17. Thermistors

The term thermistor refers to semiconducting ceramic materials, generally oxides, acting as sensing elements of devices for measuring temperature. A very extensive literature is available on this subject: especially valuable is a book by Sachse (1975), and many papers in Temperature, Its Measurement and Control in Science and Industry, Vol. 4 (1972) and Vol. 5 (1982).

It is difficult to discuss thermistors within the framework of this document; their characteristics are much more device-dependent than those of other thermometers, so their properties must be related to specific commercial devices and a general description cannot be given in terms of materials, at least for a moderately high level of accuracy. On the other hand, the thermistor is very widely used and may show a stability comparable with that of an IPRT.

The range of use of each particular thermistor is narrow since the resistance/temperature relationship is exponential of the form

$$R = R_0 \exp[-b((1/T) - (1/T_0))] \tag{17.1}$$

where R_0 is the zero-power resistance (typically between 2 and 30 kΩ) of the thermistor at some reference temperature T_0 (kelvins), frequently 298 K (zero power resistance is the resistance when the current is low enough to produce negligibly small self-heating). The constant b is such that R changes about 4 percent per kelvin. Therefore a suitable type of thermistor must be chosen for each specific application.

Although thermistors can be used at very low temperatures (liquid helium [Schlosser and Munnings (1972)]) and at high temperatures (above 500 °C [Sachse (1975)]), the main area of application is between about -80 °C and 250 °C. They may be considered as secondary thermometers (accurate to within 50 mK to 5 mK) only in an even narrower range, between 0 °C and 100 °C. The following discussion is restricted to this latter range.

Both disk and bead types can have this quality when they are glass-coated to limit the deleterious effect of moisture. Apart from the effect of moisture on the thermistor itself, the probe where the thermistor is usually mounted can also be moisture-sensitive; for example, moisture can cause shunting between the connecting leads.

Interchangeability of thermistors can be within 50 mK, especially with disk types because the larger sensing element more easily allows constancy in the unit-to-unit distribution of materials in the mixture of oxides.

Stability on thermal cycling is the main guide to thermometer quality. Several studies [LaMers et al. (1982), Wood et al. (1978), Edwards (1983), Mangum (1986)] reveal a large variety of behaviours. As with germanium thermometers, it is difficult to express a general rule on stability or even on drift trends. In the most extensive of these studies, Wood et al. (1978) present a large number of figures that show the aging of a large variety of thermistors at various temperatures. The reader is referred to these figures for the details. Some types from two manufacturers appear to show a stability better than 10 mK/year .

Mangum (1986) found the bead-in-glass thermistors to be much more stable than the disk type. During about 4000 h aging at 100 °C, 11 of 12 bead-type thermistors were stable to within 5 mK but 10 of 11 disk-type thermistors changed several tenths of a degree. The bead-type sensors became much less stable if subjected to heating at 300 °C. When they were thermally cycled to 150 °C, about 30% of a sample of 20 changed by 50 to 250 mK. Mangum found no significant differences between the products of various manufacturers.

Moderately large calibration changes due to drift are reported [Code (1985)] to be retrievable by a single-point recalibration, since the whole characteristic shifts by the same amount in the whole temperature range.

Since the sensing element is generally mounted in a stem, the self-heating effect, dynamic response, and immersion error are determined essentially by the stem; therefore the magnitudes of these are common to those of other types of thermometers used in the same temperature range, such as IPRTs (see Section 16.3).

Interpolation equations of the exponential type, with two or more exponential terms, or the following inverse equation:

$$T^{-1} = A + B \ln R + C (\ln R)^3 \qquad (17.2)$$

can be used for approximation of the thermistor R-T characteristics within a few millikelvins over several tens of kelvins [Sapoff et al. (1982), Steinhart and Hart (1968)].