Characteristics of instruments

Accuracy

Accuracy is a property of a complete measurement rather than a single element.

Accuracy is quantified using measurement error:

E = measured value – true value
= system output – system input

Accuracy and Precision

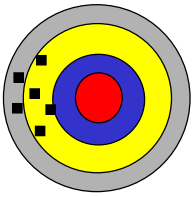
- **Accuracy**: **is the closeness of a measurement (or a set of observations) to the true value**
  - *Higher the accuracy, lower the error*

- **Precision:** **is the closeness of multiple observations or repeatability of a measurement**
  - *Refers to how close a set of measurement are to each other*

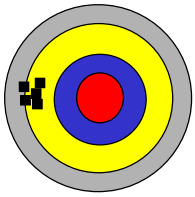
Accuracy versus Precision

(shooting at a target)

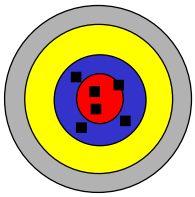
Not accurate or Precise



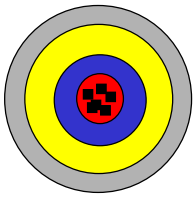
Precise but NOT accurate



Accurate and NOT Precise



Accurate AND Precise



Percentage error

The error of measuring system is expressed as a percentage of the measuring range of the equipment

percentage error = indicated value – true value x 100%
scale value

Exercise 4

A 0^0 – 100^0C thermometer is found to have a constant error of 0.2^0C.

Calculate the percentage error at readings of
(a) 10^0 C
(b) 50 ^{0}C
(c) 100 ^{0}C

Exercise 4 (Solution)

$$PE_1 = \frac{0.2 \times 100}{10} = 2\ \%$$

$$PE_2 = \frac{0.2 \times 100}{50} = 0.4\ \%$$

$$PE_3 = \frac{0.2 \times 100}{100} = 0.2\ \%$$

Exercise 3

A 0 to 10 bar pressure gauge was found to have an error of ± 2 bar when calibrated by the manufacturer

Calculate

(a) the percentage error of the gauge

(b) the possible error for a 5 bar reading

Possible and Probable Errors

Ex: A measuring system with 3 elements has maximum possible errors
±a%, ± b%, ± c%

Maximum Possible Error = ±(a + b + c)

Probable Error = ± $\sqrt{a^2 + b^2 + c^2}$

Exercise 5

A general measuring system has the following errors:

- transducer ± 2%
- signal conditioner ± 3%
- recorder ± 4%

Calculate

- the maximum possible error
- the probable error

Exercise 5 (Solution)

Maximum possible error = ± (2 + 3 + 4)% = ± 9 %

Probable error = $\pm \sqrt{(2^2 + 3^2 + 4^2)}$

= ± 5.4 %

Exercise 6

A vibration measuring system involves the use of a piezo-electric transducer, a charge amplifier and a recorder. If the maximum errors are

- transducer ± 0.5%
- amplifier ± 1%
- recorder ± 1.5%

Calculate

- the maximum possible error
- the probable error

Exercise 6 (Solution)

Maximum possible error = ± (0.5 + 1 + 1.5)% = ± 3 %

Probable error = $\pm \sqrt{(0.5^2 + 1^2 + 1.5^2)}$

= ± 1.87 %

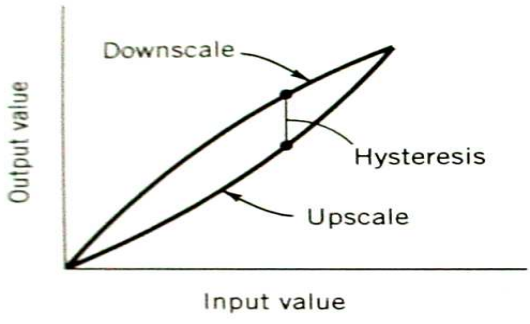
Types of Instrument Errors

- Hysteresis Error
- Linearity Error
- Repeatability Error
- Reproducibility Error

Hysteresis Error

Many measuring systems have the undesirable characteristic of giving a different value when the input is increasing than when it is decreasing. This is called **hysteresis**.

Hysteresis may be the result of mechanical friction, magnetic effects, elastic deformation, or thermal effects.



(a) Hysteresis error

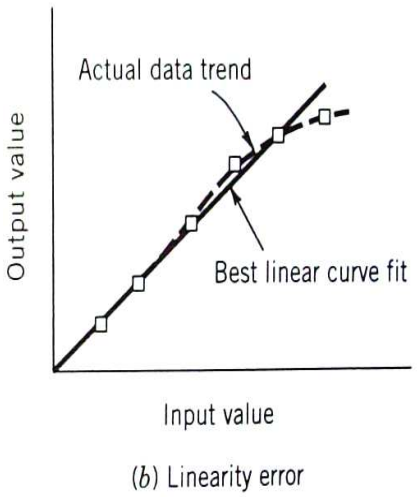
Linearity Error

Many types of measuring systems have linear input/output behavior, at least within a narrow range of inputs. The measuring systems thus follow an input/output relation like

$$y_L = a_0 + a_1 x.$$

The data you get is the slope of the input/output relation (a_1) and the zero input value (a_0). For these types of measuring systems, the deviation from linear behavior can be calculated:

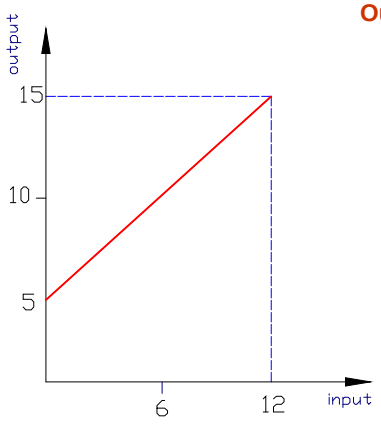
$$e_L = y - y_L$$



(b) Linearity error

Linearity error - Example

Input x = 6 units
Output y = 11 units



$$y_L = a_0 + a_1 x.$$

$$= 5 + \frac{10}{12} \cdot 6 = 10 \text{ units}$$

$$e_L = y - y_L =$$

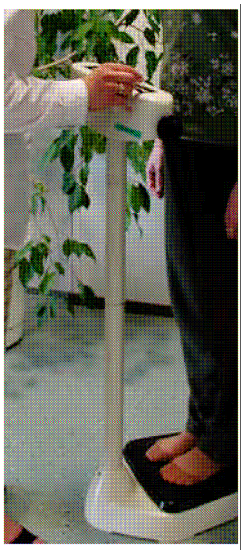
$$11 - 10 = 1 \text{ unit}$$

Repeatability

Repeatability is the variation between the measurements obtained when an operator measures the same dimension (characteristic) several times under the following conditions:

- the same measuring instrument;
- on the same parts;
- in the same location on the part;
- under the same conditions of use;
- over a short period of time.

Repeatability example



If a person wants his weight to be measured, repeatability requires the measurements to give the same weight of the same person on the same weightbridge and with all the other conditions the same

Reproducibility

Reproducibility is a measure of the ability of the instrument to give the same reading of the same measurand, if repeated under different *conditions*.

The *conditions* include the effects of the method, operator, location, etc…

Reproducibility example

Assuming that the two fish above are the same, reproducibility requires the measurements to give the same length, even if the location and the people (operators) are different.