

Keep thermocouple extension cables outside hot zones!

Now that all fewer technicians have to care for and maintain more and more measuring devices, it's not easy to keep track of how everything functions. Frequent questions to Pentronic concern the extension cable and how it influences the measurement results as it passes through varying temperature zones.

See the connection arrangement in Figure 1. A thermocouple measures the temperature in a warming oven. The extension cable to the thermocouple passes through a number of cooling zones before it reaches a temperature indicator at room temperature. The thermocouple measures the temperature difference between the measuring junction in the probe tip and the connection to the indicator. A signal or thermo emf (voltage at the μV level) is only created on the sections of the thermocouple that lie in a temperature gradient that is different from zero. In the figure these sections are marked with red circles.

Overall, where the temperature curve in the diagram is horizontal (the temperature gradient = 0) no signal is created at all. Normally, the thermocouple's tip would be calibrated and the depth of the calibration bath or oven would usually then determine the location along the tip where its properties are determined, i.e. calibrated. In the figure, the calibration location can very well coincide with the red circle that marks the passage through the insulated wall. In this case the contribution will be the temperature difference $[\text{°C}]$ times the thermocouple's sensitivity $[\mu\text{V}/\text{°C}]$. With inserted values, approximately $(120 - 80) \times 40 \mu\text{V}$. See the grey facts box and Figure 2.

In the thermocouple's insulated connector joint (or connectors) the sheath material in the probe tip is replaced by an extension cable (also type K), which is marked by the green colour

of the insulation. The cable itself is seldom calibrated so that its properties are apparent from the thermocouple's inspection certificate. For want of anything else, we are left with the tolerance limits in the IEC 60584 standard. Within the temperature range $[0 \dots 120 \text{ °C}]$ the relevant tolerances are $\pm 1.5 \text{ °C}$ (class 1) and $\pm 2.5 \text{ °C}$ (class 2) respectively for a new cable. Since the temperature gradient = 0 and the temperature is therefore constant at the insulated connector joint, the measured value is not affected here.

In contrast, between zones 2 and 3 at the red ring there is a gradient different from zero. To estimate the maximum error that can occur via the extension cable, we can use the above-stated tolerance limits. If, for example, we assume that the probe tip's calibration is at, say, maximum plus tolerance, we get a difference of $\pm 1.5 \text{ °C}$, that is, 3.0 °C . Normally the entire length of the extension cable comes from the same manufacturing batch, and it's sensitivity can be regarded constant over length. This means that the thermocouple contributes $(120 - 80)/(120 - 20) = 40/100$ of the measured value that is correct according to the calibration and the extension cable contributes the rest $(80 - 20)/(120 - 20) =$

$60/100$. In other words, the error caused by the extension cable will affect the measured value by 60%. In our case (class 1) this means that the maximum error is $60 \times 3.0/100 = 1.8 \text{ °C}$, which should be clearly visible on an indicator with 0.1 degree of resolution.

However, the most important thing is to completely avoid laying uncalibrated extension cables in zones with higher temperatures. Let the calibrated thermocouple's probe tip cover as much as possible of the temperature gradients above room temperature. You can thereby avoid being concerned about the error contributed by the extension cable and are free to focus on more important tasks.

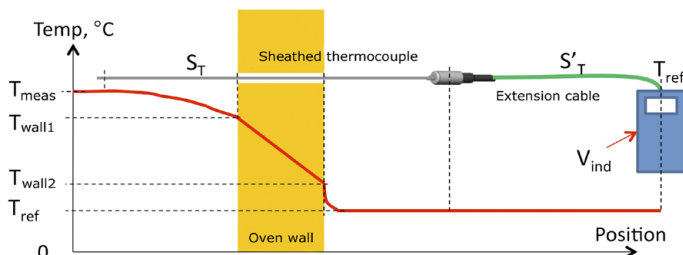


Figure 2. A general diagram of where in a thermocouple circuit the temperature signal is created. The most accurate measurement is achieved if the temperature gradients are located only along the length of the calibrated thermocouple.

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

FACTS

General calculation of the total signal from a thermocouple. The example concerns a sheathed thermocouple that is inserted in an oven. The red curve in Figure 2 shows the temperature distribution along the thermocouple, which is connected via an extension cable to a temperature indicator.

The general formula for a thermocouple output signal is:

$$V_{\text{IND}} = S_T (T_{\text{MEAS}} - T_{\text{REF}}), \quad (1)$$

where

V_{IND} = The thermo emf voltage in the indicator $[\text{°C}]$

S_T = The Seebeck coefficient for the thermocouple $[\mu\text{V}/\text{°C}]$

T_{MEAS} and T_{REF} = the respective temperatures at the measuring junction and reference junction $[\text{°C}]$

The reference junction's temperature can be the same as the ambient temperature but is not always.

Equation (1) applied to Figure 2 gives after breakdown by vertical lines, where S'_T is the unknown (uncalibrated) Seebeck coefficient for the extension cable and $(T_{\text{REF}} - 0)$ the indicator's compensation for the reference junction's temperature:

$$V_{\text{IND}} = S_T \{ (T_{\text{MEAS}} - T_{\text{WALL1}}) + (T_{\text{WALL1}} - T_{\text{WALL2}}) + (T_{\text{WALL2}} - T_{\text{REF}}) \} + S'_T \{ (T_{\text{REF}} - T_{\text{REF}}) + (T_{\text{REF}} - 0) \} \quad (2)$$

$$V_{\text{IND}} = S_T \{ T_{\text{MEAS}} - T_{\text{REF}} \} + S'_T T_{\text{REF}} \quad (3)$$

If in equation (3) $S_T = S'_T$, then $V_{\text{IND}} = S_T T_{\text{MEAS}}$ where we can resolve $T_{\text{MEAS}} = V_{\text{IND}} / S_T$. If $S_T \neq S'_T$, then there is a measurement error. In Figure 2 there is no temperature difference across the extension cable. Therefore no voltage is introduced across it. See the second-last term in equation (2), which is zero.

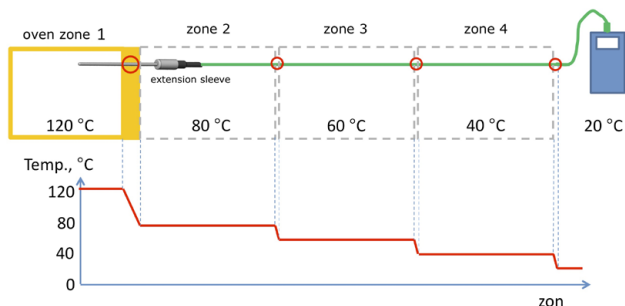


Figure 1. A calibrated thermocouple measures the temperature inside an oven. The thermocouple's extension lead passes through a number of zones with different temperatures on its way to the temperature indicator. How does this affect the measured value?