11-Tips to consider when calibrating temperature sensors

Let’s dig into the actual calibration of temperature sensors and the different things to consider....

1 - Handling of the temperature sensor

Different sensors have different mechanical structures and robustness.

The most accurate temperature sensors (RTD’s), used as reference sensors in temperature laboratories, are very fragile. If the sensor is dropped, the sensor must be checked before any further use.

Luckily most of the industrial temperature sensors are robust and will survive normal handling. There are some industrial sensors that are made very robust and then can withstand pretty rough handling. But if you are not sure of the structure of the sensor you should calibrate, it is better to be safe than sorry.

It’s never wrong to handle any sensor as if it was a RTD.

In addition to mechanical shocks, thermal shock to the sensor can damage it or affect the accuracy. Thermocouples are typically not as sensitive as RTD probes.

2 - Preparation

A visual inspection should be performed in order to see that the sensor looks ok and make sure it has not been bent or damaged, and that the wires are good.

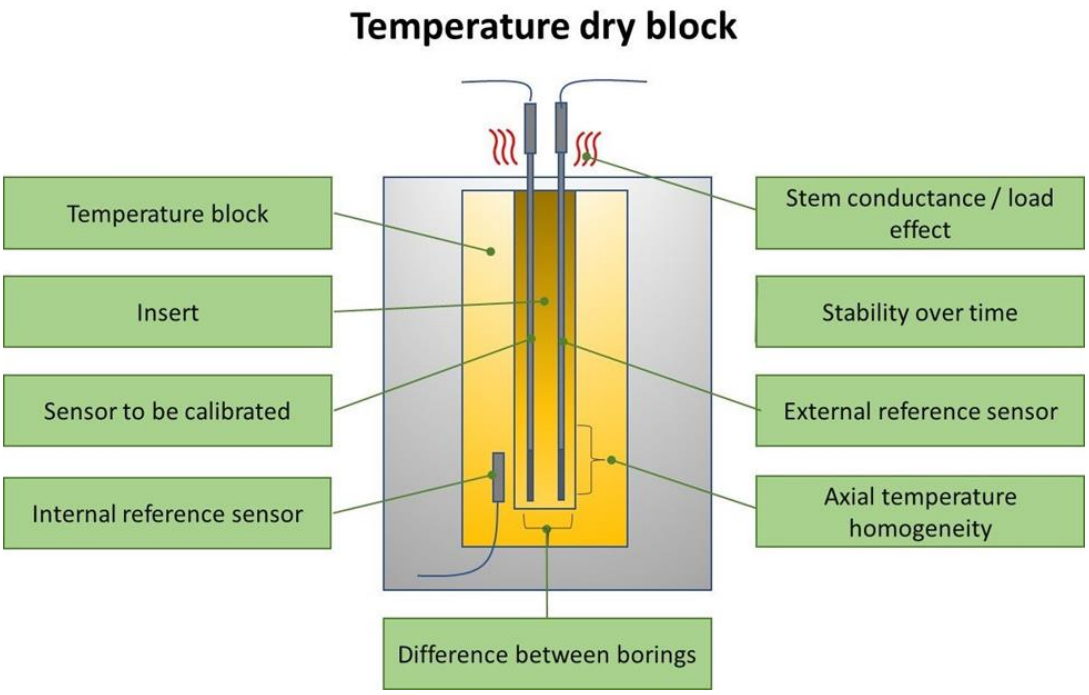
Contamination may be an issue, so it is good to know where the sensor has been used and what kind of media it has been measuring. Always clean the sensor before calibration, especially if you plan to use a liquid bath for calibration.

The insulation resistance of an RTD sensor may be measured prior to calibration. This is to make sure that the sensor is not damaged and the resistance is high enough between the sensor and the body. A drop in the insulation resistance may cause error in measurements and is a sign of a sensor damage.

3 - Temperature source

You need to have a temperature source to calibrate a temperature sensor. It is not possible to simulate temperature.

For industrial purposes, the commonly used is a temperature dry-block. It is handy, portable and typically has enough accuracy.



A liquid bath may be used for higher accuracy. To bulky for portability, however it may be used in laboratory conditions.

A stirred ice-bath is often used for zero Centigrade point calibration. It is simple, affordable and provides a good accuracy for the zero point. Fixed-point cells offer the most accurate temperature however, they are very expensive. Those are mostly used in accurate (and accredited) temperature calibration laboratories.

4 - Reference temperature sensor

You need to know with a very high degree of accuracy the temperature of the heat source. Dry-blocks and liquid baths offer an internal reference sensor that measures the temperature. For more accurate results, you should be using a separate, accurate reference temperature sensor that is inserted in the same temperature as the sensor(s) to be calibrated. That kind of reference sensor will more accurately measure the temperature than the sensor being calibrated.

The reference sensor should have a valid, traceable calibration. It is easier to send a

reference sensor out for calibration than sending the whole temperature source. Keep in mind the temperature gradient of the temperature block if you always use the reference sensor calibrated and not the block.

As for thermodynamic characteristics, the reference sensor should be as similar as possible compared to the sensor to be calibrated, to ensure they behave the same way during changes in temperature.

The reference sensor and test sensor should be immersed to the same depth in the temperature source. Typically, all sensors are immersed to the bottom of a dry-block. Very short sensors are more difficult as they will only immerse a limited depth into the temperature source, make sure that your reference sensor is immersed equally as deep. In some cases, this requires use of a dedicated short reference sensor.

Using fixed-point cells, you won't need any reference sensor, because the temperature is based on physical phenomena and is very accurate by its nature.

5 - Measuring the temperature sensor output signal

Most temperature sensors have an electrical output (resistance or voltage) that needs to be measured and converted to temperature. You need to have a device to be used for the measurement. Some temperature sources offer measurement functions for the sensors, both the device under test (DUT) and reference sensor.

If you measure the electrical output, you will need to convert that into temperature. In most industrial cases, you will use a measurement device that can do the conversion for you, so you can see the signal conveniently in the temperature unit (C or F).

Whatever means you use for the measurement, make sure you know the accuracy and uncertainty of the device and ensure it has valid traceable calibration.

6 - Immersion depth

How deep you insert the sensor into temperature source is one important consideration when calibrating temperature sensors.

Temperature calibration labs use this rule of thumb when using a stirred liquid bath:

- 1% accuracy - immerse 5 diameters + length of the sensing element
- 0.01% accuracy - immerse 10 diameters + length of the sensing element
- 0.0001% accuracy - immerse 15 diameters + length of the sensing element

Heat conduction in a stirred liquid bath is better than in a dry-block and the required immersion depth is smaller. For dry-blocks, it's recommended that you immerse the probe 15-times the diameter of the sensor added with the length of the sensor element. Sometimes it is difficult to know how long the actual element is inside the sensor, but it should be mentioned in the sensor specifications.

Also, you should be aware of where the sensor element is located (it is not always in the very tip of the sensor) i.e. spring loaded vs. tight fit.

The sensor to be calibrated and the reference sensor should be immersed into the same depth so that the middle points of the actual sensor elements are in the same depth.

Naturally with very short sensors, it is not possible to immerse them very deep. That is one reason for the high uncertainty when calibrating short sensors.

7 - Stabilization

Remember that a temperature sensor always measures its own temperature!

Temperature changes pretty slowly and you should always wait long enough to have all parts stabilized to the target temperature. When you insert the sensor into a temperature, it will always take some time before the temperature of the sensor has reached that temperature and stabilized.

Your reference sensor and the sensor to be calibrated (DUT) may have very different thermodynamic characteristics, especially if they are mechanically different.

Often one of the biggest uncertainties related to temperature calibration can be that the calibration is done too quickly.

If you most often calibrate similar kinds of sensors, it is wise to make some type of tests to learn the behavior of those sensors.

8 - Temperature sensor handle

The sensor handle part, or the transition junction, typically has a high temperature limit. If it is heated too high, damage may occur to the sensor. Make sure you know the specifications of the sensors you calibrate.

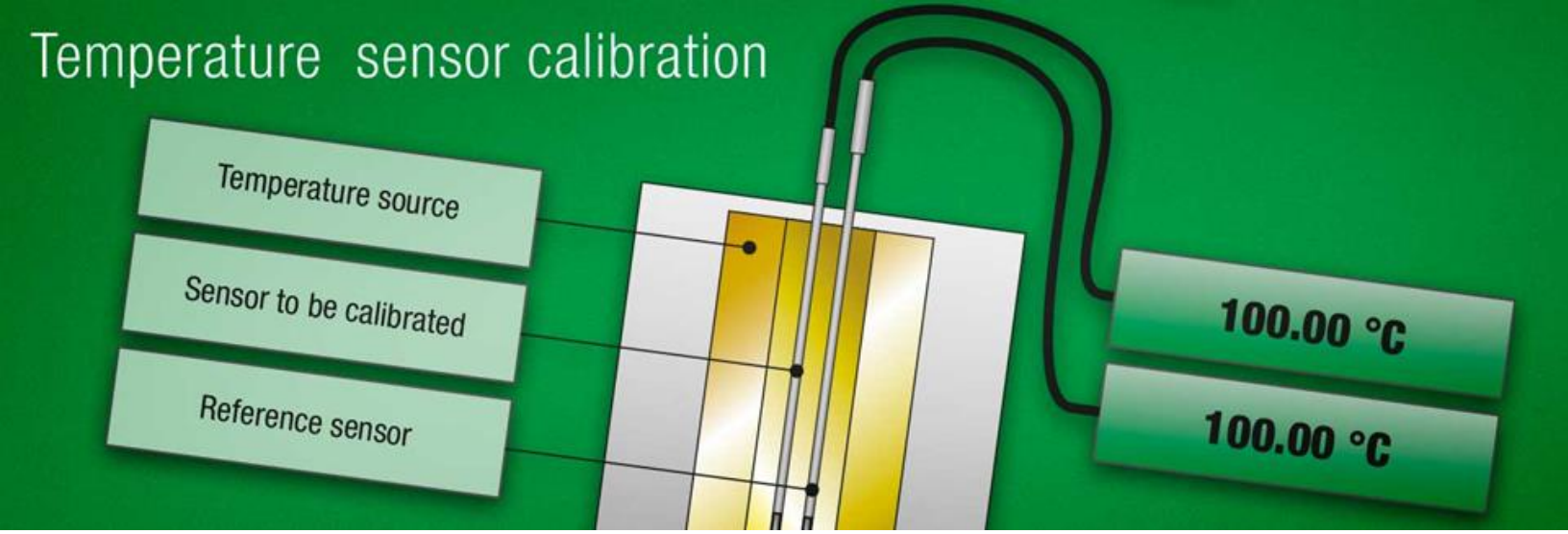
If you calibrate in high temperatures, it is recommended to use a temperature shield to protect the sensor handle.

9 - Calibrated temperature range

With temperature sensors, it is pretty common that you don’t calibrate the whole temperature range of the sensor.

The very top of the range is something you should be careful in calibrating. For example, an RTD sensor may drift permanently if you calibrate it in too high of a temperature.

Also, the coldest points of the sensor’s temperature range can be difficult/expensive to calibrate. So, it is recommended to calibrate the temperature range that the sensor is going to be used in.



10 - Calibration points

You need to pick enough calibration points in industrial calibration to see that the sensor is linear. Often it is enough to calibrate 3 to 5 points throughout the range.

Depending on the sensor type, you may need to take more points, if you know that the sensor may not be linear.

If you calibrate platinum sensors and you plan to calculate coefficients based of the calibration results, you will need to calibrate at suitable temperature points to be able to calculate the coefficients.

When sensors are calibrated in an accredited laboratory, the points may also be selected based on the lab's smallest uncertainty.

11 - Adjusting / trimming a temperature sensor

Unfortunately, most temperature sensors can't be adjusted or trimmed. So, if you find an error in calibration, you cannot adjust that. Instead you will need to use coefficients to correct the sensor's reading.

In some cases, you may compensate for the sensor error in other parts of the temperature measurement loop (in the transmitter or in DCS).

Please check what Martel can offer you for **temperature calibration** or for **other calibration devices** at the following link:

https://www.k-iinstruments.com/calibration-validation-services

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