Mechanical Measurements

Measurement:

It is the process of comparing unknown magnitude of certain parameters with the known predefined of that parameter.

1. Scope of Measurement:

(1) Measurements are one of crucial parts of engineering fields.

(2) Every branch of engineering involves two processes:

(A) Design and (B) Operations and maintance.

* The Design may be building design, circuit design, transportation design automobile design etc.
* The operation parts involves operations of the machine, automobiles, various plants, circuits etc.

3. Requirements of measurements:

(1) The standard used for comparision purposes must be accurately defined and should be commonly acceptable.

(2) The standard must be of the same character as the measurand.

(3) The apparatus used and the method adopted for the purposes of comparision must be provable.

Methods of measurement:

There are two basic methods of measurement.

1. direct comparision with either a primary or a secondary standard
2. Indirect comparision through the use of a calibrated system.

Direct comparision In these methods, the unknown quantity (measurand) is directly compared against a standard. The result is expressed as a numerical number and a unit. Direct methods are quite common for the measurement of physical quantities like ~~strength~~ length, mass and time.

Indirect method: This method makes use of some form of transducing device coupled to a chain of connecting apparatus, which we will call, as for the measuring system. This chain of devices converts the basic form of input into an analogous form, which it then processes and presents at the output as a known function of the original input. Such a conversion is often necessary so that the desired information will be intelligible. The human senses are simply not designed to detect the strain in a machine member, for instance. Assistance is required from a system that senses, converts, and finally presents. Assistance is required from a system that senses, converts and finally presents an analogous output in the form of a displacement on a scale or

chart or as a digital readout.

Processing of the analogous signal may take many forms. Often it is necessary to increase an amplitude or a power through some form of amplification. Or in another case it may be necessary to extract the desired information from a mass of extraneous input by a process of filtering. A remote reading or recording may be needed, such a ground recording of a temperature or pressure within a rocket in flight. In this case the pressure or temp. measurement must be combined with a radio-frequency signal for transmission to the ground.

Classification of measuring instruments

① On the basis of mode:

② Primary: * In primary measuring instrument the value of physical parameter is determined by comparing it directly with reference standards.

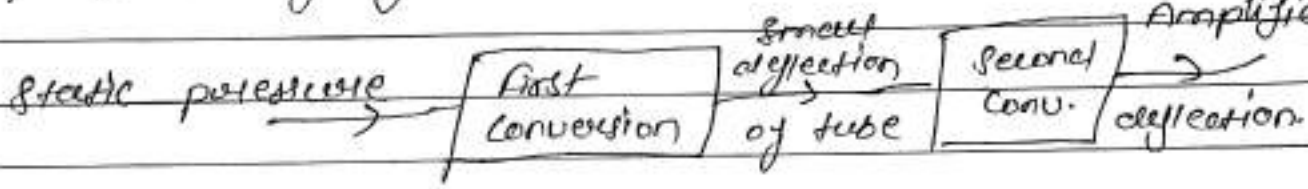
* It provides subjective information only.
* It totally depends upon the human sense.

③ Secondary measuring instruments: It is also known as indirect measurement as it involves one conversion of the physical variable into easily measurable signals (i.e, electrical signals).

Eg: (i) Conversion of pressure into displacement by means of bellows.
(ii) The conversion of force into displacement by means of springs.

(c) Tertiary measuring instruments
It involves two step conversion of the physical variable into easily measurable signal.

Eg: Pressure measurement by bourdon tube pressure gauge.



(2) On the basis of Contact b/w instrument and Object
(a) Contact type: When physical contact occurs b/w the sensing element of the measuring device and the medium or object whose characteristics are being measured, it is known as contact type measuring instrument.

(b) Non-contact type: When there is no physical contact b/w the sensing elements of measuring device and the object whose characteristics are being measured, it is known as non-contact type measuring instrument.

③ On the Basis of Nature of Signals:

(a) Analog Instruments: The instruments which deals the indications or signals which vary in a continuous fashion and have an infinity of values in any given range are called analog measuring instruments.
Eg. Voltmeter, Ammeter etc.

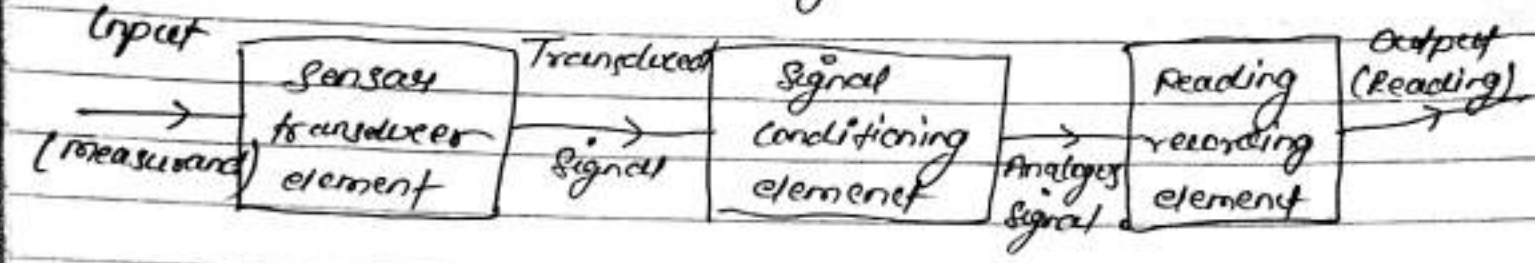
(b) Digital Instruments: These are the instruments which deal with discrete signals which vary in steps.
Eg. Digital Tachometer, digital vernier etc.

④ On the Basis of Pointer:

(a) Deflection type mes. Instru.:- The instruments in which the pointer deflects to give us the value of measurable item is called deflection type measuring instruments.
Eg: Voltmeter, Ammeter etc.

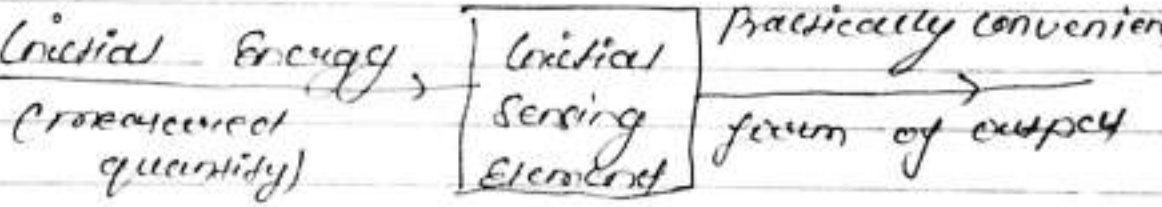
(b) Null Type Mes. Instru.: The instrument in which the pointer is fixed at a null point or constant point to compare the value of measurable item is called null type measuring instruments.

Block Diagram Representation of a Generalised Measurement System



Various Elements and their functions:

(a) Initial Sensing Element: It is also known as sensor transducer element or simply transducer element. It is the first element which detects or senses the measurand.



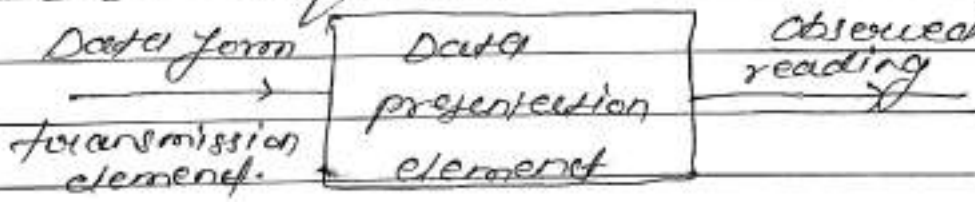
Function: It is the point which first receives ~~receives~~ energy from the measured medium and converts this input into a more practically convenient form of output.

(b) Signal Conditioning Element:
Signal conditioning elements are used to modify the transduced information into a form that is acceptable to recording recording elements. These includes variable transformation element, variable manipulation element and data transmission element.

function:- many times, the output of the transducer is so small that it is ~~element is not able to~~ insufficient to operate an indicatory. Hence, it should be suitably manipulated by signal conditioning element.

© Reading Recording Element:
It is also called data presentation element. The data is finally transmitted to data presentation element. This element is used to display information of measured quantity to the observer.

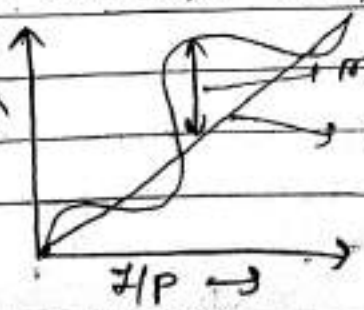
function:
① These element act as data storage elements.
② The desired data may be retrieved repeatedly whenever required.



4. Static Calibration Characteristics
↳ It is defined as process of determining o/p scale of measuring instrument.

① Linearity
It is defined as the ability to reproduce the input characteristics symmetrically, and this can be expressed by the straight line equation

$y = mx + c$ → Intercept on o/p axis.
o/p ← slope → I/p



Linearity can be computed with reference to straight line showing the relationship b/w input and output. The line which expresses the input output relationship is called an idealized straight line.

$$\% \text{ linearity} = \frac{\text{max. deviation}}{\text{full scale reading}} \times 100$$

② Static Sensitivity :

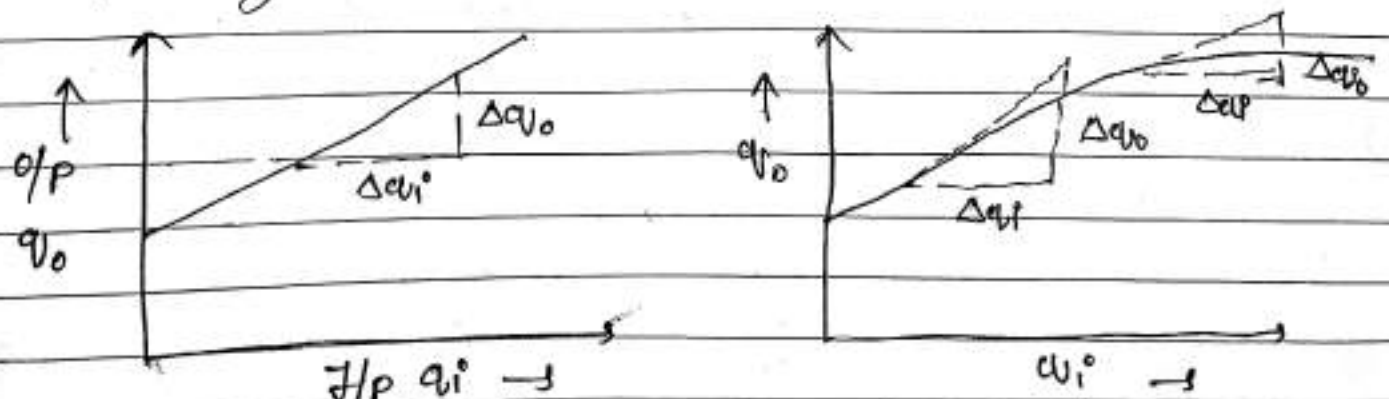
It is defined as the ratio of the output to the input.

O/P → response

I/P → to be measured

$$\text{Static sensitivity} = \frac{\text{O/P}}{\text{I/P}} = \frac{\Delta q_o}{\Delta q_i}$$

* For linear calibration curve, sensitivity is the slope of calibration curve.



* Reciprocal of static sensitivity is known as deflection factor or inverse sensitivity.
* Sensitivity of an instrument should be high and have some margin for accidental overloads.

③ **Repeatability:** It is defined as the ability of a measuring system to reproduce o/p readings when the same input value is applied to it consecutively under the same conditions and in the same direction.

* Repeatability is the limiting factor in the calibration process.
* Repeatability is the min. uncertainty in the comparison between o/p and reference.

④ **Range:** The region between the limits within which an instrument is designed to operate for measuring, indicating or recording a physical quantity is called range of the instrument.

⑤ **Stability:** It is the ability of a measurement system to produce the same value over time when measuring the same sample.

It deals with the degree to which sensor characteristics remain constant over time.

Accuracy: Accuracy is defined as closeness of the output to the true value of measured quantity.

* It depends on systematic errors.
* It is determined by calibration of the instrument.

$$\% \text{ accuracy} = \frac{\text{Measured value} - \text{True value}}{\text{True value}} \times 100$$

Precision: It is defined as the ability to reproduce the same o/p repeatedly for the same input.
* It depends on random errors.
* It is determined by statistical analysis.

Speed of Response: The quickness of instruments to read the measured quantity is called speed of response.

Error: An error can be defined as difference between measured value and true value.

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Calibration: Calibration may be defined as process of determining output scale of a measuring instrument. For this known magnitudes of the input quantity must be fed into the sensor - transducer and the system's output behaviour has to be observed. Such comparision allows the magnitude of output to be correctly interpreted in terms of the magnitude of the input. Hence, calibration establishes the correct output scale for the measuring instrument.

(1) Single Point Calibration - A single value of input and corresponding output is sufficient to evaluate the constant of proportionality.

(ii) Multi Point Calibration: If the input is not proportional to the output, then to improve accuracy of calibration, a no. of input values are fed to the instrument and the corresponding output deflections are observed.

Static Calibration:

In static calibration, a known value is input to the system under calibration and the system output is recorded.

The term static refers to a calibration procedure in which the value of the variables involved remain constant during a measurement i.e they do not change with time.

* Only the mag. of known I/p and the measured O/p are important in static cal..

Dimensional Tolerance:

The permissible variation in a dimension is called dimensional tolerance of the dimension. It is the difference between the upper limit and the lower limit of the dimension.

Dim. Tol.

- Unilateral
  - * tolerance is given only in one direction
- Bilateral
  - * tolerance can be given in both direction.

Geometric Tolerance:

The tolerance provided to control the shape and form of a component is known as geometric tolerance.

It is used only when the shape or form has a particular function and errors in shape or form would result in poor performance.

* Geo. Tol. is a system of controlling the deviations in geometry which may be straightness, roundness, flatness, circularity etc.

Sensors: These are the devices which senses the condition, shape or value of the process variable and produce an O/p corresponding to its condition or state.

Types of sensors

(i) Thermal sensors
(ii) motion sensors → Linear M.S
                    → Angular M.S
(iii) Speed sensors
(iv) Force sensors
(v) Thickness sensor

Role of sensors:

* The primary sensing element is the first and foremost requirement for measurement and automatic control.

* These sensing elements (sensors) sense the condition, state or value of the process variable and produce an output which reflects this condition, state or value.

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Transducer

It is a sensing device which converts physical quantity into electrical quantity.

(In other words, transducer is a device which converts the energy from one form to another such as electrical energy into mechanical energy and non-electrical physical quantity into electrical signal.

Types of Transducer

(i) Capacitive Transducer
(ii) Electron Tube "
(iii) Inductive "
(iv) magneto electric.
(v) Photoelectric "
(vi) Piezoelectric "
(vii) Radioactive "
(viii) Resistive "
(ix) Thermoelectric "

Role of Transducer

* Transducer transforms the energy of the process variable to an output of some other type of energy which is able to operate some control device.

Characteristics:

* Small sized and light in weight
* are reliable
* Highly sensitive.
* withstand wide range of environmental conditions.
* Have linear relationship b/w Inp. & O/p

Active transducers

* Does not require any auxiliary power source to produce its o/p.
* Normally gives small o/p.
* Amplifier is essential.

Eg. Thermocouple and thermopile photovoltaic etc.

Passive transducers

* It derives the power required for transduction from an auxiliary power source.
* Normally gives large o/p.
* Amplifier is not required.

Eg. Resistance, capacitance, inductance etc.