Standards for temperature sensors and wake analysis

Many standards exist for temperature measurement. Some of them govern the sensors' electrical data, others their construction. There are also standardised methods for industry-specific phenomena such as taking high-temperature measurements in steel production or wake analysis plus many other standards. We discuss some of them in this article.

The electrical data for Pt100s are standardised in IEC 60751 (2008), where IEC stands for International Electrotechnical Commission, which means this is an international standard. It refers to temperature as a function of resistance, specifying the tolerance limits for deviations in resistors and assembled temperature sensors respectively, taking into account the type of resistor (wirewound or film). See the table in Figure 1. The standard also prescribes the identification of single and double resistor circuits by means of the colours of the wires inside the connection cable. See Figure 2. The standard also gives advice on test methods to verify that the temperature sensor meets its specifications.

For thermocouples the relevant standard is IEC 60584 (2013), which also contains electrical data about the relationship of temperature as a function of thermovoltage and vice versa. The relevant tolerances are presented, as are the relevant intervals for each thermocouple type, which are currently 10. The thermocouple types are identified in terms of their thermocouple wire, extension cable, and compensation cables (where they exist). See Figure 3.

Build sensors for their measurement task

Standardisation in terms of sensors' outer form is not considered necessary in EU member states. The exception is Germany with its extensive chemical industry, where almost identical pipes and vessels make it desirable
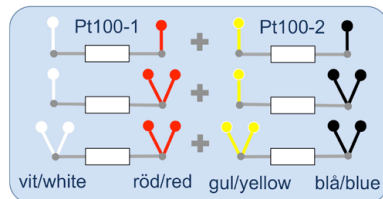
Figure 2. IEC 60751 (2008) prescribes the colour coding of Pt100 sensors' cable wires as shown here. The left column shows the colours for a single Pt100 with red and white on each side of the resistor. If the same sheathing contains a double Pt100, resistor circuit 2 should then be surrounded by yellow and black (grey) colours on the wires.

to standardise the forms and measurements of sensors and protection tubes. This is why Germany has the DIN 43772 (2000) standard, even though sensors and protection tubes should as much as possible be dimensioned to suit their measurement task. Measurement accuracy is frequently in opposition to such properties as durability. Companies that make sensors for the German market are, of course, instructed to follow the DIN standard.

Wake analysis

The American standard ASME PTC 19.3 TW (2010) describes a method of calculating Kármán vortex streets, which can influence fixed thermowells in pipe flows. What can happen is that the wake effect's oscillation frequency can approach the thermowell's natural frequency and thereby cause the thermowell to oscillate violently, with the result that it can break apart

Figure 3. IEC 60584 (2013) contains 10 different thermocouple types, which are identified by colour where possible. *) Types C (WRe5-WRe26) and A (WRe5-WRe20) have been included in the standard but (to the best of our knowledge) their colour codes have not yet been assigned. The code for type C in the figure is that given in the de facto standard.

or break free from its mounting. Wake-effect oscillations can also be beneficial. A vortex-flow meter uses the flow's oscillation effect as the basis for its flow measurements.

ASME PTC 19.3 TW provides calculation software for various basic types of thermowells made of lathed rod materials. This includes thermowells that are welded in, screwed in, or attached by a flange to a vessel wall, plus straight, conical, and two-step diameter-reducing shapes. A customer need only input data on the measurements, material and shape of the thermowell plus data on the relevant measurement environment. The software will then calculate the disruptive oscillation frequencies and state whether or not they are at safe levels in relation to the thermowell's natural frequency.

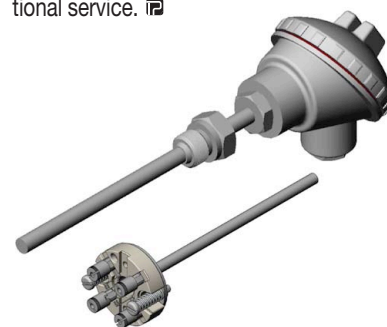Pentronic offers wake analysis as an optional service. ▣

Figure 4. DIN 43772 (2000) describes various types of construction of sensors designed to operate in pipes and vessels. Shown here is a modified "form 2" (previously "form B") with a short neck and replaceable Ø 6 mm measurement insert. The air gap between insert and protection tube is eliminated by a metal bushing to improve heat transfer to the Pt100 resistor.

Figure 5. A thermowell's protruding section up to the probe tip has a resonance frequency, in this case two. The wake frequency of the flow influences the sensor with oscillations, which are governed by the construction, material and measurement environment. The ASME PTC 19.3 TW (2010) standard presents a method for determining if the wake frequency is limited enough not to initiate destructive resonance effects.

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Tolerance classes for Pt resistors				Tolerance classes for complete Pt sensors			Tolerance for temperature T
Wirewound (W)		Film type (F)			Temperature range [°C]		[°C]
Tolerance class	Temperature range [°C]	Tolerance class	Temperature range [°C]	Tolerance class	Wirewound (W)	Film type (F)	
W 0.1	-100 – 350	F 0.1	0 – 150	AA	-50 – 250	0 – 150	± (0.1 + 0.0017·|T|)
W 0.15	-100 – 450	F 0.15	-30 – 300	A	-100 – 450	-30 – 300	± (0.15 + 0.002·|T|)
W 0.3	-196 – 660	F 0.3	-50 – 500	B	-196 – 600	-50 – 500	± (0.3 + 0.005·|T|)
W 0.6	-196 – 660	F 0.6	-50 – 600	C	-196 – 600	-50 – 600	± (0.6 + 0.01·|T|)

Figure 1. IEC 60751 (2008) has adapted its standard to suit today's Pt100 resistors and assembled Pt100 sensors.