A Pt100 or a thermocouple, that is the question

Whether to use a Pt100 or a thermocouple is a common question for temperatures under 500 °C. Both sensor types have advantages and disadvantages. Here is a brief guide to choosing a sensor.

Most base metal thermocouples and Pt100 sensors can be dimensioned for temperatures from -200 up to 500 to 600 °C. Thermocouples, such as types K and N, can measure even higher, up to 1200 °C. In this article we will discuss the most common temperature range, from, say, -50 to 500 °C.

A Pt100 is a resistive sensor whose electrical resistance increases with temperature by approximately 0.4 ohms per degree, starting from 100 ohms at 0 °C. The resistance consists of either a platinum wire (called a wire wound resistor) or a continuous pattern in a platinum layer (called a thin film resistor). To measure resistance you need a known current, normally within 0.2 to 1 mA, and a voltmeter. See diagrams 1a and b.

Thermocouples do not require any excitation current; instead they self-generate a voltage that is in reasonable proportion to the temperature difference between the measuring junction and the reference junction. The sensitivity of thermocouples is approximately 40 µV per degree for the base metal types. Type K, which is the most common, consists largely of a nickel-chromium wire versus a nickel-aluminium one. The wires are joined in the probe tip and attached to the indicator (the voltmeter) in the reference junction. See diagram 3.

The Pt100 sensor requires added power, e.g. 1 mA x 140 ohm, which gives 0.14 mW at 100 °C, while a thermocouple gives 4 mV over perhaps 10 Mohms input resistance, which is nil power in this context. Due to its own self-heating ability, the Pt100 sensor can

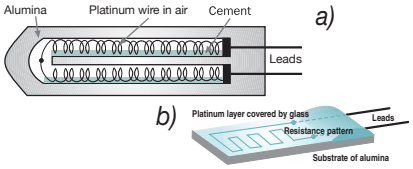

Diagram 1. a) A wire wound Pt100 detector with 80% non-fixed wire is the most stable industrial temperature sensor. b) Thinfilm detector.

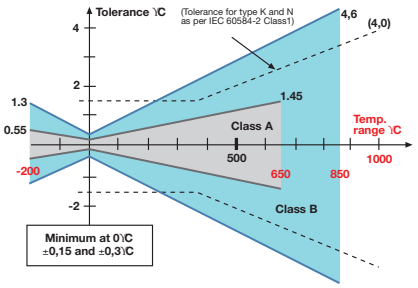

Diagram 2. Tolerances for a Pt100 according to IEC 60751 classes A (grey) and B (blue).

therefore measure too high a temperature in critical environments such as still air or inside insulation materials.

Pt100 IS ACCURATE

The biggest advantage of the Pt100 sensor is its accuracy. The reason is that platinum has well known and predictable properties. The IEC 60751 standard sets relatively high tolerance limits (see diagram 2). Wire wound Pt100 detectors that are made with either slightly too short or slightly too long wires are still comprised of the same materials, and after calibration their measuring properties are equally good regardless of the offset error. Annual drift for the partly fixed wire wound types is given at better than 0.01 degrees in a benign environment. In contrast, thermocouples consist of so many kinds of base metal materials in addition to the basic components that they have difficulty staying within their tolerance limits (IEC 60584-2, see diagram 2). For type K, at under approximately 200 degrees the measurement error is in the order of magnitude of a couple of tenths of a degree even when the materials come from the same manufacturing batch. This is because thermocouples generate their voltage along the entire length from the measuring junction to the reference junction.

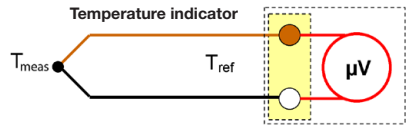

Diagram 3. A simple thermocouple circuit with measuring junction T_{meas} and reference junction T_{ref}. The reference junction temperature is normally kept at 0 °C or is measured by an internal thermometer and added to the result.

THERMOCOUPLES ARE ROBUST

The biggest advantage of thermocouples is their robustness. The metal-sheathed cable of compacted magnesia that encases the wires is extremely resistant to physical forces and vibrations and is also moisture proof.

The usual diameter of these cables ranges from 0.5 to 8 mm, the thicker of which is naturally the strongest. The thinner diameter ones are very easily worked and can be bent with a finger to adjust them to the object being measured.

This type of cables can be compared to steel wire. Sharp folds or repeated bending will cause breaks in the outer sheath and wires. The measuring junction consists of welded wires, and this, together with the plasticity of the cable, means that vibrations do not cause any problems.

For the Pt100, impacts, jolts and vibrations are always matters of concern. The reason is that the stability properties (accuracy) of the best detectors is based largely on non-fixed wire coils. However, the Pt100 detector can be sheathed in shock-absorbing materials at temperatures up to approximately 130-200 °C. Alternatively, thermocouples can be used. The Pt100 can also be encased in a metal-sheathed cable with nickel conductors, normally with a 3, 4, 5 or 6 mm outer diameter. The cable is as impervious, robust and shock absorbent as the thermocouples but the Pt100 detector remains fragile.

VARYING RESPONSE TIMES

The response times of Pt100 sensors and thermocouples depend on many factors. In addition to the shared factors such as the medium, the flow velocity, the fasteners, walls, etc., the Pt100 has a detector which must normally be encased. A thermocouple wire can be extremely thin, as can a metal-sheathed cable. It is therefore possible to have a thermocouple with a short response time, whereas the Pt100 detector usually has a minimum threshold value of response time that cannot be avoided. As is so often the case, it is the specific application that finally determines whether a Pt100 or a thermocouple is the best choice.

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