Transmitter-Sensor Matching Improves RTD Accuracy

RTD sensors never follow the ideal curve, but transmitter-sensor matching makes them as accurate as possible.

By Keith Riley, Pressure+Temperature Product Marketing Manager

Temperature is the most common measurement in the chemical industry. It is employed for a wide variety of purposes from simple monitoring to control of critical processes.

If monitoring and trending are the ultimate goals, a stable, highly repeatable measurement is all that is typically required. However, when the temperature measurement is being used for process or quality control, the accuracy of the reading is much more critical.

An example of a monitoring RTD application would be on the inlet and outlet tube temperatures on a heat exchanger. Over time, the tubes of a heat exchanger will become fouled, and heat transfer will become less efficient. This efficiency drop is indicated by a reduced difference between inlet and outlet temperature. Inlet and outlet temperatures can be monitored to ensure proper heat exchange is occurring.

Operators responsible for controlling critical chemical processes where trustworthy temperature information is required want to be certain that offsets in temperature measurements don't develop over time. The control system will act as it is programmed based on the measurements it receives. Still, you need operators to oversee what the control system is managing. Sometimes even small shifts in reactor temperature measurements can help guide an experienced operator or equipment maintenance personnel to question process or process equipment function.

Those responsible for process optimization initiatives where the objective is to fine tune the efficiency or throughput of a process unit depend on reliable trending data to make decisions on process adjustments. For example, you don't want the temperature information you are analyzing while benchmarking performance or trouble shooting a distillation column to be compromised by an RTD offset somewhere in the data trends/history.

How accurate is an RTD?

When precise control is the goal, this leads to the inevitable question: "Who manufactures the most accurate RTD?", but this is the wrong question. The question that should be asked instead is: "Does XYZ company manufacture RTDs in compliance to International Standard IEC 60751?"

IEC 60751 specifies the ideal resistance to temperature relationship. It also qualifies the RTD classification concept, giving tolerances for each classification and test procedures.

The ideal curve established by IEC60751 for RTDs is the theoretical relationship between the resistance output of the temperature probe and the temperature of the process. Unfortunately, no RTD ever follows this ideal curve. Component differences such as wire diameter or manufacturing tolerances prevent the temperature probe performance from matching the ideal curve. Consequently, IEC 60751 has identified four classifications (Figure 1) to quantify the accuracy of individual RTDs.

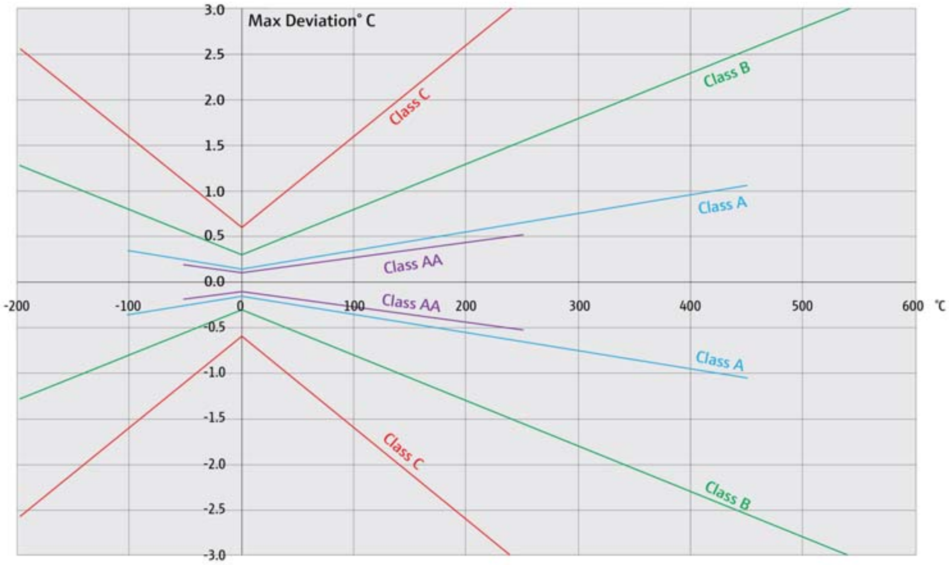


Figure 1: IEC60751 developed this chart to define accuracy of RTDs.

The four classes are:

1. Class AA – allows a tolerance of ± 0.1°C @ 0°C, this is the smallest tolerance or minimal allowable deviation from the ideal curve.
2. Class A – allows a tolerance of ± 0.15°C @ 0°C
3. Class B – allows a tolerance of 0.3°C @ 0°C
4. Class C – allows a tolerance of ± 0.6°C @ 0°C, this is the largest tolerance or deviation from the ideal curve.

Testing to determine an RTD's classification is always performed at a controlled temperature of 0°C (Figure 2), the only valid test point per IEC 60751. This classification is what determines RTD accuracy, not the manufacturer. From this chart you can see, per IEC 60751, that Class AA RTDs provide the best accuracy.

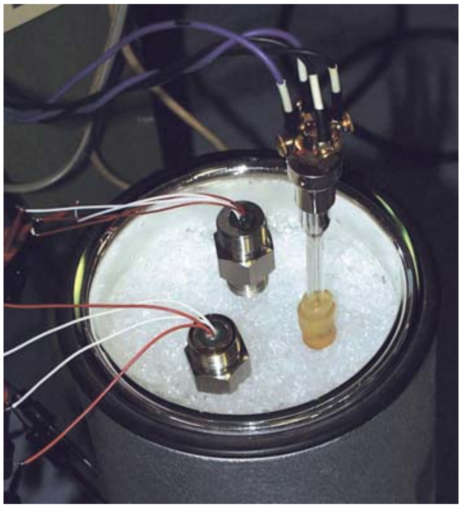


Figure 2: Here, RTD probes are immersed in an ice bath at 0°C.

What avenues are available if your RTD is being used for control and the standard IEC 60751 tolerance bandwidth is not sufficient? You have the option for improving temperature measurement accuracy through transmitter–sensor matching.

Ideal curve not ideal

Default information programmed into a temperature transmitter is based upon the ideal curve. This means that at a given resistance value, the transmitter assumes the corresponding process temperature matches the ideal curve (Figure 3). As we have already demonstrated, this will not be the case.

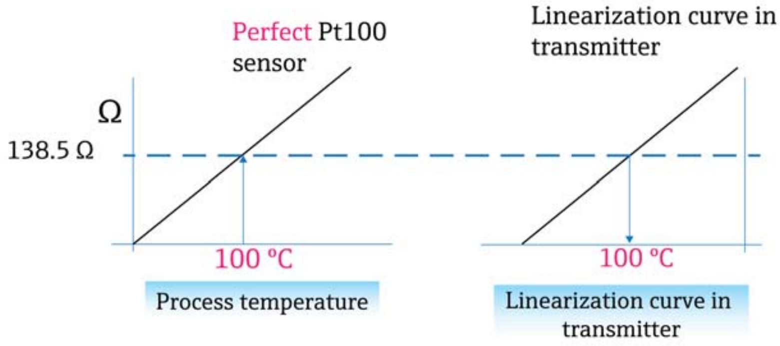


Figure 3: In a perfect world, the linearization curve will match the actual temperature.

Example: Using the ideal curve for a Pt100 RTD, the resistance at a process temperature of 100°C would be 138.5 Ω. This is also the information the associated transmitter is expecting to see. However, this particular RTD actually provides a resistance value of 138.2 Ω when the process temperature is 100°C.

A transmitter using ideal curve programming will provide the control system with a temperature value of 99.2°C based upon the 138.2 Ω resistance value it receives versus 100°C. This produces a 0.8°C measured error (Figure 4).

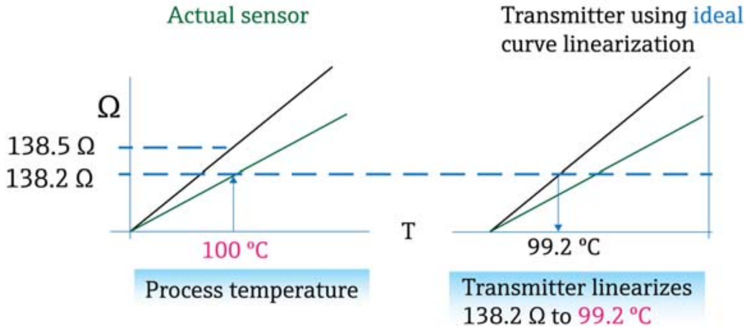


Figure 4: Standard linearization techniques in a temperature transmitter will produce errors. Here, the error is 0.8°C. The left side shows the comparison between the actual temperature sensor resistance value(green) and the ideal curve value at 100°C. The right side shows what the transmitter is going to actually generate as the value to the control system (black)–99.2°C.

IEC 60751 identifies a process for platinum Pt100 RTDs where an equation developed by Hugh Longbourne Callendar and M.S. Van Dusen can be used to identify the unique performance curve for an individual RTD. This equation is described as:

$R_T=R_0\{1+AT+BT^2+C(T\text{-}100)T^3\}$

Where R_T is resistance at temperature T, R_0 is resistance at T=0°C, and A, B, and C are constants, commonly referred to as CVD (Callendar Van Dusen) coefficients. These values are specifically derived from each RTD sensor during calibration using laboratory controlled baths at predetermined temperatures. The actual resistance at each of these points is recorded and used to develop the CVD constants, and to produce a performance curve unique to that specific RTD.

The CVD constants developed from the testing process are then programmed into the corresponding transmitter mated with the RTD temperature sensor. This produces a much more accurate linearization curve for that specific probe, and allows for optimal system accuracy.

If transmitter–sensor matching is performed on the RTD described in Figure 3, the 0.8°C error will be eliminated, producing a much more accurate measurement (Figure 5).

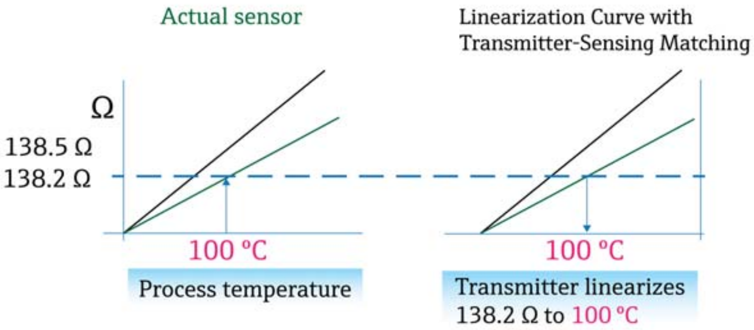


Figure 5: Transmitter–Sensor matching produces a more accurate linearization curve than the Ideal Curve. The green line on the right shows the transmitter output that was linearized using Transmitter–Sensor matching.

RTDs aren't identical

The expected improvement in accuracy with transmitter–sensor matching is difficult to quantify. Some manufacturers state that transmitter–sensor matching will improve accuracy by up to 75%. Depending upon the RTD in question, this may or may not be true. This degree of improvement may not be consistently realized for two reasons:

1. Accuracy will never be 100% as there are a limited set of known test points when determining the real linearization curve for the RTD. Resistance versus temperature points not included in the testing of the RTD will not sit directly on the curve.

2. How close to the ideal curve was the RTD performing prior to identifying the real linearization curve? Even if the RTD is a Class AA, the percentage of improvement will vary depending upon if the unit was performing at the maximum allowable deviation, or at a point closer to the ideal curve.

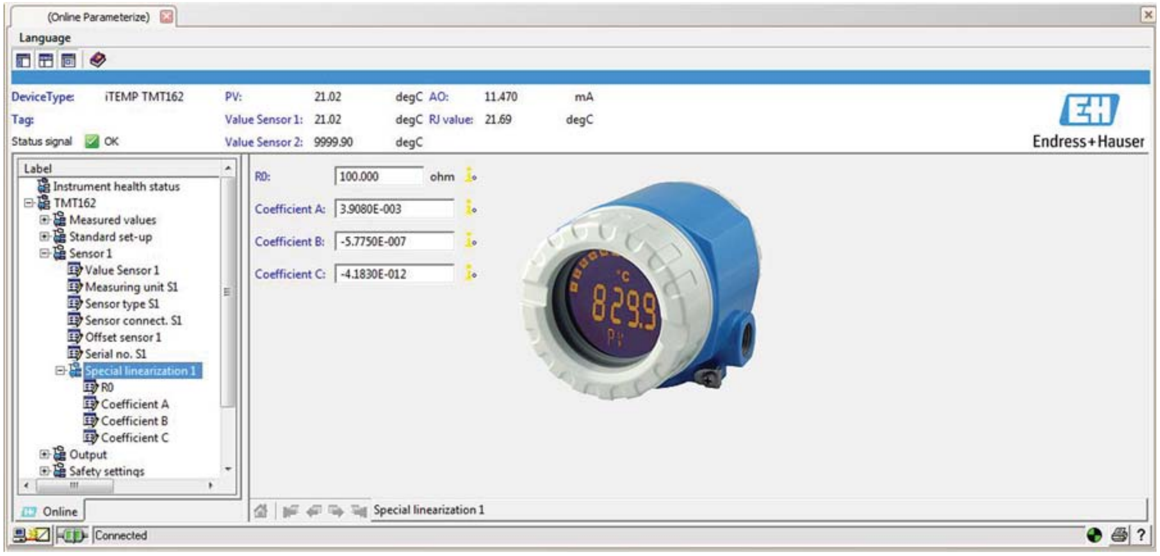
A good analogy to the uniqueness of RTDs is monozygotic or identical twins. Even though identical twins are conceived at the same time from exactly the same "material," they are still unique individuals. On the surface, twins will look and even sometimes act alike, but they still maintain traits defining them as individuals. The same is true for RTDs, even those manufactured at exactly the same time using materials from the same production run.

It is important to remember that CVD constants are unique to a specific RTD. Consequently, if there is a transmitter/sensor matched assembly and it becomes necessary to replace only the RTD temperature sensor, a new set of CVD constants for the RTD must be programmed into the transmitter. Should this step be overlooked or forgotten, the overall performance of the assembly will likely be worse than what would be realized by simply using the ideal curve values.

If a new RTD sensor is needed, there are three basic ways to reprogram the transmitter. The first is to send the RTD sensor and transmitter to a calibration facility, where the two will be matched in a laboratory (Figure 6). For example, Endress+Hauser and several other instrument manufacturers provide such a service.

Figure 6: This Endress+Hauser lab can calibrate a sensor and transmitter, or determine CVD constants for an RTD and probe.

The second method is to reprogram the transmitter, using CVD constants provided by the RTD manufacturer. With most smart transmitters, this is a relatively simple process. For example, Endress+Hauser provides CVD data for input to its FieldCare instrument maintenance software. An operator, maintenance technician or a service representative from Endress+Hauser will use the FieldCare software and the CVD data to program a temperature transmitter with the correct information (Figure 7). Most instrument vendors provide similar tools.



DeviceType: iTEMP TMT162
Tag:
Status signal ✓ OK

PV: 21.02 degC
Value Sensor 1: 21.02 degC
Value Sensor 2: 9999.90 degC

AO: 11.470 mA
RJ value: 21.69 degC

R0: 100.000 ohm
Coefficient A: 3.9080E-003
Coefficient B: -5.7750E-007
Coefficient C: -4.1830E-012

Connected

Figure 7: CVD data is programmed into an Endress+Hauser temperature transmitter on this screen.

If the chemical plant has an extensive instrument calibration laboratory, it can determine the CVD constants, and reprogram the transmitter accordingly.

Summary

The decision on how to proceed—that is, use the normal IEC 60751 ideal curve or transmitter–sensor matching?—is as unique as an RTD.

Questions to ask include:
- What performance do you require?
- What risks are you facing?
- Do you have a cost/benefit concern?

For most monitoring applications, using the ideal curve and standard Class AA, A, B or C performance expectations may be sufficient.

But for control of critical applications or processes, transmitter–sensor matching might be needed. Overall system accuracy is not simply a matter of the RTD measured error. It must also incorporate the performance of the transmitter as well, which is independent of the temperature sensor. Only calculating the combined effect of both components will yield realistic expectations for the accuracy of the temperature measurement.

Notes

Keith Riley has been a Product Business Manager with Endress+Hauser since April 2008. Prior to this, he was a Product Manager and Regional Sales Manager with L.J. Star Incorporated as well as a Product Manager for Penberthy (Tyco Valves). Overall, he has over 20 years of sales, marketing and instrumentation experience in the process industry.

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