In situ calibration of types K and N thermocouples at high temperatures (2)

In the last issue of Pentronic News we described how type N thermocouples produce lower calibration errors at high temperatures than type K. Previously we also asserted that it is better to replace base metal thermocouples with new ones than to invest time in doing unreliable calibration. However, if you must still verify that a thermocouple lies within a tolerance range, one method that can work is in situ calibration.

A number of error sources exist that can lead to very unreliable calibration at high temperatures of about 1000 °C. One is the SRO phenomenon, which affects both types K and N thermocouples but in different temperature ranges and with different amounts of error. The error will be particularly great when a long thermocouple passes through a furnace wall, say 2 metres from the probe tip, and when the same thermocouple is calibrated in a separate block calibrator only 0.2 metres from the probe tip. SRO is a hysteresis phenomenon whose effect on the temperature signal varies according to the previous history of the measuring device with regard to warm-up times and temperature level. [Ref 1]

Another problem is that the probe tip is located in what is basically a constant temperature environment whilst the wall passage where the measurement signal is generated has a temperature gradient from room temperature up to the 1000 °C level. This normally means that the thermocouple degenerates differently – develops a different sensitivity – where the calibration is done compared with where the measurement occurs. The difference between these two becomes a calibration error. [Ref 2]

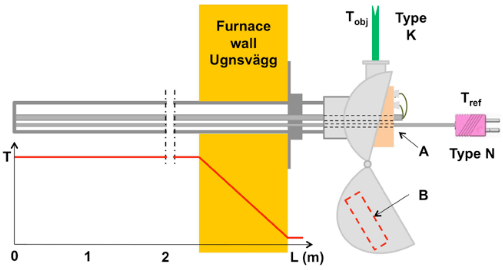

Figure 1. Thermoelectric voltage is almost always only created inside the furnace wall where the temperature gradient slopes (≠ 0). Both the measurement object T_{obj} and the reference thermocouple T_{ref} take measurements under conditions that are as identical as possible. There are terminal blocks equipped with an extra hole for inserting the reference thermocouple into position, see A. When using a transmitter the solution can be to mount it inside the lid, see B.

Calibrate at the right place

It is therefore important to calibrate where the signal is actually physically generated. We must achieve a temperature gradient almost identical to that inside the furnace wall. This is scarcely possible when doing a stand-alone calibration outside the furnace. So what should we do?

The solution is called "in situ calibration" (calibration in place). We already have the furnace. What is needed is a little planning to leave room for a reference thermocouple beside the calibration object, which will remain in place. See Figure 1. The outer protection tube keeps both thermocouples at the same temperature, which is essential for a reliable calibration. It is of course important to lock the reference thermocouple's use only to a specific protection tube length. Otherwise there is a risk that both the SRO phenomenon and different amounts of ageing inside the furnace and in the wall can worsen the calibration's accuracy.

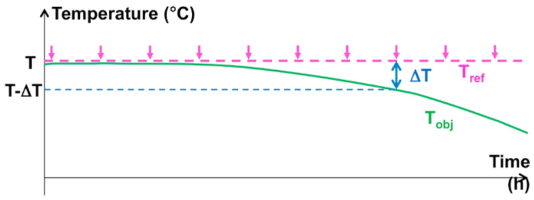

Figure 2. The pink dotted line is the reference temperature T. The solid green line shows the calibration object's degeneration over time. If we take brief measurements (say 15 minutes) at regular intervals with the reference thermocouple, its operating time will be very short and its properties will be stable. We can then monitor the degeneration and decide at what ΔT the calibration object must be replaced.

Short-term effect

In this example we presume that we can use a sheathed thermocouple. We use a type N thermocouple as the reference whilst the calibration object is a type K. It is also possible to use a type K as the reference. The point is that the reference thermocouple is used for a short time compared with the process thermocouple. See Figure 2. The reference thermocouple can therefore be regarded as stable whilst the furnace thermocouple might operate for hundreds of hours and thereby have the time to degenerate significantly. By regularly calibrating the furnace thermocouple in situ, you can follow the changes in its output signal over time. If you have a maximum ΔT that cannot be exceeded, you can easily see when the limit value is reached and then replace the thermocouple.

Practical tips

Furnace thermocouples with terminal head can be equipped with a terminal block with extra hole for a reference thermocouple. If you use a transmitter you can choose to have a terminal head with a lid mounting for transmitters. The thermocouple can then be terminated with a terminal block with extra holes. See A and B in Figure 2. If you only have a protection tube inside the furnace into which a sheathed element with a connector has been inserted, you probably can also easily find room for a reference thermocouple with a connector inside the protection tube. If there is no such protection tube it will be more difficult to arrange for identical temperatures and insertion depths. It may be possible to tie the probe tips together or place them in a piece of metal with suitable holes bored in it. The metal distributes the temperature well. See Figure 3.

In situ calibration requires some extra preparation when furnaces are being designed. It is nevertheless completely clear that in situ calibration reduces the uncertainty of the calibration result.

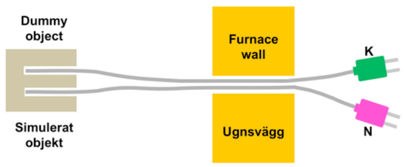

Figure 3. If there is no protection tube, we can use a dummy measurement object in metal with two bored holes. The heat transfer will be almost identical to that inside a block calibrator. Even in this case we must control the thermocouples' lengths to ensure that the wall passage for the calibration event is the same as it is during normal operation.

References see www.pentronic.se > News > Pentronic News > Pentronic News Archive
[Ref 1] Pentronic News 2014-2 p 4
[Ref 2] Pentronic News 2012-1 p 4

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