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Handout

Industrial Maintenance

For 3 ETT Students Domain ST

Written by :

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University year: 2023 / 2024

Foreword

Aligned with the LMD curriculum, this handout is intended for third-year university students in the field of Technology Sciences, specializing in Electrotechnics. It is designed according to the official pedagogical program of the Ministry of Higher Education and Scientific Research, aiming to master a number of methods and tools for technical communication. Among these are the comprehensive approach and types of maintenance of the production system, Organization and structures of maintenance, Techniques used in maintenance, Relationships and interfaces with other functions of the industrial enterprise, etc. Maintenance is not merely about being able to restart a faulty equipment, but rather about mastering these equipment to the point of scheduling their maintenance. This function should be a means of optimizing downtime and reducing production losses. It should be based on choices supported by rationality rather than intuition. The aim of this handout is to provide students with a means to strengthen their knowledge in the field of Industrial Maintenance.

This course will be divided into four chapters as follows:

Educational Objectives:

- Ensure the continuity of service of an industrial installation, identify the functions and components of electrical and electronic equipment, determine the causes of system failures, and repair them.

Recommended Prerequisite Knowledge:

- Statistics, apparatus, measurements, and instrumentation.

Content of the material:

Chapter 1. Generalities on maintenance: (4 weeks)

- History (concepts and standardized terminology, ...), Role of maintenance and troubleshooting of equipment in industry, Elements of mathematics applied to maintenance, Behavior of equipment in service, Failure rates and reliability laws, Reliability models, Different forms of maintenance, Maintenance organization and troubleshooting of electrical equipment, Classification of planned maintenance of electrical equipment.

Chapter 2. Organization and management of maintenance: (4 weeks)

- Structure of workshops specialized in the troubleshooting of electromechanical converters, Organization of maintenance operations, Main steps of technology for troubleshooting electrical machines, Study of different breakdowns of electrical machines and methods for their detection, Disassembly and reassembly techniques, Tests and diagnostics before troubleshooting.

Chapter 3. Troubleshooting of different parts of electrical machines: (4 weeks)

- Troubleshooting of the mechanical part, Troubleshooting of the electrical part, Calculation and verification of parameters of electro-energetic systems, Recalculation of electro-energetic systems based on other data from the nameplate, Assembly work and testing method after troubleshooting.

Chapter 4. Generalities on Computer-Aided Maintenance (CAM): (3 weeks)

- Computer-Aided Maintenance Management The general objectives of this present work are: - Understand, analyze, and try to optimize maintenance costs and times to specify the least expensive type of maintenance and improve the lifespan of equipment. - Understand and exploit scheduling methods to manage interventions more judiciously. - Know CAM to simplify and facilitate decision-making and also assist maintenance services.

Chapter 1 of the handout provides a comprehensive overview of industrial maintenance, covering its historical evolution, role, function, service, applied mathematics elements, equipment behavior, failure rates, reliability laws, and system reliability.

General information on Maintenance

Chapter I

Dr. Berbaoui Brahim

1.1. HISTORICAL

Before 1900, the primary emphasis was on repair. Between 1900 and 1970, spurred by advancements in railways, automobiles, aviation, and weaponry during the World Wars, the focus shifted from "repair" to "maintenance." From 1970 to the present day, this evolution continued with significant developments in high-risk sectors and modern tools, solidifying "maintenance" as the preferred term. The shift from repair to maintenance was driven by several factors:

1. Technological evolution
2. Cost considerations
3. Automation
4. Depreciation
5. Regulatory constraints

These factors collectively contributed to the transformation and modernization of maintenance practices across various industries.

1.2. THE ROLE OF MAINTENANCE

1.2.1. Definition

According to AFNOR (French Association for Standardization), industrial maintenance is defined as "The set of actions allowing to maintain or restore an asset to a specified condition, or to a condition where it is able to provide a determined service" (NF X60-010). This definition encompasses:

1. **Maintenance:** Focuses on preventive actions while the system is operational, aiming to prevent deterioration or failure.
2. **Restoration:** Involves corrective measures taken after a loss of function to return the asset to its specified condition or operational state.

This dual approach ensures that assets are consistently able to meet the required operational standards and provide reliable service.

1.2.2. Objectives

1. **Ensuring Equipment Profitability:** It must optimize the profitability of equipment while adhering to the company's established policies.
2. **Conducting Preliminary Studies:** This involves conducting studies aimed at reducing costs and interventions, thereby improving efficiency.
3. **Preparing Work:** It includes preparing for maintenance activities by studying operational conditions, anticipating potential failures, and assessing intervention requirements thoroughly.

1.2.3. Placement of the maintenance function

The placement of the maintenance function within a company can vary based on organizational structure and operational needs. Generally, the maintenance function is strategically positioned to ensure efficient support and optimization of production processes. Key considerations include:

1. **Integration with Production:** Maintenance is often closely integrated with production departments to ensure timely support for equipment upkeep and operational continuity.
2. **Reporting Structure:** Depending on company size and industry, maintenance may report to operations, engineering, or even directly to senior management to align priorities with overall business objectives.
3. **Centralization vs. Decentralization:** Maintenance departments may be centralized, providing unified oversight and resource management, or decentralized, aligning maintenance teams more closely with specific production units or facilities.
4. **Support Functions:** It also encompasses support functions like logistics, procurement, and quality assurance to ensure adequate resource availability and compliance with standards.
5. **Strategic Role:** In modern contexts, maintenance is increasingly seen as a strategic function contributing to asset management, lifecycle planning, and overall operational efficiency.

Placement of the maintenance function is crucial to achieving operational reliability, cost-effectiveness, and alignment with company goals in various industrial settings.

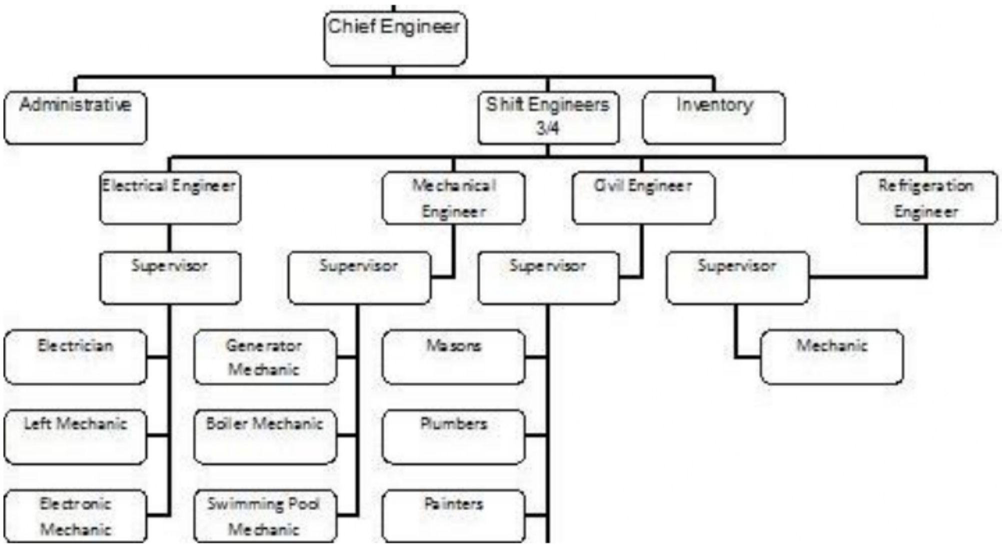


Fig. 1-1: Placement of the Maintenance Service within the Industrial Company

1.2.4. Role of maintenance

The maintenance function within a company plays several critical roles that are essential for ensuring operational efficiency, asset reliability, and overall business success. These roles include:

1. **Asset Reliability and Availability:** Maintenance ensures that all critical assets and equipment are maintained in optimal condition to minimize downtime and maximize availability for production.
2. **Preventive Maintenance:** Implementing scheduled inspections, servicing, and repairs to prevent equipment breakdowns and costly disruptions to operations.
3. **Corrective Maintenance:** Addressing and resolving equipment failures promptly to minimize production downtime and mitigate potential losses.
4. **Predictive Maintenance:** Using data-driven techniques and technologies to predict equipment failures before they occur, allowing for proactive maintenance interventions.
5. **Continuous Improvement:** Identifying opportunities for enhancing equipment performance, reliability, and efficiency through ongoing evaluation and optimization of maintenance strategies.
6. **Cost Management:** Balancing maintenance costs with operational needs and budget constraints, optimizing resource allocation and procurement of spare parts.

7. **Health, Safety, and Environmental Compliance:** Ensuring that maintenance activities adhere to health, safety, and environmental regulations to protect personnel and minimize environmental impact.
8. **Training and Development:** Providing training and development opportunities for maintenance personnel to enhance technical skills and knowledge, ensuring competence in handling advanced technologies and equipment.
9. **Collaboration and Communication:** Facilitating effective communication and collaboration with other departments, particularly production, engineering, and procurement, to align maintenance activities with overall business objectives.
10. **Asset Management and Lifecycle Planning:** Contributing to strategic asset management initiatives, including planning for asset lifecycle, upgrades, replacements, and decommissioning, to optimize long-term asset performance and return on investment.

Overall, the maintenance function plays a pivotal role in ensuring the reliability, efficiency, and sustainability of operations within the company, contributing directly to its competitiveness and profitability in the market.

1.2.5. Maintenance function policy

In the strategy of industrial maintenance, the objective is to prevent breakdowns while ensuring the cost-effectiveness of maintenance actions. Achieving this goal requires calculating the probability of breakdown occurrences and their potential consequences. With a well-defined maintenance policy and strategic approach, breakdowns are anticipated rather than reactive, making budgetary control a standard procedure. Consequently, the maintenance function needs to consider the following:

a. **Long-term Forecasts:**

- These forecasts are aligned with the company's policies and aid in planning expenses, inventory management, and equipment investments over extended periods.

b. **Medium-term Forecasts:**

- Ensuring minimal disruption to production schedules requires scheduling maintenance interventions well in advance to maintain the company's operational capacity. These interventions have a significant impact on production planning.

c. **Short-term Forecasts:**

- Focuses on reducing equipment downtime and intervention costs through proactive analysis. Preparation involves studying operational conditions, identifying potential failures, and planning execution conditions for interventions. The technical department associated with this function provides qualitative and quantitative information crucial for aligning with the company's specific policies.

In summary, effective industrial maintenance strategy involves proactive planning at different time horizons to optimize equipment reliability, minimize downtime, and uphold cost-efficiency in maintenance operations.

1.3. THE MAINTENANCE SERVICE

1.3.1. Levels of Action Within the Maintenance Service

In the realm of maintenance policy, it is crucial to delineate between two distinct levels:

- **Global Level of the Company:** Here, a comprehensive maintenance policy is crafted to provide a framework that guides all maintenance activities across the organization.
- **Local Level of Machines or Equipment:** Maintenance strategies are tailored based on economic, strategic, and operational criteria specific to each machine or equipment.

The overarching maintenance policy serves to establish the groundwork for understanding and organizing maintenance activities across various stakeholders and related services. It encompasses:

- Defining the maintenance budget.
- Choosing the type of maintenance and implementing cost reduction measures.
- Investment policies related to maintenance.
- Strategies for major maintenance initiatives.
- Approaches to outsourcing maintenance tasks.
- Policies governing routine maintenance.

- Specific strategies for continuous improvement within the maintenance service and contributions to broader company-wide improvement programs.
- Policies for managing and enhancing competencies within the maintenance team.

This structured approach ensures alignment between organizational objectives and operational realities, fostering efficiency, reliability, and continuous enhancement of maintenance practices.

1.3.2. Responsibilities of the Maintenance Service

1.3.2.1. Responsibilities of the Maintenance Service

the responsibilities that the maintenance service must ensure and assume include:

1. **Managing Equipment Maintenance:**
   - Overseeing the equipment maintenance budget to allocate resources effectively and optimize maintenance activities.
2. **Performing Various Types of Work:**
   - Executing diverse tasks such as new installations, safety modifications, and other maintenance-related projects as required.
3. **Managing Maintenance Resources:**
   - Efficiently managing maintenance resources, including:
     - Personnel: Ensuring skilled and adequately trained staff for maintenance tasks.
     - Workshop and Offices: Maintaining facilities conducive to effective maintenance operations.
     - Machinery and Tools: Managing supplies, spare parts, and tools necessary for maintenance activities.

These responsibilities are critical for maintaining operational efficiency, ensuring equipment reliability, and supporting the overall functioning of the organization's infrastructure and facilities.

1.3.2.2. Limits of Responsibility

- The maintenance service typically does not bear responsibility for manufacturing tooling or its maintenance. This management falls under the purview of the manufacturing department or production methods. In this context, maintenance often functions as a supplier of services and support.
- Similarly, the maintenance service is not responsible for modifications aimed at enhancing product quality, increasing productivity, or automating workstations. These initiatives generally fall within the domain of production engineering, process improvement teams, or other relevant departments focused on operational enhancements.

1.4. AREAS OF RESPONSIBILITY FOR THE MAINTENANCE SERVICE

The various tasks for which a maintenance service may be responsible include:

- **Maintenance of Equipment:** Regular upkeep and servicing of machinery and assets to ensure operational reliability.
- **Improvement of Equipment:** Enhancements focused on quality, productivity, or safety standards.
- **New Projects:** Involvement in initiatives such as:
  - Participation in the selection of new equipment.
  - Installation and commissioning of new equipment.
- **Hygiene, Safety, Environment, Pollution, and Energy Management:** Activities aimed at maintaining compliance and sustainability, including initiatives related to workplace safety, environmental protection, pollution control, and energy efficiency.
- **Premises Conversion, Layout, and Demolition:** Managing changes to facility layouts, including renovations and demolitions.
- **Repair of Spare Parts:** Executing repairs on components and spare parts to extend their lifecycle and minimize replacement costs.
- **Production Support Services:** Providing various services to support production operations, such as assembly assistance.
- **Maintenance of Facilities:** Overseeing upkeep and repairs for industrial buildings, administrative offices, social facilities, vehicle fleets, green spaces, and other infrastructure.

These tasks collectively ensure the smooth functioning of operations, uphold safety and regulatory standards, and contribute to the overall efficiency and sustainability of the organization.

1.5. APPLIED MATHEMATICS ELEMENTS IN MAINTENANCE

In the realm of industrial maintenance, it is often necessary to derive specific measures from a limited set of known values. This section aims to reinforce fundamental mathematical elements typically taught in secondary education and apply them to contexts relevant to industrial maintenance.

Probability Theory

The probability of an event E is obtained either through enumeration:

$$P_{(E)} = \frac{number\ of\ favorable\ cases}{number\ of\ possible\ cases} \quad (1)$$

This is the true probability of the element "E". Or experimentally:

$$\underset{n\to\infty}{P_{(E)}} \approx f_{(E)}) \quad (2)$$

f(E) is the observed frequency of event "E". The larger the number of observations, the closer this frequency gets to the true probability of having E.

$0 \leq P_{(E)} \leq 1$

1.6. EQUIPMENT BEHAVIOR IN SERVICE

The equipment designer, typically not involved in the operations of the installations they design, often faces challenges in fully considering the specific operating conditions of their clients. As a result, they may overlook the importance of maintainability in their designs. This oversight complicates the task of selecting a reliability calculation law for equipment behavior. Ensuring operational safety of a machine, which includes safety aspects and criteria aimed at minimizing frequent, difficult, and costly maintenance, can be summarized in three key points encapsulated by the acronym FMD, essential for designers to incorporate into their engineering studies:

- **Operational Safety:** Ensuring that the equipment operates safely under normal operating conditions, addressing risks and hazards effectively.
- **Maintainability:** Designing equipment with ease of maintenance in mind, facilitating straightforward access for repairs, part replacement, and upkeep tasks.
- **Availability and Reliability:** Maximizing the uptime of the equipment (availability) and its ability to perform consistently over time without breakdowns (reliability), thus minimizing disruptions to operations.

By focusing on these aspects during engineering studies, designers can enhance the overall performance and longevity of the equipment they design, meeting both safety standards and operational efficiency goals effectively.

1.6.1 Maintainability

Under given conditions, maintainability is the ability of an asset to be maintained or restored to an operational state where it can perform a required function when maintenance is carried out under given conditions, using prescribed procedures and means. Maintainability = being quickly repaired. It is also the probability of restoring a system to specified operating conditions within desired time limits when maintenance is performed under given conditions, using prescribed procedures and means. The maintainability of equipment depends on many factors, including:

1. **Design Considerations**: The initial design of the equipment plays a significant role in its maintainability. Design features that facilitate access to components, ease of disassembly, and simplicity of repair procedures contribute to better maintainability.
2. **Component Accessibility**: The ease with which maintenance personnel can access various components of the equipment directly affects maintainability. Components that are difficult to reach or require extensive disassembly for maintenance increase downtime and complexity.
3. **Standardization of Components**: Standardizing components across equipment models or within a facility can simplify maintenance processes. Interchangeable parts reduce the need for specialized tools and training, streamlining maintenance activities.
4. **Availability of Spare Parts:** Ready availability of spare parts is crucial for maintaining equipment uptime. Delays in obtaining necessary components can prolong repair times and lead to increased downtime.

5. **Documentation and Manuals**: Comprehensive documentation, including maintenance manuals, schematics, and troubleshooting guides, aids maintenance personnel in performing tasks efficiently. Clear, accurate documentation is essential for diagnosing issues and executing repairs effectively.
6. **Training and Skills of Maintenance Personnel:** Adequate training and skill levels among maintenance staff are essential for ensuring efficient equipment maintenance. Well-trained personnel can identify problems quickly, perform repairs accurately, and minimize downtime.
7. **Predictive Maintenance Tools:** Utilizing predictive maintenance techniques, such as condition monitoring and predictive analytics, can enhance equipment maintainability by enabling proactive identification of potential failures and scheduling maintenance activities accordingly.
8. **Workplace Safety Considerations:** Safety protocols and ergonomic considerations in equipment design and maintenance procedures contribute to maintainability by reducing the risk of accidents or injuries during maintenance tasks.
9. **Environmental Factors:** Environmental conditions, such as temperature, humidity, and exposure to contaminants, can impact equipment reliability and maintainability. Designing equipment to withstand environmental stressors and implementing appropriate maintenance strategies are essential.
10. **Supplier and Vendor Support**: Strong support from equipment suppliers and vendors, including timely technical assistance, training programs, and access to expert advice, can facilitate efficient equipment maintenance and troubleshooting.
11. **Feedback and Continuous Improvement:** Establishing mechanisms for collecting feedback from maintenance personnel and incorporating lessons learned into equipment design and maintenance procedures promotes continuous improvement in maintainability.

Considering these factors holistically can help organizations optimize equipment maintainability, leading to improved operational efficiency, reduced downtime, and enhanced asset performance.

1.6.2 Availability

When studying reliability, our interest extends beyond the probability of failure to include considerations such as the frequency of failures and the time required for repairs. In this context, two crucial parameters of reliability come into focus:

- **Availability:** Availability refers to the probability that a system is operational and available for use at any given point in time. It signifies the capability of an entity to perform its intended function under specified conditions, either instantly or during a defined time interval, assuming external support is provided.
- **Operational Availability:** Operational availability specifically denotes the probability that a system is available for use at an exact moment (t), emphasizing instantaneous readiness rather than the cumulative uptime from time 0 to t.

These definitions underline the distinction between reliability, which encompasses the system's overall performance over time, and availability, which emphasizes the immediate readiness of the system to perform its function at any specific moment. Both parameters are critical in assessing and optimizing the performance and reliability of systems in industrial contexts.

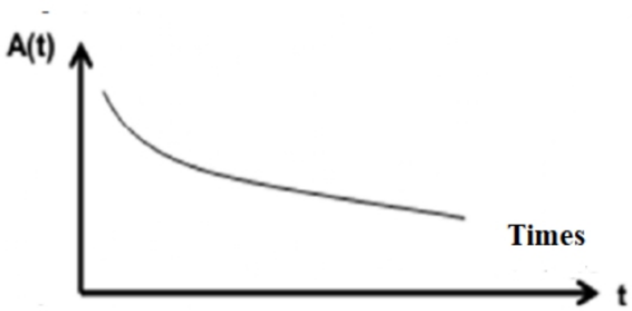


Figure. 1.2: Evolution of equipment availability over time

1.6.3 Reliability

Reliability: The probability that an item will perform its assigned mission satisfactorily for the stated period when used according to the specified conditions. The reliability of engineering systems has become an important issue during their design because of the increasing dependence of our daily lives and schedules on the satisfactory functioning of these systems. Some examples of these systems are aircraft, trains, computers, automobiles, space satellites, and nuclear power–generating reactors. Many of these systems have become highly complex and sophisticated. Normally, the required reliability of engineering systems is specified in the design specification, and during the design phase every effort is made to fulfill this requirement effectively. Some of the factors that play a key role in increasing the importance of reliability in designed systems are the increasing number of reliability- and quality related lawsuits, competition, public pressures, high acquisition cost, past well publicized system failures, loss of prestige, and complex and sophisticated systems

1.6.3.1 bathtub hazard rate concept

This is a well-known concept used to represent failure behavior of various engineering items because the failure rate of such items is a function of time (i.e., it changes with time). A bathtub hazard rate curve is shown in Figure 1.3. It is divided into three regions (i.e., Region I, Region II, and Region III). Region I is known as the burn-in region, debugging region, infant mortality region, or break-in region. During this period or region, the item hazard rate (i.e., time-dependent failure rate) decreases because of failures occurring for reasons. Region II is referred to as the "useful life period," during which the item hazard rate remains constant. Region III is known as the "wear-out period," during which the hazard rate increases because of failures occurring for reasons

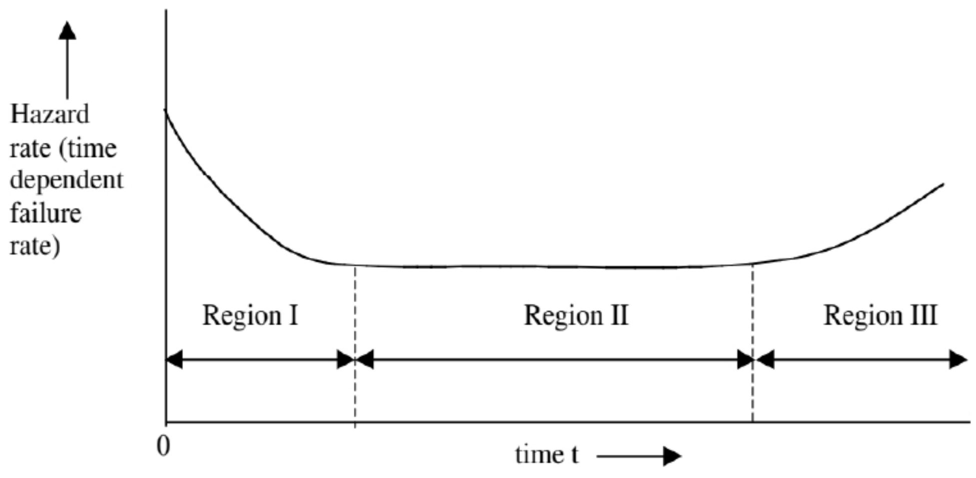


Figure 1.3 Bathtub hazard rate curve.

1.6.3.2 General reliability analysis formulas

Several formulas, based on the reliability function, frequently are used to perform various types of reliability analysis. This section presents four of these formulas.

a) Failure density function

This is expressed by

$$f(t) = -\frac{dR(t)}{dt} \quad (3)$$

where t is time, $f(t)$ is the failure (or probability) density function, and $R(t)$ is the item reliability at time t.

Example 1

Assume that the reliability of an item is defined by the following function:

$$R(t) = e^{-\lambda t} \quad (4)$$

where γ is the item's constant failure rate

Obtain an expression for the item's failure density function.

$$f(t) = -\frac{d\,e^{-\lambda t}}{dt} = \lambda\, e^{-\lambda t} \quad (5)$$

Example 2

The reliability of a spindle bearing for 20,000 hours of operation equals 0.9, meaning: There are 90 out of 100 chances probability that the bearing operates without signs of wear required function for 20,000 hours given time at an average rotation speed of 1500 rpm given conditions.

1.6.3.3 Failure rates and reliability laws

Failure, as defined by AFNOR Standard X 60-010, refers to the alteration or cessation of an entity's ability to perform a required function. This pivotal definition underpins maintenance actions, which are typically triggered by the occurrence of a failure in an asset. In broader terms, failure and breakdown are defined as follows:

- **Failure:** The moment when an asset ceases to perform its intended function as required. It marks the onset of a performance issue or incapacity.
- **Breakdown:** Refers to the state of the asset immediately following a failure. It denotes the condition where the asset is no longer operational or functioning properly.

These definitions are crucial in the field of maintenance, guiding efforts to prevent, predict, or promptly address failures to minimize downtime, enhance reliability, and prolong the operational lifespan of assets. Various non-standardized synonyms for failure include malfunction, damage, impairment, anomalies, faults, breakdowns, incidents, defects, and deterioration, reflecting different perspectives or nuances in describing asset performance issues or operational disruptions.

Reliability Function R(t) - Failure Function F(t)

Let's consider a piece of equipment for which we are studying reliability. Let Z be the random variable that associates, for each piece of equipment, its time of proper functioning. We randomly select one of these pieces of equipment. Let the events be:

A: "The equipment is in a state of proper functioning at time t" And B: "The equipment fails at time 't + Δt'" We then have:

$$p(A) = p(T > t) \; et \; p(T \leq t + \Delta t)$$

(6)

$$p(A \cap B) = p(t < T \leq t + \Delta t)$$

$$= F(t + \Delta t) - F(t)$$

$$= \left(1 - R(t + \Delta t)\right) - \left(1 - R(t)\right)$$

$$= R(t) - R(t + \Delta t)$$

We can deduce that:

$$p(\frac{B}{A}) = \frac{p(A \cap B)}{p(A)} = \frac{R(t) - R(t + \Delta t)}{R(t)} \quad (7)$$

We call the failure function the function F defined for all $\mathbf{t \geq 0}$

$$F(t) = p(t \leq t) \quad (8)$$

The number F(t) represents the probability that a randomly chosen device will fail before time t.

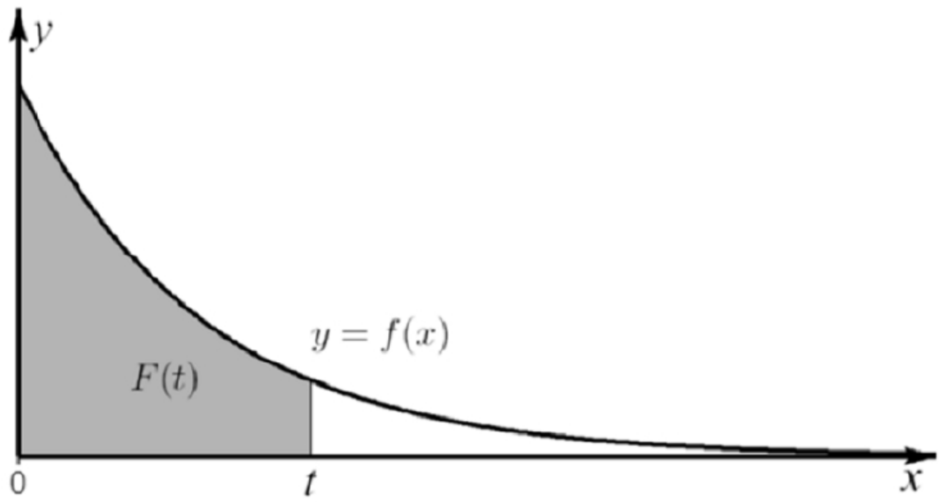


Fig 1.4: Failure Function

This function naturally leads us to an associated function: the reliability function R defined for all **t ≥ 0** by: **R(t) = 1- F (t).** The number **R(t)** represents the probability that a randomly chosen device from the population will not fail before time t.

Instantaneous failure rate:

It is the probability (0 ≤ R ≤ 1); a product must perform satisfactorily a required function, under given conditions, and for a given period. The mathematical expression of the instantaneous failure rate at time t, denoted λ(t), defined on IR is as follows:

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{1}{\Delta t} * \frac{R(t) - R(t + \Delta t)}{R(t)} \quad (9)$$

Physically, the term λ(t) Δt measures the probability that a device failure occurs in the time interval [t, t + Δt], knowing that this device has functioned properly up to time t.

$$\lambda(t) = \frac{dR(t)}{d(t)} * \frac{1}{R(t)} = \frac{dF(t)}{d(t)} * \frac{1}{R(t)} = \frac{f(t)}{R(t)} = \frac{f(t)}{1 - R(t)} \quad (10)$$

Where R is the reliability function of this equipment. This leads us to solve a first-order differential equation. Indeed, if λ is known, solving the first-order linear differential equation gives the reliability function R of the equipment. We then deduce the failure function F, which is the cumulative distribution function of the variable Z, and then the probability density function f of Z, which is the derivative of F. Thus, we have:

$$R(t)` + \lambda(t)R(t) = 0 \quad (11)$$

Give the reliability function R of the equipment. Then, we deduce the failure function F, which is the cumulative distribution function of the variable Z, and then the probability density function f of Z, which is the derivative of F. Thus, we have:

$$R(t) = e^{-\int_0^t \lambda(x)dx} \ et \ F(t) = 1 - e^{-\int_0^t \lambda(x)dx} \quad (12)$$

Reliability Indicators (λ) and (MTBF). Previously the failure rate λ has been defined by mathematical expressions through a probability calculation. It can also be expressed by a physical expression. It characterizes the rate of change of reliability over time. The duration of proper functioning is equal to the total service time minus the duration of failures.

$$\lambda = \frac{total\ number\ of\ failures\ during\ service}{total\ duration\ of\ good\ operation} \quad (13)$$

Average Time Between Failures

The MTBF value (= Mean Time Between Failure) is defined as the time between two errors of an assembly or device. Typical values lie between 300‘000 and 1‘200‘000 hours. Failure rates are identified by means of life testing experiments and experience from the field. The MTBF results from the inverse FIT or λ values. Summing the MTBF values of single components or subassemblies gives the MTBF of the full system. A large influence comes from the ambient conditions such as temperature variations, vibrations, and so on.

Therefore, MTBF values are determined with the help of manuals that include these conditions. The MTBF is often translated as the average of operating times but represents the average time between two failures. In other words, it corresponds to the expected lifespan t.

MTBF=$\int_0^\infty \boldsymbol{R(t)}$

Physically, the MTBF can be expressed as the ratio of times.

$$MTBF = \frac{total\ number\ of\ failures\ during\ service}{total\ duration\ of\ good\ operation} \quad (14)$$

If λ is constant: MTBF = 1/**λ**. The MTBF is the average lifespan of the system.

Example 3: An industrial compressor has operated for 8000 hours in continuous service with 5 failures, with respective durations of 7, 22, 8.5, 3.5, and 9 hours. Determine its MTBF.

$$MTBF = \frac{8000 - (7 + 22 + 8{,}5 + 9)}{5} = 1590\ hours$$

And if λ is assumed to be constant **λ = 1/MTFB = 6.289** × **10−4** failures/hour. The graph below shows the evolution of the failure rate for the different entities.

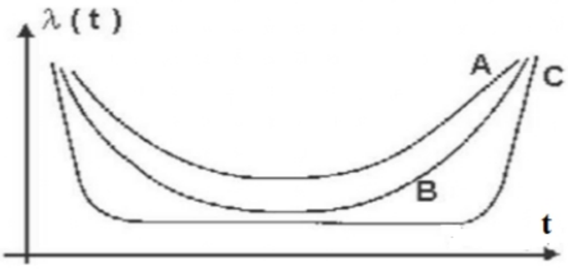


Fig.1. 5: Failure Rate Characteristic

The failure rate curves exhibit a general bathtub shape, but they nevertheless differ according to the principal technology of the studied system: A. Mechanical. B. Electromechanical. C. Electronic.

Failure Rate for Electronic Components

Experience has shown that for electronic components, the curve depicting the failure rate over time (t) resembles the shape of a bathtub curve, which consists of three distinct phases:

Phase 1: **Infancy Period** During this phase, there is a rapid decrease in the failure rate of electronic components. This decline is attributed to the elimination of defects resulting from poorly controlled design or manufacturing processes, or from faulty components within a batch. Advances in manufacturing practices have minimized this phase significantly in modern components. Manufacturers now rigorously verify the quality of their products at the end of the manufacturing process to mitigate early-life failures.

Phase 2: **Useful Life Period** The useful life period is typically long, characterized by a nearly constant failure rate. Failures in this phase are considered random and are not correlated with the age of the component but may result from various damaging mechanisms such as environmental stress, operational conditions, or inherent wear-out factors. Reliability calculations during this period often rely on models like the exponential distribution, which assumes memoryless properties and is suitable for predicting random failures.

Phase 3: **Aging Period** In the aging period, there is a progressive increase in the failure rate of electronic components as they age. This escalation is due to aging phenomena such as wear, erosion, chemical degradation, or other physical deterioration mechanisms. This phase extends well beyond the nominal lifespan of the component. Accelerated aging tests are sometimes conducted to simulate and identify potential failure modes that may manifest over extended periods of use.

Understanding these phases of the bathtub curve is crucial for designing robust reliability strategies and maintenance plans to enhance the longevity and performance of electronic components throughout their lifecycle.

Failure Rate for Mechanical Components

Mechanical components are subjected to wear or aging from the beginning of their life. If we plot the failure rate curve as a function of time, we obtain a curve that does not exhibit the plateau of the useful life period (constant failure rate) or it is reduced. The failure rate of the device is a nonlinear function of time in each phase of its life.

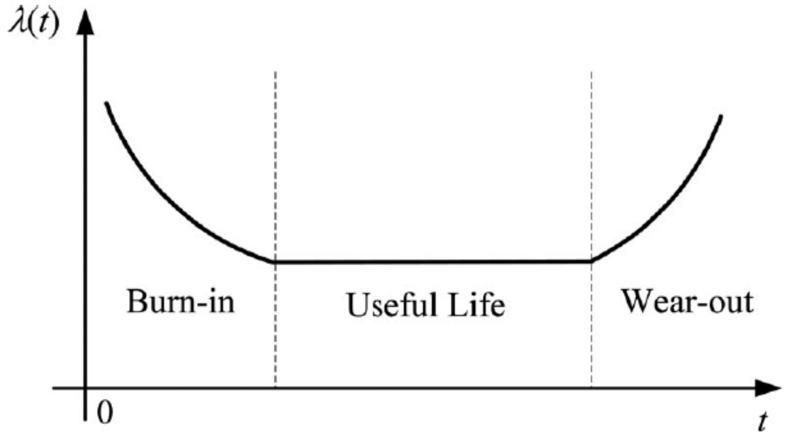


Fig. 1.6: Failure Rate Curve in Mechanics

Phase 1: The first phase defines the period of infant mortality. It is a relatively short lifespan, typically characterized by a gradual decrease in the failure rate over time due to improvements in internal characteristics (defect characteristics) and interfaces, as well as pre-running of parts. Therefore, it is not desirable to test mechanical components during this period of their life.

Phase 2: The final phase defines the aging period, which encompasses most of the device's life. It is characterized by a progressive increase in the failure rate. Mechanical parts are subject to multiple aging phenomena that can act in combination: corrosion, wear, deformation, fatigue, and ultimately loss of resilience or embrittlement. Unlike electronic components, reliability calculations for mechanical components are primarily performed during the aging period, using probability laws where the failure rate is a function of time, such as the Log-normal, Weibull, etc.

1.6.3.4 Mean time to failure

This is an important reliability measure, and it can be obtained by using any of the following three formulas:

$$MTTF = \int_0^{\infty} R(t)dt \qquad (15)$$

$$MTTF = \int_0^{\infty} t\, f(t)dt \qquad (16)$$

$$MTTF = \lim_{S \to 0} R(s) \qquad (17)$$

where s is the Laplace transform variable, MTTF is the mean time to failure, and R(s) is the Laplace transform of the reliability function R(t)

Example 4

Prove by using Equation 18 that Equation 15 to Equation 17 yield the same result for MTTF. Thus, by inserting Equation 18 into Equation 15, we get.

$$R(t) = e^{-\lambda t} \quad (18)$$

$$MTTF = \int_0^{\infty} e^{-\lambda t}\ dt\ = \frac{1}{\lambda} \quad (19)$$

1.6.4 Reliability networks

A system can form various configurations in performing reliability analysis. This section is concerned with the reliability evaluation of such commonly occurring configurations or networks.

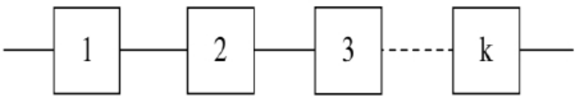


Fig 1.7 A k-unit series system.

1.6.4.1 Series networks

This is probably the most commonly occurring configuration in engineering systems, and its block diagram is shown in Figure 1.7. The diagram represents a k-unit system, and each block in the diagram denotes a unit. All units must work normally for the successful operation of the series system.

The series system (shown in Figure 1.7) reliability is expressed by

$$R_s = P(E_1 E_2 E_3 E_4 \ldots\ldots E_k) \quad (20)$$

where *Ej* denotes the successful operation (i.e., success event) of unit *j* for *j* = 1, 2, 3, …., *k*; *Rs* is the series system reliability; and is the occurrence probability of events *E*1, *E*2, *E*3, …, and

Ek.

For independently failing units, Equation 20 becomes

$$R_s = P(E_1)\,P(E_2)\,P(E_3)\;\;P(E_4)\ldots\ldots P(E_k) \tag{21}$$

where *P*(*Ej*) is the probability of occurrence of event *Ej* for *j* = 1, 2, 3, …, *k*. If we let *Rj* = *P*(*Ej*) for *j* = 1, 2, 3…, *k* in Equation 21 becomes

$$R_s = R_1 R_2 R_3 \ldots\ldots\ldots R_k \tag{22}$$

where *R j* is the unit *j* reliability for *j* = 1, 2, 3, …, *k*. or the constant failure rate *λj* of unit *j* (i.e., for *λj*(*t*) = *λj*), we get

$$R_j(t) = e^{-\lambda_j t}$$

(23)

where *Rj* (*t*) is the reliability of unit *j* at time *t*. Substituting Equation 23 into Equation 24 yields

$$R_s(t) = e^{-\sum_{j=1}^{k}\lambda_j t} \tag{24}$$

where *Rs* (*t*) is the series system reliability at time *t*

$$MTTF_s = \int_0^{\infty} e^{-\sum_{j=1}^{k}\lambda_j t}\,dt \;= \frac{1}{\sum_{j=1}^{k}\lambda_j} \tag{25}$$

where *MTTFs* is the series system mean time to failure.

Example 5 Assume that a system is composed of five independent and identical subsystems in series. The constant failure rate of each subsystem is 0.0025 failures per hour. Calculate the reliability of the system for a 50-hour mission and the system mean time to failure. By substituting the given data into Equation 24 we get

$$R_s(100) = e^{-(0.0025)(50)} = 0.5353$$

Using the specified data values in Equation 25 yields

$$MTTF_s = \frac{1}{5(0.0025)} = 80\ hours$$

Thus, the system reliability and mean time to failure are 0.5353 and 80 hours, respectively.

1.6.4.2 Parallel networks

In this case, the system is composed of k simultaneously operating units, and at least one of these units must operate normally for system success. The block diagram of a k-unit parallel system is shown in Fig 1.8, and each block in the diagram represents a unit.

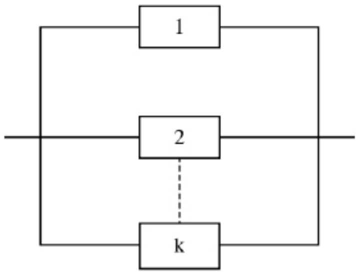


Fig 1.8 Block diagram of a k-unit parallel system.

The parallel system (shown in Figure 1.8) failure probability is given by

$$F_{ps} = p(\overline{E_1}\,\overline{E_2} \ldots\ldots \overline{E_k}) \tag{26}$$

where F_{ps} is the parallel system failure probability, denotes the failure (i.e., failure event) of unit j, for j = 1, 2, …, k, and is the occurrence probability of events $\overline{E_1}\,\overline{E_1} \ldots\ldots \overline{E_k}$. For independently failing parallel units, Equation 26 becomes

$$F_{ps} = p(\bar{E}_1)\,p(\bar{E}_2)\ldots\ldots\ldots p(\bar{E}_k) \tag{27}$$

where $P(E_j)$ is the probability of occurrence of event (E_j) for j = 1, 2, …., k. If we let $F_j = p(\bar{E}_j)$ for j = 1, 2, …., k, Equation 26 becomes

$$F_{ps} = F_1 F_2 \ldots\ldots F_k \tag{28}$$

where F_j is the unit j failure probability for $j = 1, 2, \ldots, k$. By subtracting Equation 28 from unity, we get

$$R_{ps} = 1 - F_{ps} = 1 - F_1 F_2 \ldots\ldots F_k \quad (29)$$

where R_{ps} is the parallel system reliability. For constant failure rate λ_j of unit j, subtracting Equation 23 from unity and then substituting it into Equation 29 yields

$$R_{ps} = 1 - (1 - e^{-\lambda_1 t})(1 - e^{-\lambda_2 t}) \ldots\ldots\ldots (1 - e^{-\lambda_k t}) \quad (30)$$

where $R_{ps}(t)$ is the parallel system reliability at time t. For identical units, substituting Equation 30 into Equation 15 yields

$$MTTF_{ps} = \int_0^{\infty} \left[1 - e^{-\lambda t})^k\right] dt = \frac{1}{\lambda} \sum_{j=1}^{k} \frac{1}{j} \quad (31)$$

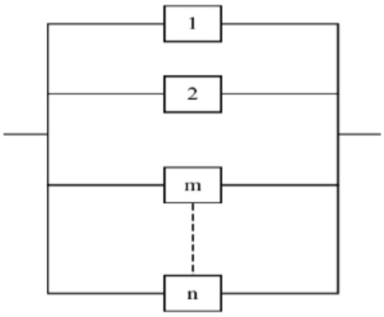


Fig 1.8 Block diagram of the m-out-of-n unit system

where $MTTF_{ps}$ is the parallel system mean time to failure and λ is the unit constant failure rate.

Example 6 A system is composed of three independent and identical subsystems. At least one of the subsystems must operate normally for the system to work successfully. Calculate the system's reliability if each subsystem's probability of failure is 0.1. By substituting the given data into Equation 29 we get.

$R_{ps} = 1 - (0.1)(0.1)(0.1) = 0.999$ Thus, the system's reliability is 0.999.

Chapter 2 of the handout discusses the implementation of maintenance strategies within an organization, focusing on interfaces with other departments, hierarchical positioning, different organizational structures, internal organization of the maintenance service, and means implemented.

Organization of Maintenance

Chapter I I

Dr. Berbaoui Brahim

2.1. INTRODUCTION

Organizing is the process of arranging resources (people, materials, technology etc.) together to achieve the organization's strategies and goals. The way in which the various parts of an organization are formally arranged is referred to as the organization structure. It is a system involving the interaction of inputs and outputs. It is characterized by task assignments, workflow, reporting relationships, and communication channels that link together the work of diverse individuals and groups.

2.2 Maintenance Organization Objectives and Responsibility

A maintenance organization and its position in the plant/whole organization is heavily impacted by the following elements or factors:

• Type of business, *e.g.,* whether it is high tech, labor intensive, production or service.
• Objectives: may include profit maximization, increasing market share and other social objectives.
• Size and structure of the organization.
• Culture of the organization.
• Range of responsibility assigned to maintenance.

Figure 2.1. Maintenance organizing as a function of the management process

Organizations seek one or several of the following objectives: profit maximization, specific quality level of service or products, minimizing costs, safe and clean environment, or human resource development. All these objectives are heavily impacted by maintenance and therefore the objectives of maintenance must be aligned with the objectives of the organization.

2.3. DIFFERENT ORGANIZATIONS

The organization of maintenance services evolves due to several factors, including:

- Economic constraints
- Computerization requirements
- Total Productive Maintenance (TPM), which encourages integration
- Reliability
- Increasing incorporation of diagnostic tools into machinery
- Enhancements in outsourcing options

To be effective, various types of maintenance organizations must adopt a mindset grounded in the systemic or corporate approach described below.

2.3. 1. Systemic Approach or Corporate Approach

The systemic approach examines a company's operations through the lens of information, material, and financial flows, rather than focusing on individual departments. Figure 2-2 illustrates two information flows related to maintenance within a company. Effective execution of an intervention or order necessitates collaboration among multiple departments, each with its own priorities that may not always align seamlessly. These interdepartmental transfers pose significant risks of malfunctions that can affect maintenance times and, consequently, the overall performance of the production unit. Recognizing this, many companies have integrated this perspective into their industrial maintenance strategies.

The primary criteria influencing organizations include:

- **Total Productive Maintenance (TPM):** This approach emphasizes the integration of operators and technicians, highlighting the need for cohesive collaboration.
- **Incorporation of Diagnostic Tools:** The growing use of diagnostic tools in machinery demands higher technical expertise at the production site.

- **Enhanced Outsourcing Options:** Improved outsourcing services are often more competitive and efficient than internal resources.
- **Focus on Core Competencies:** There is a strong desire to concentrate on core trades and specialized skills.

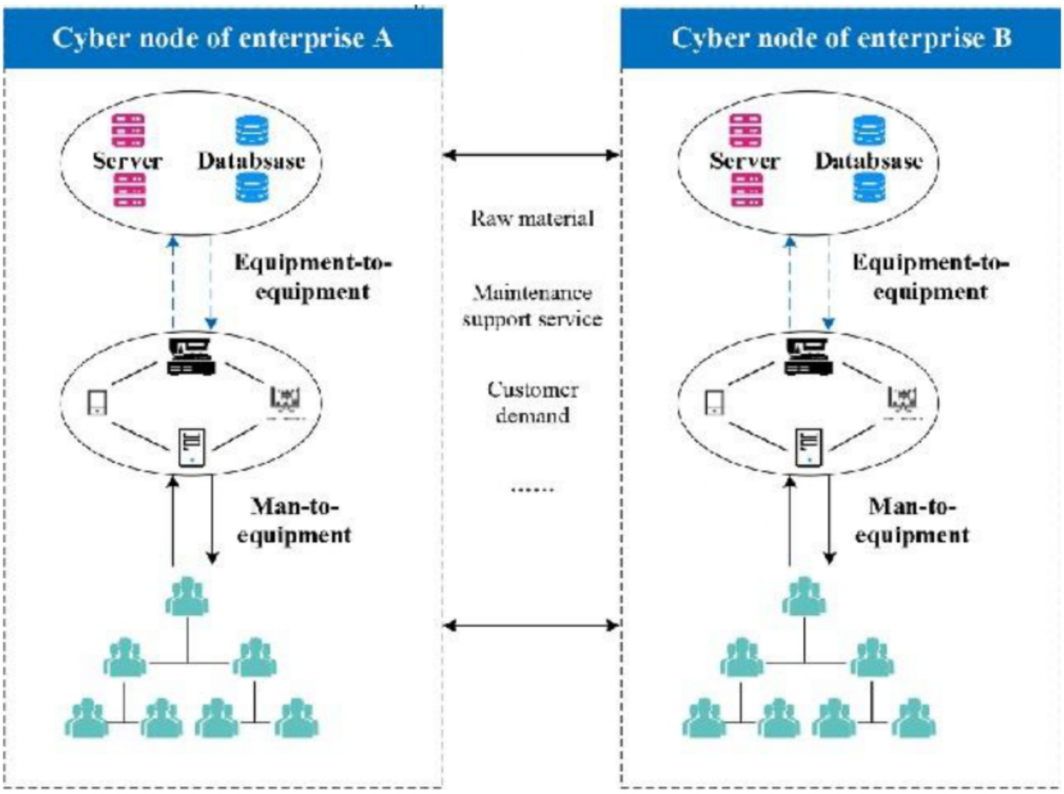


Figure. 2-2: Information Flow in Maintenance

2.3.2. Management Mode of the Maintenance Function

The management approach for the maintenance function is specifically tailored for the upkeep of production equipment and infrastructure. In these scenarios, preventive maintenance plans are established for numerous machines and equipment. These plans include operating procedures that help determine the workload by specialization (e.g., mechanic, electronics technician, hydraulics technician).

Key questions for effective maintenance management include:

- What tasks should be performed internally, and what should be outsourced?

- Which maintenance management model to adopt: centralized or decentralized?
- How should maintenance operations be scheduled?
- What spare parts should be stocked?
- What quantity of spare parts is needed?

Given the diverse ways the maintenance function is implemented in companies, the primary organizational models and their essential characteristics are outlined below.

a. Centralized Maintenance

This section describes the traditional organization of maintenance (Figures 2-3 and 2-4), which operates separately from production and includes all technical services. This approach is essential when production staff cannot perform self-maintenance, especially when dealing with highly technical equipment, stringent safety constraints, or various regulations. It comprises a methods department responsible for work scheduling and preparation, technical intervention teams, storekeepers, and more. In a centralized maintenance management model, the entire maintenance function is provided by a single service.

Advantages:

- Optimization of the use of expensive resources.
- Better cost control.
- Standardization of procedures.
- Consistent monitoring of equipment lifespan.
- Easier personnel management.

Disadvantages:

- Silo mentality.
- Detachment from production concerns.
- Effectiveness depends on the quality and organization of communication with the production function.

Figure. 2-3 : Centralized Maintenance

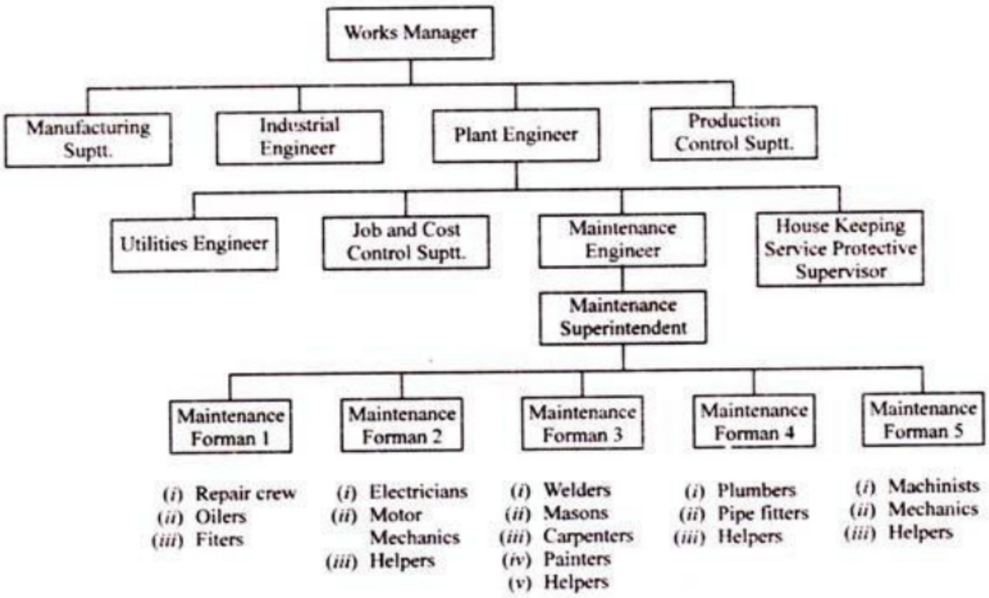


Figure. 2-4: Organizational Structure of Centralized Maintenance

b. Decentralized or Distributed Management Mode

A segment of maintenance, known as close maintenance or platform maintenance, is integrated into production and operation teams Figure 2-5. Platform technicians are responsible for diagnostics, determining necessary skills, managing orders, overseeing refurbishment work, and contributing to improvements. In the decentralized management model, maintenance is not managed by a single service. Instead, the maintenance service relinquishes some of its previous responsibilities. General maintenance and potentially subcontracted maintenance remain under its purview, while equipment maintenance is transferred to production services.

Advantages:

- Improved prevention and control of the degradation process.
- Enhanced opportunities to influence operating processes.
- Reduction of compartmentalization and increased collaboration.
- Decrease in micro-failures.
- Facilitation of quality actions at the source of malfunctions.
- Greater cost awareness due to proximity to production.
- Delegation of responsibility to team leaders at branch levels.
- Improved relations between maintenance and production.
- Benefits from working in versatile teams.
- Increased efficiency of maintenance interventions.

Disadvantages:

- Technical expertise is shared between maintenance and production functions.
- Risk of redundancies with centralized maintenance, requiring strong coordination and strict procedures for subcontracting to avoid excessive use of costly overqualified specialists.

The choice between decentralized or centralized management of the maintenance function depends on the company's size, the nature of the techniques, and the personnel in place.

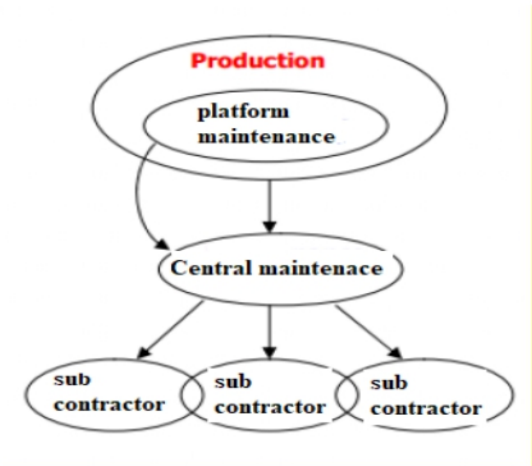


Figure. 2-5: Distributed Maintenance

c. Mixed Organization

The platform maintenance function is closely integrated with process management. Degradation processes are better controlled through integrated monitoring systems designed into the installations from the outset. Except for highly specialized skills (often outsourced), the General Maintenance Company (GMC) manages routine maintenance and oversees all logistical aspects compared to platform maintenance.

Advantages:

- Effective distribution of skills and mastery of aging processes.
- Preservation of knowledge and technical expertise.

Disadvantages:

- Requires production operators to have a high technical level to interpret and act on information from diagnostic systems.
- Significant redefinition of the maintenance role.

d. Outsourced Maintenance

Some companies have opted for total outsourcing with performance obligations. In this model, the service provider, or General Maintenance Company (GMC), may subcontract certain activities requiring specialized skills and, if necessary, manage spare parts inventories.

Advantages:

- Significant gains by reducing the number of interfaces and interventions from different trades.
- The GMC, arriving on-site with a fresh perspective, is not hindered by established habits and inertia, enabling the implementation of a new maintenance policy more easily.
- The GMC must provide strong organizational skills, with its technical expertise supplemented by specialized subcontractors.
- Responsible for detecting malfunctions, initiating preventive maintenance, and calling in specialists.

Disadvantages:

- Risk of loss of technical control.
- Risk of reduced staff mobility, depending on the contract terms and the human resources policy of the GMC.

2.4 DESIGN OF THE MAINTENANCE ORGANISATION

A maintenance organization is subjected to frequent changes due to uncertainty and desire for excellence in maintenance. Maintenance and plant managers are always swinging from supporters of centralized maintenance to decentralized ones, and back again. The result of this frequent change is the creation of responsibility channels and direction of the new organization's accomplishments vs the accomplishments of the former structure. So, the craftsmen must adjust to the new roles. To establish a maintenance organization an objective method that caters for factors that influence the effectiveness of the organization is needed. Competencies and continuous improvement should be the driving considerations behind an organization's design and re-design

2.4.1 Current Criteria for Organizational Change

Many organizations were re-designed to fix a perceived problem. This approach in many cases may raise more issues than solve the specific problem. Among the reasons to change a specific maintenance organization's design are:

1. Dissatisfaction with maintenance performance by the organization or plant management.

2. A desire for increased accountability.

3. A desire to minimize manufacturing costs, so maintenance resources are moved to report to a production supervisor, thereby eliminating the (perceived) need for the maintenance supervisor.

4. Many plant managers are frustrated that maintenance seems slow paced, that is, every job requires excessive time to get done. Maintenance people fail to understand the business of manufacturing, and don't seem to be part of the team.

2.4.2 Criteria to Assess Organizational Effectiveness

Rather than designing the organization to solve a specific problem, it is more important to establish a set of criteria to identify an effective organization. The following could be considered as the most important criteria:

1. Roles and responsibilities are clearly defined and assigned.
2. The organization puts maintenance in the right place in the organization.
3. Flow of information is both from top-down and bottom-up.
4. Span of control is effective and supported with well-trained personal.
5. Maintenance work is effectively controlled.
6. Continuous improvement is built in the structure.
7. Maintenance costs are minimized.
8. Motivation and organization culture.

2.5. MEANS IMPLEMENTED

To fulfill its mission effectively, the maintenance service must be equipped with human and material resources that are both qualitatively and quantitatively suited to the tasks assigned to it.

2.5.1. Human Resources

These qualifications encompass a wide range of roles, from laborers to carefully selected senior executives, each equipped to fulfill specific requirements:

1. Supervision
2. Technical or methodological expertise (often at a high level)
3. Programming skills
4. Execution capabilities (often at an advanced level)

2.5.2. Material Resources

The equipment, materials, and tools necessary for maintenance are categorized as follows:

a. Necessary Equipment:

1. **Intervention tools:**
    - Individual tools
    - Collective tools
    - Specialized tools
2. **Handling and dismantling equipment:**
    - Bridges
    - Carts
    - Jacks
3. **Means of transportation:**
    - Trucks
    - Vans
    - Cars
    - Motorcycles
    - Bicycles
4. **Storage facilities:**
    - Central warehouses
    - Local warehouses

b. Equipment with Specific Needs:

1. **Machining equipment:**
    - Workbench
    - Machine tools
    - Welding stations
2. **Premises and workspace:**
    - Machining workshop
    - Repair workshop

2.6 EDUCATION AND TRAINING

Nowadays it is also recognized that the employers should not only select and place personnel but should promote schemes and provide facilities for their further education and training, to increase individual proficiency, and provide recruits for the supervisory and senior grades. For senior staff, refresher courses comprise lectures on specific aspects of their work; they also encourage the interchange of ideas and discussion. The further education of technical grades, craft workers, and apprentices is usually achieved through joint schemes, sponsored by employers in conjunction with the local education authority. Employees should be encouraged to take advantage of these schemes, to improve proficiency and promotion prospects. A normal trade background is often inadequate to cope with the continuing developments in technology.

The increasing complexity and importance of maintenance engineering warrants a marked increase in training of machine operators and maintenance craftsmen through formal school courses, reinforced by informed instruction by experienced supervisors. The organization must have a well-defined training program for each employee.

The following provides guidelines for developing and assessing the effectiveness of the training program:

- Evaluate current personnel performance.
- Assess training need analysis.
- Design the training program.
- Implement the program.
- Evaluate the program effectiveness.

The evaluation is done either through a certification program or by assessing the ability to achieve desired performance by persons who have taken a particular training program. The implementation of the above five steps provides the organization with a framework to motivate personnel and improve performance.

2.7 CORRECTIVE AND PREVENTIVE MAINTENANCE

Corrective maintenance is the remedial action performed because of failure or deficiencies found during preventive maintenance or otherwise, to repair an item to its operating state. Normally, corrective maintenance is an unplanned maintenance action that requires urgent attention that must be added, integrated with, or substituted for previously scheduled work. Corrective maintenance or repair is an important element of overall maintenance activity.

Preventive maintenance is an important element of a maintenance activity and within a maintenance department it normally accounts for a significant proportion of the overall maintenance activity. Preventive maintenance is the care and servicing by maintenance personnel to keep facilities in a satisfactory operational state by providing for systematic inspection, detection, and correction of incipient failures either before their development into major failures or before their occurrence.

2.7.1 Type of corrective maintenance

Corrective maintenance may be grouped under the following five categories

Fail repair: This is concerned with restoring the failed item or equipment to its operational state.

Overhaul: This is concerned with repairing or restoring an item or equipment to its complete serviceable state meeting requirements outlined in maintenance serviceability standards, using the "inspect and repair only as appropriate" method.

Salvage: This is concerned with the disposal of nonrepairable materials and utilization of salvaged materials from items that cannot be repaired in the overhaul, repair, or rebuild programs.

Servicing: This type of corrective maintenance may be required because of a corrective maintenance action; for example, engine repair can result in requirement for crankcase refill, welding on, and so on.

Rebuild: This is concerned with restoring an item or equipment to a standard as close as possible to its original state with respect to appearance, performance, and life expectancy. This is accomplished through actions such as complete disassembly, examination of all parts, replacement or repair of unserviceable or worn components according to original specifications and manufacturing tolerances, and reassembly and testing to original production requirements.

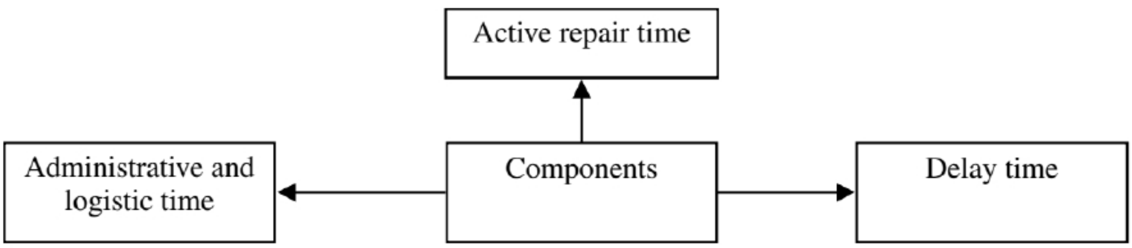


Figure 2.6 Major corrective maintenance downtime components.

Chapter 3 provides comprehensive guidance on troubleshooting mechanical and electrical components of electric motors. It emphasizes the critical role of regular motor maintenance in ensuring uninterrupted factory operations, given the high cost associated with unexpected downtime.

Troubleshooting different parts of electrical machines

Chapter I I I

Dr. Berbaoui Brahim

3.1. INTRODUCTION

Proper maintenance of an electric motor is crucial for ensuring a factory's smooth operation and overall success. The high expenses tied to unplanned downtime have made regular motor upkeep a top priority for factories. When a motor fails, it can lead to reduced system reliability, accelerated system wear, or even the shutdown of the entire facility. A motor's nameplate provides essential information, including rated power, speed, voltage, and the service factor if it differs from 1.0. The service factor serves as a multiplier that allows the motor to manage occasional overloads effectively.

3.2. TROUBLESHOOTING OF THE MECHANICAL AND ELECTRICAL COMPONENTS OF AN ELECTRIC MACHINE

3.2.1. Analysis of the actual condition of the equipment

To analyze the actual condition of the equipment, the troubleshooter must conduct preliminary checks, such as:

a. Presence of power sources:

The voltage value across the power and control circuits is measured to ensure it matches the machine's nominal voltage.

b. Condition of protections and control components

Protection elements such as fuses, thermal relays, and circuit breakers are inspected for proper calibration, adjustment, and tripping functionality. In the control circuit, the condition and operation of contactors are also verified.

c. Mechanical checks

The simplest check involves manually rotating the machine's shaft to ensure smooth rotation and the absence of mechanical blockages. We can use our senses to detect certain defects:

- **Visual Inspection:** Look for signs of oscillation, such as vibrations and noises. Bearing wear and misalignment can lead to machine failure.
- **Tactile Inspection:** The motor or generator should be warm but not hot. Excessive heat may indicate issues with coil cooling, clogged gears, overly tensioned belts, or a lack of oil in the bearings.

- **Auditory Inspection:** Listen for unusual sounds. A rumbling noise might indicate worn bearings, while high-pitched sounds can suggest poorly lubricated parts.
- **Olfactory Inspection:** Notice any unusual odors. A defective motor or generator might emit smells from coil insulation overheating or friction at the bearing level. A burnt-out motor will produce a distinct acrid odor of burnt plastic.

d. Electrical Checks

If the issue isn't immediately apparent, a startup test must be conducted to observe symptoms and pinpoint test points. These checks involve using measurement instruments such as a multimeter, ohmmeter, grog nard, tachymeter, and accelerometer (for vibrations). For instance, one can measure supply voltage, absorbed current, excitation current, rotational speed, coil resistances, resistances relative to ground, and vibrations. The readings from these measurements are then compared to reference values provided in the technical documentation supplied by the manufacturer. The values specified in the technical specifications and electrical and mechanical characteristics of the machine help the troubleshooter identify discrepancies and determine the cause of the malfunction.

3.2.2. Example of troubleshooting the mechanical/electrical part of a DC motor

a. The motor doesn't start

If the motor fails to start, first ensure that the power supply to the control unit is adequate. If the power supply is confirmed to be suitable for the control box, but the motor still doesn't start when the switch is activated, the issue likely stems from an open circuit in the induction circuit. This circuit includes the armature winding, the fields (including series and commutator poles if present), the motor terminals, and certain parts of the motor control circuit. To determine whether the problem lies with the motor itself or the control circuit, press the start button and measure the voltage at the terminals and the armature and shunt field using a DC voltmeter. If the desired voltage is present, the issue is within the motor. If the reading is zero or very low, there is likely an abnormality in the control circuit.

b. Issue with the motor

When determining that the problem originates from the motor, first examine the brushes. Ensure they are correctly positioned in the commutator and that no wires are loose. Weak contact of the brushes or brush terminals can prevent the motor from starting. Replace any brushes that are too short or damaged. Once the brushes are properly in place, press the start button. If the motor still does not operate, disconnect the power source from the motor and use an ohmmeter to check the continuity of the armature circuit. An infinite reading on the ohmmeter indicates that the circuit is open, preventing the motor from starting. An open connection in the armature circuit can be caused by:

- A broken or disconnected strap between coils.
- An open circuit in the interpole or coil winding.
- Open armature coils.

c. Issue in the control circuit

When zero or very little voltage is obtained at the motor terminals upon pressing the start button, it indicates a problem with the control circuit. This circuit includes components such as the thermal relay, starting resistors, contactors, fuses, and the main power supply connecting the motor to the control unit. Any interruption in this circuit will prevent the motor from starting. Here are several points to check when diagnosing a problem in the control circuit:

- **Overload Relay:** Ensure it has not tripped.
- **Starting Resistors:** Check for the presence of an open circuit.
- **Contactors:** Verify that they are properly closed.
- **Fuses:** Ensure they are not blown.
- **Starting Power Supply:** Check for continuity.
- **Connections:** Ensure all connections are securely fastened.

Issue 1: Overload relay tripping or fuses blowing upon motor startup

The tripping of the overload relay or blowing of fuses upon motor startup are very common problems associated with motor failure. These issues occur when the startup current is too high due to various reasons:

- Grounded winding.
- Short-circuited armature winding.
- Defective windings.
- Mechanical problems with the motor or equipment components it drives.
- Premature short circuits in starting resistors.

Issue 2: Motor running at a higher speed than the nominal revolutions

A motor that operates satisfactorily may suddenly start running at a higher or lower speed than the intended number of revolutions. If it runs at a higher speed under full load, the problem lies either in the voltage supply or in the motor winding. To pinpoint the issue, measure the armature and field voltages at the motor terminals. The motor speed will increase if the armature voltage is higher than specified. Additionally, the speed may be elevated if the voltage applied to the field is lower than the value shown on the nameplate. If the applied voltage matches the motor's capacity and the motor still runs at a higher number of revolutions than its capacity, there is a fault in the winding. The issue could stem from grounded, short-circuited coils, or an open circuit in the field windings. Any of these situations could lead to an increase in speed.

Issue 3: Motor running at a lower speed than indicated

If the motor operates at a significantly lower speed than its capacity, the problem likely lies in the voltage supply or in the connections of the armature circuit. Measure the armature voltage and compare it to the value indicated on the nameplate. A reduced armature voltage will result in a decrease in motor speed. If the voltage applied to the armature matches the motor's capacity and the motor still runs at a lower speed than indicated, the issue manifests as high resistance in the armature circuit. This problem can be detected by first checking all connections in the armature circuit for the presence of high resistance in the straps, caused by loose connections. Check for hot spots and discoloration of the insulation around the connections. Next, ensure that all contactors in the regulator provide good contact when closed. Contactors that can short-circuit the starting resistors must be closed during operation. Otherwise, if there are straps with high resistance anywhere in the armature circuit, the motor will run slower than its nominal speed. If the motor speed continuously varies under constant voltage (e.g., the armature slows down, then accelerates, etc.), the problem lies in the armature winding. This type of failure indicates short-circuited coils. To detect this issue, follow the method described earlier in Issue 1: Overload relay tripping or fuses blowing upon motor startup.

Issue 4: Sparks under the brushes

Sparks under the brushes indicate commutation problems, which are a common cause of failure in DC motors. Although sparks can result from various factors, mechanical issues are typically the primary cause rather than electrical ones.

To isolate the source of sparks, it's crucial to address mechanical issues associated with the brushes:

- Ensure all brushes are present and correctly installed in the collector.
- Check that main brushes are intact and securely attached to their holders and verify the pressure of the brush springs.
- Confirm that brushes are properly adjusted and move freely in their housings without being too tight or loose.
- Ensure the brush holder is securely fastened and not loose.

If the brushes seem to be functioning correctly, the issue may lie with the collector. Poorly maintained collectors can cause sparks as brushes may bounce on the surface. Carefully inspect the collector:

- Ensure no segments are protruding or flattened.
- Check for excessive mica build-up.
- Ensure no foreign objects are lodged between collector bars.
- If the collector shows signs of excessive eccentricity or burnt, rough segments, it may need machining with a sharp tool to restore smoothness.

Excessive vibrations caused by an unbalanced armature or driven equipment can also lead to brush bouncing and sparks. To determine if the motor or driven equipment is faulty, run the motor unloaded and observe for sparks.

Additionally, excessively worn bearings can cause sparks by moving the armature frame, creating uneven air gaps under the brushes. Inspect bearings for wear and replace as necessary to mitigate this issue.

Issue 5: Newly installed motor not starting or failing shortly after installation

If a recently repaired motor fails upon being put back into service, the following steps should be taken:

1. **Check the Control Unit and Main Power Supply Connections:**
   - Verify that the control unit is providing the correct voltage and is functioning properly.
   - Ensure all connections in the main power supply are correct and securely tightened.
2. **Perform Initial Checks:**
   - Confirm that there are no obvious issues with the motor's installation or immediate environment.
   - Inspect for any signs of damage or misalignment that could affect operation.
3. **Follow Troubleshooting Procedures:**
   - Proceed with troubleshooting procedures as previously described, including:
     - Conducting a thorough motor inspection.
     - Checking the insulation resistance of the winding.
     - Verifying proper functioning of protection elements such as fuses, relays, and contactors.
     - Checking for proper voltage at motor terminals during startup.
     - Ensuring mechanical components like bearings and brushes are in good condition.

By systematically checking these areas, you can identify the cause of the motor failure and take appropriate corrective actions. If initial checks and troubleshooting do not reveal the issue, further detailed inspection and possibly consultation with a qualified technician may be necessary.

Issue 6: Newly installed motor running at a higher speed

Sometimes, a newly installed motor will run at a higher speed than its capacity. Reversed polarities in the field can cause compound-wound motors to operate beyond their nominal capacity. To correct the situation, interchange the conductors (S1 and S2). A DC motor with a dual-voltage shunt connected in series for high voltage and in parallel for low voltage can also run at a higher speed than its capacity if the fields are improperly connected. To return the motor speed to normal, reconnect the shunt for low voltage operation. A poorly wound armature can also cause the motor to run at a speed higher than its capacity. This will occur if the new winding has fewer turns than the old one. Such an error is more common in smaller armatures, as they have more turns than larger versions.

3.2.3. Example of troubleshooting the mechanical/electrical part of an alternating current motor:

Figure III.1 illustrates a troubleshooting flowchart that provides logical methods, step by step, to identify and correct issues with an alternating current machine [28,29]. Caution: The internal parts of a motor may be at line potential even if it is not running. Disconnect all power to the motor before performing any maintenance operation that may require contact with internal parts.

3.3. ASSEMBLY WORK AND TESTING METHOD AFTER TROUBLESHOOTING

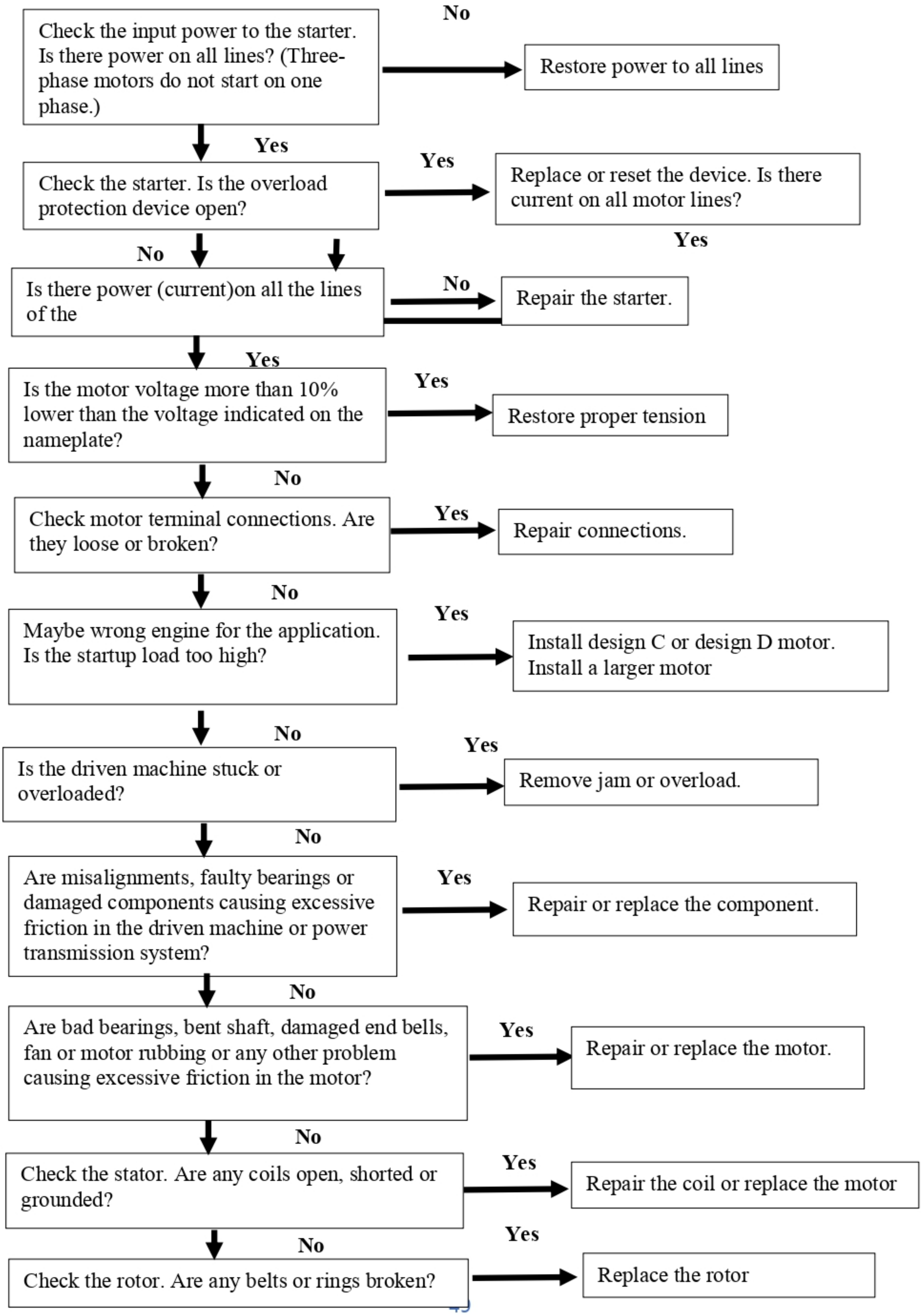
Reassembly is carried out by starting with the last disassembly operation, then tightening all disassembled parts and rotating the rotor by hand to ensure its free rotation. Electric machines arriving for repair may vary in power, versions, and designs. To better understand this step, an example of maintenance and troubleshooting of an asynchronous squirrel-cage motor has been assembled and disassembled.

3.3.1. Disassembly and Reassembly

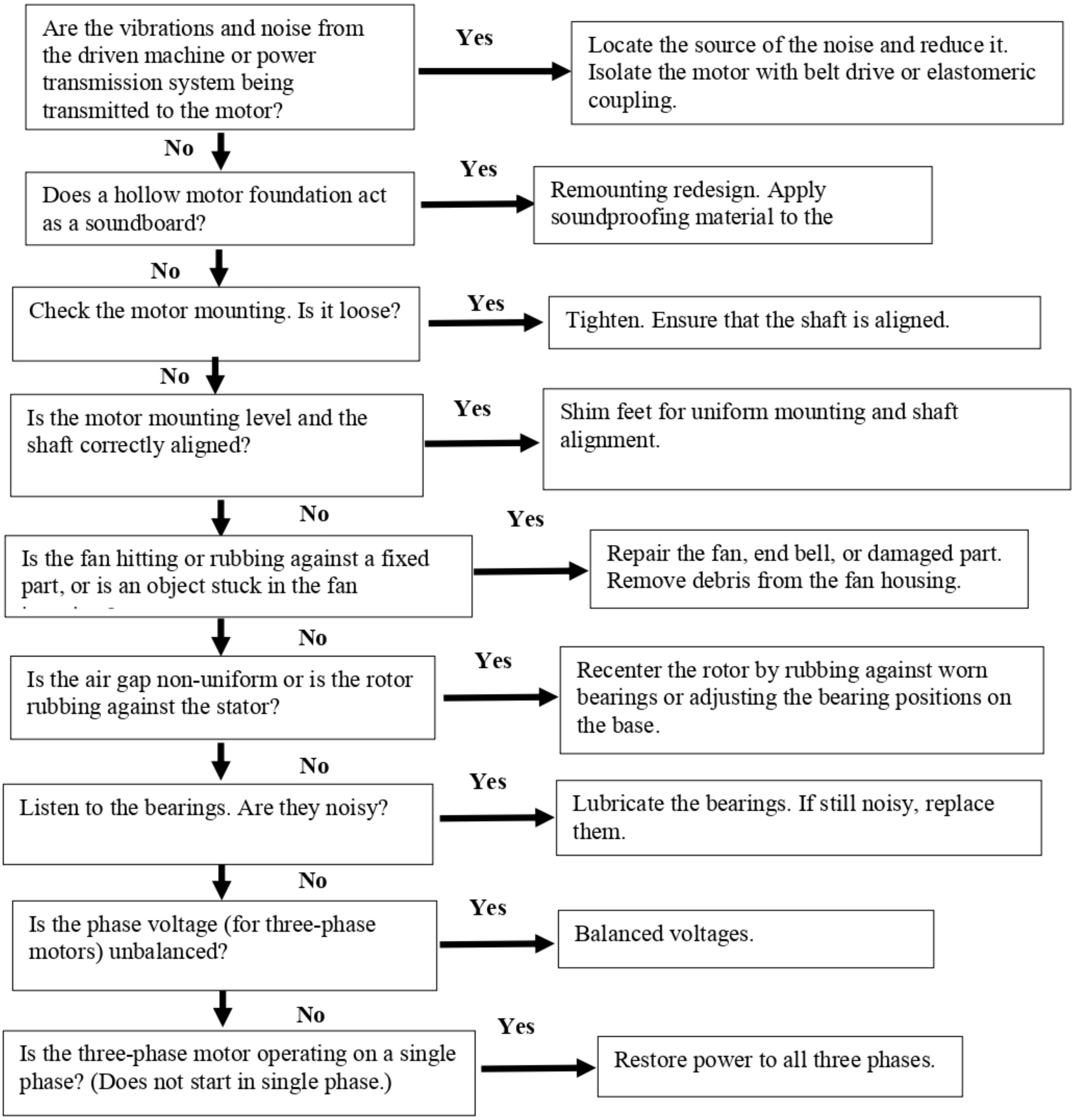
The disassembly order of each machine is determined by its construction and the aim to reuse parts in good condition as much as possible. The extent of disassembly is determined by the volume and nature of the repair work to be carried out. As an example, we can consider the disassembly and reassembly of a three-phase asynchronous motor.

1, 9, 17 - Bolts; 2, 23 - Keys; 3 - Rotor shaft; 1, 22 - Roller and ball bearings; 5, 6 - Outer and inner bearing covers; 7 - Retaining ring; 8, 21 - Flanged bearings; 10 - End shield; 11 - Stator winding; 12, 14 - Stator and rotor cores; 13 - Stator core fixing screws on the end shield; 15 - Rotor core; 16 - Fan blade; 18, 20 - Fans; 19 - Fan shroud; 24 - Rotor phase winding; 25 - Rotor feed rings; 26 - Stator winding outputs.

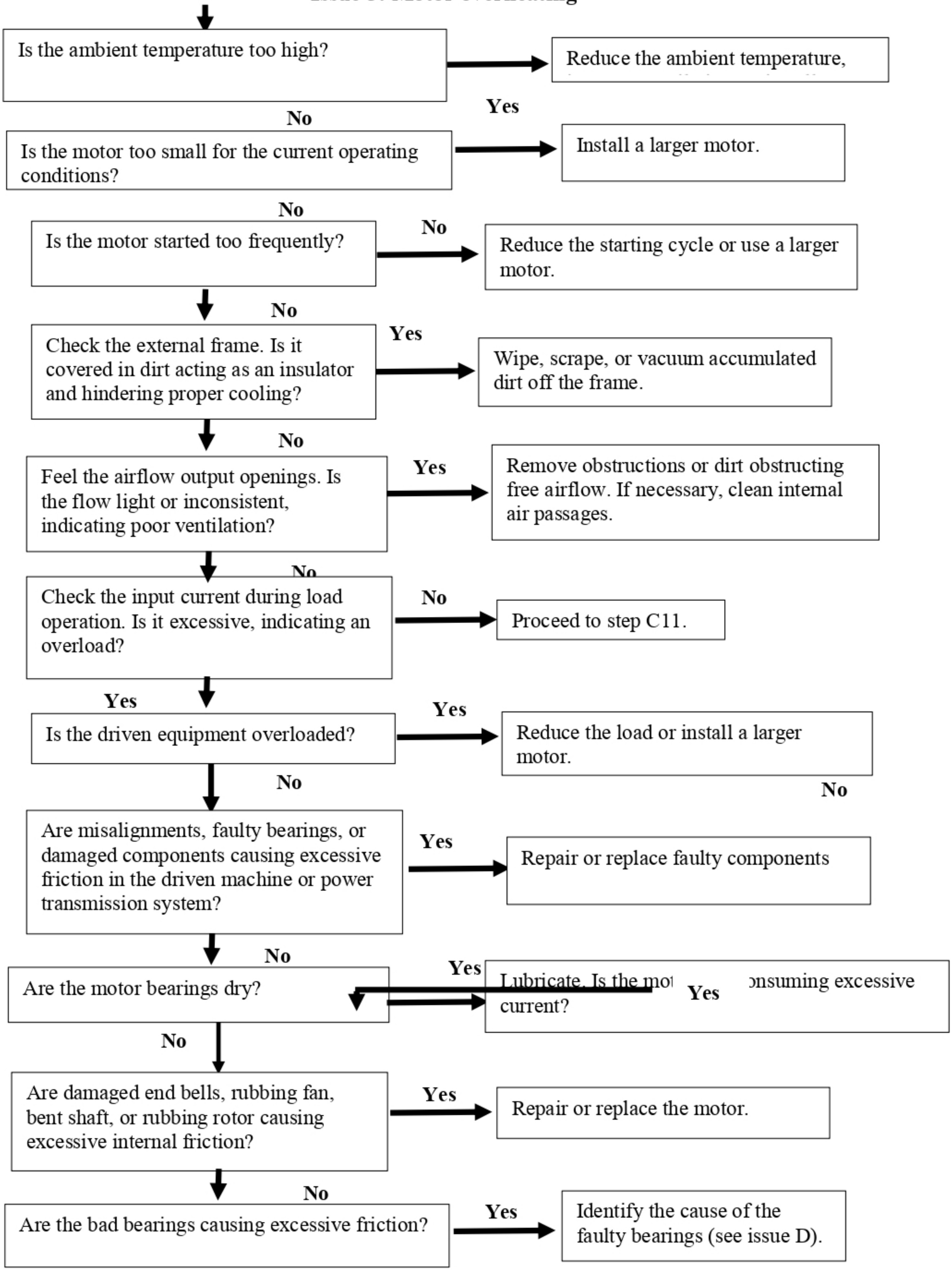
Issue 1: The motor does not start or accelerates too slowly.



Issue 2: The motor is running loudly.



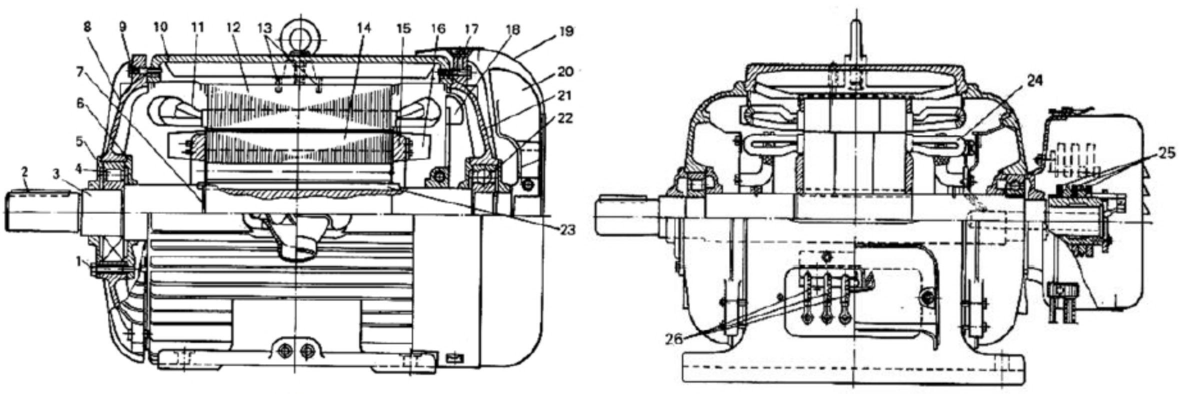
Issue 3: Motor overheating



Issue 4: The motor bearings are hot and noisy.

	Yes →
Check the loading. Is there excessive side pressure, end load, or vibration overload bearings?	Reduce the overload. * Install a larger motor.
No ↓ Is the sleeve-bearing motor mounted at an angle causing end thrust?	Mount horizontally * or install ball bearing motor.
No ↓ Are the shaft overload bearings twisted or misaligned?	Replace bent shaft or align shaft. *
No ↓ Is the end bell overload shaft loose or damaged?	Tighten or replace end bell. *
No ↓ Are the bearings dry?	Lubricate. *
No ↓ Is the bearing lubricant dirty, contaminated, or of poor quality?	Clean bearings and lubricate with appropriate grade. *
No ↓ Remove end bells. Are the bearings misaligned, worn, or damaged?	Replace.

Fig.3.1 - Troubleshooting Flowchart for an Alternating Current Machine .



(a) (b)

Fig.3.2 - Three-phase asynchronous motors from the AO2 series with short-circuited rotor (a) and wound rotor (b):

The disassembly operations are as follows:

- ✓ Mark the end shields in relation to the motor frame.
- ✓ Remove the outer fan cover (19) from the external fan (20).
- ✓ Take off the fan (20).
- ✓ Unscrew the bolts securing the flanged bearings (8) and (21) to the end shield (10).
- ✓ Unscrew the bolts securing the covers (5) and (6) of the bearing (4) from the rear flange (8).
- ✓ Remove the rear flange bearing (8) by detaching it from the end shield (10) with light hammer blows through a wooden or aluminum wedge.
- ✓ Prepare the rotor for extraction from the stator bore by gently tapping on the end of the shaft (3) with a hammer through a wedge.
- ✓ Extract the rotor once it has moved towards the front flanged bearing (21).
- ✓ Remove the front flanged bearing from the bearing fitted on the rotor shaft, after unscrewing the bolts securing the bearing covers.

When disassembling a machine with a wound rotor, first remove the feed ring casing, then the brushes and the shaft bearings using a bearing puller. Reassembly starts with the last disassembly operation, then tighten all disassembled parts and rotate the rotor by hand to ensure free rotation.

3.3.2. Repair and Component Replacement

Once the machine has been disassembled and the elements inspected during disassembly, certain components may show failures and need to be replaced with their equivalents, such as bearings, fan, starting capacitors or interference suppressors, brushes, etc. Others may need to be repaired, for example, the commutator, stator coils, pole coils, collector rings, brake linings.

3.3.3. Adjustment of New Parameters

After replacement or repair, certain parameters need to be adjusted again.

3.3.4. Verification of Equipment Operation after Troubleshooting

Before carrying out the electrical test of the equipment, ensure that all connections in the power and control circuits are securely tightened. This operation is important because a loose connection can cause various incidents: abnormal heating, voltage drop, short circuit.

a. Verification of the Power Circuit

This verification, which is done with the equipment de-energized, ensures that the wiring of the power circuit conforms to the diagram. In most cases, since the operator does not have the motors, it is performed using a test lamp.

b. Verification of the Control Circuit (wire-to-wire check)

This verification, usually done with the equipment energized, aims to ensure that the wiring of the control circuit conforms to the diagram. It also allows checking the proper functioning of the devices. To carry out the tests safely, it is essential to completely separate the power circuit from the control circuit throughout these tests.

c. Verification of the Drive Unit (motor)

After disassembly, check the condition of the coils, collector rings, bearings, and after reassembly, check the tightening of all disassembled parts. Rotate the motor shaft by hand to ensure free rotation. When powered from the network, check for noise and vibration and ensure there is no excessive heat or strange odor.

d. Overall Test

Once the power line and all external "power" and "control" circuits are connected according to the diagram, it is possible to proceed with the overall test of the equipment. The purpose of the overall test is to ensure that the operation of the equipment matches the specifications. It also allows checking for incidents resulting from operator error in machine operation.

Note:
During checks, the troubleshooter must use insulated hand tools and possibly insulated gloves, safety glasses, and insulated sole shoes. The area must be marked off to ensure safety.

Chapter 4 introduces Computerized Maintenance Management Systems (CMMS), specialized software designed to manage technical services efficiently. It highlights the general characteristics of CMMS, including its ability to construct a database covering various aspects of maintenance operations such as store items, suppliers, asset management, interventions management, and financial analysis.

Computerized maintenance management system (CMMS)

Chapter IV

Dr. Berbaoui Brahim

4.1. DEFINITION

A computerized maintenance management system (CMMS) is any software package that maintains a computer database of information about an organization`s maintenance operations This information is intended to help maintenance workers do their jobs more effectively (for example, determining which machines require maintenance and which storerooms contain the spare parts they need) and to help management make informed decisions (for example, calculating the cost of machine breakdown repair versus preventive maintenance for each machine, possibly leading to better allocation of resources). CMMS data may also be used to verify regulatory compliance. To properly control the maintenance of a facility, information is required to analyze what is occurring. Manually, this requires a tremendous amount of effort and time. A CMMS also allows for record keeping, to track completed and assigned tasks in a timely and cost-effective manner.

4.1.1 General Characteristics:

A CMMS software allows the construction of a database that includes:

- Store items,
- Suppliers,
- Management of item entries and exits,
- Purchasing management,
- Asset management (equipment and subassemblies),
- Management of corrective interventions,
- Management of preventive interventions,
- Management of intervention requests,
- Financial analysis and maintenance indicator tracking,
- Management of customer contacts and invoicing.

4.2. CMMS INTEREST

- Lower Energy Use: Keeping equipment in go

- od condition helps it run more efficiently, reducing energy consumption.
- Efficient Preventive Maintenance: Better planning can cut down the time needed for routine maintenance.
- Less Overtime: Fixing issues promptly and outside of regular hours reduces the need for overtime.
- Shorter Repair Times: Time needed for corrective maintenance decreases.
- Reduced Production Downtime: Fewer breakdowns lead to less production loss.
- Streamlined Administration: Less time is spent on managing maintenance services.
- Longer Equipment Life: Good preventive maintenance extends the lifespan of equipment.

4.3. DEVELOPMENT OF A CMMS PLAN

Developing a plan in this area involves structuring the information and organization system of the maintenance service towards various fundamental objectives.

4.3.1. Creation of maintenance policy development systems

- Definition of maintenance policies,
- Basic maintenance program,
- Maintenance schedule.

4.3.2 Maintenance Sheets

Creation of systems related to triggering preventive or corrective interventions:

- Diagnosis, search for the origin of the breakdown and possibly its cause,
- Management of requests for corrective and improvement work,
- Triggering preventive interventions.

4.3.3 Creation of modules related to work execution

- ***Preparation of Interventions*:** Getting ready for maintenance tasks.
- ***Planning Interventions and Resources*:** Scheduling maintenance activities and allocating necessary resources.
- ***Launching*:** Initiating maintenance work.
- ***Monitoring Work Execution:*** Keeping track of how the maintenance work is progressing.

- ***Creating a Maintenance Database*:** Building a history of maintenance activities.

Implementing these systems involves two complementary approaches:

- ***At the Production Site:***
    - Understanding information networks.
    - Handling data related to equipment.
    - Creating intervention reports.
    - Managing spare parts inventory.
    - Knowing the limits of interventions.
- ***At the Management or Headquarters Level:***
    - Utilizing information from other production sites.
    - Adhering to company standards.
    - Setting maintenance-related goals, like improving equipment availability and sharing experiences across units.

An effective IT strategy should prioritize:

- ***Codification:*** Establishing a standardized naming system.
- ***Database Creation*:** Developing comprehensive databases.
- ***Leveraging Existing IT Resources*:** Utilizing current technology and acquiring new resources as needed.
- ***Tracking Results*:** Monitoring outcomes to assess effectiveness.

4.4. INVENTORY OF MAO SOFTWARE

With the increasing emphasis on efficiency, speed, and technical expertise, computer-assisted maintenance is becoming more critical. Numerous software programs have been developed for this purpose, and choosing the best one requires proper classification. Here are some proposed categories:

- ***CMMS for Industry*:** Focuses on industrial maintenance management, including technical ratios, warehousing, machine sheets, project tracking, PERT, and planning.
- ***CMMS for Tertiary Sector*:** Deals with building management, encompassing planning and accounting aspects.
- ***After-Sales CMMS*:** Involves customer follow-up and analysis of customer returns.

- ***Algorithmic Diagnostic Assistance*:** Utilizes fault trees, maintenance trees, and similar methods for diagnostics.
- ***Monitoring Systems:*** Includes signal analysis, alarm systems, and conditional preventive maintenance.
- ***Expert System Diagnostic Aid*:** Uses expert systems to assist in diagnostics.
- ***Reliability Software*:** Focuses on statistics and data analysis to ensure reliability.

4.5. EXPERT SYSTEM

4.5.1. Generalities

Expert systems can help industrialists solve problems that require specialists. They do not entirely replace them but duplicate their knowledge, thus benefiting a larger number of people, skills, and expertise from these "experts". Thus, these systems must contain all the knowledge of the domain and be capable of having a resolution method like human reasoning.

4.5.2. Expert System and Maintenance

To enhance maintainability, facilitating fault diagnosis and minimizing downtime are essential. An expert system (E.S.) proves to be a valuable tool in this context. It leverages human reasoning methods and can enrich itself through users' experiences. An effective expert system should:

- ***Problem-Solving*:** Identify the cause of faults.
- ***Result Explanation*:** Clearly explain the results of its diagnostics.
- ***Learning from Experience*:** Continuously learn and adapt based on new information and experiences.
- ***Knowledge Restructuring*:** Update and reorganize its knowledge base as needed.
- ***Rule Transgression*:** Override rules when necessary.
- ***Data Relevance Judgment*:** Assess the importance and relevance of data.
- ***Competence Assessment*:** Evaluate its ability to solve a given problem and ensure it has the necessary expertise.

4.6. PRESENTATION OF FUNCTIONAL MODULES

All CMMS software packages share the same modular structure offering the same functions. However, depending on the software, the fulfilled functions are differently named, differently distributed, and differently organized. The "specifications" proposed for each module do not aim to be exhaustive (each maintenance service has its own criteria), but to draw attention to certain often neglected points. The analyzed modules are as follows:

4.6.1. "Equipment Management" Module

This module aims to describe and code the breakdown structure going from the entire fleet to be maintained to the identified and characterized equipment by their TDE (Technical Equipment File) and their history, then to their own functional breakdown. From the equipment's specific code, the module should allow: • to locate and identify a sub-assembly in the breakdown structure; • to know the functional criticality index of the equipment, its usage duration recorded by meter; • quick access to the equipment's "maintenance plan"; • to find its technical, historical, and commercial characteristics from the TDE; • to locate a mobile assembly, find its TDE and history (multi-site management) • to know its energy and lubricant consumption, etc. • to know the list of consumed spare parts; • to know the code of the operating and maintenance managers of the equipment; • access to drawings and diagrams related to the equipment contained in a document management software (outside of TDE).

4.6.2. Operational Equipment Tracking Module

Through the equipment performance tracking module, the goal is to retrieve reliability, maintainability, availability indicators, and the Overall Equipment Effectiveness (OEE) if Total Productive Maintenance (TPM) is considered or implemented. The choice of indicators predetermines the nature of the required inputs. These inputs must be able to be entered "at the machine" and in real-time, both for requests and reports.

Within the scope of technical tracking through the Availability indicator *:* The module must be capable of managing by displaying:

- Evolution graphs of Availability over monitoring periods.
- Pareto charts relating to equipment by the nature of downtime.
- Recall of MTA (Mean Time Between Failures) or MTTR (Mean Time To Repair) indicator values for the latest periods.

In the context of tracking through OEE: The module must be capable, based on operational data related to losses in performance, quality, and availability, to calculate the three rates and their product (OEE) per period, to show their evolution, and to present Analytical display of values after selection, for diagnosis. More generally, the Methods agent should be able to find through this module all the quantitative elements allowing them to deepen analysis of logistics, reliability, maintainability, or availability.

4.6.3. Module "Intervention Management"

We are aware that in scheduling, there are several procedures adapted to the nature of the work. For many small tasks, there is no work request (WR) or assignment of a number, but rather a quick recording afterward of their duration, location, and nature. It is necessary to create a library of various relevant codes related to the interveners, different statuses of the intervention. Furthermore, each piece of equipment must correspond to a library of standard codes related to equipment breakdown, triggering effect (often mistakenly called the "cause" of the stoppage), and the identified cause.

For Work Requests (WR) and Work Orders (WO): The module should allow

- Creation of a WR number.
- Timestamping of the request, with identification of the requester and the sector (client code) and the assigned urgency or deadline.
- Possible tracking of the request status by the requester (code of different statuses).

For Work Order Preparation**:** The module should allow

- Insertion of pre-established maintenance ranges.
- Reservations of tools, special equipment, spare parts, etc.
- Assignment of resources.
- Grouping of maintenance range with plans, pictograms, and diagrams extracted from a document management software.
- Automatic insertion of safety procedures related to certain sectors or equipment.
- Integration of a work group into a project manager, with Gantt and PERT charts.

For Intervention Reports: The module should allow

- Easy and quick entry (a very important criterion) of parameters and characterization of the intervention, even and especially if it is a correction of a micro-failure.
- Use by repairers of a self-service terminal, located near the intervention site, thus reducing distances and intervention entry times.
- Characterization of the intervention by equipment library codes (location, cause, etc.).
- Assignment of work to analytical accounts.
- Differentiation between intervention durations and unavailability durations.
- Chronological enrichment of the equipment's history immediately after closing the work order.
- Knowing the consumption of parts used, possibly their values.
- Drafting of free text containing remarks and suggestions from the intervener.

However, it should not give the impression of an "inquisition" but rather a need to know to better understand and improve with the help of the intervention technician.

For Outsourced Work Management: The module should allow management similar to internal preparation and scheduling procedures:

- Issuance of External Work Requests (EWR) for occasional services.
- Creation of standard contracts (technical, economic, and safety clauses) that only need to be adapted to each order.

4.6.4. Module "Preventive Maintenance Management"

The module will manage systematic maintenance through a Calendar schedule per equipment, with dates being predetermined or determined from a meter reading (or measurement in the case of conditional maintenance). Activation will be automatic, through a weekly list of operations planned for the week. Each operation will be defined by its preventive range. The module should also allow for "manual opportunity" activation, for example, by anticipating a preventive operation following an unexpected shutdown.

Module "Stock Management"

The system relies on the "item file" in stock, including "maintenance batches" per equipment and on the incoming/outgoing movements of the store. An item sheet should include:

- The item code defined by the internal organization, its name, and technical designation.
- The item code(s) from supplier(s) and the supplier code (and possibly manufacturer).
- The location code in the store.
- Substitution item codes in case of stockout.
- Linkage to equipment possessing this item.
- Unit price and automatically calculated weighted average price.
- Quantities in stock, ordered and pending.
- Replenishment method and parameters (safety stock, maximum stock, etc.).
- Dates of last movements.
- Consumption history.

The tools for stock analysis in quantity and value are:

- Classification of items in stock by value and turnover rate.
- Value of stocks by nature and by period (month by month).
- List of "dormant" items.
- List of stockout cases (unfulfilled requests).

It is important to verify certain potentialities of the module:

- The possibility or not of automatic parameter updating based on consumption.
- The possibility of having consumption profiles and plotting the ABC curve in values.
- Possibilities related to store transactions: provisional or final receipts, returns to the supplier in case of non-conformity, etc.
- Printing of reserved items on a preparation (WO number for allocation).
- Presence of an inventory screen including different item criteria.
- The possibility of conducting multicriteria searches and analyses.

Module "Procurement and Purchasing Management"

Characteristics of the maintenance function: many references and suppliers for small quantities and short deadlines. This module should, in interface with the "purchase" service software, allow easy control and management of:

- The supplier and manufacturer file with their prices linked to quantities.

- Issuing calls for tender to suppliers.
- Printing standard or customized purchase orders and tracking spending authorizations.
- Invoice control.
- Automatic generation of internal and supplier codifications (transcoding).
- Tracking of order states.
- Tracking of total, partial receipts, and refusals.
- Estimating supplier quality through reception checks and monitoring deadlines.
- Automatic generation of reminder letters for delays.

Module "Failure Analysis"

The foundation of this module is built upon historical data, automatically fed by each entry of BPT (bon de petits travaux - small work order) and OT (ordre de travail - work order) grouped by their imputation codes. Starting from a given equipment, it should enable:

- Quantitative analysis establishment through Pareto charts, considering multiple criteria (such as MTTR, TA; downtime), and various categorizations (by cause, location, type of failure, etc.) over different analysis periods (yesterday, the past week, the last three months, the year, etc.).
- Subsequently, qualitative analysis of selected critical failures, potentially in the form of Failure Mode and Effects Analysis).

The productivity of failure analysis as a tool for progress renders this function within CMMS (Computerized Maintenance Management System) strategic. It's essential to understand who, when, and how these analyses will be organized to test the software's alignment with the module's specifications.

This module serves as the foundation of RCM (Reliability Centered Maintenance).

Budget and Expense Tracking Module

Analytical management only allows for "macro-analyses" of accounts. A finer breakdown of the maintenance function should thus enable detailed analyses through CMMS, with the objective of tracking expense evolution by activity within a given budget. Several elements from the specifications need clarification, such as:

- Can the module create a new budget by modifying sections of the old one?
- Is it capable of comparing across multiple fiscal periods?
- Does it account for general service overheads?
- Can it differentiate between direct and indirect costs (quality losses, production losses, etc.)?
- Is it able to allocate costs by equipment, by client, by maintenance activity type, by failure origin, by common "fragile" subsystems across multiple equipments, etc.?
- Does it allow for comparing forecasted and actual expenses?
- Can it handle transactions in multiple currencies: francs, euros, dollars, etc.?
- Is there an option to export accounting results to accounting software?
- Does it offer a structural breakdown of the budget into consolidatable sub-budgets?
- Can it track costs to establish the Life Cycle Cost (LCC) of an equipment?

Human Resources Management Module

Specifically tailored to the maintenance service, this module will primarily serve as an aid to scheduling. It will be centered around a "technician file" capable of encompassing, for each technician:

- Qualifications, certifications, diplomas, seniority in their current position, various assignments, current assignment, etc.
- Training completed, requested, and competency assessments.
- Leave taken, requested, and accrued recovery days (data necessary for work scheduling).
- Attendance and absence times (history of work stoppages).
- Hourly rates for each qualification (for cost allocation of interventions).

It's worth noting the benefit for each technician to access their own information regarding remaining leave entitlements or general company information via the CMMS, from the workshop terminal. This serves as a factor in the acceptance of the information system.

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