

Chapter 2 : Industrial maintenance

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I Organization and management of maintenance

1. Introduction

The organization and management of maintenance encompass all activities, methods, and means implemented to ensure the proper functioning, durability, and safety of a company's equipment and installations.

2. Structure of workshops specializing in troubleshooting electromechanical converters

2.1. Definition

We define a maintenance workshop as a set of resources (technicians, intervention stations, tools, spare parts, magazines) intended to guarantee the longevity of production machines. Its role is to detect the origin of failures on a defective machine and to restore its operation (corrective maintenance).

An example of an organizational chart is given in Figure 2. This is only one possibility; each technical director is free to organize it according to their convictions. However, it does show functions that are essential for the maintenance function to be effective.

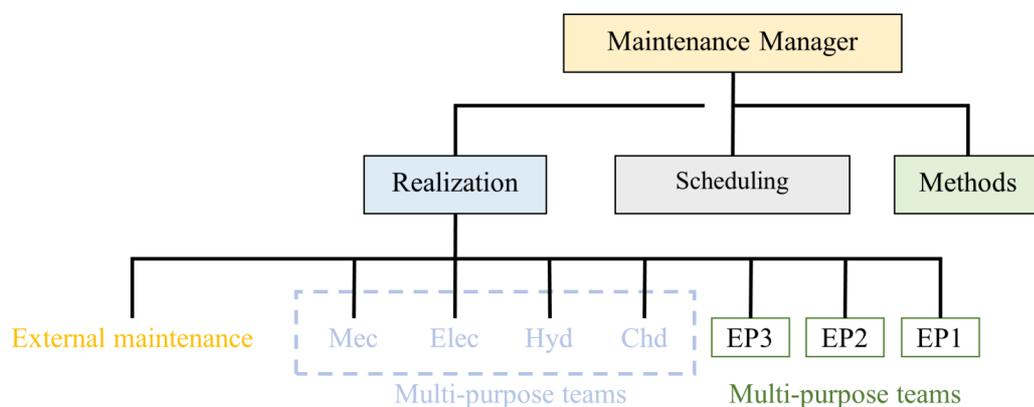


Figure 7 : Typical structure with partial sectorization

2.2. Realization function

The implementation team is multi-ethnic and has a composition adapted to the equipment. For example, it includes a team leader, an electrician, a mechanic, and a hydraulic engineer. It is responsible for carrying out maintenance tasks planned by the methods department.

The main tasks to fulfill this function are as follows:

- Install machines and equipment (reception, inspection, etc.);
- Inform staff on how to use equipment and perform upgrades;
- Apply health, safety, and working conditions guidelines;
- Manage maintenance scheduling and interventions and diagnose equipment failures;
- Coordinate maintenance interventions and restart equipment after intervention;
- Manage material resources (spare parts, tools, etc.).

2.3. Methods function

The methods function consists of optimizing all tasks based on the criteria selected when formulating the maintenance policy. This section combines four primary functions.

The first task, relating to the technical study as indicated in figure 8, consists of:

- Research improvements in the production system that are likely to provide the desired added value;
- Participate in the design of new projects while taking into account the maintenance aspect of the production equipment;
- Participate in the analysis of workplace accidents to try to remedy them by providing safety instructions first and corrective and preventive maintenance actions second.

The second task, relating to preparation and scheduling, consists of:

- Prepare the necessary instruction sheets to carry out interventions;
- Compile documentation for all types of interventions;
- Establish schedules for preventive and supply interventions (inventory management policy depends on the company's policy);
- Receive and file documents relating to the intervention.

The third task, relating to the economic and financial study, involves several stages such as:

- Manage procurement to optimize the management of raw materials required for the production process;
- Analyze maintenance, failure, and operating costs, which will have a direct impact on the maintenance policy chosen by the manufacturing company and also on production costs;
- Participate in the drafting of specifications to take into account the maintainability and reliability of the systems to be controlled;
- Manage the monitoring and execution of work to update the historical section of the machine technical file.

To fulfill the study and method function with all its components as mentioned above, the staff must have technical files summarizing the technical characteristics of the machines and wear parts; history sheets summarizing the operations already carried out, in other words, the behavior of the machine; constantly updated supplier documentation summarizing the evolution of techniques and databases (possibly).

2.4. Scheduling function

The Scheduling function enables optimal intervention at the right time, utilizing all necessary resources, including personnel, tools, preparation, technical files, safety instructions, special equipment (such as lifting equipment and scaffolding), and spare parts.

a) Role of scheduling in maintenance

Scheduling represents the "conductor" function. In a maintenance department characterized by an extreme variety of tasks in terms of nature, duration, urgency, and criticality, the absence of a conductor quickly leads to cacophony, regardless of the brilliance of the soloists. Scheduling is located between the method function, which is responsible for defining the tasks to be performed and the means to be implemented, and the implementation function, which is responsible for their execution

The term "scheduling" is often replaced by the term "planning" in businesses. But for us, and according to standards, scheduling is planning that takes into account available resources and means.

b) Scheduling missions

Responsible for the management and synchronization of internal or outsourced maintenance actions, the scheduling function has the following mission:

- Plan the timeline for the various tasks;
- Optimize the necessary resources based on deadlines and critical paths;
- Adjust workloads to known capacities;
- Start work at the chosen time, making all necessary resources available;
- Monitor the progress and completion of work;
- Manage projects (forecasting, logistics optimization, progress, and compliance with deadlines);
- Analyze gaps between forecasts and actual results.

This can be expressed in the form: plan a time t and a place x where a staff member p , equipped with tools o and materials m , will carry out task M in harmony with other related work.

3. Conditions for the success of a maintenance management program

A maintenance management program cannot achieve the desired results without proper site preparation and staff involvement. These two conditions are essential for the success of a maintenance management system. Other conditions must also be added for the successful implementation of the system:

- Set a fixed objective: This objective will help outline the guidelines for the maintenance policy. It depends significantly on the company's mission. Take, for example, a hotel company seeking customer comfort. This cannot have the same maintenance department as a mining company seeking to reduce the cost per kilogram of ore;
- Foster motivated management and staff for the implementation of maintenance;
- Employ rigorous procedures for collecting, processing, and archiving relevant data. This data will be used in the maintenance management system;
- Ensure communication between the various team members;
- Establish procedures for monitoring, evaluating performance, and displaying performance indicators.

4. Stages of designing a maintenance workshop

The design of a maintenance workshop is a critical step in ensuring the functionality, efficiency, and safety of maintenance operations. Maintenance is, therefore, a key area of focus in the search for improved company performance. However, maintenance methods and techniques are not unique and universal. Depending on the type of industrial processes to be maintained and the nature of the systems, subsystems, or equipment, specific methods will need to be implemented, taking into account the technologies deployed in each case:

- dynamic mechanical systems: motors, pumps, etc.,
- programmed digital systems,
- hydraulic or thermohydraulic systems,
- electrical or electronic systems: sensors, programmable logic controllers.

In the process of designing a maintenance workshop, we distinguish three main phases:

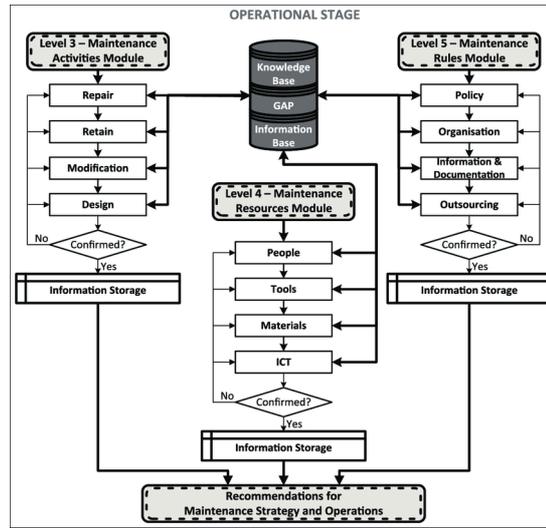


Figure 8 : Stages of designing a maintenance workshop

Sentence A: Analysis

This phase involves studying all production machines. Its purpose is to determine which machines should be prioritized for the study. Then, the functional failures of the selected machines are examined and linked to the shortcomings of the various equipment that compose them. These failures are analyzed from the point of view of failure mode, its possible causes, and its effects on the equipment's functions.

Phase B: Determination of maintenance workshop resources

In this phase, we qualitatively determine the resources that comprise the maintenance workshop, including intervention stations, technicians, and spare parts for replacement. The structural organization of the maintenance workshop is then defined.

Phase C: Maintenance Plan Development Phase

In this phase, the type of action that needs to be implemented for each piece of equipment is defined. This leads to the development of an initial schedule of the various maintenance tasks.

5. Organization of maintenance operations

Organizing maintenance operations is a crucial step in ensuring the efficiency, reliability, and durability of equipment and facilities. Here are the main aspects to consider when organizing maintenance operations:

5.1. Strategic Planning:

- Define maintenance objectives aligned with the company's overall goals.
- Establish a maintenance strategy (preventive, corrective, predictive, etc.) based on the specific needs of the equipment and facilities.

5.2. Organization of Resources:

- Allocate the necessary human, material, and financial resources to carry out maintenance activities efficiently and effectively.
- Determine the roles and responsibilities of maintenance personnel, including technicians, supervisors, and managers.

5.3. Asset Management:

- Establish a comprehensive inventory of equipment and assets that require maintenance.
- Implement an asset management system to track their performance, maintenance history, and total cost of ownership.

5.4. Planning of Interventions:

- Develop a preventive maintenance schedule to plan regular interventions based on the equipment's specific needs.
- Establish procedures to manage corrective maintenance requests responsively and efficiently.

5.5. Inventory Management:

- Manage spare parts and supplies required for maintenance to avoid extended downtime.
- Implement an inventory management system to control stock levels, replenishment, and rotation.

5.6. Documentation and Monitoring:

- Maintain accurate records of maintenance activities, including interventions performed, parts replaced, and associated costs.
- Use computerized maintenance management systems (CMMS) to automate documentation and facilitate activity tracking.

5.7. Communication and Collaboration:

- Foster effective communication and collaboration among maintenance teams, operations, suppliers, and other key stakeholders.
- Establish clear communication channels to report issues, share knowledge, and coordinate activities.

6. Study of the various breakdowns of electrical machines

Studying the various breakdowns of electrical machines is essential for understanding the underlying causes of failures and implementing preventive measures to avoid their recurrence. Here is a table that covers the common breakdowns encountered in electrical machines.

Table 3 : the common breakdowns encountered in electrical machines

6.1. Stator faults

- Short circuit between turns: overvoltage, excessive temperature, vibration, humidity.
- Short circuit between phases: high temperature, power supply imbalance, installation fault.
- Insulation fault: frequent starting, partial discharge, extreme conditions, and temperature and humidity fluctuations.
- Stator-frame fault: thermal cycling, insulation abrasion, winding fouling by the frame, presence of sharp points in the slots, shock.
- Conductor displacement: frequent starting, coil head vibration.
- Connector failure: excessive vibration.
- Frame vibration: improper installation, magnetic imbalance, power supply imbalance, overload, winding movement, contact with the rotor.

6.2. Rotor defects

- Bearing failure: improper installation, magnetic imbalance, high temperature, lubricant loss, unbalanced load, corrosion.
- Bar failure: thermal cycling, long-term transient conditions, magnetic imbalance.
- Ring failure: thermal cycling.
- Eccentricity: improper installation, magnetic imbalance, bearing failure.
- Bearing misalignment: coupling fault, improper installation, overload.
- Magnetic circuit failure: manufacturing defect, overload, thermal cycling.
- Mechanical imbalance: misalignment, short-circuit ring movement.

a) Bearing defects

- The majority of faults in electrical machines involve bearing defects, which have numerous causes, such as fatigue spalling, lubricant contamination, excessive load, or electrical causes, such as the flow of leakage currents induced by inverters.
- Bearing defects typically produce several mechanical effects in machines, including increased noise levels and the appearance of vibrations due to rotor movement around the machine's longitudinal axis. This type of fault also induces variations (oscillations) in the load torque of the asynchronous machine.
- The ultimate point of bearing failure is the rotor lock.

b) Eccentricity

The consequences of mechanical defects generally manifest themselves at the air gap through eccentricity defects. The eccentricity of an electrical machine is a phenomenon that evolves and exists from its manufacturing stage. This process involves various machining and assembly steps that cause the rotor to be decenter relative to the stator.

Three categories of eccentricity are generally distinguished:

- **Static eccentricity** – generally due to a misalignment of the rotor's rotational axis relative to the stator's axis. The leading cause is a centering defect of the flanges.
- **Dynamic eccentricity** – corresponds to a rotor rotation center different from the geometric center of the stator, but, in addition, the rotor center rotates around the geometric center of the stator [24]. This type of eccentricity is caused by deformation of the rotor cylinder, the stator cylinder, or damage to the ball bearings.
- **Mixed eccentricity** – the sum of the two cases presented above

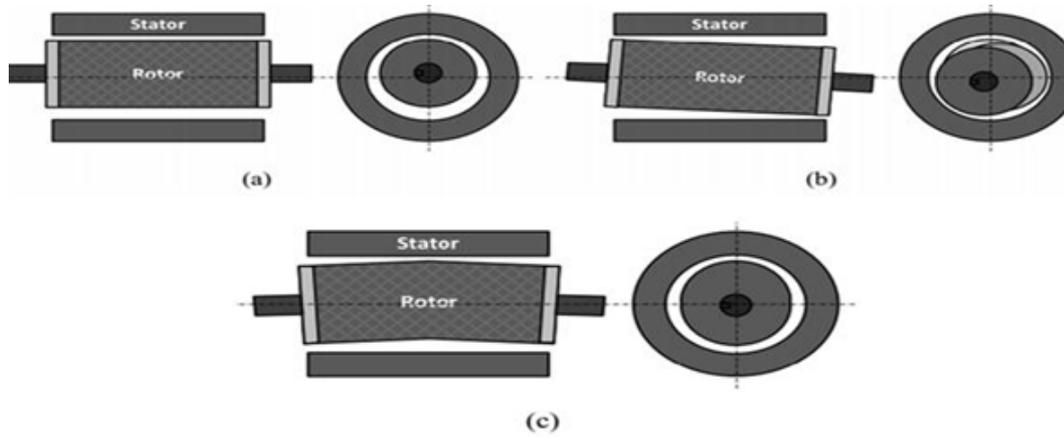


Figure 9 : Eccentricity defects

c) Busbar and short-circuit ring break faults

The same faults as in the stator can be found in a wound rotor. For an asynchronous machine with a squirrel-cage rotor, faults are limited to broken bars or broken short-circuit rings.

Breakages of bars or ring sections can be caused, for example, by mechanical overload (such as frequent starts), excessive local heating, or a manufacturing defect (such as air bubbles or poor welding). This causes oscillations in the currents and electromagnetic torque, which are more pronounced when the inertia is very high (constant speed).

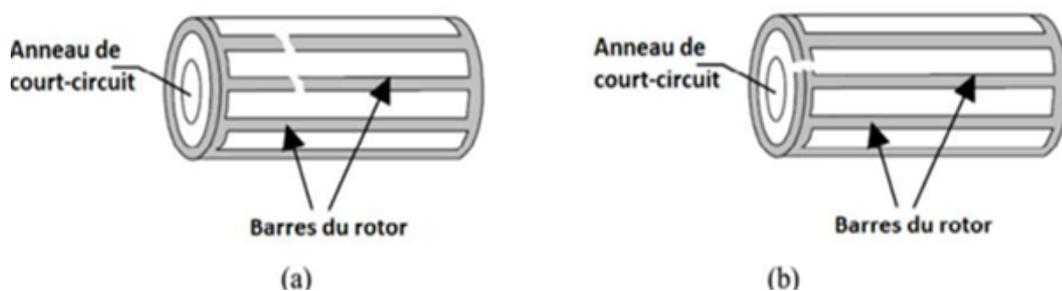


Figure 10 : Bar break and short-circuit ring faults

7. Methods for detecting faults in electrical machines

To detect electrical machine faults early and effectively, several monitoring and diagnostic methods and techniques are used.

7.1. Methods of knowledge

Knowledge methods do not use a mathematical model to describe cause-and-effect relationships. Knowledge is based solely on human experience, supported by feedback.

7.2. Analytical redundancy methods

Based on quantitative modeling of the system and exploiting the relationships between the variables of the system considered to identify the physical parameters to monitor.

7.3. Signal modeling methods

These are methods based on signal modeling, spectral content, variance, and time evolution of the measured variables. These methods mainly exploit electrical, magnetic, vibrational, thermal signatures, or instantaneous power.

8. Disassembly and reassembly technique

Disassembling a mechanism is often necessary for diagnosis, troubleshooting, or repair. A disassembly phase must be organized so that the maintenance technician performs a minimal amount of disassembly relative to the need for it, which avoids:

- Loss of time
- Risk of component damage

In maintenance, disassembly can be classified into two categories:

- Total disassembly during a complete overhaul of an installation.
- Partial or targeted disassembly to replace a defective component.

8.1. Disassembly methodology

1. Study the assembly drawing.
2. Locate the component to be disassembled in the case of partial disassembly.
3. Locate the connecting elements (screws, etc.).
4. Identify the independent subassemblies.
5. Identify the position of the parts during disassembly, if necessary.
6. Use the appropriate tools.

8.2. Disassembly vocabulary

Safety: Familiarize yourself with and apply the procedures for locking out or securing people and property:

- Affix the STOP MAINTENANCE sign.
- Lock out the system (padlocks, disconnect switches).
- Purge the system (compressed air, oil).
- Neutralize movement by locking the transmission systems (belts, chains, couplings).

Drain: Empty the contents of a mechanism of used lubricating products (oil, grease).

Clean: Remove impurities to allow examination of components or subassemblies and facilitate handling.

Mark: Mark the position of components with light center punches before disassembly or removal.

Unscrew: Use a disassembly tool to free a component (usually a threaded component, screw, or nut) without removing it.

Remove: Remove and place a component or subassembly on a support.

Unscrew: Remove a threaded component from a mechanism.

Drive: Push a component or subassembly out of its housing using a suitable tool.

Extract: The action of using an extractor.

8.3. Reassembly Vocabulary

Reassembly work: This complementary phase to disassembly can be prepared following the same principle by searching for prior works.

Engage: Replace a component or subassembly on a shaft or in a housing.

Screw: Operate a threaded element to bring it into contact with another part of the mechanism without locking it (Adjustment).

Screw: Lock - Bring the threaded element into contact with another part of the mechanism and immobilize it to break it (Tightening torque).

Refill: Introduce new lubricant into the mechanism in accordance with the specifications and quantities recommended by the manufacturer.

Refit: Replace a subassembly in the position it occupied before removal.

Adjust: Fine-tune the operation of an assembly or subassembly.

Test: Operate the assembly or subassembly to perfect the adjustments to ensure the system's performance.

Control: Check or Measure performance to ensure the conformity of an item (Spare Part).

8.4. MARKING before dismantling

Before any disassembly, it is essential to mark the motor so that it can be reassembled as it was before disassembly. There are two main criteria to follow:

The direction of the stator frame

- o The "pulley" side
- o The "fan" side

The mounting of the end plates

- o Sometimes, the mounting brackets are not equidistant from each other

Note: The marking on the fan side must be done once the cover is removed. It is also possible to mark the motor with a drawing on paper, which has the advantage of not "dirtying" the motor, especially if the motor is not standard and has a specific mounting.

8.5. Testing and diagnostics before troubleshooting

Before troubleshooting electric motors, it is crucial to perform testing and diagnostics to identify the source of the problem correctly.

a) Before dismantling

A. **Sensory controls:** Sensory testing is an inspection method that uses the human senses to detect anomalies or problems in a process or equipment, see Figure 11.

1. **Visual Inspection:** It is the use of sight to visually examine equipment, components, or products to detect any signs of damage, defects, or abnormalities.
2. **Listening:** Listening carefully to the sounds made by machinery or equipment can reveal unusual sounds, such as clicking, grinding, rubbing, or excessive vibration, which could indicate mechanical problems.
3. **Touch:** Touch can be used to detect temperature variations, vibrations, surface defects, or fluid leaks, which could indicate operational or safety issues.
4. **Olfaction:** Smell can be used to detect unusual odors or dangerous gases that could indicate leaks, electrical fires, or other problems.
5. **Taste:** (in certain particular and controlled cases): In specific situations, such as when detecting certain chemical substances, taste can be used to detect anomalies or contamination.
6. **Color Observation:** Visual perception of changes in color or shade may reveal variations or anomalies in materials or products.
7. **Observation of movements:** Observing the movements of equipment, parts, or products can help identify irregularities in operation, such as jerky movements, sudden stops, or oscillations.
8. **Observation of sparks or electric arcs:** In electrical equipment, the observation of sparks or electric arcs can indicate problems with insulation, short circuits, or component wear.



Figure 11 : Sensory checks before dismantling an electric motor

A. **Electrical control:** Electrical testing of an electric motor involves the use of various tools and methods to evaluate the electrical operation of the motor and identify potential problems. Here are some of the techniques commonly used for electrical testing of an electric motor:

1. **Voltage and Current Measurement:** Use a multimeter to measure the motor's supply voltage and the current flowing through the motor windings. Compare these measurements to the motor's specifications to verify that it is operating within normal limits.
2. **Continuity Test:** Use an ohmmeter to check the continuity of the motor windings. Ensure there are no short circuits or opens in the windings.

Equipment Used: Ohmmeter calibrated on a small scale (200 Ω).

Expected Results:

Resistance $\neq 0 \Omega$,

Resistance $\neq \infty$,

Identical resistances on all three windings.

Zero resistance indicates a short circuit.

Infinite resistance indicates an open winding.

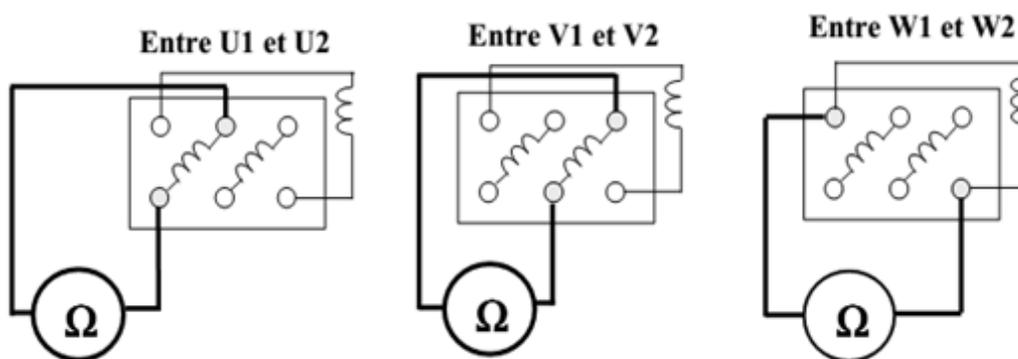


Figure 12 : Continuity Test

A. **Checking the insulation of the windings between them:** Use a megohmmeter to measure the motor's insulation resistance between the windings and the ground. Ensure it is high enough to ensure adequate insulation.

Equipment used: ohmmeter calibrated to a large scale (1 M Ω).

Expected results: very high resistance exceeding the scale (here $R \geq 1 \text{ M}\Omega$) for all three measurements.

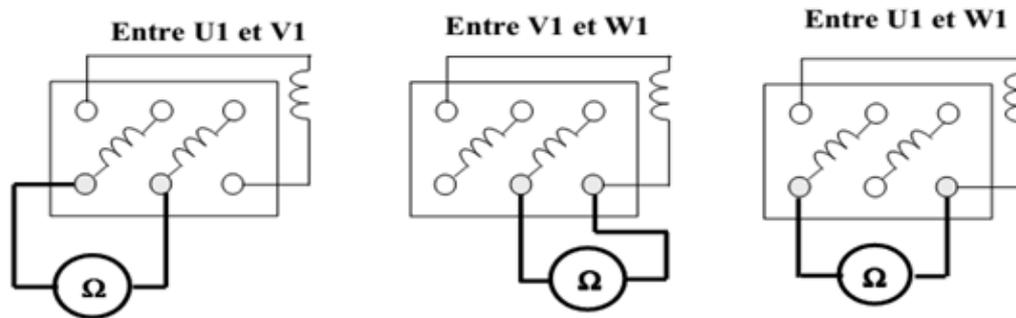


Figure 13 : Checking the insulation of the windings between them

- A. **Rotation Test:** Apply a test voltage to the motor to rotate it. Check that the motor starts and rotates in the intended direction without excessive noise or abnormal vibration.
- B. **Overload Test:** Apply a mechanical load to the motor and monitor its operating current. Check that the motor can withstand the rated load without overheating or overcurrent.
- C. **Start and Stop Test:** Test the engine to ensure it starts and stops properly in response to start and stop commands.
- D. **Inspection of protective devices:** Check the proper functioning of protective devices such as thermal relays, fuses, circuit breakers, etc. Make sure they are not tripped and are functioning correctly.
- E. **Temperature measurement:** Use an infrared thermometer or temperature sensors to monitor the engine temperature while it is running. Ensure it remains within normal limits to avoid overheating.