Calibration Process

In measurement technology and metrology, **calibration** is the comparison of measurement values delivered by a device under test with those of a calibration standard of known accuracy. Such a standard could be another measurement device of known accuracy, a device generating the quantity to be measured such as a voltage, a sound tone, or a physical artifact, such as a meter ruler.

The outcome of the comparison can result in one of the following:

- no significant error being noted on the device under test
- a significant error being noted but no adjustment made
- an adjustment made to correct the error to an acceptable level

Strictly speaking, the term "calibration" means just the act of comparison and does not include any subsequent adjustment.

The calibration standard is normally traceable to a national standard held by a national metrological body.

alibration may be required for the following reasons:

- a new instrument
- after an instrument has been repaired or modified
- when a specified time period has elapsed
- when a specified usage (operating hours) has elapsed
- before and/or after a critical measurement
- after an event, for example
    - after an instrument has been exposed to a shock, vibration, or physical damage, which might potentially have compromised the integrity of its calibration
    - sudden changes in weather

- whenever observations appear questionable or instrument indications do not match the output of surrogate instruments
- as specified by a requirement, e.g., customer specification, instrument manufacturer recommendation.

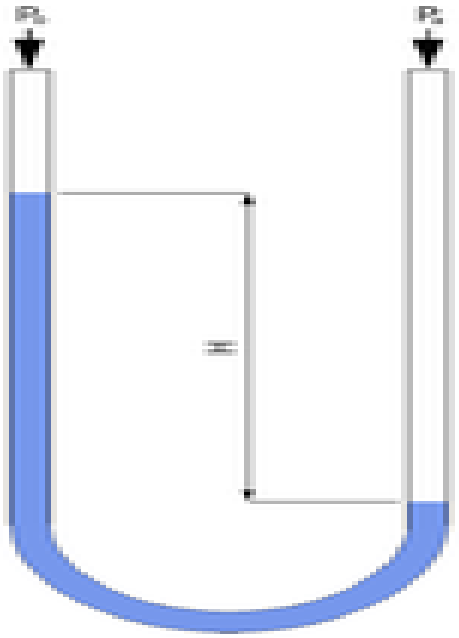
In general use, calibration is often regarded as including the process of **adjusting** the output or indication on a measurement instrument to agree with value of the applied standard, within a specified accuracy. For example, a thermometer could be calibrated so the error of indication or the correction is determined, and adjusted (e.g. via calibration constants) so that it shows the true temperature in Celsius at specific points on the scale. This is the perception of the instrument's end-user. However, very few instruments can be adjusted to exactly match the standards they are compared to. For the vast majority of calibrations, the calibration process is actually the comparison of an unknown to a known and recording the results.

Example

One of the earliest pressure measurement devices was the Mercury barometer, credited to Torricelli (1643), which read atmospheric pressure using Mercury. Soon after, water-filled manometers were designed. All these would have linear calibrations using gravimetric principles, where the difference in levels was proportional to pressure. The normal units of measure would be the convenient inches of mercury or water.

In the direct reading hydrostatic manometer design on the right, applied pressure P_a pushes the liquid down the right side of the manometer U-tube, while a length scale next to the tube measures the difference of levels. The resulting height difference "H" is a direct measurement of the pressure or vacuum with respect to atmospheric pressure. In the absence of differential pressure both levels would be equal, and this would be used as the zero point.

The Industrial Revolution saw the adoption of "indirect" pressure measuring devices, which were more practical than the manometer. An example is in high pressure (up to 50 psi) steam engines, where mercury was used to reduce the scale length to about 60 inches, but such a manometer was expensive and prone to damage.[21] This stimulated the development of indirect reading instruments, of which the Bourdon tube invented by Eugène Bourdon is a notable example.



Indirect reading design showing a Bourdon tube from the front (left) and the rear (right).

In the front and back views of a Bourdon gauge on the right, applied pressure at the bottom fitting reduces the curl on the flattened pipe proportionally to pressure. This moves the free end of the tube which is linked to the pointer. The instrument would be calibrated against a manometer, which would be the calibration standard. For measurement of indirect quantities of pressure per unit area, the calibration uncertainty would be dependent on the density of the manometer fluid, and the means of measuring the height difference. From this other units such as pounds per square inch could be inferred and marked on the scale.