
# Troubleshooting RTDs and Thermocouples



## Your Host and Presenter



Presenter

Bill Bergquist, Sr. Applications Engineer and RTDologist™

- 30+ years experience in temperature measurement with RTDs and thermocouples in the aerospace, industrial, and laboratory markets.

Host

Jeff Wigen, National Sales Manager

- 25 years in sales and marketing of custom designed made-to-order products for the industrial and biotech markets.



## What we will cover today



- RTDs
  - Troubleshooting guide
  - Ice bath resistance test
  - Insulation resistance
  - Error sources
    - Stem conduction
- Thermocouples
  - Check polarity of the thermocouple
  - Check for oxidation or corrosion
  - Comparison test
  - Test meter and extension wires

## RTD Troubleshooting Guide

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| Symptom | Cause | Solution |
|---|---|---|
| Erratic output | Element damage; RFI or EMI | -Replace<br>-Add shielded cable, metal head<br>-Route wiring away from the noise source |
| No signal | Element damage; wired incorrectly | -Replace<br>-Correct wiring |
| Step change in output after short time in service | Insulation resistance, moisture has entered the probe causing a low temperature indication | -Replace<br>-Dry out and monitor IR |



Electromagnetic or radio frequency interference are the two most common causes of erratic output from an RTD. Second place, is damage to the sensing element from vibration or mechanical shock. Vibration damage begins as erratic output or a shift up in indicated temperature and then eventually goes to an open circuit.

A step change in measured temperature (usually an increase) is caused by moisture inside the probe. Moisture causes a drop in resistance and a corresponding low measurement. As the process heats up the moisture is driven out of the probe and the measured temperature increases to normal. This symptom will be noticed on startup of a heated process. The moisture seal in the probe has failed and there is no good method to repair it. Replacement is recommended.

## RTD Lead Wire Colors

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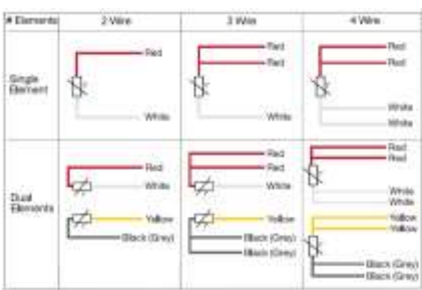
RTDs colors defined by ASTM 1137 and IEC 60751

- There are also custom colors with the most prevalent being green in place of the yellow leads in dual elements






No signal from the RTD can be caused by a wiring error. Landing the wires on the wrong terminals of a transmitter or PLC will not damage the probe. Make the correction and all should be okay.

## Insulation Resistance

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Insulation resistance

- First and most important calibration/verification check
- Low IR can cause a low temperature measurement due to shunting between the sensing element wires
- Most IR failures are due to moisture and/or contaminants that may have entered the probe



This is a typical wire wound sensing element. They are about 1” long and 1/16” diameter and are potted inside a stainless steel sheath. If moisture gets into the sheath and sensing element the result can be a shorter path for the excitation current and the result is a low resistance measurement.

## Insulation Resistance

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Test method

- Lower resistance = lower measured temperature
- Test at 50 VDC minimum
- IR should be >100 megohms at 25°C



IR decreases with an increase in temperature so at room temperature a value much higher than what is really needed for an accurate measurement is required.

An industrial grade RTD accuracy is not significantly affected until the IR drops below a few megohms. The measurement is made by touching one lead of a megohmeter to the leads and the other to the probe sheath. Some industrial grade probes are tested to higher levels to insure maximum performance at high temperatures.

## Insulation Resistance

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Low insulation resistance ($R_{IR}$ or IR)

IR acts as a shunt resistor to the measurement circuit the lower the IR the higher the effect on the accuracy of the probe. The equation for calculating theoretical effect of IR on the measurement is basically the equation for calculating the overall resistance of resistor in parallel, where one resistor is the PRT ($R_{PRT}$) and the other is the insulation resistance ( $R_{IR}$)

$$R_{Measured} = \frac{[R_{PRT} x R_{IR}]}{[R_{PRT} + R_{IR}]}$$

Where: $R_{Measured}$ = Resultant measured resistance
$R_{PRT}$ = Resistance of PRT element
$R_{IR}$ = Insulation resistance value

So for example: a probe that reads 100Ω at 0ºC that then degrades to IR of 0.1 MΩ the measured resistance will be 99.900 which equates to approximately -0.26ºC.



For those of you that like a little math with your calibration, this example shows how to calculate the effect IR has on RTD accuracy.

## RTD Troubleshooting Guide

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| Symptom | Cause | Solution |
|---|---|---|
| One of the temp sensors drops out occasionally and takes anywhere from 5-10 minutes to get back to temperature again | Maximum service temperature exceeded damaging potting material. May be a transmitter failure. | -Replace RTD<br>-Check for correct wiring.<br>-Test transmitter for correct output and time delay settings |
| Output changes after short time in service | RTD drifting due to high vibration or shock. | -Test to verify drift<br>-Replace with heavy duty RTD<br>-Use a thermocouple |



The first item on this list is an unusual situation that occurred recently. A response time that changes from when the probe was installed new can be caused by the potting material changing thermal properties after being exposed to excessive temperature. This situation though was tracked down to faulty wiring in another part of the measurement loop. Delays in response can also be caused by a delay setting in the transmitter programming. Many programmable transmitters have a delay setting.

## RTD Accuracy Check

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Verification in an ice bath

- Resistance at 0°C most important and easiest to check
- Standard interchangeability tolerances established by either ASTM E1137, or IEC 60751

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An ice bath is the easiest and most important temperature point to check. A properly made ice bath will have an accuracy of ± 0.002°C. How do I make one you ask? Read on…

## Ice Point Check

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Using an Ice Bath and DMM, check resistance at 0°C

Crushed ice, purified water, and an insulated container

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Crushed ice made with purified water is packed into an insulated container. Purified water is added to fill in the gaps. If the ice floats, you have added too much water. Adding a stirring feature to keep the water flowing around the ice minimizes temperature gradients within the bath. Each probe should be immersed at least 4”. Do not use the probe to beat a hole in the ice. You may damage the sensing element. Use a scrap probe or similar size rod to form the holes.

## Interchangeability

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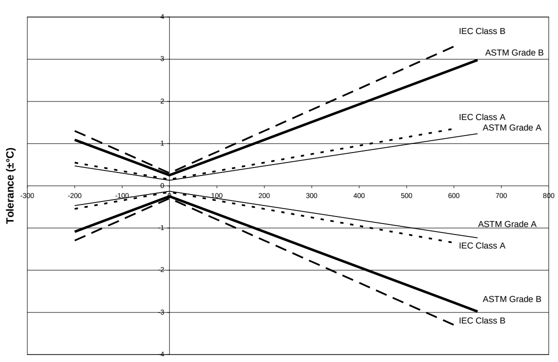


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Interchangeability is the performance specification from the RTD standards that determine how closely the RTD matches a nominal R vs. T relationship. Try as we might, RTD manufacturers cannot build everything to exact nominal values. Note that the ASTM standard has slightly tighter tolerances for the two grades of sensors. All RTDs are built with the tightest tolerance at 0°C and as the temperature diverges from 0°C the tolerance increases. The vertical line on the graph represents 0°C and the tolerance on the y axis is expressed in ± °C from nominal.

## Interchangeability



| Standard | Tolerance | Defining Equation[1] |
|---|---|---|
| ASTM E1137 | Grade A | ± [ .13 + 0.0017 \| t \| ] |
| ASTM E1137 | Grade B | ± [ .25 + 0.0042 \| t \| ] |
| IEC 607512 | Class AA2 | ± [ .1 + 0.0017 \| t \| ] |
| IEC 60751 | Class A | ± [ .15 + 0.002 \| t \| ] |
| IEC 60751 | Class B | ± [ .3 + 0.005 \| t \| ] |
| IEC 607512 | Class C2 | ± [ .6 + 0.01 \| t \| ] |

Note 1: | t | = absolute value of temperature of interest in °C

Note 2: These tolerance classes are included in a pending change to the IEC 60751 standard.



These equations can be used to calculate the interchangeability at any temperature. Note that the temperature t is an absolute value in °C. The result is the interchangeability in ± °C.

## RTD Troubleshooting Guide



| Symptom | Cause | Solution |
|---|---|---|
| Difficulty tuning measurement loop | Probe time response too fast or too slow | -Replace RTD with a faster version<br>-Add thermal insulating material to probe sheath<br>-Set a time delay in transmitter software. |
| Probe checks out okay in calibration bath but reads high/low in service | Stem conduction | -Increase immersion length<br>-Replace with probe designed for short immersion<br>-Insulate exterior portions of the assembly<br>-Check probe contacts bottom of thermowell.<br>-Bore diameter closely matches probe diameter |

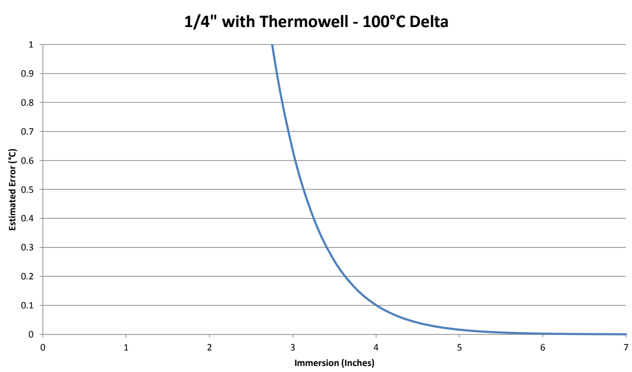


Difficulty tuning a measurement loop can be attributed to a sensor that responds either too fast or too slow to keep up with the process changes. The solution is to replace the probe with a faster one or to change the installation method to improve the response time. Probes that are too fast can be slowed down by adding an insulation material such as a Teflon® sleeve over the sensitive portion of the probe or programming a delay in the transmitter if so equipped.

Stem conduction is the most common cause of a measurement error. Insufficient immersion of the probe in the process to overcome the effects of ambient conditions is the main cause. Other sources can be radiation from a near by heat source, fan blowing on the sensor, or a probe that is not fitted properly in a thermowell.

## Stem Conduction Error



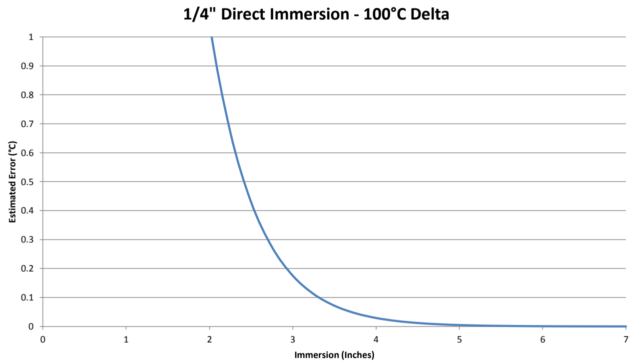





This graph shows the affect of stem conduction error on a ¼" diameter RTD installed in a thermowell and a 100C differential between ambient and process. As the immersion length is increased the error decreases. Also note that if the delta is decreased the error also decreases and goes to zero when ambient equals the process temperature.

## Stem Conduction Error



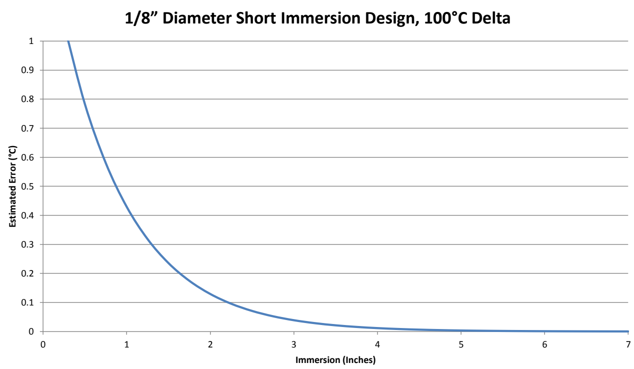





By removing the thermowell and immersing the probe directly the error decreases now requiring about 3.5” of immersion to get a reasonable measurement for most processes.

## Stem Conduction Error








Further improvement in the measurement accuracy is obtained by using a smaller diameter probe that has an internal construction specifically for short immersion lengths. An accurate measurement requires about 2” of immersion.

## Other Sources of Trouble



Corroded terminals can cause high resistance in the leads

3-wire RTD circuits are susceptible – accuracy depends on each conductor having exactly the same resistance

- Terminals clean and tight
- Terminal block clean and dry, secured to head
- Wires are tinned, or terminated with spade lugs
- Connector pins connect firmly and are clean
- Use gold plated pins in a high quality connector

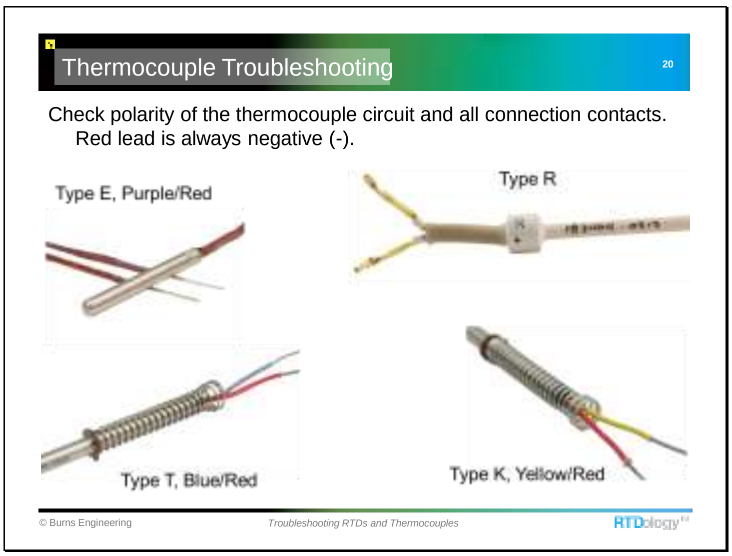
4-wire circuits also compensate for some poor maintenance

- Compensate fully for all lead wire resistance in the circuit

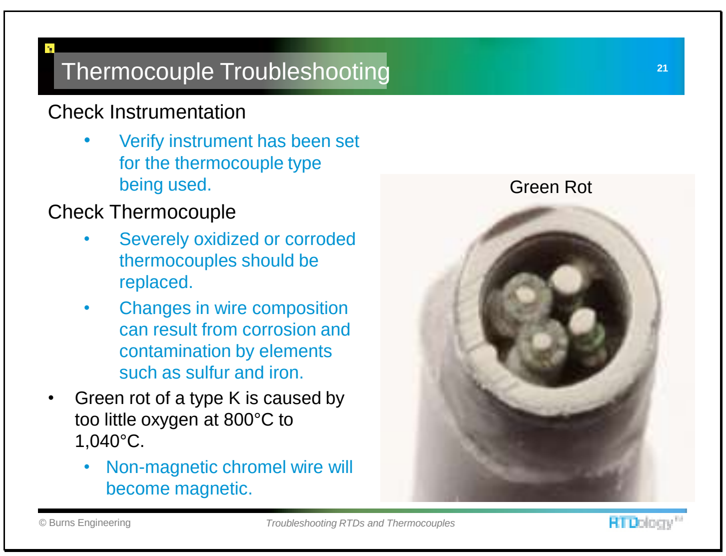


If you have a connector in the measurement circuit I recommend using a 4 wire connection to the RTD. This will compensate for any resistance differences in the leads due to worn or corroded pins/sockets on the connection.


The connection head shown in the lower right corner had a lot of dust in it that caused some electrical leakage between the terminals resulting in a bad temperature reading.




First step in troubleshooting a thermocouple is to check that the leads are connected correctly. The red lead is always negative. A type R thermocouple may not have color codes present so look for the manufacturer's mark indicating which is the plus or minus. This example has it marked +. A type J thermocouple has one red lead and one white lead. The positive lead is iron so it will be highly magnetic.




Each thermocouple type has a unique voltage vs. temperature relationship so the connected instrument must be adjusted for that type of thermocouple.

## Thermocouple Troubleshooting



Test Meter and Extension Wires

- Connect the extension wires to a test thermocouple of known accuracy and observe the temperature reading
- Use a thermocouple simulator/calibrator

Extension wires

- Check that it is the same type as the thermocouple
- Short circuit or low insulation resistance will cause an error

RFI/EMI - Thermocouples are susceptible to electrical interference

- Use shielded twisted pair cables
- Short runs

Check probe and thermowell assemblies to insure that probe contacts bottom of thermowell.

- Bore diameter closely matches probe diameter



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## Thank you for attending!

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