CH0302 Process Instrumentation

Lecture 3 – Introduction

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Introduction - outline

- Types of Instruments
- Characteristics of Instruments
- Static Characteristics
- Dynamic Characteristics
- Summary

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Introduction – Types

- Automatic
- Manual
- Self operated
- Power operated
- Self contained
- Non-self contained

Introduction – Types

Automatic	– does not require service of an operator in fulfilling its function
Manual	– requires service of an operator
Self operated	– instrument like mercury-in-thermometer derives its power wholly from thermal expansion of mercury
Power operated	– instrument requires a source of auxiliary power such as compressed air, electricity, hydraulic supply or mechanical source of power.
Self contained	– instrument such as mercury-in-thermometer, all the parts from primary element to functioning element are contained in one assembly
Non-self contained	- primary element will be located at some distance, say 15 – 100 ft from the secondary element. Indicating element may also be remotely located

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Introduction – Characteristics of Instruments

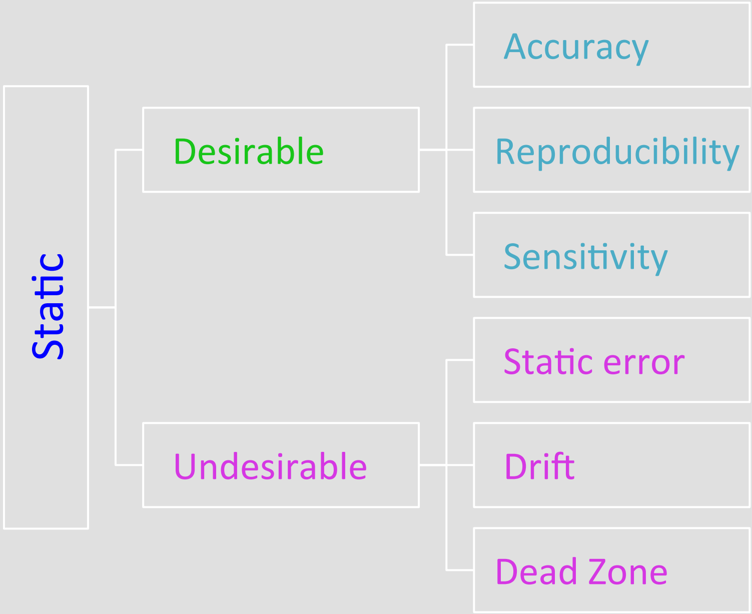
- Static
- Dynamic

Introduction – Static and Dynamic Characteristic

- Static characteristic of an instrument are, in general those that must be considered when instrument is used to measure a condition or quantity not varying with time.

- On the other hand, when industrial instrument is used for measuring quantities that fluctuates with time is called as the dynamic characteristic of the equipment.

Introduction – Static and Dynamic Characteristic



Range and Span

- In an indicating or recording instrument the value of the measured quantity is indicated on a scale or chart by a pointer or some similar means.
- Suppose that the highest point of calibration is b units and the lowest point a units and the calibration is continuous between these two points.
- Then the instrument range is from a to b and the span is given by the difference between b and a. i.e. span = $(b - a)$

Range and Span

- For a pyrometer calibrated 0 to 1000 ^{O}C . What is the range and span?

Range and Span

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- The range is from 0 to 1000 ^{O}C

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- The Span is 1000 ^{O}C

Range and Span

- For a pyrometer calibrated 0 to 1000 ^{O}C . What is the range and span?
- The range is from 0 to 1000 ^{O}C
- The Span is 1000 ^{O}C

Range and Span

- If a pyrometer calibrated between 500 to 1000 ^{O}C . What is the range and span?

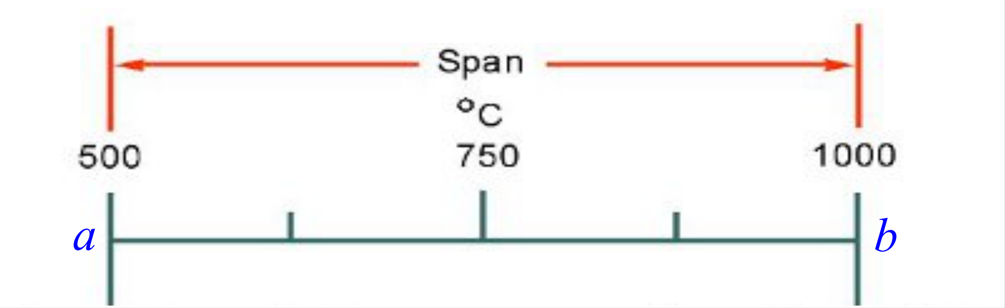
Range and Span - *Pyrometer*

Range is 500 to 1000 ^{O}C

Span is 500 ^{O}C

Lowest point

Highest point



Accuracy

- Accuracy of an instrument is expressed in many ways.
- A common method is to specify "accurate to within ± x percentage".

Accuracy

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Accuracy – Self contained instrument

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- Therefore the accuracy of pyrometer is ± 0.5 per cent times (1800 – 1000) ^{O}C or ± 4 ^{O}C

- i.e. (0.5/100) x (800) = ± 4 ^{O}C

Accuracy – Non-self contained instrument

- Many instruments used in industries are not self contained but are composed of separate units/elements.
- For example, in a pressure-gage transmitter receiver system there are separate units or elements.
- The accuracy for these kind of systems are obtained by the accuracy limit specified for each unit/limit of the system.
- Hence the accuracy of each unit be within $\pm a$, within $\pm b$, within $\pm c$ and so on.

Accuracy – Non self contained

- The least accuracy for these systems in percentage is given by

Within ± $(a + b + c + \text{etc.})$

- The root square accuracy in percentage is given by

Within ± $\sqrt{a^2 + b^2 + c^2 + etc}$

Accuracy – Non self contained

Example:

- For a general measuring system where the errors in the transducer, signal conditioner and recorder are within ± 2%, within ± 3% and within ± 4% respectively. Calculate the least accuracy and square root accuracy of the given system.
- Least Accuracy ?
- Root-square accuracy?

Accuracy – Non self contained

Example:

- For a general measuring system where the errors in the transducer, signal conditioner and recorder are within ± 2%, within ± 3% and within ± 4% respectively. Calculate the least accuracy and square root accuracy of the given system.
- Least Accuracy ?

Introduction – Static Characteristics (desirable)

Accuracy – Non self contained

Example:

- For a general measuring system where the errors in the transducer, signal conditioner and recorder are within ± 2%, within ± 3% and within ± 4% respectively. Calculate the least accuracy and square root accuracy of the given system.
- Least Accuracy = ± 9%
- Root-square accuracy?

Accuracy – Non self contained

Example:

- For a general measuring system where the errors in the transducer, signal conditioner and recorder are within ± 2%, within ± 3% and within ± 4% respectively. Calculate the least accuracy and square root accuracy of the given system.
- Least Accuracy = ± 9%
- Root-square accuracy = ± 5.4%

Introduction – Static Characteristics (desirable)

Reproducibility

- Degree of closeness with which the given value may be repeatedly measured.

- In other words, ability of an instrument to display the same reading for a given input applied on number of occasions.

- Can be expressed in terms of units for a given period of time.

- Perfect reproducibility means that the instrument has no drift

Sensitivity

- Denotes the smallest change in value of a measured variable to which an instrument responds.

- In other words it is defined as the change in output towards the change in input at steady state.

- Sensitivity (K) is given by $K = \frac{\Delta\theta_o}{\Delta\theta_i}$

Static Error

- The difference between true value of the quantity not changing with time and value indicated by the instrument.

- It is expressed in $+x$ units or in $-x$ units.

True Value + Static Error = Instrument Reading

- For + Static error the instrument reads high

- For – Static error the instrument reads low

Static Error – Example

- If the accuracy of a temperature measuring instrument, with full range of 0 ^{O}C to 500 ^{O}C is specified as ±0.5%. When this instrument is used to measure a temperature of a liquid system, it indicates 250 ^{O}C. What is the static error and true value in + and -?

Introduction – Static Characteristics (Undesirable)

Static Error – Solution

- Error = (500 – 0) x ± 0.5/100 = ± 2.5 ^{O}C
- For + Static Error,

  The True Value = 250 + 2.5 = 252 ^{O}C

- For – Static Error,

  The True Vale = 250 – 2.5 = 247.5 ^{O}C

Introduction – Static Characteristics (Undesirable)

Drift

– Slow change in response or output of an instrument.

– if an instrument does not produce the same reading at different times of measurement from the same input, it is said to have drift.

Note : If an instrument is said to have perfect reproducibility, it is said to have no drift.

Introduction – Static Characteristics (Undesirable)

Types of Drift

- Drift
  - Zero
  - Span
  - Zonal

Introduction – Static Characteristics (Undesirable)

Drift – Slow change in response or output of an instrument

Zero drift – Changes in instrument output when the input signal remains zero.

– In other words, the changes that occur in the output when there is zero input.

– In an indicating or recording element it is easily corrected by shifting the pen or pointer position.

– It is due to some kind of simple effect such as permanent set or slippage.

Introduction – Static Characteristics (Undesirable)

Drift – Slow change in response or output of an instrument

Span drift – Proportional changes in instrument output all along the upward scale.

– This may be caused by a gradual change in a spring action.

Introduction – Static Characteristics (Undesirable)

Drift – Slow change in response or output of an instrument

Zone drift – It occurs when only one portion a calibration changes.

- This may be caused by high stress on some portion of the instrument .

Introduction – Static Characteristics (Undesirable)

Drift – Slow change in response or output of an instrument

Example - Assume that an instrument is used in calibration where input to and output from the instrument is made. The following data is available from the calibration and given in four tables.

Table. 1

Input, x units	Output_I, x Units	Output_II, x units
0	0	10
10	10	20
20	20	30
30	30	40
40	40	50
50	50	60
60	60	70

Table. 2

Input, x units	Output_I, x Units	Output_II, x units
0	0	0
10	10	20
20	20	40
30	30	60
40	40	80
50	50	100
60	60	120

Drift – Slow change in response or output of an instrument

Example - Assume that an instrument is used in calibration where input to and output from the instrument is made. The following data is available from the calibration and given in four tables.

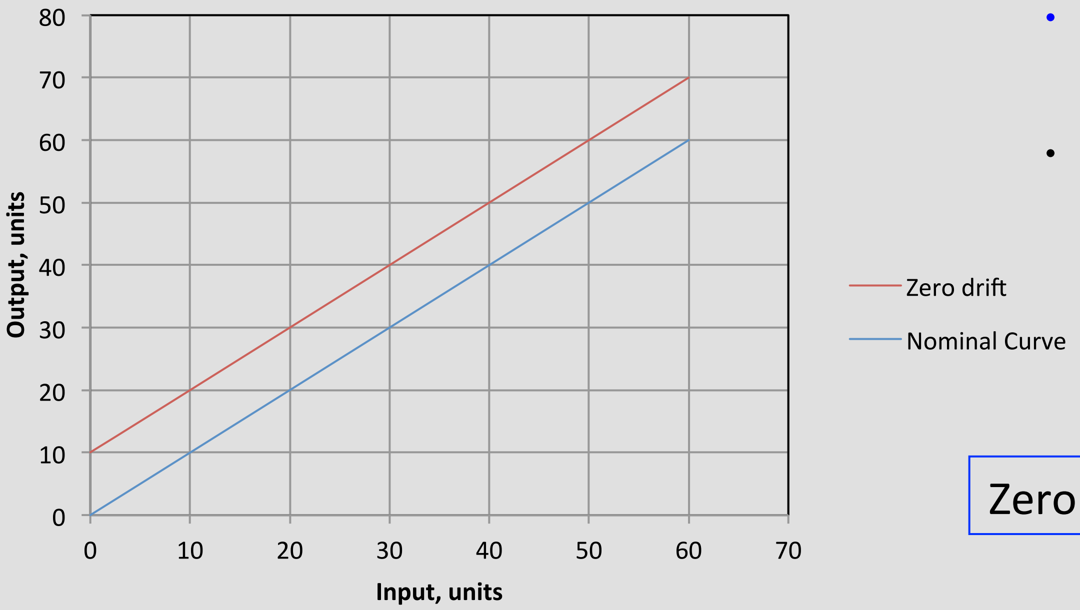
Table. 3

Input, x units	Output_I, x Units
0	0
10	10
20	20
30	30
40	40
50	50
60	60

Table. 4

Input_II, x units	Output_II, x Units
0	0
2	10
6	30
8	40
10	50
12	60

Introduction – Static Characteristics (Undesirable)

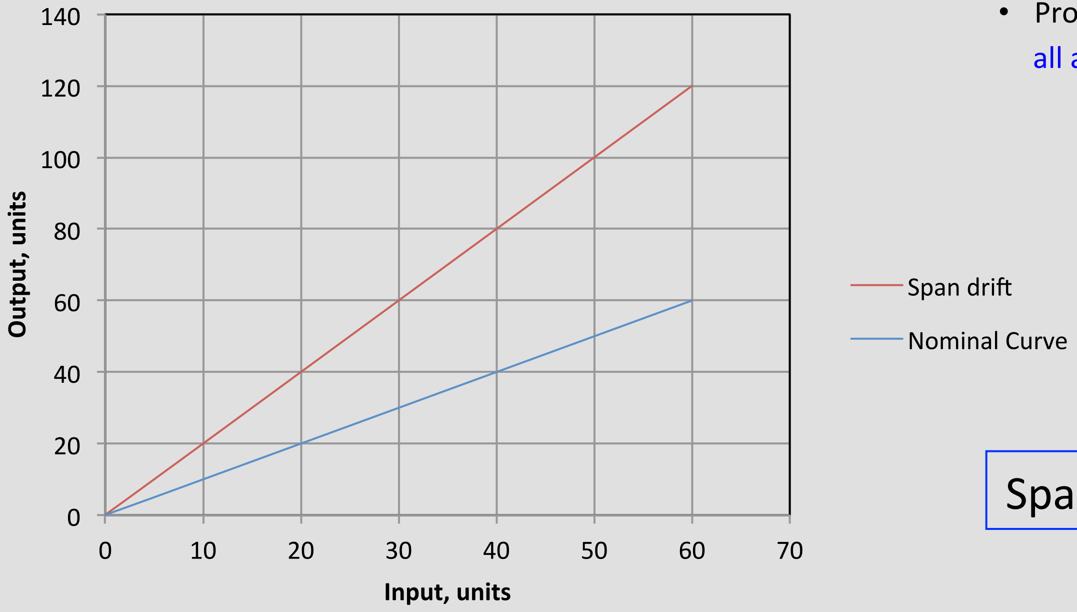


- Changes in instrument output when the input signal remains zero.

- In other words, the changes that occur in the output when there is zero input.

Zero Drift

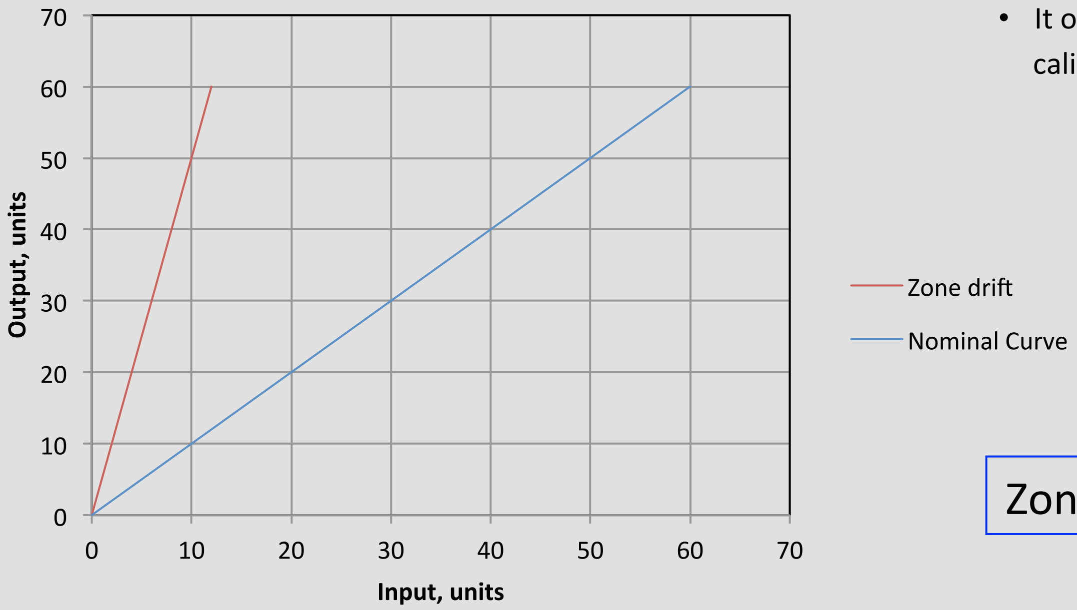
Introduction – Static Characteristics (desirable)



- Proportional changes in instrument output all along the upward scale

Span Drift

Introduction – Static Characteristics (Undesirable)



- It occurs when only one portion a calibration changes.

Zone drift

Dead Zone

- It is the largest change in the physical variable to which the instrument does not respond.

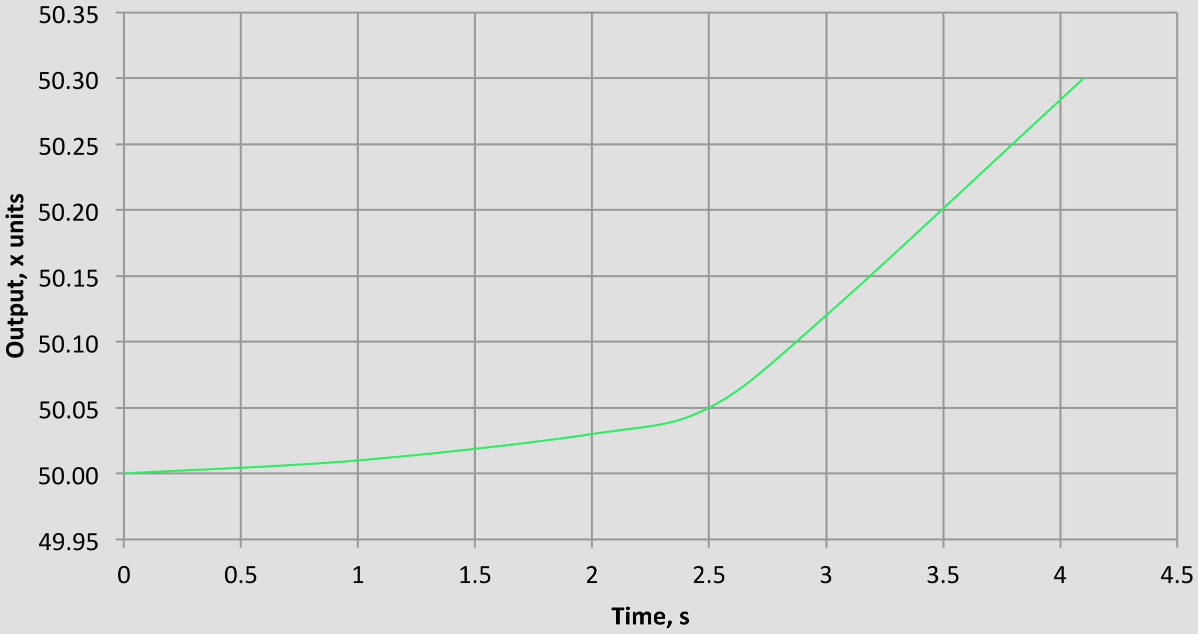
- i.e. the region up to which the instrument does not respond for an input is called dead zone.

Dead Zone

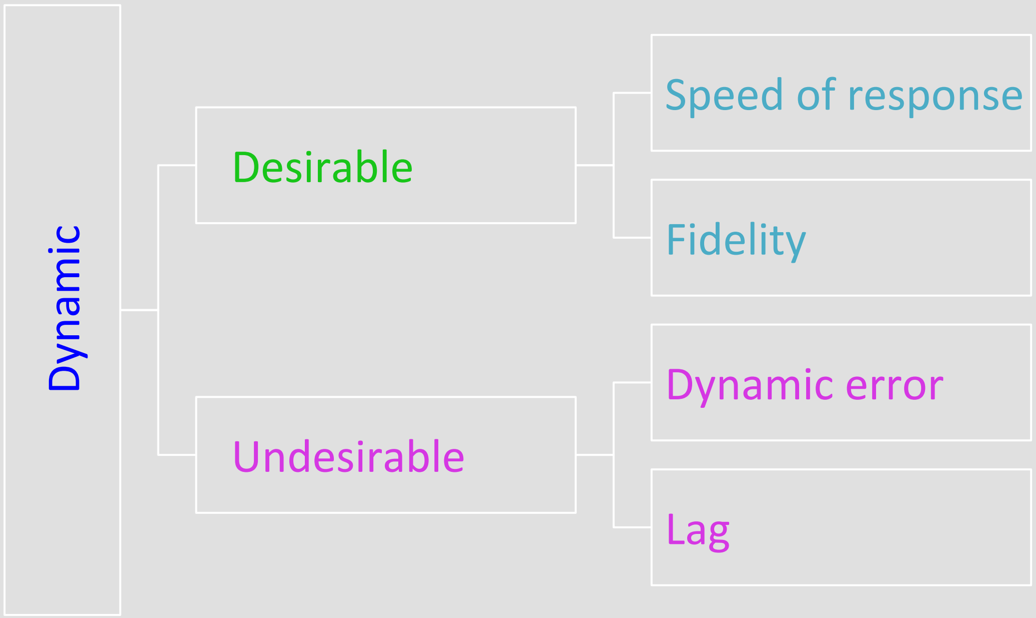
Example - An instrument is used to measure a physical quantity the the results of measurement is given below. Plot a graph and show the dead zone.

Time (s)	Out put, x units
0	50.00
1	50.01
2	50.03
2.5	50.05
3	50.12
4.1	50.30

Introduction – Static Characteristics (Undesirable)



Introduction – Dynamic Characteristic



Speed of Response

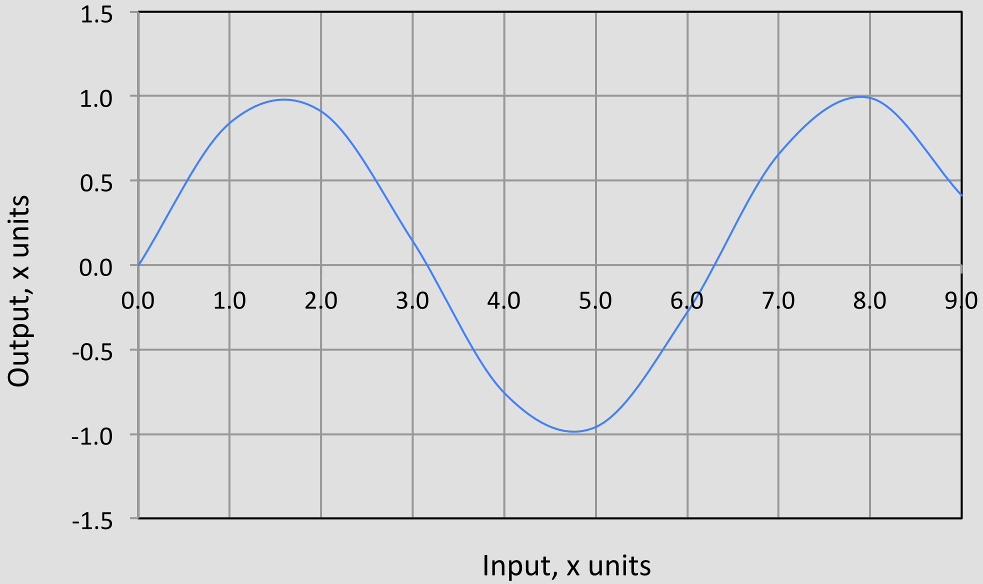
- The quickness with which the instrument respond to a change in the output signal.

Fidelity

- It is the ability of the measurement system to reproduce the output in the same form as the input.

i.e. if the input of the system is sine wave, the system is said to have 100% fidelity if the output is a sine wave

Fidelity



Reproduce the output in the same form as the input.

Introduction – Dynamic Characteristic (Undesirable)

Lag

- It is the delay in response of an instrument to a change in the input signal.

- It is also called as **measuring lag** .

- Response of a system immediately begins on a change in measured value variable may also called dead time.

Dynamic Error

- Difference between indicated quantity and the true value of the time varying quantity is called dynamic error.

Time Constant

- Generally, time required for an instrument to indicate reading resulting from an input signal.

Introduction – Static Characteristics (Undesirable)

First Order System Response – Mercury –in-glass thermometer

References

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