MOORE INDUSTRIES

Rules of Thumb for RTD's

While RTD's offer high accuracy, resolution and linearity, numerous pitfalls await every one in a plant. Lead wires may break, corroded splices and terminal blocks can unbalance resistance on the leads, or the sensor itself could fail.

Each of these situations jeopardize your temperature-monitoring system. This article explains how these failures happen and techniques for avoiding for them.

Table 1. *Sensor comparison chart.*

	RTD	Thermistor	Thermocouple
Accuracy	0.01–0.1°F	0.1–1°F	1–10°F
Stability	<0.1% in 5 years	0.2°F per year	1°F per year
Sensitivity	0.1–10Ω/°F (Moderate)	50–500Ω/°F (Best)	5–50µV/°F (Low)
Linearity	Best	Poor	Moderate
Range	-328–1562°F -200–850°C	-150–550°F -102–228°C	-310–3308°F -190–1821°C
Overall	Highest Accuracy Best Stability	Best Sensitivity	High Temperatures

Good Reasons to Use an RTD

For temperature ranges between -328 to 1562°F (-200°C and 850°C), RTD's offer the highest accuracy (see Table 1). They create highly linear outputs, and what little non-linearities remain can be easily corrected. That a typical RTD drifts less that 0.1% in five years shows the stability of this sensor type.

Deciding Which RTD to Use

The basic RTD consists of a sensing element connected to two lead wires. When a slight current is applied to the RTD, it creates a resistance that varies with temperature. The challenge in using RTD's is to avoid adding any resistance to the signal created by the sensor.

RTD's may be purchased with 2, 3, or 4 lead wires from the sensor. The recommended number of wires depends upon:

- Accuracy required
- Stability
- Installed system cost
- Location of the sensor & receiving device
- Atmospheric quality (corrosion potential)
- Nominal sensor resistance & range

Few Applications Suit 2-Wire RTD's

This simplest of the RTD's provides fair temperature measurement when the receiving device connects directly to the sensor, without using extension wire or long couplings. This is also the least expensive RTD installation.

To assure good temperature measurements, do not use a 2-wire RTD when extension wires will be used between the sensor leads and receiving device. The inherent resistance of these wires can not be compensated for on a 2-wire RTD. In addition, corrosion may develop on extension wires, changing their resistance and further degrading the reading.

The liabilities associated with a 2-wire configuration are less severe with a 1000Ω RTD compared to a 100Ω RTD (Figure 1).

Use 3-Wire RTD's with Caution

Use a 3-wire RTD when an application calls for running extension wires between the sensor and receiving device. The additional lead in this RTD circuit compensates for extension wire length when the wires have the exact same resistance values.

While the third lead does solve resistance *length* issues, it can not compensate for other resistance problems. For example, if corrosion develops on the wires of a 3-wire RTD the resistance will change, thus reducing the signal's integrity. To prevent this, a

3-wire RTD should only be used in a benign (corrosion-free) environment.

When installing extension wires with any RTD, they must not be stressed or bent. Such "work-hardening" decreases accuracy by creating unbalanced resistance between the wires. Also, RTD extension wires must be precisely the same length or else the resistance will vary between them, resulting in an inaccurate reading. Resistance variance even exists on new wires of the same gauge and length as their diameters are not exactly equal (Figure 2).

4-wire RTD's Deliver Best Performance

For the highest degree of accuracy and reliability, choose the 4-wire RTD. Unlike a 3-wire RTD, a 4-wire RTD circuit cancels out all errors due to length and resistance imbalance between the leads. Consequently, a 4-wire RTD does not have to be replaced if work hardening or corrosion occurs.

2- and 3-wire RTD's also require heavier (more expensive) lead wire because heavy wire creates less resistance to the sensor. But, lead resistance is a non-issue for 4-wire RTD's, so smaller gauge wire (22AWG) can be used with no ill effect.

With these advantages, 4-wire RTD's belong in applications unsuitable for 2- and 3-wire sensors. These include high-accuracy requirements, corrosive atmospheres and those with the sensor installed far from the receiving device. While a 4-wire RTD costs a few pennies more to install, the higher performance justifies the expense (Figure 3).

Figure 1. *A 2-wire RTD circuit.**

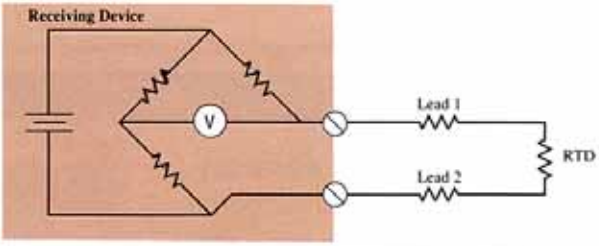


Figure 2. *A 3-wire RTD circuit.**

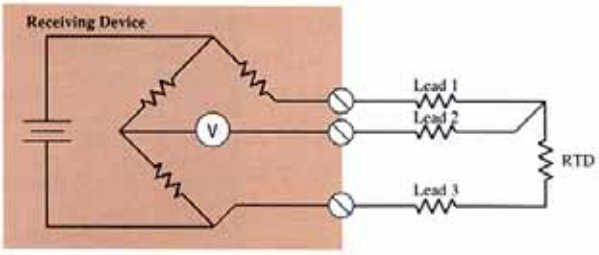
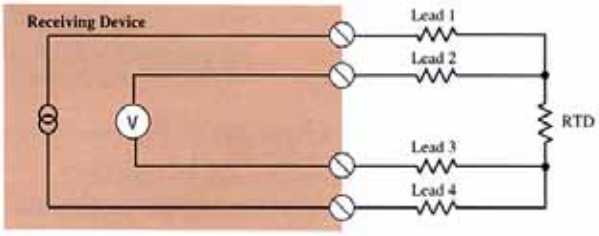


Figure 3. *A 4-wire RTD circuit.**



** These typical circuits show a "Wheatstone Bridge." Other circuits exist, but the lead issues remain the same.*

How Lead Resistance Affects Accuracy

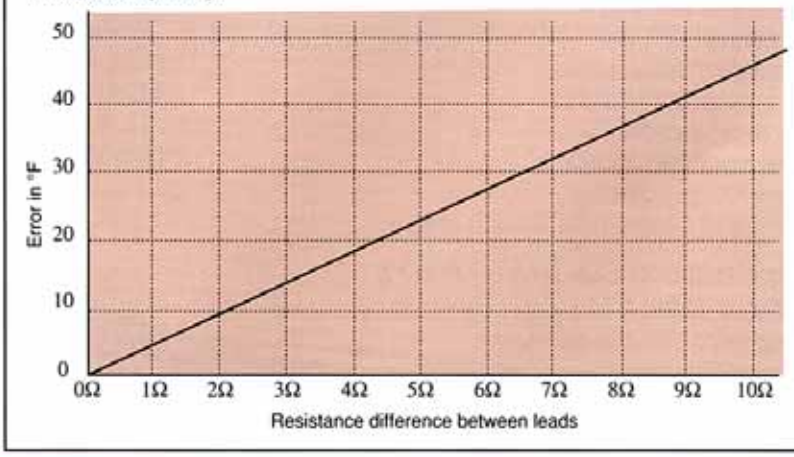
Temperature, work hardening, manufacturing tolerances and plain old age can cause uneven resistance among RTD wires. Resistance variance also develops when RTD extension wires corrode, both at splices run through terminal blocks and even between the element and lead wires within the sheath.

A resistance variance causes substantial error in the signal from an RTD. For example, a 1 ohm uncompensated difference in resistance equates to almost a 5°F error on a 0-100°F range (Table 2).

As mentioned above, 2- and 3-wire RTD's do not compensate for lead errors of this type.

To assure a signal is unaffected by these common problems, use the RIY (Programmable RTD Transmitter), SPT (Site-Programmable Transmitter) and SPA (Site-Programmable Alarm) with 4-wire RTD's. These instruments, elite among RTD receiving devices for accepting 4-wire sensors, discern and compensate for unmatched resistance to produce a highly accurate temperature measurement.

Table 2. *This graph represents a 100Ω PRTD with a 385 alpha and 100°F reference point. The "y" axis shows the °F of temperature error for every Ω change in resistance (x axis).*



What Happens When Something Breaks

Any of the RTD's components—the sensor, lead wires soldered to the sensor, any extension wires and/or terminal blocks—can fail. The sensor may break, the leads can be severed from the sensor, the extension wires may crack and connections at terminal blocks may loosen or corrode.

A conventional RTD receiving device, such as a transmitter or direct-input control system, provides only a generic response when one of these failures occurs. The unit may indicate a "Sensor Failure" (if it has a display) and eventually drive the output either upscale or downscale. Historically, the instruments drove the output up for certain failures and down for others (Figure 4).

Neither of these responses provide enough information to quickly diagnose the problem nor identify what requires repair. Given the numerous possible failure points, finding the actual cause of the problem often requires a time-consuming, expensive manual diagnosis.

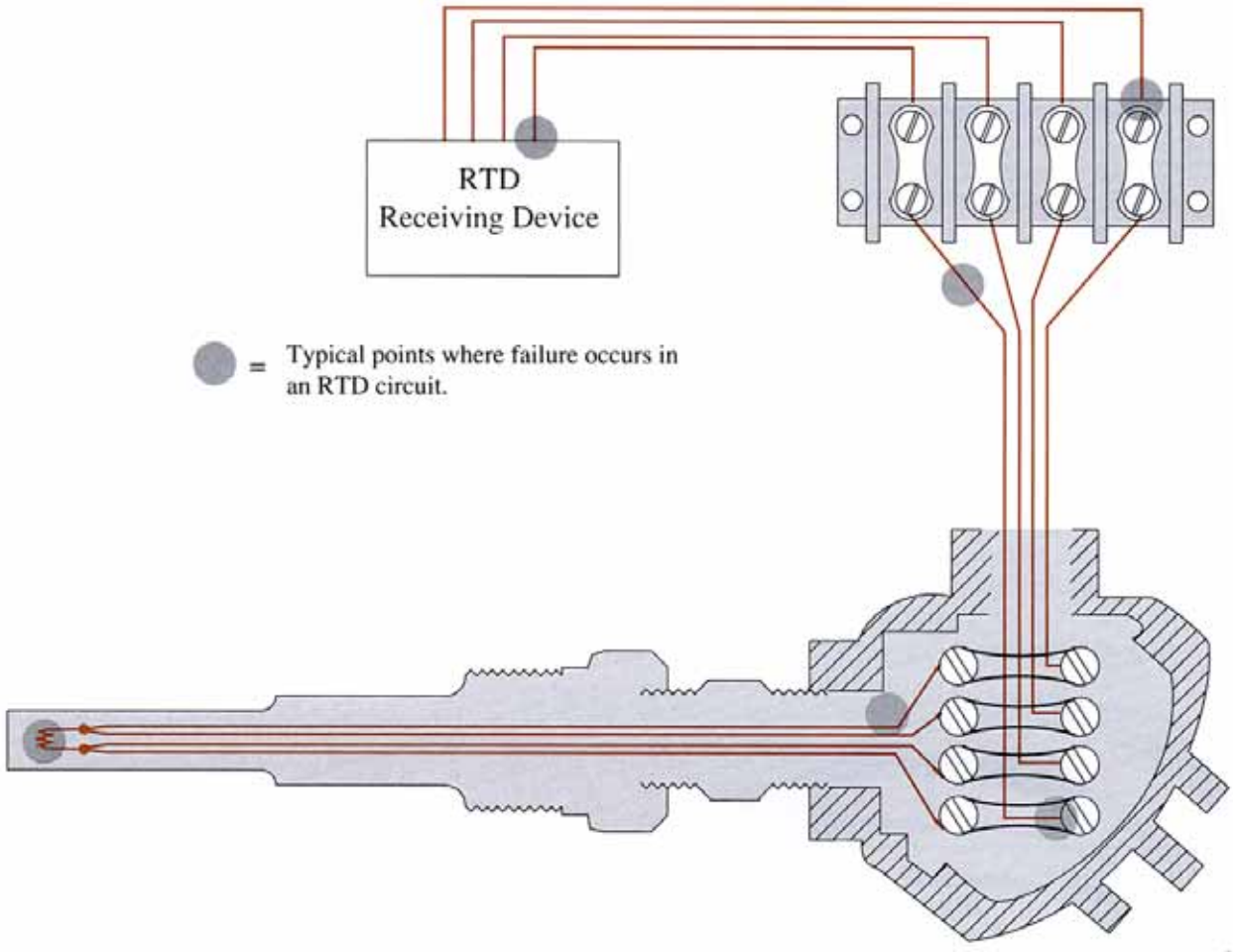
The only instruments which eliminate this ambiguity are those with Moore Industries' unique **Total Sensor Diagnostics**. An instrument with this feature (available in our RIY, SPT and SPA instruments) constantly monitors all aspects of an RTD input circuit and diagnoses any failure.

Advantages of Total Sensor Diagnostics

If an RTD lead wire breaks, a message on the built-in indicator of an instrument with Total Sensor Diagnostics tells the operator exactly which lead has failed. In the event of an open sensor, the display again shows the exact trouble via an error message. An instrument with Total Sensor Diagnostics also identifies the problem to your control system by driving the output upscale or downscale (field configurable).

This twin-warning function allows field operators to know right away when a problem occurs and provides the control system with an immediate response.

Figure 4. *An RTD may fail at any of the points indicated. Without sensor diagnostics, the only response is to send the output upscale or downscale—at best—to indicate "sensor failure."*



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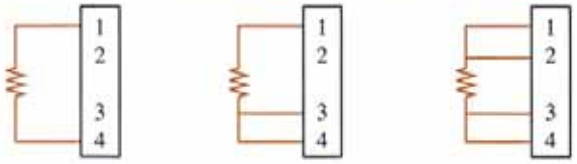
No question exists as to the type or location of the problem (Figure 5).

Total Sensor Diagnostics work with 2-, 3- and 4-wire RTD's. Once configured for the number of RTD wires it should receive input from (the sensor configuration), the unit continuously tests the circuit to make sure it is fine.

Operating with one sensor:

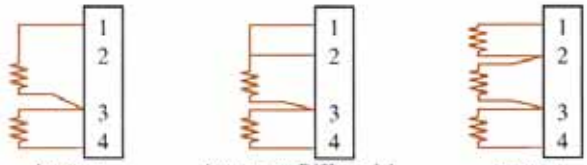
L1 = Lead #1 is open L2 = Lead #2 is open
L3 = Lead #3 is open L4 = Lead #4 is open



In addition, the instruments perform Total Sensor Diagnostics when connected to multiple RTD's—up to three separate sensors. For example, the RIY Programmable RTD Transmitter alerts operators to sensor problems with these self-explanatory messages:

Operating with several sensors (up to 3)

EL1 = Element #1 is open
EL2 = Element #2 is open
EL3 = Element #3 is open



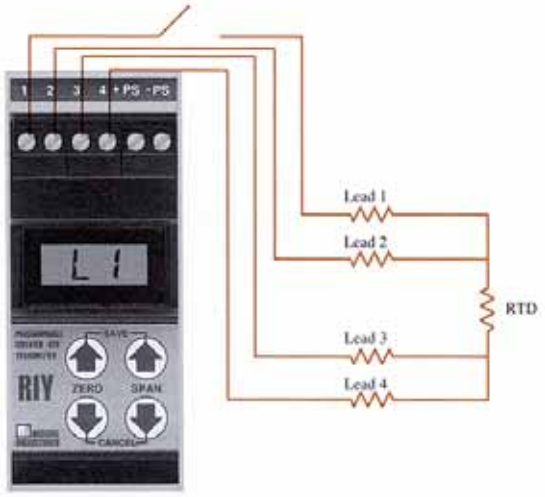
Average or Differential Temperature

Average or Differential Temperature with Lead Compensation

Average Temperature

These diagnostic messages eliminate the work of removing a sensor or checking all lead wires to diagnose an RTD problem, an especially valuable consideration during startup.

Figure 5. *With Total Sensor Diagnostics, the indicator tells the exact source of the problem. For instance, "L1" means lead 1 has opened.*



Conclusion

Within a certain temperature range, RTD's offer higher accuracy than thermocouples. When an RTD is deemed the suitable choice for a particular application, either a 2-, 3- or 4-wire sensor must be selected.

A break in the sensor, extension wires or leads on any RTD type (2-, 3- or 4-wire) results in poor temperature measurement and potentially costly diagnostic efforts. Only an instrument with Total Sensor Diagnostics, available solely from Moore Industries, can eliminate this problem by exactly identifying a break.

Total Sensor Diagnostics allows industry to take full advantage of all RTD types, while minimizing their associated problems. Instruments with Total Sensor Diagnostics, especially when used with a 4-wire RTD, provide the most secure and trouble-free temperature measurement.

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