A Refresher on Resistance Temperature Detectors

To be sure of getting the temperature measurements you need for a process application, brush up on the options you'll have to consider when selecting an RTD.

J.R. Madden, Moore Industries–International, Inc.

Most process temperatures fall between freezing and 1472°F (800°C). Resistance temperature detectors (RTDs), contact sensing devices, are well suited to process applications because of their temperature range, linearity, stability (typically <0.1% over five years), and ruggedness.

The basic RTD consists of a metal sensing element connected to two lead wires. As the process temperature changes, the element's resistance will change. This temperature/resistance relationship can be predicted using a constant, α, the temperature coefficient of resistance. No two metals have the same α; once the metal's properties are known, a resistance vs. temperature curve can be established.

RTDs are generally used with a signal conditioner that converts their output to either a voltage or a current proportional to temperature. This high-level signal can then be transmitted to display, recording, or control units.

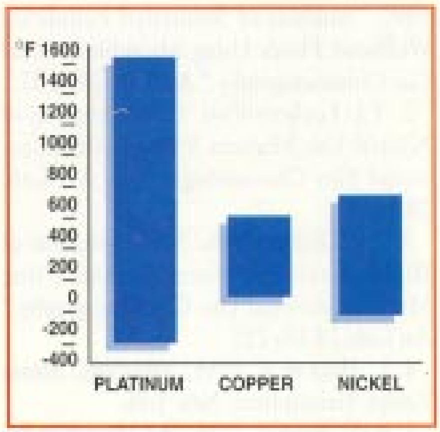

Figure 1. *RTD sensors suit applications that require high accuracy and operate within the sensor's temperature range. Platinum is chosen most often because it remains stable within a wide temperature range and is the most precise.*

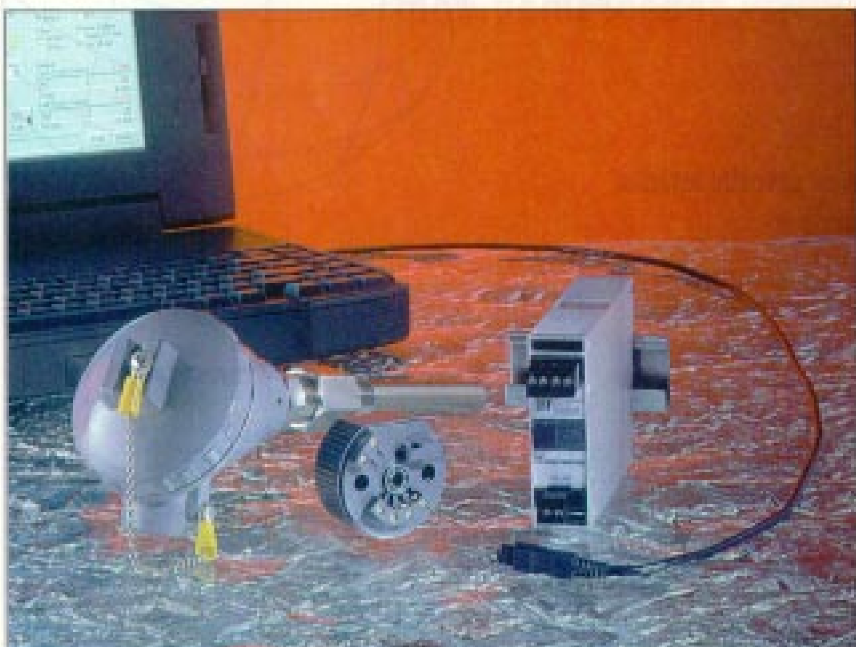

Photo 1. *The TRY PC-programmable temperature transmitter features both simplicity and versatility. From a single configuration window, in one minute, all operating parameters can be selected using point-and-click technology with Windows intelligent configuration software.*

Candidate Metals

A metal's α may be changed by combining it with another metal or by mechanically stressing it. It is therefore possible to produce a wide range of RTDs from only a few metals. The most common are platinum, nickel, and copper (see Figure 1). All three exhibit:

- Stability, changing in a predictable and repeatable manner when exposed to temperature changes
- High change in resistance for a corresponding change in temperature
- Increased resistance at higher temperatures

Platinum. Platinum's resistance-temperature relationship over a very large range, –346°F to 1562°F (–200°C to 850°C), makes it the best metal for RTDs. Its high melting point allows its use in environments that would oxidize copper and nickel.

A special consideration when selecting a platinum RTD is the base ohm value. The choices, typically 100 Ω, 200 Ω, 500 Ω, and 1000 Ω at 32°F (0°C), represent distinct degrees of sensitivity in relationship to resistance. For example, if you are working in a narrow temperature range, a 100 Ω RTD would output a 2 Ω change for a 10°F (2°C) change in temperature. For the same range, a 1000 Ω RTD outputs a 20 Ω change for a 10°F temperature change. Thus, the greater the resistance in ohm change per degree, the greater the resolution in narrow ranges. Platinum RTDs are excellent, but, of course, more expensive than copper or nickel units.

Copper. Copper's small total resistance to temperature change, typically a span of only 10 Ω, limits its usefulness as an RTD. Its tendency to oxidize at high temperatures gives it an operating range of only –94°F to 302°F (–70°C to 150°C). The chief reason to use a copper instead of a platinum RTD is cost—generally as much as a 30% savings. Also on the plus side is copper's status as the most linear of the three metals. This linearity simplifies the process of accurately scaling an RTD reading. Copper RTDs are used most commonly in motor windings, generators, and turbines.

Nickel. Nickel is the middle-of-the-road RTD. Less expensive than platinum, its temperature range of –112°F to 608°F (–80°C to 320°C) is broader than that of copper. It has a relatively high temperature coefficient of resistance, with a base value of 120 Ω. Nickel's limitations stem from its tendency to become nonlinear at temperatures >572°F (300°C).

Element Configurations

The resistance element must generally be built into a probe or an assembly designed to withstand the application's operating conditions. Two of the most common configurations are wirewound and thin film.

Wirewound—the Partially Supported Element. Wirewound elements are made by winding a piece of precision wire into a coil and placing it through small holes in a ceramic, mica, or glass insulator (see Figure 2). The element is held in place with an adhesive and packed with an oxide (usually aluminum or magnesium) determined by the manufacturer. When the entire assembly is fired, the heat fuses part of the metal coil to the assembly. The remainder of each coil is free to move and a resistance measurement is possible. Available designs are shock resistant (up to 30 g causes no change in calibration) and perform well within temperature ranges of –436°F to 1562°F (–260°C to 850°C). Although the wirewound element is accurate enough to satisfy most industrial applications, each assembly must be measured and precut, adding to the cost of fabrication. These devices are best used for extreme temperature applications.

Thin Film—the Fully Supported Element. To produce a thin film sensing element, platinum wire is set on the surface of an insulating support piece, usually ceramic (see Figure 3, page 68). These elements do not require precise measurement prior to manufacture. Simple resistance adjustments can easily be made using laser technology. For example, the film can take the form of a grid whose filaments can be severed with a laser beam to produce the desired accuracy. Film-type sensors are rugged and provide a fast response to temperature changes. They are also less expensive to produce because fabrication methods permit considerable automation. The downside is that they are more susceptible to strain gauge effects. They are best used in midrange (–58°F to 1112°F, or –50°C to 600°C) temperature applications.

Two, Three, or Four Wires?

The basic RTD consists of a sensing element connected to two, three, or four lead wires on the order of 6–8 in. long. Ideally, these wires do not add any resistance to the sensor signal (see Figure 4, page 68).

The recommended number of lead wires is a function of:

- Accuracy and stability required
- Installed system cost
- Location of sensor and receiver
- Ambient conditions (e.g., corrosive potential of the atmosphere)
- Nominal sensor resistance and range

Two-Wire. This RTD (see Figure 5, page 69), the least expensive and simplest to install, provides fair temperature measurement when accuracy is not critical and when the receiver connects directly to the sensor with no extension wire or long couplings attached to the lead wires. The 2-wire RTD cannot compensate for the inherent resistance of these add-ons. Furthermore, corrosion can develop on extension wires, changing their resistance and degrading the reading. The problem is less severe with a 1000 Ω than with a 100 Ω RTD.

Three-Wire. Three-wire RTDs are a good choice for applications that require extension wires between the sensor and the receiver. The additional lead wire requires a 3-wire transmitter to compensate for the increased amount of wiring, as long as the wires are of identical length and have identical resistance values. Wires of different lengths will not have the same resistance, and even new wires of the same gauge and length frequently can have slightly differing diameters. Corrosion can change the resistance of the wires and compromise the integrity of the signal, so 3-wire RTDs should be restricted to benign environments. Stressing or bending the extension wires during installation also creates an unbalanced resistance and reduces measurement accuracy.

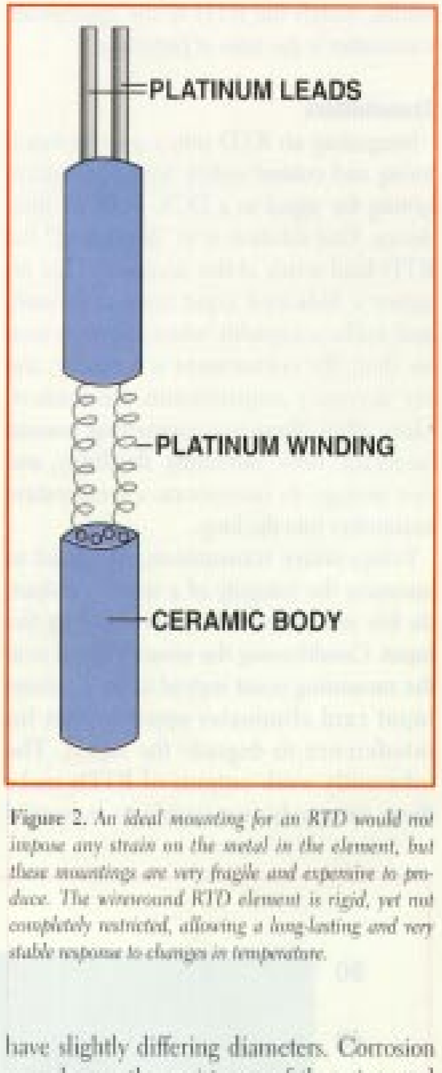

Figure 2. An ideal mounting for an RTD would not impose any strain on the metal in the element, but these mountings are very fragile and expensive to produce. The wirewound RTD element is rigid, yet not completely restricted, allowing a long-lasting and very stable response to changes in temperature.

Four-Wire. The fourth wire in a 4-wire RTD circuit cancels out all errors due to resistance imbalance among the leads arising from variations in length, corrosion on or stressing of the wires, and manufacturing irregularities. Another advantage of 4-wire RTDs is their ability to operate on lighter gauge, less expensive wire (22 AWG vs. the 4, 16, or 18 AWG required by 2- and 3-wire ▶

detectors to decrease measurement distortion by creating less resistance to the measured signal). Four-wire RTDs are the best choice for high-accuracy applications and installations characterized by corrosive atmospheres and considerable distance between the sensor and the receiver. The 4-wire RTD is also very important for critical temperature measurement applications where accuracy is a must. For optimum results, match the RTD to the appropriate transmitter at the time of purchase.

Transmitters

Integrating an RTD into a process monitoring and control system typically requires getting the signal to a DCS, PLC, or other device. One solution is to "direct land" the RTD lead wires at the receiver. This requires a dedicated input conversion card, and works acceptably when the wire runs are short, the environment is not noisy, and the accuracy requirements are modest. More often, there are compelling reasons (accuracy, noise immunity, flexibility, and cost savings) to incorporate a temperature transmitter into the loop.

Temperature transmitters, designed to maintain the integrity of a sensor's output, do the job better than direct-landing the input. Conditioning the sensor's signal near the measuring point instead of on a remote input card eliminates opportunities for interference to degrade the signal. The inherently weak outputs of RTDs make them extremely susceptible to industrial noise from sources such as radio or electromagnetic devices. By converting the low-level signal to a more robust 4–20 mA and providing RFI/EMI protection, a transmitter can reduce or even eliminate noise problems. Another benefit of transmitters is the isolation they provide to sensor signals. Without isolation, a signal can carry a power surge into the receiver. More commonly, an unisolated signal assumes an inaccurate value by picking current up from or losing it to a ground loop.

Transmitters enhance a system's flexibility by making it possible to send the sensor signal to several receivers, which can be indicators, emergency shutdown systems, DCSs, or anything else the process requires. When the transmitter's 4–20 mA signal reaches the DCS or other control device, it can be processed immediately. This is in contrast to a direct-landed signal that the DCS must condition, isolate, and linearize. Processing time, by affecting the computer's ability to perform other functions, limits the number of signals that can be successfully monitored and increases the reaction time between the RTD and the DCS.

Laying RTD extension wire through a plant from the sensor to the receiver is an expensive chore. On the other hand, most plants have pairs of standard twisted-pair shielded wires available in cable. An alternative solution is to lay copper wires, which are rugged, durable, and generally less fragile than extension wire. For 3- or 4-wire RTDs, transmitters reduce the total number of wires that must be bought and installed. Even if sensor wire were run through the plant, a DCS or PLC requires a special board to convert the signal to a usable format. The boards cost more than standard I/V boards, and, because of the additional terminals required to land an RTD input, landing signals on these boards usually costs more per point. The most cost-effective signal conversion is accomplished by buying transmitters that exactly match the number of signals required. When more sensing points are needed, transmitters can easily be installed to convert the signals.

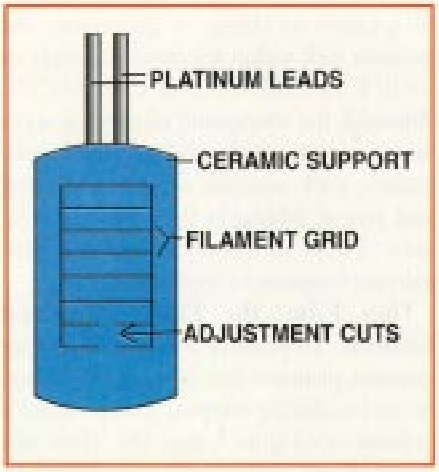

Figure 3. *The surface mounted thin film RTD element provides a low-cost, high-quality platinum sensor suitable for most midrange temperature applications. This element's response time is ~4 × faster than that of the wirewound type.*

Troubleshooting with the TRY

Any RTD component can fail. The sensor can break, its leads can be severed from it, extension wires can crack, and connections at terminal blocks may loosen or corrode. A conventional RTD receiver such as a transmitter or direct-input control system provides only a generic response when one of these failures occurs. If the receiver has a display, a sensor failure message may appear and the output may eventually be driven upscale or downscale, depending on the type of failure. Neither response gives the operator enough information to quickly diagnose the problem and identify what needs repairing; the upshot is likely to be a time-consuming, expensive manual diagnosis.

The TRY PC-programmable temperature transmitter (see Photo 1, page 66) handles 23 types of RTD (2-, 3-, and 4-wire; platinum, copper, and nickel; 10–1000 Ω). It provides an isolated (up to 1500 V_{rms}) 4–20 mA out-

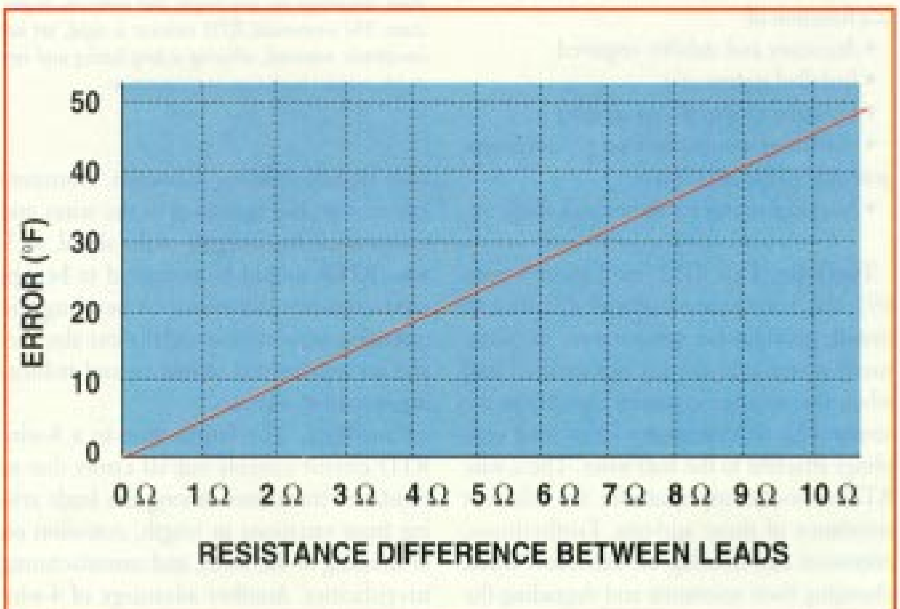

Figure 4. *In this plot of a 100 Ω RTD with a 385 α and 100°F reference point, the Y axis shows the °F of temperature error for every Ω change in resistance (X axis).*

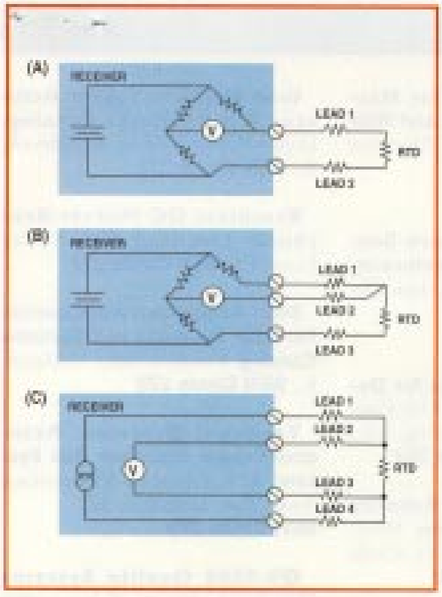

Figure 5. *The performance of an RTD is not easy to predict unless all the operating parameters are known. The 2-wire (A) is the least expensive and most common configuration, but for applications requiring greater accuracy, a 3- or 4-wire (B,C) should be used in conjunction with an RTD transmitter.*

put that is scalable via the configuration software, and ready for direct interface with readout instruments, recorders, DCSs, and other computer-based SCADA systems.

TRY also incorporates total sensor diagnostics that detect a sensor break, follow up with an alert, and then provide a clear error message on the software window to help track and correct the problem. At startup, the transmitter verifies that the RTD type it is programmed to accept (2-, 3-, or 4-wire) matches that to which it is connected. If a conflict is sensed, an error message in plain English identifies the RTD wire that is broken or not properly connected. If a wire breaks or otherwise stops sending a signal during operation, the transmitter sends the output upscale or downscale (user's choice) to warn of trouble. ■

J.R. Madden is an Applications Engineer, Moore Industries–International, Inc., 16650 Schoenborn St., Sepulveda, CA 91343-6196; 800-999-2900 or 818-894-7111, fax 818-891-2816.