Static and Dynamic characteristics of Instruments

Characteristics of measurement systems

- To choose the one most suited to a particular measurement application, we have to know the system characteristics.

- The performance characteristics may be broadly divided into two groups, namely '***static***' and '***dynamic***' characteristics

Static characteristics

- the performance criteria for the measurement of quantities that remain constant, or vary only quite slowly.

Dynamic characteristics

- the relationship between the system input and output when the measured quantity (measurand) is varying rapidly.

- ***In practice***, *the characteristics of the one group may well influence the characteristics of the other. In order to access overall instrument performance, however, the two groups of characteristics are normally studied separately and then a semi-quantitative superposition is carried out.*

1. Accuracy

- This is the closeness with which the measuring instrument can measure the ‘true value’ of the measurand under stated conditions of use, i.e. its ability to ‘tell the truth’.

- The accuracy of an instrument is quantified by the difference of its readings and the one given by the ultimate or primary standard.

Accuracy depends on inherent limitations of instrument and shortcomings in measurement process.

Unit of accuracy:

1. Percentage of true value (% of T.V.)

$$= \frac{(\text{Measured value} - \text{True value}) * 100}{\text{True value}}$$

2. Percentage of Full Scale Deflection (% of fsd) $= \frac{(\text{Measured value} - \text{True value}) * 100}{\text{Maximum Scale value}}$

2. Precision

- Precision is defined as the ability of instrument to reproduce a certain set of readings within given accuracy.
- Precision describes an instrument’s degree of random variations in its output when measuring a constant quantity.
- Precision depends upon repeatability.

3. Repeatability

- Repeatability is defined as ability of instrument to reproduce a group of measurements of same measured quantity, made by same observer, using same instrument, under same conditions.

Precision is often confused with accuracy. High precision does not imply anything about measurement accuracy.

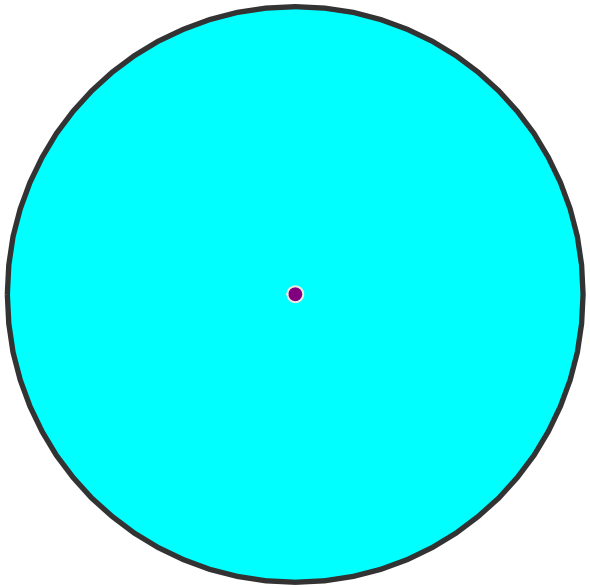
Accuracy

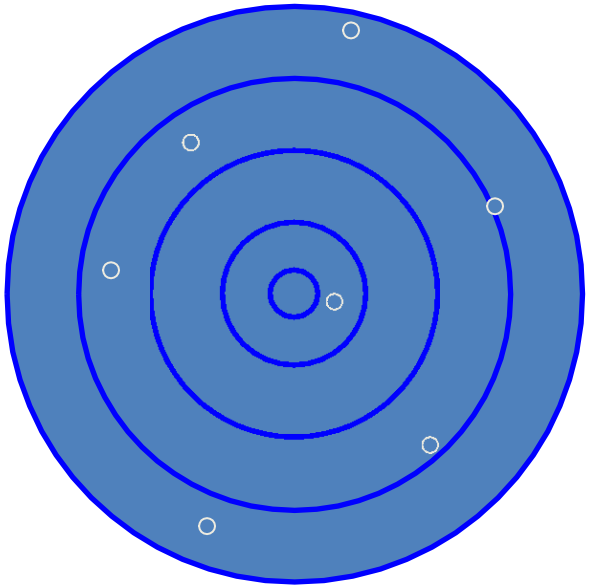
- Accuracy represents degree of correctness of the measured value w.r.t. true value.
- Accuracy of instrument depends on systematic errors.

Precision

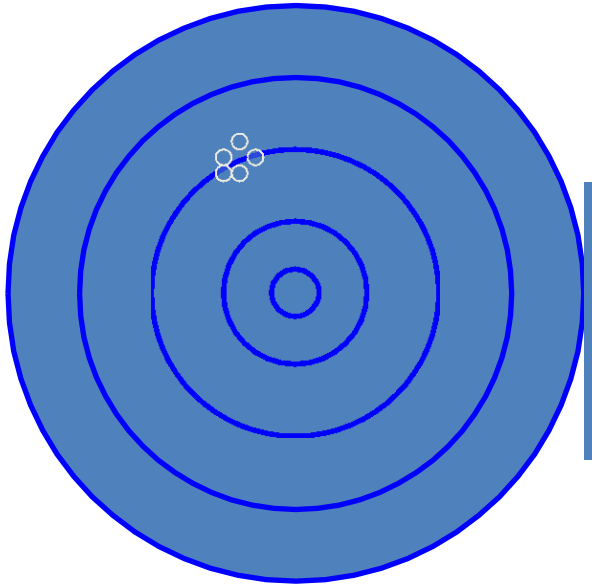
- Precision represents degree of repeatability of several independent measurements of desired input at the same reference conditions
- Precision of instruments depends on factors that cause random or accidental errors.

Measuring a fixed target position

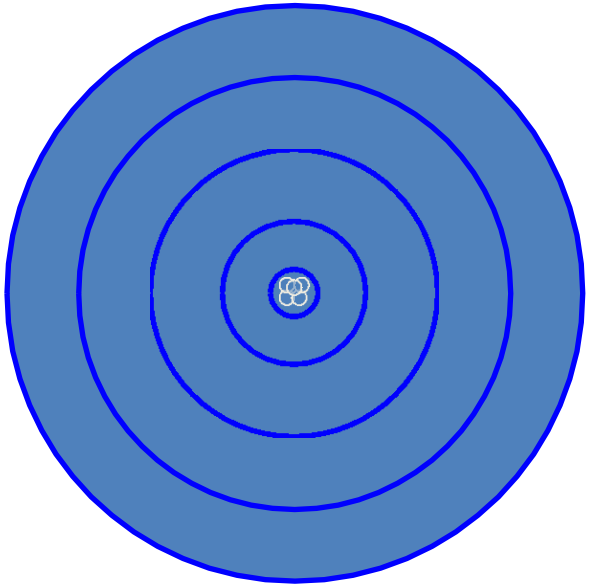




Low precision, low accuracy



High precision, low accuracy



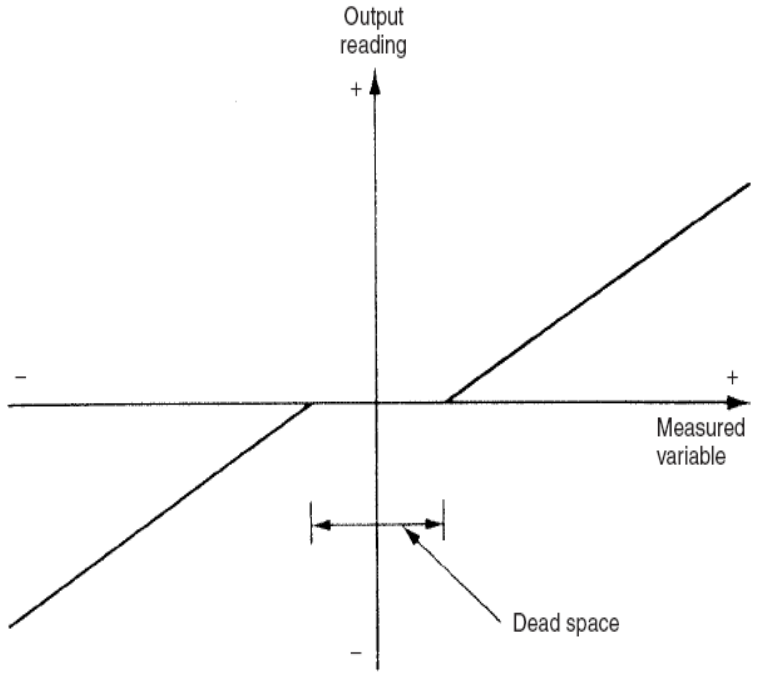
High precision, High accuracy

4. Resolution (Discrimination)

- It is the minimum change or smallest increment in the measured value that can be detected with certainty by the instrument.
- It can be least count of instrument.

5. Dead Space : Threshold

Dead space/ Threshold
is defined as the range
of different input values
over which there is no
change in output value.



6. Tolerance

- *Tolerance is a term that is closely related to accuracy and defines the maximum* error that is to be expected in some value.
- Tolerance describes the maximum deviation of a manufactured component from some specified value

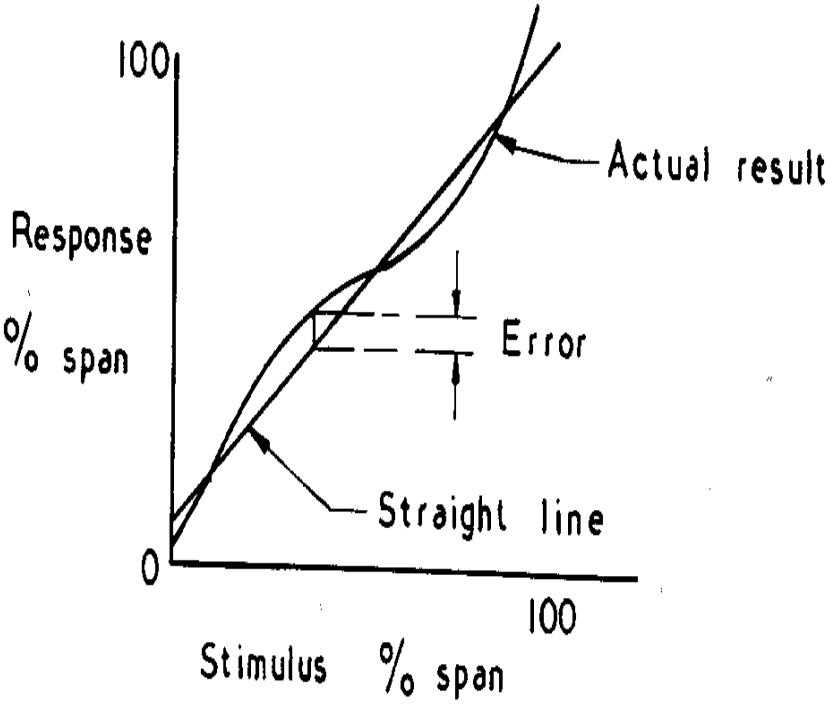
7. Range or span

- The *range or span of an instrument defines the minimum and maximum values of a* quantity that the instrument is designed to measure.

8. Linearity

This is the closeness to a straight line of the relationship between the true process variable and the measurement.
i.e. deviation of transducer output curve from a specified straight line.

1. Independent of Input
2. Proportional to Input
3. Combined independent & proportional to Input.



Linearity is usually reported as non-linearity, which is the maximum of the deviation between the calibration curve and a straight line positioned so that the maximum deviation is minimized.

9. Sensitivity of measurement

The sensitivity of measurement is a measure of the change in instrument output that occurs when the quantity being measured changes by a given amount. Thus, sensitivity is the ratio:

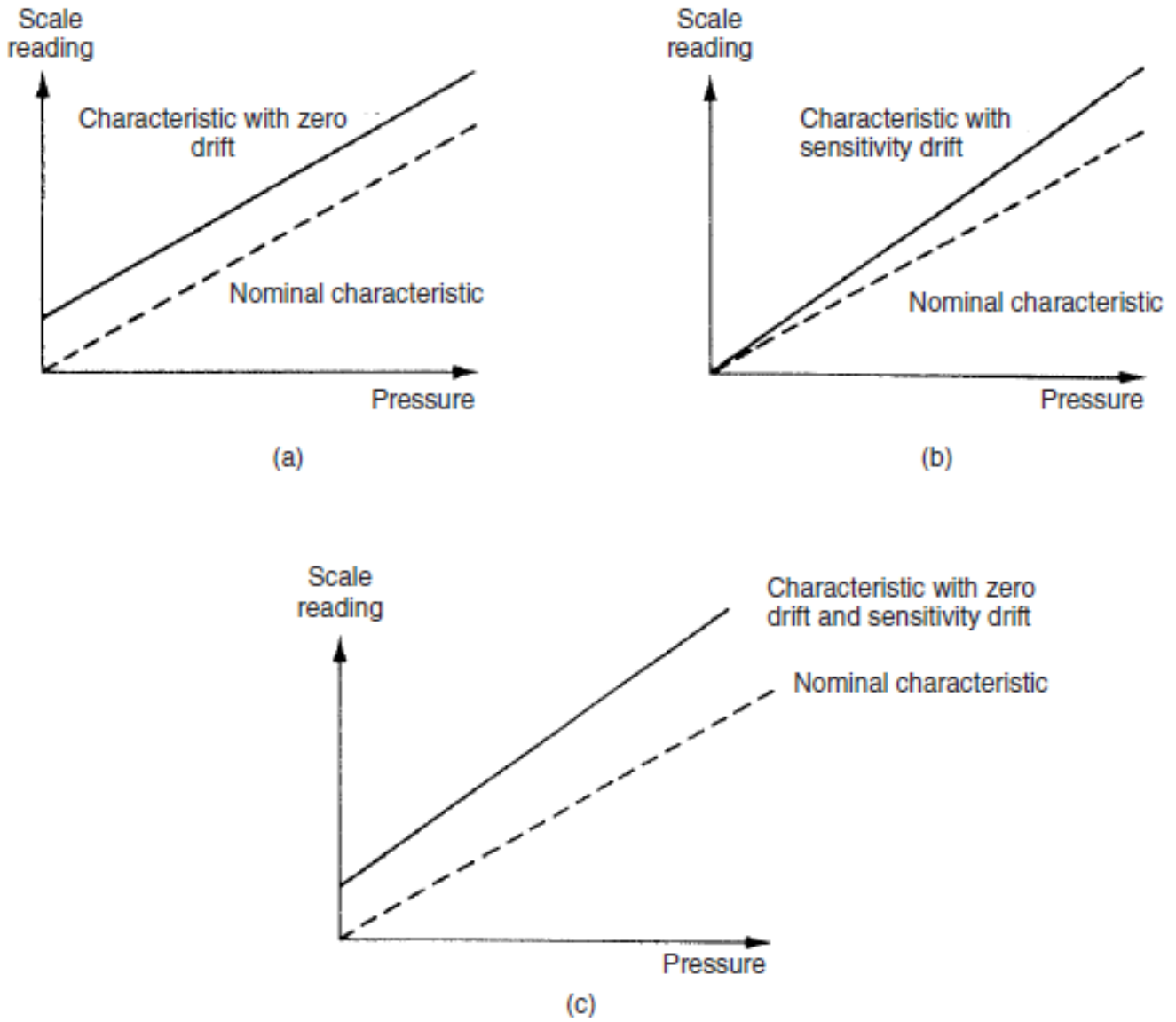
$$\text{Static Sensitivity } K = \frac{\text{Change of Output Signal}}{\text{Change in Input Signal}} = \frac{\Delta qo}{\Delta qi}$$

10. Reliability

Reliability is the probability that a device will adequately perform (as specified) for a period of time under specified operating conditions. Some sensors are required for safety or product quality, and therefore, they should be very reliable.

11. Instrument Drift

- It is defined as the variation of output for a given input caused due to change in sensitivity of the instrument due to certain interfering inputs like temperature changes, component instabilities, etc.
- Prime sources occur as chemical structural changes and changing mechanical stresses.
- Drift is a complex phenomenon for which the observed effects are that the sensitivity and offset values vary.
- It also can alter the accuracy of the instrument differently at the various amplitudes of the signal present.

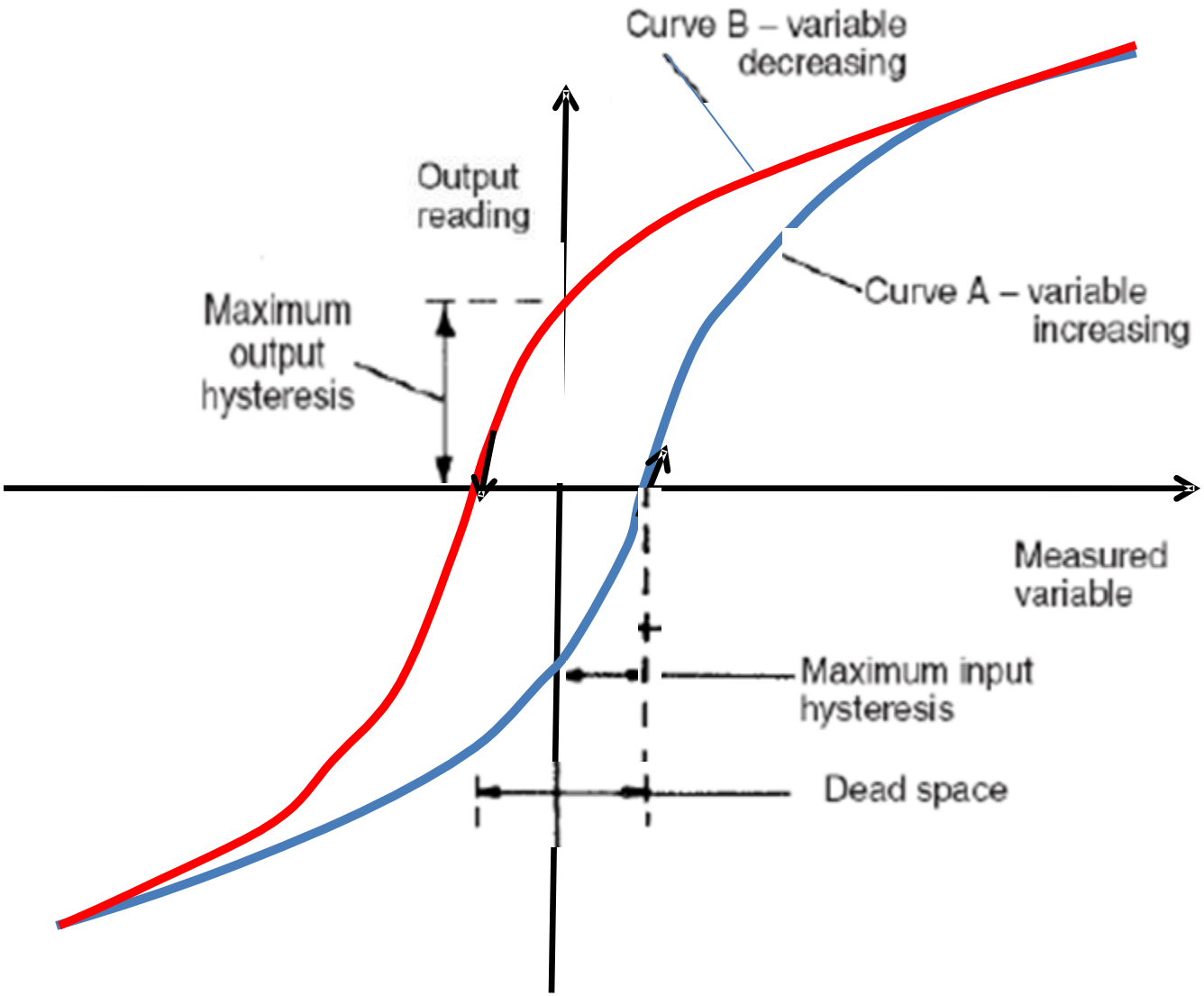


Effects of disturbance: (a) zero drift; (b) sensitivity drift; (c) zero drift plus sensitivity drift.

12. Hysteresis

- Careful observation of the output/input relationship of a block will sometimes reveal different results as the signals vary in direction of the movement.
- Mechanical systems will often show a small difference in length as the direction of the applied force is reversed.
- The same effect arises as a magnetic field is reversed in a magnetic material.
- This characteristic is called *hysteresis.*
- *Hysteresis* is defined as the magnitude of error caused in the output for a given value of input, when this value is approached from opposite directions ; i.e. from ascending order & then descending order.
- *Causes* are backlash, elastic deformations, magnetic characteristics, frictional effects (mainly).
- Hysteresis can be eliminated by taking readings in both direction and then taking its arithmetic mean.

Instrument characteristic with hysteresis.



13. Backlash

- It is defined as the maximum distance or angle through which any part of mechanical system may be moved in one direction without causing motion of next part.
- Can be minimized if components are made to very close tolerances.