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Thermocouples – Compensating Circuits

This is the final article in a short series examining ways of looking after thermocouples (1–3).

A thermocouple converts a temperature difference into a voltage which is converted into a reading by a temperature indicator. The voltage is generated by the lengths of wire in the temperature gradient between the hot junction in the furnace and the cold junction at the indicator. In practice, the temperatures between the indicator and the furnace wall are low and the gradients are small. To reduce costs these lengths of thermocouple wire are replaced by base metal 'compensating wire', connected at the thermocouple 'head'.

Compensating wires should generate the same voltage as the thermocouple wires they replace. (The indicating instrument corrects for the difference between its terminal temperature and the standard cold junction temperature of 0°C.) Users can choose wire grades A or B (4) to replace thermocouple wire Types R (Pt versus 13RhPt) and S (Pt versus 10RhPt). Grade A has an error of ≤ 30 μV (equivalent to ≤ 2.6°C at 1000°C), with a maximum operating temperature of 100°C. Grade B has a maximum permitted error of ± 60 μV but has suitable insulation for use up to an operating temperature of 200°C.

The compensating wires used for Types R or S are very similar: pure copper for the positive limb and 0.6%NiCu for the negative one. The international standard for insulation colour coding specifies orange for the outer insulation, orange for the positive and white for the negative. (The superseded U.K. standard (5) specified a green lead with white to code for the positive wire. Green is now used for Type K leads.)

Thermocouple Types R and S, made to either the International Practical Temperature Scale of 1968 (IPTS-68) or the International Temperature Scale of 1990 (ITS-90), can use the same compensating wire, as their voltage outputs differ by only 2 μV at 100°C and 28 μV at 200°C.

Type B (6RhPt versus 30RhPt) thermocouples require only connecting, rather than compensating, leads because the output is low at low temperatures. Using copper lead, with the thermocouple head at 80°C, reduces the output by 17 μV, equivalent to an error of only –1.9°C when measuring 1000°C. However, the error will increase to –10°C if the head is at 150°C. The connecting wires should be colour coded grey and white (to lessen risk of connection to a mains voltage supply).

To check a Type R or S compensating circuit, link the limbs at the thermocouple head – the indicator should then show the head temperature; this can be independently verified. Alternatively, disconnect the lead from the head, twist the compensating wires together to form a 'hot' junction and place in boiling water, the indicator should show close to 100°C.

Potential errors, when the head is at 80°C, the indicator terminals at 30°C and the hot junction at 1000°C are:

(a) Type R used with copper cable under-reads by –330 μV (–25°C).

(b) Type R used with compensating lead with the polarity reversed under-reads by –660 μV (–50°C).

(c) Type R used with Type K cable reads high by +1734 μV (+130°C).

(d) Type B used with Type R/S compensating lead reads high by +311 μV (+34°C).

Minimising the head temperature by careful location, radiation shields or forced cooling, will keep the compensating wires within their operating range. Correctly used, compensating leads offer significant cost saving with only a small impact on measurement accuracy.

References

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