Industrial Instrumentation

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Course Outline

Instruments are our eyes

- Fundamentals of Electrical Technology and digital logic employed in the measurement
- Review of Scientific principles employed in instruments
- Parts of Instrument
- Performance Characteristics of Instruments
- Selection and Calibration of Instruments
- Instruments Identification and Line Symbols
- Principle measurements desired in industry

  (a) Temperature
  (b) Pressure, Load
  (c) Level
  (d) Flow
  (e) Others (Weight, Composition, pH etc.)
  (f) Transducers
- Installation and Installation Costs
- Case Studies

Sensors

- Human natural observation capabilities are generally not designed for process conditions.
- Instruments must have desired capabilities to match process conditions.
- Process Control has the role of a decision makers (Like brain)

Sensors feel the condition and originate the signal followed by modification and amplification for effective display /transmission or control objectives.

Importance of effective measurement in process industry

Failure to measure effectively the level of liquid in bottom of the tower lead to

--- Fire

--- Explosion

- *Typical components of instrument*

  - ***A Sensor**:*

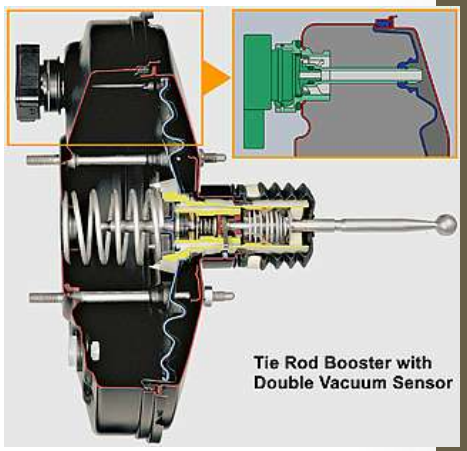
  (measures a physical quantity and converts it into a signal)

  - ***A Modifier***

  (Change the type of signal)

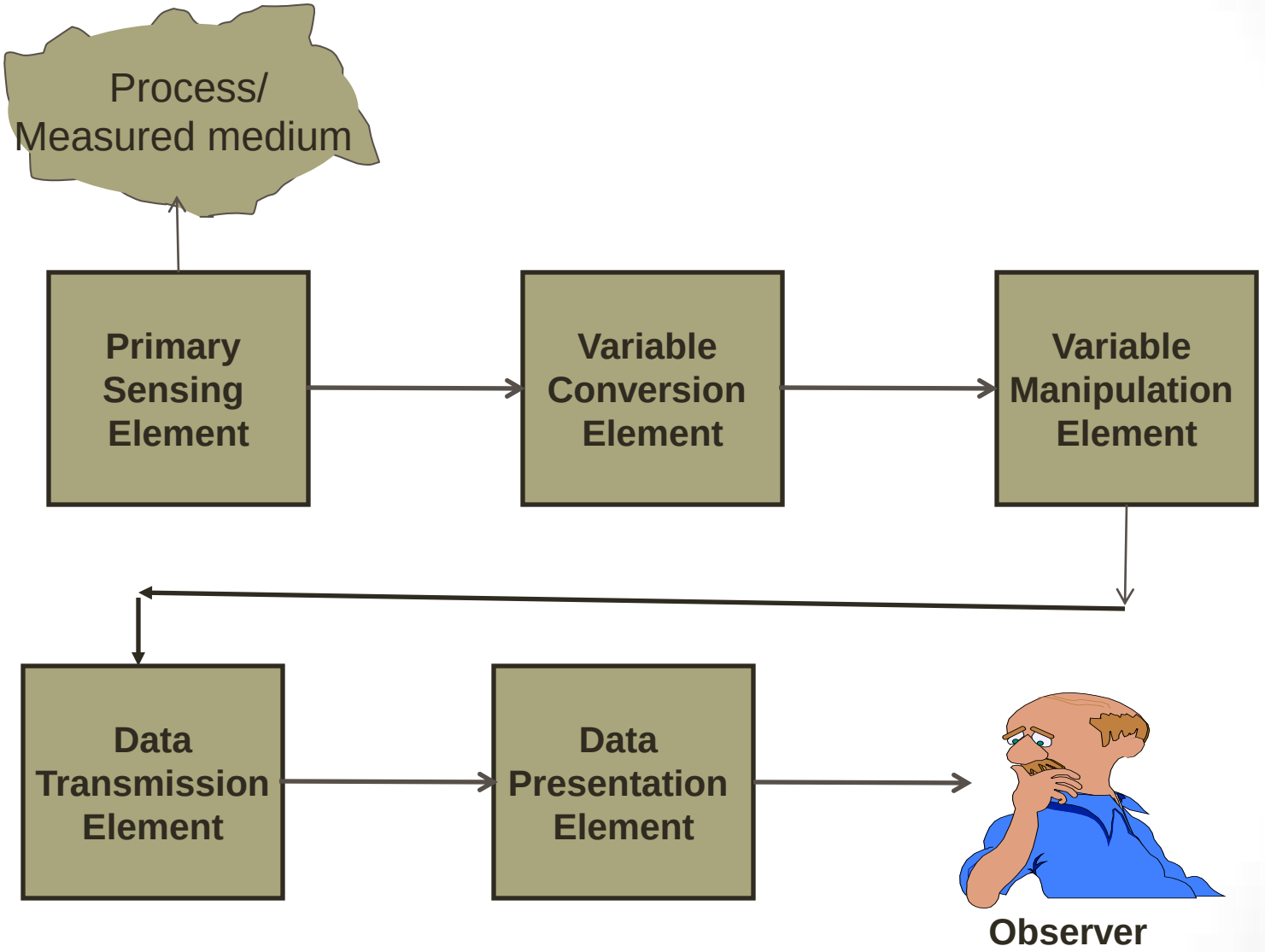
  - ***A Display unit***

  (transmitting arrangement)



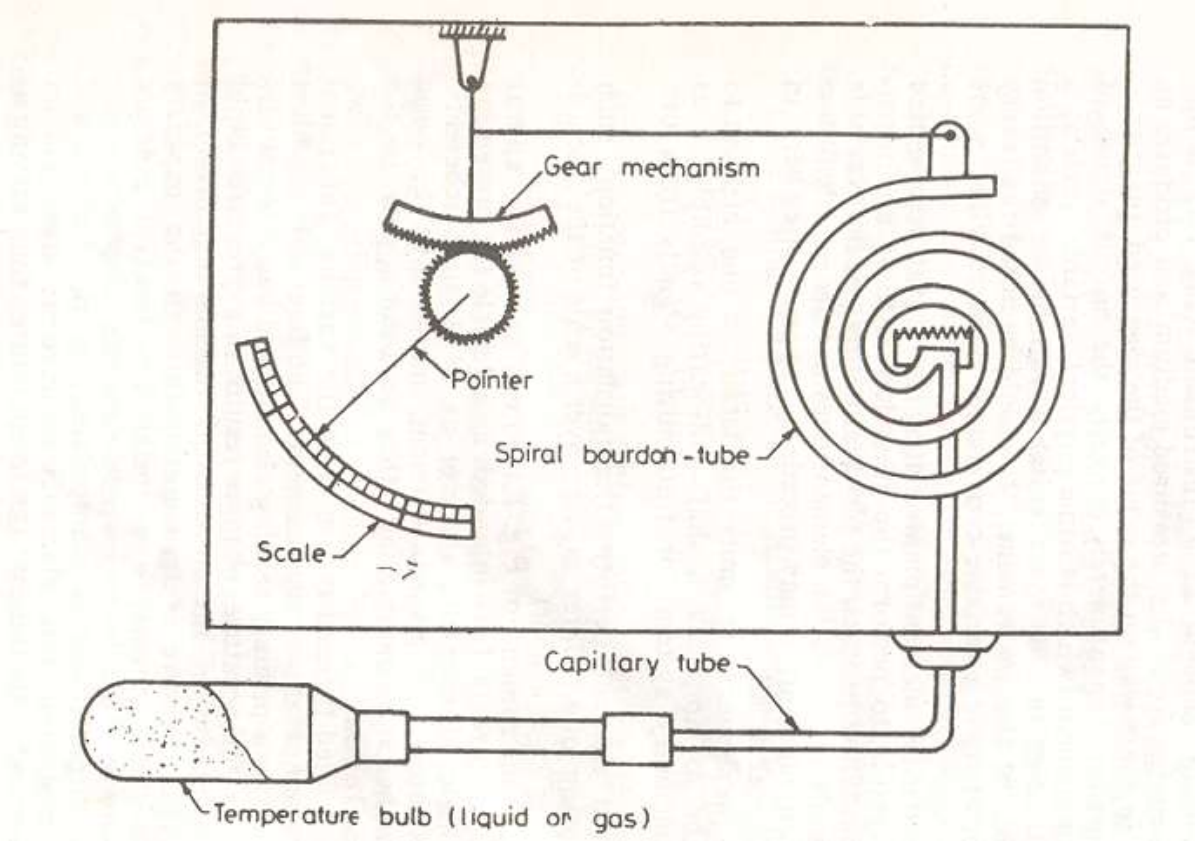
Perhaps the best advice for engineering students is that **"instruments are *always* incorrect"!!!!**.

Functional Elements of an Instrument

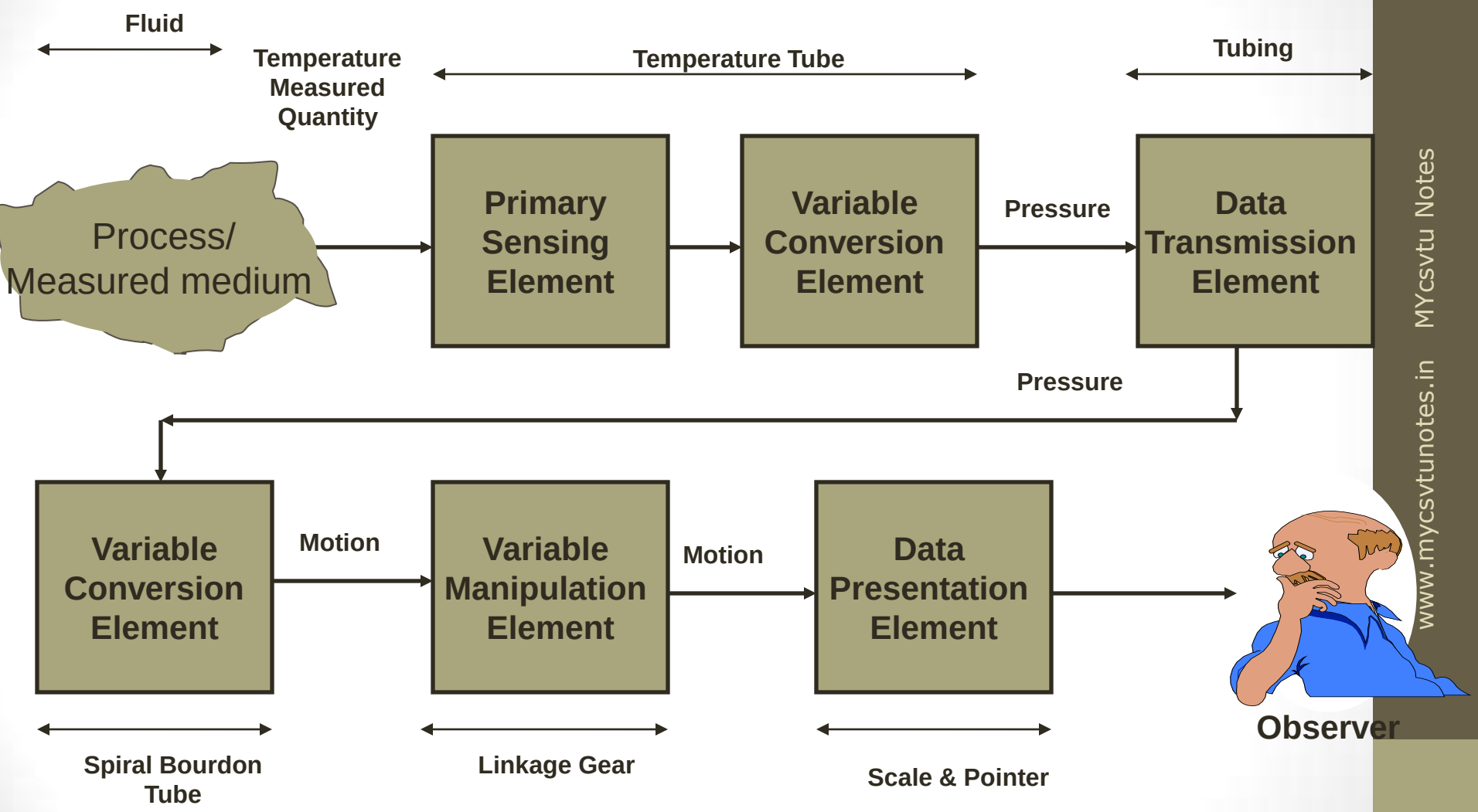


Functional Elements of an Instrument (Cont'd)

Typical Example:



Functional Elements of an Instrument (Cont'd)



Performance Characteristics of Instruments

- Static characteristics
- Dynamic characteristics

Performance Characteristics of Instruments (Cont'd)

- Static characteristics

Static characteristics of an instrument includes;

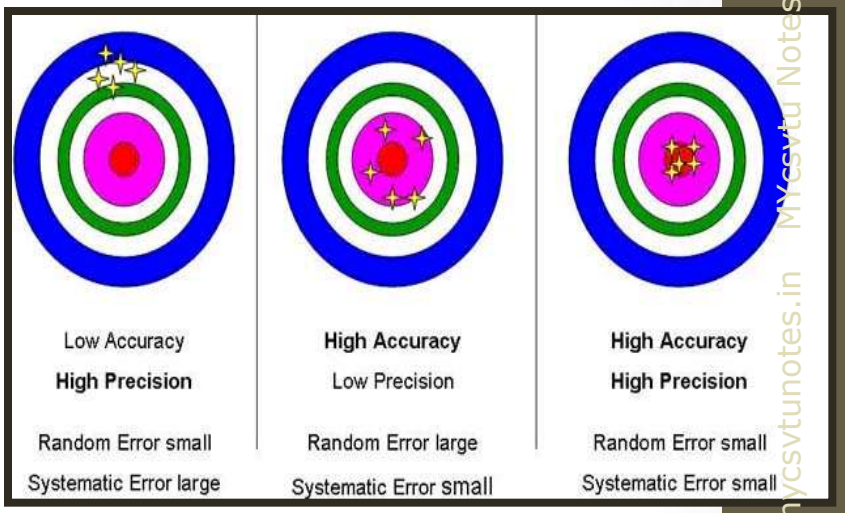
- **Accuracy**
- **Precision**
- **Repeatability**
- **Range**
- **Resolution**
- **Others (Sensitivity , Dead zone etc.)**

Static Characteristics

Static characteristics of an instrument includes;

1. **Accuracy**

Accuracy is the degree of conformity of the measured value with the accepted standard or ideal value, which we can take as the true physical variable.



Accuracy is usually expressed in engineering units or as a percentage of the sensor range, for example:

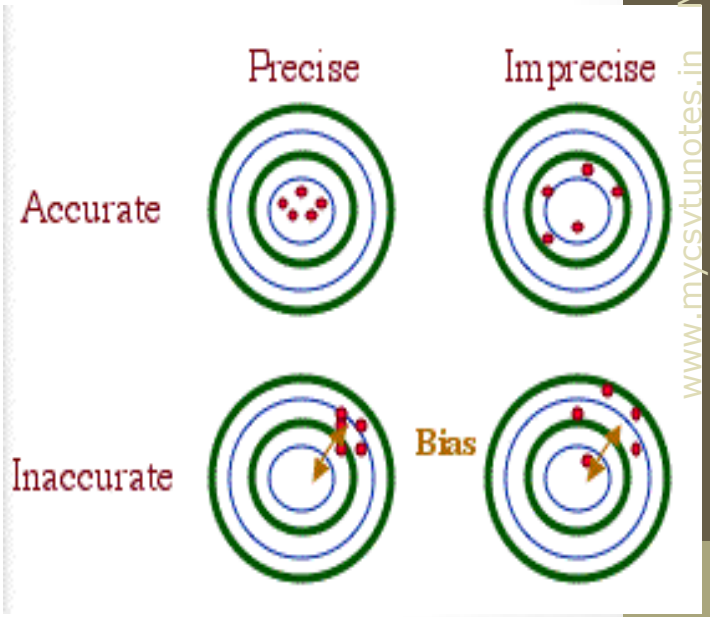
- Thermocouple temperature sensor with accuracy of ± 1.5 K.
- Orifice flow meters with accuracy of ±3% of maximum flow range

Static Characteristics

Static characteristics of an instrument includes;

2. Precision

- Precision is the degree of exactness for which an instrument is designed or intended to perform.
- It is composed of two characteristics;
  1. Conformity
  2. Number of significant figures



Static Characteristics

Static characteristics of an instrument includes;

3. Repeatability

The closeness of agreement among a number of consecutive measurements of the same variable (value) under the same operating conditions, approaching in the same direction.

The term "approaching in the same direction" means that the variable is increasing (decreasing) to the value for all replications of the experiment.

Static Characteristics

Static characteristics of an instrument includes;

4. Reproducibility

- The closeness of agreement among a number of consecutive measurements of the same variable (value) under the same operating conditions over a period of time, approaching from both directions.

The period of time is "long", so that changes occurring over longer times of plant operation are included.

Reproducibility includes hysteresis, dead band, drift and repeatability.

Drift

- Gradual change in instruments measurements.

OR

- Measure of difference in repeatability.

- Under laboratory conditions drift of an element can be determined by one of two ways;

1. Point drift
2. Calibration drift

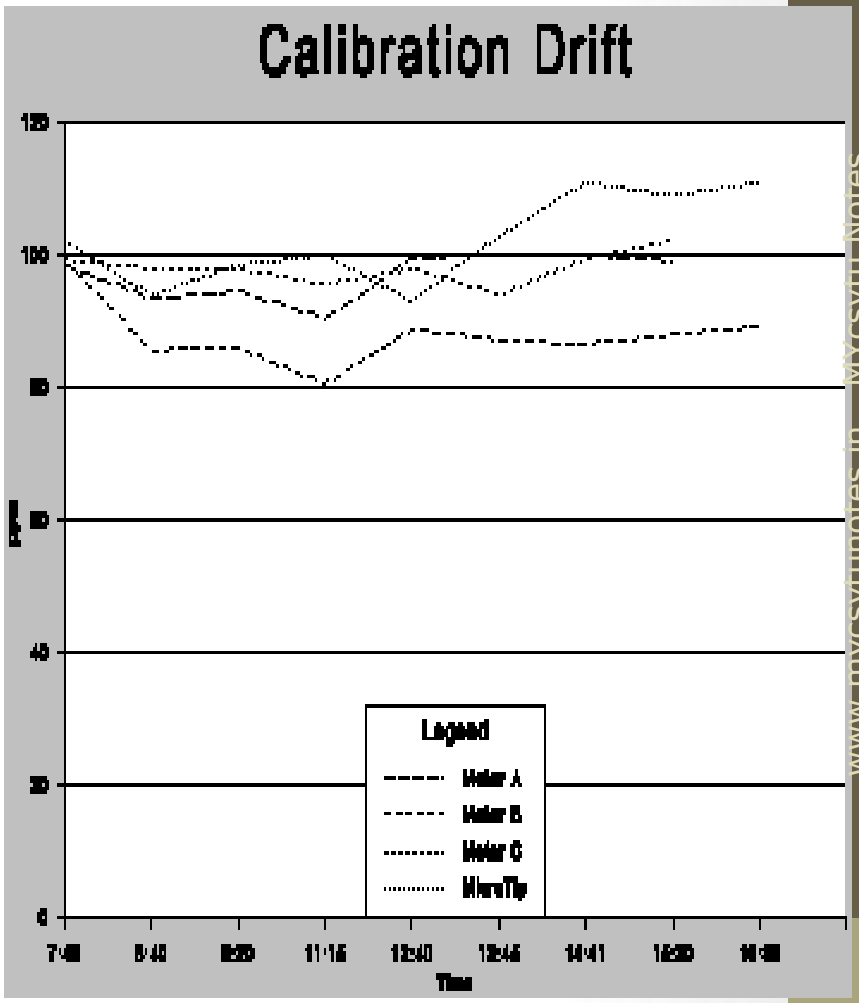
Point Drift

- By maintaining exact operating and load conditions , monitoring of output variations for a fixed input signals as a function of time is called point drift.

- Used for stable process conditions

Calibration Drift

- By maintaining input signals, operating conditions, a load approximately constant comparison of calibration curves at the beginning and at specified intervals of time is called Calibration drift.
- Used for varying process conditions



Dead Zone

- Dead zone is the largest range of values of a measured variable to which the instrument does not respond.
- This is sometimes called dead spot and hysteresis.

Backlash

- Backlash or mechanical hysteresis is defined as that lost motion or free play which is inherent in mechanical elements such as gears, linkages or other mechanical transmission devices that are not rigidly connected.

Static Characteristics

Static characteristics of an instrument includes;

5. Range/Span

- Range represents the minimum and maximum values which can be determined by an instrument or equipment.
- Difference between upper and lower range is known as Span.
- Span can be the same for two different range instruments.

If a chemical reactor typically operates at 300 °C, the engineer might select a range of 250-350 °C.

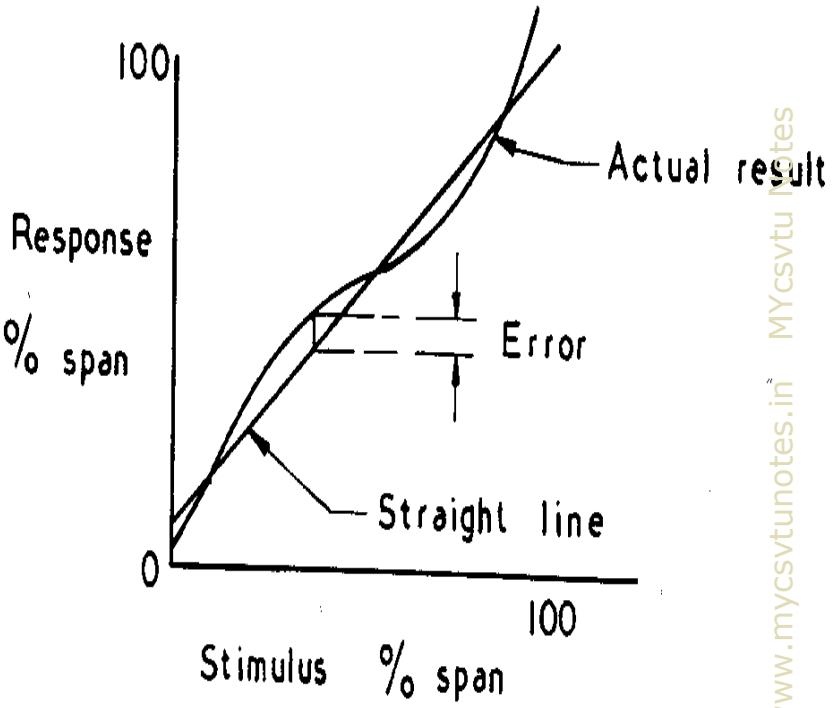
Since the reactor will be started up from ambient temperature occasionally, an additional sensor should be provided with a range of -50 to 400 °C.

Static Characteristics

Static characteristics of an instrument includes;

5. Linearity

This is the closeness to a straight line of the relationship between the true process variable and the measurement. Lack of linearity does not necessarily degrade sensor performance. If the nonlinearity can be modeled and an appropriate correction applied to the measurement before it is used for monitoring and control, the effect of the non-linearity can be eliminated.



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

Static Characteristics

Static characteristics of an instrument includes;

6. 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.

If sensor reliability is very important, the engineer can provide duplicate sensors, so that a single failure does not require a process shutdown

Calibration

Assigning standard values to an equipment is calibration.

Static Error

- Numerical differences between true value of a quantity and its value as obtained by measurement.

- Static errors are generally of three types;

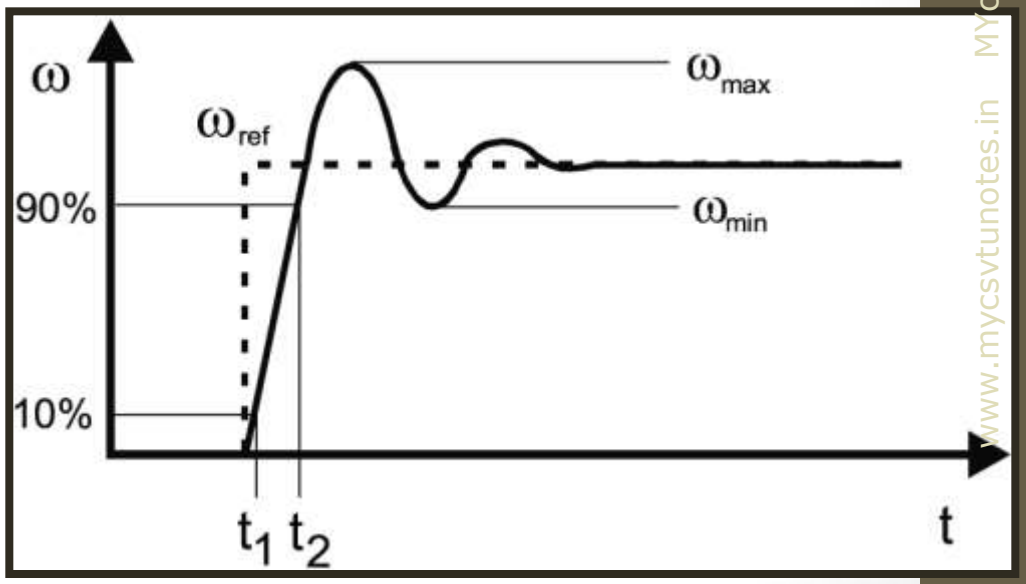
1. Mistake or gross error (human mistakes)
2. Systematic errors (instrumental or environmental errors)
3. Random or accidental errors (unknown)

Performance Characteristics

- Dynamic characteristics

Dynamic Characteristics of an instrument includes;

1. Speed of response
2. Fidelity
3. Lag
4. Drift



Other Issues

1. Maintenance
2. Consistency with process environment
3. Safety
4. Cost

Consistency with process environment

- **Direct contact –**

Sensors such as orifice plates and level floats have direct contact with process fluids.

Sheath protection –

Sensors such as thermocouples and pressure diaphragms have a sheath between the process fluid and the sensor element

- **Sample extraction –**

When the process environment is very hostile or the sensor is delicate and performs a complex physiochemical transformation on the process material, a sample can be extracted.

Location of Measurement Displays

Local display

Local panel display

Centralized control room

Remote monitoring

The Smart Sensor Revolution

Digital conversion and transmission

Diagnostics

Signal conditioning

Configuration

Principle measurements desired in Industry

Principle measurements desired in industry

(a) Temperature

(b) Pressure

(c) Level

(d) Flow

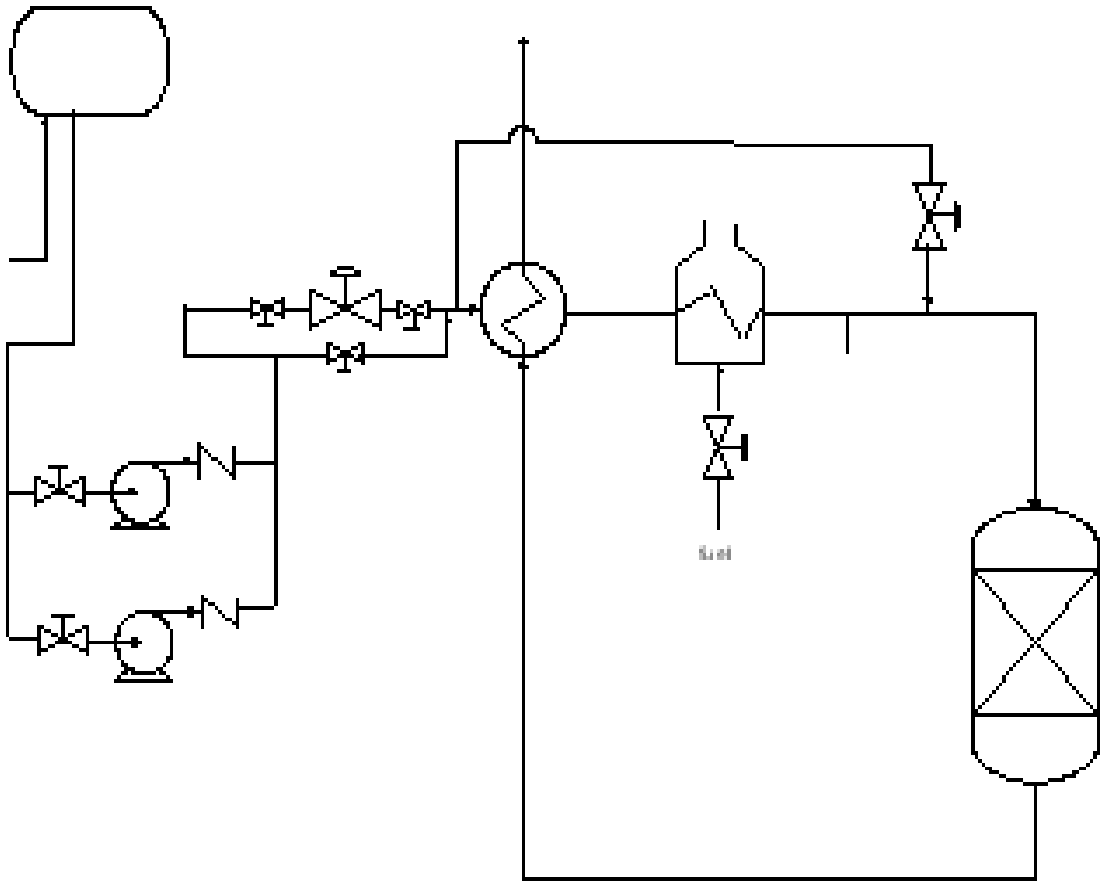
(e) Others (Composition, pH etc.)

Home Work

You have two challenges

What variables should be measured?

What sensor should be specified for each measurement?



Reactor with feed-effluent heat exchange

Discussion & Questions?