Temperature limits in types K and N thermocouples

Two of the most common standards for thermocouples are IEC 60584 and ASTM E230. They describe different temperature intervals and different associated tolerances. Both standards state that they only apply to unused thermocouples, which indicates that thermocouples are perishable goods. How can we determine the service life of metal-sheathed thermocouples such as types K and N for a specific measurement environment or temperature level?

One reason for using base metal thermocouples in metal-sheathed form is the advantages they offer when used to take mobile readings. For example, they can travel with an object through a tunnel furnace in order to determine the temperature distribution along the furnace, and also from the surface to the core of the object requiring heat treatment.

IEC 60584:2013 is the current applicable international standard for thermocouples and ASTM E230/E230M-12 is the applicable American standard from 2012, which has a lot of international influence. See Figure 1 for the tolerances in types K and N plus [Ref 1] for other thermocouples in the standards.

Unused thermocouples are defined as type K or N if they meet the standards' tolerances for the relevant type. Many factors in the user's measurement environment can influence a thermocouple's service life, which is therefore very hard to predict. ASTM spans a larger temperature range, which can be harder to achieve than the somewhat closer intervals given by IEC.

The service life is determined by the requirements for measurement accuracy. We would emphasise that the tolerances apply to unused thermocouples. See Figure 2. The diameter of sheathed thermocouples influences their service life, which generally speaking increases with the sheath diameter. The construction of a sheathed thermocouple is shown in Figure 3. The insulation between the sheath and the wires very often consists of highly compressed magnesium oxide, MgO. Metallic sheath and/or protection tube do not guarantee that foreign materials will be prevented from diffusing into the thermocouple's wires when the temperature approaches 1000 °C. If the wires react with external substances from the measurement environment or internally between the metal casing, the insulation or the wires, the result is often an altered Seebeck coefficient, that is, a different sensitivity, and the thermocouple displays deviating values over time. If the product of the reaction is a non-conducting material, the instrumentation will indicate a break, as the entire area of the wire has been "eaten up" somewhere by the reaction.

Type K & N	IEC 60584 Tolerance (°C)		
Tolerance class	1	2	3
Range	-40 < T < 1000	-40 < T < 1200	-200 < T < 40
Greatest of	±1.5 or ±0.004•|T|	±2.5 or ±0.0075•|T|	±2.5 or ±0.0075•|T|
Type K & N	**ASTM E230/E230M-12 Tolerance (°C)**		
Tolerance class	Special	Standard	Standard (K)
Range	0 < T < 1260	0 < T < 1260	-200 < T < 0
Greatest of	±1.1 or ±0.004•T	±2.2 or ±0.0075•T	±2.2 or ±0.02•T

Figure 1. Tolerance classes for types K & N thermocouples given in the international IEC standard and the American ASTM standard. Note the difference in the measuring ranges between the standards and the respective tolerance classes. Note that the data only applies to unused thermocouples!

Diameter (mm)	Temperature (°C)
∅ 0.5	700
∅ 1.0	700
∅ 1.5	920
∅ 2.0	920
∅ 3.0	1070
∅ 4.5	1150
∅ 6.0	1150
∅ 8.0	1150

Figure 2. General temperature limits recommended by ASTM E 608/E 608M for various diameters of types K & N sheathed thermocouples. No account has been taken of aggravating environments. Higher temperatures lead to a shorter service life and/or more unstable measurement values.

Sheath material

Unavoidable contaminants in the molten material used to make the wires can also cause the thermocouple's readings to vary according to its position in the furnace. Similar behaviour is caused by the SRO hysteresis phenomenon in types K and N thermocouples. Type K can display up to +5 °C of error at around 400 °C and type N about +1 °C of error at around 750 °C, the latter assuming that an Inconel sheath is used, which is the most common type. See [Ref 2]. Sheath material comes in various types of metal, which also have limit values for their operational use and melting point. See Figure 4.

The operating time until disruptive measurement errors start occurring therefore varies according to the measurement environment and the sensor's properties. You can obtain a basis for deciding what operating time is sufficient before replacing the thermocouple by doing an in situ calibration [Ref 3].

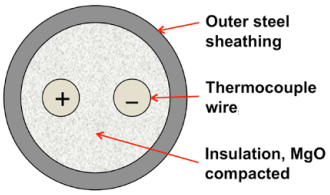

Figure 3. A metal-sheathed thermocouple in cross-section with an outer diameter of D. The sheath's thickness is approx. 0.1 D and that of the wires approx. 0.2 D.

Inappropriate use can also cause large measurement error. Magnesium oxide, MgO, has many good physical properties but loses its insulating ability dramatically over 600 °C. This can lead to some electrical shunting effects for those parts of the thermocouple that pass through high temperatures, for instance in a tunnel furnace, with large measurement errors as a result. For fixed installations, such errors can be avoided by using thermocouple wires in highly pure ceramic and with highly pure, closed outer protection tubes. The noble metal types R, S and B are examples of such fixed installation temperature sensors.

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Types K and N thermocouples should be used in oxidative environments. Accordingly, reducing environments such as hydrogen gas can cause measurement error. Vacuum environments cause the evaporation of various substances to occur at considerably lower temperatures than at normal pressure. In this way, the composition and sensitivity of the thermocouple wires can be affected even at a low temperature. In addition, the heat transfer to the thermocouple is impeded in that no convection occurs.

In conclusion, it is extremely difficult to accurately predict a thermocouple's operating time. The best way is to measure the temperature drift using the in situ method, where that is relevant, and, based on the result and on your own wishes, to adjust such factors as the diameter. Before the maximum deviation is reached, the thermocouple should be scrapped and replaced with a new one. In cases of doubt you are welcome to consult Pentronic.

Temperature limits for sheathing materials (°C)			
Material	Max. working temp.		Melting point
	Rec. contin.	Max. in air	
AISI 304	900	1050	1404
AISI 316	925	900	1371
Inconel 600	1150	1095	1399

Figure 4. The maximum operating temperature limits recommended for various sheath materials for continual use and for use in the air, plus their respective melting points, given in the ASTM's Manual on the Use of Thermocouples in Temperature Measurement*, 4th edition, 1993.*

References, see www.pentronic.se > ...
[Ref 1]: ... > To download > Useful links > Thermocouples > IEC 60584:2013
[Ref 2]: ... > News > Pentronic News > P N Archive > PN 2014-2 p. 4
[Ref 3]: ... > News > Pentronic News > P N Archive > PN 2014-3 p. 4

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