Safeguarding Thermocouple Performance

Thermocouples are simple devices that on the face of it are easy to use and repair. Platinum metals alloy thermocouples are considered to have the additional benefit of being resistant to all forms of chemical attack. There are basically three types of thermocouple: R, S and B. Types R and S are suitable up to 1500°C and Type B up to 1600°C for continuous use in favourable conditions. In the metal-clad or mineral-insulated (MI) form they are often regarded as "fit and forget". However, sometimes users may experience problems that can be avoided. Three catagories of problems will be considered:

- drift and thermocouple wire output errors;
- mechanical failure of the wires; and
- errors produced by compensation circuits connecting the thermocouple and the temperature indicator.

Understanding drift or output errors requires an understanding of the way the signal is generated. A thermocouple comprises two dissimilar wire limbs joined at one end to form the hot junction. When the junction is heated a voltage is produced across the free ends or cold junction. For characterised wire combinations (thermocouple "types"), measuring the voltage and the temperature of the cold junction gives the hot junction temperature either from look-up tables or, more commonly, from a digital indicator that combines all three functions.

It must be appreciated that the voltages produced are very small, and the changes with temperature are even smaller. For example, a Type R (Pt versus 13RhPt) thermocouple changes output from 0.013228 volts at 1200°C to 0.013242 volts at 1201°C, a fraction over 0.1%, so it is important that every part of the measuring circuit is operating correctly.

In fact, the voltage is only generated in the lengths of wire that are in a temperature gradient; the remainder provide an electrical connection. A Pt wire produces a larger charge separation than a RhPt alloy wire (and the higher the Rh content, the smaller the charge). As the charge is negative, the Pt limb in a thermcouple is negative with respect to the alloy limb.

The size of the voltage generated by a thermocouple depends not only on the temperature difference and wire combination but also on its condition. It is useful to consider that any factor which increases the mechanical hardness or strain in the limb will also reduce the voltage. These common factors are:

- residual work hardening from wire manufacture
- deformation during thermocouple assembly; and
- contamination by alloying elements in service.

Even the act of quenching-in too many vacancies by cooling too quickly after annealing the Pt limb is said to produce a very small but detectable reduction (but much less than not annealing).

The wire manufacturer is responsible for ensuring that the initial composition of the two limbs is correct and homogeneous: a difference of 100 ppm or 0.01 wt.% Rh affects the output of a Type S (Pt versus 10RhPt) thermocouple by approximately 7 μV or 0.5°C.

The amount of work hardening in the limbs is a joint responsibility as the customer will require a certain minimum tensile strength, especially in fine Pt wires, to ease assembly of the thermocouple, but must then anneal the couple before use to achieve the specified output. It is always preferable to anneal an assembled couple as assembly strains can produce a detectable error of up to 0.5°C. It is not sufficient to suggest in-service temperatures will anneal the couple, as one end remains cold to produce the voltage.

The issues of contamination in service, Rh drift and advice on using and looking after thermocouples will be published in the next issue of this Journal.

R. WILKINSON

Roger Wilkinson is a Senior Materials Scientist at Johnson Matthey Noble Metals in Royston, U.K. He has worked with platinum thermocouples since 1987 in manufacturing, calibration and customer technical support.