Burns Engineering Presents -

Q & A on Temperature Topics

Answers to your questions about measuring temperature with resistance temperature detectors.

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FAQ's that we'll answer today

- Confusing Terminology
- IR – What is it and why does it matter?
- Is it possible to measure temperature accurately in small pipes?
- Surface sensors, how accurate?
- Does cable length really make a difference?
- 3 wire or 4 wire?
- When and why use a transmitter?
- Is a smaller diameter sensor really better?
- Your questions about these or other topics!

Acronyms and Terminology

- RTD vs PRT?
  - RTD - resistance temperature detector
  - PRT - platinum resistance thermometer
- Coefficients
  - TCR - temperature coefficient of resistance
  - α - Alpha - same as TCR
- Traceability & Confidence
  - NIST - National Institute of Standards and Technology
  - NVLAP – National Voluntary Laboratory Accreditation Program

A PRT is a type of RTD made from platinum wire. Other less common metals used are nickel and copper.

Acronyms and Terminology

- Standards
  - DIN 43760 – Deutsches Institut für Normung eV
  - IEC 60751 – International Electrotechnical Commission
- Temperature Scales
  - ITS-90 – International Temperature Scale
  - IPTS-68 – International Practical Temperature Scale
    - CVD – Callendar-Van Dusen
- TPW – triple point of water 0.01°C

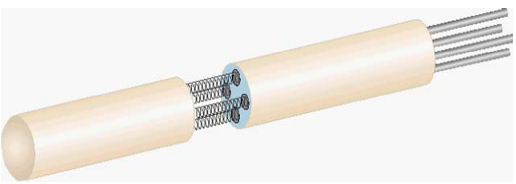
The current international standard that defines performance for a PRT with a .00385 ohms/ohm/°C temperature coefficient is the IEC 60751. ASTM E 1137 is the current US version and is nearly identical in performance parameters. DIN 43760 was similar to both and is not current.

ITS-90 is the current temperature scale defined by thermodynamic temperatures. It replaced the IPTS-68 and provides for more accurate interpolation and extrapolation of temperature values between thermodynamic fixed points.

IR – What is it?

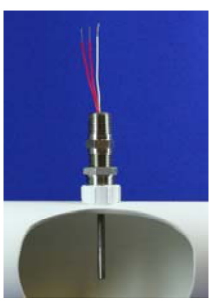
- Insulation Resistance - An Important Electrical Measurement
  - Measured between lead wire and probe sheath
  - May also be measured between elements of dual element probes
  - Can cause a significant resistance error

Shunting



Moisture or contamination causes a low resistance reading by shunting between coils or leads of the element.

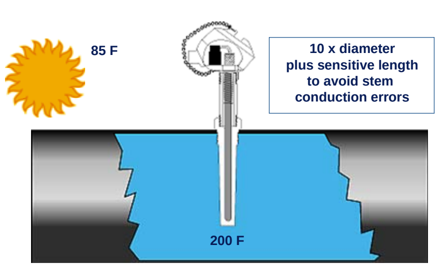
Small Diameter Lines



- Immersion depth is the key to an accurate measurement

In pipes smaller than 4”, immersion depth is the key to an accurate measurement. Too short and the measurement will be affected by the ambient conditions.

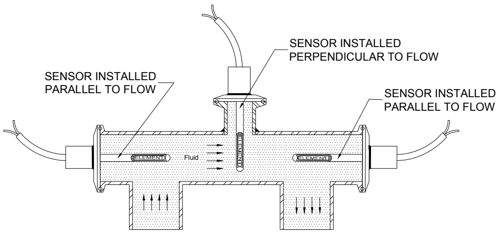
Small Diameter Lines



Immersion length is critical to insure an accurate measurement. Conduction error occurs when the ambient conditions affect the measured temperature. Heat conducts from the external portions to the internal and can have an adverse effect on accuracy. Sufficient immersion will nullify this effect.

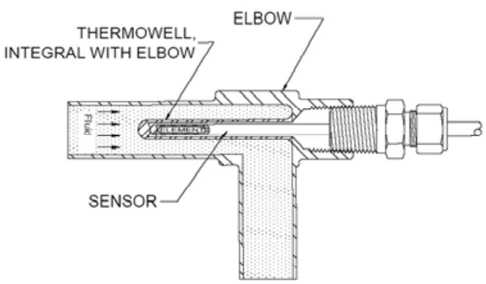
For any thermowell or direct immersion sensor the rule of thumb is 10 x the diameter, plus the sensitive length. Most sensors have a 1” sensitive length. Example: a 0.25” diameter direct immersion sensor needs 3.5” of immersion.

Small Diameter Lines



Installation into a tee with the sensor parallel to the flow can allow for longer immersion length.

Small Diameter Lines

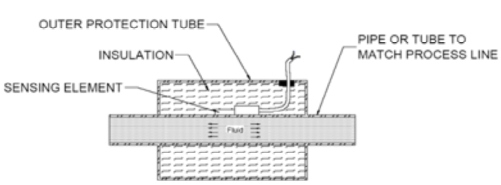


A special elbow fitting with an integral thermowell allows for sufficient immersion length in tubes down to 0.5” diameter.

Small Diameter Lines

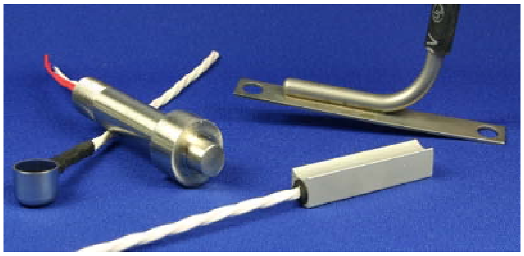
In tubes smaller than 1” the tube is flared to allow for the thermowell without constricting flow through the elbow.

Small Diameter Lines



Another solution is to mount a sensor on the pipe surface. This approach however can compromise accuracy.

Surface Sensor Accuracy



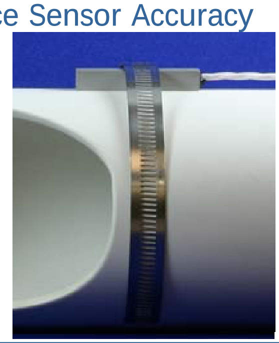
There are many styles of surface mount sensors and each has a preferred mounting method. Whether bolted, strapped or glued each suffers accuracy declines from the effects of the ambient conditions and mounting location.

Surface Sensor Accuracy

- Sensor is just as accurate as other style RTD's
- Errors are related to installation
  - Ambient conditions
  - Location

The sensing elements used in these sensors are the same as used in other sensors and have the same accuracy. The measurement error is due to the effects of ambient conditions and location of the sensor.

Surface Sensor Accuracy



Installation of a surface mount sensor can be accomplished with a hose clamp, tape, or an adhesive. Remember that the sensor is measuring the surface of the pipe and not the process fluid so a substantial error can exist. Addition of insulation can help shield the sensor from the ambient conditions and improve the measurement accuracy.

Surface Sensor Accuracy

- Measures pipe surface
- Protection from ambient conditions
  - Requires insulation for best accuracy

Surface Sensor Accuracy

- Accuracy varies widely
  - With sufficient insulation it can be the same as an immersion sensor
  - Errors of 0.5°C or greater are common

Even with a properly insulated pipe there may be a significant measurement error depending on the efficiency of the insulation and the difference in temperature from ambient and process conditions. Magnitude of the error increases as the difference increases.

Cable Considerations

“How far can I run the lead wires from the RTD to signal conditioner?” is a commonly asked question and one with more than one answer.

Cable Considerations

- Transmitter/controller limitations
- Errors
  - 2 wire connection adds series resistance
  - For a 3 wire circuit +0.16°F per 100 feet of 18 AWG
  - Larger AWG cable has less error
  - Smaller AWG cable has larger error

Limitations may be defined by the controller/transmitter or the length may be limited by accuracy requirements of the measurement.

Cable Considerations

- All conductors are not created equal
  - Each conductor varies in resistance from another
  - Thermally induced voltages (EMF) caused by junctions of dissimilar metals
- How can these be eliminated?

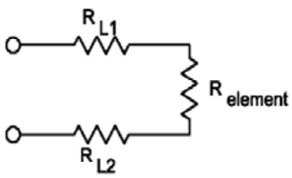
Three wire RTD circuits have an inherent error associated with them because of differences in resistance of each lead wire. There are methods to minimize these errors.

Cable Considerations

- How can this be eliminated?
  - Use a 4 wire circuit
    - Fully compensates for lead resistance
    - Also compensates for any terminal block or connector pin resistances
  - Make adjustments to the three wire circuit

The best method is to use a 4 wire circuit which fully compensates for lead wire resistance in the circuit. Three wire circuits can be trimmed so that each leg is of equal resistance.

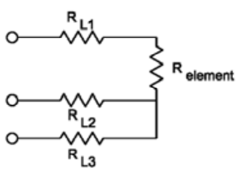
Cable Considerations – 2 Wire



$$R_{measured} = R_{L1} + R_{element} + R_{L2}$$

Two wire circuits are typically used for 1000 ohm RTD's in HVAC applications where low cost control equipment is used. The lead resistance becomes a very small percentage of the circuit and has minimal effect on accuracy when used with a 1000 ohm or greater sensor.

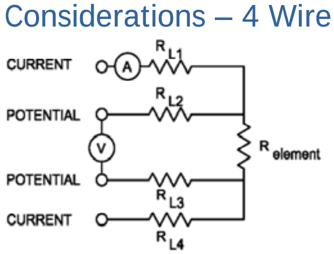
Cable Considerations – 3 Wire



$$R_{measured} = R_{L1} + R_{element} + R_{L2} - [R_{L2} + R_{L3}]$$
$$= R_{L1} + R_{element} - R_{L3}$$
$$= R_{element} \quad (\text{if } R_{L1} = R_{L3})$$

A 3 wire circuit provides an accurate measurement if the resistance in L1 = L3.

Cable Considerations – 4 Wire



$$R_{measured} = \frac{V}{A}$$

Using the current potential method in a 4 wire circuit eliminates all lead resistance and any terminal block or connector resistance. A known current is applied to L1 and L4 and a voltage measurement is made between L2 and L3. Then just do the math to find the resistance.

Cable Considerations

- For 3-wire sensors, error is directly related to variation in lead resistance
  - Every .04 ohm variation results in ~ 0.1°C error
- Examples – assume 10% mismatch in resistance worst case
  - 22 AWG copper, nominal resistance .016Ω/foot
    - .004°C/foot error, typical 10' cable = .04°C error
  - 30 AWG copper, nominal resistance .104 Ω/foot
    - .026°C/foot error, typical 10' cable = .26°C error

Some examples of measurement errors due to lead wires in a 3 wire circuit. As you can see, the error grows quite fast with decreasing cable size and length.

Extension Cable

- Size and insulation – refer to the electrical codes for your region
- RFI/EMI protection
  - Ground the shield at the controller end and leave the instrument end open

Cable types vary widely depending on local codes and facility requirements. Most common size is 16 or 18 AWG for connection. Smaller cables are used with the sensors because of space constraints and they typically do not extend more than a few feet from the sensor.

Shielding may be required depending on how prevalent radio frequency and electro magnetic interference is in your facility. When in doubt, use shielded cable. EMI or RFI can cause erratic readings in both thermocouples and RTDs.

Transmitters and Accuracy

- When and why use a transmitter?
- Distance
  - >250 ft
- Matching to the RTD
  - Improves accuracy
- Robust signal
- RFI/EMI

One method to avoid the error from a long cable run is to add a transmitter near the sensor. Additional accuracy can be obtained by matching the RTD to the transmitter. Other benefits are that the signal from the transmitter is more robust and is less affected by EMI or RFI.

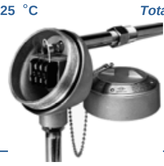
Accuracy Improvements

Standard RTD / transmitter at 100 °C

TL Transmitter	± .05 °C
Interchangeability	± .2 °C
Total	±.25 °C

Matched RTD / transmitter at 100 °C

TL Transmitter	± .05 °C
Calibrated Sensor	± .05 °C
Total	±.1 °C



Matching the transmitter to the RTD can improve accuracy by at least a factor of 2x. RTD is calibrated so the actual resistance values are known at the zero and span points, then those numbers are used to adjust the transmitter.

Cost of Inaccuracy

- **Process Fluid:** **Water**
- **Flow Rate:** **100 GPM**
- **Control Temperature:** **100 °F**
- **Energy Cost:** **6¢ / KW-hour**

Annual Cost of Energy Per °F Error

$8000 / year

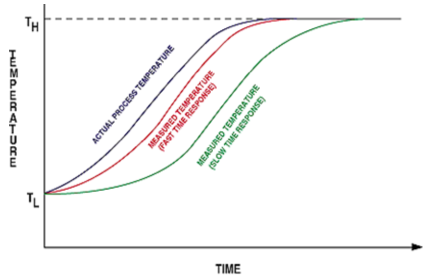
High accuracy insures product quality and efficient use of your energy dollar.

Is Smaller Better?

- Sometimes
- Immersion length – stem conduction
- Less durable
- Sensing element is just as accurate
- Packaging and installation determine measurement accuracy
- Time response – smaller is usually faster and that can mean a more accurate measurement

Another question with multiple answers but only one good one – sometimes. Usually for small diameter lines or other confined spaces there is no choice but to go smaller. The sensing elements used in these small sensors are the same as those in larger sensors so their accuracy is the same. Errors are due to the installation, lead wires, and other sources. One of the larger errors that can be addressed by a smaller sensor is time constant. Smaller sensors are usually faster to respond and if the process is changing rapidly the sensor will better keep up with it.

Time Response



As you can see from this graph a slow responding sensor can easily indicate several degrees of error from the actual process temperature. A faster responding and usually smaller sensor does a better job of keeping up.

Questions?

Use the chat window to send us a question now or click the raise your hand button and you can have the floor to ask your question.

Contact us later at 800-328-3871 ext. 13 or 11
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