glass WORLDWIDE

Understanding the value of precision control

In his last article, René Meuleman explained what can be expected from a process control system within the dynamics of a process. There are a number of components that impact the accuracy of a control loop, however and they all need to be taken into account to understand where control precision can be lost.

Since the beginnings of process control, the glass industry has struggled to get sufficient and accurate information from melting and refining processes. This is not surprising because such temperatures and environments are close to the edge of what can be expected from practicable sensors.

Although many different measuring methods have come and gone over the years, few showed better or more stable results than the 'old' thermocouples, which are still mostly used to measure refractory temperature and protect the melting tank, refiners and forehearths from overheating. The same thermocouples are used to measure glass temperature as a representation of its viscosity.

Due to the high temperatures that need to be measured and the harsh environment in which thermocouples have to operate, it is not surprising that the cost of the thermocouples sometimes exceeds the cost of the process control system. It makes sense, therefore, to take a closer look at the entire temperature control loop to understand what performance can be expected and what can be done to improve it, without spending too much money.

TEMPERATURE SENSORS

Mainly type R, S and B thermocouples are suitable to be used in glass industry applications due to the high temperatures that need to be measured. These are composed of pure platinum and/or platinum/rhodium alloys, making them relatively expensive. In some cases, the ceramics are further protected by platinum-rhodium alloy thimbles to achieve an acceptable life span.

Looking at table 1, type B seems to be the most suitable platinum-based thermocouple, as it can measure up to 1700°C/3100°F and shows less temperature drift over time compared to types R and S. However, Type B generates less millivolts, is not available in class 1 and should not be used to measure temperatures below 600°C/1112°F.

What does this all mean in practice? Comparing R and S against B, table 2 shows that type B is less accurate because it is only available in Class 2. Accuracy can be measured and managed by the control software but in-situ drift (see table 3) is much more difficult to deal with. The answer is to choose a thermocouple that specifies a low drift.

The build quality of the thermocouple assemblies should also not be underestimated. It is of high importance that the thermocouple junctions are positioned accurately, to ensure that each thermocouple measures the same if placed in an identical position. In other words, when spending a lot of money on a thermocouple, make sure it is built to narrow specifications!

This whole area of expertise is where glass customers can draw on Eurotherm's experience in metal heat treatment applications. The company has spent many years developing and perfecting methods of calibrating and managing temperature sensors to meet the high regulatory standards of the automotive and aerospace industries in terms of accuracy and drift. This expertise can also be applied to the glass industry to improve the preciseness of temperature control for better reproducibility.

FROM SENSOR TO CABLING

Assuming that a state-of-the-art thermocouple is used, the next step is to get the signal from the process to the system. To keep the measurements achievable, it is not viable to run the platinum/rhodium wires all the way from the thermocouple to the measurement end. Therefore, >

	IEC 60584-2	Class 1	Class 2
R			
S	Temperature range	0°C to +1100°C	0°C to +600°C
	Error	±1.0°C	±1.5°C
	Temperature range	1100°C to 1600°C	600°C to 1600°C
	Error	±1 + 0.003*(t – 1100))°C	±0.0025*t°C
B	Temperature range	N/A	600°C to 1700°C
	Error	N/A	±0.0025*t°C

Table 1: Thermocouple accuracy and tolerance specifications (t represents the temperature of the hot junction).

	T/C type at temperature	Class 1 error	Class 2 error
Forehearth	R or S @1140°C	±1.12°C	±2.85°C
	B @1140°C	N/A	±2.85°C
Crown	R or S @1560°C	±2.38°C	±3.9°C
	B @1560°C	N/A	±3.9°C

Table 2: Thermocouple accuracy in glass applications.

DRIFT

Thermocouple drift is caused mainly by contamination and migration of rhodium. Rhodium tends to migrate from the leg with the highest content of rhodium into the leg with less rhodium, causing misreading. According to a study by Samsung Corning, there is also a change of grain size over time, affecting the drift of noble metal thermocouples[1]. Migration occurs at high temperatures and mainly during temperature changes. All platinum/rhodium alloys show very small contaminations, causing misreadings. Some of the contaminations evaporate at high temperatures, making the thermocouple more accurate. However, some chemical components evaporate out of the ceramic material and diffuse into the thermocouple legs, causing drift. High purity ceramic materials should be preferred.

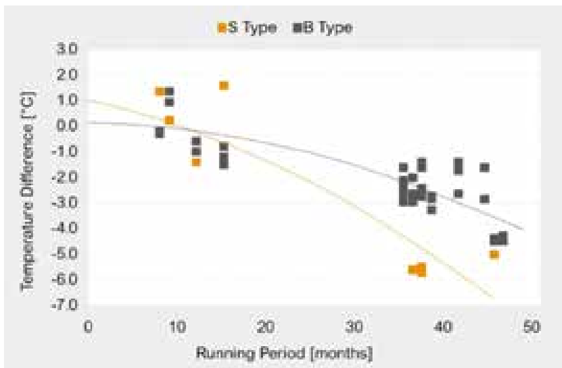

Table 3: Example of thermocouple drift, over time in °C*[1].

COMPENSATING CABLES

Compensating cables are made from copper alloys that show a similar electrical behaviour to the precious metal thermocouple wiring but they are much cheaper, of course. Be aware that compensating cables can only be applied, from an electrical behaviour point of view, to a curtain maximum temperature, typically 200°C/400°F. The temperature that the insulation material can withstand also needs to be considered. Note, some insulation materials can withstand very high temperatures but are sensitive to water or moisture.

compensation cable is used from the connection head of the thermocouple assembly up to the measurement system.

There are several specification and design aspects to consider to prevent the introduction of misreadings in the signal. For example, it is important to make good connections and check that the temperature of the joint between the thermocouple head and the extension cable is within the cable's specified temperature range. Special care should also be taken to choose suitable cable routes between sensor and measuring device. Keep in mind that the signal running through the cable is very 'weak' and could be subjected to noise coming from high power systems like furnace and forehearth boosting, IGBT variable motor drives and softstarters.

Also, keep compensation cable away from areas in which water could come into contact with it, like bubbling and electrode cooling, water-cooled batch chargers and camera systems. Be aware that in emergency situations when water may need to be used in areas where it is not normally expected, severe deviations in temperature readings may occur. Next to the thermocouple, the compensating cable wiring has a huge impact on the total performance of the loop and all the above-mentioned points can cause misreadings. Again, Eurotherm's calibration engineers have vast experience with cabling and can help improve overall measurement performance.

FROM CABLING TO INTERFACE

Once carefully built thermocouples have been selected and installed in the correct way using the right compensating cabling and cable routes, another factor needs to be considered: 'Cold junction compensation'. If all connections in a loop had the same electrical properties and the wires had been connected to each other in a proper way, cold junctions would not be an issue. However, as soon as different materials are connected, a difference in the millivolt value occurs and this needs to be taken into account.

Most of the time, the measuring device will be an instrument or a process control I/O-interface and it is obviously impossible for all its internal components to be made from a material that matches the electrical properties of the thermocouple. So to compensate for the cold junction, the instrument or interface typically measures the temperature of the junction and performs the compensation in software via a digital algorithm.

There is, of course, a concern about the accuracy of the cold junction temperature measurement as well, as it will affect the overall temperature measurement. Expensive thermocouple assemblies and well-chosen compensating cabling deserve equipment that has been specifically designed using suitably placed, high accuracy cold junction compensation (CJC) sensors and compensation algorithms. Otherwise, the measuring device becomes the weakest link when considering total accuracy of the loop.

FROM INTERFACE TO SYSTEM

From now on, if the correct measuring or process control system choices have been made, the thermocouple signal simply runs through some analogue components and filters, preparing it to be converted into a digital representation. In an earlier article entitled 'Understanding the value of precision process control' (*Glass Worldwide* January/February 2016), Eurotherm explained that systems need to be designed carefully to convert the sensitive signals accurately.

Conversion speed and accuracy are conflicting in some ways and potentially, conversion speed does not need to exceed temperature control speed. Temperature control loops should not run much faster than the process is capable of reacting and in most cases, a glass process does not actually require fast acting controls. They cannot react to sudden changes due to the limitations of their design and specification and control engineers would not want them to. Overall, temperature interfacing and control is a science and should not be underestimated. Accuracy and reproducibility are key and the whole hardware loop, including the analogue/digital conversion circuit, is part of that.

CONCLUSIONS

There is clearly a need to differentiate between accuracy and repeatability or reproducibility and to understand what is important for the process. Eurotherm has developed methods to overcome accuracy issues through the diligent design quality of its product range but reproducibility needs to be tackled at a customer's plant. Its global engineering team has found that it is possible to make improvements without excessive capital spend, having learned how to improve the accuracy of temperature measurements and deal with drift from experience in heat treatment applications. It has also been realised that there are opportunities for improvements through applying that knowledge and experience in the glass industry.

Eurotherm's team of glass experts are able to show customers how their systems are performing and help them understand what can be achieved by applying some simple methods and choosing the right systems. They can also explain the sense and nonsense of 'speed', 'accuracy' and 'reproducibility' and believe that basically, it is all physics and not sales gibberish. ■

COLD JUNCTION COMPENSATION

Most modern instruments or systems compensate cold junctions by measuring the temperature via a sensor situated as close as possible to the cold junction. To calculate the typical accuracy of the circuit, square the accuracies of both the thermocouple and and the CJC and square root the result. Example:

$$\sqrt{TCaccuracy^2 + CJCaccuracy^2}$$

For the worst case, add them together. Example: TC accuracy + CJC accuracy

REFERENCE

1. Study on thermal drift of noble metal thermocouples by Sung-Sin So, Hyun-Min Park and Yeun-Joon Jung.

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