BURNS ENGINEERING

Optimizing Temperature Measurement in Existing Installations

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What we'll discuss today

While designing a sensor specifically for an application yields the best temperature measurement, there are things that can be done to improve measurements in your existing installations.

Today we'll discuss actions you can take to optimize your measurements and also create a helpful checklist to assist you in your sensor/measurement review.

- The goal is to improve accuracy and achieve lowest life cycle cost
  - ❑ Preventive maintenance
  - ❑ Calibration
  - ❑ Probe life
  - ❑ Transmitter
  - ❑ Thermowell
  - ❑ Control system
  - ❑ Component replacement

Lowest life cycle cost includes all the costs of making and maintaining the temperature measurement and minimizing energy costs associated with the process. Accurate temperature measurement results in efficient use of energy and consistent product quality. Regular maintenance and adjustments to your existing equipment will go a long way towards achieving this goal. We will review these maintenance items and adjustments and construct a checklist you can use for your temperature measurement system. Also there is a discussion of component replacement and what features to look for to obtain best accuracy and lowest life cycle cost.

Insulation Resistance

- First and most important electrical check to make on the RTD
  - 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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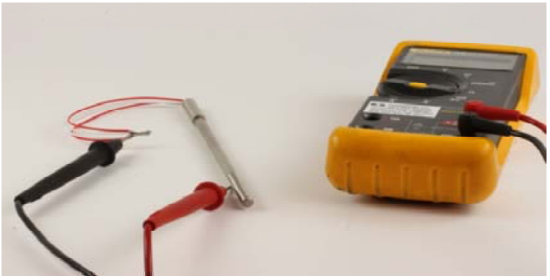
Test method

- Lower resistance = lower measured temperature
- Test at 50 VDC
- IR should be >200 megohms at room temperature



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.

An ounce of prevention…

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Preventive maintenance

- The RTD
  - ☑ Check insulation resistance
  - ☑ Check ice point resistance

The ice point resistance check is the easiest and very accurate method to verify the accuracy of an RTD. A properly made ice bath will have an accuracy of +/- 0.002C.

Ice Point Check

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Using and Ice Bath, check resistance at 0°C

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 rod to form the holes.

Ice Point Check

Using a high accuracy meter

- Reading should be 100 ± 0.12 ohms for Class B and 100 ± 0.06 ohms for Class A per the ASTM E 1137 or IEC 60751 standards
- Outside this range and the probe should be replaced

If the probe does not meet the resistance tolerance it should be replaced. There is not any reliable and cost effective method to repair it. Save the sensor for recycling! There is $$ worth of platinum in each probe. Save it up for a department lunch.

An ounce of prevention…

Preventive maintenance

- The RTD
  - ☑ Check insulation resistance
  - ☑ Check ice point resistance
  - ☑ RTD and transmitter matching

Matching the resistance characteristics of an RTD to a transmitter is an economical way of improving accuracy of the system. About 85% of the off-the-shelf inaccuracy can be eliminated.

Match RTD to Transmitter

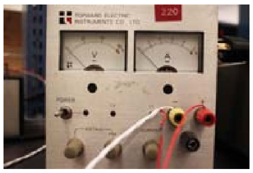
Requires calibration of the RTD

- Zero and span temperatures
- Full calibration with coefficients over service range for transmitters with curve matching capability

At a minimum, the RTD resistance is checked in a temperature bath at the zero and span temperatures. Those resistance values are used to adjust the transmitter output. For those transmitters that have curve fitting capability, a full calibration of the RTD is performed and the resulting coefficients are entered into the transmitter.

Match RTD to Transmitter

Equipment used



Some of the equipment required for matching an RTD to a transmitter.
-Software and interface for PC programmable transmitters
-Decade box and ammeter for analog transmitters with adjustment potentiometers.

Match RTD to Transmitter

Matched transmitter example:

- RTD in a process at 121°C using a transmitter with .1°C accuracy.

	Grade B Sensor	Grade A Sensor	Matched Sensor
Sensor at 121°C	±.76°C	.34	.05
Transmitter Accuracy	±.10°C	.10	.10
Combined System (RSS)	**± .77°C**	**.35°C**	**.11°C**

As you can see, matching is a very economical method to improve your system accuracy.

An ounce of prevention…

Preventive maintenance

- The RTD
  - ☑ Check insulation resistance
  - ☑ Check ice point resistance
  - ☑ RTD and transmitter matching
  - ☑ Frequency of checks –
    - Process dictates the calibration cycle
      - – Probe drift
        - » Vibration
        - » Shock
        - » Temperature range and cycling
      - – Product value
      - – Complete 5 cycles w/o shift then double the interval

A reasonable interval for making the calibration checks must be determined in collaboration with the RTD manufacturer and the process engineer.

An ounce of prevention…

Preventive maintenance

- The RTD
- The Connection Head
  - ☑ Shielding – RFI/EMI
  - ☑ General condition, corrosion, discoloration, threads, cracks
  - ☑ Water inside the connection head
  - ☑ Conduit seal for hazardous atmospheres
  - ☑ Wire insulation
  - ☑ Corrosion on terminal connections

Connection heads provide protection to the lead wire end of the probe and allow for mounting a transmitter or terminal block to connect the facility wiring.

Connection Head

Corroded terminals can cause high resistance in the leads

- 3-wire 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 lug
  - 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

Connection Head

The good

and bad

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.

Connection Head

- Connection head seals out moisture and contaminants
  - Conduit seal
  - Cover gasket
  - Cover tightened securely

An ounce of prevention…

Preventive maintenance

- The RTD
- The Connection Head
- Environmental Considerations
  - ☑ Fan blowing on sensor location
  - ☑ Insulation covering the external portions of sensor
  - ☑ Sunlight - solar heating right where you don't want it
  - ☑ Wash down

Something as innocuous as a fan blowing can cause a measurement error if it is directed on the external portions of the temperature assembly.

An ounce of prevention…

Preventive maintenance

- The RTD
- The Connection Head
- Environmental Considerations
- The Thermowell
  - ☑ Bore cleaning
  - ☑ Heat transfer compound
  - ☑ Product buildup on wetted portion
  - ☑ Cracks in flange weld or leaky gasket
  - ☑ RTD bottoms in well and spring loads

Time response and stem conduction error can be adversely affected by a dirty bore, product build-up on the wetted portion, or lack of heat transfer paste. Using a heat transfer fluid can cut the time constant in half.

An ounce of prevention…

Preventive maintenance

- The RTD
- The Connection Head
- Environmental Considerations
- The Thermowell
- Controller
  - ☑ RTD temperature coefficient is set correctly in controller

Example

- A temperature is being measured with a sensor having a temperature coefficient of .003916 but due to a sensor failure it was replaced with a sensor having a temperature coefficient of .00385. If the transmitter/ controller is not recalibrated, at 100°C it will measure 1.7°C low.

Understanding your controller and the settings is necessary to get the best measurement from the RTD. A mismatch of the coefficient will cause a significant error.

An ounce of prevention…

Preventive maintenance

- The RTD
- The Connection Head
- Environmental Considerations
- The Thermowell
- Controller
- Transmitter
  - ☑ Wires connected securely
  - ☑ Check output at zero and span and/or at control temperature

A stray wire strand can easily short the terminals together on a transmitter or terminal block.

…A Pound of Cure

At some point it will be necessary to replace the sensor, here's what to keep in mind when replacing a sensor:

Component replacement

- ❑ RTD
- ❑ Thermowell
- ❑ Transmitter or controller
- ❑ Connection head
- ❑ Wiring

When maintenance and adjustment of your existing equipment doesn't achieve your desired accuracy and life cycle expectations, the next step is to replace components. A thorough understanding of the process and variety of components available is necessary. We'll look at these five main areas.

Component Replacement

RTD

- ☑ Choose the correct temperature coefficient. Most common is a .00385 conforming to IEC 60751 or ASTM E1137
- ☑ 3 or 4 wire
- ☑ Choose correct probe length to match thermowell or provide sufficient immersion to avoid stem conduction
  - 10x probe diameter + sensitive length = minimum immersion
- ☑ Interchangeability

A 4 wire system provides the best accuracy and should be considered especially if the lead wire run from RTD to controller exceeds a couple hundred feet. A 3 wire system has a potential error of +0.16F per 100 feet of 18 AWG cable.

Interchangeability

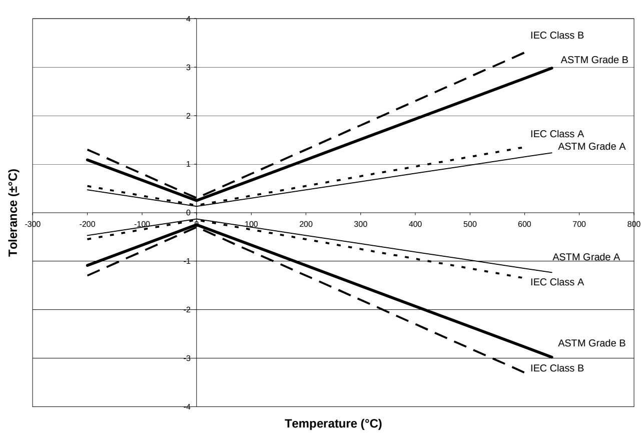
Standard	Tolerance	Defining Equation[1]
ASTM E1137	Grade A	± [.13 + 0.0017 | t |]
ASTM E1137	Grade B	± [.25 + 0.0042 | t |]
IEC 60751[2]	Class AA	± [.1 + 0.0017 | t |]
IEC 60751	Class A	± [.15 + 0.002 | t |]
IEC 60751	Class B	± [.3 + 0.005 | t |]
IEC 60751[2]	Class C	± [.6 + 0.01 | t |]

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 resultant is the interchangeability in ± °C.

Interchangeability



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 like on the graph represents 0°C and the tolerance on the y axis is expressed in ± °C from nominal.

Component Replacement

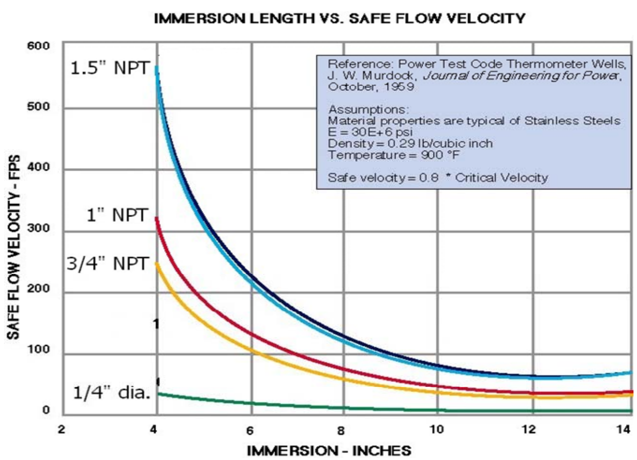
RTD

Thermowell selection

- ☑ Corrosion
- ☑ Erosion
- ☑ Wake frequency and strength
- ☑ Time response
- ☑ Immersion length

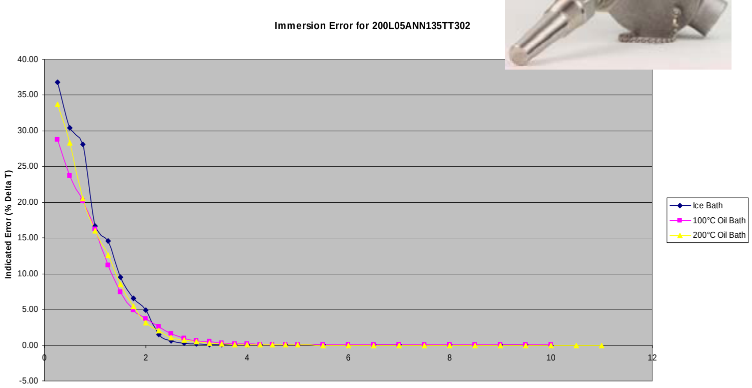
A proper thermowell will have sufficient immersion length to minimize stem conduction errors, and will resist corrosive and erosive process conditions. Also, it must be sized correctly to meet strength and wake frequency considerations.

Thermowell Sizing



This graph shows the acceptable flow rates for various thermowell designs and a ¼" diameter RTD.

Immersion Depth



A thermowell and RTD assembly was immersed in a bath to determine the stem conduction at various depths. At 4.5 inches most of the error has disappeared. As you can see the error is mostly independent of the bath temperature used. As an example a thermowell with 2.5" immersion gives us an error of about 0.45°C.

Component Replacement

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RTD
Thermowell selection
Transmitter

- Mount RTD with transmitter
  - ☑ Minimize lead length for 3 wire circuits
  - ☑ Matching to RTD
- Environmental
  - ☑ Explosive atmosphere
  - ☑ Sunlight
  - ☑ Water
  - ☑ Forklift

For a more detailed review, visit the Selection and Application presentation/notes available at www.burnsengineering.com/rtdology

When replacing a transmitter some consideration should be given to adding matching capability and locating the transmitter as close as possible to the RTD.

Choose components that are compatible with the environmental conditions including the "forklift" like events that seem to always happen. Temperature assemblies and I'm sure other similar items are sometimes used as foot steps, or other uses for which they are not necessarily designed. Accepting those things and choosing equipment that is durable enough to survive will help achieve a low life cycle cost.

Optimization Checklist

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- ❑ Environmental considerations
  - ❑ Fan blowing on sensor location – can be bad
  - ❑ Insulation covering the external portions of sensor - good
  - ❑ Sunlight - solar heating right where you don't want it
  - ❑ Wash down
- ❑ Thermowell
  - ❑ Bore cleaning
  - ❑ Heat transfer compound
  - ❑ Product buildup on wetted portion
  - ❑ Cracks in flange weld or leaky gasket
  - ❑ RTD bottoms in well and spring loads
- ❑ Controller
  - ❑ RTD temperature coefficient is set correctly in controller
  - ❑ 3 or 4 wire circuit connected correctly with correct wire type

Replacement Checklist

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- ❑ RTD
  - ❑ Choose the correct temperature coefficient. Most common is a .00385 conforming to IEC 60751 or ASTM E1137
  - ❑ Interchangeability – choose class A for better accuracy
  - ❑ 3 or 4 wire – 4 wire provides better accuracy
  - ❑ Choose correct length to match thermowell or provide significant immersion to avoid stem conduction – for a direct immersion probe minimum immersion = 10x probe diameter + sensitive length
- ❑ Thermowell selection
  - ❑ Corrosion
  - ❑ Erosion
  - ❑ Wake frequency and strength
  - ❑ Time response
  - ❑ Immersion length

Replacement Checklist

- Connection head
  - Ease of probe removal for calibration
  - High quality terminal block
  - Wash down
    - Add an epoxy coating or other corrosion preventive coating
  - Hazardous atmospheres
- Transmitter
  - Mount RTD with transmitter to minimize lead length for 3 wire circuits
  - Matching to RTD
- Environmental
  - Sunlight
  - Water
  - Forklift proof

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