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| **MAINTENANCE ENGINEERING** | | | | |
| Academic Year | 2021- 2022 | **Question Bank** | Programme | Mechanical |
| Year / Semester | IV / VII | Course Coordinator | Dr.N.RAMANUJAM |
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| **Course Objectives** | **Course Outcomes** |
| 1. To Understand The principals, Fuctions and Practices Adopted in industry for the successful management of maintenance activities. 2. To explain the difference maintenance categories like preventive maintenance, condition monitoring 3. To illustrate some of the simple instruments used for condition monitoring in industries. | On completion of the course, students will be able to  CO1: Explain the Principles and Practices of Maintenance Planning  CO2: Discuss maintenance policies with special reference to  preventive maintenance  CO3: Predict appropriate condition monitoring techniques  CO4: Distinguish various repair methods for basic machine  elements  CO5: Summarize repair methods for material handling equipment |

**UNIT I: TITLE**

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| **PART – A (2 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO1 :** Explain the Principles and Practices of Maintenance Planning | | | |
| 1 | Define maintenance? | 2 | K2 |
| 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? | 2 | K2 |
| 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? | 2 | K2 |
| The main advantages of imposing reliability requirements are increased  productivity and reductions in forced outage equipment due to planned maintenance activity. |  |
| 4 | What is Mean Failure Rate? | 2 | K2 |
| The mean failure rate h is obtained by finding the mean of the failures rates  for specified period of time.  h = (Z1 + Z2 + Z3+....+ZT)  failure rates over the specified period of time T.T where Zt represents |  |
| 5 | Define Mean Time to Failure. | 2 | K2 |
| Let t1 is the time to failure for the first specimen, t2 is the time to failure for the second specimen and t n is the time to failure for the Nth specimen. Hence the mean time to failure for N specimens are MTTR = (t1+t2+......+t N) /N |  |
| 6 | Define Maintenance Action Rate? | 2 | K1 |
| Maintenance action rate is the number of maintenance action that can be  carried out on equipment per hour. |  |
| 7 | State the types of reliability? | 2 | K1 |
| 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. |  |
| 8 | Draw the equipment life cycle and name the various phases ln it? | 2 | K1 |
| 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 to aging of the equipment. |  |
| 9 | State the advantages of life cycle cost analysis. | 2 | K2 |
| (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 equipment’s due to cost analysis  over span of time.  (iii) It leads to the selection of proper and economically viable equipment. |  |
| 10 | State the components of maintenance cost? | 2 | K1 |
| 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. |  |
| 11 | State the types of maintenance budget? | 2 | K2 |
| (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. |  |
| 12 | 20. List the main factors of maintenance cost? | 2 | K1 |
| 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. |  |
| 13 | 16. Draw the curve to determine the economic life of equipment? | 2 | K1 |
| 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. |  |
| 14 | 18. State the role of maintenance budget | 2 | K1 |
| The maintenance budget is used to set aside certain amount of money to meet  the expenditures incurred in achieving the objectives of maintenance. |  |
| 15 | 14. Define availability? | 2 | K1 |
| 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 equipment’s uptime to the equipment uptime and downtime over a specified period of time. |  |

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| **PART – B (12 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO1 :** Explain the Principles and Practices of Maintenance Planning | | |  |
| 1 | 1) What are the principles of maintenance? | **12** | K3 |
| a) Plant management in maintenance work:  The main role of a maintenance function is to provide safe and effective operation of the equipment to achive 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 these targets. 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 difficulty 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:  j) 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? | **12** | K2 |
| 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 the 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  o Selection of activities for maintenance  o Determination of the frequency of preventive maintenance  o 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 is depended 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, 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.  • Organizing 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 of the  processes.  g) Estimation of maintenance work:  h) 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 | Mention the maintenance function and activities? | **12** | K2 |
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| 4 | what are the different types of organizations are in use in Indian industries? | **12** | K2 |
| 1. line organization     b)line staff organization    C) maintenance functional organization    d) centrally controlled maintenance organization    e)area maintenance organization |  |
| 5 | **State the various objectives and principles of maintenance planning?** | **12** | K2 |
| The most important objective of the maintenance is the maximization of  availability of equipment’s and facilities so as to help in achieving the ultimate goals of the  organization. The following are the objectives of planned maintenance activity:   To achieve minimum breakdown and to keep the plant in good  working condition at the lowest possible cost.   To ensure the availability of the machines and services in an  optimum working condition.   To keep the machines and other facilities in a condition to be used to  achieve the maximum profit without any interruption or hindrance.   To keep the time schedule of delivery to the customers or to the  sections for further processing.   To meet the availability requirements for critical equipment’s.   To keep the maintenance costs as low as possible for non-critical  equipment’s.   To control the cost of maintenance related activities   To provide effective and trained supervision.   To meet the quality requirements of the product.   To increase the profits of production systems.  **Principles:**  Maintenance principles are followed in a system to guide the staff to work  efficiently and effectively to achieve the overall objectives of the maintenance system.  **(i) Plant Management in Maintenance work**  The main role of the maintenance function is to provide safe and effective  operation of the equipment to achieve the desired targets on time with  economic usage of resource.  **(ii) Production and Maintenance objectives**  The plant operation is driven by the production targets. The objective of  maintenance function is to support these targets. The achievement of  desired goals of the production system are to be supported by both the  production and maintenance department to ensure smooth and successful  operation of the industry.  **(iii) Establishment of Work order and Recording system**  The maintenance system should have proper work order 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 functions. This record is useful in formulating the  future maintenance plans and scheduling to meet the desired objectives of  the organization.  **(iv) 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 requirements of the industry.  **(v) Adherence to Planned Maintenance Strategy**  A sound maintenance management should adhere to the planned  maintenance strategy. This also includes the use of manufacturer’s  information on the life and maintenance schedules of the equipment and  other materials.  **(vi) Planning of Maintenance Functions**  All the maintenance functions are to be carefully executed by a way of  proper planning to ensure the effective utilization of manpower and  materials.  **(vii) Manpower for Maintenance**  The manpower requirements of the maintenance system must be carefully  evaluated based on the time and motion study. The requirements should  also satisfies the need arising in cases of overhauls, component  replacement, emergency and unscheduled repairs.  **(viii) Workforce Control**  Determination of exact workforce required to meet the maintenance  objectives of the system are difficult task due to the element of uncertainty.  Hence the proper control and monitoring of workforce are needs to be  ensured.  **(ix) 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 works.  **(x) Training of the Maintenance Workforce**  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, knowledge of  sophisticated instruments and to chalk out a strategy to meet the growing  demands of the industry.  **(ii) Derive the expression for determining Mean Time to Failure (MTTF)** (**NOV/DEC**  **2015, NOV/DEC 2009) (8)**  Let t, is the time to failure for the first specimen, t is the time to failure for  the second specimen and tn is the time to failure for the N specimen. Hence the  mean time to failure for N specimens are  HTTF = (t1+t2+.......tn) /n  = 1/N  It is difficult to record the failure for each component when the numbers of  specimens tested are large. Instead, we can record the number which fails  during the specific intervals of time.  If n1 is the number of specimens that failed during the first hour, n2 is the number  that failed during the second hour and nk is the number that failed during the kth hour.  Then the mean time to failure for N specimens is  MTTF = (n1 + 2n2 + 3n3 +....knk) / N  It is better to represent the time as interval of the time as such as. Hence the time interval  is Δt instead of one hour.  Then MTTF is calculated as  MTTF = (n1 Δt +2n2 Δt +. ... + knkΔt +..... + lnl Δt) /N  MTTF = (n1 Δt +2n2 Δt +. ... + knkΔt +..... + rnr Δt) /N  MTTF = 1/N Σ knkΔt (k = 1 to r)  Where n1 is the number of specimens that failed during the first interval, n2 is the number  of specimens that failed during the second interval and nk is the number of specimens that  failed during the kth time interval and so on. |  |
| 6 | **What are The objectives of maintenance organization and what are the different types of organizations?** | **12** | K2 |
|  Identification of organization roles pertaining to maintenance function.   Determination of maintenance workload.   Uniform distribution of total maintenance work to all the personal in the  department.   Identification and assignment of essential works to the various sections of  the maintenance department.   Proper knowledge about the technical expertise/experience of the workers  deputed for the particular job.   Proper training of the staff of maintenance to meet the growing demands of  the industry and to catch up with the modern trends in maintenance.   Designing the policies and procedures at an early stage to help the maintenance department to achieve the goals of the industry.  **Types of maintenance organization:**  The selection of a type of maintenance system will largely depend on the structure  of an industry. Maintenance organization can be broadly classified into three types as  follows,  **(i) Decentralized**  This is suitable for large sized plants where inter unit communication is difficult to  get. In this type of organization, the maintenance is under the control of chief engineer of  production to ensure better understanding between the production and maintenance  department.  **(ii)Centralized**  This is suitable for small units where unit communication is feasible. In this  type of organization, the maintenance is under the control of chief maintenance engineer.  The responsibilities and accountability is with the concerned department heads.  **(iii)Partially Centralized**  This is the modified version of centralized maintenance organization and suitable  for the industry where units are located at far away locations. In this type of organization,  the maintenance person attached with production unit will carry out the routine  maintenance works. Scheduled maintenance works such as overhauls, planned  maintenance work, procurement of spare parts is under the control of chief maintenance  engineer at the central office.  There are basically two at least two types of organization are followed in most of  the industries. They are,  a. Line organization  b. Line staff organization  **Line Organization**:  Line organization consists of a general foreman and a number of specialist foremen with their under them is shown below. The specialist foreman executes maintenance work in their respective areas while the general foreman supervises the total work under his control and the various maintenance tasks carried out in the industry. This kind of structure is an old type maintenance organization.    **Line staff organization:**  A few more staff members such as storekeeper and clerk are added to the line organization to form the line organization structure as given below. The advantage lies in separating the maintenance work from the store keeping and the role of clerk is to record the maintenance activities. The recording of maintenance related activities helps the organization to restructure the strategies adopted to achieve the objectives of  maintenance.  **3. (i) Define availability and method of measuring availability. (8)**  **(Or) What is equipment availability and describe the three basic approaches in detail.**  **Availability: (APR 16, NOV/DEC 2014)**  It is the ratio of the time at which the 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 ration of equipment’s uptime to the equipment uptime and down time  over a specified period of time. |  |  |

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| **PART – C (20 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO1 :** : Explain the Principles and Practices of Maintenance Planning | | | |
| 1. | Define Availability and method of measuring availability? | 10 | K3 |
| **Availability:**  It is the ratio of the time at which the 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 ration of equipment’s uptime to the equipment uptime and down time over a specified period of time.  The uptime of a machine / equipment is the time for which it is in actually available to complete the desired function. The downtime or outage of a machine is the period of time during which it is not in an acceptable working condition.  The three types of availability are  (i) Inherent availability  (ii) Achieved availability  (iii) Operational availability  **Inherent availability:**  It is the probability that a system or equipment shall operate satisfactorily when used under prescribed conditions in a ideal support environment without any scheduled or preventive maintenance at any given time.  Inherent availability = MTBM/ MTBM+MTTR  **Achieved availability:**  It is the probability that a system or equipment shall operate satisfactorily when used under prescribed conditions in an ideal support environment with periodic preventive and corrective maintenance at any given time.  **Operational Availability:**  In industrial system a certain amount of delay will always cause by time element such as supply downtime and administrative downtime.  Operational availability = MTBM/ MTBM+MDT  Where MDT is the mean downtime is the satisfied mean of the downtimes including the supply downtime and administrative downtime. In general availability of a system is a complex function of reliability, maintainability and supply effectiveness.  As = f (Rs, Ms, Se)  **(ii) Explain maintenance economics.**  **Life cycle cost analysis:**  The factors to be considered in the purchase of equipment of industries include the cost, quality, performance and maintenance requirements. Some balance is to be made between the capital cost and operating cost of the equipment in finding the suitability of the equipment. The evaluation of any equipment for purchase should be made by keeping |  |
|  | **ii) Life cycle cost analysis:** | 10 |  |
|  | The factors to be considered in the purchase of equipment of industries include the cost, quality, performance and maintenance requirements. Some balance is to be made between the capital cost and operating cost of the equipment in finding the suitability of the equipment. The evaluation of any equipment for purchase should be made by keeping  into considerations that total cost incurred by the equipment over a span of time say ten years. Life cycle costing is the cost analysis for the equipment in an industry that accounts the total cost of the equipment over a span of time which includes the capital  cost, operating cost and maintenance costs. This analysis is the integration of engineering, economic and financial strategies in relation to the equipment to be purchased. The aim of life cycle costing is to ascertain the total cost of equipment over the span of its entire life period.  **Advantages of life cycle costing:**  Integration of engineering, economics and financial aspects lead to the way of robust metric for the selection and purchase equipment required for the industry. Reduced operating and maintenance cost of equipment’s due to cost analysis over span of time.  It leads to the selection of proper and economically viable equipment.  Integration of engineering, economics and financial aspects lead to the way of robust metric for the selection and purchase equipment required for the industry. Reduced operating and maintenance cost of equipment’s due to cost analysis over span of time.  It leads to the selection of proper and economically viable equipment.  **Estimation of 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.  **Maintenance Cost:**  Budgets are allocated for all the activities in planning stage itself which includes the maintenance cost. The cost of maintenance is difficult to measure due to random nature of failures.    The records on maintenance history may be useful in determining the cost. The analysis of maintenance cost is helpful in taking a decision regarding replacement of a machine or any of its components.  **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. The following are 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  **Cost minimization in maintenance organization:**  Centralized planning, scheduling and control Grouping of specialized workforce Effective labor utilization strategies Budgetary control and proper check mechanism to implement the cost control strategies.  Proper and effective use of contract maintenance system to reduce the overhead costs on equipment and manpower.  Purchase of reliable equipment and spares.  Use of skilled and trained workforce.  Proper selection of suitable type of spares, materials and lubricating.  Proper safety education and formulating the safe practice.  Constant appraisal and education to workforce about the objectives, strategies and modern techniques adopted in the area of maintenance. |  |  |
| 2. | **i)State the steps necessary to reduce the maintenance cost in an industry** | 20 | K3 |
| Maintenance should be one of the key strategies to keeping the plant's assets  healthy. While equipment upkeep and parts replacements are necessary, there are  steps that can reduce maintenance costs without decreasing industry processing  facility's operational efficiencies.  **a) Examine the necessary things to do and not:**   When first purchasing the equipment in an industry, ensure the review  its maintenance requirements with the manufacturers and the subject  matter experts, whether those are engineers or senior maintenance  professionals.   It should confirm that all of the suggested maintenance is actually  needed, as unnecessary maintenance can actually induce equipment  failure.   For example, at one of the plant, pumps were undergoing preventive  maintenance every quarter to prevent pump failures. This maintenance  was actually inducing premature failure.   After engineering performed a detailed root-cause analysis, a different  pump was specified and preventive maintenance was moved to a yearly  event, leading to better system performance and reduced maintenance  costs.   Benefits: Decreased labor costs, Reduced parts purchases, Increased  the efficiency and overall uptime of the system  **c) Pick the optimal time to perform maintenance:**   Preventive maintenance should be scheduled maintenance, tuned to the  specific needs of the production schedule.   This way, processing plant can take assets out of service at a time that  allows maximizing the uptime or efficiency.   Most companies complete their preventive maintenance in the cooler  months of the year.   Compressor and evaporator rebuild are easier to perform in the winter  because the temperatures are not as hot, requiring less of a refrigeration  load. This offsets labor costs, too.  **Maximize the efficiency of the industry staff:**   By training production workers to provide preventive maintenance  assistance on a daily or weekly basis, have to maximize the efficiency of  processing plant staff and take the preventive maintenance burden off of  the senior professionals.   Preventive maintenance tasks that production workers can complete  include:  Cleaning up the equipment  Inspecting specific items  Watching particular equipment characteristics   However, once a monitored characteristic is showing signs of needing  preventive maintenance, you need to bring in a subject matter expert to  complete the work or provide additional planning.  **e) Develop an overall maintenance strategy:**   Preventive maintenance is only one type of maintenance that should be  part of the overall strategy, including: Preventive maintenance,  Predictive maintenance, Reactive maintenance.   If preventive maintenance in conjunction with a predictive and reactive  maintenance strategy, maintenance costs can control while managing  downtime and maximizing uptime.  **ii) Briefly describe the Accelerated Testing. (ALT)** (**NOV/DEC 2013) (8)**   Accelerated Life Testing is a method for stress testing of manufactured  products that attempt to duplicate the normal wear and tear that would  normally be experienced over the usable lifetime of the product in a  shorter time period.   Accelerate cause (something) to happen sooner, Life is the period of  duration, usefulness, or popularity of something, testing means by which  the presence, quality, or genuineness of anything is determined  by means of trial.  Goals of ALT Accelerated Life Testing: Most Important goals of Up  Front Product Life Testing (In-house or Beta Sites) & Data analyses are  to gain information for Fundamental Improvements and Proactive  reliability improvement before Product Release.   Purpose of ALT: Reliability estimation at user level and dominant  failures mechanism identification.   Types of accelerated tests: a) ESS and burn-in. b) Qualitative tests, c)  Quantitative tests   Environmental Stress Screening (ESS):  A process involving the application of environmental stimuli to  products. The goal of ESS is to expose, identify and eliminate latent  defects which cannot be detected by visual inspection or electrical  testing but which will cause failures in the field. ESS is performed on  the entire population and does not involve sampling.   Burn-in:  Burn-in can be regarded as special case of ESS. It is a test performed for  the purpose of screening or eliminating marginal devices. These devices  are those with inherent defects or defects resulting from manufacturing  aberrations which cause time and stress dependent failures. As with  ESS, burn-in is performed on the entire population.   Qualitative tests:  An accelerated test that yields failure information or failure modes only  is commonly called a qualitative test or elephant test. Over stressing of  products to “quickly” obtain failures is perhaps the oldest form of  reliability testing. It increases reliability by revealing probable failure  modes.   Quantitative tests:  Quantitative accelerated life testing, unlike Qualitative testing, is  designed to provide reliability information on the product, component or system. |  |
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**UNIT II: TITLE**

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| **PART – A (2 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO2 :** Discuss maintenance policies with special reference to preventive maintenance | | | |
| 1 | Define the term Preventive Maintenance? | 2 | K2 |
| 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 equipment’s. | 2 |
| 2 | Define predictive maintenance? | 2 | K2 |
| 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? | 2 | K2 |
| It is a type of maintenance approach in which equipment is allowed to function /operate till no failure occurs that no maintenance work is carried out in advance to prevent failure. |  |
| 4 | Classify various planned maintenance approach. | 2 | K2 |
| 1. preventive maintenance  2. corrective maintenance  3. predictive maintenance  4. condition based maintenance |  |
| 5 | Define corrective maintenance approach. | 2 | K2 |
| Corrective maintenance is the program focused on regular planed tasks that will maintain all critical machinery and system in optimum operation conditions. |  |
| 6 | List the objectives of corrective maintenance? | 2 | K1 |
| 1. Elimination break downs  2. Elimination deviations from optimum operating condition.  3. Elimination unnecessary repairs |  |
| 7 | list out some condition-based monitoring techniques and briefly discuss | 2 | K1 |
| 1. Vibration monitoring  2. thermograph  3. tribology  4. electrical motor analysis |  |
| 8 | What is meant by reliability centered maintenance (RCM)? | 2 | K1 |
| 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. |  |
| 9 | What is total productive maintenance and discuss its similarities with TQM? | 2 | K2 |
| Total productive maintenance is a maintenance program which involves a newly defined concept of maintaining plants and equipment’s. The goal of tpm program is to significantly increase the production, at the same time increasing employee morale and job satisfaction. |  |
| 10 | What is meant by reliability centered maintenance? | 2 | K1 |
| 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. |  |
| 11 | What does safety, health and environment pillar of TPM aims at? | 2 | K2 |
| This pillar aims at achieving Zero accident, Zero health damage and Zero fires |  |
| 12 | What is limitation of breakdown maintenance? | 2 | K1 |
| 1. 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.  2. 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. |  |
| 13 | list the benefits of implementing preventive maintenance. | 2 | K1 |
| 1. It maintains the equipment in good condition to prevent them from bigger  problems.  2. Prolongs the effective life of the equipment’s.  3. Detects the problem at earlier stages.  4. minimizes/eliminates the rework/scrap and helps in reducing the process  variability  5. Significantly reduces unplanned downtime. |  |
| 14 | Name the five S principles used for implementations of TPM. | 2 | K1 |
| 1. SEIRI – Sort out  2. SEITON –Organize  3. SEISO – Shine workplace  4. SEIKETSU – Standardization  5. SHITSUKE – Self discipline |  |
| 15 | List the various pillars of TPM? | 2 | K1 |
| 1. 5, S Principle  2. josh dozen (JH)  3. Kaizen  4. planned maintenance  5. Quality maintenance.  6. training  7. office TPM  8. Safety, health and environment |  |

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| **PART – B (12 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO2 :** Discuss maintenance policies with special reference to preventive maintenance | | |  |
| 1 | Explain with sketch various types of maintenance  approach? | **12** | K2 |
| 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  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  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 the equipment’s.   Detects the problem at earlier stages.   Minimize/eliminates the rework/scrap and helps in reducing the  process variability.   Significantly reduces unplanned  downtime. 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 equipment’s/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  1. Target products or systems of maintenance should be clearly identified  and necessary data should be collected  2. 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. |  |
| 2 | Explain briefly about TPM with the help of flow chart? | **12** | K2 |
| TPM is a maintenance program which involves a newly defined  concept of maintaining plants and equipment’s. 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 on gain  process. The five S principles used for implementations of TPM.  • SEIRI – Sort out  • SEITON –Organize  • SEISO – Shine workplace  • SEIKETSU – Standardization  • SHITSUKE – Self discipline  various pillars of  TPM  • 5,S Principle  • josh hozen(JH)  • Kaizen  • planned maintenance  • Quality maintenance.  • training  • office TPM  • Safety, health and environment  Implementation of TPM:      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. |  |
| 3 | Discuss in brief the roles of various stakeholders of maintenance  scheduling communication chain? | **12** | K2 |
| 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. |  |
| 4 | Write a brief notes on JISHU HOZEN (autonomous maintenance) and its benefits? | **12** | K2 |
| b) JISHU HOZEN Target:  1.Reduce oil consumptionby50%  2.Reduce process time by 50%  3.Increase use of JH by 50%  . |  |
| 5 |  | **12** | K2 |
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| 6 |  | **12** | K2 |
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| **PART – C (20 Mark Questions with Key)** | | | |
| **S. No.** | **Questions** | **Mark** | **BTL** |
| **CO2 : :** Discuss maintenance policies with special reference to preventive maintenance | | | |
| 1. | **Discuss the different types of maintenance system in detail.** | 20 | K3 |
| Classification of Maintenance Approach:    Planned maintenance may further be classified into  A) Preventive Maintenance  B) Corrective Maintenance  C) Predictive Maintenance  D) Condition Based Maintenance  E) Reliability Centered Maintenance  **BREAK DOWN MAINTENANCE OR REACTIVE MAINTENANCE**   In this category, less attention is given to the operating condition of  critical machinery, equipment or system. Here the equipment is allowed  to function till no failure occurs no long as the equipment is functioning  at a minimum acceptable level, it is assumed to be effective. This means  the people wait till the equipment fails and repair. This approach of  maintenance is ineffective and extremely expensive. The following factors contribute to high maintenance costs.  i) Poor planning  ii) Incomplete repair  **Limitations:**  a) 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.  b) This approach focusses 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.  **PREVENTIVE MAINTENANCE**   It is a maintenance program which is committed to the elimination or  prevention of corrective and breakdown maintenance. 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.  **Benefits of Preventive Maintenance:**  In general, the cost incurred towards breakdown maintenance is usually higher than  the cost incurred on preventive maintenance.  It maintains the equipment in good condition to preventing them from bigger  problems.  Prolongs the effective life of the equipment’s.  Detects the problem at earlier stages.  Minimizes / eliminates the rewash/ scrap and help in reducing the process  variability.  Significantly reduces unplanned downtime.  **CORRECTIVE MAINTENANCE**   Corrective Maintenance is the program focused on regular planned tasks  that will maintain all critical machinery and system in optimum  operating conditions. The effectiveness of this program is judged on the  cycle cost of critical equipment rather than on how quickly the broken  machines are restored to working conditions. It is proactive approach  towards maintenance management  The main objectives of this program are to  i) Eliminate breakdowns  ii) Eliminate deviations from optimum operating conditions.  iii) Eliminate unnecessary repairs.  iv) Optimize all critical plant systems.  As per this program, all the repairs are well planned and implemented by properly  trained people and the equipment or system is verified and returned to service.  **PREREQUISITES OF CORRECTIVE MAINTENANCE:**  (i) Existence of trained full time maintenance planners for accurate  identification of roof cause of all incipient problems.  (ii) Properly trained craftsmen with necessary skill to complete the repair of  each incipient problem.  (iii) Standard maintenance procedure for recurring repairs and maintenance  task.  (iv) Allowing sufficient time to maintenance amidst tight production schedules  and management constraints.  (v) A thorough verification process to ensure the completion of repair.  **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. It is not a solution for all the factors that limit total plant  performance.  **CONDITION BASED MAINTENANCE**  The various techniques are  Vibration Monitoring –determines the actual condition of equipment’s / machines  by studying the noise or vibration produced during functioning.  Thermography –determines the condition of plant machinery systems etc. by  studying the emission of infra-red energy i.e. temperature.  Tribology –determines the dynamic condition of bearing lubrication, rotor support  structure of machinery etc. by adopting any one of the techniques like lubricating  oil analysis, spectrographic analysis, xerography and wear particle analysis  **REALIBILITY CENTERED MAINTENANCE (RCM)**   It 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. The rough process  of a CM 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 produced or systems are  systematically analyzed.   Preventive or corrective maintenance operations are considered  selection of operations is done based on rational calculation of  effectiveness of such operations for achieving required maintenance  quality, such as reliability, cost etc.  **Applications 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. |  |
| 2. | **Describe the benefits and steps of preventive maintenance.** | 20 | K3 |
| **(a) PREVENTIVE MAINTENANCE**   It is a maintenance program which is committed to the elimination or prevention  of corrective and breakdown maintenance. 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.  **Benefits of Preventive Maintenance:**  In general, the cost incurred towards breakdown maintenance is usually higher than  the cost incurred on preventive maintenance.  It maintains the equipment in good condition to preventing them from bigger  problems.  Prolongs the effective life of the equipment’s.  Detects the problem at earlier stages.  Minimizes / eliminates the rewash/ scrap and help in reducing the process  variability.  Significantly reduces unplanned downtime.  **STEPS FOR ESTABLISHING A PREVENTIVE MAINTENANCE (PM)**  **PROGRAM**   There are a number of steps involved in developing a PM program. The figure  presents six steps for establishing a highly effective PM program in a short period.  Each step is discussed below.  **1. Identify and choose the areas:**  Identify and selection of one or two important areas to concentrate the initial PM effort.  These areas should be crucial to the success of overall plant operations and may be  experiencing a high degree of maintenance actions. The main objective of this step is to  obtain immediate results in highly visible areas, as well as to win concerned management  support.  **2. Identify the PM needs:**  Define the PM requirements. Then, establish a schedule of two types of tasks: daily PM  inspections and periodic PM assignments. The daily PM inspections could be conducted  by either maintenance or production personnel. An example of a daily PM inspection is  to check the waste water, settle able solids concentration. Periodic PM assignments  usually are performed by the maintenance workers. Examples of such assignments are  replacing throwaway filters, replacing drive belts, and cleaning steam traps and  permanent filters.  **3. Establish assignment frequency:**  Establish the frequency of the assignments. This involves reviewing the equipment  condition and records. Normally, the basis for establishing the frequency is the  experience of those familiar with the equipment and the recommendations of vendors and  engineering. It must be remembered that vendor recommendations are generally based on  the typical usage of items under consideration.  **4. Prepare the PM assignments:**  Daily and periodic assignments are identified and described in detail, then submitted for  approval.  **5. Schedule the PM assignments on annual basis:**  The defined PM assignments are scheduled on the basis of a twelve-month period.  **6. Expand the PM program as necessary:**  After the implementation of all PM daily inspections and periodic assignments in the  initially selected areas, the PM can be expanded to other areas. Experience gained from  the pilot PM projects is instrumental to expanding the program.    **ii) Write short notes on RCM and its process.**  **(b) RCM (REALIBILITY CENTERED MAINTENANCE) PROCESS**  The basic RCM process is composed of the following steps:  **1. Identify important items with respect to maintenance:**  Usually, maintenance important items are identified using techniques such as failure,  mode, effects, and criticality analysis (FMECA) and fault tree analysis (FTA).  **2. Obtain appropriate failure data:**  In determining occurrence probabilities and assessing criticality, the availability of  data on part failure rate, operator error probability, and inspection efficiency is essential.  These types of data come from field experience, generic failure databanks, etc.  **3. Develop fault tree analysis data:**  Probabilities of occurrence of fault events basic, intermediate, and top events are  calculated as per combinatorial properties of the logic elements in the fault tree.  **4. Apply decision logic to critical failure modes:**  The decision logic is designed to lead, by asking standard assessment questions, to  the most desirable preventive maintenance task combinations. The same logic is applied  to each crucial mode of failure of each maintenance-important item.  **5. Classify maintenance requirements:**  Maintenance requirements are categorized into three classifications: on-condition  maintenance requirements, condition-monitoring maintenance requirements, and hard time maintenance requirements.  **6. Implement RCM decisions:**  Task frequencies and intervals are set/enacted as part of the overall maintenance  strategy or plan.  **7. Apply sustaining-engineering on the basis of field experience:**  Once the system/equipment start operating, the real-life data begin to accumulate.  At that time, one of the most urgent steps is to re-evaluate all RCM-associated default  decisions. |  |