# The right extension cable is important when measuring outdoors

More and more industries are starting to measure temperature in order to increase the efficiency of their energy consumption or to meet mandatory regulations. It is important to use the correct extension cable with thermocouples, especially when the cables pass through different temperature zones. In such instances there can be dramatic measurement errors, as we see in this article.

Recent years have seen a large increase in the number of outdoor temperature measurements being taken with thermocouples. The extension cables used to take these readings are affected by the ambient temperatures, which in their turn can vary widely due to the season or time of day. One such situation is the monitoring of piles of wood chips or pellets, as the piles become warm and can spontaneously combust. Other situations involve monitoring controlled drying processes or chemical reactors in which the signals travel outdoors en route to the electronic signal conditioning systems. Another such industry is power generation, where measurement errors can lead to large costs. Often, mandatory regulations lie behind the necessity to take these readings.

### **Temperature distribution**

Figure 1 shows a typical installation for measuring the temperature inside a pile of wood chips. Indicator A is placed inside a control cabinet heated by power circuits and Indicator B is connected in parallel with A and is located outdoors. The diagram in Figure 1 also shows how the temperature is distributed across the thermocouples, connectors, extension cables, and the indicators where compensation occurs for the temperature of

the "cold junction". The diagram is very useful for localising critical parts of the measurement chain. We present the calculations in more detail in the sidebar.

#### **Dramatic measurement errors**

The measurement process functions correctly if we use the correct extension cables. In such a case, only insignificant measurement errors can arise due to the allowed tolerances in the measurement chain. Let us assume now that we replace KX with a copper cable, Cu/ Cu, from A to B. The relative sensitivity of two identical cables is 0 µV/°C. The diagram shows that the temperature difference between A and B is 30 °C. Instrument B does not recognise the signal but compensates for a temperature of 10 °C. Indicator A shows the correct temperature of 90 °C whilst B shows 60 °C. We can say that B's reference junction has been moved to A's control cabinet but the temperature compensation occurs at B.

#### **Cannot be calibrated away**

One approach would be to calibrate away the temperature differences. However, this is not possible because calibration requires constant conditions over time. It is easiest to get things right from the beginning. This approach also makes it possible to handle extreme conditions like those in deserts or on tundras. Read the sidebar and then test your knowledge by letting Indicator B sit in -10 °C connected with a copper cable!

Another incorrect connection that can occur is to combine different thermocouple materials, e.g. type N connected to a KX cable. In this case the errors described in the above example will be smaller, the smaller the differences there are between the sensitivities [Ref 1].

## **FACTS**

In general, the sensitivity of the thermocouple material (the Seebeck coefficient) is multiplied by the temperature difference across the same zone. These terms are then added up along the entire measurement chain from the measuring junction to the reference junction to get the total temperature signal in microvolts (See Figure 1). If we apply this to Indicator A we get:

$$\begin{split} V(T_A) &= S_K \left[ (T1 - T2) + (T2 - T3) \right] + S_{KX} \left[ (T3 - T4) \right. \\ &+ (T4 - T5) + (T5 - 0) \right] \end{split}$$

Because we are accepting normal tolerance differences we can use SK = SKX in the equations given below. The blue term is the compensation for the temperature of the reference junction: the procedure is to add the temperature difference to 0 °C.

For Indicator A the equation is:

$$\begin{split} V(T_A) &= S_K \left[ (90-80) + (80-10) + (10-10) + \\ (10-40) + (40-0) \right] \\ V(T_A) &= S_K \cdot 90 \end{split}$$

For Indicator B the equation is:

$$\begin{split} V(T_B) &= S_K \left[ (90-80) + (80-10) + (10-10) + \\ (10-40) + (40-10) + (10-10) + (10-0) \right] \\ V(T_B) &= S_K \bullet 90 \end{split}$$

Both the indicators display the expected value. Let us now replace the cable between A and B with copper wires.  $S_{CU}=0$  °C because two identical materials cannot create a Seebeck voltage. The sensitivity here is therefore  $0\,\mu\text{V/°C}$ . See the red term.

$$V(T_B) = S_K [(90 - 80) + (80 - 10) + (10 - 10) + (10 - 40)] + S_{C_U} [(40 - 10) + (10 - 10)] + S_K (10 - 0)$$

$$V(T_B) = S_K [(90 - 40)] + 0 + S_K (10 - 0)$$

$$V(T_B) = S_K \cdot 60 \text{ and Indicator B reads 30 degrees}$$

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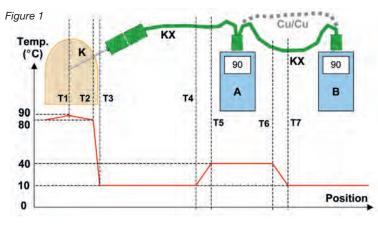


Figure 1. Temperature measurement inside a pile of wood chips. Indicator A is located indoors inside a warm control cabinet whilst B is outdoors. Both indicators display the same temperature because the installation has been correctly designed using a KX extension cable and the indicators have both been compensated for the temperatures of their respective reference junctions. What happens if an ordinary Cu/Cu signal cable is used to connect the indicators?

[Ref 1] Pentronic News 2010-6, p 4

too low.

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