

Rely on the tolerance limits or calibrate?

What is the significance of tolerances for temperature sensors like thermocouples and Pt100 resistance thermometers? Can you get a smaller measurement error by using wire and detectors from the same manufacturing batch? How can calibration help? Here are the answers.

The IEC and other organisations have standardised thermocouples and Pt100 sensors. The standards specify the tolerances and tables for the output signals as a function of temperature, as well as for the extension cables, including colour coding. The reason for these standards is partly to make sensors of the same type interchangeable, and partly to reduce the number of different varieties of sensors in what is an increasingly global market.

To achieve interchangeability between sensors of the same type, we must create an interval, ΔT , within which the output signals are allowed to vary, in order for the sensor to be categorised as, for example, a type K thermocouple. ΔT is called the "tolerance" and is shown in Figure 1. Tolerance is usually divided into different classes, which for type K and N thermocouples are called classes 1 and 2. Note also that the temperature intervals of the tolerance classes can differ within the same thermocouple type and between standards organisations.

Pt100 sensors have tolerances in a corresponding way but there are more classes. These are AA, A, B and C in accordance with IEC60751:2008. Figure 2 shows classes A and B. A number of standards exist, including an American one and a Japanese one. The IEC standard is also followed to some extent in other parts of the world. Like the tolerance limits of the Pt100, those of the Pt1000 are equal in degrees but the resistance per degree is ten times greater.

Tolerances too wide

If you rely only on the stated tolerances, you must expect a relatively large deviation when you replace a sensor. In the worst case, you can, at a given temperature, replace a sensor that is close to the upper tolerance limit with one that is close to the lower tolerance limit. An estimate of the size of these deviations is presented by the tolerances shown in Figures 1 and 2. It is not certain that the output signal would show a proportional deviation throughout the entire temperature interval. The deviation curve for a specific

sensor can very well "meander" between the tolerance limits, especially in the case of non-noble-metal thermocouples such as E, J, K, N and T at higher temperatures. Wire-wound Pt100 sensors are very predictable on an individual basis.

The same batch

It is possible to easily reduce the effect of the stated tolerances when replacing a sensor. Just order a number of thermocouples made from the same manufacturing batch of thermocouple wire or metal-sheathed cable. This solution works because the deviations along the length of these materials are fairly homogeneous. At low temperatures up to a couple of hundred degrees Celsius, the difference can be counted in one- or two-tenths of a degree, and the operating time normally has little effect in a non-harsh environment. At higher temperatures the difference is ten to twenty times greater and can rapidly increase even more after the thermocouple has been operating for a while.

In the case of Pt100/Pt1000 sensors, it helps that platinum is a stable metal. When replacing a sensor, it is possible to experience the same situation of going from one tolerance extreme to the other. You can limit this by ordering a detector from a closer tolerance class, if one exists. Otherwise, the best approach is to use individual calibration (see below).

The effect of operating time

The risk is high that the performance of thermocouples changes in proportion to their operating time; they are perishable items. This is particularly true at high temperatures and especially in combination with frequent cyclings between high and low temperatures. These changes occur relatively slowly and can therefore be difficult to detect without special investigation.

Pt100 sensors that are assembled in unsanitary conditions or that are exposed to heavy metals or any other harsh environment, and that are used or cycled at high temperatures, also risk undergoing changes as a result of their operating time. In this case, too, deviations in their readings are hard to detect without investigation. At low temperatures and in non-harsh environments, the sensors' temperature drift is very limited.

Calibration gives certainty

By far the lowest measurement uncertainty comes from doing individual calibration. The

basic rule is that a sensor should be calibrated at a temperature that is close to its operating temperature. If the sensor is used to take readings within a temperature interval, it is best to calibrate at these two end points plus preferably also at other important points within the interval. Large intervals require more calibration points than small ones do. Internationally accepted calibration rules advise against extrapolation outside the calibrated interval.

Figures 1 and 2 show some calibration points with approximate measurement uncertainties for the sensor at various temperatures.


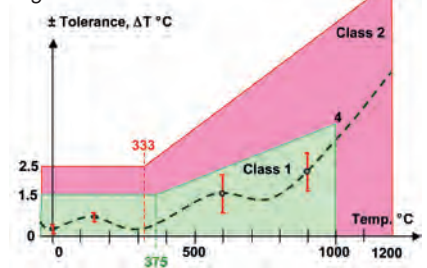
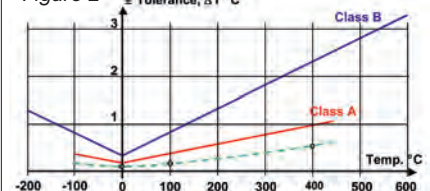
When using Pt100 sensors, it is especially beneficial to calibrate throughout the sensor's entire temperature range. Under accreditation it is possible to use a few calibration points to map the sensor between the outer points and present the results in a table. 

Figure 1



The positive tolerance ΔT for types K and N thermocouples in accordance with IEC60584. Calibration at low temperature (e.g. 0 and 150 °C) provides data about the specific thermocouple's (dotted line) properties. The uncertainty interval (shown by the red markers) is ± 0.1 to ± 0.2 °C. At high temperatures (in this case 600 and 900 °C) the uncertainty is reduced, at least initially, to approx. ± 0.7 °C by calibration.

Figure 2



The positive tolerance for wire-wound Pt100 sensors in accordance with IEC60751:2008 classes A and B. For a calibrated individual sensor (dotted line) the measurement uncertainty is reduced to approx. ± 0.02 °C, which in this case is so small that it is included in the grey calibration points.

If you have questions or comments, contact Hans Wenegård:
hans.wenegard@pentronic.se