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WHITE PAPER | A Discussion of Unit Calibration vs. Bulk Wire Calibration of Type R and S Profile thermocouples

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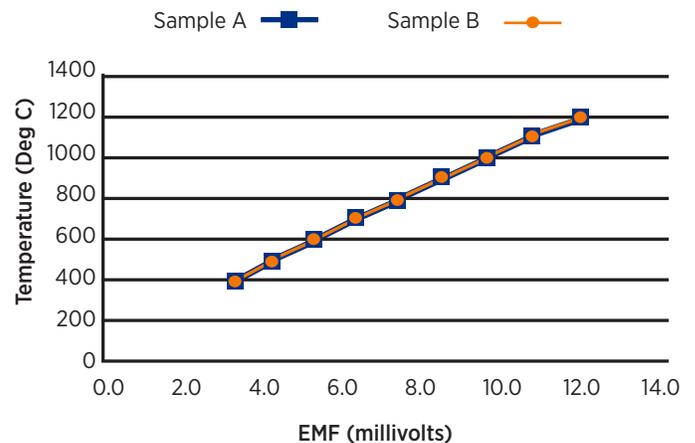
When purchasing a thermocouple as a component of temperature control in an industrial process, one must determine if they will use a standard wire curve to interpret the sensor output or if the process requires device-specific data from the thermocouple manufacturer. This paper describes two different approaches that are available for obtaining device-specific thermocouple data.

At Conax Technologies, our quality control system dictates that when each spool of Type R or Type S thermocouple wire is received for incoming inspection that a sample of that wire is used to construct a simple thermocouple. That thermocouple is then calibrated to confirm conformance to the appropriate standard, and the data is saved. For a large percentage of the thermocouples that are produced with the wire from each spool, the sensor calibration table characterizing the sensor output that is supplied with the device is created with the initial wire sample calibration data. The customers then have that data available to them to interpret the EMF output of the sensors. Alternatively, some customers instead purchase individual calibrations for each thermocouple. Which approach has more merit for profile thermocouples?

The rationale of using the wire lot data to characterize the thermocouples constructed with that lot has as its basis both data as well as accepted practice. In 2012, Conax sought to verify that each piece of a long section of type S wire would yield the same results when calibrated with the highest level of calibration techniques by comparison methods. In order to verify this, a sample of type S wire was sent to the United States Department of Commerce National Institute of Standards and Technology in Gaithersburg, Maryland, USA (NIST). NIST was instructed to take one sample of wire from each end of the section and calibrate it by comparison technique. After being electrically annealed in air, each thermocouple was individually calibrated by welding its junction to the NIST standard type S reference. Coefficients characterizing the EMF output of each sample were supplied to Conax. An analysis of the data began with a graph of the output from 400°C to 1200°C, but the two lines were indistinguishable. (See Chart 1.)

Next, the Seebeck Coefficient (in °C/mv) at each temperature was calculated from the data so that the temperature difference could be determined. As can be seen in Table 1, the temperature differences between each end of the wire for the range of 400 to 1200°C were each less than 0.1°C. NIST publishes the uncertainty¹ of thermocouple calibrations done by comparison from 400°C to 1093°C to be 0.28°C, increasing to not more than 1.67°C at 1454°C, with a 95% confidence level. The difference in data from each end of wire fell well within the uncertainty of the calibration. This data strongly supports the concept of using incoming wire sample calibration data to characterize thermocouples made with the spool. When the incoming wire sample calibration is conducted at Conax, the first step is to electrically anneal the wire in air. Then instead of welding the sample thermocouple junction to the standard as is done at NIST, the two junctions are wired together with platinum wire to ensure that they are exposed to the same temperature. The calibration is then conducted by comparison in a manner very much like the procedure used at NIST.

Chart 1
End to End Type S Wire Comparison





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Table 1

Temp (°C)	EMF End A (mv)	EMF End B (mv)	Difference (mv)	Seebeck Coefficient (°C/mv)	Difference (C°)
400	3.260782	3.261490	0.00071	0.0096	0.074
500	4.235561	4.236246	0.00068	0.0099	0.069
600	5.242047	5.242681	0.00063	0.0102	0.062
700	6.279968	6.280552	0.00058	0.0105	0.055
800	7.351370	7.351931	0.00056	0.0109	0.052
900	8.457625	8.458218	0.00059	0.0112	0.053
1000	9.597831	9.598536	0.00071	0.0116	0.061
1100	10.769983	10.770902	0.00092	0.0118	0.078
1200	11.966775	11.967932	0.00116	0.0120	0.096

The concept of applying calibration data from one sample of wire on a spool to other devices made from the same wire also has a basis in practice. In the production of base metal thermocouples, it is recommended that one unit from each lot is calibrated and discarded, and the remaining units are put into service with the calibration data from the discarded thermocouple. This is justified because if the wire is homogeneous in composition, then any section of the wire will perform equivalently to any other section of the wire. In base metal thermocouples, the act of calibrating a unit will alter its output, which is why the unit calibrated is discarded. Although profile thermocouples are typically made with platinum wire, the theory that each thermocouple in the lot will have the same calibration within the limits of uncertainty has merit; however, the act of calibrating a unit one time does not cause the data to shift in a destructive way.

In some cases, customers request that each thermocouple probe be calibrated individually. For single circuit thermocouples with junctions located on the end of the probe, the units are calibrated in an isothermal block to ensure that the device under test junctions and the standard are exposed to the same temperature. However, profile thermocouples typically have three, four or five junctions at different locations; a different standard must be placed at each junction location. Due to physical constraints of the various designs of the profile thermocouples, the junctions of the device and the related standards are placed in close proximity, but they cannot be physically connected as they are in the wire sample calibrations or placed in an isothermal block as they are in other calibrations. Profile thermocouples with pocketed insulators present an added challenge because the junctions are located on different sides of the insulator, so some may be in contact with the furnace tube or insulators from other sensors. Because Conax cannot simulate the physical environment and thermal distribution of the customer’s application, the correction data supplied from a unit calibration of a profile thermocouple could contain influences from factors in the calibration environment that do not pertain to the ultimate application environment.

For most customers, the wire lot calibration data that can be supplied with any profile thermocouple adequately characterizes the EMF output of each of the thermocouple circuits. Both objective data and common practice have supported the applicability of the wire lot data to the performance of each circuit made with the lot of wire. In the event that a unit calibration is deemed preferable, the data must be used with an understanding that while it accurately represents the performance of each junction in a calibration furnace, it may be influenced by factors that are not present in the target application environment.

¹ In every temperature measurement, there is some degree of doubt. Uncertainty is a way of expressing how sure one is of what the temperature really is. For instance, if you say it is 27.0°C +/- 0.1°C with 90% confidence, then you give your audience the understanding that you are 90% sure that the temperature lies between 26.9°C and 27.1°C.