Metrology

❖ Definition:

It is the field of knowledge that is concerned with measurement.

❖ The **principal fields** of metrology are**:**

(A) **Units of measurements** and their standards
(B) **Measurement Process.**
(C) **Instruments.**
(D) **Observers.**

❖ There are several parts of metrology. They may be:

1) **General Metrology: It is the part of metrology that deals with problems common to all metrological fields irrespective of the quantity to be measured.**

2) **Technical Metrology: It deals with problems of metrology in technology.**

3) **Quality Metrology: It deals with problems of quality control.**

4) **Theoretical Metrology: It deals with the theoretical problems measurement.**

5) **Legal Metrology : It deals with all aspects of measurement e.g. instrument, process units in relation to the mandatory (legal and technical) requirements with the main aim of ensuring public safety and appropriate accuracy.**

❖ **Fields of sciences** needed for metrology**.**

This branch of science requires sound knowledge in certain basic mathematical and physical principles. Some knowledge of applied mathematics, mechanics and physics are considered an asset to the proper understanding of the operation of instruments and the design of the gauges and measuring equipment.

Some of the fields of sciences that are required are:

1) **Mathematics:** since most of the calculations used in metrology are trigonometrical in nature and the majority can be solved involving the right-

angle triangle rules. Further, most of the equations involved are linear in nature and can be easily solved using elementary rules of algebra.

2) **Mechanics:** from this branch of science we are mainly interested in the theory of elasticity of materials. This theory tells us among many other things that nothing is rigid or unchangeable in shape and position. This fact is extremely important when accuracy is of utmost importance e.g. accuracy of about 1/1000 mm.
3) **Optics:** though this is not so strictly within the realm of metrology, however, most of the modern instruments utilize optical principles in their operation. Basic knowledge of reflection and interference of light is needed.
4) **Heat and temperature:** this part of the science is one of the greatest problems in the science of metrology as it affects the precision of measurement. This is due to the fact that most of the materials change their dimensions as their temperature changes, which affects the accuracy of measurement. Therefore, the standard temperature for engineering measurement is 20 ^{o}C (68 F) and all accurate measurements should be made within this temperature range.

❖ Metrology and inspection.

All engineers, regardless of their field of specialization, are constantly faced with the problem of measurement. It may be of length, time, temperature …etc. Almost invariably, the result of this measurement process will decide the next course of action to be taken by the engineer. Therefore:

1) The **purpose** of measurement is to provide service of certain type to enable certain decisions to be taken. This service is not completed unless,
2) The **accuracy** of measurement is attained as required. Therefore, it is necessary not only to state the quantity to be measured, but also the degree of accuracy to which the measurement process has been executed.
3) The operator has to have a sound knowledge of the **systems** used and followed by different countries.
4) The operator has to use the proper **standard** in the proper way.

Inspection

❖ Definition:

It means checking the dimensions of the produced or under-process piece to compare it with the specified dimensional accuracy.

Traditionally, measurements were made after the part has been finished, this is known as **Post-Process Inspection**. The current trend is to make measurement while the piece is under process. This is known as **In-process or Real-Time inspection**.

❖ **The amount of time** required for the inspection depends on**:**

1. The nature of the product.
2. The degree of accuracy required,
3. Type of equipment used, and,
4. How skilled the operator is.

The basic requirements of the inspector should be:

1. Given an authoritative position for certain decision making.
2. Ability to do his work.
3. Impartial, and
4. Good experience in his field.

Measurement

❖ Definition.

It is the process of quantitative comparison between a predetermined standard and an unknown magnitude.

❖ Conditions for acceptance of a measurement process.

In order that the process of measurement may be acceptable:

1. The **procedure** used in the process must be **provable**.
2. The **apparatus** used in the process must be **provable**.
3. The **instrument** used in the process must be **correct**, and,
4. The **standard** used for comparison must be **correct**.

❖ Classification Methods of measurement instruments.

Most of the mechanical measurements can be classified as :

1) Based on their **operational method**:

- ***Self-operated type.***
- ***Power type.***

2) According to the **arrangement of its parts**:

- ***Remote sensing.***
- ***Self contained.***

3) Based on **the nature of their operation**:

- ***Manual type.***
- ***Automatic type.***

❖ Fundamental Methods of measurements.

Based on the nature of comparative procedure used in the measurement they can be classified as:

1. *Direct method.*

In this method the parameter to be measured is directly compared with either a primary or secondary standard.

2. *Indirect method.*

In this method the comparison is done with a standard through use of calibrated system.

❖ Factors affecting the selection of measurements systems.

Whenever any quantity is to be measured, the following fundamental points has to be present in the mind:

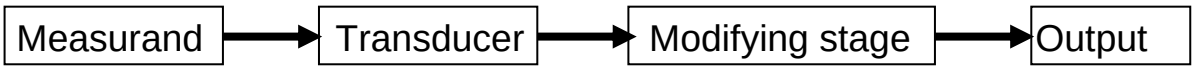
1. **Degree of accuracy** of measurement to be made.
2. **Time of delivery** of final data.
3. The **cost** criteria.
4. The **form in which the data has to be presented**.
5. The **type of data** to be measured.

In view of the above, **the most fundamental rule of measurement states**: "*Never demand an accuracy of measurement higher than that which is really needed, and never forget that each degree of accuracy, if demanded, is likely to have a disproportionate effect on the complexity and cost of the measuring apparatus*."

❖ Measurement systems.

There are three or four phases in most of the measuring systems, each phase being made up of a distinct component or grouping of components which perform required and definite steps in measurement viz , (i) primary sensing device, (ii) transducer (iii) intermediate modifying stage, (iv) terminating stage, i.e. secondary indicating instrument. All measuring systems include three basic stages. They are:

(A) **A detecting and measuring element** (Transducer) which detects the physical variable to be measured (Measurand) e.g. pressure, temperature, rate of flow …etc, and converts it into more usable form.
(B) **An intermediate stage**, which modifies the signal from the transducer so that a desirable output, is available.
(C) **An indicating and recording stage.** Which provides the required out put and necessary action?



Now let us explain the basic functions of each stage of the system:

1. *Transducers*.

These are the devices which converts the quantity being measured (measurand) into optical, mechanical or more frequently electrical signal.

2. *Signal modifying or conditioning.*

It is the process of preparing these signals before they are being displayed or recorded is called *signal conditioning*.

3. *Recording and displaying units.*

It is the component that provides the results of the measurements.

The basic difference between recording and displaying is that recording produces permanent record of the signal, while displaying unit does not.

Explanation:

(A) Sometimes the **primary sensing device and the transducers** are integrated into one device. The sensing element must be sensitive to the input quantity (i.e. variable to be measured) so that it can sense or detect it, and at the same time sensing device must be insensitive to other variables. In other words the sensing device must be selective, as far as possible; of course, it can't be made completely selective. After sensing the desired inputs it provides, an analogous output with the help of transducers.

Actually the transducer converts the input signal into another type of quantity which is more-useful and is, of course proportional to the input quantity. A brief mention of different types of basic detectors-transducers is made here. These can be of **mechanical type** in which category they may utilize contacting spindle, spring mass, elastic devices such as Bourdon tube, proving ring etc. The hydraulic-pneumatic types of detectors consist of buoyant float, orifice, venturi, vane, propeller etc.

The **optical detectors** consist of photo-electric cell, photo-voltaic cell, photoconductive cell, infrared detectors, ultra-violet detectors, photographic films and a host of others. Nowadays the **electrical detectors** are most commonly used and these have been developed to such an extent that they can be used for nearly all the applications. The electrical-sensing elements and transducers utilize the following:
Conductor, resistance, capacitance, inductance, piezo-electric crystal, thermocouple, moving electrode, streaming potential and several other such devices.

(B) The **intermediate modifying stage** modifies the transduced signal into a form which is suitable to be used as input to the terminating stage. It also increases the amplitude or power of the signal to the level required to drive the secondary indicating instrument. It may also perform the operations, of selecting, modifying, integrating etc., as may be required. The various intermediate modifying devices can be of the following types: mechanical, hydraulic-pneumatic, optical and electrical.

The mechanical devices include gearing, cranks, slides, connecting links, cams etc; the hydraulic-pneumatic devices include piping, dash pots etc;

The optical devices may comprise of lenses, mirrors, light levers, filters …etc ; **The electrical devices**, the most commonly used devices include amplifying or attenuating systems, matching devices, filters ….etc.

(C) The terminating stage provides the information or recording in the form which may be evaluated by an unaided human sense.

❖ Functions of the Instrument.

It has already been pointed out that the primary sensing element of the instrument first utilizes energy from the measured medium to produce a condition representing the value of the measured variable.
Then a secondary element known as transducer merely converts the condition produced by the primary element into a more useful quantity, usually an electrical impulse which can be amplified sufficiently to operate the actuating mechanisms. Sometimes a manipulation element is also incorporated in between which modifies the signal of the transducers, e.g., it may correct the non-linearity in the preceding conversion processes or may automatically compensate for change of temperature ….etc.

Finally the output is indicated in the form of a movement of the needle. This final instrument may be required to do the following functions:

(i) Indication. The value of the quantity can be read by the movement of needle on a calibrated scale provided in the instrument.

In fact where highly accurate and exact readings are desired, use of digital readouts is recommended.

(ii) Signalling. In this case the instrument is provided with signalling contacts which can be set at any value throughout the scale of the instrument. When the indicating needle shows the reading corresponding to the value at which signalling contact has been set, a contact is made or broken which can be utilised for initiating audible or visual alarm or for taking some corrective action in the plant automatically.

(iii) Registering. In such instruments the instrument merely indicates, by numbers or some other symbol of discrete increments the value of some quantity.

(iv) Recording. In this case the instrument continuously records, with pen and ink, the value of the measured quantity against some other variable or against time.

(v) Transmitting. In certain instances, transmitters are also provided in the instrument which provides a signal corresponding to the value of the quantity being measured.

(vi) To perform various manipulations. In certain cases, instruments may be required to do operations such as addition, subtraction, multiplication, differentiation, integration, ratio control etc. Sometimes instruments are used to find solution of rather larger complex or algebraic or differential equations.