

# Hysteresis in type K thermocouples

Type K has been the most common type of thermocouple for decades. As a result, its advantages and disadvantages are well known. This article explains the most important source of error and gives an approximate indication of the error size involved.

Type K is presumably so popular due to its wide range of use, from -200 till +1200 °C, and because an oxidising environment (air) does not harm exposed wires. The international standard that defines the working range for type K is IEC 60584-2 (see Figure 1).

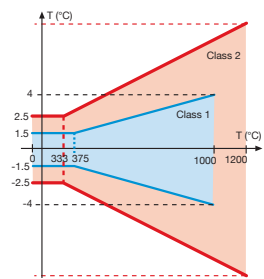


Figure 1: Tolerances for types K and N thermocouples in accordance with IEC 60584-2. Class 1: the greater of 1.5 °C or 0.004 x t, (t in °C) and Class 2: the greater of 2.5 °C or 0.0075 x t.

impossible to always maintain tolerance classes (see the list in Figure 2). Measurement errors and uncertainties always increase as temperatures increase, and this is just something we have to accept.

Error source for thermocouple K	Deviation max temperature (°C)	<200 °C	<600 °C	<1200 °C
1 Tolerance IEC 584 class 2	± 2.5	± 4.5	± 9	
2 Homogeneity	≤ 0.1	0.1-1	2-6	
3 Ageing	≤ 0.1	< 2	1-50	
4 Hysteresis	–	2-5	2-5	
5 Green root corrosion	–	–	10-100	
6 Reference junction	0.3-3	0.3-3	0.3-3	
7 Sensor installation	0.1-5	1-10	2-20	

Figure 2: Measurement errors that can affect type K thermocouples within various temperature ranges. The sizes of the errors are estimated relatively roughly but they can still act as guidelines for where to look for the biggest sources of error in an installation.

To many people, hysteresis is an unknown property of base-metal thermocouples. Because types K and N are the most common, they have been studied the most. Figure 3 shows what happens to the sensitivity of type K after heat treatment for various lengths of time at various temperatures. The yellow curve, for example, shows that the Seebeck coefficient changes by 0.3 μV/°C after only 5 minutes at 450 °C. The coefficient normally

lies at about 40 μV/°C, which means that it has increased by 0.3/40 = 0.75%. The thermocouple would therefore read 0.75 °C too high for every 100-degree temperature difference.

From Figure 3 we see that the critical temperature range for type K is between 200 and 600 °C. The diagram shows the increase of the Seebeck coefficient up to 30 days. Other data confirm that this increase can continue for up to 100 days, although by smaller and smaller increments as time goes on. The hysteresis is due to the fact that the Seebeck coefficient increases through the critical range of 200–600 °C. In contrast, nothing happens under 200 degrees, and over 600 degrees the Seebeck coefficient decreases back down to its base value. Figures 4 and 5 show practical examples of how the hysteresis manifests.

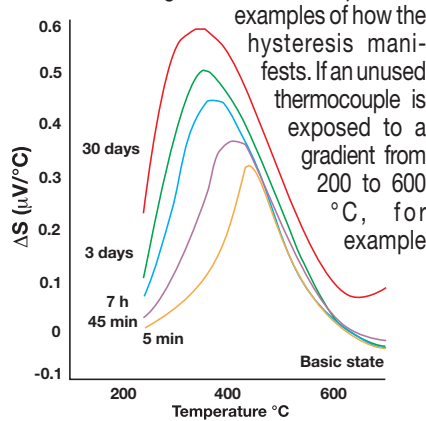


Figure 3: Changes in the Seebeck coefficient for type K thermocouples as a function of temperature level and exposure time. The critical zone is 200-600 °C.

during passage through an oven wall, the Seebeck coefficient, ΔS, changes over time as shown in Figure 4. As a result, the measurement signal increases (see Figure 4a). The part of the thermocouple that remains at a constant temperature, for instance 400 °C, has its Seebeck coefficient evenly altered. Because the temperature is constant throughout this part of the thermocouple, the measurement signal is not affected at all. But if we pulled the thermocouple out a bit, this part of the thermocouple would then be within the gradient and the change to the Seebeck coefficient would then take full effect (See Figure 4b). If we push the thermocouple in farther so that previously unaffected material enters the temperature zone, the process of change starts all over again from the beginning (see Figure 4c).

Exposure to temperatures over 600 °C results in the Seebeck coefficient returning to its original level (see Figure 5c). If you want to

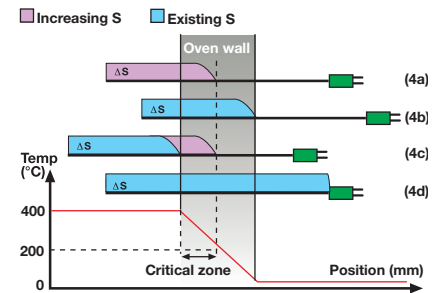


Figure 4 a-d: Oven temperatures under 600 °C. Hypothetical changes to the Seebeck coefficient, ΔS, at varying insertion depths using type K thermocouples. (a) Starting level for an unused thermocouple. ΔS increases over time. (b) A smaller insertion depth gives greater ΔS within the gradient, which results in increased error. (c) A larger insertion depth gives a new formation of ΔS as was the case in (a). (d) Heat treatment gives the same ΔS regardless of the time duration and insertion depth.

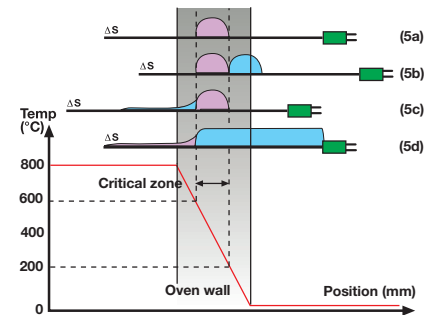


Figure 5 a-d: The same holds true for oven temperatures above 600 °C. (a) Starting level for an unused thermocouple. ΔS increases over time. (b) With a smaller insertion depth ΔS is newly formed in the 200-600 °C zone. Previously formed ΔS contributes to errors at lower temperatures. (c) A larger insertion depth leads to a reduction of ΔS in the zone above 600 °C. (d) The benefit of heat treatment in this case is doubtful.

retain the original level at room temperature, cooling must occur quickly past the critical zone. Otherwise there is a risk that the level will rise again as shown in Figures 3 and 5b. Measurement error due to hysteresis is usually negligible. For very precise measurements under 600 °C, Pt100 sensors can be an alternative. By using type N thermocouples, the main effect of the hysteresis is moved to approx. 700 °C. In addition, the deviation is lower than for type K and is of the magnitude of about 1 °C. Type K material that is composed with the aim of reducing hysteresis is now also starting to come on the market.

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