Mechanics

Level-V

Based on December 2024, Curriculum Version 2

Module Title: Measuring System for Specific Process

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Table of Contents

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Acronym

TTLM	Teaching Training Learning Materials
TVT	Technical and Vocational Training
LAP	Learning Activity Performance.
ASQ	American society of quality
IEEE	Institute of electrical and electronics engineers
IPR	Intellectual property rights
ISO	International standard organization
OSHA	Occupational safety and health administration
RAND	Reasonable and nondiscriminatory
SDO	Standard development organization
WBS	Work breakdown structure
NIST	National Institute of Standards and Technology
EPA	Environmental Protection Agency
DUT	Device Under Test
FMEA	Failure Mode Effect Analysis
CMMS	Computerized Maintenance Management System
EMS	Environmental Management System

Introduction to Module

This module is Measuring System for Specific Process which is used to given for Technical Trainings in TVT Institutions. It is a short briefing on the basics of measuring system, to check equipment, calibrate equipment, monitor and manage on-going technical process and monitoring environmental performance of an object. This module is designed to meet the industry requirement under Mechanics Occupational Standard, particularly for the unit of competency: **Determine Appropriate Measuring System for Specific Process.**

This module covers the units:-

- Check and Validate/Calibrate measuring equipment
- Monitor and manage on-going technical processes
- Work Programs And Schedules
- Monitor plant and resources with environmental performance
- Plan corrective action

Learning Objective of the Module:-

- Check and Validate/Calibrate precision measuring equipment
- Monitor and manage on-going technical processes/ operations
- Develop work programs and schedules and tax the costs of precision
- Monitor the condition of plant and resources with environmental performance
- Plan corrective action as required to improve specific parts of the process

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit.
2. Accomplish the Self-checks at the end of each unit.
3. Perform Operation Sheets which were provided at the end of units.
4. Do the “LAP test” given at the end of each unit.
5. Read the identified reference book for examples and exercise.

Unit One: Checking and Validation of Measuring Equipment

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Introduction to Measuring System
- Measuring Components and Integrated Operations
- Calibration Devices
- Calibration measuring equipment
- Re-commissioning equipment

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify Measuring System
- IdentifyChecking for Components
- Identify Checking for Integrated Operations
- Perform calibration measuring equipment
- Identify correct calibration devices
- Perform Re-commissioning equipment

1.1. Introduction to Measuring System

A measurement system is a collection of units of measurement and rules that relate them to each other. It allows us to measure things like length, weight, mass, temperature, and capacity. The units used to measure depend on the system used.

Measuring is a comparison of a given unknown quality with one of its predetermined standard value adopted as a unit. Measurement provides us with means of describing various phenomena in qualitative terms. It plays an important requirement role in all branches of engineering and science. There are two important requirement of the measurement:

1. The standard used for comparison must be accurate and internationally accepted and
2. The apparatus or instrument and the process used for comparison must be provable.

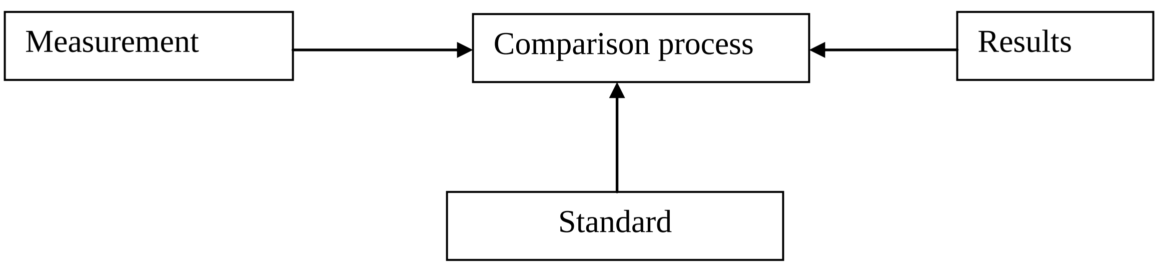

Figure 1.1. Fundamental measuring process

Measuring systems play a crucial role in various fields, including science, engineering, and everyday life. They provide the means to quantify physical properties such as length, mass, temperature, and time. Measuring systems are essential tools used to quantify physical properties in various fields, including science, engineering, and everyday activities. They help in understanding the world around us by providing precise and reliable data. A measuring system comprises three main components: the sensor (or transducer), the signal processing unit, and the display or output unit. Each of these components plays a vital role in the measurement process, contributing to the accuracy and usefulness of the data collected.

1.1.1. Measurement and measuring tools

Measuring can be considered to be the most important process in engineering. Without the ability to measure accurately, we cannot: Calibration, “Calibration is the comparing of an unknown measurement device against equal or better known standard under specified conditions".Measuring Tools: Measuring tools are classified in to two according to the capacity to measuring an object:

1. Precision Measuring Tool
2. Non- Precision Measuring Tool

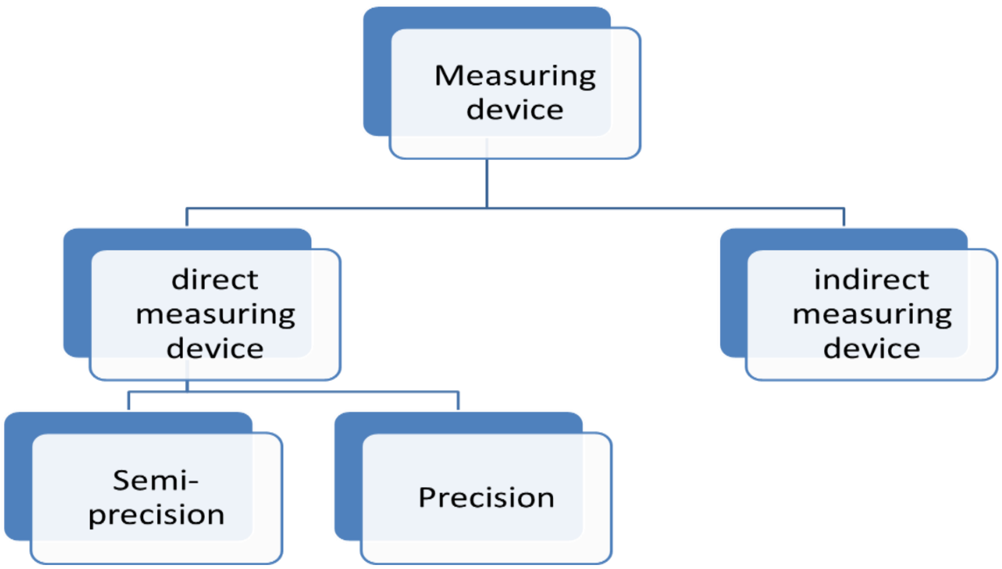

Figure 1.2. Classification of measuring devices

Precision Measuring Tool: is a tool that can be able to measure high accurate measuring results, like: Vernier caliper, micrometers, dial indicator…

Non rescission measuring tools: is a tool used to measuring a conventionally measured object, which is less amount of accuracy was existed like: steel rules, tap rules…..

1.1.2. Error and Relative Error of Measurement

The difference between the result of a measurement and its true value is known as the error of the measurement. Since a true value cannot be determined, the error, as defined, cannot be determined as well. A conventional true value is therefore used in practice to determine an error.

The relative error is obtained by dividing the error by the average of the measured value. When it is necessary to distinguish an error from a relative error, the former is sometimes called the absolute error of measurement. As the error could be positive or negative of another term, the absolute value of the error is used to express the magnitude (or modulus) of the error.

As an example, suppose we want to determine the error of a digital millimeter at a nominal voltage level of 10V DC. The millimeter is connected to a DC voltage standard supplying a voltage of 10V

DC and the reading is noted down. The procedure is repeated several times, say five times. The mean of the five readings is calculated and found to be 10.2V.

The error is then calculated as 10.2 – 10.0=0.2V. The relative error is obtained by dividing 0.2V by 10.2V, giving 0.02. The relative error as a percentage is obtained by multiplying the relative error (0.02) by 100; that is, the relative error is 0.2% of the reading.In this example a conventional true value is used, namely, the voltage of 10V DC supplied by the voltage standard, to determine the error of the instrument.

Random Error

The random error of measurement arises from unpredictable variations of one or more influence quantities. The effects of such variations are known as random effects .For example, in determining the length of a bar or gauge block, the variation in temperature of the environment gives rise to an error in the measured value. This error is due to a random effect, namely, the unpredictable variation in the environmental temperature. It is not possible to compensate for random errors. However, the uncertainties arising from random effects can be quantified by repeating the experiment a number of times.

Systematic Error

An error that occurs due to a more or less constant effect is a systematic error . If the zero of a measuring instrument has been shifted by a constant amount this would give rise to a systematic error. In measuring the voltage across a resistance using a voltmeter, the finite impedance of the voltmeter often causes a systematic error. A correction can be computed if the impedance of the voltmeter and the value of the resistance are known.

Often, measuring instruments and systems are adjusted or calibrated using measurement standards and reference materials to eliminate systematic effects. However, the uncertainties associated with the standard or the reference materials are incorporated in the uncertainty of the calibration. The error of the measurement is the difference between the result of the measurement and the true value of the quantity being measured.

Example:

- Let the true value of the object is 13.00mm
- If the measurement value is 12.95mm the error will be.

13-12.95=0.05mm

Other safety decisions: the consistency and accuracy of these inspections, measuring, and testing equipment assures improved quality and increased confidence in the results.

1.1.3. Accuracy and precision

In order to produce finished objects in the work shop the first steps before making and cutting is to measure the size of the object. Terms commonly used to describe the performance of measurements are: Accuracy, precision and error

Accuracy: accuracy is how close a measured value is to the actual (true) value.

- It is the exactness of the measuring device,
- It is defined as the degree of free from error.
- It is the lowest dimension that can be measured by using the measuring device.
- The degree of agreement between a measured value and the accepted reference value.

Precision: precision is how close the measured values are to each other. It is generally used to describe the closeness or the agreement occurring between the results obtained for a quantity when it is measured several times under the same condition.

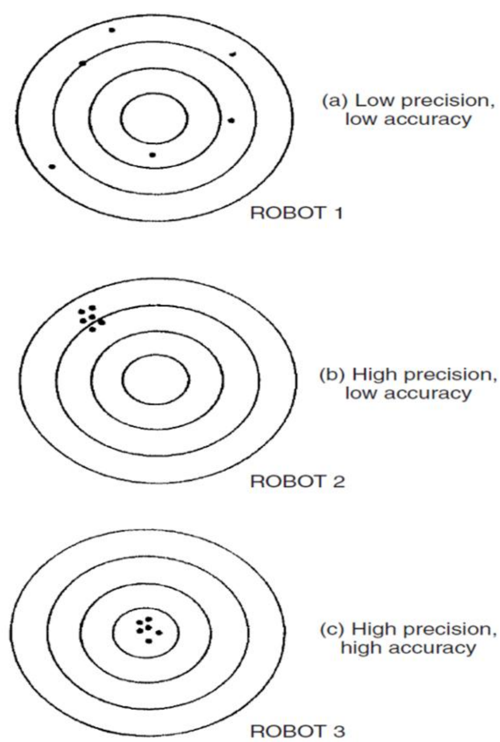

Figure 1.3. Comparison of accuracy and precision

1.2. Measuring Components and Integrated Operations

Integrated measurement is an approach to measuring and analyzing complex systems that involves combining multiple types of measurements or data sources. In traditional measurement methods, each type of measurement is taken separately and then analyzed in isolation from other measurements. However, integrated measurement takes into account all available data sources simultaneously, allowing for more comprehensive analysis and insights. This can be particularly useful in fields such as engineering, physics, and economics where complex systems must be understood and optimized.

Integrated measurement is a method of measuring multiple parameters simultaneously using a single instrument or system. It involves combining separate measurements into one coherent result that represents the overall performance of a process or system. This approach can save time and resources compared to traditional methods of taking individual measurements for each parameter.

Some examples of integrated measurement include flow rate, temperature, pressure, and level measurements in a chemical plant; or heart rate, blood pressure, and oxygen saturation monitoring in a hospital setting.

1.2.1. Types of Integrated Measurements

1. Single-point integration: This type of integration involves measuring the response at one specific point on an instrument or system being tested. It is useful for determining the accuracy and precision of the instrument or system.

2. Multi-point integration: In this type of integration, multiple points are measured simultaneously to determine the overall performance of the instrument or system. It is used in situations where it is difficult or impossible to measure at just one point.

3. Continuous integration: This type of integration involves measuring the response over time to obtain a continuous reading. It is commonly used in applications such as monitoring equipment or systems that change over time.

4. Mixed-mode integration: This type of integration combines both single-point and multi-point integrations. It allows for more accurate and precise measurements than either method alone

.1.2.2.Advantages and disadvantages of integrated measurement

Advantages of integrated measurement include:

1. Simplified setup: Integrated measurement systems can be easier to set up than separate instruments for each parameter being measured.
2. Cost savings: Integrated measurement systems can save money on equipment costs since fewer instruments are needed.
3. Easier data analysis: With an integrated system, all measurements can be taken in one place, making it easier to analyze the data.
4. Increased accuracy: Since all measurements are taken at once, there is less chance of human error or inconsistencies between different measurements.

Disadvantages of integrated measurement include:

1. Limited flexibility: Integrated measurement systems may not be as flexible as separate instruments since they cannot measure every possible parameter.
2. Complexity: Integrated measurement systems can be more complex to operate and maintain than separate instruments.
3. Higher cost: Integrated measurement systems can be more expensive than separate instruments due to the added complexity.

1.2.3. Techniques used for integrated measurement

There are several techniques used in integrated measurement, including:

1. Time-domain integration: This technique involves measuring the voltage or current of an AC signal over time to obtain its average value. It is commonly used in power systems and electronics.
2. Frequency-domain integration: In this technique, the frequency response of a system is measured by integrating the output signal over different frequencies. It is useful in analyzing the behavior of filters and amplifiers.
3. Spectral analysis: This method involves decomposing a complex signal into its individual frequency components using Fourier analysis. It is widely used in communication systems and signal processing.
4. Waveform reconstruction: This technique reconstructs the original waveform from its partial derivatives obtained through differentiation. It is often used in medical imaging and geophysical exploration.
5. Cross-correlation: This method compares two signals to determine how closely they match. It is utilized in speech recognition and radar applications.

1.2.4. Checking of measuring components

Making appropriate checks of components, for wear, loose connections or other faults. Making appropriate checks of components, for wear, loose connections or other faults is important because:

- to increase the life of the equipment before total failure takes place
- to reduce the risk of hazard

FMEA: a systematic set of activities intended to Recognize and evaluate the potential failure of a product/process and the consequential effects of failure (risk management).

- Identify actions that could eliminate or reduce the chance of the potential failure occurring (improvement)
- Document the entire process
- Needs a 'team approach' to be successful
- Objective is to systematically address all possible failure modes and the associated effects on a technical system
- The underlying equipment and components of the system are analysed in order to eliminate, mitigate or reduce the failure or the failure effect
- Best suited for mechanical and electrical hardware systems evaluations

Failure: inability to produce work in appropriate manner

Equipment / machine failure on production floor – worn out bearing, pump, pressure leaks, broken shaft, overheated machine etc.

Equipment failure in office: failure of power supply, air-conditioned system, computer network, and photocopy machine, Can diagnose (identifies) causes of equipment failures should be trained to recognize the cause of failure and excessive wear.

Table 1.1. Failure Mode Effect Analysis

Potential Failure Mode	Potential Effects of Failure	Potential Causes of Failure	Comments	Recommendations
Open indicator switch failed	Wrong indication of valve back to control system causing possible incorrect controller action to be taken	Wear and tear	Commissioning and test procedures must ensure that all diverter equipment indicators are correctly wired to the diverter control system	The integrity of the position indicators for the Diverter system equipment is critical to the logic of the control system.It is recommended that the position indicators are discretely function tested prior to commencement of each program

1.3. Calibration devices

Calibration is the process of evaluating and adjusting measurement devices to achieve true accuracy. When equipment is calibrated, you can be sure that the readings are accurate and precise. Calibration is the act of comparing a device under test (DUT) of an unknown value with a reference standard of a known value. A person typically performs a calibration to determine the error or verify the accuracy of the DUT's unknown value. Calibration devices are used to compare a device's readings to a standard reference to ensure the device is accurate and reliable:

- **Reference standard**: A device with a known value, such as another measurement device, a physical artifact, or a device that generates the quantity being measured
- **Device under test (DUT)**: The device being tested, which has an unknown value

Calibration is important in many industrial sectors, including food and manufacturing. It helps to ensure that instruments produce reliable data, which can improve product quality, safety, and regulatory compliance.

Some examples of calibration include:

- **Measuring a thermometer**: To calibrate a thermometer, you can compare its readings to a calibrated reference thermometer placed in water at its known boiling point
- **Using an automatically calibrated device**: Some devices can be automatically calibrated

When calibrating a device, it's important to check the tolerance of the device being calibrated and compare it to the device calibrating it. The calibrating device should have a larger tolerance. For example, if you're calibrating a gauge to 0.1 mm tolerance, the calibrating device should have 0.01 or more tolerance. Calibration of measuring devices deals with one of the three sources of uncertainty. Measurement devices produce data used to ensure processes are in control and capable of meeting requirements. Measurements include uncertainty, which may interfere with good decision-making. Measurement uncertainties involve three components: accuracy, precision, and random variability. The use of the stopwatch function on a personal device provides a good illustration of each.

Figure 1.4. Calibration of Measuring Devices

1.4. Calibration of measuring equipment

A calibration is a process used to compare the inspection, measuring, and test instruments to a recognized reference standard of known certified accuracy and precision, noting the difference and adjusting the instrument, where possible, to agree with the standard. Fundamental to a systematic program of instrument calibration and periodic recalibration is the idea that the instruments are not constant.

Various types of instruments are used to inspect, measure, and test products or their components. It provides valuable information to assess the conformance of a product to a standard or a specification and to assist in the "fitness-for-use"

Instrument calibration is one of the primary processes used to maintain instrument accuracy. Calibration is the process of configuring an instrument to provide a result for a sample within **an acceptable range.** Eliminating or minimizing factors that cause inaccurate measurements is a fundamental aspect of instrumentation design.

Calibration of equipment needs to be carried out on a regular basis. This is because instruments tend to deviate owing to hard operating conditions, mechanical shocks or exposure to extreme temperature or pressure. Frequency of calibration would depend on the tolerance level. When the objective of the measurement is **critical** calibration would need to be carried out more frequently and with great accuracy.

Calibration of an instrument is the process of **determining its accuracy.** The process involves obtaining a reading from the instrument and measuring its variation from the reading obtained from a standard instrument. Calibration of an instrument also involves adjusting its precision and accuracy so that its readings come in accordance with the established standard.

To assure accuracy in instrument calibration, it is vital to ensure that each component of the measuring instrument is conforming to its specified standard. Regular equipment calibration carried out in a set format helps you obtain valid data and operate in a safe working environment.

Extended use, wear, design, environment, and time are some of the factors that degrade the instrument performance and its accuracy. A calibration system is designed to assure the verification, maintenance, and validation of the instrument's desired accuracy and precision.

Selection of appropriate inspection, measuring, and test equipment is an integral part of inspection planning, and success depends on such factors as measurements to be made and accuracy requirements. Included are hardware items, such as instruments, fixtures, gauges, and templates, software for computer-aided inspections, and process instrumentation. Also included in all testing equipment used in the development, manufacture, installation, and servicing of a product.

1.4.1. Types of Calibration

Pressure Calibration: under pressure calibration service gas and hydraulic pressure are typically measured across a variety of sectors.

Temperature Calibration: temperature calibration is carried out in all processes where temperature readings play a critical role. Temperature calibration is carried out in a controlled environment.

Flow Calibration: flow calibration services needs to be carried out on a routine basis for flow meters that check Electrical calibration

Electrical calibration is required for checking the veracity of electrical instruments across a diverse range of industries. Under electrical calibration elements such as current frequency, resistance and voltage are checked. Product or feedstock quality and quantity, fuel/energy quantity or function in a critical process.

Mechanical calibration: mechanical calibration services are invoked for a range of mechanical instruments. Under this process a number of elements such as mass, force, dimension, angle, volume, flatness, torque and vibration are calibrated in a temperature controlled facility. Some of the most frequently tested instruments for mechanical calibration include:

- Accelerometers
- Load Cells & Force Gauges
- Micrometers, Vernier, Height Gauges
- Scales/Balances
- Torque Wrenches & Screwdrivers
- Weight & Mass Sets

1.4.2. Equipment Calibration

Calibration of equipment is not just desirable, it is rather a necessity. All measuring instruments, whether they are used in factories, laboratories or at home, need to be calibrated on **a periodic basis** to ensure they are offering accurate results. However, in factories and laboratories, measurement results are usually of a critical value. Deviation from accuracy can not only affect productivity but also cause threat to the life of workers. Hence, it is imperative that instrument calibration be carried out carefully and at regular intervals.

1.4.3. Equipment Validation

Equipment validation comprehensively establishes in a documented way the instrument is working accurately. A validation process offers evidence that the components critically contributing to accurate functioning of the equipment consistently meet the predefined specifications and operational attributes. The process involves keenly identifying and quantifying each constituting element that has a bearing upon the result produced during analytical measurements. Validation is a commercial grade assurance that internal malfunctioning of the equipment will not adversely impact the result's quality.

Equipment validation is the characteristic of assurance that certifies the accurate functioning of an instrument under the prescribed range of operating environment and conditions, while steadfastly adhering to the correct operating specifications.

Validation facilitates meeting industry and regulatory standards set down to govern the accuracy of instrumentation. The validation protocol's format and content can be tailored to comply with the user's requirements. This further helps in assuring the accuracy level to a high degree.

Validation generates confidence in the analytical results generated by the equipment. This is critical as even a minor deviation from the standard operating course can bring about failures having the potential of inviting an industrial catastrophe or mishap.

Validation is the recognized means of demonstrating that the functioning of each constituent element of equipment complies with specification. This confers absolute confidence in the analytical measurements. It ensures that the accuracy, reliability and perfection of the equipment are not compromised in any manner. However, to maintain the accuracy of an instrument in use, instrument calibration is needed.

1.4.4. Difference between Calibration & Validation of Equipment

Equipment calibration deals with assessing the accuracy of equipment's results by measuring the variation against a defined standard to decide upon the relevant correction factors. The equipment is accordingly adjusted to fine tune its performance to tally with accepted standard or specification.

Equipment validation is a documented assurance that each constituent of the equipment is complying with the manufacturer's specification under defined operating environment and standard. This is pulled off by checking the performance against traceable control standards.

1.4.5. Calibration System Requirements

Requirements and control of accuracy and precision of inspection, measuring, and testing equipment is an important element of a company's Quality System. In order to improve the consistency of these requirements, they are incorporated in specific standards that are often referenced contractually by the purchaser of the products and services.

The importance and emphasis on international Quality Systems Standards such as ISO-9000. Clause 7.6 (Control of monitoring and measuring devices) of ISO-9001-2008 standard describes the requirements for a calibration system. The requirements for the calibration laboratories are covered in ISO/ Guide 17025 and include requirements such as

- Legal identity
- Impartiality,
- Premises,
- Equipment, and
- Technical competency of personnel, procedures, and self-assessment.

1.5. Re-commissioning equipment

To understand the way of re commissioning equipment that Work is done regularly to keep equipment, buildings and grounds in good condition and working order

Maintenance is a set of organized activities that are carried out in order to keep an item in its best operational condition with minimum cost acquired.

Re-commissioning measuring equipment involves several key steps to ensure that the instruments are functioning correctly and providing accurate measurements after a period of inactivity or after maintenance.

1.5.1. Steps for Re-Commissioning Measuring Equipment

Visual Inspection

- Check for physical damage or wear.
- Ensure all components are intact and properly connected.

Calibration Check

- Verify that the equipment is calibrated according to manufacturer specifications.
- Use standard reference materials to compare measurements.

Functional Testing

- Perform tests to ensure the equipment operates as intended.
- Check all modes and settings.

1.5.2. Diagnosis and Troubleshooting Instrumentation and process control system

Diagnosis is the systematic approach to find where and what type of fault occur in a system. Trouble shooting/repair is the activity of correcting the fault and enabling the system to restore to its normal operation condition. To find fault of a system, systematic and logical approach should be followed. The fault of the system should be observed and tested on each sub-system of input and output by following logical order (flow) of the process in the system. If a closed control system has got a problem of control, check the presence of correct amount of input and out of sensor and its sub components (transducer, conditioning unit, transmitter, and transmission line), actuator, controller.

Self-Check 1.1.

Part I: Multiple Choice Questions

1. What is a fundamental component of a measurement system?

A) Calibration device C) Output unit

B) Signal processing unit D) All of the above

2. Which type of error arises from unpredictable variations?

A) Systematic error C) Absolute error

B) Random error D) Relative error

3. What is the purpose of calibration?

A) To increase the cost of equipment C) To replace old measuring tools

B) To ensure devices provide accurate and precise readings D) To simplify measurement processes

4. Which type of measurement integration involves measuring multiple points simultaneously?

A) Single-point integration C) Continuous integration

B) Multi-point integration D) Mixed-mode integration

5. What is the primary difference between calibration and validation?

A) Calibration is for accuracy; validation is for compliance.

B) Calibration adjusts readings; validation checks standards.

C) Calibration is done periodically; validation is a one-time process.

D) Both are the same process.

Part II: Short Answer Questions

1. Define a measurement system and its components.
2. What are precision measuring tools? Give two examples.
3. Explain the term "systematic error."
4. What is the role of the Failure Mode Effect Analysis (FMEA)?
5. Describe the importance of regular calibration of measuring equipment.

Part III: Matching Type Questions

Match the terms in Column A with their definitions in Column B.

Column A Column B

1. Unpredictable variations in measurement	A. Calibration
2. A systematic approach to identify potential failures	B. Systematic Error
3. Process of adjusting a device to ensure accuracy	C. Random Error
4. Combining multiple measurements for comprehensive analysis	D. Integrated Measurement
5. Consistent bias in measurement results	E. FMEA

Operation Sheet 1.1.

Operation title: Checking of measuring components

Purpose: To Checking of measuring components using FMEA.

Conditions or situations for the operations:

- Use proper data
- Selection of equipment
- Selection of working process

Equipment Tools and Materials:

- Measuring devices
- Testing equipments

Quality Criteria: to properly checked the measuring devices and equipments and the consequential effects of failure (risk management) using FMEA

Operation steps

- Identify actions that could eliminate or reduce the chance of the potential failure occurring (improvement)
- Document the entire process
- Needs a 'team approach' to be successful
- Objective is to systematically address all possible failure modes and the associated effects on a technical system
- The underlying equipment and components of the system are analysed in order to eliminate, mitigate or reduce the failure or the failure effect
- Best suited for mechanical and electrical hardware systems evaluations

LAP Test 1.1

Practical Demonstration

Instruction: Checking of measuring components

Task 1: Identify the measuring devices/equipments

Task 2: Identify the way of checking the measuring systems

Task 3: identify the potential failures of the measuring devices using FMEA.

Table. Failure Mode Effect Analysis

Potential Failure Mode	Potential Effects of Failure	Potential Causes of Failure	Comments	Recommendations

Unit Two: On-going Technical Processes Monitoring

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Range of on-going technical processes
- Measuring Equipment and Process
- On-going technical processes Documentation

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Analyzing a range of on-going technical processes
- Identify measuring equipment and process
- Documenting on-going technical processes

2.1. Range of on-going technical processes

The measuring range is the range of measured values for a measured, in which defined, agreed, or guaranteed error limits are not exceeded. It is delimited by a lower and an upper measuring range limit that define the measuring span. In the world of measurements, the range refers to the difference between the highest and lowest values observed. It's a simple way to express the spread or extent of a particular measurement. Think of it like the distance between the two ends of a measuring tape it tells you how much space the measurement covers.

Ongoing technical processes monitoring can help organizations: Identify performance bottlenecks, Identify system failures, Identify resource constraints, Optimize resources, and Ensure smooth process execution.

Ongoing monitoring is the process of regularly reviewing and assessing your business operations to ensure compliance with regulations, identify potential risks, and make necessary adjustments to mitigate those risks.

Ongoing monitoring can also refer to the process of regularly reviewing and assessing a business's operations to ensure compliance with regulations and identify potential risks. This process can help organizations identify and mitigate financial crimes and other risks.

Ongoing monitoring, also referred to as continuous monitoring, is a vital process in the any manufacturing company's compliance program. It involves regularly checking and verifying customer information to ensure ongoing compliance with regulatory requirements and to detect any illegal or suspicious activities.

Monitoring is the systematic and routine (repeat habit) collection of information from projects and programs for four main purposes:

1. To learn from experiences to improve practices and activities in the future.
2. To have internal and external accountability of the resources used and the results obtained;
3. To take informed decisions on the future of the initiative;
4. To promote empowerment of beneficiaries of the initiative.

Monitoring allows results, processes and experiences to be documented and used as a basis to steer decision-making and learning processes. Monitoring is checking progress against plans. The data acquired through monitoring is used for evaluation.

Monitoring involves:

Establishing indicators of efficiency, effectiveness and impact;

- Setting up systems to collect information relating to these indicators;
- Collecting and recording the information;
- Analyzing the information;
- Using the information to inform day-to-day management.
- Monitoring is an internal function in any project or organization.

2.2. Measure equipment and process

The selection of measuring equipment includes in its scope activities both associated with choosing the method of realization of measurement process and also the need to define the characteristics of the required equipment to assemble the ships propulsion system.

Appropriate analysis of criteria gives the opportunity to select the measuring equipment which may allow to provide the service of measurement and gives the results of measurement with required accuracy and reliability. Measuring equipment which is used affects the quality of the entire production process and thereby on competitiveness and customer confidence to the company.

2.2.1. Classification of Analytical Instruments

Analytical instruments are devices that measure the composition, structure, or properties of a substance. They can be used to determine the identity and content of elements, and the chemical makeup of a sample. The basic components of analytical instrument are classified in to two:

1. **Instrumen**t: A device used to collect the scientific data and measurement of results
2. **Equipment:** Refers to the various supporting tools used for performing analysis in the laboratory.

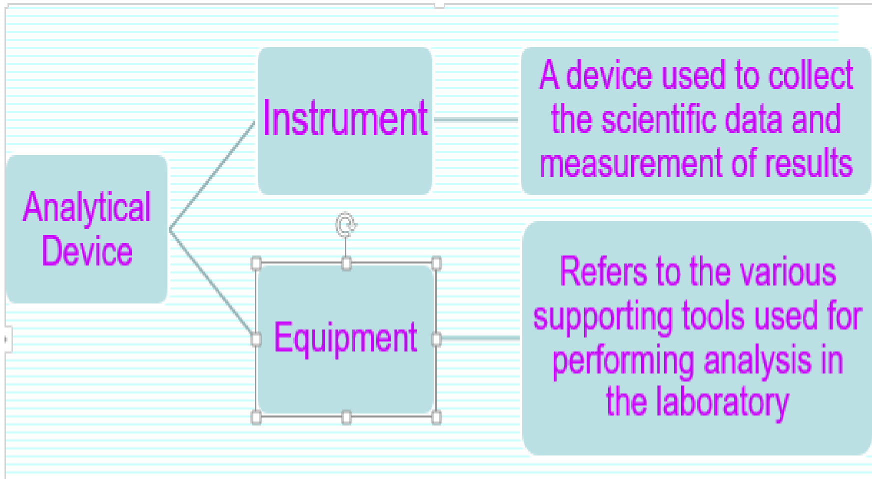

Figure 2.1. Classifications of Equipment/Instrument

The collective analytical measurement instruments, in conjunction with firmware, assembled to perform a mechanical process and a device or collection of components that perform a process to produce a result.

2.2.2. Criteria of the Selection Of Measuring Instruments

In all types of measurements the proper selection of measuring instruments plays an important role. The selection is decided by the criteria for both technical and metrological, which are linked to the characteristics of measuring instruments and devices. The analysis of subsequent criteria of selection of measuring equipment allows distinguishing from many measuring equipment those which are the best for the realized measurement process. In mechanical engineering criteria for rational selection of measuring instrument are:

- Kind of measured dimension,
- Means of determining and fixing the measured item,
- Means to receive information about the measured,
- The possibility to develop a performance result of a measurement,
- The possibility of a direct transfer the measurement's results to the data analysis system,
- Value of a measured,
- Optimal uncertainty of measurement.

When selection the measuring instruments is taken into account the required accuracy of the product, batch size, degree of mechanization and automatization, measurement and economic characteristics of the measuring tool must be kept in mind.

2.2.3. Selection of Measuring Equipment

Selection of measuring equipment for the measurement process and the selection of its properties in accordance with the requirements is provided through a well-organized measurement management system. The scope of this system, which can differentiate the supervision of measuring equipment, can be divided into three phases:

1. Planning, in which needs are defined in terms of access, the use of measurement systems, requirements, properties, time and place and quantity of the necessary equipment, and with this range of purchases and the necessary training. Information necessary for planning are derived from all areas of production.
2. The management of measuring equipment, which includes the disposition and management of data related to the equipment, evaluation and data analysis of metrological confirmation system, as well as documenting the activities of its control.
3. Control of the characteristics include an evaluation of purchased equipment and systematic monitoring of its metrological characteristics. The scope of these activities is checking equipment purchased or repaired for fulfilling the established requirements.

2.3. On-going technical processes Documentation

Documentation is one of the systems which are used to communicate, instruct and record the information for any reference or operational purpose. They are very useful for representing the formal flow of the present system. With the help of documentation it is very easy to track the flow of the system's progress and the working of the system can be explained very easily.

System documentation describes the system itself and its parts. It includes requirements documents, design decisions, architecture descriptions, program source code, etc. User documentation covers manuals mainly prepared for product end-users and system administrators.

Process documentation is the act of capturing or documenting all of the steps in a particular task. Ideally, it should happen in real time. As employees perform a task, they document each step they take. The four kinds of documentation are:

- Learning-oriented tutorials.
- Goal-oriented how-to guides.
- Understanding-oriented discussions.
- Information-oriented reference material.

Self check 2.1.

Part I: Multiple Choice Questions

1. What does the measuring range define?

A) The accuracy of the measuring equipment

B) The difference between the highest and lowest values measured

D) The cost of measuring equipment

2. What is the main purpose of ongoing technical processes monitoring?

A) To reduce employee workload

B) To identify performance bottlenecks and optimize resources

C) To increase manufacturing costs

D) To eliminate all risks

3. Which of the following is NOT a criterion for selecting measuring instruments?

A) Kind of measured dimension C) Optimal uncertainty of measurement

B) Color of the instrument D) Means of determining the measured item

4. What are analytical instruments used for?

A) Measuring temperature only

B) Measuring the composition, structure, or properties of a substance

C) Performing mechanical work

D) Storing data

5. Which phase is NOT part of the measurement management system?

A) Planning C) Documentation of financial transactions

B) Management of measuring equipment D) Control of characteristics

Part II: Short Answer Questions

1. Define ongoing monitoring in the context of technical processes.
2. What are the basic components of analytical instruments?
3. List two advantages of documenting ongoing technical processes.
4. What is the significance of selecting appropriate measuring equipment?
5. What are the four kinds of process documentation?

Part III: Matching Type Questions

Match the terms in Column A with their corresponding descriptions in Column B.

Column A	Column B
1.Evaluating the performance of measuring instruments	A. Measuring Range
2. The act of capturing all steps in a task	B. Ongoing Monitoring
3. Range of measured values within defined limits	C. Analytical Instruments
4. Devices measuring composition or properties	D. Selection Criteria
5.Regular assessment of operations and compliance	E. Process Documentation

Unit Three: Work Programs and Schedules

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Human and Physical Resources
- Maintenance Schedule
- Purchase Schedule
- Taxing Costs
- Set precision

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify human resources and physical resources
- Create a maintenance Schedule
- Create a purchase Schedule
- Identify Taxing costs
- Setting precision

3.1. Human and Physical Resources

Resources are products, services or systems necessary to produce an outcome(s) that satisfies the needs of a person, group or organization. Resource requirements are implemented to ensure the accurate and timely development and deployment of products to meet mission-critical objectives and life safety requirements.

The first step is to produce a detailed list of all the individual resources needed to complete the project. Start by listing each of the major resource groups (eg: Labor, **e**quipment and Materials), then list the individual components of each group.

- **Labor:** identify all the roles responsible for or involved with the completion of any activity specified in the Project Plan. Remember to include any external or contract staff that will be brought in for specific tasks.
- **Equipment:** identify all the equipment which will be needed to complete the project, eg: office equipment (PCs, photocopiers, mobile phones etc.), telecommunications equipment (cabling, switches etc.) and machinery (heavy and light machinery).
- **Materials:** consumables (eg: photocopy paper, stationery, ink cartridges) are often needed to complete project activities. Other materials (eg: wood, steel and concrete) may be needed to produce physical deliverables. Draw up a detailed list of all the materials required to complete the project. This should be as accurate as possible, since it will be used to produce the *Resource Schedule* and *Expense Schedule*. Identifying required human resources and physical resources for the ongoing process

Calibration system should have Technical competent personnel these human resources may be employed through

- Awards
- contracts
- subcontracts
- may include professionals, Para-professionals, trade and non-professionals.

Training

Since it is people who are going to store and handle the measuring instruments for calibration, the individuals involved should be provided with suitable training. This training should be in line with the following elements:

- Training should be given to all newly recruited personnel in a laboratory;
- Trainers could be the senior laboratory personnel, professional trainers or experts from the instrument manufacturers or suppliers;
- Such training should not be a onetime affair but should be conducted periodically.

3.2. Maintenance and system Scheduling

Maintenance scheduling is a strategic process within maintenance management aimed at organizing and executing tasks such as equipment inspections, preventive maintenance, and corrective repairs. This systematic approach ensures that all necessary maintenance activities are performed in a timely manner, which prevents unforeseen equipment failures.

The primary objective of maintenance scheduling is to minimize downtime while maximizing the efficiency and lifespan of equipment. By adhering to a well-defined schedule, organizations can achieve a higher level of reliability and performance. This ensures that machinery and assets continue to function without issues over time.

3.2.1. The Importance of Maintenance Planning and Scheduling

Finding synergy between maintenance planning and scheduling is the backbone of an effective maintenance strategy. Planning identifies what maintenance tasks need to be executed while scheduling pinpoints the best timing for these activities. The collaboration is vital for preventing unexpected equipment breakdowns while managing maintenance costs.

Moreover, this harmony in process means that maintenance operations are conducted with maximum efficiency. Nailing this will significantly minimize downtime. Through meticulous planning and scheduling maintenance, organizations will optimize their equipment. In turn, that supports continuous production – improving the overall product and productivity.

3.2.2. Best Practices for Scheduled Maintenance

Efficient maintenance is not about fixing what is broken. It is about preventing problems before them start. Utilize these best practices to harness the full potential of scheduled maintenance.

1. Conduct Regular Inspections

Know what is wrong before it happens. The foundation of any maintenance program is the regular inspection of equipment. These inspections should be systematic, utilizing detailed checklists to make sure no step is overlooked. Determine the frequency of these inspections based on the equipment's usage rates and the manufacturer's recommendations. By identifying issues early, maintenance teams can address them before they escalate into costly repairs – or result in equipment downtime.

2. Implement Preventive Maintenance

Foster an environment that looks to solve problems now – not later. Preventive maintenance software schedules maintenance activities for equipment before issues arise. The proactive approach follows equipment manufacturers' maintenance guidelines and keeps meticulous records of all maintenance activities and inspections. This transparency supports a culture of accountability and continuous improvement while providing valuable data for future planning.

3. Equipment Monitoring

Smart organizations continuously analyze their operations. Use sensors and monitoring systems to regularly track equipment performance. This data is vital for condition-based maintenance, where maintenance tasks are performed based on the actual condition of the equipment rather than on a predetermined schedule. Combine this information with predictive maintenance techniques to accurately forecast potential failures. This means maintenance can be scheduled at the most opportune times while avoiding unplanned downtime.

4. Staff Training and Communication

Knowledge is power – and empowering. A well-trained maintenance team is the fuel that powers maintenance programs. Training should cover routine procedures along with troubleshooting and emergency response. Keep open lines of communication between the maintenance team, operations staff, and management. Share insights and action points that can lead to process improvements. Encourage feedback from staff to build more innovative solutions and a more cohesive maintenance strategy.

5. Continuous Improvement

Look how to get better every day. The maintenance process should be dynamic, with regular reviews of schedules, procedures, and outcomes. Incorporate learning's and feedback from maintenance staff and equipment operators. Know that there is always an opportunity to become more efficient and effective. Embrace and utilize modern technologies and techniques to drive innovation and improve equipment performance.

6. Utilize Maintenance Scheduling Software

Do not ignore the potential of technology. For instance, a Computerized Maintenance Management System (CMMS) will transform maintenance scheduling from a complex, time-consuming process into a streamlined operation. Key features of maintenance management software include automated scheduling of maintenance tasks, easy access to maintenance records, and the ability to generate reports and other useful data. Integrate the software with other systems – such as inventory management or operational monitoring – to provide a comprehensive view of the organization's maintenance needs and performance.

3.2.3. Benefits of Maintenance Scheduling

Once best practices are implemented, organizations will start to see the benefits of their investment. Here are a few that leaders can expect.

The ability to capture, process, analyze, and act on data in real time allows brands to automate demand forecasting and supply-chain planning to optimize everything from inventory assortment to customer engagement and promotions."

1. Reduced Downtime

Stay ahead of problems and avoid issues. Maintenance scheduling stays ahead of equipment failures and therefore minimizes unscheduled downtime. By systematically planning maintenance activities, it ensures machinery undergoes necessary upkeep before breakdowns occur. This proactive approach reduces major failures and ensures an uninterrupted operational flow. The ripple effects can be profound – enhancing productivity while making sure production targets are consistently met.

2. Improve Equipment Performance

Tap the full potential of resources. Regularly scheduled maintenance is key for maintaining equipment at its peak performance. Through routine care, each piece of equipment avoids any major setbacks while improving the lifespan of the machinery. This means a significant reduction in replacements or other unexpected costs. It is about optimizing equipment to the highest level while getting the most out of equipment over its life.

3. Cost Savings

Do not spend money that does not need to be spent. Maintenance scheduling helps avoid expensive repairs due to equipment neglect or sudden failures. It allows for the early detection of minor issues and prevents them from evolving into more severe and costly problems. The sum of these savings can contribute significantly to an organization's financial health. Use those funds for more strategic investments.

4. Streamline Safety Checks and Compliance

Keep team members safe and remain compliant. Routine safety checks and verifications ensure that all equipment adheres to the highest safety standards. That reduces the likelihood of accidents while providing a safe work environment for employees. It also streamlines compliance with tricky industry regulations. That protects an organization from potential fines or legal complications. It fosters a culture of safety and compliance that increases overall efficiency while considering the well-being of every individual on the production floor.

3.2.4. Classified maintenance

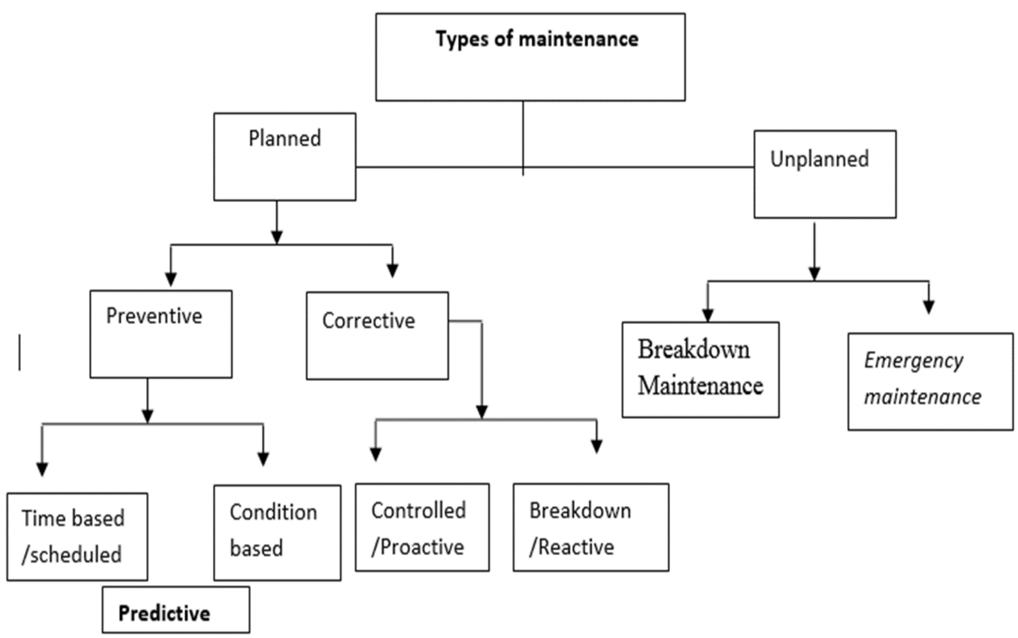

Figure 3.1. Classification Maintenance

Reactive Maintenance: Maintenance work performed as a response to a failure, breakdown, or other urgent equipment situation.

Proactive maintenance performed a head off failure and breakdown

1) Unplanned Maintenance: "The maintenance carried out to no predetermined plan."

2) **Planned Maintenance:** "The maintenance organized and carried out with planning, control and the use of records to a predetermined plan."

Preventive Maintenance (PM)

Preventive maintenance is planned maintenance of plant and equipment that is designed to improve equipment life and avoid any unplanned maintenance activity. PM includes painting, lubrication, cleaning, adjusting, and minor component replacement to extend the life of equipment and facilities. Preventive maintenance program should include:

- Non-destructive testing
- Periodic inspection
- Preplanned maintenance activities

Reasons for Preventive Maintenance

- Business loss due to production delays
- Reduction of insurance inventories
- Longer equipment life
- Production of a higher quality product
- Just-in-time manufacturing
- Reduction in equipment redundancies

Condition-based Maintenance:

In predictive maintenance, machinery conditions are periodically monitored and this enables the maintenance team to take timely actions, such as machine adjustment, repair or overhaul

- It makes use of human sense and other sensitive instruments, such as pressure, temperature and resistance strain gauges etc.
- Unusual sounds coming out of a rotating equipment predicts a problem
- An excessively hot electric cable predicts a problem
- Simple hand touch can point out many unusual equipment conditions and thus predicts a problem.

Scheduled Maintenance: “The preventive maintenance carried out to a predetermined interval of time, number of operations, etc. Scheduled maintenance is a stitch-in-time procedure and incorporates

- inspection
- lubrication
- repair and overhaul of equipment’s
- If neglected can result in breakdown

Corrective maintenance: The unscheduled maintenance or repair to return items/equipment to a defined state and carried out because maintenance persons or users perceived deficiencies or failures.

Predictive maintenance: The use of modern measurement and signal processing methods to accurately diagnose item/equipment condition during operation.

Maintenance concept: A statement of the overall concept of the item/product specification or policy that controls the type of maintenance action to be employed for the item under consideration.

3.2.5. Maintenance Terms And Definitions

Maintenance: All actions appropriate for retaining (supporting) an item/part/equipment in, or restoring it to, a given condition. The activity of equipment/item maintenance that develops concepts, criteria, and technical requirements in conception and acquisition phases to be used and maintained in a current status during the operating phase to assure effective maintenance support of equipment.

Maintenance plan: A document that outlines the management and technical procedure to be employed to maintain an item; usually describes facilities, tools, schedules, and resources.

Reliability: The probability that an item will perform its stated function satisfactorily for the desired period when used per the specified conditions.

Maintainability: The probability that a failed item will be restored to adequately working condition.

Active repair time: The component of downtime when repair persons are active to effect a repair.

Mean time to repair (MTTR): Mean time to repair (MTTR) is probably the most widely used maintainability measure. It measures the elapsed time required to perform a given maintenance activity.

Overhaul: A comprehensive inspection and restoration of an item or a piece of equipment to an acceptable level at a durability time or usage limit.

Quality: The degree to which an item, function, or process satisfies requirements of customer and user.

Maintenance person: An individual who conducts preventive maintenance and responds to a user's service call to a repair facility, and performs corrective maintenance on an item. Also called custom engineer, service person, technician, field engineer, mechanic, repair person, etc.

Inspection: The qualitative observation of an item's performance or condition.

3.2.6. Scheduling (production processes)

Scheduling: is an important tool for manufacturing and engineering, where it can have a major impact on the productivity of a process.In manufacturing, the purpose of scheduling is to minimize the production time and costs, by telling a production facility when to make, with which staff, and on which equipment.

Production scheduling aims to maximize the efficiency of the operation and reduce costs.Companies use backward and forward scheduling to allocate plant and machinery resources, plan human resources, plan production processes and purchase materials. Backward scheduling is planning the tasks from the due date or required-by date to determine the start date and/or any changes in capacity required.Forward scheduling is planning the tasks from the date resources become available to determine the shipping date or the due date.

The benefits of production scheduling include:

- Process change
- Inventory reduction, leveling
- Reduced scheduling effort
- Increased production efficiency
- Labor load leveling
- Accurate delivery date quotes
- Real time information

3.3. Purchasing Schedule

A purchase schedule is a timetable that outlines the planned supply of materials. It's a more detailed way to specify delivery dates and times for each item than a standard purchase order. Purchase schedules are often used for long-term purchasing with frequent deliveries, and are usually supported by a purchase contract.A purchase schedule is a timetable for the planned delivery of materials, and it usually includes the following requirements:

- **Item requirements**: All requirements for the same item, including the buy-from and ship-from business partners, purchase office, and warehouse
- **Delivery dates and times**: A detailed specification of delivery dates and times for each item
- **Support for long-term purchasing**: Frequent deliveries that support long-term purchasing
- **Purchase contract**: Usually backed by a purchase contract

Purchase schedules are used instead of standard purchase orders when more detailed visibility and time phasing of material requirements is needed.

3.3.1. Objectives of the Purchasing

- To maintain uninterrupted flow of materials to support the development schedules.
- To procure materials economically at a cost consistent with the quality and service required. However, generally all purchases may be attempted at the lowest cost.
- To provide the necessary expertise, advice, information to the Curators and Education Officers with regard to the best quality of material available in the market, supplier's capability and performance etc.
- To develop and maintain good buyer-seller relationship.
- To promote source development.
- To maintain NCSM's reputation and credibility in the market by fair dealings and prompt payments.

3.3.2. Purchase Procedure

The purchasing procedure is a process that outlines how to obtain goods and services through a supply chain. The process typically includes the following steps:

- **Identify the need**: Determine the need for the goods or services
- **Specify requirements**: Clearly define the requirements for the goods or services
- **Find a supplier**: Locate and select a supplier
- **Negotiate costs**: Negotiate the cost of the goods or services
- **Get order approval**: Obtain approval for the order
- **Place the order**: Place the order with the supplier
- **Receive and approve the order**: Receive the order and approve it
- **Review supplier performance**: Evaluate the supplier's performance

Other steps in the purchasing process include: Creating a purchase requisition, Issuing a purchase order (PO), Having the supplier approve the PO, Recording and filing the PO, and Approving and paying for the order.

A purchase order is a document that outlines a systematic method for buying goods and services. It ensures that all purchases are necessary and intentional.

Table 3.1. Mode of Purchase

	Up to Rs.250 In each cash memo	By local/cash purchase in accordance with rules in force, after recording that purchase has been made after a thorough market search and after ensuring that price has been reasonable.	
	Rs.251 to Rs.500 In each cash memo	Same as in item 5.1 along with a certificate that in view of extreme urgency, it was not possible to effect the purchase by inviting quotations.	
		i.	by limited tender: through issuing enquiries to a limited number of suppliers/contractors as approved by the Stores & Purchase Committee: based on the lowest technically acceptable tender/quotation out of at least three valid tenders/quotations.
		ii.	by emergent tender: by obtaining three sealed quotations after making a thorough market search by a committee specially appointed by the

			Director. for extremely urgent and strict time-targeted requirements and only in exceptional circumstances when normal issue of enquiries is not permissible because of extreme urgency. All such cases shall require prior approval of Director
	Above Rs.20,000 For each item of purchase/work	i.	by open tender: through press advertisement, and based on the lowest technically acceptable tender out of at l east three valid tenders.
		ii.	by single tender: directly from the manufacturer or sole distributor when the article to be purchased is a proprietary item. For purchase on the basis of single tender for non-proprietary items, the case shall be referred to Executive Committee or Director General when the amount exceeds Rs.10,000.

3.4. Taxing costs

Tax costs generally refers either to increased tax liabilities resulting from a corporate transaction or more frequently as a motion of a losing party to challenge paying certain costs of the winning party in litigation. Tax transaction costs study has two components: administrative cost and compliance cost. Administrative costs are those that are incurred by the state to administer the tax system, while compliance cost are those incurred by taxpayers to comply with the tax system:

A tax transaction cost consists of:

Where:

CCT=Tax Transaction Costs

CC=Tax payer Compliance Cost

CA=Administrative Cost

3.5. Setting precision

The setting of precision in measurement refers to the conditions under which repeated measurements are taken to determine the closeness of the results:

Repeatability: The variation in results when the same instrument and operator are used to make repeated measurements in a short time period.

Reproducibility: The variation in results when the same measurement process is used with different instruments and operators over a longer time period. Precision is a measure of how close multiple measurements of the same item are to each other. It's different from accuracy, which is a measure of how close a measurement is to the true value. For example, if you throw darts at a dartboard, you can be precise but not accurate if your darts are close together but far from the bulls-eye. To express the precision of a measurement, you can use a measure of imprecision like the standard deviation.

Measurement precision is a measure of how close repeated measurements of the same item are to each other. It's usually expressed as a standard deviation (SD), coefficient of variation (CV), or %CV. Here are some ways to determine the precision of a measurement:

Calculate the range: Find the difference between the highest and lowest measured values.

Calculate the average deviation: Subtract the average value from each measured value, then calculate the average of those values. The precision is the average value plus or minus the average deviation.

Precision is different from accuracy, which is how close the measurement results are to the accepted value. It's possible to be precise but not accurate, or vice versa. For example, if darts are close together but far from the bulls-eye, there is precision but not accuracy.

- To improve the accuracy and precision of measurements, you can:
- Conduct routine maintenance on your instruments.
- Check the user manual and contact the equipment manufacturer to ensure you're taking the right steps to keep your instruments running well.

Self Check 3.1.

Part I: Multiple Choice Questions

1. What is the first step in identifying resources for a project?

    A) Listing individual components of each resource group C) Training personnel

    B) Establishing a budget D) Scheduling maintenance tasks

2. What is the primary objective of maintenance scheduling?

    A) To increase labor costs C) To repair broken equipment

    B) To minimize downtime and maximize equipment efficiency D) To hire more staff

3. Which of the following is NOT a type of maintenance discussed?

    A) Preventive Maintenance C) Corrective Maintenance

    B) Predictive Maintenance D) Reactive Maintenance

4. What does a purchase schedule typically outline?

    A) Project timelines C) Employee roles

    B) Planned supply of materials and delivery dates D) Maintenance tasks

5. What does the term 'setting precision' refer to in measurements?

    A) The accuracy of a single measurement

    B) The conditions under which repeated measurements are taken

    C) The average of all measurements

    D) The total number of measurements taken

Part II: Short Answer Questions

1. List three major resource groups that should be identified for project completion.
2. What is the significance of preventive maintenance?
3. Describe the purchasing procedure steps briefly.
4. What are the two components of tax transaction costs?
5. Explain the difference between repeatability and reproducibility in measurements.

Part III: Matching Type Questions

Match the terms in Column A with their corresponding descriptions in Column B.

Column A Column B

1.Time table for planned supply of materials	A. Maintenance Scheduling
2.Actions taken to restore an item to working condition	B. Preventive Maintenance
3. Systematic approach to organizing maintenance tasks	C. Purchase Schedule
4. Costs associated with tax compliance	D. Taxing Costs
5.Conditions for measuring accuracy and consistency	E. Setting Precision

Unit Four: Monitoring plant resources and environmental performance

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Plant And Resources Monitoring
- Diagnosing performance problems
- Energy and resource minimization plan
- Conducting regular environmental audits
- Communicating environmental audits

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify Plant And Resources Monitoring
- Diagnosing performance problems
- Identify Energy and resource minimization plan
- Conducting regular environmental audits
- Identify Communicating environmental audits

4.1. Plant and Resources Monitoring

Resource Inventory: The process of acquiring, managing, and analyzing information on resources of a factory, including but not limited to the raw materials work in progress and finished goods.

Resource Monitoring: The systematic collection and analysis of resource data at regular intervals, in perpetuity, to predict or detect natural and human-induced changes, and to provide the basis for appropriate management response**.**

Plant and resources monitoring systems use sensors and other tools to collect and analyze data about plant health and growth, and equipment performance:

Plant monitoring systems

These systems use sensors to measure environmental factors that affect plant growth, such as temperature, humidity, light, soil moisture, and nutrient levels. The data collected can be used to make decisions about watering, fertilizing, lighting, and temperature, and to detect early signs of disease or stress.

Equipment monitoring systems

These systems use sensors to collect real-time data on parameters like temperature, pressure, and flow rate. Automated systems can be used to collect and analyze data.

Plant performance and efficiency monitoring

This involves collecting and analyzing data from plant operations using tools like sensors, meters, control systems, and data loggers. The data should be accurate, consistent, and timely, and analyzed using statistical techniques.

4.2. Diagnosis performance problems

Diagnosis is one measurement capacity enhancement in any production industry. It is simply define/ express that:

- Systematic approach to understand present state of organization.
- Specifies nature of problem and causes.
- Provides basis for selecting strategies.

- Involves systematic analysis of data.

Critical Issues in Diagnosis

- Simplicity.
- Visibility.
- Involvement.
- Primary factors.
- Measure what's important.
- Sense of urgency.

The Process of Diagnosis which is cyclical process it involving

- Data gathering.
- Identification of problem areas.
- Interpretation.
- Potential action program

Steps in Diagnosis

Step 1: Tentative problem identified.

Step 2: Collect data.

Step 3: Analyze data.

Step 4: Feedback data.

Step 5: More data needed?

Step 6: Problem areas identified.

Step 7: Is client motivated?

Step 8: Diagnosis and work on problem.

Step 9: Monitor and assess results.

Some problems with measuring diagnostic performance include:

Defining diagnostic errors: A diagnostic error is when a patient's health problem isn't explained accurately or in a timely manner, or when the explanation isn't communicated effectively.

External factors: Factors like legal pressures, reimbursement issues, clinical productivity, and administrative demands can affect diagnostic performance.

Lack of data: Some programs are difficult to measure because data is not available.

Stakeholder views: Stakeholders may have a different view of a program than the program managers.

4.3. Energy and resource minimization plan

An energy and resource minimization plan can include an integrated resource plan (IRP), an energy management plan, or an energy action plan (EAP):

Integrated resource plan (IRP)

A roadmap that uses both supply and demand resources to meet projected energy demand. The goal is to provide reliable service to customers in a cost-effective way.

Energy management plan

A plan that involves:

- Measuring and tracking energy use
- Identifying opportunities for improvement
- Taking action to save energy
- Verifying savings

Energy action plan (EAP)

A framework that governments and large organizations use to map out their current energy consumption and strategies to reduce it.

Some techniques for minimizing energy consumption include:

- Incorporating passive solar design concepts into your home, such as using energy-efficient windows
- Properly insulating and air sealing your home
- Selecting an energy-efficient heating system that doesn't use electricity
- Purchasing an Energy Star heat pump water heater
- Monitoring monthly energy bills
- Upgrading to energy-saving light bulbs

4.4. Conducting Regular Environmental Audits

Environmental audits help businesses ensure they are complying with environmental regulations and policies, and are doing their part to preserve the environment. Here are some steps to consider when conducting an environmental audit:

Plan the audit: Define the scope and objectives, such as the areas or processes to be audited.

Assemble the audit team: Select qualified auditors with the right expertise, and assign specific roles and responsibilities.

Develop an audit plan: Create a timeline with key milestones, and prepare checklists and tools.

Gather relevant documents: Collect policies, permits, previous reports, and other relevant documents.

Notify stakeholders: Inform management and department heads about the audit, and engage stakeholders early.

Prepare for the audit phase: Establish ground rules, and prepare for site inspections, document reviews, and sample collection.

Conduct the audit: Evaluate operations for compliance, and cross-examine personnel.

Prepare the post-audit report: List confirmed issues, action items, and required follow-up.

Environmental audits typically include three elements: agreed metrics, performance measured against those metrics, and reporting on compliance or variance.

Environmental audits typically include:

6. Agreed metrics, which define what should be measured and how
7. Performance measured against those metrics
8. Reporting on the levels of compliance or variance

4.4.1. Environmental performance

Performance Gap: Difference between what organizations could do and what organization is doing.

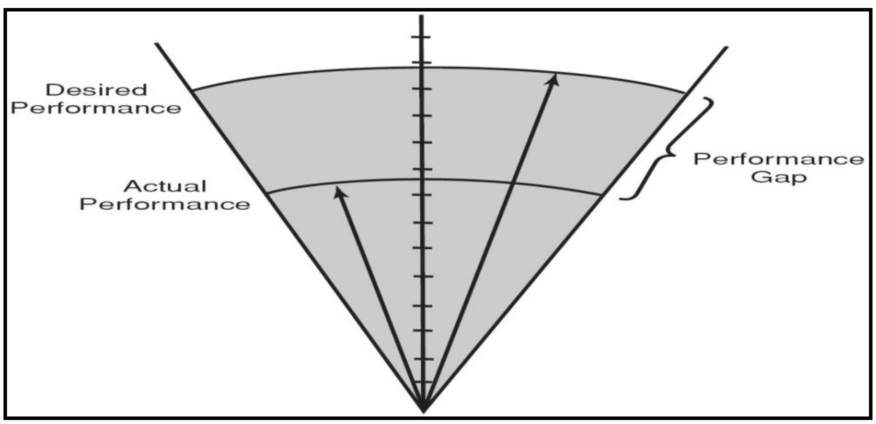

Figure 4.1. Performance Gap

Self-Assessment Gap Analysis of Four Key Areas for the identification of Performance Gap

- Organization's strengths.
- What can be done to take advantage of strengths
- Organization's weaknesses.
- What can be done to alleviate weaknesses**?**

4.4.2. Environmental Management System

- It is an Environmental Management System (EMS) that uses a continual improvement approach in achieving and demonstrating sound environmental performance.
- The goal is for organizations to control the impacts that their activities, products and services have on the environment.
- ISO 14000 is the standard, and ISO 14001 is the document containing the requirements.
- Organizations are becoming increasingly concerned in achieving & demonstrating sound environmental performance, often delivering cost savings.
- Marketing Tool: Shows customers, shareholders, vendors, etc. that you are a “Good Corporate Citizen”

4.4.3. General Requirements

- The organization must develop an effective system that meets the requirements of the Standard.
- Document, implement and maintain the system.
- The EMS documents need to be controlled.
- Follow a Plan-Do-Check-Act approach.

Plan - Establish the objectives and processes needed to deliver the results (in line with the EMS).

Do - Implement the needed processes of the EMS.

Check - Check the processes against the policy, objectives, targets, regulations, and report on the results. (Auditing)

Act - Take actions that will continually improve the EMS.

4.5. Communicating environmental audits

The purpose of an environmental audit is to: assess the nature and extent of the risk of harm to human health or the environment. This may be from contaminated land, waste, pollution or an activity. Recommend measures to manage the risk of harm to human health or the environment.

Effective communication is an essential part of the environmental audit process, ensuring that the report is understood by the intended audience. Here are some tips for communicating environmental audits:

Develop a communication plan

A well-structured plan can improve the transparency, efficiency, and impact of the audit process.

Communicate the report effectively

Make sure the report is delivered, received, and understood by the audit and other relevant stakeholders.

Introduce the audit team

Confirm the audit plan, summarize audit activities, and review roles and responsibilities.

Provide an opportunity for questions

Allow the audit to ask questions.

Other aspects of environmental audits include:

Defining the scope and objectives

Specify what will be audited, and what standards will be used to evaluate it.

Stakeholder engagement and communication

Assess how the organization communicates environmental performance and risks to stakeholders.

Regulatory compliance

Audits can help an organization comply with current regulations by identifying areas that need improvement.

An environmental audit typically contains three elements**:** agreed metrics (what should be measured and how), performance measured against those metrics, and reporting on the levels of compliance or variance.

The 5 Stages of Environmental Audit: The steps of environmental audit

Step 1: Schedule the Audit. ...

Step 2: Plan the Audit. ...

Step 3: Conduct the Audit. ...

Step 4: Develop an Audit Report/Action Plan. ...

Step 5: Audit Follow-Up.

Self check 4.1.

Part I: Multiple Choice Questions

1. What is the primary purpose of resource monitoring?

   A) To increase production speed
   C) To reduce workforce size
   B) To collect and analyze resource data regularly
   D) To eliminate waste completely

2. Which of the following is NOT a step in the diagnosis process?

   A) Collect data
   C) Implement immediate solutions
   B) Identify problem areas
   D) Monitor and assess results

3. What does an Integrated Resource Plan (IRP) aim to achieve?

   A) Increase operational costs
   C) Meet projected energy demand cost-effectively
   B) Provide unreliable service
   D) Reduce workforce requirements

4. Which element is NOT included in the environmental audit process?

A) Defining the scope and objectives
C) Preparing a post-audit report
B) Conducting market research
D) Gathering relevant documents

5. According to the document, what is a key feature of an Environmental Management System (EMS)?

   A) Focus on increasing production
   B) Emphasis on regulatory compliance alone
   C) Continuous improvement in environmental performance
   D) Reduction of employee training

Part II: Short Answer Questions

1. What is the role of sensors in plant monitoring systems?
2. List two techniques for minimizing energy consumption.
3. Describe the importance of conducting regular environmental audits.
4. What are the three elements typically included in an environmental audit?
5. Explain the significance of stakeholder engagement in the environmental audit process.

Part III: Matching Type Questions

Match the terms in Column A with their corresponding descriptions in Column B.

Column A	Column B
1. Framework for mapping current energy consumption	A. Resource Inventory

2.Systematic collection and analysis of resource data B. Energy Management Plan

3. Documented process to track and improve energy use C. Environmental Audit

4. Process to assess compliance with environmental standards D. Integrated Resource Plan (IRP)

5. System for controlling environmental impacts of activities E. Environmental Management System (EMS)

Unit Five: Corrective Action Planning

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Critical areas for performance improvement
- Altering Process to control variation
- Rectifying faults
- Seek feedback and Communicating customers

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identify Critical areas for performance improvement
- Identify Altering Process to control variation
- Identify Rectify faults
- Seeking feedback for customer
- Documentation changes on the process.
- Identify Communication customers/stakeholders

5.1. Critical Areas for Performance Improvement

To identify the Key Performance Indicators and using key metrics for performance

- Understand how KPIs are deployed as relevant local goals
- Used to identify, measure and monitor the performance of key elements of the process
- KPI’s are part of policy deployment

Tracking Instruments for Calibration Status

- Each instrument given a unique identifier
- Instrumentation details associated with this number must be documented and available (e.g. serial number, model number, location, etc.)
- Each instrument should be labeled with the unique identifier
- Calibration status of each instrument , the date of calibration, the next calibration date and the identification of person performing calibration should be readily available
- Appropriate systems to document calibration status include calibration logs and calibration stickers

Calibration Process

- Written calibration procedures that use traceable calibration standards or calibration equipment.
- Qualified individuals (having the appropriate education, training, background and experience) responsible for calibrating & maintaining instrumentation
- Second person check of all calibration tests
- Qualified individuals responsible for monitoring the calibration
- Ensure the calibration program and procedures are reviewed and approved by Quality

Out-of-Calibration Procedure

- If calibration is not complete within time.
- Results from the calibration do no meet set criteria.

Other areas for performance improvement include: Interpersonal communication, Problem-solving abilities, Emotional intelligence, Organizational skills, and Technical skills.

5.2. Altering Process to Control Variation

Taking corrective action: After the reasons for deviations have been determined, managers can then develop solutions for issues with meeting the standards and make changes to processes or behaviors. To control process variation, you can use process improvement methods like Six Sigma, Lean, or Kaizen. These methods can help to reduce or eliminate the sources of variation, and optimize the process performance. Here are some other ways to manage process variations:

- **Change assessment**

Evaluate the impact of a proposed change on the project, including how it may affect the project's scope, timeline, budget, and other key parameters.

- **Change planning**

Systematically evaluate proposed changes, identify potential risks, allocate resources, and integrate changes into existing project timelines.

- **Change prioritization**

Use a structured prioritization process to ensure alignment with broader organizational goals and reduce the risk of changes that might not yield significant benefits.

- **Compare and review process variations**

Compare all process variations for each standard process and assess which are legitimately needed.

- **Execute the change and provide training**

Provide training to all relevant personnel on the approved changes so that everyone involved understands the new processes, procedures, and modifications.

5.3. Rectify faults

Rectifying faults means to correct or improve something that is wrong or faulty. For example, you might rectify a misspelling in an article before printing it. Here are some other definitions of rectify:

- **Rectification of errors**: To revise a mistake and make amends for it
- **Rectification**: The act of correcting an error or fault
- **Correct**: To take action to remove errors, faults, deviations, or defects

Synonyms of rectify include amend, correct, and remedy. There are a few ways to rectify faults in a measuring system, including:

Calibration: Compare the instrument's readings to a known standard to reduce systematic errors.

Controlled conditions: Ensure measurements are taken under controlled conditions.

Double-check: Double-check all observations, recordings, and measurements.

Avoid external changes: Avoid changes in external conditions such as humidity, pressure, and temperature.

5.4. Communication and Seek feedback

Communication is the process of sharing ideas and thoughts between people to achieve understanding. Feedback is a dialogue that allows people to reflect on how another person's performance or behavior is perceived. Feedback is a key part of the communication process and is essential for achieving effective two-way communication. Here are some listed points about communication and seeking feedback:

- **Active listening**

Pay close attention to the speaker, respond with verbal and non-verbal cues, and try to understand their message.

- **Empathy**

Understand and share the emotions of others.

- **Respect**

Know when to initiate communication and respond, and allow others to speak without interruption.

- **Ask clarifying questions**

Demonstrate your commitment to understanding the feedback better by asking specific examples or suggestions for improvement.

- **Be friendly**

In friendships and workplace relationships, honesty and kindness can foster trust and understanding.

- **Make eye contact**

Eye contact is a key part of non-verbal communication that can help you build a connection with the person or audience you're speaking to.

- **Develop public speaking skills**

Improve your overall communication skills, including your body language, vocal control, and audience engagement.

5.4.1. Communication Methods

There are several communication methods that are used to share information among project stakeholders. These methods are broadly classified as follows:

- Interactive communication. Between two or more parties performing a multidirectional exchange of information. It is the most efficient way to ensure a common understanding by all participants on specified topics, and includes meetings, phone calls, instant messaging, video conferencing, etc.
- Push communication. Sent to specific recipients who need to receive the information. This ensures that the information is distributed but does not ensure that it actually reached or was understood by the intended audience. Push communications include letters, memos, reports, emails, faxes, voice mails, blogs, press releases, etc.
- Pull communication. Used for very large volumes of information, or for very large audiences, and requires the recipients to access the communication content at their own discretion. These methods include intranet sites, e-learning, lessons learned databases, knowledge repositories, etc.

The choices of communication methods that are used for a project may need to be discussed and agreed upon by the project stakeholders based on communication requirements; cost and time constraints; and familiarity and availability of the required tools and resources that may be applicable to the communications process.

5.4.2. Feedback in communication

Feedback in communication is the response, reaction, or information given by the recipient of a message to the sender. It is the processes of letting someone know which areas they need to improve .Feedback in communication is the response, reaction, or information given by the recipient of a message to the sender. It is the processes of letting someone know which areas they need to improve.

Feedback is essential to effective communication because it helps the sender check that their message has been understood and received as intended and modify their communication strategy as needed. Feedback is crucial in two-way communication to ensure both sides are on the same page and can prevent misunderstandings or confusion. It also strengthens the bonds of trust and rapport between the sender and the recipient.

Figure 5.1. Feed back of communication

5.4.3. Types of feedback in communication

There are several types of feedback in communication, each serving a specific purpose in the communication process. Here are some of the most common types of feedback:

Formal feedback: many companies adopt this type of feedback for evaluating productivity in a given time. Its structure is simple and objective, giving both the managers and employees a chance to talk about what they can improve in their work and communication strategy;

Evaluative feedback is a way to describe an individual's behavior and has beneficial results only when it's positive. This type of feedback is not always recommended because it can often be perceived as too personal;

Prescriptive feedback is a form of advice in which the recipient tells the sender how to correct their way of working. Although this type of feedback can be helpful in the early stages, such as training or on boarding, it can also be a way to avoid giving constructive feedback on the individual's work;

Descriptive feedback: as the name implies, this type of feedback is used to describe the effects of an individual's action, which leads to the presentation of a relevant opinion. Descriptive feedback is considered the best form of evaluation in the workplace and other fields, such as education and science. To be motivated, especially when working for someone else, team members need to feel appreciated, even when improvements need to be made. A proven way to provide good feedback is by combining the necessary recommendations with the quality of their work to conclude positively about the evaluated person.

Self-Check 5.1.

Part I: Multiple Choice Questions

1. What is the purpose of Key Performance Indicators (KPIs)?

   A) To increase production costs

   B) To measure and monitor the performance of key elements of a process

   C) To eliminate employee feedback

   D) To solely track financial performance

2. Which of the following is NOT a method mentioned for controlling process variation?

   A) Six Sigma C) Random Sampling

   B) Lean D) Kaizen

3. What does the term "rectifying faults" primarily mean?

   A) Avoiding mistakes C) Ignoring errors

   B) Correcting or improving something that is wrong D) Increasing production speed

4. What method of communication ensures a multidirectional exchange of information?

   A) Push communication C) Interactive communication

   B) Pull communication D) Written communication

5. What type of feedback is considered the best form of evaluation in the workplace?

   A) Evaluative feedback C) Descriptive feedback

   B) Formal feedback D) Prescriptive feedback

Part II: Short Answer Questions

1. Define the term "calibration" in the context of performance improvement.
2. List two key aspects involved in the calibration process.
3. What are the steps to take when out-of-calibration is identified?
4. Explain the importance of active listening in communication.
5. What is the significance of feedback in the communication process?

Part III: Matching Type Questions

Match the terms in Column A with their corresponding descriptions in Column B.

Column A	Column B
1. Process of sharing ideas and thoughts	A. Key Performance Indicators (KPIs)

2. Correcting or improving something B. Calibration

3.Measures for monitoring performance C. Feedback

4. Multidirectional exchange of information D. Interactive Communication

5.Comparing instrument readings to a known standard E. Rectifying Faults

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