Cold junction – the hidden measuring junction

The article on temperature drift in temperature measuring devices on page 4 presumes that the reader knows that thermocouples work by measuring a temperature difference. If this is not the case, then we recommend that the reader consults this article first.

Figure 1 shows a differentially measuring thermocouple consisting of wires A and B. Assuming that the voltmeter connectors are both at the same temperature Tv then the voltmeter V will display a voltage that is more or less proportional to the temperature difference between T1 and T2. Let us call T1 the measuring junction and T2 the reference junction.

If we move the voltmeter connection in Figure 1 to the split reference junction T2 in Figure 2, we get a more well-known picture of how thermocouples are usually drawn. The thermocouples in both figures function in the same way: $V = S_{AB}$ (T1 – T2). S_{AB} is the relative Seebeck co-efficient (sensitivity) [μV/°C]) for the thermocouple AB.

Let us give an example: T1 = 100 °C and T2 = 20 °C. Then $V = 80\ S_{AB}$ [μV]. In practice, the corresponding temperature difference is then 80 °C. This example is a good indication of the typical measurement error that occurs if we have not compensated for the temperature of the cold junction.

To obtain the "correct" temperature of the measuring junction T1 = 100 °C we must compensate for the current room temperature of T2. We can do this in two ways:

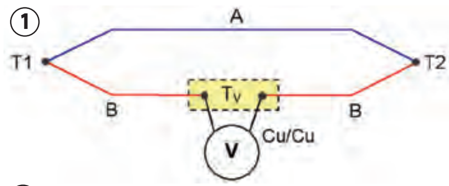

Figure 1. A general thermocouple circuit measures temperature difference (T1 – T2).

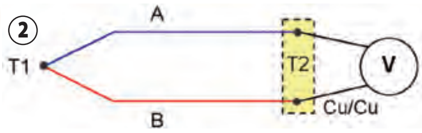

Figure 2. With a thermocouple circuit as shown here it is easy to forget the reference junction's temperature (T2).

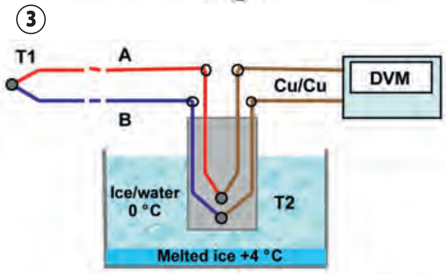

Figure 3. Locking of the reference junction's temperature at 0 degrees in an ice water bath (T2 = 0).

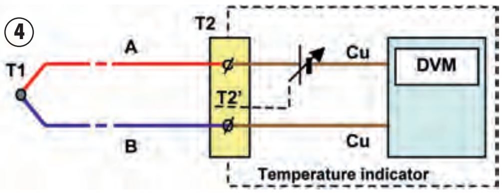

Figure 4. Electronic compensation according to an old principle whereby the reference junction's measured temperature governs an appropriate bias voltage +T2'. Nowadays the signal from T2' is handled by software.

1. The connection points A/Cu and B/Cu are placed in e.g. an ice water bath. T2 is then locked at 0 °C. See Figure 3.

2. The indicator (DVM) is equipped with an extra temperature sensor, which is mounted in good thermal contact with the reference junction. The sensor, which we can call T2', then measures the current temperature of the reference junction (T2) and can eliminate it. $V = S_{AB}$ (T1 – T2 + T2'). See Figure 4.

Even though T2' is handled by software in modern indicators we must not forget that the linearity of the sensor T2' and how the sensor is mounted are of the greatest importance for keeping measurement errors as small as possible. The usual rule tends to apply: the cheaper the solution the worse the measurement quality.