Thermocouple problem solving

Dave Ayres from Benrhos talks us through the six point procedure the company uses to determine the cause of problems its customers experience with their thermocouple temperature measuring systems

When it comes to thermocouples – or T/Cs – there are two things that need to be remembered. Firstly, while thermometers such as a platinum resistance versions measure the temperature of the sensor, the output of T/Cs depends on the temperature difference between the measuring junction and the reference junction, commonly termed hot junction and cold junction (CJ) respectively.

Published standards that give the conversion of commonly used T/Cs voltages to temperature are based on the reference junction being at 0°C. As long as the reference junction temperature is known then the temperature at the measuring end can be calculated so the CJ can be at any known temperature. This is the basis of most modern industrial temperature measurements made with T/Cs (see Figure 1). The reference end of the T/C is not held at 0°C but hovers around the local ambient temperature and is then measured using another type of sensor and converted to the equivalent T/C voltage, a process known as cold junction compensation (CJC). The voltages from the T/C and the reference junction sensor are added and the result used to compute the measuring junction's temperature.

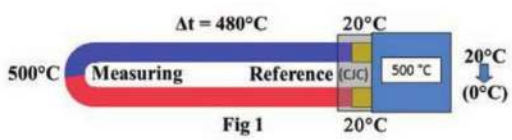

Fig 1

Secondly, the voltage is produced at the temperature gradients and not at the junctions. The sum of all the voltages produced at the various gradients gives the measured voltage which is then converted to temperature using either a published standard such as BS EN 60584-3 (2008) or a validated method such as a computer program that uses the equations from a standard and has been checked to prove it works correctly. Figure 2 shows that the temperature difference of 480°C on the T/C will produce part of the voltage signal and the CJC will produce the rest. The addition of these voltages will then be converted to temperature by the instrument. As long as the T/C materials are homogeneous the gradient or gradients can fall anywhere on the T/C and the reading will remain the same. If there is inhomogeneity in the wires or a change in the type of wire, then measurement problems can arise.

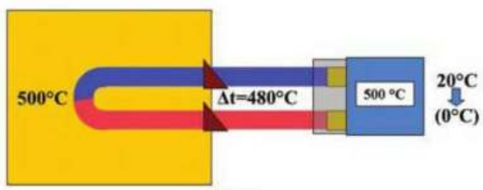

Fig 2

Determining problems

If a customer comes to us with a problem with their thermocouple temperature measuring systems, however, we use a six point procedure to determine the cause of the problem. The bullet points below refer to the numbers shown in Figure 3, above right, which is a schematic of a T/C measuring an object in a vacuum furnace with connections to a digital temperature indicator that has its own CJC.

1. Make sure the measuring junction is in the correct position to give the required temperature to the uncertainty or tolerance that is specified – this is often missed, especially in applications where there is insufficient immersion of the sensor into the object whose temperature is to be measured. A simple rule of thumb is that the immersion should be more than 20x diameter plus the length of the sensing part of the thermometer.

So, for a 6mm diameter metal sheathed T/C we need at least 120mm plus about 5mm because the measuring junction may not be at the end of the sheath. This assumes there is a good contact between the object and the thermometer (about 0.5mm clearance in a pocket or immersed in a liquid), and that the object's temperature is uniform. If in doubt, use a deeper immersion. If the thermometer is in a thermal well (pocket) that itself is in the process medium, then use the pocket's dimensions to estimate if it is immersed sufficiently.

A simple test to determine if there is an immersion problem is to withdraw the thermometer by 1-2cm to see if or when the reading changes significantly – any changes may be due to the lack of immersion or to a non-isothermal condition, but for T/Cs it could also be due to contaminated or strained wires in the T/C. Remember voltages are produced at the temperature gradients so if a T/C is moved so the gradient falls on a different part of the T/C where the wires (or a wire) are physically or chemically different from the gradients original position, then the output voltage will change and so will the indicated temperature.

2. The temperature gradients should occur on the T/C used for the temperature measurement rather than on any connectors and extension or compensating cables.

If the T/C has been calibrated then the temperature gradient in use should ideally occur in a similar way as when it was calibrated. An example of this mistake can be seen in Figure 4, when a hand-held digital temperature indicator (DTI) with a metal probe on the end of a plug-in cable is used to measure the temperature of, say, a fridge. Often the probe is placed completely inside the fridge and the door shut onto the connecting cable. The door seal is where most of the temperature gradient is located so this is the site where the voltage is being produced.

Such connecting cables could be made from inferior T/C wires that are not good enough to be made into cables that meet the standard, so there is potential for a significant error to occur. If the DTI and probe have been thermally calibrated then it is likely the probe has been put into a bath and had the gradients of the calibration temperatures put on it, not onto the cable. Hence the calibration certificate does not represent the way in which the DTI and T/C are being used. As a result, the measurements made in the fridge may not stand-up in a court of law.

3. The T/C should be of the correct type and tolerance for the application from the measuring end right through to where it is terminated. It is possible to buy Class 1 mineral insulated metal sheathed (MIMS) T/Cs where only the metal sheathed part of the T/C is Class 1 and the tails and connections are made from inferior extension or compensating cables. If there is a significant gradient on the tails then the reading may be incorrect.

This is a potential problem where types R, S and B T/Cs are used because the transition from expensive platinum based R, S and B T/Cs to lower cost compensating cable is made as soon as is practical to save costs. This may mean there is a significant temperature gradient on the compensating cable

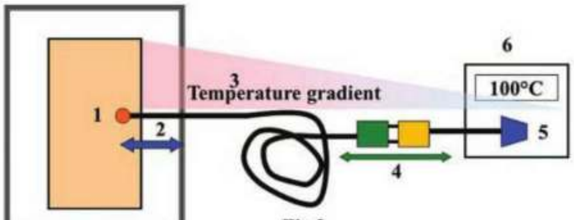

Fig 3

which can cause a substantial error. In Benrhos's experience, for a 20°C gradient along some compensating cables used for R & S T/Cs, errors of about +1°C are common.

4. Always use good quality connectors of the correct T/C type. Note that colour codes have changed – a green connector now identifies it as type K where it was formerly a compensating connector for Types R and S. All connections should be at a uniform temperature with no temperature gradients on them wherever possible. If you suspect there is a problem hold the connector in your hand and warm it, or reduce the temperature gradient on it and see if the indicated temperature changes significantly. We have seen male to female connectors that have both been wired the wrong way around so appear to be OK until a temperature gradient falls upon them.

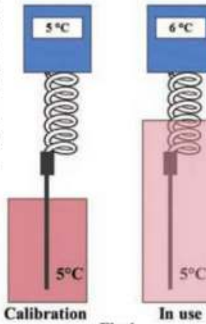

Fig 4

5. The reference end (CJ) of the T/C is usually in an instrument that compensates electronically for it not being at 0°C (CJC). Electronic compensation can be a major source of error, especially for data logging systems with a large number of inputs but only a few connection-temperature sensing points along the input terminals. Look at the maker's specification and if it is not clear take the worst-case situation. Accuracies of ±0.5°C over a reasonable ambient range are common.

An example of instrument misuse is when a DTI+T/C, as described above, has been calibrated in a laboratory whose ambient is stated to be 20°C ±2°C, then taken inside to measure the temperature of a walk in freezer where the ambient could be -20°C – so the complete instrument is subjected to the freezer's temperature. The CJC may perform completely differently between being at about +20°C in the lab and -20°C in a freezer. Again if the DTI had a calibration certificate it would not apply for this type of use, because the instrument is being used outside the ambient range of 20°C ±2°C it was calibrated at. Also, the measuring probe is also not under similar conditions as it was during calibration. Furthermore as there is little or no temperature gradient on the T/C wires, because they are all at the temperature of the freezer, then they are not producing any voltage. Therefore, the indicated temperature is solely down to the value produced by the CJC. Another source of error could arise due to the CJC being inside the DTI so it may not even be at the temperature of the freezer.

6. The temperature indicator should be fit for purpose and located in a position where the ambient conditions do not affect it. The best way to calibrate a T/C system in an industrial process is to put a calibrated reliable thermometer next to the T/C in the process and compare the readings. If the process T/C is removed to be calibrated elsewhere then it is unlikely the temperature gradients will be the same as when it is in the process and an error may occur. This is more likely to happen at high temperatures where the T/C wires are ageing.

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