

"Extension leads" with thermocouples – good or bad?

Thermocouples measure the temperature difference between the measuring junction and the reference junction. What effect is there on the risk of errors if you use an "extension lead" up as far as the reference junction – given that the lead is designed to work with the specific type thermocouple involved?

There are three correct terms for such an "extension lead": thermocouple wire, extension cable, and compensation cable. A thermocouple wire meets its specified tolerances in accordance with IEC 60584-2 class 1 or 2 up to at least the temperature limit of the insulation material. Whether they are in the form of a wire or a metal-sheathed cable, thermocouples are designated with a letter of the alphabet, e.g. "type K". IEC standards are the widely used global standards, whilst ASTM standards are used in the USA. See Figure 1.

Extension cables are also standardised according to IEC 60584-3 into tolerance classes 1 and 2. The material is designated with the additional letter X – e.g. KX. In the case of KX, the cable laying temperature range is limited to -25 to 200 °C. The material is the same as that of the thermocouple but has only undergone the heat treatments required to meet the tolerances in the closer temperature range.

Compensation cables are designated with other letters, e.g. KCA or KCB, where the C indicates that the material is completely different than that of the thermocouple but has

similar properties within the limited temperature ranges of A or B respectively, e.g. 0–150 or 0–100 °C respectively. The compensation materials are only available in tolerance class 2. See Figure 2.

Using compensation cables with base metal thermocouples should be avoided. The only economic justification for using compensation cables is with the noble metal types S and R. However, be careful to keep the junction (the terminal head) as close to room temperature as possible.

The effect of tolerances

Because thermocouples and extension cables have tolerances, the Seebeck co-efficient of the measuring junction is mostly likely different than that at the reference junction. This is not a problem as long as both ends of the extension cable have equal temperatures. In this situation, it doesn't even matter if you use class 1 or class 2. If the temperature at both ends of the extension cable is equal, the cable will generate no output voltage at all. In this situation only the thermocouple, which is usually mapped by calibration, will contribute to the input voltage of the instrumentation. That is why, to take an example, thermocouple types J (IEC) and L (DIN), which at 200 °C differ by 3 degrees, can use the same type of extension cable. However, if you connect an extension cable to the thermocouple at a temperature of 200 °C and the instrumentation is at room temperature, the difference becomes obvious if you use, for example, an L sensor, a JX cable and an L input for display.

Only the probe tip in the hot zone

Thermocouples and extension cables also exhibit differences in output signals. If you follow the basic rule of only allowing the sensor component of the measurement chain to be exposed to temperature differences, a few degrees of difference along the extension cable play an insignificant role. In Figure 3 and Case TC2, the maximum error contribution will be $(100-20)/(200-20) = 0.44$ of the deviation, which can be a maximum of 2×1.5 °C for type K class 1 extended by KX class 1, i.e. 1.3 °C. Under the same conditions, type K class 1 extended by KX class 2 gives 1.8 °C and type K class 2 extended by KX class 2 gives a maximum error contribution of 2.2 °C. These results do not include the thermocouple connectors, but in their case only 5/180 (approx. 3%) of the deviation will have an effect, which can be disregarded in this context.

In many cases these error contributions can be acceptable. If you want to reduce the measurement uncertainty, you can either calibrate the entire measurement chain in situ under its specific operational conditions or concentrate the dependence of the readings only to the sensor's probe tip. The latter scenario is undoubtedly the simplest because you can then use separate sensor calibration. You should therefore avoid placing anything other than the probe tip in the hot zone.

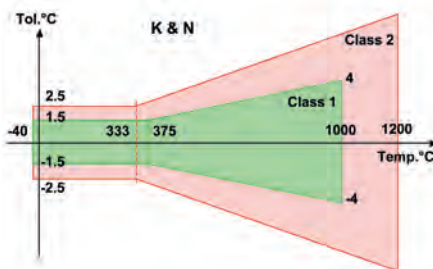


Figure 1. Tolerances in °C for types K and N thermocouples in accordance with IEC 60584-2 classes 1 and 2.

Opinions and questions are welcome at: hans.wenegard@pentronic.se

Type	Tolerance class		Cable temp. Min/max (°C)	Estimation of error		
	1 (±µV)	2 (±µV)		Meas. junction (°C)	Error T.cl. 1 (°C)	Error T.cl. 2 (°C)
TX	30	60	-25/100	300	0.5	1.0
JX	85	140	-25/200	500	1.5	2.5
EX	120	200	-25/200	500	1.5	2.5
KX	60	100	-25/200	900	1.5	2.5
NX	60	100	-25/200	900	1.5	2.5
KCA	-	100	0/150	900	-	2.5
KCB	-	100	0/100	900	-	2.5
NC	-	100	0/150	900	-	2.5
SCA	-	30	0/100	1000	-	2.5
SCB	-	60	0/200	1000	-	5.0
RCA	-	30	0/100	1000	-	2.5
RCB	-	60	0/200	1000	-	5.0

Figure 2. Tolerances for extension and compensation cables in accordance with IEC 60584-3. The laying temperature refers to the thermocouple wires. Insulation materials can further limit the temperature. The list of estimated errors is a complement to the standard.

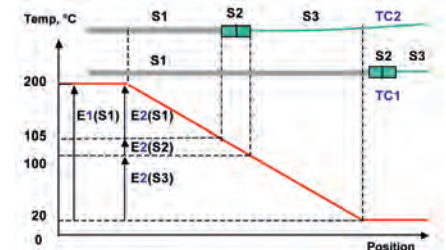


Figure 3. TC1 is the most reliable installation to use. All the temperature differences exist along the temperature sensor, a sheathed thermocouple, which generates the signal E1(S1). The connectors and cable do not contribute any output voltage because the temperature along them is constant. In contrast, the TC2 installation receives signal contributions from all the components of the measurement chain: $E2(S1) + E2(S2) + E2(S3)$. Because normally only $E(S1)$ is calibrated, the output signal is therefore unpredictable.