Temperature Measurement

Temperature control is important for separation and reaction processes, and temperature must be maintained within limits to ensure safe and reliable operation of process equipment. Temperature can be measured by many methods; several of the more common are described in this subsection. You should understand the strengths and limitations of each sensor, so that you can select the best sensor for each application.

In nearly all cases, the temperature sensor is protected from the process materials to prevent interference with proper sensing and to eliminate damage to the sensor. Thus, some physically strong, chemically resistant barrier exists between the process and sensor; often, this barrier is termed a sheath or **thermowell**, especially for thermocouple sensors. An additional advantage of such a barrier is the ability to remove, replace, and calibrate the sensor without disrupting the process operation.

Thermocouples: When the junctions of two dissimilar metals are at different temperatures, an electromotive force (emf) is developed. The cold junction, referred to as the reference, is maintained at a known temperature, and the measuring junction is located where the temperature is to be determined. The temperature difference can be determined from the measured emf. The relationship between temperature difference and emf has been determined for several commonly used combinations of metals; the mildly nonlinear relationships are available in tabular form along with polynomial equations relating emf to temperature (Omega, 1995).

> The thermocouple provides a good balance of accuracy, reliability and cost and is one of the most widely used temperature-measuring devices in the process industries.

Resistance Temperature Detectors (RTD): The electrical resistance of many metals changes with temperature; metals for which resistance increases with temperature are used in RTDs. Temperature can therefore be determined from the change in the electrical resistance of the metal wire according to

Effect of temperature on resistance

$$R_T = R_{TO}(1 + \alpha T) \qquad \textbf{(1)}$$

with R_T the resistance, R_{T0} the resistance at base temperature of 0 °C, T the temperature of the sensor (to be determined from R_T) and a the temperature coefficient of the metal. This linear relationship sometimes provides sufficient accuracy, but nonlinear correlations are available for higher accuracy (Omega, 1995). RTDs are commonly used for applications in which higher accuracy than provided by thermocouples is required.

Thermistor:This sensor is similar to an RTD, but applies metals for which the resistance decreases with increasing temperature. The relationship is often very nonlinear, but thermistors can provide very accurate temperature measurements for small spans and low temperatures.

Bimetallic:Metals expand with increasing temperature, and the rate of expansion differs among metals. A spiral constructed of two bonded metal strips will coil (uncoil) as the temperature changes. The changing position of the coil can be detected and used to determine the temperature. This provides a rugged, low cost sensor that is often used for local displays and for on-off temperature control, i.e., a thermostat.

Filled systems:A fluid expands with increasing temperature and exerts a varying pressure on the containing vessel. When the vessel is similar to a bourbon tube, the varying pressure causes a deformation that changes the position detected to determine the temperature.

Table 1. Summary of temperature sensors

Sensor Type	Limits of Application (°C)	Accuracy[1,2]	Dynamics: t (s)	Advantages	Disadvantages
Thermocouple					
type E: chromel-constantan	-100 to 1000	±1.5 or 0.5% for 0 to 900 °C	see note 3	-good reproducibility -wide range	-minimum span of 40 °C -temperature vs. emf not exactly linear -drift over time -low emf corrupted by noise
type J: iron-constantan	0 to 750	±2.2 or 0.75%			
type K: chromel-nickel	0 to 1250	±2.2 or 0.75%			
type T: copper-constantan	-160 to 400	±1.0 or 1.5% for -160 to 0 °C			
RTD	-200 to 650	0.15 + 0.2|T|	see note 3	-good accuracy -small span possible -linearity	-self-heating -less physically rugged -self-heating error
Thermister	-40 to 150	± 0.10 °C	see note 3	-good accuracy -little drift	-highly nonlinear -only small span -less physically rugged -drift
Bimetallic	-	± 2%	-	-low cost -physically rugged	-local display
Filled system	-200 to 800	± 1%	1 to 10	-simple and low cost -no hazards	-not high temperatures -sensitive to external pressure

Notes:

1. Accuracy is measured in °C or % of span, whichever is larger.
2. With RTDs, the inaccuracy increases approximately linearly with temperature deviation from 0 °C.
3. The dynamics depend strongly on the sheath or thermowell (material, diameter, and wall thickness), the location of the element in the sheath (i.e. bonded or air space, the fluid type, and the fluid velocity. Typical values are 2 to 5 seconds for high fluid velocities.

Source: http://pc-education.mcmaster.ca/Instrumentation/go_inst.htm