Calibration is the process of evaluating and adjusting the precision and accuracy of measurement equipment. Proper calibration of an instrument allows people to have a safe working environment and produce valid data for future reference.

**Purpose of instrument calibration**

Calibration refers to the act of evaluating and adjusting the precision and accuracy of measurement equipment. Instrument calibration is intended to eliminate or reduce bias in an instrument's readings over a range for all continuous values.

- **Precision** is the degree to which repeated measurements under unchanged conditions show the same result
- **Accuracy** is the degree of closeness of measurements of a quantity to its actual true value.

For this purpose, reference standards with known values for selected points covering the range of interest are measured with the instrument in question. Then a functional relationship is established between the values of the standards and the corresponding measurements. There are two basic situations:

- **Instruments which require correction for bias**: The instrument reads in the same units as the reference standards. The purpose of the calibration is to identify and eliminate any bias in the instrument relative to the defined unit of measurement. For example, optical imaging systems that measure the width of lines on semiconductors read in micrometers, the unit of interest. Nonetheless, these instruments must be calibrated to values of reference standards if line width measurements across the industry are to agree with each other.

- **Instruments whose measurements act as surrogates for other measurements**: The instrument reads in different units than the reference standards. The purpose of the calibration is to convert the instrument readings to the units of interest. An example is densitometer measurements that act as surrogates for measurements of radiation dosage. For this purpose, reference standards are irradiated at several dosage levels and then measured by radiometry. The same reference standards are measured by densitometer. The calibrated results of future densitometer readings on medical devices are the basis for deciding if the devices have been sterilized at the proper radiation level.

**Basic steps for correcting the instrument for bias**

The calibration method is the same for both situations stated above and requires the following basic steps:

1. Selection of reference standards with known values to cover the range of interest.
2. Measurements on the reference standards with the instrument to be calibrated.
3. Functional relationship between the measured and known values of the reference standards (usually a least-squares fit to the data) called a **calibration curve**.
4. Correction of all measurements by the inverse of the calibration curve.

Some people mix up field check and calibration. Field check is when two instruments have the same reading; this does not mean they are calibrated; it may be that both instruments are wrong. Let's use thermometer as an example; if a thermometer always reads .25 degree higher, this error can not be eliminated by taking averages, because this error is constant. The easiest way to determine if it is accurate and fix it is to send the thermometer to a calibration laboratory. Another way to reveal constant errors is to have one or more similar thermometers. One thermometer is used and then replaced by another thermometer. If readings are divided among two or more thermometers, inconsistencies among the
When do instruments need to be calibrated?

- Before major critical measurements
  - Before any measurements that requires highly accurate data, send the instruments out for calibration and remain unused before the test.

- After major critical measurements
  - Send the instrument for calibration after the test helps user decide whether the data obtained were reliable or not. Also, when using an instrument for a long time, the instrument's conditions will change.

- After an event
  - The event here refers to any event that happens to the instrument. For example, when something hits the instrument or any kinds of accidents that might impact the instrument's accuracy. A safety check is also recommended.

- When observations appear questionable
  - When you suspect the data's accuracy that is due to instrumental errors, send the instrument to calibrate.

- Per requirements
  - Some experiments require calibration certificates. Check the requirements first before starting the experiment.

- Indicated by manufacturer
  - Every instrument will need to be calibrated periodically to make sure it can function properly and safely. Manufacturers will indicate how often the instrument will need to be calibrated.

Figure 1: For instance, the pH electrode used in titration experiments must be calibrated before the beginning of data collection.
Why does calibration of instrument so important?

Let's say if you are going to publish a paper and you submitted the paper with data obtained from an uncalibrated instrument. What if someone repeated you experiment and find out that your result is wrong? This will hurt your reputation in the field, decrease the reliability on your future works. Another example, if you are going to work with a chemical that will explode when it gets in contact with air temperature above 50°C. So you adjust the room temperature before you start working, then check the temperature with an uncalibrated thermometer. If the termometer gives a lower temperature than the true temperature, then you will be working in an unsafe environment. This example may be unrealistic, but there are many chemical and substance out there that require accurate and precise measurements in order to provide others a safe working environment.

References


Contributors

- NIST Engineering Statistics Handbook
- Jenny Wu (University of California, Davis)