- Selection of proper type and size
- Proper installation
- Proper use of service
- Proper maintenance of unit in it entire life

16. Name the factors that contribute to tooth breakage.

The common reasons for gear tooth breakage may be due to any of the following reasons

- Fatigue
- Heavy wear
- Overload
- Cracking

17. List some of the inspection performed on gears.

- Pitch error
- Axial and
- Radial run out
- Tooth profile etc.

18. Name some of the geometric properties that are checked for guide ways.

- Straightness
- Flatness
- Parallel both on horizontal and vertical surfaces

19. What are the factors influence the performance of sleeve bearings.

The following are the factors that affect the bearing performance:

- Dirt
- Fatigue
- Hot Shot phenomenon and
- Crush problem

20. Define Crush

Normally, the bearings are manufactured so that they are slightly longer circumferentially than the mating housing. The bearing will be elastically deformed during assembly. If the amount of crush is insufficient, relative motion occurs between the bearing and its bore, which causes fretting and makes the bearing back a highly polished or pitted.

Unit –V

1. State few examples of material handling equipments.

Material handling equipments include carts, hand trucks, forklifts, conveyors, shelf pickers and other specialized industrial trucks powered by electric motors or internal combustion engines.

2. State the benefits of proper maintenance of material handling equipments.

The benefits of a maintenance program for material handling equipments are to maintain the high efficiency, keep them in running condition, reduce the cost of repairs, safer operation and enhanced productivity.

3. State the major stages in preventive maintenance of material handling equipments.

There are three stages of preventive maintenance are:

- Inspection
- Repair And
- Overhaul

4. State the various phases present in a good maintenance management system.

- Work identification
- Planning
- Scheduling
- Execution

- Recording and
- Analysis

5. Define the term Computerized Maintenance Management System (CMMS).

Computerized maintenance management system is the application of computers in planning, scheduling, monitoring and control of maintenance activities.

6. State the objectives of CMMS.

- Maintenance of existing equipments
- Inspection and service of the equipment
- installation or revamping of the equipment
- Maintenance storekeeping
- craft administration

7. State the advantages of CMMS.

- Improve maintenance efficiency
- Reduce maintenance costs
- Reduce the equipment downtime by proper scheduling preventative maintenance.
- Provide maintenance reports in specific formats depending on the requirements.
- Quicker access to plant maintenance statistics

8. Define work order system.

Work order system is the information system used by the industry to keep track of its maintenance works.

9. Mention the use of work order backlog.

Work order back log is used to find out all active maintenance works order in an industry.

10. What is work permit?

Work permits are components of work order. Maintenance department issues work permits to different executing agencies permitting them to start their work.

11. What is job card?

Job cards contain necessary details for performing individual job in maintenance organizations. Job card may be in the form of a card, sheet or printout.

12. State the benefits of job card system.

- Information about maintenance history
- Knowledge of frequency of frequency of maintenance for equipments
- Details of equipments which require maximum resources
- Helps in job auditing
- Evaluation of cost of maintenance

13. State the role equipment records in maintenance.

Equipment records are information containing the details of installation, service, repair, maintenance activities, schedules and plans for future implementation. Equipment records are to be used to maintain control on maintenance cost, reliability and availability.

14. State the benefits of keeping equipments records.

- Clear picture about the details of maintenance programmes is obtained
- information about completed, pending and regular jobs carried out to the equipment are available
- Records disseminated to various units of the industry
- Helps in standardization of procedures
- Evaluation of performance of maintenance tasks

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20. What are two main types of infrared Thermography?

- Passive Thermography
- Active Thermography

16 MARKS QUESTIONS AND ANSWERS

UNIT I

1) What are the principles of maintenance?

a) Plant Management In Maintenance Work:
The main role of a maintenance function is to provide safe and effective operation of the equipment to achieve the desired targets on time with economics usage of resources.

b) Production And Maintenance Objectives:
The plant operation is driven by the production targets. The objective of maintenance function is to support this target. The achievement of desired goals of the production system is to be supported by both the production and maintenance department to ensure smooth and successful operation of the industry.

c) Establishment of Work Order And Recording System:
The maintenance system should have proper work and recording system. The work order for the maintenance function indicates the nature of work to be performed and the series of operations to be followed to execute a particular job. It is necessary to maintain proper records and entries to monitor the maintenance function.

d) Information Based Decision Making:
The maintenance objectives are successfully achieved by the use of reliable information system. This information is used to meet the manpower and spare parts re4quirements of the industry.

e) Adherence to Planned Maintenance Strategy:
A sound maintenance management should adhere to the planned maintenance strategy. This also includes the use of manufacturer information on the life and maintenance schedules of the equipment and other material resources available.

f) Planning of Maintenance Function:
All the maintenance function are to be carefully executed by a way of proper planning to ensure the effective utilization of manpower and materials.
g) Manpower for Maintenance:
The manpower requirement of the maintenance system must be carefully evaluated based on the time and motion study. The requirements should also satisfies the need arising in case of overhauls, component replacement, emergency and unscheduled repair.

h) Work Force Control:
Determination of exact work force required to meet the maintenance objectives of the system is difficult task due to the element of uncertainty. Hence the proper control and monitoring of workforce are needs to be ensured.

i) Role of Spare Parts:
A good maintenance management system requires appropriate tools. So the system should have good quality tools and that too available in required quantities to ensure the proper function of the maintenance work.

k) Training of Maintenance Work Force:
Training of the workforce must be integral part of any good maintenance management system. Training helps the workforce to learn about the modern techniques, recent trends in maintenance and to chalk out a strategy to meet the growing demands of the industry.

2) What are important factors considered in maintenance planning?

a) Job Distribution:
The first and foremost task in maintenance planning is the distribution of the jobs to the personnel for preventive and emergency maintenance works. It is the practice to form two separate task groups to tackle both. If not possible a same group can also be used to tackle both the situations in such way that during scheduling, time must be devoted for unforeseen breakdowns or situations in maintenance.

b) Programme:
The development of maintenance programs involves

- Selection of activities for maintenance
- Determination of the frequency of preventive maintenance
- Decision on the cost effective methodology
- Selection of activities: This selection is based on cost involved between preventive and breakdown maintenance.

c) Manpower Allocation:
The manpower allocation is the most important task of the maintenance management group. It provides adequate manpower to execute various jobs in the system. This should also take into consideration the skill level of personal deputed for the maintenance tasks. The central idea of manpower allocation can be drafted using the information available from maintenance records and planning the task to meet the objectives of the organization.

d) Staffing:
Staffing is the task of providing the required manpower for the maintenance function. This has to be achieved at optimum cost. Staffing depends upon the ability of the organization to tackle the regular as well as attending the unforeseen situations. Staffing should be sufficient to handle preventive and emergency maintenance task.

e) Planning Technique:
The planning methods are Gantt charts, Milestone method, and Critical path method and program evaluation review. Evolutionary computation based techniques are recently used for maintenance planning and scheduling.

f) Planning Procedure:

Planning procedure involves four step processes.

- Organising maintenance resources to ensure their effective use in future
- Scheduling the resources for the planned period
- Execution of plans according to the schedules
- Establishing a feedback system for all the above processes, to know the deficiencies of each process.

g) Estimation Of Maintenance Work:

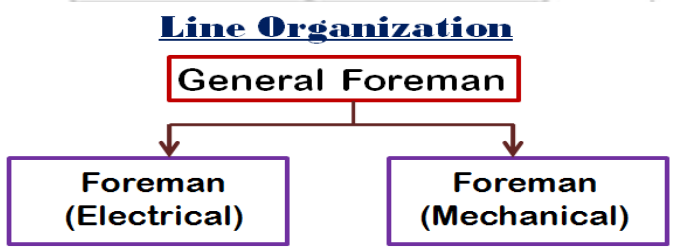
Estimation is used to find out the quantity and quality of the maintenance work. This will help in allocation of the required manpower. The following methods are used for the estimation of maintenance work. Measurement by estimates, historical data and by conventional standard time data.

i) Maintenance Control:

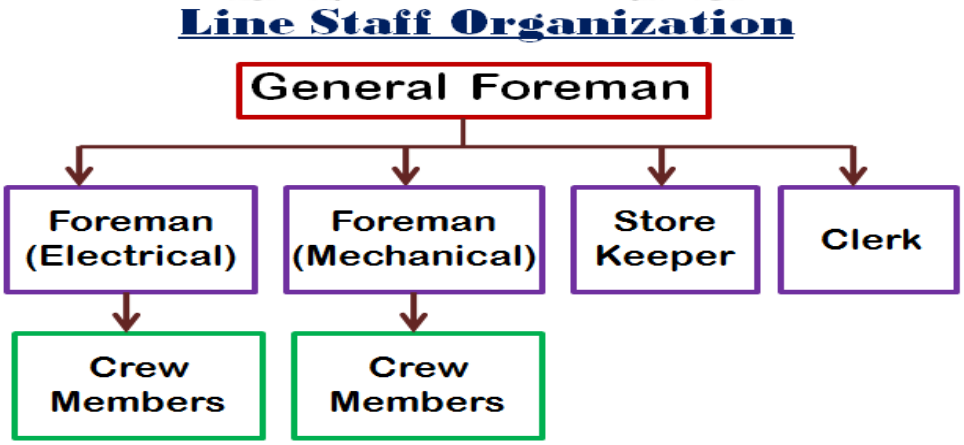
Maintenance control is the auditing techniques to ensure the effective utilization of the maintenance budget. This involves the integration of accountability within the system. Rope accounting of maintenance work should be carried out at every level of the maintenance organization.

3) What are the different types of organizations are in use in Indian industries?

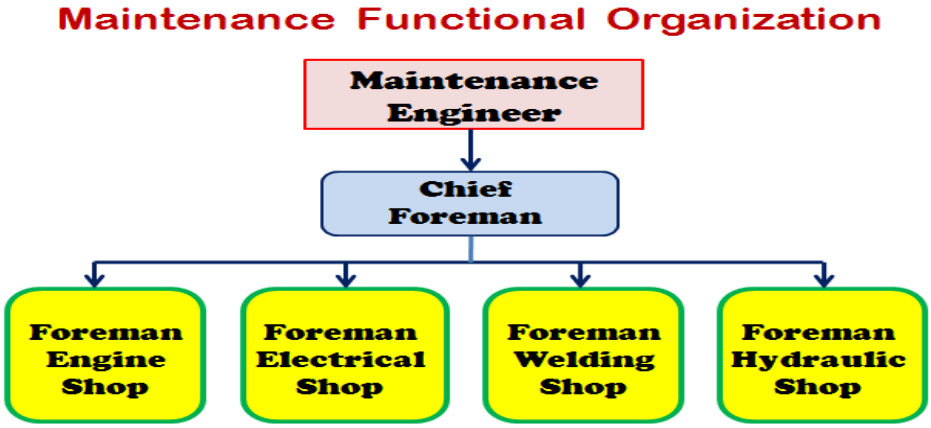
a) Line Organization:



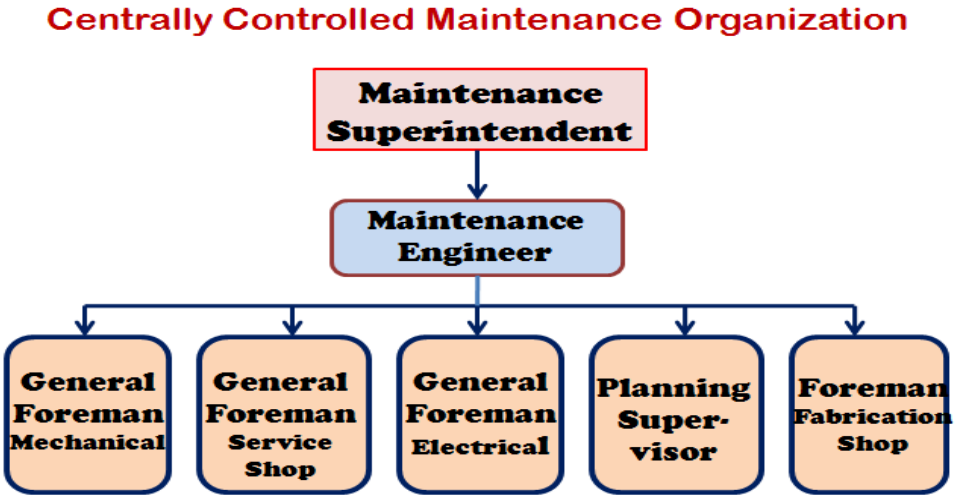
b) Line Staff Organization:



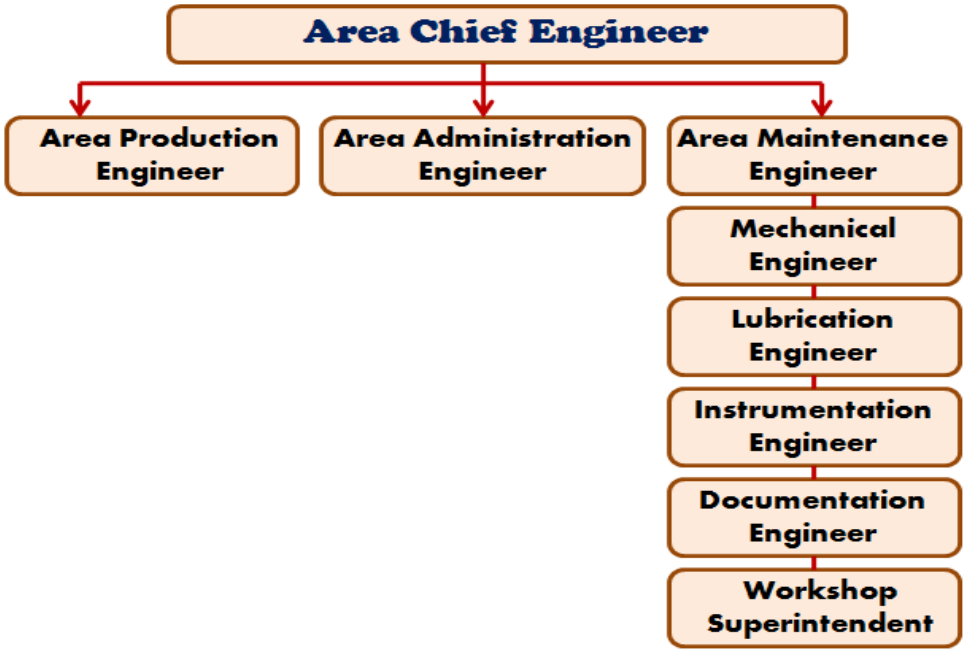
c) Maintenance Functional Organization:



d) Centrally Controlled Maintenance Organization:



e) Area Maintenance Organization:



4) Mention the maintenance function and activities?

The functions and activities of the maintenance organization are as follows:

(i) Identifying areas for implementation of preventive maintenance program

(ii) Making suitable arrangements for maintenance facilities for carrying out the maintenance work properly

(iii) Planning and scheduling the total maintenance work

(iv) Ensuring proper and timely supply of spare parts

(v) Managing proper inventory control of materials spares and tools required for the maintenance

(vi) Standardization of maintenance work

(vii) Implementing modifications to the existing equipment wherever possible

(viii) Assisting the purchase department in procuring materials Disbursement of services such as water, electricity, steam, compressed air and other amenities required to carryout the maintenance

(ix) Identification of obsolete and surplus equipment for replacement and disposal

(x) Designing the systematic way for disposal of equipment and for maintaining floor space

(xi) Training of maintenance personnel

(xii) Analysis of future demands and forecast the role of maintenance activities

(xiii) Implementation safety norms and procedures

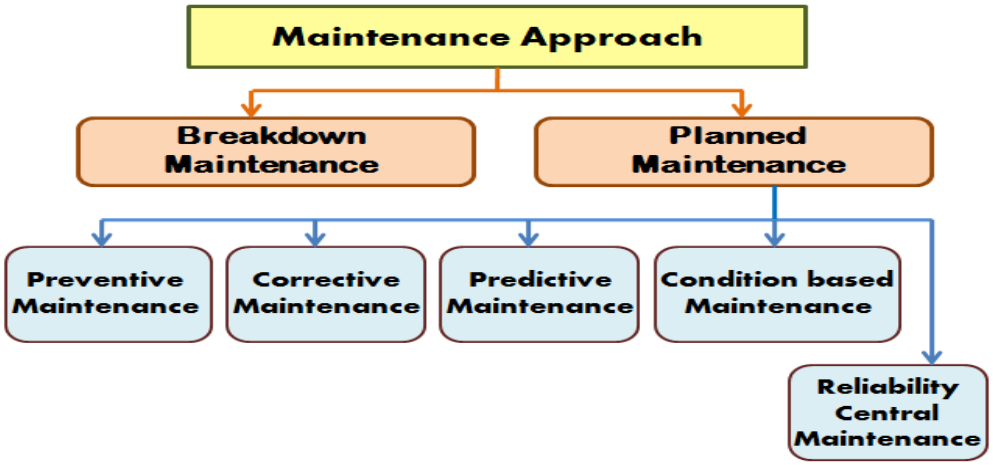
(xiv) Ensuring safety of personnel and equipment

Unit II

5) Explain with sketch various types of maintenance approach?

Basically there are two types of maintenance tasks, they are

- ❖ Breakdown maintenance
- ❖ Planned maintenance



Planned maintenance may further be classified into

- Preventive maintenance
- Corrective maintenance
- Predictive maintenance
- Condition based maintenance
- Reliability centered maintenance

✪ Preventive Maintenance:

It is a maintenance program which is committed to the elimination or prevention of corrective and break down maintenance.

Benefits of Preventive Maintenance:

- It maintains the equipment in good condition to preventing them from bigger problems
- Prolongs the effective life of equipments
- Detects the problem at earlier stages
- Minimize/eliminates the rework/scrap and helps in reducing the process variability
- Significantly reduces unplanned downtime

✪ Corrective Maintenance:

The main objectives of this program are to

- Eliminate breakdowns
- Eliminate deviations from optimum operating conditions
- Eliminate unnecessary repairs
- Optimize all critical plant systems

✪ Predictive Maintenance:

Predictive maintenance is a management technique that uses regular evaluation of the actual operating conditions of the plant equipment.

Benefits of preventive maintenance

- Reduced breakdown losses.
- Reduction of quality defects.
- Increased net operating profit
- Reduced maintenance costs

✪ Condition Based Maintenance Techniques:

❑ Vibration Monitoring - Determines the actual conditions of equipments/machines by studying the noise or vibration produced during functioning.

❑ Thermography - Determines the condition of plant machinery, systems etc. by studying the emissions of infra red energy (i.e.) temperature.

✪ Reliability Centered Maintenance:

The rough process of RCM is as follows

- Target products or systems of maintenance should be clearly identified and necessary data should be collected
- All possible failures and their effect on target products or systems are systematically analyzed

Application of RCM:

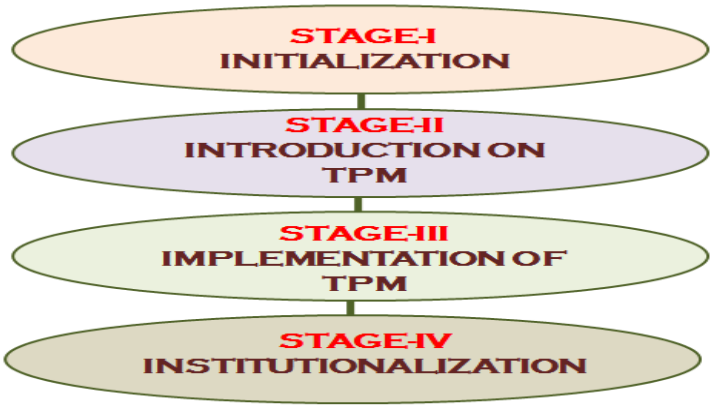
- When designing, selecting and installing new systems in a plant.
- When setting up preventive maintenance for complex equipment and systems for which we are not clear on how they work.
- When teaching people the basics of reliability it helps to explain the matters in a detailed fashion using RCM.

6. Explain briefly about TPM with the help of flow chart?

TPM is a maintenance program which involves a newly defined concept of maintaining plants and equipments. The goal of TPM program is to significantly increases the production, at the same time increasing employee morale and job satisfaction. TPM philosophically resembles TQM in many aspects such as

- Requirements of commitment by top level management
- Requirement of empowering employees to initiate corrective action
- Accepting long range plan on any ongoing process.

IMPLEMENTATION OF TPM



STAGE-I INITIALIZATION

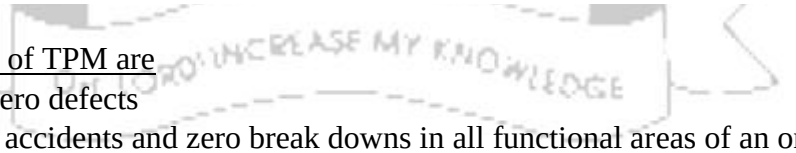
STEP I: Announcement by Management about TPM
STEP II: Initial Education
STEP III: Setting up TPM Departmental Committees
STEP IV: Establishing TPM Working System and Target
STEP V: Plan for Institutionalizing

STAGE-II INTRODUCTION ON TPM

STAGE-III IMPLEMENTATION OF TPM

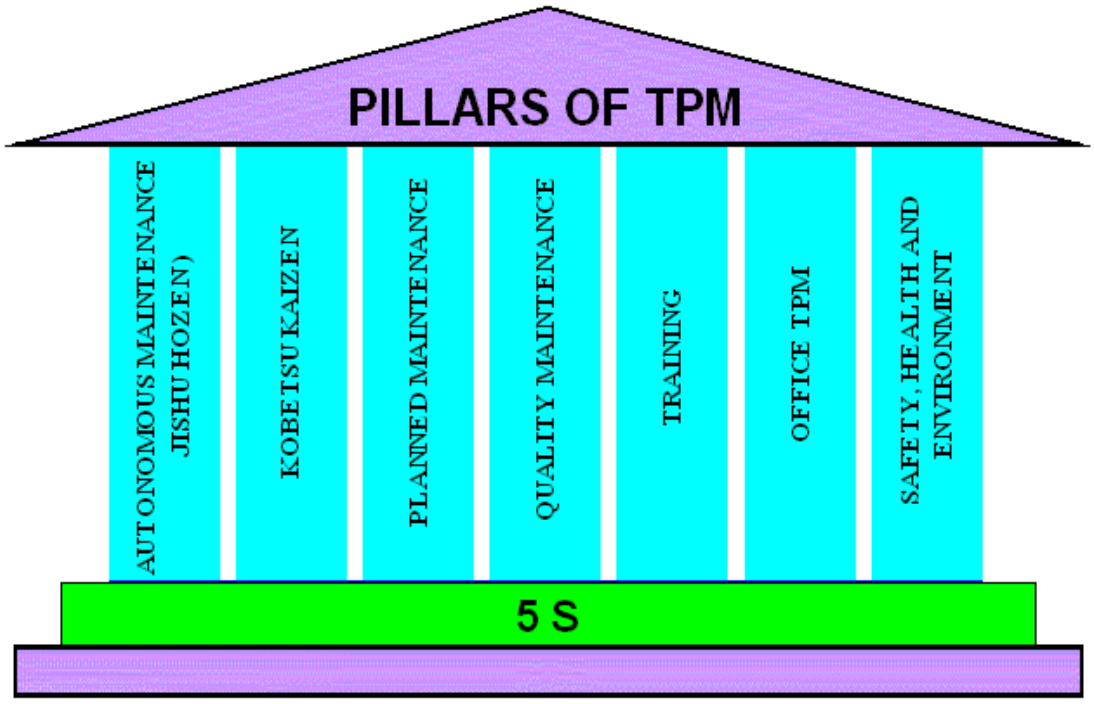
- 5'S Principle
- Autonomous Maintenance (JISHU HOZEN)
- KAIZEN
- Planned Maintenance
- Quality Maintenance
- Training
- Office TPM
- Safety, Health and Environment

STAGE-IV INSTITUTIONALIZATION



The main objectives of TPM are

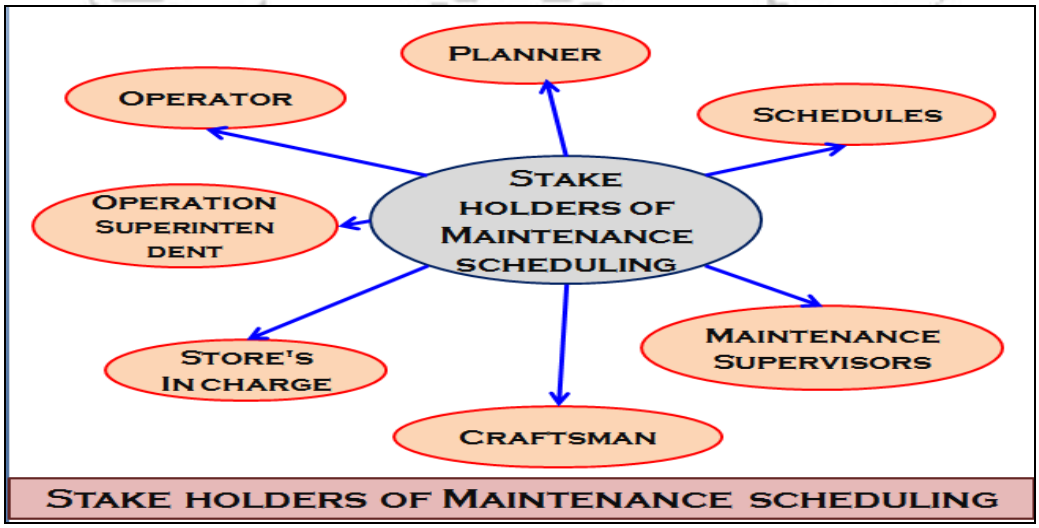
- To achieve zero defects
- achieve zero accidents and zero break downs in all functional areas of an organization
- To create different team of people to have active participation
- To aim at minimization of defects and
- To inculcate autonomous policy



7) Discuss in brief the roles of various stakeholders of maintenance scheduling communication chain?

Maintenance scheduling is a joint maintenance operations activity in which maintenance agrees to make the recourses available at a specific time when the unit can also be made available by operations various stakeholders of maintenance scheduling.

- Operators
- Planners
- Schedulers
- Maintenance Supervisors
- Craftsman
- Store's in Charge
- Operation Superintendent



Planner:
He/She should ensure that the work is properly planned with respect to customer requirements, stores material, directly purchased material and special service mentioned on work order. Also the work to be carried out with the line of safety requirements should be described.

Scheduler:
He/She should ensure that

- Trades are available to conduct the work during the schedule duration
- Materials and/or service availability
- Communicating the details of the above to person involved in maintenance and operations

Maintenance Supervisor:
He/She will be the responsible for the day-to-day activities comprised in weekly schedule and also determines the business availability. They attend to specify such as to who-what-where-when.

Craftsman:
He/She executes the assigned task and keep informing the maintenance team, the outcome as well as any practical difficulty in their part, for any further analysis

Storeroom Personnel:
They maintain the records of the receipt of goods and notify if any damages exists.

Operations Superintendent:
He must be kept informed in advance about the equipment condition. Since he is well aware of production schedule, should determine the opportune time with maintenance to release the equipment.

Operator:
He is the person responsible for securing the equipment and report back to the maintenance personnel if any deviation is observed.

8) Write a brief notes on JISHU HOZEN (Autonomous Maintenance) and its benefits?

(a) POLICY:

- Uninterrupted operation of equipments
- Flexible operators to operate and maintain other equipments
- Eliminating the defect at source through active employee participation
- Stepwise implementation of JH activities

(b) JISHU-HOZEN TARGETS

- Reduce oil consumption by 50%
- Reduce process time by 50%
- Increase use of JH by 50%

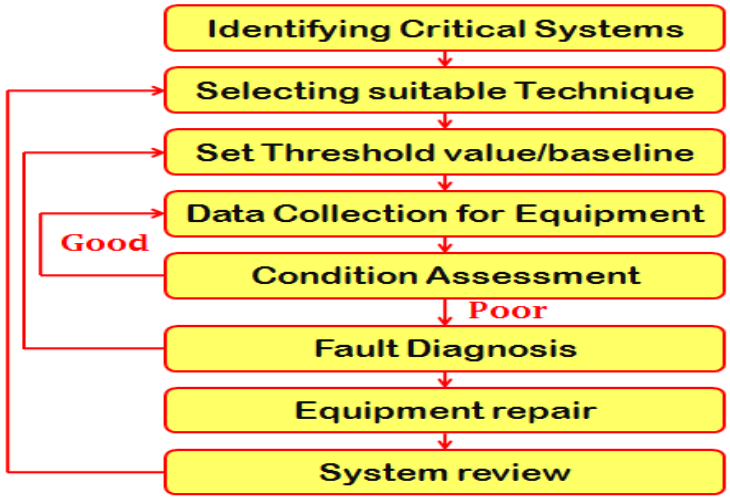
(c) Steps in JISHU-HOZEN

- Training employees
- Initial cleanup of machines
- Taking counter measures
- Fixing tentative JH standards
- General inspection
- Autonomous inspection
- Standardization
- Autonomous management

Unit III

8. Explain briefly the process involved in condition monitoring?

Conditions monitoring is one of the maintenance methods which are used to assess the health and condition of equipments machines, systems or process by absorbing checking, measuring and monitoring several parameters. This technique is also called as equipment health monitoring.



1. Identifying critical systems
2. Selecting suitable techniques for condition monitoring
3. Setting baselines
4. Data collection
5. Data assessment
6. Fault diagnosis and repair
7. System review

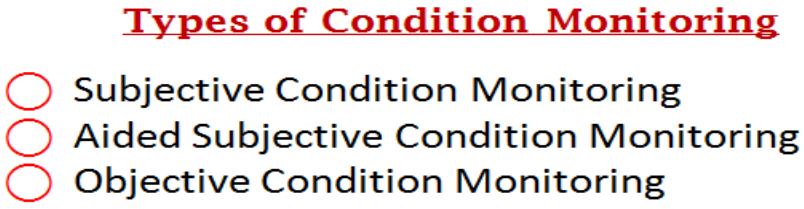
Advantages

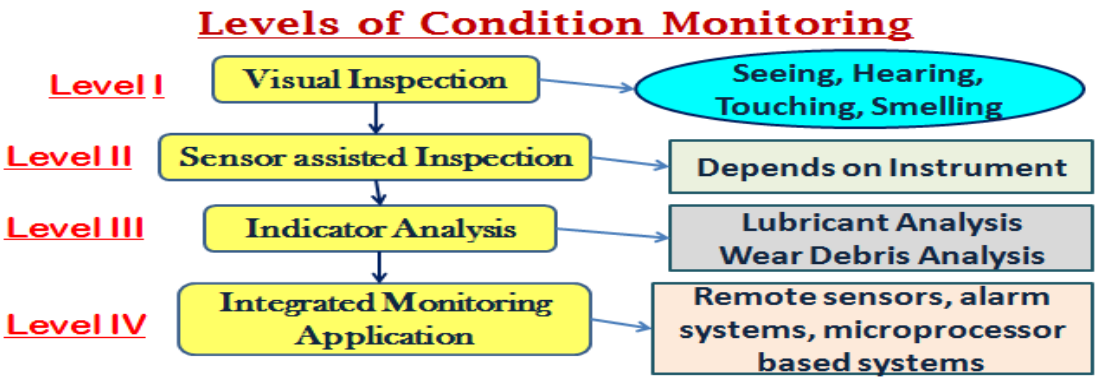
- Improved availability of equipment
- Minimized breakdown cost
- Improved reliability

Disadvantages

- Gives only marginal benefits
- Increased running cost
- Sometimes difficult to organize

9) Discuss the various levels of condition monitoring?





S.NO	Parameters to measure	Instrument used
1	Temperature	Pistol therometer,Pyrometer,temperature sensitive taps
2	Speed and distance	Tachometer,odometer
3	Vibration	Accelerometer,vibration analyzer
4	Electrical quantities such as volt,amp,ohm	Voltmeter,ammeter
5	Wear	Thickness gauges
6	Corrosion	Corrosion monitor
7	Fits and clearence	Proximitymeter

Visual monitoring:
Machine components are visually inspected to determine their condition
a. Sight Leaks: Smoke or casing colour change, indicating overheating.
b. Smell: Overheating Leaks
c. Hearing**:** Abnormal noise, indicating some malfunction.
d. Feel: Abnormal vibration, indicating some malfunction, high casing temperatures, indicating overheating.

Wear debris and contaminant monitoring.
1. Direct detection of the debris in the oil in the machine optical methods.
2. Electrically conducting filters.
3. Inductive and capacitative methods.
4. Collection of the debris in the machine for regular examination.
5. Existing filtration system.
6. Special filters.
7. Magnetic plugs.
8. Regular sampling of the lubricant for an analysis of its contents.
9. Elemental (spectrometric) analysis.
10. Magnetic particle separation.
11. Automatic particle counting.

10) Explain on-load and off-load testing used in condition monitoring with its flow chart?

Condition monitoring can be done in two methods viz, off-line or online. In off-line condition monitoring, the machine is withdrawn from service and disconnected from its normal supply. Measurements

therefore, tended to be taken more infrequently to provide satisfactory trending data for diagnosing and identifying rapidly developing fault conditions. In this system, monitoring equipments are used in parallel to the equipment to be monitored. Various monitoring points are provided for attaching such equipments as and when needed. *Off load monitoring* is for interior or inaccessible parts which need to be stopped temporarily to check the condition. However, there may be several situations like, the two-shift working or the plant's temporary shut down for other reasons, when this class can be conducted without productions loss.

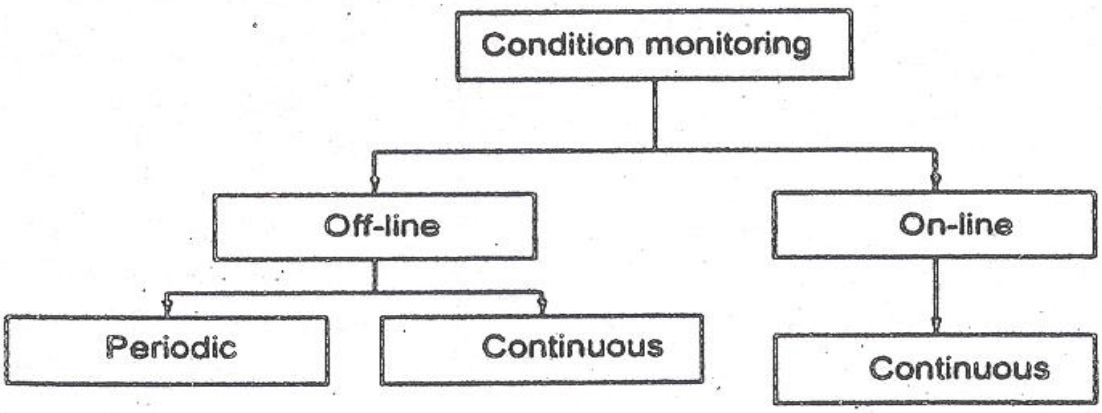
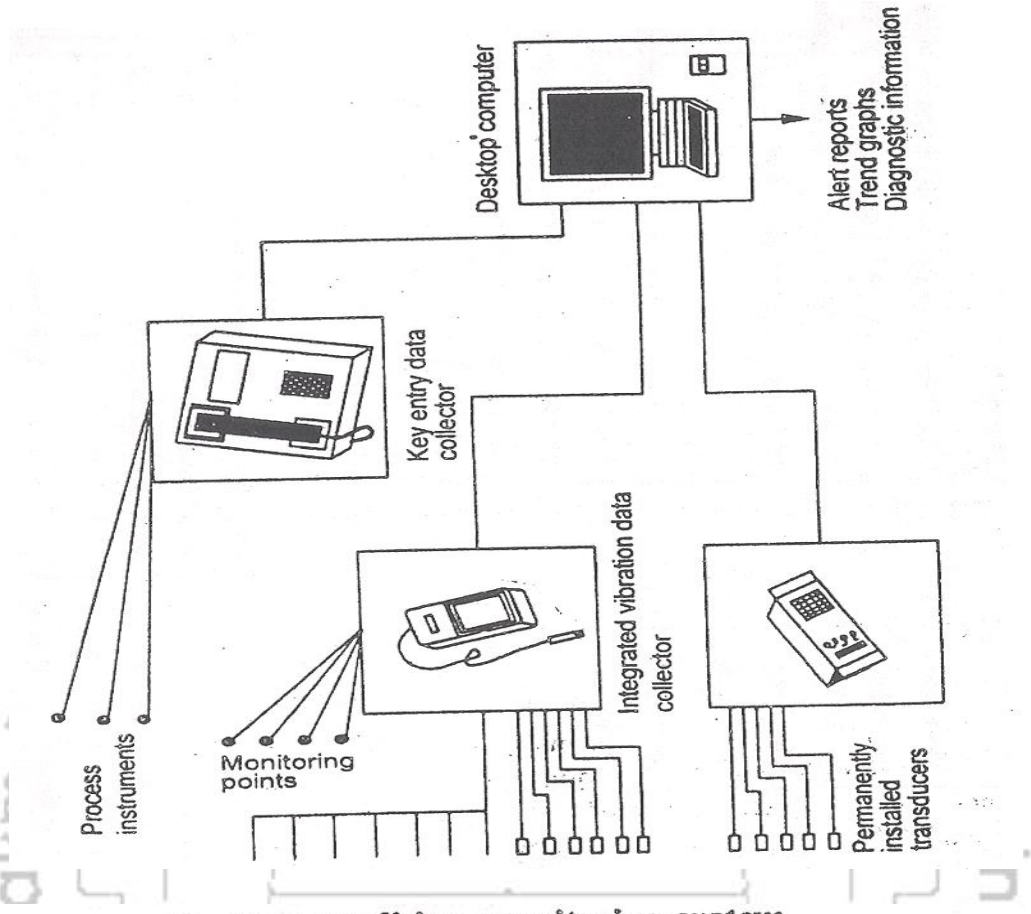


Figure 3.7 Block diagram of Online and Off-line system

O itoring systems can be periodic or continuous. In periodic system, monitoring equipments are connected during the time of monitoring or taking data or reading and then removed. In continuous monitoring, the monitoring equipments or instruments are connected as long as equipments operate.

On load monitoring means monitoring or adjusting the parameters while the machine or equipment is running. Thus, it is done for superficial, easily accessible and non-interfering parts of the equipment which can be carried out without interruption to the operation.

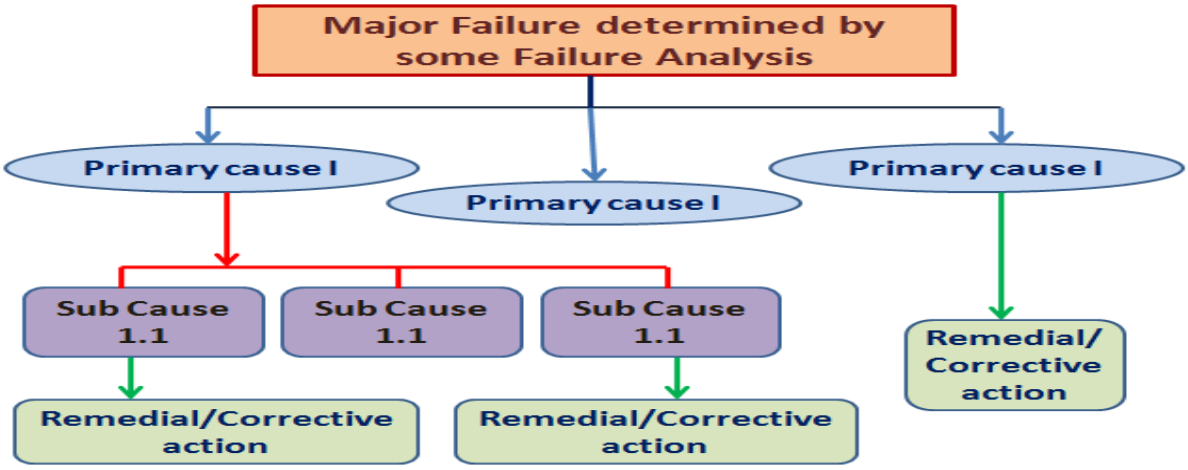


On-line condition monitoring system

On-line continuous monitoring techniques allow developing faults to be detected before they lead to a catastrophic failure. It allows the change in maintenance programs from 'periodic' to 'condition' based leading to be more effective and reduced maintenance costs. In this type of system, monitoring equipment are built in or installed in series with the running equipment. On-line monitoring system is generally continuous with provision to bypass.

Unit- IV

11) Write short notes of Fault Tree Diagram?



FTA is a graphical technique used to determine the various combinations of hardware (and software) failures and human errors, which can result in an undesirable outcome. The specified undesirable outcome is referred to as a 'top event', where the deductive analysis about the general conclusions and their causes is often described as a 'top down' approach. A Fault Tree Analysis begins with a construction of a fault tree, relating the sequences of events leading to the top event. This may be illustrated by considering the probabilities of events and by constructing a tree with AND and OR logicgates. Basically, the steps involved in a fault tree analysis are:

- ✪ Define the Top Event
- ✪ Know the system
- ✪ Construct the tree
- ✪ Validate the tree
- ✪ Evaluate the tree
- ✪ Study tradeoffs
- ✪ Consider alternatives and recommend actions

A fault tree analysis can also include human error contribution to the overall system, if the probabilities for human error are described in the same term as component and hardware failures.

Thus the main purpose of fault tree analysis is to evaluate the probability of the top event using analytical and statistical methods. By providing useful information concerning the likelihood of a failure and its means, efforts can be made to improve system safety and reliability. It also evaluates the effectiveness and the need for redundancy. Hence, the resulting benefits of fault tree analysis to project management are reduction of analysis time and precision in identifying and correcting deficiencies Fault tree diagrams are logic block diagrams that display the state of a system in terms of the states of its components.

Capabilities of Fault Tree Diagram:

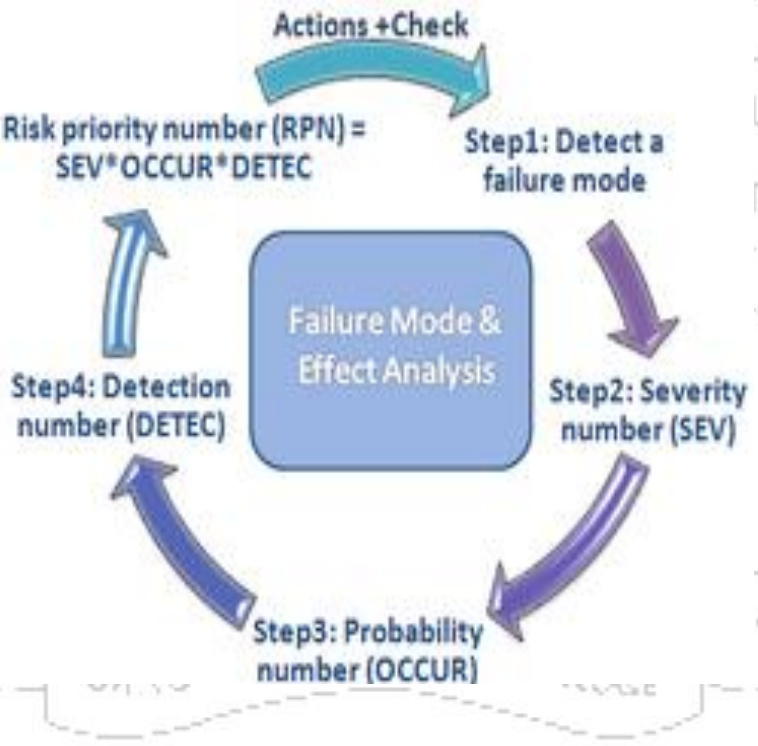
- Fault tree analysis and failure modes and effects analysis,
- Design for reliability
- Design for safety

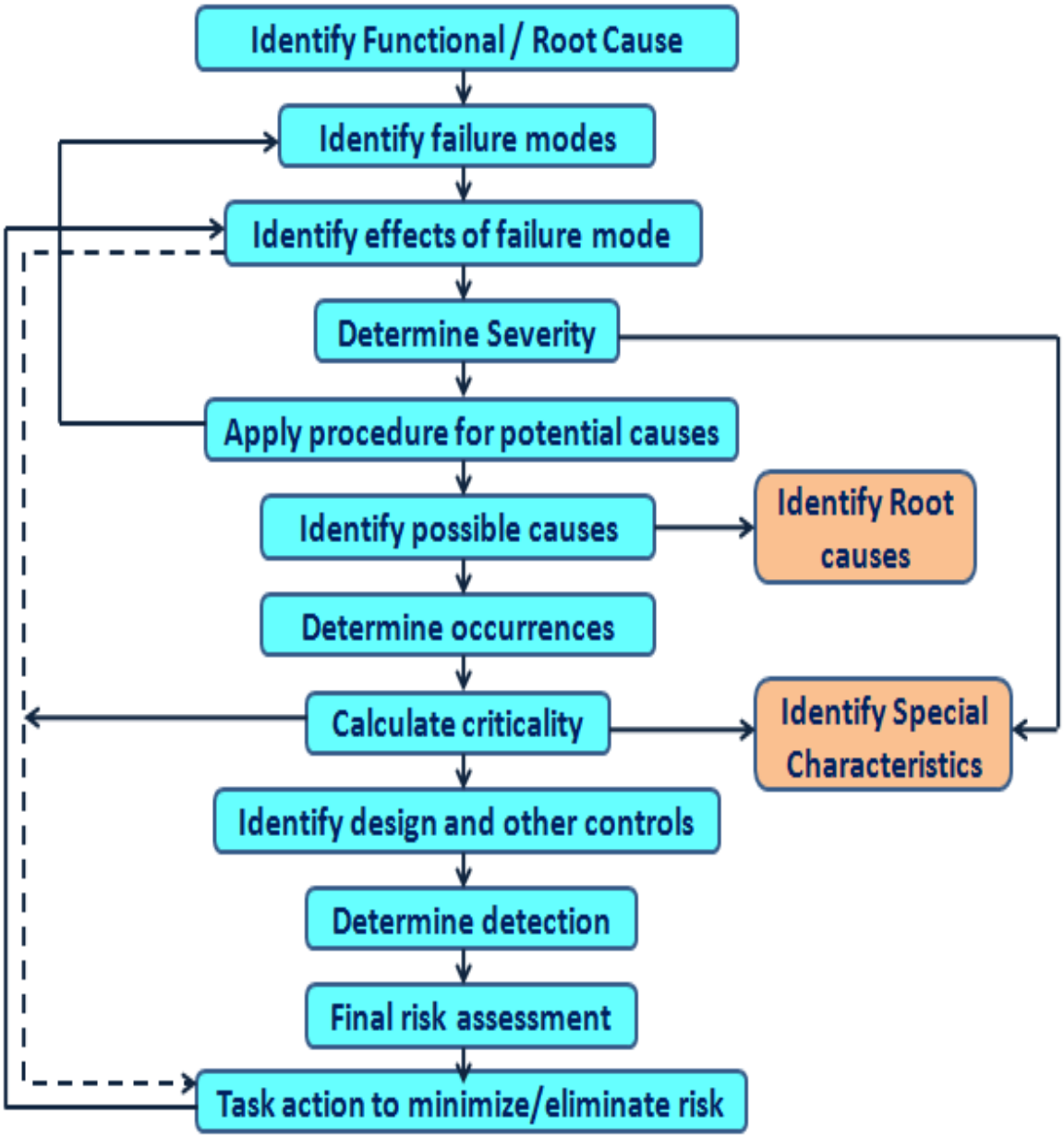
Benefits of fault tree diagram:

- Used to identify possible system reliability or safety problems at design time
- Used to assess system reliability or safety during operation
- Helps to improve understanding of the system
- Can identify root cause of equipment failures

12) Explain briefly with the help flow chart about FMEA?

FMEA is methodology for analyzing potential reliability problems early in the development cycle where it is easier to take actions to overcome the issues, thereby enhancing reliability through design FMEA is a procedure in operations management for analysis of potential failure modes within a system for classification by severity or determination of the effect of failures on the system. It is widely used in manufacturing industries in various phases of the product life cycle and is now increasingly finding use in the service industry. Failure modes are errors or defects in a process, design, or item, especially those that affect the customer, and can be potential or actual. *Effects analysis* refers to studying the consequences of those failures.





FMEA cycle:

Failure mode: "The manner by which a failure is observed; it generally describes the way the failure occurs."

Failure effect: Immediate consequences of a failure on operation, function or functionality, or status of some item

Indenture levels: An identifier for item complexity. Complexity increases as levels are closer to one.

Local effect: The Failure effect as it applies to the item under analysis. Next higher level effect: The Failure effect as it applies at the next higher indenture level.

End effect: The failure effect at the highest indenture level or total system.

Failure cause: Defects in design, process, quality, or part application, which are the underlying cause of the failure or which initiate a process which leads to failure.

Severity: "The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, or system damage that could ultimately

Advantages

- Improve the quality, reliability and safety of a product/process
- Improve company image and competitiveness
- Increase user satisfaction
- Reduce system development timing and cost
- Collect information to reduce future failures, capture engineering knowledge
- Reduce the potential for warranty concerns
- Early identification and elimination of potential failure modes
- Emphasize problem prevention
- Minimize late changes and associated cost
- Catalyst for teamwork and idea exchange between functions
- Reduce the possibility of same kind of failure in future

Limitations

FMEA is effectively dependent on the members of the committee which examines product failures; it is limited by their experience of previous failures. If a failure mode cannot be identified, then external help is needed from consultants who are aware of the many different types of product failure. FMEA is thus part of a larger system of quality control, where documentation is vital to implementation. General texts and detailed publications are available in forensic engineering and failure analysis. It is a general requirement of many specific national and international standards that FMEA is used in evaluating product integrity. If used as a top-down tool, FMEA may only identify major failure modes in a system. Fault tree analysis (FTA) is better suited for "top-down" analysis. When used as a "bottom-up" tool FMEA can augment or complement FTA and identify many more causes and failure modes resulting in top-level symptoms. It is not able to discover complex failure modes involving multiple failures within a subsystem or to FaultTree+ are a fully interactive graphics and analysis program for performing probabilistic risk assessment using integrated fault tree, event tree and Markov analyses.

Unit-V

12) Explain the detail repair methods for material handling equipment?

The proper maintenance of material handling equipment is extremely essential for preventing the occurrence of bottlenecks or points of congestions. Production line flow can be maintained only if the material handling equipment is in proper working order. Out of many maintenance techniques available, preventive maintenance is the one of the best maintenance techniques suggested in case of material handling equipment.

These are three stages of preventive maintenance and they are

- Inspection
- Repair
- Overhauls

Maintenance strategies for hoists and cranes:

Portable crane:

- It is necessary to keep loads within design limits on portable cranes that are mounted on wheels platforms.
- Frequent inspection of brakes, load hoisting and lowering mechanism
- Inspection of boom, base and platform for any sign of stress e.g.: cracks, bends, breaks

Over head cranes:

- Keep the attachments in overhead cranes loaded within the rating capacity.
- Maintain safety factors for replacement parts according to manufacturer specifications
- Check welded connections for cracks, bends abrasion and corrosion

Maintenance strategies for conveyers:

- Conveyer system needs to be inspected on a regular basis. The important areas include rollers, bearings chains and belts. All of these moving parts are subjected to wear and tear
- Check conveyers to detect any bolt slippage, dragging or defective rollers
- Moving equipment parts are subjected to breaks caused by metal fatigue, loose bearing and obstructions.

A typical scheduled conveyor maintenance plan:

- ✪ Check/lubricate all bearings, universal joints, and pulleys.
- ✪ Check chain tension, wear and lubricate
- ✪ Check sprocket alignment, wear and screw set
- ✪ Check flat belt tension, wear and acing
- ✪ Check V-belt tension, wear and sheave alignment.
- ✪ Check general condition of system
- ✪ Operate entire system after service
- ✪ List any items requiring replacement or repair

13) Explain the general structure of six phases of good maintenance management?

The proper operation of an industry requires appropriate strategies in Maintenance management. This is ensured by the effective integration of various phases involved in management. A good maintenance management can be considered as having six phases as shown.

They are

- ✪ Work identification
- ✪ Planning
- ✪ Scheduling
- ✪ Execution
- ✪ Recording
- ✪ Analysis

The important steps in this system approach are

- ✪ Codification and cataloguing
- ✪ Preparation of history sheet
- ✪ Preparation of instruction and operating manual
- ✪ Preparation of maintenance manual
- ✪ Maintenance operation liaison
- ✪ Maintenance work order and permit system
- ✪ Job execution, monitoring, feedback and control

14) Explain the general structure of computerized maintenance management system?

Computerized maintenance management system is the application of computers in planning, scheduling, monitoring and control of maintenance activities.

A computerized maintenance management system includes the following aspects:

- Development of a database
- Analysis of available past records
- Development of maintenance schedules
- Availability of maintenance material
- Feedback control system
- Project management

<u>The objectives of CMMS:</u>

- ✪ Maintenance of existing equipments
- ✪ Inspection and service of the equipment
- ✪ Installation or revamping of the equipment
- ✪ Maintenance storekeeping
- ✪ Craft administration

<u>The advantages of CMMS:</u>

- Improve maintenance efficiency
- Reduce maintenance costs
- Reduce the equipment downtime by proper scheduling preventative maintenance
- Provide maintenance reports in specific formats depending on the requirements
- Quicker access to plant maintenance statistics

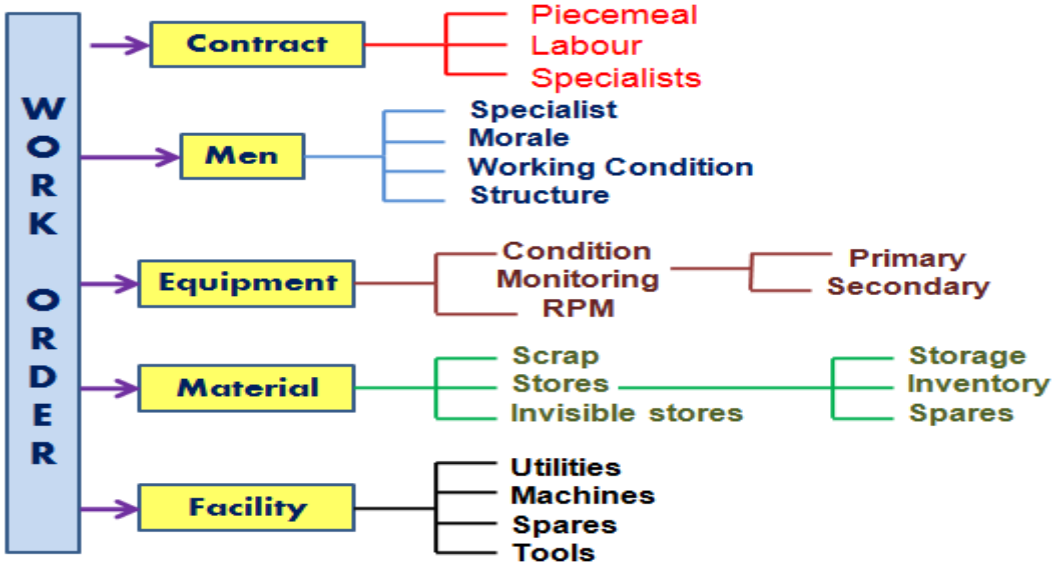
15) Explain the work order flow diagram?

Work order system is the information system used by the industry to keep track of its maintenance works. Work permits are components of work order. Maintenance department issues work permits to different executing agencies permitting them to start their work.

Work order flow diagram:

A maintenance work order generally gives the following information:

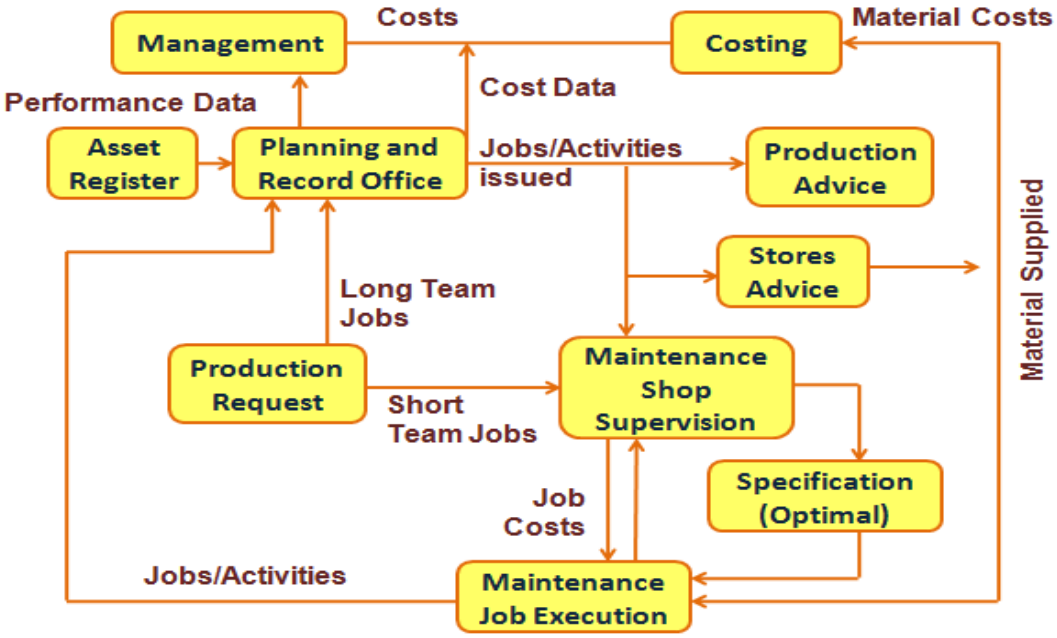
- Work order number and code
- Departments address and code
- Date of issue
- Detail of approval
- Date of receipt of work order
- Priority
- Location
- Equipment details
- Nature of work
- Material requirement
- Completion data and report
- Special requirement



Work permit are components of work order. Maintenance department issues work permits to different executing agencies permitting them to start their work. A work permit mentions the work permit number, work order number, section from which work originated and information as mentioned in work order.

16) Explain about maintenance Monitoring, Execution and Control?

A well designed organization should have proper strategies to execute, monitor and control over the various maintenance tasks**.**



✪ Monitoring:

- Gather information about deviation and delay in execution of maintenance may provide idea about the need to add more resources to complete the maintenance task in scheduled time frame
- Communication of the changes in job content to the various follow up agencies
- Provide information about constraints in technical issues and necessary steps can be taken to improve the existing techniques

Method of Monitoring:

I. Feedback:

- Unscheduled / pending job
- Work status
- Suspended work
- Work completion
- Manpower requirements and actual utilization
- Cost of maintenance
- Technical difficulties

II. Control:

- Continuous or periodical monitoring
- Inspection of status
- Comparison of status with the predetermined standard and initiating corrective measures

IMPORTANT TERMS IN MAINTENANCE ENGINEERING

Availability – The degree to a piece of equipment or a weapon system works properly when it is required. Computed as uptime divided by both uptime plus downtime. Availability can be most easily improved by increasing Reliability or decreasing the Maintenance Turn Time.

Backlog Maintenance – Preventative Maintenance that is necessary to prevent the deterioration of the asset or its function, but which has not been carried out.

Block Replacement – A method of repairing an isolated ambiguity group by replacing all suspected repair items as a block.

Can Not Duplicate (CND) – A fault indicated by BIT, or another sensor or health management reasoner, which cannot be confirmed at the first level of maintenance.

Condition-Based Maintenance – A form of Predictive Maintenance initiated as a result of knowledge of the condition of an item from routine or continuous monitoring.

Corrective Maintenance – A Maintenance Event performed in response to a failure. Also called Fault-Induced or Reactive Maintenance. Although this "run it until it breaks" maintenance mode is still practiced, it is very inefficient and contributes to not only a high life cycle cost and low operational availability, but also to the risk of possible damage through secondary failures.

Deferred Maintenance – Preventative or Corrective Maintenance that has been deferred until a future budget cycle, or postponed until funds or parts become available. This leaves the system, by definition, in a partially degraded state, but one in which the system is Partially Mission Capable.

Degradation – The decline in a system or subsystem's performance.

Degraded Mode – A mode in which the system is Partially Mission Capable, due to either complete or partial failure of one or more components. This may be due to a range of performance parameters that fall outside the normal acceptance value but have not resulted in a fault condition. This degraded mode covers the parameter range of a time domain failure mode from the beginning of normal wear degradation to the limit of the operational acceptance. A degraded mode may be used both as a simulation parameter and to provide design knowledge for prognostics development.

Dependability – The probability that a system can be used to perform task when desired (including the impact of downtime due to any type of maintenance).

Depot Level Maintenance– Maintenance in which the faulty SRU is tested to determine the cause of the malfunction. Faulty components are removed and replaced, and the SRU is verified ready for service by successful performance tests at the depot or sent to the factory for test and repair. In both two and three-level approaches to maintenance, D-Level Maintenance typically constitutes the last maintenance level.

Downtime – The amount of time a system is unable to perform its expected function due to scheduled or unscheduled maintenance.

Environment– A set of elements outside of the system, which may influence or may be influenced by the system.

Emergency Maintenance – Preventative or Corrective Maintenance carried out at the highest priority to prevent a critical situation from occurring or continuing to occur.

Fault-Induced Maintenance – A Maintenance Event performed in response to a failure. Also called Corrective or Reactive Maintenance. Although this "run it until it breaks" maintenance mode is still practiced, it is very inefficient and contributes to not only a high life cycle cost and low operational availability, but also to the risk of possible damage through secondary failures.

Fully Mission Capable (FMC) – The system is in full working order, capable of performing any of its assigned missions.

Inherent Availability (A_I) – The probability a system will be ready for operational use when required, based on the design characteristics only. Calculated as the ratio of mean time between downing events and the mean downtime (not including Logistics Delay Time). Compare with Operational Availability, which takes Logistics Delay Time into account.

Intermediate Maintenance (I-Level Maintenance) – Maintenance in which the malfunctioning assembly is tested to determine the cause of the malfunction and isolate the failure to a SRU. Repair is effected by removal and replacement of the faulty SRU and successful performance of the LRU to verify that it is ready for service. In three-level approaches to maintenance, I-Level Maintenance (which is sometimes called shop-level maintenenance) is typically the second level of maintenance. In two-level approaches to maintenance, This level is sometimes eliminated.

Life Unit – A generic term for a standard time-based or event-based unit of measure, against which operational conditions are evaluated. Typical life units include flying hours, operating hours, sorties and calendar or clock time.

Line Replaceable Unit (LRU) – A component within a system where all of the maintenance actions required to replace component can be performed without having to return the system to a maintenance facility. Typically this requires that the maintenance actions do not require heavy industrial tools.

Logistics Requirements – Equipment, facilities, personnel, technical data or other resources required to support the maintenance concept.

Logistics Delay Time – The downtime incurred as a result of waiting for equipment, facilities or other logistics resources to become available in order to support a maintenance event.

Maintainability– Describes the ease with which an item to be retained in, or restored to, a specified condition when maintenance is performed by personnel having specified skills using prescribed procedures and resources at each prescribed level of maintenance and repair. See also Software Maintainability.

Maintenance – All actions necessary for retaining an item in or restoring it to a specified condition.

Maintenance Action – One, of possibly many, elements of a maintenance event.

Maintenance Event – The performing of those maintenance actions, including troubleshooting and diagnostics, required to restore a system to working order.

Maintenance Event Time – The sum of unscheduled and scheduled maintenance action times spent on a specific maintenance event.

Maintenance Hours per Life Unit – The maintenance hours required divided by the appropriate life unit.

Maintenance Ratio – A measure of the total maintenance manpower burden required to maintain a system. The ratio is expressed as the cumulative number of manhours of maintenance expended divided by the cumulative number of end item operating hours during the same time.

Maintenance Schedule– A predetermined schedule, set of intervals, or by which maintenance events are carried out.

Maintenance Turn Time – The time required to service and return to a system to mission-ready. This includes any setup required to prepare the system for its next mission.

Mean Downtime (MDT) – The average elapsed time between losing Mission Capable status and restoring the system to at least partially mission capable status. Calculated as the ratio of total downtime over the number of downing events–most often, the total maintenance time over the number of maintenance events.

Mean Time to Repair (MTTR) – The reliability weighted mean of repair times for an operational end item This includes test time, access time, fault isolation time, remove and replace or repair time, checkout time, and access secure time.

Mean Time Between Maintenance Actions (MTBMA) – A ratio of the total uptime over the number of scheduled and unscheduled maintenance events.

Mean Time Between Preventative Maintenance (MTBPM)– A ratio of the total uptime over the number of preventative maintenance events.

Mean Time Between Scheduled Maintenance (MTBSM) – A ratio of the total uptime over the number of scheduled maintenance events.

Mean Time Between Unscheduled Maintenance (MTBUM) – A ratio of the total uptime over the number of unscheduled maintenance events.

Mean Repair Time (MRT)– The average corrective maintenance time in an operational environment, calculated as the total corrective maintenance time over the number of corrective maintenance events.

Mission Capable (MC) – An assessment of a system's ability to perform its required tasks, in either a Fully Mission Capable (FMC) or Partially Mission Capable (PMC) status.

Operating & Support (O&S) – The phase of a system's life cycle during which it is operated and maintained.

Operational Availability (Ao) – The probability a system will be ready for operational use when required in an operational environment. Calculated as the ratio of mean time between downing events and the mean downtime (including Logistics Delay Time). Compare with Inherent Availability, which does not take Logistics Delay Time into account.

Operational Dependability (Do) – The ratio of the Mean Time Between Critical Failures (MTBCF) over the sum of the MTBCF and the Mean Time to Restore Function (MTTRF). This measure is used to determine the degree to which the system satisfies the need for critical management information.

Operational Effectiveness – The ratio of sucessful missions and the total number of missions attempted.

Operational Maintenance (O-Level Maintenance) – Maintenance in which the repair action consists of the removal and replacement of the malfunctioning assembly (LRU, black box, equipment). In both two and three-level approaches to maintenance, O-Level Maintenenace typlically constitutes the first level.

Operational Sustainability– A measure of the degree to which a system can continue to maintain the necessary level of support for a specified duration of operations beyond its initial deployment period.

Operational R&M – The reliability and maintainability achieved in actual use.

Operational Readiness– The probability that the system is operating satisfactorily at any point in time, excluding downtime for scheduled maintenance or training.

Partially Mission Capable (PMC) – The system is operating in an impaired condition. It can perform at least one, but not all of its assigned missions.

Periodic (or Scheduled) Maintenance – A form of Planned Maintenance where the prescheduled events are predictably spaced throughout the system's life unit, typically at intervals of time or number of operations.

Planned Maintenance – A form of Preventative Maintenance characterized by maintenance events that are prescheduled that prevent one or more failure mechanisms from occuring.

Predictive Maintenance – A form of Preventative Maintenance where maintenance is only performed when a failure is predicted to be highly probable and imminent, in an attempt to achieve the maximum availability without impacting mission reliability. Predictive Maintenance typically makes use of equipment maintenance records to focus attention on key failures that lead to equipment availability and downtime. The field of Predictive Maintenance is currently

being reassessed through the development of Prognostics to more accurately predict failures based on time domain failure trends.

Preventative Maintenance – A Maintenance Event performed prior to a failure in order to prevent its occurance. May be based on Scheduled or Predictive Maintenance. Preventative Maintenance is employed to increase mission reliability, at theexpense of availability and (arguably) maintenance costs.

Prioritized Replacement – Also called Serial Replacement. A method of repairing an isolated ambiguity group by replacing suspected repair items one at a time and then retesting to determine if a fault has been corrected. Prioritized replacement is used to improve maintenance costs (sometimes at the expense of a higher Mean Time To Repair).

Proactive Maintenance – Activities and actions applied to environment prior to and during operations to prevent problems, gain greatest reliability, and minimize failure. (Compare with Preventative Maintenance).

Readiness– The ability of the system to perform the tasks, for which it was designed, without unacceptable delays.

Reactive Maintenance (RM) - A Maintenance Event performed in response to a failure. Also called Fault-Induced or Corrective Maintenance. Although this "run it until it breaks" maintenance mode is still practiced, it is very inefficient and contributes to not only a high life cycle cost and low operational availability, but also to the risk of possible damage through secondary failures.

Repair Time– The corrective maintenance time, calculated as either a mean or maximum time, that is required to return a system or part to operational status. Repair time includes set-up, access, troubleshooting, disassembly, repair, reassembly, repair verification, system test, and readying procedures.

Restoral Time – The maximum maintenance downtime incurred as part of restoring the a system to Mission Capable status.

Retest OK (RTOK) – A maintenance event where the failure that triggered the event performs satisfactorily at the off-equipment maintenance level, or at the next higher level of maintenance. As a result of this event, personnel may return the item to service without taking corrective action. The RTOK rate is the percentage of items removed from an end item as a result of BIT or another sensor or health management response, that subsequently pass all related testing at the next maintenance level. (Compare with Can Not Duplicate).

Scheduled Maintenance – Maintenance performed according to a predetermined plan or guideline.

Serial Replacement – Also called Prioritized Replacement. A method of repairing an isolated ambiguity group by replacing suspected repair items one at a time and then retesting to determine if a fault has been corrected. Serial replacement is used to improve maintenance costs (sometimes at the expense of a higher Mean Time To Repair).

Shop Replaceable Unit (SRU) – A component where one or more maintenance actions cannot be performed in the field, forcing the system to return to a maintenance facility.

Software Maintainability – The ease in which software modifications are made as enabled by documentation, manuals, source listings, and other support documents.

Software Maturity – A measure of the evolution of software to satisfy operational requirements, as indicated by the number and severity of required changes.

Subsystem Utilization Rate – The percentage of life unit time that the subsystem will operate, including time in standby mode.

Sustainability – The ability to support a system, including all Logistics Requirements, in order to maintain the necessary level and duration of operations to achieve varying mission objectives.

System Safety – The degree to which system operates in the absence of failures that contribute to injury or loss of life.

Unplanned Maintenance – Maintenance carried out to no predetermined plan.

Uptime – The total time in which the system is considered operational.