

The effect of poor insulation on temperature sensors

Pentronic's final inspection certificate states that the insulation between the circuits and the sheathing of a temperature sensor is greater than a specified number of Mohm at a specified test voltage. The significance of this measurement may not be immediately apparent. In this article we explain what consequences can result from low insulation values..

Pentronic tests the insulation resistance of thermocouples that are designed to contain insulation between the sensor's circuits and its metal protective tube. The company also tests sheathed Pt100 sensors. The test voltages, the diameters of the protective tubes, and the insulation requirements are listed in Figure 1.

Insulation material

Thermocouples and Pt100s with flexible sensor probes use metal sheathed cable with highly compacted magnesium oxide (MgO) as insulation material. This oxide has excellent properties with regard to retaining the geometrical uniformity of the cable when drawing it into thinner dimensions and bending it to create special angles. The magnesium oxide's resistivity is also very high at room temperature but declines drastically as temperature increases (see Figure 2 and [Ref 1]). Magnesium oxide easily absorbs atmospheric humidity if it is exposed during the manufacturing process or due to damage to the metal sheathing. In both these cases, the material's isolating ability is then dramatically reduced.

Other insulation materials used when sensors are encapsulated in steel tubes can be thermocouple wires or Pt100 leads featuring insulation made from all kinds of soft materials ranging from PVC to ceramic fibres. For high temperatures, and especially for noble metal thermocouples, tubes with two or more bores inside protective tubes made of very pure aluminium oxide (Al₂O₃) must be used so as not to contaminate the noble metals. It is essential to keep in mind that the component with the lowest temperature resistance is the one that limits how and where the sensor can be used.

Crucial in autoclaves

Figure 3 shows a theoretical model of the resulting extra pathway RM that insufficient insulation can open up for the current (I). Poor insulation may have the biggest con-

sequences in thermocouple circuits because the conductor resistances are up to 40 times larger than, for instance, for silver wire, which is often used in Pt100s. Large series resistance causes voltage drops, because the current starts to flow via a zone of low insulation resistance. Figure 4 shows the size of measurement errors that are created when Pt100 sensors are shunted by different sized zones of insulation resistance. In difficult environments such as steam autoclaves, which require very consistent temperatures, even small measurement errors can have major consequences.

Virtual measuring junction

The measuring junction in a thermocouple consists of the last short circuit between the wires prior to the measuring instrumentation. Normally, the measuring junction is located in the probe tip (see Figure 3). If a short circuit, i.e. 0 ohm, were to occur between the measuring junction and the measuring instrumentation, the short circuit would become the ruling measuring junction. If there were a temperature difference between the measuring junction at the probe tip and the one at the short circuit, the thermoelectric voltages would create a circulating current undetectable by the measuring instrumentation.

Tunnel furnaces

This phenomenon can also be very noticeable with long thermocouples used to measure along tunnel furnaces featuring a high-temperature zone that worsens the effect of the insulation in the middle of a measuring distance. If the real measuring junction is located within a lower temperature zone on the other side of the hot zone, it can, due to series resistance and poor insulation in the thermocouple, cause the readings to indicate a far higher temperature than the real one. This is because the negative thermoelectric voltage from the probe is shunted away in hot zones that cause poor insulation while the positive voltage from the measuring instrumentation to the hot zone retains its size. Consequently, the net voltage that produces the measuring junction's temperature becomes too high. See further [Ref 2].

See www.pentronic.se > Pentronic News > Archive

[Ref 1] Pentronic News 2009-1 p. 4

[Ref 2] Pentronic News 2011-2 p. 4

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

Figure 1

Probe diam. D (mm)	Test voltage (VDC)	Requirement at room temp. (Mohm)
Metal sheathed thermocouples (IEC 61515:1995)		
D < 0.8	1	> 20
0.8 < D ≤ 1.5	75 ± 25	1000
D > 1.5	500 ± 50	> 1000
Pt100 sensors, Pentronic's requirements		
All D	500	> 1000
Pt100 sensors, IEC 60751:2008 requirements		
All D	100	> 100

Figure 1. Acceptance tests at Pentronic also include testing the insulation as specified in this table. Note that Pentronic's requirements are more stringent than those in accordance with IEC 60751: 2008 for Pt100 sensors.

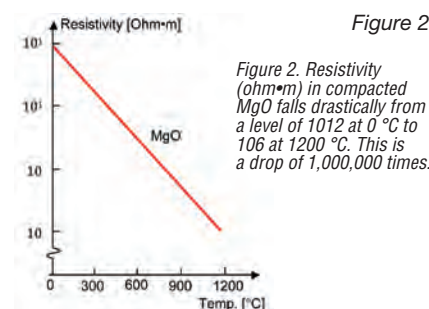


Figure 2. Resistivity (ohm·m) in compacted MgO falls drastically from a level of 10¹² at 0 °C to 10² at 1200 °C. This is a drop of 1,000,000 times.

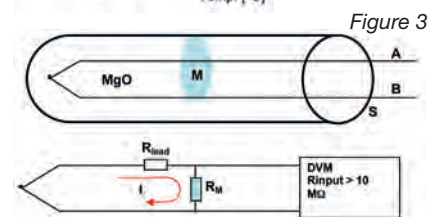


Figure 3. A metal sheathed thermocouple (S) with MgO insulation. At M, dampness is entering or there is a high temperature, which worsens the insulation in the immediate area. This then creates a new pathway for the electric current (I) via the resistance RM, which is created by the parallel coupling of the resistances between the wires (A and B) and then to the sheathing (S) respectively. If RM is small enough, the signal from the probe will be reduced due to the series resistance Rlead. If RM is extremely small, it will function as a virtual measuring junction and indicate the temperature at its location.

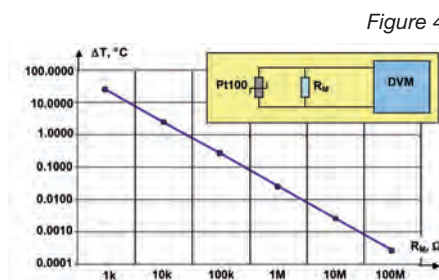


Figure 4. In the same way as in Figure 3, the resulting insulation resistance of the Pt100 sensor can be symbolized with RM, which shunts the sensor signal. This diagram shows how measurement error in Pt100 sensors (ΔT) varies with insulation resistance. (RM).